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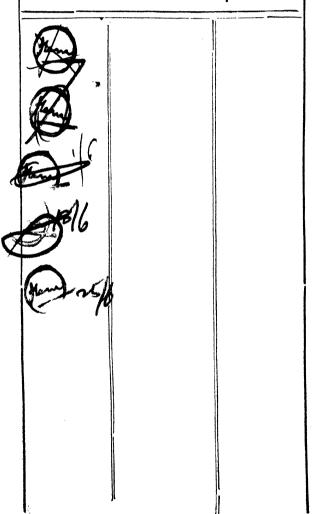
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# **PLUMBING**

# FOR SECONDARY TECHNICAL SCHOOLS OF BUILDING

#### SECONDARY TECHNICAL SERIES

Prepared under the Editorship of E. G. WARLAND, M.I.Struct.E.

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# PLUMBING

#### **FOR**

# SECONDARY TECHNICAL SCHOOLS OF BUILDING

# By

#### H. PENNINGTON

L.I.O.B., R.P., A.M.I.P., M.R.San.I.

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#### GENERAL EDITOR'S NOTE

THE books in this series have been compiled to meet the demand for class books suitable for pre-apprentice students attending Secondary Technical Schools of Building.

Every effort has been made to explain and illustrate the fundamental principles of building practice, while the ancillary subjects, such as Mathematics, Science and Mechanics, are presented in a clear and concise manner with a definite bias to the requirements of building technique. The order of treatment of the various subjects follows the recognised syllabuses, therefore teachers using these books will be assisted in keeping their teaching within the scope of Junior Technical School requirements.

The author of each volume in this series is a well-known teacher of building whose experience has enabled him to present facts and data in such a form that the young student may readily assimilate the information.

Every care has been taken to make the subject matter interesting and sound in principle.

E. G. W.

#### PREFACE

This book is compiled and written to meet the requirements of Secondary Technical Schools.

Its object and function is to give clear concise details of the elementary materials, fittings, science applications, workshop instruction and exercises in the above category.

Every effort has been made to make the illustrations easy to follow and accurate in detail.

The majority of the drawing required to illustrate plumbing work is done freehand and the illustrations on the whole are well within the capabilities of the junior student.

The subject matter is framed to reveal the generally unknown facts and inside knowledge of plumbing work without excessive elaboration.

Drawing instruction and more detailed science matter as applied to plumbing have been omitted, these having been adequately dealt with in other volumes in this series.

This book will be found to cover a two-year course of instruction in Secondary Technical Schools, where Plumbing is included as one of the major building trade subjects.

The author wishes to express his thanks to Mr. E. G. Warland, M.I.Struct.E., for permission to include illustrations from *Building Construction for National Certificate*, Vol. I, and also to the following for permission to include illustrations of their products:

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H. P.

1950.

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#### INTRODUCTION

Plumbing as one of the trades in the building industry covers a very wide range of work.

This range of work includes the use of various materials, of which a good general knowledge is necessary. A high degree of skill is also required to utilise these materials for plumbing work.

To the average student plumbing as a trade usually has little appeal, due to a lack of knowledge of the scope of the work involved.

To give a brief summary of the scope of plumbing work, the following are involved:

- 1. Roof covering.
- 2. Ensuring a roof is watertight.
- 3. Collection of rainwater and discharge to ground level.
- 4. Laying of drains where cast iron pipes are required.
- 5. Supply of water.
- 6. Distribution of internal water supply.
- 7. Installation and distribution of domestic hot water supplies.
- 8. Collection and discharge of waste water and soil.
- 9. Installation of all sanitary fittings.
- 10. Installation of central heating apparatus.
- 11. Installation of gas supplies, fittings and heaters.
- 12. Brazing and welding.
- 13. Chemical plumbing in chemical works installations.
- 14. Installation of lead X-ray protection.

Plumbing work generally is inconspicuous if carried out efficiently, and the workmanship is of a high standard. On the other hand, plumbing work is incorporated as an architectural feature in design of buildings, in the form of rainwater heads, discharge pipes and roof coverings. It is in this form that the plumber is able to display his skill and craft to the full extent.

The situation of sanitary fittings, etc., in a building is determined by the designing architect, according to the general design and layout. When it comes to the position of distribu-

tion and pipe systems, it is generally left to the discretion of the plumber, and this fact also applies to the detailed finishing of roofwork coverings.

Hence the necessity for the plumber to possess a full knowledge of his craft, and the application of his scientific knowledge in its execution.

Modern methods of construction in building work have not materially affected plumbing work in principle. Sanitary fittings and appliances are in greater demand, and it is only in regard to the materials used that any changes have taken place. Whether pipe systems are concealed or exposed, does not alter the fact that a communication pipe is necessary to supply water to fittings or appliances. With regard to external plumbing work, there is always the desire for a choice of design, and the plumber is always able to apply his craft to conform with the design submitted by an architect.

#### CHAPTER I

#### METALS AND THEIR USES

#### Lead.

LEAD can be traced back to very historic times, as far back as the Egyptians of the Bible. Lead is usually found together with other metals in varying quantities.

Properties. The chemical symbol for lead is Pb, from the Latin Plumbum, hence the name "Plumber," meaning "leadworker." Lead when freshly cut has a bright metallic lustre, but it tarnishes very quickly when left exposed to the air. It is soft, heavy, and bluish-grey in colour, very malleable and easily cut.

Lead responds quickly to heat, it expands rapidly and contracts on cooling, but it does not always contract to its original size or condition.

Constant movement by expansion and contraction causes distortion and fracture, and allowances have to be made for this in lead roofwork and lead pipe installations.

Manufacture. Lead is found in the form of an ore, chiefly mineral galena, which is a compound of lead and sulphur, roughly 87 per cent. lead, and 13 per cent. sulphur. The mineral is found in many different parts of the world, and the principal sources of supply at the present time are U.S.A., Spain, Germany, Mexico, Australia, Canada and Burma. English mines at one time produced a large quantity of the lead ore.

Smelting is done by several processes, according to the type of ore to be dealt with. The chief method adopted is that of the Reverberatory Furnace. In the smelting of lead ore, the other metals which are found are antimony, tin, copper, gold and silver in small quantities. Some of these are removed by oxidisation when the lead is heated, and eventually removed with the dross or scum.

The metals still remaining are gold and silver, and these are removed by other means.

Reverberatory Furnace. The reverberatory furnace is long and narrow in structure, and the bottom, or hearth, slopes

down to the centre from each end of the furnace to the tap hole, as shown in Fig. 1. The top of the furnace is arch-shaped, and falls gradually towards the flue outlet.

The principle of a furnace of this type is that the flames and direct heat do not impinge direct on to the metal ore to be reduced. The heat required is deflected down from the arch roof of the furnace. This arrangement obtains the maximum effect of separating the metal from the waste matter.

Following the mining of lead ore, it is crushed and washed to remove the earthy matter, after which it is dried, and put in through the hopper at the top of the furnace. Previous to this the hearth is prepared to receive the crushed ore. When the furnace has been charged with ore the heat is increased in stages, and the ore is gradually reduced. The ore is turned over, and kept moving to increase the rate of reduction. As a quantity of the molten lead accumulates in the hearth, the slag is run off at a higher tap hole. Following this the molten lead is run off at the lower tap hole.

If lead is found to be rich in silver, this metal has to be removed, and is carried out by other processes. Two of these processes are known as the Cupellation, and Pattinson processes.

Lead is produced, after being refined, in the form of pigs, which usually weigh from 80 to 120 lb.

Uses. Lead is used for the manufacture of sheet lead, lead pipe, red lead and white lead, solders and alloys.

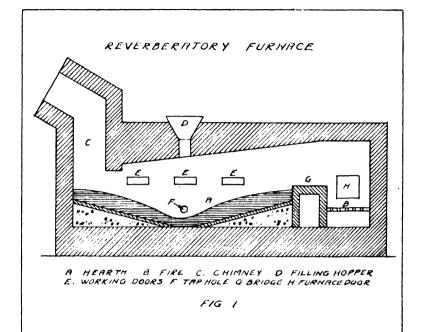
Sheet lead is manufactured in two forms, namely, milled or rolled sheet lead, and cast sheet lead. Most of the sheet lead used today is milled.

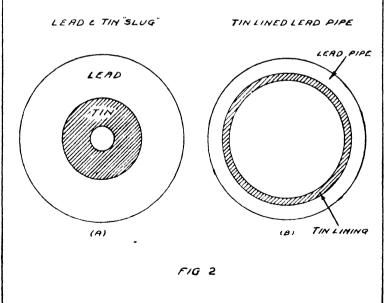
#### Sheet Lead.

The process of milling is carried out by first melting down pigs of lead and casting it into a slab about 5 in. thick. The slab is then rolled between big heavy rollers to a reduced thickness of 1 in., and the size of the slab is proportionately increased.

This slab is then cut into suitable size pieces, each of which is rolled backwards and forwards until the required weight and thickness is obtained.

Sheet lead is known by its weight in pounds per square foot, e.g. three-pound lead—four-pound lead, etc.





The usual commercial size of rolls of sheet lead is from 15 to 40 ft. in length, and from 7 to 9 ft. in width.

Cast sheet lead is produced by running molten lead over a prepared bed of sand on a casting bench. The sizes of the benches vary, and this determines the size of the sheets produced.

Cast sheet lead and milled sheet lead have different characteristics, and the cast lead is considered to be the superior. In cast lead the molecules of the lead are in their natural position and undistorted, with the result that the metal is soft and very pliable. With milled sheet lead the molecules are distorted, squeezed together and pushed out of place, with the result that the metal is harder and less pliable. Milled lead has also greater tensile strength compared with cast lead.

Lead is very suitable for casting purposes, and lends itself to the casting of ornamental features or roof coverings in architectural design.

### Lead Pipe.

Nowadays lead pipe is manufactured by means of extrusion presses using hydraulic power. These presses vary in construction and design, and the press shown in Fig. 3 is a type which has a combined die and core, the core being supported by a bridge piece. This method of supporting the core may be considered unsatisfactory, as the lead contained in the cylinder has to be at exactly the correct temperature before being extruded in the form of pipe. If the lead is too cool the bridge piece forms a permanent seam in the structure of the pipe, on being extruded from the press.

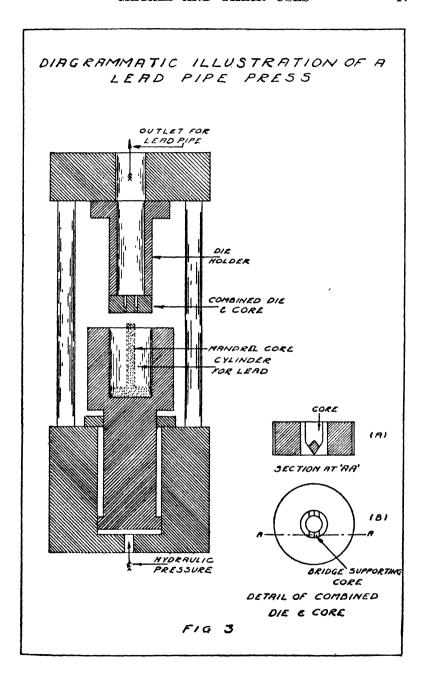
The use of this type of die and core is confined to the manufacture of small pipes up to  $\frac{3}{4}$  in. internal diameter.

For the manufacture of larger sizes of pipe the mandrel core is used as shown in Fig. 3. With a steel mandrel of 1 in. diameter and upwards, no distortion is likely to occur due to the heat.

The mandrel forms the internal diameter of the pipe, and the plain steel ring die forms the external diameter of the pipe.

In some types of press the fire to heat the lead is part of the press, and a fresh remelt of lead has to be completed before a further length of lead pipe can be produced.

The alternative method is to have the press separate from,



but adjoining a lead furnace, from which fresh charges of molten lead may be obtained. This means that the production of lead pipe can be made a continuous process.

In the press shown in Fig. 3 the molten lead is run into the cylinder until it is level with the top, and then allowed to cool down. The die holder has the die and combined core fitted, the core determining the internal diameter of the pipe and the die the external diameter, also the thickness of the walls of the finished pipe (see Fig. 3 (a) and (b)).

A modern and now generally adopted addition to the die fixture is a specially made plug which screws into the die. On the end of this plug is a wheel, with indented numerals and letters, which produces at regular intervals, along the entire length of the pipe in relief, numerals indicating the size and weight of the pipe, together with the code letters of the manufacturer.

When the lead is at the correct temperature, which is indicated by a pyrometer, the hydraulic power is operated, and the cylinder rises with the lead pipe issuing from the outlet at the top. The pipe is directed to coil formers, and coiled into standard lengths. Pipes of 2 in. diameter or more are not coiled, but kept in straight lengths, usually 12 ft. long for ordinary commercial use.

Composition Pipe. Pipe for gas supplies is made from a composition of lead and antimony, which gives the pipe rigidity to compensate for the thinness of the wall of the pipe. This composition pipe is sometimes required to be tin washed on the outside, to make good any faults likely in this form of pipe. This is done by pouring a small quantity of molten tin into the outlet of the press, just as extrusion has started. The heat of the pipe on extrusion keeps the tin molten, and the pipe has a brilliant tin coating as it issues from the press. This condition makes it necessary to coil the pipe on to a large wooden drum, spaced apart, to avoid the coils sticking together while it cools. After cooling the pipe is coiled into correct lengths.

Lead pipes up to about 2 in. diameter are known by their weight in pounds per yard length. In the larger diameters of lead pipe, the thickness of the walls of the pipe is measured and given in terms of pounds per square foot.

Tin-Protected Pipe. Special types of lead pipe are some-

times required, such as tin-washed or tin-lined lead pipe. The tin-washed pipe is produced in a similar manner to the composition gas pipe, except that the tin is poured down the inside of the pipe. Tin washing of lead pipe, as it is called, is unsatisfactory, as the hot tin takes up some lead in solution as it passes through the hot lead pipe. The result is that by the time the end of a long length of pipe is reached, the tin wash becomes a solder wash.

A guaranteed protection for lead pipe is a tin lining, or lead-encased tin pipe. This pipe is produced by casting "slugs" of lead and tin in the cylinder of the press, as shown in Fig. 2 (a). The two metals are then extruded together, producing a completely lead-encased tin pipe as shown in Fig. 2 (b).

War conditions and world shortages of raw materials, namely lead, has caused manufacturers to seek other combinations of metals to reduce the lead content. One innovation is a pipe composed of a combination of silver, copper and lead.

As may be expected, this pipe is harder and more rigid, and water authorities generally make concessions, and allow thinner walls for pipes for corresponding pressures to which the pipes may be subject.

#### Red Lead.

Red lead is the red oxide of lead. Commercial red lead is a red or scarlet crystalline powder, and is lead which has been reduced to an oxide of lead, and ground to a fine powder. Red lead is used as a pigment in paint manufacture, and serves as a valuable protection for iron and steelwork, and a reliable jointing material for pipe joints and ironwork.

#### White Lead.

White lead is a carbonate of lead, and is manufactured in a number of ways. The oldest known process is the Dutch process. In this perforated cast lead plates or slabs are placed over the tops of earthenware pots. The pots contain a small quantity of acetic acid, as well as a small roll of lead. Numbers of these pots are arranged in layers, and successions of these layers form stacks. Between each layer and under the pots is a layer of decaying vegetable matter, and heat generated by the decay heats the acid in the pots. Thus vaporisation

of the acid takes place, which in turn acts on the lead and forms a white flaky substance. The white substance is collected at the end of the process, and refined, and then mixed with oil to make it safe for use in industry.

Uses. As a pigment for paint manufacture; jointing compound for pipe installations.

# Copper.

The chemical symbol for copper is Cu, which is derived from the historical fact that the Romans obtained their main supply from Cyprus.

Properties. Copper is reddish brown in colour, and when it is clean has a bright lustre. It is tough, soft and capable of being drawn into fine wire and hammered into sheets. Continual manipulation of copper makes it brittle, but by heating it to a red heat and cooling in water it becomes annealed. Copper is a good conductor of heat and electricity.

Manufacture. Copper ore is known as Cuprite or Copper Pyrites, which is found in various parts of the world. The ore is reduced by one of two processes, dependent on the sulphur content of the ore. Non-sulphur ore, such as Cuprite, is smelted in a furnace similar to that used for iron and tin. Sulphur ore, such as Pyrites, is reduced by a long process commencing with the reverberatory furnace.

Uses. Copper is used for roofwork in sheet form, boilers and cylinders for hot water installations, tubing for water distribution and waste water disposal and the making of alloys. Copper tubing is now generally produced solid drawn, without a seam along its entire length. This process is carried out by piercing a solid billet of copper, and rolling to a workable thickness. Afterwards, the tube is cold drawn on a draw bench until the required diameter and thickness of tubing is obtained.

#### Cast Iron.

Properties. It is produced by purification of pig iron. It contains a percentage of carbon which makes it brittle. The strength of cast iron varies, as it is weak in tension and strong in compression. The degree of fluidity in its molten state enables fine castings to be made. Cast iron does not corrode rapidly on exposure to the atmosphere.

Uses. It is used for the manufacture of water main, soil and rainwater pipes, roof gutters, heating boilers, baths, cisterns and other sanitary fittings.

# Wrought Iron.

This is the first type of iron used by man in early history. *Properties*. Is very tough, and when heated it can be hammered into any shape. It is easily welded but cannot be cast, and is the purest form of iron. Wrought iron rapidly corrodes when exposed to the atmosphere.

Manufacture. Wrought iron is produced by purifying cast iron, and this is carried out in a puddling furnace.

Uses. Wrought iron is used for the manufacture of tubing for gas, water and steam supplies, tanks and containers, and heating apparatus.

#### Zinc.

The chemical symbol for Zinc is Zn.

Properties. Zinc is bluish-white in appearance and normally brittle. At high temperatures it can be drawn into wire or rolled into sheets. Zinc is easily melted and unaffected by dry or moist air, but is readily destroyed when exposed to an acid-laden atmosphere, such as may be found in smoky towns.

Manufacture. Zinc ore is known as Calamine or Zinc Blende, and it is reduced firstly by being heated until it is reduced to a powdered zinc oxide. The zinc oxide is then mixed with coal, roasted in retorts and the zinc which escapes in the form of fumes is condensed and collected. The zinc collected is then melted and cast into ingots, and then known as spelter.

Uses. Zinc is used for roofwork in sheet form, roof gutters, rainwater pipes, galvanising to protect iron and steel, making of alloys.

#### Zinc Oxide.

This is a white powder usually known as Zinc White. It is obtained during the process of reducing zinc ore, and it is used as a pigment as an alternative to white lead in the manufacture of paint. Zinc White is non-poisonous, but is not as effective a protective as white lead.

#### Tin.

The chemical symbol for tin is Sn.

Properties. Tin is a white metal with a very bright lustre which is not readily tarnished. It is hard, but can be drawn into wire or beaten into sheets. Tin is affected by strong acids, but unaffected by atmospheric conditions. It is harder than lead, and softer than zinc. Tin can be distinguished by a crackling noise emitted when it is bent backwards and forwards, caused by the friction of the crystals of tin.

Manufacture. Tin ore is known as Tinstone, and is reduced by first crushing and then washing the ore. The ore is then heated in a reverberatory furnace to remove the combustible substance. Re-heating of the metal in the reverberatory furnace is carried out to purify the metal for final use.

Uses. Tin is used as a protective coating to metal receptacles of all kinds, protection of lead pipes, making of alloys, e.g. solder.

#### Aluminium.

Aluminium is a pale bluish metal and is obtained from the mineral bauxite.

Properties. It is very light in weight and its strength varies according to the process by which it has been produced.

Aluminium is harder than lead, and can be rolled into sheets and extruded, or cast into any shape.

Manufacture. The mineral bauxite is refined by a series of chemical and high-voltage electrical operations.

Aluminium is usually used as an alloy to increase its strength and is supplied in two forms: the casting alloys and the wrought alloys.

The casting alloy is used for castings and the wrought alloy for rolling, forging or extrusion, where the maximum strength is required.

Uses. Aluminium is a new metal in the group of plumbing metals, and its use has been fostered by the industrial conditions prevailing, and the shortage of the standard materials. It is at present in use for the manufacture of rainwater pipes, gutters and rainwater heads.

#### CHAPTER II

#### ALLOYS

#### Definition.

An alloy is a mixture of two or more metals. All metals do not "mix" together to form an alloy, but on the other hand certain metals will "mix" readily in all proportions.

A precise definition of an alloy is a true mixture of two or more metals, which results in a metal that has different properties and characteristics from the constituents of the alloy.

The melting-point of an alloy is invariably different, and usually lower than any of its constituents.

#### Common Types of Alloys

#### Solders.

A solder, to be effective, must alloy or mix with the surfaces of the metals to be joined, and this is assisted by the use of fluxes.

It is also essential that a solder must have a lower meltingpoint than the metals to be joined together, and thus a lead-tin solder melts at a lower temperature than lead or tin.

Soft Solders are composed chiefly of lead and tin; and the proportions of these vary according to the type of work to be carried out. The three main solders used by plumbers are blowpipe solder, fine solder and plumbing solder.

The blowpipe solder contains a high percentage of tin, which enables the solder to flow when heat is applied to it in the process of making a joint.

Fine solder is used for copper bit and tinsmiths' work, where the tin content is reduced, and the solder is heated and applied by means of a soldering iron.

Plumbing solder contains a high percentage of lead, and the correct proportions of lead to tin produce a solder which, when used in a molten condition, in the process of making a joint on a lead pipe, remains in a plastic condition over a maximum period of time. This period of plasticity enables

the plumber to shape and make a joint before the solder solidifies completely.

Present-day commercially produced plumbing solder contains a small percentage of antimony, which substitutes some of the tin and thus reduces the cost of production.

C	MMO.	N Sc	AT TARY	DС

Name.		Constituents.		Melting-point.	Uses.
Blowpipe solder . Fine solder		1 1	2 1	340° F. 370° F.	Blowpipe joints Tinsmiths' and
Plumbing solder.	•	2	1	441° F.	plumbers' copper bit work Plumbers' wiped joints

Hard Solders are solders which melt at high temperatures, and are used for joining iron, brass and copper, and thus are proportionately stronger than soft solders. Hard solders contain varying percentages of copper, zinc and solder, and some types are known as "silver solder" or spelter.

#### Pewter.

Pewter is an alloy containing 3 to 4 parts tin to 1 part lead, and has a blue-grey colour. It polishes well, and is often used for domestic utensils and hotel fittings.

#### Brass.

Brasses are alloys of copper and zinc and are readily distinguished by their yellow appearance. The quality of brass is determined by the percentage of copper it contains, and this varies according to the purpose for which it is required.

BRASSES

Name.	 	Zinc.	Copper.	Uses.
Common brass English brass		1	1 2	Common brass fittings High-grade fittings. Taps and
Muntz metal	•	1	3	sanitary fittings For ship work fittings, etc., as it is unaffected by sea-water

ALLOYS 25

#### Gunmetal or Bronze.

Bronzes are a combination mainly of copper and tin. The commonest form of bronze used in plumbing work is gunmetal, which contains 8 to 9 parts copper to 1 part tin. Gunmetal is the strongest alloy of copper and tin, and is used for water and steam fittings, valves, and accessories of ironmongery used in the building industry. Gunmetal is also used as a substitute for yellow brass, in cases where fittings made of brass would be destroyed by the water. Acidulated waters, or water of a similar nature, would affect the zinc in brasswork, and thus destroy the alloy.

#### White Metal.

White metal is an alloy which contains varying quantities of copper, tin, zinc, lead, nickel and antimony according to the individual manufacturer. White metal is used for water fittings and sanitary fittings, and the object of its use is to facilitate the process of nickel or chromium plating. When the plating begins to wear off, the white metal shows a better appearance than if the fitting was made of brass or gunmetal.

#### CHAPTER III

#### FLUXES

ALL metals when cleaned and exposed to the atmosphere oxidise, and there forms an oxide coating on the surface. This oxidisation varies with different metals, and is accelerated when heat is applied to the metal.

In the process of soft or hard soldering, where the metals to be joined together have to be cleaned, this oxidisation has to be prevented, and this is done by the use of fluxes.

Fluxes also serve the purpose of assisting the solder to alloy, or "mix" with the surface of the metals being joined together. Some fluxes can be applied in their natural condition, such as tallow, soldering paste or fluid, to the surfaces to be joined. Other fluxes have to be applied by the use of heat, which calls for correct manipulation of the solder and flux, and application of the heat to ensure that the flux covers the cleaned surfaces before they oxidise.

Lead burning is the only instance where a flux is not required in joining metals together.

Tallow is the chief flux used by a plumber, and it is used for joining lead to lead, or any types of copper or brass fittings. The tallow can be obtained either loose or in the form of tallow candles or "dips." In connection with gas fittings and the making of blowpipe joints the tallow candle is invaluable, as it provides the flux, illumination when used in a dark place and the heat to make the joint when used with a mouth blowpipe.

Resin is the best flux for joining brass and copper or lead when used with blowpipe or fine solder, as it assists the flow of the solder when heated. Resin is obtained in lump form, and requires to be crushed and powdered to enable it to be used. Soldering pastes are used as a substitute for resin and are easily applied, and in some cases are stronger than resin in assisting the alloying action when soldering.

Killed Spirits is the term given to Zinc Chloride, or Spirits of Salts which has been "killed" by the introduction of small

pieces of zinc into it. This flux is corrosive in action and is very effective for soldering zinc, copper, iron and brass.

Borax or Sal-Ammoniac are used for all forms of hard soldering such as joining steel and iron and are quite distinct from the fluxes used for welding.

Fluxes.	Uses.
Tallow	For joining lead to lead and copper or brass fittings with plumbing solder Ditto, but with blowpipe or fine solder
Killed spirits	For soldering zine, copper, brass and iron
	For hard soldering copper, brass, iron and steel

#### CHAPTER IV

#### TOOLS

#### Wood Tools.

ONE important branch of plumbing work is the working of sheet copper, lead and zinc for covering roof surfaces or protection of surfaces in numerous examples in industry.

To work these metals wooden tools are used which will not damage the metal or destroy its efficiency. The type of wood used is usually boxwood, lignum vitæ, beech or holly.

Wood tools are also used in the process of lead pipe bending.

The sizes and weights of wood tools are determined by the weight in the case of lead, or strength in the case of copper or zinc which is to be worked with. Wood tools which are to be used for outdoor work should be well soaked in raw linseed oil to prevent the wood absorbing water if exposed to rain or wet conditions.

Wood tools which are to be used for sheet lead work should have all sharp edges rounded off to prevent puncturing of the metal by improper use of the tools.

Flat Dresser is used for beating flat surfaces, and the cross-section is such as to enable angles to be set in with the setting-in edge of the dresser with the use of a mallet (see Fig. 4).

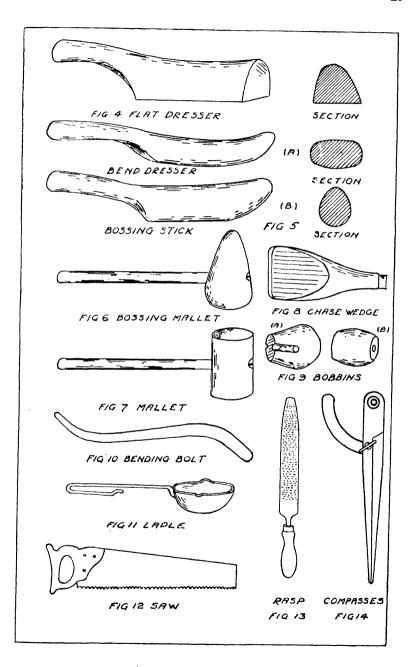
Spoon or Bend Dresser—Round Dresser or Bossing Stick. Both are used for bossing and working sheet lead breaks and corners and also for working bends in lead pipe (see Fig. 5 (a) and (b)).

Bossing Mallet is used in conjunction with bossing dressers for working breaks and corners. The shaft is usually made of malacca cane (see Fig. 6).

Mallet is used for impelling or hitting wood dressers or timber pieces used for setting up sheet metal (see Fig. 7).

Chase Wedge is used for setting in sharp angles on completion of a sheet metal work job (see Fig. 8).

Bobbin is used for lead pipe bending and is of different types as shown in Fig. 9 (a) and (b).



# Lead Pipe Jointing Tools.

Bending Bolt consists of a steel rod of varying sizes, with one end tapered and both ends bent slightly 3 to 4 in. from each end. It is used for opening out holes for pipe branches and working sharp bends on the ends of pipes (see Fig. 10).

Blowlamp. The two main types are benzoline and paraffin. The benzoline type burns petrol and the flame is derived from superheated vaporised petrol drawn up to the vaporising chamber by a wick inside the chamber. This type of blow-lamp is small and compact, and suitable for indoor work free from wind and draughts which are likely to put the flame out (see Fig. 16).

The paraffin type burns paraffin and the flame is derived from superheated vaporised paraffin which is subjected to pressure and is projected from a fine jet. The pressure is obtained by means of a pump, and maintained by a small non-return valve. Higher temperatures can be obtained with a paraffin blowlamp, and it is safer for all-round uses and can be used indoors or outdoors without fear of the flame being extinguished.

An essential accessory required for use with a paraffin blowlamp is a pricker to keep the jet clear from carbonisation or impurities obtained from the paraffin (see Fig. 15).

Compasses are the equivalent of dividers and are used for marking sheet lead and scribing joint lines in conjunction with a scribing gauge (see Fig. 14).

Ladle is a hemispherical hollow steel scoop fixed to a handle and made in varying sizes. The handle is usually long, and should be bent as shown in Fig. 11 to enable a good grip to be made of the ladle and ensure full control when it is full of molten metal. The two pouring lips on the scoop make it usable for left- or right-hand manipulation.

Lampblack or Tarnish is a black substance which can be made by mixing glue or size and vegetable black, or obtained ready made under a proprietary name in the form of a powder or solid block in a tin. It is used for blacking or "soiling" lead pipe or a fitting, in the preparation of a joint to be soldered, and it is applied in a moist state with a small brush.

Metal Pot is a cast pot shaped like a ladle but on a larger scale and in varying sizes. A swivel handle is fitted and

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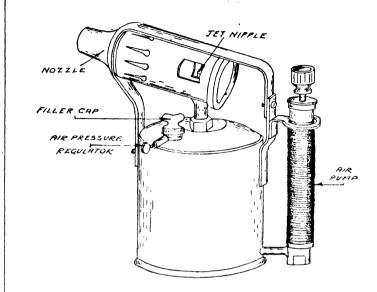


FIG 15 PARAFFIN BLOWLAMP

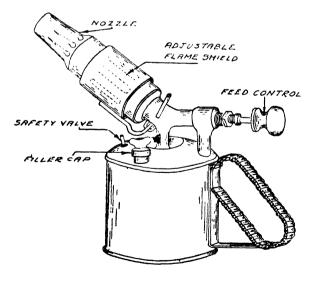


FIG 16 BENZOLINE BLOWLAMP

feet are cast on to enable it to stand on a flat surface (see Fig. 17).

Rasp is the equivalent of a steel file but possessing large projecting individual teeth which vary in coarseness as required. It is used for shaping the ends of lead pipe and reducing sharp edges on lead work (see Fig. 13).

Saw is usually about 12 to 15 in. long and equal to a coarse cross-cut wood saw. It is used for cutting lead pipes (see Fig. 12).

Shavehook is a heart-shaped steel blade fixed to a steel shaft; the shaft being tapered at the opposite end and square in section. The tapered shank passes through the centre of the wood handle, a washer fitted and the end riveted over. This is done to prevent the handle being pulled off the shank, as this action of pulling is constant when the shavehook is in use. It is used for shaving or cleaning lead for any type of jointing, the thoroughness of which depends on the edge of the blade being kept sharp (see Fig. 18).

Scribing Gauge is a brass plate of a specified shape as shown in Fig. 19, and has holes drilled at regular intervals down its centre in which to put the point of compasses.

It is used for marking the joint lines in setting out branch joints.

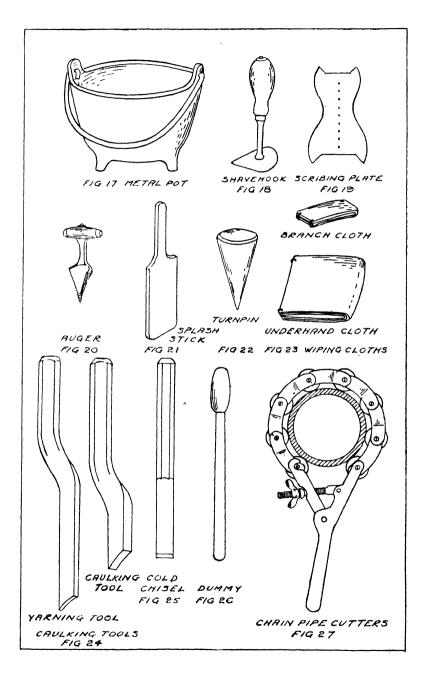
Shell Gimlet or Auger is an outsize gimlet with a rapidly increasing width hollow blade, the edges of which are sharpened to a cutting edge (see Fig. 20). It is used for boring holes in lead pipes in the preparation of branch joints.

Splash Stick is usually made of a piece of scrap wood or sheet iron fitted with a wooden handle. It is used to splash solder out of a ladle on to a joint when making a joint with a metal pot (see Fig. 21).

Turnpin or Tanpin is made of boxwood and shaped like a long tapering cone. It is used for opening the socket end of a lead pipe in preparation for making a joint (see Fig. 22).

Wiping Cloth is a thick cloth pad composed of several layers of moleskin, sometimes known as fustian. A wiping cloth can be home made to any size or thickness according to the work it is required for. In the making of the cloth the main cords or "grain" of the material should be arranged parallel to the sides of the cloth (see Fig. 23).

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#### Miscellaneous Tools.

Caulking and Yarning Tools are steel chisels shaped as shown in Fig. 24, and vary in size and thickness according to the size of the job. They are used for caulking or packing yarn and lead into a joint on a cast iron pipe.

Chain Pipe Cutters are composed of links each containing a wheel cutter, and these links can be added or removed according to the size of the pipe to be cut. These cutters are used for cutting cast iron pipes, as an evenly distributed pressure is exerted on the pipe and a clean cut is obtained very speedily (see Fig. 27).

Cold Chisel is used for cutting building fabric to make way for pipes or any other purpose, and any rough cutting of hard metals (see Fig. 25).

Dummy is a shaft of malacca cane or steel with a lead or solder bulb fixed on the end. It is used for lead pipe bending, and enables the walls of large-size lead pipes to be bossed out when indented in the process of bending.

Straight dummies are made of malacca cane and possess the spring suitable for this work. Steel shaft dummies are bent a short distance from the end and can be manipulated round the curve of a bend. The bulb end is best made of solder either cast or wiped on, as it is harder than lead and maintains a smooth finish (see Fig. 26).

Gas Pliers are similar to the standard type of square nose pliers, but with the jaws designed as shown in Fig. 28. These toothed jaws enable an efficient grip to be made of small unions and pipes in small installation work. Usually one leg of the pliers has a screwdriver end and the other pointed.

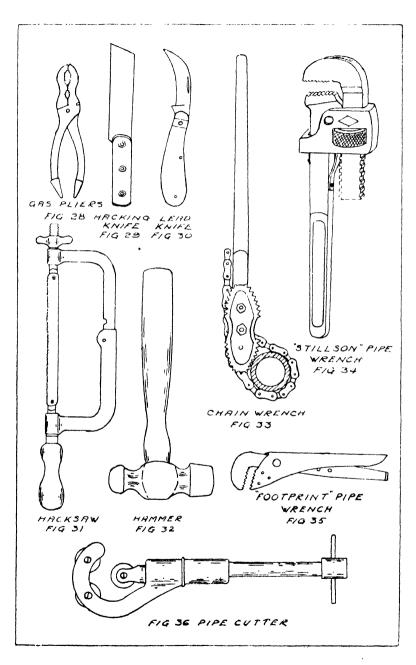
Hacking Knife is a strong thick blade with a leather handle riveted to it. It is used for cutting lead or hacking out frames. The thick blade enables it to be used with a hammer without damage to it (see Fig. 29).

Hacksaw is used for cutting cast iron, steel, copper and all metals and materials used in plumbing work. The frame is adjustable to various sizes of blades (see Fig. 31).

Hammer is usually of the engineers' type as shown in Fig. 32 and of about  $1\frac{1}{2}$  to  $1\frac{3}{4}$  lb. weight. It is used with cutting and drilling chisels, and is also used for pulling bobbins through a lead pipe in the process of bending.

Lead Knife is a specially shaped knife as shown in Fig. 30.

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This shape of the blade enables a pointed end to be maintained, which facilitates the cutting of sheet lead.

Pipe Wrench. There are three main types of pipe wrench:

- (a) Chain wrench; (b) Footprint; (c) Stillson pipe wrench.
- (a) Chain Wrench is made of steel and designed as shown in Fig. 33. It has reversible jaws, and when the teeth get worn they can be changed. The chain enables the wrench to be adapted to all sizes of pipe, and the grip on the pipe is very efficient and reliable without the danger of crushing the pipe when used on wrought iron screwed pipe.
- (b) Footprint. The jaws of the wrench are adjustable and very adaptable to nuts and unions, and for screwing wrought iron pipes together (see Fig. 35).
- (c) Stillson Pipe Wrench. The jaws are adjustable to any size of pipe according to the size of the wrench. The grip is very reliable and a maximum leverage is obtainable with ease (see Fig. 34).

Pipe Vice is used for holding a pipe firmly while it is being cut or threaded. The body of the vice is pivoted on one side so that it can be thrown over clear of the pipe and replaced and speedily secured by a swing eatch (see Fig. 37).

Pipe Cutters are adjustable by means of the movement of one wheel cutter to any size of pipe. They are used for cutting wrought iron pipe (see Fig. 36).

Soldering Iron is sometimes known as a copper bit and is made in two shapes, the straight bit (a) and the hatchet bit (b), as shown in Fig. 39.

The end or bit is made of copper which varies in size depending on the size of the work to be done, as the larger the copper bit, the longer the heat will be retained.

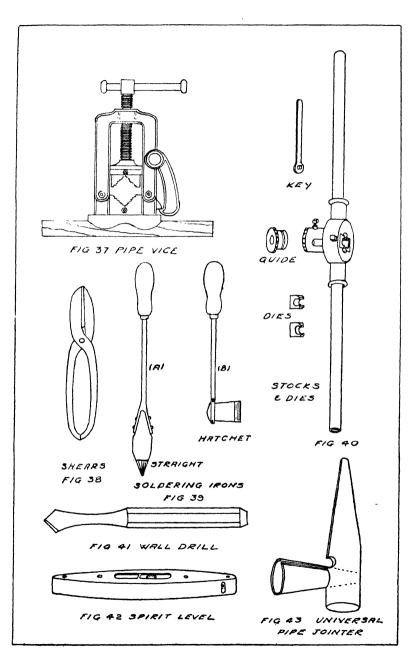
The copper bit is used for soldering with tinsmiths' or fine solder.

Shears are used for cutting sheet metal, and sometimes have the blades curved to facilitate the cutting of internal curves on hard sheet metal (see Fig. 38).

Stocks and Dies as shown in Fig. 40 are not self-adjusting but have the dies separately adjusted by hand. The dies are interchangeable according to the size of the pipe to be threaded. The guide is interchangeable also, and this ensures that the thread cut is in correct alignment with the pipe.

Spirit Level is used for setting brackets and sanitary fittings

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level, and to ensure the efficient working of apparatus and a workmanlike appearance on completion (see Fig. 42).

Wall Drill is a steel drill with a diamond point. It is used for drilling building fabric prior to fixing cast iron rainwater or soil pipes or appliances to solid floors. Some wall drills are made from steel bar fluted along its entire length. This fluting enables the waste fabric to clear the drill, and prevent choking in the drill hole (see Fig. 41).

Universal Pipe Jointer is designed as a double purpose tool. It is used for preparing lead gas pipe joints, and cuts a bevel on the end of a pipe and opens out the end of a pipe as well as scraping the inside for jointing (see Fig. 43).

#### CHAPTER V

#### SHEET LEAD ROOFWORK

THE plumber's art and skill in the manipulation of sheet lead in roofwork is sometimes considered to be dying out. Considerable amounts of sheet leadwork are carried out today, but not on the scale that has been done in the last century.

Sheet lead as a roof covering has been replaced in many cases by asphalt, reinforced bitumen felts and copper. Cast iron and asbestos have replaced lead for the making of rainwater pipes and heads and gutters of all types, particularly the parapet gutters.

Lead has proved itself durable under all conditions without the aid of paint or preservative, as compared with cast iron, which soon rusts away if not protected.

Deterioration of rainwater fittings results in the destruction and decay of building fabric, and the eventual loss of valuable buildings.

#### Cast and Milled Sheet Lead.

The qualities of cast and milled sheet lead vary considerably. Cast sheet lead is very pliable, but does not lend itself to extensive working owing to its roughness and thickness. On the other hand it will resist the strain of expansion and contraction due to exposure to the heat of the sun.

Lead is also readily adaptable for casting to any shape or artistic design to comply with an architectural detail submitted by an architect.

Milled sheet lead is more tenacious and durable at a comparatively reduced thickness, and it can be worked conveniently to any shape required.

## Working of Sheet Lead.

The manipulation of sheet lead is known as "bossing," and this is done by the use of the various wood tools as described in Chapter IV. "Bossing" of sheet lead is the art of making the metal "flow," and this art requires considerable skill, which is gained by a lengthy process of practice and training.

This skill is necessary to shape the lead to the intricate and ornamental shapes required in roofwork, and maintain a uniform thickness.

#### Support of Sheet Lead.

The efficiency and durability of sheet lead depends chiefly on the support provided for the lead, which is generally timber. The lead being of considerable weight requires substantial, firm and rigid support. Lead being a soft metal requires a smooth, sound and regular surface to lie on, free from any sharp edges, projections or anything likely to damage the lead.

Wood boarding for sheet lead should be laid in the same direction as the "fall" of the lead flat or gutter, or in the direction of the flow of the water and not at right angles to it.

#### Weights of Lead and Uses.

The various thicknesses or weights of sheet lead are used according to the part of the roof where they are going to be used. The following is a list of the weights and situations where they would be used.

Lead flats and gur	tters			•		6-8				
Valley gutters						5-7	,,	,,	,,	,,
Hip and ridge roll	s					6-7				
Aprons, step and	cover	flas	hings			5	,,	,,	,,	,,
Secret gutters						5	,,	,,	,,	,,
Soakers	_	_	_		_	3-4				

#### Joints on Lead Roofwork

#### The Roll.

A roll may be one of two kinds, namely, solid or hollow. A roll is used to join pieces of sheet lead together on a flat area, and it is normally fixed in the direction of the flow of the water.

The solid roll is more suitable for use on a flat roof where it would be liable to damage. On the other hand a hollow roll is more suitable for steep roof pitches such as turrets and towers.

Solid Roll. The arrangement of the lead pieces on the solid roll, where the edges stand up against the wood roll to its full height, proves adequate to cope with any volume of water which may accumulate on the flat lead surface.

The lead covering on the top of the roll or "overcloak" completes the weathering of the timber.

Shape of Wood Roll. Note the shape of the wood roll as shown in Fig. 44 (a), which is undercut at the sides. This is provided to form a key for the lead to fit into and prevent the force of the wind lifting the lead.

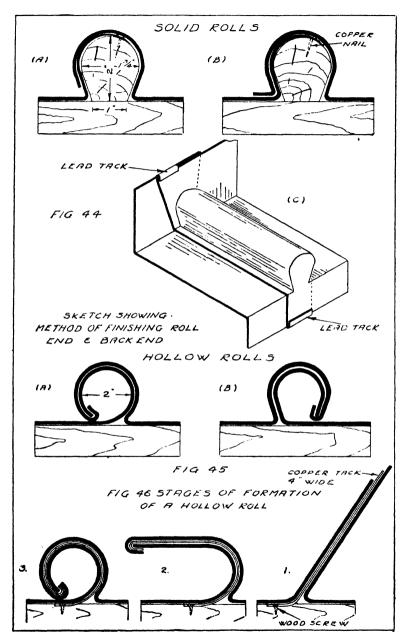
Fixing of the Lead. In the process of fixing lead pieces to a roll, the wood roll is securely nailed in position if the lead covering is small in area. On a large lead flat the positions of the rolls are marked and the rolls are nailed in position as each piece of lead is bedded into position. The "undercloak" is fitted first and taken roughly two-thirds round the roll as shown in Fig. 44 (a). The undercloak is normally nailed half an inch from the edge at intervals, and then the raw edge of the undercloak is finished off to a feather edge by means of a shavehook. This prevents the edge of the undercloak lead distorting the overcloak lead, and forming a ridge along the top of the finished roll.

In preparing pieces of lead for covering a roll the allowances required for a 2-in. roll are 3 in. for the undercloak, and 7 in. for the overcloak.

Finishing of the Roll. There are two methods of finishing off or trimming the overcloak to a solid roll as shown in Fig. 44 (a) and (b). At (b) the overcloak is trimmed off on the flat, and the strength and stiffness of the lead in the angle forms a good key which is very important in cases where a roof is exposed to strong winds. The method shown at (a) is adopted on the grounds of prevention of capillary attraction. The weakness of this method is that rain assisted by wind could get inside, and the key on the roll would be lost when the edges of the overcloak lifted.

Hollow Roll. Shape of the Roll. The hollow roll or seam roll as it is sometimes called varies in shape, two of which are shown in Fig. 45 (a) and (b), and the shape adopted is just a matter of taste.

Fixing of the Lead. Hollow rolls may be formed with or without copper tacks screwed to the woodwork as shown in Fig. 46. The copper tack, which should be about 3 in. wide and long enough to clip over the edge of the undercloak, is screwed to the woodwork as shown, and forms a secure fixing for the lead to prevent it lifting from the woodwork.



The process of forming a hollow roll is as shown in the illustrated stages of manipulation (Fig. 46).

#### The Drip.

A drip is introduced on a lead flat or lead gutter, and it is fixed across the flow of water. The depth of the drip should be not less than 2 in., as this is found sufficient to avoid capillary attraction taking place.

The drip can be one of two types, the vertical type and the splayed type as shown in Figs. 47 and 48.

Vertical Drip. A sectional view of a vertical drip (Fig. 47) shows the lower gutter turned up at the drip, and turned over on to the sole of the upper gutter which is shown rebated to receive the lead. This rebate houses the edge of the lead, which is nailed and leaves a flush surface for the upper gutter. The upper gutter or overcloak can be finished in two ways as shown in Fig. 47, where it can either be trimmed on the sole of the lower gutter or above the sole of the gutter.

A capillary groove is sometimes introduced on the vertical drip as a precaution against capillary attraction (see Fig. 47 (b)).

Splayed Drip. The splayed drip is introduced as an alternative to the vertical drip, and its chief advantage is the ease of working the lead in its formation (Fig. 48).

#### Welts.

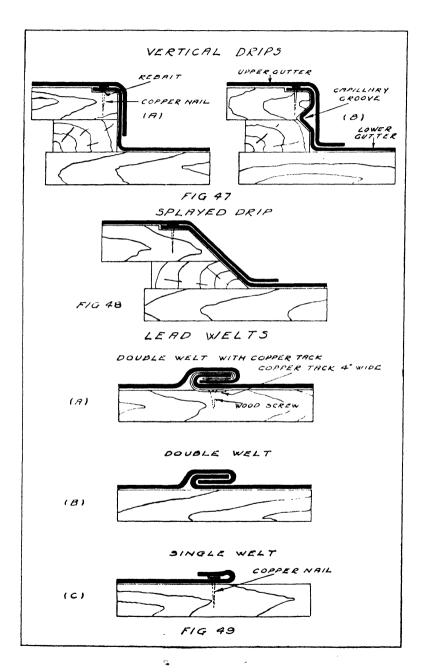
Welts are used for joining pieces of lead together on weatherings to cornices or frontages to buildings, or finishing edges of lead roof covering.

There are two types of welts: (c) single welt, (a-b) double welt.

Single Welt. The single welt is a means of covering copper nailing which is securing the edge of a piece of lead in an exposed position (see Fig. 49 (c)).

Double Welt. The double welt is used for joining two pieces of lead together, and forms an efficient joint without soldering. This joint is used on weathering to stone and wood facings where there is no accumulation of water.

Where the welt is fixed in an exposed position, for example on a turret or tower, a copper tack is introduced and turned over with the lead welt as shown in Fig. 49 (a).



#### Soldering.

Sheet lead roofwork should be as free as possible from soldered joints or seams. When pieces of lead on a roof are soldered together there is no allowance for expansion and contraction.

Where a soldered seam has been made, as in a repair or an alternative to faulty construction, the lead usually cracks near the seam or on the seam itself.

Soldering is resorted to in the form of soldered dots or tacks for securing vertical surfaces of lead, and in the making up of cesspools and connecting of the outlets (see Fig. 50 (a), (b) and (c)).

#### Cesspools and Gutters

#### Gutters.

Lead gutters may be situated between two sloping roof surfaces, or between a sloping roof surface and a wall which is usually a parapet wall.

The setting out and construction of a lead gutter is largely the responsibility of the carpenter, who works in co-operation with the plumber in deciding the positions of drips and rolls, etc.; which are governed by the sizes of the lead the plumber can use.

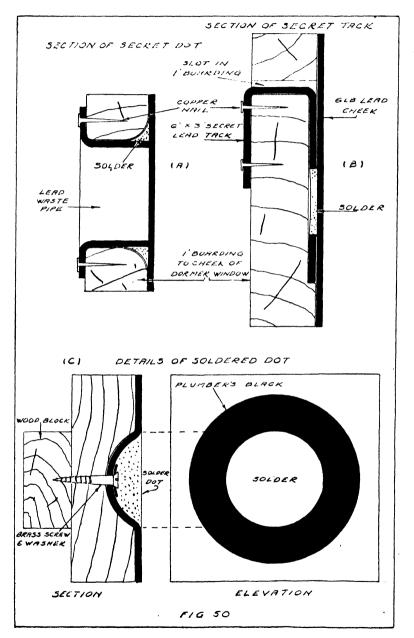
Size of Pieces. In lead gutters the accepted maximum length for a piece of lead is 10 ft. The drips are arranged in order that each gutter length does not exceed the maximum.

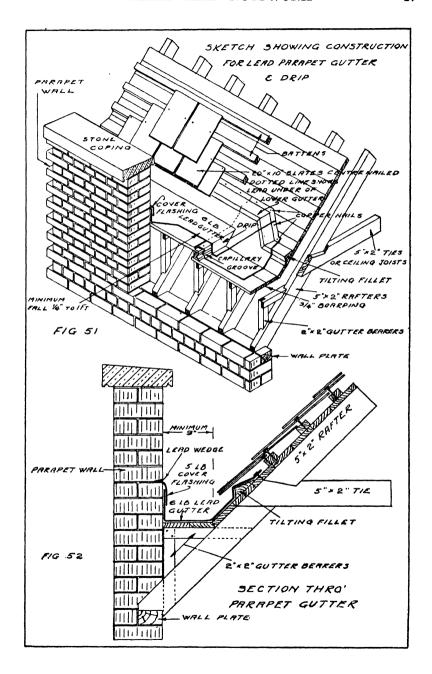
The minimum width for the bottom or sole of the gutter should be 9 in., to provide access along it without liability of damage to the slates or tiles (see Figs. 51 and 52).

Fall. Gutters collect water which has to be disposed of quickly. The speed of disposal is determined by the "fall" of the gutter, which should not be less than \(\frac{1}{4}\) in. for each foot in length. The lowest point of a lead gutter usually discharges into a cesspool, a description of which follows.

## Cesspools.

A cesspool is simply a lead box which is made up in several ways. The box may be made from a single piece of lead with the corners bossed up, or the corner pieces cut out, the sides turned up and the angles soldered or lead burned.





Bossing up of a lead box entails considerable labour, as some of the corners have to be 12 in. deep, so that the popular method adopted is soldered angles (see Fig. 53).

The development of a cesspool drawn to scale and cut out of stiff paper makes an instructive exercise.

Outlet. The outlet to a cesspool is of lead and may be jointed into the bottom or connected in "Bird's Mouth" fashion. The method of connecting to the bottom of a cesspool is shown in Fig. 55.

The "Bird's Mouth" connection is adopted where an obstruction in the building structure occurs under the cesspool, and prevents the outlet being fitted to the bottom. This type of outlet is also considered more efficient, not being liable to be covered up by leaves, etc., like a bottom outlet, as the water would get away through the side portion of the opening (see Fig. 56).

Another type of outlet to a lead gutter is the method of carrying the gutter direct through the wall in the form of a chute, as shown in Fig. 58. The chute is a superior outlet to the cesspool method but consideration for architectural features may not permit its use.

Overflow. An essential safety measure adopted to avoid flooding caused by snow and obstruction in gutters and cesspools, is the fitting of an overflow pipe to the cesspool. The overflow pipe is of lead, and it is connected by a soldered joint to the cesspool at a point below the level of the drip of the gutter, as shown in Fig. 57.

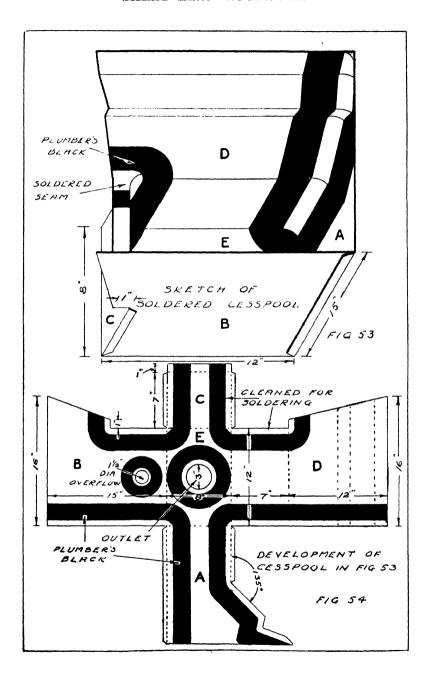
#### Lead Flats

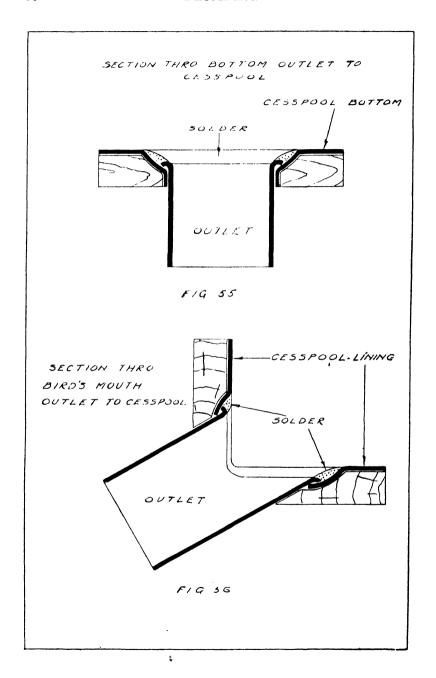
A lead flat is the term given to a flat roof surface which is covered entirely with sheet lead (see Fig. 58). As with lead gutters or on any form of lead roofwork, the sizes of the pieces of lead must be limited.

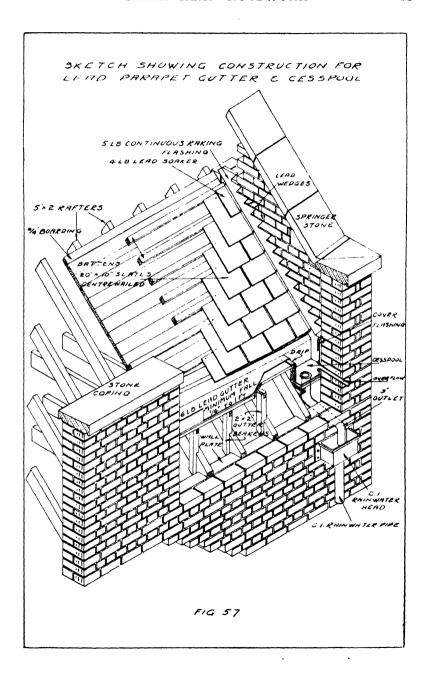
The "bays" or sections between the rolls and drips should be kept within a maximum of 7 ft. in length and 2 ft. 8 in. in width.

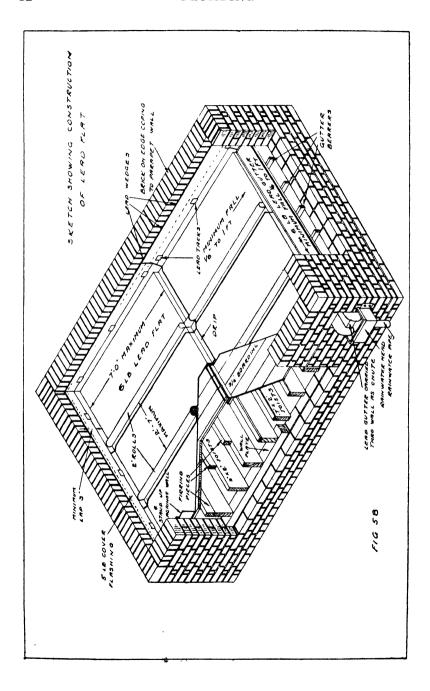
Fall. In the case of lead flats the fall should not be less than  $\frac{1}{8}$  in. to each foot in length, as distinct from the fall given for lead gutters.

Setting Out. The main considerations in the setting out of a lead flat are (1) the gutter, (2) the rolls, and (3) the drips.









Each of these details have been previously described and the rolls are set out in the direction of the flow of water and the drips across the flow of water (see Fig. 58).

#### Hip and Ridge Rolls

A hip or ridge is the section of a roof where the slopes of a roof intersect or meet, and though the roof covering itself may be efficient, additional means have to be adopted to make the roof watertight at the intersections. The commonest method adopted is the use of purpose-made tiles made from earthenware or similar material.

An alternative method is the use of sheet lead, copper or zinc, and in the case of the ridge, a standard size wood roll is nailed to a packing piece, and this is nailed to the top of the ridge member of the roof (see Fig. 59).

The conditions for fixing hip rolls are similar to those for ridge rolls, except for the top end fixing of each piece, where it is nailed to prevent the lead sliding down.

#### Flashings and Valley Gutters

Sloping roof surfaces at some part of a roof meet a wall or chimney stack, and the joint between the roof covering and the wall requires to be weathered and made watertight.

Lead lends itself for this purpose and is very reliable.

The initial part of the weathering is the soaker flashing or an alternative method known as a secret gutter.

#### Soakers.

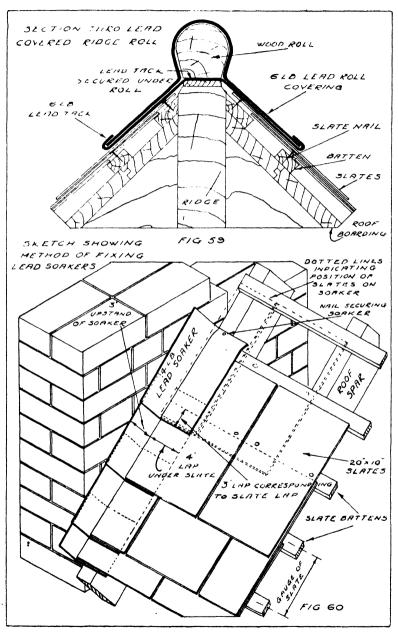
A soaker is a piece of lead which has one side turned up at right angles, which fits against the wall (see Figs. 60 and 64). The standard sizes for the width are 3 in. against the wall and 4 in. under the slates.

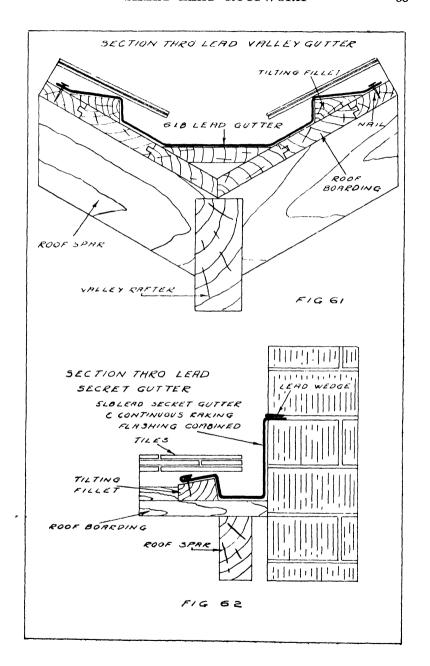
The length is determined according to the length of the slates or tiles being used.

The length of a soaker is calculated as follows:

Length of slate or tile  $- lap \div 2 + 3$  in. + 1 in.

The result after dividing by 2 gives the gauge of the slate or tile, and the 3 in. is the addition for the lap or weathering, plus the 1 in. which is to allow for turning the top edge over the batten and nailing at the top of the slate.





When a roof job is in progress the plumber determines the sizes required and prepares the soakers. The soakers are passed to the slater who fixes them as he progresses up the roof slope. The soakers are fixed lapping each other an equal amount to the lap of the slates.

#### Secret Gutter.

This is an alternative weathering which is usually adopted on tiled roofs where, due to small tile sizes, the soakers would be so numerous and a greater quantity of lead required.

A secret gutter consists of one continuous piece of lead, formed in the shape of a small gutter in place of the soakers (see Fig. 62). The advantage of this method of weathering is that it can be completed before the slates are fixed.

## Step Flashings.

The weathering to the upstand of the soakers or secret gutter against the wall requires to be completed, and this is done by the arrangement of step flashings.

Step flashings vary in design, but the two principal types adopted are the separate or individual step flashing, and the continuous raking flashing. Both types are efficient if the work is carried out correctly.

## Separate Step Flashings.

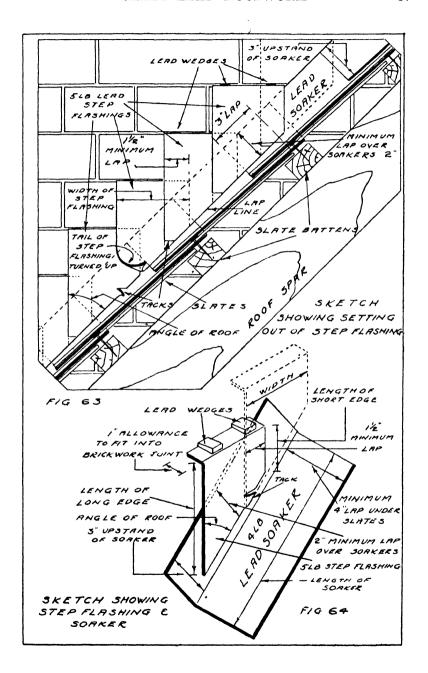
These are separate pieces of lead cut out to the required width and length, with the bottom edge cut on an angle corresponding to the slope of the roof. Allowance is made in the length of 1 in. extra to fit into the brickwork joint.

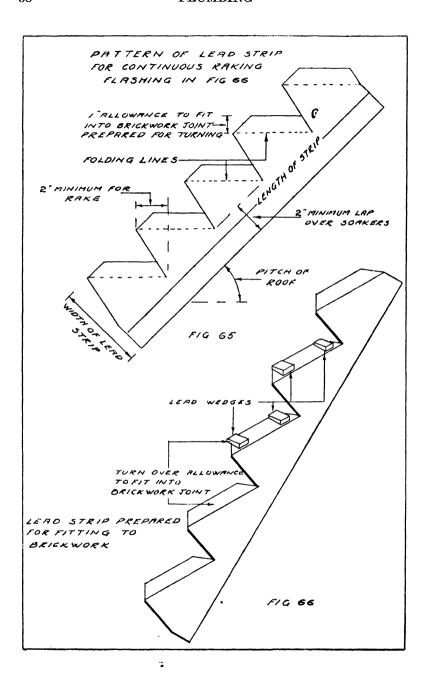
Each step flashing laps over the next a minimum of  $1\frac{1}{2}$  in. and this forms the basis of the setting out to obtain the shape of each piece (see Fig. 64).

The minimum lap of the flashings over the top edge of the soakers should be 2 in., measured perpendicular to the roof slope.

The flashings are fitted into the joints of the brickwork which have previously been raked out, and the flashings are secured by lead wedges which are cast in sand.

The joints of the brickwork are pointed up afterwards with oil mastic to complete the weathering. The tail or pointed end of each step flashing is secured by the underneath flashing being cut to form a tack (see Fig. 64).





#### Continuous Raking Flashing.

This consists of lengths of narrow strips of lead cut to a pattern to cover the soakers, and fit into the brickwork joints according to the slope of the roof. The weathering is dependent on the rake of the edge of the lead between each brick joint (see Fig. 67). The method of setting out a raking flashing is as follows. The rake of the front or forward edge of the lead between each brick joint should not be less than 2 in. measured horizontally (see Fig. 65).

The distance from the top of the rake down to the roof slope and measured perpendicular to it, allowing 2 in. lap on the soakers, gives the width of the flashing piece (see Fig. 67). A minimum of 4 in. lap is allowed joining each length of the flashing. When the width of the strip is determined the lead is held in position against the wall with the bottom edge lineable with the lap line, and the joints of the brickwork marked on the lead to show the turning points. This is done to allow for any variations in the brickwork. Where the brickwork consists of regular shaped pressed or selected facing bricks, the entire setting out may be carried out on the bench.

The usual allowance is made of 1 in. to fit into the brick joints at each step, and they are secured with lead wedges and the joints pointed as for step flashings (see Figs. 65, 66 and 67).

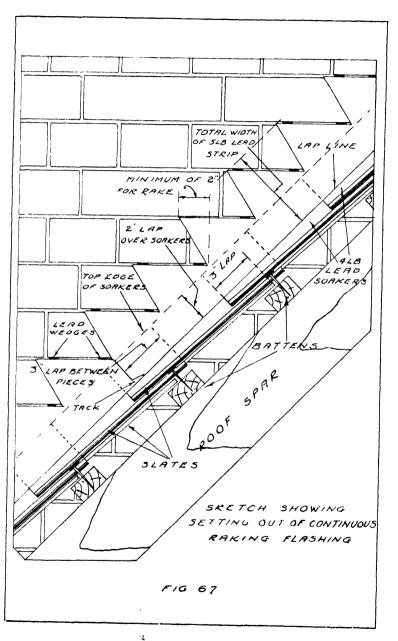
## Valley Gutters.

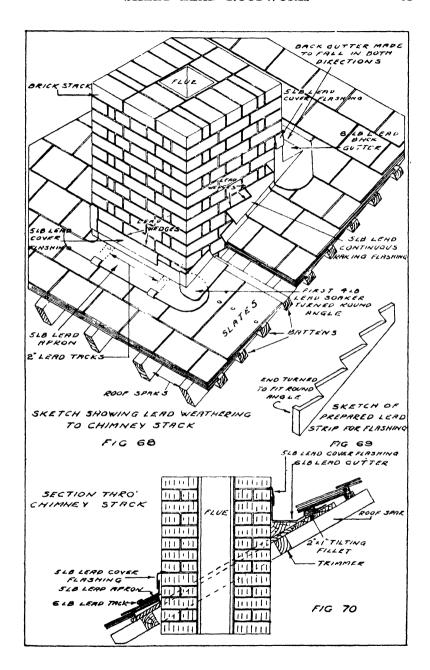
Valley gutters occur at the intersection of sloping roof surfaces, and lead lends itself as an efficient means of weathering at these junctions.

The lead is supported by boards in the angle of the roof, and nailed on each side and at the top end of each piece. The lengths of the lead pieces are kept to a maximum of 7 ft., and the width measured to allow for 6 in. under the slates on each side. The lap between each length should not be less than 6 in. (see Fig. 61).

## Weathering to Chimneys

Where a chimney penetrates a roof below the ridge the main parts of the weathering are: (1) Apron; (2) Soakers; (3) Step Flashing; (4) Back Gutter; (5) Cover Flashing.





Where the chimney penetrates at the ridge the back gutter is eliminated and two aprons are used.

The fixing procedure for the first case is that as the slating proceeds and reaches the chimney, the apron is fixed, next the soakers and the back gutter, followed by the cover flashing to the apron, then the step flashings and finally the cover flashing on the back gutter.

The lead tacks shown in the figure support the lead on the roof slope (see Figs. 68, 69 and 70).

#### CHAPTER VI

#### PIPE JOINTS

A MAJOR part of plumbing work is concerned with the fixing of pipes, which may be made of any of the various metals already dealt with in a previous chapter.

Each metal used for a particular type of pipe necessitates the adoption of a particular type of joint, which is also determined by the need which the pipe is required to fulfil.

The following descriptions of pipe joints will be dealt with in groups according to the metal the pipe is made of.

The metals to be dealt with will be lead, copper, steel, wrought iron and cast iron.

#### Lead Pipe Joints

Lead pipe joints are of three main types, namely blowpipe or gas joints, wiped joints and lead burned joints.

On blowpipe or gas joints blowpipe solder is used, on wiped joints plumbers' solder is used, and lead burned joints are made with lead strip and the use of lead burning equipment.

The descriptions to follow will only include blowpipe and wiped soldered joints.

## Lip Joint.

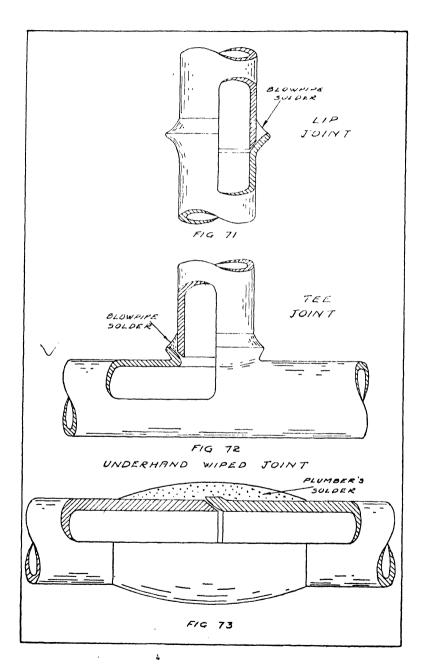
This joint is used for jointing straight lengths of lead or composition gas pipe. This type of joint is sometimes used for jointing waste pipes (see Fig. 71).

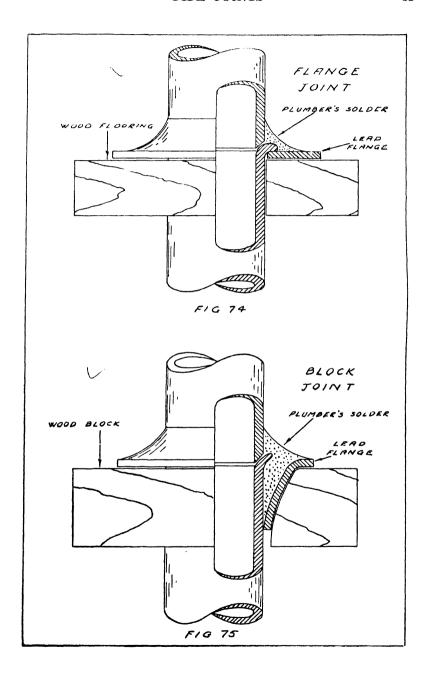
## √Tee Joint.

This is a method of jointing gas pipe to form a branch joint (see Fig. 72).

## Underhand Wiped Joint.

This joint is used for jointing straight lengths of any form of lead pipe, of any size and for any requirements; namely, water, waste, soil or gas (see Fig. 73).





## -Flange Joint.

This joint is used for jointing lead waste pipes which are fixed vertically and where they pass through a floor. Lead pipe, by virtue of its weight and pliability, requires to be adequately supported, and the flange joint serves as a means of support and an efficient joint combined (see Fig. 74).

#### Block Joint.

This joint is very similar to the flange joint, except that the support to the lower pipe is more substantial where it is of any length.

This type of joint is adopted on a pipe which is to be fixed in a chase or recess built in a brick wall to receive it. The flange and block joints are used on soil, waste, vent and rainwater pipe (see Fig. 75).

## /Branch Joint.

Branch joints are of two types, namely, the pitched branch and right angle branch joints. The pitched branch joint is the type necessary to be adopted for connecting branch pipes to a main soil or waste pipe. The branch requires to be pitched in the direction of the flow in the main waste pipe. The pitching of the branch facilitates the disposal of the waste water and matter passing through the pipe, and minimises any possibility of stoppages.

The square or right angle branch joint is adopted for branch connections on water supply pipes used for hot or cold water services (see Figs. 76–77).

## Copper Pipe Joints

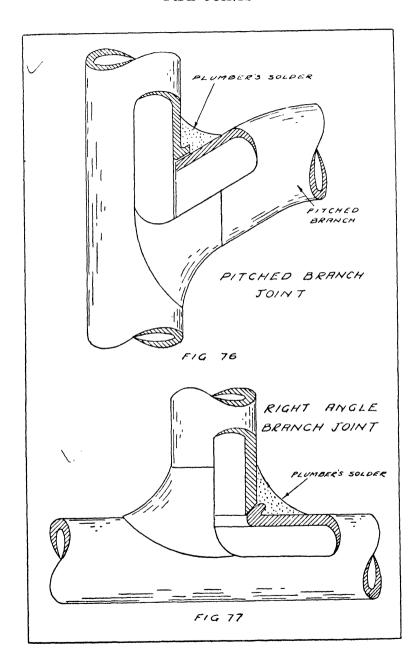
Copper pipe or tube may be jointed in several ways, and may be done by the use of brass or gunmetal fittings, brazing and welding.

The following descriptions will only deal with the use of brass or gunmetal fittings.

Copper pipe joints are divided into two main groups, namely, Medium-Gauge and Light-Gauge types.

## Medium-Gauge Type.

This type of joint is used on medium-gauge copper tubing where the actual joint is a threaded joint.



# MEDIUM GAUGE COPPER PIPE JOINTS COUPLING JOINT ALL THREADS HOUSED FINE SOLDER IN FITTING COPPER TUBE GUNMETAL FITTING F1G 78 UNION CONNECTION GUNMETAL FITTING FINE SOLDER COPPER TUBE UNION NUT-FIG 79

A special fine thread is adopted for these joints and the couplings, elbows, tees, etc., are of gunmetal or similar copper alloy.

The gauge of the copper tube used for these joints varies from ½-in. diameter 15 Standard Wire Gauge to 4-in. diameter 10 S.W.G.

The cutting of a thread reduces the thickness of the walls of the tube, and the medium gauge or thickness of the copper allows for this reduction, while still maintaining the strength necessary to be of service.

The thread should be cut just long enough to be completely housed in the fitting. To complete the sealing of the joint, the threads on the spigot and in the socket should be fluxed and tinned, and the two screwed together while the heat of a blowlamp flame is applied. The groove and outer edge of the socket should be filled up with solder.

Fig. 78 shows a straight coupling joint and Fig. 79 shows a union coupling joint which facilitates the assembly or dismembering of the joint for alteration or maintenance purposes.

## Light-Gauge Type.

This type of joint is used on light-gauge copper tubing which may be jointed with several types of fittings and which can be classified under three headings.

- 1. Manipulative.
- 2. Non-manipulative.
- 3. Capillary.

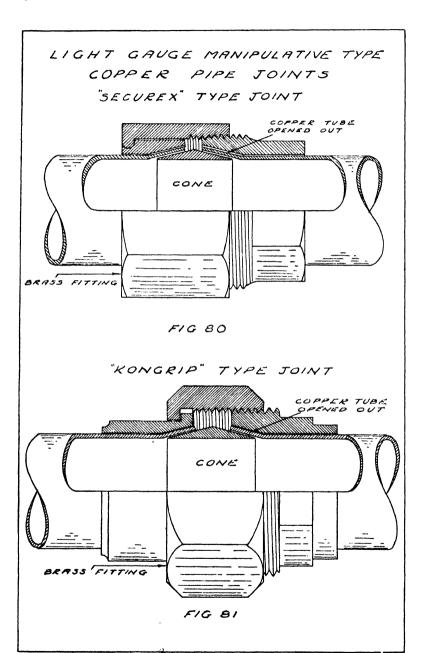
Manipulated and non-manipulated joints both come under the heading of Surface Compression Joints.

Light-gauge copper tubing, used for the fittings to be described, varies in strength from ½-in. diameter 19 S.W.G., to 4-in. diameter 14 S.W.G.

The jointing material used for these type of joints varies, and the best all-round substance is any form of graphite composition or paste.

## Manipulative.

Joints under this heading are classified as such because the ends of the copper tubing have to be shaped and prepared to suit the type of fitting to be used. Fig. 80 shows a "Securex"



type of joint where the ends of the tubing are opened out with a specially shaped drift or punch. The ends are opened out sufficient to receive half the cone which fits between the ends of the tubing. The compression set up when the fitting is screwed up ensures a watertight joint. Fig. 81 shows a "Kongrip" type of joint which is similar to the "Securex" joint, but varies in construction and requires the same preparation and manipulation of the copper tube.

## Non-Manipulative.

Joints of this type are of various kinds, and the only work entailed is the cutting to length and squaring of the tubing, assembling the fitting with the tubing and screwing together. The compression set up in the joint is the only factor keeping it watertight.

Fig. 82 shows a "Kontite" type of joint where the sleeve nipple is wedge-shaped, and the screwing together of the fitting tightens the wedge on the pipe.

Fig. 83 shows an "Instantor" type of joint where the sleeve nipple is grooved, and the screwing together of the fitting forces the nipple to indent itself into the tubing.

## Capillary Joints.

Joints of this type are becoming more popular because of their low cost, ease of assembly and fixing, and their neat appearance when fixed in a prominent position.

A capillary joint is a soft soldered joint in which the copper tubing fits tightly into the socket of a fitting, and on applying heat, flux and solder, the solder flows by capillarity round the joint, filling the space between the socket and the tubing.

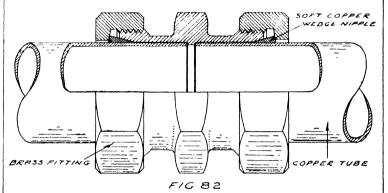
The fittings available for this type of joint vary, some being made of gunmetal and others of hot stamped copper. Also some fittings have a ring of solder inserted in the socket, which serves to complete the joint when heat is applied.

Fig. 84 shows a "Yorkshire" type of fitting which is manufactured from a corrosion-resisting brass and includes the solder rings.

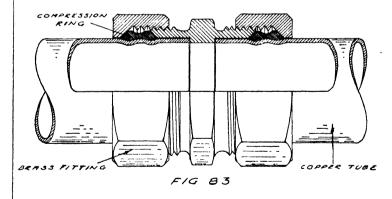
In making a capillary joint, it is always advisable to clean the inside of the socket of the fitting and the end of the tubing with fine glass paper or steel wool, before applying flux prior to making the joint.

# LIGHT GAUGE NON-MANIPULATIVE TYPE COPPER PIPE JOINTS

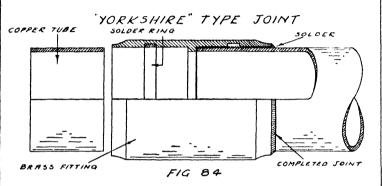
"KONTITE" TYPE JOINT



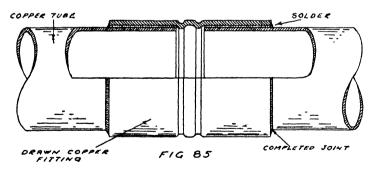
"INSTANTOR" TYPE JOINT



# LIGHT GAUGE CAPILLARY TYPE COPPER PIPE JOINTS



#### DRAWN COPPER FITTING TYPE JOINT



When using a fitting without the inserted solder ring as shown in Fig. 85, the solder stick is touched at the outer end of the socket when it has been heated to the melting-point of the solder, and the solder flows round the joint.

An up-to-date substitute for the solder stick and flux is the introduction of solder paste which is a combination of solder and flux. The paste is applied to the parts to be joined and then the joint heated, proving very efficient and greatly simplifying the fitting work.

## Steel and Wrought Iron Pipe Joints

Steel and wrought iron pipes are jointed by one of two methods, namely, welding or screwed joints with the use of special fittings.

The following descriptions will only deal with screwed joints.

The threads to be cut on the end of a piece of tubing should be just long enough to be housed in the fitting as shown in Fig. 86, with an effective taper on the thread to tighten up in the fitting socket and make a sound joint.

The jointing material used for screwed joints varies, but an efficient all-round substance is any form of graphite composition, or paste.

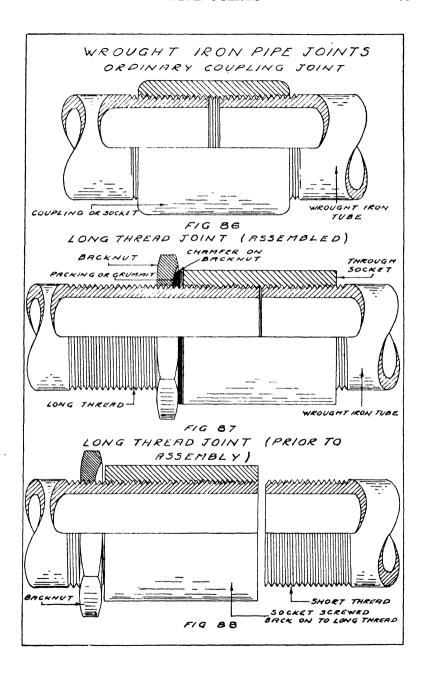
In conjunction with the graphite, sisal hemp is used which is stranded and wrapped round the threads and assists in tightening up the joint and filling in any deficiencies in the threads.

## Ordinary Coupling Joint.

This joint is a standard method of jointing wrought iron or steel tubing in use for gas, water or steam supplies (see Fig. 86).

# Long Thread Joint.

This joint is similar to the ordinary coupling joint, but the provision of a long thread and the use of a straight-through socket or coupling and a backnut facilitates the assembly and dismembering of the joint. This facility is necessary where both ends of the tubing to be joined cannot be manipulated or are fixed.



The long thread requires to be sufficiently long to accommodate the backnut and socket completely. The backnut has one face chamfered inwards as shown in Fig. 88 to house the ring packing or grummit when the joint is finally made secure. A grummit is a ring packing formed by plaiting some strands of hemp into a ring.

Fig. 88 shows the joint prepared, prior to assembly, and Fig. 87 shows the joint screwed up and completed.

#### High-Pressure Joint.

This joint is distinct from other types of joints as the threads on the ends of the tubing are made left and right handed.

This arrangement enables the ends of the tubing to be drawn together on turning the socket or coupling in one direction.

This joint is used on high-pressure type heating systems, and the actual joint is made between two metal faces, the end of one tube being sharp bevelled edged, and the opposite end being squared as shown in Fig. 89.

This metal to metal joint proves efficient to withstand pressures up to 3 or 4 tons per sq. in.

## Tin-Lined Iron Pipe Joint.

This joint is utilised on iron pipe which contains an inner protective lining of tin, or is a pipe within a pipe. The threads on the iron pipe are left and right handed, and when the pipe is cut the tin lining should be allowed to project  $\frac{1}{4}$  in. beyond the end of the iron pipe and flanged over the end as shown in Fig. 90.

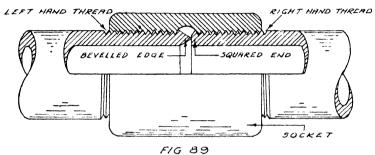
The actual joint is made with a leather washer between the two tin lining flanges, which are drawn together when the coupling or socket which is made of gunmetal is screwed up.

The socket has a clearance groove round the centre inside, with a hole drilled into it from outside as shown in Fig. 90. This hole and groove enables any indication of leakage in the joint to reveal itself without corroding the threads.

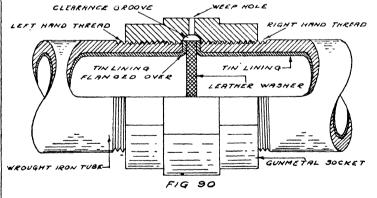
This type of joint is used on what is known as "Walker's Health" pipe, which is used where stability of the piping is required, but where the water to be supplied through it has a soft characteristic and a very corrosive effect on iron.

# WROUGHT IRON PIPE JOINTS

#### HIGH PRESSURE COUPLING JOINT



# TIN LINED IRON PIPE JOINT



#### Cast Iron Pipe Joints

Cast iron pipe joints can be divided into two groups, namely, those used on pipes laid underground and those used on pipes fixed above ground.

The jointing materials vary according to the requirements and conditions under which the pipe is to be fixed.

#### Lead to Cast Iron Joint.

This joint is used for connecting lead pipe to cast iron pipe used for waste or soil disposal purposes.

The actual joint is usually made by caulking the clearance round the cast iron socket with gaskin or spun yarn and then lead caulking the joint or filling it up with red lead putty, which is pointed off and painted.

This caulking and filling up of the socket is liable to damage the lead pipe and thus, to avoid this, a brass ferrule or sleeve is fitted over the lead pipe and fixed in position with a wiped underhand joint, as shown in Fig. 91.

#### Cast Iron to Stoneware Joint.

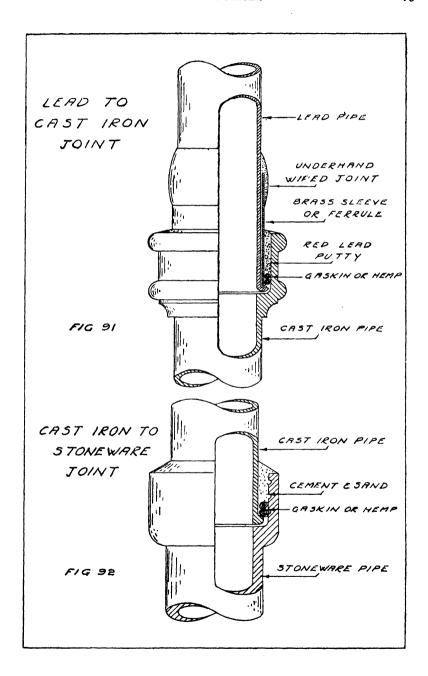
This is a joint usually fixed below ground and is used on rainwater, waste and soil pipes. The jointing material consists of gaskin or spun yarn caulked in the joint, and the remaining space in the socket filled up with a mixture of cement and sand to the proportions of 2 parts of sand to 1 part of cement.

The purpose of gaskin or spun yarn which is used for caulking into the pipe sockets is first to fix the spigot end of a pipe evenly in the socket. Secondly it acts as a barrier to the jointing substance, and prevents it being forced into the interior of the pipe.

Care has to be exercised in caulking with the spun yarn or gaskin that it also does not slip into the interior of the pipe, as it may cause an obstruction to waste matter passing through it (see Fig. 92).

#### Cast Iron to Cast Iron Joint.

The design of this joint varies according to the weight and purpose for which the pipe is to be used.



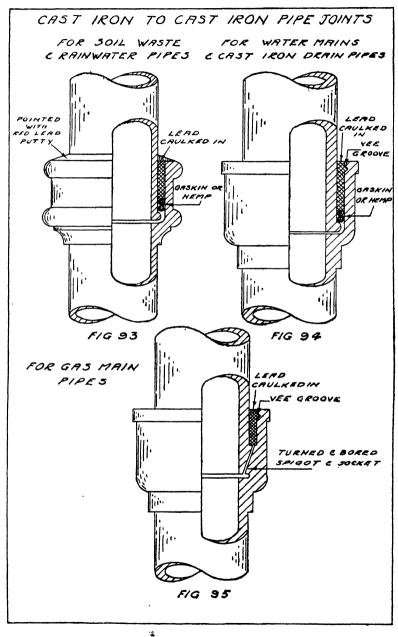


Fig. 93 shows the type of joint used on cast iron rain water, waste and soil pipes fixed above ground. The jointing material varies according to the use of the pipe. For rainwater pipes and waste pipes, red lead putty is generally used.

For soil pipes the socket is filled with molten lead, which on cooling off is then caulked in to consolidate it and ensure a sound watertight and gas-tight joint.

Fig. 94 shows the type of joint generally used on heavy cast iron pipes used for water mains or cast iron drains fixed underground.

The socket has a vee groove near the outer edge which acts as a key to retain the lead filling which is run in, in a molten state, and caulked in with a caulking tool.

To fill the socket with lead when it is in a horizontal position, a clay ring is packed round the socket with an opening left at the top. The molten lead is poured in the opening and it flows round the socket, cools off and solidifies ready for caulking.

Where a case arises that the pipe joint to be made is under water in an excavation, molten lead cannot be used. To overcome this difficulty "lead wool" is used, which consists of hanks of very finely extruded lead in fine threads, and this is packed and caulked into the socket without the application of heat.

Fig. 95 shows the type of joint usually used on gas mains fixed underground.

The spigot end of the pipe has a machine-turned taper which fits into a machine-bored taper socket. This type of joint facilitates the laying of gas mains without the necessity of cutting off the gas supply.

A stopper is fitted in the socket end, and the taper spigot is painted with a mixture of red and white lead and wound round with some fine threads of gaskin. On removal of the stopper from the socket of the live gas main, the painted spigot is inserted in the socket in the trench excavation, and driven in. This serves as a sound gas-tight joint without any further attention.

The socket may be filled up with lead afterwards as an added precaution, similar to that done on water mains.

#### CHAPTER VII

#### TAPS AND VALVES

A MAJOR part of plumbing work is concerned with water and gas supplies. The control of these supplies at the discharge point, or at an intermediate point, is obtained by the use of taps or valves.

Water supply obtained from service mains is controlled by Waterworks Undertakings, and they exercise a rigid control on the whole of the distribution of water under their supervision.

The most important point in the distribution which requires the exercise of essential regulations, is the point of supply or the consumer end.

These essential regulations govern all the fittings used in water supply, and the design and types of fittings permitted are specified.

In most cases such fittings as taps, valves, and water closet cisterns, etc., are required to be of an approved type and tested by the Water Authority, and stamped by them before they are permitted to be used.

This rigid control is exercised with the object of conforming to the Water Acts and Model Bye Laws, and the prevention of unnecessary waste of water due to defective fittings. This objective is vital in maintaining an adequate water service.

Taps and valves are of four main types, namely, screw down, plug, gate or full-way and lever taps.

The metals used in their manufacture are brass, gunmetal or white metal.

Taps and valves are supplied in various finishes such as rough-cast finish, polished and plated according to requirements.

# Screw Down Taps

All screw down taps are designed on the same principle, and Fig. 96 shows the main parts in their construction.

The body of the tap is formed as shown in section in Fig. 96. The back fixing may provide a tail piece for

jointing to a lead pipe with a wiped soldered joint, or a screwed thread for screwing into a screwed boss, or an elbow wall plate (see Figs. 96–97).

The spindle body or cover contains the working parts of the tap, which include the crutch or capstan head, spindle, gland or stuffing box screw, valve or jumper, and the washer and fixing nut.

The spindle body of the tap is screwed securely to the main body, and the spindle is screwed up and down, controlling the pressure on the valve, which in turn is lifted by the pressure of the water or by the peg when it is secured to the spindle.

The gland or stuffing box keeps the water from percolating past the moving spindle.

The top of the spindle may be fitted with a tee-crutch or a capstan head with an index for hot, cold or drinking water, etc. (see Fig. 98).

In some cases the valve requires to be "fixed" as shown in Fig. 98. A fixed valve moves up and down with the turning of the spindle, but is free to swivel round.

This fixed valve is necessary where the water pressure is insufficient to ensure the lifting of the valve when the tap is opened.

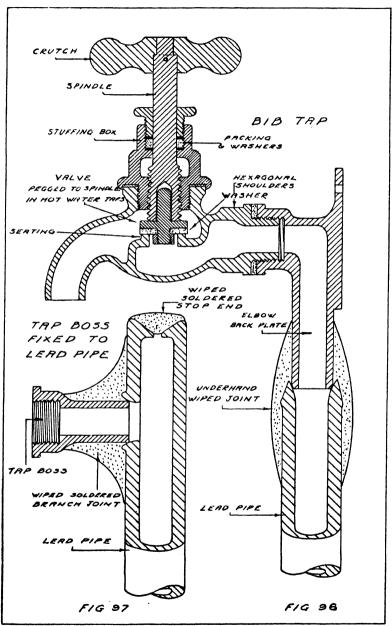
The washer fitted on the valve consists of a disc-shaped piece of leather, fibre or vulcanised rubber, the former being for cold water supply and the latter two being for hot water supply.

The brass nut on the threaded spindle of the valve secures the washer in position.

# Maintenance and Repairs.

Constant movement and pressure of the washer on the seating eventually reduces it to a thin wafer or it wears away. At this stage the tap will not shut off properly, and then a new washer is required to be fitted.

Much debate arises as to the best type of washer to use for screw down taps. This depends on the nature of the water, whether it is hot or cold, and what pressure the tap is subject to. Hot and cold type washers have been mentioned previously, but where a tap is subject to high pressure, usually on a main water supply, a rubber washer of any type should be avoided. A rubber washer tends to cause water hammer,



which may take any form, from a sharp hammering noise in the pipes to a high-pitched screech when the tap is opened.

Wear and tear also causes water to leak past the spindle at the stuffing box, which then requires repacking with greased cord.

After prolonged use the seating of the tap may show signs of wear by developing small pit holes or a groove in the seating. This condition necessitates the renewal of the tap, or a process of reseating with special equipment.

#### Bib Tap.

This type of tap is used for all purposes of supply where it is not required to be fixed to the fitting to be supplied (see Fig. 96).

## Pillar Tap.

This tap is designed to fit into a lavatory basin, and the outlet spout is shaped according to the shape of the fitting it is required for.

Fig. 98 shows the tap fitted with an easy-clean cover which covers the structure of the spindle body and presents a smooth, clean appearance.

# Globe Bath Tap.

This is the usual type of tap designed for fitting to a bath, where the taps are fixed in the side of the bath (see Fig. 99).

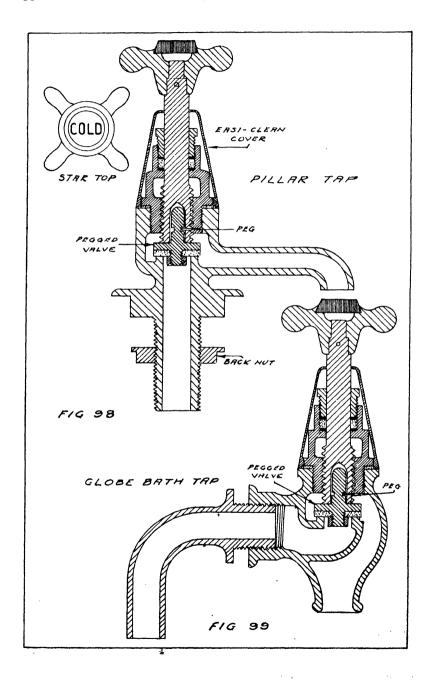
## The "Supatap."

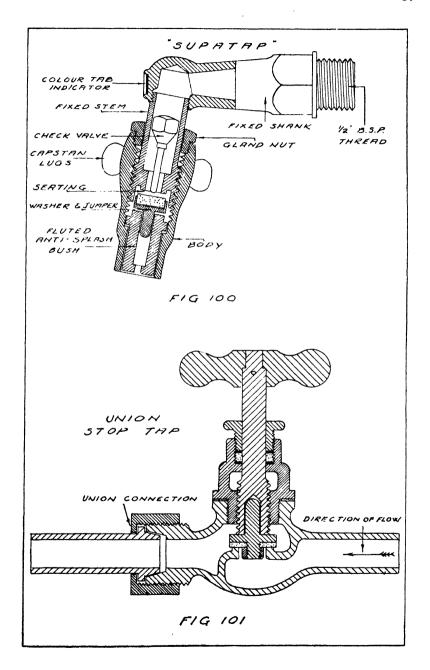
This is a revolutionary design of tap and is of the nozzle type—the nozzle rotating down to open and up to shut.

The valve is contained in the stem and is operated by the up and down rotation of the nozzle. When the nozzle is removed the check valve seats down and closes the water supply, thus enabling rewashering to be carried out without the trouble of using stopcocks and turning off the main water supply or draining of the hot water pipes. The built-in antisplash ensures an even and non-splashing jet of water (see Fig. 100).

## Union Stop Tap.

This is a type of tap which is fixed at an intermediate point on a water supply, to control the supply to either a section





of a pipe system, or fixed underground to control the supply to a premises. Where it is to be fixed underground the tap top should be secured by means of a set-screw.

The important point about this type of tap is that it must be fixed in the correct way. The flow of the water passing through it should lift the valve as shown in Fig. 101.

Usually these taps are supplied with an arrow marked on the side of the body to indicate the correct way for fixing.

The union connection shown in Fig. 101 facilitates the fixing and disconnecting of the supply where lead pipe is in use.

#### Plug Taps

These taps are mainly used on gas supply, as they are not subject to great pressure.

Fig. 102 shows a section of a typical plug tap, consisting of a ground taper bore body into which fits a ground taper plug, and this is retained in position by a nut and washer.

The passage way for the gas through the tap is usually a small-bore hole or a narrow slot, and the supply is turned on and off by a quarter turn of the plug.

The top of the plug is provided with a tee-crutch, a lever handle, or may have a square head for a loose lever key. If the top of the plug has a square head, it is marked with a groove to indicate the "on" or "off" position.

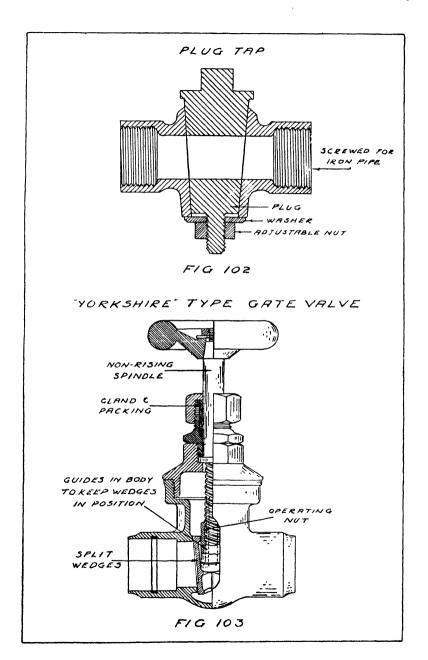
A plug tap is sometimes used on a water supply, but usually in a case where it would be used at rare intervals. Such a case would be as an emptying tap on a boiler, or as a control at an intermediate point on a supply system.

Where a plug tap is used on a water supply, the tap is usually designed in such a way that the plug has a full-bore water way through it, equal to the bore of the pipe on the supply.

# Gate or Full-Way Valves

A gate or full-way valve is designed to control water supply without checking the flow of water passing through it too suddenly, when it is shut off. At the same time, it provides a full-bore water way through when it is open.

Sudden checking of the flow of water through a pipe such as occurs with a plug tap causes water hammer, and may cause



the pipe to be damaged or fractured depending on the existing circumstances.

The gate valve derives its name from the fact that it contains a gate or wedge, which is sometimes split in two halves, as shown in Fig. 103, and slides in and out of position when the spindle is turned.

When the valve is shut the gate or wedge is jammed into position, with ground metal to metal faces ensuring the closure of the supply to be complete. The gates move up and down the threaded spindle, guided by guides cast in the body of the valve, as shown in Fig. 103.

#### Lever Valves

The common type of lever valve in general use is the ball tap or valve.

Ball taps are of two main types, the standard pattern with the plunger operating horizontally, and the Croydon type which has the plunger operating vertically.

Fig. 104 shows the Portsmouth type ball tap, and Fig. 105 the Croydon pattern.

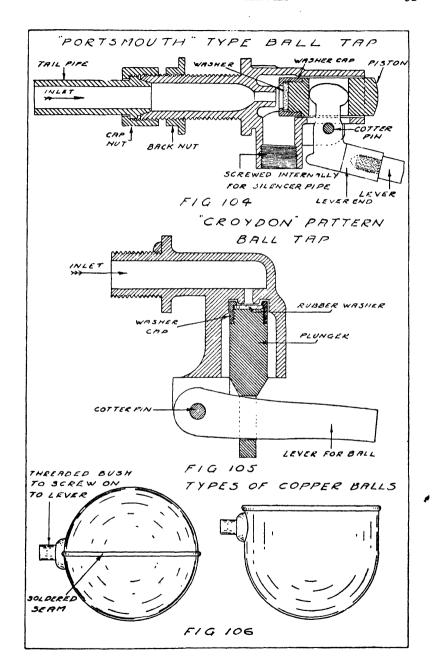
The working of a ball tap is based on the principle of levers. The mechanical advantage of a long lever with a light buoyant ball screwed on the end, overcomes the resistance or pressure of water acting against the plunger and short lever, with a pivot pin acting as the fulcrum.

A ball tap consists of a plunger or piston, which slides in and out of the body of the tap. A slot is cut in the plunger to receive the short leg of the lever.

The pivot pin acting as a fulcrum is usually a cotter pin, the ends being opened out to prevent it working out of position.

The inner end of the plunger has a detachable screwed cap, as shown in Fig. 104. This secures a small disc washer, of good quality rubber about  $\frac{1}{8}$  in. thick, in position.

The outlet nozzle on the body of the tap is sometimes screwed inside as shown, for a silencer pipe to be fitted if required. A silencer pipe is a short length of tube fitted with the outlet end under water, and thus eliminating the undesirable noise of water splashing. Also when a silencer pipe is fitted, at least three small holes about  $\frac{1}{8}$  in. diameter must be drilled in the top end near the thread. These holes prevent



water in the cistern being syphoned back into the supply pipes, should the supply be cut off.

The long lever has a threaded end for screwing on the ball. Balls for ball valves are made from several materials such as copper, bakelite and china.

Very light-gauge copper is the most common in use, and the ball consists of a dome bottom section and a flat top, or is made into a complete globe with a seam round the middle.

This seam is usually soldered to make the ball watertight. A threaded bush is soldered on to the ball to screw on to the lever.

The essential factor about a ball is that it must be free from water to retain its maximum buoyancy. When it is found to contain water after a period of use, the water must be removed and the ball resoldered (see Fig. 106).

The size of the aperture at the seating of a ball tap is usually not more than  $\frac{1}{8}$  in. diameter, and this applies to what is known as a high-pressure ball tap.

Where a low pressure of water is to be met, a low-pressure full-bore ball tap is permitted to ensure speedy filling of a sanitary appliance.

#### CHAPTER VIII

#### PLUMBING SCIENCE

#### Heat and Temperature

ALL solids, liquids, gases, and the atmosphere in which we live, contain heat in varying amounts.

A natural method of trying to measure or compare the amount of heat in two articles, for instance, would be to touch them by hand. For example, if a piece of steel and a piece of soft wood were selected, on touching with the hand, the steel would feel cold in comparison to the wood.

Heat in the atmosphere could be distinguished by comparing that in a heated room with that out of doors during frosty weather.

The above examples are instances where it is only possible to distinguish between hot and cold bodies, but not to measure the intensity of heat.

#### Effects of Heat.

Heat has an effect on all solids, liquids and gases, and in nearly all cases it causes them to expand or increase in size.

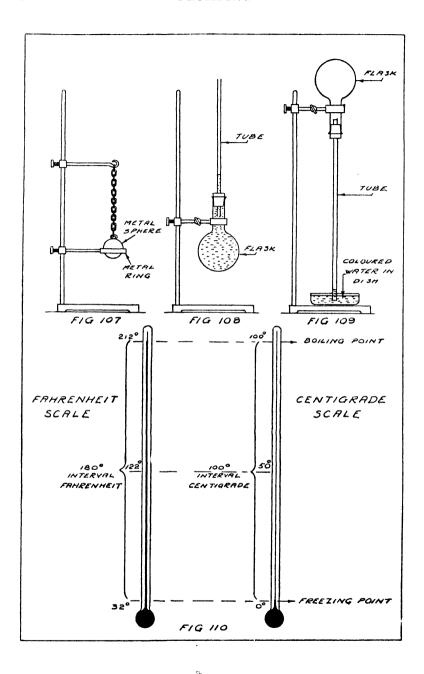
The amount of expansion varies with the amount of heat applied to them, and conversely when heat is withdrawn they contract or reduce in size.

EXPERIMENT 1. Fig. 107 shows a metal ball fitting inside a metal ring and suspended on a chain.

When cold the ball just passes through the ring, and on being heated and fitted back into the ring it fails to pass through, but does so when left to cool down for a short period. This illustrates the expansion and contraction of metals.

EXPERIMENT 2. Fig. 108 shows a glass flask completely filled with coloured water. An indiarubber stopper with a narrow-bore glass tube fitted through it is secured into the neck of the flask. The coloured water will show in the tube, and on applying heat to the flask the water will rise quickly in the tube, and slowly fall as the flask is allowed to cool. This illustrates the expansion and contraction of liquids.

EXPERIMENT 3. Fig. 109 shows a glass flask fitted with



an airtight stopper and a glass tube fitted through it as shown. The lower end of the tube is dipped into coloured water held in a dish. Application of heat to the flask, or holding of the hands on the flask, causes air bubbles to be forced out at the lower end of the tube. On leaving the flask to cool off and return to normal, the coloured water will be seen to rise in the tube at the bottom, thus indicating the contraction of the air in the flask.

Heat also brings about, in many cases, a change of state of a substance.

For example, wax or fat as a solid will change to a liquid when heated.

Water as a liquid will change to a gas in the form of steam when heated to boiling-point.

The usual sequence of the change of state when heat is applied is that a solid changes to a liquid, and a liquid to a gas.

#### Temperature.

Heat and temperature are not the same thing. Heat is the amount of energy contained in a substance, which is perceived by our sense of touch.

A substance is said to be hot when heat passes from it to the finger and cold when heat passes from the finger to the substance.

Temperature is the intensity of heat in a substance or, to put it in simple terms, how hot it feels to touch.

MEASUREMENT OF TEMPERATURE. Temperature is measured by means of a thermometer.

A thermometer is a very fine-bore glass tube with a hollow bulb blown on the lower end, and containing mercury or alcohol (see Fig. 110).

The tube is marked or graduated, and from this the temperature can be measured in terms of degrees.

The two fixed points taken as a standard to work from are:

- 1. The melting-point of ice.
- 2. The boiling-point of water.

First, it is found that water always freezes, or ice melts, at the same temperature.

Secondly, when atmospheric pressure is normal, water always boils at the same temperature.

The distance between the fixed points is divided into a number of equal parts called degrees. To determine the scale of degrees, two commonly known scales are used, namely, Fahrenheit and centigrade.

Centigrade Scale. This is the simplest scale and the freezing-point or melting-point of ice is known as zero or 0° C. The thermometer is marked when the mercury stands at this level. When the thermometer is placed in steam, the mercury reaches a level which is known as boiling-point or 100° C. The distance between the fixed points is divided into 100 parts in units of 10, so that the reading of the thermometer may be simplified (see Fig. 110).

Fahrenheit Scale. In this scale the freezing-point is marked as 32° F., and the boiling-point as 212° F., which means that the distance between is divided into 180 parts. This scale s generally used in England (see Fig. 110).

Conversion of Thermometer Scales. The fact of having two measuring systems for temperature in general use makes it necessary to have a method of converting the readings of one scale to the corresponding reading on the other scale.

This can be done by calculation.

$$0^{\circ}$$
 centigrade = 32° Fahrenheit.  
 $100^{\circ}$  centigrade = 212° Fahrenheit.  
Interval between freezing- and boiling-point =  $100^{\circ}$  C. =  $180^{\circ}$  F.  
 $1^{\circ}$  C. interval =  $\frac{180^{\circ}}{100}$  F. or  $\frac{9^{\circ}}{5}$  F.  
 $1^{\circ}$  F. interval =  $\frac{5^{\circ}}{9}$  C.

also

This means that every degree Fahrenheit is equivalent to  $\frac{5^{\circ}}{9}$  C., and every degree centigrade is equivalent to  $\frac{9^{\circ}}{5}$  F.

When converting centigrade scale to Fahrenheit scale, the resultant figure represents the number of degrees above freezing-point. On the Fahrenheit scale there are 32° below freezing-point and thus this number requires to be added to the above resultant figure to arrive at the correct corresponding reading.

Similarly, but in reverse, when it is required to convert

Fahrenheit to centigrade, the Fahrenheit reading includes the  $32^{\circ}$  below freezing-point. This  $32^{\circ}$  must first be subtracted from the Fahrenheit reading, and the remainder multiplied by  $\frac{5}{9}$  which gives the corresponding reading in degrees centigrade.

Example 1. Convert  $50^{\circ}$  centigrade to the corresponding temperature Fahrenheit.

$$50^{\circ}$$
 C. =  $50^{\circ}$  C. above freezing-point. 
$$=\frac{50}{1}\times\frac{9}{5}=90^{\circ}$$
 F. above freezing-point. 
$$=90\,+32\,=122^{\circ}$$
 F.

Example 2. Convert  $140^{\circ}$  F. into the corresponding temperature centigrade.

140° F. = 140 
$$-$$
 32 = 108° F. above freezing-point.  
=  $\frac{108}{1} \times \frac{5}{9}$   
=  $60^{\circ}$  C.

Liquids in Thermometers. Any liquid would be suitable for use in a thermometer until it either solidified or boiled.

Alcohol and mercury are the most common in use, and they each have their own advantages over other liquids.

Alcohol has a very low freezing-point and also a low boilingpoint, which makes it unsuitable for use in high temperatures.

Mercury is the best liquid to use in a thermometer and its advantages are as follows:

- 1. It remains liquid over a long range of temperature.
- 2. It does not stick to the glass.
- 3. It is easily seen in the glass.
- 4. It is a good conductor and quickly absorbs and indicates the temperature of the substance surrounding it.

Liquid.				Freezes.	Boils.
Mercury Alcohol.		:		- 39·5° C. - 150° C.	350° C. 80° C.

## Expansion of Solids-Examples and Application

Having understood the simple process of expansion or enlargement of a solid on being subject to heat, the next fact to establish is the precise amount of the expansion.

The first point to make clear is that a solid expands in all directions, and measurement of this expansion may be made in one of three ways, namely:

1. Linear. 2. Superficial. 3. Cubical.

Linear expansion is an increase in length.

Superficial expansion is an increase in area.

Cubical expansion is an increase in volume.

## Linear Expansion.

This, as has already been stated, is the increase in length of a solid when heat is applied to it.

## Coefficient of Linear Expansion.

All solids expand at different rates, and therefore it is necessary to determine the fractional increase in length of the solid when heated through 1° F.

This fractional increase in length is known as the Coefficient of Linear Expansion, and it is defined as the fraction of the original length which the solid expands when heated through 1° F.

The following is the ratio for determining the Coefficient of Linear Expansion:

Coefficient of Linear Expansion =  $\frac{\text{Increase in length for } 1^{\circ} \text{ F.}}{\text{Original length}}$ 

# Superficial Expansion.

This is an increase in area of a solid when heat is applied. The following is the ratio for determining the Coefficient of Superficial Expansion:

Coefficient of Superficial Expansion =  $\frac{\text{Increase in area for 1}^{\circ} \text{ F.}}{\text{Original area}}$ 

To simplify the process of calculation, it is found that the Coefficient of Superficial Expansion is approximately twice the Coefficient of Linear Expansion.

## Cubical Expansion.

This is an increase in the volume of a solid when heat is applied.

The following is the ratio for determining the Coefficient of Cubical Expansion:

Coefficient of Cubical Expansion =  $\frac{\text{Increase in volume for 1}^{\circ} \text{ F.}}{\text{Original volume}}$ 

Calculation of cubical expansion may be simplified, as it is found that the Coefficient of Cubical Expansion is approximately three times the Coefficient of Linear Expansion.

EXPERIMENT 4. Fig. 111 illustrates the different rates of expansion of two metals.

Two flat strips of metal, one of copper and one of iron, are riveted together and fixed straight.

Heat is then applied to the middle of the metal strips and expansion takes place, the strips curving with the copper on the outside and the iron on the inside.

On cooling the strips straighten out again, thus indicating that copper has a higher expansion rate than iron.

Example 3. An iron bar is 10 ft. long at a temperature of  $40^{\circ}$  F. What will its length be at  $200^{\circ}$  F.? Coefficient of Linear Expansion of iron = 0.0000068.

Increase in length of

1 ft. for  $1^{\circ}$  F. = 0.0000068 ft.

10 ft. for  $1^{\circ}$  F. = 0.000068 ft.

 $10 \, \text{ft.} \, \text{for} \, (200^{\circ} - 40^{\circ} \, \text{F.}) = 0.000068 \times 160$ 

= 0.01088 ft.

Total length = Original length + increase in length = 10 + 0.01088 = 10.01088 ft.

Example 4. A length of copper tube is 40 ft. long at a temperature of  $45^{\circ}$  F. Find its length when water at  $200^{\circ}$  F. is passed through it. Coefficient of Linear Expansion of copper = 0.00000955.

Increase in length of

1 ft. for  $1^{\circ}$  F. = 0.00000955 ft.

40 ft. for  $1^{\circ}$  F. = 0.000382 ft.

40 ft. for  $(200^{\circ} - 45^{\circ} \text{ F.}) = 0.000382 \times 155$ 

= 0.05921 ft.

Total length = Original length + increase in length

=40+0.05921

= 40.05921 ft.

Substance.	Linear Expansion.	Substance.	Linear Expansion.
Cast iron Copper Brass Wrought iron . Steel	0·00000617 0·00000955 0·00001037 0·00000686 0·00000599	Zine Tin Lead Glass Mercury	0·00001634 0·00001410 0·00001650 0·00000494 0·00003334

TABLE OF COEFFICIENTS OF LINEAR EXPANSION

#### Practical Applications of Expansion.

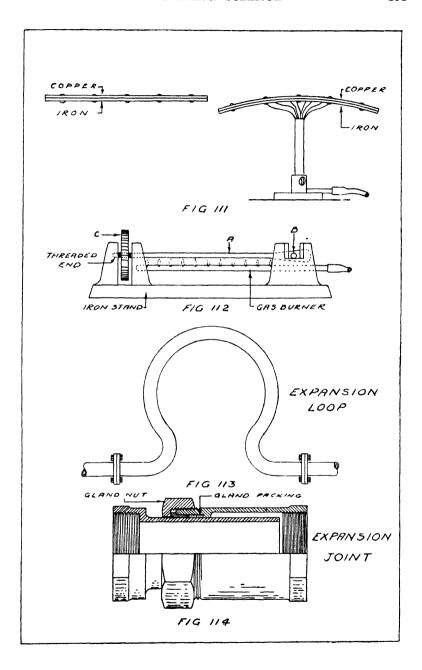
EXPERIMENT 5. Fig. 112 shows an apparatus for demonstrating expansion and contraction of metals. It consists of an iron stand with a wrought iron rod A placed along its length. One end of the rod is bored about \(\frac{1}{4}\) in. diameter, through which is fitted a cast iron pin B. The other end of the rod is threaded, and can be tightened with a nut C. If the nut is adjusted to push the pin out and the gas burner is lit, the heat will expand the rod and break the iron pin. With a new pin inserted, and the nut adjusted to pull the pin while the rod is hot, the pin will break when the rod is allowed to cool off, by force of contraction.

This expansion factor is directly applied to the laying of railway lines. The lengths of rails are fixed with a slight gap between the ends to allow for expansion, due to the effects of the heat of the sun. It will be noticed on close examination that this gap is less in summer than in winter.

In plumbing work, allowance is made for expansion by the use of expansion joints.

Fig. 113 shows the method of forming the pipe into a loop which acts more or less as a spring, and is known as an expansion loop. The loop is fixed in a horizontal position in a steam or hot water service to avoid forming a trap in the service.

Fig. 114 shows an expansion joint of a mechanical type compared with the expansion loop, which requires no attention and has no moving parts. The expansion joint shown is utilised on iron or copper pipe services, and consists of one tube sliding in and out of another with the joint between them being kept watertight with a gland packing as shown.



## Expansion of Liquids-Examples and Application

An example of expansion of a liquid was described in Experiment 2, Fig. 108.

When this experiment is carried out under close observation the water level in the tube first drops slightly when heat is first applied to the flask.

This is due to the momentary expansion of the flask, and thus causing greater capacity, but on the temperatures of the flask and liquid equalising the water in the tube levels up again. After this adjustment the water rises in the tube as the heat is applied.

Expansion of liquids is considered as Cubical Expansion. The following is the ratio for determining the Coefficient of Cubical Expansion of a liquid:

Coefficient of Expansion of a liquid

# $= \frac{\text{Increase in volume of liquid for 1° F.}}{\text{Original volume}}$

#### COEFFICIENT OF LIQUIDS (CUBICAL)

Liquid.	Coefficient.			
Mercury				0.00018
Alcohol				0.0013
Turpentine .				0.0011
Water (approx.)	•	•		0.00049

EXPERIMENT 6. Fig. 115 shows a method of comparing the ratio of expansion of various liquids. Three flasks, each with a stopper and a glass tube, are each filled with a different liquid and all at a common level.

One flask is filled with water, one with turpentine and the other with alcohol.

All these flasks are placed in a tank containing hot water and held there for 1 or 2 minutes. On observation, it will be found that the water is much slower in expanding than the alcohol, which rises rapidly.

# Practical Applications of Expansion.

Allowance for the expansion of water has to be made in plumbing work in connection with domestic hot water and heating installations.

In a domestic hot water system the air or vent pipe from the top of the cylinder or hot storage tank (see Fig. 148), and sometimes known as the expansion pipe, has to be taken up above the level of the water in the supply tank.

The height of the outlet of the vent pipe above the tank water level has to be sufficient to allow the water in the system to expand, when heat is applied to the boiler, without it discharging through the open end. To counteract this tendency, an allowance of 1 in. for each vertical foot of cold water column between the tank and the cylinder is allowed for the height of the vent pipe above the tank water level (see Fig. 148).

In a medium-pressure heating system, the  $\sup \rho |y|$  cistern to feed the pipe system is of comparatively small size, and is usually narrow and deep. The ball tap control has a long lever and it is fixed above the overflow invert. This long lever enables the supply to be controlled, leaving the cistern filled to about one-third of its capacity.

This tap maintains the system full, and the surplus capacity of the tank accommodates the water which flows back from the system due to expansion when heating and circulation takes place (see Fig. 116).

# **Expansion of Gases**

An example of expansion of a gas was described in Experiment 3, Fig. 109.

When tests are made on air and other gases, it is revealed that all gases expand at the same rate when heated.

Gases expand very rapidly when heated. The standard Coefficient of Expansion for all gases is 0.00366.

# Practical Applications of Expansion.

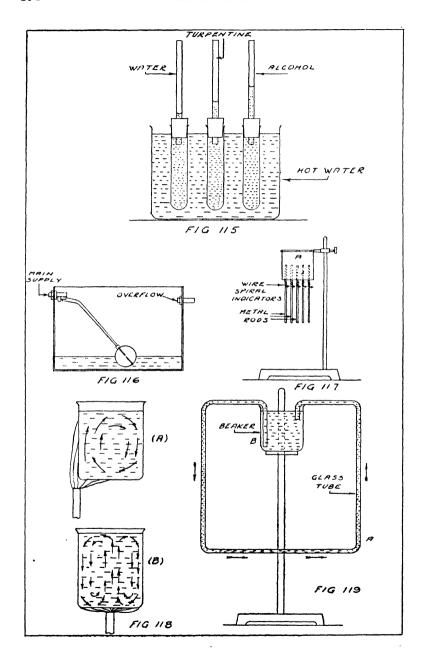
Expansion of air and gases on being heated affects their density and therefore they become lighter.

This change of density causes air for example to rise, and this movement is the basis of the principle of ventilation, as applied to rooms containing heating appliances and open fires.

The definition for gases may be stated as follows:

At constant pressure, the volume of a gas increases by  $\frac{1}{273}$  of its volume at 0° C. for every rise in temperature of 1° C.

This definition is known as "Charles's Law."



At  $0^{\circ}$  C. a gas still has volume, and to bring this volume to zero 273 is added to the centigrade temperature. The correct temperature reading of the gas when its volume is zero is  $-273^{\circ}$  C., which is known as the "absolute temperature."

It can now be stated that the volume of a gas is proportional to its absolute temperature if the pressure remains constant.

Example 5. At 5° C. the volume of a gas is 55 cu. ft. Find its volume at  $50^{\circ}$  C.

Converting to absolute temperature

$$5^{\circ}$$
 C. =  $5 + 273 = 278^{\circ}$  A.  
 $50^{\circ}$  C. =  $50 + 273 = 323^{\circ}$  A.  
Volume of gas at  $278^{\circ}$  A. =  $55$  cu. ft.  
Volume of gas at  $323^{\circ}$  A. =  $\frac{55 \times 323}{278}$   
=  $63.92$  cu. ft.

#### Gases Subject to Heat and Pressure.

When gases are subject to pressure in addition to heat, another law is involved known as "Boyle's Law."

Boyle's Law states that at constant temperature, the volume of a gas is inversely proportional to the pressure exerted upon it.

If P = pressure and V = volume, we may write

$$P \times V = a \text{ constant}$$
  
 $P_1V_1 = P_2V_2$ 

or

Example 6. 40 cu. ft. of air at 15 lb. per sq. in. is compressed to 16 cu. ft. at constant temperature. What is the new pressure?

$$P_{1}V_{1} = P_{2}V_{2}$$
 $15 \times 40 = P_{2} \times 16$ 
 $P_{2} = \frac{15 \times 40}{16}$ 

= 37.5 lb. per sq. in.

Boyle's Law and Charles's Law combined give us the following equation:

$$\frac{\mathbf{P_1V_1}}{\mathbf{T_1}} = \frac{\mathbf{P_2V_2}}{\mathbf{T_2}}$$

When

 $P_1$  = first pressure.  $V_1$  = first volume.  $T_1$  = absolute temperature.

Example 7. 24 cu. ft. of air at a pressure of 15 lb. per sq. in., and at a temperature of  $30^{\circ}$  C., is compressed to 5 cu. ft., the temperature rising to  $40^{\circ}$  C. Calculate the new pressure.

 $P_1 = 15 \text{ lb. per sq. in.}$   $V_1 = 24 \text{ cu. ft.}$   $T_1 = 273 + 30$   $P_2 = x$   $V_2 = 5 \text{ cu. ft.}$   $T_2 = 273 + 40$   $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$   $\frac{15 \times 24}{303} = \frac{x \times 5}{313}$   $\therefore x = \frac{15 \times 24 \times 313}{303 \times 5}$   $P_2 = 74.37 \text{ lb. per sq. in.}$ 

### Transmission of Heat

### Conduction.

This is transmission of heat by its movement along a solid, where the heat is passed from particle to particle without the particles moving.

The speed of this movement varies in various solids, and particularly in metals.

The solid through which heat passes is known as a "conductor."

EXPERIMENT 7. Fig. 117 shows an apparatus designed to illustrate the relative conductivities of metals.

The metal container A has rods of different metals fixed in the bottom, and inserted to the same height as shown.

Round each rod underneath the container is fitted a small spiral of wire, with one end shaped as an arrow, and secured in position by melting paraffin wax on them.

On pouring hot water into the container, the heat is transmitted by conduction down the rods and thus melts the wax.

This releases the wire indicators, which fall at varying rates. Each rests finally when the temperature is the same in each case; that is, the melting-point of the wax used.

The wire spiral or indicator which has dropped the lowest will indicate the best conductor, and the wire which is highest the poorest conductor.

Between solids, liquids and gases, solids are the best conductors, liquids and gases are poor conductors.

Substance.				Comparative Figure.	Substance.	Cemparative Figure.			
Silver Copper Brass . Iron .	•		•	786 743 171 143	Tin Lead	107 57 10·7 1·0			

TABLE OF RELATIVE CONDUCTIVITIES

PRACTICAL APPLICATIONS OF CONDUCTORS. Metals which are good conductors of heat are utilised for various purposes.

Copper and iron are used for boilers and heating pipes owing to their high conductivity, and copper is used for soldering irons because of its conductivity and heat-retaining powers.

#### Non-Conductors.

Substances which are poor conductors of heat are utilised for conserving heat contained in good conductors to prevent loss of heat by radiation.

Substance.			Relative Value.	Substance.	Relative Value.
Felt .	•		1.00	Sawdust	0.68
Straw			0.75	Wood	0.50
Cork .	•		0.71	Asbestos	0.50

TABLE OF NON-CONDUCTORS

PRACTICAL APPLICATIONS OF Non-Conductors. Non-conducting materials are utilised for protecting and covering steam and hot water pipes to prevent heat losses.

On the other hand, pipes fixed out of doors are protected and covered to avoid damage by frost. Where a cold water pipe is fixed in a moist or steam-laden atmosphere, it is coated with gold size or varnish, and covered with cork dust to prevent condensation on the pipe, which can be very objectionable.

#### Convection.

Convection is a method of transmitting heat by means of water or gas, where the heat is passed on by the actual movement of the particles.

Convection in Liquids. Water when heated expands, and therefore becomes lighter or less dense. This change of density causes it to rise and be replaced by colder water which forces the hotter and lighter water upwards.

Transmission of heat by water is carried out by what is known as "convection currents."

EXPERIMENT 8. Fig. 118 shows a beaker containing water, having heat applied at (a) to the side. If colouring matter or a little sawdust is placed in the water, the movement of the water will be as indicated by the arrows. The water in the vicinity of the heat expands, becomes lighter and is forced to the top by the colder and denser water.

This movement continues until the whole of the water is heated to boiling-point, when a change of state takes place, the water changing to a gas, i.e. steam.

Fig. 118 (b) shows the movement of the water when heat is applied centrally underneath the beaker.

CIRCULATION OF WATER IN HEATING SYSTEMS. Convection currents in water are the means by which circulation is promoted in heating appliances and pipe systems.

EXPERIMENT 9. Fig. 119 shows a beaker containing water, supported on a stand. In addition a glass tube, bent to the shape as shown and filled with water, is placed in the beaker.

The glass tube represents a pipe of a heating system, and the point at which heat is applied to the boiler. A few crystals of potassium permanganate are dropped in the beaker, and allowed to dissolve, and form a purple layer at the bottom of the beaker.

Heat is applied at A, and after a few seconds the coloured solution will begin to flow up the tube at B. Presently the coloured stream will travel right round the tube past the heating point and back to the beaker.

On the coloured solution arriving back at the beaker it will

form a layer on the top, and not mix immediately with the colder water.

When the circulation has been maintained for a while the top of the beaker will contain hot water and the lower part cold water. The effect of heating the tube at A causes the water to expand, become less dense and lighter, and the cold water of greater density to move the heated water along the tube.

The practical application of circulation is dealt with in Chapter IX.

Convection in Gases. Experiment 10. Fig. 120 shows a long totally enclosed box with two holes bored in the lid at each end. Underneath the hole at one end is placed a short stump of a candle, and over each hole is placed a glass lamp chimney. A piece of paper is lit and allowed to smoulder, and the candle is lit. The smoke from the paper is directed to the lamp chimney at A, and immediately it will be drawn down the glass chimney and discharged from the one at B.

Heat of the candlelight sets up air currents, and heated air rising is replaced by cold air passing down chimney A, which forces the heated or lighter air upwards, and taking with it the smoke from the paper.

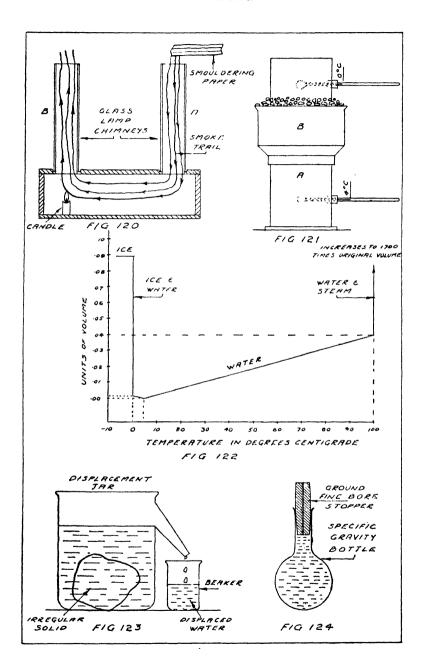
APPLICATION OF CONVECTION IN GASES. Air convection has an important application in plumbing work, where ventilation is essential in the installation of drains, soil and waste pipes, where the products of decomposition have to be disposed of effectively.

#### Radiation.

Radiation is the process of transmitting heat in direct rays or lines from the source, without heating the intervening space.

When seated before a fire or a very hot object, the heat is felt direct, and it can be cut off by placing a screen in the intervening space.

APPLICATIONS OF RADIATION are found in the use of gas fires, open fires, radiators, electric fires, etc., which radiate the heat in varying intensities.



### Peculiar Behaviour of Water

When considering the expansion of liquids due to the application of heat, and contraction on cooling, it applies to almost all liquids.

Water as a liquid behaves differently from any other.

Water is converted to steam at 212° F. or 100° C. From 212° F. or 100° C. down to 39.2° F. or 4° C. the water contracts, and it is at this point it reaches its maximum density.

On cooling further, the water expands until 32° F. or 0° C. is reached, where the water becomes ice and expands suddenly and considerably.

EXPERIMENT 11. Fig. 121 shows "Hope's Apparatus," which demonstrates the characteristic changes of the volume of water.

The metal cylindrical vessel A has an encircling trough B attached to it, and at the top and bottom are inserted thermometers as shown.

Water is placed in A to cover both thermometers, and ice is packed in the trough B. Both thermometers will be read and checked regularly. The top reading will be stationary, but the lower one will steadily fall, showing that the cooled water, being more dense, is sinking to the bottom.

This continues until the bottom reading shows 4° C., where it will remain stationary. The top reading will now begin to fall, showing that the cooled water now below 4° C. is rising due to its expansion at this stage.

This change of movement continues until the top reading reaches  $0^{\circ}$  C., when ice will begin to form. The ice will float on the top of the water, proving it to be lighter in weight, and the bottom reading will remain at  $4^{\circ}$  C.

# Effects of Water Freezing on Plumbing Work.

The behaviour of water as described is responsible for burst pipes in plumbing work when they are exposed to frost.

A number of defects occur in fittings of all kinds, due to the action of water on freezing.

A pipe is burst during the formation of the ice, and it is only revealed when the ice thaws and water begins to leak from the burst.

Water pipes which unavoidably must be fixed in exposed positions should be protected and covered with felt, sawdust

and straw, etc., which are poor conductors of heat. Also the non-conducting material used must be protected from absorption of moisture, otherwise the properties of the material will become reduced in efficiency.

Likewise, pipes which are laid underground are laid to a minimum depth to avoid the frost penetrating the earth and freezing the pipe.

## Specific Gravity and Density

All substances are composed of matter, and the amount of matter in a body is called its mass.

The mass of unit volumes of substances varies, and this mass or weight of a unit volume of a body is called its "density."

If a cubic foot of water was weighed, it would be found to weigh 62.5 lb. or 1,000 oz. (approx.).

A cubic foot of cast iron, when weighed, would be 450 lb., thus indicating that unit volumes of substances vary in weight.

When weights of unit volumes of substances are compared with the weight of a unit volume of water, the resultant figure is known as the "Relative Density" or "Specific Gravity" of the substance.

Example 8. Given that a cubic foot of cast iron weighs 450 lb., determine the Specific Gravity. (1 cu. ft. of water = 62.5 lb.)

1 cu. ft. of water = 62.5 lb.

1 cu. ft. of cast iron = 450 lb.

1 cu. ft. of cast iron =  $\frac{450}{62.5}$ 

= 7.199 times heavier than 1 cu. ft. of water

Specific Gravity of Cast Iron = 7.199

Specific Gravity =  $\frac{\text{Weight of a unit volume of substance}}{\text{Weight of an equal unit volume of water}}$ 

# Specific Gravity of Solids.

Solids may be of regular or irregular shape, and the method of finding the Specific Gravity of each shape varies.

With a regular shaped solid, the volume can be found easily, to arrive at the units of volume.

Example 9. A slab of lead 24 in. long by 12 in. wide by 3 in. thick, weighs 356.25 lb. Find (a) its Specific Gravity, (b) the weight of a cubic foot of mercury having a Specific Gravity of 13.56. (1 cu. ft. of water = 62.5 lb.)

(a) Volume of lead slab = 
$$\frac{24 \times 12 \times 3}{1728} = 0.5$$
 cu. ft.

Weight of  $\frac{1}{2}$  cu. ft. of lead = 356.25 lb.

Weight of 
$$\frac{1}{2}$$
 cu. ft. of water  $=\frac{62\cdot5}{2}=31\cdot25$  lb

Specific Gravity of Lead = 
$$\frac{356.25}{31.25} = \underline{11.4}$$

(b) 1 cu. ft. of water = 
$$62.5$$
 lb. Specific Gravity of Mercury =  $13.56$  Weight of 1 cu. ft. of mercury =  $62.5 \times 13.56$  =  $847.4$  lb.

With an irregular shaped solid, the volume can be found by displacement.

This method of displacement is carried out by immersing the solid in water, which displaces a volume of water equal to its own volume.

EXPERIMENT 12. Fig. 123 shows a displacement jar with a solid immersed in water. The jar is filled with water up to the overflow point prior to immersing the solid. By measuring the volume of water displaced, the volume of the solid can be ascertained.

It also holds true that the amount of water displaced can be weighed, and used in direct comparison with the weight of the solid before immersion.

Example 10. The weight of a piece of stone is found to be 50 lb. On immersing the stone in water, it was found to displace 4 lb. of water. What is the Specific Gravity of the stone?

Weight of stone = 50 lb.  
Weight of water displaced = 4 lb.  
Specific Gravity of Stone = 
$$\frac{50}{4} = \underline{12.5}$$

# Specific Gravities of Liquids.

To find the Specific Gravity of a liquid requires the use of a Specific Gravity bottle.

EXPERIMENT 13. Fig. 124 shows a bottle or flask which is used. An accurately ground stopper with a fine hole bored through it is fitted. Any liquid to be dealt with is filled into the flask nearly up to the lip of the neck, and then the stopper is carefully pushed in.

This ensures an exact measurement of the volume of a liquid, to enable its Specific Gravity to be found.

Specific Gravity of a liquid  $=\frac{\text{Weight of the liquid}}{\text{Weight of equal volume of water}}$ 

Solids.		S.G.	Liquids.	S.G.
Cork		0.24	Alcohol	0.795
Ebony		1.19	Methylated spirit .	0.82
Glass		$2 \cdot 5$	Water at 4° C	1.00
Zine	.	$7 \cdot 2$	Sea-water	1.026
Cast iron		$7 \cdot 2$	Sulphuric acid	1.854
Wrought iron	.	7.79	Mercury	13.56
Steel		7.79	, ,	
Copper		8.79		
Lead		11.36		

TABLE OF SPECIFIC GRAVITIES

# Principle of Archimedes.

This principle defines that a solid when immersed in water, loses weight equal to the weight of the water displaced.

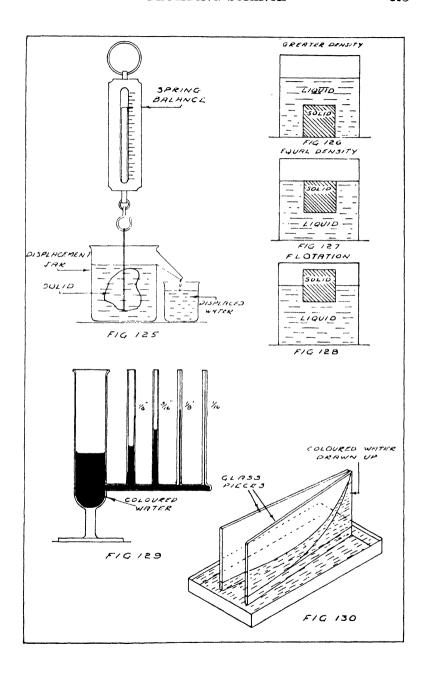
This effect is brought about by the upward force or buoyancy exerted by the water.

As the relative density of a solid decreases, so this upward force decreases until equality is reached, and the solid "floats" under the surface of the liquid (see Figs. 126, 127 and 128).

EXPERIMENT 14. Fig. 125 shows a spring balance with a solid suspended from the hook. The weight is noted first, and then the solid is immersed in water in the displacement jar as shown. The weight is again noted and then, on weighing the water which has been displaced, it will be found to equal the loss of weight shown on the spring balance.

The Principle of Archimedes has an important application in the factor of "flotation."

ř



Where a solid is less dense than water a unit volume of the solid will weigh less than the unit volume of water.

Thus when the solid is placed in water it will only be partly immersed, or what is known as float on the surface.

Where a body floats on water the water it displaces is equal to the weight of the body (see Fig. 128).

Example 11. A copper ball 6 in. in diameter floats with one-fifth of its volume submerged. What is the weight of the

copper ball? (Volume of sphere 
$$=\frac{\pi D^3}{6}$$
.)

Volume of ball  $=\frac{22 \times 1 \times 1 \times 1}{6}$ 

Volume of ball = 
$$\frac{22 \times 1 \times 1 \times 1}{7 \times 6 \times 2 \times 2 \times 2} = \frac{11}{168}$$
 cu. ft.

Volume of ball submerged 
$$=\frac{11}{168\times 5}=\frac{11}{840}$$
 cu. ft.

Weight of 1 cu. ft. of water = 62.5 lb.

Weight of copper ball = 
$$\frac{11 \times 62.5 \times 16}{840}$$
  
=  $13.09$  oz.

# Capillary Attraction

Capillary attraction, or what is sometimes called "surface tension," is the "attraction" or "repulsion" that solids and liquids have for each other.

When a liquid will wet the surface of a solid, it tends to be drawn up the surface of the solid by attractive forces. Those that will not wet the surface tend to be depressed down by repulsive forces, as illustrated in Fig. 134 (a) and (b).

The distance vertically which liquids will rise or be depressed in tubes by capillary attraction, varies inversely as the diameter of the tube.

EXPERIMENT 15. Fig. 129 shows a series of tubes with bores of varying diameters from  $\frac{1}{32}$  in. up to  $\frac{1}{4}$  in. attached to a common stem. The tubes are filled with coloured water, and the result will show the level in the standard tube A at a normal level. The levels in the small tubes will show varying levels up to the highest in the  $\frac{1}{48}$ -in. diameter bore tube.

EXPERIMENT 16. Fig. 130 shows another method of illustrating capillary attraction.

Two pieces of glass are supported on their edges with the ends at one end touching and the opposite ends spaced about in a part. The pieces of glass are held in a shallow tray containing coloured water. The water will rise almost to the top of the closed ends of the glass pieces, and curve down to the level of the water at the open ends.

Capillary attraction has to be reckoned with in plumbing work, and means adopted to prevent it.

Fig. 47 (b) in Chapter V illustrates the drip to a lead flat or gutter, where the capillary groove prevents the water rising.

Laps and passings are required to be relative to the pitch or slope of the roof in addition to the capillary groove.

Syphonage of traps on waste pipes from sanitary fittings can take place due to pieces of rag or fabric lodging on the outlet of the trap.

### Atmospheric Pressure

The air or atmosphere surrounding the earth's surface has weight, and therefore exerts pressure on the earth's surface and all bodies upon the earth.

This factor may be illustrated by the following experiment. EXPERIMENT 17. Fig. 132 shows a tumbler which has been filled up to the top carefully with water, and a sheet of firm

paper placed over the top.

A level-surface plate is held over the paper while the whole is inverted, and on removing the plate the paper will support the water in the tumbler.

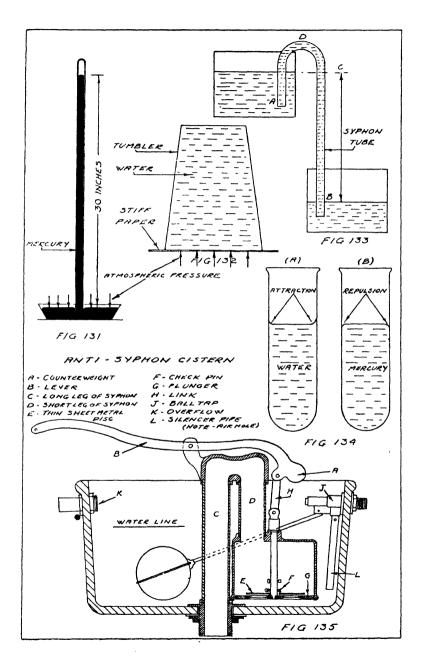
This is due to the fact that the upward pressure of the atmosphere is greater than the weight of the water acting downwards.

The pressure of the atmosphere varies according to the moisture it contains, and the position above sea level.

Atmospheric pressure can be measured by a "Barometer," which is illustrated as follows.

EXPERIMENT 18. Fig. 131 shows a glass tube about 36 in. long, which has one end sealed and is filled with mercury.

The open end of the tube is closed with the thumb while it is inverted in a basin of mercury. On releasing the mercury, it drops in the tube to a certain level, leaving the top part empty, where a vacuum exists.



The atmospheric pressure is indicated by measuring the distance from the level of the mercury in the dish to the level in the tube, which at sea level should be 30 in.

This figure reduces as the distance above sea level increases.

A barometer is used to indicate the state of weather, and the variation in atmospheric pressure can be measured according to the water vapour in the air. Wet or dry weather can therefore be anticipated by taking note of the readings.

Atmospheric pressure supporting a 30-in. column of mercury determines the pressure in terms of pressure per square inch, which is approximately 14.7 lb. per sq. in.

## Application of Atmospheric Pressure.

Atmospheric pressure makes possible the action of syphons and pumps.

**Syphons.** A definition of a syphon is a bent tube having one leg longer than the other.

EXPERIMENT 19. Fig. 133 shows a piece of glass tube bent with one leg longer than the other.

The short leg is placed in a container of water, and the long leg hanging down the outside to a lower container. Air is drawn out of the long leg by suction, drawing the water round the tube. The water flows from A to B, and continues to do so until the water in A drops below the end of the short leg.

This syphonage depends on the pressure of the atmosphere on the water at A, plus the weight of the water in the tube between C and B.

The maximum height of the short leg above the water in A must not exceed 34 ft., as in theory the atmosphere will only support a column of water not more than 34 ft. high.

At this height it exerts a pressure equal to the atmosphere. Rules for maintaining syphonage are:

- 1. BD must be longer than AD.
- 2. A must be under the water.
- 3. AD must not exceed 34 ft.

The principle of the syphon is applied in plumbing work to sanitary appliances, such as hand-operated or automatic flushing cisterns, and in emptying cylinders or tanks during repairs.

VALVELESS SYPHON CISTERN. Fig. 135 shows a section of

a valveless syphon cistern of a standard type. To flush the cistern, the lever is depressed, lifting the plunger in the bell and the water above it up the narrow tube. The water flows over the top of the syphon and down the long leg of the syphon or flush pipe. This causes a temporary vacuum at the top, and thus draws the water out of the cistern, which flows with full discharge until the cistern is empty. This action is assisted by atmospheric pressure on the water in the cistern.

AUTOMATIC FLUSHING CISTERN. Fig. 136 shows a section of a "Roger Field" type automatic flushing cistern. C forms the short leg, and B the long leg of the syphon. Water fills into the tank, and as it rises inside the dome C, compression is set up, with some of the air escaping past the water seal at A. The air hole at D allows the water to rise in the dome so far, before compression takes place.

The water reaches the top of the stand pipe B, and as it rises higher in the tank the water drops clear of the sides inside B, due to the perforated inverted cone-shaped flange at G. This dripping water absorbs air, taking it past the seal at A and thus reducing the pressure inside B. Eventually this pressure is overcome by the pressure due to the level of the water in the tank plus atmospheric pressure, and syphonage is set up, which continues until the tank is empty.

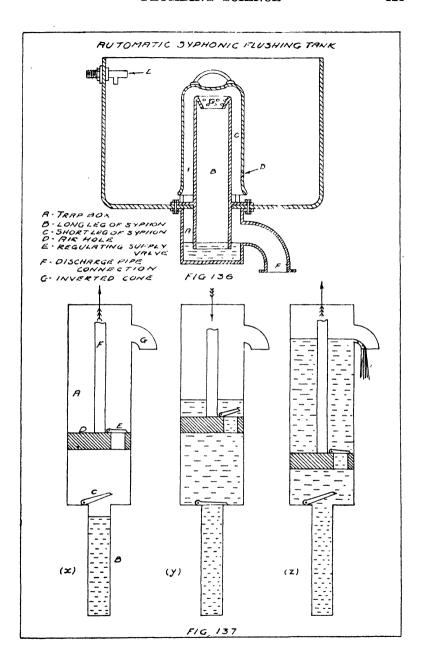
**Pumps.** A pump is used to raise water to a higher level than its source, and its working depends entirely on atmospheric pressure.

Fig. 137 shows a simple type of pump consisting of a barrel A with a pipe B attached to the base, known as the suction pipe. At the top of the suction pipe is fitted a hinged and weighted valve C, called the suction valve. The plunger or piston D slides up and down the barrel, and is fitted with a hinged and weighted valve E, and known as the bucket valve. The plunger or piston is operated by the pump rod or shaft F.

At the top of the barrel is fitted the discharge pipe or spout G.

ACTION OF A PUMP. The base of the suction pipe is under the water level, and the plunger is lifted as shown at (x), Fig. 137.

Valve E is closed and valve C opens, and the pressure in the suction pipe is reduced. The partial vacuum caused is replaced by the water rising in the pipe, assisted by the



atmospheric pressure on the water outside. On the downward stroke of the plunger valve E opens and valve C closes, and the water drawn up the suction pipe is held. On the second upward stroke E closes, C opens, the water rising further in B and into the barrel A.

On the second downward stroke E opens, C closes, and water passes through valve E as shown in (y), Fig. 137. On the third upward stroke E closes and C opens, and the water in the barrel A is lifted and discharged through the spout G, as shown in (z), Fig. 137.

As previously stated, atmospheric pressure will not support a column of water exceeding 34 ft. in height.

Theoretically a pump will not lift water more than 34 ft. below the plunger.

In actual practice it is found that a pump will not lift water more than 25 ft. below the plunger, due to the impossibility of maintaining a perfect vacuum.

Where water is required to be raised from greater depths than 25 ft., special types of pumps are used, such as suction lift, and lift and force pumps.

In these types of pumps the top of the barrel is sealed, and the spout acts as the delivery pipe, and the pump itself is fixed near the surface of the water.

### CHAPTER IX

#### DOMESTIC HOT WATER SUPPLY

THE subject of domestic hot water supply involves a very wide range of factors, but here it is only intended to cover the simple types of installation.

Some of the factors requiring consideration include the following:

- 1. The means of heating, i.e. types of fuels to be used.
- 2. Storage or instantaneous supply:
- 3. Forced or gravity circulation, which determines the design of the installation.
- 4. Type of heating unit.
- 5. Characteristic of water available.

The principle of the working of a gravity hot water system and the circulation of the water is based on the convection currents occurring in water when it is heated as explained in Chapter VIII.

The two main types of domestic hot water systems are the "storage" and "instantaneous" types.

The storage system utilises any of the fuels available such as solid fuel, gas or electricity.

The instantaneous system can only operate by the use of gas, and as a subject of an advanced character it will be omitted from this Chapter.

# Storage Hot Water Systems

Storage systems are of two main types, namely, the "cylinder" system and "tank" system.

Diagrams of the above systems are shown in Figs. 148-156.

A hot water system is comprised of the following main units:

- 1. Boiler or Heating Unit.
- 2. Cylinder or Tank.
- 3. Cold Water Storage Cistern.

### Boiler or Heating Unit.

The boiler may be one of two main types:

One type is built into the back of a fireplace and is of the block type with or without an arch flue, or shaped like a boot and known as a boot boiler (see Figs. 138, 139 and 140).

The alternative type of boiler is one known as an independent boiler, designed in the form of a water jacket to accommodate and burn solid fuel (see Fig. 141).

MATERIALS FOR BOILERS. Hot water boilers are made of the following metals: Cast iron, copper and wrought iron.

The metal selected is determined by the factor of enonomy, and the characteristics of the water supplied for use.

Cast Iron is the cheapest metal for general use and suitable for moderately soft water districts. It is not suitable for very soft water districts as the water causes rapid corrosion, and this results in discoloration of the water. Cast iron is not suitable for temporary hard water districts, as the removal of lime deposit, which has to be carried out periodically, cannot be done without the possibility of damage to the metal.

Copper is very suitable for soft and moderately soft water districts, as no corrosion or discoloration takes place. It is not suitable for hard water districts for the same reason as stated for cast iron.

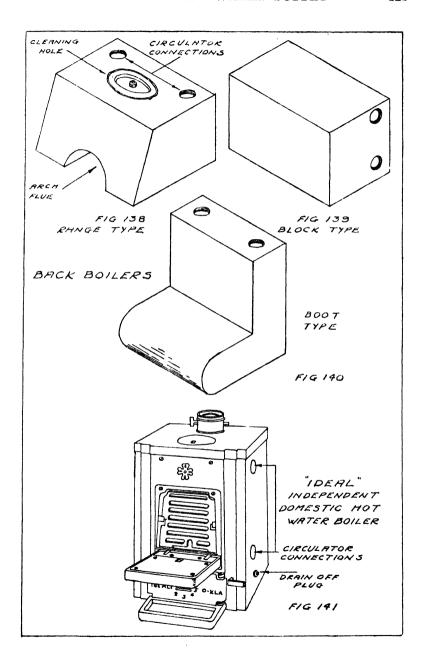
Copper is expensive and wherever coke is likely to be used as a solid fuel, rapid fire corrosion will take place, and thus the life of the boiler will be reduced.

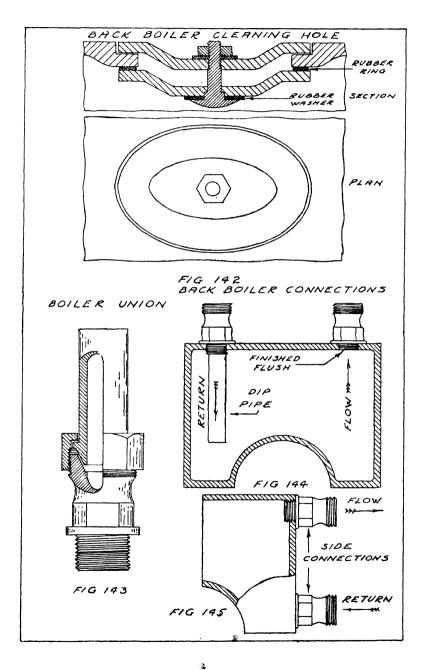
Wrought Iron is very suitable for hard water districts, as it will withstand hard treatment in the process of the removal of lime deposit. It is not suitable for soft water districts, as corrosion and discoloration are very rapid.

CLEANING HOLE. Where access to the inside of the boiler is required for cleaning and scaling purposes, the boiler is provided with a cleaning hole as shown in Fig. 142.

The opening is elliptical in shape, which enables the inner plate to be inserted inside the boiler complete with the rubber packing ring. The outer plate or bridge piece acts as a bearing for tightening the nut on the bolt to pull the inner plate up and make it watertight.

BOILER CONNECTIONS. The positions of the connections to a back boiler vary according to the type of range or fireplace into which it is fitted.





Alternative positions are shown in Figs. 144 and 145 and in the former both connections are shown on the top. In this case it is necessary to fit an extension tube known as a dip pipe as shown, and this is screwed into the return pipe connection.

The dip pipe directs the cooler or return water to the bottom of the boiler and ensures an efficient and rapid circulation of the water between the boiler and cylinder.

The pipe connections to the boiler are made with boiler unions (see Fig. 143) fitted with a tail pipe to join to a lead pipe. Special fittings are designed to connect to light- or heavy-gauge copper tubes.

Where the flow connection is fitted to the top of a boiler, there should be no projection on the underside, but a flush finish (see Fig. 144).

Likewise, where the flow connection is in the side it must be made as near to the top as possible (see Fig. 145).

These requirements are necessary to avoid a steam pocket forming at the top of the boiler or the trapping of air, which may cause the metal in this portion of the boiler to be rapidly burnt away.

# Cylinder or Tank.

A cylinder or tank serves the same purpose, namely, the storage of hot water.

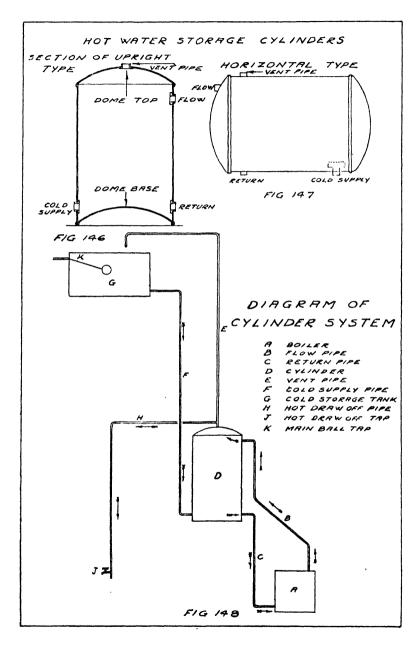
Cylinders. The cylinder is the most commonly used, as its shape give maximum strength to withstand water pressure when made of relatively light-gauge sheet metal.

The cylindrical shape is also convenient for the general type of installation, where it is fixed in an upright position. Fig. 146 shows a section of a cylinder for upright fixing, where the dome top and base also give strength to withstand internal pressure.

Cylinders are sometimes fixed in a horizontal position, and in these cases the dome ends are fitted externally at both ends (see Fig. 147).

MATERIALS FOR CYLINDERS. Cylinders are made of copper and wrought iron sheeting.

Copper is the most common in use, as it is suitable for most types of installations. It is clean and does not cause any



corrosion or discoloration of the water. A copper cylinder should be made with its seams brazed and welted.

Wrought Iron is suitable for heavy duty work where the storage vessel is liable to be damaged. Wrought iron cylinders are made with welded and riveted seams, and galvanised to protect the metal from corrosion.

In spite of this protection they are only suitable for very hard water districts.

Tanks. A hot water storage tank is usually rectangular in shape, and has a bolted manlid cover (see Fig. 156).

MATERIALS FOR TANKS. Tanks are made of wrought iron or mild steel sheeting to withstand the water pressure due to their shape, and are made with welded and riveted seams.

They are galvanised for protection against corrosion, and as referred to under Cylinders are only suitable for very hard water districts.

## Cold Water Storage Cistern.

This cistern may be the cold water storage supply for the whole of the premises. It supplies all the cold water taps not supplied direct from the main, in addition to the hot water supply.

The type of cold storage tank does not influence the working of a hot water system, provided there is an adequate storage of cold water to meet the demand for hot water from the system over a specified period.

# Design of a Storage System

The principles governing the design of a storage hot water system are the provision of a vessel of adequate size or storage, to contain the amount of hot water required in a specified time.

The next consideration is a boiler or heating unit, with sufficient heating surface to heat the quantity of water in the hot storage vessel efficiently and rapidly.

This must be followed by an adequate cold water storage, to replace the hot water storage as it is withdrawn.

It will be observed from the above that the three important units to be considered are the boiler, hot storage and cold storage. The positions in which they are fixed have to be considered in relation to each other and the arrangement of the necessary pipes to and from them.

# Cylinder System.

Fig. 148 shows a line diagram of the details of a simple cylinder system.

A-Boiler or Heating Unit.

B-Flow Circulating Pipe.

C—Return Circulating Pipe.

D—Cylinder for Hot Water Storage.

E-Expansion Relief, or Vent Pipe.

F-Cold Water Supply Pipe.

G-Cold Water Storage Cistern.

H—Hot Water Draw Off Pipe.

J-Hot Water Draw Off Tap.

K-Ball Tap Controlling Main Water Supply.

Circulating Pipes. The flow and return pipes (B and C, Fig. 148) are known as the circulating pipes between the boiler and cylinder. The cylinder D should be fixed as near to the boiler A as possible, and in an elevated position with its base level with or above the top of the boiler. This means that the circulating pipes are kept short, and they should be kept as short as possible when considering the situation for the cylinder in relation to the boiler.

The circulating pipes should not be less than  $\frac{3}{4}$  in. diameter, and where any horizontal position is encountered they should be fixed with a good fall towards the boiler. This promotes circulation and avoids the formation of air pockets in the pipes.

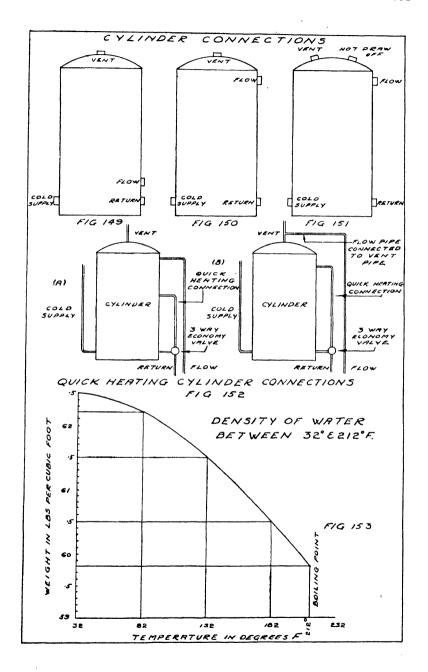
Cylinder Connections. The positions of the connections vary according to the particular circumstances and requirements.

Fig. 149 shows the standard positions for cylinder connections.

In this case, when the heated water from the boiler passes into the cylinder, it has to pass through the body of colder water to reach the top to accumulate.

This makes the process of heating the cylinder water a long one.

The alternative position for the flow pipe connection shown in Fig. 150 eliminates this fault, and speeds up the delivery



of hot water in the top of the cylinder. Thus a small amount of hot water is made available in a comparatively short space of time.

Fig. 152 (a) and (b) shows the alternative arrangements of the pipes to include the three-way valve, which makes possible the use of part or the whole of the hot water storage.

When the circulating pipes are being fixed and connected particular care has to be exercised to see that the return pipe is connected to the return pipe connection on the boiler.

Should the connection be reversed the circulation will be reversed, and the heating of the hot water will be sluggish and unsatisfactory.

Fig. 148 shows the direction of the circulation of the water. The heated water in the boiler becomes less dense, and is pushed out or displaced through the flow pipe to the cylinder. In the cylinder it meets cold water of a greater density, and here again it rises to the top of the cylinder.

The chart shown in Fig. 153 indicates the change in density of water when it is heated from 30° F. to 212° F.

Expansion or Vent Pipe. This serves as a relief pipe to enable the system to be filled with water, and acts as an outlet for air and steam from the hot water, particularly when overheating occurs.

The vent pipe should not be less than  $\frac{3}{4}$  in. diameter. No part of the pipe run should be fixed horizontally, but fixed vertically or with a good fall rising from the top of the cylinder.

The open end of the vent pipe may be arranged to discharge over the cold water storage cistern, or fitted through the roof to discharge outside.

The usual method is to turn the end over the cold water cistern.

When the water in the system is heated, the water level in the vent pipe will be higher than the level in the cold water eistern.

To allow for this expansion an allowance of I in. for each vertical foot head of cold water column is made in the height of the vent pipe above the cold water tank level.

It is important that any part of the vent pipe containing water which is liable to freezing should be well protected.

Also, when the end of the vent pipe is turned over the cold water cistern, it should not be allowed to dip into the water in the cistern. This precaution is necessary to avoid syphonic action or a circulation of water to the storage cistern which can take place.

Cold Water Supply Pipe. This pipe keeps the system filled with water to replace the hot water withdrawn.

It should be connected at the lowest point on the cylinder, and as far away as possible from the circulating pipe connections, but never connected to the boiler or the return pipe.

The size of the cold water feed pipe is important, as it should be adequate to cope with the withdrawal of hot water, and this is affected by the head of water available.

When a hot water tap is opened on the system shown in Fig. 149, the water level in the vent pipe falls. If the hot water withdrawn is not replaced by the inflow of cold water, this fall will drop below the hot branch and cut the hot supply, or result in an erratic spluttering supply of air and water.

Any control valve fixed on the cold water feed pipe should be of a full-way type, and be fixed as near as possible to the cold water storage cistern. For convenience a control valve may also be fixed near to the cylinder.

Hot Water Supply Pipe and Tap. The hot water supply pipe should be connected to the vent pipe as close as possible to the top of the cylinder. Usually a tee-piece fitting is used immediately on the top of the cylinder for this purpose. No hot water supply pipe should be connected to the cylinder below the top connection, as it is necessary to ensure that the cylinder remains full of water at all times.

Where the cold water storage tank is fixed immediately above the hot storage cylinder, the danger of drawing air at the hot tap is more pronounced.

This can be avoided by fixing a large-size cold water pipe, or by having a separate connection on the top of the cylinder for the hot water pipe in addition to the vent pipe connection (see Fig. 151).

## Electric Immersion Heater.

An alternative means of heating the water in the hot storage cylinder without interfering with the existing system, is the introduction of an "electric immersion heater."

An immersion heater is an enclosed and protected electric heating element inserted into the shell of the storage cylinder

and made watertight. The water surrounding the element is heated, and circulates within the cylinder.

Up-to-date models of immersion heaters are fitted with a thermostat control, which switches the electric power on and off when the temperature of the water falls below or rises above a predetermined figure.

Immersion heaters are fixed in the side or on the top of a cylinder, and where they are fixed in the top they are of varying lengths according to the immediate amount of water required to be heated.

Immersion heaters fixed on the top of a cylinder have a metal tube enclosing the element (see Fig. 154), which is open at the bottom and has slots at the top, as shown. This tube is fitted to promote a definite circulation within the cylinder, where the heated water within the tube rises and exits through the slots, and is replaced by the cold water entering at the bottom.

### Tank System.

A tank system arrangement is shown in Fig. 156. It is similar in most details to the cylinder system.

The hot storage tank D is fixed on an upper floor, and thus the circulating pipes are lengthy, which means greater heat losses.

The flow pipe connection to the hot storage tank is situated half-way or one-third of the way down from the top of the tank.

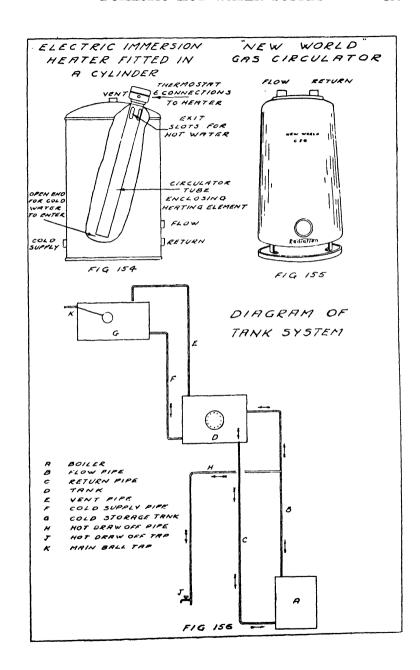
The hot water supply pipe is connected to the flow pipe between the boiler and hot storage tank.

The main drawback of this system is that water is drawn from two directions when hot water is withdrawn.

Water is drawn from the boiler and the hot storage tank simultaneously, and when the small capacity of hot water in the boiler is withdrawn it is quickly replaced by cold water, which is discharged at the hot tap.

This results in the supply of a tepid mixture of water, leaving hot water in the hot storage tank.

A separate hot water supply pipe may be taken from the hot storage tank to avoid the possibility of this mixing of hot and cold water.



#### Gas Circulators.

Where gas is available, a modern gas circulator will serve as the main source of domestic hot water, or as an auxiliary, or a summer alternative to an existing solid fuel boiler.

A gas circulator is a compact unit designed to heat the water in a storage tank or cylinder; cold water from the cylinder passes to the heater, where it is heated, and back to the cylinder, through "circulating" pipes.

The stored hot water can be drawn off for use at a high flow rate, limited only by the size of the pipes and hot water taps.

The gas to the circulator is reduced or shut off by a thermostat, when the circulating water is fully heated. A small pilot light ignites the main burner and also operates a safety device.

Fig. 155 shows a "New World" gas circulator; this has a heat exchange made of corrosion-resisting metal, and it can be left working for very long periods with a minimum of attention by the Gas Fitter.

The use of an Economy Valve with a gas circulator enables the user to have available either a few gallons of hot water for domestic needs, or a larger quantity for baths, thus effecting economy in fuel cost.

#### CHAPTER X

### SIMPLE HYDROSTATICS

This is a subject where the pressure of a liquid is considered when it is static or at rest. For our purpose, water is our main consideration.

Water finds its own level at all times. Water has weight and therefore exerts pressure.

EXPERIMENT 20. A simple demonstration of water pressure may be carried out by taking a glass tube shaped as shown in Fig. 157 and filling the bend with mercury to the top of the short leg. The tube is lowered into water, as shown, and the mercury will be seen to rise in the long leg. The lower the tube is immersed into the water the higher the mercury will rise.

#### Pascal's Law.

Water transmits pressure equally in all directions at any point.

This characteristic of water was discovered by Pascal, who demonstrated his theory by using what is now known as Pascal's Vases.

EXPERIMENT 21. Fig. 158 shows various shaped glass vessels, all the same length and with the same base sectional area. The ends are open and the lower ends are covered with metal plates, held in position with strings.

Each vessel is lowered into water to the same depth, and the plate is found to be held in position by the pressure or upward thrust of the water when the string is released.

Water is poured carefully into the vessel, and it is found that the plate does not fall away until the water inside reaches the level of the water on the outside. This is the result of the downward and upward thrusts being equalised.

The purpose of the varied shaped vessels is shown by comparing the results on repeating the above procedure for each vessel in turn.

It is found that on immersing each vessel the equalising of the levels of water is the deciding factor, and not the quantity of water poured into the vessel. Head of Water. The pressure exerted by water due to its depth or height is known as the "head of water," or "pressure due to head of water."

This head of water is always measured vertically.

Unit of Pressure. Pressure of water on a surface is measured per unit area, which is one square inch and expressed in terms of lbs. and fractions of a lb.

#### Water Pressure.

The base of a tank or container holding water is subject to pressure due to the weight of water. This pressure remains constant so long as the depth of the water does not alter.

The quantity of water in the tank does not influence the pressure on a unit area of one square inch of the base.

Any increase in size and capacity of the tank without increasing the depth would only increase the quantity of water proportionately.

### TABLE OF WATER CONSTANTS

1 cubic foot of water	==	62.5	lb.
1 cubic foot of water	==	6.25	gallons
1 cubic foot of water	==	1,000	oz.
1 gallon of water	==	0.16	cubic foot
1 gallon of water	==	10	lb.
1 gallon of water	==	$266 \cdot 274$	cubic inches
1 cubic inch of water	==	0.036	lb.
1 cubic inch of water	==	0.0036	gallons
35.6 cubic feet of water	=	1	ton
224 gallons of water	=	1	ton

The above constants are given for water at 4°C.

To calculate the pressure on a unit area of 1 sq. in. when given the head of water, it is first of all necessary to know the weight of, or the pressure exerted by, a 1-ft. column of water on 1 sq. in.

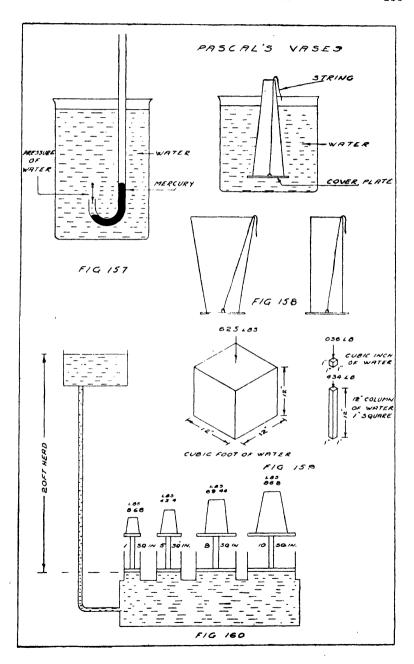
One cubic foot of water weighs 62.5 lb., and this weight is exerted on an area of 12 in.  $\times$  12 in. or 144 sq. in.

Therefore the weight exerted on each square inch

$$= \frac{62.5}{144} = \underline{0.434 \text{ lb.}}$$

A column of water 1 in. square and 12 in. high weighs 0.434 lb. (Fig. 159).

To calculate the pressure per square inch due to head of



or

water, the head in feet is multiplied by 0.434, giving the answer in pounds per square inch.

Example 1. A boiler is fixed 50 ft. below a supply tank. What is the pressure per square inch exerted on the boiler?

```
Head of water = 50 ft.

Pressure for 1 ft. head = 0.434 lb.

Pressure = 0.434 \times 50

= 21.7 lb. per sq. in.
```

Where pressure on a surface area is required, as distinct from the pressure on a unit area, a practical example of Pascal's Law is involved.

First, the pressure per unit area is required and this is multiplied by the total area subject to the pressure.

Example 2. A boiler with 5 sq. ft. of interior surface is fixed 38 ft. below a supply tank. What is the total pressure on the interior surface of the boiler?

```
Head of water = 38 ft.

Pressure for 1 ft. head = 0.434 lb.

Surface area = 144 \times 5 sq. in.

Pressure per square inch = 0.434 \times 38

= 16.492 lb. per sq. in.

Total pressure = 16.492 \times 144 \times 5

= 11874.24 lb.

= 5 tons 6 cwt. 2 lb.
```

From the above example it will be seen that the total pressure on a surface increases in direct proportion to the increase in area of the surface.

EXPERIMENT 22. An apparatus to demonstrate the above conclusion is shown in Fig. 160. The head of water is 20 ft., and the area of each piston varies as shown. To balance the upward thrust or pressure of the water the weights as they are indicated have to be increased proportional to the increase in area of the pistons.

This characteristic of a liquid or water, where a small force can be utilised to exert a much greater force, has many important practical applications.

When fluid or water is used in an appliance for pressure application it is known as a hydraulic apparatus.

Hydraulic appliances include hydraulic lifts, hydraulic

presses for compressing substances, hydraulic operating mechanism in vehicles and aircraft.

All these appliances work on the principle of the mechanical advantage of the pressure on a small area being multiplied over a large area.

Example 3. A safety valve fitted on a heating boiler is of the dead weight type. The orifice of the valve is  $\frac{3}{4}$  in. diameter and the level of the water in the supply tank is 40 ft. above the valve.

What weight will have to be placed on the valve to equal the pressure of water?

Diameter of valve 
$$=\frac{3}{4}$$
 in.  
Head of water  $=40$  ft.

Area of valve  $=\frac{22}{7} \times \frac{3}{4 \times 2} \times \frac{3}{4 \times 2}$ 
 $=0.442$  sq. in.

Pressure per square inch  $=0.434 \times 40$ 
 $=17.36$  lb. per sq. in.

Weight required on the valve  $=17.36 \times 0.442$ 
 $=7.672$  lb.

Example 4. A back boiler has inside dimensions of 12 in. by 10 in. by 9 in. deep, and it is subject to a 45-ft. head of water from its base. What is (a) the pressure per square inch on the base and (b) the total pressure on the interior surface?

(a) Pressure per square inch on base = 
$$0.434 \times 45$$
  
=  $19.53$  lb. per sq. in.

(b) Mean pressure per square inch = 
$$0.434 \times (45 \text{ ft.} - 5 \text{ in.})$$
  
=  $0.434 \times 44.58$   
=  $19.35 \text{ lb. per sq. in.}$ 

Internal area of boiler

(top and base) = 
$$12 \times 10 \times 2 = 240$$
  
(sides) =  $12 \times 9 \times 2 = 216$   
(ends) =  $10 \times 9 \times 2 = 180$   
Total area = 636 sq. in.

Total pressure on internal boiler surface

$$= 19.35 \times 636$$
  
= 12,306 lb.  
= 5 tons 9 cwt. 98 lb.

When calculating the pressure in storage cisterns, the pressure on the base of a cistern with perpendicular sides is equal to the weight of the water in the tank.

The pressure against the side of a tank is found by multiplying the area of the side by half the depth of the water, or the mean depth.

The pressure per unit area against the side at the surface of the water is nil, and at the bottom of the tank the pressure is the maximum, equal to the full depth of the water. Therefore, the mean pressure will be equal to the mean depth of the water in the tank, i.e. the top plus bottom pressures divided by two.

Example 5. A tank measures 6 ft. square by 5 ft. deep. Calculate the pressure (a) on the base and (b) on one side of the tank when it is full of water.

(a) Volume of tank =  $6 \times 6 \times 5 = 180$  cu. ft.

Total pressure on base of tank =  $180 \times 62.5 = 11,250$  lb.

or

= 5 tons 0 cwt. 50 lb.(b) Mean depth of water

Pressure on side of tank =  $6 \times 5 \times 62.5 \times 2.5$ = 4687.5 lb.

= 2 tons 1 cwt. 95.5 lb.

 $\mathbf{or}$ 

# Calculating Capacities of Pipes and Cylinders.

In calculating the capacity of a pipe or cylinder two simple formulæ may be used. The formulæ are evolved to include the use of the diameter in terms of inches and the length in terms of feet and the results obtained are approximate.

The capacity of 1 ft. length or 12 in. of a pipe

$$= 3.1416 \times \frac{D}{2} \times \frac{D}{2} \times 12 \times 0.036$$

$$= \frac{D^{2} \times 0.34 \text{ lb.}}{2 \times 2}$$
or
$$= 3.1416 \times \frac{D}{2} \times \frac{D}{2} \times 12 \times 0.0036$$

$$= \frac{D^{2} \times 0.034 \text{ gallons}}{2 \times 2 \times 2}$$

Where D = diameter of pipe in inches 0.036 = weight in pounds of 1 cu. in. of water.0.0036 = gallons in 1 cu. in. of water. Using the above formulæ, the capacity of a pipe or cylinder can be obtained by multiplying by the length in feet.

Example 6. An 8-in. diameter pipe is 50 ft. in length. Calculate the capacity of the pipe in gallons.

No. of gallons in 1 ft. length of 8-in. diameter pipe

$$= 8 \times 8 \times 0.034$$
 gallons

No. of gallons in 50 ft. of 8-in. pipe = 
$$8 \times 8 \times 0.034 \times 50$$
  
=  $108.8$  gallons

Example 7. A 7-in. diameter pipe has water flowing through it at half bore and the rate of flow is 6 ft. per second discharging into a tank. Find the time taken to fill the tank, which has a capacity of 2000 gallons.

Gallons capacity of 1 ft. of 7-in. pipe =  $7 \times 7 \times 0.034$  gallons Gallons capacity of 6 ft. of 7-in. pipe at half bore

$$=\frac{7\times7\times0.034\times6}{2}$$

Discharge per second = 4.998 gallons

Time taken to fill tank =  $\frac{2000}{4.998}$ 

= 400 seconds

= 6 minutes 40 seconds

Example 8. A cylindrical tank with square ends is to be fixed in a horizontal position. The tank is 2 ft. 6 in. diameter and 12 ft. long. What weight of water will have to be considered in erecting supports for the tank?

Weight of water in 1 ft. length of tank =  $30 \times 30 \times 0.34$  lb.

Total weight of water in tank =  $30 \times 30 \times 0.34 \times 12$ 

= 3672 lb.

= 1 ton 12 cwt. 88 lb.

#### CHAPTER XI

#### WORKSHOP PRACTICE

PRACTICAL work as carried out in a workshop for the purpose of giving instruction to trade students has a limited scope.

The general nature of the instruction includes bossing of sheet lead; pipe jointing and bending in lead, copper and wrought iron; welding; and the manipulation of sheet copper and zinc.

In this chapter it is only intended to deal with the elementary practical workshop exercises.

Inability of a student to carry out exercise work correctly and efficiently is nearly always due to an incorrect approach and wrong procedure.

Too much emphasis cannot be made in this matter of correct approach and procedure in the execution of practical work, and the development of good craftsmanship.

Correct approach to a job shows a measure of confidence. Correct procedure, when developed, becomes automatic and makes for the best use of all the tools with a minimum of energy, coupled with speed and first-class workmanship.

# Lead Pipe Jointing

Pipe jointing is a major part of plumbing work. The soundness and efficiency of a joint is always dependent upon the thoroughness of the preparation. Whatever jointing substances are used in the way of solder or composition, they only serve to complete the joint in whatever shapes or finish they may take.

Therefore correct preparation should be concentrated on at all times.

In commencing the preparation of straight or branch joints there are two essential requirements.

The first essential is to straighten the end of the pipe. This can be done by dressing the pipe on the bench with a flat dresser, or inserting the taper end of a bent bolt in the bore of the pipe and straightening the pipe by hand manipulation.

Care should be exercised in the use of the bent bolt to avoid damage to the inside of the pipe.

Straightening of lead pipe by hand manipulation is more efficient and satisfactory than by the use of brute force. The use of a hammer or mallet, etc., only tends to indent and distort the shape of the pipe.

Secondly, the end of the pipe should be squared with a rasp or a sharp knife, and any surplus burr cut off inside the pipe.

## Gas Pipe Joints

## Lip Joint.

The end of the top length of pipe is bevelled with a knife or universal jointer. The other end to be joined is opened out with a small turnpin sufficient to receive the bevelled end, and leave a lip for solder (see Fig. 71).

The outside surface of the bevelled end and the inside of the socket end are scraped clean, and tallow applied. The ends are brought together and made secure. The blowpipe solder is heated in the blowpipe flame, and dipped into the resin which adheres to the solder. The resin is then applied to the joint while being heated.

When sufficient resin has been applied round the joint it is heated up to the melting-point of the solder, which melts and flows freely round the joint. When the lip is completely and evenly filled with solder the blowpipe flame is removed.

Tallow is applied to the pipe above the joint to melt and run on to it to prevent the flux from setting hard.

The joint is then wiped with a cloth to leave it clean, with all the tallow and resin removed.

#### Tee Joint.

The end of the branch pipe is first bevelled with a knife, jointer, file or fine rasp, and the position for the branch marked on the main pipe. The point of a sharp stout knife or an auger is pierced into the main pipe by a continuous twisting, and a hole made about  $\frac{1}{4}$  in. in diameter. The taper tang end of a pair of gas pliers is inserted in the hole, and with the use of a hammer it is opened out to receive the branch pipe. Care should be taken to see that the branch pipe does not project

into the main pipe. The end and socket are cleaned and jointed in a similar manner to the lip joint.

## Water Pipe Joints

### Underhand Wiped Joint.

One end of the pipe is bevelled with a rasp, and the other end is opened out with a turnpin just sufficient to house the bevelled end.

The projecting edge on the opened end is rasped level with the pipe (see Fig. 161).

Lampblack or tarnish is applied to the pipe not less than  $3\frac{1}{2}$  in. from the ends, but not before all traces of grease have been removed. The grease can be removed by rubbing the pipe with chalk or an abrasive, such as card wire or steel wool. This grease may originate from the tallow in use or from the sweat of the hands.

The tarnish is allowed to dry, and the two ends put together. Measuring equally on each side of the joint the length of the joint is marked, anything from  $2\frac{1}{2}$  in. to  $3\frac{1}{4}$  in. long. With the use of a shavehook, the pipe ends are shaved or cleaned, and then tallow applied. The inside wall of the socket end should also be cleaned inside and tallowed.

The joint is assembled and fixed securely to eliminate any movement—this is most essential. The joint is now ready for making with a blowlamp, or molten solder from a metal pot.

Where the joint is to be made with molten solder from a metal pot, the tarnish should be applied 3 to 4 in. longer on the pipe ends.

Blowlamp Jointing. With a blowlamp in working order, and a tray placed underneath the joint to catch the surplus solder, and the wiping cloth set in position, all is in order to proceed.

The joint is heated to the melting-point of the plumber's solder, and completely tinned with the solder. The solder bar is then melted off on to the joint until sufficient has been placed to complete the joint.

With the wiping cloth in the palm of the left hand, and held underneath the joint, the solder pile is melted on to the cloth. At the same time the pipe on each side of the joint is heated. The molten solder, now changed to a plastic mass,

is shaped round the joint roughly, and then wiping of the joint commences.

Wiping is continued, keeping the solder plastic by applying heat, always in the same direction; that is, up at the front, over and down the back.

The edges of the joint should be wiped clean to the margins of the tarnish.

Having completed a perfectly clean joint with the surplus solder brought on to the top, this is wiped off lengthways with a piece of linen or coarse cloth.

Metal Pot Jointing. First the solder must be melted and at the correct heat. Often the solder will be found to be too hot, and a simple temperature test is to dip a spill of paper into the solder, and if the paper chars rapidly it indicates that the temperature is too high.

Solder which is too hot requires skilful manipulation.

Care should be exercised to see that the ladle to be used is warmed before inserting it into the molten solder, to avoid condensation causing the metal to fly.

Small pellets of solder may be run out and left to cool. These can be used to cool a ladle of hot solder when required.

On commencing to practise making a wiped joint, it is advised that a ladle half full of solder be taken from the pot. A full ladle should not be taken, as it may be too heavy for a student to hold over a period.

The standing position in wiping an underhand joint is at the right-hand end, with the right side to the bench. The ladle should be held on the back side of the joint, and the cloth in the left hand under the joint. Pouring the solder on to the joint as slowly as possible, the movement should be backwards and forwards parallel with the pipe. The solder should be poured on the joint and on the pipe 4 in. on either side of the joint to heat the pipe.

The movement of the cloth should coincide with the movement of the ladle so as to catch the solder. Any solder which collects on the wiping cloth should be placed on the top of the joint, while at the same time holding the ladle under the joint to catch any surplus solder dropping. This should be done periodically.

As the pipe gets hotter, the molten solder runs off, and that which is held on the cloth tins the joint underneath.

When the pipe is sufficiently heated, and enough solder is on the pipe, the ladle is laid down. Taking the cloth, the surplus solder on either side of the joint is removed and the joint shaped and cleaned off before the solder loses its plasticity and becomes hard.

### **Branch Joint**

The end of the branch pipe is bevelled with a rasp, and the position for the branch marked on the main pipe. On this mark, a hole about  $\frac{3}{8}$  in diameter is pierced with a plumber's auger. Using the taper end of a bent bolt and a hammer, the hole is opened out as shown in Fig. 163 to receive the branch pipe. The bent bolt should be used as shown to prevent a burr forming on the inside of the bore. Care should be taken to see that the branch pipe does not project into the main pipe (Fig. 164).

The branch pipe and main pipe are now tarnished, not less than 3 in. from the end and the branch socket.

The tarnish is allowed to dry, and the branch pipe shaved 1 in. from the shoulder of the bevel. The main pipe should be shaved 1 in. on either side of the socket, and half-way down the diameter of the pipe.

Tallow is now applied to the shaved parts, and the joint assembled with the branch pipe in an upright position and made secure.

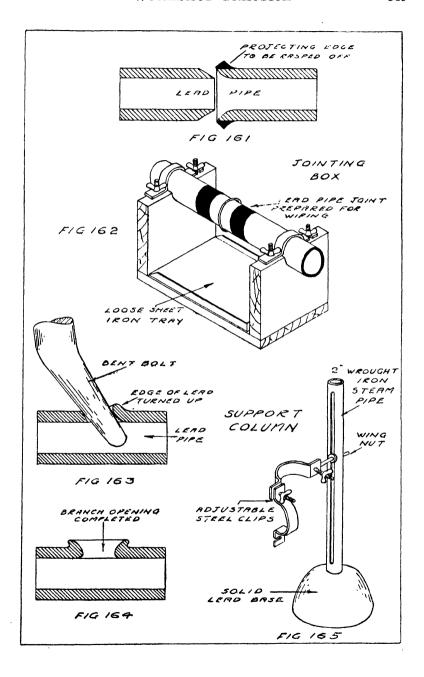
Blowlamp Jointing. First the joint is tinned, and then sufficient solder melted on to the joint to complete the shape.

While the solder is in a plastic condition, it is shaped by working the solder from the back to the front and cleaning off downwards the surplus at the front. A wiping cloth about 2 in. wide is used to make this joint.

Metal Pot Jointing. Having assembled and secured the joint, a tray is placed underneath the joint to catch the solder droppings.

Solder is splashed on to the joint from a ladle with a splash stick to tin it.

Then the solder is splashed on the upright pipe, and along the main pipe until it runs off, and then sufficient is placed on the joint to shape it. Wiping is done from the back to the front, and round the top edge first. Finally the joint is



shaped, keeping the edges clean, and the surplus solder wiped off downwards at the front.

## Securing Pipes for Joint Wiping

Many and varied methods are adopted for securing lead pipes for joint wiping.

In many school establishments the joint wiping is strictly confined to one particular bench, but this is not always possible where facilities are restricted.

The following methods described are adaptable for any circumstances, and allow for complete freedom of movement for working positions.

For underhand joints a box or frame as shown in Fig. 162 is adaptable to any size of pipe, where the shaped steel clips can be reversed and screwed down with the wing nuts.

The box is made of stout timber, and fitted with a loose sheet iron tray for catching the surplus solder. The tray should have one end open to allow the solder to slide out into the metal pot when it is being emptied.

For branch joints, the box as described above can be used for supporting the main pipe, and a support column used, as shown in Fig. 165, to support the branch pipe.

This support column can be made in the workshop and proves invaluable for supporting all sizes of branches, and pipe joints erected for upright wiping, as it can be moved to any position.

The column consists of a 24-in. length of 2-in. diameter wrought iron steam pipe. This pipe has a slot  $\frac{1}{2}$  in. wide cut down opposite sides as shown, up to 1 in. from the top end and 6 in. from the other end.

The pipe is stood upright in an 8- or 10-in. diameter metal pot full of molten lead, with the top end in the lead.

Prior to placing the tube in the lead the bore will require to be plugged at the end and part filled with sand, to prevent the molten lead getting inside.

When the lead is cooled it is lifted out with the pipe, the whole reversed, and the lead block slid down the tube by ramming the tube on the floor. The result is a level base of lead supporting the slotted pipe as shown.

The slot in the pipe is fitted with clamps and wing nuts

as shown, which can be moved and interchanged according to the size of pipe in use.

These columns eliminate the necessity of using string and pieces of wood for supports. They are also very useful where universal jointed pipe clamps are used.

### Copper Bit Work

This is a method of jointing sheet lead and pipes and was commonly used in old-time plumbing.

Before lead pipes and traps were made by the extrusion process in hydraulic presses, they had to be made and worked from sheet lead. The joint consisted of a copper bit seam made with tinman's solder.

To join two pieces of sheet lead, the edges to be joined are first trimmed straight and then chamfered to eliminate any gaps. The faces of the lead pieces are tarnished 1 in. from the edge, and then shaved  $\frac{1}{8}$  in. to  $\frac{1}{4}$  in. from the edge. To get the shaving straight, a steel rule or straight-edge should be used as a guide for the shavehook.

The shaved edges are tallowed and then brought together. A large soldering iron is used for this work to retain the heat for a long period. Powdered resin is the flux used, and this is sprinkled lightly along the seam.

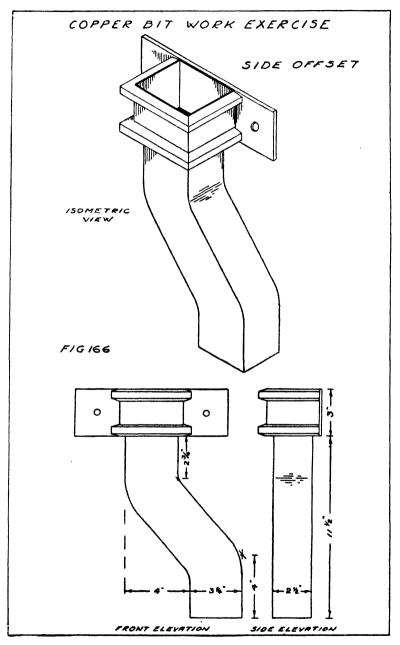
The heated soldering iron is applied to the stick of solder, and melted on to the seam. The ends of the seam are tacked together first before proceeding to complete the seam.

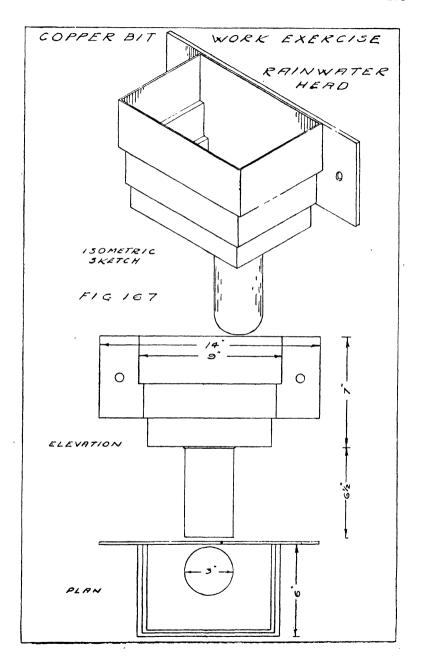
The soldering iron does not touch the lead, but the heat is transmitted to it through the solder, and the solder is floated to form the seam. The solder is fed to the soldering iron, which is moved along the seam without the iron being lifted away until it is completed.

This method of jointing sheet lead is readily adaptable for the purpose of fabricating decorative rainwater pipe sections and rainwater heads as workshop exercises.

Examples of exercises which can be carried out by students in the above work are shown in Figs. 166 and 167.

Added features and modifications can be easily introduced to retain the student's interest in this creative work.





## Working Sheet Lead

The most important point to avoid in the working of sheet lead is creasing or kinking of the lead. Also, if it is folded too sharply it causes the lead to crack on opening it out again.

Thus any sign of buckling or creasing should be avoided during the whole process of working or bossing.

While the working or bossing is being carried out the thickness of the lead must be maintained as evenly as possible.

The examples of leadwork to be described are commonly used in roofwork, and include the external corner, internal corner or break, and lead slate.

#### Procedure.

Correct procedure is most important, and first the lead should be set out correctly with chalk, and using a steel square which is usually 24 in. by 18 in. and marked in inches and eighths. When the lead is being marked out, one corner should be set out square and the remaining measurements taken from it.

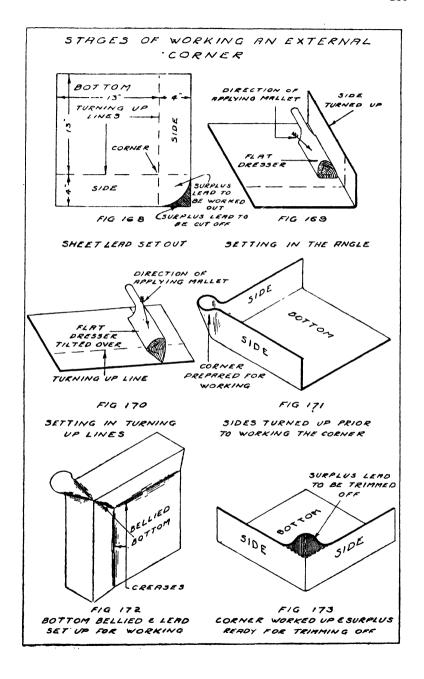
Where large pieces of lead are being handled on roofwork, a long wood straight-edge or chalk line is used for marking out.

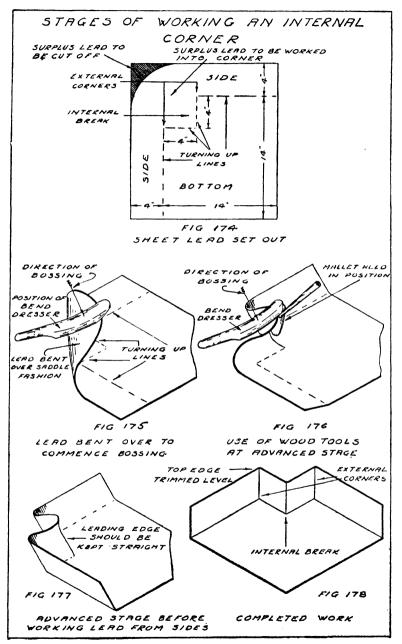
### External Corner.

In the case of an external corner to be worked in sheet lead, the lead is set out as shown in Fig. 168.

If the corner was to be soldered up, the corner piece would be cut out, but in this case it has to be worked out, and to facilitate this some of the surplus should be cut off as shown. Next the turning up lines should be "set in" with the setting-in edge of a flat dresser and a mallet (see Fig. 170). Next the sides require to be turned up, and this may be done by the use of a flat dresser or a block of wood, say 4 in. by 4 in. by 12 in. long. The edge of the dresser or block should be placed in from the turning line, and held down firmly in position with one hand, and the other hand spread out under the side to be turned up, and the side lifted up smartly.

The outer face of the side would be dressed up reasonably straight, and this followed by slightly setting in the angle formed on the inside with the setting in edge of a flat dresser (see Fig. 169).





This procedure would be repeated for the other side, and the result would be as shown in Fig. 171. Next the under side of the bottom would be bellied, as shown in Fig. 172, with the edge of a flat dresser. This strengthens the corner, and prevents it curling up while being worked.

The lead is now ready for working, and is arranged to stand up conveniently, as shown in Fig. 172.

The wood tools used for bossing and working a corner are a bossing stick and bossing mallet.

The mallet is held on the inside, while the bossing stick is exercised on the outside to work and move the surplus lead out of the corner. The bossing is commenced about 1 in. from the bottom, and the lead worked down to the bottom of the corner to fix and consolidate the angle.

Following this, the lead is worked and bossed up to the top of the sides, the lead being laminated between the mallet and the bossing stick. The angle or corner should be kept rounded all the time, and made sharper and finished off when bossing is completed.

The surplus lead should be trimmed level with the sides on completion (see Fig. 173), and the bellied bottom flattened down.

#### Internal Break or Corner.

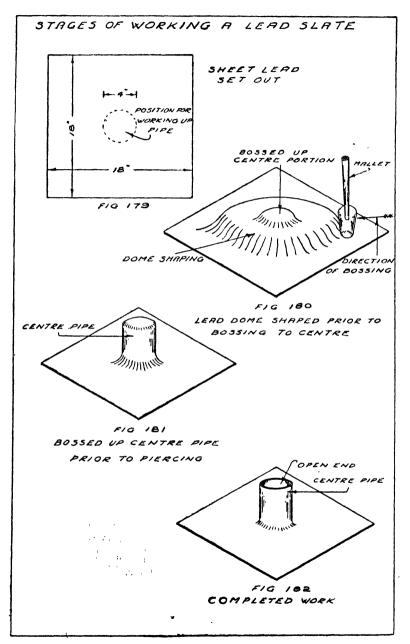
The setting out of an internal break is shown in Fig. 174, which also combines two external corners.

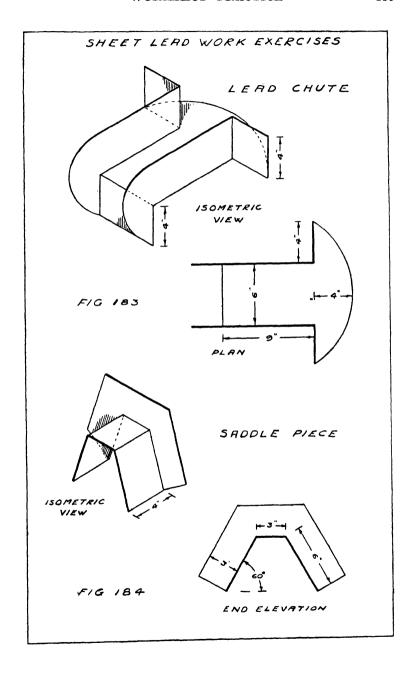
The methods of working an internal break vary, but the following method is speedy and efficient.

First some surplus lead is cut off as shown. An internal break or corner is an example where lead has to be made to flow into it, as there is no question of disposing of surplus lead.

The first move is to slightly set in the bottom turning up lines. Next the surplus portion is doubled over saddle fashion, as shown in Fig. 175, and starting from the outer edge opposite the internal corner the lead is driven down into the internal corner with a bend or duck back dresser. This is repeated until an effective start has been made, but all the time keeping the bottom corners down flat after each working.

This is followed by the use of two bossing mallets, or mallet and bend dresser, and the surplus lead is driven down continuously into the corner, the leading angle being kept as





straight as possible all the time (see Figs. 176 and 177). When a maximum amount of the surplus lead has been worked down, the lead from both sides of the corner are driven and worked into it, until eventually the angle is vertical (see Fig. 178).

### Lead Slate.

The setting out of a lead slate is shown in Fig. 179. A mandrel or circular section piece of hardwood with a diameter equal to the size of the required opening would be required. First the under side of the lead would be bossed up slightly within the chalk ring. Next the edges of the lead would be buckled and bossed down with a mallet, as shown in Fig. 180, into a dome shape. Having obtained this shape, bossing would commence, and the lead driven into the centre chalk ring using the mallet. This process would be repeated, keeping the curling up edges down flat all the time, until the pipe shape form in the centre could be held in the hand.

The bossing process would be carried on, turning the lead round slowly all the time, but now using a bend dresser until the pipe centre had reached the required height (see Fig. 181).

The pipe centre would then be pierced and opened out, slipped over the mandrel and trimmed off level, as shown completed in Fig. 182.

#### Sheet Lead Exercises.

Two simple sheet lead work exercises suitable for executing in the workshop are shown in Figs. 183 and 184, which have a practical application to roofwork.

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