







# AIRCRAFT DRAFTING

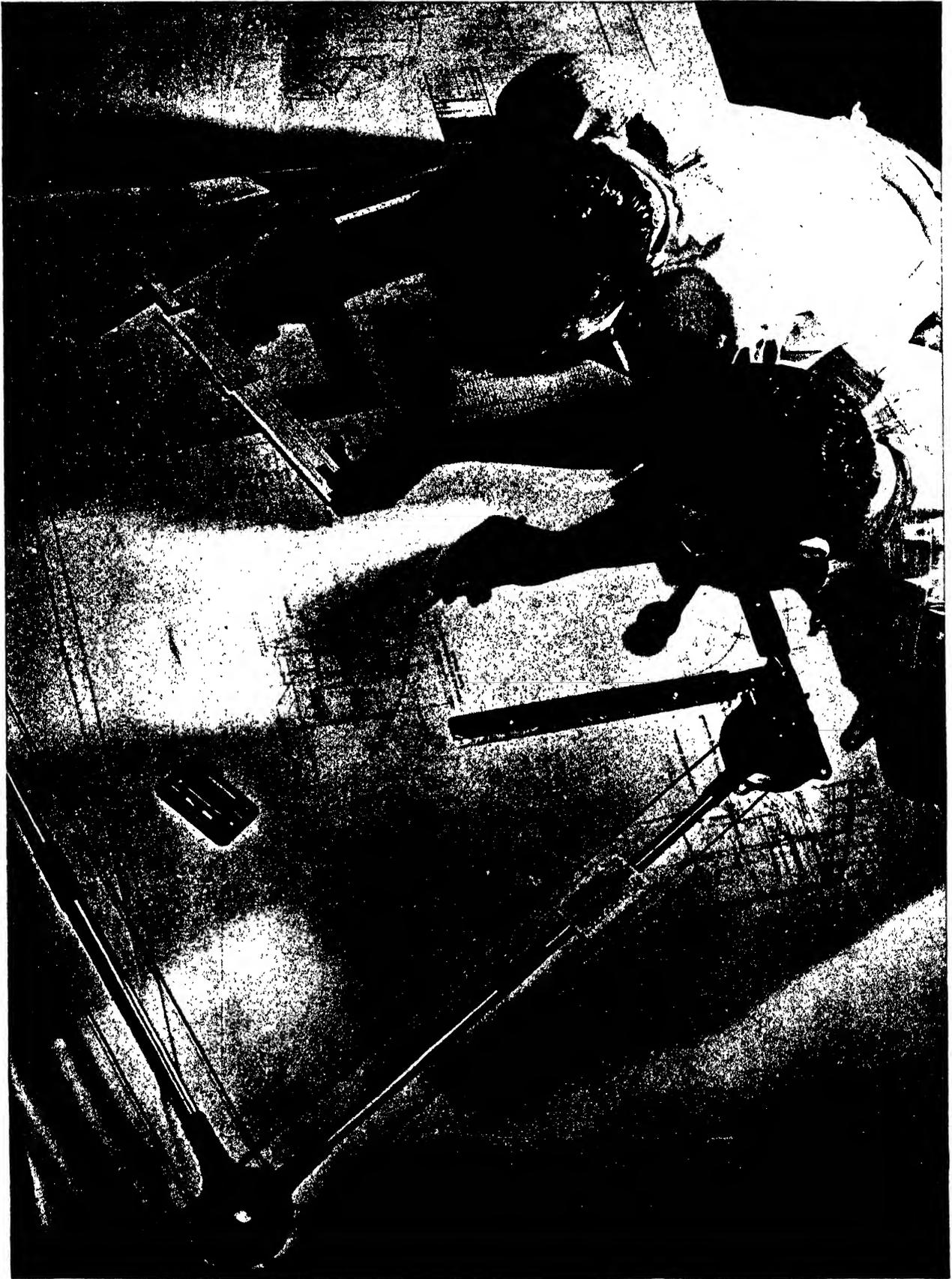


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# AIRCRAFT DRAFTING

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*This book is dedicated to my father  
whose encouragement has made it possible*



# PREFACE

This volume is intended as a text and reference book for beginners, students, and other draftsmen who desire to enter the engineering branch of the aircraft industry. It is basic and assumes no previous drafting or special technical training.

The author has kept before him the employer's point of view: he has attempted to coordinate aircraft drafting with functional engineering information, for one without the other is of little practical value in an aeronautical drafting department; the aircraft draftsman is not a "copier" of drawings but an analytical and creative individual.

During the war years the subjects of lofting and pictorial drawing have made an impressive mark on the science of engineering drawing. Lofting especially has become, in some companies, an integral part of drafting procedure. Pictorial drawing is more specialized but is important to the over-all picture. This text, therefore, attempts to give the student a working knowledge of both these subjects.

An effort has been made to keep all examples, problems, and illustrative material thoroughly practical, and it is hoped that the student will get some feeling of the actual aircraft drafting room.

A complete picture of all the drafting practices in the industry is beyond the scope of this text, but enough general applications have been presented to allow for the fundamentals. The detailed drafting systems, procedures, and characteristics of a specific company may be obtained from the company Engineering Manual (or Drafting Room Manual): in fact, the first assignment to a new draftsman is to read and become familiar with the company book. A great deal of related technical matter, only touched on in this text, is also offered to the draftsman by the company. Never in industrial history has such intensive training, education, and assistance been given engineering employees as in the aircraft industry. The engineering draftsman has a great opportunity to make a permanent place for himself in this great, but relatively new field.

I want to express my appreciation to the following organizations for their suggestions, contributions, and interest; they have encouraged and assisted the author in this undertaking: Aluminum Company of America, American Magnesium Corporation, Boeing Aircraft Company, Boots Aircraft Nut Corporation, Consolidated-Vultee Aircraft Corporation, The Glenn L. Martin Company, B. F. Goodrich Company, Lockheed Aircraft Corporation, National Advisory Committee for Aeronautics, The National Screw & Manufacturing Company, The Republic Aviation Corporation, Rohm & Haas Company, and the Bell Aircraft Corporation, United States Blue Print Paper Company, Aviation Engineering Incorporated, and Douglas Aircraft Company.

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*Hyman H. Katz*

New York City



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# AIRCRAFT DRAFTING



## CHAPTER ONE

# THE AIRPLANE

### *Why an Aeronautical Background?*

Although the primary concern of this book is the technique of aircraft drafting, we must not neglect the end product of the drafting itself—the airplane, and what makes it tick.

A student familiar with the history and theory of flight is better equipped to enter this great industry—as a mechanic, a clerk, a draftsman, or in almost any capacity. To the draftsman, however, the subject is of especial importance, for he works in an engineering atmosphere where his work, discussion about his work, and even everyday conversation in the shop require some aeronautical background, however slight.

### THE BEGINNINGS OF AVIATION

For centuries man has had the desire to conquer the skies. The idea of flight has always been a challenge to his ingenuity and resourcefulness. Birds flew, and man believed there was some way for him to rise and soar through the air. This theme runs through the mythology and folklore of many peoples, and almost as soon as modern man really began to study the world he lived in, he also began to try to apply his new scientific knowledge and method to the problem of flight.

Roger Bacon, the thirteenth century scholar and alchemist who was ahead of his time in so many ways, interested himself in the subject. In the fifteenth century, Leonardo da Vinci conducted actual experiments and research into the possibility of flight. His attempts, however, though interesting, were all unsuccessful and contributed very little to the science.

Man's first conquest of the air was in a balloon. Early experimenters with the balloon learned that a bag filled with hot air would rise, and all other experiments were based on this

discovery. The first important balloon, which was 35 feet in diameter and had a capacity of 23,000 cubic feet, was constructed in 1783. This early aeronautical creation was nothing more than a large linen-lined paper bag. It rose to an altitude of about 1000 feet, traveled about a

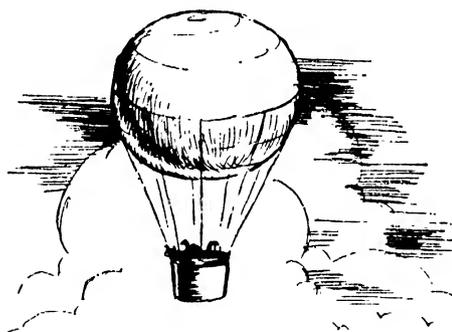


Fig. 1. About 150 years ago the balloon of the Montgolfier brothers rose with the first living cargo—a duck, a rooster, and a lamb

mile, then slowly settled to earth as the air inside it cooled. This was only the first of many balloon experiments, some successful, some disastrous.

As men accumulated experience with devices that would hold them, at least for a time, in the air, they began to tackle the problem of controlling their movements aloft. The first dirigible was built and flown by a Frenchman in 1851. This ship was propelled by a one cylinder gasoline engine which developed 3 horsepower and a speed of 6 miles an hour. Ten years later a German aviation enthusiast built a dirigible which made about 10 miles an hour and which first introduced "semirigid" construction. Aviation was really beginning to make progress. Balloons had a limited military use in the Franco-Prussian War of 1870, and flight was becoming already more than a possibility.

The nineteenth century saw the development of gliders as well as progress with lighter-than-air craft. The first experimenter in this field was Sir George Cayley, who constructed a glider of wood and cloth in the early part of the century. When cast into the wind from the top of a hill, the model flew very well, but not to Cayley's satisfaction. He tried building a glider with a greater wing area, only to find that the larger

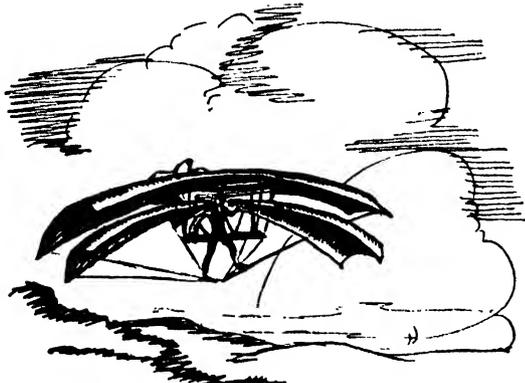


Fig. 2. Montgomery's sea gull glider

wings caused sluggish performance. Next, inspired by a dream in which he saw hundreds of gliders in action, some flying under others and in the same direction, Cayley built a model with double wings, creating the first biplane. His next model was large enough to carry a man. Though not spectacular, the flight was a success.

Another important pioneer in glider investigation was John Montgomery, who has been called the "father of gliding." His first craft, modeled after a sea gull, had long wings of downward slope. This attempt was unsuccessful, but later Montgomery built a glider in which he made a remarkable flight of over 600 feet. This was only the first of Montgomery's many successful designs.

A glider with birdlike wings attached to the pilot was tried out by another experimenter, who believed that by the use of wings he could soar through the air like a bird. In 1891 this pioneer constructed a biplane glider of willow sapling and cotton cloth, which he hoped to manipulate upward or downward by sliding his body backward or forward. The idea did not prove to be practicable, but the builder was greatly surprised and pleased at the length of his

first flight. Through his experiment the possibilities of soaring were discovered.

Through these and countless other attempts, aviation enthusiasts learned much that was to prove essential to the development of the airplane as we know it today. The possibilities of heavier-than-air craft, however, were limited by lack of any practicable engine to furnish motive power. Until the internal combustion engine was

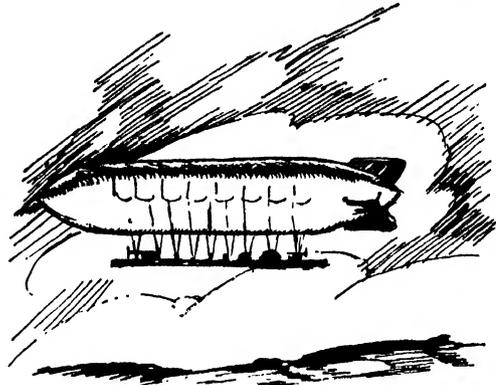


Fig. 3. Count Zeppelin introduces an airship of rigid construction, aluminum beltframes and stringers

developed, gliding remained a sport, a curiosity, with no practical importance.

This was not true, however, of lighter-than-air craft. The dirigible appealed to governments, military men, scientists, and industrialists alike, so progress in its development in the late nineteenth and early twentieth centuries was rapid.

A name familiar to us all and one that shines out in aviation history is that of Zeppelin, builder of the famous Zeppelin dirigibles. In 1898 this inventor came forth with the largest airship yet built. This ship was 420 feet in length, 39 feet in diameter, and was powered by a 16 horsepower gasoline engine. The next Zeppelin airship was disappointing in its speed of only 8½ miles per hour. Excess weight was responsible for the low speed. Later that year a second flight was made in a lighter ship that reached the very satisfactory speed of 20 miles per hour, with 11 passengers aboard. In 1910 Zeppelin built a dirigible capable of traveling at a speed of 45 miles per hour, and in the next 4 years he made over 800 voyages over the continent of Europe. During this time a ship that could fly at the amazing speed of 50 miles per hour was perfected. Regular trips began to be

scheduled, and the airships Zeppelin built carried 14,000 passengers over 100,000 miles. Thus we have the beginning of air travel.

In the United States, development of the dirigible proceeded more slowly than in Europe, where military-minded governments subsidized the industry liberally. In 1903 an American built and flew a "semirigid" airship. Its performance at first was not satisfactory because of its inefficient motive power. The following year, however, an experienced balloonist secured an engine suitable for installation in an airship. With this plant the ship's performance was very gratifying and encouraging. After exhibition in several cities, this ship attracted the attention and the interest of the United States Government, and the builders were commissioned to construct an experimental dirigible for the War Department. The ship was successful and in 1908 was put into service by the army in training men for the new military aviation.

Heavier-than-air craft began entering the field to compete with the airship and the dirigible for supremacy of the air. The service of the dirigible was very important in World War I, and throughout the late 1920's and early 30's its commercial development seemed assured. There were numerous disasters with dirigibles which undermined public confidence, however, and progress was cut short by the Hindenburg disaster in 1937.

The progress made in aviation was greatly accelerated by the efforts of the builders of the lighter-than-air ships. Our modern aircraft industry owes much to these persevering early pioneers of aviation.

#### THE FLYING MACHINE

In 1899 Wilbur and Orville Wright, brothers who were destined to become the principal figures in the development of modern aircraft, entered the field of glider experimentation. They first worked with a box kite manipulated by wires from the ground. The kite was made to go through maneuvers never seen before. In this simple way, the advantage of curved or warped wings over straight wings was discovered.

The Wright brothers later built a man-carrying glider, but this experiment was unsuccessful.

The glider could not be made to leave the ground. In 1901 they went to Kitty Hawk to try out a larger and greatly improved glider, with which they reached an altitude of 600 feet. This glider was followed by a number of other successful craft.

The Wright brothers also constructed the world's first wind tunnel. Their crude tunnel was 8 feet long and approximately 16 inches

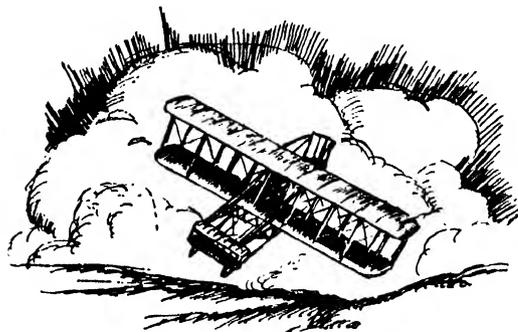


Fig. 4. The Wright brothers—Dec. 17, 1903

square, with a fan placed at one end and balancing devices on the other. As a result of their wind tunnel experiments, the brothers built a huge glider equipped with a vertical fin to assist in maintaining balance. Although they suffered many falls, they continued their work undaunted. In 1902 Orville Wright had the idea of hinging the vertical fin so that the glider could be turned from left to right. The resulting experiment was an astounding success.

After their success in glider experiments, the Wright brothers turned their efforts toward designing and building an engine to power their heavier-than-air craft.

The first engine was, naturally, very crude. So that it would stand the terrific vibrations, the entire glider framework was strengthened and reinforced. On its completion the gross weight of the plane including the pilot load was 750 pounds.

The Wright brothers dismembered the ship, sent it to Kitty Hawk, and on December 17, 1903, made the first successful flight of an engine-powered heavier-than-air craft. A total course of 120 feet was flown at a height of about 9 feet in 59 seconds.

This was a fine achievement, but the inventors realized that much remained to be done to make

their plane practical. The plane had still to be made maneuverable; that is, it had to be able to bank, turn, climb, and land successfully. The inventors continued their research and experiment work, and with each successful flight they made improvements and gained greater skill.

On October 5, 1904, Wilbur Wright piloted their plane on its longest flight up to that time—a distance of about 24 miles. After this remarkable achievement, the brothers began to see the vast possibilities of the airplane. Most people still were skeptical of the practicability of the flying machine. But the inventors were not discouraged and kept up their work.

The United States Government declined an offer by the Wright brothers to sell their patents to the government. But foreign governments were anxious to learn about the airplane, and France and Germany sent representatives to see the plane and to make offers for the patent rights.

In 1908 Wilbur Wright demonstrated his and Orville's ship in France for the Astra Company, a French manufacturer of airships. Every expectation was surpassed, and the French government, the Astra officials, and the French press were truly astounded.

After seeing the interest of European nations in the airplane, U. S. Army officials asked the Wright brothers to come to Washington to discuss the possibilities of the airplane in war. Out of these discussions came several interesting specifications for the first military plane. The requirements were that it should be capable of making a sustained flight of 10 miles, carrying the pilot and one passenger, and attain a speed of 40 miles per hour.

Work was started, and the plane was completed about a year later. Its first tests were not fully successful. Another plane was built which met the requirements and was accepted by the Army. This plane bettered the government specifications by attaining an average speed of 42 miles per hour. The airplane was on its way toward taking its vital place in modern warfare.

Another renowned name in aviation history familiar to all of us is that of Glenn Curtiss, the builder of the famous Curtiss aircraft engines, who spent most of his working life experi-

menting with and building engines. About 1908 the idea of an engine suitable to power a plane attracted the keen interest of Mr. Curtiss. Research work was done, experiments were made and corrected, and much progress was made.

Ours was not the only government interested in the new "flying machine." In England, in France, and indeed all over Europe its potentialities for war, for commerce, and for sport were interesting more and more people. In July 1909 Bleriot made the first successful flight from Paris to London; by 1911 the importance of the airplane as a military weapon was generally recognized; and in the years immediately preceding World War I rapid improvements in performance were made.

As was to be expected, the design and manufacture of airplanes was greatly accelerated by the outbreak of the war. In the United States, World War I found us with an air force equipped with 82 planes. The sudden pressing need for military planes forced expansion of sad-

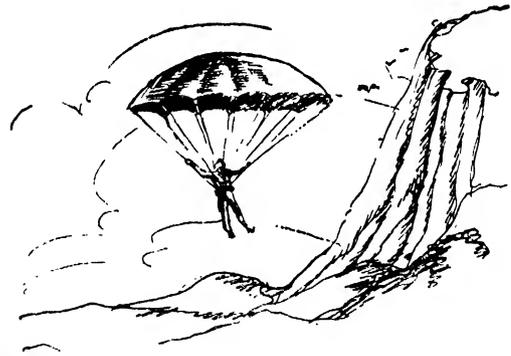


Fig. 5. In the latter part of the 15th century, the notebooks of Leonardo da Vinci included his idea of a "Fall breaker"

ly inadequate manufacturing facilities, and thus mass production of aircraft had its origin.

Though planes were used chiefly for scouting, their importance speeded up progress in design tremendously. In fact the years 1914 to 1918 probably saw advances which would have required 15 years of peacetime progress. In the decade 1910 to 1920, for example, the speed record went from 66.2 to 194.5 miles per hour; the altitude record from 10,170 to 33,114 feet, and the nonstop flight record from 8 hours 13 minutes to 24 hours 9 minutes.

The parachute, too, came in for attention. This device was by no means new—in fact, Leo-

nardo da Vinci's "fall breaker" (Fig. 5) might be considered its ancestor. It, like the airplane, was greatly improved during the war, though not to the extent it has been today.

The barnstorming era, 1919 to 1926, is one of the most colorful periods in aviation history. After the war, there was a great surplus of airplanes available. Former army and navy pilots were able to buy these planes at a very low figure. Many did just that and started out making a name for themselves over the country.

At country fairs and carnivals, these daredevil flyers thrilled us all with such stunts as parachute jumping, wing walking, and changing planes in midair. Later, air circuses, air races, dog fights, sky writing, and other spectacular feats attracted tremendous numbers of people. However, civil aviation still was considered just a "thrilling sport" by the public.

As time passed, these barnstormers began to contribute something real to the progress of aviation. Not only did they help to popularize aviation, but their spectacular achievements furnished stimulus to airplane designers and engineers, and from their ranks came many of the great flyers of their generation.

In general the history of aviation in the United States between World War I and World War II is a record of spectacular exploits and the steady growth of commercial aviation. Until war loomed again in Europe, relatively little attention was paid to military airplanes, and the aviation industry received less encouragement and subsidy from the government here than in many European countries.

Several attempts were made in the 1920's to cross the Atlantic ocean. Many of these attempts were ill-fated. But some were successful, and those successes spurred others on to make further attempts.

Everyone will remember the famous nonstop flight from New York to Paris made by Charles A. Lindbergh in 1927. This flight, the first of its kind to be made, proved that it was possible for a plane to fly long distances nonstop over water. Lindbergh's accomplishment was a prime factor in the development of transoceanic travel.

Wiley Post and Harold Gatty are credited with one of the most colorful feats in aviation.

These two men flew around the world, covering a distance of approximately 15,500 miles in the record time of a little over 8 days.

Many experimental flights have been made from coast to coast for the purpose of setting speed records. Each flight cut down the time, and today airliners and military planes cross the country at greatly accelerated speeds.

Amelia Earhart was probably the most famous woman flyer in aviation history. Her enthusiasm and daring made for her a niche in the aviation hall of fame. In 1935 Miss Earhart set a speed record of 18 hours in a flight from Honolulu to Oakland, California. Several other record-breaking flights were made by this famous aviatrix. On another flight across the Pacific ocean in 1937 Miss Earhart was lost somewhere near the settlement of Lae, New Guinea.

During the 1920's attention was turned to the commercial possibilities of the airplane. The first experiments in this field were made by establishing short air mail routes across the country. These experiments were successful beyond expectations, and, as a result, a vast net of air mail routes spread throughout the nation.

Shortly after the mail routes were established, commercial airlines began springing up here and there. These airline companies carefully considered scheduled operations, passenger comfort, and safety.

No challenge was too great for our airline companies. Constant effort was expended in building better planes and airfields, in working out a transcontinental weather reporting bureau, in blind flying, in establishing safety practices, and in improving service in every way possible.

Now we have sleek, powerful airliners crossing the country at great speeds. These modern planes are provided with every convenience for the comfort and safety of passengers. Before the war, more and more people were using commercial airlines for routine travel, and in the post-war years air travel shows every promise of becoming as common as train or automobile travel. The future of the commercial airlines is truly a great one.

Today we also have huge planes capable of carrying enormous loads of miscellaneous cargo

(Fig. 6). The efficient service rendered by these planes is as valuable in time of peace as in time of war.

The first airplanes, like the first smelly horseless carriages, gave little indication of their vast cargo transport possibilities. Reluctance to employ air freight service has been shown in the



Fig. 6. Cargo ship

past, but its advantages have made themselves apparent, and the public generally is accepting this vital new method of cargo transportation more generally each day.

Modern man demands speed in his travel and in the transportation of the things he uses. Time is money; and the public has been saved a huge amount of money and time that could not be bought at any price by the efficient service of these modern cargo planes. Cargo transport by air is a comparatively new field, but it is certain that this new method of transportation of goods is destined to grow by leaps and bounds.

The tremendous effort of the United States to produce the innumerable implements of modern war is, of course, absorbing the attention of the airplane industry today. Designers, engineers, and industrialists alike concentrate their energies on producing the airplanes needed for war throughout the world. Again, as in World War I, progress in airplane design and manufacture is speeded up beyond calculation.

The airplane today is one of the most important instruments of war. It is used for precision bombing, for strafing enemy lines and communications, for softening up enemy centers, for mass troop movements, and in many other military operations.

Airplanes roll off the assembly lines in staggering numbers. Undreamed-of numbers of our citizens fly them, build them, understand them. The future of aviation is safe and glorious in their hands.

#### WHAT MAKES AN AIRPLANE FLY

*Air*

Many people believe because they cannot see air that it has no weight. This certainly is not true. Air is a mass, a gaseous substance, which has measurable weight, just as water has weight, which has measurable density, and which offers measurable resistance. If we keep this in mind, we will readily and clearly understand the principles of aerodynamics, which is simply the study of air movements and of the forces acting on a plane in flight.

The earth is surrounded to a depth of almost 7 miles by a sea of air whose density varies in relation to altitude above the surface of the earth. At a low altitude the air is relatively thick and heavy; as altitude increases the air is progressively thinner and lighter. A plane can fly comparatively slowly at low altitudes because the greater thickness of the air offers greater resistance. A plane can fly much faster at a high altitude because of the decreased resistance of the thinner air. It follows that a plane can reach an altitude so high that the air will be too thin to support the ship properly. The plane will then begin to wash around sloppily and fail to gain further altitude.

Four aerodynamic forces, thrust, lift, drag, and gravity, act upon an airplane. Thrust and lift help flight; drag and gravity hamper it and

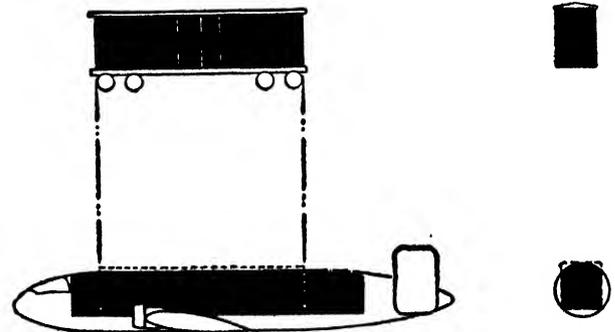


Fig. 7. Comparison of cargo capacity-freight car and cargo plane

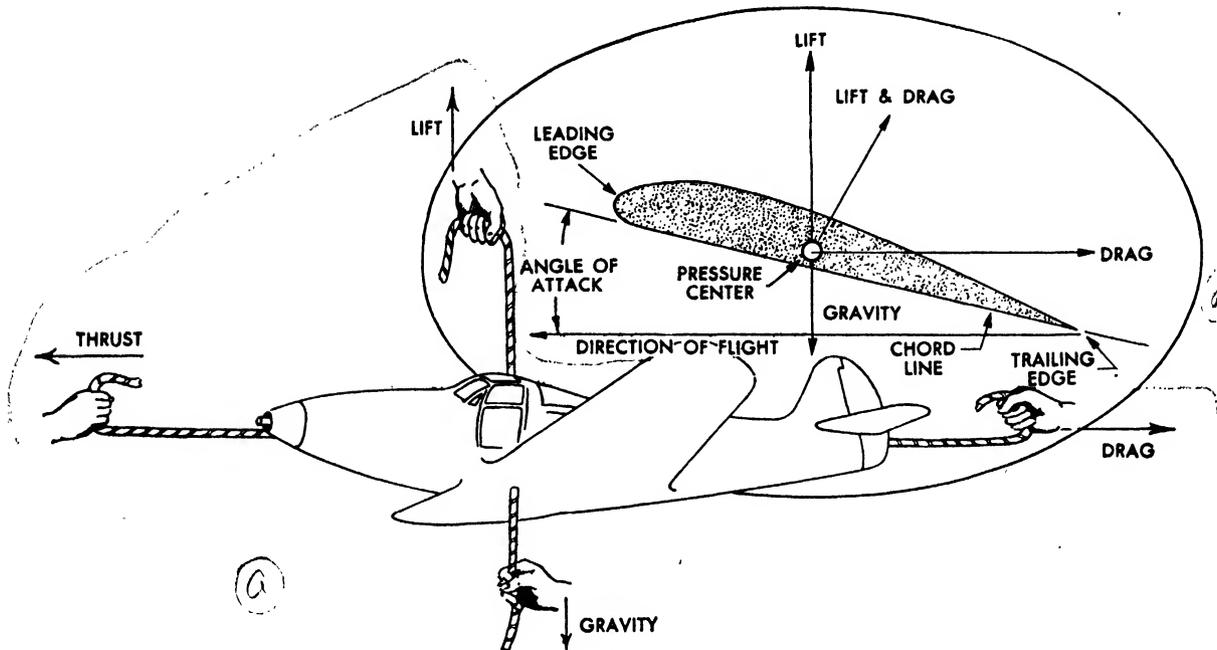


Fig. 8. Forces acting on an airplane

must be overcome in flight. (See Fig. 8.) We shall first discuss thrust.

### Thrust

Most laymen do not understand the function of a propeller. It is generally assumed that the propeller raises a plane from the ground, but actually it is used only to pull the craft forward, producing a forward action called "thrust."

Thrust can be explained by the use of a simple illustration familiar to everyone. All of us have driven a screw into a piece of wood with a screw driver. As the screw is turned, it is driven into the wood, and at the same time is pulled forward. The same thing happens when a propeller begins to turn. The blades are set at an angle so they will cut or bite into the air (like the threads on the screw). When the propeller starts cutting into the air, it produces a screwlike action which pulls the airplane forward.

Thrust may also be obtained by a reaction jet. The principle of jet propulsion may be simply illustrated by inflating a toy balloon with air and then releasing the nozzle. The balloon will be thrown forward as the air escapes from the rear or nozzle end of the balloon. In jet propelled aircraft, the thrust is obtained by a stream

of rapidly moving gas which derives its energy by direct expansion following combustion.

Although jet propulsion promises to take an important part in the development of modern aircraft, the idea itself is not new. Sir Isaac Newton designed a horseless carriage based on a form of glass vessel with a protruding tapered neck. A fire was to be ignited under the water-filled vessel, making the air expand and rush out through the neck; this was expected to drive the carriage forward by reaction.

### Lift

Let us now consider lift, which is another important factor in the flight of a plane. Lift is the force which takes an airplane off the ground and sustains its flight. To understand lift, we must study the wing of a plane. As soon as a plane starts to move forward, air starts to flow around the wing, which is so shaped that this flowing air is forced to exert an upward pressure beneath the wing and also to cause a partial vacuum on top of the wing (Fig. 9). The pressure below and the vacuum above the wing combine to lift the plane.

A common illustration of lift is the reaction of a hand held out the window of a moving auto-

mobile. If a person holds his hand parallel to the ground, his hand merely cuts through the air like a knife with no noticeable reaction. But let him hold his hand at an angle to the ground (angle of attack), and his hand immediately will be swept up and back by the air. The action pushing the hand up is lift.

Another illustration of lift is the suction action of a vacuum cleaner. When there is a vacuum, there is also a suction, because air

mize this tendency, rounded wing tips and tapered plan or top form are used. Modern practice calls for a wing that tapers both in plan and thickness to a small round wing tip. The proportion of the length (or span) of a wing to its width (or chord) is called its "aspect ratio." The average wing has an aspect ratio of from five to eight. In other words, the wing is five to eight times as long as it is wide. Usually, a high aspect ratio makes a wing more stable and efficient.

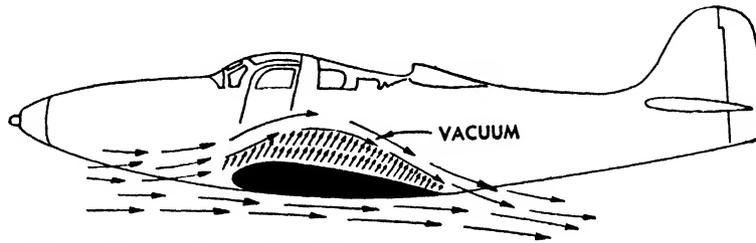


Fig. 9. Flow of air on the wing

rushes in to fill the vacuum. The vacuum cleaner creates a vacuum over the surface on which it moves. Now we have a vacuum and a suction: all that is necessary to cause lift. Under these conditions, let us see what happens to the dirt on the rug or other surface over which the vacuum cleaner is moved. We all know the dirt is sucked up or lifted up into the cleaner. Now we will apply what we already have seen happen in the case of the vacuum cleaner to the airplane wing. Isn't it logical that if this principle works in one place it will work in another? The answer is obvious—the airplane will be lifted up by the suction action produced by the vacuum. Approximately 70 per cent of lift is caused by this partial vacuum, 30 per cent by the force of the air striking under the wing.

The shape of the wing affects lift greatly because air tends to curl around from under the rear edge and disturb the vacuum that has been created above the wing. This is more noticeable at the outer tips of the wing. In order to mini-

### Drag

Now let us consider drag, one of the forces that hampers flight. Drag must be overcome by the propeller.

Resistance of the air to an object passing through it creates drag. The shape of an object determines how much resistance it will meet in passing through the air. (See Fig. 10.) If a flat, ball-shaped, or other unstreamlined object is projected through the air, the air attempts to pull away from it, causing a partial vacuum behind the object. Then the air tries to return to the low-pressure area created behind the object by the vacuum. Unevenness, resistance, and drag are caused by that action, and there is a suction behind the object tending to pull it backward. As we can see, this suction slows the speed of the object very noticeably.

A streamlined object resembling a raindrop meets with considerably less resistance than a flat or ball-shaped surface because streamlining decreases the low-pressure area behind it. The

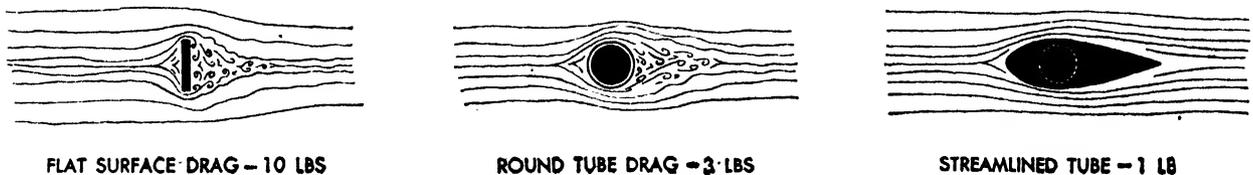


Fig. 10. Comparison of drag

backward resistance also is lessened, of course, and a remarkable increase in the speed of the object results.)

There are many parts on a plane that hold down its speed. Plowing down of air by a wing causes drag. As we already have seen, the shape of a wing determines the amount of drag, so we have long, narrow, tapered wings which produce relatively little drag. Protruding rivet heads cause considerable drag, but this resistance is overcome by countersinking the rivet heads so they do not extend past the surface of the ship. The landing gear, too, creates considerable drag. Retractable landing gear which fold up into the wing of a plane after it leaves the ground increase speed to a very satisfactory degree. From these illustrations of drag, we can see the vital importance of streamline design in an airplane.

### Gravity

Gravity is the last of the forces acting on a plane in flight. Since its action is familiar to all of us, we will mention it only briefly. Just as gravity, the magnetic attraction of the earth, pulls a thrown ball back to the ground, so it pulls down an airplane. In this respect weight in an airplane is critical. In order to minimize gravity, a plane must be as light in weight as

possible. Lift is the force that counteracts the force of gravity and holds the plane up in the air.)

### The Three Axes

(A plane moves in many directions and must balance on three different axes (Fig. 11). The first of these is the longitudinal axis—an axis running from the nose to the tail. When a plane moves about this axis, it rolls to one side or the other. This movement, called “banking,” is regulated by the ailerons, which are sections located on the rear or trailing edge of the wing. The ailerons are moved up or down by moving the stick from left to right.)

(The lateral axis of an airplane runs from wing tip to wing tip. When a plane moves about this axis, its nose moves up or down. A plane climbs or dives on this axis. Movement about the lateral axis is regulated by the elevators, which are sections located on the horizontal portion of the tail. A pilot moves the elevators up or down by moving the stick forward or backward.)

We are concerned next with the vertical axis of a plane. When the plane is in a normal position, this axis runs through the ship vertically. A plane flying level moves from left to right on the vertical axis. The rudder, which is attached to the vertical section of the tail, regulates the

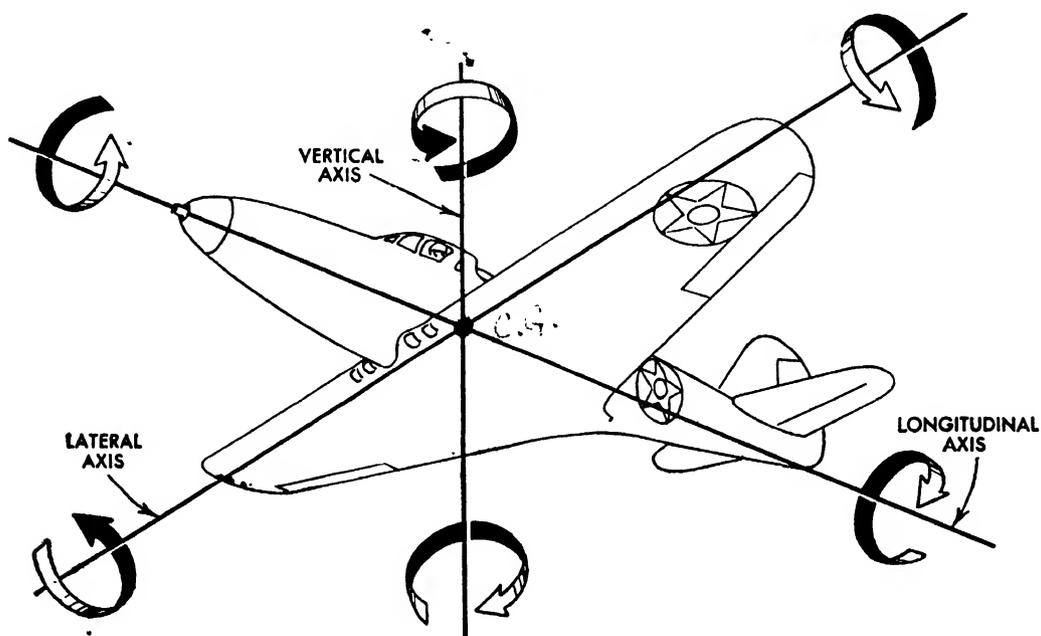


Fig. 11. The three axes

AIRCRAFT DRAFTING

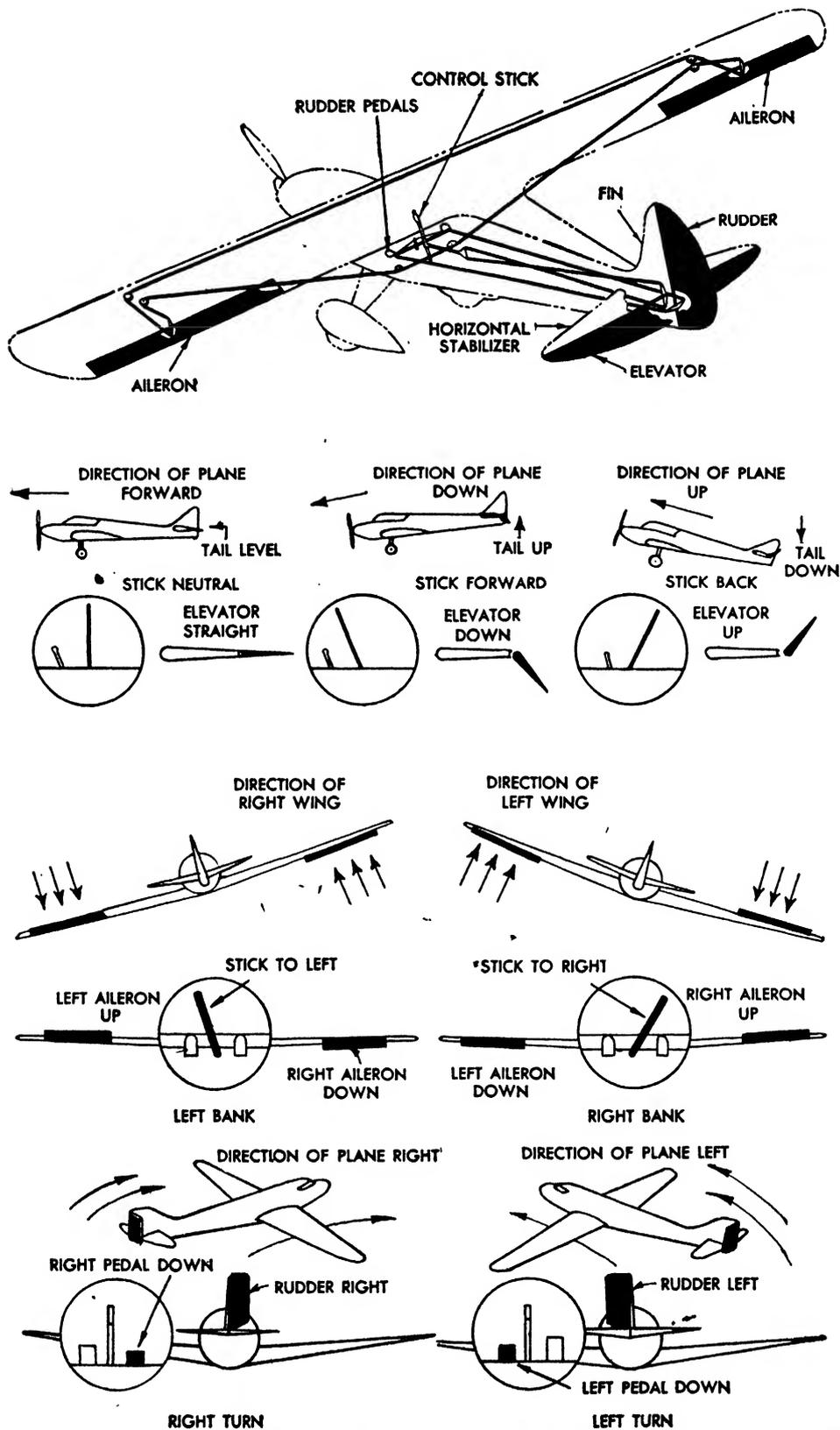


Fig. 12. Pushing the control stick forward or backward works the elevators. Moving it from left to right controls the ailerons. Pushing on the right rudder pedal or heel rest directs the rudder to the right as the left pedal will direct it to the left. All controls are coordinated for proper maneuvering

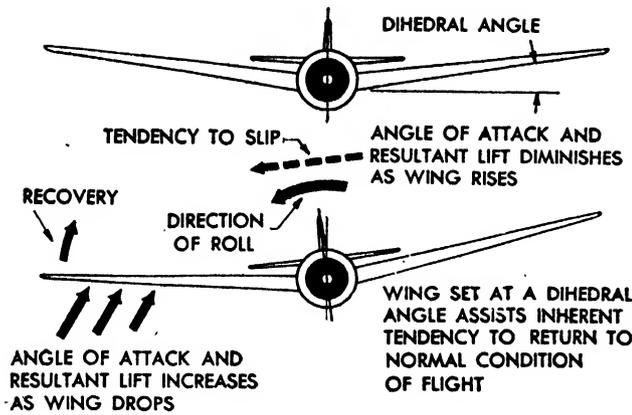


Fig. 13. Angle of dihedral

movement on this axis. If a flyer wants to turn his plane to the left or right, he pushes down the left or right rudder pedal. Figure 12 illustrates the principles of controlling a plane in flight.

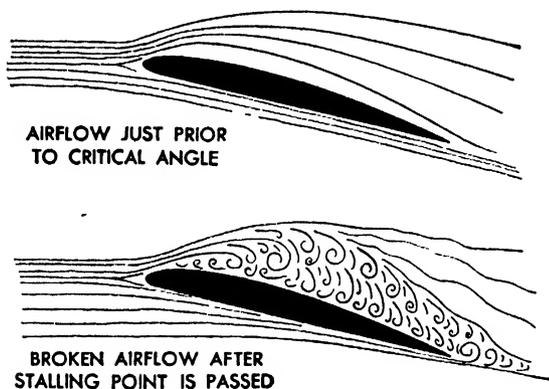


Fig. 14

*Stability*

Let us now consider the stability of an airplane on these axes. A plane may be stable on one axis and unstable on the others, or vice versa. Longitudinal stability is controlled by the area and location of the tail surfaces relative to wing surfaces and the placement of both in relation to the center of gravity, which is the point of intersection of the three axes.

Stability around the longitudinal axis, or lateral stability, is gained by wing dihedral. The angle of dihedral of a plane is the angle at which a wing is placed on the body or fuselage. In other words, the wing is not placed so that its surface is flat and parallel to the ground but is set at an upward angle of approximately 2 to 6 de-

grees to the ground (Fig. 13). This wing placement helps to create lateral stability.

Directional stability is the term applied to stability on the vertical axis. The design and the shape of the fuselage, as well as the action of the horizontal and vertical stabilizers, assist the plane in maintaining a true course.

To make it possible for fast airplanes to land at safer and lower speeds, flaps and slots are used. Slots are openings parallel to the leading or front edge of the wing. During normal flight, these slots are part of the leading edge. The moment the plane reaches the stalling speed, caused by the air striking the wing at too large an angle, these slots open, allowing the air to pass through the opening and over the surface of the wing (Figs. 14 and 15). This flow of air prevents the air above the wing from churning or bubbling and

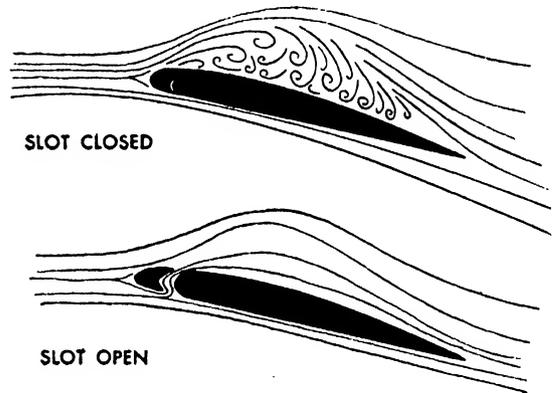


Fig. 15. Slots

destroying the lift created by the vacuum on the wing top.

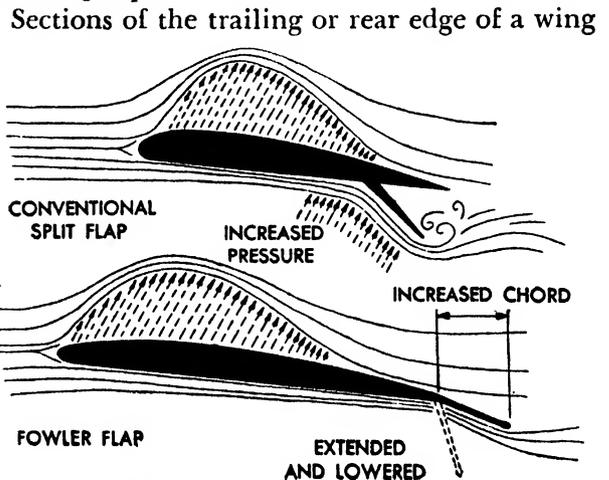


Fig. 16. Flaps

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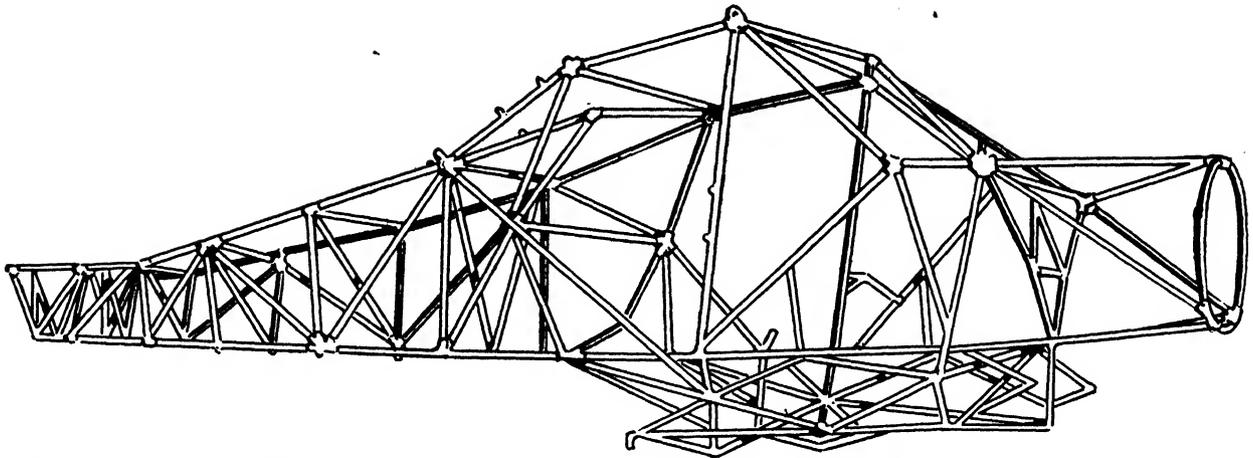


Fig. 17. Truss type of fuselage

which can be lowered by the use of hinges, or similar methods, are called "flaps." Flaps are used to lower the landing speed of an airplane. The flaps are designed to act as aerial brakes. When lowered, they present a large frontal area, causing drag which slows the speed of the ship. Fowler flaps are sometimes used. These flaps extend outward, conforming with the shape of the wing and thus increasing the width or chord of the wing. This gives the wing more area and,

consequently, more lift. By using flaps, a plane is enabled to travel through the air at a lower rate of speed. We see now that slots and flaps are very important in the flight of an airplane.

#### THE ANATOMY OF THE AIRPLANE

##### *The Fuselage*

The fuselage is the body of the airplane. It houses the pilot, crew, passengers, fuel, and cargo. The fuselage must act as a support for the

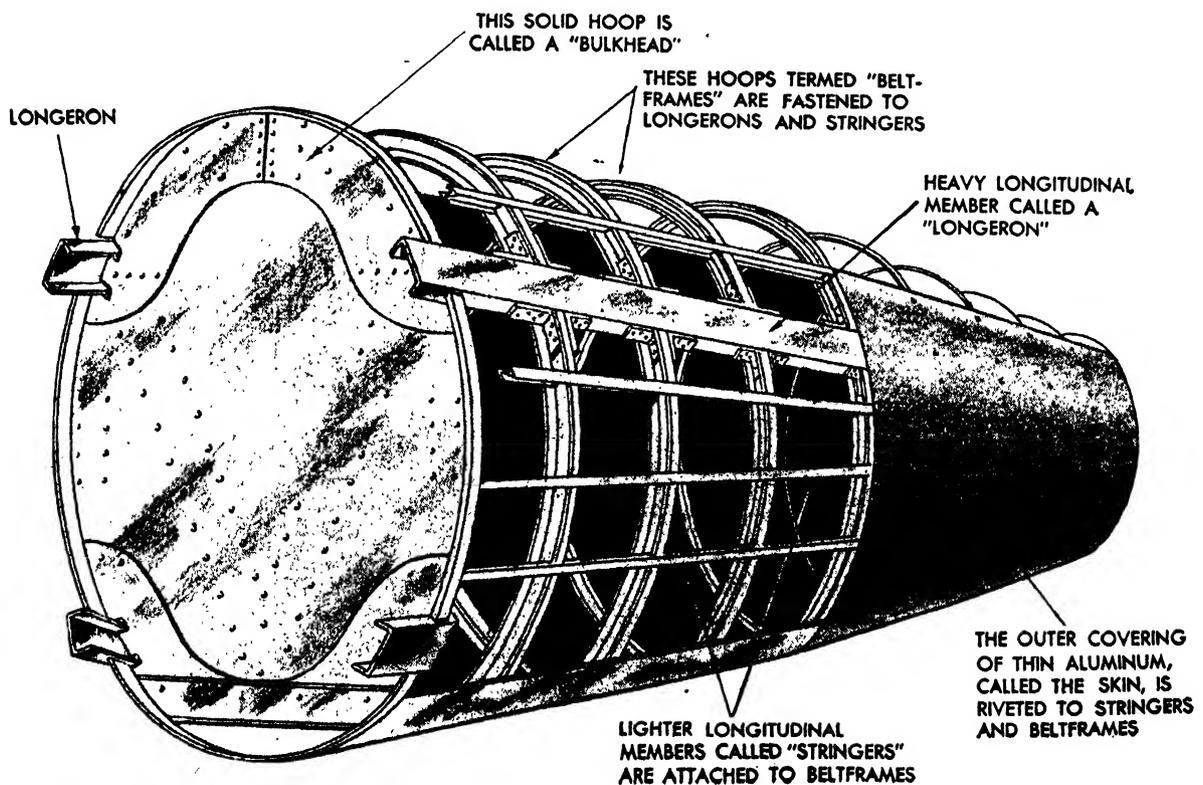


Fig. 18. Semimonocoque type of fuselage

empennage or tail group, the wings, sometimes the engine and landing gear, and other protruding parts of the plane. The body of a flying boat is called the "hull." It is interesting that this term, like a great number of typical nautical terms, for instance, keel, chine, bulkhead, and stringers, has been carried over to aircraft construction from the older shipbuilding industry.

On large modern bombers now under construction, provisions are made to house a ten or eleven man crew in compartments, enclosures,

or cabins. Bombers are designed to carry great loads of explosives, and numerous gun stations and turrets are installed for defensive operation.

Cargo and transport planes with large fuselages, capable of carrying over 500 passengers and many tons of cargo, are being designed today.

Fuselage construction may be broken down into three predominant classes.

The "truss" type consists of a welded tubular structure covered with linen or cotton fabric.

The "monocoque" type consists of a strong

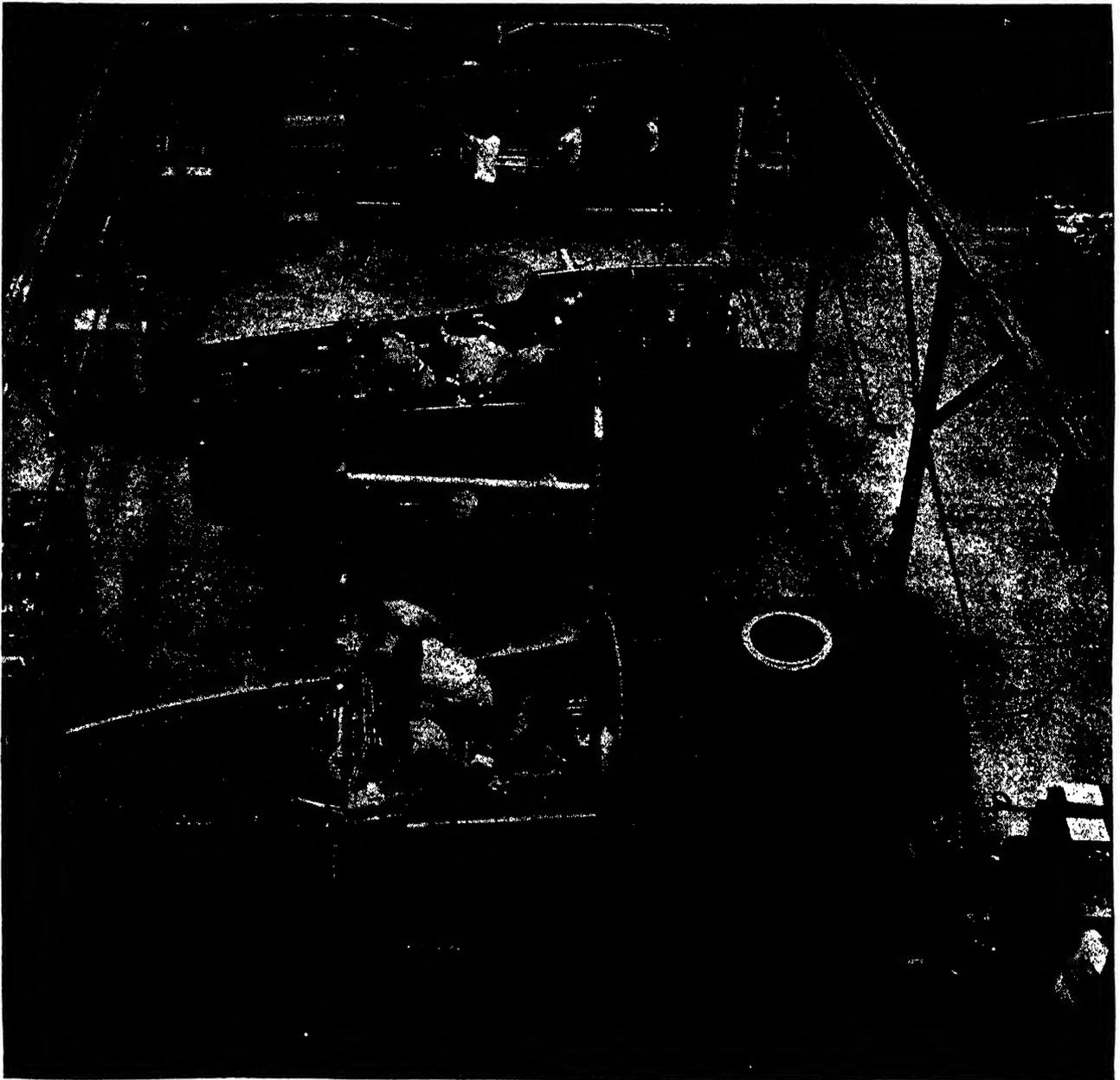


Fig. 19. Nose section of the Consolidated B-24 fuselage being assembled. Note the top section assembly in the rear

outer skin or shell, from which the fuselage primarily derives its strength.

The "semimonocoque" type is the more popular fuselage construction. The strength is obtained by aluminum skin reinforced by stringers, longerons, beltframes, and bulkheads.

Beltframes are either rims of sheet metal stock that have been bent and flanged in one operation on a hydropress to conform to the contour of the plane; or channels, angles, or standard parts formed to fit the desired contour.

Before the frames are bent, cutouts are made so that the longerons and stringers (longitudinal pieces) may pass through and be attached to the frame.

Bulkheads are solid or semisolid frames used for the same purpose as the beltframes but

placed where the greater stresses are likely to occur or at any point in the fuselage that requires special strength and solidity.

The fuselage is generally built in three sections or assemblies, the nose, the center section, and the aft section. When the assemblies are completed they are joined to form the entire fuselage. (See Figs. 19, 20, and 21.)

### *The Wing*

The wing (Fig. 22) is the main supporting part of the airplane. Wings must be light in weight yet strong enough to absorb punishing stresses in flight. They must support the weight of the engines and on many craft house the landing gear and fuel tanks.

The front portion is called the "leading edge,"



Fig. 20. Aft section of B-24 fuselage being transported by overhead crane to final assembly



Fig. 21. Internal view of B-24 fuselage. Note the type of frame, stringers, longerons, stringer cutouts

the rear portion, the "trailing edge." The top curvature is called the "upper camber," the bottom curve, the "lower camber." The wing root is that part of the wing which joins and is rooted in the fuselage. The wing extremity is called the "wing tip."

The major components of the wing are the ribs, bulkheads, spars, stringers, and skin.

The ribs (sometimes called "fish" because of their shape) supply lateral strength and determine the contour of the wing. The spars offer longitudinal support and are the principal structural members. The spar nearest the leading edge is called the "front spar" (F. S.), and the "rear spar" (R. S.) is close to the trailing edge. When weight resting on the wings warrants additional strength, intermediate spars may be added. Flaps are movable parts hinged on the trailing edge of the wing to facilitate lowering the speed at landing. The aileron is a movable

section of the wing that controls the banking of the plane. It is composed of ribs and a spar and is usually fabric covered. It is hinged by its only spar, which is its leading edge, to the rear spar of the main section of the wing.

On the monoplane the aileron usually extends about half the distance from the wing tip to the fuselage in length and is located a few inches away from the wing tip. On biplanes, ailerons may be placed on the upper or lower wing or on both wings.

The wing, like the fuselage, is constructed in sections or assemblies (Fig. 23). The inner, main, and outer sections are joined with the ailerons, flaps, and wing tip into the resultant wing.

#### *The Tail Group*

The tail group or empennage (Fig. 24) situated on the aft end of the fuselage consists of

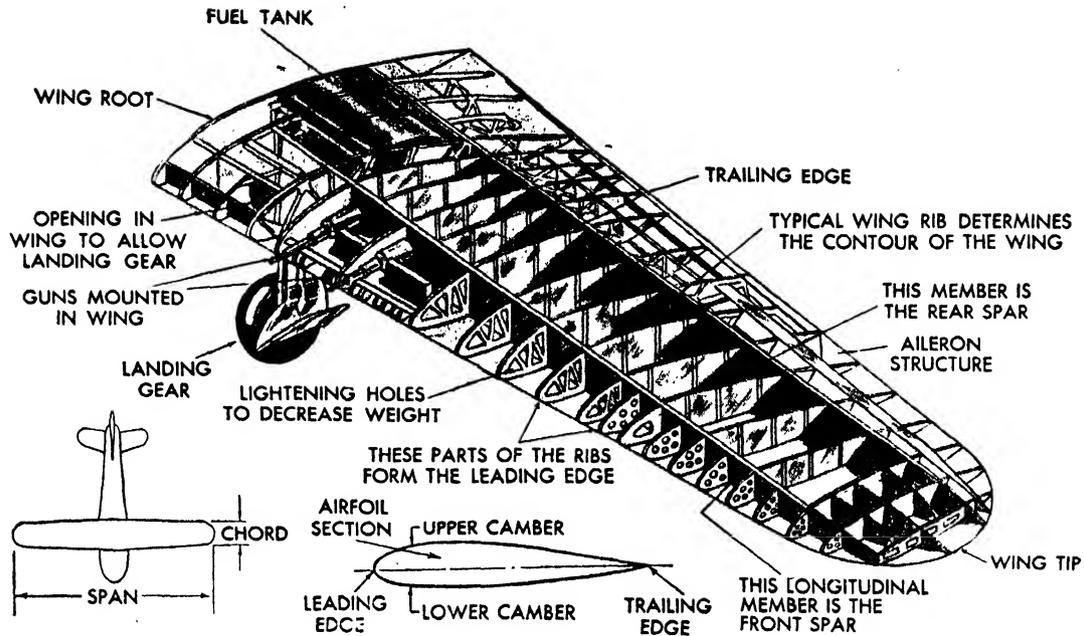


Fig. 22. The wing

the horizontal stabilizer, vertical stabilizer or fin, rudder, and elevators.

The horizontal stabilizer functions just as its name implies. Without the stabilizer the entire tail section would flap up and down, and the craft would lack control. The horizontal and vertical stabilizers are immovable. They are either bolted to, or an integral part of, the fuselage. The movable surfaces of the rudder and elevators are hinged to the stationary vertical and horizontal stabilizers, respectively.

On some planes the horizontal stabilizers support the entire assembly of the vertical fin and rudder. The tail groups of our modern planes are internally braced; that is, there are no struts, wires, or braces supporting the protruding parts of the ship. To insert the bracing internally necessitates an airfoil of somewhat deeper cross section.

The vertical stabilizer tends to keep the direction of the plane stable. It serves the same purpose as the feathers on an arrow. The Boeing Flying Fortress uses a type of vertical stabilizer called the "dorsal fin," which has a long gentle slope, tapering well into the fuselage.

The rudder serves to turn the ship to the right or left. It is controlled by two pedals similar in appearance to clutch and brake pedals on the automobile. Control cables connect the

rudder pedals and the rudder. When the left rudder pedal is depressed, the plane turns to the left, etc. The rudder is usually secured to the vertical stabilizer by hinges.

Elevators attached to the horizontal stabilizer determine the ascent or descent of the plane. The leading edges of the elevators and rudders are hinged to the trailing edge of the stabilizers. A typical construction and assembly of the tail group members are shown in Figs. 24 and 25.

The components of the tail group are somewhat similar in construction to the wing as they require ribs to determine their contour and a spar or spars for rigidity. The movable surfaces of the rudder and elevator are generally fabric covered, even in many all-metal craft. The reason for the use of fabric is its lightness of weight, which will move the center of gravity of the surface nearer the leading edge and hinges. This increases the maneuverability of the section and considerably minimizes the tendency to flutter or vibrate that is typical of metal-covered sections.

### Landing Gear

Landing gear may be of the stationary or retractable type (Fig. 26). The stationary type is seldom used except on private or training planes because the excessive drag caused by the pro-



Fig. 23. Assembly of B-24 wings

trusion of the fixed gear results in considerable loss of speed.

Tires must take great punishment and are consequently of the heavy-duty type (Fig. 27). Landing gear brakes facilitate ground maneuverability and have become standard equipment of almost all modern aircraft. Shock-absorbing devices also accompany the gear to allow landings without damage or distortion of the airplane structure.

#### TYPES OF AIRCRAFT

Aircraft may be classified into two basic categories: landplanes and seaplanes. These groups may again be divided into a great variety of types depending on their purpose and functions and the predominant characteristics of their construction, for example, the number of engines,

placement of engines, type of wing, type of landing gear, or whether the craft is propelled by jet propulsion or by conventional engines.

Landplanes and seaplanes (commonly referred to by the shorter names "planes" and "ships" respectively) consist primarily of military, commercial, or personal craft. A similar classification in the automotive industry would be tanks, trucks, and pleasure cars.

The names of military planes are characteristic of their functions. Thus we have fighters or pursuits, heavy, light, attack, and dive bombers, scout, observation, and trainer craft.

Cargo or commercial craft are used in peacetime to transport passengers and merchandise, and they fill similar military needs.

Personal craft, smaller and less expensive,

# AIRCRAFT DRAFTING

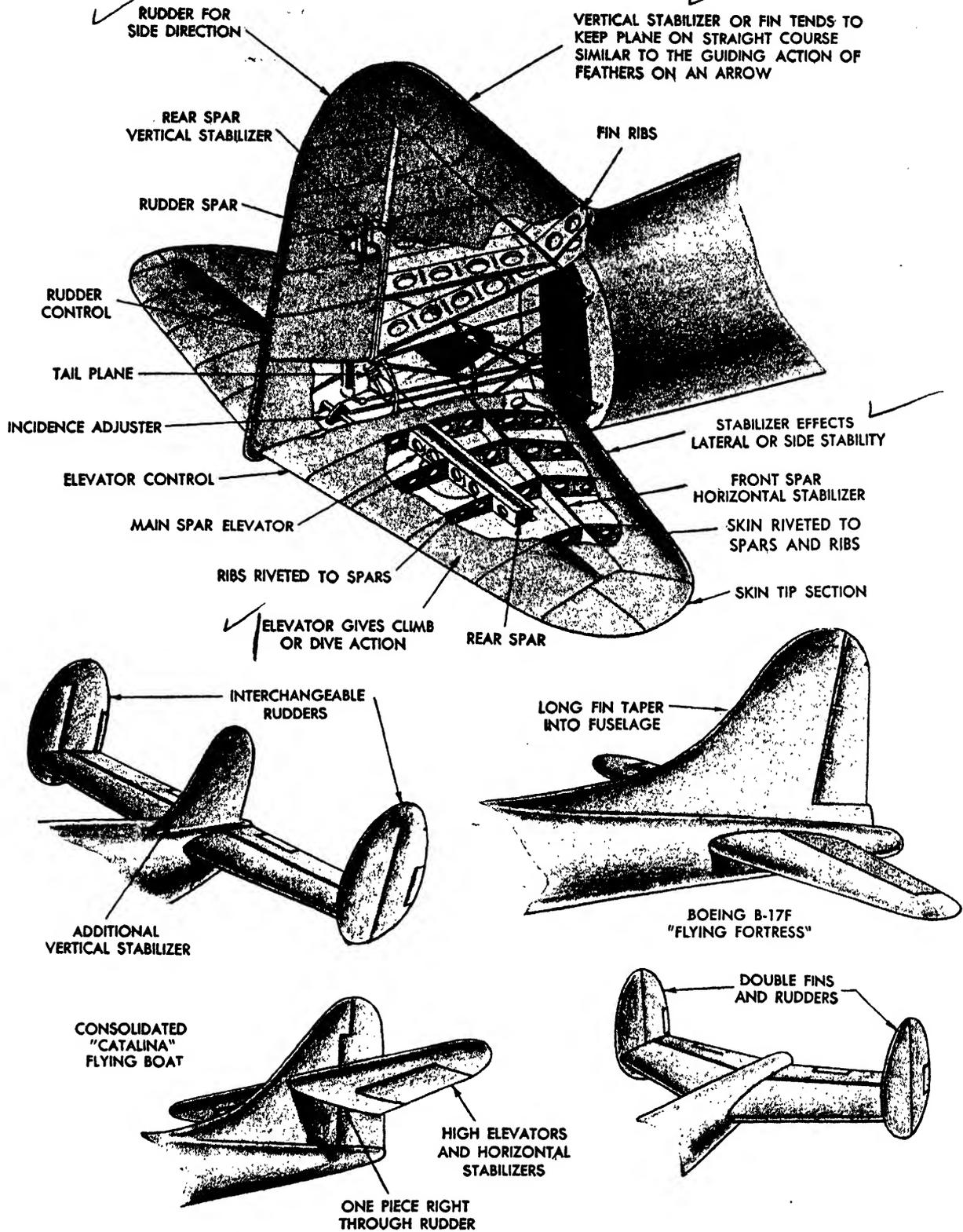


Fig. 24. The tail group

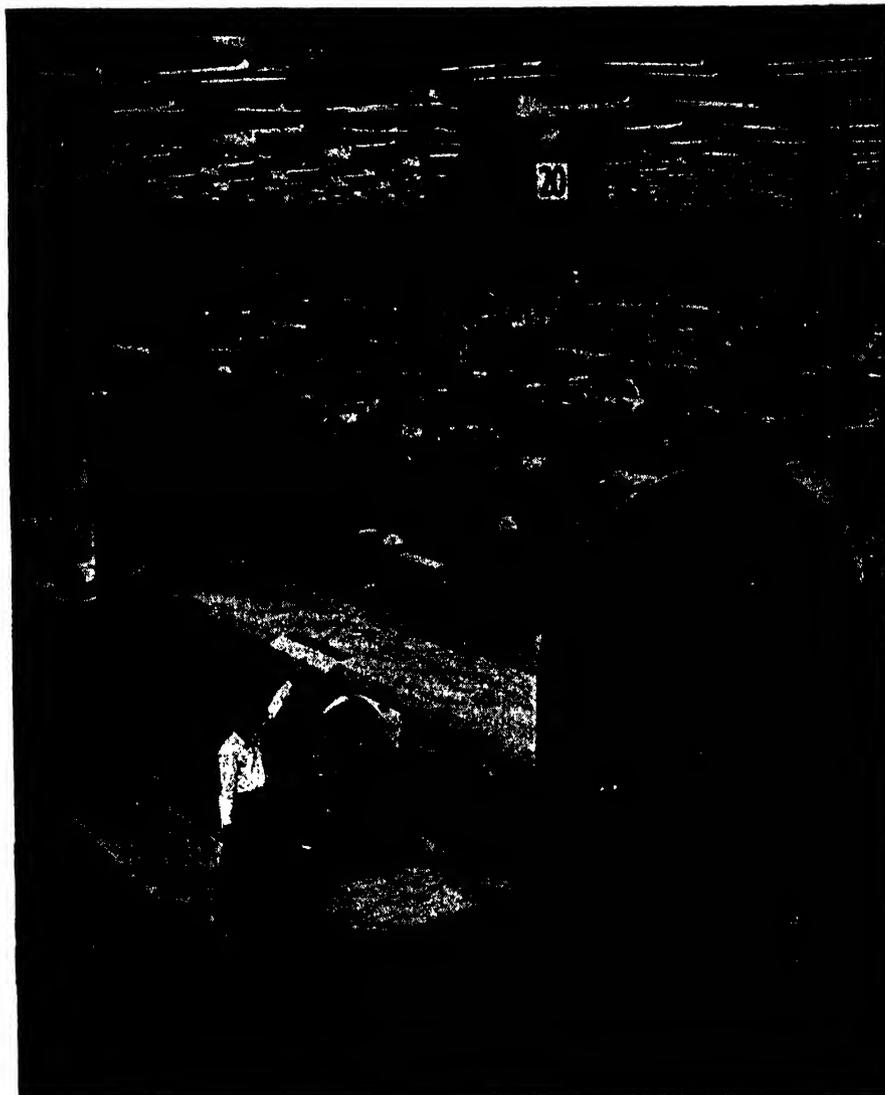


Fig. 25. Empennage of B-24 being lowered by overhead crane on final assembly

serve much the same function as the everyday automobile and will take its place as a common means of personal transportation.

When an airplane is powered by one engine, usually fixed to the nose of the fuselage, it is called a "single engine" plane. Two engines, usually mounted on the wings, characterize a twin or bi-engine plane. Any craft of more than two engines is called a "multi-engine" plane.

Planes whose engines are mounted on the leading edge of the wing or in the nose of the fuselage are termed "tractor" planes, as the engines tend to *pull* the planes forward. Engines are sometimes mounted on the trailing edge of the wing, and because they tend to *push* the planes forward, the planes are said to be of a

pusher type. The pusher propeller throws the plane forward much as does an outboard motor on a boat. The chief reason for pusher propeller design is to offer a wider range of vision for the pilot. Tractor engines have proved to be more effective when mounted on the nose of the fuselage of single engine planes. The pusher type is adaptable mainly on multi-engine craft. Some large cargo planes under construction are of the pusher type.

Helicopters and autogiros are usually powered by large propeller blades or rotors mounted horizontally above the fuselage and wing. The rotation of these blades about an approximate vertical axis enables the craft to climb or descend in a vertical direction.

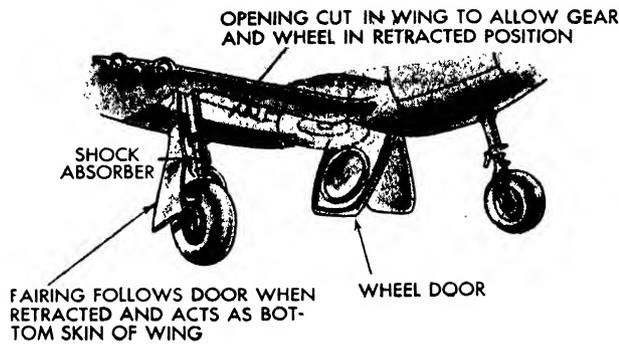


Fig. 26a. The original Wright brothers craft had no landing gear but slid along on a greased runway to take off. The advent of landing gear naturally made landing and take-off easier. Because of the drag caused by the fixed gears they are now retracted into the wing

A biplane has two wings, that is, double wings; the left and right wings of a plane are often spoken of together as a "wing." Biplane wings are attached to the fuselage and braced by wires and struts. A monoplane has one wing. The monoplane wing may be braced to the fuselage externally, that is, by supporting struts, or the union of the wing and body may take place within the fuselage or superstructure area. This type is referred to as a "cantilever" wing. Wings are designed in a wide variety of schemes and shapes (Fig. 31) and may be attached to different levels of the fuselage or hull.

Airplanes are sometimes basically described by the type of landing gear. Planes have been built with one, two, three, and four wheels or skids. The most popular undercarriage is the tricycle type, two main wheels and a third supporting wheel at the nose or tail end of the fuselage.

To take off and land, seaplanes use floats attached by struts or other means to the bottom of the hull or wing. Flying boats alight and land on their hulls. Amphibian planes are designed for both land and sea use. They have hulls like flying boats, but are also equipped with wheels that retract into the hull.

Skiplanes are used for snowy or icy terrain. Gliders are heavier-than-air, engineless craft that may be manipulated to some degree by control surfaces but are dependent in flight on air currents. Gliders may be towed by aircraft, providing transportation for more cargo and men than the aircraft alone could carry.

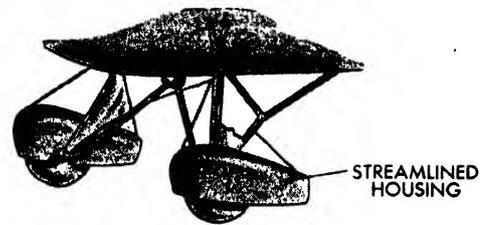


Fig. 26b. Fixed landing gear. Although many of the smaller planes still retain the nonretractable fixed gear, an attempt has been made to embrace them with a streamlined cover to decrease drag as much as possible

#### THE DRAFTSMAN'S RELATIONSHIP TO THE AIRPLANE

The aeronautical engineering draftsman has a most important role in the development and completion of a new airplane. Without him it would be impossible to produce a modern airplane, because the day is long past when a new design could be made to take shape without a complete set of drawings. However, the draftsman must depend on many groups of men for the information he needs. Some of these are executive, preliminary design, development, consultation, and design groups. In order to picture more clearly the complexity and interdependence of the various groups of engineering

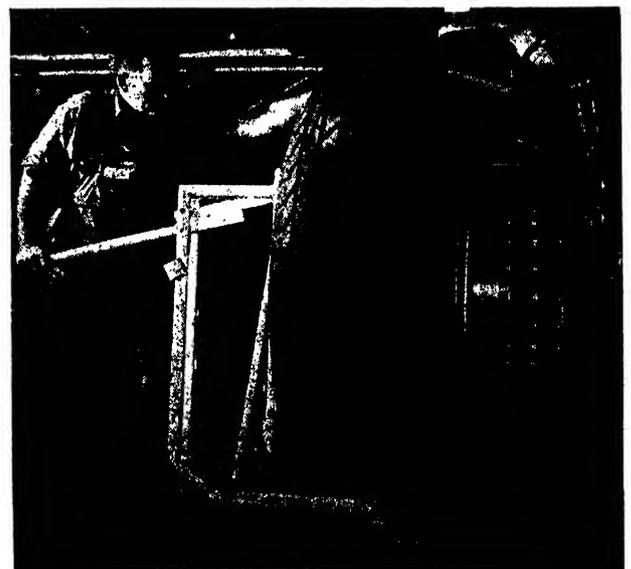


Fig. 27. An interesting comparison of the size of a man and the tire of a Liberator

personnel, we present a "Flow Chart of Engineering Information" (Fig. 34), taken from the Glenn L. Martin Company's "Engineering Lecture No. 14," along with comments on the general scheme and duties of the engineering groups in most aircraft companies.

The conception of any new airplane generally begins with the customer, who may be an army or navy, an airline company, or a private individual. A customer who wants a new airplane designed and produced invites one or more aircraft companies to bid on it by submitting preliminary drawings and estimated cost sheets.

As soon as such an invitation is received by a company, its executives and chief engineer discuss the specifications as set up by the customer and decide whether or not the design would be worth undertaking. If it is agreed to submit a design for the airplane in question, the chief engineer in conjunction with the planning and development (preliminary design) groups work out a tentative plan.

The planning group prepares all engineering time estimates, schedules, and costs; the development group interprets the specifications and prepares layout drawings for the general design. The product of these two groups, the proposed design and an estimate of time and cost, is then submitted to the customer.

If the customer accepts the proposed airplane, the actual work of detail design is begun. The development group makes such changes as are required at this time, and then the specifications, schedules, and preliminary proposals are turned over to the chief project engineer. He and his staff of project engineers organize the various project design groups and supervise detail design. Each of the project design groups (wing, tail, hull or fuselage, etc., as shown on the flow chart) has a group leader or group engineer. These group engineers coordinate their work directly with the project engineers, and they supervise the detail design and drafting work in their own groups. Each group engineer and his men must also work in close harmony with the other groups so that a complete and congruous airplane will result.

The chief draftsman works with all the project design groups; it is his responsibility to see that

all drawings are prepared according to company policy and to supervise all checking.

There are also several supplementary, but highly important, groups in an engineering department whose duties are to supply necessary information to the project engineers and the project design groups. They are called consultation and design groups or general design groups, and some of them are the laboratory, weights, and structures as shown on the flow chart. In general, their work is research.

When the information from the project engineers and consultation groups reaches the group engineers of the project design groups, it is turned over to the aeronautical engineering draftsmen whose duty it is to translate the data into tangible permanent records—engineering drawings. This translation is no small task, for it involves a great deal of detail designing, redesigning, and changing, as well as accurately making all the thousands of detail drawings in such an unmistakable fashion that the men in the shop will be able to build a good airplane.

As the detail drawings are finished, they are signed for release by the group checker, group engineer, structures, and project engineer. They are then sent to a special group called the release group, which records all drawings and parts required, orders material, and issues blueprints of the drawings to the shop for fabrication.

One more special group is the liaison group who coordinate all supplementary information between engineering and the shops.

Thus each of the many divisions in an engineering department, as well as every individual member of it, plays a small but vital part in the materialization of a new airplane.

Opportunities for the draftsman are great. His function no longer is merely to "copy" drawings. He is given opportunity to exercise his own ingenuity and constructive imagination. Because he combines the analytical and creative qualities of the engineer with his drafting skill, he is now termed a "draftsman-engineer." Never in industrial history has such intensive training, education, and assistance been given engineering employees as in the aircraft industry. The engineering draftsman has a great opportunity to make a permanent place in this great new industry.

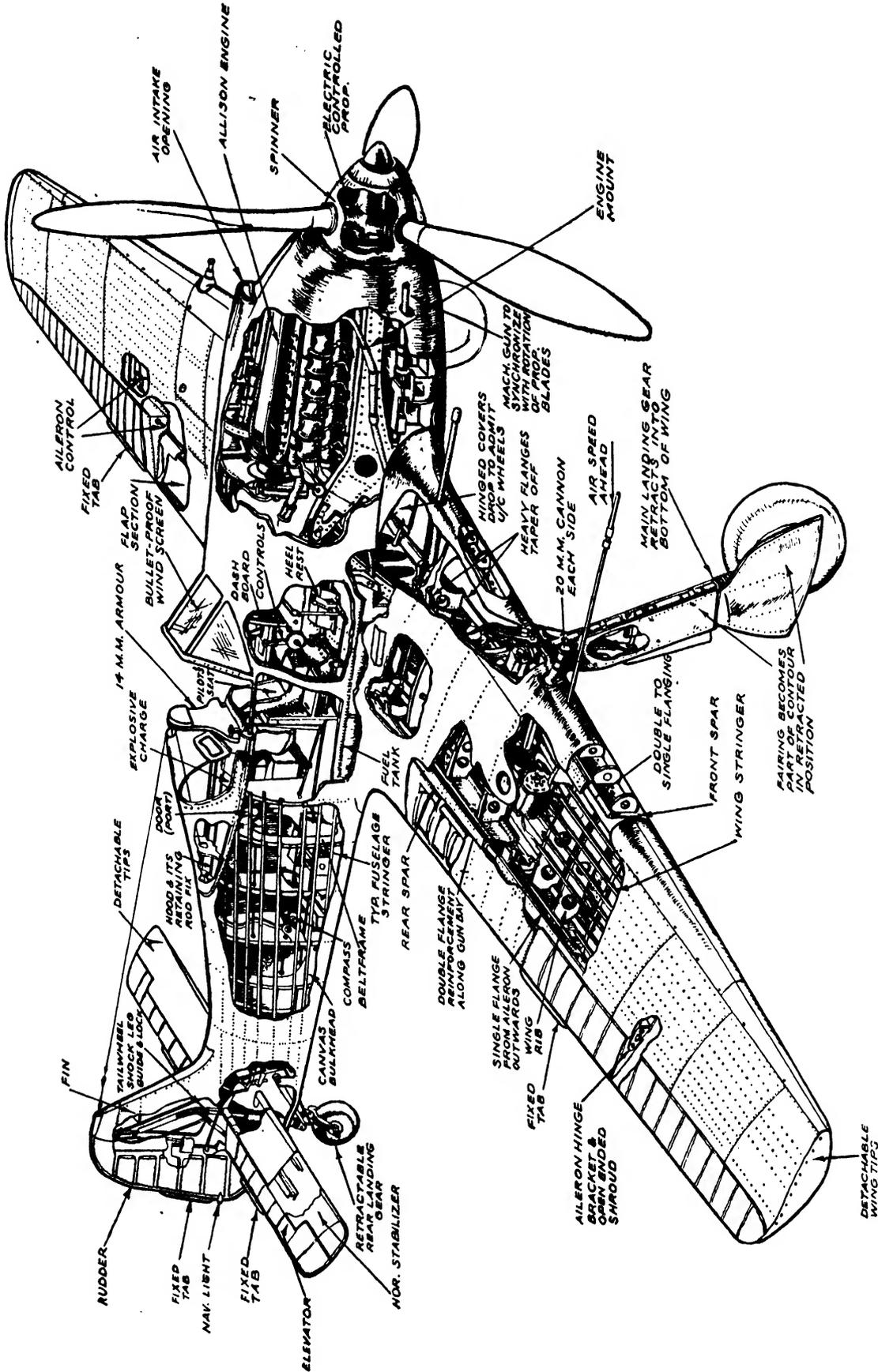


Fig. 28. Anatomy of a pursuit plane

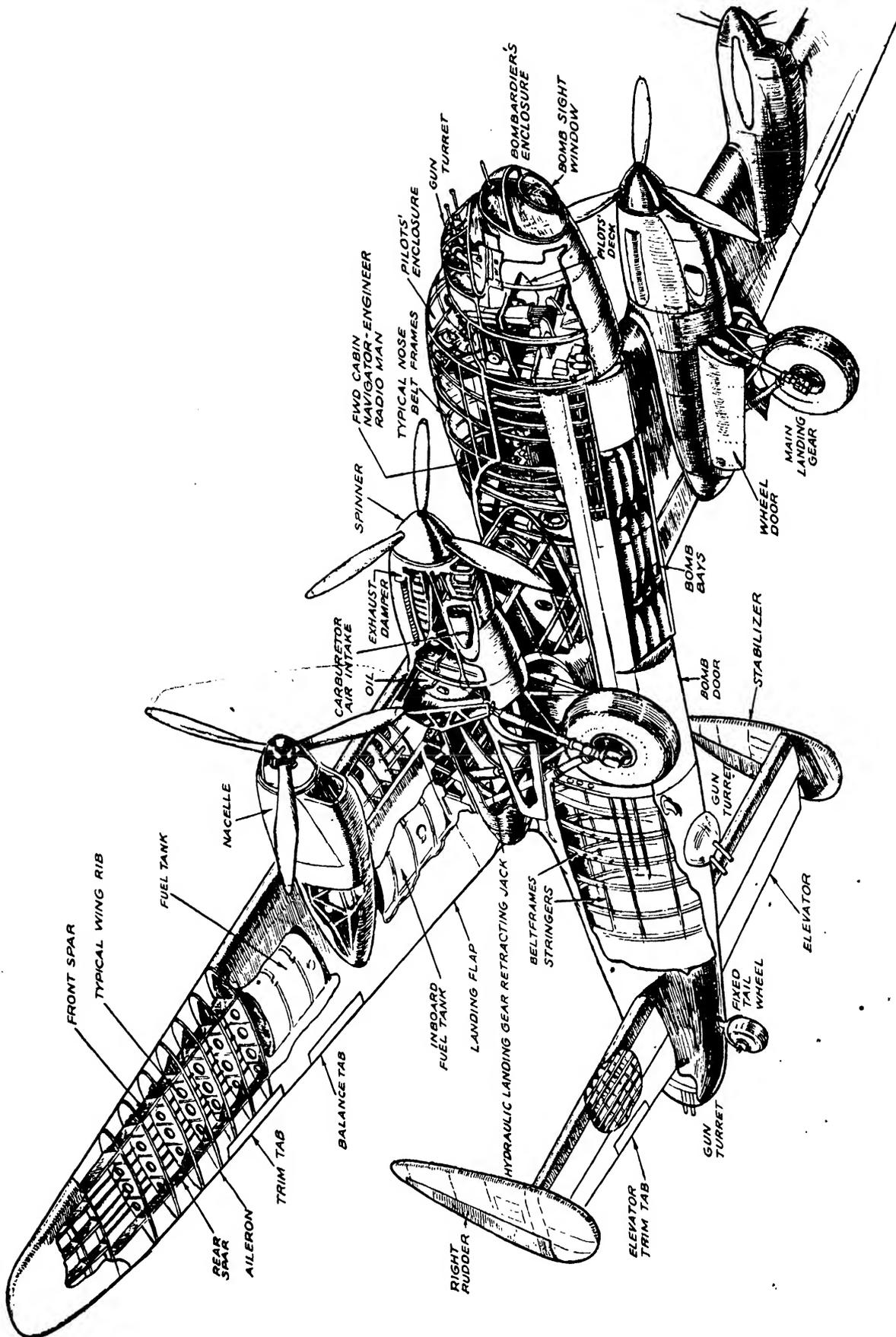


Fig. 29. Anatomy of a bomber.

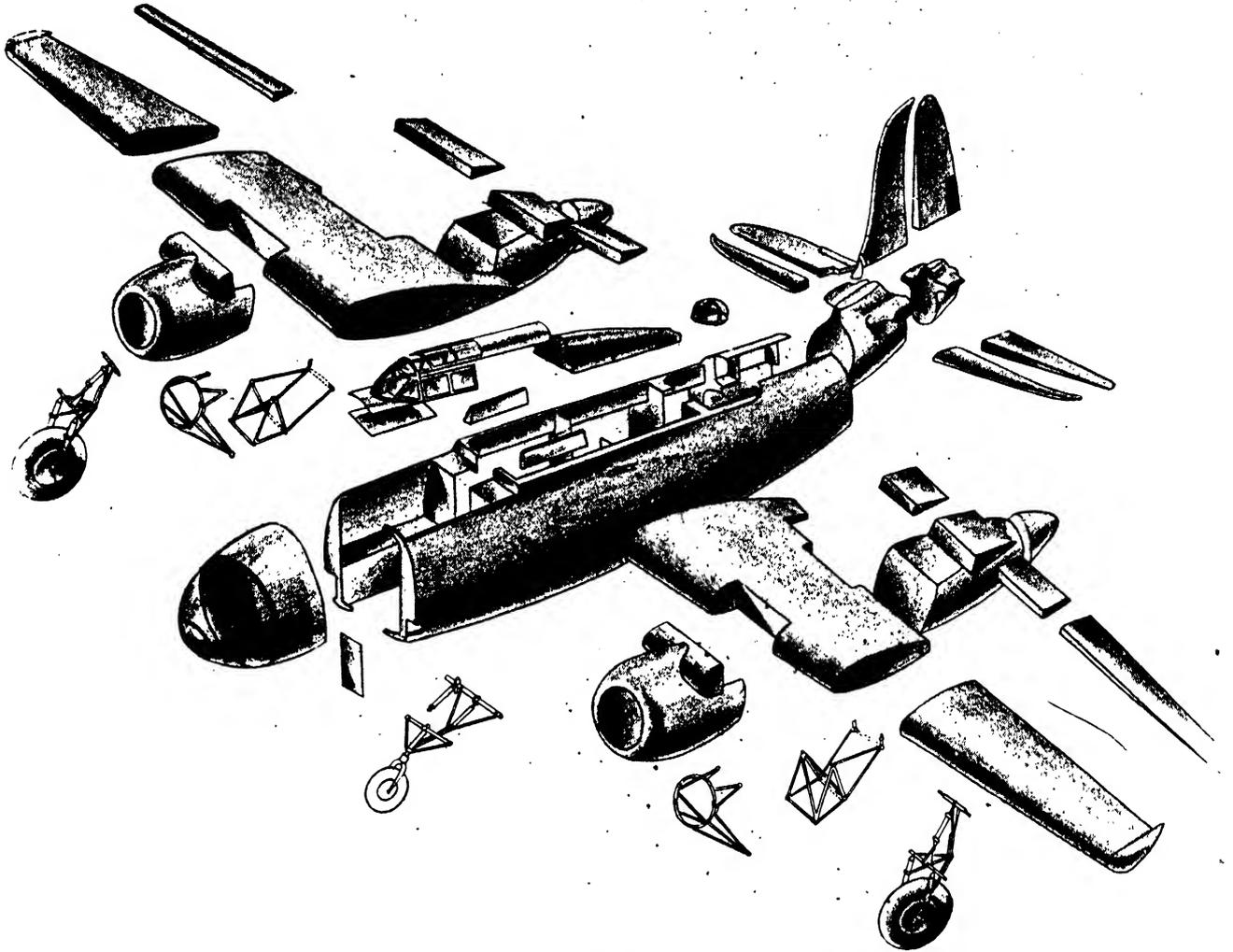
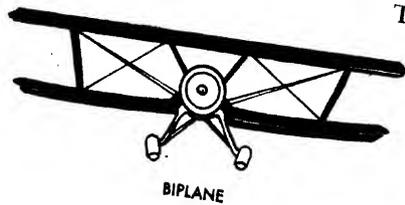
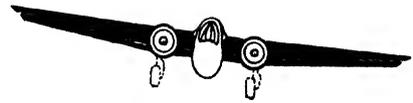


Fig. 30. An airplane is composed of thousands of parts. Groups of parts are fastened together to form small units or assemblies. These assemblies in turn are incorporated into larger assemblies—wing or tail sections. This production breakdown shows the various sections that compose a light bomber



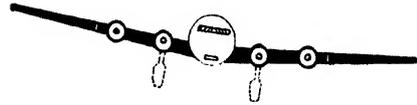
BIPLANE



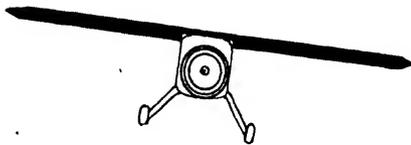
TWO ENGINE, LOW-WING  
CANTILEVER MONOPLANE



HIGH-WING MONOPLANE



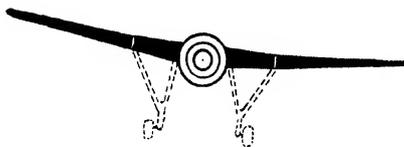
FOUR ENGINE, LOW-WING  
CANTILEVER MONOPLANE



HIGH-WING  
CANTILEVER MONOPLANE



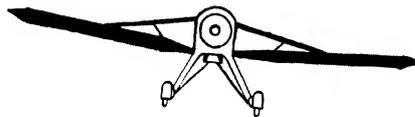
SEMICANTILEVER  
FLYING BOAT



MIDWING  
CANTILEVER MONOPLANE



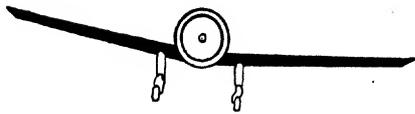
CANTILEVER FLYING BOAT



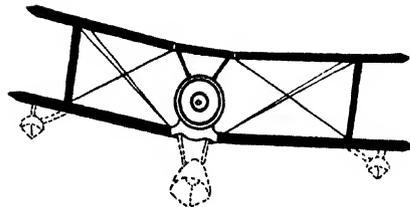
LOW-WING  
CANTILEVER MONOPLANE



HULL SPONSONS  
FOR STABILIZER



LOW-WING  
CANTILEVER MONOPLANE



SINGLE FLOAT  
BIPLANE SEAPLANE



LOW-WING  
CANTILEVER MONOPLANE

Fig. 31. Wing types

AIRCRAFT DRAFTING

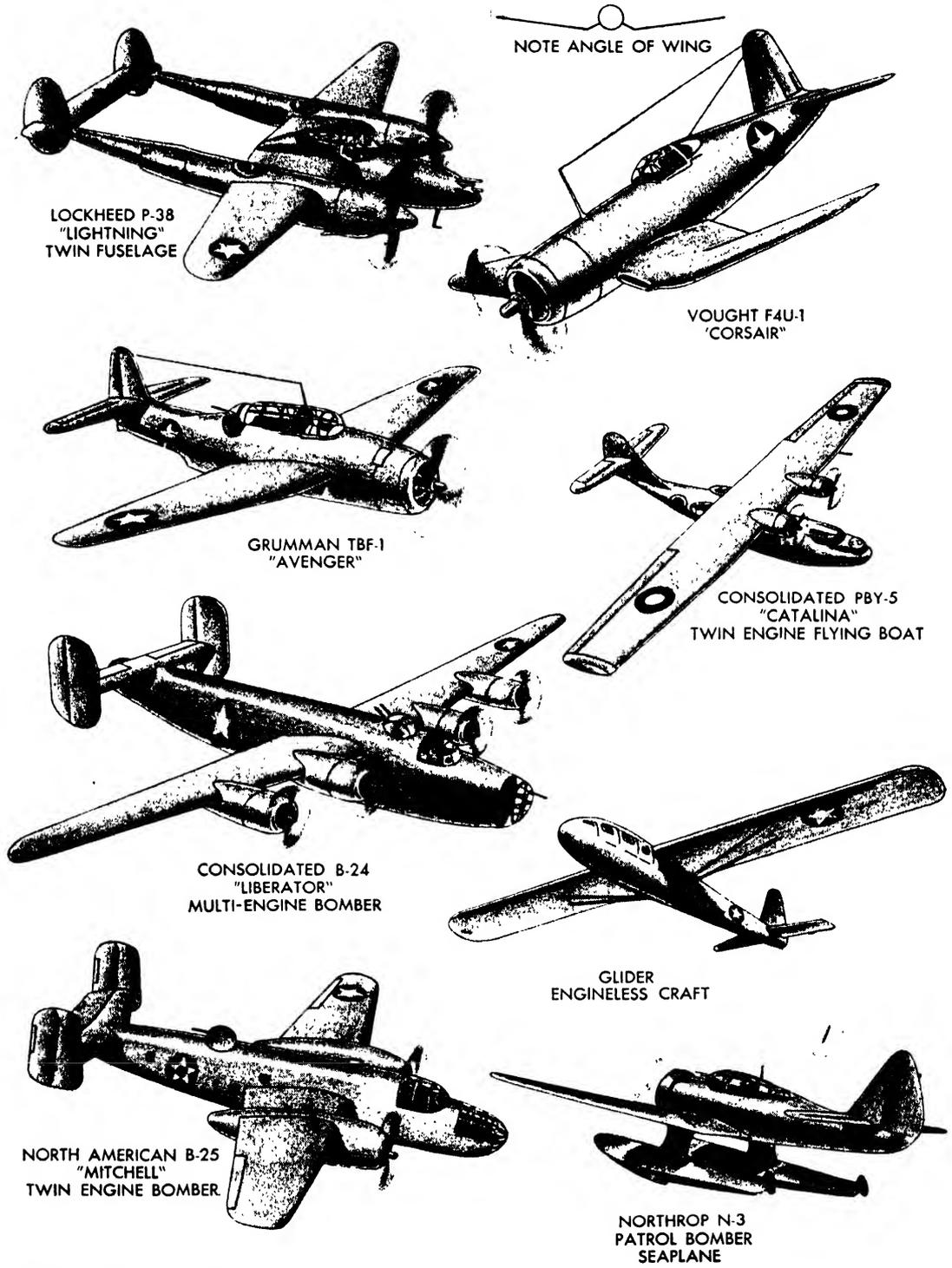
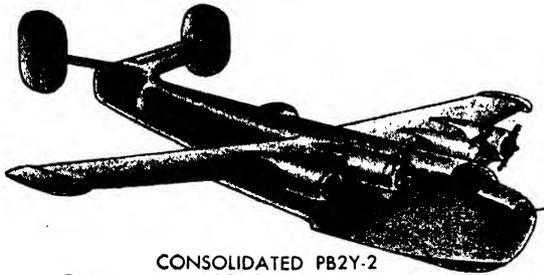
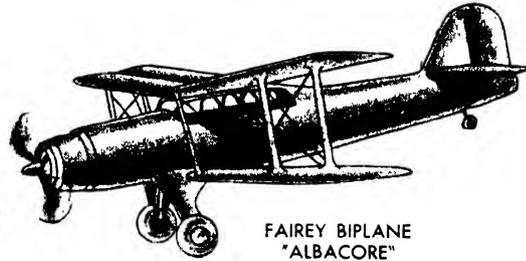


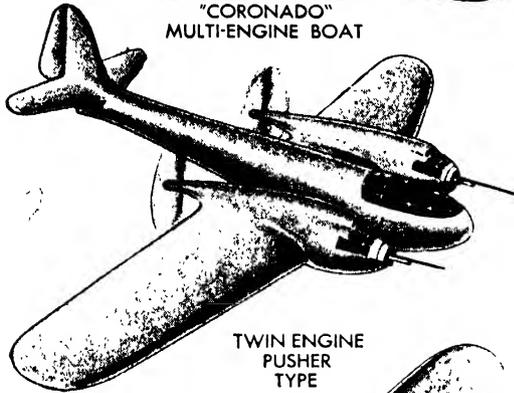
Fig. 32. Types of aircraft



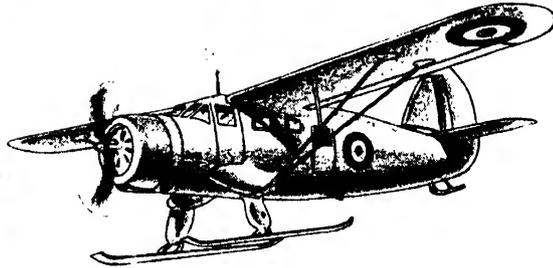
CONSOLIDATED PB2Y-2  
"CORONADO"  
MULTI-ENGINE BOAT



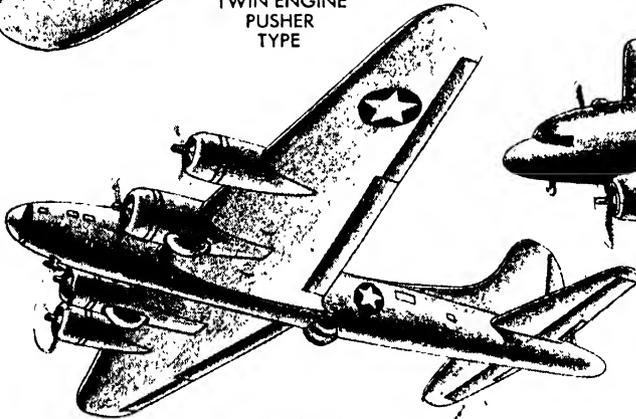
FAIREY BIPLANE  
"ALBACORE"  
FIXED LANDING GEAR



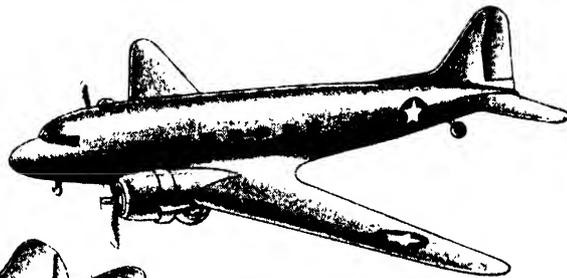
TWIN ENGINE  
PUSHER  
TYPE



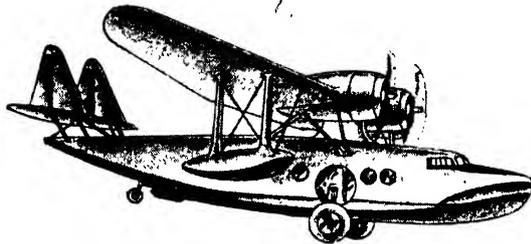
SKIPLANE



BOEING B-17  
"FLYING FORTRESS"



DOUGLAS DC-3  
TRANSPORT



VOUGHT-SIKORSKY VS-43-B  
AMPHIBIAN



SIKORSKY HELICOPTER

Fig. 33. Types of Aircraft (continued)

# FLOW CHART OF ENGINEERING INFORMATION

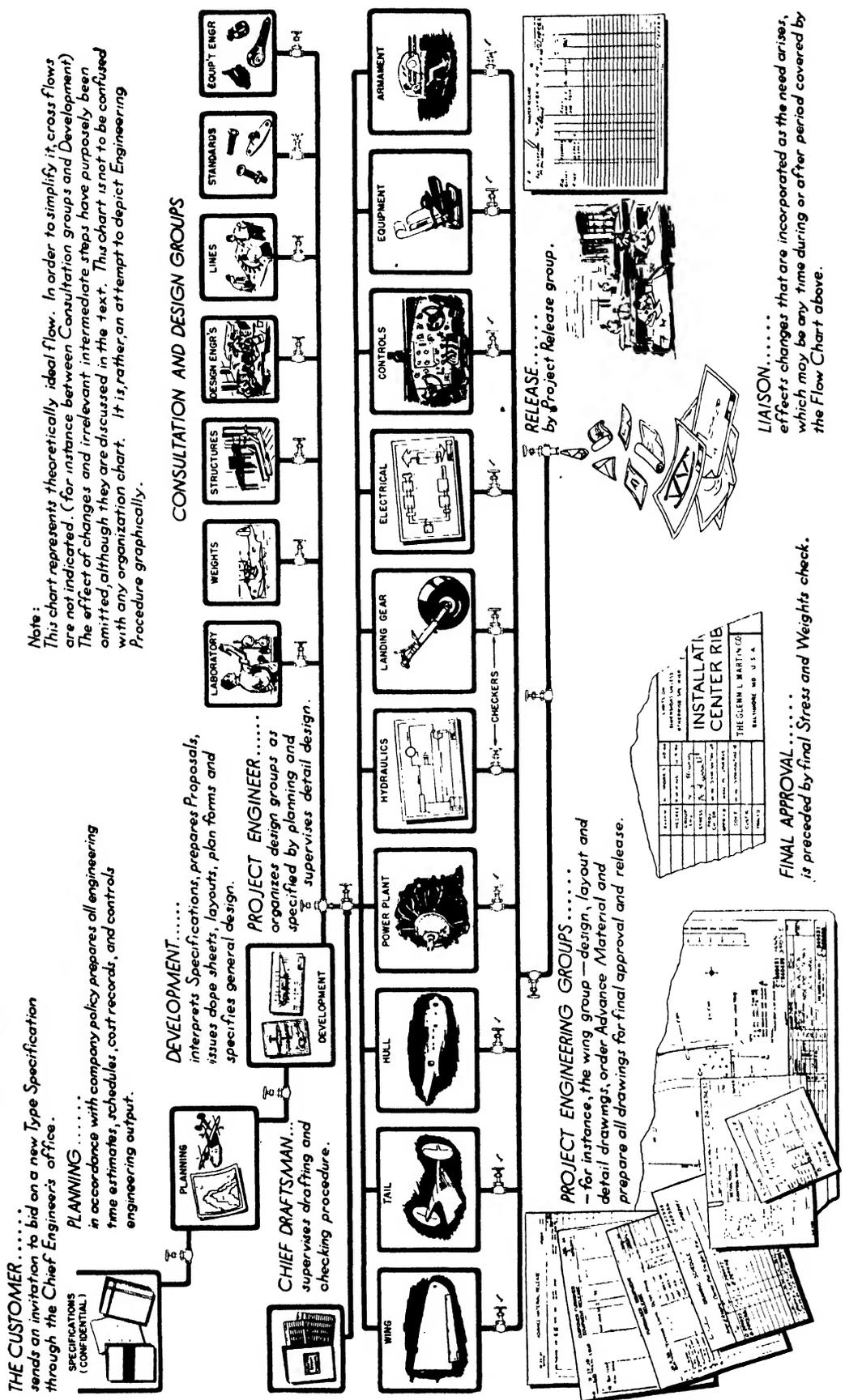


Fig. 34



Fig. 35. Engineering drafting room of the Consolidated Vultee Plant, Fort Worth division

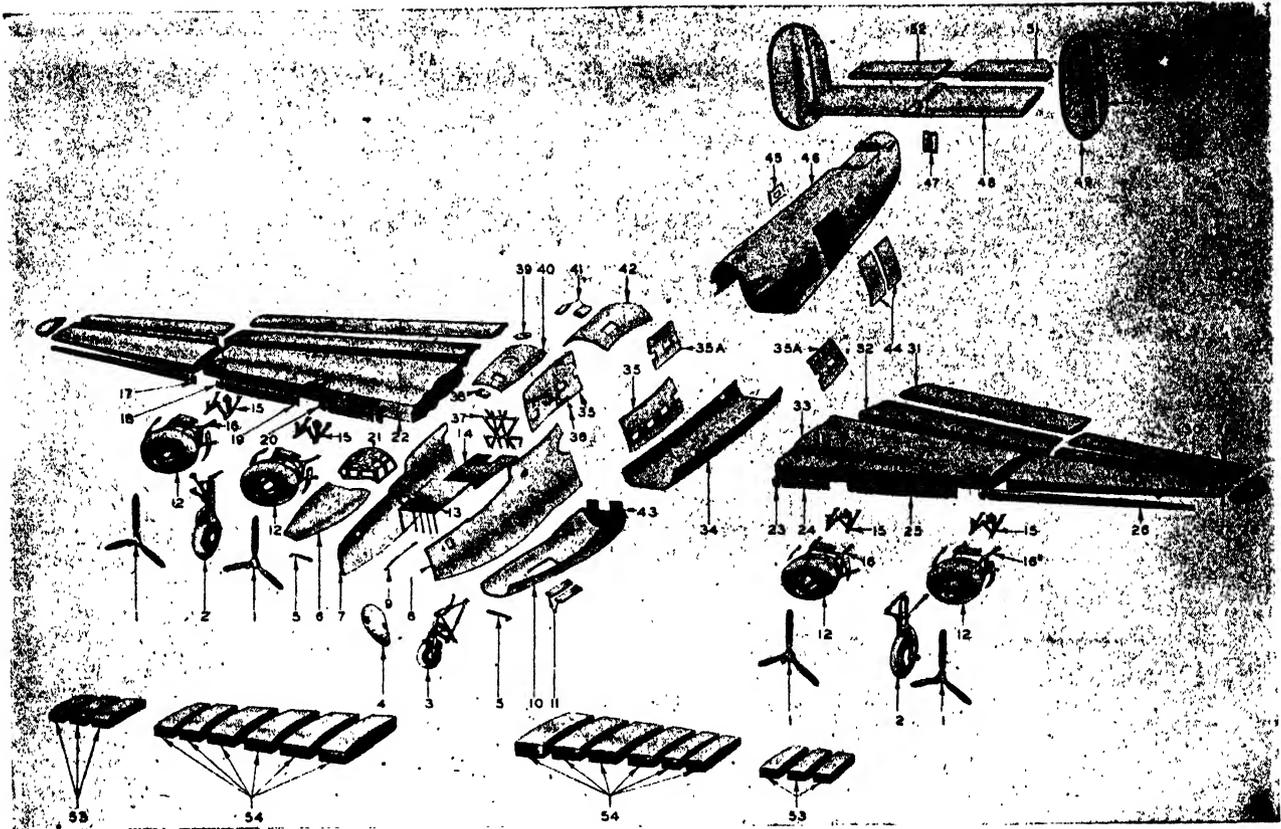


Fig. 36. Component breakdown and nomenclature of multi-engine airplane

- |   |   |
|---|---|
| 1 Propeller   | 26 L/R wing outer panel leading edge                                    |
| 2 Main landing gear   | 27 L/R wing outer panel   |
| 3 Nose landing gear   | 28 L/R wing tip   |
| 4 Nose door   | 29 L/R aileron  |
| 5 Pilot mast  | 30 L/R wing outer panel trailing edge                                   |
| 6 Upper nose section  | 31 L/R flap   |
| 7 Forward section R. H.                                       | 32 L/R wing center section trailing edge                                |
| 8 Forward section L. H.                                       | 33 Wing center section  |
| 9 Hand rail   | 34 Bottom panel fuselage (station 2.0 to 4.0)                           |
| 10 Nose section bottom panel                                  | 35 L/R side panel fuselage with windows                                 |
| 11 Nose landing gear doors                                    | 35A L/R side panel fuselage with windows                                |
| 12 Power plant installation                                   | 36 Truss fuselage to wing (station 4.1 to 4.2)                          |
| 13 Pilot's floor  | 37 Truss bulkhead station 4.1   |
| 14 Radio operator's floor                                     | 38 Pilot's escape hatch   |
| 15 Engine mount support                                       | 39 Navigator's airdrome   |
| 16 Engine mount   | 40 Fuselage nose section upper rear deck                                |
| 17 L/R outboard nacelle to wing leading edge fairing outboard | 41 Life raft hatch  |
| 18 L/R outboard nacelle to wing leading edge fairing inboard  | 42 Fuselage section top panel   |
| 19 L/R inboard nacelle to wing leading edge fairing outboard  | 43 Segment bulkhead at station 4.0                                      |
| 20 L/R inboard nacelle to wing leading edge fairing inboard   | 44 Cargo doors  |
| 21 Pilot's enclosure  | 45 Escape hatch right side of fuselage                                  |
| 22 Front spar of wing   | 46 Tail section fuselage  |
| 23 L/R wing center section leading edge attaching panel       | 47 Tail door  |
| 24 L/R wing center section leading edge                       | 48 Horizontal stabilizer  |
| 25 L/R wing center section leading edge (between nacelles)    | 49 L/R vertical stabilizer  |
|   | 50 L/R Rudder   |
|   | 51 Elevator   |
|   | 52 Elevator Tabs  |
|   | 53 L/R auxiliary fuel cells at outboard nacelles in wing center section |
|   | 54 Main fuel cells wing center section                                  |

# NOMENCLATURE<sup>1</sup>

**aerodynamics.** The branch of dynamics that treats of the motion of air and other gaseous fluids and of the forces acting on solids in motion relative to such fluids.

**aileron.** A hinged or movable portion of an airplane wing, the primary function of which is to impress a rolling motion on the airplane. It is usually part of the trailing edge of a wing.

*external aileron.* A separate airfoil mounted clear of the wing surfaces of an airplane but usually attached to them and deflected for lateral control.

*Frise aileron.* An aileron having the nose portion projecting ahead of the hinge axis, the lower surface being in line with the lower surface of the wing. When the trailing edge of the aileron is raised, the nose portion protrudes below the lower surface of the wing, increasing the drag.

*slotted aileron.* An aileron having a nose and axis arrangement somewhat similar to a Frise aileron but having a smooth air passage between the nose portion of the aileron and the wing for the purpose of maintaining a smooth air flow over the upper surface of the aileron when its trailing edge is deflected downward.

*upper-surface aileron.* A split flap forming the rear upper surface of a wing, deflected for lateral control.

**aircraft.** Any weight-carrying device designed to be supported by the air, either by buoyancy or by dynamic action.

**airfoil.** Any surface, such as an airplane wing, aileron, or rudder, designed to obtain reaction from the air through which it moves.

**airfoil profile.** The outline of an airfoil section.

**airfoil section.** A cross section of an airfoil parallel to the plane of symmetry or to a specified reference plane.

**airline.** An established system of aerial transportation, its equipment, or the company owning or operating it.

**airplane.** A mechanically driven fixed-wing aircraft, heavier than air, which is supported by the dynamic reaction of the air against its wings.

*canard airplane.* A type of airplane having the horizontal stabilizing and control surfaces in front of the main supporting surfaces.

*pusher airplane.* An airplane with the propeller or propellers aft of the main supporting surfaces.

*tailless airplane.* An airplane in which the devices used to obtain stability and control are incorporated in the wing.

*tractor airplane.* An airplane with the propeller or propellers forward of the main supporting surfaces.

**airship.** An aerostat provided with a propelling system and with means of controlling the direction of motion.

*nonrigid airship.* An airship whose form is maintained by the internal pressure in the gas bags and ballonets.

*pressure-rigid airship.* An airship combining the principles used in both rigid and nonrigid airships to maintain shape and skin tautness.

*rigid airship.* An airship whose form is maintained by a rigid structure.

*semirigid airship.* An airship whose shape is maintained by means of a rigid or jointed keel in conjunction with internal pressure in the gas containers and ballonets.

**air speed.** The speed of an aircraft relative to the air.

**air-speed head.** An instrument which, in combination with a gage, is used to measure the speed of an aircraft relative to the air. It usually consists of a pitot-static tube or a pitot-venturi tube.

**airworthiness.** The quality of an aircraft denoting its fitness and safety for operation in the air under normal flying conditions.

**amphibian.** An airplane designed to rise from and alight on either land or water.

**angle:**

*aileron angle.* The angular displacement of an aileron from its neutral position. It is positive when the trailing edge of the aileron is below the neutral position.

*dihedral angle.* The acute angle between a line perpendicular to the plane of symmetry and the projection of the wing axis on a plane per-

<sup>1</sup> This section is from *Nomenclature for Aeronautics*, Technical Report No. 474, National Advisory Committee for Aeronautics.

pendicular to the longitudinal axis of the airplane. If the wing axis is not approximately a straight line, the angle is measured from the projection of a line joining the intersection of the wing axis with the plane of symmetry and the aerodynamic center of the half-wing on either side of the plane of symmetry.

*elevator angle.* The angular displacement of the elevator from its neutral position. It is positive when the trailing edge of the elevator is below the neutral position.

*landing angle.* The acute angle between the wing chord and the horizontal when the airplane is resting on level ground in its normal position; also called "ground angle."

*rudder angle.* The acute angle between the rudder and the plane of symmetry of the aircraft. It is positive when the trailing edge has moved to the left with reference to the normal position of the pilot.

*trim angle.* The angle between the horizontal and the longitudinal baseline of a seaplane float or flying boat hull. It is positive when the bow is higher than the stern.

**angle of attack.** The acute angle between a reference line in a body and the line of the relative wind direction projected on a plane containing the reference line and parallel to the plane of symmetry.

*absolute angle of attack.* The angle of attack of an airfoil, measured from the attitude of zero lift.

*critical angle of attack.* The angle of attack at which the flow about an airfoil changes abruptly as shown by corresponding abrupt changes in the lift and drag.

*induced angle of attack.* The difference between the actual angle of attack and the angle of attack for infinite aspect ratio of an airfoil for the same lift coefficient.

**angle of incidence.** Same as angle of wing setting. In British terminology the angle of incidence is equivalent to the American term, "angle of attack."

**angle of roll (or angle of bank).** The angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into the horizontal plane. The angle is positive when the left side is higher than the right.

**angle of stabilizer setting.** The acute angle between the longitudinal axis of an airplane and the chord of the stabilizer. The angle is positive when the leading edge is higher than the trailing edge.

**angle of wing setting.** The acute angle between the plane of the wing chord and the longitudinal axis of the airplane. The angle is positive when the leading edge is higher than the trailing edge.

**angle of yaw.** The acute angle between the direction of the relative wind and the plane of symmetry of an aircraft. The angle is positive when the aircraft turns to the right.

**aspect ratio.** The ratio of the span to the mean chord of an airfoil; i.e., the ratio of the square of the span to the total area of an airfoil.

**autogiro.** A type of rotor plane whose support in the air is chiefly derived from airfoils rotated about an approximately vertical axis by aerodynamic forces, and in which the lift on opposite sides of the plane of symmetry is equalized by the vertical oscillation of the blades.

**axes of an aircraft.** Three fixed lines of reference, usually centroidal and mutually perpendicular. The horizontal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the "longitudinal" axis; the axis perpendicular to this in the plane of symmetry is called the "normal" axis; and the third axis perpendicular to the other two is called the "lateral" axis. In mathematical discussions, the first of these axes, drawn from rear to front, is called the X axis; the second, drawn downward, the Z axis; and the third, running from left to right, the Y axis.

*elastic axis (stress analysis).* The locus of all points through which a force may be applied to a structure without causing torsional deflection.

*wing axis.* The locus of the aerodynamic centers of all the wing sections.

**balance.** A condition of steady flight in which the resultant force and moment on the airplane are zero.

**balanced surface:**

*aerodynamic balanced surface.* A control surface that extends on both sides of the axis of the hinge or pivot or that has auxiliary devices or extensions connected with it in such a manner as to effect a small or zero resultant moment of the air forces about the hinge axis.

*static balanced surface.* A control surface whose center of mass is in the hinge axis.

**bank.** The position of an airplane when its lateral axis is inclined to the horizontal. A right bank is the position with the lateral axis inclined downward to the right.

**bank.** To incline an airplane laterally; i.e., to rotate it about its longitudinal axis.

**beaching gear.** An arrangement of wheels to be attached to the hull of a seaplane to permit handling ashore.

**biplane.** An airplane with two main supporting surfaces placed one above the other.

**cabane.** An arrangement of struts used for bracing on an aircraft.

**camber.** The rise of the curve of an airfoil section, usually expressed as the ratio of the departure of the curve from a straight line joining the extremities of the curve to the length of this straight line. "Upper camber" refers to the upper surface; "lower camber" to the lower surface; and "mean camber" to the mean line of the section. Camber is positive when the departure is upward, and negative when it is downward.

**cap strip.** A continuous member on the outer edge of a wing rib.

**center section.** The central panel of a wing; in the case of a continuous wing or any wing having no central panel, the limits of the center section are arbitrarily defined by the location of points of attachment to the cabane struts or fuselage.

**chine.** The intersection of the bottom with the sides or deck of a seaplane float.

**chord.** An arbitrary datum line from which the ordinates and angles of an airfoil are measured. It is usually the straight line tangent to the lower surface at two points, the straight line joining the ends of the mean line, or the straight line between the leading and trailing edges.

*mean chord of a wing.* The quotient obtained by dividing the wing area by the span.

**control column.** A lever having a rotatable wheel mounted at its upper end for operating the longitudinal and lateral control surfaces of an airplane. This type of control is called "wheel control."

**controls.** A general term applied to the means provided to enable the pilot to control the speed, direction of flight, attitude, power, etc., of an aircraft.

**control stick.** The vertical lever by means of which the longitudinal and lateral control surfaces of an airplane are operated. The elevator is operated by a fore-and-aft movement of the stick; the ailerons, by a side-to-side movement.

**control surface.** A movable airfoil designed to be rotated or otherwise moved by the pilot in order to change the attitude of the aircraft.

**cowling.** A removable covering.

*cockpit cowling.* A metal or plywood cowling placed around a cockpit.

*engine cowling.* A removable covering placed around all or part of an airplane engine.

*N.A.C.A. cowling.* A cowling enclosing a radial air-cooled engine, consisting of a hood, or ring,

and a portion of the body behind the engine so arranged that the cooling air smoothly enters the hood at the front and leaves through a smooth annular slot between the body and the rear of the hood; the whole forming a relatively low-drag body with a passage through a portion of it for the cooling air.

**decalage.** The difference between the angular settings of the wings of a biplane or multiplane. The decalage is measured by the acute angle between the chords in a plane parallel to the plane of symmetry. The decalage is considered positive if the upper wing is set at the larger angle.

**dihedral angle.** See "angle, dihedral."

**dive.** A steep descent, with or without power, in which the air speed is greater than the maximum speed in horizontal flight.

**dope.** The liquid material applied to the fabric surfaces of airplanes to increase their strength, to produce tautness by shrinking, and to act as a filler for maintaining airtightness.

**drag.** The component of the total air force on a body parallel to the relative wind.

*induced drag.* That part of the drag induced by the lift.

*parasite drag.* That portion of the drag of an aircraft exclusive of the induced drag of the wings.

*profile drag.* The difference between the total wing drag and the induced drag.

*effective profile drag.* The difference between the total wing drag and the induced drag of a wing with the same geometric aspect ratio but elliptically loaded.

**drag strut.** A fore-and-aft compression member of the internal bracing system of an aircraft.

**elevator.** A movable auxiliary airfoil, the function of which is to impress a pitching moment on the aircraft. It is usually hinged to the stabilizer.

**empennage.** See "tail."

**engine:**

*axial-type engine.* An engine having its cylinders equidistant from and parallel to the main shaft. Power is transmitted to the shaft through a wobble plate, swash plate, or gears.

*cam engine.* A type of engine in which the pistons are reciprocated by means of a cam-and-roller mechanism.

*compression-ignition engine.* A type of engine in which the fuel is sprayed into the cylinder and ignited by the heat of compression of the air charge.

**double-row radial engine.** An engine having two rows of cylinders arranged radially around a common crankshaft. The corresponding front and rear cylinders may or may not be in line.

**left-hand engine.** An engine whose propeller shaft, to an observer facing the propeller from the engine end of the shaft, rotates in a counter-clockwise direction.

**right-hand engine.** An engine whose propeller shaft, to an observer facing the propeller from the engine end of the shaft, rotates in a clockwise direction.

**supercharged engine.** An engine with a compressor for increasing the air or mixture charge taken into the cylinder beyond that inducted normally at the existing atmospheric pressure.

**factor of safety (stress analysis).** The ratio of the ultimate load to any applied load. This term usually refers to the probable minimum factor of safety, which is the ratio of the ultimate load to the probable maximum applied load.

**fairing.** An auxiliary member or structure whose primary function is to reduce the drag of the part to which it is fitted.

**fin.** A fixed or adjustable airfoil, attached to an aircraft approximately parallel to the plane of symmetry, to afford directional stability; for example, tail fin, skid fin, etc.

**fitting.** A generic term for any small part used in the structure of an airplane or airship. If without qualification, a metal part is usually understood. It may refer to other parts, such as fabric fittings.

**flap.** A hinged or pivoted airfoil forming the rear portion of an airfoil, used to vary the effective camber.

**float.** A completely enclosed watertight structure attached to an aircraft to give it buoyancy and stability when in contact with water.

*inboard stabilizing float.* A stabilizing float placed relatively close to the main float or hull.

*outboard (or wing-tip) stabilizing float.* A stabilizing float placed relatively far out from the main float or hull, usually at or very near the tip of the wing.

*single float.* A single central float fitted under a seaplane and usually requiring two stabilizing floats to give adequate stability and complete the float system.

*stabilizing (or side) float.* A float used in addition to a single float or hull and intended to provide lateral stability while the seaplane or flying boat is at rest on the water.

**float system.** The complete system of permanent

floats, used to give buoyancy and stability to a seaplane or a flying boat while it is at rest on the water, and to provide hydrodynamic lift while it is taking off.

**flutter.** An oscillation of definite period but unstable character set up in any part of an aircraft by a momentary disturbance, and maintained by a combination of the aerodynamic, inertial, and elastic characteristics of the member itself.

**flying boat.** A form of seaplane whose main body or hull provides flotation.

**fuselage.** The body, of approximately streamline form, to which the wings and tail unit of an airplane are attached.

**gap.** The distance separating two adjacent wings of a multiplane.

**glide.** To descend at a normal angle of attack with little or no thrust.

**glider.** An aircraft heavier than air, similar to an airplane but without a power plant.

*primary-type glider.* A ruggedly built glider designed for use in elementary training of student glider pilots.

*secondary-type glider.* A glider designed to have better aerodynamic performance than the primary type, but rugged enough for the use of pilots with limited training.

*performance-type glider.* A glider having a high degree of aerodynamic refinement and low minimum sinking speed.

**helicopter.** A type of rotor plane whose support in the air is normally derived from airfoils mechanically rotated about an approximately vertical axis.

**horn.** A short lever attached to a control surface of an aircraft, to which the operating wire or rod is connected.

**hull:**

*airship hull.* The main structure of a rigid airship, consisting of a covered elongated framework which incloses the gas cells and supports the cars and other equipment.

*seaplane hull.* That portion of a flying boat which furnishes buoyancy when in contact with the surface of the water. It contains accommodations for the crew and passengers, usually combining the functions of both float and fuselage.

**keel.** The assembly of members at the bottom of the hull of a semirigid or rigid airship, which provides special strength to resist hogging and sagging and also serves to distribute the effect of concentrated loads along the hull.

**landing gear.** The understructure which supports the weight of an aircraft when in contact with the land or water and which usually contains a mechanism for reducing the shock of landing. Also called "undercarriage."

**landplane.** An airplane designed to rise from and alight on the land.

**leading edge.** The foremost edge of airfoil or propeller blade.

**lift/drag ratio.** The ratio of the lift to the drag of any body.

**load:**

*basic load (stress analysis).* The load on a structural member or part in any condition of static equilibrium of an airplane. When a specific basic load is meant, the particular condition of equilibrium must be indicated in the context.

*design load (stress analysis).* A specified load below which a structural member or part should not fail. It is the probable maximum applied load multiplied by the factor of safety. Also, in many cases, an appropriate basic load multiplied by a design load factor.

*full load.* Weight empty plus useful load; also called gross weight.

*normal load (stress analysis).* The load on that part of a wing assumed to be unaffected by tip losses or similar corrections. In any given case, it may be a basic, design, gross, net, or ultimate load, depending on the context.

*pay load.* That part of the useful load from which revenue is derived, viz., passengers and freight.

*ultimate load (stress analysis).* The load that causes destructive failure in a member during a strength test, or the load that, according to computations, should cause destructive failure in the member.

*useful load.* The crew and passengers, oil and fuel, ballast other than emergency, ordnance, and portable equipment.

**longeron.** A principal longitudinal member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support.

**maneuverability.** That quality in an aircraft which determines the rate at which its attitude and direction of flight can be changed.

**monoplane.** An airplane with but one main supporting surface, sometimes divided into two parts by the fuselage.

*high-wing monoplane.* A monoplane in which the wing is located at, or near, the top of the fuselage.

*low-wing monoplane.* A monoplane in which

the wing is located at, or near, the bottom of the fuselage.

*midwing monoplane.* A monoplane in which the wing is located approximately midway between the top and bottom of the fuselage.

*parasol monoplane.* A monoplane in which the wing is above the fuselage.

**multiplane.** An airplane with two or more main supporting surfaces placed one above another.

**nacelle.** An enclosed shelter for personnel or for a power plant. A nacelle is usually shorter than a fuselage, and does not carry the tail unit.

**ornithopter.** A form of aircraft heavier than air, deriving its chief support and propelling force from flapping wings.

**over-all length.** The distance from the extreme front to the rear of an aircraft, including the propeller and the tail unit.

**overhang.** (1) One half of the difference in span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (2) The distance from the outer strut attachment to the tip of a wing.

**panel (airplane).** A portion of an airplane wing constructed separately from the rest of the wing to which it is attached.

**pitch.** An angular displacement about an axis parallel to the lateral axis of an aircraft.

**pitch of a propeller:**

*effective pitch.* The distance an aircraft advances along its flight path for one revolution of the propeller.

*geometrical pitch.* The distance an element of a propeller would advance in one revolution if it were moving along a helix having an angle equal to its blade angle.

*zero-thrust pitch.* The distance a propeller would have to advance in one revolution to give no thrust. Also called "experimental mean pitch."

**pitot tube.** A cylindrical tube with an open end pointed upstream. Used in measuring impact pressure.

**plan form:**

*developed plan form.* The plan of an airfoil as drawn with the chord lines at each section rotated about the airfoil axis into a plane parallel to the plane of projection and with the airfoil axis rotated or developed and projected into the plane of projection.

*projected plan form.* The contour as viewed from above.

**primary structure (stress analysis).** The main framework, including fittings and attachments. Any structural member, the failure of which would seriously impair the safety of the airplane, is a part of the primary structure.

**profile thickness.** The maximum distance between the upper and lower contours of an airfoil, measured perpendicularly to the mean line of the profile.

**propeller.** Any device for propelling a craft through a fluid, such as water or air; especially a device having blades which, when mounted on a power-driven shaft, produce a thrust by their action on the fluid.

*adjustable propeller.* A propeller whose blades are so attached to the hub that the pitch may be changed while the propeller is at rest.

*automatic propeller.* A propeller whose blades are attached to a mechanism that automatically sets them at their optimum pitch for various flight conditions.

*controllable propeller.* A propeller whose blades are so mounted that the pitch may be changed while the propeller is rotating.

*geared propeller.* A propeller driven through gearing, generally at some speed other than the engine speed.

*pusher propeller.* A propeller mounted on the rear end of the engine or propeller shaft.

*tractor propeller.* A propeller mounted on the forward end of the engine or propeller shaft.

**rate of climb indicator.** An instrument that indicates the rate of ascent or descent of an aircraft.

**roll.** A maneuver in which a complete revolution about the longitudinal axis is made, the horizontal direction of flight being approximately maintained.

**roll.** An angular displacement about an axis parallel to the longitudinal axis of an aircraft.

**rolling.** Angular motion about the longitudinal axis.

**rotor.** The complete rotating portion of a rotary wing system.

**rotor plane.** A form of aircraft whose support in the air is chiefly derived from the vertical component of the force produced by rotating airfoils.

**rudder.** A hinged or movable auxiliary airfoil on an aircraft, the function of which is to impress a yawing moment on the aircraft.

**rudder bar.** The foot bar by means of which the control cables leading to the rudder are operated.

**rudder pedals.** The foot pedals by means of which the controls leading to the rudder are operated.

**sailplane.** A performance-type glider.

**seaplane.** An airplane designed to rise from and alight on the water.

**slot.** The nozzle-shaped passage through a wing whose primary object is to improve the flow conditions at high angles of attack. It is usually near the leading edge and formed by a main and an auxiliary airfoil, or *slat*.

**span.** The maximum distance, measured parallel to the lateral axis, from tip to tip of an airfoil, of an airplane wing inclusive of ailerons, or of a stabilizer inclusive of elevator.

*effective span.* The true span of a wing less corrections for tip loss.

**spinner.** A fairing of approximately conical or paraboloidal shape, which is fitted coaxially with the propeller hub and revolves with the propeller.

**sponson.** A protuberance from a seaplane hull designed to increase the beam or give lateral stability at rest.

**stability.** That property of a body which causes it, when its equilibrium is disturbed, to develop forces or moments tending to restore the original condition.

*automatic stability.* Stability dependent upon movable control surfaces automatically operated by mechanical means.

*directional stability.* Stability with reference to disturbances about the normal axis of an aircraft, i.e., disturbances which tend to cause yawing.

*dynamic stability.* That property of an aircraft which causes it, when its state of steady flight is disturbed, to damp the oscillations set up by the restoring forces and moments and gradually return to its original state.

*inherent stability.* Stability of an aircraft due solely to the disposition and arrangement of its fixed parts; i.e., that property which causes it, when disturbed, to return to its normal attitude of flight without the use of the controls or the interposition of any mechanical device.

*lateral stability.* Stability with reference to disturbances about the longitudinal axis; i.e., disturbances involving rolling or side slipping. The term lateral stability is sometimes used to include both directional and lateral stability, since these cannot be entirely separated in flight.

*static stability.* That property of an aircraft which causes it, when its state of steady flight

is disturbed, to develop forces and moments tending to restore its original condition.

**stabilizer (airplane).** Any airfoil whose primary function is to increase the stability of an aircraft. It usually refers to the fixed horizontal tail surface of an airplane, as distinguished from the fixed vertical surface.

**stagger.** A term referring to the longitudinal position of the axes of two wings of an airplane. Stagger of any section is measured by the acute angle between a line joining the wing axes and a line perpendicular to the upper wing chord, both lines lying in a plane parallel to the plane of symmetry. The stagger is positive when the upper wing is in advance of the lower.

**step.** A break in the form of the bottom of a float or hull, designed to diminish resistance, to lessen the suction effects, and to improve control over longitudinal attitude.

**streamline.** The path of a particle of a fluid, supposedly continuous, commonly taken relative to a solid body past which the fluid is moving; generally used only of such flows as are not eddying.

**strut.** A compression member of a truss frame.  
*oleo strut.* A shock-absorbing telescopic strut in which an oleo gear is incorporated.

**sweepback.** The acute angle between a line perpendicular to the plane of symmetry and the plan projection of a reference line in the wing.

**tab.** An auxiliary airfoil attached to a control surface for the purpose of reducing the control force or trimming the aircraft.

**tail (airplane).** The rear part of an airplane, usually consisting of a group of stabilizing planes, or fins, to which are attached certain controlling surfaces such as elevators and rudders; also called "empennage."

**tail skid.** A skid for supporting the tail of an airplane on the ground.

**tail surface.** A stabilizing or control surface in the tail of an aircraft.

**taper in plan only.** A gradual change (usually a decrease) in the chord length along the wing span from the root to the tip, with the wing sections remaining geometrically similar.

**trailing edge.** The rearmost edge of an airfoil or of a propeller blade.

**turn and bank indicator.** An instrument combining in one case a turn indicator and a lateral inclinometer.

**turn indicator.** An instrument for indicating the existence and approximate magnitude of angular velocity about the normal axis of an aircraft.

**turnmeter.** An instrument that measures the rate of turn of an aircraft about any predetermined axis.

**venturi tube (or venturi).** A short tube of varying cross section. The flow through the venturi causes a pressure drop in the smallest section, the amount of the drop being a function of the velocity of flow.

**warp.** To change the form of a wing by twisting it. Warping was formerly used to perform the function now performed by ailerons.

**weight:**

*dischargeable (or consumable) weight (airship).* All weight that can be consumed or discharged and still leave the airship in safe operating condition with a specified reserve of fuel, oil, water ballast, and provisions, and with the normal crew.

*empty weight.* The structure, power plant, and fixed equipment of an aircraft. Included in this fixed equipment are the water in the radiator and cooling system, all essential instruments and furnishings, fixed electric wiring for lighting, heating, etc. In the case of an aerostat, it also includes the amount of ballast that must be carried to assist in making a safe landing.

*fixed weight (airship).* The weight of the machinery and all equipment and parts that are fixed in position and nonconsumable. Liquids in the cooling systems of the engines are included.

*fixed power plant weight for a given airplane weight.* The weight of the power plant and its accessories, exclusive of fuel and oil and their tanks.

*gross weight (airplane).* The total weight of an airplane when fully loaded. (Cf. *load, full.*)

*net weight (stress analysis).* The gross weight, less some specific partial weight. Very often the partial weight is the dead weight of the wings, but it may be the useful load. The partial weight in question should always be clearly indicated by the context.

**wheel, tail.** A wheel used to support the tail of an airplane when on the ground. It may be steerable or nonsteerable, fixed or swiveling.

**wind indicator.** A device that indicates the direction and velocity of the surface wind.

**wind tunnel.** An apparatus producing an artificial wind or air stream, in which objects are placed for investigating the air flow about them and the aerodynamic forces exerted on them.

**wing.** A general term applied to the airfoil, or one of the airfoils, designed to develop a major part of the lift of a heavier-than-air craft.

*equivalent wing (stress analysis).* A wing of the same span as the actual wing, but with the chord at each section reduced in proportion to the ratio of the average beam load at that section to the average beam load at the section taken as the standard.

**wing profile.** The outline of a wing section.

**wing rib.** A chordwise member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars.

*compression wing rib.* A heavy rib designed to perform the function of an ordinary wing rib and also to act as a strut opposing the pull of the wires in the internal drag truss.

*former (or false) wing rib.* An incomplete rib, frequently consisting only of a strip of wood extending from the leading edge to the front spar, which is used to assist in maintaining the form of the wing where the curvature of the airfoil section is sharpest.

**wing section.** A cross section of a wing parallel to the plane of symmetry, or to a specified reference plane.

**wing skid.** A skid placed near the wing tip to protect the wing from contact with the ground.

**wing spar.** A principal spanwise member of the wing structure of an airplane.

**wing tip.** The outer end of an airplane wing.

**wire (airplane):**

*antidrag wire.* A wire intended primarily to resist the forces acting forward in the chord direction. It is generally enclosed in the wing.

*drag wire.* A wire intended primarily to resist the forces acting backward in the chord direction. It is generally enclosed in the wing.

*landing wire.* A wire or cable which braces the wing against the forces opposite to the normal direction of the lift.

*lift wire.* A wire or cable which braces the wings against the lift force; sometimes called "flying wire."

*stagger wire.* A wire connecting the upper and lower wings of an airplane and lying in a plane substantially parallel to the plane of symmetry; also called "incidence wire."

**yaw.** An angular displacement about an axis parallel to the normal axis of an aircraft.

**yawing.** angular motion about the normal axis.

## CHAPTER TWO

# DRAWING INSTRUMENTS AND THEIR USE

### *Introduction*

The draftsman's tools should be of the best quality on the market. Cheap and poorly constructed instruments give unsatisfactory results and are short-lived. Many inferior instruments, however, look like those of finer grade. Since it is hard for a beginner to recognize the relative merits of various pieces of equipment, he should ask the help of his instructor or a practicing draftsman in making his selection.

The first thing a draftsman must know is how to use his tools; this means he must keep in practice, and he must treat his instruments with respect.

The proper handling of instruments should become a habit. The draftsman must be able to handle his tools with ease and precision. The first thing to learn is accuracy. Speed will come later.

This chapter includes a short description of the most common tools of the aeronautical drafting room.

### *List of a Student Draftsman's Materials and Instruments*

#### USUALLY SUPPLIED BY THE DRAFTSMAN

- Set of drawing instruments.
- Large (18 by 24 inch) drawing board.
- Small (10 by 12 inch) drawing board.
- T square.
- Celluloid triangles—30 by 60 degrees, 10 inches high, and 45 degrees, 8 inches high.
- Steel scale (6 inch) and architectural scale (12 inch)—flat or triangular.
- Draft square or hole template.
- Protractor—6 inches.
- Lettering triangle.
- Art gum and ruby eraser.
- Erasing shield.
- Thumbtacks or Scotch tape.
- Dusting brush.
- Drawing pencils—6H, 4H, 2H, F, and HB.

- Irregular curves and ship curves.
- White drawing paper.
- Razor blades or pocket knife (for sharpening pencils).
- Sandpaper pad.

#### USUALLY SUPPLIED BY AIRCRAFT COMPANIES

- Parallel rule attachments.
- Drafting machines.
- Spline and ducks.
- T square, triangles.
- Vellum and bond paper.
- Staples, brushes, and Scotch tape.
- Pencils and erasers.
- Beam compass, trammel points and bars.

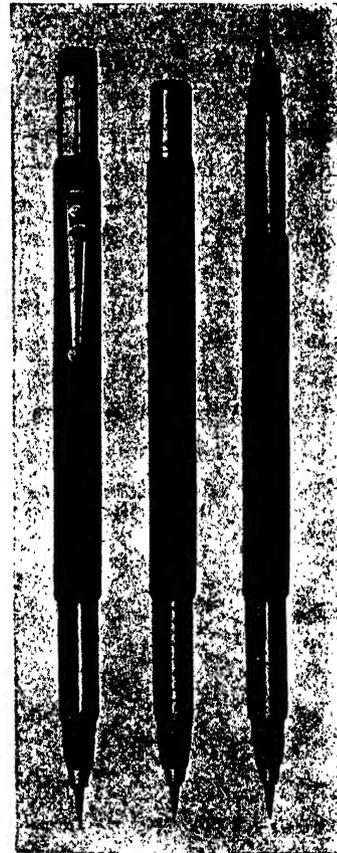


Fig. 37. Mechanical drawing pencils

### Pencils

Pencils, the principal tool in aircraft drafting, are made in 18 different degrees of hardness. The degree of hardness varies from very soft, 7B, to very hard, 9H. Pencils are graded thus: 7B, 6B, 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, 8H, 9H.

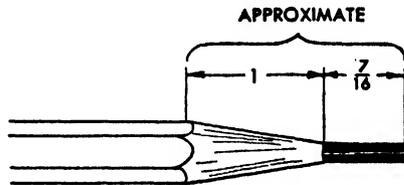


Fig. 38

In aircraft drafting the 6H or 4H pencil is generally used for layout work and the 2H, H, or F for darkening lines. The H or F is used for lettering and the HB for sketching.

Mechanical drafting pencils (Fig. 37) are practical and convenient, as they eliminate the bother of sharpening wooden pencils and working with short pencils.

*Points and Sharpening.* Several types of pencil sharpeners are satisfactory. The ordinary pencil sharpener may be used to sharpen a point for lettering, but it is not desirable for pointing a pencil for drawing purposes. A draftsman's pencil sharpener, which has an automatic feeder device, a pen knife, or a razor blade can be used to sharpen a pencil to the approximate proportion designated in Fig. 38. The point must then be further refined with the sandpaper pad (Fig. 39). Because graphite accumulates on the sand-

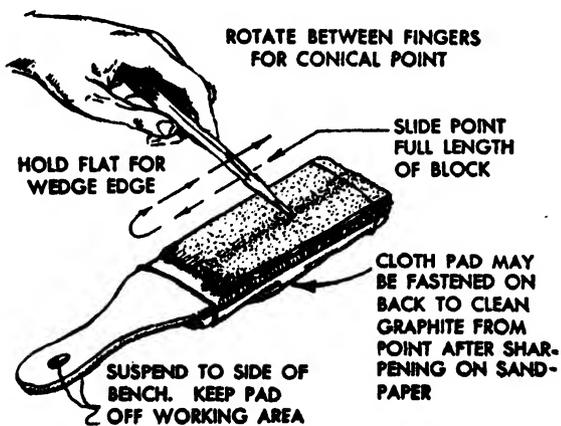


Fig. 39

paper pad, care should be taken to keep the pad away from the drawing at all times. Many draftsmen hang it from one side of the drawing table or bench by a rubber band or string. There it is readily accessible for use but safely out of the way.

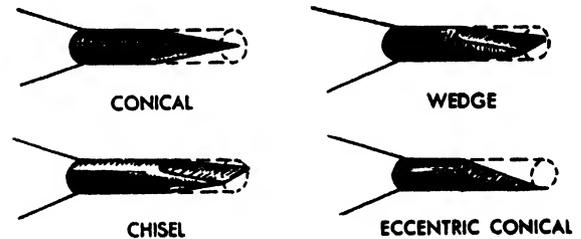


Fig. 40. Types of points

The pencil may be given any one of several types of points (Fig. 40). The conical point is used for drawing straight and curved lines, arrowheads, details, lettering, etc. This point is made by rotating the sharpened pencil between the fingers, with the point touching the sandpaper at an angle. The degree of sharpness should vary with the desired thickness of line.

Many aircraft drawings call for straight lines as long as 4 or 5 feet. The chisel point is useful in drawing these lines and lines spaced close together. Because of its width, the chisel point can make a long fine sharp line in one stroke without resharpening. To acquire the chisel point, hold the pencil flat, slide it the full length of the sandpaper pad until half the lead is tapered, then turn the pencil over and repeat the operation on the other side. Sharpening after each application is necessary to retain chisel sharpness. The wedge and eccentric conical points are variations of the chisel and conical points.

### Compass Leads and Points

Compass leads (Fig. 41) may be purchased, but many draftsmen prefer to cut the wood casing away from a pencil and use the pencil lead. The lead should be inserted into the compass so that the needle point is slightly longer, to allow for perfect contact between lead and paper when the needle sinks into the paper. The compass lead is pointed after the lead has been

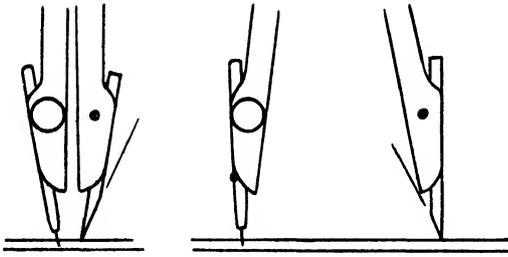


Fig. 41. Compass leads

inserted into the compass and tightened. The compass is opened to allow contact with the sandpaper block. Most leads are sharpened to a chisel point. However, conical or eccentric conical points are used for smaller circles.

### The Drawing Boards and T Square

Drawing boards are usually made of white pine. They should be composed of a series of pieces glued together and cleated to prevent

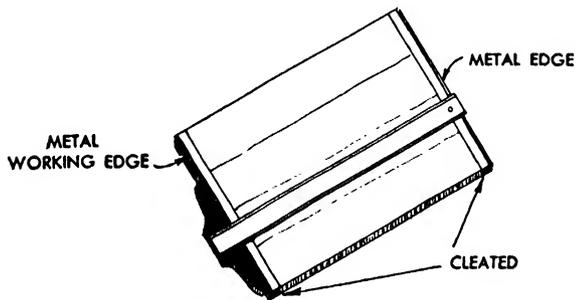


Fig. 42. Drawing board

warping. Those boards with steel edges secured to the two short sides or working edges (Fig. 42) are recommended, as such edges assure better contact with the head of the T square.

The T square (Fig. 43) is used for drawing horizontal lines and also as a guide for triangles in drawing vertical and slanting lines. It consists of a blade and a head, fastened together by screws. The head of the T square should always be manipulated by the left hand in order that the right hand may be free to work. Only the upper edge of the T square (the working edge) is used. In drawing vertical lines the left hand may be moved over to hold the triangles, care being taken, however, to hold the T square rigid. For left-handed students the process is reversed. The student should always maintain the alignment of the T square head and the drawing board. It

is common for beginners to neglect the constant checking necessary to keep this alignment. Poor and inaccurate work results.

The miniature drawing board (Fig. 44) is useful in sketching. Since it is small and can be carried easily it can be used to make small sketches and drawings in the shop. It is 10 by 12 inches in size and has a T square and two triangles, one 45 degrees and the other 30 by 60 degrees, secured to the back. The student will find the small drawing board convenient for lecture sketching and home work.

### Triangles

The triangles universally used are the 45 degree and the 30 by 60 degree. The 45 degree triangle (Fig. 45) has two 45 degree angles and

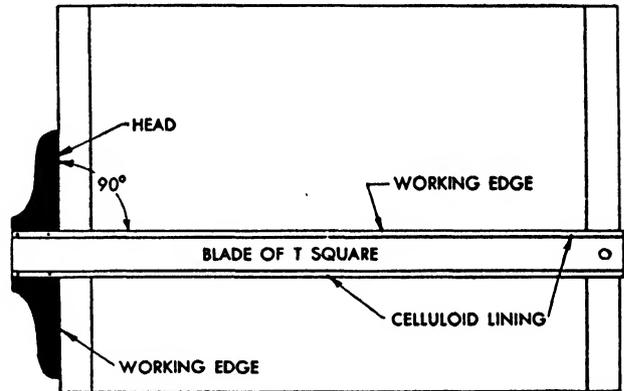


Fig. 43. T square and drawing board

one 90 degree angle. The 30 by 60 triangle has a 30 degree, a 60 degree, and a 90 degree angle (Fig. 46). These triangles are made of celluloid and may be purchased in various sizes.

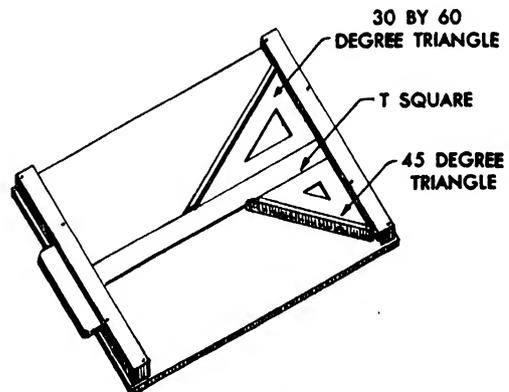


Fig. 44. The miniature drawing board

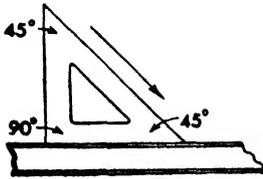


Fig. 45. 45° Triangle

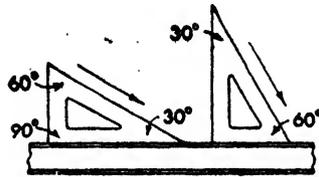


Fig. 46. 30° x 60° Triangle

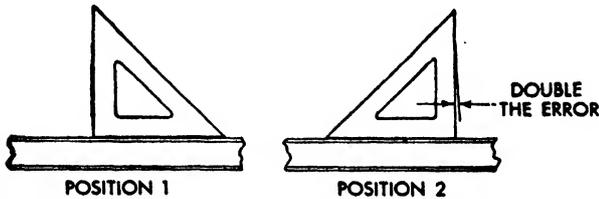


Fig. 47

With the aid of the T square, triangles may be tested for squareness by drawing a line as designated in Fig. 47, position 1, and turning the triangle over as in position 2. If the edge of the triangle coincides with the first drawn line, the triangle is square. Any variation determines the degree of error. Many draftsmen prefer to

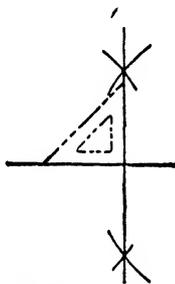


Fig. 48

check squareness by a geometric construction (Fig. 48). A line perpendicular to a horizontal line is constructed, and the triangle is carefully placed to check on the 90 degree corner.

The primary use of the T square and triangles

is in drawing horizontal, vertical, and diagonal lines. Horizontal lines are drawn along the working edge of the T square. Vertical lines are drawn (See Fig. 49) by placing the base of the triangle against the blade of the T square and drawing along the edge of the triangle, which is one side of the 90 degree angle. The head of the T square must be kept flush with the working edge of the drawing board while using the triangles. This may be done by holding the left hand firmly on both the triangle and the blade of the T square while the right hand is drawing the line.

The triangles are also useful for drawing various angles. Of course angles of 30, 45, 60, or 90 degrees can be drawn. It is also possible to draw angles of 15, 75, and 105 degrees by using the triangles in combination (Fig. 50).

Nearly all drawings can be made with the triangles and T square together.

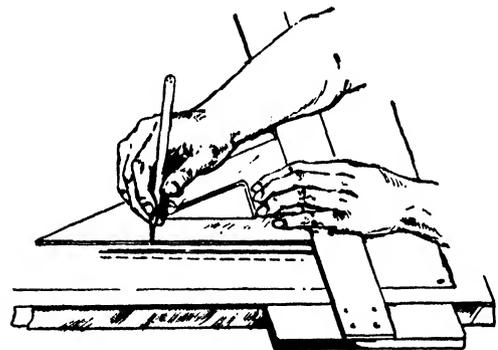


Fig. 49. Drawing vertical lines

To draw parallel lines at off angles, either the T square and the triangle or the two triangles may be used in combination. In the former case, the base of the triangle is placed against the blade of the T square, and the two are moved

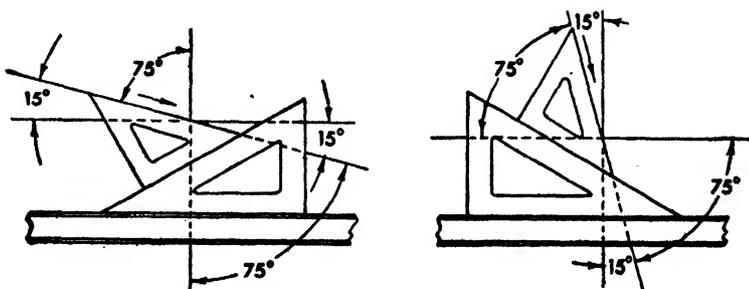


Fig. 50a. Use of the triangles in combination

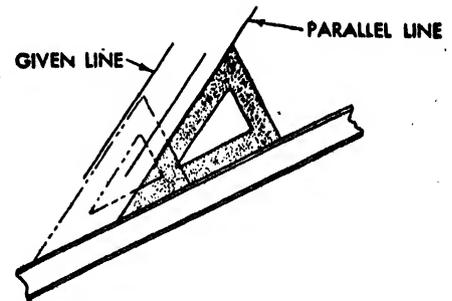


Fig. 50b

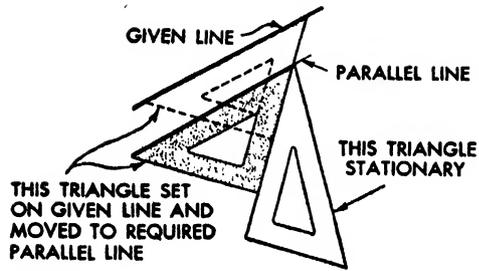


Fig. 51

together until the hypotenuse of the triangle coincides with the given line (Fig. 50). The triangle is then moved away from the line, with its base on the T square which is held stationary, to a point where a parallel line is desired. Figure 51 illustrates the use of the triangles in combination to draw parallel lines. The triangles may be used to draw perpendicular lines as shown in Fig. 52.

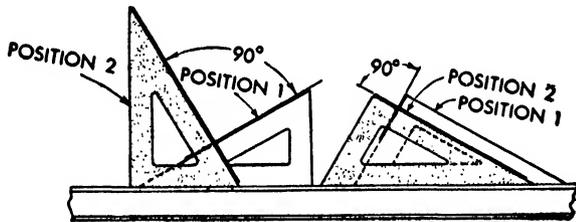


Fig. 52

### The Case Instruments

Drawing instruments are usually sold in sets, but the individual pieces may be bought separately. The better instruments are machined

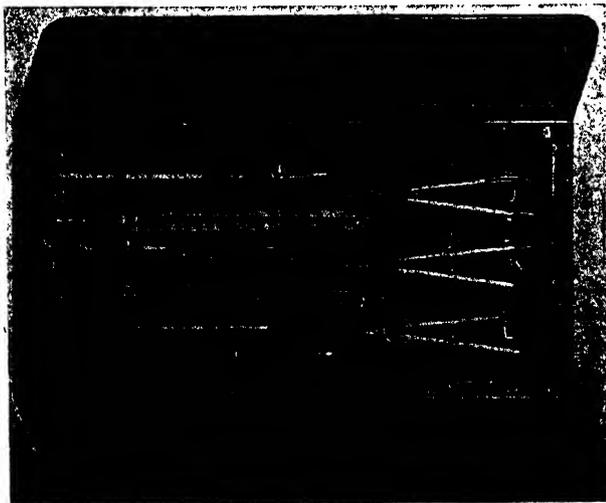


Fig. 53. The case instruments

from noncorrosive nickel silver, with such parts as ruling pen blades, springs, screws, and points fabricated from a good grade of tool steel. It is difficult for the novice to judge the rigidity and construction of these tools, and care should be taken in their purchase. A typical set of drawing tools, commonly termed "case instruments" contains the following instruments (see Fig. 53):

- Ruling pen, 5½ inch metal handle (A).
- Dividers, 6 inches (B).
- Compass pen part (C).
- Compass pencil parts (D).
- Key and lead box (E).
- Compass, 6 inches (F).
- Lengthening bar (G).
- Metal handle (H).
- Repair box (I).
- Bow pen, 3½ inches (J).
- Bow divider, 3½ inches (K).
- Bow pencil, 3½ inches (L).

### The Dividers

The dividers (Fig. 54) are a most useful instrument. They are manufactured in two types, the "plain," constructed with two solid edges, or

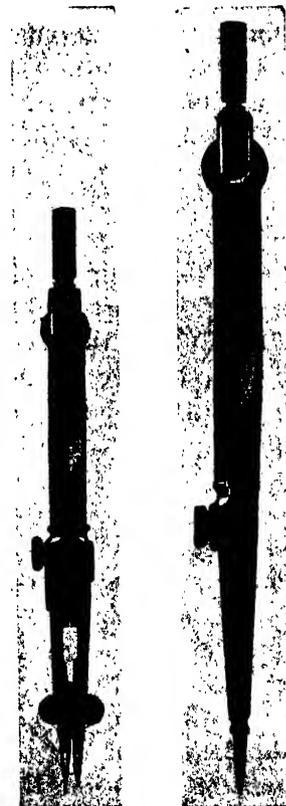


Fig. 54. Dividers

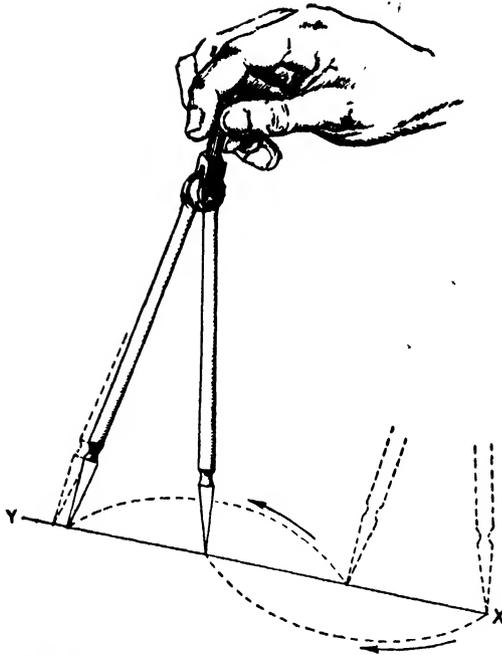


Fig. 55

the "hair spring," which contain a small spring fastened to the upper section of one leg with an adjusting screw so that small variations in the width or setting may be regulated. They serve three purposes: transferring dimensions, measuring or setting off certain distances, and dividing a given line into a number of parts.

The dividers should be adjusted with the hand that manipulates them. Constant practice is necessary to handle the dividers successfully.

Perhaps the most common application of this instrument is to divide a line into equal parts. This "trial method" is illustrated in Fig. 55.

To divide line YX into three equal parts:

1. Approximate one-third the distance of line YX in the first setting of the dividers.
2. Rotate the dividers clockwise, stopping on line YX.
3. Rotate the dividers again 180 degrees but this time counterclockwise.
4. If the dividers fall short or beyond the given line, divide the remaining distance into the given number of parts.

In this illustration the dividers fall short. To complete the process, readjust the dividers to include an added third of the remaining distance, and repeat the operation. If the last prick of the dividers falls beyond the line, lessen the trial radius one-third the excess distance.

### Compasses

The two most common types of compasses are the beveled and the flat. The beveled or square type (Fig. 56) is the American type, and the flat (Fig. 57) is a European type. A tongue joint formerly used to fasten the legs proved unsatisfactory because there was no way of taking up the clearance caused by wear on the tongue, and this rendered the compass unfit for use in a short time. On modern instruments the tongue joint has been replaced by a "pivot" joint (see Fig. 57) which has adjustable pivots on either side of the head. These make it possible to maintain enough friction to hold the legs rigid throughout the life of the compass. A yoke is used to support both the pivot and the handle.

Socket joints are provided on nearly all compasses so that a compass may be used as a pencil compass, inking compass, or dividers. The socket is also employed to insert a "lengthening bar" to draw larger circles. Although, like the divid-

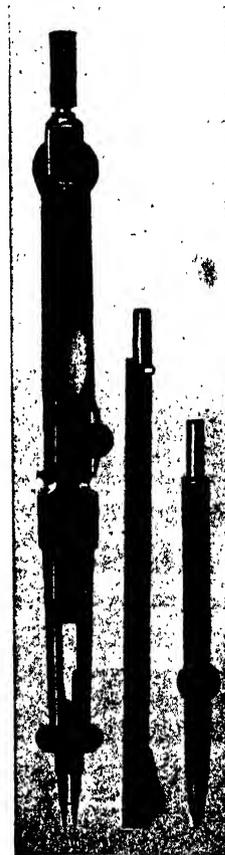


Fig. 56. The beveled-type compass with lengthening bow and ink attachment

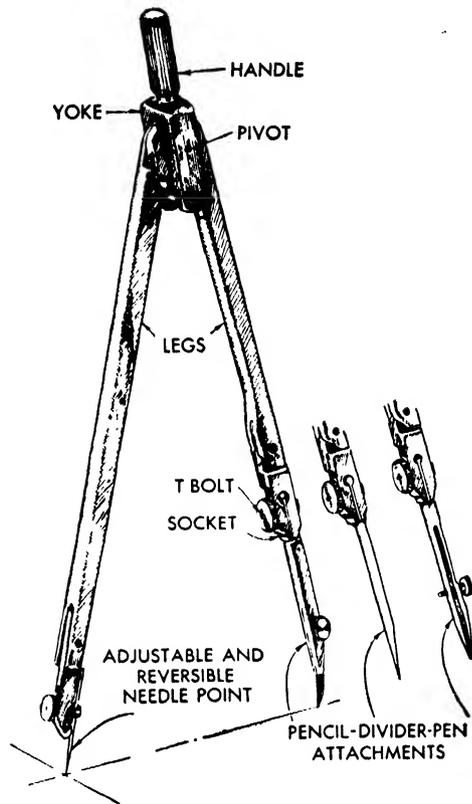


Fig. 57. The flat type compass

ers, compasses are manufactured in plain and hair spring styles, the hair spring is not needed in the compasses as badly as in the dividers.

To draw a pencil circle (Fig. 58):

1. Draw the center lines of the circle.
2. Set off the required radius on one center line with the scale.
3. Carefully guide the needle point of the compass (adjusted a trifle longer than the compass lead) into the intersection of the center lines.
4. Adjust the compass to the radius length.
5. Holding the handle securely, draw the circle to the right (clockwise), tilting the compass in the direction in which the circle is being drawn. Guide the compass *only* with the handle—not from the pencil leg.

Compasses are made in various sizes ranging from the "bow" compass (for circles having a radius of 1 inch or less) through the "large" or "6 inch" compass to the "beam" compass (for circles of 12 to 18 inches radius). The trammel bar is used to construct still larger circles.

The large or 6 inch compass may be of either the flat or the beveled type. It is used to draw

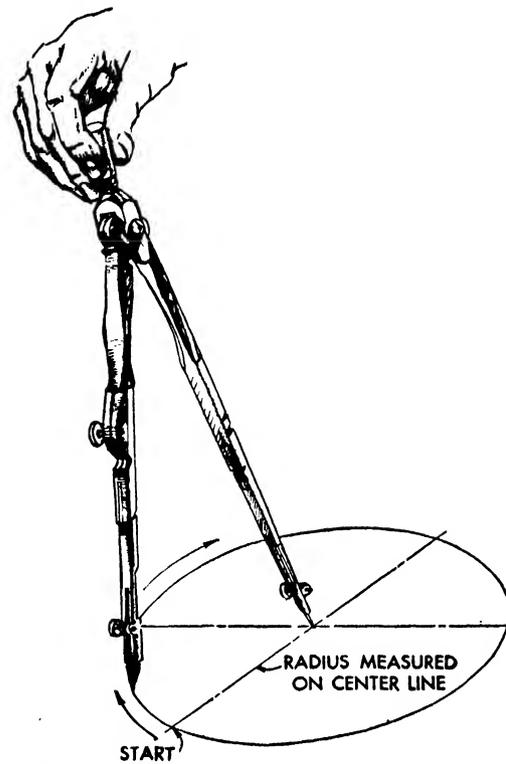


Fig. 58

circles whose radii range between 1 and 12 inches.

For circles of over 2½ inches radius, "break" the legs of the compass (Fig. 59) so that the

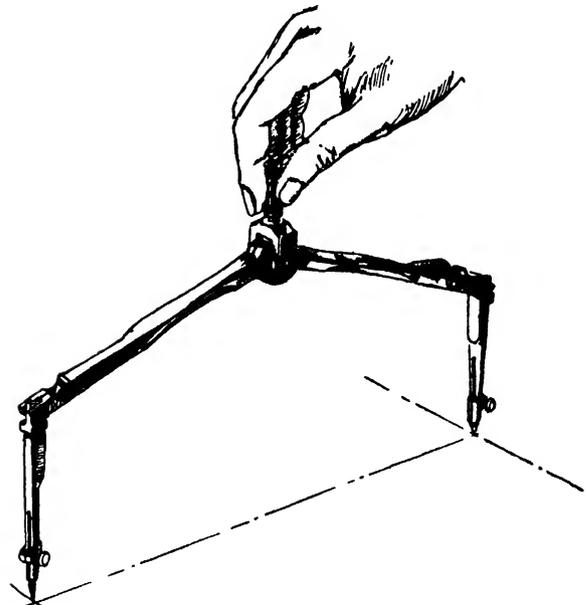


Fig. 59. Breaking the legs

## AIRCRAFT DRAFTING

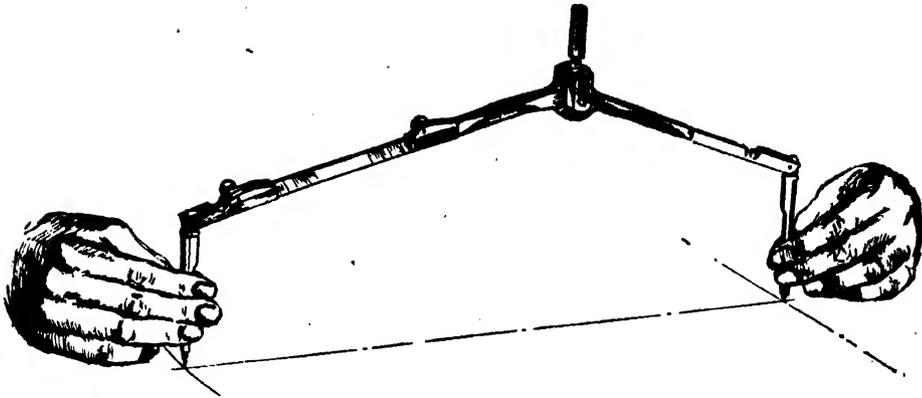


Fig. 60. Breaking the legs

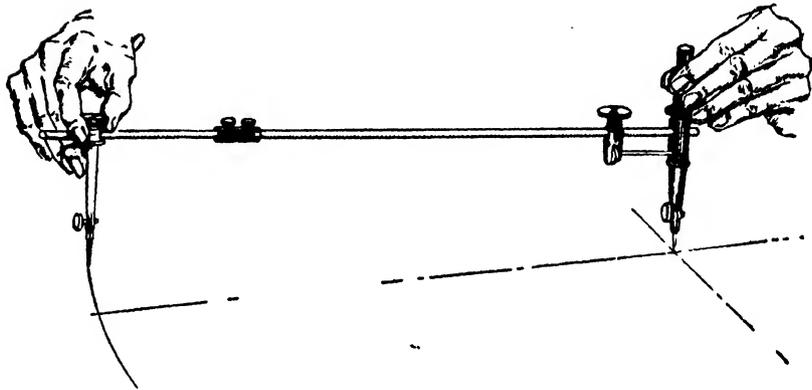


Fig. 61. Tubular beam compass

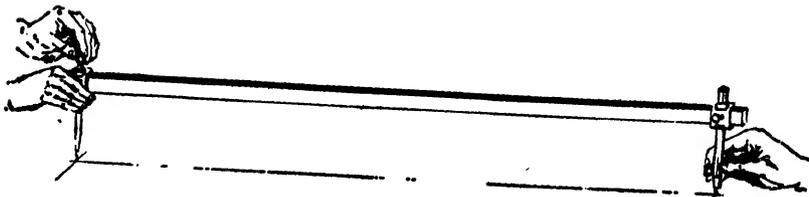


Fig. 62. Trammel bar

needle and lead touch the paper perpendicularly.

To draw circles of over  $5\frac{1}{2}$  inches radius, use the lengthening bar (Fig. 60). The common bar supplied in the case instruments is 4 to 6 inches long. Use both hands, and be careful not to vary the radius.

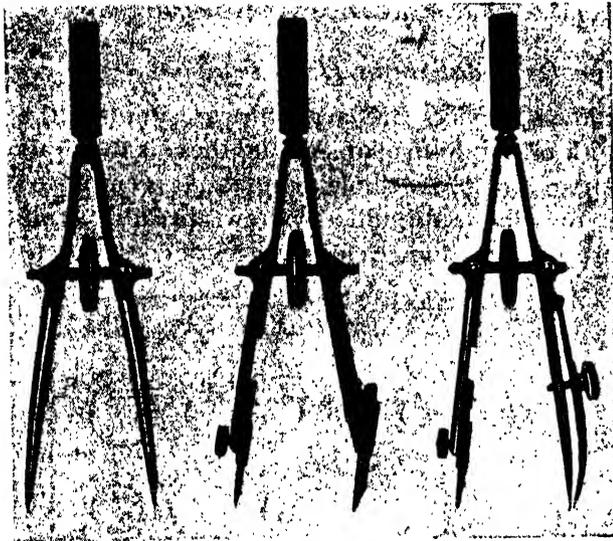


Fig. 63. Center-screw bow compasses

The beam compass is a very common instrument in the aircraft drafting room. With it circles of from 12 to 18 inches radius may be drawn, or it may be used as dividers within that range. The tubular beam compass (Fig. 61) is supplied with a micrometer adjuster to allow slight radius variations. A coupling is also supplied to secure a lengthening bar to the main beam.

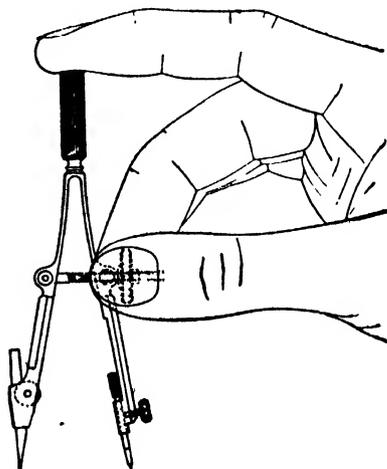


Fig. 65a

Beam compasses come in various designs; lengthening bars may be tubular, septagonal, or rectangular bars and either metal or hardwood.

The "trammel bar" (Fig. 62) is used to draw arcs of over 18 inches radius. Trammel points are inserted into a rectangular wooden bar sometimes 5 to 6 feet long. Although good seasoned

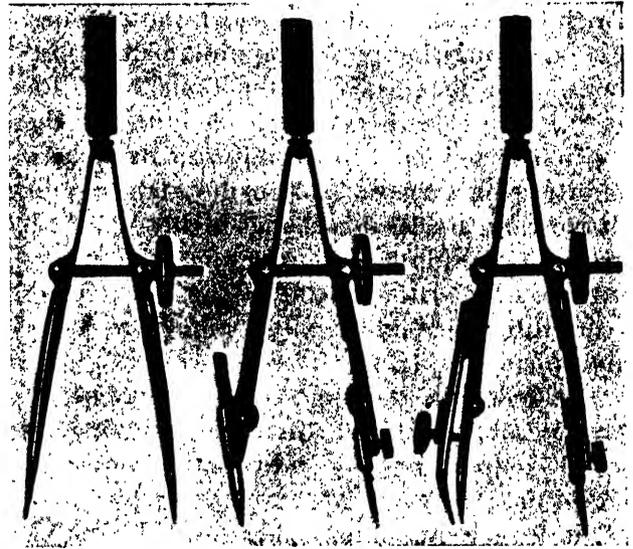


Fig. 64. Side-screw bow compasses

hardwood is generally used, careful consideration is given to the trueness of the bar. Two men are required to swing the arc. The radius is set off on the center line, one man sets the center, and the other swings the arc. The trammel bar is more common in the lofting department than in the drafting room, since the loft works only to full scale.

The bow compass is used for drawing small

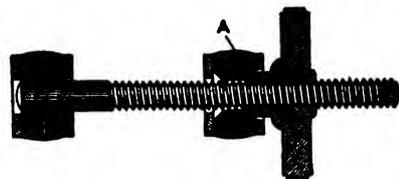


Fig. 65b

circles and a number of small circles of the same diameter. It is manufactured in a variety of designs, the two common types being the center screw (Fig. 63) and the side screw (Fig. 64). The length of the radius is adjusted by manipulating these screws. The center or side screws are large enough in diameter to provide a firm grip so that the compass can be set with the hand in which it is held, whether on or off the drawing. The screw may be spun for approximate adjustment, then readjusted in the same hand for final accurate setting. Figure 65 indicates the position of the hand in the adjustment process. The bearing surfaces "A" on the higher grade instruments are hardened and highly polished, reducing friction to a minimum. The spring must be strong enough to allow the bow to open to its full width and flexible enough to allow convenient closing.

The bow, like the large compass, may be interchangeable with the dividers or inking or pencil compass, or may individually consist of one of these types.

The large bow compass (Fig. 66) is becoming increasingly popular with aeronautical draftsmen. This compass is rigid in construction and

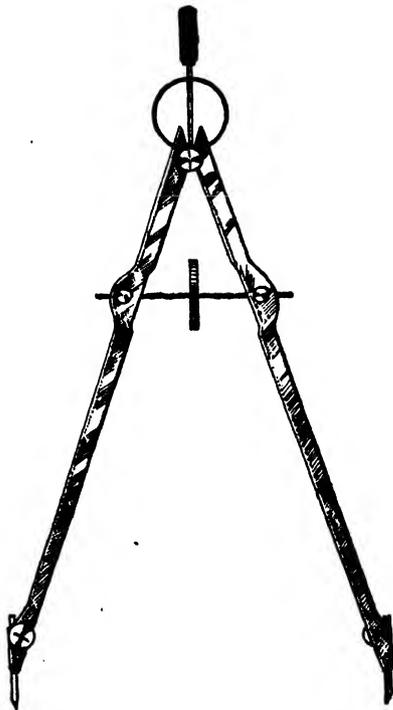


Fig. 66. Large or "master" bow compass

will draw circles from 8 to 11 inches in diameter, a range covering well over 60 per cent of the circles drawn in the drafting room.

The drop center compass, sometimes called the "rotating" compass, is used for drawing extremely small radii or small circles of the same radius. This compass has a center pin that remains stationary while the tube to which the pencil section is attached is revolved.

*The Draft Square or Hole Template*

Many devices are available to simplify the work of the draftsman. Among these is the draft square (Fig. 67a) or hole template. It is employed in drawing radii, fillets, screw threads, Acme threads, nuts, and circumferences of circles up to

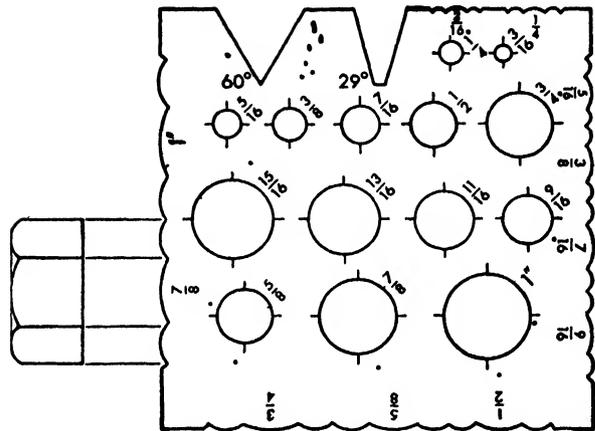


Fig. 67a. The draft square and its various applications

1 inch in diameter. Without the draft square these are tedious and time-consuming operations.

If, for instance, a 7/8 inch nut is to be layed out, the size and shape of the nut are taken from one side of the template designated as 7/8 (Fig. 67a).

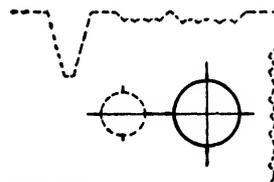


Fig. 67b

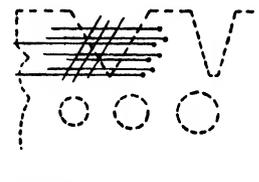


Fig. 67c

To draw a circle with prescribed dimensions of less than 1 inch diameter (Fig. 67b), draw the center lines of the circle on the paper. Place the draft square over the center line so that the

quadrant lines of the required diameter on the draft square coincide with the center lines of the required circle, and draw the circle.

Small appropriately spaced punch holes on the template formulate guide lines for lettering as illustrated in Fig. 67c.

One of the most common uses of the draft

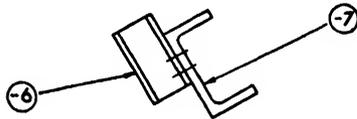


Fig. 67d

square is the drawing of circles to enclose dash numbers (Fig. 67d). These are usually  $\frac{3}{8}$  inch or  $\frac{1}{2}$  inch diameter circles, depending on company preference.

To draw radii, first construct the tangent lines on the drawing. For example, Fig. 67e,

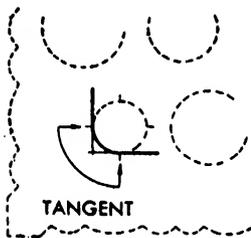


Fig. 67e

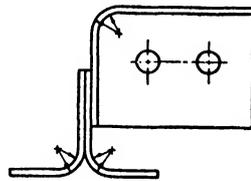


Fig. 67f

set the hole in the template of the required  $\frac{1}{4}$  inch radius ( $\frac{1}{2}$  inch diameter circle) to coincide with the tangent lines at the quadrant marks and draw the radius as illustrated.

In a sheet metal part, Fig. 67f, the gage of material is given as  $\frac{1}{8}$  and the required bend radius is  $\frac{1}{4}$ . Use the  $\frac{1}{2}$  inch circle in the draft square to draw the inside radius and the  $\frac{3}{8}$  circle to draw the outside bend radius. This is a typical construction. Many varied bend radii may be drawn in a similar manner as long as the diameters of the holes coincide with the appro-

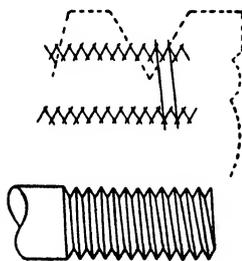


Fig. 67g

priate inside and outside radii of the bend.

The method for laying out 60 degree screw threads is illustrated in Fig. 67g. First lay out the outside and root diameters, and use the 60 degree angle on the draft square to obtain the connecting lines between the major diameter and the root of the thread. Lay out Acme threads in the same manner, using the 29 degree angle on the template.

### Irregular Curves

Celluloid curved patterns or "irregular curves" designed mathematically in a variety of shapes are used to draw curves that cannot be executed with the compass. Irregular curves vary in size from the small circular "French curve" to the long flat "ship curves" (Fig. 68).

To use the irregular curve:

1. Plot points by setting off given distances on horizontal and vertical intersecting lines as designated in Fig. 70 and problems 24, 25, and 26.

2. Sketch a light freehand curved line through these determined points so that the curve appears as a "natural line," unbroken and smooth.

3. Manipulate the irregular curve until a section of its contour coincides with the plotted points and the sketched line. Now use the edge of the curve as a guide to draw the finished section of the curve.

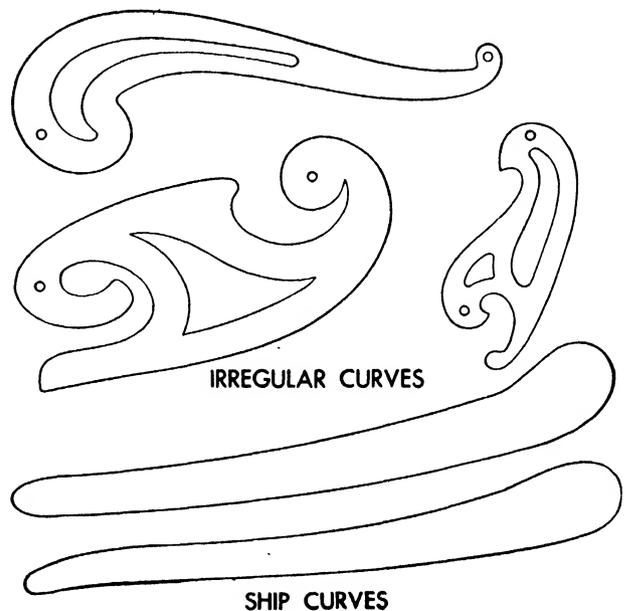


Fig. 68

4. Do not draw quite as much of the finished curve as the section of the irregular curve fits. Stop a little short on the sketched line as this allows a more natural continuation to the next portion of the curve.

Plexiglas, or cellulose, strong, yet flexible enough to be bent to connect plotted points to form a smooth faired line. The spline is grooved on its top side to allow for the prongs of the ducks. The weight of the ducks holds the spline

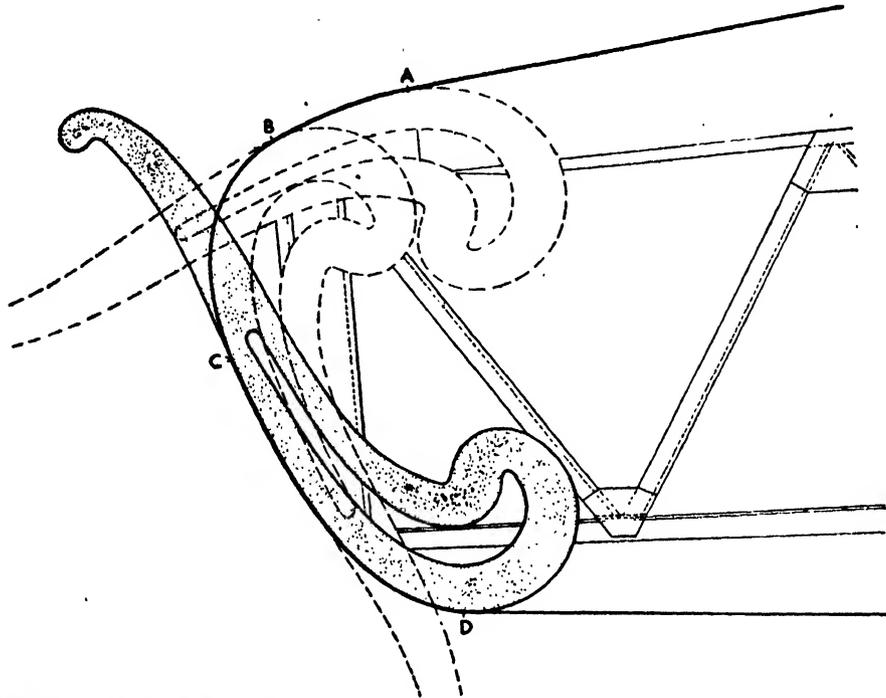


Fig. 69. The irregular curve

5. Shift the irregular curve about so that the various sections of the drawn curve blend into one another without noticeable change of direction.

Figure 69 illustrates the use of the irregular curve in drawing a wing tip. Distance AB is drawn first. The curve is set to include distance BC and then CD tangent to the trailing edge. Note the stopping short on curve lengths.

The ship curve is very similar to the French curve except that it is usually flatter and longer and is used to draw contours and beltframe arcs too large for the ordinary irregular curve.

### *Spline and Ducks*

Neither the irregular curve nor the ship curve can be used to construct the long, smooth, fair lines typical of aircraft contour. For this purpose, ducks and splines are provided.

A duck is a lead weight to one end of which is attached a bent wire or prong.

A spline is a long thin strip of wood, metal,

stationary on the plotted points, and the bottom edge of the spline (sometimes beveled) acts as a guide for the pencil in drawing the curve. Splines are purchased or made by the draftsman in a great variety of lengths.

Figure 70 illustrates the steps taken to spline a line.

1. First plot the points.
2. Draw a light freehand line connecting the points.

3. Set the spline to touch the points and secure it to each point by a duck. Paper is usually laid under each duck to keep the drawing clean.

It is common aircraft practice to call for long curved parallel lines spaced from 0.032 to 0.092 inch apart (thickness of sheet metal). To facilitate drawing such lines a small circular disk of about 2 inches diameter may be used. The disk may be made from celluloid or thin sheet metal, with small holes punched at various distances from the circumference.

Once the spline has been set and the initial

line drawn, a sharp pencil point is inserted into the desired hole, and the disk is then brought to bear tangent to the spline. The edge of the disk is guided against the spline. The pencil then makes a uniform parallel line of the required width.

### Inking

The inking of drawings is minimized in aircraft drafting both to save time and because designs are constantly changing. Where inking is required, the ruling pen is used to ink all straight lines and irregular curves.

Since this pen is the instrument most frequently used in inking, it should be of the highest quality. The nibs should be carefully sharpened and kept clean. A drop or two of ink is inserted between the nibs of the ruling pen or inking attachment nibs of the compass by means of the quill fastened to the ink bottle cover. Be careful not to insert too much ink. About  $\frac{3}{16}$  inch is enough. Place the pen against

the straightedge in a nearly vertical position with both nibs resting lightly on the paper. The pen should bear along the straightedge only enough to guide the direction. If the pen is inclined toward the straightedge, the ink will run under the straightedge, making a blotted line. Apply uniform pressure to the pen while drawing a line to ensure consistency of width. Start and end the line quickly to prevent a bulb forming at the beginning and end.

### Protractors

Protractors (Fig. 71) are used to measure or to lay out angles that cannot be constructed with the 45 and 60 degree triangles. There are several types of protractors, but the celluloid or stamped steel protractor is satisfactory for ordinary work.

### Paper

Bond paper, supplied by most aircraft companies in large rolls, is used for roughs and layouts.

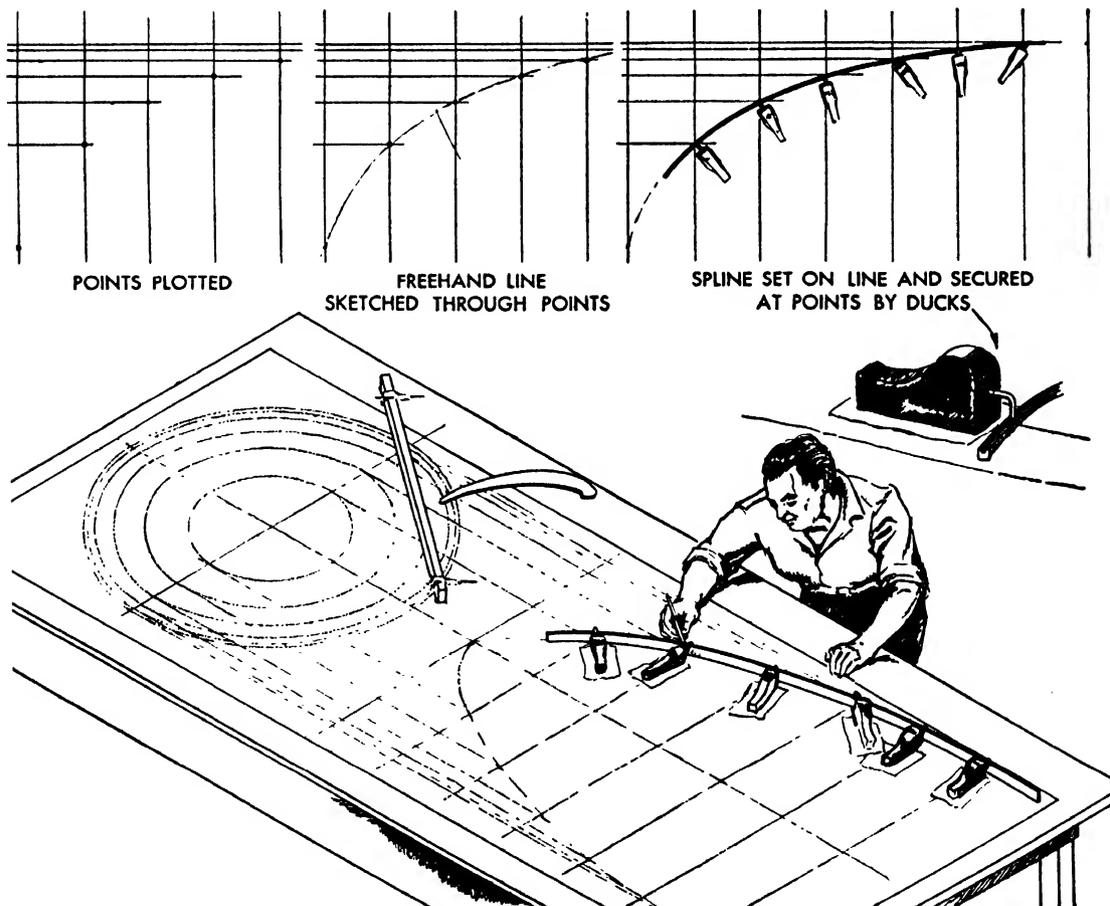


Fig. 70. The use of the spline and ducks

Nearly all pencil drawings are now made directly on vellum or tracing cloth, from which they can be reproduced. The vellum sheets usually come printed with a border and a bill of material block in the right-hand corner. Drawings are sometimes classified by the size of the sheet they are drawn on. The five or six sizes (Fig. 72) range from  $8\frac{1}{2}$  by 11 to 36 by 96 inches. A symbol designates each size; for example,  $8\frac{1}{2}$  by 11 inches may be an "A" size sheet, and 36 by 96 inches a "K" size sheet; or  $8\frac{1}{2}$  by 11 inches may be a "one" size sheet, etc.

To hold the paper securely to the drawing board, thumbtacks, drafting tape, or wire brads may be used. Many draftsmen prefer to use drafting tape because thumbtacks impede the movement of T square and triangles, and they also leave unsightly holes in the paper. Drafting tape holds the paper firmly and eliminates these disadvantages.

### *The Drafting Machine*

The drafting machine has been almost universally accepted by the aircraft companies, replacing the conventional T square, triangles, protractor, and scale. Although this machine is expensive and is usually inaccessible to the student, a description and an explanation of its applications are presented, for the student will

undoubtedly find it his chief tool in actual aircraft drawing.

The drafting machine (Fig. 73) has been designed to afford a well-balanced combination of speed and accuracy.

It enables the draftsman to place his scale where he wants it and in any desired angular position with a minimum of time and effort. An indexing device renders possible a quick setting of the scales and straightedge to any of the angles formerly laid off by the protractor or triangles.

Vertical and horizontal lines are readily laid out on any area of the drawing by the respective scales.

The working draftsman employs this machine to full advantage but still finds frequent occasion to use his scales, triangles, protractors, and other conventional instruments. The student should be under no illusions, therefore, that the existence of the drafting machine makes it less important for him to gain accuracy and speed in handling his regular tools.

Before attempting any drafting, the operator should familiarize himself with the proper manipulation of the drafting machine as outlined in the following paragraphs.

The drafting machine is attached to the upper edge of the board by a strong, single-screw clamp which usually, though not invariably, should be

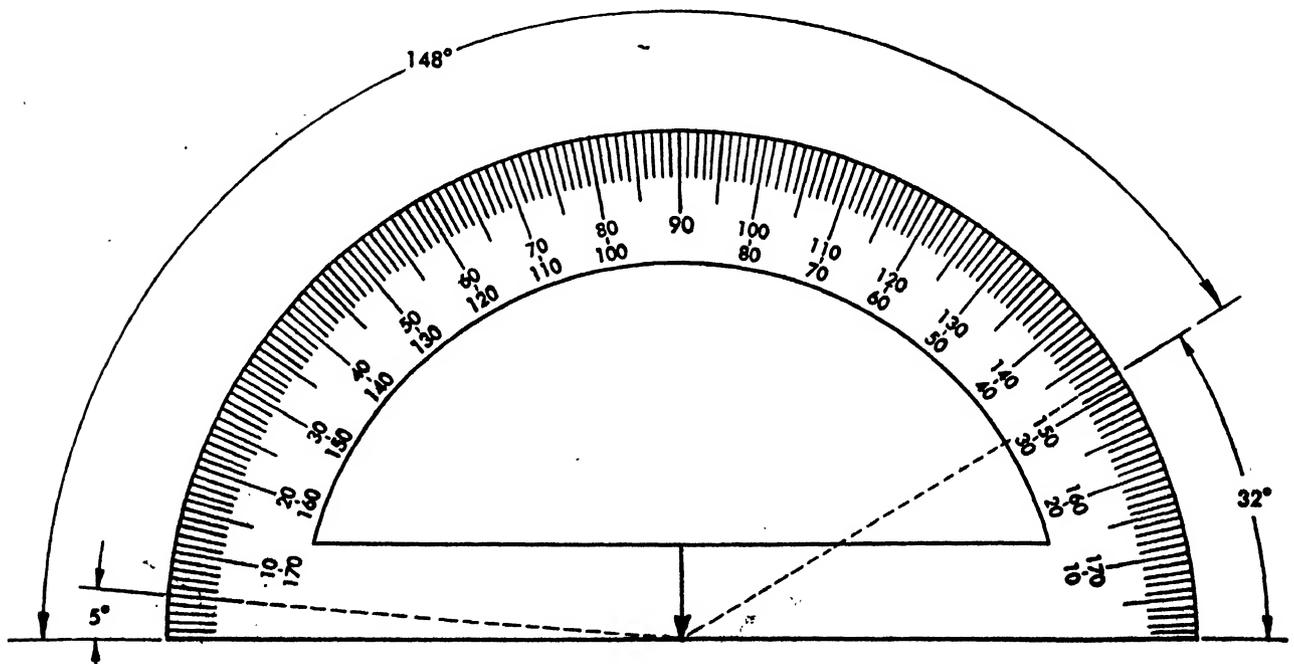


Fig. 71. The protractor

placed about 8 inches to the left of the center line of the work. The clamp is so constructed that it can easily be released, and the operator should not hesitate to change its position whenever this procedure will expedite his work.

To set a scale in the instrument, place the scale flat on the board and in alignment with the scale chuck on the machine. Then press the chuck plate on the scale firmly into the chuck. Be careful not to drive it in. To remove the scale, steady the drafting head with the left hand while the right hand strikes the scale sharply with a sliding movement away from the drafting head. The resilient scale chucks hold the scales firmly, yet release them readily.

*Elbow Brake.* The single brake nut "7" can be adjusted to prevent sliding on an inclined table. Tighten the nut just sufficiently to accomplish its purpose. On a horizontal surface, the nut should be released.

The braking action afforded by the large brake linings "9" and "10" is effective in preventing sliding without interfering with the proper movement of the drafting head over the table. However, it should be used only on a gently inclined table. Avoid slopes exceeding 12 degrees if this can be done conveniently. The

entire brake can readily be removed by screwing off the brake nut "7" and pressing down on the screw that projects above the upper brake disk "8."

*Indexing Mechanism.* The indexing thumbpiece is conveniently located in the handle. Normally the base plate, which comprises the protractor arm and carries the scales, is firmly locked at one of the predetermined angles (multiples of 15 degrees). To release it, make sure that the protractor wing nut "29" is released. Place the left hand on the handle and press the thumbpiece "26." The base plate can then be turned to any position by firmly gripping the drafting head handle "35" and rotating it. Use the left hand on the handle to steady the head while the right hand, placed upon the remote end of the horizontal scale, slides the protractor arm around into the desired angular position. This is the only way of accurately setting any drafting machine at positions between the predetermined angles, and a standardized procedure for all positions will be more efficient than frequent changes from one method to another.

A distinct click will be noticed as the protractor arm arrives at each 15 degree position. By counting these clicks, the operator can set

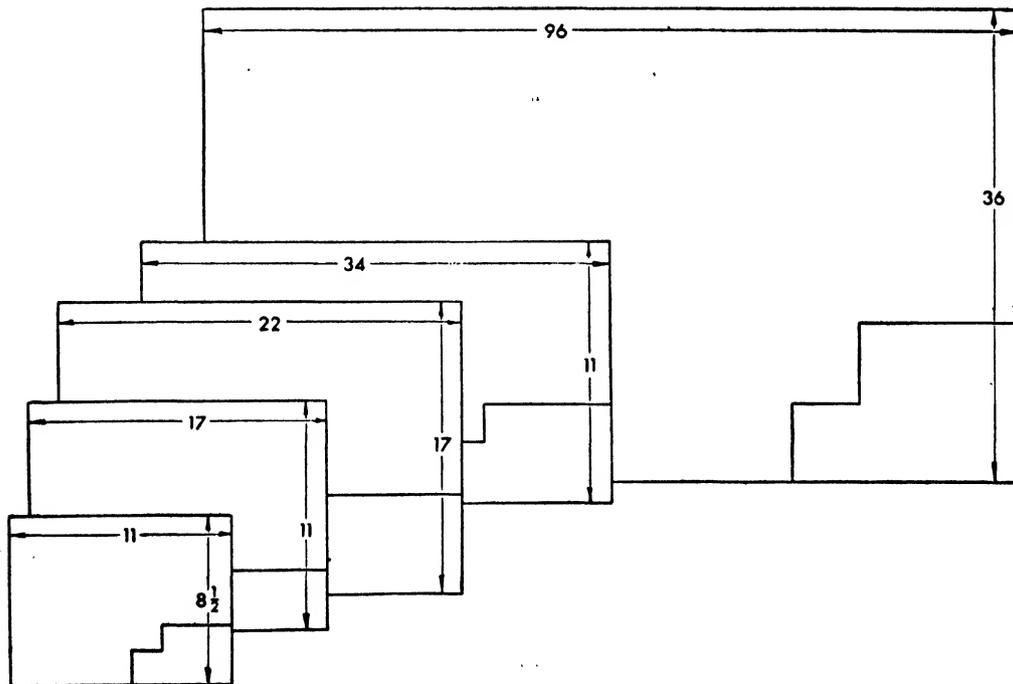
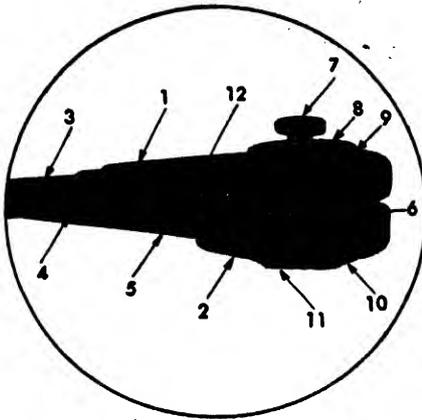


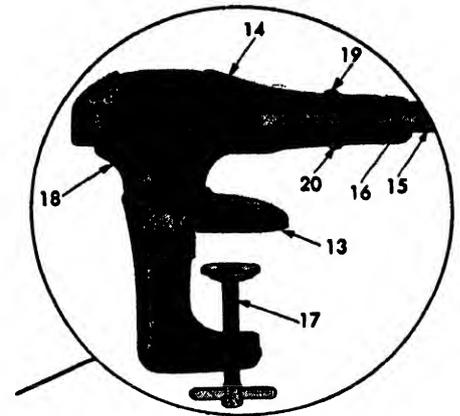
Fig. 72. Common vellum sizes

# AIRCRAFT DRAFTING

## ELBOW ASSEMBLY

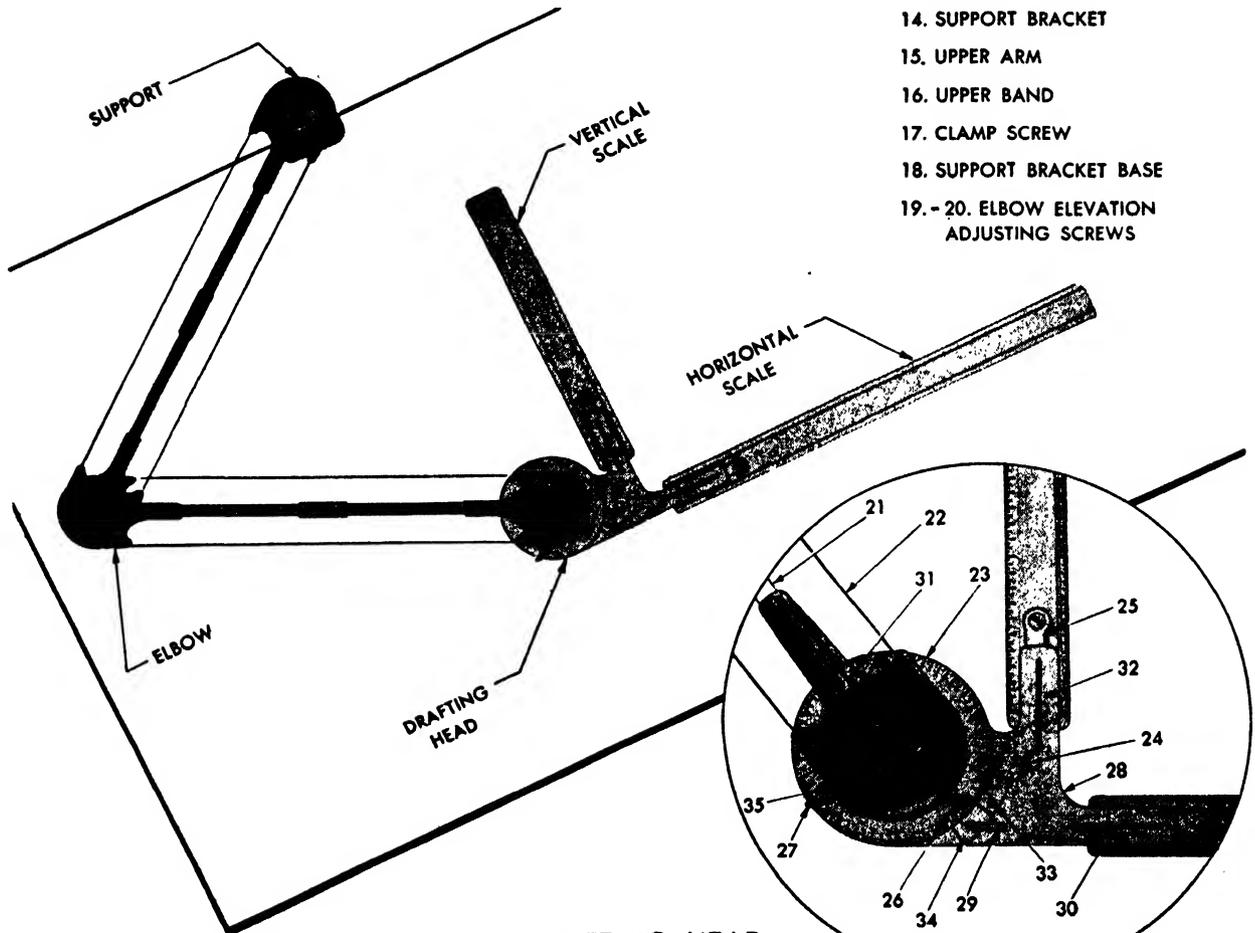


- 1. UPPER ELBOW BRACKET
- 2. LOWER ELBOW BRACKET
- 3. UPPER ARM
- 4. UPPER BAND
- 5. LOWER BAND
- 6. ELBOW PULLEY
- 7. BRAKE NUT
- 8. UPPER BRAKE DISK
- 9. UPPER BRAKE LINING
- 10. LOWER BRAKE LINING
- 11. LOWER BRAKE DISK
- 12. BAND-TIGHTENING PIN HOLE



## SUPPORT ASSEMBLY

- 13 CLAMP
- 14. SUPPORT BRACKET
- 15. UPPER ARM
- 16. UPPER BAND
- 17. CLAMP SCREW
- 18. SUPPORT BRACKET BASE
- 19.- 20. ELBOW ELEVATION ADJUSTING SCREWS

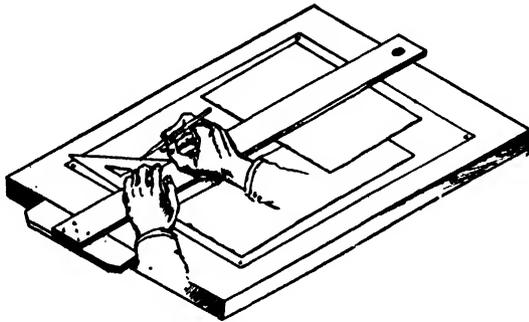


## DRAFTING HEAD ASSEMBLY

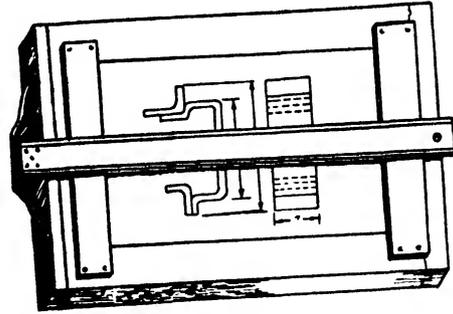
- 21. LOWER ARM
- 22. LOWER BAND
- 23. PROTRACTOR
- 24. VERNIER PLATE
- 25. CHUCK PLATE
- 26. INDEXING THUMB PIECE
- 27. BASELINE WING NUT
- 28. BASE PLATE (PROTRACTOR ARM)
- 29. PROTRACTOR BRAKE WING NUT
- 30. HORIZONTAL SCALE CHUCK
- 31. HEAD BRACKET
- 32. VERTICAL SCALE CHUCK
- 33. VERNIER PLATE SCREWS
- 34. PROTRACTOR BRAKE
- 35. HANDLE

Fig. 73

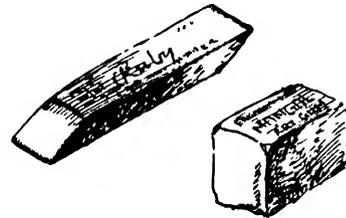
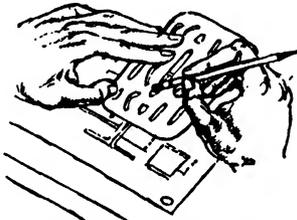
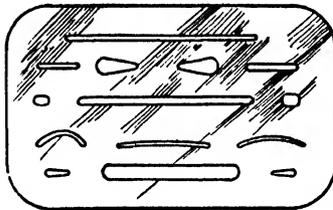
KEEPING THE DRAWING CLEAN



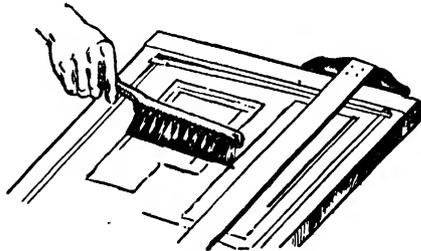
IF THE PARTS OF A DRAWING NOT BEING WORKED ON ARE COVERED WITH CLEAN SHEETS OF PAPER, THE DRAFTSMAN WILL PRODUCE A NEATER AND CLEANER PRODUCT



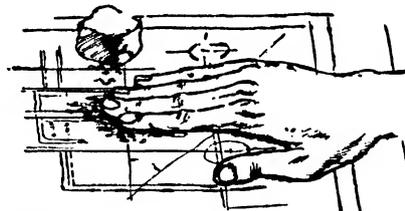
TO KEEP THE T SQUARE FROM SMUDGING THE DRAWING, STAPLE OR TACK A FEW SHEETS OF PAPER ON EACH END OF THE BOARD TO RAISE THE T SQUARE SLIGHTLY ABOVE THE DRAWING



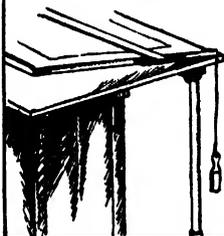
THE CUTOUT SHAPES IN THE ERASING SHIELD ALLOW SMALL PORTIONS OF THE DRAWING TO BE ERASED WITHOUT INJURY TO ADJACENT LINES. HOLD THE SHIELD FIRMLY OVER THE DRAWING. THE ERASER END OF A PENCIL MAY BE CONVENIENTLY USED. RUBY ERASERS ARE UNIVERSALLY USED FOR MOST DETAIL WORK. ART GUM IS USED FOR OVER-ALL CLEANING



A DUST BRUSH IS USEFUL TO CLEAN THE ERASURES FROM THE DRAWING



TO REMOVE SURFACE DIRT AND GRIME WITHOUT MARRING THE LINES, GATHER SHAVINGS OF THE ART GUM INTO A PILE AND RUB THEM LIGHTLY OVER THE FACE OF THE DRAWING WITH THE FINGERS OR PALM



KEEP THE SANDPAPER PAD AWAY FROM THE WORKING AREA OF THE DRAWING



TO KEEP TRIANGLES FROM SMEARING THE DRAWING, GLUE THIN PIECES OF CELLULOID TO ONE SIDE

Fig. 74

the arm at any of the predetermined positions without having to read the protractor. Releasing the thumbpiece permits the indexing mechanism to lock the arm firmly at any of the predetermined positions.

*Intermediate Angles.* The change for setting intermediate angles is effected simply by pressing the thumbpiece in the handle, moving it laterally toward the operator, and then releasing it. The left hand steadies the drafting head while the right hand, placed upon one of the scales, slides the protractor arm around until the desired angular reading is indicated by the vernier. The protractor brake can then be set by tightening the brake wing nut "29" with the left thumb.

*Baseline Setting.* The protractor can readily be set so that its zero point lies in any desired azimuth. Use the indexing mechanism to lock the protractor arm at the zero position on the protractor. Then release the baseline wing nut

"27." Now align one of the scales with the baseline on the drawing and tighten the wing nut. This procedure is obviously advantageous when several lines are to be drawn at specified angles with respect to some particular line which may lie in any direction.

The baseline wing nut must be tight to prevent the baseline adjustment from slipping and to clear the protractor brake wing nut "29." Even when very tight it can readily be loosened. Simply place the left hand on the handle in such a manner that the thumb is practically straight as it presses against the baseline wing nut; then rotate the hand with respect to the handle. As a machine is used, the baseline wing nut can be pressed more easily to clear the protractor brake wing nut, and for this reason the clearance is made small in a new machine. Strongly tightening and loosening the baseline wing nut several times will result in a clearance in any new machine.

## CHAPTER THREE

# THE SCALES AND THEIR USE

Aircraft drawings are usually made on paper. The object represented may be drawn in its actual size or either larger or smaller, depending on the size of the part or group of parts and the nature of the drawing.

Full or actual size drawings are used whenever possible so that the draftsman can draw and design the part with maximum ease and accuracy. Actual size also aids the workman to visualize the part.

Most pictures in books, newspapers, etc., are reduced in size as a matter of convenience to the reader in handling the material, for the ease in preserving it, and to meet the practical limitations of printing and distribution. Large aircraft parts are drawn in reduced size for the same reasons. If all parts were to be drawn actual size, drawing benches would have to be too large to work at conveniently. The prints would be too unwieldy for the shopman to handle, and the necessary recording and filing of all blueprints would be impractical. Therefore, we may conclude that the prime reason for drawing an object smaller than actual size is to reduce the size of the paper the part is to be drawn on, and this reduction is applied only when full size is impractical. When drawing in reduced size, the student should always *think* of the part in full size, as the manufacturing of the object in the shop is governed only by the dimensions specified and not by the area on the blueprint.

The unit of measurement for all aircraft parts is 1 inch. The subdivisions of an inch are shown in Fig. 75.

Parts must be reduced proportionally and accurately, and the tool employed is called the "scale." Most beginners refer to this instrument by the nonpreferred term "ruler."

Almost everyone is familiar with the scale.

Fortunately, the scale used in aircraft work is the architectural scale, which is universally used for general applications outside the industry.

A common type of architectural scale is the triangular type (Fig. 76). This has the advantage of combining eleven scales on one stick, but the draftsman must usually hunt about to find the desired scale.

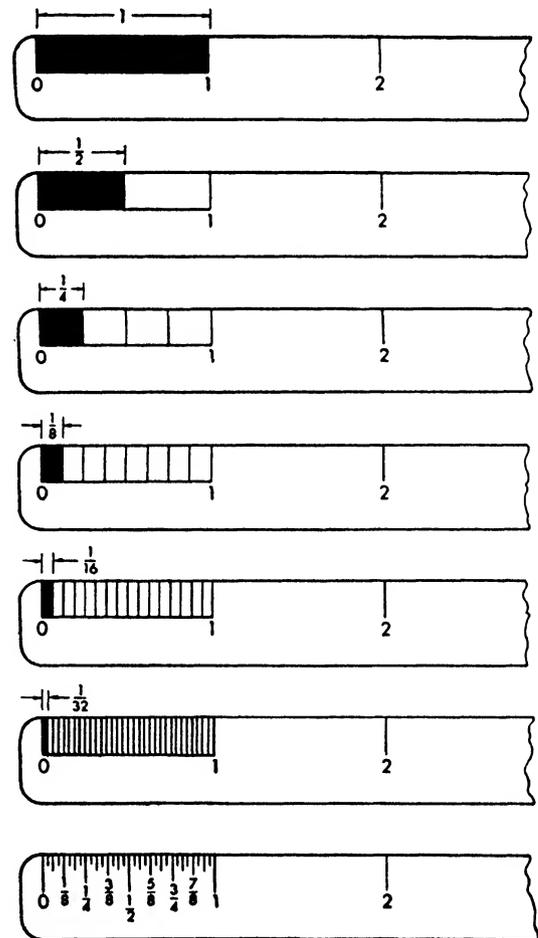


Fig. 75. Subdivision of one inch

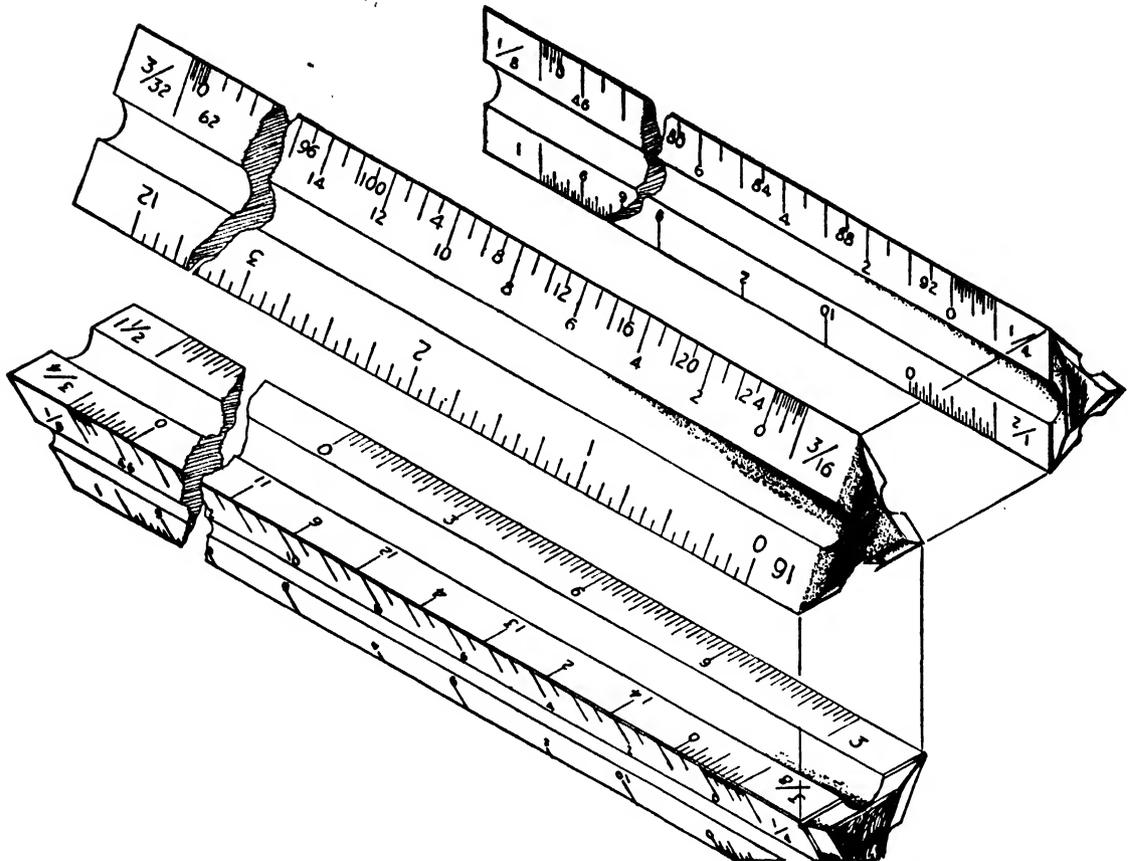


Fig. 76. The triangular scale

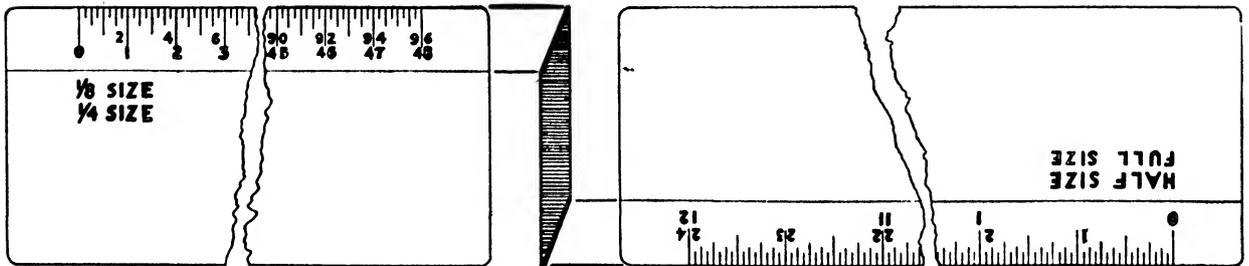


Fig. 77. Mechanical engineer's scale

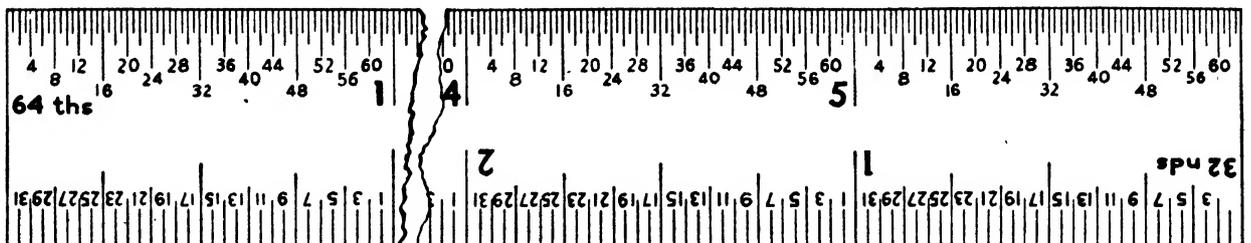


Fig. 78. The steel 6-inch scale

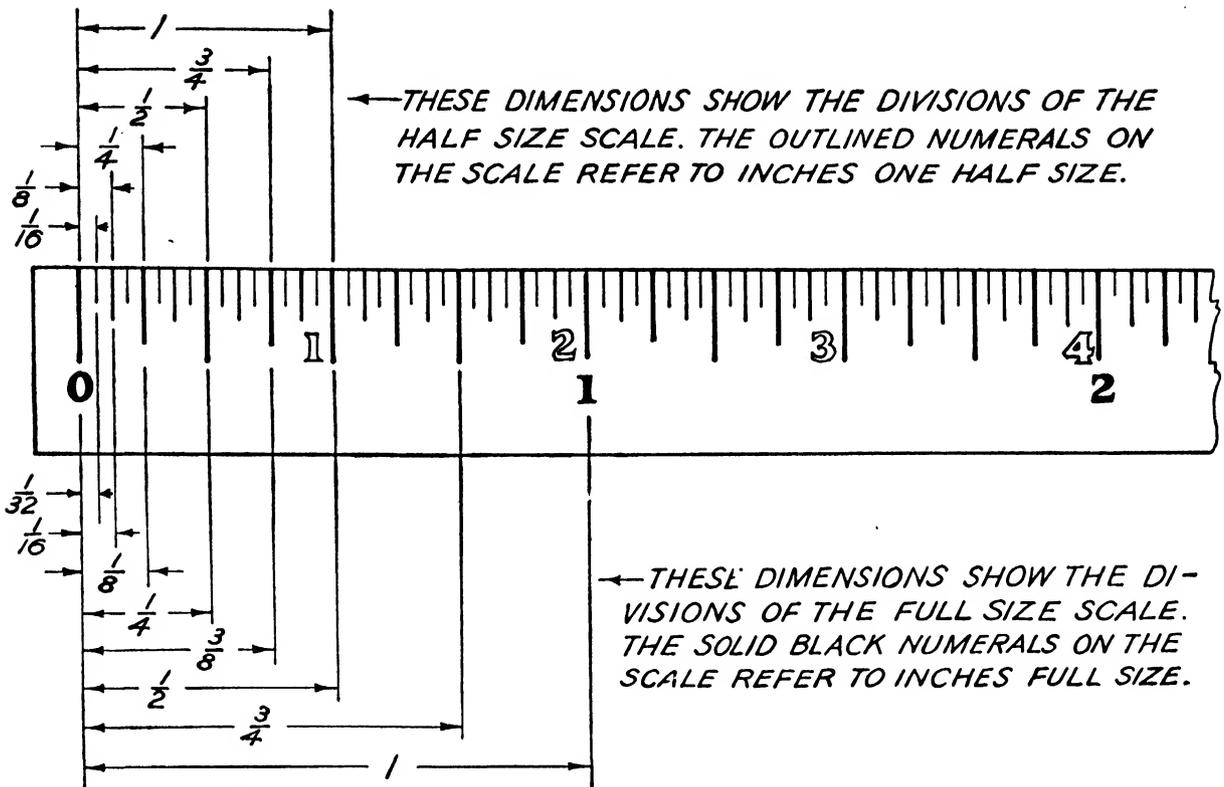


Fig. 79. Method of using the full and half-full divided scale

Mechanical engineers' scales (Fig. 77) are usually made from boxwood with a porcelainlike composition on the edges upon which the divisions are engraved. This type of scale is most commonly used by the practicing draftsman. In drawing an object quarter size, the scale marked "¼ size" would be employed. Here every actual quarter inch is equal to 1 inch.

The 6 inch steel scale, graduated in thirty-seconds and sixty-fourths of an inch, is often used in layout work and drawings, to determine gages of material, and to establish clearances (Fig. 78). The graduations are numbered for easy reading, and the scale usually contains a table of decimal equivalents on the opposite side.

Some steel scales are graduated into sixty-fourths and one-hundredths of an inch, but these scales find use mostly in the lofting department, where extreme accuracy is required.

Scales may be of the open divided or full divided types. An open divided scale is one whose end unit only is subdivided. A full divided scale is one whose units are subdivided throughout its entire length.

The methods of reading the full divided scale are shown in Figs. 79 and 80.

The methods of reading an open divided scale are shown in Figs. 81 and 82.

Full size, which is designated by the notation  $12'' = 1'0''$ , means that the drawing is actually the same size as the finished part will be (see Fig. 83). This scale should always be used when practical, as it gives the truest picture of an object. It is used to establish and to check clearances, for greater accuracy of design, and for details, sections, and views of a part drawn to a reduced size.

The notation  $6'' = 1'0''$  designates half size in which each inch is represented by  $\frac{1}{2}$  inch. The drawing will be one-half the size of the object. It is used for layouts, large members, parts of members that are too large to be drawn to full size, and for a large number of sections, details, and views of a reduced main view drawing.

Quarter size means that the drawing is one-quarter the size of the finished part, and each inch will be represented by  $\frac{1}{4}$  inch; therefore, every 3 inches will be equal to 12 inches. The

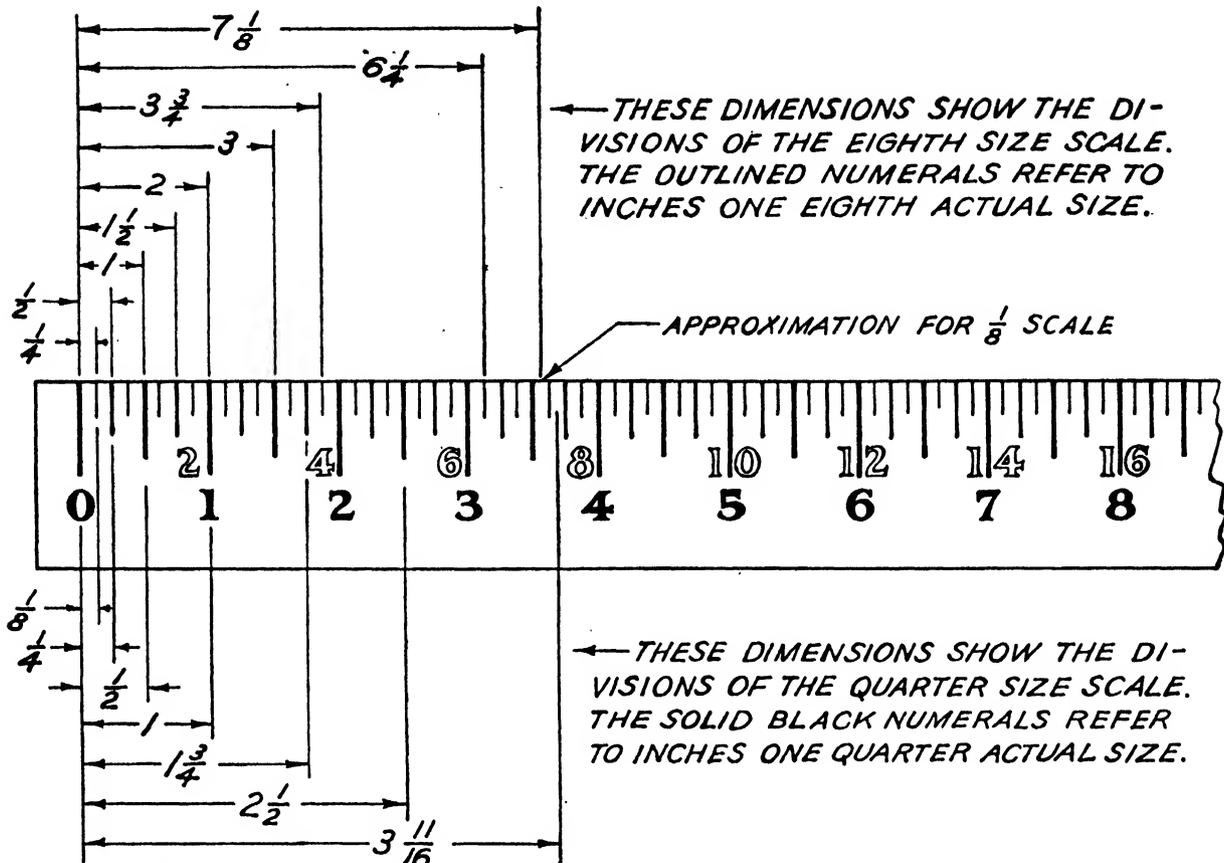


Fig. 80. Method of using the  $\frac{1}{4}$  and  $\frac{1}{8}$  full-divided scale

scale is indicated by the notation  $3'' = 1'0''$ . One-quarter size is used for large assembly drawings and for installation drawings.

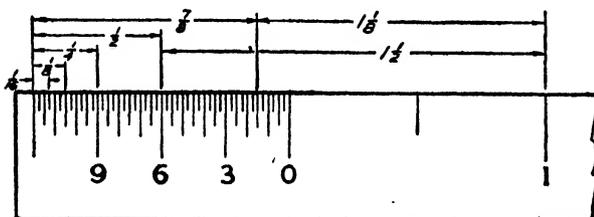
When an over-all picture of large parts of a plane is desired and accuracy is not warranted, eighth size may be used; it is designated by  $1\frac{1}{2}'' = 1'0''$ .

In small detail parts, full size drawings of which would not provide sufficient clarity for shop use, double size is employed to enlarge the part. It is noted by  $24'' = 1'0''$ .

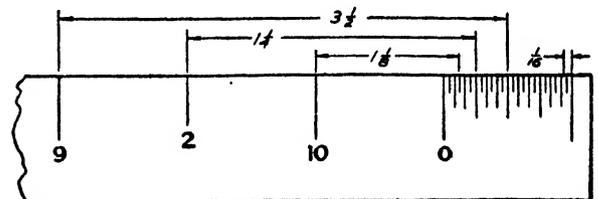
Accuracy in the use of the scale depends largely on its correct handling in setting off dis-

tances. Use a very sharp pencil to mark off each measurement accurately. If extreme accuracy is desired, make a tiny prick at the required point with a metal scribe or stylus. Place the scale on the drawing with the edge parallel to the line on which the measurement is to be made, and make a small point or dash at the correct graduation mark.

To avoid cumulative errors, set off a series of distances, end to end, at one setting of the scale. Never set them off individually, moving the scale to the new position each time, as slight errors may accumulate and add up to a large

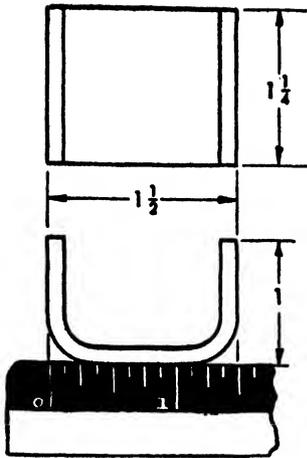


FULL SIZE SCALE :  $12'' = 1'0''$



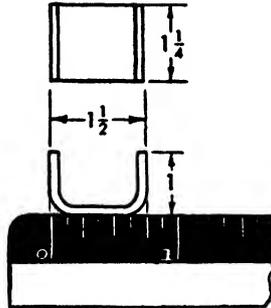
HALF SIZE SCALE :  $6'' = 1'0''$

Figs. 81 and 82. Methods of using the subdivided scale



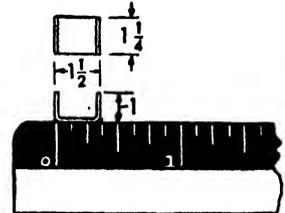
**FULL SIZE: 12"=1'0"**

THIS CHANNEL IS DRAWN FULL SIZE. EACH INCH ON THE DRAWING IS EQUAL TO AN INCH ON THE SCALE. A FULL SIZE DRAWING SHOULD BE USED WHENEVER PRACTICAL, AS IT GIVES THE TRUEST PICTURE OF THE OBJECT



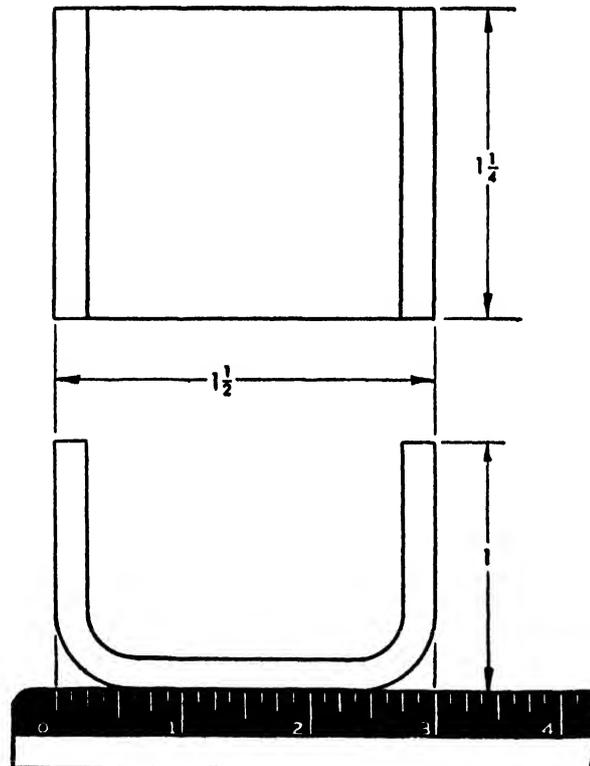
**HALF SIZE: 6"=1'0"**

THE CHANNEL IS DRAWN HALF SIZE. EACH INCH ON THE DRAWING IS EQUAL TO ONE-HALF INCH ON THE SCALE



**QUARTER SIZE: 3"=1'0"**

THE CHANNEL IS DRAWN QUARTER SIZE. EACH INCH ON THE DRAWING IS EQUAL TO ONE-QUARTER INCH ON THE SCALE



THE CHANNEL IS DRAWN DOUBLE SIZE. IT IS TWICE THE ACTUAL SIZE OF THE OBJECT. EACH INCH ON THE DRAWING EQUALS TWO INCHES ON THE SCALE

Fig. 83. Application of full, reduced and double scales

error. Do not take measurements off the scale with dividers or compass.

Out-of-scale dimensions on a drawing are underlined; a dimension change that radically changes the shape of an object necessitates a new drawing.

Scales, except drafting machine scales, are never to be used as straightedges because they are precision instruments and must be taken care of to maintain accuracy.

### *Fractions and Decimal Equivalents*

Fractions can be easily read in the architectural scale by remembering that the numerator, such as the 17 of  $\frac{17}{64}$ , is always an odd number, and the denominator, 64, is always an even number. Any fraction with even numbers in both numerator and denominator must be reduced to a lower equivalent— $\frac{12}{16}$  is reduced to  $\frac{3}{4}$ .

The very close tolerances specified for certain airplane parts are usually stated in decimal

dimensions. These decimal equivalents are arrived at by taking a fraction of an inch, for example,  $\frac{1}{8}$ , and dividing the numerator 1 by the denominator 8, thereby obtaining 0.125000, which is called its "decimal equivalent." Any fraction may be converted to a decimal equivalent.

The chart shown on the front end paper gives the decimal equivalents of all fractions from  $\frac{1}{64}$  inch to 1 inch. It is not necessary that the draftsman memorize all of these, but he should commit to memory those most frequently used:  $\frac{1}{8}$ ,  $\frac{1}{4}$ ,  $\frac{3}{8}$ ,  $\frac{1}{2}$ ,  $\frac{5}{8}$ ,  $\frac{3}{4}$ , and  $\frac{7}{8}$ .

The draftsman must know how to read a decimal equivalent. Starting with the first number, they are read: units, tenths, hundredths, thousands, ten-thousandths, and so on. One-sixteenth, or 0.06250, would be read sixty-two and one-half thousandths. One-eighth would be read twelve and one-half hundredths, or one hundred twenty-five thousandths, of an inch.

# CHAPTER FOUR

## THE ALPHABET OF LINES

### Introduction

After a drawing leaves the draftsman's bench, a number of blueprints are made from the tracing. One of these blueprints is routed to the shop, where the specific part will be manufactured without any further instructions from the engineering department. The draftsman must remember that a sharp, clear blueprint can be made only if his drawing follows the rules of good drafting technique.

A blueprint is read by interpreting the lines and symbols that compose it, much as the letters of the written alphabet are combined into words, the words into sentences. The lines are the ingredients of the drawing, presented so that they describe the shape and specify the size of the object to be manufactured. It follows that definite familiarity with the significance and meaning of the different lines is necessary to read or execute a drawing.

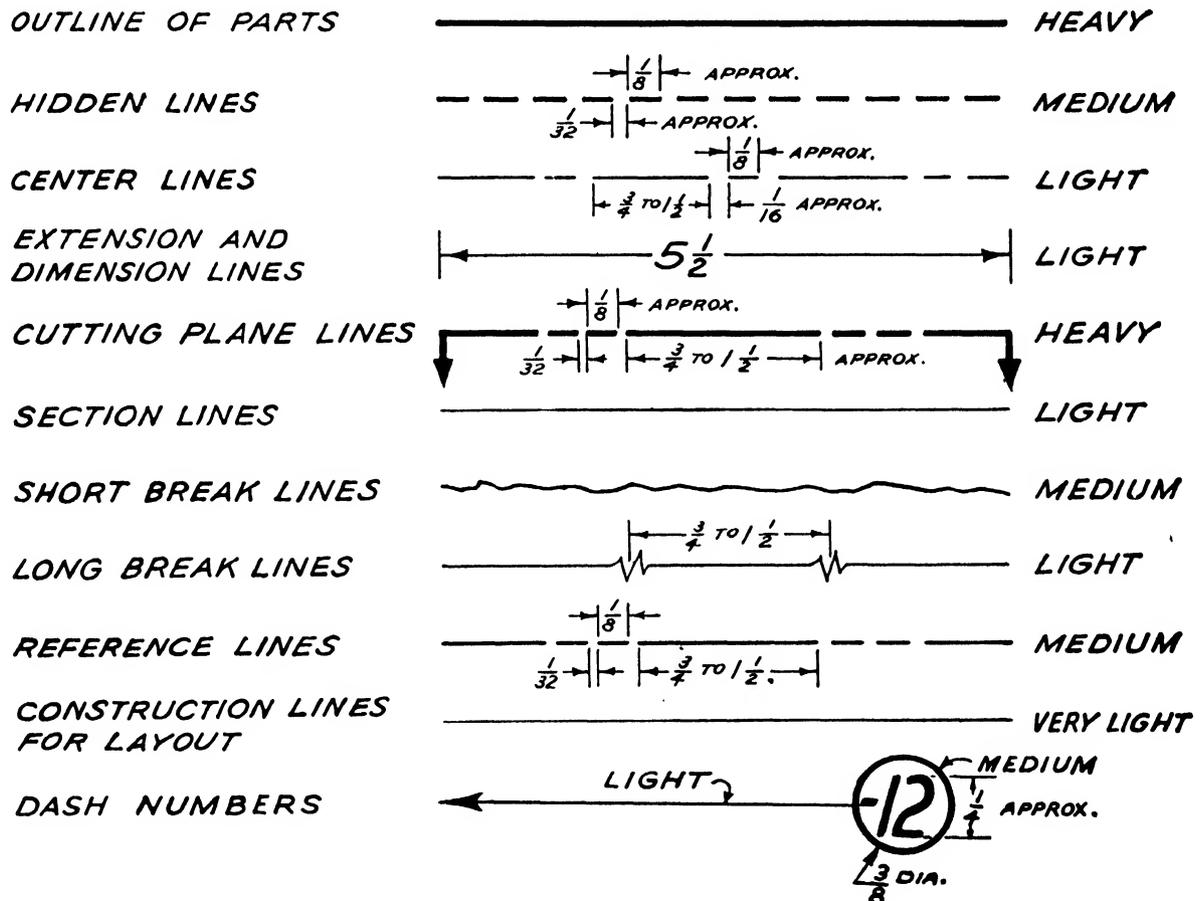


Fig. 84. The alphabet of lines

Since workmen are trained to read blueprints, incorrect use of the alphabet of lines would confuse them much as would written instructions without punctuation marks, periods, or capital letters and with misspelled words.

A certain dignity and respect between shop and engineering must be maintained. The engineering department expects instructions to be carried out accurately and conscientiously in the shop. *The shopman expects blueprints, his source of instructions, to be drawn legibly and methodically!*

THE ALPHABET OF LINES

Various attempts have been made to standardize engineering drawing for the aircraft industry. The process has been difficult because of the different procedures developed by individual companies. Engineering procedure is set forth by each company in a booklet called the company D.R.M. (Drafting Room Manual), or En-

gineering Manual, which sets forth the company's method of drawing.

Some standards have been determined. Perhaps the most important is the alphabet of lines, illustrated in Fig. 84.

Object Lines

The object line is the predominant line of the drawing. It outlines the exterior contour and shape of a part, and must be firm and bold.

Hidden Lines

Hidden lines are used to describe edges and contours of an object that are not visible to the eye of an observer. They should be slightly narrower than the object line.

Center Lines

A center line is used to designate the center plane of symmetry of an object. The vertical and horizontal center lines of circles are generally

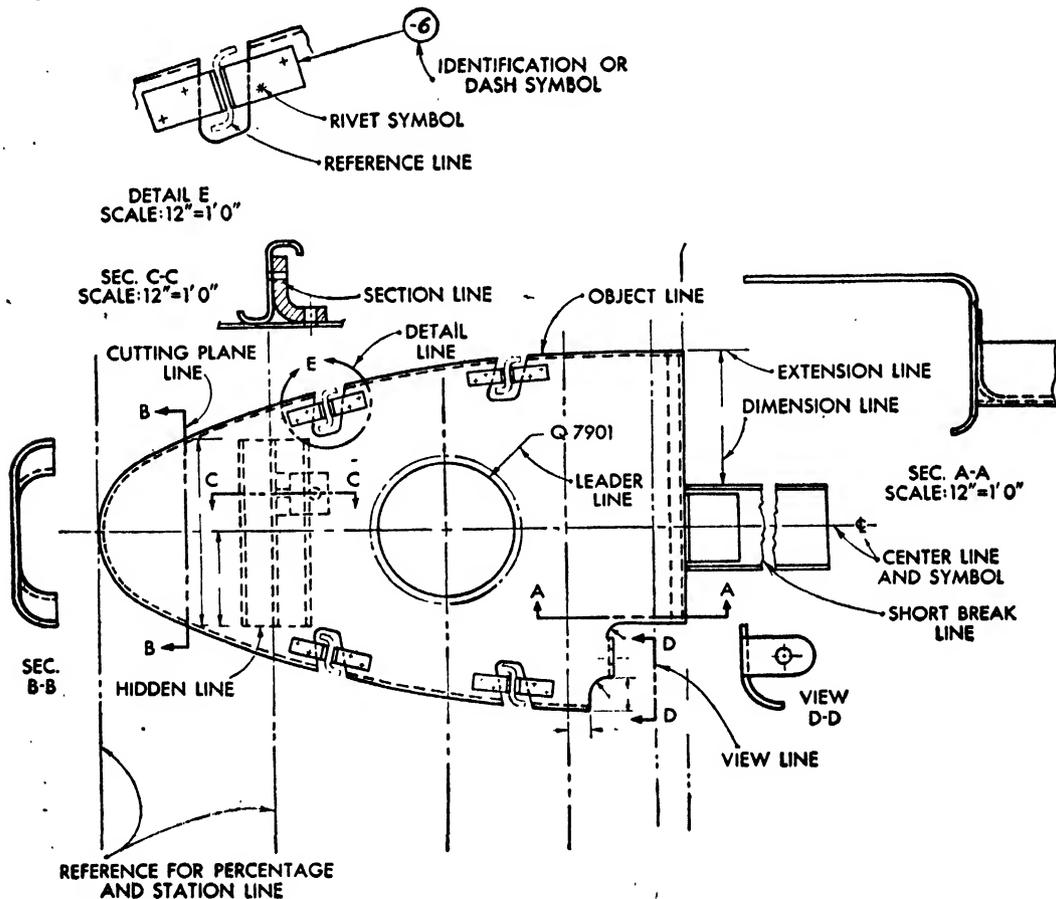


Fig. 85. Analysis of lines

indicated. Center lines of large shapes usually are marked by the symbol  $\Phi$  and any notations that may pertain to it.

#### *Dimension and Extension Lines*

A dimension line is used to indicate the length or size of a part. It is a fine solid line near the middle of which the numerals are inserted. An extension line is drawn from a view to show the stopping point for a dimension line. It also is a thin solid line.

#### *Cutting Plane Lines*

A cutting plane line marks the cutting plane to show a section view. The arrowheads of the line point in the direction from which the section is to be seen.

#### *View Lines*

A view line is like a cutting plane line except that it does not cut through a part. It is a view taken from the outside of an object.

#### *Detail Lines*

A detail line is just like a sectional line except that it is circular and encloses a part that is to be enlarged.

#### *Section Lines*

Since many objects are complicated in structure, it is difficult to describe their interiors by the use of hidden lines in the customary views. For this reason, the object may be cut through or into so that the interior may be seen and described. This is called a "sectional view." Thin parallel section lines about  $\frac{1}{16}$  inch apart are drawn at an angle through that area of the object through which the cutting plane has passed.

#### *Break Lines*

Break lines are used when an object is so large that it would be impossible to get the drawing on a sheet of paper. It is usually a free-hand, zigzag line of medium width.

#### *Reference or Phantom Lines*

A reference or phantom line is used to draw an object which has already been made but

must be referred to in the drawing, or as a key line from which measurements are taken. Reference lines are sometimes used to show the alternate positions of movable parts.

#### *Construction Lines*

Construction lines, as the name implies, are used to construct the drawing and serve as a base for subsequent darkening. These lines should be drawn very lightly, with a sharp hard lead, so that no erasing is necessary to remove them from the finished drawing.

#### *Leader Lines*

A leader line is a fine solid line which leads from a note or dimension and which is designated by an arrowhead pointing to the part to be noted.

#### *Dash Number Line and Symbol*

A dash number line is similar to a leader line except that, in place of a note, a dash and a number are printed in a  $\frac{3}{8}$  or  $\frac{1}{2}$  inch diameter circle.

### THE TECHNIQUE OF DRAWING PENCIL LINES

In aircraft drafting very little inking is done because good clear pencil drawings are regarded as adequate.

The meaning of the different lines is indicated by thickness as well as by construction (see Figs. 84 and 85).

The body or weight of lines is usually measured in three degrees of thickness, heavy, medium, and light. The contrast in thickness, not the degree of blackness, determines the variations in types of lines.

Contrast of the different widths must be uniform throughout the drawing, but *all lines should be clean, sharp, and equally black*, regardless of their thickness. A weak line will not show on the blueprint. On a large drawing, an object line may be somewhat wider than it would be in a smaller drawing. The relative width of the lines should be proportionate.

The width of a line is determined by the grade of pencil and the type of point used. Generally, lightweight lines may be drawn with a 4H or 2H pencil. F or H pencils are generally used for medium and heavy lines. A conical point is

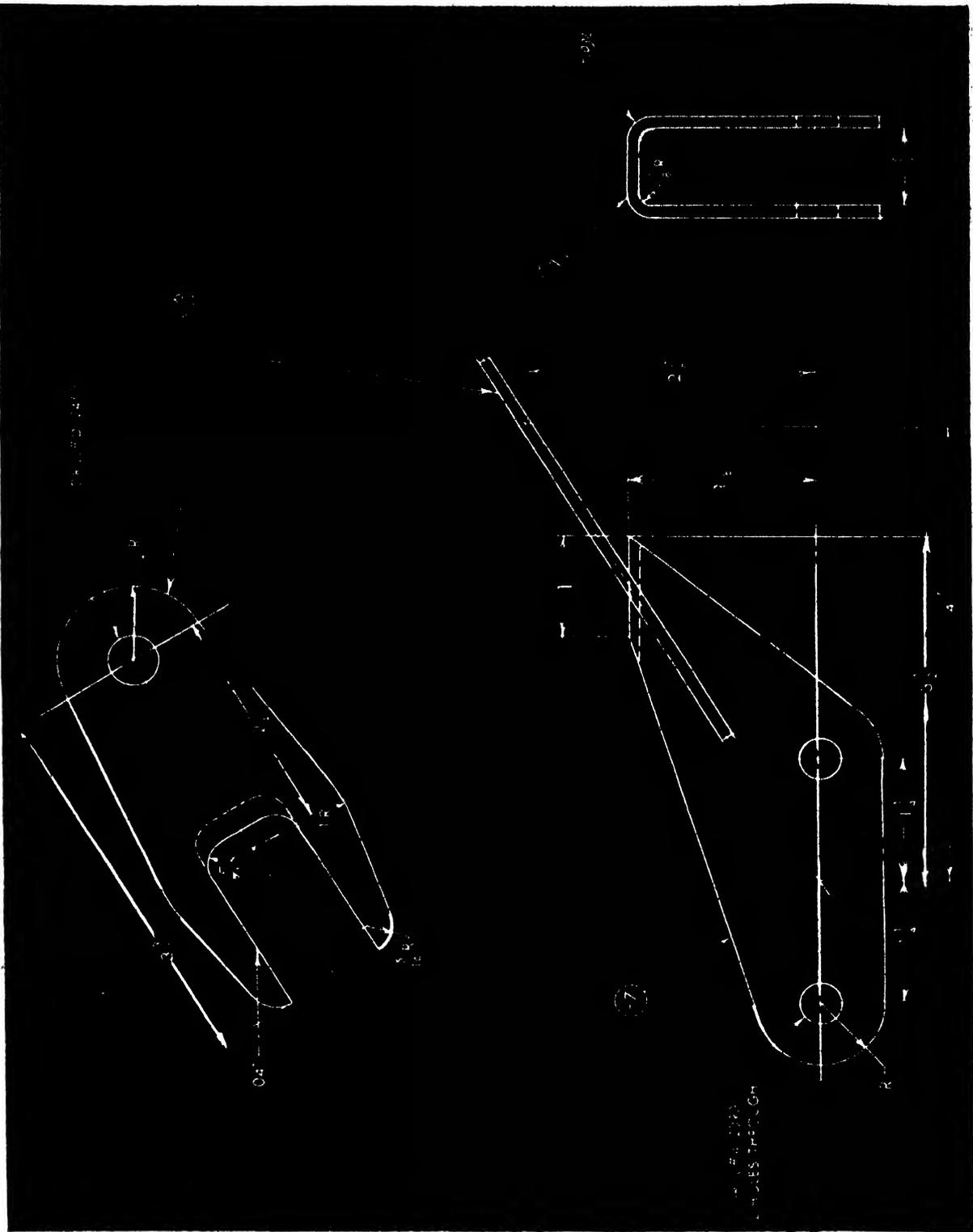


Fig. 86. Careless technique makes a poor blueprint

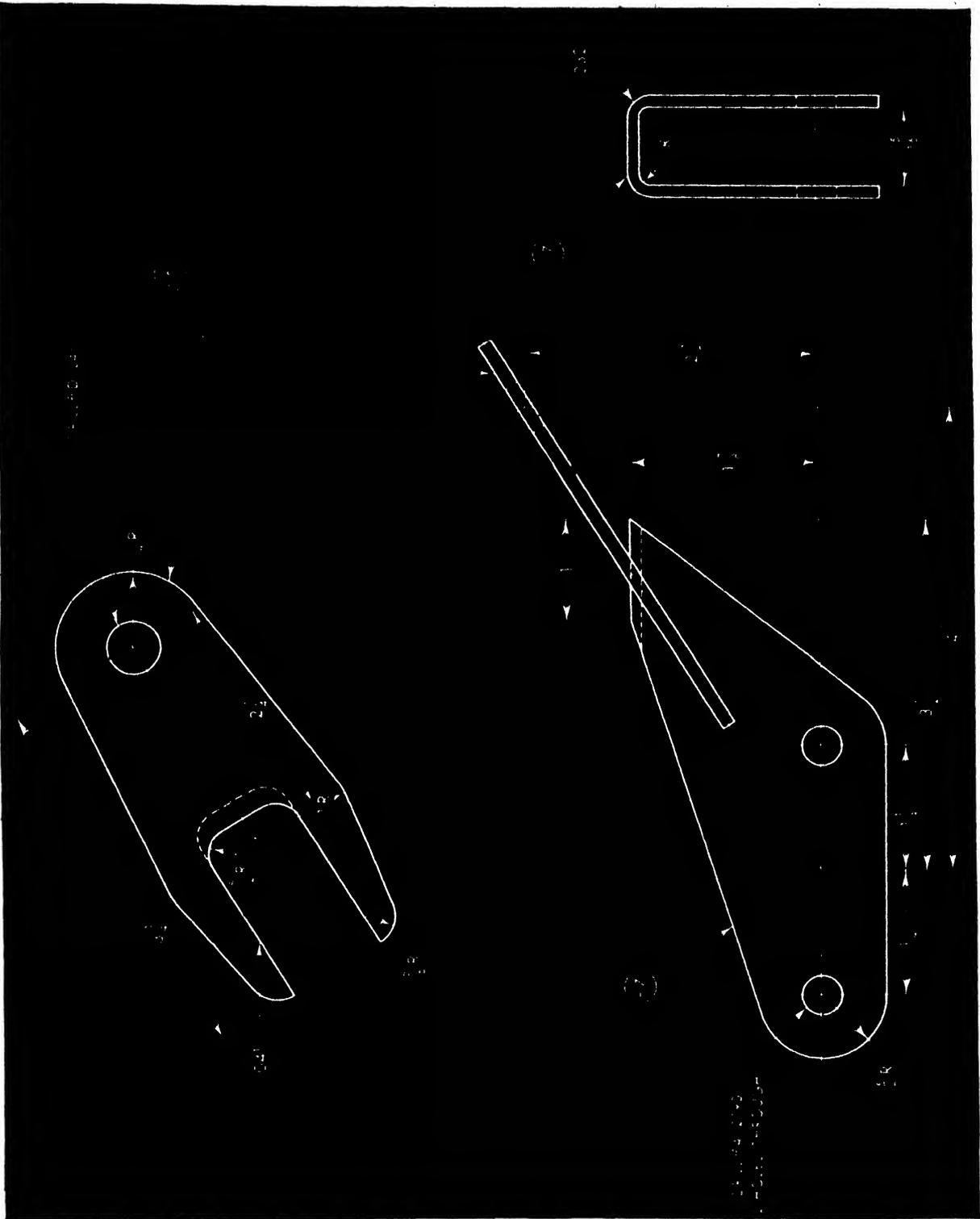


Fig. 87. Legibility and the careful consideration of proper line widths and technique assure a good blue print

used for most detail work and a chisel point for long lines.

To obtain consistency, the same grade of pencil should be used on each type of line. This, however, is not sufficient. The lead must be resharpened as soon as the line drawn begins to vary noticeably in thickness. Each new point should produce a line matching the original in thickness. This can be checked by comparing a few trial lines on scrap paper with the lines on the drawing.

In drawing long straight or curved lines, a chisel point will hold its original thickness along a greater length. Very long lines cannot be drawn with a soft lead pencil in one stroke. The lines will become wider as the lead wears.

A good draftsman is forever conscious of the

uniformity of lines in his drawings. No special skill or talent is required, only a habit of carefulness.

Lines meeting at corners should join squarely to form a sharp clean corner. Sloppy, carelessly drawn corners that fall short of contact or overlap each other mark the amateur.

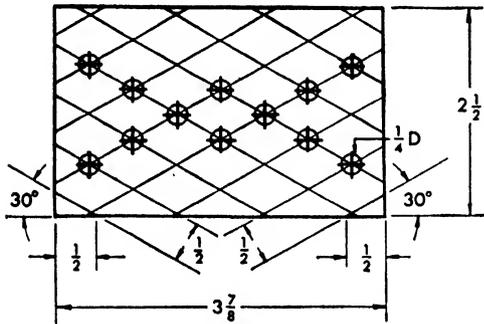
Points of tangency should not be made obvious by "bumps" or irregularities in thickness of lines. Tangent lines should be smooth and should blend together so that in darkness and width the lines are uniform at the point of contact.

Since it is difficult to apply the same pressure on the compass lead as on the pencil, a softer lead may be used in the compass to compensate for the lack of pressure.

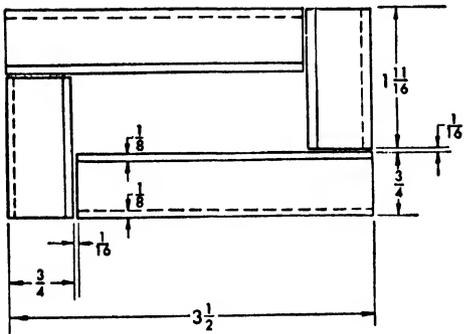
# PROBLEMS FOR CHAPTERS TWO TO FOUR

## Problems 1-12

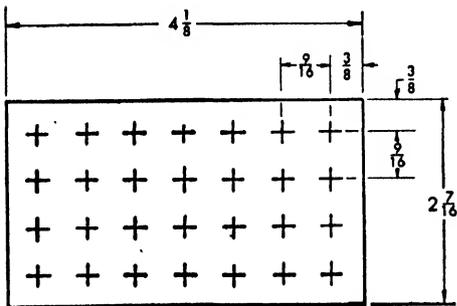
Use a 4H pencil to construct the figures lightly and an H pencil to darken the lines. Small circles may be drawn with the bow compass or hole template. Do not include dimensions on the drawing.



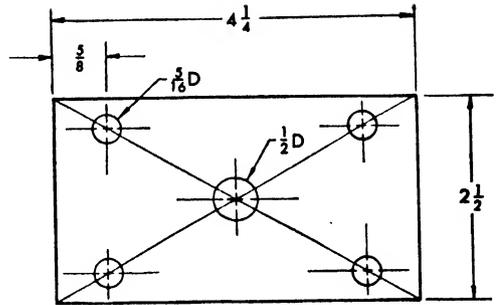
Problem 1



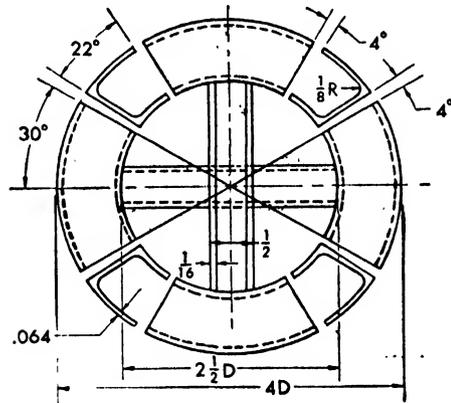
Problem 2



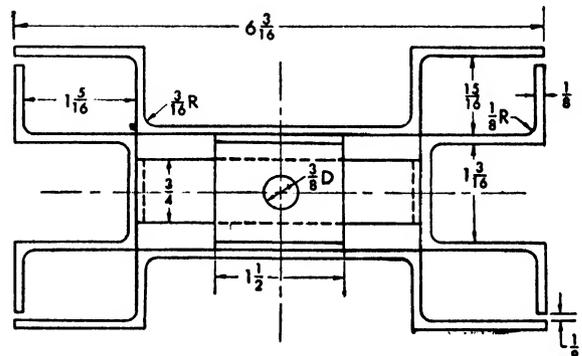
Problem 3



Problem 4

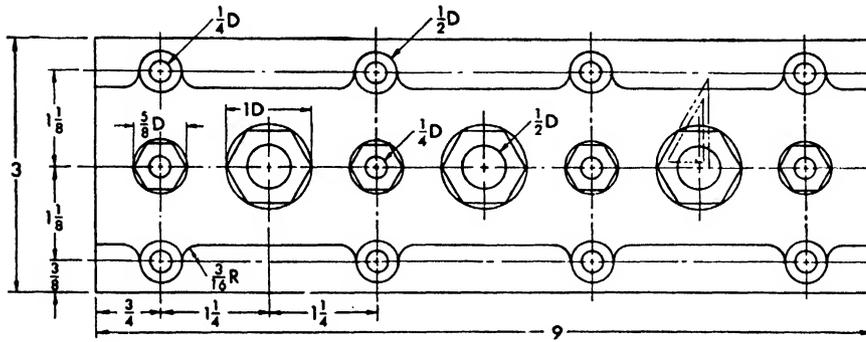


Problem 5



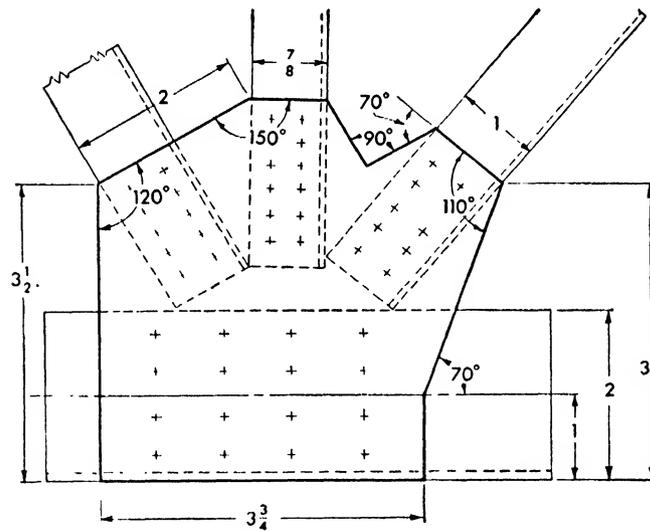
Problem 6





**Problem 13**

Use an H pencil to construct figures as shown. Darken with a 2H or H. Use the hole template whenever possible for arcs and circles.

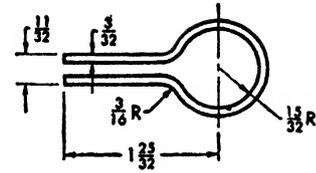


**Problem 14**

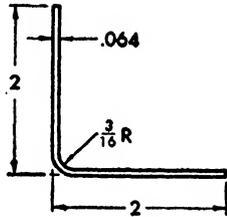
Draw gusset plate as shown, using a protractor to determine angles. Rivet crosses may be omitted.

Problems 15-23

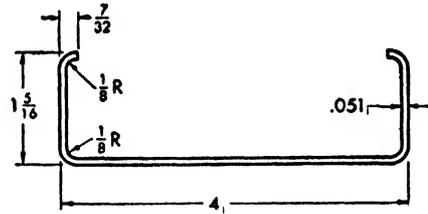
Draw the bent sheet metal sections as shown. Decimal gages of material may be varied slightly so that the bend radii may be drawn with the hole template.



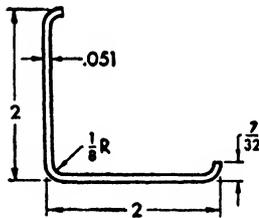
Problem 19



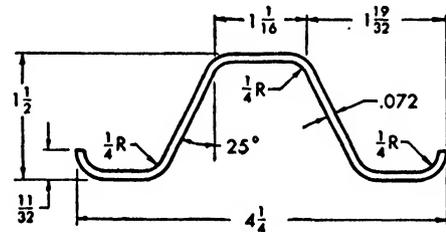
Problem 15



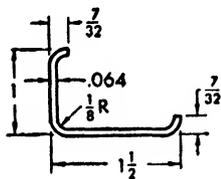
Problem 20



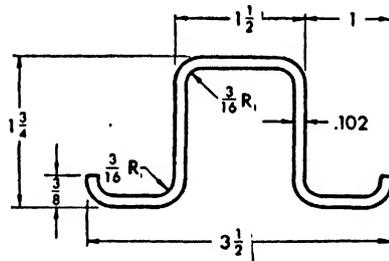
Problem 16



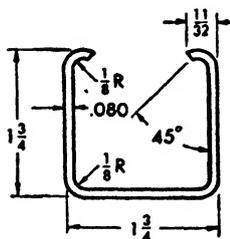
Problem 21



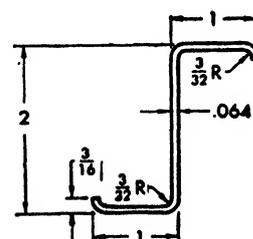
Problem 17



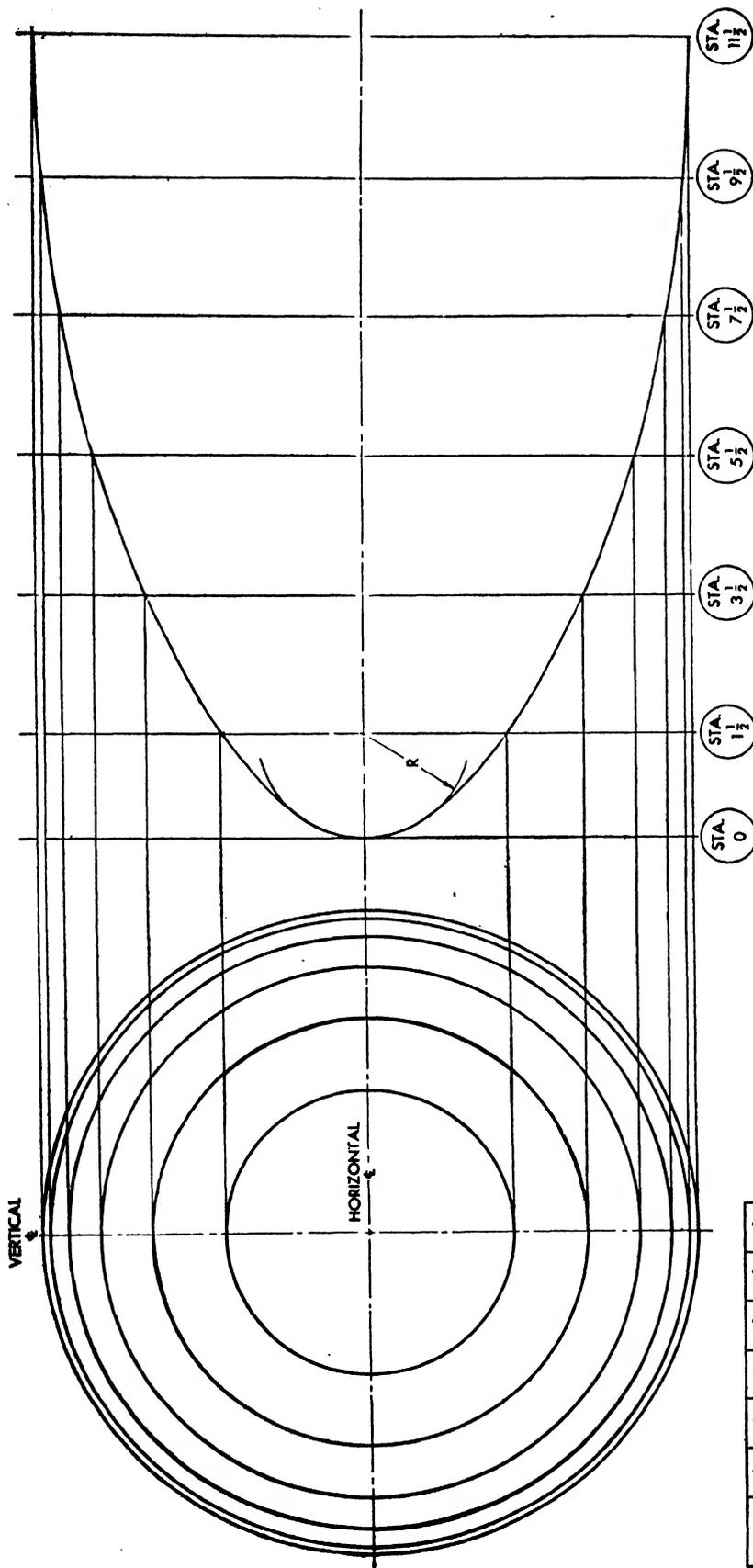
Problem 22



Problem 18



Problem 23

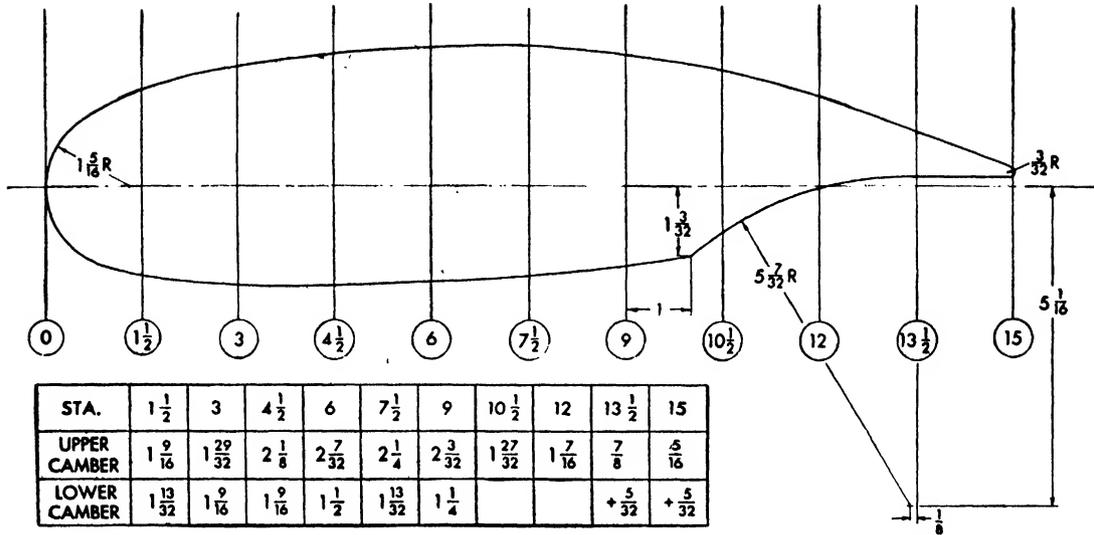


STA.	1 1/2	3 1/2	5 1/2	7 1/2	9 1/2	11 1/2
RADI	2	3 1/16	3 1/4	5 1/2	7 1/2	9 1/2

#### Problem 24

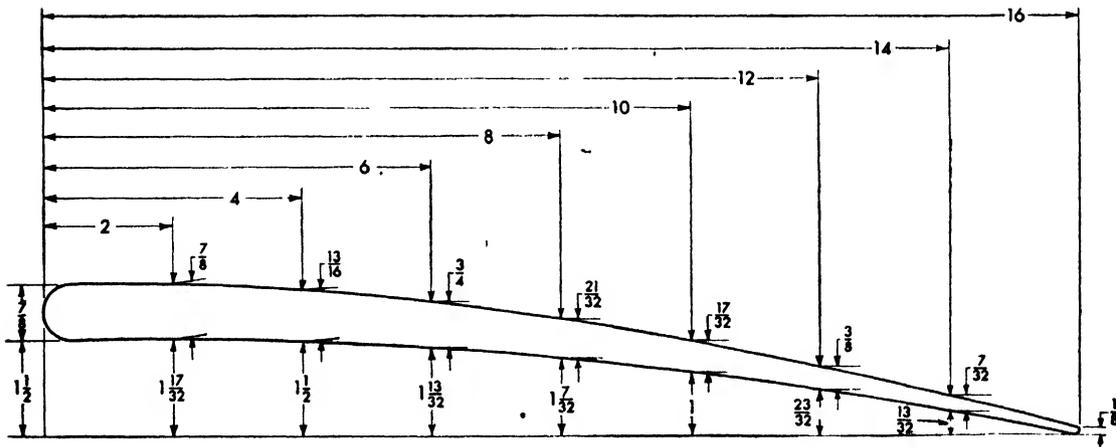
Draw nose contour as shown. Construct vertical and horizontal center lines. Swing the belt-frame diameters as designated by "Radii" in chart. Lay off station lines perpendicular to horizontal center line. The location of each station is determined by the number of inches between it and station 0. Project reference

lines from the intersections of the vertical center line and the circles to the respective station lines, thus establishing points. Connect points with the irregular curve to obtain the profile contour of the nose.



**Problem 25**

Draw wing section as shown. Construct horizontal center line. Set off perpendicular station lines as indicated on the chart. To determine points for the curve, set off distances above and below the horizontal center line on the respective station lines as indicated by "upper and lower camber" in the chart. Connect points with the irregular curve. Centers for circular arcs may be located as shown.



**Problem 26**

Draw an airfoil section as shown. Construct a reference baseline and a perpendicular to the left side. Construct vertical lines of the dimensions indicated. Set off points on the vertical line to determine contour shape. Connect the points with the ship curve.

# CHAPTER FIVE

## LETTERING

### *Introduction*

Lettering is an integral part of aircraft drawing. Letters and numerals are used for various purposes: to specify the size of a part and to indicate methods of manufacturing, the accuracy required, the proper relationship of detail drawings to each other or to master drawings, and the correct order of assembly, as well as to tabulate parts and fill out the bill of material.

Most beginners think that drafting means drawing a "picture of an object." Actually, an aircraft drawing is of no value without lettering, and an excellent drawing may be ruined by poor lettering. The test of lettering comes in the shop. There an illegible number or note may be misinterpreted with very costly results. Many companies, therefore, gage a draftsman's ability by the quality of his lettering.

It does not require any particular natural talent to letter well. Since practically all aircraft drawings are executed in pencil, the aeronautical draftsman may acquire legibility and uniformity—the two primary requisites of lettering—with reasonable rapidity.

By following two basic rules, any average person can learn to letter:

1. *Be constantly alert to the construction of each letter.*
2. *Practice patiently, with a conscious effort to improve.*

Writing in longhand is almost automatic. Little or no attention is paid to the construction of symbols. In lettering, however, the student should be as precise in constructing each letter as he is in executing any other part of the drawing.

If practice is regarded as a monotonous chore, to be hurried through, little or no gain will be derived from it. Practice—and a great deal of it—is necessary for proper lettering. But practice

will help only if the student approaches it in an earnest and interested spirit.

For instance, when the student comes upon the word RIVETS in his practicing and finds it difficult to draw the letter S, he should redraw that letter on the same practice line several times. The initial purpose of practice is not to turn out a perfect lettering sheet but to familiarize the student with letter and word structure.

### *Pencils*

In general, H, F, or HB pencils are used for lettering. The conical point made by the ordinary pencil sharpener is satisfactory. However, many draftsmen prefer a slightly rounded tip.

Rotate the pencil between the thumb and index finger after every few letters as this tends to keep the stroke of the pencil uniform. When much lettering is to be done, sharpen the pencil at intervals to prevent the strokes from broadening.

Place a clean piece of paper under your hand to keep the drawing clean.

### *Guidelines—the Lettering Triangle*

Even an experienced draftsman uses a guideline for his lettering, so the student should never attempt to letter without this necessary support. The formation of the actual letters, however, is done freehand, without the aid of a straightedge or any other mechanical device.

Guidelines may be drawn with the T square and lettering triangle (see Fig. 88). Insert a sharp pencil, 4 or 6H, into the countersunk holes at the appropriate spacing, and slide the triangle back and forth along the T square.

The heights of guidelines are graded in thirty-seconds of an inch at the bottom of each row of holes on the triangle. Hence, the row marked 5 is the line for letters  $\frac{5}{32}$  inch high, row 6 is

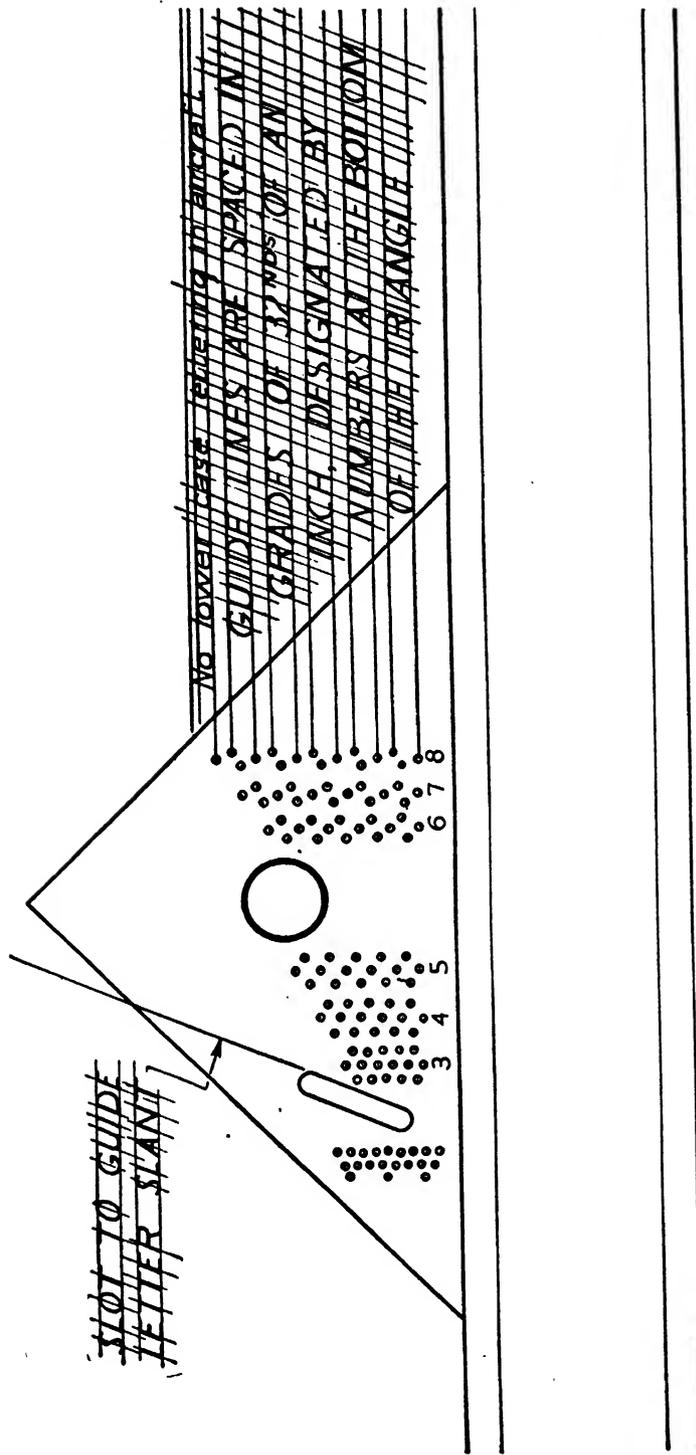


Fig. 88. The Braddock-Rowe Lettering Triangle

for letters  $\frac{5}{8}$  (or  $\frac{3}{8}$ ) inch high, etc. The lettering triangle has holes for both upper and lower case lettering, but do not draw lower case lines. Only upper case lettering is used in aircraft drawings.

To assure uniformity of slant, a slot is provided so that sloping guidelines for the inclined letters may be drawn through the horizontal guidelines.

### *The Gothic Alphabet*

Examination of some books, magazines, or

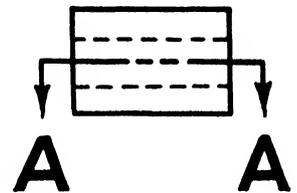
newspapers (particularly the advertisements) will convince anyone that there are many ways of drawing the letters of our alphabet. Not only size, but proportions, weight, and construction of the letters vary widely. However, we are concerned only with aircraft lettering, which is of the single-stroke gothic type. Every stroke or line is uniform in width.

Four rules for aircraft lettering are listed in Fig. 89.

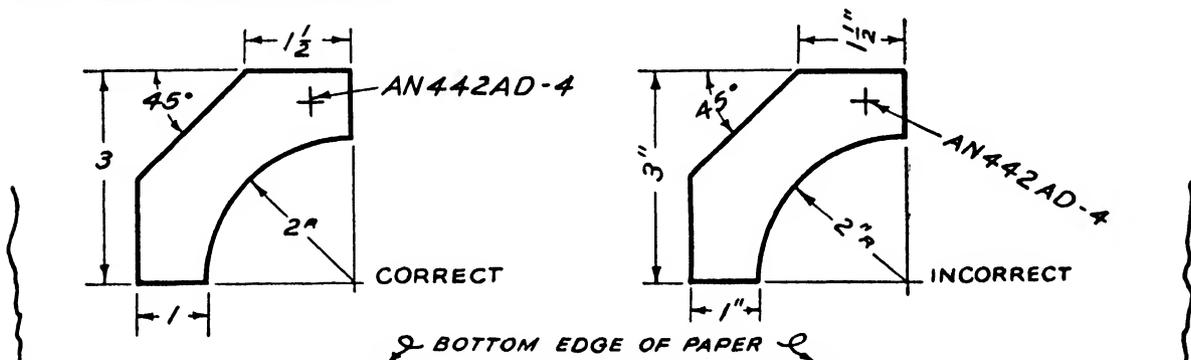
A draftsman eventually develops his own style of lettering, but the foundation of all good air-

**1. UPPER CASE LETTERING APPROXIMATELY  $\frac{1}{8}$  INCH HIGH SHOULD BE USED FOR ALL GENERAL PRINTING ON THE DRAWING.**

**2. LETTERS USED TO DESIGNATE A VIEW OR SECTION SHOULD BE OF THE BLOCK TYPE AND AT LEAST  $\frac{1}{4}$  INCH HIGH.**



**3. LETTERS AND FIGURES SHOULD BE PLACED ON THE DRAWING IN A HORIZONTAL POSITION, E.G. PARALLEL TO THE BOTTOM EDGE OF THE PAPER, REGARDLESS IF THE DIMENSION LINES ARE VERTICAL, HORIZONTAL OR ANGULAR.**



**4. NEVER USE INCH MARKS AS ALL DIMENSIONS ARE UNDERSTOOD TO BE IN INCHES.**

Fig. 89

craft lettering is the standard gothic alphabet. No attempt should be made to execute fancy or elaborate letters, as these are confusing and are usually a disguise for bad craftsmanship.

The gothic alphabet may be either vertical or inclined. Some draftsmen prefer the one, some the other. Aircraft companies may specify which is to be employed or leave it to the draftsman's discretion.

### *The Vertical Gothic Alphabet*

The construction of the single-stroke, vertical gothic letters is shown in Fig. 90. The dimensions are measured in squares. Hence, the letter A is drawn 6 squares wide and 6 squares high.

Practice the construction of individual letters by working first on squared graph paper and later on plain paper with the aid of guidelines. Analyze and practice each letter individually until it is mastered. Prolong the curved letters C, G, O, Q, S, and J slightly above and below the guidelines to offset an optical illusion that makes them look smaller when drawn to the same scale as the other letters. The two legs of A should protrude slightly beneath the baseline, the vertex of the lines in the center of the W slightly above the upper guidelines.

The heights of the numerals and letters in

Fig. 91 are approximate. Such usages vary from company to company, but one general rule should be observed: The taller the letter, the thicker the stroke. However, section letters are generally of the block type, and in the words SECTION or VIEW may be light or heavy faced, as in Fig. 92.

### *The Inclined Gothic Alphabet*

The advantages of the inclined alphabet over the vertical are that it is easier to draw the inclined letters rapidly and slight variations of slant are less easily discernible. The letters are inclined at the American standard of slant of two in five, approximately 68 degrees and 12 minutes (see Fig. 93).

Maintain this slant by drawing very light guidelines across the horizontal guidelines, using the slot in the lettering triangle or a combination of the T square and any of the regular triangles. Draw these slanting lines at random but not precisely on the letter stroke. As dexterity and confidence increase, the appropriate slant will be found without the aid of the diagonal supporting line.

### *Numerals and Fractions*

Since the sizes of parts in a drawing are desig-

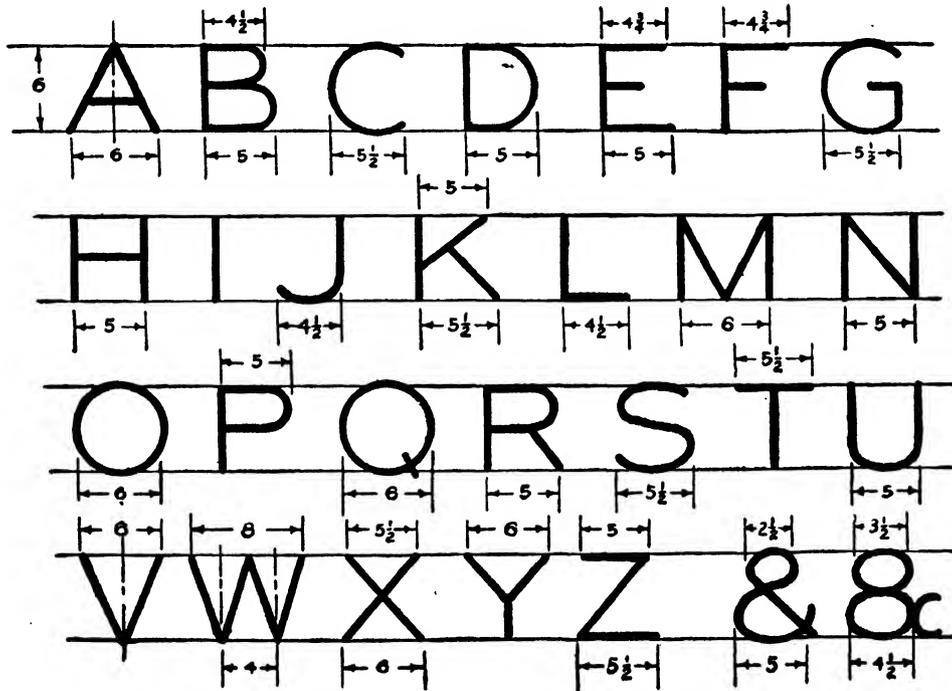


Fig. 90. The vertical Gothic alphabet

FOR NOTES - EXAMPLE: ALL BEND RADII  $\frac{1}{8}$  UNLESS OTHERWISE NOTED  $\frac{7}{64}$

FOR TITLES - EXAMPLE: BELTFRAME-FUSEL-STATION 221  $\frac{3}{16}$

FOR PART NUMBERS - EXAMPLE: 37B0215  $\frac{5}{16}$

FOR SECTIONS & VIEWS -

ABCDEFGHIJKLM  $\frac{5}{16}$   
 NOPQRSTUVWXYZ

EXAMPLES:

SECTION A-A  
 VIEW D-D

Fig. 91. Various lengths of letters and numerals used for various purposes

nated by numerals, obviously these must be legible. Figures 94 and 95 illustrate the construction of numerals. Note that all the numerals except 1 and 4 lie within a 6 by 5 square area. To the beginner the use of guidelines is essential in drawing legible numerals. Seven guidelines are employed, and the vertical proportions are indicated on the figure. Numerals should be approximately  $\frac{1}{3}$  inch high. A fraction must be about one and two-thirds the height of a whole number.

Figure 96 illustrates seven common errors in the drawing of numerals. They are:

- The fraction  $\frac{1}{2}$  is shown equal in height to the numeral 5.
- Numerator and denominator touch the division line.

- The numeral is too far from the related fraction.
- The slant of the numerator is not the same as that of the denominator.
- The numerals are crowded, the fraction too close to its whole number and not tall enough.
- The dimension containing several numerals is allotted insufficient space.
- The division line in the fraction is placed too high in relation to the whole number.

VIEW A A  
 VIEW A A

Fig. 92



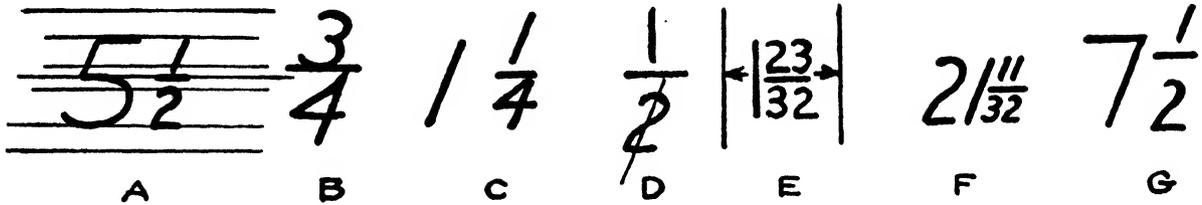


Fig. 96. Common errors

REQ							
CAL. WT	-8	.032 x 16 1/2 x 20 1/4	24ST DURAL			/	
	-7	.041 x 21 3/32 x 7 1/4	17ST DURAL			/	
ACT. WT	-6	.064 x 2 1/4 x 6 1/2	17ST ALCLAD			/	
	PART NO	STOCK	MATERIAL	SPEC	LH	RH	LH
					REQ		RE
SHOWN	PARTS LIST PER ASSY.					0	

Fig. 97. Use of diagonal division line

THREAD AS CLOSE

Fig. 98. These letters are mechanically spaced. Note unequal shaded areas.

THREAD AS CLOSE

Fig. 99. These letters are optically spaced. Shaded areas are now more nearly equal.

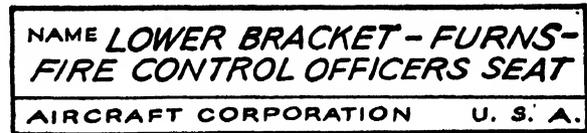
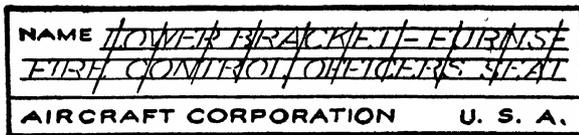
ATTACH TOOL WHERE

Fig. 100(a). Mechanically spaced

ATTACH TOOL WHERE

Fig. 100(b). Optically spaced

# COMPOSITION



~~NOTE: DIMENSIONS WITH ASTERISK  
(\* ) DO NOT NEED MACHINING IF  
CASTING IS PERMANENT MOLD,  
ANTIOCH OR OSBRINK PROCESS  
CASTING.~~

**NOTE: DIMENSIONS WITH ASTERISK  
(\* ) DO NOT NEED MACHINING IF  
CASTING IS PERMANENT MOLD,  
ANTIOCH OR OSBRINK PROCESS  
CASTING.**

Fig. 101

Diagonal divisions for fractions may be used occasionally as in listing the part numbers on the bill of materials block (Fig. 97).

### Spacing the Letters

Forming an individual letter is rather like making a detailed drawing of a small part. Just as the part must be coordinated into a whole, so the letters must be assembled into words. Bad spacing of the letters composing a word is a serious fault of lettering, however well the separate letters are formed.

To space letters correctly, do not attempt to set them a uniform distance apart, but make sure that the areas between the letters are as uniform as possible. To accomplish this, space by eye rather than by any mechanical means. In Fig. 98 the letters are mechanically spaced, and as a result the shaded areas between the letters are very unequal. In Fig. 99 the letters have been spaced by eye so that the shaded areas appear more uniform and attractive. Figure 100 presents other mechanically spaced letters.

After drawing guidelines, pencil in the letters lightly until they appear properly spaced. Evaluate the spaces between the letters and if necessary readjust them. Skill can be attained by diligent practice. Follow these rules in spacing both vertical and inclined capital letters:

*Allow ample distance between letters with straight, parallel sides, such as M, I, and L.*

*Allow less distance between two circular letters, like O G or O C.*

*If necessary, overlap two letters like LT or LV.*

*If necessary, shorten the width of the base stroke of L when A follows it.*

### Arranging the Words

As subassemblies fit into a plane, so words must be assimilated into a comprehensible title, phrase, or sentence. Spaces between words should be approximately as wide as the letters are high.

For example, to lay out a title box in the bill of material, first draw guidelines and sketch in the title (Fig. 101) so lightly that the letters may be spread or condensed if necessary to make the words fit into the available space. A word may be arranged around a center line, but the trial and error method is more common.

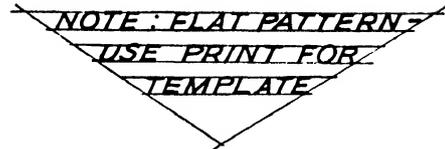
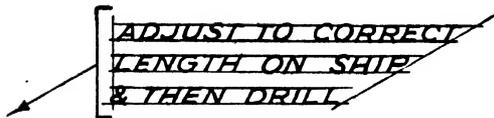
"Box in" four or five lines of lettering as in Fig. 102. Before darkening, arrange and rearrange the letters until the desired effect is achieved.

It is sometimes necessary to adjust a line of lettering into a given space. This may warrant condensing or stretching of letters or words. Figure 103 illustrates the normal, the extended, and the condensed arrangement of the word DURAL.

### Nonconventional Lettering

In actual work in the engineering department, lettering is used to convey necessary information clearly and efficiently. It should absorb a minimum of the draftsman's time. The draftsman should develop a character or style in his lettering that inspires confidence in the users of his drawings. Slanted, rather broad letters, approximately  $\frac{3}{8}$  inch high, are recommended (see Fig.

**X** NOTE: DIMENSIONS WITH ASTERISK (\*) DO NOT NEED MACHINING IF CASTING IS PERMANENT MOLD, ANTIOCH OR OSBRINK PROCESS.



**X** DRILL  $\frac{23}{64}$   
 DEPTH  $\frac{5}{8}$   
 REAM .375  $\begin{matrix} +.0005 \\ -.001 \end{matrix}$   
 DEPTH  $\frac{3}{8}$

DRILL  $\frac{23}{64}$   
 DEPTH  $\frac{5}{8}$   
 REAM .375  $\begin{matrix} +.0005 \\ -.001 \end{matrix}$   
 DEPTH  $\frac{3}{8}$

Fig. 102. Examples of spacing

104). Occasionally a single guideline facilitates speed in a free, nonconventional style.

Accentuation of certain characteristics will counteract inaccuracy in the shape of some letters. This trick of emphasizing particular features maintains the proper weight of the letter in the word. For example, the horizontal bar distinguishes the A. When the bar is too short, the letter is definitely weak. Furthermore, if the proportionate slope of the two side lines is not exactly right, the letter is askew. By curving the two side lines and adequately thickening the horizontal bar, the letter is redeemed.

If the bottom portion of a letter such as B or S is almost as wide as the top, the letter looks bad, but if the upper portion is made narrower than the bottom, the letter has better balance. Therefore, when lettering rapidly, make the upper portion of such letters definitely smaller.

Letters like E and F, with three and two horizontal lines, respectively, must be formed either accurately, with uniformly horizontal lines of proportionate lengths, or with a slightly curved baseline in the E or a slightly curved and extended middle line in the E and the corresponding lower line in the F. Thus, the lack of parallelism is counteracted by well-placed irregularities.

The upper portion of letters like K, P, and R is most noticeable, and therefore should be accentuated slightly. A faint curve in the lower stroke of K and R will help their appearance. N, M, U, and sometimes H may also be stylized to assist rapid lettering.

Letter an alphabet and try to get character in your lettering. Compare it to Fig. 104. Measure the width of the letters, and see if a ten-letter word is from  $1\frac{1}{2}$  to  $1\frac{3}{4}$  inches in length.

DURAL  
 DURAL  
 DURAL

A B C D E F G H I J K L M N O  
 P Q R S T U V W X Y Z  
 1 2 3 4 5 6 7 8 9

Fig. 103. Normal, extended, and condensed adjustments

Fig. 104

# LETTERING

BOEING ENGINEERING  
SCHOOL . . . . SEATTLE

A B C D E F G H I J

K L M N O P Q R S

T U V W X Y Z &

1 2 3 4 5 6 7 8 9 0

"  $\frac{7}{16}$   $\frac{9}{32}$   $\frac{23}{64}$  \$ % ¢  $\frac{1}{2}$   $\frac{2}{3}$   $\frac{3}{4}$   $\frac{5}{8}$  "

A SIMPLE GUIDE FOR  
**GOOD SPACING      LETTER SPACING      BAD SPACING**

LETTERS FITTED TOGETHER  
SO SPACES APPEAR UNIFORM

FROM THE ORIGINAL TEXT BOOK, COPYRIGHT BY BOEING AIRCRAFT COMPANY

NO ALLOWANCE MADE FOR  
DIFFERENCE IN LETTER FORM

**MAOW** | **D O K L O** | **MAOW**  
WIDE · NORMAL · ROUND · WIDE      TOO DARK · TOO DARK | DARK · TOO DARK

'A' SHOWS FULL SPACE AS IT LOOKS BETWEEN STRAIGHT LETTERS... 'B' SHOWS HOW CIRCULAR LETTERS CUT INTO IT... 'C' SHOWS HOW IT LOOKS BETWEEN A STRAIGHT AND A CIRCULAR LETTER... 'D' THE SPACING OF IRREGULAR AND STRAIGHT LETTERS ... 'E' SHOWS HOW IRREGULAR AND CIRCULAR LETTERS SHOULD BE SPACED..

USE AN 'F' PENCIL .. WORK WITH A COMBINED FINGER AND ARM MOVEMENT .. STRIVE TO GET CLEAN, FIRM LINES.. THIN WEAK LINES DO NOT MAKE LEGIBLE BLUE PRINTS.. LETTERS SHOULD BE FITTED TOGETHER SO THAT THE SPACES APPEAR UNIFORMLY EQUALIZED .. WIDE LETTERS LOOK TOO DARK WHEN SQUEEZED INTO A TIGHT SPACE.

Fig. 105. Example of engineering lettering sheet. Boeing Aircraft Company

## LETTERING EXERCISES

## PROBLEM 1

Draw the vertical and inclined alphabet on squared graph paper, following the proportions given on pages 78 and 80.

## PROBLEM 2

Draw on squared graph paper the vertical and inclined fractions given on page 80.

## PROBLEM 3

Draw a vertical and an inclined alphabet, with lettering guidelines  $\frac{1}{4}$  inch high and  $\frac{1}{8}$  inch space between the letter lines.

## PROBLEM 4

Practice those letters found troublesome in problem 3.

## PROBLEM 5

Draw five rectangular title boxes, each  $\frac{3}{4}$  by  $4\frac{1}{2}$  inches. Draw top guidelines  $\frac{1}{8}$  inch from the upper edge. Make the letter spaces  $\frac{3}{16}$  inch high, with  $\frac{1}{8}$  inch between spaces. Letter the following titles:

1. PEDAL INSTALL-CONTROLS-RUDDER
2. BRACKET-SUPPORT FOOD LOCKER
3. ASSY.-IDLER ARM-FUSEL-NOSE WHEEL DOOR MECH.
4. FITTING-FUSEL.-TORQUE SHAFT-N.W. DOOR MECH.
5. INSTALLATION-NOSE WHEEL DOOR MECH.

## PROBLEM 6

Use the lettering triangle to draw guidelines for  $\frac{1}{8}$  inch letters and lines  $\frac{3}{8}$  inches long. Draw the following notes:

1. FLANGE OF 42B0641 MAY BE BENT IF NECESSARY TO CLEAR CONTROL CABLES.
2. CUT OUT APPROXIMATELY AS SHOWN TO CLEAR GUIDE AND CABLE FOR COMPLETE RUDDER PEDAL ASSEMBLY. LOCATE CUTOUT AFTER 42B0642 IS INSTALLED IN SHIP.
3. JOGGLE-7 UNDER 59B0021 AFTER INSTALLATION OF -9, -10, AND -11.
4. SYM. ABOUT CENTER LINE OF PLANE.
5. ASSEMBLY PROCEDURE:
  1. PRESS AXLE (48-901B) INTO SLEEVE ASSY. (48-9045B0)

2. PRESS SUB. ASSY. INTO KNUCKLE APPLYING PRESSURE INTO SLEEVE ASSY. ONLY
3. INSTALL LUG (48-9001B)

## PROBLEM 7

With same spacing as in exercise 6, but with lines  $1\frac{1}{2}$  inches long, letter the following notes:

- |  |  |
|--|--|
| 1. FORMER—2 REQ.<br>.040 2450 ALC. SHEET<br>SPEC. 11067<br>H.T. SPEC. 98-10026                     | 6. DRILL $\frac{1}{8}$ (.125)<br>$\frac{1}{2}$ DEEP<br>C' DRILL $\frac{1}{4}$ (.250)<br>$\frac{1}{4}$ DEEP |
| 2. GRIND—.496<br>.495<br>BEFORE PLATING  | 7. DRILL #Q (.332)<br>C' SINK 110 DE-<br>GREES X $\frac{3}{4}$<br>TAP $\frac{3}{8}$ -24NF3                 |
| 3. DRILL #11 (.191)<br>12 HOLES<br>CSK. 100° X .375  | 8. DRILL $\frac{23}{64}$ (.359)<br>$\frac{7}{8}$ DEEP<br>C' DRILL $\frac{1}{2}$<br>$\frac{1}{2}$ DEEP      |
| 4. MAY BE MADE FROM<br>K4A BEARING<br>FAFNIR BEARING CO.<br>NEW BRITAIN,<br>CONN.<br>OR EQUIVALENT | 9. CHAMFER 45° X $\frac{3}{16}$<br>THREAD $\frac{3}{8}$ -24NF3<br>LEFT HAND                                |
| 5. STRINGER—1 REQ.<br>.032 XLS 160<br>24ST ALCLAD SHEET<br>SPEC. 11067                             | 10. REAM HOLE FOR<br>SMALL END OF<br>TAPER TO BE FROM<br>$\frac{1}{8}$ OVER FLUSH<br>WITH SURFACE          |

## PROBLEM 8

Draw 6 rectangular blocks  $\frac{1}{2}$  inch wide by  $2\frac{1}{2}$  inches long. Place top guidelines  $\frac{3}{32}$  inch down from top edge. Make the letters  $\frac{5}{16}$  inch high. Draw the following part numbers:

- |           |            |
|-----------|------------|
| 1.—430021 | 4.—21W8906 |
| 2.—37A369 | 5.—X20348  |
| 3.—XM0219 | 6.—38E723  |

## PROBLEM 9

Section and View words to be  $\frac{1}{8}$  inch high. Section and view designation letters  $\frac{5}{16}$  inch high. Scale letters to be  $\frac{1}{8}$  inch high. Draw the following:

SECTION A-A  
SCALE: 12" = 1'0"

SECTION C-C  
SCALE: FULL SIZE

SECTION D-D  
SCALE: 3" = 1'0"

SECTION R-R  
SCALE: DOUBLE SIZE

VIEW D-D  
SCALE: 6" = 1'0"

VIEW N-N  
SCALE: 24" = 1'0"

SECTION S-S  
SCALE: ACTUAL SIZE

## CHAPTER SIX

# APPLIED GEOMETRY

### *Introduction*

The airplane is made of thousands of individual parts, carefully designed and manufactured, multitudinous in shape, and weighing from a fraction of an ounce to hundreds of pounds. All these parts originate on the drawing board and are based on geometric constructions. Figure 106 illustrates the breaking down of a typical airplane section into geometric shapes.

Intelligent application of the geometric constructions presented in this chapter will enable the student to progress, for an understanding of

the elements of geometrical construction is essential to all later study. Geometric figures are not difficult to draw, but their construction must be practiced conscientiously. The exercises should be executed with the greatest possible accuracy and with light, sharp lines like those used in the preliminary layout of actual detail drawings. Pencils and compass leads should be hard (4H or 6H), and the points should be kept needle sharp. A precisely set dot at the intersection of two straight lines or arcs will accentuate the point of intersection. If nu-

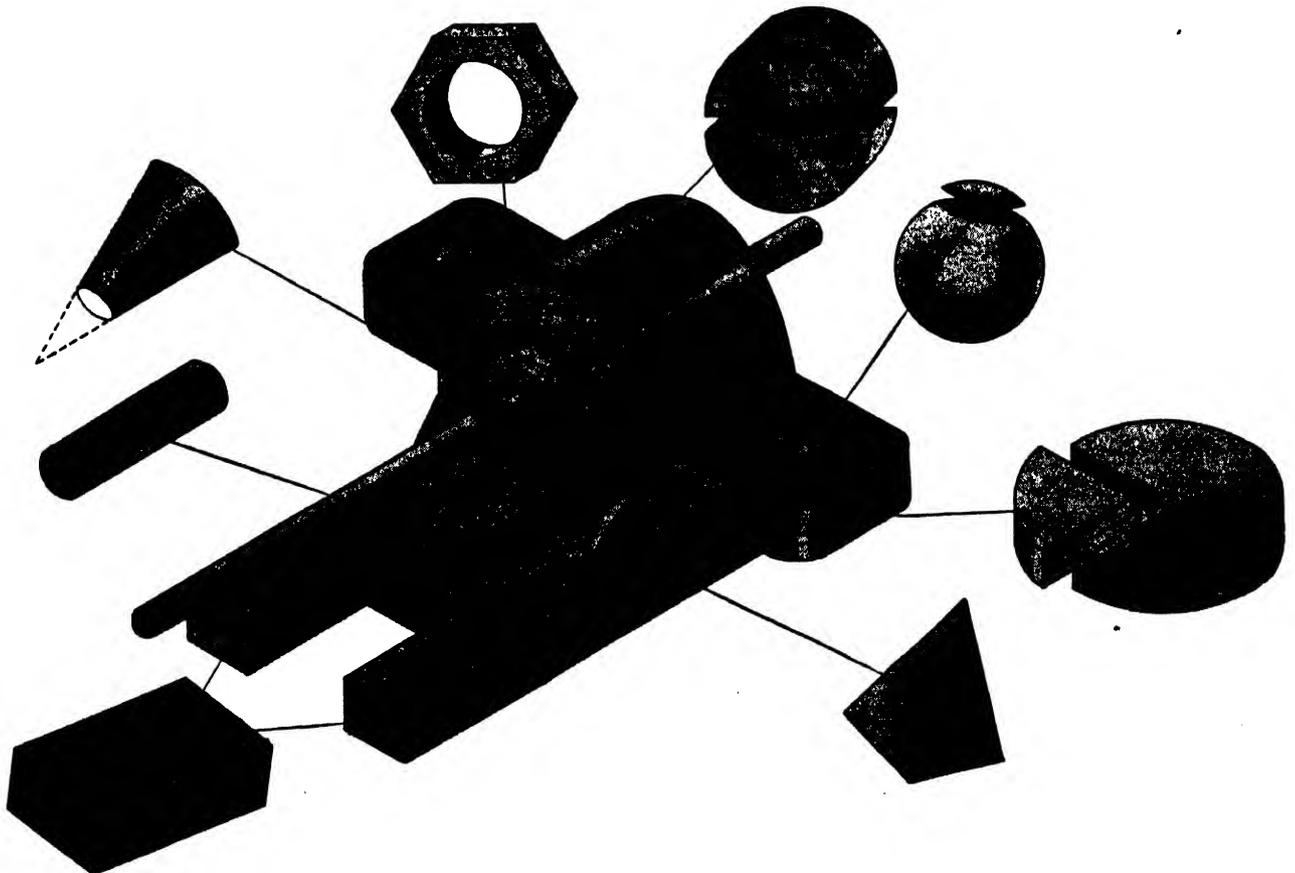


Fig. 106

merous points are to be taken from intersections of arcs or straight lines, to clarify their position these points may be enclosed in small, lightly drawn freehand circles.

The actual time taken to draw an arc or a line is negligible. A circle or an arc can be swung in a second. But time is well spent on determining the direction of a line and its exact beginning and end, and on a careful effort to make it uniform in width. A student may diligently draw and redraw an arc only to find that it does not fall tangent, when it might have been right the first time if proper care had been taken to set the compass needle on the exact center point. This habit of precision is emphasized here because, when it is once acquired, the draftsman can work methodically and rapidly. In addition, a draftsman required to dimension a detail may do so successfully from a preliminary construction if it has been drawn precisely.

#### *Common Geometric Terms*

The terms presented in this chapter are such an essential part of the "graphic language" that without them it would be difficult to discuss drafting intelligently. Some students are already familiar with these terms, but some may have forgotten the subject or be unfamiliar with it. In any case, complete familiarity with these terms is indispensable.

A **POINT** shows position. When a point moves, it makes a **LINE**, which may be either **CURVED** or **STRAIGHT**.

A **SURFACE** is produced by moving a line.

A **PLANE SURFACE** includes two intersecting or parallel straight lines. The prisms in Fig. 108 contain plane surfaces. Cones and cylinders are composed of single curved surfaces.

A **CIRCLE** is a plane figure enclosed by a curved line, any point of which is equidistant from a fixed point called the **CENTER**. The various parts of the circle are described as follows: The distance around the circle is called the **CIRCUMFERENCE**. An **ARC** is any part of the circumference. A **CHORD** is any straight line touching the circumference at two points. The **DIAMETER** is a chord passing through the center. The **RADIUS** is the distance from the center to any

point on the circumference. A **SEGMENT** is the area enclosed by an arc and a chord. A **SECTOR** is the area enclosed by two radii and an arc. A **SEMICIRCLE** is the area enclosed by the diameter and half the circumference. **QUADRANTS** are the four equal sectors formed by lines perpendicular to each other and intersecting at the center.

A **TANGENT** is a line perpendicular to a radius at its point of contact on the circumference. **CONCENTRIC CIRCLES** have the same center but different diameters. **ECCENTRIC CIRCLES** are on the same center line but have different centers.

Many airplanes have circular fuselage design, and usually the center lines are marked horizontal and vertical. Points are often located by employing **BUTTOCK LINES**, measured from the left or right of the vertical center line, and by **WATER LINES**, measured parallel to the horizontal center line from a reference baseline. On some airplanes the horizontal center line becomes water lined. Point A in Fig. 107 is drawn in reference to the location of a point in the circular frame with the notation: **WATER LINE 15 BUTTOCK LINE 10**.

#### *Rules Relative to the Circle and the Sphere*

To find the circumference

multiply the diameter by 3.1416 ( $\pi$ )

or multiply the radius by 2 times 3.1416

To find the diameter

divide circumference by 3.1416

To find the radius

divide the circumference by 6.28318

To find the area

multiply the circumference by one-quarter the diameter

or multiply the square of the diameter by 0.7854

or multiply the square of the circumference by 0.07958

or multiply the square of one-half the diameter by 3.1416.

To find the surface of a sphere or globe

multiply the diameter by the circumference or multiply the square of the diameter by 3.1416

or multiply 4 times the square of the radius by 3.1416

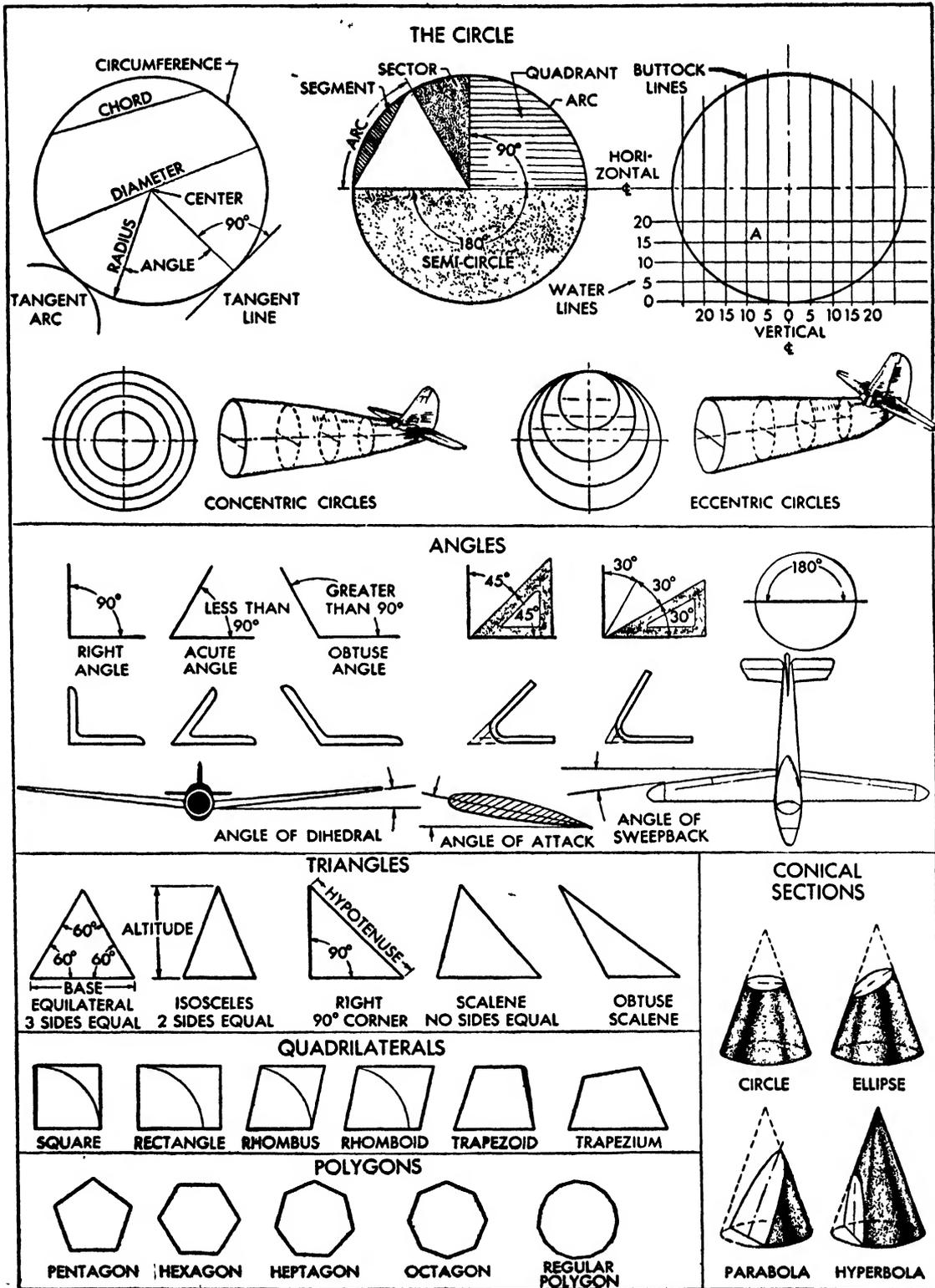
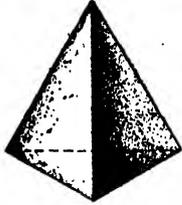
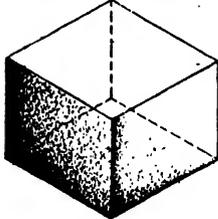


Fig. 107

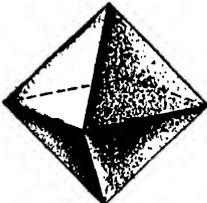
REGULAR POLYHEDRONS



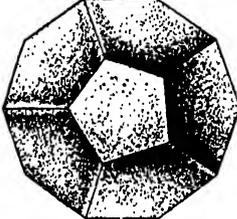
TETRAHEDRON



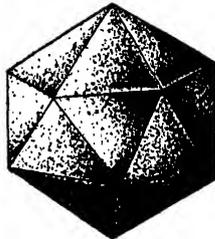
CUBE



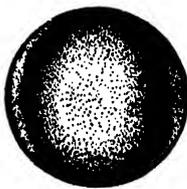
OCTAHEDRON



DODECAHEDRON

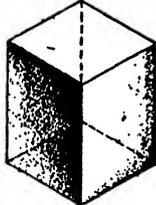


ICOSAHEDRON

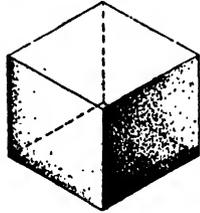


SPHERE

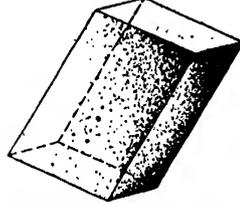
PRISMS



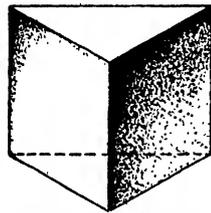
SQUARE



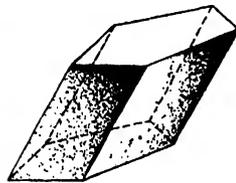
CUBE



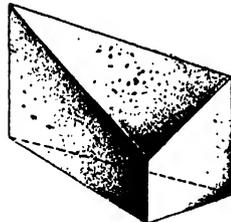
OBLIQUE RECTANGULAR



RIGHT TRIANGULAR

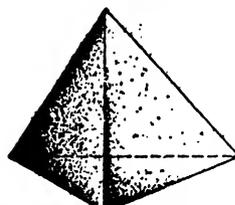


OBLIQUE PENTAGONAL

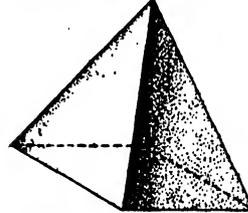


TRUNCATED TRIANGULAR

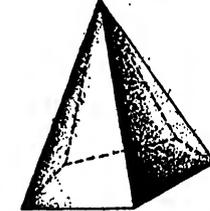
PYRAMIDS



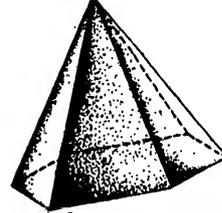
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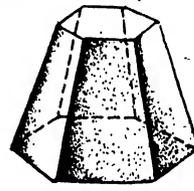
RIGHT RECTANGULAR



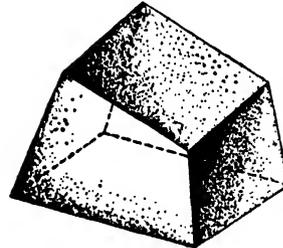
OBLIQUE PENTAGONAL



OBLIQUE HEXAGONAL



FRUSTRUM

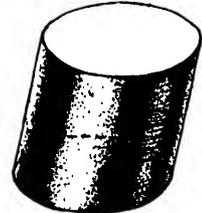


TRUNCATED PYRAMID

CYLINDERS



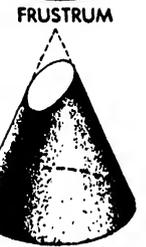
RIGHT



OBLIQUE



CONES



FRUSTRUM



OBLIQUE



SQUARE



ROUND

PLINTHS

Fig. 108

*Facts about the Circle*

A line from the center to the midpoint of a chord is perpendicular to the chord.

Equal chords are equidistant from the center.

Two tangents to a circle from any common point outside the circle are equal.

Any angle in a semicircle formed by two chord lines starting from opposite points of the diameter and meeting at a common point on the circumference is a right angle.

The opposite angles of any quadrilateral inscribed in a circle will equal two right angles.

*Angles*

When two straight lines intersect, they form **ANGLES**. The size of any angle is determined by the distance between the intersecting lines, measured in **DEGREES**. A complete revolution of a line about a fixed point, i.e., a circle, contains 360 degrees; therefore an angle whose sides are perpendicular to each other, i.e., an angle that marks off a quadrant, contains 90 degrees. When closer accuracy is desired each degree is divided into 60 lesser angles, called **MINUTES**. For very exact measurements each minute is divided into 60 still smaller angles, called **SECONDS**. Degrees ( $^{\circ}$ ), minutes ( $'$ ), and seconds ( $''$ ) may be designated thus in the measurement of an angle:  $15^{\circ} 25' 15''$ . Angles may be measured by a protractor.

An angle of less than 90 degrees is called an **ACUTE**, or sometimes a **CLOSED**, angle. An angle of more than 90 degrees is called an **OBTUSE** or an **OPEN** angle. An angle greater than two right angles is called a **REFLEX** angle. Angles constituting together a right angle are called **COMPLEMENTARY** angles, and those constituting together two right angles are called **SUPPLEMENTARY** angles.

In aircraft work, some common extruded (square corner) and drawn (round or bent) structural shapes are called angles.

*Triangles*

A **TRIANGLE** is a plane figure bounded by three straight lines. Every triangle has three angles which total 180 degrees; hence, if two angles are known, the third can be determined

by totaling the two known angles and subtracting their sum from 180 degrees.

Triangles are named by the nature of their sides or angles: equilateral, isosceles, scalene, right, and obtuse. An **EQUILATERAL** triangle has three equal angles and sides, an **ISOSCELES** triangle has two equal sides, while none of the sides are equal in a **SCALENE** triangle. A **RIGHT** triangle has one 90 degree angle, and an **OBTUSE SCALENE** triangle has one obtuse angle.

In a right triangle the square of the hypotenuse is equal to the sum of the squares of the other two sides. Problems concerning right triangles may be solved by referring to the chart on page 350.

The student should acquire a good table of "natural trigonometric functions" and learn the simple applications of the formulas.

*Quadrilaterals*

A **QUADRILATERAL** is a plane figure bound by four straight lines or sides.

Quadrilaterals whose opposite sides are parallel are called **PARALLELOGRAMS**. The rectangle, square, rhombus, and rhomboid defined below are parallelograms.

A **RECTANGLE** contains four 90 degree angles.

A **SQUARE** is a rectangle wherein all sides are equal.

A **RHOMBUS** is bounded by four equal sides like the square but does not contain 90 degree angles.

A **RHOMBOID** is like the rhombus except that one pair of sides is longer than the other.

A **TRAPEZOID** is a quadrilateral with only two sides parallel.

A **TRAPEZIUM** is a quadrilateral that has no parallel sides.

*Polygons*

A **POLYGON** is a plane figure bound by three or more sides. The name is derived from the Greek words *poly*, meaning many, and *gonia*, meaning angles. A polygon of equal sides and angles is called a **REGULAR POLYGON**. The following are the most common regular polygons:

**PENTAGON**, five angles and five sides

**HEXAGON**, six angles and six sides

**HEPTAGON**, seven angles and seven sides

**OCTAGON**, eight angles and eight sides

Polygons may be circumscribed around or inscribed in a circle. When all angles of a polygon project out, it is called a **CONVEX POLYGON**. When all the angles swerve in, it is called a **CONCAVE POLYGON**.

*Conic Sections*

A **RIGHT CIRCULAR CONE** or **CONE** is a solid generated by the rotation of a right triangle about one of its legs as an axis.

When a plane cuts such a cone, the resulting plane surface is a **CONIC SECTION**.

When the plane cuts the cone perpendicular to the axis, the intersection is a circle. When the plane cuts the cone at an angle to the axis greater than that of the elements or surface of the cone, the intersection is an **ELLIPSE**. The intersection of a cone with a plane cutting the axis and parallel to the side of the cone forms a **PARABOLA**, and the intersection of a cone with a plane that is parallel to or makes a smaller angle with the axis than do the sides is a **HYPERBOLA**.

*Solids*

Let us consider a drawing board. It is made of wood and contains six plane surfaces, four narrow rectangles about the sides and two large flat rectangles on top and bottom. The board is a geometric solid, as is any solid bounded by plane geometric surfaces (see Fig. 108). The plane surfaces are called **FACES**, and the intersections of the faces are called **EDGES**. On a drawing, the edge of a plane surface is represented by a line.

Geometric solids bound by plane surfaces are called **POLYHEDRONS**. A regular polyhedron is a convex solid, the faces of which are equal regular polygons. There are five regular polyhedrons:

**TETRAHEDRON**, four faces that are equilateral triangles

**HEXAHEDRON**, or **CUBE**, six faces that are squares

**OCTAHEDRON**, eight faces that are equilateral triangles

**DODECAHEDRON**, twelve faces that are regular pentagons

**ICOSAHEDRON**, twenty faces that are equilateral triangles

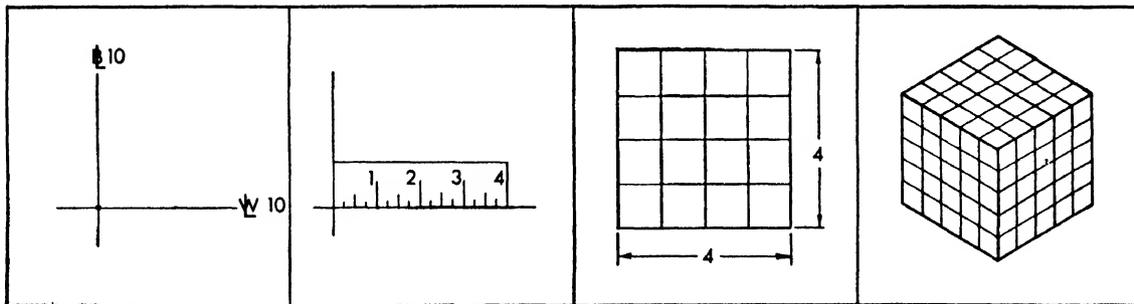
*Prisms*

Prisms are the most common polyhedrons. They are differentiated by reference to their bases. Thus, a right **TRIANGULAR** prism has a right triangle as its base, a **RECTANGULAR** prism has a rectangle as its base, etc. A prism is **OBLIQUE** when its edges form an oblique angle to the base. A **TRUNCATED** prism has nonparallel bases. The **FRUSTRUM** of a prism is the portion between the base and an intersection cut by a plane parallel to the base.

*Pyramids*

A **PYRAMID** has a plane geometric figure for its base and triangles for sides, the sides converging at a common vertex.

Like prisms, pyramids are named according to the nature of their bases and the relationship



**Fig. 109.** A point designates a position in space. A line has length, linear measure, and one dimension. A plane surface has area, square measure, and two dimensions. A solid figure has volume, cubic measure, and three dimensions.

of the edges of the other faces to the bases, for example, RIGHT RECTANGULAR.

### Cylinders and Cones

A cylindrical surface is a curved surface traced by one side of a rectangle rotated around the parallel side as an axis. A CYLINDER is a solid bounded by a cylindrical surface, called the

LATERAL SURFACE, and two parallel PLANE SURFACES or bases.

A CIRCULAR CONE is one with a circle as base. (For definition of cone, see conic sections.)

A SPHERE is a solid enclosed by a curved surface any point on which is equidistant from the central point of the solid.

### GEOMETRIC CONSTRUCTIONS

#### (1) To Bisect a Line or an Arc (Fig. 110):

Given line XZ. Draw an arc with X as center and any radius greater than XO. With Z as center, and the same radius, draw an arc intersecting the first arc at 1 and 2. Connect points 1 and 2 with a straight line. This line bisects the line or arc XZ.

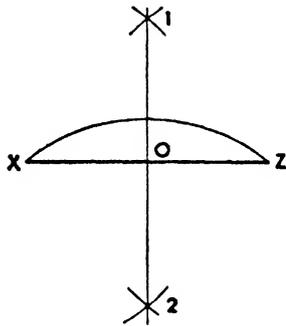


Fig. 110

#### (2) To Bisect an Angle (Fig. 111):

Using X as center, describe an arc CD. With C as center, and any radius greater than one-half CD, describe another arc. With D as center and the same radius as before, draw an arc to intersect at O. Draw a line from X to O. The line XO bisects the angle.

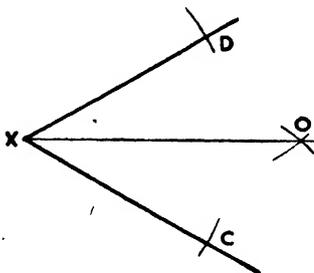


Fig. 111

#### (3) To Draw Parallel Lines (Two Methods):

Method (a) (Fig. 112):

Given line EF. To draw a parallel line at point H, with H as center and any common radius, describe the arc OP intersecting line EF at P. Employing P as center and with the same radius, draw arc HT. With center P and radius HT, swing an arc intersecting OP at O. Line OH is the required line.

Method (b) (Fig. 113):

Swing arcs with any convenient points on the given line as centers, using the desired distance as a radius. A line tangent to these arcs is the required parallel line. Parallel lines may also be drawn as indicated in Figs. 50 and 51.

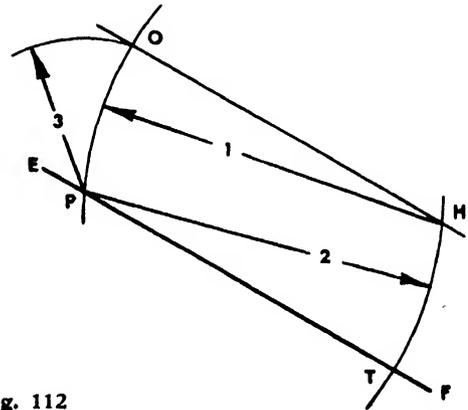


Fig. 112

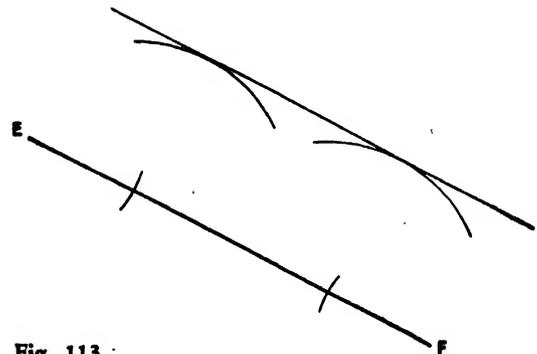


Fig. 113

(4) *To Divide a Line into Equal Parts (Fig. 114):*

Given the line XY. To divide this line into eight equal parts. Draw the line XO at any angle with XY. On the line XO set off seven equal parts from X, using the dividers or scale. Draw a line connecting O with Y. Draw lines parallel with OY from the points of line XO to line XY. The intersections of the parallel lines on line XY will determine the division points.

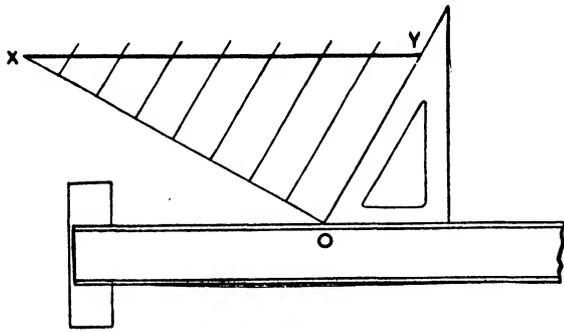


Fig. 114

(5) *To Divide a Line into Proportional Parts (Fig. 115):*

Given the line XY. To divide this line into proportional parts, 2:5:9, draw line XO—any length—at a convenient angle with XY. Set off nine equal parts on line XO. Extend a line from point 9 to Y. Draw lines, parallel to 9Y, from points 2 and 5 to line XY. The intersections of the parallel lines with XY will determine the proportional parts.

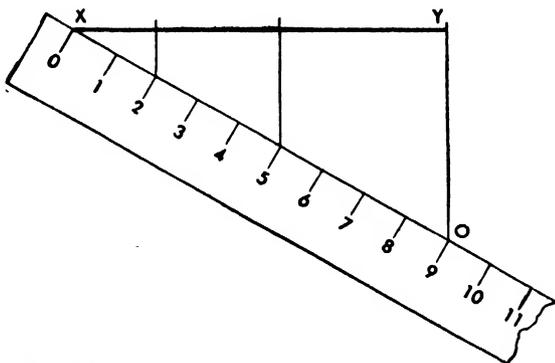


Fig. 115

(6) *Drawing a Tangent (Fig. 116):*

Given the arc EGF. To draw a tangent at point G. Use a triangle in combination with the

T square so that the hypotenuse passes through the center O and G. Then hold the T square in place and turn the triangle until the hypotenuse passes through G. The tangent lies along the hypotenuse.

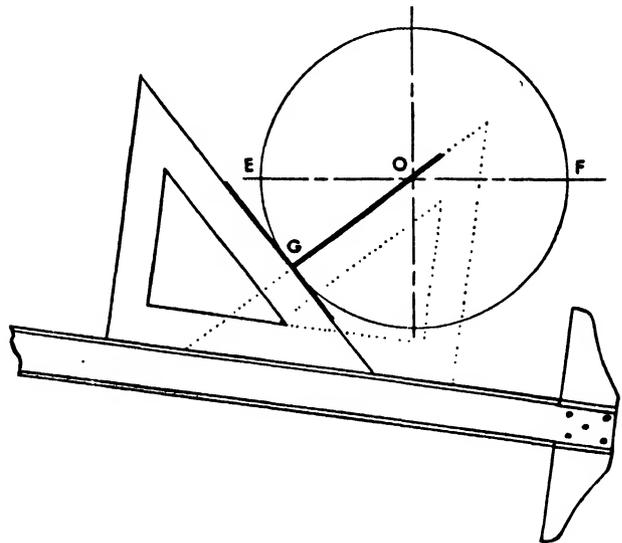


Fig. 116

(7) *Rectifying an Arc (Fig. 117):*

To draw tangent FG to arc FE, open the dividers a small distance. Starting at point E, set off points along the arc to the point nearest F. Without lifting the dividers, set off the same number of points on the tangent FG. The straight line is assumed to equal the arc.

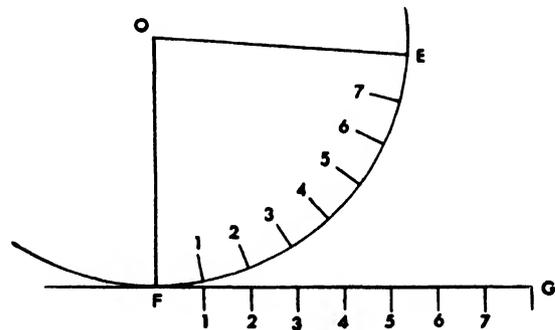


Fig. 117

(8) *To Copy an Angle (Fig. 118):*

Given the angle LMO. Draw the line M'O' in the desired location. With M as center and any convenient radius, describe arcs CD and C'D'. With the distance CD as radius and with D' as center, draw an arc to locate the point C'. Draw M'L' through C'.

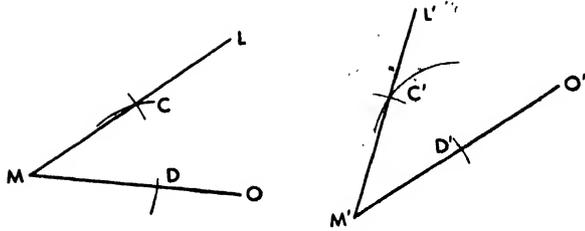


Fig. 118

(9) To Draw a Circle Through Three Given Points (Fig. 119):

Given the points G, F, and E. Erect perpendicular bisectors of lines GF and FE. The intersection of these perpendicular bisectors will be the center of the required circle. With O as center and any of the given points as radius, swing a circle.

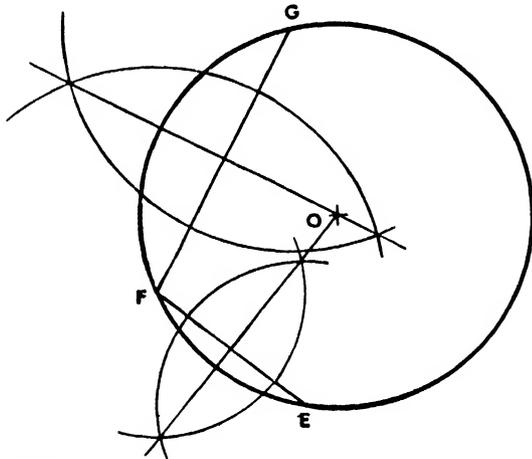


Fig. 119

(10) To Draw the Involute of a Triangle (Fig. 120):

Given the triangle EFG. Take E as center and EF as radius and draw an arc intersecting the extended line GE at point 1. With G as center and G1 as radius, swing an arc intersecting the extended line FG at point 2. The curve can be continued by increasing each succeeding radius as shown.

(11) To Draw the Involute of a Square (Fig. 121):

Given the square EFGH. With E as center and EG as radius, swing an arc from G intersecting line FE extended at point 1. With F as center and F1 as radius, describe an arc inter-

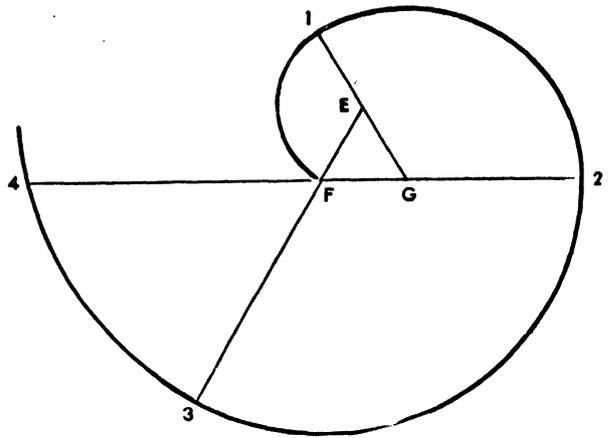


Fig. 120

secting line HF extended at point 2. With H as center and H2 as radius, draw another arc intersecting line GH extended at point 3. Complete the involute of the square by employing the same procedure.

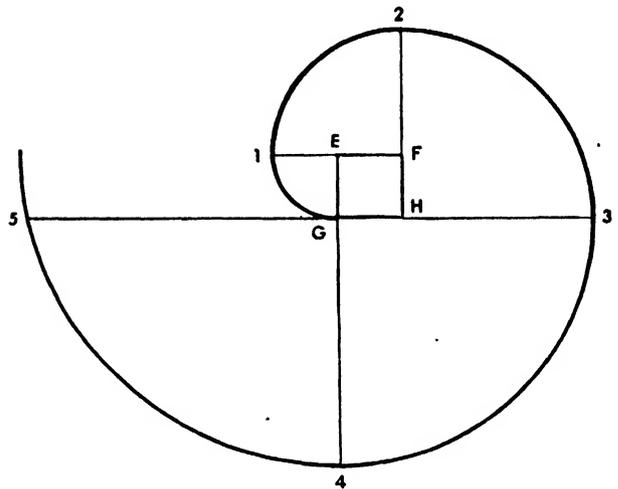


Fig. 121

(12) To Draw the Involute of a Circle (Fig. 122):

Given a circle. Divide the circumference into a number of equal parts, using, for the sake of convenience, 15 or 20 degrees as intervals. The smaller the number of degrees in the intervals, the more accurate the involute. Draw radial lines to these points, as OA, OB, etc. Draw tangents at each point as shown. Starting with B, lay off B2 on the tangent equal to the arc BAX. On each tangent, lay off a distance from the point of tangency equal to the arc of the circle, measured from the point of tangency to point X.

Draw a curve from X through points 1, 2, 3, 4, 5, and so forth, to form the involute.

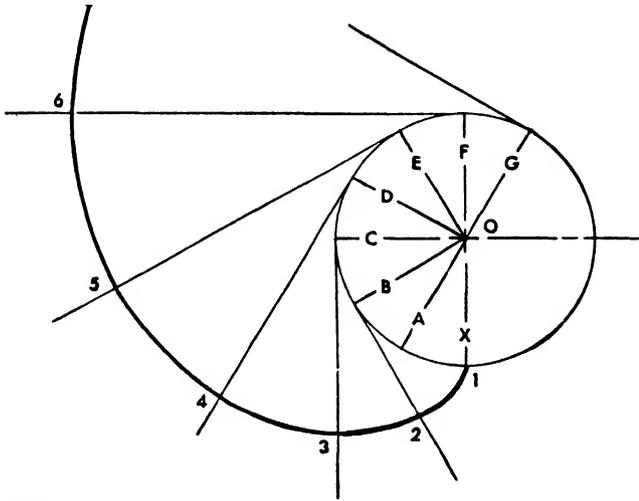


Fig. 122

(13) To Draw a Hexagon Given the Long Diameter (Fig. 123):

Given the diameter XY. Use a 30 by 60 degree triangle and a T square to draw the line OX at an angle of 60 degrees with the diameter XY. Draw the line OY at a 30 degree angle with XY. OX is one side of the hexagon. Draw construction lines as shown to complete the hexagon.

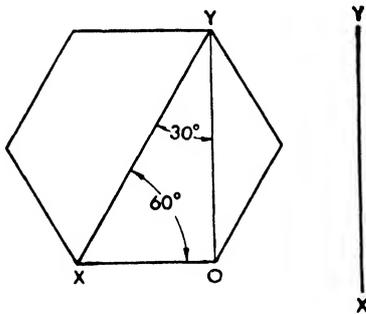


Fig. 123

(14) To Draw a Hexagon Given the Short Diameter (Fig. 124):

Given the short diameter XY. Draw XY as the vertical diameter. Draw the line OY at an angle of 30 degrees with the vertical diameter, and draw OX at a 60 degree angle with OY. The line OX is one side of the hexagon. Draw the construction lines shown to complete the hexagon.

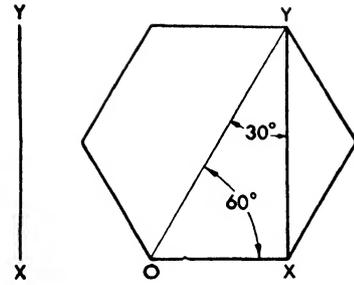


Fig. 124

(15) To Draw a Hexagon in a Circle (Fig. 125):

Describe a circle and draw the horizontal diameter. With L and M as centers and a radius equal to half the diameter of the circle, swing arcs that intersect the circumference of the circle at A, B, C, and D. Draw lines connecting the points on the circumference.

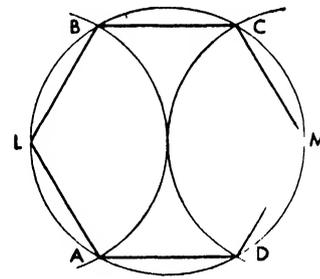


Fig. 125

(16) To Draw a Hexagon with One Side Given (Fig. 126):

Given the side XY of the hexagon. Describe a circle with a radius XY; then, with the compass opened to the distance XY, set off six points on the circumference of the circle. Draw lines connecting these six points.

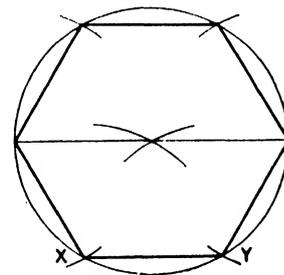


Fig. 126

(17) To Draw an Octagon in a Circle (Fig. 127):

Given the circle in which to construct an octagon. Draw diameters AB and CD, then four more diameters forming 45 degree angles. Connect the intersection points of the diameters and the circumference.

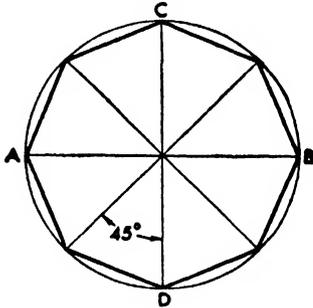


Fig. 127

(18) To Construct an Octagon in a Square (Fig. 128):

Given the square LMNO. Using the corners of the square as centers and half the diagonal as radius, describe arcs intersecting the sides of the square. Draw lines connecting these points.

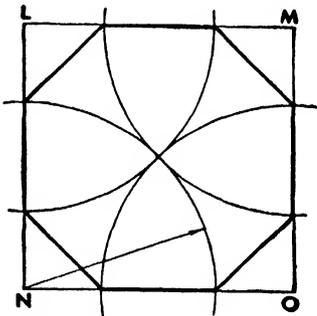


Fig. 128

(19) To Construct a Regular Pentagon (Fig. 129):

Describe a circle and draw the vertical and horizontal diameters. Bisect the radius AO at G. With G as center and GC as radius, draw the arc CD. With C as center and CD as radius, describe an arc intersecting the circumference at E. Draw the line CE. This is one side of the required pentagon. Using the same radius CE, set off points along the circumference of the circle, and draw lines connecting the points, which will be the sides of the pentagon. This

is one of the most difficult constructions, and every step should be carefully taken. If arc CE does not divide the circumference exactly into five equal arcs, the student should repeat the procedure until he is adept.

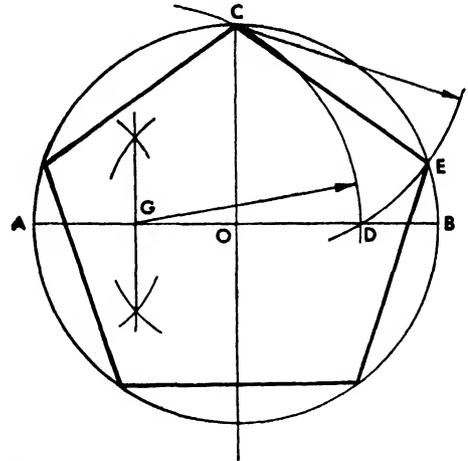


Fig. 129

(20) To Construct a Regular Polygon on a Given Side (Fig. 130):

Given the distance LM, assume the number of sides to be seven, with LM as the side given. Taking LM as a radius and L as center, describe a semicircle. Divide the semicircle into seven equal parts. Using the second division point O, draw the lines LO and LM. These are two sides of the polygon. Bisect LO and LM. Using the intersection of the bisectors as a center, draw a circle passing through points M, L, and O. With chord LO or LM, set off points along the circumference of the circle. Draw lines connecting the points of the required polygon.

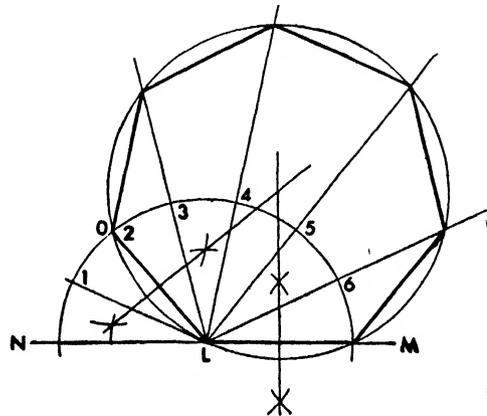


Fig. 130

(21) To Draw a Circular Arc Tangent to Two Straight Lines at 90 Degrees (Fig. 131):

Construct lines AB and CD at right angles to each other. With the intersection of these two lines as a center and XY as the radius, draw an arc to intersect AB and CD at L and M, respectively. With the same radius and these points as centers, draw arcs to intersect at O. With O as center, describe the required arc.

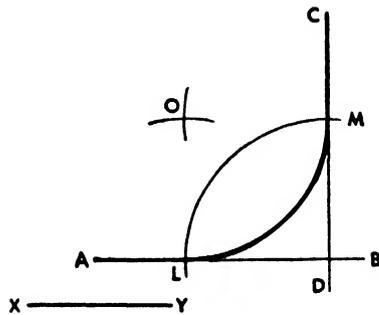


Fig. 131

(22) To Draw a Circular Arc Tangent to Two Straight Lines Not at 90 Degrees (Fig. 132):

Given the lines CD and AB and the radius XY. Draw two lines parallel to AB and CD at a distance equal to XY. With the intersection O as center and with XY as the radius, describe the required arc. Perpendiculars erected from AB and CD to O determine the points of tangency.

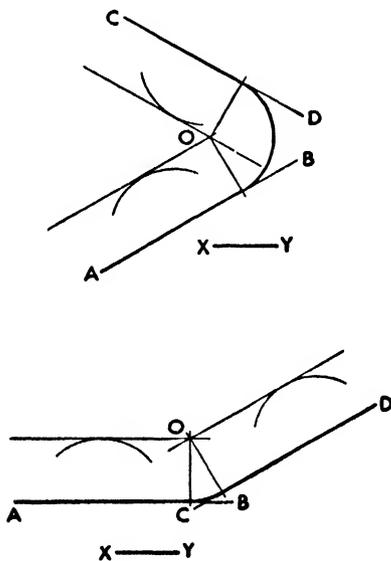


Fig. 132

(23) To draw an Arc Tangent to a Straight Line and an Arc (Three Methods) (Fig. 133):

Methods (a) and (b):

Let LM be the arc and O the center, with AB the straight line, and XY the radius of the required arc. Draw the line CD parallel to the line AB at a distance equal to XY. With O as center, and with XY plus the radius of the arc LM as a radius, describe an arc parallel to LM, intersecting the line CD at point F. Using F as center and with XY as the radius, draw a circular arc tangent to the line AB and the arc LM. A perpendicular erected from AB to point F determines the point of tangency on AB. Line OF determines the other point of tangency.

Method (c):

Point F is found by swinging an arc from point O with the radius of arc LM minus XY.

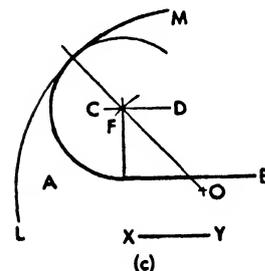
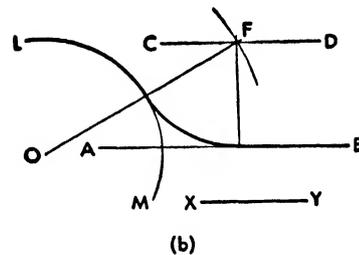
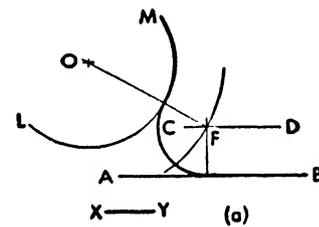


Fig. 133

(24) To Draw an Arc Tangent to Two Arcs (Four Methods) (Fig. 134):

Method (a):

Let  $XY$  be the radius of the required arc, and  $M$  and  $N$  the centers of the two given arcs  $AB$  and  $CD$  which are drawn with the same radius. From  $M$  and  $N$  as centers and with  $XY$  plus the radius of arcs  $AB$  and  $CD$  as a radius, describe arcs intersecting at point  $O$ . Point  $O$  is the center of the required arc. The center lines  $MO$  and  $NO$  determine the points of tangency. With point  $O$  as center, and  $XY$  the radius, describe the required arc.

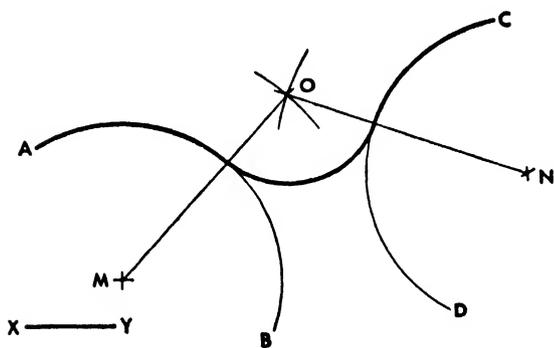


Fig. 134(a)

Method (b):

Let  $XY$  be the radius of the required arc, and  $M$  and  $N$  the centers of the two given arcs  $AB$  and  $CD$ . Using  $M$  as center and with a radius equal to the radius of arc  $AB$  plus  $XY$ , draw an arc parallel to arc  $AB$ . With  $N$  as center and with a radius equal to the radius of arc  $CD$  minus  $XY$ , describe an arc parallel to the arc  $CD$ . With the intersection point of these arcs,  $O$  as center, and with radius  $XY$  draw the required arc.

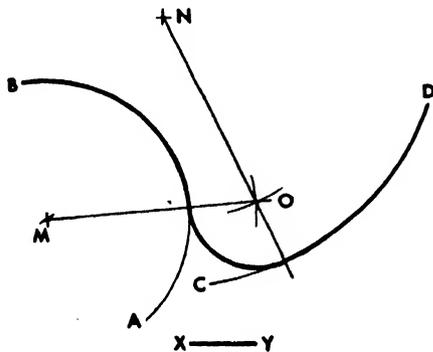


Fig. 134(b)

Method (c):

Let  $XY$  be the radius of the required arc, and  $M$  and  $N$  be the centers of the two given arcs  $AB$  and  $CD$ . Taking  $M$  as center and with a radius equal to  $XY$  plus the radius of arc  $AB$ , describe an arc parallel to arc  $AB$ . With  $N$  as center and with a radius equal to  $XY$  minus the radius of arc  $CD$ , describe an arc. With the intersection point of these arcs  $O$  as center and with  $XY$  as radius, draw the required arc.

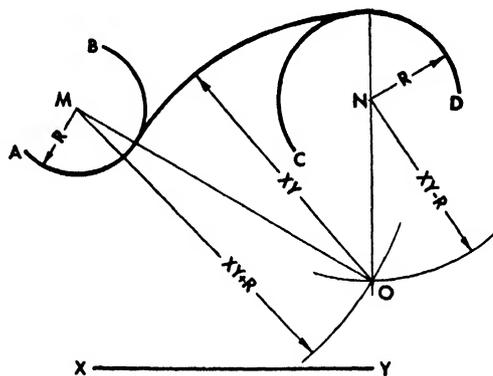


Fig. 134(c)

Method (d):

Let  $XY$  be the radius of the required arc and  $M$  and  $N$  the centers of the two given arcs  $AB$  and  $CD$ . From  $M$  as center with a radius equal to  $XY$  minus the radius of arc  $AB$ , describe an arc. With  $N$  as center and with a radius equal to  $XY$  minus the radius of arc  $CD$ , describe an arc. With the intersection point of these two arcs  $O$  as center and with radius  $XY$ , draw the required arc.

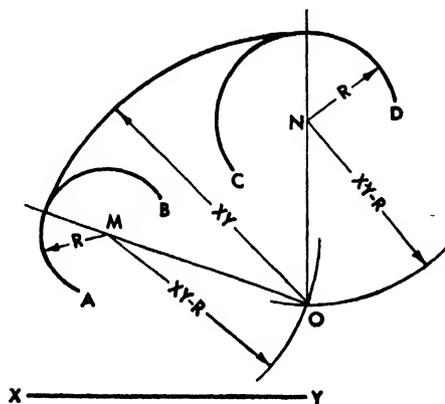


Fig. 134(d)

(25) To Draw an Ogee Curve (Fig. 135):

Let AB and CD be two parallel lines. At B and C erect perpendiculars BO and CE to the lines AB and CD. Draw the line BC and assume any point X on this line where the ogee curve will intersect it. Draw perpendicular bisectors of CX and BX. The intersections O and E of these bisectors and the lines BO and CE, respectively, are centers of the required arcs. With O as center and OB as radius, draw the arc BX. Using E as center and EC as radius, draw the arc XC. The desired ogee curve is BXC.

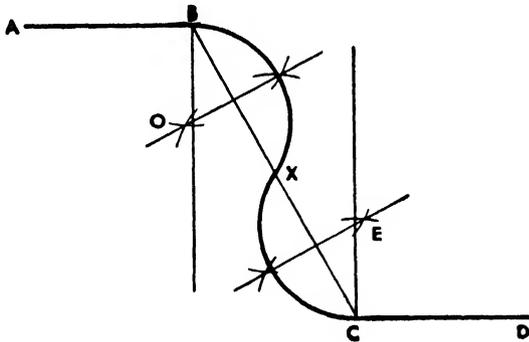


Fig. 135

(26) To Draw an Oval by the Isometric Method (Fig. 136):

Given the diameters LM and FB. To construct the figure AODF, erect perpendicular bisectors to AO, OD, DF, and FA. With A as center and AE as radius, describe the arc EM. With D as center and the same radius, describe the arc LB. Taking H as center and HL as radius, draw the arc LE. With G as center and the same radius, describe the arc BM. This method is also used in constructing isometric circles.

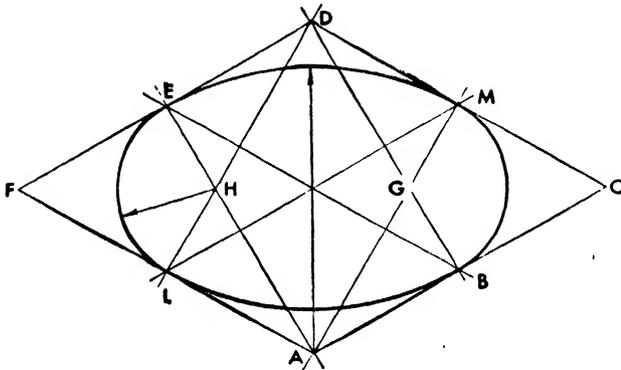


Fig. 136

(27) To Draw an Ellipse (Two Methods):

Method (a), the concentric circle (Fig. 137):

From X as center, draw two circles with the major and minor axes as diameters. With intervals of 15 degrees, set off points L, M, N, O, P, etc., on the major circle, and connect these to X. Where these intersect the minor circle, mark the points with 1, 2, 3, 4, 5, etc. Draw lines from these numbered points parallel to the major axis, and draw perpendiculars to these lines from L, M, N, O, P, etc. The intersections of the perpendiculars and parallel lines will determine points on the ellipse. Draw a smooth line through these points with an irregular curve.

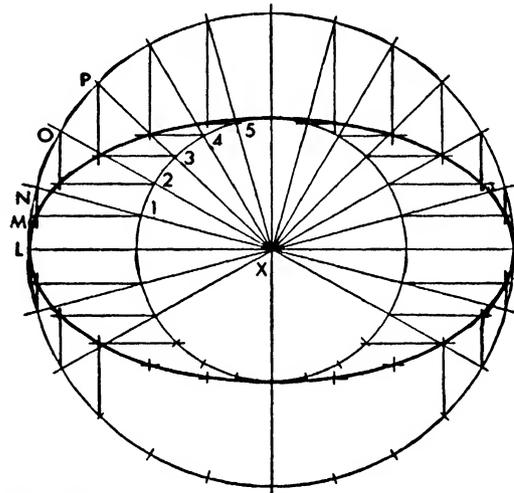


Fig. 137

Method (b) (Fig. 138):

Given the axis XY and LM. Draw the circumscribed rectangle ABCD and its diagonals. Draw

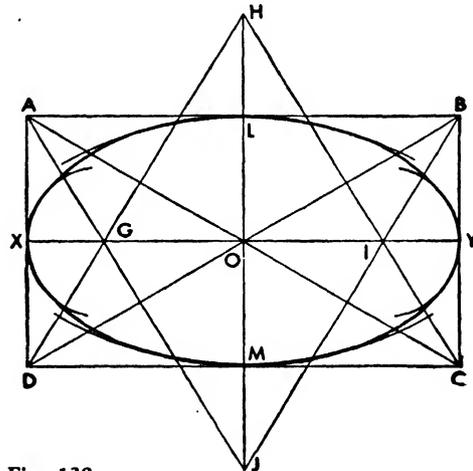


Fig. 138

perpendiculars to the diagonals from the corners, establishing the points GHI and J. With G and I as centers and with radius GX, draw two other tangent arcs as shown. With H and J as centers and with radius JL, draw two other tangent arcs. Join these four arcs with a smooth curve to form the ellipse.

S on the strip falls. Repeat this procedure, moving the strip of paper but always having R and T touching the minor and major axes, respectively. When enough points have been set off in the rectangle, they can be connected to form a true ellipse, either freehand or with a French curve.

(28) To Construct an Ellipse of a Certain Size (Fig. 139):

Given a rectangle with the sides equal to the major and minor axes of the required ellipse. On a strip of paper, set off half the length of the given major axis. Mark this R and S, as shown in (a).

Place the strip of paper along the minor axis and set off from S one-half of the minor axis, as shown in (b). Call this point T.

Then mark the point on the rectangle where

(29) To Draw a Helix (Fig. 140):

Given the diameter and the pitch of a cylinder. Draw a circle of the given diameter and divide into twelve equal parts, numbered 1, 2, 3, 4, etc. Draw horizontal lines through each point. Divide the pitch into the same number of equal linear parts. Draw vertical lines through these points. The intersections of the horizontal and vertical lines are the points of the required helix. Draw a smooth curve through these points.

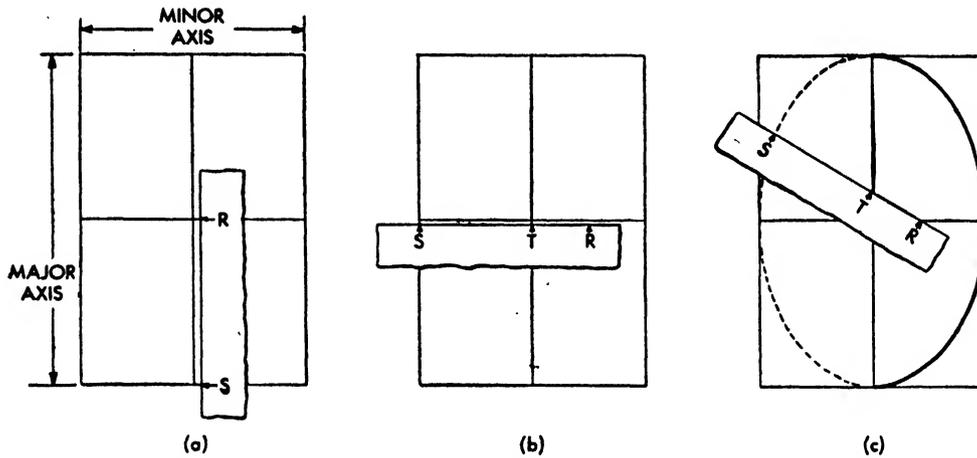


Fig. 139

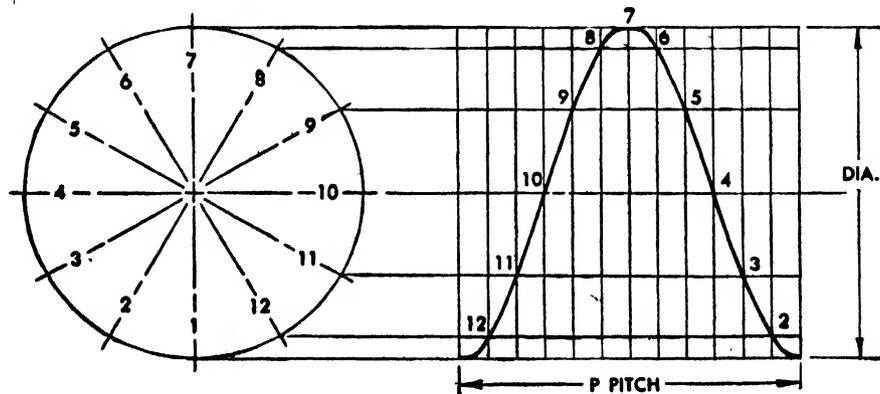


Fig. 140

## PROBLEMS FOR CHAPTER SIX

1. Draw a diagonal line  $4\frac{1}{2}$  inches long and bisect it.

2. Swing an arc of approximately  $3\frac{1}{2}$  inches with a 4 inch radius and bisect it.

3. Draw an acute angle and bisect it.

Draw an obtuse angle and bisect it.

4. Draw a right angle within a semicircle. Bisect the right angle and check it with a 45 degree triangle and a protractor.

5. Draw a horizontal line approximately 4 $\frac{1}{2}$  inches long. Place a point approximately 2 $\frac{1}{2}$  inches above the line and draw a parallel line through the point.

6. Draw a diagonal line. Place a point approximately 3 inches to the right of the line, and another point approximately the same distance to the left. Draw through these points two lines parallel to the original diagonal line.

7. Draw an equilateral triangle, with each side approximately 5 inches. Draw a proportional triangle within this triangle by drawing parallel lines.

8. Draw a horizontal line approximately 5 $\frac{1}{2}$  inches long. Assume this dimension; do not scale it. Divide the line into seven equal parts.

9. Draw an inclined line approximately 5 $\frac{1}{2}$  inches long. Assume this dimension; do not scale it. Divide the line into four equal parts.

10. Draw a horizontal line approximately 7 inches long. Divide this line into proportional parts of 3:7:9.

11. Swing a circle with a 2 inch radius. Draw three radial lines 120 degrees apart. Draw the tangents to these lines.

12. Swing a circle with a 14 inch radius to  $\frac{1}{4}$  size ( $3'' = 1'$ ). Draw vertical center line. Draw a line tangent to the bottom of the vertical center line. This line will be water line 0. Where water line 19 intersects the circumference, place a point, and draw a radial line from that point. Draw a tangent to the radial line.

13. Swing a circle with a 2 inch radius. With

vertical and horizontal center lines, form four quadrants. Rectify one arc of a quadrant, using dividers.

14. Find the circumference of the circle in problem 13 ( $C = 2 \pi R$ ). Scale the straight line in problem 13, multiply by 4, and check the accuracy of the solution.

15. Draw an acute angle, one side of which is a horizontal line. Transfer that angle so that the horizontal line of the original angle is inclined.

16. Using any circular object, trace a circle. Place three points on the circumference and find the center of the circle.

17. Draw an equilateral triangle, each side 1 inch. Draw the involute of that triangle.

18. Draw a square, side 1 $\frac{1}{2}$  inches. Draw the involute of that square.

19. Draw a circle with a 3 inch diameter. Draw the involute of that circle.

20. Draw a hexagon with a long diameter of 2 inches.

21. Draw a hexagon with a short diameter of 1 $\frac{1}{2}$  inches.

22. Draw a circle with a 3 $\frac{1}{2}$  inch diameter. Inscribe a hexagon.

23. Draw a hexagon with one side equal to  $\frac{1}{2}$  inch.

24. Draw an octagon within a circle of 4 inches diameter.

25. Construct an octagon in a square with 2 inch sides.

26. Construct a regular pentagon in a circle of 3 $\frac{1}{2}$  inches diameter.

27. Construct a regular polygon of nine sides, each side equal to  $\frac{3}{4}$  inch.

28. Draw a rectangle 2 inches wide by 4 inches long. Construct tangent arcs of  $\frac{1}{2}$  inch radius to the inside corners.

29. Draw a square of 3 inch sides. Draw parallel lines about the sides of the square  $\frac{1}{8}$  inch away. Draw tangent arcs of  $\frac{5}{8}$  inch radius to the

inside corners and tangent arcs of  $\frac{1}{2}$  inch radius to the outside corners.

30. Draw a sheet of 0.125 aluminum alloy bent at 35 degrees to outside edge of the sheet at a  $\frac{1}{2}$  inch radius, the sides of the open angle to be approximately 2 inches long. Determine the points of tangency.

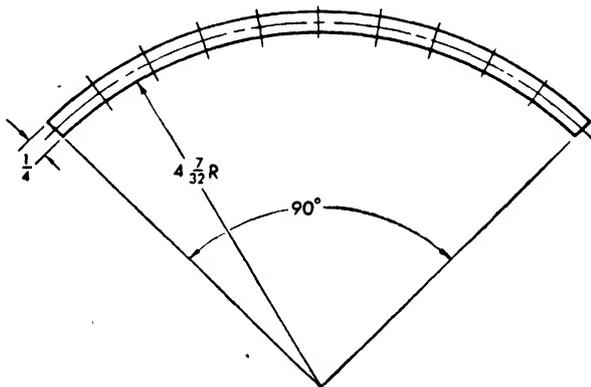
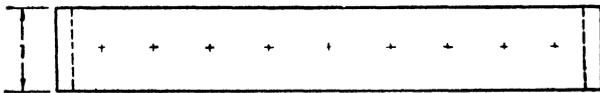
31. Draw a sheet of 0.125 aluminum alloy bent at 120 degrees to the outside edge of the sheet at a  $\frac{3}{4}$  inch radius, the sides of the closed angle to be approximately  $2\frac{1}{2}$  inches long. Determine points of tangency.

32. Draw a circle of 2 inches diameter. Draw a line tangent to a 45 degree radial line. Construct an arc of  $\frac{1}{2}$  inch radius tangent to the circumference and to the tangent line.

33. Draw two circles of 2 and 1 inch diameters respectively, the centers of which are on a 45 degree diagonal line. The distance between the centers is 2 inches. Draw an arc of  $\frac{3}{8}$  inch radius tangent to the circles.

34. Draw two parallel inclined lines about 2 inches apart. Pick any convenient point on each line. Connect them with an ogee curve tangent to the two parallel lines.

35. Draw an oval (isometric circle) diameter equal to 3 inches.



**Problem 40**

Draw the two views of the contour plate. Determine the rivet spacing by finding the length of the arc.

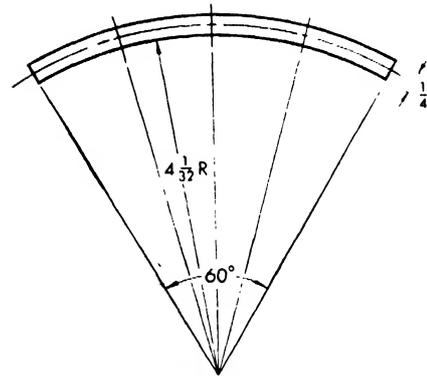
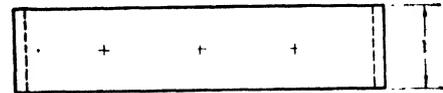
36. Draw an ellipse (concentric circle method) having a minor diameter of 2 inches and a major diameter of 4 inches.

37. Using the tangent method, construct an ellipse whose major axis is horizontal and  $3\frac{1}{4}$  inches long, and whose minor axis is vertical and  $2\frac{3}{8}$  inches long.

38. With the same axes as those in problem 37, draw an ellipse by the trammel method.

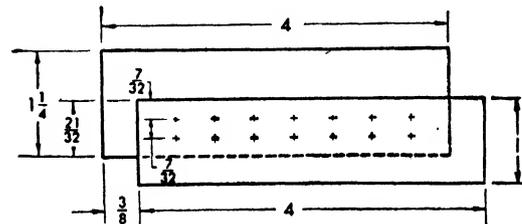
39. This is a trick problem common in many engineering drafting rooms, requiring your personal ingenuity to be proved (Q.E.D.) and not by trial and error.

Given: any acute angle any point within the angle, to draw: a circle passing through the point and tangent to the legs of the angle.



**Problem 41**

Draw the two views of the contour plate as shown. Locate three rivets by first bisecting the arc, and then bisecting the two 30 degree angles.

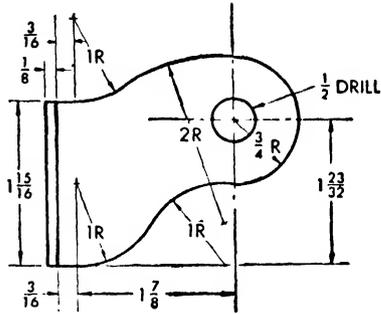


**Problem 42**

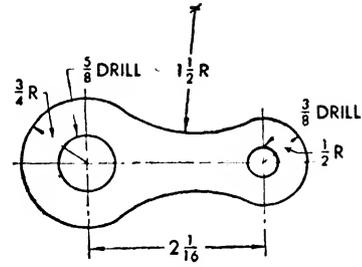
Draw the splice plates. Locate two rows of rivets by dividing the lines geometrically.

Problems 43-47

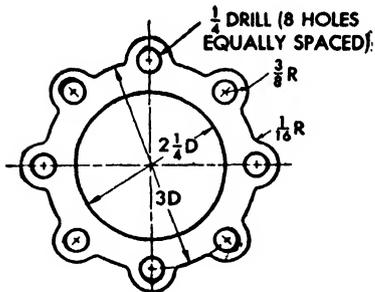
Lay out figures as shown, using a sharp 4H pencil. Check for tangency.



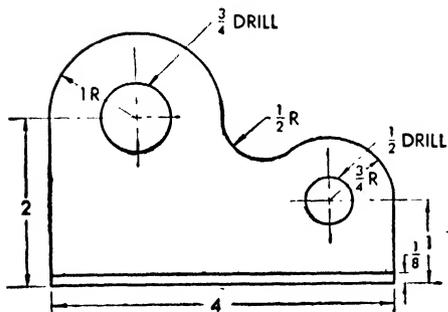
Problem 43



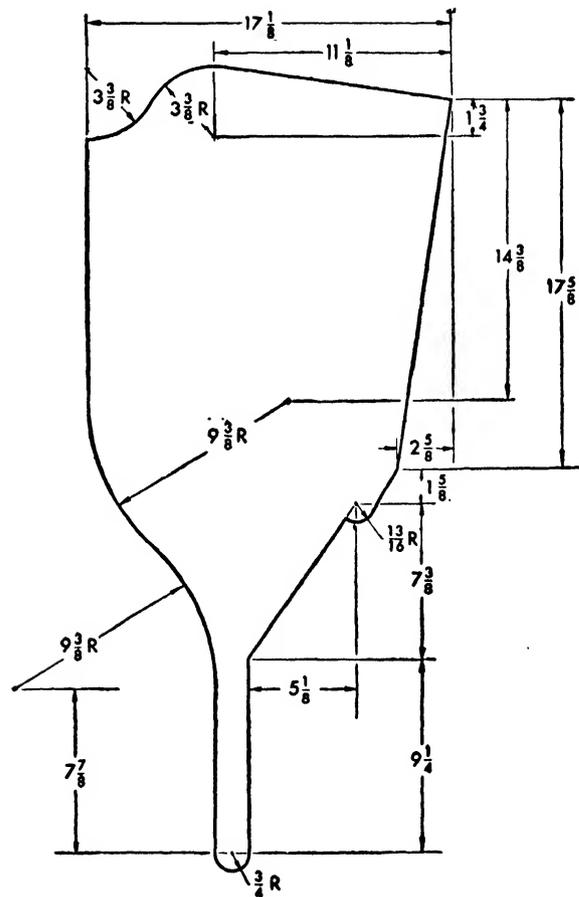
Problem 46



Problem 44



Problem 45

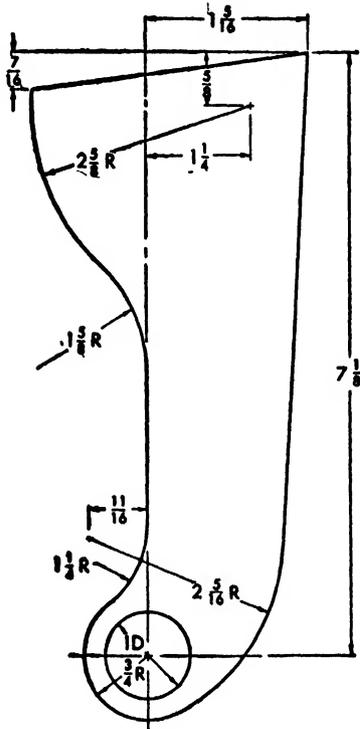


Problem 47

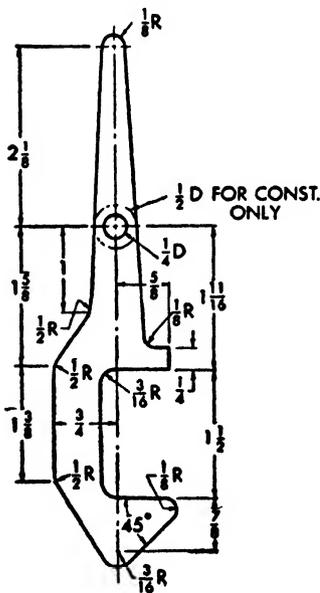
Draw landing gear cutout to  $\frac{1}{4}$  size, ( $3'' = 1'0''$ ).

Problems 48-50

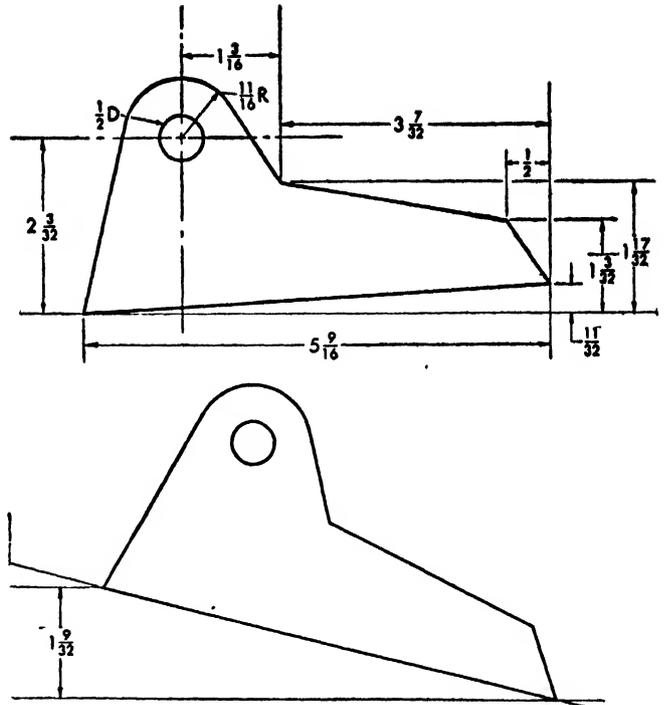
Draw figures as shown. Use a 4H pencil for construction. Darken with a well-pointed H or F.



Problem 48

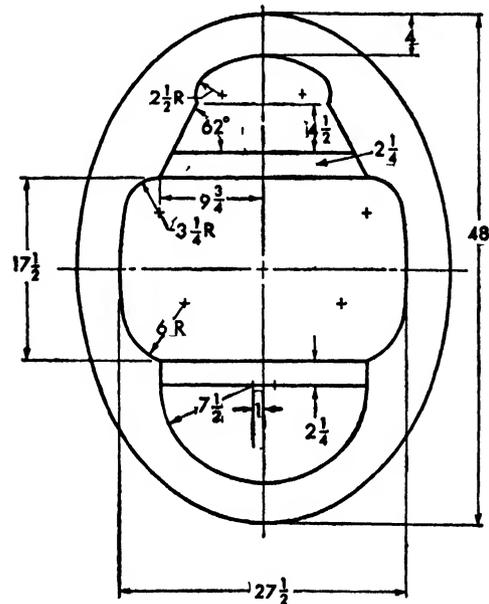


Problem 49



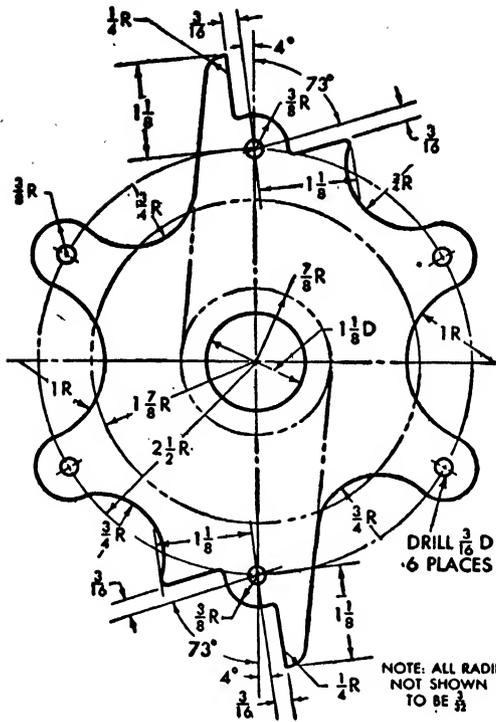
Problem 50

Draw bracket plate, then transfer figure from horizontal reference baseline as designated.

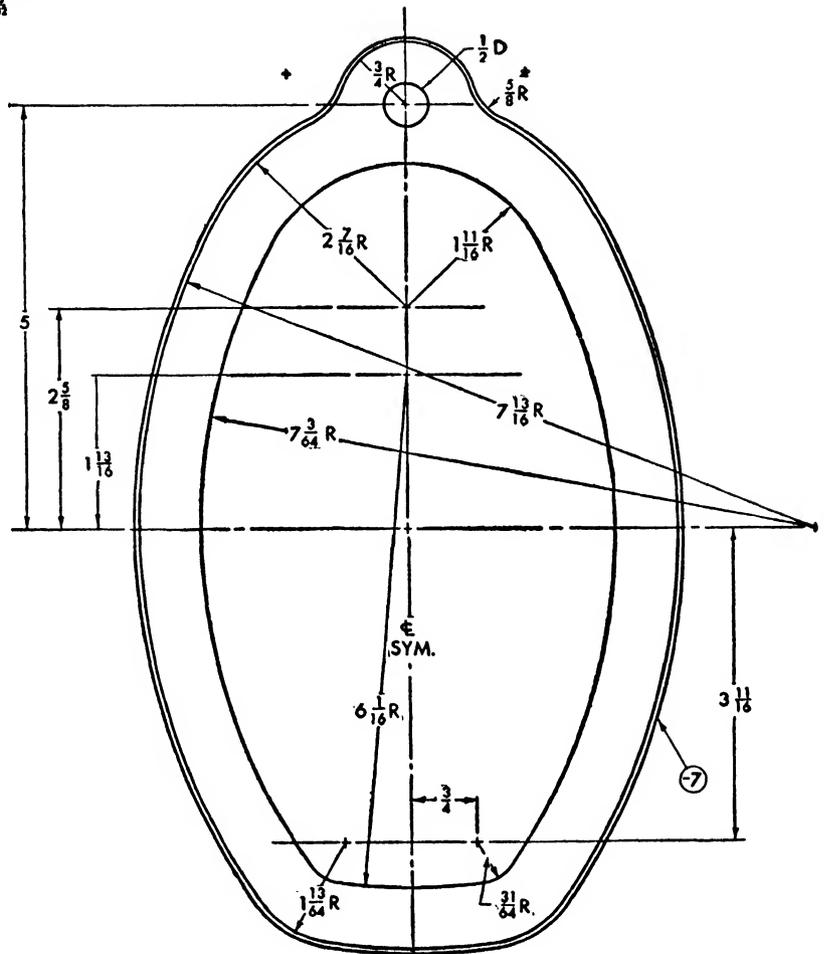


Problem 51

Construct the elliptical bulkhead, using  $\frac{1}{4}$  or  $\frac{1}{8}$  size. Minor diameter of the ellipse is  $35\frac{1}{2}$  inches. Figure is symmetrical except as noted.



**Problem 52**  
Lay out and darken the hatch cam as shown.



**Problem 53**  
Draw the frame to full or  $\frac{1}{2}$  size.

# CHAPTER SEVEN

## ORTHOGRAPHIC PROJECTION

### Introduction

A writer may employ poetry, prose, drama, or exposition to express an idea or describe an object, but a poet and a botanist, for instance, may differ greatly in describing a tree. The poet is an artist, the botanist a scientist.

The graphic language, too, employs different mediums of expression, each with its own advantages, limitations, and uses (Fig. 141). When an artist paints or draws a picture, he transfers his personal impressions of an object. Many artists omit or merely suggest certain details in a picture so that the observer may complete the picture by exercising his own imagination.

The engineer, on the other hand, draws a picture without concern for aesthetic appeal. The student draftsman must remember that his picture will not be regarded as a work of art, but will find its way to the shop, where the part is fabricated and eventually installed in a plane (Fig. 142). The merit of his drawing lies in clarity and objectivity, in the information it gives the men who must make and install the

part, and in the successful functioning of that part in the plane.

The engineering drawing supplies accurate and complete information about the appearance of the part and its method of construction. It leaves nothing to the imagination of the observer. An artist's drawing may have a variety of interpretations; the engineer's must have but one.

In early days of machine manufacture, either design and execution of an object were the task of the same individual, or the designer would hand the basic plans—or ideas—to a mechanic. The successful functioning of the part depended on the ingenuity of the mechanic, who often had to supply dimensions or modify the design to make it practicable. The highly specialized procedures of modern production require complete details in a drawing. Today, the men in the shop are not supposed to use originality but must follow the instructions set forth in the blueprint. These blueprints must be capable of but one interpretation.

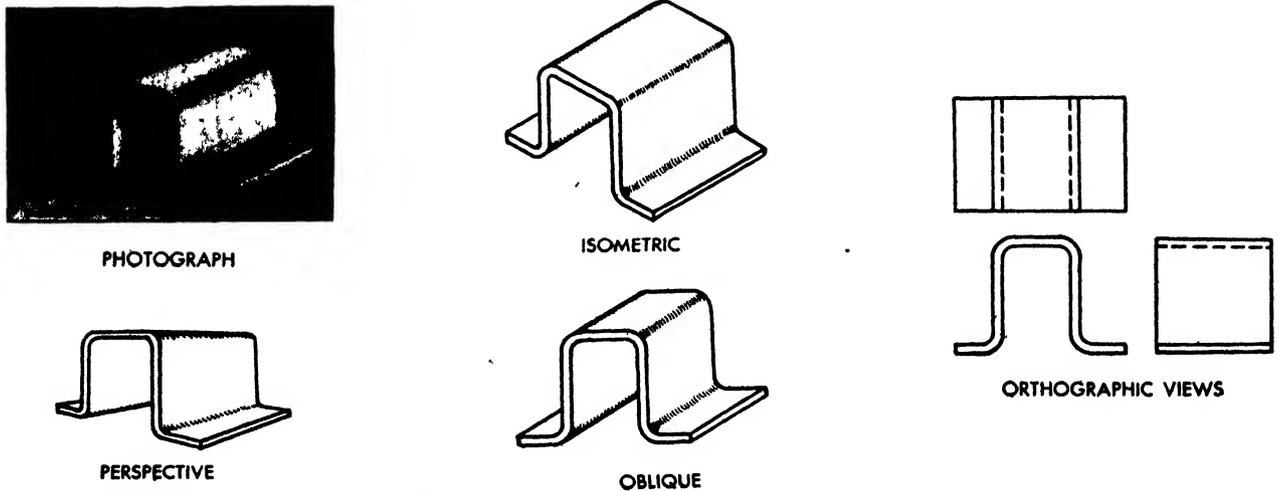


Fig. 141. Methods of graphic representation

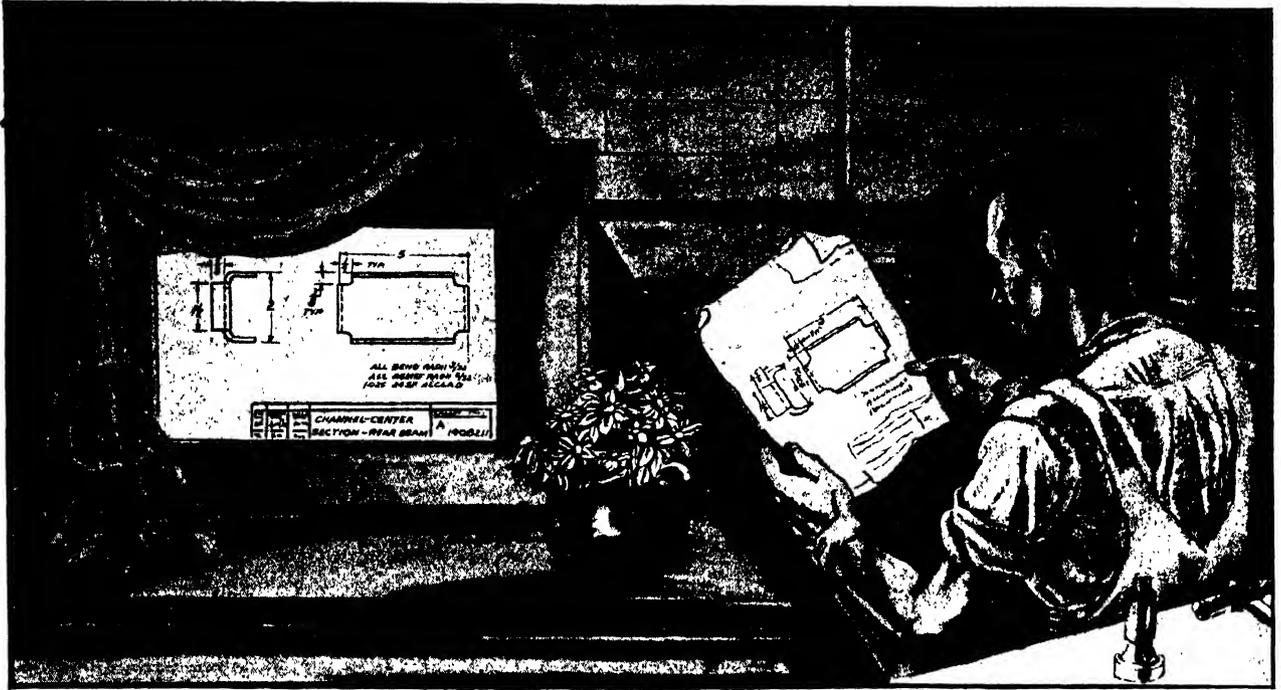


Fig. 142. Engineering drawings are not created for display but as a guide in manufacturing

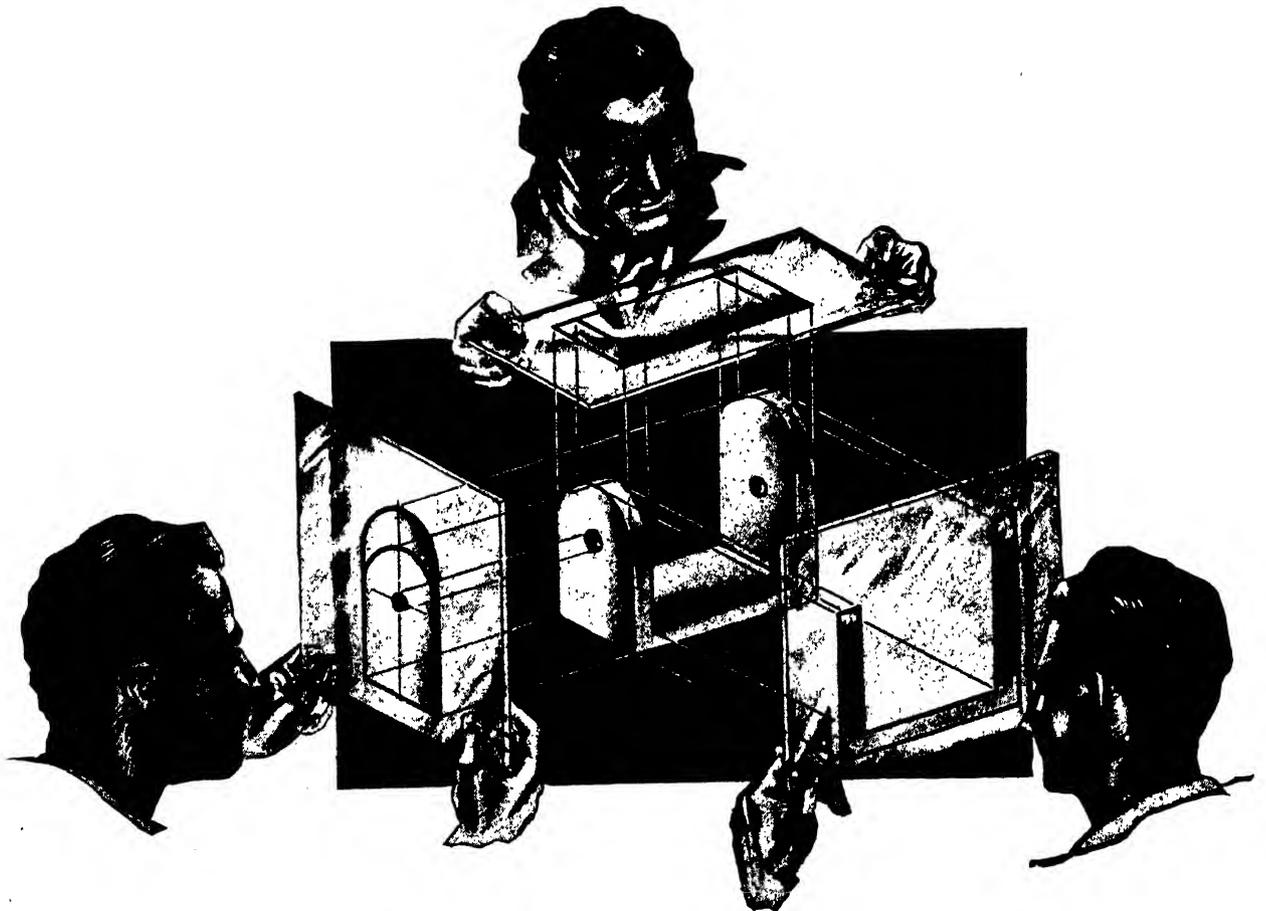


Fig. 143. Obtaining views by varying the position of the observer

### *Methods of Describing the Shape of Objects*

The common ways of describing an object graphically are shown in Fig. 141. These representations are obtained by projecting the object on a plane. A landscape artist projects or transfers the landscape to the canvas. A motion picture projector throws pictures on the screen. We transfer views of an aircraft part on the vellum or "plane of the paper." The nature of the projection or picture depends upon the position of the observer, who may rotate the object or change his position in respect to it.

We associate the representation of an object with its pictorial perspective, because, in general, we observe things in three dimensions. Although pictorial drawing may offer a layman the commonly associated characteristics of an ob-

ject, it seldom can supply the accurate detail of size and shape needed for production purposes.

Therefore, we must resort to a method which shows the true size and shape of every part of an object both internally and externally. This can be done by employing a series of pictures or **VIEWS** of the different sides of an object. The views are obtained by looking perpendicularly at each side of the part, to capture its true size and shape. The views are then systematically grouped so that the person reading the drawing can easily coordinate them into an accurate visualization of the part. This system is called "orthographic projection" or "orthographic drawing." *Ortho* denotes a right angle, and *graphic* means written or drawn. This system is sometimes called a "multiview," or in machine design a "three-view" drawing.

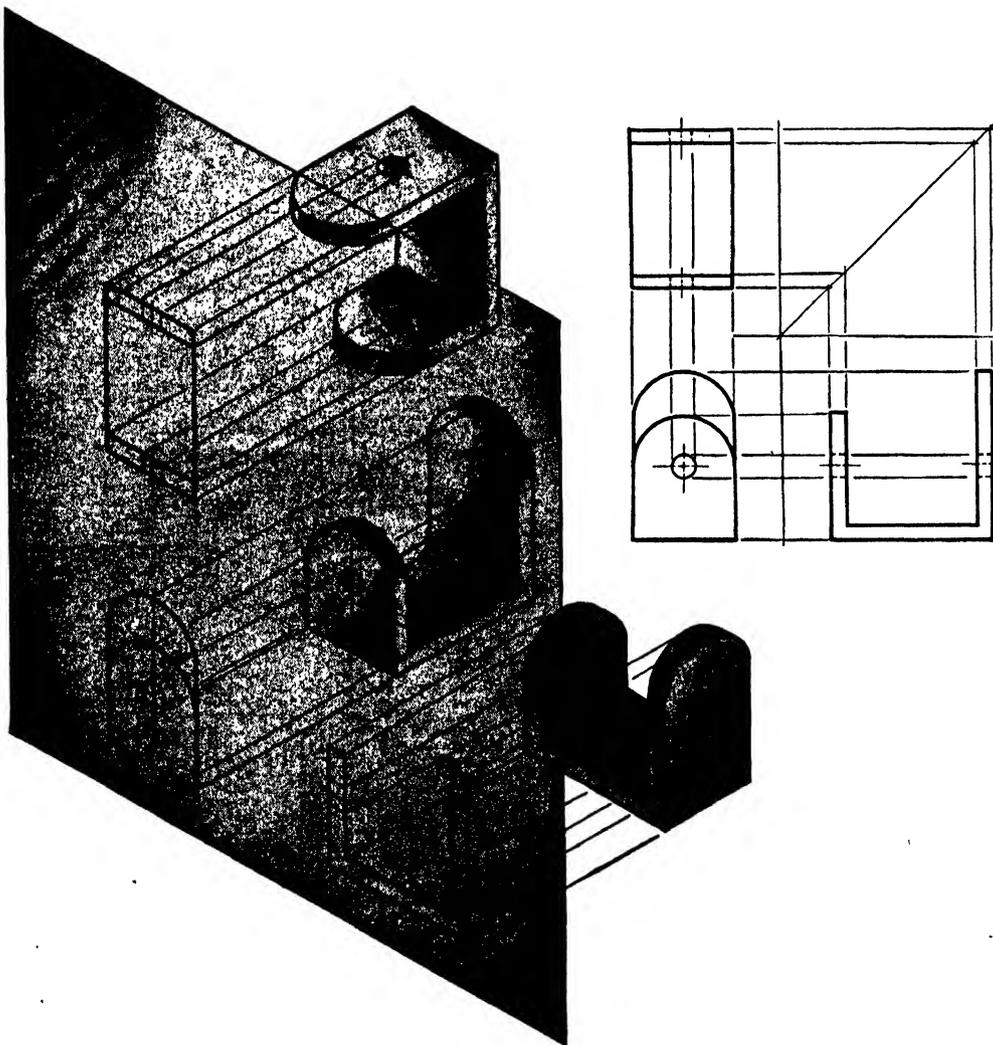


Fig. 144. Obtaining views by moving the object in respect to the observer

*Obtaining Views*

To gain each view, the observer may imagine that he is looking perpendicularly at one side of the object through a sheet of glass placed parallel to the observed side. The side of the object is projected to the sheet of glass in its true and actual shape by imaginary lines perpendicular to the object and the glass plane (Fig. 143). The views are transferred from the imaginary sheets of glass and are grouped to make a three-view drawing. Views may also be obtained by turning the object about until the desired sides are parallel to the plane of projection. Occasionally this is called the "natural method" (Fig. 144).

view describes the width and height of the object as well as the shape of the short and long flanges. A rear view is seldom used, for it merely repeats the information given in the front view. The right side reveals the length of the object and the thickness of the various sides. The top view describes the width and length of the object, but since it repeats the information presented in the front and side views, it is not always needed.

From Figs. 143 and 144 we see that the front

*The Glass Box.* The proper projection and arrangement of views may be visualized by the "glass box method." Let us assume that the channel bracket shown in Fig. 145(a) is suspended in a box with hinged glass panels. The outlines of the sides of the channel bracket are transferred to the corresponding sides of the glass

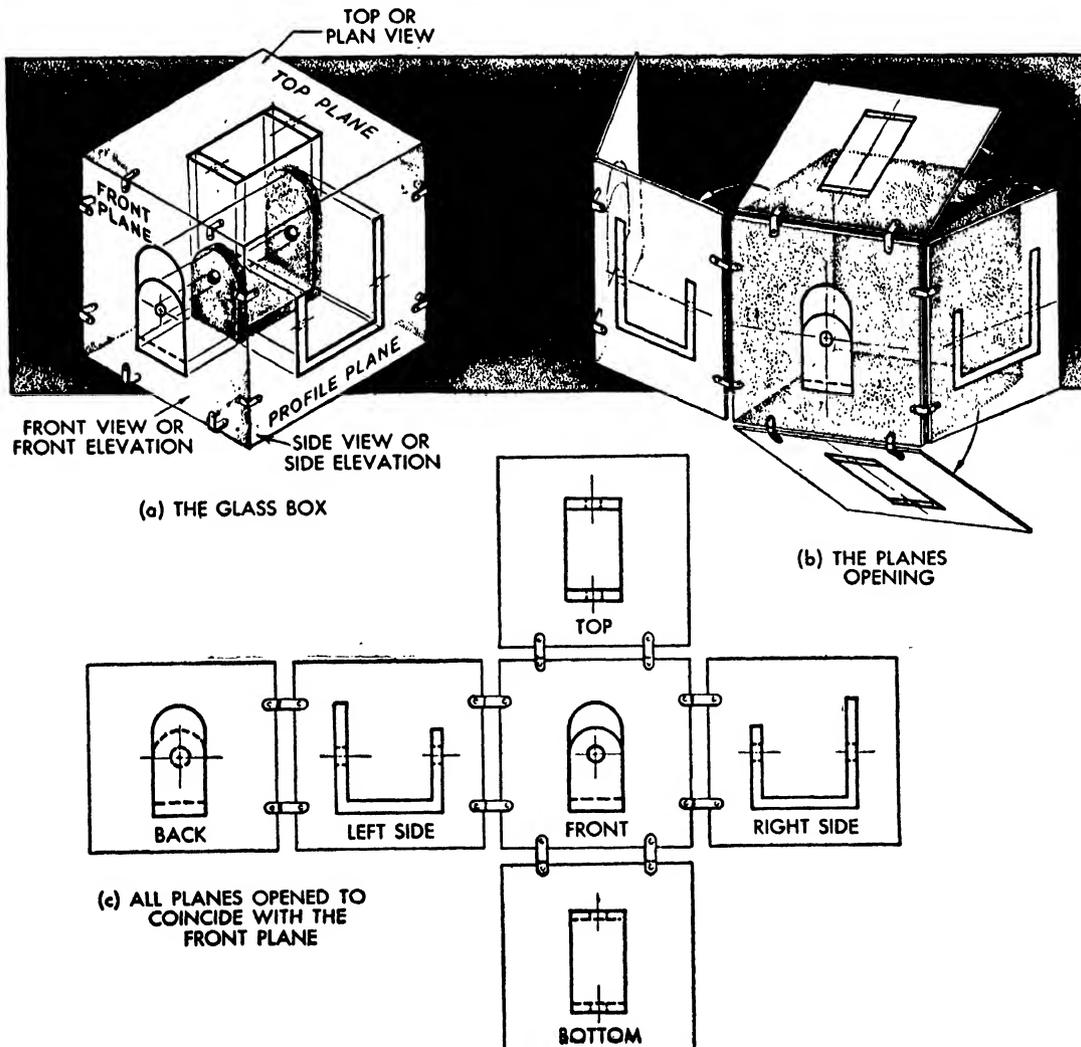


Fig. 145

AIRCRAFT DRAFTING

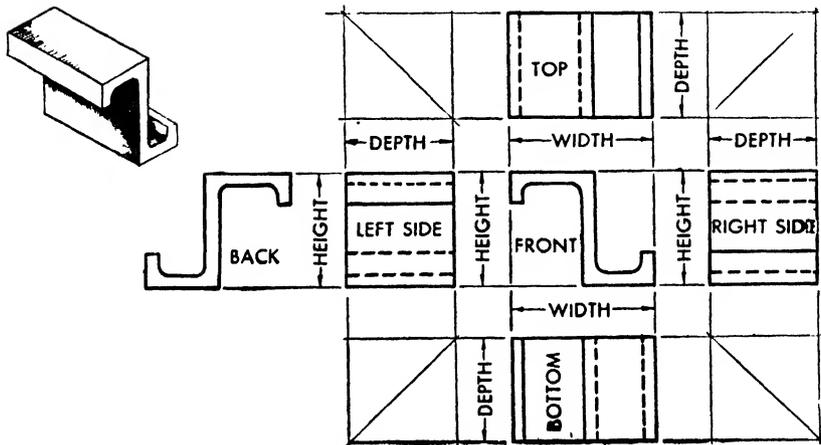
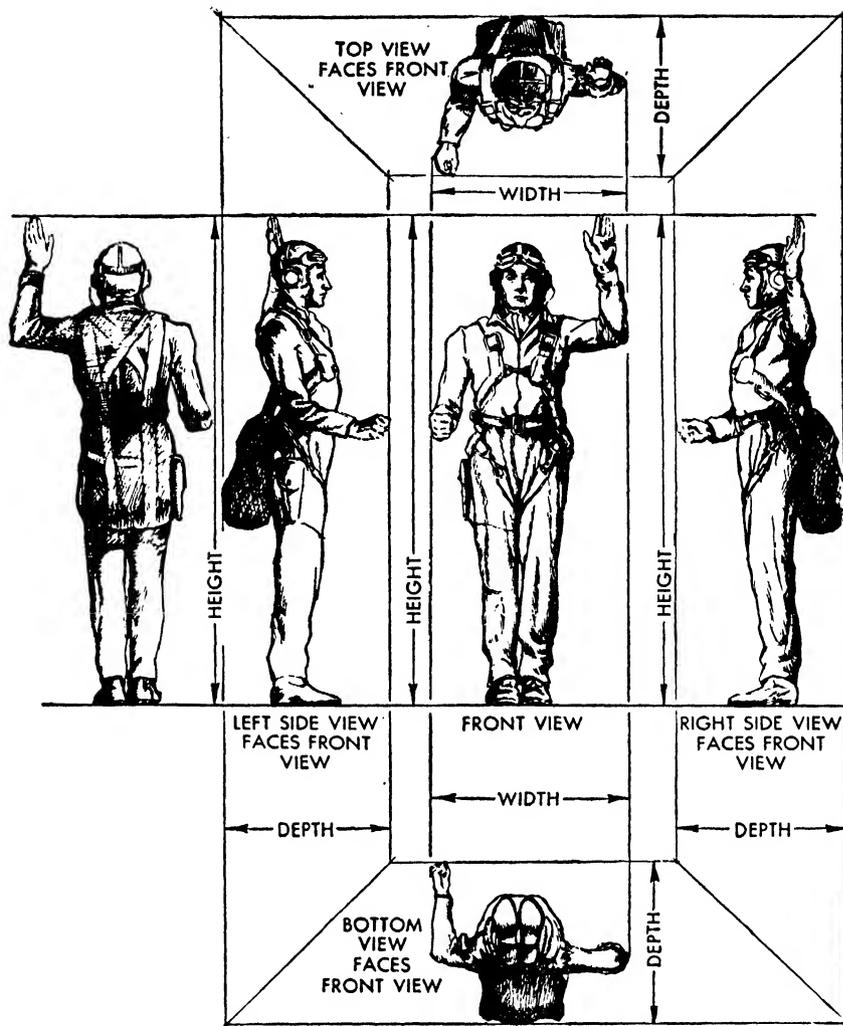


Fig. 146



Fig. 147

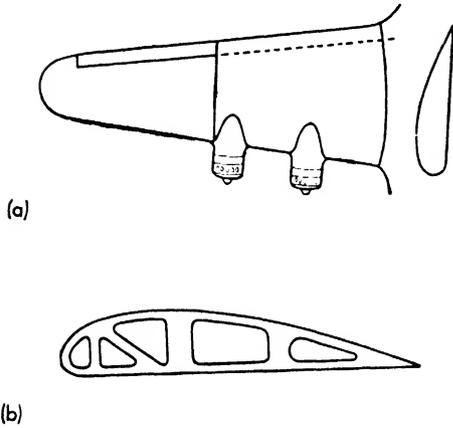


Fig. 148

box by imaginary perpendicular lines, called "projectors."

The front plane projection is called the "front view" or "front elevation." The side plane projection is called the "side view" or "side eleva-

tion." The top plane is called the "top" or "plan" view.

*Arrangement of Views*

The sides of the box are now swung open (Fig. 145b) until all sides advance to the front plane. They are then maneuvered about until they fall on the plane of the paper (Fig. 145c), resulting in the accepted arrangement of views called the "American standard." In this method of arrangement, the views are of little value unless they are in their proper place.

The standard arrangement may be achieved in the following manner:

1. Visualize the object to be drawn as if it were in a glass box, project the sides of the object on the glass, and then open the panels to the plane of the paper.

2. As illustrated in Fig. 146, turn the projection of the object in relation to the front view. Observe the following rules of arrangement:

- a. The front face of the side, top, and bottom views face the front view.
- b. The front, side, and end views are of equal height.
- c. The side, top, and bottom views are of equal depth.

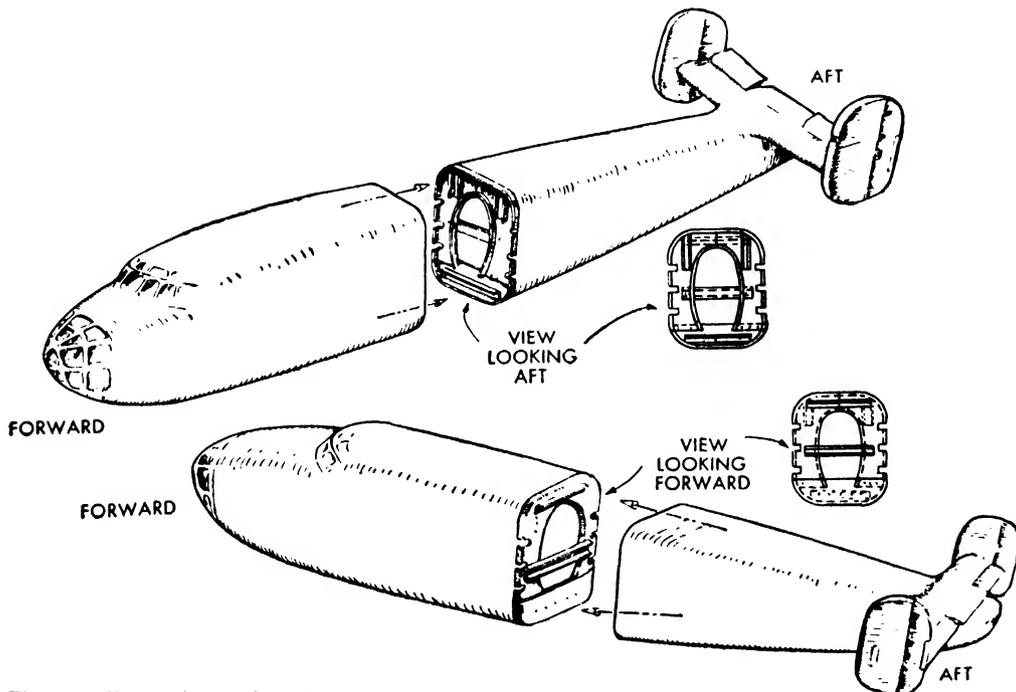


Fig. 149. Forward and aft views

- d. The front, top, bottom, and rear views are of equal width.
- e. The top view is directly above the front view.
- f. The bottom view is directly below the front view.
- g. The side views are horizontally in line with the front view, excepting where the side views are to the right or to the left of the top view.

Subassemblies and details should be viewed from the most convenient angle for proper portrayal. In general, a sheet metal detail should be drawn with the largest flat surface in the plane of the paper.

*FORWARD and AFT Views*

On drawings of beltframes, bulkheads, and other large aircraft parts it is customary to note

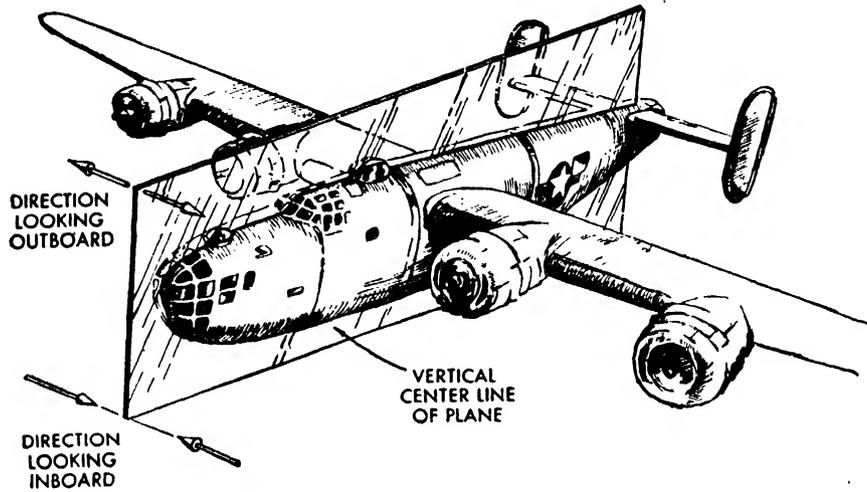


Fig. 150. Inboard and outboard views

*General Arrangement of Assemblies*

Layouts, major assemblies, and installations should be drawn within a side view of the plane, headed left (Fig. 147). Deviations from this custom are usually noted on the drawing. Generally, wings and horizontal control surfaces are drawn with their leading edges facing the bottom or the left side margin of the drawing sheet (Fig. 148).

the direction in which they are viewed. For example, if the view of a beltframe drawing is obtained by looking toward the tail or aft end of the plane, the drawing is noted **VIEW LOOKING AFT**. When the view of the frame is obtained by looking toward the nose or forward section of the plane, it is termed a **VIEW LOOKING FWD** (Fig. 149). The view looking forward describes

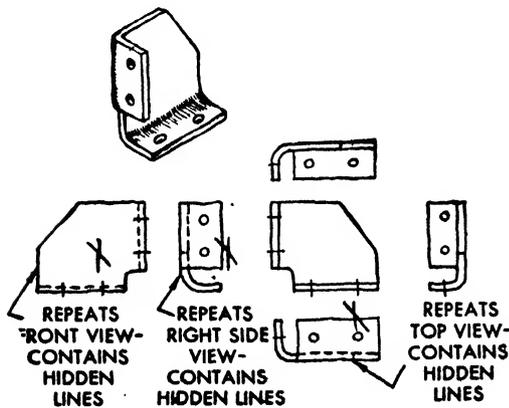


Fig. 151a

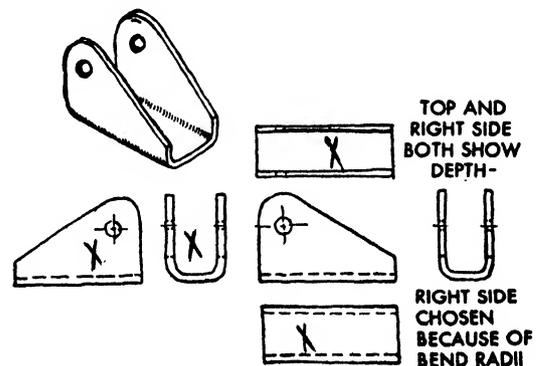


Fig. 151b

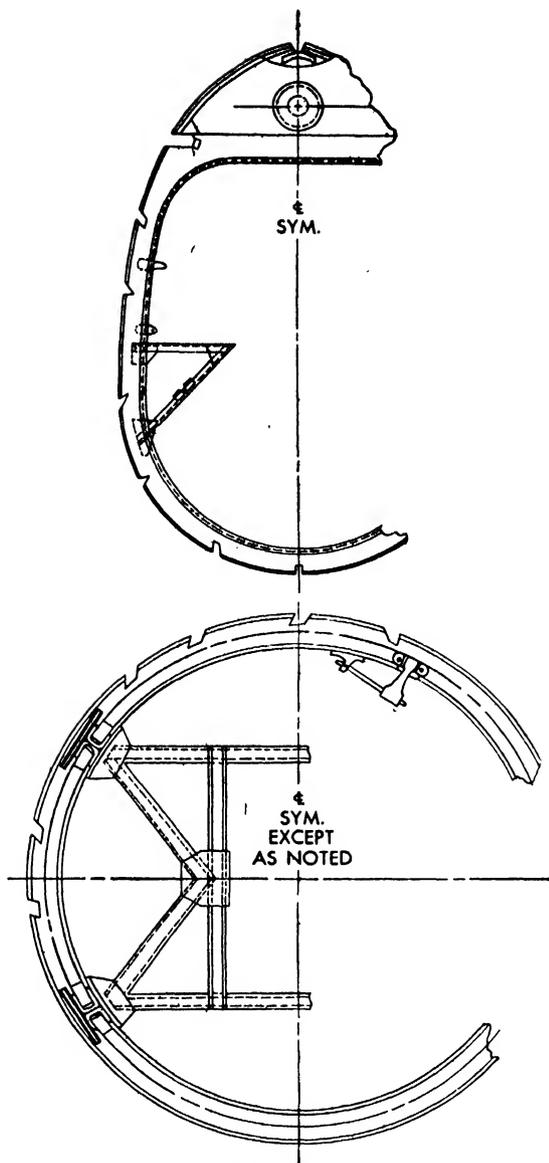


Fig. 152. Drawing of symmetrical parts

the aft or back of the frame itself; the view looking aft describes the front.

**VIEWS LOOKING INBOARD and OUTBOARD**

A view obtained by looking away from the vertical center line of the plane is termed an **OUTBOARD VIEW**, and a view obtained by looking into the vertical center line is termed an **INBOARD VIEW** (Fig. 150).

**Selection of Views**

An aircraft drawing must be presented accurately, clearly, and without any repetition of

information. All six possible views of a rectangular object are rarely necessary to describe its shape. Only those views essential to a complete but succinct description are used. Pictorial and orthographic thumbnail sketches will aid greatly in visualizing and determining the views of an object and their arrangement (Fig. 151). Thumbnail sketches are small, rough, free-hand drawings, and constant practice in drawing them is one of the best means of mastering orthographic drawing. The student should make a thumbnail sketch of almost every problem.

Repetition of views costs time and money. The shape of every object to be drawn should be considered carefully so that only the essential views are chosen. Views containing only object lines are preferable to those with hidden lines.

The front view may be referred to as the "central," "principal," or "contour" view. As the views of the aviator (Fig. 146) demonstrate, the contour view describes the object with the greatest clarity and shows its contours most completely. In general, the front view is drawn in its most familiar position, or the one it might oc-

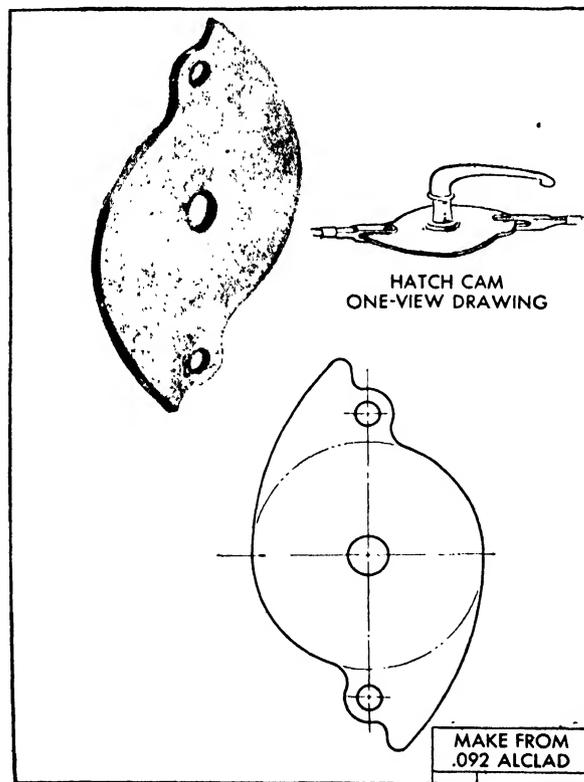


Fig. 153

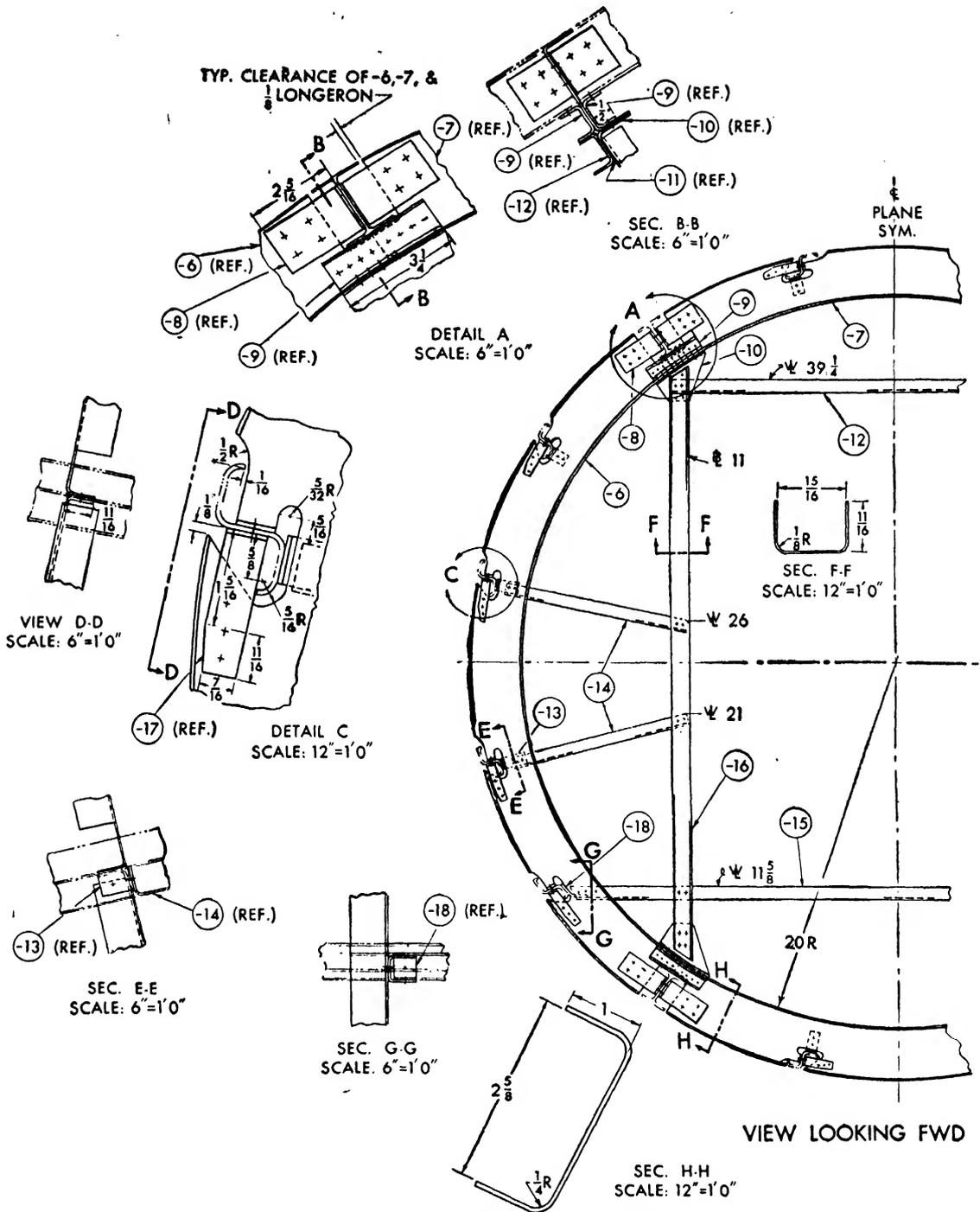


Fig. 154. Typical one-view drawing with sections, details, and views employed

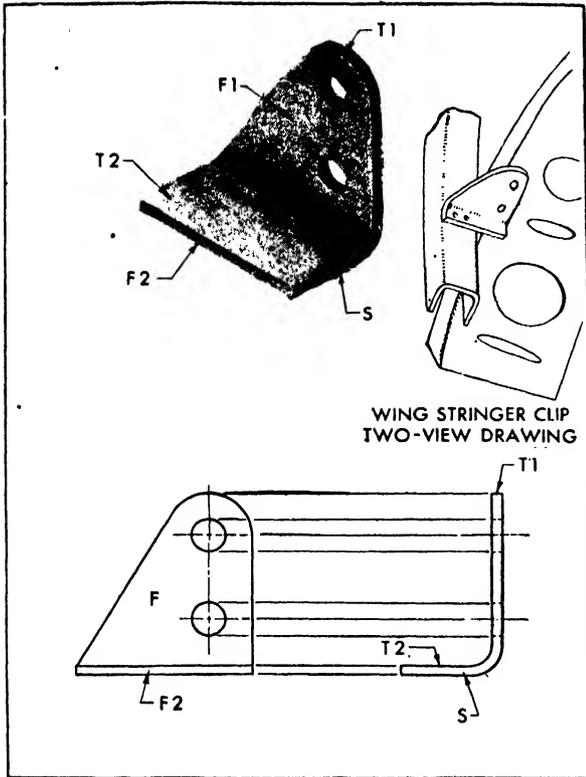


Fig. 155

copy in the plane. However, this does not always apply to castings, forgings, clips, and machined parts.

*Symmetrical Parts*

An airplane is essentially a symmetrical machine having identical left and right sides about a vertical center line. When symmetrical, only the left sides of large objects, such as bulkheads, beltframes, or wing ribs are drawn, with the symbol  $\text{C}$  intersecting the center line and the notation **CENTER LINE SYMMETRICAL** (see Fig. 152). If an object is symmetrical except for minor details, the notation on the center line is modified to read  $\text{C}$  **SYMMETRICAL EXCEPT AS NOTED**. These are called "half views." A partial view is also used when only a certain detail necessary for the clarity of the construction is projected (see Auxiliary Views).

*One-View Drawings*

The front view supplies the height and the width, but a second view is generally necessary to reveal the depth. In some cases, however, the

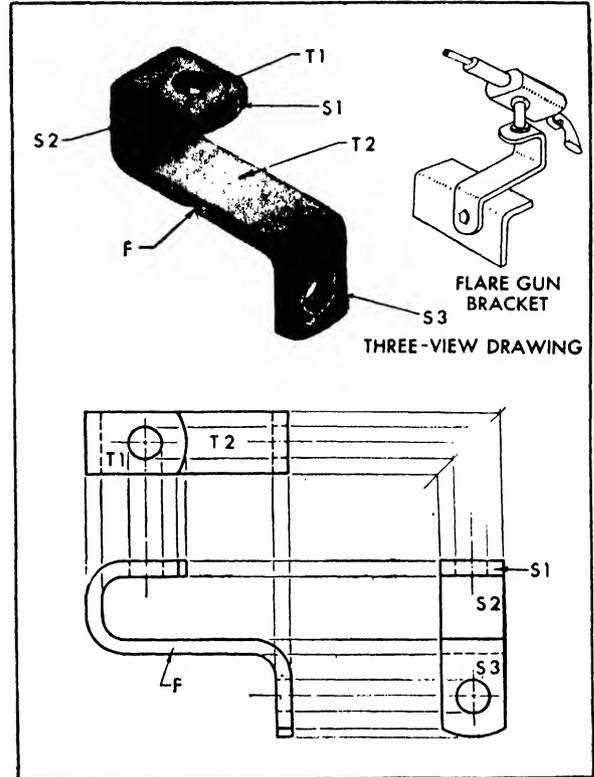


Fig. 156

front view suffices, if the depth and substance are given in the bill of materials at the lower right-hand corner of the drawing. Figure 153 shows a drawing of a hatch cam, with the notation **MAKE FROM .092 ALCLAD** (an aluminum alloy) replacing an additional view describing thickness.

Many large aircraft drawings are composed

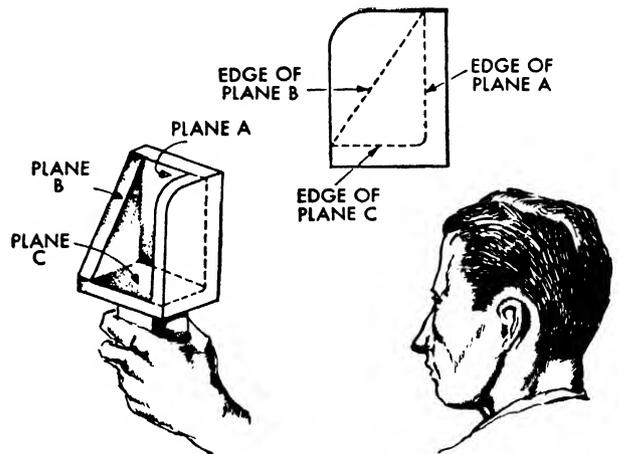


Fig. 157

of one principal view accompanied by numerous sections and views taken through this main view. This is typical of the drawings of belt-frames, bulkheads, wing ribs, etc. (Fig. 154).

fords more information. In the thumbnail sketch (Fig. 151b) the right side view describing the bend radius and the depth is the second view. This is termed a "two-view drawing." The wing rib clip in Fig. 155 is another example of a two-view drawing.

*Two-View Drawings*

*Three-View Drawings*

We see from Fig. 146 that the depth of an object is noted in the side, top, and bottom views. When two views are necessary for understanding, it is customary to choose the top or the right side view to accompany the front view. The choice depends on which of these two af-

Complex parts frequently require three-view descriptions. In such cases, front, top, and right side views are generally used (Fig. 156). Three-view drawings are typical of castings, forgings,

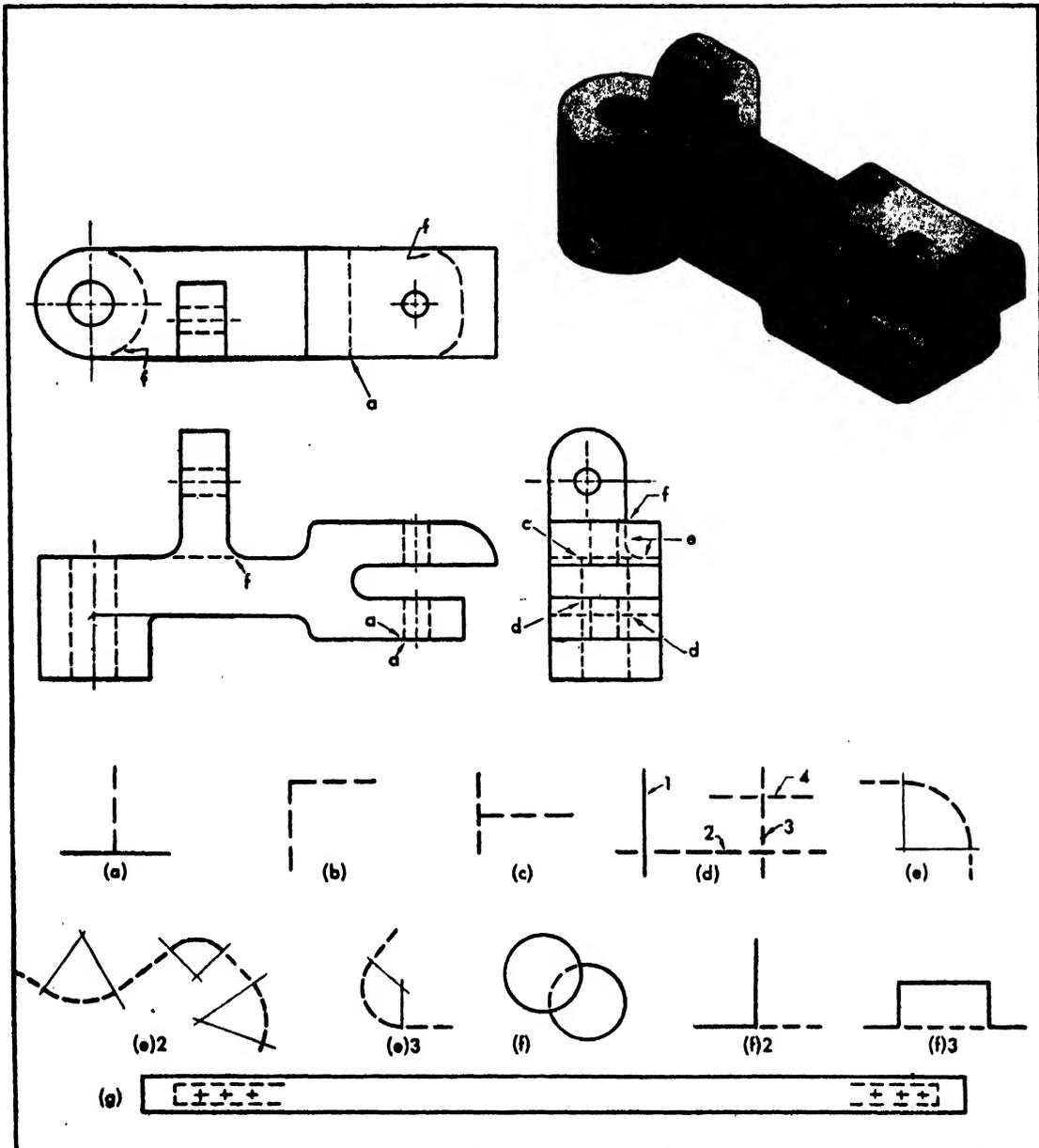


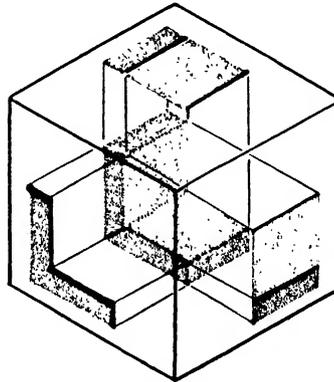
Fig. 158. Hidden lines

PRINCIPLES OF ORTHOGRAPHIC PROJECTION

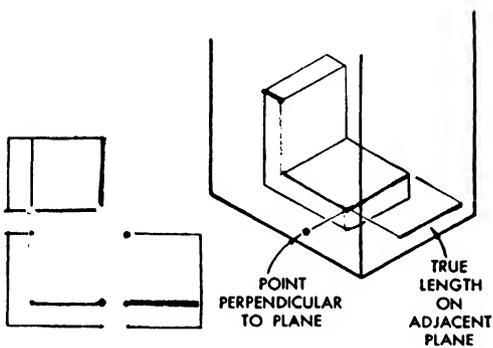
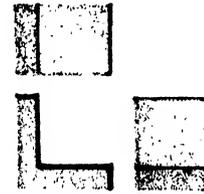
1. WHERE A PLANE SURFACE IS PARALLEL TO A PLANE OF PROJECTION IT IS PROJECTED IN ITS TRUE SHAPE ON THAT PLANE AND APPEARS AS A LINE ON THE ADJACENT PLANES

2. A LINE PERPENDICULAR TO A PLANE OF PROJECTION APPEARS AS A POINT ON THAT PLANE AND IS INDICATED IN ITS TRUE LENGTH ON ADJACENT PLANES

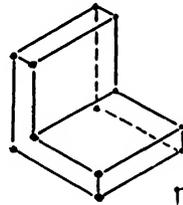
3. A LINE PARALLEL TO A PLANE OF PROJECTION BUT OBLIQUE TO ADJACENT PLANES, APPEARS IN ITS TRUE LENGTH ON THE PARALLEL PLANE AND FORTSHORTENED ON ADJACENT PLANES



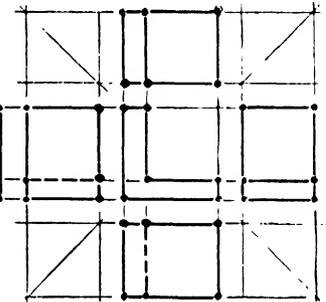
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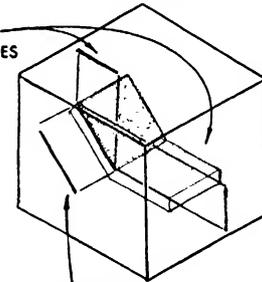
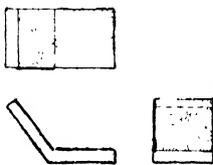


PROJECTION OF POINTS



3

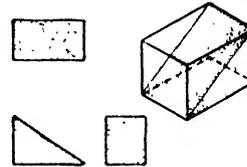
FORTSHORTENED ON ADJACENT PLANES



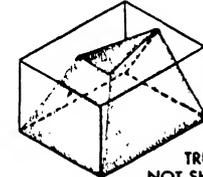
TRUE LENGTH ON PARALLEL PLANES

4

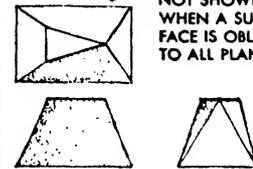
IF A PLANE SURFACE IS PERPENDICULAR TO A PLANE OF PROJECTION AND OBLIQUE TO ADJACENT PLANES IT APPEARS AS A LINE ON THE PERPENDICULAR PLANE AND FORTSHORTENED ON ADJACENT PLANES



5



TRUE SIZE NOT SHOWN WHEN A SURFACE IS OBLIQUE TO ALL PLANES

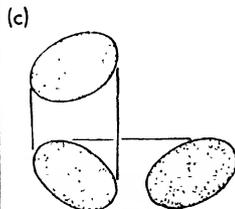
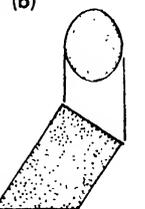
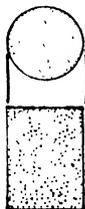
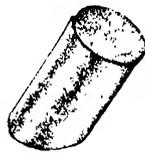


6

(a) A CIRCLE PARALLEL TO A PLANE OF PROJECTION IS PROJECTED IN ITS TRUE SIZE ON THAT PLANE AND AS A LINE ON ADJACENT PLANES

(b) A CIRCLE PERPENDICULAR TO A PLANE OF PROJECTION BUT OBLIQUE TO ADJACENT PLANES IS PROJECTED AS A LINE ON THE PERPENDICULAR PLANE AND AS ELLIPSES ON ADJACENT PLANES

(c) A CIRCLE OBLIQUE TO ALL PLANES OF PROJECTION IS PROJECTED AS AN ELLIPSE ON ALL PLANES

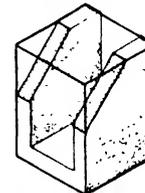
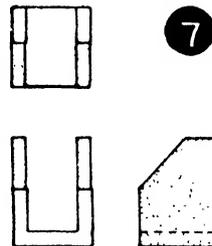


(a)

(b)

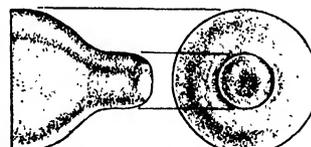
(c)

7



WHEN TWO LINES ARE PARALLEL THEIR PROJECTION IN ANY VIEW IS PARALLEL

8



THE TRUE SIZE AND SHAPE OF A CURVED SURFACE ARE NOT SHOWN IN ANY VIEW - BUT CAN BE COMPLETELY DESCRIBED BY THE VIEWS

Fig. 159



and machined parts. Additional views or sections may be added if the drawing becomes too complicated.

**Hidden Lines**

“Hidden” or “invisible” lines are used to represent edges and contours invisible to the observer in a particular view (Fig. 157). A hidden line is drawn with a series of short dashes as designated in the alphabet of lines. The length of the dash may vary with the size of the object presented, but care should be taken to keep all hidden lines uniform within the same drawing.

Methods of drawing hidden lines are illustrated in Fig. 158. Observe these rules:

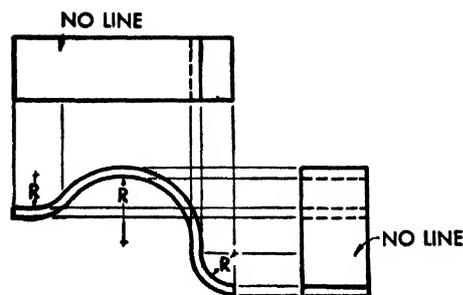
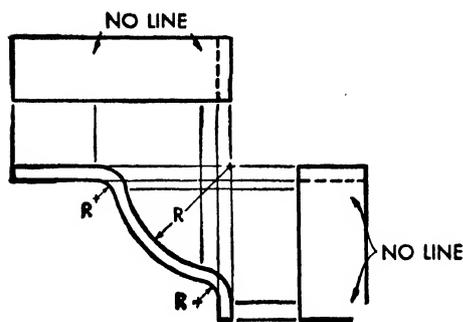
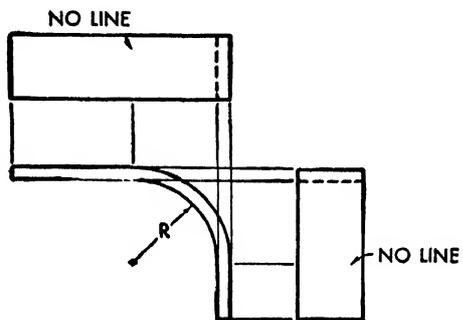
(a) Always start a hidden line with a dash,

unless it is the continuation of an object line.

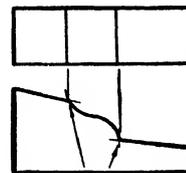
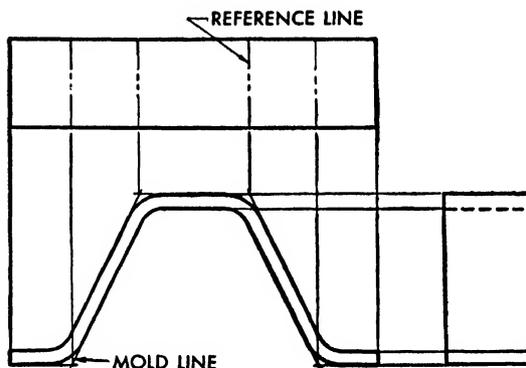
(b) Make the dashes meet at corners.

(c) If it is not possible to connect the dashes at corners, make the end of a dash in one of the hidden lines touch the center of a dash in the other.

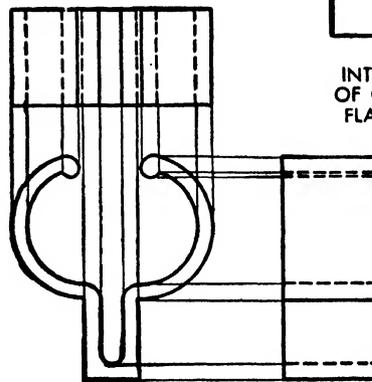
(d) Do not cross an object line with a dash. The object line takes precedence, and by passing through the opening between the dashes of a hidden line, makes this hidden line appear to recede. Apply the same principle when drawing hidden lines that cross each other. The hidden line closer to the observer takes precedence and passes through the openings of the receding hidden line. The lines in Fig. 158(d) are numbered in respect to their recession.



TANGENT SURFACES



INTERSECTIONS OF CURVED AND FLAT SURFACES



PROJECTION STUDY

Fig. 160. Projection of curved surfaces

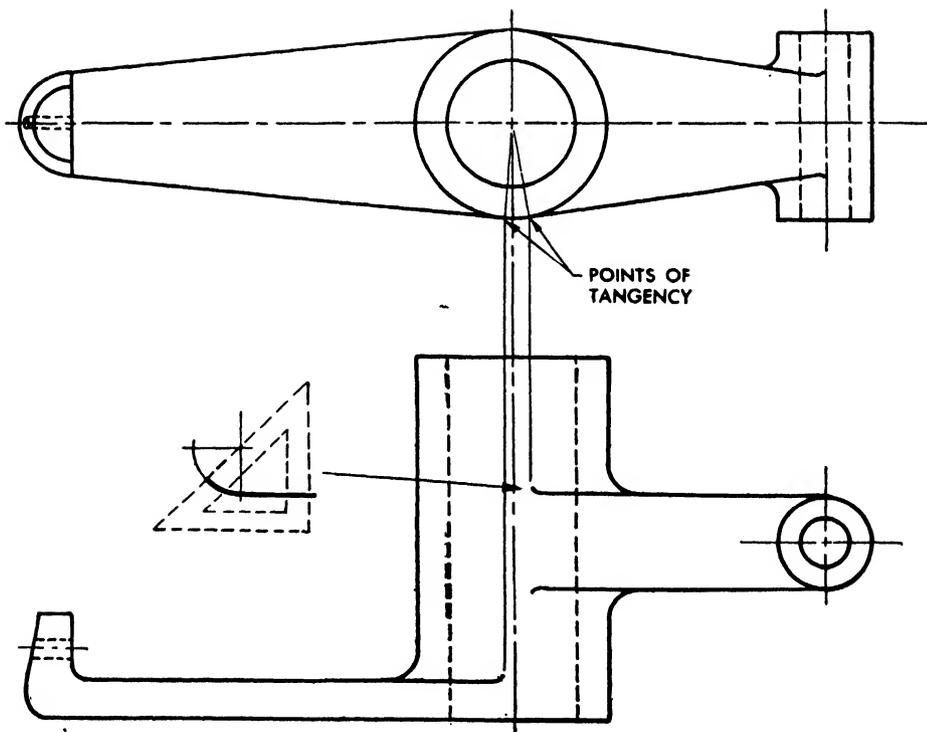
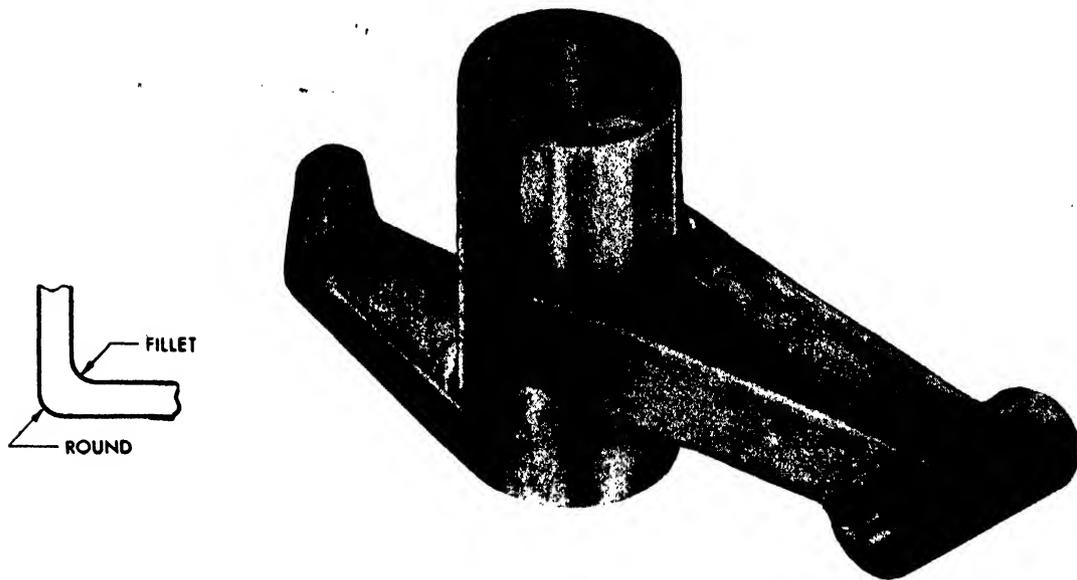


Fig. 161

(e) Begin hidden arcs with a dash at their point of tangency.

(f) When an object line is partially hidden, make a break at the junction of the object line and the hidden line.

(g) Indicate long hidden lines by drawing only their extremities.

Do not indicate a hidden line directly behind an object line.

Use hidden lines as little as possible. Usually, views with an abundance of hidden lines should be replaced by sectional drawings. Use hidden lines only if they clarify the drawing. However, the beginner, while practicing the fundamentals of projection, should include all hidden lines.

*Principles of Orthographic Projection*

The basic principles of orthographic projection are given in Fig. 159. The student should think of a line, not in an abstract sense, but as the edge of a surface. In order to memorize this basic principle, copy the example with colored pencils and apply this same method to several problems.

*Projection of Curved Surfaces*

The junction of a curved surface tangent to a plane (see Fig. 160) is not projected to an adjacent view as a line unless the plane is perpendicular to that view. When a curved surface intersects a plane surface, the line of intersection is drawn. The contour edge of a curved surface is projected to an adjacent view.

In some sheet metal forms, as that of corrugated sections, the intersection of the "mold lines" or "bend lines" may be projected by a reference line to the adjacent view. This should be done only when the shape of the view must be clarified for fabrication.

*Projection of Fillets and Rounds*

The inside angles on castings and forgings are called "fillets," the outside angles are called "rounds." Remember that these corners in castings or forgings can never be sharp.

Methods of projecting fillet radii in reference to plane surfaces tangent to cylinders are illustrated in Fig. 161, where construction of a fillet radius is diagrammed at the left of the front

view. The fillet radius at the point in the figure is drawn only one-half the actual arc of the fillet radius, that is, equal to one-eighth of a circle.

*Projection of Relief Radii*

Relief radii pertain to bent sheet metal parts. When flanges of a sheet are bent on two edges at right angles to each other, the corner has a tendency to crumple at the intersection of the flanges. This is due to an excess of metal at that point. To correct this condition, before bending, metal is cut away at the corner by a "relief radius." Projections of two views of typical relief radii are shown in Fig. 162.

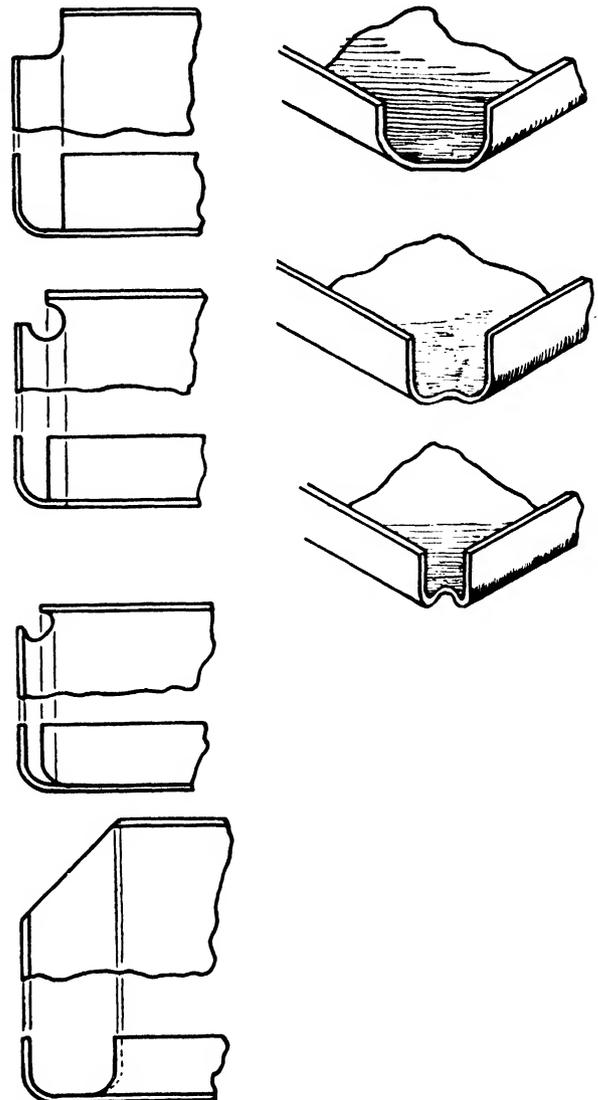


Fig. 162

# CHAPTER EIGHT

## MAKING A DRAWING

### *Types of Drawings*

Various types of aircraft drawings are used to describe parts in their different stages of fabrication and assembly. Designs are made on many sizes of vellum (Fig. 72, Chapter Two). Each sheet is usually supplied with a printed bill of material in the lower right-hand corner. Occasionally, the assorted sizes are designated by a code number or letter, such as size A drawing, 8½ by 11 inches, size B drawing, 11 by 17 inches, etc., or size 1, 2, or 3 drawing.

Drawings used in production generally fall into one of the following classes:

**DETAIL** drawings of single elemental parts. They contain all information needed for the manufacture of this part.

**ASSEMBLY** drawings. These give all the data required to join two or more parts together by riveting, bolting, press fitting, welding, spot welding, glueing, or some other process. They may or may not provide information for making any or all of the component parts.

**INSTALLATION** drawings. These include all necessary dimensions, parts, and information required for installing a part or assembly in final position. They may or may not include information for the construction of assemblies or detail parts.

Frequently, assembly and installation drawings are made on the same sheet, and may include many subassemblies and details.

**DIAGRAMS** showing fuel, oil, conduit, flight control, electrical, and similar systems.

**CHARTS**, such as tube bending or lubrication charts.

**LAYOUT** drawings. These are the key drawings from which details, assemblies, etc., are developed. The layout is the designer's idea, accurately set down, of how to determine adapta-

bility, arrangement, function, clearance, etc., of the part or section of the plane to be made. Its purpose is to determine basic dimensions. Since the greatest possible accuracy is necessary, sharp, hard leads are used. The success of all subsequent drawings depends on the original layout. Colored pencils are sometimes used to underline information.

Of course, all forms of drawings are "layouts" in that they are "laid out," that is, planned and arranged, before darkening for reproduction.

### *Source of Information*

In the aircraft plant the detailer obtains his drawing information from the designer's layout. Sometimes the information may be supplied by a rough orthographic or pictorial sketch; or the detailer may be given written or, less frequently, oral instructions to change an existing blueprint or drawing. The student's source of information lies mainly in the "exercises" provided by orthographic, auxiliary, and sectioning problems.

### *Visualization*

Before a line is drawn, the student should familiarize himself with the object in order to form a clear mental picture. Many beginners in the drafting room start to draw an object or assembly, especially if it is a casting or a built-up sheet metal part, without a clear mental conception of the object's appearance or the disposition of its views and dimensions on paper. Visualization and arrangement must never be left to chance, in the hope that they will solve themselves during the actual drawing. The experienced draftsman, accustomed to aircraft structure, design, and procedure, usually requires a minimum of preparation to execute the finished drawing, but the beginner must

coordinate an ability to draw well with a tidy arrangement of views and a clear visualization of the part to be drawn. Although the drawing is made on one plane only, the student should attempt constantly to envisage the object in three dimensions, as it will appear when fabricated.

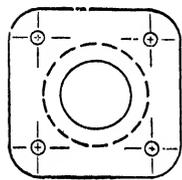
*Freehand Pictorial Sketch.* A preliminary free-hand pictorial sketch of the object may aid in visualization. This sketch need not be a "work of art" or accurate in scale, but a basic proportion must be attained. Its purpose is to establish the "picture of the object."

*Coloring Planes.* Visualization and projection may also be aided by coloring the planes of the object in the pictorial sketch (see color plate, page 117). A set of ordinary colored pencils will prove well worth their cost. Color the front view of a plane green and draw it in its true shape, parallel to the plane of projection. In the adja-

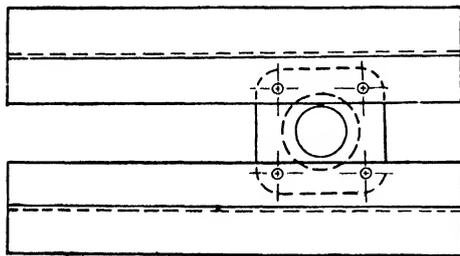
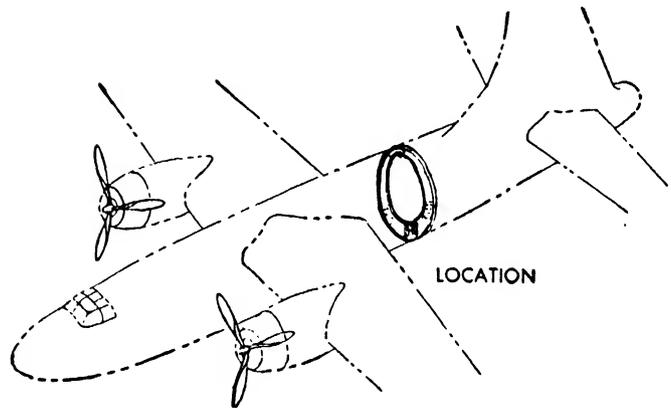
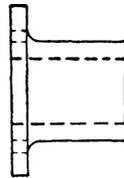
cent planes the front plane will appear as a green line. This system tends to establish the line as being the edge of a plane.

*Clay Models.* Clay models (Fig. 164) are invaluable in visualizing. They create a three-dimensional materialization and bring home the feeling that a drawing is really the first step in manufacturing the part. Too many students think of a drawing as a particular type of picture and consider that its purpose is served when it is completed. The clay model imparts a feeling of realism. By a careful observation of it the student can easily answer for himself such questions as how a certain plane will appear in a projected view or how a given shape will appear in the various views.

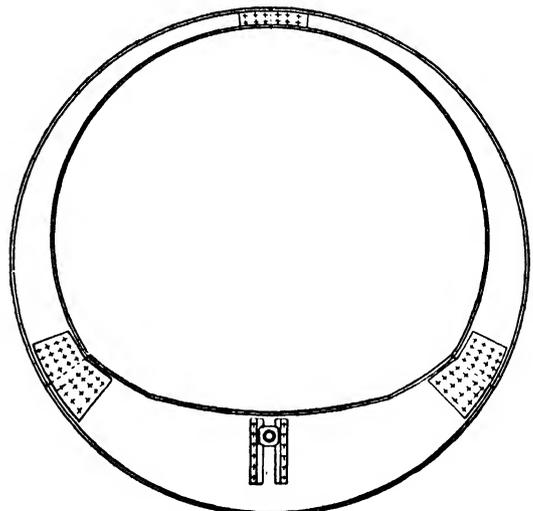
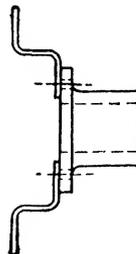
This method is not just a student's tool. Experienced engineers will construct a complicated clay model so as to visualize a fuselage joint,



(a) THE DETAIL



(b) THE ASSEMBLY



(c) THE INSTALLATION

Fig. 163

where steel tubes issuing from different planes terminate at a common point, or to comprehend the shape of double or complex curved surfaces. However, the clay model need be scaled with only sufficient accuracy to convey a rather general idea of the physical characteristics of the

object. The advanced student requires these visualization procedures only for the more complicated parts, but they are indispensable to the beginner.

*Projection by Points.* To aid in the proper projection of views, the corners of the pictorial

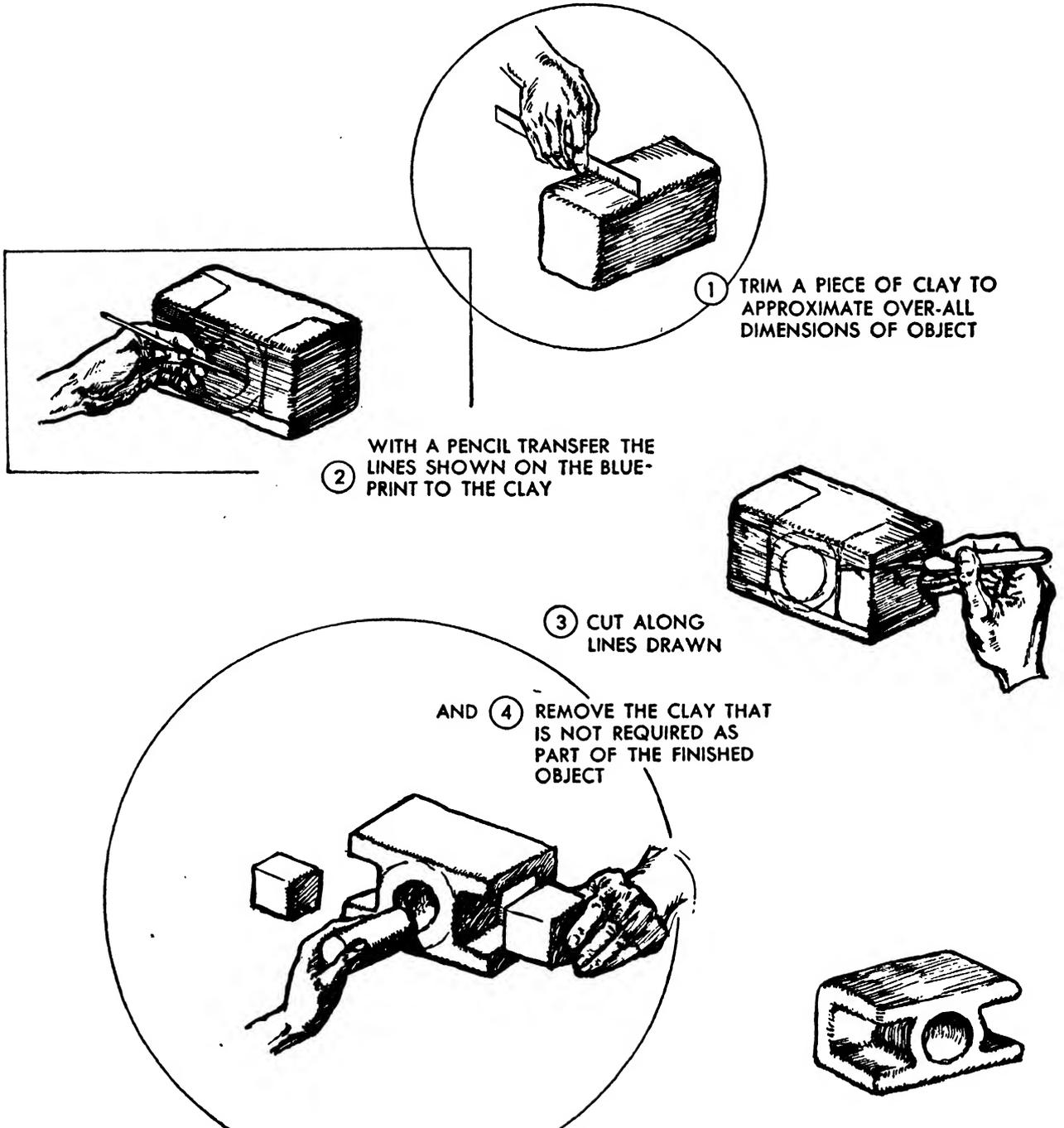


Fig. 164. Clay is an excellent material with which to form simple objects from working drawings for purposes of visualizing their shape and size. Work a piece of clay into the shape of a ball and proceed as shown above.

sketch or model may be numbered as shown in Fig. 165. The corners are first established on the most obvious orthographic view, and then projected to the other views as shown. Once the points have been located, they should be joined after close observation of the pictorial sketch. This system is most adaptable to those problems which contain complex angles.

*Selection of Views*

After the part has been visualized, the student draftsman should draw a thumbnail sketch to determine the necessary views. He can then analyze and choose the necessary views and, at the same time, obtain valuable practice in quick orthographic sketching—a method of graphic conversation employed by engineers and draftsmen. The detailer is often provided with rapid thumbnail sketches for development into a blueprint.

*Layout*

In general, this step applies only to student problems of the more complex and dimensioned types. However, in the engineering drafting room, the draftsman may be called upon to add many features of design and to decide dimensions and clearances. In this event a preliminary drawing of the view is made on bond paper.

Since this drawing is not used for reproduction, all lines are drawn light and sharp (a 4H pencil), the primary objective being to project the views accurately so that the required dimensions and information may be scaled from this drawing. Although another step toward the completed drawing, this layout actually saves time as it gives the draftsman these advantages:

It determines the standard size of vellum for the finished drawing. It may be actual size or reduced proportionately.

It determines the amount of space between views appropriate to their shape, the amount of dimensioning that will be necessary to specify the size of the parts, and what notations, if any, will be needed.

It dispenses with erasures and changes on the finished drawing as this layout or preliminary drawing may be verified by the group checker or group engineer for design adaptability and procedure. The suggestions and revisions will be tested on the layout until a satisfactory result is achieved, ready for placement on the vellum.

*Drawing Procedure*

The vellum is placed on the board and allowed to "set" and stretch. If you use ordinary drawing paper, be sure that it lies flat and that the bottom edge lines up with the edge of the T square. It may be fastened to the wood with Scotch tape, masking tape, or staples, but the

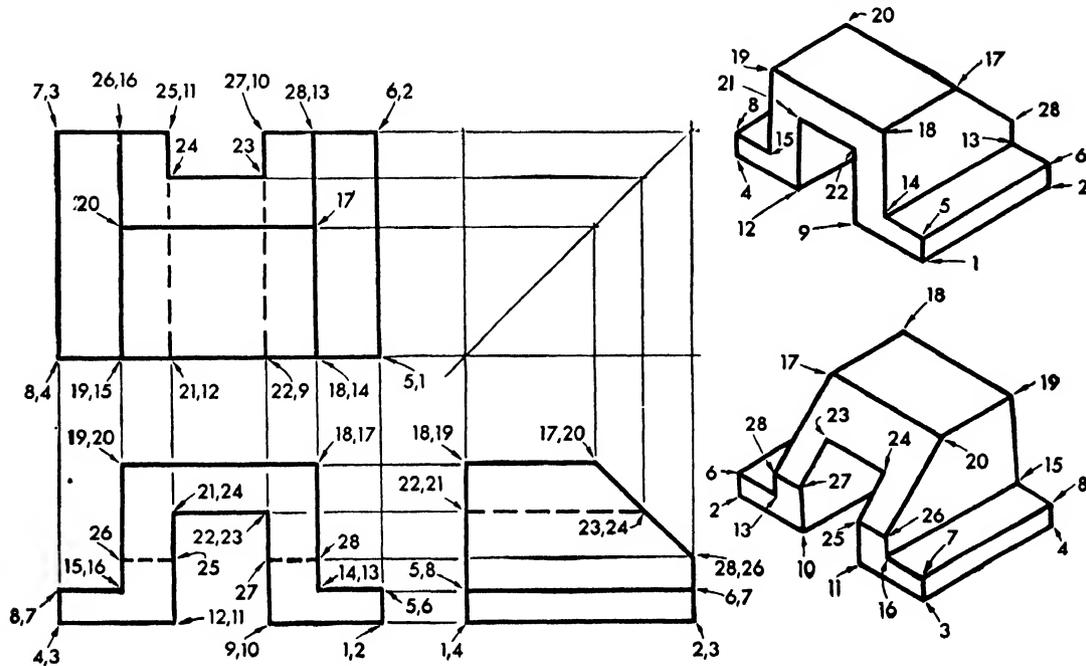
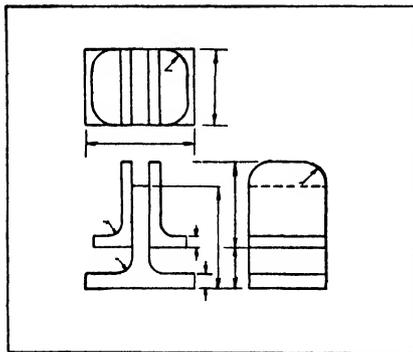
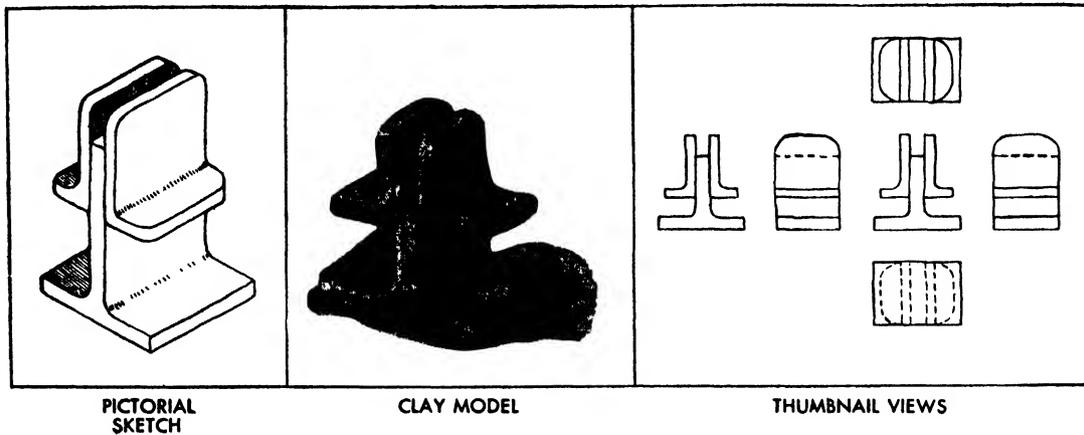


Fig. 165

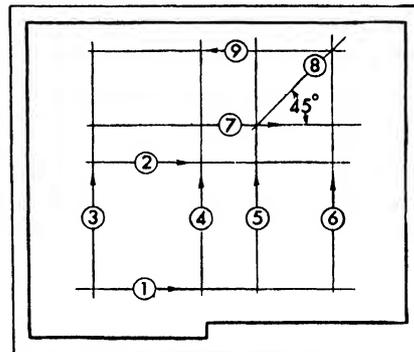
paper must lie flat and smooth (see Fig. 166). If a layout has not been previously made, and, for practice purposes, the views are to be drawn orthographically without dimensions, the distances between views should be approximately equal, as in Fig. 166(c). The spaces between the

outside edges of the views and the outside of the sheet should be as uniform as possible.

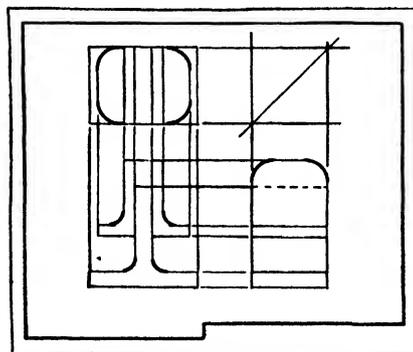
In drawing most aircraft parts, the views should be placed methodically and legibly. A drawing with clearly separated views is easier to read than one with views so interlocked that



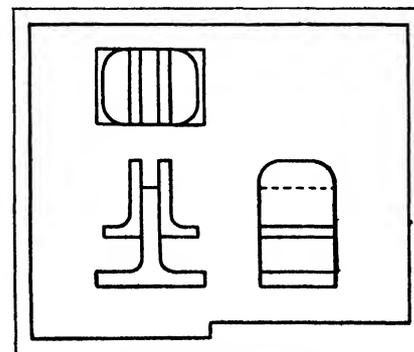
(a) LAYOUT



(b) BASIC LINES



(c) VIEWS "BLOCK IN" ARCS DARKENED



(d) VIEWS COMPLETED

Fig. 166

they confuse the workman. Always remember that the shopman expects the information on the blueprint to be logically presented.

The over-all sizes of the parts may be determined and set off as in Fig. 166(b). Draw the baseline (line 1) across the sheet, followed by another horizontal line (line 2) designating the height. Mark off the width of the object between the

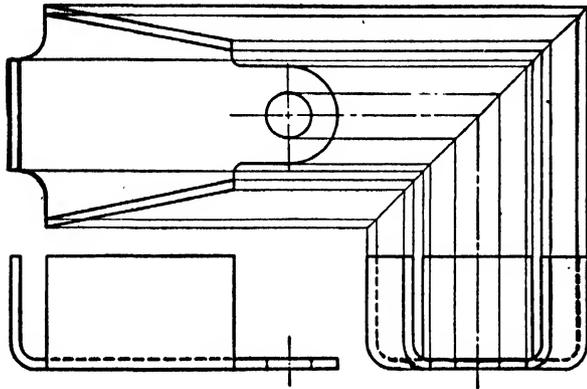


Fig. 167a. Projection by the miter method

vertical lines 3 and 4. Determine the approximate space between views and draw lines 5 and 6 to locate the depth of the part. Place line 7 about as far from line 2 as line 4 is from line 5. Set the miter line at an angle of 45 degrees, at the intersection of lines 7 and 5. At the intersection of 8 and 6 draw the horizontal line 9 intersecting lines 3 and 4, to establish the over-all area of the top view—a distance that may be transferred with the dividers or scale. However, projection by means of the miter or arc method designated in Fig. 167 is most useful to learn for more complex parts.

**Blocking In.** “Block in” the detail (see Fig. 166c) and draw in the construction lines very lightly so that they will not blueprint—dispensing with erasure. The front view is blocked in first, after which the corners of the angles are rounded, thickened, and projected to the top and side views. For more complex parts project all views before completing any one view. This facilitates the accurate transference of information from one view to another.

#### Completing the Drawing

Darken the arcs with a 2H or H pencil, and draw straight object lines tangent to the arcs

(see Fig. 166(d)). The drawing is now ready for extension and dimension lines.

#### Company Practices

The following notations regarding company practices in the preparation of engineering drawings are taken from the *Engineering Manual* of the Republic Aviation Corporation.

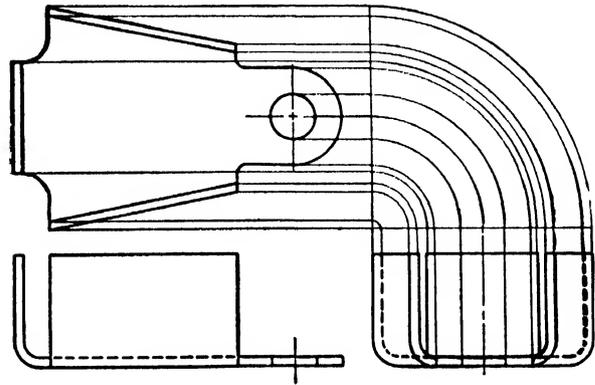


Fig. 167b. Projection by the arc method

**“Handling of Drawings.** . . . Keep drawings rolled up when not in use. If they remain on the drawing board overnight, protect them from dirt. . . . Avoid creasing drawings. . . . Keep drawings free from smudges. Expose only those sections which are being developed.

**“Ink Tracings.** . . . Ink tracings should conform to all the latest drafting techniques. All lettering should be carefully executed, and arranged to avoid any appearance of unbalance or crowding. As in the case of pencil drawings, two widths of lines shall be used: (a) *Heavy* (scant  $\frac{3}{32}$ " wide) for visible outlines, (b) *Medium* (about  $\frac{1}{84}$ " wide) for all other lines and symbols.

**“Pencil Drawings.** . . . When making drawings in pencil, ‘bear down’ on lines, but do not ‘dig in.’ Lines which are ‘dug’ into the paper or cloth leave impressions after erasure and result in faint lines on reproductions. . . . Fine work on drawings should be directed toward (1) legibility after reproduction, and (2) contrast to facilitate interpretation . . . two weights of lines are specified: (a) *Heavy line*—black, opaque, about  $\frac{3}{32}$ " thick, made with a medium soft lead that does not smudge. Use this line for visible outlines, broken lines, cutting planes, and all lettering and numerals. (b) *Medium line*—black,

opaque, about  $\frac{1}{4}$ " thick, made with a medium lead. Use this line for all lines except those in (a), and for all symbols.

*"Legibility. . . .* Legibility is a prime requirement on drawings. Do everything reasonable to obtain it. Slight exaggeration is often useful and necessary. . . . Be liberal in arranging and spacing views. Choose ample drawing sizes. Figures should be clear, well formed, extended and open, not compressed or crowded. Do not hesitate to resort to sections and added views when the body features many details. . . . When a drawing leaves your hands, whether on first release or revision, ask yourself, 'Will this drawing make a legible reproduction?' If the answer is 'No' or 'Maybe not,' then take the proper measures to insure that its prints will be legible to the last detail.

*"Length of Drawings. . . .* Lengths of drawings greater than 'G' (standard cut size) shall be in increments of eleven inches, with a four inch flap provided at the left hand border, and at least a ten inch flap at the right.

*"Width of Drawings. . . .* It is desirable that all roll size (over standard cut sizes) drawings be 34 inches wide. In exceptional cases the width may be 42 inches. Widths between 34 and 42 inches shall not be used.

*"Lettering Style. . . .* Use single stroke, upper case, commercial Gothic letters, vertical pre-

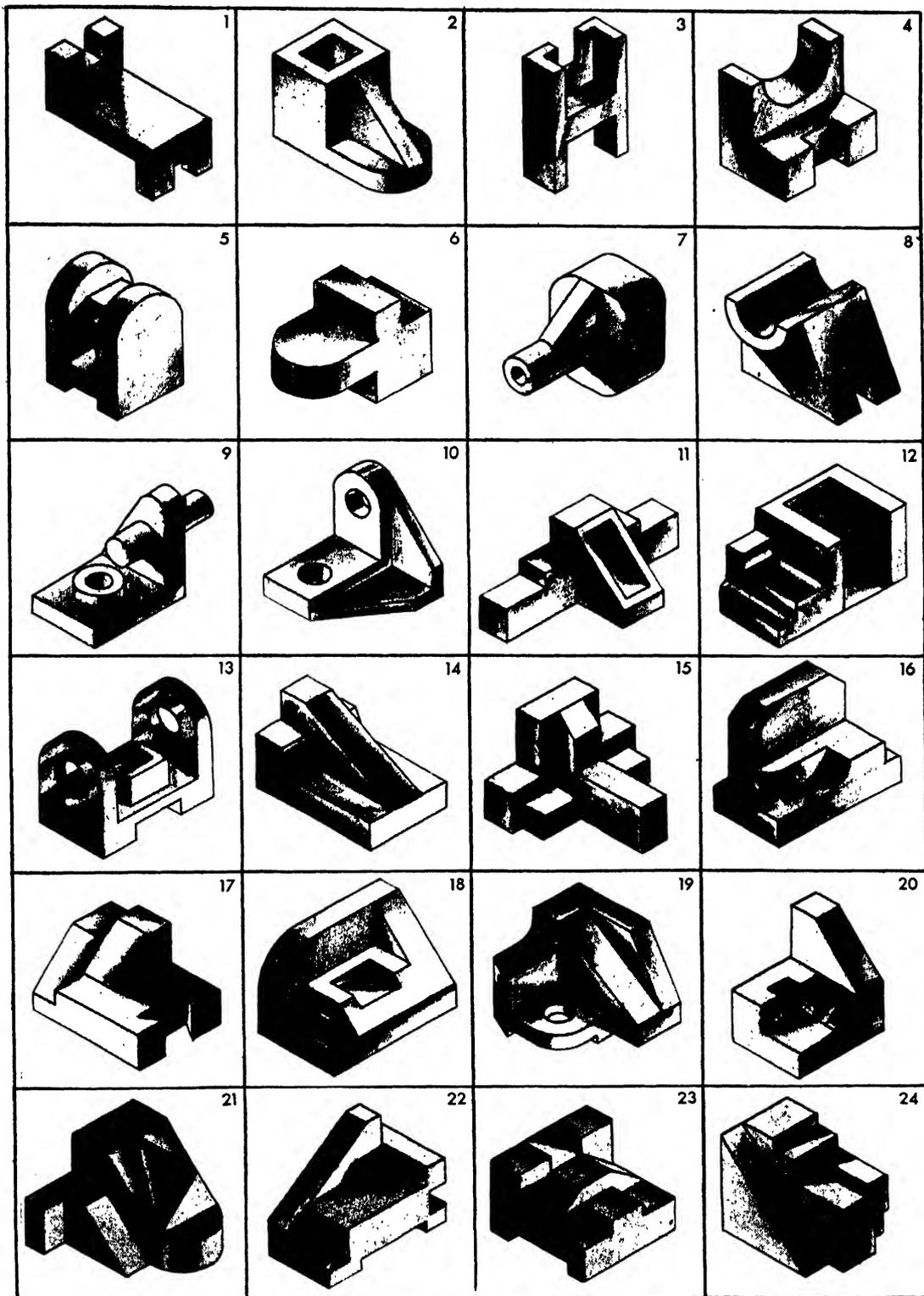
ferred. Slant lettering may be used if the inclination is  $67\frac{1}{2}^{\circ}$  approximately. The numerals specified by the U. S. Army for clarity should be used [see numerals in Fig. 104, Chapter Five]: These numerals are not in conformity with traditional engineering practice, but close inspection will reveal many advantages.

*"Zones on Drawings. . . .* All drawings longer than 66 inches shall provide horizontal and vertical zoning by alphabetical entry in the left and right hand borders and numerical entry in the upper and lower borders. Each part appearing on such drawings (except for A-N Standard parts and Republic standard rivets) shall be located by zone in the 'zone' column of the Bill of Material.

*"Zones shall measure 11 inches horizontally, starting from the outside of the right hand border, and shall be numbered in order, from right to left. The zone number, or letter, shall appear in the center of the space within the border.*

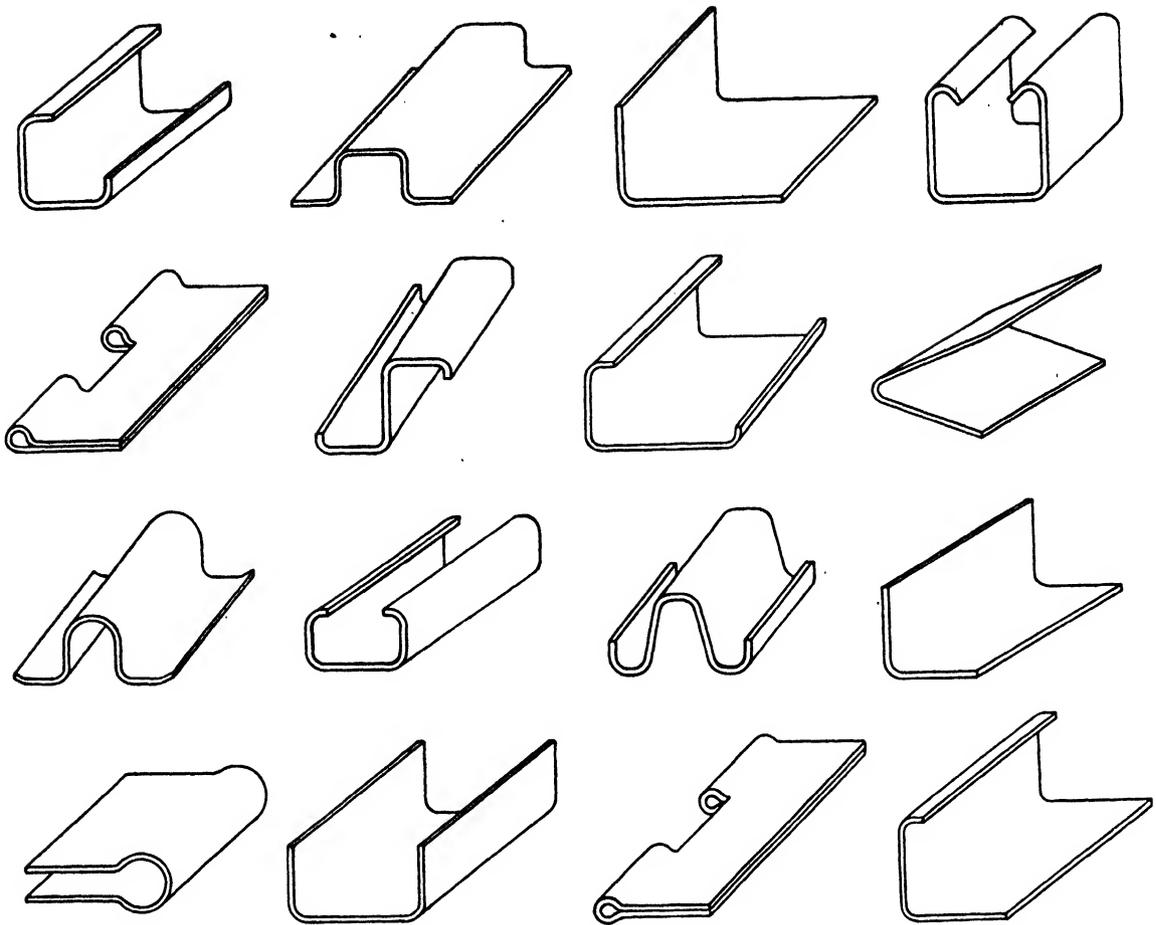
*"Zones shall measure  $8\frac{1}{2}$  inches vertically and shall be designated by letters A, B, C, and D, reading up. Use letter E, in addition, on 42 inch rolls. The zones shall extend from outside to outside of borders. In referring to zones, the number shall be placed first, followed by a dash, and then the letter. Example: 7-C."*

# PROBLEMS FOR CHAPTERS SEVEN AND EIGHT

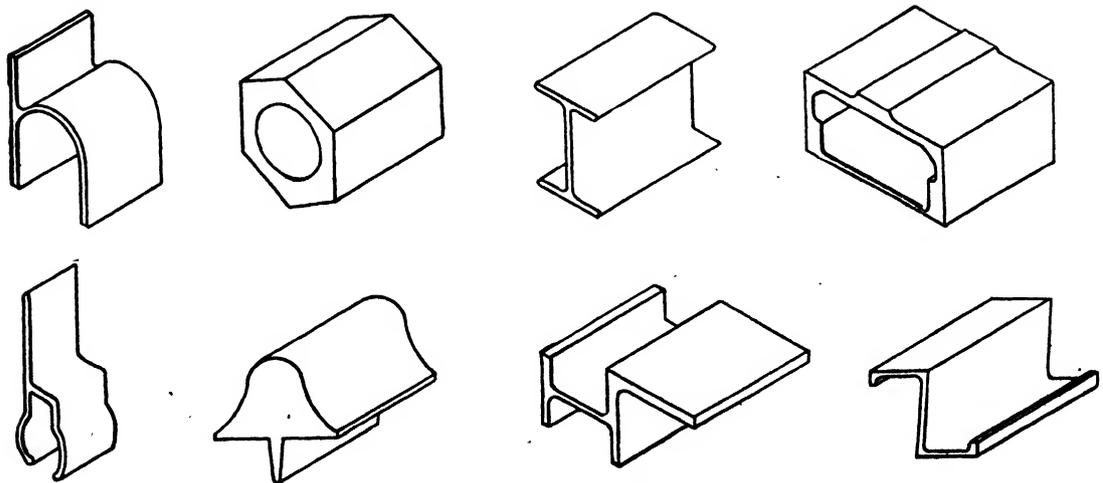


**Problem 1**

Make freehand orthographic sketches, approximate proportion, 6 views.



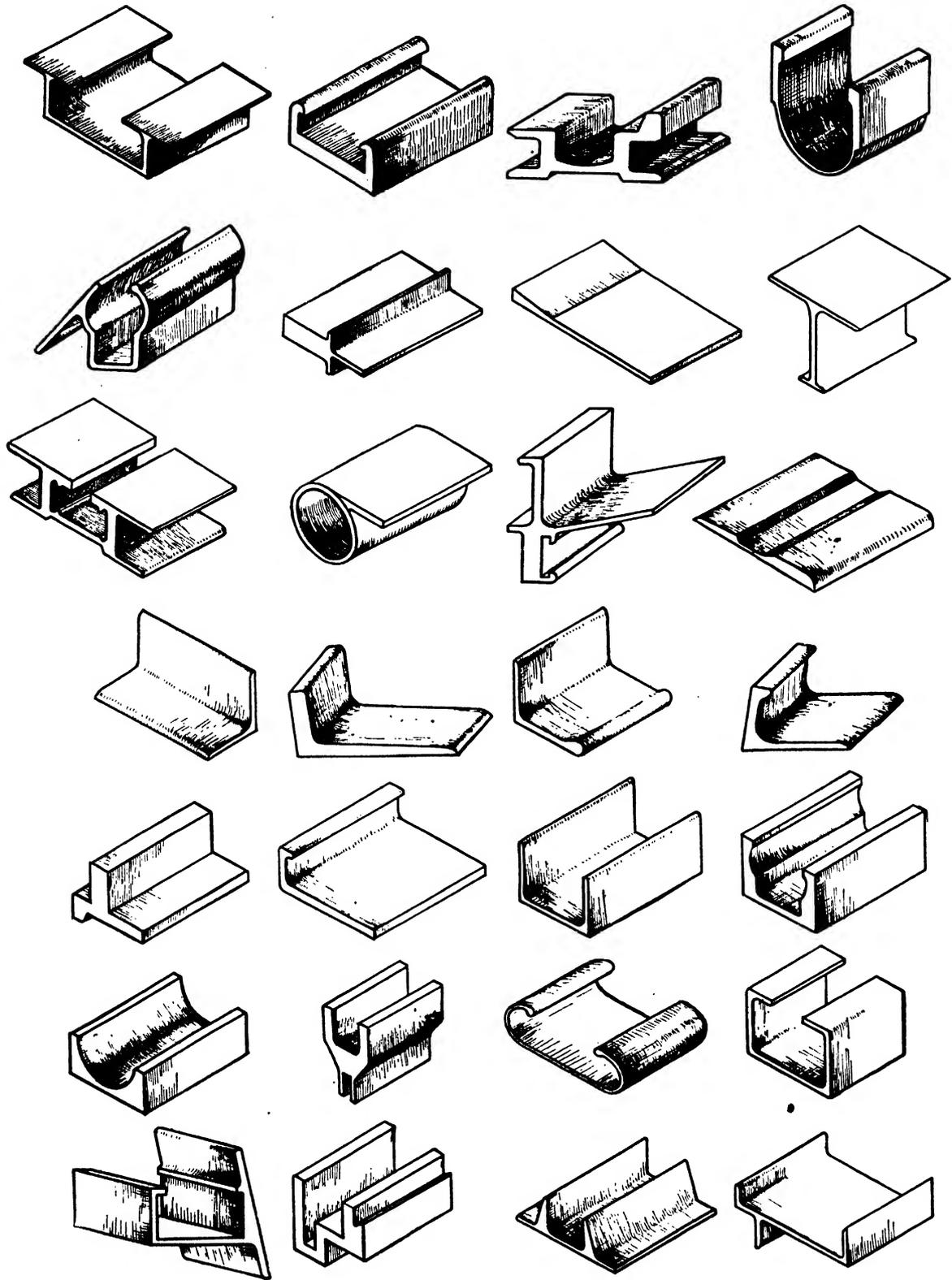
DRAWN AND ROLLED SECTIONS



EXTRUDED SECTIONS

**Problem 2**

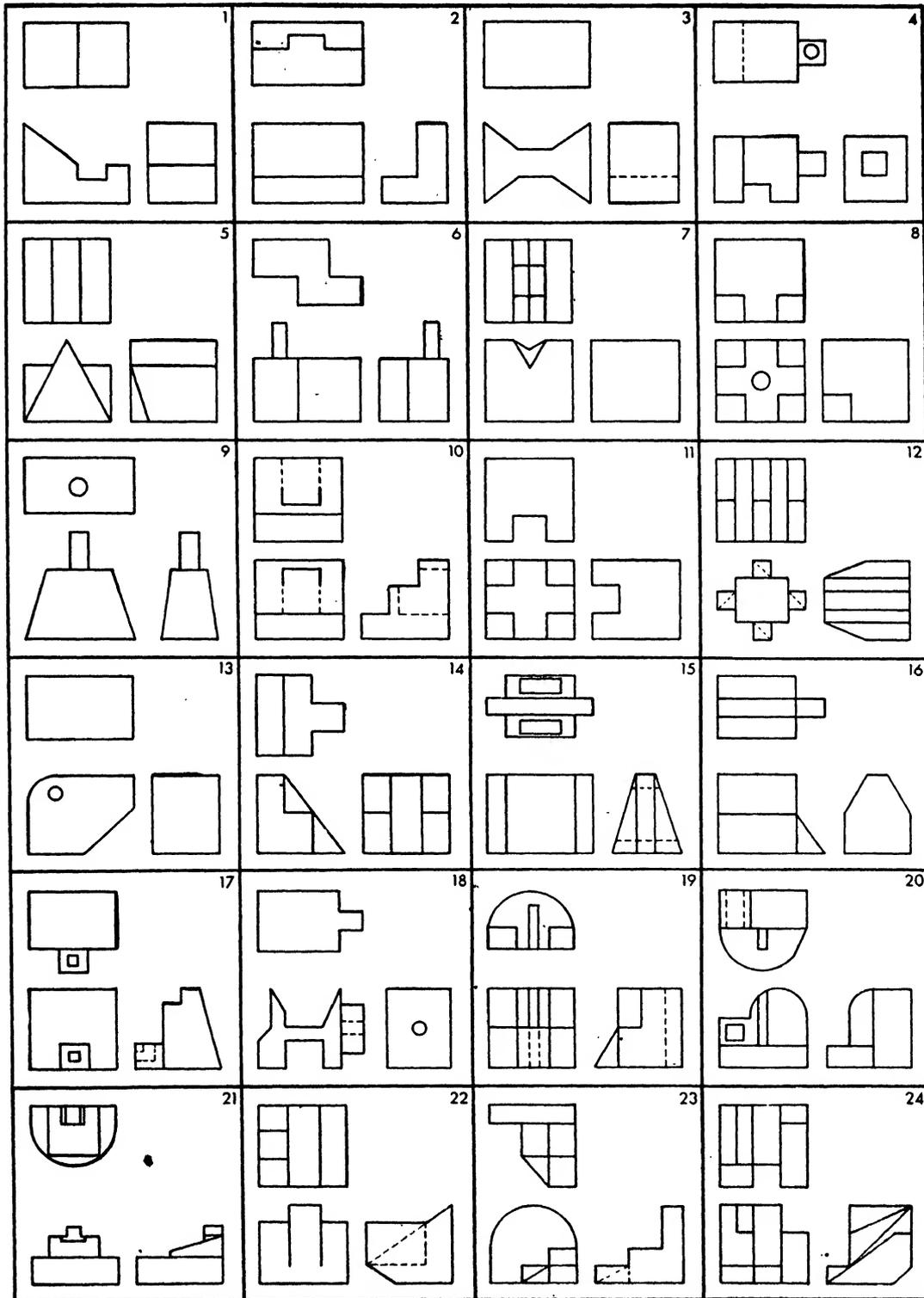
Make freehand orthographic studies, use 5 views.



**Problem 3**

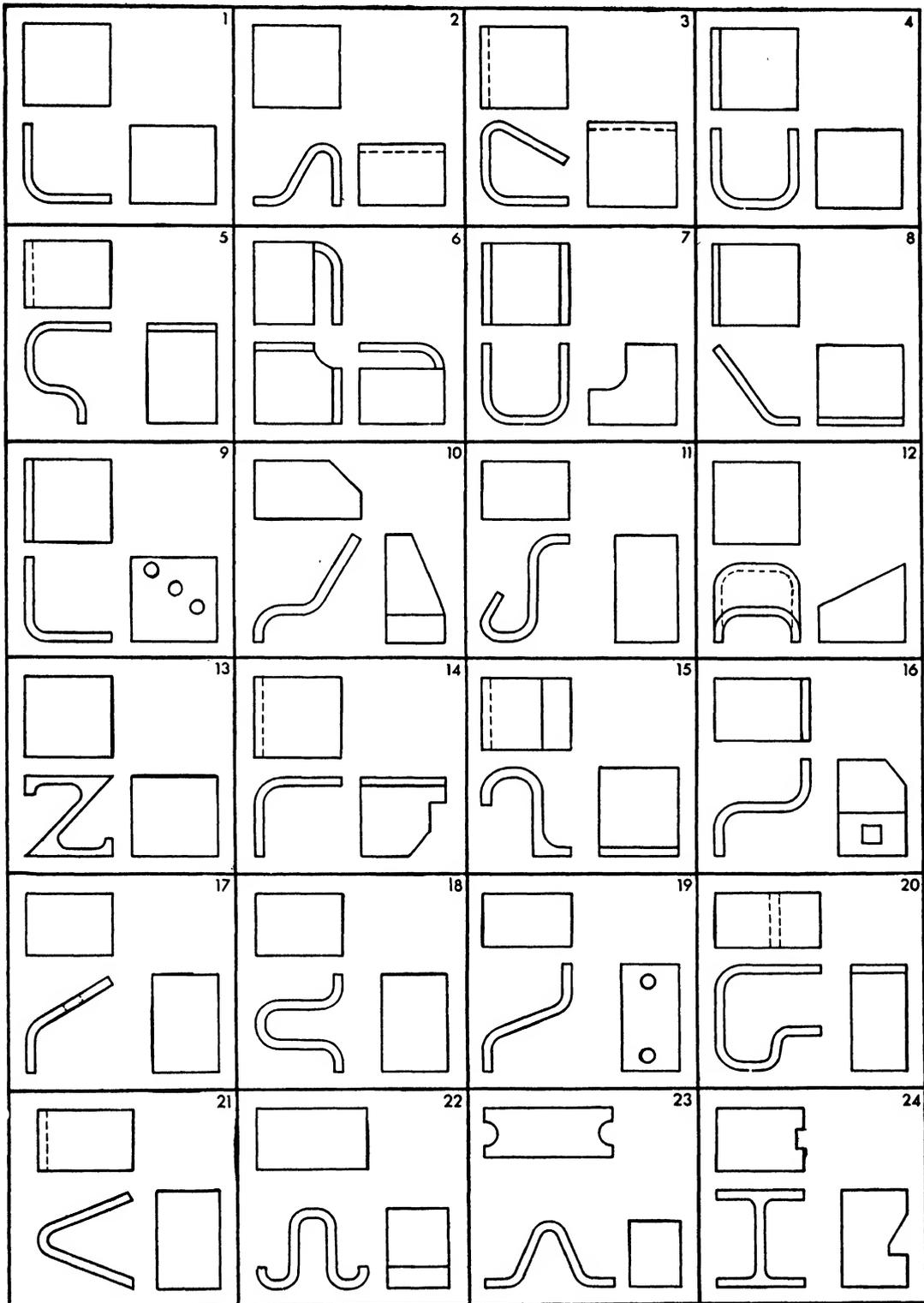
(1) Extruded structural shapes. Make freehand orthographic studies, approximate proportions, use 5 views.

AIRCRAFT DRAFTING



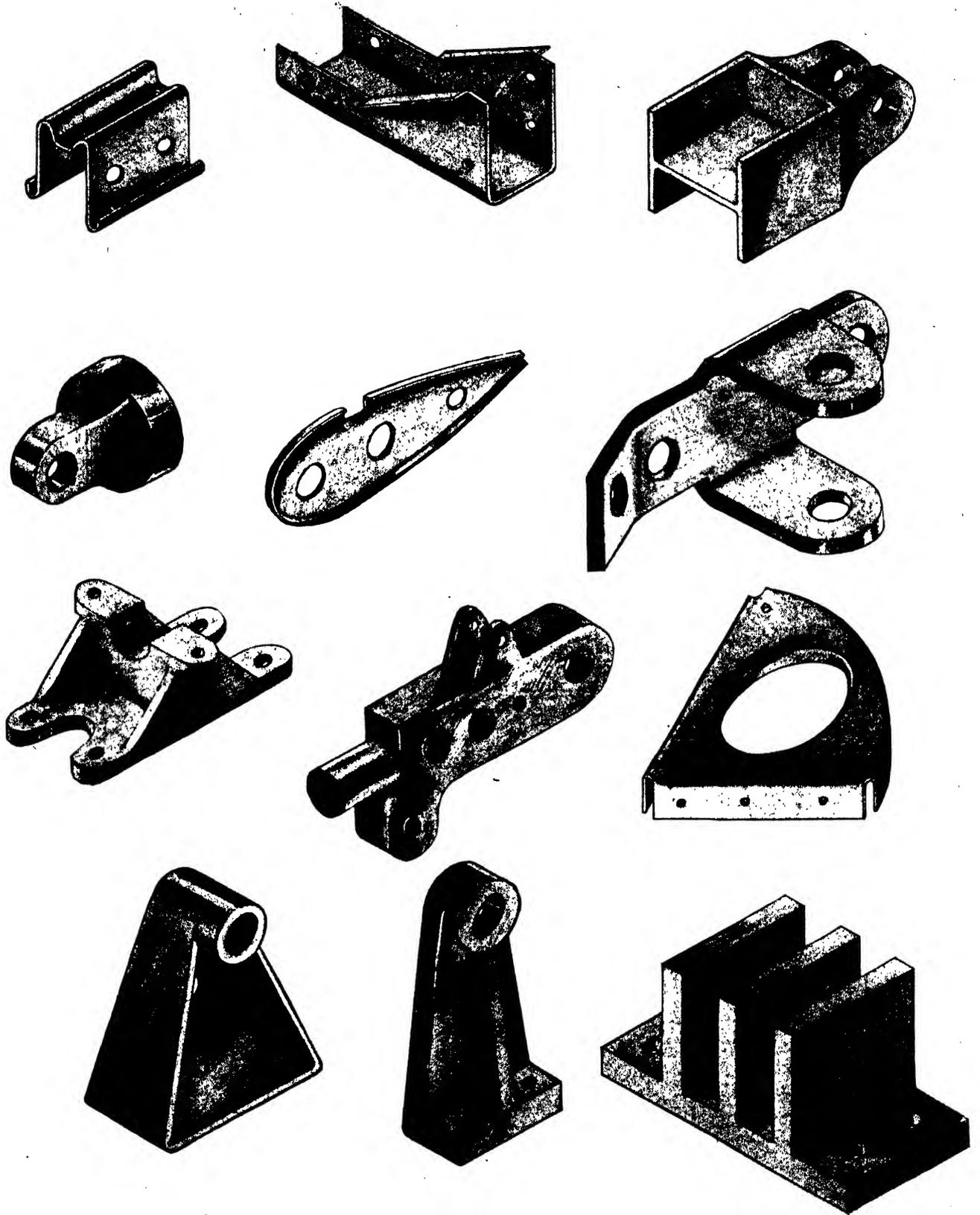
Problem 4

Missing line problems. Draw views, include missing lines.



**Problem 5**

Missing line problems. Draw views, include missing lines.



**Problem 6**

Make freehand orthographic studies. Draw with instruments, supply own dimensions.

1	2	3	
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24

**Problem 7**

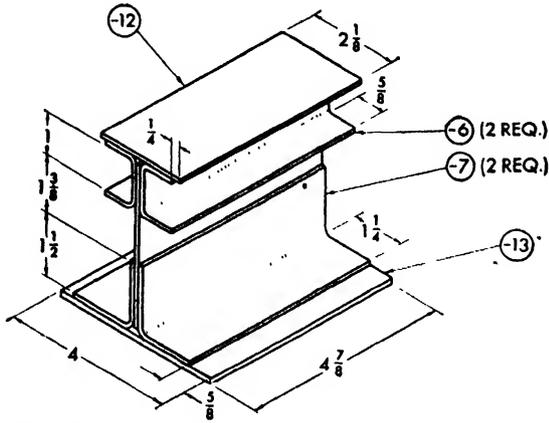
Top view is given. Supply possible front and right side views. Make freehand studies.

Problems 8-19

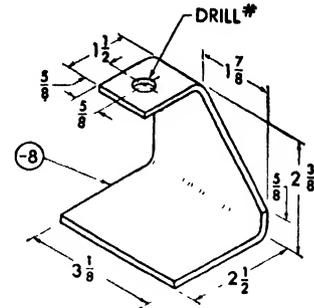
Draw necessary views. Bend radii may be determined from dash number chart and standard bend radii chart for aluminum alloy sheet.

DASH NUMBER MATERIAL CHART

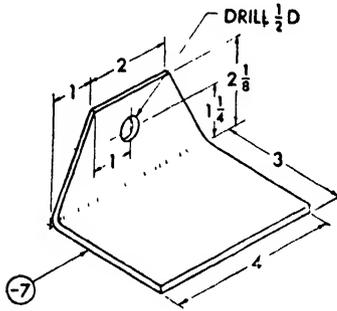
-6	-7	-8	-9	-10	-11	-12	-13
.064	.051	.064	.072	.032	.040	.102	.091
24SO	24ST	24ST	24SO	24ST	24ST	24SO	24SO



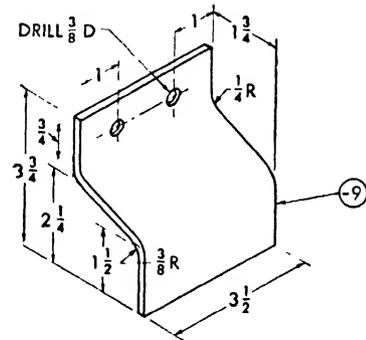
Problem 8



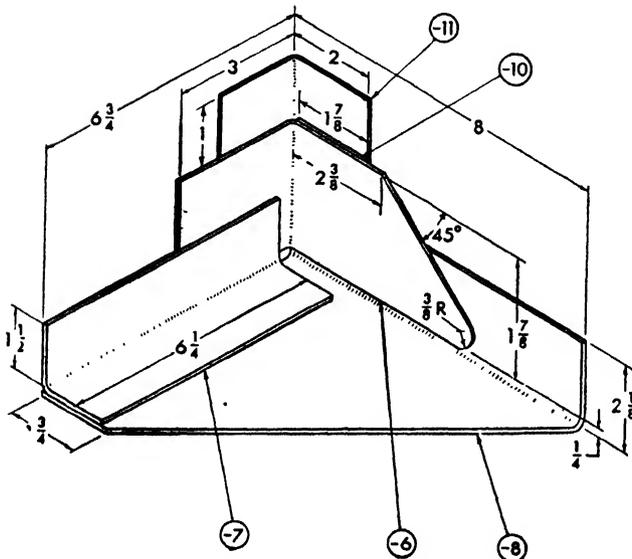
Problem 11



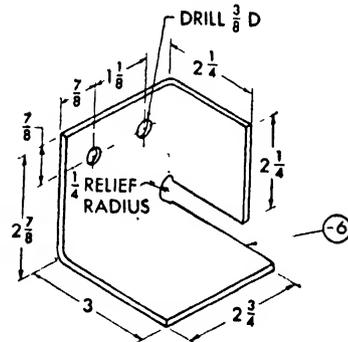
Problem 9



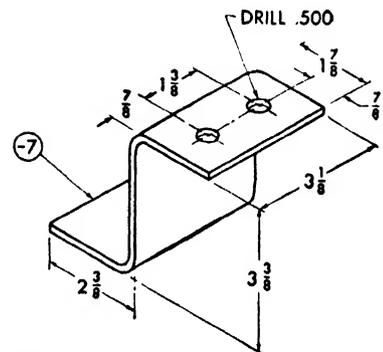
Problem 12



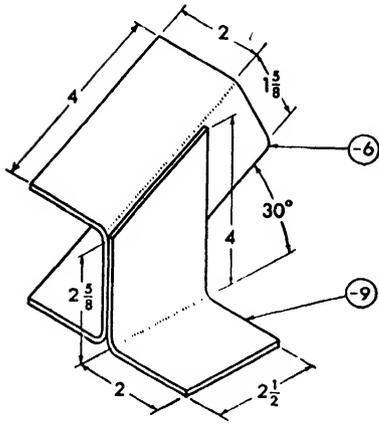
Problem 10



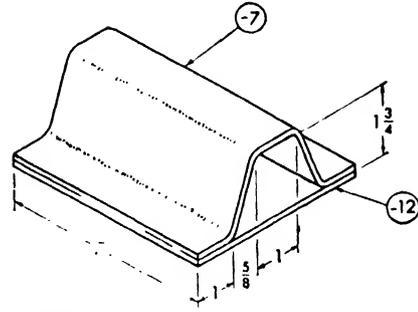
Problem 13



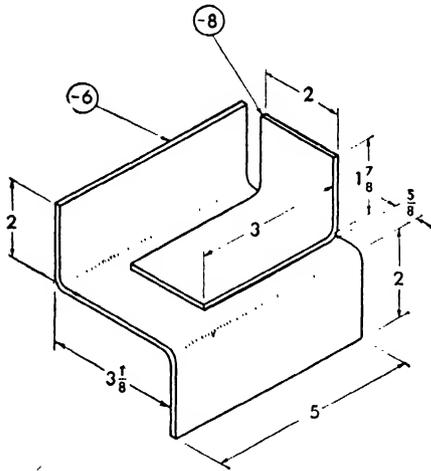
Problem 14



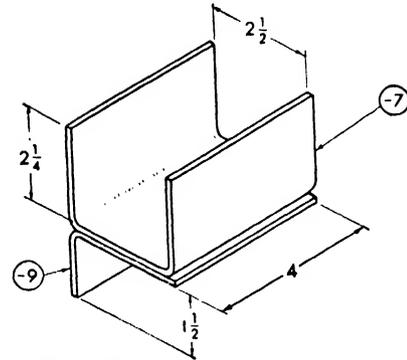
Problem 15



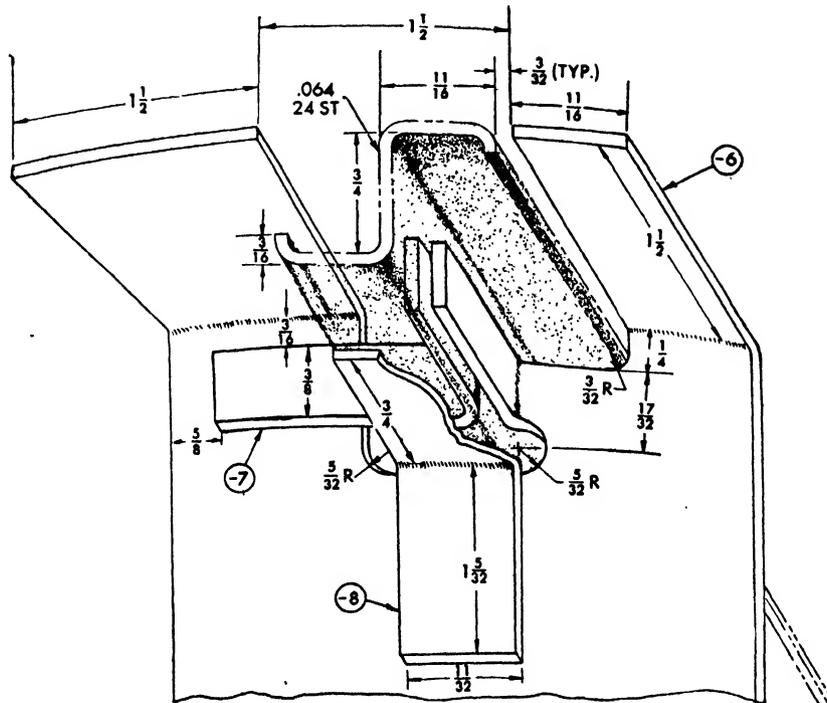
Problem 17



Problem 16

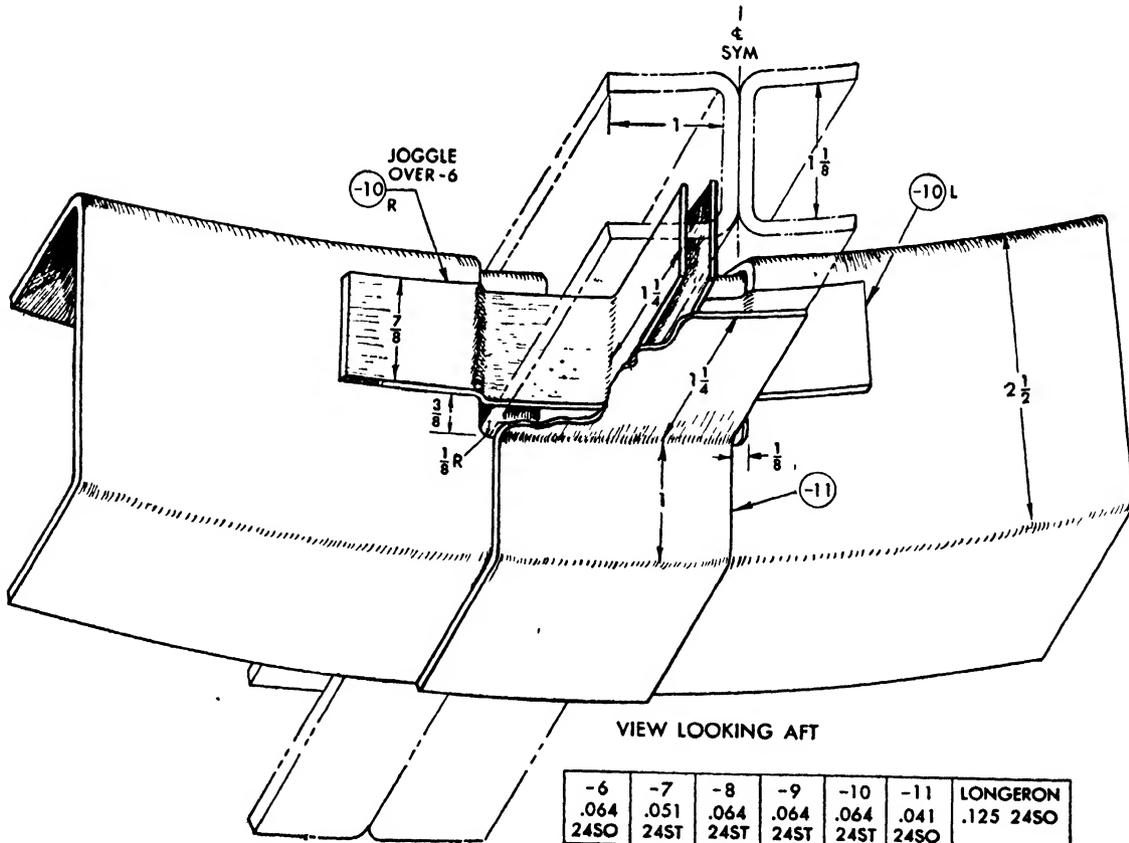
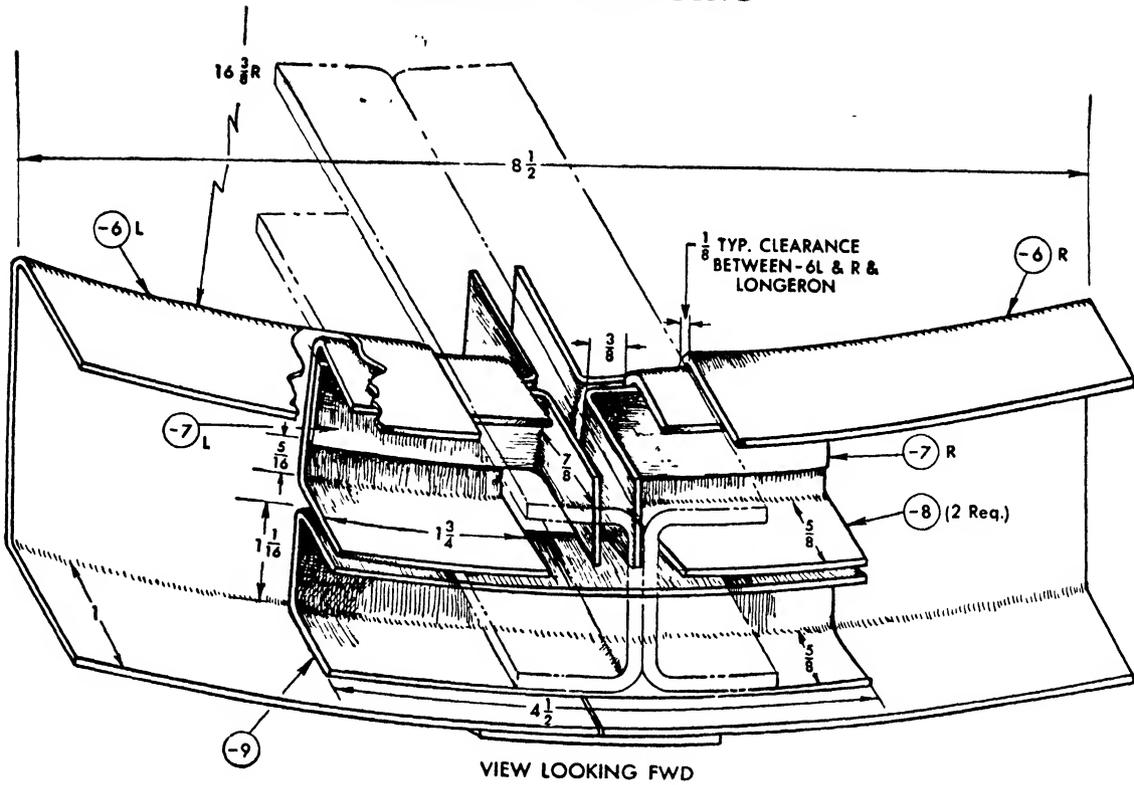


Problem 18



Problem 19

AIRCRAFT DRAFTING



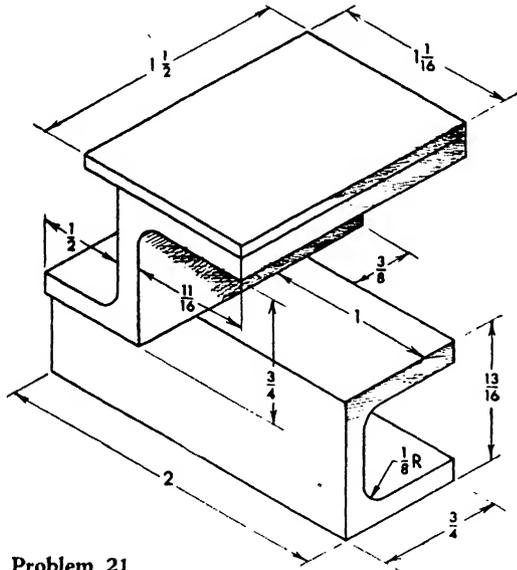
-6	-7	-8	-9	-10	-11	LONGERON
.064	.051	.064	.064	.064	.041	.125 24SO
24SO	24ST	24ST	24ST	24ST	24SO	

Problem 20

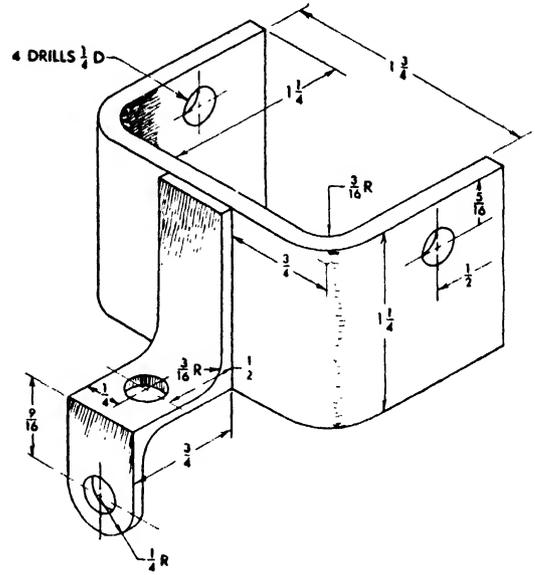
Draw necessary views of longeron splice. Use standard bend radii.

Problems 21-26

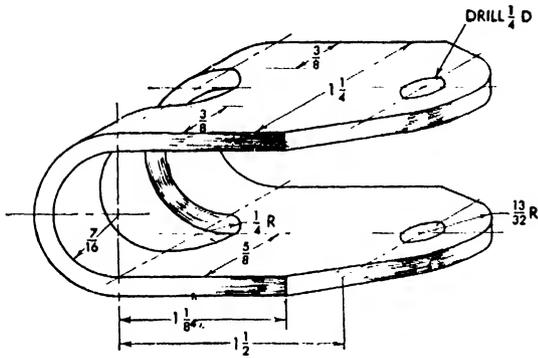
Draw necessary views. Problems may be dimensional; all gage thicknesses  $\frac{1}{8}$  inch.



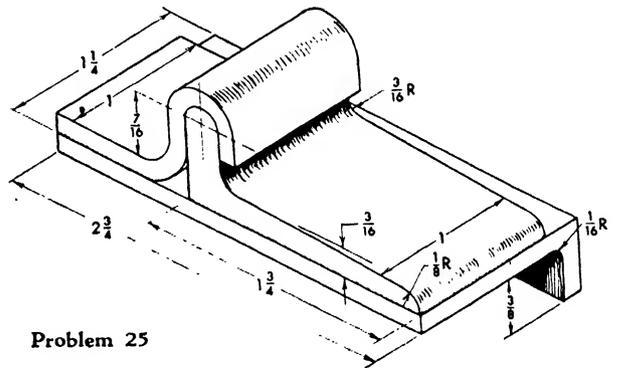
Problem 21



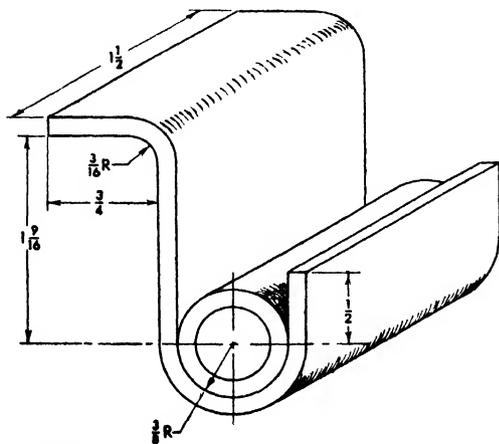
Problem 24



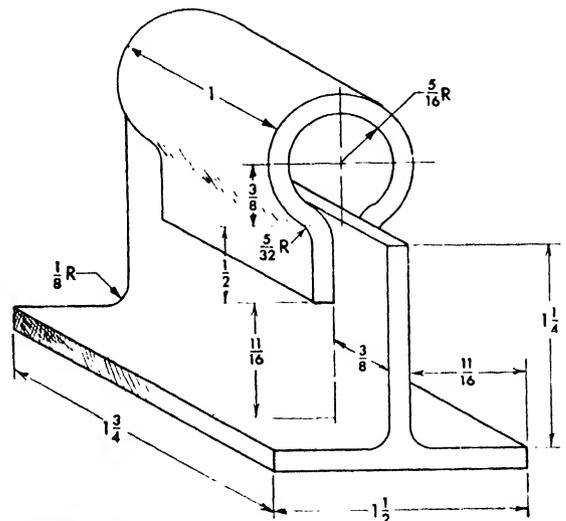
Problem 22



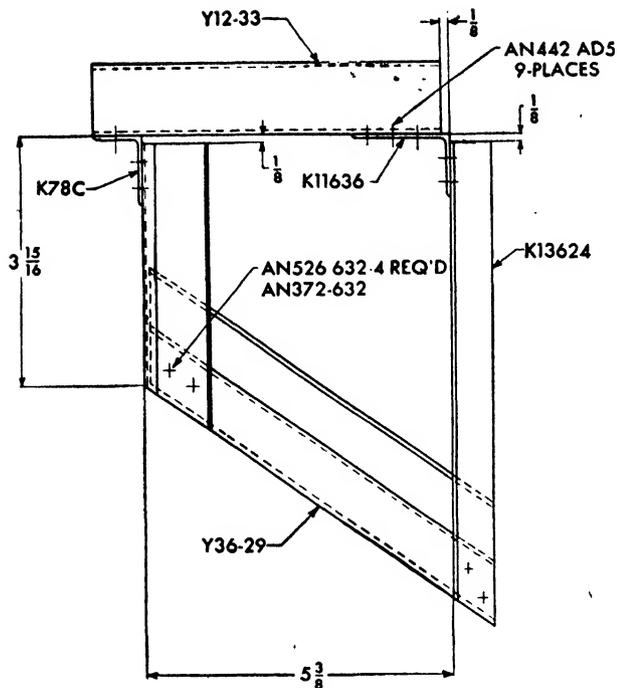
Problem 25



Problem 23

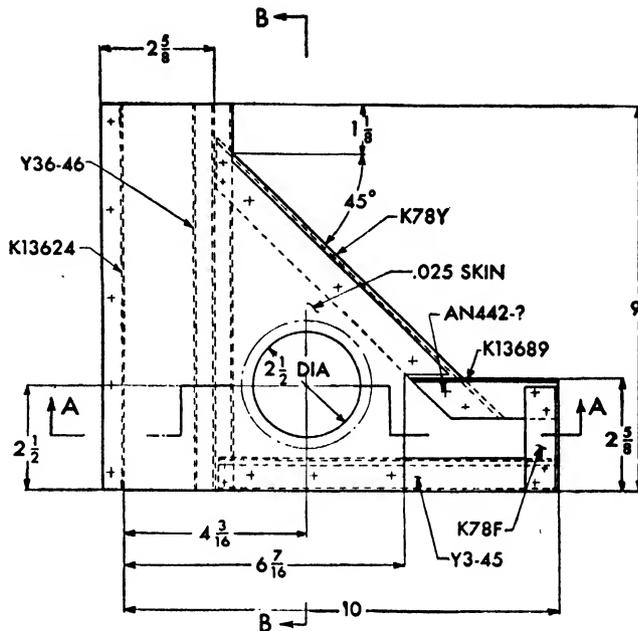


Problem 26



**Problem 27**

Draw view shown & R.H. view. Give all dimensions necessary to make part.

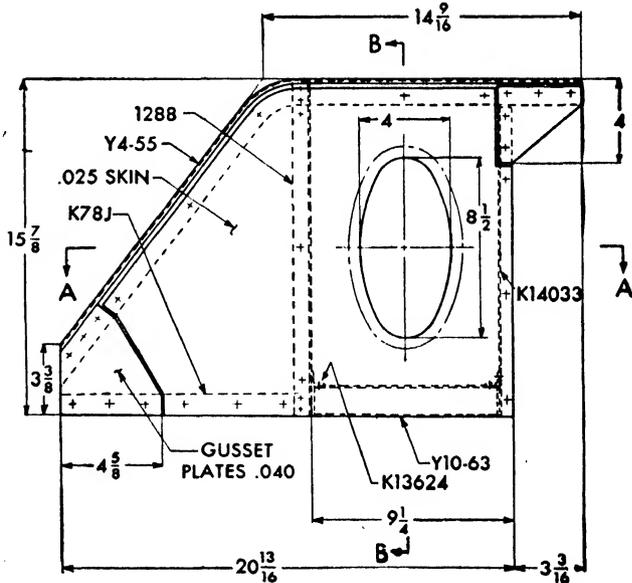


**Problem 28**

Draw view shown, sections A-A & B-B. Give all dimensions to make the part, including joggles where necessary. Fill in B.M.

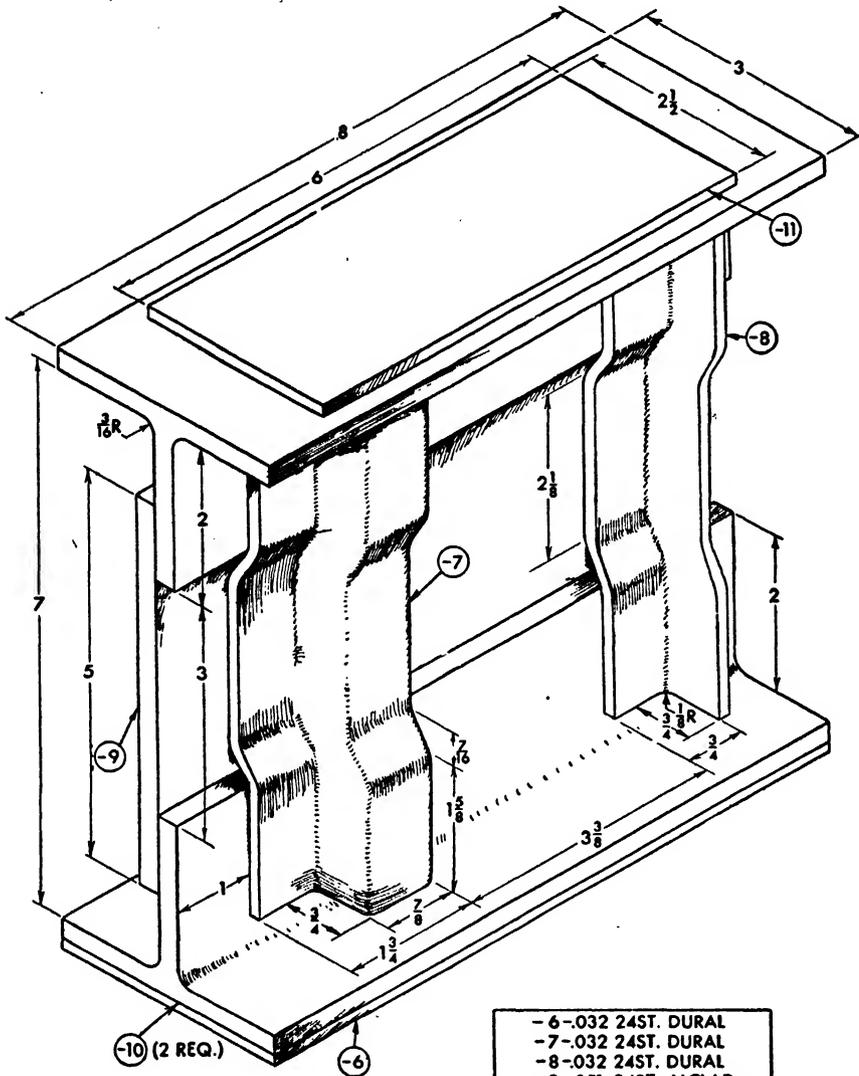
**STANDARD EXTRUSIONS**

K78C		1288	
K78F		Y3-45	
K78J		Y4-55	
K78Y		Y10-63	
K13624		Y12-33	
K11636		Y36-29	
K13689		Y36-46	
K14033			



**Problem 29**

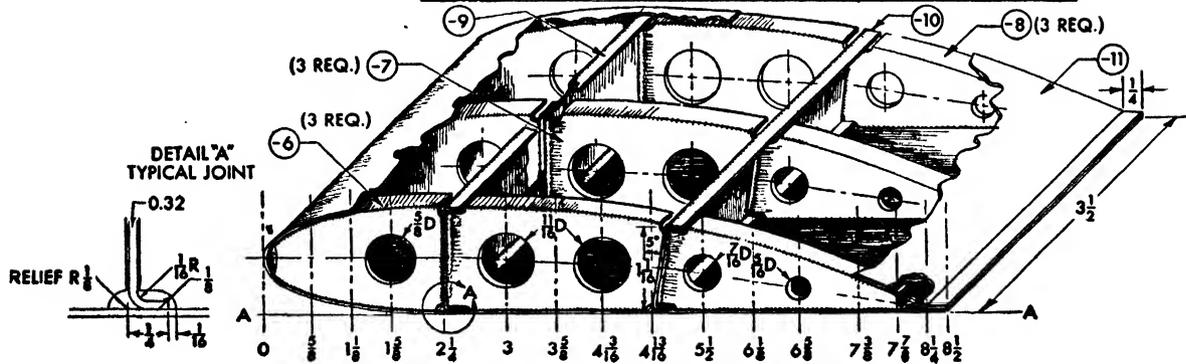
Draw view shown with sections A-A & B-B. Give all dimensions necessary, fill in B.M. & calculate the weight.



Problem 30

- 6-.032 24ST. DURAL
  - 7-.032 24ST. DURAL
  - 8-.032 24ST. DURAL
  - 9-.051 24ST. ALCLAD
  - 10-.051 24ST. ALCLAD
  - 11-.032 24ST. ALCLAD
- USE STANDARD BEND RADIUS

STATION	0	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$2\frac{1}{4}$	3	$3\frac{3}{8}$	$4\frac{3}{8}$	$4\frac{13}{16}$	$5\frac{1}{2}$	$6\frac{1}{8}$	$6\frac{5}{8}$	$7\frac{3}{8}$	$7\frac{7}{8}$	$8\frac{1}{4}$	$8\frac{1}{2}$
UPPER		$1\frac{3}{16}$	$1\frac{5}{16}$	$1\frac{11}{32}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{11}{32}$	$1\frac{5}{16}$	$1\frac{5}{32}$	$1\frac{1}{16}$	$\frac{29}{32}$	$\frac{3}{4}$	$\frac{15}{32}$	$\frac{1}{4}$	$\frac{3}{32}$	$\frac{3}{32}$
LOWER		$\frac{3}{4}$	$\frac{7}{32}$	$\frac{3}{32}$	$\frac{1}{32}$											



Problem 31



## CHAPTER NINE

# AUXILIARY VIEWS

Most objects may be described by the ordinary orthographic views, but it sometimes happens that a major side slopes to two projection planes and is perpendicular to a third. Orthographic views will not describe this sort of object clearly.

An example is the slanted flange of the bracket in Fig. 168. The front view reveals its true length, but the flange appears foreshortened in the top view and the right side view as it is inclined to the top and right side planes of projection.

An exact view of this surface may be obtained by adding to the normal views an auxiliary projecting plane parallel to the slanting surface. Imagine that the object is enclosed in a glass box with sides hinged to the front plane and parallel to the sides of the object (see Fig. 169a). Project the sides of the object to the glass planes, then swing the glass planes open to obtain the views shown in Fig. 169b. An auxiliary view may also be obtained by looking perpendicularly into the slanted surface.

The auxiliary view permits a true picture of the inclined surface to be drawn, but, as shown in Fig. 170, the top flange is foreshortened. To economize in drafting time, the detail of the surface may be drawn parallel to the projection plane, and the foreshortened part may be cut off with a break line, as in Fig. 171.

### *Types of Auxiliary Views*

Auxiliary views are classified in three groups:

Auxiliary elevations

Auxiliary left and right views

Auxiliary front and rear views

As shown in Fig. 172, the type of view is determined by the relationship of the inclined surface to the normal planes of projection. Left or right auxiliary views are most often used.

The slanted surface of an **AUXILIARY ELEVATION** is perpendicular to the top plane and inclined to the front and side planes. The auxiliary elevation is projected from the top, where the true length of the inclined surface is indicated by an authentic edge. The height of the surface is transferred from the front view to the auxiliary elevation. The auxiliary view must be projected from the orthographic view that shows the true length of the slanted surface.

The slanted surface of an **AUXILIARY LEFT OR RIGHT VIEW** is perpendicular to the front plane and slopes to the top and side planes. The auxiliary view is projected from the edge of the slanted surface, shown in its true length in the front view. The depth is transferred from the top to the auxiliary view.

The slanted surface of an **AUXILIARY FRONT OR REAR VIEW** is perpendicular to the side pro-

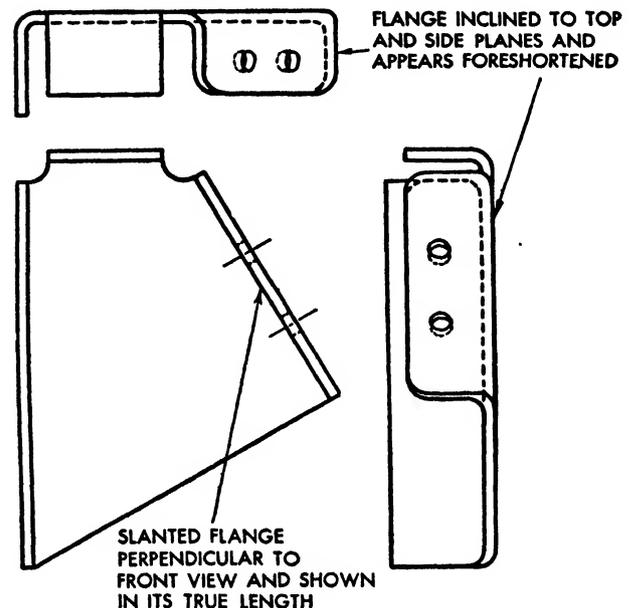


Fig. 168. Normal orthographic projection of an inclined surface

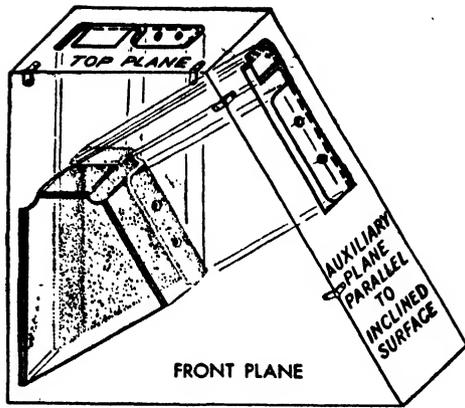


Fig. 169a. The auxiliary plane

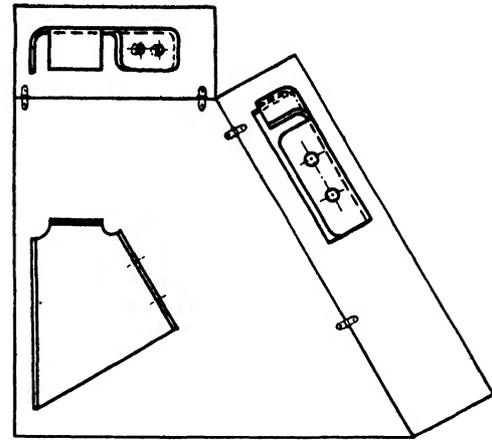


Fig. 169b. The planes opened to obtain view

jection plane and inclined toward the front or rear and top planes. The surface width is transferred from the front to the auxiliary view.

*Drawing Auxiliary Views*

To draw an auxiliary view, assume the existence of a reference plane placed against the side or cutting through the body of the object perpendicular to the surface to be projected. Place this reference plane where it is most helpful in constructing the auxiliary view. For flat, rec-

tangular shapes easily built on a baseline, use a reference plane that leans upon a main side of the object, as in Fig. 173. If a surface is built around a center line, the reference plane cuts through the center of the surface as in Fig. 174.

The reference plane in Fig. 173 purportedly rests against the back of the object. It is then turned so that it rests parallel to the inclined surface to be projected and is drawn as a ref-

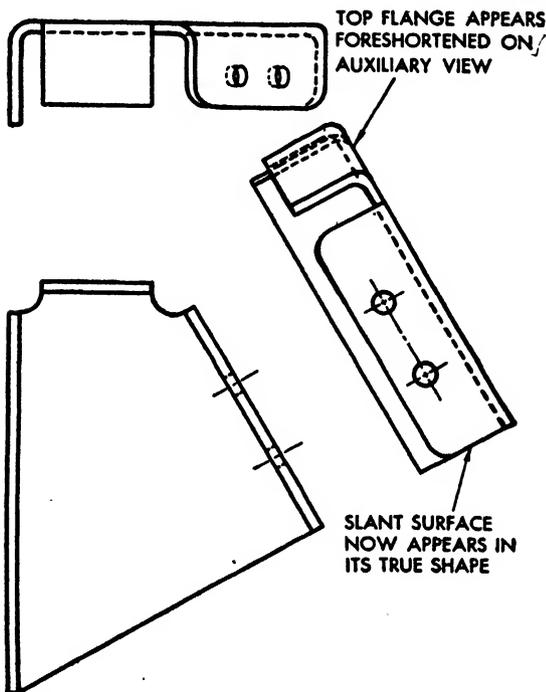


Fig. 170. The complete auxiliary view

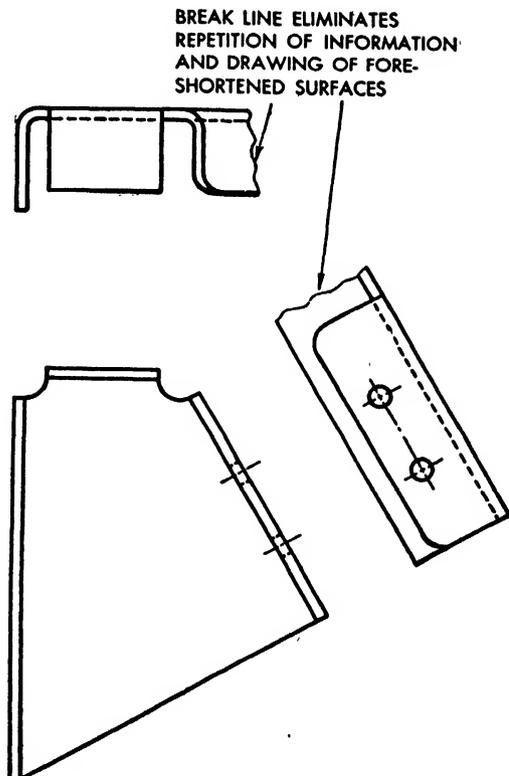


Fig. 171

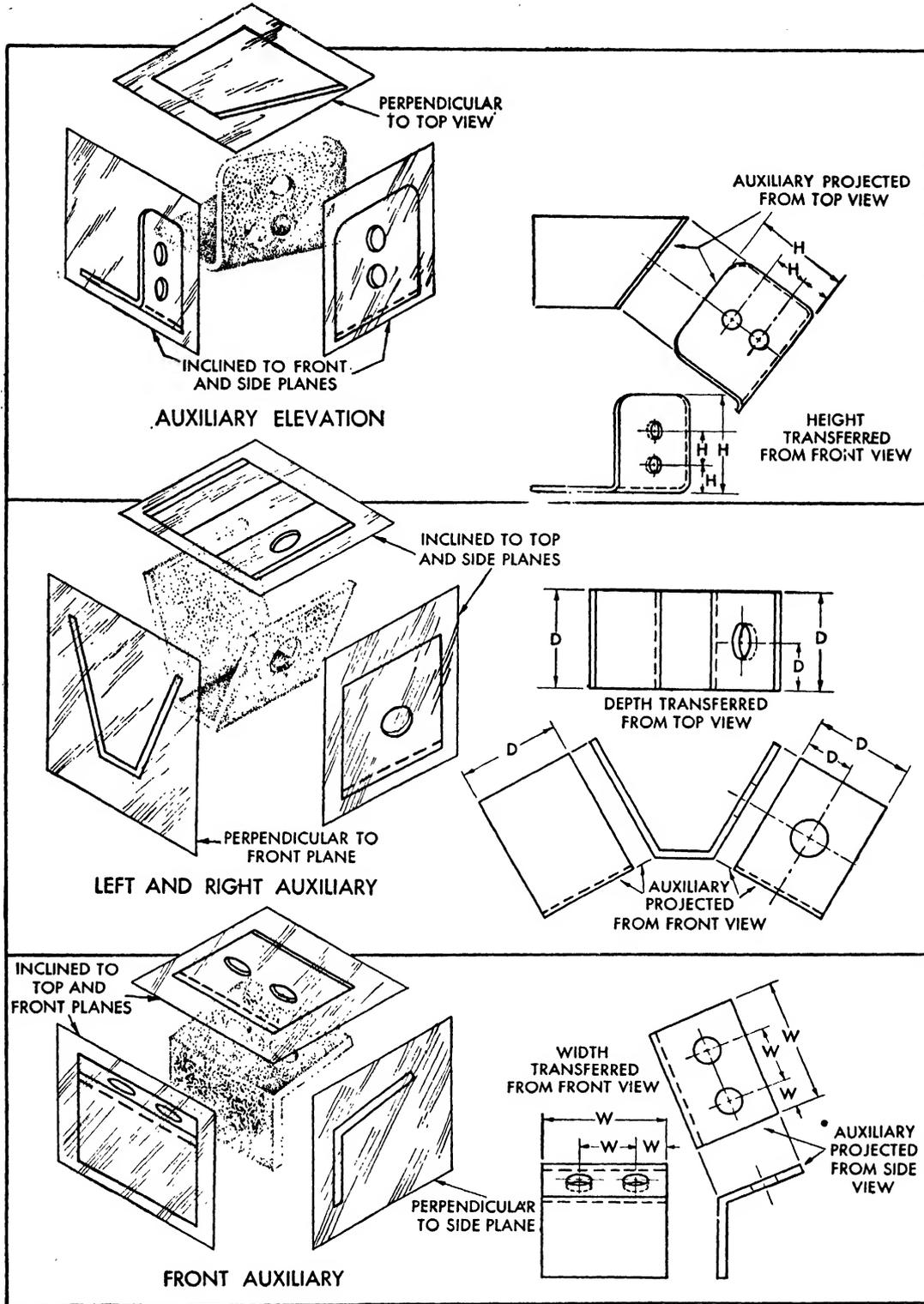


Fig. 172. Types of auxiliary views

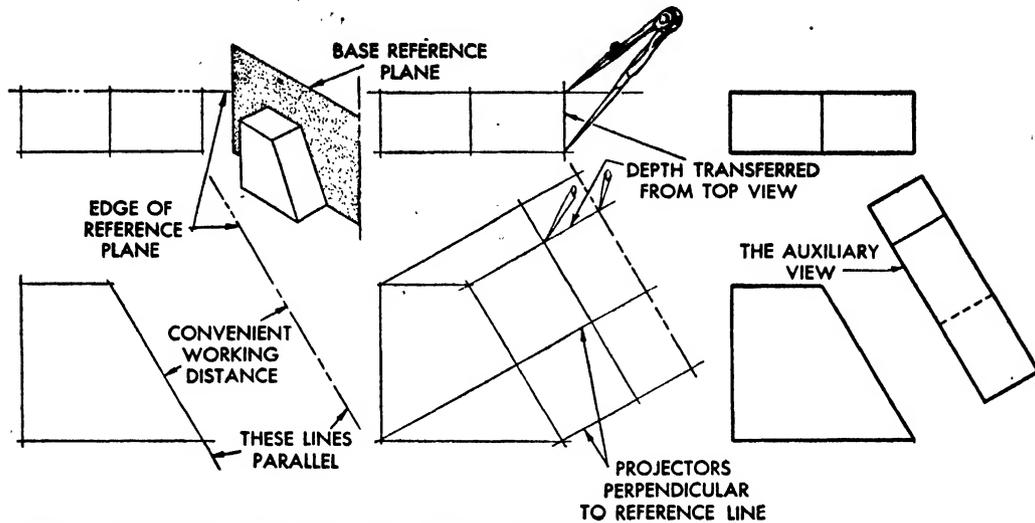


Fig. 173. Drawing an auxiliary view—baseline method

reference line or, in other words, the edge of the reference plane. The reference line is placed at a convenient working distance and may be approximated easily by considering the depth of the object in the top view and the desired distance between views. Of course, in an auxiliary elevation or a front or rear auxiliary view the height or width of the object, respectively, would be taken into consideration before drawing a reference line.

Basic construction lines are projected from the front view perpendicular to the reference line. The depth of the object is then transferred with dividers from the top view to the auxiliary view, and the views are completed.

In the center line method shown in Fig. 174, the same procedure is followed, except that the depth of the surface is transferred about the center line.

*Drawing Curves in Auxiliary Views.* Drawing curves in auxiliary views is illustrated in Fig. 175 by the auxiliary view of a cylinder.

The center line XX is assumed to be the edge of a central reference plane perpendicular to the inclined surface in the top view and parallel to the inclined surface in the auxiliary view.

In the front view, conveniently located points A, B, C, D, etc., along the edge of the inclined surface are projected perpendicular to XX in the top view and in the auxiliary.

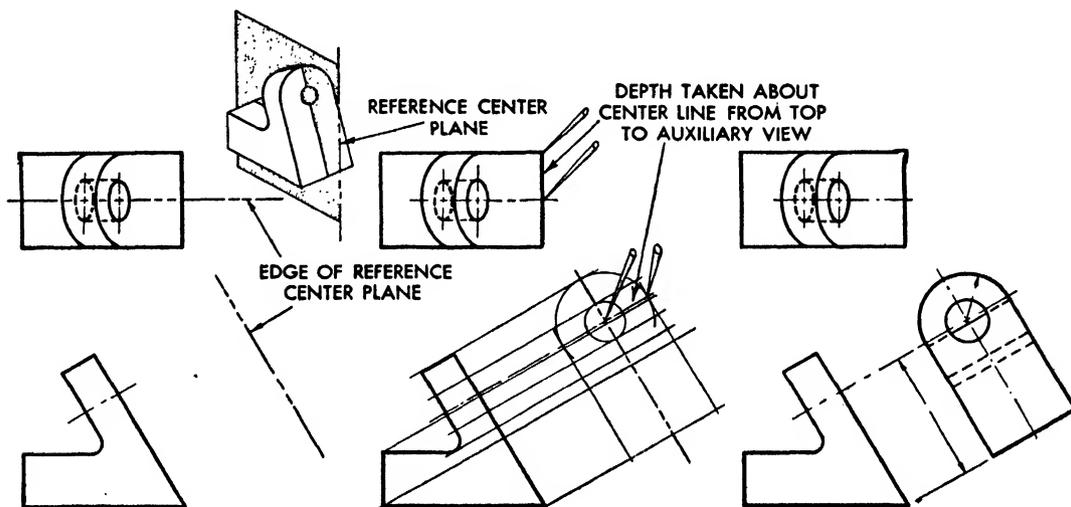


Fig. 174. Drawing an auxiliary view—center line method

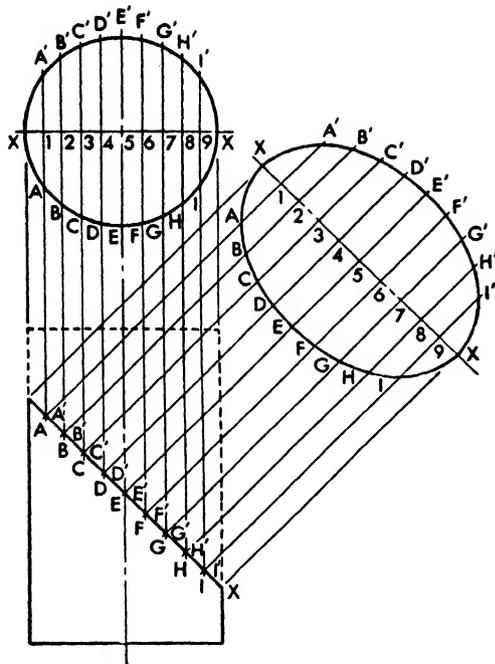


Fig. 175. Auxiliary view—cylinder

The distances  $A1$ ,  $1A'$ ,  $B2$ ,  $2B'$ , etc., are transferred with dividers from the top view to the auxiliary view. The points are connected with a smooth curve to form an ellipse in the auxiliary view.

The auxiliary view of the cut surface of the cone in Fig. 176 is drawn as follows:

1. Divide the base (top view) into equal parts, marked 1, 2, 3, etc.
2. Project points 1, 2, 3, etc., to front view.
3. Connect the points to the vertex of the cone. These lines or elements will intersect the edge of the cut surface or secant plane at points A, B, C, etc.
4. Project points A, B, C, etc., to the top view. The intersection of the perpendiculars

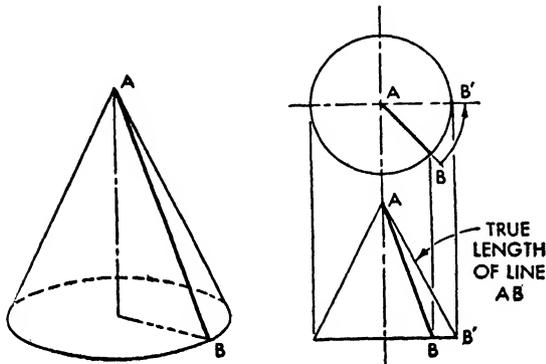


Fig. 177. True length of a line—rotation

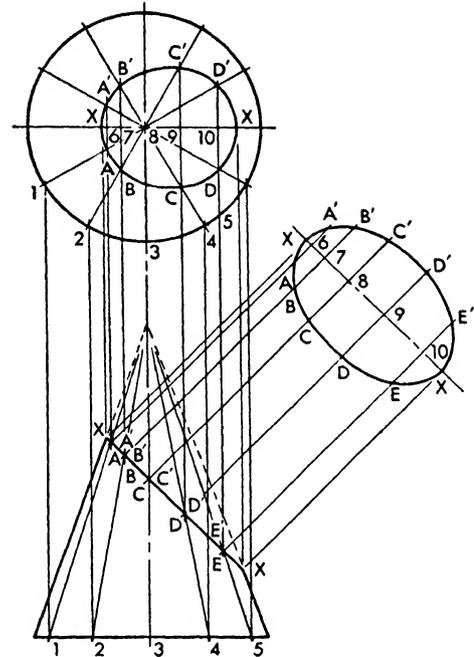


Fig. 176. Auxiliary view—cone

with the radial division lines 1, 2, 3, etc., establishes the exact location of points A, B, C, etc. When these are connected with a smooth curve they result in the top view of the cut surface.

5. Project points A, B, C, etc., on the edge of the cut surface in the front view perpendicular to the edge of the central reference plane XX in the auxiliary view.

6. Transfer the distances  $A6$ ,  $6A'$ ,  $B7$ ,  $7B'$ , etc., with dividers from the top view to the auxiliary view, as shown. A smooth curve connecting the points in an ellipse gives the auxiliary view.

*The True Length of a Line.* A line that is

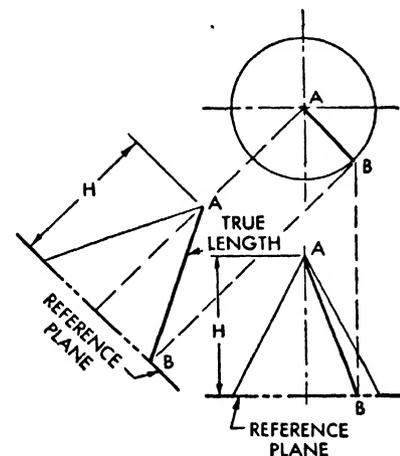


Fig. 178. True length of a line—auxiliary method

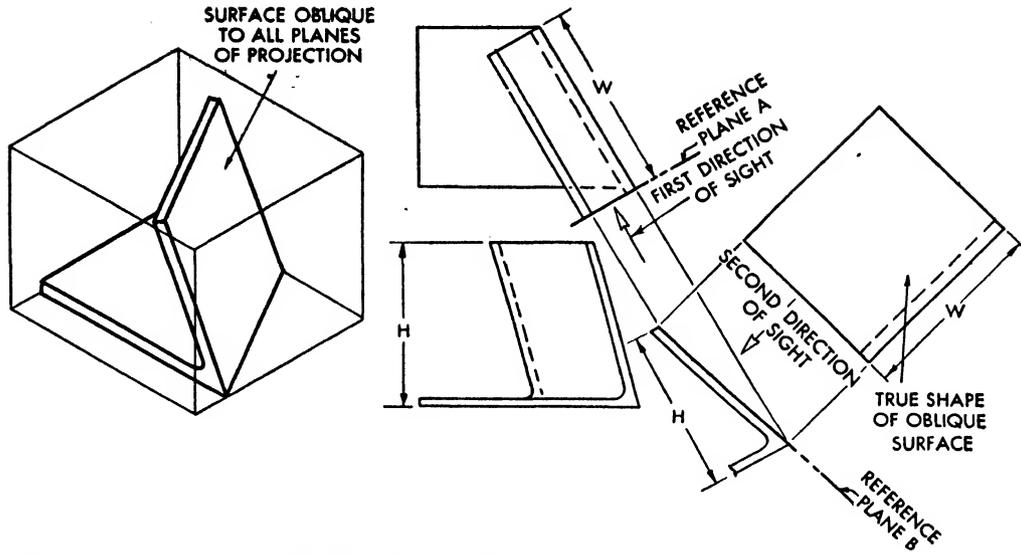


Fig. 179. To obtain the true shape of an oblique surface

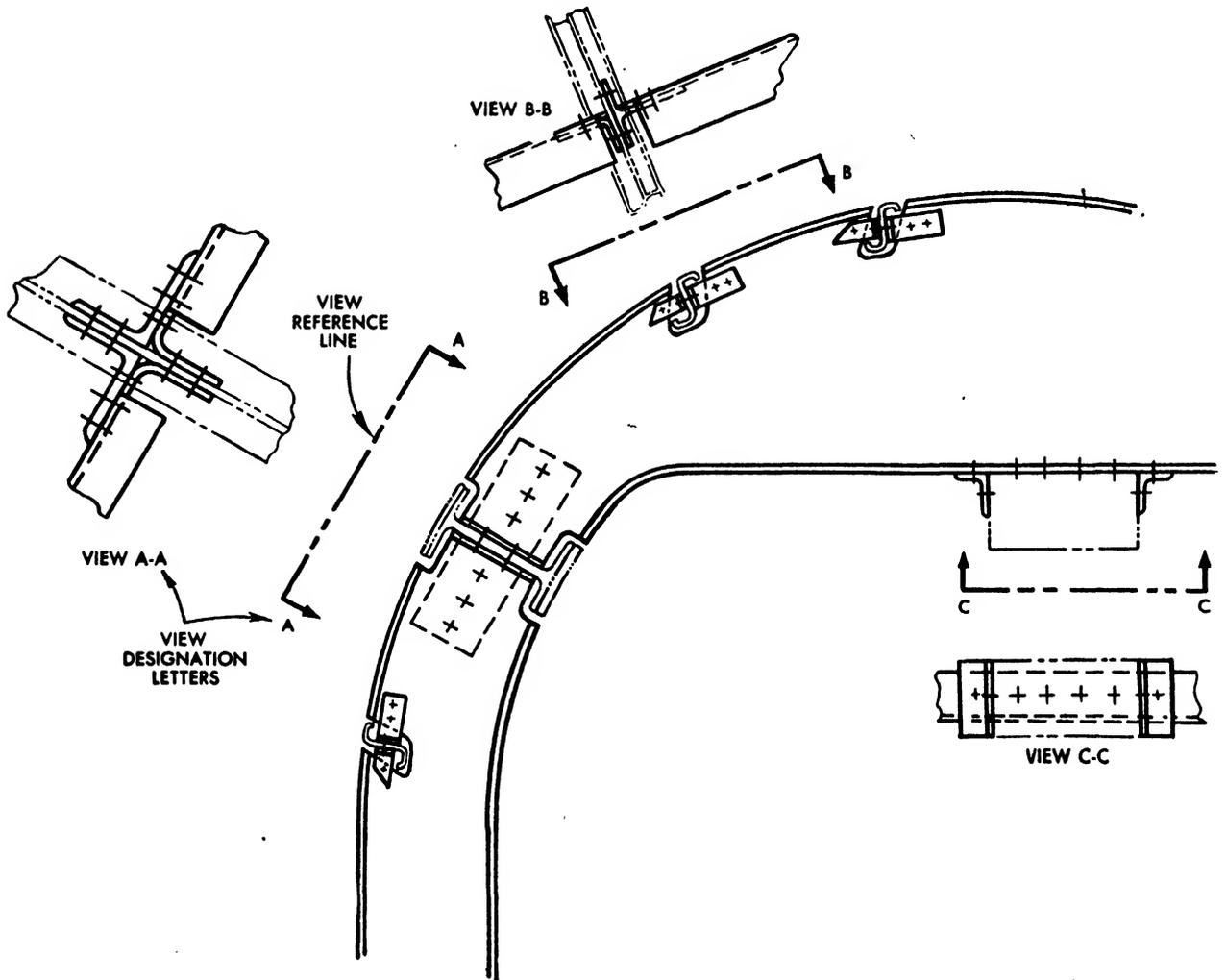


Fig. 180

inclined to all the normal planes of projection cannot be shown in its true length. This may be readily seen in Fig. 177, where line AB, an element of a cone, appears foreshortened in the principal views.

If the line is rotated until it becomes parallel to a plane of projection, its true length can be

1. Obtain a view in which the oblique surface is seen as an edge. This may be obtained by employing a reference plane perpendicular to the oblique surface and to a regular plane of projection, in this case, plane A, the top plane.

2. Project a second reference plane (in this case, plane B) parallel to the edge view of the

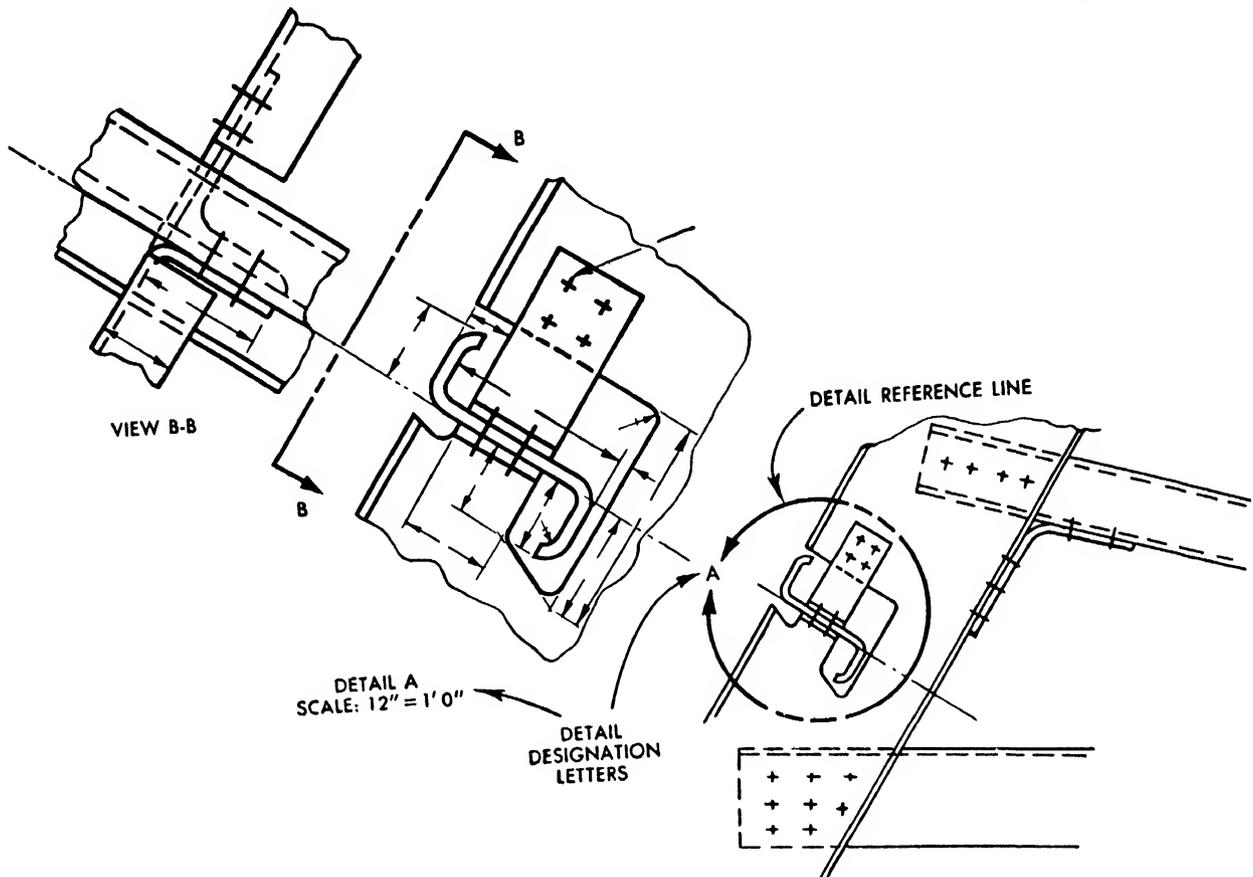


Fig. 181

shown. As illustrated in the top view of the cone, line AB has been swung to position AB', parallel to the front plane of projection, and appears in its true length in the front view.

The true length of a line may also be obtained, as shown in Fig. 178, by the use of a reference plane of projection, parallel to the line and perpendicular to a regular plane of projection.

#### Double Auxiliary Views

If a surface is inclined to all planes of projection, it is called an "oblique surface." To show its true shape, the following two steps (see Fig. 179) are necessary:

oblique surface. This will give the true shape of the oblique surface, as shown.

#### Partial Auxiliary Views

Partial auxiliary views, shown in Fig. 180, are a great aid in elucidating large main view drawings, common in sheet metal assemblies.

A view reference line, indicating the edge of a reference plane, is drawn parallel to the area to be projected. The line is drawn as a reference line, but with the same intensity as an object line.

Arrowheads, perpendicular to the reference line, indicate the direction in which the view is taken. The partial auxiliary view embraces all the

matter between the arrowheads. Break lines are used to terminate the sides of the partial view.

The partial auxiliary view should be placed directly behind the view reference line. If the nature of the drawing does not allow this placement, the view may be drawn to the left or right of the view reference line, but the view must always be drawn parallel to the reference line and geographically close to the portion of the main view being described.

Partial auxiliary views are not restricted to the main view alone. They may be taken from enlarged sections or from details of the main view, as shown in Fig. 181.

Clearly legible letters, approximately  $\frac{1}{4}$  inch high, are drawn in the vicinity of the arrowheads on the view line and are repeated on the partial view, preceded by the word **VIEW**. If the partial view is drawn to a larger scale than the main view, the scale should be clearly indicated, e.g.,

**VIEW DD**  
SCALE: 12" = 1'0"

*or*

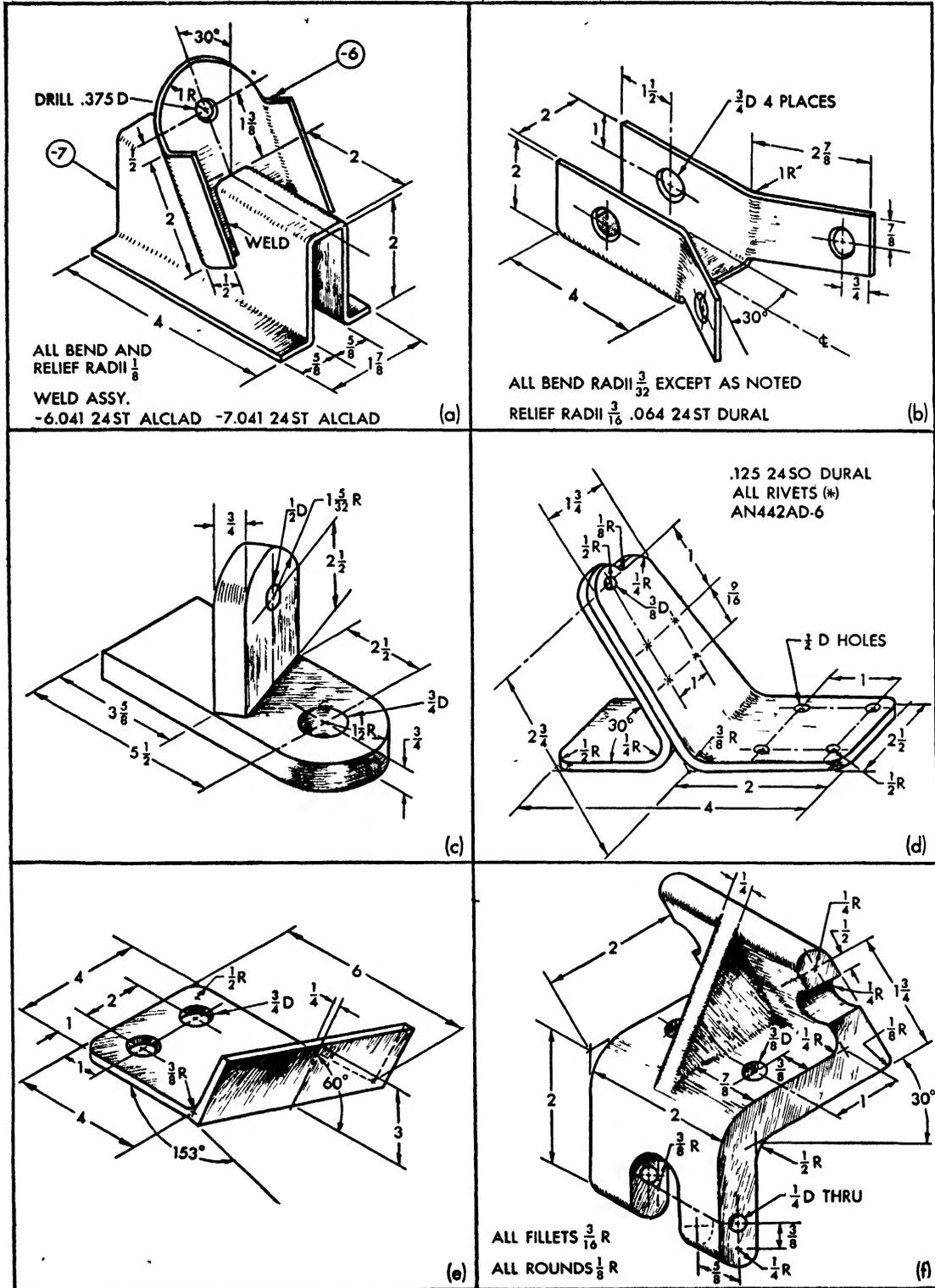
**VIEW DD**  
FULL SIZE

Since large, one-view aircraft drawings employ numerous auxiliary views, sections, and details, view designation letters facilitate rapid identification of the partial view in relation to the main view, and eliminate any confusion that might arise from adjacent descriptions.

### *Details*

Large assembly drawings must necessarily be made to a reduced scale. It is often desirable to "blow up" a certain area so that dimensioning and shape description may be more clearly shown. A circular reference line, terminated by arrowheads, is drawn about the area. This line has the same weight as the view reference line. The enlarged area is drawn parallel and geographically close to the smaller area in the main view. A detail designation letter, approximately  $\frac{1}{4}$  inch high, is placed between the arrowheads in the detail reference line and repeated under the enlarged detail, with the scale clearly noted as in Fig. 181.





**Problem 3**  
 Draw necessary views; dimension.



# CHAPTER TEN

## SECTIONAL VIEWS

Hidden lines are used to describe the shape of invisible edges, but too many dashed lines make a drawing confusing and difficult to read (see Fig. 182). The more complicated the internal structure of an object, the more this holds true.

In such cases it is advisable to use sectional views that give a clear, well-defined picture of a complicated partial view. To obtain a sectional view, imagine that the object is cut through as shown in Fig. 183 and opened to reveal the actual shape of the interior. A convenient view of this internal picture is then used to replace the conventional view (Fig. 184).

Many large aircraft drawings of sheet metal assemblies are composed of one main view. It is common to cut the sectional views through or within this main view. This practice not only clarifies the description, but also saves drafting time and avoids the repetition of information that would be necessary if additional main views were drawn.

the view is sighted. Near these arrows heavy letters are drawn. These letters are repeated on the sectional view to help identify the view. Sectional designation letters must be at least  $\frac{1}{4}$  inch high on large drawings and about  $\frac{3}{16}$  inch high on the average detail drawing.

In many machined parts the cut line is not indicated when its position is obviously identical with the center line, as it is in Fig. 184, for example. However, when more than one center line or cut line is employed, the symbol of the cut line takes precedence over the symbol of the center line, if the two coincide.

When the section cut is very long and straight, it is permissible to show only a portion of the cut line at the extremities, as in Fig. 186.

Since most large main views are drawn in reduced size, the drawing of the sectional view, or "section" as it is more commonly called, is usually enlarged for greater clarity of description and dimensioning. If there is a discrepancy between the scale of the section and that of the

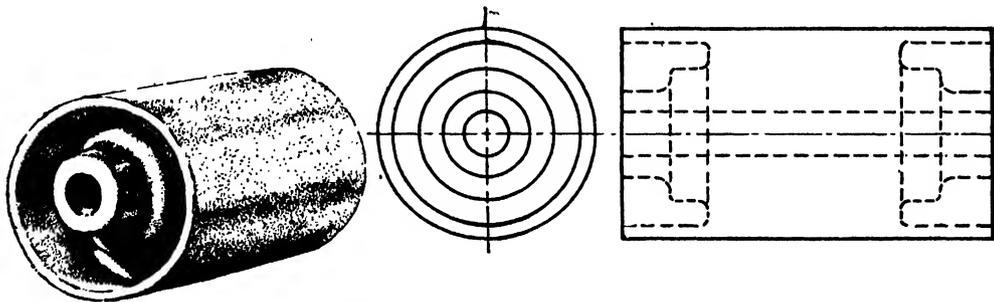


Fig. 182. Too many hidden lines make the drawing difficult to interpret

A typical sheet metal section cut is shown in Fig. 185. As already explained, the view is obtained by passing an imaginary cutting plane through the object. The edge of this cutting plane is represented on the main drawing by a *sectional cut line* (see Chapter Four).

Arrowheads indicate the direction from which

main view, it should be clearly noted; for example,

SECTION A-A  
FULL SIZE

### *Section Lining*

The exposed cut surface of a sectional view

taken through a machined part, a casting, or a forging is usually indicated by crosshatching or sectional lines. These lines help to distinguish the cut surface from any detail beyond the cutting plane. The direction of the crosshatching or sectional lines differentiates the adjacent members that compose a cut surface.

is drawn, the crosshatching of all sections should be uniform in spacing and direction.

If one of the principal outlines of a part coincides or is almost parallel with the 45 degree section lines, use another angle for the crosshatching.

*Symbolic Linings.* Section linings may be used

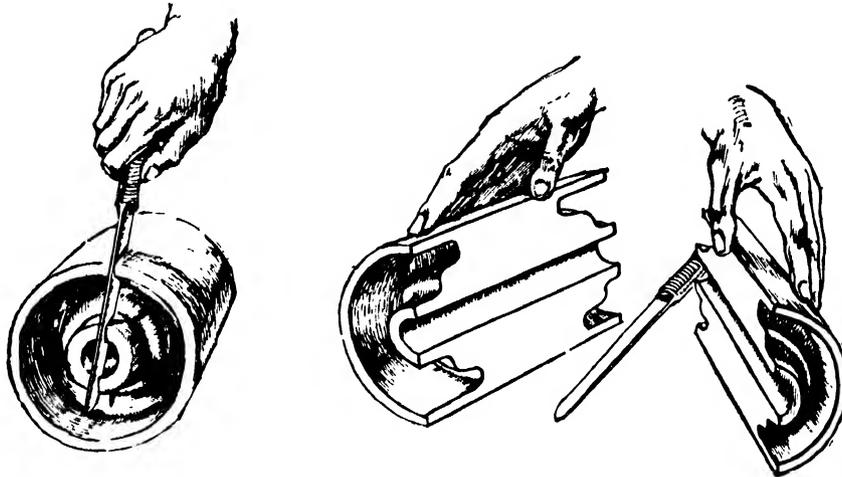


Fig. 183. The object cut through and opened

Sectional lines are drawn lightly, parallel to each other, at 45 degrees with the border edge of the drawing (see Fig. 187). For the average detail drawing or small section, a spacing of about  $\frac{1}{16}$  inch is used. The spacing between lines on large sections is usually  $\frac{1}{8}$  inch. The student should practice estimating these distances without the use of a scale.

Two adjacent parts are crosshatched in opposite directions (see Fig. 188). If there are three

to indicate the various materials from which the object is to be made (Fig. 190). However, such symbolic linings are used only to call special attention to some material.

Since material specifications are presented in the bill of materials accompanying each drawing, symbolic lining is usually not necessary. The 45 degree crosshatching, normally used to indicate a cut surface regardless of material, is the symbol of cast iron.

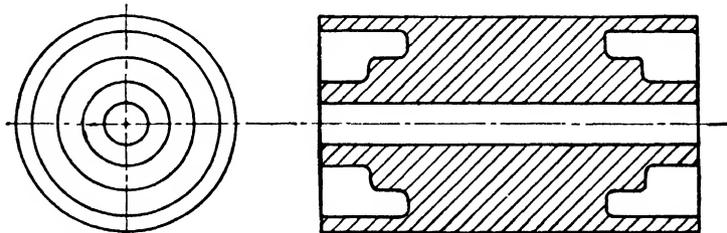


Fig. 184. The interior or sectional view used in place of the regular exterior view

adjacent parts, one must be lined at an angle of 30 or 60 degrees.

Large sections may be crosshatched only around their outlines, as in Fig. 189, as this will help to define the cut surface and save the time involved in crosshatching large areas.

If more than one section of a single member

*Exceptions.* Bolts, nuts, rivets, holes, or similar elements with axes in the cutting plane are not lined.

Sheet metal sections are not crosshatched, but if distinction between members is indispensable for clarity, the surfaces are shaded with a light pencil (see Fig. 191).

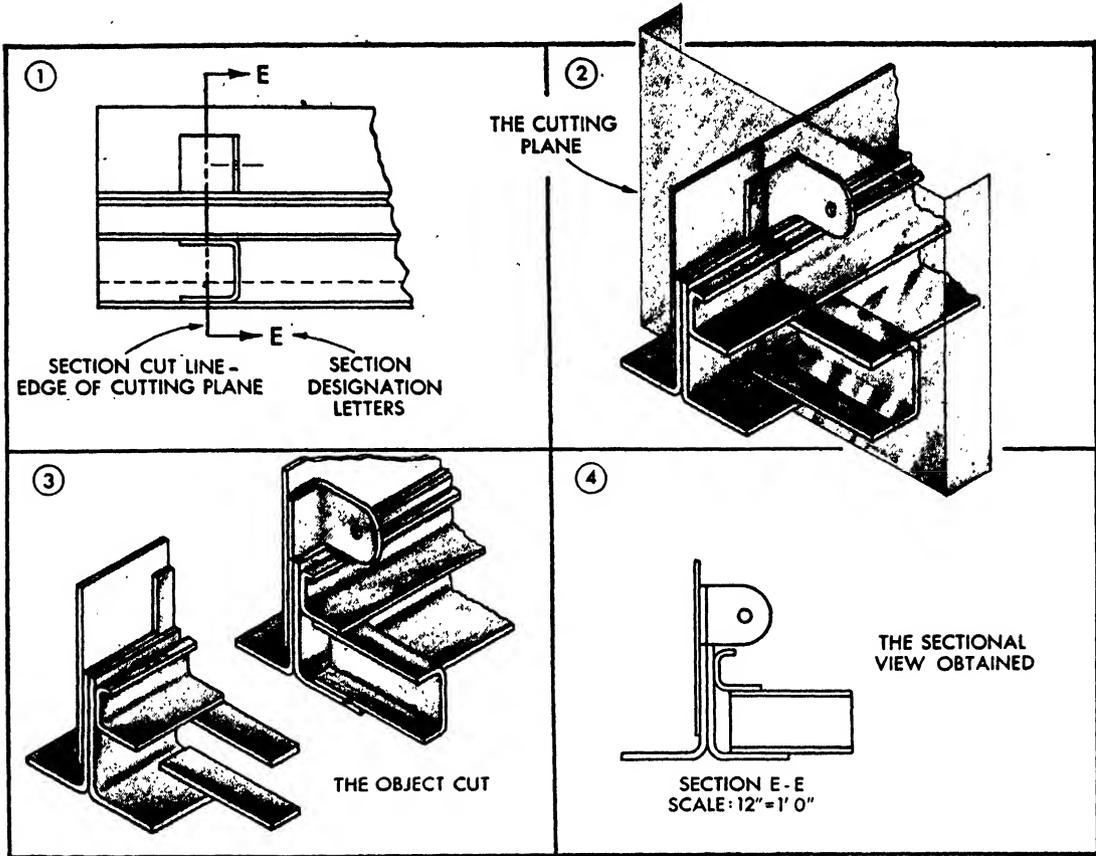


Fig. 185

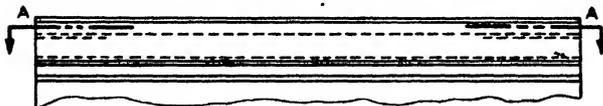


Fig. 186

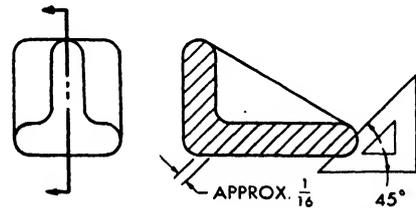


Fig. 187. Construction of crosshatching

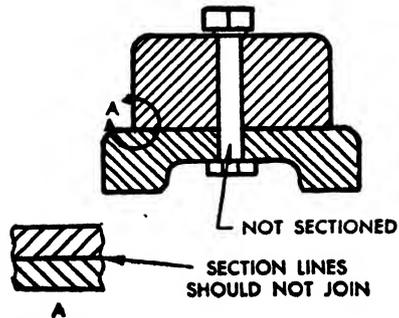


Fig. 188

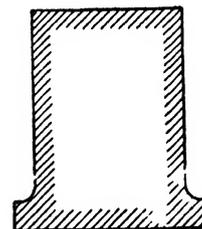


Fig. 189. Outline sectioning

Colored pencils are used to designate different sectional surfaces in layouts, design studies, notebooks, etc., but should not be used on tracings for reproduction.

*Details Beyond the Cutting Plane*

Important visible edges beyond the cutting plane should be shown in the section view (Fig. 192). But in large sheet metal assemblies it would be impractical to show all visible lines beyond the cutting plane. Select only those that are essential for a complete description of the particular section (Fig. 193). Unless absolutely necessary, hidden lines should not be used on sectional views (Fig. 194).

*Types of Sections*

A FULL SECTIONAL VIEW is obtained by passing an imaginary cutting plane through an object (Fig. 184).

A HALF SECTION is produced by passing the cutting plane half through the object. The center line separates the crosshatched section from the uncut surface (Fig. 195). If it is necessary to describe some particular detail within a large surface, the cut section may be localized as shown in Fig. 196. Such a section, called a "partial section," is usually drawn with break lines at its ends. This type of sectioning is employed mostly in large drawings of sheet metal assemblies.

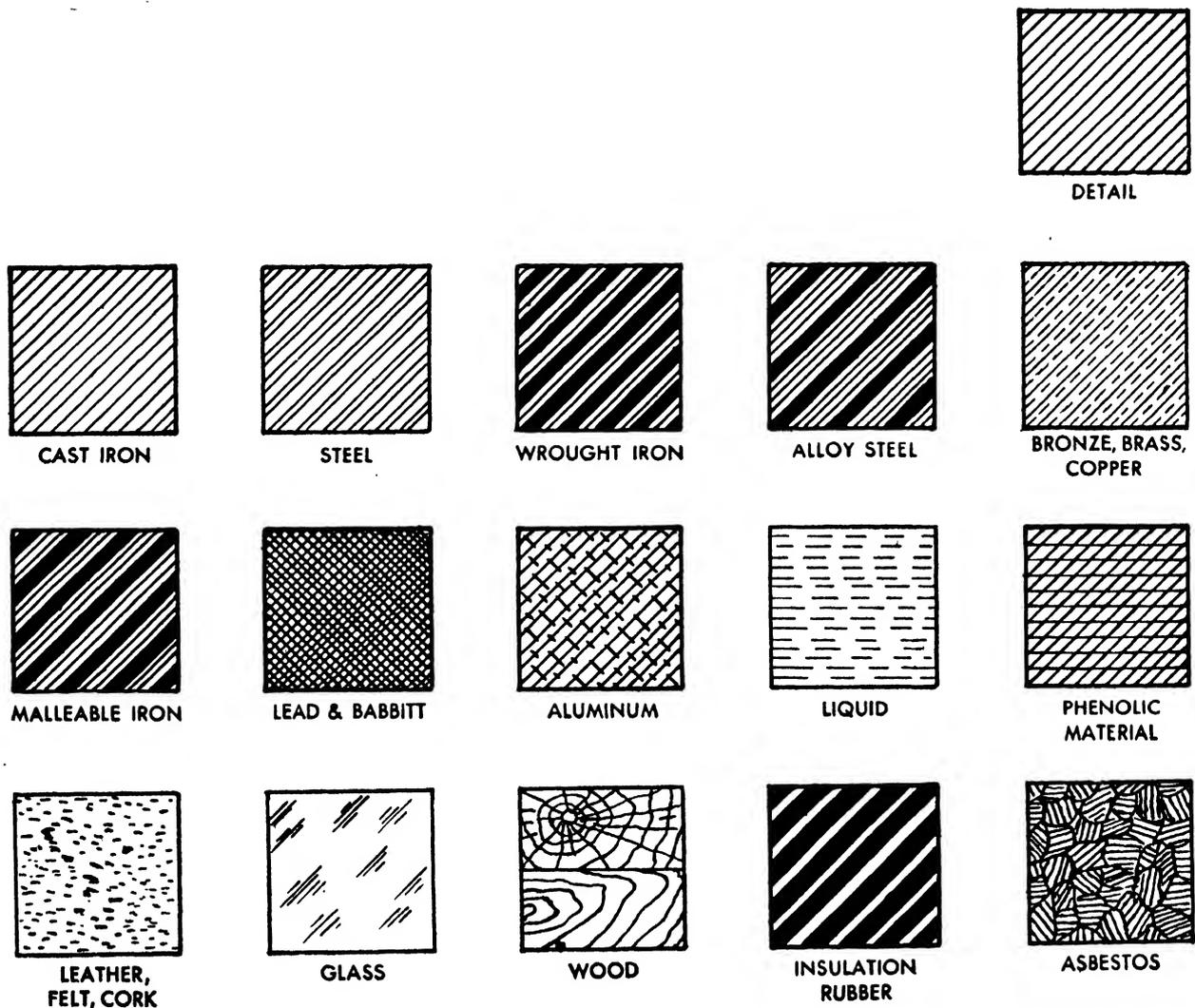


Fig. 190. Symbolic lines



Fig. 191

An imaginary section cutting plane may be continuous or broken. The broken or offset cutting plane is used to obtain a sectional view that includes details all of which are not in one cutting plane. The offsets of the cutting plane are shown on the main view but are not indicated in the sectional drawing (see Fig. 197).

Revolved sections are created by imagining the cutting plane perpendicular to the axis of the object and then rotating the section at 90

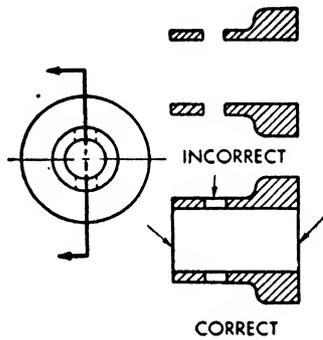


Fig. 192. Important lines behind the cutting lines should be drawn

degrees about a center line at right angles to the axis. Break lines indicate the ends of the particular revolved section. Examples of this type of sectioning are illustrated in Figs. 198, 199, and 200.

*Placement of Sections*

The sectional view is placed in the proper orthographic projection plane, which is in the opposite direction from the arrows of the reference line. Figure 201 describes the method of cutting and placing the sections. The assumption is that the object is gradually turned after cutting until the section surface lines up behind the reference line's arrows. This placement is usually applied to sectional drawings of machined parts and smaller sheet metal pieces.

However, in large drawings it may become impossible or impractical to adhere strictly to this rule, because the sectional view would interfere with the main view or be too far from the section reference line.

A section should be placed as close to the cutting plane line as possible so that the two may be readily associated. Since large drawings employ numerous sections, much time can be lost in trying to locate poorly placed sectional views.

The legibility of a drawing is greatly aided by placing the sectional view parallel to the cutting plane, in other words, at the same angle to the main view as the reference line.

Figure 202 shows various placements of sections in relation to the cutting plane line.

Placement 1 is the proper projection, oppo-

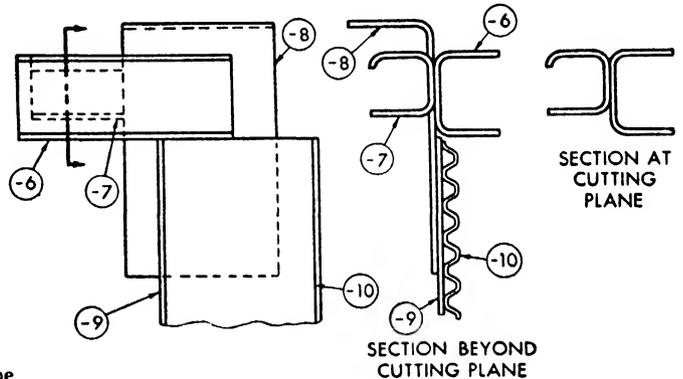


Fig. 193

site to the direction of the arrowheads. Placement 2 is a permissible variation. Although not placed behind the arrows, it is close to and parallel with the cutting line. Placement 3 is

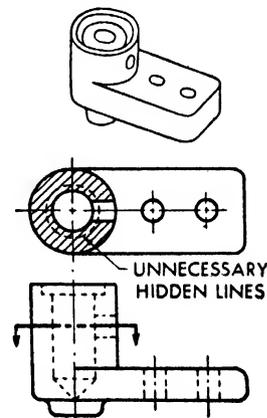


Fig. 194

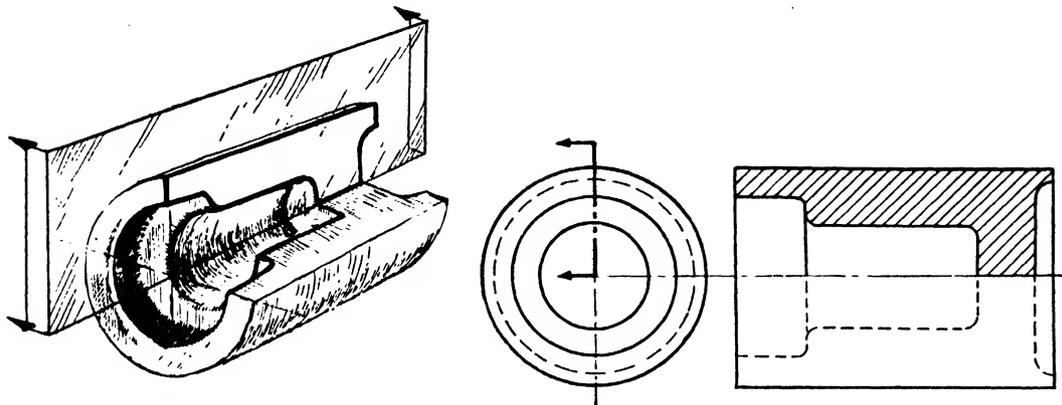


Fig. 195. Half section

also acceptable when the section cannot be placed behind the arrows or to the left of the cutting line. Placement 4 should be employed only if none of the former three positions can serve. Placement 5 is an incorrect and unacceptable projection. Placement 6 is a rotated view, not parallel to the cutting plane. In rare cases such a view may be used, but it should be avoided unless absolutely necessary, as it complicates the reading of the drawing. If a rotated view is used, the degree of the rotation should be noted.

In some conditions the actual projection of certain sectional views do not lend themselves to correct description or offer a clear picture for

manufacturing purposes. This is most common on cylindrical-shaped parts around the circumference of which lugs, holes, bosses, arms, and the like, may project on radials slanting to the section plane of projection.

For the sake of clarity it is permissible to revolve the necessary radial units until parallel to the section projection plane and draw it in true shape specifying actual dimension. These are commonly called *symmetrical sections*.

Some group checkers will permit this deviation from orthodox practice without notation, while others may require a note under the sectional view directing the shopman's attention to this type of sectional representation.

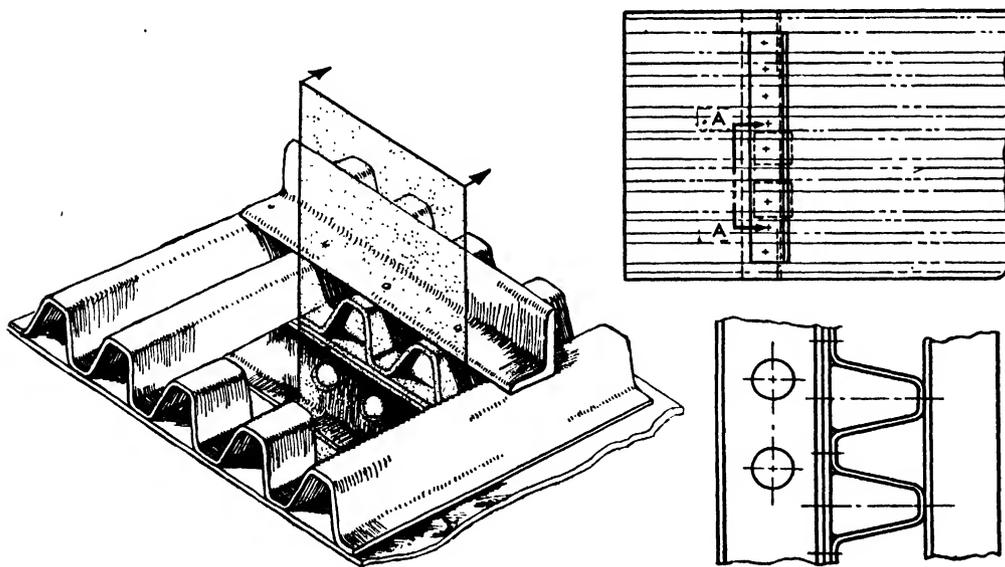


Fig. 196. Partial section

SEC. A-A  
SCALE: 12" = 1' 0"

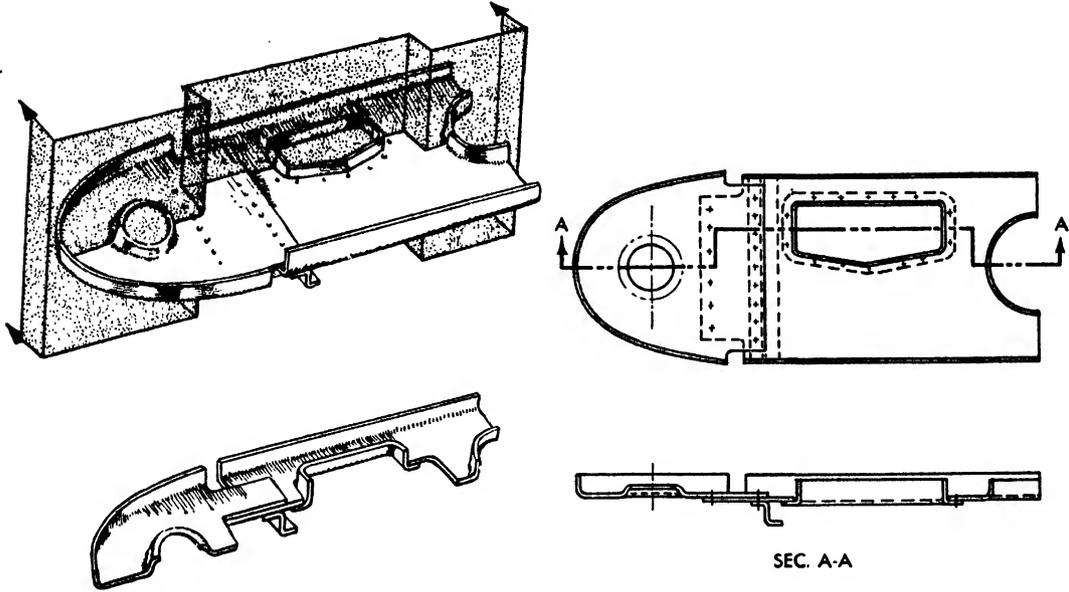


Fig. 197. Broken or offset section

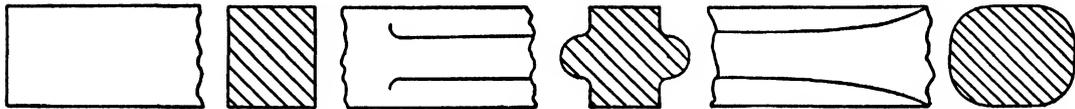


Fig. 198. Method of description by revolved sections

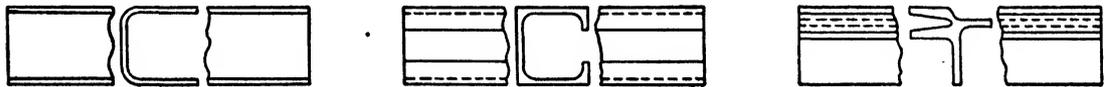


Fig. 199. Breaks to clarify standard sections

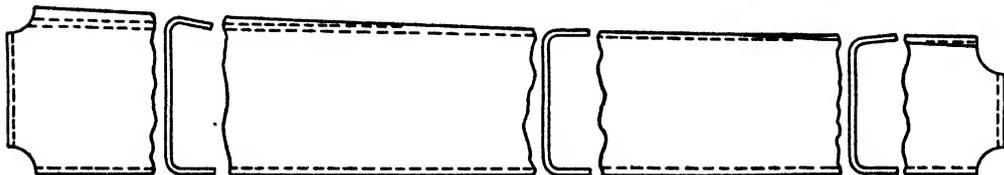


Fig. 200. Methods of breaks and sections to describe change in flange angle

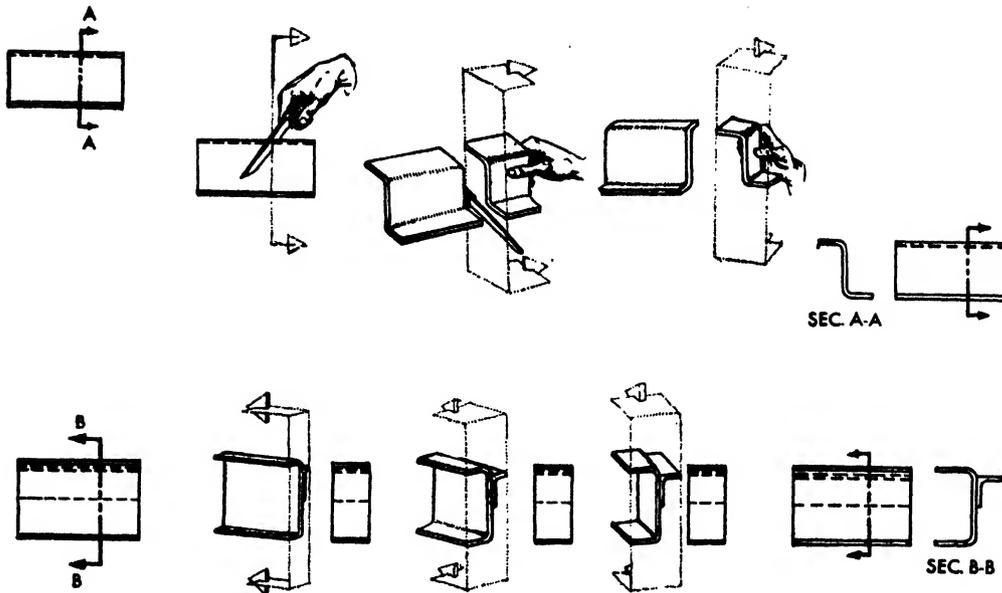
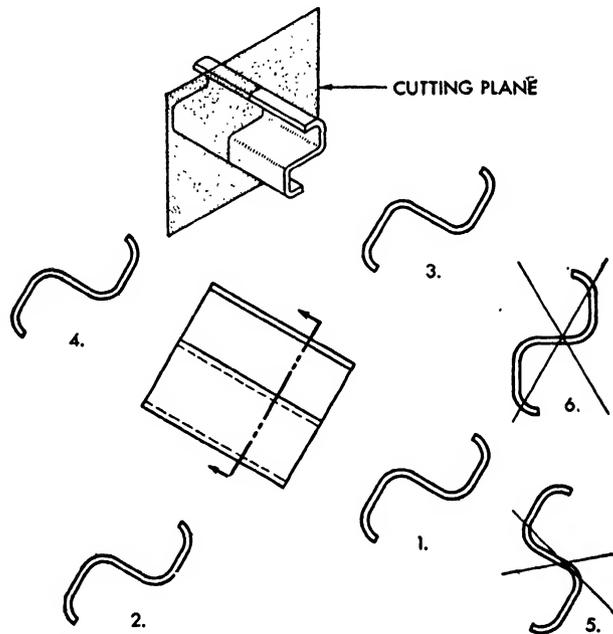


Fig. 201. Cutting, turning and placing sections

Perhaps the most rarely used type of sectioning used in aircraft is the *hidden or phantom* sectional view. Here, an ordinary orthographic view is drawn as seen from the outside (usually

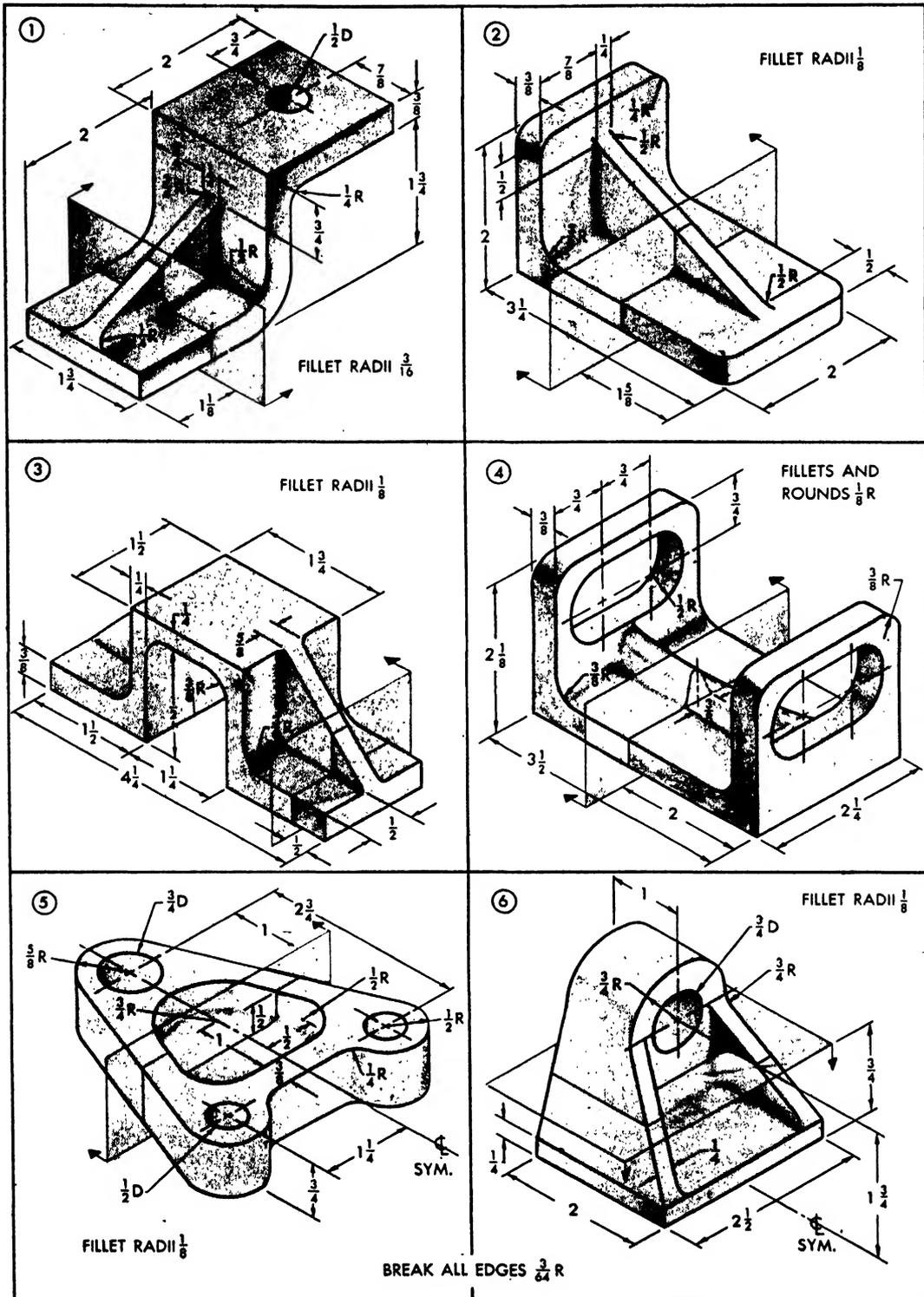
a symmetrical object). The areas of a partial section will be indicated by phantom or broken lines in place of the customary section lining employed in a regular section.



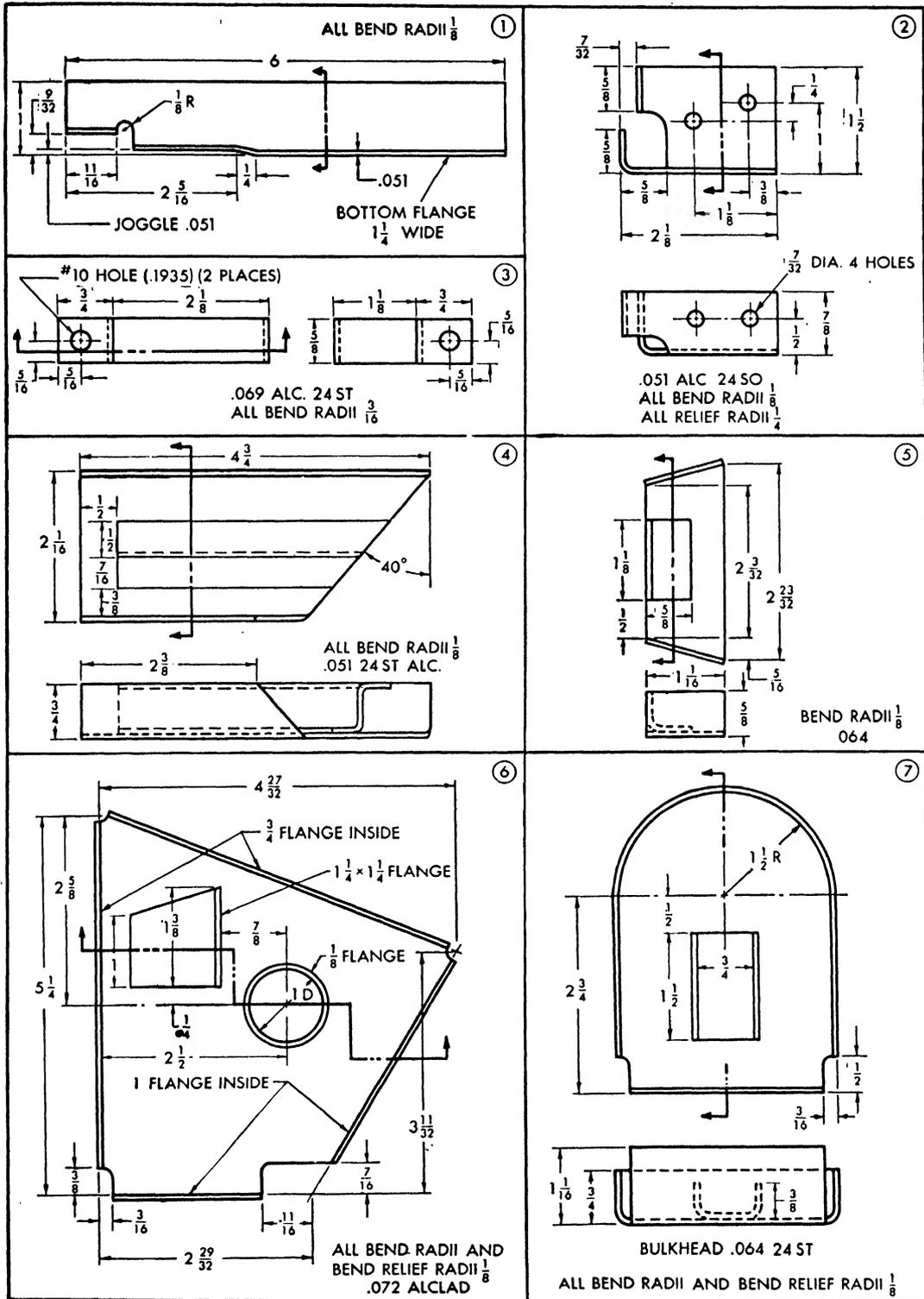
1. FIRST PREFERENCE-CORRECT VIEW IN LINE OF PROJECTION
2. PERMISSIBLE-WHEN NATURE OF DETAIL IN DRAWING DOES
3. NOT ALLOW SECTIONAL VIEW TO BE PLACED IN LINE OF PROJECTION
4. PROJECTION
5. INCORRECT-WRONG PROJECTION OF VIEW
6. INCORRECT-ROTATED VIEW

Fig. 202. Placement of sectional views

# PROBLEMS FOR CHAPTER TEN



Problem 1



Problem 2

# CHAPTER ELEVEN

## DIMENSIONING

### Introduction

The student has learned by now how to describe the shape of a part orthographically, but this is only half the job confronting him, as he must learn how to specify its size. A system of dimensioning is used for specifying size so exactly that the part drawn can be made in the shop exactly as indicated without any misunderstandings, necessity for additional information, or tedious scaling of the drawings.

The basic principles of dimensioning may be found in any good textbook, but knowledge of his company's shop practices and manufacturing methods is essential to the working draftsman.

If the student could take the mechanic's place

for a time and actually work on producing a part, he would soon realize that the dimensions given on a blueprint are his chief source of information and instruction. The success, accuracy, and rapidity of the fabrication depend in great measure on the functional nature and placement of the dimensions.

Drilled holes present an example of the functional nature of dimensioning. Holes are located by their center lines, and the dimensions of spacing are given from center line to center line and never between circumferences. The workman in the shop begins by establishing the intersection of the center lines of a hole. These lines are measured off and marked at their inter-

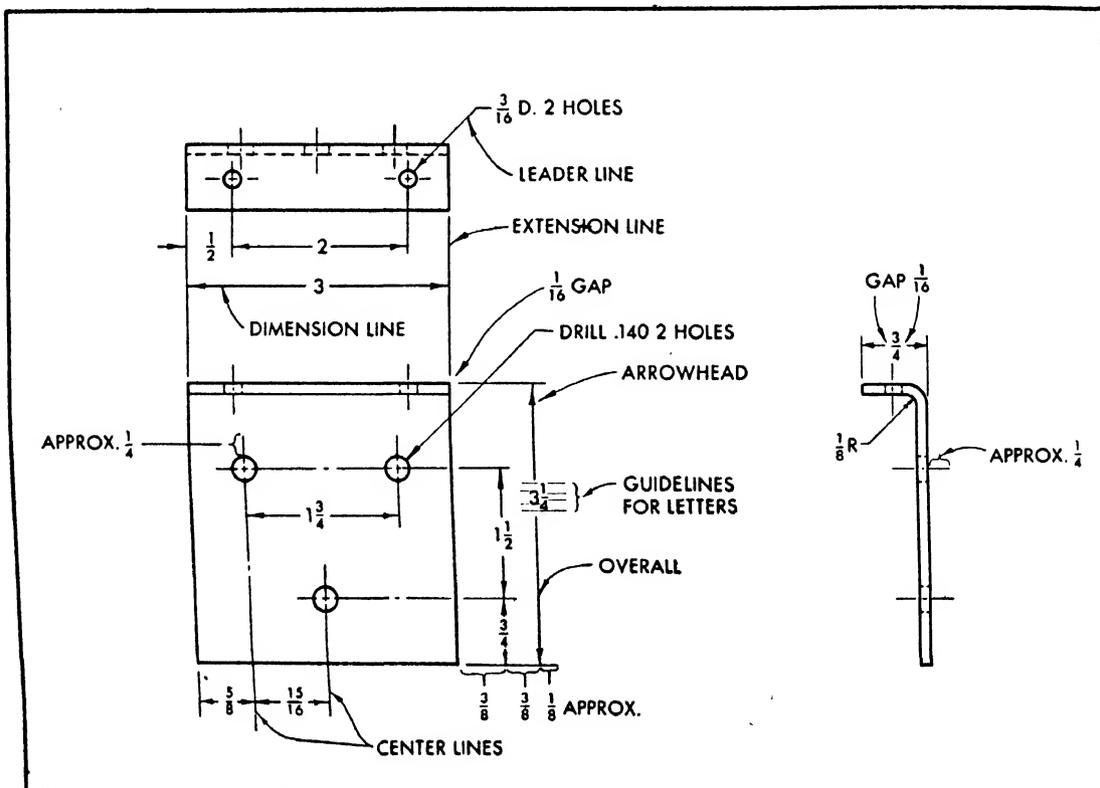


Fig. 203. Dimensioning analysis

section with a small prick punch which acts as a guide for the point of the drill bit. The next step is to drill the hole, and to do this the mechanic must know the diameter of the hole rather than the radius, because he must choose a particular drill bit known to him by its diameter. Should an inexperienced draftsman give dimensions between circumferences for location and radii for the sizes of the holes, what complications would occur!

Unfortunately work in the shop is not possible for most students. However, much shop information may be obtained from:

- Observing and analyzing fabricated parts
- Talking with intelligent workmen about methods of fabrication
- Using technical books in the library
- Subscribing to one or more of the fine trade journals in the aircraft field

Since each part presents its own dimensioning problems, it is not possible to give a series of rules covering every contingency, but one principle underlies all practice:

*Dimension parts to show how they should be made, not how they were drawn.*

**Lines and Symbols**

The lines and symbols used in dimensioning practice are illustrated in Fig. 203.

A DIMENSION LINE is a thin, sharp line, broken near its center to leave space for the numeral specifying the distance. As already noted (Chapter Four), the dimension line must be distinctly thinner than the object line so that it will contrast with and not confuse the shape description of the object. The dimension line is placed

approximately  $\frac{3}{8}$  inch from the object or from an adjacent dimension line. This distance may vary somewhat with the individual requirements of a drawing, but under no circumstances should it be so close as to confuse the shape of the object or make the numerals hard to read.

ARROWHEADS mark the ends of the dimension line. As shown in Fig. 204, an arrow head is about three and one-half times as long as it is wide, and may easily be drawn in three strokes. It must be solid black. The best arrowheads have slightly concave sides. Usually, an arrowhead is  $\frac{3}{16}$  inch long, but this length may vary according to the size and nature of the drawing. However, once the size is established, it must be consistent throughout the particular drawing. Good construction of arrowheads takes practice. Study the correct and incorrect examples shown in Fig. 205.

AN EXTENSION LINE is a thin, sharp line of the same intensity as the dimension line. As the name implies, it is used to extend the dimensions so that size specifications do not confuse shape description. The extension line should extend about  $\frac{1}{8}$  inch past the dimension line, and a gap of about  $\frac{1}{16}$  inch should be left between it and the outline of the object.

A CENTER LINE indicating the axis of a symmetrical object is a thin, sharp line constructed with alternate short and long dashes. Center lines are used as extension lines in locating holes and as important general reference lines. The center line should extend approximately  $\frac{1}{4}$  inch above and below the area to which it applies unless it is used as a regular extension line, in which case it extends beyond the outlines of the object.

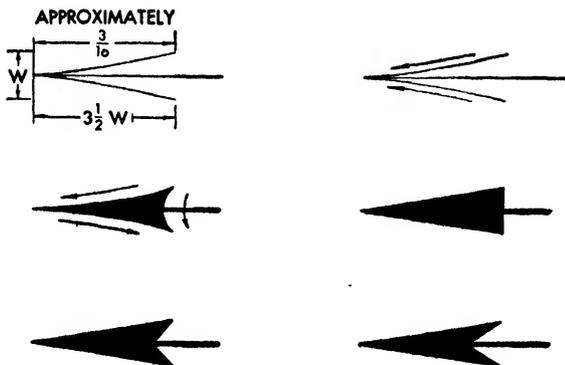


Fig. 204. Construction of arrowheads

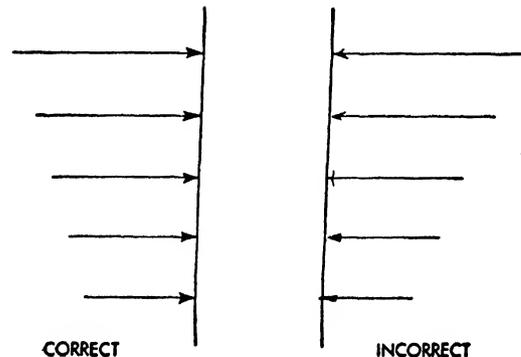


Fig. 205. Examples of arrowheads

EXAMPLES OF REFERENCE LINES  
PERTAINING TO AIRCRAFT



**BUTTOCK LINE**  
ANY IMAGINARY PLANE PASSING THROUGH THE AIRPLANE PARALLEL TO THE VERTICAL CENTER LINE OF THE PLANE IS TERMED A BUTTOCK LINE. A BUTTOCK LINE MAY BE EITHER "L" OR "R" DEPENDING WHETHER IT IS LOCATED IN THE LEFT OR RIGHT OF THE ZERO LINE (VERTICAL CENTER LINE) AND IS MEASURED BY ITS DISTANCE FROM THE ZERO LINE.



**WATER LINE**  
ANY IMAGINARY PLANE PASSING THROUGH THE AIRPLANE PARALLEL TO THE HORIZONTAL BASE LINE OF THE PLANE IS TERMED A WATER LINE. THE HORIZONTAL BASE LINE IS CALLED "W.L. 0". FIVE INCHES ABOVE THE ZERO LINE IS CALLED "W.L. +5" FIVE INCHES BELOW IS CALLED "W.L. -5".



**STATION LINE**  
ANY IMAGINARY PLANE PASSING THROUGH THE AIRPLANE PERPENDICULAR TO THE FUSelage REFERENCE LINE IS TERMED A STATION LINE. A STATION LINE IS MEASURED FROM THE DISTANCE IT IS LOCATED FROM THE NOSE OF THE PLANE. WING STATIONS ARE CREATED BY PASSING PLANES PARALLEL TO THE VERTICAL CENTER LINE OF THE PLANE AND ARE MEASURED OUTBOARD FROM THE CENTER LINE.

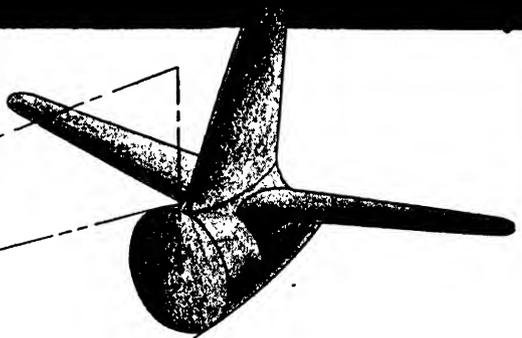
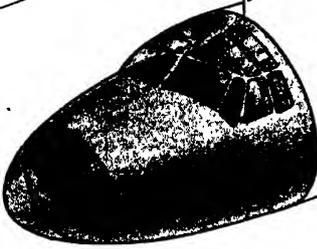
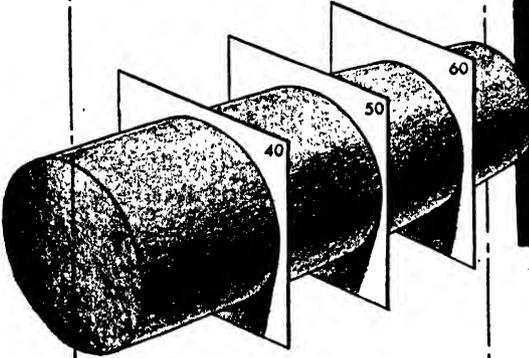
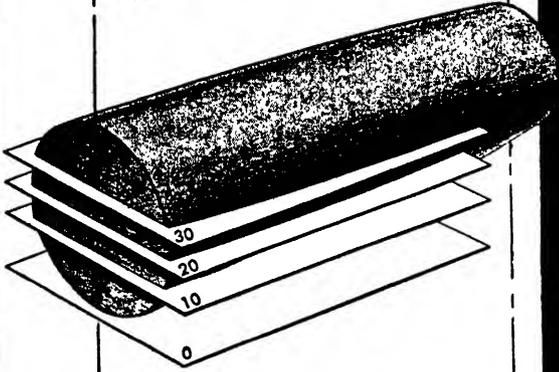
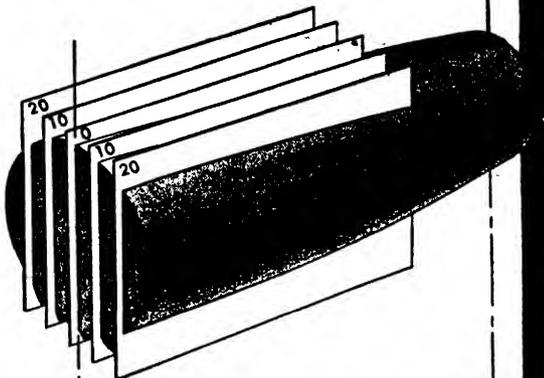


Fig. 206 (see p. 165)

A **LEADER LINE** is a fine, sharp line connecting a note to its related object. It ends with an arrow-head.

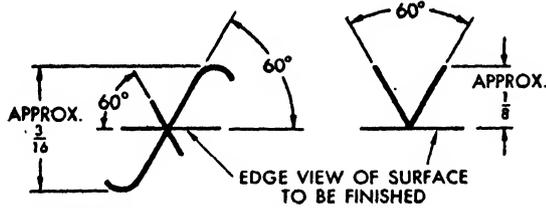


Fig. 207. Construction of finish marks

**AIRCRAFT REFERENCE LINES** are ingenious means for locating points in large areas of an airplane. As explained in Fig. 206, **BUTTOCK LINES**, **WATER LINES**, and **STATION LINES** are measured in inches from their respective zero lines. They are drawn as reference or phantom lines (see Chapter Four), and a numeral expressing the lines' distance from the zero line is placed within a  $\frac{5}{8}$  or  $\frac{3}{4}$  inch diameter circle at one end of the line. Some companies prefer to insert the numeral within a break made at the tail end of the line.

**FINISH MARKS** are used to indicate a surface that is to be machined smooth. The mark is placed only on the edge view of that surface. Either the older "f" or the more recent American Standard "V" may be used (see Fig. 207).

$\sqrt{R}$ ROUGH MACHINE FINISH	$\sqrt{G}$ GRIND
$\sqrt{V}$ SMOOTH MACHINE FINISH	$\sqrt{P}$ POLISH
$\sqrt{R,G}$ ROUGH GRIND	$\sqrt{F}$ FILE

AMERICAN STANDARD FINISH MARKS

Fig. 208

Fig. 206 (p. 164)

When the left and right sides of a fuselage drawing are noted and obvious, it is not necessary to specify buttock lines as L and R.

In many airplanes (especially concentric circular fuselage designs) water line O coincides with the horizontal centerline of the airplane, and the values are + or - relative to this line.

Some aircraft use the firewall or some point on the propeller spinner as station O, although most modern large planes retain the extreme forward tip or "nose point." When an aircraft wing is set at a dihedral angle (determined by the intersection of the jig reference line of the wing and the vertical centerline of the fuselage), the wing stations are normal to the jig reference line.

Various finishes may be indicated by the American Standard code (Fig. 208) or by a numeral inserted into a circle and attached to the end of the f mark (Fig. 209).

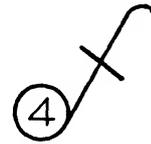


Fig. 209. The italic "f" finish mark and number attachment to designate a particular finish

*Rules for Using Lines*

Try to place extension lines so that they will not cross. If it is necessary to cross them, leave a break on one line at the intersection (see Fig. 210).

Never use an object line for a dimension line (see Fig. 211).

Extension lines should be perpendicular to the dimension lines. In some instances, however, you may construct oblique extension lines, as shown in Fig. 212.

Never draw a broken dimension line on a drawing interrupted by break lines (Fig. 213).

Do not use a center line or a reference line as a regular dimension line.

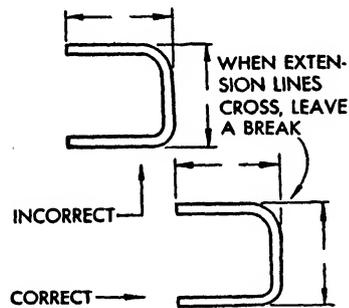
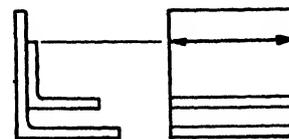
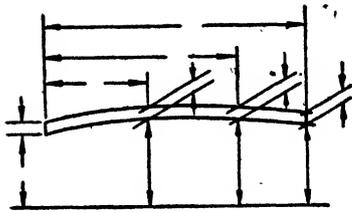


Fig. 210



NEVER USE AN OBJECT LINE FOR A DIMENSION LINE

Fig. 211



USE OF OBLIQUE  
EXTENSION LINES

Fig. 212

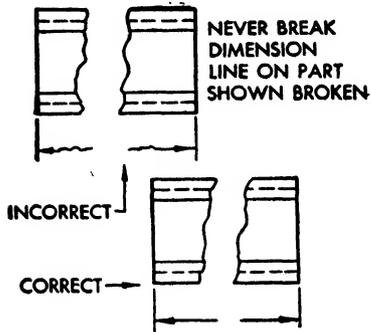


Fig. 213

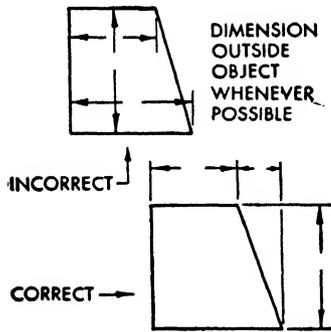


Fig. 214

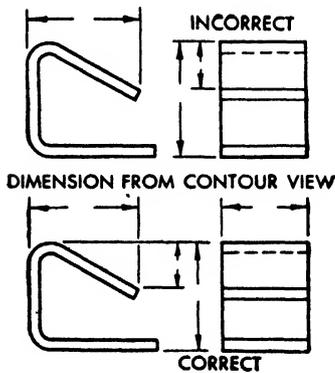


Fig. 215

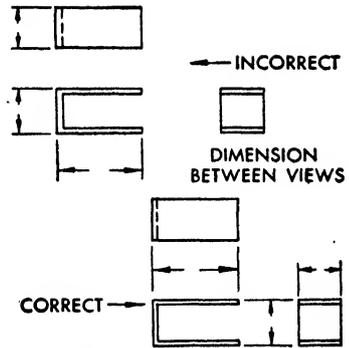


Fig. 216

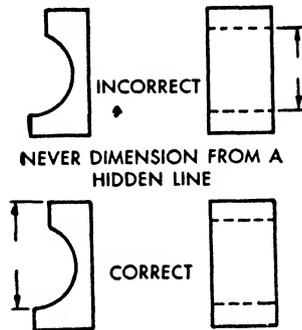


Fig. 217

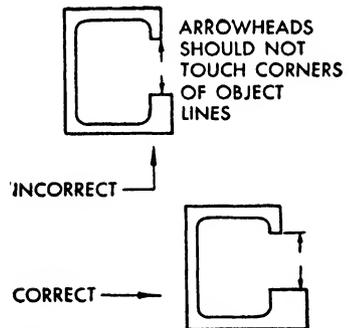


Fig. 218

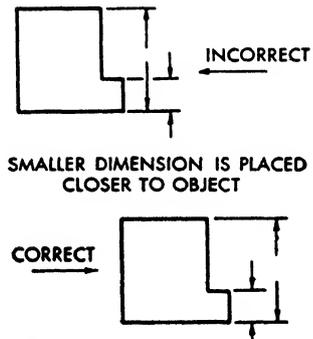


Fig. 219

*Placement of Dimensions*

Place the dimension lines outside the object whenever possible (Fig. 214). Dimensions drawn within a small part tend to distort the true shape of the part. This rule can be followed in most instances. On large drawings, however, dimensioning within the object may be unavoidable if the dimensions are to be close to the appropriate parts.

Place important dimensions adjacent to contour views. Since the principal view best de-

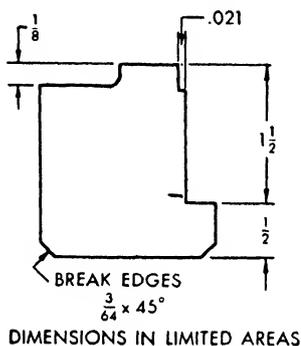


Fig. 220

scribes the shape of a part, the man in the shop will look to it first for important size specifications. The height and width of rectangular shapes are generally given in the front view and the depth in the side or top view (Fig. 215).

If possible place dimensions that pertain to two views between the two views (Fig. 216).

Do not dimension a hidden line when it is possible to dimension an object line (Fig. 217).

Do not crowd the arrowheads of dimension lines until they touch corners formed by object lines. Use extension lines (Fig. 218).

Place the smallest dimension closest to the object, and each increasing one progressively farther away (Fig. 219).

Do not crowd the numerals when space is

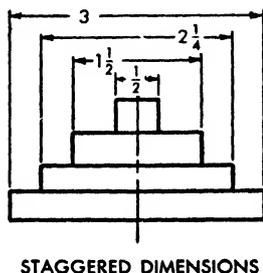


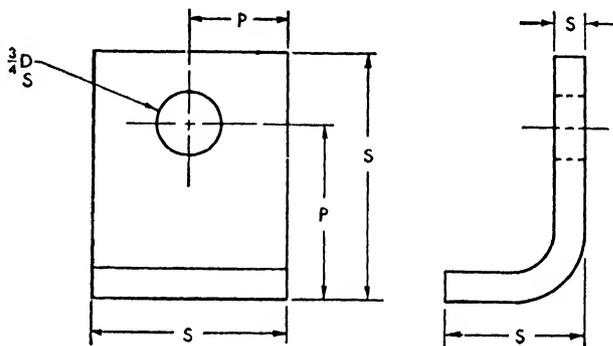
Fig. 221

limited. See Fig. 220 for practical suggestions.

For easier reading, stagger the numerals of dimensions placed above one another (Fig. 221).

*Principles of Aircraft Dimensioning*

Most designs of aircraft parts can be broken down into basic geometric shapes. Because the cross section of sheet metal parts remains constant and the material usually is thin, the shapes may be considered as plane geometric figures. Machined parts, castings, etc., may be expressed



THE APPLICATION OF SIZE DIMENSIONS (S) AND POSITION DIMENSIONS (P)

Fig. 222

as cones, cylinders, prisms, and other geometric solids (see Fig. 106).

Plane flat areas are created by milling, planing, or similar manufacturing processes, while circular shapes are the result of rotary motion, such as that of a shaft turned on a lathe or a hole drilled or punched.

The purpose of dimensioning is to specify the over-all size and component shapes within a part and to indicate the location of the component shapes. Hence, the hole shown in Fig. 222 is

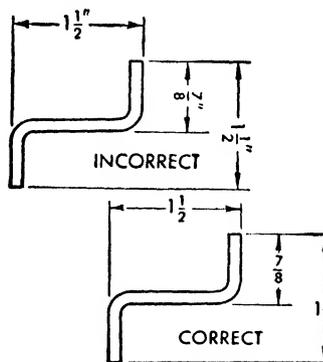


Fig. 223

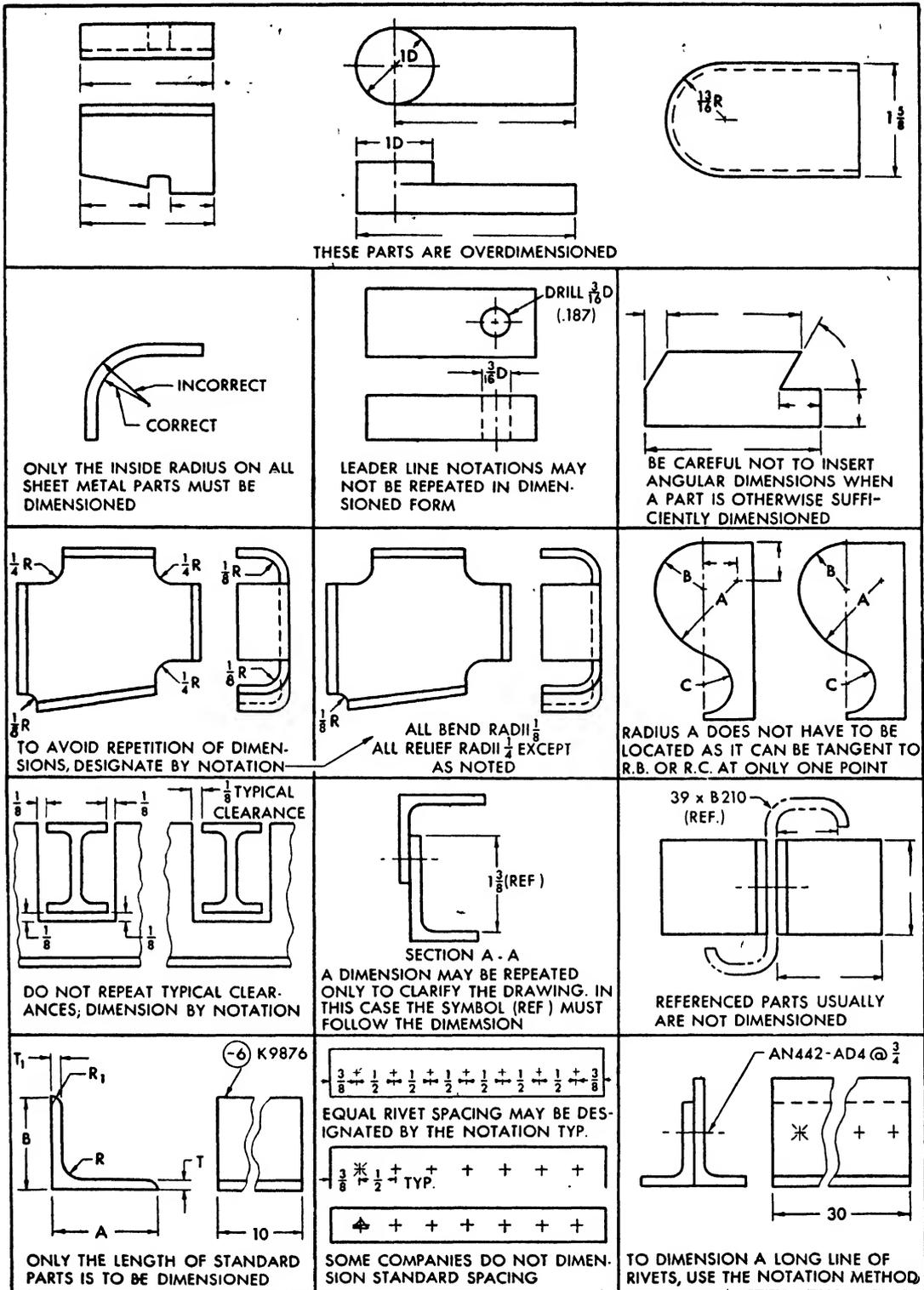


Fig. 224. Minimizing dimensions

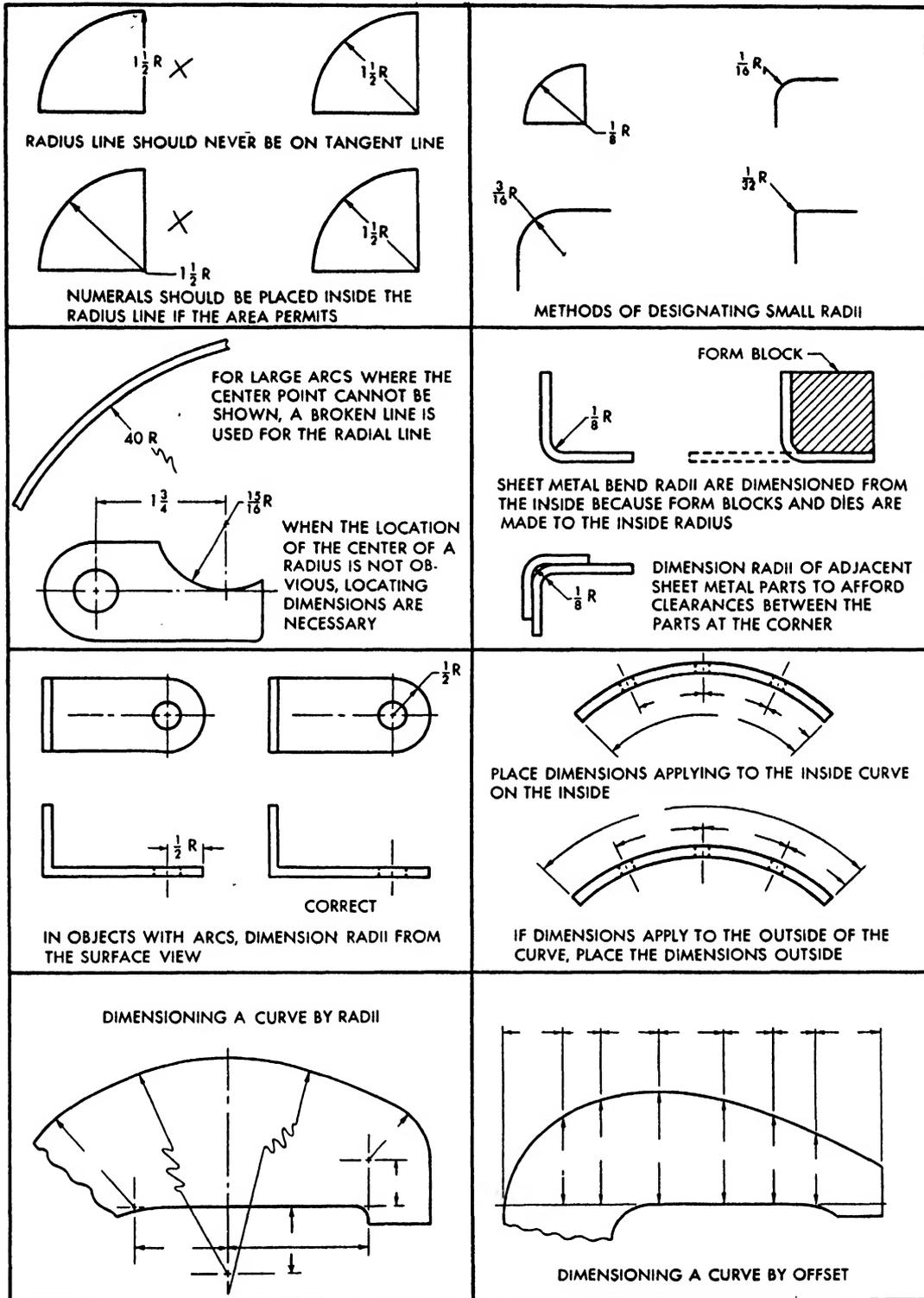


Fig. 225. Dimensioning curves

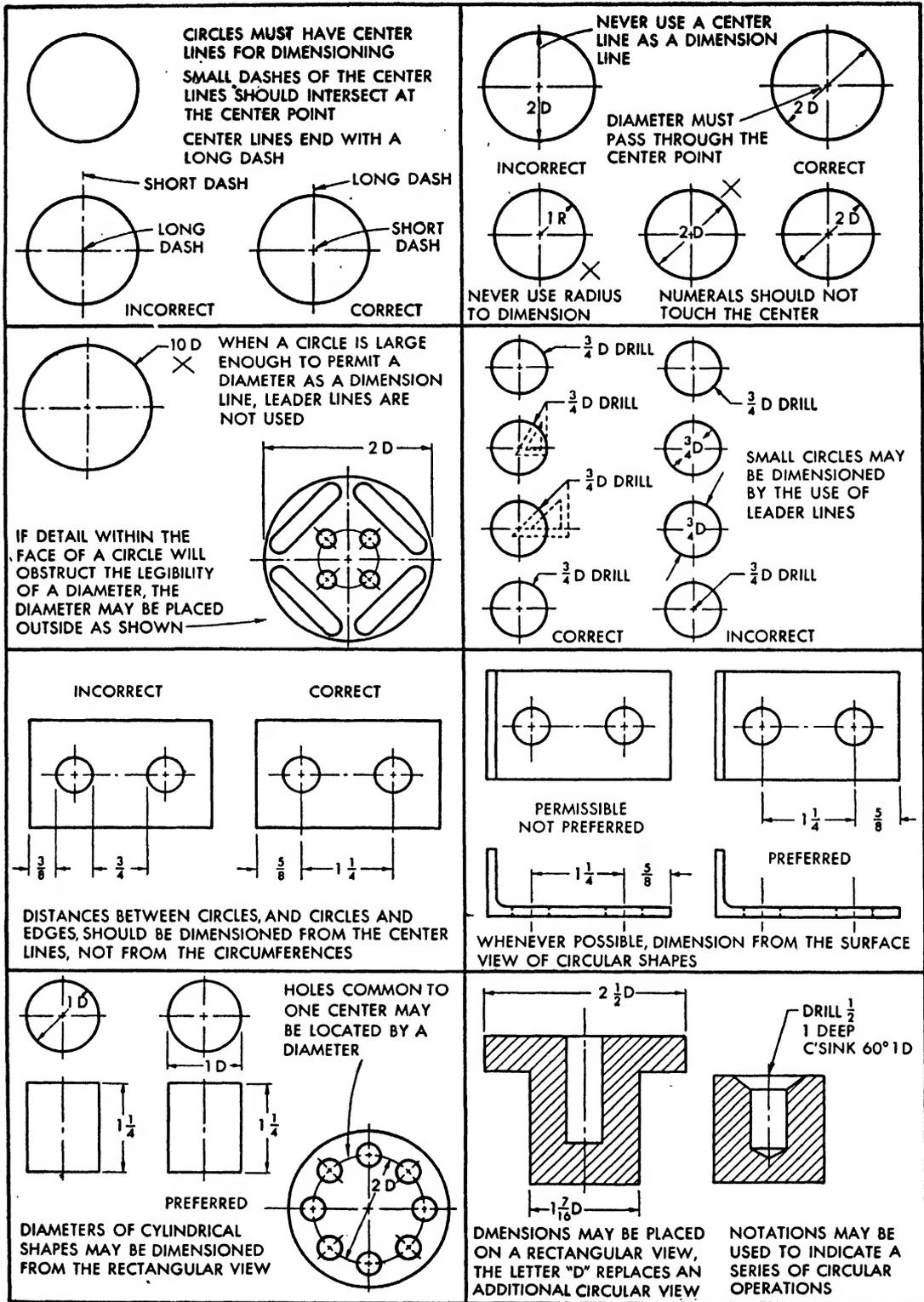


Fig. 226. Dimensioning circles and circular objects

specified by a *size* dimension as having a  $\frac{3}{4}$  inch diameter, while the location is indicated by a *position* dimension.

### *Aircraft Dimensioning Practices*

The following dimensioning practices are common among aircraft companies and characterize aircraft drafting:

All notations are lettered in upper case. Letters and numerals may be either vertical or inclined, depending on company preference.

All dimensions are in inches. Inch marks are not usually used. Such marks do appear, however, in the notation of a scale, for instance,  $6'' = 1'0''$ , and sometimes in the designation of 1 inch followed immediately by a word, for example,  $1''$  DIA.

Numerals are placed parallel to the bottom edge for legibility, whether the dimensions are horizontal, vertical, or angular (see Fig. 223).

Only really necessary dimensions are indicated. If there is a standard company practice for spacing rivets, beads, etc., such dimensions need not be entered. Dimensions are not repeated, and care is taken not to overdimension a part. If it is necessary to repeat a dimension on a large drawing, it is followed by a reference notation (REF), for example,  $17\frac{1}{2}$  (REF). If a dimension is repeated from another drawing (to clarify location) it is also followed by the notation (REF).

Notes are used to minimize the number of dimensions (see Fig. 224). For example, if all relief and bend radii are the same, the notation reads: **Note: ALL BEND RADII  $\frac{1}{8}$ . ALL RELIEF RADII  $\frac{3}{16}$ .** If all radii are equal, except one or two, the note is modified: **ALL BEND RADII  $\frac{1}{8}$  EXCEPT AS NOTED or ALL RELIEF RADII  $\frac{3}{16}$  UNLESS OTHERWISE NOTED.**

If a clearance of a cutout is standard, the notation should read:  $\frac{1}{8}$  TYPICAL CLEARANCE FOR CUTOUT.

Notes may also be used to give information and instruction, such as **DRILL #10 (.1935) 3 HOLES, SPOTFACE  $\frac{1}{2}$  DIAMETER.**

Notes save drafting time, but should not be used to replace important dimensions.

### *Dimensioning Curves*

Curves may be dimensioned by radii or off-

sets. If a circular arc is to be specified, a radius is employed. The radial line is broken like an ordinary dimension line to give space for the numeral. The numeral must always be followed by a small R. An arrowhead terminates the radial line as it touches the inside of the arc.

Large, irregular curves are dimensioned sometimes by a series of radii but more often by offsets that locate points which, when connected, produce the irregular curves or splines. Figure 225 illustrates various methods of dimensioning curves and radii.

### *Dimensioning Circles and Circular Objects*

Circles are dimensioned by their diameters. A diameter line drawn within the circle is broken at one side of the center for the numeral. Arrowheads terminate the diameter line at its points of contact with the circumference. This method is satisfactory for large circles, but in one view drawings, where the detail within the circle does not permit the placement of an inside diameter line, extension lines are projected from the extremities of the center lines and regular dimension lines are used (see Fig. 226).

Small circles are dimensioned by leader lines, with a note specifying the diameter. Circular operations, such as drilling, reaming, counter-boring, or countersinking, are also noted by leader lines the arrowheads of which touch the circumference of the hole concerned; the operation note is placed at the opposite end of the leader. The proper dimensioning of small holes is shown in Fig. 226.

Only two dimensions are necessary to establish the size of a cylinder: the diameter of its top circular face and the height. It is preferred practice to place the diameter dimension over a rectangular view rather than within a circular face. The rectangular view of a circular object contains the diameter dimension as a regular dimension line. In many instances it is not necessary to make an additional circular view.

In whatever manner a diameter is dimensioned, the numeral must always be followed by a small D or the abbreviation DIA.

### *Dimensioning Angles*

Angles may be dimensioned either by linear

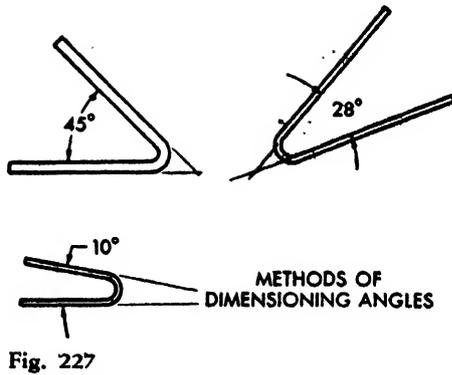


Fig. 227

measurements or by noting the distance between the lines in degrees.

When degrees are used, an arc of the same blackness as a dimension line is swung. It has a break to allow space for the numeral. The center of the circular arc is the intersection point of the two lines that form the dimensioned angle. Arrowheads terminate the arc at its points of contact with the sides of the angle. For illustrations, see Figs. 227 and 228.

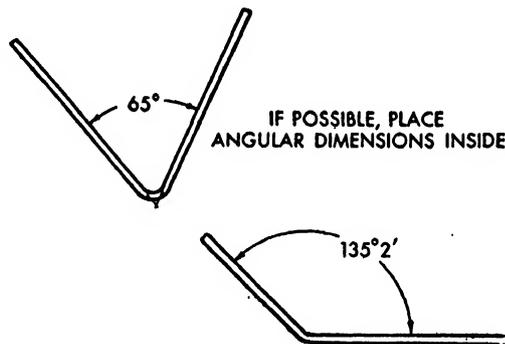


Fig. 228

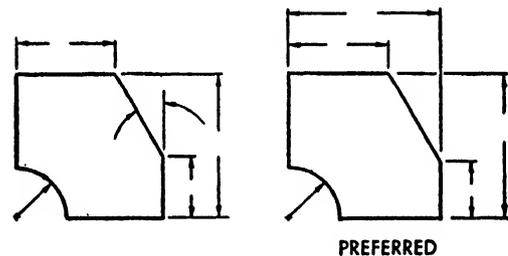
The offset or linear method is generally used for dimensioning angles on flat sheet metal work (Fig. 229). Degrees are used, however, to indicate the angle enclosed by the bend of a sheet metal object. Machined cuts on flat surfaces are sometimes dimensioned both by degrees and by offset, the angle being used as a reference dimension. Such treatment is customary for parts set up for milling operations.

#### Method of Approach

"What shall I dimension first?" is a common question among students. Usually, the center line or the baseline is the basis for dimensioning. Figure 230(a) illustrates dimensioning from a center line, typical of many sheet metal parts.

The loft will first establish the vertical center line and determine the dimensions of the entire shape by working from that line with radii and tangent lines. As shown in Fig. 230(b), noncircular as well as circular objects may be dimensioned from a center line.

Dimensioning of machined parts may start from the baseline, usually the edge of a finished, smooth surface. Flat or rectangular sheet metal shapes are commonly dimensioned from a side or end unless a center line distance must be held, as in the left view of Fig. 230(c). Figure 230(d) shows the application of baseline dimensioning. Dimensions may be progressive, consecutive, or both. **PROGRESSIVE DIMENSIONS** are so called because each dimension is based on a common line, such as the center line of Fig. 230c or the right-hand and bottom baselines of Fig. 230d. Increasing dimensions are placed progressively farther from the object. This principle may be violated when it is more convenient to note a



LINEAR DIMENSIONS ARE PREFERRED TO ANGULAR DIMENSIONS IN OFFSETS

Fig. 229

larger dimension first so that it may be closer to the particular portion it denotes.

This is an accurate method of dimensioning, for it isolates each individual dimension and avoids accumulation of tolerances and errors.

**CONSECUTIVE OR INTERMEDIATE DIMENSIONS** are the components of an over-all dimension. They follow one another as shown in Figs. 230(e) and 230(f).

A **CLOSED** dimension is one that contains a series of complete intermediate dimensions and an over-all dimension as well. This method is not recommended. In almost every part, especially a sheet metal one, there is one dimension that is not critical. If over-all and consecutive dimensions are used, this noncritical dimension



should be omitted. The omitted dimension supplies an outlet for the accumulated tolerances. The over-all dimension is, of course, controlling.

#### *Location of Dimension on Assembly and Installation Drawings*

When holes, cutouts, fasteners, details, etc., must be located in an assembly, the dimensions of the location should be set off from some measurable point on the largest member in the assembly, or from a station line or some other convenient reference line (Fig. 206). Usually assemblies are located on installation drawings by dimensioning from a reference line.

#### *Limits on Sheet Metal*

The engineer may instruct the man in the shop to make a sheet metal clip 2 inches wide, but inevitable errors in the manufacturing process will modify slightly the width of the actual part. To be functional, dimensioning must take this anticipated error into account and allow a permissible variation from the given dimensions. The specific degree of error that may be tolerated is noted in the bill of materials under "Limits on Dimensions," for example,  $\pm \frac{1}{32}$ . The plus and minus signs indicate that the dimension may be  $\frac{1}{32}$  inch larger or smaller than the given one. Hence, the clip mentioned may be specified as 2 inches wide on the drawing, but will pass inspection if it measures actually  $1\frac{31}{32}$  inches or  $2\frac{1}{32}$  inches.

The amount of leeway given the shop in dimensions of a particular part depends on the degree of accuracy required for the successful functioning of the part. Since sheet metal parts usually do not need close fitting, dimensions are given in common fractional parts of an inch, such as  $\frac{3}{8}$ ,  $\frac{5}{16}$ , or  $\frac{1}{4}$ . In general, thirty-seconds of an inch are the smallest fractions used, although occasionally sixty-fourths of an inch may be employed.

A common limit on linear dimensions of sheet metal parts is  $\pm \frac{1}{32}$  inch and on angular dimensions  $\pm \frac{1}{2}$  degree. It is extremely difficult to maintain a greater accuracy in sheet metal angles. It is obvious that the greater the accuracy required, the greater the time and effort

necessary in the production process. Forcing a mechanic to adhere to extremely close tolerances when a part will function just as well with a more liberal degree of variation wastes manufacturing time and is uneconomical.

Decimal fractions are generally used to express tolerances of sheet metal contour parts and of mating holes, as these require accurate fitting. Some aircraft companies dimension their drawings entirely in decimals. This practice is limited to only a few companies.

#### *Limits on Machined Parts*

Dimensioning regulates the proper mating of machined parts so that sufficient clearance or leeway is provided for smooth operation. Dimensioning also supplies a system of specifications which permit the mass manufacture of parts, providing for the advantages of interchangeability.

Because of the nature of the materials used, the exact processes of manufacture, and the scientific measurements possible, machined parts today can be made to extremely close tolerances. For the sake of greater accuracy, decimal fractions are used in measurement. Hence,  $\frac{1}{2}$  inch is expressed as 0.5000 inch and may be given an expected accuracy of 0.0001 (one ten-thousandth inch). Or the same dimension may be expressed to three places only, as 0.500, with an expected accuracy of 0.001.

The following terms must be well understood before machined parts can be dimensioned successfully:

**STANDARD SIZES** are those indicated by common fractions, customary in the dimensioning of sheet metal parts. When machined parts are dimensioned in fractions, it means that no great accuracy is required.

**NOMINAL SIZES** are close approximations to standard sizes without specific limits of accuracy.

**BASIC SIZE** is the exact size without any tolerances and is an indication of great accuracy. Basic size dimensions are expressed in decimal fractions.

**ALLOWANCE** is the difference between mating parts or the minimum amount of play allowed between mating parts. Allowance, for example, describes the difference between the maximum diameter of a shaft and the minimum diameter of a hole. A bolt shaft machined to a diameter of 0.756 and

the bolt hole to a diameter of 0.757 gives a difference of 0.001 between the two members, which means that the intentional degree of play is 0.001 inch.

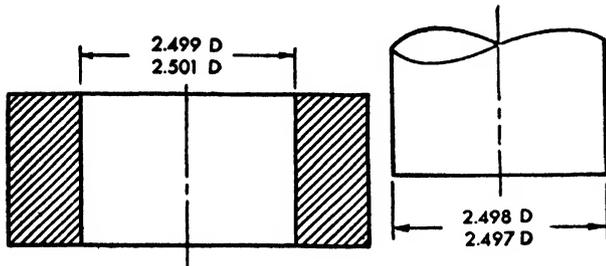


Fig. 231. Limits

LIMITS designate the maximum range of variations allowable in a dimension. The limits in shafting are the greatest and the smallest diameter of the hole and of the shaft. A shaft may be dimensioned as  $0.756 \begin{smallmatrix} +0.005 \\ -0.001 \end{smallmatrix}$ . By adding 0.005 to the basic dimension, 0.756, we determine the maximum limit of the shaft as 0.761. By subtracting 0.001, we determine the minimum limit, 0.755. Limits placed on a drawing are shown in Fig. 231. Two diameters are given. The smaller dimension of the hole is placed on top, because a hole gets larger as it is worked on. For the shaft, the larger dimension appears on top, since the shaft gets smaller as it is turned. The limits may also be shown by tolerances, as illustrated in Fig. 232.

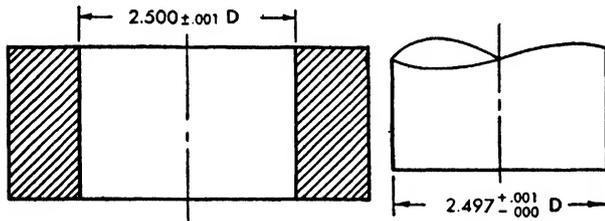


Fig. 232. Limits by tolerance

TOLERANCE is the degree of permissible variation in a dimension, beyond which the part must be scrapped or reworked. If a hole is dimensioned as  $0.750 \begin{smallmatrix} +0.001 \\ -0.000 \end{smallmatrix}$  and the shaft as  $0.749 \begin{smallmatrix} +0.000 \\ -0.001 \end{smallmatrix}$ , the tightest fit would be 0.750 for the hole and 0.749 for the shaft, with a clearance of 0.001. The loosest fit would be 0.751 for the hole and 0.748 for the shaft, or a clearance of 0.003. Any fit between these two limits is acceptable.

To find the tolerance of an over-all dimension when intermediate dimensions are given, the following method is employed:

Add all the basic dimensions. Add all the plus tolerances and all the minus tolerances separately. Using Fig. 233 as an example:

0.750	+0.003	-0.002
0.325	+0.003	-0.003
1.125	+0.002	-0.002
<hr/>		
2.200	+0.008	-0.007

The total over-all dimension is  $2.200 + 0.008 - 0.007$ .

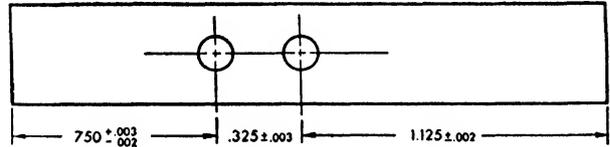


Fig. 233

Various classes of fits have been established by the American Standards Association, along with tables regulating the limits of these fits. The classifications of fits follow; the tables may be obtained from any aircraft company, school, or library.

#### CLASSIFICATION OF FITS<sup>1</sup>

- LOOSE FIT (CLASS 1). Large Allowance, Interchangeable—This fit provides for considerable freedom and embraces certain fits where accuracy is not essential.
- FREE FIT (CLASS 2). Liberal Allowance, Interchangeable—For running fits with speeds of 600 r.p.m. or over, and journal pressures of 600 pounds per square inch or over.
- MEDIUM FIT (CLASS 3). Medium Allowance, Interchangeable—For running fits under 600 r.p.m. and with journal pressures less than 600 pounds per square inch; also for sliding fits, and the more accurate machine-tool and automotive parts.
- SNUG FIT (CLASS 4). Zero Allowance, Interchangeable—This is the closest fit which can be assembled by hand and necessitates work of considerable precision. It should be used where no perceptible shake is permissible and where moving parts are not intended to move freely under load.
- WRINGING FIT (CLASS 5). Zero to Negative Allowance, Selective Assembly—This is also known as a "tunking fit" and it is practically metal-to-metal. Assembly is usually selective and not interchangeable.
- TIGHT FIT (CLASS 6). Slight Negative Allowance, Selective Assembly—Light pressure is required to assemble these fits, and the parts are more or less permanently assembled, such as the fixed ends of studs for gears, pulleys, rocker arms, etc.
- MEDIUM FORCE FIT (CLASS 7). Slight Negative Allowance, Selective Assembly—Slight Negative Allowance—Considerable pressure is required to assemble these fits, and the parts are considered

<sup>1</sup> From American Standard ASA B 4a.

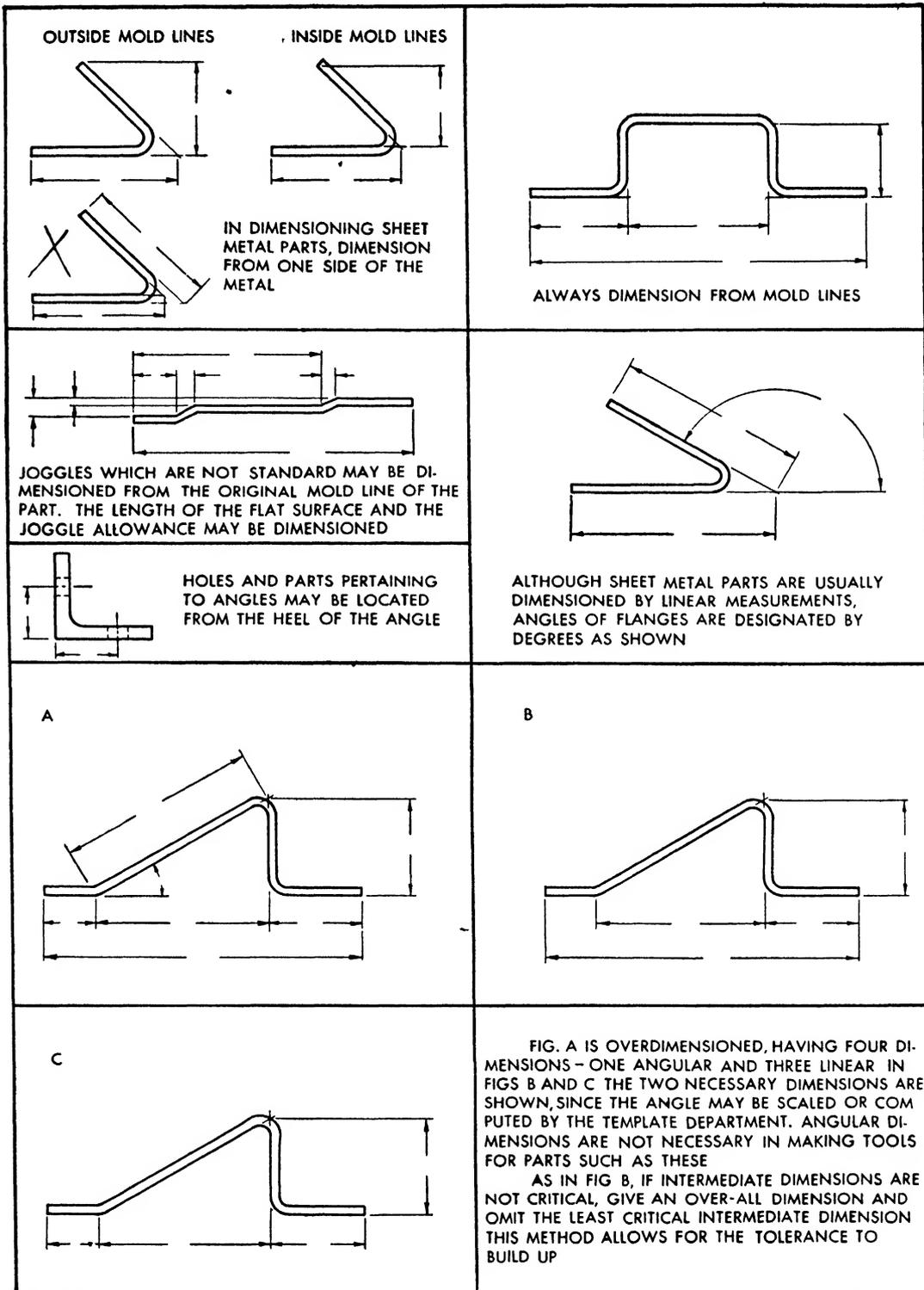


Fig. 234 Dimensioning

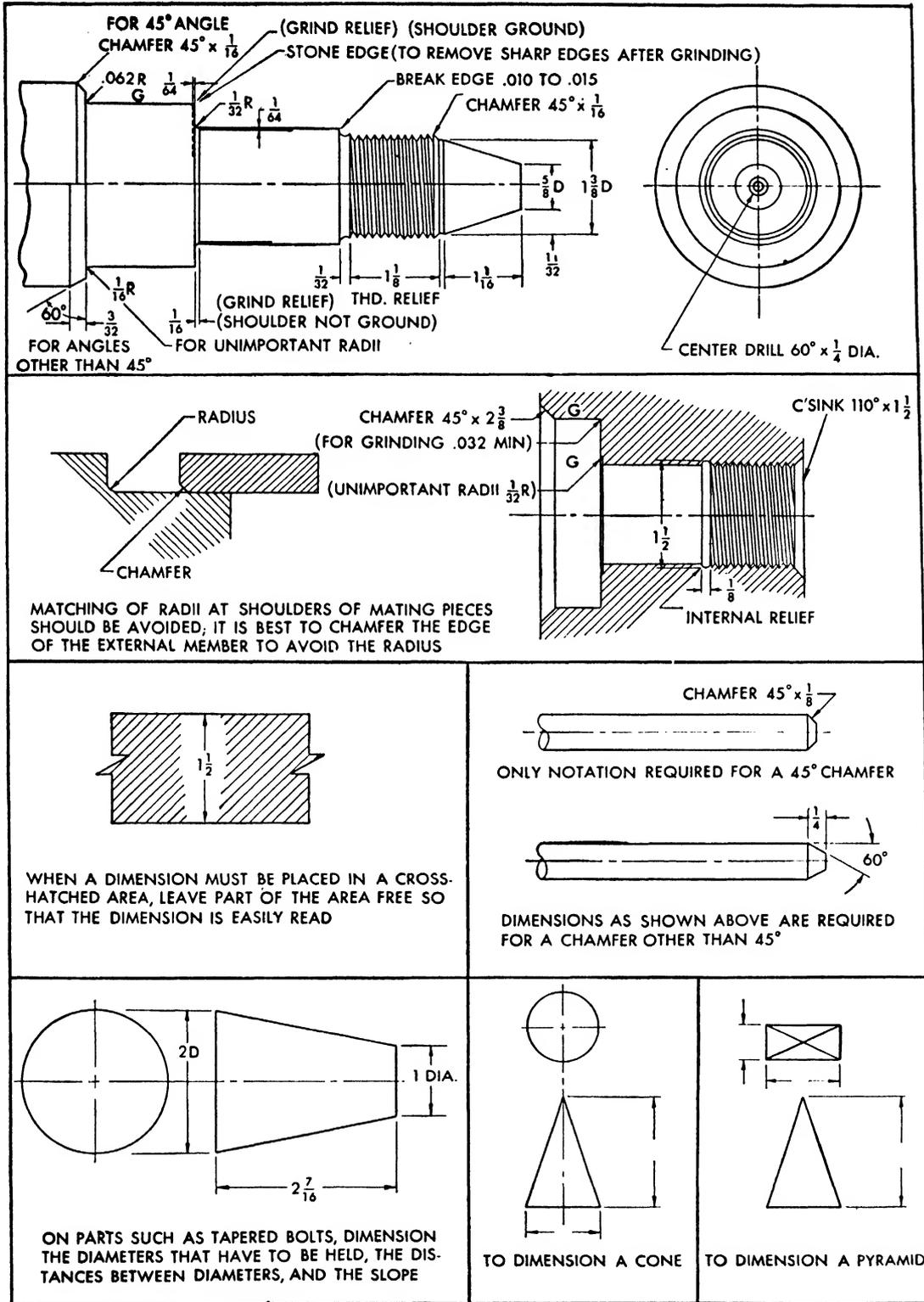


Fig. 235

permanently assembled. These fits are used in fastening locomotive wheels, car wheels, armatures on dynamos and motors, and crank disks to their axles or shafts.

**HEAVY FORCE AND SHRINK FIT (CLASS 8).** Considerable Negative Allowance—These fits are used for steel holes where the metal can be highly stressed without exceeding its elastic limit. These fits cause excessive stress for cast-iron holes. Shrink fits are used where heavy force fits are impractical, as on locomotive wheel tires, heavy crank disks of large engines, etc.

#### DIMENSIONING SHEET METAL

Most of the rules discussed in this chapter apply to drawings of sheet metal parts. Additional characteristics of sheet metal dimensioning are described in Fig. 234.

Angular sheet metal views are dimensioned from mold lines. The mold lines are created by continuing the straight sides of the object with extension lines or by continuing the tangent lines with extension lines past the bend radii, as shown in Fig. 234. Either the inside or the outside mold lines may be used, but any one drawing should be dimensioned consistently to one side of the metal.

Some aircraft companies prefer dimensioning flanged parts to the inside of the bend to facilitate the fabrication and checking of the forming dies.

#### DIMENSIONING MACHINED PARTS

Because of mass production and the interchangeability of parts, each machined part must be dimensioned completely, without reference to any other part. Machined parts may be dimensioned in common fractions, but when greater accuracy is desired, decimals carried to at least three places should be used. Baseline dimensioning from finished surfaces is usually expressed in decimals. Figure 235 shows notations to drawings of machined parts.

Usually, on the drawing of a casting or a forging it is possible to show the rough edge from which the first machining will be measured. All other machined surfaces should be dimensioned in reference to this basic surface.

Most aircraft companies issue design standards and rules for dimensioning commonly contained in a booklet or drawing room manual (D.R.M.).

## CHAPTER TWELVE

# PICTORIAL DRAWING

### *Introduction*

The average student draftsman shys away from "picture drawing" and feels that only a gifted few are capable of executing drawings "in the round." A natural talent is of unquestionable advantage, but with practice any intelligent person can learn to draw pictorially.

"One picture is worth ten thousand words," is an old adage among engineers. Drafting room shop talk always involves a pencil and a scratch

pad. A quick sketch can illustrate and answer readily and intelligently such questions as: "Can I cut this flange this way?" "Is this a good idea?" or "Does it look like this?"

Pictorial drawing serves two distinct functions. It is a tool in the hands of the draftsman engineer who develops designs, and it aids the shop to produce a part.

The skilled pictorial draftsman develops a keen sense of visualization and, in consequence,



**Fig. 236. Pictorial draftsman**

becomes more adept at engineering drawing. He can express himself when triangles, straightedges, and other mechanical devices are not at hand. He is a competent and efficient craftsman.

Pictorial representations are often needed in the course of regular orthographic drawing. Although subsidiary to working drawings, effective pictorial representations have saved countless man hours in engineering departments. Good pictorial drawings of large assemblies enable the design engineer to visualize the various steps he must express in orthographic drawings. General changes and reconsiderations may be noted quickly without tedious scrutiny of complicated blueprints.

Pictorial drawings are used to coordinate the various design groups. An airplane design is worked out by many specific groups of draftsmen. Each group (wing, fuselage, controls, electrical, etc.) works independently, absorbed with its own particular problems. However, the fuselage group, for example, may be asked for pictorial drawings so that the electrical, controls,

and armament groups may get an over-all picture of the fuselage that will help them to determine clearances, accessibility, placement of apparatus and cables, etc.

Pictorial drawings are also used by engineering departments to work out preliminary and basic designs of the airplane and to represent assemblies and objects like the schematic diagram of an air speed piping system (Fig. 237) that are hard to understand orthographically.

PRODUCTION ILLUSTRATIONS are the pictorial drawings used in the shop to expedite production. This type of illustration is particularly useful in the aircraft industry where, at times, blueprints become complicated and difficult to interpret. In fact, production illustration is becoming a specialized and permanent branch of engineering drawing. Workmen untrained in blueprint reading, or with limited constructive imagination, can still assemble certain parts if they follow the instructions set forth in these illustrations.

These drawings are employed primarily to

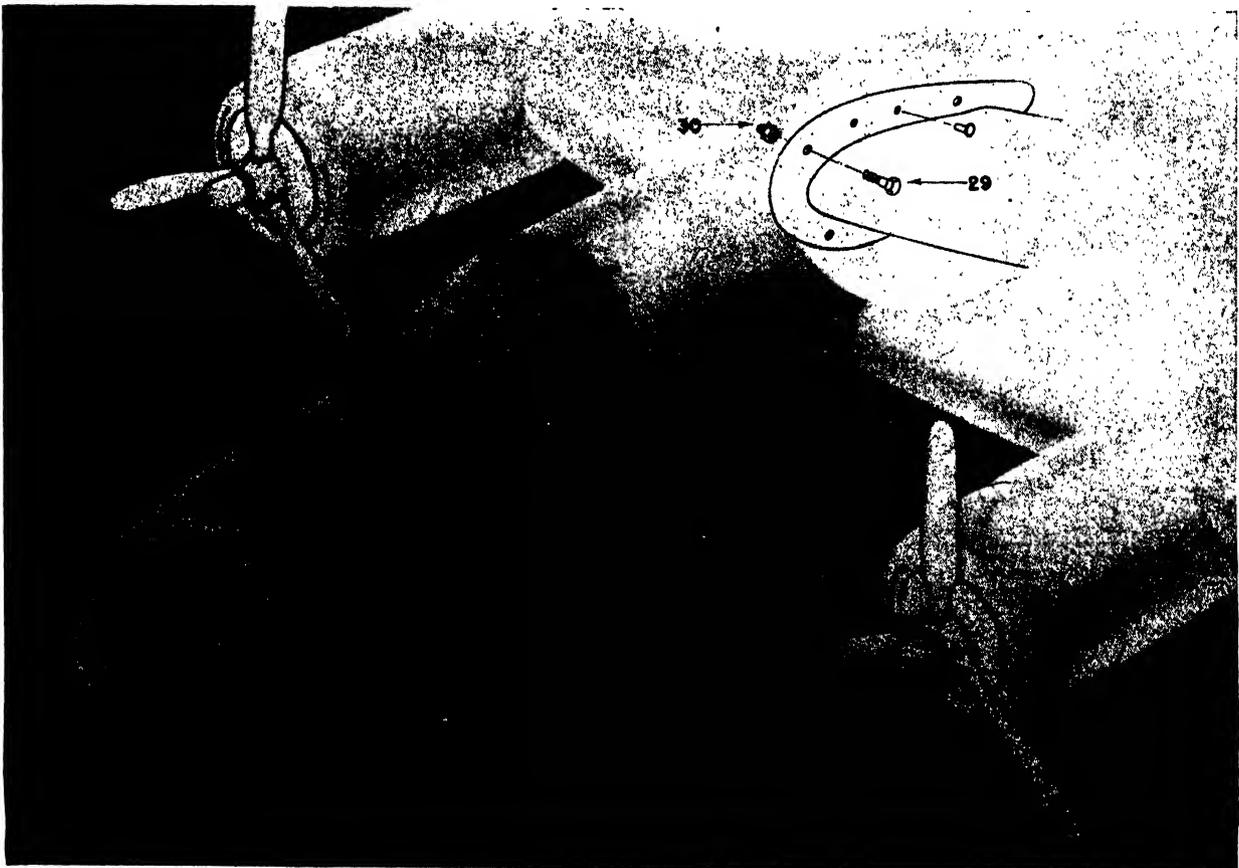


Fig. 237. Airspeed piping diagram

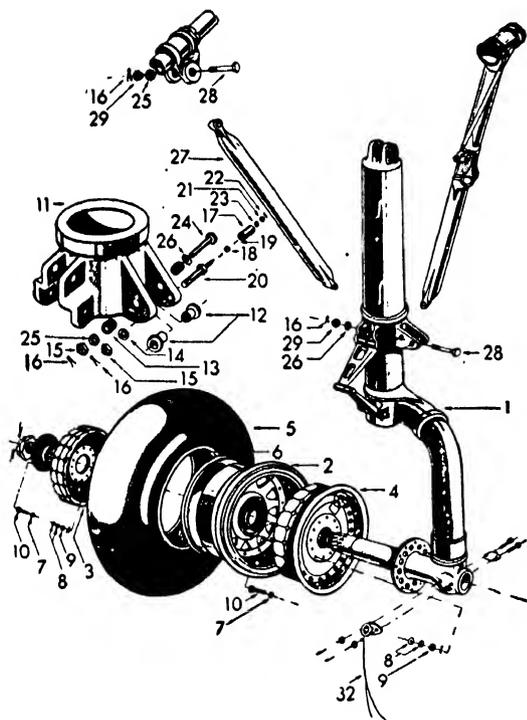


Fig. 238. "Exploded" view of main landing gear wheel and brake

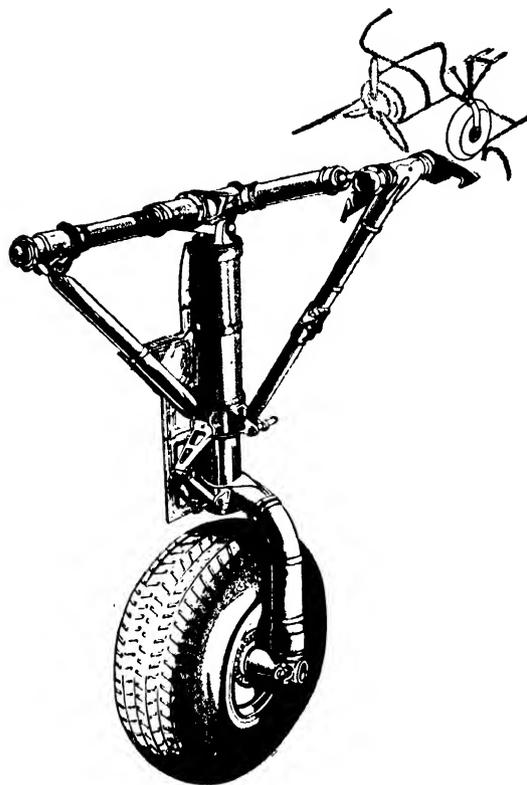


Fig. 239. Main landing gear assembled

help the inexperienced workman on the production line to see the position of each part and its final role in the assembled structure.

Probably the two most popular forms of production illustrations are the EXPLODED and the ASSEMBLY types. Such an illustration of an assembly, a fixture, or an installation tells a story. It reveals the outward appearance of the object and the inner assemblage of nuts, springs, wires, etc. The main landing gear in Fig. 238, for example, is exploded or blown apart. Each shaft, bolt, nut, fitting, etc., is drawn to show the proper interrelationship and its position in the assembly. Figure 239 represents the completely assembled landing gear as seen from the outside.

In some drawings, the external covering is cut away to reveal internal construction and detail. An example of this exposed type of drawing is shown in the wing center section in Fig. 240.

Service and maintenance manuals and parts catalogues are profusely illustrated with schematic, assembly, and exploded drawings.

Essentially, these manuals are textbooks for the proper servicing, maintenance, and repair

of plane assemblies and parts. Figure 241 shows a typical manual drawing, showing the exploded and assembled views of a brake valve and de-boost器 as well as its location in the plane. The drawings are presented clearly and simply, with each component piece designated by a lead line indicating the part and its name or by a key, a number, or a symbol drawn at the end of the lead line and repeated, with the part name, at the bottom of the drawing.

As in orthographic drawing, where dexterity must be combined with at least rudimentary engineering knowledge, the best production illustrations are made, not by authentic "artists," but by engineer illustrators. Skill in pictorial drawing must always be accompanied by ability in orthographic drawing and by an understanding of the subject matter. A mechanic can draw a far more correct representation of a cylinder head than can an artist who is rather hazy about its exact function.

This chapter deals with the mechanics of isometric, oblique, and perspective drawing. The different construction principles are ex-

plained, but many of the theoretical complications are eliminated.

Practice the mechanical application of every principle, but make a freehand study for each, as well.

### Isometric Projection

Isometric drawing combines realism of shape with specification of size. It permits the presentation of three surfaces of an object in one view and the dimensioning of certain lines. Conscientious practice of isometric drawing will lead to skill in freehand sketching.

For isometric projections, the principal edges of the object are placed at equal angles to the plane of projection and are thus equally foreshortened. The positions of the object and the

plane of projection which will meet this requirement may be determined by revolving the object relative to the plane of projection.

The principle of isometric projection is described in Fig. 242. Three orthographic views of a book resting on a table are shown in Fig. 242a.

In Fig. 242b the book is turned at an angle of about 45 degrees, with two sides visible.

Figure 242c presents the book tipped forward to reveal three sides forming equal angles with the front projection plane. The three edges AE, AB, and AC converge at the front corner and form equal angles of 120 degrees with each other.

### Isometric Drawing

The method of drawing an isometric rectangle is shown in Fig. 243. (The 30 by 60 degree

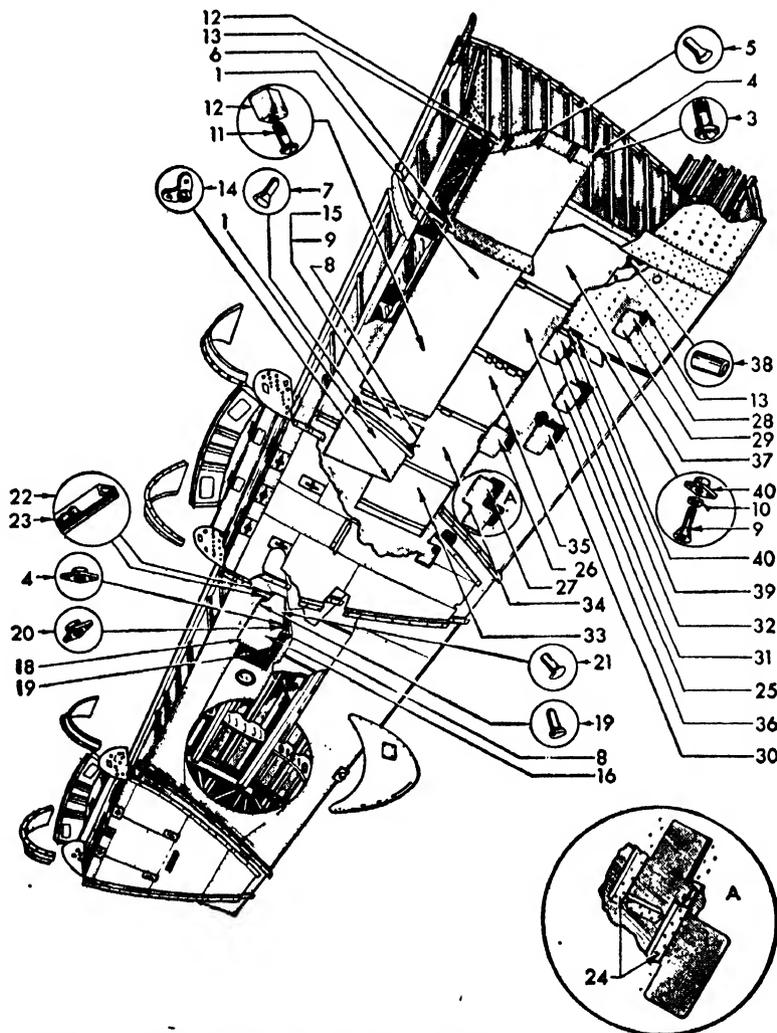


Fig. 240. Cutaway drawing of wing center section

triangle and the regular architectural scale are used.) This is termed an "isometric drawing" rather than an "isometric projection" since it does not retain the true isometric angle and scale. Practically all aircraft isometrics are made in this manner, because they are pictorially adequate and can be drawn with simple instruments.

Follow these rules in isometric drawing:

Keep in mind the construction of the three principal planes.

Measure only isometric lines.

Add hidden lines only if they clarify the drawing.

*Locating Rectangular Objects*

Figure 244 describes the method of locating the relative positions of two or more rectangles in one unit with the help of two isometric axes.

*Nonisometric Lines*

Figure 245a shows isometric axes meeting at corner A, forming angles of 120 degrees. By employing this construction principle, we can draw a cube isometrically on the basis of an orthographic drawing in which all planes and lines meet at 90 degrees. In Fig. 245b we find that line AB does not encounter the other lines of the prism at 90 degrees and is not parallel to

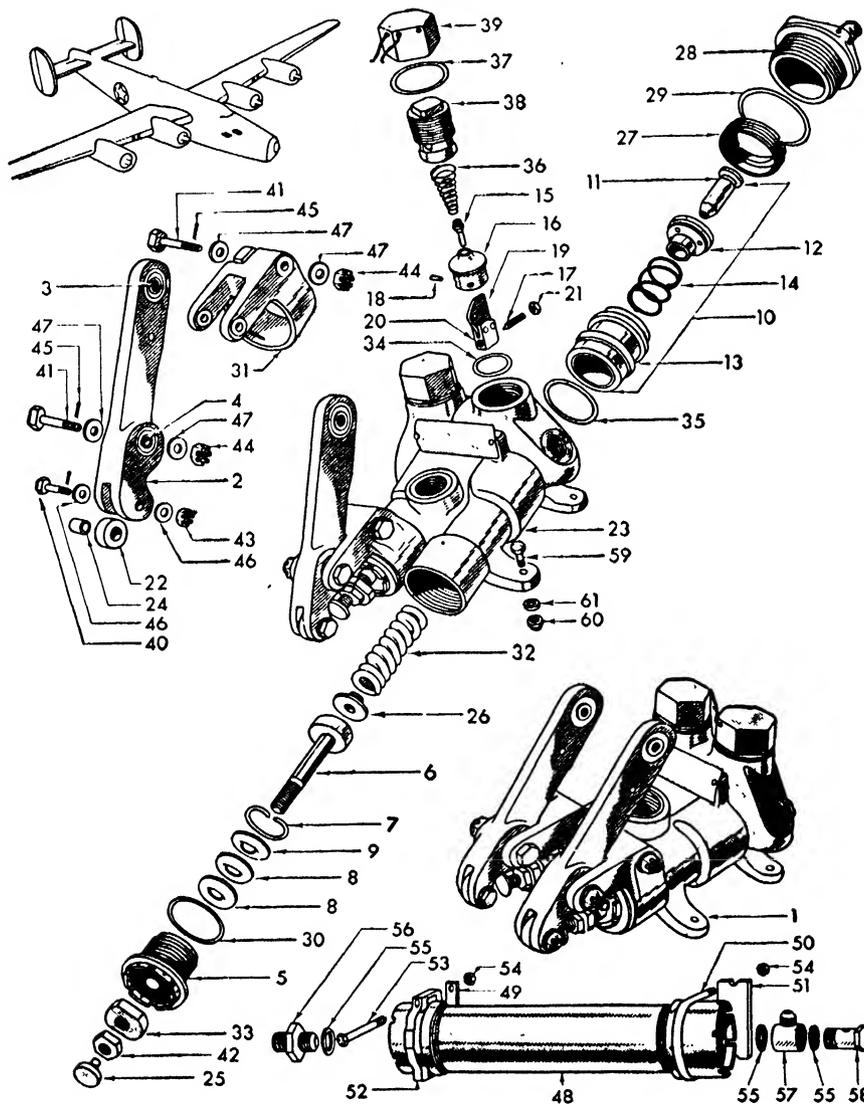


Fig. 241. Manual drawing of brake valve and booster

the isometric axes. Any line not parallel to the isometric axes cannot be measured isometrically and does not appear in its true length on the drawing. These are called "nonisometric lines" and must be located by establishing contact points. As illustrated, the line AB is located from its contact point A on the side of the isometric box.

*Box Method.* When an object contains several nonisometric lines, it must be drawn either by

the box or by the offset method. In the first, the object is enclosed in an imaginary rectangular box, as in the orthographic views of the object. (See Fig. 246b.) The box is then drawn isometrically, and the object is located by its contact points as in Fig. 246b and Fig. 247. In general, this method is employed for objects with nonisometric lines in isometric planes. As shown in Fig. 248, parts may have rectangular projections or recesses with one or more sides coincident to

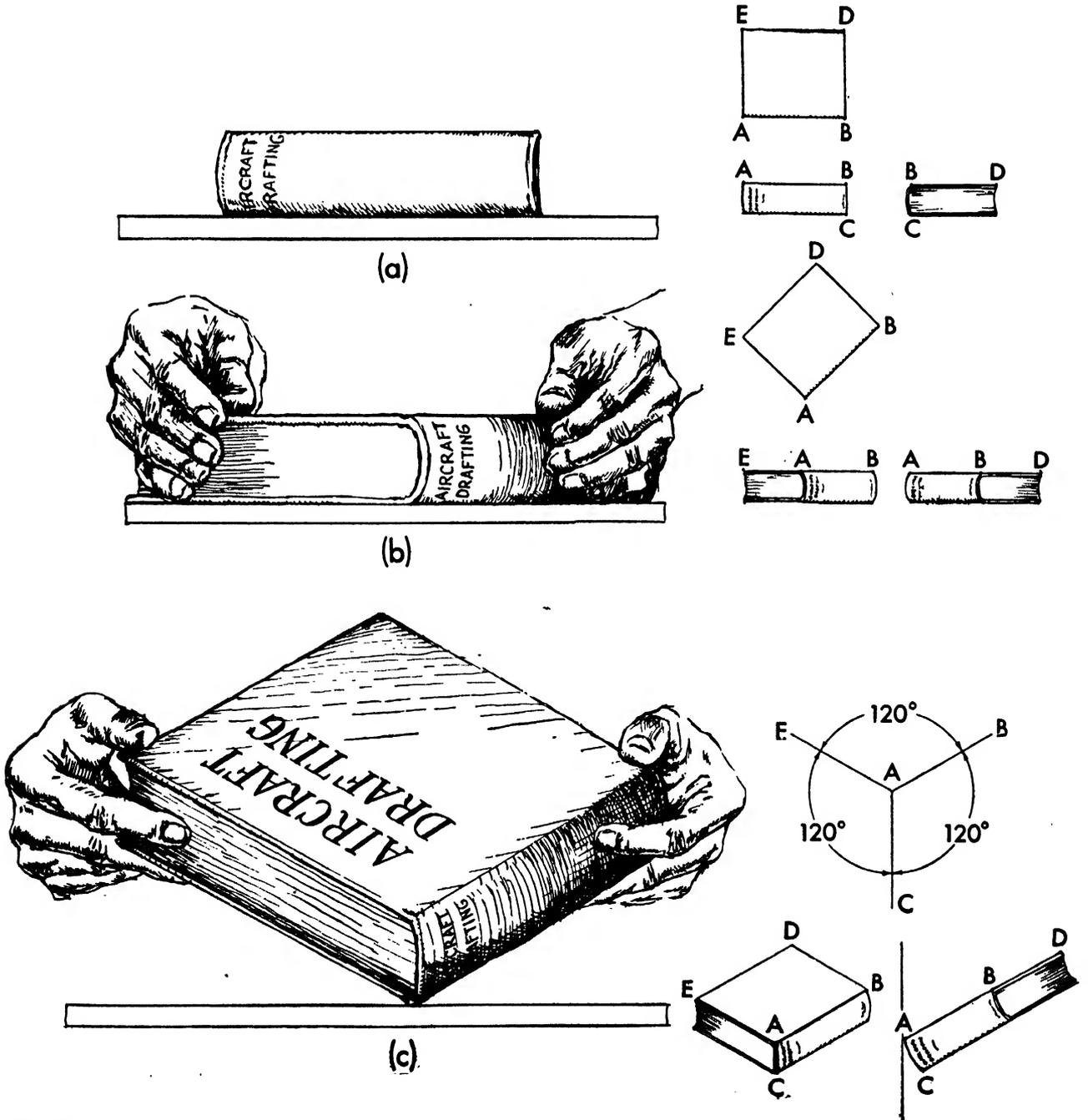


Fig. 242

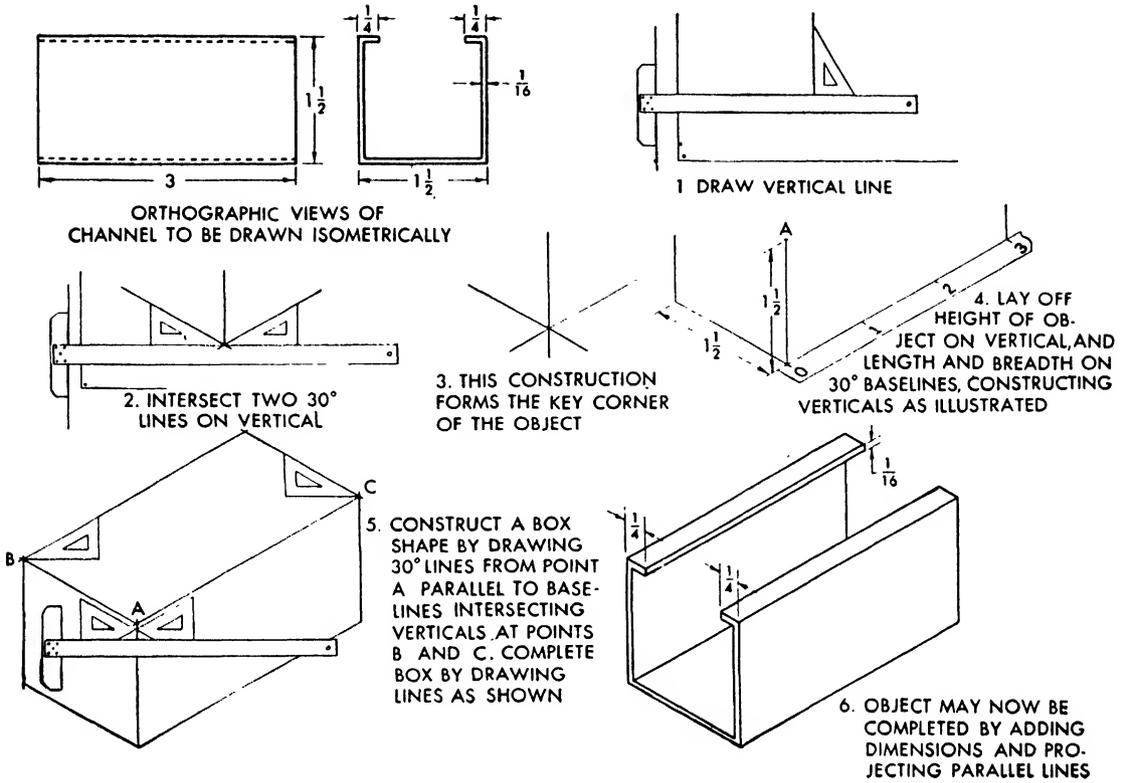


Fig. 243. To draw a rectangular object in isometric

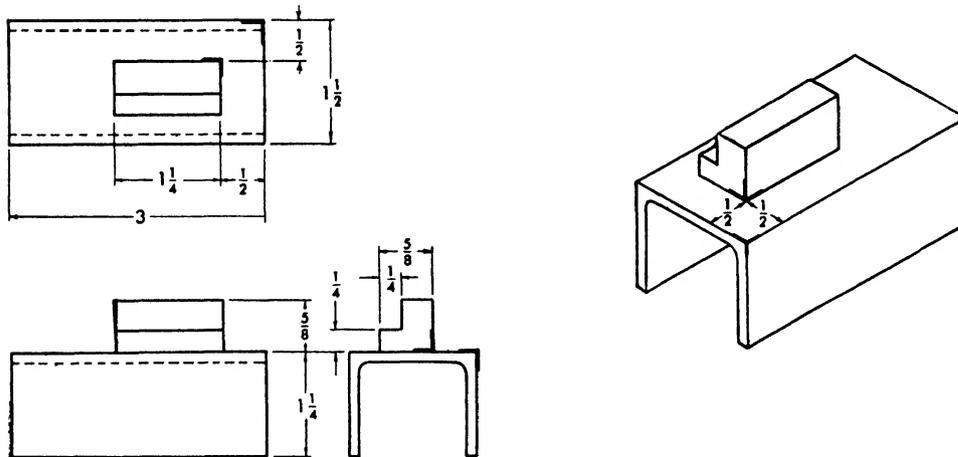


Fig. 244. Locating rectangular objects in isometric

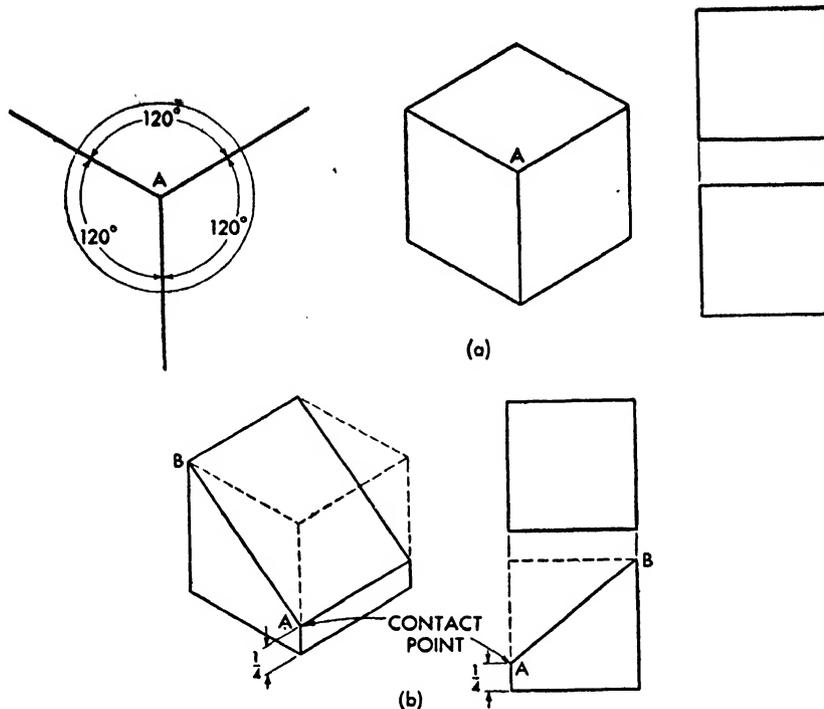


Fig. 245

the sides of the main object. Such objects are also drawn by the box method.

**Offset Method.** When an object is made up of planes at different angles, the extremities of the edges are located by the offset method. These points are first determined on the orthographic view (Fig. 249a) and are then transferred with dividers to the isometric view. Once the base points are established, the height is found by setting off the respective vertical distances from the front orthographic view to vertical lines constructed on the isometric base (see Fig. 249b). Connecting these points finishes the drawing (Fig. 249c).

**Irregular Curves.** A curve on the face of a rectangular object will not show its true shape when the part is drawn isometrically. Therefore the curve is first drawn orthographically; on this, arbitrarily placed coordinates are plotted (see Fig. 250a). The imaginary box enclosing the object is drawn isometrically, and the coordinates are transferred to the side of the box (Fig. 250b). The first curve is then projected isometrically to the plane of the second (Fig. 250c), and the points are joined freehand and are smoothed with the help of the irregular curve (Fig. 250d).

**Angles.** An obtuse or an acute angle cannot be transferred directly to the isometric drawing. Figure 251 illustrates a method of locating angles. The orthographic view (Fig. 251a) is divided into right triangles (Fig. 251b). As the legs of the triangles form angles of 90 degrees, they are drawn isometrically and the hypotenuse is connected, establishing the required isometric representation of the angle. The variation between the actual and the isometric angles is noted, as in Fig. 251c. This method is employed generally in isometric drawings of beams, ribs, and trusses.

**Isometric Circles.** A true isometric circle should be plotted in the same way as an irregular curve. Because circles are frequently drawn isometrically, and because the plotting of points is a tedious task, a simpler method of approximation is usually employed. The drawing of an approximate isometric circle is described in Fig. 252. (The 30 by 60 degree triangle, used to construct rectangular shapes, is again utilized in the construction of isometric circles.)

**Isometric Arcs.** Isometric arcs, like isometric circles, may be drawn by a method of approximation. Figure 253 describes simplified means of drawing arcs and circles.

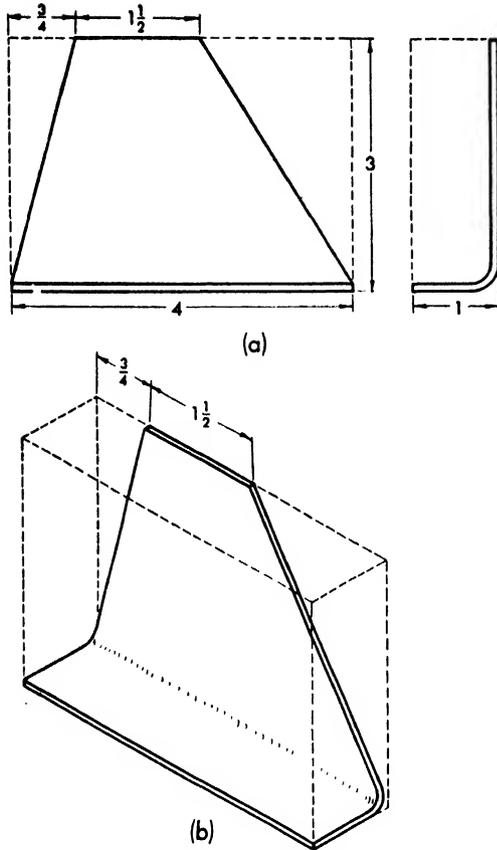


Fig. 246

*Rotating the Isometric Axes.* The isometric axes may be rotated to any desired position (Fig. 254). The axes should be placed in such a position as to present the best picture or to illustrate a particular characteristic of the object. The angle between axes, however, must remain 120 degrees.

*Oblique Projections*

Oblique projections are a simple form of pictorial drawing. The projectors are oblique to the projection plane and parallel to each other. Usually, one of the principal faces of the object is parallel to the projection plane.

The oblique projection is made from the orthographic view (see Fig. 255a). The front face is assumed to be parallel to the plane of projection. The receding axis AD may be drawn at any convenient angle from the front and the projection plane. Then, the axes AC and AB are constructed perpendicular to each other (Fig. 255b), and the front face and the over-all measurements are laid out (Fig. 255c). The front

face is drawn before the receding lines (Fig. 255d), and the full size detail drawing of the object is completed (Fig. 255e).

*Receding Axes.* Figure 256 shows various projections produced by changing the position of the receding axes while maintaining a constant relationship between the axes.

Oblique projections appear unnatural if the receding arms are long. The oblique is called a "cavalier" projection (Fig. 257a) when the projected lines form a 45 degree angle with the projection plane and all the axis lines perpendicular to that plane are projected in true size.

Optical acceptance is increased by drawing the receding lines half scale; this method is

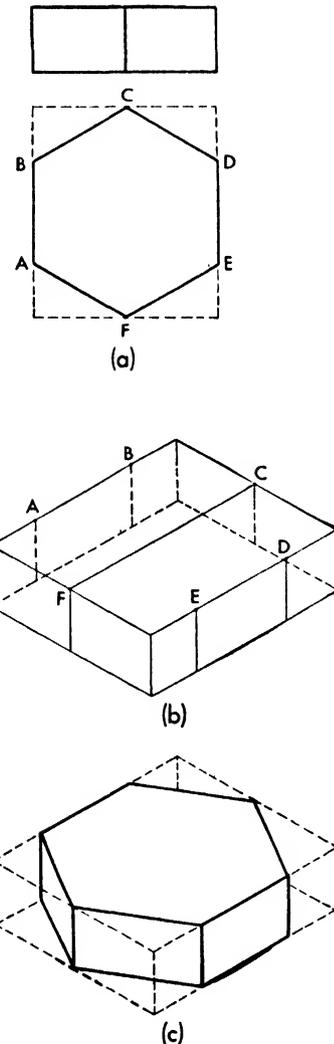


Fig. 247. The box method of locating non-isometric lines

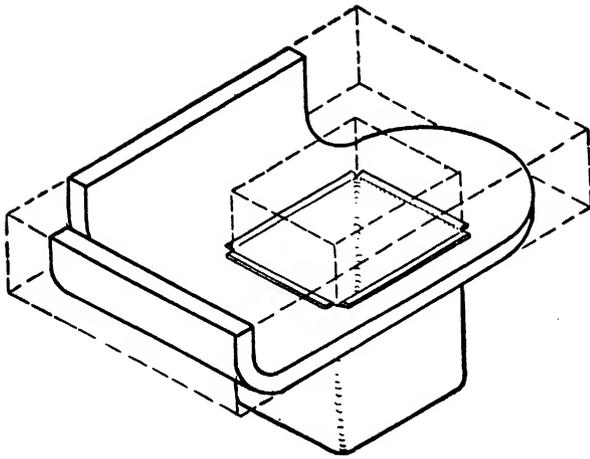


Fig. 248a

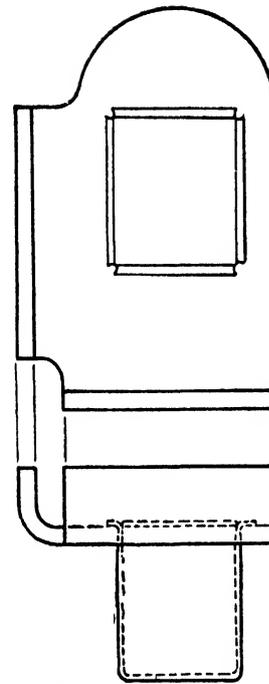
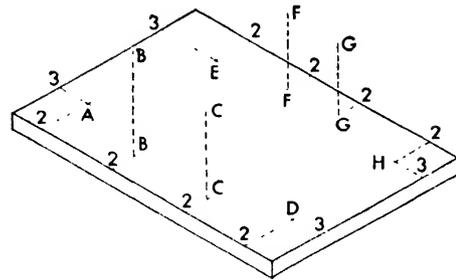
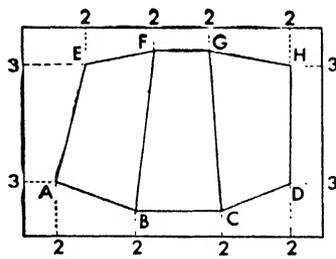
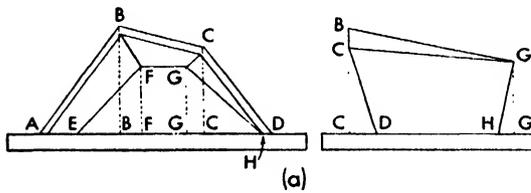


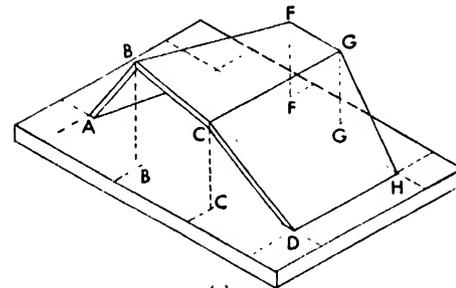
Fig. 248b



(b)



(a)



(c)

Fig. 249. Isometric construction by offset method

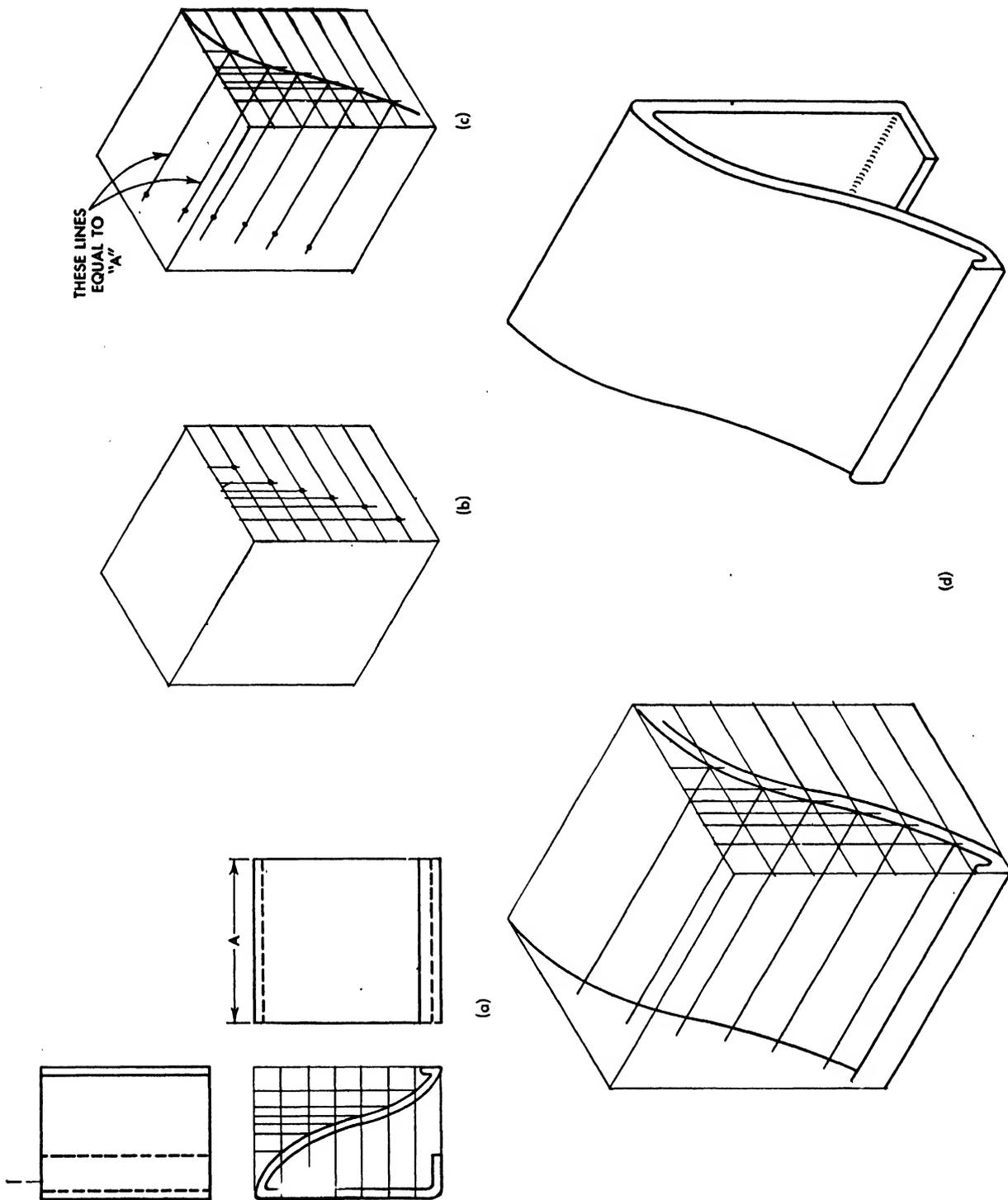


Fig. 250. To draw an irregular curve isometrically

known as a "cabinet" projection (Fig. 257b).

**Position of Projection.** Oblique drawings can be executed rapidly, which of course is an advantage. Sheet metal and extruded parts are drawn by sketching in the front or contour view orthographically before adding the receding axes to form a three-dimensional picture. The view showing the most characteristic shape of the part is placed parallel to the plane of projection. Since in an oblique projection a circle may be shown in its true size as a circle, considerable time is saved by drawing the view of an object that contains circles and arcs parallel to the projection plane. To minimize distortion, long narrow parts should be drawn with their longest side parallel to the plane of projection (Fig. 258).

**Projecting Curves.** If the circle or circular arc to be projected is not parallel to the plane of projection, it can be projected either as a four-center oval or by the offset method. The four-center method is used if the parallelogram framing the circle is equilateral. This method of projecting a circle not parallel to the projection plane is similar to the approximate isometric drawing of a circle. However, the perpendiculars

from the midpoints of the sides do not intersect at the corners of the parallelogram as they do in isometric drawings, but are extended as indicated in Fig. 259.

If the circles or circular arcs cannot be constructed by the four-center method, the offset method may be used. In this system, the offsets along the receding axes must be reduced in the same proportion (Fig. 260).

### Perspective

Perspective or central projection offers the most realistic of all pictorial drawing forms. Figure 261 describes this form of projection.

Point E is assumed to be the station point from which the object is observed. The picture is formed on the picture or projection plane by the intersection of the projectors or sight lines from point E through the plane.

The method presented in Fig. 262 embodies all the principles of standard plan view perspective drawing; that is, a drawing which is created by working from the standard plan, or top, or the graphic view. However, many of the complicated projections involved in the "picture plane"

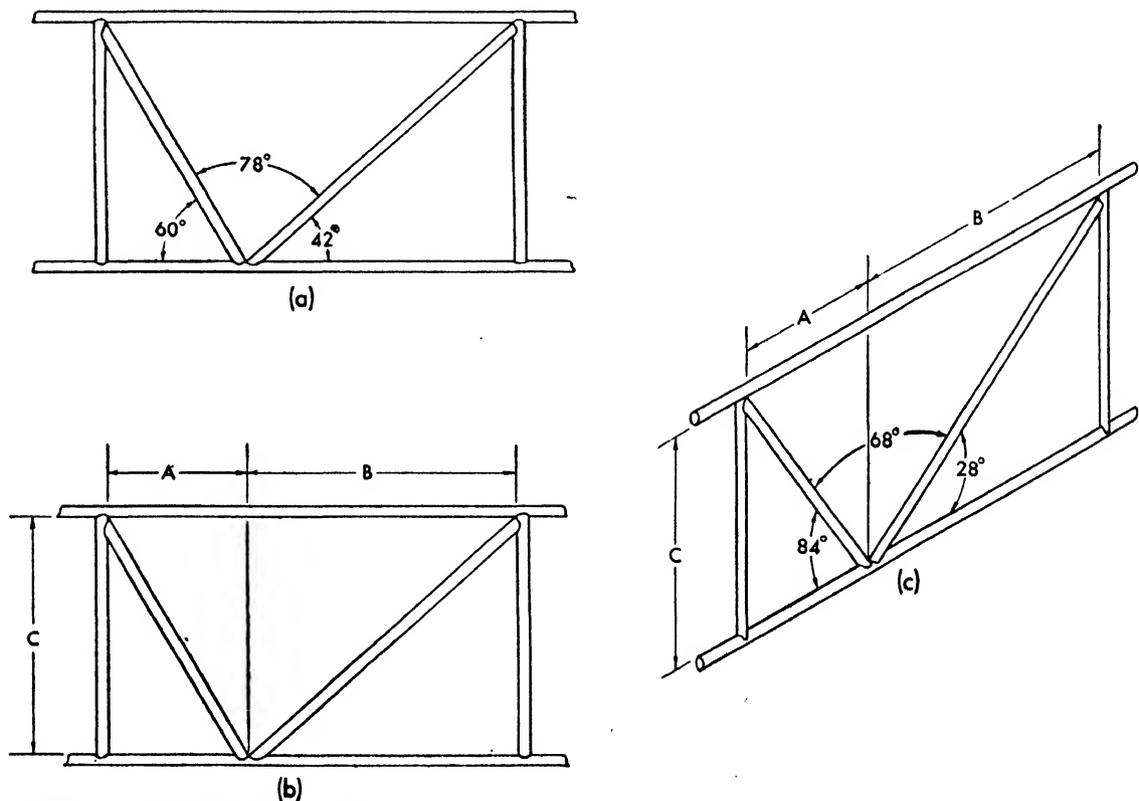
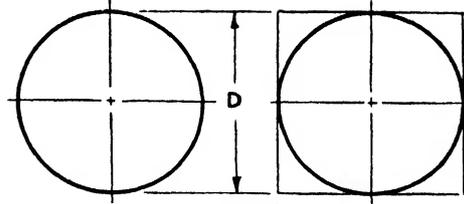


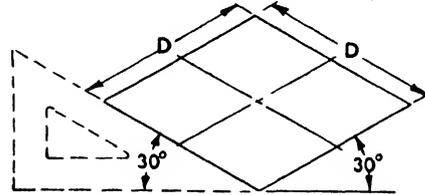
Fig. 251. To draw angles in isometric

A CIRCLE TO BE DRAWN ISOMETRICALLY IS FIRST INSCRIBED IN A SQUARE

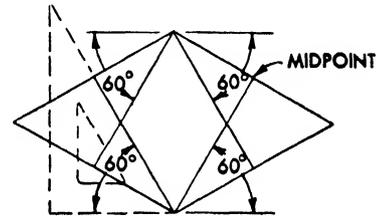


THIS IS THE APPROXIMATE METHOD. AN EXACT ISOMETRIC CIRCLE MUST BE PLOTTED

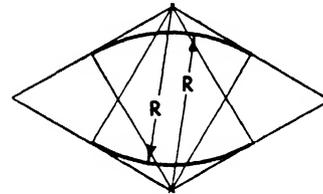
1. DRAW THE SQUARE ISOMETRICALLY



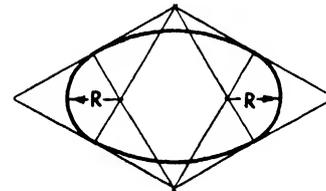
2. LOCATE THE MIDPOINTS OF EACH SIDE, USING 30°-60° TRIANGLE. THESE NEW LINES ARE PERPENDICULAR BISECTORS



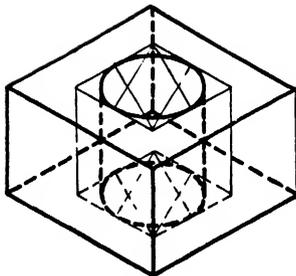
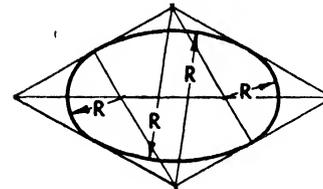
3. USING EACH OBTUSE ANGLE AS A CENTER, AND THE PERPENDICULAR BISECTORS AS RADII, DRAW THE TWO LARGE ARCS OF THE ELLIPSE (THE ISOMETRIC OF THE CIRCLE)



4. USING THE INTERSECTIONS OF THE PERPENDICULAR BISECTORS AS CENTERS, AND THE DISTANCE FROM CENTER TO MIDPOINT AS A RADIUS, DRAW THE SMALLER ARCS IN EACH ACUTE ANGLE



A SIMPLER METHOD IS TO LOCATE THE MIDPOINTS OF TWO NONADJACENT SIDES, DRAW A HORIZONTAL LINE TO INTERSECT THESE LINES, AND USE THE POINTS AS CENTERS



EXAMPLES SHOWING THE PARALLELISM OR COINCIDENCE OF ALL AXES USED IN THE CONSTRUCTION OF A HOLE OR CYLINDER

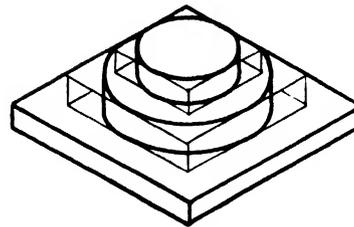


Fig. 252. Drawing isometric circles

idea have been eliminated for the sake of simplicity.

Study the dimensions and characteristics of the object to be drawn in scale perspective. When the exact specifications are fixed definitely in mind, decide from how far away and from how far above (or below) the object is to be viewed. Choose any convenient angle. It is advisable to draw the most complicated side of the object lengthwise to the view angle.

In constructing the perspective drawing shown in Fig. 262 proceed as follows:

1. Arbitrarily place a horizontal, representing the STATION LINE, near the bottom of the sheet.
2. Locate and establish on this line a STATION POINT from which the object is to be viewed.
3. Draw a vertical line perpendicular to the station line through the station point. This is the VERTICAL MEASURING LINE.
4. From the station point construct an angle of some 30 degrees on the side of the vertical measuring line, and erect the complement of that angle (60 degrees) on the reverse side of the vertical measuring line. The small angle is the VIEW ANGLE.

5. From the station point, along the vertical measuring line, scale off the distance from which the object is to be viewed and establish a point.

6. Draw a horizontal line parallel to the station line through a point on the vertical measuring line. This is the HORIZON.

7. The two points at which the view angle projection intersects the horizon will be known, respectively, as the LEFT VANISHING POINT and the RIGHT VANISHING POINT. All perspective lines radiate from a vanishing point. A perspective drawing looks best when the object is contained within an 80 degree angle, although a slight deviation will not impair the drawing. Such deviation may be necessary when the 30 degree angle does not permit the 60 degree angle side to show clearly.

The distance from an object should be two and a half or three times the height or the greatest length of the object. This will prevent an abrupt or distorted view. When calculating the vanishing points, the angle and the distance from the object are given. This distance—from a vertical line of intersection on the eye level to

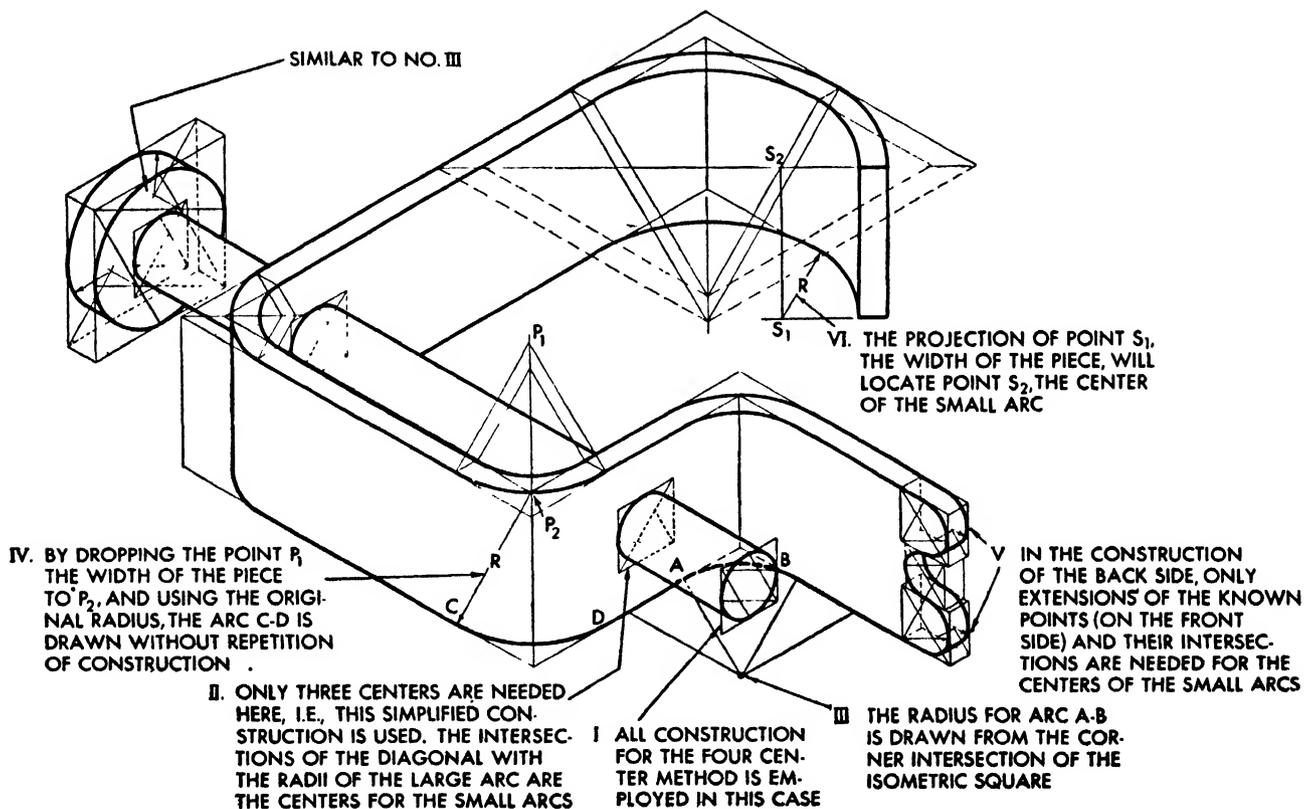


Fig. 253. Method of drawing arcs in isometric

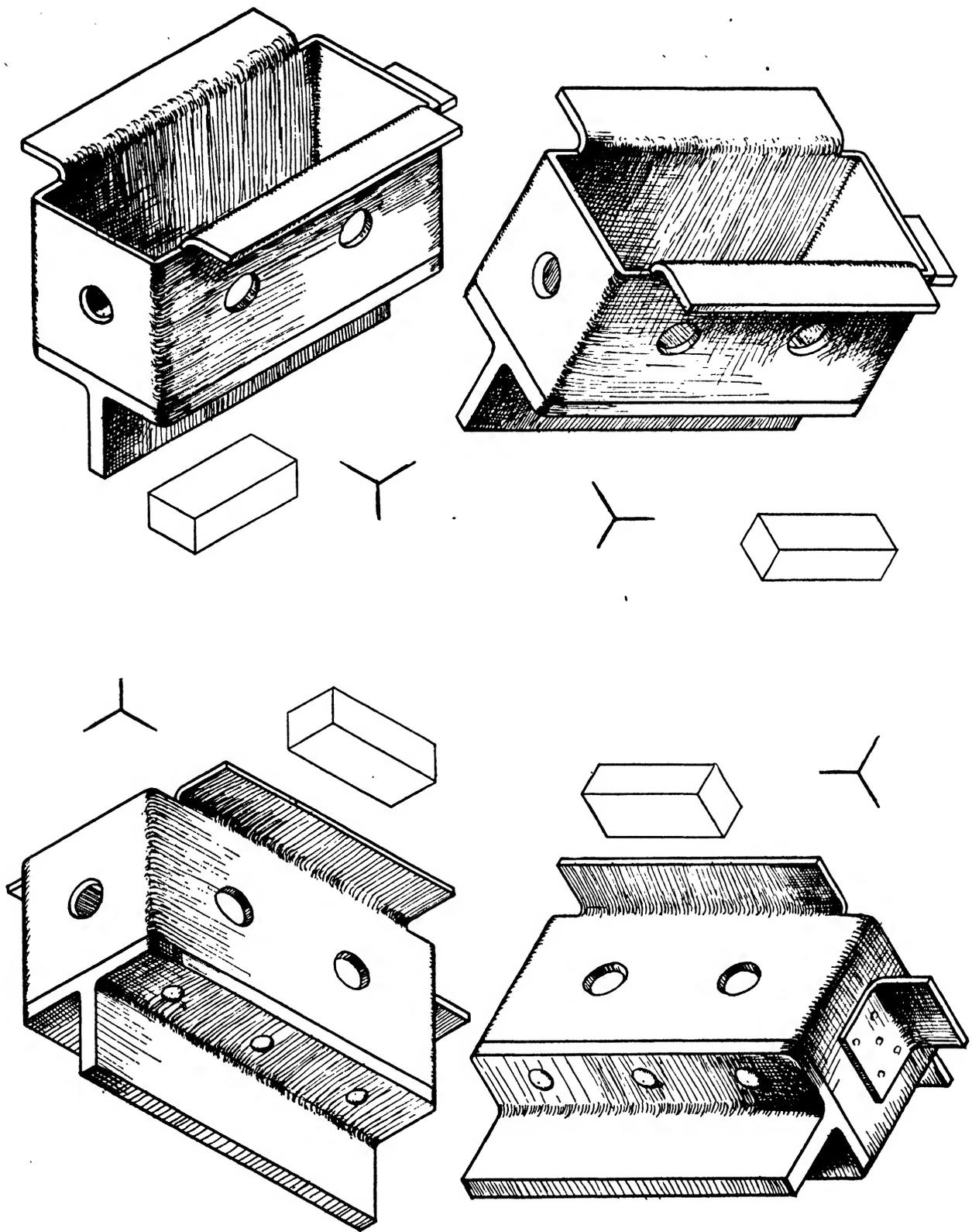


Fig. 254. Rotating the isometric axis

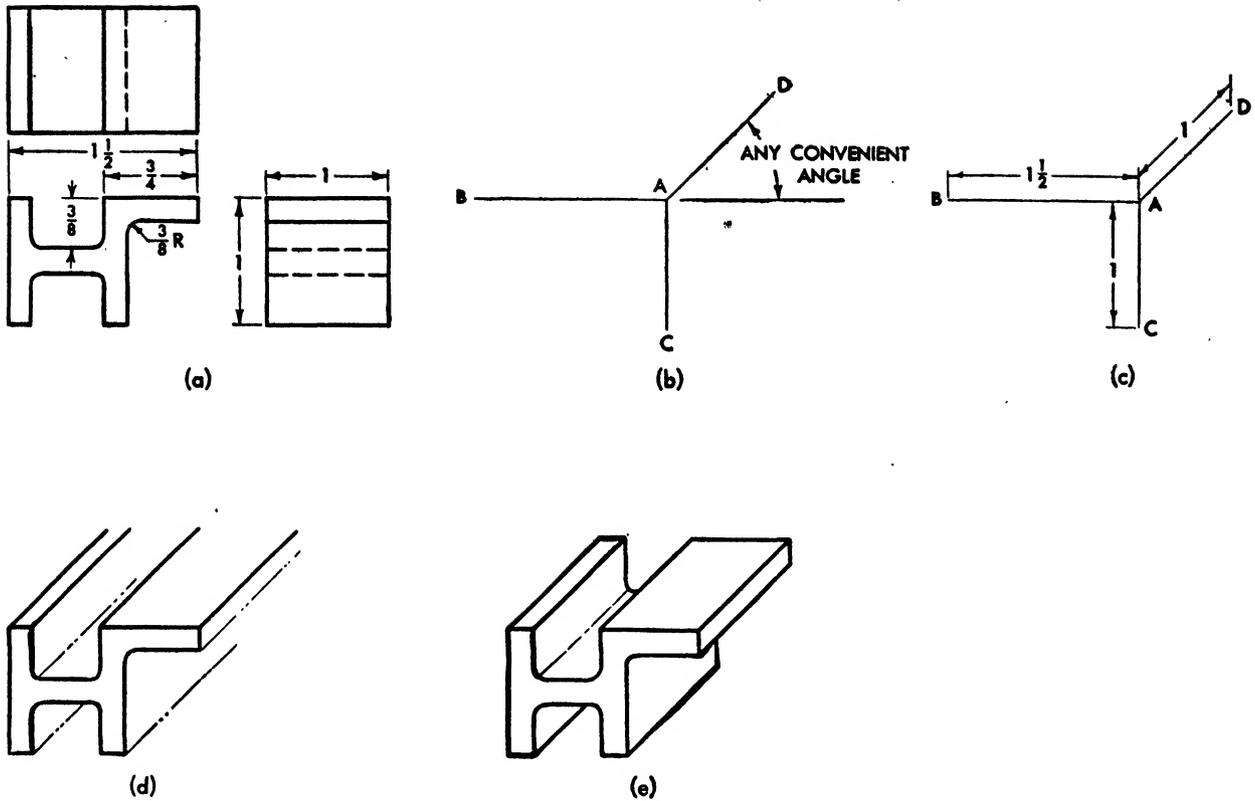


Fig. 255. To make an oblique drawing

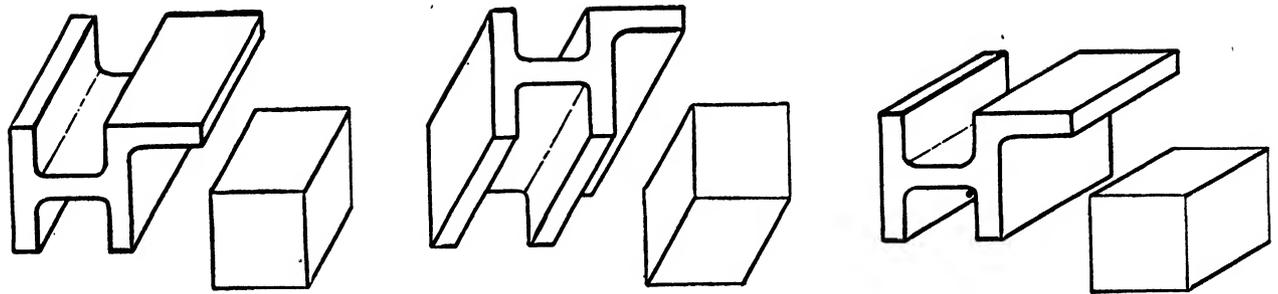


Fig. 256. Varying the receding axes

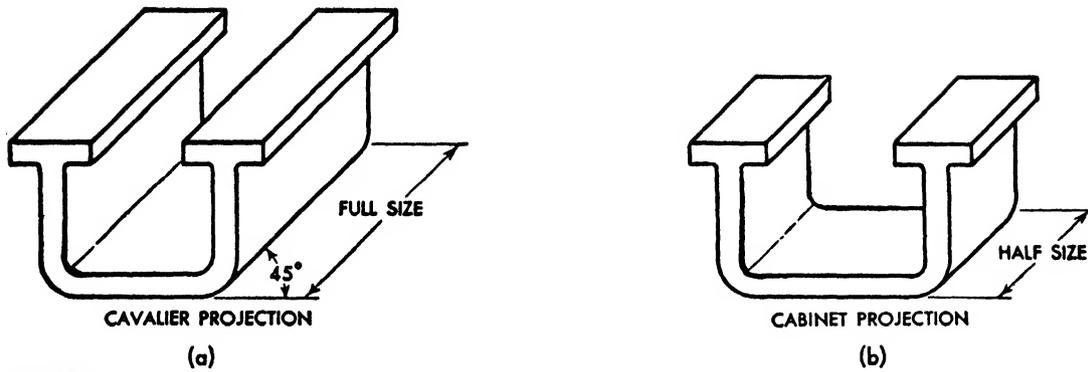


Fig. 257

the vanishing point—can be determined by using a trigonometric formula.

8. Scale on the vertical measuring line the distance from the horizon to the object and establish a point. This is the distance above the object.

9. Through this point draw a horizontal line parallel to the horizon and station lines. This represents the GROUND LINE OF THE HORIZONTAL MEASURING LINE. To form the OBJECT LINES, connect the intersection points of the ground line and the vertical measuring line with the left and the right vanishing points.

10. Use the right vanishing point as the center and with the distance of the right vanishing point to the station point as radius, construct a right measuring point on the horizon.

11. Construct the LEFT MEASURING POINT on the horizon by swinging an arc with a radius equal to the distance from the left vanishing point to the station point.

12. In order to develop any horizontal dimension in perspective, scale off the actual measurement A from the vertical measuring line along the ground line. A line linking this point with either the left or the right measuring point—whichever is on the opposite side of the vertical measuring line—will give the true scale perspective dimension at the intersection with the object line, point B. Place vertical measurements on the vertical measuring line, scaled up from the ground line and connected with the vanishing point.

Figure 263 shows examples of orthographic views drawn in true perspective.

The device known as a “linear perspective” is not accessible to most students, but, because of its popularity in the production illustrating departments of aircraft companies, the method is given.

I. Establish the vanishing point R (see Fig.

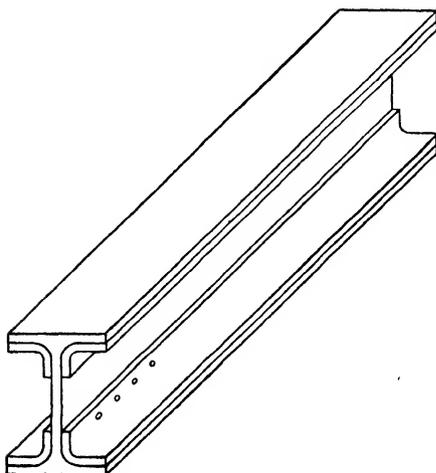


Fig. 258a

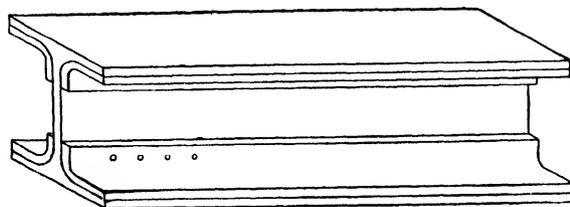


Fig. 258b



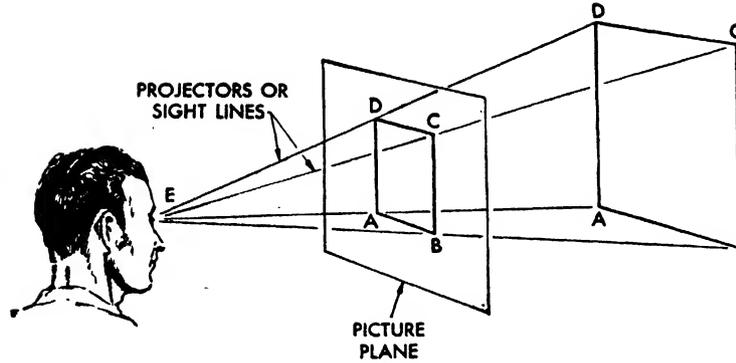


Fig. 261

(T to X or T to Y). The distance from the vanishing point R to the vertical line at point T should be 24 inches. Then  $8 \times 8 = 64$  and  $\frac{64}{4} = 16$ , meaning that the intersection point Z must be placed 16 inches away from the vertical line toward the drawing. To establish the perspective lines at the opposite side of the drawing, remove the outer arm and fasten it into the extension at the reverse end of the head, and proceed as before.

*The Layout*

A "rough layout" is the first rough drawing made to determine the approximate size, shape, and view of the object to be drawn. The rough layout ensures correct arrangement and well-balanced composition in the finished drawing.

The work on the rough layout is the creative

part of making an illustration. It determines the approach, arrangement, size, and view. The balance of the work is routine.

In planning your layout, be keenly aware of each article to be treated before making a "key" to those articles on a scribble sheet. This key is merely a small proportional sketch of the matter to be included in the layout. Once the key has shown the relative sizes of the articles—a necessary preliminary to balancing a composition—make a series of sketches to find a pleasant arrangement and grouping. All this may be done on the scribble sheet (see Figs. 266, 267, and 268).

*The Comprehensive Layout.* After the completion of the rough layout, incorporating all

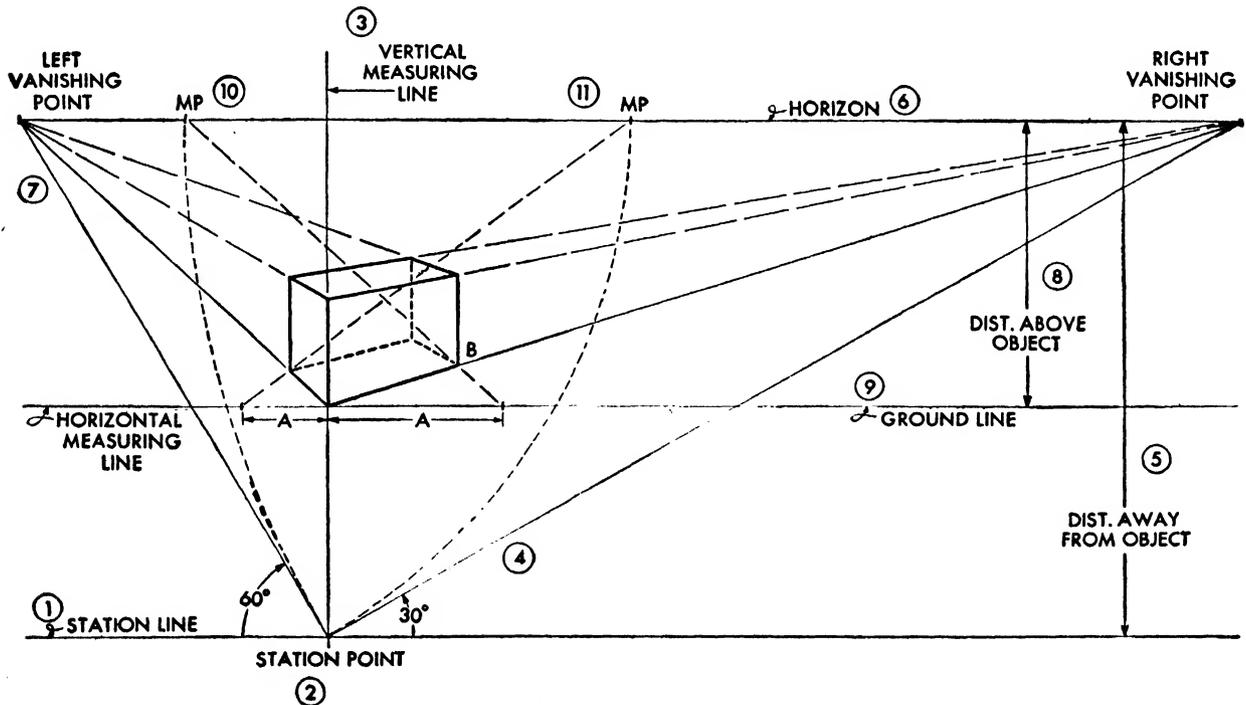


Fig. 262. Method of drawing an object in perspective

possible improvements, place a sheet of tracing paper over the rough layout and begin the comprehensive layout.

A comprehensive layout is a refined outline, a real test of the illustrator-draftsman's technical skill. Begin the comprehensive layout by checking all vertical, horizontal, and diagonal lines to be sure that they are true and that they follow their proper vanishing lines.

Check curved lines and ellipses too, and with especial care, as the correctness of these lines is vital to a professional appearance. If certain lines prove false and rather off their terminal points, but the draftsman hopes to cover up his errors in some way, he lacks the primary requisite of good workmanship—accuracy.

The importance of the comprehensive layout cannot be overemphasized, for in this step details are organized and given specific form, and definite lines are strengthened (Figs. 269, 270, and 271).

*Shading.* Pictorial presentation of an object is the expression of a definite form, an attempt to reproduce its shape, arrangement, beauty, and symmetry. The success of a drawing depends on the draftsman-illustrator's ability to represent the object's appearance and texture in terms of light and shade. Shading expresses form, and without it the drawing looks "spotted," curved surfaces do not appear curved but flat and dull. Shading enables the workman or engineer to understand and recognize every feature of the rendered object quickly, completely, and without conscious effort.

When starting to shade, set a dot above and slightly to one side of the object. This dot represents the light source. Place it so as to bring out effectively the form and detail of the object. A little experimentation enables the student to establish his light source correctly in each drawing. Two or three shade layouts may be needed before the best solution is found. A sheet of

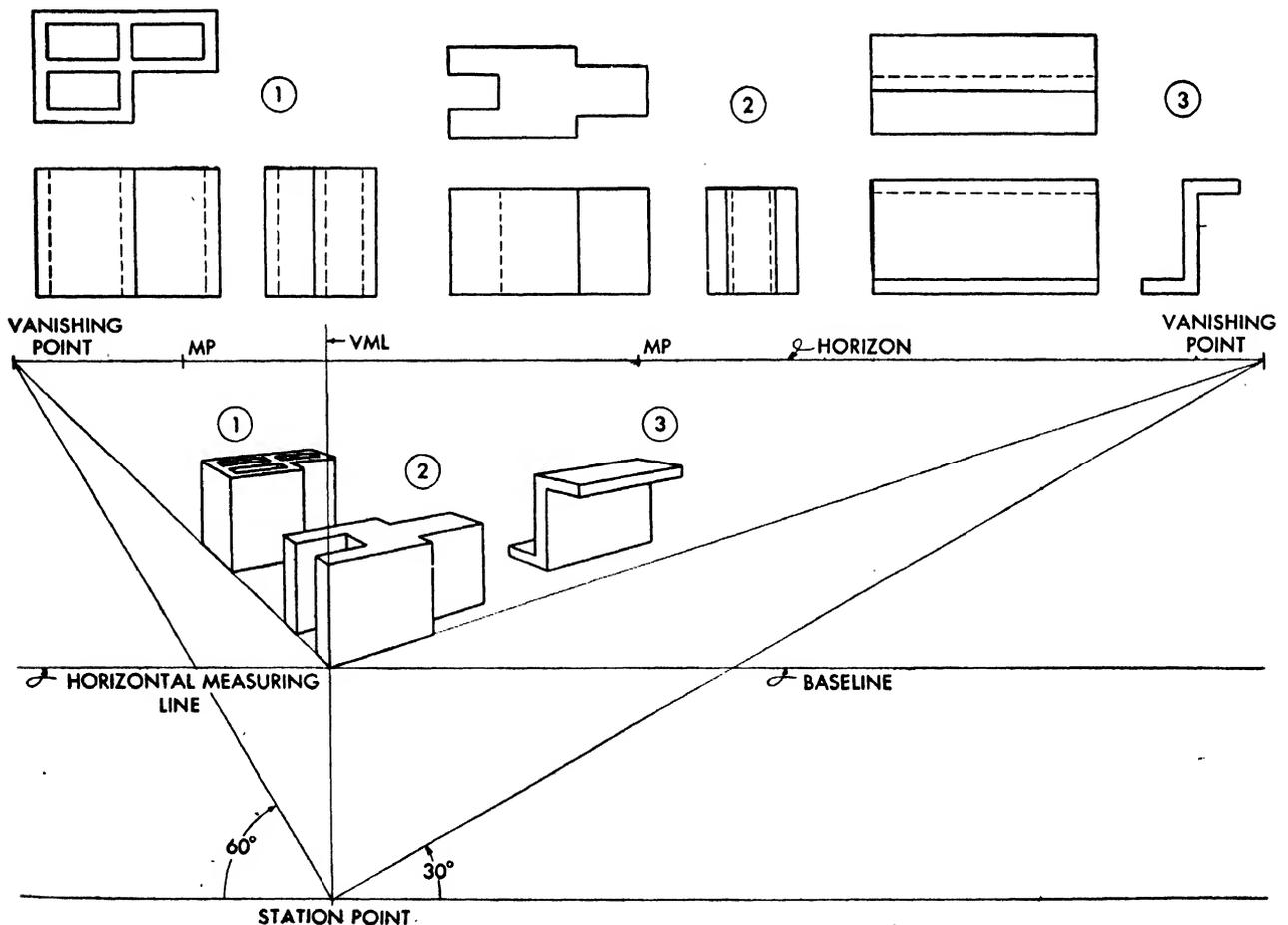


Fig. 263. Examples of orthographic projection drawn in perspective

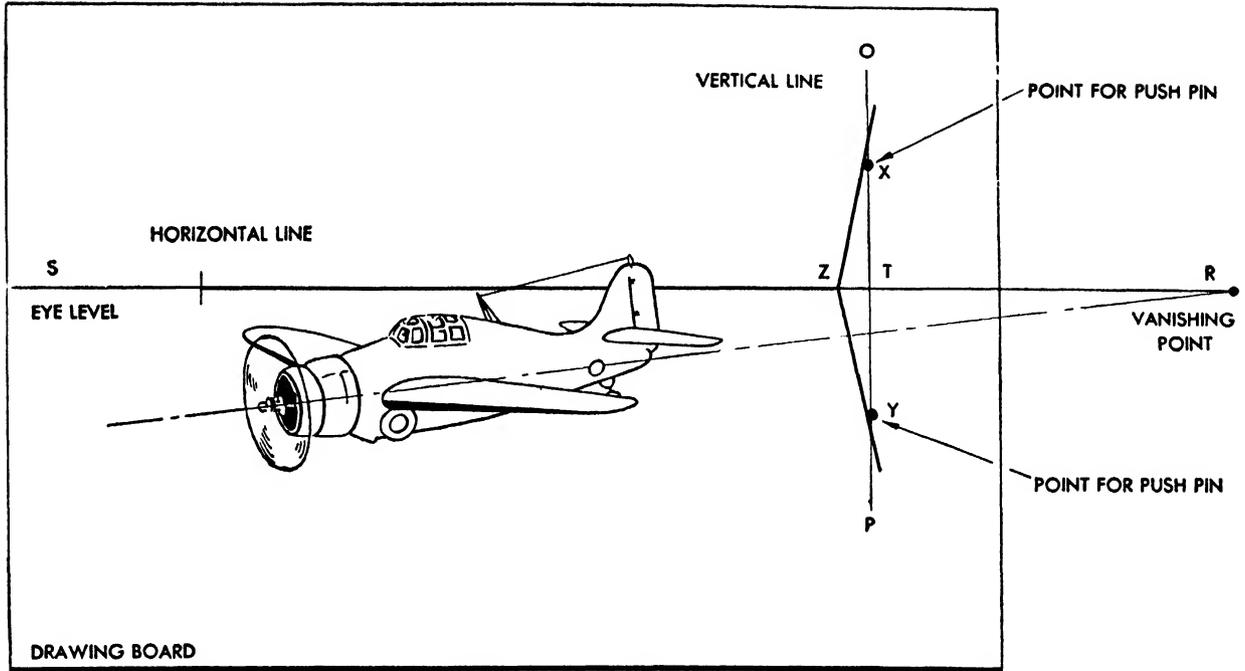


Fig. 264. "Setting up" the perspective linead

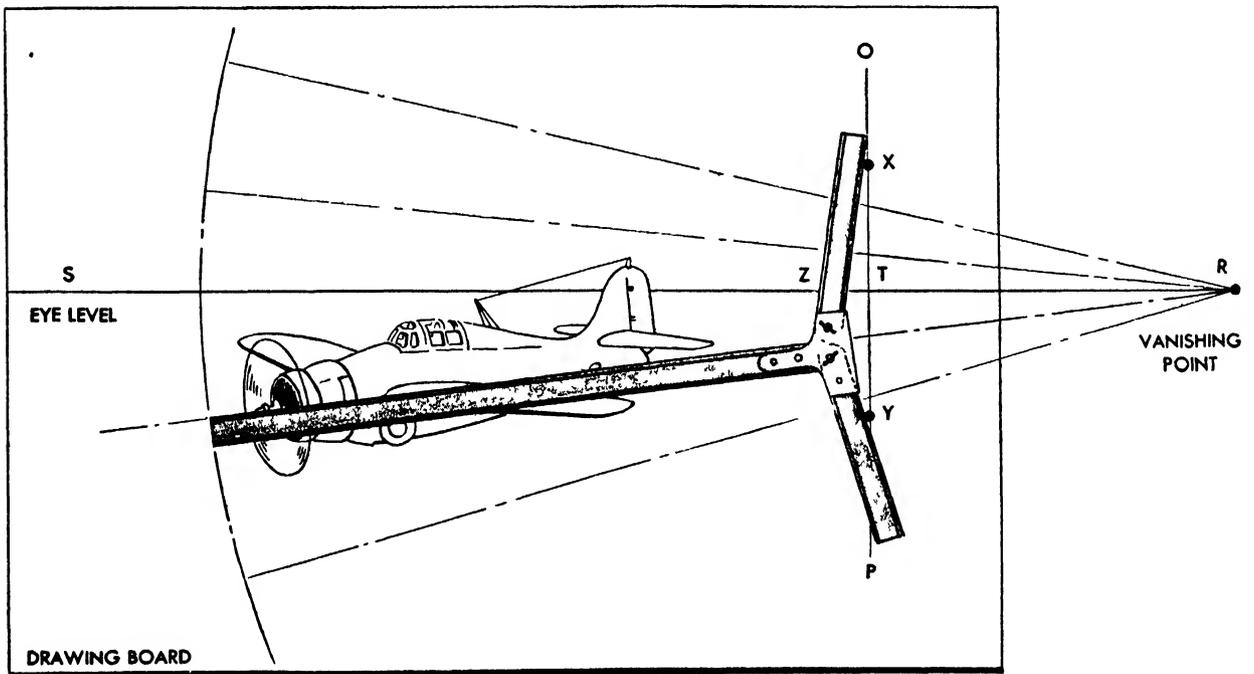


Fig. 265. Application of the perspective linead

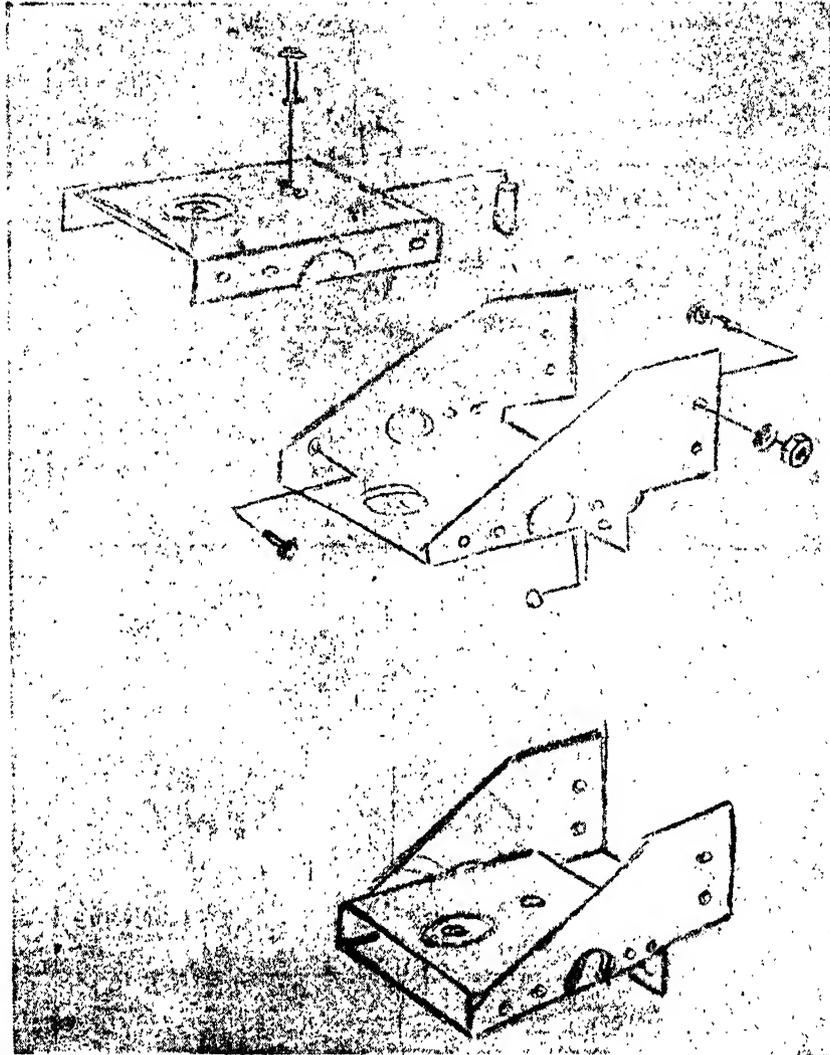


Fig. 266

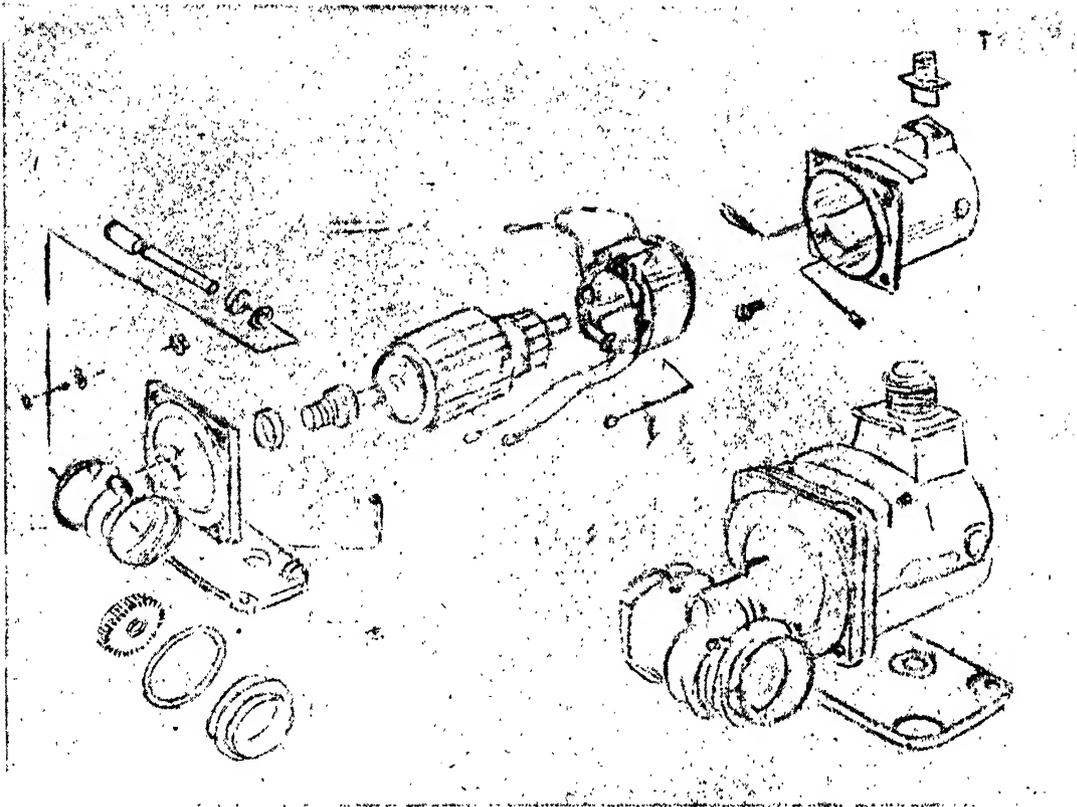


Fig. 267

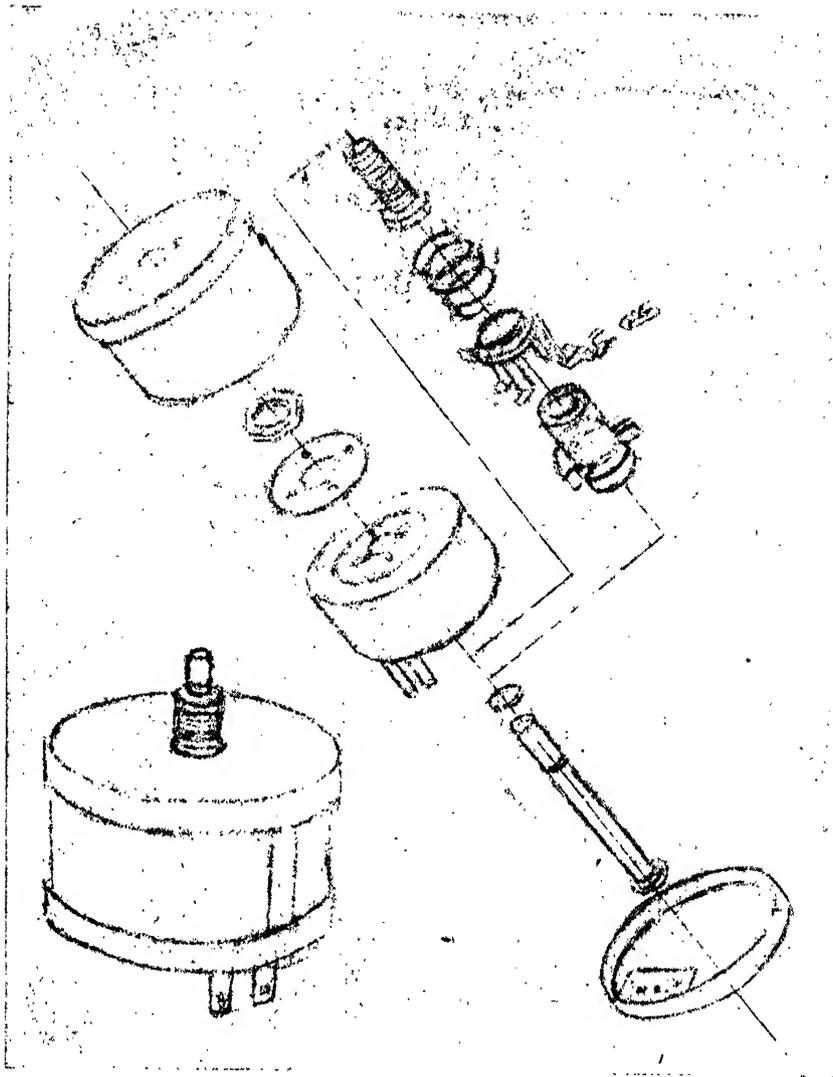


Fig. 268

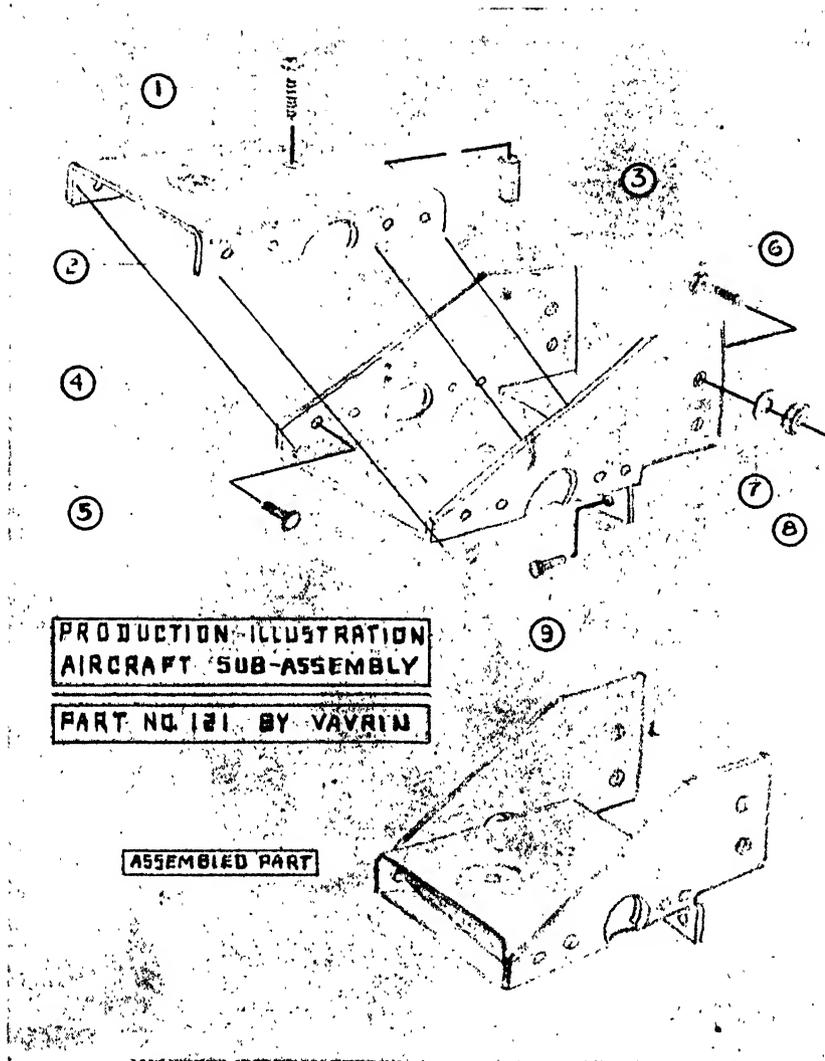


Fig. 269

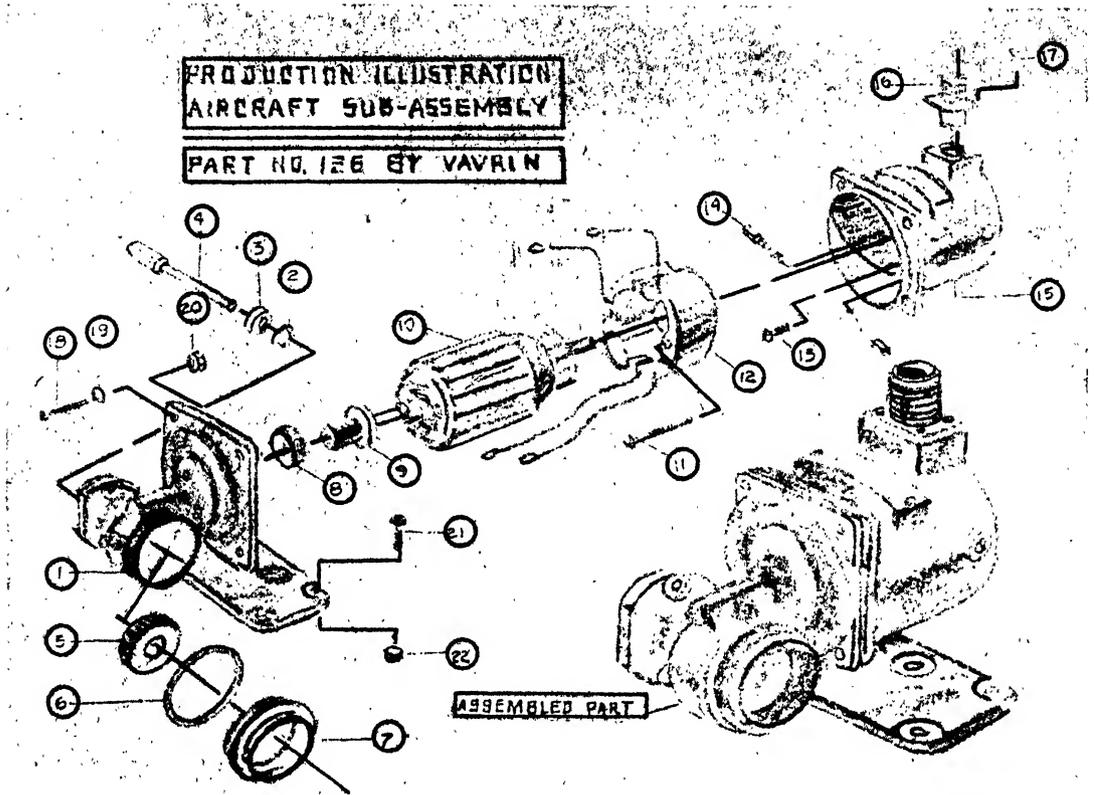


Fig. 270

PRODUCTION ILLUSTRATION  
AIRCRAFT SUB-ASSEMBLY  
PART NO 130 BY VAVRIN

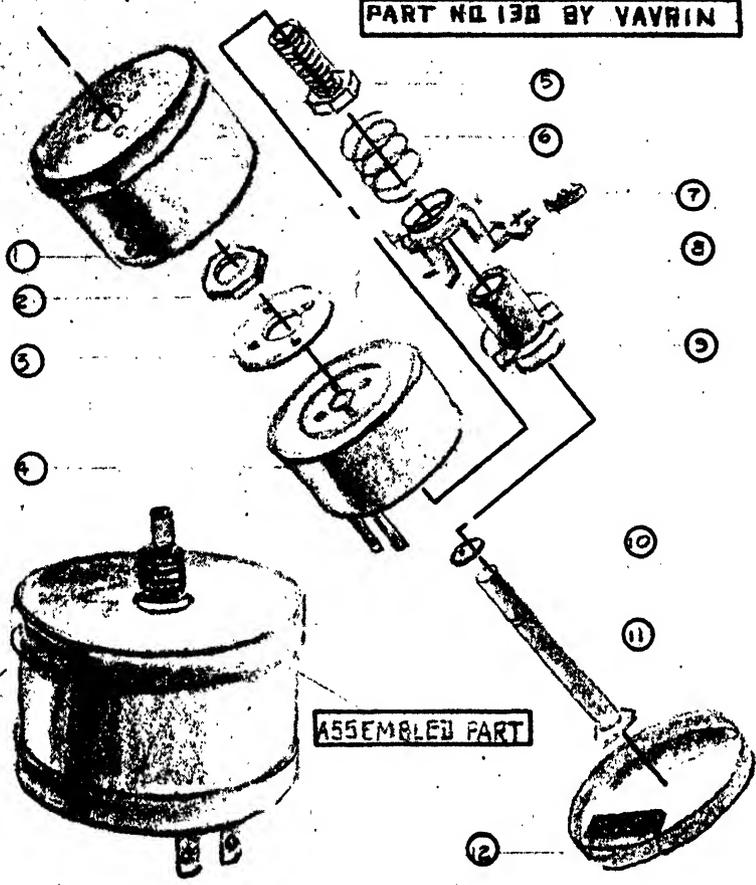


Fig. 271

tracing paper over the outline helps to obtain a series of shade attempts quickly. Render the most successful sketch on the finished drawing.

*Mechanical Shading.* Objects drawn in perspective may be shaded mechanically by the method presented in Fig. 272.

1. Establish point A, the light source, at a convenient location between vanishing points and above eye level.

2. Establish point B by drawing a vertical line from point A to the eye level line.

3. Connect point B to points C, D, and E of the object, and extend the lines.

4. Draw lines from point A through points F, G, and H of the object.

5. Establish point R where the continuation of lines AF and BE intersect.

6. Establish point S where the continuation of lines AG and BD intersect.

7. Establish point T where the continuation of lines AH and BC intersect.

8. Connect points E and R, R and S, S and T, and C and T, outlining the object's shade area resulting from the predetermined source of light.

*Freehand Shading.* Mechanical drawing takes time, and realistic effects are difficult to obtain

because of the numerous reflections of light that occur in nature.

Most aircraft parts may be shaded more effectively and swiftly by a nonmechanical method. Analyze the examples in Fig. 273 for their basic construction. You will find that they are composed of cylinders, prisms, and cones. Since most parts can be broken down into simple geometric solids, practice freehand shading of cylinders, cones, prisms, spheres, etc. By varying the light source on these objects, and by adjusting them in different positions, you will acquire skill in drawing and shading these shapes. Then shade a fairly complicated piece which, in general, is based upon a series of simple geometric solids.

Hard lead pencils are not recommended for shading. HB pencils or carbon pencils of the H and 2B grade are best. Blended tones may be made by manipulating the pressure.

Some mediums, like carbon pencil and litho crayons, have a greasy base and are difficult to erase. Therefore work lightly at first before bearing down to achieve the final effect.

Pen and ink shading is somewhat specialized. It is difficult, and only long practice will enable the student to give a professional appearance to his ink shading. To begin with, use a soft, sharply pointed pencil and imitate pen lines. When

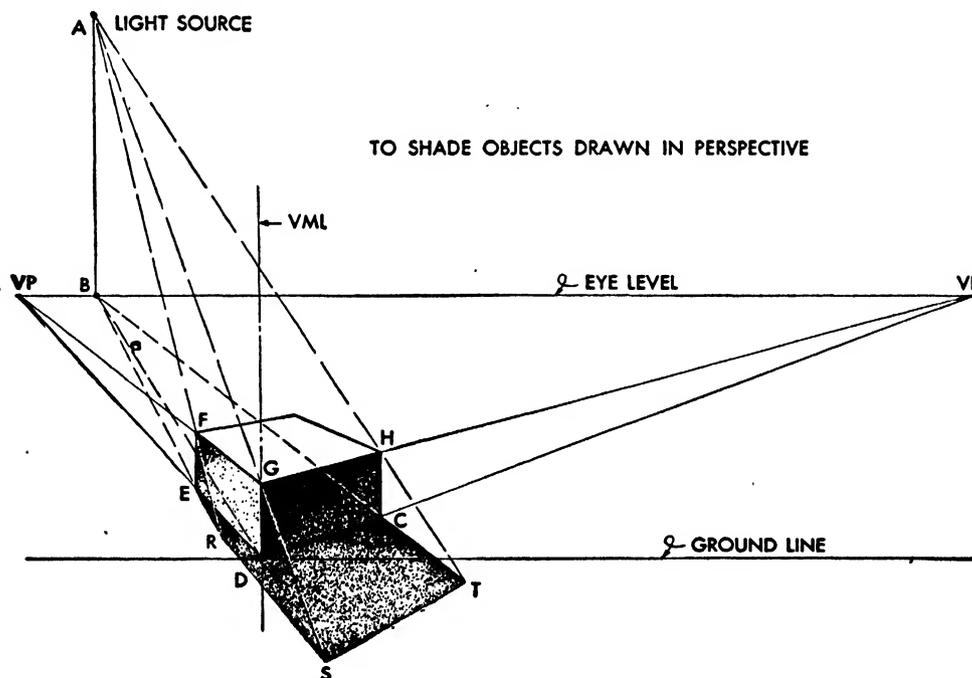
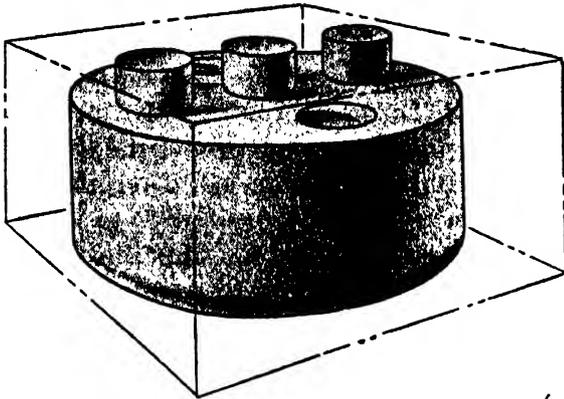
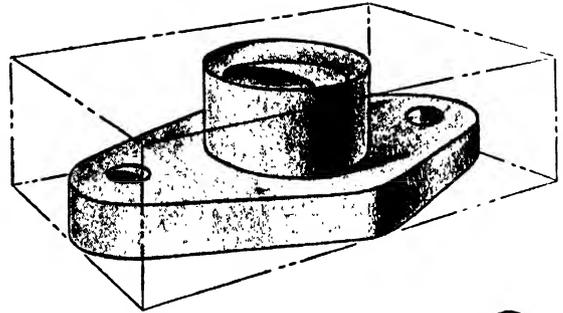


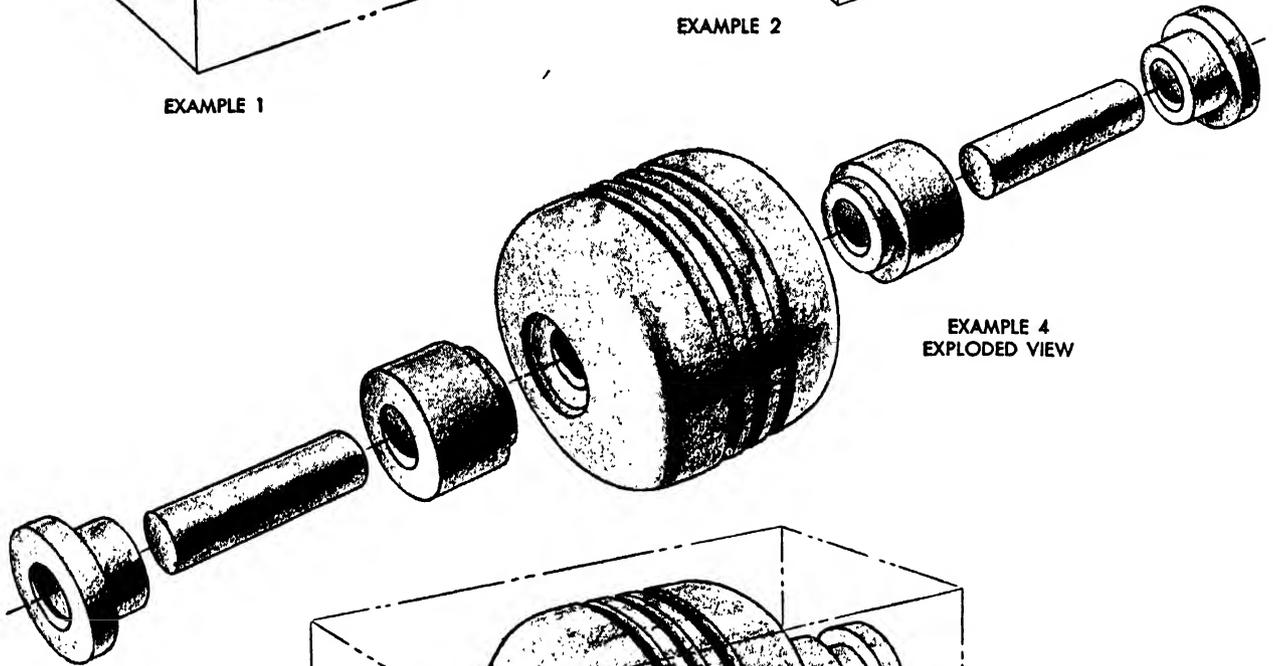
Fig. 272



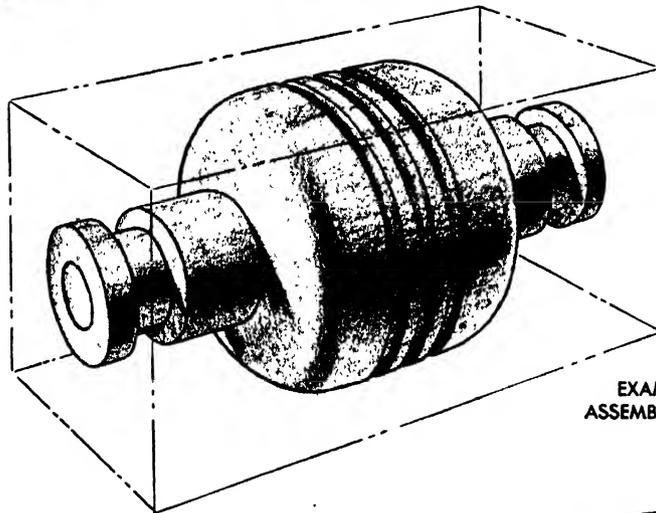
EXAMPLE 1



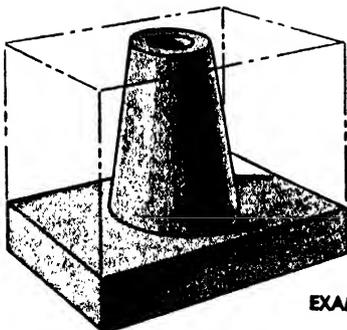
EXAMPLE 2



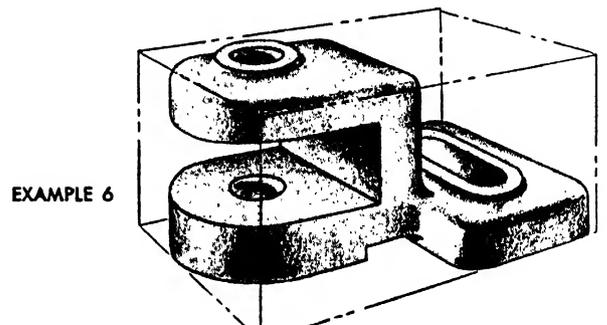
EXAMPLE 4  
EXPLODED VIEW



EXAMPLE 3  
ASSEMBLED VIEW



EXAMPLE 5



EXAMPLE 6

Fig. 273. Objects drawn in perspective

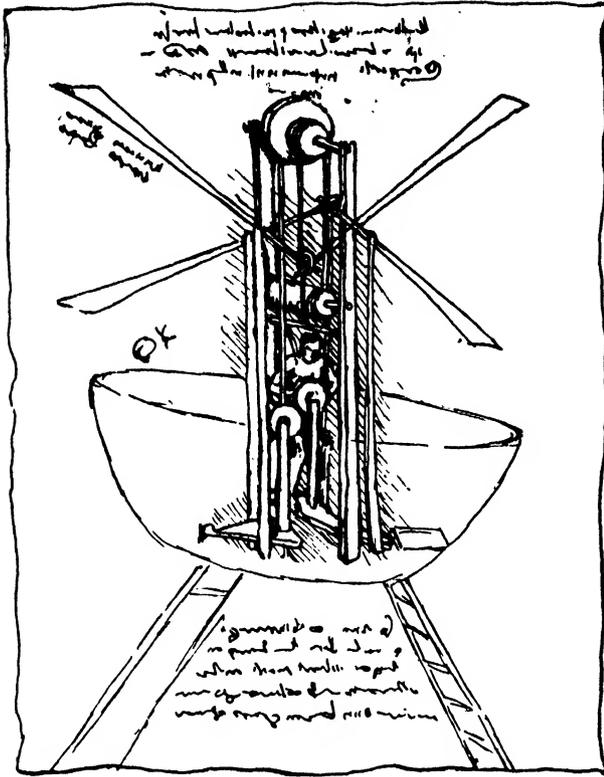


Fig. 274. Sketch of airplane idea by Leonardo da Vinci

the desired shading has been achieved, retrace the pencil lines with pen and ink.

### Tracing the Comprehensive

To transfer a drawing from the tracing paper to the illustration board, scribble with an HB pencil on the back of the comprehensive layout. Then take a scrap of paper and rub it over the scribbling to remove the surplus graphite and to prevent smears and smudges. Securely fasten the comprehensive over the illustration board

with staples or masking tape and trace with a 3H or 4H pencil. The pencil should be fairly sharp to produce clear, precise lines on the illustration board. Do not apply excessive pressure as it may cut the tracing and groove the illustration board. Experimentation will determine the correct pressure. Trace carefully to avoid crooked and sketchy lines on the illustration board. Try first for accuracy in transferring the lines from the comprehensive; speed will come with practice.

### Rendering the Finished Drawing

Production illustrations (unlike orthographic working drawings) are usually inked, as the inking technique is better suited for black and white reproduction. To make a good rendering after the comprehensive has been traced, be sure that all lines are definite and clear. Never assume that bad lines will be straightened out when the drawing is inked. It is then too late to wish the basic tracing lines had been correct.

Ink in a small section of the detail anywhere on the board, with concern for the correct thickness of line. Using the small inked-in section as a guide, ink in the remainder of the drawing. Check the drawing for heavy, fuzzy lines, and touch up the errors with Chinese white. There are four ways of rendering a production illustration:

1. The ink outline on "Craftint" board, shaded with "Double tone" wash to bring out the dark shadows, and with "Single tone" to bring out the light shadows.
2. The ink outline on two- or three-ply cold-pressed "Strathmore" board, shaded with a "Wolfe" carbon pencil.
3. The ink outline on "Croquille" board,

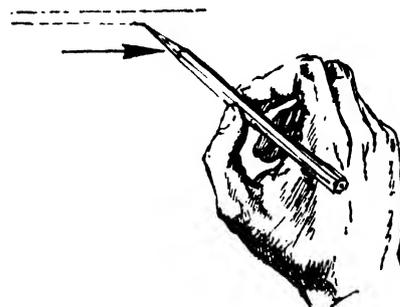
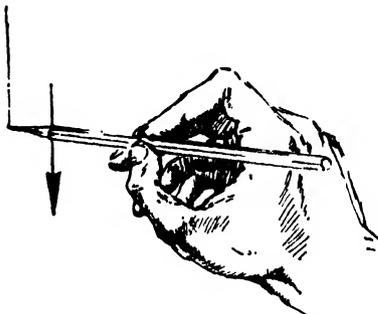


Fig. 275. Direction of freehand strokes

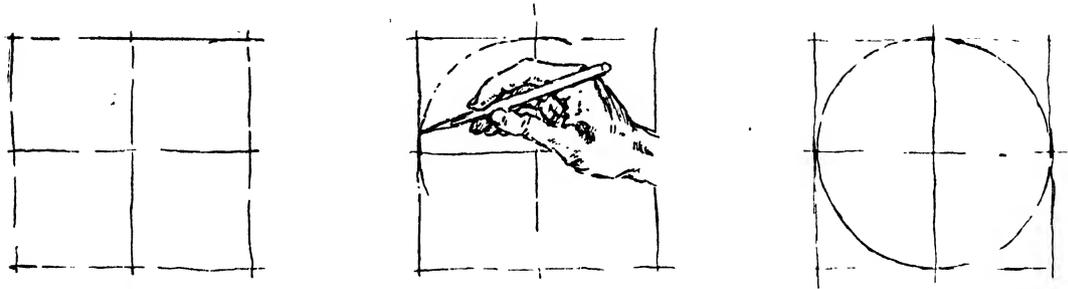


Fig. 276. Method of drawing freehand circles

shaded with litho-pencil. This particular method produces a spotted effect, important in some types of illustration.

4. The ink outline on cold-pressed two- or three-ply "Strathmore" board, using a line technique for shading.

Lettering and lead lines, indicating the various parts, play a major role in production illustrations. Here again we must consider the composition of the layout. The leads and call-out

well-known mechanical devices should be used. The "Leroy," "Wrico," and "Dietzgen" systems are all very good and will ensure uniformity and neatness.

*Freehand Sketching*

The freehand sketch is perhaps the most practical and certainly the most spontaneous means of expression in the graphic language. This is

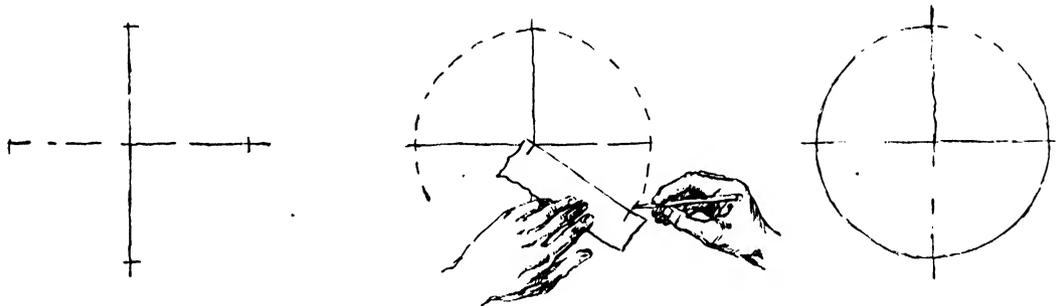


Fig. 277

numbers must be arranged so as to maintain good balance. In general a call-out number is placed at the end of the lead line. This number refers to an index that gives the proper names for parts of the subassembly—nuts, bolts, etc. All numbers and letters are made to read parallel to the baseline in order to make it unnecessary to revolve the rendering in search of a part.

When perfect lettering is wanted, one of the

proved by the fact that a thousand inventions, developments, and designs were first recorded in rough "idea" sketches. The great Leonardo da Vinci noted many such sketches in his famous notebooks. His version of a "flying machine" is illustrated in Fig. 274.

As we have said earlier, engineering conversation and shop talk usually are carried on with the aid of sketches on the scratch pad. These



Fig. 278. To draw a freehand ellipse

freehand representations must necessarily be made rapidly, but they should be neither carelessly nor haphazardly drawn. Freehand sketching must always be presented methodically.

Isometric, oblique, and perspective drawings are used most frequently as bases for freehand pictorial studies. The ability to draw may be acquired by making mechanical pictorials and copying them without the aid of instruments. While doing so, bear in mind the basic structure lines, such as the angles of the isometric axes, the receding axes of the oblique, and the perspective vanishing points.

The student should practice drawing simple rectangular objects in freehand perspective. Although the construction of actual vanishing points is not necessary, all horizontal lines of the object should tend to converge at imaginary points. First attempts may be awkward, but constant practice and checking the freehand study by extending the sides to see if they meet at a common point will soon bring satisfactory results.

Drawing from actual models is another great aid in freehand pictorial sketching. Once again, the mechanical principles should be brought into play. Perspective is of primary importance here since it is the most realistic of the drawing aids. Isometric principles are applicable to some small objects, but the unnatural appearance of obliques distorts the model. The engineering draftsman finds little occasion to sketch actual objects. He is concerned mostly with visualizing and presenting objects that are not yet made. Therefore, he should first obtain the practice of sketching actual models and should incorporate his experience in the original sketches.

The importance of freehand sketching as a means of visualizing and as an aid to mastering the mechanics of orthographic projection cannot be overemphasized. Whenever possible a freehand pictorial study should accompany the orthographic problem.

Freehand orthographic sketches perform the same functions as pictorial sketches, and, since they are more directly connected, by their na-

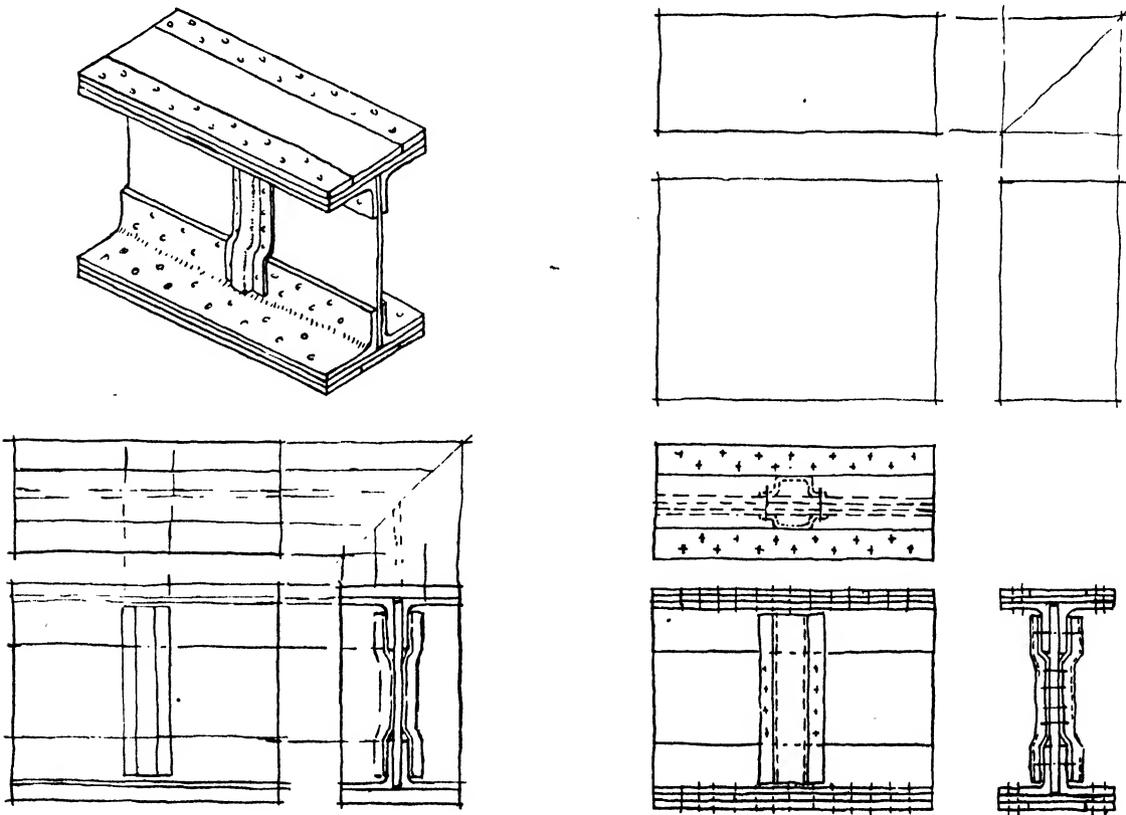


Fig. 279. To draw a freehand orthographic from a pictorial sketch

ture, to the actual blueprint, find greater application on the drawing board. Many tasks are given to the detailer in the form of quick orthographic sketches. Specific information about a part of a drawing in progress may be required in some other department, or may be desired by a fellow draftsman working on an adjacent structure. Such information might be given in the form of a freehand orthographic sketch. Changes on drawings are presented on engineering order forms by freehand orthographics. Another prominent use of this kind of drawing is in the thumb-nail sketches described in Chapters Seven and Eight.

Although freehand, this type of drawing should be made with all the care and precision of mechanical drawing. Projection rules should be carefully followed, and the lines should be neat and clear and according to the Alphabet of Lines (Chapter Four).

Though it is desirable to capture the object's general proportion, make no attempt at an actual scaled sketch. The primary function of the freehand sketch is to transfer a fairly broad conception of the object to the observer. Dimensions on a freehand working drawing may be lettered,

although it is assumed to be out of scale.

The degree of detail in a sketch depends entirely upon its purpose. If the sketch pertains to a flange cutout on a wing rib, draw only the portion concerned and do not waste time on a pretty picture of the entire rib.

*Technique of Freehand Sketching.* Soft pencils of the H, F, or HB type are best for freehand sketching. A conical point is used, but the degree of sharpness depends upon the type of line desired. Construction should be kept dull and light and lines are accented only when the entire sketch has been "blocked in." A soft pencil eraser is desirable, although on most rapid work little or no erasing should be done. Errors may be corrected and modifications made during the blocking-in process.

A freehand sketch does not seek to imitate a mechanical drawing. Lines are not perfectly straight or curved but are characterized by a feeling of freedom, verve, and individuality. However, this is not an excuse for sloppy and careless representation. A clear mental picture must be formed, and the drawing must be methodical and neat.

*Straight Lines.* Vertical lines may be drawn

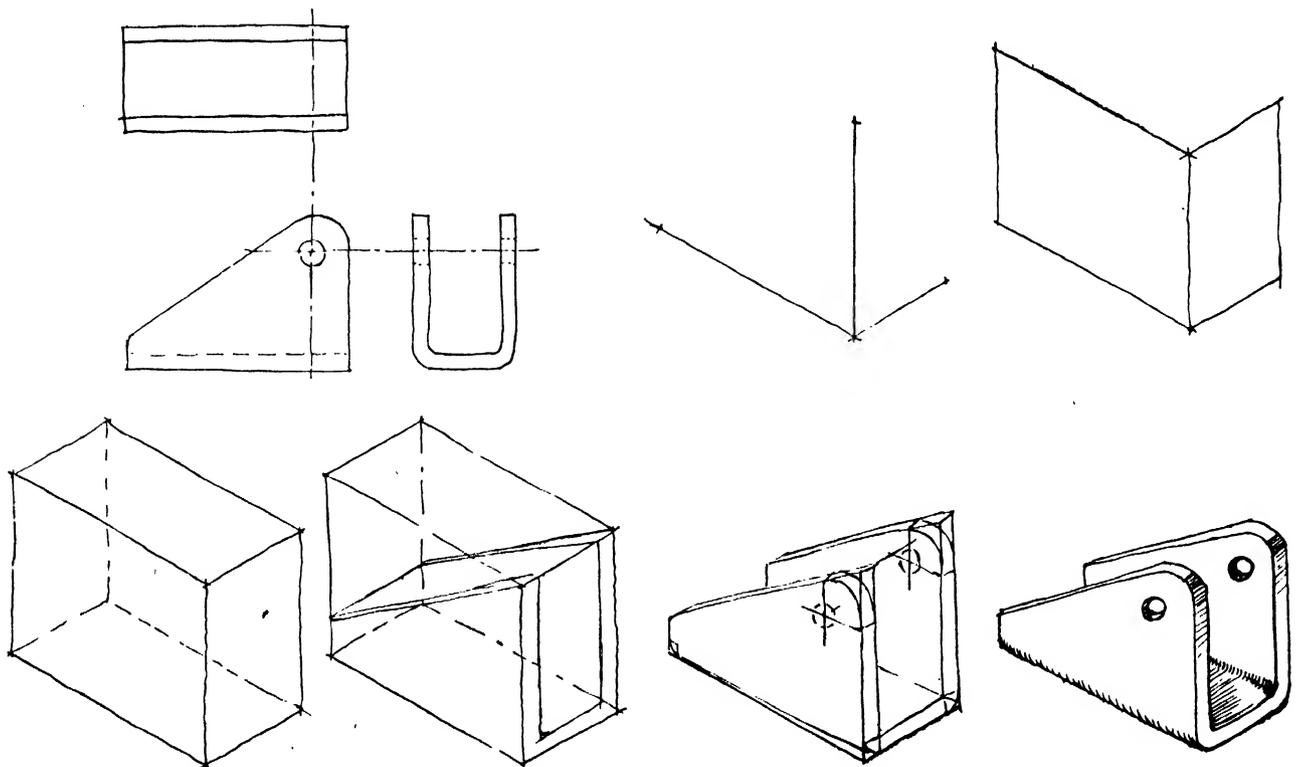


Fig. 280. To draw a freehand pictorial from an orthographic

in a downward direction with a finger or a finger and wrist movement. Horizontal lines may be drawn from left to right with a wrist and arm movement. Diagonal lines may be made by shifting the hand or by turning the paper about with respect to the hand's position (Fig. 275).

Parallel lines may be formed conveniently by turning the paper about as for diagonal lines. The pencil glides quickly over the initial line so that the arm movement coincides with the direction of that stroke. The paper is then carefully moved while the arm (in the same position) repeats the parallel stroke. Draw long lines in a series of wide dashes. This tends to make a straighter and more uniform effect. Light dots may be placed on the extremities of the line or along the line if it is of considerable length. A light construction line may be guided by dots, then accented.

*Drawing Circles and Arcs.* The amount of time spent in drawing freehand circles and arcs depends on the degree of accuracy required. Small circles may be drawn within a square, or,

for greater accuracy, the square may be broken into quadrants with an arc sketched lightly into each quadrant (Fig. 276).

Large circles can be made with a strip of paper marked with the required radius. The paper is placed so that one mark constantly touches the center while the strip is rotated. Guiding points are established for the required circumference, as described in Fig. 277.

Elliptical shapes may be drawn as shown in Fig. 278.

*Drawing a Freehand Orthographic Sketch from a Pictorial.* Study the construction of the object carefully. Determine the necessary views, approximating their proportion and over-all shape. Place the "blocks" in which the views will be drawn so that they give the sketch a well-balanced appearance. Block in the general characteristics of the object and draw light lines to the other views. The drawing may now be accented and hidden lines added to complete the views (see Fig. 279).

*Drawing a Freehand Pictorial Sketch from*

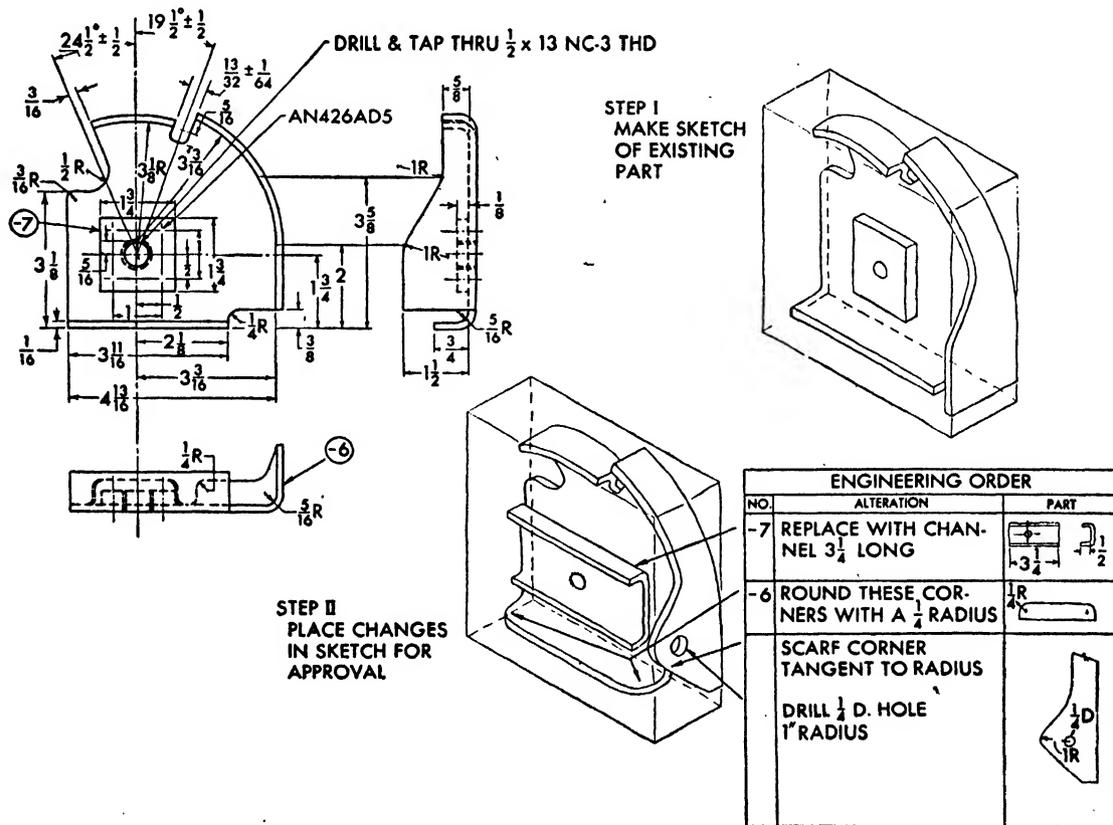


Fig. 281. Pictorial sketch as an aid to drawing changes

*an Orthographic.* When making a freehand pictorial sketch, be sure to study the subject thoroughly until a clear mental picture is formed.

Most small objects can be constructed on the isometric axes—one vertical line and two lines intersecting it at 60 degrees. With reasonable practice these angles may be approximated by eye. An imaginary box or crate is constructed to hold the desired object. The sides of this crate must be approximately proportional to the sides of the object. The general characteristics of the object are blocked in. Center lines and tangent lines are carefully approximated, and ellipses and arcs are drawn. The figure is completed by adding a few lines to throw the form into relief (see Fig. 280). Hidden lines are used only if they tend to clarify the drawing.

*Use of Freehand Drawings to the Draftsman.* Freehand sketches are useful in planning how

to incorporate changes on drawings. Such changes are one of the first assignments given draftsmen. An engineering order describing the changes to be made accompanies the tracing.

If the draftsman is in doubt as to the nature of the change, or cannot quite visualize the modification, he should draw a sketch of the existing part and make the changes on the sketch first.

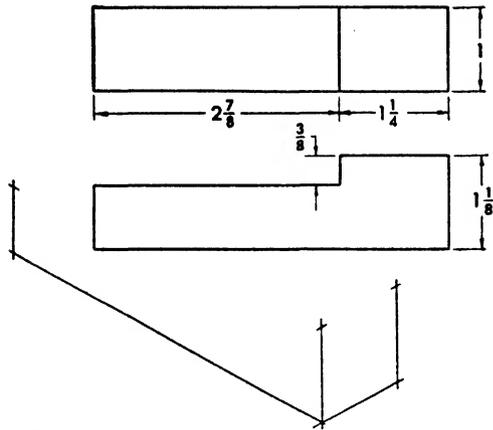
Working out a pictorial sketch for verification by more experienced draftsmen will save time and make progress more rapid for the beginner and his group.

A group engineer can explain the function or describe the shape of an object far more easily if a pictorial sketch is presented to him than when he must rely only on words. Seeing the sketch, he can discern immediately the beginner's degree of familiarity with and understanding of the project and can supply more readily the desired information.

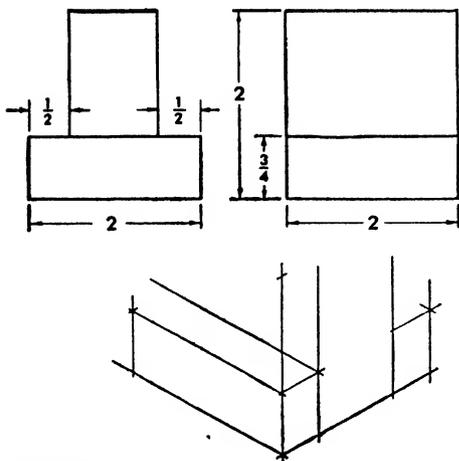
# PROBLEMS FOR CHAPTER TWELVE

Problems 1-17

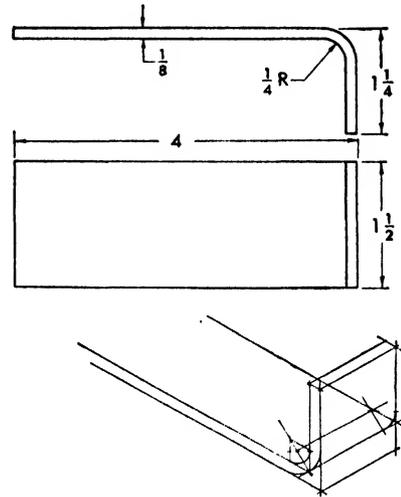
Draw isometric views.



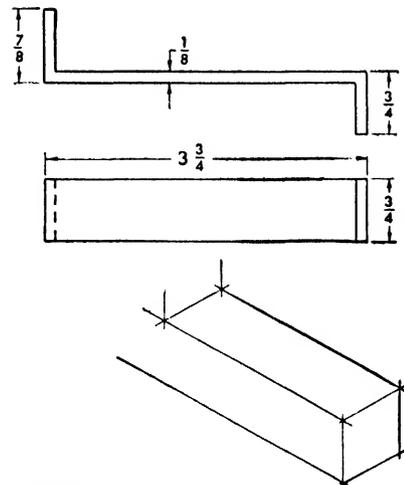
Problem 1



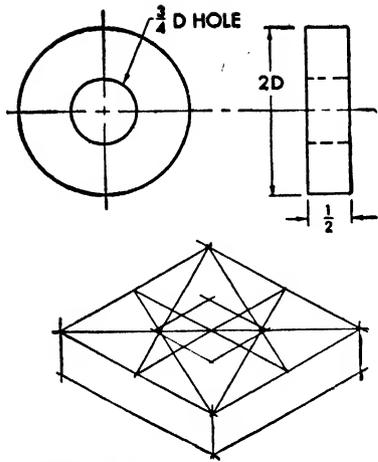
Problem 2



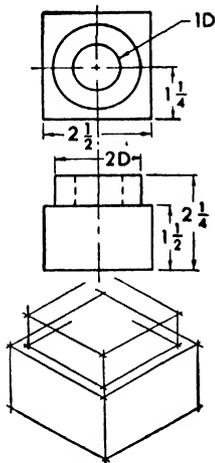
Problem 3



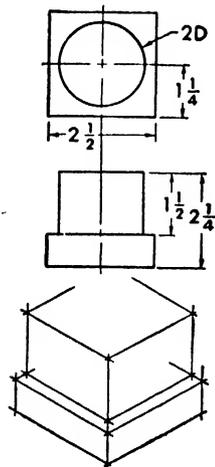
Problem 4



Problem 5



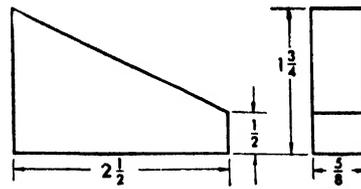
Problem 6



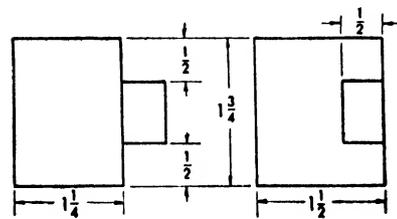
Problem 7

Problems 8-19

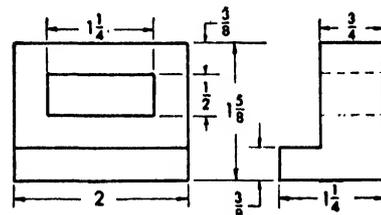
Draw problems 8-19 in oblique, isometric, perspective free-hand sketches.



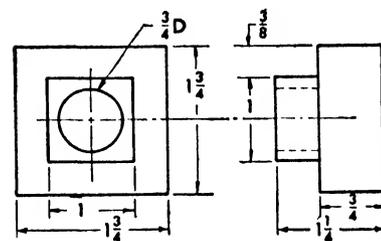
Problem 8



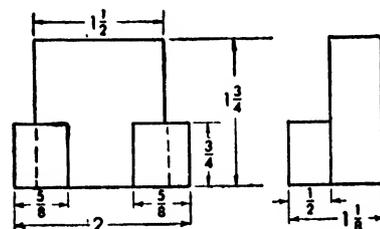
Problem 9



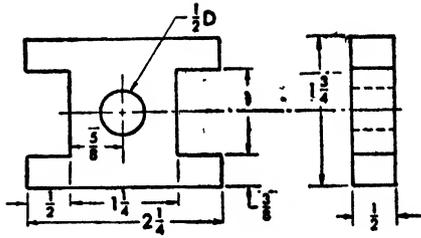
Problem 10



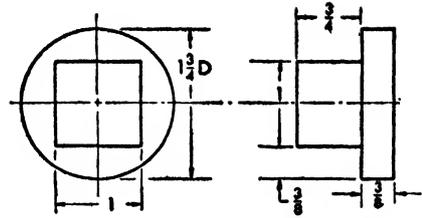
Problem 11



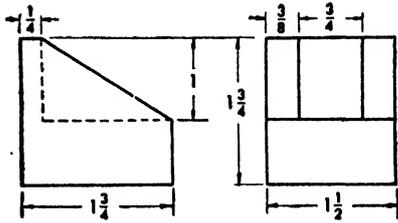
Problem 12



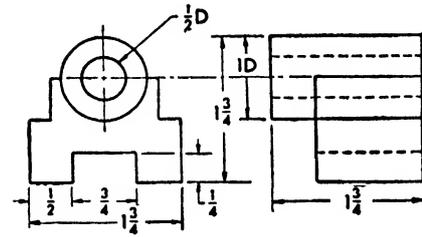
Problem 13



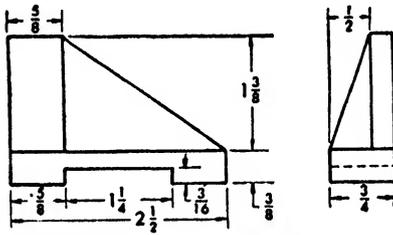
Problem 18



Problem 14



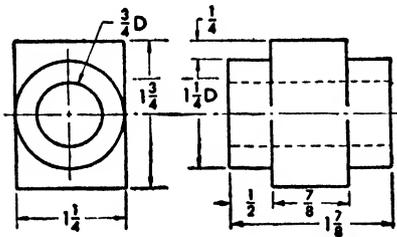
Problem 19



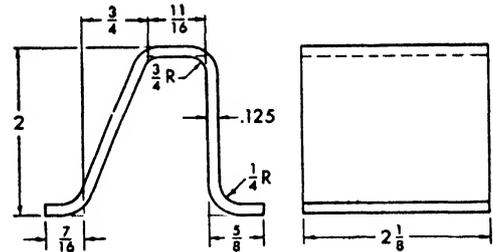
Problem 15

Problems 20-37

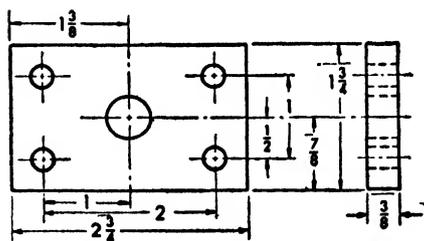
Draw oblique, isometric free-hand sketches.



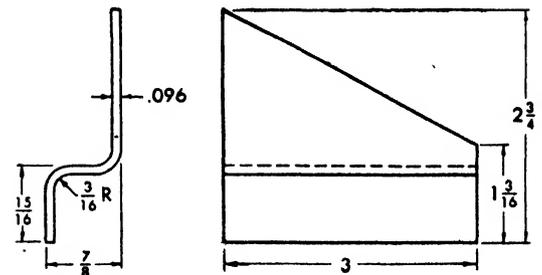
Problem 16



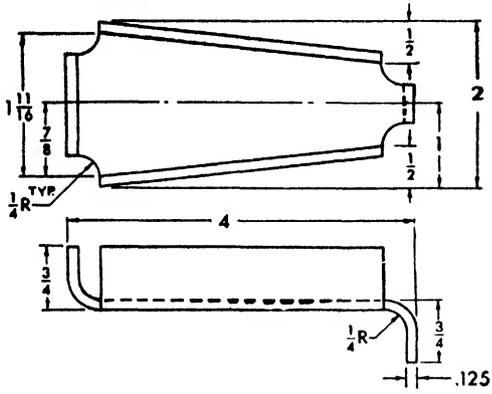
Problem 20



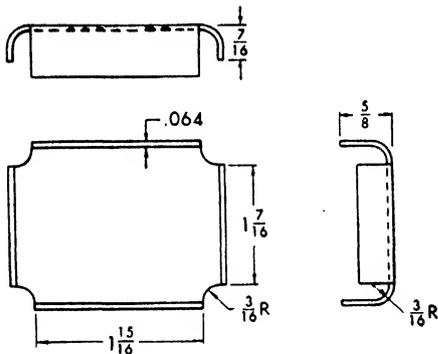
Problem 17



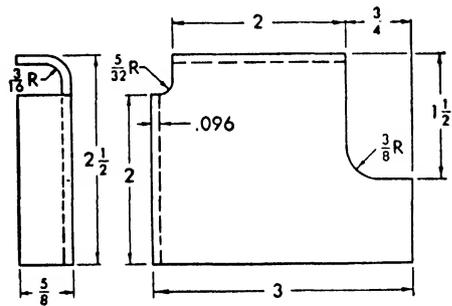
Problem 21



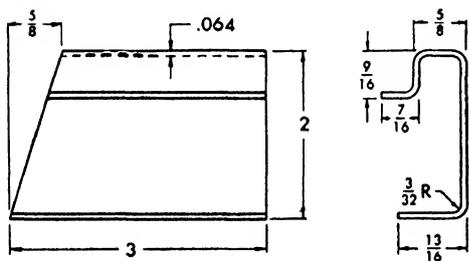
Problem 22



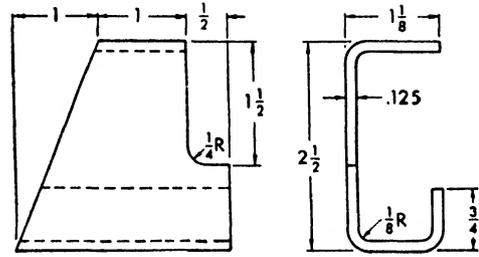
Problem 23



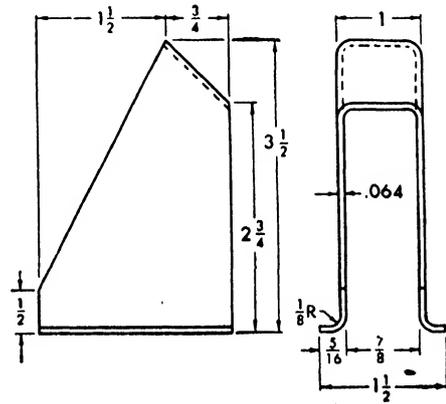
Problem 24



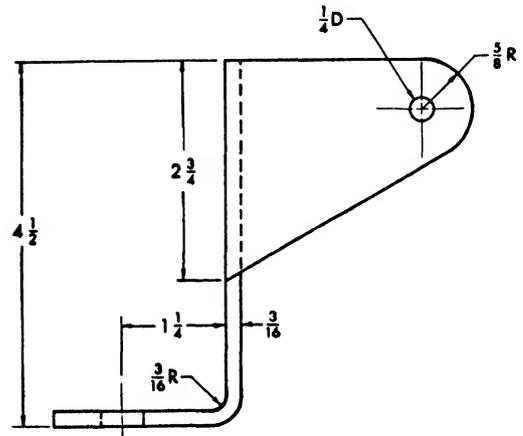
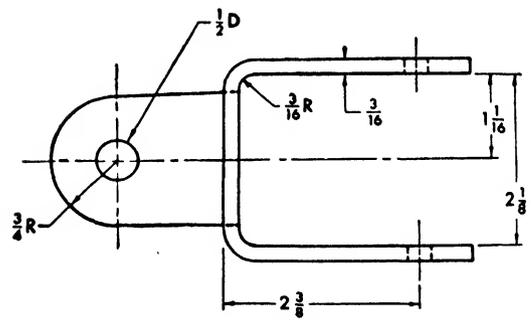
Problem 25



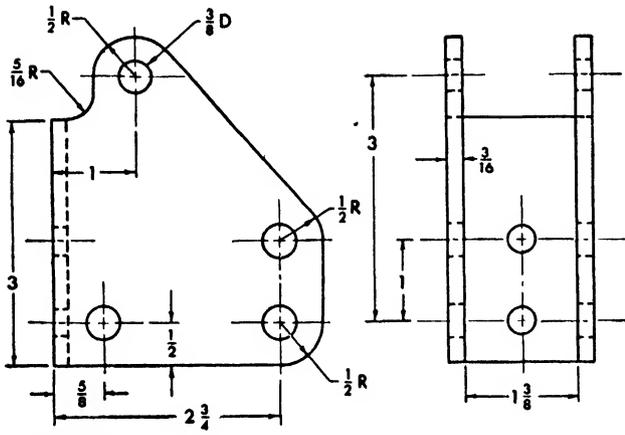
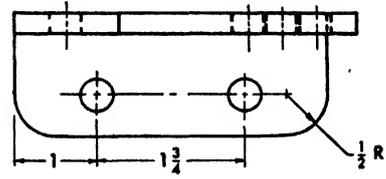
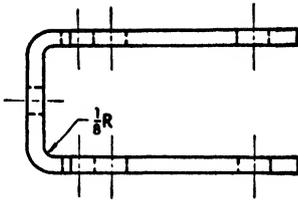
Problem 26



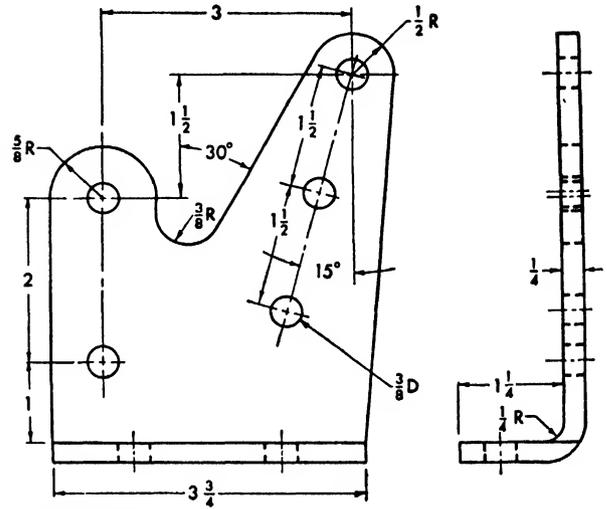
Problem 27



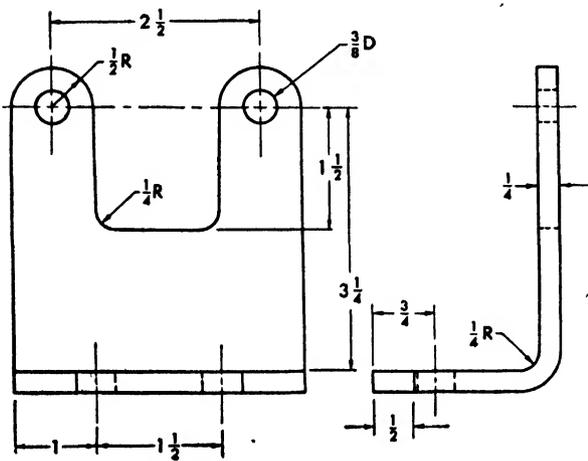
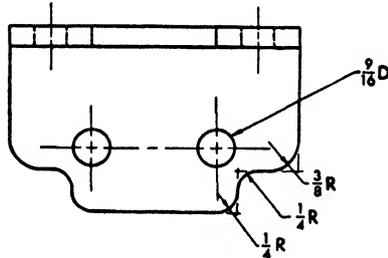
Problem 28



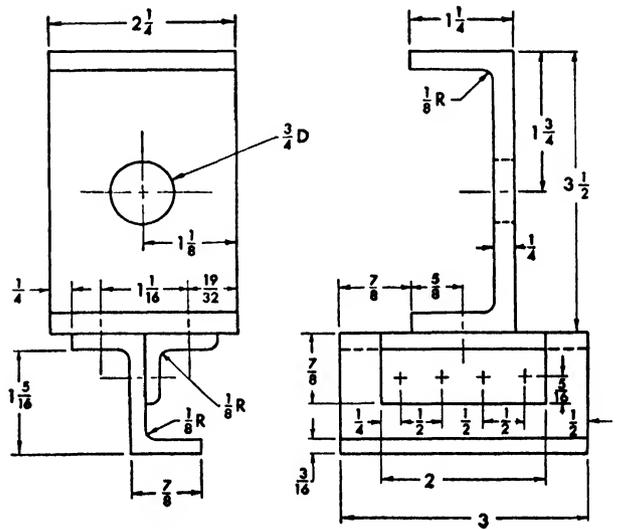
Problem 29



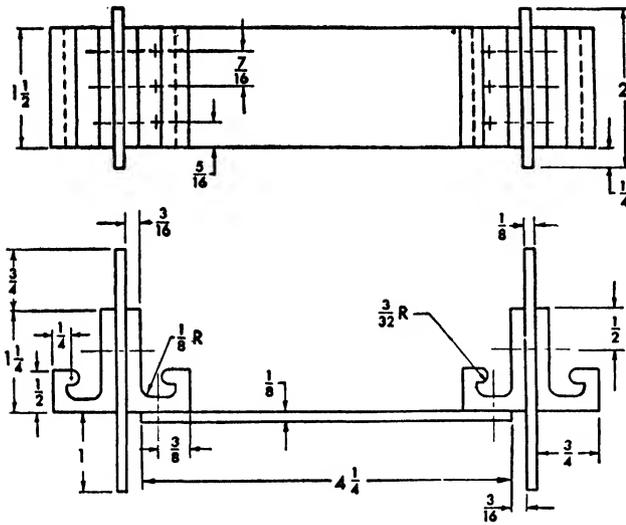
Problem 31



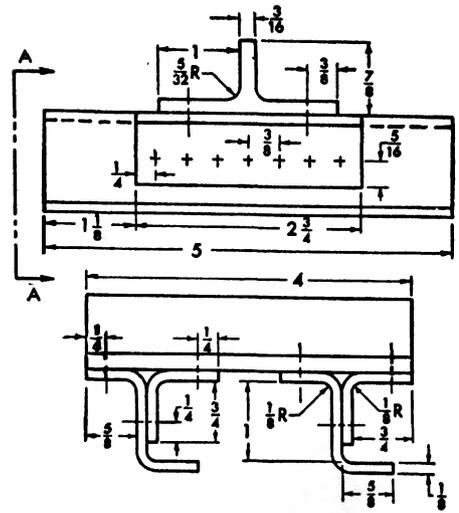
Problem 30



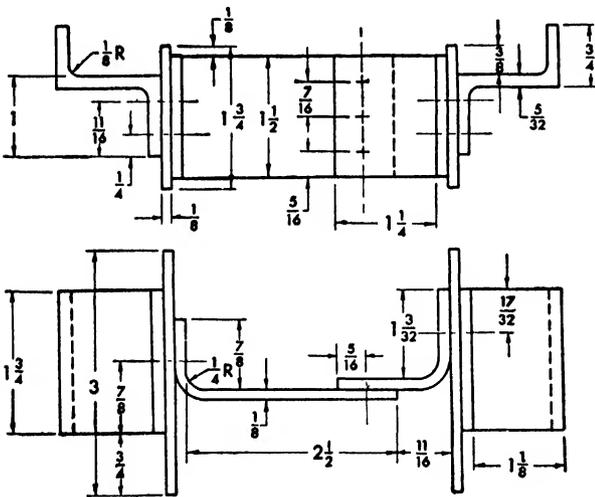
Problem 32



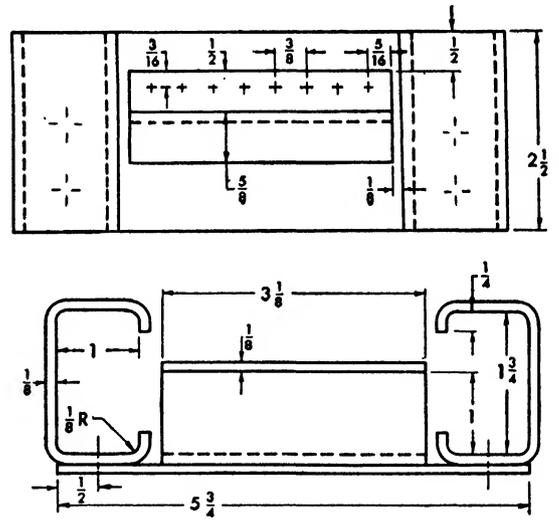
Problem 33



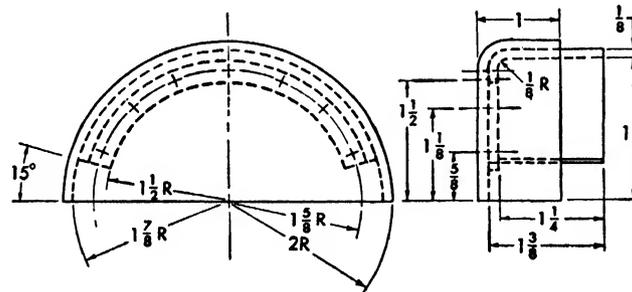
Problem 35



Problem 34



Problem 36



Problem 37

## CHAPTER THIRTEEN

# PRODUCTION CHANGES IN AIRCRAFT DRAWINGS

Of all modern industries, none has compressed its development and growth into so short a span of years as has the aircraft industry. A system of production flexible enough to allow for almost daily changes in design and techniques is the natural, necessary result.

Any such change, introducing new materials or new design details, is initiated by the engineering department of the aircraft plant. The practical task of passing on the information from the point of origin—perhaps in the field of operations or on the assembly line—to the central engineering group is usually assigned to the engineering representative group or, as they are commonly called, the liaison engineers. When the information reaches the central engineering group in the engineering department, it is assigned to a member of the project group that works on the particular part. This group studies the proposed change thoroughly and, if it approves, works out the detailed specifications, including the materials to be employed and the types of planes affected, and notifies all departments concerned in the production of such parts.

All changes are recorded in the engineering department to make certain that the new parts will be fabricated or purchased at the proper time.

Many people connected with aircraft production underestimate the importance of changes. The cost of the average change, including no material and production costs but only the correction of records, is more than \$50. Some of the larger aircraft corporations spend well over a million dollars annually on minor changes alone. The major ones may cost as much as half or three-quarters of a million dollars each. An effi-

ciently run project office can usually reduce this expenditure by eliminating many suggested minor changes that do not benefit production or operation.

The three standard types of changes are record change, production improvement, and design change.

### *Record Change*

This type of change is essential but not urgent, because the parts themselves do not suffer alterations and the departments using the parts are usually familiar with the corrections in the records. Nevertheless, this correction must go through the usual channels to ensure that engineering drawings, release records, and other documents are up to date. The procedure is the same as for all other types of changes, but the engineering department does not need to make a prolonged study of the proposition.

Record changes are most often concerned with corrections in the number of parts used or with the elimination of unnecessary or duplicate information or of misleading notes from engineering drawings or release sheets.

Usually, record changes are caused by mistakes in the engineering department, due either to negligence or to insufficient shop information.

### *Production Improvement*

Probably the most common changes are those affecting production improvements. This type includes all kinds of changes that speed up production, reduce costs, or improve assembly methods. Such changes are approved only after considerable study and only if they are proved to be more efficient than the methods they re-

place. Production improvement suggestions travel through the regular channels but involve an additional group known as the industrial engineering department. This department makes time and motion studies in shops, in offices, on the assembly line, and wherever time is an essential factor. The industrial engineers examine the proposed production changes from the point of view of time costs. Sometimes suggestions are submitted first to the industrial engineering department, which, if it approves, turns them over to the engineering representatives who then expedite them through the regular channels.

*Design Change*

Design changes are not only the most important type of change, but also the most costly. They are made as the result of tests, trials, and much deliberation and, for the most part, are inherent in the rapid progress of aeronautics as a whole. The keen competition of various companies and of various countries engenders a continuous race that makes the airplane of today almost obsolete by tomorrow. From its introduc-

tion to its replacement—an average life span of but 3 or 4 years—a particular model may be subject to several hundred changes, half of them design changes. The first model may be lacking in power, range, or some aerodynamic feature. The imperfection may not be detected in the preflight tests, but will appear under difficult flying conditions. For example, suppose controls respond in the experimental tests, but under actual flight conditions the ship proves refractory to control action. As a result, the aileron, the rudder, or the stabilizer may be enlarged to give the expected response.

*Engineering Order or Advance Engineering Information*

Because of the great number of changes, especially record and production changes, it has been necessary to establish a standard form for their introduction. The form generally accepted by the major aircraft plants is known as the "engineering order" or "engineering advance information." In minor respects it may vary a little from company to company, but the major entries

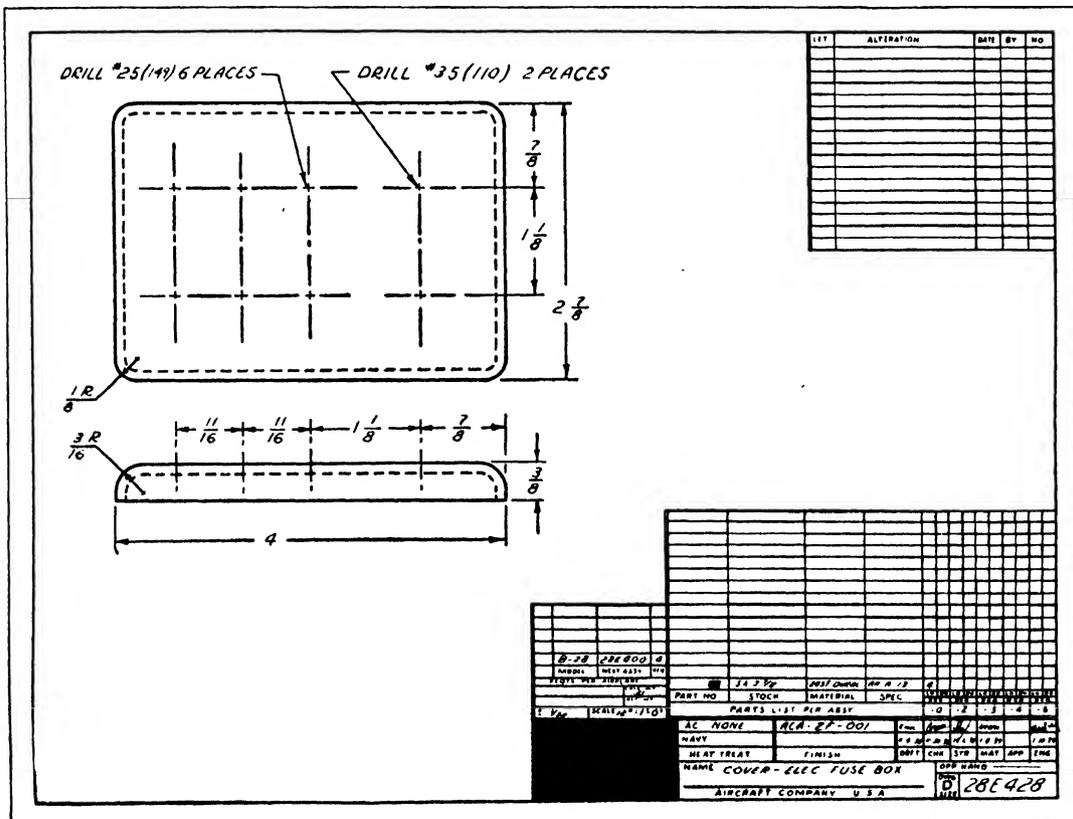


Fig. 282. The original tracing #28E428

are approximately the same everywhere. These are the title and the number of the part affected, the reasons for the change, the airplane subject to change, and, as a rule, an illustration along with the full description of the change.

While the engineering order is the standard form, there are many miscellaneous forms authorizing changes. Some of the widely used miscellaneous forms are the "engineering drawing change request," "change request," and "AVO's" (avoid verbal orders), used to correct drawings that contain errors due to oversight or lack of information. Engineering change instructions and factory liaison requests are issued for the same purpose as the engineering order: to transmit information to all departments concerned as well as to the central engineering group.

Incorporation of a change on the production drawing is the final step in effecting the change requested on any of the different forms. The standard procedure varies only slightly from plant to plant. All changes not yet incorporated in the drawing are gathered and their dates of issuance are studied. The last authoritative change invalidates all prior changes of a similar nature. After the changes are arranged chronologically and checked for duplication and cancellation, the release records are checked for release requirements and for the models that will be affected. Should the drawing instructions and the release records disagree, the latter usually take precedence.

The alteration block is probably the most important record. It is a permanent record stating

AIRCRAFT U.S.A. COMPANY		ENGINEERING ORDER					S-7459
STATUS OF MAT UNAFECTED	DIS OF STOCK REWORK	CHGD Hwy	CHKD Hwy	GR. ENG Hwy	STRUCT SMITH	PRO ENG Hwy	SERIAL NO. PART NO.
PART NAME COVER - ELEC. FUSE BOX							28E428
REASON FOR CHANGE SWITCH EL. 735-6 REPLACED BY #5W 410-8 FOR NEW HEATER CIRCUIT		MODEL B-28	EFFECTIVE ON ALL				
							DATE 1-28-43
<p>CORRECT FACE OF DRAWING AS SHOWN BELOW</p>							
<p>INT. CHG. NEG.</p>							
<p>TOOLING UNAFECTED</p>							

Fig. 283. The Engineering Order effecting a change on tracing # 28E428

concisely all the items that have been altered since the release of the first model. Entries on this alteration block are made only after the changes have been completed on the face of the drawing and the bill of materials has been revised. The information in the bill of materials includes all the parts needed to complete the object of the drawing, and it must correspond to the face of the drawing. Any omissions on the bill of materials may seriously impede the usability of the fabricated part.

Always remember that the change, no matter how small, is essential to the production of the plane. It may affect only a minor part, but it is vital for efficient and successful production.

PROCEDURE

1. Check change requests against prior incorporations on drawing.
2. Check authorization for change (E.O.) for following information:
  - a. Is change authorized?
  - b. Do part number and part name agree with those on the tracing to be corrected?
  - c. What is the reason for change?

- d. What is the disposition of stock on hand?
- e. Is complete information given with regard to:
  - (1) necessary dimensions
  - (2) requirements for corresponding parts (e.g., bolts and nuts)
  - (3) locating lines, parts, etc.
  - (4) weight changes.
- f. Is interchangeability affected,
  - (1) If the part changed is not interchangeable with those installed on previous planes, is the point of replacement noted?
  - (2) If interchangeability is affected, is there a new assembly created, releasing parts for the planes designated on the request?
- g. After checking all the information regarding the change, incorporate the change on the drawing as shown in Fig. 284.
- h. After completion, record the change completely and concisely in the alteration block above the bill of material. A circled letter drawn in the vicinity of the change is repeated in the alteration block with explanation.
- i. Releasing a changed drawing is the same as the procedure in releasing a new drawing. It is checked for:
  - (1) Number of parts used per plane
  - (2) Increase or decrease in material stock.

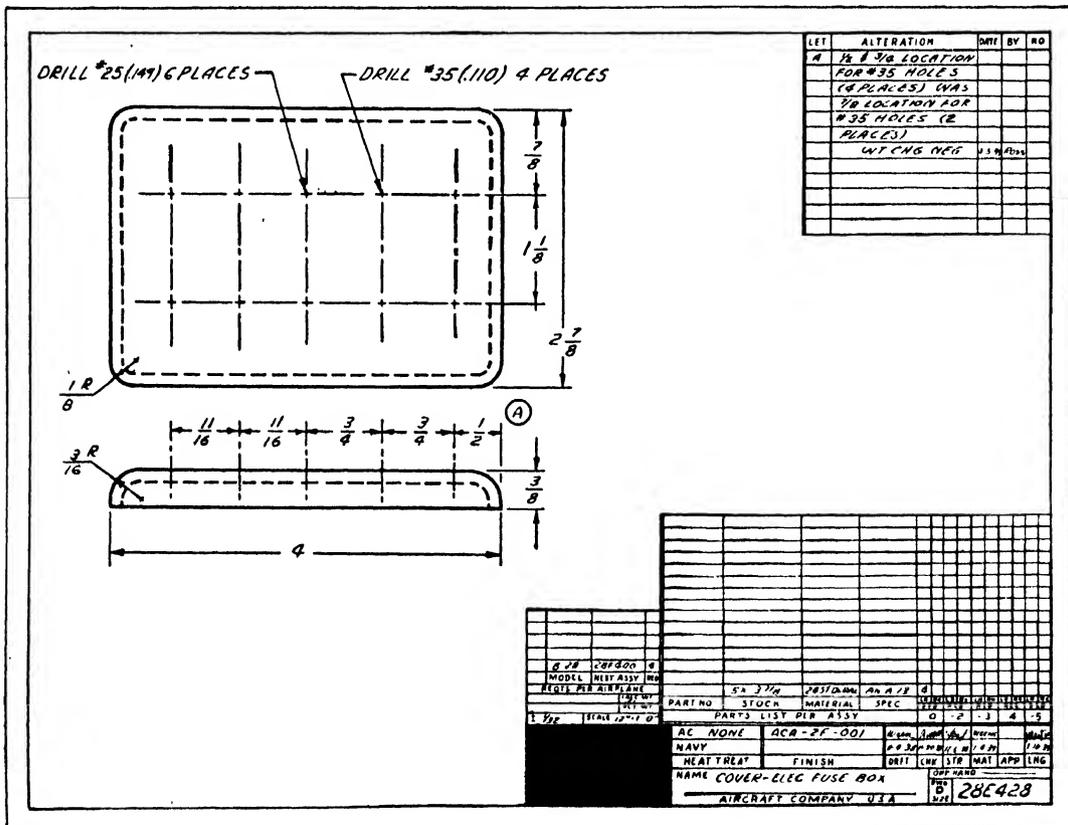


Fig. 284. The change incorporated on tracing #28E428

## CHAPTER FOURTEEN

# MATERIALS IN AIRCRAFT

There is an interesting history behind the materials used to build present-day airplanes. In fact, one of the most important reasons for the tremendous advance in aircraft has been the constant improvement in materials. Our modern airplanes, characterized by their size, their streamlined appearance, and their ability to carry profitable loads great distances, could not have been created without the progressive improvement in materials. Nor will the super airplanes of tomorrow reach our expectations if our knowledge of materials is not increased.

For many years after the birth of aviation, airplanes were in the "stick and wire" stage. These ships were almost entirely wooden. The structural parts were covered with fabric, which is really nonstructural. The strength of the plane came, in part, from external bracing, usually wire. Spruce was the strongest and lightest wood available for aircraft, but its strength-weight ratio was extremely low as compared to the aluminum alloys now employed. The cloth covering was coated with dope, which made it taut and able to retain its shape in flight but added practically nothing to the strength of the plane. External bracing of wing structures would make modern designers shudder, because of the decreased efficiency due to air resistance, but the early builders did not know how to eliminate the wires and struts that served to support their wooden frames.

Originally, the use of metal was limited almost entirely to engines, which weighed several pounds per horsepower. Stronger and lighter metals and improved design methods have lightened the typical modern airplane engine to about 1 pound per horsepower.

Wood construction for fuselage framework was soon superseded by welded steel tubing—sturdier, less voluminous, and sometimes even

lighter. As the stronger aluminum alloys were developed and were made available, they were universally accepted by airplane designers. Although magnesium parts are being designed increasingly, experience is insufficient to warrant large scale replacement of aluminum as yet. Not only the major parts of primary structures, but almost universally the outer coverings of wings, fuselage, and tail as well, are now made of aluminum alloys. The metallic skin has resulted in much more efficient designing because of its greater rigidity and because this skin is capable of taking a good portion of the loads formerly carried by the primary structure alone. Where a metal skin carries such loads, the structure is called "monocoque," and this development has eliminated the use of external bracing on all modern airplanes, except a few of the trainer class.

The engineering draftsman has been trained to think and to visualize, plan, and design. He actually works with pencil and paper but creates structures which will be composed of aluminum alloys, steel, magnesium, and other materials. His ability to put himself in the mechanic's place, and to think in terms of structural materials, enables him to plan his work efficiently and to design a part which can be made with a minimum amount of difficulty, and which will effectively serve its intended purpose.

In designing a part, the proper choice of material is essential. Here, experience is the best teacher, although technical reasons have to be considered. If high strength is required and limited space is available, steel is generally used. Moderately high strength calls for aluminum. Lightly loaded parts requiring little strength often are of magnesium. If the space is not restricted, other materials such as wood, plastics, and micarta may be utilized. But weight is the

determining factor in the selection of materials.

Nearly all of the metals used in aircraft construction are alloys. For example, some aluminum alloys contain, in addition to aluminum, small amounts of copper, manganese, magnesium, silicon, and chromium. By altering combinations and percentages of metals, various alloys of different characteristics are produced. To illustrate this point, the ultimate obtainable strength of a "2S" alloy is about 25,000 pounds per square inch, while that for a "24S" alloy is over 70,000 pounds per square inch. The various aluminum alloys are identified by numbers such as 2S, 3S, 15S, 17S, 24S, 52S, 53S, 61S. Steel and magnesium are also produced in several different alloys.

Not only do various alloys possess different characteristics in their original form, but they react individually to processes such as rolling, stretching, or heat treating. If the draftsman-engineer wishes to design efficiently he must become acquainted with the materials commonly used, their alloys, their reactions to processing, and their applications.

A good draftsman-engineer will always remember that his product must be satisfactory not only for test flights but also for long service. For this reason, he is vitally interested in the surface protection each part is to receive. Certain materials possess superior corrosion resistance, for example, aluminum alloy can be coated with pure aluminum to produce "Alclad," resistant to the elements. Before painting, chemical treatment is usually given all metal parts. The various surface treatments are specified by the army and navy. Every engineer should be able to choose the proper "finish" for his design.

#### STRENGTH OF MATERIALS TERMS

The study of strength of materials lies within the realm of "bona fide" aircraft engineering rather than that of aircraft drafting. No attempt is made here to analyze strength of materials, but the knowledge of certain terminology has a very real value to the aircraft draftsman. An understanding of terms enables the draftsman to comprehend some of the basic reasons for the structure of the parts he draws, and may explain the necessity for drawing changes he is asked to

make. In addition, this terminology enables him to use intelligently tables and charts of simple stress calculations.

#### *Stress and Strain*

Any cause that produces or modifies motion is termed "force." A gust of wind striking the side of the plane exerts a force on that side of the plane. The landing impact of the plane exerts force on the landing gear. When such outside forces, called "loads," are applied to a body, an inside force called "stress" develops within the body to counteract the outside applied force. Force acting upon the material may produce tension, compression, shear, bearing, bending, torsion, or a combination of these. The degree of applied force or "load" is measured in pounds per square inch (abbreviated psi). If stress is not too great, the material will return to its original shape and size after the applied load has been removed. If the load is excessive, the material will not return to its original shape but remains deformed. This deformation is called "permanent set." Although assembled materials must resist deformation in the operation of the airplane, it sometimes becomes necessary to deform them in the process of their manufacture by drawing, stretching, bending, etc.

#### *Stresses on the Plane*

The word "tension" originates from the Latin *tendere*, to stretch. TENSION is a force that tends to pull an object apart (see Fig. 285). A weight suspended on a wire creates tension within the wire. A force applied under the wing tends to pull the supporting strut away from the fuselage.

COMPRESSION is a force that tends to crush an object (Fig. 285). When an airplane lands, the landing gear strikes the ground, and this compresses the shock absorber. The force exerted on the metal between two forming dies is compression.

BEARING strength is the resistance of a body against tear. It may be illustrated by puncturing a piece of paper or light cardboard with a pencil and pulling the paper away from the stationary pencil (Fig. 285). The paper will rip. Similarly, in a riveted joint, the metal will tear if undue pressure is applied to the sheet. The limits of

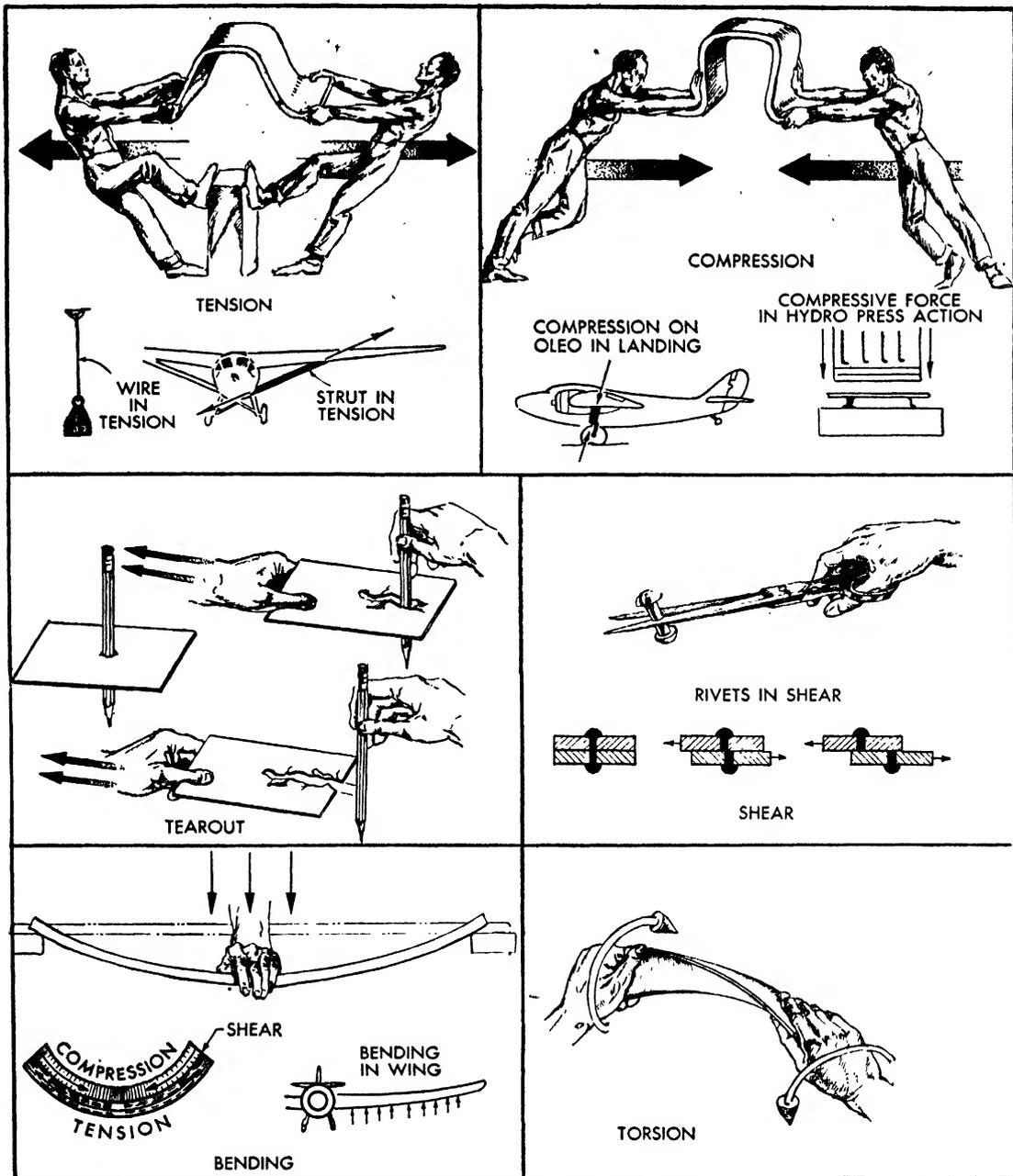


Fig. 285

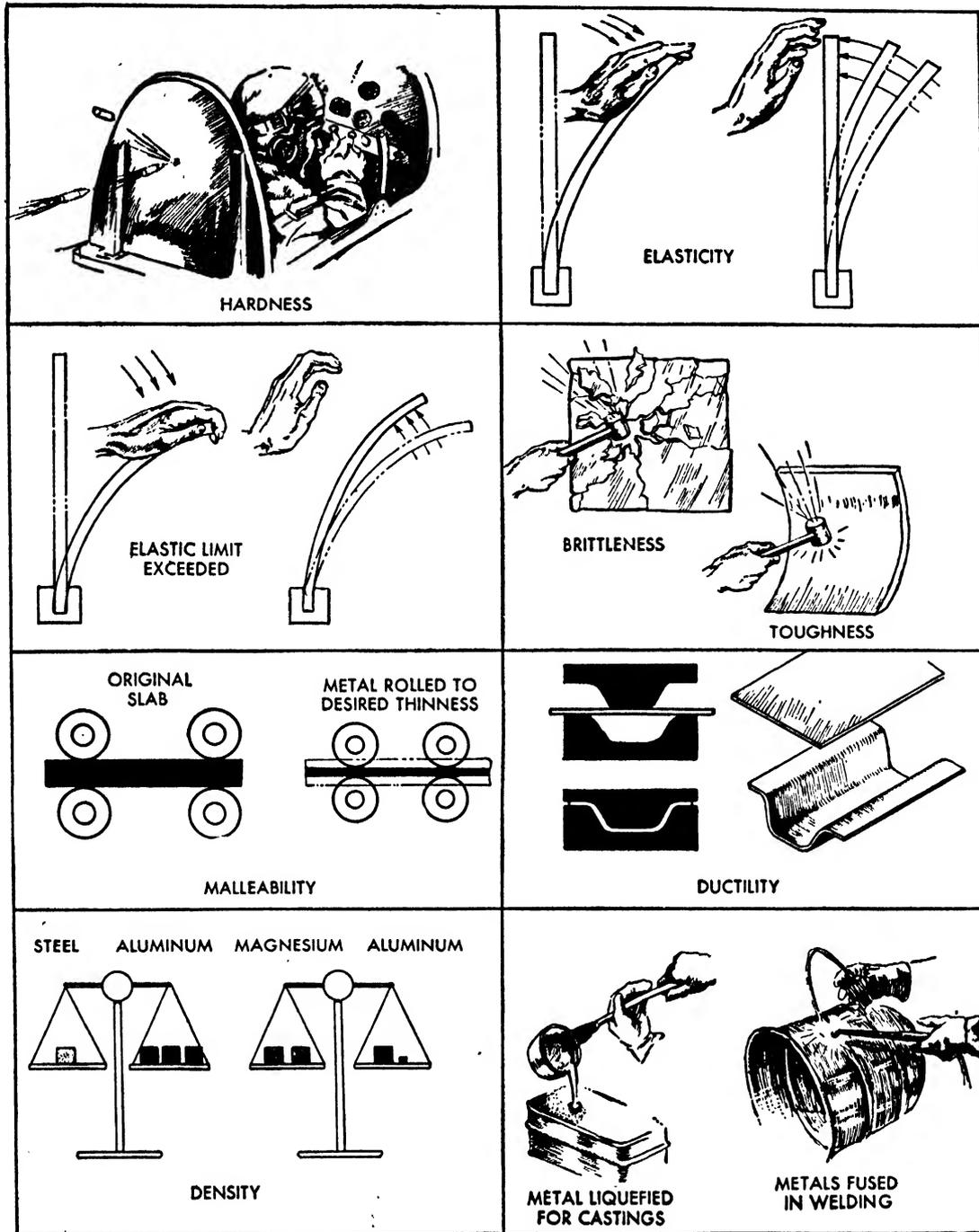


Fig. 286

bearing strength for various gages of aluminum sheet are given in Table 9.

**SHEAR** is a force that makes molecules of a material slide over one another, cutting the body (Fig. 285). It may be compared to the cutting action of a pair of shears. If we take the example described in the preceding paragraph and replace the paper by two sheets of aluminum alloy with a hole drilled to allow a pencil to pass through, then pull the sheets in opposite directions, they will tend to shear or cut the pencil in two. Rivets shear when the attached sheets are subjected to an excess force and when the shear strength of the rivet is less than the bearing strength of the sheet. Shear strength is expressed in terms of the resistance offered by a body against cutting. Shear strength values for aluminum alloy rivets are given in Table 7.

**BENDING** is a combination of forces which results in curving the body from its original position. As shown in Fig. 285, the upper part of the body is compressed, the fibers are crushed together, but the lower part is in tension since the fibers are stretched. Under certain conditions, a third stress, a shear, occurs along the neutral axis or center of the body between the compressive and tensile forces.

**TORSION** is a twisting force (Fig. 285). It occurs when two forces contort a body in opposite directions or when one end of the body is held securely while the opposite end is twisted.

**TENSILE STRENGTH**, usually referred to as "ultimate tensile strength" (abbreviated uts), is the measure of a material's maximum resistance to an applied stretching or tensile force. The tensile strength of a material is expressed in pounds per



Fig. 287. Aluminum framework and skin being assembled on a Consolidated B-24

square inch. The word "tenacity" is sometimes used to express tensile strength.

**ELASTIC LIMIT** is the measure of the greatest possible load a material can withstand and still return to its original shape after the load has been removed (Fig. 286).

**ELONGATION** is the extension that remains in a metal after stretching. The elongation is expressed in percentages of the original gage length of the metal. This gage length is frequently 2 inches.

**YIELD STRENGTH** is expressed in the measure of the load (in pounds per square inch) under which a material shows a specified permanent set. The yield point is the load per square inch at which the degree of deformation increases considerably without any increase in the load.

**PROPERTIES OF MATERIALS IN GENERAL**

An understanding of the various properties of materials is a decided asset to the aircraft draftsman. The sooner a beginner can develop into a designer, who can choose the proper materials for his assignment, the more valuable he will be to his employers. But even a detail draftsman needs to know what specifications of bend radii, design limitations, forming characteristics, etc., mean and how to fill out a bill of materials correctly. All this can be best accomplished by understanding the character of the materials involved.

Each metal has its particular characteristics and qualities. Some of these may make it suitable for a particular use in a plane, and some may make it unsuitable. Many metal manufacturing companies experiment continually to produce metals with maximum desirable qualities and without (or with a minimum of) the unwanted characteristics. These experiments account for the great range of alloys and tempers at the disposal of the aircraft engineer. From the point of view of aircraft production, the most important properties of metals are as follows:

**HARDNESS.** This property enables the metal to withstand penetration and wear (see the pilot's armor in Fig. 286). Although strength and hardness are not identical—and the expressions should not be used interchangeably—they are rather similar. The draftsman may obtain the

strength of a given material by referring to the proper chart in this chapter. Hardness may be determined by any one of four popular methods: Brinell, Rockwell, Vickers, and Shore. These methods record the impressions or indentations made on the material by a hard steel ball, by a cone shaped diamond, or by the rebound of a small hammer dropped from a specified height.

**ELASTICITY.** When a force is applied to a body, it is subject to a change of shape. If the force is not too great, the material will return to its original form and position after the applied force has been removed. The property permitting this reversion is called "elasticity." If the applied force is so great that the material will not return to its original shape after the removal of the load, its **ELASTIC LIMIT** has been exceeded.

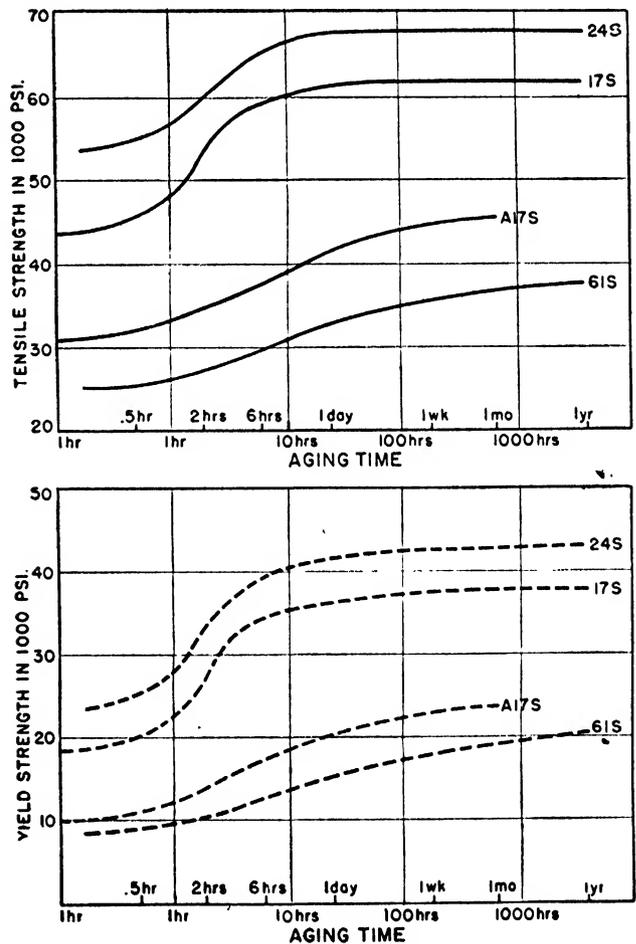


Fig. 288. Room temperature aging of 24S, 17S, A17S, and 61S

**BRITTLINESS.** This property is responsible for the fracture of a material subjected to a sudden shock or compressive force. Brittleness and hardness are not the same thing, although a hard material is generally more brittle than a soft material. A sheet of glass is hard and will fracture readily when struck by an external force. A sheet of aluminum, on the other hand, may "give" when subjected to the same force and not break. Brittle materials are not usable in aircraft structure, as they may fail under shock loads.

**TOUGHNESS.** This property is the direct opposite of brittleness. A tough material will not fracture when bent, twisted, stretched, or formed. Tough metals will stretch under tension and will not shear readily.

**MALLEABILITY.** This property permits a metal to be hammered, bent, twisted, or otherwise permanently distorted without rupture. The name is derived from the Latin word *malleus*, meaning "hammer." The malleability of a metal depends on its toughness and tensile strength. The relative malleability of metals may be

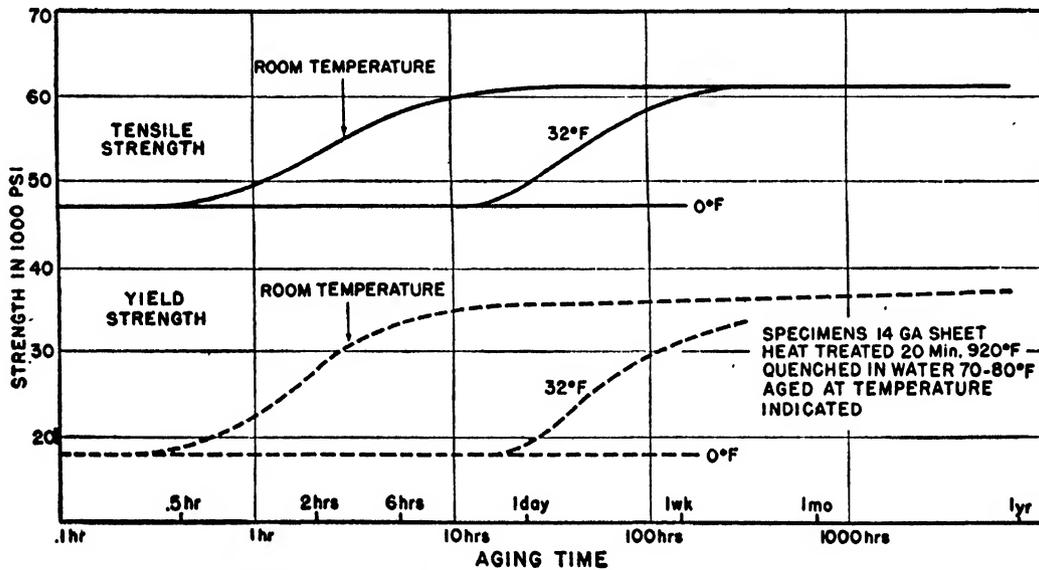


Fig. 289. Aging of 17S at various temperatures

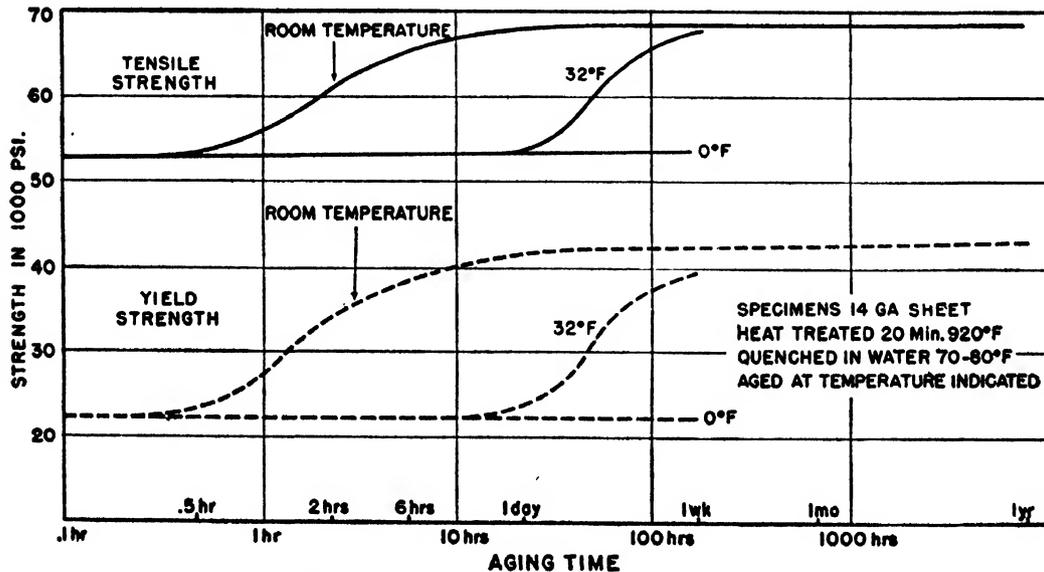


Fig. 290. Aging of 24S at various temperatures

judged from the thinness to which they may be reduced by rolling or hammering from the same original thickness.

**DUCTILITY.** The word is from the Latin *ducere*, to lead. It indicates the degree to which the metal may be lengthened when drawn out by tensile force. This property is essential in materials for the manufacture of wire and tubing. The ease with which a metal may be drawn out depends on its softness, but the thinness to which the cross section can be stretched depends on the inherent tensile strength.

Ductility is similar to malleability in nature, and in aircraft engineering the term is preferred to describe the ability of the metal to be easily formed without rupture. Since ductile metals usually lack the hardness and strength required in structural parts, they are strengthened after formation. However, harder materials that can be conveniently formed are used to replace the softer metals whenever possible.

**DENSITY.** This property expresses the specific gravity of a material, that is, the weight of a unit volume of material as compared with an equal volume of water at a standard temperature and pressure. However, the draftsman is more interested in the actual weight of a material per cubic inch, because this measure helps him to calculate relative weights. The relative weights of steel, aluminum, and magnesium are shown in Fig. 286.

**MELTING POINT.** The melting point of a material is the temperature at which it will turn from a solid into a liquid state. Aluminum melts at approximately 1215 degrees Fahrenheit, nickel at approximately 2642 degrees. Alloys are poured in liquid form into molds for casting.

**FUSIBILITY.** Metals are fused together in the welding process. Fusible alloys have an unusually low melting temperature. When combined with others, some metals melt at a lower temperature than in the unalloyed state. Aluminum alloys fuse at approximately 1100 degrees Fahrenheit.

STOCK NOMENCLATURE

**SHEET.** In aircraft usage, sheet usually refers to a flat stock of aluminum, magnesium, or steel 0.187 inch or less in thickness (or aluminum alloy 0.25 inch in thickness). To produce sheet

stock, the raw ingot is heated until pliable and is passed repeatedly through a rolling mill until it is broken down to the desired thickness. The stock is delivered to the aircraft plant in large rectangular sheets. If less than 14 inches wide, it is called a "strip." Very narrow strips are referred to as "ribbon" or "coil" stock. The thickness of the stock is sometimes expressed in fractions of an inch, as  $\frac{1}{16}$  or  $\frac{1}{32}$  inch, but more commonly in decimal equivalents, such as 0.064 or 0.032 inch.

Flat sheet has a variety of uses in airplane production, from large skin coverings and beam webs to small bent-up clips. Corrugated sheet is sometimes used under the wing skin, for flooring and other miscellaneous purposes, to strengthen high stressed sections.

**PLATE.** Flat stock of over 0.187 inch thickness is called "plate." Plate is produced in a manner similar to sheet. Plate is used conservatively because of its bulk and weight. The parts of the plane requiring greatest strength may be composed partially of plate. In war planes, armor

TABLE 1.\* TEMPER DESIGNATIONS FOR HEAT-TREATABLE ALLOYS

Type	Description	Temper Designation	Example
Wrought Alloys	Annealed condition	"O"	24S-O
	Heat treated and quenched but not aged completely	"W" <sup>1</sup>	61S-W
	Full heat treated condition	"T"	24S-T
	Heat treated and subsequently cold worked a prescribed amount	"RT"	24S-RT
Cast Alloys	Specific tempers attained by different heat treatments are indicated by number	"T4" "T6," etc.	195-T4 195-T6
	FOR NONHEAT-TREATABLE ALLOYS		
Type	Description	Temper Designation	Example
Wrought Alloys	Annealed condition	"O"	3S-O
	Intermediate tempers produced by cold working various amounts	" $\frac{1}{4}$ H" " $\frac{1}{2}$ H" " $\frac{3}{4}$ H"	53S- $\frac{1}{4}$ H
	Full hard temper obtained by maximum commercial degree of cold working	"H"	2S-H
Cast Alloys	No temper designation	—	43

<sup>1</sup> "W" Temper is applied only to those alloys which require an artificial aging treatment to produce the fully heat treated "T" condition.

\* Tables 1-18 are from *Aluminum in Aircraft*, 1943 edition, a copyrighted booklet of the Aluminum Co. of America.

protection for engine and man is made of steel plate.

**ROD.** A solid cylinder section,  $\frac{3}{8}$  inch in diameter and over, is termed a "rod."

**BAR.** Rectangular, square, hexagonal, and other shapes having a cross section of  $\frac{3}{8}$  inch and over are termed "bars." The method of producing rods and bars is similar to that of producing

sheet and plate in that rolling pressure is employed. The rolls, however, instead of having flat faces, are grooved to produce the desired shape. A number of rollers are used, each with a reduced groove area, and the material is passed progressively from the largest to the smallest. Rods may be fabricated by drawing also.

Rods and bars are used primarily in the ma-

TABLE 2. GOVERNMENT SPECIFICATIONS FOR ALCOA ALUMINUM ALLOY PRODUCTS

		WROUGHT PRODUCTS					
<i>Aluminum Products and Nominal Composition<sup>1</sup></i>	<i>Temper</i>	<i>Army-Navy (AN) Aeronautical</i>	<i>Federal<sup>2</sup></i>	<i>Army Air Forces<sup>2</sup></i>	<i>Navy<sup>2</sup></i>	<i>Typical Aircraft Uses</i>	
<b>2S</b> (99.0% Min. Aluminum)							
Sheet	O, $\frac{1}{2}$ H, $\frac{3}{4}$ H, H	.....	QQ-A-561	Federal	47A2	Tanks, ducts	
Plate	As Rolled	.....	QQ-A-561	Federal	47A2	Nonstructural	
Wire	O, $\frac{1}{2}$ H, $\frac{3}{4}$ H, H	.....	QQ-A-411	Federal	46A3	General, nonstructural	
Bar, Rod and Shapes	O, As Fabricated	.....	QQ-A-411	Federal	46A3	General, nonstructural	
Tubing, Round	O, $\frac{1}{2}$ H, $\frac{3}{4}$ H, H	.....	WW-T-783	Federal	44T19	Conduit, electric	
Rivets	As Fabricated	AN-FF-R-551	.....	.....	43R5	Nonstructural	
Rivet Wire and Rod	Special	AN-QQ-W-298	.....	.....	43R5	Nonstructural rivets	
Welding Rods	.....	.....	QQ-R-571	Federal	46R7	Welding 2S or 3S	
Wire for Metal Spraying	.....	.....	.....	10285	...	Corrosion-resistant coatings	
<b>3S</b> (1.2% Manganese)							
Sheet	O, $\frac{1}{2}$ H, $\frac{3}{4}$ H, H	.....	QQ-A-359	Federal	47A4	Tanks, ducts	
Plate	As Rolled	.....	QQ-A-359	Federal	47A4	Nonstructural	
Wire	O, $\frac{1}{2}$ H, $\frac{3}{4}$ H, H	.....	QQ-A-356	Federal	46A6	General, nonstructural	
Bar, Rod and Shapes	O, As Fabricated	.....	QQ-A-356	Federal	46A6	General, nonstructural	
Tubing, Round	O, $\frac{1}{2}$ H, $\frac{3}{4}$ H, H	.....	WW-T-788	Federal	44T20	Not standard	
Rivets	As Fabricated	.....	.....	.....	43R5	Nonstructural	
Rivet Wire and Rod	Special	.....	.....	.....	43R5	Nonstructural rivets	
<b>A17S</b> (2.5% Cu, 0.3% Mg)							
Rivets	T	AN-FF-R-551	.....	.....	43R5	General purpose	
Rivet Wire and Rod	Special	AN-QQ-W-298	.....	.....	43R5	General-purpose rivets	
<b>18S</b> (4.0% Cu, 0.5% Mg, 2.0% Ni)							
Forgings	T	.....	QQ-A-367	Federal	46A7	Pistons	
<b>24S</b> (4.5% Cu, 0.6% Mn, 1.5% Mg)							
Sheet and Plate	O, T, RT <sup>4</sup>	AN-A-12	QQ-A-355	.....	47A10	Structural	
Tubing, Round	O, T	.....	.....	10235	44T28	Structural	
Tubing, Streamline	T	.....	.....	57-187-2 <sup>3</sup>	44T31	Struts	
Bar, Rod, Wire, Shapes	O, T	.....	QQ-A-354	Federal	46A9	Structural fittings	
Rivets	T	AN-FF-R-551	.....	.....	43R5	High-strength joints	
Rivet Wire and Rod	Special	AN-QQ-W-298	.....	.....	43R5	Rivets	
Machine Screws, Nuts	T	.....	FF-S-91	.....	43S4, 42S5	Fastenings	
Bolts	T	AN-B-3	.....	.....	.....	Fastenings	
Nuts	T	AN-B-40	.....	29-26	.....	Fastenings	
<b>14S</b> (4.4% Cu, 0.8% Si, 0.8% Mn, 0.4% Mg)							
Forgings	T	.....	QQ-A-367	Federal	46A7	Structural fittings	
Extrusions	O, W, T	AN-A-8	.....	.....	.....	Airframe structures	

Footnotes are at end of table, on page 234.

TABLE 2. GOVERNMENT SPECIFICATIONS FOR ALCOA ALUMINUM ALLOY PRODUCTS (Continued)

WROUGHT PRODUCTS (Continued)

<i>Aluminum Products and Nominal Composition<sup>1</sup></i>	<i>Tempers</i>	<i>Army-Navy (AN) Aeronautical</i>	<i>Federal<sup>2</sup></i>	<i>Army Air Forces<sup>2</sup></i>	<i>Navy<sup>2</sup></i>	<i>Typical Aircraft Uses</i>
<b>17S</b> (4.0% Cu, 0.5% Mn, 0.5% Mg)						
Sheet and Plate	O, T	.....	QQ-A-353	Federal	47A3	Not standard
Bar, Rod, Wire, Shapes	O, T	.....	QQ-A-351	Federal	46A4	Machined fittings
Tubing, Round	O, T	.....	WW-T-786	Federal	44T21	Not standard
Tubing, Streamline	T	.....	.....	57-187-2 <sup>2</sup>	44T22	Not standard
Forgings	T	.....	QQ-A-367	Federal	46A7	Structural fittings
Rivets	T	AN-FF-R-551	.....	.....	43R5	Structural rivets
Rivet Wire and Rod	Special	AN-QQ-W-298	.....	.....	43R5	Rivets
<b>52S</b> (2.5% Mg, 0.25% Cr)						
Sheet	O, 1/4H, 1/2H, 3/4H, H	QQ-A-318	Federal	.....	47A11	Tanks and fairings
Plate	As Rolled <sup>5</sup>	QQ-A-318	Federal	.....	47A11	.....
Tubing	O	WW-T-787	.....	.....	44T32	Oil, fuel, instrument, etc. lines
Wire	O, 1/4H, 1/2H, H	.....	.....	.....	46A11	.....
Bar and Rod	O, As Fabricated	.....	.....	.....	46A11	.....
<b>53S</b> (0.7% Si, 1.3% Mg, 0.25% Cr)						
Sheet and Plate	O, W, T	QQ-A-334	Federal	.....	47A12	Not standard
Bar, Rod, Wire, Shapes	O, W, T	QQ-A-331	Federal	.....	46A10	Semistructural uses
Tubing, Round	O, W, T	WW-T-790	11327	.....	44T30	Not standard
Rivets	W	.....	.....	.....	43R5	.....
<b>61S</b> (0.25% Cu, 0.6% Si, 1.0% Mg, 0.25% Cr)						
Sheet	O, W, T	QQ-A-327	11326	.....	47A12	Engine baffles, fairings
Tubing	O, W, T	WW-T-789	.....	.....	44T30	Engine push rod tubes
Alclad <b>24S</b> Sheet (24S Core)	O, T, RT	AN-A-13	QQ-A-362	.....	.....	Highly corrosion-resistant structural
<b>25S</b> (4.5% Cu, 0.8% Si, 0.8% Mn)						
Forgings	T	.....	QQ-A-367	Federal	46A7	Propellers, engine parts
<b>32S</b> (0.9% Cu, 12.5% Si, 1.0% Mg, 0.9% Ni)						
Forgings	T	.....	QQ-A-367	Federal	46A7	Pistons
<b>43S</b> (5.0% Si)						
Welding Rods	.....	.....	QQ-R-571	Federal	46R7	Welding castings
<b>A51S</b> (1.0% Si, 0.6% Mg, 0.25% Cr)						
Forgings	T	.....	QQ-A-367	Federal	46A7	Fittings and engine parts

SAND CASTINGS

<i>Aluminum Products and Nominal Composition<sup>1</sup></i>	<i>Tempers</i>	<i>Federal<sup>2</sup></i>	<i>Army-Navy<sup>2</sup> (AN) Aeronautical</i>	<i>Navy<sup>2</sup></i>	<i>Typical Aircraft Uses</i>
<b>43</b> (5.0% Si)	As Cast	QQ-A-601	AN-QQ-A-405	46A1	Nonstructural fittings
<b>122</b> (10.0% Cu, 1.2% Fe, 0.2% Mg)	T2, T61	QQ-A-601	Federal	Federal	Engine cylinder heads

Footnotes are at end of table, on page 234.

## AIRCRAFT DRAFTING

TABLE 2. GOVERNMENT SPECIFICATIONS FOR ALCOA ALUMINUM ALLOY PRODUCTS (Continued)

SAND CASTINGS (Continued)						
<i>Aluminum Products and Nominal Composition<sup>1</sup></i>	<i>Temper</i>	<i>Federal<sup>2</sup></i>	<i>Army-Navy (AN) Aeronauticals</i>	<i>Navy<sup>3</sup></i>	<i>Typical Aircraft Uses</i>	
<b>142</b> (4.0% Cu, 1.5% Mg, 2.0% Ni)	T2, T61 <sup>4</sup>	QQ-A-601	AN-QQ-A-379	. . .	Engine cylinder heads	
<b>195</b> (4.0% Cu)	T4, T6	QQ-A-601	AN-QQ-A-390	46A1	General high-strength structural parts	
<b>214</b> (3.8% Mg)	As Cast	QQ-A-601	AN-QQ-A-402	. . .	Nonstructural fittings (high resistance to corrosion)	
<b>220</b> (10.0% Mg)	T4	. . . . .	AN-QQ-A-392	. . .	High-strength structural fittings	
<b>355</b> (1.3% Cu, 5.0% Si, 0.5% Mg)	T6	QQ-A-601	AN-QQ-A-376	. . .	Structural fittings, crankcases	
<b>A355</b> (1.4% Cu, 5.0% Si, 0.5% Mg, 0.8% Ni, 0.8% Mn)	T51	QQ-A-601	Federal	. . .	Cylinder heads, small engines	
<b>356</b> (7.0% Si, 0.3% Mg)	T4, T6 <sup>7</sup>	QQ-A-601	AN-QQ-A-394	46A1	Structural fittings	
PERMANENT MOLD CASTINGS						
<i>Aluminum Products and Nominal Composition<sup>1</sup></i>	<i>Temper</i>	<i>Federal<sup>2</sup></i>	<i>Army-Navy<sup>3</sup> (AN) Aeronauticals</i>	<i>Navy<sup>3</sup></i>	<i>Typical Aircraft Uses</i>	
<b>43</b> (5.0% Si)	As cast	QQ-A-596	. . . . .	46A15	Tank fittings	
<b>A132</b> (0.8% Cu, 0.8% Fe, 12.0% Si, 1.0% Mg, 2.5% Ni)	T551, T4 <sup>8</sup>	QQ-A-596	AN-QQ-A-386 <sup>8</sup>	46A15	Engine pistons	
<b>142</b> (4.0% Cu, 1.5% Mg, 2.0% Ni)	T61, T571	QQ-A-596	AN-QQ-A-379 <sup>9</sup>	46A15	Structural fittings	
<b>B195</b> (4.5% Cu, 2.5% Si)	T4	QQ-A-596	AN-QQ-A-383 <sup>10</sup>	46A15	Miscellaneous engine parts, landing wheels	
<b>355</b> (1.3% Cu, 5.0% Si, 0.5% Mg)	T4, T6	QQ-A-596	AN-QQ-A-376 <sup>11</sup>	46A15	Structural fittings and miscellaneous engine parts	
<b>356</b> (7.0% Si, 0.3% Mg)	T4, T6	QQ-A-596	. . . . .	46A15	Small engine parts	
DIE CASTINGS						
<b>13</b> (12.0% Si)	As cast	QQ-A-591	AN-QQ-A-366	46A14	Junction boxes, small housings and covers, misc. small nonstructural parts	
<b>85</b> (4.0% Cu, 5.0% Si)	As cast	QQ-A-591	AN-QQ-A-366	46A14		
<b>218</b> (8.0% Mg)	As cast	QQ-A-591	AN-QQ-A-366	46A14		

<sup>1</sup> Balance is commercially pure aluminum.<sup>2</sup> Revisions not indicated.<sup>3</sup> U. S. Army Specification.<sup>4</sup> Also includes as fabricated flattened wire.<sup>5</sup> The Federal specification includes ½H and ¾H plate<sup>6</sup> AN specification does not cover T2 temper.<sup>7</sup> AN specification covers T6 temper only.<sup>8</sup> AN specification covers T4 temper.<sup>9</sup> AN specification covers T61 temper.<sup>10</sup> AN specification covers T4 and T6 tempers.<sup>11</sup> AN specification covers T6 temper.

chine shop. Prongs, pins, brackets, fittings, studs, and a multitude of miscellaneous machined parts are made from bar and rod stock.

**TUBING.** Hollowed rod or bar stock is referred to as "tubing." It may be obtained in a variety of shapes, square, rectangular, round, etc. Tubing is measured by its inside and outside diameter or the distance across its widest interior and exterior. Because of its fine structural qualities, tubing finds many uses. Some fuselage designs are almost completely constructed from steel tubing.

**WIRE.** Any cylindrical section less than  $\frac{3}{8}$  inch in diameter is termed "wire." Wire is produced by drawing or pulling a rod through a series of dies with holes of decreasing diameters. Cables composed of steel wire serve numerous purposes in the airplane, especially in the controls.

**STANDARD SHAPES.** There are many standard structural shapes such as channels, angles, I beams, and Z and T sections. Standard structural shapes are classed into two categories: drawn or rolled, and extruded.

**ROLLED** sections are produced by passing ribbon stock between a series of double rollers. The shape between each pair of rollers conforms gradually to the shape of the section desired.

**DRAWN** sections are produced by drawing or pulling ribbon stock through various progressive dies, or a single tapered die. The method is much like that used in producing wire.

The process of manufacturing **EXTRUDED** sections might be compared to the squeezing of tooth paste from a tube. The metal in a solid plastic state is forced hydraulically through the opening of a die, the shape of the opening conforming to the required cross section of the piece.

**CHARACTERISTICS OF SPECIFIC MATERIALS**

*Aluminum*

The airplane must be strongly constructed to withstand the numerous forces that act upon it. In other branches of engineering, greater strength might easily be obtained by adding bulk and weight to a structure. But the airplane must be light enough to obtain speed and to carry sufficient cargo for commercial practicability.

The aeronautical engineer has chosen aluminum as a light strong material from which to build his machines. Aluminum is one of the lightest of the common metals. Commercially pure aluminum weighs 0.098 pound per cubic inch, corresponding to a specific gravity of 2.71. Aluminum alloys weigh about 0.10 pound per cubic inch, one-third as much as steel.

Aluminum and its alloys not only have the advantage of lightness, but are easily formed into intricate shapes, can be developed into high strength metals, and possess desirable noncorrosive qualities. For these reasons, and also be-

**TABLE 3. APPROXIMATE INSIDE RADII FOR 90 DEGREE COLD BEND IN SHEET**

Minimum permissible radius varies with nature of forming operation, type of forming equipment and design and condition of tools. Minimum working radius for given material or hardest alloy and temper for a given radius can be ascertained only by actual trial under contemplated conditions of fabrication. The values in this table may be considered a relative index of workability.

<i>Alloy and Temper</i>	<i>Bend Classification<sup>1</sup></i>	<i>Alloy and Temper</i>	<i>Bend Classification</i>
2S-O	A	24S-O <sup>2</sup>	B
2S- $\frac{1}{4}$ H	B	24S-T <sup>2,3</sup>	J
2S- $\frac{1}{2}$ H	B	24S-RT <sup>2</sup>	K
2S- $\frac{3}{4}$ H	D		
2S-H	F	52S-O	A
		52S- $\frac{1}{4}$ H	C
3S-O	A	52S- $\frac{1}{2}$ H	D
3S- $\frac{1}{4}$ H	B	52S- $\frac{3}{4}$ H	F
3S- $\frac{1}{2}$ H	C	52S-H	G
3S- $\frac{3}{4}$ H	E		
3S-H	G	61S-O	B
		61S-W	E
		61S-T	F

<sup>1</sup> For corresponding bend radii see table below.

<sup>2</sup> Alclad 24S can be bent over slightly smaller radii than the corresponding tempers of the uncoated alloy.

<sup>3</sup> Immediately after quenching, these alloys can be formed over appreciably smaller radii.

**RADII REQUIRED FOR 90 DEGREE BEND IN TERMS OF THICKNESS, t**

		APPROXIMATE THICKNESS, INCHES					
		26	20	14	8	5	2
		0.016	0.032	0.064	0.128	0.182	0.258
		$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$
BEND CLASSIFICATION	A	0	0	0	0	0	0
	B	0	0	0	0	0-1t	0-1t
	C	0	0	0	0-1t	0-1t	$\frac{1}{2}$ t-1 $\frac{1}{2}$ t
	D	0	0	0-1t	$\frac{1}{2}$ t-1 $\frac{1}{2}$ t	1t-2t	1 $\frac{1}{2}$ t-3t
	E	0-1t	0-1t	$\frac{1}{2}$ t-1 $\frac{1}{2}$ t	1t-2t	1 $\frac{1}{2}$ t-3t	2t-4t
	F	0-1t	$\frac{1}{2}$ t-1 $\frac{1}{2}$ t	1t-2t	1 $\frac{1}{2}$ t-3t	2t-4t	2t-4t
	G	$\frac{1}{2}$ t-1 $\frac{1}{2}$ t	1t-2t	1 $\frac{1}{2}$ t-3t	2t-4t	3t-5t	4t-6t
	H	1t-2t	1 $\frac{1}{2}$ t-3t	2t-4t	3t-5t	4t-6t	4t-6t
	J	1 $\frac{1}{2}$ t-3t	2t-4t	3t-5t	4t-6t	4t-6t	5t-7t
	K	2t-4t	3t-5t	3t-5t	4t-6t	5t-7t	6t-10t

cause aluminum can be obtained in a great variety of forms, the general structure of most aircraft is made of aluminum alloys (Fig. 287).

Commercially pure aluminum contains 99 per cent aluminum, the remaining 1 per cent consisting of normally present impurities, principally iron and silicon. Annealed pure aluminum is relatively low in strength (having only 12,000 pounds per square inch tensile strength), but it possesses great ductility and can be easily formed into complicated shapes. Pure aluminum has great resistance to corrosion, too. Nevertheless, with all the favorable properties, pure alu-

minum, because of its low strength, is not suitable for aircraft structural parts.

Pure aluminum may be sufficiently strengthened by alloying, cold working, or heat treatment.

*Alloying.* Alloying is the process of combining small quantities of various metals with a parent metal to obtain desirable properties, in this case increase in hardness and strength and decrease in melting point and conductivity. This combining may take place by admixture of the metals in molten state. The resulting homogeneous mass is called an "alloy" of the parent metal.

TABLE 4. TYPICAL<sup>1</sup> MECHANICAL PROPERTIES OF WROUGHT ALUMINUM ALLOYS

ALLOY AND TEMPER	TENSION				HARDNESS Brinell, 500 kg. Load 10 mm Ball	SHEAR Shearing Strength, psi	FATIGUE Endurance Limit, psi
	Yield Strength (Set=0.2%), psi	Ultimate Strength, psi	Elongation, Per Cent in 2 In.				
			Sheet Specimen ( $\frac{1}{8}$ Inch Thick)	Round Specimen ( $\frac{1}{2}$ Inch Diameter)			
2S-O	5,000	13,000	35	45	23	9,500	5,000
2S- $\frac{1}{4}$ H	13,000	15,000	12	25	28	10,000	6,000
2S- $\frac{1}{2}$ H	14,000	17,000	9	20	32	11,000	7,000
2S- $\frac{3}{4}$ H	17,000	20,000	6	17	38	12,000	8,500
2S-H	21,000	24,000	5	15	44	13,000	8,500
3S-O	6,000	16,000	30	40	28	11,000	7,000
3S- $\frac{1}{4}$ H	15,000	18,000	10	20	35	12,000	8,000
3S- $\frac{1}{2}$ H	18,000	21,000	8	16	40	14,000	9,000
3S- $\frac{3}{4}$ H	21,000	25,000	5	14	47	15,000	9,500
3S-H	25,000	29,000	4	10	55	16,000	10,000
17S-O	10,000	26,000	20	22	45	18,000	11,000
17S-T	40,000	62,000	20	22	100	36,000	16,000
A17S-T	24,000	43,000	..	27	70	26,000	13,500
24S-O	10,000	26,000	20	22	42	18,000	12,000
24S-T	46,000	68,000	19	22	105	41,000	18,000
24S-RT	57,000	73,000	13	..	116	42,000	..
Alclad 24S-T	43,000	64,000	18	..	..	40,000	..
Alclad 24S-RT	53,000	67,000	11	..	..	41,000	..
52S-O	14,000	29,000	25	30	45	18,000	17,000
52S- $\frac{1}{4}$ H	26,000	34,000	12	18	62	20,000	17,500
52S- $\frac{1}{2}$ H	29,000	37,000	10	14	67	21,000	18,000
52S- $\frac{3}{4}$ H	34,000	39,000	8	10	74	23,000	18,500
52S-H	36,000	41,000	7	8	85	24,000	19,000
53S-O	7,000	16,000	25	35	26	11,000	7,500
53S-W	20,000	33,000	22	30	65	20,000	10,000
53S-T	33,000	39,000	14	20	80	24,000	11,000
61S-O	8,000	18,000	22	..	30	12,500	8,000
61S-W	21,000	35,000	22	..	65	24,000	12,500
61S-T	39,000	45,000	12	..	95	30,000	12,500

<sup>1</sup> These values are NOT guaranteed.

TABLE 5. MECHANICAL PROPERTIES OF ALUMINUM SAND CASTING ALLOYS

ALLOY	MINIMUM VALUES FOR SPECIFICATIONS		TYPICAL VALUES (not guaranteed)							
	Tension <sup>1</sup>		Tension <sup>1</sup>			Compression <sup>2</sup>	Hardness <sup>1</sup>	Shear	Fatigue	Density
	Ultimate Strength, psi	Elongation, Per Cent in 2 Inches	Yield Strength (Set =0.2%), psi	Ultimate Strength, psi	Elongation, Per Cent in 2 Inches	Yield Strength (Set=0.2%), psi	Brinell, 500 kg Load 10 mm Ball	Shearing Strength, psi	Endurance Limit, psi	pci
43	17,000	3.0	9,000	19,000	6.0	10,000	40	14,000	6,500	0.096
122-T2	23,000	3	20,000	25,000	1.0	20,000	75	21,000	9,500	0.103
122-T61	30,000	3	30,000	36,000	1.0	43,000	100	29,000	. . .	0.103
142-T2	23,000	3	18,000	27,000	1.0	18,000	75	21,000	6,500	0.099
142-T61	32,000	3	32,000	37,000	0.5	47,000	100	32,000	8,000	0.099
195-T4 <sup>4</sup>	29,000	6.0	16,000	31,000	8.5	16,000	65	24,000	6,000	0.100
195-T6	32,000	3.0	22,000	36,000	5.0	25,000	80	30,000	6,500	0.100
214	22,000	6.0	12,000	25,000	9.0	12,000	50	20,000	7,000	0.095
220-T4	42,000	12.0	25,000	45,000	14.0	26,000	75	33,000	7,000	0.092
355-T6	32,000	2.0	25,000	35,000	3.5	29,000	80	30,000	8,500	0.097
355-T7	35,000	3	35,000	38,000	1.0	35,000	85	26,500	. . .	0.097
A355-T51	25,000	3	24,000	28,000	1.5	24,000	65	22,000	8,500	0.099
356-T4 <sup>4</sup>	26,000	5.0	16,000	28,000	6.0	18,000	55	22,000	. . .	0.095
356-T6	30,000	3.0	22,000	32,000	4.0	22,000	70	27,000	8,000	0.095

<sup>1</sup> Tension and hardness values determined from standard 0.5 inch diameter tensile test specimens, individually cast in green sand molds and tested without machining off the surface.

<sup>2</sup> Results of tests on specimens having an *l/r* ratio of 12.

<sup>3</sup> Not specified. The error in determining low elongations is comparable with the value being measured.

<sup>4</sup> On standing at room temperature for several weeks, properties approach those of T6 condition.

TABLE 6. MECHANICAL PROPERTIES OF ALUMINUM PERMANENT-MOLD CASTING ALLOYS

ALLOY	MINIMUM VALUES FOR SPECIFICATIONS		TYPICAL VALUES (not guaranteed)							
	Tension <sup>1</sup>		Tension <sup>1</sup>			Compression <sup>2</sup>	Hardness <sup>1</sup>	Shear	Fatigue	Density
	Ultimate Strength, psi	Elongation, Per Cent in 2 Inches	Yield Strength (Set =0.2%), psi	Ultimate Strength, psi	Elongation, Per Cent in 2 Inches	Yield Strength (Set=0.2%), psi	Brinell, 500 kg Load 10 mm Ball	Shearing Strength, psi	Endurance Limit, psi	pci
43	21,000	2.5	9,000	24,000	6.0	9,000	40	18,000	. . .	0.097
A132-T551	31,000	3	28,000	36,000	0.5	30,000	105	24,000	. . .	0.097
142-T61	40,000	3	42,000	47,000	0.5	46,000	110	31,000	9,500	0.100
142-T571	34,000	3	34,000	40,000	0.0	34,000	105	26,000	10,500	0.100
B195-T4 <sup>4</sup>	33,000	4.5	22,000	40,000	10.0	22,000	75	30,000	9,500	0.101
B195-T6	35,000	2.0	33,000	45,000	5.0	33,000	90	32,000	10,000	0.101
A214	22,000	2.5	16,000	27,000	5.0	17,000	60	22,000	. . .	0.096
355-T6	37,000	1.5	26,000	43,000	4.0	26,000	90	30,000	9,000	0.097
356-T4 <sup>4</sup>	28,000	5.0	18,000	32,000	9.0	18,000	60	. . .	. . .	0.095
356-T6	33,000	3.0	24,000	40,000	5.0	24,000	90	. . .	. . .	0.095

<sup>1</sup> Tension and hardness values obtained from standard half-inch diameter tensile test specimens, individually cast in a permanent mold, and tested without machining off the surface.

<sup>2</sup> Results of tests on specimens having an *l/r* ratio of 12.

<sup>3</sup> Not specified. The error in determining low elongations is comparable with the value being measured.

<sup>4</sup> On standing at room temperature for several weeks, properties approach those of T6 condition.

Copper, silicon, manganese, magnesium, chromium, iron, zinc, and nickel are the metals commonly used to produce aluminum alloys. They are employed singly or in combination, depending on the properties desired. The proportion of alloying ingredients for wrought aluminum seldom exceeds 7 per cent, but this percentage is considerably higher for cast aluminum.

Gain of strength in alloying is offset to some extent by a sacrifice in ease of fabrication, by possible lessening of resistance to corrosion, and

occasionally by some gain of weight. This gain in weight, however, seldom exceeds 3 per cent of the specific gravity, and several alloys are lighter than the pure aluminum.

*Cold Working.* Oddly enough, when certain metals are hammered, bent, rolled, or otherwise worked upon, they increase considerably in strength. This cold working produces strain, hardening the metal. The increase in strength depends upon the amount of work expended on the metal. A rivet, for example, becomes harder and stronger after it has been driven because of

TABLE 7. ALLOWABLE SINGLE SHEAR STRENGTH OF ALUMINUM ALLOY RIVETS

(Values from ANC-5—"Strength of Aircraft Elements," issued by Army-Navy-Civil Committee on Aircraft Design Criteria)

RIVET ALLOY	ALLOWABLE SHEAR, LB, FOR VARIOUS RIVET DIAMETERS, INCHES							
	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4
A17ST and 56S-H ( $F_{su} = 27,000$ psi)	83	186	331	518	745	1,325	2,071	2,984
17ST ( $F_{su} = 30,000$ psi)	92	206	368	574	828	1,472	2,300	3,313
24ST ( $F_{su} = 35,000$ psi)	107	241	429	670	966	1,718	2,684	3,865

TABLE 8. SHEAR STRENGTH<sup>1</sup> OF SPOT WELDS

Minimum strength required for qualification under U. S. Army Air Corps Specification No. 20011-B. Single spot specimens tested in shear.

METAL THICKNESS, <sup>2</sup> INCHES	SHEAR STRENGTH, POUNDS	
	Alclad 24S-T	52S <sup>3</sup> and 61S <sup>3</sup>
0.012	80	75
0.016	110	105
0.020	140	137
0.024	175	170
0.028	214	200
0.030	235	217
0.035	290	260
0.040	345	310
0.045	405	365
0.050	465	427
0.065	705	632
0.070	800	705
0.080	1,025	852
0.090	1,265	1,000

<sup>1</sup> The tabular values are approximately 65 per cent of actual average results. The use of spacing less than eight times metal thickness or edge distance less than four times metal thickness will substantially decrease the strength of spot welds.

<sup>2</sup> When sheets of different thicknesses are joined, strength listed for thinner sheet applies.

<sup>3</sup> Any temper.

TABLE 9. ALLOWABLE BEARING STRENGTH OF ALUMINUM ALLOY SHEET

(Values from ANC-5—"Strength of Aircraft Elements," issued by Army-Navy-Civil Committee on Aircraft Design Criteria)

SHEET THICKNESS, INCHES	ALLOWABLE BEARING STRENGTH, LB, FOR VARIOUS RIVET DIAMETERS, INCHES							
	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4
24S-T SHEET ( $F_{br} = 90,000$ psi)								
0.014	78							
0.016	90							
0.018	101	151						
0.020	112	168						
0.025	140	210	281					
0.032	180	269	360	449				
0.036	202	303	405	506	607			
0.040	225	337	450	562	675			
0.045	253	379	506	632	759			
0.051	286	430	573	716	860	1,147		
0.064	360	539	720	899	1,080	1,440	1,800	
0.072	405	607	810	1,012	1,215	1,620	2,025	2,430
0.081	455	683	910	1,138	1,366	1,822	2,278	2,733
0.091	511	767	1,023	1,279	1,535	2,047	2,559	3,071
0.102	573	860	1,147	1,434	1,721	2,295	2,868	3,442
0.128	720	1,079	1,440	1,799	2,160	2,880	3,600	4,320
5/32	878	1,317	1,757	2,195	2,635	3,514	4,393	5,271
3/10	1,054	1,581	2,109	2,635	3,164	4,218	5,273	6,328
1/4	1,406	2,108	2,812	3,514	4,218	5,625	7,031	8,437
ALCLAD 24S-T SHEET ( $F_{br} = 82,000$ psi)								
0.014	71							
0.016	82							
0.018	92	138						
0.020	102	153						
0.025	128	192	256					
0.032	164	245	328	409				
0.036	184	276	369	461	553			
0.040	205	307	410	512	615			
0.045	230	345	461	576	691			
0.051	261	391	522	653	784	1,045		
0.064	328	491	656	819	984	1,312	1,640	
0.072	369	553	738	922	1,107	1,476	1,845	2,214
0.081	415	622	830	1,037	1,245	1,660	2,075	2,490
0.091	466	699	932	1,165	1,399	1,865	2,331	2,798
0.102	522	783	1,045	1,306	1,568	2,091	2,613	3,136
0.128	656	983	1,312	1,639	1,968	2,624	3,280	3,936
5/32	800	1,200	1,601	2,000	2,401	3,202	4,002	4,803
3/10	960	1,440	1,921	2,401	2,882	3,843	4,804	5,765
1/4	1,281	1,920	2,562	3,202	3,843	5,125	6,406	7,687

Ed. Note: Specification AN-A-13, issued since this table was prepared, reduces the cladding thickness by half for Alclad sheet 0.064 inch and thicker. It is suggested that the values below the line might be intermediate between those shown for Alclad 24S-T and for bare 24S-T.

the hammering and the swelling of the shank.

In drop hammer and certain other forming operations, hammering by the ram strain-hardens the metal, necessitating annealing or softening at various stages of the operation to allow complete forming without rupture.

*Heat Treatment.* Heat treatment likewise increases the strength of the aluminum alloys. As an aluminum alloy hardens or freezes from the molten state, an unequal distribution of the

hardening agents occurs throughout the grains of the metal. Heat treatment offers a means of redistributing the hardening agents evenly.

The metal is placed in a hot air or salt-fused bath furnace at a prescribed temperature, which must be maintained for a specified length of time. If the temperature is too low, the optimum mechanical properties may not develop; if it is too high, melting may occur at the grain boundaries, in which event the metal may be im-

TABLE 10. ALLOWABLE STRENGTH OF FLUSH-RIVETED JOINTS

100 DEGREE HEAD ANGLE RIVETS

(Values from ANC-5—"Strength of Aircraft Elements," issued by Army-Navy-Civil Committee on Aircraft Design Criteria)

SHEAR Allowable Strength, Pounds per Rivet	MACHINE COUNTERSUNK					DIMPLED					
	Rivet Alloy	Rivet Diameter, Inches				Rivet Alloy	Rivet Diameter, Inches				
		$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$		$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	
	A17S-T	186	331	518	745	A17S-T	276	480	735	1020	
	17S-T	206	368	574	828	17S-T	300	530	810	1130	
	24S-T	241	429	670	966	24S-T	350	620	950	1325	
BEARING Allowable Strength, Pounds per Rivet	Thickness of Thinnest Sheet, Inches	Rivet Diameter, Inches				Thickness of Thinnest Sheet, Inches	Rivet Diameter, Inches				
		$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$		$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	
	24S-T	0.020	131	162	..	..	0.020	243	291	..	..
		0.025	149	189	..	..	0.025	265	340	485	..
		0.032	172	226	302	..	0.032	276	410	540	864
		0.036	186	249	327	..	0.036	316	430	570	945
		0.040	199	271	353	496	0.040	334	453	604	975
		0.045	217	299	385	589	0.045	350	480	643	1045
		0.051	237	332	424	648	0.051	350	518	690	1130
		0.064	241	405	507	775	0.064	350	593	793	1315
		0.072	241	429	558	850	0.072	..	620	858	1325
		0.081	241	429	600	940	0.081	..	..	929	1325
	0.091	241	429	650	966	0.091	..	..	..	1325	
0.102	..	429	670	966	0.102	..	..	..	1325		
0.128	..	..	670	966	..	..	..	..	..		
Alclad 24S-T	0.020	122	150	..	..	0.020	225	270	..	..	
	0.025	138	175	..	..	0.025	246	315	450	..	
	0.032	160	210	280	..	0.032	276	380	500	800	
	0.036	173	231	303	..	0.036	293	398	530	875	
	0.040	185	251	327	460	0.040	310	420	560	905	
	0.045	201	277	357	545	0.045	332	446	596	970	
	0.051	220	308	393	600	0.051	350	480	640	1050	
	0.064	241	376	470	717	0.064	350	550	735	1220	
	0.072	241	417	518	788	0.072	..	593	795	1325	
	0.081	241	429	557	870	0.081	..	..	860	1325	
	0.091	241	429	602	966	0.091	..	..	..	1325	
	0.102	..	429	652	966	0.102	..	..	..	1325	
	0.128	..	..	670	966	..	..	..	..	..	

Ed. Note: Specification AN-A-13, issued since this table was prepared, reduces the cladding thickness by half for Alclad sheet 0.064 inch and thicker. It is suggested that the values below the line might be intermediate between those shown for Alclad 24S-T and for bare 24S-T.

paired. The thicker the material, the longer is the required heating time.

As soon as the metal is removed from the furnace it is quenched in a tank of cold water. This operation is done rapidly, because the metal should be immersed at a temperature as near to the heat treatment level as possible. The quenching process should cool the metal swiftly to prevent precipitation. Continuous addition of cold running water maintains the required temperature in the quenching tank.

Cold water quenching ensures the required

mechanical properties of the metal, but it may warp the piece. Therefore, it is sometimes replaced by quenching in cold oil or boiling water, at some sacrifice of mechanical properties and resistance to corrosion.

After quenching, the strength of the metal increases further. The degree of this increase depends on the particular alloy and on the temperature of the room in which it is kept. This "age hardening" is attributed to the precipitation of hardening ingredients from the solid solution, a process which tends to prevent movement

TABLE 11. MECHANICAL PROPERTIES SPECIFICATIONS SHEET AND PLATE 2S, 3S, 52S

SHEET										
GRADE AND TEMPER	TENSILE STRENGTH, PSI MINIMUM EXCEPT FOR SOFT (O) TEMPER	MINIMUM ELONGATION <sup>1</sup> , PER CENT IN 2 INCHES								
		.249"- .204"	5-6 Gage .203"- .162"	7-9 Gage .161"- .114"	10-16 Gage .113"- .051"	17-20 Gage .050"- .032"	21-24 Gage .031"- .020"	25-28 Gage .019"- .013"	29-32 Gage .012"- .008"	33-35 Gage .007"- .006"
		2S-O	15,500 <sup>2</sup>	30	30	30	30	25	20	15
2S-½H	14,000	9	9	9	8	6	4	3	..	..
2S-¼H	16,000	6	6	6	5	4	3	2	1	..
2S-⅓H	19,000	..	..	4	4	3	2	1	1	1
2S-H	22,000	..	..	4	4	3	2	1	1	1
3S-O	19,000 <sup>2</sup>	25	25	25	25	23	20	20	18	16
3S-H	17,000	8	8	7	6	5	4	3	..	..
3S-½H	19,500	7	7	6	5	4	3	2	1	..
3S-⅓H	23,500	..	..	4	4	3	2	1	1	1
3S-H	27,000	..	..	4	4	3	2	1	1	1
52S-O	31,000 <sup>2</sup>	20	20	20	20	20	18	15	..	..
52S-½H	31,000	9	9	9	7	5	5	4	..	..
52S-¼H	34,000	7	7	7	6	4	4	3	..	..
52S-⅓H	37,000	..	..	4	4	4	3	3	..	..
52S-H	39,000	..	..	4	4	4	3	3	..	..

PLATE

2S, 3S, 52S, As Rolled—No physical tests required.

½H, ⅓H—Physical properties same as for 0.249 in. sheet in same alloy and temper.

MAXIMUM AND MINIMUM COMMERCIAL THICKNESS OF FLAT AND COILED SHEET IN ALL TEMPER

TEMPER	FLAT SHEET Thickness, Inches		COILED SHEET Thickness, Inches	
	Maximum	Minimum	Maximum	Minimum
	O	0.249	0.006	0.102
½H	0.249	0.017	0.102	0.017
¼H	0.249	0.0095	0.085	0.0095
⅓H	0.162	0.006	0.053	0.006
H	0.128	0.006	0.102	0.006

<sup>1</sup> Test specimens taken parallel to direction of rolling from flat and coiled sheet in ½H and ⅓H tempers.

<sup>2</sup> Maximum. So specified to ensure complete annealing.

TABLE 12. MECHANICAL PROPERTIES OF ALUMINUM ALLOY FORGINGS

ALLOY	MINIMUM SPECIFICATION VALUES				TYPICAL VALUES (not guaranteed)		
	Tension <sup>2</sup>			Hardness <sup>2</sup>	Shear	Fatigue	Density
	Yield Strength <sup>1</sup> (Set = 0.2%), psi	Ultimate Strength, psi	Elongation, <sup>1</sup> Per Cent in 2 Inches	Brinell, 500 kg Load 10 mm Ball	Shearing Strength, <sup>1</sup> psi	Endurance Limit, <sup>1</sup> psi	pci
14S-T	50,000	65,000	10.0	125	45,000	16,000	0.101
17S-T	30,000	55,000	16.0	100	36,000	15,000	0.101
18S-T	40,000	55,000	10.0	100	35,000	14,500	0.103
25S-T	30,000	55,000	16.0	100	35,000	15,000	0.101
32S-T	40,000	52,000	5.0	115	38,000	14,000	0.097
A51S-T	34,000	44,000	12.0	90	32,000	10,500	0.097
53S-T	30,000	36,000	14.0	75	24,000	11,000	0.097

<sup>1</sup> These properties apply to forgings up to 4 inches in diameter or thickness. Long axis of test specimen taken parallel to direction of grain flow.

<sup>2</sup> Tension and hardness values determined from standard half-inch diameter test specimens. Values in compression at least equal to values in tension.

TABLE 13. MINIMUM LONGITUDINAL AND TRANSVERSE MECHANICAL PROPERTIES OF AIRCRAFT FITTINGS STOCK<sup>1</sup>

(Longitudinal properties are guaranteed; transverse properties not guaranteed)

CLASS	GRADE AND TEMPER	MECHANICAL PROPERTIES <sup>2</sup>	SIZES							
			Up to 5 x 5 in. or 25 sq in.		Up to 6 x 6 in. or 36 sq in.		Up to 8 x 8 in. or 64 sq in.		Greater than 8 x 8 in. or 64 sq in.	
			Long.	Trans.	Long.	Trans.	Long.	Trans.	Long.	Trans.
Rod and bar	17S-T <sup>3</sup>	Ultimate Tensile Strength Yield Strength Elongation	55,000 32,000 16	50,000 28,000 8	55,000 32,000 16	50,000 28,000 8				
	24S-T <sup>4</sup>	Ultimate Tensile Strength Yield Strength Elongation	62,000 40,000 14	55,000 38,000 6						
Specially processed hand forgings <sup>5</sup>	17S-T	Ultimate Tensile Strength Yield Strength Elongation	55,000 30,000 16	52,000 30,000 12	55,000 30,000 16	51,000 30,000 10	53,000 30,000 14	50,000 28,000 8	52,000 30,000 12	50,000 28,000 6
	14S-T	Ultimate Tensile Strength Yield Strength Elongation	65,000 50,000 10	62,000 50,000 6	65,000 50,000 10	61,000 50,000 5	62,000 50,000 8	60,000 48,000 4	62,000 50,000 7	60,000 48,000 3

<sup>1</sup> Longitudinal properties for smaller sizes of 17S-T and 24S-T rod and bar and transverse properties for 17S-T and 24S-T plate are given in Tables 16 and 17.

<sup>2</sup> Ultimate tensile and yield strengths are in pounds per square inch. Elongations are in per cent of the gauge length (2 in. for standard round test specimens, four times the diameter of the specimens for subsize test specimens, where required). Where flat specimens are used the elongation is in per cent of 2 in.

<sup>3</sup> Maximum cross section of 17S-T bar is 36 sq in. Maximum diameter of 17S-T rod is 6 in.

<sup>4</sup> Maximum cross section of 24S-T bar is 24 sq in. Maximum diameter of 24S-T rod is 5 1/4 in.

<sup>5</sup> The transverse properties listed apply to forged blanks having a length not greater than twice the width.

within the crystalline structure of the material.

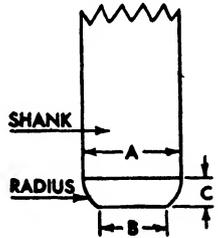
Generally, the structural parts of an airplane are composed of aluminum alloys that can be strengthened by heat treatment.

**Annealing.** Annealing includes heating the metal to a required temperature and cooling it slowly to ordinary temperatures. This treatment tends to make the metal softer and to increase its formative properties.

TABLE 14. STANDARD SIZES OF RIVETS WITH CHAMFERED SHANK  
(in inches)

- A = Shank Diameter
- B = Diameter of End
- C = Length of Radius

Formulas  
 $C = 0.25 \times A$   
 Radius =  $0.3125 \times A$



Diameter of Rivet	B	Diameter of Rivet	B
1/16	0.047	5/32	0.118
3/32	0.071	3/16	0.137
1/8	0.092	1/4	0.185

LENGTH, INCHES	DIAMETER, INCHES, AND HEAD TYPE <sup>1</sup>											
	1/16		3/32		1/8		5/32		3/16		1/4	
	A	B	A	B	A	B	A	B	A	B	A	B
1/16	X	X										
1/8	X	X	X	X	X	X						
3/16	X	X	X	X	X	X	X	X				
1/4	X	X	X	X	X	X	X	X	X	X	X	X
5/16	X	X	X	X	X	X	X	X	X	X	X	X
3/8	X	X	X	X	X	X	X	X	X	X	X	X
7/16	X		X	X	X	X	X	X	X	X	X	X
1/2	X		X	X	X	X	X	X	X	X	X	X
9/16			X	X	X	X	X	X	X	X	X	X
5/8			X	X	X	X	X	X	X	X	X	X
11/16			X	X	X	X	X	X	X	X	X	X
3/4			X	X	X	X	X	X	X	X	X	X
13/16					X	X	X	X	X	X	X	X
7/8					X	X	X	X	X	X	X	X
15/16					X	X	X	X	X	X	X	X
1					X	X	X	X	X	X	X	X
1 1/8							X	X	X	X	X	X
1 1/4							X	X	X	X	X	X
1 3/8								X	X	X	X	X
1 1/2									X	X	X	X
1 5/8										X	X	X
1 3/4										X	X	X
1 7/8										X	X	X
2										X	X	X

<sup>1</sup> A covers standard round, button, mushroom, brazier or modified brazier heads.  
<sup>2</sup> B covers standard flat, flat countersunk, oval countersunk, or 100 degree flat countersunk heads.

When annealed metals are required, they are ordinarily purchased in that condition from the metal producers. However, it is often necessary to remove the hardening effects of cold working or previous heat treatment in metals during the manufacturing process.

The cold-worked alloys will anneal when heated to 650° F. and allowed to cool at any convenient rate (the 3S alloy is the exception to this, requiring a temperature of 750° F.).

This annealing treatment is applicable to the heat treated alloys, but will not completely remove the hardening effects. The heat treated alloys require a temperature of 750° to 800° F. for complete softening and a regulated cooling rate.

TABLE 15. MECHANICAL PROPERTIES SPECIFICATIONS—14S EXTRUDED SHAPES

Temper	Thickness, Inches	Tensile Strength, psi Minimum Except for 14S-O <sup>1</sup>	Yield Strength (Set=0.2%), psi Minimum	Elongation, Per Cent in 2 inches or in 4D (Minimum)
14S-O	0.125 and over	35,000 <sup>1</sup>		12
14S-W	0.125 and over	50,000	32,000	12
14S-T	0.125 to 0.499	60,000	50,000	7
	0.500 to 0.749	65,000	55,000	7
	0.750 and over <sup>2</sup>	68,000	58,000	7

<sup>1</sup> Maximum. So specified to insure complete annealing.  
<sup>2</sup> The properties apply to sections having a cross-sectional area not over 15 sq in.

TABLE 16. MECHANICAL PROPERTIES SPECIFICATIONS—17S ALLOY PRODUCTS

Material	Dimensions, Inches	WIRE, ROD, AND SHAPES		
		Tensile Strength, psi Minimum Except for 17S-O <sup>1</sup>	Yield Strength (Set =0.2%), psi Minimum	Elongation, Per Cent in 2 Inches or in 4D (Minimum)
17S-O Wire	up to 0.124	35,000 <sup>1</sup>		
17S-O Rod	0.125-8.000	35,000 <sup>1</sup>		12
17S-T Wire	up to 0.124	55,000		
17S-T Rounds, squares, } hexagons (rolled) }	0.125-3.000 3.001-8.000	55,000 55,000	32,000 32,000	18 16
17S-T Structural shapes (rolled)		55,000	32,000	16
17S-T Extruded shapes		50,000	35,000	12

FORGINGS

17S-T	up to 4	55,000	30,000	16
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<sup>1</sup> Maximum. So specified to ensure complete annealing.

**Dural**

The Aluminum Company of America developed the first aluminum alloy that could be successfully heat-treated. This alloy contains 4 per cent copper, 0.5 per cent manganese, and 0.5 per cent magnesium. It is called "Duralumin" but is commonly referred to as "Dural."

The name Dural is commonly associated with a variety of aluminum alloys of similar composition. The group constitutes one of the most popular and important of the aluminum alloys.

**Alclad.** Because alloying generally decreases the anticorrosive qualities of aluminum, a product was developed by the Aluminum Company of America which consists of a sheet of highly strengthened aluminum alloy, covered on both sides with a thin layer of pure aluminum or with a highly anticorrosive aluminum alloy. This product is called "Alclad."

The aluminum covering protects the alloy core in two ways:

It prevents contact with corrosive agents.

TABLE 17. MECHANICAL PROPERTIES SPECIFICATIONS—24S ALLOY PRODUCTS

Material	Dimensions, Inches	Tensile Strength, psi	Yield Strength (Set =0.2%), psi	Elongation, Per Cent in 2 Inches or in 4D, (Minimum)	Material	Dimensions, Inches	Tensile Strength, psi	Yield Strength (Set =0.2%), psi	Elongation Per Cent in 2 Inches or in 4D, (Minimum)	
		Minimum Except for 24S-O <sup>1</sup>	Minimum				Minimum Except for 24S-O <sup>1</sup>	Minimum		
SHEET AND PLATE					WIRE, ROD, BAR, AND SHAPES					
24S-O <sup>2</sup>	0.012-0.050	35,000 <sup>1</sup>	. . .	12	24S-O Wire	up to 0.124 incl.	35,000 <sup>1</sup>	. . .	. . .	
24S-T Flat Sheet <sup>2</sup>	0.012-0.020	64,000	42,000	10	24S-O Bars, rods, shapes	0.125-8.000	35,000 <sup>1</sup>	. . .	12	
	0.021-0.051	64,000	42,000	13						
	0.052-0.128	64,000	42,000	15						
	0.129-0.249	64,000	42,000	14						
24S-T Coiled Sheet	0.012-0.020	62,000	40,000	12	24S-T Wire	up to 0.124	62,000	. . .	. . .	
	0.021-0.051	62,000	40,000	15	24S-T Rounds	0.125-5.500	62,000	40,000	14	
	0.052-0.064	62,000	40,000	17	24S-T Squares, hexagons, octagons (rolled)	0.125-4.000	62,000	40,000	14	
24S-T Plate	0.250-0.500	62,000	40,000	12						24S-T Rectangular bars (rolled)
	0.501-1.000	62,000	40,000	8						
	1.001-1.500	60,000	40,000	7						
24S-RT Flat Sheet and Plate	1.501-2.000	60,000	40,000	6	24S-T Extruded shapes <sup>2</sup>	Section thickness: Less than 0.250 0.250-0.749 0.750-1.499 1.500 and over <sup>3</sup>	57,000 60,000 65,000 70,000	42,000 44,000 46,000 52,000	12 12 10 10	
	0.020-0.031	69,000	52,000	10						
	0.032-0.036	69,000	52,000	11						
	0.037-0.188	69,000	52,000	12						
Alclad 24S-O <sup>2</sup>	0.189-0.500	69,000	52,000	10	TUBING <sup>2</sup>					
	0.012-0.032	33,000 <sup>1</sup>	. . .	8	24S-O	All	35,000 <sup>1</sup>	. . .	. . .	
	0.033-0.063	33,000 <sup>1</sup>	. . .	10						
0.064-0.500	34,000 <sup>1</sup>	. . .	12							
Alclad 24S-T Flat Sheet <sup>2</sup>	0.012-0.020	59,000	39,000	10	24S-T	Diameter <sup>1</sup> / <sub>4</sub> to 2 inches	Wall thickness:	64,000	42,000	12
	0.021-0.063	59,000	39,000	13						
	0.064-0.128	62,000	40,000	13						
	0.129-0.249	62,000	40,000	11						
Alclad 24S-T Coiled Sheet	0.012-0.020	56,000	37,000	11	Diameter greater than 2 to 8 inches	Wall thickness:	64,000	42,000	10	
	0.021-0.040	56,000	37,000	14						
	0.041-0.063	56,000	37,000	15						
Alclad 24S-T Plate	0.064	60,000	38,000	13	0.025-0.049	0.050-0.259	64,000	42,000	11	
	0.250-0.500	62,000	40,000	11						0.260-0.500
Alclad 24S-RT Flat Sheet and Plate	0.020-0.031	62,000	48,000	8	0.025-0.049	0.050-0.259	64,000	42,000	11	
	0.032-0.040	62,000	48,000	9						
	0.041-0.063	62,000	48,000	10						
	0.064-0.188	66,000	50,000	10						
	0.189-0.500	66,000	50,000	9						

<sup>1</sup> Maximum. So specified to insure complete annealing.

<sup>2</sup> Flat sheet, tubing, and extruded shapes heat treated by the user are not required to have higher tensile and yield strength than the values below:

	Tensile Strength psi	Yield Strength psi
24S-T Flat Sheet . . . . .	62,000	40,000
Alclad 24S-T Flat Sheet 0.063 and thinner . . . . .	56,000	37,000
0.064 and thicker . . . . .	60,000	38,000
24S-T Tubing . . . . .	64,000	40,000
24S-T Extruded Shapes . . . . .	57,000	38,000

<sup>3</sup> Up to a maximum cross-sectional area of 10 sq. in.

By electrolytic action it prevents any corrosion of the base alloy where it becomes exposed by scratching of the surface, or by cutting at the sheared edges.

This "healing" action greatly extends the usefulness of Alclad in aircraft production. For example, riveted sections of Alclad skin are pro-

TECTED by this electrolytic action.

Alclad maintains most of its initial strength over a period of years, and is therefore used for parts which are subjected to severe service.

Tests of Alclad sheet have shown that it can withstand the effects of salt spray for a period of 5 years without loss of strength. Hence, it is used

TABLE 18. FLAT SHEET AND PLATE.  
ALCOA STANDARD SIZES

Thickness, Inches	2S-O	2S- $\frac{1}{4}$ H	2S- $\frac{1}{2}$ H	52S- $\frac{1}{4}$ H
0.012	24 x 72	24 x 72	36 x 96	.....
	36 x 96	36 x 96	.....	.....
0.016	24 x 72	24 x 72	36 x 96	.....
	36 x 96	36 x 96	.....	.....
0.020	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	.....	.....
0.025	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	.....	.....
0.032	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.040	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.051	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.064	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.081	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.091	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.102	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.125	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.156	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.188	24 x 72	24 x 72	36 x 96	36 x 96
	36 x 96	36 x 96	48 x 144	48 x 144
	.....	48 x 144	.....	.....
0.250	.....	24 x 72	36 x 96	.....
	.....	36 x 96	48 x 144	.....

TABLE 18A. FLAT SHEET AND PLATE.  
ALCOA STANDARD SIZES

Thickness, Inches	61S-T	24S <sup>1</sup> O and T	Alclad 24S <sup>1</sup> O and T
0.012	.....	.....	24 x 120
0.016	.....	.....	36 x 144
0.020	.....	36 x 144	36 x 144
0.025	36 x 144	48 x 144	48 x 144
0.032	48 x 144	48 x 144	48 x 144
0.040	48 x 144	48 x 144	48 x 144
0.051	48 x 144	48 x 144	48 x 144
0.064	48 x 144	48 x 144	48 x 144
0.072	48 x 144	48 x 144	48 x 144
0.081	48 x 144	48 x 144	48 x 144
0.091	48 x 144	48 x 144	48 x 144
0.102	48 x 144	48 x 144	48 x 144
0.125	48 x 144	48 x 144	48 x 144
0.156	48 x 144	48 x 144	48 x 144
0.188	48 x 144	48 x 144	48 x 144
0.250	48 x 144	48 x 144	48 x 144
0.312	.....	48 x 144	.....
0.375	48 x 144	24 x 72	.....
	.....	48 x 144	.....
0.500	48 x 144	24 x 72	.....
	.....	48 x 144	.....

<sup>1</sup> The following smaller standard sizes result from salvaging the Alcoa Standard Sizes by reshearing.

48" x 120"	36" x 144"	*24" x 120"
48" x 96"	36" x 120"	*24" x 96"
48" x 72"	36" x 96"	*24" x 72"
	36" x 72"	

\* Not supplied in 0.032 inch thickness and heavier. Orders for Alcoa Standard Size sheet usually permit a maximum of 20 per cent to be supplied in these random standard sizes.

to cover most aircraft and finds special application in hulls and floats of seaplanes.

### Nomenclature

Aluminum alloys used in aircraft production are of two types: cast (in bulk form for castings) and wrought (sheet, bar, rod, etc.).

The Aluminum Company of America designates the various alloys by numbers. The cast alloys are identified by numbers alone, while the wrought alloys receive the letter "S" in addition to the number, for example, 17S, 24S, 75S.

Some of the more commonly used cast alloys are 43, 195, 220, 214.

TABLE 19. MAZLO CASTING ALLOYS—AVAILABLE FORMS, CHARACTERISTICS AND USES

MAZLO ALLOY NO.	TYPE OF CASTING			HEAT-TREATABLE	CHIEF CHARACTERISTICS	TYPICAL USES
	Sand	Permanent mold	Die			
AM230	...	...	*	....	Good die casting characteristics.	Die castings of intricate design or very thin sections.
AM240	*	*	...	*	Good permanent mold casting characteristics and strength. Good pressure tightness.	Permanent mold cast parts of good strength.
AM246	*	*	...	*	Highest available hardness.	Parts requiring high hardness, where ductility is not required.
AM260	*	*	...	*	Highest strength in heat treated condition, high resistance to corrosion, good casting characteristics and pressure tightness.	Highly stressed structural castings of intricate design.
AM263	...	...	*	.....	Higher ductility than AM230, but not as readily die cast into intricate shapes.	Standard die casting alloy.
AM265	*	...	...	*	Highest strength in as-cast condition. Corrosion resistance equal to AM260, casting characteristics and pressure tightness somewhat inferior.	Sand castings requiring good average strength in as-cast condition.
AM403	*	...	...	....	Good torch weldability and corrosion resistance, low strength; suitable only for simple castings.	Low-stressed sand castings requiring good torch weldability.

TABLE 20. TYPICAL PROPERTIES OF CAST AND WROUGHT MAZLO MAGNESIUM ALLOYS

MAZLO ALLOY NO.	CONDITION	APPROX. SPECIFIC GRAVITY	APPROX. WEIGHT, PCI	STRENGTH <sup>1,2</sup>							RELATIVE RATINGS			PHYSICAL CONSTANTS <sup>5</sup>			
				Tension			Compressive Yield Strength	Shear Strength	Endurance Limits	Brinell Hardness	Workability <sup>6</sup>	Weldability <sup>6</sup>		Resistance to Salt Water <sup>7</sup>	Melting Point, Degrees F.	Thermal Conductivity (100-300° C.) C.G.S. Units	Electrical Conductivity, Per Cent of International Annealed Copper Standard
				Ultimate Tensile Strength	Yield Strength	Elongation % in 2 In.						Torch	Resistance				
				1000 psi	%	1000 psi											
SAND AND PERMANENT MOLD CASTINGS																	
AM240-C	As-cast	1.81	0.066	20	11	2	11	18	8	52	..	C	A	C	1100	0.17	11.5
AM240-T4	Heat treated	1.81	0.066	35	12	9	12	20	11	52	..	C	A	D	1100	0.17	9.9
AM240-T6	H. T. & aged	1.81	0.066	35	16	4	16	21	8	60	..	C	A	D	1100	0.17	11.0
AM240-T61	H. T. & aged	1.81	0.066	36	19	1	19	22	8	69	..	C	A	D	1100	0.17	12.3
AM244-C	As-cast	1.76	0.064	24	9	6	9	14	..	44	..	B	X	D	1160	0.23	17.2
AM246-C	As-cast	1.82	0.066	19	14	0.5	14	17	6	65	..	X	X	C+	1075	0.16	10.5
AM246-T6	H. T. & aged	1.82	0.066	32	20	0.5	20	19	7	85	..	X	X	C+	1075	0.16	12.3
AM260-C	As-cast	1.82	0.066	23	14	1	14	18	12	65	..	C	A	B	1110	0.17	12.3
AM260-T4	Heat treated	1.82	0.066	39	14	10	14	20	12	63	..	C	A	B-	1110	0.17	10.5
AM260-T6	H. T. & aged	1.82	0.066	38	20	3	20	22	11	78	..	C	A	B	1110	0.17	12.3
AM265-C	As-cast	1.84	0.066	27	11	6	11	18	11	48	..	C	A	B	1155	0.18	15.0
AM265-T4	Heat treated	1.84	0.066	37	12	9	12	18	11	51	..	C	A	B-	1155	0.18	12.3
AM265-T6	H. T. & aged	1.84	0.066	36	18	4	18	20	9	69	..	C	A	B	1155	0.18	13.8
AM403-C	As-cast	1.76	0.064	14	4.5	5	4.5	11	..	33	..	A	X	A	1200	0.30	26.5
DIE CASTINGS																	
AM230-C	As-cast	1.81	0.066	32	22	1.5	..	..	13.5	63	..	X	B	B	1100	0.17	11.5
AM263-C	As-cast	1.81	0.066	34	22	3	..	..	14	60	..	X	X	B	1120	0.17	10.2

Footnotes are at end of table, on p. 246.

TABLE 20. TYPICAL PROPERTIES OF CAST AND WROUGHT MAZLO MAGNESIUM ALLOYS (Continued)

MAZLO ALLOY NO.	CONDITION	APPROX. SPECIFIC GRAVITY	APPROX. WEIGHT, PCI	STRENGTH <sup>1,2</sup>							RELATIVE RATINGS				PHYSICAL CONSTANTS <sup>9</sup>		
				Tension				Compressive Yield Strength	Shear Strength	Endurance Limits	Brinell Hardness	Weldability <sup>6</sup>		Resistance to Salt Water <sup>7</sup>	Melting Point, Degrees F.	Thermal Conductivity (100-300°C.) C.G.S. Units	Electrical Conductivity, Per Cent of International Annealed Copper Standard
				Ultimate Tensile Strength	Yield Strength	Elongation % in 2 In.	1000 psi					1000 psi	Workability <sup>8</sup>				
				1000 psi	1000 psi			1000 psi									
EXTRUDED ROD, BAR AND SHAPES <sup>9</sup>																	
AM3S	As extruded	1.76	0.064	35-40	26-30	6-7	11	16	10.5	40	B+	A	A	B+	1200	0.30	34.5
AM52S	As extruded	1.79	0.064	39-40	28-30	15-17	20	19	15	50	A	B	A	B	1180	0.23	17.2
AM-C52S	As extruded	1.79	0.064	39-40	28-30	15-17	20	19	15	50	A	B	A	A	1180	0.23	17.2
AM57S	As extruded	1.80	0.065	44	30-32	14-15	20.5	20.5	17	55	C	C	A	D+	1150	0.19	12.3
AMC57S	As extruded	1.80	0.065	44	30-32	14	20.5	20.5	17	55	C	C	A	A	1150	0.19	12.3
AM58S	As extruded	1.81	0.066	46-47	32-35	12	22	21.5	17.5	60	D	D	A	C	1110	0.18	10.8
AM-C58S	As extruded	1.81	0.066	46-47	32-35	12	22	21.5	17.5	60	D	D	A	B+	1110	0.18	10.8
AM59S	As extruded	1.82	0.066	48-51	37-38	9	27	23	18	70	E	E	X	D	1110	0.17	9.7
AM-C74S	As extruded	1.82	0.066	42	25-30	17-19	20	20	17	50	X	X	X	B+	1175	0.20	14.4
AM-C74S-T5	Ext. & aged	1.82	0.066	43-44	28-34	13-14	26	21	17	55	X	X	X	B+	1175	0.21	15.7
EXTRUDED TUBING																	
AM3S	As extruded	1.76	0.064	35	25	5	..	..	..	40	B+	A	A	B+	1200	0.30	34.5
AM52S	As extruded	1.79	0.064	35	22	11	..	..	..	50	A	B	A	B	1180	0.23	17.2
AM-C52S	As extruded	1.79	0.064	35	22	11	..	..	..	50	A	B	A	A	1180	0.23	17.2
AM57S	As extruded	1.80	0.065	40	19	9	..	..	..	55	C	C	A	D+	1150	0.19	12.3
AM-C57S	As extruded	1.80	0.065	40	19	9	..	..	..	55	C	C	A	A	1150	0.19	12.3
AM-C58S-T5	Ext. & aged	1.81	0.066	42	29	5	..	..	..	60	D	D	A	B+	1110	0.19	11.5
AM-C74S	As extruded	1.82	0.066	40	19	9	..	..	..	55	X	X	X	B+	1175	0.20	14.4
AM-C74S-T5	Ext. & aged	1.82	0.066	41	22	7	..	..	..	60	X	X	X	B+	1175	0.21	15.7
SHEET AND PLATE <sup>10, 11</sup>																	
AM3S-O	Annealed	1.76	0.064	32	17	16	15	19	8	44	B+	A	A	A	1200	0.30	34.5
AM3S-H	Hard rolled	1.76	0.064	36	27	9	22	20	10.5	52	B	A	A	B+	1200	0.30	34.5
AM-C52S-O	Annealed	1.79	0.064	38	25	18	16	21	11	54	A	B	A	A	1180	0.23	17.2
AM-C52S-H	Hard rolled	1.79	0.064	46	34	10	33	21	11.5	71	C	B	A	B+	1180	0.23	17.2
AM-C57S-O	Annealed	1.80	0.065	42	26	10	17	20	12.5	56	C	C	A	A	1150	0.19	12.3
AM-C57S-H	Hard rolled	1.80	0.065	50	35	6	29	22	..	74	C	C	A	B+	1150	0.19	12.3
FORGINGS																	
AM-C57S	Press forged	1.80	0.065	42	26	8	..	21	16	55	..	X	A	A	1150	0.19	12.3
AM-C58S	Press forged	1.81	0.066	45	30	6	..	22	17	60	..	X	A	B+	1110	0.18	10.8
AM65S	Ham. forged	1.87	0.067	38	22	12	..	16	10.5	52	..	X	A	C	..	..	..
AM-C74S	Press forged	1.82	0.066	41	24	16	..	20	16	59	..	X	X	B+	1175	0.20	14.4
AM-C74S-T5	Press forged and aged	1.82	0.066	42	28	14	..	21	16	62	..	X	X	B+	1175	0.21	15.7

<sup>1</sup> For all Mazlo magnesium alloys, cast or wrought, the following data apply: (a) Modulus of elasticity is 6,500,000 psi; (b) Poisson's Ratio is 0.34; (c) Bearing strength may be taken as approximately 1.6 times the tensile strength, provided the edge distance, in the direction of stressing, is not less than twice the diameter of the hole.

<sup>2</sup> Mechanical properties are obtained on A.S.T.M. specimens. Properties given are typical values from which variations must be expected in practice.

<sup>3</sup> Yield strength is the stress at which the material exhibits a permanent set of 0.2 per cent.

<sup>4</sup> Shear strengths are single-shear values obtained from double-shear tests.

<sup>5</sup> Endurance limits are based on 500 million cycles of completely reversed stress. For all products except sheet, the R. R. Moore type of machine and specimen is used. For sheet, a repeated flexure type of machine with a cantilever-beam specimen is employed.

<sup>6</sup> Rating "A" indicates best characteristics, rating "E" the least favorable characteristics. Rating "X", commercial practices not developed.

<sup>7</sup> An "A" rating is highest based on results of standard salt-spray tests.

Under many conditions of service, alloys rated "D" are used with entirely satisfactory results. The difference in stability between all alloys under atmospheric conditions is small and all have good resistance to atmospheric corrosion.

<sup>8</sup> For all alloys, the mean coefficient of thermal expansion (68 to 212 degrees F.) is about 0.000145 per degrees F., and the mean specific heat (68 to 212 degrees F.) approximately 0.249 calories.

<sup>9</sup> Where two values are shown, the lower applies to extruded shapes, the higher to extruded rod and bar. Where one value is shown it applies to extruded rod and bar. Rod and bar properties apply to sizes up to 7 sq. in. of cross-sectional area. On larger sizes slightly lower properties are obtained.

<sup>10</sup> Sheet heavier than 10 gage (0.102 inch) and plate are supplied in the "as-hot-rolled" (R) condition instead of the "hard rolled" (H) condition. Designations are AM3S-R, AM-C52S-R, AM-C57S-R. Mechanical properties of "as-hot-rolled" material are intermediate between those of hard rolled and annealed sheet.

<sup>11</sup> The compressive yield strength values given for sheet alloys are based on very limited data.

The wrought alloys are classified as nonheat-treatable and heat-treatable. The nonheat-treatable alloys derive their strength from strain hardening produced by cold working. The degree of hardness, or "temper," of the alloy depends on the amount of working, or reduction, it receives. When the maximum amount of cold working that is practical has been exercised on an alloy, it is designated by the letter "H." Hence, "52 SH" means "number 52S wrought aluminum alloy, cold worked to its hardest temper."

Varying degrees of cold working are denoted by the fractional symbols  $\frac{1}{2}$ H,  $\frac{1}{4}$ H,  $\frac{3}{4}$ H. If the metal is subjected to annealing temperatures, the effects of cold working are removed and the alloy is designated with the letter "O" indicating a softened condition.

The following are a few examples of designations for cold worked aluminum alloys:

52S $\frac{1}{2}$ H	52S wrought aluminum alloy cold worked to half hard temper.
3SO	3S wrought aluminum alloy in soft or annealed condition.
2SH	2S wrought aluminum alloy cold worked to its maximum degree of hardness.

Sheet and tubing are usually manufactured from cold worked alloys. Bar, rod, plate, and wire are extruded and rolled hot, but are finished cold worked.

The various cold worked aluminum alloy sheets serve the following purposes:

**HARD:**

when the sheet is not formed, and stiffness is the primary requisite.

**THREE-QUARTERS HARD:**

for moderate forming but where strength is of prime importance. If the part for which this sheet is used must be bent, liberal radii should be allowed.

**HALF HARD:**

for bent parts of moderate radii and good structural qualities.

**ONE-QUARTER HARD:**

for parts with light structural requirements needing more complex forming than  $\frac{1}{2}$  H could be subjected to.

**SOFT:**

for complicated forming and deep drawing operations.

The tempers of heat-treatable alloys are designated by letters. The letter "T" following the alloy number indicates that the alloy has been heat treated and age hardened. Some alloys, like 17S-T and 24S-T, age naturally at room temperature, their full strength being developed within approximately four days. Others, such as 53S-T and 61S-T, are artificially age-hardened at slightly higher temperatures.\*

Some alloys can reach a greater degree of hardness when they are cold worked after heat treatment. This property is designated by the letter "R" inserted between the "S" and the "T," for example, 24S-RT.

When certain special heat treatment and cold working processes have been used, the temper derived is designated by the letter "T" followed by a number, for example, 195-T4, meaning number 195 cast aluminum alloy tempered to a specific condition (T4).

In some cases a letter precedes the alloy number to indicate a slight variation in composition, for example, A17S, a special alloy for rivets.

The letter "O" designates a heat-treatable alloy in the soft or annealed condition, just as it designates the soft condition of nonheat-treatable alloys.

### *Magnesium*

Because of the urgent need for large planes, designers have sought in every way to reduce weight without impairing strength. Lightness of weight means reduced operating costs, better performance, and increased payload.

\* When heat-treatable aluminum alloys were being developed, it was recognized that the strength of some of them was considerably increased by artificial aging, but it was not at first realized that alloys of the 17S and 24S type responded in a similar manner to the elevated temperature treatments. As a result, the room temperature aged tempers of the alloys like 14S, 53S, and 61S were considered to represent "fully aged material" and the temper was designated by the letter "T." For those alloys which were known to respond to artificial aging, the temper resulting from aging at room temperature after the solution heat treatment, was designated by the letter "W."

Recently it has been recognized that the strength of 24S which was fully aged at room temperature can be increased further by suitable artificial aging treatments, so that the temper which has for some years been designated by the letter "T" should properly be called "W." Since changing the designation at this late date would result in considerable confusion, the designation, "T80" has been adopted for 24S which has been heat treated and artificially aged. To indicate the different levels of strength which result in aged material which has been cold worked in varying amounts prior to aging, the designations "T81," "T86," etc. are employed, each indicating a different amount of cold work.—From *Aluminum and Its Alloys*, 1944, copyrighted by the Aluminum Company of America.

TABLE 21. SPECIFICATIONS AND COMPOSITIONS OF PRINCIPAL MAZLO MAGNESIUM ALLOYS

MAZLO ALLOY NUMBER	SPECIFICATIONS <sup>1</sup>								NOMINAL COMPOSITIONS IN PER CENT (balance magnesium and normal impurities)			
	<i>Army Air Forces</i>		<i>Navy Department</i>		<i>A.S.T.M.</i>		<i>S.A.E.</i>	<i>A.M.S.</i>	<i>Aluminum</i>	<i>Zinc</i>	<i>Manganese</i>	<i>Others</i>
	<i>Number</i>	<i>Grade</i>	<i>Number</i>	<i>Grade</i>	<i>Number</i>	<i>Grade</i>						
SAND CASTINGS												
AM246 <sup>2</sup>	..	..	..	..	B80-41T	3	..	..	12	..	0.2	..
AM260 <sup>2</sup>	AN-QQ-M-56 <sup>3</sup>	C	AN-QQ-M-56 <sup>3</sup>	C	B80-41T	17	500	4434 <sup>4</sup>	9	2	0.2	..
AM265 <sup>3</sup>	AN-QQ-M-56 <sup>3</sup>	A	AN-QQ-M-56 <sup>3</sup>	A	B80-41T	4	50	4420, 4422, 4424 <sup>5</sup>	6	3	0.2	..
AM403	AN-QQ-M-56 <sup>3</sup>	B	AN-QQ-M-56 <sup>3</sup>	B	B80-41T	11	..	..	..	..	1.5	..
PERMANENT-MOLD CASTINGS												
AM240 <sup>2</sup>	11348	..	..	..	..	..	502	..	10	..	0.2	..
AM260 <sup>2</sup>	11349	..	..	..	..	..	503	..	9	2	0.2	..
DIE CASTINGS												
AM230	11319 <sup>6</sup>	1	46-M-11	..	B94-40T	12	..	..	10	..	0.2	0.5 Si
AM263	11319 <sup>6</sup>	1	46-M-11	..	B94-40T	13	501	4490	9	1	0.2	..
EXTRUDED BAR, ROD, SHAPES												
AM3S	11336	..	M-314 <sup>7</sup>	11	B107-41T	11	..	..	..	..	1.5	..
AM52S	..	..	..	..	B107-41T	18	..	..	3	1	0.2	..
AM-C52S	..	..	..	..	B107-41T	18X	52	..	3	1	0.2	..
AM57S	..	..	..	..	B107-41T	8	520	..	6.5	1	0.2	..
AM-C57S	11335	..	M-314 <sup>7</sup>	8	B107-41T	8X	520	4350	6.5	1	0.2	..
AM58S	..	..	..	..	B107-41T	9	..	..	8.5	0.5	0.2	..
AM-C58S	..	..	..	..	B107-41T	9X	..	..	8.5	0.5	0.2	..
AM59S	..	..	..	..	..	..	..	..	10	..	0.2	..
AM-C74S	11337	..	M-314 <sup>7</sup>	15	B107-41T	15X	521	..	3	3	0.2	..
AM-C74S-T5	..	..	M-314 <sup>7</sup>	15a	B107-41T	15XA	521	..	3	3	0.2	..
SHEET AND PLATE <sup>8</sup>												
AM3S	11339	..	47-M-2	11	B90-41T	11	51	4370 <sup>9</sup>	..	..	1.5	..
AM-C52S	11340	..	47-M-2	18	B90-41T	..	510	..	3	1	0.2	..
AM-C57S	11338	..	47-M-2	8	B90-41T	8X	511	4380-4381	6.5	1	0.2	..
TUBING												
AM3S	11333	..	44-T-35	11	..	..	..	..	..	..	1.5	..
AM-C52S	..	..	..	..	..	..	..	..	3	1	0.2	..
AM57S	..	..	..	..	..	..	..	..	6.5	1	0.2	..
AM-C57S	11332	..	44-T-35	8	..	..	..	..	6.5	1	0.2	..
AM-C58S-T5	..	..	..	..	..	..	..	..	8.5	0.5	0.2	..
AM-C74S	11334	..	44-T-35	15	..	..	..	..	3	3	0.2	..
PRESS FORGINGS												
AM-C57S	11345	..	46-M-13	8	B91-41T	8X	531	4350	6.5	1.0	0.2	..
AM-C58S	11321A	..	46-M-13	9	B91-41T	9X	532	4360	8.5	0.5	0.2	..
AM-C58S-T5	11321A	..	..	..	..	..	..	..	8.5	0.5	0.2	..
AM-C74S	..	..	46-M-13	15	B91-41T	15X	..	..	3	3	0.2	..
AM-C74S-T5	..	..	46-M-13	15A	B91-41T	15XA	..	..	3	3	0.2	..
HAMMER FORGINGS												
AM65S	11346	..	46-M-13	16	B91-41T	16	53	..	3.5	..	0.5	5 Sn

<sup>1</sup> Suffixes indicating the revision currently in force are omitted.

<sup>2</sup> Heat treating tempers are omitted in alloy designations.

<sup>3</sup> Army-Navy Aeronautical Specification.

<sup>4</sup> Applies to AM260-T6 only.

<sup>5</sup> 4420 applies to AM265-C; 4422 to AM265-T4; 4424 to AM265-T6.

<sup>6</sup> Army Air Corps Specification.

<sup>7</sup> Navy Aeronautical Specification.

<sup>8</sup> Designations of rolling temper are omitted in alloy designation.

<sup>9</sup> Applies to AM3S-O only.

TABLE 22. MAZLO MAGNESIUM WROUGHT ALLOYS—AVAILABLE FORMS, CHARACTERISTICS AND USES

MAZLO ALLOY NO.	FORMS COMMONLY AVAILABLE									Heat-Treatable	CHIEF CHARACTERISTICS	TYPICAL USES
	Sheet and Plate	Rod and Bar	Extruded Shapes	Extruded Tubing	Wire	Hammer Forgings	Press Forgings	Pressings				
AM3S	*	*	*	*	*	*	..	..	..	..	Good torch welding and forming characteristics, good resistance to corrosion. Very good extrusion and rolling properties.	Welded and low or moderately stressed parts of aircraft structures requiring forming. Extruded hollow seamless shapes.
AM52S	*	*	*	*	*	..	..	*	..	..	Forming characteristics superior to AM3S, but less torch weldable and less resistant to corrosion. Good extrusion and rolling properties.	General purpose sheet, plate, and extrusion alloy. Extruded hollow seamless shapes of relatively simple design.
AM-C52S	*	*	*	*	..	..	..	*	..	..	Same properties as AM52S, but improved resistance to corrosion (about equal to AM3S).	Welded and formed aircraft sheet structures requiring higher strength than AM3S.
AM57S	..	*	*	*	*	..	..	*	..	..	Combination of good strength and elongation, and good extrusion characteristics. Torch weldability and formability limited.	General purpose alloy for extruded shapes. Screw machine parts.
AM-C57S	*	*	*	*	..	..	*	*	..	..	Properties same as AM57S, but greatly improved resistance to corrosion (best of all magnesium alloys).	High-strength aircraft sheet parts not requiring torch welding and forming. Aircraft screw machine parts.
AM58S	..	*	*	..	..	..	..	..	..	*	High yield strength combined with good elongation. Less readily extruded than AM57S. Not ordinarily torch welded or formed. Yield strength can be increased by aging.	High-strength structural extruded shapes.
AM-C58S	..	..	..	*	..	..	*	..	..	*	Same properties as AM58S, but greatly improved resistance to corrosion (about equal to AM3S).	High-strength forgings for aircraft. Tubing with high yield strength.
AM59S	..	*	*	..	..	..	..	..	..	*	Highest yield strength and hardness, comparatively low elongation. Cannot be torch welded or formed. Least readily extruded. Yield strength can be raised by aging.	Extruded shapes requiring highest available yield strength and hardness.
AM65S	..	*	..	..	..	*	..	*	..	..	Good hammer forging characteristics; strength lower than, resistance to corrosion equal to AM58S.	Moderate-strength forgings.
AM-C74S	..	*	*	*	..	..	*	..	..	*	Similar to AM-C57S, but resistance to corrosion, welding and forming properties slightly lower, strength in aged condition slightly higher.	Aircraft parts with good strength and corrosion resistance, to be aged after forming.

Magnesium, a metal of extremely light weight, has opened up new avenues in aircraft design. When alloyed with aluminum, manganese, zinc, tin, or cadmium, magnesium presents a wide range of desirable properties.

The most important quality of magnesium is its lightness. It weighs only 23 per cent of an equal volume of iron and 64 per cent of an equal

volume of aluminum. Structural magnesium alloys have a specific gravity ranging from 1.78 to 1.86 (approximately), which corresponds to a weight of 0.063 to 0.066 pound per cubic inch.

Weight limitations govern all aircraft design. Magnesium, under some conditions, permits the use of thick, structurally safe sections without a penalty of increased weight.

TABLE 23. SPECIFIED MINIMUM PROPERTIES OF CAST AND WROUGHT MAZLO MAGNESIUM ALLOYS

MAZLO ALLOY NO.	SPECIFIED MINIMUM PROPERTIES <sup>1</sup>		
	Ultimate Tensile Strength, psi	Tensile Yield Strength, <sup>2</sup> psi	Elongation, Per Cent in 2 Inches
SAND AND PERMANENT MOLD CASTINGS			
AM240-C	18,000	10,000	1
AM240-T4	29,000	10,000	6
AM240-T6	29,000	15,000	2
AM240-T61	29,000	17,000	..
AM244-C	20,000	8,000	4
AM246-C	17,000	11,000	..
AM246-T6	27,000	17,000	..
AM260-C	20,000	10,000	..
AM260-T4	32,000	10,000	6
AM260-T6	34,000	18,000	1
AM265-C	24,000	10,000	4
AM265-T4	32,000	10,000	7
AM265-T6	34,000	16,000	3
AM403-C	12,000	4,000	3
EXTRUDED ROD AND BAR <sup>3</sup>			
AM3S	32,000	20,000	5
AM52S	37,000	25,000	12
AM-C52S	37,000	25,000	12
AM57S	40,000	26,000	12
AM-C57S	40,000	26,000	12
AM58S	43,000	29,000	9
AM-C58S	43,000	29,000	9
AM59S	45,000	33,000	6
AM-C74S	40,000	26,000	15
AM-C74S-T5	41,000	30,000	10
EXTRUDED SHAPES <sup>4</sup>			
AM3S	32,000	17,000	3
AM52S	35,000	22,000	11
AM-C52S	35,000	22,000	11
AM57S	38,000	23,000	9
AM-C57S	38,000	23,000	10
AM58S	42,000	27,000	8
AM-C58S	42,000	27,000	8
AM59S	45,000	30,000	6
AM-C74S	39,000	23,000	10
AM-C74S-T5	40,000	25,000	8

<sup>1</sup> Properties are obtained on A.S.T.M. specimens.

<sup>2</sup> Yield strength is the stress at which the material exhibits a permanent set of 0.2 per cent.

MAZLO ALLOY NO.	SPECIFIED MINIMUM PROPERTIES <sup>1</sup>		
	Ultimate Tensile Strength, psi	Tensile Yield Strength, <sup>2</sup> psi	Elongation, Per Cent in 2 Inches
EXTRUDED TUBING			
AM3S	32,000	17,000	3
AM52S	32,000	18,000	..
AM-C52S	32,000	18,000	..
AM57S	36,000	17,000	7
AM-C57S	36,000	17,000	7
AM-C58S-T5	39,000	25,000	4
AM-C74S	36,000	17,000	7
AM-C74S-T5	37,000	19,000	6
ROLLED SHEET			
AM3S-O	28,000 35,000 max. <sup>5</sup>	24,000 max. <sup>5</sup>	12
AM3S-H	32,000	24,000	4
AM-C52S-O	32,000 38,000 max. <sup>5</sup>	..	12
AM-C52S-H	38,000	26,000	4
AM-C57S-O	37,000 45,000 max. <sup>5</sup>	..	8
AM-C57S-H	40,000	28,000	3
FORGINGS			
AM-C57S	38,000	22,000	6
AM-C58S	42,000	26,000	5
AM65S	35,000	20,000	6
AM-C74S	38,000	20,000	9
AM-C74S-T5	38,000	22,000	7

<sup>3</sup> Properties apply to material up to 1½ in. round or square.

<sup>4</sup> Properties do not apply to shapes of unusual cross section; very heavy shapes; and shapes whose thickness is ¼ in. or less.

$$\text{Factor} = \frac{\text{Shape perimeter} \times 0.064}{\text{Magnesium weight per foot}}$$

<sup>5</sup> Maximum strength is specified for annealed sheet to insure complete annealing.

Like aluminum, magnesium alloys are available in two forms: cast and wrought. Wrought magnesium alloys are rolled into sheet and plate and are extruded into rod, bar, wire, and tubing, which can be forged. Castings range in weight

Sheet stock is usually fastened by aluminum alloy rivets.

Magnesium castings are used in such secondary structures as brackets and housings for engines and other mechanisms. Even though

TABLE 24. CHEMICAL TREATMENTS FOR MAZLO MAGNESIUM ALLOYS

AMC TREATMENT	COMMERCIAL NAME	PURPOSE OF COATING	RATING OF PROTECTIVE VALUE (A= BEST)	MAGNESIUM ALLOYS RECOMMENDED FOR COATING	APPROX. DIMENSIONAL CHANGE (FOR EACH SURFACE)	SPECIFICATIONS		
						U. S. Army	U. S. Navy	A.M.S.
A	Chrome pickle (Dichromate dip)	Prevention of tarnish, paint base.	E	All	Minus 0.001"	98-20010-B	M-303b	2475
C	Chrome sulphate	Low dielectric strength.	D	All	None	98-20010-B	M-408	..
E	Chrome-alum	Same as "A," but especially suitable for die castings.	C	Die-casting alloys.	None	.....	.....	..
G	Dichromate	Paint base, or protective coating of some decorative value for interior applications.	A	All except AM3S	None	98-20010-B	M-407	2475
H	Modified alkali-chromate	Same as "G."	B	All except AM3S	None	.....	M-382a	..
K	Galvanic anodize	Paint base for exterior and marine applications.	A	All	None	.....	M-395	..
L	Sealed chrome pickle	Paint base, especially for welded sheet parts.	A	All	Minus 0.001"	.....	M-406a	..
M	Borax	Decorative, comparatively hard.	D	AM3S, AM52S	None	.....	.....	..
O	Pressure	Hardest coating available for magnesium alloys	A <sup>1</sup>	All except die castings. Wrought alloys preferred	Plus 0.001"	.....	.....	..

<sup>1</sup> Rating A in atmosphere, E in salt spray.

from a fraction of a pound to hundreds of pounds.

Magnesium alloys have good machining properties. Machining time is short, and a smooth finish is readily obtained. However, special care must be taken in machining magnesium, because fine grains and shavings are highly inflammable. Magnesium alloys can be joined by welding.

TABLE 25. RANGE OF STANDARD COMMERCIAL SIZES OF EXTRUDED MAZLO MAGNESIUM WIRE, ROD AND BAR

COMMODITY	DIMENSIONS, INCHES	
	Smallest	Largest
Round wire <sup>1</sup>	0.0254 diameter	0.114 diameter
Round rod	$\frac{1}{8}$ diameter	8 diameter
Square bar	$\frac{1}{8} \times \frac{1}{8}$	8 x 8
Hexagonal bar	$\frac{1}{4}$ across flats	3 across flats
Square-edge rectangular bar <sup>2</sup>	$\frac{1}{8} \times \frac{3}{8}$	$7\frac{1}{2} \times 8$

<sup>1</sup> Smallest diameter: 0.0254 inch for AM3S, 0.064 inch for AM52S, 0.091 inch for AM57S.

<sup>2</sup> Minimum standard thickness:  $\frac{1}{8}$  inch for widths up to 5 inches;  $\frac{3}{16}$  inch for widths over 5 to 8 inches.

TABLE 26. RANGE OF STANDARD COMMERCIAL SIZES OF EXTRUDED ROUND MAZLO MAGNESIUM TUBING<sup>1</sup>

OUTSIDE DIAMETER, INCHES	WALL THICKNESS <sup>2</sup> , INCHES	
	Smallest	Largest
$\frac{3}{8}$	0.028	0.042
$\frac{1}{2}$	0.028	0.095
$\frac{5}{8}$	0.028	0.120
$\frac{3}{4}$	0.028	0.148
1	0.032	0.180
$1\frac{1}{4}$	0.035	0.259
$1\frac{1}{2}$	0.035	0.375
$1\frac{3}{4}$	0.035	0.450
2	0.049	0.500
$2\frac{1}{2}$	0.065	0.625
3	0.072	0.750
$3\frac{1}{2}$	0.083	0.750
4	0.083	1.000
$4\frac{1}{2}$	0.095	1.000
5	0.109	1.000
$5\frac{1}{2}$	0.120	1.000
6	0.134	1.000
$7\frac{1}{2}$	0.165	1.000

<sup>1</sup> A number of intermediate outside diameters and wall thicknesses are available.

<sup>2</sup> Sizes with 0.042-inch wall and less are available in AM3S alloy only.

magnesium is extremely light, some castings reach a strength of 35,000 to 40,000 pounds per square inch. Wrought forms attain a strength of 45,000 to 50,000 pounds per square inch.

Weight savings up to one-third may be realized by changing from aluminum to magnesium alloys. A magnesium sheet is over two times as stiff as aluminum sheet of the same weight and eighteen times as stiff as a steel sheet of the same weight. Much aircraft flooring is constructed from corrugated sheets of magnesium alloy.

TABLE 27. RANGE OF STANDARD COMMERCIAL SIZES OF MAZLO MAGNESIUM SHEET<sup>1</sup>

<i>Alloys</i>	<i>Thickness, Inches</i>	<i>Maximum Width, Inches<sup>2</sup></i>	<i>Maximum Length, Inches</i>
AM3S	0.032 and over <sup>1</sup>	36	144
	0.031 to 0.025	30	144
	0.024 to 0.016	24	96
	0.015 to 0.010	20	72
AM-C52S	0.040 and over <sup>1</sup>	36	144
	0.039 to 0.032	30	144
	0.031 to 0.020	24	96
	0.019 to 0.016	20	72
AM-C57S	0.064 and over <sup>1</sup>	36	144
	0.063 to 0.040	30	120
	0.039 to 0.020	24	96
	0.019 to 0.016	20	72

<sup>1</sup> Maximum weight per piece, 120 lb.

<sup>2</sup> New rolling equipment being installed will soon make it possible to furnish greater widths than shown for sheet of 0.032 in. thickness and over, and for plate.

Under ordinary conditions, the rate of corrosion of magnesium alloys is lower than that of mild steel but higher than that of most aluminum alloys. In salt air and under other corrosive circumstances the magnesium alloy parts must be protected by suitable paints.

On volume basis, pure magnesium has approximately 38 per cent of the electrical conductivity of copper, while commercially pure aluminum's conductivity is 64 per cent of that of copper. This is an asset in spot welding because it permits the welding of greater thicknesses with equipment of a given power.

*Nomenclature.* Most magnesium products in this country are produced by the Dow Chemical Co. and the American Magnesium Corporation. The Dow Chemical Co. products are named "Dowmetal," and the various alloys are identi-

fied by a letter, for example, "Dowmetal J," "Dowmetal H."

The American Magnesium Corporation designates its alloys with a system similar to that used by the Aluminum Company of America for aluminum alloys. Hence, AM263 and AM260 represent cast alloy, while AM3S and AM-C52S represent wrought alloys.

The differences in designations of similar magnesium alloys are stated below.

DESIGNATIONS

<i>American Magnesium Corporation</i>	<i>Dow Chemical Company</i>
265 . . . . .	H
C57s . . . . .	J-1
C58S . . . . .	O-1
3S . . . . .	M
230 . . . . .	K
263 . . . . .	R
C74S . . . . .	X-1
260 . . . . .	C

The preceding tables, 19-27, present interesting data regarding the properties and uses of magnesium alloys. They were prepared by the American Magnesium Corporation.

*Steel*

As was stated previously, steel is used in aircraft production where strength is required and space is limited or for parts that are exposed to overheating. Some examples of the application of steel are engine mounts, guns and gun fittings, landing gear struts, bolts, nuts, collector rings, fire walls, and other parts adjacent to the engine.

Actually, all steels are alloys. They are usually classified, however, as "carbon" or "alloy," carbon steel being steel whose chief alloying constituent is carbon. The carbon content may vary between 0.08 and 0.96 per cent. This kind of steel can be hardened progressively with increasing carbon content. But this increase in percentage of carbon prevents welding, for no steel with more than 0.40 per cent carbon can be welded.

If high strength, toughness, or resistance to corrosion are desired, one of the alloy steels will meet the requirements. Alloy steels may also be hardened, and some are readily welded.

The Society of Automotive Engineers (SAE) has assigned identification code numbers to var-

ious steels. Each number contains four digits. The first digit denotes the type of steel as follows:

- |                    |                      |
|--------------------|----------------------|
| 1. Carbon          | 5. Chromium          |
| 2. Nickel          | 6. Chromium-vanadium |
| 3. Nickel-chromium | 7. Tungsten          |
| 4. Molybdenum      | 8. Silicon-manganese |

The second digit gives the percentage of the predominant alloying element. The last two digits denote the carbon content in hundredths of 1 per cent. For example, SAE 2330 steel is a nickel steel which contains approximately 3 per cent nickel and 0.30 per cent carbon.

In some instances, the prefix "X" is used to denote a variation in the range of manganese, sulfur, or chromium. The prefix "T" is used to denote a variation in some manganese steels.

*Nomenclature.* The most important steels for aircraft production and their applications are listed below.

FREEMACHINING steel is generally used for parts that require a considerable amount of machining and when strength is immaterial. One of the most frequently employed steels in this group is SAE 1314.

NICKEL steels are often used for making bolts, screws, and fittings. Their shock resistance and heat resistance are high. An important steel in this group is SAE 2330.

CHROME MOLY (chromium-molybdenum) steels have a wide range of application and are used extensively in aircraft production. Steel will lend itself to greater hardening when chromium and molybdenum are added, and such steel is used for heavy, high-strength sections. Chrome moly steel can be welded if their carbon content does not exceed 0.40 per cent. They are utilized in aircraft production in all shapes of wrought stock, sheet, bar, rod, strip, and tubing, as well as forgings and castings. SAE 4140 and X4130 are two of the preferred steels in this group.

CHROME MOLY NICKEL steels are chrome moly steels to which nickel has been added to increase further the hardening propensity. High-strength castings and many other parts may be produced from these steels. SAE 4340 is the most popular in this category.

STAINLESS steels usually contain about 18 per cent chromium and 8 per cent nickel, which makes them highly resistant to corrosion and

heat. Steel parts exposed to weather or to high temperatures are usually made of stainless steel. Fire walls, hydraulic lines, engine exhaust collector rings, shrouds, and hot air ducts are typical applications of stainless steel. The AISI (American Iron and Steel Institute) designations are used generally to identify these steels.

Stainless steel that contains 18 per cent chromium and 8 per cent nickel must be hardened by rolling and straining, because it cannot be treated with heat. But it may be welded if proper amounts of columbium and titanium are added. AISI 303, 304, 321, and 347 are commonly used steels of this type. AISI 410 is a chromium stainless steel without nickel. If it contains a sufficient amount of carbon it can be hardened by heat treatment.

The table below gives some pertinent information about the steels commonly used in aircraft production.

Steel SAE No.	Condition	Tensile Strength, psi	Weldability
X1314	Normalized	55,000 (min.)	Good
1025	Normalized	55,000 (min.)	Good
X4130	Normalized	90/110,000	Good
1045	H. T.	120/145,000	Poor
1065	H. T.	120/145,000	Poor
2330	H. T.	120/145,000	Good
4027	H. T.	120/145,000	Good
X4130	H. T.	120/145,000	Good
NF8630	H. T.	120/145,000	Good
NF8735	H. T.	120/145,000	Good
2330	H. T.	145/170,000	Good
4037	H. T.	145/170,000	Fair
X4130	H. T.	145/170,000	Good
4140	H. T.	145/170,000	Fair
X4340	Normalized	150,000 (max.)	Good
NE8630	H. T.	145/170,000	Good
NE8949	H. T.	145/170,000	Good
X4130	H. T.	170/190,000	Good
4140	H. T.	170/190,000	Fair
X4340	H. T.	170/190,000	Good
NF8630	H. T.	170/190,000	Good
NF8735	H. T.	170/190,000	Good
NE8949	H. T.	170/190,000	Poor
X4130	H. T.	190/220,000	Good
4140	H. T.	190/220,000	Fair
X4340	H. T.	190/220,000	Good
Stainless Steels A.I.S.I.	Condition	Tensile Strength, psi	Weldability
303	Annealed	80,000 (max.)	
304	Annealed	100,000 (max.)	
321	Annealed	100,000 (max.)	Good
431	H. T.	115,000	
304	½ Hard	125,000	
303	½ Hard	125,000	
304	¾ Hard	150,000	
431	H. T.	175,000	

Knowledge of the proper heat treatments is essential to the successful utilization of steel. Some of the commonly used terms are explained in the following:

Steel hot formed in the rolling mill is called **HOT ROLLED**. If a smooth outer surface and greater strength are required, the steel is then **COLD ROLLED**. If a soft, ductile steel is needed, it is **ANNEALED** by heating to a temperature above the critical range of 1300 to 1600 degrees Fahrenheit and cooling slowly in the furnace. Internal stresses caused by rolling are thus relieved.

**NORMALIZING** is similar to annealing except that the steel is cooled in air at a faster rate. This relieves most of the internal stresses, but a somewhat harder material results. Most welded steel assemblies are normalized to relieve the stresses set up by the heat of welding.

**HARDENING** is done by heating the metal to a temperature above the critical point and quenching it rapidly in water or oil. This produces a very hard and brittle steel. The brittleness is then removed by a further heat treatment called **TEMPERING**. In this process the steel is heated to slightly below the critical temperature before cooling in air. Tempering toughens the steel and eliminates brittleness. But the nearer the critical temperature reached the softer the steel will become.

**CARBURIZING** is the addition of carbon to the outer surface of a low-carbon steel, which makes it possible to procure a hard surface on a low-carbon steel part. This is accomplished by heating to above the critical temperature in the presence of carbon.

### Nickel Alloys

Nickel is the major constituent of a number of ferrous alloys used for special applications in aircraft production.

All nickel alloys are noted for their exceptional resistance to corrosion. In this respect they are equal, and often superior, to stainless steel.

These alloys can be readily formed and machined and are available in common stock forms. Three nickel alloys find particular use in aircraft; these are Inconel, Monel, and K Monel.

### Inconel

This alloy is characterized by its ability to retain corrosion resistance and strength at elevated temperatures. It is therefore suitable for exhaust collectors, heating system ducts, etc. Inconel is composed of the following approximate percentages:

<i>Element</i>	<i>Per Cent</i>
Nickel	78
Chromium	13.5
Iron	6.9
Manganese	0.35
Copper	0.4
Silicon	0.35
Carbon	0.08

Although it contains some iron and carbon, Inconel is classified as a nonferrous material. The iron content is negligible and does not transmit any of the characteristics of steel.

The alloy cannot be hardened by heat treatment and is heated only to relieve strains set up during cold working. Inconel is sufficiently ductile in the annealed state to be easily formed. Sheet stock can usually be bent to a radius equal to the thickness of the sheet. It may be successfully machined, cast, forged, and welded.

### STRENGTH OF PROPERTIES

	<i>Tensile Strength,</i> <i>psi</i>	<i>Yield Point,</i> <i>psi</i>	<i>Elongation,</i> <i>Per Cent in</i> <i>2 Inches</i>
Sheet			
- Annealed	80,000- 95,000	30,000- 40,000	55-35
Full hard	125,000	100,000	7
Strip			
Annealed	80,000- 95,000	30,000- 40,000	55-35
¼ hard	100,000-115,000	60,000	30-20
½ hard	115,000-130,000		28-18
¾ hard	120,000-140,000		24-12
Hard	130,000-150,000		17-7
Full hard	145,000-170,000		10-2
Rod			
Annealed	80,000- 95,000	30,000- 40,000	55-35
Cold drawn	100,000-130,000	80,000-105,000	30-20
Wire			
Annealed	80,000- 95,000	30,000- 40,000	55-35
Spring temper	175,000-200,000		10-2

### Monel

Monel metal is a high-nickel copper alloy, combining a noncorrosive property with high strength and favorable working characteristics. Monel, like Inconel, can be hardened only by cold working.

## K Monel

K Monel is an alloy of nickel, copper, and aluminum. This alloy, like Monel and Inconel, is highly noncorrosive. It possesses exceptional strength which may be further increased by heat treatment. It is nonmagnetic and is therefore used for structural parts of a plane in the vicinity of compasses. Many machined parts exposed to weather and subject to corrosion, such as landing gear equipment, are produced from this alloy.

### *Copper, Brass, and Bronze*

The application of these metals is limited in aircraft production to bearings, oil lines, and electrical wiring.

### *Plastics*

Plastics are a product of man's ingenuity; they are chemically created materials not found in nature. The first plastic was formed by treating cotton cellulose with nitric acid. The resulting nitrocellulose compound was called "celluloid." The addition of sour milk to formaldehyde resulted in another plastic used in the manufacture of buttons and buckles.

Many varieties of plastics are available today, and it seems safe to predict that more types will be available in the future. Uses of plastics, too, are continually expanding. They find many applications in industry today, and many types in many forms—molded, cast, and laminated—are of increasing importance.

Plastics used in aircraft are of two types, transparent and phenolic.

### *Transparent Plastics*

The transparent type is used in sheet form for enclosures, windows, windshields, etc., and is usually one of three kinds: **PLASTICELE** (cellulose acetate base), **PLEXIGLAS** (acrylate base), and **NON-SCATTERABLE LAMINATED GLASS**, which is composed of two sheets of glass bound together by a single-ply filler of transparent plastic.

### *Phenolic Plastics*

Phenolic plastics result from the admixture of phenol and formaldehyde, molded with various

suitable fillers. They are more commonly known by their trade names: **BAKELITE**, **MICARTA**, and **FORMICA**. These products are manufactured by saturating a filler material, such as paper, fabric, or asbestos, in the phenol-formaldehyde resinoid at high temperature and pressure. The required temperature and pressure fluctuate with the various materials and grades, but are approximately 360 degrees Fahrenheit and 2000 to 3500 pounds per square inch.

Phenolic products are characterized by their relative permanence, hardness, strength, and excellent electrical insulating qualities. Because of their insulating qualities and their suitability for machining, these plastics find innumerable uses in electrical work. Dashboards and cabin panels constructed from flat sheets, control pulleys, handles, tab controls, etc., are a few of their applications.

United States Air Corps specifications for the requirements of phenol-formaldehyde plastics designate the plastic by type number and grade as listed below:

#### TYPE AND GRADES:

- Type I, Paper base, laminated phenolic material, Grades X, XX, and XXX.
- Type II, Fabric base, laminated phenolic material, Grades C and L.
- Type III, Fabric base, macerated phenolic material.

#### APPLICATIONS:

- Grade X, used for insulating washers and plates for low tension not exceeding 200 volts.
- Grade XX, used for radio insulation. It is inferior to Grade XXX in electrical properties at radio frequencies.
- Grade XXX, used for coil construction, high-tension sheet insulation, solenoids, low-tension circuits, insulating bushings for ignition equipment and switches.
- Grade C, a heavy weave fabric base material, used primarily for mechanical purposes but sometimes for low-voltage insulation.
- Grade L, a fine weave fabric base material, used primarily for mechanical purposes but also for low-voltage insulation.
- Type III, macerated material, used for pulleys, cam followers, fair leads, and like parts subjected to wear.

### Thermoplastics

The plastics may be broken into two other groups: thermoplastics and thermosetting plastics. The thermoplastics (typical of the transparent plastics) are stiff at normal temperatures but soften and become exceptionally pliable at elevated temperatures. In the soft state they may be given almost any desired contour by the application of moderate pressure. As previously stated, these plastics are used for coverings requiring transparency, such as enclosures and windows.

### Thermosetting Plastics

The thermosetting plastics such as Bakelite and Micarta will deform at first under the influence of heat, but will not further alter their position upon subsequent heating.

Designations, specifications, and properties of aircraft plastics are shown in Table 28.

sistency from soft, tacky semiliquids to fairly hard and tough thermoplastic solids.

*Characteristics of Plexiglas.* Plexiglas is one of the hardest acrylic resins. Despite its similarity to glass in appearance, it is not brittle. Thin sheets are flexible, and the larger sheets possess a resiliency which enables them to withstand blows that would easily shatter glass. Although Plexiglas is a hard transparent plastic, its surface is only as hard as copper and it will scratch easily.

Plexiglas is known for its colorless transparency. It is more transparent than optical glass and satisfactorily transmits every color of the spectrum. Its light transmission value of 92 per cent, surpassing that of plate glass, is due to the quality of its surface and to the inherent clarity of the material. Its chemical resistance and stability under use and weather enable Plexiglas

TABLE 28. PLASTICS

CLASSIFICATION	DESIGNATION	SPECIFICATIONS		STRENGTH AS RECEIVED		REMARKS
		Army	Navy	Tensile	Compressive	
Molded Phenolic Cellulose Filler	Thermal-setting	AC 32212 Type I		6,000 U Y El.	25,000 U Y El.	Wood flour filler especially suited for wall sections
Molded Phenolic Cellulose Filler	Thermal-setting	AC 32212 Type II		6,200 U Y El.	26,000 U Y El.	Shredded fabric filler. Has good impact resistance
Molded Phenolic	Thermal-setting	AC 32212 Type III		5,000 U Y El.	15,000 U Y El.	Usually mica filler. Has good electrical insulating properties
Laminated Phenolic Paper Base	Thermal-setting	HH-P-256 Type I Gr X		9,000 U Y El.	35,000 U (av)	Fabric base is recommended
Laminated Phenolic Fabric Base	Thermal-setting	HH-P-256 Type II Gr C		7,500 U Y El.	35,000 U Y El.	For fairleads and abrasive strips
Sheet, Transparent Cellulose Acetate	Tenite Lumarith	12025	33C3	4,500 U Y 20% El.		For applications requiring non-inflammable transparent sheet
Sheet, Transparent Cellulose Nitrate	Celluloid					For grommets, inspection holes, etc. Inflammable material. Miscellaneous uses requiring transparent sheets for windows, grommets, etc. Can be formed readily by heat
Sheet, Transparent Methyl Methacrylate	Plexiglas	94-12014	P-41 Gr. A	5,800 U (Max) 8,800 Y (Max)		

### Plexiglas

Plexiglas is a synthetic resin of the acrylic type. Resins are obtained by a complicated chemical synthesis from raw materials such as coal, petroleum, air, and water. They range in con-

to withstand the tremendous air pressure encountered in modern aircraft.

It is light, weighing half as much as glass—a very favorable aircraft characteristic.

The plastic may be easily formed into intri-

cate shapes and curvatures at a moderate temperature, and may also be readily machined.

**Machining.** Plexiglas may be sawed or carved like wood and machined, drilled, and threaded like any soft metal. The cutting edges of the machine tools used on this plastic have no rake and apply a scraping rather than a cutting action. Unlike glass, Plexiglas may be cut by any of the saws used for wood or metal.

**Forming.** When heated to 220 to 300 degrees Fahrenheit, somewhat higher than the temperature of boiling water, the plastic softens and can be bent to almost any shape. Since no chemical change is involved, the process can be re-

peated several times without affecting the properties of the material. Because of this thermoplastic property, Plexiglas can be easily made into curved windows, pilot's enclosures, etc.

The heated plastic is cooled somewhat and then set on a desired form. Very little pressure is required for forming. For example, for shapes of thin Plexiglas, the weight of the plastic itself is sufficient. The plastic will gradually hug the contour of the mold as it cools. More complicated pieces may be formed by applying pressure from a metal ring set about the bottom edges of the plastic. The inside dimensions of the ring conform to the outside dimension of the Plexiglas as it touches the bottom of the form, reducing to a minimum the contact with the hot plastic, which will mar easily.

Many three-dimensional shapes can be made by stretching Plexiglas across a form. The Plexiglas is heated slightly hotter than for simple forming. During the short cooling period before forming, a number of wood carpenter's clamps are fastened to the edges, 6 to 10 inches apart. Holding the plastic in these clamps, the workmen draw the sheet around the form. A metal ring may be clamped around the edges to complete the forming operation (see Fig. 291).

**Installation.** Plexiglas can prove its favorable qualities only if it is properly installed in the plane. The plastic is usually set into rubber or



Fig. 291a. The hot pliable sheet is laid across a form

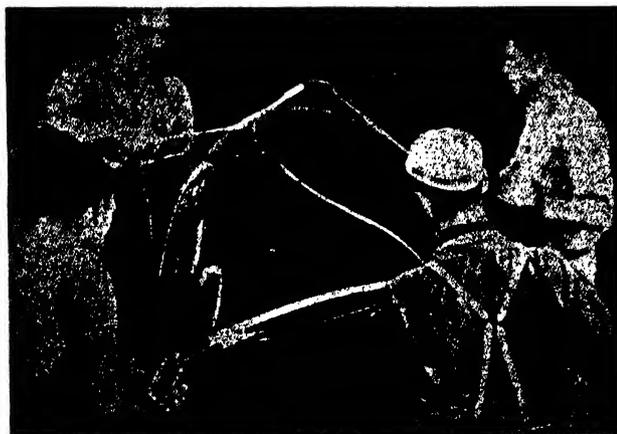


Fig. 291b. The clamps are attached and the Plexiglas is stretched



Fig. 291c. Metal rings hold the cooling Plexiglas against form

felt packed aluminum alloy channels. The rubber gaskets fulfill three functions: to make the installation airtight and waterproof, to reduce vibration, and to compensate for the difference in thickness between the Plexiglas and the channel.

Various stresses make it necessary that Plexiglas be secured to the channel by clamping or by the careful placement and application of bolts and nuts or riveting. The illustration of an installation (Fig. 292) describes a channel and clamp mounting. It is interesting to note that:

No bolts, screws, or rivets pass through the Plexiglas.

The open "bell mouth" of the channel makes assembly faster than a sharp edge channel would and it reduces the hazard of scratching the plastic during installation.

The channel is oversized to prevent free linear expansion or contraction of the Plexiglas relative to the extruded aluminum frame.

The rubber packing strips are coated with adhesive on one side. This packing is quickly wrapped around the edge of the Plexiglas and stays in place while the panel is being inserted.

Figure 293 illustrates a rivet and spacer installation. It should be noted that the holes drilled in Plexiglas are larger than the diameter of the rivet or bolt to allow for expansion or contraction of the plastic relative to the frame.

A tubular spacer protects the plastic from direct pressure.

*Aircraft Applications.* Combining the transparency of glass with less than half its weight, and possessing the versatility and strength of a synthetic plastic, this material has found many important uses in aircraft production.

Nose sections, cockpit enclosures, gun turrets, and landing light covers, as well as windows and windshields, are made of curved Plexiglas and mounted with lightweight channels, flush with

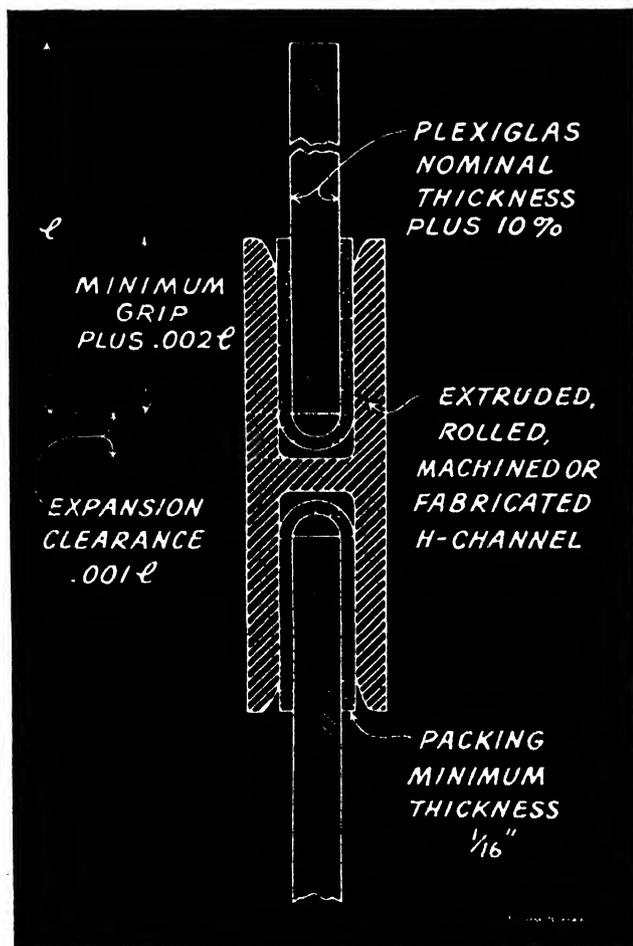


Fig. 292

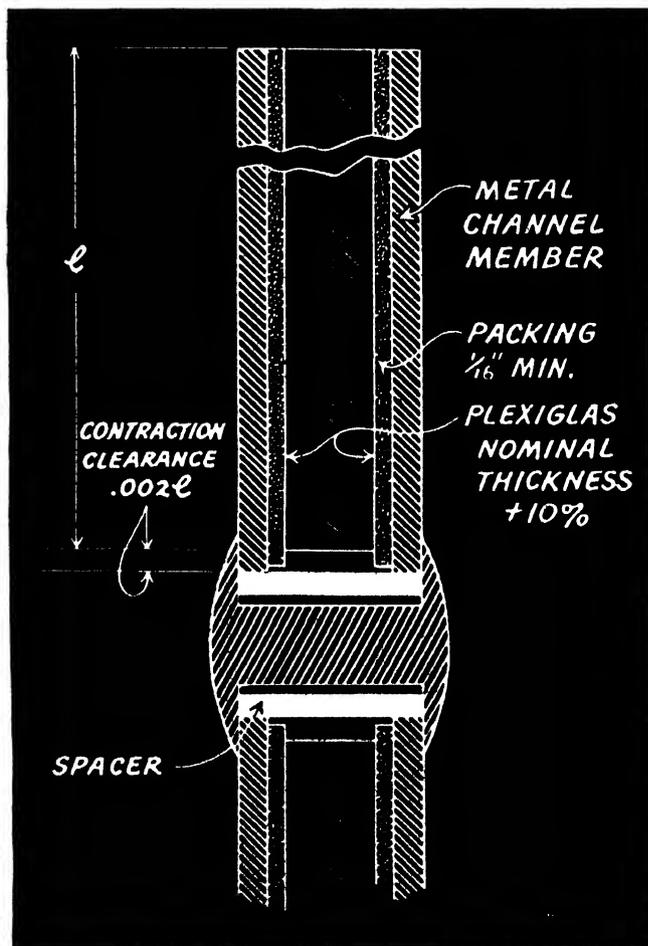


Fig. 293



Fig. 294

the skin, to offer a streamlined contour (see Figs. 294 and 295). The availability of large sheets of Plexiglas has enabled the designer to extend the pilot's range of vision. A further development has been the use of Plexiglas as housing for radio and range finding antennas. Mounted in a plastic nose section, for example, the loops offer no wind resistance yet are some distance from the nearest metal part, and reception is not reduced. The Plexiglas housing is reported to have cut down static and other interferences and to exceed in service the metal that it has replaced.

**Plastic Plywood**

While the modern aircraft is essentially of metal, some wood is used on it, principally plywood that has reasonable strength and can be formed easily (see Figs. 296 and 297). During the era of aircraft mass production serious shortages of metal necessitated substitutions. Experimentation has proved the effectiveness of plastic plywood as a metal substitute. There has been a recent tendency to further the application of this material, along with some other aircraft woods, for complete aircraft bodies. The English

Mosquito bomber, or "flying furniture" as it is sometimes called, has been constructed almost entirely from wood, and proved structurally substantial.

Plywood is composed by gluing together a number of very thin sheets of wood or veneer. The grains of the adjacent layers of veneer run at right angles to each other, reinforcing the plywood's strength and rigidity in two directions. Veneers are very thin in cross section, seldom over  $\frac{1}{16}$  inch. Plywoods range from two to fifteen layers of veneer, the most common being the three ply. All except the two-ply sheets are made up of an odd number of plies. The center or core plies are somewhat thicker and softer than the outside plies. A hardwood ply is used for the extreme outside covering to give a better finish and resistance to abrasion.

TABLE 29. PROPERTIES OF PLEXIGLAS

Since Plexiglas is a thermoplastic, its properties will be found to vary with the temperature of the material. The values given apply for 25 to 30 degrees C. (77 to 86 degrees F.).

OPTICAL PROPERTIES	
Clarity . . . . .	Light Transmission—91-92% Scattering Effect —Practically nil
Refractive Index Na. . . . .	.1.488-1.489
Dispersion . . . . .	.0.008
PHYSICAL PROPERTIES	
Specific Gravity . . . . .	1.18-1.19
Hardness:	
Mohr . . . . .	2-3
Vickers . . . . .	18-20
Brinell . . . . .	18-20 (500 kg, 10 mm ball)
Tensile Strength . . . . .	7,000-8,000 psi
(Elongation at failure) . . . . .	5-15%
Flexural Strength . . . . .	14,000-16,000 psi
Compressive Strength . . . . .	11,000-13,000 psi
Impact Resistance . . . . .	0.3-0.5 ft lb (A.S.T.M. Charpy notched bar)
Modulus of Elasticity . . . . .	3-5 x 10 <sup>5</sup> psi
Coefficient of expansion . . . . .	8 x 10 <sup>-6</sup> /degrees C.
Water absorption by Weight	
24 hr. . . . .	0.3%
48 hr. . . . .	0.5%
500 hr. . . . .	1.5% (Equilibrium)
ELECTRICAL PROPERTIES	
Dielectric Constant	
60 cycles . . . . .	3.4 to 3.6
1,000,000 cycles . . . . .	3.2
Power Factor (at 60 cycles) . . . . .	5 to 6%
Volume Resistance . . . . .	10 <sup>15</sup> ohms/cm <sup>3</sup>
Dielectric Strength	
short time test . . . . .	500 volts/mil
one minute stepwise . . . . .	400 volts/mil

Plexiglas is the trade mark, Reg. U. S. Pat. Off., for the acrylic resin thermoplastic sheets and rods manufactured by the Rohm & Haas Company.

The following table lists the various woods used for plywood:

<i>Hard Faces</i> (extreme outside cover)	<i>Cores</i> (soft center plies)	<i>Semihard Faces</i> (between core and outside face)
Birch	Mahogany	Basswood
Beech	Sycamore	Douglas fir
Maple (hard)	White elm	Gum
	Maple (soft)	Pine
	Redgum (heart)	Poplar
	Port Orford cedar	Redwood
	Spruce	Spruce
		Port Orford cedar (Western hemlock)

*Plastic Bonded Plywood.* A thermosetting phenol-formaldehyde resin glue is commonly used to assemble the veneers. It may be placed between the veneers in the form of solid sheets or applied as a liquid. The sheets of veneer are then subjected to heat and pressure to cure the

glue. This results in a plastic impregnated product, resistant to water and fungus. Bending and forming may be accomplished by steaming or soaking in boiling water without any effect on the glue.

An interesting comparison of the shear strength of the plastic plywood and the standard plywood is indicated by the following: Both forms of plywood will withstand 300 pounds per square inch pressure in their dry state. When soaked in water for 2 days, the standard will fail at 160 pounds per square inch, the phenolic, at 250 pounds per square inch. After a 10 day fungus exposure, the standard has little resistance to shear, but the plastic plywood will still withstand 250 pounds per square inch.

*Density.* The plastic plywood can be assembled under a far greater pressure than is employed in

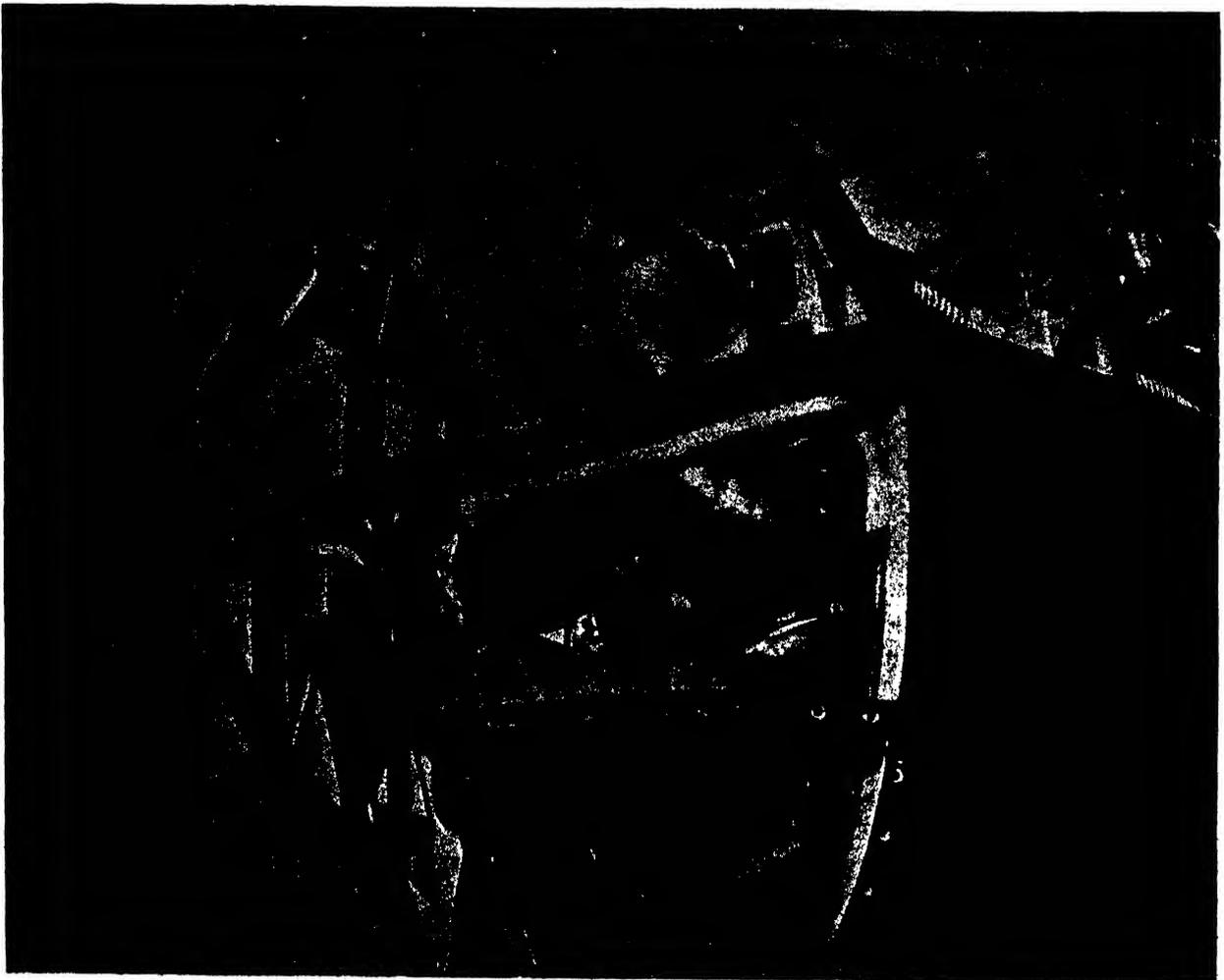


Fig. 295

its regular manufacture. This elevated pressure increases the density of the product. Tests have proved that when the density of the plywood is increased twofold, the shear strength increases approximately seven times.

*Molded Plastic Plywoods.* With appropriate dies under specific temperature and pressure, resin-bonded plywood may be easily curved in the original manufacturing process into suitable aircraft shapes and contours, making unnecessary any further steaming, soaking, or other fabricating processes in the aircraft plant. Examples of this process are shown in Figs. 297 and 298.

*Sealing and Finishing.* After forming, the plywood must be protected by a sealer and a finish to avoid moisture absorption by the wood. Army and navy specifications permit a limit of 7 to 12 per cent of moisture content in the plywood at delivery. However, the plywood may acquire relatively higher or lower percentages of moisture during shipment, in stock, in working, or during assembly. Proper sealing of plywood surfaces and edges for moisture control is of prime importance. This is easily understood if we visualize the typical conditions that the plywood parts must meet in action:

Desert temperature of 150 degrees Fahrenheit for 6 hours, followed within 15 minutes by subzero

stratosphere temperature held for 1 hour, then back to desert temperatures.

Tropical temperature of 110 degrees with relative humidity of 90 per cent for 6 hours, followed within a space of 15 minutes by subzero stratosphere temperature held for 1 hour, then back to tropical conditions.

Planes grounded for prolonged periods, no air circulation in interior surfaces of wing sections and other parts, temperatures fluctuating, producing moisture on interior surfaces.

In addition to the normal stresses created by changing temperature and humidity, plywood must also resist the effects of varying vibration under varying temperatures.

If a sealer could completely impregnate the wood, difficulties due to expansion and contraction would be overcome or at least minimized. Authorities state, however, that 100 per cent impregnation of wood by sealer cannot be achieved.

The lower the moisture content of the wood, the dryer the wood fiber becomes. These wood fibers act as "wicks," and the dryer they are, the more effectively can the sealer penetrate to the greatest depth. However, if a wood is dried to below 7 per cent of its moisture content, it loses some of its structural strength.

Fully sealed plywood surfaces can be obtained



Fig. 296



Fig. 297

by the application of various sealers that penetrate thoroughly into the fibers and cavities of the wood. In this way, the protective film is so anchored as to resist vibration, sudden changes in temperature, and other weather conditions.

For open grained woods the following finishing steps are applied:

- A sealer brushed, dipped, or sprayed.
- A synthetic filler coat brushed across the grain.
- A pigmented sealer sprayed.
- A camouflage enamel or lacquer sprayed across the grain.

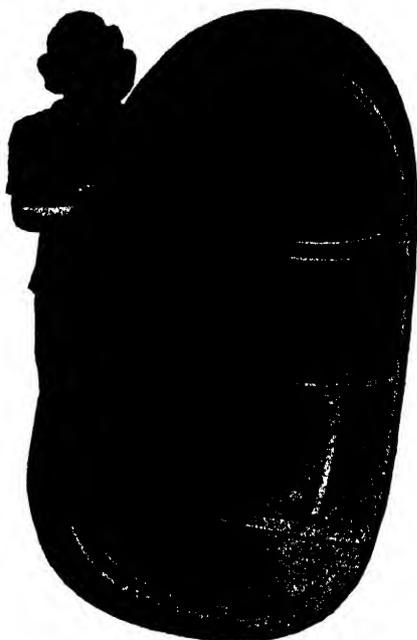


Fig. 298

For closed grained woods:

- A sealer brushed, dipped, or sprayed.
- A pigmented sealer brushed across the grain.
- A camouflage enamel or lacquer sprayed.

*Applications to Aircraft Production.* Parts commonly constructed from plastic plywood arc control surfaces, bomb bay doors, tail cone fairings, nacelle fairings, landing gear doors, entrance doors, nose doors, wing tips, etc.

*Fabric*

Fabric covering is used for most gliders, and fabric also has an important place in modern metal aircraft. Some small commercial planes, as well as the majority of gliders, use fabric covered fuselages, wings, and control surfaces. Military and large transport planes, essentially all metal, use thin sheet aluminum skin but frequently employ fabric covering for the ailerons, rudders, and elevators. For these surfaces weight saving is of prime importance, and the fabric surface, being lighter than metal, enables the center of gravity to be nearer the hinge, reducing the required counterbalance and preventing control surface fluttering.

*Nomenclature.* The following terms are used for the identification of fabrics:

WARP is the direction along the length of the fabric. WARP THREADS OR WARP ENDS are the woven threads that run the full length of the fabric.

TABLE 30. BEARING STRENGTH OF AIRCRAFT PLYWOOD (Estimated)

NOMINAL THICKNESS, INCHES	NUMBER OF PLYS	FACE PLYS→ INNER PLYS→	BIRCH BIRCH		BIRCH POPLAR		MAHOGANY POPLAR		POPLAR POPLAR	
			Long.	Tran.	Long.	Tran.	Long.	Tran.	Long.	Trans.
1/4	3		230	154	221	110	202	115	154	106
1/8	3		307	269	298	182	269	192	202	182
3/16	3		451	317	442	221	394	221	307	211
1/4	3		461	528	451	365	403	314	317	355
5/16	3		614	614	595	432	538	432	413	413
3/8	3		739	739	720	518	643	518	499	499
1/2	5		720	739	624	509	576	509	490	499
5/8	5		1,306	566	1,114	394	1,037	403	893	374
3/4	5		1,325	768	1,123	538	1,046	538	902	518
7/8	5		1,613	787	1,373	547	1,277	547	1,094	518
1	5		1,478	1,478	1,219	1,018	1,142	1,018	998	998
1 1/8	7				1,517	1,171	1,421	1,171	1,238	1,142
1 1/4	7				1,728	1,363	1,632	1,363	1,450	1,334
1 1/2	7				2,016	1,373	1,891	1,382	1,651	1,342
1 3/4	9				2,131	1,498	2,035	1,498	1,853	1,469
1 7/8	9				2,515	1,872	2,390	1,882	2,150	1,843

**WEFT OR FILLING** is the direction across the width of the fabric.

**WEFT THREADS OR WEFT PICKS** are the woven threads running across the fabric.

**COUNT** is the number of threads per inch in warp or weft.

**PLY** is the number of yarns making up a thread. A thread designated as 16/4 has four yarns of size sixteen, twisted together to form a single thread.

**TWIST** refers to the direction of twist of a yarn making up a thread. Twist is called "right-handed" when a thread, held vertically, has its yarns spiraling downward in a right-hand direction.

**MERCERIZATION** is the process of dipping cotton yarn or fabric, preferably under tension, into a hot solution of dilute caustic soda. The material is given greater strength and luster by this treatment. The process, however, tends to reduce somewhat the material's stretch.

**SIZING** is a material, such as starch, used to condition the threads for weaving.

The fabric used in this country is a high grade cotton product, while linen is used in several foreign countries. To meet the requirements of government specifications, a "grade A" type of fabric is used. It contains about 80 threads per inch in both warp and filling, and a two-ply yarn is used. To acquire maximum strength, the yarn is mercerized before the weaving process. The tensile strength is 80 pounds per inch in both warp and filling. The fabric weighs approximately 4 ounces per square yard, although application of dope and finish increases the weight to approximately 9.5 ounces per square

yard. Grade A fabric must have a smooth, napless surface for best results. Sizing content is limited to a maximum of 2½ per cent. A 60/2 yarn answers the required strength for this fabric.

Proper fitting of cloth or skin over the skeleton of the plane is of prime importance to appearance as well as to performance. Two systems of fitting are generally used, the envelope method and the blanket method, or a combination of both.

In the envelope method, a series of fabric widths are sewed together to the dimensions of the outside contour of the airfoil. It is then fitted over the framework of the structure in a glovelike fashion.

In the blanket method, a series of widths are sewed together, or single widths of fabric are sewed to the framework individually. This system is primarily used when interferences occur on the contour. The envelope method, or sleeve method as it is sometimes called, is preferred as it employs almost entirely machine sewing. Most airfoils necessitate a combination of the two methods.

To provide a neat, smooth, and finished appearance and sound construction, a surface or finishing tape is doped over the seams of the sewed fabric. The edges of the tape are sometimes cut in a sawtooth pattern to produce a secure edge adhesion. This is known as a

TABLE 31. TENSILE STRENGTH OF AIRCRAFT PLYWOOD (Estimated)

NOMINAL THICKNESS, INCHES	NUMBER OF PLYS	FACE PLYS→ INNER PLYS→	BIRCH BIRCH		BIRCH POPLAR		MAHOGANY POPLAR		POPLAR POPLAR	
			Long.	Tran.	Long.	Tran.	Long.	Tran.	Long.	Tran.
3/16	3		600	440	600	260	300	240	340	250
1/8	3		820	730	810	430	430	390	470	420
5/16	3		1,210	880	1,200	530	620	470	680	520
1/4	3		1,270	1,420	1,260	820	680	760	740	810
3/8	3		1,670	1,670	1,660	970	880	890	970	970
1/2	3		2,000	2,000	1,990	1,170	1,050	1,075	1,160	1,160
5/8	5				1,660	1,170	1,085	1,100	1,140	1,160
3/4	5				2,740	1,060	1,800	970	1,910	1,050
7/8	5				2,790	1,340	1,860	1,230	1,960	1,320
1	5				3,400	1,420	2,240	1,300	2,370	1,410
1 1/8	5				3,150	2,340	2,220	2,230	2,320	2,320
1 1/4	7				3,900	2,720	2,730	2,600	2,870	2,700
1 1/2	7				4,370	3,160	3,210	3,040	3,340	3,140
1 3/4	7				5,120	3,250	3,510	3,090	3,740	3,230
1 7/8	9				5,230	3,570	4,070	3,440	4,190	3,550
2	9				6,290	4,410	4,740	4,250	4,900	4,390

"pinked" edge. A strong fabric reinforcing tape is placed over the fabric and under the rib stitching to prevent the cutting of the fabric by the stitching cord.

After the fabric is placed on the framework, it is made more taut and air- and watertight by a series of applications of DOPE (a solution of nitrocellulose or cellulose acetate and a plasticizer, with a thinner added for proper consistency). Two or three coats of clear dope are applied. The first and second coats are brushed on uniformly throughout the fabric; the third coat is usually sprayed. Since a smooth surface guarantees better flight performance by minimizing skin friction, each coat is carefully sanded. Colored or pigmented dopes are sprayed for the exterior finish.

Other uses of fabric in aircraft include preserver cushions, curtains, tank strips, pads, cock-

pit and other covers, pickets and bags; denim and whipcord are used for seat cushion covering.

### *Rubber*

Rubber is used in aircraft for tires, deicers, gasoline tanks, and abrasion shoes. It also finds a multitude of minor applications for upholstery, padding, base connections, gaskets, washers, weather stripping, shock chords, and matting (Fig. 299).

Rubber is available in the pure, sponge, and synthetic types. Neoprene, Duprene, and Corprene are some of the more commonly used trade names for synthetic rubber. The airplane uses rubber also for sheets, mattings, strips, extruded tubing, and molded shapes.

*Sheet.* Pure gum rubber sheet is used for miscellaneous gaskets and seals. When backed with fabric, it is employed to prevent abrasion

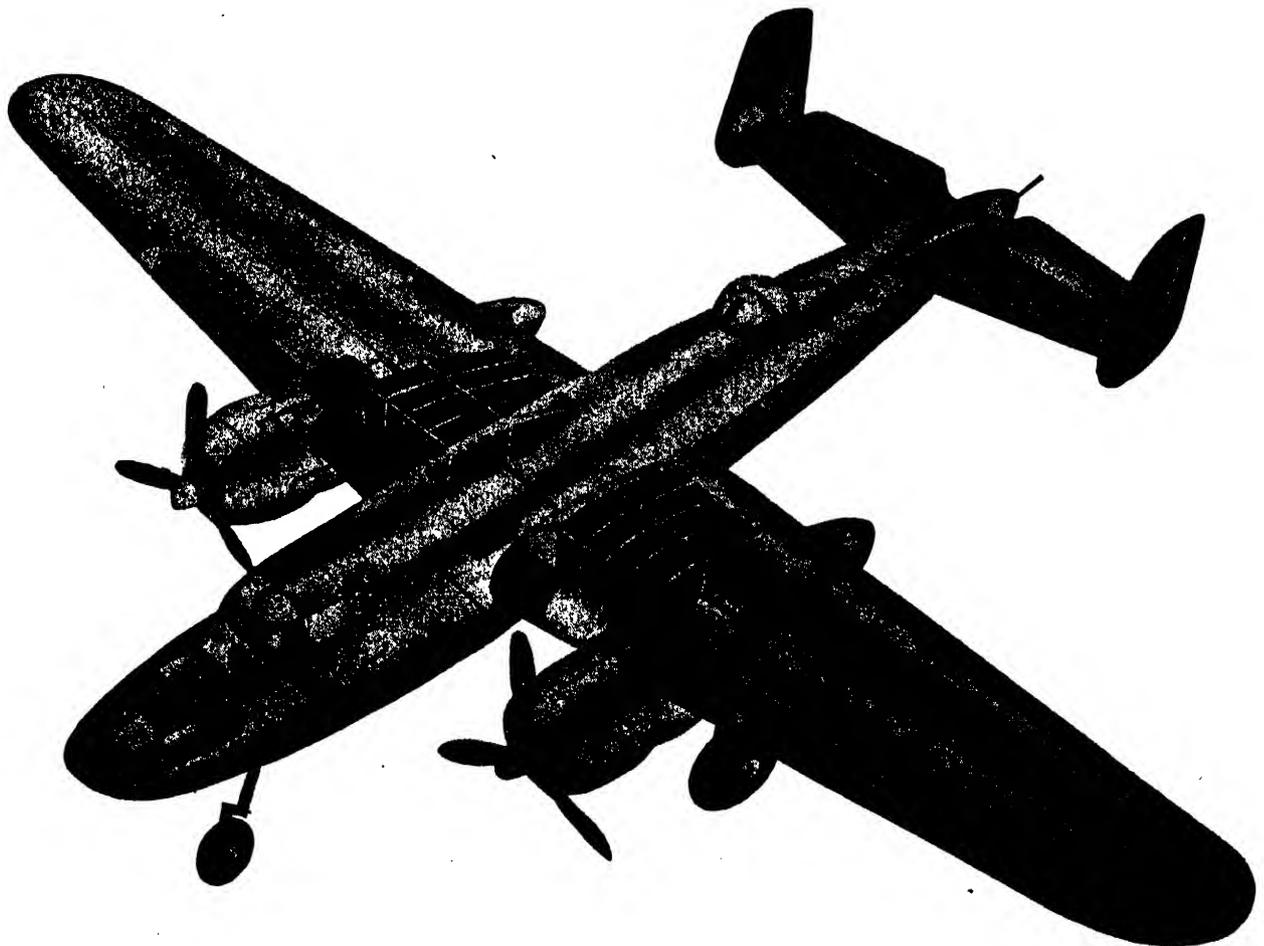


Fig. 299. Darkened areas indicate rubber applications

of aluminum alloy surfaces. Surfaces requiring a foothold are covered with a rubber matting, one side of which has an irregular impression. Rubber strips, usually Neoprene, are used for sealing purposes around enclosures, hatches, doors, and windshields. Thin strips of Neoprene, usually  $\frac{1}{4}$  inch in width, are sometimes used to seal exterior riveted joints and seams of a pressurized plane.

*Extruded Molded Shapes.* Rubber extrusions are employed where special sealing protection and weather stripping is required, as in the installation of Plexiglas (see page 258). Rubber extrusions are manufactured by forcing a prepared rubber compound through a single die, capable of forming a continuous rubber strip or tubular shapes of intricate design.

Parts beyond 4 inches in width or diameter are not practical for the extruding process and are molded. Rubber products can be formed and

vulcanized with polished steel molds and powerful hydraulic presses. Upon the application of heat and pressure, the rubber compound fills the mold cavity to the desired shape.

Typical of small molded parts are grommets and bushings, used principally as protective cushioning and insulation devices where pipelines, mechanically operated rods and shafts, electrical lines, etc., pass through metal or wood openings. Rubber rings and buttons are used as shock mountings for instruments, radio and electrical equipment, etc.

*Sponge Rubber.* Sponge rubber, produced in slab form, is easily die cut or otherwise shaped to fit required areas. It is principally used as an insulating material. Sponge cord is used for gaskets, shock absorbers, windlace, and other types of seals. Sponge molded shapes are manufactured as radio earphone cushions, eye goggle cushions, beader strips, channel strips, etc.

# CHAPTER FIFTEEN

## MACHINES AND PROCESSES

### Introduction

Many draftsmen wonder why they need to be concerned with manufacturing methods and processes when their drawing is exact and every graphic detail is complete with good lines, proper projections, and legible lettering. But since most aircraft draftsmen are called upon to design parts, the mechanics of drawing become

drawing must present a part that can be made and at a minimum of cost.

Can the part be made? How much will it cost? Too much emphasis cannot be placed on these questions. They both relate to manufacturing methods and processes and must be satisfactorily answered before the draftsman can consider his task completed.

What tools will be required to make the part? Are they available? How many operations must be performed before the part will be installed in the plane? Are the specified limits on dimensions too close for practical production? Are dimensions placed on the drawing so that they will facilitate the work in the shop? The answers to these questions will aid in making drawings functional and practical.

Usually, production departments have ample equipment available to manufacture the items

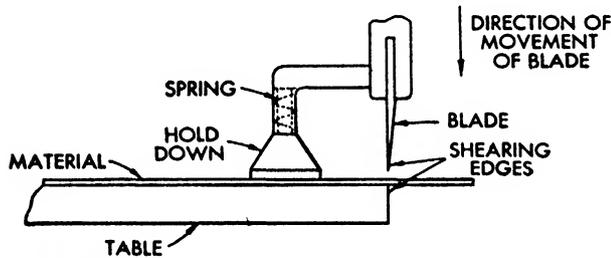


Fig. 300

merely the means by which the design idea is converted into an actual airplane part. Furthermore, to be of any value to the company, the

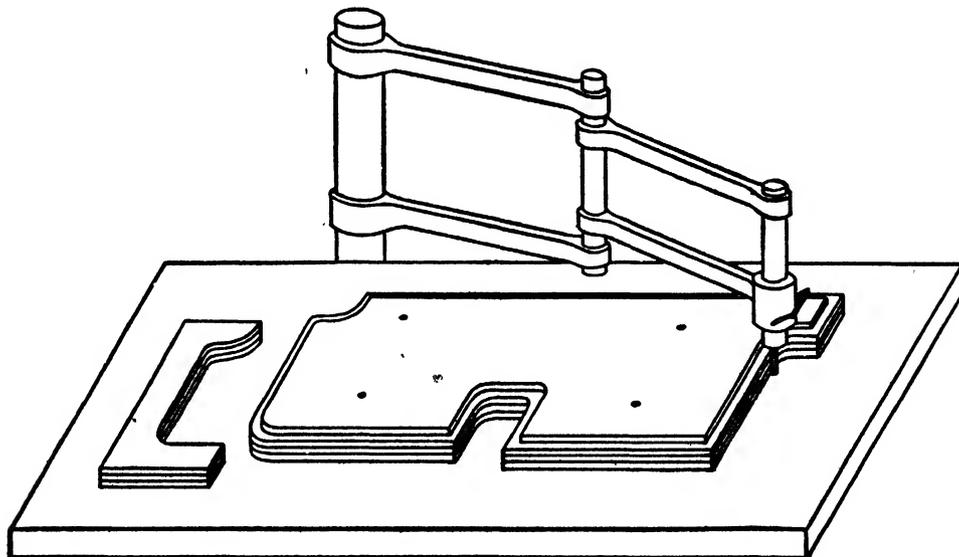


Fig. 301. The swinging arm router

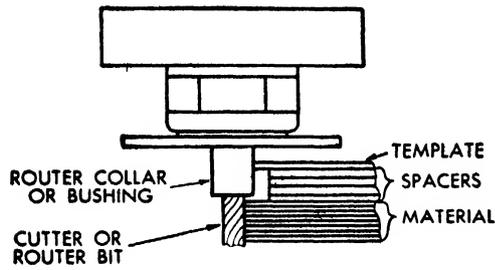


Fig. 302

specified by the draftsman, but all equipment does have its limitations, and these should be known by the draftsman.

Actual participation in the manufacturing end is the most direct means of acquiring this information, but, as this is not always possible, the most practical alternative is to visit the shop frequently, observe carefully, and then discuss the production problems with the operators, for they have first-hand knowledge of what will or will not work.

In any case, the inexperienced draftsman should develop a sense of curiosity and a habit

of observation regarding manufacturing processes. Find out why and how parts are fabricated. Make use of engineering libraries, subscribe to trade journals, and take courses related to manufacturing.

About 85 per cent of the aircraft's structure is formed of sheet metal. Examination of any modern airplane proves this fact. Beltframes, bulkheads, stringers, skin, etc., all are composed of some type of sheet metal. As a result a great part of aircraft manufacturing involves cutting, forming, and assembling sheet metal parts. (Extruded and tubular aluminum alloy sections are also handled in the sheet metal department.)

In highly stressed parts, or where extreme rigidity is required, castings or forgings are employed. If the inexperienced draftsman does not understand the casting process, he may design a part so that casting will be impossible.

A general knowledge of machine shop practice is also essential, for a great many parts originate in that shop.

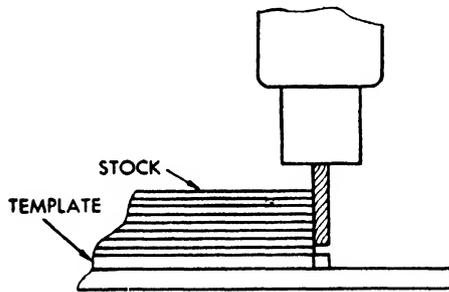


Fig. 303. Pin router

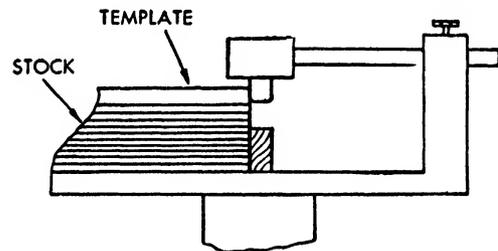
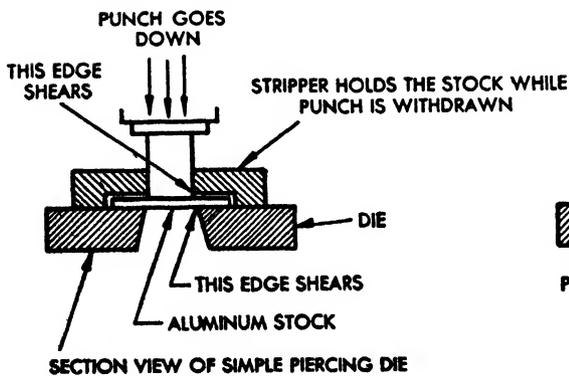


Fig. 304. Table router



SECTION VIEW OF SIMPLE PIERCING DIE

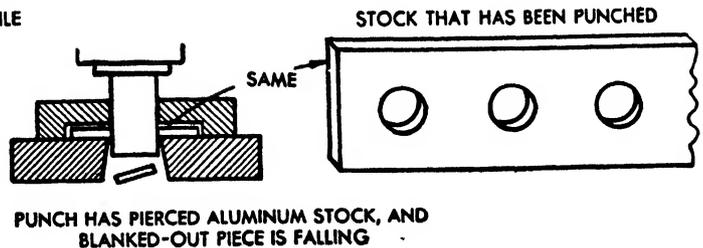


Fig. 305. Blanking operation performed with steel dies

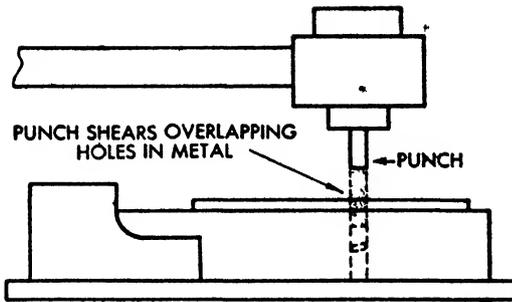


Fig. 306. Schematic diagram of nibbler

### Sheet Metal Cutting

In general, cutting is the first manufacturing operation. Sheet stock is received from the metal manufacturers in large, flat rectangles and in rolls of various widths. These sheets are cut to obtain the greatest number of parts with a minimum of waste. The smaller parts are cut to required

dimensions at this point in the manufacturing process. Many of the larger pieces, however, must be cut again after forming to trim off excess material. Cutting may be carried out by shearing, routing, nibbling, sawing, or by the use of dies—depending on the kind and the gage of the metal, the accuracy and the type of edge required, and the number of parts which are to be produced.

### Power or Squaring Shears

Power shears, which work on the principle of the guillotine, perform the bulk of basic cutting. The sheet stock is placed flat on a large table. A slightly slanted cutting blade descends vertically and shears the metal (see Fig. 300). Although most operations on this machine are for rough cuts and approximate sizes, guides may be set



Fig. 307. Cutting rolls machine

so that required lengths can be readily cut to close tolerances.

The lengths of the various squaring shears used in the factories range from 36 inches to 18 feet. This machine is capable only of straight line cuts.

### *Router*

For cutting a small number of irregularly shaped parts, the router is perhaps the most versatile and inexpensive machine to operate. Routing consists of stacking a number of sheets on a table, drilling them, placing a pattern on the stack, and following along the edge of the pattern with a cutting tool, thus cutting the stacked sheets in one operation.

The swinging arm router is the most commonly used model of this machine. This type of router has a large stationary post, securely

fastened to the floor, with either one or two swivel jointed arms projecting from it (see Fig. 301).

A router head, containing the cutting mechanism, is attached to the ends of the jointed arms, and the swivel action of the arms facilitates movement of the head over a large working area, usually of 16 feet diameter, to about 1 foot from the stationary post. The router head may be raised during the feeding operation.

The router bit or cutter, projecting from the bottom of the head, is a single lipped spiral mill-end, usually some  $\frac{5}{16}$  inch in diameter. The bit revolves at a high speed of from 15,000 to 18,000 revolutions per minute. The bit is guided against the work by a collar or bushing fitted to the chuck shank. The guiding collar, larger in diameter than the bit, rests against the router template fastened to the top of the work (Fig.



Fig. 308. Band saw

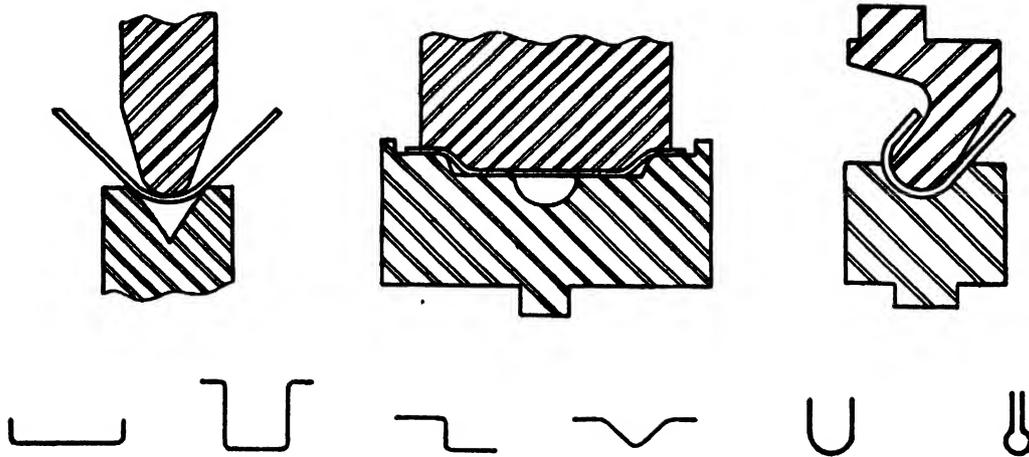


Fig. 309. Power brake dies and common formed sections

302). The difference in diameter between the bit and the router collar determines how much larger the desired cut part will be than the router template.

The router can cut a number of parts in one operation, regardless of whether the part contains straight lines or complicated curves. As many as twenty-five aluminum alloy sheets may be stacked upon each other and cut to identical shapes in the time it would take to cut one individual piece.

The router, furthermore, dispenses with rough cutting of the sheets. This saving of time is sometimes made up for by a waste in material.

The draftsman should remember that the router cannot cut a square inside corner. For this reason, and because square inside corners are poor structural design, all inside corners

should have a radius equal to or larger than the router bit. Outside square corners can be cut, but, in general, a  $\frac{3}{32}$  inch minimum radius is allowed.

Router operations are applied primarily to large parts that cannot be conveniently cut with a blanking die or to smaller parts that are too few in number to justify the expense of making a die.

#### *Pin and Table Router*

The pin router, another model of a routing machine, is designed to cut small parts that cannot be fastened conveniently to the table of the large swinging arm router.

The router head mounted above the work remains stationary, while the work is moved about and cut against the rotating bit. A template, the same size as the desired cut part, is fastened to the bottom of the sheets to be cut. The template is guided against a stationary pin projecting from the table. The guiding pin is of the same diameter as the cutter and directly beneath it, as shown in Fig. 303.

The table router is similar to the pin router, except that the motor is mounted under the table and the position of the bit and guide are reversed (see Fig. 304). In other words, the bit protrudes through the table top, and the guide, above the bit, is held in place by a frame secured to the table. The same type of template is used as on the smaller pin router but it is placed above the material. Therefore, this machine is easier to operate. Pressure can be

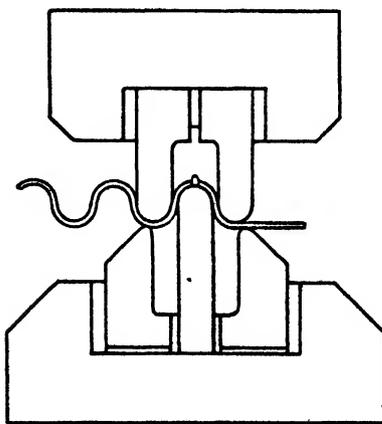


Fig. 310. Forming of corrugation on power brake

applied naturally when the cutting operator pushes the work down and away from him on the table against the router pin or guide. When using either of these machines, the operator must be very careful not to let the pattern slip after the cutting operation has started. Clamping the parts and the pattern together reduces the danger of slipping.

#### *Cutting by Dies*

Blanking by dies is the most efficient and most widely used method for cutting a great many parts of the same shape. Speed and uniformity give it priority over other forms of cutting.

The initial cost of this method is high, however, as the dies are very expensive to manufacture. It is warranted only when a large number of similar parts are needed.

The blanking operation is performed with dies similar to the ones shown in Fig. 305. The female die is a cavity in the exact shape of the desired part. The male die serves to force the

sheet stock through the cavity die and shears it. The dies are placed in a machine called a

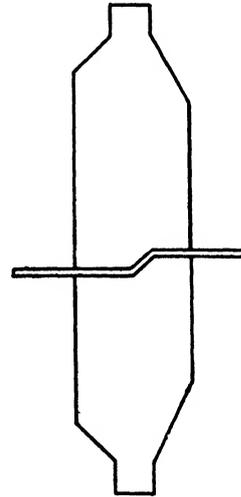


Fig. 312. Joggle die

“punch” or “power press,” which cuts many parts rapidly. The pieces of sheet stock used on the punch press must first be cut to a rough size, from which one or a number of different pieces may be blanked.

Cutting dies may be designed to perform many combined operations, the most common of which are blanking and piercing and blanking and forming. In blanking and piercing, the exterior shape or blank of the piece is cut and, in the same operation, interior holes are punched or pierced through the part. A combination die may contain both cutting and forming elements, to cut a hole and flange its edge in order to reinforce and lighten it.

#### *Nibbling*

For cutting formed parts—parts that need trimming or are of a heavy and tough gage of dural or steel sheet—a machine known as a “nibbler” is used (see Fig. 306). This machine cuts by a rapid perforating action. A small male die punches overlapping holes along the desired edge. The stationary nibblers are power driven so that the operator may use both hands freely. Portable nibblers are also manufactured to facilitate cutting on an already formed structure. With this machine, the operator can make cuts running into the inner area from the edge of the stock, or cuts that are entirely inside the edges of the piece. However, the round punch

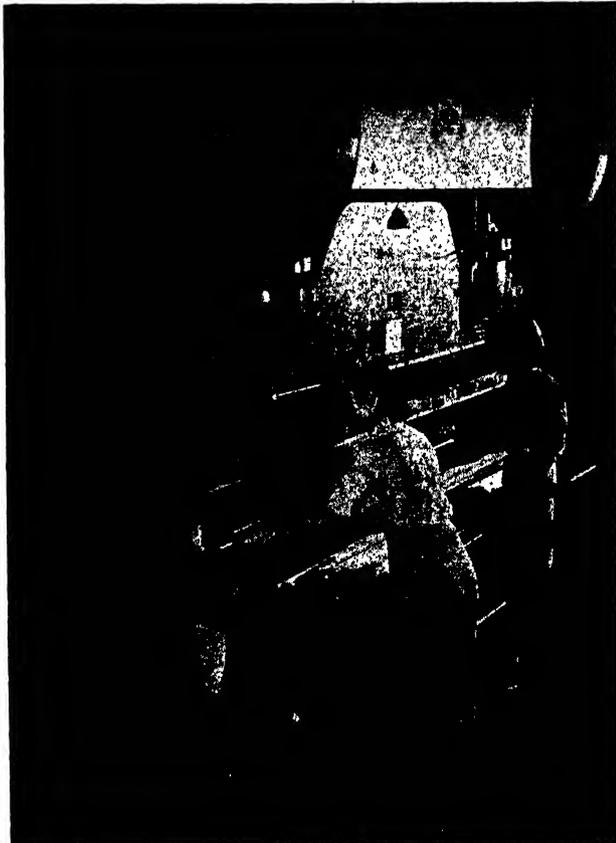


Fig. 311. Gang punching on brake

of the nibbler leaves a rough edge that usually must be finished off by sanding or filing.

### *Cutting Rolls*

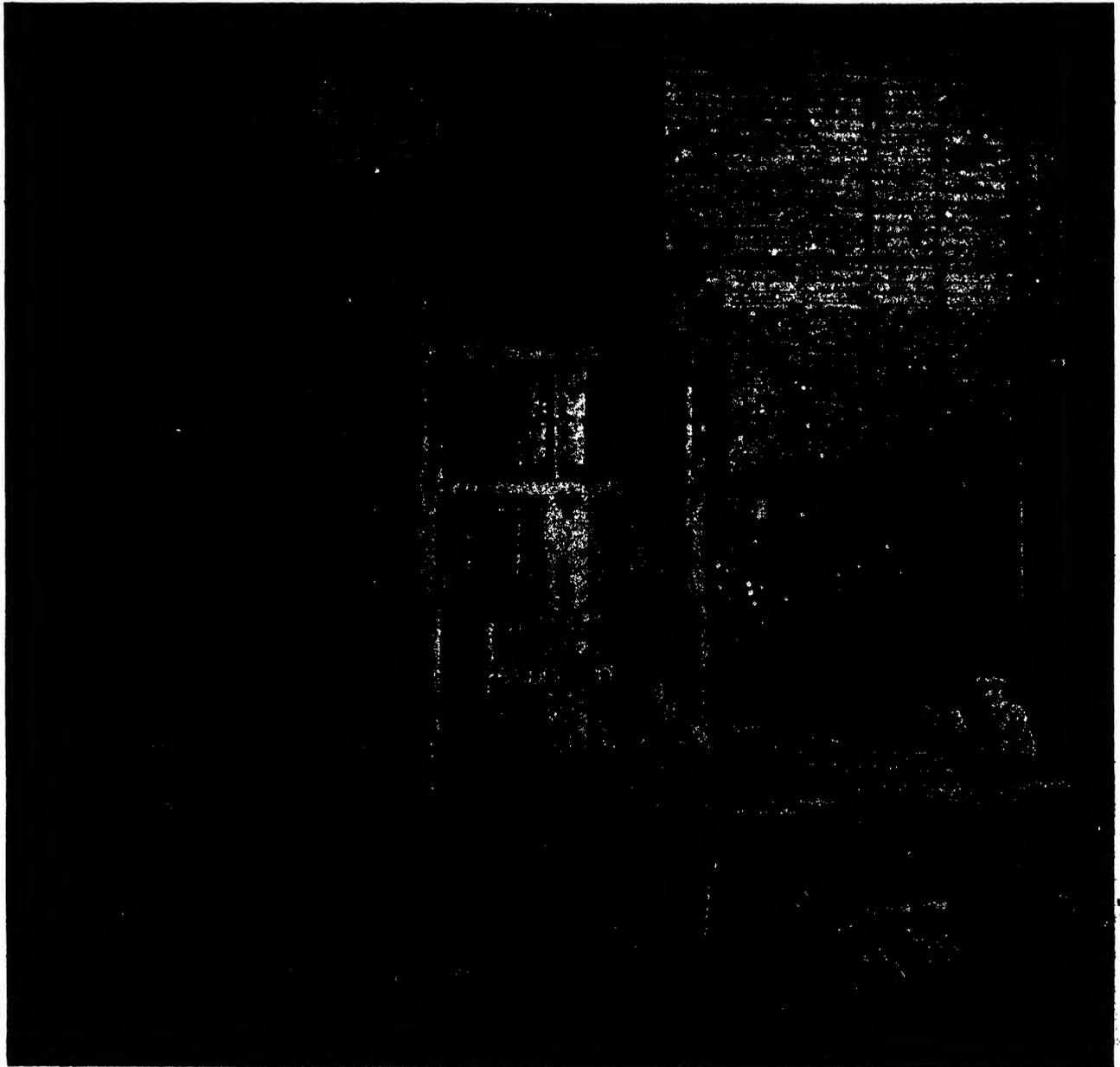
One of the fastest and least expensive methods of cutting sheet metal is by cutting rolls. However, only straight line cuts can be made with these rolls. Cutting rolls are used in draw bench departments to cut ribbon stock to be formed on the draw bench. These cutting rolls are large, thick wheels made of very hard tool steel, and they vary in width from less than 1 to more

than 3 inches. The cutting rolls are mounted on a large shaft (see Fig. 307). The sheet stock is fed between these rolls and is sheared to uniform strips or ribbons that are rolled on large spools and stored for further processing.

### *Saws*

Band saws similar to the one shown in Fig. 308 are used to cut aluminum alloy plate, bar, drawn, or extruded stock and to rough-trim formed stock.

Special contour saws are used to cut heavy



**Fig. 313. The hydropress**

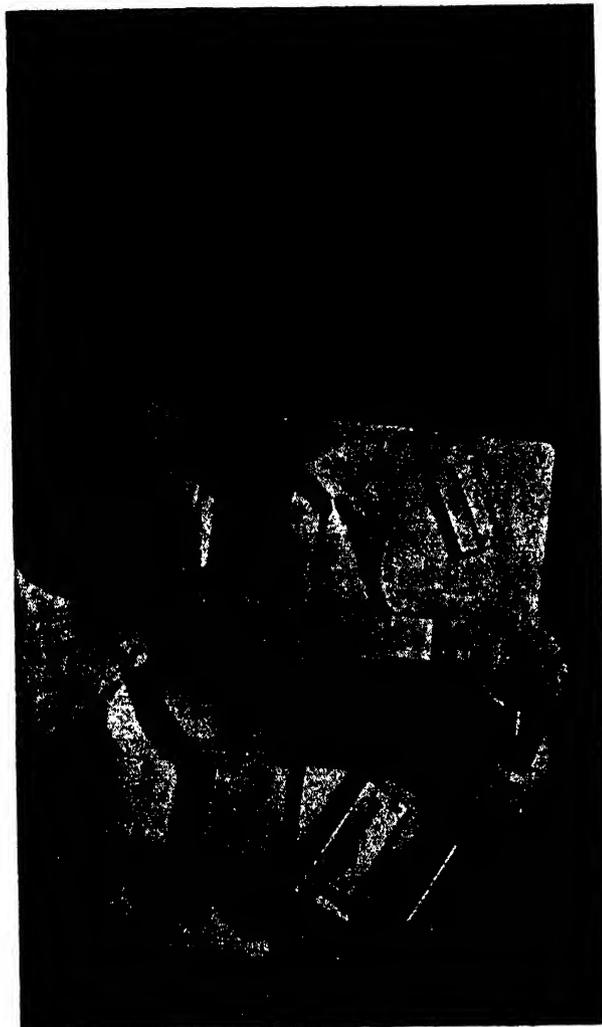


Fig. 314. Die forms

aluminum alloy and steel stock. These are classed as precision instruments, although the resulting edge on the cut piece is usually rough and requires finishing.

### Forming

To form means to bend, draw, or otherwise shape sheet metal flat stock into structural shapes such as angles, hats, Z's, etc. If the bends are straight, power brakes, power rolls, or draw bench machines are used. If the bends are curved or not parallel, hydropress or die forming machines are employed.

If the sheet stock has to be formed into a large, open, smooth shape, such as wing and fuselage skin coverings, stretch-press operation is employed. The material is stretched over a curved die to a degree beyond its yield strength,

causing a permanent set to the contour shape.

A flat sheet may be formed into a cup or tray shape by a drawing process in which the extreme edges of the sheet are clamped tight while a male die forces, or draws, the sheet into a cavity die. The drop hammer is used for deep draws, and the hydropress or die forming machines for moderate draws.

### Power Brake

One of the most common tools in the aircraft sheet metal department is the power brake or press brake. This machine is very versatile and is adaptable to various production methods, for it is easily set up, requires few individual dies, and, once set, is capable of producing large quantities of parts. The brake is composed of a male and a female die. The male die is carried by a movable ram, and the female die is set on the bed plate of the brake. The most common operation performed on the press brake is that

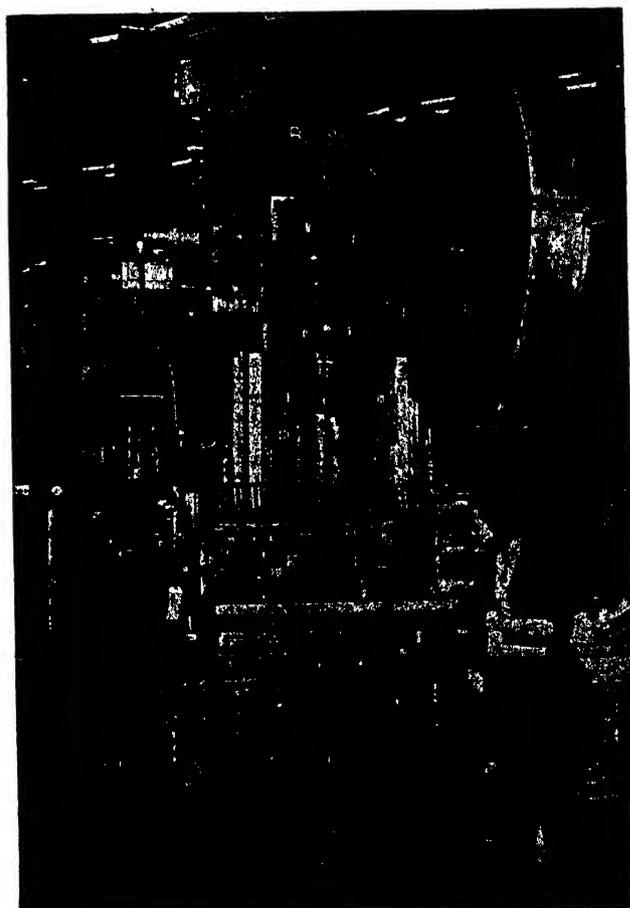


Fig. 315. Punch press

of bending parts of various radii to different degrees of bend, as shown in Figs. 309 and 310. The sheet is placed on the female die, and the male die moves down to the required depth and bends the part into the proper shape. The operator can set his machine so that the ram or male die will reach only a certain depth, thereby controlling the degree to which the part is bent. By the use of special dies, the brake can be converted into a punch press that will pierce holes in Z's, channels, hats, and similar sections (see Fig. 311). Joggle dies can be used to form offsets or joggles on parts (Fig. 312). It is very important, however, to remember that the brake is capable of bending parts on a straight line only.

### Hydropress

Among the many machines for forming sheet metal parts, the hydropress is perhaps the most

used. On this machine, parts with single contours—and, if the draw is not too great, parts with double contours—can be formed as shown in Fig. 313. The hydropress is composed basically of a large hydraulic tank, a plunger that drives a ram with a rubber platten attached underneath, and a mobile steel plate. The sheet metal parts are formed over dies or form blocks shaped exactly like the *inside* of the part to be made. Usually, the form blocks are made of Dural, Kirksite, steel, Masonite, or some other durable material. Form blocks can be made fairly quickly and their cost is comparatively low. They will endure a great deal of hard use and are easily repaired or replaced.

The forming operation on the hydropress follows a comparatively simple routine. The cut part is located properly on the form block by holes drilled in the piece, which contact projecting locating pins in the block. It is then moved



Fig. 316. First forming operation

under the press, and the press is set in motion. The ram with the rubber platten moves down over the form block. When the downward stroke is completed, the ram settles on the steel table. The rubber, which is now in a semisolid state due to the enormous pressure of the hydropress, forces the flat pattern around the block. Large hydropresses are capable of pressures of 65,000 pounds per square inch, and with this tremendous force, thick sheets of metal can be shaped. Since the hydropress only bends the metal and does not strike it (which would render it semihard), the springback of the metal must be reckoned with when some gages and tempers of material are employed. This springback is taken care of by cutting the block back farther than the part is to be bent. Also, to offset some springback, unhardened materials may be used.

Metal dies may likewise serve on the hydropress. The dies are fastened to the ram and the

bed of the press and take the place of the block and the rubber platten. This method is much more expensive because patterns must be made for both dies and more time is required for setting the machine.

#### *Steel Form Dies*

Steel form dies, similar to the one shown in Fig. 314, are employed in the most rapid method of forming parts. However, the initial cost of steel dies is very high, and a large number of parts must be produced to justify this expense. Steel dies are sometimes designed to perform two or more operations in the same action; for instance, blanking and forming dies cut and form a part in one operation. Steel dies are used in machines called "punch presses" (see Fig. 315). These machines are capable of rapid action. In Fig. 316, the sheet metal part on the right is ready to be formed on the first operation, and



Fig. 317. Second forming operation

the one on the left is ready to be formed on the second. In Fig. 317, the part on the left is finished, that on the right is ready for the final step. Note that pins are used to hold the parts in place on these dies. These pins do not fit holes in the part and on the form block but match the outline of the part.

### Drop Hammer

This machine is used on parts that are to be formed on a double contour or that have a deep draw. These parts could be formed on steel dies, but the drop hammer is preferred to produce a small number of parts, as the cost of drop hammer dies is low compared to that of steel dies.

Their tendency to spread and distort with use is what makes drop hammer dies unsuitable for producing a large number of parts.

There are two common types of drop hammer. The one shown in Fig. 318 is the manual or rope operated drop hammer. (Figure 319 illustrates a part being removed from the female die.) Another type is the air or hydraulic operated hammer. Both of these machines are important

tools of the sheet metal department. Ordinarily, the manually operated hammer is used on small parts, while the hydraulic hammer is reserved for parts that require large, heavy dies.

Drop hammer dies consist usually of a hard female die that is fastened to the bed of the drop hammer and a soft-faced male die attached to the ram. Kirksite is one of the most common alloys for female dies and for cores of male dies, since it has a very low melting point and is very hard and durable. Lead is used to face the punch or male die.

Casting is usually the simplest and least expensive method of making the ordinary drop hammer dies. Plaster dies are made over skeleton or box templates designed by the lofting department. This procedure is described in Chapter Twenty-One. Wood patterns are made from contour templates. The pattern maker checks the shape of the pattern with these templates at different sections of the part. The completed patterns are sent to the foundry, and sand molds are made from them. Molten Kirksite, lead, Dural, or sometimes plastic material is used to make the

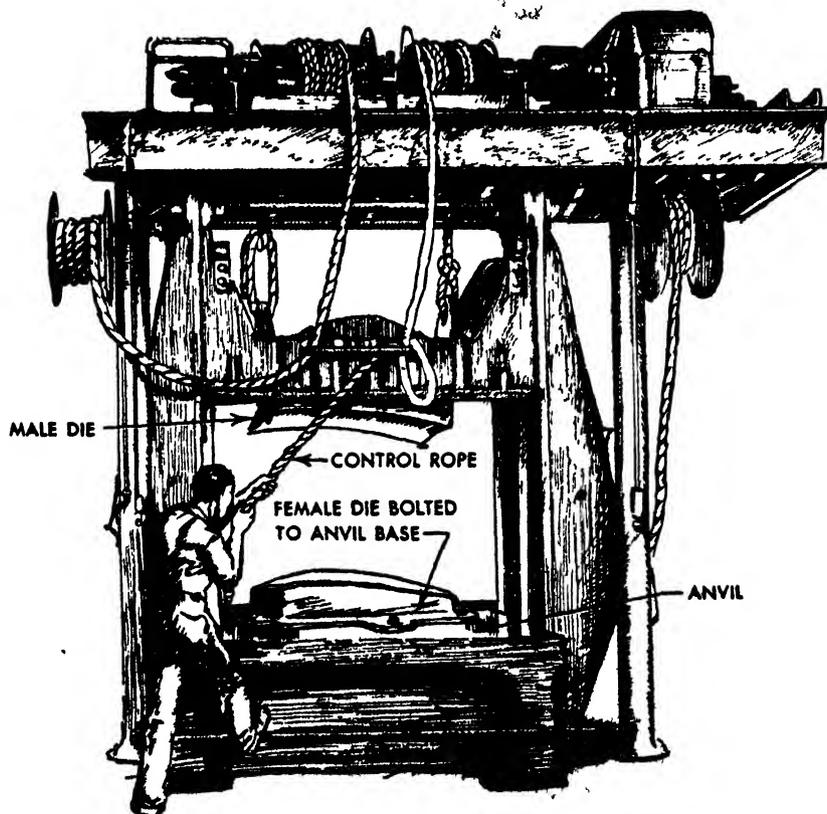


Fig. 318. The drop hammer

die. When the die is taken from the mold it is finished by hand and then mounted in the drop hammer.

The forming operation is fairly simple, but some parts may require much time. The rope operated hammer is much slower than the air-driven hammer, and it is more difficult to keep the amount of pressure of each stroke constant. Therefore the rope hammer must be worked by an experienced operator. The quality of the product depends largely on the skill of the operator. The air-driven hammer can strike as hard as desired, and though some experience is necessary to operate it, the operator is not subjected to as tedious and exacting a task as is the operator of the rope hammer.

There are several different methods of forming parts on the drop hammer, and the depth of the draw in the part usually determines the method used. A part with a very deep draw may be made either by progressive forming with



Fig. 319. Removing formed part from hammer

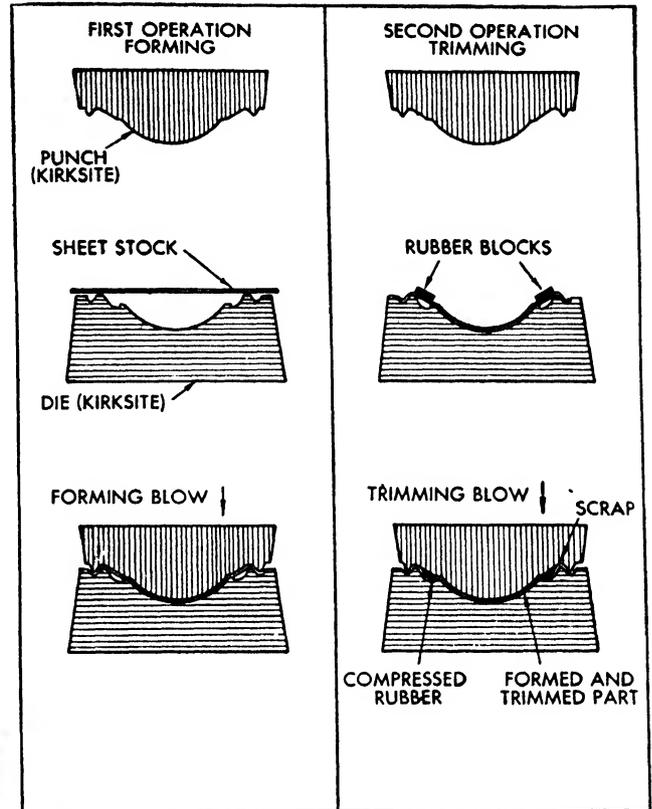


Fig. 320. Forming and blanking on drop hammer

several dies or by progressive forming with one die and the use of wooden shims or spacers. When several dies are used, the part is formed partially with a starting die, furthered with an intermediate die, and completed with a finishing die. (The draftsman should note that this method requires at least two sets of dies.) By using wooden spacers, the sheet metal part can be formed in several operations on one set of dies. If the part has a fairly deep draw, six spacers are used. First, the part is formed with all six spacers in place, then the spacers are removed, one at a time, and the part is further formed until it is finished. Should the part have only a small amount of draw, it can usually be formed in one drop hammer operation. It is placed on the die and hit two or three times, first a forming stroke and then one or two finishing strokes.

Each stroke of the hammer cold-works the material, thus in some cases it is necessary to anneal the piece between blows, so that final forming may be accomplished without rupture.

Most drop hammer made parts must be trimmed after formation. This is done usually on a saw, nibbler, or unishear, but sometimes the part can be trimmed while it is still in the die, as shown in Fig. 320. The edges of parts formed with a drop hammer have a tendency to wrinkle as the blank is drawn into the die cavity. If the wrinkled area is necessary to the design, it must be smoothed, and if it is not needed, trimmed.

### *Bumper*

The bumper or speed hammer, shown in Fig. 321, forms sheet stock into double contour shapes or smooths already formed parts by quick hammer action. Check blocks designed by the lofting department are used to determine the shape of the part. Since the successful fabrication of a part on this machine depends almost entirely on the skill of the operator, it cannot be considered an efficient production tool.



Fig. 321. The bumper

### *Extruded, Rolled, and Drawn Parts*

Many airplane parts can be made up in large quantities and put in stock for later use. The most common of the standard parts are Z's, T's, angles, etc., in long lengths of uniform cross section. These parts may be fabricated by extruding, rolling, or drawing.

The extruded sections are forced through dies while the metal is in a plastic state. These sections are usually characterized by sharp outside corners and they are rigid. These "extrusions," as they are commonly called, are procured generally from a metal manufacturing company.

Rolled sections are formed from cold ribbon sheet metal stock that is run through rolls of various shapes (see Fig. 322). After the parts are rolled, they may be heat treated and stretched straight by a hydrostretcher, as shown in Fig. 323. Rolled sections are usually made in the plant where they are used, or are produced in a parts plant and then sent to the assembly plant.

Drawn sections are formed by pulling the ribbon stock through a die opening (Fig. 324). The shape of the die opening determines the cross-sectional shape. After forcing an end of the ribbon stock through the die, it is clamped and pulled by hydraulic action. Although slower than rolling, the drawing process is less expensive, as only one die is necessary instead of a series of carefully designed rolls.

### *Contour Rolls*

Machines have been developed to roll contours in flat sheet or on formed parts. The principle of contour rolls can be illustrated by pulling a strand of hair through one's finger nails. By exerting different pressures, the hair may be curled into a tiny ball or may be merely waved. Contour rolls usually consist of one stationary roll and two adjustable rolls, as shown in Fig. 325. The gage of the material and the degree of required curvature determine the set of the rolls. Figure 326 illustrates the rolling of channel sections.

"Wiping" consists of placing the part on a block shaped to a desired contour, as shown in Fig. 327, and then forcing the part around the block with a ram.

*Hydrostretcher*

It is sometimes necessary to form large flat contours of relatively slight reverse curvatures by a stretching process. The sheet stock is placed over a form block shaped to the desired contour. The ends of the stock are then fastened by a row of pneumatic or hydraulic clamps (see Fig. 328). Hydraulically operated cylinders under the block, force it upward to a determined degree, stretching and forming the material. The permanent set of the sheet is reached after its elastic limit has been exceeded. This limit depends on the maximum elongation capacity of the ma-

terial. Although the material is substantially thinned in stretching, no loss of strength occurs, for the tensile strength is increased when the elastic limit is exceeded. In the bill of material stock size specifications, the draftsman should allow approximately 15 inches extra length on parts to be stretch-formed. This is needed for clamping the ends of the sheets.

*Wrap Bending*

Sections may be conveniently bent by a hydraulic wrap bending machine shown in Fig. 329. As the name implies, the section is wrapped

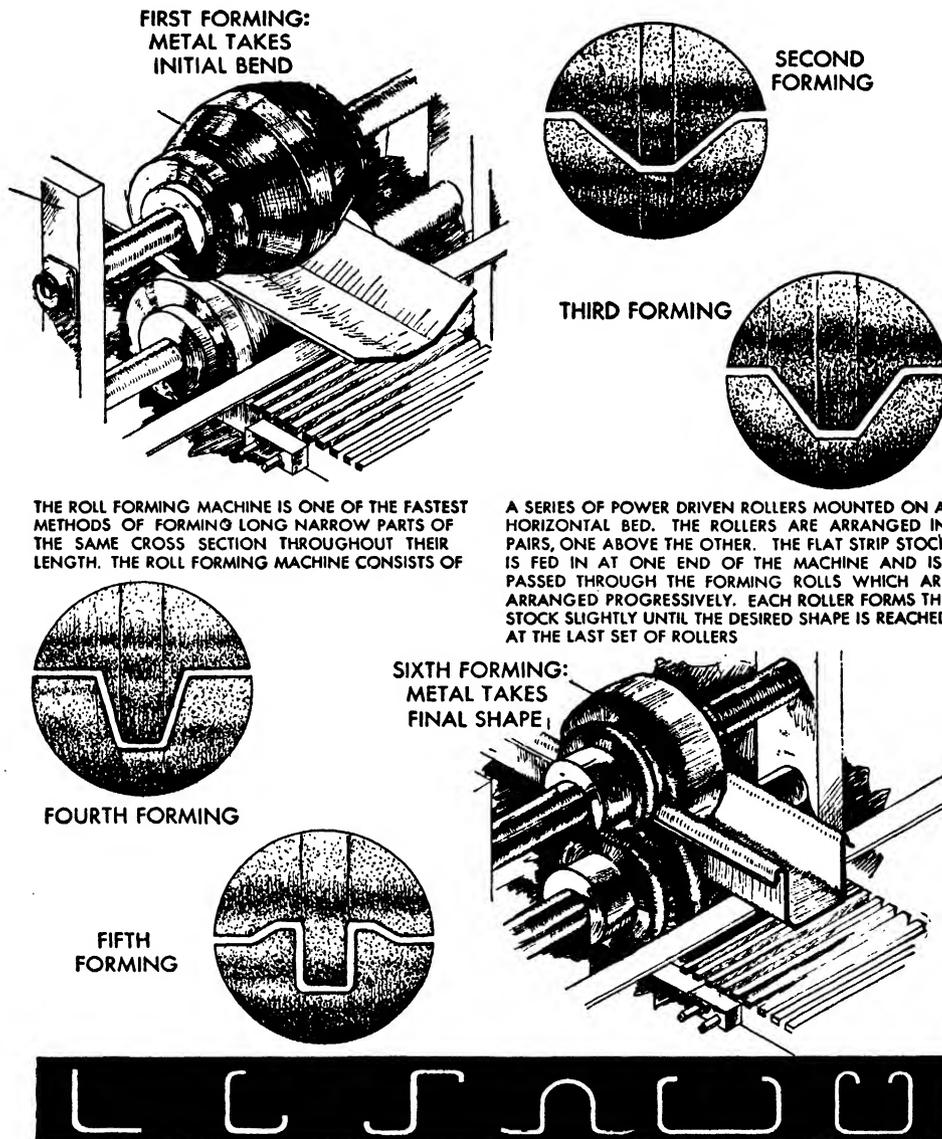


Fig. 322. The forming of rolled sections

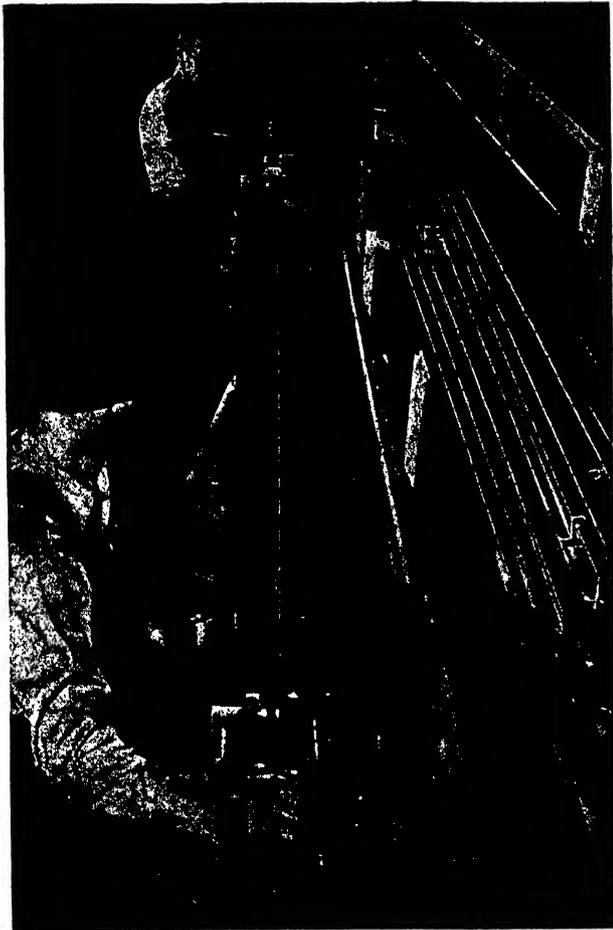


Fig. 323. Stretching rolled sections straight

about a specially prepared die by means of swinging table legs and hydraulically operated clamps.

### Sand Casting

In brief, the casting process consists of first preparing a cavity form by impressing the shape of a wood pattern in sand and then pouring molten metal into this cavity or mold. The metal freezes and solidifies in the shape of the cavity to a facsimile of the wood pattern.

Knowledge of the following casting terms is needed for an understanding of the process:

- MOLD.** A cavity or the material in which the cavity has been shaped.
- FLASK.** A framework made of two basic sections housing the mold.
- COPE.** Upper section of the flask.
- DRAG.** Lower section of the flask.
- MOLDING BOARD.** A wood panel upon which a pattern section is placed in the process of forming the mold.

**BASE OR BOTTOM BOARD.** The base or bottom of the flask.

**MOLDING SAND.** The common substance used to form a mold. It is employed because of its inherent resistance to fusion under the heat of molten metal and because its porosity allows the escape of gases and air enclosed within the mold.

**GREEN SAND.** Sand without admixture of a binder.

**DRY SAND.** Sand mixed with a binding ingredient and hardened by baking.

**CORE.** A sand form, usually cylindrical, supported within the open area of the cavity, used to fashion a hollow area (usually a hole in the casting).

**SPRUE.** An opening through the cope to the mold cavity, facilitating the pouring of the metal into the mold.

**GATE.** An opening connecting the bottom of the sprue to the mold proper.

**STRAINER.** A perforated disk of hardened sand, located between the sprue and the gate. The strainer is used to control and regulate the flow of metal into the mold.

**FEEDER.** A cylindrical opening through the cope into the cavity, used to compensate for shrinkage of the metal within the mold. Enough molten metal is poured into the mold to fill the feeder, too. As the metal solidifies in the mold, it shrinks. The additional metal in the feeder is drawn down into the mold to compensate for this deficit.

**VENT.** A hollow in the sand, usually made with a steel wire of required diameter, to allow the escape of gas produced by the contact of liquid metal and sand.

**DRAFT ANGLE.** The taper or slant of the sides of the casting, necessary for the removal of pattern and casting from the mold.

**PARTING LINE.** The dividing line of the pattern or the mold.

**FLASH.** Excess material, usually at the parting line, gate, sprue, or feeder connections, to be removed from the casting by machining or sand blasting.

The following procedure is used in casting the bracket shown in Fig. 330:

A pattern or wood model of the bracket is made (Fig. 331). This facsimile of the part to be cast is necessary to create the mold into which the metal will be poured. The pattern is intentionally carved somewhat larger than actual casting dimensions, to compensate for anticipated shrinkage that occurs as the molten metal solidifies in the mold. The pattern is cut in half, thus determining the parting line of the casting. To facilitate contact, holes drilled in one half are mated with locating pins in the opposite half.

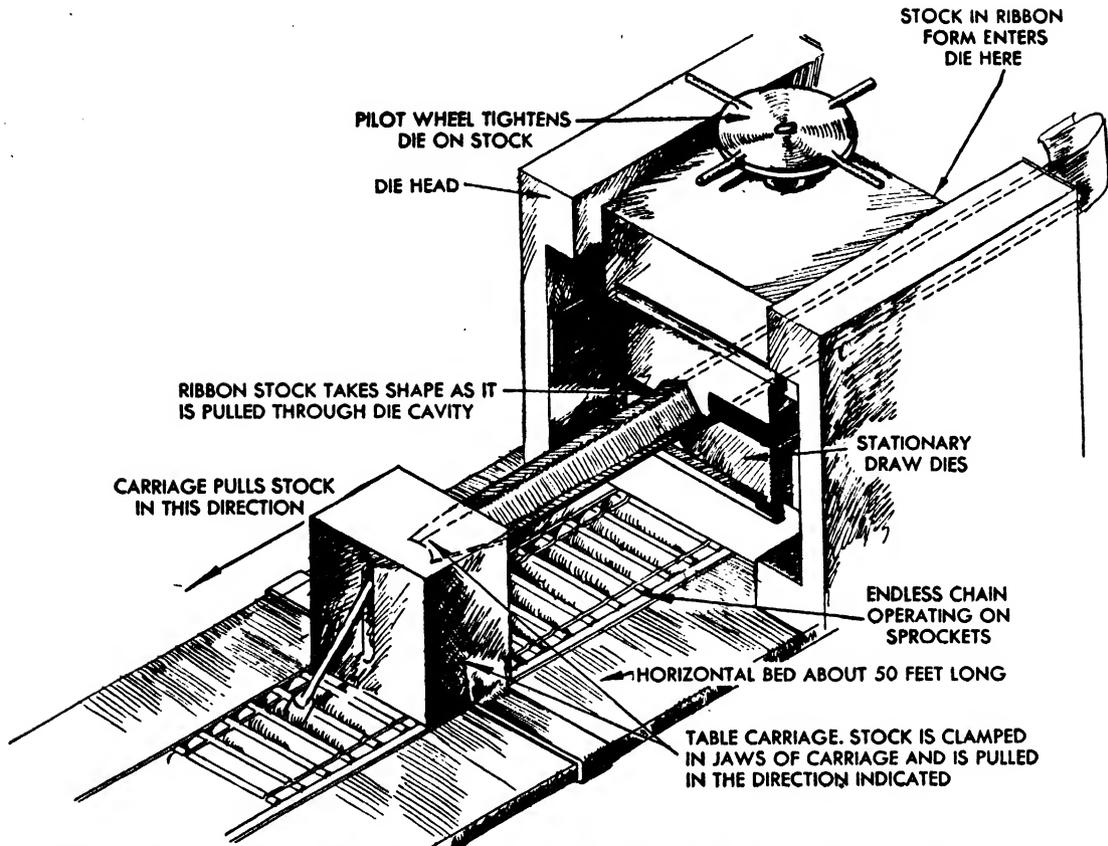


Fig. 324. The drawing process. The draw bench consists of a horizontal bed about 50 ft. in length upon which is mounted a stationary die head and a mobile draw head. In the bed itself is mounted an endless chain operating on two sprockets, one at either end of the bed. Metal is drawn through the die by being clamped to the draw head or carriage, which in turn is hooked to the moving chain and consequently pulls the metal through the die

The half pattern is placed on a molding board, and the drag half of the flask is set on top of the board. Sand is packed and rammed around the pattern, as shown in Fig. 332.

A bottom board is set on top of the drag, and the drag is then turned over so that it assumes its position at the bottom of the flask. Locating pins unite the cope half of the pattern to the drag half. The cope half of the flask is then mounted above the drag. Pins are set to form hollows for the sprue and the feeder, and sand

is packed and rammed around pins and pattern (Fig. 333).

The flask is separated, the pins and patterns are removed, and the cores for the holes are attached to the sides of the mold wall by means of chaplets, small pieces of iron or steel. The top of the sprue is widened to provide a basin for the molten metal. A gate is formed, connecting the sprue to the mold cavity, and a strainer is inserted as shown in Fig. 334. Vent holes are punched, and the flask is reassembled.

The metal is poured (Fig. 335) until the feeder is supplied with the compensating liquid. After the metal has solidified, the flask is opened. The casting is removed and permitted to cool.

The sand cores are then blown or otherwise forced from the casting. The sprue, gate, feeder, and parting line flash are removed, and the casting is cleaned before it is dispatched to the machine shop for surface finishing specified in the blueprint (Fig. 336).

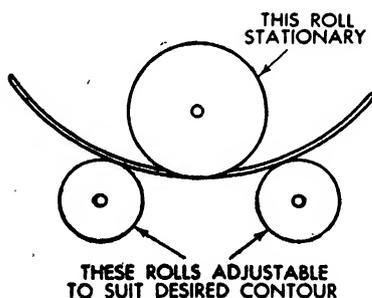


Fig. 325. Principle of contour rolls

Of all the casting methods the sand mold is the most common type, due primarily to its design flexibility. The tooling costs are comparatively low, and therefore, it is often economical to design for a sand casting even though one part is needed. On a production basis, the per piece costs are relatively high because direct labor is required for molding, melting, shaking out, cleaning, etc. Inspection costs are also relatively high due to the constant vigilance that is necessary to keep to dimensional specifications throughout production runs. However, reduced costs and the improved appearance of finished products are readily obtainable by the use of castings. With casting design the number of parts in an assembly may be reduced, machined operations minimized, and bolted, riveted, or welded joints may be eliminated.

While the strength-weight ratio of cast metal is low compared to forgings and the wrought alloys, the virtually unrestricted distribution of metal and the elimination of joints in the casting process offers two features which make possibilities for attaining equal or better overall strength-weight ratios on finished products.



Fig. 326. Bending channels in the contour roll machine

Sand castings may be used for structural purposes. To insure soundness, special consideration should be given to the design of junctions and the gradual transition between sections of different thicknesses. Wide expanses of thin sections should be avoided, especially if the material is steel or magnesium.

#### *Permanent Mold Casting*

Permanent mold casting, as the name implies, differs from sand casting in that the mold is of a durable nature, machined from cast iron blocks. These molds may be used repeatedly, and, aside from a production consideration, are preferred to sand castings, because they result in a finer grain, smoother finish, and greater dimensional accuracy.

With the combined use of sand cores, a great deal of design flexibility is possible in this process, especially in the manufacture of small castings. Sand cores, however, do away with some of the main advantages of the permanent mold process, and their use should, whenever possible, be avoided by designing castings so that straight pull metal cores can be used.

As stated previously, tolerances and surface finishes are better than those obtained by sand casting, but the tooling costs are greater. Of course, the quantity required is one of the critical considerations in choosing the permanent mold process as against sand mold castings. If the production run is great enough the cost of the dies will be justified. In quantities of about a thousand pieces, permanent mold castings frequently prove to be more economical than sand castings, considering procurement charges only. In addition the superior dimensional uniformity facilitates machine tooling, reduces inspection costs, and often permits elimination of some machine operations.

Heat treatable aluminum and magnesium alloys may be cast in this process. The products are comparatively dense and fine grained, adapting them to structural and leakproof applications.

#### *Die Casting*

This type of casting forces the molten metal by mechanical, pneumatic, or hydraulic pressure

into a metal mold or die. The die or pressure casting may contain thin partitions, and holds accurate shape and sharp outlines. It is a production method often preferred to the permanent mold, but the products lack the tensile strength of permanent mold castings.

The molten metal is forced or "injected" into the mold with pressures ranging from 2,000 to 35,000 p.s.i. Pressure is maintained until the casting solidifies. The dies generally consist of one stationary and one movable block, and are usually made from hard, tough, heat resistant steel.

Die castings are manufactured in fast working machines. One block is attached to a stationary bed and the other is mounted on a movable platen. The parting surface is established in a vertical plane normal to the direction in which the movable block is actuated. Very heavy toggle

locks are required to prevent spring back of the blocks when the injection "shot" is made.

Die equipment for die casting is usually more costly than any other type of casting. But this initial die expense is counterbalanced by low operating costs. The casting cycle is a matter of seconds and only one man is required to operate the machine. Very little flash results, and the small degree of "cleanup" also tends to reduce overall cost.

Due to the inherent porosity of the metal (characterized in this process) die castings are limited to non-structural applications in the airplane. The chilled surface material is the soundest. It is advisable to design for minimum machining so that this porous interior will not be exposed.

Aluminum and magnesium alloys, zinc and bronze may be die cast.



Fig. 327. Wiping

The following structural design considerations are from the *Engineering Manual* of the Republic Aviation Corporation:

*“Structural Classifications”*

“(1) Class A-1. . . . Includes those castings in which the ratio of the test to design load of the weakest of the test castings is less than 3. . . . These castings receive at least 25 per cent radiographic inspection in production.

“(2) Class A-2. . . . Includes castings in which the ratio of the test to design load of the weakest of the test castings lies between 3 and 10. . . . These castings receive at least 10 per cent radiographic inspection in production.

“(3) Class A-3. . . . Includes those castings in which the ratio of test to design load of the weakest of the test castings is greater than 10. . . . Regular radiographic inspection is not required.

“(4) Class B. . . . Castings which Structures

Group determine by stress analysis to have a margin of safety of at least 900 per cent. . . . Regular radiographic inspection is not required.

*“Design Limitations”*

“(1) No Class A casting having an elongation less than 3 per cent shall be designed that will not withstand a test load of 1.5 times the ultimate design load, when loaded to destruction in a manner simulating the actual loading of the castings as installed in the airplane. Castings having an elongation of 3 per cent or greater will be accepted if they support a load equal to the ultimate design load. In no case shall the stress at limit load exceed the actual yield stress of the material, nor shall permanent set occur at limit load.

“(2) In the design of magnesium alloy castings, wall thickness shall not be less than  $5/32$  inch, and generous fillets shall be provided at junctures of all sections. The design shall be such that all castings are free from sharp corners, discontinuities of contour, or thin webs either in the rough casting, or in the final machined part, as a result of machining operations, such as spot-facing. The minimum radius at any point due to machining shall not be less than .050 inch; and the machined casting must be free from sharp tool marks. Castings which are lacking in generous fillets and radii, as well as bosses for machining surfaces, and which are not free of tool marks sharp corners and recesses, will not be considered acceptable as Class A-1 castings.

“(3) Castings shall not be used for wire pull lugs or in any fittings or members where large concentrated alternating tension loads are present.

“(4) When used in control systems or fittings, Class A castings shall be accessible for visual inspection.

“(5) Die castings may be used for Class B castings, but shall not be used for Class A castings.

*“Designing of Casting Sections, Junctions and Fillet Radii”*

“Thin sections cool and contract faster than heavy sections unless special (usually expensive) corrective measures are taken by the foundry.

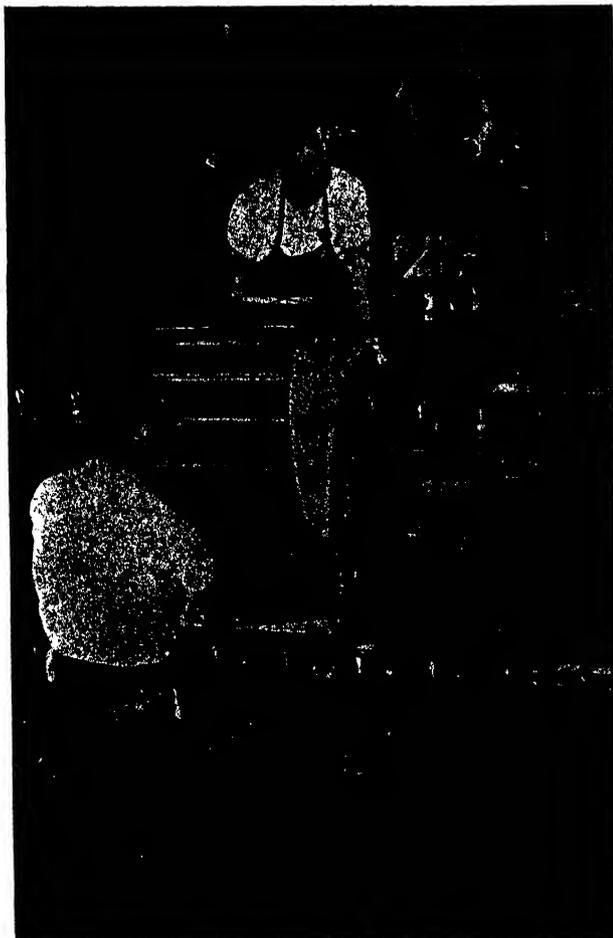


Fig. 328. Stretch press

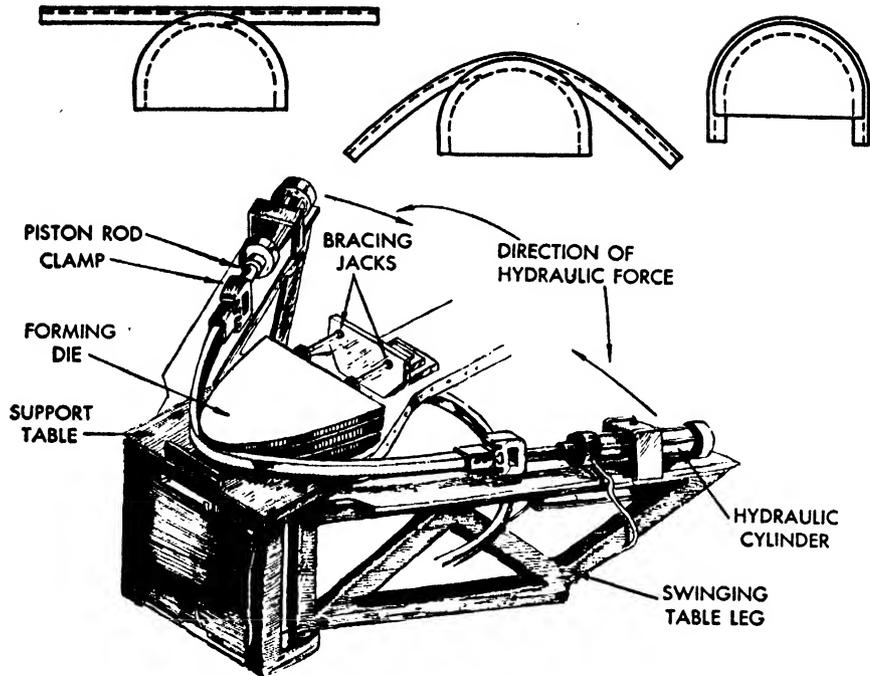


Fig. 329. Hydraulic wrap binding machine

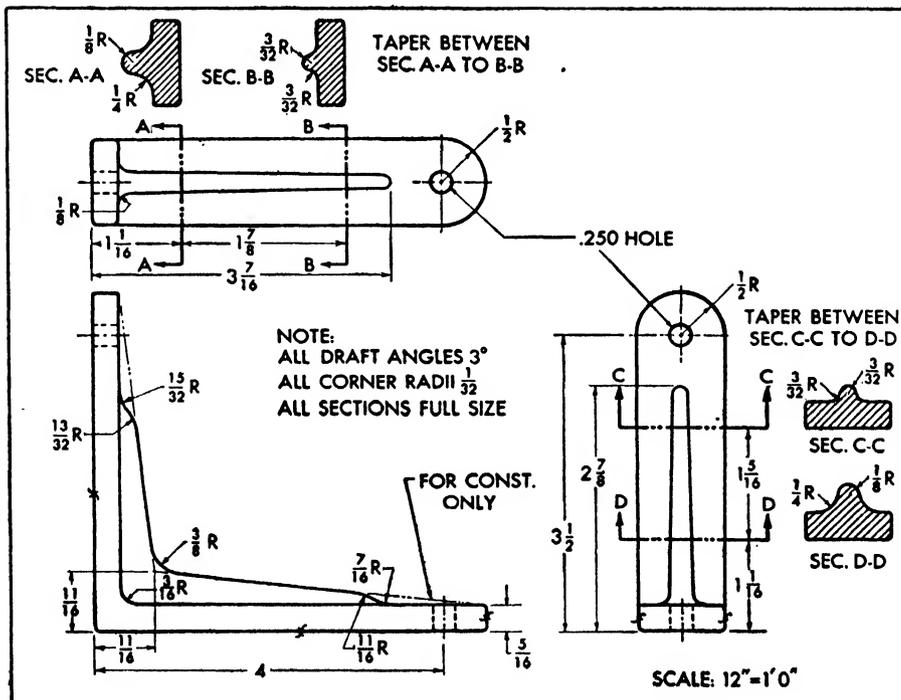


Fig. 330. Print of bracket to be cast

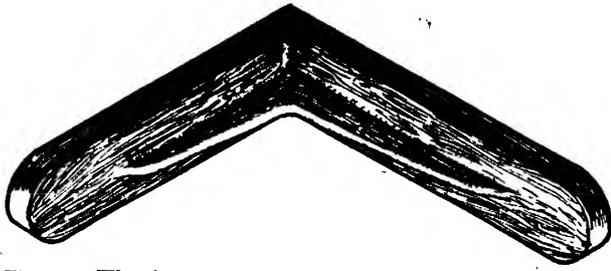


Fig. 331. Wood pattern

Isolated, partially solidified heavy sections, being comparatively weak, are severely stressed by the earlier contraction of surrounding thin sections unless the junction is properly proportioned. . . . Wide expanses of very thin sections are difficult

the average thickness of the intersecting walls.

“(3) Wide expanses of very thin sections shall be avoided, especially in magnesium and steel castings.”

### Forging

Forging differs from casting in that the metal to be formed is heated to a plastic rather than to a molten state and is hammered or pressed into shape. Power driven forging machines lift the upper half of the die and impact it against the plastic metal held over the lower half.

Steam-operated hammers may be used to form parts too few in number to justify the expense

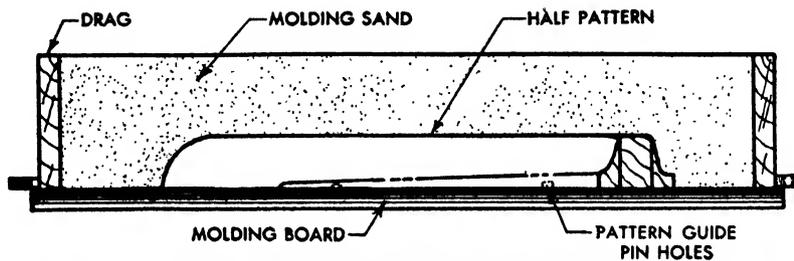


Fig. 332. The half pattern set in drag half of flask and sand packed

to cast sound because the metal tends to harden before completely filling the mold, causing voids or cold shuts.

### “Design Rules for Sections, Junctions and Fillet Radii

“(1) When conditions permit, section thicknesses shall be designed uniformly.

“(2) Fillet radii shall, in general, be equal to

of steel dies or parts larger than the usual run of forgings. The part is roughly formed and heated to the plastic state. A descending hammer strikes the metal held on the anvil or base of the machine. The successful forming of the piece depends to a great extent on the operator’s skill in manipulating the plastic metal with each blow of the hammer in a manner similar to blacksmithing.

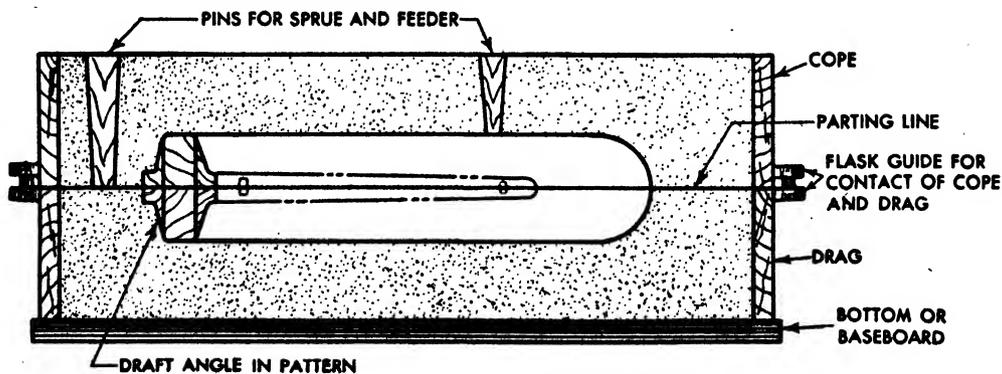


Fig. 333. Pattern, cope and drag united. Feeder and sprue pins set, sand packed

Forgings can develop greater strength than castings, for the hammer blows cause the grain of the metal to "flow" and follow the contour of the part. Stress concentrations are thus minimized, whereas the internal structure of a casting is comparatively open and porous.

Many large and heavy parts may be made by forcing the metal under tremendous pressures to fill a die cavity; the resulting product is called a

"press forging." The steady heavy pressure brings about the metal flow, replacing the repeated impacts of the hammer in the drop forging process. A uniform force is transmitted to the center of product section by the slow, steady acting press. The interior grain, as well as the exterior, is thus affected, resulting in a substantial structure throughout the piece.

Press forgings require less draft and can be

ALCOA ALUMINUM ALLOY FORGING TOLERANCES<sup>1</sup>

TABLE 1. THICKNESS TOLERANCES (INCHES)

Thickness tolerance applies to the overall thickness of the forging. This thickness is in a direction perpendicular to the parting plane, or parallel to the ram travel.

Net Weight, Lb.	Tolerance, Inch	
	Minus	Plus
0- 0.250	0.010	0.032
0.251- 1.00	0.015	0.032
1.01 - 4.00	0.032	0.045
4.01 -17.00	0.032	0.062
17.01 -24.00	0.032	0.078
24.01 and up	0.032	0.093

Any deviation from these tolerances will involve either a coin press die or a complete cold restriking die.

Thickness tolerances shall be applied separately and independently of any other tolerance.

TABLE 2. STRAIGHTENING TOLERANCE

Length or Width, Inches	Tolerance, Inch	
	Commercial	Close
0 to 9 inclusive	1/64	0.010
9 to 18 inclusive	1/32	0.015
18 to 30 inclusive	3/64	0.030
30 to 45 inclusive	1/16	0.040
45 to 60 inclusive	3/32	0.050
60 to 80 inclusive	1/8	0.060

Any deviation from the commercial tolerance will require a straightening die.

Straightening tolerances shall be applied separately and independently of any other tolerances.

TABLE 3. DRAFT ANGLE TOLERANCES FOR FORGINGS (DEGREES)

Tolerance	Drop-Hammer Forgings				Upset Forgings			
	Plus		Minus		Plus		Minus	
	Nominal Angle	or Minus	Nominal Angle	or Minus	Nominal Angle	or Minus	Nominal Angle	or Minus
Outside	7°	1°	1°	1/2°				
Inside holes and depressions	7°	1°	1°	1/2°				

TABLE 4. SHRINKAGE AND MISMATCHING TOLERANCES (INCHES)

SHRINKAGE

Shrink is the contraction of the forgings, in all directions, caused by the cooling of the metal.

Length or Width, Inches	Shrinkage Tolerance, Inch	
	Plus	Minus
1	0.004	0.002
2	0.008	0.004
3	0.012	0.006
4	0.014	0.008
5	0.020	0.010
6	0.024	0.012

Each Additional Inch, Add

0.001 0.002

For Example:

12	0.048	0.024
18	0.072	0.036
24	0.096	0.048
36	0.144	0.072
48	0.192	0.096
60	0.240	0.120

MISMATCH

Mismatch is the shift of that part of a forging along the parting line from its relative position to the other part of the forging.

Net Weight, Lb.	Mismatch Tolerance, Inch
Up to 2.500	0.015
6.250	0.018
8.500	0.021
15.000	0.024
20.000	0.028
25.000 and up	0.032

When designing a forging, metal should be added to take care of shrink and mismatch. Shrink and mismatch shall be used in conjunction with each other; never as the sum of the two, but as the critical of the two. If stock for machining is required, it shall be in addition to the critical of the two.

<sup>1</sup> From *Tolerances, Allowances and Other Design Information for Alcoa Aluminum Alloy Hammer Forgings*, published by the Aluminum Company of America.

produced to closer tolerances than hammer forgings, thus offering the advantage of less machining for finishing. Press forgings are also replacing hammering in cases where high grade steel is required.

Forgings are used in those parts of the air-

plane requiring great strength in restricted areas. Some applications are: wing fittings, propellers, landing gear components, hinges, mechanisms, etc. Magnesium alloys, steel, aluminum alloys and Inconel are commonly employed as forging materials.

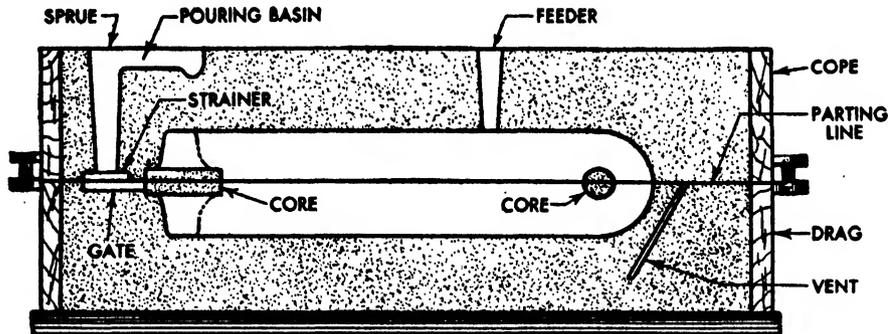


Fig. 334. Patterns and pins removed from flask, pouring basin, gate, and vents formed in sand. Cores attached, strainer set

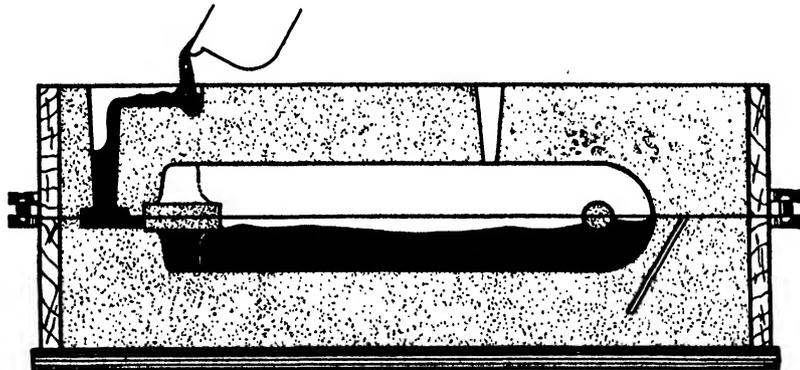


Fig. 335. Molten metal poured

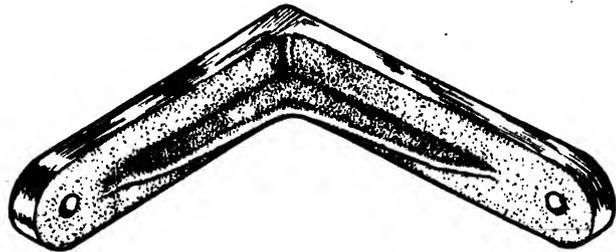


Fig. 336. Casting removed from flask and finished, surfaces machined

# CHAPTER SIXTEEN

## FASTENERS

Aircraft parts are joined together by three kinds of fasteners: rivets, bolts and nuts, and welds. The choice of fasteners depends primarily on whether the parts are to be secured permanently or temporarily. Riveting and welding are permanent methods of fastening; bolts, screws, keys, etc., secure parts that may later be removed. Other factors such as type of material, degree of strength required, and nature of anticipated stress also influence the choice of fasteners.

Since the draftsman encounters fasteners almost every day in assembly drawings and has to make provisions for them in details, it is important that he gain familiarity with their characteristics, functions, and nomenclature.

### RIVETING

Riveting is the most common method of fastening aircraft parts together. A rivet has a head and a shank that contains enough excess metal to allow a second closing head to be formed on its end. A bucking bar or "dolly," having a cavity of a shape inverse to the desired head, is held against the unformed end of the rivet shank while it is driven or tapped on its preformed head, usually by pneumatic hammers or the rivet gun (Fig. 337).

Sheets of aluminum alloy and standard structural shapes may be fastened together with very good results by aluminum alloy rivets. These rivets are manufactured with various diameters and heads and from a variety of alloys.

#### *How to Designate Rivets on the Drawing*

The heads of aluminum alloy rivets are classified as button, round, brazier, flat, countersunk, etc. (Fig. 338). These types are designated by numbers listed in the standard books. For example, a flat headed rivet conforming to army and

navy standards is AN442, a countersunk rivet is AN426. "AN" signifies Army and Navy approval and "426" and "442" the type of rivet head. NAS-1 means National Aircraft Standard; number 1, countersunk rivet. Aircraft companies prefix the code number with their own letter: for example, in Q4305, Q designates a company standard part and 4305 a brazier head rivet.

Aluminum alloy rivets may be made from any of the wrought aluminum alloys, but the following are the most common:

A17S-T, 17S-T aluminum alloy in the soft annealed state.

17S-T, 17S-T aluminum alloy in the hardened state.

24S-T, 24S-T aluminum alloy in the hardened state.

The A17S-T aluminum alloy rivet is the Army standard rivet. It is driven as received from the manufacturer, without reheating. It is softer and less strong than the 17S-T or 24S-T aluminum alloy rivets, but ease in driving makes it popular. All rivets of  $\frac{5}{32}$  and  $\frac{3}{16}$  inch diameter or less are generally of A17S-T. Rivets made from 17S-T and 24S-T aluminum alloys are used for joints requiring greater strength. Received from the manufacturer in a hardened state, they are difficult to drive and must be annealed and stored in dry ice to prevent their reverting to their original hardened condition. These are commonly called "ice box rivets." Rivets with diameters of more than  $\frac{3}{16}$  inch are usually made from 17S-T or 24S-T. In the process of driving, larger hardened rivets have a tendency to stretch and to deform the metal if it is not of substantial thickness or is not backed by a strong member. Although they are undoubtedly necessary, the use of such rivets should be minimized because of the difficulty in handling and driving.

The following is the code for some standard types, as listed in the AN book:

AD=A17S-T rivets  
 D=17S-T rivets  
 DD=24S-T rivets  
 A=pure aluminum rivets.

Therefore,

AN442AD is an Army and Navy (AN) flat head (442) rivet of A17S-T soft alloy (AD).

AN426D is an Army and Navy (AN) 100 degree countersunk rivet (426) of 17S-T aluminum alloy, hardened (D).

The diameter of a rivet is designated in thirty-seconds of an inch. Hence, AN426D4 means Army and Navy (AN) standard countersunk rivet (426) of 17S-T aluminum alloy, hardened (D), with  $\frac{1}{8}$  inch diameter ( $\frac{4}{32}$  inch).

The length of the rivet is designated by sixteenths of an inch, following the diameter number after a dash. AN426D4-4 designates an Army and Navy standard countersunk rivet, etc., of  $\frac{1}{4}$  inch length. Most aircraft companies prefer not to note the length of rivets on the drawing but let the shop determine the correct length, because gages of materials may vary or misalignment may occur in parts, and a short rivet would cause damage by the rivet hammer.

Following are examples of rivet numbers taken from the AN book:

AN426A3-12. Army and Navy standard countersunk rivet from 2S aluminum composition, half hardened, of  $\frac{3}{32}$  inch diameter,  $\frac{3}{4}$  inch long.

AN426AD3-12. Army and Navy standard countersunk rivet from A17-ST aluminum alloy in annealed state, of  $\frac{3}{32}$  inch diameter,  $\frac{3}{4}$  inch long.

AN426DD3-12. Army and Navy standard countersunk rivet from 24S-T aluminum alloy, hardened, of  $\frac{3}{32}$  inch diameter,  $\frac{3}{4}$  inch long.

AN426D3-12. Army and Navy standard countersunk rivet from 17S-T aluminum alloy, hardened, of  $\frac{3}{32}$  inch diameter,  $\frac{3}{4}$  inch long.

Rivet symbols are used to simplify the description of rivets. The different aircraft companies employ various symbols. Consolidated Vultee symbols are shown in Fig. 339.

*Size and Placement of Rivets*

Internal rivets are usually of the flat head type, AN442, unless countersunk rivets are necessary. External rivets, except where flush types are desired, are generally brazier headed.

When countersunk rivets of less than  $\frac{1}{8}$  inch diameter are required, the AN426 rivet, countersunk at 100 degrees, is generally employed. Rivets

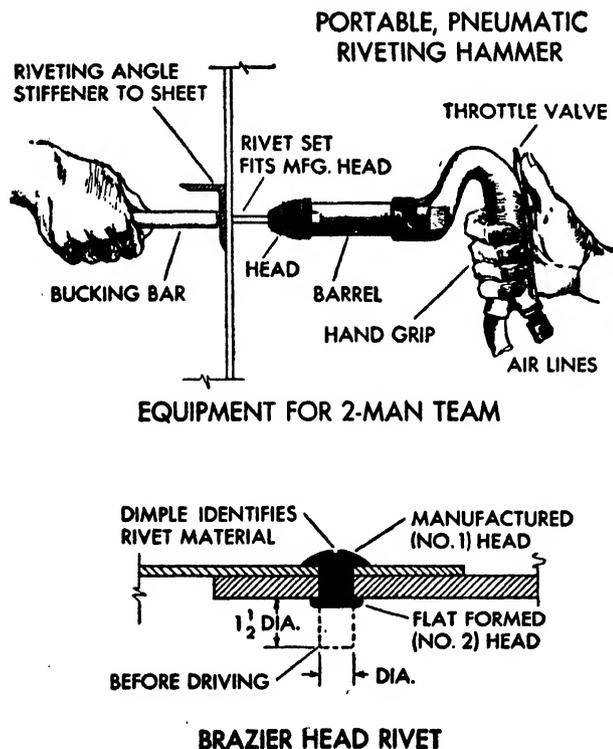
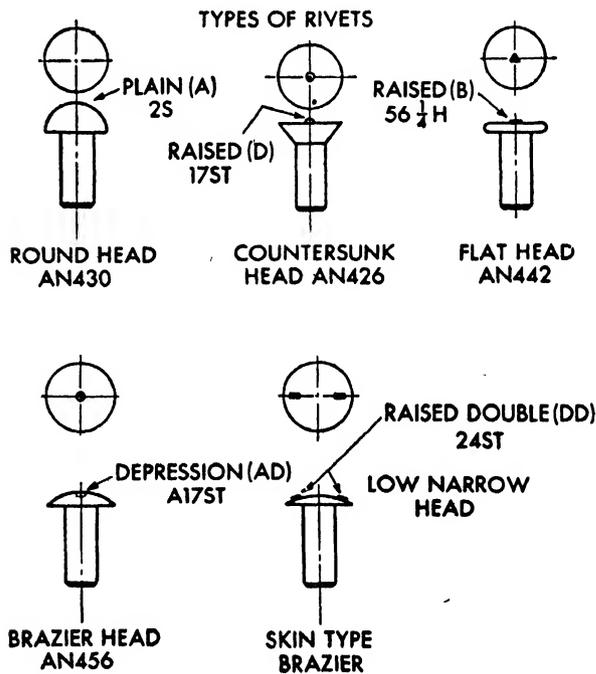


Fig. 337. Rivet process



NOTE: MATERIAL DESIGNATED BY MARKING ON HEAD. TYPICAL OF ANY HEAD SHAPE

Fig. 338

on large wings penetrating through skin and stringers generally are of  $\frac{3}{16}$  inch diameter and are spaced at 1 inch distances. They are countersunk on the upper surface from the leading edge back to an arbitrary percentage line or the rear spar. Rivets on the lower surfaces are  $\frac{3}{16}$  inch diameter or under, and are usually brazier headed.

*Edge Distance and Spacing*

A minimum edge distance of two diameters, termed "2d," is allowed except for very thin sheets where it should be greater than two diameters. Under certain conditions  $1\frac{1}{2}$  diameter edge distance is allowed. Rivets should be spaced no closer than three times their diameter (3d). Rivets are spaced on their center lines. For flush riveting, an edge distance of 2.5 diameters is desirable. Edge distances on dimpled sheets should be 2.5 diameters. (For methods of dimpling and countersinking, see Fig. 340.)

*Tolerances on Edge Distances*

To take care of discrepancies during fabrication, the following minimum limits are established on all general riveting. All work within

these limits is adequate in strength. Work not within these tolerances might be the subject of an inspection repair report.

Rivet Size, Inches	Edge Distance, Inches	Thickness of Sheet, Inches
$\frac{1}{8}$	$\frac{3}{4}$	Under 0.032
$\frac{3}{16}$	$\frac{1}{2}$	0.032 and over
$\frac{1}{4}$	$\frac{3}{4}$	Under 0.040
$\frac{5}{16}$	$\frac{1}{2}$	0.040 and over
$\frac{3}{8}$	$\frac{3}{4}$	Under 0.050
$\frac{7}{16}$	$\frac{1}{2}$	0.050 and over
$\frac{1}{2}$	$\frac{3}{4}$	Under 0.064
$\frac{5}{8}$	$\frac{1}{2}$	0.064 and over

*Accessibility*

The fact that rivets must be driven from one end and bucked from the other is too often overlooked. Extreme care should be taken to study any design for accessibility for bucking and driving rivets and the possibility of interference by adjacent structures, which would not allow ample clearance for riveting operations.

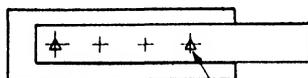
*Blind Riveting*

Blind riveting is a process where the nature

RIVETS MAY BE DESIGNATED ON THE FACE OF THE DRAWING BY THE FOLLOWING SYMBOLS. THE COMPANY RIVET STAMP MUST BE USED ON THE DRAWING WHENEVER RIVET SYMBOLS ARE EMPLOYED ON THE FACE OF THE DRAWING

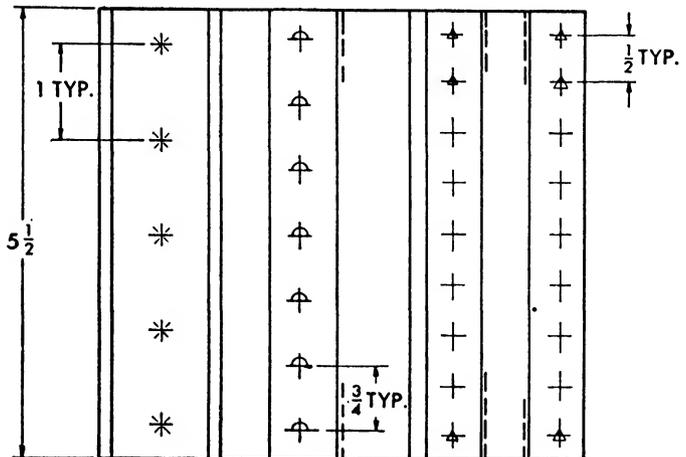
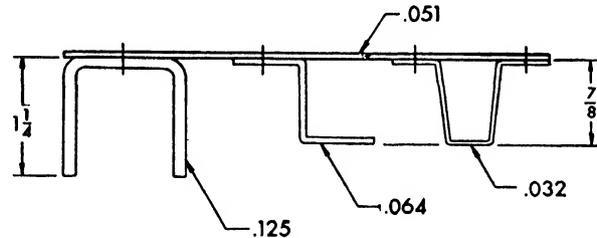
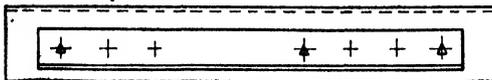
$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
+	◆	⊕	⊖	*	⊙	⊗	⊘

METHODS OF DESIGNATING RIVETS



AN442AD  
(RIVET DIA. IS LEFT OFF CODE NO. AND REPLACED BY  $\frac{1}{8}$  RIVET SYMBOL ◆)

IN A LONG LINE OF RIVETS AN OCCASIONAL SYMBOL DESIGNATES THE TYPE OF THE ENTIRE LINE



METHOD USED TO LOCATE AND SPECIFY RIVETS BY SYMBOLS

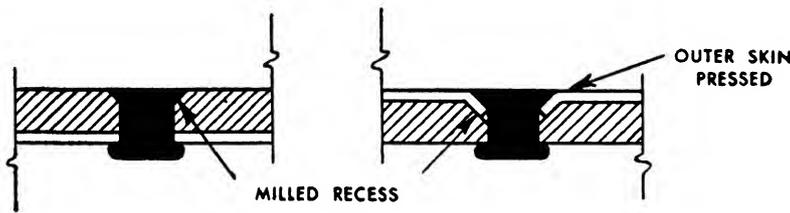
Fig. 339. Methods of designating rivets by symbols (standard edge distances are not dimensioned)

of the structure is such that it is impossible to get behind the rivet to buck it. There are two common methods of blind riveting, the Cherry rivet and the explosive rivet (Fig. 341).

The Cherry blind rivet is used for nonstructural parts. It is a hollow rivet with a stem or mandrel down the center of the shank. The bottom of the stem has a balled form. When the stem is pulled up by gun pressure, the ball forces the metal at the bottom of the shank outward,

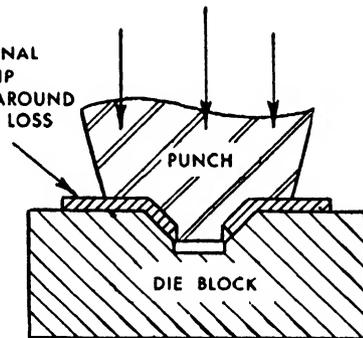
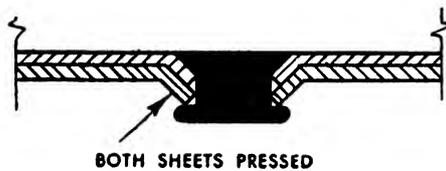
forming a closing head. This rivet may be used only when structural requirements are slight. The hollow shank and the type of closing head lessens its structural value considerably.

The explosive rivet is also utilized for blind riveting. This rivet is made from 17S-T aluminum alloy (heat treated and anodized), and contains a small powder charge inserted in a cavity at the end of the rivet shank. The application of an electrically heated riveting iron on the

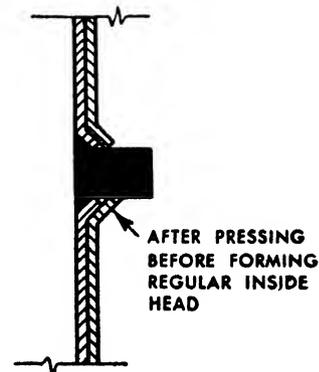
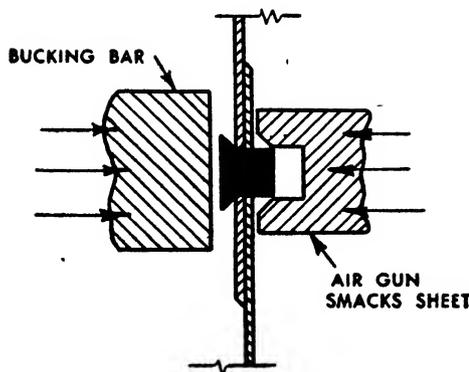


**FLUSH RIVET COUNTERSINKING**

WHEN A FLUSH SURFACE IS DESIRED ON THIN SHEET, CONVENTIONAL COUNTERSINKING IS NOT USED BECAUSE IT CUTS DOWN THE GRIP AREA OF THE SHEET. DIMPLING BENDS THE EDGE OF THE METAL AROUND THE HOLE DOWN TO ALLOW THE COUNTERSUNK HEAD WITHOUT LOSS OF GRIP AREA TO THE SHEET



**PRESS DIMPLING**



**AIR-GUN DIMPLING**

Fig. 340. Countersinking and dimpling

preformed head causes the charge in the rivet shank end to explode, creating the second head.

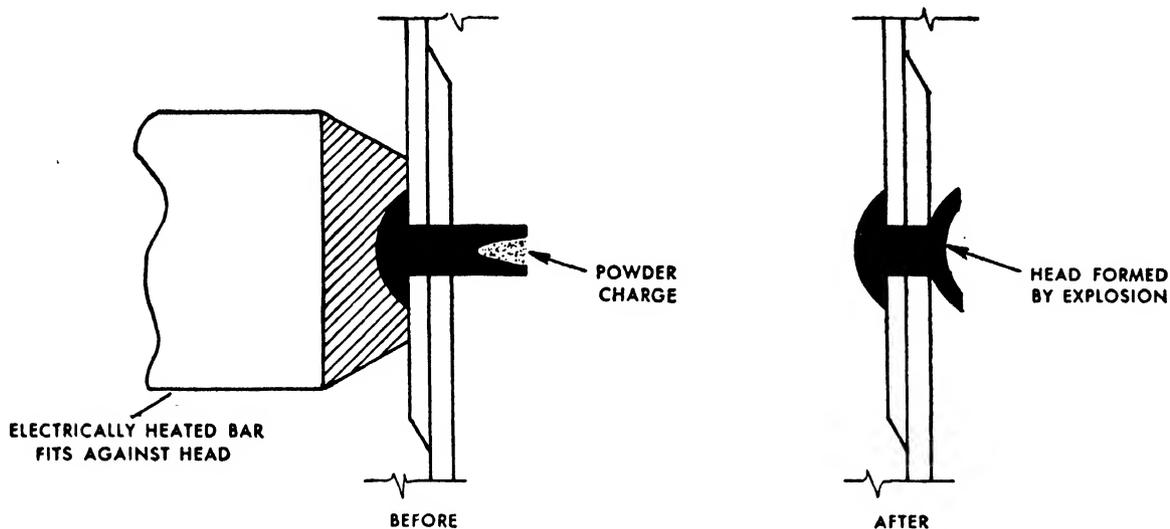
is necessary to discuss threads first in this type of fastener.

**BOLTS AND NUTS**

Bolts and nuts and a great variety of movable fasteners are actuated by threads. Therefore it

Although the aircraft draftsman is mostly concerned with threads as a device to fasten objects together, these also have other important applications. Threads may be used to *adjust* a

**EXPLOSIVE RIVET**



**CHERRY RIVET**

THIS RIVET IS A STANDARD AIRCRAFT RIVET THROUGH WHICH PASSES AN ALUMINUM ALLOY STEM

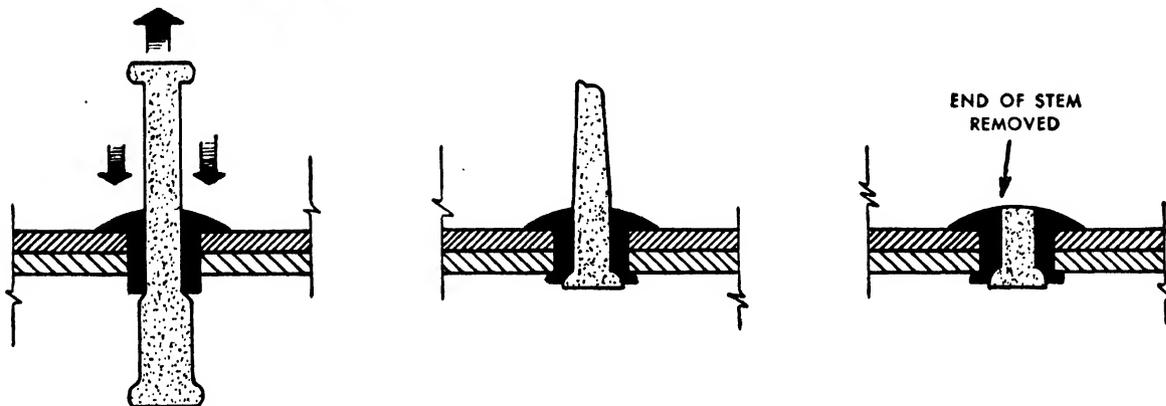
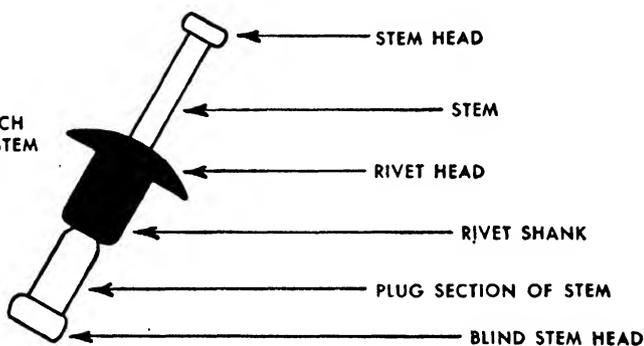


Fig. 341. Blind riveting. The stem in the self-plugging cherry rivet, when pulled up by a special gun, forms a tulip head, expands the rivet shank, permanently plugs the rivet, and breaks, releasing the gun. Then the stem is trimmed.

part; for example, a hatch hinge on a flying boat is adjusted on installation by varying the pressure of the bolts. Threads are used in jacks to exert pressure; they are used to transmit motion as in the lead screw of a lathe.

### Thread Terminology

The following terms and definitions apply to threads:\*

**SCREW THREADS.** A ridge of uniform section in the form of a helix on the external or internal surface of a cylinder.

**EXTERNAL THREAD.** A thread on the outside of a member such as the ridges or threads on a bolt.

**INTERNAL THREAD.** A thread on the inside of a member such as the ridges or threads in a nut.

**MAJOR DIAMETER.** The largest diameter of a screw thread. This applies to both internal and external threads.

**MINOR DIAMETER.** The smallest diameter of a screw thread. This applies to both internal and external threads.

**PITCH.** The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis. The pitch  $P$  is given by the formula

$$P = \frac{1 \text{ inch}}{\text{number of threads per inch}}$$

**LEAD.** The distance a screw thread advances axially in one turn.

**CREST.** The top surface joining two sides of a thread.

**ROOT.** The bottom surface joining the sides of two adjacent threads.

**SIDE.** The surface of the thread connecting the crest with the root.

**DEPTH OF THREAD.** The distance between the crest and the root of the thread, measured normal to the axis.

\* The American Standard Screw Threads, *ASA, Bulletin, 1.1, 1935.*

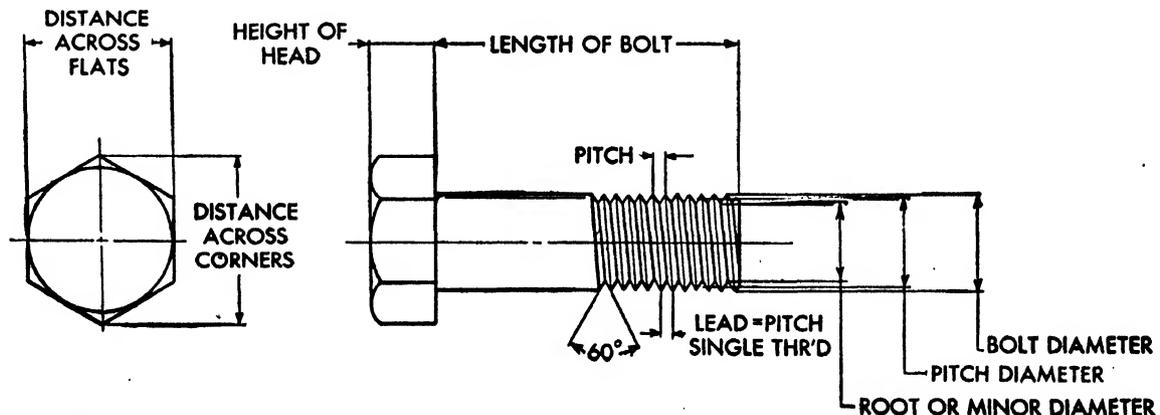


Fig. 342

**FORM OF THREAD.** The cross section of thread cut by a plane containing the axis.

**SERIES OF THREAD.** Standard tables fixing the number of threads per inch for various diameters.

A thread may be either left- or right-hand, depending on the direction it must be turned to make it advance. If no designation is given on a drawing, the threads are understood to be right-hand.

Threads may be single, double, or triple cut. Single cut threads are the most common. This thread is composed of one ridge and the lead is equal to the pitch. When threads are cut so that two ridges run side by side, it is called a "double thread," and the lead is equal to twice the pitch. Three ridges cut side by side constitute a triple thread, the lead equaling three times the pitch. Double and triple threads are used when a rapid advance is desired and power is secondary. Tooth paste caps, fountain pen tops, and the like are typical applications of multiple threads.

### The American Standard Threads

In aircraft production the American (National) Standard threads are used most frequently. These resemble in cross section a 60 degree V cut, slightly flattened at the root and crest.

Five series of threads are included in this standard. All have the same basic form but vary in the pitch or number of threads per inch for given diameters. Of this series the *coarse* and *fine* types are the most commonly used.

The **COARSE THREAD (N.C.)** is used for all general applications.

The **FINE THREAD (N.F.)** contains a greater

number of threads per inch and finds special predominance in aircraft work where additional threads are needed to offset constant vibration.

The **EIGHT PITCH THREAD (N8)** contains 8 threads per inch in all diameters from 1 to 6 inches.

The **TWELVE PITCH THREAD (N12)** contains 12 threads per inch in all diameters from  $\frac{1}{2}$  to 6 inches.

The **SIXTEEN PITCH THREAD (N16)** contains 16 threads per inch in all diameters from  $\frac{3}{4}$  to 4 inches.

The American Standards Association has established four classes of fits. These fits are referred to by number when designating threads on the drawing. The classes are as follows:\*

**CLASS 1 FIT.** Recommended only for screw thread work where clearance between mating parts is essential for rapid assembly and where shake or play is not objectionable.

**CLASS 2 FIT.** Represents a high quality of commercial thread product and is recommended for the great bulk of interchangeable screw thread work.

**CLASS 3 FIT.** Represents an exceptionally high quality of commercially threaded product and is recommended only in cases where the high cost of precision tools and continual checking is warranted.

**CLASS 4 FIT.** Intended to meet very unusual requirements, more exacting than those for which Class 3 is intended. It is a selective fit if initial assembly by hand is required. It is not, as yet, adaptable to quantity production.

#### Methods of Drawing and Calling Out Threads

It is obvious that, because of their complex shape, the draftsman would spend unwarranted time in drawing bolts, nuts, and threads. Therefore a more rapid method is employed, as shown in Fig. 343. Since most movable fasteners are

standardized, a center line with a notation is frequently used instead of this system (see Fig. 352).

Threads are called out on the drawing by a notation, for example,  $\frac{1}{2} \times 13\text{NC}-3$ . The first number designates the major diameter,  $\frac{1}{2}$  inch. The second number indicates the number of threads per inch, 13. The letters NC define the threads series: National Coarse. The -3 identifies the class of fit.

As a rule, steel bolts smaller than  $\frac{5}{16}$  and aluminum alloy bolts smaller than  $\frac{1}{4}$  are not used in primary or vital structures.

Standard hexagonal head bolts (AN3 through AN16) are satisfactory for use in all joints except those subject to heavy hammering action. The holes must be reamed for the bolts when they are used in joints subject to reversal of load or when more than one bolt shares the load in a joint.

Since the bolts may vary  $\frac{1}{8}$  inch in length, it is sometimes necessary and permissible to use pack washers. When it is known that washers will be necessary, they must be specified on the drawing, but in assembly, the shop may use pack washers whenever necessary without any specification on the print.

Steel clevis bolts (AN23 through AN28) are satisfactory in all joints subject to shear only, or to shear and axial load of not more than half the rated tensile load of a standard aircraft hexagonal head bolt of the same diameter.

Whenever design demands, special bolts or studs are machined. This process is expensive and time consuming and should be resorted to only when standard bolts cannot be used or cannot be modified.

\* ASA B 1.1, 1935.

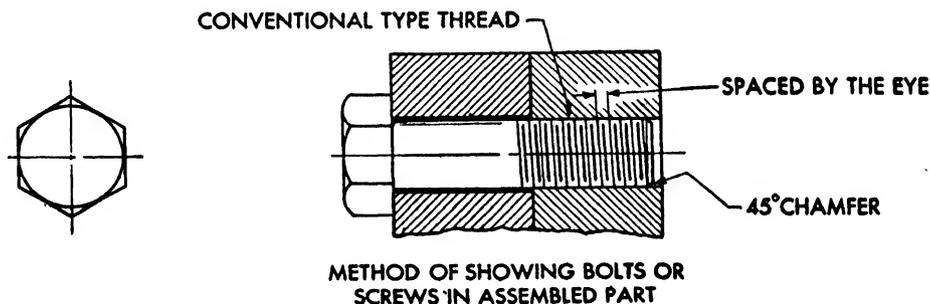


Fig. 343

AIRCRAFT DRAFTING

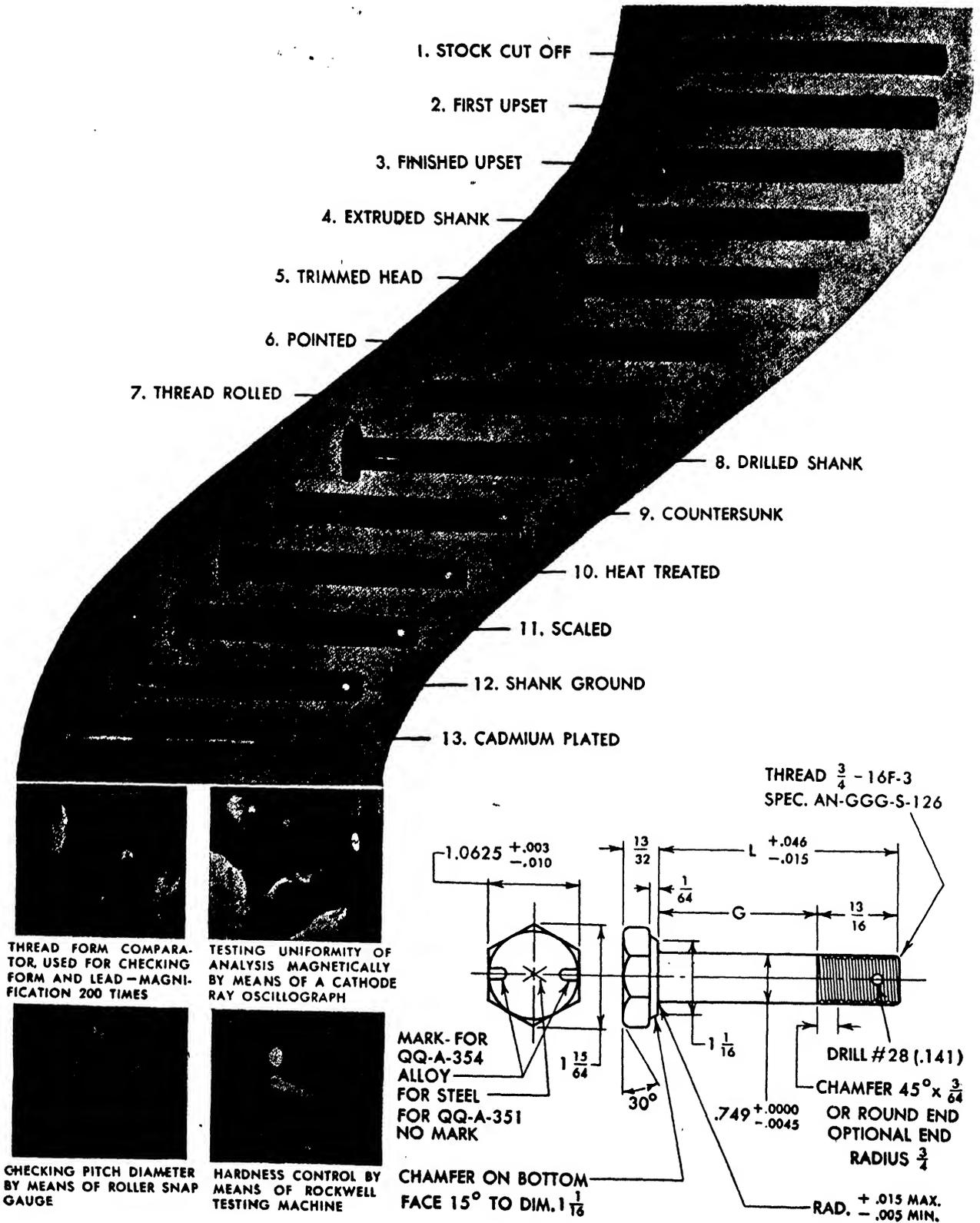


Fig. 344. Army and Navy specifications and steps in manufacturing an aircraft bolt

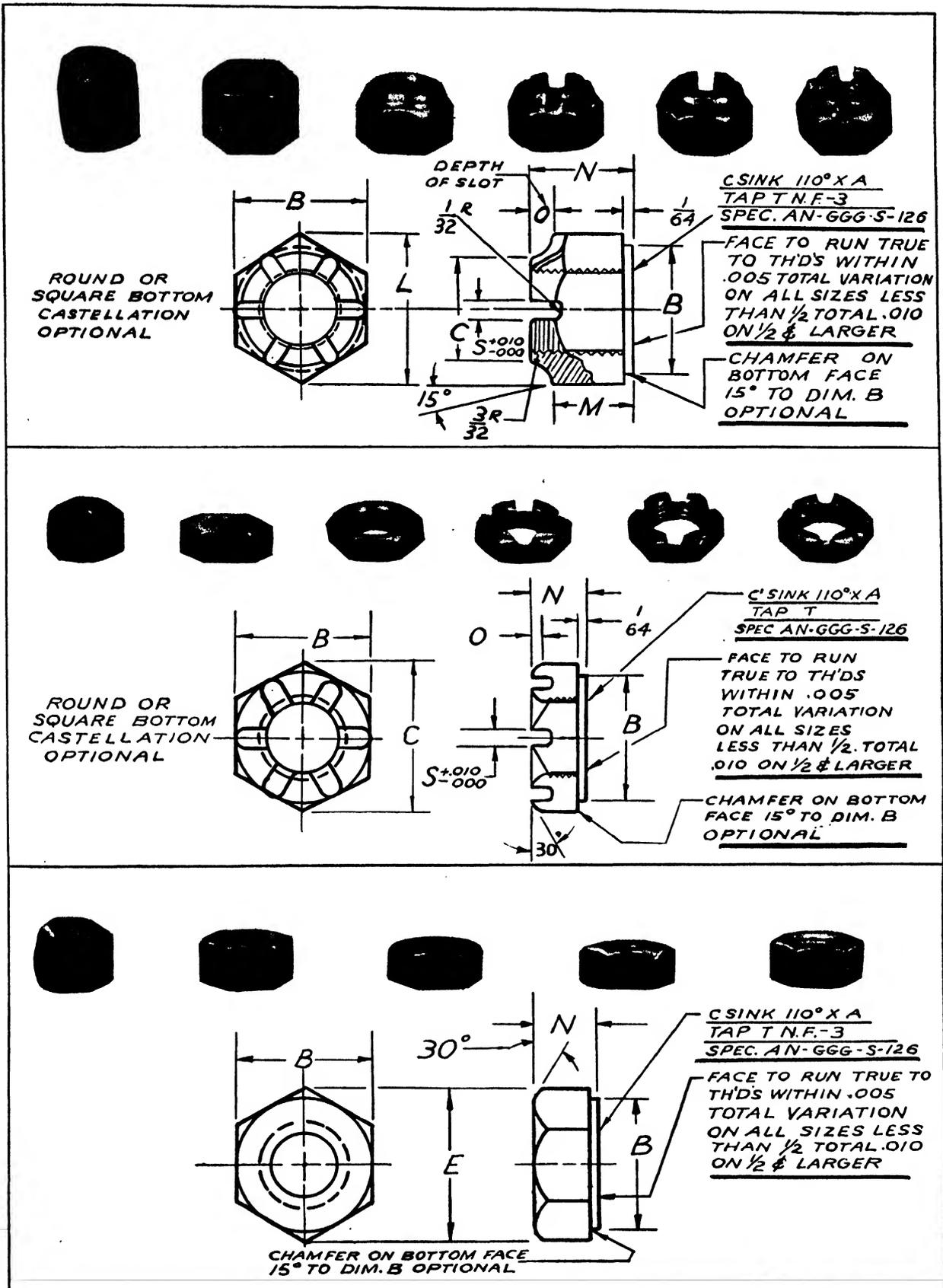


Fig. 345. Army and Navy specifications and methods of manufacturing aircraft nuts

Various questions come up regularly in the drafting room. They are:

1. *Does a part of an assembly require removal every now and then to permit changes of equipment or because of wear?*

If so, use a series of special bolts that have been standardized by the Army and Navy and appear in the AN book (AN3 to AN16). They are made to closer tolerances than the average commercial bolt.

2. *What size bolts shall I use?*

Use no steel bolts of less than  $\frac{3}{16}$  inch diameter and no aluminum alloy bolts of less than  $\frac{1}{4}$  inch diameter in any primary structure. Aluminum alloy bolts of less than  $\frac{1}{4}$  inch diameter may be used in secondary structures.

On primary structures the threaded portion of a bolt should not take shear loads, and the threads must not take bearing. Use standard spacer washers (AN960). Use standard AN bolts whenever possible.

3. *What type nut shall I use?*

Use a castellated (AN310) nut and lock with

cotter pins (AN380) when the removal of bolt and nut may be required. Another type would be the self-locking nut, approved by the Air Corps and called out as AC365. The latter type should not be used where the nut or bolt are subject to rotation. Neither should they be used with bolts that have been drilled for cotter pins, or where the temperature exceeds 250 degrees Fahrenheit.

The draftsman should also remember a few specific facts:

Aluminum alloy nuts are not to be used on bolts in tension.

Aluminum alloy nuts may be used on landplanes. Aluminum alloy nuts should not be used on seaplanes.

Aluminum alloy nuts and bolts should not be used where they will be repeatedly removed.

Commercial machine screws and bolts should not be substituted for the AN standard screws and bolts.

Washers may be used under nuts when necessary.

Many aircraft parts must be removed from time to time because of equipment wear, inspection, or modification. These parts—generally machined parts, castings, forgings, and thicker sheet metal parts—are fastened by bolts and nuts.

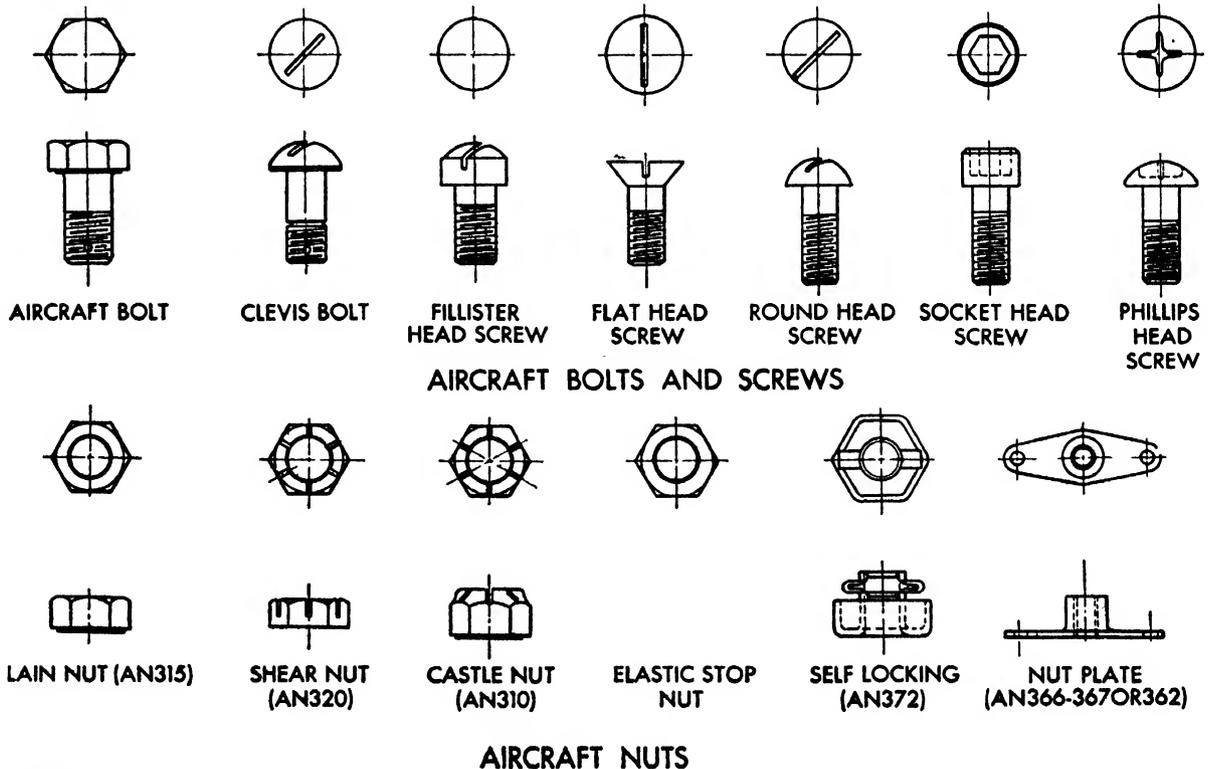


Fig. 346

Besides permitting temporary fastening, the additional strength that bolts give to the part on which they are used is a factor in their frequent application in certain structural joints. A bolt may be applied to a threaded part, going partially into the object, or it may be set into holes drilled through pieces to be joined and then tightened by a nut. Usually, the term "bolt" is applied to a through bolt going directly through the parts to be joined and fastened by a nut.

Screws are similar to the through bolts, but they have more threads and generally do not need a nut. The gripping action is obtained by threading the part into which the screw enters.

Screws generally fall into three types: the machine screw, used for fastening small machine parts, the cap screw—similar to the machine screw but larger—and the set screw used to secure wheels, pulleys, etc., to a rotating shaft.

A stud is usually made from a steel rod, without a head, and threaded on both ends. The stud is generally passed through a hole in one part and is screwed into another part that has

been threaded to receive it. A nut may be used on the free end. (See Chapter Twenty-Two for design data on studs.)

### The AN Bolts

Like rivets, bolts and nuts have been standardized because of their wide range of application in the airplane.

The most common type of bolt has been standardized by the Army and Navy and appears in the *AN Standard Parts Book*. Because bolts are the first of the standard parts listed in this book, they have the lowest AN numbers, starting from AN3.

The popular hexagon head aircraft bolts are listed from AN3 to AN16.

The bolts are made especially for the aircraft industry from a high-strength steel and to much closer tolerances than the ordinary commercial bolts. Figure 344 describes the process of manufacturing this type of bolt, along with the specifications of the bolt as they appear in the AN book.

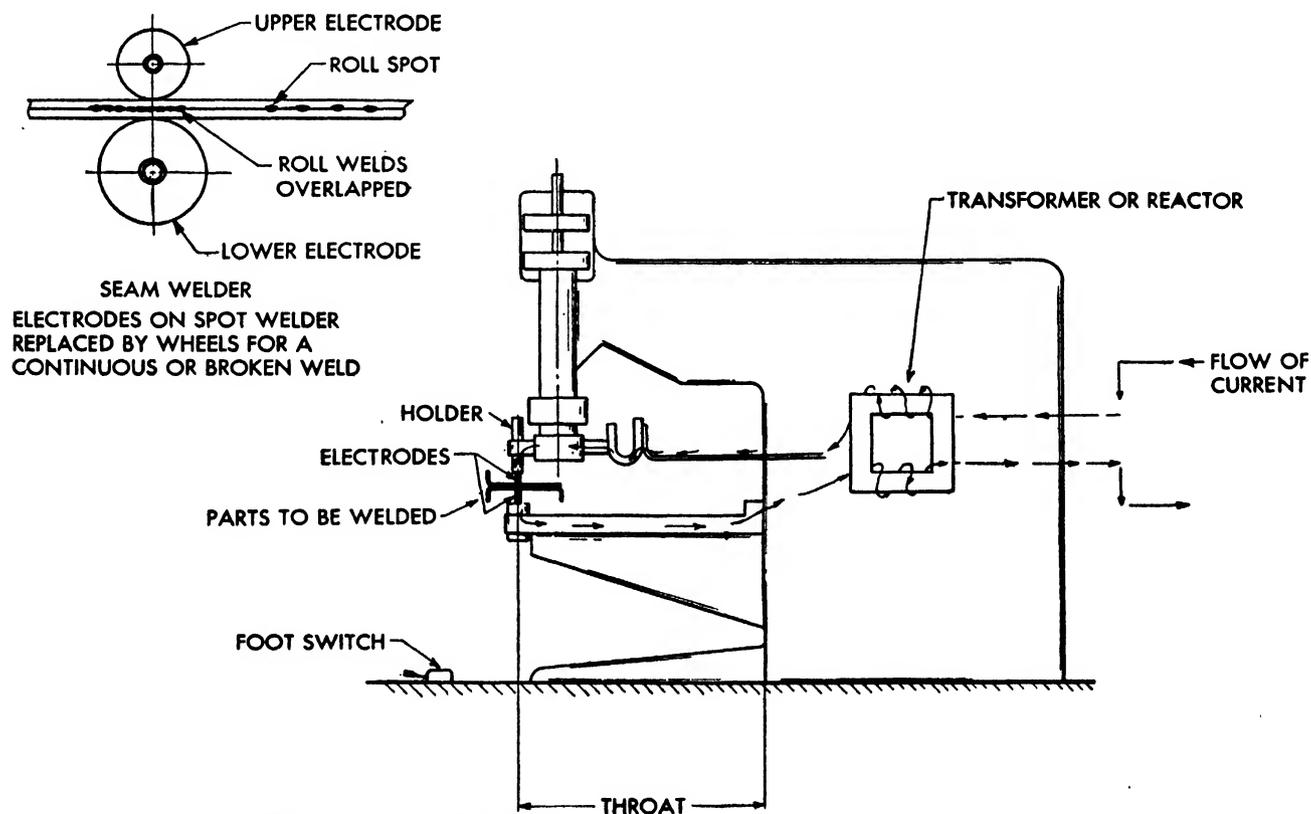


Fig. 347. Schematic diagram of spot welding machine

*Method of Calling Out*

The aircraft bolts from AN3 to AN16 are called out on the face of the drawing in the following manner: The number after the letters AN designates the diameter of the bolt shank in sixteenths of an inch. For example, AN4 indicates a bolt of  $\frac{1}{4}$  inch diameter, AN5, a bolt of  $\frac{5}{16}$  inch diameter, etc. A dash number following the shank designation indicates the length of the bolt in grades of  $\frac{1}{8}$  inch. Hence, AN4-6 would be  $\frac{3}{4}$  inch long and AN4-5 would be  $\frac{5}{8}$  inch long. These grades follow up to -7. Dash 8 and -9 have been eliminated, and -10 indicates a bolt 1 inch in length. A bolt  $1\frac{1}{2}$  inches long would be called out as -14 (the  $\frac{1}{8}$  inch grades resuming after -10). Dash 20 designates a bolt 2 inches long, -25, a bolt  $2\frac{5}{8}$  inches long, and so forth. Bolts without cotter pins are designated by adding an "A" to the part number, e.g., AN 3-6A. See Figure 354 for illustration of AN4 page of the AN book, Vol. I.



Fig. 348. Spot welding enclosure framework

*Aircraft Nuts*

Numerous types of steel nuts may be used with aircraft bolts. Some of the most common are the castle nut, the plain nut, the shear nut and the elastic stop nut.

The castle nut is so called because its shape resembles the turrets of a medieval castle. These nuts are kept in place on the bolts by a cotter pin (AN380) which passes through a turret opening of the nut and through a cotter pin hole drilled in the bolt. They are called out on the drawing by AN310 and a dash number pertaining to the bolt number. Hence, a castle nut for an AN3 bolt is called AN310-3, etc.

The plain nuts are indexed as AN315. The method of further identification is similar to the castle nut, insofar as it is followed by a dash number pertaining to the length of the bolt, but the letters R or L follow to indicate a right- or left-hand thread. Hence, a plain nut for an AN5 bolt is called out as AN315-5R or AN315-5L.

Elastic stop nuts have a tight elastic fiber bushing that contacts the threads of the bolt upon application. This gripping action tends to keep the nut stable, and it will not loosen itself under constant vibration. They may be found in the AN book listed as AN365.

The steps in manufacturing castle, shear, and plain nuts are shown in Fig. 345 along with their specifications in the AN book.

These nuts are precisely manufactured and pass rigid inspection before they are used in the plane. Some of the varied types of aircraft bolts and nuts are shown in Fig. 346.

## WELDING

Since the introduction of aluminum to the aircraft industry, the welding of aluminum has been studied extensively, not only to reduce the weight of planes but to step up production. Welding aluminum is difficult because of the metal's great conductivity and the resulting quick loss of heat. Nevertheless, remarkable progress has been made lately, especially in the field of resistance welding. This is a process whereby two or more pieces of metal are fused together by an electric current passed through the contacting surfaces.

Two types of resistance welding are commonly used in the aircraft industry, spot welding and seam welding. These processes not only save time and money, but also produce a finished part that could not be attained if rivets were employed. For example, a flange is to be attached to a duct for use in the cabin pressure system. Since the duct must be pressure tight, a riveted joint is out of question because it is subject to leakage. A good, pressure-tight flange is obtained by the seam welding process (Fig. 347). On many other parts with light loads, seam welding is more satisfactory than other forms of welding or riveting. Spot welded parts (Fig. 348) are usually designed to carry shear loads but can take loads in tension, providing the load is not great. Strength of weld depends greatly on the thickness of the material welded and the setting of the machine. A good weld is one that extends one-half the thickness of the sheet. Of course, if the operator allows too much time and current, the result will be a weld that has burned completely through the sheets and also through the protective Alclad coating, inviting corrosion.

The draftsman or the designer should not permit the spot welding of two sheets of aluminum of which one is more than three times as thick as the other, for example, an 0.064 and an 0.016 inch plate. An attempt at welding will cause the thin plate to burn. Spot welds should be placed  $\frac{1}{2}$  inch apart on a running length for gages up to 0.032 inch, and 1 inch for heavier gages. In accord with Army specifications, a rivet should be placed at the far ends of the spot welds.

#### *Edge Distance for Spot Welding*

Edge distance is very important in spot welding, just as in riveted joints, and is governed by the gage size. The edge distance for gages up to 0.040 inch should not be less than  $\frac{3}{8}$  inch. Gages over 0.040 through 0.102 inch should be  $\frac{1}{2}$  inch and should be called out on the drawing. If the edge distance is too close, a loss in current results, weakening the weld. The distance between spot welds varies with the gage of the material and should be looked up in the company welding manual, or the welding section of the Engineering Manual.

#### *Seam Welder*

The seam welder is similar to the spot welder, but the electrodes are replaced by a pair of rollers 6 to 9 inches in diameter. A continuous weld or a roll spot can thus be made with one setting of the machine. A continuous air- and watertight weld usually requires a double continuous seam weld, providing the part is rather large. But care must be taken by the operator of the machine, or leakage will result. If a roll seam is desired where air- and watertight qualities are unimportant, the desired weld may be called out on the drawing as SEAM WELD 1 INCH LONG EVERY 5 INCHES.

#### *Other Welding Methods*

Other methods of welding are not used as extensively as those previously mentioned—gas welding or welding with oxyacetylene or oxyhydrogen flames take time and practice before good results are accomplished. Engine mounts (Fig. 349) are sometimes gas welded with good results from aluminum tube. However, most air-



Fig. 349. Arc welding engine mount

craft companies prefer mounts made from welded stainless steel tubing.

In certain cases, it is more practical to torch weld rather than seam weld water tanks and oil coolers. Space is the governing factor, for example, in the oil cooler in the nacelle of an airplane. Seam welding would require a flange on the tank for welding purposes, thus increasing the size of the tank.

In torch welding an aluminum tank or any other part, where distortion may occur due to the required high temperature of welding, tack welding is done, that is, welds from 1 to 2 inches apart are made before the final welding. However, such tack welding is necessary only when the material is  $\frac{1}{8}$  inch thick or less. (See Chapter Twenty-Two for welding design data.)

#### *Commonly Used Fasteners*

In addition to bolts, screws, nuts, etc., the aircraft industry employs a number of less familiar fasteners. The more common of these are listed below.

**RIVNUTS.** The head is formed on the inaccessible side of an internally threaded hollow rivet by a special tool which is threaded into the rivet. This type may also be used as a nut plate.

**SELF LOCKING NUTS.** These eliminate the necessity for the use of cotter pins. The first two types are made

in the form of nut plates, gang channels, and other special applications.

*Elastic stop nuts*, which are prevented from loosening from the mating bolt by a fiber insert in the top of the nut which maintains a constant pressure between the threads of the nut and bolt.

*Boots nuts*, which are essentially two nuts connected by a spring section. After the bolt has passed through the lower part of the nut, it reaches the upper part, the threads of which are out of lead with the lower part. The spring section allows the upper part to extend until the threads engage, and thereafter maintains a constant pressure between the threads of the nut and bolt, preventing loosening.

*Tinnerman speed nuts*, which are simple nuts formed from a single piece of sheet metal. They have many stock forms and nonstructural applications.

*Dzus type fasteners*, which are used as positive fastenings in sheet metal parts requiring frequent engagement and disengagement.

*Dzus fasteners*, which consist essentially of a slotted post on the part to be fastened. This post may be turned to positively engage a wire spring riveted to the fixed structure. A number of different types of post heads are available as well as special springs for difficult locations.

*Shakeproof fasteners*, which perform the same function as Dzus fasteners. Instead of the post being slotted, it is pierced by a projecting pin and the spring is replaced by a sheet metal plate. The pin rides on a cam-shaped track on the plate to accomplish the positive fastening.

## CHAPTER SEVENTEEN

# STANDARD PARTS

It would be highly impractical to design and produce fresh rivets, bolts, nuts, fittings, and structural sections for each new airplane. Therefore, various agencies have compiled lists of thousands of parts designed for versatility of application, ease of quantity manufacture, and urgency of demand.

A standard part is one that is applicable to many designs, not limited to one airplane. The use of standard parts, of course, saves time and expense, but it also serves a more vital need. In servicing and inspecting airplanes in the field, replacement parts are frequently required, and if the parts are standard these are readily obtainable. In wartime or in the operation of an airline, this consideration is especially important, because delay in obtaining some special bolt or fitting may keep a plane on the ground for days or even weeks.

Standard parts are usually in such demand that mass production is essential. While a special part must be made practically by hand, a standard part can be manufactured much more quickly and economically by machine. It would be unwise to make large numbers of special parts before their use was assured, but the number of standard parts required can be anticipated to a

certain extent, and therefore they can be stocked when and where they are likely to be needed. A good rule for a draftsman to follow is: "wherever possible, use a standard part."

Much time and expense may be saved in designing such miscellaneous pieces as clips and brackets by modifying standard parts. For example, we can readily see that the manufacture of the clip shown in Fig. 351 would require an elaborate and expensive procedure. Yet, by altering an already formed standard part, such as the common extruded angle, that may be stocked in large quantities in the stock room, manufacturing becomes simple. The notation on the drawing will read: MAKE FROM EXTRUDED ANGLE OF MAKE FROM K11671 (the number of the extruded angle).

Another reason to use standard parts is that a great deal of drafting time is eliminated. For instance, instead of actually drawing a picture of every bolt, nut, and rivet on an assembly, only their center lines may be shown, and by means of an arrow and a leader they are called out and identified (Fig. 352). In cross-sectional views, bolts may be shown as short center lines and rivets as short, unbroken lines.

Some companies have even dispensed with

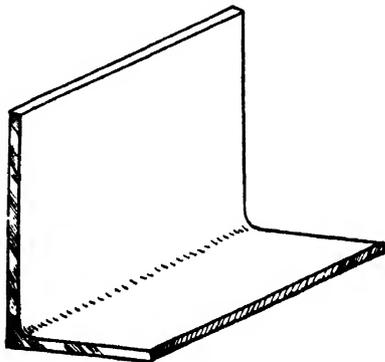


Fig. 350. Extruded angle

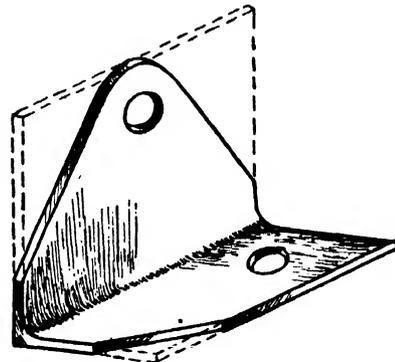


Fig. 351. Clip made from extruded angle

labeling rivets. Instead, a code of rivet symbols is stamped on the bottom of the drawing sheet, near the bill of materials and the title block. Thus much tedious work is eliminated for the draftsman. The symbols in use at Consolidated Vultee are shown in Fig. 339.

There are several agencies which design and publish catalogues of standard parts. The most important are the Army Air Corps, the Navy, the Naval Aircraft Factory, the various aircraft

on this page are of  $\frac{1}{4}$  inch diameter and have 28 threads per inch. Looking through the table, it is found that the required  $\frac{1}{8}$  inch grip is given as "-11." This, then, is the desired bolt. It is called out on the drawings as "AN4-11." Of course, the length from head to thread end should also be checked to see that the bolt is not too long or too short for the purpose.

It will be noticed that the standard plain nut and the standard castle nut with cotter pin are

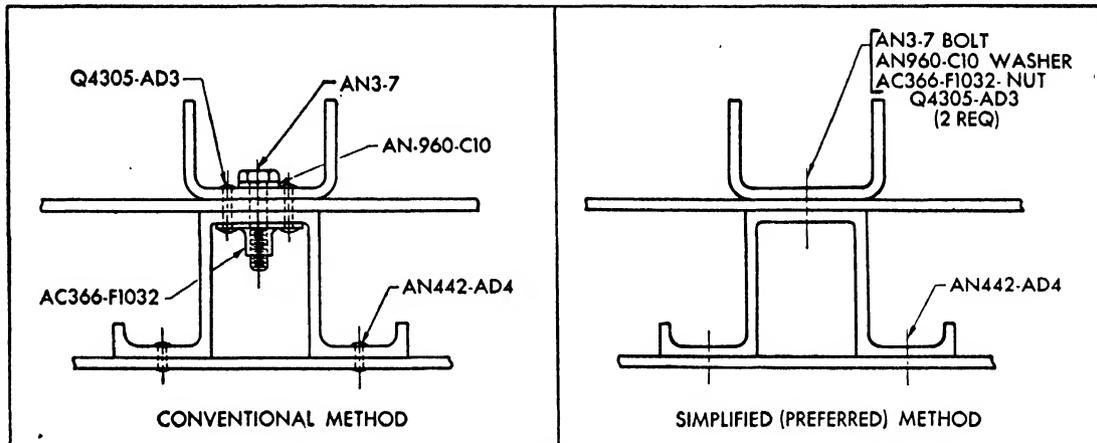


Fig. 352

companies, and a large number of parts manufacturers.

The parts standardized by the Air Corps and the Navy are listed in a book called the "AN book." It includes the specifications of bolts, nuts, pins, washers, rod ends, turnbuckles, etc. A large number appears in the lower right-hand corner on each page of the AN book, serving as page number and as the basic drawing or part number. Each page has a name, and this name applies to the part listed thereon, regardless of size. Since many sizes are given on each sheet and since each sheet has only one basic number, a code system is used to identify these sizes. Some of the basic drawing numbers are prefixed by the letters "AN." This means that the part has been approved by both the Army Air Corps and the Navy Standards Committee.

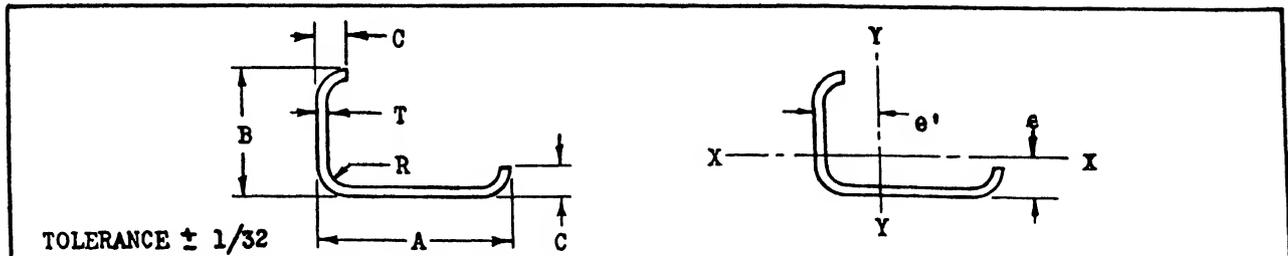
Suppose, for example, that, in designing a joint, a  $\frac{1}{4}$  inch diameter steel bolt is required with an  $\frac{1}{8}$  inch grip length. The page in the AN book numbered "AN4" is entitled "Bolt Aircraft- $\frac{1}{4}$  28," which means that all bolts listed

listed on the same page, and one of these should be used with this bolt. The bolt has a hole drilled through its threaded end for the cotter pin. Therefore, locking nuts with fiber inserts should not be used with it because sharp edges of the hole would cut the fiber.

Most parts listed in the AN book are coded in a similar manner, and with a little practice the draftsman will have no difficulty finding the number of a part.

The classifications of many of the navy standard parts are issued in conjunction with the army. However, some are published independently by the Naval Aircraft Factory, and these may be found either in a separate book or in the back section of the AN book.

Aircraft companies use a great many of their own standard parts. These parts are listed in one or more standards books, and some are shown on regular drawing sheets which have been given a special number. For instance, Consolidated Vultee assigns numbers to standard drawings, preceded by the letters "XM." The same



TOLERANCE  $\pm 1/32$

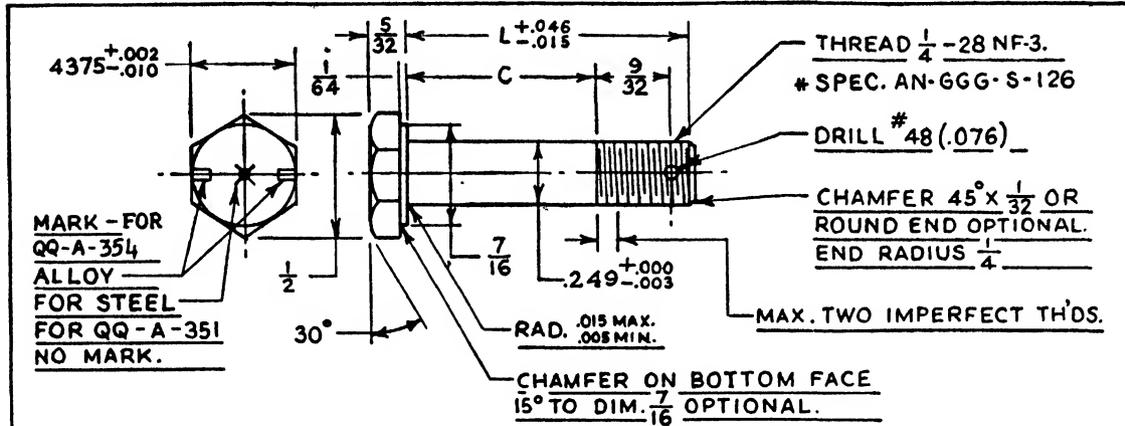
DASH NO.	SIZE					STRIP WIDTH	AREA SQ. IN.	WT. #/IN.	X-X AXIS			Y-Y AXIS		
	A	B	C	R	T				I IN. <sup>4</sup>	$\rho$ IN.	e IN.	I IN. <sup>4</sup>	$\rho$ IN.	e' IN.
-10	3/4	5/8	3/16	1/8	.032	1 1/2	.0480	.0046	.00205	.208	.191	.00306	.255	.256
-11	3/4	5/8	3/16	1/8	.040	1 7/16	.0575	.0060	.00238	.203	.192	.00364	.251	.257
-21	1	3/4	3/16	1/8	.040	1 13/16	.0724	.0070	.00431	.244	.208	.00831	.338	.337
-22	1	3/4	3/16	1/8	.051	1 13/16	.0910	.0089	.00517	.239	.209	.01007	.333	.339
-23	1	3/4	3/16	1/8	.064	1 3/4	.1120	.0106	.00604	.234	.211	.01190	.329	.341
-27	1	7/8	7/32	1/8	.072	1 15/16	.1370	.0134	.01065	.280	.265	.01456	.327	.329
-28	1	7/8	3/16	1/8	.064	1 15/16	.1200	.0120	.00922	.279	.255	.01262	.310	.320
-30	1	7/8	3/16	1/8	.051	1 15/16	.0972	.0098	.00782	.284	.254	.01065	.316	.318
-36	1 1/4	7/8	3/16	1/8	.051	2 3/16	.1099	.0111	.00839	.277	.228	.01924	.419	.419
-37	1 1/4	7/8	3/16	1/8	.064	2 3/16	.1379	.0133	.00991	.271	.229	.02261	.409	.420
-38	1 1/4	7/8	7/32	1/8	.072	2 3/16	.1552	.0158	.01149	.273	.238	.02652	.415	.431
-39	1 1/4	7/8	7/32	1/8	.080	2 3/16	.1700	.0165	.01224	.269	.239	.02847	.411	.432
-42	1 1/4	1	3/16	1/8	.051	2 5/16	.1163	.0119	.01199	.322	.271	.02018	.417	.398
-43	1 1/4	1	3/16	1/8	.064	2 1/4	.1440	.0143	.01428	.316	.271	.02371	.407	.398
-45	1 1/4	1	7/32	1/8	.080	2 1/4	.1800	.0172	.01766	.314	.282	.02994	.409	.411
-74	1 1/2	1	7/32	1/8	.080	2 1/2	.2000	.0200	.01873	.307	.257	.04893	.496	.514
-75	1 1/2	1	7/32	1/8	.091	2 1/2	.2226	.0217	.02065	.305	.259	.05365	.491	.516

*Handwritten initials*

DRAWN	<i>Boyle</i>	<i>Kuzman</i>	ANGLE - UNEQUAL - 90° - FLANGED	PART NUMBER
APPROVED	<i>Hagan</i>	6-19-41		<b>Y7</b>
APPROVED	<i>Miller</i>	6/21/41		
CONSOLIDATED AIRCRAFT CORPORATION LINDBERGH FIELD SAN DIEGO, CALIF				

Fig. 353

U. S. ARMY AIR CORPS, MATERIEL DIVISION, DAYTON, OHIO



DASH NOS.	L'GTH	G									
			22	2 1/4	1 13/16	42	4 1/4	3 13/16	62	6 1/4	5 13/16
3	3/8	0	23	2 3/8	1 15/16	43	4 3/8	3 15/16	63	6 3/8	5 15/16
4	1/2	1/16	24	2 1/2	2 1/16	44	4 1/2	4 1/16	64	6 1/2	6 1/16
6	5/8	3/16	25	2 5/8	2 3/16	45	4 5/8	4 3/16	65	6 5/8	6 3/16
6	3/4	5/16	26	2 3/4	2 5/16	46	4 3/4	4 5/16	66	6 3/4	6 5/16
7	7/8	7/16	27	2 7/8	2 7/16	47	4 7/8	4 7/16	67	6 7/8	6 7/16
10	1	9/16	30	3	2 9/16	50	5	4 9/16	70	7	6 9/16
11	1 1/8	11/16	31	3 1/8	2 11/16	51	5 1/8	4 11/16	71	7 1/8	6 11/16
12	1 1/4	13/16	32	3 1/4	2 13/16	52	5 1/4	4 13/16	72	7 1/4	6 13/16
13	1 3/8	15/16	33	3 3/8	2 15/16	53	5 3/8	4 15/16	73	7 3/8	6 15/16
14	1 1/2	1 1/16	34	3 1/2	3 1/16	54	5 1/2	5 1/16	74	7 1/2	7 1/16
15	1 5/8	1 3/16	35	3 5/8	3 3/16	55	5 5/8	5 3/16	75	7 5/8	7 3/16
16	1 3/4	1 5/16	36	3 3/4	3 5/16	56	5 3/4	5 5/16	76	7 3/4	7 5/16
17	1 7/8	1 7/16	37	3 7/8	3 7/16	57	5 7/8	5 7/16	77	7 7/8	7 7/16
20	2	1 9/16	40	4	3 9/16	60	6	5 9/16	80	8	7 9/16
21	2 1/8	1 11/16	41	4 1/8	3 11/16	61	6 1/8	5 11/16			

ENGINEERING INFORMATION

MATERIAL	STAND. PLAIN NUT	STAND. CASTLE NUT COTTER PIN AN380-2-2	TEN. STR. AT ROOT DIA.	YIELD STR. AT ROOT DIA.	SINGLE SHEAR FULL DIA.
STEEL	AN315-4R	AN310-4	3980#	3180#	3680#
ALUM. AL. QQ-A-354	AN315D4R MAX. GRIP = G + 1/8	AN310D4 MAX. GRIP = G + 1/8	1970#	1270#	1710#
ALUM. AL. QQ-A-351			1750#	950#	1470#

EXAMPLE OF PART NO. - AN4-4 = BOLT - STEEL  
 AN4D4 = BOLT - ALUM. ALLOY (QQ-A-351)  
 AN4DD4 = BOLT - ALUM. ALLOY (QQ-A-354)  
 \* ADD "A" TO PART NUMBERS TO DESIGNATE BOLTS WITHOUT COTTER PIN HOLES  
 AS AN4-4A, AN4D4A, AN4DD4A

NOTE - BOLTS OF QQ-A-351 INACTIVE FOR

DESIGN AND PROCUREMENT.

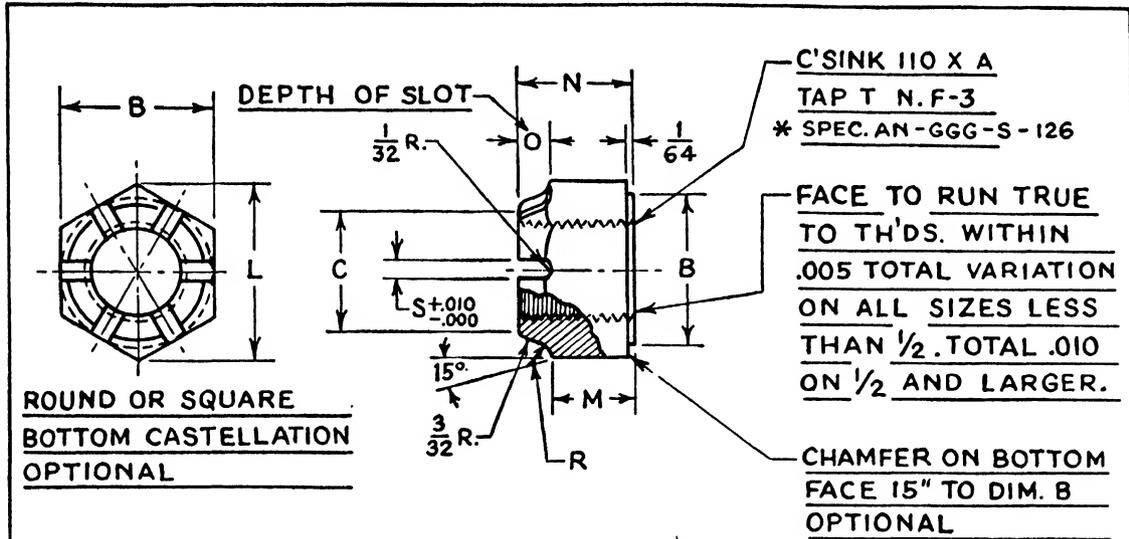
SPECIFICATION 29-59  
 LIMITS ON DIMENSIONS ±.010 UNLESS OTHERWISE SPECIFIED

B/M

APPROVED	AIR CORPS STOCK CLASSIFICATION 04A	ARMY & NAVY STD.
3-22-26	BOLT - AIRCRAFT - 1/4-28	<b>AN 4</b>

Fig. 354

U. S. ARMY AIR CORPS, MATERIEL DIVISION, DAYTON, OHIO



DASH NUMBERS		TAP T	A	B	N	M	O	S	C	R	L
STEEL	ALUM. AL.										
3	D3	#10-32	.190	$\frac{3}{8} +.002$ $-.010$	$\frac{1}{4}$	.110	$\frac{9}{64}$	$\frac{5}{64}$	.221	$\frac{3}{32}$	$\frac{7}{16}$
4	D4	$\frac{1}{4}$ -28	$\frac{1}{4}$	$\frac{7}{16} +.002$ $-.010$	$\frac{9}{32}$	.125	$\frac{5}{32}$	$\frac{5}{64}$	.312	$\frac{3}{32}$	$\frac{1}{2}$
5	D5	$\frac{5}{16}$ -24	$\frac{5}{16}$	$\frac{1}{2} +.002$ $-.010$	$\frac{21}{64}$	.172	$\frac{5}{32}$	$\frac{5}{64}$	.375	$\frac{3}{32}$	$\frac{37}{64}$
6	D6	$\frac{3}{8}$ -24	$\frac{3}{8}$	$\frac{9}{16} +.0025$ $-.010$	$\frac{13}{32}$	.218	$\frac{3}{16}$	$\frac{1}{8}$	.437	$\frac{3}{32}$	$\frac{21}{32}$
7	D7	$\frac{7}{16}$ -20	$\frac{7}{16}$	$\frac{5}{8} +.0025$ $-.010$	$\frac{29}{64}$	.265	$\frac{3}{16}$	$\frac{1}{8}$	.532	$\frac{3}{32}$	$\frac{23}{32}$
8	D8	$\frac{1}{2}$ -20	$\frac{1}{2}$	$\frac{3}{4} +.0025$ $-.010$	$\frac{9}{16}$	.359	$\frac{13}{64}$	$\frac{1}{8}$	.594	$\frac{1}{8}$	$\frac{7}{8}$
9	D9	$\frac{9}{16}$ -18	$\frac{9}{16}$	$\frac{7}{8} +.0025$ $-.010$	$\frac{39}{64}$	.390	$\frac{7}{32}$	$\frac{5}{32}$	.657	$\frac{5}{32}$	$1\frac{1}{64}$
10	D10	$\frac{5}{8}$ -18	$\frac{5}{8}$	$1 +.0025$ $-.010$	$\frac{11}{16}$	.468	$\frac{7}{32}$	$\frac{5}{32}$	.719	$\frac{5}{32}$	$1\frac{5}{32}$
12	D12	$\frac{3}{4}$ -16	$\frac{3}{4}$	$1\frac{1}{8} +.005$ $-.010$	$\frac{13}{16}$	.562	$\frac{1}{4}$	$\frac{5}{32}$	.875	$\frac{3}{16}$	$1\frac{19}{64}$
14	D14	$\frac{7}{8}$ -14	$\frac{7}{8}$	$1\frac{5}{16} +.003$ $-.010$	$\frac{29}{32}$	.656	$\frac{1}{4}$	$\frac{5}{32}$	1.000	$\frac{3}{16}$	$1\frac{33}{64}$
16	D16	1-14	1	$1\frac{1}{2} +.003$ $-.010$	1	.750	$\frac{1}{4}$	$\frac{5}{32}$	1.125	$\frac{3}{16}$	$1\frac{47}{64}$

EXAMPLE OF PART NUMBER - AN310-4  
AN310D4

\* SPECIFICATION 29-26  
LIMITS ON DIMENSIONS ±.010 UNLESS OTHERWISE SPECIFIED

B/M

APPROVED	AIR CORPS STOCK CLASSIFICATION 04A	ARMY & NAVY STD.
3-22-26	NUT - AIRCRAFT - CASTLE	<b>AN310</b>

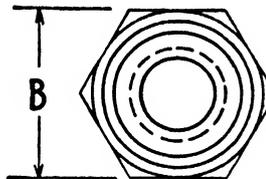
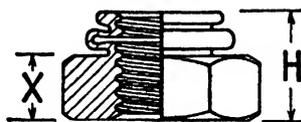
Fig. 355

ENGINEERING DATA AND LIST PRICES

BOOTS  
BELLOWS  
HEXAGON  
NUTS  
B2

BELLOWS STYLE HEXAGON NUTS

ALUMINUM ALLOY — ANODIZED



Boots Part Number	Army Air Corps Number	Navy Air Factory Number	Size and Threads	Class Thread Fit	Normal Dimensions			Weight in lbs. per 1000	List Price per 1000
					B	H	X		
B2D832	365-D832	1137-D832	#8-32	#2	11/32"	15/64"	7/64"	1.2	\$13.75
B2D836		1137-D836	#8-36	#2	11/32	15/64	7/64	1.2	13.75
B2D1024	365-D1024	1137-D1024	#10-24	#3	3/8	1/4	1/8	1.6	13.75
B2D1032	365-D1032	1137-D1032	#10-32	#3	3/8	1/4	1/8	1.6	13.75
B2D420	365-D420	1137-D420	1/4"-20	#3	7/16	5/16	5/32	2.7	17.40
B2D428	365-D428	1137-D428	1/4"-28	#3	7/16	5/16	5/32	2.7	17.40
B2D518	365-D518	1137-D518	5/16"-18	#3	1/2	23/64	3/16	4.0	21.50
B2D524	365-D524	1137-D524	5/16"-24	#3	1/2	23/64	3/16	4.0	21.50
B2D616	365-D616	1137-D616	3/8"-16	#3	9/16	29/64	1/4	6.0	30.00
B2D624	365-D624	1137-D624	3/8"-24	#3	9/16	29/64	1/4	6.0	30.00

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BOOTS AIRCRAFT NUT CORP., NEW CANAAN, CONN.

[ Page 45 ]

Date: May 15, 1942  
Supersedes: B2 of July 1, 1941

Fig. 356. Example of vendor's catalogue

company has three standards books: K, Y, and Q. The K book includes all extruded structural sections. It is actually a listing of standard extrusion shapes, for which the dies are owned and used by the Aluminum Company of America but are commonly employed also by Vultee. The Y book is a list of all drawn structural sections used and made by Consolidated Vultee (Fig. 353). The Q book includes all the miscellaneous standard parts designed by the company. The parts in this book are coded in much the same way as the AN parts, but the Y and K sections are listed more simply (Figs. 354 and 355).

The Republic Aviation Corporation compiles a listing of all company standard structural sections in a book titled, "Standard Extruded and Formed Sections." The contents are similar in form to the Consolidated Vultee K and Y books. Republic Aviation assigns numbers to their own standard parts and processes, preceded by the letter "S," for example; S-278 is the number of a standard company extrusion, and S-435 is a standard process for bend reliefs.

The *Martin Die Pool Book* contains the most comprehensive list of standard structural sections used in the aircraft industry. The list has been compiled with the assistance of the larger aircraft companies, thus presenting to the designer an over-all picture of standard aircraft shapes.

The *Martin Die Pool Book* should be used only if the required section is not contained in the company standards book.

Parts manufacturers catering to the aircraft industry issue catalogues of their products, and

these are available to the draftsman (Fig. 356). Some aircraft companies have compiled lists of the commonly used manufacturer's standard parts, indexed according to the type of product. Thus, the draftsman has only to specify a number from this book on his drawing instead of giving the manufacturer's name. If a certain desired product is not available, an equivalent substitute may be chosen without changing the drawing.

In general, basic knowledge of standard parts, their uses, and their reference listings is essential both to layout draftsmen and to detailers.

The draftsman will gain considerable design information, dimensioning procedure, etc., if he refers to and studies the illustrations in the standards books. For example, if the draftsman is called upon to detail or design a special bolt, he should refer to a standard bolt in the AN book, resembling the type he is required to draw, and thus find a basis for good design and presentation methods. Here he will find proper threading designations, chamfering information, production tolerances, specifications, etc. An examination of AN4 (Fig. 354) illustrates these correct engineering practices. This procedure may be applied to hundreds of mechanical and structural parts, contained in the AN, individual companies, and various vendors' standard books.

The draftsman should be aware of, and take advantage of this wealth of information in the method discussed above, whether it be for the actual use or modification of a standard part, or for purposes of obtaining engineering information for new designs.

# CHAPTER EIGHTEEN

## DASH NUMBERS

### *The Anatomy and Use of Dash Numbers*

The use of dash numbers in aircraft drawings is almost universal. The system saves drafting time and expense because it enables the draftsman to define a part quickly and clearly as it eliminates the necessity for separate drawings of each part. For example, if ten parts on an assembly drawing can be assigned dash numbers, ten separate detail drawings are made superfluous. A dash number is a symbol consisting of a numeral, approximately  $\frac{1}{4}$  inch high, preceded by a short dash and placed inside a  $\frac{3}{8}$  or  $\frac{1}{2}$  inch circle. An arrowed leader is drawn from the circle to the nearest edge of the part (see Chapter Four). The dash number is customarily located near the part it pertains to, but not closer than  $\frac{1}{2}$  inch.

It is quite impossible in this space to review all the individual aircraft company systems pertaining to dash numbers; the following deals with those items most characteristic of their general application.

### *Titled Dash Numbers*

Some dash numbers are titled; that is, the name of the part is lettered beside the circle. This is done to identify any part that might be unclear to the reader. Typical terms are FILLER, NUT, BOLT, SPACE, WEB, SUBASSEMBLY, CLIP. Some companies require that all dash numbers be given titles.

### *Referenced Dash Numbers*

When showing several views and sections, it is sometimes necessary to draw a dash number symbol more than once. In this case, it is called out only once, either in the major view or in the view that most clearly describes the part. It is not necessary to note it in other views, details, or sections if they can easily be associated with

the already dash numbered view. But should confusion be conceivable, the dash number is repeated and the letters "(REF)" are printed beside the number.

Some companies advise against encircling referenced dash numbers. However, circles around dash numbers, referenced or not, are a great aid in quickly locating and identifying a part, especially on large drawings which may reach 6 feet in length. The proper use of reference dash numbers is indicated in the illustrations of Chapters Eighteen and Nineteen.

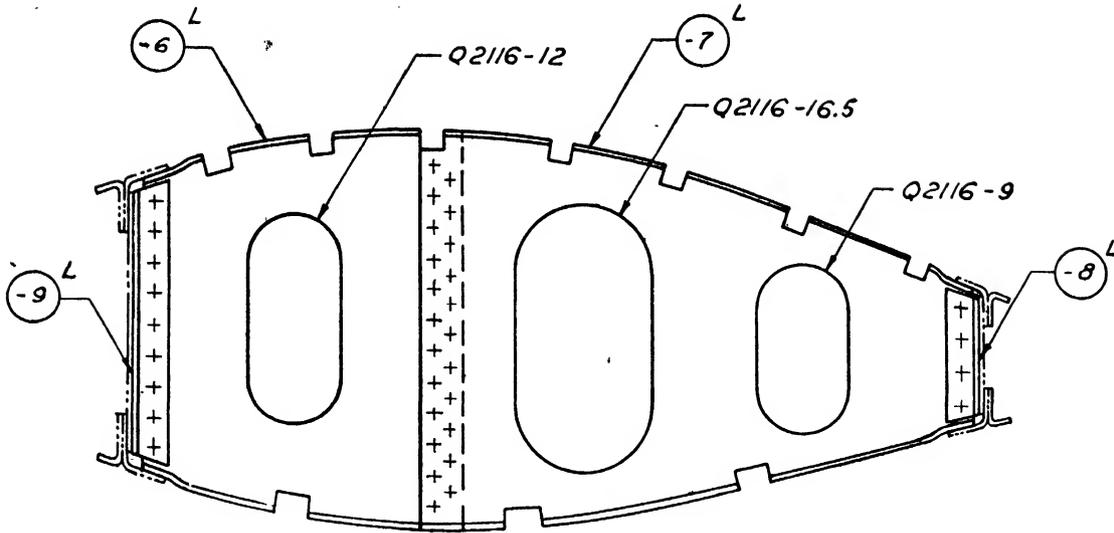
### *Miscellaneous Application of Dash Numbers*

A detail may be used in a number of different positions in an assembly drawing. It is only dimensioned once, but it is dash numbered in each position, and the total number of the details required for the assembly is noted in the bill of materials.

When a dash numbered part is shown on a drawing other than the original one for which it was created, it is identified by both the dash number and the number of the original drawing. For example, in drawing 24R1621, a clip is called out as -21. It is found that the particular clip may be used again in a new assembly drawing. On this drawing, the clip is referred to as 24R1621-21.

Other systems take an entirely different viewpoint: a dash numbered part of an assembly should never be called out on another drawing; when such an individual part is required for another use a separate detail drawing should be made of it. When this is done, the dash number of the original assembly is eliminated and the new detail number is substituted for it on a drawing revision. The model block of the new detail indicates the original assembly as one of

DASH NUMBERS



REQUIREMENTS PER AIRPLANE				PARTS LIST PER ASSY.											
REPLACES	MODEL	NEXT ASSY	REQ	PART NO	STOCK	MATERIAL	SPEC	LH	RH	LH	RH	LH	RH	LH	RH
-R	B-56	56W570	1	-9R	734TT x 17 3/4	AL AL EXTR.	QQ-A-354-T	1							
-L	B-56	56W570	1	-9L	734TT x 17 3/4	AL AL EXTR.	QQ-A-354-T	1							
				-8R	734TT x 8 1/2	AL AL EXTR.	QQ-A-354-T	1							
				-8L	734TT x 8 1/2	AL AL EXTR.	QQ-A-354-T	1							
				-7R	.040 x 30 x 37	ALCLAD	AN-A-13-T	1							
				-7L	.040 x 30 x 37	ALCLAD	AN-A-13-T	1							
				-6R	.051 x 21 1/2 x 30	ALCLAD	AN-A-13-T	1							
				-6L	.051 x 21 1/2 x 30	ALCLAD	AN-A-13-T	1							
REQUIRES PER AIRPLANE RECALC WGT: 10.4* RECALC WGT: ACT WGT				PART NO STOCK MATERIAL SPEC				REQ REQ REQ REQ REQ REQ							
LIMIT ON DIMENSIONS UNLESS OTHERWISE SPECIFIED SCALE: 1/32 1 1/2" = 1'-0"				STAMP PART NUMBER WHERE SHOWN				PARTS LIST PER ASSY. -0 -2 -3 -4 -5							
A/C NOTED CVAC 56-ZP-001				NAVY				HEAT TREAT FINISH DRAFT CHECK STRUCT MAT APPROV ENG							
NAME BULKHEAD #4 - WING (STATION 325)				OPP HAND 56W563-P				DWG G 56W/563							
CONSOLIDATED VULTEE AIRCRAFT CORP FORT WORTH DIVISION				SIZE				56W/563							

Fig. 357. Example of right- and left-hand dash numbers

the next assembly drawing numbers on which the part is used.

If a dash numbered part is not actually assembled on a drawing, but is shown merely for purposes of clarity or reference, the part itself is drawn in a reference line and is identified by its dash number and basic drawing number, and the usual abbreviation (REF) is added. For example, a stringer 24B0002-9 is drawn on a belt-frame assembly drawing 24B00079 to clarify the nature of the stringer cutouts in the rim of the frame and the method of fastening the stringer to the frame. In this case, the stringer itself is drawn in a reference line and is called out on the face of the beltframe assembly (24B00079) as 24B0002-9 (REF).

It happens frequently that dash numbers are redesigned, replaced with others, or canceled. In such cases, the old dash numbers are removed and, if required, new ones are substituted. Once

a dash number has become obsolete, it must never be used again because confusion can too easily result from manufacturing and stocking two different parts with the same number.

After a dash number drawing is released the dash number designations of the existing parts should not be varied or interchanged. (Substitution of a new dash number in place of the original dash number designation on an existing part or assembly will require a change on all tools which have been numbered, making it difficult to furnish replacement parts.)

Dash numbers are not required for dope, print, glue, welding materials, cement, solder, and thread.

When detailing castings, a somewhat different situation is encountered. Since any part deserving a dash number must be completely dimensioned and shown in its final form, a rough casting, not yet machined, cannot properly earn a

<p>32F039-17 2 1/2 x 6 1/2 x 11 ALC 243T 57-152-2-II</p> <p>AN442-AD-4</p> <p>-10 Y2A45T x 17 1/2 53 3T 00-A-391 (A) 1</p> <p>-9 K5401 x 12 ALC 243T 57-251-2-II 1</p> <p>32F039-8 .040 x 12 x 78 -6 SUB ASSY.</p>								
<p>AC365-DB32</p> <p>ANS15-DB20</p> <p>QB12-05-18</p> <p>-701 MAKE FROM-17</p> <p>32F039-20 MAKE FROM-17</p> <p>-16 3/4 DIA. x 12 24 30 00-A-354(A) 1</p> <p>-15L 3/8 x 12 17 50 57-107-19 1</p> <p>-14R 1.00 x .049 x 10 17 50 NW-T-786-A 1</p> <p>-14L 1.00 x .049 x 10 17 50 NW-T-786-A 1</p> <p>-7 .032 x 5 x 8 1/2 ALC 243T 57-152-2-II 1</p> <p>32F039 = SUB ASSY.</p>								
<p>2R P82Y-3 29F6230R 1</p> <p>2L P82Y-3 29F6230L 1</p> <p>3L P82Y-3 29F51822 2</p> <p>3R P82Y-3 29F4182 4</p> <p>3L P82Y-3 29F4182 4</p> <p>2R B24 32F1012 1</p> <p>2L B24 32F1012 1</p> <p>R B24 32F1012 2</p> <p>L B24 32F1012 2</p>								
<p>REQUIREMENTS PER AIRPLANE</p> <p>REPLACES 32F039 of 5-11-43</p> <p>REPLACED BY 32F039</p> <p>SCALE 12" = 1'-0"</p> <p>STAMP PART NUMBER WHERE SHOWN</p>								
<p>PART No.</p> <p>STOCK</p> <p>MATERIAL</p> <p>SPEC.</p>				<p>LH RH LH RH LH RH LH RH LH RH</p> <p>REQ. REQ. REQ. REQ. REQ.</p> <p>0 -2 -3 -4 -5</p>				
<p>AC</p> <p>NAVY</p> <p>HEAT TREAT</p> <p>FINISH</p> <p>DRAFT</p> <p>CHECK</p> <p>STRUCT</p> <p>MAT.</p> <p>APPROV.</p> <p>ENG.</p>				<p>SMITH JANSEN</p> <p>6-12-42 6-12-42</p> <p>NAME BRACKET-NAVIGATORS INSTRUMENT</p> <p>OPP. HAND 32F039-R</p> <p>DWG. J</p> <p>CONSOLIDATED AIRCRAFT CORP. FORT WORTH</p> <p>SIZE</p>				

Fig. 358. Example of sub-assembly dash numbers in bill of materials

dash number. The custom is to assign the basic drawing number to the rough casting and to assign a dash number with the same drawing number to the finished part. Hence the basic drawing number of a casting taken from the mold is, for example, 24B0067, and after it has been machined it becomes 24B0067-6.

An interesting system to designate castings and forgings is used at the Republic Aviation Corporation. For example, a typical casting number, 04F94213-1, may be broken down as follows: 04 (the project number), F (location, in this case the fuselage), 9 (designating a casting or forging), 4 (group classification, in this case the Landing Gear group), 2 (sub-group classification—the tail wheel), 13 (the detail number in group). The drawing number of the machined part, made from this casting is obtained by changing the "9" to an "0", hence 04F04213-1 is the number

of the machined part. Typical of this company's practice *all* details, assemblies and installations carry a dash number (usually -1) with their basic drawing number; hence the casting blank (04F94213-1) and the machined casting (04F04213-1) carry dash numbers.

*Left- and Right-Hand Parts*

Hundreds of parts in any airplane have opposites. A part and its opposite are usually employed in similar locations on opposite sides of the plane. Such a part is identical to its opposite in size and material but reverse in shape. If the student will observe his left and right hands, he will find a good example. The hands are similar, yet not interchangeable.

It would be a waste of time and money to detail opposite parts separately. Therefore, for convenience, the left-hand (pilot's side) part is

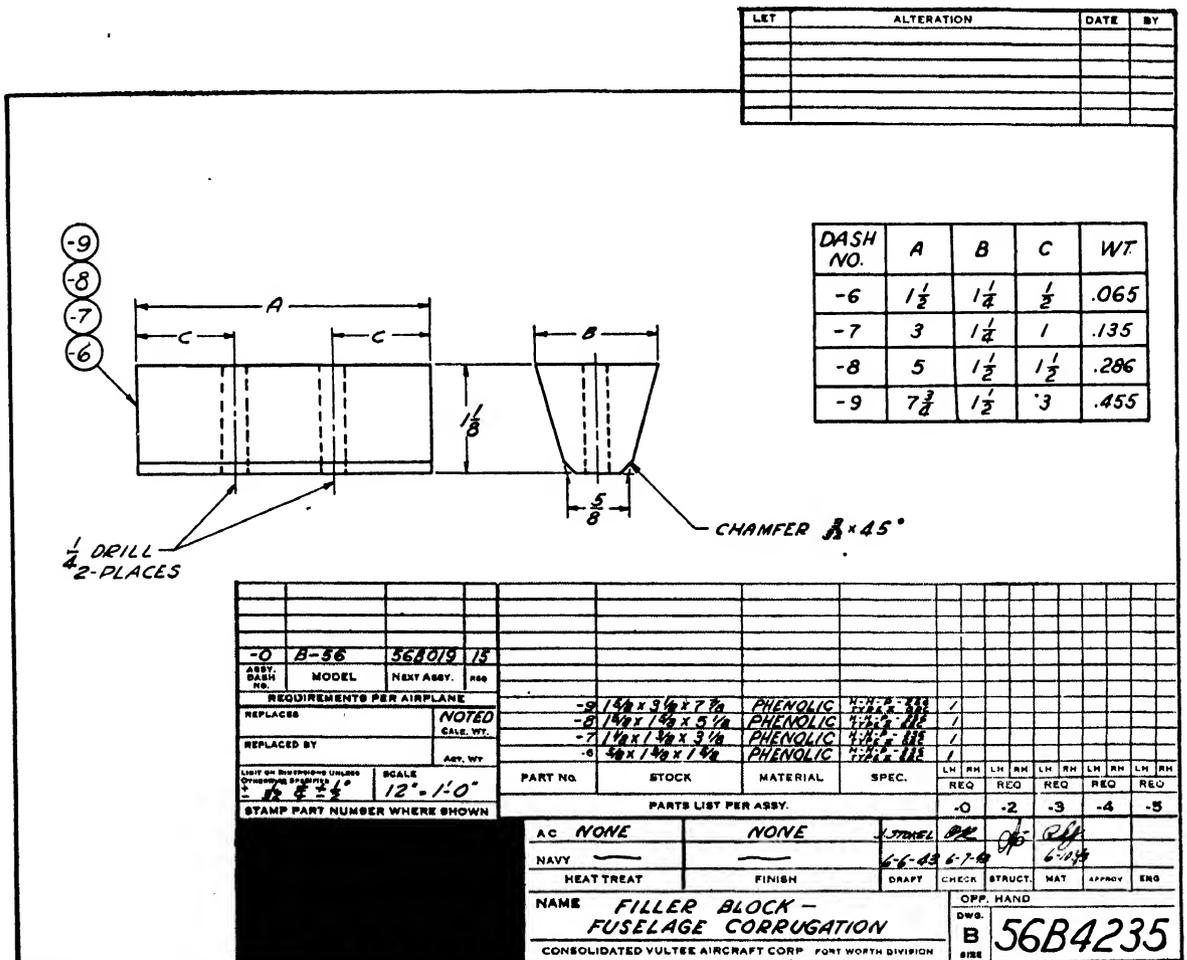


Fig. 359

drawn and the right-hand part is merely called out in the bill of materials (Fig. 357), which also lists the left-hand part. Some companies require that all left-hand parts be given even dash numbers, such as -0, -2, -4, and all right-hand parts be given odd dash numbers, as -1, -3, -5. Another system commonly employed is to assign dash numbers in consecutive order to the left-hand parts, adding "L" after the number. Similarly, an "R" is added to the number of the right-hand part.

#### *Left- and Right-Hand Assemblies*

Not only right- and left-hand detail parts but also whole drawings of left- and right-hand assemblies are designated "L" and "R." The title block of a drawing always provides some means to distinguish the left and right assemblies. Usually a space just above or to the side of the drawing number is labeled **OPPOSITE HAND** or **PART NUMBER OF OPPOSITE HAND PART**, or there may be two blocks, one captioned **SHOWN** and the other **OPPOSITE**.

If a drawing has a right-hand assembly, the basic drawing part number is repeated here with the addition of an "R" or a numeral, for instance, 35W007-R or 35W007-1. It should be noted that the basic drawing number does not carry an "L" as a suffix, but if it is actually left hand, it is commonly referred to as "35-W007-L" (see Chapter Nineteen, Bill of Materials).

If a right-hand assembly is drawn in place of the usual left-hand assembly, the drawing is labeled **RIGHT HAND SHOWN**, the basic drawing number is followed by an "R" (35W002-R), or the fact is noted in some other way.

Some companies do not have printed provisions in the Bill of Materials for left- and right-hand designations. The note, "L. H. shown R. H. opposite" is lettered to the left of the Bill of Materials, and only the left-hand quantities are called for. However, the L and R requirements are conveniently taken care of by noting "1L & 1R of -1" in "The number per airplane" block. Where details, assemblies or installations

are basically left and right hand, although one part may have minor differences, such as additional holes, cut-outs, parts, etc., the variations are shown on the field of the drawing by notes, such as, "For -1R assembly only." The Bill of Materials indicates the variation in parts also, by following the LH and RH column system. When details, assemblies, or installations are complex in their differences between left and right hand, separate drawings are made and separate drawing numbers are assigned.

#### *Subassembly Dash Numbers*

Most assembly drawings have large numbers of parts: dash numbered, standard, and detailed parts. When an assembly is being produced, it is usually more convenient to assemble certain groups of parts and then combine these into the assembly, rather than to attempt to assemble the structure piece by piece. These individual units, called "subassemblies," are assigned dash numbers and are treated like distinct parts in themselves. In Fig. 358, for example, subassembly "-6" consists of a part previously designed in another drawing (32F039-8), two new parts (-9, -10), and flat head rivets AN442-AD-4.

#### *Dash Numbers in Tabulated Drawings*

Time and money are saved by the use of dash numbers if several parts are identical except for one or two dimensions. In such cases only one part is drawn, approximately to the size of the average, and the dimensions that vary are given letters. Then these lettered dimensions are tabulated on the face of the drawing to note the variations in the dash numbers (Fig. 359).

A large percentage of the standard parts, such as nuts, bolts, or extruded and drawn sections, make the fullest use of this system. Literally thousands of pages in a standards book are eliminated, not to mention man hours and expense. Most standards books and drawings employ similar methods for tabulation of dimensions and other data. A little study will make the draftsman familiar with this everyday practice.

# CHAPTER NINETEEN

## BILL OF MATERIALS

In any manufacturing business, whether its product is buttons or airplanes, an accurate record must be kept of all materials in stock, ordered, and to be ordered. Any aircraft company employs a sizeable group of people whose job it is to keep records of all materials, and this group is closely allied with the engineering department. The source of information from which this group determines what to order for any particular airplane is the bill of materials on the engineering drawings. Therefore, to avoid any delay in the delivery of purchased parts and stock, every draftsman must make it his personal responsibility to see that the bill of materials on each of his drawings is accurate in every detail.

### *The B/M Block*

A bill of materials (abbreviated B/M) is a list of all parts required on the drawing. The B/M block, Fig. 360, is placed in the lower right-hand corner of the drawing, just above the title block. It is usually printed in black ink on the reverse side of the sheet so that erasures can be made without removing the lines. The listing of parts begins at the bottom and continues upward.

Dash numbers are listed first, starting with the lowest and going up in consecutive order. Naturally, the  $\frac{3}{8}$  inch circle is omitted from the dash numbers in the B/M. When dash numbers refer to left- and right-hand parts, the left-hand number is listed first and the right-hand number on the next line above it. Some companies list basic dash numbers only, if L and R designations are required they are listed in a "Number required column." After the last dash number, a space of several lines is left blank for later possible additions.

If it is an assembly drawing, the required de-

tail drawing part numbers are listed next in numerical order. After leaving space for later additions, the parts purchased from outside sources are then listed, followed by the aircraft company's own standard parts, and lastly, army and navy standard parts. This listing procedure varies from company to company.

### *Stock Sizes*

Since dash numbered parts are detailed on the drawing, stock sizes, materials, and specifications must be included in the bill of materials. Although some companies prefer exact stock sizes, in most cases the stock size gives the dimensions of the rough blank to be cut from the specified material of the part.

If a dash number is made from an extrusion or a drawn section, the stock column will contain the section number (see Chapter Seventeen) and the length. This length should contain a small allowance for cutting tolerance. The proper allowance is left more or less to the judgment of the draftsman; however,  $\frac{1}{8}$  inch is customary for medium and short lengths, more for long parts and for parts that will require bending. In any case, stock lengths should be given in eighths of an inch rather than in sixteenths or thirty-seconds. For example, if a part were  $10\frac{3}{16}$  inches long on the face of a drawing, and if  $\frac{1}{8}$  inch were to be added for cutting tolerance, the B/M stock length would read  $10\frac{3}{8}$ ,  $\frac{1}{8}$  inch having been added to make a round figure in eighths. Naturally, the use of the fractions  $\frac{1}{2}$  and  $\frac{1}{4}$  is permissible.

If a dash numbered part is to be cut or formed from sheet metal, the stock column in the bill of material must show in decimals the gage or thickness of the material, in addition to width and length in whole numbers and fractions. When a part is made from a block of material,

suitable cutting tolerance is required for each dimension. In tubing, the three stock dimensions are outside diameter, wall thickness, and length; cutting tolerance is allowed for length only.

*Material and Specification*

The material column of a bill of materials tells what kind of material the parts are made from. Examples of these notations are "Alclad," "Dural," or "Aluminum Alloy," usually abbreviated "Al.Alloy"; "Cold Rolled Steel," abbreviated "C.R.Steel"; "Micarta"; "Spruce"; "Aluminum Alloy Extrusion," abbreviated "Al.Al.Extr.," etc.

The purpose of the specification column of a bill of materials is to list the official specification number for the material as set up by the Army Air Forces or the Navy. The Army specification is used when the airplane is produced for the

army, and, of course, the Navy specification is used when the plane is for the navy. These agencies issue their material specifications to the various aircraft companies who, in turn, prepare lists of the more commonly used materials for the engineering departments. These specifications are revised quite frequently as improvements in materials are made and as new materials are developed. At the time of writing, the Army specification for 24 S-T aluminum alloy extrusions, for example, is "QQ-A-354-T." The latest information is always available to the aircraft draftsman.

Information on stock, material, and specifications are required for most dash numbers in the bill of materials, but some short-cuts can be made. For instance, Consolidated Vultee has listed all its standard drawn sheet structural sections in a book called the "Y book," and a num-

AIRPLANE SERIAL NUMBERS		VEGA		BOUSLAD		BORING		PART NUMBER	QUANTITY	USED ON	FINISH	PART NAME	DRAWING SHEET NUMBER	REL. COL. NO.	
								1-320 (INCL)	0-0000-0	0-177	24	0-1000-0	CRANK ASSY	1	1A
								280 2 Q2	0-0000-0	0-177	24	0-1000-0	CRANK ASSY	1	
								1-320 (INCL)	0-0000-0	0-177	24	0-1000-0	CRANK ASSY	1	

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											

QTY	UNIT	DESCRIPTION	SCALE	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED	DATE	BY	CHKD	APPROVED
2	✓	10	CRANK ASSY												
2	✓	10	BEARING												
2	✓	10	PLATE												
2	✓	2	7	ANGLE											
✓		1	4	CHANNEL											
✓		2	4	ANGLE											
✓		1	2	BAC-00											
✓		1	3	PLATE											
✓		1	2	CRANK											
✓		2	4	CRANK ASSY											







ber and letter code is employed to identify these parts. A typical Y section part in the B/M would be Y2A45Tx 25½. The Y shows that the part is to be found in the Y book; the 2 designates page 2, which covers 90 degree angles with equal legs; A stands for Alclad; 45 is the number given on page 2 in the Y book for an angle the thickness of which is 0.064 and the leg length of which is 1 inch; T means that the part is to be hardened to full temper. Of course, 25½ describes the stock length of the part. All of this coded information is put in the stock column, and the material and specification columns are left blank.

### *Number Required*

The bill of materials must also contain the required number of each part. This applies to everything except rivets, which are rarely counted. It will be noticed in Fig. 360 that each assembly column is divided into L.H. and R.H., designating left and right hand. If a drawing has an opposite, such as a wing bulkhead, both L.H. and R.H. columns must be filled in, but if the drawing is of an assembly that has no opposite, such as a fuselage bulkhead, only the L.H. column is used, and the number required for both L and R parts is entered there. The method of designating whether or not a drawing has an opposite hand is described in the previous chapter.

### *Scale*

Every bill of materials contains a small block in which is noted the scale to which the parts are drawn. It is generally given either as 3"=1' 0" or ¼ size; 6"=1' 0" or ½ size, depending on company preference. Section and detail views are usually shown full size on the face of the drawing, even though the main views are drawn to a smaller scale. If so, the scale of each section or detail view should be labeled on the face of the drawing, and the B/M should state, for instance, 3"=1'0" AND NOTED.

### *Tolerance*

Tolerance on dimensions is another item which must be specified in the B/M. A block is provided for this purpose, and the printed

notation usually reads LIMIT ON DIMENSIONS UNLESS OTHERWISE SPECIFIED ————. For the manufacture of the majority of sheet metal parts and for most assemblies, the customary tolerance is  $\pm\frac{1}{32}$ . Naturally, for machined parts the tolerances must be much less, and they are given in decimals, such as  $\pm.010$ ".

### *Finish*

Nearly all of the thousands of parts in an airplane are given some kind of coating or finish in order to protect them from the elements and to prevent corrosion or oxidation. The draftsman must specify the type of finish required on each part in his drawings. Finish specifications are coded and are governed by type of part, model of plane, and whether the plane is to be made for the army or for the navy. The specification of the particular finish can be found in books available to the drafting room or in the engineering library. Republic Aviation simplifies the draftsman's task with a general note: "Republic Report 520," lettered in the finish block of the B/M. This covers the standard finish for various materials.

### *Next Assembly*

A complete set of drawings for an airplane consists of a few main assembly drawings, a larger number of installation and subordinate assembly drawings, and a great number of detail drawings. To make it possible to locate each part of the assembly easily and quickly, a system for noting the sequence of drawings has been set up. Each detail part is shown and called out on one or more assembly drawings, and each assembly drawing is shown and called out on one or more installation drawings. It will be noticed in Fig. 361 that a place has been provided for NEXT ASSEMBLY. The purpose of this block is to designate the drawing or assembly on which the part or assembly in question is next shown. Each detail part number is called out on its assembly drawing, and each assembly drawing number is called out on its installation drawing. However, detail parts are not called out on any drawings except their next assemblies.

*Heat Treatment*

Required heat treatments for parts must also be specified in the B/M. The draftsman should learn the correct designation for heat treatment from his superior or from the materials engineer. Specifications for heat treatment differ by companies, and there are so many exceptions and special cases that the subject cannot be fully treated within the scope of this book.

*Naming of Drawings*

In the drawing titles of parts, assemblies and installations, the noun that most clearly classifies the item appears first, for example, DOOR-WING BOTTOM COVER ACCESS. The descriptive unit or article name of which it is a part follows, so that the name reads straight through after the noun. This may be tested by placing the noun after the descriptive portion following the dash. In assemblies or installations the word "assembly" or "installation" is placed second, for example, DOOR ASSEMBLY-AILERON IDLER ACCESS.

Words like "power plant" are treated as a single noun, hence the words "assembly" or "installation" may appear third: POWER PLANT INSTALLATION.

Casting and forging drawings are titled as detail parts except that the word "casting" or "forging" is placed first: CASTING DOOR-WING BOTTOM COVER ACCESS. In reading through the word "casting" is mentally eliminated.

The following rules may be generally applied to constructing titles:

1. The basic location, Wing, Fuselage, etc., is usually placed after the noun.
2. When appropriate, the nomenclature of structural members should include station locations in decimals correct to two places.
3. If an assembly contains only one part using the chosen noun, then the main name with the noun is sufficient: CLIP-TAIL WHEEL CONTROL.
4. Abbreviations should be used only when space is limited. Common and accepted abbreviations are listed in the following table:

TABLE OF STANDARD ABBREVIATIONS

absolute ceiling . . . . .	H or c/a	cantilever . . . . .	cantil.
accessory . . . . .	aces.	casting . . . . .	castg.
actuating . . . . .	act.	center . . . . .	ctr.
adjusting . . . . .	adj.	center of bouyancy . . . . .	C/B
adjustment . . . . .	adj.	center of gravity . . . . .	C/G
aileron . . . . .	ail.	center line . . . . .	C.L. or <b>C</b>
Air Corps . . . . .	A.C.	center of pressure . . . . .	C/P
Alclad . . . . .	alc.	centimeters . . . . .	cm
altitude . . . . .	alt.	centimeters per second . . . . .	cm/sec
aluminum . . . . .	alum.	change . . . . .	chg.
aluminum alloy . . . . .	al. alloy	chapter . . . . .	chap.
ammunition . . . . .	amm.	charge . . . . .	chg.
approximate . . . . .	approx.	check . . . . .	chk.
Army and Navy . . . . .	AN	chrome-molybdenum . . . . .	C.M.
arresting . . . . .	arrest.	command . . . . .	comd.
assembly . . . . .	assy.	commercial . . . . .	coml.
assistant . . . . .	asst.	compartment . . . . .	compt.
attached . . . . .	att.	connecting . . . . .	con.
attachment . . . . .	att.	contract . . . . .	cont.
auxiliary . . . . .	aux.	control . . . . .	cont.
baggage . . . . .	bag.	corrugated . . . . .	corr.
bearing . . . . .	brng.	countersink . . . . .	csk.
bill of material . . . . .	B/M	countersunk . . . . .	csk.
bracket . . . . .	brkt.	covered . . . . .	cov.
bulkhead . . . . .	bulkd.	cowling . . . . .	(do not abbreviate)
Bureau of Aeronautics . . . . .	BUAERO	cubic centimeters . . . . .	cc
bushing . . . . .	bush.	cubic feet . . . . .	cu ft
buttock line . . . . .	B.L. or <b>B</b>	cubic meters . . . . .	cu m
caliber . . . . .	cal.	cylinder . . . . .	cyl.
canceled . . . . .	can.	department . . . . .	dept.

design . . . . .	des.	information . . . . .	info.
designation . . . . .	desig.	inside diameter . . . . .	I.D.
desired loose fit . . . . .	des. l.	inspector . . . . .	insp.
desired tight fit . . . . .	des. t.	Inspector of Naval Aircraft . . . . .	I.N.A.
developed width . . . . .	.D.W.	installation . . . . .	instal.
developed length . . . . .	D.L.	instruction . . . . .	inst.
diagonal . . . . .	diag.	instrument . . . . .	inst.
diagram . . . . .	diag.	instrument panel . . . . .	inst. panel
diameter . . . . .	dia.	intermediate . . . . .	inter.
differential . . . . .	diff.	junction . . . . .	junct.
dimension . . . . .	dim.	kilograms . . . . .	kg
direction finder . . . . .	D/F	kilograms per square centimeter . . . . .	kg/sq cm
distribution . . . . .	distr.	kilometers per hour . . . . .	kph
distributor . . . . .	distr.	landing . . . . .	ldg.
ditto . . . . .	do.	landing gear . . . . .	ldg. gr.
dozen . . . . .	doz.	leading edge . . . . .	L.E.
draftsman . . . . .	dftsmn.	left-hand . . . . .	L.H.
drafting . . . . .	dftg.	length . . . . .	leng.
Drafting Room Manual . . . . .	D.R.M.	longeron . . . . .	long.
drawing . . . . .	dwg.	longitudinal . . . . .	long.
Duralumin . . . . .	Dural.	lubricating . . . . .	lub.
each . . . . .	ea.	lubrication . . . . .	lub.
electrical . . . . .	elect.	machine . . . . .	mach.
elevator . . . . .	elev.	maintenance . . . . .	main.
emergency . . . . .	emer.	manufacturer . . . . .	mfrg.
enclosure . . . . .	encl.	material . . . . .	matl.
engine . . . . .	eng.	maximum loose fit . . . . .	max. l.
engineering . . . . .	eng.	maximum tight fit . . . . .	max. t.
equipment . . . . .	equip.	mean aerodynamic chord . . . . .	M.A.C.
equivalent . . . . .	equiv.	mechanical . . . . .	mech.
exhaust . . . . .	exh.	mechanism . . . . .	mech.
extinguisher . . . . .	ext.	meters . . . . .	m
extrusion . . . . .	extn.	miles . . . . .	mi
fairing . . . . .	fair.	miles per hour . . . . .	mph
federal . . . . .	fed.	millimeters . . . . .	mm
feet . . . . .	ft	minimum loose fit . . . . .	min. l.
feet per minute . . . . .	ft/min	minimum tight fit . . . . .	min. t.
fillet . . . . .	fil.	minutes . . . . .	min
fillister head . . . . .	fil. hd.	miscellaneous . . . . .	misc.
fitting . . . . .	fit.	mount . . . . .	mt.
flat head . . . . .	F.H.	mounting . . . . .	mtg.
flexible . . . . .	flex.	nacelle . . . . .	nac.
flotation . . . . .	flot.	Naval Aircraft Factory . . . . .	N.A.F.
forward . . . . .	forwd. or F'W'D'	number . . . . .	no.
frequency . . . . .	freq.	number required . . . . .	no. req.
front . . . . .	fr.	observation . . . . .	obs.
fuselage . . . . .	fus.	observer . . . . .	obs.
gage . . . . .	ga.	obsolete . . . . .	obs.
gallons . . . . .	gal	opening . . . . .	opng.
general . . . . .	genl.	operating . . . . .	oper.
generator . . . . .	gen.	oscillator . . . . .	oscil.
hardware . . . . .	hdwe.	outboard . . . . .	outbd.
handbook . . . . .	hndbk.	outside diameter . . . . .	O.D.
head . . . . .	hd.	parachute flare . . . . .	para. flare
holder . . . . .	hldr.	passenger . . . . .	pas.
hour . . . . .	hr	patent . . . . .	pat.
horizontal . . . . .	hor.	permanent . . . . .	perm.
horsepower . . . . .	hp	piece . . . . .	pc.
hydraulic . . . . .	hyd.	position . . . . .	pos.
ignition . . . . .	ign.	pounds . . . . .	lb
inches . . . . .	in.	pounds per horsepower . . . . .	lb/hp
inboard . . . . .	inbd.	pounds per square foot . . . . .	lb/sq ft
indicator . . . . .	ind.	pounds per square inch . . . . .	lb/sq in. or psi or #1/in <sup>2</sup> or #/in <sup>2</sup>

preliminary . . . . .	prelim.	shock absorber . . . . .	sh. abs.
pressure . . . . .	pres.	special . . . . .	spec.
propeller . . . . .	prop.	specification . . . . .	spec.
pyrotechnics . . . . .	pyro.	spherical radius . . . . .	sph. r.
radius . . . . .	R	square feet . . . . .	sq ft
rear . . . . .	rr.	square inches . . . . .	sq in.
receiver . . . . .	rec.	stabilizer . . . . .	stab.
reference . . . . .	ref.	standard . . . . .	std.
reinforcement . . . . .	reinf.	station . . . . .	sta.
reinforcing . . . . .	reinf.	stiffener . . . . .	stif.
release . . . . .	rel.	stock length . . . . .	S.L.
required . . . . .	req.	stock width . . . . .	S.W.
requirements . . . . .	reqmts.	structure . . . . .	struc.
retainer . . . . .	ret.	supercharger . . . . .	supchg.
retracting . . . . .	retrg.	superseded . . . . .	sup.
revised . . . . .	rev.	support . . . . .	sup.
revision . . . . .	rev.	supporting . . . . .	sup.
revolutions per minute . . . . .	rpm	symmetrical . . . . .	sym.
right-hand . . . . .	R.H.	synchronize . . . . .	synchr.
round head . . . . .	R.H.	system . . . . .	syst.
rubbing . . . . .	rub.	temperature . . . . .	temp.
rudder . . . . .	rud.	thread . . . . .	thd.
sea level . . . . .	S.L.	trailing edge . . . . .	T.E.
second . . . . .	sec	transformer . . . . .	transf.
section . . . . .	sec.	transmitter . . . . .	transm.
segment . . . . .	seg.	transverse . . . . .	transv.
selector . . . . .	sel.	typical . . . . .	typ.
separate . . . . .	sep.	vertical . . . . .	vert.
service ceiling . . . . .	ser. ceil.	weight . . . . .	wt.

*Drawing Numbers*

The numbering of drawings follows a system. The system used at Consolidated Vultee gives the model number first, the group letter second, and the number assigned to each particular drawing last. The letters used to designate some of the groups are: A, Armament; B, Fuselage or Hull; C, Controls; E, Electrical; F, Furnishings; L, Landing Gear; P, Power Plant; W, Wing. Other letters are used for nonproduction drawings; for example, R is used for proposal drawings, T for test, and Z for mock-up. Examples of drawing numbers are: 28W946, 29F1035, 32B1020, 33C483.

*Model Block*

A block system of model designations is specified by the AAF for production airplanes. For example, P47N-1-RE is the block designation for a certain specified quantity of airplanes, all of which possess the same basic features of safety, utility, and interchangeability of parts. The designation may be analyzed as follows: P, type of plane (pursuit); 47, model number (as-

signed by AAF); N, basic design letter; -1, indicates first block of "N" design planes; RE, manufacturing firm (Republic).

The block system method of designation is used to permit the manufacturer to make sizeable uninterrupted production runs, and to provide an adequate system of identifying airplanes and their component parts for servicing and spares requirements.

*Number per Airplane*

In computing quantities required per plane, determine how many of the parts, assemblies, or installations are used on the next assembly; this number, multiplied by the number of times the next assembly is used on the airplane, is the number entered in the Number per Plane column. Example: 2 of -1, or 11./1R of -2.

*Glen L. Martin B/M*

The Glen L. Martin Company provides for a separate Parts Release Sheet on which the material is listed, and is identified by dash numbers shown in "bubbles" on the engineering drawing.

## CHAPTER TWENTY

# CALCULATION OF WEIGHTS

### *Importance of Weight*

All the various branches of engineering—civil, chemical, electrical, mechanical, or aeronautical—are concerned with the same natural laws. However, each branch differs from the others in that it focuses its primary interest on a particular set of these laws. Aeronautical engineering, for example, is most interested in the law of gravity (Fig. 364).

In the design of a bridge, dam, or battleship the essential consideration is strength, and in order to make certain of meeting this requirement, a safety factor of from six to ten is often used. Such practice is obviously out of the question in aircraft design, for the simple reason that it adds excess weight, and the success of any airplane depends largely upon its lightness.

When a part of an assembly is first designed, its acceptance depends to a great extent upon

its weight, as determined by the draftsman. Therefore, every aircraft draftsman must know how to calculate the weight of any part he draws.

Every aircraft company's engineering department includes a group of men who devote all their time to problems involving weights: the preliminary determinations of the total weight, the location of the center of gravity of an airplane, the breakdown and distribution of this weight in order to assure the plane's balance, and the maintenance of a complete record as well as the checking of detailed weight calculations computed by the draftsmen.

### *Procedure*

The universal procedure for computing the weight of any part is to determine the volume of each material—usually in cubic inches—in the part and then to multiply this by the weight per unit volume, pounds per cubic inch. These unit weights can be found in various handbooks, including that of the American Society of Weights Engineers, most vendor's catalogues, and the aircraft company's own book of weights. The first step is to compute the volume. The length, breadth, or thickness of a part are single dimensions; the area of some surface of a part is the product of two dimensions (in.<sup>2</sup>,  $\square$ , or sq in.); and a volume is the product of three dimensions (in.<sup>3</sup>, or cu in.). Therefore, a volume can be expressed also as a product of a dimension and an area.

Most airplane parts are fabricated from sheet metal. The thickness of a sheet metal part is a constant dimension. Therefore, if we can find the total surface area and multiply it by the thickness, we will have calculated the volume. As the thickness is usually given, it is necessary to know only how to find the area of any given surface.

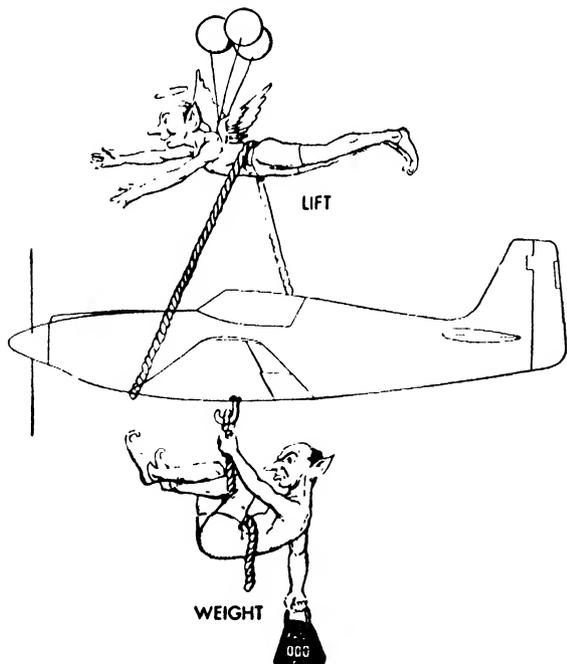


Fig. 364. The gremlins

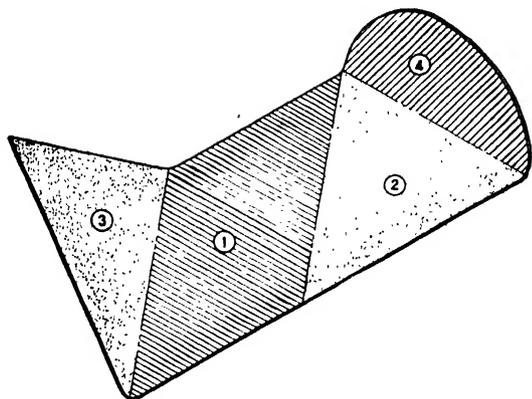


Fig. 365. Most parts may be divided into simple geometric shapes

Every surface, no matter what its shape, is composed of basic geometric areas. If the part is divided into such basic areas it is relatively simple to find and add up their sizes (see Fig. 365). For example, to find the surface area of the typical flying boat hull floor beam, shown in Fig. 366, the part is divided into six different basic areas. These areas are computed separately, and then added to obtain the total. Area 1 is a triangle; areas 2, 3, and 4 are rectangles; and areas 5 and 6 are circles. The formulas for computing their sizes are given in Fig. 367. Since area 3 is identical with area 4 and since area 5 is identical with area 6 it is necessary only to calculate the sizes of areas 1, 2, 3, and 5. Area 1 is not a perfect triangle, because of the small bend-relief radii cut out of each corner, but common sense tells us that the error introduced by disregarding this slight irregularity will be negligible. Using the formula for the area of

a triangle, it is found that

$$A_1 = \frac{34.64 \times 10}{2} = 173.2 \text{ sq in.}$$

Similarly,

$$A_2 = 34.64 \times 1 = 34.64 \text{ sq in.}$$

$$A_3 = 20 \times 1 = 20.00 \text{ sq in.}$$

$$A_5 = \pi \times 3^2 = 3.1416 \times 9 = 28.2744 \text{ sq in.}$$

Adding the areas,

$A_1$ 173.20	$A_5$ 28.27
$A_2$ 34.64	$A_6$ 28.27
$A_3$ 20.00	$\overline{56.54}$ sq in.
$A_4$ 20.00	
$\overline{217.84}$ sq in.	

Subtracting totals,

$$\begin{array}{r} 247.84 \\ -56.54 \\ \hline 191.30 \text{ sq in.} \end{array}$$

Thus, we find that the total surface area of the part is 191.30 square inches.

We are now ready to determine the volume of metal in the part. We have calculated the surface area, and the thickness is given as 0.064 inch. Therefore,

$$V = 191.30 \times 0.064 = 12.24 \text{ cu in.}$$

The remaining operation is to multiply this figure by the weight per unit volume of the material of which the part is made.

This beam is formed from aluminum alloy, and from Fig. 368 it is found that the unit weight is almost exactly 0.10 pound per cubic inch.

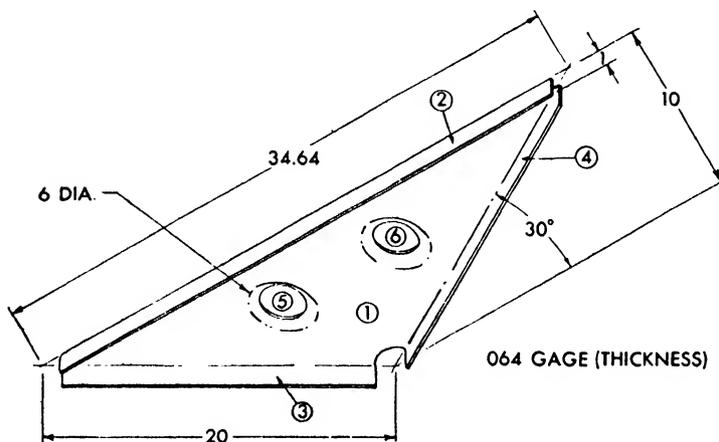


Fig. 366

Therefore, the calculated weight of the floor beam is  $12.24 \times 0.10 = 1.224$  pounds.

The same answer would have been obtained if the volume had been multiplied by 0.0064 (the product of  $0.064 \times 0.10$ ). When calculating the weights of aluminum alloy sheet parts, it is always customary to multiply the thickness (gage) by 0.10, for example,  $0.040 \times 0.10 = 1.0040$ ,

$0.032 \times 0.10 = 0.0032$ . This figure is then multiplied by the surface area to give the weight.

The unit weights of other aircraft materials are not so convenient, but the same principle of calculation applies. If the floor beam were made of magnesium alloy, we would multiply the volume, 12.24 cubic inches, by 0.064 (see Fig. 368) to get the weight of the part, 0.783 pounds

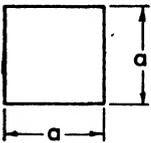
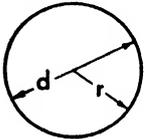
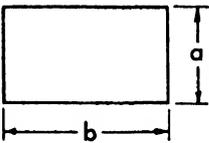
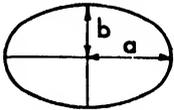
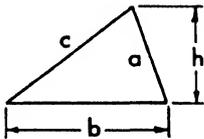
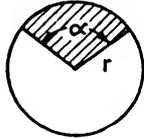
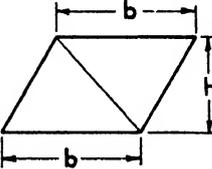
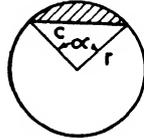
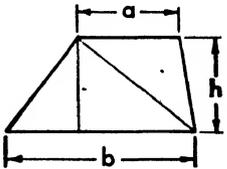
AREAS OF PLANE FIGURES			
FIGURE	FORMULA FOR AREA	FIGURE	FORMULA FOR AREA
 <p>SQUARE</p>	$a^2$	 <p>CIRCLE</p>	$\pi r^2$ or $\frac{\pi d^2}{4}$ $(\pi = 3.1416)$
 <p>RECTANGLE</p>	$a \times b$	 <p>ELLIPSE</p>	$\pi \times a \times b$
 <p>TRIANGLE</p>	$\frac{b \times h}{2}$ or $\sqrt{s(s-a)(s-b)(s-c)}$ where $s = \frac{1}{2}(a+b+c)$	 <p>ANY SECTOR OF A CIRCLE</p>	$\pi r^2 \times \frac{\alpha}{360^\circ}$
 <p>PARALLELOGRAM</p>	$b \times h$	 <p>SEGMENT OF A CIRCLE SUBTENDED BY ANGLE <math>\alpha</math> LESS THAN <math>180^\circ</math></p>	$\frac{\pi r^2 \alpha}{360^\circ} - (s-r)\sqrt{s(s-c)}$ where $s = \frac{1}{2}(c+2r)$
 <p>TRAPEZOID</p>	$\frac{a \times h}{2} + \frac{b \times h}{2}$ or $\frac{h}{2}(a+b)$	 <p>SEGMENT OF A CIRCLE SUBTENDED BY ANGLE <math>\alpha</math> GREATER THAN <math>180^\circ</math></p>	$\frac{\pi r^2 \alpha}{360^\circ} + (s-r)\sqrt{s(s-c)}$ where $s = \frac{1}{2}(c+2r)$

Fig. 367



Fig. 368 (Continued)

TABLE OF WEIGHTS

WEIGHT OF MISCELLANEOUS MATERIALS (continued)				WEIGHT OF MISCELLANEOUS MATERIALS (continued)			
	Per Cubic Inch	Per Square Inch	Per Lineal Inch		Per Cubic Inch	Per Square Inch	Per Lineal Inch
Insulation—Corning Wool Assy.				Flex Tube . . . . .	.0420		
2" Thick . . . . .	.00154			Shock Cord $\frac{1}{8}$ " . . . . .			.0900
Plain Wool . . . . .	.00091			Cork & Sponge 110C Tan . . . . .	.0175		
Insurok Graphited Micarta . . . . .	.0477			Rubber Matting (Diamond Pat) . . . . .	.0272		
Kapok Felt . . . . .	.0026			Seapack . . . . .		.00052	
Latex (Rubberized Hair) . . . . .	.00138			Seapack Quilted (A= $\frac{1}{4}$ " Layer) . . . . .		.00066	
Leather (Artificial) . . . . .		.00111		Screen			
Leather (Dry) . . . . .	.0310			Steel 100 Mesh . . . . .		.00092	
Leather (Greased) . . . . .	.0370			Nickel 100 Mesh . . . . .		.00103	
Linoleum (Aero Floor) . . . . .		.00154		Brass 20 Mesh . . . . .		.00260	
Lumarith . . . . .	.0482			Brass 50 Mesh . . . . .		.00220	
Micarta . . . . .	.0560			Brass 8 Mesh . . . . .		.00300	
Moleskin . . . . .		.00025		Alum. 10 Mesh . . . . .		.00100	
Mohair . . . . .		.001		Soundproofing Material			
Muslin . . . . .		.00083		D.G. K-B201 Felt .14" Thick .15"		.00121	
Mycalex . . . . .	.1100			D.G. 111 Asphalt Felt .12" Thick		.00131	
Neoprene . . . . .	.0480			D.G. 203 Asphalt Felt .11-.12"			
Pantasote "A" Airplane FAB. . . . .		.00039		Thick . . . . .		.00299	
Paper . . . . .	.0336			Tape (Cotton Average) . . . . .		.00025	
Phenol . . . . .	.04722			Tape (Friction) . . . . .		.0004	
Phenolic Fabric . . . . .	.0504			Tenite . . . . .	.04560		
Plastacelle . . . . .	.0555			Textasote (Waterproof Fabric) . . . . .		.00097	
Plastic Wood (after 5 days) . . . . .	.0240			Texolite . . . . .	.05000		
Plywood (F YBR—Tech) $\frac{1}{8}$ " . . . . .	.02160	.0027		Vellumoid .094" Thick . . . . .		.0035	
Rope (Manilla)				Wax . . . . .	.0350		
$\frac{1}{8}$ " . . . . .			.015	Webbing			
$\frac{1}{4}$ " . . . . .			.029	$\frac{1}{8}$ " Thick (Cotton) . . . . .		.0014	
$\frac{3}{8}$ " . . . . .			.053	$\frac{1}{4}$ " Thick . . . . .		.00275	
$\frac{1}{2}$ " . . . . .			.075	Wood			
$\frac{5}{8}$ " . . . . .			.104	Balsa . . . . .	.0058		
$\frac{3}{4}$ " . . . . .			.133	Cork . . . . .	.0090		
$\frac{7}{8}$ " . . . . .			.167	Hemlock . . . . .	.0168		
1" . . . . .			.195	Mahogany . . . . .	.0197		
$1\frac{1}{8}$ " . . . . .			.225	Plywood (Plypanel #54) . . . . .	.0197		
Rubber				Plywood (Algoma) . . . . .	.0137		
Sponge . . . . .	.01960			Redwood . . . . .	.0160		
Shock Disk . . . . .	.0420			Spruce . . . . .	.0156		

Solids

While most modern airplane parts are fabricated from sheet metal, there are always many solid parts such as castings, forgings, and machined elements. The procedure for calculating the weights of these parts is, in general, the same as for sheet metal; however, there usually is no constant dimension by which the surface area can be multiplied to obtain the volume.

Any solid shape can be broken down into its components, which are simple, basic geometric solids. The formulas for finding the volumes of these basic solids are given in Fig. 369. To find the weight of a solid object, it is first divided into its simpler component parts, the volumes of which are then found and summed up to give the total volume of the part. This total volume is multiplied by the unit weight of

the material to obtain the calculated weight of the part.

For example, the weight of the machined part show in Fig. 370(a), a steel landing gear fitting, is calculated as follows.

In Fig. 370(b) the part has been shown "exploded" into its component volumes. Volume 1 is a rectangular solid. Its size, or volume, is the product of its three dimensions:  $6 \times 2.5 \times 4 = 60$  cubic inches. Volume 2 is a solid cylinder. Its size is the product of its base area ( $\pi \times 0.5^2 = 0.7854$  square inches) times its length:  $0.7854 \times 3 = 2.356$  cubic inches. Volume 3 is another rectangular solid and its size is  $0.625 \times 2.5 \times 3 = 4.688$  cubic inches. Volume 4 is one-half a solid cylinder, and its size is equal to its base area times its length:  $\frac{1}{2}(\pi \times 1.5^2) \times 2.5 = 8.836$  cubic inches. Volume 5 is another one-half a solid

cylinder, and its size is equal to its base area times its length:  $\frac{1}{2}(\pi \times 2^2) \times 2.5 = 15.708$  cubic inches. Volume 6 is itself a combination of volumes:

Short-cut methods are usually employed in such a case, but for illustration the precise calculation is shown here. Since volume 6 is flat and has a constant thickness, its weight is calculated

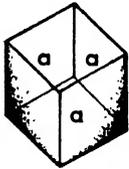
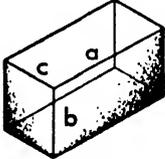
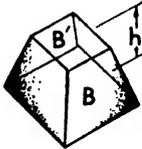
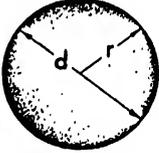
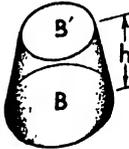
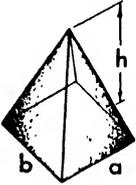
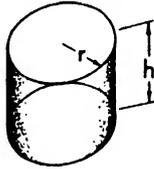
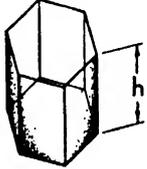
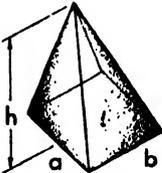
VOLUMES			
FIGURE	FORMULA FOR VOLUME	FIGURE	FORMULA FOR VOLUME
 CUBE	$a^3$	 OBLIQUE CONE	$\frac{1}{3} \times \pi \times r^2 \times h$ or $\frac{1}{3} \times \text{Base Area} \times h$
 RECTANGULAR SOLID	$a \times b \times c$	 FRUSTRUM OF PYRAMID	$\frac{1}{3} \times h \times (B + B' + \sqrt{B \times B'})$
 SPHERE	$\frac{4}{3} \times \pi \times r^3$ or $\frac{1}{6} \times \pi \times d^3$	 FRUSTRUM OF CONE	$\frac{1}{3} \times h \times (B + B' + \sqrt{B \times B'})$
 RIGHT PYRAMID	$\frac{1}{3} \times a \times b \times h$ or $\frac{1}{3} \times \text{Base Area} \times h$	 CYLINDER (RIGHT OR OBLIQUE)	$\pi \times r^2 \times h$ or $\text{Base Area} \times h$
 RIGHT CONE	$\frac{1}{3} \times \pi \times r^2 \times h$ or $\frac{1}{3} \times \text{Base Area} \times h$	 PRISM (RIGHT OR OBLIQUE)	$\text{Base Area} \times h$
 OBLIQUE PYRAMID	$\frac{1}{3} \times a \times b \times h$ or $\frac{1}{3} \times \text{Base Area} \times h$		

Fig. 369

the same way as that of a sheet metal part. Its surface area is first divided into three triangles and a sector of a circle as shown in Fig. 370(c). Area  $6_1$  is equal to  $(2 \times 1.5)/2 = 1.5$  square inches. In area  $6_2$  the height is equal to the length of side BE which is known to be 0.5 inch. The base is equal to side AB, and this is found to be 1.73 inches, either by trigonometric calculations or by actually laying the figure out on paper. Therefore, area  $6_2 = (0.5 \times 1.73)/2 = 0.43$  square inch. Area  $6_3$  is identical to  $6_2$ . Area  $6_4 = \pi \times 0.5^2 \times 142.83/360$ , the angle  $\alpha = 142.83$  degrees being found either by trigonometry or by layout. Thus, area  $6_4 = 0.312$  square inch.

The total surface area of volume 6, then, is equal to the sum of  $1.5 + 0.43 + 0.43 + 0.31$  or 2.67 square inches. Finally, volume 6 is the product of  $2.67 \times 0.1875 = 0.501$  cubic inch. Volume 7 is identical with volume 6.

So far, we have found volumes 1 through 7.

These volumes all contribute to the weight of the part. The sum of these volumes is 92.59 cubic inches. It now remains for us to subtract the volumes of the holes, which are numbered from 8 to 13. They are all solid cylinders as shown in Fig. 370(b).

$$\text{Volume 8} = \pi \times 0.5^2 \times 2.5 = 1.96 \text{ cu in.}$$

$$\text{Volume 9} = \pi \times 0.625^2 \times 2.5 = 3.06 \text{ cu in.}$$

$$\text{Volume 10} = \pi \times 0.75^2 \times 2.5 = 4.41 \text{ cu in.}$$

$$\text{Volume 11} = \pi \times 0.875^2 \times 2.5 = 6.00 \text{ cu in.}$$

$$\text{Volume 12} = \pi \times 0.25^2 \times 0.1875 = 0.0368 \text{ cu in. or, to the nearest hundredth} = 0.04 \text{ cu in.}$$

Volume 13 is identical to 12.

The total volume to be subtracted, then, is the sum of volumes 8 through 13, which is:

$$1.96 + 3.06 + 4.41 + 6.00 + 0.04 = 15.51 \text{ cu in.}$$

The actual volume of steel in the part is the difference between 92.59 and 15.51 cubic inches, or 77.08 cubic inches. Multiplying this volume by the weight per cubic inch of steel (taken from Fig. 368) we find that 77.08 cubic inches  $\times$  0.282 pound per cubic inch = 21.74 pounds. It will be noticed that the weight of the fillets in the part was neglected. This is customary unless the fillet radii are large.

The preceding examples are only illustrations of the computation of weights, but every aircraft draftsman or engineer has plenty of opportunity to become proficient in this work through practice.

The calculation of the weight of a piece of tubing is merely a special case of calculating the weight of a cylinder. The volume of the cylinder the diameter of which is the inside diameter of the tube is simply subtracted from the volume of the cylinder the diameter of which is the outside diameter of the tube. If the tube has a thin wall, its volume can be closely approximated by multiplying its circumference by its wall thickness and its length. In either case the volume of the tube is then multiplied by the weight per unit volume of its material to obtain the calculated weight. Some catalogues and standard books give

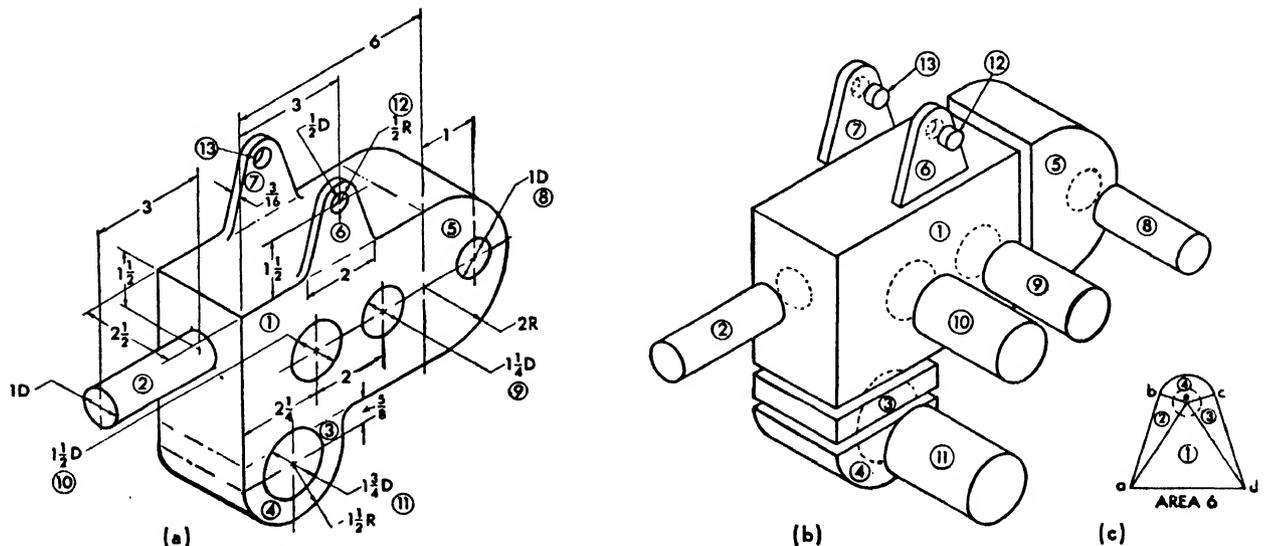


Fig. 370. Method of analyzing a solid part for weight calculation

the weight of tubing as weight per unit length. In this case it is only necessary to multiply this figure by the length of the tube.

As already stated in reference to tubing, many standard books give weight per unit length (usually 1 inch) for parts that have the same cross section throughout their entire length. The draftsman has merely to multiply this figure by the length of the part to obtain its calculated weight. Extruded and drawn structural sections are good examples of this system.

It will be noticed that an important difference is inferred between "calculated" and "actual" weights. The reason for this is that the weight of rivets and of paint and sealing materials is never calculated, a certain small cutting tolerance on materials cannot be figured, and the draftsman's figures may contain some minute error. In view of these unknown factors, it is common practice to add 3 to 5 per cent to the calculated weight of a drawn part, depending upon its size and complexity.

#### *Be Weight Conscious*

Although some weight items are beyond the control of designers and draftsmen, a great deal of the structures and some of the systems and equipment are subject to their efforts to reduce weight. After World War II the aircraft companies again resumed a keen competition in the design of commercial craft. Here weight is of utmost importance—weight reduction is worth money. Some estimates based on operating costs place high value on weight saving, that is, from \$2 to \$10 per ounce or \$32 to \$160 per pound per ship. Whenever the draftsman sees an opportunity to save weight, he should check with his supervisor or the Stress and Weights Groups.

#### *Weight Saving Hints*

1. Maximum efficiency and light weight result when every ounce of material is employed to its maximum good.

2. A member in tension can usually be designed lighter than a member in compression.

3. Two structural members may duplicate each other. It is sometimes more efficient to increase the size of one to carry both loads.

4. Do not combine different types of loads (as compression and bending); lower efficiency and

added weight will be the result.

5. Non-structural parts may contain a great deal of excess weight. It is here that the draftsman can do maximum good by displaying practical ingenuity, personal initiative and common sense. Too often the design of such parts are based on previous designs that have served a similar function without consideration of the weight penalty.

6. Evaluate the physical properties of suitable materials so that the most efficient material may be used for a particular part.

7. Use the lightest possible material for space fillers. Check with the Stress group for the lightest possible gages to carry the load.

8. Consider the use of the light magnesium alloys. Local sturdiness may be gained without the use of added stiffeners due to the greater bulk of magnesium for equal weights compared with other metals.

9. Often, critical stresses in moving or vibrating parts may be reduced by employing the lightweight magnesium alloys. This also allows weight savings in adjacent structure.

10. Be aware of the possible uses of magnesium, but remember that strength, formability and corrosion-resistance requirements must be carefully considered.

11. Welded sheet assemblies are often lighter than castings and forgings.

12. Excessive joints add weight; properly designed castings may eliminate this weight penalty. However, consider sheet metal stampings of integral design to replace the heavier castings or extrusions.

13. When two or more designed parts are equal in other respects, the light-weight design is considered the best.

14. Beads, flanged or beaded lightening holes and similar integral reinforcement, eliminate the weight of added stiffeners. See Figs. 415-416.

15. The individual weight of nuts, bolts, screws, etc., may seem insignificant, but a weight savings from 150 to 300 pounds may be realized in a 30,000 pound airplane by the proper choice of fasteners.

16. The use of clevis bolts in shear in place of the regular AN bolts results in a weight savings of 25 to 50 per cent.

# CHAPTER TWENTY-ONE

## LOFTING

### *Introduction*

Long before the airplane was developed, shipbuilders found that the most accurate and satisfactory results were obtained from full scale layouts of the parts to be made. Workmen were trained in this type of work, and usually their workroom was located high in the rafters of the building. Thus the term "loft" came into general use, and the workers were called "loftsmen." When the aircraft industry developed its own production methods, the term "loft" was one of the many borrowed from the shipbuilders.

The loft plays an important role in both industries, since its job is to determine the lines of the plane or ship and to break down the blueprints for use in the shop. The lines of a plane determine its contour, and the contour is simply the outside shape seen from the plan, side, and end views. The blueprints are broken down by making actual size layouts, called "master layouts," from the blueprints on large sheets of painted metal or on a wooden platform painted white, black, or blue. These layouts must be made on metal or wood, because paper expands and contracts far too much for the tolerance allowed to the loftsmen. Usually the layout is first drawn lightly with a hard pencil; later it is either darkened with a softer pencil or scribed. Scribing consists of cutting through the paint with a pointed metal instrument about the size of a long drawing pencil and very similar in construction to an ice pick.

The tolerances mentioned are very important to the finished airplane. Should the loft be allowed as much tolerance, or even half as much, as the workers on the production line, it is easy to see that a part leaving the loft approximately  $\frac{1}{32}$  inch too large which is then handled by several other departments in the plant (all of which are allowed tolerances) might differ greatly

from the original on the blueprint. For this reason, loftsmen must be able to make layouts correctly to 0.007 inch. To do this the workman needs not only skill but many special tools such as large straightedges, wire stretchers, scales graduated in hundredths, magnifying glasses, trammel points, dividers, and scribes.

Master layouts for both the experimental and the production models are made on metal or wood. When the layouts have been completed and checked, the loft must then provide templates for all parts and the tools that the shop will need in fabricating all sections of the plane. It is also the responsibility of the loft to furnish any special information relative to the lines or any detail parts of the plane to engineers, tool designers, or shop workers to aid in design, tooling, or fabrication.

The loftsmen must solve problems that arise daily when the information on a blueprint or in an engineering instruction is incomplete. To do this and to cope with many other tasks confronting him, the loftsmen must have a working knowledge of drafting procedure, tooling methods, trigonometry, and descriptive geometry, as well as a definite idea of what he is about to do and how to do it swiftly, surely, and skillfully.

### *Relationship between Lofting and Design Drafting*

Both the loftsmen and the design engineer have a distinct function in the preparation of a plane for production, and for this reason each must have a definite respect for the other's knowledge and skill. The loft is in direct contact with the tool designers and the shop; it is sort of a clearing house between the engineer and the shop. Both the loftsmen and the design engineer have as definite a place in the aircraft industry as a welder or a riveter, but their work

overlaps to such an extent that in recent years some of the larger aircraft companies have incorporated their design and lofting departments in one unit. In doing this, they found that the time between the start and the completion of the preliminary design of a plane can be greatly reduced, in spite of new routine and new procedure.

This union has brought about some changes in procedure, though the fundamentals remain the same. For instance, the parts of the plane are still designed by a designer engineer and checked by a structural engineer, but the design is laid out on the loft board whereas it formerly was done on paper. This speeds information to the loftsmen, and he can finish his part of the job more quickly.

The engineer must now supply an approved sketch that may be done freehand if the correct dimensions are called out. Formerly, it was necessary to prepare a complete layout to scale on paper from which to make the preliminary print.

The new method eliminates the preparation of both preliminary blueprints and loft layouts, and this is much more satisfactory because of the saving in time and materials.

Considerable time is also saved by having the loftsmen and the designing engineer work together on the job. Should a question arise, the loftsmen can immediately obtain the needed information from the engineer who designed the part. The common practice used to be to send the blueprint back to the engineer, requesting him to answer questions on work that had long since "grown cold."

After the loft layouts have been completed and checked, the layouts are photographed. The reduced size photographs are used as negatives for the prints for the shop, and these photo prints serve the same purpose as blueprints. Full scale reproductions on metal can also be furnished to the shop with sufficient information to call out any part because it is a reproduction of the original master layout. Also the necessary in-

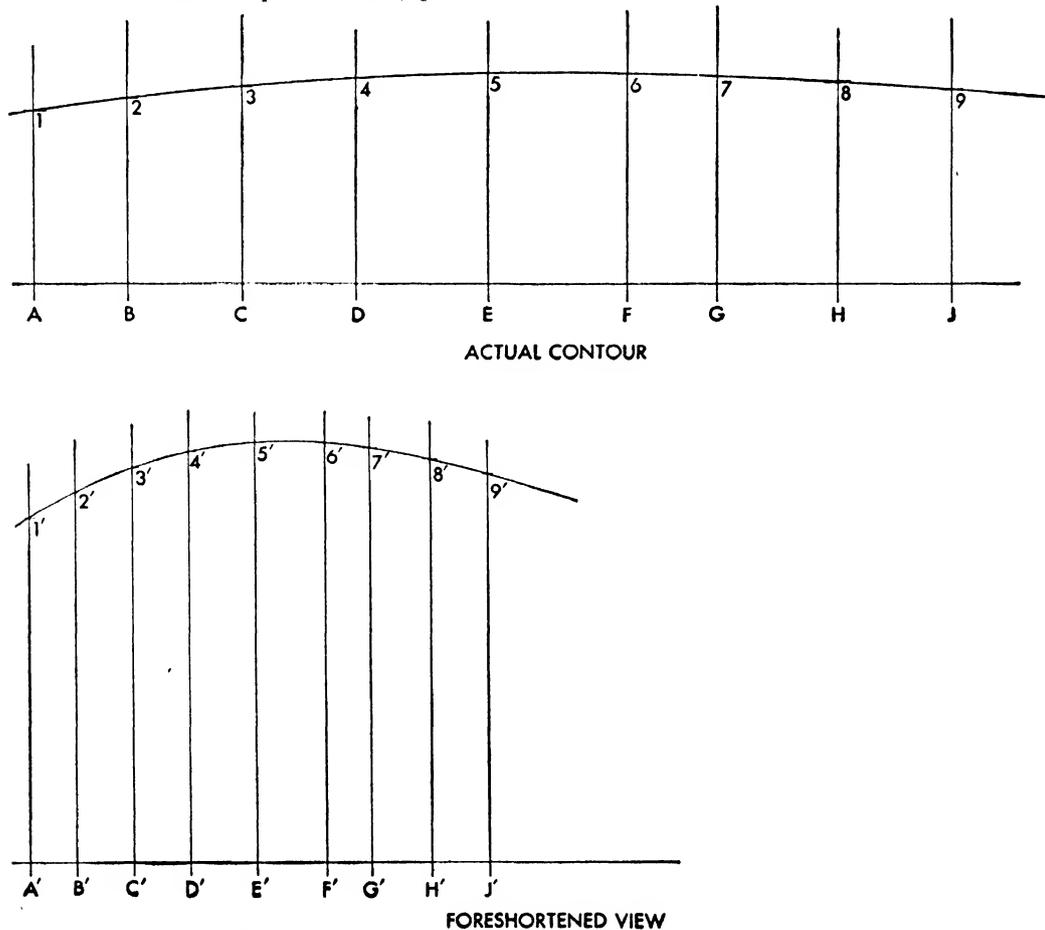


Fig. 371. Foreshortening method of proving lines "fair"

formation regarding tools is either available or can be readily obtained from the loft, and no delay should occur. When changes are necessary, the master layout is changed, new photographs are made, and new prints are released to take the place of the original prints, which are called in.

The loftsmen and the design engineer can learn a great deal from each other. From the engineer, the loftsmen can gain a better knowledge of design practice, and the engineer can often improve his accuracy and gain a clearer picture of production problems through his association with the loftsmen and the loft board. By seeing the parts laid out in actual size, he will be better able to see the clearances and tolerances necessary and design the parts accordingly.

The consolidation of the design and loft groups in some engineering departments has been so complete that the workers might be called "loft draftsmen."

To further speed production of the experimental plane, many aircraft companies have combined the lofting and design functions to the degree that the initial design is drawn full size on metal by the design layout man. The regular orthographic views are used, and whenever practical, the flanges of the various sheet metal members are developed flat in a reference line directly on the orthographic view. The layout may then be reproduced by direct contact or some similar actual size reproductive method. It is then ready for cutting and forming by the

shop. Smaller reproductions are made for filing and record purposes.

The metal, prepared with a special cream white paint surface, has a good texture for pencil drawing and errors may be easily rectified by erasing.

The conventional alphabet of lines is eliminated. All lines are sharp and thin (about the intensity of a fine dimension line), drawn with a 4 to 9H pencil. Chisel points are used for long lines, conical points for details.

Since all design is drawn actual size and the cutting-out lines are fully developed, very little dimensioning is necessary.

### General Procedure

No attempt has been made in this chapter to list in detail all formulas, routines, techniques, and procedures needed by a loftsmen in an aircraft plant. But this text will supply the beginner with the required basic functional information. Emphasis has been placed on the tools used by the loftsmen and on the fact that he not only must acquire a technical knowledge but must also be a skilled workman, for, should a loftsmen make some small error on a layout or a template, it *might* not be caught until the parts had been made and fitted to the plane. All the time spent laying out the template and all the time spent making the part, as well as the valuable material, would then be wasted, and the completion of the planes would be held up for lack of that

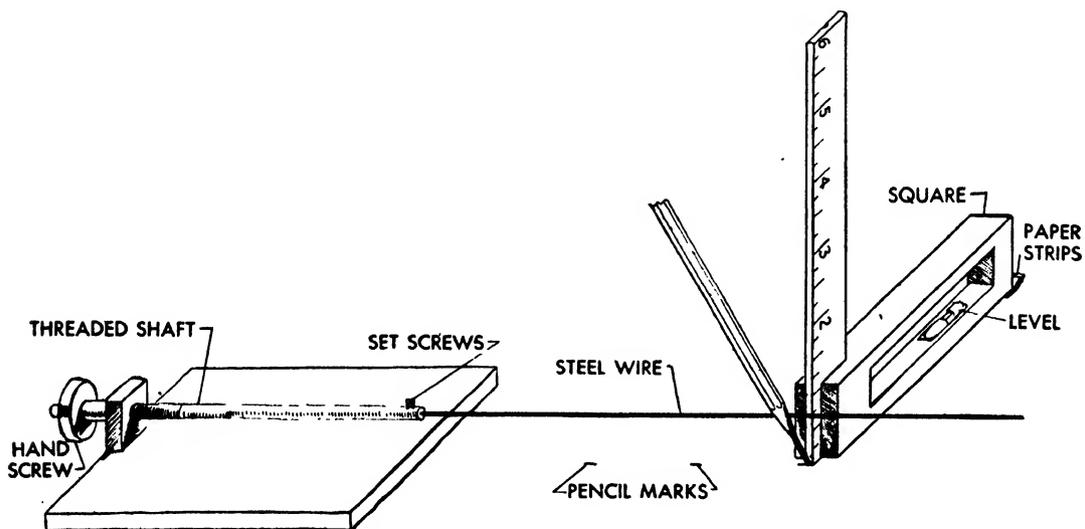


Fig. 372. Method of constructing line by wire stretcher and square

part. Template development and layout have been mentioned particularly because the loft draftsman who has had previous training in the template group is usually better equipped to handle a job in any other part of the loft.

Chapters could be written on the methods of obtaining fair lines and calculating offsets of the fuselage and the wing, for it is the job of the loft to supply information to the engineering draftsmen, tool designers, template makers, and production departments concerning all lines and offsets relative to the plane. One chapter is not enough to discuss all the details pertaining to the actual development of the lines of a plane. However, the principal methods and layouts will be explained so that when they are referred to the draftsman is not left in the dark.

Before an experimental airplane can be built, a great many technical problems must be solved. The aerodynamics group must supply the design groups with sufficient information to make small size drawings of particular sections of the plane. These drawings are usually made  $\frac{1}{2}$  or  $\frac{1}{8}$  of the actual size, and from them a mock-up and a wind tunnel model are made and the full scale lines of the plane are determined. The loft will then furnish the actual offsets and ordi-

nates of the fuselage and wings. The offsets of the fuselage of a plane are the dimensions from the horizontal and vertical center lines of the plane to its contour or skin line, and the ordinates of the wing are the dimensions above and below the chord plane of the wing to its contour.

Since the shape of the contour determines the successful aerodynamic function of the plane, the loft must "fair" all these lines. This means checking all lines for possible irregularities, such as bumps, recesses, or sharp corners. When a line is proved to be free of all irregularities, it is referred to as a "fair" or "natural" line.

Lines may be proved fair by foreshortening. This method consists of drawing the lines on which the offsets are taken closer, to one-half their original dimension, and doubling the length of the original ordinates. This gives a ratio of 1 to 4 and is standard practice, as indicated in Fig. 371. This process intensifies the curve, so that slight errors will become quite obvious.

Along with fairing lines and preparing offsets, the loft also develops all surfaces exposed to the airstream so that a minimum of air resistance will be obtained. Sufficient material is available in trade journals and company engi-

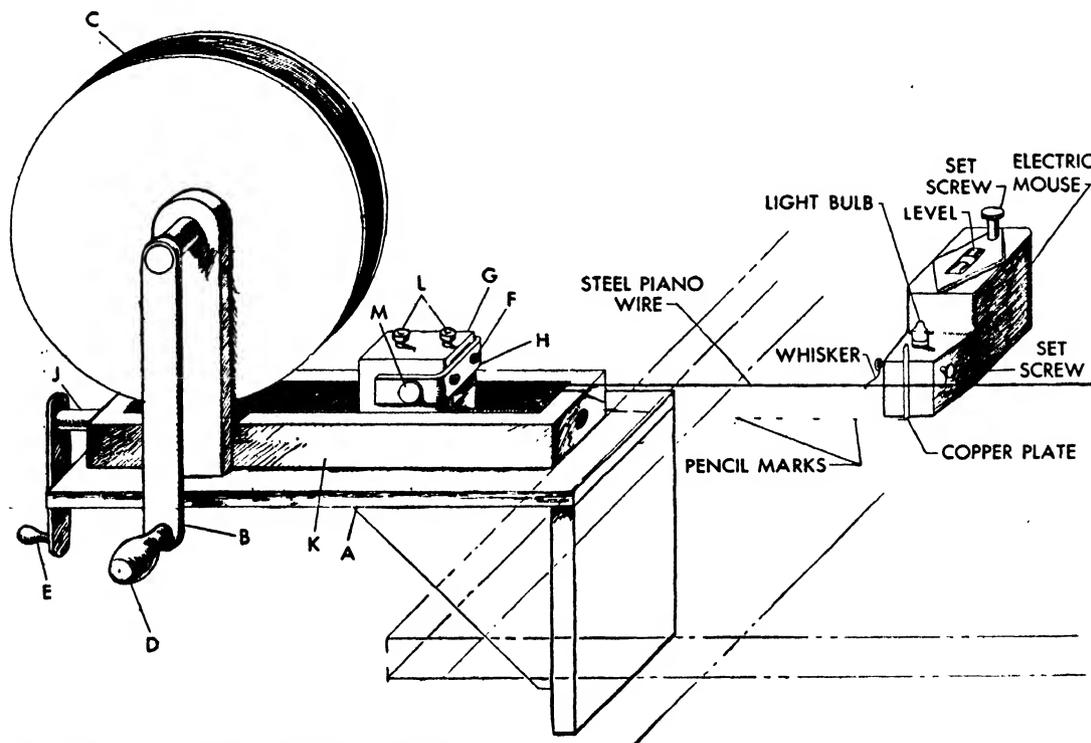


Fig. 373. Improved wire stretcher and "mouse"

neering libraries so that the loftsmen or draftsman interested in this particular field can acquire a working knowledge of the principles involved.

Mathematical formulas and methods of projection have been compiled whereby the loftsmen can plot an irregular curve or any contour relative to the airplane and be definitely sure that the line is fair, abolishing the old method of "fairing by eye." Lines have been classed or grouped so that the loftsmen can quickly choose a reliable method when a certain type of line is specified. These methods are in use in many of the large factories where the personnel has had sufficient experience to handle them. Later, perhaps, when all personnel can be more thoroughly trained, the less scientific methods now in use will be abandoned completely.

The mock-up, a full size plane built of wood, is made to facilitate the design and installation of all structural parts, fuselage, wing, hydraulic, electrical, radio, and miscellaneous equipment and furnishings that are to be placed in the plane. Unsatisfactory parts are redesigned and installed on the mock-up. The loft furnishes layouts for all parts of this wooden plane. These parts are usually made of plywood and, since only one mock-up is to be made, these layouts are drawn directly on the wood and are then cut out and installed. Before work can begin on the experimental model, the mock-up must be approved. This approval comes from a mock-

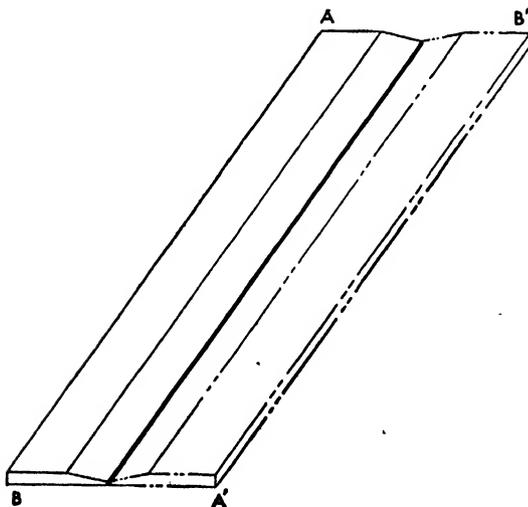


Fig. 374. Method of checking accuracy of a straightedge

up board, composed of either army, navy or commercial engineers, who decide whether the actual plane will bear the same design as the mock-up. As soon as this mock-up board sends its approval to the company, the loft, in conjunction with the design groups, starts the layouts of such major structures of the plane as fuselage bulkheads, beltframes, longerons, wing spars, and bulkheads. After these layouts have been made, templates, described further in this chapter, are developed. Since only one or perhaps two experimental models of the plane will be made, the number of tools used on them is kept to a minimum.

After the experimental model has been produced and flown, parts that do not react satisfactorily must be replaced, and sometimes entire assemblies are redesigned. Again, the loft must make the necessary layouts and have them checked.

After this is done, production tools are made, and as many of the experimental tools as possible are used. Production tools must be correct, for now not one, but twenty, thirty, or fifty planes are to be made from the same set of tools. On the experimental plane, the part might be reshaped by the shop worker if it did not fit exactly, but now, should the part not fit, a large number of parts would be in the same condition, and valuable time, material, and money would be wasted if the worker attempted to correct these errors at his bench. Therefore, all production templates and tools are carefully checked before they are released so that no hand work will be necessary.

After the plane is put into production, the loft still works diligently to keep all departments supplied with current tools, for changes in design and tooling of the plane are common. During routine flights, it is not unusual to find some parts that still render unsatisfactory service, and these must be changed. Also, design improvements may be made, and as these are usually incorporated if they are sound, it is easily seen why the loft is seldom idle.

#### *New Methods*

In recent years drastic changes have taken place in some of the loft departments of aircraft

companies. With the production of multi-engine planes, the loftsmen encountered many perplexing problems, particularly that of drawing a line of any great length and being certain that it was straight. Many methods were tried. The most satisfactory proved to be the use of a wire stretcher and a small steel square provided with a level. The first wire stretchers made were similar to the one shown in Fig. 372. They had small iron frames with threaded shafts and hand screws. These stretchers were fastened with C clamps at either end of the table on which the line was to be drawn. The wire was run the length of the table, through the shaft on each stretcher, and was held in place by two small setscrews. The hand screws were adjusted, and the wire became fairly taut. The wire was seldom stretched to its limit, for the heavy steel piano wire used will take a considerable amount of tension. After the wire had been stretched, the operators, usually working in pairs, would lay in points with their squares. If the square was not perfectly level, it had to be jacked up at either end, usually with paper strips, until it became level and produced a perpendicular projection from the edge of the wire to the layout. When

the square and the wire were in perfect contact (when the square touched the wire without moving it), the worker made a small pencil mark at the bottom edge of the square, as shown in Fig. 372. Setting the square level was very important, for, whatever the care taken while leveling the table, certain sections might not be true.

After the square had been set, perpendicular contact had been established with the wire, and the pencil marks had been made, the process would be repeated for checking. This usually required a magnifying glass and a good deal of patience, for many such points are needed before the line can be drawn. About one point every 2 feet is desirable. As can be imagined, the drawing of a long line necessitated endless labor by the loftsmen, for, after all the points had been located, they had to be connected with a straight-edge. This was not too satisfactory a system, because contact with the square caused the wire to deflect, and the length of the table tended to let the wire sag.

An improved wire stretcher has now come into use. A sketch of one of the new models is shown in Fig. 373. This stretcher is much heavier than the small original model, and it has two adjust-

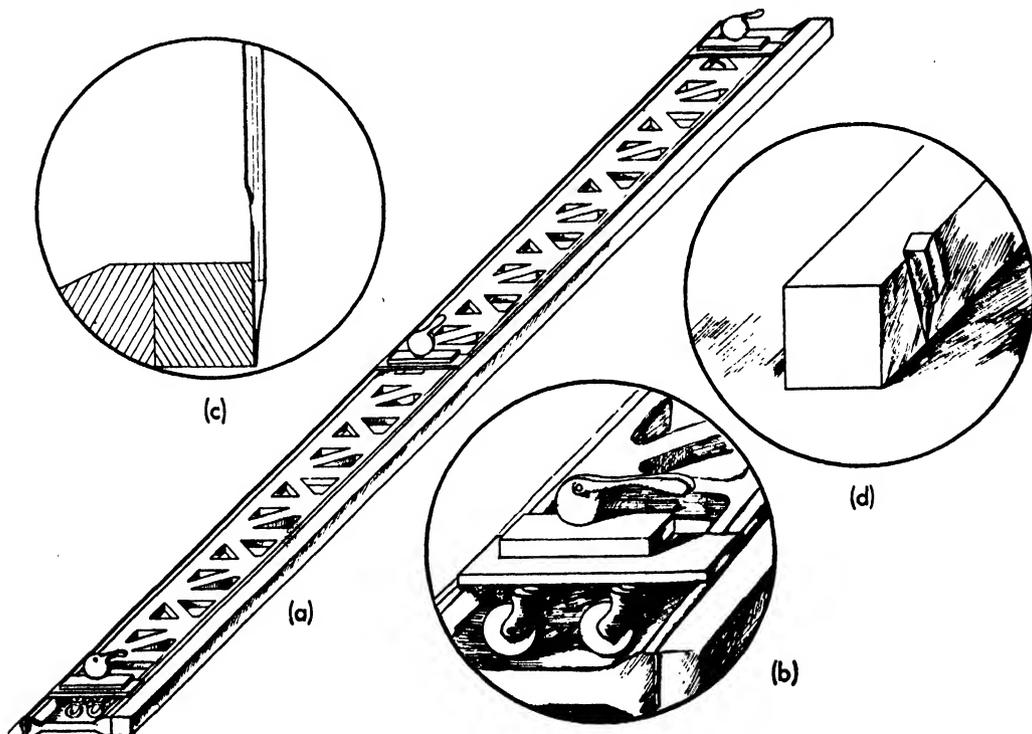


Fig. 375. Use of pencil and scribe with a 12-foot straightedge

ments. The first is spool C, on which the wire is wound. When spool C is tightened by handle D and lever B, the wire can be made fairly taut. It is then locked in block G, with two set screws L, and the wire can now be stretched to any degree of tautness required by turning the threaded shaft J with handle E, thereby pulling block G along track K. Frame H is held to block G by two set screws F. Set screws M regulate any possible lateral motion. Two such stretchers may be used on a table if its length necessitates it; otherwise one can be used at one end of the table and a stationary holder at the other end.

In connection with the wire stretcher, another tool has been developed which eliminates a great deal of tedious labor involved in using a square. It also assures minimum deflection of the stretched wire. Several different versions of this tool have been introduced, but they have all borne the same name, "the electric mouse." This gadget has been brought into popular use and in some plants has replaced the small square almost completely.

The "mouse" is easily constructed and is very

simple to operate. The case is made of hardwood, Masonite, or some other nonconductive material, and may be designed in a variety of shapes. It has a small dry cell battery inside, and it is advisable to have a level set in the top of it, with an adjustment screw at the back to facilitate leveling. A brass, copper, or steel plate is placed in the front of the "mouse" so that it will contact the electrode of the battery, and a small flashlight bulb is placed so as to touch the top of the battery case. This bulb is held in place by two set screws with long, fine wires, or "whiskers," attached to them, and these "whiskers" extend in front of the "mouse." The whiskers slide above and below the stretched piano wire and are so fine that they cannot deflect it. When the copper plate comes in contact with the stretched wire, the circuit is completed through the wire by the whiskers and the copper plate, the bulb flickers, and a perfect contact is established between the stretched wire and the mouse with minimum deflection of the piano wire. Should the bulb glow long and bright, the loftsmen knows that too much pressure has been placed



Fig. 376. Loftsmen on loft table

on the stretched wire by the mouse, and that the pressure must be relieved by moving the mouse. When a perfect contact has been established, the loftsmen makes a fine pencil mark at the base of the copper plate and moves on to the next location about 2 feet away. One man can now lay in a line in less time than it took two men previously, and the results are more satisfactory. The mouse is now definitely at home in the loft.

After all the necessary points have been located with the wire and mouse, the worker is ready to draw the line through the points. This is done with a straightedge the same way as it was done with the old wire stretcher and square. Before using a straightedge, it should be checked for accuracy. To do this, a line is drawn, using the good side of the straightedge, which then is turned around (A to A' and B to B') as in Fig. 374. The ends of the straightedge are lined up with the ends of the line, and another line is drawn. If the two lines coincide, the straightedge is accurate. If two lines are obtained—the worker can easily distinguish them with the aid of a magnifying glass—the straightedge is off one-half the distance between the lines. For instance, if the two lines coincide at both ends but diverge in the middle, the distance between them being  $\frac{1}{8}$  inch, the straightedge is off  $\frac{1}{16}$  inch.

When using a 12 or 14 foot straightedge, a flat scribe or special cut pencil should be employed. Figure 375a shows the 12 foot rigidly constructed straightedge mounted on casters (Fig. 375b) for ease in moving, and the inset in Fig. 375c shows how to cut a pencil for use with this tool. Inset d exhibits a type of flat scribe that may be used. This particular scribe is made of high temper tool steel, and the cutting edge can be made any width desired. About 0.006 inch is good, and the tool must be kept sharp for best results. A small drop of oil placed on the face of the scribe that slides along the straightedge will facilitate the operation. Take care not to get oil on the layout, for a dirty messy layout reflects badly upon the skill of the worker.

The size of the layouts presents two problems, the first being the worker's fatiguing position. When working on the large loft layouts, the worker must lie flat on his stomach for long periods or must work in a kneeling or squatting

position. Any one of these soon becomes very uncomfortable. To relieve the discomfort of such positions (Fig. 376), dollies, like the one in Fig. 377, are used. These dollies are wooden platforms mounted on casters and well padded so that the body of the worker will not touch the hard surface of the table. Since it is mounted on wheels, the dolly can be rolled anywhere quickly and saves time as well as wear and tear on the worker's hands, knees, and clothes.

The second problem is that of shortage of floor space. Formerly, all layouts were made on horizontal tables or the loft floor, but when space started to be at a premium during the last world war, the idea was conceived to work on vertical boards. These are usually designed to accommodate two 5 by 12 foot layouts, one on either side. The boards were first stationary, but are now made with counterbalances so that they can be easily raised and lowered to suit the loftsmen. Straightedges suspended from the top of the board can also be counterbalanced in the same manner, so that the loftsmen can hold the straightedge and draw a line simultaneously. However, it was discovered that, due to a great chance for error, it was impractical to lay in basic lines on these boards, so all reference lines and contour lines are laid in on a horizontal table, and then the sheet of metal is transferred to the vertical board where all the necessary detail is inserted. This method is found to be very satisfactory, and some elaborate vertical drawing boards have been designed.



Fig. 377. Workers on dollies

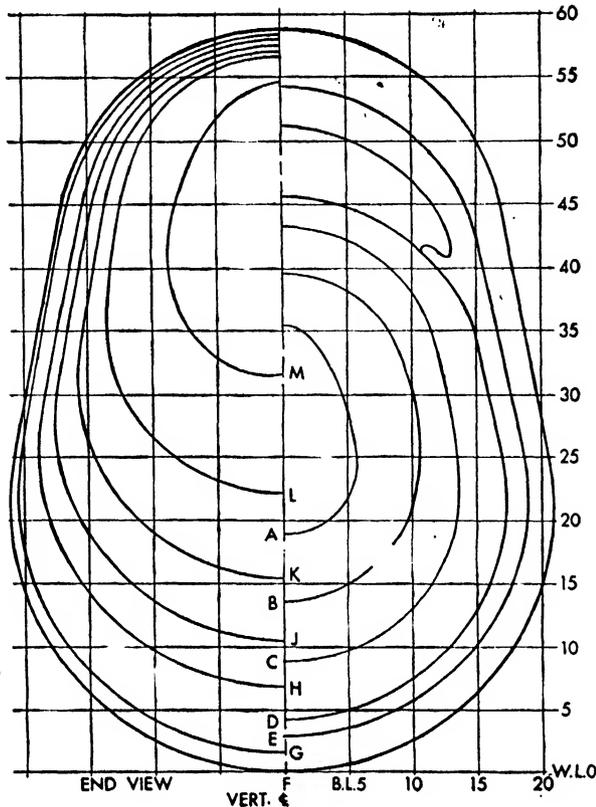


Fig. 378. End view fuselage body plan

The importance of layouts of the basic lines cannot be overemphasized, since all the master layouts, major assembly jigs, and templates are made from them. Accuracy is of prime importance, and the layman cannot appreciate the tedious hours spent to maintain the standard required in most companies. The lines of layouts are sometimes complicated, and views often overlap. By letting the plan, and perhaps the side view overlap, a great deal of space is saved and reference lines common to both views can be used. Some of these are listed below with a brief explanation to enable the beginner to recognize the names of various layouts, should he be referred to them in the course of his work.

*Fuselage Body Plan*

The body plan of the fuselage, commonly drawn as in Fig. 378, shows the contour and location of all the stations in the plane, also the location of the stringers, longerons, window and door frames, the pilot's enclosure, and any other opening there might be in the fuselage

of the plane. All these locations and offsets pertaining to the contour must be correct, for everything concerning them on the other layouts, jigs, and tools will be taken from this layout.

*Wing Layout*

The wing is usually laid out in a view looking inboard parallel to the chord plane, as in Fig. 381. This layout shows a true view of each station normal to the chord plane and all the stringer locations that run spanwise in the wing. It is very important that this be carefully laid out and thoroughly checked when completed to assure accuracy.

*Engine Nacelles*

The engine nacelle (or nacelle, as it is called) is the fairing that connects the engine housing with the wing proper. It shows the lines of the nacelle wing intersection and all the station lines of the nacelle. The nacelle often houses fuel or hydraulic tanks, the landing gear, or miscellaneous parts of the engine, and for this reason clearances are vitally important.

*Control Surfaces*

Layouts are made for all the control surfaces consisting of the flaps, ailerons, rudder, elevators,

Fig. 379  
FUSELAGE OFFSETS

B. L.	A	B	C	D	E
C	2 1/8	1 1/2	1 1/8	1 1/8	—
1	3	1 1/8	1	1 1/8	1/2
2	3 1/2	2 1/8	1 1/4	1 1/8	1/2
3	—	—	2 1/8	2 1/8	1 1/2
4	—	—	—	—	3
W. L.					
1	—	—	1	1 1/8	2 1/8
2	—	1 1/2	2 1/8	2 1/8	3 1/8
3	1	2 1/8	3 1/8	3 1/8	4
4	1 1/8	2 1/8	3 1/8	3 1/8	4 1/8
5	2 1/8	2 1/8	3 1/8	3 1/8	4 1/8
6	2 1/8	2 1/8	3 1/8	3 1/8	3 1/8
7	1 1/8	2 1/8	2 1/8	3 1/8	3 1/8
8	—	1 1/2	2 1/8	3 1/8	3 1/8
9	—	—	1/2	2 1/8	3 1/8
10	—	—	—	2 1/8	3 1/8
11	—	—	—	—	2 1/8
B. L.					
C	7 1/8	8 1/8	9 1/8	10 1/8	11 1/8
1	7 1/8	8 1/8	8 1/8	10 1/8	11 1/8
2	6 1/8	7 1/8	8 1/8	10 1/8	11 1/8
3	—	—	—	6 1/8	8 1/8
4	—	—	—	—	5 1/8

and the vertical and horizontal stabilizers. Lines must be constructed showing their contour and intersection with the fuselage.

### *Problems for Study*

In order that the draftsman may acquire a better understanding of the fuselage and the wing of an airplane, fuselage offsets and wing ordinates have been prepared. From them the draftsman can gain actual experience in plotting contours, using an offset chart for reference.

The body offsets, though partially shown in reference to the entire plane, produce station lines similar to those in Fig. 378. When a plane is lofted, the end view is usually shown as in Fig. 378. The station lines in the forward section of the plane are placed on the right-hand side of the vertical center line, and the ones in the aft

section are placed on the left-hand side. This method eliminates a great deal of work that would be required to plot both sides of a station, and it also simplifies the layout by using as few lines as possible to convey the necessary information. The accuracy of this method is also commendable, for it is very difficult to plot identical curves, and since the plane is symmetrical about the vertical center line, by laying in one half only, there is less chance for error.

The worker in the loft should always remember that *the minimum of actual work for the maximum of information is always desirable*. The result will be simplified, and the chances for error will be greatly reduced.

The offset chart shown in Fig. 379 gives the necessary information for laying in fuselage stations A, B, C, D, and E. First a horizontal and

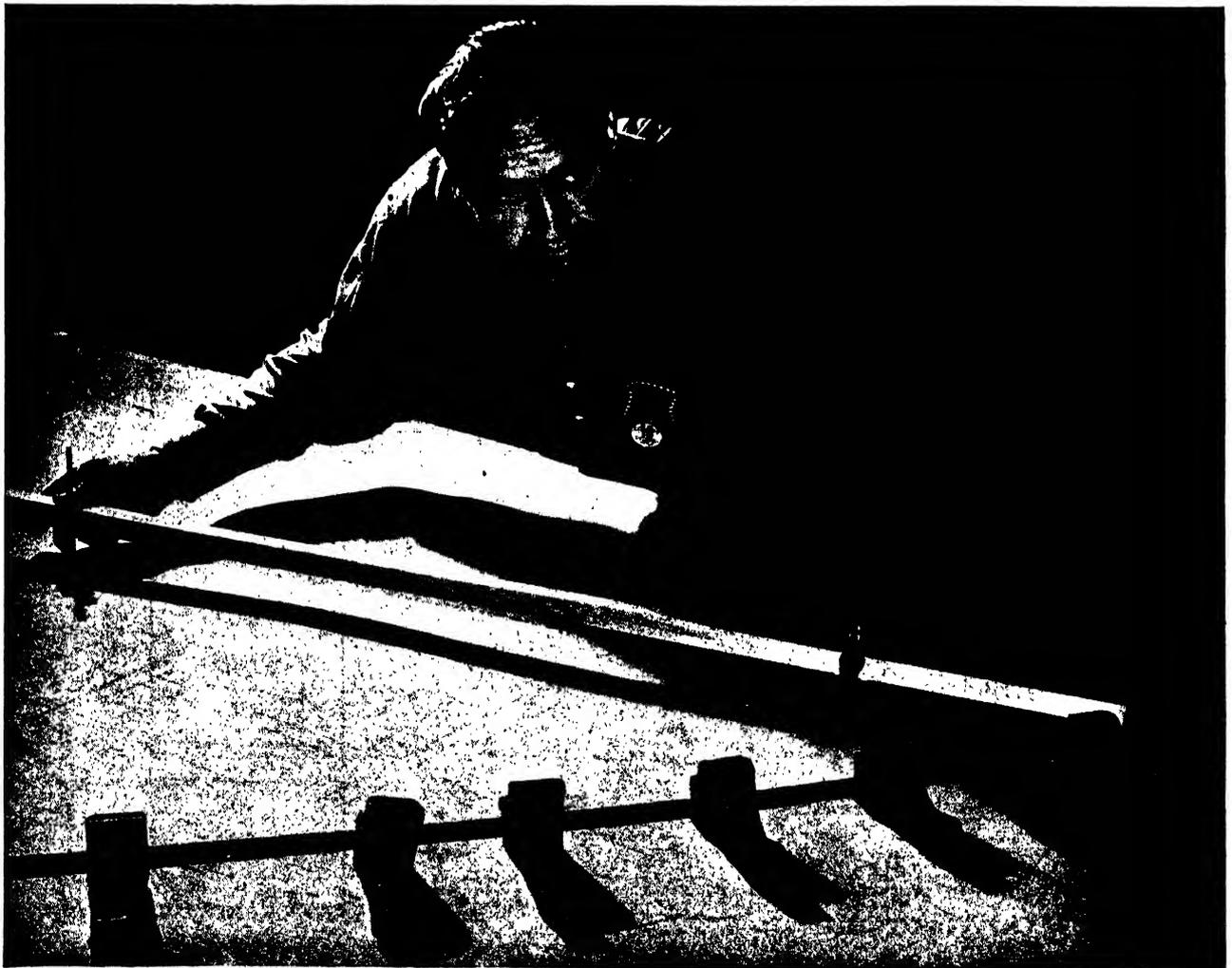


Fig. 380. Trammel points, spline, and ducks in use

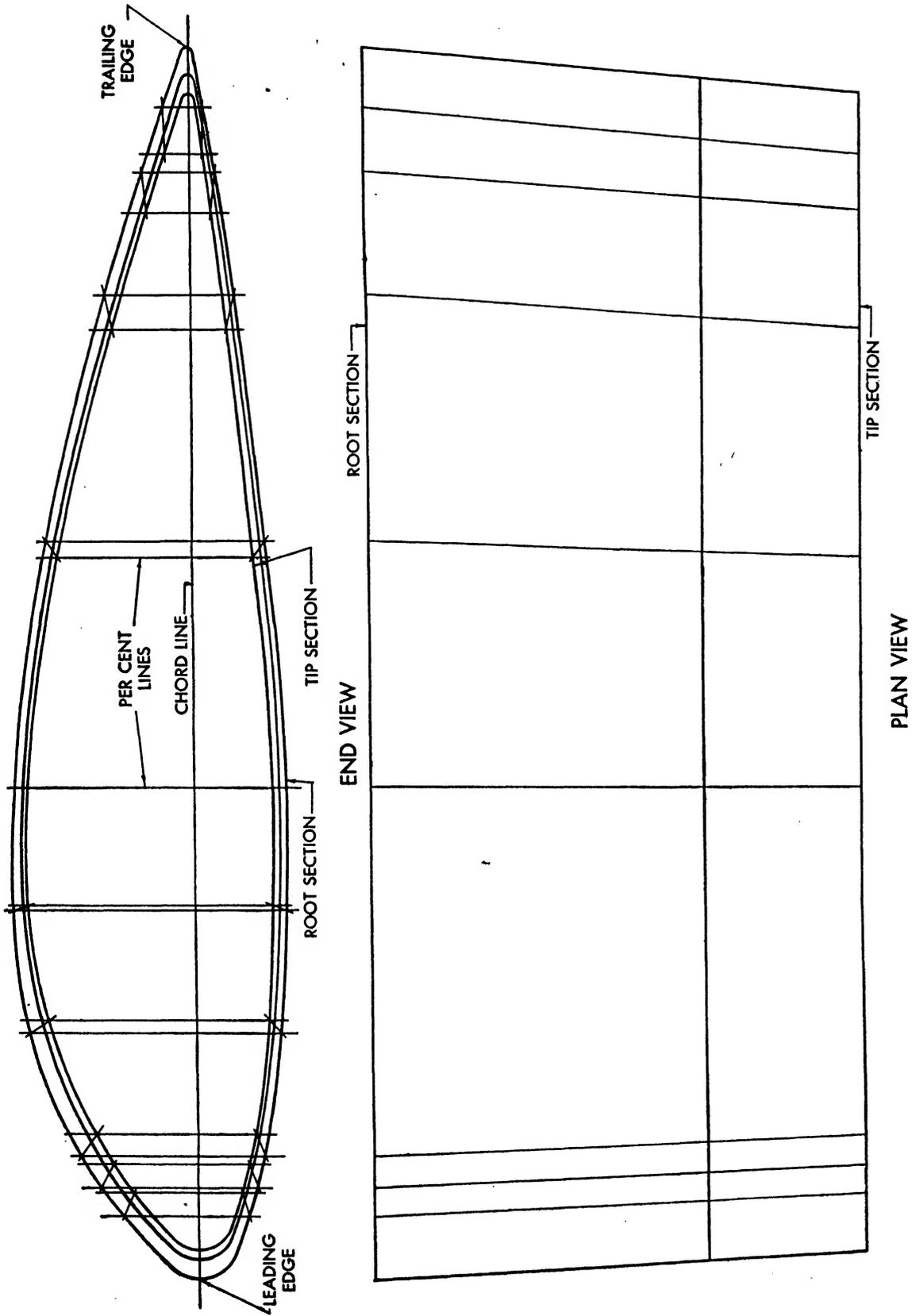


Fig. 381. Wing layout

vertical reference line should be laid in. Eleven horizontal reference lines, or water lines, are necessary and five vertical lines, or buttock lines. These lines are spaced 1 inch apart and constitute a grid.

In Fig. 379, under the column at the left headed B.L. the buttock lines are shown as B.L. C (center line), 1, 2, 3, etc. Under each station (A, B, C, etc.) the distance of the buttock line from water line 0 is given. For station A, the offset or distance from W.L. 0 on the vertical center line is  $2\frac{1}{8}$  inches at the bottom and  $7\frac{1}{8}$  inches at the top. On buttock line 1, it is

3 inches at the bottom and  $7\frac{3}{8}$  inches at the top. On buttock line 2, it is  $3\frac{1}{4}$  inches at the bottom and  $6\frac{1}{8}$  inches at the top, and so on. Under the column headed W.L., the water lines are shown as W.L. 1, 2, 3, etc.; and under each station the water line distance is given from the vertical center line. On W.L. 4 the offset for station A is  $1\frac{3}{8}$  inches from the vertical center line; on W.L. 5, it is  $2\frac{1}{8}$  inches; on W.L. 6, it is  $2\frac{1}{2}$  inches, and so on until all the points have been located for the station A.

When all the points have been located on the proper water lines and buttock lines, they may be connected with a spline or curve. All the other stations will be plotted by the same method. When using a spline, be sure to select one that is straight. It is advisable to start splining a curve from its center rather than from the ends. A loftsman using trammel points and a spline set with ducks is shown in Fig. 380.

The wing layout is a series of airfoil sections of the wing taken at different station locations along the chord plane as in Fig. 381. In Fig. 382 are shown all the ordinates necessary for laying in the root tip and an intermediate station on a theoretical wing. In order to lay out these airfoil sections, first draw a horizontal reference line which will be the chord line. Under the column headed STATION are found the dimensions, in inches, from the leading edge of the wing to the per cent lines, which we shall call stations. If the chord length of a certain section is 40 inches, which would be 100 per cent, then 10 per cent would be 4 inches, and the 10 per cent line would be located 4 inches from the leading edge; 20 per cent would be 8 inches, and the 20 per cent line would be located 8 inches from the leading edge of the wing, and so on.

When making the layouts for the tip and intermediate sections, all measurements must be taken from a per cent line normal to all sections in the wing. In this particular problem the 40 per cent line is normal and the different sections will be located in reference to this plane.

On the chord line that has been drawn, locate all the stations, using the figures in the second column that correspond to the section being drawn. On each one of these locations, letter in lightly the per cent line it represents, and

Fig. 382

WING ORDINATES

ROOT SECTION

Per Cent	Station	Upper	Lower
0	—	—	—
5	2.06	1.96	1.33
10	4.14	2.78	1.58
20	8.26	3.66	1.76
30	12.40	3.99	1.84
40	16.53	3.94	1.86
60	24.80	3.19	1.59
80	33.06	1.88	0.98
90	37.19	1.01	0.55
100	41.33	—	—

Radius for the leading edge .850  
 Radius for the trailing edge .031

TIP SECTION

Per Cent	Station	Upper	Lower
0	—	—	—
5	1.94	1.80	1.23
10	3.88	2.55	1.45
20	7.74	3.38	1.61
30	11.61	3.68	1.69
40	15.48	3.63	1.71
60	23.23	2.93	1.46
80	30.96	1.73	0.90
90	34.83	0.93	0.51
100	38.70	—	—

Radius for the leading edge .788  
 Radius for the trailing edge .030

INTERMEDIATE SECTION

Per Cent	Station	Upper	Lower
0	—	—	—
5	1.99	1.86	1.26
10	3.98	2.64	1.51
20	7.95	2.70	1.68
30	11.93	3.80	1.75
40	15.90	3.75	1.78
60	23.85	3.03	1.51
80	31.80	1.79	0.93
90	35.78	0.96	0.53
100	39.75	—	—

Radius for the leading edge .81  
 Radius for the trailing edge .031

through each one of these points erect a perpendicular and extend it on either side of the chord line beyond the maximum lower and upper ordinates. When this is done, the layout is ready for the ordinates to be drawn in.

The figures on the chart headed **ROOT SECTION** are the ordinates to be used when laying in the root section of the wing, and all the necessary information for that section can be obtained from these figures. Under the column headed **UPPER**, the ordinates for the contour *above* the chord line are given, and under the column headed **LOWER** the ordinates for the contour *below* the chord line are given. On each per cent line set off the distances above and below the chord line indicated in the chart.

When all the points have been located on the per cent lines, swing radii for the leading and trailing edges. The center points of these radii will fall on the chord line and the arcs will pass through the 0 and 100 per cent lines.

The intermediate and tip sections are similarly constructed.

*Templates*

On the preceding pages the word "template" has appeared quite frequently. The word is often spelled "templet" and both this spelling and "template" are correct, the latter being preferred in most aircraft plants. Webster defines the word as follows: "a mold or pattern used by masons, bricklayers, etc. in cutting or setting out their work," and the word has a similar meaning in the aircraft industry, as templates are made for parts of the plane and for tools with which these parts can be formed and fabricated.

Templates are not actual parts, but are flat patterns for parts and tools. Template layout and development is one of the most important phases of the tooling of an airplane, and many different kinds of templates are needed to make the various parts and sections of a plane.

These templates are used in the shop as patterns and give information relative to cutting, forming, drilling, or punching holes, and checking parts and tools. Some templates are used to mark around and determine the shape of the

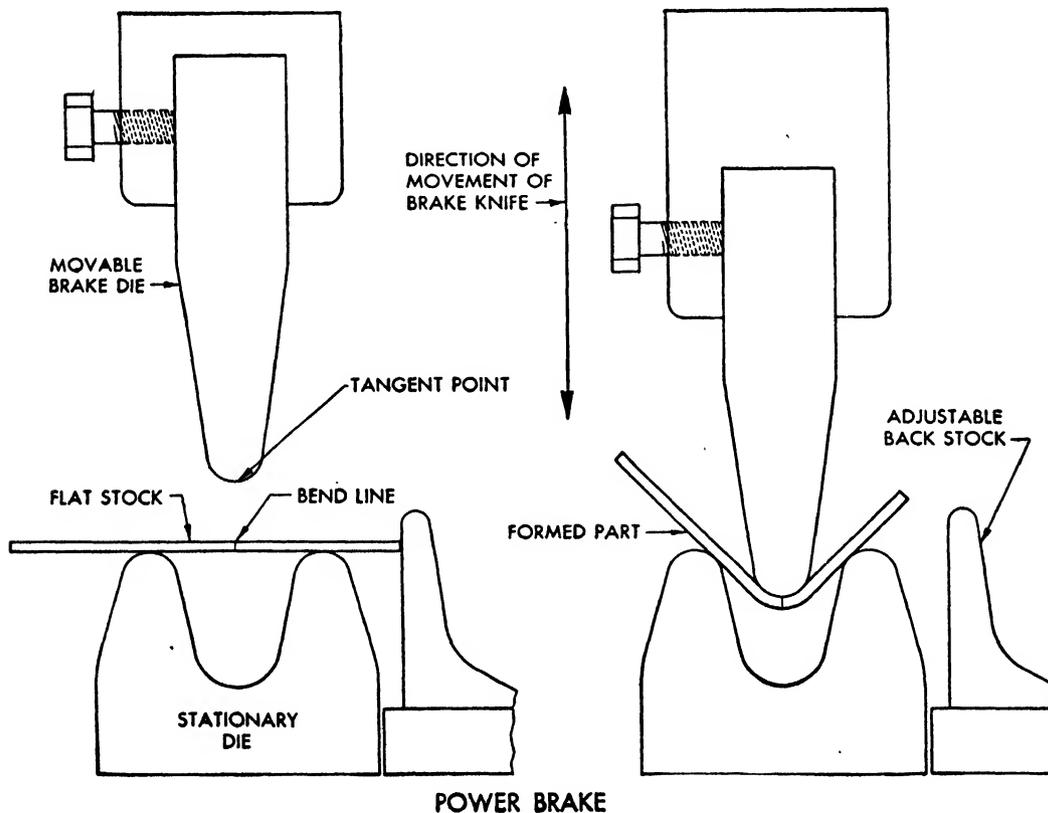


Fig. 383

part to be cut or to locate any bend lines from which the power brake will be set as in Fig. 383.

These templates also determine the shape of dies with which the part is cut in power presses, similar to the one shown in Fig. 384. The shape of form blocks made from Dural, Kirksite, Masonite, wood, or steel are determined from a "form block" template. The sheet metal part is placed on this block, as in Fig. 385, and pressure is applied so that the metal is bent or formed about the block.

With this template, another template is used to determine both the shape of the sheet metal part before it is formed on the form block and the position of the locating holes which must match the locating pins in the form block. These locating pins hold the part in place while it is being formed on the hydropress as shown in Fig. 385. There are several variations of this template; for example, it may contain holes, so that rivet and bolt holes can be drilled in the part, or it may contain holes so that the template can be used to set punch dies or as a check for the finished part.

Many templates have holes located with variable spacing and are used as guides in setting punch dies. Or they may be used to check finished parts or permanent dies which cut and punch holes in the part in one operation. Tem-

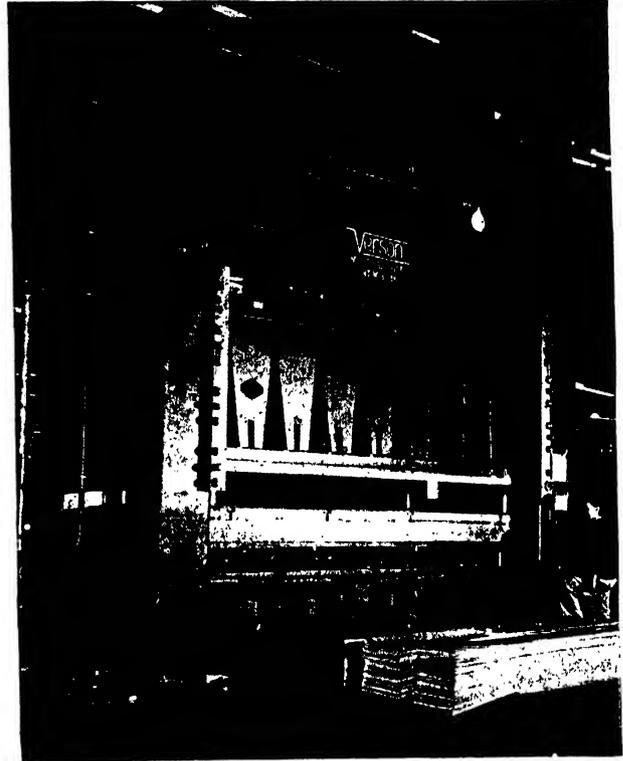


Fig. 384. Large mechanical punch press

plates used to drill holes in the part are made with an oversize hole to allow a bushing to fit into the hole when the part is drilled, thereby eliminating damage to the template when the

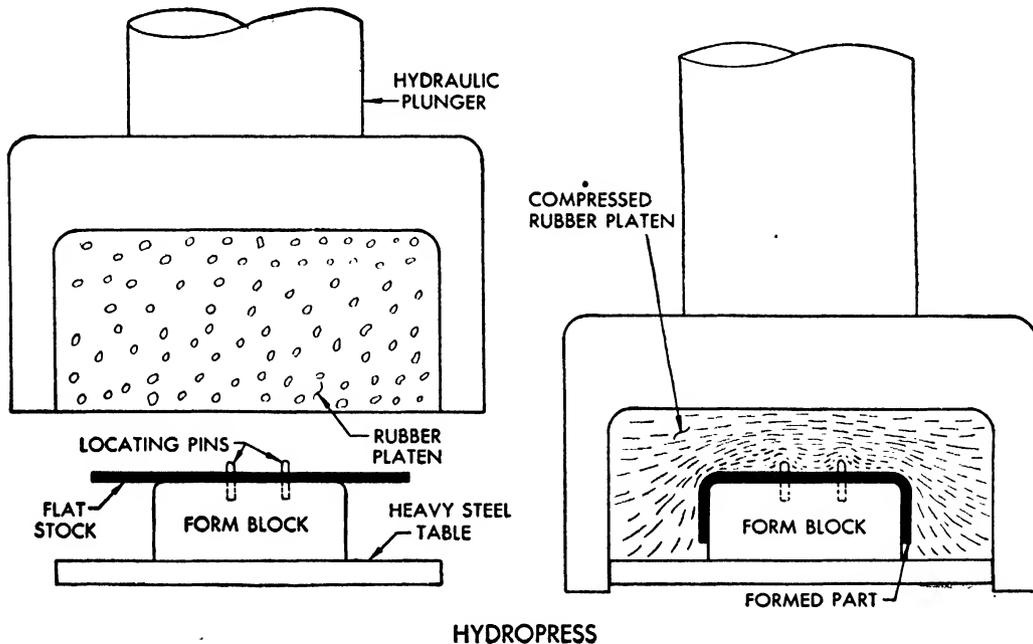


Fig. 385

HYDROPRESS

drilling operation is performed and permitting it to be used many times over.

Box templates are made for the pattern shop and are used for foundations of plaster patterns, as in Fig. 386; these in turn are used in the foundry. Quite often the patterns are used in conjunction with the speed hammer or bumper as check blocks for parts with double or warped contours. Check templates or contour templates usually accompany box templates so that the pattern maker will have a check for the shape of his finished pattern.

Similar templates are used to make wood patterns, which are employed in the same manner as the plaster pattern. Figure 387 shows workers pouring molten metal into a sand form made from one of the described patterns. Figure 388 shows a cast die in the final stages of completion, and Fig. 389 shows a finished die in the drop hammer.

Router templates are made smaller than the actual part so that a machine known as a "router" can be used in the cutting operation. The size of the bushing or collar used on the router determines how much smaller this template is cut than the actual part; for example, if

the bushing is  $\frac{7}{32}$  larger in radius than the cutter bit, the template would be made  $\frac{7}{32}$  inch smaller than the actual part.

The loft draftsman will come across these templates daily, but many others too are needed to give the shop complete information regarding the part to be fabricated. The loftsman must place complete information on his template so that the workman in the shop will not be in doubt about what is to be done with it or how it is to be applied. He must also follow the operation sheet that is furnished by the tooling department and make sure that the correct template is made for each operation called out on this sheet.

*Template Layout and Development.* In the development of templates the loftsman works from the master layout, a blueprint, or a reproduction of the part. The first step is to calculate accurately the developed shape or flat pattern of a sheet metal part. Figures 390a and 390b show two simple parts unfolded step by step. The ideal method is to have all the master layouts prepared in advance for tooling and to reproduce any part ordered. Then the loftsman need only develop the flanges and locate the speci-

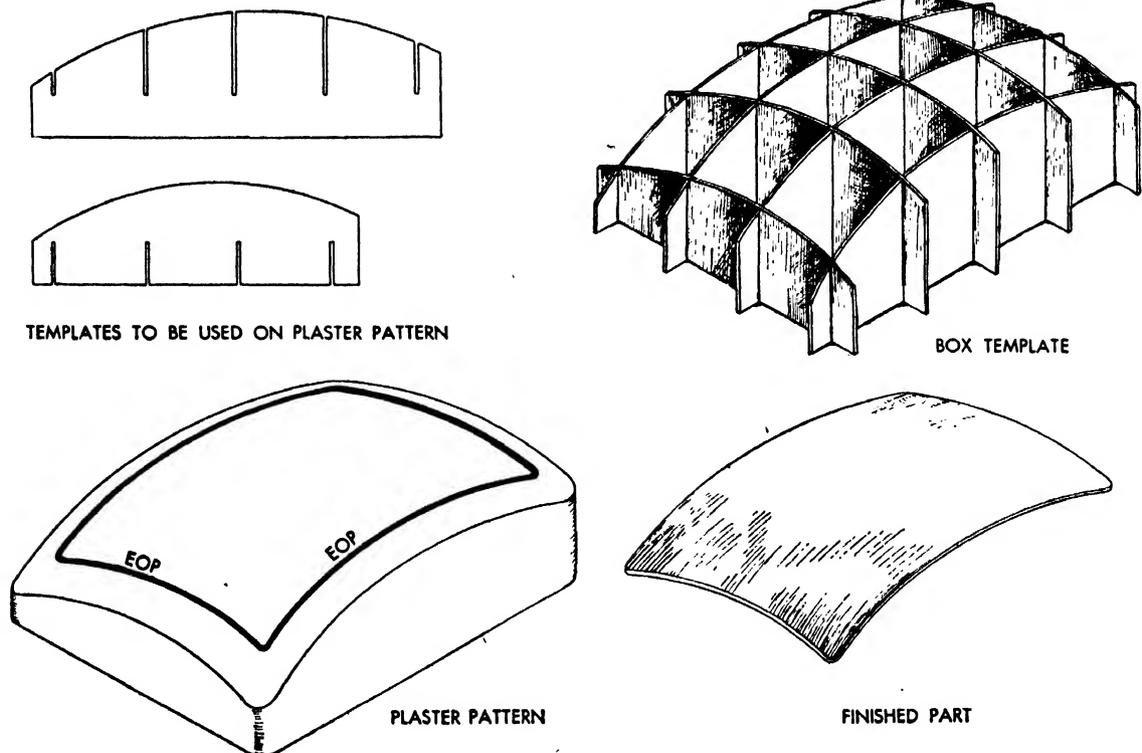


Fig. 386



Fig. 387. Pouring a die in an earthen mold

fied holes, beads, rings, dimples, etc., without having to lay out the part completely. This is not always practicable, however, and therefore a trained worker produces the best results for the job at hand. Tools used by the template maker are shown in Fig. 391.

Trigonometry is perhaps the foremost aid in lofting. The draftsman who is trying to gain an understanding of the lofting procedure must have a basic knowledge of trigonometry if he is to solve problems in template development and in any other section of the loft. In this chapter, no attempt has been made to explain the fundamentals of trigonometry. The student can find the information in any standard textbook on the subject. Functional trigonometry, however, may be learned by employing the formulas for finding angles and sides of right triangles shown in Fig. 392. Anyone of average intelligence can apply these formulas; *they do not require extensive mathematical training.*

The student should not shy away from formulas with the thought that "it's above me," for formulas are tools that can be used to advantage. When working with templates the loftsman encounters many problems in trigonometry, and it is important that he be able to break his problems down into problems of right triangles to simplify their resolution.

To use the chart in Fig. 392, the worker must first determine the nature of the problem. If the number of degrees of an angle in a right triangle is needed, the chart gives the necessary informa-



Fig. 388. Finishing drop hammer die

tion. Simply choose from the column at the left whichever formula fits the problem at hand. For example, if angle C is needed and hypotenuse a and side c are given, side c divided by hypotenuse a will give the sine of angle C. This figure must be found in a trigonometry table to determine the number of degrees in angle C. If two sides b and c are given, then side c divided by side b will give the tangent of angle C. A similar procedure can be used when solving for the hypotenuse a or either of the two sides b and c of a right triangle. Most sheet metal parts of the airplane can be developed with the proper application of trigonometry, projection, and the use of methods described later in this chapter. Many problems require the use of all three.



Fig. 389. A drop hammer die in place with part on bottom section

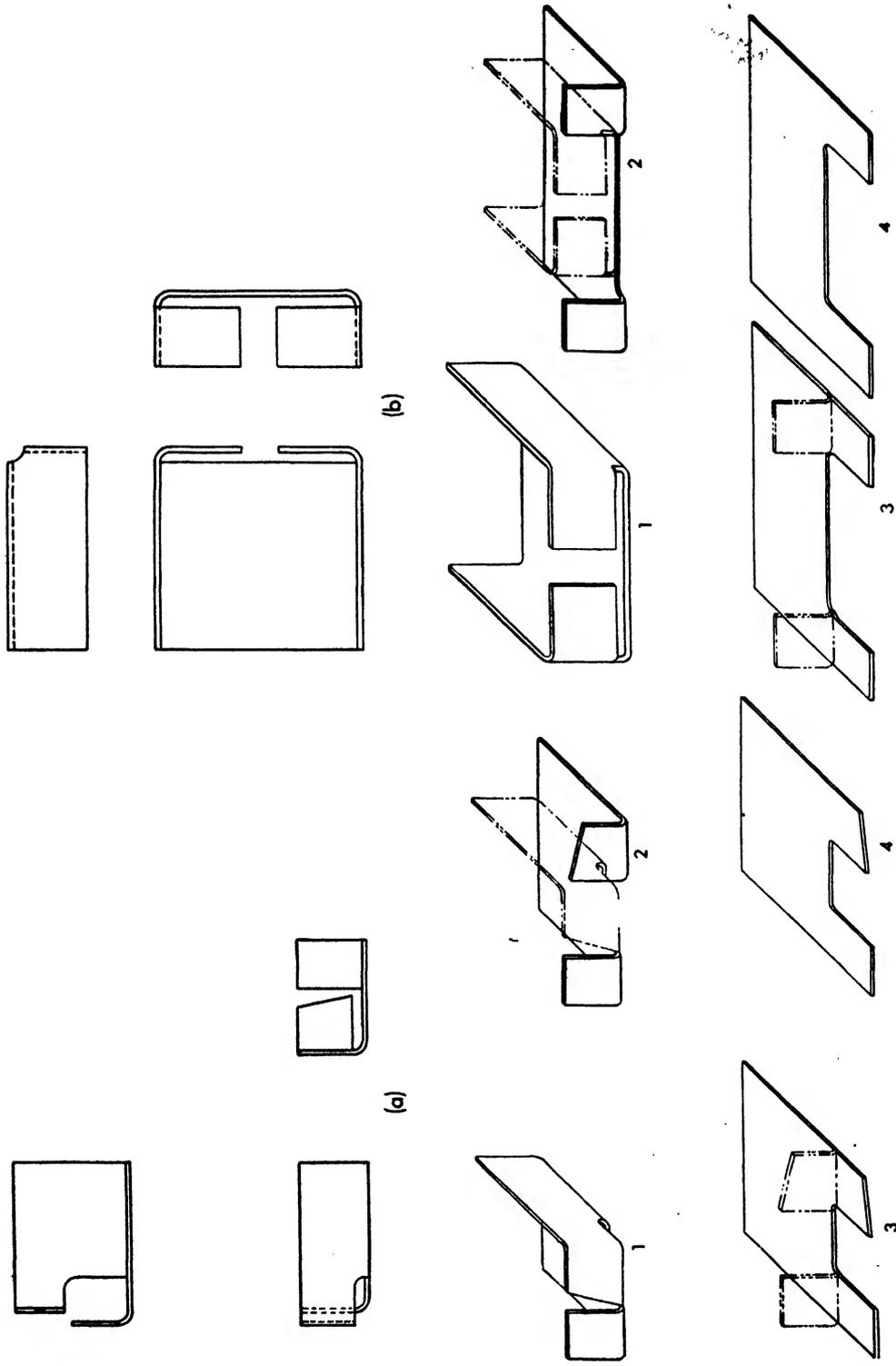


Fig. 390. Unfolding simple sheet metal parts

It is not possible to bend sheet metal on a sharp square corner without tearing it, and for this reason a radius is always used when a part is bent. There are two common methods of calculating the flat pattern of a bent sheet metal part. Both are accurate, either will produce the same result. The problem itself will usually determine which is more easily applied.

The first of these is called "bend allowance," and by this method one calculates the exact amount of material required to bend around a given radius through a given number of degrees, or, to simplify matters, the amount of material from tangent point to tangent point. An empirical formula—  $(0.01743 \text{ bend radius}) + (0.0078 \text{ thickness of material}) \text{ degrees of bend}$ —is used in calculating bend allowance. Its application is illustrated by the three different examples in Fig. 393 (0.064 inch material bent on a  $\frac{1}{8}$  inch radius). The first is bent 90 degrees, the second

120 degrees, and the third 60 degrees from the flat sheet.

Bend allowance is applicable to any or all of these problems, although the other method might be shorter. In some factories, however, only bend allowance is recognized as the correct method of calculating a flat pattern. In the chart in Fig. 394 the bend allowance for 1 degree of bend for various gages of metal is given, thus eliminating a considerable amount of tedious calculation. The figure under 0.064 inch material and opposite  $\frac{1}{8}$  inch radius in this chart is 0.00268, the bend allowance for 0.064 inch material bent on a  $\frac{1}{8}$  inch radius through 1 degree. In any problem concerning 0.064 inch material bent on a  $\frac{1}{8}$  inch radius, this figure multiplied by the number of degrees in the bend will give the bend allowance.

In Fig. 393, example 1, the angle of bend is 90 degrees. By multiplying 0.00268 by 90, the

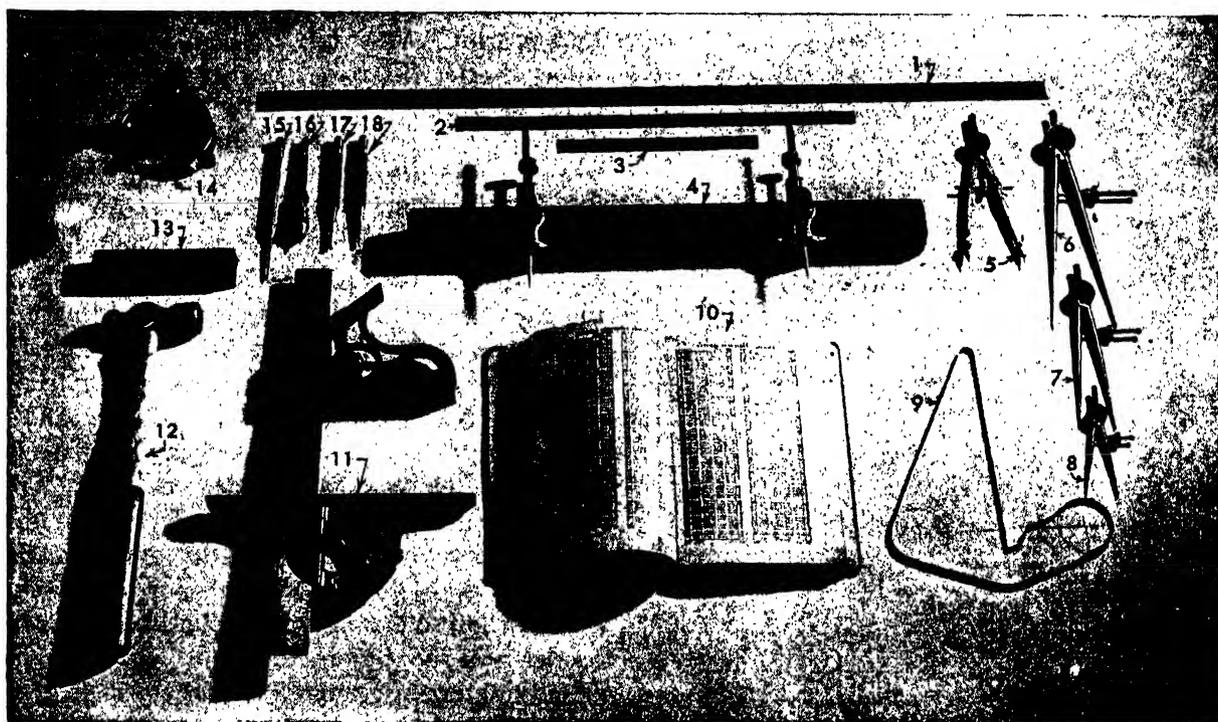


Fig. 391. Template maker's personal tools

- |  |                           |
|--|---------------------------|
| 1. 2-foot scale graduated in hundredths  | 10. Trigonometry tables   |
| 2. 12-inch scale graduated in hundredths | 11. Protractor and square |
| 3. 6-inch rule graduated in hundredths   | 12. Ball peen hammer      |
| 4. Trammel points in trammel bar         | 13. Oil stone             |
| 5. Bow compass                           | 14. Magnifying glass      |
| 6. 6-inch dividers                       | 15. Scribe                |
| 7. 4-inch dividers                       | 16. Pin holder            |
| 8. 2-inch dividers                       | 17. Locating punch        |
| 9. Contour square                        | 18. Center punch          |

bend allowance for 90 degrees is obtained. The result of this operation is 0.2412 inch, which can be added to the tangent point dimensions of the part, in this case  $3\frac{1}{2}$  and  $3\frac{1}{2}$  inches, respectively, and the developed width of the part will be found to be 7.2412 inches.

In example 2 the angle of bend is 120 degrees, and 0.00268 multiplied by 120 gives 0.3216 inch for the bend allowance. This added to the tangent point dimensions, which are  $3\frac{1}{4}$  and  $3\frac{1}{4}$  inches respectively, is equal to 6.8216 inches, the developed width of the part.

In example 3, the angle of bend is 60 degrees,

and 0.00268 multiplied by 60 equals 0.1608 inch, the bend allowance. This added to the tangent point dimensions, which are  $2\frac{1}{8}$  and  $2\frac{7}{8}$  inches, respectively, is equal to 5.5358 inches. Since bend allowance gives the exact amount of material required to bend around a given radius through a given number of degrees, dimensions must always be known to the tangent point of the radius of bend. In every instance bend allowance is *added* to, the *tangent* point dimensions on the part. It is very important that the beginner understand and remember this, *always add bend allowance to the tangent point dimensions.*

The second of these two methods is called "setback," and setback is always *subtracted* from the *outside dimensions* of the part. Setback represents the difference between the sum of the outside dimensions of a part or angle and the actual amount of material necessary to form the angle. Imagine a small boy walking along a sidewalk by a vacant corner lot. If the boy follows the sidewalk, he will travel farther than he would if he cut diagonally across the lot. The setback or distance saved would be the difference in the length of the sidewalk from the point where the boy left it and the point where he returned and the actual distance he traveled when he cut across the lot. Charts have been compiled showing the setback for various gages of metal when they are bent on different radii. One chart gives the setback for different gages bent on various radii through 90 degrees (Fig. 395). Another called the "J chart" gives the setback for material bent more or less than 90 degrees (Fig. 396). The student will note that the J chart in this book is very small and therefore should not be used unless absolutely necessary, for the lines at the right fall so close together that unsatisfactory results will be obtained when working with closed angles. Any angle more than 50 degrees open or closed should not be calculated from any J chart.

When using a J chart, a straightedge is required, and it must be lined up with the bend radius on the right-hand side of the chart and the metal thickness on the left side. The reading is taken on the degree line which corresponds to the number of degrees "open" or "closed" from

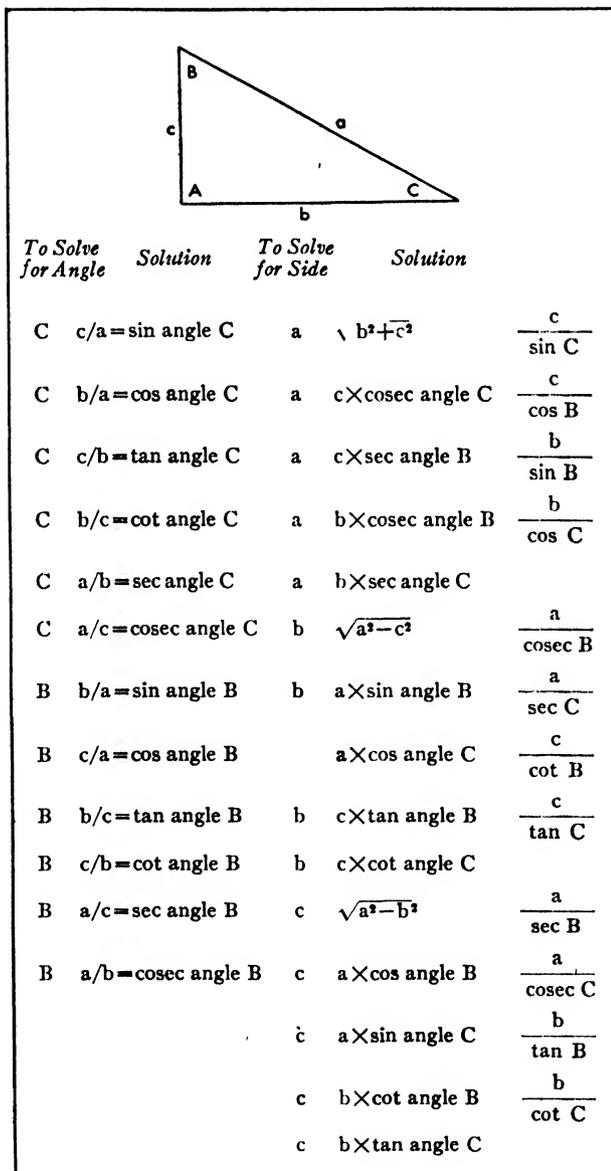


Fig. 392

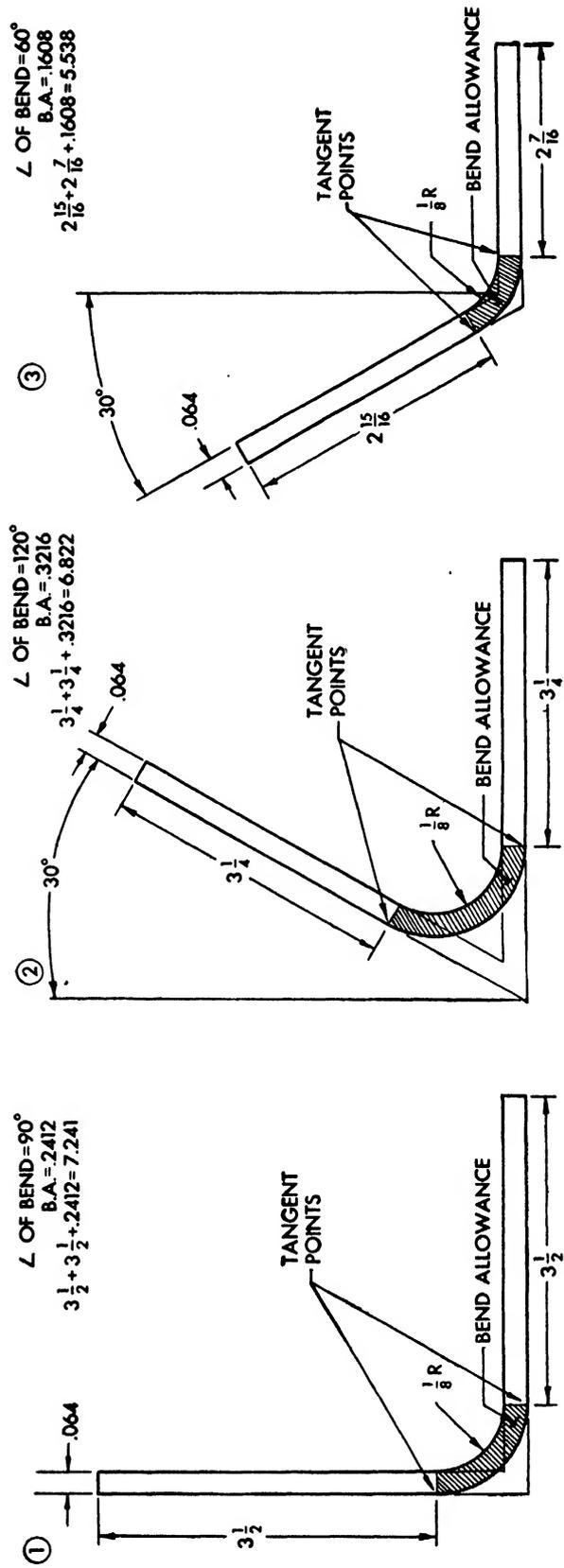


Fig. 393. Examples of bend allowance

AIRCRAFT DRAFTING

Fig. 394

BEND ALLOWANCE FOR 1 DEGREE OF BEND

RADIUS	THICKNESS OF MATERIAL												
	.016	.020	.025	.032	.040	.051	.064	.072	.081	.091	.102	.125	
1/16	.00067	.00070	.00074	.00079									
3/16	.00121	.00125	.00129	.00135	.00140	.00145	.00159	.00165					
1/4	.00176	.00179	.00183	.00188	.00195	.00203	.00213	.00220	.00226	.00234	.00243		
5/16	.00230	.00234	.00238	.00243	.00249	.00258	.00268	.00274	.00281	.00289	.00297	.00315	
3/8	.00285	.00288	.00292	.00297	.00304	.00312	.00322	.00328	.00335	.00343	.00352	.00370	
7/16	.00339	.00342	.00347	.00352	.00358	.00367	.00377	.00383	.00390	.00398	.00406	.00424	
1/2	.00394	.00397	.00401	.00406	.00412	.00421	.00431	.00437	.00444	.00452	.00461	.00479	
5/8	.00448	.00451	.00456	.00461	.00467	.00476	.00486	.00492	.00499	.00507	.00515	.00533	
3/4	.00501	.00506	.00510	.00515	.00521	.00530	.00540	.00546	.00553	.00561	.00570	.00588	
7/8	.00557	.00560	.00564	.00570	.00576	.00584	.00595	.00601	.00608	.00616	.00624	.00642	
1	.00612	.00615	.00619	.00624	.00630	.00639	.00649	.00655	.00662	.00670	.00679	.00697	
1 1/8	.00666	.00669	.00673	.00679	.00685	.00693	.00704	.00710	.00717	.00725	.00733	.00751	
1 1/4	.00721	.00724	.00728	.00733	.00739	.00748	.00758	.00764	.00771	.00779	.00787	.00806	
1 1/2	.00775	.00778	.00782	.00787	.00794	.00802	.00812	.00819	.00826	.00834	.00842	.00860	
1 3/4	.00829	.00833	.00837	.00842	.00848	.00857	.00867	.00873	.00880	.00888	.00896	.00915	
2	.00884	.00887	.00891	.00896	.00903	.00911	.00921	.00928	.00935	.00943	.00951	.00969	
2 1/4	.00938	.00942	.00946	.00951	.00957	.00966	.00976	.00982	.00989	.00997	.01005	.01023	
2 1/2	.00993	.00996	.01000	.01005	.01012	.01020	.01030	.01037	.01043	.01051	.01058	.01078	
2 3/4	.01047	.01051	.01055	.01060	.01065	.01073	.01083	.01091	.01098	.01105	.01114	.01132	
3	.01102	.01105	.01109	.01114	.01121	.01129	.01139	.01146	.01152	.01160	.01170	.01187	
3 1/4	.01156	.01160	.01164	.01170	.01175	.01183	.01193	.01200	.01207	.01214	.01223	.01241	
3 1/2	.01211	.01214	.01218	.01223	.01230	.01238	.01248	.01254	.01261	.01269	.01276	.01296	
3 3/4	.01265	.01268	.01273	.01276	.01283	.01291	.01301	.01309	.01316	.01322	.01332	.01350	
4	.01320	.01323	.01327	.01332	.01338	.01347	.01357	.01363	.01370	.01378	.01386	.01405	
4 1/4	.01374	.01378	.01381	.01386	.01392	.01401	.01411	.01418	.01425	.01432	.01441	.01459	
4 1/2	.01429	.01432	.01436	.01441	.01447	.01456	.01466	.01472	.01479	.01487	.01494	.01514	
4 3/4	.01483	.01486	.01490	.01494	.01501	.01509	.01519	.01527	.01534	.01540	.01550	.01568	
5	.01538	.01541	.01545	.01550	.01556	.01565	.01575	.01581	.01588	.01596	.01604	.01623	
5 1/4	.01592	.01595	.01599	.01604	.01611	.01619	.01629	.01636	.01643	.01650	.01659	.01677	
5 1/2	.01646	.01650	.01654	.01659	.01665	.01674	.01684	.01690	.01697	.01705	.01712	.01732	
5 3/4	.01701	.01704	.01708	.01712	.01718	.01727	.01737	.01745	.01752	.01758	.01768	.01786	
6	.01755	.01759	.01763	.01768	.01774	.01783	.01793	.01799	.01806	.01814	.01823	.01841	

Fig. 395

SETBACK CHART FOR 90 DEGREES

RADIUS	THICKNESS OF MATERIAL													
	.016	.020	.025	.032	.040	.051	.064	.072	.081	.091	.102	.125	.156	.187
1/16	.034	.039	.046	.055	.065									
3/16	.041	.046	.053	.062	.072									
1/4	.048	.053	.059	.068	.079	.093								
5/16	.054	.059	.065	.074	.085	.100								
3/8	.061	.066	.073	.082	.092	.107	.124	.134	.146	.159				
1/2	.068	.073	.080	.089	.099	.113	.130	.141	.152	.165				
5/8	.075	.079	.086	.095	.106	.120	.137	.147	.159	.172	.186	.217		
3/4	.081	.086	.093	.102	.113	.127	.144	.154	.166	.179	.193	.223		
7/8	.088	.093	.100	.109	.119	.134	.151	.161	.173	.186	.199	.230	.270	
1	.095	.099	.106	.115	.125	.139	.156	.167	.178	.191	.206	.236	.276	
1 1/8	.102	.107	.113	.122	.133	.147	.164	.174	.186	.199	.214	.243	.283	.323
1 1/4	.108	.114	.120	.129	.140	.153	.171	.181	.193	.206	.220	.250	.290	.330
1 1/2	.115	.120	.127	.136	.147	.161	.178	.188	.200	.213	.227	.256	.297	.336
1 3/4	.122	.127	.134	.143	.153	.167	.184	.195	.206	.219	.234	.263	.304	.344
2	.129	.134	.140	.149	.160	.174	.191	.201	.213	.226	.240	.270	.310	.351
2 1/4	.144	.147	.154	.163	.174	.188	.205	.215	.227	.240	.254	.283	.324	.364
2 1/2	.156	.161	.167	.176	.187	.201	.218	.228	.240	.253	.267	.297	.337	.377
2 3/4	.183	.188	.194	.203	.214	.228	.245	.255	.267	.280	.294	.324	.364	.404
3	.210	.215	.221	.230	.240	.255	.272	.282	.294	.306	.321	.351	.391	.431
3 1/4	.236	.242	.248	.258	.268	.282	.299	.309	.321	.333	.348	.378	.418	.458

90 degrees. In other words, a part bent 100 degrees would be 10 degrees closed from, and a part bent 80 degrees would be 10 degrees open from, 90 degrees.

In Fig. 397 are several examples of setback applied to parts of 0.064 inch material bent on a  $\frac{1}{8}$  inch radius through different angles of bend. In example 1 the outside dimensions are  $4\frac{1}{2}$  and  $4\frac{1}{2}$  inches respectively, and the setback found in the chart for 90 degrees in Fig. 395 is 0.137 inch. The sum of the outside dimensions, which is 9 inches, minus the setback, 0.137 inch, equals 8.863 inches, the developed width.

In example 2 the outside dimensions are 5 inches and 5 inches, respectively, the part is

bent 120 degrees and the setback angle is 30 degrees closed. The setback for 0.064 inch material bent on a  $\frac{1}{8}$  inch radius, 30 degrees closed, is 0.333 inch. The sum of the outside dimensions is 10 inches, minus the setback, 0.333 inch, equaling 9.667 inches.

In example 3 the part is bent 60 degrees, and the setback angle is 30 degrees open. The setback for 0.064 inch material bent on a  $\frac{1}{8}$  inch radius for a 30 degree open angle is 0.057 inch. The sum of the outside dimensions,  $6\frac{1}{2}$ , minus the setback, 0.057, is equal to 6.443 inches.

The beginner must always remember that the *outside dimensions must always be known when using setback and that setback is always sub-*

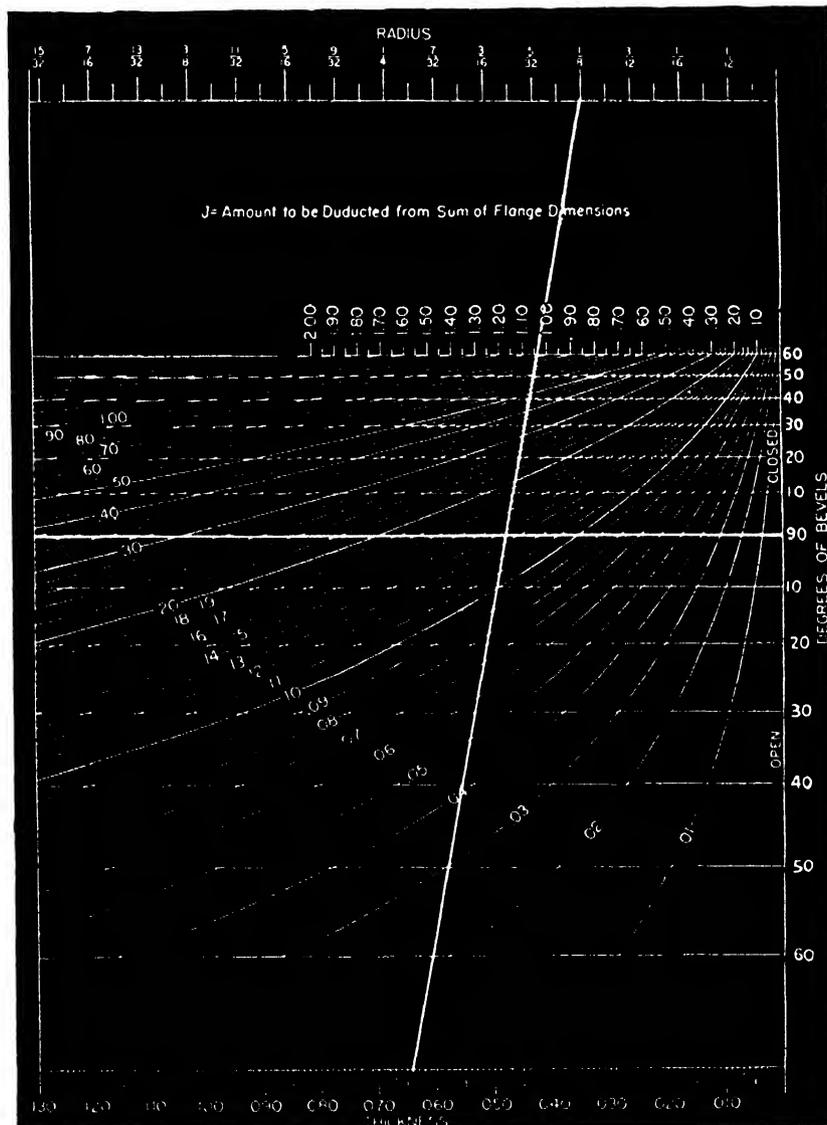


Fig. 396. "J" chart

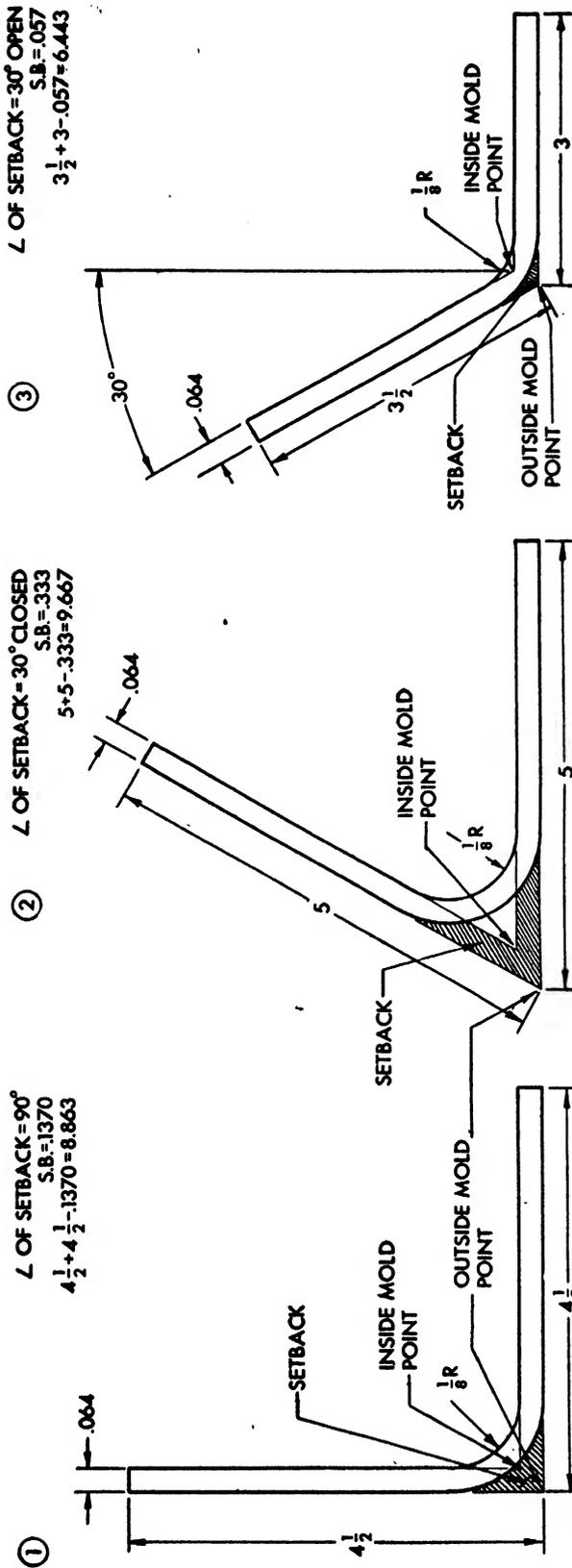


Fig. 397

tracted from these outside dimensions.

In the process of making prints for parts, it is not always possible for the draftsman to give the tangent point dimension or the outside dimension, so the loft draftsman must be able to find this dimension for himself. Formulas have been compiled to ease the solution of these problems, and in Fig. 398 are shown three different drawings representing pieces of metal, one bent more than 90 degrees, one bent less than 90 degrees, and one bent exactly 90 degrees. With these figures and the accompanying formulas, the beginner should encounter no trouble in solving any problem of moving a dimension from the inside to the outside mold point, from the out-

side mold point to the tangent point, or from the inside mold point to the tangent point.

Should a dimension be given to the inside mold point and the worker wish to use a setback, one of the formulas in Fig. 398 should be applied, for the outside dimension must be known before a setback can be used as in Fig. 397. The formula to be applied here could be called the X formula. As in Fig. 398, the X dimension represents the distance between the outside and inside mold points. Using this formula, the worker simply multiplies the metal thickness by the tangent of one-half the angle of bend. Should the worker decide to use bend allowance, and inside dimensions are given, the Y formula

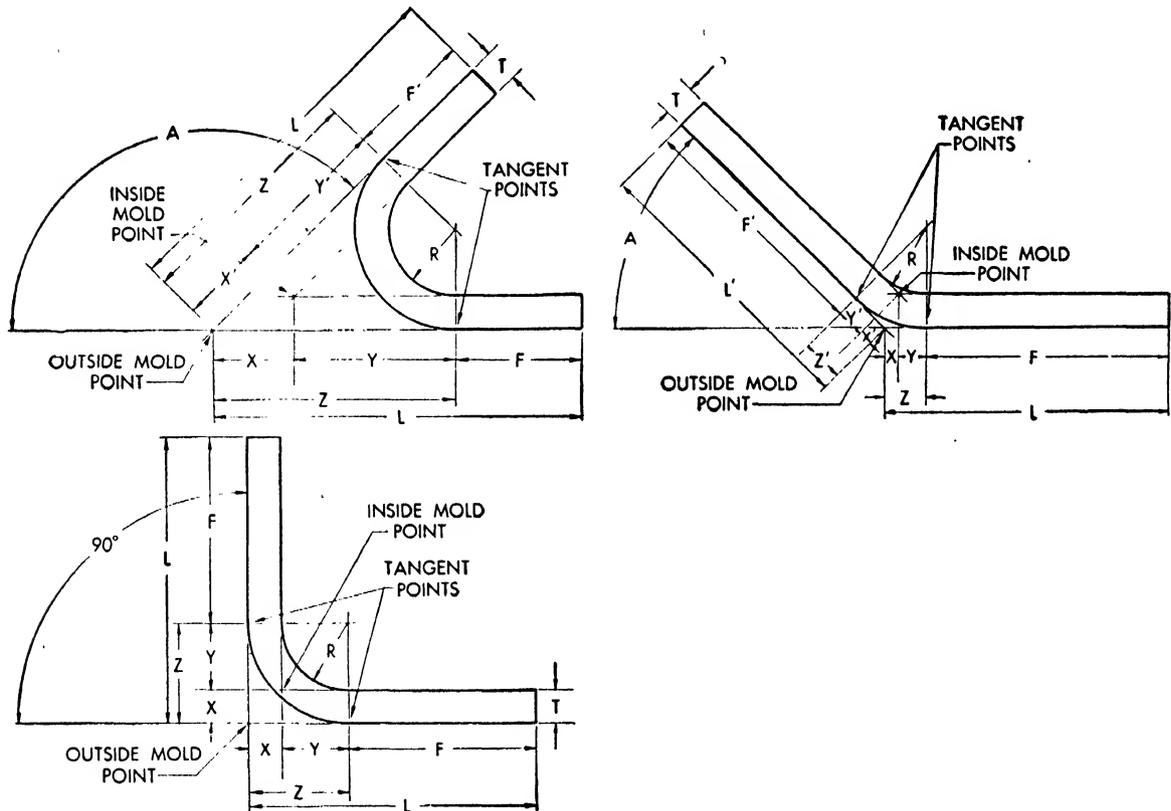


Fig. 398. Code:

- A = Angle of bend
- F = Dimension to tangent point
- L = Outside dimension
- R = Radius
- T = Gauge of material
- X = Distance from inside to outside
- Y = Distance from inside to tangent point
- Z = Distance from outside to tangent point

Formulas:

$$X = T \tan \frac{1}{2} \text{ angle } A$$

$$Y = R \tan \frac{1}{2} \text{ angle } A$$

$$Z = R \times T \tan \frac{1}{2} \text{ angle } A$$

Note:

For 90° angles only

$$X = T$$

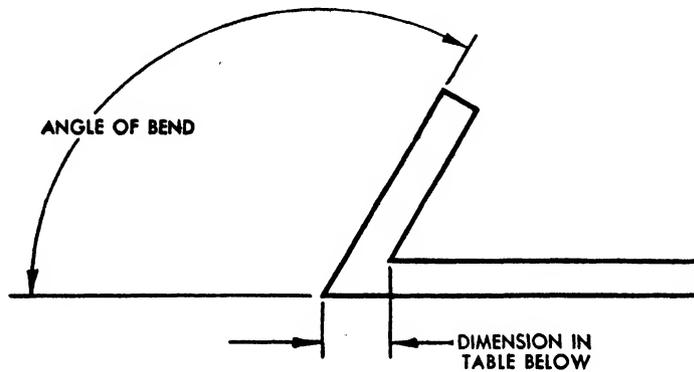
$$Y = R$$

$$Z = R + T$$

could be applied, and if the part were dimensioned to the outside mold point and bend allowance were to be used, the Z dimension would be used.

The student should remember that a great deal of calculation can be saved if the angle of

bend is 90 degrees. For 90 degree angles alone, the distance from the inside mold point to the outside mold point is always the thickness of the metal, the distance from the outside mold point to the tangent point on the radius is the metal thickness plus the radius, and the distance from

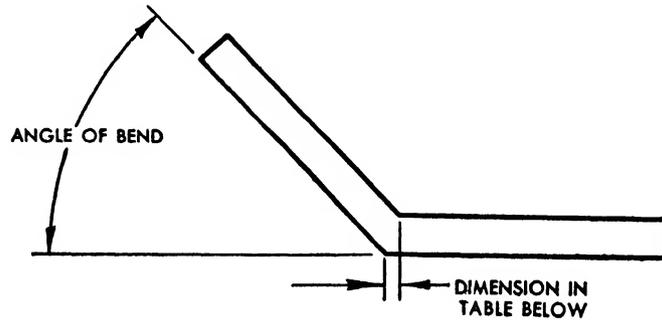


DEGREES IN ANGLE OF BEND	THICKNESS OF MATERIAL							
	.020	.025	.032	.040	.051	.064	.072	.091
90	.020	.025	.032	.040	.051	.064	.072	.091
91	.0204	.0254	.0326	.0407	.0519	.0651	.0733	.0926
92	.0207	.0259	.0331	.0414	.0528	.0663	.0746	.0942
93	.0211	.0263	.0337	.0422	.0537	.0674	.0759	.0959
94	.0214	.0268	.0343	.0429	.0547	.0686	.0772	.0976
95	.0218	.0273	.0349	.0437	.0557	.0698	.0786	.0993
96	.0222	.0278	.0355	.0444	.0566	.0711	.0800	.1011
97	.0226	.0283	.0362	.0452	.0576	.0723	.0814	.1029
98	.0230	.0288	.0368	.0460	.0587	.0736	.0828	.1047
99	.0234	.0293	.0375	.0468	.0597	.0749	.0843	.1065
100	.0238	.0298	.0381	.0477	.0608	.0763	.0858	.1084
101	.0243	.0303	.0388	.0485	.0619	.0776	.0863	.1104
102	.0247	.0309	.0395	.0494	.0630	.0790	.0889	.1124
103	.0251	.0314	.0402	.0503	.0641	.0805	.0905	.1144
104	.0256	.0320	.0410	.0512	.0653	.0819	.0922	.1165
105	.0261	.0326	.0417	.0521	.0665	.0834	.0938	.1186
106	.0265	.0332	.0425	.0531	.0677	.0849	.0955	.1208
107	.0270	.0338	.0432	.0541	.0689	.0865	.0973	.1230
108	.0275	.0344	.0440	.0551	.0702	.0881	.0991	.1253
109	.0280	.0350	.0449	.0561	.0715	.0897	.1009	.1276
110	.0286	.0357	.0457	.0571	.0728	.0914	.1028	.1300
111	.0291	.0364	.0466	.0582	.0742	.0931	.1048	.1324
112	.0297	.0371	.0474	.0593	.0756	.0949	.1067	.1345
113	.0302	.0378	.0483	.0604	.0771	.0967	.1088	.1375
114	.0308	.0385	.0493	.0616	.0785	.0986	.1109	.1401
115	.0314	.0392	.0502	.0628	.0801	.1005	.1130	.1428
116	.0320	.0400	.0512	.0640	.0816	.1024	.1152	.1456
117	.0326	.0408	.0522	.0653	.0832	.1044	.1175	.1485
118	.0333	.0416	.0533	.0666	.0849	.1065	.1198	.1515
119	.0340	.0424	.0543	.0679	.0866	.1087	.1222	.1545
120	.0346	.0433	.0554	.0693	.0883	.1109	.1247	.1576
121	.0354	.0442	.0566	.0707	.0901	.1131	.1273	.1608
122	.0361	.0451	.0577	.0722	.0920	.1155	.1299	.1642
123	.0368	.0460	.0589	.0737	.0939	.1179	.1326	.1676
124	.0376	.0470	.0602	.0752	.0959	.1204	.1354	.1711
125	.0384	.0480	.0615	.0768	.0980	.1229	.1383	.1748
126	.0393	.0491	.0628	.0785	.1001	.1256	.1413	.1786
127	.0401	.0501	.0642	.0802	.1023	.1284	.1444	.1825
128	.0410	.0513	.0656	.0820	.1046	.1312	.1476	.1866
129	.0419	.0524	.0671	.0839	.1069	.1342	.1509	.1908
130	.0429	.0536	.0686	.0858	.1094	.1372	.1544	.1951

Fig. 399

the inside mold point to the tangent point on the radius is equal to the radius. The problems in Fig. 398 contain some good examples, and the loft draftsman should practice as much as possible, for it is necessary to be able to apply quickly all such information even though the problem is not encountered daily.

Other charts have been compiled, giving the distances from the inside mold point to the outside mold point for different gages of material bent from 50 to 130 degrees. These charts, found in Figs. 399 and 400, are self-explanatory, but in case of doubt, the number of degrees is found in the column at the left of the page and the



DEGREES IN ANGLE OF BEND	THICKNESS OF MATERIAL.							
	.020	.025	.032	.040	.051	.064	.072	.091
50	.0093	.0117	.0149	.0187	.0238	.0298	.0335	.0424
51	.0095	.0119	.0153	.0191	.0243	.0306	.0343	.0434
52	.0098	.0122	.0156	.0195	.0249	.0312	.0351	.0444
53	.0100	.0125	.0160	.0199	.0254	.0319	.0359	.0454
54	.0102	.0127	.0163	.0204	.0260	.0326	.0367	.0464
55	.0104	.0130	.0167	.0208	.0265	.0333	.0375	.0474
56	.0106	.0133	.0170	.0213	.0271	.0340	.0383	.0484
57	.0109	.0136	.0174	.0217	.0277	.0347	.0391	.0494
58	.0112	.0139	.0177	.0222	.0283	.0355	.0399	.0504
59	.0113	.0141	.0181	.0226	.0289	.0362	.0407	.0515
60	.0115	.0144	.0185	.0231	.0294	.0369	.0416	.0525
61	.0118	.0147	.0188	.0236	.0300	.0377	.0424	.0536
62	.0120	.0150	.0192	.0240	.0306	.0385	.0433	.0547
63	.0122	.0153	.0196	.0245	.0313	.0392	.0441	.0558
64	.0125	.0156	.0110	.0250	.0319	.0400	.0450	.0569
65	.0127	.0159	.0204	.0255	.0325	.0408	.0459	.0580
66	.0130	.0162	.0208	.0260	.0331	.0416	.0468	.0591
67	.0132	.0165	.0212	.0265	.0338	.0424	.0478	.0602
68	.0135	.0169	.0216	.0270	.0344	.0432	.0486	.0614
69	.0137	.0172	.0220	.0275	.0351	.0440	.0495	.0625
70	.0140	.0175	.0224	.0280	.0357	.0448	.0504	.0637
71	.0143	.0178	.0228	.0285	.0364	.0457	.0514	.0649
72	.0145	.0182	.0232	.0291	.0371	.0465	.0523	.0661
73	.0148	.0185	.0237	.0296	.0377	.0474	.0533	.0673
74	.0151	.0188	.0241	.0301	.0384	.0482	.0543	.0686
75	.0153	.0192	.0246	.0307	.0391	.0491	.0552	.0698
76	.0156	.0195	.0250	.0313	.0398	.0500	.0563	.0711
77	.0159	.0199	.0255	.0318	.0406	.0509	.0573	.0724
78	.0162	.0202	.0259	.0324	.0413	.0518	.0583	.0737
79	.0165	.0206	.0264	.0330	.0420	.0530	.0594	.0750
80	.0168	.0210	.0269	.0336	.0428	.0537	.0604	.0764
81	.0171	.0214	.0273	.0342	.0436	.0547	.0615	.0777
82	.0174	.0217	.0278	.0348	.0443	.0556	.0626	.0791
83	.0177	.0221	.0283	.0354	.0451	.0566	.0637	.0805
84	.0180	.0225	.0288	.0360	.0459	.0576	.0648	.0819
85	.0183	.0229	.0293	.0367	.0467	.0586	.0660	.0834
86	.0187	.0233	.0298	.0373	.0476	.0597	.0671	.0849
87	.0190	.0237	.0304	.0380	.0484	.0607	.0683	.0864
88	.0193	.0241	.0309	.0386	.0493	.0618	.0695	.0879
89	.0197	.0246	.0314	.0093	.0501	.0629	.0708	.0894
90	.020	.025	.032	.040	.051	.064	.072	.091

Fig. 400

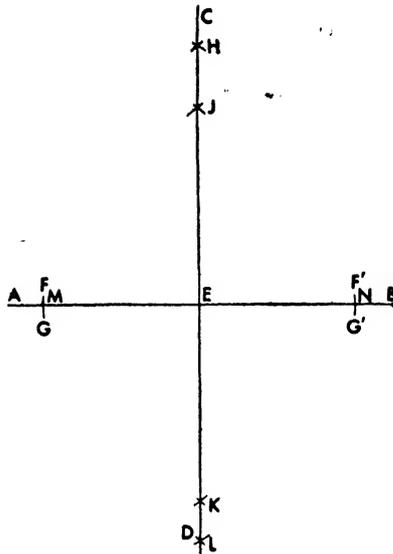


Fig. 401

gage of material at the top of the page. Should the worker wish to find the X dimension for 0.064 inch material bent 101 degrees, it would be located under the column headed 0.064 at the top of the page and opposite the number of degrees at the left, in this instance 101 degrees, and it would be 0.0776 inch. The loft draftsman must remember that *only* the X dimension can be obtained from these charts.

In all parts of the loft and particularly in the development of templates, where a great amount of geometric construction is necessary, one of the most difficult problems the newcomer will encounter is the construction of perpendicular

lines. To the draftsman this usually seems trifling, but it is very important to the loftsmen, for a line that is off  $\frac{1}{100}$  inch or more when it is supposed to be perpendicular may throw the entire layout off and render it useless. In Figs. 401, 402, and 403 are shown three simple geometric constructions encountered daily by the template maker. First in Fig. 401, line CD has been constructed perpendicular to AB. To do this, on AB locate any point E, through which the line CD will pass, allowing enough distance at either side of point E to swing arcs FG and F'G', using E as a center and any convenient radius. Using the two points M and N, established by the intersection of arcs FG and F'G' and line AB, as center points, swing two sets of intersecting arcs above, and if possible below, line AB, establishing points H, J, K, and L. The reason for two sets of arcs is that, the more points established on a straight line, the less chance there is for error. If the straightedge lines up with points H, J, K, L, and E, the line can be drawn, but if the straightedge misses one or more of these points, all the points should be checked, particularly M and N, for misplacement of these two points is a common error.

Another useful way of constructing a perpendicular is shown in Fig. 402. This method enables the worker to construct a perpendicular at the end of a line and, though not as accurate as the first method, will for practical purposes enable the template maker to save a great deal of material if done correctly. The line AB is given,

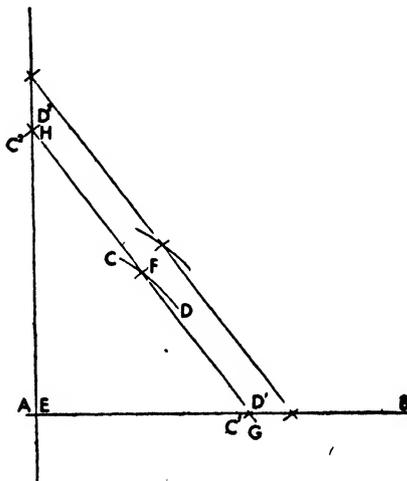


Fig. 402

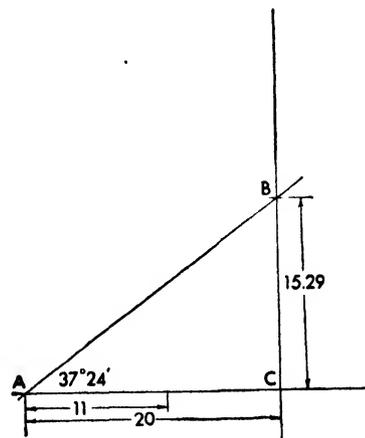


Fig. 403

and a perpendicular is necessary as near the end of the line as possible. Using E on line AB as a center point and any radius, swing arc CD above or below AB. Select a point F on this arc *approximately* 45 degrees above line AB. Using it as a center point, swing arc C<sup>1</sup>D<sup>1</sup> intersecting AB at point G and arc C<sup>2</sup>D<sup>2</sup> above point E. With a straightedge connect points G on AB, and F on arc CD; then, with the straightedge still in position, draw a short dash line through arc C<sup>2</sup>D<sup>2</sup>, establishing point H. Now connect points H and E, and the perpendicular will be constructed. This method involves several operations, and should an error occur in any one of them, it would be multiplied in the final result.

The construction of angles is also very important in loft work. Small celluloid protractors are not accurate, and they should never be employed. *Always use geometric construction to determine any angle of importance on a loft layout or a template.*

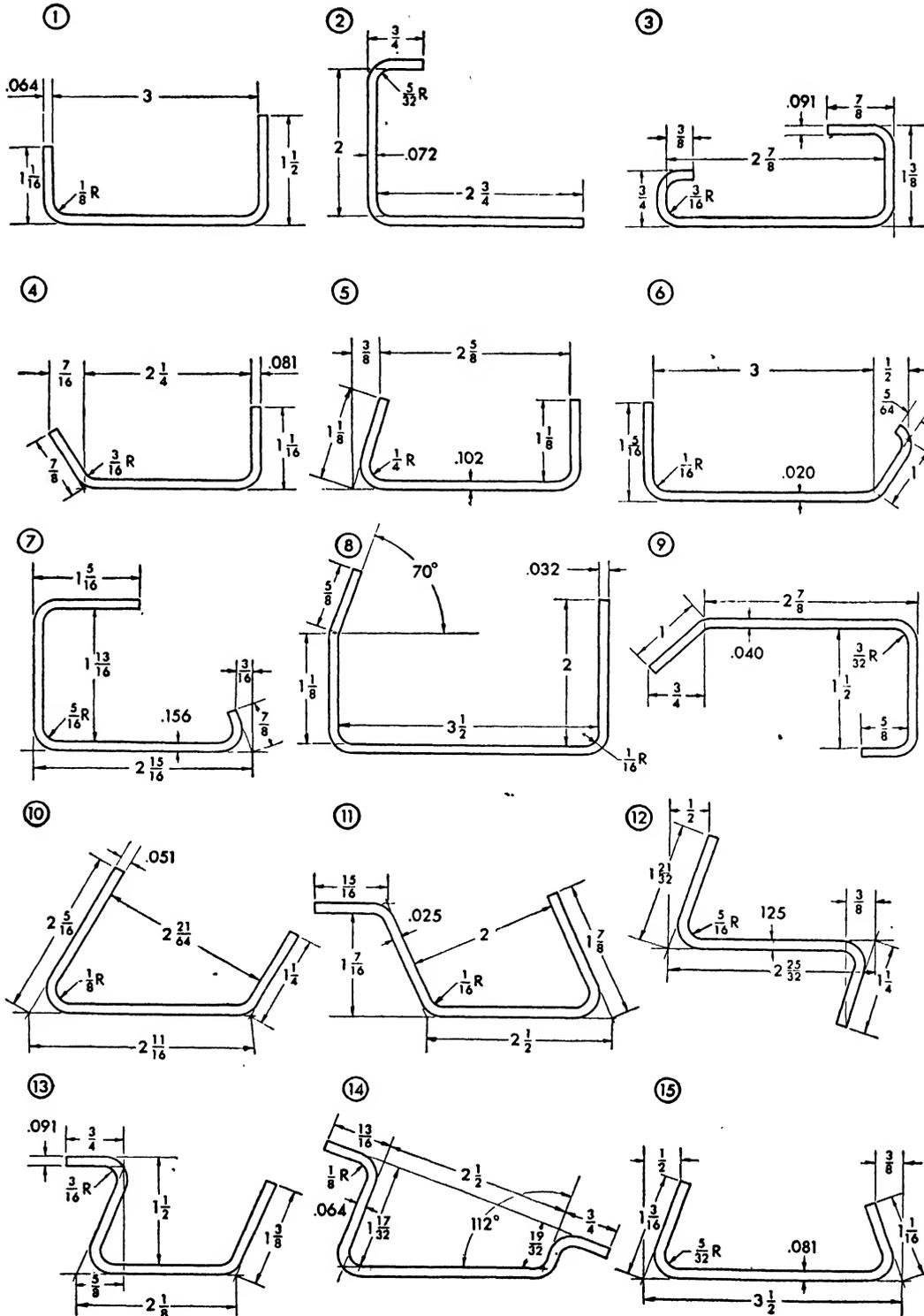
When constructing an angle, it is always best to "blow up" the construction to decrease the

error that might occur. For example, in Fig. 403 is an angle of 37 degrees 24 minutes with one leg 11 inches long. Extend the 11 inch leg to 20 inches, and, using it as the base of a right triangle, erect a perpendicular at the 20 inch mark. Find the tangent of 37 degrees 24 minutes, given in a trigonometry table, and multiply it by 20. In this example the result is 15.29 inches. Set this dimension in on the perpendicular line, and through points A and B draw a straight line to obtain the desired angle. The student might test his layout skill by *accurately* constructing a polygon on a given side (page 96).

#### *Problems for Study*

The problems have been prepared to give the beginner practice in calculating simple bends. By applying all the formulas and procedures set forth in this chapter, the student should have no difficulty in solving these problems. The answers to the problems are given so that the student can check himself.

# PROBLEMS FOR CHAPTER TWENTY-ONE



ANSWERS TO PROBLEMS

1. Setback—.137  
Developed length—5.417
2. Setback—.161  
Developed length—5.394
3. Setback—.199  
Developed length—5.728
4. Angle— $30^\circ$   
Setback  $90^\circ$ —.186  
Setback  $30^\circ$  open—.076  
Developed length—1.007
5. Angle— $19^\circ 28'$   
Setback  $19\frac{1}{2}^\circ$  closed—.432  
Setback  $90^\circ$ —.241  
Developed length—4.781
6. Angle— $30^\circ$   
Setback  $30^\circ$  open—.020  
Setback  $90^\circ$ —.053  
Inside to outside mold pt.—.0115  
Developed length—5.348
7. Angle— $12^\circ 22'$   
Bend allowance  $102\frac{1}{2}^\circ$ —.6837  
Outside to tangent pt.—.5823 ( $102\frac{1}{2}^\circ$ )  
Bend allowance  $90^\circ$ —.6003  
Setback  $12\frac{1}{2}^\circ$  closed—.481  
Setback  $90^\circ$ —.337  
Outside to tangent pt.—.4685 ( $90^\circ$ )  
Developed length—6.0945
8. Bend allowance  $20^\circ$ —.027  
Setback  $90^\circ$ —.068  
Inside mold pt. to tangent pt.  $20^\circ$ —.011  
Developed length—7.247
9. Angle— $48^\circ 36'$   
Setback  $48\frac{1}{2}^\circ$ —.020 (open)  
Setback  $90^\circ$ —.092  
Developed length—5.916
10. Angles— $25^\circ$  open and closed  
Setback  $25^\circ$  open—.057  
Setback  $25^\circ$  closed—.256  
Developed length—5.937
11. Angles— $34^\circ 54'$  open and closed  
Setback  $35^\circ$  open—.020  
Setback  $35^\circ$  closed—.175  
Length of leg—1.766  
Developed length—6.864
12. Angles— $17^\circ 34'$  and  $17^\circ 28'$   
Setback  $17\frac{1}{2}^\circ$  closed—.508  
Developed length—4.671
13. Angles— $21\frac{1}{2}^\circ$  open and closed  
Setback  $21\frac{1}{2}^\circ$  open—.107  
Setback  $21\frac{1}{2}^\circ$  closed—.386  
Length of leg—1.709  
Developed length—5.347  
Ots. to ins. mold pt.—.1334 (clsd)
14. Angles— $22^\circ$  open and closed  
Setback— $22^\circ$  closed—.223  
Setback  $22^\circ$  open—.073  
Outside to inside mold pt. closed—.0919  
Outside to inside mold pt. open—.0432  
Developed length—6.122
15. Angles— $24^\circ 54'$  and  $20^\circ 40'$   
Setback  $25^\circ$  closed—.370  
Setback  $21^\circ$  closed—.319  
Developed length—5.061

# CHAPTER TWENTY-TWO

## DESIGN

No attempt is made here to analyze complete airplane design data. The aim is to acquaint the beginner draftsman with certain basic design elements and considerations that pertain to the preparation of details and minor layouts. Most aircraft companies do not want their draftsmen turned into "copiers" or tracers of drawings, but want them to exercise their own initiative and the inventive and analytical qualities of an engineer. Many opportunities for this are offered the draftsman.

Good design requires a working knowledge of mathematics, engineering drawing, and familiarity with fabrications and assembly methods. But the ability to analyze a problem and create a practical solution is perhaps the greatest asset. Whether the degree of one's ingenuity is inherent or not, it may be developed considerably.

Study interesting designs that have been proved successful. One who has noted a wide range of solutions to a particular type of problem is more likely to cope with a similar situation. This does not mean that ideas are to be

copied, but rather that basic successful principles may be followed.

The better trade magazines of the aircraft industry offer the new designer a wealth of information. Not only may the latest design developments be analyzed in these publications, but assistance may be gained from the research carried on by the manufacturers of aircraft parts and materials. In their advertisements, manufacturers constantly offer booklets and other data pertaining to their products. Since these larger manufacturers employ skilled aircraft specialists to develop their designs, many applications of the product may be found in these booklets. A manufacturer of fasteners, for example, offers not only complete engineering data but suggestions for possible applications.

Too often this source of information is neglected. It is an excellent idea for the beginner to accumulate gradually a "morgue" or reference filing system of engineering data, alphabetically arranged so that a particular subject will be readily accessible.

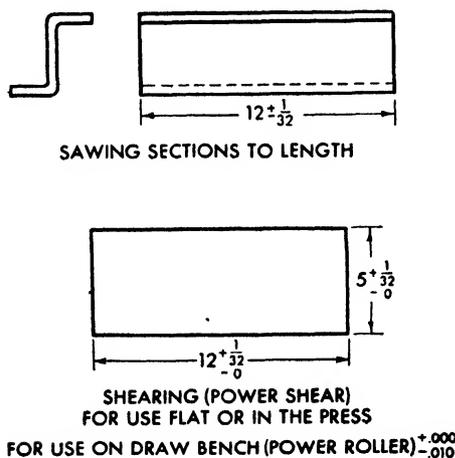


Fig. 404. General working tolerances

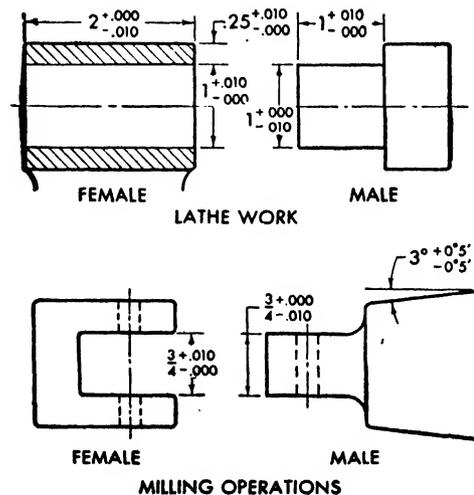


Fig. 405. General working tolerances

Books are also a source of design background, and many excellent books on aircraft design have been written. The draftsman need only visit his public library and find the shelf marked "Aeronautical Engineering."

Parts must be designed so that they can be made. To this end most aircraft manufacturers have compiled a series of books called the "company manuals" pertaining to the practical design practice of that particular company. In many instances general design practice is included in the Drawing Room Manual (DRM), but complete manuals are offered on such subjects as spot welding, hydopress, drop hammer, and loft operations. Study of these company books will provide the design draftsman with most of the information necessary in the fabrication processes of particular machines and/or materials. Too often the draftsman will search far afield for information that he might have readily acquired from his own company manuals. Complete engineering and design data cannot be absorbed and thoroughly digested by any one man. The correct procedure is to *know where* to find a particular formula, weight, mechanical property, etc. The keynote is to be methodical. It is a good idea to keep a small file on every layout job. Cardinal dimensions, loads, and new information pertaining to the job may be kept in a small folder so that references and records are readily available.

**Standard Parts**

A designer should consider the cost of material, equipment available for fabrications, and labor. The use of standard parts is highly desirable. The draftsman might find it of great practical advantage to become familiar with the company standard parts books. Standard extruded and drawn sections of a wide variety of gages and shapes are kept in stock. The student can easily visualize the great labor saving in calling for a standard extruded channel section in a design rather than for the special machine processes necessary to fabricate a special channel. Frequently, the already existing standard part may be modified to suit a particular condition. For example, if a  $1\frac{3}{8}$  inch flange is desired and a standard section (X21) contains a  $1\frac{1}{4}$  inch

flange, it may conveniently be used by simply noting: -6 MAKE FROM X21.

Blanking and forming dies are expensive and difficult to obtain. Do not call for special beads, joggles, cutouts, etc., when a suitable existing die may be obtained by reference to the company standard book. Standard bolts, nuts, rivets, and miscellaneous fasteners should be used at all times, unless exceptional design conditions demand a special member, and in that case the group engineer should be consulted.

**Minimize Number of Parts**

The number of parts used should be kept to a minimum. This facilitates stocking, handling, and assembly. If one part can be designed to do the work of two, it is preferable.

**Material**

Because of its fine mechanical properties, the most common stock used in aircraft fabrication is 24S Dural or 24S Alclad. 24SO soft sheet stock renders the best results for forming and is indispensable for deep draws. After forming, the part must be strengthened by heat treatment

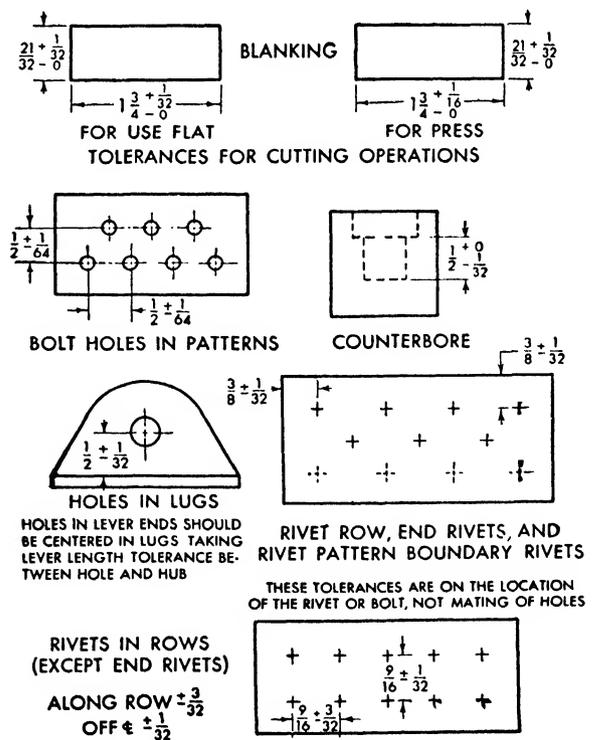


Fig. 406. General working tolerances

which warps the piece to some degree. Hence, heat treated (ST) or cold worked stock (H) is preferable wherever fabrication will allow. 24S-T material is limited, however, by the sharpness of bend and the degree of cold working administered to it.

A strong, corrosion-resistant, and readily workable aluminum alloy, designated R-301, has recently been developed by the Reynolds Metal Company. Because R-301 develops a typical tensile yield strength of 60,000 psi, it is commonly employed in sheet stock fabrication.

It is sometimes desirable to replace aluminum

alloys with steel in general structure, but only when strength is paramount or when the gage of the steel can be reduced sufficiently to match the thicker gage of aluminum from a weight standpoint. This is especially true in the design of certain airtight pressurized joints, where thin sheets of steel may be conveniently welded airtight and still reasonably match thicker gages of aluminum in strength and weight. The tempered aluminum alloys can be welded, but the heat of welding softens the material, rendering it non-structural. For further design consideration regarding material, see Chapter Fourteen.

Fig. 407

## TOLERANCES FOR INTERCHANGEABLE MACHINE WORK

- |  |   |
|--|---|
| I. Automatic Screw Machine                         | $\frac{1}{4}D$ to $\frac{1}{2}D$ —0.004             |
| a. Threading                                       | $\frac{1}{2}D$ to $\frac{3}{4}D$ —0.005             |
| O. D. 0.003  | $\frac{3}{4}D$ to $1D$ —0.007                       |
| Pitch Dia. 0.002                                   | $1D$ to $2D$ —0.010                                 |
| b. Turning   | V. Reaming  |
| Box Tool 0.003                                     | a. Hand   |
| c. Drilling  | Dia. up to 1 in.—0.001                              |
| Drills   | Dia. over 1 in.—0.002                               |
| # 60 to 30—0.002                                   | b. Machine  |
| # 30 to 1—0.003                                    | Dia. up to $\frac{1}{2}D$ —0.0005                   |
| $\frac{1}{4}D$ to $\frac{1}{2}D$ —0.004            | $\frac{1}{2}D$ to $1D$ —0.00075-0.001               |
| $\frac{1}{2}D$ to $\frac{3}{4}D$ —0.005            | Dia. over $1D$ —0.0015                              |
| $\frac{3}{4}D$ to $1D$ —0.007                      | VI. Grinding  |
| d. Shoulder Work                                   | a. Cylindrical—0.0005                               |
| 0.003 to 0.005                                     | b. Surface—0.001                                    |
| II. Lathe  | c. Vertical surface—0.001-0.002                     |
| a. Rough Turning                                   | VII. Planing and Shaping                            |
| $\frac{1}{4}D$ to $\frac{1}{2}D$ —0.005            | Large flat pieces—0.005-0.010                       |
| $\frac{1}{2}D$ to $1D$ —0.007                      | VIII. Slot Milling                                  |
| $1D$ to $2D$ —0.015                                | Widths  |
| b. Finish Turning                                  | $\frac{1}{4}$ to $\frac{1}{2}$ in.—0.005            |
| $\frac{1}{4}D$ to $\frac{1}{2}D$ —0.002            | $\frac{1}{2}$ to $\frac{3}{4}$ in.—0.008            |
| $\frac{1}{2}D$ to $1D$ —0.003                      | $\frac{3}{4}$ to 1 in.—0.010                        |
| $1D$ to $2D$ —0.005                                | IX. Power Milling                                   |
| Larger Dia.—0.007                                  | a. Single—flat pieces—0.002-0.003                   |
| More accurate turning may be acquired by grinding. | b. Simultaneous milling—0.004-0.005                 |
| III. Boring  | c. Straddle milling—0.005                           |
| a. Rough   | d. Form cutters—0.005                               |
| 1 to 2 in. dia.—0.008                              | X. Turret Lathe                                     |
| Larger dia.—0.010 to 0.015                         | a. Dia.—0.002                                       |
| b. Finished  | b. Shoulder—0.005                                   |
| 1 to 2 in. dia.—0.002                              | XI. Profiling                                       |
| IV. Drilling Machine                               | a. Hand—Radial and diametrical simple contour—0.004 |
| Drills   | Complicated Contour—0.008                           |
| # 60 to 30—0.002                                   | b. Automatic—0.005-0.015                            |
| # 30 to 1—0.003                                    |   |

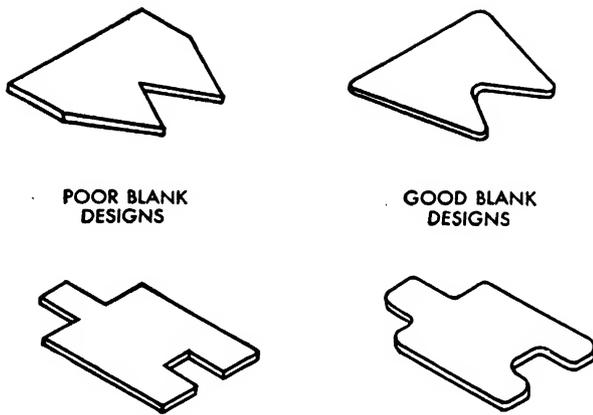


Fig. 408. Blanking designs—sharp and round inside corners

*Tolerances*

A knowledge of shop practice and process will enable the draftsman to design parts requiring a minimum of operations for their fabrication. The closer the tolerance required, the greater is the cost of the part. Therefore close tolerances should not be called for if the part will function properly with more liberal limits. General working tolerances are shown in Figs. 404, 405, and 406, along with others pertaining to various operations throughout this chapter. Tolerances for interchangeable machine work are indicated in Fig. 407.

*Weight*

Weight saved in construction of the airplane means increased pay load and efficiency. Every

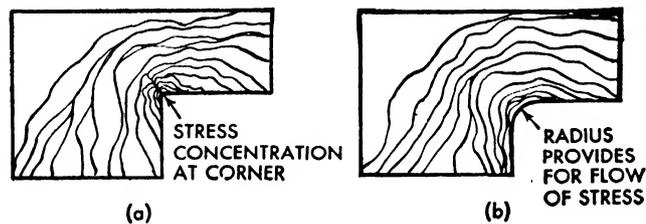


Fig. 409. Inside corner radii

effort should be exercised to keep weight to a minimum and to regulate the weight of a part to the strength and rigidity required.

The best way for the beginner to design with a minimum of weight is for him to understand the structural requirements of the design. The weight saving hints set forth on page 331, con-

tain some basic rudiments that the student would do well in following.

*Inside Corners*

Avoid sharp inside corners on all designs. From a production standpoint, they are difficult to fabricate, causing a problem for blanking dies, and often they require hand filing (Fig. 408).

In cutting, the shears may overlap at the corner and thus begin a rupture. The general shop practice is to drill a hole tangent to the intersecting lines of the corner and then cut straight from the edge of the material to the point of tangency. Certain machines, such as the router, require a minimum inside radius equal to one half the router cutter diameter.

From a structural standpoint, sharp inside corners cause stress concentrations and subsequent rupture of the material at the corner as shown in Fig. 409.

*Flanges*

A flange is an edge area of a member bent or otherwise formed to create a projecting rim or edge for fastening and/or stiffening.

Flat sheet metal may be flanged to form interchangeable channels, Z's hats, etc., for structural or nonstructural parts of the airplane. Flanges

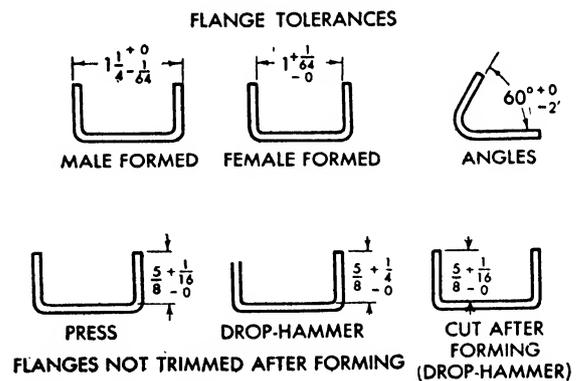


Fig. 410

help to eliminate riveted seams and provide a minimum of detail parts in the final assembly. Flange tolerances are illustrated in Fig. 410.

*Flange Sizes. Hydropress.* Since the flange width tends to stiffen the member, ample flange is desirable within the strength-weight ratio.

For hydropress forming a 1/8 inch flange is de-

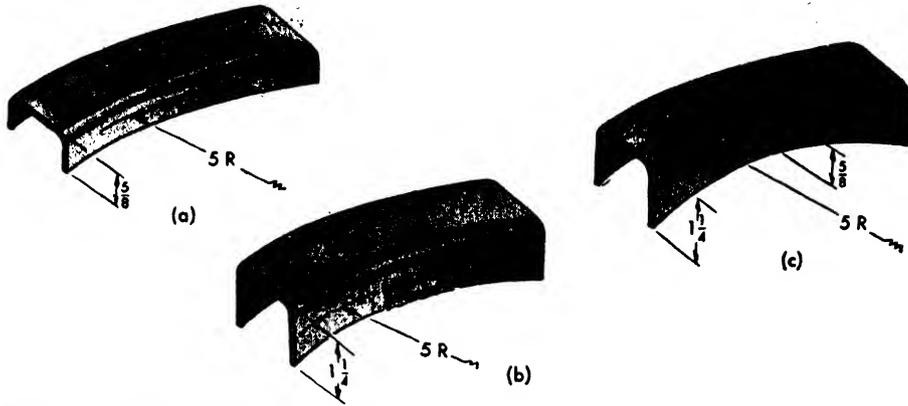


Fig. 411. Flange proportion on radii

signed for each inch of radius, as shown in Fig. 411a; hence, a  $\frac{5}{8}$  inch flange for a 5 inch radius. As illustrated in Fig. 411b, a flange of a larger proportion tends to rip. Since the rupture occurs in the center, it is sometimes possible to design a tapered flange, as shown in Fig. 411c, for maximum strength under the forming conditions.

radius as possible. The chart shown in Fig. 413 states a standard and minimum radius for the more common gages of material. The minimum radii should be used only when a smaller radius is indispensable for added flat material for clearance or for riveting edge distance.

Bend radii should not be guessed or approxi-

Fig. 412

CHART FOR BENDING 24SO AND 24ST ON BRAKE

Gage	Bend Radius, Inches		Minimum Flange, inches	
	24SO	24ST	24SO	24ST
0.016	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$
0.020	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
0.025	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
0.032	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
0.040	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
0.051	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
0.064	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
0.072	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
0.081	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
0.091	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
0.102	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
0.125	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$
0.156	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$
0.187	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$
0.210	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$

The bend radii and stock thicknesses in this chart are to be considered standard min. for all parts formed on the brake.

In determining the correct min. flange length, use a figure which corresponds to the bend radius. The stock thickness is not necessarily a deciding factor.

**Flange Sizes. Brake.** Flanges designed too small for fabrication are a constant source of irritation to the shop.

In brake bending a minimum flange distance is required as indicated in the chart in Fig. 412.

**Bend Radii**

Sheet stock should be bent on as liberal a

Fig. 413

BEND RADII FOR ALUMINUM ALLOY SHEET<sup>1</sup>  
STANDARD BEND RADII

Gage	24SO	24ST	2S, 3S, and 52S
0.016	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{4}$
0.020	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{4}$
0.025	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{4}$
0.032	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{3}{4}$
0.040	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$
0.051	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$
0.064	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
0.072	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{4}$
0.081	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$
0.091	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$
0.102	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
0.125	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
0.156	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
0.187	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$

<sup>1</sup> Avoid use of minimum bend radii unless design limitations require them.

MINIMUM BEND RADII

Gage	24SO <sup>2</sup>	24ST <sup>2</sup>	2S, 3S and 52S
0.016	0	$\frac{1}{8}$	0
0.020	0	$\frac{1}{8}$	0
0.025	0	$\frac{3}{8}$	0
0.032	0	$\frac{1}{8}$	0
0.040	0	$\frac{3}{8}$	0
0.051	0	$\frac{1}{8}$	0
0.064	0	$\frac{1}{2}$	0
0.072	0	$\frac{1}{8}$	0
0.081	0	$\frac{3}{8}$	0
0.091	0	$\frac{1}{8}$	0
0.102	0	$\frac{1}{8}$	0
0.125	0	$\frac{1}{2}$	0
0.156	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
0.187	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$

<sup>2</sup> These values in accordance with Navy Spec. S.A. 4D.

mated. Accurate and constant reference to the chart assures the draftsman of a competent layout. Because of constant experimentation in the development of materials the radii requirements change. The radii shown in Fig. 413 were determined at the time of writing.

**Relief Radii**

Flanges bent at right angles on two edges of sheet stock require relief radii to facilitate the bending without crumbling and tearing at the corners. Figure 414 illustrates types of relief radii. The most common relief radius is shown in Fig. 414a. Here the distance A determines the edge of the flanges. If added flange area is needed for rivet edge distance, b or c may be used. The flanges pass the tangent bend lines in b and stop on the tangent lines in c. If square flanges and rivet edge distances are not important, d may be used as it entails a minimum of effort to fabricate and is desirable for production.

**Beads**

Beads are recessions impressed in flat sheet stock for the sole purpose of stiffening the sheet (Fig. 415). The direction and position of the bead is relative to the applied load. A serious

consideration of possible beading will frequently eliminate weight, lessen the number of parts, and minimize assembly costs.

Buttons are circular recessions impressed in sheet metal (Fig. 416) to strengthen and/or stiffen the sheet.

**Lightening Holes**

A hole in sheet metal that is flanged or beaded around its edge is called a "lightening" or "reinforcing" hole (Fig. 416). These holes substantially reduce the weight of the member, provide accessibility in assembly, or allow for cable, electrical, or other installations through solid structure. In many instances a beaded hole imparts greater strength to the piece while still lightening it. From a strength-weight point of view it is often desirable to use a heavier gage of material with lightening holes than a solid sheet of less thickness.

**Drop Hammer**

Design for drop hammer process only when the part cannot be formed by a more economical method. In drop hammer design provide for as liberal a corner radius as possible. Sharp corners tend to workharden and crack the piece. The

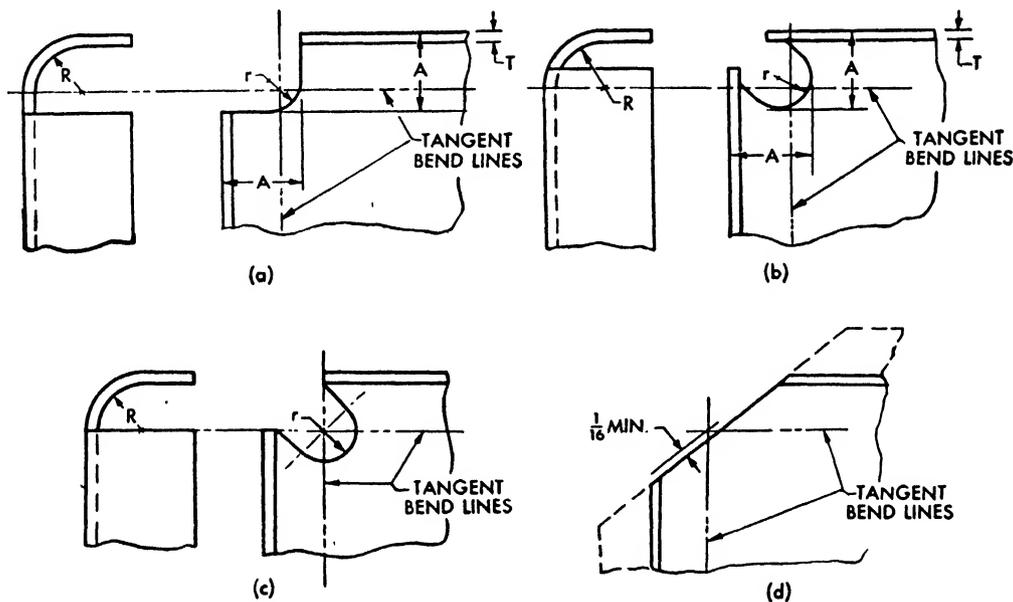


Fig. 414. Types of relief radii

- R = Bend radius
- T = Stock thickness
- $A = T + R + \frac{1}{8}$
- r = Minimum relief radius

Stock Thickness (T)	Minimum Radius (r)
.025 to .040	$\frac{1}{8}$
.040 to .064	$\frac{1}{16}$
.064 to .091	$\frac{1}{4}$

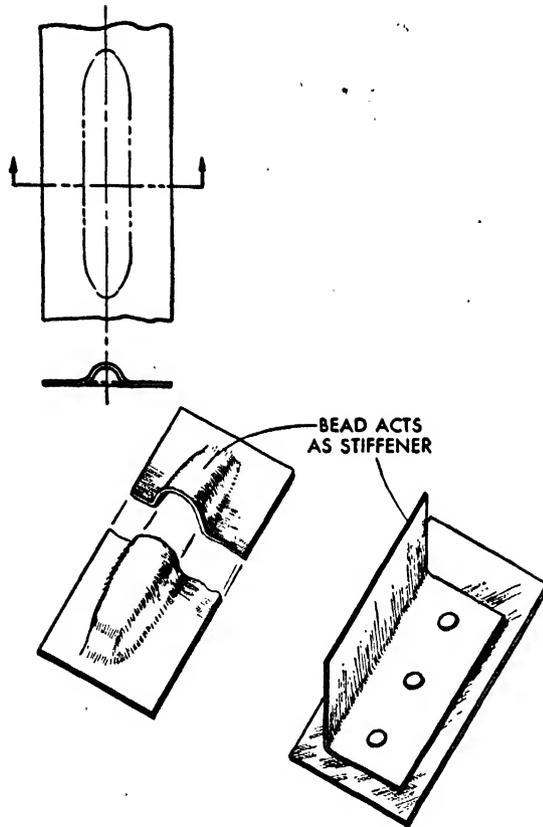


Fig. 415. Straight beads

general tolerances should be as liberal as possible, for the drop hammer is not a precision machine. Too close tolerances cause excessive production costs. Minimum and average radii are shown in Fig. 417, tolerances are indicated in Fig. 418. In both cases the values are approximate.

### Castings

In the design of castings:

Allow necessary draft in the direction in which the casting is to be removed from the mold. Usually the degree of draft is left to the discretion of the pattern maker. If specified on the design,  $\frac{1}{2}$  degree of  $\frac{1}{32}$  inch run is sufficient.

Allow sufficient edge distance on holes, bosses, etc., to avoid cracking the casting when riveted or when a somewhat greater load than anticipated is applied.

Minimum wall thickness should not be less than  $\frac{1}{8}$  inch  $\pm \frac{1}{32}$  inch. The minimum permissible wall thickness for lugs and bosses should be specified after machining. Avoid designs that re-

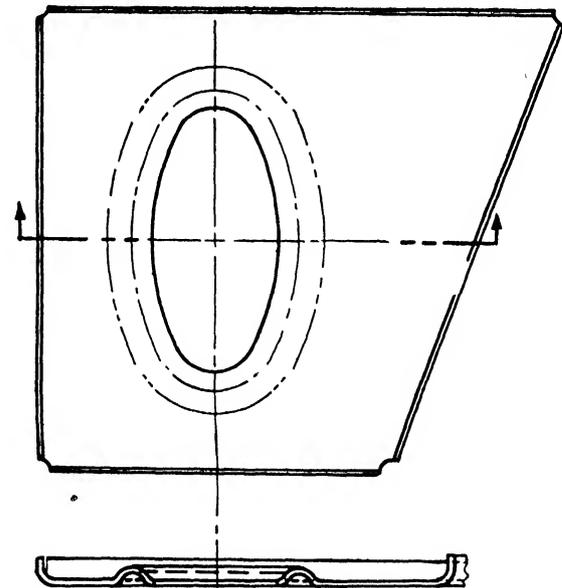
quire machine finishing of large flat base surfaces. It is better to call for bosses at the corners; the added weight compensates the machining cost.

Minimum fillets should be  $\frac{1}{8}$  inch radius, but more liberal radii are desirable. Fillets should not be less than the thickness of adjacent walls.

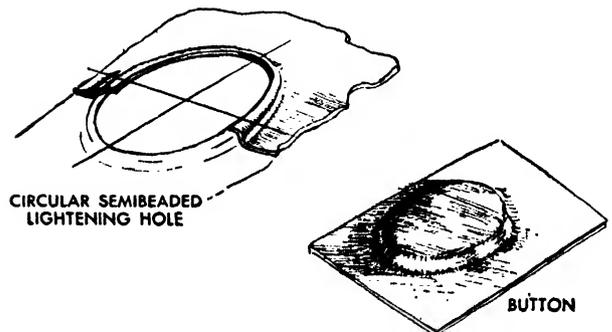
Tolerances on castings vary with the size of the castings (Fig. 419).

Avoid sudden changes in sections, notches on surface, or sharp corners. All these conditions do not allow for flow of load, and arouse stress concentrations.

If a large number of pieces with close tolerances and smooth surface are required, the use of permanent mold castings in place of sand should be considered.



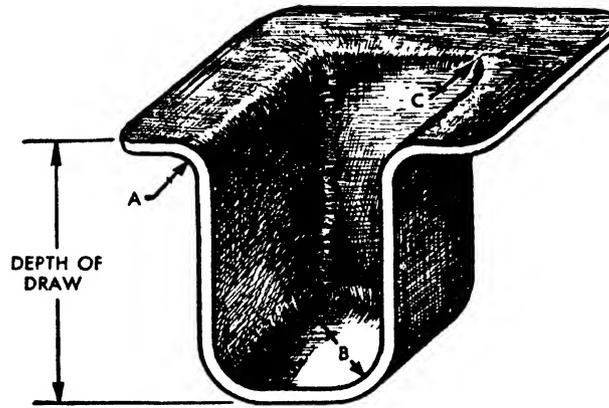
ELLIPTICAL BEADED LIGHTENING HOLE



CIRCULAR SEMIBEADED LIGHTENING HOLE

BUTTON

Fig. 416. Lightening holes and button



BEND RADII FOR DROP HAMMER PARTS

FOR RADIUS OF "A" (AVERAGE)

FOR RADIUS OF "A" (MINIMUM)

Depth of Draw (Inches)	Radius "A"
1	$\frac{9}{32}$
2	$\frac{3}{4}$
3	$\frac{3}{4}$
4	$\frac{1}{2}$
5	$\frac{3}{8}$
6	$\frac{3}{4}$
7	$\frac{1}{16}$

Depth of Draw (Inches)	Radius "A"
8	1
9	$1\frac{5}{32}$
10	$1\frac{1}{2}$
11	$1\frac{1}{2}$
12	$1\frac{1}{2}$
13	$1\frac{9}{16}$
14	$1\frac{9}{16}$

Depth of Draw (Inches)	Radius "A"
1	$\frac{1}{8}$
2	$\frac{3}{16}$
3	$\frac{3}{16}$
4	$\frac{1}{4}$
5	$\frac{1}{4}$
6	$\frac{1}{2}$
7	$\frac{1}{2}$

Depth of Draw (Inches)	Radius "A"
8	$\frac{9}{16}$
9	$\frac{3}{8}$
10	$\frac{3}{8}$
11	$\frac{1}{8}$
12	$\frac{3}{8}$
13	$\frac{3}{4}$
14	$\frac{3}{4}$

FOR RADIUS OF "B" (AVERAGE)

FOR RADIUS OF "B" (MINIMUM)

Depth of Draw (Inches)	Radius "B"
1	$\frac{1}{2}$
2	$\frac{1}{16}$
3	$\frac{3}{32}$
4	$\frac{1}{8}$
5	$1\frac{9}{32}$
6	$1\frac{1}{32}$
7	$1\frac{1}{32}$

Depth of Draw (Inches)	Radius "B"
8	$2\frac{1}{32}$
9	$2\frac{1}{16}$
10	$2\frac{9}{16}$
11	$2\frac{3}{32}$
12	$2\frac{3}{32}$
13	3
14	$3\frac{1}{32}$

Depth of Draw (Inches)	Radius "B"
1	$\frac{1}{4}$
2	$\frac{1}{16}$
3	$\frac{1}{16}$
4	$\frac{1}{16}$
5	$\frac{3}{32}$
6	$\frac{1}{4}$
7	1

Depth of Draw (Inches)	Radius "B"
8	$1\frac{1}{32}$
9	$1\frac{1}{32}$
10	$1\frac{1}{32}$
11	$1\frac{1}{2}$
12	$1\frac{1}{32}$
13	$1\frac{1}{32}$
14	$1\frac{1}{32}$

FOR RADIUS OF "C" (AVERAGE)

FOR RADIUS OF "C" (MINIMUM)

Depth of Draw (Inches)	Radius "C"
1	$\frac{5}{8}$
2	1
3	$1\frac{1}{2}$
4	2
5	$2\frac{1}{2}$
6	$3\frac{1}{8}$
7	$3\frac{1}{8}$

Depth of Draw (Inches)	Radius "C"
8	$4\frac{1}{2}$
9	$4\frac{1}{2}$
10	5
11	$5\frac{1}{2}$
12	$5\frac{1}{2}$
13	$5\frac{1}{2}$
14	6

Depth of Draw (Inches)	Radius "C"
1	$\frac{1}{2}$
2	$\frac{1}{4}$
3	$\frac{3}{8}$
4	$1\frac{1}{32}$
5	$1\frac{1}{2}$
6	$1\frac{1}{2}$
7	$1\frac{1}{2}$

Depth of Draw (Inches)	Radius "C"
8	$2\frac{1}{32}$
9	$2\frac{1}{16}$
10	$2\frac{1}{32}$
11	$2\frac{1}{32}$
12	$2\frac{1}{32}$
13	3
14	$3\frac{1}{32}$

Fig. 417

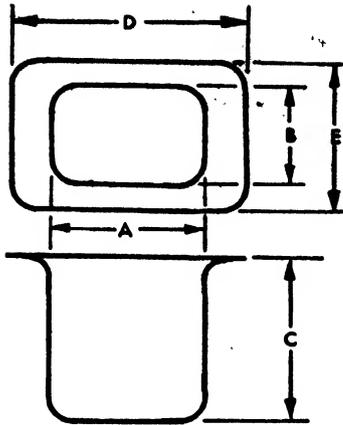


Fig. 418. Approximate tolerances on drop hammer dimensions

- C = tolerance of .03125-.046875 (from 2 to 6 inches)
- C = tolerance of .046875-.0625 (from 6 to 10 inches)
- A-B = tolerance of .03125-.0625 (from 6 to 20 inches)
- A-B = tolerance of .0625-.09375 (from 20 to 34 inches)
- D-E = tolerance of .03125-.0625 (from 10 to 30 inches)
- D-E = tolerance of .0625 to .09375 (from 30 to 50 inches)

**Forgings**

If large quantities of structural or nonstructural steel or aluminum alloy parts are desired,

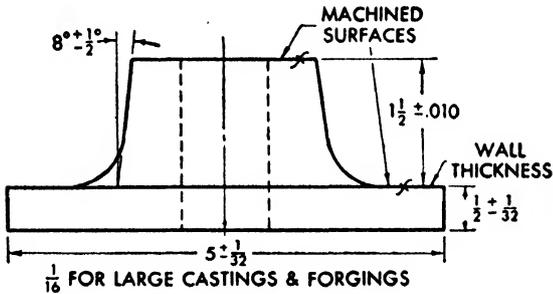


Fig. 419. Casting and forging tolerances

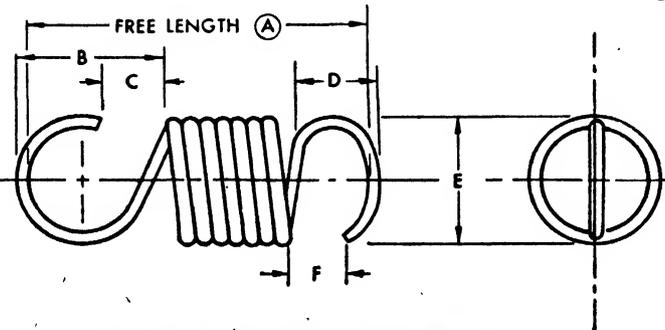


Fig. 421. Approximate<sup>1</sup> extension spring design

- (A) Dimension free length and give extended length and what load
- (B) Equal to O.D.
- (C) Equal one third O.D.
- (D) Equal two thirds O.D.<sup>2</sup>
- (E) Outside Coil Diameter (O.D.)

<sup>1</sup> All proportions given are approximate.  
<sup>2</sup> Ends are designed in line and on center.

they may be forged, but the number of pieces must be great enough to justify the cost of dies. The design considerations pertaining to forgings apply to castings except that a draft angle of at least 7 degrees must be specified in the direction away from the parting line.

**Spring Designs**

Spring designs are usually fabricated by spring manufacturers. Only basic information is required on the drawing, as shown in Figs. 420 and 421. The manufacturer generally determines the wire size, the pitch, and the number of coils. The extension spring ends shown in Figs. 421 and 422 can be made on automatic spring machines and require no special tools for fabrication.

The following terms are used in conjunction with spring fabrication:

- INITIAL TENSION. Maximum load applied to a close-wound spring without causing extension.
- SET. The loss of length in a compression spring when deflected beyond elastic limit.
- SPRING RATING. Pounds per inch of spring travel.
- SAFE LOAD. The maximum load applied to a spring without its taking a permanent set.

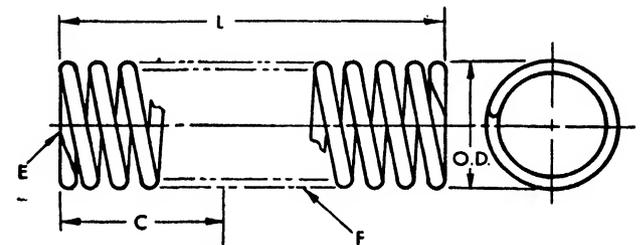


Fig. 420. Compression spring

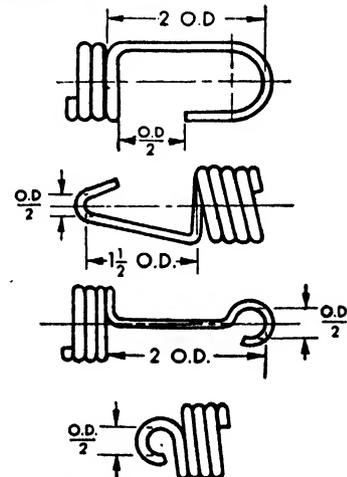


Fig. 422. Extension type ends (proportions are approximate)

**FACTOR OF SAFETY.** Ratio of safe load to maximum applied load.

**RANGE.** Difference between highest stress at full load and lowest stress at starting load on spring.

**SPRING INDEX.** Ratio of mean diameter of coil to diameter of wire.

**O. D.** Outside diameter of coil.

**I. D.** Inside diameter of coil.

### *Design for Assembly*

In the early days of aircraft manufacture, planes were custom built without regard for production processes. An entire wing was constructed slowly in one section in a complicated and intricate jig.

Modern design provides a system where the entire wing or other major section may be first broken down into a number of component

assemblies, thus facilitating rapid and uniform assembly of the section in quantity.

These component assemblies may be classed as follows:

1. Bench or detail assembly, sometimes termed "subassembly," in which parts that compose brackets, clips, ribs, or parts of minor assemblies are put together.
2. Minor assembly, in which a complete unit as a beltframe, spar, bulkhead, etc., is completed.
3. Major assembly, in which minor assemblies are joined into the wing, fuselage sections, empennage.
4. Final assembly, wherein the major units are mated, systems are installed, and finishing touches are put on.

"Jigs" provide a framework to hold the parts of the various assemblies together until they are



**Fig. 423.** Double assembly line operations during World War II at what was probably the largest aircraft factory in the world, Consolidated's Fort Worth plant. The line in the background contains both C-87 Liberator express transports and B-24 Liberator bombers. The line in the foreground inaugurates assembly line methods of modification to the B-24 bombers.

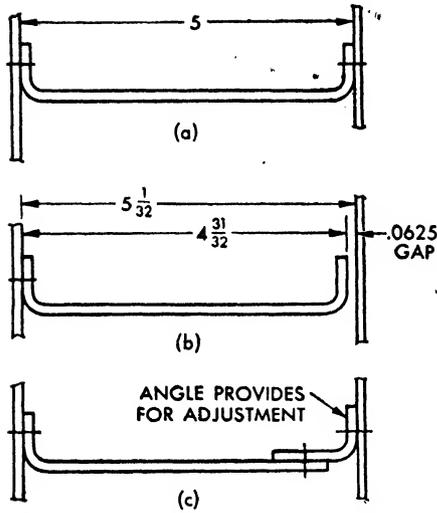


Fig. 424. Providing for adjustment

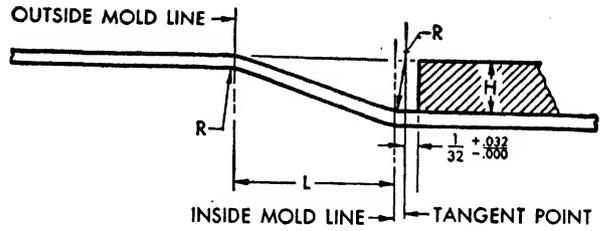


Fig. 428. A standard joggle for hydropress and sheet stock

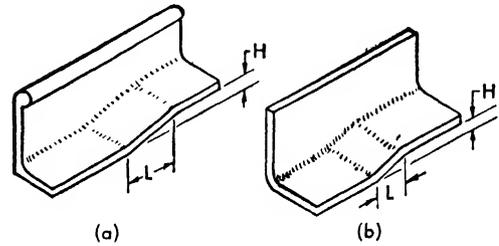


Fig. 429. Joggles for extruded and drawn sections



Fig. 425

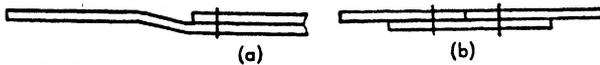


Fig. 426



Fig. 427

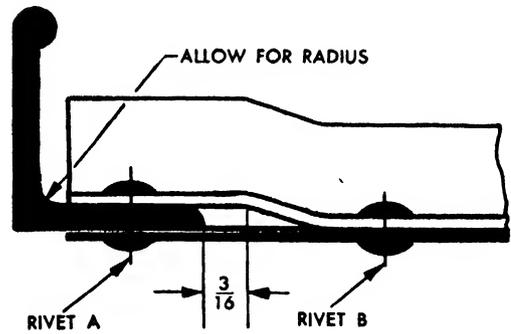


Fig. 430

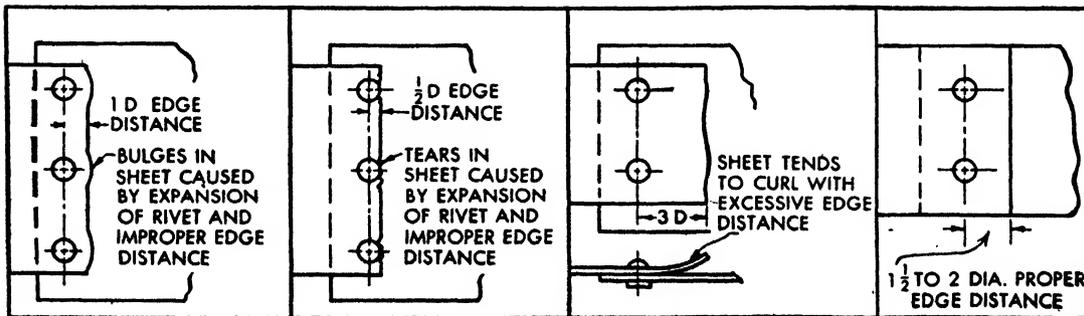


Fig. 431. Incorrect and proper rivet edge distances

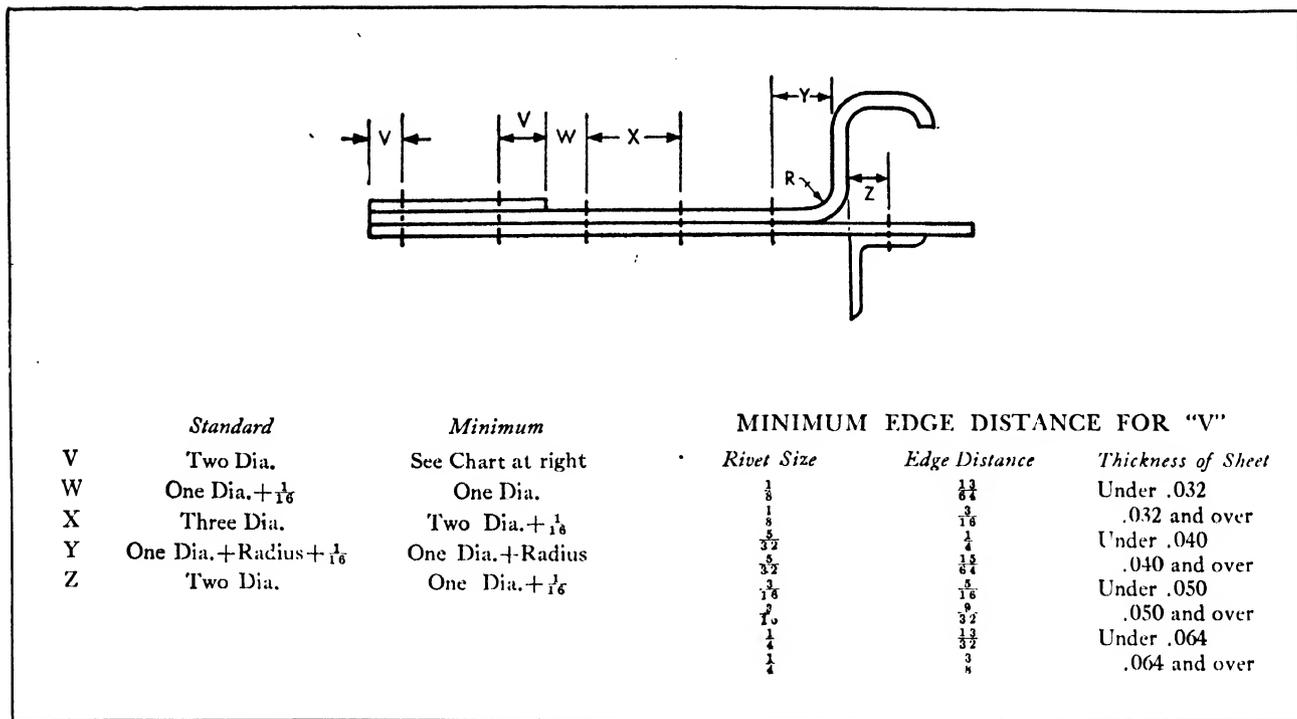


Fig. 432. Rivet layout

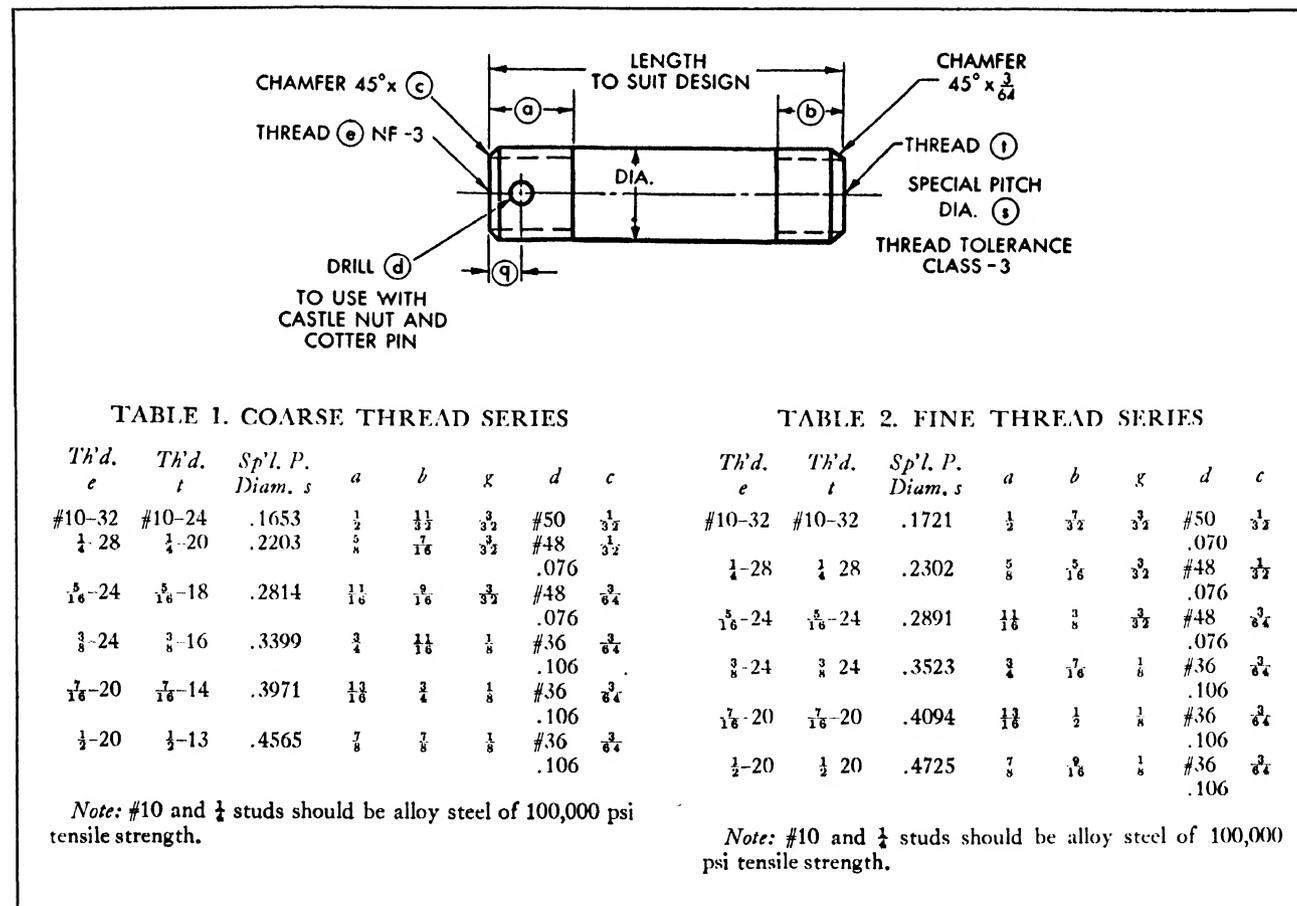


Fig. 433. Stud design

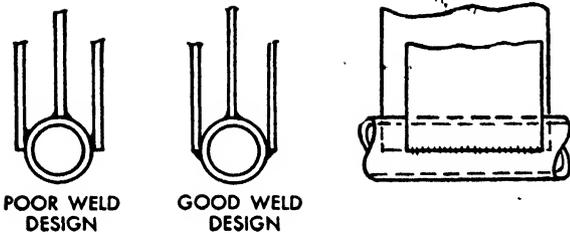


Fig. 434. Accessible welding

joined. These jigs are designed to hold the parts to the smallest fractional tolerance.

The designer-draftsman should endeavor to design assemblies with regard to their production. Specific rules cannot be made, as each assembly presents an individual problem, but this basic principle should be followed: *Design*

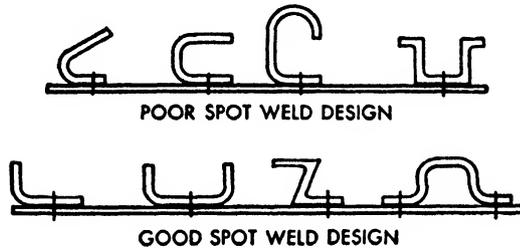


Fig. 435

*larger assemblies so they may be broken down into smaller units.*

*Advantages of Breakdown.* Production rate increases if large units are broken down into detail and minor assemblies. This allows the parts to be moved to stationary and highly mechanized machines for fast and uniform joining, not possible in larger units where smaller and less effi-

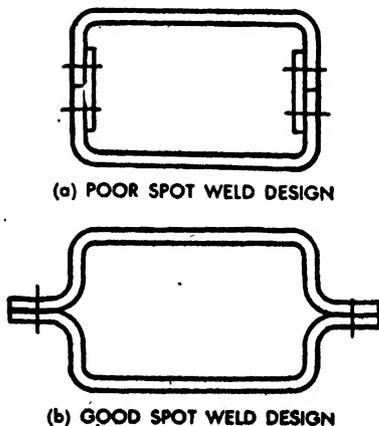


Fig. 436

cient machines must be brought to the work.

Greater accuracy may be obtained in smaller assembly work, for the detail and minor assembly jigs can hold closer tolerances than the larger assembly jigs.

Workmen prefer small assembly work because of the convenience of maneuvering the work about on the bench. Production increases as the worker becomes specialized and skilled at the job of assembling small parts. Newcomers are easier to "break in" on small assembly jobs.

The working area inside the airplane is small, and only a limited number of men can work in the final assembly. Minimizing the work in final assembly hastens production. It is an irksome and awkward task to install gussets, brackets, etc., in a final or a major assembly, whereas in a detail or minor assembly the task is simple.

*Adjustments*

Assembly designs should consider the possible shop errors accumulated in the permissible tolerance given in fabrication. In Fig. 424a the channel attachment between the two webs is dimensioned as 5 inches. Since  $\pm \frac{1}{32}$  inch is the general tolerance on dimensions, the 5 inch di-

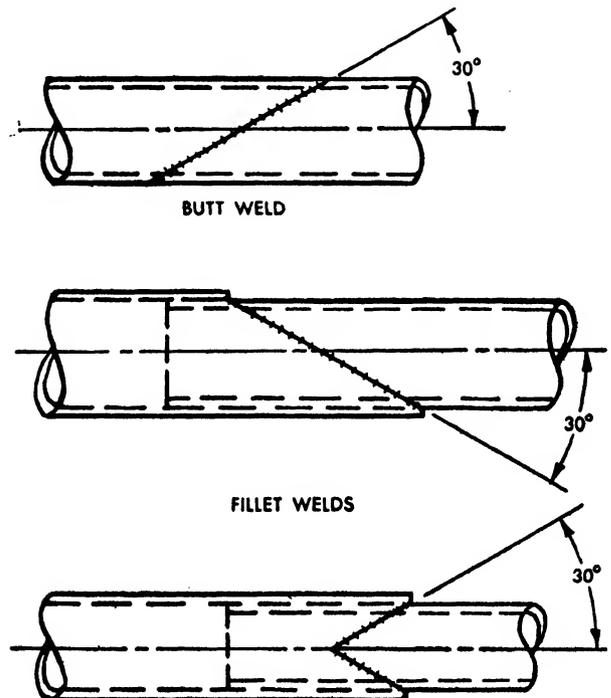


Fig. 437. Butt and fillet welds on tubular members

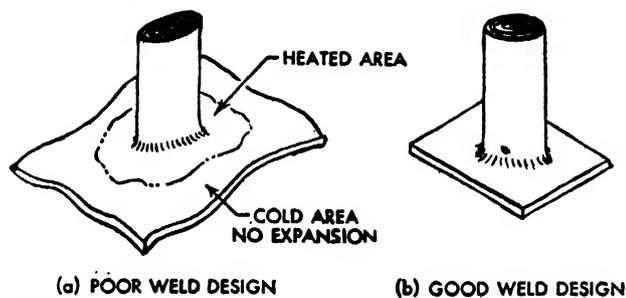


Fig. 438

mension between webs might pick up  $\frac{1}{32}$  inch, resulting in a  $5\frac{1}{32}$  inch dimension, the channel might lose  $\frac{1}{32}$ , resulting in a  $4\frac{3}{32}$  inch dimension and a gap of 0.0625 inch between web and

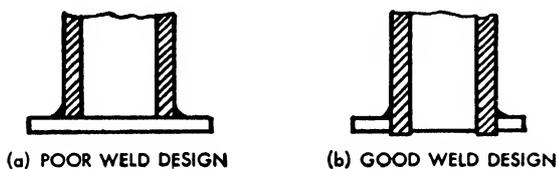


Fig. 439

channel, as shown in Fig. 424b. By breaking the channel into two angles, proper adjustment may be obtained as illustrated in Fig. 424c. This manner of adjustment has the disadvantage of an additional part and of more riveting, but this is compensated by the certainty of a proper fit in assembly. The single channel in Fig. 424a may be used if the webs are not entirely rigid, and if sufficient deflection is possible to bring them in contact with the channel.

Cutouts for stringers, longerons, etc., should not be designed to fit the exact shape of the member, but a clearance of approximately  $\frac{1}{8}$  inch should be allowed around the entire member.

If two clips are to be tied into a stringer passing through a beltframe, it is advisable to design only one clip as an integral part of the frame and leave the second free for adjustment.

Riveting accessibility is often overlooked. The designer-draftsman should remember that rivets must be driven from one end and bucked from the other. Sufficient working area must be allowed.

**Joggles**

A joggle is an offset in the contour of a member to facilitate the attachment of a part over or under a thicker member, or the achievement of

a smooth contour in the overlapping and joining of sheet stock. Figure 425 illustrates a typical joggle of a standard angle in a built-up spar beam. Figure 426a describes the joggle attachment of sheet stock as compared with another method shown in Fig. 426b. The joggle method is desirable because it eliminates an additional part, minimizes the number of rivets, facilitates assembly, and offers a more homogeneous joint. Because the unevenness of overlapping in very thin sheet stock is negligible, sheets 0.032 inch and under do not require joggling (Fig. 427).

Figure 428 describes a standard proportion for joggles of sheet stock.  $R$  = standard bend radius for 24S-T;  $L$  (length of joggle) =  $3H$  (height of joggle).

For extruded shapes, a standard joggle is equal to  $L = 6H$  (Fig. 429a).

For drawn or rolled shapes, a standard joggle is equal to  $L = 4H$  (Fig. 429b).

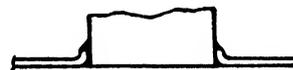


Fig. 440

Standard joggles vary with individual company practice, but the draftsman should endeavor to comply with a standard proportion whenever possible.

In a design of an extruded section joggle (24S-T) the draftsman-engineer should provide the maximum leg of angle under joggle to permit possible adjustment of the joggled part and

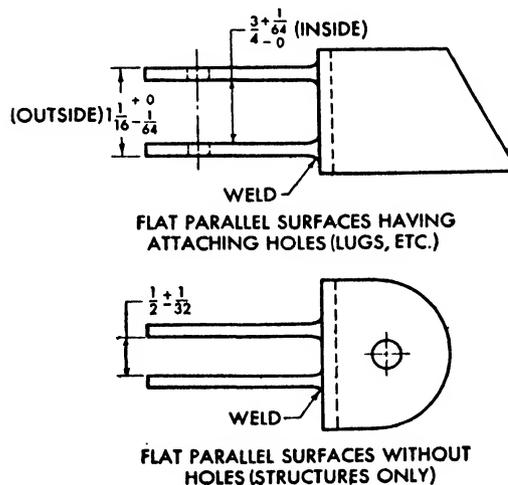


Fig. 441. Weld working tolerances

Fig. 442

SIZES OF TWIST DRILLS FROM 1/2 INCH TO NO. 80 WITH DECIMAL EQUIVALENTS

Size	Decimal Equivalents	Size	Decimal Equivalents	Size	Decimal Equivalents	Size	Decimal Equivalents
1/2	.5000	G	.2610	23	.1540	1/8	.0625
3/16	.4844	F	.2570	24	.1520	53	.0595
1/4	.4687	E 1/4	.2500	25	.1495	54	.0550
5/16	.4531	D	.2460	26	.1470	55	.0520
3/8	.4375	C	.2420	27	.1440	56	.0469
7/16	.4219	B	.2380	28	.1406	57	.0465
1/2	.4130	11 1/2	.2344	28	.1405	57	.0430
5/8	.4062	A	.2340	29	.1360	58	.0420
3/4	.4040	No. 1	.2280	30	.1285	59	.0410
7/8	.3970	2	.2210	31	.1250	60	.0400
1	.3906	3 1/2	.2187	31	.1200	61	.0390
1 1/16	.3860	3	.2130	32	.1160	62	.0380
1 1/8	.3770	4	.2090	33	.1130	63	.0370
1 1/4	.3750	5	.2055	34	.1110	64	.0360
1 3/8	.3680	6	.2040	35	.1100	65	.0350
1 1/2	.3594	7 1/2	.2031	36	.1094	66	.0330
1 5/8	.3580	7	.2010	36	.1065	67	.0320
1 3/4	.3480	8	.1990	37	.1040	68	.0313
1 7/8	.3437	9	.1960	38	.1015	68	.0310
2	.3390	10	.1935	39	.0995	69	.0292
2 1/16	.3320	11	.1910	40	.0980	70	.0280
2 1/8	.3281	12	.1890	41	.0960	71	.0260
2 1/4	.3230	13 1/2	.1875	42	.0937	72	.0250
2 3/8	.3160	13	.1850	43	.0935	73	.0240
2 1/2	.3125	14	.1820	44	.0890	74	.0225
2 5/8	.3020	15	.1800	45	.0860	75	.0210
2 3/4	.2969	16	.1770	46	.0820	76	.0200
2 7/8	.2950	17	.1730	47	.0810	77	.0180
3	.2900	18 1/2	.1719	48	.0785	78	.0160
3 1/16	.2812	18	.1695	49	.0781	79	.0156
3 1/8	.2810	19	.1660	50	.0760	80	.0145
3 1/4	.2770	20	.1610	51	.0730		.0135
3 3/8	.2720	21	.1590	52	.0700		
3 1/2	.2660	22	.1570		.0670		
3 5/8	.2656	23 1/2	.1562		.0635		

Fig. 443

DRILL AND REAM SIZES FOR BOLTS AND SCREWS

DRILL SIZES FOR BOLTS AND SCREWS		REAM SIZES <sup>1</sup>	DRILL SIZES FOR MICARTA	
Screw or Bolt Size	Drill Size		FOR	FOR
4	#32 (.116)		#31 (.120)	
6	#28 (.1405)		#25 (.1495)	
8	#18 (.1695)		#16 (.177)	
10	#10 (.1935)	.190 <sup>2</sup>	#7 (.201)	
1 1/16	1/16	.250	G. (.261)	
1 1/8	3/16	.3125		
1 1/4	1/4	.375		
1 3/8	5/16	.4375		
1 1/2	3/8	.500		
1 5/8	7/16	.5625		
1 3/4	1/2	.625		
1 7/8	9/16	.750		
2	5/8	.875		
2 1/16	3/4	1.000		

Fig. 444

DRILL SIZES FOR RIVETS

Rivet Dia.	Drill Size	Rivet Dia.	Drill Size
1/8	51 (.067)	3/8	10 (.1935)
3/16	41 (.096)	1/2	F (.257)
1/4	30 (.1285)	5/8	P (.323)
5/16	20 (.161)	3/4	W (.386)

Fig. 445

STANDARD SHEET METAL STOCK SIZES

(in inches)

1. 12 x 24	24 x 24	36 x 36
2. 12 x 36	24 x 36	36 x 48
3. 12 x 48	24 x 48	36 x 60
4. 12 x 60	24 x 60	36 x 72
5. 12 x 72	24 x 72	36 x 96
6. 12 x 96	24 x 96	36 x 120
7. 48 x 48	60 x 60	84 x 72
8. 48 x 60	60 x 60	84 x 96
9. 48 x 72	60 x 96	84 x 120
10. 48 x 96	60 x 120	84 x 144
11. 48 x 120	60 x 144	84 x 168

<sup>1</sup> For both hex. head and clevis head bolts. Tolerances are +.0005, -.001 for reamed holes.

<sup>2</sup> For a hex. head bolt. For clevis head bolt, use .1875 reamer size.

still maintain adequate rivet edge distance (Fig. 430). An approximate  $\frac{3}{16}$  inch flat distance on joggle members allows for locating adjustment.

Rivets A and B should not be tied. The shop will locate rivet B as close to the beginning of the joggle as practical.

The most popular rivet sizes are  $\frac{1}{8}$ ,  $\frac{5}{32}$ , and  $\frac{3}{16}$  inch diameters.

The group engineer should be consulted regarding the practical use of  $\frac{5}{16}$  or  $\frac{3}{8}$  inch diameter rivets.

Aluminum rivets of the A type should be used to rivet aluminum sheet. The regular AD & D aluminum alloy rivets have a tendency to crush the

Fig. 446

SPOT FACE DATA<sup>1</sup>

WASHER PLAIN			HEX. HEAD NUTS		SCREWS				
Diam. Hole	O.D.	Spot Face	Across Corner	Spot Face	Size	Round Head	Spot Face	Fill. Head	Spot Face
$\frac{3}{16}$	$\frac{7}{16}$	$\frac{3}{8}$	.361	$\frac{7}{16}$	#6	.250	$\frac{3}{8}$		
$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{8}$	.433	$\frac{1}{2}$	#8	.298	$\frac{3}{8}$	.260	$\frac{5}{16}$
$\frac{5}{16}$	$\frac{1}{8}$	$\frac{7}{16}$	.433	$\frac{1}{2}$	#10	.346	$\frac{7}{16}$	.302	$\frac{3}{4}$
$\frac{3}{8}$	$\frac{1}{2}$	$\frac{9}{16}$	.505	$\frac{9}{16}$	$\frac{1}{4}$	.458	$\frac{1}{2}$	.399	$\frac{7}{16}$
$\frac{7}{16}$	$\frac{1}{8}$	$\frac{5}{8}$	.578	$\frac{5}{8}$	$\frac{3}{8}$	.573	$\frac{5}{8}$	.504	$\frac{9}{16}$
$\frac{1}{2}$	$\frac{1}{8}$	$\frac{3}{4}$	.650	$\frac{3}{4}$	$\frac{1}{2}$	.688	$\frac{5}{8}$	.606	$\frac{11}{16}$
$\frac{5}{8}$	$\frac{1}{8}$	$\frac{7}{8}$	.718	$\frac{3}{4}$	$\frac{7}{8}$		$\frac{3}{4}$	.709	$\frac{3}{4}$
$\frac{3}{4}$	$\frac{1}{8}$	1	.866	$\frac{11}{8}$	$\frac{1}{2}$			.811	$\frac{7}{8}$
$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{1}{8}$	1.011	$1\frac{1}{8}$	$\frac{9}{16}$				
$\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	1.083	$1\frac{1}{4}$	$\frac{5}{8}$				

<sup>1</sup> Spot face sizes shown are the minimum; larger sizes may be used. Lock washers take the same spot face as do heads or nuts under which they are used.

**Riveting**

Riveting comprises one of the greatest assembly costs. Therefore only enough rivets that are structurally needed to carry the load should be specified.

Whenever possible, parts should be designed into subassemblies that may be fastened by the automatic or squeeze riveting machines rather than with the pneumatic gun. This facilitates a faster, more uniform, and less expensive assembly.

Proper edge distances should be maintained at all times as shown in Figs. 431 and 432.

Greater strength may be obtained in riveting thin sheet joints by counterpunching or dimpling the holes rather than by machine countersinking. Generally, whenever the depth of the rivet head is greater than the thickness of the outside sheet, the holes should be dimpled.

The following considerations regarding riveting should be carefully noted:

Use AD rivets whenever practical. These rivets are easier to handle and to drive than the D or DD types.

Do not use the D or DD types on thin sheets as they tend to buckle and stretch the sheet.

Avoid the use of  $\frac{1}{8}$  inch rivets as their small diameter size makes them difficult to handle.

aluminum sheet in the riveting process.

Blind riveting should be applied to nonstructural parts only and should not be used as an excuse for poor design of inaccessible parts.

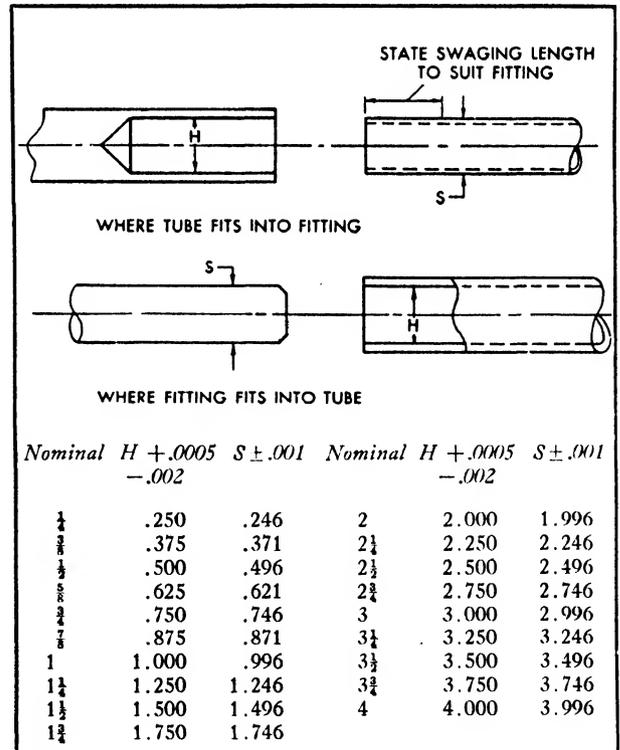


Fig. 447. Tube fittings

**Bolts**

Standard bolts, AN3-AN16, should be used almost entirely as they are especially made to close tolerances for aircraft use and are heat treated to a minimum of 125,000 pounds per square inch ultimate tensile strength.

Bolt and screw lengths should be determined on the basis of a grip at least  $\frac{1}{16}$  inch larger than the computed grip. If the total thickness of the metal does not equal this grip, washers will be used.

The following considerations pertaining to bolts and pins should be carefully noted:

Bolts under  $\frac{3}{8}$  inch diameters on land planes should be of the steel type. Generally, steel bolts under  $\frac{3}{16}$  inch diameters or aluminum alloy bolts under  $\frac{1}{4}$  inch diameters should not be used on primary structures.

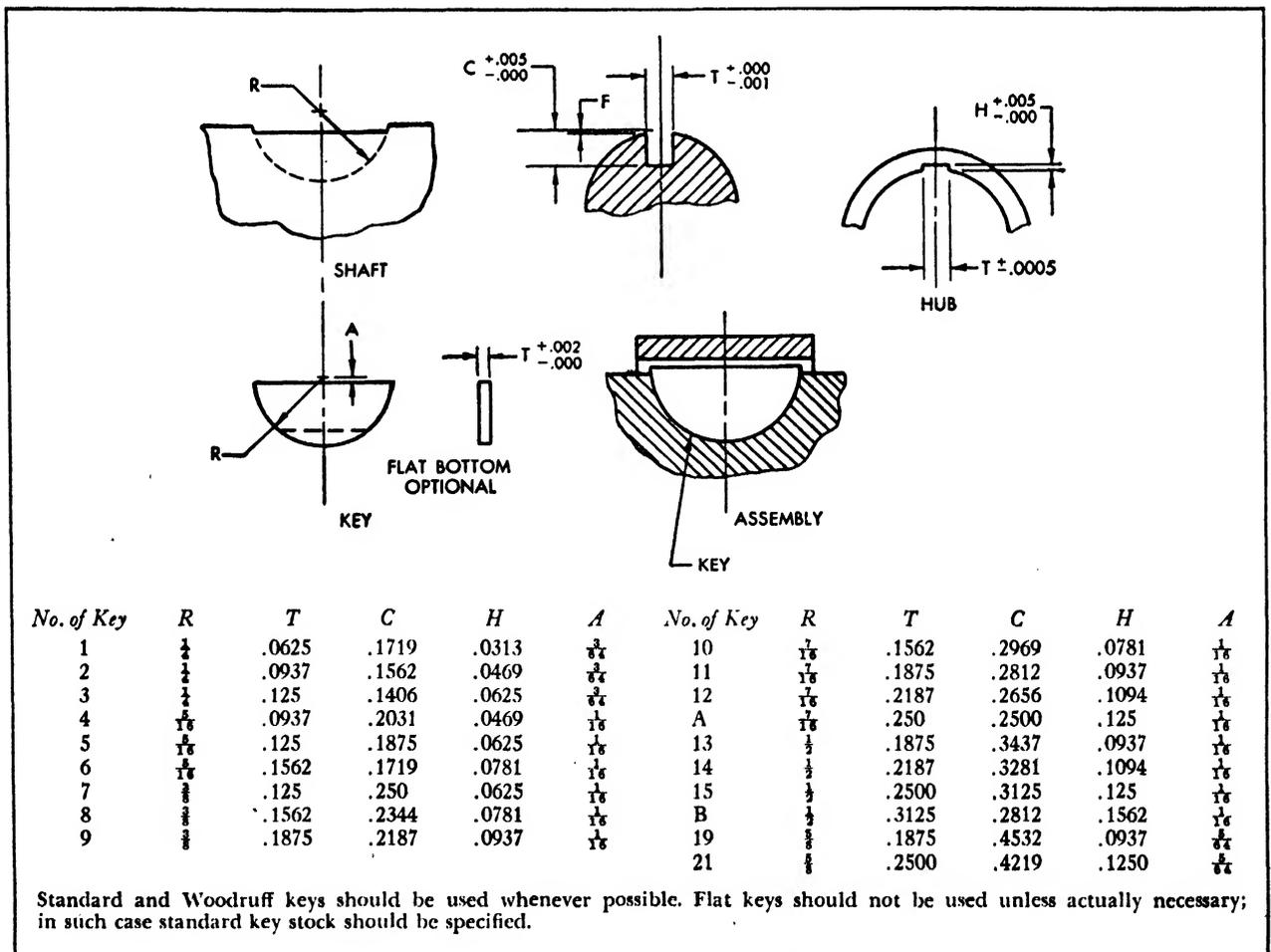
The more popular size of the smaller bolts is AN 4 =  $\frac{1}{4}$  diameter.

**Fig. 448**

**TOLERANCES FOR SLIP AND PRESS FITS**

Nominal Dia., inches	Limits	Tolerances for Standard Holes	Slip Fit	Press Fit
Up to $\frac{1}{4}$	High	+ .0005	-.0010	+ .0010
	Low	- .0005	-.0020	+ .0005
$\frac{1}{4}$ -1	High	+ .0010	-.0015	+ .0020
	Low	- .0005	-.0030	+ .0015
1-2	High	+ .0010	-.0020	+ .0040
	Low	- .0005	-.0040	+ .0030
2-3	High	+ .0015	-.0025	+ .0060
	Low	- .0010	-.0045	+ .0045
3-4	High	+ .0015	-.0030	+ .0080
	Low	- .0010	-.0050	+ .0060

When possible, tolerances should be designated in the direction of practical functional error. For example, a shaft should be given the maximum allowable dimension with the minimum size as tolerance, and a hole should be given the minimum allowable dimension with the maximum size as tolerance.



**Fig. 449. Key design**

The threaded part of a bolt should never be subjected to shear loads.

Major fittings, such as superstructure and landing gear, usually employ at least a  $\frac{3}{8}$  inch diameter bolt.

It should be specified when elastic stop nuts are to be used with type A (nondrilled) bolts.

Bolts should be shown on the drawing in the manner they will be installed. The bolthead should be above the nut.

Removable bolts should employ a castellated nut and a cotter pin.

Clevis bolts and shear nuts are used only where there is no tensile load.

Clevis pins are to be used in tie rods and locked with cotter pins.

Taper pins are to be used in permanent connections permitting no leeway.

*Screws and Threads*

Generally a coarse thread is specified for No. 8 screws and under and a fine thread for No. 10

CHECKING GUIDE FOR DRAWINGS	Dwg. No. _____
1. EASE OF READING. Is drawing understandable without too much study? _____	
2. VIEWS—SECTIONS	
A. Are all necessary views and sections shown? _____	
3. DIMENSIONS	
A. Are tolerances too fine or too coarse? _____	
B. Do dimensions of mating parts provide correct fit? _____	
4. PART NUMBERING	
A. Do parts called on face agree with B/M? _____	
B. Are L.H. and R.H. parts correctly called out? _____	
C. Are dash numbers assigned where necessary? _____	
D. Should details shown as dash numbers, be drawn as separate detail drawings? _____	
E. Are subassembly numbers assigned where necessary? _____	
F. Are company numbers for catalogue parts called out? _____	
G. Are castings and forgings correctly numbered? _____	
H. Are predrilled parts correctly numbered? _____	
5. STANDARD PARTS	
A. Are correct type and length of bolts and screws specified? _____	
B. Do threads match on mating screws, bolts, and nuts? _____	
C. Are self-locking nuts used wherever possible? _____	
D. Are dissimilar metals on matings bolts (or screws) and nuts called for? _____	
E. Are insulating washers specified where necessary? _____	
F. Are Dural bolts under $\frac{3}{8}$ in. dia. specified? _____	
G. Are countersunk rivets unnecessarily used? _____	
H. Have drawn sections and extruded parts been used wherever practical? _____	
6. BILL OF MATERIAL	
A. Is B/M properly arranged? _____	
B. Is stock size correct? _____	
C. Is material correctly specified and available? _____	
D. Are quantities in agreement with face of drawing? _____	
E. Is finish correctly designated? _____	
F. Is proper heat treat specified? _____	
G. Is scale of drawing noted correctly? _____	
H. Has the weight been correctly calculated? _____	
I. Are next assembly and model requirements correct? _____	
7. RIVETING	
A. Is sufficient edge distance allowed? _____	
B. Is spacing sufficient? _____	
C. Are rivets omitted where necessary to avoid interference on later assemblies? _____	
8. GENERAL	
A. Have standard tools been utilized for holes, slots, etc.? _____	

Fig. 450

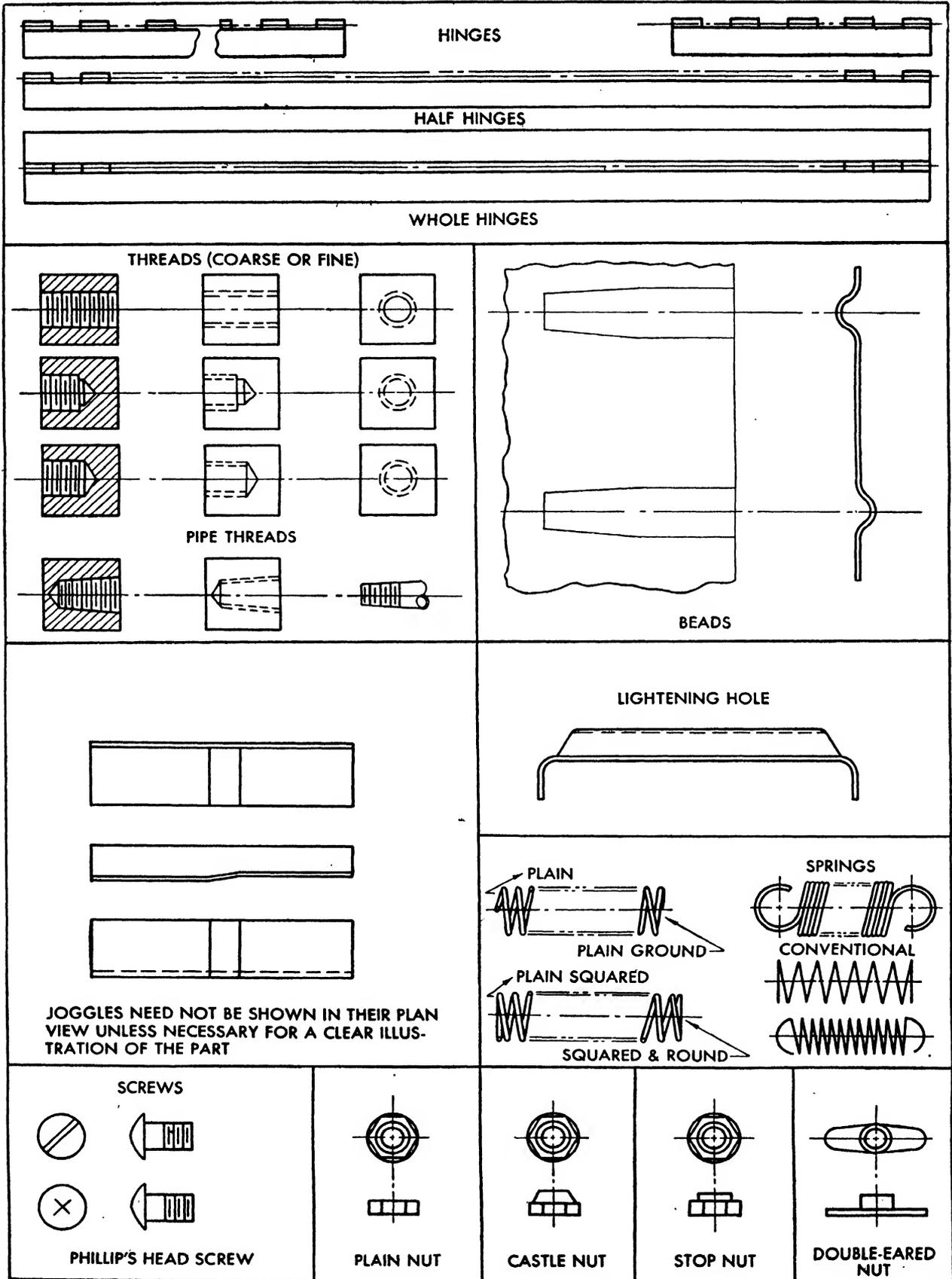


Fig. 451. Conventional representations

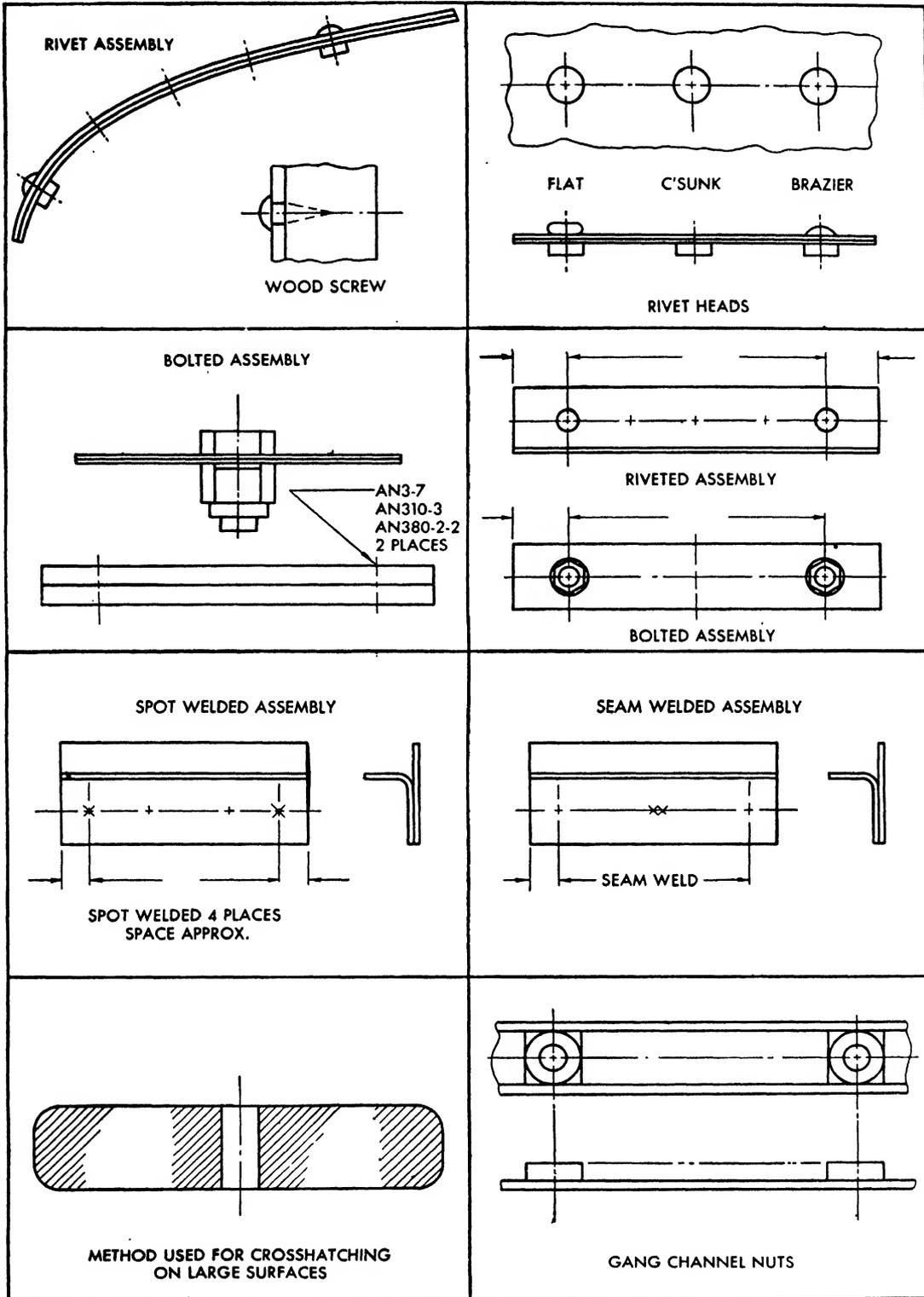


Fig. 452. Conventional representations

screws and over. (See also Chap. 16.)

Threads for parts on which standard aircraft bolts and nuts are to be used also call for a coarse thread on No. 8 and under, and a fine thread on No. 10 and over. An exception to this is in the tapping of aluminum or aluminum alloy castings, where only the coarse thread series is specified.

### *Studs*

Studs are usually made from round bar stock. One end is threaded to enter a tapped hole; the other projecting end may be threaded if it is to be applied to a tapped connection or it may be smooth if it is to be used as a dowel.

Studs are used when design or assembly conditions do not allow the use of bolts. Sometimes the location of a tapped hole would necessitate "blind" feeling for the entrance of the bolt. High operation temperatures often render impractical the use of bolts by seriously altering the size and shape of the threads. Studs remedy this condition. They are sometimes rusted into place before assembly by the application of corroding solutions. Stud threads may also be expanded by thermal treatments that lock and rust the threads permanently in place. The most common application of setting studs is to call for white lead covering of the threads. This prevents galling and substantially increases the tightness of the threads when set.

Studs are not kept in stock and require designing as a special detail; consequently, their use should be minimized. Figure 433 lists the necessary data for stud design.

Studs to be set in aluminum alloy should be of the coarse thread series (Table 1). For setting

in steel or bronze, the fine thread series is used (Table 2).

### *Welding*

Welding, like riveting, calls for accessibility. Figure 434 describes the proper location of welds, and Figs. 435 and 436 illustrate poor and preferred welding designs.

The following examples are illustrated:

The welding of the channel box in Fig. 436a requires four rows of spot welds, accomplished with a copper mandrel, inside the member to facilitate the electrical welding process. By flanging the channels into hats (Fig. 436b), only two rows of spots do the job, reducing the number of parts and the time to a minimum.

Figure 437 illustrates the welding of tubular members in the butt and fillet methods.

It is not practical to weld a large, flat, thin member to a heavier one in the manner illustrated in Fig. 438a. The localized heated area around the weld expands and warps the piece. Figure 438b illustrates a better design. The bottom plate is lessened in area so that the heat of welding covers the entire plate, resulting in very little warpage.

Tubular sections to be welded to flat stock should go directly through the sheet, permitting a more substantial weld (Fig. 439).

When flat sheet stock up to 0.083 inch is to be welded to a hub, the stock should be flanged as shown in Fig. 440. The hub cannot expand or contract as rapidly as the sheet, therefore the sheet will distort excessively without the flange provision.

Welding working tolerances are illustrated in Fig. 441.

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