PLUMBING

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BUILDING CRAFT SERIES

PLUMBING

BY

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WITH 64 DRAWINGS BY THE AUTHOR

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PREFACE

FACED with extraordinary demands on its capacity the building industry of this country will have to enlarge its personnel. In its turn the plumbing craft will have to expand to a size far larger than at any time in the past.

Craftsmen will have to be trained and the gradual but inevitable changes in technique will insist that the new craftsmen obtain some of their training through training courses. Thus there will be an increase in the number of students attending Junior Technical Schools for Building, Technical Colleges and Government Training Centres.

This book has been written for the beginner in the craft and should prove useful to a candidate for the City and Guilds of London Institute's Intermediate Certificate in Plumbers' Work.

No attempt has been made to include Geometry, Calculations or any detailed Science, for most students will be taking organized courses which will include special classes in these subjects. Sanitation, as such, and the long diatribes on ancient sanitary fittings, so often found in text-books on Plumbing, have been excluded and the book has been designed deliberately to deal only with the more practical aspects of plumbing as encountered in everyday life.

The variations in design and handling required when copper is used have been touched on, and as the use of hard metals develops so will the need for precision. As drawing encourages precision, and because it is desirable that a plumber should understand drawing, a chapter on drawing and sketching has been included.

I am indebted to Mr W. B. McKay, M.Sc., Head of the Building Department in the Manchester College of Technology, for his encouragement and for his practical help by allowing me to use certain of his drawings as a basis for mine and for his permission to adapt the chapter on drawing from one of his books.

I also wish to acknowledge the help I have received in the preparation of this book from Mr W. White, R.P., of Leeds, and Mr F. Hanson, R.P., a colleague of mine. Both these gentlemen have given me the benefit of their long experience in the plumbing craft.

R. H. W.

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In recent years a great deal of investigation into the best ways of using materials and executing work has been carried out, and the author has used publications of the following bodies as the source of much of his information :—

The Lead Industries' Development Council, Rex House, 38 King William Street, London, E.C.4.
The International Tin Research and Development Council, 378 Strand, London, W.C.2.
The Copper Development Association. *Temporary Address*—9 Bilton Road, Rugby.
The Institute of Plumbers. *Temporary Address*—252 High Street, Dorking.
The British Standards Institution, Publications Department, 28 Victoria Street, London, S.W.1.

The author also acknowledges the generous assistance given by the Yorkshire Copper Works and Messrs Claughtons, both of Leeds, in the preparation of those parts of the book connected with copper tubes and flushing tanks respectively.

CONTENTS

INTRODUCTION

The character of plumbing work. The need for skill and competence. Training.

It is desirable that a *student* should understand clearly the nature of the work of a plumber before commencing even the preliminary study of the details of plumbing.

In this book only those aspects of plumbers' work connected with building will be considered. These constitute by far the larger part of plumbing work, although plumbers are also employed in shipbuilding and in the chemical industry.

In a building under erection a plumber's work can be divided into two distinct sections, namely :—

1. External or roofwork.
2. Internal or pipework.

External plumbing consists of providing the means of preventing rain-water from entering the building, and also the collecting and removing of rain-water from the premises. The roof of a building may be constructed wholly of lead sheets laid over a wooden or similar foundation, or if the roof is slated or tiled the plumber will fix lead flashings to make watertight the joints where the slates or tiles meet brickwork. Gutters to roofs are often constructed in lead and these, together with the cast-iron gutters and down pipes (usually present round the eaves of roofs), are fixed by plumbers.

Internal plumbing is rather more complex in character than external work. The plumber here is called upon to fix various fittings such as wash bowls, baths, sinks and water-closets and provide the pipes supplying water to these fittings. He also has to provide the pipes which remove the waste water and matter from these fittings. Where these fittings require hot water, the installation of the necessary pipes as well as the means of heating forms part of a plumber's duties. Gas pipes, and fittings using gas, also come within the range of the work of a plumber, and he must also understand the principles of drainage for the pipes which remove waste matter from buildings discharge into drains, and the plumber is often called upon to lay drains ; particularly if the drain pipes are in metal.

From the preceding it will be seen that good plumbing work is essential if a building is to be fit for human habitation. The health of the occupants and indeed the community at large is dependent on a building being kept free from dampness, pure water being supplied and waste water and excretion being rapidly removed. The importance of these points is such that they are controlled by the byelaws and regulations of local authorities who insist on adequate and efficient provision being made in all buildings for damp exclusion, sanitation and water supply under various National Health Acts passed by Parliament. The plumber is required to have a working knowledge (of the requirements) of these regulations in so far as they affect his work.

Historically the ancient craft of plumbing has been concerned mainly with lead. The Romans' word for lead was *plumbum* and in many museums in this country examples of leadwork made during the Roman occupation of Britain are to be seen. Lead is still chiefly used for both roofwork and pipework in buildings because it is durable, readily worked and bent to the various and sometimes awkward shapes required by the design of the building in which it is situated. Recently there has been a growth in the use of copper both for roofwork and for pipework in buildings. The modern plumber has therefore to be skilful also in working and fixing of this material.

Lead and copper working and fixing do not by any means comprise the full scope of plumbing work. Wrought and cast iron pipes and fittings are handled by plumbers, and many of the sanitary fittings in buildings are of stoneware or earthenware with taps and outlets of brass. Many of these fittings are highly finished, costly and require great care and skill in fixing. A plumber is also called upon to be a " glazier," that is, he cuts and fixes the glass in windows.

A very large part of plumbers' work is concerned with upkeep and maintenance. Repairs often call for skilful and rapid work in positions difficult of access, where considerable ingenuity is required to avoid damage to decorations and fixtures in buildings.

The skilled craftsman must be able to organize and set out his work neatly and rapidly. Whilst pipework is not generally decorative it is often coupled to fittings which are, and the setting out of the pipework can make or mar the final result. In any case nothing looks worse than pipework " hung all over the place." In some buildings the external leadwork is highly ornamental and skill is required to obtain a satisfactory result. Good setting out also leads to the economical use of expensive materials. The plumber must also control his labourer or " mate." He must be clean in his work, know the material he is using and be able to distinguish between good and inferior qualities of materials and fittings. A knowledge of the difference in the mechanisms of the various fittings he uses is essential to competence as a craftsman, and he should be able to read plans. A good plumber will also salvage the " scrap."

From the above brief summary the apprentice will gain some idea of the character of the work required from a plumber. His first wishes will be to handle the various tools and commence working with lead. He will find, however, that for some considerable time in his apprenticeship he will not be entrusted to execute anything but the very simplest of work. Acting as a " mate " to a journeyman, he will attend on the latter, doing minor duties, such as cleaning and preparing joints for soldering, passing tools and holding work being done by the craftsman. This actually is his opportunity. He should watch how the work is being done and note each stage carefully. In the "shop" he should practise the various operations and if he can attend a technical college, he will find that there he will be trained carefully, stage by stage, in all processes of his craft. If he couples this training with constant practice at every opportunity when at his work, and gives intelligent co-operation to the journeyman with whom he works, he will find that he will rapidly acquire that skill and capacity which will lead him to be entrusted with more difficult tasks in plumbing work.

PLUMBING

CHAPTER ONE

MATERIALS

Production and properties of lead. The manufacture of lead sheets and pipes Solder—its properties and uses. Production and properties of tin. Copper—its production and properties. The manufacture of copper sheets and tubes. Production and properties of zinc and iron. Brass and bronze. Fluxes. Tarnish.

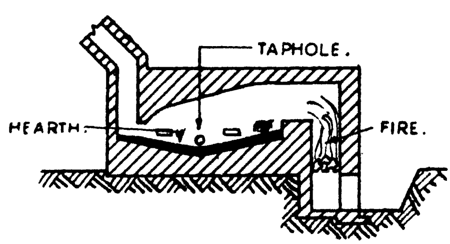
THE plumber is a metal worker and the metals used by him on external roofwork must be durable, easily worked, cut and joined, for they will be fixed in positions not easy of access both during, and after, the erection of the building.

Metals fulfilling these requirements are lead and copper.

Similar requirements apply to the pipework executed by plumbers. Here the metals used must also resist corrosion by water, and in the case of waste pipes, various dilute chemical liquids. Lead and copper again are satisfactory and, for certain work, cast iron is useful.

LEAD

Lead is produced chiefly from a natural ore known as galena (mainly lead sulphide). This is a chemical combination of lead and sulphur. Though formerly mined on a considerable scale in Britain the chief sources of galena are now the United States of America, Spain, Australia, Canada and Mexico.



REVERBERATORY FURNACE

Fig. 1

PRODUCTION OF LEAD.—The ore is roasted in reverberatory furnaces (see Fig. 1) in which the furnace fuel and the ore do not make contact, the heat from the furnace being transmitted to the ore by the hot furnace gases and by reflection from the furnace roof. The ore rests in a hearth and, under the action of the heat, the lead melts out whilst the sulphur burns away into the flue gases. Other impurities float on the surface of the lead and are skimmed off. The crude molten lead is then run into pots. At this stage the lead still contains impurities and is brittle. Further melting and skimming results in soft lead which is cast into bars called "pigs," each weighing about 1-cwt. Certain lead ores may contain enough silver to warrant special treatment to extract the silver.

PHYSICAL PROPERTIES OF LEAD.—Lead weighs 710-lb. per cub. ft., and is among the heaviest of metals. It is soft, very malleable and easily worked. It possesses the property known as "flow," that is, by beating it with wooden tools (metal tools would mark or even cut the surface), the actual metal can be transferred to required points. (The movement of the metal can be compared to that seen in a sheet of soft clay when pushed and modelled with the fingers.) The great value of this "flow" in the practical working of lead will be seen when Chapter Five is read. Lead melts at about 327° C., or 620° F. It has a high coefficient of linear expansion (0·000029 per ° C., or 0·000016 per ° F., *i.e.*, approximately two-and-a-half times that of steel). There is therefore considerable expansion and contraction with large temperature changes and, owing to its great weight causing strong friction with its supporting surfaces and to its softness, it does not always contract fully and evenly on cooling after expansion. It is liable to remain distorted or bulging and may even crack. This distortion known as "creep" is very prevalent on steeply sloping roofs where the lead sheets practically hang from their upper edges. Thus it is necessary to keep lead sheets relatively small in size (24-sq. ft. maximum size) and to fix securely only two adjoining sides of each sheet, the remaining sides having joints which will allow movement. In Chapter Two the common fixing methods will be detailed. Lead is extremely durable, resisting attack from most acids. It is liable to decay when in constant contact with wet plaster or decaying vegetable matter. Water from peaty moorland sources slowly dissolves lead, but such water is usually treated by water works' authorities to prevent such action. Lead when freshly cut is bright and silvery in colour, but tarnishes after exposure to the air to a dull blue-grey colour. This colour is due to the formation of a thin protective coat of lead carbonate.

SHEET LEAD: MANUFACTURE, PROPERTIES AND USE.—Sheet lead, used principally for covering roofs, flashings and gutters, can be manufactured as (*a*) cast sheet lead, or (*b*) milled or rolled sheet lead. It is not strong enough to support itself and is always laid above other materials such as wood boarding on bearers.

(a) *Cast Sheet Lead* is made by melting pig lead and pouring it on to a bed of sand. This sand bed is prepared in a frame 12 to 15-ft. long and 4 to 6-ft. wide and about 5-in. deep. The sand is packed and levelled off inside the frame to well below the edge of the frame. The depth of the sand below the frame edge governs the sheet thickness. The molten lead is placed in a semicircular trough at one end of the frame. On tilting the trough the lead flows on to the sand, where it is pushed forward over the sand bed by a stick or bar running on guides fixed to the frame side at a height which will give the required thickness.

The high cost of cast sheet lead limits its use to those buildings where the lead roofwork is an ornamental feature in the architectural design. It has a rougher surface texture, and has a brighter grey colour than milled sheet lead. It is the practice to use cast lead in thicker sheets rather than "milled," because firstly, the sheets are not perfectly even in thickness, and secondly, if the sheets were thin, small defects arising out of the casting might go right through the sheet.

(b) *Milled or Rolled Sheet Lead* is made by casting from lead pigs a slab of lead about 5-in. thick and measuring about 5 to 7-ft. long by 4 to 6-ft. wide. The rolling mill consists of a long bed comprised of steel rollers. Across the centre of the bed are a pair of heavy rollers. The slab of lead is placed on the bed and passed to and fro through the heavy rollers in a manner rather resembling that of a domestic wringing machine. The pressure of the rollers reduces the slab to 1-in. thickness. The sheet may then measure 7 to 9-ft. wide and be about 30 to 40-ft. long. After cutting to suitable sizes the inch sheets are rolled in a finishing mill to the required weight and thickness, and formed up into rolls as purchased by the plumber.

This form of sheet lead is the one most commonly used in roofwork. It comes from the rolling mill with a smooth surface and with an even thickness and is free from flaws. It is the practice to specify rolled sheet lead by its weight in pounds per square foot. For building purposes it can be obtained in sheets weighing from 3 to 8-lb. per sq. ft. The weights normally specified are :—

Flats, pitched roofs and gutters . .	6, 7 or 8-lb. lead per sq. ft.
Hips and ridges	6 or 7-lb. lead per sq. ft.
Flashings	5-lb. lead per sq. ft.
Soakers	3 or 4-lb. lead per sq. ft.

(The explanation of the above technical roofing terms will be found in Chapter Two.)

The weights given are the minimum for really satisfactory work, but in cheap work it is often found that 5-lb of lead may be the heaviest used, to the detriment of the quality and permanence of the work. To check the weight of sheet lead it is not necessary to cut a square foot out of the sheet. If a piece having an area of 9-sq. in. is weighed, its weight in ounces will correspond to the weight of a square foot in pounds. Thus if a piece of lead measuring 9-sq. in. ($\frac{1}{16}$ sq. ft.) weighs 5-oz. ($\frac{1}{16}$ of 5-lb.) the sheet from which it is cut is 5-lb. of lead.

The thickness of sheet lead is also readily calculated as follows :—

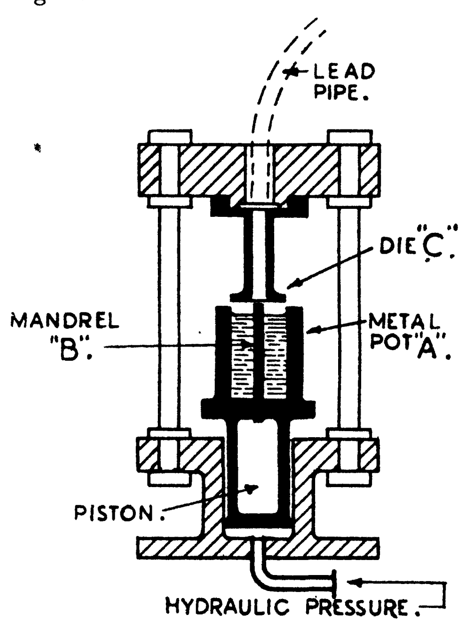
Lead weighs 710-lb. per cub. ft., therefore, 1-sq. ft. weighing 710-lb. is 12-in. deep, and 1-sq. ft. weighing 1-lb. is 12÷710 or 0·017-in. deep (thick), thus, 3-lb. sheet is 0·051-in. thick; 4-lb., 0·068-in.; 5-lb., 0·085-in.; 6-lb., 0·102-in.; 7-lb., 0·119-in.; 8-lb., 0·136-in.

Lead Piping : Manufacture, Properties and Use.—Lead pipe can be made in three ways, namely, (*a*) Seamed pipes, (*b*) Cast Pipes, (*c*) Drawn pipes.

(a) *Seamed Pipes* are made by wrapping sheet lead round a mandrel and " lead-burning " the joint. This method is only used in special cases where a standard type of drawn pipe is not suitable.

(b) *Cast Pipes* are made by casting lead in sand moulds. They are again for special cases generally for ornamental use.

(c) *Drawn Pipes* are made by forcing molten lead through a hollow die which during the pressure contains a mandrel of required internal pipe diameter. Between the die and the mandrel a space equal to the pipe wall thickness is left. Fig. 2 shows at A the metal pot for the molten lead with the mandrel B. The pot is supported on a piston. Hydraulic pressure applied to the piston causes the metal pot to rise. The mandrel enters the hollow die C which has a flanged lower end fitting exactly the metal pot. The lead is thus trapped and put under pressure. It escapes up the space (equal to the pipe wall thickness) left between the mandrel and the die. Emerging as a pipe from the upper end of the die it is (up to 2-in. diameter) coiled. Larger diameters are supported and kept in vertical lengths.



LEAD PIPE PRESS

Fig. 2

Lead piping up to 2-in. diameter is specified by the weight in pounds per yard run. Various weights are available. Larger pipes of from 3 to 4-in. diameter are better specified in weight in pounds per yard run, but are sometimes required to be equivalent to a specified sheet lead weight.

The table below gives the lead pipe sizes in common use by plumbers.

Type of Pipe.	Weight in Pounds per Yard Run.						
Bore	$\frac{3}{8}$-in.	$\frac{1}{2}$-in.	$\frac{3}{4}$-in.	1-in.	$1\frac{1}{4}$-in.	$1\frac{1}{2}$-in.	2-in.
Under pressure from mains up to 65-lb. per sq. in.[1]	4·5	6	9	12·5	16	18	28
Distributing pipes under tank pressure only	4	5	8	11	14	18	24
Pipes not under pressure (with open end) [2]	..	3	4	6	7	9	12

For larger pipes the weights are 3-in., 15-lb.; $3\frac{1}{2}$-in., $19\frac{1}{2}$-lb.; 4-in., $22\frac{1}{2}$-lb.

It must be noted that in those areas where water supply authorities exist, legally enforceable regulations governing pipe sizes and weights are almost certain to be in force and must be followed. The student is also referred to the Minimum Specifications issued by the Institute of Plumbers and the British Standard Specification 602 for full information on pipe sizes and weights.

SOLDER

SOLDER, CONSTITUTION, PHYSICAL CHARACTERISTICS AND USES.—Solder is used to join lead pipes together and to form the connection between lead and brass pipes. Lead is too soft a metal to take any form of screwed connection. To withstand the stresses imposed on the joint by expansion and contraction by temperature differences (these can be considerable in hot-water pipes and waste pipes), and to prevent leakage from water under pressure through the joint, it is necessary to use "wiped" joints. In this form of joint the solder is applied quite thickly, and to prevent the joints being porous the solder is squeezed by hand pressure applied through a "wiping cloth." (Further details will be found in Chapter Five.) The essential points for the solder, therefore, are (*a*) that it must melt at a lower temperature than lead, otherwise its application would melt the lead pipes; (*b*) that it must be plastic, *i.e.*, pasty, whilst being applied; (*c*) its plastic nature must be "long lived" as the temperature falls.

The solder fulfilling the above requirements consists of lead, 70 per cent., and tin, 30 per cent., or, more roughly, 2 parts of lead to 1 part of tin, and is known as *Plumbers' Solder*. It completely liquefies at 257° C. (496° F.), which is 70° C. (124° F.) below the melting point of lead. This gives an ample margin of safety against melting the lead when applied

[1] B.S.S. 602. [2] Min. Specification, Institute of Plumbers, 1943.

thereto. The temperature at which this solder solidifies is 183° C. (359° F.), or 74° C. (137° F.) below its melting point. The range of temperature lying between the melting and solidifying points is known as the " freezing " range. Within this range the solder is " pasty," becoming stiffer as the temperature falls, but the range is great enough to allow the plumber ample time to form his joint. Plumbers' solder, sometimes known as soft solder, has a bright silvery appearance both as a solid or liquid ; it can be purchased in ingots weighing about 28-lb. each or in flat sticks weighing approximately 1-lb. and about 1-in. wide and 12 to 16-in. long.

The presence of metals other than lead and tin in solder can adversely affect its working properties. Zinc and aluminium in solder in minute quantities cause it to be sluggish when fluid and brittle and porous when hard. Copper has similar effects. It is permissible to have a little antimony (not more than 1·7 per cent.) in solder. Antimony is cheaper than tin, and is thus used as an adulterant. A solder containing a little antimony gives a brighter, smoother finished joint, but the " freezing " range and working qualities of the solder are somewhat adversely affected. Larger proportions of antimony can ruin the solder.

When solder becomes difficult to work or gives coarse and gritty joints it is generally due to either (*a*) having lost some of its tin through overheating, or (*b*) the presence of foreign matter, usually metals. In the first case the working qualities of the solder can be restored by adding tin, but in the second case purification is necessary. Plumbers can often cleanse the solder by heating it to a red heat, mixing in brimstone (sulphur) and tallow. The surface scum is removed at intervals and tin is added.

To test solder it is usual for plumbers to pour a little of it on to a cold surface of metal or stone. If a few distinctive spots show on the metal when it " freezes " it is considered to be in condition. The only really satisfactory test, however, is to wipe a joint with the metal.

Plumbers' solder (lead, 2 parts ; tin, 1 part) is also known as " coarse " solder and, as stated above, is used for " wiping." For certain other work needing the use of a soldering iron, " fine " solder (lead, 1 part ; tin, 2 parts) or " ordinary " solder (lead, 1 part ; tin, 1 part) is necessary.

It should be noted that lead and tin mixed together in almost any proportions form solder. As the amount, however, increases above 83 per cent., so the solidifying range or pasty period decreases. Thus the solder is difficult to wipe and the danger of the lead piping melting during wiping is increased. On the other hand, as the lead content decreases below 83 per cent. and the proportion of tin increases, the solidifying temperature remains constant at 183° C. (359° F.), but the pasty period remains generous enough for wiping purposes down to a 66 per cent. lead content. Below this figure the solder is too rich in tin and solidifies too rapidly for wiping. A solder containing 38 per cent. lead and 62 per cent. tin has no pasty period ; it changes on cooling directly from liquid to solid form. This is known as " eutectic " (easy melting) solder. When the solder is still richer in tin there is again a freezing range but one which is too small to be used for wiping purposes, and the solder has become more costly because of the expensive nature of tin. It is readily seen, however, that where solder is worked in the liquid state, it must be of a kind which is richer in tin than plumbers' solder.

TIN

PRODUCTION, PROPERTIES AND USES.—Tin is produced from tin stone ore or cassiterite, which is found either deposited in river beds, as in Malaya, or mined, as in Cornwall. The ore, after washing, is calcined (reduced to a powder by heat). It is washed again and afterwards mixed with charcoal and smelted in a reverberatory furnace, similar to that used for lead. Next it is cast into ingots. These are remelted, run into hot iron ladles, skimmed and cast again as ingots. Tin is a white, bright metal and resists most acids. It does not tarnish readily. Its weight is about 455-lb. per cub. ft. and its melting point is 230° C. (450° F.), *i.e.*, lower than that of lead. The coefficient of expansion of tin approximates to that of lead. It possesses the useful property also of adhering to other metals as a fine coating.

Tin is a relatively rare metal and is costly. For this reason it is not often used by itself. Its chief use in plumbing is as one of the constituents of solder or as a thin coating to the insides of lead and copper pipes. Plumbers also use copper sheets, which have been dipped in liquid tin and " beaten and planished " to incorporate the tin with the copper, to line sinks, or cover draining boards. Pipes, made from pure tin, and bar counters, covered with pure tin sheets, are occasionally used in the beer and spirit trade.

The word " tin " is almost universally used by the general public when referring to " tinned " steel or iron, commonly used for food containers and similar articles. The real name for this is tinplate, and the student should clearly understand that " tin " or " block tin " refers to the pure metal which only appears on tinplate as a minutely thin covering.

COPPER

This metal is found in a natural state in the United States of America and in Cornwall, but the principal source of supply is in the form of an ore containing copper, iron and sulphur in combination, as copper and iron sulphides. These are to be found in many countries including Great Britain. Nowadays, however, Great Britain has ceased to produce copper on a large scale and the United States, Spain, Canada, Rhodesia and Australia all share in providing the world's supply of copper.

PRODUCTION OF COPPER.—Copper ore, as mined, is mixed with other minerals from which it must be separated. The first process is to grind the ore to extreme fineness and mix it with water. By introducing bubbles in the form of froth into the mixture the particles of copper sulphide are brought to the surface, then removed, and the water extracted, leaving a moist powder known as " concentrate " which may contain as much as 50 per cent. copper.

The concentrate is next placed in reverberatory furnaces (see Fig. 1) fired by pulverized coal. Here the concentrate loses most of the iron and sulphur impurities which burn away or are removed in the slag as it is skimmed off. The metal, still containing much sulphur and some iron, is tapped off into ladles. The molten metal known as " matte " is next placed into " converters." These are a pear-shaped type of furnace capable of being tilted, in which air is blown through the molten metal. The remaining iron and sulphur is removed in this process by burning and slagging, and the metal, now largely copper, is cast into " pigs " known as " blister copper." This contains excess oxygen in the form of black copper oxide, and refining is necessary to produce the pure metal.

" Blister " from pure types of ores is refined by melting in a reverberatory furnace, covering the molten metal with charcoal and stirring the metal with green (freshly cut) hardwood poles. The gases evolved from the poles, together with the charcoal, remove the oxygen from the copper oxide leaving only pure copper. This is cast into ingots for manufacturing processes. Where the " blister " copper contains small amounts of valuable metals and other impurities not removable by " poling," an " electrolytic " refining process is used. An ingot of " blister " copper called an anode is placed in a large tank of copper sulphate. At some distance away in the same tank is a sheet of pure copper known as the cathode. On passing an electric current from the anode to the cathode, pure copper gathers on the cathode whilst the anode (" blister " copper) loses copper. Impurities fall to the tank bottom and can be removed and the valuable metals recovered by other processes. The cathodes, when completed, are melted and further refined in reverberatory furnaces before being cast into ingots for manufacturing processes.

When copper is to be welded it undergoes a further process to remove all oxygen in it and is sold as deoxidized copper.

PHYSICAL PROPERTIES OF COPPER.—Copper weighs 558-lb. per cub. ft. It is soft and easily worked, when cold, if it has been previously heated to redness. It hardens whilst being worked, *i.e.*, beaten, stretched or drawn. This hardening affects the method of working copper. The plumber should strike a few hard blows at copper rather than keep " tapping " the metal as he would with lead.

The metal, when heated, readily combines with oxygen from the atmosphere, and a black skin of copper oxide is formed. This skin is readily removed if the hot copper is cooled (quenched) in water. It can be rolled into thin sheets, being very malleable, and can be drawn into wires and tubes as it is ductile. The metal as normally used is almost pure copper (99·25 per cent. copper), but slight traces of arsenic improve the working qualities of the metal. Compared with lead its melting point 1083° C. (1981° F.) is high, its coefficient of linear expansion is 0·0000166 per ° C. (0·000009 per ° F.). Precautions, similar to those taken in fixing lead, are necessary to prevent adverse effects due to expansion and contraction. In Chapter Two some fixing methods are detailed. Copper is very durable and resists most dilute acids. It is not dissolved by water and therefore can be used for pipes as well as roofing. It is, however, liable to deteriorate if it is in contact with iron in damp situations. There is a rather similar effect if copper, solder and water are in contact (*e.g.* if a copper pipe joint is soldered). In this case the adverse effect is on the tin in the solder, and deterioration can be rapid if the water is warm. Copper is red in colour (it is the only red metal) and can be polished. When exposed to the atmosphere a protective skin called " patina " slowly forms. This is green in colour and is considered to improve the appearance of copper-sheeted roofs. The " patina " is due to a slight trace of sulphur from the atmosphere combining with the copper to form an insoluble sulphate. It should not be confused with " verdigris," similar in colour but which pits the copper and is evidence of decay. " Verdigris " is produced when copper is in contact with decaying organic matter ; a state of affairs hardly possible on roofs.

SHEET COPPER : MANUFACTURE, PROPERTIES AND USES.—Copper sheets are produced by rolling in a manner similar to that used in producing sheet lead. Because of the higher melting point of copper, however, it is possible to roll the sheets either " cold " or " hot." " Cold " rolled sheets have a bright polished surface, but are hard and not suitable for roofing work unless annealed by being brought to a dull red heat and allowed to cool. " Hot " rolled sheets have dull surfaces, are soft and fit for direct use for roof purposes. Practical difficulties arising in the manufacture of thin sheets make it costly to produce them wider than 4-ft. As only thin sheets are used for roofing, their width never exceeds this figure.

It is usual to specify " hot rolled " copper sheet for roofing purposes and to state the gauge. The two gauges (standard wire gauge) used are given below. It is only on rare occasions that thicker sheet is used as the cost becomes excessive.

Gauge.	Thickness.	Approximate Weight per Square Foot.
S.W.G.	Inches.	Ounces.
23	0·024 or 24/1000	19
24	0·022 or 22/1000	16

Sheets up to 12-ft. long can be obtained, a common size is 6-ft. by 3-ft. As with sheet lead there is very considerable expansion and contraction with temperature changes, and similar provision for this movement should be made in the jointing of the sheets. Support for the sheets is necessary in the form of underboarding, and in order to prevent the sheets contacting the iron nails in the boarding, and setting up electrolytic action,[1] roofing felt or building paper is laid over the boards. Sheet copper can also be used for partially supported gutters (*i.e.*, without underboards) if the " cold rolled " type is employed. The gauges are similar to those used for roofing. Some copper roofing details are given in Chapter Two. The thickness of sheets can be checked by weighing.

(15-sq. in. of 23 gauge should weigh approximately 2-oz.)
(9 ,, ,, 24 ,, ,, ,, 1-oz.)

COPPER PIPING : MANUFACTURE, PROPERTIES AND USES.—It is the usual practice to refer to copper pipes as " tubes." The manufacturing processes are much more involved than those used for lead pipes, and the tubes pass through several stages before being completed.

Electrolytic copper of great purity (99·9 per cent. copper) is melted in reverberatory furnaces and is treated to make it tougher and more ductile for pipe manufacture. It is also deoxidized by adding some phosphorus to extract oxygen. (Any residual phosphorus helps any later welding processes.) The treated molten metal is next cast into cylindrical billets about 4-ft. long, varying in diameter according to the diameter of tube to be made. When cool the billets are removed from their moulds and stored until required. They are then re-heated in gas-fired furnaces and fed into a " piercer " (piercing machine) where two rapidly rotating conical rollers force it forward and forge it into a tubular shell.

Now cold, this shell passes on to the " draw-benches." These are extremely long and narrow tables on which a small travelling carriage can be engaged with a moving chain and drawn powerfully along the table. A die of somewhat smaller diameter than the shell's exterior is fixed firmly across the table. The shell is threaded on a long steel mandrel. Both shell and mandrel are next inserted in the die (a few inches length, at one end of the tube, has previously been crimped to a diameter which will pass through the die) and are gripped on the other side by the carriage, which is then pulled by the chain along the table, drawing shell and mandrel through the die. The external and internal diameters of the shell are reduced to those of the die and mandrel respectively, and it increases in length. The shell, now called a tube, may have to undergo several " passes," as the drawings are called, to reach its required bore and gauge. Although the copper is soft originally, it " work-hardens " during its " passes " and may need annealing at times between " passes " to soften it sufficiently for further size reduction. Annealing is accomplished by passing tubes

[1] Electrolytic action is the setting up of a slight electric current between the copper and the iron nail in the presence of damp with a consequent decay in the copper.

gradually forward through increasing heat into a "correct" heat chamber which is kept oxygen free to prevent oxidization. The tubes then pass forward from the chamber, cooling gradually. In some instances it is possible to use the heat given off during cooling to supplement the heat required at the entry end. After annealing, the tubes are immersed first in cold water and then in acid to remove scale. They are then washed in hot water to remove all traces of acid. A final drawing stage gives the correct size, gauge and temper.

Finally, the tubes pass a hydraulic test of 1000-lb. per sq. in., are straightened, checked for gauge and bore, and have their internal and external surfaces examined. Samples from each batch manufactured are subjected to a "flaring" test. (Tubes must be capable of a percentage end expansion.)

Copper is just as suitable as lead, from a health and purity point of view, for use in pipework connected with water supply. It withstands corrosion and is practically insoluble in water. Acid waters which may tend to dissolve copper also dissolve lead. Water authorities who handle acid waters always treat them to reduce their acidity and prevent such attacks. Any prejudice on health grounds against the use of copper for water pipes is founded on bias or ignorance.

For plumbing work the bores used correspond with those used for lead in similar circumstances. Two types of tube are used in buildings. "Heavy" gauge has tube walls strong enough to take screwed joints whilst "light" gauge requires joints which can be made secure without forming threads on the tube (see p. 109). The former type is used in high-class work and is comparatively expensive to install. For domestic work "light" gauge tubing jointed with "compression," "capillary" or "bronze-welded" connections is being increasingly used. Fixed in this way there is no great difference between the cost of using lead or "light" gauge copper for the pipe system of a small house, particularly if the use of copper is restricted to the pressure pipes.

The following are the gauges normally used in plumbing work.

COPPER TUBES

(For screwed connections and pressures up to 125-lb. per sq. in.)

Pipe Bore.	Standard Wire Gauge.	Weight per Foot Run.
In.	S.W.G.	Lb.
½	14	0·53
¾	13	0·89
1	12	1·33
1¼	12	1·64
1½	12	1·96
2	12	2·61
4	8	7·93

COPPER TUBES

(For compression, capillary or bronze-welded joints and pressures up to 150-lb. per sq. in.)

Pipe Bore.	Standard Wire Gauge.	Weight per Foot Run.
In.	S.W.G.	Lb.
½	18	0·32
¾	18	0·46
1	17	0·71
1¼	17	0·88
1½	16	1·05
2	15	1·60
4	13	4·55

The above tables are based on those contained in the British Standard Specifications (No. 61, 1913) and (No. 659, 1936).

Gauges may be subject to local variations and the water authority should be consulted where any doubt exists about the size of gauge to be used.

Copper Nails.—These are used by plumbers for nailing any fixed edges of lead or copper sheets to supporting woodwork.

ZINC

This metal is produced chiefly from zinc sulphide which is a chemical combination of zinc and sulphur. Another important source of supply is zinc carbonate, the metal in this case being in combination with carbon and oxygen. Zinc ores are found in many parts of the world, principally in the United States of America, Canada, Australia, Northern Rhodesia, Germany and Poland.

Production of Zinc.—The mined ore is finely ground and concentrated in a similar manner to that described for copper. The concentrate is then roasted, losing its sulphur content (or in the case of zinc carbonate ore, its carbon), and becomes zinc oxide (zinc and oxygen combined). After this stage there are two principal methods of manufacturing the pure metal. The first way is to heat the roasted ore mixed with coke (carbon) in horizontal fireclay retorts, the zinc comes off as a vapour and is condensed and further refined. In the second process the roasted ore is dissolved in vitriol (sulphuric acid). The liquid is purified and then by passing an electric current from anode to cathode extremely pure zinc is deposited on the cathode. The trade name for zinc in slab (ingot) form is spelter.

Physical Properties of Zinc.—Zinc weighs 440-lb. per cub. ft. As cast in slab form it is brittle, but if heated to between 100° C. (212° F.) and 150° C. (302° F.) it becomes malleable and can be rolled into sheets or drawn into wire. Its melting point, 420° C. (790° F.), is low and in thin sheets it can burn. The coefficient of linear expansion is high, being 0·0000395 per ° C. (0·000017 per ° F.). When used in sheets for roofing, precautions similar to those described for lead and copper must therefore be taken. Zinc is not as durable as lead or copper as it dissolves when exposed to acids.

Zinc is bluish white in colour. It tarnishes when exposed to the atmosphere and acquires a protective coat of zinc oxide, it is harder than lead but is softer than copper.

USES OF ZINC.—Zinc is not very strong and its life on a roof in smoky atmospheres can be very short so that, except for inferior work, the more durable metals, copper and lead, are usually preferred. Its principal use in plumbers' work is to provide a protective coating for the stronger but less durable metal, iron. Zinc-coated (galvanized) iron sheet is much used by plumbers in the form of water tanks. Galvanized corrugated iron sheets are also used for roofing

The iron sheets to be galvanized have rust and scale removed by "pickling" them in baths of dilute sulphuric or hydrochloric acid. The sheets are then washed in water to remove all traces of acid and are next passed through a layer of zinc and ammonium chlorides which further cleanse their surfaces and act as a flux to spread the zinc evenly. Next, the sheets enter a bath of molten zinc, having been preheated, before entering the molten metal. The galvanized sheets on leaving the bath are rolled to give an even zinc coating and are allowed to cool. Zinc coatings to iron can be given also, electrolytically, by placing the iron articles in a tank containing zinc sulphate solution. A pure zinc anode is used, the article undergoing galvanizing being the cathode. Small iron fittings are often "sherardized." In this process they are first thoroughly cleaned by "pickling" or by sand blasting. They are then placed in a container and surrounded by zinc powder. The container is heated to about 350° C. (662° F.) and this temperature is maintained for some considerable time. The zinc first forms an iron zinc alloy coating with the iron and finally coats the alloy with pure zinc. The container is not opened until cool, as the coating might otherwise be affected adversely.

A further important use of zinc is to form alloys with copper and other metals. Brass (described later) is one of these.

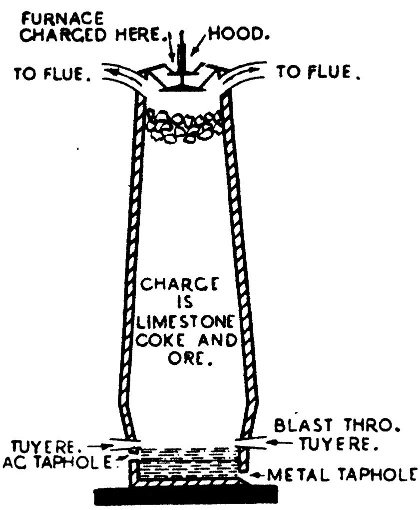
IRON

Iron ores vary largely in their constitution, but the most common forms are iron oxides (iron combined with oxygen in various proportions) and iron carbonate (iron combined with carbon and oxygen). The various forms of iron ore are found in Great Britain, the United States of America, Sweden, Germany, Spain, Belgium and France.

Production of Iron.—As the manufacture of iron varies very considerably, according to its ultimate form as cast iron, wrought iron or one of the many forms of steel, only one of the ways of producing cast iron will be described. Plumbers use cast iron very considerably.

The first stage in the production of cast iron is carried out in a blast furnace (see Fig. 3). This may be up to 100-ft. high and 25-ft. wide and is a steel cylinder lined with firebrick. At the top is a hood to prevent the escape of the flue gases. At the foot hot air is blown in through "tuyères" (air pipes) above a hearth where the molten metal collects. The process is continuous, the furnace, operating for months at a time, being tapped and charged all the time.

Iron ore, previously calcined to remove most of its sulphur, is mixed with carefully ascertained proportions of limestone and furnace coke. The limestone is used as a flux for impurities and to absorb sulphur. Furnace coke is specially produced, free from sulphur, the presence of which in cast iron is harmful. The hot blast (800° C.—1472° F.) causes the coke to turn into carbon monoxide which rises in the furnace and absorbs oxygen from the iron ore, turning this into spongy iron. As the process continues this spongy iron descends and melts in the hottest part of the furnace, collecting on the hearth, whence it is tapped off at intervals. Floating on the surface of the molten iron is a liquid slag consisting of the molten limestone and its absorbed impurities. This is drawn off at a higher level than the iron. The furnace is kept charged by tipping in truckfuls of ore, coke and limestone. The hot flue gases are drawn off at the top and their heat is used to warm up the blast. They can also be used as fuel for gas engines used on the plant.



BLAST FURNACE

Fig. 3

The molten iron from the furnace is run off into channels, semicircular in section, formed in sand. The main channel has smaller channels running off at right angles. These are known as "pigs" whilst the main channel is called the "sow." When cool the pigs and sow are broken off into lengths weighing about 2-cwt.

Pig iron contains 3 to 4 per cent. of carbon, partly combined with iron and partly free. To produce cast iron as used for pipes and gutters it is remelted at a foundry in a furnace which resembles a blast furnace but is considerably smaller. Furnace coke and pig iron are fed in at the top and the blast is reduced in amount and pressure so as to merely provide the air necessary to allow the coke to burn at the required temperature. Scrap iron is added to control the amount of iron in the finished casting. The molten iron is run off into the ladles from which it is poured into moulds prepared in foundry sand. Where the castings are required in large numbers to one pattern, steel moulds are often used.

PROPERTIES AND USES OF CAST IRON.—Cast iron weighs 450-lb. per cub. ft. It is brittle if subjected to a sharp impact but otherwise is strong and self supporting. It is durable and rusts slowly, but it is necessary to protect it by painting or galvanizing. The coefficient of linear expansion is 0·000011 per ° C. (0·000006 per ° F.). Before rusting it is dark grey in colour and when broken the fractured surface is crystalline (similar to finely grained lump sugar) in appearance. Its principal uses in plumbing are in the form of castings such as gutters, rain-water pipes, soil pipes, water mains, drain pipes, gratings for gullies, manhole covers and sometimes as gullies and traps.

BRASS

Brass is a combination of copper and zinc. The proportions of copper to zinc vary according to the ultimate purpose for which the brass is to be used. It is made by adding zinc to molten copper contained in a heated crucible.

PROPERTIES AND USES OF BRASS.—Brass weighs 520-lb. per cub. ft., and melts at about 945° C. (1733° F.). Its coefficient of linear expansion is 0·000018 per ° C. (0·00001 per ° F.). The colour is yellow, varying from a light straw to a deeper and more reddish hue as the proportion of copper to zinc increases. In plumbing work a mixture of 2 parts of copper to 1 part of zinc is usually employed for castings. Where fittings are made by " extruding " (forcing the brass into shape by heavy pressure whilst hot), the proportion of zinc is higher, the brass being 55 per cent. copper and 45 per cent. zinc. Brass is hard, and is used for taps, valves, traps, unions and similar connecting fittings. It will take a high polish and is very durable, but when exposed to acid the zinc is liable to corrode and leave the surface of the fitting pitted.

BRONZE

Bronze is, strictly speaking, an alloy of copper and tin. Other alloys, mainly copper and tin, but containing either zinc, manganese, phosphorus or aluminium are, however, also called bronze.

PROPERTIES AND USES OF BRONZE.—Bronze weighs about 525-lb. per cub. ft. and its melting point is 955° C. (1751° F.). Its coefficient of linear expansion is 0·000018 per ° C. (0·00001 per ° F.). Its colour, like brass, varies with its constitution from straw colour through greenish browns to dark chocolate brown. It is hard, extremely durable and highly resistant to corrosion. It is used by plumbers for valves, taps and connections, particularly where exposure to acids and fumes is expected, as in chemical laboratories.

LEAD ALLOYS

TERNARY ALLOYS consisting of either :—

Lead, 99¼ per cent. Cadmium, ¼ per cent. Antimony, ½ per cent.	or	Lead, 98¼ per cent. Cadmium, ¼ per cent. Tin, 1½ per cent.

can be used instead of ordinary lead for pipes.

As the pipes are much stronger a reduction in weight is possible. The reduction is generally about one-third, *i.e.*, a 6-lb. per yd. ternary alloy pipe could be used instead of a 9-lb. per yd. lead pipe. (See British Standard Specification 603 for recommended weights.) It should be noted, however, that the pipes are more difficult to work as the ternary alloy is not only stronger but harder than ordinary lead. They are jointed in the same way as lead pipes.

Tellurium lead is lead containing a slight amount of tellurium ($\frac{1}{20}$ to $\frac{1}{10}$ per cent.). This alloy possesses the property of hardening as it is worked. Both pipes and sheets are obtainable in tellurium lead and can be obtained either in a softened or toughened condition. If in the soft state, the hardening property can be developed by working or stressing the alloy.

PHYSICAL PROPERTIES OF METALS COMMONLY USED IN PLUMBING

Metal.	Weight per Cubic Foot.	Melting Point.		Coefficient of Linear Expansion.	
	Lb.	° C.	° F.	° C.	° F.
Lead . .	710	327	620	0·000029	0·0000163
Tin . . .	455	230	450	0·000021	0·0000117
Copper . .	558	1083	1981	0·0000166	0·0000094
Zinc . .	440	420	790	0·000025	0·000014
Brass [1] . .	520	945	1733	0·000018	0·00001
Bronze [1] . .	525	955	1751	0·000018	0·00001
Iron [2] . .	450	1260	2300	0·000011	0·0000061

[1] As these are alloys there can be considerable variation in their properties.
[2] Iron has many different values which vary according to its type and quality.

MATERIALS OTHER THAN METALS

FLUXES.—These are materials which are used to simplify the operation of making soldered joints. They are smeared over the surfaces (previously cleansed to brightness) of the lead, copper or brass to be soldered. They melt and run when heat is applied and prevent the metals from oxidizing (tarnishing). The solder when molten follows the flux and readily adheres to the metals to be joined. Without a flux it is extremely difficult to make a soldered joint.

The common fluxes used by plumbers are : (1) Tallow, (2) Resin and (3) Zinc Chloride.

(1) *Tallow* is crude mutton fat which has been melted down. It is also called " Russian " tallow and sometimes is named " touch." It is used for lead to lead, and lead to brass or gunmetal, joints made with plumbers' solder.

(2) *Resin* is brown, semi-transparent hard gum which exudes from cuts made in pitch pine trees. It is found in most cone-bearing trees, but the pitch pine is the most usual source. Resin is used with solders richer in tin than plumbers' solder, and also for tinning brass preparatory to soldering. It also forms the basis of many of the paste fluxes sold under various trade names.

(3) *Zinc Chloride* (also called " killed spirits " or " soldering fluid ") is made by dropping small pieces of zinc into dilute hydrochloric acid (also called spirits of salts) until no more will dissolve. It is used for tinning copper soldering bits, and for soldering clean zinc, brass and copper, particularly when a soldering iron is to be used. " Unkilled " spirits or dilute hydrochloric acid is used as a flux for uncleaned zinc.

(Zinc chloride first dries on the joint as a dirty whitish sediment when heat is applied and runs later under the greater heat from the solder.)

TARNISH.—This is a material to which solder will not adhere. It is used by the plumber to prevent the solder from running into ragged, untidy edges when making a joint. It is applied by a brush around the boundary of the joint.

Tarnish is a mixture of lampblack, size and whiting. Lampblack is a form of carbon (soot), size is a weak form of glue, and whiting is chalk. The whiting is to give " body " to the tarnish and the size is obviously used to make the tarnish stick to the metal on which it is applied. Tarnish is also known as " Plumbers' Black " or " Plumbers' Soil."

CHAPTER TWO

EXTERNAL PLUMBING

Definitions and terms. Sheet leadwork—conditions and terms. Chimney flashings—their design and fixing. Ridge, hip and valley flashings. Lead gutters—tapering and parallel. Lead flats. Sheet copper work—essential differences compared with lead—general conditions for fixing. Various flashings in copper. Rain-water goods—types, terms and fixing.

PLUMBING work on the exteriors of buildings can be broadly divided into two kinds, namely : (1) Roofwork using sheet lead or copper, and (2) pipe and gutter work, generally using cast iron, enamelled iron or asbestos-cement prefabricated fittings.

1. ROOFWORK.—This again can be subdivided into (*a*) the making of watertight joints between slates (or tiles) and brickwork (or masonry) using lead or copper sheet as " flashings," (*b*) the making watertight by " flashings " of the joints occurring in slated or tiled roofs at change of direction, (*c*) the covering of roofs entirely with lead or copper sheets and (*d*) the making of gutters and down pipes from lead or copper sheet to collect and remove water from roofs.

2. PIPE and GUTTER WORK.—This is concerned with fixing in position of gutters and down pipes which are purchased in standard sizes and shapes ready for use. It also includes the fixing of external waste pipes and soil pipes.

ROOFING TERMS (see Fig. 4).—Before proceeding to the detailed study of roofwork the student should identify the following roofing terms on Fig. 4.

Pitched Roof.—A roof formed of one or more obviously sloping surfaces.

Flat Roof.—A roof which has a horizontal or almost horizontal surface. If covered with lead or copper sheets the slope is just sufficient to allow rain-water to drain away.

Gable.—This is the triangular shape formed by the intersection of the vertical wall surface with the sloping roof surface or surfaces.

Ridge.—The line formed by two opposite roof slopes at the apex of a roof. Normally it is horizontal. (Rain-water runs down and away from a ridge.)

Hip.—The line formed when a roof surface changes direction abruptly and forms an *external* angle. (Rain-water runs down and away from a hip.)

Valley.—The line formed by two roof slopes running downwards and meeting. It is also the line formed when a roof surface changes direction and forms an internal angle. (Rain-water runs down and into a valley, which thus needs a gutter.)

Eaves.—The lower edge of a sloping roof. Normally it is horizontal. (Rain-water runs down to the eaves, which require a gutter.)

Parapet.—The continuation of the external wall upwards above the edge of the roof.

Flashings.—These are the special joints required to render water-tight the junctions between roof surfaces and protruding walls such as parapets and chimneys. They are generally made from lead or copper sheet.

Gutters are channels used to collect and remove the rain-water which runs down roof surfaces. They can be "prefabricated" (ready-made) and brought in standard sections to the job for fixing. These types will be either wood, cast iron or asbestos-cement. They can also be made from lead or copper sheets resting on wood forms. Parallel gutters (sometimes called box or trough gutters) are of uniform width (not less than 10-in.). A special type of wood construction is needed for parallel gutters, and so "tapering" gutters are often used. These increase in width as they rise from their lower ends because the distance across the valley increases with the rise.

Rain-water Pipes.—Sometimes called down pipes, these are the pipes which conduct the rain-water from the gutters down the walls to the drains. They can be made from cast iron, lead, copper or asbestos-cement. Fittings used with down pipes are rain-water heads (small boxes or troughs which are fitted to the down pipe and receive other pipes) and rain-water shoes (short projecting lengths of down pipe to throw the rain-water outwards to the gully—a dished receptacle which is connected to the drains).

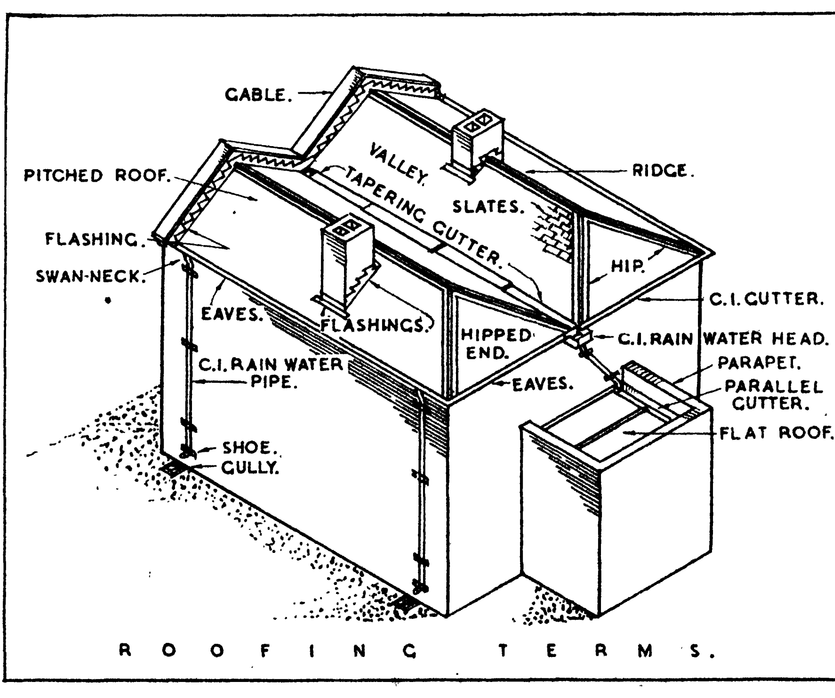


Fig. 4

OTHER ROOFING TERMS (not shown in Fig. 4).

Span.—The horizontal distance between the walls supporting the roof.

Rise.—The vertical height of a roof.

Pitch.—The slope or inclination of a roof surface measured from the horizontal either in degrees or in the proportion $\frac{\text{Rise}}{\text{Span}}$.

The following table lists the most common roof coverings and the *least* slopes (pitches) at which each should be used.[1]

Covering.	Rise per 10-ft. Run.	Pitch.	Angle.
Asphalt, copper, lead and zinc	1½-in.	$\frac{1}{160}$	$\frac{3}{4}^\circ$
Roofing felt, corrugated iron and asbestos sheets	1-ft. 0-in.	$\frac{1}{20}$	$5\frac{3}{4}^\circ$
Slates, large	1-ft. 0-in.	$\frac{1}{5}$	$21\frac{3}{4}^\circ$
Slates, ordinary	5-ft. 0-in.	$\frac{1}{4}$	$26\frac{1}{2}^\circ$
Slates, small	6-ft. 0-in.	$\frac{1}{3}$	$33\frac{1}{3}^\circ$
Plain tiles	10-ft. 0-in.	$\frac{1}{2}$	45°

It will be seen from the above table that the smaller the unit the steeper is the pitch. Small units such as tiles have many joints, and the sharper slope removes the rain-water rapidly. The small unit also weighs less and will *hang* on a roof, whereas larger units must lie on the roof. These latter, however, have fewer joints. (Lead is often used in large sheets on steep pitches, but there is always the possibility of trouble arising.)

SHEET LEADWORK ON ROOFS. — *General Conditions, Methods and Terms.*—It is necessary to grasp a few general considerations arising in fixing leadwork to roofs before commencing detailed study. The ideal method would be to use and so joint the lead as to make it in effect one large sheet. In practice this is impossible for the reasons stated in Chapter One. On roofs, lead is subjected to extreme temperature changes, and the expansion and contraction of the metal, added to the slight movements in the mass of the building fabric due both to temperature changes and settlement, would soon distort and tear the lead.

Sheet leadwork must therefore conform to the following requirements :—

(*a*) The sheets must not exceed 8-ft. in any dimensions, and 24-sq. ft. in area.

(*b*) Rigid fixing must be avoided ; not more than two *adjoining* sides being secured and only one if possible.

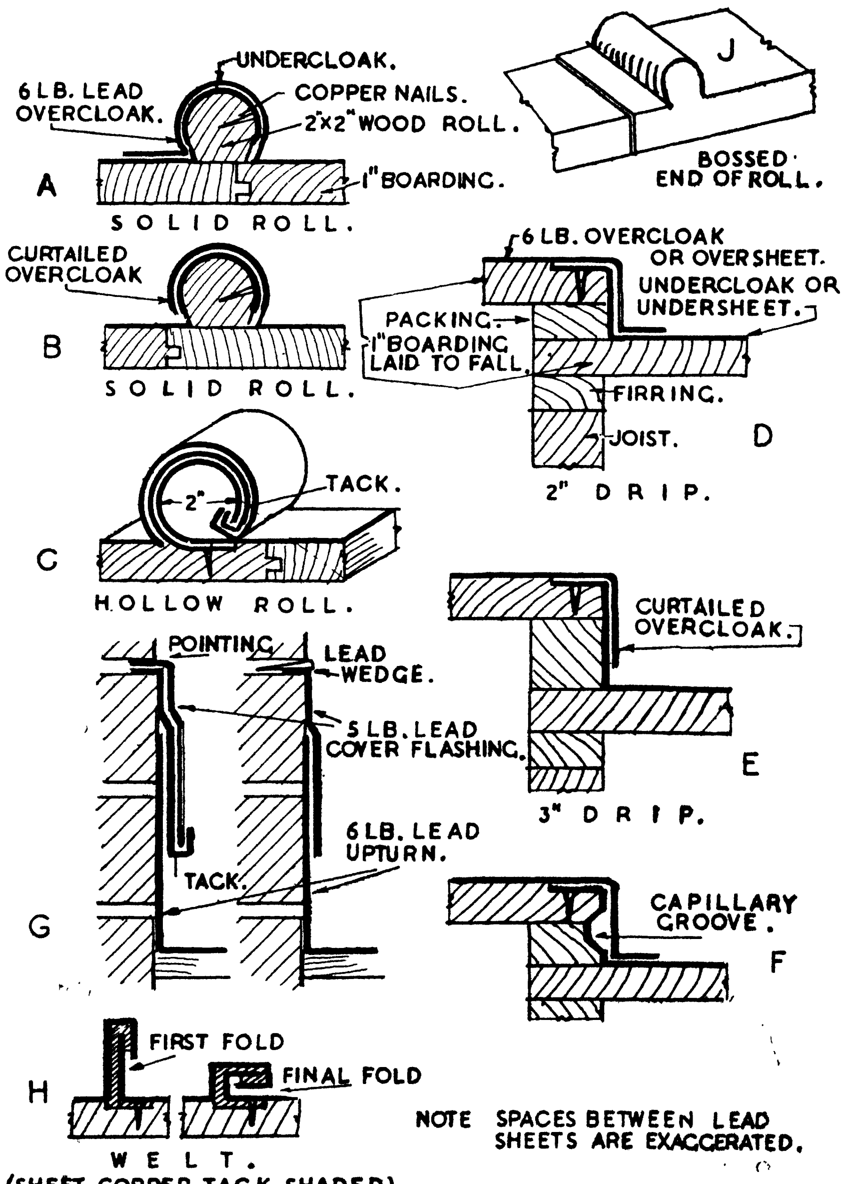
(*c*) The sheets must not be fixed by nailing, if this can be avoided. If nailed the nails must be out of reach of any water (the nail obviously makes a hole through the sheet, and subsequent lead movements would enlarge the hole however tightly the nail was driven). Copper nails should be used.

[1] Although the plumber does not fix many of these materials, his services are almost always required in connection with flashings to them, and he should know the minimum pitches for the various materials.

Common methods of fixing sheets so as to comply with the above requirements are shown in Fig. 5. They fall into two general types :

(*a*) Sheet to brickwork, *i.e.*, upturns and cover flashings.

(*b*) Sheet to sheet, *i.e.*, rolls, welts, drips and laps.



SHEET LEAD JOINTS

Fig. 5

(a) *Upturns and Cover Flashings* (see G, Fig. 5).—These consist of turning up the edge of sheets to form an " upturn " or " upstand " of 4 to 6-in. A sheet of lead not less than 5-in. wide, known as a cover flashing, has its upper edge inserted for 1-in. into a raked out brickwork joint immediately above the " upstand." This sheet is secured by lead wedges every 12 to 18-in. driven into the brickwork joint. The cover flashing is dressed down about 2 to 3-in. over the upturn.

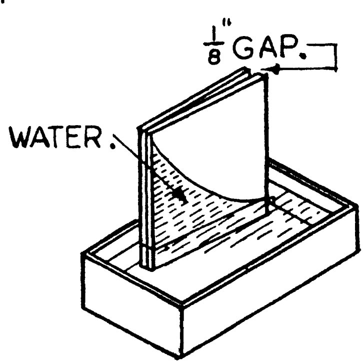
(b) *Rolls, Welts, Drips and Laps.*—These sheet-to-sheet joints can be divided into three classes. Rolls and welts are joints used in the direction of the fall on the roof. Drips are joints across the flow on flat pitched roofs. Laps are joints across the flow on steep pitched roofs or at the ends of cover flashings.

Rolls.—The solid roll (see A and B, Fig. 5) is the most common form of joint in the direction of the fall. It is formed over a wood roll, one of the sheet edges to be joined being dressed into the angle of the roll and the boarding and over the roll as shown. It is then nailed with copper nails at 2 to 6-in. apart and is known as the undercloak. The other sheet edge is dressed into its roll angle and over the roll top to lie down on the adjoining sheet for 2-in., being well worked into the angle. This is known as the overcloak. In some districts the overcloak is trimmed off before reaching the adjoining sheet. Roll ends are bossed into the shape shown at J, Fig. 5. Hollow rolls (see C, Fig. 5) can also be used particularly on curved roofs such as domes where it is difficult to provide wood rolls except at great cost. To make a hollow roll, the undercloak is turned up and then strong 2-in. wide heavy lead strips (7 to 8-lb. lead), known as " tacks," " tingles " or " clips " are nailed into slight recesses in the underboarding to stand at 2-ft. intervals along the upturned undercloak. " Tacks " are often made from heavy gauge copper secured with brass screws. The " tack " ends are then clipped over the undercloak. Next the overcloak is turned up alongside the undercloak with its upper edge 1-in. higher than the undercloak. The edge is then turned down to clip over the undercloak, and the whole is then dressed into form. The hollow roll should not be used where it can be trodden on or damaged by ladders resting against it.

Welts.—These joints in the direction of the flow are also known as " seams." They are made in a manner similar to that employed for the hollow roll, but instead of dressing down into roll form the clipped edges are turned down and dressed to be flat, as shown at H in Fig. 5. Welts are used for steeply pitched roofs and for curved surfaces. They are not suitable for flat roofs. (Rolls and welts are used for other roofing purposes, and further reference to them is made later in this chapter.)

Drips (see D, E and F, Fig. 5).—For joints across the fall on low pitched roofs the type known as a " drip " or " step " is used. To provide for this joint a 2 to 3-in. step down in the underboarding is made by the joiner. The lower sheet, known as the " undersheet," is brought up to this and an upstand formed against the step. The top of the upstand is dressed down over the edge of the step into a shallow rebate formed in the boarding to which the lead sheet is close copper nailed. The rebate prevents a ridge being formed across the edge of the drip. The upper sheet, called the "oversheet," is next laid, and its edge dressed down the drip and over the undersheet for 2-in. Often the oversheet is merely dressed over the drip and trimmed off about ¼-in. short of the undersheet.

Laps.—These are joints across the fall on steep pitched roofs and are also the means of jointing employed at the ends of the 8-ft. lengths of cover flashings and upstands. They are sometimes called passings. On steep pitched roofs they are merely the extension of one sheet over the next lower sheet to form a horizontal joint. The amount of lap is 6-in. for pitches greater than 45° and 9-in. for pitches lower than 45°. For joints in cover flashings, upturns, horizontal aprons, ridge, hip and valley flashings, the lap is 4 to 6-in.



CAPILLARITY EXPERIMENT

Fig. 6

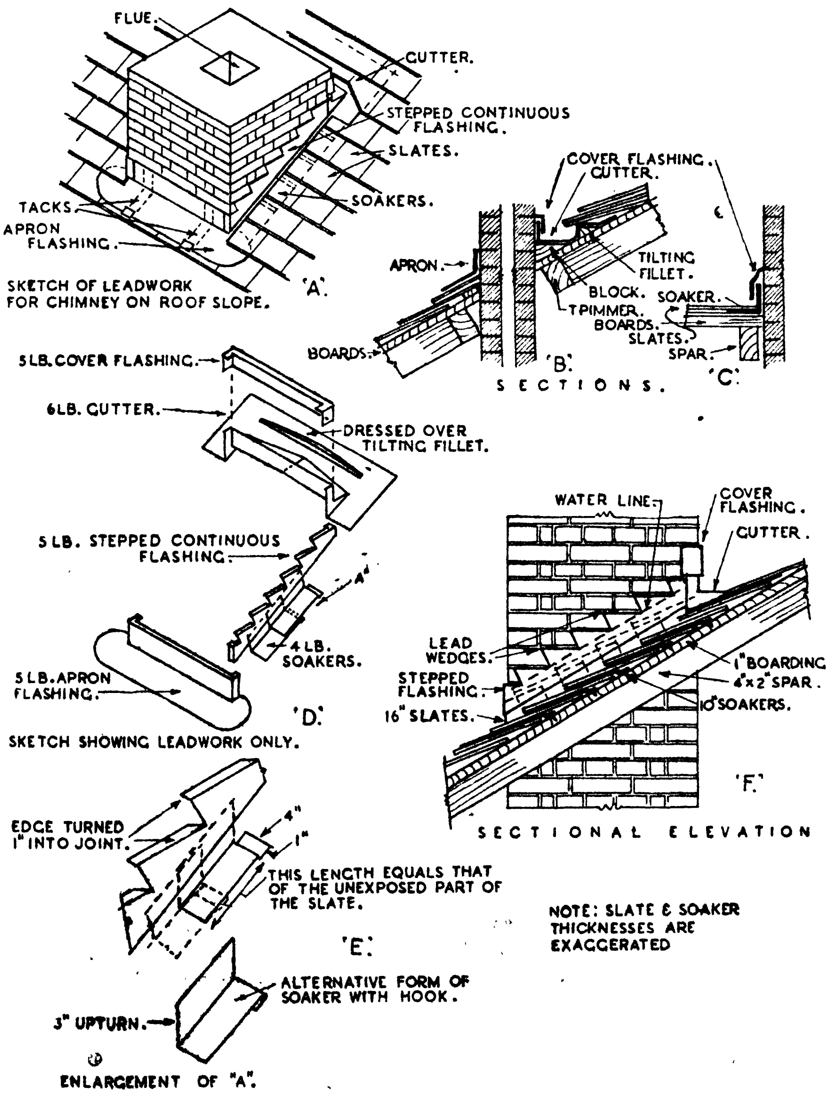
Capillarity.—Where two surfaces are in close contact there is always the possibility of water travelling for a considerable distance between the surfaces, even if the joint is vertical. The explanation of capillary attraction is rather involved, but the following simple experiment will demonstrate its existence.

Take two small sheets of glass, about 6-in. square, and fix them to form a narrow V-shape with the contacting and open edges of the V vertical, the opening of the V should be ⅛-in. (see Fig. 6). Stand them in a trough containing some coloured water. This will rise in a curve increasing considerably in height towards the narrow end of the V.

To counteract capillary attraction it is possible to form capillary grooves across steps and similar places (see F, Fig. 5) and dress the undersheet into the groove. The widening between the contacting surfaces prevents the passage of water. In practice, however, this excellent procedure is rarely used. Further, it is generally found that temperature movements cause the oversheet to protrude and act as a capillary groove.

LEADWORK ON ROOFS

Lead Flashings to Chimneys.—In Figs. 7 and 9 two of the more common types of chimney are shown, namely, (*a*) one protruding through a roof slope and (*b*) one emerging through the roof at the ridge.



CHIMNEY FLASHING

Fig. 7

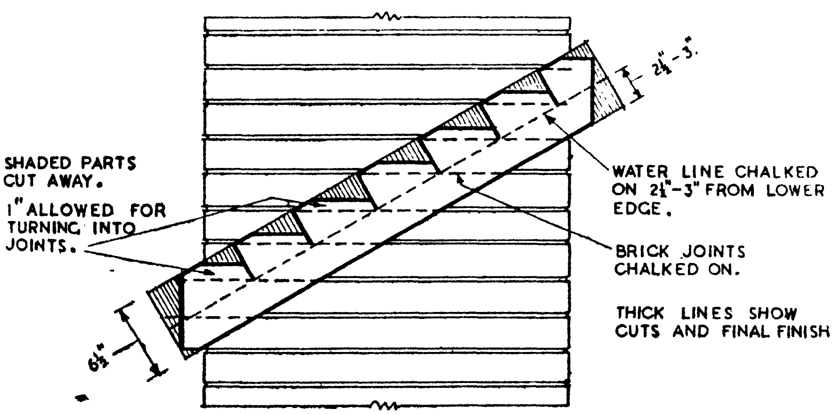
In the first case (see Fig. 7), rain-water running down the roofing surface (slates in this case) has to be caught in the gutter and turned left and right to pass down the sides of the chimney. This water has next to be prevented from entering the building by side flashings (soakers) and by the apron flashing resting on top of the slates at the foot of the chimney. Water running down the vertical chimney faces is turned by cover flashings let into the brickwork and dressed down over the upturns of the gutter and soakers. (In the case of the apron the cover flashing usually is worked on the same piece of lead as the apron with its upper edge again turned into the brickwork joint.)

THE GUTTER.—To provide for this the joiner must fix in the angle formed by the brickwork and the rafters either a board or triangular wood block (see section B, Fig. 7) to form a horizontal surface about 6-in. wide extending across the width of the brickwork at the back of the stack. In good class work this block or board will be so shaped as to have a slight fall from the centre of the stack to each back corner. A " tilting " fillet (see section B, Fig. 7) will be fixed across the rafters on a board just above the block. This fillet tightens the slates by tilting them slightly upwards. The tilt also helps to turn rain-water right and left past the chimney. The tilting fillet (not always used) should be dressed off by the joiner to a feather edge so as to cause a gradual rise and fall in the line of slates. The leadwork for the gutter is shown in position at A in Fig. 7 and separately at D in Fig. 7. It is made from 5 or 6-lb. lead dressed over the gutter bottom and up over the tilting fillet for about 1 to 2-in., and also has an upturn of 4 or 5-in. bossed to return 2-in. round the chimney corners. The sloping part and the gutter bottom exceeds the width of the brickwork by 6-in. at each end. The gutter has to be fixed in position before the slates are laid. The cover flashing is of 5-lb. lead and is made from a sheet about 6-in. wide turned over 1-in. and is tucked into a raked out horizontal joint in the brickwork and pointed. It is secured by lead wedges, and the cover flashing is dressed down to lie close over the upturn of the gutter. It should lap over the upturn for 3-in. or more. The ends of the cover flashing are returned round the chimney stack corners for 3-in., the top edge being tucked in and pointed in a similar manner. The returned ends are dressed down over the side cover flashings.

SIDE FLASHINGS.—These consist of soakers and cover flashings. Soakers (shown at E in Fig. 7) are cut from 4-lb. lead, being relatively thin because they are fixed " sandwiched " between the slates. They are 4-in. wide with an upturn of 3-in. The length of the upturn of the soaker equals the length of the covered (hidden from sight) portion of each course of slates, but the part of the soaker which lies between the slates is 1-in. longer than the upturn. This extra inch is turned over to form a hook over the top edge of the slate if the slates are fixed to battens, or acts as a flat nailing down strip if slates are fixed to roof boarding. The lengths of the soakers are such that each one laps over the one below several inches, and so effectively " turns " the rain-water. The plumber prepares the soakers for the slater, who places them in position as he slates.

The plumbing student should study the methods of fixing plain slate and tiles. These will be found described in any good book on construction, such as " Building Construction," Volume One, by McKay, published by Longmans. Much of a plumber's work is connected with the final waterproofing of such roofs. Here it is only possible to state that slates and tiles are laid to certain gauges according to their sizes. They may be secured directly on to boards, on battens fixed to boards, or on battens nailed directly on to the rafters. In this latter case it is necessary to provide underboarding to many roof flashings in order to support them. Plain slates and tiles are laid so that the exposed portion is less than half the full length of the slate or tile. The unexposed portion which governs the length of a soaker may be as much as 4-in. longer than the exposed part.

The cover flashing used over the soakers for chimney sides may be either in one length of lead (see D, Fig. 7), or made from short lengths. Because of the slope of the slating, the top edge is not turned into one horizontal joint in the brickwork, but steps down in turn from one joint to the next below. Where the cover flashing is in one length of lead it is known as a *Continuous Stepped Flushing*. To make this, a piece of 5 or 6-lb. lead, being 6½-in. wide and 4-in. longer than the length of the brickwork, is used. This is laid against the side of the chimney, as shown in Fig. 8,



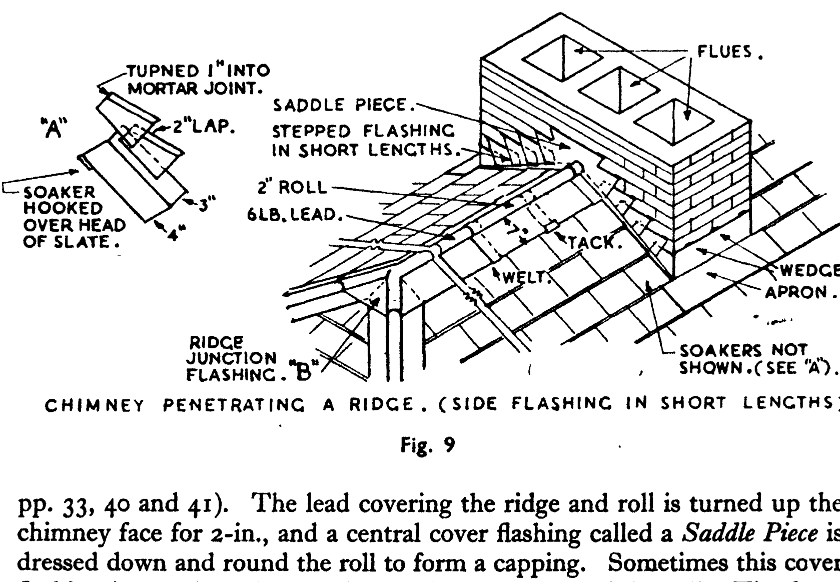
METHOD OF SETTING OUT A CONTINUOUS STEPPED FLASHING

Fig. 8

and the line of the brickwork joints are marked on *with chalk*. Next, the lines of the steps are set out so that they will rake slightly backwards when fixed. The allowance (1-in.) for the turned-in edges is made and the lead in the triangular shapes is cut away. The horizontal edges are next turned over, the ends turned and the flashing is ready for fixing. The size of the steps is governed by the thickness of the bricks and the slope of the roof.

In a correctly designed flashing the " water line " joining the apexes of the cuts should not be less than 2-in. from the bottom edge. Fixing is accomplished by inserting the " turn-ins " into the previously raked out brick joints and securing the flashing in position by lead wedges. The flashing is dressed down over the upturn of the soakers and round the chimney corners so that the lower end lies under the cover flashing to the chimney back and over the upturn of the front apron flashing. The other method of making a stepped flashing is known as a *Stepped Flashing in Single Steps*. It consists of making the cover flashing from small pieces of 5 or 6-lb. lead, to the shape shown in Fig. 9. Each piece should lap the next below by 2 to 3-in., and is secured by wedges. It is more water-tight than the continuous flashing, because any water penetrating the raked back front edges is intercepted by the flashing next below.

Fig. 9 shows a chimney which has this type of flashing penetrating a ridge. In this drawing the ridge is shown covered with a lead roll (see



CHIMNEY PENETRATING A RIDGE. (SIDE FLASHING IN SHORT LENGTHS).

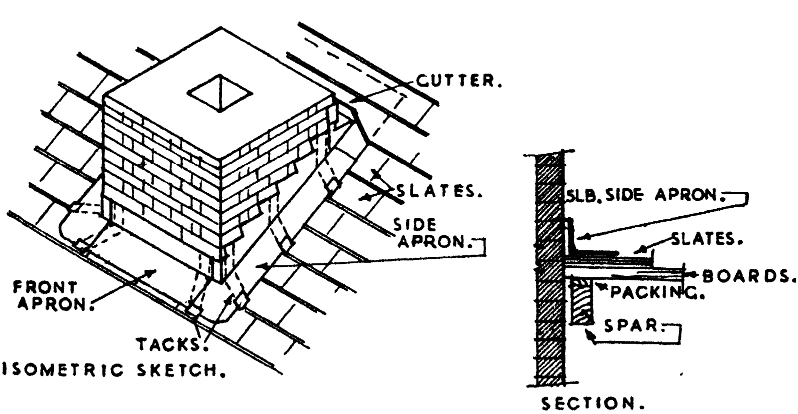
Fig. 9

pp. 33, 40 and 41). The lead covering the ridge and roll is turned up the chimney face for 2-in., and a central cover flashing called a *Saddle Piece* is dressed down and round the roll to form a capping. Sometimes this cover flashing is merely scribed and cut off to the shape of the roll. The front flashing, called the *Apron Flashing*, is formed by bossing a sheet of 5 or 6-lb. lead to the shape shown in Fig. 7. Its cross dimension is that of the brick-work of the chimney front plus 6-in. at each end. The apron (the part which lies on the slates) is normally 7-in. deep, but the upturn must be measured to suit the brickwork joints. The top edge of the upturn must be turned over 1-in. and the ends of the upturn returned round the chimney corners for 1½ to 4-in. It is fixed during slating, as it lies part on and part under the slates. The upturn has its " turn-in " secured by wedges into the brickwork as before described. When the apron is long there is a danger of its being lifted by heavy winds, and it is usual, therefore, where the overall length of the apron exceeds 2-ft. 6-in., to secure the lower edge. Nails or screws cannot be used because of the slates, and nail holes in any case would allow water to penetrate the roof covering. The method of securing the lower edge is to use " tacks." These are cut from heavy lead (6 or 7-lb.) 2 to 3-in. wide. They are fixed in the brickwork joints *under* the " turn-in " of the upturn and are long enough to pass under the apron and be turned up 1-in. to clip it. In good work tacks are made from heavy gauge sheet copper. Tacks must be used at not more than 2-ft. 6-in. apart. In some instances the apron flashing is made with a plain upturn and a separate cover flashing is used.

The order of fixing the various flashings is as follows : The apron flashing is fixed by the plumber when the course of slates below the chimney is in position. The slater continues slating up the chimney sides and fixes the soakers. Next the plumber fixes the gutter, and the slater then continues his slating behind the chimney over the tilting fillet. The stepped flashings are next fixed, followed by the back cover flashings. These lap over the stepped side flashings which in their turn overlap the upturn (or cover flashing) to the apron. The raked out joints in the brickwork taking the " turn-ins " of the cover flashings are then all pointed.

It is possible to make the special shapes required for the gutter and apron flashings by a method other than " lead bossing." This is by the " lead burning " process in which the shapes are developed geometrically and set out on flat sheets of lead. These are then bent into shape and the joints fused together by an oxy-acetylene blowpipe flame. This method is not commonly used for the simpler flashings, as the " bossing " method requires simple tools only and is readily and quickly done. Solder must never be used for any joints in flashings. Lead burning is more likely to be used in repetition work. This process is described further in Chapter Five.

Two variations in the leadwork to chimneys are shown in Figs. 10 and 11. The principal difference is in the method of flashing the chimney



SIDE APRON CHIMNEY FLASHING.

Fig. 10

sides, the gutter and front apron being very similar to those previously described. Fig. 10 shows the *Side Apron Flashing* method commonly used where the roof covering is of single thickness such as patent tiling. Here soakers are omitted and the continuous stepped flashing is continued down and dressed over the slates for 6-in. as an apron. Its outer edge is held down by tacks fixed to a slight fall. The upper end goes under the wings of the gutter and the lower end over the apron of the front flashing. In good class work the slates will be laid with a slight tilt downwards and outwards from the brickwork, and the lead apron conforms with this so that the rain-water tends to run away from the angle of the flashing on to the slates. In Fig. 11 a further way of treating the side flashing to a

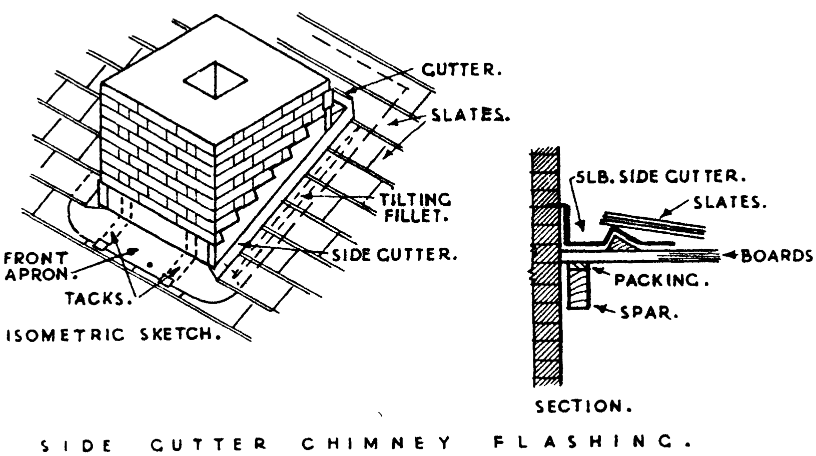
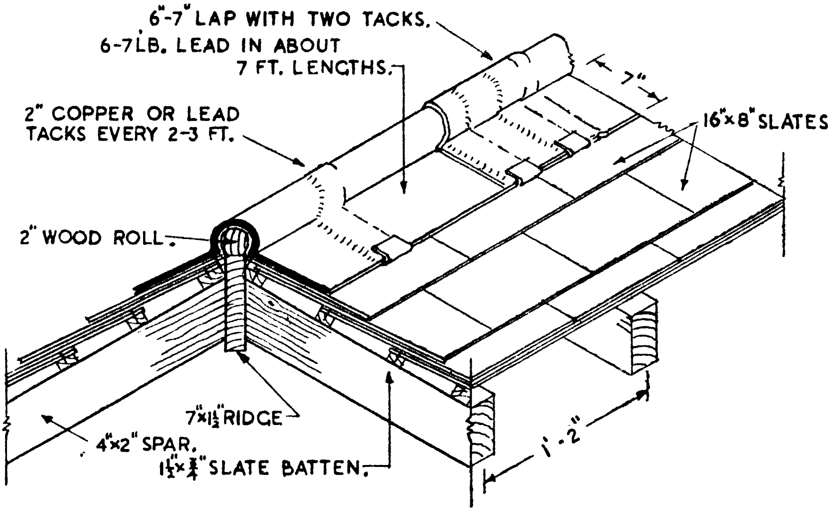


Fig. 11

chimney, called a *Side Gutter*, is shown. In this case the slates are so laid that there is a 3-in. clearance between the edge of the slates and the brickwork. A smaller clearance can be used if there is a desire to hide the leadwork. Under the slates is a tilting fillet, and a lead side gutter is formed with a 2 to 3-in. upturn by dressing the lead across to and over the tilting fillet, which is eased off to a feather edge at the ends so that the slates do not " ride " up at the ends of the fillet. Here the flashing is close copper nailed.

Flashings to Ridges and Hips on Slated Roofs (see Fig. 12).—The common rafters supporting the slating on a roof are fixed at the ridge and hips to timbers known as the ridge-piece and hip-rafter respectively. These are from 1½ to 2½-in. wide. The slates should, when fixed, finish flush with their angles.

To form a watertight finish in lead a 2-in. wood roll (of section shown at A, Fig. 5) is screwed to the ridge-piece and hip-rafters, being carefully mitred at their junction (see Fig. 12). Lead or copper tacks are next fixed to the sides of the rolls at intervals of 2 to 3-ft. The tacks can, if



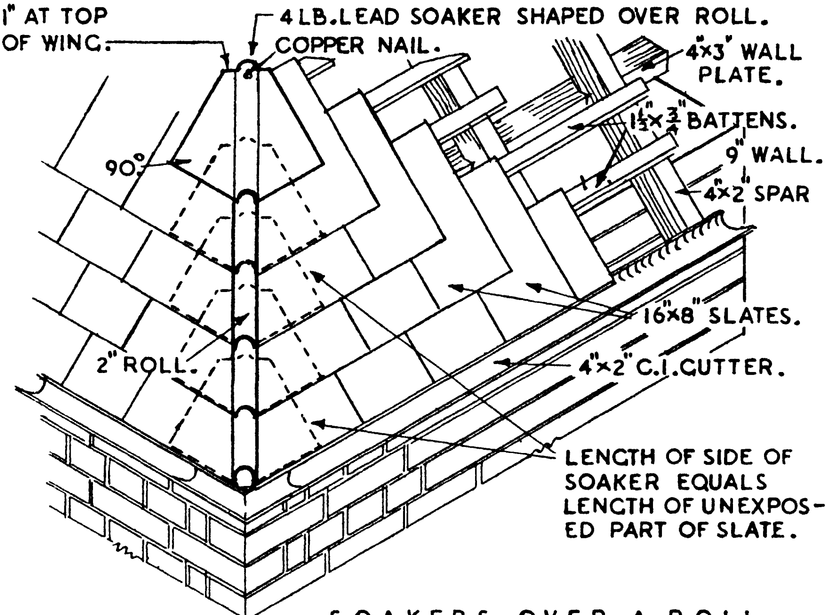
LEAD RIDGE ROLL

Fig. 12

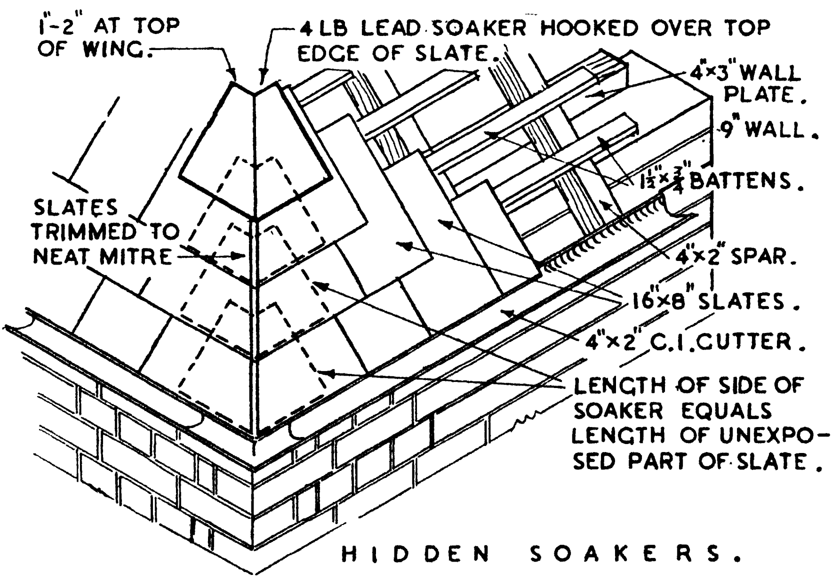
desired, be fixed to the ridge-piece and hip-rafters before the rolls are screwed on. Heavy lead (6 to 7-lb.) in about 7-ft. lengths is dressed tight round the rolls and down over the slating for about 7-in., the lower edge being secured against lifting by clipping over the tacks. The joints between lengths are lapped 6-in. and secured by two tacks. In good work the joints are often welted (see H, Fig. 5). At the junction of the ridge and the hips the lead is bossed over the meeting of the rolls, as shown at B, Fig. 9. At the lower ends of the hips the lead is bossed over the end of the rolls (generally sawn back behind the perpendicular), and the ends of the aprons returned back under the edge of the slates.

OTHER HIP FLASHINGS TO SLATED ROOFS.—It is possible to use the " soaker " method of flashing on hips. There are two common ways, namely, (*a*) with soakers exposed to view as they pass over a roll, and (*b*) soakers hidden behind the slates. This latter method is known as a " secret " flashing.

(a) *Soakers over Roll* (see Fig. 13).—The soakers are cut from 4-lb. lead and shaped to pass over a roll. Their length is again the length of the unexposed portion of the slate, the wings of the soaker should be cut to give a 1-in. wing, at least, at the top of the soaker. The length of the lower edge of the soaker varies with the roof slope. They are fixed in with the slates and secured with copper nails into the roll at the top. The slates are neatly trimmed up to the side of the roll, and the exposed lower edge of each soaker coincides with the horizontal line formed by each course of slates, giving a good external appearance. This method is very suitable for exposed roofs.



SOAKERS OVER A ROLL.



HIDDEN SOAKERS.

HIP FLASHINGS.

Fig. 13

(b) *Hidden Soakers* (see Fig. 13).—The soaker is cut from 4-lb. lead. In effect, it acts as a " bent slate." Its shape is four-sided, the length of two adjoining sides being that of the unexposed length of slate. The length of the bend equals the length of the unexposed slate, measured up the hip. They are fixed with the slates and nailed at the head to the hip-rafter with a copper nail. In this case the slates on either side of the hip are neatly trimmed so as to touch each other and hide the lead. This form of hip flashing is used for good quality work where the slating forms a feature of the building's elevation.

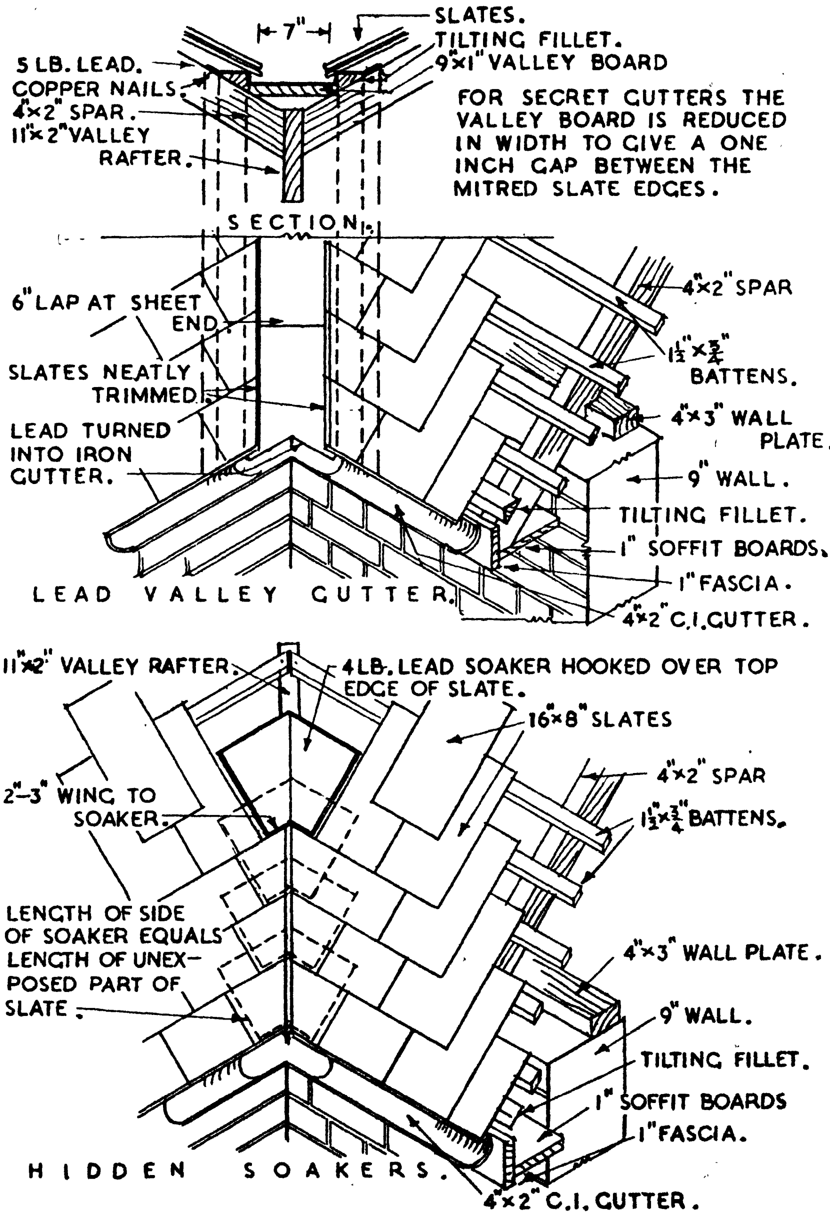
Flashings to Sloping Valleys on Slated Roofs.—In this form of valley, formed where a roof surface changes direction abruptly to form an internal sloping angle, the common rafters are secured to a valley rafter with their upper surfaces flush. Rain-water drains down into a valley from two roof surfaces (rain-water runs away from a hip), and it is highly essential for the valley flashing to be a sound piece of work.

There are three common methods of flashing valleys, (*a*) open gutter, (*b*) secret gutter and (*c*) soakers.

(a) *Open Gutter* (see Fig. 14).—This method, which is commonly used, gives a sound job, but is not very attractive; it consists of fixing a 9-in. board down the valley for the lead to rest on. Tilting fillets are fixed up the valley parallel to the board, and strips of lead 7-ft. long and 18-in. wide are laid up the valley and dressed over the tilting fillet. Each sheet laps the one below by 6-in., the undersheet being close copper nailed along top edge, the lower end being left free. The slating is carefully trimmed to parallel lines, leaving a 7-in. gap, this allows foot room for men undertaking any repair work at a later date.

(b) *Secret Gutter*.—This way uses a narrower valley board and brings the trimmed edges closer, leaving only a 1-in. gap. The strips of lead used are only 10-in. wide and are dressed over the tilting fillets as previously described. The method of securing and the lapping of each sheet over the one below are also similar. This method is considered to have a better appearance than the former, but it is liable to choke with leaves and rubbish, and water will then flow over the gutter edges into the roof. It should never be used with roofs of flat pitch.

(c) *Soakers* (see Fig. 14).—This method, using soakers, closely resembles the way described for soakers on hips. In effect it is using pieces of lead again as " bent " slates. Fig. 14 shows the soaker which is cut from 4-lb. lead. Its two lower sides are again the true length of the unexposed part of the slate plus the 1-in. allowance for hooking on the slates at either side, whilst the fold in the soaker is the length of the unexposed part of the slate measured along the valley. The soaker shape will vary from a square to almost a triangle according to the roof pitch. They are fixed by hooking on to the upper edge of the slates as they are laid. The slating is trimmed to a close fit, completely hiding the soakers. The method is very sound and is used where the slating forms a feature of the elevation.



VALLEY FLASHINGS.

Fig. 14

Other Roof Flashings.—Where a slated roof abuts on to brick walls the leadwork resembles that provided for chimneys. For a sloping junction soakers and step flashings are used, whereas for a horizontal junction an apron flashing is used. In this latter case, as the leadwork may extend for some distance, it is usual to have an apron with a simple upturn and to use a separate cover flashing. This method allows for expansion and contraction, this consideration also fixes the maximum length of each piece of lead at about 7-ft. Tacks are used at the usual intervals.

It should be understood that the preceding methods of lead flashing apply equally well to plain tiling. The side gutter method of flashing is often used with tiles in preference to soakers.

LEAD GUTTERS

Sheet lead is used almost universally for gutters situated behind parapet walls. It is *never* used for overhanging gutters at the eaves of a roof, because it needs some form of continuous support. Awkward projections, turns and twists in the run of the gutter are readily worked in lead, whereas if cast iron were used, each projection or turn would require its own special casting. Lead is also used for gutters running along the bottom of valleys between parallel roof slopes.

General Description.—Roof gutters, because they lie in exposed positions, must comform to the general conditions previously laid down as to size and length of sheet. Each section or bay of a gutter consists of a sheet of lead 7 to 8-ft. long laid on boards to form the gutter bottom or " sole " which normally should be 9-in. wide. The two long sides of the sheet are either upturned 5 to 6-in. to form a trough, or are inclined up under the slating through a vertical height of 5 to 6-in. One end of the sheet is turned up to form an undercloak, and the other is turned down to form an overcloak to the drips used as cross-joints in the gutter. Each section of the gutter must have a slight fall of 1½-in. in 10-ft. to remove water. Except in unusual cases this fall is never exceeded, as a sharper inclination would bring the summit of the gutter so high as to require an especially high parapet, or cause the lower part of the gutter to come below the ceiling of the room underneath. For similar reasons, it is necessary to limit the number of bays to three and drips to two. This means that a lead gutter can run right and left from its summit (here the adjoining sheets are worked over a roll) for three 8-ft. bays, giving 45 to 48-ft. as the maximum possible length between outlets. These are formed by dressing the bottom end of each lowest sheet as an overcloak into a small lead tank, 6-in. deep, and the same width as the gutter at that point. This tank is called a cesspool, and is connected by a lead pipe to the down pipe. The joint between the pipe and cesspool is now lead burned. Formerly it was soldered. It is absolutely essential for the lead to be

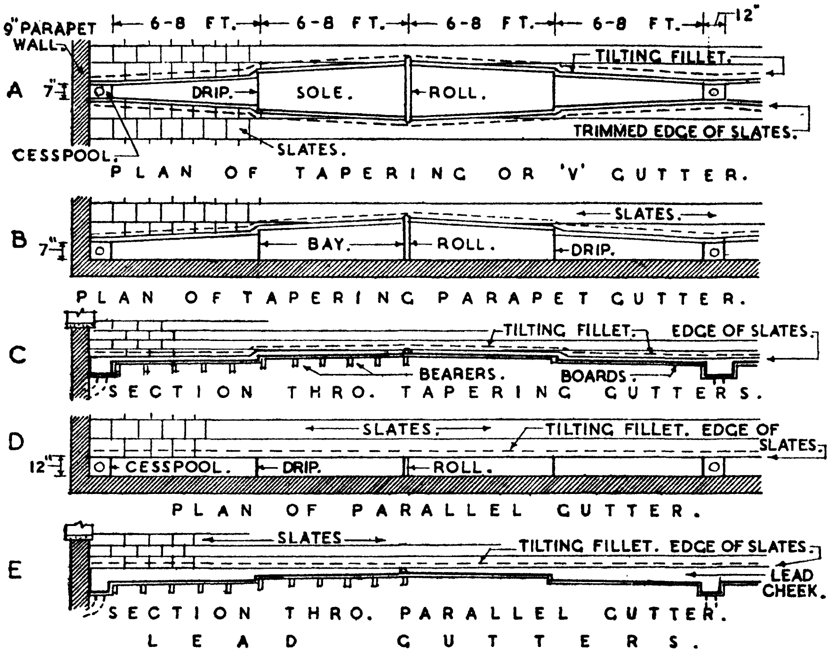


Fig. 15

supported by boarding *which must run in the direction of the fall.* If there is no underboarding to the slating, boards must be fixed over the feet of the rafters to support any lead fixed under the slates. The gutter boarding, 1-in. thick, must be laid to slight falls with 2 to 3-in. drips at distances not exceeding 8-ft. apart. A roll is fixed at the summit where the gutter falls run right and left. The boarding is supported on 3-in. by 2-in. bearers fixed with one end in the parapet wall, and the other nailed to the rafters or to a parallel bearer known as a " pole plate." In a valley gutter both ends of the bearers are fixed in the rafters. The bearers are adjusted to suit the falls and drips (see Figs. 16 and 17 for details of the woodwork).

There are three types of lead covered gutters, namely, (*a*) the tapering V-gutter between two roof slopes, (*b*) the tapering parapet gutter and (*c*) the parallel parapet gutter.

Tapering Valley Gutter (or V-Gutter) (see A and C, Fig. 15, and A, Fig. 16).—This form of lead gutter follows the broad lines previously laid down in that it is divided into bays, each not longer than 8-ft., with the cross-joints consisting of drips. It can fall continuously in one direction or be arranged to fall right and left of summits. The lowest bays discharge into cesspools. Each bay is made from one sheet of 6-lb. lead, and is virtually a long trough. The long sides are inclined outwards at the same angle as the adjoining roofs, whilst the higher and lower ends respectively form the undercloaks and overcloaks to the drips. The bearers supporting the gutter boarding are fixed horizontally across the V formed by the common rafters on either side of the gutter. To secure a fall, each bearer, taken in order from cesspool to summit, is fixed higher than its predecessor. This means that each bearer is also longer as the summit is approached, and consequently the gutter sole widens as it rises. This change in width, from which arises the term "tapering," is shown at A in Fig. 15. The method of ascertaining the width at various points in the gutter is shown at A, Fig. 16. The edges of the roof boarding, tilting fillets and lower edges of the slating all run parallel to the rake of the gutter boarding.

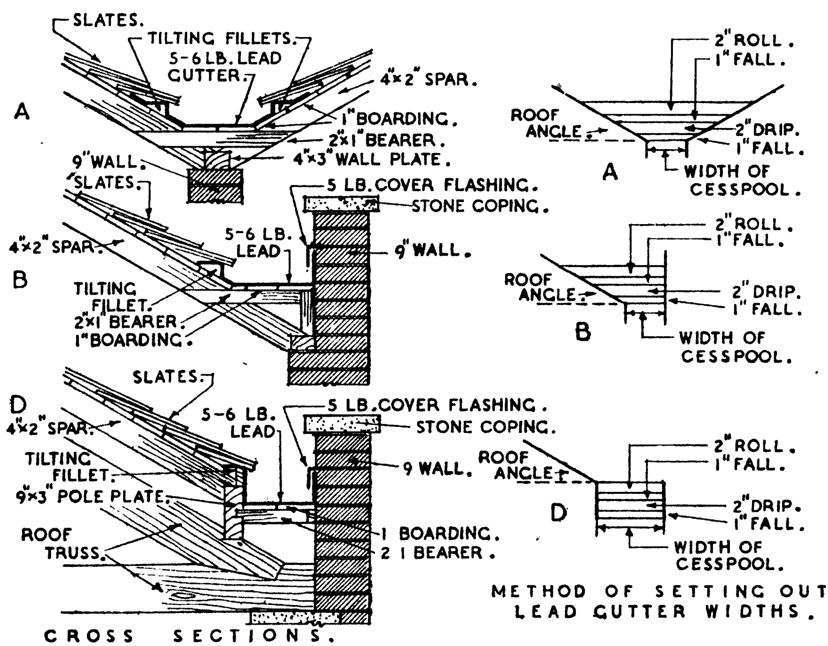


Fig. 16

Cesspool.—A wooden box is made for each cesspool at least 6-in. deep below the level of the gutter boarding. The width of the box equals that of the gutter adjoining the cesspool, and the length is 9 to 12-in. The box is lined with 6-lb. lead bossed from one flat piece of sheet lead. (Alternatively the box may be made from a flat sheet cut so as to form a box when turned up. The angles are then "lead burned.") The sides of the lining to the cesspool form wings and are dressed up over the tilting fillet, except where any side abuts on to the wall. In this case the wall side will be continued up a further 3 to 4-in as an upstand which will be covered subsequently by a wall cover flashing (see Fig. 17). The outlet to a cesspool is a 3 to 4-in. lead pipe, fixed by "lead burning" or solder to the bottom.

Lowest Bays.—The narrowest point of a V-gutter occurs where the gutter discharges into the cesspool. The least width should be at least 6-in. measured across the boarding with wings of a minimum width of 9-in. dressed up the roof boarding on each side. As the slating normally finishes 3-in. back from the angle formed by the gutter and roof boarding, a similar amount (3-in.) of lead forming the wings will be exposed before they pass under the slates to be dressed over the tilting fillet, where they are trimmed off 2-in. above the fillet (see A, Fig. 16). To make a satisfactory job, a horizontal line across the gutter joining the upper edges of the wings should be 6-in. above the sole. At the lower end of the bay the lead across the sole is dressed down for 4-in. into the cesspool, whilst the wings lap 4-in. over those of the cesspool. Where the cesspool receives water at each end the wings from the adjoining bays are lapped 4-in. over the cesspool wings, whilst the adjoining soles are dressed down into the cesspool for 2 to 3-in.

If the roof and the cesspool abut on a parapet the wings along each side of the pool are turned up at the ends to form 3 to 4-in. upstands against the parapet over which the stepped cover flashing is fixed. This cover flashing will also cover the upstand on the cesspool end. The upper end of the lower bay is dressed up to form an undercloak against the step in the gutter boarding.

Intermediate Bays.—The lower end is dressed down over the drip as an overcloak, the wings being lapped 4 to 6-in. over the wings of the bay below. The treatment of the wings and their sizes resemble those of lower bays. Except for its greater width, the upper end is also the same as that for a lower bay.

Highest Bays.—The lower end is as described under the intermediate bays. If the upper end abuts against a wall it is formed into an upstand to take a cover flashing. Where, however, it meets an adjoining bay to form a summit, the two bay ends are worked over a wood roll, one being the undercloak and the other the overcloak. The roll dies out into the roof surfaces at each side. The wings are under the slates and above the roll, and are lapped 4 to 6-in. The slates are trimmed round the roll.

TAPERING PARAPET GUTTERS (see B and C, Fig. 15, and B, Fig. 16).—The general requirements for this form of gutter are similar in most respects to those described for the V-gutter. The principal difference is that one side is turned up against a parapet, there being slating on one side only. The treatment of the leadwork to each bay on the side next to the slating is precisely the same as is used in the previous gutter. On the parapet side, however, a 6-in. upstand is formed over which a cover flashing is fixed in the convenient brickwork joints. The width of the lead in a bay at any point is the width across the gutter bottom plus a 6-in. upstand and a 9-in. wing. The top of the cover flashing is horizontal, but steps down one joint at each drip. The lower edge of the cover flashing is trimmed off parallel to the fall of the sole. A detail of the lap in the upstands and cover flashings is shown in Fig. 17. Cesspools will always have one and sometimes two sides abutting the parapet. These sides are brought up 6-in. above the level of the gutter boarding. The cover flashing is taken over them.

PARALLEL PARAPET GUTTER (see D and E, Fig. 15, D, Fig. 16, and Fig. 17).—Also known as a " box " or " trough " gutter, this type can be used at the foot of slated roofs and is essential for the foot of sloping or flat lead-covered roofs. The minimum width for a parallel lead gutter is 10-in., and it is necessary to have a beam at least 9-in. deep running parallel to the parapet at the required distance (gutter width) from the wall. The beam supports the lower edge of the roof discharging into the gutter, as well as one end of the bearers carrying the boarding to the gutter bottom. The other end of the bearers is secured to the inside of the parapet wall. The bearers are so fixed as to give the necessary falls and drips for the various bays of the gutter boarding. The gutter, however, instead of diminishing in width towards the cesspools, as in the case of the tapering type, presents a gradually deepening lead-lined vertical face as the cesspool is approached.

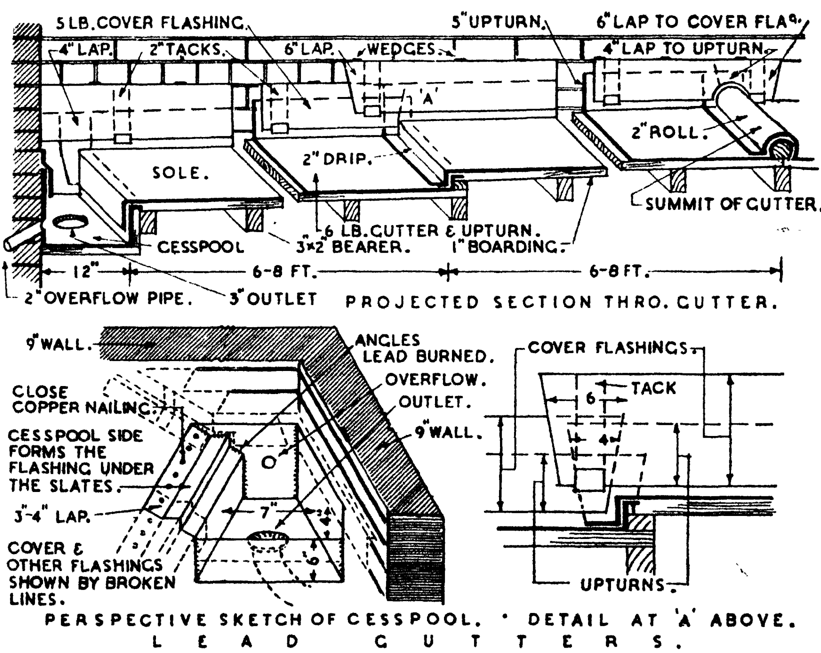


Fig. 17

Cesspools.—The general form is the same as described before. The side against the roof forms the wing over the tilting fillet, whilst the sides which abut in the brickwork stand up 6-in. above the level of the gutter boarding. The end of the cesspool lining over which the water will discharge is trimmed off level with the top of the gutter boarding or dressed into a groove in the gutter boarding.

Lowest Bays.—The lead is laid over the gutter bottom and an upstand 6-in. high is formed on the parapet side. On the roof side the lead is upturned vertically on the gutter cheek and over the tilting fillet, which, in this case, will be fixed at the edge of the gutter cheek (the edge of the slates will project 2-in. over the gutter—see D, Fig. 16). The depth of the cheek varies along each bay and can be measured from the section (see D, Fig. 16). At the lower end of the bay the lead in the sole is dressed 4-in. down as an overcloak into the cesspool. The upturn on the roof side laps 3 to 4-in. over the cesspool side, whilst on the wall side it is trimmed off just past the drip. At its upper end the lead to the bay is formed into an undercloak with the upturns on each side being trimmed off 2-in. beyond the step (see Fig. 17).

Intermediate Bays.—These again have an upturn on the wall side of 6-in. and on the roof side an upturn brought up the cheek and over the tilting fillet, the height being regulated by the fall in the gutter. The lower ends of these bays are turned down as overcloaks and the upturns are lapped 4 to 6-in.

Highest Bays.—The lower ends resemble those described for intermediate bays. If the gutter has a summit between two adjoining bays, the junction is made over a wood roll fixed across the trough. The upstands are lapped 4 to 6-in. When the gutter at its highest point finishes against a wall the upper end of the top bay is bossed up, so that the upstand on the slating side is continued round to meet the upstand on the parapet side.

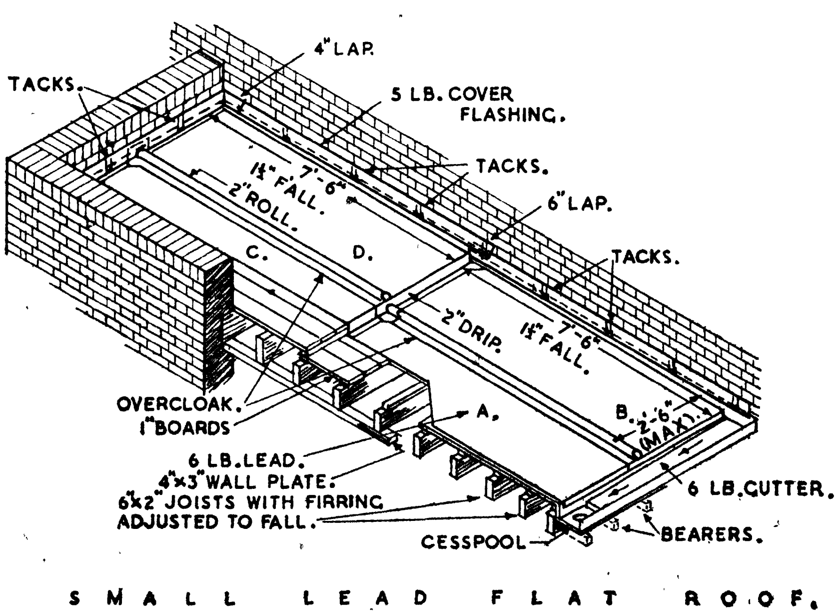
The order of fixing the various parts of gutters is as follows: First the cesspool is lined. Next, the adjoining bays to the cesspool are fixed, and the overcloaks dressed over the cesspool ends and sides. The higher bays are then laid in order as they ascend the gutter, each drip being formed and the wings and upstands dressed into position against the walls and over the tilting fillets. The leadwork is completed by wedging the cover flashings into the raked out joints in the brickwork. These are dressed down and the joints are pointed. The slating then follows.

SNOW BOARDS.—If any of the preceding gutters overflow, the water can enter directly into the building. This can easily occur when the gutter is choked with snow which has slipped down the roof surfaces. To keep a free passage for water under the snow it is usual to provide snow boards consisting of two longitudinal bearers (4-in. by 2-in.) with 2-in. by $\frac{3}{4}$-in. transverse laths nailed on at $\frac{1}{2}$-in. apart. Each snow board fits one bay with the lower snow board extending over the cesspool. The snow boards also protect the leadwork against damage from traffic along the gutter. Snow boards should be creosoted to preserve them against decay.

LEAD COVERED FLAT ROOFS

(Fig. 18)

General Description.—These are still a common provision in buildings, although in late years there has been a tendency to use concrete covered with a layer of asphalt for flat roofs. Lead flats, as these roofs are generally termed, will normally be found to be completely surrounded by walls. These walls may be either the main wall of the building or low parapets merely surrounding the flat. The lower edges of lead flats discharge into parallel lead gutters. A lead flat may fall either in two opposing directions or in one direction only. When designing a lead flat, care should be taken to see that the individual sheets do not exceed the sizes laid down on p. 31. This ensures that there is no excess contraction or expansion due to temperature changes. Care should also be taken to so design the size of the sheets that they can be cut from rolls of sheet lead without waste. Thus, if the roll of lead used is 8-ft. broad, then the longest dimension of any sheet laid on the roof should be 8-ft., when allowance has been made for the joints. As the maximum area of a sheet when laid should not exceed 24-sq. ft. (see p. 31) the other dimension of the sheet should be not more than 3-ft. after allowing for joints. The normal size, therefore, of one long bay will be about 7-ft. 6-in. by 2-ft. 6-in. measured from drip to drip and centre to centre of rolls. The sheets are fixed on underboarding laid to proper falls (see below for the description



SMALL LEAD FLAT ROOF.

Fig. 18

of the underboarding). Drips are used for joints across the fall and rolls for joints in the direction of the fall. Where the roof falls away in two directions from a summit, the sheets are joined on a roll, but where they abut on a vertical wall surface an upturn is formed and covered by a cover flashing. Although it is possible to use hollow rolls or welts for joints in lead flats, solid rolls are to be preferred, because they are not so liable to damage by people walking on the flat. Flats are obviously more likely to have more traffic on them than are pitched roofs.

UNDERBOARDING.—This consists of 1-in. boards *laid in the direction of the fall.* They should preferably be narrow to prevent their warping and disturbing the smoothness of the fall. When laid, they should be dressed over with a plane to remove any protruding edges.

The boards are nailed to wood joists (running across the fall). At the lower end of the flat a joist is placed parallel to the fall, so that its distance from the wall will give the desired width for the parallel gutter. Other joists of the same depth are placed at about 14-in. centres parallel to the first joist. The last joist of the bay must be under the line of the drip. To create the fall (1½-in. to 10-ft.) firring pieces equal in width to the joist and each slightly deeper than the previous one are nailed to the top of the joists. To these the boards are nailed. To form the drip a packing piece is nailed on to boarding to give the proper height for the drip (see Fig. 18). The depth of the joist to the next higher bay will exceed those of the lower bay by the height of the drip. *It is important that the height of the drip should exceed that of the wood rolls* because the overcloak is dressed over the rolls, and water could creep in if this part of the overcloak were higher than the surface of the sheet above. Another important point is that all iron nails and screws be well driven home, so that they will not make contact with the lead when laid. It is the practice in high-class work to lay roofing felt (with butt joints) on top of the boarding.

LAYING A FLAT (see Fig. 18).—The lead should be at least 6-lb. The gutter is first laid as described on p. 48. Sheet A is then laid. Its lower edge is dressed over the upstand of the gutter, one long side is formed into the undercloak on the roll and the other into an upturn to the parapet. The top edge forms the undercloak to the drip. Next, sheet B is laid. One long side forms the overcloak to the roll and the other the upturn to the wall, whilst the upper and lower ends are treated as for sheet A. Sheet C follows with one long side and the top formed into upturns and the other long side again is the undercloak on the roll. The lower end forms an overcloak to the drip. The last sheet D has its top end and one long side as upturns, the other long side as an overcloak to the roll and its lower edge as an overcloak to the drip. The ends of the wood roll are cut back slightly and the lead bossed to form a capping at the end. Along the drip the overcloak is bossed over the rolls and where the drip abuts into a wall the undercloak is bossed so as to make a neat finish into the angle between the drip and wall to form an upturn. The overcloak is similarly dressed down neatly in the same angle with its upturn continued to form a lap of about 4-in. Cover flashings are then fixed. They should coincide in length with the bays and have similar laps. Sufficient lead tacks should be used, and it is important to have tacks at tie laps. The work is completed by pointing the raked out joints.

SHEET COPPER WORK ON ROOFS

A full description of roofwork in copper is beyond the scope of this book, and it is only proposed to deal with those simpler points of roof-work where there is no great difference in treatment from that employed when lead is used.

Generally speaking the same precautions against expansion and contraction due to temperature changes are necessary. Underboarding has similarly to be provided, but has some slight changes in detail. The thinness of the copper sheet employed allows joints across the flow to be made in the form of welts, if the fall is sharp. Thus in gutters it is possible to substitute a sharp slope in place of a drip, and welt the bays across the slope (see Fig. 22). Joints along the fall can be in the form of rolls with the sheets welted on one side of the roll (see Fig. 21), or they can be formed with standing welts (see Fig. 19).

Because copper hardens when beaten (it has been known to harden with vibration), and also lacks the property of " flow," the bossing of angles and other parts is not possible. It is therefore necessary to develop geometrically the more complicated forms of roofwork, set them out on the flat sheet, bend them up, and add those portions which in lead would be bossed, by either welting or welding them in.

It is the usual practice to fix sheet copper roofing with a building felt or paper underlay. This serves two purposes. Firstly, it prevents contact between any iron nails or screws and the copper (nail heads and screws should in any case be driven well home); secondly, it acts as an airtight cushion for the copper. It is important that the copper, which is very thin and of no great weight, should not be subject to rippling movements due to the action of the wind either below or above the sheet. Such action can cause the copper to harden and become brittle. The felt or paper also acts as a sound deadener from the pattering sound of rain.

WELTS.—These form the basis of all joints in sheet copper work apart from welding. There are three common forms of welts. The first, known as the single lock (see Fig. 19), consists of folding back for ½-in. the edges of the sheets to be joined. They are then engaged and beaten tightly together. The single lock seam should only be used on vertical or almost vertical surfaces. The double lock welt (see Fig. 19) has a double turnover in each sheet. It is dressed down to be flat on the sheet surface. It measures about ½-in. when complete and uses up about 1½-in. of the edge of the sheet. It is very watertight and can be used for joints across the flow as well as with it. If in a very flat pitched roof there is danger of water being held up by the cross-welt, a ploughed groove can be made in the underboarding, deep enough to take the welt. A third form is the standing seam, also shown in Fig. 19. One upstand measures $1\frac{1}{2}$-in. and the other $1\frac{1}{4}$-in. The excess upstand $\frac{1}{4}$-in. is folded over the other and then both are folded down, leaving a standing seam about $\frac{3}{4}$-in. high. This type is used for joints in the direction of the flow in positions where it is not likely to be trodden on.

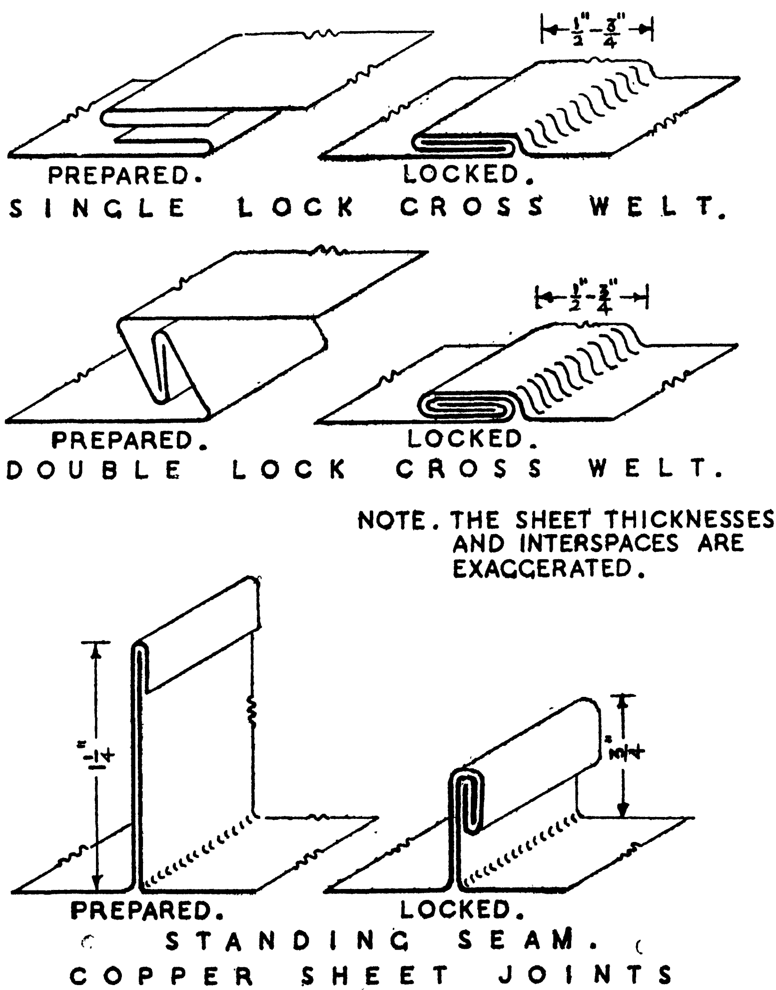


Fig. 19

UPTURNS AND COVER FLASHINGS.—Upturns are simply made by turning sheets up along their edges for 2 to 4-in. as required. External corners in upturns can be made by forming a " pig's ear " or by welding, whilst internal corners must have a " gusset " welted or welded in (see Fig. 20).

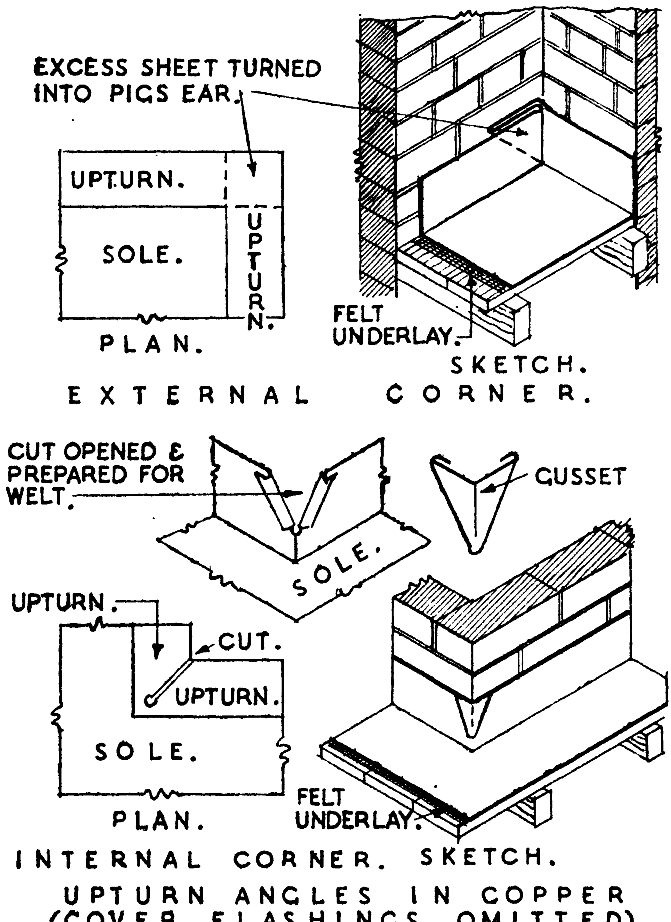


Fig. 20

Cover flashings are made by turning over the upper edge for $\frac{3}{4}$-in. and wedging it into the brickwork joints. The wedgings must be of copper and are formed by folding scrap pieces of sheet to the necessary thickness. The lower edge of cover flashings and the exposed edge of any laps in cover flashings are generally turned under for $\frac{1}{4}$-in. to stiffen the work against disturbance by the wind. The depths of cover flashings resemble those of lead.

Solid Rolls.—These can be roughly grouped as follows: (*a*) joints where the two sheets are linked directly together and (*b*) joints where the two sheets are linked by means of a separate capping. In the first type (see Fig. 21), known as the "conical roll," the wood roll is triangular in sections, with the apex rounded off. The base of the roll measures 2-in. and the height 1¾-in. Each sheet is brought up the side of the roll, one side (the overcloak) being 1-in. higher than the other (the undercloak). A single lock welt is then formed along the side. The second type has many variations. One is shown in Fig. 21. Here, a slightly tapered wood batten is used about 1½-in. by 1½-in. Upstands, ½-in. higher than the batten sides, are formed along the sheet edges. These are then turned out horizontally, the capping is laid with its edges turned in and is slid into position and turned down. It should be noted that in both examples shown, the shape of the roll does not hold the sheet down on the roof. It is therefore necessary to secure copper tacks to the rolls and fold them into the seams. This will prevent any lifting by the wind.

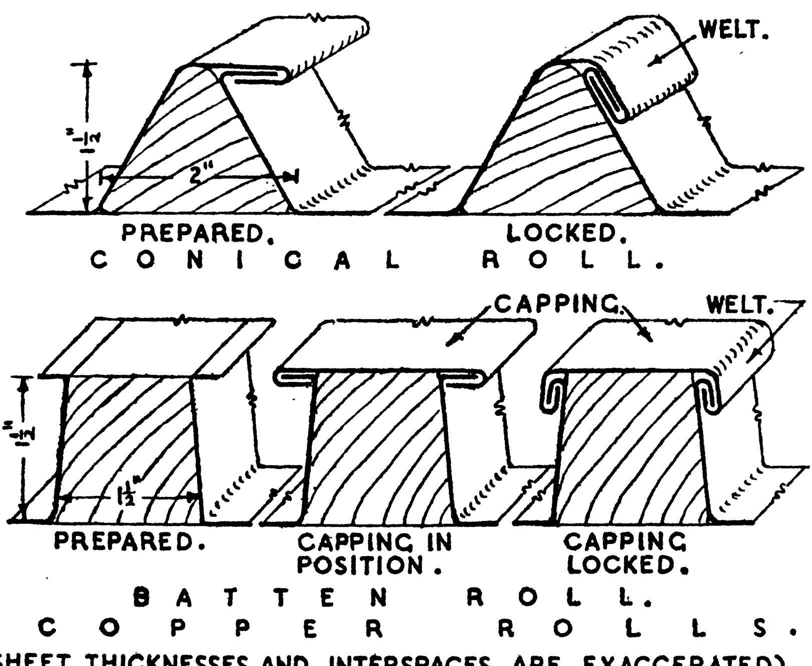
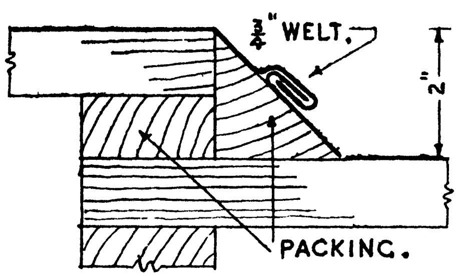


Fig. 21

Drips.—Fig. 22 shows a drip as modified for copper sheets. The height is the same as for lead, but instead of a vertical face a 45° splay is used. A double lock welt joins the sheets and can be placed either half-way down the slope or at its top edge.



DRIP (COPPER SHEET).

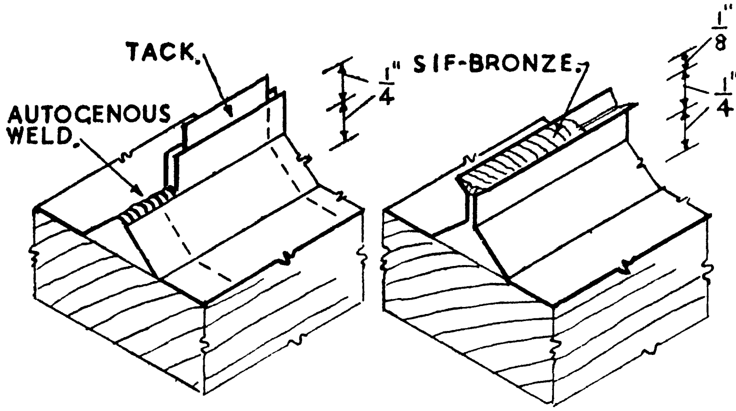
Fig. 22

LAPS.—In sheet copper work, laps are used for upturns and cover flashings in precisely the same way as for lead. They are not used for joints across the fall in steeply pitched roofs, the double cross-welt being preferred.

WELDED JOINTS.—There are two methods of welding copper sheets. The first method, known as " autogenous " or " flash " welding, consists of providing a turn-up of ½-in. at the sheet ends or an extra ½-in. on upstands and bringing them together. They are then fused together with an oxy-acetylene flame from a blowpipe. No metal other than the excess upstand is needed. This method is considered very suitable for roof-work. The ends of tacks are welded into the joint. It is absolutely essential to use " deoxidized " copper where welding is intended. In seams the provision for expansion and contraction is made by the 45° splays which take up the movement of the sheets. The second method, known as " sif-bronze " or " bronze " welding, consists of melting, by the oxy-acetylene flame, an alloy into prepared channels. The alloy, consisting of copper, phosphorus and zinc or tin, melts at a lower temperature than copper. It adheres to the copper and holds the sheets strongly together. Lapped joints can also be welded by melting the bronze filling rod down on to the joint in a continuous narrow ½-in. stream, so that it rests equally on each sheet. The distinctive bright yellow colour of the welding alloy is considered unsightly by many people who prefer " flash " welding for roofs where appearance counts. The " bronze " process is simpler than the " flash " method and is more easily employed in awkward situations. Examples of " bronze " welded joints are shown in Fig. 23.

It is possible to execute both forms of welding *in situ* over wood boarding and rolls if precautions are taken against the possibility of the wood igniting. Asbestos sheet may be used under the copper sheet in place of felting or paper and left under after completion, or it is possible to have the asbestos sheet withdrawn after welding.

Welding does not give the same freedom of movement along the joints from temperature changes as does welting, because it really makes several



WELDED SEAMS (COPPER).

Fig. 23

sheets into one complete whole. It is essential, therefore, to give serious consideration to the provision of expansion joints.

CHIMNEY FLASHING

The stepped flashings and soakers are cut, made and fixed in precisely the same manner as described for lead. To stiffen the lower edge of the stepped flashings an extra depth of ¼-in. may be allowed. This can then be turned up on the inside. If the stepped flashing is in single steps this ¼-in. turn-up can be used to link up the lower edges of the steps. The gutter is formed, as shown in Fig. 24, with a gusset welded or welted on. The front apron can be formed with its lower edge stiffened and with the extension to the apron welted or welded, as shown in Fig. 24. Both the gutter and apron flashings are normally made at the workshop from careful measurements on the job. It is difficult to work them *in situ*, whereas the stiffness of the copper enables them to be transported from workshop to job without fear of damage. The order of fixing is as for lead. It is possible to execute a side gutter type of flashing to a chimney in the same way as described for lead. The only variation is that the side flashing will be welted at the bottom to the apron wing and to the back gutter wing at the top. The side apron flashing method for a chimney is not very practical because some difficulty might be experienced in getting the copper dressed down tightly to the slates owing to its tendency to " spring " up a little. There is also the possibility of temperature changes causing the copper to lift.

FLASHINGS TO RIDGES AND HIPS ON SLATED ROOFS.—It is possible to use the same type of roll as for lead and to work the copper into the angle,

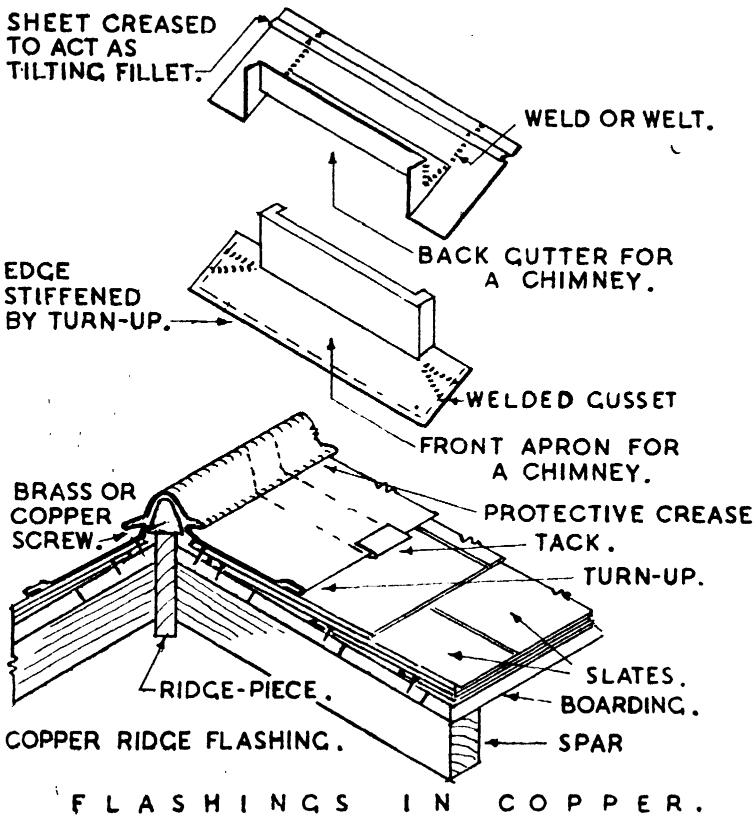


Fig. 24

using tacks to secure the lower edge which can again be stiffened by turning under ¼-in. Some difficulty may be experienced in getting a very tight fit to the roll. Another method is shown in Fig. 24. A conical wood roll can be used or the roll can be hollow. Fixing is secured by using brass or copper screws and washers under the small projection. The lower edge of the apron is stiffened by a ½-in. turn-up and held by tacks.

Other Hip Flashings to Slated Roofs.—Both the "soakers over roll" and the "hidden soaker" method of hip flashing are perfectly feasible in copper and are carried out as for lead.

The end of a roll will need to have a piece welded on as a finish as it is impossible to boss the copper over.

Flashings to Sloping Valleys in Slated Roofs.—All three common methods mentioned on p. 43 are feasible in copper.

Open and Secret Gutters.—The various lengths will be joined by double cross welts although they could be lapped as for lead. Otherwise they resemble their corresponding lead members in shape and size, but they will be made off the job and fixed ready-made.

SOAKERS.—The methods of making and fixing exactly follows those described for lead.

GUTTERS.—These resemble lead gutters in their general design. The principal difference is in the drips, which are made on a slope as described on p. 45. The various bays are made off the job from careful measurements and are delivered ready for fixing with the initial turns for the linking cross welts already fashioned. Certain gussets need to be inserted and these are best " flash " or " bronze " welded. Angles are also best welded, though in poorer work they may be " pigs eared." Where a bay discharges into a cesspool it is double cross welted. The cesspool which has its vertical angles welded is also made off the job, but the connection of the discharge pipe is normally welded in on the job. Sometimes, however, a short length of discharge pipe is welded on and dropped into a 3 to 4-in. long socket formed in the remainder of the discharge pipe. This socket will be a fairly close fit to the spigot. Cover flashings resemble those of lead and have similar laps. Their lower edges can be stiffened as previously described.

RAIN-WATER GOODS

Gutters fixed to the eaves of buildings together with the down pipes which lead the water from the gutter down to the drains are classified under the term " rain-water goods." Any special fittings used with them come under the same name.

As practically every building is fitted with gutters and down pipes, a considerable part of plumbing work is concerned with their installation.

Gutters and down pipes are made of cast iron, enamelled iron and lead. A recent development is the use of asbestos-cement in their manufacture.

In some localities gutters are called " spouts." Similarly a down pipe may be called variously a rain-water pipe, fall pipe, down comer, down spout, or stack pipe.

It is also the practice in some districts to use a wooden gutter with metal down pipes, but the more common method is to use cast iron throughout.

EAVES GUTTERS.—These are manufactured to various shaped sections, such as half-round, deep half-round, ogee and various moulded sections (see Fig. 25). There are many stock sizes varying upwards from 4-in. in width measured externally. The thicknesses are $\frac{1}{4}$-in. (" extra heavy grade "), $\frac{13}{64}$-in. (" heavy grade "), $\frac{3}{16}$-in. (" medium grade "), and $\frac{1}{8}$-in. " ordinary grade "). The two latter are usually used, the heavier grades being for special work. Gutters are cast with a socket (faucet or flange) at one end. This receives the plain (spigot) end of the adjoining lengths. The socket is normally outside the spigot, but they can be obtained with inside sockets. The standard length is 6-ft. excluding the socket which may lap 1½ to 2-in. Shorter lengths are obtainable or the lengths may be cut down with a hack-saw.

Special castings are available for a variety of internal and external angles. There are also stop ends to fit either socket or spigot ends, outlet lengths with nozzles or drops to fit into down pipes, and union clips used for connecting two spigot ends (see Fig. 25).

The half-round and deep half-round gutters are more commonly used nowadays. They have a satisfactory appearance and possess the advantage that they can be painted both inside and all round the outside, whereas the moulded types have a square back which, when they are fixed to fascia boards, cannot be painted on the outside.

Fixing of Eaves Gutters.—The gutters are fixed so as to have a slight fall towards the outlet into the down pipe. Sometimes the fall is specified as 1-in. to 10-ft., but in actual practice the fall is adjusted to suit the particular position because the gutter must not be fixed so that the lower edge of the slating or tiling enters it, as this will tend to block the gutter, nor must the gutter be so low that water from the roof can be blown back by the wind and not enter the gutter. The least vertical distance between the edge of the slates and the gutter edge should be ¼-in. and the greatest distance 1½-in. The slates should project about 1-in. over the back edge of the gutter.

Gutters are supported by wrought-iron brackets shaped to conform with the gutter outline. They rest on the brackets which can be secured in a variety of ways. In Fig. 25 five different types of brackets are shown. Those at A and B are for screwing to the spars or rafters, whilst at C and D are shown types of brackets for fixing to fascia boards. At E a bracket is shown which can be driven into joints in a brick or stone wall. As the joints will normally be horizontal there is a screw adjustment to adjust the bracket to the fall. Usually two brackets are fixed to each 6-ft. length of gutter.

The joints between each length are made watertight with a mastic (putty) made from powdered red lead and linseed oil. This is placed in the socket and the spigot end laid in position. A gutter bolt is then inserted and by using a screw-driver to the counter-sunk head of the bolt the nut is tightened, squeezing out any excess mastic. This is wiped off. Both inside and outside joints are shown in Fig. 25.

Cast-iron parallel-sided trough gutters of large section are often used in factories instead of lead lined parapet and V-gutters.

Asbestos-cement Gutters are a recent innovation. They are available in half-round forms and are fixed in the same manner as cast-iron gutters. Being brittle, asbestos-cement gutters are liable to damage from ladders. A special jointing preparation is supplied by the manufacturers.

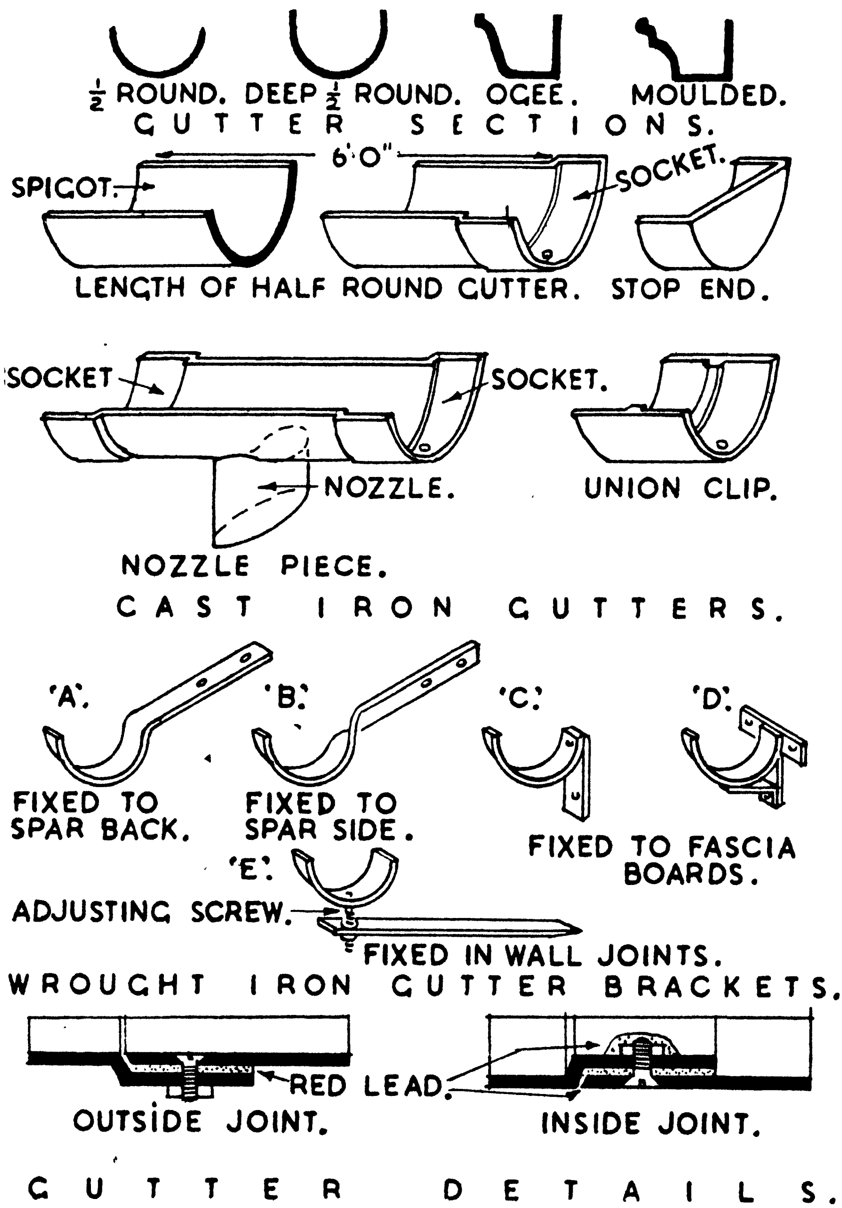


Fig. 25

Enamelled Iron Gutters are also comparatively new. They are jointed with a bituminous compound.

Both the above types do not need painting.

Lead Eaves Gutters.—Though it is possible to use lead for eaves gutters its use is uncommon as the gutters are liable to damage by ladders.

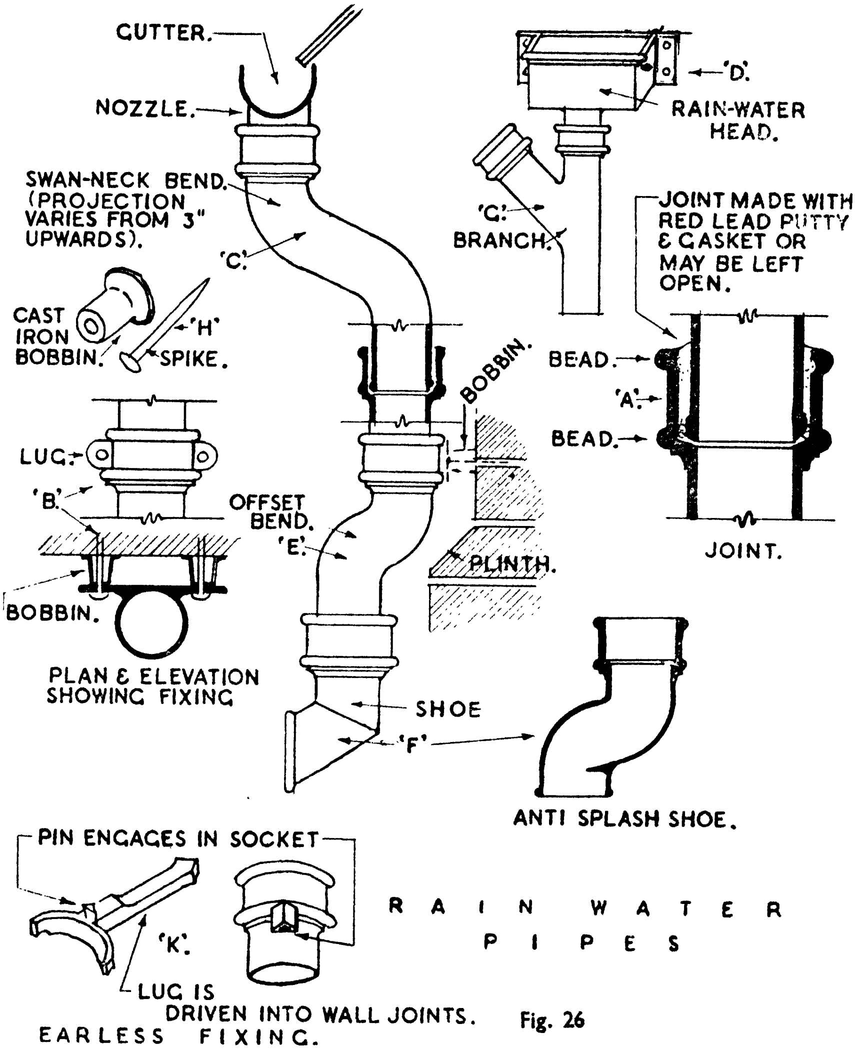


Fig. 26

Down Pipes.—The most common shapes of down pipes are circular, rectangular or square in cross-section. They are obtainable over the same range of materials as eaves gutters and to the same weights. The circular type vary in diameter from 2-in. up to 12-in., and there is a corresponding range for the other types. It is, however, unusual to find pipes over 6-in. diameter being used for rain-water. For houses the size used is generally about 2½ to 3-in. They are cast in 6-ft. lengths with a socket (included in the length) at the upper end. The socket is 2½-in. for the smaller diameter pipes, but is increased in depth for the larger diameters. Two half round beads are cast on the socket to increase their strength (see A, Fig. 26). In addition, the most commonly used type of down pipe has two fixing lugs or ears also cast on the socket (see B, Fig. 26). Lengths shorter than 6-ft. are obtainable or the pipes can be cut with a hack-saw.

As it is rarely possible to run a down pipe in a dead straight line from gutter to rain-water gully, many special fittings are necessary. These cover a wide range, but the most common are shown in Fig. 26 and their particular uses given below.

Swan-necks (see C, Fig. 26).—These connect the outlets of overhanging eaves gutters to the down pipe. They can be obtained for projections of 3-in. and upwards.

Rain-water Heads (see D, Fig. 26).—These are in effect funnels. They are used to collect water from outlets to lead gutters, particularly where the gutter outlet is the open end of a trough. They are also used for collecting the discharges from bath and wash-bowl waste pipes, and are sometimes fixed at the top of a down pipe as ornamental features; the swan-necks being led into them instead of into the plain spigot end. They are obtainable in a variety of sizes and designs with fixing lugs cast on.

Offsets (see E, Fig. 26).—These resemble swan-necks and are used to bring the pipe forward from the wall face over a projection such as a plinth. Double (or pass-over) offsets are used to pass the pipe over a horizontal projection in the wall.

Shoes (see F, Fig. 26).—These are short lengths with either a sharp angular end of 135° outwards (the standard form) or an offset (anti-splash type). Both are used to deliver water over the gratings of gullies. The anti-splash type is used where the pipe discharges waste water from baths, because the rapid and heavy discharge of discoloured water is otherwise likely to splash about and be a nuisance.

Branches (see G, Fig. 26) are use for bringing two or three pipes into one common down pipe. They can be obtained in single, double and Y types. Branches for connecting pipes of lesser diameter to others of larger diameter can also be obtained.

Various forms of bends for changes of direction across the face of the wall are available.

All the above special types of pipe have sockets with lugs cast on. It is possible, however, to get all types of down pipes without lugs if so desired.

FIXING OF DOWN PIPES.—Cast-iron down pipes require painting at regular intervals and should be fixed 2-in. clear of the wall face so that the back of the pipe is accessible to the paint brush. Where the pipes have lugs they are fixed with cast-iron or hardwood bobbins (acting as distance pieces) behind the lugs. Stout spikes (see B and H, Fig. 26) are passed through the holes in the lugs, the bobbins are threaded on the spikes, which are then driven home into wood plugs let in the wall.

Pipes without lugs are fixed by spiking a special fitting to the wall and passing a wrought iron ring round the socket and securing it to the fitting with a nut and bolt. Alternatively there is a type of pipe which has a small triangular hook cast on the back of its socket. A special lug with a triangular pin to fit the hook is built into the wall and each length of pipe is hooked on (see K, Fig. 26). This fitting is used for good class work and particularly for walls in masonry.

Joints are made with the same red lead putty used for gutters. A short length of gasket is wrapped round the spigot end and forced down into the socket. This centres the pipes and prevents the putty entering the pipe. The putty is pressed well home and smoothed off as a fillet. For purely rain-water pipes, however, it is common practice not to use any filling material in the joints. They are left open and the shaking of the pipe by the wind is prevented by inserting lead or wrought-iron wedges between the socket and spigot. (Wood wedges should not be used as they swell and may burst the sockets.)

Asbestos-cement and enamelled iron down pipes resemble cast iron in most particulars. Because, however, they do not require painting they can be fixed close to wall surfaces.

Lead can be used for both down pipes and rain-water heads. It lends itself readily to ornamental effects and is generally used for the down pipes on buildings of high architectural quality. The pipes in these cases are usually rectangular in section. Lead also possesses advantages in that it can be fixed close to the wall face as it does not require painting and it is readily worked into offsets to pass over mouldings and string-courses.

It should be borne in mind that the bottom lengths of down pipes are liable to damage by vehicles or malicious people. Lead can be cut or dinted, asbestos-cement is brittle and easily fractured by kicking. Cast iron stands up better to rough treatment. Using heavier weights of pipe, placing the pipes in internal angles of the wall or sinking the lower length flush with the wall surface are some of the methods employed to protect down pipes from damage.

CHAPTER THREE

INTERNAL PLUMBING

Description of internal plumbing work. Pipework—definitions and terms. Lead pipe joints. Cocks, valves and taps. Traps. Principles governing the design of sanitary fittings. Sinks, wash-bowls, baths and their fixing. The water-closet—general principles of design—its fixing. Flush tanks—general principles of design—the siphon—types of flush tank—their fixing. Pipe lines—terms and sizes. The design of pipe lines for cold and hot water. Hot water—principles underlying its supply. Boilers, cylinders and tanks. Installing a hot-water system. Lead pipe fixing. Iron pipe fixing. Copper pipework—jointing and fixing. Iron water pipes.

PLUMBING work inside buildings is highly vital to their efficient use and has a great deal to do with the health and comfort of the occupants. Practically every building erected requires the services of the plumber for some of its interior fixtures, and each different type of building has its own particular plumbing problems. A high degree of skill and knowledge is thus required from the individual plumber who is often called upon to fix valuable fittings which are highly susceptible to damage and which will not work efficiently unless properly installed.

Internal plumbing work can be briefly summarized as follows :—

(*a*) The fixing of sanitary fittings such as sinks, wash-bowls, water-closets, urinals, together with their taps, valves and flushing tanks.

(*b*) The designing and installing of pipe lines to convey cold and hot water to the above fittings together with the provision of pipe lines to remove the waste liquids (and solids) from them.

(*c*) The designing of systems for providing hot water for fittings and the installation of the necessary boilers and storage tanks.

(*d*) Similar work in connection with the provision of systems for the heating of buildings by hot water.

(*e*) The installation of fittings for cooking, heating and artificial lighting by coal-gas together with their pipe lines.

In carrying out work connected with the above the plumber is faced not only with problems imposed by the differing characters of individual buildings but also with the special requirements of varying types of fittings (there are literally hundreds of fittings connected with plumbers' work, each of which possesses some special characteristic). Also, it must be borne in mind that water supply authorities all have regulations which govern both the water fittings and pipe lines connected to their water mains, whilst local building authorities also have bye-laws controlling the installation of sanitary fittings.

It is only possible in this book to deal with those aspects of internal plumbing work connected with a small house which has the following fittings : a kitchen sink, a bath and wash-bowl, and a water-closet. Cold water is supplied directly from the main and hot water provided by a fireback boiler. Attention will be drawn at the appropriate places to any points in design and layout affected by bye-laws and regulations.

PIPES INSIDE A SMALL HOUSE (TYPES AND USES) (see Figs. 42 and 43)

PIPES UNDER PRESSURE.—These fall into two general classes : (*a*) those connected directly to the water main and subject to full mains pressure, and (*b*) those connected to water tanks fed from the mains and subject (generally) to a lower pressure than those under (*a*).

(a) *Service Pipes* bring cold water at mains pressure from the mains either directly to the various taps and valves or to a storage tank. Sizes : main pipes, ½ to ¾-in., internal diameter ; branches, ⅜ to ½-in., internal diameter.

(b) *Distributing Pipes* are those which bring water at less than mains pressure from the storage tank to the hot-water cylinder, and from the cylinder to the hot-water taps. Where the cold-water taps are fed from a tank the pipes used also come under this heading as do the " flow and return " circulating pipes fitted between the fireback boiler and the cylinder. Sizes are as above for main and branches. Flow and return pipes will be ¾ or 1-in. internal diameter.

NON-PRESSURE PIPES.—These, generally, have one or both ends open and consequently do not have to withstand pressure. The various types are defined below.

Flushing Pipes connect flushing tanks with the w.c. fitting. Their diameter is 1¼ to 1½-in. Low-level flushing tanks may have pipes up to 2-in.

Overflow or Warning Pipes.—These are fixed to flushing and storage tanks and sometimes to sinks, wash-bowls and baths. (Modern types of these latter fittings have self-contained overflows.) The diameter is always larger than the service or distributing pipes serving the fitting. Usual diameters are ¾ or 1-in.

Waste Pipes run from the sink, wash-bowl and bath to either gullies or rain-water heads outside the building. The diameter is from 1¼ to 2-in.

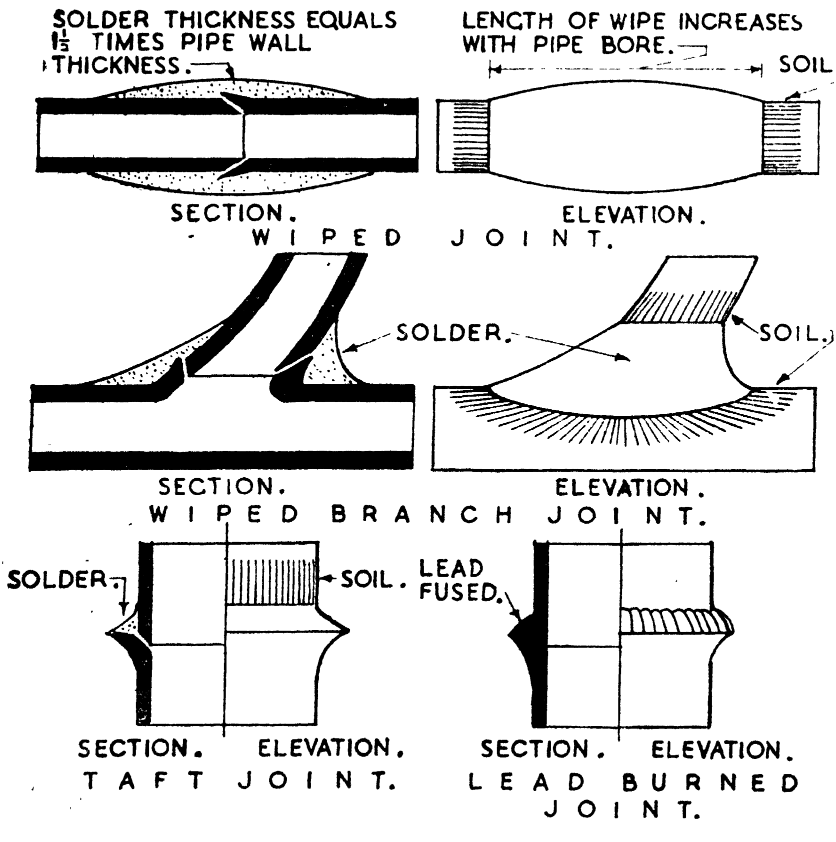
Soil Pipes link the w.c. to the commencement of the drain. The diameter is either 3½ or 4-in.

The weights of the above pipes (in lead) are given on p. 95.

JOINTS IN LEAD PIPES

Lead to Lead.—Lead pipes are generally jointed together by soldered joints, of which there are two common forms, namely, (*a*) the " wiped " joint and (*b*) the " taft " or " copper bit joint. " For joints in pressure pipes the wiped joint must be used. The taft joint *can* be used for joints in non-pressure pipes (excluding soil pipes). It is usual, however, to use the wiped form for every joint in good quality work. It is possible also to use a lead " burned " or " fused " joint for non-pressure pipes.

Wiped Joints (see Fig. 27).—The method of making a wiped joint is described in Chapter Five. It consists of rasping one pipe end



LEAD PIPE JOINTS.

Fig. 27

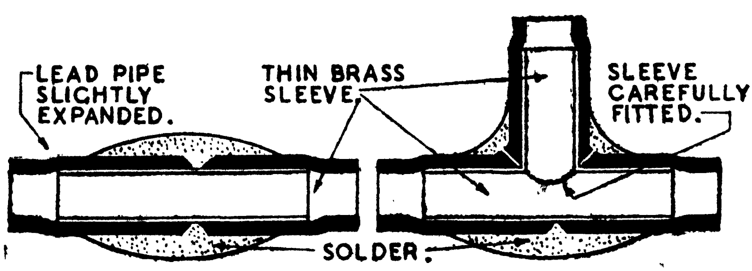
to a sharp edge and fitting it to the slightly expanded end of the other pipe. After other preparation a band of plumbers' solder is worked round the pipe. This band is thickest where the pipes abut. The maximum thickness of solder need not exceed one and a half to two times the thickness of the pipe wall. Excess thickness does not necessarily strengthen the joint. The length of the joint varies with the pipe diameter as follows : up to 1-in. diameter (internal), 2¾-in. long ; 1¼ and 1½-in. diameter, 3-in. long ; 2 to 2½-in. diameter, 3½-in. long ; 3 to 4-in. diameter, 3½-in. long. In some districts the above lengths are increased by ½-in.

TAFT JOINTS (see Fig. 27).—The making of this form of joint is described in Chapter Five. In this case one pipe end is rasped to a fine edge whilst the other is opened out as a funnel. When placed together the funnel should be wide enough to allow a ring of solder ¼ to ⅜-in. wide to be placed round the joint. This joint is rarely used for pipes exceeding 2-in. in diameter, and then only for end to end (running) joints.

BRANCH JOINTS (see Fig. 27).—This is the name given to the joints required where one pipe joins another at an angle. In most cases the incoming pipe is swept round in an easy curve to join the main pipe. This curve must be in the direction of the flow in waste and soil pipes. In water pipes, however, the joint is generally made at right angles. Branch joints are nearly always wiped, but lead burned joints can be used.

LEAD BURNED JOINTS (see Fig. 27).—These are formed by cleaning the pipe ends and fitting them together as described under wiped joints. They are then fused together with an oxy-acetylene blowpipe feeding further lead in to strengthen the joint. Generally the use of this form of joint in small house work will be limited to non-pressure joints which it is possible to make away from the job.

JOINTS IN TIN-LINED LEAD PIPES.—In high-class work lead pipes lined with tin are sometimes used. Because the wiping temperature at



JOINTS TO TIN LINED LEAD PIPES.

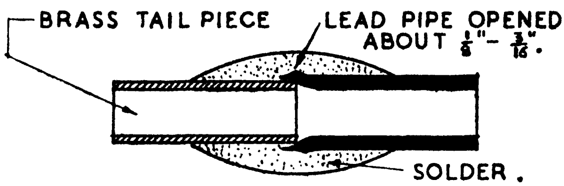
Fig. 28

the pipe joint will be above the melting point of tin and cause the lining to melt, it is usual to slightly enlarge each pipe end and insert a thin tinned brass tube of the same internal diameter as the pipes being joined. This tube should be slightly longer than the length of wiped joint when finished. The joint is then wiped in the normal way. In the case of branch joints the main pipe is cut and a brass tube inserted in the manner just described.

A piece of brass tube is similarly fitted to the branch pipe end. The hole to receive the branch is then made in the main pipe and the brass tubes carefully fitted. The joint is then wiped as a combined main and branch pipe joint (see Fig. 28).

LEAD TO BRASS (see Fig. 29).—Taps, valves and similar fittings are joined to lead pipes with wiped joints. They are provided with "tail-pieces" which are brass pipes of the same internal bore as the lead pipe. The lead pipe end is expanded, cleaned internally and the tailpiece, previously tinned, is inserted for not more than $\frac{1}{8}$ to $\frac{3}{16}$-in. The joint is then wiped in the ordinary way.

Joints between lead and iron pipes, lead and earthenware, and between earthenware and iron pipes will be described later in this chapter.



JOINT BETWEEN BRASS TAIL PIECE & LEAD PIPE.

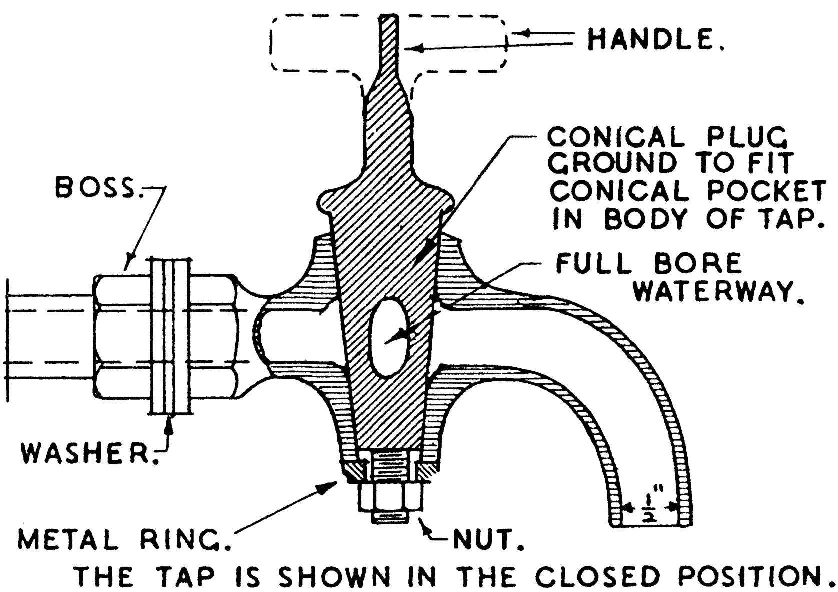
Fig. 29

COCKS, VALVES AND TAPS

The above terms are names given to devices which control the flow of liquids or gases through pipes. A cock consists of a conical plug which can be rotated in the passage-way of the pipe. The plug is pierced so that in one position free passage is given to the fluid. A right-angled turn of the plug closes the passage-way. In a valve a disc, often faced with a washer, is moved gradually on to a seating by the motion either of a screw or lever. This closes the passage-way of the fluid *gradually*. The term tap is applied loosely to either cocks or valves. The prefix "bib" before the words cock, valve or tap means that the fluid is delivered downwards from the pipe into the open, whereas the prefix "stop" indicates that the fitting is part of a pipe line introduced to shut off the flow of liquid.

Taps are made of brass, gunmetal (bronze) and phosphor-bronze. Brass is most commonly used, but bronze or gunmetal are used where there is a possibility of corrosion from the presence of acid in the water, which can act on the zinc in brass. Bronze is, however, used in high quality fittings. As waters of acid character are nowadays almost always treated to neutralize the acidity the need to use bronze is rarely present. It is, however, used in laboratory fittings and often for the movable parts of fittings because it resists wear and corrosion better than brass. High quality taps are made of white metal. Some common forms of taps are described below.

Plug Cocks (see Fig. 30).—This form of tap consists of a conical plug carefully fitted to rotate in a conical pocket in the body of the tap. On the top a handle is formed and the bottom of the plug is screwed to receive a nut and washer, which hold the plug in position. A hole is drilled through the plug in line with and of the same bore as the passage-way through the tap. A quarter-turn closes or opens the tap. The use of plug taps is prohibited by most water authorities because they close

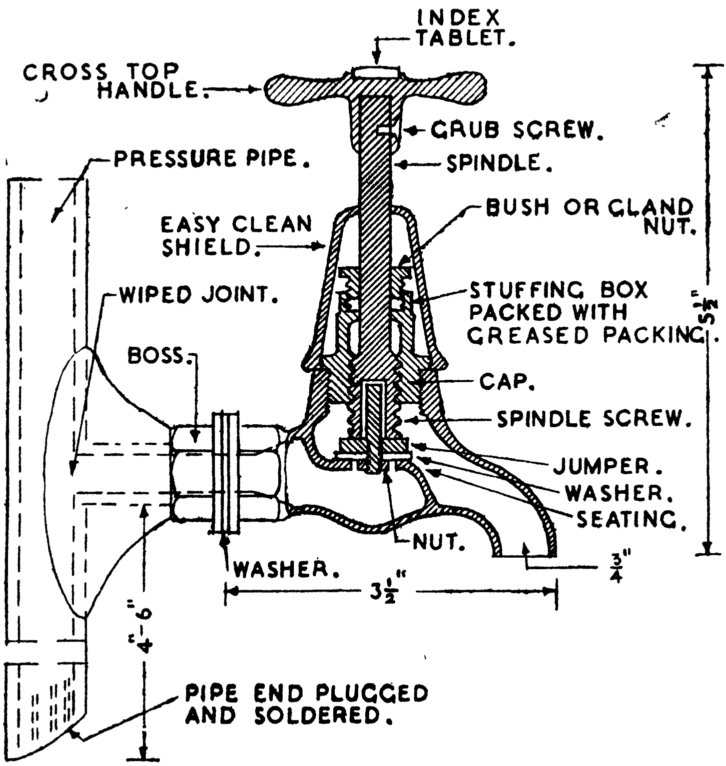


A PLUG COCK OR TAP.

Fig. 30

the water-way too rapidly, and the sudden check to the water's flow can cause an increase of pressure which may fracture the pipe. They tend to wear rapidly, for the ground surfaces score and groove through the grinding action of minute particles of grit in the water. Fine adjustment of the flow of water is not possible with plug cocks. Their use is now almost always confined to gas services. For fixing they can be obtained with plain slightly tapered tails for soldering, or with screwed male or female ends, or one end male and one female for screwed pipework.

Screw-down Taps (see Figs. 31 and 32).—All forms of screw-down taps follow the same general principles of design. The body of the tap is enlarged to receive a spindle which moves up or down by screw action when rotated. The spindle works in a cap which screws into the body of the tap. To prevent leakage around the spindle it is passed through a stuffing box capped by a bush which can be screwed downwards into the stuffing box. When greased gasket is placed in the stuffing box and compressed by screwing down the bush, a watertight joint which gives free action to the spindle is secured. The lower end of the spindle is drilled vertically to receive the tailpiece of the jumper or valve plate. This is a flat circular disc, the lower surface of which is faced with either a hard rubber or leather washer held in position by a small nut. (Hard rubber can be used both for hot or cold water, but leather can only be used



A BIB TAP.

Fig. 31

for cold water.) The tailpiece is a loose fit to the hole in the spindle. The water-way through the body of the tap is closed by a flat platform through which a circular hole is drilled immediately under the spindle. A carefully ground seating for the jumper is provided round the hole. There are various forms of grips available for the head of the spindle. They are either riveted on or fixed by a grub screw. Alternatively the spindle shank can be squared off and a loose key provided.

STOPTAPS can be provided with slightly tapered tails for fixing to lead pipes by means of wiped joints, but it is better to use stoptaps which have unions and tailpieces. The tailpieces are fixed by wiped joints and the tap secured in position by the unions. This method enables the whole tap to be removed without " melting-off " the wiped joints.

Bib Taps may be fixed to the wall above the fittings as in the case of sinks or directly on the fitting as in the case of wash-bowls and baths. In the former case the tap is fixed to lead water pipe at *right angles* to the pipe, about 4 to 6-in. from the pipe end which is closed by a stopped end (see Fig. 31). This is formed by cutting off the pipe to form a splayed end and inserting a lead wedge about ⅛-in. back from the cut. The end is then soldered across. Paper or rag should not be used instead of the lead wedge as they rot away and can cause trouble later. Splay cutting

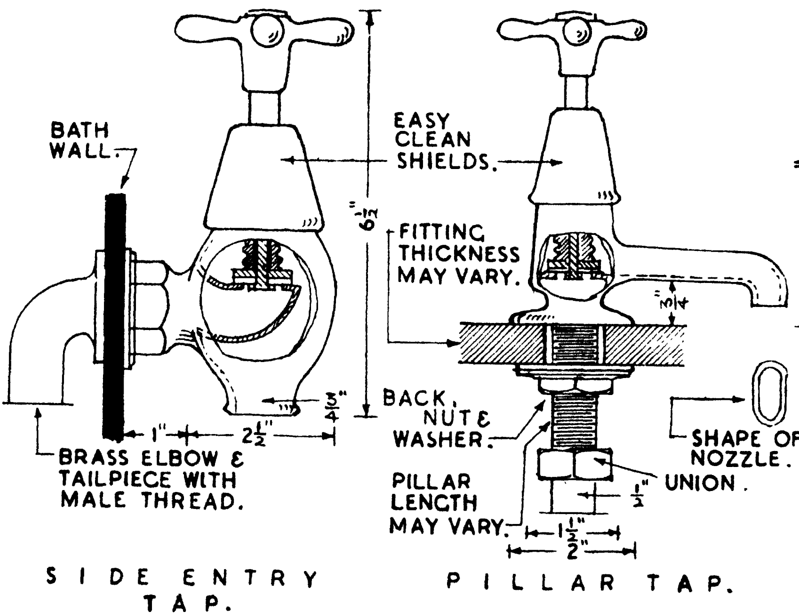


Fig. 32

gives a larger area for the solder to grip. The tailpiece of the tap is inserted into a hole in the pipe wall so as not to project inside the pipe and a wiped joint formed. Alternatively a boss is used, secured to the water pipe in the same way (see Fig. 31). The tap is then screwed into the boss. This way of fixing is the better one, for it enables a tap to be removed without melting off the solder. As it is common practice to fix tiles behind sinks, the lead pipe is generally hidden and access to the pipe, without damaging the tiles, is impossible, so that boss fixing is highly desirable. Flanged bosses which neatly cover the hole in the tiling are available.

Pillar Taps (see Fig. 32).—These are screw-down taps specially designed for fixing to wash-bowls and baths. The water-way is at right angles to the spout which extends so as to discharge well over the wall of the basin. The shank is long enough to take various thicknesses of fittings. It is screwed on the outside and fitted with a union and tailpiece. To fix the tap it is inserted in the hole in the fitting and a nut is screwed up the pillar to bear on a rubber or soft metal washer and hold the tap tightly in position. The tailpiece of the union is wiped on to the end of the lead water pipe and screwed into position.

SIDE-ENTRY TAPS (see Fig. 32).—These are fixed to bath sides by screwing into an elbow against a lead washer. The elbow is wiped on to the water pipe.

All types of bib taps can now be obtained with easy-clean conical casings which cover the stuffing box and body nut and give a smooth continuous surface to the tap exterior. The exteriors of bib taps are generally supplied with either a nickel or chromium plated finish.

BALL VALVES OR TAPS.—These are automatic in their action in that they are operated by the action of a hollow copper ball fixed to a lever.

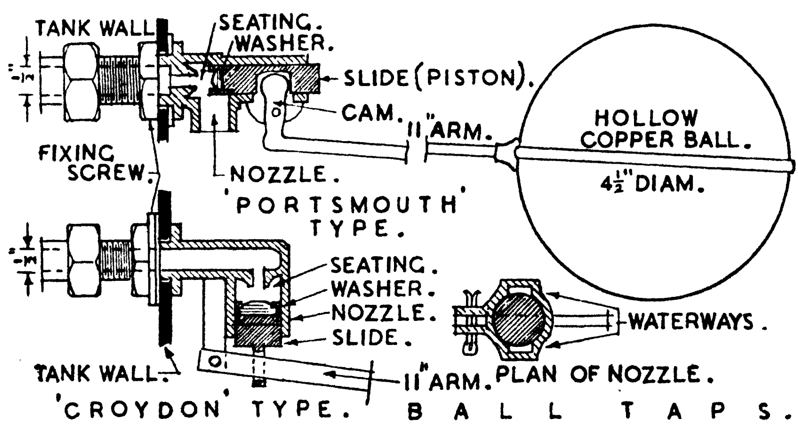


Fig. 33

They allow tanks to be filled with water up to a desired level, gradually cutting off the water as the level is approached. The valve is operated by the lever which is attached to a copper ball floating on the water surface. As the water rises in the tank so the ball lifts the lever, gradually closing the valve. If the water level falls so does the valve open. There are many types of ball valve in use, and two types are shown in Fig. 33.

The Portsmouth valve has a horizontal action. It consists of a cylindrical plug working in a cylindrical slide. The plug has a rubber washer which, if moved forward, will impinge on a nozzle through which the water enters. There is a slot in the plug and the cranked end of the ball lever engages in the slot. The lever works about a pin immediately below the slot. If the lever rises the plug moves forward and cuts off the water. Conversely, if it falls the plug moves away from the seating and allows water to flow down into the tank. To reduce the hissing noises prevalent with ball taps a vertical extension pipe (pierced with a small hole above water-level) is often fixed downwards from the orifice to the bottom of the tank to act as a silencer. The small hole prevents any water being drawn back into the main from the tank. The plug should fit the slide closely as otherwise water can spray out horizontally. In some types of valve a screwed cap is provided for the outer end of the slide. The tap is secured in position by a nut on the outside. Connection to the lead water pipe is achieved by a wiped joint and brass union.

The Croydon valve has a vertical action and is suitable for high pressure water. The plug in this case acts in a vertical slide which has by-passes for the water on each side. At the bottom of the plug is a loop through which the lever is passed. The loop is a loose fit on the lever and ensures that the plug comes down with the lever when it falls. The valve is fixed to the tank wall in the same way as the Portsmouth type.

TRAPS (see Fig. 34) ✓

Waste and soil pipes, which remove waste from fittings, soon become coated on their interior surfaces with a slimy deposit. This deposit is not readily removed even by flushing with clean water. It is organic in character and decomposes rapidly, giving off offensive odours. Such deposits are also breeding grounds for bacteria. It is highly necessary to prevent these foul gases from entering a house, and appliances known as *traps* have been devised to stop the movement of gas into the building through the pipes.

A trap is a carefully designed bend (in the vertical plane) in a pipe line which will retain sufficient liquid to lock completely the bore of the pipe against the movement of gases. The depth of liquid measured from the surface to the tip of the curvature in the upper wall of the bend is known as the " seal " or " water seal." For gases to pass the trap it would be necessary for them to develop sufficient pressure or suction to force aside a column of liquid equal in depth to the seal. This is not likely to happen in pipes serving single fittings, where the pipe has one end open. Traps are the only solution of the problem, but they are not perfect, because they retain a certain amount of more or less foul liquid and tend to collect solid matter. To reduce the length of untrapped pipe it is necessary to place them adjacent to the fitting and thus this foul matter is actually retained inside the building for varying lengths of time. Further, should the liquid in the trap dry or leak out the trap becomes useless.

A trap should possess the following features in its design. It should be self-cleaning, have a smooth interior surface, offer little impediment to the free flow of water through it and be readily coupled to the fitting and pipe line. In pipes of less than 3-in. bore, where there is liability to choking through the collection of solid matter in the trap, a cleaning eye should be fixed.

Traps may be embodied in the material of the fitting itself, *e.g.*, the w.c. pan, but more often they are separate articles in a different material which have to be coupled to the sanitary fitting. This is nearly always the case for baths, wash-bowls and sinks. For these fittings the traps can be made of lead, copper, brass or gunmetal.

Copper, brass and gunmetal traps are generally castings, although copper traps can be formed by bending copper tube. The bores should be smooth, and traps can be obtained with polished exteriors for exposed work. They are coupled to the fittings with unions, and where they serve lead pipes these are attached by a wiped joint to the tailpiece of a union

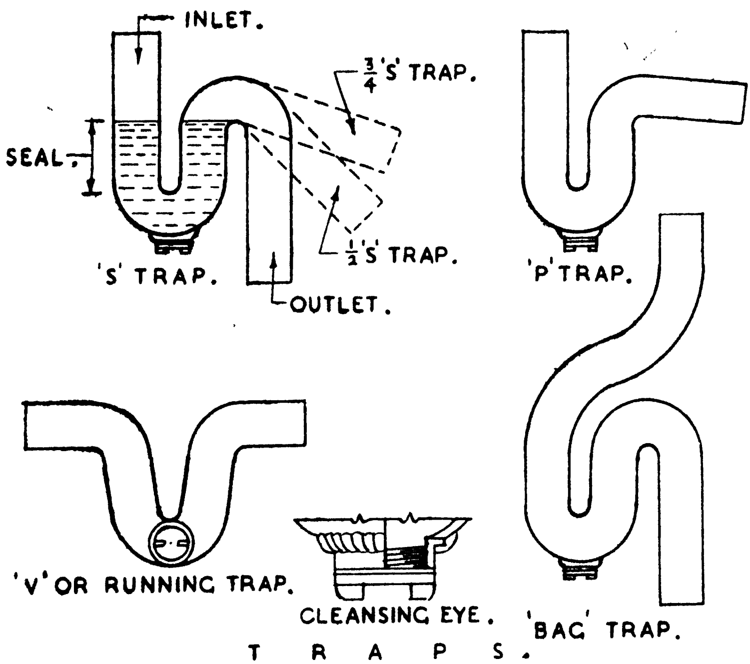


Fig. 34

at the outlet of the trap. These types of trap are much more expensive than lead ones.

Lead traps are normally made by machinery, and are known as " solid drawn." They are sold in all common pipe diameters, ranging from 1 to 4-in., and to various weights. Up to 2-in. diameter they can be obtained with a cleansing eye consisting of a screwed brass socket and cover lead burned to the foot or side of the bend if desired. It is usual to name traps according to the direction of their inlet and outlet. Six common forms described below are shown in Fig. 34 :—

P trap. Inlet vertical, outlet just below horizontal, making an angle of about 95° with inlet.

S trap. Inlet and outlet both vertical.

½-S trap. Inlet vertical, outlet steeper than for P trap, making an angle of about 110° with entry.

$\frac{3}{4}$-S trap. Inlet vertical, outlet makes an angle of about 135° with entry.

" Bag " trap. Inlet and outlet both vertical and in same straight line.

V or " Running " trap. Inlet and outlet both in same horizontal line.

Lead traps are fixed by wiping a brass union tailpiece to the entry end and forming a wiped joint between the flow end and the continuing lead pipe. (In cheaper work this is often a " taft " joint.)

Traps and waste pipes are subject to rapid changes of temperature, due to the intermittent discharge of hot and cold water from the fittings to which they are fixed. Considerable movement in the pipe arises from this, and the trap, in particular, is subject to stress. The walls of the trap should therefore be as heavy as, or heavier than, those of the waste pipe, *i.e.*, if the waste pipe weighs 7-lb. per yd. the trap should be from equivalent lead.

The common depths of " seal " are as follows :—

1 to 2½-in internal diameter . . .	1½-in. seal.
3 ,, 4-in. ,, ,, . . .	2-in. seal.

Traps must always be the same bore as the pipe to which they are fitted.

SANITARY FITTINGS

General Principles of Design.—Certain general principles control the design of sanitary fittings. They are as follows :—

1. They should be made of durable non-porous materials with smooth, easily cleaned surfaces free from grooves and angles.
2. Corners and " arrises " should be rounded.
3. Overflows should be easily cleaned.
4. It must be possible to make simple and efficient connections between all pipes and the fittings.
5. The connections should be readily accessible for attention and repair.
6. The fittings should be self-cleaning as far as possible.
7. The fittings should be capable of being supported in a rigid manner without the use of wooden enclosures.

Sinks (see Fig. 35).—These are rectangular tanks made from fireclay which has been burned in kilns until it is almost impervious. The better types are made from fireclays which are almost white when burnt. They are covered inside and out with an enamel consisting of china clay, chalk, crushed flints, borax and potash or soda which is fused on at a high temperature, giving a smooth white surface almost like porcelain.

The finished surface must be free from cracks, specks and bubbles, and must resist damage from temperature changes due to the use of hot and cold liquids. All internal and external angles must be rounded off, and the floor of the sink should fall gently towards the outlet hole which is circular and has a rebate worked around it to take the waste fitting.

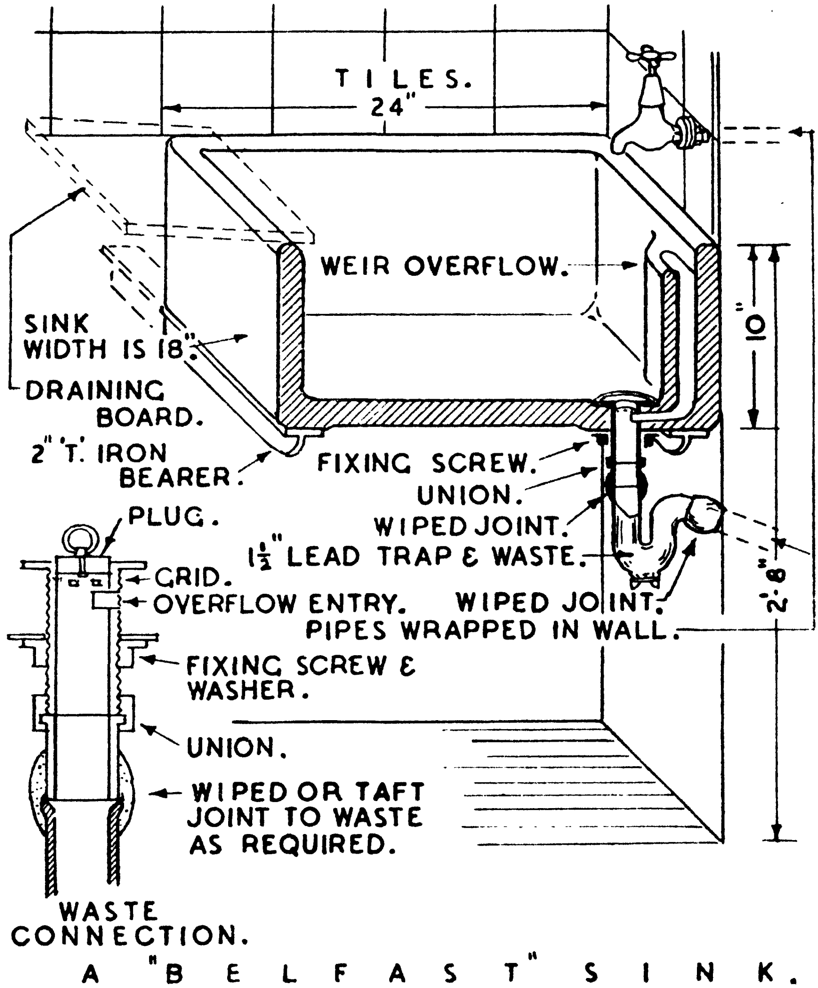


Fig. 35

The best type of sinks now have tapered outlets. The waste fitting is designed to be self-centering in the outlet. At the outlet end an overflow is provided. The end wall of the sink is thickened into the sink and a weir overflow is formed below the rim of the sink. This leads into the side of the circular outlet. The overflow should measure about 2-in. by 1-in. in section so that it can be cleaned out with a brush. Sinks which have overflows entered through small holes should never be used.

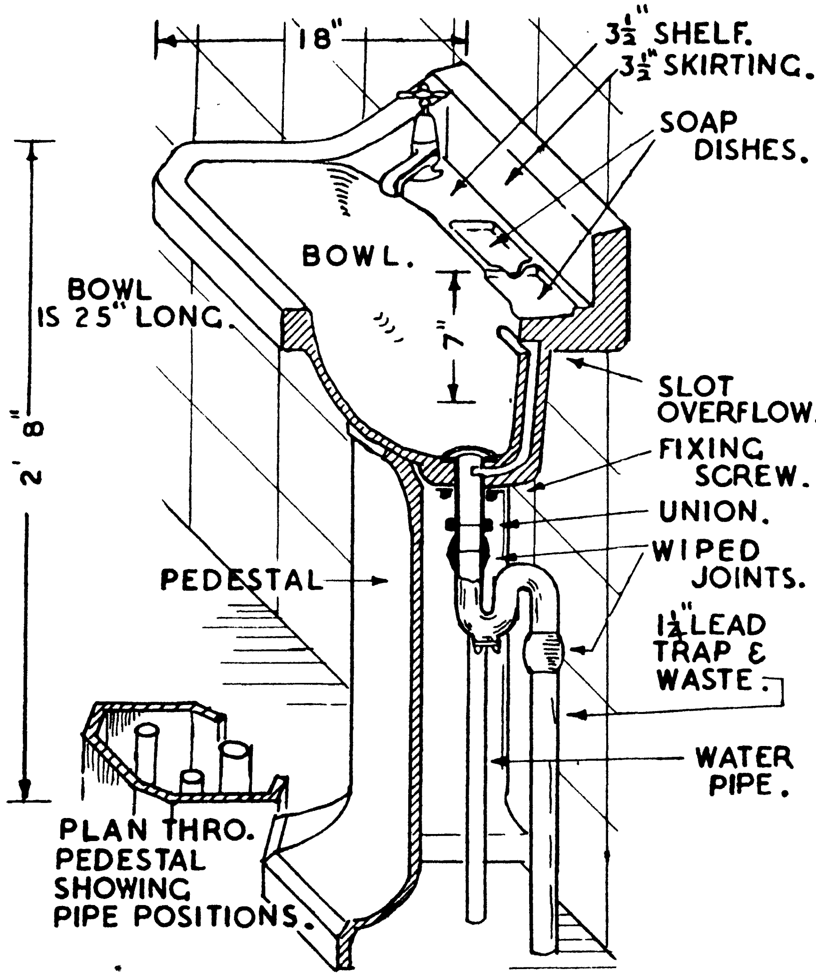
Fixing Sinks.—Sinks should be supported on either cast-iron or T-iron cantilever bearers built into the wall, with either one long side or one long side and one end tight against the bare brickwork. The rim should be 2-ft. 8-in. from the floor, and care should be taken to see that the slight fall to the outlet is maintained, as nothing is more irritating to the housewife than a sink in which water does not completely drain away. Sinks can also be supported on 4½-in. brick walls (preferably glazed brick) or on wooden brackets. Neither of these methods is as good as the cantilever method. The brick wall does not allow a clear uninterrupted floor space under the sink and wood brackets frequently shrink and so give slightly under the heavy weight of the sink. Hot and cold bib taps are fixed either over one end or in the centre of one long side. The tap nozzles should be 14-in. above the floor of the sink so that buckets can be easily filled. The pipes serving the taps are fixed tight to the brick-work by clips and bosses for the taps are wiped on at right angles. Wall tiling is then placed in position to finish tight down on the sink rim. If tiling is not to be used, the plaster will be brought down to the sink rim and the pipes will be fixed to a 4½-in. by ¾-in. pipe board on the surface of the plaster. Where the pipes are to be buried in plaster or cement mortar they should be wrapped with building paper. This allows a little movement of the pipes due to expansion or contraction through temperature changes. It also prevents any corrosion from contact with lime or cement in a damp state. The taps are fixed by screwing them into the bosses. The fitting used for the waste pipe is a 1½ or 2-in. brass tube with a flange at the upper end. The tube has slightly bevelled seating at the top to take a correspondingly bevelled vulcanite plug and has a brass grating fixed across just below the plug seating. A horizontal slot is cut in the tube to fit opposite to lower end of the overflow. The outside of the tube is threaded with a brass nut running on it, and the lower end is fitted as a union. To fix the waste, putty is placed on the sink outlet and the waste inserted so that its slot coincides with the overflow outlet, care being taken to see that the putty does not block the outlet. The nut on the waste tube is then screwed tight up against a rubber or lead washer between the nut and the underside of the sink. If the trap is lead it will have been joined previously to the waste pipe by a wiped or " taft " joint and have had the union tailpiece wiped on. Connection between the waste fitting and the trap is then easily made by screwing the union tight.

Sinks are made to many varying sizes and depths. The size most commonly used in small houses is 24-in. by 18-in. by 10-in. deep, measured outside. It is highly desirable that the waste should not be less than 1½-in. diameter, and preferably 2-in.

Sinks can be obtained with a horizontal shelf along one side or end on which pillar taps can be fixed.

There are many other forms of sinks, including wooden boxes lined with lead, tin or tinned copper, and sinks formed by extruding stout metal non-tarnishable alloys into the combined shape of draining board and sink.

In some parts of the country sinks made by dishing out blocks of stone were, at one time, universally used, but their unsightly appearance, coupled with the difficulty experienced in keeping them clean and sanitary, has led to their gradual disuse.



A PEDESTAL WASH BOWL.

Fig. 36

WASH-BOWLS (OR WASH-BASINS) (see Fig. 36).—The better types are made of vitreous china (a form of porcelain vitrified, glassy throughout and non-porous even before glazing has been applied). Bowls are also made of fireclay burned and enamelled in the way described for sinks. They can be obtained in colours other than white. A large variety of shapes is available, but there are certain features common to practically all kinds. All angles will be rounded off in easy curves, and the cross-section from back to front taken through the centre will show that the greatest depth (over the outlet) is about 7-in. and diminishes in a sweeping curve up to the front rim which will be about 1½-in. wide. At the back there will be a shelf 3½ to 4-in. wide with two or three slight dishings for soap and brushes. These dishings should drain towards the basin by small open channels. The rim is swept up towards the back of the basin to form a 3½ to 4-in. high skirting. The shelf is generally pierced for the two taps in the angles of the basin. The overflow may be of the weir type open to the top or may terminate in a 2-in. by ¾-in. slot just below the shelf. The outlet is circular and rebated as in the case of a sink.

FIXING WASH-BOWLS.—There are three common ways of supporting wash-bowls, namely, (*a*) on cantilever brackets, (*b*) towel-rail brackets and (*c*) on pedestals.

(*a*) In this case the undersurface of the bowl is prepared to receive cast-iron cantilever brackets built into the wall. These may be quite plain but are often enamelled to match the bowl, and may have a second rail to take towels.

(*b*) Towel-rail brackets, often used, are fixed by screws to wooden grounds.

(*c*) The pedestal is of the same ware, with the same finish, as the bowl. They have broad bases enabling them to stand upright without any other fixing, although some models can be screwed to the floor. The bowl sits firmly, or is clipped, on a seating at the top of the pedestal, which is of the section shown in Fig. 36. The pipes to the wash-bowl travel up the " U " and are easily accessible. (Some pedestals are rectangular with slots at the rear, and the pipes pass up the centre.)

The rim of the wash-bowl should be about 2-ft. 8-in. above floor level. The skirting should be fixed tight up to or even slightly into the plaster. Where tiling is provided the skirting can be tight up to the face of the brickwork, or, alternatively, up to the face of the tiling.

Pillar taps are used for wash-bowls. They are passed through the holes in the shelf, which are packed with putty, and screwed up tight from below with a leather washer between the nut and the underside of the shelf. If the pillar is a loose fit in the hole it should be wrapped with a strip of lead. The water pipes are connected by unions. The waste fitting is fitted in a manner precisely similar to that described for a sink. The diameter of the waste pipe should not be less than 1¼-in. and can usefully be 1½-in.

Wash-bowls with decorations in low relief on their surface, with overflows consisting of small perforations, or with small tubular drains to the soap dishes are now not recommended, as it is difficult to keep them clean and sanitary.

Wash-bowls are made to a variety of sizes. The smallest size suitable for a small house is about 22-in. by 16-in., but a more useful size is 25-in. by 18-in. The waste-pipe size has already been given.

There are many varieties of wash-bowls designed for special requirements, especially for hospital uses. There are also many types designed for use in groups (" ranges ").

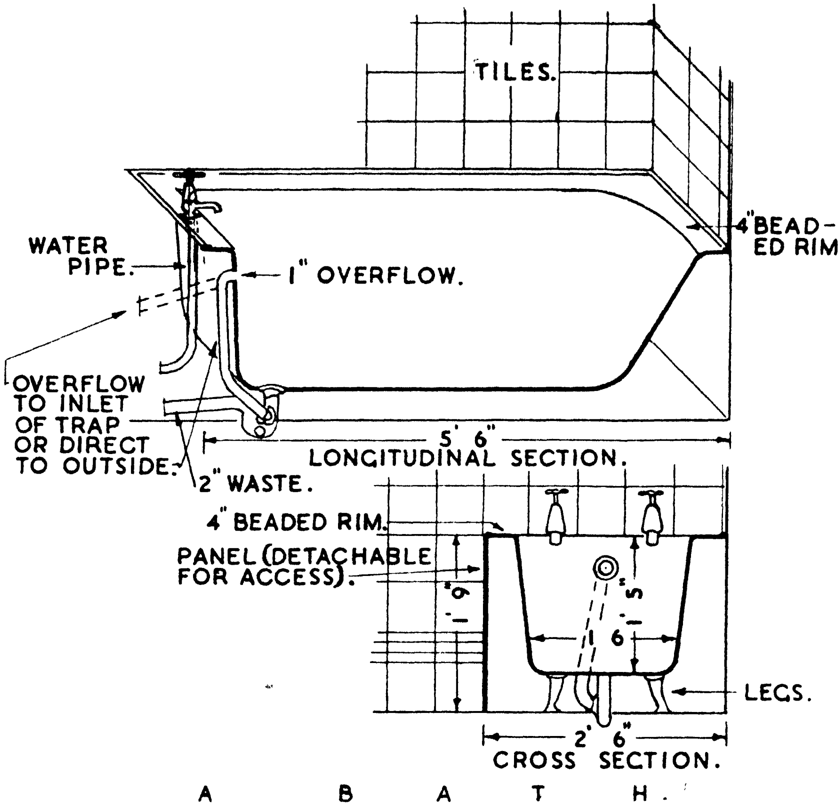


Fig. 37

Baths (see Fig. 37).—Modern forms of baths have their long sides parallel, with the outlet end at right angles to the sides, whilst the other end is curved, often semicircular on plan. The three rectangular sides are almost vertical, but the curved end slopes backward from the floor of the bath at about 60°. The floor of the bath is also slightly rounded and drains to the outlet. All internal corners in baths are rounded off. It is usual nowadays for the bath to have a flat rim about 4-in. wide, with the outer edge of the rim turned down for 1-in. or finished with a slightly raised bead. The rim is often rectangular on plan, having wide spandrels at the semicircular end. Baths can be obtained with the rim extended down to the floor as an apron on either one long side (the other three sides being fixed against walls), one long side and one end (for fitting into an angle), two long sides and one end (for fitting projecting from a wall) or on all four sides (for " island " fitting). They are made from cast iron and are heavily enamelled to various shades on the interior, rim and aprons (if provided). The undersides are painted. The price of the bath governs the quality of the finish, but the cheaper baths to-day have a very good finish. Cast-iron baths generally stand on four short legs. They stand about 2-ft. from floor to rim and are about 19-in. deep internally. Some patterns have pillar taps fixed to the rim, whilst others have side-entry globe taps secured on the wall of the bath. The overflow is generally in the form of a grating in the wall of the bath about 4-in. below the rim. (The overflow should also be below the tap nozzles when the taps are fixed to the bath wall.) The overflow is served by a 1½-in. diameter pipe wiped to the brass elbow behind the grating. This pipe can discharge independently outside the building or can be taken to the inlet side of the trap to the waste pipe. The fitting for the waste resembles that described for a sink. The trap, if of lead, is wiped on to the union tailpiece, but often a brass trap is provided with the bath. Sometimes there is not sufficient height to fix a trap of standard height under a bath. If in these cases a standard trap is used, it can be placed in a slot in the flooring, but the trap should have the cleansing eye at the side and the slot be large enough to admit both the hand and a small can to allow the cleansing of the trap without damaging the ceiling underneath. It is possible also to use a running trap some distance away from the outlet, but this leaves a considerable length of waste pipe untrapped on the bath side of the trap. Baths can be obtained in enamelled fireclay, but their weight is such that a specially strong floor is needed if fixed above the ground floor. This, together with the necessity for providing a very copious amount of hot water, prohibits their use in the average house.

Baths are obtainable in many patterns and sizes. Two common sizes are given below :—

Overall Length.	Overall Breadth.	Inside Depth.
5-ft. 6-in.	2-ft. 6½-in.	1-ft. 5-in.
6-ft.	2-ft. 9-in.	1-ft. 7-in.

It should be noted that the above sizes are only approximate, as each maker has many variations in size.

Fixing Baths.—The practice of fixing baths free from enclosures, so that the floor under the bath could be readily cleaned, has in recent times largely fallen into disuse, and baths are now nearly always fixed in recesses with three sides against walls or in an angle with two sides against walls. The exposed sides are then enclosed with aprons cast on the bath or with sheets of vitrolite or other hard panelling. This should fit closely to both bath and floor. Care must be taken to see that ready access to the pipes and trap is provided in any type of enclosure. If tiling above the bath rim is provided, the rim should be taken almost up to the brickwork surface so that the tiling can have a firm and watertight finish to the bath rim. A common cause of dissatisfaction with tiling round baths is that a gap gradually forms between the bottom edge of the tiles and the bath rim. This is due to the rather considerable weight of the bath, when filled, causing the four legs of the bath (these often have very little bearing surface) to sink slightly into the floor boards. If a piece of ¼-in. iron plate 4 or 5-in. square is placed under each leg this will be obviated. Taps and waste pipe are connected as described for the wash-bowls. A 2-in. waste pipe is most satisfactory for baths as a large amount of water has to be cleared rapidly. The waste should never be less than 1½-in. diameter.

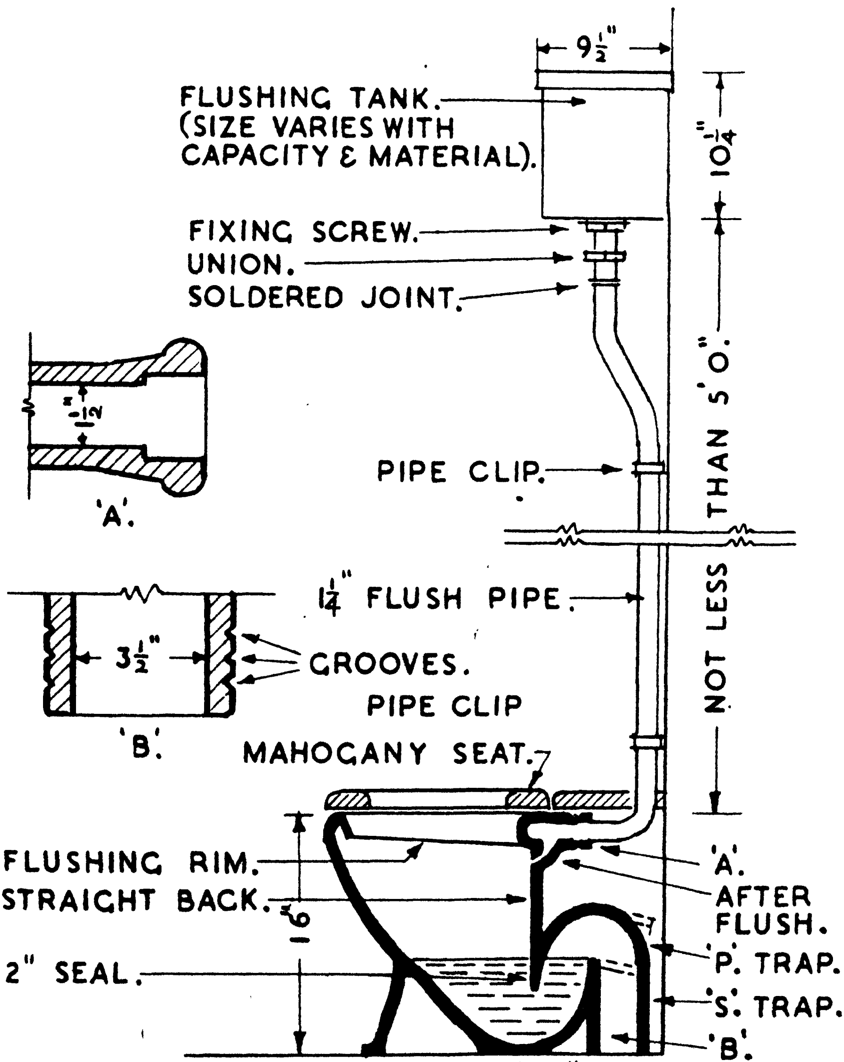
WATER-CLOSETS (see Fig. 38).—The simpler type of modern water-closet has a pan with a flushing rim and a trap moulded in one piece as a pedestal fitting standing on a broad base. The water retained by the trap shows as an open surface at the bottom of the pan and receives the deposit of excreta. In this way the fouling of the sides of the pan is largely obviated. The contents of the pan are removed by a flush of water from the rim. This in a well-designed fitting should clear the pan, clean the pan's sides and refill the trap and pan bottom. The rim is connected to a 1½ or 2-in. diameter socket moulded on the fitting, whilst the trap outlet (generally 3½-in. diameter) may be either S or P pattern, and can also be obtained with a right or left hand outlet. The fitting is made from either glazed fireclay, earthenware or vitreous china. A seat hinged to an extension or fixing piece bolted to the fitting is generally fitted, and for household closets a cover to the seat also hinged to the fixing piece is provided. These seats and covers are usually made from hardwood, but can now also be obtained in bakelite or similar plastic material.

There are a great number of patterns of water-closets in use. Many of the older forms are inefficient, some being actually insanitary. The kinds used to-day are the " wash-down," the " siphonic " and the " valve." (The " valve " type must be a modern design by a reputable firm as many old types of valve closet are inefficient.) Fittings of the types called " plug," " wash out," long or short " hopper " closets, or those with a joint between pan and trap are not normally fixed nowadays, and some local authorities prohibit their use entirely. For ordinary domestic use a pedestal " wash-down " fitting will be used in most cases. A good pattern should comply with the following requirements. (The student should check these with Fig. 38 and also on one or two actual fittings.)

Requirements for a wash-down water-closet fitting :—

1. Pan and trap to be in one piece of non-porous earthenware, fireclay, or vitreous china, glazed inside and out.
2. The fitting should have a perfectly smooth internal and external surface, free from angles, recesses and relief ornament likely to harbour grime or dirt.
3. The back of the pan should either recede slightly from the top or be vertical to obviate fouling. (In no case should a fitting be used which has the lower part of the back protruding further forward than the flushing rim.)
4. The front and sides should contract in sweeping curves, but must leave an area of water at the pan bottom sufficient for the reception and immersion of the deposit of excreta.

5. The water retained in the pan must be the smallest volume consistent with the preceding requirements. (Too great a volume of water would retard the flushing action.)
6. The least cross-section must be at the bottom of the pan, and this bore should continue unchanged to the outlet of the fitting.
7. The water seal must be 2-in.



A PEDESTAL "WASH-DOWN" WATER CLOSET.

Fig. 38

8. The flushing rim must direct the flush round the sides to meet in front and cascade forwards and downwards and at the same time cascade down the back to remove contents of pan, scour sides and recharge pan and trap. An " after-flush," which is a pocket in the flushing rim holding water sufficient to ensure the recharge, of the trap is advantageous.
9. Flushing rim socket and trap outlet should be designed to allow ready connections to their respective pipes.
10. The fitting should be self-supporting and not need any wood enclosure.

Except where water-closets are designed for some special purpose, such as for use by small children only, the height of a fitting from floor to rim is 16-in. The other dimensions vary considerably. Every manufacturer has his own sizes for each of his types. A typical small fitting may measure about 22-in. from back of trap to front of rim and be about 14-in. greatest overall width with the largest internal dimensions of the flushing rim measuring 13-in. back to front and 11-in. width.

FIXING A WASH-DOWN WATER-CLOSET.—The pedestal is fixed to the floor by long screws passed through holes in the base of the pedestal after the joints to the flush and branch soil pipe have been made. Care should be taken to allow sufficient room to fix the flush pipe to the pan and to form the joint to the soil pipe, but the fitting should not be placed too far forward because the flush pipe must not run horizontally more than the distance needed for making the joint or the speed of the flush will be diminished. The joint (A, Fig. 38) between the flush pipe and the fitting can be made in various ways, some of which are shown in Fig. 39.

Wrapped Joints (see A, Fig. 39).—The end of the flush pipe is opened out with a tampin to fit the socket into which it is inserted, the space between the pipe and socket being packed with red lead putty or ordinary putty. The joint is then tightly wrapped with a strip of canvas soaked in paint and bound in position with copper wire. Alternatively rubberized canvas can be used as the wrapping.

Lead Clipped Joints.—The " octopus " joint (see B, Fig. 39) is formed by sliding on the flush pipe a cast lead " octopus," which is a disc pierced at its centre to fit the pipe with its external circumference slotted to form arms. This is fixed about 2½-in. from the flush pipe end, which is opened out to fit the socket. The joint is packed with red lead putty or a rubber ring, the arms of the " octopus " are clipped down over the flange of the socket and bound with copper wire. Another form is shown at C, Fig. 39. This is used where there is no flange on the socket. A cast lead connector of the shape shown is soldered on to the flush pipe end. A rubber ring is placed between the flush pipe and the connector, and the pipe end inserted and forced up to the ring. The connector is then bound to the socket with copper wire.

A third way is to use a cast metal clip. The flush pipe end is opened

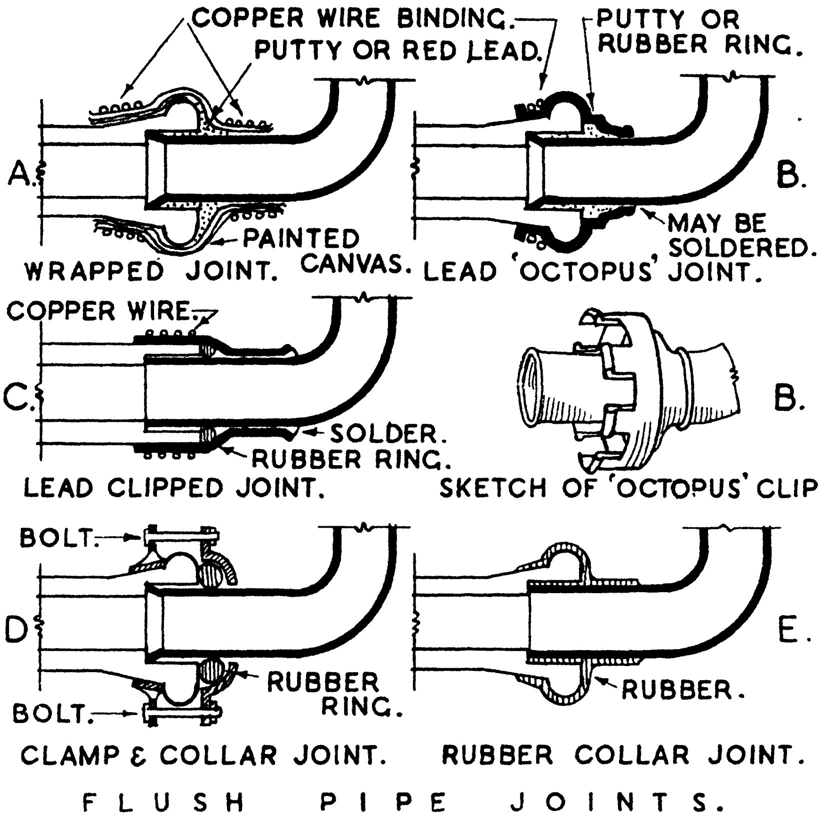


Fig. 39

out, packed with red lead putty and the clip is secured in position by bolts passed through wings on the two halves of the clip.

Rubber Joints.—One type consists of a stout rubber tube moulded so that one end will be a tight fit to the exterior of the socket and the other a tight fit on the flush pipe. To fix, the tube is slipped on the flush pipe, the end of which can either be opened out and packed with red lead putty, in a manner similar to that previously described, or be fully expanded to fit the socket without packing. After the flush pipe has been inserted into the socket the rubber tube is rolled over the socket to grip both socket and pipe. The ends of the tube are then bound with copper wire. There are also several patented forms of rubber connection. One of these is a stout rubber tube, about 3-in. long, which grips the flush pipe tightly when fixed by sliding it on so that it covers the end of the flush pipe. Moulded on about half-way along the tube is a second tube of larger diameter (see E, Fig. 39). The joint is completed by inserting into the socket the flush pipe end. The rubber tube, which at this end is slightly grooved and wedge-shaped, seals the space between the pipe and socket.

The outer rubber tube is passed over the outside of the socket. The joint is watertight, slightly flexible, and does not require bending. There are also some forms of joint in which a rubber ring or a tubular rubber wedge is slipped into the flush pipe end and forced into position and held by brass collars and bolts. One of these is shown at D, Fig. 39.

The joint (B, Fig. 38) between the pan and the branch pipe leading to the external soil pipe depends on the material from which the branch is made. This may be lead, cast iron and (for ground floors) sometimes stoneware. A lead branch pipe is usually preferred because, even if the external soil pipe is cast iron, a lead pipe can be shaped and eased into position and, moreover, will give a little without cracking any joints if there is any slight settlement. Cast iron, on the other hand, is only obtainable to certain angles, and slight settlement of the building is liable to crack joints.

Pot to Lead Branch Joint (see Fig. 40).—This is formed by wiping a brass socket (thimble) on the end of the 3½-in. branch which has been previously shaped and fitted for its position. The outlet spigot of the trap is inserted into the thimble. Gasket previously dipped in liquid cement is then wrapped round the spigot and forced home. This centres the spigot, and the joint is finished by packing the space between spigot and socket with neat Portland cement mortar, which is pointed tidily around the socket edge. (The cement used should not be " hot," that is, it should have been left exposed to the air as a dry powder in a dry room for some days before using. Hot or fresh cement expands when setting and can crack the joint.) A better but more expensive joint is to use gasket dipped in bitumen with a packing of bitumen jointing compound. The other end of the lead branch will be wiped to the outside or main soil pipe if this is of lead. If it is of cast iron, however, the end of the lead branch will be reinforced with a brass sleeve, with a ¼-in. flange, worked on the end. The sleeve is wiped on to the branch pipe and inserted into the junction socket of the cast-iron soil pipe, and can be finished with a gasket and red lead putty joint or any of the recognized cast-iron soil pipe joints (see Fig. 40). It should be noted that in Fig. 40 the brass sleeve is fitted outside the lead pipe which is passed through the sleeve and worked over the flange of the sleeve. Sockets or thimbles can be obtained for fitting outside or inside the lead pipe. Externally fitted thimbles have the lead pipe passed through and flanged over a rebate formed in the wider part of thimble. Internal fitted thimbles are passed about 2-in. into the pipe before wiping them on.

Pot to Cast-iron Branch Joint (see Fig. 40).—There will be a socket on the branch piece, and the making of the joint consists of inserting the spigot, centering it with gasket (cement-soaked) and finishing the joint with Portland cement packing as described above. Alternatively, bitumen or red lead putty may be used as the jointing material.

Pot to Stoneware Joint.—The earthenware drain will have a socket and the joint can be made as just described.

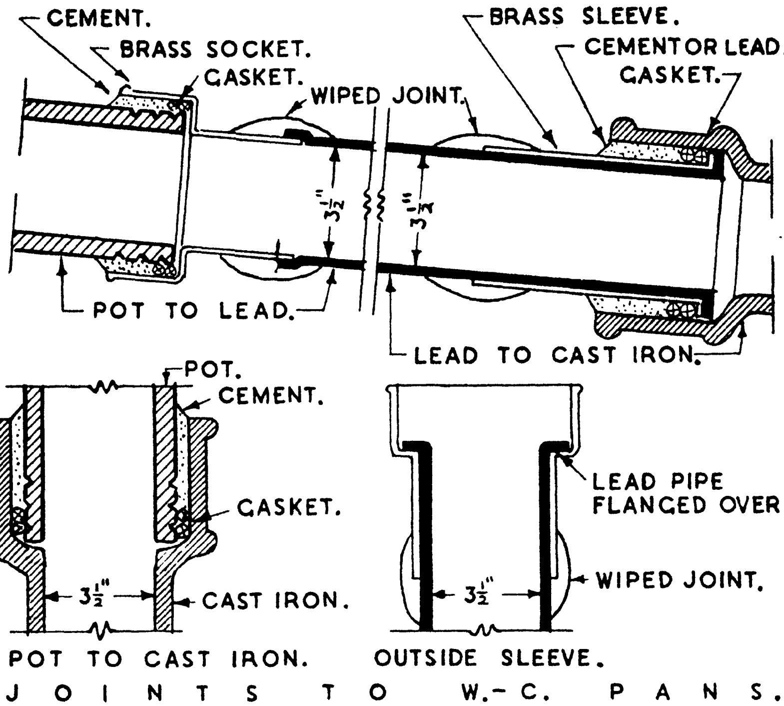


Fig. 40

Flushing or Flush Tanks (Cisterns).—To flush and scour a water-closet effectively it is necessary for a considerable volume of water to be discharged via the flushing rim into the w.c. pan. If the flushing action is violent and rapid it will be more efficient and use less water to effect its purpose than if water were allowed to enter the pan slowly. Local authorities' water regulations control the design of flush tanks. Though the regulations vary considerably in detail from one district to another, they will specify the following :—

1. The material from which the tank may be made and its internal finish.

2. The capacity of the tank.

(Most authorities limit the capacity to 2-gals., but some allow from 2½ to 3-gals. Others allow larger flushes if the water is paid for on the basis of measurement by a water meter.)

3. The method of discharging the tank.

(Water regulations usually stipulate that the tank be a " water-waste preventer." This means that, on the operation of the discharge lever, the tank will discharge its full specified flush (say 2 or 3-gals. as the case may be), but will not allow any further water to pass into the flush pipe even if the lever is held down in the discharge position.)

4. The method of filling the tank and the size and position of the overflow.

(Automatic filling of the tank is generally effected by a ball tap (see Fig. 33). When the tank is empty water enters rapidly and is gradually cut off as the ball rises, being finally cut off when the ball reaches the permitted water level. The distance of the overflow below the ball valve is usually specified as 1-in., together with the bore of the overflow pipe ($\frac{3}{4}$ to 1-in.). Many authorities require the overflow pipe to discharge in a prominent place outside the building, so that attention is directed to any discharge of water caused by a faulty ball tap.)

5. The height of the tank above the w.c. fitting and the bore of the flush pipe.

(The height of the tank, which must not be less than 5-ft. above the flushing rim, and the bore of the flush pipe, which should not be less than $1\frac{1}{4}$-in., both affect the velocity and violence of the flush. It is usual to fix the flush pipe with as few bends as possible and to make the bends " easy," that is to fairly large radius.)

Flushing tanks are made from the following materials :—

(*a*) Glazed fireclay, earthenware or vitreous china, or one of the new synthetic materials termed " plastics."

(*b*) Cast iron. (Painted, galvanized or glass enamelled internally and externally.)

(*c*) Wood. (Lined internally with sheet lead or copper.)

The first type are durable and present a clean appearance. Cast iron is subject to corrosion, but galvanizing checks this, except where the water is slightly acid in character. Glass-enamelled cast-iron tanks are very durable and have a clean appearance. Wood tanks with lead or copper linings are very satisfactory in use. They are durable and not subject to corrosion. When fireclay, earthenware, or cast-iron tanks freeze up they sometimes crack. A metal-lined wood tank will be forced out of shape, and this can generally be repaired.

To some extent the choice of material for flushing tanks is governed by the mechanical action of the flushing system. If this needs heavy bearings, then cast iron may have to be used.

In order to give a flush complying with condition (3) above, the flushing mechanism is normally dependent on siphonic action. A simple explanation of the working of a siphon is given below.

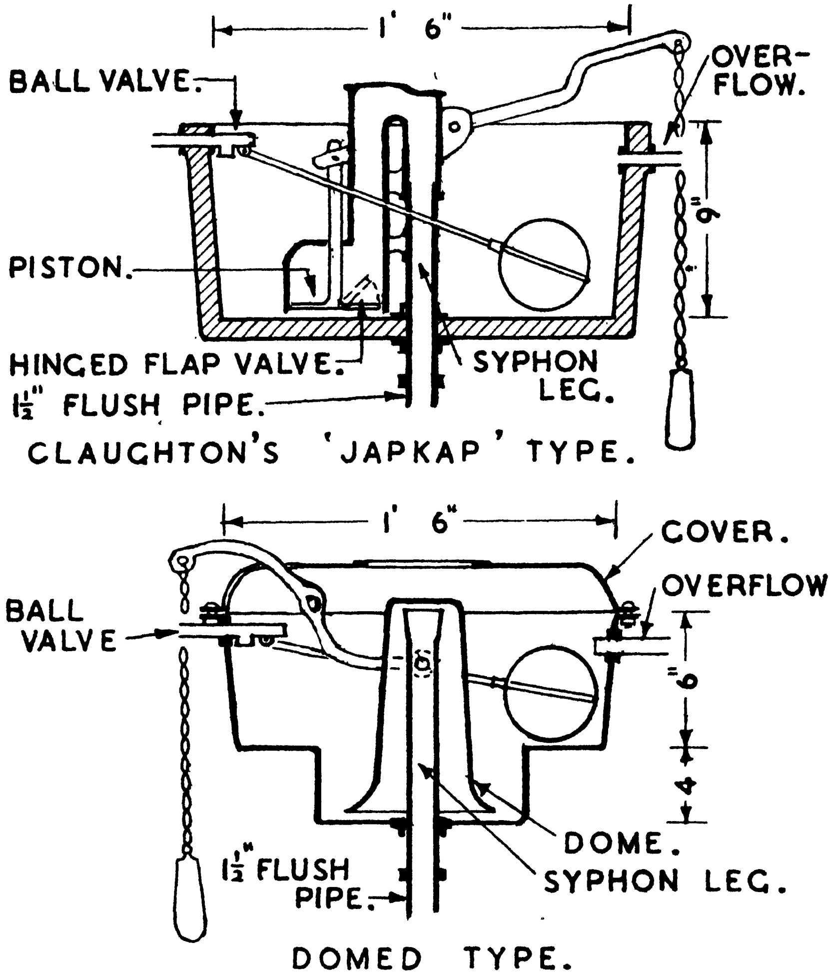
THE SIPHON.—If one end of a tube is inserted into a vessel containing water or some other liquid and the other end is taken over the edge of the vessel to a point below the level of the water, the arrangement is known as a siphon. The end of the pipe dipping into the water is called the " short " or " feeding " leg and the other is called the " long " or " discharging " leg. If the air pressure in the tube is reduced, the normal atmosphere pressure on the surface of the water in the vessel will force water up the " short " leg, over the bend and down the " long " leg. The water will continue to flow until the surface of the water in the vessel falls low enough to admit air to the " short " leg, thus bringing the air pressure in the tube to normal. The same action occurs if water, sufficient to fill the " short " leg, bend and " long " leg to just below the water level in the vessel, is introduced into the tube. A simple comparison can be made with a rope which hangs down on either side of a pulley. If one side is considerably longer than the other it will drag the shorter end upwards over the pulley, that is, the rope will " flow " towards the longer end.

This action is highly suitable for flush tanks, as the flow ceases when the bottom of the " short " leg of the siphon becomes uncovered. Thus if the flush pipe to a cistern is taken up through the bottom of the tank to a point above normal water level and then turned down to the bottom of the tank to act as a siphon, then it only needs the provision of some mechanical appliance to either reduce the air pressure in the siphon or fill it with water in order to give a flushing action complying with condition (3).

Many different types of mechanical actions to charge siphons in flushing tanks have been devised. Two types of flushing tank are shown in Fig. 41. Both are siphon " water-waste preventers."

" JAP-KAP " (see Fig. 41).—In this the short leg of the siphon is enlarged to form a squat chamber open at the bottom. A piston which is an easy fit in the cylinder is connected to the operating lever, and a flap, hinged to lift only, is fitted on the piston. The ball valve and its lever are placed well clear of the siphon. A tailpipe can be fitted to the ball valve so that water will discharge quietly into the tank. The shape of the cylinder and siphon have been carefully designed to ensure an efficient flush, and the top of the siphon is well above the water line. When the tank is full the water will be at the same level inside and outside the short leg of the siphon, and a pull on the chain lifts the piston and forces water up the short leg over the bend and down the long leg starting siphonic action, the piston flap lifts, allowing free passage of water into the short leg. The siphonic action empties the tank rapidly, and as the flush ceases the piston sinks down to the bottom of the cylinder and the tank gradually fills through the ball valve to be ready for the next operation.

DOME PATTERN FLUSHING TANK (see Fig. 41).—There are several variations of this pattern. A circular (or elliptical) well about 4-in. deep is formed in the base of the tank. Rising through the centre of the well to about ½-in. above the top edge of the tank is a stand pipe of the same diameter as the flush pipe to which it is joined and forms the long leg of the siphon. Covering the stand pipe is a metal dome circular (or elliptical) in plan. The dome is splayed outwards at the bottom and is pivoted to hang on the forked end of the operating lever. The space between the outside of the stand pipe and the inside of the dome is the short leg of the siphon. The ball-valve lever is curved to clear the dome.



F L U S H I N G T A N K S.

Fig. 41

A suitable ball valve is fitted, and this can have a tailpipe if desired. When the tank is full the water level is the same inside and outside the dome. Pulling the chain sharply lifts the dome, and when the dome falls rapidly (as it will through its considerable weight) it traps and forces water up and over into the siphon, and the siphonic action empties the tank until air is admitted under the dome, when the flush ceases and the tank refills for the next operation.

Covers can be fixed to flush tanks suitably slotted for the lever and dome where necessary. They are, however, not usually fixed to metal-lined wood tanks.

FIXING A FLUSHING TANK.—The usual method is to fix tanks on iron brackets built in, or screwed, to the wall. These may have an external finish corresponding to that of the tank. The ball valve is passed through the tank wall and held by a back nut working on the threaded exterior of the pipe. A union is provided to the ball valve and the tailpiece of this is wiped on to the water pipe which is usually ½-in. diameter. The overflow is usually a flanged short length of brass tube secured to the tank wall by a back nut. The lead overflow pipe is either wiped on to this or secured by a " taft " joint. In a properly designed tank the centre of the overflow should be below the centre of the ball valve and be ¾-in. diameter. The overflow pipe should be taken to the open air through an external wall by the most direct route, have a fall of several inches and should not discharge into any gutter or pipe. The connection to the flush pipe is made by a union with the tailpiece being wiped or tafted on to the 1½-in diameter pipe. Care should be taken to see that flushing tanks are fixed level and that they are at least 5-ft. above the flushing rim. The flush pipe itself may be secured to a pipe board with brass or similar clips. If it is a metal other than lead it may have " holderbat " fixing.

" LOW-LEVEL FLUSH TANKS."—Latterly there has been an increase in the practice of fitting flush tanks immediately above the back of the w.c. pan. This reduces the flush pipe's length and often simplifies fixing. Low-level tanks are quieter in action as the water pressure at the flushing rim is obviously much less than in the case of high-level tanks, and to obtain a rapid and efficient discharge a 2-in. diameter flush pipe is necessary. It is highly essential that this pipe should be fixed so that the flush pipe is dead in line with the axis of the pan, and that the only bend is a large radius bend necessary to lead the vertical pipe horizontally to the pan socket. The flush tank capacities obtainable are the same as those for high-level tanks, but it is wise to have as large a flush as will be permitted by the water authority.

PIPE LINES FOR COLD AND HOT WATER SERVICES

The pipes provided in buildings for supplying cold and hot water to the various types of fittings are generally lead (or one of its alloys) or copper. Of these, lead is the most commonly used, but copper is now being used to an increasing degree. For health reasons building byelaws stipulate that buildings must have an adequate supply of water. If possible, this supply must be available at all hours of the day and throughout the year. In certain country districts this latter requirement is not always possible, but in towns the local authorities are bound to see that water is readily available. This they do by collecting, purifying and storing water from reliable sources in reservoirs and distributing it in pipe lines, known as water mains, laid in the streets. The water in the mains is normally under pressure sufficient to raise it to the higher rooms in buildings. Where some doubt on this point exists the water supply authority can give the required information.

Before proceeding to the detailed study of the pipe lines required for a small house the following terms should be studied in connection with Figs. 42 and 43. These are the specific names and purposes of the pipes defined on p. 67 under the two general headings, service pipes and distributing pipes. The sizes are given later.

TERMS

COLD WATER. *Communication Pipe.*—This is laid underground between the main and the house. It is joined to the main by a specially designed nipple generally fixed by the water authority. A stopcock must be fixed on this pipe before it enters on to private property. Access to this cock is obtained by placing a 4-in. pipe or brick chamber vertically over it with a cast-iron cover and hinged lid at the top. Another stopcock at an accessible position just inside the house is a further useful provision.

Rising Main (or main service pipe).—This is the continuation upwards of the communication pipe from beyond the internal stopcock. From this pipe others branch off to the various taps.

Branches (or branch service pipes).—These conduct water from the rising main to taps and ball valves.

HOT WATER. *Feed Pipe* (or cold water feed pipe).—This runs from the feed tank (for the hot water supply system) to the bottom of the hot water storage cylinder. Through it water drawn off from the cylinder by the taps is replaced.

Expansion Pipe (or vent pipe).—This is the pipe which runs upwards from the top of the cylinder to a point above water level in the feed tank, where it turns down with its orifice over but clear from the surface of the water in the tank. Alternatively, it may be taken up to the open air through the roof. Its purpose is to allow the water in the hot water system to expand freely when heated. It also allows air and steam (if any is generated) to escape. To ensure this it must be as near the vertical as possible and must not have any dips or traps in it.

Primary Flow and Return Pipes (or circulating pipes).—These are pipes fixed between the boiler and the cylinder. They are generally fixed close together following the same route, the flow pipe is arranged to leave the boiler and enter the cylinder at points higher than those of the return pipe. The flow pipe conducts heated water from the boiler to the cylinder and the return pipe brings cooler water from the cylinder to the boiler. (These functions are explained later.)

Hot Water Branches (or hot service pipes).—These conduct hot water from the top of the cylinder to the various taps.

Emptying Pipe (or draw-off pipe).—This is a short pipe sometimes fixed to the lower part of the boiler. It will have a bib tap at its other end. It is used to drain the hot water system dry when repairs are necessary or damage by frost is anticipated.

The following table gives the sizes and weights for lead pipes, as used in a small house. It should be borne in mind that both the sizes and weights are controlled by the regulations of water authorities and thus vary from district to district.

Name of Pipe.	Hot or Cold Water.	Mains or Tank Pressure.	Internal Bore of Pipe.	Weight of Pipe per Yard.
Communication pipe	Cold	Mains	¾ or ½-in.	11 or 7-lb.
Rising main	,,	,,		
to bath	,,	,,	¾-in.	11-lb.
,, sink	,,	,,		
Branches ,, wash-bowl	,,	,,	½-in.	7-lb.
,, feed tank	,,	,,		
,, w.c. flush tank	,,	,,	½ or ⅜-in.	7 or 5-lb.
Feed pipe to cylinder	,,	Tank		
Expansion pipe	Hot	,,		
to sink	,,	,,	¾ or ½-in.	9 or 6-lb.
Branches ,, bath	,,	,,		
,, wash-bowl	,,	,,		
Circulation pipes	,,	,,	1 or ¾-in.	12 or 9-lb.
Emptying pipe	,,	,,	½-in.	6-lb.

Generally speaking the water pressure and the call for water govern the bore of the pipe. Pipes under mains pressure are normally smaller in bore but heavier in weight than pipes only under feed tank pressure, but it should be noted that the pressure in pipes supplied direct from the mains decreases as the height of the pipe above street level increases, whereas the pressure in pipes fed from a tank increases as the pipe drops below the tank. In tall buildings serious consideration has to be given to the pressure in tank-fed pipe systems as well as to the pipe bores in pipes supplied from the mains. In domestic work, however, ½-in. bore pipes normally suffice for mains pressure pipes, although it is an advantage to use ¾-in. bore for the communication pipe and the rising main as far as the last branch, especially if the mains pressure is not heavy, for these pipes may have to supply several fittings at one time. Where the pressure is reasonable the branch to a w.c. flush tank (if not serving other fittings as well) may be ⅜-in. bore because this fitting works intermittently.

Although it also is common practice to use ½-in. bore pipes in the water service, ¾-in. bore pipes are well worth fitting because they give more rapid supplies from tank pressure. It will be seen in the tables that the circulation and emptying pipes are heavy-weight pipes. This is because they are fixed to the boiler and consequently may be subject to exposure to flue gases.

THE DESIGN OF PIPE LINES

The layout of the various pipe lines in a house obviously depends on its plan, and the design of efficient cold and hot water services by a plumber can be seriously affected by the positioning of the various fittings, particularly when these are widely separated from each other. In recent years, however, the practice of grouping the rooms containing sanitary fittings has come into being, and it is not unusual to find that in small houses the bathroom and w.c. on the first floor will be placed immediately above the kitchen or scullery containing the sink and boiler. This saves piping and gives an opportunity to install an efficient hot water system.

COLD WATER SERVICES.—When designing the layout of the pipes for supplying cold water to a house, the following points should be borne in mind :—

1. The communication pipe should be laid not less than 2-ft. 6-in. below the surface of the ground, and this depth should be maintained until the pipe is well inside the building. As certain types of soil, cinders and concrete can cause decay to lead pipes, these should be wrapped with hessian and bitumen, or with bitumen felt. Alternatively, they can be laid bedded in sand in a wood trough. In any case, it is a sound job to surround the communication pipe with sand before filling in the pipe trench.

2. A stopcock should be fixed on the communication pipe at the first easily accessible place inside the building.

3. All pipes to be fixed in straight runs, wherever possible. U-shaped dips or rises MUST be avoided.

4. Branch pipes should fall towards the rising main, excepting the lowest branch, which should fall towards its bib tap.

(If there is strict adherence to points 2, 3 and 4, it should be possible to empty the pipe system by closing the stopcock and opening the bib taps.)

5. Pipes should run on internal walls, wherever possible.

6. Pipes exposed to draughts of cold air or which run on exposed external walls should be lagged (see p. 108).

7. Pipes buried in or passing through concrete or plaster should be wrapped with building paper, especially if the concrete or plaster is subject to dampness. (Lead pipes rapidly decay when in constant contact with damp plaster or concrete. These two materials also tend to grip pipes and prevent their free movement when subject to temperature changes.)

8. Where lead pipes are used, joints must be "plumbers' wiped joints." (For joints in copper pipes, see pp. 109, 110 and 111.)

9. Tanks in exposed positions in roofs should have 2 to 3-in. of lagging to their sides and bottom, and have a double wooden cover (lagged between the two thicknesses). Pipes running in the roof to the tank should be lagged, and should be kept 6-ft. from the eaves, if possible. (Pipe fixing details are given on pp. 104, 105, 106 and 107.)

Fig. 42 shows diagrammatically a typical layout for the cold water services of a small house.

HOT WATER SERVICES.—It is the general practice in this country to provide each house with its own means of heating and storing hot water for use when required. There are many ways in which this can be effected, and electricity, coal-gas, coke or coal can be used as the heating medium.

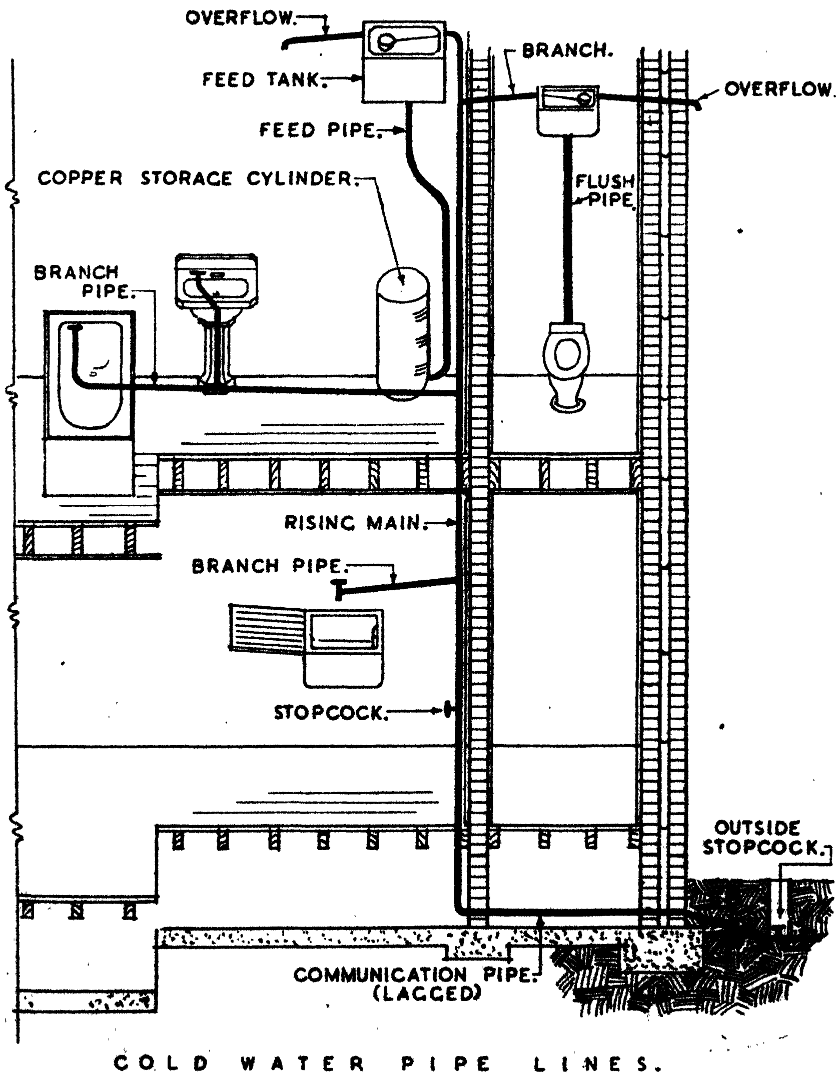


Fig. 42

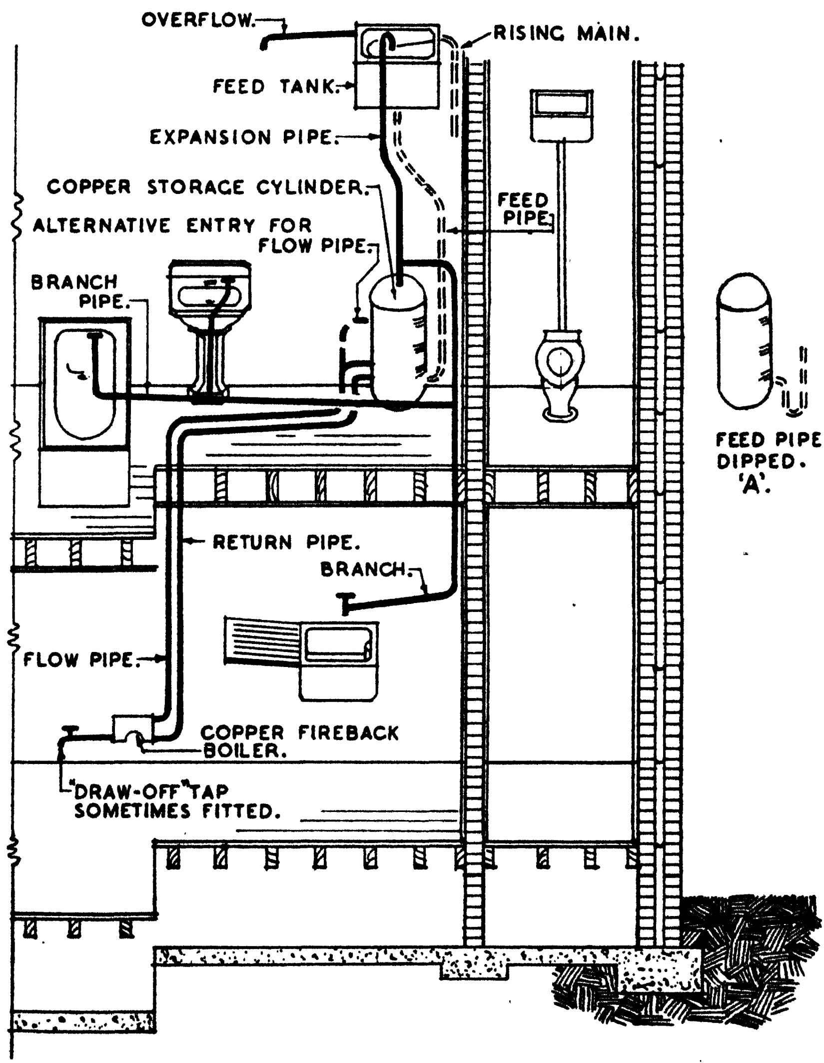
The most common method is to use an essential fire for heating the water, and usually the kitchen or scullery fire is selected as being the one which is lighted earliest and most constantly used. Many methods of utilizing fireback boilers, in combination with storage tanks, have been devised in the past, but in recent years there has been a tendency to use only the

" cylinder " system. Other systems are becoming obsolete. The underlying working principle is, however, the same in practically every type, the variations being in the shape and positioning of the part and the design of their piping.

The " Cylinder " System for Hot Water Supply.—This is shown diagrammatically in Fig. 43. The essential parts are a boiler, the cylinder and the feed tank. The method of connecting the parts by pipes is important, and the system will not work effectively unless they are as follows : Two circulation pipes are fixed between the boiler and cylinder, known as " flow " and " return " pipes respectively. The " return " pipe, fixed as near to the base of the cylinder as possible, must run continually downwards to the boiler. It must enter the boiler near the base or, if taken in at the top, must continue down inside the boiler to about 2-in. from the bottom. The " flow " pipe must leave the top of the boiler and must rise continually upwards to the cylinder to which it is connected, at least 4-in. above the " return " pipe. It is essential that these two pipes be as short as possible, and that long, almost horizontal runs be avoided. The cylinder is usually fixed in the bathroom, or a minor bedroom, on the first floor, as nearly over the boiler as possible. The cylinder base rests on the floor boards upstairs. A feed tank fed from the rising main through a ball valve must be placed higher than the cylinder and any of the hot water taps. The usual place is immediately above the cylinder, just below ceiling level. (This will give a minimum 5-ft. head of water at the taps and enables the cylinder and tank to be enclosed in tall cupboards with an airing cupboard between them.) A feed pipe is taken from the bottom of the tank to the bottom of the cylinder. From the top of the cylinder an expansion pipe runs upwards to a point higher than water level in the tank. This latter pipe can pass through to the exterior of the roof, but is usually bent down over the tank to finish well above water level. The branch supplying the hot water taps is taken off the expansion pipe immediately above the cylinder.

The system operates in the following manner : The feed tank keeps the whole system filled with water, the level in the expansion pipe being that of the water in the tank. Any water drawn off at a tap causes the tank water level to fall, and opens the ball valve until the water has been replaced. As the fire (generally controlled by a damper) heats the water in the boiler, this water expands, becomes reduced in density and, volume for volume, weighs less than colder water. Thus, colder water from the cylinder displaces warmed water in the boiler and a movement is set up. The arrangement of the circulation pipes directly aids and controls this movement by providing an easy exit via the " flow " pipe through the boiler top, whilst colder water leaves the bottom of the cylinder by the " return " pipe. The heated water collects at the top of the cylinder from where it is drawn off through the taps.

It should be noted that the boiler is relatively small in size compared with the cylinder, and that the heating action is not violent but builds up as the water from the cylinder circulates rapidly through the boiler. This circulation, however, depends on a *very slight* difference in density between heated and less heated water and can be easily impeded by the friction



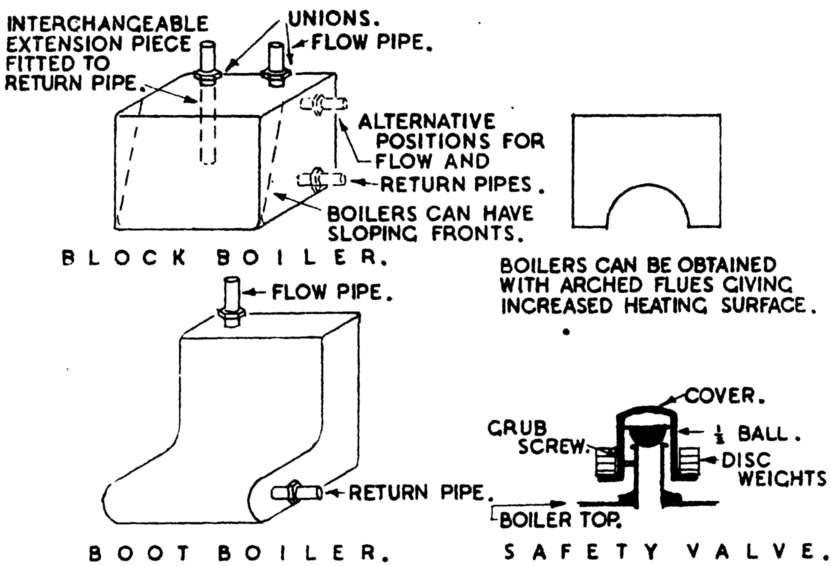
HOT WATER PIPE LINES.

Fig. 43

caused by a long circulation or bends. The expansion pipe allows any air driven out of the water, or any steam, formed by allowing the system to reach boiling point, to escape. If the feed pipe is dipped, as shown at A, Fig. 43, the possibility of hot water passing into the feed tank is almost eliminated.

BOILERS

There are many patterns of "fireback" boiler available, but many of these have been designed for fixing in specific types of ranges and fireplaces. Three types are shown in Fig. 44. The first, known as the "block"



FIRE-BACK BOILER DETAILS.

Fig. 44

type, is the most common. A similar type with an arched flue giving additional heating surface is also often used. The "boot" boiler is a very efficient type as the foot projects forward into the fire, giving a large heating surface. This type requires a deep fire, and cannot be used in many of the smaller kitchen ranges. Unless the fireplace is one which calls for some special form of fixing, boilers are bedded resting $1\frac{1}{2}$ to 2-in. on firebricks, giving a flue 3-in. high with a width only 3 to 4-in. less in length than the boiler. This flue is continued up the back of the boiler without change of section. Above the boiler the flue may be brought to a more square shape, but must maintain the same area as far as the main flue. The secondary flue, from under the boiler, is usually controlled by a damper fixed above the boiler. Firebricks are bedded on the boiler top to complete the fireback.

Boilers are made from cast iron, wrought iron or copper. The first type are cast all in one piece, whilst wrought-iron boilers are made from plate, not less than $\frac{5}{16}$-in. thick, with the seams welded. Copper boilers are made from soft rolled sheet, not less than $\frac{3}{16}$-in. thick, with the ends brazed in. Two unions are placed on the top to form the connections to the circulation pipes, and an extension downwards must be fitted to one or the other of the unions to form the " return " pipe. This extension pipe is interchangeable between the unions and should run to about 1 to 2-in. from the bottom of the boiler. Boilers fitted with side unions can be obtained. In this case no extension pipe is necessary, but care should be taken to see that the union for the flow pipe is fixed so that the top of the inside of the union bore coincides with the inside of the boiler top. If the union is fixed below the boiler top an air pocket may be formed. It is essential to fix all types of boiler level to prevent air being trapped at the boiler tops, for such pockets seriously impede their efficient working. Boilers can also be obtained with provision made for fixing a " draw-off " pipe, a safety valve or both. It is poor practice to attempt to improvise fixings for these fittings to boilers not designed to take them. Boilers sometimes have a " mud hole " which allows the boiler to be cleaned out on occasions, more particularly for the purpose of removing " furring " (see below).

Copper is the most suitable material for boilers, being durable and an efficient heat conductor. In hard water districts, however, it is the practice to use iron boilers and iron pipes for the whole of the hot water service. Hard water contains certain salts of calcium or magnesium and these salts, in waters classified as of " temporary " hardness, are partially driven out of the water when it is heated and form a deposit on the interiors of boilers and pipes. This deposit is known as " furring," and when it becomes thick the efficiency of the boiler is reduced and pipes may be blocked. To remove the " furring " it is often necessary to scrape, probe or hammer the boiler and pipes so that iron must be used to withstand this.

A high pressure can develop in a boiler if the circulation pipes are blocked with " fur " or ice. If the boiler bursts, the explosion may be very violent, and it is desirable to fix a safety valve to iron (and particularly cast-iron) boilers. On small boilers, however, this may not be possible.

Safety Valves (see Fig. 44).—The best type is the " dead-weight," consisting of a tube fixed in the boiler top. The top of the tube is ground out to act as a seating for a half ball which is held down by a cap carrying iron rings as weights. These are adjusted to just above water pressure. If it is not possible to put the safety valve directly into the boiler it should be fixed to the " return " pipe as close to the boiler as possible.

CYLINDERS

Copper cylinders are now almost universally used in domestic hot water supply systems. The sides of the cylinder generally have several bands of corrugations formed round them, whilst the ends are dished into domical shape. The seams are brazed. Fixed vertically, the bottom will be dished inwards to give a flat seating on the supporting floor. (If fixed horizontally both ends are dished outwards.) The dished ends, corrugations and cylindrical shape together create a form well suited to resist pressure and enable light gauge copper to be used. Unions are provided to give the necessary connections for the circulating expansion pipes. Various capacities and strengths are available for differing uses and pressures. These are now covered by a British Standard Specification (No. 699, 1936).

In hard water districts, where furring is prevalent, a rectangular galvanized iron closed tank is used instead of a copper cylinder. Provision is made for the usual connections and a " mud hole " with cover is provided. (See the next paragraph for the general form of tank construction.)

FEED TANKS

These are open top tanks made from galvanized *wrought* iron. The plates are welded or riveted together and should not be less than 16-gauge (about $\frac{1}{16}$-in.) in thickness for small tanks. The sides are turned in about $1\frac{1}{2}$-in. at the top to form a flat stiffening rim. A great variety of sizes and capacities is available. Tanks should be fitted with a brass union for the overflow and pierced for the ball tap. The overflow should be at least $1\frac{1}{2}$-in. below the ball tap.

INSTALLING A HOT WATER SUPPLY SYSTEM

The usual pipe sizes have been given on p. 95, and the conditions controlling pipe runs on p. 98. The following additional points should be borne in mind :—

1. It is common practice to fix the feed tank in a wood enclosure above the cylinder but just below the ceiling. Sufficient room (6-in. at least) must be left between the tank and the ceiling to leave the ball tap readily accessible.

2. The route taken by the circulating pipes must be carefully studied. These are often taken up inside the chimney and brought out of the flue near the level of the cylinder base. This is bad practice. It is impossible to secure the pipes in the flue, with the result that some 6 to 8-ft. of pipe may hang on the upper bends, straining and weakening the top sections of the pipes. The pipes also obstruct the flue and are liable to damage when the flue is swept as well as being inaccessible. Circulating pipes should be brought out of the flue as soon as possible by means of an easy bend and taken upwards on a pipe board. All bends in circulating pipes must be easy and there must be no interruption, *however slight*, of the continual upward rise.

3. In lead pipework all joints must be wiped. Iron pipe joints have screwed socket connections.

In place of the fireback boiler an independent boiler is often fixed. This consists of a water-jacketed enclosed fire, in which coke is the usual fuel. It is generally made from cast iron.

Immersion heaters, consisting of an enclosed electrical heating element, can be inserted in the top of cylinders controlled by a "three heat" switch; these are very effective.

BOILER, CYLINDER AND FEED TANK SIZES.—The sizes used depend on local practice and, of course, on the particular needs of the users of the hot water system. (Fuller details concerning the design and requirements for hot water supplies are to be found in the "Minimum Specification for Cold and Hot Water Services," published by the Institute of Plumbers.)

For a small house the following sizes are suitable :—

Boiler: Block pattern (rectangular)—base, 10-in. by 6-in.; height, 8-in.

Block pattern (inclined front)—base, 10-in. by 7-in.; top, 10-in. by 6-in.; height, 8-in.

Cylinder: 20-gal. capacity; diameter, 14-in.; height, 36-in., or 30-gal. capacity; diameter, 16-in.; height, 42-in.

Feed Tank: 20-gal. capacity, or 30-gal. capacity.

If the local practice is to take the cold supplies for the bath, wash-bowl and other fittings from the feed tank, this should have a capacity of at least 50-gal.

POSSIBLE DANGERS IN A HOT WATER SYSTEM

1. BOILER EXPLOSIONS.—These are caused by the circulation pipes being blocked either by ice or by "furring." In the former case the heat of the fire causes the water to expand and eventually boil. The increased pressure, due to the formation of steam (which cannot escape up the circulation pipes), causes the explosion. Copper boilers, being relatively weak, generally tear before the pressure becomes severe, but iron boilers may hold until there is enough pressure to cause an explosion. These latter should have safety valves fitted. A similar state of affairs exists when BOTH circulation pipes are blocked by "furring." The "return" pipe is, however, the last to become choked and the noisy and inefficient working of the system should be an adequate warning of impending trouble. As many householders disregard these warnings safety valves should be fixed. Where a "draw-off" tap is fixed to the boiler a fracture can be caused by lighting a fire under an empty boiler, especially if cold water enters the boiler whilst it is red hot. It should be noted that in a cylinder system the boiler cannot be emptied unless there is a draw-off tap to the boiler. Boilers fixed in firebacks abutting on external walls

should have 9-in. of brickwork behind them to prevent the circulating ipes from freezing close up to the boiler.

2. CYLINDER COLLAPSE.—Though this is not dangerous it can damage decorations and fittings. It is caused by the expansion pipe being exposed and freezing whilst the water in the system is very hot. Steam collects at the top of the cylinder, forcing water out of the cylinder into the feed pipe. A sudden condensation of the steam, possibly due to the opening of a tap, will cause a partial vacuum in the cylinder. External air pressure then causes the collapse. Corrugated cylinders and the practice of keeping the expansion pipe inside the building and in the same enclosure as the cylinder make this occurrence rare.

LEAD PIPE FIXING

SMALL BORE PIPES FIXED TO WALLS.—The fixing method used depends on whether the pipe runs vertically or horizontally and also whether the pipe is to be concealed or exposed. (Raking pipes are classed as vertical or horizontal according to the degree of their inclination.)

In Fig. 45 various methods of fixing to walls are shown.

VISIBLE VERTICAL FIXING. *Direct to Walls* (A, Fig. 45).—This is a cheap method. The pipe hooks are driven into joints in the brickwork. A strip of lead sheet MUST be placed between the hook and pipe to prevent the pipe being cut by any sharp edge in the hook. The maximum spacing for hooks is 3-ft. Hot water pipes require more supports than cold.

On Pipe Boards (B, Fig. 45).—Pipe boards $\frac{3}{4}$ to $\frac{7}{8}$-in. thick and varying in width to suit the number of pipes to be carried are fixed by the joiner. They can be either flush with or on top of the plaster. The pipes are secured to the boards by means of pipe clips screwed in position. Alternatively lead tacks, single or double eared, may be soldered to the pipe and screwed to the board. The maximum spacings are clips—3-ft.; single eared tacks—3-ft.; double eared tacks (for pipes 3-in. and over in diameter) —5-ft.).

CONCEALED VERTICAL FIXING. *Chase with Front Cover only* (C, Fig. 45). —In this case the brickwork is only chased sufficiently deep to take the pipe. A wood cover fitting flush with the plaster is screwed to wood plugs fixed to the brickwork. The pipe is not secured in any way to the brickwork. The method is not highly satisfactory, and if used, not more than one pipe should be put in a chase.

Chase with Back Pipe Board (D, Fig. 45).—A $\frac{3}{4}$-in. pipe board is let into a chase sufficiently deep to take the pipes and allow the access cover to fit flush with the plaster. Side lining boards of similar thickness are fitted into the chase. The cover is screwed to these side linings. The pipes are secured by clips screwed to the back board which is made

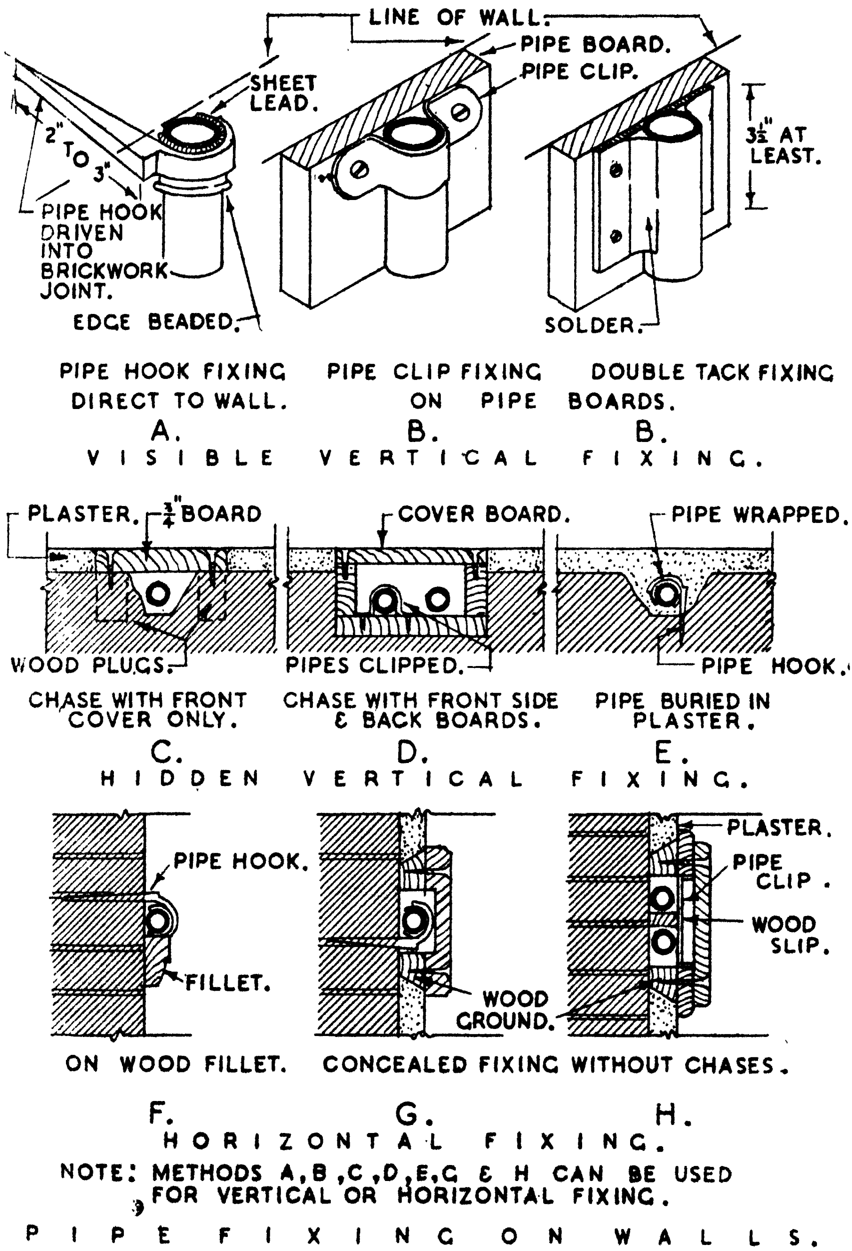

LINE OF WALL.
PIPE BOARD.
PIPE CLIP.
SHEET LEAD.
2" TO 3"
PIPE HOOK DRIVEN INTO BRICKWORK JOINT.
EDGE BEADED.
3½" AT LEAST.
SOLDER.
PIPE HOOK FIXING DIRECT TO WALL.
A.
PIPE CLIP FIXING ON PIPE BOARDS.
B.
DOUBLE TACK FIXING
B.
VISIBLE VERTICAL FIXING.
PLASTER.
¾" BOARD
COVER BOARD.
PIPE WRAPPED.
WOOD PLUGS.
PIPES CLIPPED.
PIPE HOOK.
CHASE WITH FRONT COVER ONLY.
C.
CHASE WITH FRONT SIDE & BACK BOARDS.
D.
PIPE BURIED IN PLASTER.
E.
HIDDEN VERTICAL FIXING.
PIPE HOOK.
FILLET.
WOOD GROUND.
PLASTER.
PIPE CLIP.
WOOD SLIP.
ON WOOD FILLET.
F.
CONCEALED FIXING WITHOUT CHASES.
G.
H.
HORIZONTAL FIXING.
NOTE: METHODS A, B, C, D, E, G & H CAN BE USED FOR VERTICAL OR HORIZONTAL FIXING.
PIPE FIXING ON WALLS.

Fig. 45

sufficiently wide to take the desired number of pipes. Maximum distance between clips, 3-ft.

Pipes Buried in Plaster or Cement (E, Fig. 45).—Many water authorities do not approve of this method, but it is sometimes necessary where the pipes have to pass behind wall tiling or similar finishes. The buried length should be kept as short as possible. A chase is cut in the brickwork for all but very small bore pipes, and the pipe is secured by pipe hooks as in A. The wall is then plastered in the usual way. It is highly advisable to wrap the buried length of pipe continuously with building paper or thin bituminous felt to prevent the plaster (or cement) contacting the lead.

VISIBLE HORIZONTAL FIXING.—Pipes can be fixed by pipe hooks direct to walls or by clips to boards the same way as shown for vertical pipes at A and B. The hooks or clips should not be more than 2-ft. apart. The method is not satisfactory as the pipes in time droop between the clips. Horizontal pipes should have continuous support.

On Wood Fillet (F, Fig. 45).—The thickness of the fillet depends on the bore of the pipe. The pipe can be secured either by hooks (inverted) or by laying the pipe in a groove made on the top of the fillet. Hooks can be at 4-ft. centres.

CONCEALED HORIZONTAL FIXING. *Chase with Back Pipe Board.*—This method is the same as shown for vertical pipes at D. The pipe is laid in the lower angle of the chase. If more than one pipe is to be fixed in the chase further fillets can be nailed to the back board. The pipes are held by clips with the wings at right angles or by inverted hooks.

At G and H two methods of concealed fixing, which do not involve the cutting of chases, are shown. These are suitable for either vertical or horizontal pipes.

Bends in pipes should be easy and in internal angles it may be necessary to block out the angle to sweep the pipe round with the access cover following suit. At external angles the chase is deepened to allow the pipe to pass with an easy bend.

Small Bore Pipes Fixed in Floors.—Before considering the fixing of pipes in floors it is necessary to describe the usual methods of floor construction in small houses. The upper floor will be constructed with wood joists, spanning from wall to wall. Joists are usually 2-in. thick with the depth varying from 7 to 11-in., according to the span. They are fixed about 12-in. apart parallel to each other. On the upper side of the joists floor boards are nailed to the joists, running across them at right angles. Floor boards vary in thickness from $\frac{3}{4}$ to $1\frac{1}{4}$-in., according to the quality of the work. They are generally tongued and grooved, and this, together with the form of nail employed, makes them very difficult to lift once they are fixed. On the underside of the joists, some form of lathing will be fixed to carry the plastered ceiling of the room below. Ground floors (where there is no cellar below) are similarly constructed from wood joists and boards, but in this case the joists will not be as deep as those for upper floors because it is possible to build cross walls at 5 to 7-ft. intervals to support them. These cross walls, known as "sleeper" walls, stand on a bed of concrete known as "site" concrete which, nowadays, is laid under the whole of the ground floors of houses. There are, of course, many other types of floors in buildings and the plumbing student is again advised to study their construction in any good book on Building Construction.

PIPES LAID UNDER GROUND FLOORS (see Fig. 42).—The simplest way is to allow them to rest on the "site" concrete. As the space under the floor (often called the "underdrawing") is ventilated, and can be very cold, the pipes should be lagged. Where the pipes are not lagged it is advisable to place a strip of building paper or bituminous felt between the pipe and the concrete to prevent possible lead decay through contact with concrete.

PIPES LAID IN UPPER FLOORS (see Fig. 46).—The method of fixing these depends on whether they run with or across the joists. In the first case the pipe is laid on a wood fillet nailed to the joist side. This fillet can be adjusted to give slight falls. The pipe can be held on the fillet by either inverted pipe hooks or screwed clips. In the second case there are two methods of laying the pipe. If the pipe is to run across the joists close to where the joist rests on the wall, then the upper side of the joist can be notched. (Notching weakens joists and should not be done for pipes greater than ½-in. bore.) Joists should not be notched elsewhere than near their supports as the weakening effect becomes much more serious as the centre of the span is approached. The best method of laying

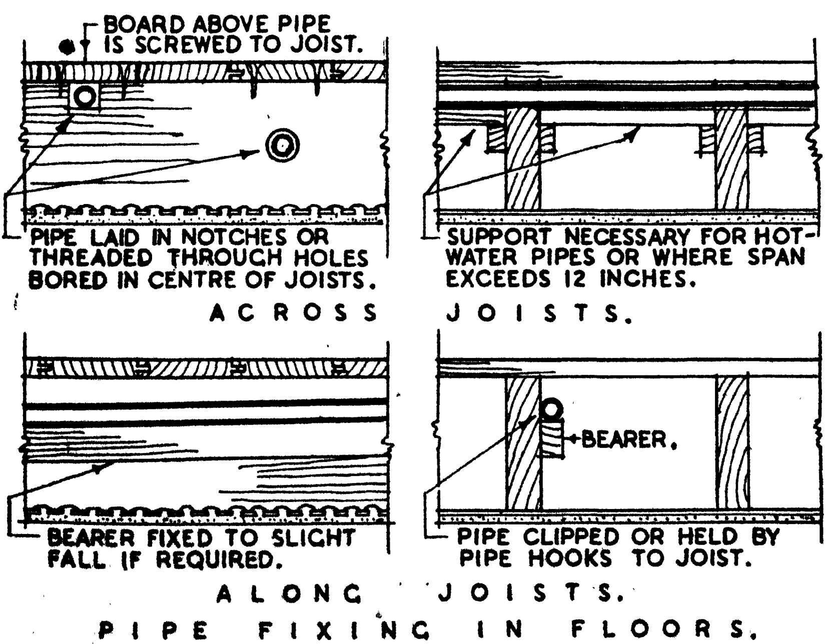


Fig. 46

pipes across joists is to thread them through holes drilled in the joists midway between the top and bottom of the joist. (Drilling joists midway through the central axis does not reduce their strength to anything like the same extent that notching the top or bottom edge does.) Cold water pipes fixed across joists which are not more than 12-in. apart do not need supporting between the joists, but where the joists are spaced more widely, or where the pipes carry hot water, support boards should be used. It is not possible to give much fall to pipes running across joists as deepening the notches or lowering the holes will weaken the floor unduly. Access to the pipes can be given by having those boards laid immediately above the pipes made with " butt " edges and using screws to hold them down. Where the pipes run with the joists they pass so many boards that access can only be arranged at a few points by having occasional lengths of board fixed with screws. It is advisable to lag pipes laid under upper floors.

LAGGING PIPES.—This can be done effectively by wrapping the pipes continuously with 2 to 3-in. wide strips of canvas-backed hair felt or similar strips of asbestos felting. These lagging strips can be obtained made specially for winding spirally on the pipes. Copper wire should be be used to bind the lagging in position. Prefabricated laggings, half-pipe shape, can also be used. They are placed together to enclose the pipe, and secured in position with clips. Lagging can also take the form of laying the pipe in wooden casings containing slag wool which is packed round the pipe. This method of lagging can also be applied to pipes fixed in chases. Hessian, straw or hay are sometimes used in casings, but are not permanent. They are also attractive to vermin and should not be used.

LARGER BORE LEAD PIPES.—In a small house the larger pipes will be 1¼ to 1½-in. waste pipes from sinks, wash-bowls or baths. The fixing of traps to waste pipes has already been described on p. 79. The waste pipe from the sink will normally pass directly from the trap through the wall and discharge over a gully outside. As it is subject to considerable expansion and contraction, it is better to wrap the pipe, where it passes through the wall, with building paper. Wastes from baths and wash-bowls may have to pass into the floor before turning through the wall. They are treated as described for small bore pipes. Fixing difficulties are eased if the pipes run with the joists. These wastes will discharge into a cast-iron rain-water head fixed at the top of a cast-iron waste pipe which in turn discharges over a gully.

FIXING CAST-IRON WASTE AND SOIL PIPES

For a small house the waste pipe will be 2-in. diameter and the soil pipe 3½ or 4-in. diameter. They are circular in cross-section and should be " medium " or " heavy " grade in weight. They are fixed to the wall with spikes passed through distance pieces in the same way as rain-water pipes. Closed jointing with gasket and red lead putty is generally used for both types of joint. Joints can also be made by pouring molten lead into the annular space between the socket and spigot after a ring of gasket has been previously inserted. The lead is then lightly caulked and trimmed off. Lead wool, consisting of lead fibre loosely wound into a rope, can be used instead of molten lead. The lead wool is inserted into the annular space and consolidated by hammering with a caulking tool. Portland cement is sometimes used in place of red lead putty being inserted down on to a gasket ring. A cement joint is generally used to connect the foot of the soil pipe to the spigot of the stoneware rest bend at the end of the drain. The soil pipe is usually continued upwards beyond the point where the branch from the w.c. enters, to act as a ventilation pipe to the drains. This extension must be of the same weight and bore as the soil pipe proper. It should terminate not less than 3-ft. above any adjoining window (this latter point is controlled by local bye-laws and may vary in different areas). The ventilation pipe should have a copper-wire cowl or basket fixed on top. Waste pipes, and particularly soil pipes, should be coated internally (and externally for good work) with Dr Angus Smith's composition to reduce corrosion. Both types of pipe should be fixed to run as vertical as possible.

INTERNAL PIPEWORK IN COPPER

Where copper pipe is used for pipework the technique of fixing differs considerably from that used with lead and calls for the exercise of a differing degree of skill. It is a hard metal, more difficult to bend than lead, and not so easy to adjust. Pipe lines in this more rigid material demand careful and accurate measurement, planning and setting out.

Using copper tubes does not affect the fixing or choice of fittings in any way, for it is possible to obtain tap, valve and other connections specially adapted to the form of copper piping used. Gauges and some other particulars relative to copper tube have been given previously on p. 22. It is not proposed to deal with "heavy" gauge screwed tubing in this book.

LIGHT GAUGE COPPER PIPEWORK

JOINTING.—Solder applied in the form of a "wiped" or "taft" joint is unsuitable for joining copper pipes, for it tends to deteriorate through electrolytic action. Other efficient types of jointing have been evolved.

The following are points with which the jointing of light gauge copper tubes should comply :—

1. The joint must not be expensive or require expensive equipment to make it.
2. The pipe bore must not be reduced to any appreciable extent.
3. The pipe wall must not be reduced in thickness.
4. The joints must not be so large as to cause the piping to have to stand out far from walls or require large wall chases when fixed in position.

5. The materials composing the joints should match the appearance of the tubing so that exposed piping can have a neat appearance if a polished finish is required.

6. It is an advantage if the piping can be taken down and reassembled, using the same material.

There are many types of jointing which comply with most of the above requirements. They can be classified into three groups, namely :—

1. Compression Joints.
2. Capillary Joints.
3. Welded Joints.

Compression Joints (see Fig. 47).—Two classes of compression joints are available. One type requires the flaring out of the tube ends whilst in the other class the ends of the tubes are cut off square.

The first kind, two forms of which are shown at A and B, Fig. 47, consist of union pieces which are slipped on to the tubes. The tube ends are then flared out with a special angle drift and a special tapered piece fitting the flares is inserted between the tube ends. Tightening the union clamps and compresses the flared ends on to the tapered piece, making a sound watertight joint.

The second kind, two types of which are shown at C and D, Fig. 47, differ in design. In the first (C) a union piece and a *soft* copper conical sleeve are slipped on each tube end. Then a linking piece, with annular recesses fitting the cones, is brought between the tube ends. The unions are tightened on to the linking piece and the soft copper cones are compressed on to the tube walls to give a tight grip. The second, shown at D, is similarly fixed, but instead of soft copper cones a corrugated metal grummet is used. This, when compressed, bites into the tube to give the required tight grip.

The fittings used in compression joints are bronze, gunmetal or brass, hard and strong enough to grip the copper tube and to carry threads secure against stripping when tightened.

Capillary Joints (see E, Fig. 47).—These consist of brass (or some similar copper alloy) connecting links with sockets bored out at each end to fit exactly the outside of the copper tube. The remainder of the bore corresponds with the internal bore of the copper tubes to be joined. The tubes are inserted into the fitting after their ends have been sawn off square, cleaned and fluxed. The tube ends must go right up to the shoulder of the sockets. There are three ways of introducing the solder. In one case solder is introduced through "touch" holes, another method is to apply solder to the junction of the tube and socket, whilst in the third method (shown) the solder is already in the fitting. The fittings, when in position, are heated and the solder runs along the joint by capillary action. The efficiency of these joints depends on an ample penetration of solder. For this full capillarity is necessary and an exact fit is vital. The fittings must be those made for the particular gauge of tube being used. The third type (with a ring of solder already in the fitting) ensures the use of the correct solder.

In view of the earlier statement prohibiting the use of " wiped " joints in copper tube, the question of probable failure of capillary joints by electrolytic action arises. This form of joint has been in use for many years in the U.S.A., and for some years in this country, and has proved satisfactory. It is considered that, in the initial electrolytic action, the extremely fine edge of solder exposed to contact with water becomes covered with an insoluble compound which prevents further decay. Further, microphotographs of the section of the joint have shown that the tin in the solder of the joint dissolves some of the contacting copper to form a copper, tin, lead alloy which is less likely to suffer from electrolytic action than tin-lead solder.

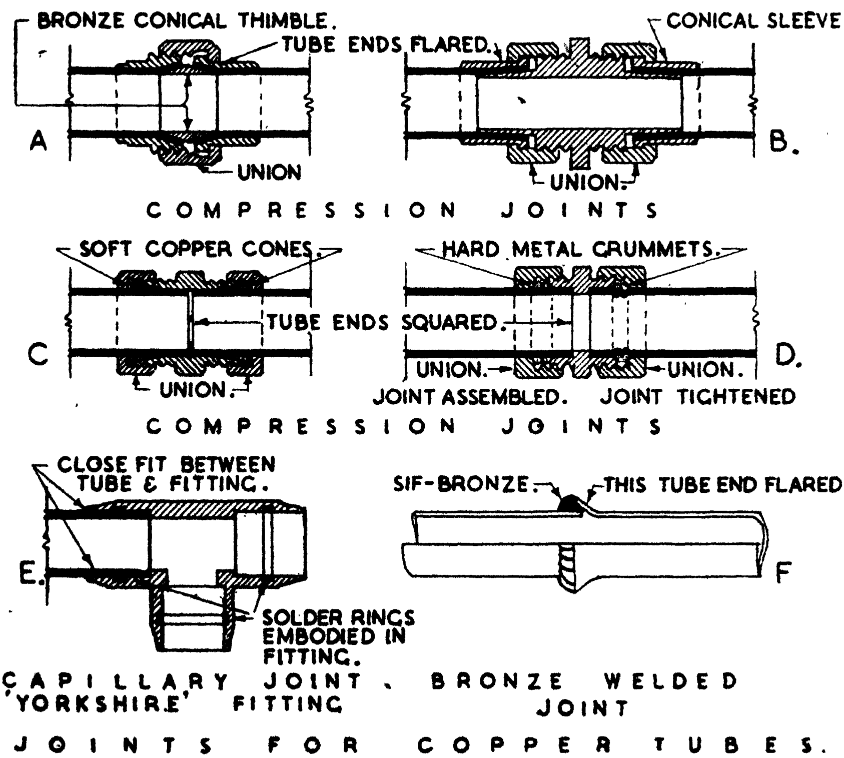
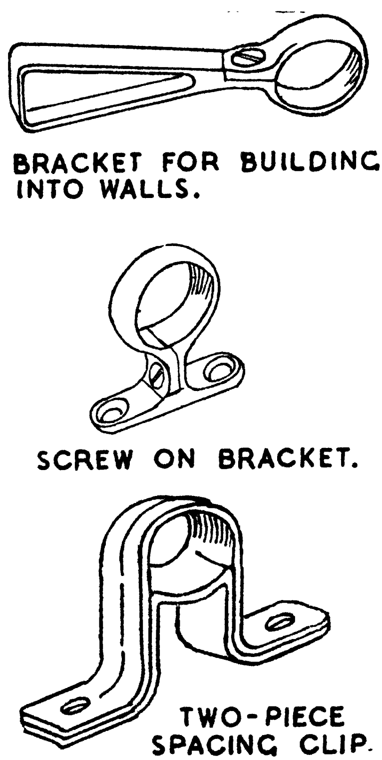


Fig. 47

Welded Joints (see F, Fig. 47).—These can be made in two ways, either using the copper itself to form the weld or by using a welding material which melts at a lower temperature than the copper. Sif-bronze (see p. 57) is generally used for this purpose. " Autogenous " welding (fusing the pipes together using copper to form the weld) is a skilled and difficult operation when the pipe walls are thin, as they are easily holed and burnt away. For ordinary work bronze welding is more easily accomplished, particularly *in situ*. In this case the filling rod of sif-bronze is melted and run into position before the copper has reached its melting point. To make the joint, one tube end is flared out by a drift and the other tube is inserted. Heat is applied from an oxy-acetylene torch and the sif-bronze is melted continuously into the flared end. Special fluxes are used. These are applied by a brush before welding if the liquid type is used. Powder fluxes are applied either by sprinkling the joint or dipping the sif-bronze rod into the powder.



BRACKETS FOR COPPER PIPES.

Fig. 48.

COPPER PIPE FIXING

The methods employed in fixing copper pipes differ somewhat from those employed for lead. As the pipes are stronger and more rigid the clips or brackets can be spaced at twice the distance specified for lead. There also is no need for continuous support to be provided for horizontal pipes which can be fixed in the manner used for vertical pipes.

Visible Fixing.—It is usual to fix pipes jointed with compression joints sufficiently clear of the wall surface to enable the joints to be readily accessible with spanners. In Fig. 48 brackets made of copper or brass are shown. These can be either built into joints or screwed to pipe boards. The pipes are clasped in a divided ring held together by set screws. If strip clips are used they should be so designed as to hold the pipe clear from the surface to which they are fixed (see Fig. 48). Pipes must not be fixed so that they are strained towards the wall surface between the nuts of the compression joints.

Capillary and welded jointed pipes are usually fixed in the above ways but, as the joints are not bulky, the pipes can be closer to the wall, and ordinary strip clips screwed to pipe boards can be used, provided the pipes are not strained between the joints.

Concealed Fixing.—Chases can be formed and used in the same way as for lead. The chases must be large enough to allow joints to be tightened. Clips or pipe hooks can be used to hold the pipes in the chases. The same precaution against straining the pipe applies.

Fixing in and Under Floors.—Pipes are secured by clips or hooks to joist sides, but there is no need to support them with wood fillets. Where pipes run across joists they are usually laid in notches because, firstly, the external diameter of copper pipes is less than that of lead pipes of equal bore, so that the notches are smaller; and, secondly, it is often impossible to pass or thread copper pipes through a series of holes drilled in joists.

Spacing of Clips for Light Gauge Copper Tubing

Fixed vertically . . .	6-ft. max.
Fixed horizontally . . .	4 to 6-ft. max.

It is not considered advisable to use light gauge copper tube for circulating pipes to boilers if they are exposed to hot gases from the fire. If, however, copper tube is used, it should be heavy gauge for boilers with top connections. Light gauge can be used if the boiler has side connections, allowing the tube to avoid contact with flue gases.

IRON PIPEWORK

In certain districts where the water supply is hard in character it is customary to use wrought iron or steel for the hot water supply pipes. Sometimes iron is used for all the pressure pipes.

Iron pipes should be protected against corrosion by being galvanized (see p. 24) inside and outside or be protected in some other equivalent manner. Local water authorities will specify the quality and gauge of pipe to be used as well as their sizes.

The following table, based on British Standard Specifications 788 and 789, is a useful guide as to gauges.

Pipe Bore.	Water Quality.	Steam Quality.
In.	S.W.G.	S.W.G.
½	11	10
¾	10	9
1	9	8
1¼	8	7
1½	7	6
4	6	5

Wrought iron and steel pipes have screwed joints. The threads are painted with a mixture of red and white lead before the pipes are screwed up.

When designing pipe systems in iron the same principles as those given for lead apply, but for the hot water services it is the practice to use pipes not less than $\frac{3}{4}$-in. diameter if " furring " is prevalent in the district where the pipes are to be fixed. Also, in such cases the circulating pipes should not be less than $1\frac{1}{4}$-in. diameter. It is good practice also to provide access junctions in the circulating pipes to enable " furring " to be removed.

The methods of fixing iron pipes to walls and in floors follow generally those described for copper. The principal difference is that external diameters of iron pipes are larger than those of copper pipes and so larger chases are required.

CHAPTER FOUR

PLUMBERS' TOOLS

Sheet lead tools. Lead pipe tools. Sheet copper tools.

To undertake his various tasks a plumber has to be familiar with the uses and purposes of a very large range of tools. The increasing use of copper in plumbing has enlarged the list of tools used by the plumber. Thus the plumber's tools vary from such simple articles as knives and shears up to bending machines and oxy-acetylene apparatus.

It is only proposed to deal with the more commonly used hand tools which would be needed on most jobs. These are shown in Fig. 49.

SHEET LEAD TOOLS.

*Dresser (A): Used for dressing lead sheets down to flat surfaces.

*Bossing Stick (B): Used for dressing lead round rolls and in forming corners to upturns in sheet lead.

*Setting-in Stick (J): Used in forming corners to upturns and for working lead into angles.

*Bossing Mallet (D): Used for striking the above tools for working lead into angles and also for holding behind lead sheets whilst the front is struck by the above tools.

*Chase Wedge (K): Of various sizes and shapes. Used for working the angles of rolls and upturns in restricted spaces.

Drawing Knife (W): Used for cutting lead. Another knife with a stout parallel blade about $\frac{3}{16}$-in. thick at the back of the blade is also used for cutting lead. It is driven through lead by hammer blows and is known as a " hacking " or " chipping " knife.

Drip Plate (L): Is inserted between two sheets of lead to prevent the undersheet from spreading whilst the top sheet is being worked, as in the case of overcloaks. The curved piece acts as a handle for withdrawal purposes.

Shears or Snips (O): Used for trimming and cutting sheet lead.

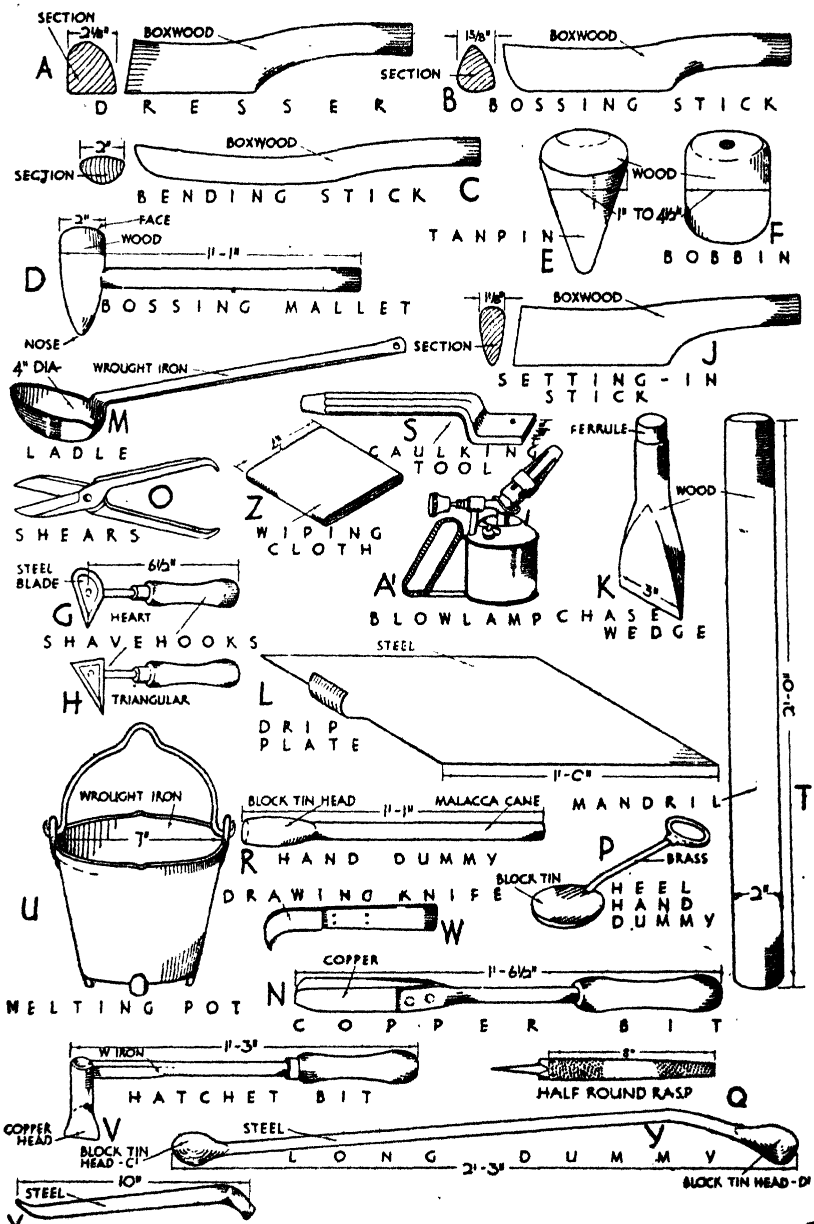
LEAD PIPE TOOLS.

*Bending Stick (C): Used for dressing the lead in pipe walls. Can also be used as an alternative to the bossing stick.

*Tampin or Turnpin (E): Sizes vary from 1 to $4\frac{1}{2}$-in. diameter at the head; used for opening out the ends of pipes.

*Bobbin (F): Sizes vary from 1 to $4\frac{1}{2}$-in. diameter and correspond

* The best qualities of the tools so marked are made from boxwood, which is a heavy close-grained strong wood which has a smooth surface and is hard to dent. The wood is difficult to split and does not form into spells and splinters.



A
SECTION
2¼"
BOXWOOD
DRESSER
B
15/8"
SECTION
BOXWOOD
BOSSING STICK
2"
SECTION
BOXWOOD
BENDING STICK C
WOOD
1" TO 4½"
TANPIN
E
F
BOBBIN
D
2"
FACE
WOOD
1'-1"
BOSSING MALLET
NOSE
1⅛"
SECTION
BOXWOOD
J
SETTING-IN STICK
4" DIA
WROUGHT IRON
M
LADLE
S
CAULKING TOOL
FERRULE
WOOD
SHEARS O
Z
WIPING CLOTH
A'
BLOWLAMP
K
3"
CHASE WEDGE
STEEL BLADE
6½"
G
HEART
SHAVEHOOKS
H
TRIANGULAR
STEEL
L
DRIP PLATE
1'-0"
2'-0"
WROUGHT IRON
7"
U
BLOCK TIN HEAD
1'-1"
MALACCA CANE
R HAND DUMMY
MANDRIL
T
P
BRASS
BLOCK TIN
HEEL HAND DUMMY
DRAWING KNIFE
W
2"
MELTING POT
COPPER
1'-6½"
N
COPPER BIT
1'-3"
W IRON
HATCHET BIT
8"
HALF ROUND RASP
Q
COPPER HEAD
V
STEEL
Y
BLOCK TIN HEAD-C'
LONG DUMMY
2'-3"
BLOCK TIN HEAD-D'
10"
STEEL
X BOLT

TOOLS

Fig. 49

to pipe bores. They are used to restore lead pipe bores to their true bore during bending processes. To use a larger bobbin, it is threaded on a stout sash cord which has a smaller heavy metal bobbin (back-weight) fixed about half-way on the cord. The bobbin is inserted in one end of the lead pipe and by pulling alternately on each end of the cord the back-weight "bumps" the bobbin gradually through the pipe. (For use of smaller bobbins, see "followers.")

Followers: These are wood bobbins slightly less in diameter than pipe bores. Their purpose is to enable a bobbin to be driven round bends in lead pipes. To do this a bobbin fitting the pipe bore is inserted in one end of the pipe and driven a little way in. Followers are then inserted as required to transmit the driving blows to the leading bobbin which forces the pipe wall to their correct shape. It is the usual practice to thread a bobbin and some followers on a cord as this facilitates withdrawal.

Mandrel (T): Sizes vary to fit pipe bores. They are used to restore lead pipe to true bore by removing dents and bulges and also to straighten pipes.

Long Dummy (Y), Hand Dummy (R) and Heel Dummy (P) are used in pipe bending.

Shave Hooks (G and H): Used for shaving clean pipe ends prior to soldering.

Rasp (Q): Resembles a file in shape, but its surface is coarser, being covered by small notches. It is used for rasping and shaping pipe ends before soldering.

Bolt or Bent Pin (X): Used for opening out holes in the sides of pipes to receive branch joints.

Metal, Melting or Solder Pot (U): Is obtainable in various diameters from 4 to 12-in. It is used to melt solder over gas ring (on benches) or over fires.

Ladle (M): Used to apply solder obtained from the metal pot.

Wiping Cloth (Z): Consists of several folded layers of moleskin cloth, and is used for wiping joints. Size varies according to type of joint.

Blowlamp (A^1): Is obtainable in many patterns using either petrol, paraffin or benzolene as fuel which is forced under air pressure through a vaporizer to the burner. Sizes vary from ½ to 2-pints. It is used for heating solder when forming joints.

Copper and Hatchet Bits (N and V): Used in forming joints of the "taft" and "lapped" type. Can also be obtained in patterns where the bit is kept at a proper temperature by gas or electricity.

Caulking Tool (S): Used for caulking lead in iron pipe joints. It is made of cast steel.

Other tools required will include files, ball-hammers, pliers, screw-drivers, spanners, wrenches, soil pot (containing plumbers' "black"), two-foot rule and square. Heavier equipment will include taps and dies for screwed connections, bending machines for hard metal pipes, various vices and oxy-acetylene apparatus for welding and bending hard metal pipes and for lead burning.

SHEET COPPER TOOLS.—Certain additional hand tools for use in sheet copper work are shown in Fig. 50.

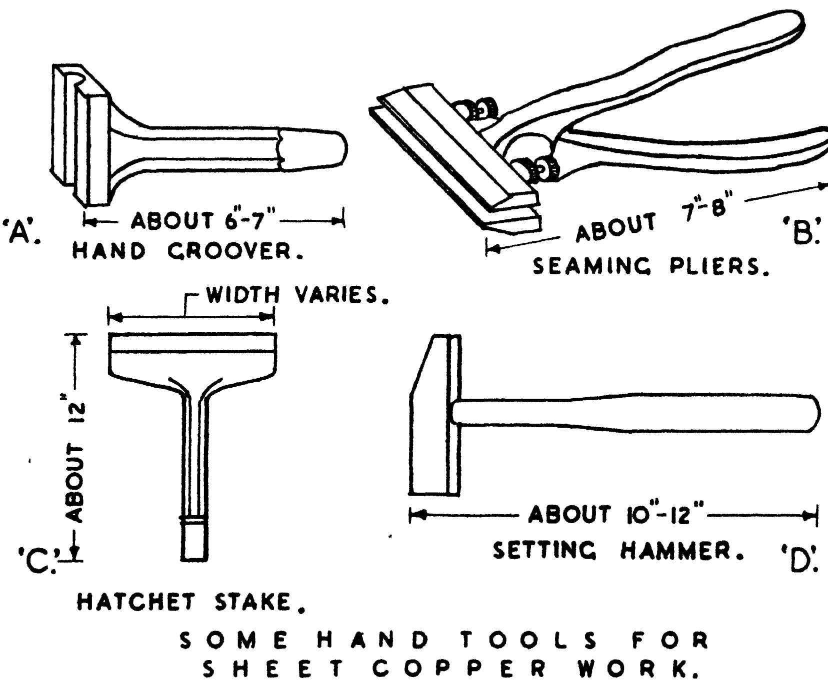


Fig. 50

Hand-groover (A) : Used for setting in welts.
Seaming Pliers (B) : Used for folding copper sheets. Larger tools are also available for this work.
Hatchet Stake (C) : Used for bending seams and folds on sheets.
Setting Hammers (D) are also necessary. The rectangular head is useful when working angles.

The various dressers and mallets described for sheet leadwork are also useful for sheet copper working.

CHAPTER FIVE

PRACTICAL WORK

Principles of sheet lead bossing. External and internal corners. Lead pipe bending for various diameters. Lead pipe jointing—general principles. Underhand, upright and branch joints. Lead burning—oxygen—acetylene. Oxy-acetylene apparatus. The method of using oxy-acetylene for lead burning.

It is not possible in any book to do more than describe methods of carrying out practical work. Competence in craftwork is only achieved by practice and study. The young plumber should therefore seek every opportunity of studying the methods used by skilled men and whenever possible practise these methods. If he attends and completes the courses of instruction available in most Technical Colleges, he will find that his skill and ability will increase by leaps and bounds. There is no short cut to competence.

SHEET LEAD BOSSING

This is an important part of the craft of plumbing. The highly durable nature of lead, coupled with its adaptability, is such that sheet lead continues, and will continue, to hold its place as an essential feature of most buildings.

Bossing sheet lead may be described as the process by which a flat lead sheet can be shaped without inserting, cutting out or jointing any lead, whilst maintaining an even thickness of sheet. Where further lead is required to complete any part it is transferred from some other point by driving it along in short stages by blows from a " bossing " or similar stick. A slightly increased thickness in the sheet is forced along to its desired position, but great care is taken not to leave the sheet unduly thin after the " wave " of lead has passed. Considerable skill and experience are necessary to plan and carry out the operation, for, in actual practice, there are limitations to the extent to which bossing can be successfully carried. The chief limitations are given below :—

(*a*) It is not economical to attempt to transfer lead over more than 12-in. and the work should always be planned to avoid excess transfer.

(*b*) Holes, cracks and cuts cannot be " worked out " by bossing. They enlarge and ruin the work.

(*c*) Creases and buckles in the sheet cause tears.

(*d*) Bossing cannot join the sides of a crack or cut.

Arising out of (*d*) it should be noted that marking out lead with a knife introduces an artificial crack and reduces the thickness of sheet where incised. Though the knife mark may be hidden by bossing, the weakness remains and the sheet usually tears before the work is completed. *Setting-out must be done with chalk lines.*

Two of the most common forms of bossing are concerned with the corners of upstands to lead gutters. One is the " external " corner where the angle formed by the upstand measures (on the sole side) less than 180°, whilst the other is the internal corner where the angle of the upstand measures (on the sole side) more than 180°. Examples of both these corners are shown in Fig. 51.

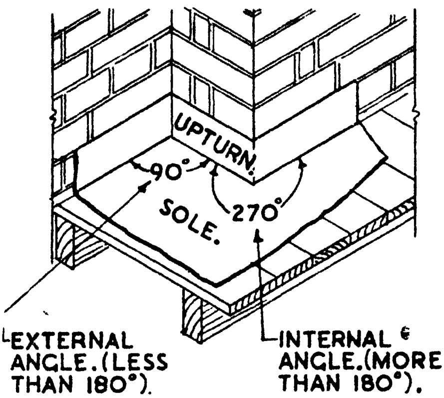


Fig. 51

Bossing corners in upstands involves the transfer of lead from one part of a sheet to another. In some cases it is necessary to " lose " lead and in others to " gain " it. The following experiment, based on Fig. 51, illustrates why this is necessary.

Cut a piece of stiff paper to the size and shape shown in Fig. 52. Rule on it lines corresponding to the broken lines on the diagram. Next fold up the edge (shown by the thick line) along the broken lines. It will be found that there is surplus paper at A and a shortage of paper at B if the upturn is to be completed.

If instead of paper the material used is sheet lead it is possible to transfer some lead at A towards and to B, provided the distance between A and B is not too great. This is effected by bossing the lead sheet in a special manner. The bossing becomes increasingly difficult as the height of the corners increases.

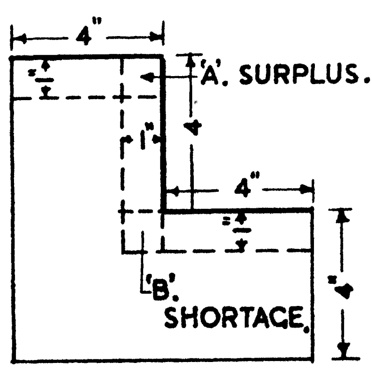


Fig. 52

The ways in which an " external " and an " internal " corner are formed are given below.

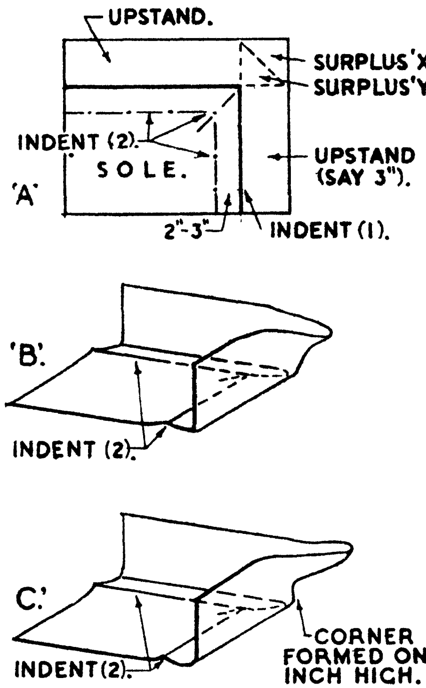
FORMING AN EXTERNAL CORNER.—Set out, with chalk lines, on a flat sheet of lead the junction line between the upstand and the sole, as shown at A in Fig. 53. With the " setting-in " stick and mallet convert this junction line into an indented line (1). Turn over the sheet and next form the indented lines (2) on the back of the sheet to stiffen the sole and fix the angle. Then turn the sheet over again to its original position.

Cut off surplus (x) and fold the upturn upwards against a wood block (former) along indent (1) working in towards the corner. The surplus lead should then appear as at B in Fig. 53.

Hold the wood block right up into the angle and gently fashion the exterior of the angle with a mallet or bossing stick until the angle is squared to about 1-in. high, as at C in Fig. 53. Next drive the lead in the lower part of the ear and immediately above the 1-in. corner inwards and upwards by placing the mallet inside the corner and beating the outside with either the bossing or bending stick. Care must be taken not to drag the corner upwards, or force it inwards, or to form creases in the lead.

Using the wood block again, fashion a further 1-in. height of corner and repeat the "knocking-up" process.

As surplus lead forms above the final height of the corner it is better trimmed off, but care must be taken to leave a margin for the final trimming.



FORMING AN EXTERNAL CORNER

Fig. 53

When the corner has been fully formed by the repetition of the above processes it can be straightened up by using the dresser against the wood block, and indent (2) in the sole can be removed by the dresser. The final stage is to trim the upstand to its correct height. Every endeavour should be made to keep the lead to an even thickness.

A wood block (or "former," as it is generally called) is extremely useful in making lead corners. It should measure about 5 in. by 2½ in. by 12-in. and should have its angles slightly rounded off.

FORMING AN INTERNAL CORNER.—A different procedure is necessary in this case. With an external corner it was necessary to "lose" lead, and now lead is to be "gained."

Set out, with chalk lines, in a flat sheet of lead the junction line between the upstand and sole, as shown in Fig. 54. It is essential to provide sufficient spare lead in the vicinity of the corner. In A, Fig. 54, the square marked M represents the area of "missing" lead required to complete the corner.

Adjoining lead 2M equal to at least twice the area of M must be allowed for when setting out. Using the "setting-in" stick and mallet convert this junction line into an indented line (1). Turn over the sheet and form the stiffening indented lines (2) and turn the sheet over again to its original position.

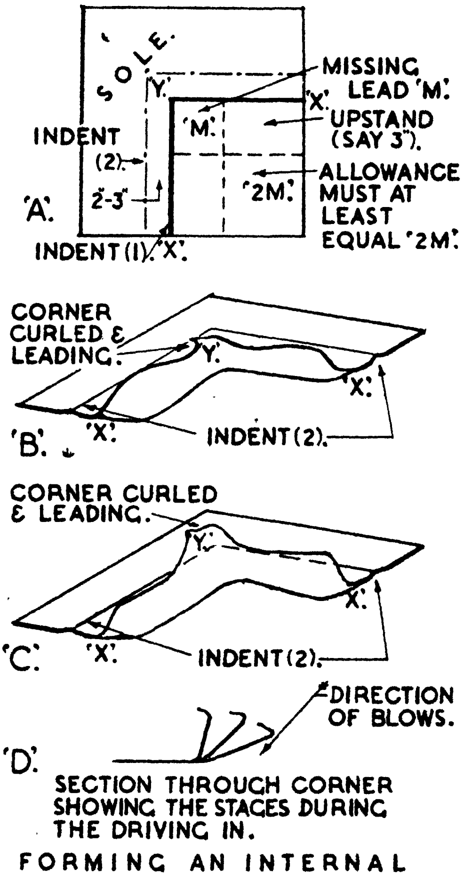


Fig. 54

In this case it is impossible to fold up the upturn right into the angle but, at points X and X (see B, Fig. 54), the upturn should be folded upwards as far as it will go without straining the lead. Next, the corner at Y (see B and C, Fig. 54) should be bent upwards and curled slightly inwards, as shown in the figure. Then, with the sheet overhanging a bench the lead should be beaten with a "bossing" stick to drive the curl inwards and downwards. This must be repeated constantly, always keeping the edge of 2M curled and leading. The stages are shown diagrammatically at D in Fig. 54. As the corner is driven in it will be found possible to bring the upturns at X and X vertical, and the lead 2M will develop as a sort of ear above the top edge of the upstand. This must be worked downwards and inwards until sufficient lead of the right thickness is in the corner. Then, using the wood block outside the corner (*i.e.* at M), it will be possible to use the " bossing " stick on the sole side of the upturn to form the corner. The upturn and sole are straightened by using the dresser and the upturn trimmed to its correct height.

An internal corner is much more difficult to accomplish than an external one, and great care must be exercised to avoid lifting or dragging the corner. The lead in the corner must not be thinner at any point than sheet thickness, and a *slight* increase in thickness is admissible.

LEAD PIPE BENDING

The method to be used in bending a lead pipe depends largely on the pipe's bore and also to some extent on the nature of the bend. Thus, for small bore pipes whose walls are comparatively thick, an easy bend can be made by pulling the pipe round over the knee. The bore of the pipe will not be unduly distorted. In the case, however, of a larger diameter pipe, the pipe walls are thin when compared with the bore and, if bent over the knee, the pipe is " kinked," the bore becomes partially obstructed, and to complete the bend it is necessary to restore the bore to its proper diameter. This is accomplished either by passing bobbins through the pipe or, in the case of large bore pipes, actually " bossing " the kink outwards by working inside the pipe with a " dummy."

Methods of forming lead bends are given below.

BENDS IN PIPES UP TO 1-in. DIAMETER.—The pipes are easily bent by pulling them round the knee or a suitably shaped former, such as the side of a mandrel. For larger radius bends (sharp bends in lead pipe are not normally used in plumbing work) there is only a slight distortion in the shape of the bore and it is not necessary to restore the bore to its original shape. Warming the pipe before bending is advantageous.

BENDS IN PIPES UP TO 3-in. BORE.—The required bend should first be set out in chalk on a board or the top of the bench. Both sides of the bend should be drawn in the setting-out. The pipe should first be straightened and any dents or bulges removed by passing a mandrel through it. (Bulges are reduced by using a sheet lead " flapper," or a dresser, against them.) Bending should be carried out by stages, each of which carries the bend a little further round. The pipe is warmed in the vicinity of the bend. This softens it and the pipe is then pulled to form an initial slight bend. Pulling may be done across the knee or against the side of a mandrel, but not over a sharp edge. On the outside (" heel ") of the bend the pipe wall is stretched and becomes slightly thinner. On the inside (" throat ") of the bend the pipe wall is compressed, thickens and tends to form a slight " kink," whilst the bore becomes oval in shape. Using the bending-stick the " cheeks " (those parts of the pipe wall lying between the throat and heel) are dressed inwards to restore the bore to approximately its original shape. The bending-stick must strike from " throat " to " heel " so as to bring lead from the thickened part of the pipe wall to the thinned part.

To keep a true bore round the bend a bobbin fitting the bore is inserted in the pipe and driven slightly forward, followers are inserted one by one and the whole driven forwards through the bend by tapping the end of a rod or mandrel inserted after the last follower. This mandrel must not be allowed to enter the bend. The bobbin and followers are more easily extracted if they are threaded on stout cord, the end of which must be passed right through the pipe. The pipe is now warmed again and the whole process repeated. Several repetitions should bring the pipe round to its proper bend. The accuracy of the bend should be checked at each stage by laying the work on the setting-out previously chalked on the bench.

Bends in Pipes of 3 to 4-in. Bore.—In these cases a different method is used. The bend is again set out in chalk on the bench and the pipe

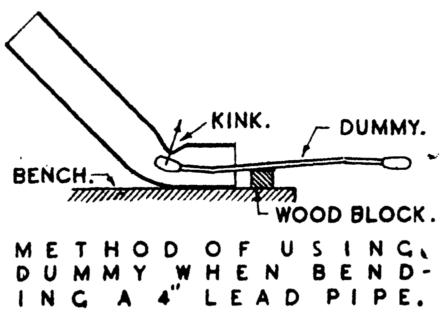


Fig. 55

warmed, and the first partial bend put in the pipe. Because of the larger pipe diameter the " kink " can be dressed out from *inside* the pipe.

The pipe is held with its heel against the bench and a dummy is inserted so that the head of the dummy is up to the " kink " which is beaten out by bumping the head of the dummy upwards against it (see Fig. 55). (The movement of the dummy is best accomplished by allowing the end of the dummy not in the pipe to project over the edge of the bench. If the left hand then holds the bar of the dummy to the bench edge, the disengaged end of the dummy can be moved smartly up and down with the right hand, causing the engaged end to contact the kink.) After the kink has been removed the bending-stick is used from " throat " to " heel " to regain roughly the original shape of bore. The operation is repeated several times until the required bend is achieved. To obtain the true bore a bobbin of suitable diameter is threaded on the cord of a back weight and inserted in the pipe (see Fig. 56). The bobbin is driven slowly forward through the bend by pulling the back weight sharply against the bobbin.

The slight marking on the exterior of the pipe caused by the bending-stick can be reduced by using a lead flapper.

If the bend is close to one end of a pipe a hand dummy can be used in place of the long one.

LEAD PIPE JOINTING

The forms of joints used on lead pipes have been described on p. 68, and the methods used in making some of the various forms of joints are given below.

PLUMBERS' WIPED JOINTS.—Plumbers' solder is used because, as explained on p. 16, it remains "pasty" for a considerable time when heated before it liquefies. Thus if the solder applied to the joint is kept at a suitable temperature it can readily be manipulated and formed into a good joint.

Suitable sizes for wiped joints have been given on p. 69, but are repeated in greater detail below. (It should be understood that these sizes may vary somewhat in different districts.)

PRESSURE PIPES

Pipe Bore.	Length of Wiped Joint.	Approximate Weight of Solder to be Used.
In.	In.	Lb.
1/2	2 3/4	1/2
3/4	2 3/4	3/4
1	2 3/4	1
1 1/4	3	1 1/2
1 1/2	3	1 3/4

NON-PRESSURE PIPES

Pipe Bore.	Length of Wiped Joint.	Approximate Weight of Solder to be Used.
In.	In.	Lb.
1 1/4	3	1 1/4
1 1/2	3	1 1/2
2	3 1/2	2
2 1/2	3 1/2	2 1/4
3	3 1/2	2 1/2
4	3 1/2	3

The maximum thickness of solder in wiped joints should be between one and a half and twice times the thickness of the pipe wall.

For purposes of wiping, joints can be grouped as follows: (*a*) "under-hand" or horizontal joints, (*b*) upright joints and (*c*) branch joints. Generally speaking, the same basic methods are employed in each case.

Certain variations in procedure peculiar to each form of joint are, however, necessary, and these are given in the detailed descriptions which follow.

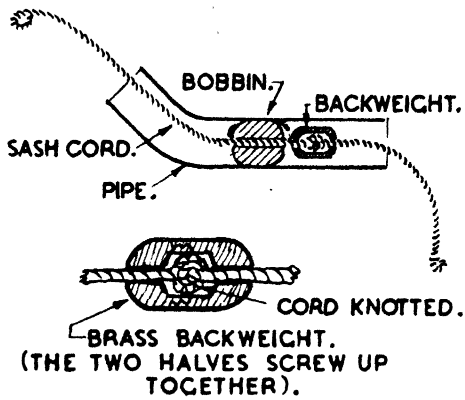


Fig. 56

It should also be noted at this point that there are in existence two distinct methods of applying heat to a wiped joint. The method which is almost universally used nowadays is to apply heat as and when required by using a blowlamp. The other and older way, now falling into disuse in most districts, is to apply heat to the joint by dribbling or splashing molten solder on to the joint where it accumulates and transfers some of its heat to the pipes. Some controversy exists as to which is the better method but, at present, candidates taking the examinations held by the City and Guilds of London Institute are not allowed to use blowlamps. Both processes, therefore, will be described.

Joints are better and more speedily wiped on the bench than *in situ*, and the plumber should try to plan his pipe lines so that he can take advantage of this point, leaving as few joints as possible to be made in their permanent position. He should also see that the joints which he has to make *in situ* are in readily accessible positions.

Whether the joint is to be wiped on the bench or *in situ* it is necessary to make arrangements for firmly holding the two pipes which are to be joined. Care must be taken to allow sufficient room (6-in.) for the wiping cloth to be worked round the pipe. Pipe clamps adjustable to various pipe diameters and angles are available, or the pipes can be tied down to wood blocks or to spikes driven in the bench or wall. Firmness during and for a little while after wiping is essential, as the slightest movement may ruin the joint.

MAKING AN UNDERHAND WIPED JOINT. *Preparation.*—The pipe ends to be joined must be sawn off square and any " burring " removed. Next, one of the pipe ends must be rasped to form a chamfer which acts as a spigot. The other pipe end is opened out to form a socket by driving in a tampin. The spigot and socket when placed together should engage about ¾-in. and be a close fit, particularly at the inner end. The outside edge of the socket in the case of thick-walled pipes is rasped down to almost its original outside diameter. The pipe ends must now be cleaned preparatory to " tinning." One way is to apply tarnish (plumbers' black) with a brush to each pipe end and then when dry mark off the length of joint specified for the pipes being jointed. Marking should be done in chalk. For the socket end half of the specified joint length is allowed, but for the spigot end a half length plus the length of the spigot entry must be used in order to get the true length when the joint is finished. Using the shave hook the pipe ends are now scraped bright and clean. The shave hook should be used firmly, scraping always from chalk mark to pipe end. It is particularly important to clean also the spigot and socket contact areas. Another method is to paste a paper wrapping round the pipes beyond the chalk marks and then scrape from the paper to the pipe ends. The tarnish (or the paper) prevents excess solder from adhering to the pipes beyond the limits of the joint when completed. Properly done, the joint will have a neat finish up to the tarnish (or paper).

Some plumbers consider that scraping from a definite line weakens the joint and therefore shave each pipe end to leave an irregular boundary and afterwards apply tarnish (or paper) as a band to give a regular boundary. If the scraping is not overdone there is no serious weakening of the pipe and therefore any of the methods described are suitable.

As soon as the scraping of the pipe ends is finished they should be coated with tallow, which prevents the newly scraped lead from tarnishing and also acts as a flux.

Wiping the Joint (*Blowlamp Method*).—The pipe ends must first be fitted together, carefully lined up and rigidly secured by tying or clamping, leaving nothing to interfere with the working of the solder. The wiping cloths to be used should next be rubbed with tallow.

The blowlamp, usually held in the left hand, is then applied to the joint and a stick of solder is held in the flame and rubbed over the tallowed surface. When the right " heat " is reached the solder will adhere to the pipe and the tallowed surface should be " tinned," particular attention being given to the actual joint. Here the solder should be given full opportunity to flow into the small space between the spigot end socket. The solder should be built up round the joint until it assumes the rough shape of the joint. A 4-in. cloth should now be held under the joint. The cloth is laid on the right hand, which is cupped slightly to make the cloth into a shallow dish. Further heat is applied until the solder shows signs of slipping, when it is caught on the cloth and the lamp laid aside. The plastic solder is then wiped round the joint as a bandage. Still slightly dished in shape the cloth is then brought under the pipe towards the operator carrying a slight wave of pasty solder before it towards the top of the joint. Here the hand is turned to bring the knuckles upwards and the cloth under the palm and the wave pushed forwards and downwards round the joint, the band being again reversed at the bottom. The operation is repeated until the wave of solder is worked away and the joint assumes its proper shape and finish. The movements must be as smooth and continuous as possible and the shaping must be finished before the solder begins to stiffen. On completion, the joint must be allowed to cool before moving it, for solder, even if hard, has no great strength when hot. Similarly, any attempt to wipe or shape the joint when the solder is stiff will break the joint.

Wiping the Joint (Pot and Ladle Method).—The solder in this case is melted in a pot and brought to a temperature slightly above the melting point of lead. This can be judged roughly by pushing a piece of newspaper into the metal. If the paper ignites the metal is too hot, but if it is only charred black, then the temperature is suitable. A tin tray is placed under the joint and solder is dribbled from a ladle over the joint. At first the solder solidifies and builds up on top of the joint but does not adhere to the lead. As the mass gets hotter the solder becomes pasty and gradually slips round the joint. It is caught in the cloth, pushed back and around the pipe until " tinning " is complete. Then the actual wiping proceeds, as described for the blowlamp method.

MAKING AN UPRIGHT WIPED JOINT.—The preparation of the joint exactly resembles that described for the underhand joint.

Wiping the Joint (Blowlamp Method).—The joint is assembled and fixed rigidly with the socket-ended pipe underneath. It is then heated and tinned. Solder is next built up round the joint. When the correct amount of solder is in position the lamp is laid aside and a 4-in. cloth used to roughly shape the joint. There will be a tendency for the solder to slip to the lower end of the joint, and the cloth must be used in circular climbing motions to bring the bulge over the joint. When the joint is roughly shaped the cloth is cupped in the hand and passed round the joint, reversing the hand as necessary. Additional heat is applied as and when necessary.

Wiping the Joint (Pot and Ladle Method).—A tray to catch the solder must be fitted immediately below the joint. Two pieces of 1¾-in. board with a half-circle equal to the outside diameter of the pipe cut out of each and arranged to clamp round the pipe will suffice. A flat tin dish made from thin sheet iron and cut radially to open out and then clasp the pipe, to which it can be tied, is more readily fixed. (In either case they should have tarnish applied to prevent the solder sticking.) Molten solder is then splashed with a stick from the ladle on to the joint until the joint is encased with solder. Surplus splashings are caught in the tin. As the heat accumulates the solder becomes plastic and tends to slip down the pipe. It should be pressed upwards and round the pipe until the joint is " tinned " and an accumulation roughly the shape of the joint formed. The cloth is then used as described for the blowlamp method to complete the joint.

MAKING A BRANCH JOINT. *Preparation.*—The preparation of this joint requires considerable care. A hole, smaller than the outside bore of the branch, is made in the main pipe. The bolt is then inserted and, using a hammer, the hole is enlarged and worked up into a socket. The end of the branch pipe is now cut (the cut may be at an angle) and rasped into a spigot. This must fit accurately into the socket and on no account project into the main pipe. Next, the spigot is tarnished and scraped clean with the shave hook. The socket is now scraped, together with a surrounding area of the previously tarnished main pipe.

Wiping the Joint (Blowlamp Method).—The joint is assembled and rigidly secured. Particular care must be taken to see that the branch is at its proper angle and setting. The joint is then heated with the lamp and "tinned," especial attention being paid to the junction. Solder is then built up round the joint and when plastic wiped to shape. (It will be found that a smaller cloth (2-in.) is necessary for branch joints.)

Wiping the Joint (Pot and Ladle Method).—The solder is splashed on to the joint using a "splash" stick, and the metal, when plastic, worked round the joint to completely "tin" the joint and wiped into shape.

It will be noticed that, in the above descriptions, stress has been laid on the importance of "tinning" the spigot and socket and also on their accurate fit. The water-tightness of the joint largely depends on this, because if properly done, the solder will flow readily and fully by capillary action into the joint. When at the proper wiping heat solder has a bright gleam. When this changes to a more chalky white colour the solder is too cold.

When using the lamp care should be taken to play it about the joint and to remove the flame clear of the work when the proper temperature is reached.

Skill in joint wiping is only acquired by constant practice.

MAKING A TAFT JOINT.—One pipe end is prepared as a spigot by rasping, whilst the other is opened out as a socket by using a tampin. This socket is wider than that made for wiped joints. The inside of the socket is then scraped and the spigot shaved for a short distance. The spigot is then inserted in the socket and the pipes secured in position. The joint is smeared with tallow and a little powdered resin is then applied to the joint. "Ordinary" or common solder (1 part tin, 1 part lead) is used in the form of a narrow strip. This is melted into the joint with the tip of a blowlamp flame or a heated copper-bit.

LEAD BURNING

This is the process by which lead sheets are joined together by actually fusing or melting the sheets at the point of junction so that they are united when the lead cools and hardens. Properly executed it is a splendid job, for the joint can be made as strong as, or stronger than, the sheets being jointed, whilst the joint consists wholly of the one metal so that deterioration through bimetallic contact is eliminated.

To carry out the process a small, almost minute, but intensely hot flame is required and, nowadays, this is almost always the oxy-acetylene flame obtained by burning acetylene gas in combination with oxygen. (Under workshop conditions coal-gas can be used instead of acetylene.)

The two gases—acetylene and oxygen—are readily obtainable, highly compressed, in steel cylinders, of which particulars are given below, together with details of the allied apparatus.

OXYGEN.—The cylinders are black in colour, and have rounded ends. The pressure in the cylinders may be in the nature of 1,800-lb. per sq. in. Reasonable care should be taken in handling them so as not to expose them to jarring and excess heat. Connections to oxygen cylinders and other apparatus such as regulators, hose and blowpipes have right-handed threads.

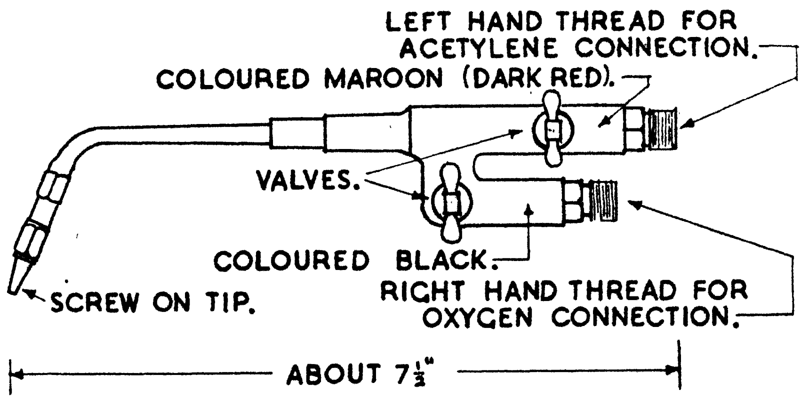
ACETYLENE.—The cylinders are painted maroon (dull red) and the bottom of the cylinder is square so that the cylinder can stand upright. Cylinders are charged to about 250-lb. per sq. in. Connections to acetylene cylinders and apparatus have left-handed threads. Because of technical difficulties of compressing acetylene safely as a gas, the cylinders are filled with a vegetable fibre saturated in acetone. This dissolves the acetylene as it is forced in the cylinder under pressure and gives it up as the pressure is released. Dissolved acetylene is perfectly safe to handle but, as mentioned for oxygen, care to avoid jarring and excess heat must be taken. Acetylene gas is inflammable and will burn furiously at any leak if ignited. It has, however, a distinctive smell and leakage is soon apparent.

For ordinary work, cylinders containing about 100-cub. ft. are the handiest size. Both types of cylinder are fitted with valves operated by loose keys. Valves should not be closed tightly by levering or hammering the key.

REGULATORS.—These screw into the cylinders and have pressure-reducing valves incorporated. It is possible to adjust the reducing valve to give off various pressures per square inch. An outlet with a stop valve, and screwed to take a hose pipe, follows the reducing valve, and regulators can be obtained fitted with gauges which state the amount of gas in the cylinder. Regulators are coloured black for use with oxygen and red for use with acetylene.

HOSE.—This is strong reinforced rubber hose coloured black or red according as to whether oxygen (right-hand thread) or acetylene (left-hand thread) connecting unions are fitted. The left-hand threaded (acetylene) unions are marked with an incision round the nut. The bore is $\frac{3}{16}$-in. or $\frac{3}{8}$-in. to suit the blowpipe being used. For lead burning $\frac{3}{16}$-in. hose will normally be used. Hose should be long so that there is no need to use the blowpipe in the vicinity of the cylinders.

BLOWPIPES.—There are many varieties of these, the types changing according to the type of work to be executed. For lead burning a light blowpipe is made with several different sizes of nozzle (tip) (see Fig. 57). It consists of a tube slightly bent at the flame end for convenience in operating. The flame end is screwed to receive one of a series of "tips." There are generally five or six of these in a series, numbered according to the size of orifice. At the hose end the blowpipe divides into two tubes which are fitted so as to connect to the oxygen and acetylene hoses. Each



OXY-ACETYLENE BLOW PIPE FOR LEAD BURNING.

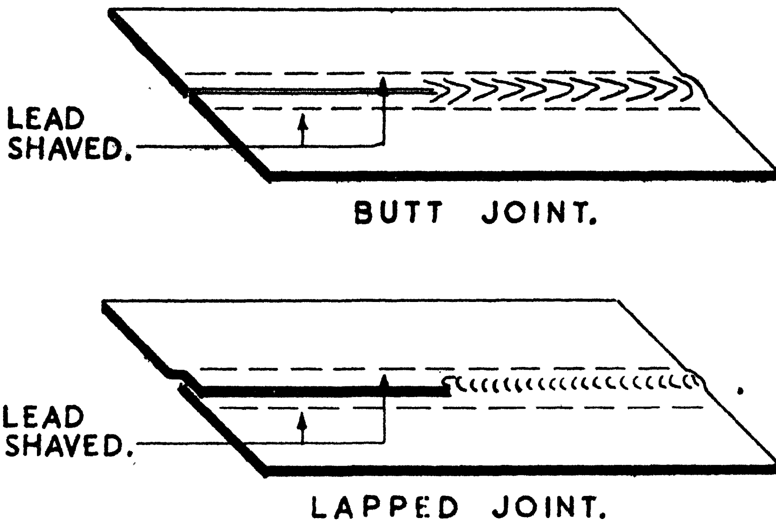
Fig. 57

of these tubes has a screw-down valve so that the mix and, to some extent, the pressures of the two gases can be adjusted.

Assembling the Apparatus.—The cylinders are placed in position. If vertical, they must be secured against overturning. (The oxygen cylinder will not stand unsecured whilst the acetylene cylinder can easily be pulled over.) If laid horizontally, they must be secured against rolling. (Acetylene cylinders are best used vertically or at least inclined.) Before the regulators are screwed into the cylinder tops the cylinder valves should be opened momentarily to blow out any grit from the valve. Regulators should be screwed on tightly but not hammered home. The hose should now be coupled to the regulator and similarly blown through. Next, the blowpipe is coupled up. Care should be taken to screw all connections well home, and not to blow out any acetylene near a naked flame.

Making Lead Burned Joints.—Lead burnt joints are made either as "butt" or "lap" joints (see Fig. 58), and as far as ordinary plumber's work is concerned are made in horizontal or vertical positions. There must be some form of support behind or under the lead being joined. Work should be planned to avoid burning joints in angles as this increases the difficulty of the task. (An extremely skilled lead burner can join sheet lead in almost any position, even overhead and without support, but this degree of skill is not usually required in plumbing work connected with buildings.)

The Flame.—The two gases are turned on at the cylinders after the regulators have been adjusted so as to give about $2\frac{1}{2}$ to 3-lb. pressure for



LEAD BURNED JOINTS ON FLAT SURFACES.

Fig. 58

both gases. The acetylene is then turned on at the blowpipe and ignited. (If the acetylene is difficult to light, or burns away from the tip, the blowpipe valve has been opened too wide and should be screwed down until the acetylene will ignite.) The acetylene flame will be yellow in colour, and should be adjusted to a length of 3 to 4-in. It should not roar, neither should it smoke. Next, the oxygen should be turned on at the blowpipe. The flame will change in character. It will shorten somewhat and the yellow colour will vanish. In its place a bright blue-white luminous cone will appear on the tip and surrounding and projecting past the cone will be a transparent non-luminous blue flame, about 2 to 3-in. long. Close inspection will show that surrounding the blue-white cone is still another, hardly discernible, cone of a greenish tinge. The intermediate cone is important, as the greatest heat of the flame is there attained. The valves should be adjusted to reduce the bright blue-white cone to about $\frac{3}{16}$-in. and the second, or greenish cone, to about $\frac{1}{4}$-in. long. A little practice will be found necessary before the correct adjustment of a flame can be made.

Burning a Flat Horizontal "Butt" Joint (Fig. 58).—The two pieces of sheet lead are shaved for a width of $\frac{3}{8}$-in. along the edges to be joined and are dressed down flat on to a board and secured firmly with the shaved edges abutting closely. The blowpipe is taken in the right hand, being gripped in the same manner as a pen, the forefinger lying along the top of the tube. A strip of lead about $\frac{3}{16}$ to $\frac{1}{4}$-in. square in section is held just above the commencement of the joint. The flame is brought down so that the blue-white cone is about $\frac{1}{4}$-in. from the strip which melts and runs on to the seam, which by a slight lowering of the flame is also fused. Thus the strip adds lead to the two edges which have melted. The flame is immediately lifted and the operation repeated on the next unmelted part of the joint. Thus the work advances in a series of steady down, across and up movements of the flame which must *follow* the lead strip. Care must be taken not to let the flame linger at any point or the lead will be holed. Neither must the luminous cone touch the travelling pool or else a slight "pop" will disperse the pool or the flame go out.

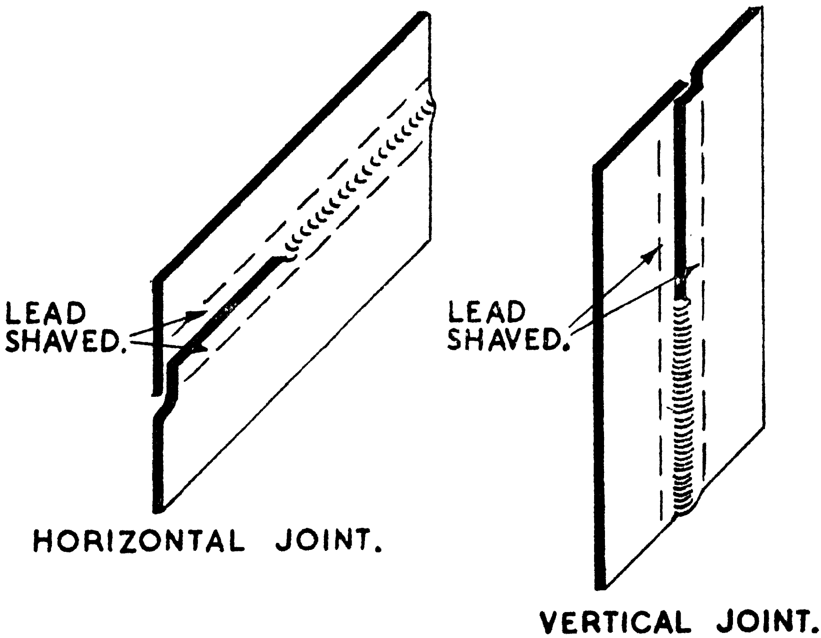
Burning a Flat Horizontal "Lap" Joint (Fig. 58).—The two sheets to be joined will be referred to as the "overcloak" and "undercloak" respectively. Both sides of the "overcloak" are shaved clean for $\frac{3}{8}$-in. and the "undercloak" to give a clean strip 1-in. wide ($\frac{1}{2}$-in. on each side of the centre line of the joint). The sheets are then dressed down to lie flat on a board and secured firmly so that the shaved edge lies tightly along the centre of the shaved strip of the undercloak. This time no lead strip is required as the overcloak will act as the lead feed. The flame is brought down as before until the blue-white cone is about $\frac{1}{4}$-in. from the edge of the "overcloak." This will melt and run into the "undercloak." The flame is immediately lifted and moved along to repeat the operation, bringing a new bead of lead down on to the one already formed. The process is repeated along the joint.

Burning a Horizontal "Lap" Joint (with the Lead Sheets in the Vertical Plane—Fig. 59).—Preparation is as before and the same method employed for burning. The operation is more difficult as the bead of lead from the "overcloak," if too large, can run down the sheet. It is necessary, therefore, to keep the flame on the small side and only bring down small beads.

Burning a Vertical "Lap" Joint (Fig. 59).—The preparation and operation are as described above. The flame must work up the joint (from bottom to top).

The burning of joints to sheets which lie in the vertical plane is much more difficult than for those which lie flat, and the student practises the operation, starting with joints slightly inclined above the horizontal plane and gradually increasing the angle until he is working on the vertical plane.

It is not possible to use " butt " joints for work where the sheets lie in the vertical plane without using special aids.



LEAD BURNED JOINTS ON VERTICAL SURFACES.

Fig. 59

Burning Joints in Lead Pipes.—For end-to-end joints, one pipe end must be enlarged into a socket to take the other pipe end. The spigot must be well shaved and enter the socket for $\frac{1}{2}$ to $\frac{3}{4}$-in. Burning is as before described, a filling strip being used to fill up the socket.

For pressure pipes the joint must be built up until it resembles, in shape, a wiped joint.

CHAPTER SIX

DRAWING EQUIPMENT AND DRAWING

Necessary equipment. Hints on drawing. Some methods of representation. The scale—dimensions. Lettering. Sketching.

IT is vital that the young plumber should be conversant with drawings and drawing methods. Drawings are the common means by which instructions are given and taken, and a craftsman can never hope for a position of some responsibility unless he can interpret drawings and, if need be, make them.

Every plumbing student should devote time to scale drawing and free-hand sketching, and should equip himself so that he can carry out this side of his work.

The following are the minimum requirements: drawing board, T-square, two set squares, protractor, compasses with pencil point, pencil, rubber, drawing paper, four drawing pins and a notebook or pad.

DRAWING BOARD.—The size most convenient for beginners is 23-in. by 16-in. This will take a half-imperial sheet of paper. A suitable type of board is made from plywood and is between $\frac{3}{8}$-in. and $\frac{1}{2}$-in. in thickness.

T-SQUARE.—This consists of a hard wood blade screwed at right angles to a short head. The blade (for half-imperial work) will be 24-in. long. There are many qualities of T-square available, but the cheaper forms, made from beechwood, are quite satisfactory.

SET SQUARES.—Two are required, *i.e.*, a " 45° " and a " 60°." The sides adjacent to the right angle of the 45° set square should measure about 6-in. and the longest vertical side in the 60° set square should be about 8-in. long. Square-edged celluloid set squares of the " open pattern " (with central triangular spaces) are best.

SCALE.—The Armstrong scale, of oval cross-section, should be used. It has eight scales, *i.e.*, $\frac{1}{8}$-in., $\frac{1}{4}$-in., $\frac{1}{2}$-in. and 1-in. to 1-ft. on one side and $\frac{3}{8}$-in., $\frac{3}{4}$-in., $1\frac{1}{2}$-in. and 3-in. to 1-ft. on the reverse. It can be obtained either 6 or 12-in. in length in boxwood, ivory, boxwood with white celluloid edges or in black ebonite with white divisions. The boxwood and ebonite types are cheaper, and are quite satisfactory.

PROTRACTOR.—A semicircular celluloid type, about 4 or 5-in. diameter, is suitable.

COMPASSES.—These should be selected with care, for very cheap compasses develop defects and lead to poor draughtsmanship. The student should consider the purchase of a small set of instruments for, whilst a pair of compasses is all that is needed at first, deeper interest in drawing will cause a wish to have additional instruments.

There are many sets of instruments marketed in neat cases suitable for students' use. The compasses should be about 5-in. length, and convertible for pencil or ink use, and also, in the simpler types, into dividers.

PENCIL.—A good quality " H." or " H.B." pencil should be used.

RUBBER.—This must be soft and free from grit to avoid damaging the surface of the drawing paper. For erasing ink, a special eraser can be purchased.

DRAWING PAPER, ETC.—Good paper with a reasonably smooth surface is essential. The size is 22-in. by 15-in. and is known as " half-imperial." Drawing pins and a *sharp* penknife are also essential requirements.

NOTEBOOKS OR PADS.—One or the other of these is needed for sketching and should be about 12-in. by 9-in. They should not be ruled if used for sketching. Where a notebook is also used for notes, a book containing alternate lined and plain sheets should be selected.

HINTS ON DRAUGHTSMANSHIP.—It is not always possible to discern any difference between the two sides of a sheet of drawing paper, but with some of the " cartridge " (cartridge paper, obtainable in many qualities, is a cheaper machine-made paper as distinct from the more expensive hand-made drawing papers) in use, a close inspection will show that one side appears to have marks resembling closely a fine wire mesh. This is the back of the sheet and should be laid contacting the drawing board. To fix a sheet of paper preparatory to drawing, a drawing pin is inserted in the top left-hand corner of the sheet and board. The sheet is " squared " by using the T-square to check that the top edge of the sheet is parallel to that of the board. The sheet is next made taut by passing the hand diagonally over the sheet and pinning the right-hand corner. The paper is then similarly stretched towards and pinned down to the two remaining corners.

All horizontal lines are drawn aided by the T-square. The head should be pressed against the left edge of the board by the left hand, and the T-square is slid up or down until the blade is in the desired position, and this pressure is maintained until the line is drawn. The pencil point should be held in contact with the *bottom* of the ruling edge of the blade as the line is drawn from left to right. As the T-square is moved from one position to another it is wise to lift it slightly from the sheet so as to avoid smudging lines already drawn.

Vertical lines should be drawn with the assistance of a set square. The T-square is placed in a suitable position against the left edge of the board, as described before. The position is maintained as the left hand traverses and presses on the blade to a position where it can hold the set square planted with its base against the upper edge of the T-square blade and its vertical side in the required position. Both T-square and set square are held by the left hand, whilst the vertical line is drawn with the pencil contacting the bottom of the vertical edge. Set squares are also used for drawing lines at 30°, 45°, 60°, etc.

The scale should never be used as a ruler, as its edge will become damaged by the action of the pencil—or pen—against it.

Each line should be of uniform thickness. Students should practise drawing lines of varying thicknesses against the edges of squares until they can with certainty produce lines of the desired strength.

It cannot be too strongly emphasized *that the quality of draughtsmanship is largely dependent upon the condition of the pencil, and blunt pencils are a common cause of drawings which are inaccurate and of unsatisfactory appearance.* Hence the pencil should be sharpened to a long (at least ¾-in. with ¼-in. lead exposure) and tapering point and it *must be maintained in this condition by the frequent application of a sharp knife.*

Before commencing drawing the squares and scale should be wiped clean to prevent the sheet soiling.

The pencil should be applied *lightly* to the paper as the beginner is apt to smudge the sheet by rubbing his squares over the lines as he draws. Also corrections with the eraser are more readily made. After the drawing has been completed the sheet should be cleaned down with an eraser, leaving the pencil lines just visible. The drawing is then "lined in." *Before this is attempted the pencil should be sharpened and the squares cleaned.* "Lining in" should commence at the top of the paper, working from left to right and gradually to the bottom. Any printed matter is left until the "lining in" has been completed. Some notes on lettering are given on p. 141.

METHODS OF REPRESENTATION.—A student attending a complete course of instruction will be taught in his geometry class several methods of representing on paper various geometrical solids (such as cubes, prisms, pyramids, etc.), and consideration will be given to the practical application of solid geometry to building problems. It is therefore only proposed to make brief reference here to these methods of representation. These are: (1) Orthographic Projection. (2) Isometric Projection. (3) Oblique Projection.

(1) *Orthographic Projection* (see Fig. 60).—This is the form of representation which is chiefly used. It is adopted for working drawings comprising plans, elevations and sections of buildings and their parts.

A *Plan* (see Fig. 60) is the view presented when looking vertically down on an object. Drawn to scale the plan will show the true shape of the object and the correct relationship of the various parts, but it does not show heights. Thus the plan of a room will show its shape, the position of the fireplace, windows, doors, and any other desired details, such as the run and length of horizontal pipes. It will not show the length of vertical pipes but will show their diameters as sections (see below).

An *Elevation* (see Fig. 60) is the view obtained when looking in a

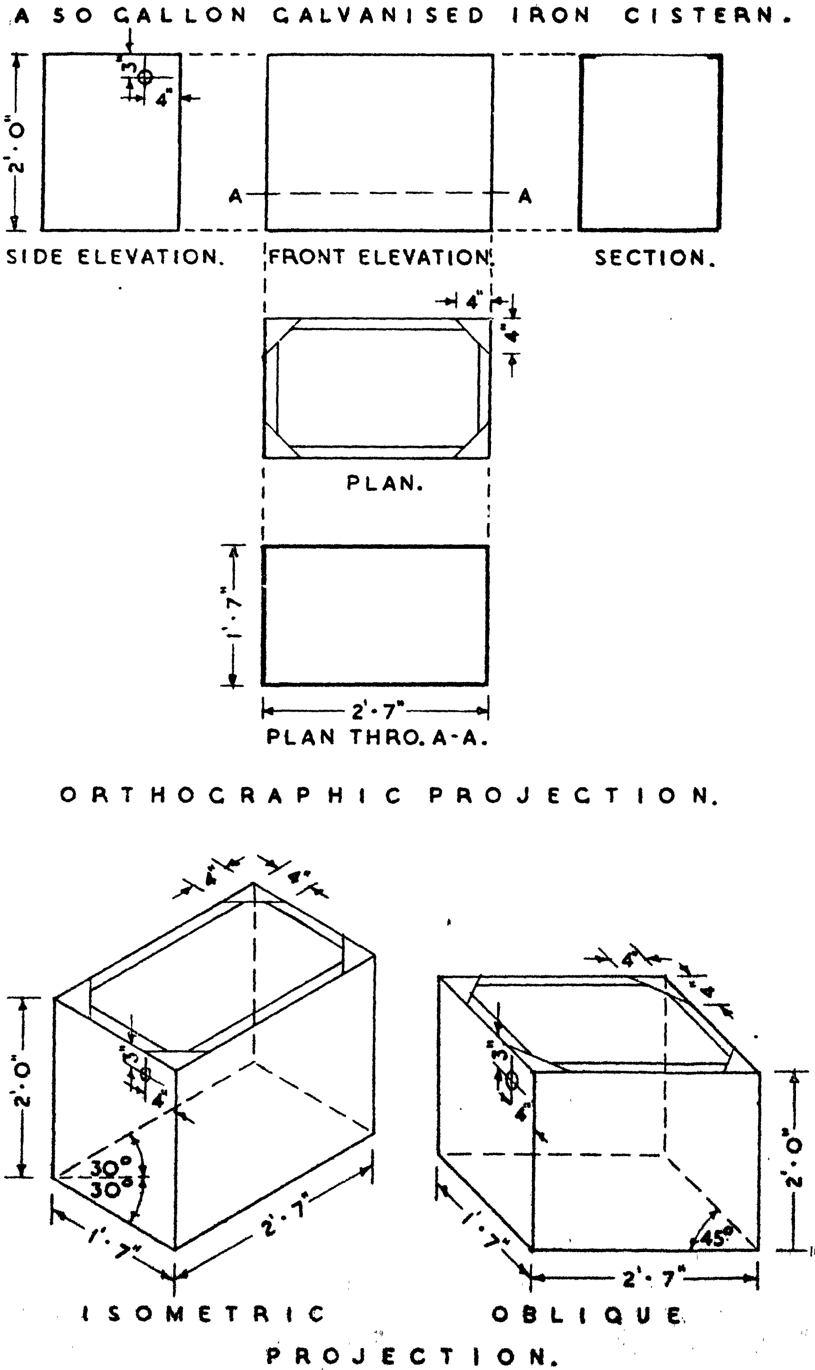

A 50 GALLON GALVANISED IRON CISTERN.
3"
4"
2'·0"
A
A
SIDE ELEVATION.
FRONT ELEVATION.
SECTION.
4"
4"
PLAN.
1'·7"
2'·7"
PLAN THRO. A-A.
ORTHOGRAPHIC PROJECTION.
4"
4"
2'·0"
3"
4"
30°
30°
1'·7"
2'·7"
4"
4"
3"
4"
2'·0"
45°
1'·7"
2'·7"
ISOMETRIC
OBLIQUE
PROJECTION.

Fig. 60

horizontal direction towards an object. Vertical and horizontal dimensions are true to length, but depths do not show.

A *Section* (see Fig. 60) is the true shape of an object presented after it has been cut through (or assumed to have been divided) on a plane and the portion between the observer and the plane removed. The planes usually used are the vertical and horizontal. If the cutting is vertical, then a vertical section results. Such a section shows heights and lengths correctly and would show true lengths and runs of pipes running vertically, but would show the sections and circumferences of pipes coming towards the observer. Horizontal sections are produced by horizontal cuts. Plans showing the inner arrangements of objects are really horizontal sections to which the general term " plan " has been given. It is a common practice to put lines on plans and elevations indicating where the sections have been taken. See pp. 85 and 92 for examples of sections.

(2) *Isometric Projection.*—In orthographic projection three separate drawings are used to show the plan and two elevations of an object. When isometric projection is employed these three views can be embodied in a single drawing. In an isometric drawing the length and width of a rectangular object are drawn to scale along lines set at 30° from the horizontal, whilst the height is measured and drawn by a vertical line. Other lines drawn parallel to the foregoing complete the drawing. Thus two adjacent faces and the top of the object can be shown on one drawing (see Fig. 60).

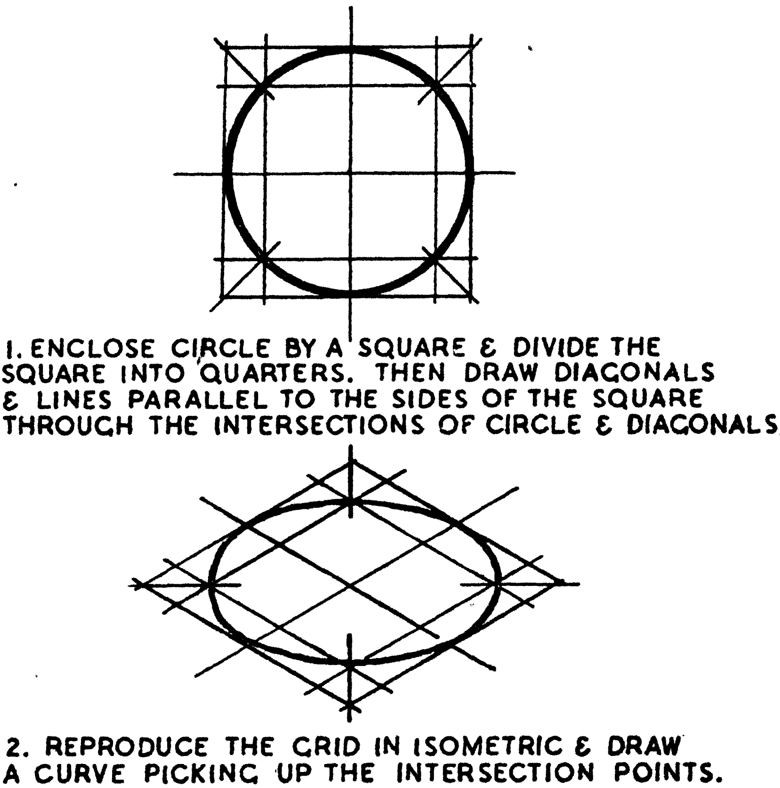
It should be noted that an isometric drawing is only true to scale along its vertical lines and those inclined at 30°. All other lines, such as diagonals, are distorted, and angles measure 120° or 60° instead of the true 90°. This method of representation is, nevertheless, most useful and is often employed in either drawing to scale or in sketching. In Fig. 61 the method used for drawing a circle in isometric is shown. Figs. 7 and 18 are examples of isometric drawing to scale.

(3) *Oblique Projection* (see Fig. 60).—In this case one of the vertical faces is drawn true to scale and shape at right angles to the line of sight (*i.e.*, as an elevation). The adjacent vertical face is drawn obliquely, usually with the 45° set square, although any angle may be used. The top of the object is drawn as a parallelogram. In plumbing drawing it is often convenient to draw a true section to scale and then to project the adjacent sides obliquely. This has been done in Figs. 17 and 35.

Application of the Scale.—When a drawing is made the same size as the object which it represents it is said to be " drawn to full size."

Most plumbing details, however, have to be drawn to reduced dimensions as their large size makes it impracticable to do otherwise. For instance, if a bath were drawn full size an enormous sheet of paper would be required and the actual process would be laborious in the extreme.

The extent of the reduction depends upon the size of the object to be drawn, the purpose of the drawing and the size of paper used. In drawings where it is desired to show considerable detail, scales of 1-in. to 1-ft. or larger are commonly used. (The term 1-in. to 1-ft. is sometimes abbreviated to "1-in. scale.") By this is meant that every foot of actual length is shown in the drawing by 1-in. Hence a pipe 8-ft. 10-in. long would be represented on a drawing by a length of $8\frac{10}{12}$-in. If the Armstrong scale is used, as recommended on p. 135, it will be found that one of the scales (marked 1-in.) is divided into twelve 1-in. units and the right handed 1-in.



DRAWING A CIRCLE IN ISOMETRIC.

Fig. 61

is divided into twelfths and each of the latter into either halves or quarters. By using this scale, therefore, it is possible to represent an actual measurement of, say, 8-ft. $7\frac{1}{2}$-in. by scaling of a length of 8-in. and $7\frac{1}{2}$ twelfths of 1-in.

It will be seen from the foregoing that a scale drawing is proportionate to the actual object. This ratio of reduction is called the ***representative fraction***, and the scale is often referred to by such a fraction. Thus, the representative fraction of the $1\frac{1}{2}$-in. scale $\frac{1\frac{1}{2}\text{-in.}}{12\text{-in.}} = \frac{1}{8}$. The following are, therefore, the eight scales with their representative fractions which appear on an Armstrong scale :—

$\frac{1}{8}$-in. to 1-ft., or 8-ft. to 1-in., or $\frac{1}{96}$.
$\frac{1}{4}$-in. to 1-ft., or 4-ft. to 1-in., or $\frac{1}{48}$.
$\frac{1}{2}$-in. to 1-ft., or 2-ft. to 1-in., or $\frac{1}{24}$.
1-in. to 1-ft., or 1-ft. to 1-in., or $\frac{1}{12}$.
1$\frac{1}{2}$-in. to 1-ft., or $\frac{1}{8}$.
3-in. to 1-ft., or $\frac{1}{4}$.
$\frac{3}{8}$-in. to 1-ft., or $\frac{1}{32}$ } Less frequently used.
$\frac{3}{4}$-in. to 1-ft., or $\frac{1}{16}$ }

Drawings should have their scales clearly indicated on them, either by (*a*) a printed statement, such as " Scale, 1-in. to 1-ft.," or (*b*) by drawing a portion of the scale on the sheet in a convenient position, generally at the bottom.

DIMENSIONS.—Drawings should be fully and clearly dimensioned. This is most important, as serious delay and expense can be caused in actual practice if dimensions are missing and have to be assumed. Every care must be taken to see that indicated dimensions are the correct ones. Special care must be taken when printing the figures 3 and 5. Dimension lines should be lightly drawn and terminate against short thin lines which are continuous with the ends of the portion of the drawing concerned. Small arrow-heads or dots should indicate the points between which the dimension runs.

PRINTING OR LETTERING.—A drawing is not complete without a printed title or heading, sub-titles and any necessary notes. Good lettering improves a drawing and, conversely, the appearance of a sheet is spoilt by bad lettering. The first essential of lettering is obviously that it be legible. Elaborate printing is now rarely called for and it is the practice in many drawing offices to spend as little time as possible on lettering.

A recommended plain type of lettering which, after a little practice, is easy to do is shown in Fig. 62. The student should study this carefully. Each letter is shown within a square in order that the proportions may be better appreciated and to help comparison. He should note those letters which occupy half squares, three-quarter squares and whole squares so as to be able to give the proper proportions to the lettering which he does. Figures are also shown. If sloping lettering is used the angle of inclination from the vertical should be 10°. Most beginners find this form of lettering more difficult than the upright version.

The size of lettering used depends upon various factors, such as the size of the sheet and the purpose of the lettering, but for a half-imperial sheet it will be found that the $\frac{3}{8}$-in. letters will be suitable for the main title, $\frac{1}{8}$ to $\frac{1}{4}$-in. for sub-titles and $\frac{1}{8}$ to $\frac{1}{4}$-in. for notes and specification.

Letters and figures, no matter how small, should be between *very faint* bottom and top guide lines, if untidy and uneven lettering is to be avoided.

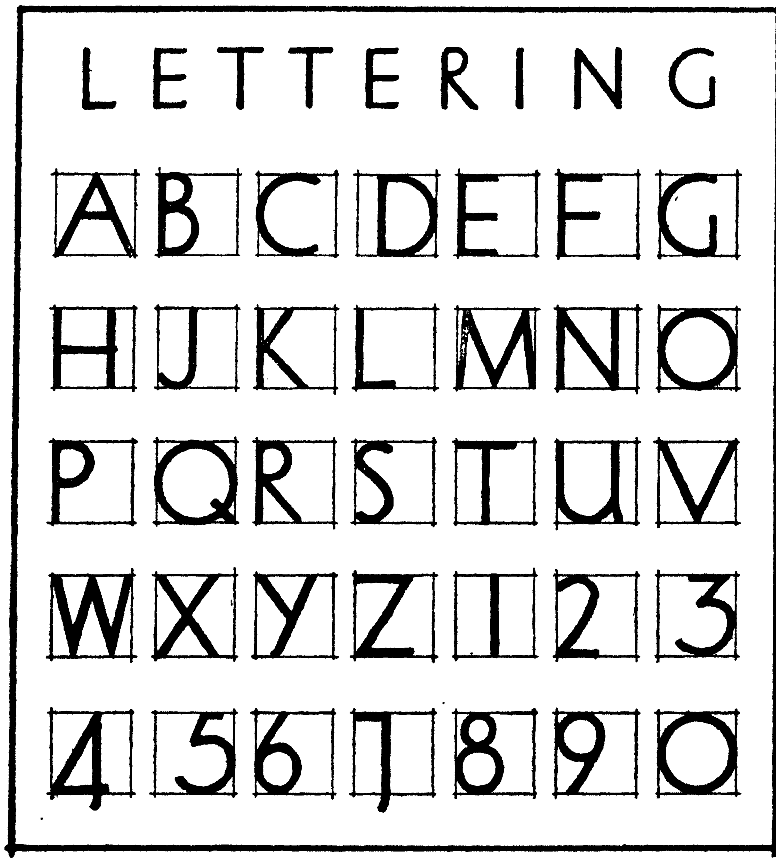


Fig. 62

GOOD LETTERING DEPENDS LARGELY UPON CORRECT SPACING.—Letters in a word should not be placed the same distance apart, although the spaces between them should *appear* equal. No mechanical rule can be given owing to the varying shape and sequence of the letters, but special care should be taken when spacing adjacent letters such as A and V, A and W, L and T, R and I, P and A, O and W, W and Y, etc. These combinations can be made to fit into each other somewhat to preserve the appearance of equal spacing (see Fig. 63).

A simple method of setting out lettering, where space allows, is to draw faint vertical lines across the guide lines. These act as centre lines for the letters which are firmly pencilled in freehand over them. The vertical lines should be about one and a half times the height of the lettering apart. The distance between words should be twice that between letters (see Fig. 63).

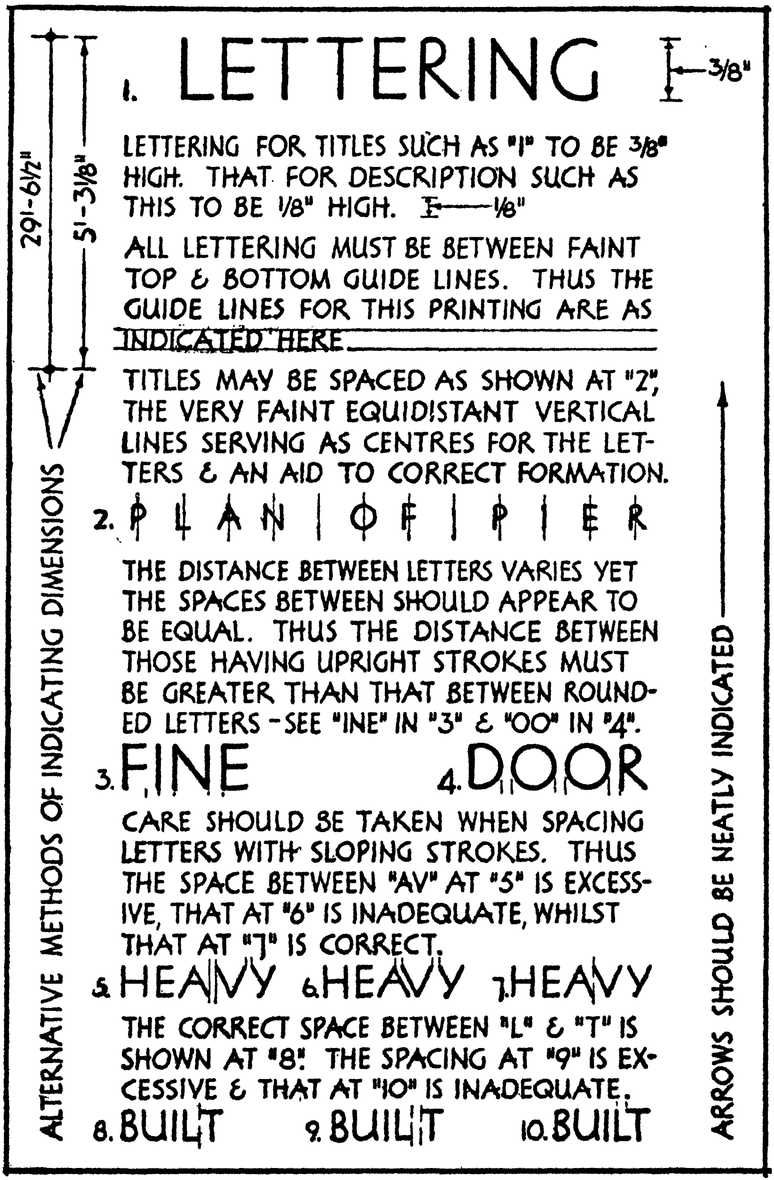


Fig. 63

Arrows.—These should be neatly drawn (preferably aided by the T-square or set square) and finished with *small* heads.

Border.—This completes a sheet of drawing and should preferably be a single heavy line drawn to leave about a ½-in. wide margin. Finicking or fancy corners should be avoided.

Summary.—In general, each sheet of drawings produced should :—

1. Consist of neat and accurate details drawn lightly at first and subsequently lined in, and arranged with the elevation over and projected from the plan.

2. Be carefully set out to ensure a reasonable balance, *i.e.*, details should be suitably spaced to ensure a uniform covering of the sheet and the avoidance of local overcrowding and large blank spaces.

3. Have the scale or scales clearly indicated.

4. Be numbered, dated and signed. Usually the number is placed in the top right-hand corner and the student's name, with the date underneath, printed in the bottom right-hand corner.

Sketching.—Many of the fittings used by plumbers are curved in shape, and the curves are not part of a circle and cannot therefore be drawn by compasses. It is highly essential for a plumber to be able to sketch well so that he may draw accurately the many fittings which he will handle.

Sketches are made with the pencil but, occasionally, they may be in ink for permanence. For the former a well-conditioned " H.B." pencil of good quality is best. The paper used, if in a notebook or pad, should be plain with a smooth surface. It is recommended from the outset that no mechanical aid, such as scale, ruler, set square, lined or squared paper should be employed, as such assistance, if continued, results in an imperfectly trained eye, hand and sense of proportion. This does not prohibit the student from drawing *freehand* some major limiting lines of the object he is sketching to give him his proportions.

Sketches should be neat, well proportioned and workmanlike. They should be of a reasonably large size ; puny sketches are strongly condemned. Each freehand line should be drawn freely from end to end with a single stroke ; many students cultivate the bad habit of sketching each line with a series of short strokes. The beginner should practise simple exercises, such as sketching horizontal and vertical lines of varying thickness which are afterwards checked with the scale and squares ; bisecting and dividing lines into a given number of parts ; lines inclined at 30°, 45°, and 60° ; curved lines. Assiduously practising these and similar exercises will gradually increase his confidence and technique.

When sketching the student should observe with close concentration each detail and thoroughly understand it before commencing to sketch ; this will help the memory. Merely copying lines serves little useful purpose. It is a common fault with students, when sketching from the blackboard, to make frequent reference to the board—at least one or two glances per line sketched ; a preliminary careful study will obviate this. Dimensions and lettering must be clear. Some examples of the stages of sketching are given in Fig. 64.

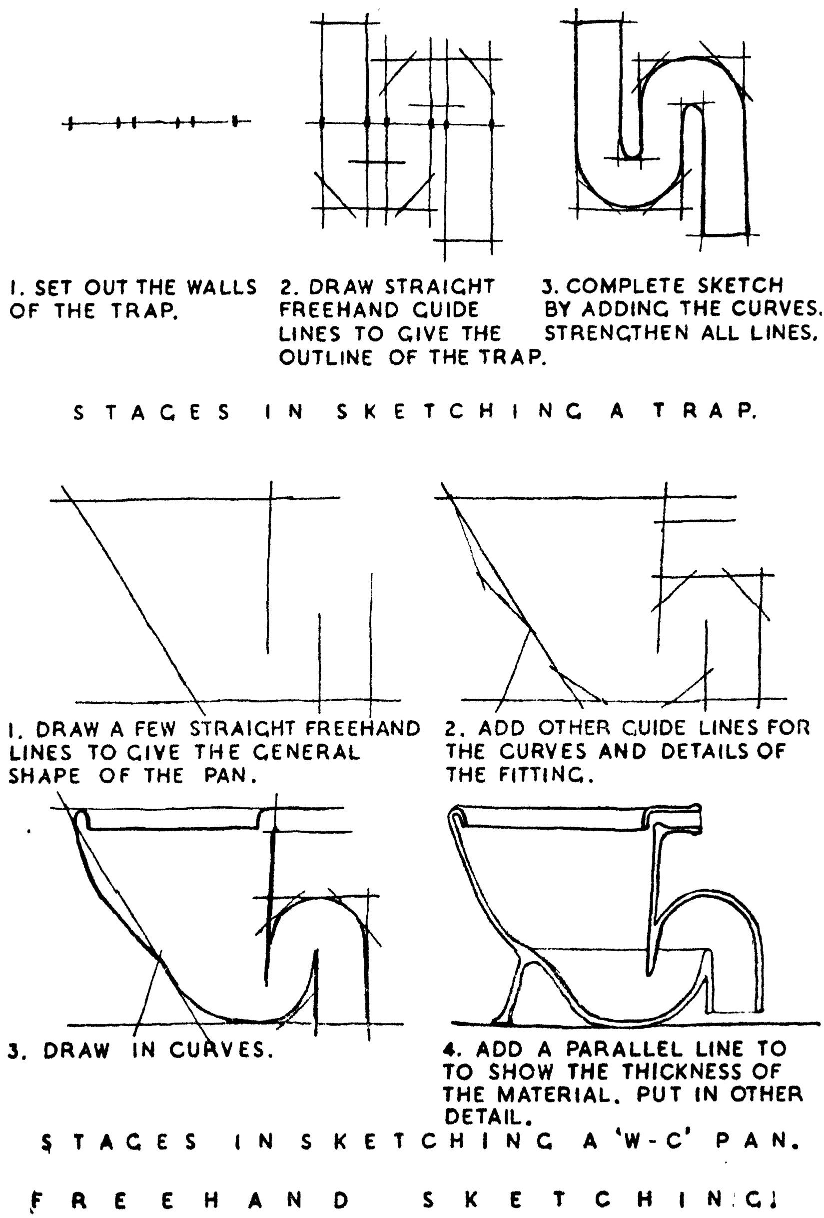

1. SET OUT THE WALLS OF THE TRAP.
2. DRAW STRAIGHT FREEHAND GUIDE LINES TO GIVE THE OUTLINE OF THE TRAP.
3. COMPLETE SKETCH BY ADDING THE CURVES. STRENGTHEN ALL LINES.
STAGES IN SKETCHING A TRAP.
1. DRAW A FEW STRAIGHT FREEHAND LINES TO GIVE THE GENERAL SHAPE OF THE PAN.
2. ADD OTHER GUIDE LINES FOR THE CURVES AND DETAILS OF THE FITTING.
3. DRAW IN CURVES.
4. ADD A PARALLEL LINE TO TO SHOW THE THICKNESS OF THE MATERIAL. PUT IN OTHER DETAIL.
STAGES IN SKETCHING A 'W-C' PAN.
FREEHAND SKETCHING

Fig. 64

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