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THE MATERIALS AND CONSTRUCTION OF TRUNK AND DISTRIBUTION PIPE-LINES FOR WATER SUPPLY, USING METAL PIPES.

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1. Introduction.

The system of distribution of water for domestic and industrial supplies through pressure pipes is of comparatively modern growth.

Water supply works of considerable magnitude were in existence in ancient times and many examples can be found in India, Egypt, China, Peru and also in the various countries whose territory formed part of the Roman Empire, but these ancient water supply systems were almost invariably of the non-pressure type, that is, water was conveyed in masonry or brick work channels or aqueducts, not under any pressure head of water, on similar principles to the irrigation canals and channels of the present day in India.

In ancient times such as in the Roman Empire, iron and steel pipes were unknown. There were, however, some instances of pressure pipes of lead, utilized to carry water from the storage reservoirs or tanks fed from the main or subsidiary non-pressure aqueducts or ducts, into subsidiary tanks, baths, fountains and other points where water was required for use and it has been related that in some cases the amount of water passed to the consumer was measured by a short "tube" of suitable size.

The distribution arrangements in connection with these ancient water supply schemes were of a very rudimentary character, because of the impossibility of conveying water to various levels, in the absence of pipes of metal capable of withstanding internal hydraulic pressure, such as are employed in the present day.

After the fall of the Roman Empire the Roman water-works systems fell into disuse and it was only about three hundred years ago as a result of slow development of rational ideas in connection with hygiene and sanitation, that interest was gradually revived in Europe in connection with the need of the protection of water supplies against pollution. This was given an impetus by the development of various forms of pumping engines, the first of which was produced in Europe about the end of the sixteenth century, operated by water power.

About the same time, the first pressure distribution pipe-lines were laid in London by the New River Company and this installation may be said to be the first "modern" system of water supply. It is of interest to note this Company continued to function until 1904 when, along with other water supply authorities serving London, it was merged into the Metropolitan Water Board, the largest public water supply authority in the world.

The first large pressure water supply pipes in Europe were made of elm wood logs the cores of which were removed, while another form consisted of built up pipes made with wood staves bound by hoops of metal like a barrel. This type is still employed in the United States of America. It is related that cast lead and sheet lead pipes were also employed—the early use of lead being undoubtedly due to its comparatively low cost and to the easy working of this metal owing to its low melting point, and its high resistance to corrosion.

The introduction of steam and the development of steam driven machinery about the beginning of last century lead to improvements in the manufacture of iron and brought about the development of cast iron pipes, which were first used about 1746 in London. They did not come into general use, however, till about 1810, when they finally displaced wood pipes.

The manufacture of cast iron pipes has been gradually improved and it can be said to-day as justly as 80 years ago that cast iron is still the standard material for pipes over two inches diameter for water supply works. Of comparatively late years, iron and steel pipes have been used to a considerable extent and recent developments consist of improvements to the manufacture and to the lining and coating of such pipes to extend the life of the pipes against corrosion.

For service pipes and connections, that is the small pipes used to convey the water from the public distribution pipe-lines or mains into buildings and to distribute the water inside the buildings, lead pipes still hold the field in Great Britain. In many cases due to liability to lead poisoning when soft waters are passed through the lead pipes, lead pipes have been lined with tin and of recent years a tendency to utilize copper in place of lead pipes has been noticed. In India and in the East generally, service pipes and connections of galvanised iron is the general rule.

2. Working pressure on water supply pipe-lines.

The working pressures on water supply pipes, vary considerably depending on the local conditions of each undertaking.

In Great Britain, the usual working pressure on distribution systems varies from about 60 feet to about 200 feet vertical head of water, while the greatest working pressures on trunk mains, *i.e.*, the pipe-lines which carry the water from the source of supply to the service or distribution reservoir, are seldom in excess of about 1,000 feet vertical head of water, and such high pressures are possible only on a few of the gravity schemes serving the large industrial areas of the west and north, where the sources of supply consist of catchment areas situated in high-level upland regions.

In India, the usual working pressures in distribution systems are less than the figures given for Great Britain, but in mountainous regions, the working head, particularly on the trunk pipe-lines may be much greater, for obvious reasons. An example of this is the Guma Waterworks rising main of the Simla Municipality where the head on the pumping installation at Guma when the pumps are pumping the water into Carrignanan reservoir Mashobra is well over 4 000 feet. There are several other instances in the Punjab, of working pressures of 1,000 to 1,500 feet vertical head of water, in schemes in hilly regions.

Service pipes and fittings are seldom subjected to a working pressure in excess of 200 feet head, except in hilly regions.

3. Cast iron pipes and specials.

Cast iron pipes for water, gas and sewage used generally in Great Britain as well as in India, have been standardised since 1917 by the British Engineering Standards Association, in accordance with specification No. 78-1917 of that body. These pipes are vertically cast and are manufactured in a large number of foundries in Great Britain and by two manufacturers in India.

4. Classes of cast iron pipes.

There are four standard classes of pipes and specials, tested to the following proof pressures at the works of manufacture:—

Class " A " ..	..200 feet head of water.
Class " B " ..	..400 feet head of water.
Class " C " ..	..600 feet head of water.
Class " D " ..	..800 feet head of water.

The usual practice, recommended by the British Engineering Standards Association is to arrange that the working pressures shall not exceed one-half of the respective test pressures.

It follows from this that ordinarily the heaviest standard cast iron pipes are not suitable for working pressures in excess of 400 feet vertical head of water, and where pipe-lines have to be constructed for higher working pressures, either thicker cast iron pipes have to be specially manufactured, or resort is had to pipes of steel or ingot iron. The latter course is almost invariably preferred in modern practice.

Class A pipes are not generally used for water supply but are reserved for very low pressure purposes, such as gas mains and sewers. Up to 10″ dia. inclusive, the thickness of metal in classes A and B is the same, so that there is no saving whatever in cost by using class A pipes instead of class B.

For general work, that is for pipe-lines for water of standard design where the working pressure does not exceed 200 feet head of water, class B pipes are suitable, but some engineers adopt a more conservative procedure and employ class B pipes for working pressures up to 133 feet head of water only and class C pipes for working pressures ranging from 133 to 200 feet head of water. The selection of the proof pressure does not depend only on the maximum static head of water the pipe-line has to stand, but in addition the shock due to probable water hammer must be considered. This depends on the general design of the system, the design of sluice valves, the extent to and the rapidity which it will be possible in practice to arrest the flow of water in the mains. Each pipe-line or system of pipe-lines must accordingly be considered on its individual characteristics in this regard, when fixing the class of pipes to be used. Cast iron pipes are standardised for all diameters from 3″ dia. to 48″ dia. 3″ pipes are made 9 feet long (laying length), pipes from 4″ to 12″ dia. are made in 9 feet and 12 feet lengths and pipes from 14″ dia. to 48″ dia. are made in 12 feet lengths only.

5. Protection of cast iron pipes and specials.

The usual protective coating is that laid down in the British Standard specification, *viz.*, by immersing the pipes in a bath containing Dr. Angus Smith's composition, maintained at a temperature of from 300° to 330,° Fah then removing them from the bath and allowing them to drain.

It is necessary, when laying the pipes in the ground, to go carefully over the whole of the exposed external surfaces and touch up all places where the coating is damaged, (including the sockets where there may be chip marks of the caulking tools) and also all exposed surfaces of flanges and bolts and nuts, with a suitable bitumastic paint composition, after removing all rust and other impurities.

6. Life of cast iron mains.

There are many cast iron pipe-lines still in use and rendering good service which have been laid 60 years and more ago. Some of the cast iron mains of the City of Lahore water-works have been in use for over 45 years and are still rendering service. In other instances cast iron pipes have perished in less than 20 years.

A case in point is the Pind Dadan Khan Waterworks, Punjab, where a cast iron rising main 3″ dia. was laid in salt-impregnated subsoil, from a pumping station near the river Jhelum, to the town, about 20 years ago, which has practically perished already due to external corrosion from damp salt-impregnated subsoil. Pind Dadan Khan is situated a few miles from the base of the Salt Range where extensive rock salt deposits are worked and the washings and drainage of the salt mines have heavily impregnated the whole of the area surrounding the town. Similarly, cast iron pipe-lines laid in chemically impregnated soil such as town refuse, ash and cinder heaps, chemical works refuse and similar substances, which frequently are found in the vicinity of towns, are liable to heavy corrosion due to external action and in such cases the protection afforded by Dr. Angus Smith's composition is a very ineffective barrier against rapid deterioration. On the other hand in normally good subsoils such as sandy clays, sands or gravels, earth, rock or shale outcrop, as far as external corrosion is concerned, there is no reason why cast iron pipes should not last 60 to 80 years. Light subsoil which does not retain moisture for long is better than heavy clayey subsoil.

7. Incrustation.

No matter what type of water is passed through cast iron mains, at least some deposit will occur in course of time on the internal surfaces. This affects the discharge by reducing the area of water-way and also by increasing the roughness. Soft peaty waters tend to attack exposed cast iron, forming tubercles or rounded excrescencies on the internal surfaces of the pipes. The provision of an effective coating retards and limits this tubercular action, as it prevents the water from reaching the surface of the metal and even should the coating be imperfect, it prevents the spread of tuberculation beyond the places where the metal was exposed.

Hard waters tend to cause incrustation of calcareous matter. If sand or sediment is carried with the water, the friction against the lining is liable to rub it off, exposing the underlying metal surface and thus leading the way towards more rapid tuberculation and corrosive action. For this reason, very often, tuberculation and corrosion is most noticeable along the invert of an old pipe-line. At the Lahore Waterworks a brown-black powdery iron oxide deposit is found in the pipes, which blocks up fittings, meters, etc., in a relatively short space of time. The bulk of this, however, is capable of being washed out of the mains by heavy scouring or flushing.

In some cases again when old mains are cut open, practically no corrosive action is apparent.

It is impossible to determine before hand what will be the effect of water from any particular source of supply on cast iron mains. Some engineers have found that soft waters are the worst, others that waters containing the largest amounts of free carbonic acid are bad, while many consider that hard waters incline to produce the greatest amount of incrustation.

There seems to be no doubt that a very, if not, the most important factor, is the need for a perfect coating to the internal surface of the pipes and special attention, therefore, should be directed to the attainment of this object.

8. Cement lining.

A very recent development in Great Britain consists of lining cast iron pipes with a thickness of cement concrete mixture. The pipe is rotated at a suitable high speed on its axis and the cement mixture for the lining is fed from one end into the pipe and spread uniformly over the internal surface of the pipe by centrifugal action. The cement lining is claimed to stop tuberculation and incrustation and to protect fully the internal metallic surface of the pipe from corrosive action of soft waters. When pipes are to be cement lined, they are only required to be dipped externally in Dr. Angus Smith's composition and care has to be taken to see the inner surface, is entirely free from rust and other impurities before the lining is applied.

The lining of special castings and tees, has to be laid by hand as it is not possible to apply the centrifugal process to irregularly shaped articles.

9. Spun or centrifugally cast iron pipes.

The Stanton Ironworks Company, Limited, of Nottingham, England, for some years, have been manufacturing "spun" cast iron pipes by the Stanton-Delavaud patented process. The pipes are cast by spinning centrifugally and by this means, the metal of the pipes is more dense and homogenous and thereby capable of withstanding a greater safe stress than ordinary cast iron. The pipes are thus thinner and lighter in weight, as compared with British Standard pipes and the cost is appreciably less per foot length although at present (1930) the cost of Indian made standard cast iron pipes delivered at a distance from the foundries competes very favourably with that of British made spun pipes, delivered at an equal distance from any Indian Port.

Ordinary "special" castings cannot be made by the Stanton-Delavaud process and therefore the sockets and spigots of the spun straight pipes are arranged for interconnection with British Standard cast iron specials. The spun pipes are coated with Dr. Angus Smith's composition in the same manner as British Standard pipes.

10. Special castings.

The British Engineering Standards Association have standardised many of the special castings required for ordinary work, in two thicknesses, suitable for use with class A and B and class C and D pipes respectively. These standard specials consist of—

Standard	spigot	and socket	90° bends	..(Fig. 1)
,,	,,	,,	45° bends	..(Fig. 2)
,,	,,	,,	22½° bends	..(Fig. 3)
,,	,,	,,	11¼° bends	..(Fig. 4)
,,	,,	,,	tees	..(Fig. 5)
,,	,,	,,	45° branches	..(Fig. 6)
,,	,,	,,	tapers	..(Figs. 7 & 8)
,,	collars			..(Fig. 9)

In addition to these specials, the following types of special castings are usually required for general use in pipelines, and manufacturers generally keep their own standard patterns and are able to supply requirements easily :—

Caps for ends of mains .. ..(Fig. 10)
Plugs for ends of mains .. ..(Fig. 11)
Duck-foot bends, spigot and socket ..(Fig. 12)
Duck-foot bends, flanged .. ..(Fig. 13)
Flanged sockets .. ..(Fig. 14)
Flanged spigots .. ..(Fig. 15)
Spigot and socket tees with flanged branches (Fig. 16)
Blank flanges .. ..(Fig. 17)
Spigot and socket tees with washout branches (Fig. 18)

These comprise all the special castings normally required for ordinary straightforward pipe-line works for town water supplies, and as far as possible it is desirable to make every effort to utilize only these standard fittings for all external pipe-line work.

In special cases, however, for example, for river crossings, bridges, connections to reservoirs and plant and similar works, certain specially made castings are also required. These will comprise—

Double flanged 90° bends ..(Fig. 19)
" " 45° bends ..(Fig. 20)
" " 22½° bends ..(Fig. 21)
" " 11¼° bends ..(Fig. 22)
" " template bends ..(Fig. 23)
" " tees ..(Fig. 24)
" " radial junctions ..(Fig. 25)
" " tapers ..(Fig. 26)
" " anchors ..(Fig. 27)
Socket and spigot anchors ..(Fig. 28)
and, straight flanged pipes of odd lengths.

11. Steel and ingot iron pipes.

No regular standardization of the design of steel and iron pipes and specials has been effected so far. The reason is not far to seek, as the development of the steel pipe is still proceeding and some of the processes of manufacture are yet the subject of unexpired patents. One of the first forms of steel pipes used in important pipe-lines was the Ferguson lockbar jointed type used on the Coolgradie Waterworks, Western Australia, where over 300 miles of 30 inches pipes were laid in 1898—1903. This type which is illustrated in Figure 29, is no longer used, having been displaced by the solid drawn and the lap welded types of pipes. In the lockbar pipe, the plates forming the pipe were bent to a cylindrical shape and the plate edges inserted into grooves of longitudinal steel or iron lockbars, after which the bars were compressed over the plates. The pipe lengths were jointed by collars with poured lead caulked joints in a similar manner to spigot and socket cast iron pipes.

The types of steel pipes most generally in use at present are :—

(*a*) Solid drawn steel pipes, and

(*b*) Lap welded steel pipes.

Rivetted steel pipes of various types have also been used, mostly in America, for water supply purposes.

12. Solid drawn or weldless steel pipes.

Solid drawn or " weldless " steel pipes are made by several manufacturers in Great Britain and in Europe, up to over 16″ dia., the pioneers of this form of manufacture in Great Britain being the British Mannesmann Tube Company, Limited, of Landore and Newport, South Wales. The tubes are formed from billets of high tensile steel by a power operated mandril and the pipes are made in lengths up to 40 feet, depending on the size, and also on transport and shipping arrangements, and handling and laying facilities at site of the proposed pipe-line.

The pipes are usually supplied with various types of spigot and socket joints for caulked lead when used for water supply purposes, but if required they can be fitted with victaulic joints, or flanges.

For gas mains, light solid drawn steel tubes are much used, the joints being welded to form the whole into one continuous pipe-line.

Due to the method of manufacture, solid drawn or weldless pipes are sometimes not positively of uniform thickness of metal throughout their lengths.

13. Lapwelded steel pipes.

Lapwelded steel pipes are manufactured by a number of firms in Great Britain and in Europe up to 72 inches in diameter, the usual lengths being from 18 to 26 feet. In the early days of use of this class of pipes, *i.e.*, over 20 years ago it was usual in Great Britain to manufacture them to exact laying lengths of 12 feet and 9 feet like standard cast iron pipes, in order to make them interchangeable. After experience, however, it was found that this arrangement was of doubtful benefit, taking into account the extra number of joints involved and the increased cost of manufacture, wastage of metal etc., and as a result, present day practice is to lay the pipes in odd lengths, as manufactured.

The steel plates used for the manufacture of the pipes are made from open hearth steel 24 to 28 tons per square inch tensile strength, with an elongation in length on test of not less than 20 per cent. in 8 inches and a reduction of area on fracture of 45 to 50 per cent.

Various makers' analyses of the steel varies slightly as follows :—

Phosphorus	..not exceeding ·06 per cent.
Sulphur	..not exceeding ·06 per cent.
Silicon	..not exceeding from ·035 to ·05 per cent.
Manganese	..not exceeding from ·5 to ·55 per cent.
Carbon	..not exceeding from ·125 to ·15 per cent.

Large pipes are made from two plates with two longitudinal welds while the smaller sizes of pipes are made from single plates having one longitudinal weld. The plate is bent cold into a circular form generally with a lap of not less than 1½ times the thickness of the plate. This overlap is welded in a welding machine by the water gas or electric process, care being taken to ensure that no damage to the plates occurs due to uneven or excessive heating.

The pipe is then annealed in a gas fired muffle and made perfectly circular in a special rolling mill, while still heated. The strength of the weld should not be less than 85 per cent. to 90 per cent. of that of the original plate and to ensure this, pieces cut from the manufactured pipes are tested.

After rolling, the ends are machined and faced in a lathe at right angles to the axis of the pipe and the sockets, spigots, flanges or other jointing arrangements finished off.

In the case of socket and spigot pipes, the sockets are formed by hot-rolling or hot-pressing or by a combination of both operations, in suitable machines depending on the shape and design of the joints, while the spigot ends are belled or swaged to form a slight projection or " bead." The pipes are then tested for circularity, straightness and other conditions and placed under water pressure test, after which they are ready for the protective coating and lining to prevent corrosion.

The manufacturing processes are so highly perfected that pipes can be turned out as accurately in regard to straightness of axis, circularity and other dimensions as cast iron pipes. The tolerances usually allowed in regard to circularity, straightness, variations in thickness of plate, etc., vary to some extent with the size of plates, thickness of metal, diameter and effective lengths of the pipes.

The usual tolerances for good class medium size pipes say 15″ to 24″ dia. by 26 feet long are as follows :—

(*i*) Lengths of straight pipes ordered to exact lengths	..+or—1/8″
(*ii*) Sockets	..+1/8″—0
(*iii*) Spigots	..+or—1/16″
(*iv*) Circularity	..+or—1 per cent.
(*v*) Straightness of axis ..	..+or—1/8″
(*vi*) Thickness of plates ..	..—2½ per cent.
(*vii*) Actual weight against weight calculated..	—2½ per cent.

The allowable tolerances in thickness of the pipes depend largely upon the width and thickness of the rolled plates. For narrow plates it is comparatively easy to maintain constant thickness of plate when rolling, but with wide plates, due to distortion of the rolls and slight defects in the rolling plant, this is not possible and larger tolerances should be allowed.

The specials usually required in conjunction with the straight pipes are of the same descriptions as those already mentioned in para. 10 except that of course, they are made of steel.

Lapwelded bends are formed by bevelling the ends of two or more short lengths of tubing and welding them up to form the bend.

Tapers are made by bending and lapwelding a suitably shaped plate or plates, depending on the size and description of taper required. Branches and tees are made by cutting out the opening for the tee or branch and welding the shaped end of the cylinder of the tee or branch to the main pipe.

In cases where bevel welding is necessitated, the bevelling is done cold and the overlaps for welding are made usually not less than three times the thickness of the plate. Figures No. 30 and 31 illustrate typical examples of a tee and a bend. Flanges are generally of forged steel, welded on to the pipes as indicated in Figure No. 32. Loose flanges, of which there are several types, and rivetted—on or screwed—on steel plate flanges are used for water, in some instances.

14. Rivetted pipes.

Rivetted pipes of steel and iron are used for large water mains, for hydraulic power works and as inverted siphons for aqueducts and canals. Spirally made rivetted pipes have been used extensively in America for pressures up to 1,000 feet head of water. The pipe is made from steel plate strips wound helically with one edge overlapping the other, forming a lap joint which is rivetted. The pipes are usually fitted with rivetted-on flanges of forged steel and it is claimed that the spiral seam is very much stronger than those of ordinary rivetted pipes with longitudinal and circumferential joints.

An example of a very large rivetted steel pipe-line is the Bombay water-works pipe-line from Tansa Lake, consisting of a double line of rivetted steel pipes 6 feet dia. 55 miles long, which was completed a few years ago.

All rivetted pipes offer higher resistance to flow than lap-welded or solid drawn pipes, owing to the joints or seams. This disadvantage however is counter-balanced in the case of large rivetted pipes assembled, erected and rivetted at "situ," by the increased facility of transport in difficult country obtained thereby, as the plates can be made to any desired limit of size or weight. Transport by rail and sea is also cheapened as the plates can be nested in order to take up less room.

Generally, rivetted pipes with circumferential and longitudinal joints are not made under 30″ dia.

Small rivetted pipes are protected against corrosion by dipping and coating in the same manner as lap-welded or weldless steel pipes while large rivetted pipes are coated and lined with an asphaltic bituminous composition painted on. It is an advantage sometimes to keep large pipe-lines exposed in order to enable the corrosion of the outside surfaces to be watched and controlled, although this renders the pipe-line liable to increased expansion and contraction effects, due to temperature changes.

In some rivetted pipe-lines which are buried, no special means of taking up contraction and expansion are provided, the plates and the joints being designed to resist all movements and stresses due to changes of temperature.

In other cases and particularly those in which the pipelines are exposed on the surface and subjected to considerable changes of temperature, expansion joints designed to suit the special conditions of work are required.

These may be of the stuffing-box type or they may depend for their success on the bending or straightening of a special rolled out ring of metal fitted as part of the pipe-line.

15. Ingot iron pipes.

"Armco" ingot iron is almost a pure iron (guaranteed 99·84 per cent.), and is denser and more uniform than ordinary commercial iron or steel, while it is said to be free from all slag inclusions ; and it is held, as a result of its purity and its uniformity, that it has greater resistance to corrosive influences than ordinary steel or iron.

Pipes manufactured from "ingot" iron plates are thus claimed to possess a longer life as compared with ordinary steel pipes and are sometimes recommended, especially for use with very soft waters or for laying in corrosive subsoil. These pipes have been used in connection with two recent small schemes in the Punjab, *viz.*, a duplicate pipe-line for the Dalhousie water supply works laid in 1928, and in a pumping main for the water supply of the small town of Isakhel on the river Indus. In the former instance, the water passed through the pipes is exceedingly soft, while in the latter case, the pipe-line about 3 miles long is being laid in the "khader" or low lying land bordering the west bank of the river, impregnated with brackish salts.

It is too early yet to pronounce conclusions as to the behaviour of these pipes under the conditions they are working.

One of the largest mains in the world, *viz.*, a rivetted pipe-line 8 feet dia., for the San Paolo water supply works in Brazil has recently been constructed, using 26,000 tons of "Armco" ingot iron plates.

The cost of ingot iron pipes in northern India is from 15 to 25 per cent. greater than steel while the ultimate tensile strength of the material is appreciably lower, being from 21 to 22 tons per square inch, and must be borne in mind in determining the thicknesses of the pipes. The metal is excellent for welding work.

The writer's personal opinion is that for all forms of steel, wrought iron or ingot iron pipe-lines, sole dependence must be placed on the lining and coating for protection against corrosion, if they are laid in corrosive subsoil or carry aggressive waters, and in the absence of a suitable lining and coating, their life will be very short under such conditions.

16. Life of steel pipes.

There is no doubt that cast iron is a more durable metal as compared with any kind of steel or ingot iron used on a commercial scale for the manufacture of pipes, and the reasons for adoption of steel in place of cast iron as the material of pipe-lines by the ordinary waterworks engineer should not include *durability*, because the general experience obtained with such pipe-lines shews that their average life is not so long as that of cast iron. Steel pipes suitably protected have been reported in many instances to be in excellent condition after more than 30 years use. On the other hand, in certain cases, steel pipes have been badly pitted and corroded, after only a short period of use—it all depends on the nature of the subsoil in which they have been laid, on the nature of the liquid carried by them, and more important still, the efficiency of the protective coating and lining of the pipes against internal and external attack. In general, it may be said that the factors which tend to the destruction of cast iron pipes, have the same effect on steel or ingot iron pipes, but the action is much accelerated in the latter cases owing to the smaller resistance of the steel or ingot iron to corrosion, coupled with the thinner metal of the pipes.

The writer recently examined a steel pipe-line 4″ dia. with victaulic joints belonging to the Thall-Ilaqa water supply in the Salt Range, Punjab. The line was laid in a salt impregnated area, and where the metal was directly exposed to the subsoil, close to the victaulic joints, corrosive action had proceeded to such an extent that the pipes had actually been perforated at several points already, although the line was laid in 1927, only 4 years ago.

The pipes had been dipped, coated and wrapped with hessian in the usual way before delivery in India but the metal near the joints had been left exposed, and this is where the perforations had occurred.

A 9″ steel pipeline, 1/4″ thick, was laid in 1908 by the North Western Railway, Lahore, from the Lahore water-works service reservoir at Lange Mandi to the railway station in the ordinary sandy-clay subsoil prevailing at Lahore, the pipes having been dipped, coated and wrapped with hessian before laying.

The writer inspected the line in 1928 and found the pipes pitted externally in a few places where the coating was damaged, and internally in more places. The life of the pipe-line will certainly be not less than

30 years and possibly 35 to 40 years. For the 20 years 1908--1928, no trouble of any kind was experienced from leakage due to corrosion.

The simplest protection against corrosion consists in dipping the pipes in a hot bath of suitable black bituminous solution, maintained at a temperature between 300° Fah. and 400° Fah. depending on the exact specification of the composition. The pipes are thoroughly cleaned outside and inside with wire brushes to remove all scale and then thoroughly dried and heated to a temperature approximately the same as that of the bath, before immersion. Each pipe is left for a reasonable period of time immersed in the bath, say 10 to 15 minutes, and is then drained vertically in such manner that the internal coating forms a hard uniform smooth surface without shewing any rough places or grooves. The coating should set hard and should be thick, tenacious, not liable to chip or crack when cold, and in order to withstand Indian conditions, should not soften, creep or run when exposed to temperatures up to 150° Fah. for long periods.

The pipe is then transferred to a machine where hessian cloth impregnated with hot bituminous solution, maintained at a suitable temperature, is wound spirally round the pipe. The overlap is generally at least one inch.

The hessian should consist of selected jute hessian cloth of suitable width, weighing eight ounces per square yard and having a selvedge each side to prevent the material getting torn easily.

To facilitate jointing, no wrapping is done to the spigot ends for a short distance beyond the depth of the sockets of the pipes.

Another method in use on first class works in England some years ago consisted in coating the pipes with linseed oil inside and out to protect against corrosion, after cleaning free of rust, then heating to a temperature of 400° Fah. and dipping into a mixture of tar, oil, and pitch according to Dr. Angus Smith's process, the mixture in the dipping pan being maintained nearly at boiling point. After the first coating was set, the pipes were again dipped in a second and separate tank into a mixture containing 42 per cent. of the best Trinidad natural bitumen, 53 per cent. coal tar distilled free from naptha, 3 per cent. pure chalk and 2 per cent. resin. The total thickness of coating and lining was about 1/12th of an inch. The pipes were then wrapped with hessian.

The single wrapping is not satisfactory, particularly where the pipes are transported long distances by sea and rail, necessitating rehandling many times or if they are required to possess the best possible protection against external corrosion, and it is much better the pipes should be wrapped with a second layer of hessian similarly impregnated in hot bituminous solution wound spirally round the pipes over the first wrapping, but in the reverse direction and with joints crossed.

To protect the wrapping against accidental tearing and to harden the skin of the coating, the pipes should be thoroughly rolled in coarse sand before the solution on the cloth has hardened. This has a wonderful hardening and toughening effect on the surface of the wrapping. As a last precaution, if the pipes are to be sent to a hot country, the outer surfaces should be lime washed.

About 15 miles of 17″ i/d spigot and socket steel pipes for the Jaipur water-works, Rajputana, were treated as described above this year, prior to despatch from England. The pipes arrived at site of works in excellent condition, in spite of rail transport in England, shipment, unloading at Indian port, rail transport and transhipment from broad gauge to narrow gauge railway in India, unloading and transport by bullock-cart over nearly 17 miles of *katcha* roads.

Of recent years the problem of improving the lining of steel pipes has been engaging the study of manufacturers, and in England during the last few years, many miles of concrete lined steel pipes have been used on water-works installations using soft peaty moorland waters, which are notorious for their rapid corrosive action on steel pipes. The cement concrete is made very carefully of a strong mixture of cement with sand and granite chippings and is fed into the pipe from one end, the pipe being revolved on its axis at a very high speed by suitable driving arrangements, and by the action of centrifugal force, the lining material is uniformly spread over the internal surface.

The thickness of the lining varies from ½″ to 1″ and it is claimed that it effectually prevents the water attacking the metal, while no incrustation can form on the internal surface of the lining, hence there will not be any reduction in course of time in effective bore of the pipe.

Another recent development is the bitumen lined steel pipe. In this system, melted bitumen of suitable quality is applied centrifugally as already described for cement concrete lined pipes, to the inner surface of the pipe to form a smooth and glossy finished bitumen lining from 1/4″ to 3/8″ thick depending on the diameter.

It is confidently claimed that this protection is absolutely effective when acid and acidulated waters are passed through the pipes. The bitumen lining is elastic and yields with the pipe but does not increase its strength, like the cement concrete lining, which is regarded of value as a resistant to external loading.

The rising mains from the Guma pumping station to Mashobra (Simla water-works) consisting of thick solid drawn steel tubes with special hydraulic flanged joints, are heavily galvanised throughout, as a resistant against corrosion. Galvanising, however, is not a reliable protection, as certain aggressive waters have a strong affinity for zinc and in their presence, the zinc protection will disappear, leaving the steel exposed. Certain soils also contain chemicals which rapidly attack zinc and galvanised mains will have a short life if laid therein.

A new method of applying an asphaltic or bitumastic external coating to wrought iron and steel oil pipelines " in situ " has been tried in America of late years. The pipes after laying in the trench but before filling in, are cleaned free from rust and dirt and given a priming coat of suitable cold bitumastic solution, followed by a second thick coat of melted bituminous or asphaltic composition applied hot. The melted composition is poured into a canvas sling held by one or two men under the pipe and by working the sling round the pipe with rotational motion the composition is transferred uniformly on to the pipe surface, the final thickness of the coating being from 1/16″ to 1/8″. The external surface of the pipeline is thus coated for a short length at each " pouring " until the complete pipeline is dealt with.

17. Cast iron pipes versus steel pipes.

It will be seen from the preceding paragraphs that cast iron pipes possess an overwhelming advantage over steel and ingot iron pipes in regard to durability. It is true that recent improvements in the lining of steel and similar pipes by the use of concrete or solid bitumen may give a longer life, but these methods have been introduced only during the past few years and it is too early yet to pronounce final judgment. If we neglect these, the average life of steel pipes under normal conditions may be taken to be about half that of cast iron pipes, while under conditions, liable to produce heavy corrosion, it is likely the reduction in the life of steel pipes will be three or four or more times the reduction of life of cast iron pipes.

For distribution pipelines, cast iron pipes are the most suitable as the thickness of metal is greater and ferrule connections are more easily made and far less liable to cause leakages subsequently. With thin steel pipes, special ferrules have to be employed, the inner ends being expanded or beaded in order to grip inside the metal of the pipe more firmly, or clamps have to be permanently fitted round the pipes at the points of connection to give a greater thickness of metal to hold the ferrules.

The advantages of steel pipes must be sought for in other directions,

(*a*) *Cost.*

It frequently occurs in the case of pipelines of moderate size say from 12″ to 24″ dia. that steel pipes, especially those required for working pressures in excess of British Standard cast iron pipes, work out considerably cheaper than cast iron in first cost, while in the case of very large pipelines this is always the case.

(*b*) *Transport and handling.*

The weight of steel pipes generally is less than half that of cast iron pipes of corresponding diameter. There is thus an appreciable saving in handling charges and also in cost of transport by rail or road.

(*c*) *Breakages.*

Cast iron pipes are liable to be seriously damaged in course of handling and transport, while steel pipes and specials are seldom damaged excessively, although the coating and wrapping is frequently torn and has to be reconditioned before laying the pipes.

(*d*) *Behaviour under heavy stresses.*

Steel pipelines are more reliable in operation as the metal is able to absorb and take up sudden stresses set up by excessive water hammer, without fracture or breakage. Cast iron pipelines on the other hand have to be operated very carefully to avoid burst pipes, particularly when the normal working regime is upset. This is an important factor in the selection of material of construction of pipelines specially liable to shocks and sudden variations of pressure such as long pumping mains and undulating high pressure gravity pipe-lines.

(*e*) *Joints.*

Standard cast iron pipes are usually made in lengths of 9 feet and 12 feet, while steel lapwelded pipes can be obtained in lengths up to 26 or 27 feet. The number of joints on a cast iron pipeline is thus likely to be at least twice that required for a steel pipeline of the same length.

There is no doubt, a certain advantage in having numerous joints as they take up expansion and contraction movements.

The cost of caulked lead socketted joints to-day, assuming lead to cost Rs. 20 per cwt. varies from Rs. 1/8/- for a 3″ joint to about Rs. 12 for a 24″ joint.

(*f*) *Laying.*

Steel pipes being lighter, are more easily handled and laid in the trench, while there is also some saving in joint holes.

(*g*) *Discharge.*

Due largely to the longer laying lengths between joints, the carrying capacity of a solid drawn or lapwelded steel pipeline is somewhat higher than that of a cast iron one. With rivetted steel pipes ranging from 4″ to 48″ dia. however the carrying capacity has been estimated to be from 20 to 30 per cent. less than that of cast iron pipes of the same diameter, depending upon the size.

18. Pipe joints for cast iron and steel pipes.

Standard cast iron pipes are manufactured with three types of joints, *viz.* :—

(1) Plain spigots and sockets for caulked lead joints (Fig. 33).

(2) Spigot and socket half turned and bored joints (Fig. 34).

(3) Flanged joints (Fig. 35).

Steel pipes are generally used with spigot and socket joints of caulked lead and with flanged joints of various descriptions. Cast iron and steel pipes are also used with victaulic joints.

19. Plain spigot and socket joint for caulked lead.

The plain spigot and socket joint for caulked lead is used on water-supply works throughout the world and is an excellent joint, easily capable of withstanding hydraulic pressures on moderately sized mains, much over 1,000 feet head of water, that is, well above that likely to be required in practice in Great Britain or on the plains of India.

The joint is most suitable for trunk and distribution pipelines and is adapted specially for use when pipelines have to be cut for insertion of branches or for alterations, and the writer strongly recommends its adoption wherever it is possible to do so.

The depth of the standard sockets on cast iron pipes varies from three inches for pipes 3 inches diameter, up to five and a half inches for pipes, 48″ diameter.

The method of making the joint consists in forcing the spigot end of one pipe into the socket end of the preceding pipe, a gasket of spun yarn being caulked into the bottom of the joint. This keeps the two pipes concentric. Sometimes however, suitably shaped steel wedges are driven, inserted at three or four points between the spigot and the socket to ensure concentricity. Concentric rings of spun hemp yarn are packed by means of a thin steel " yarning " tool (Fig. 36) into the bottom of the joint and lightly hand caulked to ensure the yarn is solidly packed, until the whole of the joint, except the space to be left for the lead, is filled. The yarn generally used in India is a loose spun or twisted jute yarn, dark in colour, the cost of which is from Rs. 30 to Rs. 45 per cwt., depending on the quality. For first class work, however, it is best to use a white Italian loose spun or twisted hemp yarn, the cost of which is from Rs. 70 to Rs. 90 per cwt.

The width of the space between the outside of the spigot and the inside of the socket varies from 3/8″ to 7/16″, depending on the size of the pipe and the best diameter for the yarn rope is 3/8″, so that it may loosely fill the space before it is hand caulked. The yarn rings are either placed separately, the length of yarn to form each ring being carefully measured beforehand to ensure a good fit, or better still, a spiral coil of the required turns of yarn is inserted. When the former method is employed, care must be taken to see the joints of the several rings of yarn do not coincide.

The object of filling up the back of the joint with yarn is to save lead, form a suitable bed for the lead joint, and prevent the melted lead, when the joint is being filled, from passing into the interior of the pipes, the depth of the lead space of the joint being the distance from the finished surface of the yarn to the face of the socket. Jointers generally place a chisel cut or mark on the yarning tool to enable them to check easily that the lead space is correct.

Various engineers have different views in regard to depth of lead to be allowed. Some prefer to have the joint nearly filled solid with lead using only very little yarn, other use " lead wool " instead of yarn while some use more yarn and less lead.

Most tables shewing quantities of lead to be used for socket joints, specify weight of lead per joint irrespective of any allowance for varying widths of the joints which occur in practice.

The important factor is depth of the lead in the joint, not weight of lead.

Table No. 1 of the appendix shews the finished depth of the lead joint in good engineering practice for standard cast iron pipe sizes up to 24″ diameter. The weight of lead is also given in each case, based on correctly dimensioned sockets and spigots. This however may vary considerably.

These joints if carefully made and caulked will easily stand a hydraulic pressure in excess of 1,000 or 1,200 feet vertical head of water, and they may be employed without compunction for the range of working pressures normally employed on water-supply systems.

The shapes of sockets used with steel pipes vary considerably, depending on the ideas of the engineer and the manufacturer. If the sockets conform generally to the shapes of standard sockets of cast iron pipes of similar diameter, the same depths of lead joint will serve.

The lead intended to form the outer part of the joint is melted in a suitable lead pot set in a special grate or "devil" (Fig. 37), close to the joint. The outer end of the socket is then closed either by means of thoroughly kneaded clay stiffened with a core of yarn, which will serve the purpose admirably for small pipes, or by a hinged iron ring or clip or asbestos composition ring fastened to an iron clip and fitted over the spigot against the face of the socket and pulled up tight by a thumb screw at the top of the pipe, (Fig. 38), and a small "pond" about 5 or 6 square inches in area by about 1″ depth is formed in clay on the summit of the pipe, with an outlet into the top of the joint. The melted lead is poured from a metal ladle or from the lead pot into the joint till the joint is filled, the air displaced from the joint bubbling out through the melted lead in the "pond." It is essential that the joint should be filled with lead in one complete operation, otherwise there will be a joint plane between the first run lead and the other, and a leak will result. The only remedy in such cases is to cut or burn out the joint and refill the joint with lead.

The lead used is either soft English pig lead or Burma pig lead 99·9 per cent. pure, which is generally supplied in stamped pigs of one cwt. each. To facilitate caulking, it is necessary the lead should be soft.

If the coating on the spigots or sockets is thick, it should be scraped off before the joint is made, otherwise it may act as a lubricant between the lead joint and the socket and spigot surfaces. The internal surface of the clay gasket, or metal or asbestos joint ring or clip should bevelled off to leave a uniform fillet of lead projecting beyond the face of the socket all round to the extent of about 1/4″ as shewn on Fig. No. 39. This enables proper caulking to be done. To ensure that the joint is completely filled with lead, the "pond" at the inlet into the joint should be kept filled to the brim in course of pouring the melted lead.

The lead solidifies immediately after the joint is poured, and the joint ring can be removed almost at once. The lead shrinks slightly on cooling, and caulking has to be resorted to, not only to counteract the shrinkage effect but to further compress the lead to make the joint watertight.

The joint is caulked by hammering up the face uniformly with a series of special steel caulking chisels, the thickness of caulking edge varying from a little less than 1/8″ to just under the width of the lead joint, that is 3/8″ or 7/16″ as the case may be, depending on the size of the pipe.

For small pipes say from 3″ to 9″ dia. two or three chisels will suffice but for larger pipes three and four chisels of graduated thickness of edge are required, as shewn in Fig. No. 40.

Fig. No. 41 exemplifies the method of caulking.

The original face of the joint after the lead has been poured is indicated in solid lines while the dotted lines shew the effect of caulking by the first, second and third caulking tool, the finished face of the lead joint being set back about 1/16″ inside the face of the pipe socket.

Each caulking chisel should be kept perfectly true on the edges and surface of the working face, which should be ground at an angle of about 80° to 85° to the back of the tool, which must fully rest on the pipe in course of caulking, and not held at an angle.

With good caulking, the finished face of the lead joint should be smooth, and uniform all round and not shew any tool marks.

The caulking hammer is a steel hexagonal or octagonal faced tool weighing from 1½ to 2 lbs., with short wood handle.

It is essential the pipe sockets must be clean and smooth internally so as not to obstruct or catch the caulking tools. It has been found that even with good, heavily caulked joints the effect of the caulking does not penetrate into the lead beyond a distance of 1½″ to 2″ from the face. Joints made with lead to an excessive depth, therefore are unnecessary. This form of joint cannot be made in water nor can it be employed even if the sockets are damp or wet as if the lead is poured into the water, an explosion will occur and the workmen may be injured.

Caulking is sometimes performed by pneumatic caulking chisels of somewhat similar shape to those used for hand caulking, the compressed air being supplied by a portable power driven compressor. The compressed air outfit is very handy for other purposes such as rock drilling, ramming back fill, cutting pipes, cutting out joints, etc. In countries where labour is expensive, such as in America and Europe, the cost of pneumatic caulking is sometimes cheaper than that of hand caulking, but in India, with cheap manual labour this is not the case.

The greatest difficulty is to keep the pneumatic caulking plant fully at work, the number of joints to be made daily on a pipe laying gang being from 20 to 30, which is far below the output of a small portable air compressor outfit.

"Lead wool" is sometimes used in place of caulked lead and yarn either by itself or in combination with hemp yarn. The lead wool is caulked into the joint, piece meal, layer after layer, until the joint is filled with a homogenous solid mass of lead. Another system is to make the base of the joint with "lead wool," then make the middle part of the joint with caulked yarn and finally in the last section of the joint, "lead wool" is caulked. In this way it is claimed the water never gets into contact with the hemp yarn which is inclined to perish in water, while a saving of "lead wool" also results.

Opinions differ greatly on the efficiency of "lead wool" caulked joints. To ensure a first class joint, a more highly skilled caulker is required than for poured lead joints, because the homogeneity of the whole joint depends entirely on the caulking work with "lead wool," while in the case of a poured joint this is not so.

A "lead wool" joint is advantageous for use in water or under damp conditions and for emergency work, where there are no facilities for melting the lead.

Poured lead and "lead wool" caulked joints permit a reasonable amount of movement to the pipes for expansion and contraction and the pipes can also be laid on the sweep round curves, the curvature depending on the diameter and laying lengths of the pipes. Table No. 2 in the appendix, gives the smallest radii of circles of curvature to which cast iron spigot and socket pipes of standard lengths can be laid, without unduly affecting the joints.

To disconnect the joints it is necessary to cut out the lead by means of a special chisel, after which the pipes can easily be drawn apart.

The joint can also be melted out by the application of an oxy-acetylene flame from a portable apparatus. Sometimes a wood fire is lit round the joint. This achieves the same purpose but it unnecessarily damages the coating and lining of the pipes and therefore it is not recommended, although probably it may be the quickest means of disconnection.

Socket and spigot joints for steel or ingot iron pipes do not strictly follow the socket designs of standard cast iron pipes as there are limits to the extent to which the material can be deformed and shaped.

Good shaped sockets and spigots should however, conform, as nearly as possible, to the shape of standard cast iron pipe sockets. Each steel pipe manufacturer generally possesses one or more special designs of sockets and spigots and special plant for their manufacture.

Steel pipes being usually made in longer lengths cannot be laid to the same curvature as cast iron pipes of corresponding diameters. The amount of allowable deflection from straightness at each joint may however be taken as the same for both standard socket joints on cast iron pipes and the usual types of socketted joints used with steel pipes of the same size.

The essentials of a good socket and spigot joint are :—

(*i*) The lead space should be of correct shape to ensure good caulking and to secure as far as possible that the lead cannot be forced out of the joint. With standard cast iron spigot and socket pipes, a V shaped groove varying from about 7/8″ wide by 1/8″ deep for 3″ pipes to 2½″ wide by 1/8″ deep for 48″ pipes, is formed on the inside of the socket in order to impart a wedged shape to the front portion of the lead joint, which is mostly compressed by the caulking pressure, while the width of the lead ring varies from 3/8″ to 7/16″, depending on the size of the pipe.

Many steel pipe makers follow the same principles of design in the shape of the steel pipe joint. Others give a slight taper to the socket throughout its length keeping the width of the joint slightly less at the face than at the back. The width of the socket should suffice for proper caulking but should not exceed this limit, otherwise the strength of the joint is reduced.

It is largely a question of individual taste and judgment as to which arrangement is best. The personal opinion of the writer is that the maximum wedge effect should be obtained in the depth of about 1″ to 1½″ from the face of the joint as that portion is consolidated to the greatest extent by the caulking pressure.

(*ii*) The joint should have a reasonable length. Standard cast iron socket joints vary in length from 3″ to 5½″, according to the pipe diameter. It is good practice to make the socket joints of steel pipes of the same corresponding lengths, although the present tendency of some steel pipe makers is to reduce the length of the joint in the larger pipe sizes.

(*iii*). The socket should be of ample strength to resist heavy caulking pressure. With standard cast iron pipes, this is effected by thickening up the metal at the sockets. In the early days of steel pipes, a shrunk band was provided round the sockets to take the caulking pressure. This arrangement was not quite satisfactory because the shrunk band was sometimes fitted under excessive hoop tension and broke under caulking pressure. This form of joint is still employed (Fig. No. 42) and is now said to be satisfactory. Another method was to fit clamps tightened up in position round the ends of the sockets. There are many other designs in use at present for securing the same results.

Some of these are as follows :—

The turned back reinforced socket and spigot joint of Messrs. Guest, Keen & Piggott, Ltd. (Fig. 43).

The patent inserted socket joint of Messrs. Stewarts and Lloyd, Ltd., (Fig. 44).

The thickened socket joint of Messrs. The British Mannesman Tube Co., Ltd., (Fig. 45).

The corrugated reinforced socket joint of Messrs. The British Mannesman Tube Co., Ltd., (Fig. 46).

The spigot ends of the pipes are either left plain or are slightly belled or swaged to form a slight projection at the spigot end, to lock the spigot end into the socket joint, in imitation of the " bead " or thickened projection on the spigot ends of standard cast iron pipes. The coating of steel pipes is generally much thicker than that of cast iron pipes and consequently it is most necessary that the insides of the sockets and outsides of the spigots forming the joints should be scraped clean before the joints are made.

Some engineers require a small hole to be bored through the sockets opposite the centre of the V notched groove and the pipes are laid with the holes on top so as to let all air escape through the holes, when the melted lead is being poured.

For very high pressures a socket and spigot joint with guard ring is sometimes employed. A type of this joint is illustrated in Fig. 47.

Rigid and semi-rigid socketted joints are employed for special purposes such as in mining districts where subsidences of the surface occur and also for pipes to be laid in made soil or in places liable to settlement.

Figures No. 48 and 49 illustrate two forms of these joints which are to some extent, analogous with and possess the same characteristics as the turned and bored socketted joints for cast iron pipes described in the next paragraph, but as they are used with steel pipes they tend to keep tight in cases of slight settlement, the deformation being taken by the steel pipes themselves while with cast iron pipes with rigid joints, settlement would simply cause the pipes themselves to fracture.

20. Spigot and socket turned and bored joints.

The present standard type of joint indicated in figure No. 34 is known as half turned and bored, *i.e.*, only the bottom half of the socket and the corresponding section of the spigot is machined. Other forms of joints on the same principle, but with the full depth of the joint turned and bored have been used in the past. When using turned and bored pipes, it is necessary to ensure that all machined surfaces are kept well protected against corrosion, otherwise the joints will not be tight.

In all forms of turned and bored joints, the bored section of the socket is slightly tapered and a similar taper is formed in the turned surface of the spigot.

To make the joint, these machined surfaces are cleaned and the spigot is driven into the socket by blows from the succeeding pipe suspended from tackle. Sometimes, the machined surfaces are smeared over with a solution of sal-ammoniac to rust the joint, making the pipes practically one continuous metal line. As an alternative, the joint surfaces may be treated with a mixture of tallow and resin. The space behind the machined joint is sometimes left without packing while in other cases it is filled with cement, or, if the joint is intended to withstand high pressures, with run or melted lead.

Taking into account the cost of machining the joints, which enhances the cost of manufacture of the pipes, it is doubtful whether this type of joint is any cheaper in the long run than that of plain socket and spigot pipes with caulked lead and yarn, while there are many disadvantages.

One is that the joint is absolutely rigid and the pipe cannot be laid to gentle curves as in the case of the latter type of joint. The joint does not permit of any expansion and contraction at all. It is very difficult if not impossible in many cases to disconnect the pipes once the joints are made, particularly if they have been rusted by sal-ammoniac. If the pipeline has to be altered for insertion of branches after it is laid, the new pipes and collars have to be provided with plain spigot and socket joints for run lead, and for this reason British standard pipes with half turned and bored joints are so arranged that they can be interconnected with standard pipes and specials provided with plain spigots and sockets for caulked lead joints.

By reason of these disadvantages of the turned and bored joints, they have been largely superseded in Great Britain since many years by the plain spigot and socket joints for caulked lead. In the Punjab, however, their use continued till comparatively recently.

At present, however, they have been entirely superseded by the spigot and socket caulked lead joints.

21. Flanged joints.

Flanged joints for cast iron and steel pipes have been standardised by the British Engineering Standards Association as laid down in their Tables Nos. 1, 2 and 3 Publication No. 10-1904 and subsequently revised in their Publications No. 10, Parts 1—1928 and 2—1926.

Table B in Publication No. 10, Part 1—1928 is suitable for use with classes B and C Standard cast iron pipes, while Table C of the same Publication is suitable for use with class D Standard cast iron pipes.

Tables F and H of Publication No. 10, Part 2—1926 are suitable for steel pipe flanges for water-supply for proof pressures of 1,000 feet head and 1,400 feet head and Tables J and K can be used for still heavier pressures.

The bolts to be used with these flanges, for ordinary work, should consist of Standard Whitworth black mild steel bolts with hexagonal heads and nuts. The flanges generally employed for normal working pressures, say up to 800 feet vertical head of water are of the type known as "full machine faced," cast with the pipe in the case of cast iron pipes or welded on, in the case of steel pipes, and the joints are rigid for all practical purposes.

Although it is possible, if the machined surfaces are in perfect condition, to make a joint by covering the faces of the flanges with red lead and embedding therein 2 or 3 turns of string or lead wire, it is not safe to adopt this as a general procedure as it is seldom that the machine faced work is perfect, and it is therefore necessary to use a thick jointing ring.

The best joint ring consists of a tough three or four ply grey or red rubber with canvas, "insertion" ring cut to the same external diameter as the flange, the inner hole being say $\frac{1}{4}''$ to $\frac{1}{2}''$ larger in diameter than the pipe to avoid risk of obstruction to the flow when the joint ring is squeezed out.

The rubber insertion jointing should be from 1/16″ to 1/8″ thick for small pipes and from 1/8″ to 1/4″ thick for large pipes.

Plain rubber rings are sometimes used, but they are not so tough and are therefore more liable to damage by being blown out by the hydraulic pressure.

Some engineers use joint rings of " virgin " or soft lead sheet about 1/16″ thick. Another form of joint ring consists of a single corrugated ring made of brass, such as the " Taylor " ring, used with red or white lead or special jointing cement (Fig. 50).

The " Hulburd " double corrugated soft copper ring is sometimes used for high pressure flanged joints for water (Fig. 51).

It frequently occurs when the bolts of the flanges are pulled up, workmen try to make the joint tighter by inserting a length of pipe over the spanner handle to increase the leverage, and to enable two workmen to pull at the spanner. The result of this practice is that although the joint may be perfectly watertight when made, the bolts gradually slacken afterwards, and after some time a leak occurs. Care should therefore be taken in making flanged joints, that only British standard spanners are used, that no appliances for lengthening the lever arm of the spanners are permitted and only one workman of average strength is employed to pull up each bolt and nut.

For very high pressures such as hydraulic power and mining work and high head pumping installations, flanged joints with machined strip faces, plain recessed or, with male and female recessed joints, to take gutta-percha joint rings, are generally employed. A typical example is shewn in figure No. 52. Some manufacturers of flanged valves and specials used in connection with pipelines used a form of plain machined strip flanged joint as shewn in figure No. 53. In this case the width of joint ring employed should coincide with the machined strip.

Loose flanged joints are used when play is required in the joint such as where strict alignment of the pipeline is not required, or when slight diversions from straightness are desired.

They are handy when branches have to be fitted irregularly; the angle of throw of the branches can be arranged at will in any required direction, as the loose flanges can be rotated and fixed accordingly.

These classes of pipes are therefore specially useful for industrial and mining purposes, for water and steam, and for any purpose where pipelines require to be laid and removed, relaid or altered from time to time, but they are not usually employed for permanent water-supply pipelines.

There are various types of loose flanged joints, many of which depend for water tightness on a compressed packing strip ring between turned-up or thickened ends of the pipes or screwed or welded-on collars held in position by the loose flanges. Flanged pipes made with screwed-on flanges are also used for industrial purposes.

22. The Victaulic joint.

This is a patent joint used with wrought and ingot iron, steel and cast iron pipes. The pipes are made with shouldered ends which are engaged with a slight clearance with the split metal housing of the joint which holds the two ends of the pipes together.

The housing contains a special type of rubber washer, V shaped, which grips the pipe ends and keeps the joint sealed as the pressure rises, *vide* figure No. 54. The joint is very easily made by unskilled labour there being only two bolts in the housing, and it permits of a good deal of flexibility in the pipeline without leakage so that it is extremely useful for river crossings which are carried on suspended ropes, and other work in which flexibility is required.

The joint is cheap and generally compares favourably in cost with that of the spigot and socket joint for poured lead.

When the joint is required to be used with cast iron pipes, the ends of the pipes are thickened specially to take the joint, and with iron or steel pipes the ends are expanded.

23. Valves.

The valves and other fittings generally used on trunk and distribution pipelines are :—

(*i*) Sluice valves.

(*ii*) Air valves.

(*iii*) Hydrants.

(*iv*) Reflux or back pressure valves and flap valves.

(*v*) Pressure reducing valves.

(*vi*) Throttle valves.

(*vii*) Equilibrium and ball valves.

24. Sluice valves.

Sluice valves (Fig. 55), are employed for closing the water-way of pipelines in order to control the flow and to shut off for repairs. The usual practice on long mains of moderate size is to provide them at intervals of about one mile, and also on each side of special works requiring to be isolated from time to time, such as bridge and river crossings. On distribution systems, sluice valves are generally placed on all branch connections, and washouts are also controlled in a similar manner The valve consists of a vertical door of cast iron, with gun metal faces sliding in a groove (also provided with gun metal faces) in a cast iron body at right angles to the water-way, which is in line with that of the pipeline in which the valve is placed. The door is moved by the rotation of a heavy forged bronze screwed spindle passing through a packed gland or stuffing box on the valve body, on which is securely fitted a cast iron cap in the case of buried valves, or a hand wheel for exposed valves. Usually, for valves over 12″ dia., gearings of various types are employed to drive the spindle in order to permit the valve to be more easily operated, while very large valves for high pressure work are sometimes arranged for operation by hydraulic pressure or electric power, as may be found most convenient. It is not necessary in large pipelines for the valves to be the same diameter as the pipeline. A good practice for working pressures ranging from 60 to 500 feet vertical head of water, is to provide sluice valves of the same diameter as the pipeline up to 8″ inclusive. For pipelines above 8″ dia. the following sizes of valves will suit :—

Internal diameter of pipeline.	Internal diameter of sluice valves.
9″	8″
10″	8″
12″	9″
14″	12″
15″	12″
16″	12″
18″	15″
20″	15″
21″	15″
22″	18″
24″	18″

Such valves should have tapered connections to couple to the pipelines.

By the adoption of these arrangements, the number of different sizes of valves can be reduced largely, while in addition, the cost of the valves is cheapened, as it increases largely with the size.

Large valves, say over 12″ diameter, should be provided with byepasses controlled by byepass sluice valves 3″ or 4″ diameter, in order to facilitate opening and closing, the byepass valve being opened before the main sluice valve and closed after it.

Very large valves requiring considerable headway are often designed with the door sliding horizontally instead of vertically, the gearing being so arranged that the operating spindle, if required to be worked from above, is vertical.

Water hammer is largely influenced by the time of opening and closing sluice valves. The provision of gearing and of byepasses in connection with large valves, in addition to rendering easier and with less physical effort, the opening and closing of the valves, also lengthens the period of time of carrying out the operation. This is a great advantage. Valves should be opened and closed as slowly as possible, particularly the first few turns when opening, the last few turns when closing and the byepass valves.

On a long pipeline of moderate size say under a pressure of 500 feet vertical head of water, normally, it should take not less than fifteen or twenty minutes to open or close a main valve.

With cast iron spigot and socket pipes, the most economical arrangement is to use double socketted sluice valves, except if a sluice valve is to be fitted on a branch close to the point of junction with the main pipeline, when the branch should be flanged and a double flanged sluice valve fixed to it.

Sluice valves used with steel mains are generally provided with flanged joints and flanged special connections to couple on the steel pipeline either side.

Sluice valves should be tested at place of manufacture up to 2 or 3 times the maximum working head, subject to a minimum proof hydraulic pressure of 300 lbs. per square inch.

All sluice valves and other fittings operated by valve spindles, such as hydrants, air valves, screw-down valves, etc., should be arranged uniformly throughout the water-works system to open when the operating spindle is rotated in one direction, otherwise much trouble and difficulty will arise due to certain valves being closed or opened as the case may be when it is desired to carry out the reverse operation. A case known to the writer occurred some years ago of one valve at a particular point in an extensive distribution system which was arranged to open in the reverse direction to the other valves and it took over 3 months of careful systematic investigation to discover the cause of low pressures in certain sections of the distribution system.

Usually, valves are made to open by rotation of the spindle in a clockwise direction.

25. Air valves.

The object of air valves is to allow air to be discharged from the pipeline when it is being charged with water and also to permit the continuous discharge, under pressure, of air collected at summit points, in course of normal working of the pipeline.

The single air valve (Fig. 56) in its simplest form, consists of a cast iron body connected with the top of the pipeline and containing a ball of vulcanite, rubber or other suitable material. At the top of the valve, a gun-metal orifice is fixed, connected to atmosphere. When the main is full of water, the water in the air valve body floats the ball against the orifice, thus preventing leakage of water, but when air from the pipeline enters the air valve, the water surface is lowered and the ball drops by its own weight away from the orifice, allowing the air to escape. The diameter of the ball varies from $2\frac{1}{2}''$ to $5\frac{1}{2}''$ or more, depending on the working pressure on the valve.

The double air valve (Fig.57) has two separate ball chambers, one with a small orifice for discharging air under normal pressure conditions and the other with a large orifice for discharging air when the pipeline is in course of being charged up with water.

Single air valves are generally secured to a flanged tee 3″ or 4″ diameter set vertically in the pipeline, a $\frac{3}{4}''$ or 1″ nipple connection being screwed into a blank flange on the tee, with a heavy plug cock to isolate the air valve for repair.

Double air valves are bolted to flanged tees from 3″ to 12″ diameter depending on the size of the pipeline, of the same description as those provided for single air valves and a screw down valve is generally incorporated in the design of the air valve to shut off the valve for repair.

3″ tees for air valves will usually suffice for pipelines up to 15″ diameter and 4″ tees up to 20″ diameter.

Air valves, after the balls are fitted should not be placed under excessive test pressure, otherwise there is risk of distortion of the balls and leakage of water from the valves. Air valves are required to be provided on all summit points on rising mains and trunk pipelines. For distribution pipelines, some engineers hold that the service connections, public standposts, etc. are sufficient to discharge all air from the system. It is preferable however to instal air valves at a few of the most marked summit points, if any exist, especially at or near to the tails of pipelines.

26. Fire hydrants.

Fire hydrants are inserted generally on distribution pipelines for enabling a supply of water to be obtained for fire purposes. They are also useful for acting as outlets for flushing out dirt and sediment from the pipes and for filling watering carts and other purposes.

There are 3 types, the ball hydrant, the screw-down hydrant and the sluice valve hydrant.

The ball hydrant, (Fig. 58) was the first type to be used and consists of a cast iron body containing a vulcanite ball which is forced by the water pressure against a large orifice. To open the hydrant, a stand pipe fitted with an internal screwed spindle is coupled to the hydrant and, the spindle on rotation forces the ball downwards away from the orifice, allowing the water to issue through the stand pipe.

The screw-down hydrant (Fig. 59) has a screw-down valve, closing the outlet, which on being rotated by a suitable key, lifts from its seating and opens the water way.

The sluice valve hydrant (Fig. 60) consists merely of a special branch outlet fitted with a sluice valve to control the flow of water through it.

Hydrants are made with screwed outlets to fit various fire brigade threads or for instantaneous coupling, depending on the requirements of the fire authorities.

Ball hydrants are now largely out of favour, though they are still in use on some old water-works. The balls wear with use and get grooved and distorted, causing leakages. Ball hydrants act as air valves.

Fire hydrants are generally made with outlets ranging from 2″ to 5″ diameter but the usual sizes installed are 2½″ and 3″ diameter. The inlet connections are usually designed to fit 3″ diameter flanged tees set vertically in the pipe-lines.

27. Reflux or back pressure valves.

The simplest type of valve consists of a cast iron cylindrical body fitted with a hinged metal flap closing against a machined face, so as to allow water to pass in one direction but not in the other.

The valves should always have flanged inspection covers to facilitate repairs and inspection, while large valves are provided with series of hinged flaps closing on scraped gun metal seats, carried on a frame which can be removed from the body for repairs and other purposes (Fig. 61). The size of the valve should not be less than that of the pipeline in order to secure ample waterway, while a byepass 3″ or 4″ diameter with byepass sluice valve, should be provided for use in passing water in the reverse direction in case of emergency.

Reflux valves perform the same functions as sluice valves on rising mains and are far safer when positive pumps are employed, as they cannot be accidentally or negligently closed, like sluice valves. They are also useful when inserted in suitable positions on gravity pipelines crossing undulating country, to prevent reversed flow and consequent heavy wastage of water, in the event of a burst pipe or leakage on the main at a low point.

Hinged flap valves, as shewn in Fig. 62, are employed at the tails of washouts to prevent vermin from entering the pipeline when standing empty, with the washout valve open.

28. Pressure reducing valves. (Fig. 63).

These valves are employed in place of break pressure tanks or reservoirs to reduce the working pressure in a pipeline.

The valve consists of a cast iron body, containing a cylinder with ports connecting to the inlet and outlet sides. A gun-metal piston works in the valve and is connected to a piston rod passing out through a gland at the top of the valve, the rod being connected by a link to a lever, the fulcrum of which is fixed to the cover plate of the valve and the other end loaded by cheese weights. At a suitable point the lever is connected by a rod to a piston working in a dash-pot which is secured to the outside of the valve and from the bottom of which a small diameter copper or brass pressure tube is connected to the outlet side of the valve. When the moment due to the upward pressure of water in the dash-pot is greater than that due to the cheese weights, the piston in the dash-pot rises, and the piston in the valve gradually shuts off the flow of water through the valve.

When the pressure on the outlet side of the valve drops sufficiently for the cheese weights to overcome the water pressure against the piston in the dash-pot, the valve gradually opens again.

The valve works with a slight oscillating movement around the point of equilibrium. The operation of the valve being controlled solely by the pressure on its outlet or low-pressure side, it is adjustable for working under different outlet pressures by increasing or decreasing the number of cheese weights loaded on the lever arm.

The valve is liable, sometimes, to stick or jam, especially if the water contains grit or sediment, and thus tends to cause water hammer. Large pressure relief valves should be provided to prevent this as far as possible.

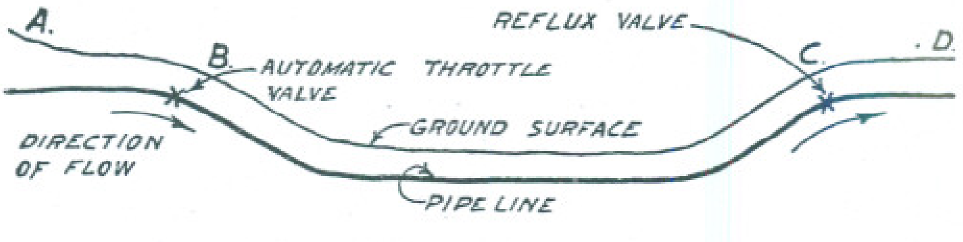
It is not so reliable as a break pressure tank arrangement for reducing pressure, but it often occurs that the cost of such a tank is prohibitive or it may be impossible to build the tank due to the pressure conditions required not being suited to the ground levels at the point where the pressure is required to be reduced, in which case a pressure reducing valve must be employed.

29. Automatic throttle valves.

In this type of valve (Fig. 64), when the velocity of flow exceeds a predetermined limit, due to a burst on its down stream side, a disc which is held by a lever and projects into the water way, moves and releases a weighted plunger rod, which in descending, turns a crank lever of a throttle in the main, thus closing the valve. The speed of closing can be regulated by a cataract cylinder and piston attached to the plunger rod. The valve should be provided with a suitable concussion or pressure relief valve to stop water hammer.

It is useful for preventing damage to property, in case of a burst pipe on the down stream side of the valve, on gravity pipelines. For example a gravity pipeline A. B. C. D. crossing a river valley, would have an automatic throttle valve at B and a reflux valve at C to protect the area along section B. C. of the pipeline, from danger due to flooding in the event of a burst between B. and C.

Longitudinal section of pipeline A B C D.



The valve, after closing, has to be reset again by hand and until this is done, the water remains shut off.

30. Equilibrium and ball valves.

These valves are required at inlets to reservoirs or tanks at the ends of rising mains or gravity pipelines.

There are 2 main types, *viz*., those in which the inlet pipe is near the full supply level of the tank or reservoir and those in which the inlet is considerably below full supply level of the tank or reservoir.

The former type, (Fig. No. 65), usually consists of a single or double seated valve working in a vertical chamber, connected to a horizontal lever by a link. The other end of the lever is fitted with a large watertight copper float and the lever is fulcrumed at a suitable point on the top of the valve. When the water surface is below full supply level, the weight of the float keeps the valve off its seat and allows water from the pipeline to pass through, but when full supply level is reached, the lever is raised by the floating ball and the valve is pressed on its seat, thus shutting off the supply. The double beat type of valve gives a greater opening for the water with a smaller variation of water level.

When the inlet is considerably below full supply level, a piston in the valve works in a vertical cylinder directly connected to a horizontal inlet pipe. A cylindrical float is connected to the piston by a vertical spindle. So long as water in the reservoir or tank is below full supply level, the piston remains in such position that the water-way through the valve is open, but as soon as the water rises to full supply level, the float actuates the piston through the vertical spindle, closing the water-way through the valve.

Sometimes the float gear and vertical spindle are not enclosed or protected, in which case it is necessary that the valve should be fixed in a small concrete or masonry valve chamber.

The float gear and spindle, however, can be enclosed in a cast iron or steel vertical column and float chamber, and thus be free of interference due to wave action (Fig. No. 66).

31. Piston type control valves

Piston valves such as the Johnson-Boving patent type manufactured by Messrs. Glenfield & Kennedy Ltd., Kilmarnock and the Larner-Johnson patent type made by Messrs. J. Blakeborough & Sons Ltd., Brighouse, Yorks, are used on large pipelines for water and hydro-electric power, for performing the functions of sluice valves.

This type of valve essentially consists of a stream-lined pointed hollow piston which slides centrally to the water-way of the valve, carried in an inner working cylinder, the water being shut off by an annular ring seat in the piston, fitting against a similar seat on the inner surface of the outer casing of the valve. The water-way through the valve consists of an annular space between the piston with its working cylinder, and the outer casing. The piston is usually moved for opening and closing by hydraulic pressure, but small valves can also be designed for operation through gearing by hand, if required.

The valve has several advantages over the ordinary sluice valve in its application to water supply pipelines, the internal design is such that friction losses are reduced to a minimum, the water-way through the valve being stream-lined; it is compact, reliable, and comparatively simple in construction and no delicate mechanism is exposed to the action of the water.

Valves of the piston type designed on some of the principles of piston control valves are now manufactured for use as throttle valves, equilibrium valves, reflux valves, pressure sustaining and pressure reducing valves on small and large pipelines.

32. Transportation of pipes.

Cast iron pipes and specials transported by rail are generally loaded in open goods trucks, and care should be taken to wedge the pipes to prevent them from shaking or rolling about in transit. Heavy canvas or jute bags bound with ropes, filled with hay or straw or other suitable packing are useful to wedge and hold pipes in position in the trucks.

Machined flanges should be coated with a tallow composition to prevent corrosion and covered with wood blank flanges bolted on to the flanges.

Steel pipes are either shipped loose or, if several sizes are required, they can be nested to save space on board ship, in which case wooden stoppers are placed in the pipe ends and a rod passed through the pipes with nuts each end of the rod to hold the stoppers in position.

Cast iron pipes and specials, unless transhipped in course of transport by rail, generally arrive at destination undamaged, the average percentage of castings damaged to such extent that they cannot be used, being less than half per cent, but if they have to undergo transhipment en route, this may cause as much as 4 or 5 per cent. breakages, unless the purchaser, at his own expense, provides special supervision at the station of transhipment.

Violent shunting operations, needless to say, are liable to produce serious breakages of cast iron pipes.

Steel pipes and specials are seldom irretrievably damaged in course of transport, but sockets are often badly dented or bulged, particularly if the metal is thin. Most of such defects however can be rectified by the purchaser, either by the use of a special expanding tool which should be supplied by the manufacturer or by judicious application of the hammer.

Steel pipes are liable to have their coating and wrapping badly damaged by ship or rail transport and handling, and it is usual for the manufacturer to supply the necessary extra jute fabric and bituminous composition to enable repairs to be executed properly by the purchaser. The wrapping and coating is liable to be damaged by rubbing against frame work in the ship's hold and in railway wagons, and by the chains or rope