STRUCTURAL DRAFTING

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BY

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PREFACE

This book has been prepared especially to meet the requirements of engineering students and structural draftsmen. It corresponds in scope to the duties of the structural-steel draftsmen in the preparation of the detailed working drawings for the members of steel structures and the corresponding bills which emanate from the drafting room. The drawings for concrete and timber structures are discussed briefly to aid the structural draftsman in this parallel work, but no attempt has been made to treat them exhaustively for the use of specialists in these fields.

Much of the material for this book first appeared in 1920 in a book entitled " Structural Drafting and the Design of Details " (later changed to " Structural Drafting and Design "). In 1938, the design portion was revised, amplified, and issued under the title " Structural Design," in the belief that the "Drafting" and the "Design" should be made available in separate volumes. The drafting portion as now presented is entirely rewritten, but it does not duplicate the methods of determining the numbers of rivets, or the lengths of welds, which are contained in the book on design. It is expected that many users will need both parts as heretofore, and frequent references are given to the design book.

Few tables are included in either volume because the "Steel Construction" handbook, described on page 2, is available; this gives the properties of the modern structural shapes and many other tables essential to students and practitioners in this field. It is assumed that such a handbook will be used as an adjunct to this book.

All the illustrative drawings have been prepared by the author, but many of them have been adapted from similar or nearly identical drawings kindly furnished by different companies. The drawings and the standards of the American Bridge Company and the Bethlehem Steel Company have been of exceptional value, and the drawings of the Berlin Construction Company, the Stone and Webster Engineering Corporation, the United Engineers and Constructors, Inc., and the Timber Engineering Company have been used to advantage.

Grateful acknowledgment is made to Mr. J. Harry Elder, Room Engineer for the American Bridge Company at Ambridge, Pennsylvania, for reading the manuscript and for his helpful criticisms and suggestions.

CARLTON T. BISHOP.

NEW HAVEN, CONNECTICUT
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INTRODUCTION

1. Scope. This book is planned to meet the requirements of engineering students, apprentices, and structural draftsmen. In scope it is designed primarily to correspond to the duties of structural draftsmen. The first few chapters give a background to show the relation of the drafting department to other departments of a structural company and allied fields. The principal chapters give the fundamentals of structural drafting, particularly of those features which are characteristically different from earlier courses in engineering drawing, a knowledge of which is presupposed. The application of these fundamentals to the drawings of some of the more common types of members is illustrated in later chapters, followed by chapters which refer to other duties of the draftsman. Those duties which are associated with design, however, are no longer included in this book but are printed separately in the author's companion volume " Structural Design "; the reader is referred to that book for determining the number of rivets, the lengths of welds, and the sizes of pins, reinforcing plates, splice plates, and stiffeners, and for other details.

2. Arrangement. This book is arranged for convenient reference rather than for a progressive course of study. This will appeal to the draftsman and usually to the student as well. Different instructors will doubtless adopt different sequences and emphases, and it is not expected that the student will devote much time to the study of the text before he begins to draw. The first drawing, if sufficiently simple, may be started at the first exercise, accompanied by references to the most important paragraphs which are relevant. This may be followed by other drawings each of which illustrates as many new points as the average student can master. The work should be progressive, but no drawing should involve points beyond the student's ability, and he should be expected to make each drawing fundamentally correct so that it would pass muster in the shop. It may be difficult to obtain excellent results at the outset owing to the multiplicity of conventions and practical points which are new to most students. At first it may be expedient to introduce some of the fundamentals by having the students make freehand drawings at their desks or at the blackboard instead of taking time for careful plotting. When drawings are made to scale, however, reasonable requirements should be laid down and enforced, and all mistakes should be corrected by the student as a safeguard against repetition; to allow violations of drafting methods and conventions to stand uncorrected is a source of trouble. Emphasis should be placed upon the portrayal, the dimensions, and the notes, rather than upon accurate scaling and technique, although a good-looking drawing inspires confidence in its usefulness and technique should not be overlooked. Above all, a drawing must be clearly legible, for it is not so easy to read a blueprint in the dimmer shop light as it is an original drawing in the drafting room. Shopmen are not allowed to scale drawings in order to determine missing values, but they must use only the given dimensions. Blueprints of typical drawings of actual members may be studied by beginners to advantage, and they may be used in writing shop bills for practice in the interpretation of notes. Though data for early drawings must be presented in detail, the statements of subsequent problems should be reduced to a minimum in order to develop the student's resourcefulness, even though as a consequence the drawings of no two students are alike. Time may be gained on tests by devoting one question to the indication of mistakes on a given drawing, i.e., practice in checking.

3. Handbooks. The " Steel Construction " handbook issued by the American Institute of Steel Construction,* is considered a necessary adjunct to this book. It gives not only the dimensions of the different commercial steel shapes, but also typical connections and other data and tables which are invaluable to draftsmen, designers, and students in engineering. The " Pocket Companion " of the Carnegie-Illinois Steel Corporation, and the " Bethlehem Manual " of the Bethlehem Steel Company have been discontinued.

4. Cross References. The figures in this book are numbered to correspond to the pages upon which they are placed, so that they may be found more readily. Page references are used instead of article numbers for the same reason. A distinction is made between two classes of references. In order to save needless repetition, a reference may be made to another page; when a reference is important to supplement the text, it is printed as part of a sentence or as a separate sentence, viz.: " See page 25 "; in general, these should be consulted. Other, less important references are given in parentheses for the convenience of those who do not grasp the full significance of a sentence or who desire additional information. When a page number seems insufficient, the paragraph number is given also, separated by a colon, thus: " page 14 : 23." References to " Structural Design " refer to the author's companion volume, published by John Wiley & Sons.

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* Copies may be obtained from the Institute, 101 Park Avenue, New York City.

CHAPTER I

THE ENGINEERING DEPARTMENT OF A STRUCTURAL COMPANY

5. **The structural draftsman** is not concerned directly with the manufacture of steel or even with the rolling of the commercial steel " shapes." His drawings show how these shapes are cut, punched, and assembled to form members which in turn go to make steel structures. But every draftsman should understand the processes which are allied to the work of his company, particularly the limitations of the different materials and alloys as regards punching, bending, or welding. The student has no time for a careful study of the different operations, but he should have a general idea of how steel is made and used. For his convenience an abstract is presented in this chapter and in the two subsequent chapters. Later he may acquire further knowledge from books or from inspection trips to rolling mills, to structural shops, and to erection sites.

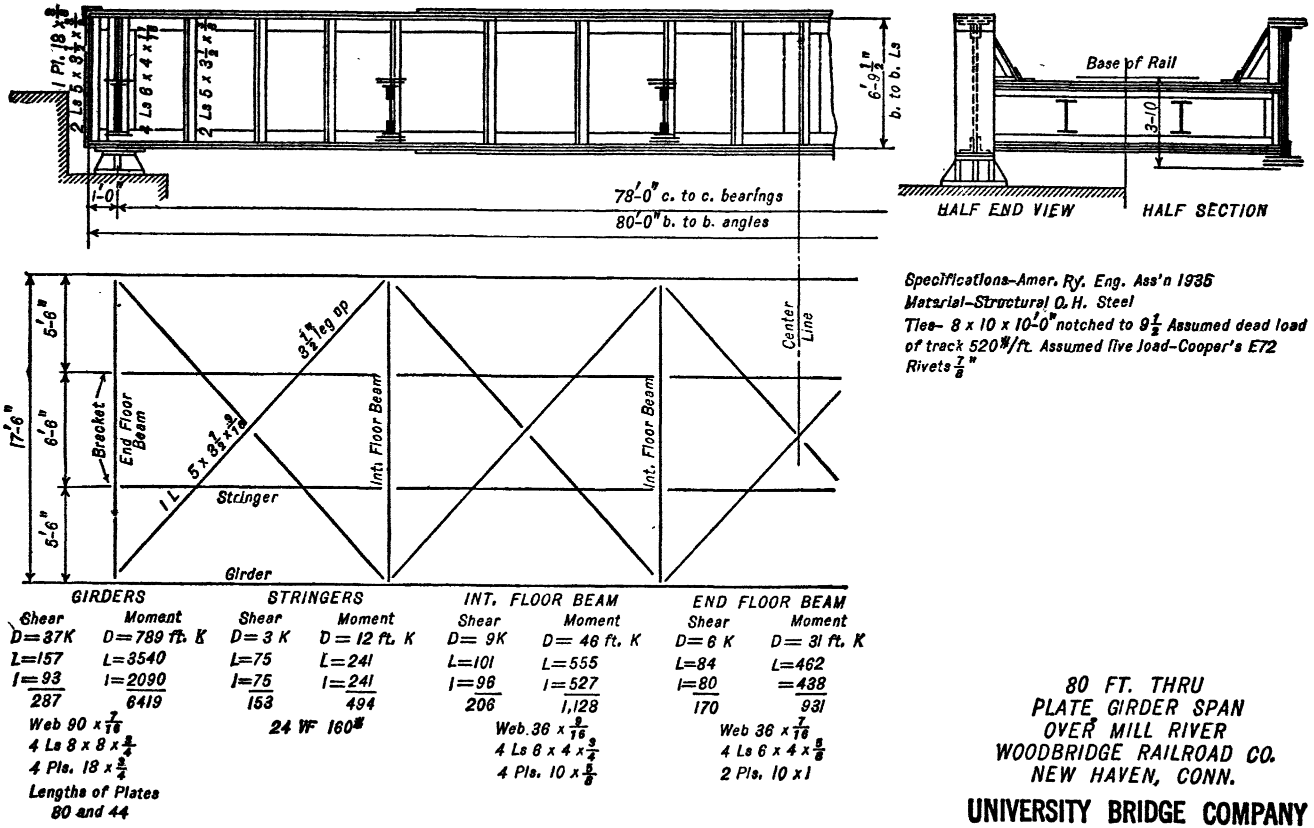
6. **The engineering department** includes the designing or estimating department and the drafting or detailing department, whether or not they are located in the same building. The drafting department is usually near the structural shop, but the designing department is often in a large city. Both departments are in charge of a chief engineer and often one or more assistant chief engineers.

7. In the **designing or estimating department** are made the preliminary design and estimate of cost of a proposed structure. These may be based upon the customer's layout or upon an original design submitted to the customer for approval. Oftentimes the customer has little conception of the type of structure best suited to his needs, and different structural companies prepare alternative designs in competition, from which the customer makes selection. The organization of the designing department differs in different companies, and the procedure depends upon the organization and upon the nature and the magnitude of the proposed structures. Some companies have contracting departments which act as intermediaries between the designing departments and the customers. Some designs are made by the customer's engineers or by consulting engineers, and the structural companies simply estimate the costs and submit bids. Some structures are so simple or so similar to other structures that the designers

or contracting engineers in charge of branch offices can make quite accurate estimates without complete designs.

8. **A design** is made according to specifications approved by the customer. An estimator must have an intimate knowledge of drafting-room methods, shop methods, erection methods, and the approximate costs of each. He must know from experience how much to allow for details of construction, such as connection plates or angles. Design sheets or stress sheets are made in the designing department to illustrate the proposed structure. These sheets are made primarily for the customer, but after a contract is awarded, the design sheets are adapted to the needs of the drafting department. The design sheets should contain all the information necessary to enable the draftsman to make the detailed working drawings. They usually show the main form and the dimensions of a structure, the principal stresses, the sizes of all main members, and special instructions regarding the details. They may be supplemented by "information sheets" which give the principal terms of the contracts, such as the kind of steel, the time of delivery, and whether the cost is quoted at a "lump sum" or at a price per pound. A simple design sheet is shown in Fig. 5.

9. **The drafting department** is in charge of a chief draftsman, or, if subdivided into different classes of work, each room may be in charge of an engineer. The subordinate draftsmen are usually divided into squads, each in charge of a "squad foreman" or "squad boss." Usually all the drawings for each contract are made by one squad, drawings for other contracts often being carried on simultaneously. The size of each squad varies with the amount of work being done under the direction of a single squad foreman from 3 or 4 to 16 or 20, the normal number being from 6 to 8. In each squad are checkers, detailers, and sometimes billers, computers, and tracers; oftentimes an individual serves in more than one capacity. The detailers make the working drawings and design the details. The drawings show how the standard shapes are cut and combined to form the different members. The number and the spacing of the rivets and holes are given so that the members may be properly constructed and so that they may be properly connected to other members. As far as practical the parts are combined in the shop in order to reduce the number of members to be shipped and to be erected at the site. The detailers are often called upon to make or to check shop and shipping bills and other lists of material. Much of the billing and the calculating of weights are done by younger men or women of limited experience, often working in a separate squad or department. The checkers "check" or verify the drawings and indicate the mistakes. They are often called upon to make drawings as well. They are men of greater experience than the detailers,



Specifications–Amer. Ry. Eng. Ass'n 1935
Material–Structural O. H. Steel
Ties– 8 x 10 x 10'-0" notched to $9\frac{1}{2}$ Assumed dead load of track 520#/ft. Assumed live load–Cooper's E72
Rivets $\frac{7}{8}$"

GIRDERS		STRINGERS		INT. FLOOR BEAM		END FLOOR BEAM	
Shear	Moment	Shear	Moment	Shear	Moment	Shear	Moment
D=37K	D=789 ft. K	D=3 K	D=12 ft. K	D= 9K	D= 46 ft. K	D=6 K	D= 31 ft. K
L=157	L=3540	L=75	L=241	L=101	L=555	L=84	L=462
I=93	I=2090	I=75	I=241	I=96	I=527	I=80	=438
287	6419	153	494	206	1,128	170	931
Web 90 x $\frac{7}{16}$ 4 Ls 8 x 8 x $\frac{3}{4}$ 4 Pls. 18 x $\frac{3}{4}$ Lengths of Plates 80 and 44		24 WF 160#		Web. 36 x $\frac{9}{16}$ 4 Ls 6 x 4 x $\frac{3}{4}$ 4 Pls. 10 x $\frac{5}{8}$		Web 36 x $\frac{7}{16}$ 4 Ls 6 x 4 x $\frac{5}{8}$ 2 Pls. 10 x 1	

80 FT. THRU
PLATE GIRDER SPAN
OVER MILL RIVER
WOODBRIDGE RAILROAD CO.
NEW HAVEN, CONN.

UNIVERSITY BRIDGE COMPANY

Fig. 5. Typical Design Sheet.

and they assist the squad foremen in laying out new work preparatory to ordering the material. As far as possible, the material must be ordered before the drawings are made so that the mills can roll the steel while the drawings and the templets are being prepared. The term " draftsman " has a double meaning; some limit its use to detailers because they do the actual drafting, whereas others apply the term to everyone in the drafting department, particularly those who have reached the rank of detailer.

10. Method of Procedure. When a new contract is received in the drafting department the chief draftsman studies the general nature of the structure, notes the time limit if any, and assigns the work to the squad foreman who can best handle it. The squad foreman makes a careful study of the whole contract and adopts the method of procedure by which the work under his direction can be carried out most efficiently. In general his first aim is to have all main material ordered as soon as possible because of the usual delay at the mills. In some types of structure either he or his more experienced men can list most of the material directly from the design sheets. In certain classes of work such as truss work it may become necessary to make small layouts of connections, or even to begin the working drawings in order to determine the lengths of the material; later these preliminary drawings may be given to detailers for completion. In other types of structure such as office buildings it may prove feasible to make the plans and diagrams before listing the material. These diagrams may be made so complete that the material may be listed from them quickly and accurately, and the detailed drawings may become routine work which can be done by men of limited experience. The preliminary lists of material are usually sent to an order department where the material is summarized and the short pieces are grouped in multiple lengths to be cut after they arrive from the mill. The squad foreman divides the drafting among the detailers to the best advantage so that the work may be carried on efficiently and in logical order. Part of the drawings may be sent to the shop before all are completed, and as far as practical an attempt should be made to complete the drawings in approximately the same order that the corresponding members will be erected. For example, the drawings of the lower columns and beams in an office building should be made before the drawings for the upper stories. Erection diagrams should be made as soon as possible so that the marks of all members may be recorded as soon as determined. Drawings should be checked shortly after they are made, and the shop bill for each drawing should be made as soon as the drawing is completely checked. A shop bill is a summary of all the material required to make all the members represented by a drawing. Later, shipping bills and lists of rivets and bolts to be used in erection are prepared.

11. The squad foreman should keep **progress sheets** so that he and the chief draftsman can tell what has been done, what is being done, and when and where the blueprints have been issued. He should keep separate files for the drawings and for the correspondence of each different contract. Usually all communications pass through the hands of the chief draftsman who writes all letters and serves as intermediary between the men in the drafting room and those outside.

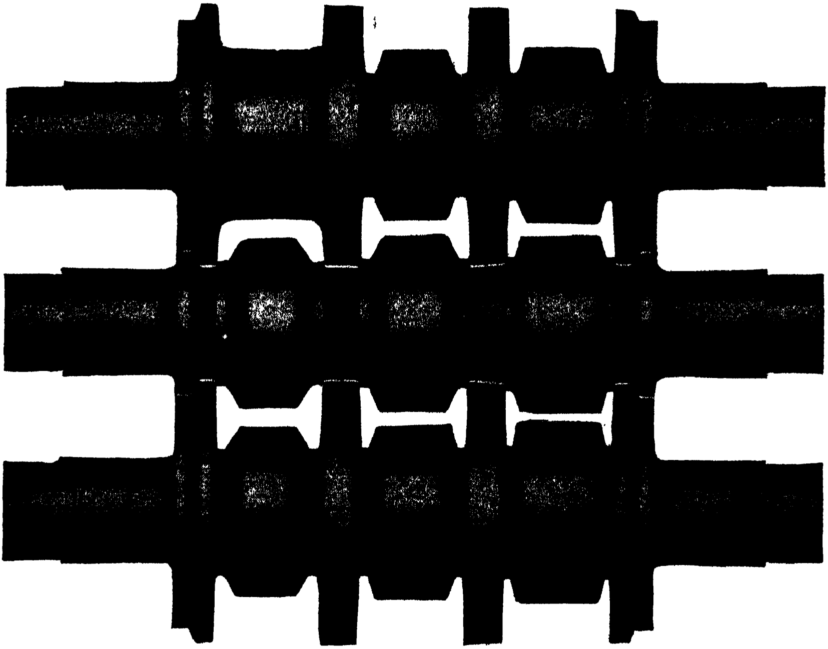
CHAPTER II

THE MANUFACTURE OF STRUCTURAL STEEL

12. Iron. Most of the iron ore is taken from open-pit mines in the Lake Superior region and shipped by boat and by rail to blast furnaces where it is smelted or reduced. The ores are oxides of iron, and the reducing agent is carbon. A blast furnace is in continuous operation. It is charged at the top and the molten iron flows by gravity to the bottom, where it accumulates until tapped at intervals of about 6 hours. Besides the ore the charge includes a flux, and the reducing agent in the form of coke which serves also as fuel. An intense heat is maintained by means of a continuous hot-air blast. The blast is heated by being passed through a " stove " lined with fire brick. Four stoves are used in turn, the ones not in use being heated by burning gases from the furnace. Limestone is the flux commonly used to unite with the impurities freed from the ore to form a fused mass called " slag." This floats on top of the iron and is tapped at a higher elevation. The iron tapped from a blast furnace is called " pig iron " because it is often cast into " pigs " of about 100 pounds for convenient handling. Pig iron is used in iron foundries for making iron castings, but most of the pig iron is made into wrought iron or steel. When the steel furnaces are near the blast furnace the iron may be transferred in the molten state in large ladles. Pig iron contains small quantities of carbon (3 to 4 per cent), silicon, sulphur, phosphorus, and manganese. It has so much carbon that it is not malleable at any temperature. The capacity of a blast furnace is from 500 to 1000 tons of iron per 24 hours.

13. Structural steel is made by the " open-hearth " process. A higher grade of steel for tools and instruments is made in crucibles or in electric furnaces. At first structural steel was made by the Bessemer process in a converter of 10 to 20 tons capacity. A cold-air blast was used for about 10 minutes, after which the steel was ready to be poured. Bessemer steel is inferior in quality and is less reliable than open-hearth steel, and the Bessemer process has been largely superseded by the open-hearth process. In the latter the charge is placed on a shallow hearth and subjected to a hot-air blast. The charge includes besides the pig iron, iron ore, steel scrap, and usually limestone. Gas is used for fuel, and when the charge is melted the flux rises to the top. This flux contains the iron ore which forms a blanket to prevent the oxygen of the air from combining with the iron. The impurities in the iron become oxidized by the iron ore, which in turn receives new oxygen from the air. The percentage of carbon and phosphorus is thus reduced. The steel is tapped into large ladles where it is " recarbonized " by adding the proper amount of carbon and other ingredients to give the desired quality. Structural steel contains from 0.15 to 0.3 per cent of carbon. The capacity of an open-hearth furnace is from 50 to 200 tons, and the operation requires from 6 to 10 hours.

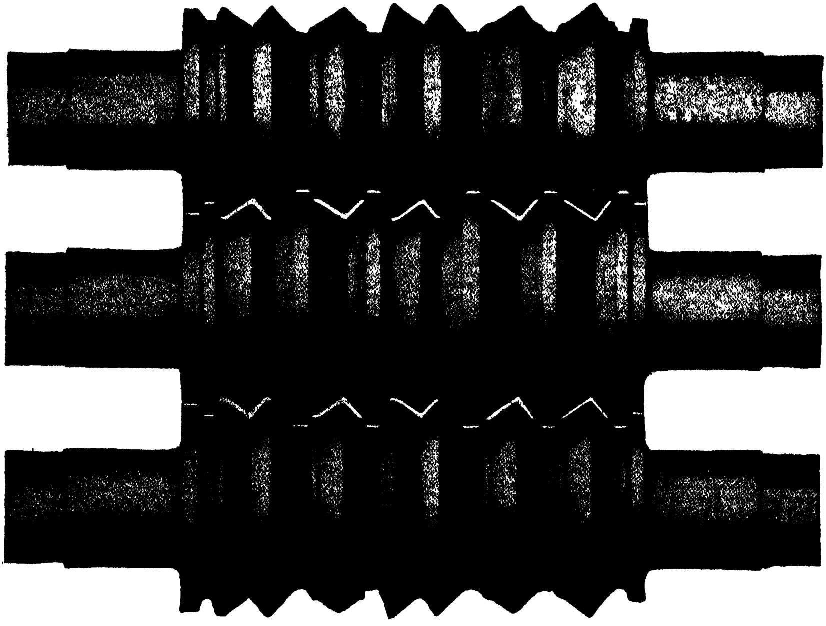
14. Rolling the Steel. From the ladles the steel is poured into ingot molds and allowed to cool until sufficient crust is formed to permit handling. The molds are then stripped off and the ingots are placed in ovens called " soaking pits " until the inside portion solidifies and the whole becomes of the proper uniform temperature for rolling. Structural shapes are formed by passing the material between rolls of the proper shape, the cross section being reduced and the piece elongated at each pass. The ingot is first passed between the two cylindrical rolls of a " blooming mill " and flattened. The rolls are then reversed and placed closer together, and the material is passed between them in the opposite direction. In this manner slabs are made of suitable size to be placed in another mill to be



(Courtesy of Pittsburgh Rolls.)

Fig. 9. Typical Roughing Rolls for an I-beam.

rolled into plates. For other shapes, the ingot is rotated at right angles between successive passes to form a " bloom " of the size best adapted to the shape of the " roughing rolls." The blooms are cut into lengths which will result in the proper lengths of the final sections. The roughing rolls are grooved to work the blooms down gradually to shapes which approximate the finished pieces, then " finishing rolls " are used. Both the roughing and finishing rolls are so shaped that at each pass the material is reduced in cross section to approach the finished shape. These rolls are " three high " so that they need not be reversed, the material passing alternately between the lower two in one direction and the upper two in the opposite direction. Typical roughing rolls for an I-beam are illustrated in Fig. 9, and finishing rolls for an angle in Fig. 10. The material is handled on roller platforms on both sides of the rolls. These platforms may be raised or lowered to receive the steel at one elevation and deliver it at another. The material may be moved longitudinally by means of the rollers, and transversely by means of arms between the rolls. The whole operation is controlled electrically. Wide-flanged beams are rolled in mills with vertical rolls close to the horizontal rolls. In the preliminary passes the flanges are flared from the web in order to reduce the roll friction, but in the final passes the flanges are flattened into the final shape.



(Courtesy of Pittsburgh Rolls.)

Fig. 10. Typical Finishing Rolls for an Angle.

15. The Effect of Spreading the Rolls. The finishing rolls are kept at a fixed distance apart during the rolling. When they are spaced at the minimum distance the lightest section of a group is made. When the rolls are spaced farther apart heavier sections are made as indicated in Fig. 11. Sometimes two different sets of grooves are made in the same rolls for the final pass so that either of two sections can be made without changing the spacing. The effect of spreading the rolls is to increase the web thickness and the flange width of an I-beam or channel without changing the depth; the variations are indicated in the tables. Spreading both the vertical and horizontal rolls increases the depth as well as the flange width and web thickness of a wide-flanged beam, as indicated in the tables. Angles of different thicknesses may be rolled in the same mill, but from the figure it is apparent that as the rolls are separated the lengths of the legs as well as the thickness will be increased; the effect, of this is more pronounced in some mills than in others. The tables indicate only the nominal lengths of legs. Since the nominal size is that only of the thinnest section of a group, the draftsman should take care to allow ample clearances for the overrun of the thicker angles. The increase in the length of the leg may be as great as the increase in thickness. On account of this variation and also because of the wearing of the rolls and of the inaccuracies in setting them, the lengths of angle legs and the widths of beams and channels are indefinite; dimensions should be referred to the backs of angles and channels and to the center lines of symmetrical beams rather than to the rolled edges.

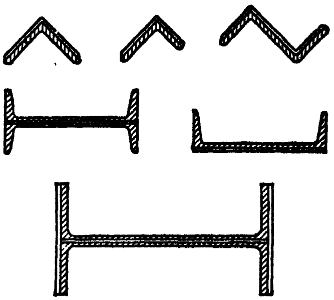


Fig. 11. The Method of Enlarging Cross Sections by Spreading the Rolls.

16. Mill Variation. Structural shapes other than plates are sawed to the ordered lengths as soon as they leave the finishing rolls, while still red hot. They must be measured and sawed into the proper number of pieces before the following pieces leave the rolls, so extreme accuracy cannot be assured. The usual tolerances, or " mill variations," are as follows:

Wide-flanged beams 8" to 24", minus ⅜", plus ⅜" up to 30' in length, and plus ⅜" + 1/16" for each 5' over 30'.
Wide-flanged beams over 24", minus ½", plus ½" up to 30' in length, and plus ½" + 1/16" for each 5' over 30'.
Standard I-beams and channels, minus ⅜", plus ⅜" up to 30' in length, plus ⅝" over 30 and up to 40', plus ⅞" over 40 and up to 50', and plus 1" over 50'.
Angles, no underrun, but plus ¾" up to 30' in length, plus 1" over 30' and up to 40', and plus 1¼" over 40'.

Drawings for beams and channels should be so made that they can be used as delivered without being recut in the shop. Maximum lengths rolled are sufficient for ordinary needs, but extreme cases should be taken up with the mills. In view of the above tolerances, material should be ordered from the mills in multiples of $\frac{1}{4}''$ or preferably $\frac{1}{2}''$. The usual tolerances in cross section, both in dimensions and in distortions, are given in the handbook.

17. Plates may be rolled in a mill with horizontal rolls only, or in a Universal Mill which has vertical rolls as well. The horizontal rolls are brought closer together between successive passes of the plate until the desired thickness is reached. Universal Mill plates (U.M. plates) or " edged plates " having rolled edges are used for cover plates of girders and columns, for built-up members of bridge trusses, and sometimes for web plates of girders, or wherever the appearance or the specifications requires a finished edge; as a matter of fact, they are used for all plates up to 24'' in width and often up to 36'' in width. Other plates are sheared or flame-cut to width at the mills. Plates are usually ordered in multiples of 1'' in width but may be obtained in multiples of $\frac{1}{2}''$; they vary in thickness in multiples of $\frac{1}{16}''$. Universal Mill plates are available in widths from 6'' to 60'', in thicknesses from $\frac{1}{4}''$ to 2'', and in lengths from 25' to 125', depending upon the widths. Sheared plates are available in widths from 24'' to 150'', in thicknesses from $\frac{1}{8}''$ to 2'', and in lengths from 12' to 70', depending upon the widths. Thicker plates called " bearing plates " or " slabs " are available up to 56'' × 8'', the standard sizes being given in the handbook.

18. Actual Shapes. The flanges of wide-flanged beams have sharp corners, but they are joined to the webs by curved fillets to facilitate rolling and to reinforce the webs at critical points. The flanges are of uniform thickness except that the inner surfaces of some of those rolled by the Bethlehem Steel Company have slopes of 5% or about $\frac{5}{8}$ in 12. The inner surfaces of the flanges of standard I-beams and channels have slopes of 2 in 12 and have curves joining them to the webs and also to the edges of the flanges. Angles are of uniform thickness, but the inner surfaces are joined together and to the edges by curves. The radii of all these curves are given in the handbook. Normally the curves are not shown in structural drafting, but they must be considered by the draftsman in order to make proper allowance for clearance.

CHAPTER III

THE FABRICATION OF STRUCTURAL STEEL

19. Fabrication. In order to make shop drawings intelligently, it is necessary that a person have a very definite conception of the use to be made of them. For those who have had no opportunity to gain this knowledge, this chapter provides an abstract of the more important steps taken in preparing or " fabricating " the steel for erection. The term " fabrication " is interpreted to include all the shop work necessary to lay out, cut, punch, assemble, and rivet or weld into complete members the steel shapes as they come from the rolling mills. In general, the steel shapes are handled cold during fabrication in contrast to hot at the steel mills. A member may be a single piece as a beam or an angle, or it may be composed of many pieces as a girder or a truss. Shop work is preferred to field work within practical limits, because of better facilities and also because the assembly of pieces in the shop results in the reduction of the number of separate members to be handled during shipment and erection at the site.

20. Only the more **elementary points** can be mentioned here,* but students or others who seek employment as draftsmen must make a careful study of shop methods. Much can be accomplished by the more observing men by making frequent trips to the shop outside of office hours, cultivating the habit or learning something new on each trip, even during short visits in the lunch hour; but many men wander blindly through the shop day after day without tangible results, and for them a limited period of shop work or field work in the capacity of timekeeper should prove beneficial.

21. Shop methods are to a certain extent dependent upon the size of the company, its equipment, and the nature of its output. In general most of the drawings are first used in the templet shop and then in the structural shop. Sometimes, as in simple beam work, the measurements may be laid out in the structural shop directly. Drawings for special work, such as eyebars, castings, rollers and pins, and forgings, are sent directly to the eyebar shop, to the pattern shop and foundry, to the machine shop, or to the forge shop. Some companies are not equipped to handle all this work but have it done elsewhere when occasion arises.

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* See Dencer's " Detailing and Fabricating Structural Steel," McGraw-Hill Book Company, New York.

22. The plant layout should be such that the material may pass from the receiving or stock yard to the shipping yard through the different operations with the least movement. The different machines should be arranged so that the material may pass from one to the other in logical order without interference. The material is handled by overhead traveling cranes, jib cranes, gantry cranes, small hoists, derricks, or small trucks or cars on narrow-gage or standard-gage tracks.

23. In the **templet shop** " templets " are made for the component parts of most plate and angle members and for some beams. These templets are virtually patterns for cutting and punching the component pieces. The templets are usually made of wood or of cardboard, but metal templets are used for some high-class work. Not only can the work be laid out on wood or cardboard with greater facility than on steel, but when so laid out the templets can be used repeatedly in marking many steel pieces which are alike or similar. Furthermore, the templets can often be completed before the steel arrives from the rolling mills, and thus the completion of a structure is hastened. The templets indicate how the steel shapes are to be cut and where holes are to be punched or drilled. The positions of all holes for shop or field rivets are carefully laid out on the templets and holes $\frac{1}{2}''$ in diameter are bored in the wood or punched in the cardboard, regardless of the size of the actual holes; through these holes in the templet " center punches " are used to make small dents in the steel to indicate the centers of the holes. Cardboard templets are used for plates and small connection angles unless the numbers of pieces are too large for their durability. Cardboard is cheaper and more easily cut and punched than wood, and small pieces can be held together by metal clips for use on angles. Wooden templets are made from $\frac{7}{8}''$ or $\frac{3}{4}''$ planed pine boards, but they may be used several times by plugging the holes and planing off the marks. Templets for angles are made of one or two pieces, as shown in Fig. 14 (*a*) and (*b*). Each strip may or may not be the same width as the corresponding angle leg, but transverse distances must be measured from the edge of the strip which will be placed at the vertex of the angle. When holes are to be punched in both legs of an angle, one piece is made full length for the holes in one leg, and fastened to it at right angles is

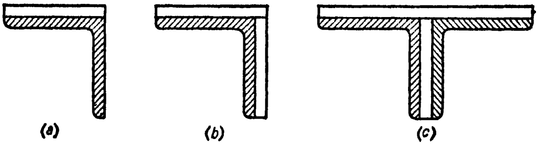


Fig. 14. Templets for Angles.

another full-length piece or else one or more short pieces for the holes in the other leg. Transverse distances are measured from the inner vertex of the templet to correspond to distances which are measured from the outer vertex of the steel angle. When angles are made in pairs, i.e., rights and lefts (page 107), as stiffening angles or flange angles, a T-shaped templet is made as shown in Fig. 14 (*c*); one-half is used for one angle and the other for the other angle, the holes in the stem serving for one leg of each angle. For large plates, templets are rigid frames made from strips of wood in order to save lumber and to facilitate handling. Strips may be used along the edges of a plate and wherever intermediate holes are located, sufficient diagonals being added to hold the strips together and prevent distortion. For beam work several types of templet may be used. For the flanges, strip templets may be used if the number of similar pieces is sufficient to justify them; otherwise the holes may be laid out directly on the steel. If wooden spiking pieces are to be bolted to the flanges, the holes may be spaced in multiples of 3″ so that a standard templet with holes every 3″ may be advantageous. Holes in the web may be laid out (1) on the steel, (2) on full-length templets, or (3) in groups on separate templets which are located by direct measurement. The third scheme is well adapted to standard connection angles, for the group templets may be used repeatedly for different contracts. Where multiple punches (page 17) are used, templets may be dispensed with, especially if spacing racks are provided. In order to economize in lumber and to reduce the number of templets to be made, handled, and stored, one templet may often be made to serve for pieces which are not identical. The pieces must be similar even though of different lengths, and most of the holes must be in the same relative positions although not all the holes need be punched in every piece; holes should not fall less than ½″ apart or they will interfere; transversely, they must be at least 2″ apart if a multiple punch is to be used. Special marks and notes are painted on the templets to indicate which cuts and which holes are to be used for each piece. The contract number, the drawing number, the size of the holes, the identification mark, and the number of pieces required are painted on each templet.

24. The Stock Yard. As the steel arrives from the rolling mill it is unloaded in the receiving yard or stock yard by overhead cranes. Usually enough material of different shapes is kept in the stock yard for the details and other parts which cannot be included in the original mill orders. Material required on account of changes or additions to a structure may often be provided in this way without delay. Most of the material for each contract is ordered specially for that contract, and it is held in the receiving yard until required. Since much of the material is ordered in multiple lengths, particularly plates and angles, it must be cut to dimension. This is usually done in the receiving yard or in the receiving end of the structural shop from the " shop bills " upon which the required material is summarized. Plates and angles are cut cold by **shearing** or are flame-cut with an oxyacetylene flame. The plate shear has one fixed horizontal blade and one movable blade which moves in a vertical plane. One end of the movable blade is slightly lower than the other so as to cut the plate gradually instead of the whole width at once. The cutting edge of the upper blade is placed so that it will just clear the cutting edge of the lower blade much as the two blades of ordinary scissors are arranged. Angle shears cut both legs at once, one leg being placed against a horizontal cutting edge and the other against a vertical one. A single knife with two cutting edges moves diagonally past these two. Diagonal cuts on plates and angles may be made by running in the material obliquely or by rotating the shears horizontally. Wide-flanged beams, I-beams, and channels are usually ordered from the mill in the desired lengths because the flanges prevent shearing them as simply as plates and angles. When beams have to be recut in the shop they are usually flame-cut, although circular " cold saws " or special beam shears are sometimes used.

25. Much rolled material has to be straightened either at the mill or at the shop. It is run through a series of **straightening rolls,** two rolls being on one side and one roll on the opposite side but located longitudinally between the other two. By changing the position of the single roll relative to the others, bends may be taken out as the material passes through. The same rolls may be used for curving material when required.

26. The first step in the fabrication of riveted work after the material is cut to length is the "**laying out.**" This includes the marking of the steel from the templets when templets are used, and also the laying out on the steel directly from the drawings when templets are not used. The wooden templets are clamped in the proper position on the steel, and all notches and special cuts are marked with a piece of soapstone. The centers of holes are indicated by small dents in the steel. These dents are made by placing a " center punch " through the $\frac{1}{2}''$ holes of the templets and striking the top of it with a hammer. The center punch is slightly smaller than the hole in the wood so that it can be centered easily, and a short sharp point protrudes from the end for making the dent. The soapstone marks which indicate the cuts are made more permanent by a series of center-punch marks. White paint is used to call attention to the presence of all marks which might otherwise be overlooked. The contract number, the identification mark, the sheet number of the corresponding drawing, and the size of the holes are also painted on the steel, the first two being painted on at the mill or in the yard where the material is cut to length.

27. Coping or Flame-Cutting. When one beam connects to another at the same elevation, its end has to be notched or "coped" to clear the flange of the beam to which it connects. This is usually done by means of an oxyacetylene flame, although special blocking-out or coping machines are still used. Either one or both flanges may have to be coped, but this may often be obviated by changing the relative elevations of the beams so that the flange of one clears that of the other. Corners of plates or angles may be cut off by the shears already described, but reentrant angles in plates are burned out with the flame. Large structural tees may be made by splitting wide-flanged beams by means of rotary shears or by flame, the flame often being advanced automatically.

28. Other preliminary operations may be required in shaping the component parts of a member before they can be assembled. For example, the ends of "stiffening angles" which are to be placed against the inner faces of other angles must be rounded to allow for the curved fillets of the second angles (page 116). This may be effected (1) by grinding, (2) by planing, or (3) by chamfering with rotating cutters. When a stiffening angle is "crimped" or offset for one leg of the angle against which it is to rest, much as the end angles are bent over the flange angle in Fig. 125, it must be taken to the forge shop and bent while hot. Plates or other shapes occasionally have to be planed on the edges, and some plates must be planed on one side to insure a uniform bearing surface. A small cutting tool is made to pass across the surface repeatedly, thus cutting a series of thin narrow strips until the desired depth or area is planed.

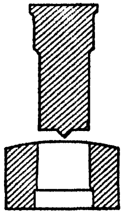


Fig. 17.

29. Punching. Holes may be punched, drilled, or bored. Rivet holes are usually punched to the desired size by "punches." The shape of the punch and the corresponding die is shown in Fig. 17. The punch housing is stationary, as shown in Fig. 18; the steel to be punched is moved with the aid of a small hoist or rollers until the dent which indicates the location of a hole is directly below the small projection on the punch shown in the figure; the punch is then released and it passes through the metal. In general, holes may be punched in metal as thick as the diameter of the punch plus $\frac{1}{8}''$. Some specifications state that no holes shall be punched in metal thicker than $\frac{3}{4}''$. Many holes are punched one at a time, or "single punched," but the larger plants are equipped with some form of multiple punch, in which any or all of the punches can be released at once. For example, a multiple punch may be used for punching groups of holes for standard connections in beams as in Fig. 19 (a), and also for punching holes in web plates, cover plates, and flange angles. In conjunction with such a multiple punch, there is often a spacing rack which can be set to limit the advance of a plate or shape to correspond to the desired rivet spacing, as in Fig. 19 (*b*). Special racks are sometimes used with an ordinary punch for duplicating connection plates. The holes are first laid out and punched in one plate, then this plate is clamped in the rack under an indicator. A blank plate of the same form is clamped in the rack in such a position that the punch is in the same relative position as the indicator of the first plate. The rack is moved until the indicator falls into a hole, then the punch is released and a corresponding hole is made in the second plate. Punches are often rigged with special dies for punching slotted holes, for coping, or for making lattice bars. The dies can be made so that curved ends of two bars and the corresponding holes can be cut at a single stroke; by means of an adjustable stop, a complete lattice bar can be made at each stroke, the workman simply advancing the bar to the stop between strokes.

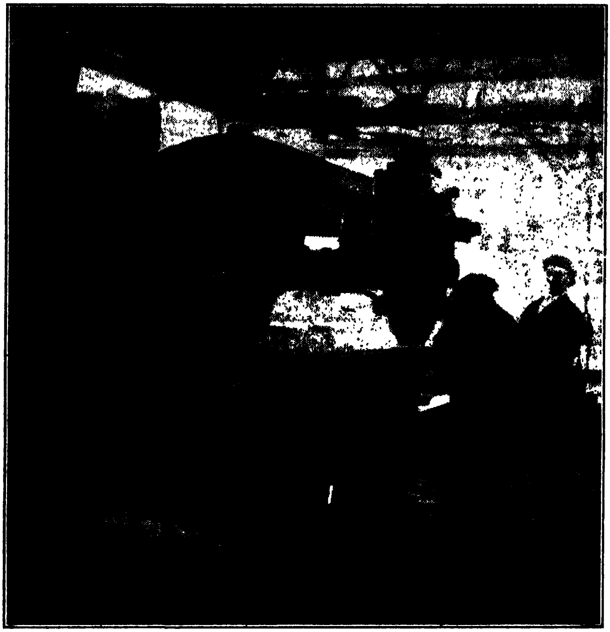
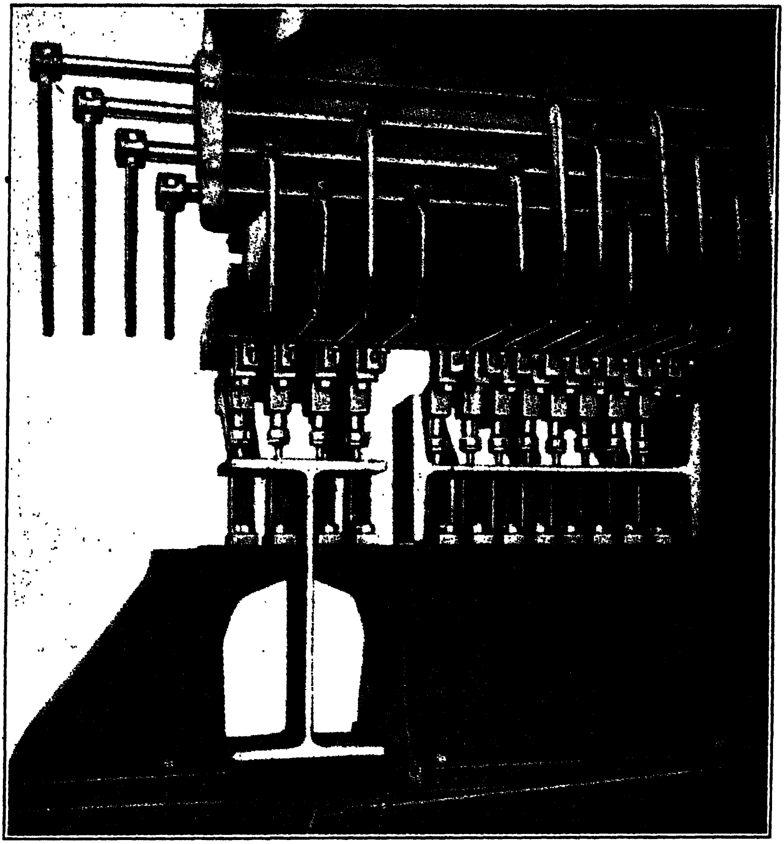


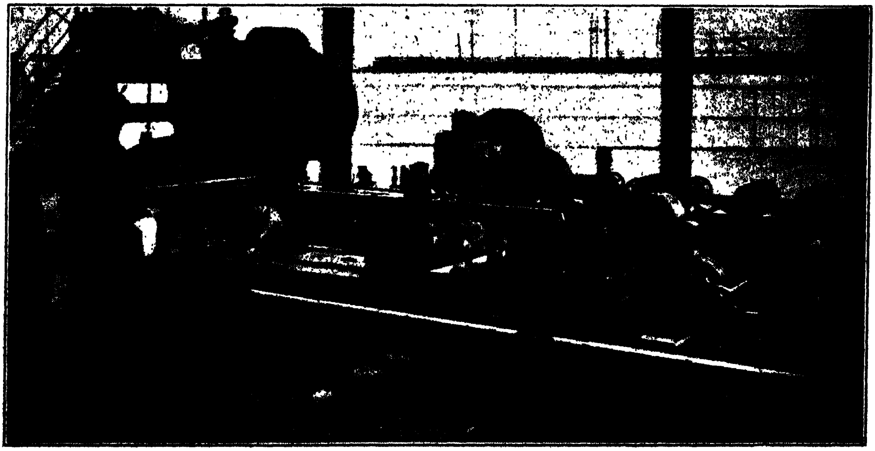
Fig. 18. Single Punch:

30. Subpunching. Since holes in connecting parts are not always in perfect alignment, the holes in some of the higher classes of work are subpunched and reamed. Holes are also subpunched and reamed in metal thicker than the maximum allowed for punching full-sized holes. The holes in each component part are punched $\frac{1}{4}''$ smaller than the desired hole;



(Courtesy of Thomas Machine Manufacturing Company.)

Fig. 19 (*a*). Multiple Punch for Beams.



(Courtesy of Thomas Machine Manufacturing Company.)

Fig. 19 (*b*). Spacing Rack for Multiple Punch.

then, after the parts are assembled, the holes are reamed out to the proper size by means of pneumatic or electric reamers, with fluted cutters (Fig. 20).

31. Drilling. Rivet holes are also drilled. In some of the highest class of work drilled holes are specified, for they may be made true cylinders, accurately centered, with less damage to the surrounding metal than punched holes. Holes for important field connections are often drilled in both connecting parts through the same metal templet so that they will match exactly. Sometimes connecting members are held together in the proper relative position and the holes are then drilled through both members at once to insure a perfect connection. Holes are also drilled in metal which is too thick to be punched. Fixed drill presses are used for small pieces such as base plates which are moved into position under the drills. Radial drills may be moved radially in an arm which can be swung about a vertical axis. Gang drills are used in some plants for drilling a

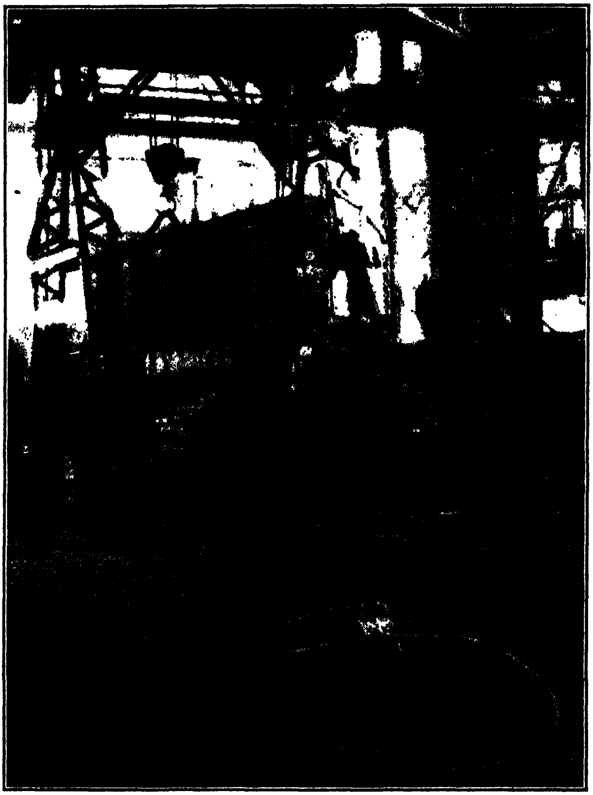
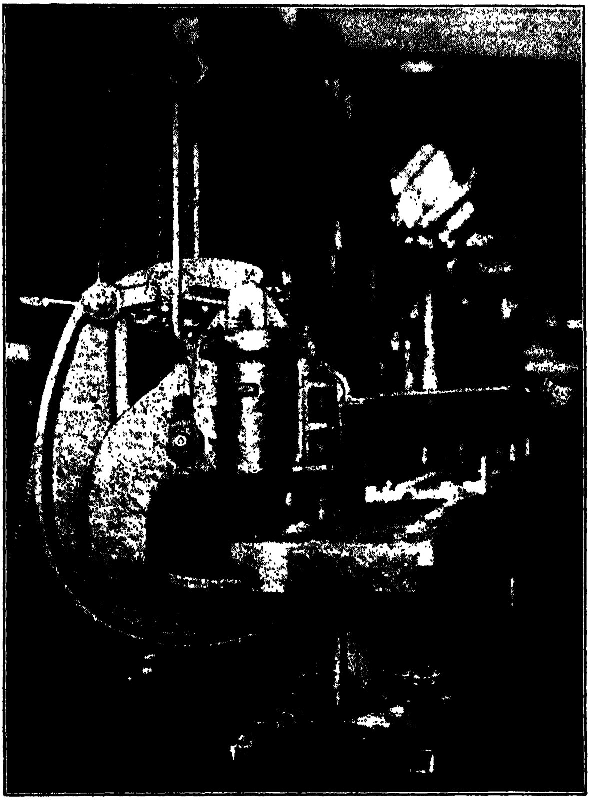


Fig. 20. Compressed-Air Riveter.

large number of holes in heavy members; these are groups of radial drills mounted in a gantry frame which passes over the material to be drilled.

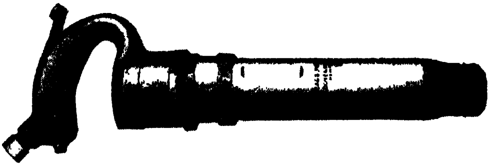
32. Assembling. After the component parts of a member are ready for riveting or welding, they are assembled or " fitted up " and held in position by shop bolts or clamps. These bolts are longer than necessary, but washers are placed under the nuts to save time and wear in tightening them; incidentally this saves having so many different lengths of bolts. At least two bolts are required for each piece to keep it from twisting.



(Courtesy of Hanna Engineering Works.)

Fig. 21. Compressed-Air Squeeze Riveter.

33. Riveting. The assembled members are taken to the riveters to have the hot shop rivets " driven." Each rivet is made with one head, but the other is formed after the rivet is put into position. The diameter of the rivet hole is made about $\frac{1}{16}''$ larger than the diameter of the shank of the rivet, so that the heated rivet can be inserted more easily. Not only should a well-driven rivet have a well-formed and centered head, but also the shank should be upset to fill the hole. Rivets may be driven (1) by compressed-air or hydraulic riveters either fixed in position as shown in Fig. 20 or mounted so that they can be raised or lowered, (2) by movable compressed-air squeeze riveters, as shown in Fig. 21, (3) by pneumatic hammers, such as shown in Fig. 22, or (4) by sledges. Power-driven rivets are worth more than hand-driven rivets, and those driven by machine are more likely to have the shanks fill the holes. Pneumatic hammers or sledges are necessary for driving rivets which are inaccessible to the other forms of riveters. When hammers are used, the rivets are held in place by "dolly bars," either of the pneumatic type or simply bent rods with cup-shaped ends to fit the rivet heads. Countersunk and flattened rivets are driven by the same methods by substituting flat dies for those which form the button heads of the ordinary rivets. Holes for countersunk rivets are reamed by special reaming tools placed in the drill presses or in the pneumatic or electric reamers. Projecting portions of countersunk rivet heads may be chipped off, if necessary, by means of a cutting tool or chisel placed in the pneumatic hammer.



(Courtesy of Chicago Pneumatic Tool Company.)

Fig. 22. Pneumatic Hammer.

34. Welding. Fusion welding is allowed by most codes as a substitute for riveting in steel structures. A structure may be fully welded, fully riveted, or shop-riveted and field-welded; in the last, advantage is taken of the quieter method of erection at the site, but the full benefits of welding cannot be obtained unless the shop connections are also welded. Permanent bolts are used for some connections. Welding may be done by oxyacetylene flame or, where electricity is available, by electric arc. Either direct or alternating current may be used, the arc being formed between the base metal to be welded acting as one electrode, and the fusion steel wire, in a suitable holder, acting as the other; the heat from the arc fuses the wire to form the weld and also fuses the base metal enough to insure adhesion. The welding current varies with the size of the wire, the size of the weld, and the kind of work, but in general is of low voltage, from 15 to 45, but of high amperage, from 25 to 600 or 800. The welding current may be transformed from the usual supply by a motor-generator set, or it may be generated by a gasoline-engine generator. The positive wire is usually connected to the work to be welded, and the negative wire to the fusion electrode, which is usually $\frac{5}{32}''$, $\frac{3}{16}''$, or $\frac{1}{4}''$ in diameter. The electrode is usually coated with a fluxing material which gives off a shielding gas to inhibit the oxidizing of the hot metal.

35. Welds. The edges or ends of two plates can be joined flush by a *butt weld,* as shown in Fig. 23 (*a*); if the plates are more than $\frac{1}{4}''$ thick, one or both must be beveled or grooved to make a single or double V, U, or J in order to permit complete fusion. A lap joint or connection of two pieces at right angles is made with a *fillet weld,* as shown in Fig. 23 (*b*). A *slot weld* is made through a hole or slot in one part, where the usual welds are insufficient. A *tack weld* is a small weld made to hold component parts of a member together until they can be welded more permanently. *Resistance welding* or *spot welding* is used without arc or flame and without additional fusion metal to fuse parts together under pressure when heated by a localized current passing through both parts; this is used in pressed-steel rather than structural-steel work. In structural work the fillet weld is the most common, usually $\frac{5}{16}''$ or $\frac{3}{8}''$ in size. The *throat* of a fillet weld is the altitude of the isosceles triangle forming the weld, and the *size* is the width of contact with each part connected, as shown in Fig. 23 (*c*). The throat of a butt weld is equal to the thickness of the thinner part connected, and the size is equal to the throat. The *length* of weld is measured along the intersection of the surfaces connected. Additional metal is often deposited in a weld to insure development of the triangular cross section; this extra metal is called *reinforcement.* Care must be taken to fill the crater at the end of a weld, or to carry the weld beyond the designated length, so that the desired strength is developed.

(a) Butt Welds

(b) Fillet Welds

Fig. 23

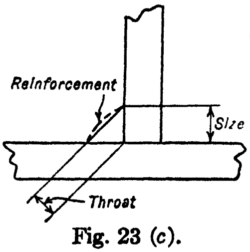


Fig. 23 (*c*).

36. Milling. The ends of members which are expected to transmit stress by direct bearing must be " planed," " faced," or " milled." This is done by means of a " milling machine " or " rotary planer " which has numerous cutters arranged near the edge of a circular cutting head. As the head slowly rotates it advances across the end of the member. Unlike the teeth of a saw, the cutters are set in the plane face of the head toward the member to be cut instead of in the periphery, and it is important that they project equal distances from the face. The member is clamped in front of the planer, which can be turned horizontally to cut the member at the proper angle. Milling machines are often used in pairs so that both ends of a member may be faced at once.

37. Boring. Holes for the pins of pin-connected structures are bored by large boring machines. These are often arranged in pairs so that the holes at each end may be bored simultaneously at the proper distance apart. The holes are usually roughed out either by punching or by flame-cutting, so that the shaft which holds the cutter may pass through. The cutter of the boring machine then enlarges the hole to the proper size.

38. Inspection. Each member is inspected when the shop work is completed. The inspector checks the important measurements and the field connections. He makes sure that every connection is provided for, and in general that the member is complete and properly made. He tests the rivets with a hammer and rejects any loose ones. He measures the welds to make sure that the full size is developed, and assures himself that the welds are properly made; sometimes X-ray tests are required.

39. Painting. Unless a member is to be imbedded in concrete or other fireproofing material, it is given a coat of paint before it is shipped. Surfaces which are inaccessible for painting after a member is completed are painted before the parts are assembled. The contract numbers and the shipping marks must be left exposed or transferred to the newly painted surface before shipment.

40. Shipping. Most members are shipped by truck or by rail on open cars. They are loaded to the best advantage, the larger members being separated by wooden blocks to prevent damage during shipment. Long girders, trusses, or chords may extend over two or more flat cars, but they must be so mounted that they will not interfere with the passage of the train around curves. Many of the smaller loose pieces are bolted to larger members for shipment in accordance with notes on the drawings; others are wired together or boxed.

41. Other operations are required to supplement those just described. Some plants are fully equipped; others have much of the miscellaneous work done elsewhere. Among the most important departments may be mentioned the machine shop, the forge shop, the foundry, the pattern shop, the eyebar shop, and the bolt, nut, and rivet shop. The machine shop provides for repairs and shop maintenance as well as for the special machine work required in the structures made for the customers. Here the various tools are sharpened and kept in good condition, and often some tools are made. Pins, rollers, and turned bolts are made in the machine shop, bed plates are planed, and castings are drilled and finished there. In the forge shop angles and other shapes are bent, rods are upset at the ends to neutralize the effect of thread cutting so that the full cross section of the rods will be developed, and loop rods, clevises, turnbuckles, etc., are made. In the foundry all steel and iron castings are made, as for example, column bases, bridge pedestals, and beveled washers. Patterns are used in making sand molds into which the molten iron or steel is poured. Patterns are made in a pattern shop by pattern makers, not by templet makers, for they require an entirely different class of workmanship. Patterns are models of the finished castings, made carefully to scale. They are made larger than the castings by means of " shrinkage scales " to allow for the shrinking of the metal while cooling. In the eyebar shop the ends of eyebars are upset in large hydraulic presses which form the heads. The pin holes are then punched and later bored to the proper size. The bars are then annealed, i.e., heated and allowed to cool slowly in order to restore the uniform properties of the steel before the ends were heated and upset. Rivets and bolts are made from heated rods in special rivet and bolt upsetting machines. Nuts are punched from flat bars. After the bolts and nuts are cool they are threaded. The separate departments mentioned in this paragraph are referred to as " shops " but this does not necessarily mean separate buildings. For example, the pattern shop and the templet shop may be under one roof, and the eyebars and the rivets and bolts may be made in the forge shop. It will be noted that similar operations are carried on in different departments as a matter of plant economy. For instance, it is cheaper to maintain milling machines and boring machines in the main structural shop or in the eyebar shop as well as in the machine shop than it is to carry all the heavy members to the machine shop for milling.

42. Erection. The different members of a structure are shipped to the site as far as practicable in the proper sequence for erection. The methods of erecting them differ with the size and the type of the structure and with its location. Usually buildings are made self-supporting from the first, but truss bridges must be supported by " falsework " or by other means until they are nearly completed. Locomotive cranes or truck cranes are used extensively in the erection of mill and factory buildings, girder bridges, and low viaducts. Derricks are used for tier buildings, and " travelers " or derricks on traveling frames for truss bridges and high viaducts. Main members are usually placed in position first and secondary members are filled in afterwards, except in so far as they may be needed to hold the main members in position. The floor system of a bridge is often erected on falsework first and then the trusses are built up around it, although it is sometimes better to erect the trusses first. Members are held in position as erected by means of temporary erection bolts, and later the connections are permanently riveted or welded unless permanent bolts are sufficient.

CHAPTER IV

THE STRUCTURAL DRAWING

43. A structural drawing is a working drawing for steel, concrete, or wood construction, and it should fully represent one or more members of a bridge, a building, or similar structure. In steel construction, each member is composed either of a single piece of structural steel or a combination of the common rolled steel shapes, and for this reason the methods used are peculiar to this form of drawing and somewhat different from other kinds of working drawings. As the component parts of the members are rolled at the mills, detailed information regarding the dimensions, the slopes, and the curves of the standard shapes is not necessary; instead information is given to show how the standard shapes are cut, punched, and combined in the structural shops. The shapes are rolled while hot, but most of the work in the structural shops is done on the cold metal. The drawings should give the information necessary for the construction of the members in the shop and also provide for their proper connection to other members during erection in the field. Much of the preliminary work is done in the templet shop before the drawings are used in the structural shop, and the draftsmen should be familiar with the needs of the templet maker in order to make the drawings most serviceable. A drawing is usually made by one person and checked carefully by another person to minimize mistakes, for the cost of replacing ruined pieces is great and the resulting delay is expensive. Errors in field connections are more serious than those in shop work, and sometimes extra checks of field connections are made to obviate trouble during erection. In some companies, field checks only are made in the belief that mistakes involving shop work will be caught in the shop before they reach serious proportions; in this case only seasoned draftsmen can be employed.

44. Projection. Working drawings are drawn in orthographic projection, and the third angle of projection is used. At times a knowledge of isometric, oblique, and cabinet projections and of perspective drawing is of benefit to the draftsman, although usually not essential. In orthographic projection, a " view " is not a true view as in perspective drawing, but it represents the projection, by parallel lines, of one face and the projecting parts of a member upon either a horizontal or a vertical plane. A view which is projected upon a horizontal plane is termed a **plan**; a view projected upon a vertical plane is termed an **elevation.** These terms are commonly used in erection diagrams, "show drawings," and design sheets, where the structure is treated as a whole, but they are not often applied to working drawings in which individual members are considered.

45. The proper views of any member should be selected to represent that member to the best advantage. Two or more views are usually necessary, but no more views should be drawn than those required to show clearly the arrangement of the different pieces of which the member is composed, together with all the necessary dimensions. Much time and space may be wasted by drawing unnecessary views. The usual views employed are: the front view or front elevation, the top view, the bottom section, and the end views. A rear view sometimes becomes necessary, and frequently one or more sectional views.

46. All views must bear a proper relation to one another as in mechanical drawing; see Fig. 27. The **top view** must be placed directly above the **front view,** and an **end view** opposite the front view near the end it represents. It is customary in making structural drawings to replace the bottom view by a **bottom sectional view** placed directly below the front view, but drawn *as seen from above.* The section plane is assumed to be passed just above the bottom details which are to be shown, in such a manner that comparatively few parts are cut. See page 34.

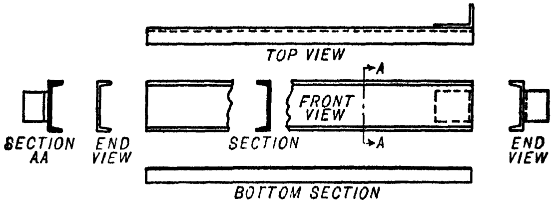


Fig. 27. Arrangement of Views.

The reason for substituting a bottom section for a bottom view is to obtain a better correlation between it and the top view, so that it will be more apparent whether a connection on one side of the top flange and a connection on the bottom flange are on the same or the opposite sides of the member.

A **sectional view,** other than the bottom section, may be placed anywhere on the sheet, provided that the position of the section is apparent or else clearly indicated by arrows as shown in the figure. It is the usual practice, however, to place a sectional view either at the end of the member adjacent to or in place of an end view, or else in a break in the main or front view at the point where the section is taken. In any event, the sectional view should be drawn as seen looking toward the parts which are to be shown in the direction of the arrows, as if the portion of the member between the view and the section plane were removed. It is awkward to have a sectional view at the wrong end; it is better to change the position of the section plane and reverse the arrows.

47. The distances between the different views of a member are not necessarily equal, but they are made just great enough to provide ample room for dimension lines, explanatory notes, and other lettering which must be put on the sheet. Provision should be made also for any projecting parts, such as gusset plates, base plates, or connection angles.

48. The Position on the Sheet. Most members are shown on the drawing separately, but in some classes of work, as for example truss work, it is convenient to draw several members together, even though they are to be shipped separately, in order to show their relation to each other and to save the duplication of details. (See Fig. 172.) As far as practicable it is well to draw horizontal members horizontally on the sheet, and to draw vertical members vertically, i.e., from the lower to the upper edges of the sheet. Long columns or other vertical members which would appear too crowded in this position may be drawn lengthwise of the sheet with the bottom at the left end. Inclined members may be drawn either horizontally or vertically in order to economize space, unless it is desired to show their relation to other members. It is desirable to draw each member in the position which seems most natural from its position on the plans without needless turning.

49. Parts Shown. Only the pieces which are to be shipped with a member should be shown on the detailed drawing of that member, although in unusual or complicated work part of a connecting member may be shown in outline by dotted or red lines. This should be done only for the benefit of other draftsmen or of the erector to make clear a connection which might otherwise be obscure or difficult to understand from the drawing — never if confusion is likely to result in the shop. In drawing any view of a member it is unnecessary to show all the parts which theoretically might appear in full or dashed lines according to the principles of orthographic projection. The vision can be limited to the face shown, without showing parts which project from other faces, even though they may project beyond the edges of the view in question; as a rule the drawing is thereby complicated and valuable time is wasted. Such parts should be shown, however, if the drawing is made more clear, or if an extra view may be dispensed with by so doing. It would not be good practice to show one projecting part and omit something which is between that part and the face being drawn. It is customary to draw the members of the left half of the far truss of a bridge.

50. If a member is practically **symmetrical** about its center line, it is necessary to show only one-half of the member with a note to the effect that it is " Symmetrical about the center line " or " Symmetrical about the center line except ——," noting the exceptions. It is customary to show the left end of the member. Simple members are usually shown completely, but the details at the right end can be referred to those at the left end. Whenever excessive duplication can be avoided, only one-half of a member is shown, although the principal lines are extended somewhat beyond the center so that it is apparent that the member does not end there. When half-trusses are drawn, the central members or central connections are shown completely, without being cut in halves.

51. The usual working units in structural work are feet and inches and fractions of inches expressed to the nearest sixteenth. Since many of the tapes used in the shop are subdivided to eighths only, it is more convenient for all concerned to use multiples of $\frac{1}{8}''$, or preferably $\frac{1}{4}''$, whenever practicable, it being understood that each dimension is correct to within $\frac{1}{32}''$, i.e., expressed to the nearest $\frac{1}{16}''$. In a few instances it may become necessary to employ dimensions in thirty-seconds, where dimensions are subdivided, or in sixty-fourths, for the sizes of pin holes.

52. The Size of the Drawing. Most structural companies have adopted standard sizes for their drawings, and most of their drawings conform to these sizes; the sizes depend upon the class of work and upon whether or not shop bills are combined on the same sheet, so the sizes are not the same for all companies. A common size is 24″ × 36″, but often plans, diagrams, or details for large trusses or members are on larger sheets. Some companies use long narrow sheets for columns. Beams, castings, forge work, bills, and miscellaneous lists are made on smaller printed forms which vary with the different companies. Drawing paper is available in rolls 30″, 36″, 42″, and wider, or in standard sheets 12 × 18, 17 × 22, 18 × 24, 19 × 24, 22 × 30, 24 × 36, and 27 × 40, but sheets may be obtained cut to any size. For student use, convenient sizes are 12 × 18, 17 × 22, 18 × 24, or 24 × 36, with 8½ × 11 sheets from separate-leaf notebooks for smaller drawings.

53. Paper or Cloth. Drawings are issued from the drafting room in the form of blueprints, and the original drawings have limited use. The usual practice is to make the drawings in pencil on tracing paper or tracing cloth, and with proper care the results are satisfactory for the general run of structural work. Complicated drawings which are on the board so long that pencil lines would become smeared, or erection plans and diagrams which receive more than ordinary handling in the drafting room, are made in ink on tracing cloth. See pages 61 and 205.

54. Reproduction. Original drawings are retained in the drafting room, but copies are issued to the shopmen and to others interested. These copies are usually blueprints made on relatively cheap sensitized paper (or cloth) and developed to show white lines on a blue background. A blackprint, giving black lines on a white background, can be made. Blue-line prints may be used by double printing by the Vandyke process; this involves making a brownprint negative or " Vandyke " on thin paper and then making blueprints from it. Photostats are often made photographically directly from the original, especially if a reduction in size is desired.

55. The Scale. Structural draftsmen use architects' scales for the most part, although they have more or less use for engineers' (decimal) scales also. The adoption of the best scale for the drawing of a large member depends upon the size of the piece, the size of the sheet, the number of the views, and the number of the dimension lines required. Sometimes more than one sheet is necessary to show a member properly. It is seldom practical to use less than ½″ = 1′ except for plans and diagrams. The most common scale is ¾″ = 1′, but on small or complicated drawings the draftsmen often prefer 1″ = 1′. The scales 1½″ = 1′ and 3″ = 1′ are suitable for enlarged details or layouts.

Either flat or triangular scales of different lengths and with different graduations may be obtained. Scales 1′ long are most common. Triangular ones have all the required scales on one piece, but some draftsmen prefer several flat scales instead. A scale guard may be used with a triangular scale to prevent mixing different scales on one drawing.

The scales are graduated in such a manner that dimensions may be plotted directly without conversion. The main numbered divisions of any of the scales represent feet, and the end foot is subdivided into inches and fractions of inches. Note that the zero mark for both the feet and the inches is at the end of this first foot instead of at the end of the scale. Dimensions less than 1′ may be plotted to a given scale by means of the graduated end foot much as they would be laid off full size with an ordinary foot rule. Dimensions over 1′ may be plotted at one setting of the scale, provided that the scale is long enough, by placing the proper foot mark at a given point and by plotting the other point opposite the proper fraction of an inch. For example, to plot 4′–5½″ to a scale of ¾″ = 1′, select the proper edge of the scale graduated to ¾″ = 1′ and place the number 4 (4′ from the zero mark) at one end of the required distance and plot the other end 5½ one-inch divisions beyond the zero mark (i.e., 6½″ from the end of the scale). Fractions smaller than those represented by the smallest subdivisions may be interpolated.

56. Although structural drawings are for the most part drawn approximately to scale, it is unnecessary and undesirable to employ the same degree of accuracy as in map work; one is never permitted to scale a drawing to obtain a dimension, but is required to use the figured dimensions only. Time should not be wasted, therefore, in too accurate plotting, but greater stress should be laid upon giving the dimensions correctly. The more complicated drawings are drawn to a definite scale to avoid crowding, and to simplify the addition of other connections. Beams are often shown the same length regardless of scale, especially if on printed forms; the details may be drawn approximately to the same scale as the depth of the beam, and the distances between details estimated roughly proportional to the length. Similarly, columns and other long members may be "telescoped," the connections being plotted to scale, but the distances between connections being reduced to save space. Small distances, such as the thicknesses of angles or plates, are usually shown conventionally without scaling, being exaggerated if necessary on small-scale drawings to prevent the lines from running together.

57. Drafting Machines. Drafting may be simplified by means of a drafting machine,* and its use is recommended. The machine is attached to the board in such a manner by arms forming parallelograms that the horizontal scale remains horizontal as it is moved over the drawing. A vertical scale is fixed at right angles to the horizontal scale, and both may be rotated through any angle as indicated on a protractor, some machines having automatic stops at 30°, 45°, 60°, and 90°. Special structural protractors have common truss and beam slopes marked. With these machines, T-squares and triangles are not required, and lines may be drawn and scaled at the same time. Other drafting aids are available as illustrated in maker's catalogs. For example, the Lesh Angle† or the Dietzgen Pro-Tract-Angle,‡ made of two triangular arms pivoted together with a protractor, may be used in conjunction with a T-square for drawing parallel lines at any slope, and in closed position they give 30°, 45°, and 60° angles without change of equipment. Similarly, the Dietzgen Draft-Scale-Angle‡ combines scales with other features. All have convenient handles.

58. In order to obtain the **best arrangement** and appearance of a drawing, the draftsman must visualize the finished drawing so as to plan the number and arrangement of the views, the main dimensions, the number of dimension lines, and the position of the principal connections.

59. The best results in drafting may be obtained by adopting some **systematic method of procedure.** This not only saves time but also minimizes the chance of making mistakes or of overlooking connections. Each draftsman may adopt his own method, and different classes of draw-

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* Made by Charles Bruning Company, Inc., New York City; The Drafto Company, Cochranton, Pennsylvania; The Frederick Post Company, Chicago, Illinois; L. G. Wright, Inc., Cleveland, Ohio; and the Universal Drafting Machine Company, Cleveland, Ohio.

† Edwin Z. Lesh, East Hartford, Connecticut.

‡ Eugene Dietzgen Company, Chicago, Illinois.

ings may require different steps, but the following order of procedure will be a guide to the student.

1. Determine the number of views, the number of dimension lines, and the main dimensions before starting the final drawing.
2. Outline the principal view first, and draw the corresponding dimension lines.
3. Outline the other views and draw the dimension lines. If preferred, the principal view may be completed first.
4. Write on the main dimensions.
5. Draw the details in the order of importance, beginning with the connections to the supports, if any. *Put on each dimension as soon as determined;* indicate the rivets, the holes, and the welds; bill all the material; and add the necessary notes before proceeding to the next connection.

   The draftsman should constantly imagine himself in the place of the men in the shop in order to determine what information is needed on a drawing and how this information can be arranged to be of the greatest service. He should improve every opportunity to watch the shopmen at work, and to become familiar with their methods. He should attempt to build up the drawing of a member in much the same order in which the member itself is built up in the shop, and he should never submit a drawing to be checked until he is satisfied that the members can be constructed as intended.

6. Complete the dimensions *between* the connections, spacing the necessary rivets or lattice bars.
7. Note the sizes of the rivets, the holes, and the welds.
8. Make the title, and add any general notes which may be required.

60. A draftsman should **check the main dimensions** of a drawing before proceeding with the details. He can often use different data in checking from those of the original computation and thus make doubly sure that the principal dimensions are correct before he wastes time in dependent work.

CHAPTER V

CONVENTIONAL METHODS OF REPRESENTATION

61. The lines of a drawing are usually made of two widths; see Fig. 33. The dimension lines, the rivet lines, the projection lines, the working lines, and the cross-section lines are *full black lines* made as *fine* as practicable, but not so fine as to appear ragged on the drawing or on the blueprint. The lines which represent the component parts of the member itself are *black lines* made *heavy* enough to show a contrast with the finer lines noted above. The lines which represent *visible* edges are made *full,* and those which represent *invisible* edges are made *dashed.* The dashes should be about $\frac{1}{8}''$ long, drawn as close together as practicable, but with sufficient space between them so that on blueprints the lines are clearly dashed lines and not full lines. In short lines, or in the lines of small-scale drawings, the dashes may be shorter, and conversely may be lengthened in very long lines, particularly in drawings which are made to a large scale. The appearance of a drawing is greatly improved if large or uneven spaces between the dashes are avoided. Where lines are close together, the inked dashed lines may be made slightly narrower than the full lines. Dashed lines are likely to be wider than full lines unless the setting of the pen is changed. Center lines are *fine black lines,* similar to dimension lines except that they are made of *dots and dashes* alternating. Lines which indicate where sections are taken are made of *dashes with two dots between.* These may be made either fine or coarse, depending upon which will show the greater contrast with the surrounding lines. They may be continuous, or portions of them may be omitted to avoid confusion with other lines.

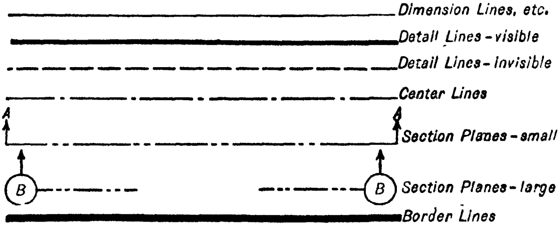


Fig. 33. The Lines of a Drawing.

Arrows should be placed at the ends of these lines to show which part of a cut member is represented in the corresponding sectional view. These lines which indicate a section should be lettered to correspond to the sectional view. Where space permits, circles may be placed at the ends of the lines with the letters inscribed; otherwise the letters may be placed at the ends of the arrows. See Fig. 33. For the use of lines wider than the main lines of the drawing, see pages 34 : 62 and 81. For the method of inking wide lines see page 68. *Dotted lines* should be reserved for indicating complicated connections (page 28).

62. Sectional views (page 27) are often " crosshatched " or " section-lined " so that they may be distinguished from other views. Only the parts which are cut by the section plane (page 27) should be section-lined, and the position of this section plane should be selected to illustrate the conditions to the best advantage. It is usually best to cut only continuous material so that the details will stand out more clearly. The cross-section lines are fine black lines (see above) drawn at uniform distances apart, inclined 45° with the principal edges of the parts cut. It is preferable to slope the section lines of adjacent component parts in opposite directions in order to accentuate the dividing surfaces. The webs of beams and channels which are cut by section planes are usually made solid black for simplicity instead of section-lined; similarly web plates are sometimes made solid, as in the bottom sectional views of plate girders. In the usual run of beam and girder work, however, it is customary to show simply the two full lines for the web without either section lines or solid filling, unless such drawings are likely to be misinterpreted.

There are many devices on the market to aid the draftsman in spacing the section lines uniformly, but with a little experience one can produce results which are quite satisfactory for this class of work with simply a T-square and a triangle. If desired, the advance of the triangle can be made more uniform by means of a small strip of wood cut slightly smaller than the opening in the triangle. By alternately holding and sliding the wood and the triangle the triangle may be advanced in accordance with the amount of clearance allowed.

63. Breaks. When part of a view is omitted the broken ends should be made so that they may be clearly distinguished from the actual ends. An irregular freehand line may be drawn to represent an imaginary cut across the member, but care should be taken not to draw such a line across a space between component parts where nothing is cut. These irregular lines may be omitted if the limits of each view stand out clearly from the dimension lines and from the other views. When a member is symmetrical about its center line and only one-half is detailed, the main lines of the drawing should not be stopped abruptly at the center line but should be extended short distances beyond; in this way one can tell at a glance whether one-half or the whole of the member is shown. Typical breaks are shown in Figs. 123, 126, 141, and 179. Occasionally it may be desirable to indicate the true shape of a simple piece at the break in order to dispense with an additional view; this method is illustrated by Fig. 35 (*a*), in which the piece is considered to be cut by a plane at 45°. This method is not recommended for the ordinary structural drawing, but it may be used to advantage in assembly drawings of trusses to show the cross sections of the web members or the number and the size of eyebars.

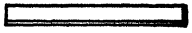


Fig. 35 (*a*).

64. Curved surfaces are seldom indicated by shade lines unless it is deemed advisable to elucidate a drawing. Most of the common structural shapes have curved surfaces, but they are incidental to the structural drawing because the curves are not made from the drawing but previously at the mill.

65. For the most part a **conventional representation** is shown for each commercial shape of structural steel whether drawn separately or in combination with other shapes. This results in a considerable saving of time and hence of money. The main dimensions are usually scaled, but an experienced draftsman may estimate the spaces between some of the lines, as, for example, those which represent the thickness of metal. As a guide to the student, suggestions are here given to enable him to show each shape in the conventional manner.

66. The shapes most used in structural work are plates, angles, wide-flanged beams, I-beams, channels, structural tees, and round rods. Less frequently, tees, Z-bars, rails, eyebars, and square rods are used.

67. A plate is indicated in any view by a rectangle of the proper dimensions. The width and the length are scaled, but the thickness is usually estimated; the thickness is often exaggerated, if necessary, to show clearly whether a dimension extends to the face of the plate or to the center line.

68. An angle is shown in its true shape in the end view (Fig. 35 (*b*)) except that the curves are omitted. The front and the top views each have three lines drawn so that they bear the proper relation to the lines of the end view in accordance with the usual principles of orthographic projection. Thus the inner line must be placed near the proper outer line and be made full or dashed according to the position of the outstanding leg. Usually a dashed line need not be drawn full length. The lengths of the legs are usually scaled, and also the thicknesses of heavy angles; the thickness of an ordinary angle may be estimated.

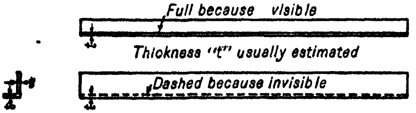


Fig. 35 (*b*). An Angle.

69. A wide-flanged beam is shown conventionally (Fig. 36 (*a*)) as follows:

End View. The depth and the flange width are plotted to scale, the flanges being symmetrical about the web. The thickness of the web is estimated and often exaggerated if necessary to indicate clearly whether a dimension extends to the face of the web or to the center line. The inner surfaces of some of the Bethlehem beams slope 5% or $\frac{5}{8}$ in 12, but it is usually not necessary to show this slope.

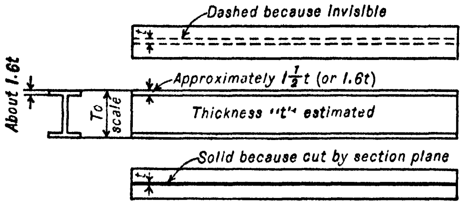


Fig. 36 (*a*). A Wide-Flanged Beam.

Front View. Each flange of the beam is represented conventionally by two full lines spaced approximately to show the mean flange thickness. The distance between the outer lines of the two flanges is the depth of the beam (either nominal or actual) to scale. If one or more end views are shown, the flange thickness should be projected from one view to the others.

Top View. Two full lines are drawn to show the flange width to scale. The web is shown midway between these lines by two dashed (invisible) lines, the web thickness being estimated as before. Usually these dashed lines need not be drawn full length.

Bottom Section. This is similar to the top view except that the web is shown either by a heavy black line equal in width to the web thickness, or by two full lines without filling the space between them when no ambiguity is likely to result.

70. An I-beam is shown conventionally (Fig. 36 (*b*)) as follows:

End View. The depth and the flange width are plotted to scale, the flanges being symmetrical about the web. The thickness of the web is estimated and often exaggerated if necessary to indicate clearly whether a dimension extends to the face of the web or to the center line. The outside edges of each flange are made approximately of the same thickness as the web, and, from the points thus located, sloping lines are drawn until they intersect the web lines; all curves are omitted. These lines are drawn to a slope of 2 in 12.

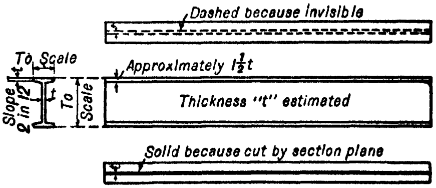


Fig. 36 (*b*). An I-beam.

The lines which represent the inner surfaces of the flanges of all standard I-beams and channels have a slope of 2 in 12. These lines may be drawn most conveniently and uniformly by means of a "beam bevel," which may be bought or easily made of celluloid, wood, or cardboard, in a form similar to that shown in Fig. 37 (*a*). For occasional use a beam bevel may be added to a celluloid triangle either by cutting the bevels on the edge of the central opening, or by scratching one or two sloping lines, as shown in Fig. 37 (*b*). One of these lines may be placed coincident with the flange line (perpendicular to the web) and then the whole triangle may be moved parallel to itself until the edge gives the desired slope line.

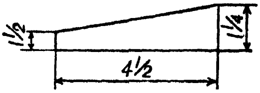


Fig. 37 (*a*).

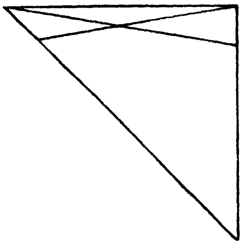


Fig. 37 (*b*).

Front View. Each flange of the I-beam is represented conventionally by two full lines spaced approximately to show the mean flange thickness. The distance between the outer lines of the two flanges is the depth of the beam to scale; each inner line is drawn so that, if extended, it would cut the sloping lines of the end view about midway between the web and the edges of the flange. The distance between the two lines of each flange is roughly one and one-half times the web thickness.

Top View. Two full lines are drawn to show the flange width to scale. The web is shown midway between these lines by two dashed (invisible) lines, the web thickness being estimated as before. Usually these dashed lines need not be drawn full length.

Bottom Section. This is similar to the top view except that the web is shown either by a heavy black line equal in width to the web thickness, or by two full lines without filling the space between them when no ambiguity is likely to result.

71. A channel is shown conventionally (Fig. 37 (*c*)) as follows:

End View. The depth and the flange width are plotted to scale. The thickness of the web is estimated and often exaggerated if necessary to indicate clearly whether a dimension extends to the back of the web or to the center line. The edge of each flange is made approximately of the same thickness as the web, and from the point thus located a sloping line is drawn until it intersects the inner web line; all curves are omitted. This line is drawn to a slope of 2 in 12. (See note in fine print under I-beam.)

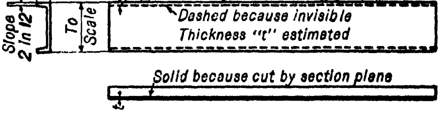


Fig. 37 (*c*). A Channel.

Front View. Each flange of the channel is represented conventionally by two lines spaced approximately to show the mean flange thickness. The distance between the outer lines of the two flanges is the depth of the channel to scale; each inner line is drawn so that, if extended, it would cut the sloping line of the end view about midway between the web and the edge of the flange. The distance between the two lines of each flange is roughly one and one-half times the web thickness. The inner lines of the flanges are full or dashed, depending upon whether the flanges are on the near side or on the far side of the web; this should correspond to the way the flanges are shown in the end view.

Top View. Two full lines are drawn to show the flange width to scale, one line showing also one face of the web; a single dashed line is added to show the other face of the web, the web thickness being estimated as before. Usually this dashed line need not be drawn full length, but it is important that it be drawn on the proper side of the flange to correspond to the other views.

Bottom Section. This is similar to the top view except that the web is shown either by a heavy black line equal in width to the web thickness, or by two full lines without filling the space between them when no ambiguity is likely to result. The web should appear on the same side as in the top view.

72. A structural tee made by splitting a wide-flanged beam is shown like one-half a wide-flanged beam, the web lines being full or dashed depending upon whether visible or invisible.

73. Round and square rods are represented by true views, the ends being shown as circles or squares, and the other views as rectangles. No shade lines are necessary.

74. A tee is shown much like an angle, except that the stem is shown in the middle of the flange by two full or dashed lines depending upon whether visible or invisible (Fig. 38 (*a*)). All curves are omitted. Both the stem and the flange taper slightly, but this is overlooked in most drawings.

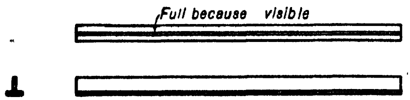


Fig. 38 (*a*). A Tee.

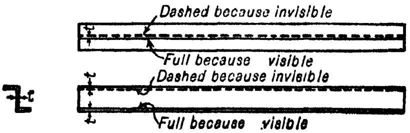


Fig. 38 (*b*). A Z-bar.

75. A Z-bar is shown conventionally (Fig. 38 (*b*)) as follows:

End View. The depth and the flange width are scaled, but the thickness is estimated and often exaggerated; the thickness of the flanges is uniform and is equal to the web thickness. All curves are omitted.

Front View. The depth is shown to scale between two full lines. Additional lines are drawn just inside of these lines to represent the inner edges of the flanges. One of these lines is full and the other dashed, because one flange is on the near side and the other is on the far side of the web; this should correspond to the way the flanges are shown in the end view.

Top View. The top flange is shown to scale between two full lines, one line showing also one face of the web; a dashed line is added to show the other face of the web, the web thickness being estimated as before. A fourth line is drawn to show the outer edge of the bottom flange, the space between it and the dashed line representing the flange width to scale. The position of the full and the dashed web lines should correspond to the other views.

76. A rail is shown conventionally (Fig. 39 (*a*)) as follows:

End View. The head, the web, and the flange are drawn from the dimensions in the handbook. On large-scale drawings these are drawn to scale, and the curves are often shown. Ordinarily, however, straight lines are sufficient without curves, the depth, the width, and the thickness of the flange being scaled.

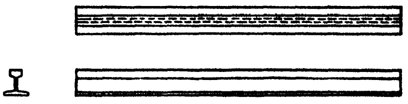


Fig. 39 (*a*). A Rail.

Front View. The head and the flange of the rail are each indicated conventionally by two lines spaced approximately to show the mean thickness. The distance between the upper line of the head and the lower line of the flange is the depth of the rail to scale; each inner line is drawn so that, if extended, it would cut the sloping lines of the end view about midway between the web and the outer edges of the head or of the flange.

Top View. The widths of the head and of the flange are each shown by two lines to scale. These lines are placed symmetrically about two dashed lines which represent the web, the web thickness being estimated.

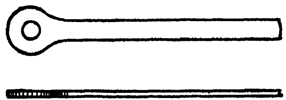


Fig. 39 (*b*). An Eyebar.

77. An eyebar is shown in the main view to scale, from the dimensions given in the handbook. The actual curves are drawn to scale. The edge and the end views appear as simple rectangles, although the curves are sometimes indicated by line shading, as in Fig. 39 (*b*).

78. Lattice bars are usually made from standard dies according to the billed size, as explained on page 48. For this reason it is unnecessary to show the bars on a drawing in detail. Usually a single full fine line is drawn from center to center of end rivets to represent each bar, but only about one and one-half such lines need be shown at each end of a group of bars, care being taken to indicate the proper slope so that the stagger will be maintained when all bars are put in position, as shown in Fig. 166. When independent systems of bars are used on opposite sides of a member they are made to slope in opposite directions, one system being shown by dashed lines for contrast; when double latticing is used, both are shown with rivets at their intersections, as in Fig. 174.

79. Bent Plates. The true projections of bent plates and angles are usually simplified as shown in Figs. 194 and 195. The dimensions must be shown accurately in the proper views, but most drawings would be complicated unnecessarily by an attempt to show all the edges. Often the drawing may be clearer and more easily interpreted if one view is drawn as if the plate or angle were not bent. The rivets and holes in inclined surfaces would appear as ellipses instead of circles, but on account of the difficulty in making small ellipses this distinction is not always made on the drawing unless ambiguity would result from the use of circles.

80. Fillers are used to fill spaces between other surfaces which are separated by intervening parts. When clearance is allowed between the edges of the fillers and the adjacent edges, additional lines (dashed if invisible) may be drawn, although these are often omitted if the drawing is clear without them; no additional lines are needed when there is no clearance. The edges of a filler are sometimes crosshatched if its location is not apparent otherwise. Round washers, shown by dashed circles, are used as fillers where single rivets are used, as at stitch rivets.

81. Shop rivets and **holes for field rivets** are usually indicated in the views where they appear as circles according to the Osborne Code, as shown in Fig. 41. An open circle of the diameter of the rivet *head* indicates a shop rivet, and a circle of the diameter of the rivet *hole*, but filled solidly, represents a hole for a field rivet. The diameter of the rivet hole is $\frac{1}{16}''$ greater than the diameter of the shank of the rivet (page 21), while the diameter of the head is as given in the handbook. The draftsman can usually estimate the sizes of the circles closely enough when drawing to an ordinary scale; but he should be particular to show a contrast in size between a shop rivet and a hole, and to fill in the hole. It is well to remember that for a rivet of a given size the diameter of the circle for a shop rivet is approximately *one and one-half* times as large as the diameter of the circle for a field rivet.

After making a sample circle preparatory to drawing a large number of rivets, the beginner should measure the diameter to see whether it is approximately to scale; in fact, this test is so quickly made that an experienced draftsman can often apply it to advantage, particularly when drawing to a small scale.

Other views of rivets and holes are shown only when an extra view may be avoided or the drawing may be made clearer thereby. In general the side or the sectional view of a hole for a field rivet is a rectangle filled in solid. A line or open rectangle represents the shank of a shop rivet to which are added semicircular heads. See *S*1, Fig. 185. When shop rivets are countersunk, cross lines are drawn perpendicularly to each other at

45° with the rivet lines. If countersunk on the *near* side (outside) the lines are only *outside* the circle, and if countersunk on the *far* side (inside) the lines are *inside*. Similarly the lines extend outside and inside if countersunk on both sides. To show this distinction in field rivets, auxiliary circles must be placed outside the others. Flattened rivets are indicated by lines which slope in one direction only. The number of sloping lines shows the height of the rivet head in eighths of an inch, i.e., three lines for $\frac{3}{8}''$ and two lines for $\frac{1}{4}''$. Rivets flattened to $\frac{1}{8}''$ would be useless but they may be countersunk without being chipped after they are driven; they will then not project more than $\frac{1}{8}''$. In order to insure the detection of countersunk or flattened rivets, notes are often added to supplement the code, especially when the rivets are in unusual places, as for example: "Rivets countersunk far side but not chipped," "Rivets countersunk and chipped both sides," or "Rivets flattened to $\frac{1}{4}''$ near side." Such notes are omitted on shoe plates and column bases, or wherever rivets are usually countersunk, provided that they are clearly indi-

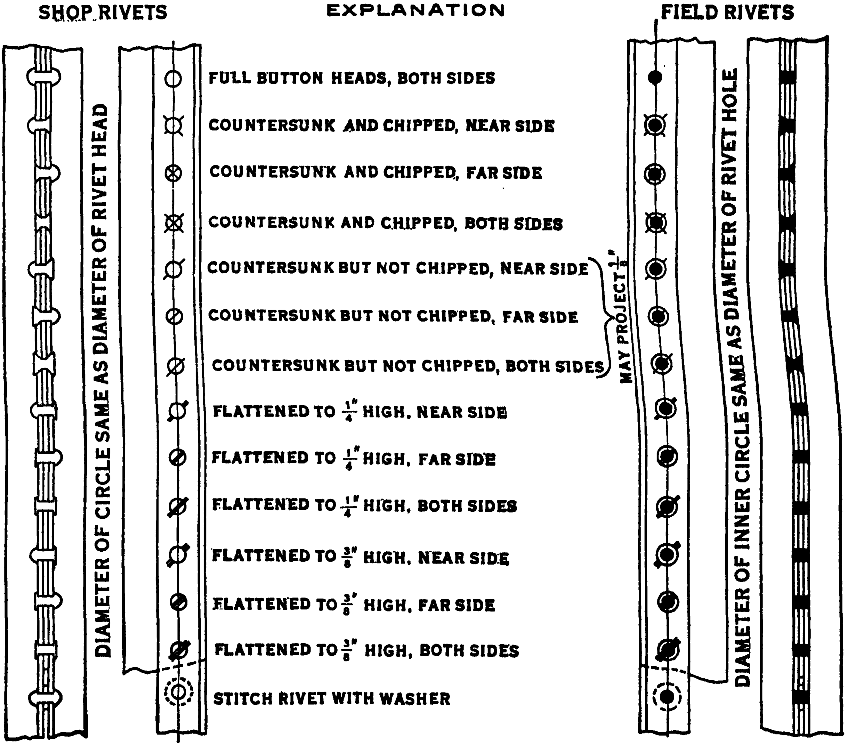


Fig. 41. Rivet Code.

cated. Rivets should never be countersunk in metal thinner than the thickness of the countersunk head as shown in the handbook. Rivets should be made on an inked drawing with a bow-pen or riveter, as explained on page 71, but most draftsmen can make freehand circles in pencil which are sufficiently accurate.

82. All holes for field rivets **are** usually **shown,** except in plate work or other work which requires a large number of field rivets, the position of which can be clearly indicated. All shop rivets should be shown in small connections and in all doubtful places, but some may be omitted when in large numbers if no ambiguity is likely to result. A short line crossing the rivet line is often used to indicate the center of a rivet. When shop rivets are dimensioned in a group (page 57), the rivets at the ends of the group are shown, but most of the intermediate ones may be omitted; it is well to indicate one space at each end of the group by means of a rivet or a cross line in order to emphasize the presence of intermediate rivets.

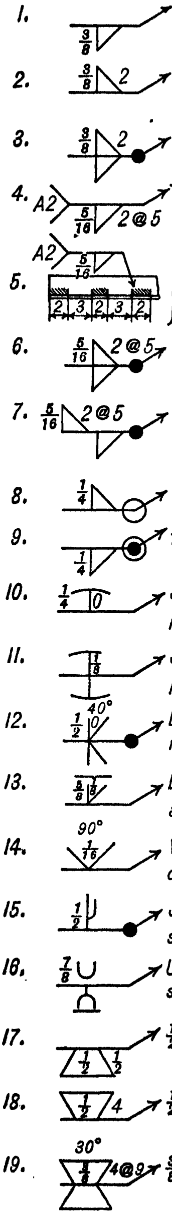
83. Shop bolts are indicated by small squares as illustrated in Fig. 185, regardless of whether the heads and nuts are to be square or hexagonal. Sometimes simply the holes for the bolts are indicated in the same way as holes for field rivets, whether the bolts are to be inserted in the shop or in the field. Shop rivets should never be shown where bolts are to be used. Bolts which are put in place permanently in the shop should be billed and noted on the drawing (page 77).

84. Fusion welds are usually not shown in position, but they are indicated on the drawing by notes in accordance with special symbols adopted by the American Welding Society. The basis is a fine-line bent arrow pointing to the junction of the parts to be welded. Along the arrow are placed symbols to show the kind of weld, the size and the length in inches, and other data; these are placed below the line if the weld is on the near side, above the line if on the far side, and above and below if on both sides, but only the symbol need be repeated when the dimensions are the same. If all the welds on a drawing are the same size, this fact may be stated in a general note near the title to obviate the necessity of giving the size of each weld. Similarly, if all the welds are to be made in accordance with the same specifications or standards, this fact may be covered in a general note; if a special clause applies to any weld, however, the reference should be placed in a V-tail added to the arrow. A straight line outside the symbol signifies that a weld is to be made flush, even though this requires chipping. A field weld is indicated by placing a small filled-in circle at the bend in the arrow. A larger open circle indicates that a detail is welded all around. If it is desired to show the extent of each weld, crosshatching may be used with definite ends, with or without dimension lines. The typical combinations of symbols shown with explanations in Fig. 43 suggest

WELDING CODE

American Welding Society

SYMBOL SIGNIFICANCE



1. $\frac{3}{8}''$ fillet shop weld, continuous, near side

2. $\frac{3}{8}''$ fillet shop weld 2" long, far side

3. $\frac{3}{8}''$ fillet field weld 2" long, both sides

4., 5. $\frac{5}{16}''$ fillet shop weld, with 2" increments spaced 5" c. to c., near side. Specification clause A2

6. $\frac{5}{16}''$ fillet field weld with 2" increments spaced 5" c. to c., both sides, opposite.

7. $\frac{5}{16}''$ fillet field weld with 2" increments spaced 5" c. to c., both sides, staggered, the 5" referring to the welds on one side only.

8. $\frac{1}{4}''$ fillet shop weld, far side, welded all around.

9. $\frac{1}{4}''$ fillet field weld, near side, welded all around.

10. Square-butt shop weld, $\frac{1}{4}''$ penetration, with no root opening between plates, far side.

11. Square-butt shop weld, full penetration, with $\frac{1}{8}''$ root opening between plates, both sides.

12. Bevel-grooved, $\frac{1}{2}''$ groove before welding, field weld, 40° (special) angle, no root opening, both sides.

13. Bevel-grooved, $\frac{5}{8}''$ groove before welding, shop weld, user's standard angle, $\frac{1}{8}''$ root opening, far side, finished flush.

14. V-grooved, shop weld, full penetration, 90° (special) angle, $\frac{1}{16}$ root opening, far side.

15. J-grooved, $\frac{1}{2}''$ groove before welding, field weld, far side, user's standard shape, incomplete penetration.

16. U-grooved, $\frac{7}{8}''$ groove before welding, shop weld, both sides, user's standard shape, incomplete penetration, finished flush.

17. $\frac{1}{2}''$ round plug weld, near side, user's standard.

18. $\frac{1}{2}''$ slot weld, 4" long, far side, user's standard.

19. $\frac{3}{8}''$ slot weld, 4" increments, 9" c. to c., both sides, 30° angle of bevel.

Fig. 43.

how the welding code is built up.* The serial numbers at the left are added for convenient reference only. Further illustrations are given in Figs. 128 and 138.

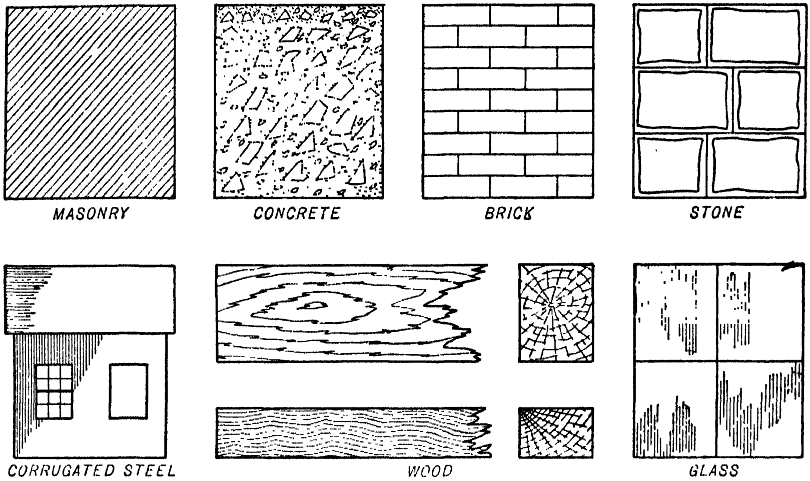


Fig. 44. Conventional Representations.

85. Other Materials. It is sometimes convenient to represent materials other than steel according to standard conventions. The more common conventions for this class of work are as shown in Fig. 44.

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* For further details, see the "Welding Handbook," American Welding Society, New York, or "Procedure Handbook of Arc Welding," Lincoln Electric Company Cleveland, Ohio.

CHAPTER VI

CONVENTIONAL METHODS OF BILLING

86. Billing. The size or description of each component part of any member should be expressed or " billed " on or near the principal view of that part. When two or more identical (or opposite) pieces occur together they may be billed together, but the number of pieces should indicate the number required at only one point of a single member. The object of billing is to show the commercial shape from which the part is to be cut, and the length of such shape required. The methods of billing must conform to the usual practice and indicate the commercial shapes in the same way that they are listed in the handbook. The bill of material serves as the " name " of a piece, not only upon the drawing, the order bill, and the shop bill, but also upon the steel itself; it is painted upon the steel at the rolling mill as soon as the steel is cut to the ordered length, and it is used for identification until the piece is placed in its final position in the structure, or until it is assembled with other pieces to form a member which is subsequently identified by means of a shipping mark (page 106). At the mill, the contract number as well as the bill of material is painted on the steel. If the material is recut in the shop to shorter lengths, the contract number and the revised bill are painted on each piece, along with the shipping mark and the assembling mark, if any (page 110). Similarly, the templets are marked to correspond. After a member is assembled and riveted it is painted before it is shipped; the contract number and the shipping mark are left uncovered or are repainted for use during shipment and erection. When shop bills are printed on the sheets with the detailed drawings, it may not be necessary to bill the pieces on the drawing, particularly when assembling marks are used; the assembling marks appear on the drawings as well as the shop bills and serve to identify the material.

87. Certain abbreviations and **conventional signs** are used in billing, as shown in the following paragraphs. The multiplication sign (×) is used simply to distinguish the different dimensions. It is read " by "; thus $8 \times \frac{1}{2} \times 12'\text{-}0''$ is read " eight *by* one-half *by* twelve feet, no inches." Similarly, the sign " # " is used for " pounds," " #/ft." for " pounds per foot " and " #/yd." for " pounds per yard." In billing, the " per foot " and often the " per yard " are omitted. The size of the cross section is expressed in inches in *billing*, even if over one foot. The length is the extreme distance at right angles to the other figures; a length of 1′-0″ or over is expressed in feet and inches, while a length less than one foot may be written in inches alone, unless it seems clearer to prefix the 0′ thus: 0′-10″. See the illustrations below. The conventional methods of billing the common structural shapes follow:

88. Plates:

Number:	Pl. (or Pls.):	width:	thickness:	length
(pieces)		(inches)	(inches)	(feet and inches)

Thus: 1 Pl. $8 \times \frac{1}{2} \times 10$, or 14 Pls. $24 \times \frac{5}{8} \times 9'\text{-}10\frac{1}{4}''$.

The width and thickness indicate the cross section of the stock from which the plate is cut, and the length the amount cut off. The width is preferably a multiple of one inch, and the widths of small plates taken from stock should conform to stock sizes. Usually the width is the smaller dimension, but this may be reversed if the longer dimension may be made a stock width more conveniently. Diagonal cuts should extend across the full width when practicable so that material may be saved by cutting several plates as shown in Fig. 46. When plates are used as fillers, the Pl. or Pls. may be replaced by Fill. or Fills. For other special abbreviations used in plate work see page 50.

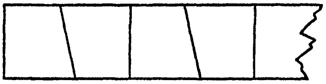

Fig. 46.

89. Angles:

Number:	L (or Ls):	longer leg:	shorter leg:	thickness:	length
(pieces)		(inches)	(inches)	(inches)	(feet and inches)

Thus: 1 L $6 \times 4 \times \frac{1}{2} \times 7\frac{1}{2}$, or 12 Ls $3 \times 2\frac{1}{2} \times \frac{5}{16} \times 10'\text{-}6''$.

In the offices of some companies, the angle sign (L) is placed after the thickness, thus: $8\text{–}5 \times 3\frac{1}{2} \times \frac{5}{8}$ Ls–18′-3″. For special abbreviations used for angles see page 50.

90. Wide-flanged beams:

Number:	depth:	WF:	weight:	length
(pieces)	(inches)		(pounds per foot)	(feet and inches)

Thus: 1–12″ WF 28# 20′-0″, or 3–30″ WF 172# 31′-7½″, or without the ″ and # thus: 1–12 WF 28 × 20′-0″.

The symbol WF is general for wide-flanged beams rolled by any steel company; when it is known that steel is to be ordered from a specific mill, a more definite symbol may be used instead, as B for beams rolled by the Bethlehem Steel Company or CB for beams rolled by the Carnegie-Illinois Steel Corporation, or it may be omitted altogether.

91. I-beams:

Number:	depth:	I (or Is):	weight:	length
(pieces)	(inches)		(pounds per foot)	(feet and inches)

Thus: 1–12″ I 31.8# 18′-0″, 2–15″ Is 42.9# 25′-7½″, or 1–12 I 31.8 × 18′-0″.

92. Channels:

Number:	depth:	$\sqcup$ (or $\sqcup_{s}$):	weight:	length
(pieces)	(inches)		(pounds per foot)	(feet and inches)

Thus: 1–12″ $\sqcup$ 20.7# 12′-10″, 7–8″ $\sqcup_{s}$ 11.5# 15′-11½″, or 1–12 $\sqcup$ 20.7 × 12′-10″.

A special interpretation is given to the channel sign on floor plans, it being made as indicated above or inverted according to which way the flanges face.

93. Structural Tees:

Number:	ST:	depth:	WF:	weight:	length
(pieces)		(inches)		(pounds per foot)	(feet and inches)

Thus: 1 ST 5″ WF 10.5# 36′-7¼″ 4 ST 8″ WF 29# 24′-3″, or 1 ST 5 WF 10.5 × 36′-7¼″.

The ST designates structural tee (or BT for Bethlehem structural tee), the WF indicates that it is cut from a wide-flanged beam, but the depth and the weight are for the tee and are taken as one-half the corresponding depth and weight of the beam.

94. Rods:

Number:	diameter or side:	$^{\phi}$ or $^{\square}$:	rod (or rods):	length
(pieces)	(inches)			(feet and inches)

Thus: 1–¾$''^{\phi}$ rod 12′-0″, or 10-1$''^{\square}$ rods 11′-0¾″.

Note that a circle with a line through it ($^{\phi}$) is used for round rods and a square ($^{\square}$) for square rods.

95. Tees:

Number:	T (or Ts):	width of flange:	length of stem:	weight:	length
(pieces)		(inches)	(inches)	(pounds per foot)	(feet and inches)

Thus: 1 T 3 × 3½ × 8.6# × 12′-11″, or 3 Ts 4 × 3 × 9.3# × 13′-2″.

Note the distinction between a 3 × 3½ (3″ flange) and a 3½ × 3 (3″ stem), etc.

96. Z-bars:

Number:	Z (or Zs):	depth:	width of flanges:	thickness:	length
(pieces)		(inches)	(inches)	(inches)	(feet and inches)

Thus: 1 Z 6 × 3½ × $\frac{9}{16}$ × 8′-3¾″, or 4 Zs $3\frac{1}{16}$ × 2¾ × $\frac{5}{16}$ × 17′-0″.

97. Rails:

Number: Rail (or Rails): weight: standard: length
(pieces) (pounds per yard) (feet and inches)

Thus: 1 Rail 85 #/yd. A.S.C.E. 20′-0″, or 16 Rails 131 #/yd. A.R.E.A. 39′-0″. Note that the weights of rails are given in pounds per *yard*, instead of pounds per foot as for other shapes; for this reason it is preferable to write the weight as above, although the " #/yd." is often written simply #. The standards of the American Society of Civil Engineers, the American Railway Engineering Association, and the American Railway Association are in common use. The usual length is 39′, but other lengths are used.

98. Eyebars:

Number : eyebar (or eyebars) : width of main bar : thickness : length c. to c. of holes
(pieces) (inches) (inches) (feet and inches)

Thus: 1 eyebar 14 × 1 × 15′-0″ c. to c. of holes, or 2 eyebars 8 × ¾ × 12′-0″ c. to c. of holes.

Note that the lengths of eyebars are given from center to center of pin holes instead of the extreme length.

Eyebars are connected by means of pins. The distances from center to center of pins are calculated, and the eyebars should be made to correspond. The heads of the eyebars are upset while hot, and the holes are then subpunched, i.e., punched to a smaller diameter than the required size. Two boring machines are carefully set so that the finished holes at both ends of a bar can be bored simultaneously at the exact specified distance apart. The overall length is therefore relatively unimportant.

99. Lattice bars:

Number: Latt. bars: width: thickness: length c. to c. of holes
(pieces) (inches) (inches) (feet and inches)

Thus: 22 Latt. bars 2¼ × ¼ × 1′-2⅜″ c. to c.

Note that the lengths of lattice bars are given from center to center of rivet holes. Since this is not in accord with the method of billing other material, the lengths should always be followed by " c. to c."

The distance center to center of holes is much more important than the extreme length in order to insure an accurate matching of the holes. Furthermore, this distance is used in setting the adjustable stop in a special lattice-bar punch. This machine cuts out the material between the curved ends of two bars and punches the holes in these ends simultaneously according to standard dies. As the bar is advanced to the adjustable stop and punched again, a complete lattice bar is made at a single stroke.

100. Washers:

Number:	diameter:	thickness:	◎
(pieces)	(inches)	(inches)	

Thus: $4\text{–}2\frac{1}{4} \times \frac{1}{4}$ ◎.

101. Rivets:

Number:	diameter:	rivet (or rivets):	length
(pieces)	(inches)		(inches)

Thus: $450\text{–}\frac{3}{4}''$ rivets $1\frac{1}{2}''$ long.

If rivets have countersunk heads the fact should be stated. The diameter of a rivet is the diameter of its shank (page 21). The length of a button-head rivet is from the underside of the head to the end. The length of a countersunk rivet is the extreme length, including the thickness of the head. The number and the lengths of rivets are seldom specified except on the rivet lists from which the field rivets are made and shipped. The size of shop rivets is given on structural drawings thus: Rivets $\frac{3}{4}''$.

102. Bolts:

Number:	bolt (or bolts):	diameter:	length
(pieces)		(inches)	(feet and inches)

Thus: 2 bolts $\frac{1}{2} \times 2$, or 4 bolts $1'' \times 1'\text{-}3''$ lg.

If a bolt has a countersunk head the fact should be stated. The diameter of a bolt is the diameter of its shank. The length of an ordinary bolt is from the underside of the head to the end. The length of a countersunk bolt is the extreme length, including the thickness of the head. The thickness of the nut is equal to the diameter of the bolt, and the bolt should protrude enough to fully develop the thread. Bolts less than 8″ in length are in multiples of $\frac{1}{4}''$, longer ones in multiples of $\frac{1}{2}''$.

Special Dardelet " Rivet-bolts " are also used.

103. Holes:

Diameter:	hole (or holes)
(inches)	

Thus: $\frac{13}{16}''$ holes.

Rivet holes are made $\frac{1}{16}''$ larger than the diameter of the rivets to be inserted. Most bolt holes in structural work are made $\frac{1}{16}''$ larger than the corresponding bolts except holes for anchor bolts, turned bolts, or special bolts. The size of holes is given on structural drawings thus: Holes $\frac{13}{16}''$.

104. Welds: see page 42.

105. Special abbreviations may be used for plates and angles to aid in identification, as for example:

Bear. Pl. for bearing plate.
Bent Pl. for bent plate.
Cov. Pl. for cover plate.
Fill. for filler.
Fl. Pl. for floor plate.
Reinf. Pl. for reinforcing plate.
Spl. Pl. for splice plate.
Web. Pl. or Web for web plate.
Flge. L. for flange angle.
Spl. L. for splice angle.
Stiff. L. or Stiff. for stiffening angle.

CHAPTER VII

CONVENTIONAL METHODS OF DIMENSIONING

106. In this book a distinction is made between the terms "**dimension**" and "**size.**" "Dimension" implies the use of a dimension line upon which the dimension is written, whereas the "size" applies to the figures which are used in billing (Chapter VI, page 45), and may refer to the depth, the width, the thickness, the weight, the length, or to various combinations of them.

107. The dimensions form one of the principal parts of the working drawing. The shopmen and the draftsmen who use the finished drawings are never permitted to scale them, but must always use the figured dimensions. Oftentimes a draftsman corrects his mistakes or modifies a drawing on account of changes in design by simply changing dimensions; this means that the resulting drawing is not to scale even though it might have been when drawn. It is therefore important that all dimensions should be accurate, and the extent of each dimension should be apparent. A dimension is worthless unless it is of some use, unless it is perfectly legible, and unless there is no ambiguity regarding the two points between which it is intended to extend.

108. Dimensions should indicate the **actual measurements** of the piece represented, regardless of the scale used in the drawing.

109. The dimensions should be **placed upon the drawing as soon as determined,** while fresh in mind. The dimensions should usually be determined in the order of importance, the main dimensions first, and those for the details last. The main dimensions for a drawing are generally determined from the erection diagrams or the design sheets, while the dimensions for the details are found in the handbook or the standards of the different steel or structural companies, or else they are supplied by the draftsman.

110. Position. Each dimension should be placed upon the drawing in such a manner that it will be of most use to those who read the drawing. The principal dimension should be made conspicuous by being placed upon a dimension line which intersects the fewest possible number of other lines. Thus the longest dimensions, such as overall lengths and extreme depths, should be placed on dimension lines which are farthest from the views to which these dimensions apply (usually the front views), and the shorter dimensions, such as those for rivet spacing and other subdivisions, should be on dimension lines nearest the views. In this way the lines for long dimensions are not crossed by the perpendicular projection lines which mark the ends of shorter dimensions. When there are several dimension lines close together, it is often desirable to make the figures of the principal dimension larger and bolder than the rest.

111. Dimension lines should be continuous black lines, as fine as practicable without appearing ragged (page 33). They should be drawn parallel to the measurements to be dimensioned, and should extend between projection lines drawn at right angles to the dimension lines to indicate the distances intended. In some complicated drawings, the parallel projection lines may be drawn at other than right angles if the drawing is clarified, but this practice is not recommended.

112. Dimension lines should usually be placed **outside of the view** dimensioned, and preferably *between* the views if more than one. At times, however, a few dimensions may be placed in a clear part of the view itself if space or clearness is gained thereby.

113. Dimension lines are usually placed about $\frac{5}{16}''$ apart, although this may be reduced to $\frac{1}{4}''$ or $\frac{3}{16}''$ if the available space is limited. The distance from the view to the nearest dimension line is made twice the **space between dimension lines,** unless it must be increased to allow for projecting details, or for other, shorter dimension lines. This double space makes the drawing stand out better and also allows for the insertion of gages, edge distances, or notes without crowding.

114. Arrow heads should be placed on the dimension lines to indicate the extent of the dimensions. They should be made definite; otherwise the dimensions are useless. The size and the style of arrow heads depend upon their location. For main overall dimensions they may be made large and bold, as in Fig. 52 (*a*). Flat curved arrow heads appear more graceful and may be used wherever there can be no ambiguity, Fig. 52 (*b*), but when a dimension extends to one of two lines which are close together, the arrow heads should be made short and wide, so that the vertex is distinct. See Fig. 52 (*c*). They should not be made large when close together. Arrow heads generally point away from the dimension figures, but in narrow spaces they may be reversed. See Fig. 52 (*d*). A dimension extends from the vertex of one arrow head to the vertex of the first arrow head in the opposite direction. Usually only one dimension is placed between these arrow heads and this should be placed midway between them (except extension figures, page 60).

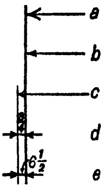

Fig. 52.

115. Dimension figures should be made large and distinct. Words if illegible can sometimes be guessed, but figures never. Each digit should be carefully drawn or printed, not hastily made as in computation. Beginners have a tendency to make the figures too small or with too thin lines; they appear still thinner if not entirely illegible on the blueprint, especially in the shop where the lighting is not so good as in the drafting room. Figures should be placed in clear spaces and not superimposed upon any lines of the drawing, even the dimension lines; the new superimposed figures may seem clear to the draftsman but on the blueprints they are obscured, in fact the lines may alter the figures definitely so that a cipher is read as 8, 7 as 4, 3 as 5, etc. Simple figures should be made; curves should be avoided where straight lines can be used, thus:

1 not *1*, *2* not *2*, *3* not *3*, *4* not *4*, *5* not *5*.

116. Dimension figures should usually be placed just **above the dimension lines.** This practice differs from the system employed in machine drawing, where the figures are placed in breaks in the lines. In structural drafting it is much simpler to draw the dimension lines full length and then subdivide them into the required number of parts at will, than it is to attempt to leave breaks for the dimensions. This is particularly true when the number of dimensions is large and it would be entirely impracticable to leave spaces; in fact, some spaces are so small that there would be no dimension line left. It would be even worse to superimpose the dimensions on the line, for reasons explained in the preceding paragraph. Dimensions should never be placed upon lines which are used for other purposes, as for example, main lines of the drawing, center lines, rivet lines, or projection lines for dimensions at right angles to the ones in question.

117. Fractions should be made with the lines horizontal, *never* inclined. Thus, not only is space economized, and the general appearance of the drawing improved, but many serious mistakes are obviated; for example, *11/16* might be either eleven-sixteenths or one and one-sixteenth. Some draftsmen omit the fraction lines altogether, as in Fig. 134, and when one figure is written directly above the other there should be no ambiguity. The figures of fractions should be nearly as large as the whole numbers, instead of one-half as high. If a figure of a whole number should be of a certain size to be clearly legible, it is equally important that each figure of a fraction should be of this size.

118. Mistakes. If a wrong figure is made it should be **erased** entirely and a correct figure should be made in its place. A correct figure should never be superimposed on an incorrect figure, even if made heavier, for the man in the shop may not know which is correct; neither should the

first figure be crossed out and a new one written above it. This is contrary to the usual practice in keeping field notes in surveying, in which a line is drawn through an incorrect measurement and the correct value written just above. In surveying this indicates to the man who plots the notes that the measurement was repeated, which fact may prove of value when the notes are adjusted. In structural work the drawings are used only by men who are interested in the correct values, and nothing can be gained by exposing the draftsman's mistakes.

119. When the **space between the arrow heads is so limited** that the dimension figures cannot be placed on the drawing in the usual manner, it is frequently possible to compress the figures laterally without reducing their height, thus making little apparent alteration, as shown in Fig. 52 (*d*). If this method cannot be adopted the figures can be placed either below the line between the arrow heads, or else a little to one side. The significance of a dimension written just outside of the space, as in Fig. 52 (*e*) is perfectly obvious without the "lead arrow" shown, and its use is not recommended when it can be avoided. These points cannot be well illustrated in the drawings of this book because of the necessary reduction to page size and because of the type figures used in reproduction. In all cases the figures should be made parallel to the dimension lines.

120. All figures and notes should be arranged so that they can be **read from the bottom edge or from the right-hand edge** of the sheet, or from a position between the two; i.e., the lettering should read from the left toward the right or from the bottom toward the top. Draftsmen soon become so familiar with figures and notes in these positions that they can read them all without turning the sheet. On lines which slope upward to the left and downward to the right, particularly on lines which are more nearly vertical than horizontal, the direction of the lettering is not so rigidly determined by a general rule but is left to the judgment of the draftsman. If the sloping dimensions of a member are used in conjunction with vertical dimensions more than with horizontal ones, it is often more convenient to have the figures read from the bottom toward the top; otherwise, it is better to print them from the left toward the right so that they can be read from the bottom of the sheet without turning the drawing.

121. All dimensions should be expressed in **feet and inches** and fractions of inches. The fractions should be reduced to the simplest form thus: $\frac{3}{4}$ *not* $\frac{12}{16}$. Usually no dimension should be used in structural drafting which is not a multiple of one-sixteenth of an inch; in fact, it is desirable to avoid fractions in sixteenths wherever possible, as explained on page 29.

122. Decimals should be avoided in dimensions. Decimals from the handbook should be converted into fractions, either by means of a table or mentally. Approximately, $0.06 = \frac{1}{16}$, and this gives the correct result if referred to the nearest quarter of an inch, as for example: 0.81 is 0.06 more than 0.75, hence $\frac{1}{16} + \frac{3}{4} = \frac{13}{16}$; and 0.19 is 0.06 less than 0.25, hence $\frac{1}{4} - \frac{1}{16} = \frac{3}{16}$. If a web thickness given in decimal form should fall midway between sixteenths, the higher sixteenth is usually chosen in dimensioning to allow for "packing," since paint, scale, bends, etc., may not permit the surfaces of two pieces to be brought into perfect contact. The tables usually express the web thicknesses in both decimal and fractional forms.

123. The abbreviations "ft." and "ins." are not used in dimensioning. A single accent mark (′) represents feet, and a double accent (″) inches. Dimensions less than one foot are usually expressed in inches alone, but to avoid ambiguity dimensions of one foot or over (even if even feet) should show both feet and inches with hyphens between; the hyphen is relatively unimportant, however, and may be omitted.

Note: The width of a plate is given in inches when *billed* (page 46), whether more or less than 12″, but when given as a dimension with a dimension line it is expressed in feet and inches if 1′-0″ or over. Hence it is no exception to the general rule.

The inch marks (″) of dimensions less than one foot may often be omitted, provided that there can be no doubt as to the meaning; but the inch marks should be used whenever the drawing can be made clearer thereby. The correct **method of writing dimension figures** can best be shown by examples, as follows:

CORRECT		INCORRECT
½	not	0½
2″ or 6½	not	0′-2″ or 0′-6½″
1′-0″	not	1′ or 12″
2′-0″	not	2′
3′-4¼″	not	3′-04¼″
4′-0¾″	not	4′-¾″ or 4′-00¾″

124. Recurring Dimensions. Ditto marks (") should never be used in place of dimensions. The use of arrows leading from one figure to two or more spaces should be avoided. Like dimensions should be repeated at every occurrence, unless grouped as explained on page 57. Ditto marks are sometimes used for words, and the abbreviation "do" for ditto is used on plans to save repeating the sizes of beams or other members.

125. A dimension which is clearly given in one view **should not be repeated** in another, for it usually complicates the drawing unnecessarily, and causes trouble if one is changed.

126. Rivets and **holes** should be located by dimensions which extend to their centers. They should be dimensioned in the views which show them as circles, although exceptions to this rule are occasionally allowed in order to dispense with additional views (page 155). "Staggered rivets," i.e., rivets which alternate on two lines, should be dimensioned, not diagonally, but parallel to the rivet lines as if the rivets were on a single line. See Fig. 56.

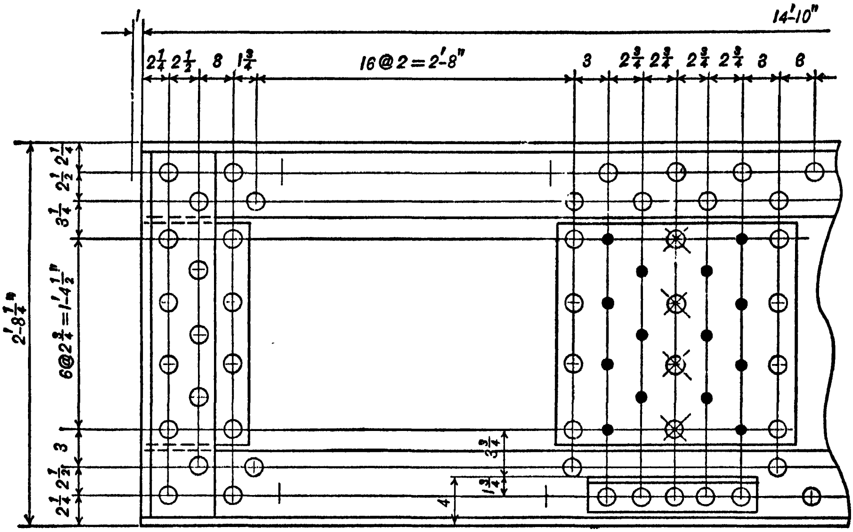

Fig. 56.

127. The standard **gages** of all structural shapes are given in the handbook. Normally these are used as given, especially when single. On many occasions special gages are used, however, especially in pairs, as for example in the flanges of girders or columns, or in connection angles, where special gages in the angles are used in order to make even figures from center to center of rivet lines, as illustrated in later chapters. The gages should always be dimensioned, whether standard or not, except in some latticed members (page 165). Gages are usually given on separate dimension lines rather than on other lines where they would interrupt continuous rivet spacing.

128. The majority of **edge distances** are omitted unless they are important. For example, a dimension should be given in order to limit an edge distance to provide ample clearance for a connecting part (page 98), or to tie a group of rivets to an important edge to which a main dimension extends (Fig. 190). But if a connection plate or angle, or a web member of a truss, is shown without edge distances, the shopmen will make the distances on opposite edges equal; with this understanding many dimensions may be omitted.

129. A line of rivet spacing should be confined to dimensions from center to center of rivets and holes, except at the ends where it is frequently necessary to give the distance from the first rivet to the end of the member or to some other definite point. Intermediate edge distances and gages should never be given on the same line, because they are not used at the same time; they should be shown as separate dimensions, usually between the line of rivet spacing and the corresponding view of the member. See Fig. 127.

130. Dimensions should never be given to the **edges of the flanges** of structural shapes, but always to the backs of channels and angles, to the center lines of beams, and similarly for other shapes. The back of an angle or a channel is a well-defined line, but the outside edges are not so well defined. More important than this, however, is the fact that the lengths of legs and the widths of flanges are frequently different from what they are supposed to be owing to the spreading or the wearing of the rolls. As a rule, such variation is of no consequence in structural work, but it should be considered, particularly in the case of thick angles (page 11). For illustration, suppose that a girder is composed of a ⅜″ web plate and 6 × 4 angles. The total width of each flange is theoretically 1′-0⅜″, but if the angles should "overrun," as they are likely to, the width would be more. Ordinarily this increase would not matter, and for this reason the dimension should not be given; if the extreme width is limited by the clear distance between column flanges or for other reasons, the dimensions should be given with the understanding that, in the event of overrun, the outside edges of the angles would have to be planed — a process too expensive to be used unnecessarily.

It is unnecessary to give the widths of flanges or the dimensions of fillets and other curves which apply to the manufacture of the steel rather than to the fabrication. It should be borne in mind that the drawings are to be used for the purpose of putting standard shapes together, and therefore many dimensions may be superfluous unless they are directly related to shearing, bending, punching, riveting, or similar processes.

When an angle with unequal legs is represented in only one view it is often necessary to indicate which leg is shown. This may be noted as for example " 3″ leg," but more frequently the length of the leg is put on in the form of a dimension with the understanding that it is no more exact than the billed length and that the angle need not be cut in case of overrun.

131. When three or more spaces are numerically equal and serve similar purposes, they may be **dimensioned in a group,** thus: 5 @ 6 = 2′-6″, or 4 @ 1′-2″ = 4′-8″, or as some companies prefer, 5 of 6 = 2′-6″. If the rivets are staggered (page 56), the spaces are given just as if the rivets were on the same line, although the abbreviation " alt. spa." for " alternate spaces " is sometimes added, thus: 5 alt. spa. @ 6 = 2′-6″. When rivets are dimensioned in a group it is unnecessary to show all the rivets or all the spaces, unless to show positions of rivets or holes when the dimensions apply to more than one group; rivets should be shown on the projection lines at the ends of the group, and also an additional rivet at each end of the group (without a projection line) to call attention to the fact that there are intermediate rivets, but care should be taken when the rivets are staggered to show the proper rivets so that the shopmen can maintain the stagger when they insert the intermediate rivets. Arrow heads should be placed at the ends of the group only, for it would defeat the purpose to show subdivisions and intermediate arrows. Edge distances and gages should not be combined with distances from center to center of rivets, even though identical, but they should be dimensioned separately. In the same way it may be desirable to separate one or more of the spaces from a group if they serve purposes in addition to those served by the rest of the group, as for example the location of rivets in splice plates or fillers on a plate girder as well as spacing of flange rivets.

132. The rivets in the ends of the **lattice bars** of a single system of latticing are dimensioned in groups much as staggered rivets are dimensioned (page 56); each space is measured parallel to the axis of the member latticed, from the center of the rivet at one end of a bar to the center of the rivet at the other end. See Fig. 166. The method of dimensioning a double system of latticing is the same as for a single system, the rivet at the intersection of each pair of bars being shown but not dimensioned. See Fig. 174. For lattice bars with two rivets at each end, see Fig. 178.

133. When a long line of shop rivets and holes for field rivets are dimensioned in a single group, and the holes occur at such intervals that spaces must be counted to determine their location, **a supplementary dimension line** may be added for the holes only.

134. For **field connections** — connections of different members in the field — the dimensions on the drawing of one member should be given in exactly the same way as the corresponding dimensions on the drawing of the other member so that each person who uses the drawings may see at a glance that these dimensions do correspond.

135. If two or more lines of dimensions extend between the same points, **the sum of the dimensions** in each line should be the same as in the others. If a line of dimensions extends practically the whole length of a member it is well to complete it by adding one or more dimensions to afford a check with the overall length. This is of special benefit to the templet maker, who would otherwise have to procure his own total for a check.

CHECKING SUBDIVISIONS: Never complete a line of dimensions between two points without adding them to see that the sum equals the proper distance between those points. Neglect of this precaution is a source of much trouble.

136. Dimensions should be placed upon the drawing in such a manner that the **shopmen will not be compelled to add or subtract** dimensions in order to obtain the figures they need. For example, one hole in the connection angle on the flange face of column *C*5, Fig. 166, is tied to one rivet in the other leg (or else each could be tied to the same end of the angle); otherwise, the templet maker could not make the templet for the angle without finding the total distances from the rivet and from the hole to the bottom of the column and then subtracting these two sums. Similarly, the holes in the connection plate *pb* near the center of this same column are dimensioned independently of the rivets; a line is drawn, however, to show that the top holes and rivets are opposite.

137. No rivets or holes should be located by more than **one method of dimensioning.** They may be determined either by dimensions at right angles to each other (rectangular coordinates), or by "slopes and distances" (polar coordinates), the slopes of the rivet lines being indicated in the usual manner (see below) and the distances along these lines being given. A combination of these two methods is not only unnecessary but is likely to cause difficulty in the shop, for the points that coincide on a small layout in the drafting room might fall noticeably apart on the full-sized templet. In order to avoid ambiguity on the drawing, should a line which locates one rivet or hole happen to pass through another rivet or hole which is located in another way, the line should be made to pass around the second rivet or hole by means of an arc of a circle, as shown in Fig. 59 (*a*). Whether the drawing is made accurately to scale or whether the line would actually pass through the center or not is immaterial, the object of the arc being to show clearly that the line is independent of the second rivet or hole. A better method, wherever practicable, is to move one or both of the rivets or holes so that the projection line of one will clear the other rivet or hole, even though they are thrown slightly off scale.

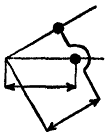

Fig. 59 (*a*).

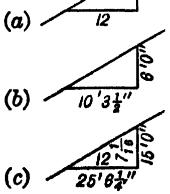

Fig. 59 (*b*).

138. The slope of a line, i.e., its "bevel," with reference to another line is given, as shown in (*a*) Fig. 59 (*b*), by indicating dimensions on two mutually perpendicular sides of a right triangle; the hypotenuse of this triangle is either coincident with or parallel to the line whose direction is to be given, and the other sides are respectively parallel and perpendicular to the reference line. The dimension on the longer perpendicular side is always 12″, while the corresponding dimension (in inches and fractions to the nearest $\frac{1}{16}$″) on the shorter side must be calculated. This shorter dimension is usually obtained directly from dimensions between working points, as explained on page 84, without the necessity of knowing the actual value of the angle. Angles are almost never given in degrees and minutes on structural drawings but the corresponding slopes are used.

A workman in the shop usually has no protractor for laying off angles, but he must work with a 2′ rule, a steel tape, or other device for laying off linear measurements, or else with a special instrument upon which angles can be set directly from the slope dimension.

Parts of trusses or bracing systems are often laid out on the floor of the templet shop from the main dimensions instead of on the bench, provided that the extreme dimensions do not exceed 30′ or 40′. If the dimensions between working points are not clearly shown on the drawing they may be given on the triangle without being reduced to a base of 12″, as shown in (*b*) Fig. 59 (*b*). The two schemes may be combined as in (*c*) Fig. 59 (*b*) in order to show the dimensions between working points for the convenience of the checker, and the corresponding reduced dimensions for use in the shop. This method may be used when a draftsman is in doubt whether the work will be laid out on the floor or on the bench.

139. "Extension figures" are used in certain classes of work to show cumulative dimensions from one end of a member to different connections, instead of distances from one connection to another. They are often of benefit to the shopmen and inspectors so that several small details may be located or checked with one setting of the tape, and they may prove helpful in the drafting room. Their use is illustrated on page 148 for beams and on page 164 for columns. Extension figures are not as a rule used for locating single holes such as holes for wood-bolts because these can usually be dimensioned to better advantage by group spacing (page 57) or by single dimensions from center to center.

140. Independent dimensions should be used for different views of a member; i.e., details on one face of a member should not be dimensioned from details on another face but should be referred to the ends of the member or to other definite points to which the principal dimension extends. If it seems desirable to tie the details on one face to those on another it should be done by means of supplementary dimensions, because the shopmen cannot conveniently measure from a point on one face to a point on another, particularly if there is an intervening flange or other obstacle.

141. For the methods of **dimensioning welds,** see page 43.

CHAPTER VIII

DRAFTING TECHNIQUE

142. Structural drawings are made primarily for use in the shop, and therefore accuracy, speed, and utility are of much greater importance than appearance. On the other hand, it is highly desirable that a drawing be neat, well arranged, and well executed, although not so important in this work as in map or architectural work. A good-looking drawing not only adds to the prestige of the draftsman but also gives to all who use it greater confidence in its accuracy. Most structural drawings are now made in pencil on tracing paper or a special kind of tracing cloth, but inked drawings are still used for complicated drawings, for drawings which are subjected to much handling, and for drawings from which it is desirable to obtain unusually sharp blueprints. Blueprints may be made satisfactorily from drawings penciled on tracing paper, and the original drawings of ordinary structural members are not handled enough to rub the pencil marks sufficiently to impair their usefulness. A penciled drawing on cloth may be made more serviceable by lacquering if desired.

143. Formerly, complete penciled drawings were made on paper and then traced by other men called **tracers.** These were usually apprentices, recent college graduates, or others of limited experience who were thus able to learn the usual conventions of the drafting room. Soon after a tracer became proficient he was allowed to make drawings himself, and his place was taken by a new tracer. In this manner it was difficult to keep the tracing up to the proper standard. It was poor economy to allow good men to spend valuable time on drawings, only to have some of the meaning and good appearance lost through careless tracing. If an inked drawing is required, it is much better for the draftsman to work directly upon tracing cloth, because many of the lines and most of the figures and notes can be made directly in ink.

144. A drawing must be carefully planned in advance if the whole or any part of it is to be drawn permanently in ink or pencil, in order to insure a good arrangement and to avoid crowding. The number of views and the number of dimension lines should be determined, and also the extreme dimensions of each view, including the main member and all projecting parts. If any sectional views are to be placed in breaks in other views, their positions should be anticipated to avoid erasing spaces for them later.

Excessive erasures on either tracing paper or cloth are likely to mar the appearance of the finished drawing; a draftsman should cultivate accuracy by strict attention to work. A preliminary layout may be drawn lightly in pencil, if necessary, to determine the position and extent of the principal lines, and then they can be repenciled, inked, or traced.

145. Tracing Paper and Tracing Cloth. Many suitable tracing papers are available, differing in surface, in toughness, in transparency, and in price. The style selected depends upon the draftsman, the company, and the class of work. Some prefer a plain white rag paper and some a treated vellum paper, but it is not so pleasant to work upon the surface of the latter although more distinct prints can be obtained from it. Special tracing cloths have been developed for pencil drawings which are superior to paper but cost several times as much; these tracing cloths take ink also, but do not withstand so much erasing as the old standard cloths. Both types of cloth may be obtained with both sides dull or with one side glazed. Books of sample papers and cloths may be obtained from the dealers or makers.* Tracing paper or tracing cloth should be handled with care and should not be folded or creased or allowed to become wet, lest permanent lines or spots render it unsuitable for inking or blueprinting.

146. The dull or unglazed side of tracing cloth is used both for pencil and for ink. The glazed side does not take pencil lines, does not ink so well or so permanently, and shows erasures more, especially when several erasures are made in one place; tracings inked on the glazed side are not so easily handled or filed because they are more likely to curl.

147. Before the cloth is stretched, **the selvage edges** should be torn off. These edges are woven with the threads closer together than in the body of the cloth, and are not so susceptible to atmospheric changes. Unless they are removed, the cloth is likely to pucker from one day to the next, particularly if there is a noticeable change in the amount of moisture in the air. It is often impossible to restretch the cloth flat until the selvage is removed, and at times it is difficult to do so at all; hence it is important to remove the selvage before the cloth is first stretched. Since the threads are parallel to the edges, the selvage may be torn off without difficulty, provided that reasonable care is exercised to prevent the cloth from tearing at right angles to the desired direction. The width of the strip to be removed is usually apparent, and varies from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch with the different makes of cloth. Enough should be removed to eliminate all the puckers and to leave the cloth perfectly flat.

148. A sheet of clean **paper** should be **placed underneath** the tracing cloth or tracing paper before a drawing is started; the paper makes the

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* For example, Charles Bruning Company, Boston, Massachusetts, Keuffel & Esser Company, Hoboken, New Jersey, or the Frederick Post Company, Chicago, Illinois.

lines more distinctly visible and also covers the thumbtack holes and other holes in the board so that there is less danger of holes being punched through by the pencil.

149. The paper or cloth should be **tightly stretched** and held in place by four or more tacks. Thumbtacks are usually employed, but some draftsmen prefer small upholsterers' tacks driven with a hammer, for although they are harder to remove they do not interfere with the use of the T-square or triangles. Some use gummed tape across the corners, but in humid weather this is likely to become sticky. The paper or cloth should be enough larger than the finished drawing so that the tack holes may be removed when the sheet is trimmed to the proper size.

150. Before beginning to ink, the draftsman should make sure that **the surface of the cloth** is in condition to receive the ink properly. This may be ascertained by trial on a small piece of the same cloth, upon the margin of the sheet, or even upon one of the lines of the drawing itself. Some of the better grades of cloth will often " take " ink without treatment, and it is preferable to use it that way. Often the surface is slightly oily and the lines appear ragged. The common method of overcoming this disadvantage is to sprinkle over the cloth a specially prepared tracing-cloth powder and rub it in with a clean cloth, removing the excess to prevent the clogging of the pen; if too much powder remains, much of the ink falls upon it rather than upon the cloth, and the lines easily wear away. When the effect of the oil is not very apparent, it may be removed with a sponge eraser; this often makes a better surface to work upon. The surface of the cloth should be kept clean, all lint, dust, and pieces of eraser being brushed off as often as necessary.

151. **Special pencils** have been developed which give distinct lines for blueprinting and still do not smear as much as the ordinary grades of drawing pencil.* Instead of sharpening pencils as they wear down, it is better to keep several different pencils sharpened and change from one to another as they wear. It is distracting to interrupt the work frequently for sharpening pencils. The degree of hardness depends upon the draftsman and upon the surface of the paper or cloth. The finer lines are usually made with a harder pencil than the wider main lines of the drawing, but rather than use a pencil so soft that the lines smear, it may be better to use the same grade with a blunter point. In general it is not so satisfactory to attempt to make the wider lines with more than one stroke. Screwdriver or wedge points may be used for lines and conical points for letters and arrow heads.

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* For example, " Mars " Lumograph, J. S. Staedtler, New York, or " Turquoise," Eagle Pencil Company, New York.

152. Ink should be high-grade black waterproof India ink. Red ink is occasionally adopted to indicate parts of other members which are to connect to the one being drawn, if the detail is complicated or unusual; the red ink is easily distinguished on the original drawing by the draftsmen who are chiefly interested, and the lines may be faintly discerned on the prints by the erector without causing confusion in the shop. However, the use of red ink should be limited, because it can be erased only with difficulty and some red inks tend to spread when the drawings are filed in cold vaults. Two bottles of black ink should be used, one for instrumental work and the other for lettering; the former should have a quill or dropper for filling the ruling pen, and the latter may have the quill cut off because it is quicker and more satisfactory to dip the lettering pen into the bottle than to use the quill. The bottle with the quill should be kept corked except when actually filling the pen, but the other may be left uncorked as long as the lettering pen is in constant use. This would not be feasible if only one bottle were used, because so much dust and so much deposit due to evaporation collect in an open bottle that the ink is soon unfit for use in drawing pens. Each new bottle of ink should be reserved for instrumental work, the remainder of the ink in the former bottles being combined for lettering. Ink should never be diluted with water; if it becomes too thick for use it should be discarded. An ink bottle should never be shaken, for no benefit is derived and the sediment is stirred up so that it is likely to get into the pen; furthermore, bubbles are formed in the neck of the bottle which draw the ink from the quill so that is it difficult to obtain enough to fill the pen. Frozen ink is useless, and it is generally unsatisfactory when thawed. The bottles should be kept away from windows in extremely cold weather to prevent the ink from freezing. The ink should also be kept where it is not likely to be spilled on the drawing.

153. The draftsman's equipment should include a **good ruling pen,** and he should not only be familiar with its use but also be able to keep it in good working order. When not in use the pen should be left with the nibs separated in order to relieve the springs. The ruling pen should be held between the thumb and forefinger, resting against the middle finger to hold it firmly. The adjusting screw should be held away from the draftsman so that it may be readily turned with the middle finger to change the setting. The nibs should be parallel to the straight-edge, and the handle should be slightly inclined, with the top in advance as drawn from left to right. The handle should remain in a plane through the line to be drawn, the plane being nearly perpendicular to the plane of the drawing. It is important to keep the pen clean. The pen should not be filled until the draftsman is ready to use it, and it should be used practically continuously while it contains ink. Even when interrupted in his work the draftsman should take time to wipe his pen before laying it down.

Old tracing cloth, thoroughly washed with soap and water, makes an ideal pen wiper. The wipers which are furnished with bottles of ink are too small to be serviceable. A pen wiper should be free from lint.

If ink is permitted to dry in the pen it should be removed before the pen is used again. If allowed to remain it will cause the pen to corrode; this will not only make it more difficult to keep clean, but will eventually prevent precise work. Dried ink should never be removed from a pen with a knife or scratcher for the inner surfaces will become so roughened that the ink will not feed properly. Furthermore, a much simpler and more effective method is to dip the pen in red ink, which will dissolve the caked ink so that it may be wiped off. To avoid all this, the draftsman should form the habit of always wiping his pen before laying it aside even momentarily, while the ink is still liquid; it takes only a moment for the ink to dry enough to clog the pen, and after this happens it is usually a waste of time to attempt to use the pen again without refilling it.

The ink should flow as soon as the pen touches the cloth. If the pen has been left unused only for a moment and the ink has dried slightly in the extreme point, the flow may often be started without refilling the pen by making a few short strokes on a piece of paper, wood, or cloth. It is a good plan to wipe occasionally the side of the pen which bears against the straight-edge, for this not only keeps the ink flowing well, but prevents, in large measure, the ink from running under the straight-edge. If, when the pen is adjusted for fine lines, the ink cannot be started by the expedients just mentioned, the nibs may be separated temporarily until a heavy line can be drawn, and then readjusted to give the desired width.

The ruling pen is usually filled by means of the quill in the cork of the ink bottle. When used immediately after a lettering pen or other pen in which considerable ink is left, the ink may be transferred from one pen to the other; this saves ink and often time, and prolongs the life of the pen wiper. Similarly, ink may be restored to the bottle by touching the pen to the quill. Care should be taken to avoid getting any ink on any part of the pen other than *between* the nibs, particularly on the part that bears against the straight-edge. The pen while being filled should never be held over a drawing.

It is important not to get too much ink in the pen, particularly for fine-line work. It is difficult to retain a constant width of line if the amount of ink in the pen is greatly increased; it is better to increase the amount slightly before the pen is entirely empty. Experience will show the proper amount to use in pens of different shape under different conditions. For short fine lines the depth of ink above the points should seldom exceed $\frac{3}{16}$ or $\frac{1}{4}$ of an inch.

154. If a pen is not working well, a draftsman should be able to fix the points so that a clear-cut even line of any width from the finest to the coarsest can be drawn. If the points are too dull it is impossible to draw fine lines satisfactorily, and if the points are of uneven length one edge or the other of a coarse line will be ragged. If a **pen is in good condition,** it should be possible to draw lines at different speeds without having them vary in width, or to stop the pen completely and start it again without leaving a pool or other evidence of having stopped it.

To sharpen a pen, rub the outside surface first of one nib and then of the other on a fine oil stone. In order to keep the outside surface of a nib curved, the pen should be moved in the form of a figure eight, with a slight rocking motion, so that the whole edge of the nib is sharpened uniformly. Care should be taken to avoid making flat spots, or sharpening one nib more than the other. After both are sharpened so that the edges show no shiny worn places, make the two nibs of the proper relative length by drawing the pen lightly along the stone, holding it in the same plane as when drawing a line, i.e., approximately normal to the stone, but swinging the handle in this plane to give a curved edge. Test the lengths of the nibs by drawing several heavy lines of different widths. If a line appears ragged on one side, the nibs do not bear evenly, or else one nib is too dull. If the pen will draw heavy lines well, test it for fine lines. The nibs may have been dulled slightly in the process of evening their lengths; if so they should be resharpened. If reasonable precautions are taken to avoid excessive grinding the draftsman should be able to obtain edges at the first trial which are even and yet of the right sharpness. The pen should not be left too sharp, for it will either cut the cloth or else make such a deep impression that it is difficult to erase a line when occasion arises.

155. The legs of **the compasses** should be bent at the knuckle joints until the pen and the arm which carries the pivot point are both perpendicular to the plane of the cloth. The compasses should be set to the proper radius by placing the pivot point at the center of the arc and moving the pen until it is immediately above the line to be inked, close to the drawing but not in contact with it. In drawing a curve the compasses should be inclined so that the top of the pen is slightly in advance of the point. A curve should be drawn with a continuous motion, and a complete circle should be closed by carrying the pen a little past the beginning. The weight of the pen is sufficient to insure a good line without additional pressure, and care should be taken to avoid pressure sufficient to alter the radius or to move the pivot so as to cause a crude junction.

156. The lettering pen should be well adapted to the individual who uses it, with a pen holder of suitable size so that the hand will not become cramped. Some draftsmen obtain excellent results with fine points while others cannot use them without spreading the nibs so as to make lines of uneven width. A long fine stub pen will usually give excellent results for most letters and figures of a structural drawing (page 53), a fine pen being provided for drawing arrows and arrow heads or special work for which the stub is too coarse. A ball-pointed pen is often used for titles and other prominent lettering. Some draftsmen use a ruling pen for lettering, but when this is done there should be a special pen for the purpose for it cannot be kept in condition for ruling. Special lettering pens with templets are made for lettering titles and notes rapidly and effectively.*

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* Wrico Lettering Guides, Spaulding-Moss Company, Boston, Massachusetts; Leroy Lettering System or Edco Spee-Dee Lettering Set, Keuffel & Esser Company, Hoboken, New Jersey.

157. The straight-edge should be placed between the draftsman and the line to be drawn; in inking, the near side of the pen bears upon the far side of the straight-edge. Care should be taken to keep the pen against the straight-edge, but to exert no more pressure than necessary to insure this. The pressure should be constant, for otherwise the width of a line will be reduced as the nibs of the pen are pressed together. The pressure of the pen or pencil upon the cloth or paper depends upon the sharpness of the point and the quality of the surface, but it should never be greater than necessary to insure an even line. Lines should be drawn along the upper or left-hand edges of the T-square, triangle, or drafting-machine scale — literally " drawn," for the pen or pencil should never be pushed backward even for a short distance.

158. The draftsman should not attempt to draw **too close to the straight-edge,** especially in ink, lest the ink run under and blot. This distance depends somewhat upon the shape of the pen and the thickness of the straight-edge, but after a little practice the draftsman will learn how close he can work to the best advantage. One-fiftieth of an inch may be taken as a guide to the beginner; this corresponds very closely to the smallest division ($\frac{1}{4}''$) on the scale of $1'' = 1''$. After inking a line one should never attempt to pick up the straight-edge until it has been moved a safe distance away from the line, i.e., toward the draftsman. Otherwise it is difficult to pick it up without letting it slip into the wet ink and cause a serious blot.

159. An easy posture should always be assumed before a line is drawn, for it is difficult to do good work in a cramped position. The drawing board may sometimes be turned to advantage. Lines should be drawn with a full arm motion, with the third and fourth fingers resting lightly upon the straight-edge as a guide to give better control. The elbow should not be rested upon the drawing. Near the end of the line the guiding fingers should be stopped just before the fingers which hold the pen, to facilitate stopping the pen at the exact point. This may be done in such a manner that the motion of the pen will not be interrupted. Very short lines may be drawn with this finger motion alone.

160. A draftsman should be familiar with the **best uses of triangles,** knowing which edge of which triangle can be used most effectively. In drawing one line parallel to another, one should use the triangles to the best advantage; in the majority of cases a single sliding of one triangle along the other is sufficient, and this is more accurate than several short alternate slidings.*

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* See any good book on engineering drawing, as, for example, " Technical Drawing," by Giesecke, Mitchell, and Spencer, The Macmillan Company, New York.

161. Each full line should be drawn with a **continuous stroke.** It is important to have sufficient ink in the pen to complete the line. If it is discovered that the ink will give out before the end of the line is reached, it is best to stop abruptly, preferably at some intersection, and to begin at the same point after refilling the pen. If the ink runs out before the draftsman is aware of its being low, the ragged part of the line should be retraced after the pen is refilled. In this event it is important to try the pen on a separate sheet to make sure that the line is of the proper width before applying it to the drawing, for a pen is likely to make a wider line after being cleaned and refilled than when nearly empty.

162. It is well to ink all lines which are of the same width at **one setting** of the pen, if possible, in order to gain uniformity. Even the pens which are made so that they may be opened and cleaned without changing the setting do not always make lines of the same width before and after cleaning. In order to produce a more constant flow, the pen should be refilled before it is entirely empty.

163. Care should be taken to **stop the pen** at the exact end of each line in order to give a finished appearance to the drawing. The pen should be lifted immediately, when the end is reached, to prevent the ink from running out and forming a pool, which it is likely to do, particularly when the pen and the cloth are not both in perfect condition. The pen should always be lifted vertically to avoid a false mark.

164. Inked lines should be drawn **away from intersections,** as far as possible, rather than toward them, particularly when several lines meet in a common point. A line should never be drawn to meet another line until the latter is perfectly dry.

165. Heavy lines which represent web sections (page 34) and other lines which are wider than the main lines or the border lines of a drawing should each be made of two or more component parts, i.e., part of the width should be drawn and *allowed to dry,* then another part, and so on until the full width is completed. If the full width is drawn with one stroke or setting of the pen, the ink will flow so freely that it will take too long to dry, will pucker the cloth, and will make it impossible to get clean intersections because the ink will form a pool where two lines meet. If *three lines are used for building up a heavy line, the first two are drawn to form the boundaries of the required line, and they should be so drawn* that they are parallel and entirely within the desired width. After these two component parts are dry, the third line may be drawn to fill in the space between them. It should not be necessary to use more than three lines and usually two will suffice. Border lines are generally not so wide that they cannot be drawn with a single stroke, but often two strokes will give better results.

166. In the inking of several **parallel lines**, the triangles or T-square should be used in the same manner as in the penciling of the lines to insure their being parallel. If only a single triangle is used in the attempt to ink over the pencil lines, a slight variation usually results, which is quite apparent. For methods of drawing many parallel lines equidistant, as in cross section lining, see page 34.

167. All curves should be inked before the straight lines which are tangent to them. A straight line is tangent to a curved line when the outer edge of the one is tangent to the outer edge of the other.

168. At practically no time should it be necessary to **wait for ink to dry.** It does not require much ingenuity to find something to do on one part of the drawing while the ink is drying on another part. The man who idly fans the ink with a triangle not only wastes valuable time but also attracts the attention of others to the fact that he is not at work.

169. On rush work of revision, or other work which is confined to a small part of the drawing, it may be desirable to ink in the vicinity of wet lines. This may be done by placing a triangle on each side of the wet lines, and then laying across these two triangles a third triangle to be used as a straight-edge. This cannot blur the wet lines since the straight-edge is elevated above the surface of the cloth in such a way that it cannot touch the lines. For a small area it may be sufficient to lay one triangle across the central opening of a large triangle. Care should be taken not to draw a line which will intersect a wet line or figure.

170. A blotter should never be laid upon wet drawing ink to hasten drying. In fact the blotter should never be used on a drawing except to absorb superfluous ink from a blot or from a line to be erased, and then only by touching its corner to the crest of the pool, without touching the cloth. If the blotter touches the cloth when wet, it makes the ink penetrate so deeply that it is difficult to erase it, in fact more difficult than if it were allowed to dry without the use of a blotter.

171. In order to obtain the best results in making the final drawing directly upon the tracing paper or cloth without tracing, a systematic **method of procedure** should be followed. The following suggestions may be helpful. For the sake of clearness in phraseology, the method of drawing *in ink on tracing cloth is used for illustration, but the method of drawing in pencil upon tracing paper is substantially the same. As soon as the number of views and dimension lines and the main dimensions of a member are determined, points may be plotted to indicate the position of each line that extends practically the full length or depth of the member in each view; pencil lines may be drawn if necessary to show where these long lines stop. Then these full-length lines, both dimension lines and lines of the main drawing, may be drawn in ink without being drawn first in pencil,* with a corresponding saving of time. If some of the lines represent parts which are to be behind details to be added later, these lines may be drawn in pencil or omitted altogether until the details have been located; then the lines may be inked, with dashes to represent the invisible portions. For example let us consider the drawing of a plate girder with cover plates. Suppose that front, top, bottom, and end views are required and that the girder is symmetrical about the center line. First we find how many dimension lines are needed, and then points may be plotted with due regard to margins and spaces between views to insure a good arrangement. Vertically: these points will show the position of all full-length dimension lines; the three lines of each flange angle in the web view, with the corresponding rivet lines (usually at the standard gage); the eight lines in the top view for the cover plate and flange angles, with the corresponding rivet lines (usually two in number); same for the bottom sectional view. Horizontally: these points will show the position of the left end and the center line of the girder; the cover-plate and flange-angle lines of the end view, and in addition the lines of the stiffening angles and their rivet lines; the full depth dimension lines. Now the pen may be filled and set for fine lines, and lines may be drawn in the following order: (1) a continuous vertical line at the end of the girder drawn from the bottom view to the top view; (2) a dot-and-dash line at the center drawn from the bottom view to the top view; (3) all horizontal dimension lines and rivet lines, including lines from the end view to the front view to indicate the depth from back to back of flange angles; the rivet lines should extend beyond the end of the girder to the proper dimension lines; (4) the rivet lines in the end view and the vertical dimension lines. Now the pen may be set for wider lines, and the following lines may be drawn: (5) the cover-plate lines of the top view, provided that the plate extends full length; (6) the lines which show the outstanding legs of the flange angles in the web view; (7) the heavy web line and the other lines of the bottom view, except the cover-plate lines which cannot be drawn until the lengths are determined; (8) the vertical lines of the end view (except the dashed lines) and the end line of each of the other three views; (9) the horizontal lines of the end view. The pen may now be set for slightly narrower lines (page 33) and the dashed lines may be drawn (10) for the flange angles and web in the top view (although these are often discontinued after the end few inches or between stiffeners, in order to save useless repetition), and (11) in the end view. The main dimensions may now be recorded in ink. Thus the drawing is well advanced without the use of a single pencil line. As soon as the stiffening angles are located, points may be plotted to show the three lines of each angle and the corresponding rivet lines. The rivet lines may be inked, then the stiffening angles in all three views, and the remaining lines of the flange angles in the web view which must be dashed behind the stiffening angles now located. As soon as the spacing of the rivets in the web view is determined and the totals checked in each panel as well as in the full half-length, the necessary rivet centers may be plotted and the corresponding lines and dimensions inked. In general, dimensions and billing should be put on as soon as determined. Similarly, the other views can be completed, and when the cover-plate lengths are definitely determined, they may be shown in the top, front, and bottom views. The rivets and holes may be put in next. These should not be drawn until the lines are drawn, for it is simpler and more satisfactory to center the rivets on a line than it is to draw a line through the centers of a row of rivets. The rivets should be drawn approximately to scale.

Few bow-pens can be adjusted to make circles small enough for the general requirements of structural drafting, and riveters or drop-pens are much better adapted to the purpose. The riveters fitted for ink only, i.e., riveting pens, are recommended instead of those which are interchangeable for ink and for pencil. A fixed needle point is held vertically while the revolving pen is twirled around it. The pen can be set to make a circle which is so small that it is virtually a period, and can be lifted out of the way while the needle point is being centered. Some draftsmen stamp holes by means of a pencil lead sharpened to the correct size and dipped in ink held on a pen point.

For the conventional method of indicating rivets and holes, and for the sizes of the circles, see page 40. All shop rivets of the same diameter should be drawn with one setting of the riveting pen in order to make them of uniform size, and the same precaution should be observed in drawing the holes for the field rivets. The latter may be filled in solid at once, but considerable time is required for the little puddles to dry so that they will not smear, and for this reason it may save delay to wait until the rest of the drawing is completed before filling in the holes or else to fill them in a few at a time while dimensioning. When filling the circles for the field rivets it is an excellent plan to slip a blotter under the cloth to absorb any ink that may run through the holes made by the needle point of the bow-pen or the riveter. By using a little forethought the draftsman can usually plan his work so that the ink will be dry on part of the drawing by the time that he completes the holes and arrow heads on the rest, so that he can proceed at once with the dimensions. On penciled drawings, the rivets and holes may be made about as satisfactorily freehand as with the pencil point of a riveter; it is not easy to obtain good results with an ordinary bow-pencil. Finally, the title, the general notes, and the border should be inked; for suggestions see page 78. As soon as the drawing is removed from the board it should be turned face downward so that the draftsman may ascertain whether any ink has passed through defects in the cloth, or through holes made by the instruments. All such blots should be removed, for they would cause spots on the prints and thereby mar the appearance just as if on the face of the drawing; they might cause serious trouble if an important figure was thus altered or obliterated.

172. To erase any part of a drawing **properly** is just as important as to ink or trace properly, and the draftsman should expect to devote a considerable part of his time to painstaking and careful erasing. In the first place, he must correct his own mistakes and errors of judgment, and in the second place, he must frequently make changes which may be due either to mistakes of others or to changes in design. Many good-looking drawings are practically ruined by careless erasing. The object of erasing is not merely to remove part of a drawing, but to remove it in such a manner that other lines and figures may be placed in the same spot without having the change apparent on the blueprint. This can be accomplished only by a person who fully realizes the difficulty, and who exercises great care and patience.

173. Erase Willingly. The first and often the only indication of friction between a beginner and his superiors usually arises because he objects to erasing. Though he should never make changes until he approves them, yet he should stand in readiness to believe that the more experienced checker has good reasons for most changes and he should try to see his point of view; moreover, the objections of the novice are more likely to be heeded if, instead of attempting to convince the checker that minor changes should not be made because they involve too much erasing, he reserves his arguments for more important matters. The friction should be between the draftsman and the drawing, *not* between the draftsman and the checker. To argue over erasing is usually futile, and more time is lost than would be used in making the corrections at once; furthermore, the draftsman is likely to lower himself in the estimation of the checker. He should be more tactful. The draftsman should profit by the criticisms of the checker, and guard against mistakes similar to those which have been corrected on former drawings. Erasing mistakes will often help him to remember them. A new man is judged not so much by the mistakes he makes, as by the mistakes he makes a second time; if he is careful not to repeat any mistake it will not be long before he will outrank the men who are not so careful.

174. Ink should be removed from tracing cloth by means of an eraser. **The secret of erasing** on cloth is to rub so lightly and slowly and with such frequent rests, that the cloth will not become noticeably heated; if it becomes a bit warm the preparation which makes the cloth transparent will become softened so that the eraser will remove it. If this preparation is once removed the cloth is made opaque so that a white spot will show on the blueprint, and the surface cannot be restored for further inking. A little experience will show how many strokes may be made without heating the cloth, the temperature of which may be tested with a *dry* finger. When there are several different parts to erase, the draftsman can rub a few strokes in one place, then in another, and so on, until enough time has elapsed to allow the first part to become entirely cool, when the process may be repeated. The cloth should be supported by a smooth hard surface before the eraser is applied; unless the drawing board is unusually free from holes and dents, a triangle or something similar should be placed under the part to be erased.

175. The Eraser. Either an " ink eraser " or a " pencil eraser " may be used for removing ink from tracing cloth. The former is more effective but it is likely to scratch or injure the cloth. One may obtain more satisfactory results with a pencil eraser if one has abundant patience and avoids excessive speed so that the cloth never becomes heated. When the ink is quite thick part of it may be removed with an ink eraser and the remainder with a pencil eraser. Whenever an ink eraser is used it should be followed by the use of a pencil eraser to clean the drawing properly. The center of contact should be kept on the ink to be removed lest the adjacent cloth become seriously damaged before the fact is realized. An eraser will often become soiled or clogged, particularly when used on heavy lines or on smooth paper. It should be cleaned by being rubbed on clean rough paper or on a clean portion of the drawing board reserved for the purpose. The white or " ruby " erasers are firmer and better adapted to the removal of ink or pencil than the " emerald " ones; they are also more likely to be self-cleaning. The Blaisdell " Klenzo " ink and pencil erasing pencils are convenient and are less likely to become dry and hard because of the paper wrappings. Motor erasers are now used extensively.

176. A special **ink eradicator** for tracing cloth is on the market but it should not be used too generally. It is not suitable for small erasures, since it cannot be confined to small areas to good advantage, and it should never be used if any erasures or scratches have been made previously within the same area. For taking out a whole detail or other large portion of a drawing the liquid eradicator usually proves satisfactory.

177. A knife or metal scratcher should not be used on a drawing in place of an eraser. The surface of the cloth is so damaged that it is impossible to re-ink or even re-pencil properly the portion which has been scratched. The cloth often becomes so opaque where a knife has been applied that the scratched portion shows on the print almost as distinctly as if the ink had not been removed, and furthermore, the lines appear ragged. A very sharp scratcher in the hands of an expert can be used sparingly to advantage; but as a rule, the resort to a knife or scratcher is a confession of laziness, for there is nothing to recommend it except that it is sometimes easier to scratch out a small section of a line than it is to erase it and then have to replace the surrounding lines which may be erased also. This advantage is offset by the fact that drawings frequently have to be retraced when a later revision necessitates inking where a knife has been used. Erasing with a knife nearly always involves the risk of injury to the cloth, and is in this sense a dangerous habit which is not justified by the results; better results are almost invariably obtained with an eraser.

178. When erasing a figure, a rivet, or small detail, which is close to other lines or figures, one may protect the surrounding parts with **an erasing shield** and thus simplify the filling in afterwards.

179. **The surface of the cloth** where any erasure has been made must be treated before ink is applied, or the ink will spread. Although tracing-cloth powder is frequently used, it is better to polish the cloth, for the new lines will be more durable if on the cloth itself than if partly on the powder. A triangle or other hard surface should be slipped under the cloth, and a smooth, clean piece of soapstone or celluloid rubbed over the erased area until the cloth shines. Other hard surfaces may be substituted for the soapstone, but they are likely to soil the cloth. An end of a celluloid triangle serves very well if the corners are rounded and used for this purpose only, care being taken to avoid the worn part when the triangle is used as a straight-edge.

180. After erasures have been made and the cloth has been polished, all **lines and figures** which have been **erased by mistake** should be replaced whether there is anything to be added or not. This point is frequently overlooked, especially if only a small portion of a line is erased, but it requires only a few such omissions to mar the appearance of a drawing. In order to prevent blurring or blotting, especially if the erased surface is not very smooth, the heavier lines should each be built up by making several fine lines until the desired width is obtained, no line being drawn until the preceding one is dry.

181. If **pencil lines** are used on the tracing cloth, they may be left until the tracing is finished, and then removed along with any accumulated dirt. The author prefers a soft sponge eraser for this purpose, particularly if it was used at the beginning instead of powder to surface the cloth (page 63). Care should be taken to rub *between* the lines as far as possible, rather than across them; rubbing the lighter lines tends to make them too dim to print well especially if the cloth has been surfaced with powder. The pencil lines may also be removed by rubbing the surface of the drawing with a cloth dampened with benzine; the benzine does not affect the waterproof ink. Care should be taken that the cloths are clean, lest the whole drawing be made dingy. Many draftsmen prefer benzine on account of its simplicity, but for various reasons many companies do not furnish it. The author feels that benzine renders the cloth more likely to crack in handling and thus the usefulness of a drawing is somewhat impaired.

CHAPTER IX

NOTES AND TITLES

182. Drawings should be made complete and clear without the use of **notes** whenever practicable, but unless the drawing is perfectly clear, short and concise notes should be added wherever necessary. Care should be taken to make each note explicit and easily understood.

183. All **general notes** which apply to the whole drawing should be placed near the title, usually to the left, as in Fig. 134. Examples of the more common general notes are those which give the sizes of rivets, holes, and washers; the maximum pitch of rivets; and information regarding specifications, paint, inspection, and erection.

184. All **other notes** should be placed in clear spaces near those parts of the drawing to which they apply. If a note is too long for the available space, it may be placed to one side with a reference to it at the proper point, as for example, "See note." If the necessity occurs more than once on one sheet, the notes may be numbered or lettered.

185. If the **rivets and holes** for any drawing are not all the same size, the general note (see above) should be modified thus: "Rivets $\frac{3}{4}''$ except as noted," or "Holes $\frac{13}{16}''$ unless noted" (Fig. 127). All rivets or holes of sizes other than those specified in the general note should be clearly noted. Such exceptional rivets or holes may be distinguished on the drawing in one of several ways, thus: (*a*) by placing the note at one end of that dimension line which locates all the rivets or holes in question but no others, as in *F*6, Fig. 185; (*b*) by drawing supplementary lines with arrows to indicate the desired rivets or holes; (*c*) by drawing arrows from the note to those rivet lines which pass through all the rivets or holes noted but no others, as in the bottom view, Fig. 125; (*d*) by encircling the desired rivets or holes by a freehand loop or ring which in turn is connected to the note; this ring should not include any dimensions or notes (page 243); (*e*) by noting all the rivets or holes in one view by a special note near the view as in Fig. 160, or by a general note near the title. In order to attract attention to a change of size, a heavy diamond is often used, as illustrated in most of the figures referred to above. Countersunk and flattened rivets are often noted as explained on page 41.

186. An identification mark is assigned to each member which is to be shipped separately. If more than one drawing appears on a sheet the identification mark should be placed conspicuously near the drawing of the corresponding member. For further description of such "shipping marks," see page 106.

187. The number of pieces to be made from each drawing should be clearly stated, either under the detail, as in Fig. 123 or Fig. 174, or at the right of the sheet above the title, as in Fig. 128. When more than one or two members are shown on one sheet a tabular "Required List" is made, as shown in Fig. 185.

188. Reference to other drawings may be made in order to save the repetition of details. Sometimes two sheets are worked together as if one large drawing, with notes to this effect near the required lists. Usually a system of assembling marks is used when details are referred to another drawing, as explained on page 110. If a connection on one sheet is like that on another, many of the detailed dimensions may be omitted from the one which is referred to the other. For convenience all field-rivet holes should be dimensioned and all material should be billed; this enables a person to check the field connection to another member or to write a shop bill without referring to the other drawing.

189. Loose Pieces Bolted. Small pieces, such as splice plates, fillers, or connection angles, which cannot be riveted in the shop without complicating the field work, may be either shipped separately, or else bolted for shipment to one of the members to which they are eventually to be attached. The latter method is to be recommended wherever feasible, for the number of items shipped is reduced, and the pieces are available at once when needed for erection. Pieces which are bolted for shipment are fastened temporarily in or near their final positions by means of two or more bolts each. On the drawing, a note may be placed immediately following the billed size of any piece so bolted, thus: "Bolt for shipment," or "Bolt to ship" (Fig. 175), but this is often considered to be standard practice without such a note. It may be well to give each piece a separate mark for identification in case it becomes detached unless the nature of the piece is such that its proper position can be readily determined.

The temporary bolts used are of odd lengths as picked up in the shop; sufficient washers are added to facilitate tightening and removing the bolts.

To avoid handling loose pieces in the field it is often feasible to make them enough longer so that they can be riveted in the shop independently of the field connections (Fig. 160); this should never be done, however, if the erection is rendered more difficult thereby.

190. If pieces are to remain bolted in the completed structure without having the bolts replaced by rivets in the field, all the holes should be filled with **permanent bolts** of the proper size. The bolts should be billed on the drawing in the usual way (page 49), directly under the billed size of the piece bolted. See Fig. 185. A note, "Bolt complete," may be added to insure the use of a full number of bolts of the proper length, instead of a few temporary bolts (see above). The bolt heads are ordinarily drawn but sometimes, for the sake of simplicity, only the holes are indicated (page 42).

191. Different Members Combined. When several members differ from each other slightly, i.e., in minor details, one drawing may be made to represent all these members and the differences may be stated in notes. This should not be done, however, unless the differences can be made clear and definite in notes which are brief and comparatively few in number; otherwise, drawings become so complicated that more time is lost by the shopmen than is saved by the draftsmen. This is often due to the fact that additional connections are discovered, or the design is changed, after the drawing is started. It is essential, therefore, to plan any combination very carefully before the drawing is commenced, using a sketch upon which the various connections are indicated. The notes regarding special connections follow the corresponding billed material, if any; otherwise, the holes may be noted as indicated on page 76. If there are more than a few simple differences, it is better either to draw an additional view (Fig. 166), or to make another drawing. In the latter case it may be possible to show on one drawing simply the outlines of all parts which are like those on the other, and to draw in detail only those parts which are different (Fig. 135). In order to shorten notes, when several different members are represented by the same drawing, one member may be referred to another after the shipping mark, as for example: " *C*12, same as *C*11 except as noted," it being understood that every note which applies to *C*11 applies also to *C*12. The mark " *C*12 " will not appear in any of the notes, therefore, except where it differs from *C*11. See also page 108.

192. All notes should be made positive, with rare exceptions. This precludes the use of the word " omit." For example, if several members are represented by one sketch, and some of the details are on part of the members only, as the holes for bracing, Fig. 134, it is better to note that the holes are " in *T*1 and *T*2 " rather than that they are " omitted in *T*3." It is much more important to all concerned in making a member to know which details are to be placed on that member than to know which are not.

193. Simple freehand letters should be used for notes, and a draftsman should practice lettering until proficient, for a good-looking drawing may be easily marred by crude lettering.* Slanting letters are preferable to vertical letters because deviations from a uniform slope are less apparent than deviations from the vertical. Most draftsmen can letter more easily

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* See any standard book on drawing, as for example, " Technical Drawing," by Giesecke, Mitchell, and Spencer, The Macmillan Company, New York.

and rapidly with sloping letters than with vertical ones. Guide lines should be used, not merely by beginners as students are wont to believe, but by experienced draftsmen as well. Guide lines are essential to all good lettering; like the carpenters' staging they are used by the best men as well as by novices, but like the carpenters' staging they should be removed after the work has been completed. Special triangles with holes in different positions or other devices are available for drawing guide lines; these are dragged along a straight-edge with a pencil placed in the proper hole for a given spacing. On a penciled drawing it is difficult to remove guide lines without rubbing some of the letters too, but yet letters with guide lines left in place look worse than letters made without guide lines. The use of a separate ruled sheet is recommended; this may be slipped under the tracing paper or cloth with the lines showing through. A convenient size is 5″ × 8″; it is difficult to place a smaller sheet under the drawing in the right position. A large number of parallel lines may be ruled on this sheet not only to provide for long notes but also to simplify placing the sheet in the desired position. Uniform spacing of $\frac{1}{16}''$ make good units, single spaces being used for small notes, two spaces for required lists, and three spaces for titles. Sheets with different spacings may be made for various sizes of letters, or different spaces may be combined on one sheet if the change is made conspicuous. Diagonal red lines drawn at the standard slope for inclined letters are of great assistance in maintaining a uniform slant in lettering. Special lettering pens with templets may be used for notes as well as for titles if desired.

194. A title is placed in the **lower right-hand corner** of each full-sized sheet, for convenient reference and for use in classification. This uniform position enables a person to look through a pile of drawings for a particular sheet by merely turning back the corners. The title is composed of two parts, one of which refers to the specific drawing, the other to the company which makes the drawing.

195. The first part of the title contains the names of the members on the sheet, or the part of the structure shown; also the name of the structure, the name of the customer, and the place where the structure is to be situated. This part of the title is usually made of freehand letters about $\frac{3}{16}''$ high, of simple Gothic style, and all capitals. Elaborate titles should be avoided, since they add to the expense and are not in harmony with the rest of the drawing. Some companies maintain small presses for printing the titles of the larger contracts. Good-looking titles can be made quickly and easily with one of the special lettering sets with templets.*

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* "Wrico Lettering Guides," Spaulding-Moss Company, Boston, Massachusetts; "Leroy Lettering System" or "Edco Spee-Dee Lettering Set," Keuffel & Esser Company, Hoboken, New Jersey.

196. The second part of the title is more general, and is usually printed in a press or placed on the drawing by means of a rubber or metal stamp. Sheets of tracing paper or cloth can be obtained from the makers with titles and borders printed to order; sometimes the titles are printed on the backs of the sheets so they are less likely to be rubbed as the drawing is being made. If the drawing is made in the drafting room of a structural company, this part of the title contains the name of the company, the name of the plant which is to fabricate the work, and blanks for the name or initials of the person in charge of the contract, of the detailer, of the checker, and sometimes of the man who makes a field check or of the engineer who approves the drawing. A date is written after each person's name or initials. Below these and at the extreme bottom of the sheet next to the border are placed the contract number and the sheet number. The contract number should be bold and conspicuous and should be placed in a uniform position; sometimes this is put on in large figures without indication of what it is, and sometimes it is placed in a space labeled " Contract Number " or " Cont. No. " Sometimes a line is printed opposite a large *C* or other symbol, with the contract number above the line and the sheet number below. Titles on drawings made in the offices of consulting engineers or in the structural departments of railroads or other companies are usually somewhat simpler than those made in the offices of structural companies, but in general they are similar.

197. The smaller drawings and lists are usually made on printed forms which contain the name of the company with blanks for the plant, the structure, the nature of the drawing, the initials of the detailer and the checker, with dates, and the contract and sheet numbers, much as shown in Fig. 148.

198. Sheet Numbers. Drawings should be numbered in different series for convenience in identifying a drawing of a certain type. If the main detailed drawings are numbered serially, other drawings and lists may have prefixed letters to distinguish them, each group being numbered independently. These prefixes differ with the different companies, but the following are suggestive: *E* for erection diagrams, *B* or *F* for beam details and other small drawings, *C* for combination sheets, *S* for shop bills, *R* for shipping bills, *SR* for combined shop and shipping bills. Some shop bills are attached to the corresponding drawings and need no additional sheet numbers, and others are sometimes given the same number as the drawing, *a*, *b*, *c*, being added according to the number of pages required.

199. A simple border should be drawn on each full-sized sheet to form the boundary, to keep the sheets of uniform size, and to improve the appearance. Ornate borders should be avoided. Corners should be simply rectangular. Borders are not drawn on the smaller printed forms.

200. An effective border is composed of a heavy line with a light line ½″ outside. The nominal dimensions of the sheet, as for example 24″ × 36″, indicate the size of the finished tracing, and a rectangle of this size should be penciled to serve as a guide in trimming the cloth. The fine line is drawn ½″ inside of this to indicate where the blueprints are usually trimmed, and the heavy line is drawn ½″ inside the fine line to form the border on the prints. This makes the dimensions inside of the border each 2″ less than the nominal size of the sheet, as for example, 22″ × 34″ for a 24″ × 36″ sheet. Sometimes an extra 1″ margin is reserved at the left end for binding drawings together. If smaller sheets are adopted, the fine line of the border had better be omitted, the heavy line only being used, ½″ inside the edge of the sheet. Both the tracing cloth and the blueprints should then be cut the same size as the sheet of paper. The heavy line should not be over $\frac{1}{32}$″ wide nor wider than can be drawn with a single stroke. See page 68.

CHAPTER X

WORKING LINES

201. The different members of a truss are drawn with reference to a **system of working lines.** Theoretically these working lines correspond to the lines of stress in the different members, and at each apex the lines should meet in a common point. The system of working lines in appearance and in dimensions closely resembles or is identical with the truss diagram used in the calculation of the stresses in the members. It is desirable to have each member placed so that its center-of-gravity axis coincides with the working line, and symmetrical members are so placed. In light riveted truss work, however, such as ordinary roof trusses, where each member is composed of one or two angles connected by one or two lines of rivets, it is customary to use the working line as the rivet line; if there are two rivet lines, the one nearer the back of the angle is chosen. The stress is transmitted to the connecting plates by the rivets and it is logical to use the rivet line as the working line, even though there is a slight eccentricity in the member itself; this eccentricity results in a tendency for the member to bend, but usually this is negligible. Similarly, in a pin-connected truss it is not always practicable to make the center-of-gravity of a top-chord member coincide with the working line which passes through the pins. In a welded truss, the joints can be arranged more conveniently so that the centers of gravity of both members and joints coincide with the working lines.

202. Bridge Trusses. The most common types of simply supported trusses for bridges are shown and described on page 169. The shape of the truss and the principal dimensions are determined by the designer. The trusses are divided into horizontal panels of equal lengths.

203. Roof Trusses. Types used for roof trusses of mill buildings are shown and described on page 129; these have sloping top chords divided into equal panels. The so-called flat-roof trusses of the Warren type are more like latticed girders (page 140) and they may have auxiliary working lines, as explained on page 85. The pitch of a symmetrical roof truss is the ratio of the center height to the full span length, as explained more fully on page 130.

204. The system of working lines may be **laid down to scale** before the lengths of intermediate members are calculated. The horizontal and vertical dimensions of a bridge truss can be plotted directly, and the working lines of the other members can be drawn in. The main working lines of a roof truss can be plotted as soon as the effective length and the rise (or the pitch) are known. The panels may be made equal by means of any convenient scale, and all working lines may be drawn even though the lengths are unknown. It may be expedient to use a scale for the working lines somewhat smaller than that to be used later for the details. As soon as the working lines are plotted, the dimension lines should be drawn. These lines should be so placed that they will not interfere with each other or with the details which are to be added later. Usually an experienced draftsman can anticipate the final positions of these lines; the beginner should use other drawings as guides, and arrange the lines to the best of his ability even though some of them have to be changed later. It is desirable to have dimension lines ready so that the computed dimensions can be recorded as soon as they are determined, in order to save copying.

205. The lengths of all members from center to center of working points should be determined to the nearest $\frac{1}{16}''$, and placed upon the drawing directly. Most lengths to be calculated are hypotenuses of right triangles with known lengths of legs, and they may be computed by squares or by logarithms. The lengths of many members may be found from other lengths by the proportions of similar triangles. In a Fink roof truss only two hypotenuses need be computed regardless of the number of panels, the remaining members being found by proportion. For example, in the truss shown in Fig. 83 the slope distance C is found from the half-span A and the rise B by means of a table of squares (or from A and the secant of the pitch angle by logarithms). This distance is divided into four equal parts; if not equally divisible, some of the panels may be made $\frac{1}{16}''$ longer than the others to maintain the proper total and still avoid thirty-seconds. The middle normal D bisects the top chord and forms two equal right triangles, one vertex being at the heel (left end) and the other at the peak (top). Each of these triangles is similar to the original half-truss, for the corresponding angles are equal; therefore the shorter leg D bears the same relation to the longer leg $\frac{C}{2}$ that the rise B

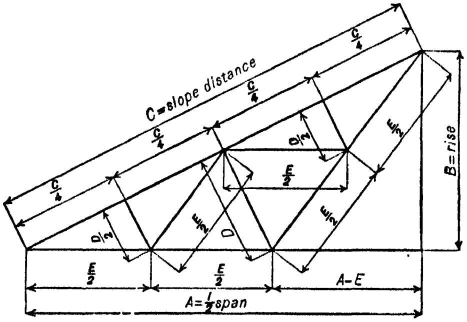

Fig. 83

bears to the half-span A (one-half for ¼ pitch). From D and $\frac{C}{2}$ the hypotenuse E may be obtained by squares or from $\frac{C}{2}$ by logarithms. The horizontal length E subtracted from A gives one leg of the central right triangle, the other leg of which is the rise B; the slope length E already found may be checked as the hypotenuse of this triangle. The lengths E and D are divided by 2 for the remaining members as indicated in the figure. In a fan truss, the sloping members may be found from small triangles one leg of which is D or $\frac{D}{2}$ and the other leg is the projection of the diagonal upon the top chord; it is usually preferable to find the horizontal and vertical components and to use these in computing both the lengths and the slopes (see next paragraph). It is better to compute the sides of the larger triangles and to get the sides of the other triangles by *division*, than to compute the shorter lengths and obtain the others by multiplication, so that each will be taken to the nearest $\frac{1}{16}''$.

206. The slope of each working line from the horizontal should be expressed to a base of 12″, as explained on page 59. The slope is found from rectangular coordinates by dividing the shorter by the longer, making a similar triangle with a base of 1′. It is better not to record the slopes on the drawing until after the members have been drawn in, but the slopes may be calculated with the lengths, for often both are found from the same rectangular coordinates. This may be done by means of parallel tables of logarithms and squares,* as illustrated in the following problem, in which the given coordinates are 3′-7¼″ and 10′-2½″. The corresponding slope and length of the diagonal as shown on the drawing are obtained as follows:

Length	Logarithm	Square
3′-7¼″	0.55680	12.9900
10′-2½″	1.00895	104.2101
	(difference) 9.54785	(sum) 117.2001
	slope = 4¼″ in 12″	length = 10′-9$\frac{15}{16}$″

Note that the tables are expressed to thirty-seconds to facilitate the selection to the *nearest* sixteenth of the desired slope or length from the corresponding logarithm or square.

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* A copy of "Parallel Tables of Logarithms and Squares," C. K. Smoley and Sons, Scranton, Pennsylvania, or an equivalent, should be included in the equipment of every structural draftsman.

207. Bracing systems in which the diagonals are each composed of one, two, or four angles are usually drawn with a system of **auxiliary working lines.** If the lines of stress at each panel point were made to meet in a common point, the clearances between the diagonals, and therefore the connecting plates, would be larger than necessary. By reducing these clearances, the lines of stress are moved but the secondary stresses due to eccentricity are negligible in view of the relatively small stresses in the diagonals. Similarly, the diagonals of light latticed girders may be referred to auxiliary working lines if the slight deviations from the stress diagram make practically no difference in the efficiency of the girders, and better connections are thus obtained. These auxiliary working lines are drawn parallel to the chords or connecting members and pass through the end rivets or holes of the diagonals if a single line of rivets is used, or midway between the end holes if two lines are used. These working points are located along the working lines by special dimensions with due allowance for clearance for other members, as shown in Figs. 142 or 185. When auxiliary working lines are used, they cannot be plotted until after the corresponding dimensions have been determined; the exact distances cannot be found until the slopes are known, but it is customary to provide clearances for extreme positions of the diagonals. In order to make the clearances the same whichever way a single angle is turned, the rivet line is usually placed in the center of the angle leg if it is 3″ or over. Even if the standard gage is used, the distance on each side is made large enough to provide clearance for the larger corner distance on the gage side, in order that the plates may be made alike or similar. The dimensions of working lines are preferably expressed in multiples of ¼″ where practicable, the clearances being modified accordingly.

208. Special directions for determining **working-line dimensions** are given for latticed girders on page 144, and for bracing on page 183.

CHAPTER XI

RIVET SPACING

209. Rivet spacing, as a general term, refers to the dimensions which locate either shop or field rivets; these dimensions extend invariably to the centers of the rivets. The spacing is dependent upon the number of rivets required to satisfy the conditions of loading, and it must conform to the usual practice. **Rivet pitch** is a more specific term usually limited to the spacing which locates the rivets that connect the main component parts of a built member in the direction parallel to the longitudinal axis. This term is most frequently applied to the flange rivets of plate girders, connecting the flange angles to the web plates; the pitch of these rivets in different panels must be calculated for each individual girder.

210. Each structural company adopts **drafting-room standards** for the guidance of its draftsmen in order to make the drawings more uniform. Many of these standards are published in the handbooks and are followed quite generally. Each draftsman should make his drawings conform to the standards of the company for which he works. He should also scrutinize the specifications which accompany each contract, and make sure that his rivet spacing does not violate any clause therein. For the most part, the standards and specifications are quite similar, and the rules of this chapter conform to the majority of them.

211. Standard Gages. The flanges of I-beams and channels are so narrow that the usual rules for driving clearance and transverse edge distance are not always applicable. Standard gages are therefore adopted which will best meet the average requirements. Standard gages are used also for wide-flanged beams, 5½″ being used quite generally except in the smaller sections. The gages are dimensioned on the drawings even though standard, a single dimension from center to center of rivets being understood to be symmetrical about the web; extra rows of rivets are used in the wider flanges of 14″ column sections. Gages for channels and angles are dimensioned from the backs of the webs or legs, except that when double rows of rivets are used in one leg (double gage) the second row is dimensioned from the first. Standard gages are commonly used for beams and channels and for single angles, except in cross bracing (page 85) and connection angles (page 120). When angles are used in pairs, as in the flanges of girders and columns, in trusses, in stiffening angles, in connection angles, etc., it is better to modify the gages slightly, if necessary, in order to maintain a more convenient distance from center to center of rivets, preferably a multiple of $\frac{1}{2}''$.

212. The minimum spacing of rivets should be such that the strength of the metal between rivets fully develops the strength of one rivet. The well-established minimum is "3 diameters," the distance center to center being 3 times the nominal diameter of the rivet shank. This rule was based upon theory, computed from smaller unit stresses than now in vogue, but the rule is still applied as the absolute minimum in any direction. The values now recommended, however, are: $4\frac{1}{2}$ for $1\frac{1}{4}$ rivets, 4 for $1\frac{1}{8}$ rivets, $3\frac{1}{2}$ for 1 rivets, 3 for $\frac{7}{8}$ rivets, $2\frac{1}{2}$ for $\frac{3}{4}$ rivets, 2 for $\frac{5}{8}$ rivets, and $1\frac{3}{4}$ for $\frac{1}{2}$ rivets. When rivets are staggered on two or more lines, the minimum longitudinal spacing depends upon the method of design, as explained in "Structural Design," page 80. The minimum longitudinal pitches for staggered flange rivets in plate girders for different specifications are given in the table below, taken from and explained more fully in "Structural Design," page 128.

USUAL MINIMUM PITCHES FOR FLANGE RIVETS

RIVETS IN SINGLE ROW			RIVETS STAGGERED IN TWO ROWS					
Extreme Minimum Three Diameters	Preferred Minimum	Rivet Diameter d	AISC 1936	AISC 1928	AREA 1935	AREA 1931	AASHO 1935	UNIT STRESSES Kips per Square Inch
			13.0	12.0	11.0	10.0	11.0	s = Shear on Web (Gross Section)
			15.0	13.5	13.5	12.0	13.5	s' = Shear on Rivets
			40.0	30.0	27.0	24.0	22.5	b = Bearing in Web
$1\frac{7}{8}$	2	$\frac{5}{8}$	$1\frac{15}{16}$	$1\frac{9}{16}$	$1\frac{9}{16}$	$1\frac{1}{2}$	$1\frac{5}{16}$	Values for staggered rivets apply to girders in which the rivets act in double shear and are limited by the bearing value. Smaller values may be used if desired in girders with thicker webs or in box girders in which the rivets act in single shear.
$2\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$2\frac{5}{16}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{13}{16}$	$1\frac{9}{16}$	
$2\frac{5}{8}$	3	$\frac{7}{8}$	$2\frac{11}{16}$	$2\frac{3}{16}$	$2\frac{3}{16}$	$2\frac{1}{8}$	$1\frac{13}{16}$	
3	$3\frac{1}{2}$	1	$3\frac{1}{16}$	$2\frac{1}{2}$	$2\frac{7}{16}$	$2\frac{3}{8}$	$2\frac{1}{16}$	
$3\frac{3}{8}$	4	$1\frac{1}{8}$	$3\frac{1}{2}$	$2\frac{13}{16}$	$2\frac{3}{4}$	$2\frac{11}{16}$	$2\frac{5}{16}$	
$3\frac{3}{4}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$3\frac{7}{8}$	$3\frac{1}{8}$	$3\frac{1}{16}$	3	$2\frac{9}{16}$	
$4\frac{1}{8}$	5	$1\frac{3}{8}$	$4\frac{1}{4}$	$3\frac{7}{16}$	$3\frac{3}{8}$	$3\frac{5}{16}$	$2\frac{13}{16}$	
$4\frac{1}{2}$	$5\frac{1}{2}$	$1\frac{1}{2}$	$4\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{11}{16}$	$3\frac{5}{8}$	$3\frac{1}{16}$	

213. The maximum spacing of rivets differs with the type of member and the size and the position of the rivets in the member, as follows:

(*a*) In the flanges of plate girders, the pitch of the flange rivets connecting the angles to the web plate should not exceed the calculated pitch for the individual span and loading, with a maximum of 6'' (or sometimes

7 times the diameter of the rivets); for deck girders supporting ties or other flooring on the top flanges, this maximum is usually 4½", and for crane girders supporting rails on the top flanges the maximum is 4".

(*b*) In the cover plates of girders, the maximum longitudinal spacing is usually 6", except that at each end of each cover plate the maximum is 4 diameters for a distance equal to 1½ times the width of the plate.

(*c*) In compression members composed of plates and shapes, the pitch in the line of stress should not exceed 16 times the thickness of the thinnest outside plate or shape or 20 times the thickness of the thinnest enclosed plate or shape, with a maximum of 12", except that at each end the pitch should not exceed 4 diameters for a distance equal to 1½ times the maximum width of the member. The spacing at right angles to the line of stress should not exceed 30 times the thickness of the thinnest plate or shape.

(*d*) In compression members composed of plates and angles with rivets staggered in the angles, the pitch in the line of stress should not exceed 12 times (24 times in each row) the thickness of the thinnest plate, with a maximum of 9" (18" in each row), except at each end the pitch should not exceed 4 diameters for a distance equal to 1½ times the maximum width of the member. The spacing at right angles to the line of stress should not exceed 30 times the thickness of the thinnest plate or angle.

(*e*) Rivets in pipe or tank work should not exceed about 4 diameters to make the joints watertight.

(*f*) Rivets which do not transmit much axial stress may be spaced up to 12" or even 18" apart in longitudinal skew-back or stiffening angles or channels riveted to the webs of floor beams or crane beams, and in similar places.

(*g*) Stitch rivets, see below.

214. "Edge distance" is a term applied to the *perpendicular* distance measured from the center of a rivet or hole to any edge of a structural shape or plate. The minimum edge distance is approximately ½ the minimum distance from center to center of rivets, the recommended values for sheared edges being 2¼ for 1¼ rivets, 2 for 1⅛ rivets, 1¾ for 1 rivets, 1½ for ⅞ rivets, 1¼ for ¾ rivets, 1⅛ for ⅝ rivets, and 1 for ½ rivets. For rolled edges, the first four may be reduced ¼" and the last three ⅛". A still further reduction is allowed in the flanges of small I-beams and channels, as determined by the standard gages, but only the smaller rivets can be used, as indicated in the tables. Thus the smallest angle legs in which different sizes of rivets can be used are 2" for ⅝", 2½" for ¾", 3" for ⅞", and 4" for 1". Some specifications further stipulate that the minimum edge distance in the line of stress shall not be less than the shearing area of the rivet shank (either single or double shear) divided by the plate thickness. The maximum edge distance is often taken as 8 times the plate thickness with a maximum of 5″, but some specifications allow 12 times the thickness with a maximum of 6″. When two or more cover plates extend 3″ or more beyond the flange angles, they should be fastened together by an extra row of rivets with a pitch twice that of the rivets which connect the plates to the angles.

215. Stitch Rivets. A member composed of two angles should have them riveted together at frequent intervals to distribute the stresses and to prevent them from buckling separately. If the angles are separated on account of connections to gusset plates, a washer is placed between them at each rivet in order to maintain a uniform distance between the angles. These equalizing rivets, with or without washers, are called "stitch rivets." They need not be dimensioned, but the proper number should be shown or else the approximate spacing should be noted. The washers need not be billed individually but the size should be given along with the sizes of rivets and holes. The distance between the last rivet of one connection and the first rivet of the next connection should be divided approximately equally. Stitch rivets are spaced from 3′-0″ to 3′-6″ apart in tension members* and 1′-6″ to 2′-0″ apart in compression members, but the ratio of slenderness $\frac{l}{r}$ for each angle should not exceed three-quarters of that for the whole member. Similarly, pairs of stitch rivets are used to fasten two channels together, bars being used instead of washers when there is a space between webs.

216. Usual Spaces. The rivets which connect the main component parts of a member are spaced as far apart as is compatible with the conditions outlined in the preceding paragraphs, in order to minimize the number of rivets to be driven. But the rivets which connect one member to another, or part of one member to another part, are placed at the usual minimum distances as far as practical, in order to reduce the size of the connecting material.

217. Similar Templets. Templets are often made to serve for several different members, and the practice in the templet shop should be understood by the draftsman so that he can space the rivets to the best advantage. Different sets of holes are often bored in the same templet with notes regarding their use for different members; the centers of these holes should not fall less than ½″ apart or they will interfere with each other. Long lines of rivet spacing in similar members should be kept alike as far as possible with the differences concentrated, so that different short templets may be used in conjunction with one long one.

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* Some specifications limit this to 1′-0″ for members composed of two angles in contact.

218. For **multiple punches** the rivet spacing should be given so that the punches can be used to the best advantage; in multiple beam punches, the spacing is usually determined by the standards. In both multiple beam punches and multiple plate punches the holes for intermediate connections should be made to line up with those for the end connections, to save moving the beams or plates laterally as they pass through the punch. Where longitudinal spacing racks are used for more or less automatic punching of similar plates or beams, the drawings should be made so that necessary changes in spacing are confined to short distances, in order that most of the spacing dogs may be used without change.

219. Single Rivets Not Used. Every separate piece to be riveted should contain at least two rivets even if one is strong enough, because a single rivet cannot be driven satisfactorily without danger of the piece being twisted; it should be held in place while the first rivet is being driven by a temporary bolt in another rivet hole. Similarly, a piece to be welded should have the welds so placed that the piece will not turn. A single bolt is sometimes used.

220. Lattice bars, or lacing bars, are used to hold the component parts of a compression member in the proper relation to one another. They serve in place of a plate to make the component parts act as a single member instead of separate members, but they should be so spaced that the ratio of slenderness $\frac{l}{r}$ of a component part between lattice bars is not more than two-thirds (three-quarters for buildings) of the ratio of the entire member. A two-angle or four-angle strut or a four-angle column may be latticed in order to save metal, but the lattice bars are not counted in the effective area of cross section as an equivalent plate would be. Two channels are often latticed across both flanges to serve as a light compression member, and the lower flanges of top-chord members of bridge trusses are latticed because continuous plates would interfere with the gusset-plate connections. A single system of lattice bars is used for members in which the transverse distance between rivet lines does not exceed 1′-3″, and a double system of bars riveted at their intersections, or a single system of lattice angles, is used for wider members. The inclination of the bars with the longitudinal axis of the member should not be less than 60° for single latticing or 45° for double latticing. The bar sizes are more or less standardized* according to the sizes of rivets used, ⅝″ rivets for flanges under 2½″, ¾″ for flanges between 2½ and 3½, and ⅞″ or 1″ for flanges over 3½. The common widths of bars and the radii of the curved ends are shown in Fig. 91 (*a*). Wide bars with two rivets at each end are used when the flanges are over 5″ wide, as illustrated in Fig. 178. The thickness of

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* For notes on design, see "Structural Design," page 89.

the bars is usually specified not less than $\frac{1}{40}$ of the distance between end rivets for single latticing, or $\frac{1}{60}$ of this distance for double latticing; some specifications allow ratios of $\frac{1}{50}$ and $\frac{1}{75}$, respectively, for secondary members. The limiting lengths for different thicknesses are given in Fig. 91 (*b*). Lattice bars are made in special machines which punch at one stroke the adjacent holes of two bars and the two curved ends between them, with $\frac{1}{2}''$ space between the ends; by setting a stop at the proper length, a complete bar can be made at each stroke of the punch, the workman simply advancing the bar to the stop between strokes. For this reason it is customary to give the lengths of bars in billing to the nearest $\frac{1}{16}''$ from center to center of end holes, instead of the usual overall lengths (page 48).

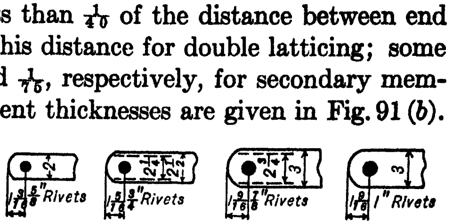
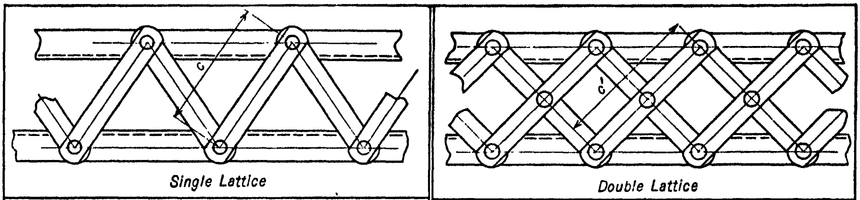


Fig. 91 (*a*).



MAXIMUM DISTANCE c			MAXIMUM DISTANCE c'		
THICKNESS t	$c=40\,t$	$c=50\,t$	THICKNESS t	$c'=60\,t$	$c'=75\,t$
$\frac{5}{8}$	2'1"	2'7¼"	$\frac{5}{8}$	3'1½"	3'10⅞"
$\frac{9}{16}$	1'10½"	2'4⅛"	$\frac{9}{16}$	2'9¾"	3'6$\frac{3}{16}$"
$\frac{1}{2}$	1'8"	2'1"	$\frac{1}{2}$	2'6"	3'1½"
$\frac{7}{16}$	1'5½"	1'9⅞"	$\frac{7}{16}$	2'2¼"	2'8$\frac{13}{16}$"
$\frac{3}{8}$	1'3"	1'6¾"	$\frac{3}{8}$	1'10½"	2'4⅛"
$\frac{5}{16}$	1'0½"	1'3⅝"	$\frac{5}{16}$	1'6¾"	1'11$\frac{7}{16}$"
$\frac{1}{4}$	10"	1'0½"	$\frac{1}{4}$	1'3"	1'6¾"

Fig. 91 (*b*).

221. Tie Plates. No system of lattice bars is complete without a plate at each end; the connection plate to another member may serve this purpose, but otherwise a special tie plate should be used. The plates at the ends should extend longitudinally at least as far as the transverse distance between the lines of rivets which attach them to the member, but intermediate plates used wherever the latticing is interrupted need be only $\frac{1}{2}$ as long. Each plate should be connected to each segment by at least three rivets with a maximum spacing of 4 diameters, 3'' being common. The thickness of each plate should not be less than $\frac{1}{50}$ of the transverse distance between rivet lines. Similar tie plates are used in tension members, without lattice bars, but they need be only $\frac{2}{3}$ as long as those in compression members.

222. Spacing of Lattice Bars. Lattice bars should be so spaced that all the bars of a group, and preferably all the bars of a member or series of members, are alike. Group spacing should be used for either single or double latticing (page 57). The longitudinal spacing should not be more than the transverse spacing for double latticing, but for single latticing it should not be more than cot 60° (or tan 30°) times the transverse distance; this may be found easily from the table of logarithms or graphically to the nearest $\frac{1}{16}''$. In planning the spacing it is well to take the longitudinal distance a multiple of $\frac{1}{8}''$, or preferably $\frac{1}{4}''$, but this may have to be changed to sixteenths to balance the system. The distance from the rivet in the tie plate to the rivet of the first bar should be sufficient to make the clearance between the plate and the bar from $\frac{1}{4}''$ to $1\frac{1}{2}''$; unless the lattice bars are between angles, the end bar may overlap the tie plate and have one rivet in common, if the spacing works out better.

223. Continuous Rivet Spacing. When component parts of a member are riveted together continuously, the spacing of the intermediate rivets is sometimes left to the templet makers, with a note giving the maximum value. Often a draftsman must space all rivets, and the following suggestions may aid the beginner. He should first locate all rivets which are determined by given conditions, such as those in connections to other members, those near the ends of compression members where the pitch is smaller, or those which must line up with other rivets on account of fixed gages or working lines. The remaining rivets are filled in with due regard to the maximum values allowed, one or more balancing spaces being inserted as needed to maintain the proper total. For the convenience of both draftsmen and shopmen, it is desirable to have spaces in multiples of $\frac{1}{4}''$ where practicable; for example, instead of using ten equal spaces in sixteenths, eight or nine spaces can be made alike leaving one or two odd spaces, not more than one of which involves sixteenths. Sometimes it is better to have two groups with slightly different spacing instead of one group with a balancing space. A balancing space between a group of small spaces and a group of large spaces should preferably be larger than the small spaces and smaller than the large spaces; this may be accomplished by combining one of the large spaces with a balancing space which would otherwise be too small, and subdividing the sum. If the rivet pitch changes at intervals, as in the flanges of plate girders, the spaces of each pitch should be sufficient to extend the proper distance from the end as determined by calculation ("Structural Design," page 116). The end rivets in stiffening angles are also flange rivets, and if the stiffeners are fixed in position the spacing of the flange rivets should be made to correspond.

When the calculated pitch in the flange is small, it may be necessary to exceed it on one or both sides of a stiffening angle in order to provide ample driving clearance from the edge of the angle for driving the rivets, but no other spaces should exceed the computed pitch. When a member is symmetrical about the center, care must be taken to have the center line fall on a rivet or midway between two rivets, whichever gives the better arrangement. When rivets are staggered on two lines, care must be taken to maintain the stagger throughout, even though it becomes necessary to add rivets; at each stiffener, the rivet nearer the back of the flange angle is used. Rivets in cover plates should be spaced to give ample driving clearance on either side of the outstanding legs of the stiffening angles. After a line of rivet spacing is completed, it should always be totaled to make sure that the sum equals the proper amount; similarly, the sum of the spaces within any definite distance should equal that distance.

CHAPTER XII

WELDING

224. General comments on **welding** may be found on page 22, and notes on the method of representation on page 42. The method of determining the sizes of welds required for given conditions may be found in "Structural Design," pages 103–105, and elsewhere.

225. As a rule, the welding to be done on any member conforms to the **standards** of the company which fabricates the work, although some differences may be written into the specifications drawn for a particular contract. When company standards are to be followed, no special notes are needed, but when certain differences are incorporated in the specifications they may be covered in general notes on the drawings, near the titles. Special references to standards or to specifications may be added to the code symbols by placing the paragraph reference in a V-tail added to the code arrow (page 43), with a general note near the title to the effect that "unless otherwise designated, all welds are to be made in accordance with welding specification No.——." Reference to special notes may be placed either in the V-tail or along the arrow next to the code symbol.

226. The **welding symbols** are not placed directly upon lines of the drawing, but on separate bent arrows pointing to the welds. The symbols should be arranged so that they are read from the bottom or right-hand edges of the drawing, and symbols below the lines so drawn apply to the near side of the member as drawn. When a weld is to be made on one side of a plate only, care should be taken to point the arrow to that side. The sloping lines in the code symbols for fillet welds or beveled grooves are drawn to the right of the normal lines, regardless of whether the arrows point toward the right or the left. The weld size is given to the left of the symbol, and the length of weld or increment to the right; the pitch from center to center of increments follows the length of increment. The pitch of staggered intermittent welds is given from center to center of the increments on one side only (not as in dimensioning staggered rivets). When intermittent welds are indicated between certain limits without crosshatching, it is understood that the increment and not the space begins at the limit. Faces of fillet welds are assumed to be at 45° unless otherwise indicated; any other angle may be recorded within the code triangle, the smaller angle being given. The size of the weld is the length of the shorter leg, and the code triangle should be drawn in the relative position which will show which is the shorter leg.

227. The Size of Weld. The most efficient welds are $\frac{3}{16}''$, $\frac{1}{4}''$, $\frac{5}{16}''$ and $\frac{3}{8}''$. Welds larger than $\frac{3}{8}''$ are usually made in two or more passes, and sometimes $\frac{3}{8}''$ welds are so made. The smaller welds are stronger per unit of volume. No weld should be greater than the thickness of the metal connected, and usually when welds are used on both sides of a plate, neither should exceed one-half the plate thickness. When limited space is available for connections, larger welds may be needed in order to furnish the proper strength. The length of weld should be at least 4 times the weld size. Small welds for holding pieces in place but with no appreciable stresses may crack when used against metal which is too thick; the maximum thickness of plate for different sizes of weld is about $\frac{3}{16}''$ to $\frac{3}{8}''$ for $\frac{3}{16}''$ weld, $\frac{3}{8}''$ to $\frac{5}{8}''$ for $\frac{1}{4}''$ weld, $\frac{5}{8}''$ to $1''$ for $\frac{5}{16}''$ weld, $1''$ to $2''$ for $\frac{3}{8}''$ weld, and $2''$ to $4''$ for $\frac{1}{2}''$ weld.

228. The edge of a plate should be **welded on both sides** if it is liable to bend and break a weld on one side; similarly a seat angle should be welded on both sides or both ends to avoid a prying action on the weld.

229. Location of Weld. Wherever possible, welds should be so located that they can be welded from above (down welding); vertical welds are the most difficult to lay correctly. Members can be turned in the shop to facilitate welding, but shop welds should be arranged for down welding with a minimum amount of handling. Field welds which can be made from above are cheaper and more convenient, and they can usually be made without falsework or special working platforms.

230. Welding Clearance. Details should be designed for welding so that the welder can hold his electrode in the proper position. This is usually in a plane normal to the face of the weld, but this varies with the relative thickness of the parts welded, the electrode being pointed more toward the thicker material in order to obtain equal penetration. Sufficient clearance should be provided so that no projecting part makes it difficult to gain access for welding.

231. When there is a **gap** between the edge of a plate and the face to which it is to be connected by a fillet weld, the weld must be increased by the amount of the gap so that the full size is measured from the edge.

CHAPTER XIII

CLEARANCE

232. Suitable **clearance** should be provided wherever possible to facilitate the assembly of the component parts of members in the shop, and also the erection of whole members in the field. It should provide for the overrun of material beyond the ordered dimensions, for certain tolerances in shop work which might prevent insertion, and additional amounts wherever practicable in order to give the shopmen and erectors greater freedom of action to expedite their work. Clearance is of greater importance in field connections than in shop work because of the difficulty in handling the larger pieces which are involved and which must be put into comparatively inaccessible places.

233. In some places **tight fits** are necessary, but this work involves additional expense and should be avoided whenever possible. For example, the stiffening angles of a plate girder are usually fitted so that the outstanding legs are in contact with the flange angles; not only must these angles be cut accurately to length, but they must also be cut to clear the curved fillets of the flange angles. Similarly, stiffeners are used under seat angles and elsewhere.

234. When **field rivets** are to be **driven parallel** to the axis of a member, very little **erection clearance** can be left between the end of that member and the face of the member to which it connects. No clearance is needed when the method of erection is such that the supporting member can be placed against the end of the given member so that the latter does not have to be inserted between two members; no clearance is needed at one end when the opposite end is wall bearing, or when it connects to a supporting member by rivets normal to its axis, because sufficient leeway may be provided at the opposite end for adjustment. When a member is inserted at right angles between the faces of two other members, however, some clearance must be provided to permit erection, even though the gap must be drawn up when the rivets are driven to make them tight; the amount of this clearance is $\frac{1}{16}''$ at each end. For beam work the tables give dimensions from the backs of the connection angles to the centers of the supporting beams, equal to $\frac{1}{2}$ the web thickness plus $\frac{1}{16}''$, expressed in multiples of $\frac{1}{16}''$. Since the backs of channels instead of the web centers are located on the plans, the distance from the backs of the angles to the backs of the webs is either $\frac{1}{16}''$ or the whole web thickness plus $\frac{1}{16}''$, depending upon which way the supporting channel is turned; this web plus $\frac{1}{16}''$ is given in the tables. Should the beam length from back to back of connection angles result in sixteenths, it is often reduced to the eighth below to avoid subdivisions in thirty-seconds, the extra $\frac{1}{16}''$ being added to the clearance at either end. If the supporting members are permanently fixed in position so that they cannot be spread during erection, special consideration must be given to the method of erection to make sure that the member can be slipped into position transversely or vertically, or else provision must be made for swinging it; this may require more clearance and perhaps enough more to justify the insertion of a loose filler after the member is in place. Sometimes the outstanding leg of one connection angle at each end is bent with a sledge to facilitate erection, after which it is bent back again.

235. When **field rivets** are to be **driven at right angles** to the axis of a member, it is usually possible to provide ample **erection clearance** because the gap does not need to be closed when the rivets are driven. This clearance is from $\frac{1}{2}''$ to $\frac{3}{4}''$ wherever practicable in order to simplify the work of swinging a heavy member into place. Beams which rest on seat angles, however, might bend the outstanding legs of the seat angles if made too short, especially if they underrun in length or if no stiffeners are used under the seats; the ends of such beams are usually placed about $\frac{1}{2}''$ from the faces of the supporting beams or columns.

236. When **top angles** are used on columns in conjunction with beam seats, they are usually placed $\frac{1}{4}''$ above the tops of the beams in order to provide for overrun or for beams out of square. These angles are usually shipped bolted in position so that they can be removed if necessary during erection; this is especially desirable on the web faces of columns for the beams may have to be lowered vertically into place. Loose fillers $\frac{1}{8}''$ thick are shipped with the field rivets to the site and inserted as needed to fill the gap between the top angle and the beam.

237. Bridge trusses should be detailed to provide for the erection of the separate members. The gusset plates are usually shop-riveted to the chords or the end posts, and the dimensions should be so coordinated that there will be $\frac{1}{8}''$ clearance ($\frac{1}{16}''$ on each side) between the web members and the plates. Similarly, clearance should be provided for bracing members which are to be inserted between two plates. When plates are to be inserted between angles, it is desirable to have the space between the angles $\frac{1}{8}''$ greater than the plate thickness, but where this is not feasible care should be taken that no shop rivets are placed in either leg of the angles which will prevent their being spread sufficiently to allow the plates to enter; if such rivets are required they should be left to be driven in the field. Often splice plates and connection angles may be held in position by one or more shop rivets, but not if erection is made more difficult, for it is better to ship the pieces bolted so they may be removed. Bridge details should be arranged so that either the trusses or girders may be completely erected before the floor system is inserted, or conversely, so that the floor system can be erected before the trusses are put in position.

238. Projecting parts should be arranged so that they will not interfere with the erection of a member. Clearance should be left between members which connect independently to the same member. It may be necessary to notch or block out part of a member or cut part of it away in order to clear another member. The amount of such clearance should be from $\frac{1}{2}''$ to $\frac{3}{4}''$. Any mistake which leads to cutting or drilling in the field is very expensive, partly because of the lack of facilities but more especially because of the number of skilled workmen who are delayed during the investigation which necessarily precedes any alteration.

An actual blunder may be cited to show the importance of studying the structure as a whole. Two girders at right angles to each other were to be connected to the same column, one to the web and the other to the flange. Each connection would be correct if used independently or if one of the girders extended in the opposite direction, but the detailer and the checker both overlooked the fact that the two girders would intersect and hence could not be in position at the same time. It was necessary to cut one girder short and make it frame into the other; also to strengthen the other column connection to support the combined load.

239. Details should be arranged to facilitate erection whenever possible, but this is especially important in replacements, such as office or loft buildings or railway bridges, so that the old structures may be left intact until the last moment. Special types of connections are often used for this class of work in order to reduce the number of field rivets or welds. The end of a beam or a girder should be supported entirely by end connection angles, or else by a seat angle or some form of bracket, but never by a combination of the two because of the difficulty in making both act at the same time. Erection seats should be provided to support girders with end connection angles until the rivets are driven (*F*1, Fig. 124); erection seats may be provided also for heavy beams or for beams which are to be connected to opposite sides of a web plate by the same rivets. The draftsman should be familiar with common methods of erection in order to anticipate special requirements for which provision should be made on the drawings. Rivet heads which protrude far enough to prevent swinging a member into position should be flattened or countersunk, or else left to be driven in the field. " Hand holes " may have to be bored through solid webs to give access to the inside of box sections for driving rivets; shop rivets may be omitted from a lattice bar or a tie plate so that they may be removed temporarily.

Rivets at the intersection of the diagonals of vertical bents or other inaccessible places which require special stagings for the riveters should be avoided whenever possible, because they are expensive.

240. Driving Clearance. Both shop and field rivets are preferably driven by machine, as explained on page 22, and if possible rivets should be so located that the machines can be used. In order that machines may be moved into the proper position for driving rivets, sufficient driving clearance must be provided between the heads and any projecting edges to allow for the dies which form the heads. The amount of driving clearance required under different conditions is given in the tables. In order to use machines for driving rivets in the cover plates of girders, such rivets must be placed far enough from the outstanding legs of stiffening angles and from the projecting heads of the rivets in the vertical legs to allow both for the rivet dies and for the carrying arm; these amounts are also shown in the tables. Rivets can be driven by hand in spaces too small for machine driving, but this should be obviated where possible. A careless draftsman sometimes locates rivets which can be driven only with the greatest difficulty, if at all. A common mistake among novices is to space the rivets in the cover plates of girders independently of those in the web; as a result the outstanding legs of the stiffeners may prevent driving the rivets in the cover plates.

241. Welding clearance should be provided so that the welder can insert his electrode and shield and use them to the best advantage. Clearance dimensions are not so definite as for riveting, but the draftsman must be familiar with welding technique in order to work out satisfactory details.

242. Shop clearances are not so important or so large as field clearances because the fitters put relatively small component parts into relatively accessible places, and it is much simpler to trim a small piece in the shop if necessary than to cut a whole member in the field. However, it is well to allow suitable clearances for shop work to provide for reasonable tolerance in workmanship and to allow for overrun of material. Working lines of trusses and the spacing of rivets can be so arranged that different truss members clear one another by ¼″. Similarly, fillers under stiffening angles are cut short enough to clear the flange angles or seat angles by ¼″, although in some bridge work this is reduced to ⅛″. Generally speaking, shop clearances are about ¼″ whereas field clearances are at least ½″.

CHAPTER XIV

LAYOUTS

243. A "**layout**" is a preliminary drawing made for the purpose of scaling distances which cannot be obtained so easily in any other way. One form of layout is used to determine the best shape and size of a connection plate for members which meet at oblique angles, with due regard to rivet spacing, edge distances, and clearances. Such a layout may be made on a separate sheet of paper to a larger scale than the working drawing but drawn more carefully; it need not be made so complete, and after it has served its purpose it may be discarded. The average draftsman should be able to obtain the same information more simply, however, by plotting lightly a few temporary critical points and lines on his working drawing, making use of the same working lines. A separate layout of an unusual or complicated connection may be worked out by one person and handed to others in order to save duplication of effort; such a layout should be more elaborate with enough lines to show conditions clearly. In ordinary work, checkers prefer to make their own simple layouts rather than use the draftsman's layout, particularly if inaccuracies in plotting will seriously affect the results. Another form of layout is a preliminary drawing made to determine lengths of material to be ordered from the mills; for example, the drawing of a roof truss may be carried far enough for the draftsman to scale the lengths of all main members with sufficient accuracy to enable him to order the material, and then the drawing may be completed later to serve as a working drawing. Freehand layouts may be used for simple work, in conjunction with "Tables of Slopes and Rises."*

244. Two common types of layout will serve as illustrations, viz.: gusset plates and lateral plates. These terms are often used interchangeably, but for convenience they are treated here as separate types with the distinction that a gusset plate connects primary members of a truss, the working lines of which meet in a common point, whereas a lateral plate connects members of a bracing system or a light latticed girder in which the stresses are so small that a single intersection is less important than a simplified detail which may be obtained by means of an auxiliary working line. In each illustration, a complete separate layout is shown in order to make it more intelligible and to serve as a guide for a more elaborate

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* C. K. Smoley and Sons, Scranton, Pennsylvania.

layout, but suggestions are given also for obtaining the same information more simply by means of a few temporary lines on the working drawing itself; the shorter method is recommended for simple connections. The principles shown can be adapted readily to more complicated connections than those illustrated. For bent-plate work, see page 190.

245. A layout of a gusset plate with lines of action which meet in a single point is illustrated by the connection of two web members to the continuous bottom chord of a roof truss, as shown in Fig. 101, each member being composed of two angles. The following method of procedure is suggested:

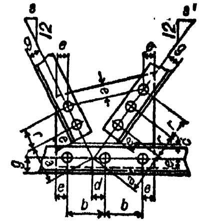


Fig. 101.

I. Determine the slopes s and s' of the diagonal members (page 84).

II. Lay down the working lines (usually the rivet lines) of all the intersecting members to the proper slopes, using a scale of $1\frac{1}{2}'' = 1'$ or $3'' = 1'$.

III. Plot the limiting lines (outside edges) of the angles, using the proper gages (page 86) and showing the backs of the angles on the proper sides.

IV. Draw a line to show the proper clearance c (page 99).

V. Cut each diagonal normal to its axis so that the nearer corner will fall in the clearance line just plotted; make sure that ample clearance is left between the diagonals.

VI. Place a rivet approximately at the desired edge distance e (page 88) from the end of each diagonal so that the distances a and a' from the working point are multiples of $\frac{1}{4}''$; these distances are dimensioned on the drawing, whereas the edge distances and clearances are not.

VII. Lay off the proper number of rivets in each diagonal at the desired distance r apart; this distance is generally made equal to the recommended minimum spacing for the given size rivet (page 87), so that the resulting plate will not be unnecessarily large.

VIII. Draw the edges of the plate vertically so that the horizontal edge distances e from the last rivets in the diagonals are approximately the desired amount, but so that the total width of the plate is a multiple of $1''$; the width along the chord should not be less than at the top.

IX. Draw the bottom edge of the plate horizontally at the desired edge distance e below the rivet line.

X. Draw the top edge of the plate parallel to a line joining the two top rivets at the desired edge distance e from the rivets, measured perpendicularly.

XI. Scale the length of the plate along the longer side at right angles to the width, which is taken as the perpendicular distance between parallel

XII. Place the rivets in the bottom chord so that they are about equal distances apart, with the end ones approximately at the desired edge distance *e* from the edges; the distance *b* from c. to c. of rivets should be dimensioned on the drawing as a multiple of $\frac{1}{4}''$, as should also the distance *d* from one of these rivets to the working point unless one of the rivets can be placed conveniently at the working point. If the number of rivets is so small that the resulting spaces appear to be too large, an extra rivet should be inserted; if the number of rivets is too large to be placed within a plate with vertical edges, they should be spaced at the usual minimum distance *r* apart and the plate reshaped; this will happen when the chord member is spliced at the joint.

XIII. The above steps may be modified as necessary to meet different conditions, but the shape of the plate should be chosen with due regard to the following points: (1) allow ample edge distance *e* from each rivet to each edge of the plate; (2) leave no corner of the plate projecting beyond the angles, i.e., each vertex should be hidden by the angles; a corner which falls behind a single angle should preferably be made to come on one edge of the angle for better appearance, but if between two angles this does not matter; (3) reduce the number of cuts to a minimum, for each cut increases the cost of the plate; (4) avoid cuts with reentrant angles, for they cannot be sheared; they must be flame-cut at added cost; (5) do not make the plate narrower along the chord than elsewhere, for the plate may not develop the necessary strength; (6) make two edges of the plate parallel and a whole number of inches apart if possible, so that the plate may be cut from one of standard stock width (page 46); (7) cut across the full width of the plate if possible, so that a number of similar plates may be cut from a long plate without waste, by alternating the cuts as shown in Fig. 46; (8) use as few different widths of plate as practicable on one drawing, and preferably on one contract, so that they can be ordered or taken from stock to better advantage with less handling; (9) the width of a rectangular plate is usually the smaller dimension, but this may be changed to the larger dimension if it cuts to better advantage; (10) the nominal length of the plate as billed on the drawing is the extreme dimension at right angles to the width, i.e., the dimensions of the including rectangle are given; this length is preferably expressed as a multiple of $\frac{1}{4}''$, but eighths are used also; (11) in ordering plates in multiple lengths, advantage should be taken of any gain which may result from (7).

246. A modified method of laying out a gusset plate on the working drawing is shown in Fig. 103. By the judicious use of a few temporary lines, the critical points may be plotted which will determine the dimensions ordinarily required. From the working lines already drawn, lay off to a scale of $3'' = 1'$ or $1\frac{1}{2}'' = 1'$ the gage *g* or *g'* of each diagonal and the distance *f* from the working line of the chord to the corner of the diagonal angle, found by adding the clearance *c* to the edge distance remaining after subtracting the gage of the chord member from the length of the leg. Lines through these points drawn parallel to the respective members intersect at the corners of the diagonals at distances x and x' from the working point, and to these distances is added the edge distance *e* to give the desired dimensions a and a' to the first rivets, taken in multiples of $\frac{1}{4}''$. Similarly, lay off y and y' equal to the distances from the working point to the last rivets of the diagonals; these can be found from the distances a and a' already found by adding the proper number of rivet spaces *r*. From these points and the horizontal edge distances *e* can be determined the width of the plate in a multiple of 1″, and also the spacing of the rivets in the bottom chord. Lay the edge of a triangle diagonally through the top rivets just plotted, measure the edge distance *e* normally from the edge of the triangle, and then slip the triangle and draw a parallel line through the new point intersecting the vertical edge of the plate at the required distance above the working point; to this distance add the bottom edge distance *e* to give the required length of the plate.

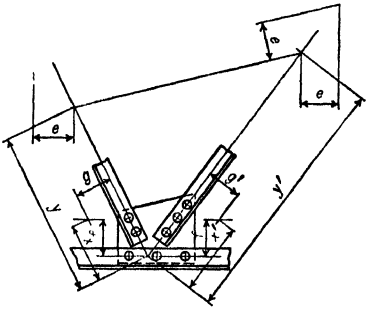


Fig. 103.

247. A lateral plate is commonly used to connect the diagonals in a lateral bracing system of a bridge or a building. A similar plate is used to connect the diagonals of a light latticed girder instead of a gusset plate, whenever the stresses are so small that a slight deviation from a single point may be made in the intersection of the working lines without causing serious eccentricity. An auxiliary working line is drawn through the end rivets of the diagonals parallel to the chord or supporting member, as explained on page 85. The working lines of the diagonals are not extended to the working line of the chord or supporting member, but the end rivets are located by rectangular coordinates according to clearances, thus reducing the size of the plate. The slopes of the diagonals cannot be determined precisely until after these coordinates are known, so it is customary to provide clearances for the diagonals in any position by using the extreme corner distance in both directions. In order to make the clearances the same whether a bracing diagonal is erected in the field in one position or turned end for end, it is customary to place the rivets in the center of the angle leg if it is 3″ or over; this may be done in a latticed girder also, even though the angles are fitted up in the shop the way they are shown on the drawing. Sometimes standard gages are used in the diagonals of a latticed girder, but the larger corner distance on the gage side is used both horizontally and vertically at the top and at the bottom so that the plates may be made alike or similar. This type of connection is illustrated by a plate for a latticed girder, as shown in Fig. 104, each member being composed of two angles.

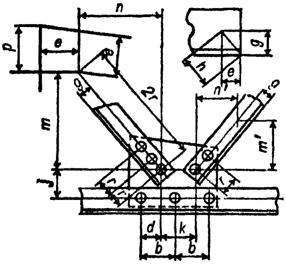


Fig. 104.

I. Determine the corner distances h and h' in the diagonals from the gages g and g' and the edge distances e; this may be done conveniently by plotting g and e full size on the sides of any rectangle, such as at the corner of a sheet of paper or on coordinate paper, and scaling the hypotenuse.

II. Compute the distance j, in a multiple of $\frac{1}{4}''$, from the auxiliary line through the end rivets to the working line of the chord member, by adding the larger corner distance h or h', the clearance c, and the edge distance in the chord.

III. Compute the distance k along the working line between the end rivets, by adding the corner distances h and h' and the clearance c; this should normally be in a multiple of $\frac{1}{4}''$ but may have to be modified to balance the panel dimensions, as explained on page 144.

IV. Compute the panel coordinates for the diagonals, and then the lengths and the slopes of the diagonals.

V. The values already found may now be plotted to scale and the remaining dimensions found by layout similar to that for a gusset plate (page 101), but this seems unnecessary in view of the simplicity of the modified method as follows:

VI. From the values computed above, lay down the system of working lines on the working drawing.

VII. Along the diagonal working lines lay off the sum of the proper number of rivet spaces r to a scale of $3'' = 1'$ or $1\frac{1}{2}'' = 1'$, and scale the corresponding rectangular coordinates m, m', n, and n'.

VIII. By means of these coordinates and other known values, determine arithmetically all the remaining rivet spaces and plate dimensions.

IX. When the numbers of rivets in the diagonals are not equal, the plate is cut diagonally unless the corners of a rectangular plate would be concealed between the angles; the length of the plate at right angles to the width between parallel edges may be found arithmetically as soon as the distance p is found from the enlarged layout. The distance p is measured vertically from the top rivet to the corner of the plate at the intersection of a vertical line and a sloping line drawn at the edge distance e from the rivet. The direction of the sloping line cannot be taken by joining the two top rivets because the rivet spaces are not plotted to the same scale as the distance k between working points; it can be found by plotting the second rivet a distance $n + k + n'$ to the right of the critical rivet and a distance $m - m'$ below it; usually it is close enough to use the slope from the small-scale drawing after the rivets are plotted on the working drawing.

CHAPTER XV

MARKING SYSTEMS

248. Two kinds of marks are in common use in structural work, the one "shipping marks" or "erection marks," and the other "assembling marks" or "piece marks." Shipping marks are used on the completed members as they are shipped from the shop to the site; they serve for identification in the drafting room, in the order office, in the shop, in shipment, and in erection. Assembling marks are used on the small component parts of members to facilitate their fabrication in the shop.

SHIPPING MARKS

249. Shipping marks should be clearly shown on the detailed drawings. From the time the draftsman determines the shipping mark of a member until the member is in its final position in a structure it is known by this mark. The mark appears on the drawing, on the order bills, the shop bills, the shipping bills, and the rivet lists, and it is painted on the templets and on the individual pieces of steel of which the member is composed. The mark is preserved when the completed member is painted before shipment, and it serves an important function during erection in enabling the erector to place the member in the proper position, as indicated by a similar mark placed on the erection diagram which is prepared by the draftsmen.

250. In general a shipping mark is composed of **two parts,** viz.: a characteristic letter or letters and a specific number, as S14 or LG2. Capital letters are used, and so far as possible the letters should be suggestive of the type of member, as C for columns, G for girders, EP for end posts, etc. These letters differ with different companies, but some of the letters commonly used are shown in the table opposite. Special systems are used in truss work and in tier buildings, as explained later in the chapter.

251. Shipping marks should be **marked conspicuously** on the drawing in bold type, together with the number of members to be made. These may be placed directly under the drawing of the members (Fig. 123), or at the right of the sheet above the title (Fig. 174). When several different members are shown on the same sheet, the marks and numbers of members may be tabulated in a "required list" above the title (Fig. 172); when these members are represented by independent drawings on the same sheet, each drawing should have the corresponding shipping marks for identification (Fig. 185). Special tabulations may be used for different shipments, as for beams (Fig. 149).

SHIPPING MARKS

Building Work	
Angle Bracing	D
Angles, miscellaneous	M
Beams	B
Bearing Plates, Masonry Plates	MP
Brackets	M
Buckled Plates	BP
Cast Bases	CB
Castings, standard	A
special	N
Column Base Plates, Slabs	MP
Columns, Posts — Mill Buildings, etc.	C
Tier Buildings	See page 110
Crane Stops	CS
Diagonals	D
Floor Plates	FP
Girders	G
Girts, Miscellaneous Framing	F
Hoppers, Bins, and Tanks	H
Knee Braces	K or KB
Latticed Girders	LG
Lintels	L
Plates, miscellaneous	M
Purlins	P
Rafters, Rails, and Railings	R
Railing Posts	R or RP
Rail Splice Plates	SP
Rods, bracing	X
tie and sag, X with length in inches	X48
Partition and Ceiling Framing	F
Smoke Flues	SF
Struts	S
Trusses, complete	T
Truss Members	See page 109

Bridge Work	
Angle Bracing, between stringers	D
bottom laterals	L
top laterals	T
Angles, miscellaneous	M
Bed Plates, expansion end	RP
fixed end	FP
Brackets	B
Buckled Plates	BP
Cast Pedestals	CP
Cross Frames	CF
End Posts	EP
Floor Beams	F or FB
Girders	G
Knee Braces	K or KB
Latticed Girders	LG
Pins	Panel Point Mark
Plates	P
Railing Posts	P or RP
Railings	R
Roller Nests	RN
Shoes, expansion	RS
fixed	FS
Stringers	S
Struts, bottom lateral	BS
portal	PS
sway bracing	SB
top lateral	TS
Trusses, complete	T
Truss Members	See page 109

252. Rights and Lefts. All members which are identical should bear the same shipping mark (except in tier buildings), and conversely, no two members should be marked the same unless they are interchangeable. When members are *exactly* opposite, both are made from the same drawing; the member which is made like the drawing is marked " R " for right, and the one which is made opposite is marked " L " for left. No indication of rights and lefts need be made on the drawing, the only difference being made in the list of members required, where rights and lefts are distinguished by adding smaller capital letters R or L to the shipping marks, placing them a little higher (Fig. 174). No member should be marked left unless there is a corresponding right. Before marking members right and left, the draftsman should satisfy himself that the members are really opposite, and that there are no other differences. A novice frequently imagines that two members are opposite when in reality they are interchangeable if inverted or turned end for end. A conception of rights and lefts may be gained from Fig. 108; if all the details are reversed about any one of the three axes of symmetry a left is obtained, but if they are reversed about any two axes one reversion counteracts the other and the member remains unchanged. The draftsman can usually visualize the reversal about one axis more conveniently than about the others because of the relative positions of the members, but the shopmen may find it simpler to think of it as being reversed about another axis. If a member were placed in front of a mirror, the right would be represented by the real member and the left by the reflected image.

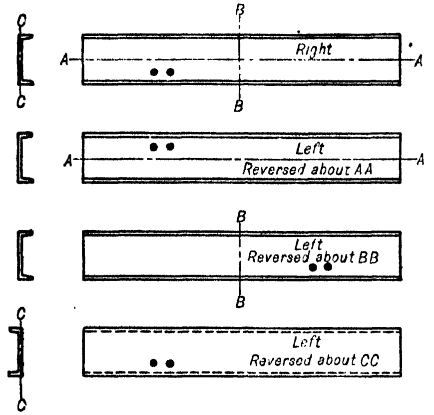


Fig. 108. Rights and Lefts.

253. Opposites. Two members which cannot be marked R and L because they are not exactly opposite may be so nearly opposite that they may still be combined on the same drawing to save duplication. They must be given different marks, but the one to be made opposite must have " Opposite " or " Left except ——," placed after the mark in the required list. Such a member would be made as if the drawing were reversed in much the same manner as a " left " is made, but in accordance with any special notes or dimensions. All details which apply only to the member marked opposite or left should be drawn in the proper relation to all other parts, subject to reversion with the rest when the member is made.

254. Members Combined. One drawing may be made to serve for different members if the differences are properly indicated or noted, as explained on page 78. Members which are marked rights and lefts may be combined with other members on a drawing, but only the shipping marks without R or L should appear in the various notes, and the details should be drawn as if only the right were shown. Similarly, opposites may be combined with other members.

255. Special interpretations of shipping marks may be made for the benefit of the erector. If the shopmen are careful to place the member right side up before painting the final shipping mark on it, this should reduce the chances of its being erected upside down. Similarly, erection is simplified if all shipping marks are painted on the left ends of the members and the marks are recorded in the corresponding positions on the diagrams. Sometimes one end of a heavy member is marked N, E, S, or W, or by some other designation which will help the erector place it in the proper position if this cannot be readily determined otherwise. Incorrect placement may be prevented by spacing the holes at one end differently from those at the other end.

256. In bridge trusses the members are marked according to the panel points between which they extend. The upper panel points are marked U1, U2, etc., and the lower panel points L0, L1, L2, etc., arranged so that vertical members have the same number at the top and at the bottom, as in Fig. 109 (*a*). Web members are marked with the panel marks at their ends, thus: L2–U2 or L2–U3. Chord members may be marked similarly, as U1–U3, or without repeating the letter, thus: U1–3, or L2–3. End posts may be marked EP or with panel letters, thus: EP1, or L0–U1.

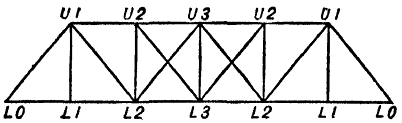


Fig. 109 (*a*).

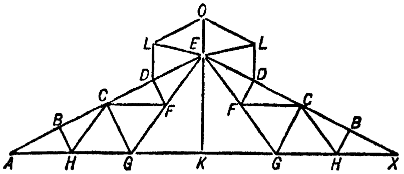


Fig. 109 (*b*).

For the sake of uniformity, drawings are made for the left-hand half of the far truss of a bridge, and the members should be marked right and left accordingly; sometimes supplementary letters are used, as N for members of the north truss and S for those of the south truss.

257. A roof truss is usually erected as a whole in order to save falsework. A small truss may be shipped completely riveted or welded, but a larger truss must be shipped in sections; these sections are assembled and riveted or welded together on the ground, and then the entire truss is lifted into position by a locomotive crane. Different systems of marks are used, but the drawings should conform to the practice of the company for which they are made. Some use T for a complete truss, HT for a half-truss, PT for part of a truss, while others use T for part of a truss and CT for a complete truss. Sometimes the panel points of a truss are lettered and the letters at the ends of a member or section are used as shipping marks; this is particularly helpful when a truss is shipped "knocked down" for export. For example, a truss that is to be shipped in sections indicated by the spaces in Fig. 109 (*b*) may have the sections marked as follows: AE, XE, EK, GG, and the monitor pieces LD, LM, LE, and ME. The details at A and X may or may not be alike, but AE and XE would be different because the peak plate would be shipped on one and not on the other, although both may be shown on the same drawing of the half-truss. An assembly table is placed on the detailed drawing or on the erection diagram to show how the different component parts are combined to make the different complete trusses, and only the marks of the complete trusses need be placed on the plans to show where they belong.

258. A special system of marks is used for **tier-building construction** in order to distinguish between members which are erected at different stages. Usually the columns are erected in two-story lengths and the two corresponding tiers of beams and girders are erected at the same time; all the derricks are then raised two stories, and the process is repeated. Members should be shipped to the site approximately in the order of erection; this is desirable because it simplifies erection, and is usually necessary because of the lack of storage facilities. All identical beams and girders in any one floor should bear the same mark; beams and girders in different floors should have different floor marks, although they may have the same specific number and be combined on the same drawing. Tier-building columns are numbered consecutively according to some definite system which will make it convenient to locate a particular number. These numbers are the same on the plans of all floors, so that each column section bears the same specific number as the column directly below or above it, but the floor marks are different. No two columns bear the same number even though interchangeable in some tiers, because they may not be interchangeable in other tiers. The floor or roof marks are indicated in different ways. The more common method is as follows: Beam or rolled girder, a specific number (without letter) followed by the floor number, thus: 62–Bsmt, 17–3Fl, or 31–R. Plate girder, regular girder mark with floor designation, thus: G2–Bsmt, G4–7Fl, or G1–R. Column, column number followed by tiers between which the column section extends, thus: Col. 8 (B–2), Col. 25 (4–6), or Col. 30 (14–R). In another method which has merit, floors are indicated by letters instead of numbers, beginning with A for the first tier, B for the second tier, and R for the roof. The rolled beams and girders are marked A62, C17, or R31, and the columns AB8, EF25, LR30, using the letters of the tiers supported; for an odd number of stories the top section might be L30 or LMR30, depending upon the length and the weight of the section.

ASSEMBLING MARKS

259. Assembling marks may or may not be used on component parts of members, depending upon the apparent benefits. The benefit to the draftsman depends upon the system used and how much repetition may be saved; the benefit to the shopmen depends upon the number of times the same detail is repeated, especially if on different sheets. The principal use of assembling marks is on large contracts with many similar details. The assembling marks usually originate in the drafting room, where they are put on the drawings, but sometimes they originate in the templet shop or structural shop where they are put on the blueprints with colored pencils. In either case, the marks are painted on the templets, and as the holes are laid out on the steel the marks are painted on the steel to aid the fitters in assembling the parts. Assembling marks assist the templet maker in using a single templet for a detail which occurs on many different sheets, although he does this to a certain extent when such marks are not employed. No further mention will be made of any system of assembling marks which may be arranged between the templet makers and the shopmen, for it has no bearing upon drafting.

260. Systems of assembling marks differ according to the practices of different companies, but the principles underlying them are essentially the same. Some companies use first letters which refer more or less significantly to the same types of detail, followed by second letters or numbers to distinguish different pieces of the same type; other companies use letters alphabetically regardless of types, with double letters after the preferred single letters are exhausted. Lower-case letters are used in order to distinguish clearly between assembling marks and shipping marks. The letters *i*, *l*, *o*, and *q* are usually omitted because they are not readily distinguishable, and sometimes *e*, *j*, *n*, *r*, *u*, *x*, and *y* are omitted. Assembling marks are usually not given to main component parts of a member, but only to those details which occur more than once on the same or different sheets. When there are only a few details of the same nature on a sheet there is less need for assembling marks than when many similar pieces might confuse the fitters. Occasionally it is convenient for the draftsman to put assembling marks on some parts, such as stiffeners and fillers of plate girders, even though marks are not used on the remainder of the contract. The assembling marks are placed immediately after the billed sizes of the details, but a mark may be repeated for identification of a part in one or more views to clarify the drawing.

261. The first letter is often suggestive of the detail, as *b* for bottom seat angles for beam connections, *f* for fillers, *m* for miscellaneous angles, *p* for miscellaneous plates, *s* for stiffening angles, *t* for top angles for beam connections, and *w* for light web members. Other letters commonly used, but not so significant, are *a* for base or cap angles of columns; *c* for base plates, cap plates, or splice plates; *h* for bent plates or angles; *y* for lattice bars; etc. Some companies differentiate between stiffeners fitted at both ends and those fitted at one end only, or between fillers with two or more rows of rivets and those with only one.

262. The second letter or number is added to distinguish similar details. For example, the end stiffeners of a plate girder might be marked *sa*, the next pair *sb*, and other, different ones *sc*, etc., double letters being used when the preferred single letters are exhausted, as *saa*, *sab*, etc.

263. When significant letters are not employed, single letters are used alphabetically until the preferred ones are exhausted, then a prefix *a* is placed before each of the preferred letters, then the prefixes *b*, *c*, etc.

264. The sheet number is usually added to the assembling mark on the templet and on the steel, but it is not necessary on the drawing itself because of the unnecessary repetition. When the same assembling mark is used for identical details on more than one sheet, the number of the sheet upon which it is first shown is placed after the mark on each drawing. For the convenience of all concerned, such a piece should be completely dimensioned and billed once on each sheet, but in all other places the dimensions and billing may be omitted. When shop bills are printed on the same sheets as the drawings, all material is listed on the shop bill so that it need not be repeated on the drawing when assembling marks are used; the assembling marks should be placed on the drawing, however, to indicate the location of the details.

265. All pieces which are identical should bear the same mark, and conversely, pieces which are not interchangeable should have different marks. **Rights and lefts** in assembling marks are usually indicated, although some companies leave this to the templet makers. Where rights and lefts are used in pairs they may be billed together with "R & L" added at the right of the marks, but a little higher.

CHAPTER XVI

PLATE GIRDERS

266. Types. Plate girders are used in every class of steel construction because of their adaptability. They resist transverse bending like beams, but they are for heavier loads, for longer spans, or for conditions for which single rolled sections are not so well adapted. Small girders are not so common now that the heavier wide-flanged beams are available. A plate girder is made with a web plate to which flanges are riveted or welded at the top and bottom edges, the most common forms of cross section being similar to those shown in Fig. 113. Flange angles are used in riveted work, with or without cover plates, as shown at (*b*) or (*c*). Similar sections may be used for welded girders, but the simplest type has only three plates, as shown at (*a*). With different depths, different forms of flanges, or different sizes of component parts, girders may be made to serve a great variety of

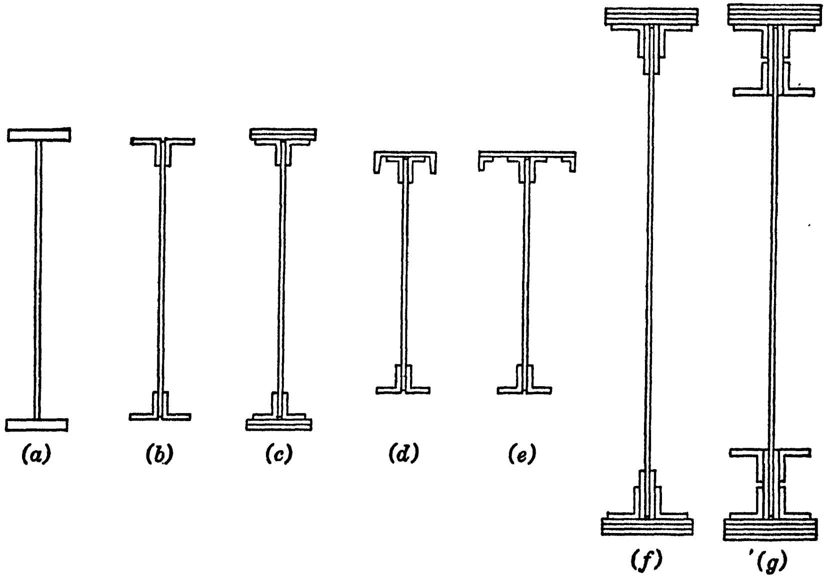


Fig. 113. Typical Girder Cross Sections.

purposes. Types (*d*) and (*e*) are for crane runways giving greater lateral stiffness, and types (*f*) and (*g*) for long-span bridges where heavier flanges are required. Wide girders with multiple webs are called " box girders."

267. Main Dimensions. The dimensioned *length* of a plate girder depends upon the type of the end connections; it is usually the most important length. If a girder is to be inserted between the faces of other members and joined by web connection angles, the principal dimension is the overall length from back to back of connection angles. If the web plate of a girder is to be connected directly to the flanges of columns, the principal dimension is from center to center of holes, for it is more important that this distance be maintained than the overall length. These main dimensions are preferably emphasized by means of heavier figures. Supplementary dimensions, such as distances from center to center of supports, are often given for convenience in the drafting room; these are tied in at each end to indicate how the main dimensions are determined, as in Figs. 126 and 127. The dimensioned *depth* of a girder with flange angles is invariably from back to back of angles, whether or not cover plates are used. Similarly, in a girder without flange angles the clear depth between flange plates is dimensioned, but also the total depth including the plates. The depth (width) of the web plate is generally a multiple of 2″, and preferably a multiple of 6″. A web plate is sheared at the mill to the ordered width, but extreme accuracy is not assured and the edges may not be exactly parallel. The fabrication of a welded girder is simplified if the edges of the web are planed to dimension, for it is easier to maintain the proper extreme depth and the conditions for welding are improved. In a riveted girder the flange angles are allowed to project $\frac{1}{4}''$ beyond the nominal edge of the web plate so that no unevennesses will interfere with the placement of the cover plates or other members. In a bridge, viaduct, or other structure in which the girder is to be exposed to the weather, the *top* angles are made flush with the edge of the plate unless cover plates are used; otherwise a rain pocket is formed which will lead to a more rapid deterioration of the girder. It is well to add a note stating whether or not any projections which may occur shall be chipped off (Fig. 124). Thus the depth from back to back of angles is $\frac{1}{2}''$ more than the nominal depth of the web plate except that in exposed girders without cover plates it is only $\frac{1}{4}''$ more. It is not feasible to draw extra dashed lines to represent the edges of the web plate behind the flange angles, but the projection of the angles is evidenced by the discrepancy between the billed width of the web plate (usually in even inches) and the dimension back to back of angles (usually with a fraction). Sometimes the web plate of a crane-runway girder is made to project $\frac{1}{16}''$ above the angles so that the rail or cover plate will bear directly upon the web; in this case it is unnecessary to provide for vertical components on the flange rivets.

268. The flange angles usually extend the full length of a girder and should be billed accordingly. They are ordered about $\frac{3}{4}''$ long and are then recut to the required length in the shop where they can be cut with greater precision than at the mill. The stringers and floor beams of railroad bridges are often milled at the ends; in other girders the angles are sheared. The extra $\frac{3}{4}''$ is indicated on the material-order bills and on the shop bills but not on the drawing.

269. A web plate should extend to the extreme ends of a girder unless end connection angles or stiffening angles are placed with their outstanding legs at the extreme ends, in which case the web plate is billed to come within $\frac{1}{4}''$ of each end; if the ends are to be milled, the plate is ordered $\frac{3}{4}''$ long, but billed on the drawing to the finished length. In a large girder the web plate must be spliced, for it is impossible to obtain the wider plates long enough to extend the full length. When more than one splice is used, they are spaced symmetrically about the center line and made alike, being designed for the largest stresses. A single pair of splice plates is used in a light girder, but additional plates on or near the flange angles are needed in a heavy girder ("Structural Design," page 110). The lengths of the web sections should be billed to allow from $\frac{1}{4}''$ to $\frac{3}{4}''$ between them. It is well to locate a splice under a pair of stiffeners to save an extra row of rivets, to reduce the thickness of the fillers, and to keep the web from buckling while the rivets are being driven.

270. Cover plates may be used on a plate girder to furnish additional metal in the flanges. Since the flange stress is a function of the bending moment, the greatest flange area is required where the moment is maximum; as the moment decreases, the flange area may be reduced. This reduction is effected by cutting off the cover plates successively at points beyond which they are no longer needed, as explained in "Structural Design," page 69. Universal-Mill plates with rolled edges are usually ordered for cover plates. If a girder is to be exposed to the weather, one plate on the top flange, and often one on the bottom flange, are made to extend the full length of the girder in order to protect the surfaces of contact between the angles and the web from the action of the elements. Similarly, all the cover plates or the cover channel on the top flange of a crane-runway girder must be continuous in order to furnish uniform bearing for the rails which rest directly upon them; this is not true of the top cover plates of a railroad deck bridge for the ties may be dapped (i.e., notched) different amounts to make up for the difference in plate thickness; the ties must be notched also for the rivet heads. Special detailed drawings are often prepared in the drafting room for the ties of a bridge, especially when they have to be sawed to provide for the superelevation of the outer rail on a curve. Plates are ordered the same as the billed lengths and detailed with 1¾'' edge distance to provide tolerance for cutting at the mill, except that full-length plates are ordered ¾'' long and recut in the shop the same as the flange angles. The flange plates of a welded girder may be made of component parts of different lengths, or a single plate may be used in each flange; this single plate may extend the full length or be butt-welded to a thinner plate at a point where the reduced area is sufficient. Cover plates may be billed with the flange angles, or in the flange views, or on separate dimension lines with dimensions to the end of the girder, as in Fig. 125. In the top view the dashed lines of the web and the flange angles need not be drawn full length for it is sufficient to show them for a short distance at the end and at each pair of stiffeners, as in Figs. 125 and 128. In the bottom sectional view the web plate may be filled in solid and the stiffeners crosshatched, as in Fig. 127, but in modern practice they are shown by full lines with no indication of which parts are cut by the section plane, as in Figs. 125 and 128.

271. Since the vertical shearing stresses of a plate girder are resisted by the web plate, they must be transmitted from the web to the supports. The web may be connected to the face of a column either directly or by means of end connection angles, as in Fig. 123. When a girder rests upon a column seat, a pedestal, or upon masonry, **end stiffeners** are used to transmit the shearing stresses; stiffening angles with fillers are used in a riveted girder, as shown in Fig. 116, but plates may be used in a welded girder. The backs of the outstanding legs are placed at the center of bearing whenever feasible. Stiffening angles are placed against the vertical legs of the flange angles, and the ends are cut to bear against the outstanding legs; the billed length is the exact distance in the clear between the outstanding legs, except that sometimes a clearance is allowed at the top to make unnecessary the cutting for the fillet. The web legs must be cut to clear the curved fillets of the flange angles; these may be cut by special cutters, planed, or ground, but no mention need be made of such cutting because the usual shop practice will be followed. It is not necessary to show the curved fillets in an end or sectional view. The stiffeners are usually cut in pairs, and if assembling marks are used they are made rights and lefts even though the angles are apparently symmetrical. Stiffeners are ordered ¼'' longer than the billed length. For the design of the stiffeners, and the number and spacing of the rivets and welds, see "Structural Design," page 107.

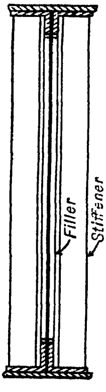


Fig. 116.

272. Unless the web plate of a girder is thick enough to resist the shearing stresses without buckling, it must be reinforced by **intermediate stiffeners,** as explained in "Structural Design," page 109. When the position of stiffening angles is definitely determined by members which are to connect to the outstanding legs or which rest on the top flange, the stiffeners must be spaced before the flange rivets; if not so fixed, they can be spaced in conjunction with the flange rivets, so that a little modification may result in better spacing. It is customary to place stiffening angles so that the backs are toward the nearer end of a girder. The billed length is the clear distance between the outstanding legs of the flange angles unless a clearance is allowed at the bottom end to make unnecessary the cutting for the fillet. The rivets in the intermediate stiffeners are made to line up with those in the end stiffeners, even though alternate rivets are omitted when the resulting spaces are not excessive (page 88) and when there are enough to support any concentrated load; a single line of dimensions at the end usually suffices for both the end and the intermediate stiffeners, but all rivets should be indicated so that there will be no doubt whether the number of rivets in the intermediate stiffeners is the same as in the end stiffeners, or whether the alternate rivets are omitted. The rivets are shown by circles at each intersection of rivet line and projection line, and usually the first rivet in each group spacing is shown; the remaining rivets may be indicated by cross lines, as shown in Fig. 123. When assembling marks are used, each different kind of stiffening angle must be completely detailed where first shown, but other like ones are drawn in but identified simply by the assembling marks without rivets, gages, or billing; sometimes it is clearer to indicate all rivets, as in Fig. 123. It may clarify the drawing to use supplementary dimension lines, as in Fig. 125. Plates may be used as stiffeners in a welded girder, as in Fig. 128.

273. Fillers are used to fill the spaces between the web plate and the stiffeners which are separated from the web by the vertical legs of the flange angles (Fig. 116). The thickness of a filler should be the same as the thickness of the flange angles unless part of the space is occupied by a splice plate or reinforcing plate; in this case the filler should be thick enough to make up the difference. Rather than use a filler less than $\frac{3}{16}''$ thick, it is usually better to make the splice plates or reinforcing plates the same thickness as the flange angles. If the thickness of the top and bottom angles differ by $\frac{1}{16}''$, the filler may be made of either thickness, preferably the smaller; if they differ by $\frac{1}{8}''$, the filler is made the mean thickness; if they differ by more than $\frac{1}{8}''$, two fillers should be used, one as thick as the thinner angle and the other equal to the difference in thickness, extending to the fillet of the thinner angle. The length of the filler should preferably be about $\frac{1}{2}''$ less than the clear distance between the flange angles, allowing the usual shop clearance of ¼″ at each end. On girders which are exposed to the weather it is well to reduce this clearance to ⅛″, and some specifications require tight fits, at least at one end, but due allowance should be made for the overrun of heavy angles. The width of a filler should be the same as the width of the superimposed stiffening angle, unless the filler is extended under two or more angles or made wide enough to take an additional row of rivets as is usual under end stiffeners. Strictly speaking, the end of each filler should be shown by a dashed line separated from the dashed line of the flange angle, unless there is no clearance when a single line will suffice; many draftsmen omit both dashed lines in order to save time. Similarly, little cross lines may be drawn in end or sectional views to show the ends of fillers, although these are often omitted.

274. Intermediate stiffening angles are sometimes **crimped** or bent over the vertical legs of the flange angles and brought into contact with the web plate, much as the end angles of Fig. 125 are crimped over the bottom flange angles, as shown in the end view. No fillers are required under crimped angles. Stiffeners which transmit direct stress, such as end stiffeners and stiffeners under concentrated loads, should not be crimped, for straight angles are more effective. Similarly, stiffeners which have holes in the outstanding legs for the connection of other members should always rest upon fillers, for better results can be obtained in this way. Most specifications permit the crimping of all other intermediate stiffeners, but many companies prefer to furnish fillers rather than bother with the forge work, particularly when the additional cost is met by the customer, as in contracts based upon a price per pound. The length of a crimped angle should include the amount of metal required for each crimp which is equal to the depth of the crimp, i.e., the thickness of the flange angle; thus the billed length of a crimped stiffener is equal to the depth of the girder from back to back of flange angles. An extra ½″ should be ordered for each crimp so that the angles can be cut to fit properly after they are bent.

275. Flange Rivets. The flange angles of a girder are fastened to the web plate by sufficient rivets to transmit the flange stress for which the angles and cover plates are designed. The rivets are usually closer together near the ends of a girder than in the central part because the increase in flange stress is greater. The pitch, or longitudinal spacing from center to center of rivets, depends upon the depth of the girder and the conditions of loading, and must be calculated for each individual girder, as explained in "Structural Design," page 116. For fixed concentrated loads, the rivet pitch is constant throughout each panel, but for uniformly distributed or moving loads the theoretical pitch varies throughout the length. It is impractical to use different spacing throughout because of the extra drafting-room and shop costs, and so it is customary to divide the girder into panels and to use a constant pitch in each panel, even though the number of rivets is thereby increased. It is convenient to change the pitch at a stiffener, but it can be changed at any point as long as the pitch is calculated accordingly. No pitch should be used nearer the end of a girder than the point for which that pitch is computed. Each pitch is usually expressed to the nearest ¼″, and the spacing must be tied in with the gage lines of the stiffeners, for a rivet in each stiffener is also a flange rivet. Standard gages are used in the stiffeners, but the gages are dimensioned on separate lines. The flange rivet on either side of a stiffener must be spaced to provide sufficient driving clearance (page 99), even though the computed pitch is exceeded. Group spacing is used for intermediate rivets, with one or more balancing spaces as required to maintain the proper distances between any fixed points (see page 92). No pitch should exceed the usual maximum spacing for rivets (pages 87 and 88). Standard gages are used in the vertical legs of the flange angles, staggered rivets being used on two lines for 6″ legs or larger. Spacing should be so arranged that the stagger is maintained throughout, even though extra rivets must be added, unless there is some special reason for breaking the stagger. The rivets in one flange are assumed to be opposite those in the other flange, and it is unnecessary to repeat the dimensions or to draw the projection lines to the second flange. Rivets are shown by circles at the stiffeners (outer gage line), at all projection lines from the dimension line, and for one space at each end of group spacing; corresponding rivets are shown in the opposite flange, as in the drawings of this chapter. When vertical flange plates are used between the web and the flange angles, or when four angles are used in each flange, the pitch in the outer angles is calculated for the stress in the outer angles and cover plates, and the additional rivets in the vertical plates or extra angles are placed opposite those in the outer angles. The pitch of these additional rivets could be made larger, as explained in " Structural Design," page 125, but it usually simplifies fabrication to place them opposite those in the outer angles.

276. Rivets in Cover Plates. The rivets which fasten the cover plates to the flange angles are placed opposite in pairs, either in single or double lines in each angle; single lines are more often used in 6″ legs, and double lines in larger angles, although some draftsmen prefer double lines in 6″ angles as well. When two or more cover plates extend 3″ or more beyond the edges of the angles, they are riveted together with extra rows of rivets. A longitudinal spacing of 3″ (or 4 diameters) is used at the end of each plate for a distance of about 1½ times the width of the plate, beginning with an edge distance of 1¾″. The remaining spaces usually do not exceed 6″ (sometimes 7 times the rivet diameter), and in some girders the pitch is made the same as in the vertical legs of the angles. In the heavier girders the pitch should be calculated ("Structural Design," page 128), but in the lighter girders this is unnecessary. No rivets in the cover plates should be placed so near the outstanding legs of stiffening angles that they cannot be driven by machine, as explained on page 99; it is well to place rivets opposite those in the stiffeners (as in Fig. 125), or else tie the nearest rivet to the rivet line of each stiffener to show that this point has not been overlooked. Holes for lateral bracing should be spaced before the stiffening angles are located, if feasible, for often the angles can be so located that their outstanding legs will not interfere with the holes which will best meet the requirements for the lateral plates. The rivets in the cover plates should be so spaced that the same templets can be used for the top plates and angles as for the bottom plates and angles; additional rivets or groups of rivets may be spaced differently to accommodate connecting members, but the remaining rivets should be opposite. If a plate ends in one flange but the corresponding plate continues in the other, the close spacing at the end should be so arranged that alternate rivets can be omitted in the continuous plate.

277. Standard gages need not be used in the outstanding legs of flange angles or stiffening angles. It is usually better to modify the gages slightly in order to make the distance between rows a multiple of $\frac{1}{2}''$; the corresponding gages are expressed to the nearest $\frac{1}{16}''$, web thicknesses in sixteenths being considered as the eighth above. Sometimes the rows in the cover plates are spread to accommodate rail clamps or other connections better, or to give better protection from the weather by riveting more closely to the edges of the angles. The gages in end-connection angles are chosen so that the distance between holes corresponds to the spacing of the holes in the column or other connecting member.

278. When the **outstanding legs** of two stiffening angles are in contact, they need not be riveted together unless exposed to the weather, when they are riveted at intervals of 1′ in girders 3′ or more in depth. It is often better to place the stiffeners at least 2″ apart so that they can be painted.

279. All **welding** should be indicated according to the code of the American Welding Society, as explained on page 42, or some special code. General methods may be covered by standards or by specifications, but the size should be given at each weld or in a general note on each drawing. If continuous welding is to be fully developed on both sides of the web, the size is limited to one-half the web thickness; sometimes continuous welding is used for weather protection even though not fully developed. For the amount of welding necessary, see "Structural Design," page 129. The extent of different sizes of continuous or intermittent welds can be indicated by dimension lines, as shown in Fig. 128, or by shading. The arrows indicating welds may be drawn to both flanges, or to only one with the understanding that one is like the other. The ends of the stiffeners are welded to the flange plates, but the position of the 2″ welds is not indicated in the illustrative drawing for this is not too important to leave to the judgment of the welder. Continuous seal welds may be required in place of intermittent welds on girders exposed to the weather.

280. Holes for rail-clamp bolts are placed in the top flanges of crane-runway girders to provide for the clamps which hold the rails in position. Clamps are placed in pairs from 2′ to 3′ apart. The size of the holes and the transverse spacing depends upon the size of the rail, and they may be found in the handbooks. Typical holes are shown in Fig. 128 for a girder without cover-plate rivets. When rivets are used in cover plates, no additional holes need be made for clamps, but rivets may be omitted at intervals, leaving open holes for the bolts.

281. Holes for anchor bolts are made $\frac{1}{16}''$ larger than the bolts which fasten a girder to a cast-steel pedestal. A girder over 70′ should have rollers under the pedestal at one end, but a shorter girder should have slotted holes at one end, with provision for expansion to the extent of $\frac{1}{8}''$ for each 10′. When only one end of a girder is drawn, round holes for one end and slotted holes for the other can both be shown and noted as in Fig. 125. When shorter girders rest directly upon masonry plates, the holes are made $\frac{5}{16}''$ or $\frac{3}{8}''$ larger than the anchor bolts; this facilitates the placement of the girder if the anchor bolts have been set, and it provides for drilling holes in the masonry if the bolts are to be placed after the girder is in position.

282. Reference dimensions are often placed on drawings for convenience in the drafting room, as for example, dimensions to the base of the rail in Figs. 124 and 126, or dimensions to the supporting members in Figs. 124 and 126. Auxiliary dimensions are sometimes given to save the shopmen the necessity of counting spaces, as for example, a line of dimensions for the rail-clamp holes in addition to the dimensions which locate both holes and shop rivets. When more than one sheet is needed to illustrate a long girder properly, a reference line should be drawn on each sheet to indicate the points which are common to both drawings.

283. A girder is sometimes "**cambered**" (i.e., curved in a vertical plane) to prevent the center from sagging lower than the ends. The amount of camber should equal the maximum deflection so that the girder will assume a horizontal position under a full load. The camber is effected partly by the proper rivet spacing, but mostly by careful shop work; in fact, slight cambers may be made entirely by the fitters and riveters by placing the proper supports under the girders while assembling and riveting them. Since a web plate cannot be curved except by elaborate cutting, the usual camber is provided for at the web splices by spacing the rows of rivets in the splice plates farther apart at the top than at the bottom so as to separate the ends of the adjacent web sections more at the top. The corresponding spaces in the top flange angles are made greater than those in the bottom angles. It is important to note the amount of camber on the drawing even if special rivet spacing is provided, for it is as easy to nullify the effects of such spacing by careless fitting up or riveting as it is difficult to avoid a curve in a girder which is intended to be straight.

284. Bridge girders are often made with **curved ends** for the sake of appearance, as illustrated in Fig. 125. It is not feasible to bend both ends of long flange angles, and so short angles are used at each end. Formerly these angles were extended far enough to be spliced to the main flange angles, but it is simpler to use smaller angles milled to bear against the ends of the flange angles at the point of zero moment, and to hold them in place by web rivets and by the bent cover plate. This plate is spliced by means of the next plate which is extended for the purpose. The bent angles are crimped over the bottom flange angles.

285. Typical drawings of plate girders are illustrated in this chapter. Figure 123 shows a typical girder without cover plates; Fig. 124, a floor beam and a bracket for a through girder railroad bridge with erection seats for the stringers; Fig. 125, a portion of a girder for the same bridge, showing how one connects to the other; Fig. 126, the floor beam of a railroad pin-connected-truss bridge, showing the method of cutting the end to clear the pin; Fig. 127, a typical floor girder with seats for beams (the necessary sectional views being omitted for lack of space); and Fig. 128, a welded girder.

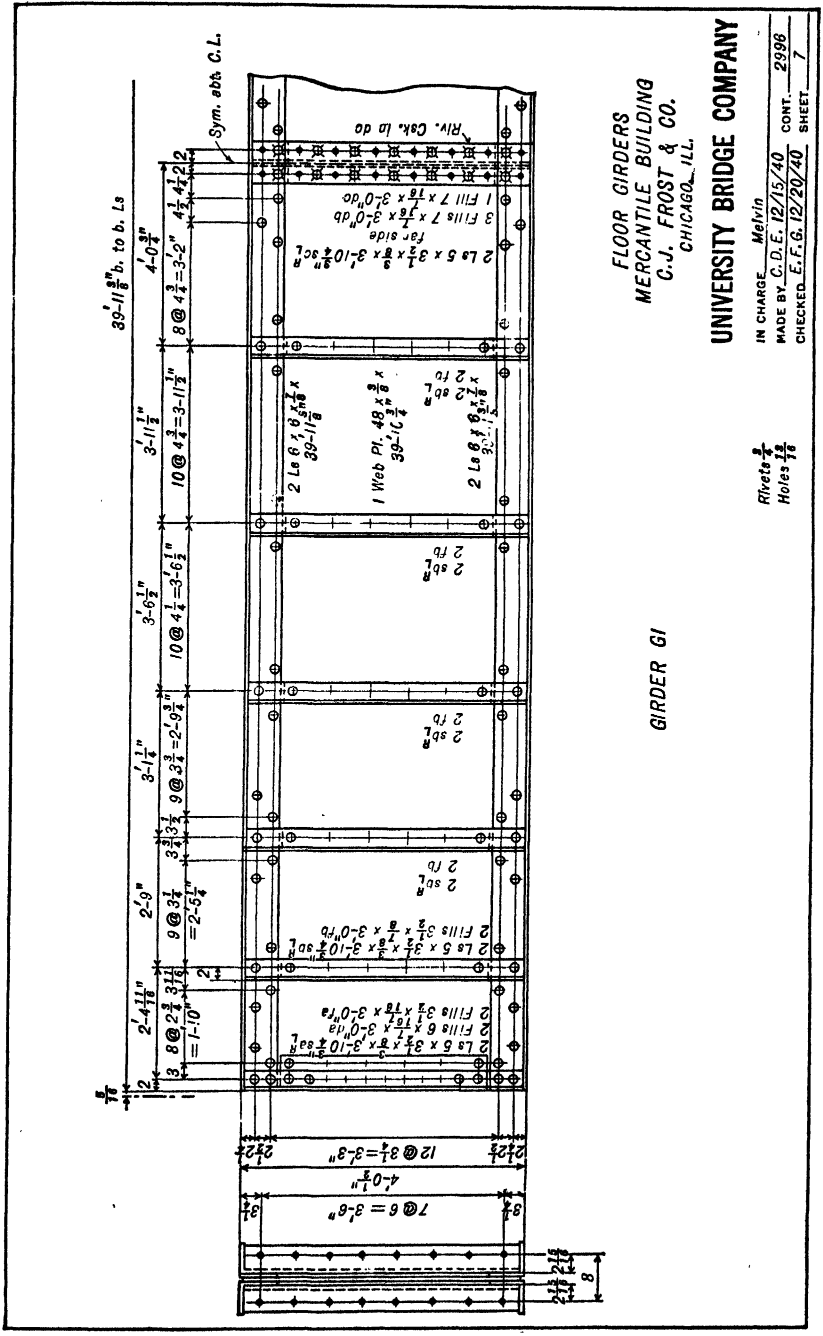


Fig. 123. Floor Girder for Building

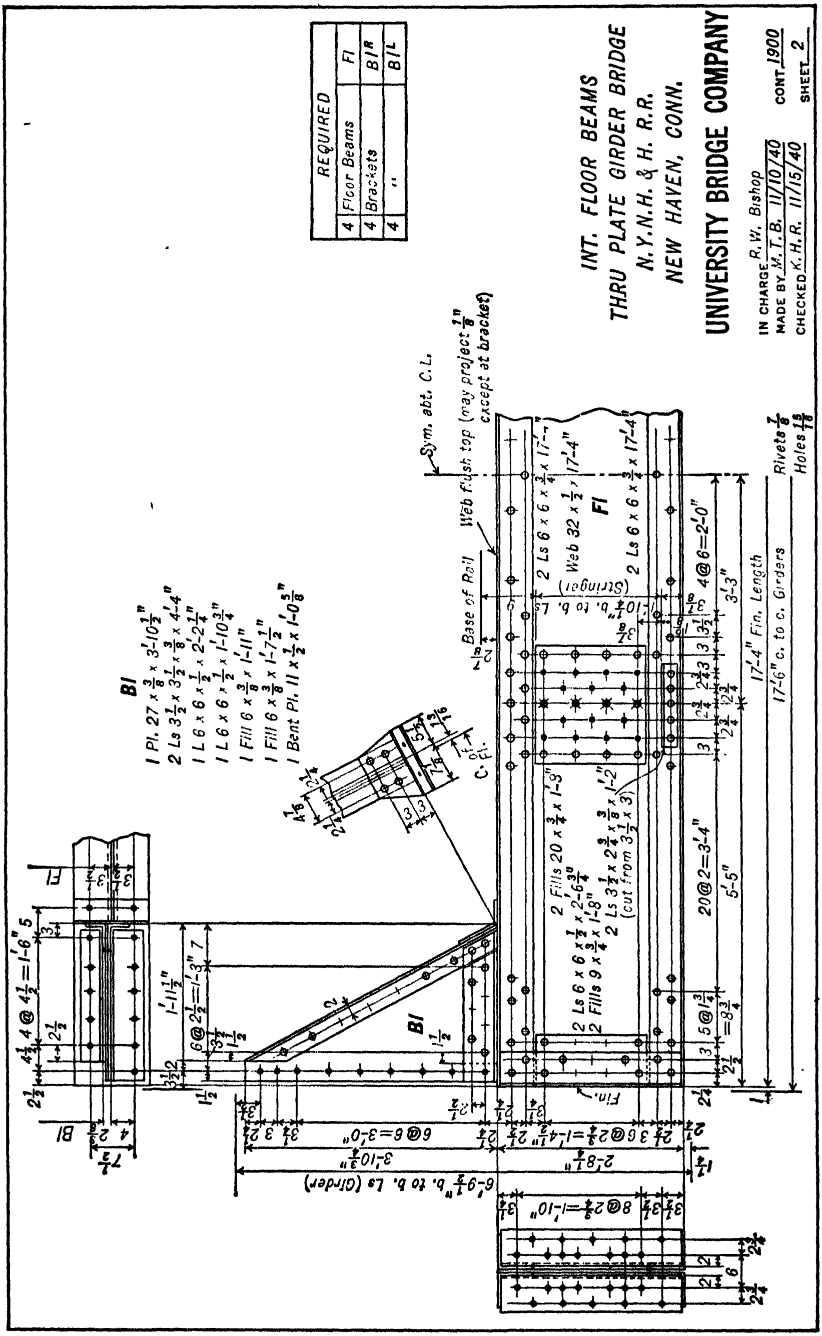


Fig. 124. Floor Beams for Through Girder Railroad Bridge.

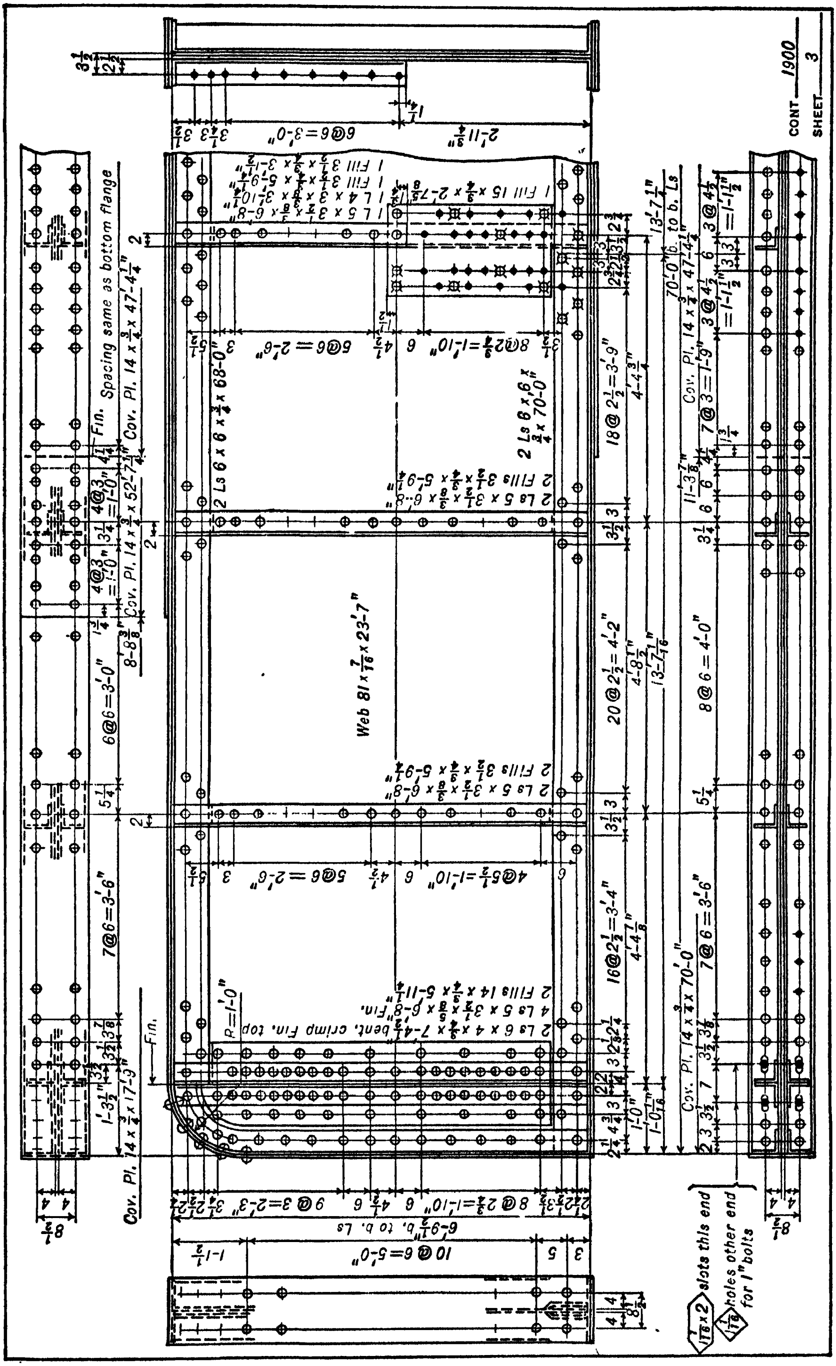


Fig. 125. Portion of Girder for Through Railroad Bridge:

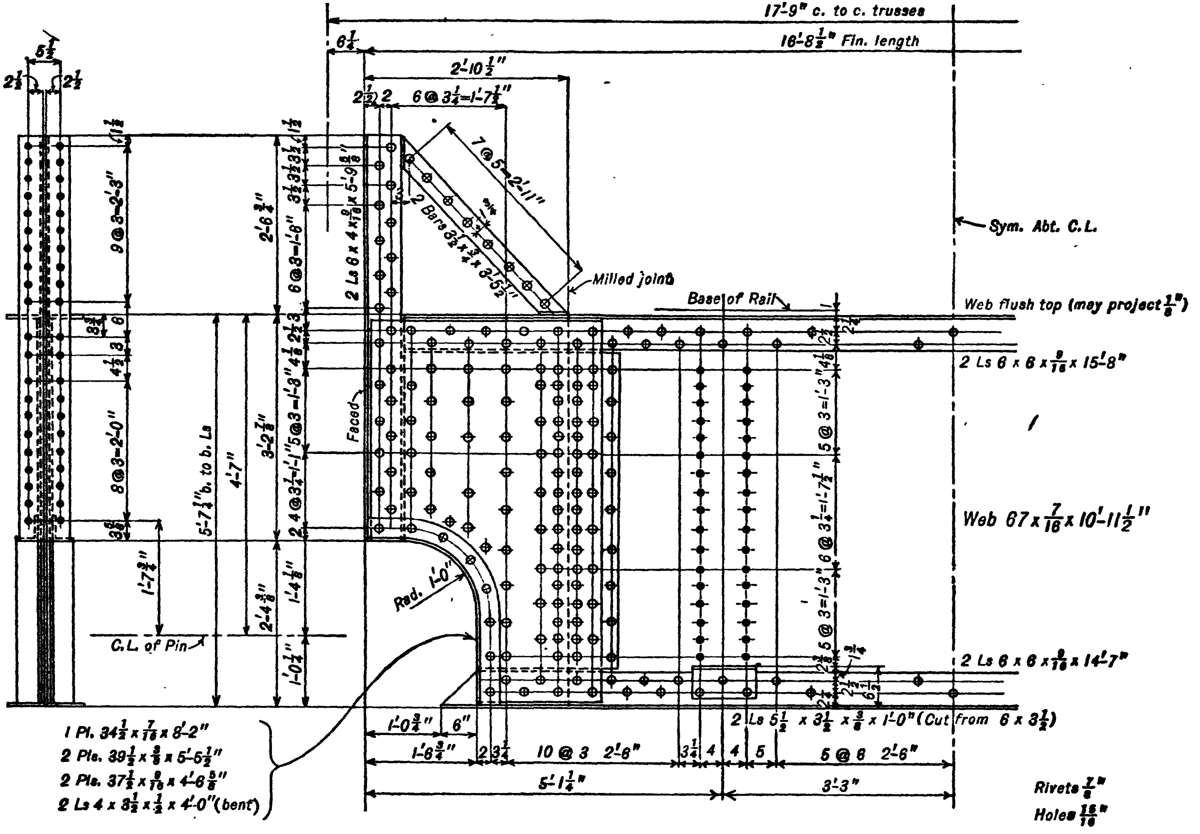


Fig. 126. Floor Beam for Pin-Connected-Truss Railroad Bridge.

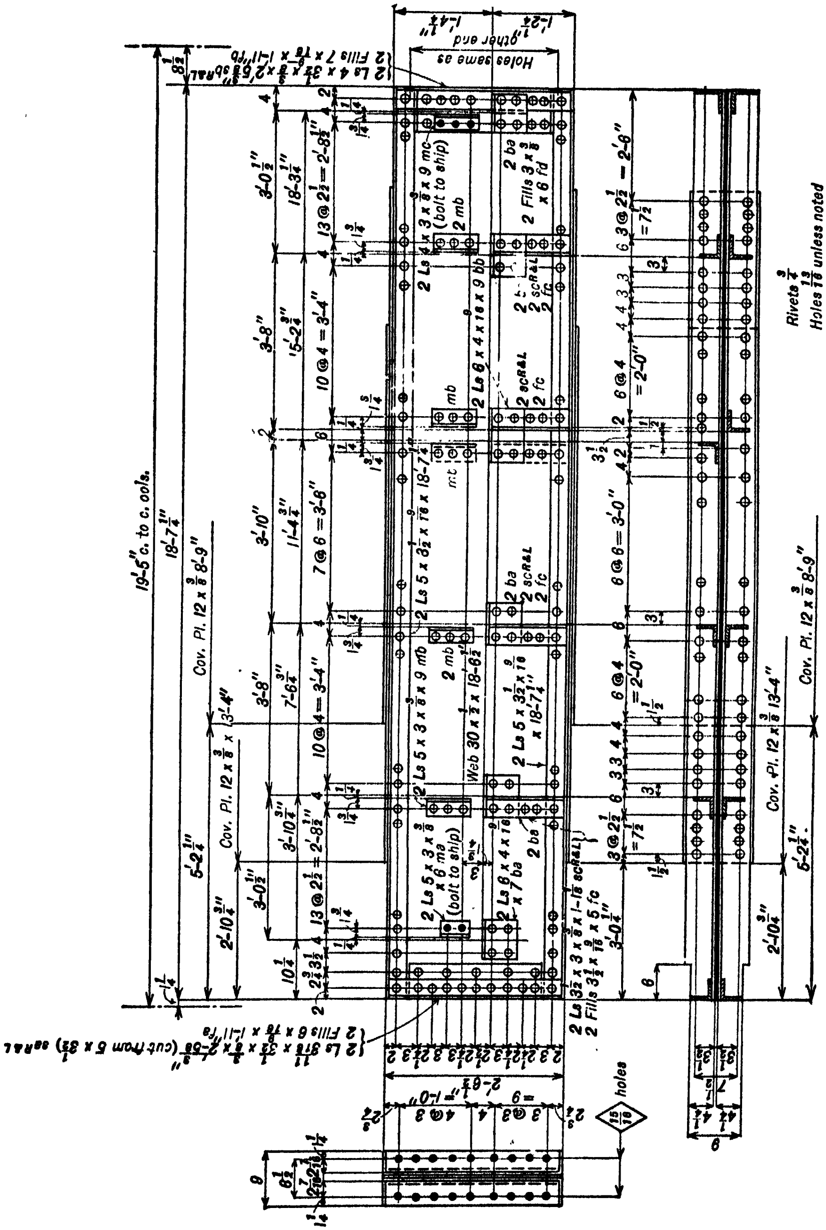


Fig. 127. Floor Girder for Building.

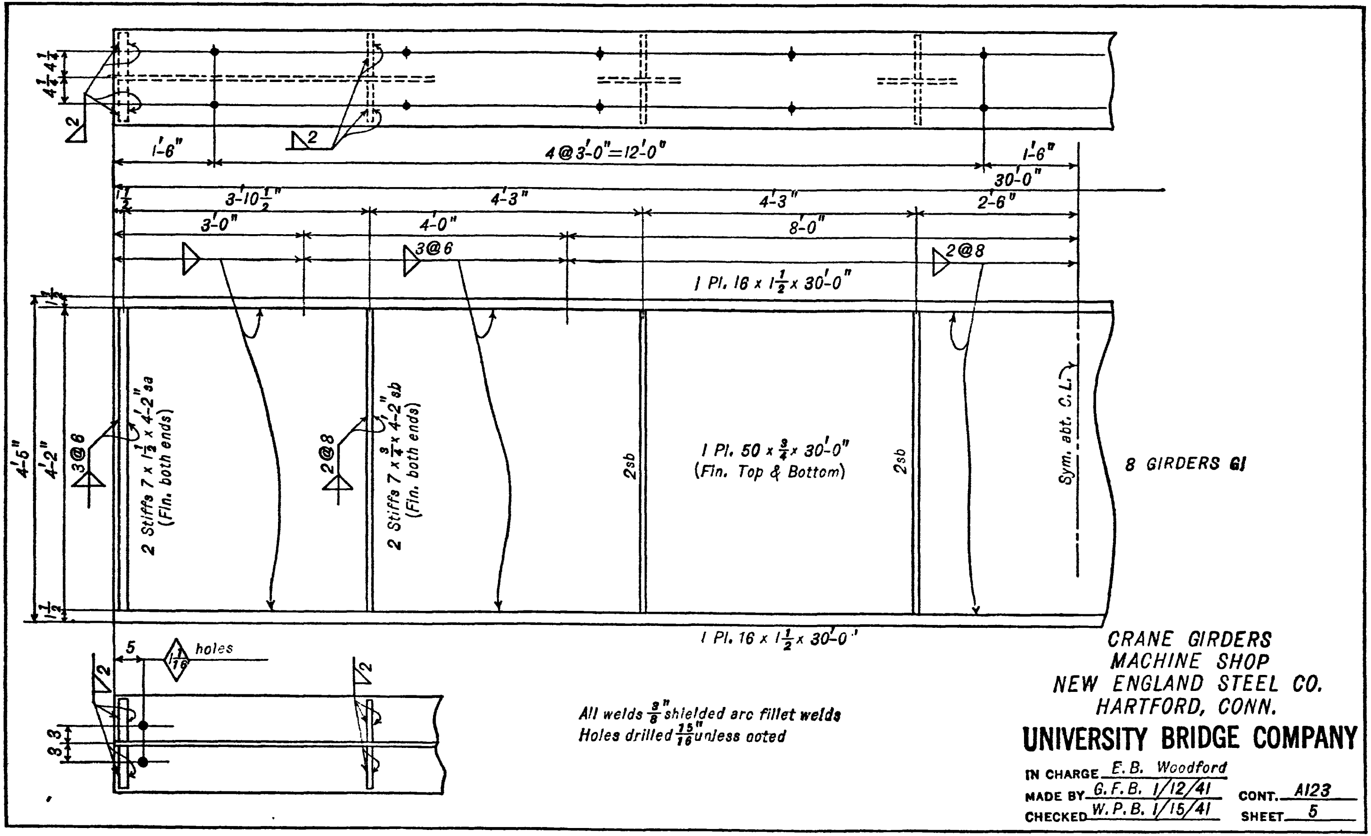


Fig. 128. Welded Girder.

CHAPTER XVII

ROOF TRUSSES

286. Types. Steel roof trusses are used in mill-building construction or wherever a comparatively large area is to be covered without intermediate columns. The more common types are shown in Fig. 129. Flat roofs with tin or composition roofing have just enough slope to provide proper drainage (about 1 in 12); they are usually supported by Warren trusses (*h*) with sloping top chords. The steep-pitched roof trusses (*a*) to (*g*) are used to support other types of roofing; they are generally of the Fink type or a modification of it called a fan truss. The top chord is divided into equal panels, and a Fink truss has a normal member at each panel point; the normal at the middle panel point of the slope divides the half-truss into two symmetrical parts, the normals in the lower part extending to the bottom chord while those in the upper part extend to the line from the peak to the lower end of the middle normal. The number of panels in each half of a Fink truss is two, four, or eight; a different number may be obtained by

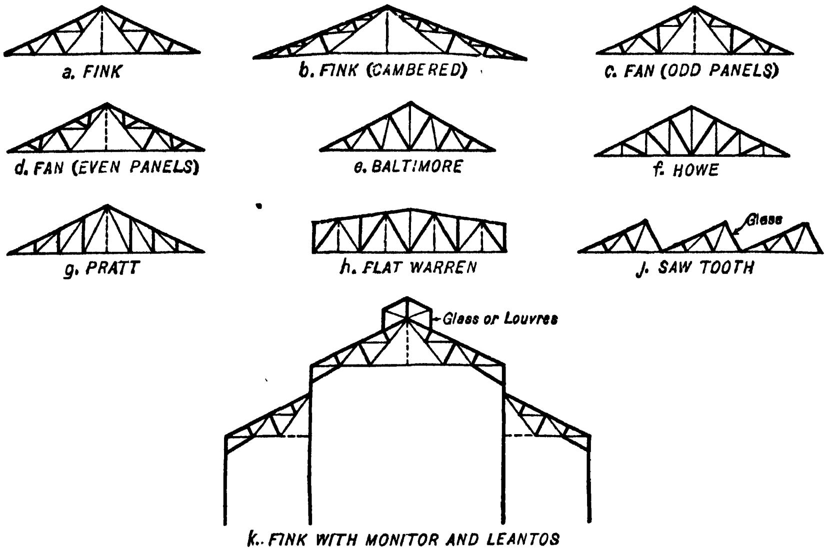

a. FINK
b. FINK (CAMBERED)
c. FAN (ODD PANELS)
d. FAN (EVEN PANELS)
e. BALTIMORE
f. HOWE
g. PRATT
h. FLAT WARREN
j. SAW TOOTH
k. FINK WITH MONITOR AND LEANTOS

Fig. 129. Types of Roof Trusses.

fanning out one, two, or three of the normals at the top so that each becomes two members with a common point at the bottom. Thus a Fink truss with four panels in each half (*a*) is made into a five-panel fan truss (*c*) by changing the middle ordinate into two members, the five panels being of equal length and the short members normal to the top chord; similarly, a six-panel (*d*) or a seven-panel fan may be formed so that, together with the three Fink types, any number of panels from two to eight can be used to accommodate different spans and different types of roofing.

287. The **pitch** of a symmetrical roof truss is the ratio of the center height to the full span length. The slope of the roof, or the tangent of the angle between the top and bottom chords, is not equal to the pitch, but to *twice* the pitch. Thus the slope of a $\frac{1}{4}$ pitch roof is 6 in 12. The most common pitch is $\frac{1}{4}$, but $\frac{1}{5}$, $\frac{1}{3}$, and 30° are also used.

288. Purlin Spacing. Purlins are longitudinal members which carry the roof loads to the trusses. The type and the approximate spacing are determined in the designing department, and they depend upon the kind of roofing. Corrugated iron or steel or certain types of tile roofing can rest directly upon steel purlins, but most other types of roofing are supported by wooden sheathing or precast slabs. Wooden sheathing is supported by wooden purlins or by steel purlins with wooden spiking pieces or nailing strips bolted to the webs. The flanges of channel purlins face down the slope when spiking pieces are used or when corrugated iron is attached by means of clinch rivets, but they are turned the other way when corrugated iron is fastened by straps. The spacing depends upon the thickness and the commercial lengths of sheathing or upon the gage and the standard lengths of corrugated iron. Lumber is usually obtained in multiples of 2′, and corrugated sheets in multiples of 6″ from 5′ to 12′. As far as possible, the sheets should extend over two purlin spaces. When feasible, the panels of the truss are so arranged that the purlins will be at or near the panel points; otherwise, the top chord must be designed for combined compression and bending.

289. Forms of Members. The web members of an ordinary roof truss are made of single or double angles with the longer legs vertical. These may be turned with the outstanding legs along either the upper or the lower edges as desired, perhaps the latter being more common; sometimes a member may be turned for symmetry or for improved end connections, especially in a welded truss. The top chord is T-shaped with the outstanding flange or legs along the upper edge to support the purlins. The T may be made from a wide-flanged beam by splitting it into halves, or from two angles with or without a plate between; if a plate is used, the longer outstanding legs of the angles are made to extend $\frac{1}{4}$″ beyond the upper edge. When two angles are used alone, the longer legs may be vertical or outstanding, depending upon the relative unsupported lengths and whether they are to resist bending due to intermediate purlin loads. The unsupported length used in conjunction with the radius of gyration about a horizontal axis is one panel length, measured along the slope. The distance between lateral supports to be used with the other radius depends upon the roofing, two purlin spaces being used for corrugated iron, but one purlin space for wooden sheathing because of its greater lateral stiffness. The bottom chord may be made of two angles with the longer legs vertical, of two channels, or of a structural T made of one-half a wide-flanged beam; the outstanding legs or flanges are along the lower edge. The channels are used when a small traveling hoist is to be supported, and some designers prefer channels or a T in order to give greater stiffness than that obtained from angles; often workmen attach block and tackle to the bottom chord for the purpose of lifting machines or other loads, even though the truss is not designed for this purpose. When two angles are used in the central panel of the bottom chord of the longer trusses, they are supported by a single-angle central hanger to give greater security against collapse under such an extra load, and also to make the chord less likely to buckle as a compression member during erection, when the whole truss is lifted by a truck crane.

290. Arrangement on Sheet. The members of a roof truss are drawn in the same relative position which they will occupy in the completed structure, even though the truss is shipped "knocked down," i.e., each member shipped separately as in export work. A roof truss is usually riveted or welded in the shop completely, or else in as large sections as can be shipped. If a truss is symmetrical about the center line, or nearly so, only one-half need be shown on the drawing, with a note added to the effect that the truss is "Sym. abt. C.L." or "Sym. abt. C.L. except ——," the exceptions being noted.

291. A system of working lines is first laid down to scale and all dimensions are referred to these lines, as explained on pages 82 to 84. These represent approximately the lines of stress in the different members, and at each apex the lines should meet in a common point. The principal dimensions indicate the lengths between intersections of working lines, and they should be recorded as soon as determined. Each member can then be drawn in proper relation to its working line. The web members are cut off at right angles with proper clearances, and the rivets are spaced from the working points. These dimensions are determined by layout as explained on page 101 or 102, being expressed in multiples of ¼″. It is usually not necessary to dimension the edge distances, for the templet maker will make the edge distances at the two ends of a member approximately equal, using the billed length which is given to the nearest ¼″.

292. The different members of a truss are connected by means of **gusset plates.** The number of rivets required in each member is determined from the stress in that member, as explained in "Structural Design," page 96. The shape and the size of each gusset plate are found graphically by means of a layout, as explained on page 101 or 102. When a structural tee or a T-shaped member composed of a plate and two angles is used for the top or bottom chord, the web members may be connected directly to the web without gusset plates, provided that there is sufficient space for the rivets or welds; if a gusset plate is used it should be properly spliced to the web. The end of a roof truss may rest directly upon a masonry wall or it may be supported by a girder or a truss, but more frequently it is riveted or welded to a column by means of a gusset plate called a heel plate. The type of heel connection depends not only upon the form of support but also upon the detail of the cornice at the eaves; this in turn is dependent upon the style of the roofing and of the side walls. An eave strut may be used to support both the roofing and the siding, and to act as the compression member of bracing systems in three planes; it is often made of two or four angles latticed, of two channels latticed, or of one channel with or without a stiffening angle along the lower edge. Separate purlins and girts are sometimes used. There are so many variables that only a few of the more common types of heel connection are shown in Fig. 133. The size of a gusset plate may be reduced if the outstanding leg of an angle is connected to the plate by means of a " lug " or connection angle, as shown in Fig. 133 (*a*); one leg only is connected as a rule, unless the number of rivets exceeds 7 or 8.

293. Each two-angle member of a riveted truss should have the angles fastened together by **stitch rivets,** as explained on page 89; the proper number of such rivets is shown, dividing equally the distance between the rivets in the connections, usually without dimensions. When the angles are separated by gusset plates, washers are used at the stitch rivets to maintain a constant distance between the angles; the size of the washers is given below the sizes of the rivets and holes. A draftsman should be careful not to show stitch rivets in single-angle members; such a blunder is not serious because it would probably be detected by the checker or templet maker before extra holes are punched, but it is better to avoid the extra erasing. Members composed of two channels are fastened together similarly by pairs of stitch rivets with rectangular fillers instead of round washers. Similar fillers can be used between the angles of a welded truss, as shown in Fig. 138, or small plates may be welded to the other legs.

294. Complete trusses are marked T with distinctive numbers as in Fig. 134, but **trusses shipped in sections** must have each section marked, as explained on page 109. The maximum height which can be shipped by rail is about 10′-6″, although the clearance heights of the overhead bridges or tunnels of some divisions provide for larger sections. If the center height exceeds this amount, the truss is shipped in sections, as shown in Fig. 109, each half-truss being shipped on the top chord as a base; should the normal

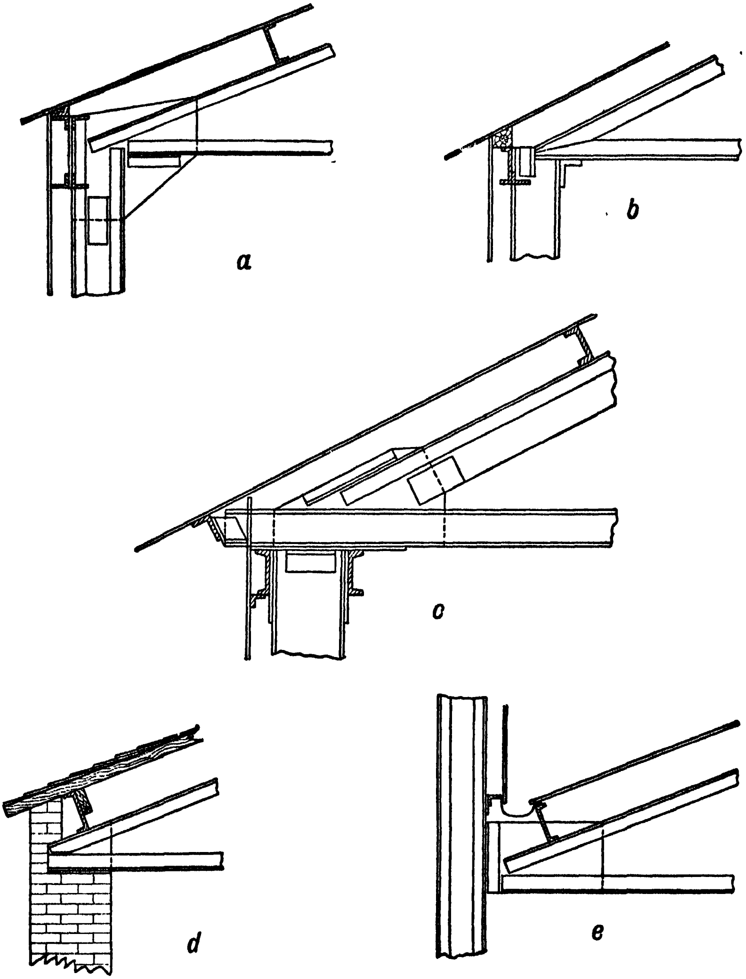


Fig. 133. Types of Heel Connections.

height exceed the shipping clearance, even smaller sections must be made. It is helpful to have a small plan of the building on the detailed drawing, as in Fig. 134, to show the locations of the different trusses and the bracing between them. If the trusses are to be shipped in sections, an additional

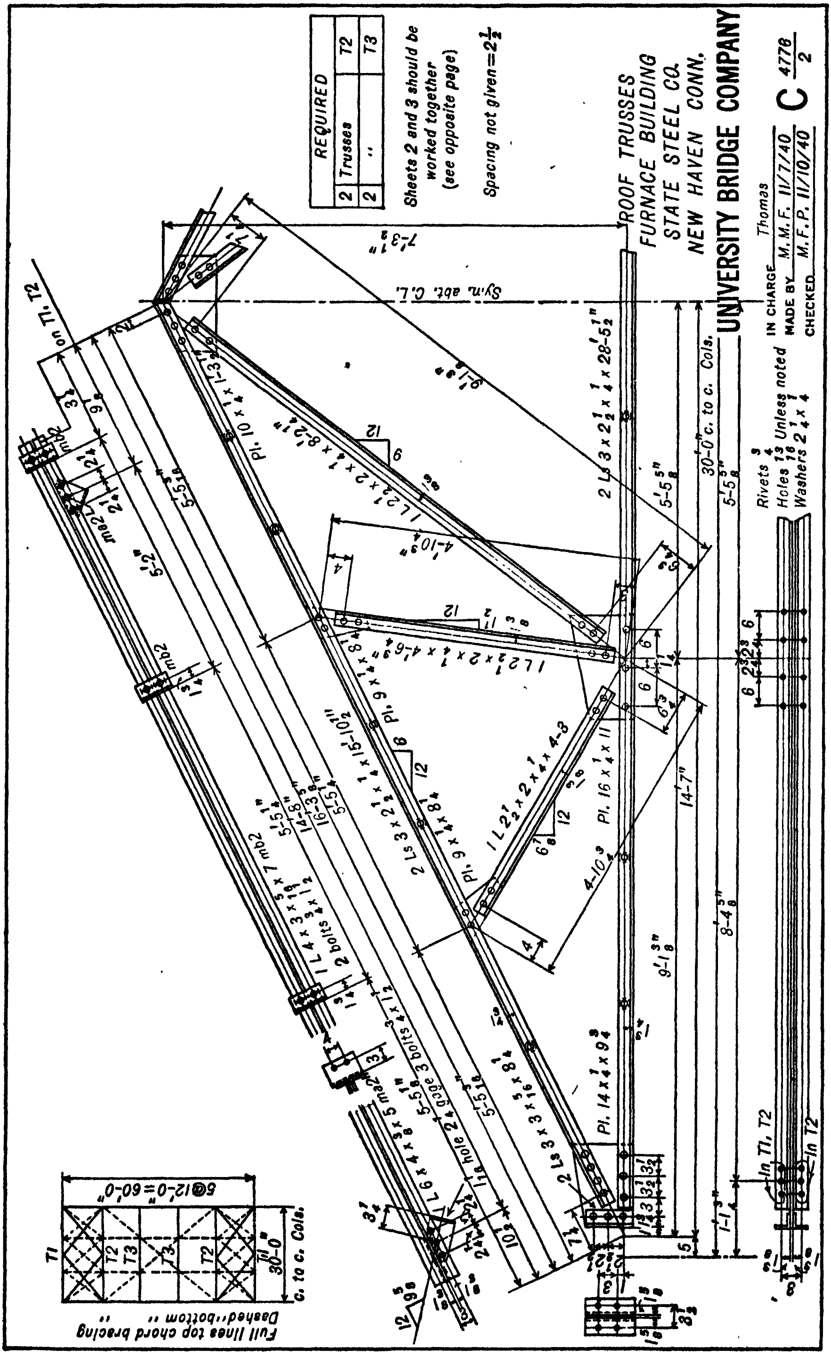


Fig. 134. Typical Drawing for a Roof Truss.

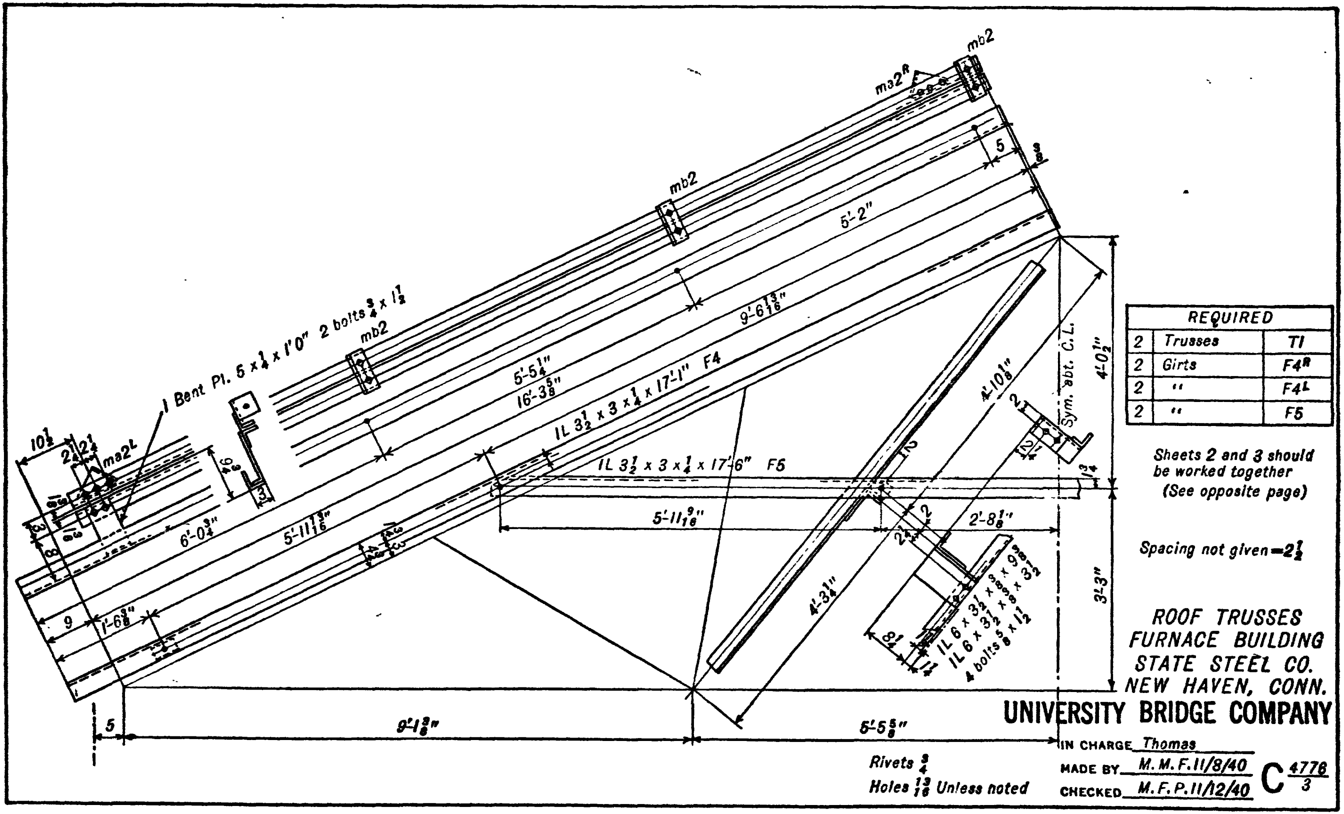


Fig. 135. Gable Girts.

assembly diagram should be added to show how the sections are to be assembled at the site before erection as complete trusses.

295. When a symmetrical monitor is placed at the center of a roof, a **ridge strut** must be provided as the compression member of the top-chord bracing system, because the roof purlins are on top of the monitor where they cannot serve this purpose. Ridge struts are used in the unbraced bays as well, although they are sometimes lighter. An I-beam or wide-flanged beam may be used as a ridge strut, connected to the peak plate by means of connection angles, the web members being cut short accordingly. More frequently a two-angle strut is used, with a connection plate between them; this plate projects beyond the ends of the angles and is inserted between two connection angles on the peak plate. The center hanger may serve as a connection angle on one side, but when so used it is offset so that the strut is in the center. If sag rods are used to give intermediate support to the purlins, the horizontal components in one slope are made to balance those in the opposite slope by connecting together the purlins at the peak by means of bent rods; if there are no peak purlins, the sag rods are connected to the ridge struts.

296. Purlin Connections. Purlins may extend over one or two bays, but erection in single bays is simpler; they are bolted to the top chord by means of clip angles. Each clip angle is connected to the truss by two bolts. There are two holes in the other leg of a 4 × 3 angle for channel purlins 8″ or under, and four holes for larger channels; the four holes are in one line of a 4 × 3 angle (3″ gage) when spiking pieces are used, or in two lines of a 6 × 4 angle otherwise, although some companies put the extra bolts through the flange instead of the web. Additional holes are provided when a purlin acts as a strut in the bracing system.

297. Bracing rods may be attached to the top chords by angle clips, as shown in Fig. 134; these clips should be so placed that the rods will pass through one leg at right angles, in order that the nuts will bear properly. The clips are placed on the under side of the outstanding legs of the chord angles so that the rods will pass under the purlins. Either one or two pairs of rods are used in each slope according to which arrangement makes the angle with the truss more nearly 45°. Rods of minor importance may be bent to pass through holes in gusset plates. Larger rods may pass through slotted holes in gusset plates, with beveled washers to give proper bearing for the nuts. Clevises are not used commonly, because other types of connection are more economical.

298. Holes must be provided for **bottom-chord bracing.** The plates are shipped loose to be connected to the underside of the chord angles. When connection angles are used to connect the bottom-chord angles to the heel plate, the connection plate is placed either between the connection angle and the chord angle, or else on top of the chord angle. When the bottom chord is spliced, the bracing plate may serve as a splice plate and the number of rivets in the vertical legs may be reduced accordingly; a suitable plate must then be provided for each truss even though there are no diagonals to be connected at this point.

299. It is advisable to provide for **future extension** of a mill building, even though such extension is not anticipated at the time of construction. If the roof truss at the end of a building is made like an intermediate truss, it does not have to be moved when the building is extended. If a special end frame is made with rafters supported by columns, not only the frame but often the roof and side coverings of one bay must be removed. If future extension is expected, some extra holes may be punched to advantage to facilitate such extension. During the author's experience one building for which no provision was made for extension was extended three times before it was completed once.

300. If the ends of a building are to be covered with corrugated iron, girts must be placed on the **gable end** to support it. When an end truss is used, the gable columns extend only to the bottom chord and the gable girts must be attached to the truss. Instead of showing these girts on the detailed drawing of the truss, it is usually better to show them on another sheet and instruct the shopmen to use the second drawing in conjunction with the first. Such a combination is shown in Figs. 134 and 135. On the second sheet the working lines are shown with enough of the principal dimensions to serve for identification, and only the truss members which have girt connections need be outlined. The sloping girt is supported at each purlin, either by the purlin if it projects beyond the center of the truss, or by an angle "outlooker" bolted to the purlin to support the roofing which extends beyond the siding, as shown in Fig. 137. At the heel, or at the peak under a monitor, where no purlin is available, the girt is supported from the truss by a bent plate or angle. This girt is cut square at each end and extends to the bottom edge of the corrugated iron. The horizontal girts are connected to the sloping girt either by a single bolt as shown, or by means of a plate bolted to the vertical legs. Intermediate supports from a web member may be made of angles as shown, or bent plates, depending upon the relative positions and also upon which way the girts of the building are turned. The required list on the second sheet should contain those members which are made wholly or in part from that drawing, while the list on the first sheet should contain the members which are made entirely from that drawing. The key plan shows all trusses.

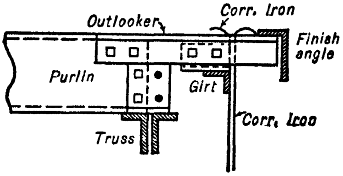
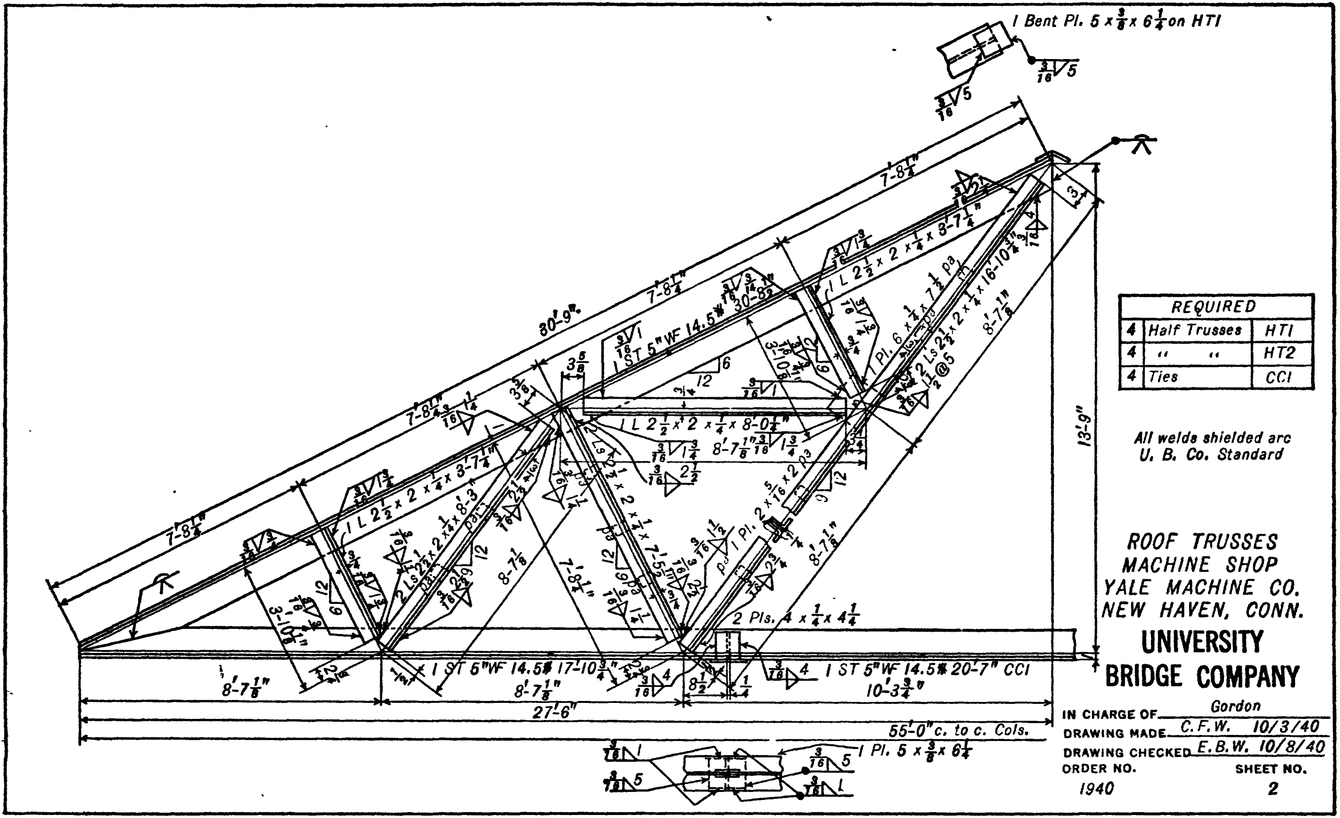


Fig. 137. Purlin with Outlooker.



REQUIRED		
4	Half Trusses	HT1
4	" "	HT2
4	Ties	CC1

All welds shielded arc
U. B. Co. Standard

ROOF TRUSSES
MACHINE SHOP
YALE MACHINE CO.
NEW HAVEN, CONN.

UNIVERSITY
BRIDGE COMPANY

IN CHARGE OF Gordon
DRAWING MADE C.F.W. 10/3/40
DRAWING CHECKED E.B.W. 10/8/40
ORDER NO. 1940
SHEET NO. 2

Fig. 138. Welded Truss.

301. In a welded truss the members are laid down so that their centers of gravity coincide with the working lines, as shown in Fig. 138. Sometimes the angles can be turned around to advantage in order to give more space for welding. The welding is so distributed along the back and opposite edge that the center of gravity of the weld lines up with the centroid of the angle. If the chords are structural tees cut from beams large enough to provide for the necessary welding, gusset plates are not required. The heel shown is of the type illustrated in Fig. 133 (*b*).

CHAPTER XVIII

LATTICED GIRDERS

302. Definition. The term " latticed girder " here signifies a comparatively light truss with parallel chords, the diagonals and often the chords each being composed of one or two angles. A girder becomes a latticed girder when the solid web is replaced by separate web members, but it also becomes a truss from the definition (page 272). The term " lattice truss " is also used; it is less distinctive because it may refer to multiple-intersection web systems such as formerly used in timber bridges, or often to any form of riveted truss with parallel chords to distinguish it from a pin-connected truss. The most common form of latticed girder is of the Warren type, with or without vertical subdivisions, as shown in Fig. 141; the Pratt type is also used. Sometimes there is a double system of web members, as in Fig. 143.

303. Proportions. The depth of a latticed girder is determined in the designing department, and it is usually a multiple of 6″. In building construction the depth is often dependent upon other framing, because the positions of both the top and the bottom may be fixed by other members. The chords may serve also as girts, or they may be latticed to crane girders to furnish lateral supports for the compression flanges. Longitudinally, one or more of the panel points may be determined by the position of fixed loads, but so far as feasible the panel lengths are made equal.

304. The different members of a truss are referred to a system of **working lines,** as explained in Chapter X, page 82. Theoretically these working lines should meet in a common point at each apex, as in Fig. 141 or Fig. 145, and when the stresses are of considerable magnitude the lines are so drawn, especially when vertical members are inserted as in Fig. 141. This system results in large spaces between adjacent diagonals, as in plate *pe*, with correspondingly large plates; this may be avoided by means of auxiliary working lines, as explained on page 85 and illustrated in Figs. 142 and 143. Such auxiliary lines are used in bracing systems which are not subject to primary stresses, and they are often applicable to light latticed girders where the stresses are not large enough to cause serious secondary stresses due to eccentricity. The working lines of riveted angle members are the rivet lines, which may be at the standard gages or in the centers of the connected legs if 3″ or more; the working lines of welded angle members are

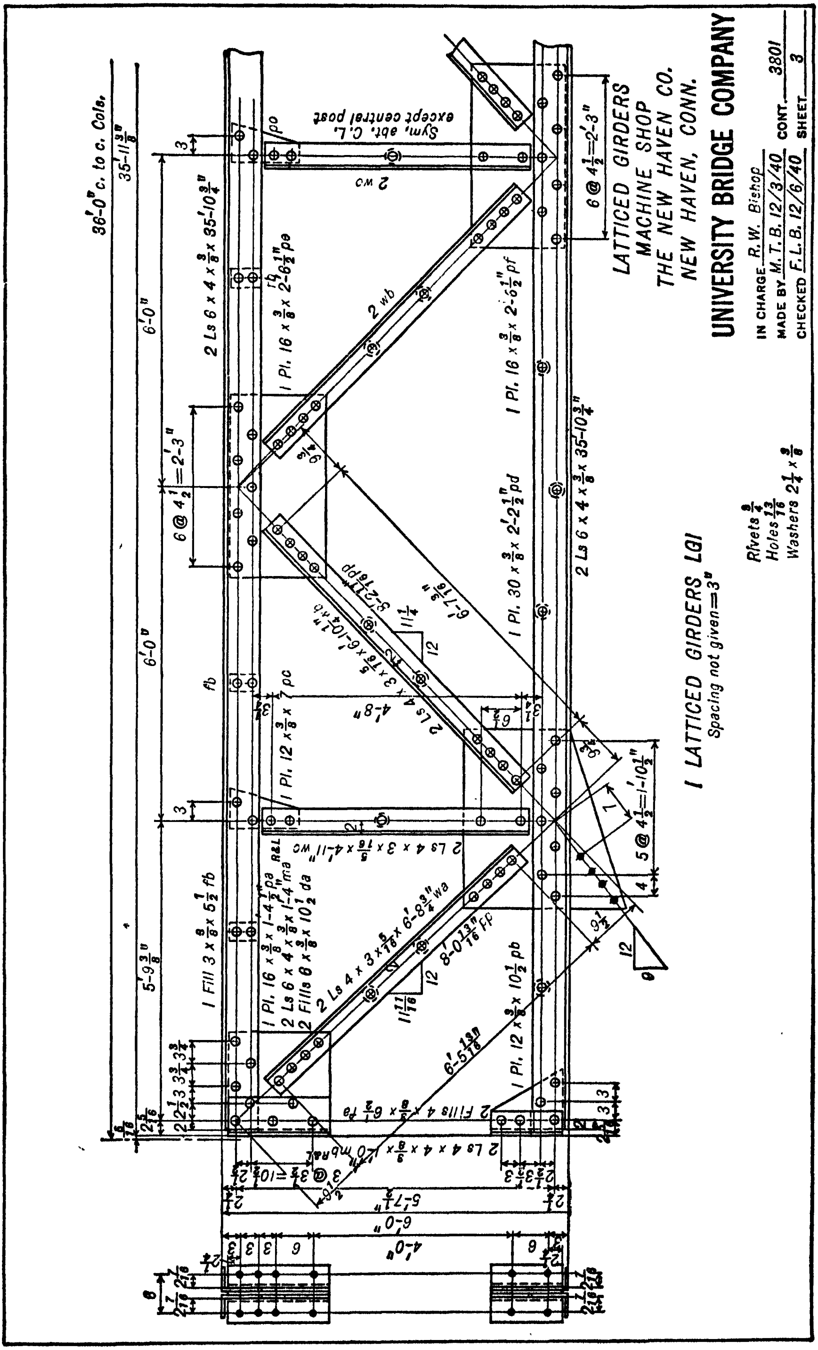


Fig. 141. Latticed Girder with Working Lines Meeting in Common Points.

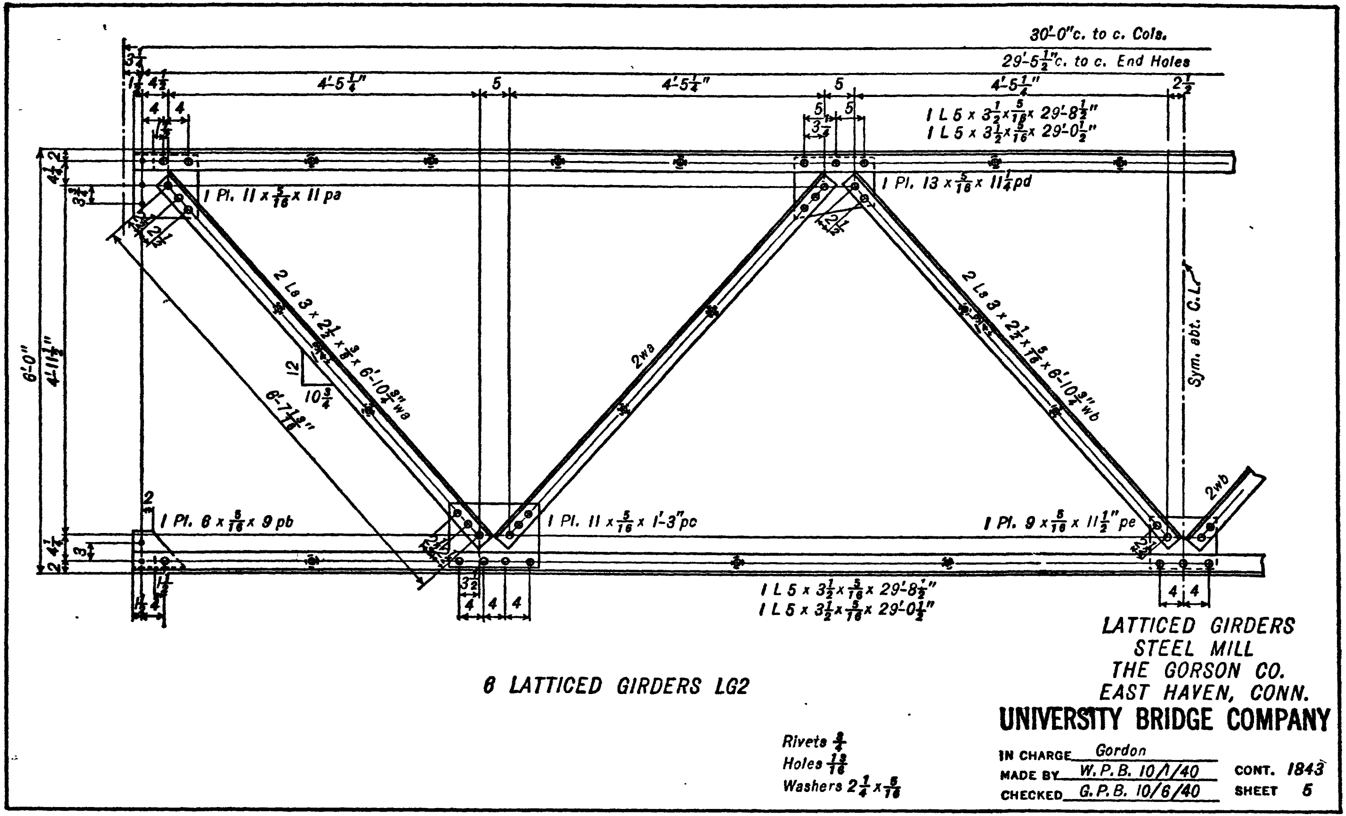


Fig. 142. Latticed Girder with Auxiliary Working Lines.

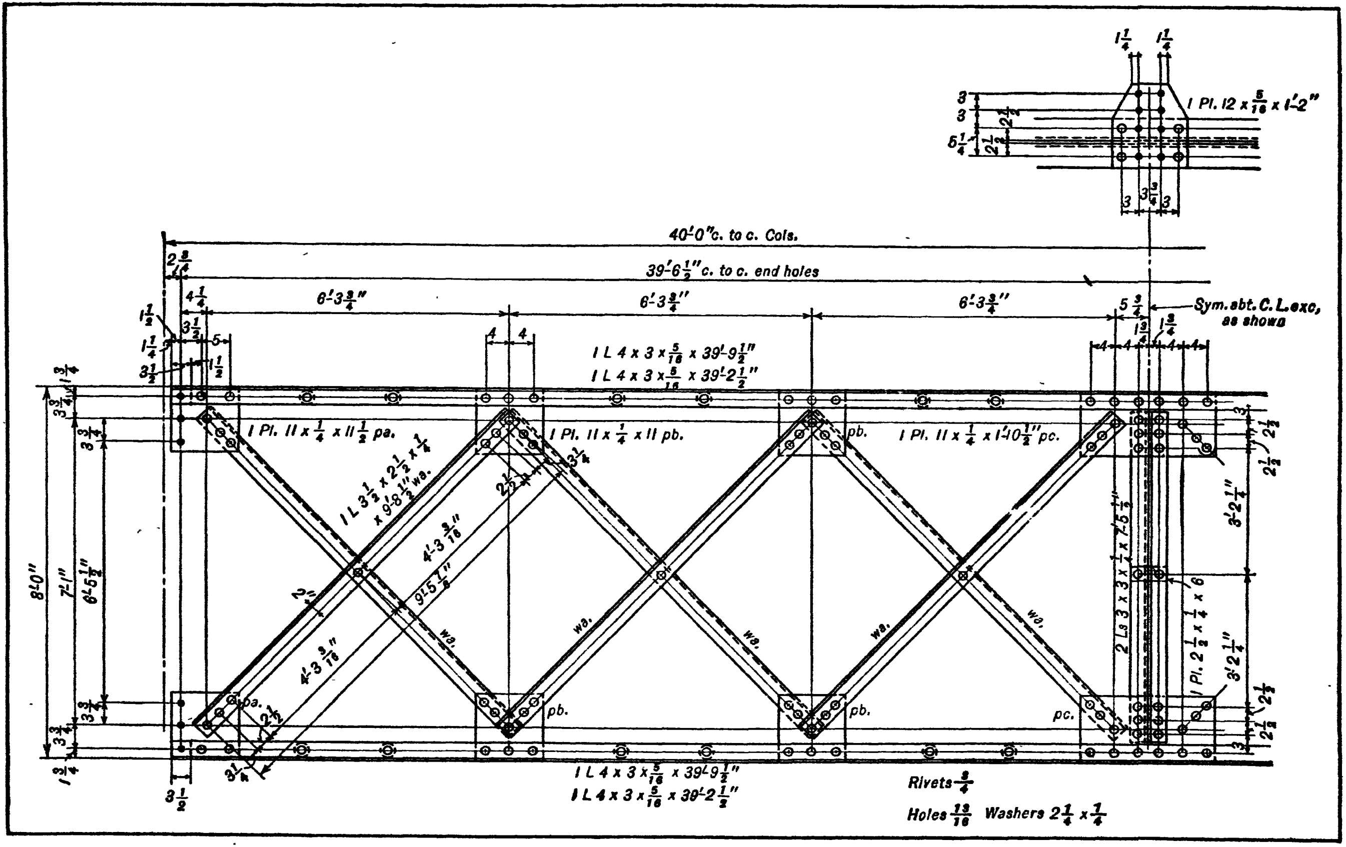


Fig. 143. Double Latticed Girder.

either the center-of-gravity lines or the centers of the legs. The working lines of riveted angle chord members are the rivet lines, the ones nearer the backs of the angles being used for double gages; the working lines of welded chord members are usually the center-of-gravity lines.

305. The end connections depend upon the relative positions of the latticed girder and the supporting column or other member. If the axis of the girder is at right angles to the face to which it connects, connection angles are used as in Fig. 141, or the girder is made to rest on seat angles as in Fig. 145. If the plane of the girder is parallel to the column face, a direct connection may be arranged either outside or inside the flanges as in Fig. 142 or Fig. 143, one chord angle and the diagonal being kept far enough from the edge of the column flange to provide the necessary erection clearance (page 98). The size of the end connection plate is usually determined by the rivets or welds in the diagonal, the corresponding rectangular plate being used as a minimum. In Fig. 141 the overall length is the principal dimension, but in Fig. 142 the distance from center to center of end holes is used because it is more important.

306. Intermediate gusset plates are shaped to inclose the proper numbers of rivets as explained on pages 101 to 104. The rivet spacing should be tied to the working points. When auxiliary working lines are used, the slopes of the diagonals cannot be determined definitely until after the working lines are established, and so it is customary to provide for the larger diagonal distances to the corners both horizontally and vertically to accommodate the angles in any position. The vertical dimensions to the auxiliary lines should be expressed to the nearest $\frac{1}{4}''$ and made the same at the top and the bottom so that the plates may be made alike or similar, as for illustration the $4\frac{1}{4}''$ in Fig. 142. Likewise, the horizontal distance (5″) between the working points should be made the same in all intermediate plates, tentatively a multiple of $\frac{1}{4}''$. From the detail at the end the distance from the point of main dimension to the end working point ($4\frac{1}{2}''$) can be found. By subtracting this and the proper number of intermediate 5″ spaces from the main dimension, the space available for diagonals is found. If this is equally divisible by the number of panels, the resulting panel lengths may be used; otherwise a slight readjustment should be made so that the system will balance. This is possible because the number of intermediate plates is not the same as the number of diagonals, and the end dimensions can be altered without affecting other plates. When verticals are definitely fixed by equal panels, as in Fig. 141, it may not be possible to keep all diagonals the same length.

307. The dimensions should be recorded on the drawing as soon as determined. When auxiliary lines are used, the panel dimensions must be determined before they can be laid out, but the angles can be drawn in and

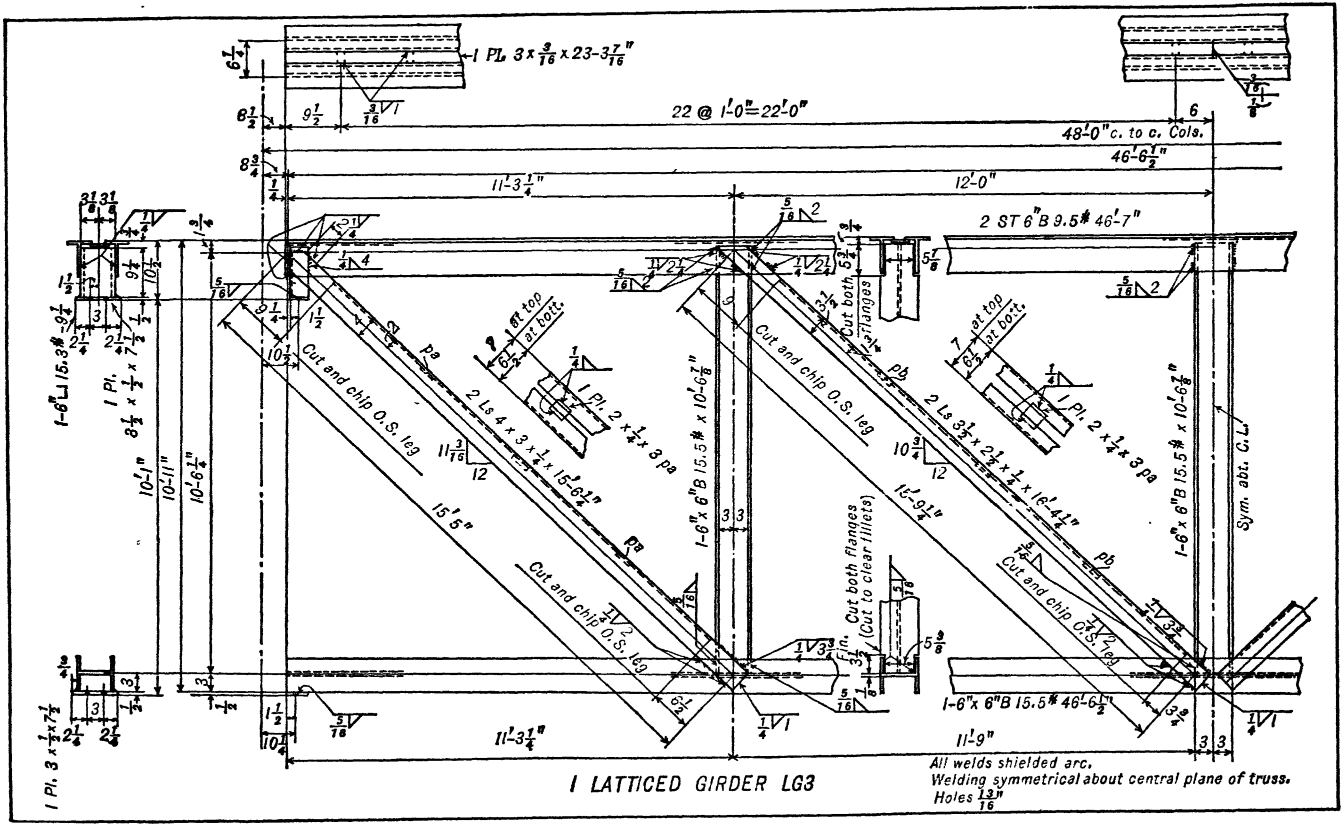


Fig. 145. Welded Latticed Girder.

billed before the plates are detailed. The gages should be dimensioned even though standard.

308. When a **double system** of diagonals is used, as in Fig. 143, two single angles on opposite sides of any plate may be made to overlap in order to take one rivet in common. The adjacent rivets must be spaced far enough from the edges of the angles to provide ample driving clearance (page 99). Such angles should be riveted at their intersections, with or without washers.

309. The chords of riveted latticed girders are commonly made of two angles separated by a space for the gusset plates. When the unsupported length of the compression chord is the same for both axes, the longer legs are together, but when the distance between lateral supports is longer than the distance between panel points, it is usually better to place the shorter legs together. The chords of welded latticed girders are commonly made of structural tees cut from wide-flanged beams, or two such tees may be used as in Fig. 145. When the centers of angle diagonals are used as working lines, the welds at the ends should be balanced about the centers, but if the center-of-gravity lines are used as working lines, most of the welds should be placed along the backs of the angles in order to make the centers of gravity of the welds coincide with the centers of gravity of the angles.

310. All riveted members which are composed of two angles should be fastened together by means of **stitch rivets,** spaced as explained on page 89. The spacing in tension diagonals may be made the same as in compression diagonals if the members are thus made practically alike. Staggered stitch rivets may be used in 6″ legs as in the bottom chord of Fig. 141, or double-rivet fillers may be used as in the compression chord of the same girder. The component parts of welded members may be joined at intervals by small plates welded in place, as in Fig. 145.

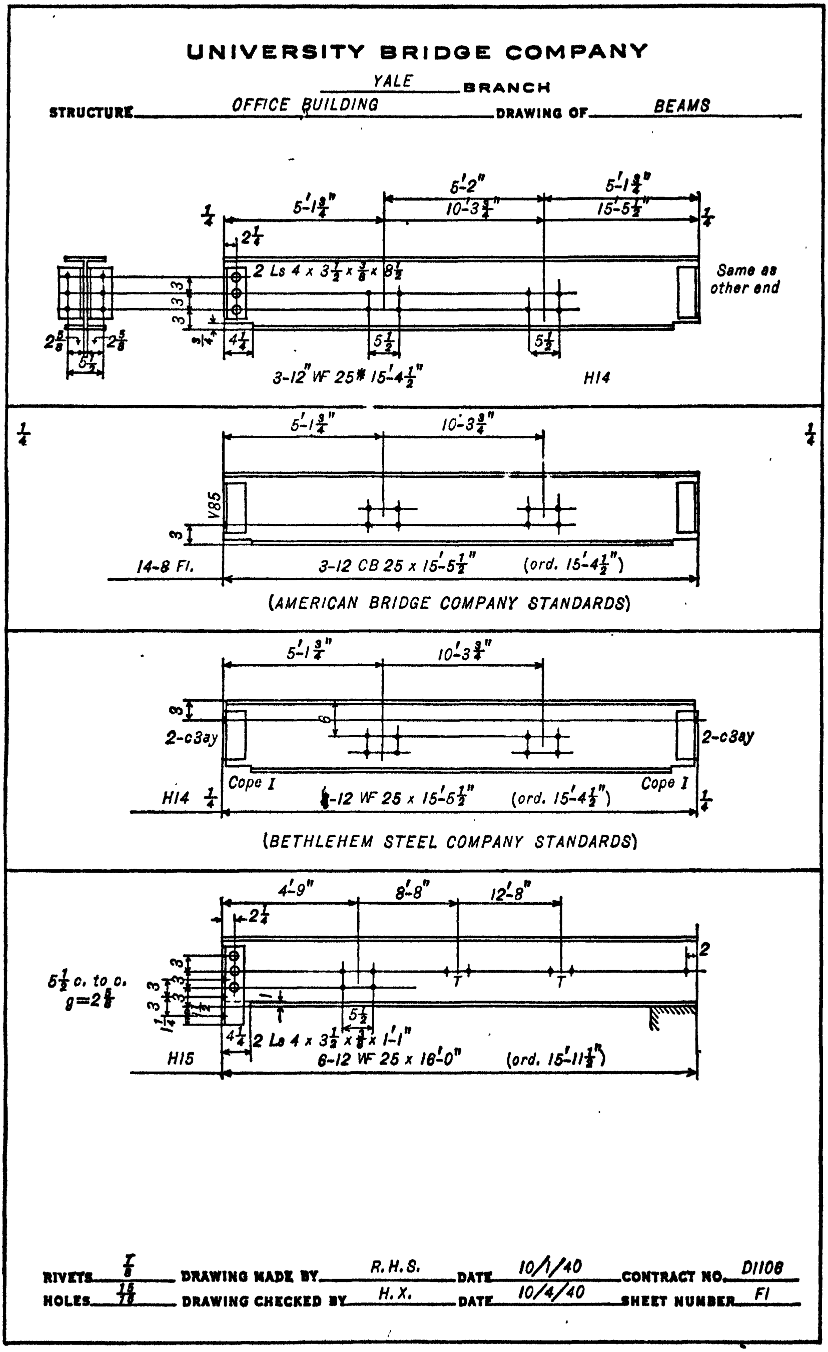
CHAPTER XIX

BEAMS

311. A beam is a member which resists flexure or cross bending. Generally speaking it is composed of a single piece, exclusive of details, and is usually of wood, steel, or concrete. In steel construction, a member which acts like a beam but is made of more than one main piece is termed a girder. The general arrangement of the beams in a structure depends upon the type of structure and its use; most often they are placed in a horizontal position and are subjected to vertical loads. Steel beams have been standardized by the different steel companies; the wide-flanged beams or H-beams are most used, having largely superseded the older I-beams and channels.

312. Working drawings for steel beams are commonly made on beam sheets or sketch sheets about 12″ × 18″, with printed captions and blanks as illustrated in this chapter. For distinction these are numbered in a separate series preceded by the letter F; often the drawings for the beams in different tiers or in different parts of a structure are further distinguished by hundreds, as F1, F2, · · · , F101, F102, · · · , F201, etc. As it is customary to draw a beam as long as the available space permits, regardless of its actual length, the completed drawings are not to scale. Usually the depth and the details are plotted to ¾″ or 1″ scale but the distances *between* the details are estimated so that they are roughly proportional to the total length. Some of the larger companies have interdepartmental understandings whereby the beam drawings can be greatly simplified by the omission of certain dimensions and sizes which are standardized, as in Fig. 148. Some companies use standard printed forms with the principal views of the beams and some of the dimension lines printed on the forms so that the draftsmen have only to draw the details. Some of these forms show the top and bottom flange views as well as the web and end views. The details are plotted to the standard scale which most nearly corresponds to the depth; some draftsmen are allowed to sketch in the beam details freehand.

313. Beams are usually shown **full length** even though they are symmetrical about the center lines. It is convenient to show the type of detail at each end, and it does not take long to repeat a group of holes. The duplication of connection angles or brackets can be reduced by the use of assembling marks or by referring the right end to the left end with a note " Same as other end."



UNIVERSITY BRIDGE COMPANY

YALE BRANCH

STRUCTURE OFFICE BUILDING DRAWING OF BEAMS

RIVETS ⅞ DRAWING MADE BY R.H.S. DATE 10/1/40 CONTRACT NO. D1108

HOLES 15/16 DRAWING CHECKED BY H.X. DATE 10/4/40 SHEET NUMBER F1

Fig. 148. Different Methods of Detailing Beams.

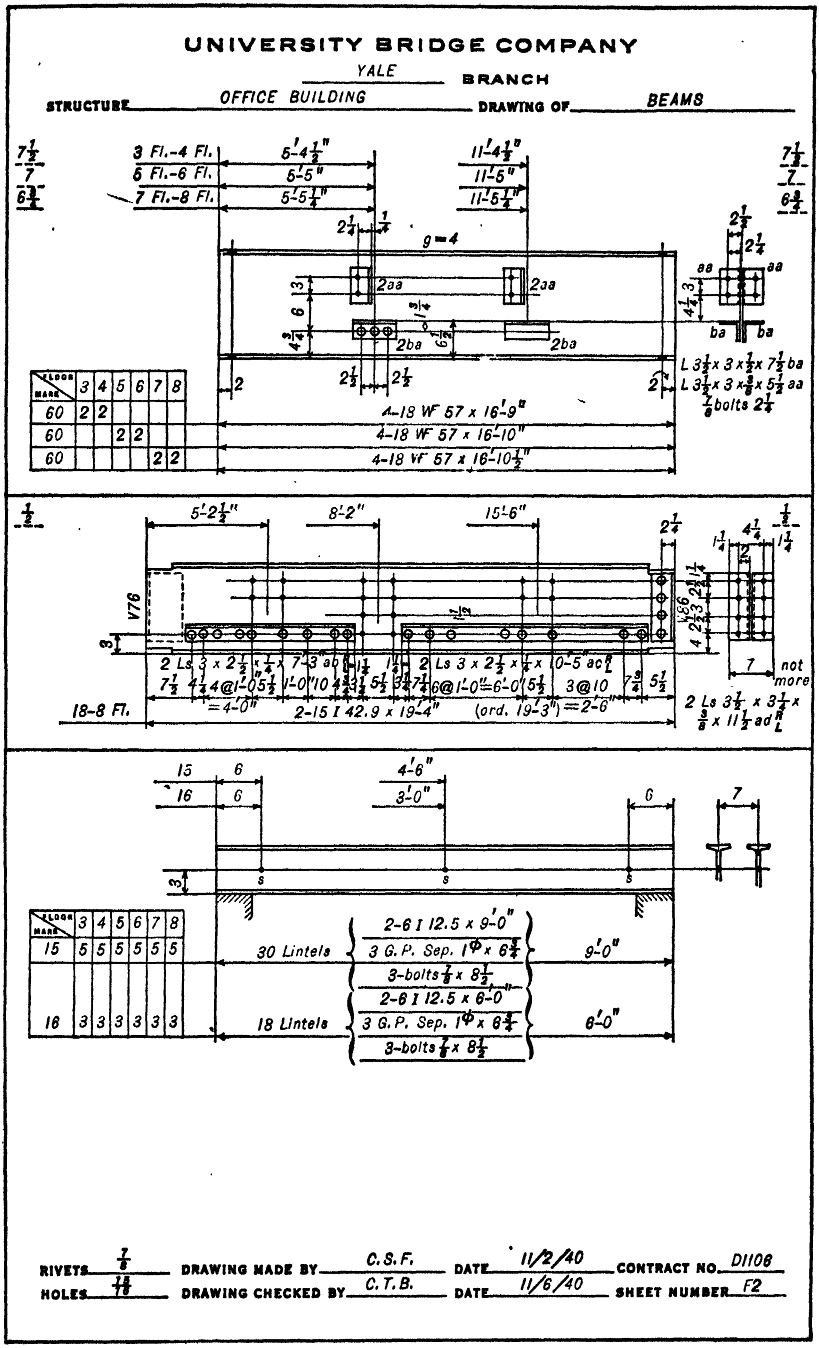


Fig. 149. Floor Beams and Lintels.

314. Standard web **connection angles** are shown in the tables for connecting the end of one beam to the web of a supporting beam or other member. Series A and H are based on $\frac{7}{8}''$ rivets, and Series B on $\frac{3}{4}''$ rivets; the H connections are stronger than the A connections. Similar special connections may be drawn to provide for different numbers or spacings of rivets. Single 6 × 6 × $\frac{7}{16}$ angles are sometimes placed on one side of the web instead of the two 6 × 4 angles, when lack of space prevents the use of the double connection, as the standard M angle, Fig. 149. Many companies merely outline the web legs of standard connection angles with or without standard marks, but without size or dimension other than the one locating the first hole, as in Fig. 148.

315. Seat angles are used in multi-story buildings or in large floor areas, as shown in Fig. 150 (*a*), in order to reduce the number of field rivets, to speed up the erection, and to provide for the erection of each beam independently of any other beam; such erection would be impossible if two beams were framed to the opposite sides of a web by means of standard connection angles with rivets in common. There is no connection to the seat angle, but the end of the beam is held in place by means of two rivets or bolts in a single side angle, as shown in Fig. 149. Similarly, beams are connected to columns by seat angles and top angles, as in Fig. 150 (*b*) or 160, with two field rivets in each flange unless more are required for wind bracing.

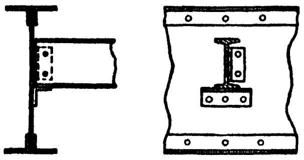


Fig. 150 (*a*). Beam Connection to Girder.

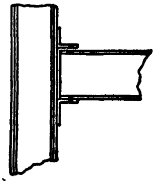


Fig. 150 (*b*). Beam Connection to Column.

316. Beams which are supported by masonry walls must rest on **bearing plates** in order that the loads may be distributed over the proper areas. The plate sizes are standardized for different sizes of beams, the width of the plate being the length of bearing, i.e., the distance which the beam must project on the wall. These bearing plates are not attached to the beams, but they are shipped loose to be set in the wall before the beams are erected. The end of each wall-bearing beam is held in place by an anchor imbedded in the wall, either a pair of angles fastened to the web, or a bent-rod " Government " anchor stuck through a single hole in the web 2" from the end. A wall-bearing beam is usually indicated conventionally by hatch lines, Fig. 148 or 149.

317. The length of a beam is the extreme dimension as shipped, even though some other dimension such as the distance center to center of holes may be more important. When connection angles are used at both ends, the length is the distance from back to back of angles and is made less than the clear distance between the faces of the supporting members to provide for erection clearance, as explained on page 96. This length depends upon the sizes of the supporting members and their distances apart. This dimension may be placed on the line of extension figures (see next page), as shown in the top sketch of Fig. 148, or combined with the billing, as in the other sketches of the same figure. The erection diagram usually shows dimensions to the centers of symmetrical beams, girders, and columns, but to the backs of channel webs. It is convenient to record at each end of the overall dimension, or in the margin (Fig. 149), the distance from that end to the corresponding center or face of the supporting member which is located on the diagram; these distances are then used in determining the overall length from the diagram distance, and also the corresponding dimensions from the ends to the first intermediate connections.

318. The ordered length of a beam may differ from the extreme dimension explained in the preceding paragraph. The beams are sawed to length at the rolling mills, and each length as rolled must be cut into the desired ordered lengths while still hot; the lengths cannot, therefore, be measured with great precision, and all lengths must be accepted if within the tolerance, or mill variation, specified by the steel companies, usually $\pm\frac{3}{8}''$ except for beams over 24″ deep. Beams are ordered in multiples of $\frac{1}{4}''$ or preferably $\frac{1}{2}''$. In order to save flame-cutting in the fabricating shop, it is well to allow greater tolerances where possible. Connection angles, if used, are made to project approximately $\frac{1}{2}''$ beyond the end of the beam as ordered. Many companies make no indication of this projection on the drawing, but it is assumed to be flush, as indeed it may be; see upper half of Fig. 148; the Bethlehem Steel Company does show the projection, as in the third sketch. The ordered length is given in parentheses on the main dimension line when combined with the billing, but when the billing is separate the ordered length is billed, as in the top sketch. The holes for the connection angles are laid out according to the correct distance from back to back of angles, the shopmen equalizing the actual projections at the two ends. Since the distance from back to back of angles is usually a multiple of $\frac{1}{8}''$, the ordered length is made about 1″ (from $\frac{3}{4}''$ to $1\frac{1}{8}''$) less, expressed to the nearest $\frac{1}{2}''$. When connection angles are at one end only, the ordered length is from $\frac{3}{8}''$ to $\frac{3}{4}''$ less than the overall length. When no connection angles are used, the ordered length must be the same as the overall length, and provision must be made for mill variation. If one or both ends of a beam are wall bearing, the mill variation is unimportant. The ordered length need not be added in parentheses when it is the same as the billed length.

319. The beam marks may be recorded under the sketch, as at the top of Fig. 148, or on an extension of the billing line, as in the other sketches. A tabular form may be used for different floors or shipments, as in Fig. 149. The floors of a tier building are either lettered or numbered (page 110), and the beams must be marked accordingly.

320. Holes for intermediate web connections are often marked on the steel by means of standard templets which are set in the correct position by tape measurements. The spacing of the holes in each group is often omitted when the standard 3″ and 5½″ are used. In order to correlate the different groups of holes, it is desirable to locate them with one setting of the tape, and for this reason it is convenient to use **extension figures** giving the distances from the left end to the center (or the first row of holes) of each group. These extension figures may be given on one line with judicious use of arrow heads, as in Fig. 148, or on noncontinuous lines, as in Fig. 149; the important distinction is that each dimension extends from the arrow just at the right of the dimension to the first arrow in the opposite direction on the left, regardless of intermediate arrows which point toward the right only. These extension figures are sometimes supplemented by another line of center-to-center dimensions for convenience in the drafting room, and sometimes the overall dimension is placed on the extension line instead of a separate line, as in the top sketch of Fig. 148; it is better not to put the same dimension on two lines lest only one be changed in case of revision. Beams are naturally detailed in the position which corresponds most nearly to their location on the diagram, but when connection angles are used at one end only, it is better to draw them at the left end so that the extension figures will extend to the more definite end. A group of holes for a channel connection should be located with due regard to the web thickness and the way the flange is turned, inasmuch as the diagram dimensions extend to the *back* of the web while the holes are symmetrical about the *center* of the web. The group templets are located vertically by dimensions from one flange either to the center or to the first hole of the group, depending upon the custom of the structural company. It is better not to tie in with both flanges because the extreme depth does not always agree with the tabular depth, owing to the wearing of the rolls or to the spreading of the flanges on the cooling beds. All vertical dimensions should extend to the same flange, usually the bottom unless the tops of many of the connecting beams are at the same elevation.

321. When beams of **different depths** frame on opposite sides of a web, standard connections should be used if possible, even though the angles have to be placed above or below the centers of the beams in order to accommodate the rivets which are in common. If the beams are not exactly opposite, it may be possible to make angles with special gages so the same rivets may be employed, or else independent single-angle connections may be used.

322. When all the holes of a group are to be punched at a single stroke by a **multiple punch,** all the holes in the web should be so located that the beams will not have to be shifted laterally as they pass through. This may be effected by raising or lowering the angles on some of the connecting beams, as in beam 18, Fig. 149. Holes for tie rods, sag rods, or wall anchors may be placed in line with the holes of adjacent connections.

323. Coping and Flame Cutting. When a beam is to frame into the web of another beam it may be necessary to cut away part of one or both of the flanges to prevent interference with the flange of the beam to which it is to connect; the end of the beam thus cut is said to be " coped." Some companies use standard coping machines for cold cutting; others flame-cut with an oxyacetylene torch. Each cut is indicated on the drawing, but it is usually unnecessary to note or dimension more than one cut on a beam if all are alike. The dimensions should be expressed to the nearest $\frac{1}{4}''$ and provide suitable clearance. The American-Bridge Company copes are standardized and referred to by number, with a curve of $\frac{3}{4}''$ radius as shown in beam 14, Fig. 148. The Bethlehem Steel Company copes are given the letter I regardless of the size of the beam for which the cope is made, as in H14, Fig. 148. When printed forms are used for the beam outline, it may not be feasible to erase the coped portion, so it is blacked out. Part or all of a flange may be burned out to clear a connecting part; if the whole flange is coped so that the web can connect directly to another member, it may be necessary to chip away any projecting parts of the flange or fillet; the drawing should then be noted " chipped," as in B1, Fig. 154.

324. Wooden floors and wooden sheathing are attached to steel beams by means of wooden **spiking pieces** or nailing strips bolted to the steel. These are usually bolted to the webs of channel purlins and to the top flanges of other beams with $\frac{1}{2}''$ or $\frac{5}{8}''$ bolts. Holes for these bolts (often made the same size as other holes) must be provided at intervals of 1′-0″ to 1′-6″, preferably in multiples of 3″ to permit the use of standard strip templets; holes in the flanges of symmetrical beams should be staggered. It is well to note these holes " for wood " or mark the dimensions " about " so that shopmen need not take undue care in spacing them. The holes in the spiking pieces are bored in the field to match the steel, and large holes may have to be provided for countersinking the bolt heads and washers where they would otherwise interfere with the planking. Care

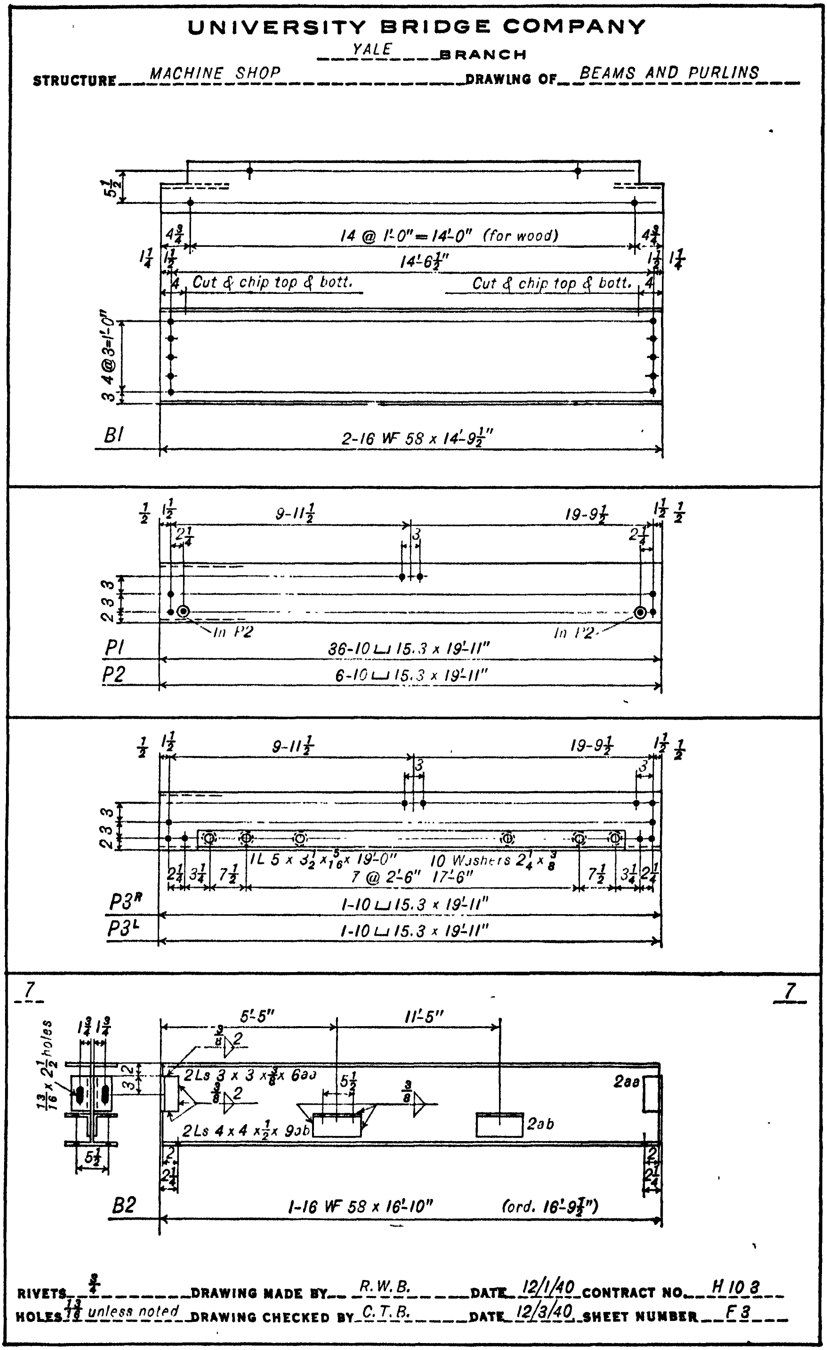


Fig. 154. Beams and Purlins.

should be taken to space the holes in the flanges far enough from web connections so that the bolts can be placed, and far enough from the ends to allow for any underrun or coping.

325. Holes in the flanges of beams are dimensioned by usual methods and not by extension figures. Important holes, such as column connections, should preferably have a dimension from center to center of holes for the convenience of the shopmen and the inspector. A few such holes may be shown by rectangles in the web view in order to dispense with top and bottom views, as in beam 60, Fig. 149. When the number of holes is large, or when the drawing might be misinterpreted, as for example when holes are staggered, flange views are shown, as in Fig. 154. If flange views are used, all flange rivets and holes should be shown there and not in the web view.

326. Purlins. The beams of flat roofs or multi-story buildings are usually similar to the corresponding floor beams. The beams may slope to give the desired pitch, but often the beams are made horizontal and the slight pitch required for drainage is provided in the slabs by varying the thickness over the beams. Steep-roof construction is quite different, and the roofing is supported by longitudinal lines of " purlins " connected to the top chords of the roof trusses or rafters. Both wooden and steel purlins are used, as explained on page 130. Steel purlins are most often channels, usually with the flanges facing down the slope. The clip-angle connections are described on page 136, and typical purlins are shown in Fig. 154; the strut angle in P3 is separated from the channel by washers to permit the use of clinch rivets for attaching corrugated steel. The purlins are usually ordered 1″ shorter than the distance between the centers of the trusses. The upper holes at the end of P3 are for an angle outlooker in the end panel, as shown in Fig. 137.

327. Sag rods are used between adjacent purlins to give intermediate support at right angles to their webs, because the resultant forces are not parallel to the webs. Wooden sheathing is considered to have sufficient stiffening effect without sag rods. When the roofing is of corrugated steel, one line of sag rods is used if the span between trusses is from 15′ to 20′, and two lines if more than 20′. The upper purlins should be tied together, or to a ridge strut, by means of bent rods, and sometimes the lower purlins are tied to the eave struts near the trusses by bent rods. The common size of rod is $\frac{5}{8}$″, but the holes are often made the same size as other web holes, unless too large to give sufficient bearing for the nuts. The holes are made in pairs 3″ apart, preferably near the top of the web, one hole being used for the rod in one panel, the other for the rod in the adjacent panel; both holes are punched even though only one is used, so that the erector does not have to plan the erection of the whole line in order to come out right. Similarly, holes for tie rods should be provided in the webs of floor beams when certain types of floor construction cause thrusts on the beam, as, for example, hollow-tile arches. Holes for rods are often marked T instead of the 3″ dimension to distinguish them from beam connections.

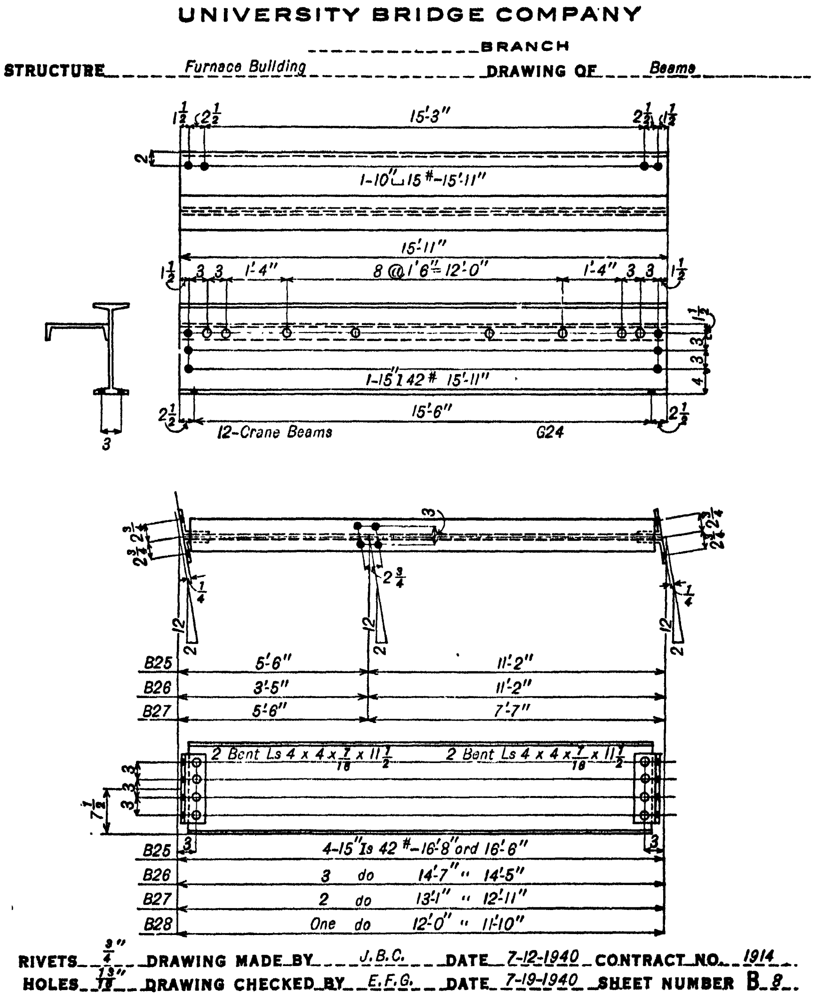


Fig. 156. Crane Beams and Skew Beams.

328. Beam Girders. In order to give greater strength or greater bearing for a wall, two beams may be placed side by side. They should be bolted together with gas-pipe separators, or with more substantial cast-iron separators or special diaphragms made of plates and angles. The separators are spaced about 4′ or 5′ apart, and from ½′ to 1′ from each wall-bearing end. The beams and separators may be shipped separately and assembled in the field, or they may be assembled in the shop, being detailed together and called a girder or a lintel, as in Fig. 149. When beams with separators are insufficient, cover plates may be added to form a box section; obviously, rivets through the inner flanges should be avoided.

329. Welded beams often have no shop welds, so the beams may be shipped directly to the site without working drawings, the field welding being provided for by the erection diagrams and supplementary detailed sketches. A typical beam with shop welds is shown in Fig. 154.

330. Miscellaneous Beams. Wall plates or flange plates are sometimes riveted or welded to the top flanges of beams which support masonry walls in order to give wider bearing. These plates are not necessarily concentric with the beams. Skew-back angles are sometimes riveted or welded to the webs of beams to support floor slabs or arches at the proper elevations, as shown in Fig. 149. Crane-runway beams are sometimes stiffened laterally by channels riveted to the webs, as shown in Fig. 156. The rivets are spaced at intervals of about 1′-6″ with about two 3″ spaces at each end. When beams do not frame at right angles to the supporting beams they may be connected by means of bent angles or bent plates, as explained more fully on page 193. When the skew is not more than 3 in 12, angles may be used, as shown in Fig. 156. The dimensions are referred to working points at the centers of the beams, and must be given so that there is no ambiguity about the direction in which they are measured.

CHAPTER XX

COLUMNS

331. Steel columns form the principal supports of all steel structures other than bridges and similar spans which rest directly upon masonry. So many different kinds of members connect to columns that it would simplify the work of the column draftsman if he could wait until the detailed drawings of all connecting members were completed before drawing the columns. This is not practicable, however, because the columns are the first members to be erected and the time schedule precludes such delay. The drawings for the columns must logically be among the first to reach the shop, and connections for other members must be anticipated. The draftsmen who draw the other members must see that the drawings conform. It is often necessary to make layouts of the more unusual connections to determine the dimensions to be put on the column drawings; these layouts are used later by the draftsmen who make the drawings of the connecting members. Many types of connection recur so frequently that drafting-room standards are prepared to simplify the work in the drafting room and the templet shop.

332. So many varied **types of columns** are used by different designers for different conditions that it is feasible to illustrate only a few of the more common ones. The wide-flanged beam sections are now so common for both beams and columns that many of the older forms have been discarded, and the former standard plate-and-angle type is reserved for conditions under which the beam section is not so well adapted. Obviously, the work in both the drafting room and the shop is minimized by the use of rolled sections without continuous riveting or welding to hold component parts together. Some of the heavier columns are made with cover plates riveted to heavy core sections, the flanges of which are so thick that the holes must be drilled. Lattice bars are not used so extensively as formerly to hold component parts together, for often the extra metal in solid plates is cheaper than the cost of the extra drafting and shop work involved in lacing.

333. It is usually desirable to draw all members in the same relative **position on the sheet** which they are to occupy in the finished structure, and columns are preferably drawn with their longer axes vertical. This is not always feasible on account of the multiplicity of details, for more space is available when they are drawn lengthwise on the sheet. Some companies use long narrow sheets for column drawings; others, sheets of standard size for the general run of work, such as 24″ × 36″. When columns are drawn lengthwise it is customary to place the bottom at the left end. It is unnecessary to draw the full length of a long column to scale. The details are scaled, commonly $\frac{3}{4}'' = 1'$, and the length is reduced to the space available, leaving room for bottom sectional views, top views, other sectional views, and the necessary dimension lines. Intermediate details are placed at approximately proportionl distances apart regardless of scale. It is usually not apparent that the spaces between details are not to scale, for even when intermediate rivets or welds are required they are dimensioned in groups and not all are shown. No breaks in the views need be shown unless the drawing can be made clearer thereby.

334. Typical **office-building columns** are shown in Figs. 160 and 161. The latter shows a column patterned after the American Bridge Company standards in which many of the dimensions are omitted because of standardization. The billing is omitted from the drawing because it is completely summarized on a shop bill printed on the same sheet and it need not be repeated, but lack of space precludes the duplication of the shop bill here. The connection angles, splice plates, and fillers are shown flush with the edges of the flange to save time, even though they are not of the same dimensions. The drawing placed opposite shows the same column more fully detailed for comparison. In this the same assembling marks are used, but the material is fully billed, the dimensions are more complete, and more attention is given to scale.

335. Column Splices. In tier buildings, the column sections are usually made in two-story lengths, with the top sections of odd-storied buildings either one or three stories in length. Longer sections have been used, but two-story lengths can usually be handled more conveniently both in shipment and in erection. The splices are located just above the floor-beam connections. The ends of the column sections are milled or faced for direct bearing, and splice plates for the flanges are standardized. Typical plates shown in Fig. 162 are taken from the standards of the American Bridge Company. The central rivet space is made $\frac{1}{16}''$ less than the sum of the two column edge distances to allow drawing the sections to a tight fit when riveting. Where the section changes abruptly, as when a 12″ column is spliced to a 14″ column, a 2″ distributing plate or slab is held in place by web angles and bolts. Fillers are placed where necessary to make up the difference in column depth. These fillers are in multiples of $\frac{1}{8}''$ and should leave a clearance of $\frac{1}{16}''$ or $\frac{1}{8}''$ on each side to facilitate erection. Fillers thicker than $\frac{1}{8}''$ are held in place by two shop rivets in

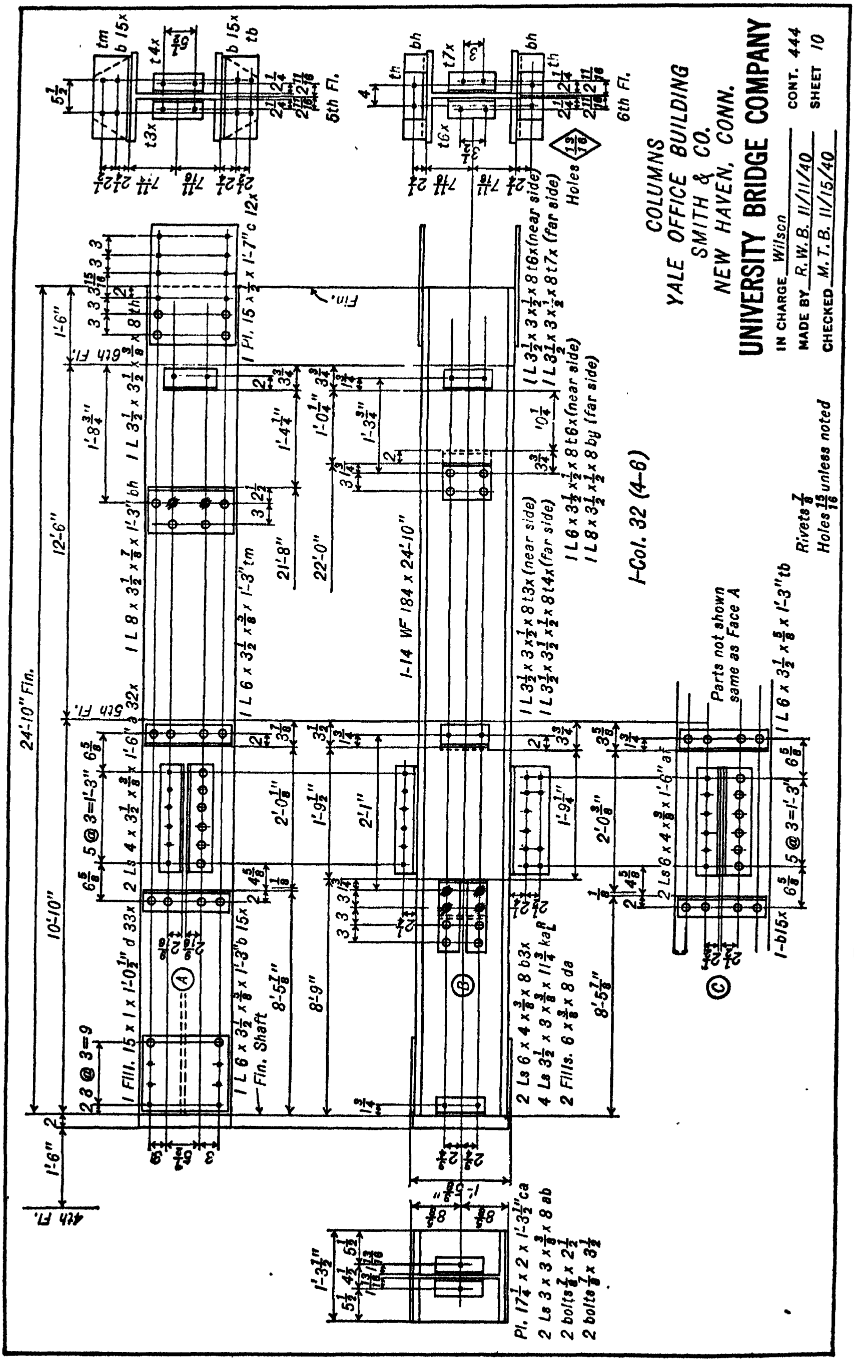


Fig. 160. Office-Building Column (General Method).

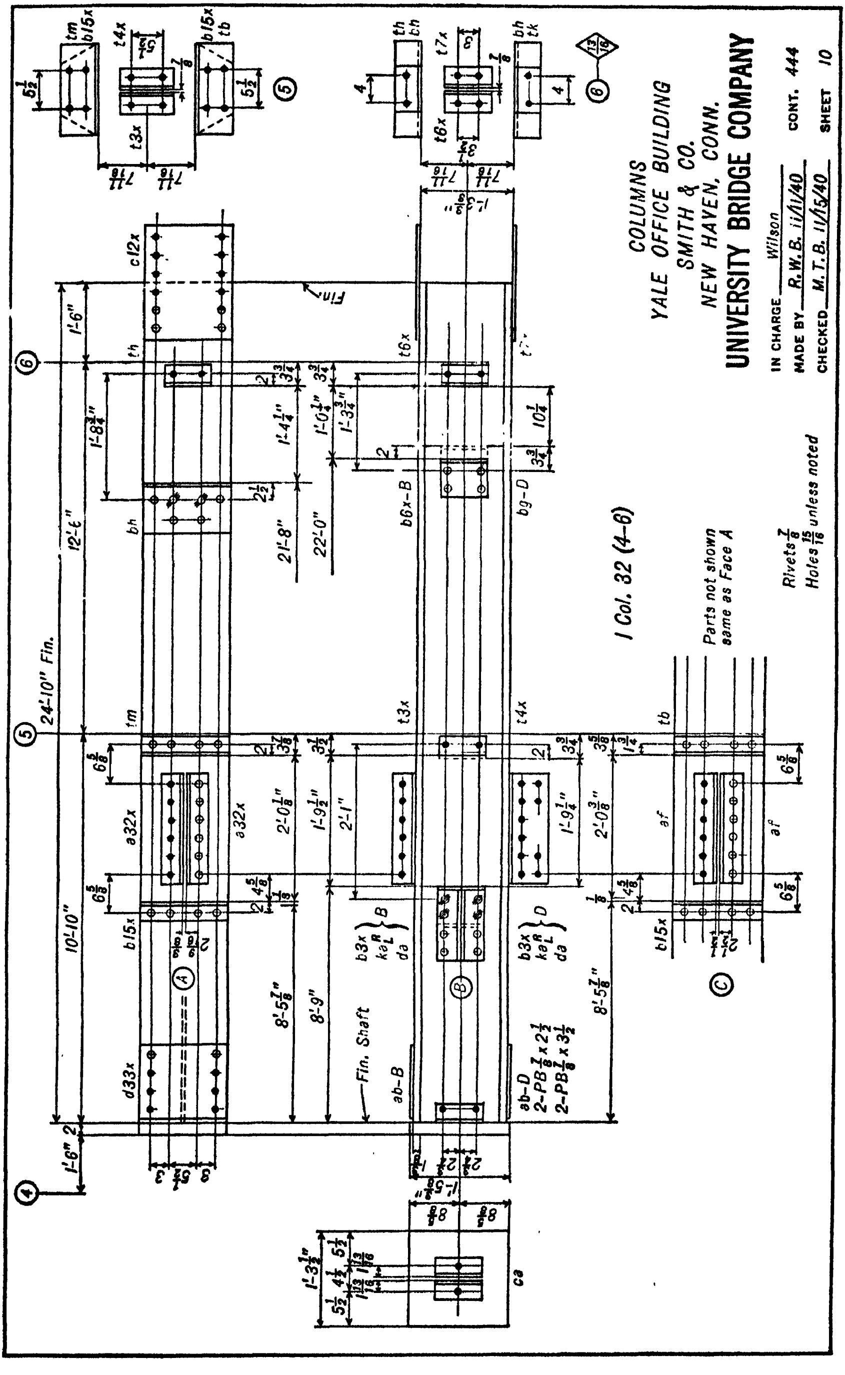
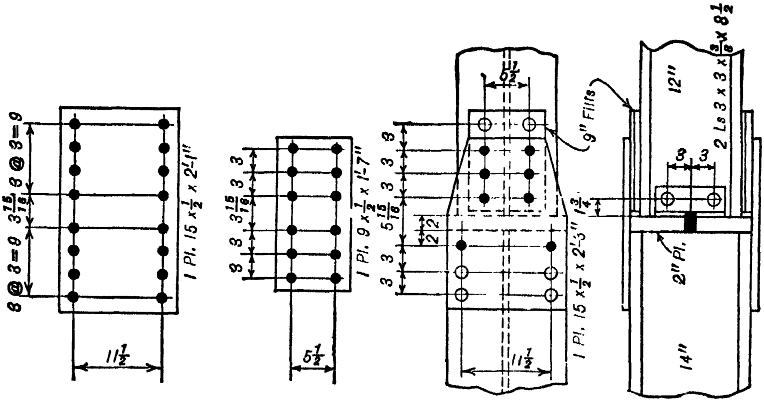


Fig. 161. Office-Building Column (Simplified).

the column above the splice plates. The fillers are usually made short so they do not have to be milled with the column shaft. The rivets are $\frac{7}{8}''$ for the splices shown; plates $\frac{5}{8}''$ thick, with $1''$ rivets, are used for some of the heavier $14''$ columns.



14" Columns 10" and 12" Columns 12" to 14" Columns

Fig. 162. Typical Column Splices.

336. The important dimension is the finished length, and this is preferably made conspicuous. Since all elevations on the diagrams are referred to the finished floor lines, it is important to show each floor line on the column drawings and to give the story heights. The beam connections are tied in to the floor lines, and in addition extension figures are used from the top of each seat angle to the milled end at the bottom, whether or not there is a base plate or distributing plate.

337. Typical **beam connections** are illustrated in the drawings. Two views of the angles are shown in which the rivets and holes appear as circles; the web view of a flange connection angle is not commonly shown merely for the sake of completeness but only if it makes the drawing more easily interpreted. Sectional views are shown for both floors unless alike; the upper one is projected directly above the web view, and the other is placed in any convenient space near by, but preferably not directly above the flange view unless it is turned at right angles to orient it properly. The sections are taken just above the top angles of the beam connections with no indicating lines, and it is assumed that the bottom angles are punched the same as the top although this is not noted; sometimes the holes in the outstanding legs are shown as rectangles in the other views of the top and bottom angles, but this is usually considered unnecessary. Beam gages are given without bisecting figures to show that they are symmetrical about their center lines. The column shaft is seldom crosshatched in the sectional views, because no misunderstanding is likely to result from such omission; in fact, in the simplified drawing the shaft is not even shown. A special gage is placed in the 6″ leg of a beam seat to bring the top rivets nearer the top and to more nearly equalize the rivet spacing if intermediate rivets are used to hold component parts of the shaft together. An ordinary seat angle is placed at the proper elevation to support the beam, but the top angle is set $\frac{1}{4}$″ high and shipped bolted to facilitate erection; if the seat and top angles are not over $\frac{1}{2}$″ thick they can be bent enough to allow driving the field rivets satisfactorily, but loose fillers $\frac{1}{8}$″ thick are shipped to the site to be used with thicker angles as needed. Loose top angles are often noted " Bolted for shipment " or else the bolts are listed, but in some companies this would be the general shop practice without such notes. When wind brackets are used in addition to web angles, as in the flange connections at the fifth floor, the bottom bracket is placed $\frac{1}{8}$″ below the bottom of the beam so that in erection the web connection will assume the full vertical reaction. When the holes in both legs of a seat angle are the same distance apart, it may be necessary to flatten the rivets in the vertical legs to give sufficient clearance for driving the rivets in the beam.

338. A typical **crane column** for a mill building is shown in Fig. 164. The bottom portion is made wider than the upper portion to support the crane girders better and to provide clearance for the crane to pass the upper portion which supports the roof. The upper part must be spliced to the lower part by enough rivets or welds to carry the direct stress and the bending; it may not be necessary to use both web and flange splices. Some type of seat is usually provided for the crane girders with a distributing plate and supporting seat angles and stiffeners. A crane column must be milled at the bottom and the top of the lower section, so that much of the crane load will be carried by direct bearing; when plates and angles are used for large crane columns, the outer angles are continuous and it is not feasible to mill the top of the lower web plate for the full width. A diaphragm is used to connect the top of the girder to the column to prevent the girder from overturning. A horizontal plate connecting to the underside of the flange, as shown in the figure, is the preferred type of diaphragm; a vertical plate riveted between the end stiffeners of the girders is not so good because the rivets are loosened by the continuous-beam action. Similarly, it is not satisfactory to connect the girder web directly to the column flange.

339. A typical **column base** is shown in the figure. This is quite different from the slab of a tier-building column because the load is relatively small and the chance of displacement by accident is much greater; anchor bolts are used to hold the base in position and to provide against uplift due to any tendency to overturn. To make the anchors effective there

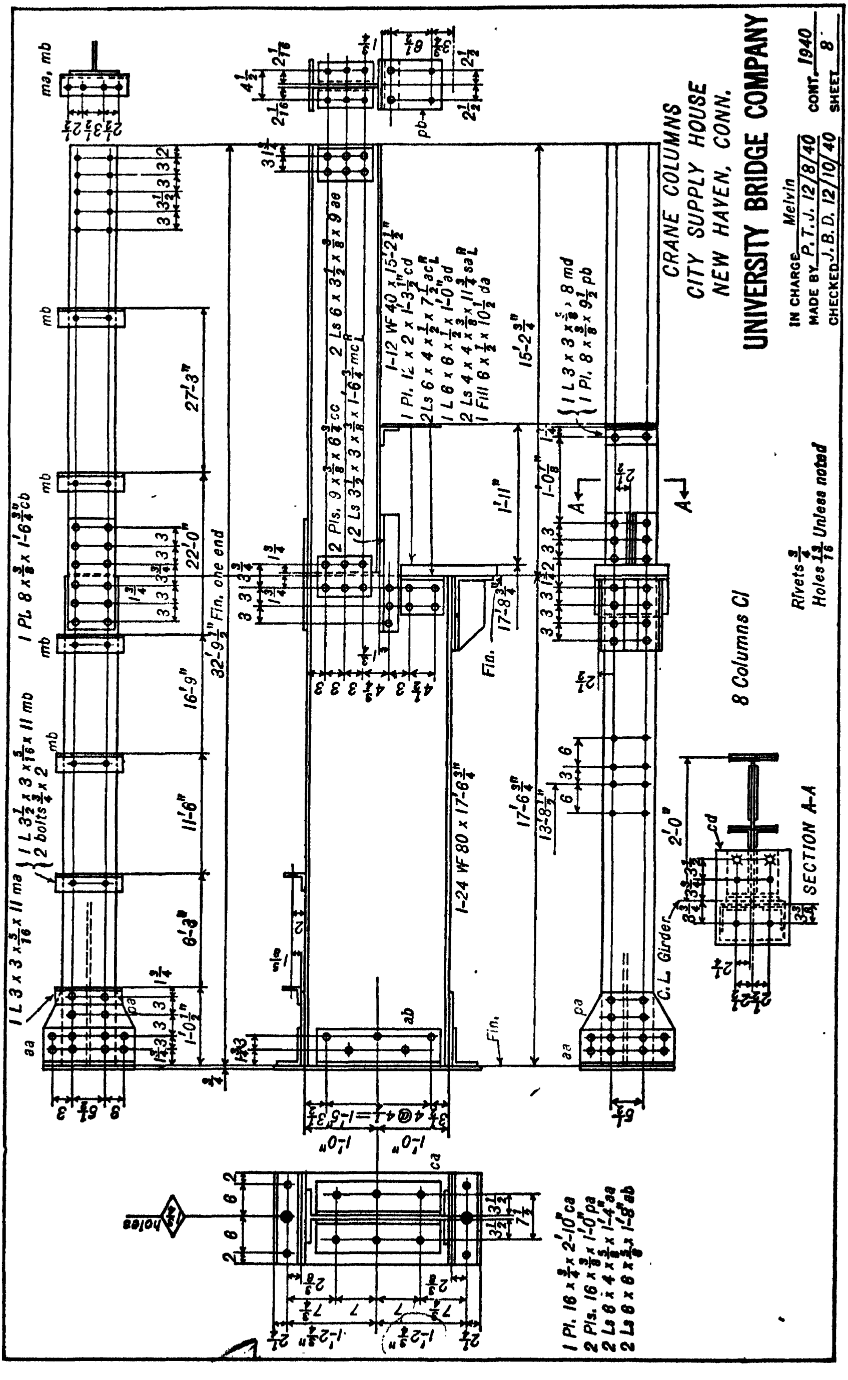


Fig. 164. Crane Column for a Mill Building.

must be enough rivets connecting the angles to the column flanges; if four in each flange are insufficient, a wing plate is used with rivets connecting the angle to the plate and a corresponding number connecting the plate to the flange. The width of the base plate is made the same as the wing plate and the angles, allowing driving clearance for the rivets; the length depends upon the column size plus the wing plates and 4″ angles, and the thickness is usually standardized. Four bolts are used in the larger columns, and angles are placed at the tops of the wing plates with stiffeners between the top and bottom angles, as shown in Fig. 165. Web angles are often added, but not always. Separate slab bases are sometimes used, but more often the plates are connected to the angles by countersunk rivets; care must be taken not to have too many rivets for they are expensive and not too important. For the method of design, see "Structural Design," page 240.

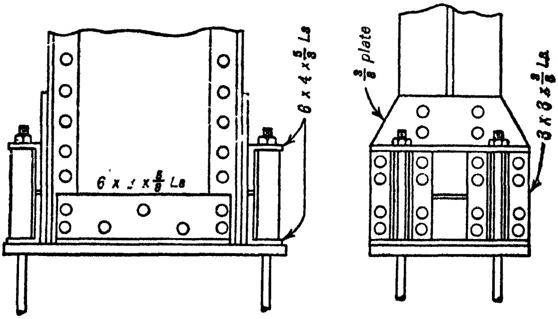


Fig. 165. Heavier Column Base.

340. Connections for girts are located by extension figures from the upper face of the base plate. These may be in the form of connection angles, as shown, for girts which are turned with the vertical legs against the corrugated steel, or they may be groups of holes for connection plates when the girts are turned the other way. Additional dimensions between connections may be used.

341. A typical **latticed column** is shown in Fig. 166, with holes at the top for a roof-truss connection, an angle connection on the flange for a lean-to rafter, and an inserted plate for an eccentric beam connection. A plate at the base between the column angles with two rivets above the base angles, balancing the two at the column center, gives the strength of six rivets to carry the column load, without milling. When lattice bars are placed between the angles, the angles are not a constant distance apart; they are separated by two overlapping bars most of the way, but only by one bar or one plate the rest of the way. Sometimes washers can be used to equalize the distances but more frequently the angles are bent to conform. If the distance varies, either the gages or the distance between flange holes must vary to correspond; if the distance is kept constant, the gages should be omitted from the drawing, and the templet maker held responsible for maintaining the proper distance. If the holes are so located that the gage is the same for all, then the gage can be dimensioned: The bars need not be shown, but the center lines of about one and one-half

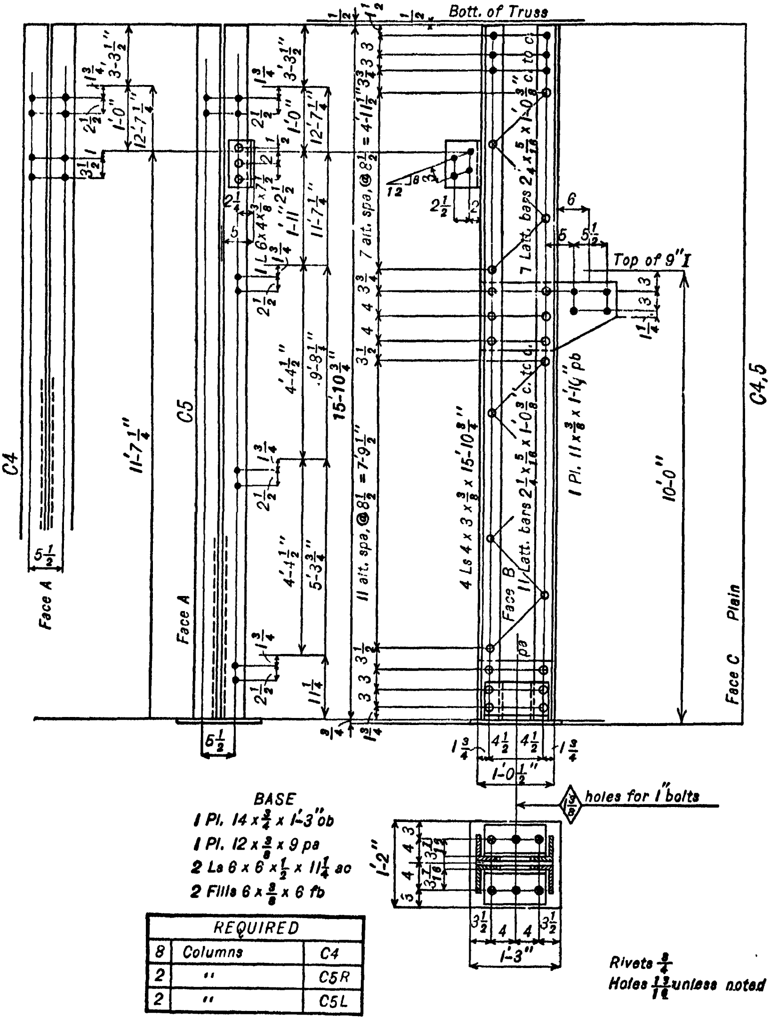


Fig. 166. Latticed Column for a Mill Building.

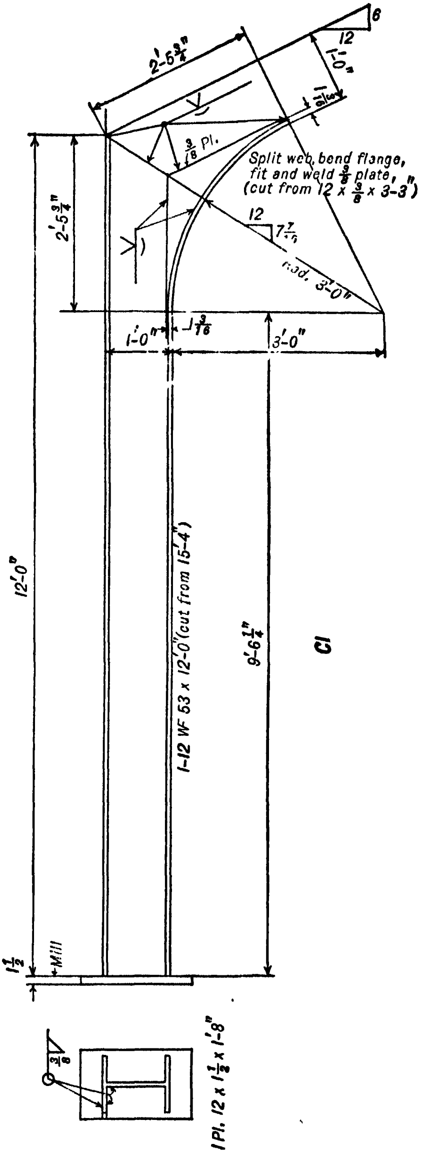


Fig. 167. Split-Beam Welded Column.

bars at each end of each group are indicated, care being taken that they slope in the proper direction so that when they are all inserted in the shop they will come out as shown. The slope of single latticing with the column axis may be either 60° or 45°, depending upon the specifications and the importance of the member. The group spacing should be arranged so that the bars in the different groups in the same member are interchangeable, and due consideration must be given to clearance between the end bars and the adjacent plates, as explained on page 92.

342. A typical **split-beam welded column** is shown in Fig. 167 for a rigid-frame column-and-rafter type of mill building. A similar connection is made by shop welding a portion of the rafter to the column and the plate, and making a square field splice with splice plates just beyond the curve. Sometimes both column and rafter are cut square, and the hip connection is similar to that shown but made up of a web plate and two flange plates.

CHAPTER XXI

BRIDGE TRUSSES

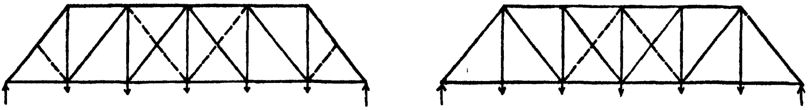
343. The most **common types** of trusses for simple-span bridges are shown in Fig. 169. Cantilever, suspension, continuous, swing, and lift bridges are beyond the scope of this book. When the floor loads are applied along the upper chord a bridge is called a " deck " bridge, but when along the lower chord it is called a " through " bridge and the traffic flows through the bridge between trusses. The compression members are represented in the figure by heavy lines and the tension members by fine lines; the dotted lines represent members in which no direct stresses result from the loads indicated, some of which (" counters ") may be stressed


(a) THROUGH WARREN

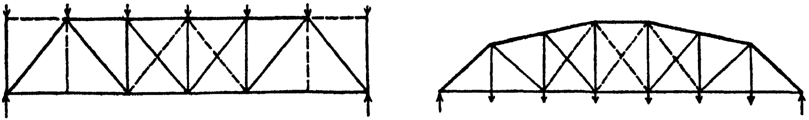
(b) DECK WARREN


(c) THROUGH SUBDIVIDED WARREN

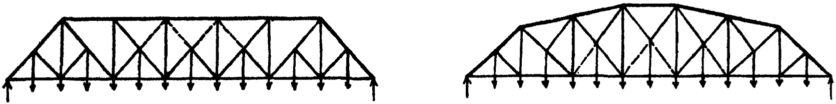
(d) DECK SUBDIVIDED WARREN


(e) THROUGH HOWE

(f) THROUGH PRATT


(g) DECK PRATT

(h) PARKER


(i) BALTIMORE

(j) PETTIT

Fig. 169. Types of Bridge Trusses.

when the bridge is partially loaded. The term "Warren" is usually applied to trusses in which both the main tension and compression web members are inclined, forming isosceles triangles with the chords, as in (*a*) or (*b*); the most favorable slope of diagonal is 45°, but this may be modified to suit the panel length and depth best adapted to conditions. The Warren truss is the favorite for comparatively short deck bridges and for through bridges up to 200′ or 250′, especially for railroads. The Pratt truss with parallel chords, (*f*) or (*g*), is used for highway bridges up to 175′, especially when pin-connected. The depth of a through bridge must be sufficient to give the required clearance between the floor or track and the overhead bracing, or else the bracing must be omitted and the bridge termed a pony-truss bridge. In spans longer than 175′ or 200′ it is usually better to increase the depth at the center more than that required for clearance, as in the inclined-chord Pratt, camel back, or Parker truss, (*h*); this keeps the chords more nearly uniform throughout. The intermediate upper panel points are placed to give a pleasing shape in which the polygonal top chord approaches a parabola. When the panel lengths exceed 25′ or 30′, the Warren truss may be subdivided as in (*c*) or (*d*), or with verticals at every panel. For spans over 300′ or 350′ it is economical to subdivide the panels by verticals which extend to the middle points of the diagonals, with auxiliary half-diagonals either below or above the centers, as (*i*) or

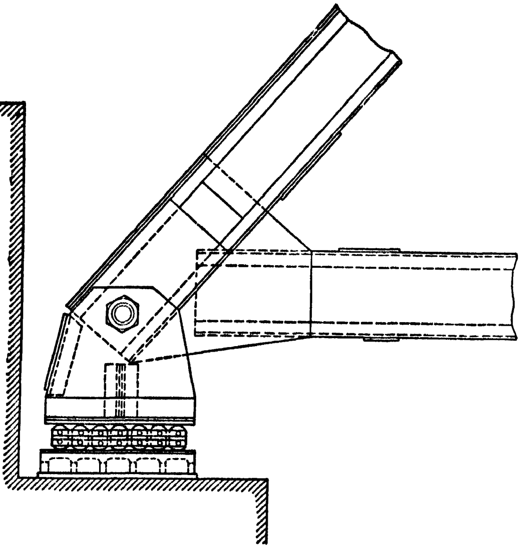


Fig. 170. Typical Bridge-Truss Shoe with Rollers.

(*j*); the parallel-chord truss then becomes a " Baltimore " and the inclined-chord truss a " Pettit." The Howe truss (*e*) is used most in timber construction; it is not so well adapted to steel bridges because of the long compression diagonals.

344. The **joints** of bridge trusses may be riveted, welded, or pin-connected. There is only one pin at each joint, and it is designed as a cylindrical beam (" Structural Design," page 135). Spans up to about 400′ have riveted joints, particularly on railways, for the sake of rigidity and durability. There are pins at the joints of longer spans because the secondary stresses which result from large riveted joints are less easily accounted for. Pins are at the supports of all long-span trusses, as shown in Fig. 170, so that the reactions remain vertical as the trusses deflect. Often the intermediate joints of the top chord are riveted even though pins are placed in the end posts and verticals so that eyebars can be used for the diagonals and bottom chords. Welded joints are being adopted more and more for the shorter trusses, but they have not yet entered the long-span field.

345. Arrangement on the Sheet. The smaller and lighter riveted or welded trusses may be drawn with the members in position in order to save the duplication of details, even though the members are to be shipped separately, as in Fig. 172. More than one sheet may be required to show all the necessary members, but they can be worked together and so noted. Reference points or lines may indicate where the dimensions or details of one sheet end and those of the next sheet begin, but in truss work it may be better to repeat a little. For example, the whole connection at panel point *L*2 is shown in the figure; on the next sheet the panel point would be repeated and the working lines and principal dimensions would be made to extend to this point. Enough of the gusset plate and holes should be repeated so that the extent of each dimension can be identified, but no attempt should be made to duplicate dimensions which are completely given on the first sheet. Each member of the larger trusses is detailed separately to avoid crowding, as in Figs. 174 to 180. All vertical members are preferably drawn vertically, and all horizontal members are drawn horizontally on the sheet; diagonals are usually drawn either vertically or horizontally in order to save space. For the sake of uniformity, the members of the left half of the truss on the far side of a bridge are shown on the drawings. Eyebars are drawn on small sheets or printed forms (page 233).

346. When members are drawn in position great care must be taken to adopt the best **arrangement of views** and of dimension lines to avoid unnecessary crowding. The position of the main elevation view of each member is necessarily determined as soon as the working lines (page 82)

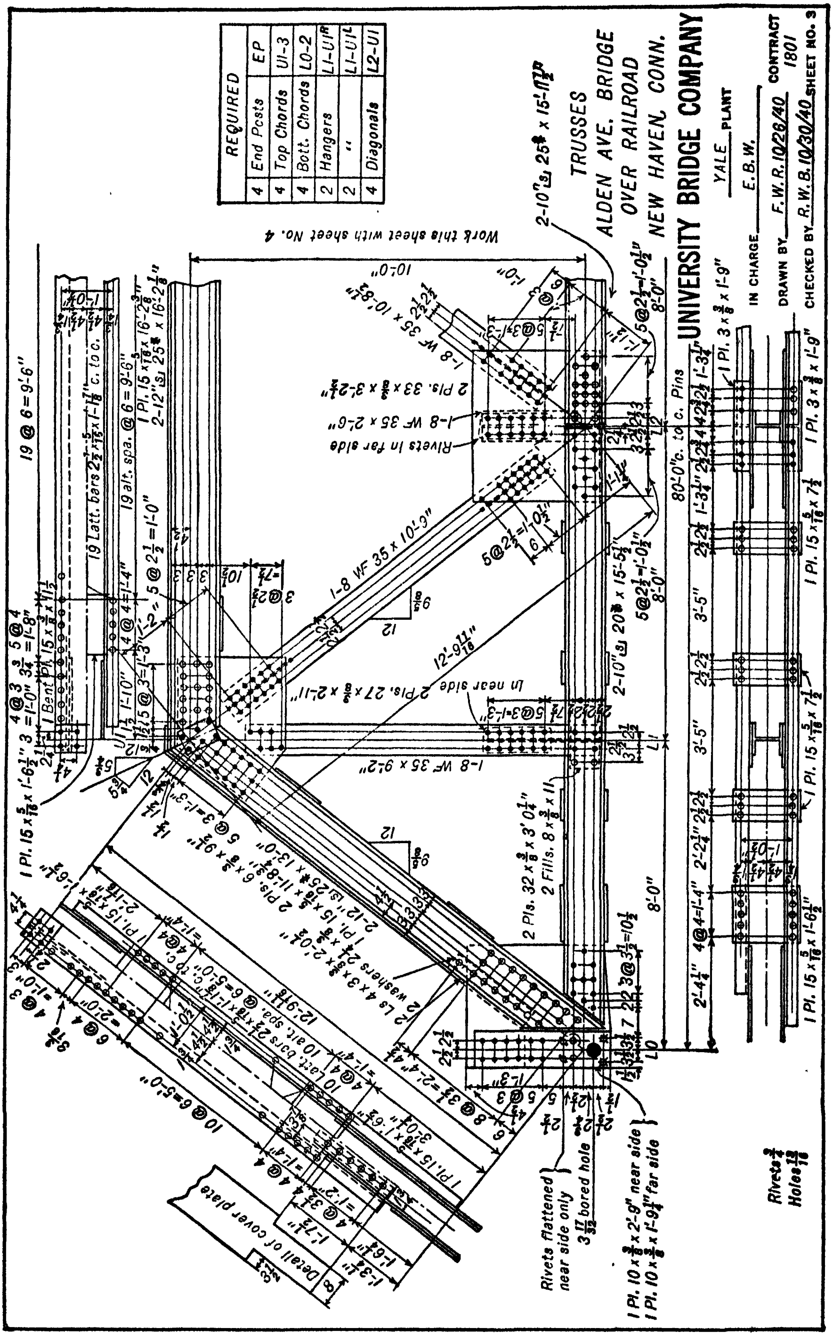


Fig. 172. Pony Truss for Highway Bridge:

are laid down, but the scale for the working lines need not be the same as for the details; in fact, no ordinary scale need be used as long as the panels are kept in correct proportion. The proper relation between views must be maintained, but views other than the front ones may be placed so that they will not interfere with the views of any other member, or so that only unimportant portions of views need be omitted. If other views of two or more verticals are required, it may be possible to combine them to save space, using different dimension lines if needed. If another view of a diagonal is required, it may be telescoped into shorter space with offset projection lines. There is seldom room for a bottom sectional view of the end post or top chord below the front view, but it may be placed between the front view and the top view. It is often feasible to draw a combined top and bottom sectional view, one-half of each being shown on one side of a common center line, as in Fig. 172. So far as feasible it is desirable to keep rivets in the top and bottom flanges of a chord opposite, although some companies do not insist upon it. In the illustration, rivets in the cover plate have been placed opposite those in the tie plates, and the rivets for lattice bars have been placed opposite those in the cover plate; this requires a few more bars than would be needed with the 7″ spacing allowed by the 60° requirement. The type of connection at the end provides for an 8″ beam railing post which also serves as a diaphragm to transfer some of the floor-beam load to the far gusset plate; since the gusset plates extend outside the end post, the cover plate must be notched and supported by auxiliary angles.

347. Types of Members. A wide-flanged beam serves as a web member where feasible, because this minimizes the fabrication cost. Two channels, two angles, or four angles are also used with lattice bars or tie plates, or four angles with a solid web. A top-chord member is often made of two channels with a cover plate on the top and lattice bars on the bottom, or of two webs, four angles, and a cover plate with lattice bars. A bottom-chord member may be made of two channels or of four angles, with or without vertical plates; tie plates are placed horizontally instead of a continuous plate, to give access to the rivets or to provide better drainage. The four angles may be arranged as in Fig. 175 with two sets of tie plates, or in the form of an H with one set of tie plates between the horizontal legs, depending upon the method of connecting the floor beams.

348. Clearance should be allowed to facilitate the erection of web members between the gusset plates which are attached to the chords or end post. The webs of the chords should be spaced to provide for the insertion of the rolled or built-up web members plus the thickness of the gusset plates plus a total clearance of $\frac{1}{8}''$. When web members are made of plates and angles the distance back to back of angles is usually $\frac{1}{2}''$ more

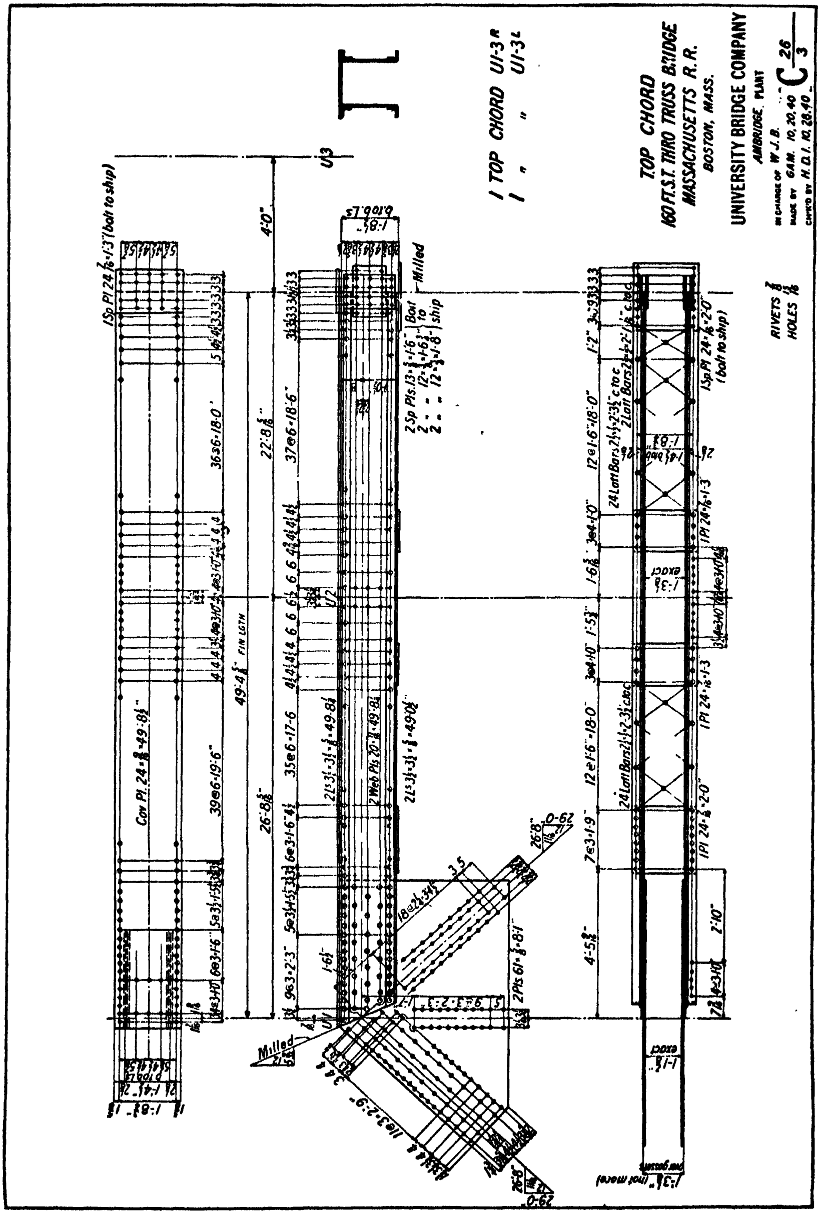


Fig. 174. Top-Chord Member for Riveted Truss Shown Opposite.

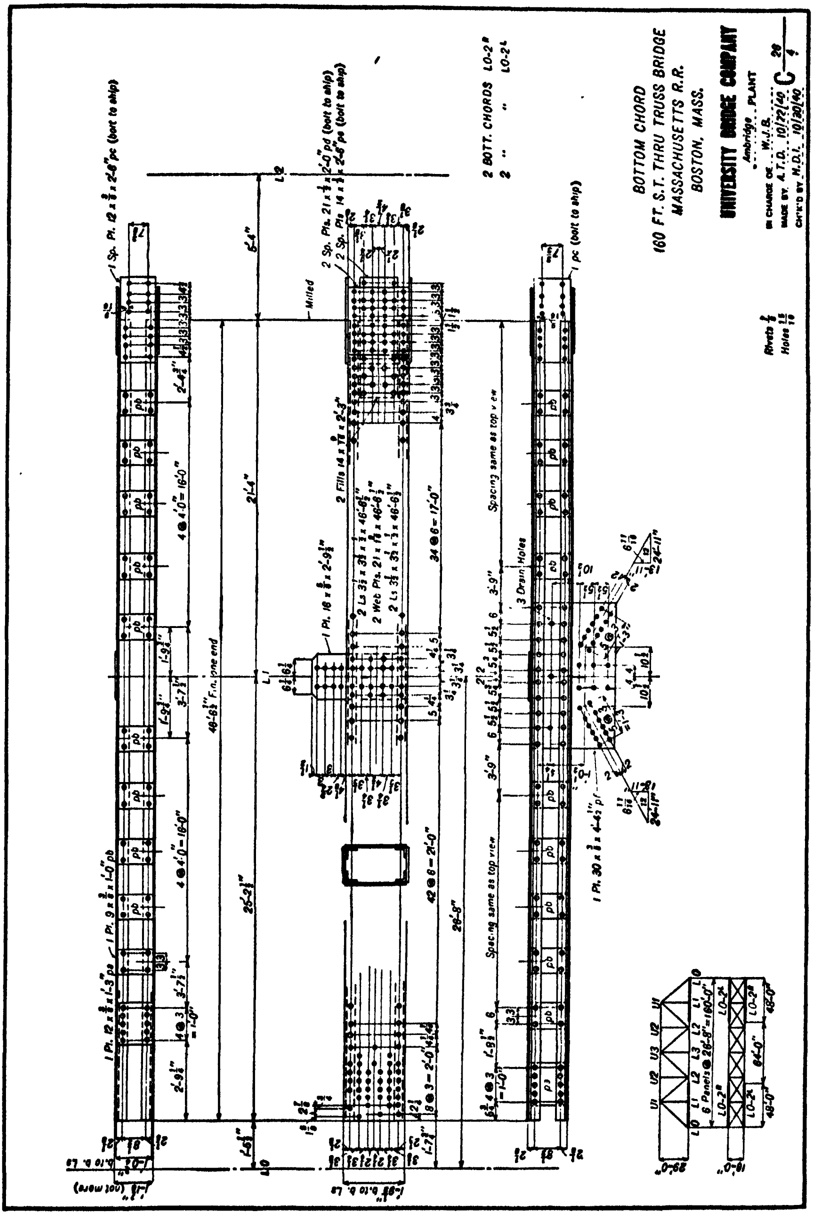


Fig. 175. Bottom-Chord Member for Riveted Truss of a Railroad Bridge.

than the plate width, but for rolled shapes the tabulated depth must be used, with fillers to make up for the differences in depth. To provide clearance at the hip joint, the distance between the webs of one member is often made $\frac{1}{8}''$ more than in the other member unless this causes difficulty at some other joint; sometimes the gusset plates of the top and bottom chords differ in thickness by $\frac{1}{16}''$.

349. Bridge trusses are built with a slight **camber** or vertical curve so that the track or floor will assume a horizontal position under the full load. This is usually effected in spans up to about 300′ by making each section of the top chord slightly longer than the bottom chord, the diagonals being calculated for the mean. The panel lengths of the loaded chord are equal to the span divided by the number of panels, and the panel lengths of the other chord are changed by about $\frac{1}{16}''$ for each 5′. A highway bridge with inclined approaches is built with considerably more camber in order to provide a smooth vertical curve in the roadway and to provide the necessary underclearance at the center with minimum heights of abutments and fills; the curve is sometimes provided in the floor system instead of in the trusses.

350. The **pin holes** are usually $\frac{1}{32}''$ (or $\frac{1}{64}''$) larger than the pins, and may be noted in the usual manner, as in Fig. 172, or by giving the size of the pin and the clearance separately, as in Fig. 178. In a pin-connected bridge this clearance should be taken into consideration in determining the lengths of the members, being added to compression members and subtracted from tension members; the lengths of eyebars from center to center of holes may be expressed in thirty-seconds, but other members are in multiples of $\frac{1}{16}''$.

351. Splices. The riveted chords of the heavier parallel-chord trusses are usually spliced independently of the gusset-plate connections of the web members, in order to avoid complications which might arise if the web members and the floor beams were connected at points where the chords change section. The splices are placed as near the gusset plates as feasible, and logically on the side of the smaller stress (Figs. 174 and 175). Top-chord sections which change slope at a panel point must be spliced at that point. The ends of top-chord sections and end posts are milled, especially in riveted joints where much of the stress can be transmitted by direct bearing. When the members are not in the same straight line a mitered joint is used, with the milled surfaces bisecting the angle between members, the slope being expressed to the nearest thirty-second instead of the usual sixteenth. At pin-connected joints a clearance of about $\frac{3}{8}''$ is left between the milled surfaces to permit independent action of the members on the pin.

352. Reinforcing Plates. The channel webs and the web plates of the built members of pin-connected trusses are seldom thick enough to transmit the proper stresses to the pins, and they must be reinforced by auxiliary plates to furnish sufficient bearing area on the pins. When the ends of two compression members bear on opposite sides of a pin, extra plates should be added or one of the reinforcing plates on each side should be extended to surround the pin; these plates should not be riveted to the other member. The purpose of these plates is to hold the members in position during erection and to minimize the chance of displacement by accident; they also help to keep water out of the joint. To avoid interference, these plates may be placed outside the web in one member and inside the web in the other, as shown in Figs. 178 and 179. For the method of designing reinforcing plates, see " Structural Design," page 141.

353. Rivet Spacing. The web members shown in Fig. 180 are for the same bridge as the chord members in Figs. 174 and 175. The holes near the bottom of the gusset plate in Fig. 174 for the connection of the tension members *L*1-*U*1 and *L*2-*U*1 are spaced farther apart than the adjacent holes in the belief that the members are made stronger. Since the effective net section depends upon the staggered rivets in the two legs, it is desirable to use a larger pitch at the point of maximum stress; after some of the stress has been transmitted through the rivets a smaller net section suffices and the pitch can be reduced. Recent tests would indicate, however, that the strength is limited by the weakest section and that no special benefit can be derived by such spacing.

354. It is often necessary to use **countersunk or flattened rivets** to prevent the interference of different members during erection. Shopmen are accustomed to look for such rivets in certain usual places so it is sufficient to indicate them with the proper conventional signs (page 41) without special notes to call attention to them. Some of the more common places where rivets may be countersunk or flattened are: (*a*) in the main plates of the shoes which bear upon the rollers or bed plates; (*b*) in chords, posts, or shoes to allow for eyebar heads, for pin nuts, or for overlapping reinforcing plates mentioned in paragraph 352 above (Fig. 178); (*c*) in the reinforcing plates or fillers under splice plates (Fig. 179); (*d*) in the tops of the end posts under the connection of the portal bracing in order to reduce the number of field rivets (Fig. 178); or (*e*) in posts where rivets are required in addition to the field rivets of the floor-beam connection. Field rivets should be so spaced that they need not be countersunk; thus, in Fig. 179, ample clearance is allowed for placing the pin nut in position. It is assumed that the countersunk or flattened rivets which are indicated in the near half of a member are also countersunk or flattened in the opposite side of the far half, unless noted otherwise. Rivets which are counter-

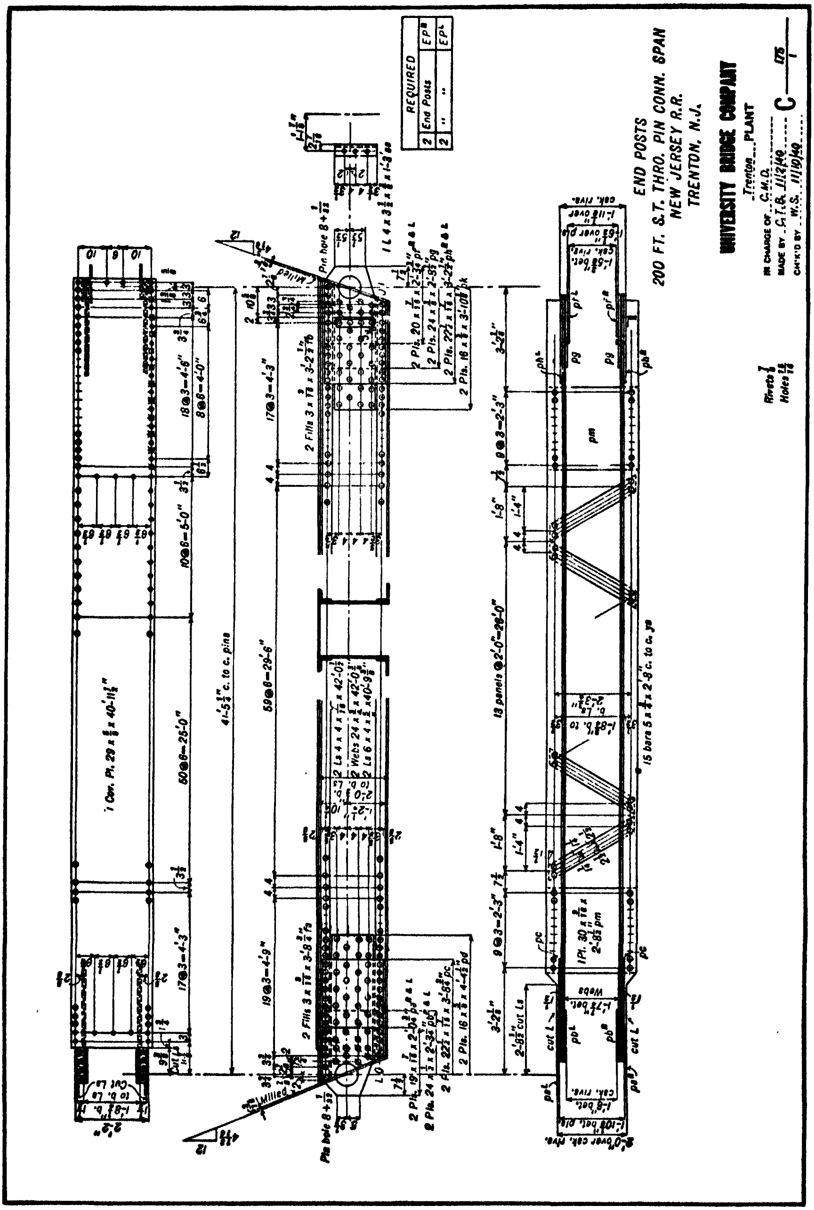


Fig. 178. End Post for Pin-Connected Truss Shown Opposite.

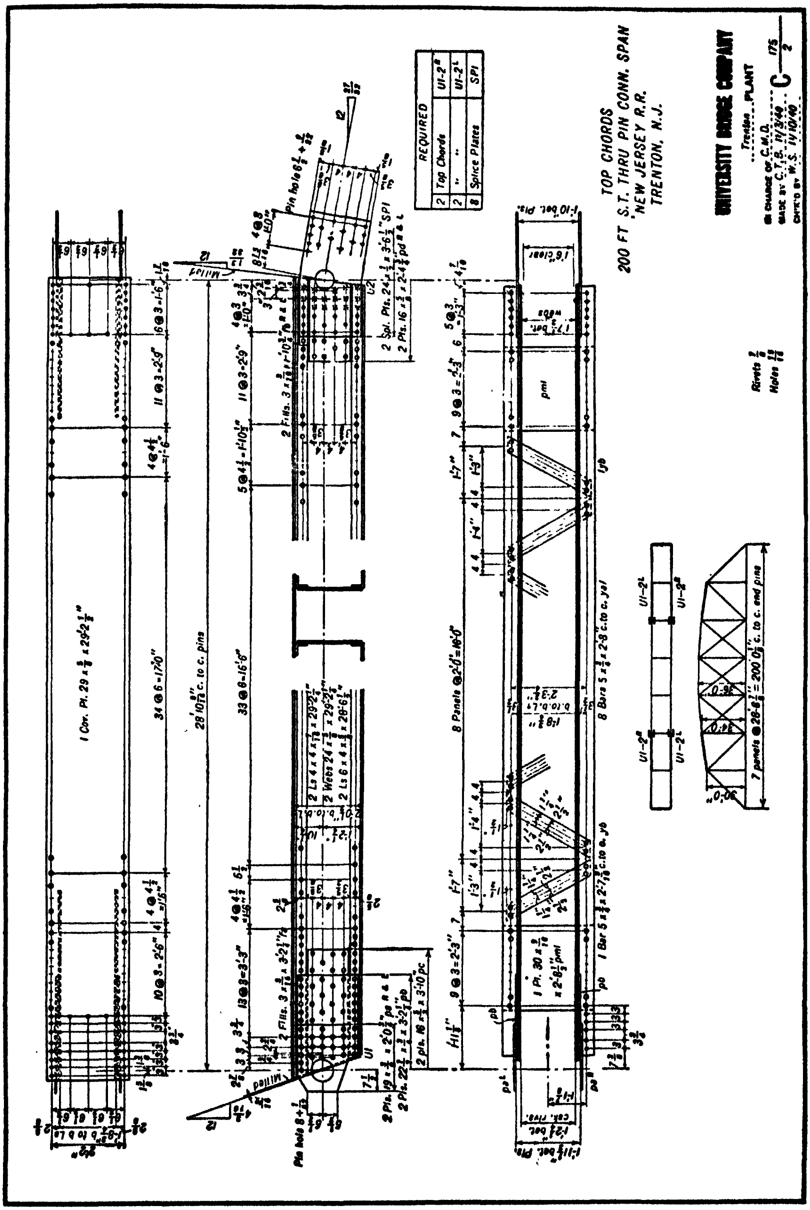


Fig. 179. Top-Chord Member for a Pin-Connected Truss of a Railroad Bridge.

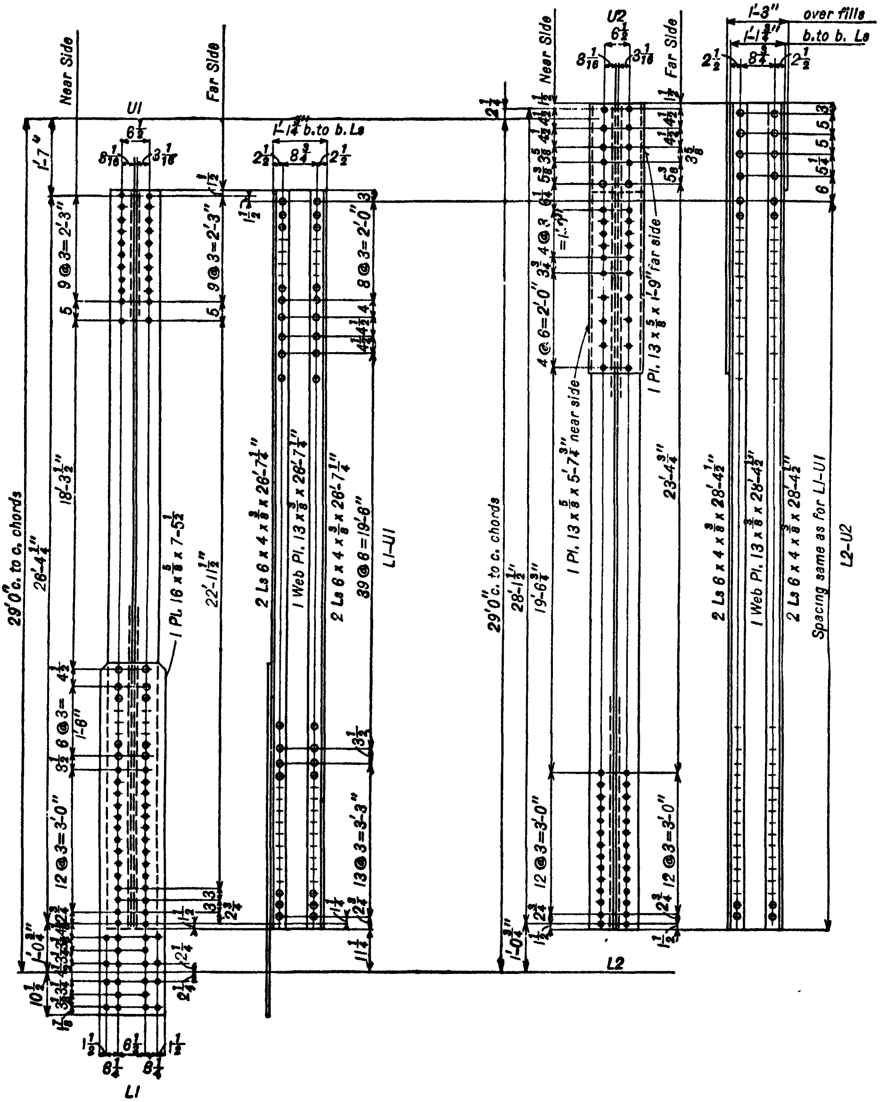


Fig. 180. Posts for Riveted Truss Shown on Page 175.

sunk in angles or fillers underneath separate splice plates are indicated by dotted lines to show that they are countersunk *back* of the plate instead of *in* it, as in Fig. 179.

355. Shipping Marks. Members of bridge trusses are commonly identified by the marks of the panel points between which they extend, as explained on page 109, although the end post is often marked EP. It is convenient to have a small key diagram on each sheet to show the location of each member detailed on that sheet, as illustrated in Figs. 175 and 179.

CHAPTER XXII

BRACING AND MISCELLANEOUS MEMBERS

356. Some **system of bracing** is usually required to secure a structure against forces which tend to distort or overturn it. These forces may result from wind, from moving loads, or during erection from derricks or travelers. Diagonal bracing is the most effective but obviously it is unsuitable in certain locations, as for example across doorways. When it is not feasible to place diagonals entirely across the panel to be braced, special brackets, knee braces, or portal struts may be employed. In some structures the joints may give ample security without special bracing, and in other structures only temporary bracing is required during erection, such as the bracing between columns which are later to be imbedded in solid masonry walls.

357. Diagonal Bracing. Bracing systems with full diagonals may be considered as trusses and so designed. The members to which the bracing connects serve as the chords of these trusses, as for example the columns, the girders, or the chords of other trusses. The " posts " or transverse compression members may be either special struts or else such members as floor beams, purlins, or cross frames. The diagonal stresses in any panel may be resisted by a single member along one diagonal of the panel, or by members placed along both diagonals to form " cross bracing." If the members are stiff enough to meet the ratio-of-slenderness requirements, each diagonal is assumed to take one-half the stress; otherwise the whole stress is considered to be taken by the tension diagonal, the other diagonal providing for forces which might cause a reversal of stress. Bracing members are often made heavier than called for by design in order to give greater stiffness, and the sizes are often standardized for given classes of work. Bracing systems with full diagonals should be statically complete, diagonals not being used unless they are supplemented by proper struts. Special struts are not always required; for instance an eave strut of a mill building may serve as a girt, as a purlin, and also as the end strut of the bracing in three different planes, viz.: the vertical sway bracing between the columns, the horizontal bracing in the plane of the bottom chords of the trusses, and the bracing parallel to the plane of the roof.

358. The **lines of stress** of all members which are connected by a single plate should meet approximately in a common point to eliminate the secondary stresses, but adherence to this rule is seldom important in bracing systems. Better connections can be made by using an auxiliary system of working lines, as explained on page 85, allowing for the necessary clearances. A plate which connects a single diagonal to another member should be so arranged that the line of action falls within the rivets or welds which connect the plate to the other member, in order to reduce the eccentricity, as in Fig. 185 or 187.

359. Arrangement. The drawings for cross bracing are usually so made that the diagonals are shown in the proper relation to each other and to the members to which they connect. The system of working lines may then be easily checked and the connections to other members may be readily compared with the drawings of the corresponding members. The centers of the end holes in the diagonals are usually chosen as working points. The system of working lines may be plotted to a smaller scale than the details in order to save space; some of the simple members or plates may be shown separately for the same reason. In the simplest form of cross bracing the diagonals are so turned that they pass each other without interference, as shown in the cross frames, Fig. 191. More frequently the outstanding legs of the two angles are made to face the same way even though one angle has to be cut and spliced at the intersection; in this way it is possible to obtain the desired clear opening without increasing the height or width of a structure.

360. Initial Tension. Diagonal bracing must be tight in order to be most effective. A long diagonal will sag under its own weight during erection unless it is drawn tight before it is bolted or riveted; the sag is minimized by placing the longer legs vertically. Considerable racking of a structure could take place without removing this sag or stressing the member. In order to make a structure more rigid by enabling the diagonals to act at once, the length from center to center of end holes is made less than the calculated distance. The member may then be drawn into position for bolting by driving tapered drift pins into the holes. Since the holes are punched $\frac{1}{16}''$ larger than the bolts or rivets, the member must be shortened that amount to take up the " play " in the holes, and it should be shortened at least another $\frac{1}{16}''$ to overcome inaccuracies in punching or erecting. Tightness is thus assured even though a certain amount of initial tension may result. The total amount to be deducted from the calculated distance from center to center of end holes should be either $\frac{1}{8}''$ or $\frac{3}{16}''$, whichever will make the main dimension a multiple of $\frac{1}{8}''$; in this way the half lengths will be expressed in multiples of $\frac{1}{16}''$ and thirty-seconds will be avoided. Sometimes the amount deducted is noted, as in *T*1, Fig. 189; the chief benefit of such a note is to give assurance that provision has been made for some deduction. No shortening should be made for comparatively short stiff members, such as the diagonals of the cross frames between the girders of a deck railroad bridge, because it would be difficult to connect them.

361. The **connection plates** of bracing systems are usually shipped separately, although some of the smaller plates may be fastened to the members. The bracing for all bridges and many buildings is fully riveted or welded in the field, but the bracing for parts of some buildings may be bolted if the specifications permit. When the field connections are to be bolted, similar shop connections may be bolted also, as in Fig. 185.

362. Gages. The rivet lines of diagonal angles $3''$ or over are placed in the centers of the legs in order to equalize clearances, but this is not feasible in smaller angles because of limited driving clearance. With standard gages, the working lines should be located so that the angles can be erected in either position, clearances on both sides being provided for the greater corner distance.

363. A mill building can have no system of bracing which will obstruct the interior and prevent the free movement of cranes and other objects. Cross bracing is common in the sides, the ends, and the roof, while knee braces are often used to stiffen the connections of the intermediate roof trusses to the columns. Rods $\frac{3}{4}''$, $\frac{7}{8}''$, or $1''$ serve as diagonals in the planes of the top chords of the trusses, and $\frac{5}{8}''$ or $\frac{3}{4}''$ rods in the tops and the sides of monitors; the rods are commonly connected by clip angles, as explained on page 136. Angles are used as diagonals in the plane of the bottom chords of the trusses and for the vertical sway bracing between columns, both on the sides and the ends of a building. The end panels and every third or fourth intermediate panel of a building are usually fully braced in all these planes. In the plane of the bottom chords additional diagonals are placed to form a large system of cross bracing which extends the full width of the building, as shown in Fig. 210; the large system may overlap so that some of the cross-bracing members serve also as members of the larger system, depending upon the number of panels in the building. The lines of struts are made to extend the full length of the building, double angles or beams being placed in the braced bays, and single angles like the diagonals in the intermediate bays.

364. The **bottom-chord bracing** for the building of Fig. 210 is shown in Fig. 185; this is arranged to connect to the trusses of the same building shown in Fig. 134. The working lines are referred to the working lines of the trusses and columns for convenience in checking the field connections. The working lines through the end holes of the diagonals are arranged to provide about $\frac{1}{2}''$ clearance between the truss angles or struts and the corners of the diagonals, taking the corner distance on the gage side so that the angles can be turned either way to simplify erection. Only one diago-

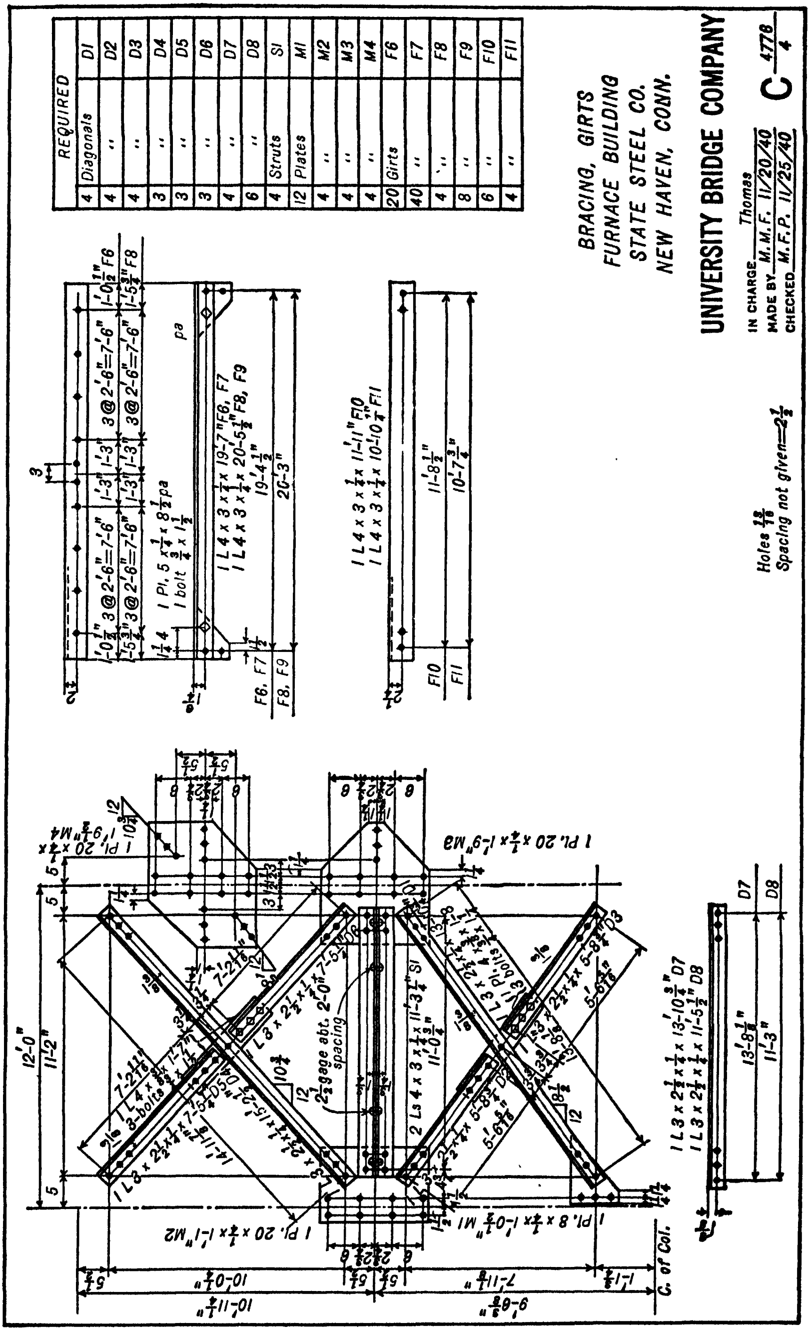


Fig. 185. Bottom-Chord Bracing for a Mill Building.

nal and one plate of each kind need be shown. A single diagonal *D*7 is like *D*1 except for the central hole; it could be combined with *D*1, but is here combined with the intermediate strut *D*8. The plate *M*4 is inserted in a convenient space where some of the dimensions need not be duplicated. The strut *S*1 is cut short at the left end so that the holes will not be over the flange of the gable column which connects to the truss at this point.

365. Unsymmetrical bracing is illustrated by the end sway bracing of Fig. 186. The bottom strut *S*7 connects to the flange of the channel of the crane column. The roof truss serves as the top strut, the bracket at the top of *D*13 being connected both to the truss and the column; note that the angle which connects to the truss is cut to clear the fillet of the angle. After the working points have been located, the length and the slope of each diagonal can be found in the usual manner. The position of the intersection of the diagonals relative to the lower working points can be found by solving the triangle of which these three points are the vertices. The angles may be easily determined and the horizontal side is known. The remaining sides may be found by equating the ratios of the sides to

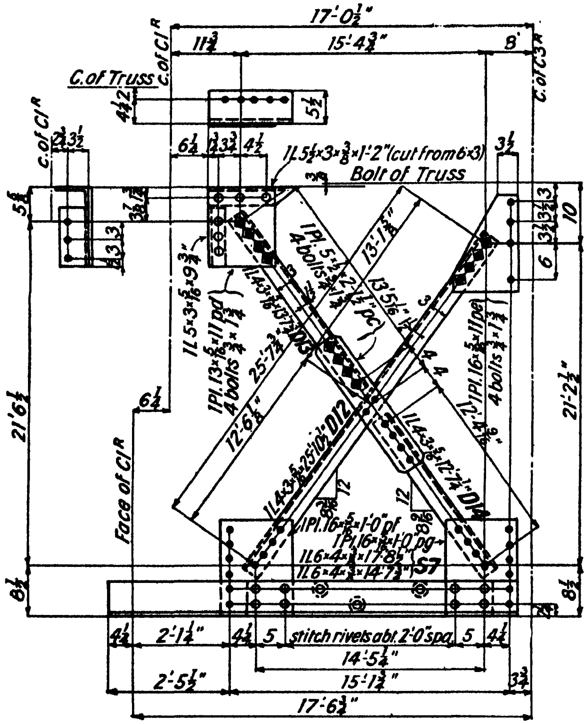


Fig. 186. End Sway Bracing for a Mill Building.

the sines of the opposite angles. For example, the angles are determined from their cotangents as follows:

$$\begin{array}{rlrl}
\log 14'\ 5\tfrac{1}{4}'' = & 1.15949 & \log 15'\ 4\tfrac{3}{4}'' = & 1.18740 \\
\log 21'\ 2\tfrac{1}{2}'' = & \underline{1.32651} & \log 21'\ 6\tfrac{1}{2}'' = & \underline{1.33328} \\
\log \cot = & 9.83298 & \log \cot = & 9.85412 \\
\text{angle} = & 55^\circ\ 45' & \text{angle} = & 54^\circ\ 27' \\
\text{third angle} = & \multicolumn{3}{l}{69^\circ\ 48' = 180^\circ - 55^\circ\ 45' - 54^\circ\ 27'}
\end{array}$$

The remaining sides are found as follows:

$$\begin{array}{rlrl}
\log 14'\ 5\tfrac{1}{4}'' = & 1.15949 & \log 14'\ 5\tfrac{1}{4}'' = & 1.15949 \\
\log \sin 55^\circ\ 45' = & 9.91729 & \log \sin 54^\circ\ 27' = & 9.91041 \\
\text{colog} \sin 69^\circ\ 48' = & \underline{0.02757} & \text{colog} \sin 69^\circ\ 48' = & \underline{0.02757} \\
 & 1.10435 & & 1.09747 \\
\text{length} = & 12'\ 8\tfrac{5}{8}'' & \text{length} = & 12'\ 6\tfrac{3}{16}''
\end{array}$$

These lengths should be reduced by $\frac{1}{16}''$ because the total lengths have been shortened $\frac{1}{8}''$ to insure tightness (page 183).

366. A typical **knee brace** to connect a crane girder to a column is shown in Fig. 187. Two types of connection are shown, one at the top and the other at the bottom; note that in each type the line of action falls well within the group of rivets (page 183).

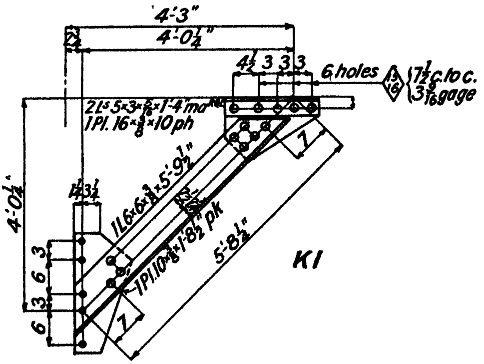


Fig. 187. Knee Brace.

367. The **top lateral system** of a through truss bridge cannot be made a complete system of cross bracing extending down the inclined end posts to the abutments because a clear passageway must be maintained at the ends of the bridge. Cross bracing is used in each panel of the main top chord, but a portal strut transmits the corresponding stresses to the end posts which act as girders to carry these stresses to the supports. There are many different types of portal struts, as for example the solid-web type, *PS*1, Fig. 188, or the latticed type, Fig. 195. The portal strut and the intermediate strut or sway brace, *SB*1, shown in Fig. 188, and the corresponding top laterals shown in Fig. 189, are for the bridge shown in Fig.

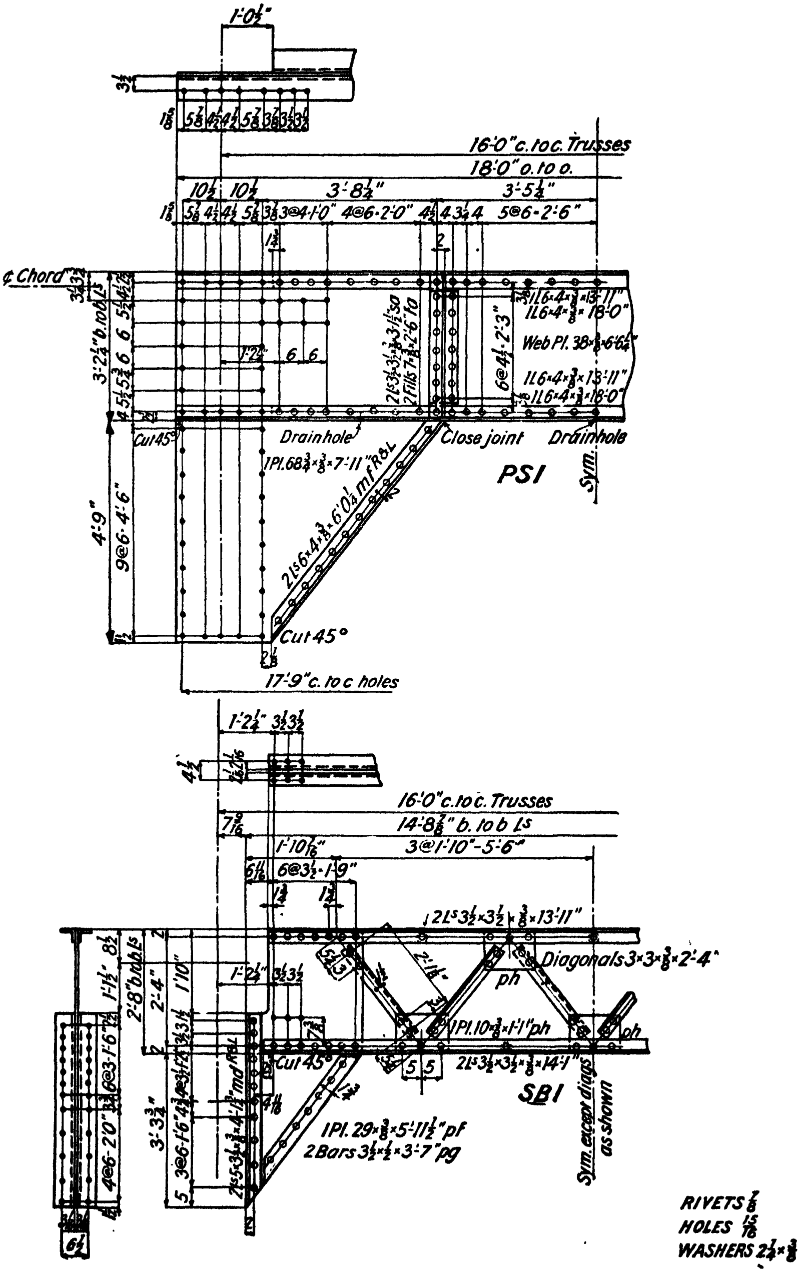


Fig. 188. Portal Strut and Sway Brace for a Railroad Bridge.

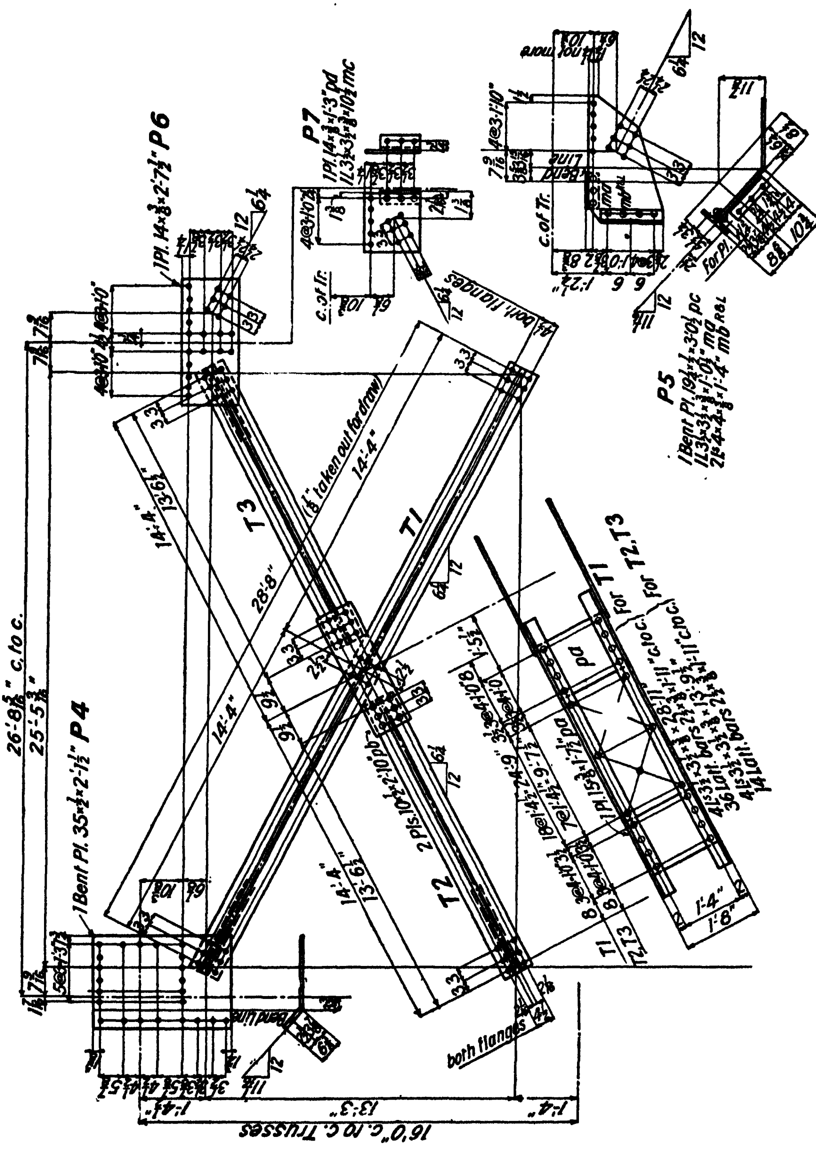


Fig. 189. Top Lateral Bracing for a Railroad Bridge.

175; they connect to the top chord and the vertical post shown in Figs. 174 and 180. The top laterals are made of two or four angles latticed, and the depth is determined by the plates which connect to the top and bottom flanges of the top-chord member. In this case, the plate *P*6, Fig. 189, rests on the cover plate of the top chord, and the plate *P7* on the top of the bottom angles of the chord, the top lateral fitting in between with a clearance of $\frac{1}{16}''$ or $\frac{1}{8}''$. The elevation views of both diagonals are combined to gain space. The portal struts are usually made as deep as the clearance will allow, and heavier than is required by the stresses in order to give greater rigidity, particularly in railroad bridges. Since the portal strut is in an inclined plane, the outer angle at the bottom forms a trough which should be provided with drain holes to prevent the accumulation of water. The intermediate sway braces are often made of four angles latticed by angles as shown, but sections in bridges with inclined chords may be more elaborate because of the greater depth available. The top angles connect to plate *P*6, and the angles *md* to the post *L*2-*U*2; the plate *pf* is notched out to clear the top chord, and is connected to the plate *P7* by the angle *mc*. The bottom angles are cut at 45° to give more clearance for driving the field rivets. The portal strut is connected way across the end post, and the bent plate *P*4 is connected to the portal and to the top chord, covering the joint between the top chord and the end post. The bent plate *P*5 at the bottom of the diagonal is connected to the bottom of the top chord and also to the web of the end post. The holes in the bent-up portion of *P*4 should appear as ellipses instead of circles, but on account of the difficulty in drawing small ellipses, circles are often used when no misunderstanding is likely to result. Similarly the angles *ma* and *mb* in *P*5 are shown conventionally rather than in strict accordance with the principles of orthographic projection for the sake of simplicity; two additional views would be required to show accurately the angles *mb* with the holes as circles. It seems equally clear and more convenient to draw the top view of the angles directly above the elevation, and to represent the angles by three lines to simplify dimensioning; care should be taken to give dimensions only in the views where the corresponding distances are shown in true projection.

368. Deck plate-girder bridges are braced vertically by means of **cross frames,** such as shown in Fig. 191. The frames at the ends of the bridge, *CF*1, are made heavier than the intermediate ones, *CF*2. The cross frames are connected to the stiffening angles of the girders and also to the plates of the lateral bracing which are attached to the undersides of the top flange angles. The key plan in the figure shows a typical layout of the lateral bracing, single angles being used for the diagonals and for the struts between cross frames. This lateral bracing is often drawn on the sheet with the

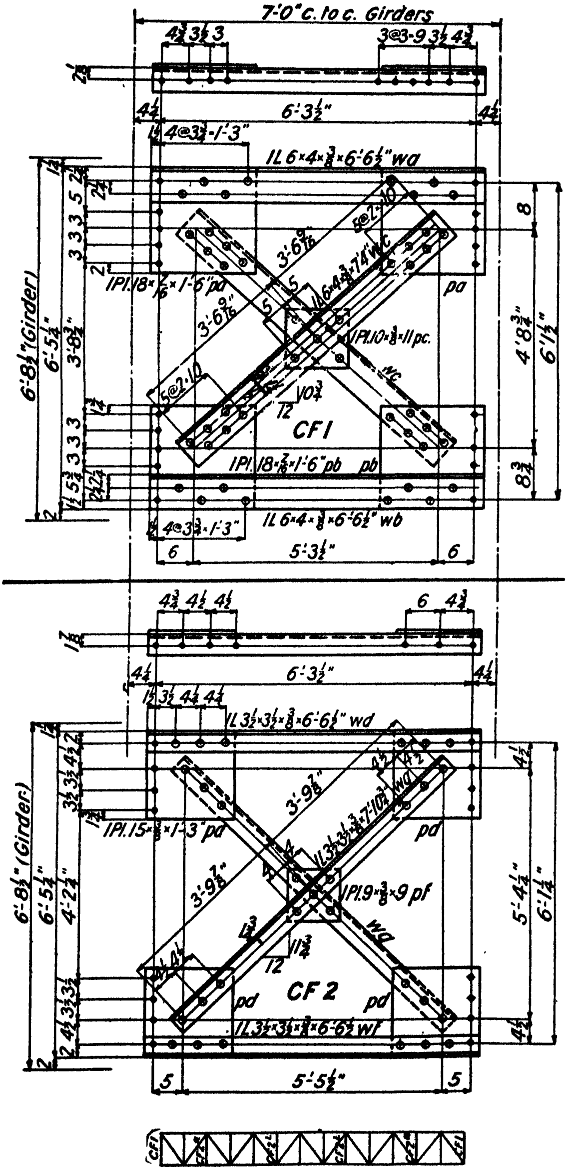


Fig. 191. Cross Frames for Deck Girder Railroad Bridge.

girders so that the connection plates can be shown in position, to save duplicating many of the dimensions. The spacing of the holes in the cross frames and the stiffening angles should be so arranged that a clearance of $\frac{1}{16}''$ is allowed between the tops of the cross frames and the lateral plates; if the cross frames connect to bottom lateral plates as well, $\frac{1}{16}''$ is allowed at the bottom and $\frac{1}{8}''$ at the top.

369. Typical **girts** are shown in Fig. 185, the upper ones having plate connections for girts with the vertical legs toward the column faces, and the lower ones for girts which are turned the other way and supported by clip angles such as those shown on the column in Fig. 164. The side girts and the end girts are combined on the same sketch, one of each having holes for bolts for attaching continuous window frames.

CHAPTER XXIII

SKEW WORK

370. Beam Connections. When two connecting members are not in the same plane, special connections must be planned. The holes in the top-and-bottom-angle connection of a beam to a column can be arranged to fit the usual holes in the beam flanges. A web connection can be made with two bent angles when the bend from normal is not over 3 in 12, as shown in Fig. 156; bent plates are used for larger bends, as shown in Fig. 194. In either case the dimensions are referred to a working point at the intersection of the center line of the beam and either the center or the face of the supporting member. The flanges on one side must be cut back to avoid interference and provide proper clearance; these may be punched out or flame-cut either diagonally or rectangularly, as in the figure, but the fillet need not be chipped off. When one end is higher than the other, the connection may be arranged as shown in the figure, with angles at the right end where the plane of the web is normal to the face of the support, but with bent plates at the left end for the skew. For shops with multiple punches it is desirable to arrange the rivets in rows parallel to the flanges, but this is not so important in other shops. The holes for intermediate beams may be arranged for standard angles, as at the left, or for a multiple punch, as at the right.

371. Skew Portal Bracing. Some of the connections encountered in structural work require more than ordinary computation in determining the proper angles and dimensions, for example, portal bracing for a skew bridge, hip and valley roof construction, bins, chutes, and hoppers. One form of skew portal is illustrated in Fig. 195; it is designed to connect to the cover-plate faces of the end posts. There are only two angles to be determined which involve the use of angles in more than one plane; these are the angle of bend (*B*) and the skew angle (*P*) in the plane of the portal. Formulas for these angles are shown in Fig. 196 in terms of the truss angle (*T*) and the skew angle (*H*) in a horizontal plane. The application of these formulas is illustrated by the determination of these angles in the portal of Fig. 195, with the following data:

22′-2½″ = the panel length of the truss.
29′-0″ = the panel depth of the truss.
16′-5″ = the distance center to center of trusses.

UNIVERSITY BRIDGE COMPANY

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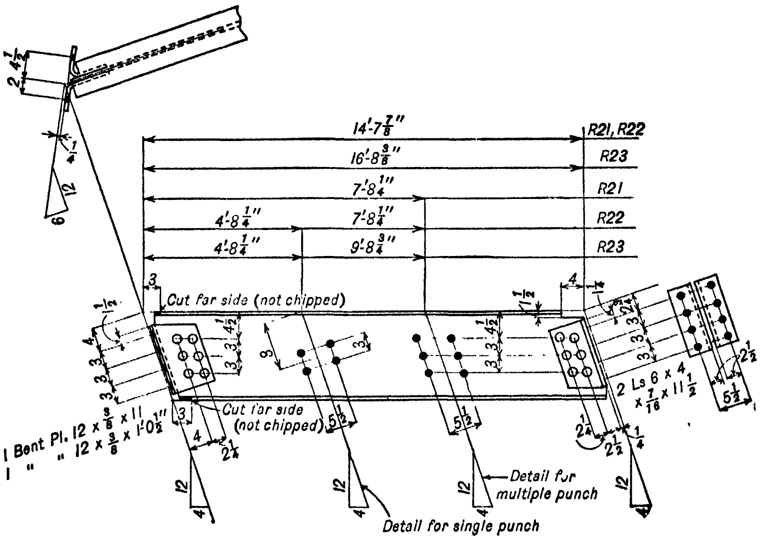
STRUCTURE Furnace Building DRAWING OF Rafters



One 15" I 45#–14' 10" R21
2– 15" Is 45#–14' 10" R22 (opposite)
2–15" Is 45#–16' 10 1/2" R23

RIVETS $\frac{3}{4}''$ DRAWING MADE BY A.J.E. DATE 7-13-1940 CONTRACT NO. 1914
HOLES $\frac{13}{16}''$ DRAWING CHECKED BY B.F.J. DATE 7-31-1940 SHEET NUMBER B 7

Fig. 194. Skew Beam or Rafter.

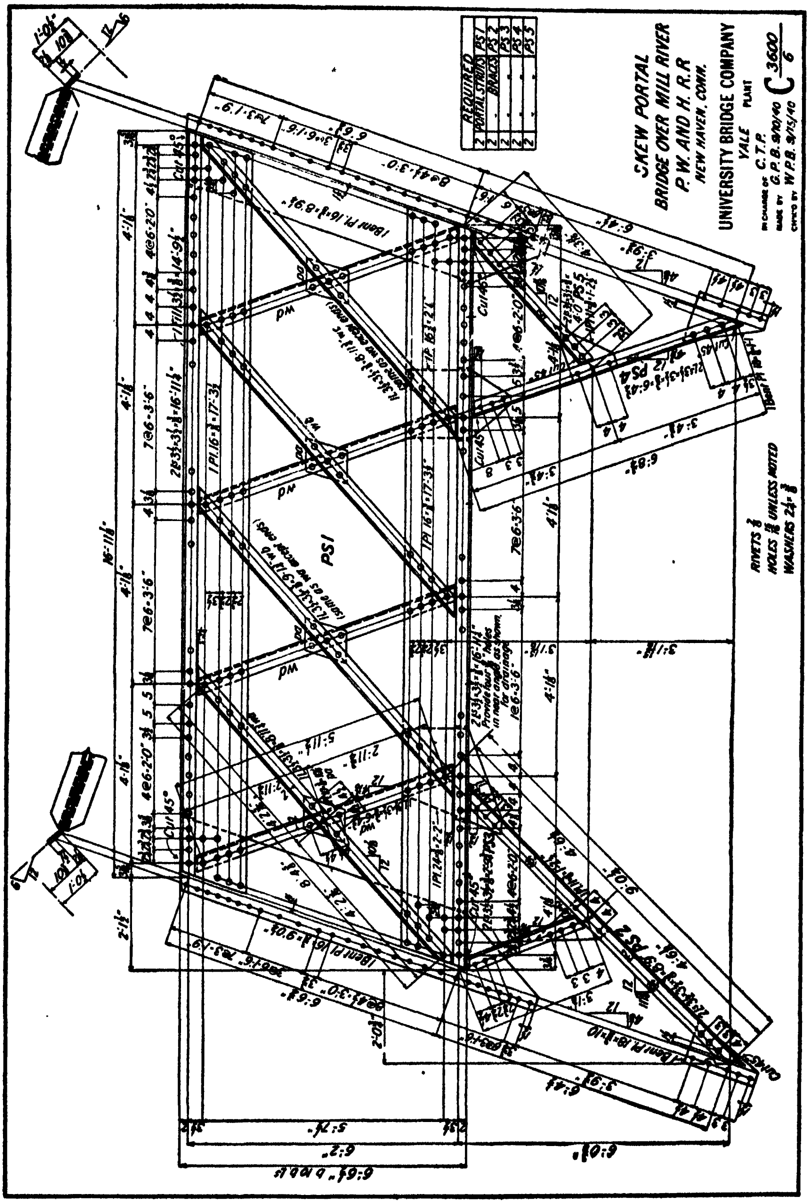


Fig. 195. Portal Bracing for a Skew Bridge.

9′-0″ = the amount or skew, or the lead of one truss in advance of the other, measured parallel to the axis of the bridge.

14′-4″ = 16′-5″ − 2(1′-0½″) = the distance center to center of working points, measured at right angles to the axis of the bridge.

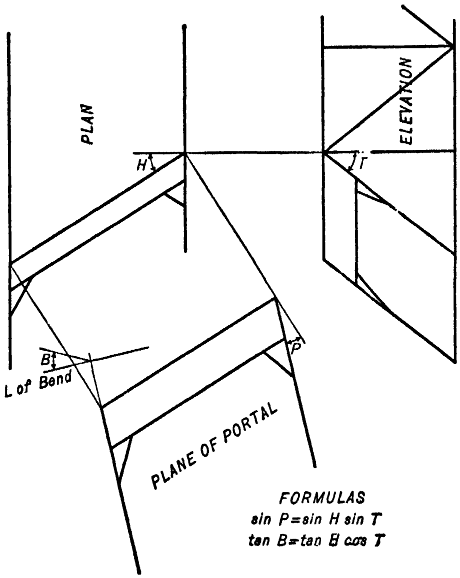


Fig. 196.

The functions of the truss angle (T) and the skew angle (H) are found as follows:

log 22′ 2½″ = 1.34652
log 29′ 0″ = 1.46240

log tan T = 9.88412
log sin T = 9.78390
log cos T = 9.89978

log 9′ 0″ = 0.95424
log 14′ 4″ = 1.15635

log tan H = 9.79789
log sin H = 9.72572

From sin P = sin H sin T, log sin H = 9.72572
log sin T = 9.78390

log sin P = 9.50962

whence the skew in the plane of the portal has a slope of 4⅛ in 12.

From tan B = tan H cos T, log tan H = 9.79789
log cos T = 9.89978

log tan B = 9.69767

whence the bend in the plate is 6 in 12.

The distances $6'\text{-}0\frac{5}{8}''$ and $6'\text{-}2''$ are determined by the allowed clearance; by multiplying them by tan P the distances $2'\text{-}0\frac{3}{4}''$ and $2'\text{-}1\frac{1}{2}''$ are found. The working points of the upper and lower ends of the diagonals are located so that the horizontal panel lengths are equal. The two different lengths of diagonals from center to center of end rivets may be calculated in the usual manner after the proper horizontal distance between the end rivets of each diagonal has been found. The rivet spacing in the top chord from left to right should be the same as the spacing in the bottom chord from right to left, in order to make the plates and angles interchangeable.

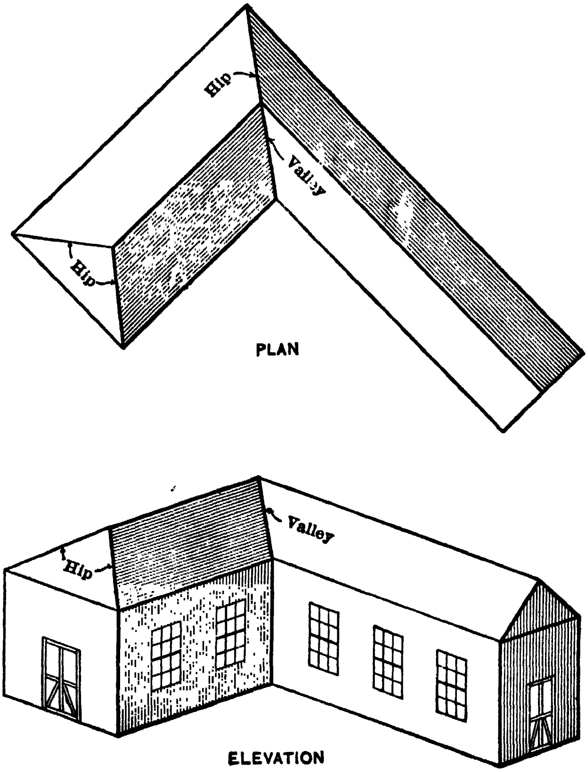


Fig. 197. Hip and Valley Roofs.

372. Hip and Valley Rafters. In building construction two roofs often intersect to form either a hip or a valley. If the two roofs are so arranged that the drainage is *away from* the line of intersection a " hip " results, but if the drainage is *toward* the intersection a " valley " is formed, as indicated in Fig. 197. The rafter which supports the purlins of both roofs at their intersection is termed a hip rafter or a valley rafter accordingly.

373. Common Cases. Ordinarily the axes of the roofs intersect at right angles, the roofs having the same or different pitches. More commonly the purlins rest on top of the main trusses or rafters, and the hip or valley rafter is so placed that the purlins are connected to the top flange by means of bent plates. The determination of some of the angles needed in making the detailed drawings of these connection plates is somewhat troublesome to the person who encounters them for the first time, and the following pages have been adapted from the author's more complete treatise, "Hip and Valley Rafters," published in 1912 but now out of print. Although the method of determining most of the necessary values would be obvious to an experienced draftsman, it is felt that he might waste much time in deciding what values were necessary, and so a complete list of formulas is tabulated on page 199. These apply to the hip rafter shown in Fig. 200 and to the valley rafter shown in Fig. 201; they also apply to similar cases where the purlin flanges face up the slopes and the plates are on the opposite side and are bent into acute angles instead of obtuse angles, as shown in the illustrative problem in Fig. 202. It should be noted that every *hip* rafter must be lowered a certain distance v to allow the purlins to clear the edge of the rafter flange. The purlins should not extend beyond the center line of a *hip* rafter lest they pierce the roof of the other slope. A *valley* rafter need not be lowered provided that the purlins do not extend beyond the center line; in this case v, u', u'', q', and q'' become zero. If preferred, the valley rafter may be lowered the full amount v and the purlins extended so that somewhat better-shaped plates may be obtained. It is better not to connect purlins from both roofs at or near the same point of the hip or valley rafter; they can be so connected to a *hip* rafter, however, as shown in Fig. 202. Note that all values which apply to the main rafter or the purlins of the steeper slope are marked ($'$), and those which apply to parts of the other roof are marked ($''$); values which apply to parts of both roofs or to the hip or valley rafter have no distinguishing mark. Angles are represented by capital letters, and their slopes, or tangents of the angles in inches to a base of 12″, by the corresponding lower-case letters. Distances are expressed by lower-case letters. The first part of the alphabet has been used for values which are given or easily found, leaving the last part of the alphabet for the values which are more difficult to determine.

FORMULAS FOR HIP AND VALLEY RAFTER CONNECTIONS

Channel purlins connecting to the flange of a hip or valley rafter.
Axes of roofs intersecting at right angles; unequal pitches.

Given: a' = the slope of the *steeper* roof (a' always greater than a'').
a'' = the slope of the other roof.
b' = the horizontal distance between the working points of the steeper roof. (Either b'' or e might be given instead.)
f = the width of the flange of the hip or valley rafter.
g' and g'' = the purlin gages.
r' and r'' = the distances from the working points to the backs of the purlins, measured along the tops of the *main* rafters.

$$\tan A' = a' \qquad \tan A'' = a''$$

$$e = b' \tan A' \qquad b'' = \frac{e}{\tan A''}$$

$$d' = \frac{b'}{\cos A'} \qquad d'' = \frac{b''}{\cos A''}$$

$$\tan C = \frac{\tan A''}{\tan A'} \qquad \tan H = \tan A' \sin C$$

$$c = \tan C \qquad h = \tan H$$

$$m = \frac{b'}{\sin C} \qquad n = \frac{m}{\cos H}$$

$$v = \frac{f}{2} \tan A' \cos C \textit{ plus } \tfrac{1}{4}'' \text{ or } \tfrac{5}{16}''$$

$$u' = v \cos A' \qquad u'' = v \cos A''$$

$$q' = v \sin A' \qquad q'' = v \sin A''$$

$$p' = \frac{(r' - q') \cos A'}{\tan C} \qquad p'' = (r'' - q'') \cos A'' \tan C$$

$$s' = \frac{p'}{\cos C \cos H} \qquad s'' = \frac{p''}{\sin C \cos H}$$

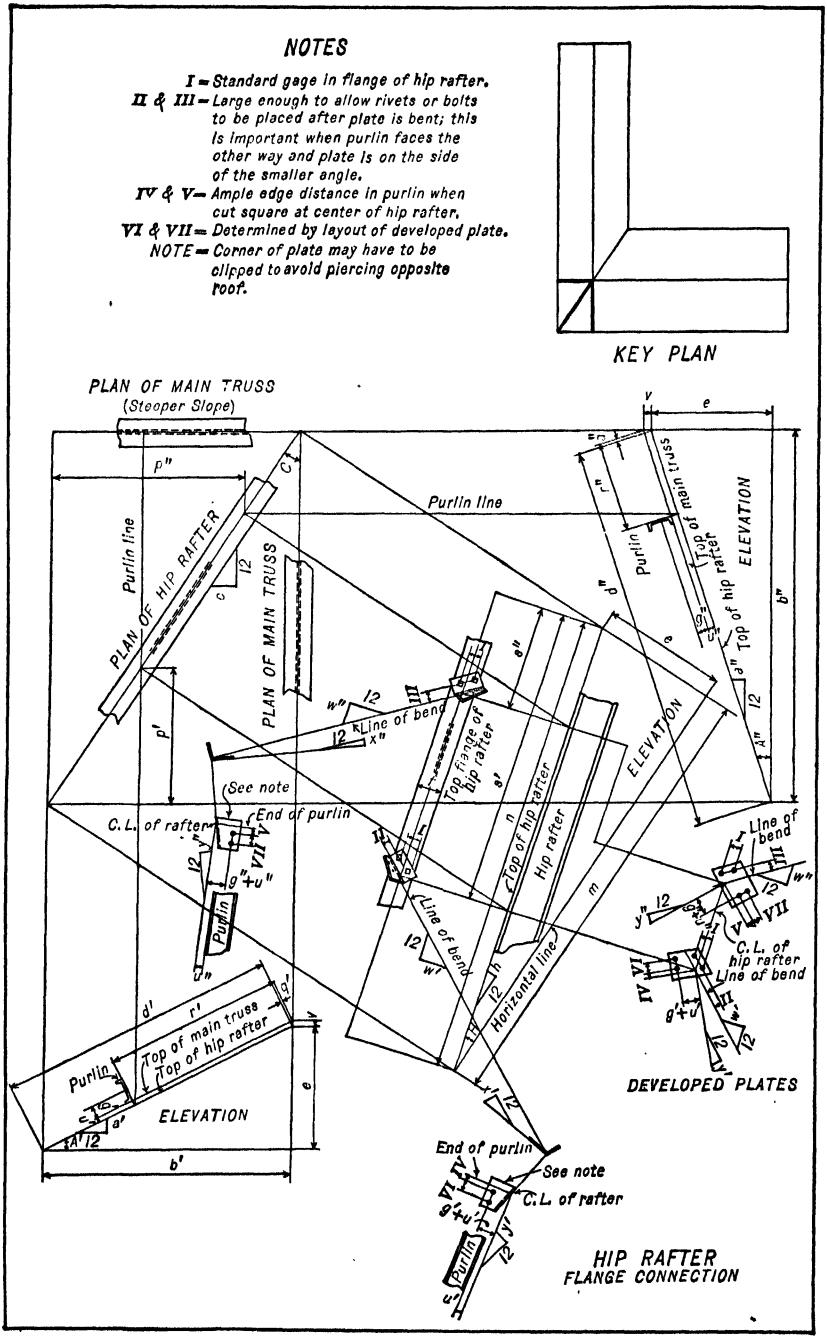
$$w' = \frac{\tan C \cos H}{\cos^2 A'} \qquad w'' = \frac{\cos^2 A'' \tan C}{\cos H}$$

$$\sin X' = \sin A' \cos^2 C \cos H \qquad \sin X'' = \sin A'' \sin^2 C \cos H$$

$$x' = \tan X' \qquad x'' = \tan X''$$

$$y' = w' \sin X' \qquad y'' = \frac{\sin X''}{w''}$$

If the value of w' or w'' is greater than 1′0″ the bevel should be reversed on the drawing so that the longer side becomes the 12″ base.



NOTES

I = Standard gage in flange of hip rafter.

II & III = Large enough to allow rivets or bolts to be placed after plate is bent; this is important when purlin faces the other way and plate is on the side of the smaller angle.

IV & V = Ample edge distance in purlin when cut square at center of hip rafter.

VI & VII = Determined by layout of developed plate.

NOTE = Corner of plate may have to be clipped to avoid piercing opposite roof.

Fig. 200. Hip Rafter.

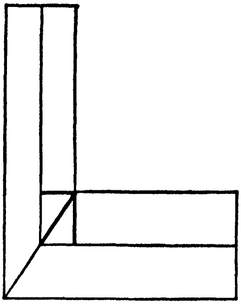
NOTES

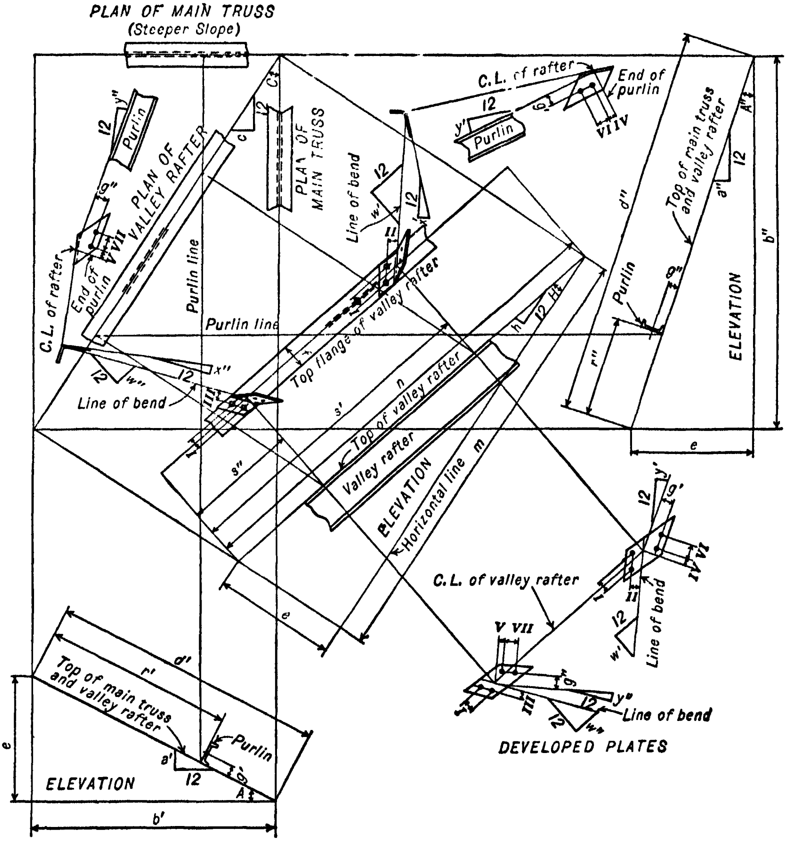
I = Standard gage in flange of valley rafter.

II & III = Large enough to allow rivets or bolts to be placed after plate is bent; this is important when purlin faces the other way and plate is on the side of the acute angle

IV & V = Ample edge distance in purlin when cut square at center of valley rafter.

VI & VII = Determined by layout of developed plate.





VALLEY RAFTER
FLANGE CONNECTION

Fig. 201. Valley Rafter.

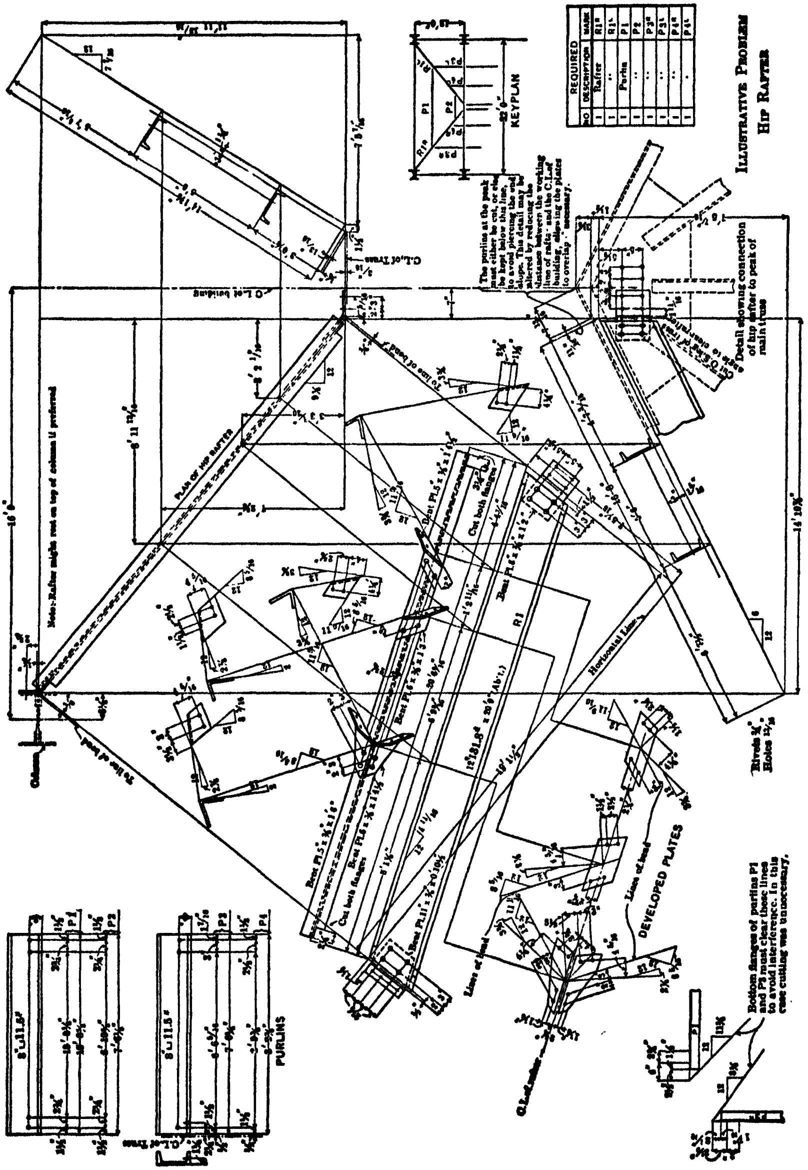


Fig. 202. Hip Rafter.

374. The formulas given apply to the special case where the two roofs are of the same pitch, although the work is simplified. When the axes of the roofs meet at an **oblique angle**, as in Fig. 203, most of the formulas are the same; the differences are shown below:

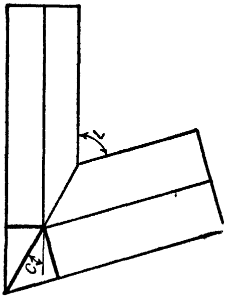


Fig 203.

$$\tan C = \frac{b' \sin L}{b'' + b' \cos L} \text{ when } L < 90^\circ \qquad s'' = \frac{p''}{\cos (L - C) \cos H}$$

$$\tan C = \frac{b' \sin L}{b'' - b' \cos L} \text{ when } L > 90^\circ \qquad w'' = \frac{\cos^2 A''}{\tan (L - C) \cos H}$$

$$p'' = \frac{(r'' - q'') \cos A''}{\tan (L - C)} \qquad \sin X'' = \sin A'' \cos^2 (L - C) \cos H$$

375. Other Cases. When the purlins are connected to the webs of the hip or valley rafters, somewhat different values must be obtained. It has seemed best not to show complete details for this, but the following formulas and the corresponding Fig. 204 may be helpful to one who tries to adapt the principles of the common case.

$$w' = \frac{\cos^2 A' \tan H}{\tan^2 C} \qquad y' = \frac{\sin A'}{\tan C}$$

$$\cos X' = \cos A' \cos C \qquad z' = \frac{\tan C}{\cos A'}$$

$$x' = \tan X'$$

This is treated more fully in the more recent printings of the author's "Structural Drafting and Design," now out of print. For a more complete treatment of all cases, the reader is referred to the author's "Hip and Valley Rafters," copies of which may be found in many libraries; this book also gives tables of values which may be used to advantage in

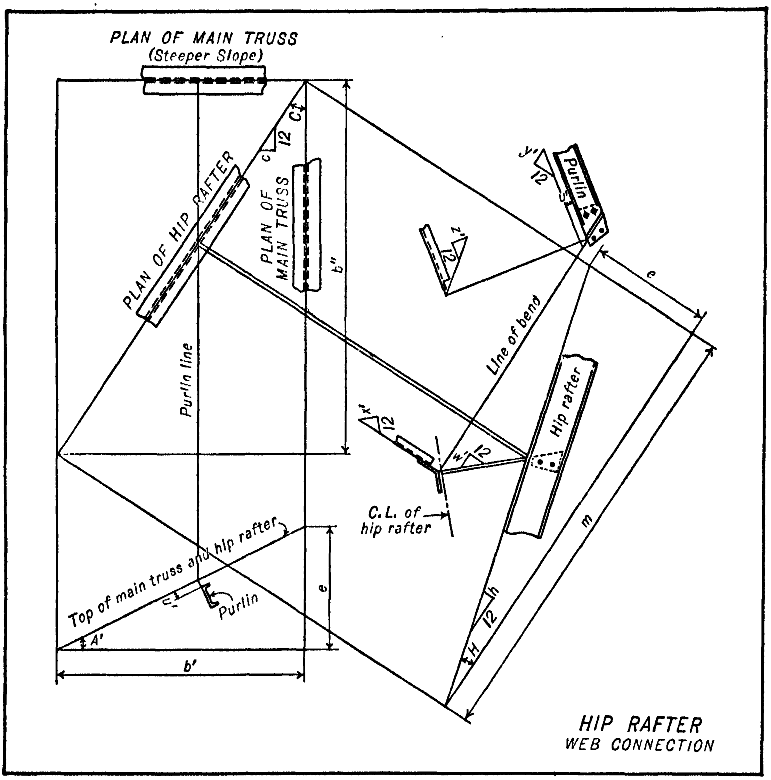


Fig. 204. Hip Rafter — Web Connection.

problems most likely to be found in practice, the derivations of the different formulas, the graphic method of finding the more difficult angles required, and a discussion of roof problems where other types of purlins are employed.

CHAPTER XXIV

ERECTION PLANS AND DIAGRAMS

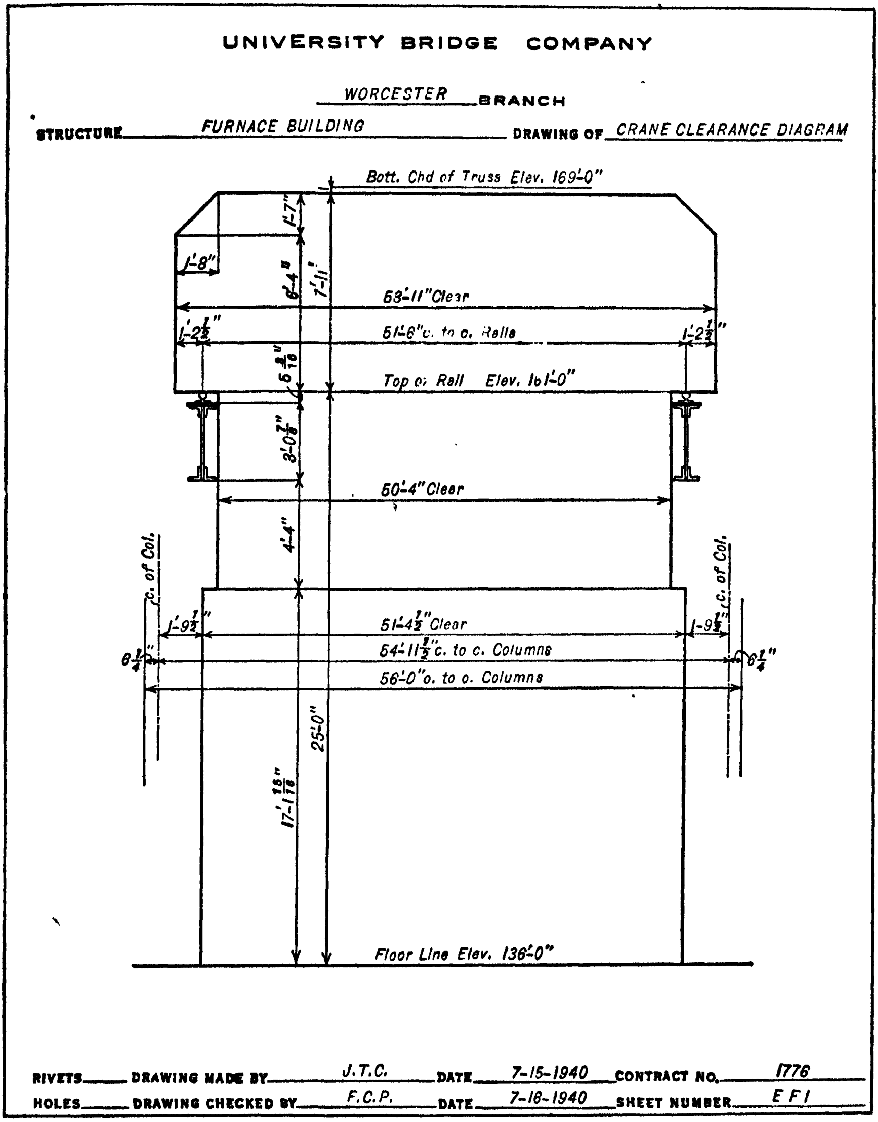
376. The **plans and diagrams** of a proposed structure serve as keys to the structure and aid in the use and interpretation of the working drawings. General dimensions, identification marks, and other information regarding the structure as a whole are thus presented to the draftsmen, the shopmen, the inspectors, the erectors, and the contractors for allied work. The diagrams are usually prepared as soon as possible after the design sheets are received in the drafting room, usually by men of considerable experience who can foresee the types of connection. In some classes of work, such as tier buildings, the diagrams are quite similar to the design sheets in general layout, and much can be traced from them; in other classes of work, such as mill buildings, the diagrams must be much more extensive in order that all the different members can be shown. The diagrams of simple structures may be combined on a single sheet, but as the number of members shipped separately increases, the diagrams become more complex and many sheets may be required. A list of all the drawings on a contract is usually placed upon one of these sheets. The draftsmen who make the detailed working drawings obtain their information largely from the diagrams which are prepared in the drafting room, although they must supplement this information from the design sheets and other available sources; they must also cooperate with other draftsmen in making connecting members conform. As soon as a draftsman determines the shipping marks of the members he is drawing, he should make sure that these marks are properly placed upon the diagrams so that no one will duplicate them. Sometimes these marks are assigned by the person who draws the diagram, but they should be verified by the detailer; the marks should also be checked by the person who checks the corresponding working drawings. Each member is usually represented on the diagram by a single heavy line; these lines are not drawn to intersect if the extent of each member is more clearly shown by means of small spaces at the ends. Often typical connections are shown on the diagrams; this insures greater uniformity when the drawings for similar members are made by different draftsmen, and enables the engineers who pass on the drawings to approve the types of connections before they have been incorporated extensively on the detailed drawings.

377. Erection diagrams are made very largely for the **erectors,** as the name implies. It is important that every identification mark should be shown so that the erectors can tell where each member is to be placed, and sufficient notes and sketches should be added to insure the proper erection. Diagrams must reveal the necessary information to other contractors who construct parts of the same structures or connecting structures. A foundation plan, or anchor-bolt plan, must be drawn for the men who build the foundations so that they can place the masonry and the anchor bolts properly, as in Fig. 208. A crane-clearance diagram must be prepared for the contractor who builds a traveling crane for a building, as in Fig. 207; this is based upon similar diagrams or upon charts furnished by crane manufacturers, but a new diagram is made for each structure and submitted to the crane manufacturer for approval to make sure that ample clearance is provided for the crane he is to furnish. Special data sheets may be required in order that machinery, shafting, hoists, or elevator equipment, may be properly provided for; such data sheets may be made either by the structural draftsman or by a draftsman for the contractor. Typical plans and diagrams for different classes of work are illustrated.

378. Plate-girder bridges of single span may usually be completely represented by one diagram. Such a diagram for a through bridge is shown in Fig. 208. The plan of anchor bolts is at the bottom, a partial elevation with important dimensions is near the middle of the sheet, while the plan of the bridge at the top of the sheet shows the relative position of the girders, the floor system, and the lateral bracing. In this simple structure all the marks appear upon the plan, which would therefore be sufficient for the erection of all the steelwork. The more detailed elevation is added, however, in order to show the relative elevations clearly so that the foundations may be placed at the proper distance below the base of rail.

379. The erection diagram for the steelwork of a **truss bridge** is shown in Fig. 209. In bridge work the *far* truss is shown in the elevation, the members in the left half being detailed in the working drawings. These members are consequently marked " right " when " rights " and " lefts " are required (page 107). A combined cross-section and end view is drawn in sufficient detail to show the main dimensions and the relative elevations of the abutments, the floor beams, the stringers, and the rails. In the plan of the floor system, portions of the single-angle diagonals between the stringers are shown in a typical panel to indicate which way the angles are to be erected.

380. Figure 210 is a typical erection diagram for a **mill building**. For larger or more complicated buildings more than one sheet would be required, particularly when additional elevation views are needed to show differences in framing. The columns and trusses may be represented by double lines or by single lines, as preferred. The truss members may be indicated by dotted lines in the end elevation to show that the end columns


UNIVERSITY BRIDGE COMPANY

WORCESTER BRANCH

STRUCTURE FURNACE BUILDING DRAWING OF CRANE CLEARANCE DIAGRAM

RIVETS ____ DRAWING MADE BY J.T.C. DATE 7-15-1940 CONTRACT NO. 1776

HOLES ____ DRAWING CHECKED BY F.C.P. DATE 7-16-1940 SHEET NUMBER E F I

Fig. 207. Crane-Clearance Diagram

and bottom-chord bracing members are placed at the panel point of the truss, but the trusses are assembled by means of a special diagram on the detailed drawing. The column marks are repeated in the different views for

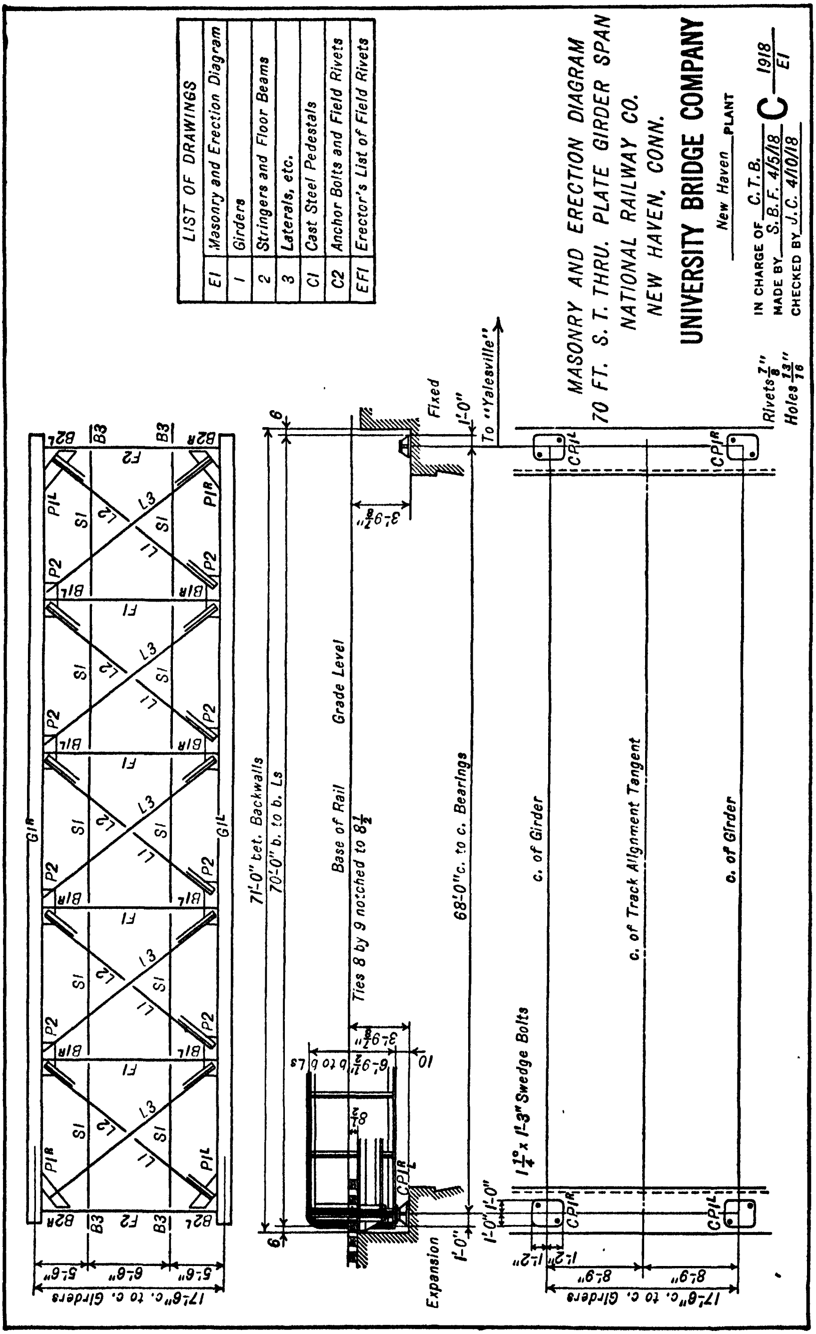


Fig. 208. Masonry and Erection Diagram for a Girder Railroad Bridge.

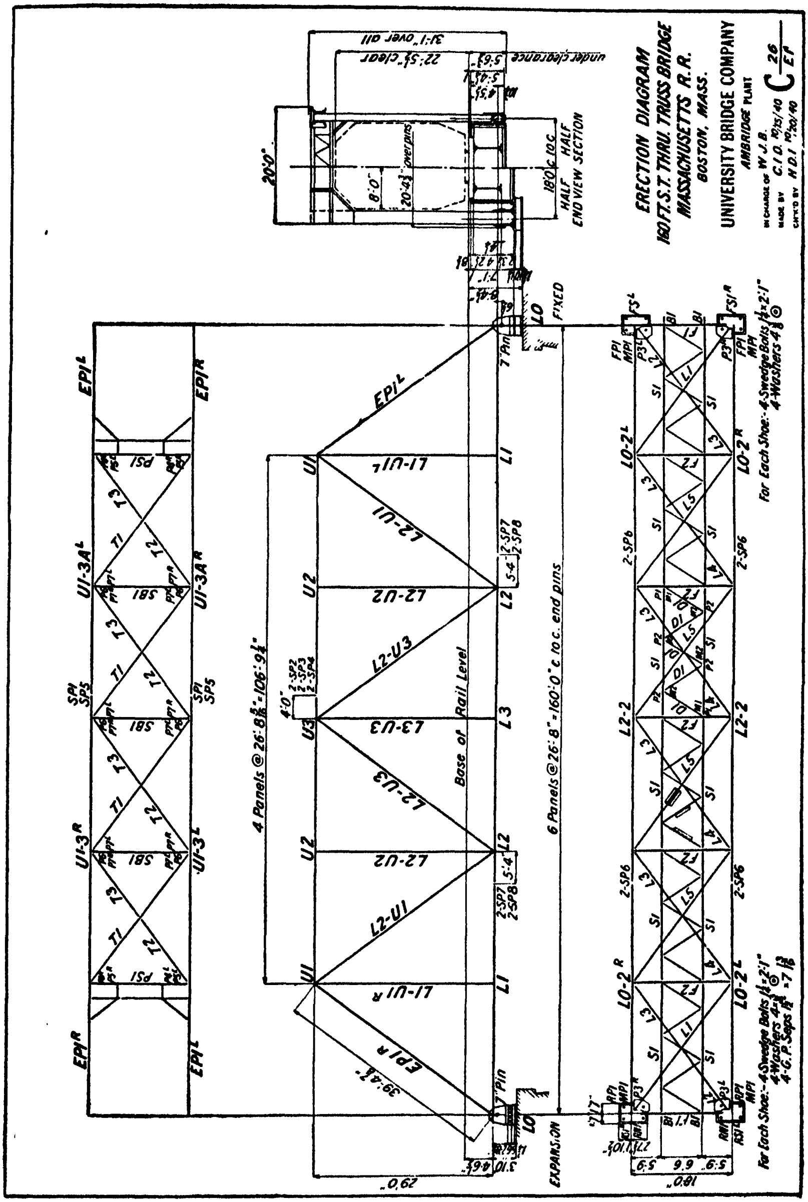


Fig. 209. Erection Diagram for a Truss Railroad Bridge.

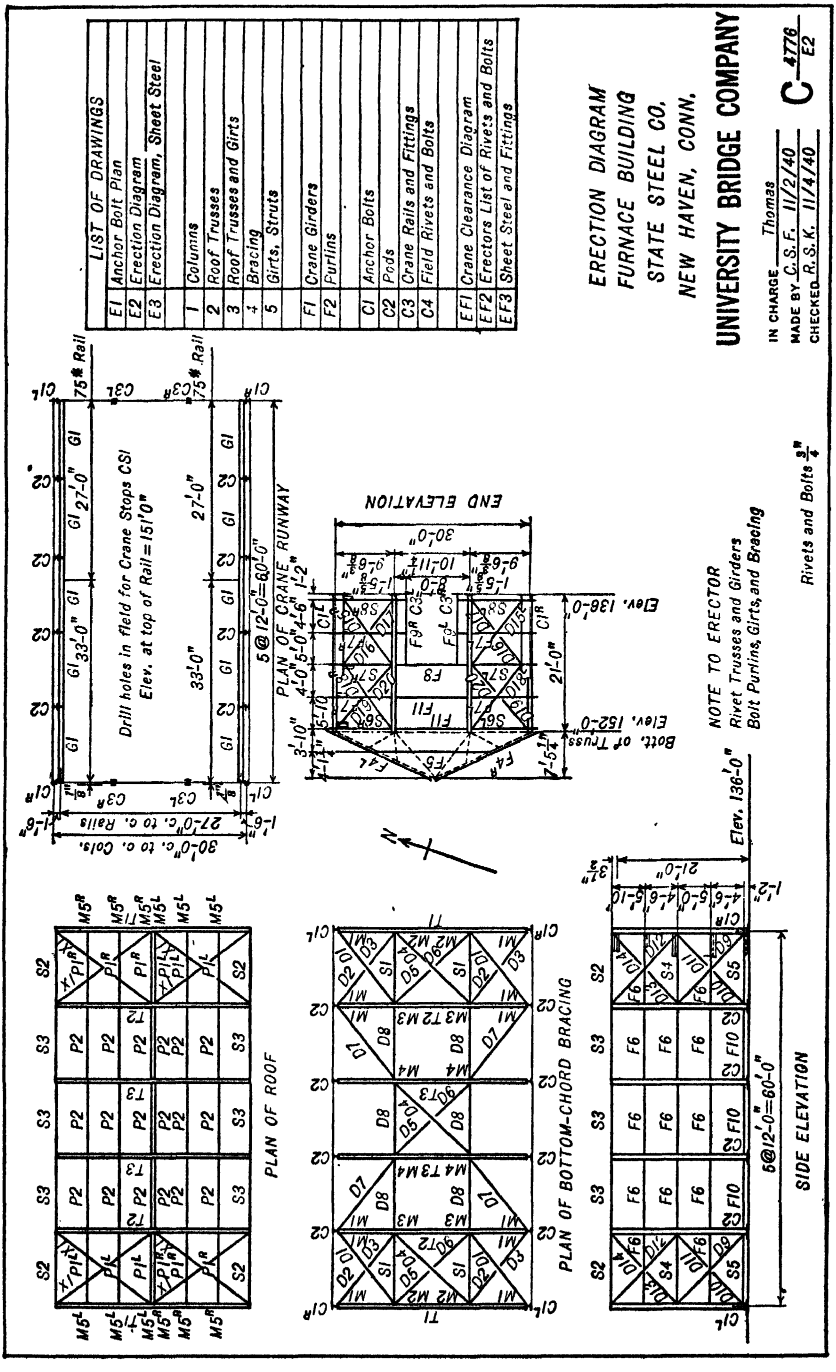
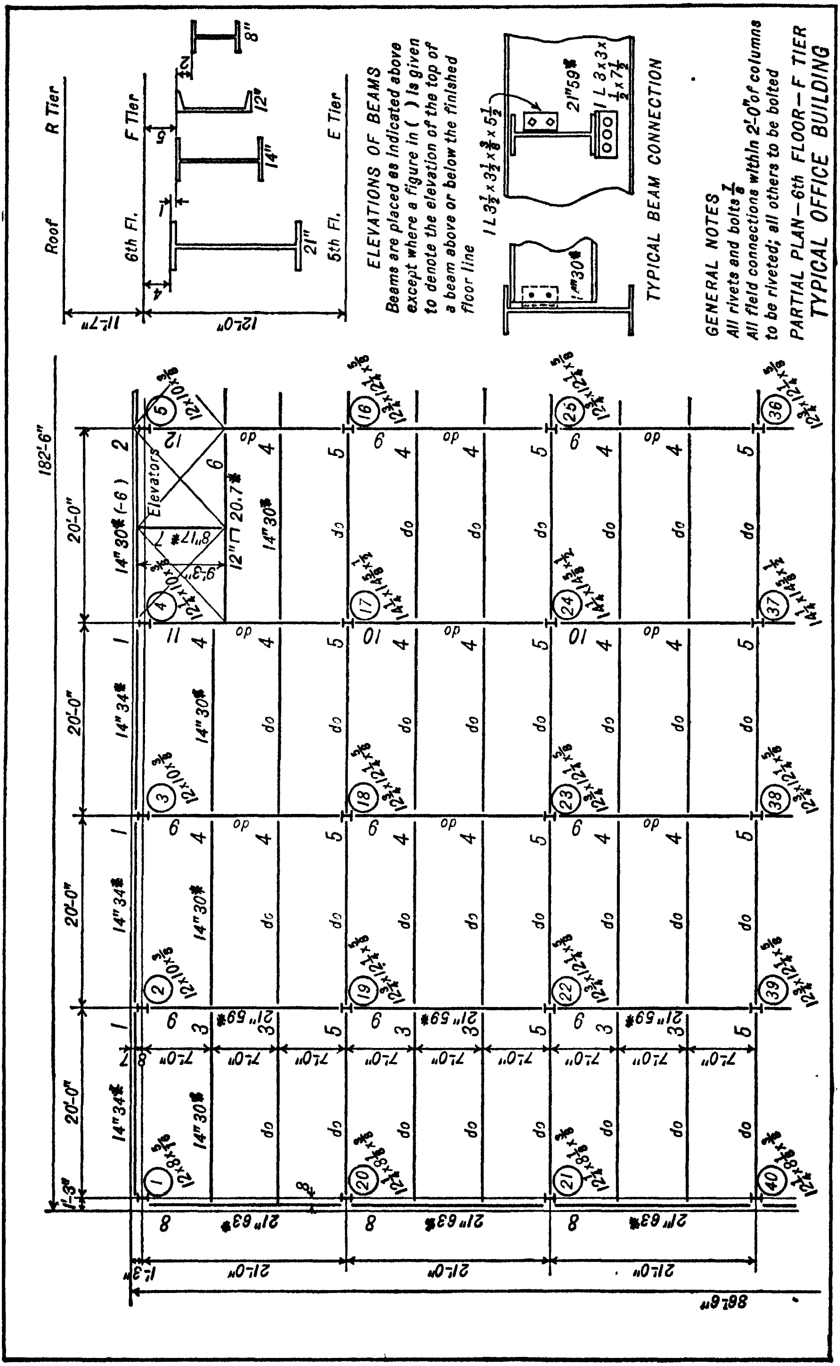


Fig. 210. Erection Diagram for a Mill Building.

the convenience of the draftsman rather than the erector. A portion of each girt (enlarged) is shown near the corner of the building to indicate which way the legs are turned; this is sometimes indicated in a sectional view instead. Special erection diagrams are drawn for corrugated iron or steel; these show where sheets of different lengths are allocated, and how some of them are cut diagonally in the field for the gable ends. Typical details are drawn to make clear the arrangement of the sheet steel and the flashing at corners, windows, doors, cornices, ventilators, etc. These diagrams are usually drawn by experienced men, and it does not seem advisable to devote space in this book to treat the subject as fully as it should be treated if at all.

381. A portion of a typical **floor plan of a tier building** appears in Fig. 212. The columns are shown conventionally to indicate the type of column and which way they are turned. The beams and girders are represented by single heavy lines, with spaces left to indicate more clearly the extent of each member. Such floor plans are often made more complete than other diagrams. Openings for stairs, elevators, stacks, etc., are indicated conventionally by light diagonal lines so that no floor will be constructed in these spaces. Each beam section is billed on the diagram, and the abbreviation " do " for " ditto " may be used to avoid repetition; ditto marks (") should be avoided, for they are not sufficiently distinctive. Care must be taken that no other beam section is inserted between one section and the corresponding " do." The diagram should make clear the way the flanges of channels turn; unless a sectional view is drawn, this can be done most simply by billing them with the channel sign turned (⊔) or (⊓) to correspond to the way the flanges face. Sometimes a small enlarged portion of the flange is sketched in for this purpose. The elevations of the tops of all beams relative to the finished floor line should be indicated; this may be done by a sketch, with a note providing for exceptions, or simply by a note to the effect that all beams are a certain distance below the floor line unless a different distance is given in parentheses. All tie rods should be indicated and the lengths given; a convenient method is to give the length in inches in a circle on one rod in each panel. It is convenient to have column dimensions on the plan; the depth, the flange width, and the web thickness are shown in the figure, but some prefer distances from the center to each face. It is usually necessary to order all material from the diagrams or the design sheets before the detailed drawings are made; sometimes the ordered lengths of beams are recorded on the diagram. An experienced draftsman can determine the lengths of all main material and he can anticipate the details with sufficient accuracy to assign shipping marks to all beams and girders, making sure that all beams in one floor which are alike are marked alike, and conversely, that no



ELEVATIONS OF BEAMS

Beams are placed as indicated above except where a figure in ( ) is given to denote the elevation of the top of a beam above or below the finished floor line

TYPICAL BEAM CONNECTION

GENERAL NOTES

All rivets and bolts $\frac{7}{8}$

All field connections within 2'-0" of columns to be riveted; all others to be bolted

PARTIAL PLAN—6th FLOOR—F TIER

TYPICAL OFFICE BUILDING

Fig. 212. Partial Floor Plan for a Tier Building.

beams are marked alike unless they are interchangeable. The columns are numbered consecutively for convenient reference, no two bearing the same number even though they are apparently interchangeable, because they may be unlike in other stories. Plans for several intermediate floors may be combined when quite similar, but usually the first floor and the roof and sometimes other floors are drawn separately. Typical connections are drawn on the diagrams, and special details give the arrangements of the wall beams, columns, and lintels. The typical details shown on the diagrams can be sent for approval before they have been incorporated in so many detailed drawings that any change would necessitate many alterations, and missing data can be detected early. After such complete plans are drawn, the drafting for the beams becomes routine work which can be done by comparatively inexperienced draftsmen with very little supervision.

382. A column schedule is often prepared for the drafting room. Such a schedule is illustrated in Fig. 214 for that portion of the typical building shown in the plan. One space is laid off for each column, and the story heights are dimensioned. Heavy lines are drawn to represent the milled ends of the column sections at the splices and at the extreme bottoms; the line at the bottom is broken when the bases are not all at the same elevation. The component material for each section is given, and sometimes the necessary fillers at the splices are billed. The 2″ distributing plates used where abrupt section changes occur are clearly indicated so that the proper deduction can be made when the main material is ordered. The loads on the different sections are sometimes recorded. If one whole column from base to roof is like another in section and length, it may be referred to the other in order to save duplication. A typical column splice may be shown on this sheet so that it may be approved before the detailed drawings are far advanced. The column schedule may be made to serve as an index to the drawings upon which the different columns are detailed, by having the sheet number placed at the top of each section; sometimes separate index sheets are made.

383. An office **record of drawings** is usually made for each contract. This provides for the initials of the draftsman and the checker for each drawing with dates showing when the drawing is completed and checked. Dates are recorded to show when prints are sent for approval and when approved, and when prints are issued to the different shops, to the inspector, to the erector, and to others interested. These tabular records are arranged to give the necessary information regarding sheets, but they do not give complete information regarding the members. In tier-building work especially there are so many similar drawings, such as columns and beams, that it is difficult to make sure that the drawings are prepared in a logical

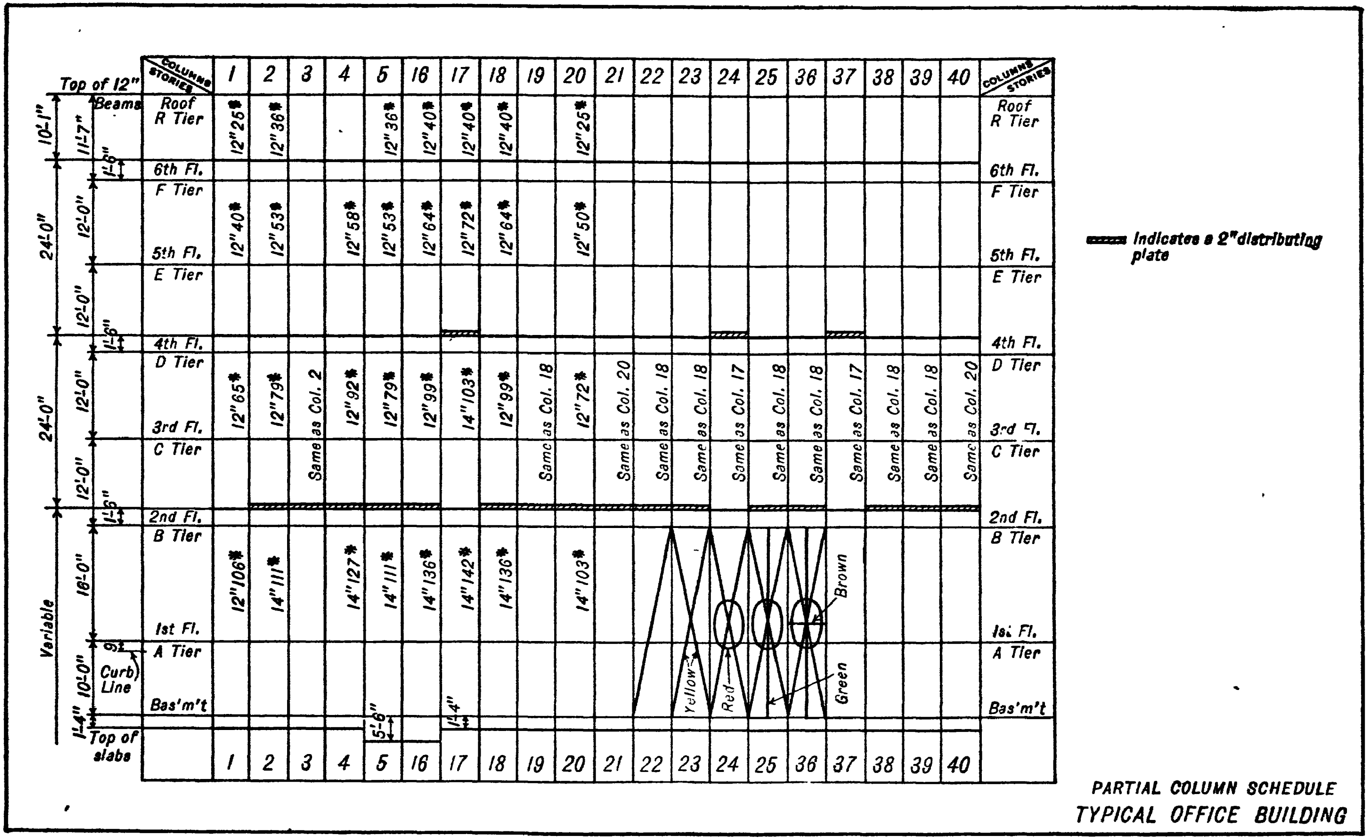


Fig. 214. Partial Column Schedule for a Tier Building.

order unless supplementary records are kept. On account of limited storage facilities near the site of an ordinary tier building all material must be shipped as required. The squad foreman should guard against having the roof beams and columns detailed while some on the first tier remain untouched. Blueprints of the plans and the column schedule may be used to excellent advantage as progress record sheets, as explained in the following paragraphs.

384. Progress Record for Beam Drawings. A blueprint of one of the floor plans is assigned to a draftsman who is to prepare the working drawings of the beams. As the drawing for each beam is completed, the draftsman should mark the plan with a distinctive color, say yellow. An ordinary check mark is not sufficient to show his progress clearly. He should draw the crayon the full length of the beam so as to obscure the white line on the blueprint completely. In this way the whole tone of the print is changed from white to yellow, and the squad foreman or the chief draftsman can tell at a glance without interrupting the draftsman what proportion of the beams are detailed. Furthermore, when the draftsman has completed the drawings he can scan the print and easily detect any beam which he may have overlooked because a lone heavy white line will stand out conspicuously among the yellow lines and the fine white dimension lines. It is desirable to have all beams on one plan detailed by one man in order to insure uniformity of details and to avoid duplication. If the available time will not permit this, the work may be assigned to more than one draftsman, but the division should be made definite so that no beam in one portion is like any beam in the other portion. This may often be accomplished by assigning the wall beams to one man and the intermediate beams to the other. If a plan represents one or more floors, the beams for all the floors are usually drawn at the same time. Many of the beams may be combined upon the same sketch provided that different marks are assigned the beams of different floors as in beam 60, Fig. 149. Another blueprint of each plan is given to the checker who marks the beams as he checks the corresponding drawings. He uses a different color of crayon, say red, but he marks the plan in the same manner as the draftsman in order to obscure the white lines of the beams.

385. A print of the column schedule may be used for a **progress record for the columns.** All records for one contract should be made upon the same print. This may be posted upon the wall if accessible space is available or it may be filed near the squad foreman's desk. It is convenient to have this record near the tabular record of drawings, for the two are frequently used together. Almost any amount of information can be recorded upon the print of the column schedule to satisfy the requirements of the men in charge of different drafting rooms. Significant colors and arrangements may be chosen for different needs. Yellow and red are most distinctive; green, brown, or black may be used when additional colors are desired. The following suggestions may serve as a guide. Each column section is represented by a rectangle bounded by adjacent vertical lines and heavy horizontal lines (see above). Any system of marks should be confined to one of these rectangles, the other rectangles being marked similarly. The draftsmen should use the same color of crayon (yellow) as in beam work. In order to indicate that he is working upon a certain column or group of columns a draftsman should draw a diagonal line across the rectangle of each column of the group so that no one else will duplicate his work (see column *AB*22, Fig. 214). When he has completed the drawing and it is ready to be checked he draws the other diagonal (*AB*23). The checker adds a red circle or oval to each column as soon as it is completely checked (*AB*24). A green vertical line may be drawn through the center of the rectangle when prints have been sent for approval (*AB*25) and a horizontal brown or black line may be drawn across the center of the rectangle when prints have been issued to the shop (*AB*36). Other records may be made by means of horizontal lines drawn across the rectangle above or below the center, using any of the above colors provided that all horizontal lines with different significance are of different colors. By drawing the lines entirely across each rectangle continuous lines are formed when all the columns are marked. This simplifies the detection of any omissions because a break in a continuous line is conspicuous.

CHAPTER XXV

MATERIAL ORDER BILLS

386. Purpose. The chief function of a structural-steel company is to build structures from steel which is already rolled into common commercial shapes. The drawings show how such shapes are cut, punched, and combined to make members which are subsequently connected to form complete structures. Some companies have their own rolling mills, but most companies procure their steel shapes elsewhere. In either case the material must be ordered from the rolling mills. Usually it takes so long to have an order filled that it is impracticable to wait until the working drawings are made before placing the order; often both the drawings and the templets can be made during the interval that elapses between the placing of the mill order and the delivery of the material. It is therefore imperative that all important material be ordered as soon as possible after a contract is made.

387. The original **material order bills** or advance bills, are prepared in the drafting room by men who are familiar not only with drafting-room methods but also with the requirements of the order department. On these lists the material is classified according to types of members, as for example, columns, trusses, beams, etc. In the order department new lists are prepared to meet the requirements of the rolling mills. On these lists the material is summarized and reclassified according to sections and lengths and an item number is assigned to each different item. Short plates and angles are usually ordered in multiple lengths to be cut to the desired lengths after they are received. Most companies carry a certain amount of material in stock for immediate use. The stock yard is under the jurisdiction of the order department, where the necessary material is ordered to keep the yard supplied with the desired amount of stock. All additions and subtractions should be so recorded that one can tell at any time just what material is in stock. In the order department it is determined whether an item shall be taken from stock or ordered from the mills.

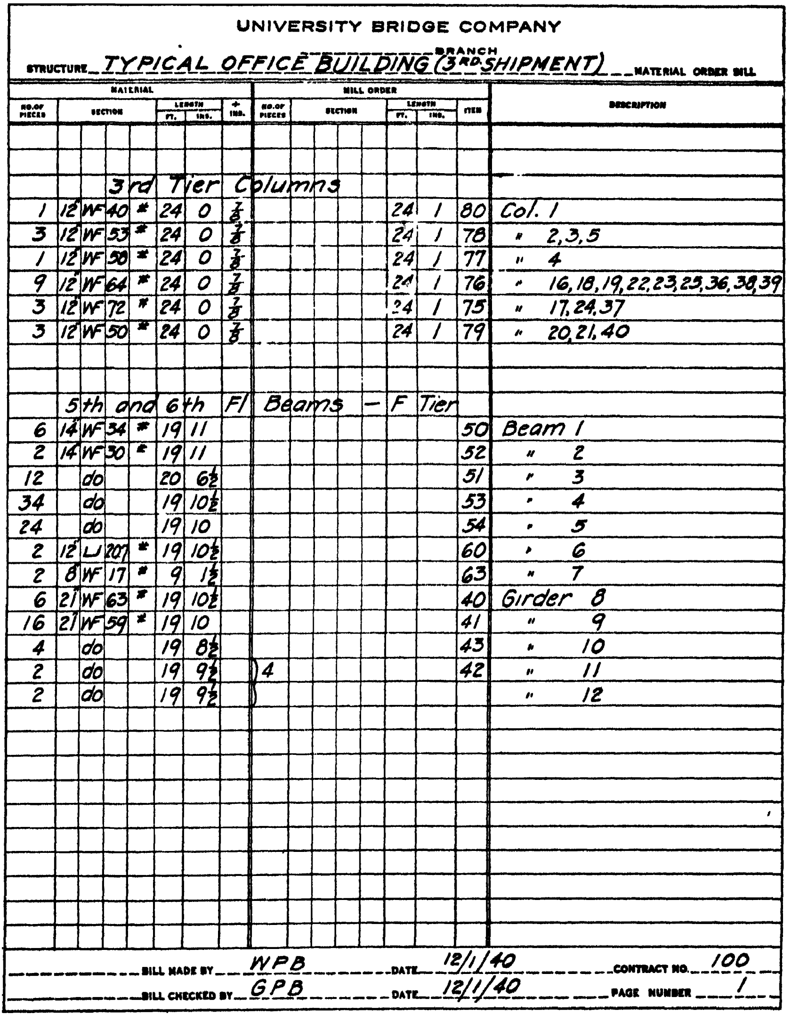
388. Methods. When market conditions are such that there is likely to be considerable delay in filling an order it is especially urgent that all main material be ordered at once. Capable men are assigned to this work in order that it may be done as efficiently and expeditiously as possible. These men can often foresee the details of construction with sufficient accuracy to enable them to order much of the material by referring to the design sheets. In more complex work they may have to lay out some of the details which determine the lengths of main material. The lengths of angles of light trusses may often be determined with sufficient accuracy for ordering by scaling a drawing without stopping to calculate the lengths. For this purpose a draftsman begins a working drawing; he lays down the working lines to scale and draws the outlines of the angles. The angles are usually ordered about 1½″ longer than the scaled lengths, to provide for inaccuracies. After the lengths are scaled the drawing may be laid aside until later, if desired. The beams and columns of office buildings can be ordered more satisfactorily after the erection plans and the column schedules have been prepared, as explained in the preceding chapter.

389. Miscellaneous material other than structural-steel shapes should also be ordered as early as possible so that all will be available when needed. Some of the more common examples of such materials are: eyebars, cranes, rails and fittings, pins, forgings, castings, pipe, corrugated steel and other roof coverings, lumber, windows and doors, and hardware.

390. The material order bills are divided into **two parts.** The first part is the main list of material and the corresponding identifying descriptions which are made in the drafting room in accordance with this chapter. These bills are then sent to the order department, a carbon copy being retained for temporary use in the drafting room. The second or central part of the bills under "mill order," Fig. 219, is filled in by the order department and the bills are returned to the drafting room. This is done after the list of material has been regrouped and the actual mill orders have been prepared. The central portion shows the item numbers assigned to the material in the mill-order list, together with any differences in numbers or sections. The section seldom differs unless the material is to be milled, planed, or recut in the shop; the length may differ by a small amount recorded in the column headed "+ ins.," or by a large amount when material is ordered in multiple lengths. The number of pieces may differ when pieces are ordered in multiples or when similar items are combined. In the latter case, the number of pieces and the length are recorded opposite the first item, and the others are referred to this by the words "See above" or "See page ——"; the item number is repeated. The information given by the order department in this portion of the bills is used by the draftsmen who "itemize" the shop bills, as explained on page 226.

391. Each draftsman must make his **drawings conform to the material ordered,** and he must report any instance where this is not feasible. Slight variations are of less consequence when the material is taken from stock or cut from the multiple lengths than when the material is cut to the desired lengths at the mill. The draftsman should, therefore, consult the original bills after they are returned; the carbon copies are used only while the originals are held by the order department.

392. The arrangement and the description of the pieces billed should be such that the material for any members may be easily found and identified. The material for similar members should be listed together under a separate heading, as the columns or the beams of Fig. 219. A more detailed description should be given opposite each item of the bill whenever this will simplify identification. In some cases the shipping mark,



UNIVERSITY BRIDGE COMPANY

STRUCTURE TYPICAL OFFICE BUILDING (3RD SHIPMENT) BRANCH MATERIAL ORDER BILL

MATERIAL					MILL ORDER					
NO. OF PIECES	SECTION	LENGTH FT.	LENGTH INS.	+ INS.	NO. OF PIECES	SECTION	LENGTH FT.	LENGTH INS.	ITEM	DESCRIPTION
	3rd Tier Columns									
1	12" WF 40 #	24	0	⅞			24	1	80	Col. 1
3	12" WF 53 #	24	0	⅞			24	1	78	" 2,3,5
1	12" WF 58 #	24	0	⅞			24	1	77	" 4
9	12" WF 64 #	24	0	⅞			24	1	76	" 16,18,19,22,23,25,36,38,39
3	12" WF 72 #	24	0	⅞			24	1	75	" 17,24,37
3	12" WF 50 #	24	0	⅞			24	1	79	" 20,21,40
	5th and 6th Fl Beams — F Tier									
6	14" WF 34 #	19	11						50	Beam 1
2	14" WF 30 #	19	11						52	" 2
12	do	20	6½						51	" 3
34	do	19	10½						53	" 4
24	do	19	10						54	" 5
2	12" ⊔ 20.7 #	19	10½						60	" 6
2	8" WF 17 #	9	1½						63	" 7
6	21" WF 63 #	19	10½						40	Girder 8
16	21" WF 59 #	19	10						41	" 9
4	do	19	8½						43	" 10
2	do	19	9½		4				42	" 11
2	do	19	9½							" 12

BILL MADE BY WPB DATE 12/1/40 CONTRACT NO. 100

BILL CHECKED BY GPB DATE 12/1/40 PAGE NUMBER 1

Fig. 219. Material Order Bill.

if known, can be used to advantage; in others it may be better to note the position of the pieces as "Flange," "Stiffeners," "Base," "Crane Seat," etc. In each group the material for the main section should be listed first, followed by the less important pieces. These should be listed in a systematic order to facilitate locating them later. As a rule the detailed material for the end connections should be listed before that for the intermediate connections; if the position of a member on the drawing can be anticipated, the material at the bottom end or the left hand end should be billed first.

393. Shipments. When contracts are divided into different sections and members are to be shipped accordingly, the order bills should be marked "First Shipment," or similarly, and all material should be grouped under the proper shipment. The last page of bills for each shipment should be marked "Complete." Each tier of office-building columns and the corresponding beams and girders should be kept separate from the others. In general, different kinds of steel should be billed separately.

394. The pages of material order bills should be **numbered** consecutively from 1 up. It may be preferable to number the pages for different shipments in different series, as 101, 102, etc., for first shipment, and 201, 202, etc., for the second.

395. On the first page or on a separate sheet should be given information regarding the **specifications,** the grade of steel, the nature of any tests which are to be made, the kind of oil or paint to be applied at the mill, if any, and the name of the inspector.

396. All **material** which is to be **shipped direct** to the site should be clearly noted. Such material as structural shapes with no shopwork, corrugated steel, lumber, etc., need not, as a rule, be sent to the structural plant.

397. All **changes** in material orders should be sent to the order department on "change slips," or "change orders." These should cover all changes or cancellations in the original orders whether due to errors or to changes in design. Such changes should be reported at once so that if possible they may be made at the mill before the material is cut. Change orders should be made out for any material which is left over after the itemizing is complete. In this way extra material may be released and made available for other contracts.

398. Ordered Lengths. The main part of the order bill should show the material as it will appear on the drawings. Any increase in length which is required on account of milling, recutting, or bending at the shop should be indicated in the column headed "+ ins." The lengths which are actually ordered from the mill should be in multiples of $\frac{1}{2}''$ wherever possible. Many of the shorter pieces, particularly plates and angles, are ordered in multiple lengths. The steel shapes are cut at the mill as they come from the rolls still hot. It is not practicable to measure the lengths with great precision and a " mill variation " in length is allowed. Hence it is inconsistent to order material in sixteenths or eighths. Some of the more important points to be considered in ordering material will now be taken up for the different shapes.

399. Because of the difficulty and waste incident to cutting, **beams** and channels are usually ordered so that they can be used as they come from the mills, unless they are to be milled. The standard mill variation in length for underrun for beams and channels is $\frac{3}{8}''$ for depths up to 24'', and $\frac{1}{2}''$ for deeper beams and all columns; the overrun is the same except for lengths over 30' when it is increased about $\frac{1}{16}''$ for each 5', as explained in more detail on page 11. Beams which are to be riveted between other beams are usually ordered about $1\frac{1}{2}''$ less than the distances between the *centers* of the webs of the supporting beams or channels; beams which are to be riveted between girders or columns are usually ordered about 1'' or $1\frac{1}{2}''$ less than the *clear distance* between supports; beams which are to be welded between other steel members should be ordered with a clearance of $\frac{1}{4}''$ or $\frac{5}{16}''$ at each end, with a note on the bill that the length must not vary more than $\pm\frac{1}{8}''$. Runway beams which support the wheels directly should be milled to give about $\frac{1}{8}''$ clearance between the ends of adjacent beams. Beams and channels used in columns or chord members are often milled to give uniform bearing. Beams to be milled should be ordered long enough to permit recutting; if milled at one end $\frac{5}{8}''$ is added, and if milled at both ends $\frac{7}{8}''$ is added. This increase is indicated in the column headed " + ins.," and the order department takes this into account in preparing the mill order. Purlins are usually ordered about 1'' less than the distance center to center of trusses. Beams which are to be cut diagonally in the shop should be ordered about 1'' long; short beams so cut may be ordered in multiple lengths, allowing about $\frac{1}{4}''$ for each cut.

400. Since **angles** can be recut at the shop more easily than beams, it is not so important to use the exact lengths that come from the mill. The angles are not likely to underrun the ordered lengths, but they may overrun $\frac{3}{4}''$ for lengths up to 30', 1'' for lengths between 30' and 40', or $1\frac{1}{4}''$ for longer angles. Better results are obtained when the angles are sheared to the proper lengths in the shop. The main flange or chord angles of girders, columns, trusses, etc., are usually ordered about $\frac{3}{4}''$ long to make recutting necessary whether or not these angles are to be milled; angles which are to be milled at one end only are ordered $\frac{1}{2}''$ long. These increases are indicated in the column headed " + ins." Stiffening angles need not be ordered long unless they are to be milled or crimped, and the excess depends upon shop standards. Two or more angles of the same length may be cut from one piece, provided that the sum does not exceed 40', but some companies do not use multiple lengths for angles of different lengths unless under 3′ in length. Bent angles should be ordered about 3″ long, and curved angles about 6″ long.

401. Plates are classified as Universal Mill plates or sheared plates, as explained on page 12, and the former must be marked " U. M." on the order bills. Universal Mill plates are used for cover plates, plates in chord members of bridge trusses, stiffeners of welded girders, webs of shallow welded girders, and wherever a straight rolled edge is desired; they are normally used for all plates up to 36″ in width. Plates may be ordered in multiples of $\frac{1}{16}''$ in thickness, and in multiples of $\frac{1}{2}''$, or preferably 1″, in width. The lengths are usually ordered in multiples of $\frac{1}{4}''$, and the extreme lengths available are shown in the handbook. Plates are usually recut in the shop, except that the cover plates which do not extend the full length of a plate girder, and often the webs are used as delivered; full-length cover plates are ordered $\frac{3}{4}''$ long for recutting. Web plates are ordered from $\frac{1}{2}''$ to $\frac{3}{4}''$ less than the distances between the centers of splices or a like amount less than the extreme lengths back to back of end stiffeners; if no stiffeners are used at the extreme ends, the web is made flush with the ends of the flange angles. The edges of web plates for welded girders are often planed; the widths should be increased an extra $\frac{1}{4}''$ for each edge planed. Gusset plates may often be cut from multiple lengths with little or no waste, provided that diagonal cuts extend entirely across the plate as in Fig. 46; advantage of this fact should be taken in ordering the material. Multiple lengths should not be ordered too closely; it is better to allow $\frac{1}{4}''$ for each extra cut and to increase the total length to an even inch. Some of the heavier gusset plates may be ordered as " sketch plates," i.e., they are cut to irregular shapes at the mill according to dimensioned sketches. There is an extra charge for this work which will offset any saving of material in the smaller plates; sketch plates should be ordered only with the approval of an experienced man. Bearing plates or slabs thicker than 2″ should be ordered according to the somewhat limited standard sizes given in the handbook. Slabs over 4″ thick cannot be straightened satisfactorily and must be planed to give suitable bearing for the columns.

402. Miscellaneous Items. Lattice bars, short tie rods or sag rods, gas pipe, and some other miscellaneous pieces are usually ordered according to the approximate total number of linear feet: these lengths can be converted to definite lengths by the order department. Rails for crane runways, etc., should be ordered to standard lengths; odd lengths may be ordered for one end of a runway to provide the proper total length between crane stops. Rails are usually rolled in 39′ lengths, but other lengths are used. " Standard punching " for splice plates is done at the mill; special punching must be done at the shop.

CHAPTER XXVI

SHOP AND SHIPPING BILLS

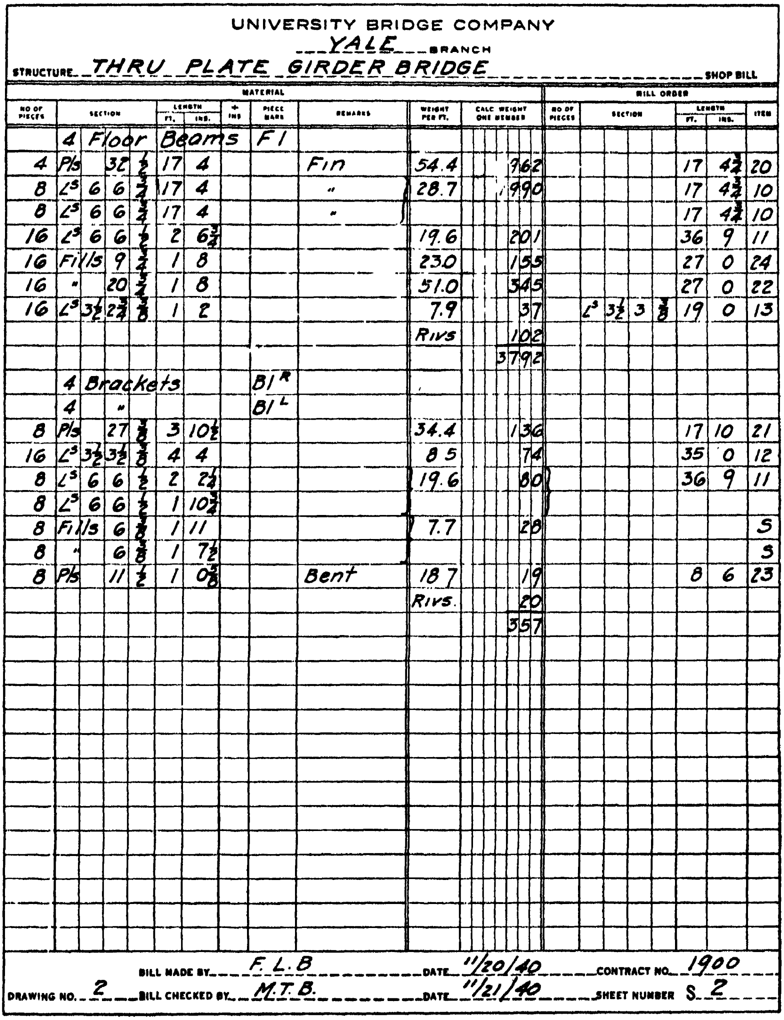
403. A shop bill is a detailed list of all the material of which one or more members are composed. Shop bills are made for all material which is fabricated in the shop in accordance with the drawings. They do not include lumber, corrugated steel, hardware, or other materials which are shipped without shop work directly from the manufacturers to the site. Shop bills are used primarily by men in the receiving yard or stock yard; these men select the material for each member and deliver it to the structural shop as needed. Much of this material is used as it comes from the rolling mill, but some must be recut to shorter lengths according to information given on the shop bills. Incidentally, shop bills are used as check lists in different shops; thus, for example, in the templet shop each item is checked off on the shop bill as soon as the corresponding templet is completed.

404. Form. Shop bills are made on printed forms, and they may be placed at the ends of the detailed working drawings, on separate sheets, in combination with shipping bills, or with sketches and shipping bills. In certain classes of work, such as columns, the shop bills are placed on the sheet with the working drawing, and it is unnecessary to bill the material on the drawing if a system of assembling marks is used for identifying the different pieces. When on separate sheets, both the drawing and the shop bill must be complete, but no shop bill should contain material for more than one sheet of drawings. These separate shop bills should be numbered to correspond to the number of the corresponding drawing, as *S*2 for sheet 2; if more than one page of shop bills are required for a single drawing they can be lettered *a*, *b*, *c*, for distinction, as *S2a*, *S2b* for drawing 2. Shop bills should be made with freehand letters, either in ink or pencil; according to common drafting-room parlance they are said to be "written," but this should not be interpreted literally. Figures should be carefully made.

405. A shop bill is divided into **three parts.** The first part is the summary of material taken from the drawing; this part is confined to the left-hand half of the shop-bill form, including the " Remarks " (Fig. 225). This part of the shop bill is usually written by boys or girls or by young men who are beginning their careers in the drafting room; sometimes they work in a separate squad under a chief biller. A bill may be checked by another member of the squad, but it is often more satisfactory to have it checked by the draftsman or checker who worked on the corresponding drawing, especially if it is somewhat unusual or complex. The signatures at the bottom of a shop bill are those of the persons who make and check this first part. The second part of a shop bill is the itemizing, as explained on page 226. These two parts must be completed before the shop bills are printed for the shop. The third part is the calculation of the weights, as explained on page 228. The weights are not usually computed unless the contract is let on a pound-price basis. The shop bills are used in calculating the weights because they summarize all material in convenient form; the weights are not a necessary part of the shop bills, but the weights of members are transferred to the shipping bills to be used as a check on the scaled weights.

406. Arrangement. In the first part of a shop bill should be listed *all* the material required in making *all* the members which are detailed together, whether or not the members bear the same mark. Thus in Fig. 225 is included all the material required in making the four floor beams and the eight brackets of Fig. 124. When only part of a member is shown on the drawing, all notes which affect the bill of material must be carefully considered. Thus for a member marked " Symmetrical about the center line " much of the material billed on the drawing must be doubled. When more than one drawing is made on a sheet, the members should be grouped on the shop bill in the same way they are grouped on the drawing. The number, the name, and the mark of each different member should be printed prominently at the head of each group without regard to the vertical lines, and immediately underneath should be listed the material required to make all members of the group. The material should be listed systematically, beginning with the main material. The details should be grouped as on the drawing, beginning at the bottom or left-hand end of the member and proceeding toward the other end. Fine vertical lines are printed under " Section " as an aid to uniformity in billing; with these lines, crosses are unnecessary. All four columns are used for angles, but the second one may be left blank for plates; for beams and channels the last column may be used for the pound sign (#) or left blank. Each item which is not common to all members of a group should be so noted, as in *F*6 and *F*8, Fig. 226. Similar marks should appear opposite the items which are " milled " or " finished " (abbreviated " Fin."), " bolted complete," or " bolted for shipment." Assembling marks should be recorded in a special column headed " Assembling Mark " or " Piece Mark." The lengths of lattice bars are billed center to center of holes, and should be noted " c. to c." Permanent bolts are usually listed on the drawing;

hence they are billed as a matter of course, washers and bolts usually being the last items to be billed. Temporary bolts for holding pieces in position during shipment are usually of odd lengths picked up in the shop; these are seldom listed on the shop bill except for " pound-price " contracts so that the weight will be included; it is usually sufficient to consider all such temporary bolts of an average length of 3″ to avoid undue investigation of details. The column headed " + ins." is used only when the material is ordered directly from the shop bills instead of from preliminary order bills,



UNIVERSITY BRIDGE COMPANY

YALE BRANCH

STRUCTURE THRU PLATE GIRDER BRIDGE SHOP BILL

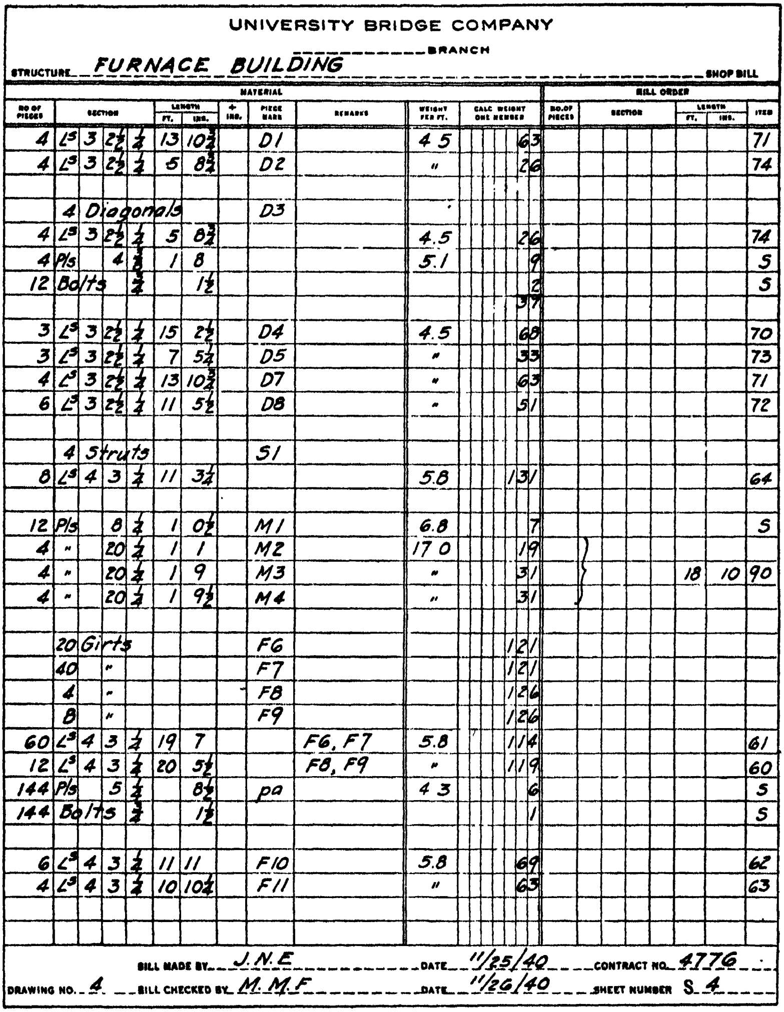
MATERIAL									BILL ORDER				
NO OF PIECES	SECTION	LENGTH FT.	LENGTH INS.	+ INS	PIECE MARK	REMARKS	WEIGHT PER FT.	CALC WEIGHT ONE MEMBER	NO OF PIECES	SECTION	LENGTH FT.	LENGTH INS.	ITEM
	4 Floor Beams				F1								
4	Pls 32 ½	17	4			Fin	54.4	962			17	4¾	20
8	∠s 6 6 ¾	17	4			"	28.7	990			17	4¾	10
8	∠s 6 6 ¾	17	4			"					17	4¾	10
16	∠s 6 6 ½	2	6¾				19.6	201			36	9	11
16	Fills 9 ¾	1	8				230	155			27	0	24
16	" 20 ¾	1	8				51.0	345			27	0	22
16	∠s 3½ 2¾ ⅜	1	2				7.9	37		∠s 3½ 3 ⅜	19	0	13
							Rivs	102					
								3792					
	4 Brackets				B1 R								
	4 "				B1 L								
8	Pls 27 ⅜	3	10½				34.4	136			17	10	21
16	∠s 3½ 3½ ⅜	4	4				8 5	74			35	0	12
8	∠s 6 6 ½	2	2¼				19.6	80			36	9	11
8	∠s 6 6 ½	1	10¾										
8	Fills 6 ⅜	1	11				7.7	28					S
8	" 6 ⅜	1	7½										S
8	Pls 11 ½	1	0⅝			Bent	18 7	19			8	6	23
							Rivs.	20					
								357					

BILL MADE BY F. L. B DATE 11/20/40 CONTRACT NO. 1900

DRAWING NO. 2 BILL CHECKED BY M.T.B. DATE 11/21/40 SHEET NUMBER S 2

Fig. 225. Shop Bill.

as for example, when the shop bills are written for drawings made by a consulting engineer. In this case the complete shop bills can be prepared as quickly as preliminary order bills, and the preliminary ones may be dispensed with. The use of this column on the shop bill is then the same as on the material order bill (page 218).



UNIVERSITY BRIDGE COMPANY

________ BRANCH

STRUCTURE FURNACE BUILDING ________ SHOP BILL

MATERIAL									BILL ORDER				
NO. OF PIECES	SECTION	LENGTH FT.	LENGTH INS.	+ INS.	PIECE MARK	REMARKS	WEIGHT PER FT.	CALC. WEIGHT ONE MEMBER	NO. OF PIECES	SECTION	LENGTH FT.	LENGTH INS.	ITEM
4	Ls 3 2½ ¼	13	10¾		D1		4 5	63					71
4	Ls 3 2½ ¼	5	8¾		D2		"	26					74
	4 Diagonals				D3								
4	Ls 3 2½ ¼	5	8¾				4.5	26					74
4	P/s 4 ⅜	1	8				5.1	9					S
12	Bolts ¾		1½					2					S
								37					
3	Ls 3 2½ ¼	15	2½		D4		4.5	68					70
3	Ls 3 2½ ¼	7	5¼		D5		"	33					73
4	Ls 3 2½ ¼	13	10¾		D7		"	63					71
6	Ls 3 2½ ¼	11	5½		D8		"	51					72
	4 Struts				S1								
8	Ls 4 3 ¼	11	3¼				5.8	131					64
12	P/s 8 ¼	1	0½		M1		6.8	7					S
4	" 20 ¼	1	1		M2		17 0	19	}				
4	" 20 ¼	1	9		M3		"	31	}		18	10	90
4	" 20 ¼	1	9½		M4		"	31	}				
	20 Girts				F6			121					
	40 "				F7			121					
	4 "				F8			126					
	8 "				F9			126					
60	Ls 4 3 ¼	19	7			F6, F7	5.8	114					61
12	Ls 4 3 ¼	20	5½			F8, F9	"	119					60
144	P/s 5 ¼		8½		pa		4 3	6					S
144	Bolts ¾		1½					1					S
6	Ls 4 3 ¼	11	11		F10		5.8	69					62
4	Ls 4 3 ¼	10	10¼		F11		"	63					63

BILL MADE BY J.N.E DATE 11/25/40 CONTRACT NO. 4776

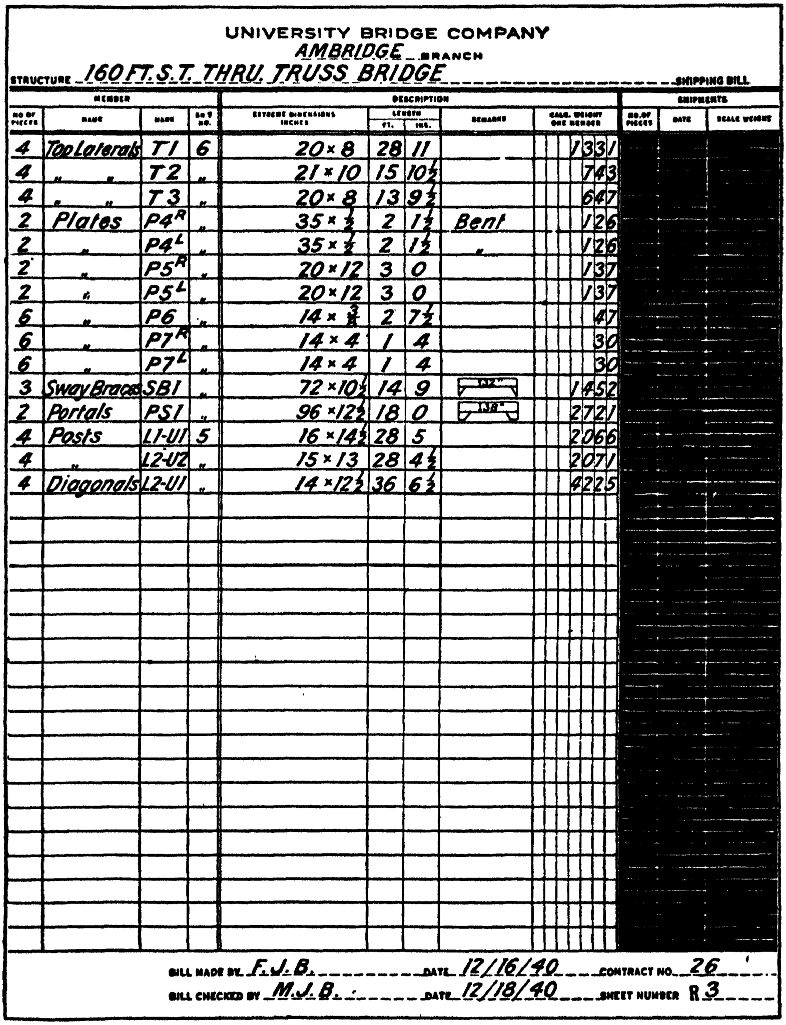
DRAWING NO. 4 BILL CHECKED BY M.M.F DATE 11/26/40 SHEET NUMBER S 4

Fig. 226. Shop Bill.

407. Itemizing. The second part of the shop bill shows the ordered material from which the yard men should select the steel for the different component parts of a member. All material which is ordered specially for a contract has the contract number and an item number painted on the steel. This item number appears on the preliminary material order bill (page 218) and it is transferred to the shop bill to indicate the proper assignment of material. The term " itemizing " is applied to the preparation of this part of the shop bill. The best results are obtained if one man itemizes all the shop bills of a single contract, or at least of a definite portion of it; this man should be conversant with the practice of the order department. Opposite each component part of a member should be placed the **item number** of the material from which it is taken, and suitable notation should be made on the material order bill so that the same pieces will not be used again. The other columns under " Mill Order " are not necessarily always used. In general, the **number of pieces** need not be given unless the material is to be ordered from the shop bill instead of from a material order bill, in which event the order department takes care of the whole mill order and no itemizing is done in the drafting room. The **section** need be entered only when it differs from that listed in the main part of the bill. For example, an angle which is to be cut from another size should be so noted on the drawing, as the 2Ls $3\frac{1}{2} \times 2\frac{3}{4} \times \frac{3}{8} \times 1'\text{-}2''$ (cut from $3\frac{1}{2} \times 3$) used as erection seats on the floor beam of Fig. 124; in the main part of the shop bill it should be billed $3\frac{1}{2} \times 2\frac{3}{4} \times \frac{3}{8}$, and the original biller should record $3\frac{1}{2} \times 3 \times \frac{3}{8}$ on the same line under " Mill Order." The itemizer then provides for the $3\frac{1}{2} \times 3 \times \frac{3}{8}$ angle. Similarly, plates may be cut from other sizes to reduce the number of items to be ordered or to permit the use of stock plates; sometimes a small plate is changed so that the length becomes the width, as for example a plate billed $6 \times \frac{1}{2} \times 1'\text{-}0''$ may be itemized as a $12 \times \frac{1}{2} \times 6$ plate. Plates which are ordered as sketch plates should have the word " sketch " written in the section column. The **length** need be given only when it differs from the length billed in the main part of the bill. This may differ by only a fraction of an inch, as in material to be milled (page 23), or by a large amount when ordered in multiple lengths (page 222). On account of different grouping on the shop bill and the order bill the number of pieces will often differ. Sometimes more than one item number will have to be placed opposite a single entry on the shop bill, the number taken from each being recorded under " No. of Pieces." More frequently the number of pieces listed on the shop bill will be less than the number on the order bill; care should be taken to make the proper record on the order bill so that the same pieces will not be reassigned. Beam separators or other materials which are assembled in the shop with the beams or other members should be billed with them in accordance with the drawings. When these materials are made from combination bills they should be itemized on the latter; to save duplication they should not be itemized on the shop bill, but reference should be made to the combination bill, as in Fig. 231. All material that is not provided for on the order bill should be itemized by the order department. Presumably this material will be taken from the plant stock, because care should be taken to write advance orders for all material which cannot be found in stock. Material taken from stock has no item number, but it is indicated by the capital letter *S* instead. No length need be recorded for stock items, but the section should be indicated if it differs from the billed section.

408. When a contract is based upon a certain price per pound, **the weight is calculated.** The payment may be made for the computed weight, using the scaled weight as a check, or conversely; either way the two weights should agree within a certain percentage agreed upon. Some contracts are based upon the calculated weight alone, and this is advocated so strongly by some companies that some of their more modern plants are not equipped for weighing. The cost and the delay incident to scaled weights makes their use of doubtful benefit. The scaled weights of like members do not agree, and this complicates the bookkeeping. The weights of the longer members have to be obtained by weighing the ends separately and adding these weights; this is not entirely satisfactory. The method of calculating the weight must be specified in the contract, for two general methods are used. In one the weight of the material as listed on the shop bills is used, whereas in the other deductions are made for material coped or cut away and for open holes. In either method the weights of the heads of shop rivets, of welds, and of an allowance for overrun are added. The shop bills are convenient for determining the weights, for they include a complete list of material; reference must be made to the drawings for the number of shop rivets, the lengths of welds, and for any deductions which may be required. The weight of each member is placed on the shipping bill, which is a summary of members, and the weights on the shop bills are simply a means toward this end. It is immaterial whether the necessary prints of the shop bills are taken before or after the weights have been added. Usually the weights are computed and checked by young men or women who specialize in this work, although draftsmen are sometimes asked to help. Most companies furnish exhaustive tables to aid them. Since not all of a group of members are completed in the shop at once or shipped in the same car, it is more convenient to have the weight of a single member on the shipping bill, rather than the total weight of a group. In computing the weight of one member as shipped, the weight of the corresponding number of component parts should be found, which in general is neither a single piece nor the total number of pieces given on the bill. Thus the weight of 1 floor beam *F*1 (Fig. 225) should include the weight of 1 web, 2 top angles, 2 bottom angles, and 4 of each other item, being one-fourth of the number of pieces required to make the four members. The weights are expressed to the nearest pound, but when members are composed of a large number of component parts it may be necessary to carry the partial weights to one decimal. Usually the first step in computing weights is to determine from the tables the weights per foot for the different sections; these weights may be recorded in the column provided for that purpose. As the weights of beams and channels are given in the main part of the shop bill they need not be repeated. The weight of each item is the product of three factors, the weight per foot, the length in feet, and the number of pieces per member. The order in which these factors are multiplied depends upon the method used and upon the factors themselves; it may be more convenient to multiply the length by one of the other factors before the inches and fractions are converted to decimals of a foot. The weights should be placed in the spaces provided for them, fine vertical lines often being printed on the forms to simplify the alignment of figures for convenience in totaling. When all members of a group weigh the same, a line can be drawn under the weight of the last item and a single total recorded under the line, as in Fig. 225. When the weights of the members of a group differ, each must have its own total; to save space each total may be recorded opposite the mark of the proper member, as in *F*6 and *F*8, Fig. 226. Care must be taken to include in these totals only the weights of the component parts which form the corresponding members. Plates are likely to overrun in weight as indicated in the handbook; usually one-half the percentage of overrun can be added to the calculated weight. The weight of the heads of shop rivets is added as a separate item. In counting the rivets from the drawing, special attention should be given to symmetrical notes and to group spacing; each rivet has two heads. The weights of 100 rivet heads are given in the tables, as also the weights of bolts and their component parts, but often greater allowances are made, as provided in the code of standard practice given in the handbook of the American Institute of Steel Construction. The weight of a washer for an ordinary stitch rivet is about ⅓ pound. A 2¼″ washer with a ⅞″ hole for a ¾″ rivet weighs 0.30 if $\frac{5}{16}$″ thick and 0.36 if ⅜″ thick. A 2¼″ washer with a 1″ hole for a ⅞″ rivet weighs 0.28 if $\frac{5}{16}$″ thick and 0.34 if ⅜″ thick. A 2½″ washer weighs about 30% more. The weights of other washers may be found by proportion or by calculation, the weight per foot being 3.4 times the net area.

409. A shipping bill is a summary of members in the form in which they are to be shipped. It is made primarily as a check list for the shipper. All members which bear the same shipping mark should be billed on the same line, but different marks should be listed separately. In each case the number, the name, the mark, and the shipping dimensions should be given; the weight is given only when required (see preceding paragraph). The sheet number of the drawing is also recorded. A portion of the bill is printed black so that white spaces will be left on the blueprints for the convenience of the shipper in making records of shipments. The shipping



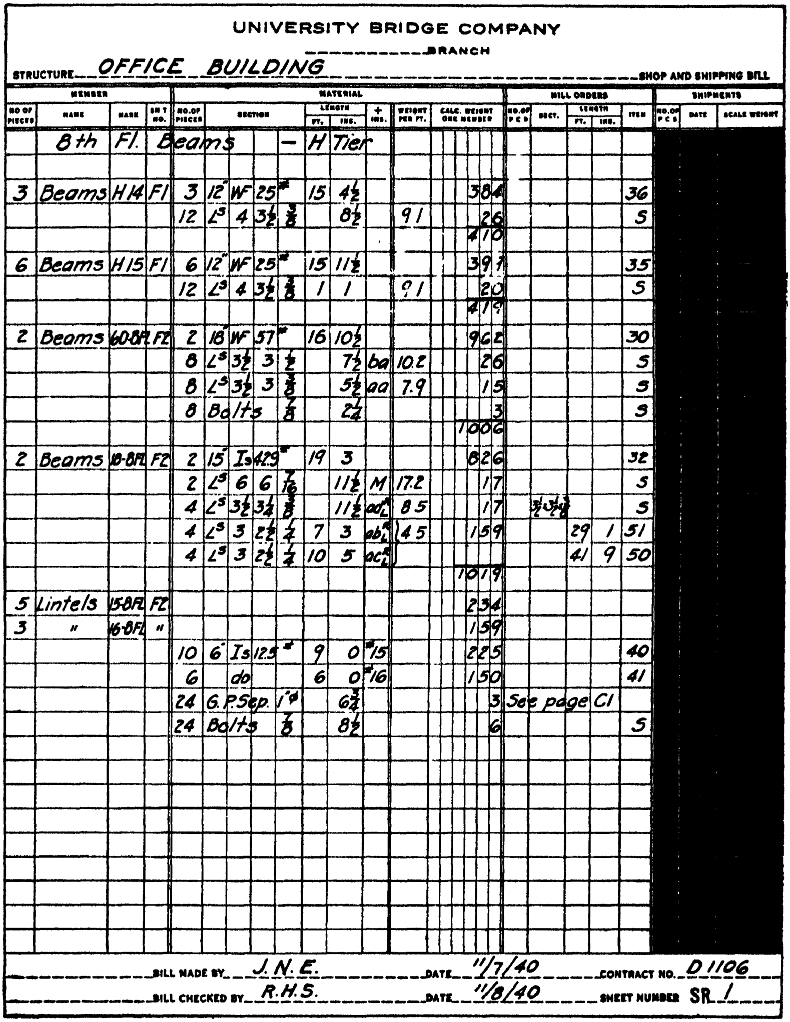
UNIVERSITY BRIDGE COMPANY
AMBRIDGE BRANCH
STRUCTURE 160 FT. S.T. THRU. TRUSS BRIDGE SHIPPING BILL

MEMBER				DESCRIPTION					SHIPMENTS		
NO OF PIECES	NAME	MARK	SH'T NO.	EXTREME DIMENSIONS INCHES	LENGTH		REMARKS	CALC. WEIGHT ONE MEMBER	NO. OF PIECES	DATE	SCALE WEIGHT
					FT.	INS.					
4	Top Laterals	T1	6	20 × 8	28	11		1331			
4	" "	T2	"	21 × 10	15	10½		743			
4	" "	T3	"	20 × 8	13	9½		647			
2	Plates	P4^R	"	35 × ½	2	1½	Bent	126			
2	"	P4^L	"	35 × ½	2	1½	"	126			
2	"	P5^R	"	20 × 12	3	0		137			
2	"	P5^L	"	20 × 12	3	0		137			
6	"	P6	"	14 × ⅜	2	7½		47			
6	"	P7^R	"	14 × 4	1	4		30			
6	"	P7^L	"	14 × 4	1	4		30			
3	Sway Braces	SB1	"	72 × 10½	14	9	112"	1452			
2	Portals	PS1	"	96 × 12½	18	0	138"	2721			
4	Posts	L1-U1	5	16 × 14½	28	5		2066			
4	"	L2-U2	"	15 × 13	28	4½		2071			
4	Diagonals	L2-U1	"	14 × 12½	36	6½		4225			

BILL MADE BY F. J. B. DATE 12/16/40 CONTRACT NO. 26
BILL CHECKED BY M. J. B. DATE 12/18/40 SHEET NUMBER R 3

Fig. 230. Shipping Bill.

dimensions are usually given to the nearest inch (or half inch). The extreme " box dimensions " are given, i.e., the three dimensions of a box which would contain the member. The length is given in feet and inches but the other two dimensions at right angles to the length and to each other are expressed in inches, the larger of the two being given first. If these dimensions do not fairly represent a large member, a freehand sketch with auxiliary dimensions may be drawn in the column headed " Remarks," as shown in Fig. 230. Members should be listed preferably in about the



UNIVERSITY BRIDGE COMPANY

__________BRANCH

STRUCTURE OFFICE BUILDING ________SHOP AND SHIPPING BILL

MEMBER				MATERIAL							MILL ORDERS					SHIPMENTS		
NO. OF PIECES	NAME	MARK	SH'T NO.	NO. OF PIECES	SECTION	LENGTH FT.	LENGTH INS.	+ INS.	WEIGHT PER FT.	CALC. WEIGHT ONE MEMBER	NO. OF PCS	SECT.	LENGTH FT.	LENGTH INS.	ITEM	NO. OF PCS	DATE	SCALE WEIGHT
	8th Fl. Beams – H Tier																	
3	Beams	H14	F1	3	12" WF 25#	15	4½			384					36			
				12	∠s 4 3½ ⅜		8½		91	26					S			
										410								
6	Beams	H15	F1	6	12" WF 25#	15	11½			397					35			
				12	∠s 4 3½ ⅜	1	1		91	20					S			
										419								
2	Beams	60-8Fl	F2	2	18" WF 57#	16	10½			962					30			
				8	∠s 3½ 3 ½		7½	ba	10.2	26					S			
				8	∠s 3½ 3 ⅜		5½	aa	7.9	15					S			
				8	Bolts ⅞		2¼			3					S			
										1006								
2	Beams	10-8Fl	F2	2	15" Is 42.9#	19	3			826					32			
				2	∠s 6 6 7/16		11½	M	17.2	17					S			
				4	∠s 3½ 3¼ ⅜		11½	ad^R_L	8 5	17		3½ 3¼ ⅜			S			
				4	∠s 3 2½ ¼	7	3	ab^R_L	4 5	159			29	1	51			
				4	∠s 3 2½ ¼	10	5	ac^R_L					41	9	50			
										1019								
5	Lintels	15-8Fl	F2							234								
3	"	16-8Fl	"							159								
				10	6" Is 12.5#	9	0	#15		225					40			
				6	do	6	0	#16		150					41			
				24	G.P.Sep. 1"φ		6¾			3	See page C1							
				24	Bolts ⅞		8½			6					S			

BILL MADE BY J. N. E. DATE 11/7/40 CONTRACT NO. D 1106

BILL CHECKED BY R. H. S. DATE 11/8/40 SHEET NUMBER SR 1

Fig. 231. Shop and Shipping Bill.

order in which they will be erected. When part of a structure is to be completed before the rest is begun, the material should be billed and shipped accordingly; the shipping bills should be marked with the shipment, as for example, " First Shipment." The last page for any shipment should be marked "Complete." Shipping bills are numbered consecutively, usually with a distinctive letter as *R*1, *R*2, etc. Bills for different shipments may be numbered in different series as *R*101, *R*102, etc., for first shipment and *R*201, *R*202, etc., for second shipment.

410. Shop and Shipping Bills are often combined on the same form, as in Fig. 231. This is done when the shop bill for each member of a drawing occupies only a few lines, i.e., when each member is composed of but few different parts. These simple shop bills may be arranged to give the necessary information to the shipper so that special shipping bills need not be prepared. It would not be feasible to use combined forms for complex members because the shipping data would be obscured by the details, and the shipper would be burdened with an unnecessarily large number of pages. Usually the combined shop and shipping bills are used for beam work and other simple work drawn on small sheets or printed forms (except those mentioned in the following paragraph); they are sometimes used for simple members drawn on large sheets. For example, the diagonals and girts of Fig. 185 might be billed on such a form instead of as in Fig. 226. In the combined form the number, the name, and the mark are listed in columns as in shipping bills, except that they are grouped as on the drawing. The remainder of the bill, except the shipper's record, is similar to the shop-bill form. The bill of material may be started on the same line as the mark, unless members which bear different marks are grouped together; then it is better to begin on the line below the last mark to avoid the confusion that might arise if part of the material were billed opposite one of the marks. Blank lines should be left between groups. In some work such as structures intended for export, the extreme shipping dimensions are given opposite each mark, just above the detailed list of material. The billed length of a beam is the length which appears on the drawing along with the depth and the weight — usually the ordered length.

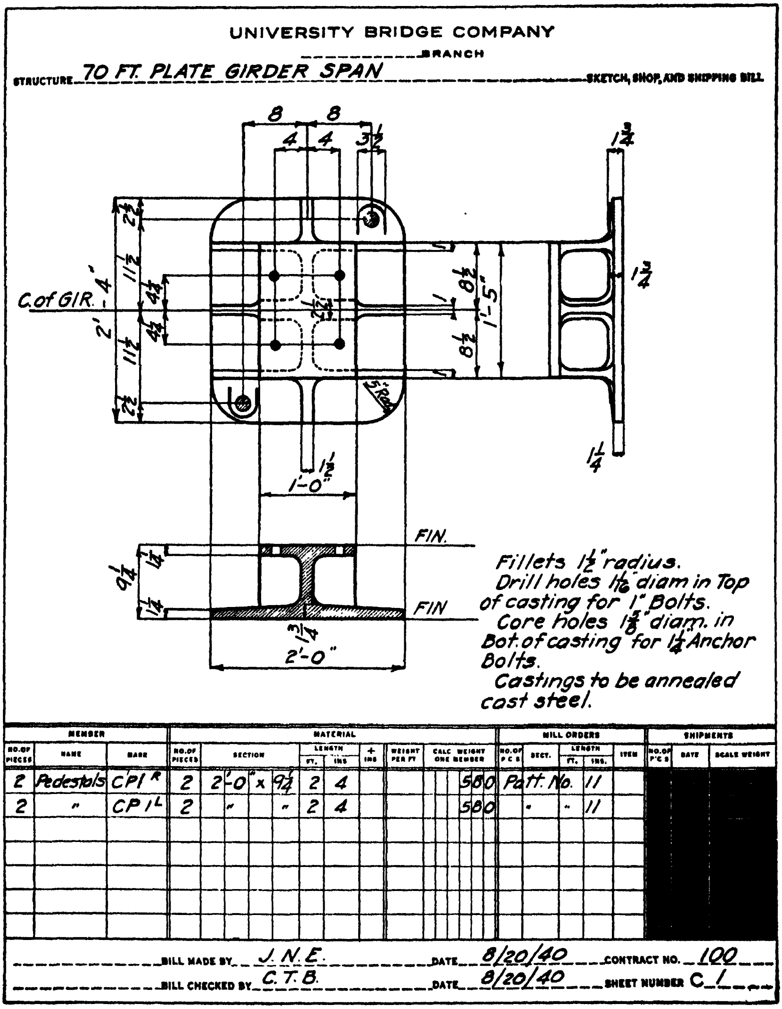
CHAPTER XXVII

MISCELLANEOUS DRAWINGS AND LISTS

411. Much of the miscellaneous material used in steel construction is made in other shops or departments than the main structural shop, and is of such a nature that **combination sheets** are used. These sheets contain the sketches or working drawings, the shop bills, and the shipping bills, thus reducing the number of prints. The combination sheets may be in the form of Fig. 234 with comparatively large drawing space, for castings, forgings, roller beds, etc., or with a small drawing space, as in Fig. 235, for rods, anchor bolts, separators, rail clamps, etc. The latter forms are used also for bearing plates, cast-iron washers, separators, etc., which need no sketches. Special **printed forms** are often used for crane rails, eyebars, loop rods, pins, clevises, turnbuckles, etc. A general drawing of one of these pieces is printed on each form with blank dimensions to be filled in. The forms may be so arranged that the different variables may be recorded in tabular form; in this way similar pieces in any contract may be listed on the same sheet.

412. A typical **casting** for a bridge pedestal is shown in Fig. 234. Such pedestals are used for the shorter girders, but more elaborate ones, with rocker pins, for the longer girders. The tops and bottoms of these pedestals are finished to furnish uniform bearing, and holes are drilled in the tops for the bolts which hold the girders in place; it would be impracticable to punch holes or to drive rivets in cast iron or steel because of the danger of cracking the casting. Cored holes, cast in place, are sometimes used for the bolts, but they should be made $\frac{1}{8}''$ larger than the bolts to allow for irregularities in the casting. Holes are cored in the bottoms for the anchor bolts; these are made $\frac{3}{8}''$ larger than the bolts to allow for inaccuracies in setting the bolts. The tabular portion is arranged as in a combination shop and shipping bill (page 232); not all the blanks are required for castings.

413. A combination sheet arranged for a larger number of items is shown in Fig. 235 for the **rods** of a mill building. It may be necessary to show more complete drawings for some rods, but usually sufficient information can be given if the rods are shown conventionally by single lines, as in the figure. It is assumed that dimensions are taken along the center lines. Main diagonal rods are marked in the usual manner with a letter X followed by a specific number. As it is impracticable to paint the mark on each individual sag rod or tie rod, they are usually shipped in bundles and the bundles are marked. Should the rods become mixed before they are used, the erector must identify them by measurement. If a rod is indicated on the erection diagram by an X and a number, the erector must refer to a list of rods to determine the proper length; this extra step may be avoided if all straight tie rods and sag rods are marked according to their lengths. Thus on the diagram the length in inches may be inscribed in a circle to



UNIVERSITY BRIDGE COMPANY

BRANCH

STRUCTURE 70 FT. PLATE GIRDER SPAN SKETCH, SHOP, AND SHIPPING BILL

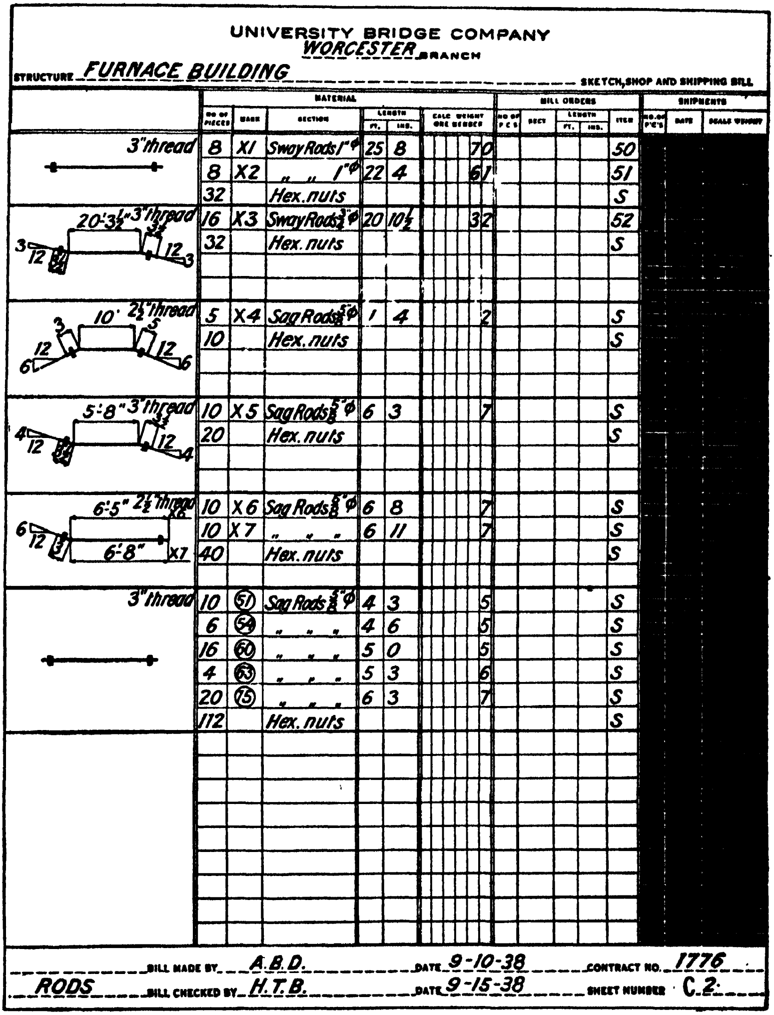
Fillets 1½" radius.
Drill holes 1 1/16" diam in Top of casting for 1" Bolts.
Core holes 1⅜" diam. in Bot. of casting for 1¼" Anchor Bolts.
Castings to be annealed cast steel.

MEMBER			MATERIAL							MILL ORDERS					SHIPMENTS		
NO. OF PIECES	NAME	MARK	NO. OF PIECES	SECTION	LENGTH FT.	LENGTH INS	+ INS	WEIGHT PER FT	CALC WEIGHT ONE MEMBER	NO. OF P C S	SECT.	LENGTH FT.	LENGTH INS.	ITEM	NO. OF P'C S	DATE	SCALE WEIGHT
2	Pedestals	$CP1^R$	2	2'-0" x 9¼	2	4			580	Patt. No.			11		[redacted]	[redacted]	[redacted]
2	"	$CP1^L$	2	" "	2	4			580		"	"	11		[redacted]	[redacted]	[redacted]
															[redacted]	[redacted]	[redacted]
															[redacted]	[redacted]	[redacted]
															[redacted]	[redacted]	[redacted]
															[redacted]	[redacted]	[redacted]
															[redacted]	[redacted]	[redacted]

BILL MADE BY J. N. E. DATE 8/20/40 CONTRACT NO. 100
BILL CHECKED BY C. T. B. DATE 8/20/40 SHEET NUMBER C 1

Fig. 234. Combination Sheet with Drawing.

distinguish the marks from others. Since the tie rods or sag rods of a given structure are usually of the same diameter, the erector needs to know only the lengths; it is more convenient for him to find the lengths where the rods are shown on the diagrams than to have to refer to a separate list. Only one rod in each panel need be marked, for the others are obviously the same. The lengths of tie rods and sag rods are usually made in multiples of 3″ and with 3″ threads in order to reduce the number of different sizes. The weights of rods and nuts may be found in the hand-



UNIVERSITY BRIDGE COMPANY
WORCESTER BRANCH
STRUCTURE FURNACE BUILDING SKETCH, SHOP AND SHIPPING BILL

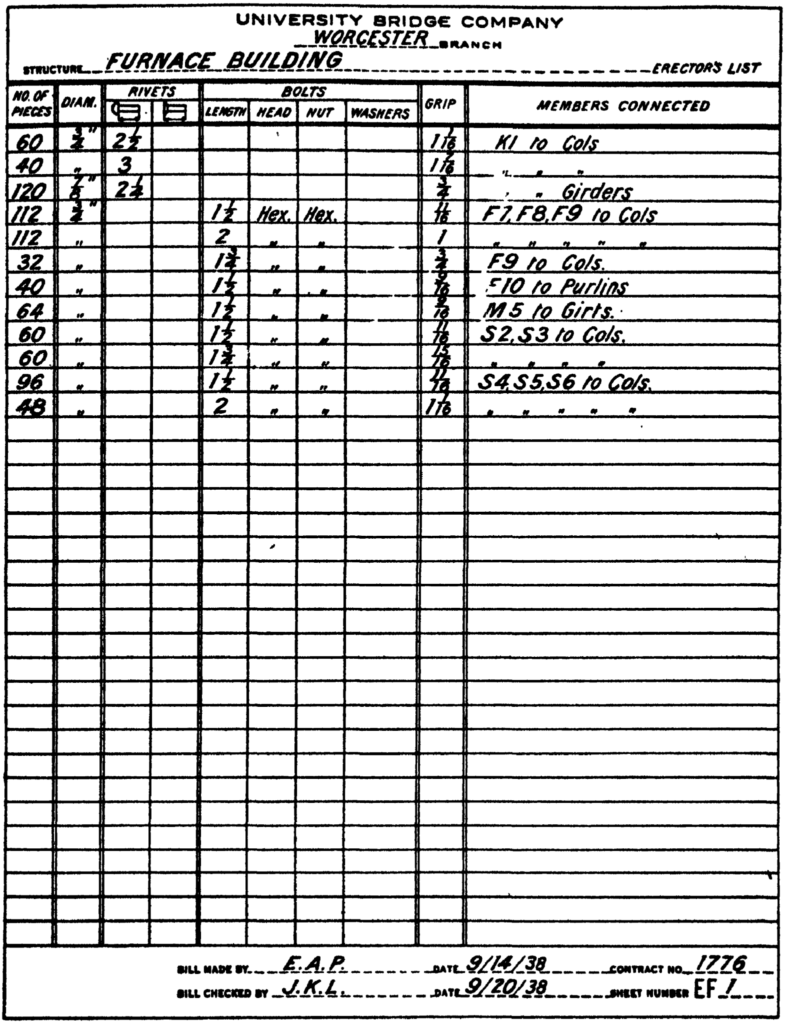
MATERIAL						MILL ORDERS					SHIPMENTS		
NO. OF PIECES	MARK	SECTION	LENGTH FT.	LENGTH INS.	CALC. WEIGHT ONE MEMBER	NO. OF PCS	SECT	LENGTH FT.	LENGTH INS.	ITEM	NO. OF PCS	DATE	SCALE WEIGHT
8	X1	Sway Rods 1"φ	25	8	70					50			
8	X2	" " 1"φ	22	4	61					51			
32		Hex. nuts								S			
16	X3	Sway Rods ¾"φ	20	10½	32					52			
32		Hex. nuts								S			
5	X4	Sag Rods ⅝"φ	1	4	2					S			
10		Hex. nuts								S			
10	X5	Sag Rods ⅝"φ	6	3	7					S			
20		Hex. nuts								S			
10	X6	Sag Rods ⅝"φ	6	8	7					S			
10	X7	" " "	6	11	7					S			
40		Hex. nuts								S			
10	(51)	Sag Rods ⅝"φ	4	3	5					S			
6	(5A)	" " "	4	6	5					S			
16	(60)	" " "	5	0	5					S			
4	(63)	" " "	5	3	6					S			
20	(75)	" " "	6	3	7					S			
112		Hex. nuts								S			

BILL MADE BY A.B.D. DATE 9-10-38 CONTRACT NO. 1776
RODS BILL CHECKED BY H.T.B. DATE 9-15-38 SHEET NUMBER C.2.

Fig. 235. Combination Sheet with Small Sketches.

book. The ends of some of the longer rods are upset according to standard upsets shown in the handbook, but for the general run of work the cost of upsetting would offset the saving in the cost of the metal.

414. Lists of field rivets and bolts must be prepared for each contract in order that the proper number of each size may be shipped to the site for use in erection. First a detailed **erector's list** is made to show the number and the size of the rivets for each connection. To have each connection provided for once, and only once, it is well to have one man list the rivets for a whole structure, or for a definite portion of it; he should work systematically to avoid duplication. Perhaps the best plan is to take one sheet at a time and list only those rivets by which each member on that sheet is connected to the *supporting* members. The rivets for all members which bear the same shipping mark should be listed together, and the rivets for similar members may be combined whenever this can be done conveniently without adding to the burdens of the erector. A typical erector's list is shown in Fig. 237 for the connection of knee braces, girts, and struts to girders and columns of a mill building. The erection diagrams serve as guides in determining the relative positions of the members. A rivet is made with one head in place; the shank should be long enough to extend through the parts connected far enough to provide sufficient metal for the formation of the second head and also for upsetting the shank to fill the enlarged hole. Rivets common in structural work are either " button head " or " countersunk " (page 21); both heads may be alike, or one may be button head and the other countersunk. The length of a button-head rivet is measured from the underside of the head, but the length of a countersunk rivet is the extreme length overall. The " grip " of a rivet is the total thickness of metal through which it must pass, i.e., the sum of the thicknesses of the parts connected. The length of a rivet is the sum of the grip and the extra length required for upsetting; this depends upon the shape of the head and the length. The handbook gives a table of lengths for different grips varying by eighths of an inch. The grips are often recorded to the nearest sixteenth, but usually the eighth above would be as satisfactory. Care should be taken to differentiate between countersunk and button-head rivets; more metal is required to form a button head than a countersunk head. It is well to record the lengths of all countersunk rivets as soon as the grips are recorded, being careful to place them in the proper column. It is usually more convenient to record the lengths of the button-head rivets after one or more pages of the erector's list are otherwise complete. Bolts are listed on the same form as the rivets, but the style of head (button, square, or hexagonal) and the style of nut (square or hexagonal) should be indicated as shown. The length of a bolt is measured from the underside of the head, and should be a multiple of $\frac{1}{4}''$. A bolt should extend from $\frac{1}{16}''$ to $\frac{1}{4}''$ beyond the nut to insure full bearing of all the threads in the nut. The thickness of the nut is the same as the diameter of the bolt. When washers are used, a bolt should be made correspondingly longer.



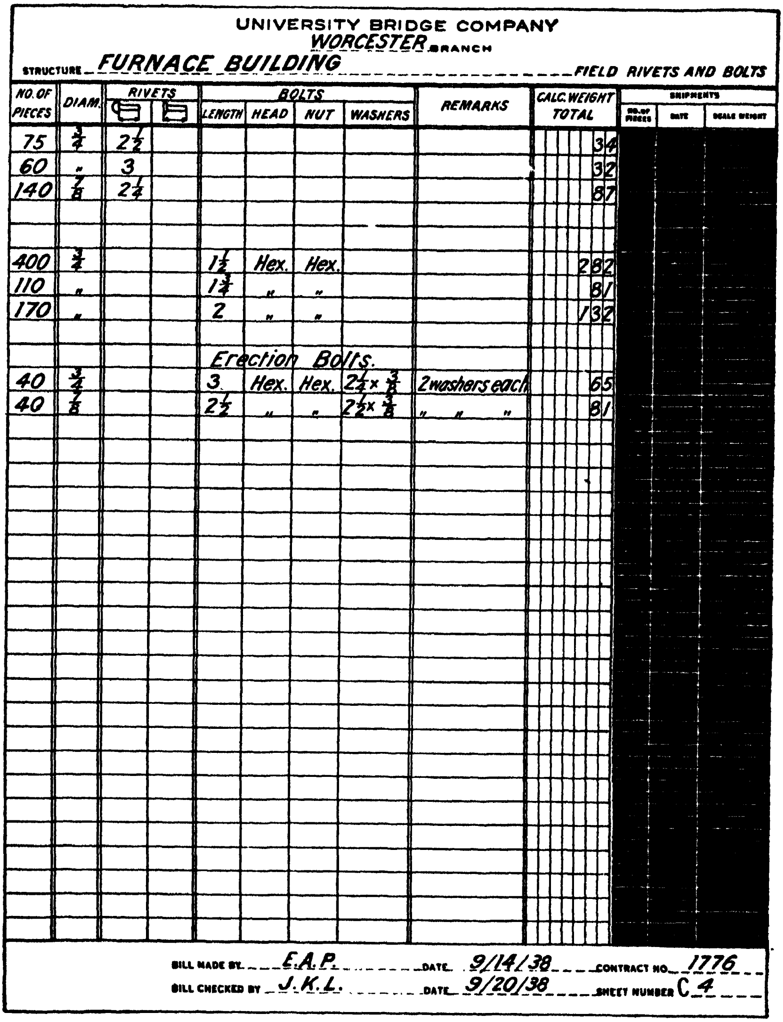
UNIVERSITY BRIDGE COMPANY
WORCESTER BRANCH
STRUCTURE FURNACE BUILDING ERECTOR'S LIST

NO. OF PIECES	DIAM.	RIVETS		BOLTS				GRIP	MEMBERS CONNECTED
				LENGTH	HEAD	NUT	WASHERS		
60	$\frac{3}{4}''$	$2\frac{1}{2}$						$1\frac{1}{16}$	K1 to Cols
40	"	3						$1\frac{7}{16}$	" " "
120	$\frac{7}{8}''$	$2\frac{1}{4}$						$\frac{3}{4}$	" " Girders
112	$\frac{3}{4}''$			$1\frac{1}{2}$	Hex.	Hex.		$\frac{11}{16}$	F7, F8, F9 to Cols
112	"			2	"	"		1	" " " " "
32	"			$1\frac{3}{4}$	"	"		$\frac{3}{4}$	F9 to Cols.
40	"			$1\frac{1}{2}$	"	"		$\frac{5}{16}$	F10 to Purlins
64	"			$1\frac{1}{2}$	"	"		$\frac{9}{16}$	M5 to Girts.
60	"			$1\frac{1}{2}$	"	"		$\frac{11}{16}$	S2, S3 to Cols.
60	"			$1\frac{3}{4}$	"	"		$\frac{15}{16}$	" " " "
96	"			$1\frac{1}{2}$	"	"		$\frac{11}{16}$	S4, S5, S6 to Cols.
48	"			2	"	"		$1\frac{1}{16}$	" " " " "

BILL MADE BY E.A.P. DATE 9/14/38 CONTRACT NO. 1776
BILL CHECKED BY J.K.L. DATE 9/20/38 SHEET NUMBER EF 1

Fig. 237. Erector's List of Field Rivets and Bolts.

415. A summary of field rivets and bolts is made on a form similar to the erector's list except that blanks for weights and shipments are substituted for the grips and list of members connected, as shown in Fig. 238. All the field rivets and bolts on a whole contract may be summarized in one list unless different portions of a structure are grouped under different shipments, when the rivets may be divided accordingly. The number of each size and style of rivet and bolt may be determined by means of a sheet ruled into columns, with a column for each different size or style. The totals should be increased by certain percentages in order to allow for waste, for miscounts, and for misplacements. These percentages should be greater for small numbers in order to provide a safe margin; they differ with different companies. In the illustration, the summary has been made



UNIVERSITY BRIDGE COMPANY
WORCESTER BRANCH
STRUCTURE FURNACE BUILDING FIELD RIVETS AND BOLTS

NO. OF PIECES	DIAM.	RIVETS		BOLTS				REMARKS	CALC. WEIGHT TOTAL	SHIPMENTS		
				LENGTH	HEAD	NUT	WASHERS			NO. OF PIECES	DATE	SCALE WEIGHT
75	$\frac{3}{4}$	$2\frac{1}{2}$							34			
60	"	3							32			
140	$\frac{7}{8}$	$2\frac{1}{4}$							87			
400	$\frac{3}{4}$			$1\frac{1}{2}$	Hex.	Hex.			282			
110	"			$1\frac{3}{4}$	"	"			81			
170	"			2	"	"			132			
				Erection Bolts.								
40	$\frac{3}{4}$			3	Hex.	Hex.	$2\frac{1}{4} \times \frac{3}{8}$	2 washers each	65			
40	$\frac{7}{8}$			$2\frac{1}{2}$	"	"	$2\frac{1}{2} \times \frac{3}{8}$	" " "	81			

BILL MADE BY E.A.P. DATE 9/14/38 CONTRACT NO. 1776
BILL CHECKED BY J.K.L. DATE 9/20/38 SHEET NUMBER C 4

Fig. 238. Summary of Field Rivets and Bolts.

simply for the rivets and bolts shown in the typical erector's list and not for the whole contract. The weights of rivets and bolts should be computed only when the weight of the other steel work is required. The weight recorded is the total weight of all the rivets or bolts listed on one line. The weights of rivets and bolts are given in the handbook, and the weights of washers on page 229.

416. Erection Bolts. As soon as a member is swung into the proper position in a structure it is held in place by erection bolts put in some of the holes of the field connections; after the remaining holes are filled with rivets these bolts are replaced by rivets. In this way the erection gang is enabled to make greater progress for they do not have to wait for the rivets to be driven; special gangs drive the rivets. If permanent bolts are to be used, the erection gang may use permanent bolts for erection so that they do not need to be replaced; these permanent bolts are provided in suitable lengths as explained above. The temporary fitting-up or erection bolts are made longer than permanent bolts, and they are provided with washers. The washers make the bolts more serviceable because a bolt may be used for different grips by varying the number of washers; incidentally the use of washers facilitates the removal of the bolts and reduces the wear. Not all structures are erected by the company that furnishes the material, and erection bolts should not be furnished unless specified. Each bolt should be provided with two $\frac{3}{8}''$ washers, and the lengths should vary by $\frac{1}{2}''$. The numbers should be based upon the numbers of field rivets furnished and upon the percentages required by the company concerned.

CHAPTER XXVIII

CHECKING AND CORRECTING DRAWINGS

417. A checker is a person who " checks " or approves the correct portions of a drawing and indicates the mistakes for correction. After these mistakes have been verified and corrected by the detailer, the checker ascertains that all corrections have been made and then signs the drawing to show that he has assumed responsibility for every detail, every figure, and every note, in short for the entire drawing. The checker is usually a man of greater experience than the detailer, and no draftsman is allowed to check the work of others until he is able to make drawings which are comparatively free from errors.

418. Not All Drawings Are Completely Checked. Some structural companies have fixed policies regarding checking; others leave to the chief draftsman or the squad foreman in charge of a given contract the decision whether or not the drawings for that contract shall be checked. The importance of careful checking depends upon the ability and the skill of the draftsman; it is essential for the drawings made by inexperienced men. The importance increases with the size of a contract and the number of draftsmen engaged upon it, because of greater difficulty in insuring the proper agreement between the drawings of connecting members. A checker can work to better advantage than the detailer because the drawings of connecting members are usually farther advanced so that he can compare the completed connections more definitely. The majority of companies have all their drawings checked because they are unwilling to assume the risk of serious mistakes which might be made if only one draftsman were responsible. Since no draftsman is infallible these companies believe that every drawing should be the product of two minds. Some companies find that it is economical to have all drawings made by experienced draftsmen whose work is comparatively free from errors without being checked; these companies maintain that it is cheaper to have occasional mistakes rectified than to have all drawings checked, particularly for structures which are to be erected within comparatively short distances from the plant. Perhaps a better method would be to have the main dimensions, the strength of the connections, and the spacing of all holes for field connections checked, but not the spacing of the shop rivets or the sizes of component parts which will necessarily be verified in the shop. Sometimes a "field check" of an entire contract is made either instead of or in addition to the usual checking. Such a check is made after most of the drawings are ready for the shop but before any of the members are shipped, and preferably before the shopwork has progressed very far. The object of this check is to insure the proper erection of the structure, and it includes the checking of all main dimensions and all field connections; it should preferably be made by one person. A field check should be unnecessary for small contracts, but it may be desirable for large contracts (*a*) when the number of field connections is relatively large, as in export work; (*b*) when the cost of field changes would be prohibitive on account of inaccessibility or the lack of facilities; or (*c*) when the drawings of connecting members have been made by a large number of detailers and checked by several checkers all working simultaneously.

419. A detailer should become familiar with the work of a checker and apply the checker's methods to his own work as far as practicable. This is especially true if his work is not to be checked by another person, but no drawing should be submitted to a checker until the detailer feels confident that it is comparatively free from error. He should never allow a mistake of which he is aware to go to the checker uncorrected. A beginner is judged not so much by the mistakes he makes as by the mistakes he repeats. A man who profits by each correction which is brought to his attention and avoids making similar mistakes on future drawings will soon surpass the men who are not so careful. The detailer will find that many of the suggestions given in this chapter may advantageously be applied to his drawing before it is submitted to the checker. Many of these checks may be made at a glance, and they should always be applied. The detailer should also determine each important dimension in more than one way if possible. He should never divide a distance into rivet spacing or other subdivisions without adding all the dimensions and comparing the sum with the proper total.

420. A checker should work systematically so that he will not miss any portion of the drawing. He should collect all data concerning the member or members shown on a given drawing, and make sure that nothing is overlooked. It is not sufficient to check what the draftsman has done; it is quite as important to discover his errors of omission. A good checker is distinguished from a poor one very largely by his ability to detect omissions. The checker should check the most important parts of a drawing first, proceeding logically so that no part will be checked until the parts upon which it is dependent are checked.

421. The following **suggestions** show the more general points to be considered in checking a drawing, arranged approximately in logical order:

(1) *General Appearance.* See that the general arrangement is satisfactory; that the proper views are used to show the member to the best advantage; that all views bear proper relations to one another; that the proper scale is used so that the drawing is clear and not crowded; and that not too many different members are combined on the same drawing thus making it too complicated.

(2) *Main Dimensions.* See that the proper type of connection is provided at the supports; that the proper clearances are allowed for erection; that the main dimensions are given conspicuously in such a manner that they will be of most service; and that the main material is billed conventionally in accordance with the main dimensions and with the design.

(3) *Connections at Supports.* See that the strength of the rivets or welds and the component material is sufficient to carry the stresses; that the size and the spacing of the holes for the field rivets correspond to those in the supporting members; and that the material is properly billed.

(4) *Other Connections.* See that provision is made for all connecting members; that the connections are properly located; that the number, the size, and the spacing of the holes for the field rivets correspond exactly to those in the connecting members; that all connecting members can be erected without interference; and that all material is properly billed.

(5) *Lattice Bars and Rivets.* See that all lattice bars, batten plates, rivets, and welds are properly spaced to conform to the specifications and to the usual rules; that all rivets and bolts are so located that they can be put into position; that sufficient clearance is allowed, if possible, so that the rivets can be driven by machine; that rivets which should be countersunk or flattened are properly indicated; and that necessary stitch rivets or welds are provided.

(6) *Edge Distances.* See that all necessary edge distances are given, as for example, those which would prevent interference with erection if increased.

(7) *Special Cutting.* See that sufficient dimensions and notes are given for special cutting or coping, particularly when a variation will cause interference or mar the appearance of the finished structure.

(8) *Dimensions.* See that interdependent dimensions bear the proper relation to one another; that the distance between any two points is the same when obtained by adding the intervening dimensions on any one of two or more parallel dimension lines; and that no dimension lines or other lines or points appear to coincide on the drawing unless it is proper that they should coincide.

(9) *Milling.* See that all surfaces to be faced, milled, or planed are properly marked.

(10) *Notes.* See that all notes are given which render the drawing clearer or more definite, such as "Symmetrical about the center line"; that all differences between members which are combined on the same drawing are clearly noted; and that all loose material which is not to be shipped separately is noted "Bolted for shipment," unless plant practice makes this unnecessary.

(11) *Shipping Marks.* See that each member is provided with the proper shipping mark; that the marks correspond to the marks on the erection diagrams; that proper distinction is made between rights and lefts; and that the required number of members is correct.

(12) *Sizes of Rivets.* See that the sizes of all rivets, bolts, holes, welds, and washers are given either in a general note or in special notes.

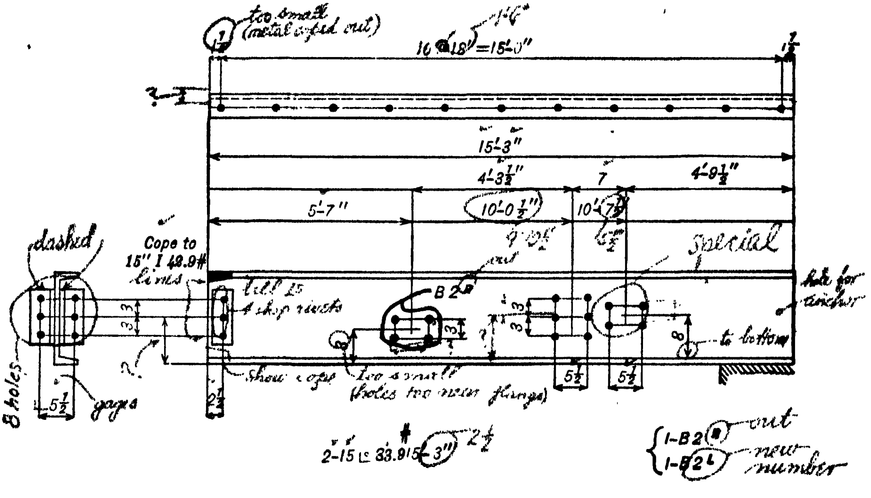


Fig. 243. Method of Indicating Mistakes.

422. Indicating Mistakes. The checker should indicate all mistakes so that the draftsman will be able to make the necessary changes without disturbing the checker's notes. See Fig. 243. Usually the checker checks a blueprint instead of the original drawing so that his marks may be preserved and the penciled original left undisturbed. Drawings made in ink on tracing cloth may be checked directly on the drawing, usually with black pencils, although sometimes blue is used. Either black or yellow pencils are used on blueprints, but red is not recommended for there are certain combinations of red crayons on blueprints which cause an unnecessary eye strain on account of an optical illusion which makes it difficult for the eye to focus on the red lines. A freehand ring or loop drawn around a dimension, a note, or a whole detail usually signifies that the enclosed portion is incorrect. A line may be drawn from the ring to a convenient clear space on the drawing where the correct value or other note may be written by the checker so that it need not be disturbed by the draftsman when he makes that or any other correction. A permanent ring is often drawn around a group of holes with a line reading to a special note (page 76), but in order to avoid ambiguity such a ring should not include figures or notes. A penciled ring may be drawn around a detail which is likely to be changed; such a ring should invite suspicion or doubt, and no use should be made of figures or other data taken without verification from within the ring. Accordingly it is not good practice to encircle any dimension or note unless it is either wrong or doubtful because of incomplete or revised information.

423. Check Marks. In checking a drawing a checker may place a dot or a v-shaped check mark over each correct dimension or note (Fig. 243). These check marks indicate his progress and make him less likely to overlook parts of the drawing; they are of special value on complicated drawings. Check marks on inked drawings may be made with a pencil and later erased, or they may be made permanently in red or blue ink for future record. If ink is used, some checkers place the check marks underneath corrected figures to distinguish them from those which were originally correct.

424. Back-Checking. A draftsman should never change a drawing according to the checker's notes until he is convinced that such changes should be made. Unless he " back-checks " or verifies each correction before making it, certain parts of the drawing are left unchecked, the values being the checker's instead of the detailer's. No checker is infallible, and every sheet that is supposed to be checked should be completely checked. A checker usually indicates the values which he believes to be correct; this is the simplest method for him. It is also the most convenient method for the detailer who back-checks conscientiously. Some checkers wish to insure back-checking by withholding the correct values until after the draftsman has supplied them. These checkers indicate mistakes for the draftsman but record the correct values for their own use in checking the corrected drawing. For convenience in identification they may number the mistakes consecutively.

425. In **checking students' drawings** it is well for the instructor to indicate the mistakes so that the students will have to determine the correct values themselves before they can correct the drawings. A practical method which has proved successful in the author's classes is to indicate not the correct values, but the reference numbers to paragraphs in the textbook which will suggest the nature of the mistakes. This may result in more work for the instructor but not so much more as might be imagined. The mistakes on the similar drawings of a whole class which are corrected at any one time cover only a limited range; most of the mistakes are made by several men, so the paragraph numbers are soon memorized. The method may be simplified by spreading the drawings out on a large table and checking one connection or other small portion of all the drawings before another portion is checked. The extra burden on the instructor seems justified by the benefit to the student. He gets a much better understanding of each correction and he is less likely to repeat the same mistake. His increased familiarity with the text makes the book more valuable for future reference. It is good practice for the students to check each other's drawings and one question on a test or examination may well be devoted to the correction of a drawing which contains many mistakes. In this work a student's grade should be based upon his net score, the number of mistakes he makes being deducted from the number which he detects.

426. Corrections. After the draftsman has verified all corrections he should carefully erase the incorrect portions of his drawing and replace them with the correct. He should also replace all lines and figures which have been erased by mistake. The incorrect figures should not be crossed out and new ones should not be superimposed as in the *unchecked* field notes of surveying. There is no necessity for preserving the incorrect figures of the draftsman after the sheet has been checked and both the checker and the draftsman are convinced that the figures are wrong. If these figures were retained, the appearance of the drawing would be marred, the drawing would be made less distinct, and the draftsman's mistakes would be exposed to all who use the drawing. It is important that all changes be made without disturbing the checker's marks. If any note of the checker is erased accidentally the draftsman should pencil a conspicuous question mark near the corresponding change to draw the attention of the checker to the change. The checker may simply check the changes and then assume responsibility for the drawing by signing his initials to the sheet. If his marks were erased he would have to recheck much or all of the drawing before he could be sure that it was correct, particularly if much time had elapsed since he first checked the drawing.

427. Revisions. If changes are made after prints have been issued, the prints must be revised or replaced by new prints. In either case the changes should be indicated conspicuously. If the old prints are revised with black ink or colored crayon the changes are apparent. If new prints are issued the revised portions should be underscored or otherwise marked with colored crayon to attract attention.

CHAPTER XXIX

REINFORCED-CONCRETE CONSTRUCTION

428. The **drawings for reinforced-concrete** structures are quite different from the working drawings for steelwork. They are made primarily for use in the field rather than in the shop. No attempt is made here to cover the subject exhaustively, but rather to suggest some of the fundamentals which may be helpful to the structural draftsman who is called upon occasionally to make drawings of this sort; at least he should be familiar with the common practice so that he can better understand the drawings of other parts of a structure which may be tied in with his steelwork. In the drawings of this chapter, the areas shown in section are crosshatched for convenient reproduction. In practice, such areas are stippled, represented conventionally as in Fig. 44, or more commonly, shaded lightly and uniformly with a pencil.

429. A portion of a typical **floor plan** is shown in Fig. 247. The columns are shown in section and shaded, the dimensions being those of the columns just above the floor represented. The columns may be numbered consecutively as in steel-framed buildings, or lettered and numbered as in the plan shown, the rows in one direction being lettered and those in the other direction being numbered, each column bearing the letter and the number of the row it is in. The columns are dimensioned from a common reference line which may be the building line, or the centers or the faces of some of the columns. The beams and girders are indicated by dashed lines, being under the floor slabs; these are lettered *B* or *G* preceded by the floor number and followed by specific numbers according to some convenient system in which like beams are given the same number, and contrariwise. A typical cross section of the floor slab is shown with bend points of the reinforcing bars located in terms of the clear span, or dimensioned specifically if clearer. The spacing of the reinforcing bars is shown in the plan, the shapes being indicated conventionally as if bent horizontally instead of vertically.

430. Typical **beam and girder details** are shown in Fig. 248. The slabs, walls, partitions, and cross beams or girders are shaded. The reinforcing bars are indicated by heavy lines with bends and hooks dimensioned. Bars in different tiers are shown at different elevations, and bar spacers may be used as shown. Bent bars and straight bars in the same

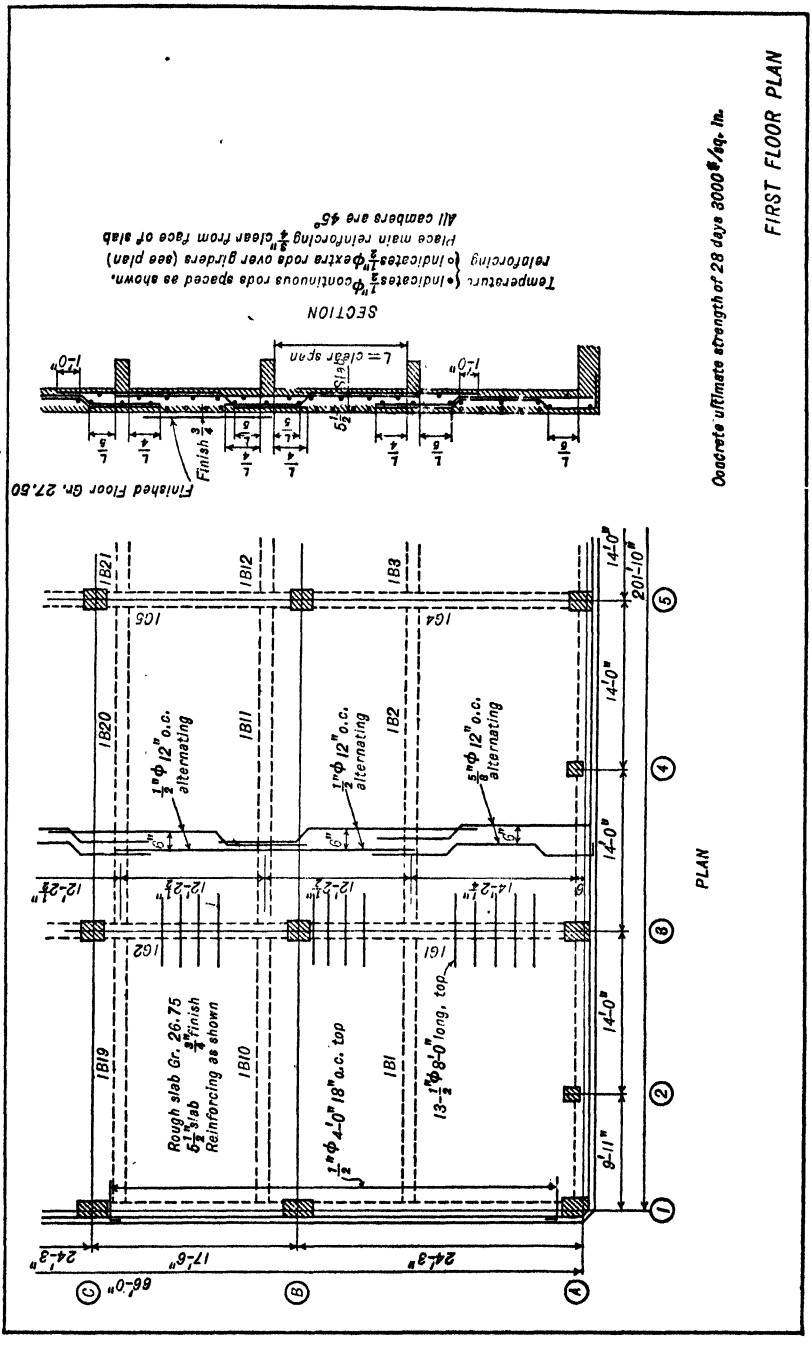
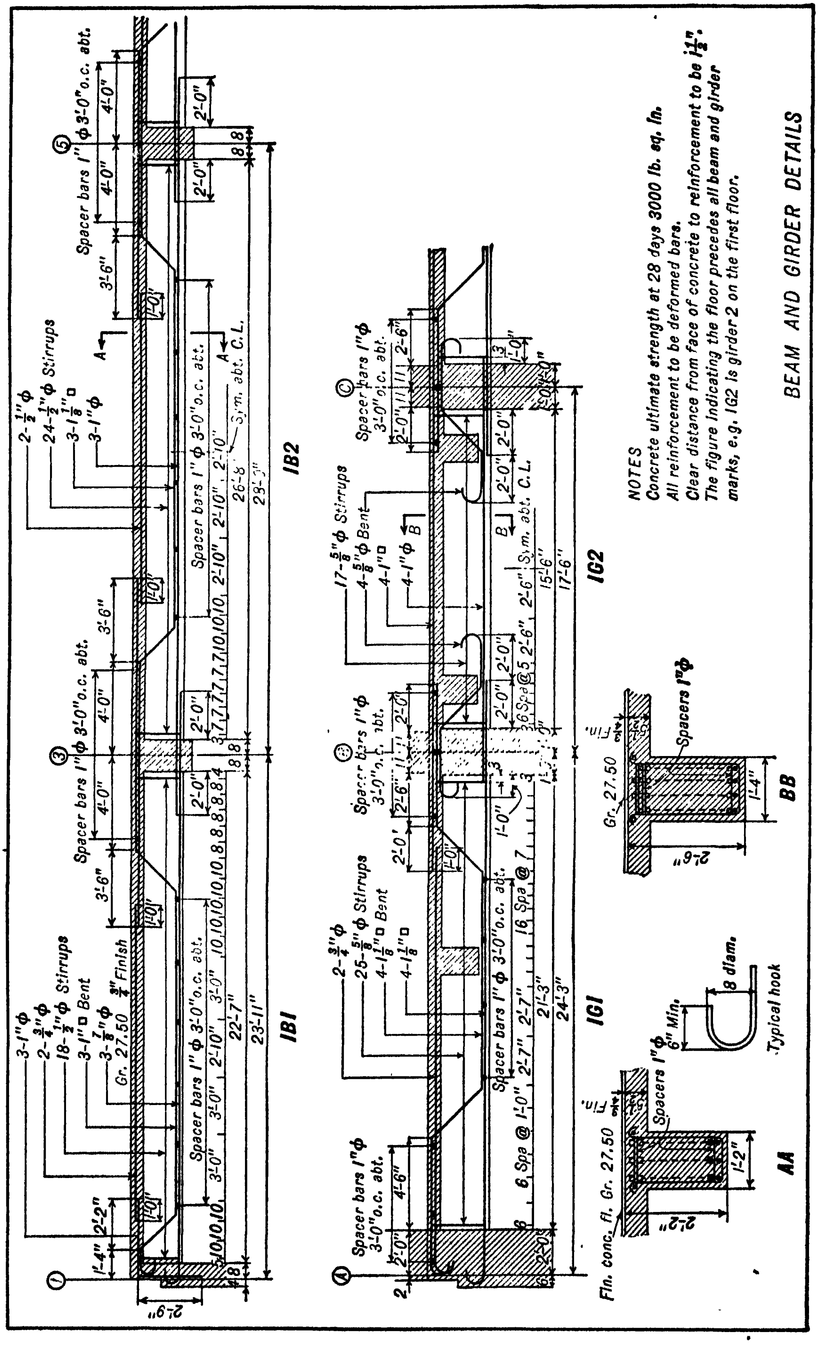


Fig. 247. Typical Floor Plan and Slab Details — Reinforced Concrete.



NOTES

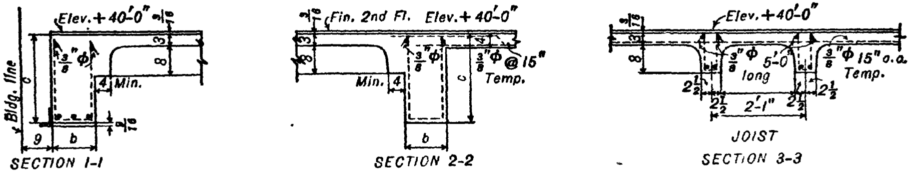
Concrete ultimate strength at 28 days 3000 lb. sq. in.

All reinforcement to be deformed bars.

Clear distance from face of concrete to reinforcement to be 1 1/2".

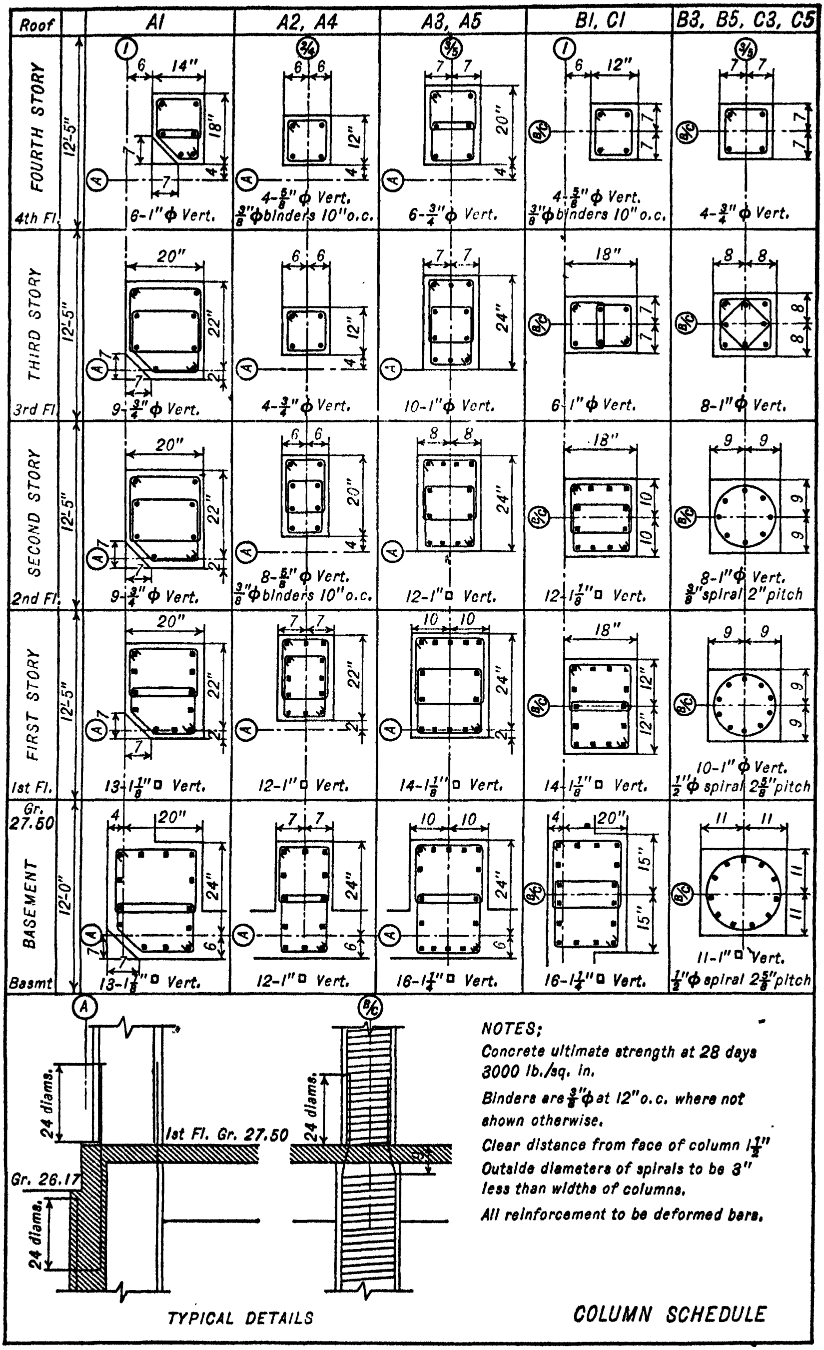
The figure indicating the floor precedes all beam and girder marks, e.g. 1G2 is girder 2 on the first floor.

Fig. 248. Beam and Girder Details — Reinforced Concrete.



BEAM SCHEDULE																																
					Straight bars in bottom							Bent bars													Stirrups A B							
Mark	Sect.	No.	Size		No.	Size	Length	No. of Hooks	Hook	Overall	Hook	No.	Size	Length	Hook	L					Hook	H o. to o.	K	L	No.	Size	Length	Type	Detail			Spacing from edge of each support
			b	c																									a	b	c	
2B1	1	2	12"	26"	2	1"Φ	20'-0"	1	1'-0"	19'-0"	—	1	1¼"□	25'-6"	1'-2"	3'-4"	1'-9"	9'-0"	1'-9"	7'-3"	—	1'-10"	2'-6"	23'-1"	16	⅜"Φ	4'-11"	A	9	22	3	2, 2 @ 4, 3 @ 6, 9. 12
2B2	2	2	10"	26"	2	1"Φ	19'-6"	1	1'-0"	18'-6"	—	1	1⅛"□	25'-0"	1'-1"	—	1'-9"	8'-10"	1'-9"	7'-1"	3'-0"	1'-10"	2'-6"	22'-4"	12	⅜"Φ	4'-9"	B	7	22	3	3, 3 @ 6, 9, 12
2J1	3	108	5"	11"	1	1"□	22'-0"	2	8	20'-8"	8	1	⅞"Φ	27'-0"	7	4'-9"	8	10'-3"	8	9'-7"	—	9	11	25'-11"	14	¼"Φ	2'-3"	B	3	9	3	3, 8 @ 7

Fig. 249. Tabular Form for Beam Details — Reinforced Concrete.



NOTES;
Concrete ultimate strength at 28 days 3000 lb./sq. in.
Binders are 3/8"ϕ at 12" o.c. where not shown otherwise.
Clear distance from face of column 1 1/2"
Outside diameters of spirals to be 3" less than widths of columns.
All reinforcement to be deformed bars.

Fig. 250. Column Schedule — Reinforced Concrete.

tier may be shown as if in different tiers for distinction, but the enlarged sectional views should show the intended positions. Bars which are cut by the section plane are filled in, whereas those beyond are left open; bent-up bars are indicated by dashed lines drawn between the upper and lower positions. The shapes of the stirrups are shown in the sectional views, but the numbers, the sizes, and the spacing are shown in the elevation, or by general notes. Dimensions for overlaps are given. The clear distance from the steel to the face of the concrete may often be given in a general note, and the spaces between bars are considered to be equal; in this manner, typical sectional views may serve for beams of different cross sections.

431. Tabular forms may be used for beams and girders, or for slabs, in order to simplify the drawings. Typical sections are drawn with common dimensions in figures and different dimensions in letters. Tables may be adapted to show the number and the mark of each beam, girder, or joist, with blanks for the section number; the dimensions of the cross section; the number and the dimensions of straight and bent bars; the shape, the number, and the size of stirrups; much as shown in Fig. 249. Hooks are shown at each end, but when no dimension is given it is assumed that there is no hook. The lines of the tabular form may be drawn on the back of the sheet to simplify alterations.

432. A portion of a typical **column schedule** is shown in Fig. 250. Each story is indicated, with dimensions or elevations to locate the finished floor lines. Vertical lines divide the different columns, but columns which are identical for the entire height may be grouped together. In each rectangle is shown the cross section of the corresponding column, with the dimensions of the concrete from the reference lines; the number, the size, and the position of the vertical bars; the size and the pitch of each spiral; and the size and the spacing of any hoops or binders. Some of this information may be given in notes if sufficiently general. The extent of each binder is indicated, and the position of the ends. Column loads may be indicated for each section according to the custom of each company. Typical column splices or other details may be drawn on the same sheet, showing the extent of the bars and the amount of overlap.

CHAPTER XXX

TIMBER CONSTRUCTION

433. The Use of Timber. Lumber was probably the first building material in this country, and it has been utilized continuously in all sorts of construction. From an engineering point of view, its use has been stimulated in recent years by the introduction of so-called timber connectors. These have made timber joints more effective and simpler to design than the former bolted joints, and timber has been restored to favor in many types of construction for which in some localities it had been largely superseded by steel or concrete. Much has been done toward the more efficient use of nails and bolts. Glue is used extensively in building large or bent laminated members and also for plywood gusset plates. Preservatives for timbers in outdoor construction are more common, and much of the timber is pre-cut before treatment.

434. References. Readers are referred to " Wood Construction "* by D. C. Holtman of the National Committee on Wood Utilization, or to the " Wood Handbook " † of the Forest Products Laboratory of the United States Department of Agriculture, for general treatises on timber resources, regions of growth, principal uses in construction, identification and grading, preservative treatments, details of construction, etc.; to " Timber Design and Construction "‡ by Jacoby and Davis for different kinds of joints and the holding power of fastenings; and to " Wood Structural Design Data," published by the National Lumber Manufacturers Association,§ for information on structural lumber grades and sizes, formulas for computing beams and columns, and tables giving required sizes for beams and columns under different conditions of loading.

435. Timber connectors, such as shown in Fig. 253, are manufactured and distributed by the Timber Engineering Company.§ They were introduced in this country by the National Committee on Wood Utilization of the United States Department of Commerce. Typical uses for the different types of connectors shown in Fig. 254 include timber-to-timber joints, timber-to-steel joints, and the joining of sawn lumber to round

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* McGraw-Hill Book Company, New York.

† Superintendent of Documents, Washington, D. C.

‡ John Wiley & Sons, New York.

§ 1337 Connecticut Ave., Washington, D. C.

piles. The connectors either fit into pre-cut grooves or are imbedded in the wood by pressure.

436. Split-Ring Connectors. The favored type of connector for truss work is the split ring, owing to its high load capacity and ease of installation. The chords and some of the web members are made of multiple timbers; the component parts of one member alternate with those of other members and are joined by split-ring connectors. The inner surfaces of these rings are beveled slightly from the center toward each edge to facilitate fitting the rings into the grooves, which are cut with a special cutter to one-half the depth of the ring in each timber. The object of the split is to double the bearing, for as the wood seasons the ring adjusts itself so that the bearing is equally effective on the inner surface of one-half the ring and the outer surface of the remainder. The timbers and the rings are held in place by through bolts with washers. The bearing on the rings distributes the stresses quite satisfactorily and gives greater efficiency than the joints previously used. Three sizes of rings are made, having diameters of 2½″, 4″, and 6″, one or more rings being used in each joint depending upon the number of pieces connected and the stresses to be carried. The bearing value depends upon the kind of wood and the direction of the grain. The "Manual of Timber Connector Construction" issued by the makers gives the necessary design

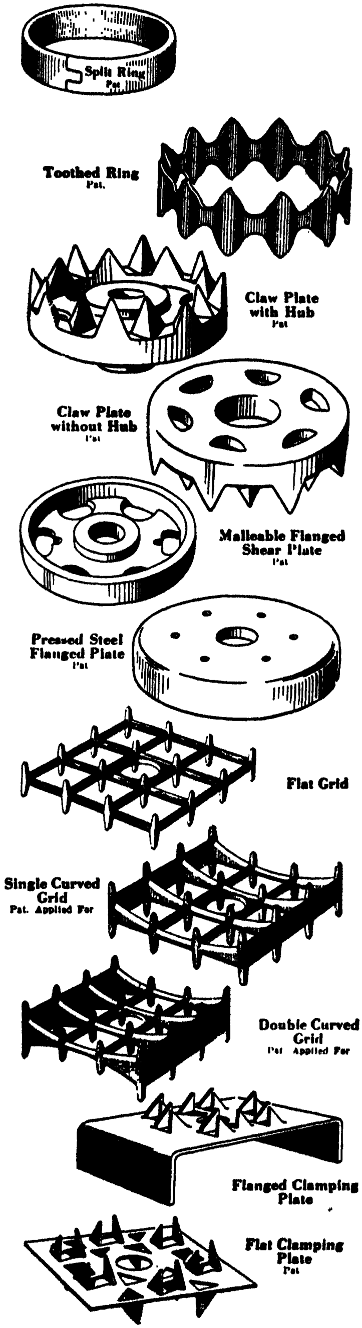


Fig. 253. Timber Connectors.

data, including the size of the connector, the size of the bolt, the minimum sizes of lumber, and the allowable load for each different kind of connector.

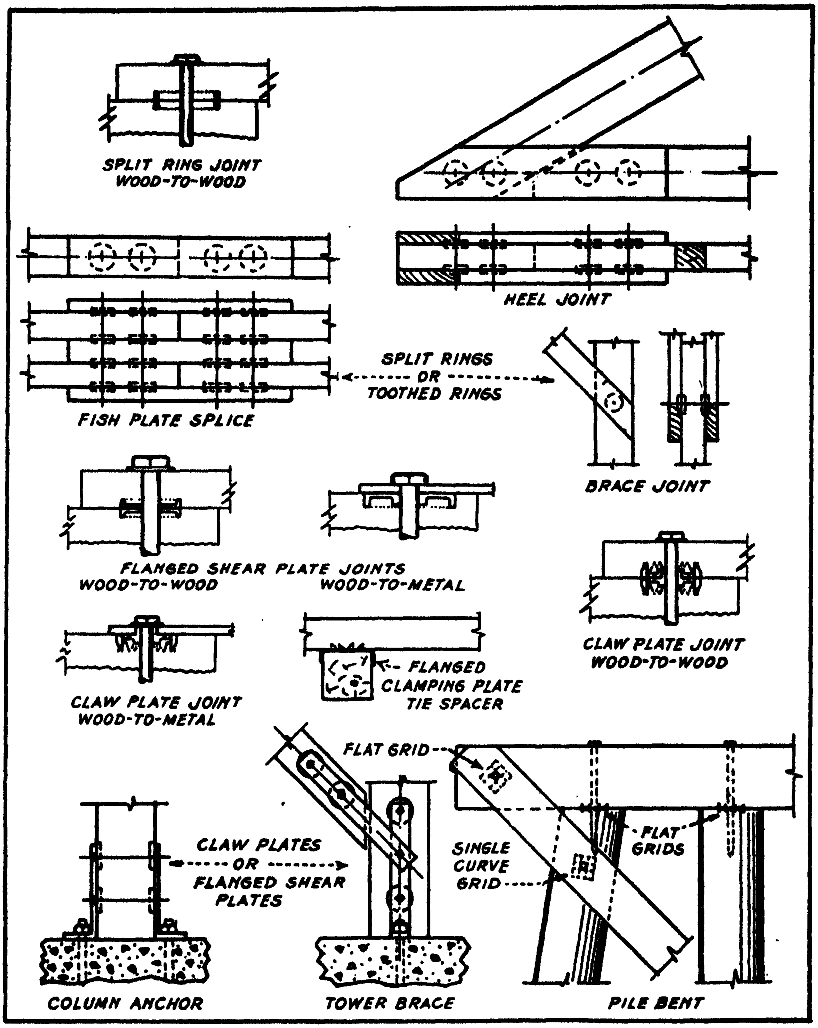


Fig. 254. Typical Joints with Timber Connectors.

437. Typical details for a bridge truss are shown in Fig. 255, and a typical drawing for a roof truss in Fig. 256. Drawings of many other typical structures may be obtained from the Timber Engineering Company.

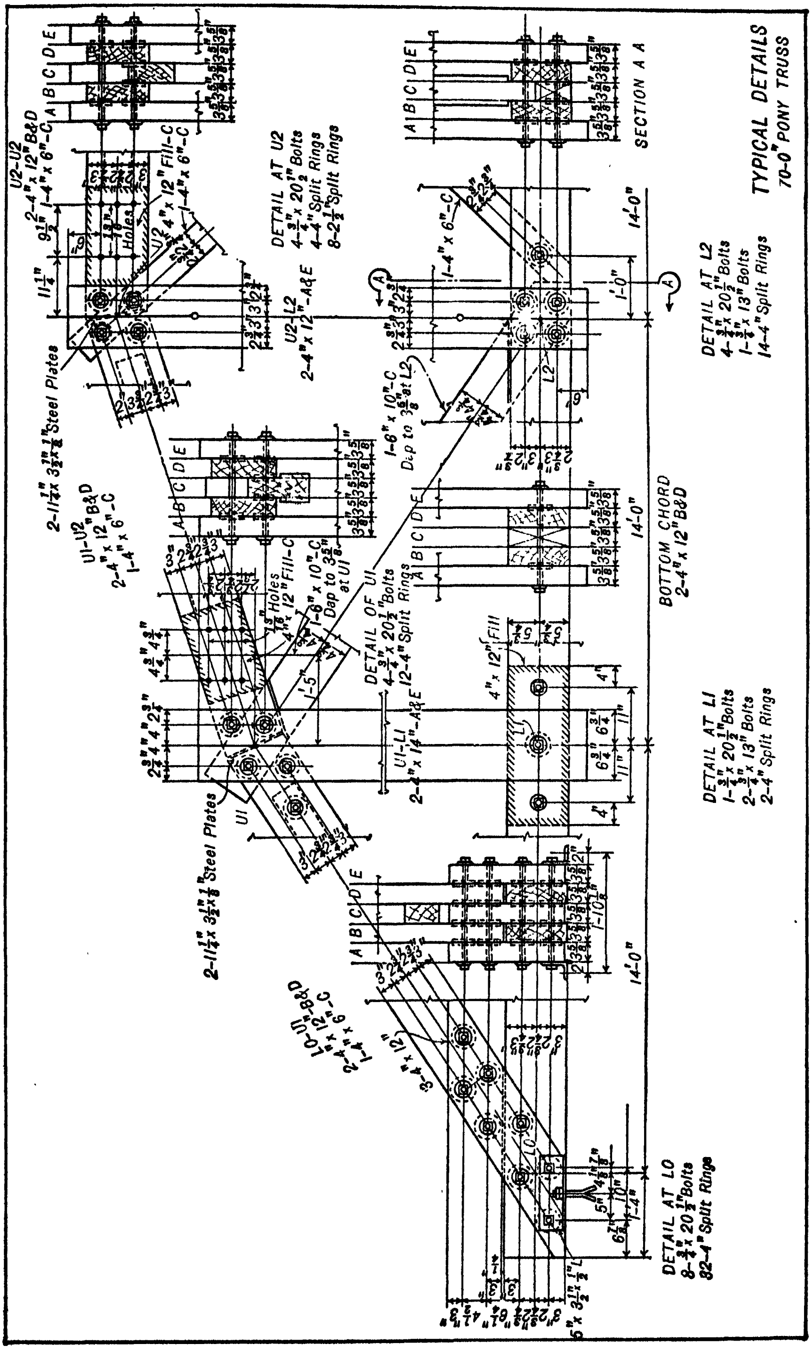
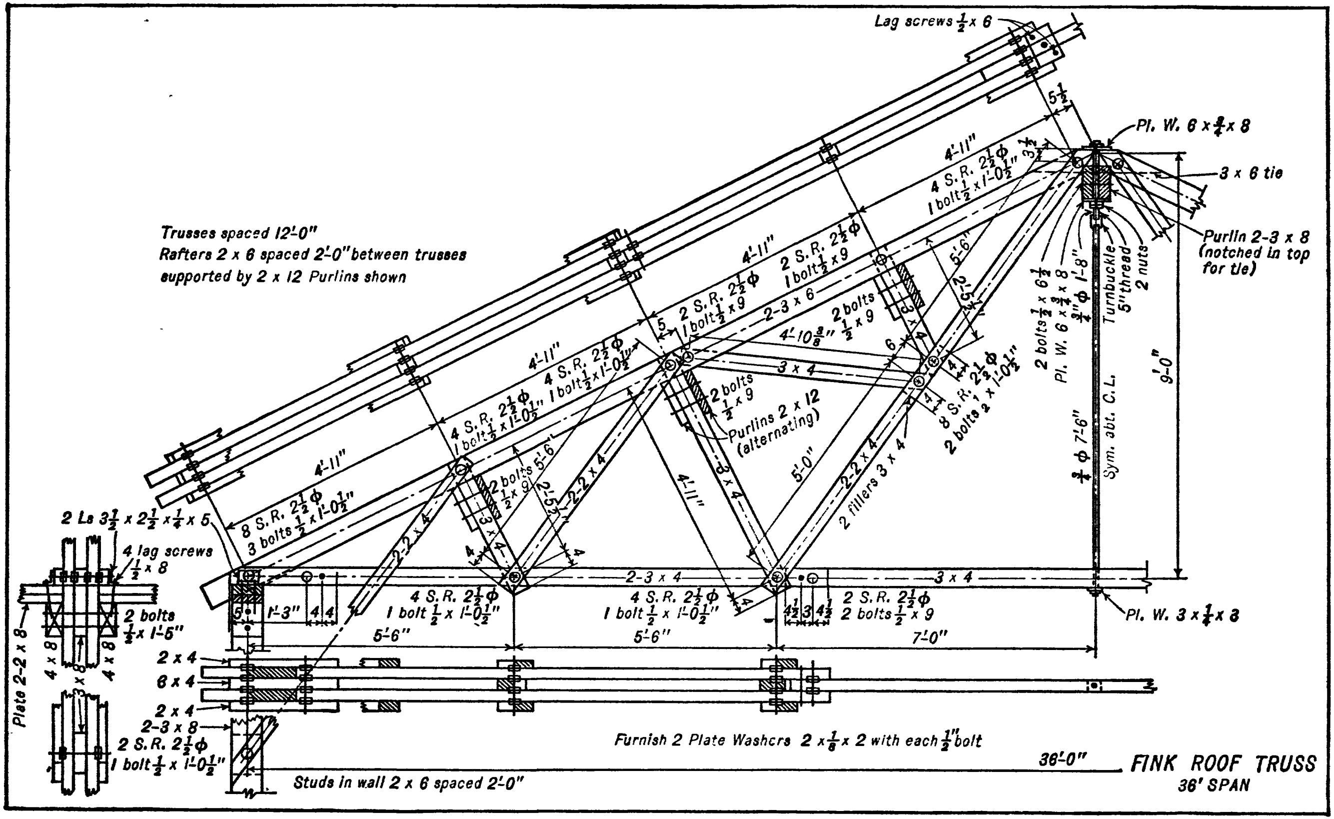


Fig. 255. Typical Details of a Bridge Truss with Timber Connectors.



Trusses spaced 12'-0"
Rafters 2 x 6 spaced 2'-0" between trusses
supported by 2 x 12 Purlins shown

Furnish 2 Plate Washers 2 x $\frac{1}{8}$ x 2 with each $\frac{1}{2}$" bolt

FINK ROOF TRUSS
36' SPAN

Fig. 256. Roof Truss with Timber Connectors.

CHAPTER XXXI

GLOSSARY OF ENGINEERING TERMS

438. In this chapter are summarized **brief definitions** of many of the engineering terms used in this book. Since the book is arranged for reference, assignments to students are given to scattered paragraphs rather than consecutive ones. Thus the students may encounter certain terms which lack significance although they may have been defined in previous paragraphs not yet assigned. Since the average student does not have convenient access to dictionaries which give the engineering meanings of many of these terms, it has seemed wise to provide definitions sufficient to explain the use of the less obvious words in the text. It is hoped that the students will be encouraged to consult these pages whenever the meaning of an engineering term is not fully comprehended. No attempt has been made to include every interpretation of the words defined, or to define such common words as " bridge " or " building."

Abutment. The masonry support at the end of a bridge or arch.

Advance Bill. Same as Material Order Bill.

Alloy Steel. Steel to which has been added silicon, manganese, nickel, or other element to give greater strength.

Anchor. A device for fastening steelwork to masonry.

Anchor Bolt. A bolt which fastens steel columns, girders, etc., to masonry.

Anchor-Bolt Plan. A drawing which shows the location of anchor bolts.

Angle. A common structural-steel shape the cross section of which is in the form of a right angle.

Anneal. The process of softening metal or making it more uniform by heating and cooling slowly.

Architects' Scale. A measuring scale graduated for convenience in plotting dimensions in feet, inches, and fractions of inches, as distinguished from an engineers' scale.

Assembling. Putting the component parts of a member together in the shop preparatory to riveting or welding.

Assembling Marks. A system of marks used on the component parts of a member to facilitate assembling in the shop.

Back-Check. To approve or check the corrections of a checker.

Baltimore Truss. See page 171.

Bar. A round, square, or deformed rod used to reinforce concrete.

Base Angle. An angle which connects the bottom of a column to the base plate.

Base Plate. A distributing plate or steel slab upon which a column bears.

Batten Plate. A plate to hold the component parts of a member at the proper distance apart. It is often used in conjunction with lattice bars.

Beam. A member which resists flexure or cross bending.

Beam Girder. A member composed of two or more beams fastened together by means of cover plates or bolts with separators.

Bearing. The support upon which a member rests. The resistance to crushing offered by a member which bears against another or upon a support, or by a component part of a member which bears on a rivet or a pin.

Bearing Plate. A plate used to distribute the bearing over a greater area, as at the end of a wall-bearing beam.

Bearing Value. The amount of pressure in bearing, either total or per unit of area.

Bending Moment. A term which expresses the measure of the tendency of a beam to bend. It is the sum of the moments of all external forces on one side of the point of moments.

Bent. A vertical frame or truss used to support other members.

Bevel. The slope of a line with reference to another line.

Beveled Washer. A cast washer arranged to fit a slotted hole and give proper bearing for the nut on a rod which passes through a member at other than a right angle.

Bill. A list of material, such as a shop bill or shipping bill. To prepare such a bill. Also to express the size of a component part of a member on a drawing.

Binder. A lateral tie or hoop used to prevent the spread of the longitudinal reinforcing bars in a concrete column.

Blast Furnace. A furnace in which iron ore is reduced to pig iron.

Block and Tackle. A set of pulley blocks with ropes used for hoisting.

Block Out. To cut out part of a member by means of a rectangular punch or other means.

Blueprint. The form of reproduction of a drawing commonly issued from the drafting department. Blueprints are made from the drawings by exposing sensitized paper to light.

Board Measure. Lumber is measured in units of one foot board measure, equal to one-twelfth of a cubic foot, two dimensions being taken in feet and the third in inches. The abbreviation M.B.M. stands for "thousand feet board measure."

Bolt. A cylindrical fastening with a head at one end and a thread and nut at the other. An ordinary bolt is termed a rough bolt to distinguish it from a turned bolt which is machined.

Bore. To enlarge a punched hole by means of a cutter which accurately pares the inner surface to fit a pin.

Box Dimensions. The dimensions of a rectangular box which would completely contain a member as shipped. Such a box is seldom used, but the extreme dimensions of a member are used in planning shipping space.

Box Girder. A compound girder with two or more web plates, which with coverplates form a closed box.

Box Section. A member in which the component parts enclose a space which is accessible only at the ends.

Brace. An inclined member placed between other members to make a structure more rigid.

Bracing System. A series of diagonals and struts placed between main members to resist wind or other lateral forces.

Bracket. A projecting type of connection usually made of a plate and angles.

Buckle. To bend or bow transversely under the effects of a force.

Buckle Plate. A steel plate which is buckled or dished at regular intervals to increase its resistance to transverse bending.

Building Code. A compilation of the laws and ordinances of a city which relate to building construction.

Butt Joint. A joint in which the ends of the parts connected are cut to bear against each other. The ends are held in place by splice plates, or by welding.

Butt Weld. A type of weld in which the edge or end of a piece is welded to the edge or end of another piece so that the pieces are in line.

Button Head. A rounded head of a rivet or bolt as distinguished from one that is countersunk, square, or hexagonal.

Camber. A comparatively flat vertical curve placed in a truss or girder to counteract the sag.

Cantilever Beam or Girder. A beam or girder which projects beyond one or both supports. A cantilever beam may have one end imbedded in a wall and the other end unsupported.

Cap Angle or Cap Plate. An angle or plate at the top of a column or portion of a column.

Casting. Anything formed by pouring molten iron, steel, or other material into a mold and allowing it to harden.

Center of Gravity or Centroid. That point through which the resultant of the parallel forces of gravity acting upon a body in any position must pass. If the body could be supported at this single point it would remain in equilibrium in any position.

Center Punch. A cylindrical piece of steel with a sharp point protruding from one end. It is inserted in the holes of templets and struck with a hammer to make dents in the steel to indicate where holes are to be punched.

Change Order or Change Slip. An order issued to make changes in the material already ordered from the mills.

Channel. A common structural-steel shape the cross section of which is similar to that of an I-beam except that the flanges are on only one side of the web.

Check. To approve the correct portions of a drawing and indicate the mistakes. To verify.

Check Marks. Small v-shaped marks or dots placed over dimensions or other quantities to indicate that they have been checked.

Checker. A person in the drafting room who checks drawings made by others.

Checkered Plate. A steel plate with raised ribs to prevent slipping. Used for floors, stair treads, etc.

Chip. To cut off projecting parts, as with a pneumatic chisel.

Chord. The main top or bottom member, or line of members, in a truss.

Chord Member. That part of the chord of a truss which is shipped separately.

Clear Span. The length of a span from face to face of abutments or other supports.

Clearance. A space left between members, or parts of members, to allow for inaccuracies in cutting and to facilitate placing them in position.

Clevis. A forging used to connect a clevis rod to a plate or angle. The clevis is arranged to screw on the end of the rod, and the plate is inserted between two flattened ends through which a pin is passed.

Clip. A small connection angle.

Column. A long member, usually vertical, which resists compression. It is the principal vertical member in a building.

Column Base. The base plate, slab, or pedestal upon which a column stands, together with the connecting angles or plates.

Column Schedule. A drawing upon which is summarized information regarding the composition and the lengths of different sections of the columns in a tier building.

Combination Sheet. A printed form upon which a drawing, a shop bill, and a shipping bill are combined.

Compass. A drawing instrument for drawing circles.

Component. One of two or more parts into which a force or stress may be resolved. The force or stress is the resultant of its components.

Compression Member. A member in which the principal stresses tend to compress or shorten the member.

Concrete. A mixture of cement, water, sand, and course aggregate (crushed stone) which hardens in forms to make structural members, slabs, walls, etc.

Connection Angle or Connection Plate. An angle or plate for connecting other parts. Connection angles are often used in pairs.

Continuous Beam or Continuous Girder. A beam or girder which rests upon more than two supports.

Contraflexure. A change in the direction of bending in any member.

Cope. To block out or flame-cut part of the flange at the end of a beam to avoid its interference with another member.

Cored Hole. A hole in a casting made by means of a core in the mold which prevents the metal from flowing into the space.

Corrugated Iron or Steel. Thin sheets of iron or steel which are stiffened by having corrugations rolled in them. They are used for covering the roofs and the sides of a building.

Cotter Pin. A cylindrical steel pin held in place by a split steel key or cotter placed through a hole in the pin.

Counter. An adjustable diagonal placed across one of the panels near the center of a bridge in the opposite direction from the main diagonal tension member in the same panel. Its function is to relieve the main diagonal from stresses which might cause compression under certain positions of the live load.

Countersink. To ream a hole to receive the conical head of a rivet, bolt, or screw so that the head will not project beyond the face of the part connected.

Cover Angle. A splice angle placed inside another angle with both legs in contact.

Cover Plate. A plate riveted or welded to the flanges of a girder or compression member to increase the area of cross section.

Crane. A hoisting machine arranged to move heavy loads both vertically and horizontally. An overhead traveling crane is commonly used in mill buildings, being supported by longitudinal girders on opposite sides of the building.

Crane-Clearance Diagram. A diagram made to show a crane manufacturer the principal column, truss, and knee-brace dimensions so that his crane can conform.

Crane Girder. A girder which supports one of the rails upon which a traveling crane runs. Also a girder of the crane itself.

Crane Stop. A cast or built-up block attached to a crane beam or girder to stop a crane at the end of a runway.

Crimp. To offset the end of an angle by forging so that it can overlap another angle without the use of a filler.

Cross Bracing. Bracing with two intersecting diagonals.

Cross Frame. Vertical transverse cross bracing between deck-bridge girders.

Cross Section. A transverse section. Also a view representing the appearance of a structure or member where cut by an imaginary section plane.

Crosshatch. To draw fine sloping lines signifying a cross section.

Curved Ruler. A guide along which irregular curved lines may be drawn.

Dap. To notch a timber to fit over another timber.

Data Sheet. A sheet upon which are given the necessary data for the manufacture of cranes, elevators, etc., that they may be made to conform to the building requirements.

Dead Load. The comparatively constant static load on a structure due to its weight, etc., as distinguished from the live or moving load.

Deck Bridge. A bridge in which the floor loads are applied along the top chord.

Deflection. A lateral movement at right angles to the principal axis of a member. Also the linear measurement of such movement.

Deformed Bar. One of many types of reinforcing bar which is rolled with projections to increase the bond to the surrounding concrete.

Derrick. A hoisting machine so pivoted that a load may be swung horizontally.

Design. To proportion one or more members or parts of a structure to fulfill the requirements properly. Also the act of designing or the results thereof.

Design Sheet. A drawing prepared by a designer to show the principal dimensions of a structure and the sizes of the designed members.

Designer. One who designs; the title given to one whose principal duty is to design structures.

Detail. To make a detailed working drawing. Also a connection or other minor part of a member in contradistinction to the main member.

Detailer. One who details; the title given to a draftsman who makes detailed working drawings.

Develop. In drafting, to represent a bent or curved plate as if it were flattened into a plane. In designing, to make a connection fully as strong as the part connected.

Diagonal. An inclined member of a truss or a bracing system.

Diagram. An outline drawing in which each member is usually represented by a single line, as in an erection diagram or a stress diagram.

Diaphragm. A stiffening plate or similar part placed between the webs of a member, or from one member to another.

Die. A steel form used in forging or cutting any piece.

Dimension. A linear measurement indicated on a drawing upon a dimension line which shows its extent and significance.

Dolly Bar. A tool for holding a rivet in place while the opposite end is being hammered to form the second head.

Double Shear. The tendency to shear, or the resistance to shear, in two planes.

Drafting. Making working drawings, usually including the design of the details.

Drafting Machine. A machine with two scales held at right angles to each other by a system of arms forming parallelograms so that the scales can be moved in any position to facilitate drafting.

Draftsman. One who drafts or makes working drawings; the title usually includes one who checks drawings.

Drift Pin. A tapered pin used in handling or assembling members in the shop or in erection; it is driven into the holes to bring them into alignment and often left to supplement the bolts until the rivets are driven.

Drill. To make a hole by means of a rotating cutting tool or drill.

Driving Clearance. The minimum distance from the center of a rivet to the nearest projecting part which might interfere with the use of the machine which drives or upsets the rivet to form the head.

Driving Nut. A nut which is temporarily screwed on the end of a bridge pin to protect it while it is being hammered into position.

Eave Strut. A longitudinal strut between the tops of the columns of a building at the eaves.

Eccentric Connection. A connection in which the line of action of the resultant stress does not pass through or near the center of the group of connecting rivets.

Eccentricity. The perpendicular distance from a resultant force to some other point or line.

Edge Distance. The perpendicular distance from the center of a rivet or a hole to the edge of the piece which contains it.

Effective Depth. The depth between centers of gravity of the chords or the depth, between the centers of pins.

Effective Length or Effective Span. The length of span measured from center to center of bearings or supporting members.

Elevation. The vertical distance from a reference surface or datum. Also a drawing or view which represents the projection of a structure or member upon a vertical plane.

End Post. The vertical or inclined compression member at the end of a bridge truss.

Engineers' Scale or Decimal Scale. A measuring scale graduated in inches and decimals of an inch, as distinguished from an architects' scale.

Equilibrium. The forces which act upon any body are said to be in equilibrium when they so balance each other that the body has no tendency to move.

Erasing Shield. A thin shield containing holes of different shapes through which parts of a drawing may be erased without disturbing the adjacent parts.

Erection. The assembling and the connecting of the different members of a structure in their proper positions at the site.

Erection Bolts. Bolts used in erection to hold members in position temporarily until the field rivets or welds are placed.

Erection Clearance. Clearance between members provided to facilitate erection.

Erection Diagram or Plan. An assembly diagram made to show the interrelation between the members of a structure to guide the erector in placing them in the proper position. The term plan more strictly applies to a floor plan or other horizontal projection than to elevation, but often all are referred to as plans.

Erection Mark. An identification mark which aids the erector in properly locating a member; same as Shipping Mark.

Erection Seat. A seat angle riveted or welded to a supporting member to support a girder or similar member during erection.

Erector. The person in charge of erection, or collectively the men who erect a structure.

Erector's List. A list of field rivets and bolts required to make the necessary field connections in a structure.

Estimate. To compile the quantities, weights, and cost of a structure as a basis for bidding.

Expansion Bolt. A bolt for attaching steel work to a masonry wall. The bolt is surrounded by a split sleeve which expands in the masonry as the bolt is tightened.

Expansion Rollers. A group of steel cylinders or segments of cylinders placed under the end of a bridge girder or truss to provide for free longitudinal movement on account of temperature changes.

Extension Figures. Cumulative dimensions from a given point used to locate several connections with the same position of the tape; they may be placed on broken lines or on the same line with arrows in one direction only except at the reference point.

Eyebar. A flat bar of rectangular cross section which is upset at each end to form an enlarged head; a hole is punched and bored in this head for the insertion of a pin.

Fabrication. The shopwork required to convert the rolled shapes into complete structural members, or in short, the work done in a structural shop.

Face. To plane or smooth a surface. Also the exterior plane surface of any solid.

Falsework. A temporary trestle for supporting a structure during erection or demolition.

Fan Truss. See page 130.

Field. A term applied to the work done on parts of a structure at or near the site, in contradistinction to work done at the shop.

Field Check. A partial checking of the drawings of a structure to insure the proper connection of the members in the field.

Field Connection. A connection of different members in the field.

Field Rivet or Field Weld. A rivet or weld placed in the field, as distinguished from a shop rivet or weld.

Filler. A plate used to fill a space between two surfaces.

Fillet. The additional metal which forms the curve at the junction of the flange and the web of a rolled shape.

Fillet Weld. The type of weld inserted in the corner formed by two surfaces at right angles.

Finish. To smooth a surface by planing or milling; to face.

Fink Truss. See page 129.

Fitter. A shop workman who assembles the component parts of a member and bolts them in position.

Flame. An oxyacetylene flame or torch used for cutting steel by burning a narrow slot by means of an intense heat.

Flange. The wide part of a beam or similar shape at each edge of the web. Also the corresponding portion of a girder or column, each flange being composed of angles, plates, or both.

Flange Angle or Flange Plate. An angle or plate in the flange of a girder or similar member.

Flange Rivet or Weld. A rivet or weld which attaches the flange of a girder or column to the web.

Flexure. Bending; commonly applied to the bending of a beam or girder.

Floor Beam. A beam in a floor. Also a transverse beam or girder placed at the panel point of a bridge to support the longitudinal stringers.

Floor Plan. A plan showing the arrangement of the beams, etc., in a floor.

Floor Plate. A plate of a steel floor such as used in a furnace building.

Floor Slab. A reinforced-concrete floor supported by beams, girders, or columns.

Footing. The masonry pier or foundation for a column.

Force. That which tends to change the state of motion of a body. A force is known when its magnitude, direction, and point of application are known.

Forging. An article formed by being hammered while hot; often a die is used for shaping the article.

Foundation Plan. A plan showing the layout of the masonry foundations that support a structure.

Gable. The triangular portion of the end of a building between the opposite slopes of the roof.

Gage or Gauge. The transverse distance which locates the rivet line in the flange of a rolled shape. The gage is measured from the back of an angle, channel, or Z-bar, but between the rivet lines in a symmetrical shape such as a beam. Also the clear distance between the heads of the rails of a track, standard gage being 4.708′ or 4′-8½″.

Gantry. A self-propelled crane supported on two bents and traveling on two rails.

Gas Pipe. Small wrought-iron pipe often used in short lengths for separators.

Gin Pole. A guyed pole, nearly vertical, equipped with block and tackle for lifting loads.

Girder. A member usually made with a web plate and flanges composed of angles, plates, or both, used to resist bending due to transverse loads, as a beam.

Girt. A horizontal member in the side or end of a building used to support side covering such as corrugated steel.

Government Anchor. A short rod with a V-shaped bend in the center, used to anchor the end of a wall-bearing beam.

Grillage. Tiers of beams laid across each other and imbedded in concrete to form the footing for a heavily loaded column.

Grip. The combined thickness of metal connected by a rivet, a bolt, or a pin.

Gross Area. The full area of cross section, in contradistinction to net area.

Group Spacing. A number of equal spaces dimensioned together, as 4 of 6″ = 2′-0″.

Grout. A fluid mixture of cement, water, and sand which can be poured to fill small voids or to smooth or level a surface of a wall or footing.

Guard Rail. An auxiliary steel rail between the service rails, or a timber outside the service rails, for keeping a train on the ties of a bridge in case of derailment.

Gusset Plate. A connection plate which stiffens a connection, such as a plate which connects several members of a truss or a bracing system.

Hand Hole. A hole made in a large member for the insertion of a hand in placing bolts or rivets which would be inaccessible otherwise.

Hanger. A vertical tension member used to support a load.

H-beam. One of the smaller wide-flanged columns or beams as distinguished from an I-beam; sometimes used for a standard wide-flanged beam as well.

Heel Plate. A gusset plate at the heel, or main support, of a roof truss.

Hinged Shoe. A shoe arranged with a pin or roller to permit rotation due to the deflection of a truss so that the pressure on the abutment will be kept vertical.

Hip. The junction of the top chord of a truss with the inclined end post. Also the intersection of two roofs where the drainage is away from the intersection, as distinguished from a valley.

Hook. The curved end of a reinforcing bar formed to increase the bond to the concrete.

Hook Bolt. A bolt with a hook at one end instead of a head.

Hoop. A lateral tie or binder used to prevent the spread of the longitudinal reinforcing bars in a concrete column.

Howe Truss. See page 171.

I-beam. A common structural-steel shape the cross section of which is in the form of a letter I.

Impact. The increased effect of live loads when suddenly applied. Impact is usually provided for by adding a certain percentage of the quiescent live load.

Information Sheet. A sheet which may accompany a drawing to provide additional information.

Ingot. The form in which molten steel from the furnace is cast preparatory to rolling.

Initial Tension. The tension placed in counters and in diagonals of bracing systems to insure tightness.

Item Number. The serial number assigned to each different item that is ordered from the rolling mills.

Itemize. To add the item numbers and other mill information to a shop bill.

Joist. A beam which supports a wooden or concrete floor in a building.

Knee Brace. A short diagonal brace usually placed between a horizontal member and a vertical one.

Lag Screw. A large screw for wood, with a square head to be turned with a wrench.

Laminated. In layers, as a wooden member built of several thinner pieces nailed, bolted, or glued together.

Lateral. Sidewise, or at right angles to the principal axis. Also a diagonal member in a system of lateral bracing.

Lateral Plate. A connection plate in a system of lateral bracing.

Lattice Bar or Lacing Bar. One of a series of zigzagged or crossed flat bars riveted to separated component parts of a member to hold them in position.

Latticed Girder or Latticed Strut. A light parallel-chord truss similar to a plate girder except that the web plate is replaced by web members usually made of one or two angles each.

Latticed Truss. Formerly a timber truss with multiple-intersection diagonals. The term is now sometimes applied to any type of riveted truss with parallel chords to distinguish it from a pin-connected truss.

Laying Out. The marking of steel from templets or otherwise, indicating where the holes are to be punched and where special cuts are to be made.

Layout. A preliminary drawing or sketch by means of which distances may be determined by scaling.

Lean-to. A building with a roof which leans against another building or wall; the roof slopes in one direction only, the higher edge being against the other building.

Left. A member is so marked when made exactly opposite a corresponding member marked " right," the latter being represented on the drawing.

Leg. One of the two flanges or parts of an angle.

Lift Bridge. A bridge which can be lifted vertically or on trunnions, as a bascule bridge, in order to accommodate river traffic.

Linear. Pertaining to line or to length. A linear dimension is usually one measured parallel to the length of a member.

Lintel. A horizontal beam which supports a wall over an opening.

Live Load. A movable load on a structure.

Locomotive Crane. A self-propelled derrick mounted on a car; often applied to a derrick mounted on a truck or caterpillar tread.

Loop Rod. A rod with a loop at the end through which a pin may be passed.

Louvres. A series of horizontal strips of bent sheet steel arranged along the sides of a monitor to provide ventilation and at the same time to exclude rain or snow.

Lug. A small projecting connection, as a connection angle.

Lump Sum. A price basis for a contract, as distinguished from a price per pound.

Masonry Plate. A bearing plate placed on masonry.

Material Order Bill or Mill Order. A list prepared in the drafting room showing the material to be ordered from the rolling mills or elsewhere.

Member. A part of a structure which is completely assembled in the shop and shipped to the site where it is combined with other members.

Mill. The machine or the plant in which plates and shapes are rolled. Also to plane the end of a member by means of a rotary planer or milling machine.

Mill Building. A steel-framed building with a roof of comparatively large pitch and span, but usually without partitions, intermediate floors, or interior bracing (except knee braces).

Mill Variation. Rolling and cutting tolerances in size or length as practiced in the rolling mills in filling orders.

Milled Joint. A joint in which the connected parts are milled or planed to bear against each other.

Milling Machine. A machine for milling or planing the end of a member for uniform bearing.

Mitered Joint. A joint in which the angle between the connected parts is bisected by the plane of contact.

Moment of Inertia. A term applied to the sum of the products of the elementary areas of a given cross section by the squares of their distances from a given axis about which the moment of inertia is said to be taken.

Monitor. The raised portion of a roof of a mill building or similar structure, arranged to give additional ventilation or light through the louvres or windows in the sides.

Multiple Punch. A machine arranged to punch two or more holes at once.

Nailing Strip. A strip of wood bolted to a steel beam or other member, to which strip wooden flooring or sheathing is nailed.

Net Area or Net Section. The effective area of metal in a cross section. The rectangular areas of all rivet holes cut by the section are deducted from the gross area of the member or part of member under consideration.

Office Building. A steel-framed building with intermediate floors and columns and a comparatively flat roof.

O. G. Washer. A flat round cast-iron washer commonly used under a bolt head or nut to bear on timber or masonry. One face is of smaller diameter than the other, and a reverse curve or " ogee " curve connects the two.

Order Bill. A material order bill.

Ordered Length. The length of a steel piece as ordered from the mill.

Ore. The raw material obtained from the mines, such as the iron oxides from which pig iron is obtained.

Orthographic Projection. See page 26.

Outlooker. A small angle or similar piece fastened to an end purlin of a building to support the roof which overhangs the gable end.

Overrun. The increase in the actual size of a structural shape above the size indicated on the drawing or order bill.

Oxyacetylene Flame or Torch. An outfit used for cutting steel by burning a narrow slot by means of an intense heat.

Packing. The arrangement of the different members on a pin.

Panel. That part of a truss between panel points.

Panel Point. The intersection of the working lines of different members of a truss.

Parabola. A curve in which the ordinates vary as the squares of the abscissas, or conversely. For the construction, see "Structural Design," page 73.

Parker Truss. See page 170.

Pattern. A wooden model for a casting, used in forming the mold.

Peak. The top point of a roof truss where the top chords meet.

Pedestal. A cast-steel stool or support for a bridge girder.

Pettit Truss. See page 171.

Piece Mark. An assembling mark.

Pier. An intermediate masonry support for a bridge. Also a column footing.

Pig Iron. The iron tapped from a blast furnace in a form suitable for castings or for conversion into steel.

Piles. Logs or steel shapes driven into soft ground to give greater support for the foundations of a structure.

Pilot Nut. A tapered nut which is temporarily screwed on the end of a bridge pin to guide it while it is being driven into position.

Pin. A steel cylinder used for connecting the members of a truss, or similarly.

Pin Plate. A reinforcing plate riveted or welded to a truss member to give greater bearing on a pin.

Pitch. The longitudinal distance between adjacent rivets in the main part of a member. Also the ratio of the center height of a roof truss to the span.

Plan. A drawing which represents the horizontal projection of a structure or part of a structure. Often less accurately used for any general drawing of a structure whether plan or elevation.

Plane. To smooth to a plane surface.

Plate. A flat piece of rolled steel of rectangular cross section.

Plate Girder. A member made with a web plate and flanges composed of angles, plates, or both, used to resist bending due to transverse loads, as a beam.

Pneumatic Tools. Tools made to operate with compressed air, as a chisel for cutting off projecting parts, a hammer or riveter for driving rivets, or a fluted reamer for enlarging holes.

Pony Truss. A bridge truss which is not deep enough to permit the use of overhead bracing between the trusses.

Portal Bracing or Portal Strut. Transverse bracing in the plane of the end posts of a bridge.

Post. A comparatively small compression member, usually vertical.

Pound Price. A price basis for a contract based upon a cost per pound, as distinguished from a lump sum.

Pratt Truss. See page 170.

Primary Stress. A stress caused by dead or live loads for which a member is designed, as distinguished from a secondary stress due to the deformation of a structure, or similarly.

Projection. See page 26.

Projection Line. A line drawn at right angles to a dimension line to indicate the extent of the dimension.

Punch. To make a full-size hole with a single stroke, as distinguished from drilling or boring. Also a punching machine.

Purlin. A horizontal longitudinal member which rests on the top chords of a roof truss to support the roof.

Radius of Gyration. The term commonly assigned to a certain mathematical expression. For a given cross section, the radius of gyration about any axis is equal to the square root of the quotient of the moment of inertia about the same axis divided by the area.

Rafter. An inclined member parallel to the roof slope which is used either to support the purlins in place of a truss, or to rest upon the purlins to carry the roofing.

Rail Clamp. A device for fastening a crane rail to the flange of a supporting girder.

Ratio of Slenderness. The ratio of the length of a compression member to the least radius of gyration of its cross section.

Reaction. The force on a beam, girder, or truss imparted by the support to balance the loads. It is equal and opposite to the pressure of the beam on the support.

Ream. To enlarge a hole by means of a rotating fluted cutter.

Reinforced Concrete. A combination of concrete and steel reinforcing bars.

Reinforcing Bar. A round, square, or deformed rod used to reinforce concrete.

Reinforcing Plate. A plate used to strengthen the weaker part of a member to develop the strength of the remaining parts, such as a plate riveted or welded to the web of a member to give greater bearing on a pin.

Resistance Weld. A weld made by fusing parts together under pressure when heated by a localized current; used chiefly in pressed-steel work.

Resisting Moment. The moment of the internal forces or stresses which resist the bending moment on a beam or girder.

Restrained Beam. A beam which is restrained or " fixed " at a support.

Resultant or Resultant Force. The simplest single force or system of forces which can replace a system of forces and have an equivalent effect.

Reversal of Stress. The change of stress from tension to compression, or vice versa.

Ridge Strut. A longitudinal strut along the ridge or peak of a roof.

Right. A member is so marked when another member marked "left" is to be made exactly opposite, from the same drawing.

Right Section. A section at right angles to the principal axis.

Rigid Frame. A bent made with rigid joints between the beam or girder and the columns or legs. The stiffness of the legs, when fixed horizontally at the bottoms, reduces the bending moment at the center of the girder.

Rivet. A short cylindrical rod of steel with upset heads used to rivet or fasten together component parts of a steel structure. One head is formed before the rivet is put in position, the other afterward.

Rivet Code. The conventional representation of rivets under different conditions.

Rivet Line. A line through the centers of a series of rivets.

Rivet Pitch. The longitudinal distance between adjacent rivets which fasten the main component parts of a member together.

Rivet Spacing. The dimensions which locate the centers of rivets.

Riveter. One who rivets or operates a riveting machine. A riveting machine. Also an instrument for drawing small circles to represent rivets, often called a riveting pen.

Rocker. A hinged shoe with a pin or other device to prevent unequal distribution of pressure upon the masonry when the supported girder or truss deflects.

Rod. A rolled bar of steel with round or square cross section.

Roller. A steel cylinder or segment of a cylinder placed under one end of a bridge girder or truss to facilitate longitudinal movement due to temperature changes. Groups of rollers are held in place in a roller box, the whole forming a roller nest.

Rolling Mill or Steel Mill. The machine or the plant in which steel is rolled into plates and commercial shapes.

Rotary Planer. A machine for planing or milling the end of a member for uniform bearing.

Round. A round rod.

Ruling Pen. An instrument for drawing ink lines.

Sag Rod. A vertical or inclined tie rod used to reduce the sagging of a girt or a purlin.

Sawtooth Roof. A roof arrangement providing for sky light without direct sunlight. The vertical or steeper slopes are glazed, but the smaller slopes toward the sun are covered with roofing material.

Scale. A flat or triangular measuring stick used in plotting a drawing in proportion to the thing represented. Also this proportion.

Seat Angle. A small angle riveted or welded to one member to support the end of another member.

Secondary Stress. An indirect stress which results because the ideal conditions which are assumed in the calculation of the principal or primary stresses are not realized, such as deformation stresses caused by the deformation of a truss.

Section. A cut across a member or structure made by an imaginary section plane. Also used in place of "sectional view."

Section Lines. Fine sloping lines used to shade an area cut by a section plane; in modern practice these lines are often omitted in sectional views.

Sectional View. The projection of one segment of a member or structure upon a section plane.

Selvage Edge. The original woven edge of a piece of cloth where the threads are closer together than in the body of the cloth.

Separator. A plate, casting, or piece of gas pipe placed between the webs of beams to keep them a fixed distance apart.

Shafting. Rotating round rods used in conjunction with belts for transmitting power mechanically from one source to different machines.

Shank. The cylindrical part of a rivet or bolt, as distinguished from the head.

Shape. A general term for structural rolled steel of any cross section other than a plate.

Shear. To cut by shearing. The machine used for shearing steel plates or angles (usually plural). Also an expression for the algebraic sum of certain forces which tend to shear a member.

Sheared Plate. A plate which is rolled between two rolls and then sheared to the desired width at the mill, as distinguished from a Universal Mill plate.

Sheathing. A wooden covering of planks or boards.

Shipping Bill. A list of members to be " shipped " or transported from the shop to the site.

Shipping Mark. An identification mark assigned to each separate member to be shipped.

Shoe. The part of a bridge that transmits the load from the end pin of a truss to the bearing plate or rollers.

Shop. The place where the component parts of a structure are fabricated into members.

Shop Bill. A summary of material required for fabricating members in the shop.

Shop Drawing. A working drawing prepared for use in the shop.

Shop Paint. The coat of paint applied at the fabricating shop.

Shop Rivet. A rivet which is driven in the shop, as distinguished from a field rivet driven at the site.

Simple Beam. An unrestrained beam which is supported at both ends only.

Single Punch. To punch one hole at a time.

Single Shear. The tendency to shear, or the resistance to shear, in one plane.

Site. The final location of a structure.

Sketch Plate. An irregular plate which is cut to dimension at the mill according to a sketch.

Sketch Sheet. A small sheet or printed form upon which a drawing is made.

Skew Back. An auxiliary angle or other support on the web of a beam for a floor slab or arch. Also a bent plate or casting used to attach a diagonal rod.

Skew Bridge or Skew Span. A bridge or span which does not cross a stream or roadway at right angles; the end of one truss or girder is not opposite the end of the other.

Skew Portal. The portal or portal bracing at the end of a skew bridge.

Skids. Parallel supports of timber or metal used to elevate members a convenient distance above the floor of a shop to make them more accessible.

Slab. A thick steel plate used as a column base or similarly. Also the portion of a reinforced-concrete floor between the supporting beams, girders, or columns.

Sleeve Nut. A long tubular nut having a right-handed thread in one half and a left-handed thread in the other, used for joining two rods and pulling them together to tighten them.

Slope. The bevel or inclination of one line with reference to another; it is measured by the tangent of the angle of inclination expressed in inches and fractions to a base of one foot.

Slot Weld. A weld made in a hole or a slot in one of the parts connected.

Slotted Hole. An elongated hole with semicircular ends and parallel sides.

Sole Plate. A plate riveted to the bottom of a girder to bear upon a masonry plate.

Span. The distance between the supports of a beam, girder, truss, etc. Also a bridge or similar structure which spans an opening.

Specifications. A set of clauses which prescribe the allowed unit stresses and give directions and restrictions regarding proper construction.

Spiking Piece. A wooden strip bolted to a steel beam or similar member to which strip planking or sheathing may be spiked or nailed.

Spiral. A small round or square rod bent in the form of a helix, used in reinforced-concrete columns to prevent the longitudinal reinforcing bars from spreading.

Splice. The joining of two similar members or segments of members in the same straight line.

Splice Angle or Splice Plate. An angle or a plate used in a splice.

Split Beam. A beam that is split to form a structural tee or bracket, or one split part way with one flange bent out to permit welding a plate in the web for strengthening the joint for rigid-frame construction.

Split-Ring Connector. A split ring used in modern timber construction to join timbers; the ring is inserted in a groove, one-half in each timber, and held in place by a bolt.

Spot Weld. A weld made by fusing parts together under pressure when heated by a localized current; used chiefly in pressed-steel work.

Squad Foreman. The person in charge of a drafting squad.

Staggered Rivets. Rivets which alternate on two parallel rivet lines.

Statical Moment. The product of an area by the distance from an axis to the center of gravity of the area.

Steel. A modified form of iron used in construction.

Steel Furnace. A furnace in which pig iron, scrap iron, etc., are formed into steel.

Stiffener or Stiffening Angle. An angle used to prevent a plate from buckling or to prevent a seat angle from bending. In welded members, a plate is used instead of an angle.

Stitch Rivets. Rivets used to hold the angles of a two-angled member together at intervals. If the angles are separated by connection plates, a washer is placed between them at each stitch rivet to maintain a constant space.

Straight-Edge. A thin strip of wood, metal, or celluloid with a straight edge used as a guide in drawing straight lines. It may be in the form of a triangle or T-square and serve other purposes as well.

Strain. The deformation in a member caused by external force. Strain is measured in linear units.

Stress. An internal force which resists the tendency of an external force to change the shape of a body.

Stress Diagram. A diagram by means of which stresses are determined graphically. Also a stress sheet showing the arrangement of members and the stresses in them.

Stringer. A longitudinal member which supports the track or the floor of a bridge; it is supported by transverse floor beams.

Structural Company. A company engaged in the construction of steel structures.

Structural Drafting. The preparation of the working drawings for the members in a structure, such as a bridge or a building, including the design of the details.

Structural Drawing. A working drawing from which members of structures are made.

Structural Shop. A shop where the rolled-steel shapes are punched, cut, riveted, welded, and otherwise prepared for use in a steel structure.

Structural Tee. A T-shaped member made by cutting a wide-flanged beam in two.

Strut. A comparatively light compression member, usually with no intermediate connection.

Subpunch. To punch a hole to a smaller diameter than required, subject to subsequent reaming after parts are assembled.

Substructure. The masonry abutments, piers, or foundation for a structure.

Superstructure. The main part of a structure above the masonry foundations or substructure.

Suspension Bridge. A bridge suspended from cables which are the main carrying elements.

Sway Bracing. Bracing in a vertical plane, as between the columns of a building or between the trusses of a bridge.

Swedge Bolt. An anchor bolt with a nut at one end but with elliptical depressions in the shank to furnish greater bond when imbedded in masonry.

Swing Bridge. A bridge which can be swung about a central bearing to permit the passage of river traffic.

Tack Weld. A small weld made to hold component parts of a member together until they can be welded more permanently.

Tamp. To compact concrete, dirt, or other material by pounding.

Tee. A structural-steel shape, the cross section of which is in the form of a letter T.

Templet. A piece of wood, cardboard, or steel upon which holes, cuts, etc., are laid out once, and used in transferring such marks to different steel pieces.

Tension Member. A member in which the principal stresses tend to lengthen the member.

Throat. The critical dimension in a weld which determines its strength. In a fillet weld it is the altitude of the isosceles triangle of the weld cross section.

Through Bridge. One in which the principal loads are applied to a floor system near the bottom, and the trains, trucks, etc., pass " through " the bridge between the trusses or girders.

Tie. A light tension member, such as the diagonal in a bracing system. Also a transverse timber which supports the rails of a track.

Tie Plate. A plate for holding the component parts of a member at the proper distance apart. Generally used in tension members or in conjunction with lattice bars.

Tie Rod. A short rod which ties the beams of a floor together when needed to counter act the thrust from a floor arch. Also a rod used similarly elsewhere.

Tier. A row or layer placed above or below a similar row or layer.

Tier Building. A multiple-story building, such as an office building or a loft building.

Timber Connector. A steel split-ring, toothed ring, claw plate, grid, or similar device used in modern timber construction for connecting timbers.

Top Angle. A connection angle used at the top of a beam in conjunction with a seat angle on a column.

Tracer. One who traces another drawing on tracing paper or tracing cloth. A title given to a person in a drafting room whose chief duty is to trace drawings made by others.

Tracing Cloth or Tracing Paper. A linen cloth or paper specially treated to make it transparent so that blueprints can be made from drawings on it.

Track. The rails, including their supports, along which a body or structure with wheels or rollers can be rolled. The track on a railway bridge includes not only the service rails and the ties, but also the steel and wooden guard rails, the bolts, spikes, and other fastenings.

Traveler. A form of derrick used in erection; it is mounted on wheels or similarly so that it can be advanced along a structure as the work progresses.

Triangle. A flat piece of celluloid or similar material used in drafting. The three edges form a right triangle, and the complementary angles are usually 45° or else 30° and 60°.

Truck Crane. A crane or derrick mounted on an automobile truck.

Truss. A framed structure which acts like a beam; the principal members form a series of triangles, and each member is primarily subjected to axial stress only.

T-Square. A T-shaped drawing instrument with a long, thin blade attached to a shorter, thicker head. The blade is used as a straight-edge for drawing parallel lines as the head is moved along the end of a drawing board.

Turnbuckle. Similar to a sleeve nut except that a transverse opening is provided at the center for the insertion of a crowbar for turning the turnbuckle.

U-bolt. A rod bent in the shape of a letter U with nuts on both ends.

Underrun. The decrease in the actual size of a structural shape below the size indicated on the drawing or order bill.

Unit Stress. The stress per unit of area, or the intensity of stress.

Universal Mill Plate or U. M. Plate. A plate rolled in a Universal Mill which is provided with vertical rolls as well as horizontal ones; a plate with rolled edges, as distinguished from a sheared plate.

Upset. To enlarge the end of a rivet, a rod, an eyebar, etc., by hammering or pressing into a die while hot.

Valley. The intersection of two roofs where the drainage is toward the intersection, as distinguished from a hip.

View. In orthographic projection, a view is the projection of an object upon a plane by means of parallel lines.

Wall Anchor. A rod or a pair of angles used to anchor a wall-bearing beam to a masonry wall.

Wall Plate. A bearing plate on a wall used to distribute the load from a steel beam or girder. Also a plate along the top of a beam to furnish bearing for a superimposed wall.

Warren Truss. See page 170.

Washer. Usually a flat disc with a central hole placed under the head or the nut of a bolt, or similarly.

Web. The web plate of a girder, column, or other built member, or the corresponding thin portion between the flanges of a beam, channel, etc.

Web Connection Angles. The angles at the end of a beam or girder used to connect to another member.

Web Member. An intermediate member of a truss or latticed girder between the chords.

Web Splice. A splice in a web or web plate.

Weld. To connect metal parts by fusion of the parts, with or without additional metal, the necessary heat being supplied by electric arc, oxyacetylene flame, or otherwise.

Welding Clearance. Necessary working space around a welded joint so that the electrode and the shield can be used to the best advantage.

Wide-Flanged Beam. A common structural-steel shape used principally as a beam or a column. It has a relatively wider flange than an I-beam.

Wind Bracing. A system of bracing which resists stresses induced by the wind.

Wind Bracket. A bracket used to stiffen a joint to resist stresses due to wind.

Working Drawing. A detailed drawing prepared for the men who make the members or parts represented.

Working Line. A reference line to which the dimensions of a member are referred; generally used in conjunction with the working lines of other members to form a system of working lines of a truss, a latticed girder, or a bracing system.

Working Point. The intersection of two or more working lines.

Z-Bar. A structural-steel shape the cross section of which is in the form of the letter Z.

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