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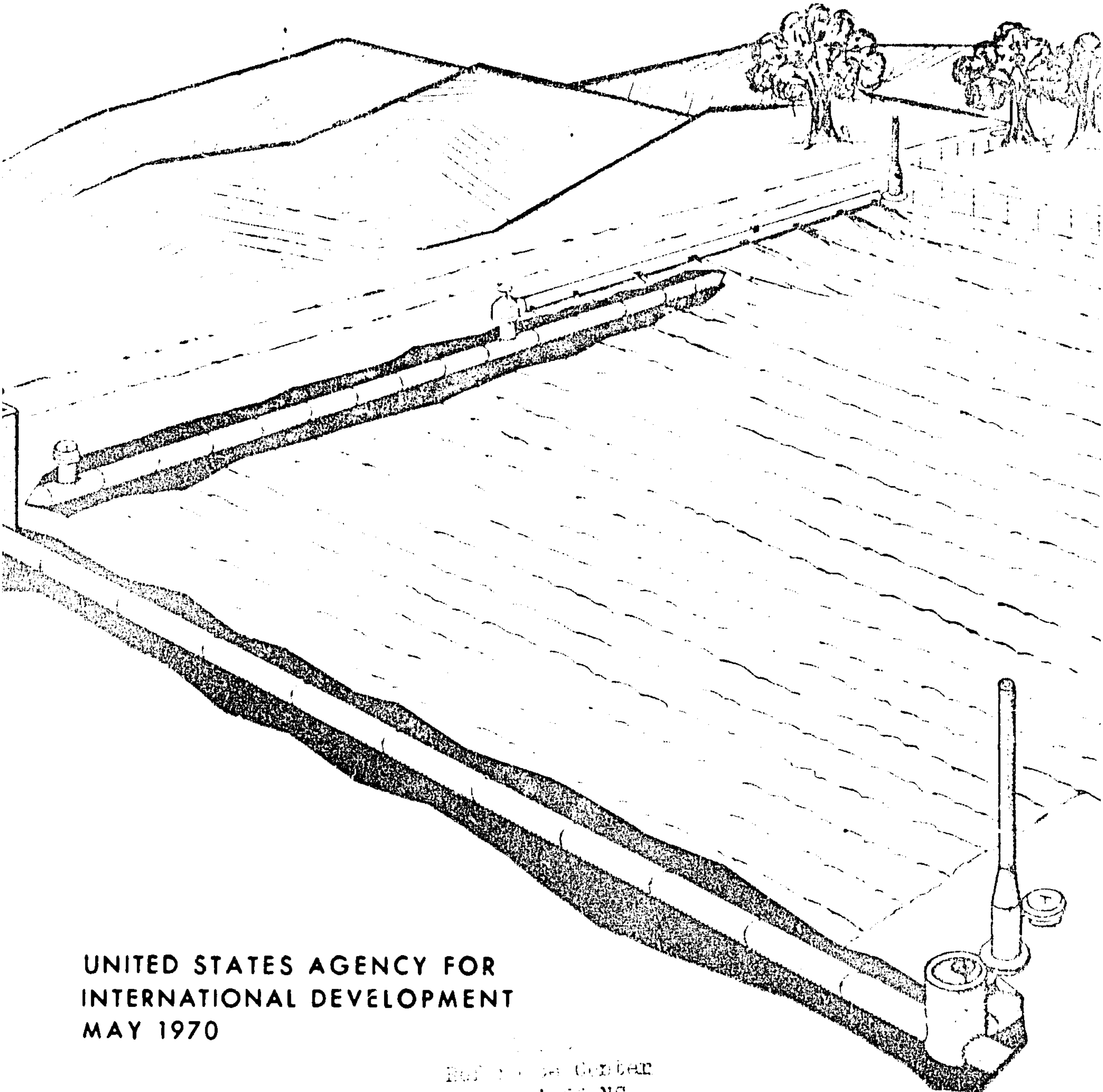
REPORT TO THE GOVERNMENT OF INDIA ON

DESIGN CRITERIA, CONSTRUCTION GUIDE AND MATERIAL STANDARDS FOR IRRIGATION PIPELINES



UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
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REPORT TO

THE GOVERNMENT OF INDIA

ON

DESIGN CRITERIA CONSTRUCTION GUIDE, AND MATERIAL STANDARDS

FOR

IRRIGATION PIPELINES

PREPARED BY

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PIPE - INDIA

IN
627.52 Dept. of Agriculture. NTIS
K81 Report to the Government of India on Design Criteria Construction Guide, and Material Standards for Irrigation Pipelines. Paul K. Koluvek. May 1970.
195 p.

1. Irrigation - India. 2. Pipe - India. I. Koluvek, Paul K. II. Title.

Errata

Page 8 Second column—line 10—read—*except that the pipe* instead except that is pipe.

Page 8 Second column—line 11—read—*placed* instead place.

Page 11 Second column—line 7—read—*Institution's* instead Institution.

Page 18 Last but one line—read—*point* instead points.

Page 19 Second column—line 10—read—*concrete* instead cnncrete.

Page 25 Second column—line 17—read—*thorough* instead thorugh.

Page 28 First column—line 3 from bottom—read—*difference* instead differences.

Page 37 First column—line 9—read—*selected* instead selcted.

Page 47 First column—line 6 —read—*203.2* instead 203.3.

Page 65 Read—*capacity up to 2 c. fs.* instead capacity up to c. fs.

Page 79 Second column—line 24—read—*lime* instead line.

Page 84 Second column—line 5 from bottom—omit *by*.

Page 90 Second column—line 1—read—*outside* instead outsied.

Page 91 Second column—line 8—read—*create* instead creat.

Page 134 Second column—line 9 from bottom—read—C_1 instead Cc.

Page 183 Second column—line 8—read—*210°* instead 21°.

Page 184 First column—line 3—read—$Q = ckd_2\sqrt{h_1 - h_2}$ instead.
$Q = ck_2d^2\sqrt{h_1 - h_2}$.

CHAPTERS

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PURPOSE AND SCOPE

This report documents the findings and recommendations of the author who was engaged as a consultant to USAID and the Government of India for a four-month period to determine what is being done in the sphere of irrigation pipelines and to appraise and make recommendations for improvement. The objectives and nature of the assignment were outlined by J.K. Jain Joint Commissioner, Minor Irrigation, Ministry of Food, Agriculture, Community Development and Cooperation on January 8, 1970.

The assignment consisted of observing the manufacturing methods used in pipe design and construction methods being used in the field, the methods of jointing irrigation pipe, and recommendations for improvements based on the observations in the field. It was suggested that the States of Gujerat, Haryana, Maharashtra, Mysore, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal, and Delhi Union Territory, where pipe is being made and/or installed, be visited.

Travel and conference schedules are recorded in Appendix B.

ACKNOWLEDGMENTS

The consultant is sincerely indebted to the many individuals who made it possible to visit the many sites and factories and to those many individuals who so generously shared their experiences and knowledge. The names of these persons are recorded in Appendix A.

The contribution of one particular individual was so great and so critical to the success of the assignment that he should share equally with the consultant any credit or feeling of accomplishment that may accrue from the report. Mr. U.S. Madan, Agronomist, USAID served as full-time advisor to the consultant during his stay in India. With greatest effectiveness, he arranged conferences with appropriate individuals, arranged field inspection trips, acted as an interpretor and assisted in the preparation of this report. This made it possible for the consultant to complete his assignment in the allotted time. For this, the consultant is deeply grateful to him.

The consultant is gratefull to the American Concrete Pipe Association and Portland Cement Association for allowing the free use of the Material published in their various handbooks. These handbooks are listed in the bibliography. "Concrete Pipe for Irrigation" Bulletin by Portland Cement Association is reproduced as Appendix J. with their consent.

Furthermore, the consultant would like to express his appreciation to the USAID Secretaries, for typing the manuscripts for this report.

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CHAPTER 1

Need and Scope for Irrigation Pipe

Irrigation water should be made available to each part of the farm irrigation system at a rate and elevation that permits proper operation of the selected methods of water application. Irrigation water should be conveyed as economically, efficiently, and safely as possible. The delivery part of the farm irrigation system should be large enough to furnish the required irrigation water to meet crop demands during peak-use periods. If the water is delivered on a rotation or turn basis, the system should be large enough to allow delivery of the water in the time allotted. Plans should provide for future needs and expansion.

With the great demand on a limited water supply in India, there is a great need for efficient use of irrigation water. One important means of meeting this problem is through the use of pipe distribution systems.

There are a number of advantages in using underground pipelines of which the followiog are important : (a) *Little loss of farm land.* Almost all of the system is buried. As a result, no significant amount of land is lost to crop production. (b) *Labor saving.* The control of water is simple and usually requires much less labor than other systems. The labor is often 25 to 50 percent less than that required with earth ditches. (c) *Permanence.* A pipeline, properly designed, made of good quality, material, and properly constructed, has a long life span. (d) *No water loss.* A pipeline system is essentially water tight, with no evaporation loss during transmission. As a result there are water savings and less pumping cost. In addition, the drainage problem is lessened. (e) *Ease of distribution.* This is important in undulating land. Water can be transported across a swale or boosted uphill, a procedure not possible with ditches unless an elaborate structure is built. (f) *Low maintenance.* Generally, maintenance costs are small, whereas earthen have to be maintained continually. (g) *No ditch bank weed problems.* There are no ditches to become choked with weeds to hinder flow. Weeds can harbor harmful insects. In addition, weed seeds, which can be transported to field in an open ditch are eliminated. (h) *Better control.* Better and easier control of the flow of water means that more efficient and better irrigation is possible. (i) *No hinderance to equipment*· There are few obstacles to hinder the movement of agricultural equipment. This is an important feature where the fields are small.

As with any system, there are disadvantages. Some of the more disadvantages of a pipeline are: (a) *Less advantage with large flows.* The cost of pipelines increases faster with capacity than does the cost of ditches. The net economy of a pipeline varies with the value of land, frequency of irrigation, and cost of irrigation labor. Thus, it is impossible to set flow limits above which ditches might have some advantage over pipelines. (b) *Cost.* A pipeline requires a greater investment than an unlined ditch or lined ditch. Economy comes in time, from savings of water, labor, maintenance, and permanence of installation. (c) *Saline conditions.* Concrete pipe used in saline or alkali soils, is subject to deterioration unless a high quality pipe is used. (d) *Subject to earthquake damage.* Although any risk involved is extremely small, concrete irrigation pipelines are subject to damage. within a limited area, from movement along earthquake faults. The remoteness of the risk is demonstrated by the fact that although faults are found throughout California, USA., and although earthquakes are relatively frequent (geologically speaking), the first movement along an earthquake fault known to have caused appreciable damage to concrete pipe systems occurred in 1952. Along a fault south of Bakersfield, California, there was severe movment. A few systems immediately over the fault were so damaged as to be considered a total loss. In spots, for a distance of 3.2 to 8.0 kilometers (2 to 5 miles) on either side of the fault line, some cracking of pipe and stands was observed, the damage decreasing with distance from the fault.

TYPES OF IRRIGATION SYSTEMS

Two general kinds of pipelines are used-low pressure and high pressure. Low pressure pipelines are open to the atmosphere and are usually used with operating heads of less than 1.4 kg/cm 2 (20 pounds per square inch). High pressure pipelines are closed to the atmosphere and are used where operating heads of more than 1.4 kg/cm 2 (20 pounds per square inch) are required. Valves are used in lieu of open vents and stands.

LOW-PRESSURE PIPELINES :

Low-pressure pipelines are used primarily with surface irrigation methods. They can be permanent, semiportable, or portable. Permanent farm systems usually consist of buried supply and distribution lines. In semiportable systems buried pipe is used for field supply lines, and some kind of quick-coupling metal pipe or flexible pipe is laid on the ground surface to distribute the water. A fully portable system uses metal or flexible surface pipe for both field supply and distribution.

Concrete generally is used for low-pressure buried lines, but steel, asbestos-cement, or plastic pipe can be used.

It is very important that a pipeline be large enough to convey the flow needed In different fields under present and future conditions. It must be large enough to supply the water required during the period of peak crop use even though this full capacity may be needed in only a small part of the total irrigating season.

Specialized structures are needed on pipelines to control water and to protect them against damage. Pipelines on sloping land may develop excessive pressure heads that must be controlled by standpipes or regulating valves. Lines fed directly from pumps also must have structures for controlling the maximum pressure automatically.

HIGH-PRESSURE PIPELINES :

High-pressure pipelines generally are used to convey water for sprinkler irrigation. Since sprinklers usually require a pressure of 2.8 kg. per cm^2 (40 pounds per square inch) or more for efficient water distribution, the pipeline must be designed as a high-pressure system to withstand this pressure. The supply line or sprinkler main line may be a permanent buried line or a portable metal surface pipeline. Buried lines cost more to install, but their maintenance and operating costs are lower than than those for surface pipe. Buried lines do not interfere with farming operations and are less likely to be damaged by farm machinery and vehicles.

A buried main line may extend from the water source to individual fields, and surface pipe is used for the field main and laterals. This permits moving the field main and laterals to other fields. Or a buried main line can extend into the fields to be the fields main and have risers and valves at the location of each lateral line.

A buried main line is either metal, asbestos-cement, or plastic pipe. Portable surface lines are aluminum pipe and can be in 6.1—, 9.1—, or 12.2—meter (20—, 30, or 40-foot) lengths with quick couplers. If the water is from an open source where debris can collect, trash screen should be installed at the pump inlet. The screens should be fine enough to remove weed seeds and other small particles that may clog sprinklers nozzles.

USE OF PIPELINES IN INDIA

In India, low pressure pipelines are adapted to the various types of irrigation projects, such as State tubewells, state canal systems, private tubewells, dugwells, and riverlifts, provided sufficient head is available to achieve the necessary economy. Given the same amount of flow and length of pipe, a higher head is needed to convey water through a small pipeline. In comparison a lower head is needed to convey water through a larger diameter pipeline. Another factor to consider is that higher the pumping lift required, the higher the pumping cost will be. As a result, some balance should be arrived at between height of stand required, pumping lift, and pipe diameter.

Generally, canal systems are least adaptable to pipelines because of insufficient head. Therefore with canal systems open channels are used to convey water because of greater economy. Pipelines are very adaptable to pumping schemes because very little extra power is required to provide the necessary head.

High pressure pipelines are not discussed in this report although standards are included.

CHAPTER 2

Observations During Visits to the Various States

In the trips to the various states, it was found that several types of pipe were being used for irigation pipelines. The various types of pipe that are being used are RCC (reinforced—concrete), NRCC (non-reinforced-concrete), asbestos-cement, and steel

Other types of material that are being manufactured and can be used for irrigation pipelines are high density polythylene (PE) and rigid polyvinyl chloride (PVC) pipe. In addition, aluminum pipe is being made for portable irrigation systems.

CONCRETE PIPE

The maojrity of the pipe used in Class NP2-RCC is according to Indian Standards, IS:458[1] (Figure 1, page 5). This pipe is primarily made by the centrifugal method. In most state government irrigation works this type of pipe is used. In some areas a hand-made cast RCC pipe is manufactured which is being used by the farmers. Sizes of pipe being used for irrigation are 152. 4—, 228. 6—, 304. 8—, 381. 0—, and 457.2mm (6—, 9—, 12—, 15, and 18—inch) diameter. Pipe length varies from 1.83 to 2.44 meters (6 to 8 feet). The NRCC pipe is referred to as class NP1 according to IS:458. Presently, there are 4 methods being used in this country to manufacture this pipe. The most common method is the handmade, cast process. The other methods being used are the centrifugal, vibrator (Figure 2, page 5) and packerhead processes. The latter two processes are being used to a very limited extent. Most of this type of pipe is being used by the farmer, although several state governments are also using this type of pipe. The diameter of pipe being used for irrigation are 152.4—, 228.6 – , and 304.8mm (6 , 9 – , and 12 – inch). In one state a 609.6—mm (24—inch) diameter pipe was being made for a supply line. The length of pipe ranged from 0.61 to 2.44 meters (2 to 8 feet).

MANUFACTURING

In the manufacturing of Class NP2-RCC pipe the following cement, sand, and gravel ratios were being used : 1:1½:3, 1:2:2, 1:2:2½, 1:2:3, 1:2:4. For the NRCC pipe a wide variety of mixes were being used. The following mixes were being used by the various manufacturers for the various types : 1:2:4 (butt end, hand-made cast; tongue and groove, spun or vibrated); 1:3:6 (butt end, hand-made cast); 1:3 (tongue and groove, packerhead; socket and spigot, hand-made cast) : 1 :1 : 1, 1 : 1½ : 1½, 1 : 2 : 2, 1 : 2 ½ (socket and spigot, hand made cast) : 1 : 2 : 2 (butt end, spun); 1 : 2 : 3 (socket and spigot, vibrator); 1 : 1½.: 3 (butt end, spun).

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[1] Specificatios for Concrete Pipes (With and Without Reinforcement)

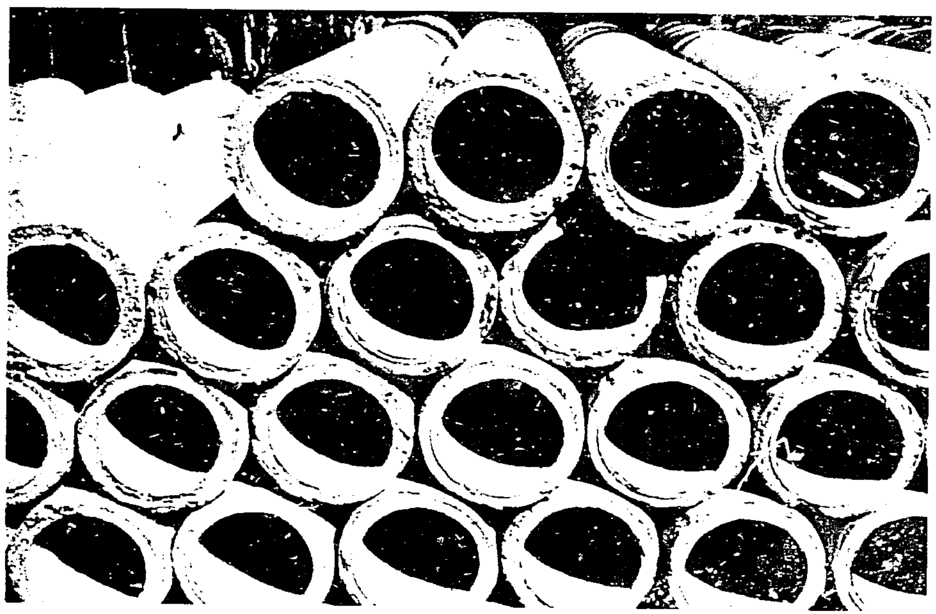

Fig. 1 Class NP2-RCC Pipe made by the centrifugal method

Fig. 2 Socket & Spigot pipe made by the vibrator method

A wide variety of aggregate was being used in concrete mixes for pipe. The quality and gradation of the aggregate could be assessed only by visual means. In general, it appeared that the aggregate lacked proper gradation, although there were some cases where the aggregate may have had rather good gradation.

The sand being used varied from a fine sand to a coarse sand. In many instances the sand was contaminated with organic matter, clay, silt, and micaceous particles or a combination of these. In a few instances some of the manufacturers either washed or screened the sand to remove undesirable material. The general source of this material is from natural sources such as river beds. A small number of manufacturers were using rock dust which was probably of good quality but may have lacked proper gradation.

The majority of coarse aggregate used comes from crushed rock although in several cases a gravel from natural sources was being used. The crushing is being done either by hand or by mechanical rock crushers. Aggregate crushed by hand was generally of a uniform, singular size, whereas the mechanically crushed rock had a variety of sizes.

Generally, the coarse aggregate was separated into the following three size ranges :

3/8 inch average size ; range-1/4 inch to 1/2 inch, often called grit

1/2 inch average size ; range-3/8 inch to 3/4 inch

3/4 inch average size ; range - 1/2 inch to 1 inch.

In many cases the 3/8 inch aggregate had sizes smaller than 1/4 inch. In one instance the average size was supposed to be 3/4 inch, but it appeared to be 1 inch average size.

For the smaller diameter pipe, 304. 8mm (12 inches) and less, the 3/8 inch aggregate was generally used, although in some cases larger aggregate was being used.

The coarse aggregate appeared to be of very good quality. In some cases basaltic and granitic rock was being used. In one case, sandstone, a very poor material was being used. This aggregate, in many cases, was also contaminated with dirt or other undesirable material.

The cause for some of the contamination is in the way the aggregate is being stored. In most cases the material is being dumped on the ground out in the open. This allows the material to be contaminated with dust and other objectionable material. In taking the material from the stockpiles when it is being made ready for the mixers dirt can be scooped up with the aggregate.

The quantity of water being used in a mix could not be assessed very readily. In one case where a 1:2:4 mix was being used, 18-20 litters was used with 0.028 cubic meters (1 cubic foot) of cement. In general the amount of water used is based on the workability and appearance of the mix.

In general the type of mixers being used by the large and small scale industries are adequate for the job. Two types of mixers are being used : the open batch mixer and the drum mixer. The open batch mixers all appeared quite old and the blades are worn. This causes inadequate mixing. At several plant sites these worn mixers were being used, and the concrete coming out was not thoroughly mixed. The mixing being done by the cottage scale industries was by hand in a sort of shallow basin. The mixtures appeared to be thoroughly mixed.

In many cases the reinforcement being used for RCC pipe was rusty. In some instances old wire or rods and in some cases, scrap metal was being used. The reinforcement cages were being manufactured according to IS:458.

When the making of RCC pipe and spun NRCC is completed the form, with the pipe inside, is set out in the open or in a open building to air dry. In the winter a fire is sometimes built inside the building to provide heat for curing. The following day the pipe is removed from the forms and immersed in water. It is kept immersed from 14 to about 21 days. The pipe was sometimes partially immersed in water and the pipe rotated daily. In addition, water is sprayed on the pipe occassionally or wet gunny bags are placed on the exposed pipe. One plant occasionally used sprinklers to cure the pipe.

In the curing of handmade NRCC pipe, a somewhat different procedure is being used. Moist sand is placed inside the inner-mould. After concrete is placed between the inner-and outer form, the inner-form is removed leaving the moist sand to support the concrete. The next day the pipe is immersed in water. Another method being used is not filling the inner-mold with sand but removing both forms after the initial setting of concrete and then keeping the concrete moist.

Where the NRCC pipe is made with a vibrator or packer head the pipe is removed immediately from the mold and left to air dry for one day before being immersed in water. In one instance the pipe was left in the mold for one day, removed from the molds and immersed in water for the prescribed time.

In the manufacture of concrete pipe there is considerable breakage or damage. This damage or breakage occurs during removal of the pipe from the forms and in the handling of pipe. According to the manufacturers, plant breakage for RCC pipe ranges from about 3 to 10 percent. In addition there is considerable damage to the ends of the pipe. This pipe may be patched or used in its damaged condition. In the transport of this pipe there is additional breakage of about 5 percent.

It was also noted that in some of the RCC pipe some of the reinforcement is nearly exposed or exposed at the ends and along the sides, both on the inside and outside of the pipe. Where the reinforcemnt was exposed, rusting was taking place after curing.

According to the manufacturers of NRCC pipe there appears to be a varying amount of breakage. This appears to depend on the mix used, method used in making pipe, and probably the water-cement ratio. There is no plant breakage where the correct type of vibrator, packer-head, or hand-made cast (socket and spigot pipe) are used and where the mix is 1:2:3 (vibrator), 1:3 (packer-head and hand cast). Where the pipe was spun with a 1:2:4 and 1:1½:3 mix the plant breakage is about 4 per cent. With the hand cast, 1:2:4 mix there is about 10% breakage. Where the platform vibrator was being used, with a 1:2:4 mix, the breakage ranged from 20 to 30 percent, including transport breakage.

The large scale and some small industries that manufacture spun pipe maintain some quality control on their products. Occasionally or at the demand of the purchaser they make some tests. These tests are the hydrostatic pressure test and three-edge-bearing test.

Manufacturers of hand-made cast pipe done on a cottage industries scale do not have equipment to make any tests and as a result can not conduct any quality control measures.

It is not known if there is any quality control on the aggregate material used. This would consist primarily of determining the gradation of the material.

LAYING OF PIPE

Current pratice is to lay a section of pipe with a mound of earth under each end so as to keep the ends of the pipe above the trench bottom. This is done to make the jointing process easier. In some places the pipe is set on mounds of rock or brick near the ends of the pipe without support in the middle. In one area this caused cracking in the circumferential direction at the midpoint of the pipe.

NRCC pipe, tongue and groove, was being set on brick for the reason given above. The spigot and socket pipe was being laid in the bottom of the trench and supported by the socket end of the pipe. In another case the end butt joint pipe, where no collar was used, was set in bottom of the trench.

JOINTS AND METHODS OF JOINTING

The ends of the RCC, Class NP2, are made so that they are suitable for a butt end joint. In spun pipe there is a recession in the end of the pipe for jute braiding. The hand made pipe does not have this provision. In most cases a reinforced concrete collar is used with this pipe.

Ir. one area, a RCC, Class NP2 pipe is being made with a spigot and socket type joint (Figure 3 and Figure 4, page 13).

The joints for NRCC pipe are being made in several different ways. Some of the pipe is made so that it is suitable for butt end jointing. Another type of joint being made is a tongue and groove. A third type has a socket and spigot.

Several different methods of jointing RCC, Class NP2 pipe were observed. One method consised of a ring of jute braiding dipped in hot bituminum placed in the recessed end of the pipe. This ring of jute is then compressed by jacking the end of the pipe. The loose concrete collar is then centered over the joint and evenly spaced around the pipe. The space is then caulked with a cement mortar and the area from the collar to the pipe is filled with mortar and beveled off at an angle of approximately 45 degrees with the outside of the collar (Figure 5, page 14). This will be referred to as "pointing" in the report.

Another method used is the same as above, except that the collar and pipe is pointed off with an opening at the bottom and top. The space between the collar and pipe is filled with grout under pressure. This is referred to as "pressure grouting".

A third method, is similar to the one above, except that the is pipe butted together and a thin coating of dry mortar is place around the joint filling all the openings. The collar is then centered and spaced evenly around the joint after which the collar and pipe is pointed off, leaving two openings at the top. A mortar slurry is then poured into the opening until the area between the collar and pipe is filled.

A fourth method consisted of placing a jute braiding, which had been dipped in hot bitumen, in the recessed end of the pipe. The pipe was then shoved together by hand, compressing the jute to some degree. A mortar collar was then made around the joint. The size of the mortar collar was approximately the same as that of a precast collar. The maximum aggregate size in this mortar appeared to be about 12.7 mm (1/2 inch.).

A fifth method is with a cast iron detachable joint. This joint is similar to the one being used with asbestos cement pipe.

In jointing the socket and spigot pipe only one side needs to be pointed. Before pointing, a jute rope, dipped in tar, is caulked into the joint.

The NRCC pipe, that is suitable for butt end jointing, is joined together by means of a mortar band. The tongue and groove pipe is being joined in the following manner. The groove end is pointed in the direction the pipe is to be laid. The groove is filled with mortar and then the tongue end is shoved into the groove. Following this, about 15 joints in back of the pipe laying, a mortar band is made around the joint.

The socket and spigot is being laid with the socket pointed in the direction the pipe is being laid. Some mortar is placed into the socket and then the spigot end of the pipe is shoved into the socket. Following this, about 6 joints in back of the pipe laying, a band of mortar is placed at the joint (Figure 6, page 14).

MORTARING AND CURING OF JOINTS

In the mortaring of the joints, it was noted in most cases, that the mortar was being placed without cleaning the pipe or collar, and with no prewetting of the pipe or collar. The most commonly used mortar mix was a 1 : 2. Other mortar mixes being used are 1 : 1, 1 : 1½ and 1 : 2½. The 1 : 2½ mix was being used by a contractor on a farmer job. Where a cement slurry was being used, the mix was a 1 . 1.

The curing of joints consists of placing soil over and around the joint or covering with wet gunny bags (Figure 7, Page 15). In one case the dirt was moistened after its placement. The actual curing is done sometime after the joint is made. In some cases considerable time passes before the joints are covered.

TRENCHES

There is some variability in the minimum depth of cover provided for concrete and asbestos cement pipe. The minimum depth of cover ranges from 0.61 to 0.91 meters (2 to 3 feet). In general, the minimum width of the trench is the diameter of the pipe plus 0.61 meters (2 feet). The includes both concrete and asbestos cement pipe

APPURTENANCES

In the various states visited a large variety of irrigation structures were being used. Following is a list of some of the important structures and their use :

1. Main chamber—used to receive water from pump so as to regulate the head, to act as a surge chamber, and as a stilling basin for measuring water through a "V" notch weir. It varies in size, depending on quantity of water discharged. It also serves as a point of distributing water to a pipeline or to several pipelines. It is built out of a combination of concrete, brick and mortar.

2. Delivery tank (See item No. 4)

3. Pump Stand (See item No. 4)

4. Pipe Stand - used to receive water from the pump to regulate the head and to act as a surge chamber. Constructed with concrete, mortar and brick, concrete pipe. Sometimes valves are used.

5. Silt collecting tank—used as a pump stand with sufficient cross section to insure low velocities. Sand and silt collects in the bottom and water flows out near the top into a stand pipe. Constructed with brick, mortar, and concrete.

6. Diversion Stand—used to control water by means of one or more valves inside the stand. Also serves as an air vent. Built with concrete pipe, concrete, brick and mortar and valves.

7. Sluice valve—used to shut off or control water in pipelines.

8. Junction box—used to deliver water to a field and serves as an air vent. It is constructed with concrete pipe, concrete, brick and mortar, and sometimes valve.

9. Riser with an alfalfa valve and riser with alfalfa valve with distribution box—used to distribute water from pipeline, constructed with concrete pipe, mortar, and alfalfa valve.

Where distribution boxes are used, concrete, mortar and brick are needed.

10. Tamper proof valve with riser or with distribution box—used to distribute water from pipeline. Constructed with tamper proof valve, concrete pipe, galvanized iron pipe. Where distribution box was used, concrete, mortar and brick are needed (Figure 8, page 15).

11. Vent—used to serve as an air vent and to prevent high pressures. Constructed of concrete and pipe.

ASBESTOS CEMENT PIPE.

There are two types of asbestos cement pipe being used for irrigation pipelines. One type, which is being used by some state governments, is made according to IS : 1592[1], which is a pressure pipe. The Class I pipe is used because it is the lowest pressure class available.

The other type of asbestos cement pipe being used is made according to IS : 1626[2]. This pipe is being sold as a nonpressure pipe for irrigation systems and, in some areas, a considerable amount of this pipe is being used by the farmer.

MANUFACTURING

The process used for manufacturing asbestos cement pressure pipe (IS : 1592) is being used in collaboration with Johns-Manville of the United States. The firms visited are maintaining quality control by continually testing their products and material.

In the manufacturing of asbestos cement building pipe (IS : 1626), a similar process is used, but with less sophisticated equipment. The large scale industries are maintaining good quality control by continually testing their products and material. The small scale industries do not maintain much in the way of quality control.

The large scale industries start curing their product after the initial setting of cement, whereas the small scale industries air dry their pipe in an open building for one day before water curing.

LAYING OF PIPE

Asbestos cement pipe is being laid in the same manner as the RCC pipe, where concrete collars are used. No other methods were observed in the field.

JOINTS AND METHODS OF JOINTING

The asbestos cement pressure pipe (IS-1592) is being joined together by one of three ways. One way, is with a asbestos cement couplers. This is a special coupling which uses 3 rubber rings for diameters up to 150 mm. Above this diameter 2 rubber rings are used. Another method, is with a cast iron detachable joint. The detachable joint consists of one center collar and two flanges of cast iron, two rubber rings and steel bolts. A third method, which is for low head, is the use of a loose concrete collar. The pipe is butted together, the collar centered and evenly spaced around the pipe. The space between the pipe is caulked with mortar and pointed. This method has only been used where asbestos cement couplers were not available.

The asbestos cement building pipe is made with a socket and spigot. Two methods can be used to make a joint. One method consists of using a a braided jute, dipped in neat cement slurry, caulked into the space between the socket and spigot. The space is then caulked with mortar and then the joint is pointed.

The other methods consists of using a rubber gasket in place of the jute packing and

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[1] Specification for Asbestos Cement Pressure Pipe

[2] Specification for Asbestos Cememt Building Pipes, Gutters and Fittings. (Spigot and Socket Type).

then the same cementing process is used. No actual field laying was observed

STEEL PIPE

The only steel pipe observed was being used in one state because of its availability and therefore deserves only a casual mention. its use would be only in areas where there are extremely high heads and then an economic evaluation would be needed against other available material such as asbestos cement pressure pipe, ployvinyl chloride (PVC) and polyethylene (PE) pipes.

PLASTIC PIPE

No plastic pipe is being used for irrigation systems where there are low heads (under 20 feet) because of its cost. This pipe is being used in connection with sprinkler irrigation systems where high pressure is required and as portable sprinkler pipe.

The manufacturers visited are working in collaboration with various foreign firms. These manufacturers are maintaining quality control by testing their pipe and material used in manufacturing.

Rigid PVC pipe is being manufactured according to IS : 4985[1]. Only one firm that manufactures high-density polyethylene pipe was visited and they are manufacturing their pipe according to DIN standards-DIN 8074/8075 and ISO recommendation. Presently the Indian Standards Institution' standards are not available but will be in the near future.

ALUMINUM PIPE

Aluminum pipe is not being used for underground, low head irrigation systems. In the near future it will be used for a gated surface pipe with a low head irrigation system. Its principal use is for portable sprinkler irrigation systems.

The pipe is being built to withstand test pressure of 21.1 kg/cm^2 (300 pounds per square inch). Modern equipment is used to manufacture this pipe. The one company visited is maintaining good quality control by continual testing of its products.

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[1] Specifications for Unplasticized PVC Pipes for Potable Water Supplies.

CHAPTER 3

Appraisal and Recommendations

In India, RCC (reinforced concrete), NRCC (non-reinforced concrete), asbestos cement, and steel pipe are being or have been used for low head irrigation pipelines. The majority of pipe being used is probably Class NP2-RCC as according to IS : 458[1]. This pipe is being used primarily by the various state governments and, in many areas, by farmers.

Probably the second most popular pipe, is the Class NPI-NRCC as according to IS : 458. This pipe is being used primarily by the farmer, although several state governments are using this pipe.

Next in order of use is asbestos cement pipe. There are two types of asbestos cement pipe being used for low head irrigation systems. The type probably being used most is asbestos cement building pipe as made according to IS : 1626[2]. This pipe is being used by farmers. Another type being used is the Class 1 asbestos cement pressure pipe as made according to IS : 1592[3]. This pipe is being used by several state governments.

Steel pipe was used in only one state. Plastic pipe is being used in conjunction with sprinkler irrigation systems and only one system was visited. Aluminum pipe is being used only for portable sprinkler irrigation systems as present. The appraisel of various pipe material is made in Chapter 4.

[1] Specifications for Concrete Pipes (with and without Reinforcement)

[2] Specification for Asbestos Cement Building Pipes, Gutters and Fittings (Spigot and Socket Type)

[3] Specifications for Asbestos Cement Pressure Pipe

CONCRETE PIPE

In the manufacture of concrete pipe there are four factors involved ; equipment, concrete material, concrete mix, and curing.

EQUIPMENT

In India the following four processes are available to make concrete pipe :

1. Centrifugal Process—Centrifugal concrete pipe is manufactured in forms rotated a high speed in such a manner that the centrifugal force compacts the concrete while it is in place, meanwhile forcing out excess water.

2 Cast, Hand Tamped Process—This process can be divided into two methods; wet cast and tamped, The wet cast process uses wet or slump concrete, similar to the product used in general concrete, placed into a space created by an inner and outer-form. Normally the concrete reaches its final set in the forms before they are removed and used again (Figure 9, page 16).

The tamped process also uses an inner—and outer-form, except that a semi-dry concrete is used. The concrete is placed into the forms

Fig. 3 A type of Class NP2-RCC pipe made with socket & Spigot

Fig. 4 Form used to make the socket and spigot pipe by centrifugal method

Fig. 5 Mortaring of a collar joint. Area from collar to pipe is filled with mortar and leveled off at about 45 degrees with outside of collar

Fig. 6 Mortaring of joint on NRCC, socket & spigot pipe

Fig. 7 Curing of mortared, collar joint with wet gunny bags

Fig. 8 Tamper proof valve with iron pipe, requires special wrench to operate

Fig. 9 Forms used in the manufacture of cast, handmade pipe

Fig. 10 Circumferential cracking due to lack of support in center of long pipe. This is a RCC Pipe.

and spaded or tamped to compact the mix. The dryness or wetness of the mix determines when the forms are removed. In India, a damp sand is placed in the center portion of the inner-form. The inner-form is removed, after the concrete is placed, and the sand acts as a form, keeping the concrete from collapsing.

3. Vibrator Process—The dry mix is compacted inside a form by means of some device that vibrates the inner core and the outside of the form. This compacts the concrete inside the form. In this process the vibrations completely expel the trapped air, give the desired density and the desired smooth finish both on the inside and outside of the completed pipe. Vibrators should operate at not less than 6,000 revolutions per minute.

4. Packerhead Process—Pipe is made by compacting very dry concrete into forms. The outside form consists of a split cylinder that can be removed easily without damage to the pipe as soon as the pipe is completed. At the start of the process the packerhead is at the bottom of the form. As the packerhead revolves at high speed, the dry mix is fed into the form and the packerhead is raised while revolving. Thus, the packerhead packs the concrete into place under pressure. The outside diameter of the packerhead is the inside diameter of the finished pipe. The concrete is dry and the force with which it is packed against the outside form is so great that the mold can be removed immediately and the green concrete pipe will stand vertically.

In India, out of these processes, the centrifugal method is probably the most widely used The second most widely use, is the cast, hand tamped process. Very little pipe is being made by the packerhead or vibrator process because of the lack of availability of equipment,

The three machine processes can produce a pipe of desirable quality. The quality of pipe; from the cast, hand tamped process, will vary because of non-uniform tamping and therefore is mainly suitable for low operating heads (maximum 3 meters). Without any test on the cast hand tamped pipe it is difficult to say what its performance will be. Cast, hand tamped pipe should be given serious consideration for use by the farmers. A hand book on various mixes should be prepared for them.

Further appraisal of manufacturing techniques is given in Chapter 10.

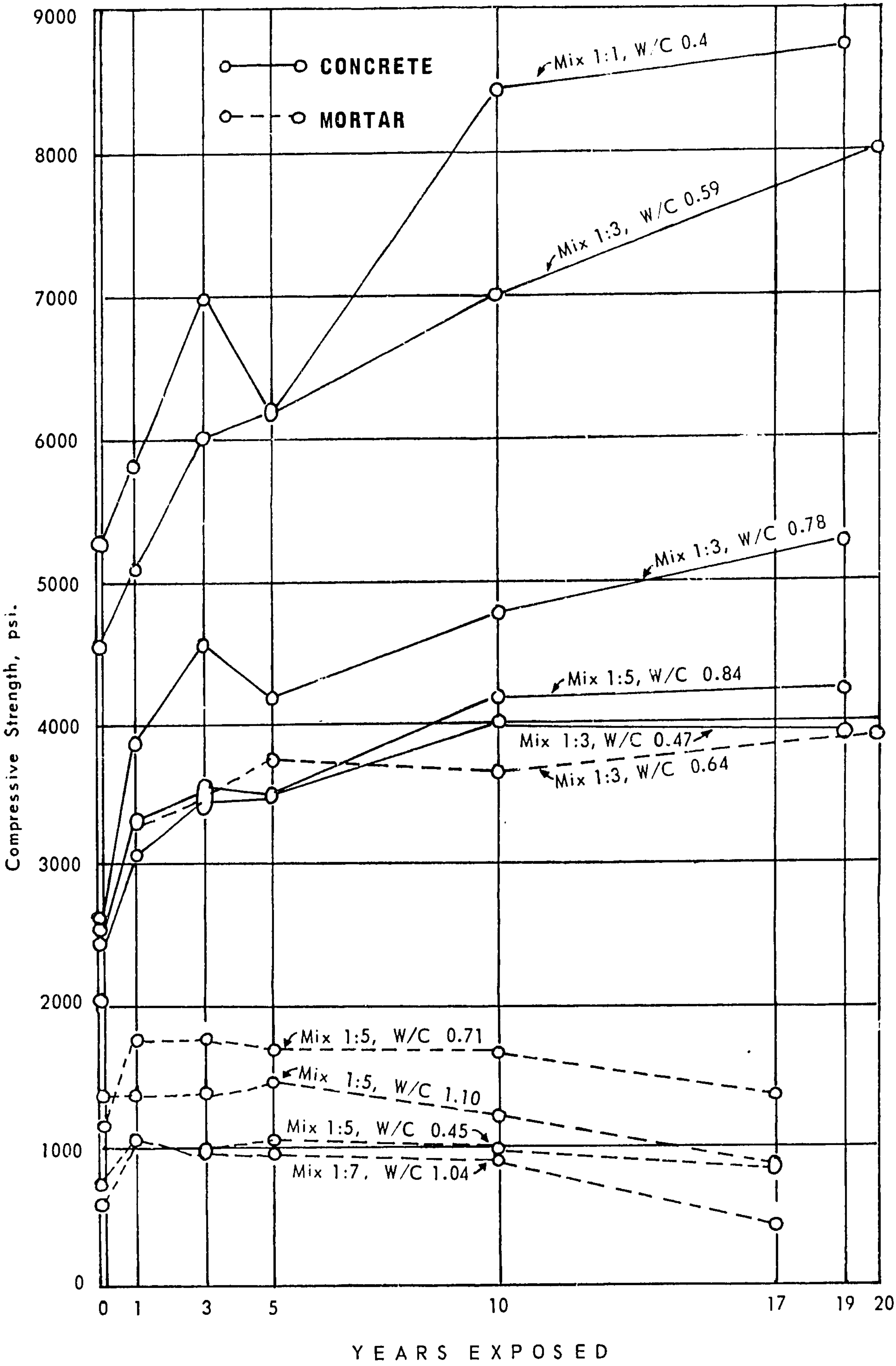
CONCRETE MIXES

A wide variety of mixes are being used to make concrete pipe. For RCC pipe the mixes range from a 1:2:2 to 1:2:4 and for NRCC from a 1:2 to 1:3:6. This results in concrete of variable quality because of the variation in mix and other factors that effect quality. In the United States, a mix approaching 1:3 is used. The sand portion can actually be any proprtion of sand and coarse aggregate that produces a quality pipe.

Figure 11, (pages 18) hows the effect of variously made concrete and mortar cylinders on compressive strength in relation to years of exposure in mineral soils.

The following mixes which are dry or semidry and used with a packerhead or vibrator process, are examples of some being used in the United States :

	Pounds	*Kg*	*Pounds*	*Kg*	*Pounds*	*Kg*	*Pounds*	*Kg*
Cement	94	42.6	94	42.6	94	42.6	94	42.6
Sand	188	85.3	265	129.2	330	151.0	356	161.5
Coarse aggregate	94	42.6	68	30.8	216	98.0	98	44.5



Strengths of variously made concrte and mortar cylinders from two mineral soils. Each points is the average of 10 cylinders from each of the two locations.

These mixes were developed by trial and error, based on the aggregate material available, which produced a pipe that would meet the specifications·

Compressive strength of concrete used in pipe should be a minimum of 281.2 kg/cm² (4,000 pounds per square inch) for test cylinders. It is better to specify the minimum design and physical test requirement and let the manufacturer produce the pipe to meet these requirements, than is is to specify a mix.

The basic principles of design of mixes may be found in any standard text book on concrete and a thorough study of such material should be undertaken before an attempt is made to design a mix for a special product such as concrete pipe. In the United States, for concrete pipe, very little has been published on this subject because each manufacturer has developed his own mix to achieve the necessary results.

For the conventional design of mixes the procedure is to :

1) Select the desired water-cement ratio,
2) Select suitable consistency,
2) Determine the maximum size aggregate,
4) Experiment with a trial mix, and
5) Make adjustments in succeeding batches based on compressive strengths.

For best results :

(1) Use suitable materials,
(2) Measure accurately,
(3) Mix thoroughly,
(4) Use a workable mix,
(5) Place properly,
(6) Cure adequately, and
(7) Test samples to confirm quality.

The criteria by which measure success or failure of the design are

(1) Strength,
(2) Durability, and
(3) Impermeability of the resulting concrete.

High strength concrete is generally durable and impermeable provided the ingredients are sound ; thus, the strength of the resulting cnncrete is probably the most important indication of the success of the design mix.

The factors that may be expected to affect compressive strength are numerous. Among these in order of their importance are :

(1) The amount of cement hydrated,
(2) The water-cement or void-cement ratio,
(3) The properties of the aggregate, including especially the surface conditions which may determine the mechanical bond, and the specific adhesion of the cement itself,
(4) Workability of the mix which is a factor in securing good packing and in lessening accidental errors,
(5) Structural features that are not properly understood, including the arrangement of particles in arches and the keying effect of large particles resisting the development of planes of weakness, and
(6) Irregularities in grading which produce humps in the grading curve.

When a tentative mix design has been decided on, trial batches should be run to determine workability, test cylinders made, cured, and broken at 7, 14 and 28 days to determine the strength obtained.

In applying the above principles to concrete pipe there are special factors which will govern the mix design such as needed for a dry mix the need for special properties of workbility—the need for great strength using small size aggregates—the need for passing strict absorption and hydrostatic tests with a thin walled product and the importance of durability.

Dry Mix : Where the vibrator and packer-head equipment are used the mix must be dry in order to remove the pipe from the forms so that the forms be used over and over again without delay. Instead of worrying about an excess of water, it is often necessary to guard against not having enough water to hydrate the cement.

Workability : Workability is of greater concern than in conventional type of concrete because the pipe walls are relatively thin ; because in thin walls there may be reinforcement; because the mix is packed, tamped vibrated or centrifugated into place instead of flowing into place by gravity as in the conventional concrete.

Strength : Strength is of special importance because the relatively thin walls necessitate the use of small size aggregates. In other words, strength must be obtained with small size aggregates and without sacrificing plasticity or workability. Thus, special emphasis must be placed on using the largest amounts of the larger of the small sized aggregates consistent with plasticity and workability.

Hydrostatic Test : Experience has shown that there is a definite relationship, in the relatively thin walled concrete pipe, between the type of grading of the aggregates and impermeability. The type of grading influences both the strength and the percolation.

Durability : As in passing the percolation test there is a relation between grading of the aggregates and durability. This also has been found by experience.

All these factors need special consideration in the design of concrete pipe mixes ; the balance between sufficient water, adequate workability and proper proportioning to give strength, impermeability and durability.

Each concrete pipe plant will have different aggregate and therefore a different mix will be needed, so it is impossible to specify rigid mix requirements.

CONCRETE MATERIALS

Four materials are being used in manufacturing concrete pipe : water, portland cement, aggregate and reinforcement.

Water : No attempt was made to assess the quality of water being used. Mixing water, that were being used, were clear. It is not known whether the waters were free from objectionable materials, such as organic matter, alkali, and other impurities, without some testing being done. Generally, if the water is clear and does not have a brackish or saline taste, testing is unnecessary.

Portland Cement : It is assumed that the cements being used are of good quality and are being made according to ISI standards.

Aggregate : There is a need to improve the quality and/or gradation of the aggregate being used in the manufacture of concrete pipe. The methods used to store the aggregate at the concrete pipe plants are not entirely satisfactory.

It is of course realized that the producer of concrete pipe has to use aggregate which are commercially available. For quality control, supplies of aggregate ought to be uniform from lot to lot both with respect to physical character and to grading. And finally, the aggregates ought to be stockpiled and handled so as to prevent contamination, segregation, and to maintain reasonable uniform moisture content in the sand.

Aggregate for concrete pipe is no different than aggregates for any first-class concrete work. A few points of emphasis favorable to pipe making is discussed in this section, but mainly the usual requirements for good aggregate are also important for concrete pipe.

There are eleven requirements which are most important in the quality and serviceability of resultant concrete :

1. The first is *good quality* and inherent durability. Such quality is indicated by appropriate tests for aggregate material. Generally, the following tests are made on aggregate : sodium sulfate roundness test, specific gravity and absorption, abrasion, number of soft particles in coarse aggregate, petrographic examination, and strength and freezing resistance in concrete cylinder specimens. Sometimes there are test results which are inconsistent with concrete performance, but a consensus of test results is a strong indication of what kind of concrete performance to expect. Each poor test should be a warning.

2. *Good grading* is important. This has much to do with the efficiency and economy of aggregate in producing a workable concrete mix, yet producing the required strength with a minimum content of cement.

Instead of total percent passing or retained on each screen, it is preferable to specify and keep separate the percent of each size in notes, plots, tests and studies of gradings.

Coarse aggregate must be well graded to full maximum size without an excess of any one size. On the basis, a good grading of coarse aggregate is generally within the following range :

IS Sieve Designation	*US Standard Sieve Designation*	*Percent of each size retained on each sieve*
4.75-mm	#4	8 to 15
—	1/4 inch	10 to 17
10-mm	3/8 inch	13 to 21
12.5-mm	1/2 inch	15 to 24
16-mm	5/8 inch	18 to 28
20-mm	3/4 inch	21 to 31

Sand should be well distributed among the standard screen sizes: 4.75-mm (No. 4), 2.36-mm (No. 8), 1.18-mm (No. 16), 600-micron (No. 30), 300-micron (No. 50), 150-micron (No. 100). Based on the discussion in the preceding paragraph, the following limits are generally considered a good grading

IS Sieve Designation	*US Standard Sieve Designation*	*Percent of each size retained on each sieve*
4.75-mm	# 4	0 to 5
2.36-mm	# 8	5 to 15
1.18-mm	# 16	10 to 25
600-micron	# 30	10 to 30
300-micron	# 50	15 to 35
150-micron	# 100	12 to 20
Pan	Pan	3 to 7

Amounts of a size outside these limits is acceptable if there is no appreciable increase in requirment of water or loss of workability.

3. **Low water requirment** in a concrete mix with the same slump is attributed to surface and shape characteristics of the aggregate. Low water requirement improves the quality by reducing drying shrinkage. It increases economy by reducing the amount of

cement required for the same W/C(water-cement ratio). This is primarily influenced by sand. As an example, one type of sand is known to require more than 136.1 Kg. of water per 0.76 cubic meters (300 pounds of the water per cubic yard). Another requires only 99.7 kg (220 pounds). As a result, a concrete mix, made with the latter sand, with a W/C of 0.50, required 72.6 Kg. (160 pounds) less cement because 36.3 Kg. (80 pounds) less water was needed. This property can be easily determined by making a few trial mixes and carefully obtaining the water rquirement for each mix.

4. **Favorable** shape of coarse aggregate contributes to achieving a workable mix with a minimum amount of mortar. When the shape of the aggregate particle approaches a fairly smooth sphere, less cement and water is required for strength and workability, which helps assure better workmanship.

Sharp angularity and flat and elongated particles, whether crushd rock or gravel, require more mortar for good workability and presentability. Shape is not a property that can be tested easily although voids in the dry-rodded material become less as particle shape is more favorable ; but it can be judged by visual comparison and measured quantitatively by knowing the surface area of similar sized particles.

5. **Surfaces favorable to bond** are common in crushed material and many gravels. Strength of concrete with the same W/C, is not attributed to the angularity, when crushed rock is used, but due to its surface texture being favorable to bond. There are some exceptions to this; slick-faced particles of quartz and felspar do have good bonding qualities. Rugosity of the surface may be enhanced by a degree that will pull cement paste into the surface and further improve the bond. Gravel usually attains a favorable bonding surface in its transportation. A relatively even surface may develop bond as well as have a low water requirement because it is the chemical hardening of very fine grained cement paste that produces bond. A coarsely rough surface is not necessary for good bond. Surface character can be judged by examination and by comparative concrete strength.

6. Aggregates must be *clean*, although it is not necessary in every case for the material to be washed to be sufficiently clean as a concrete aggregate. Dirt will adulterate the cement and increase the water requirement. Coatings of clay will impair bond, strength, and durability. Dirt in sand may increase drying shrinkage beyond that caused by increase of water in the mix. IS: 383—1963[1] provides limits of deleterious materials in Table 1, page 8.

7. **Uniformity** of various qualities, grading, and cleanness is fundamental in securing uniform concrete. Comparison of various test results and direct observations will indicate the degree of uniformity from which sufficient uniformity can be judged.

8. **Inert to expansive reaction** with alkalies in the cement after concrete is made. This reaction can unfavorably expand and crack saturated concrete such as that in concrete pipe in service.

This need not be a matter of concern provided the condition is recognized and a cement low in alkalies is used. The presence of reactive elements can be determined by petrographic examination and their effect can be measured by the mortar bar expansion tests, but this takes several months.

9. Good aggregate is to be free from *objectionable coatings*. Many hard and adherent coatings of calcites may be harmless and no adverse effects may be found from them in

[1] Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete.

comparative tests or service. Most often coatings are weak and loosen in handling. Weakness affects both bond and strength. Looseness results in irregular accumulation of fines which affect slump uniformity and water requirement.

Opaline silicate coatings are reactive with alkalies in cement and if necessary to such aggregates, low-alkali cement and possibly a correct pozzolan should be used. Gypsum coatings may influence cement hydration.

The acceptability of coated aggregate can be determined by petrographic examination, general inspection, and comparative tests of concrete properties.

10. Good concrete is to be free of *elements that cause popouts* following cycles of changing temperature and moisture. Generally, these are lightweight elements which are troublesome when they rise to the interior surface of spun pipe. Examples are certain clays and mudstone, some cherts, and argillaceous limestones. Many of the pyrites such as marcasite cause ugly rust stain when they break out of the hardened surface. These elements are best verified by observing performance, which is a good method of judging the service potential of any aggregate. Petrographic examination will identify the presence of such materilal.

Mention has been made of petrographic examinatlon as a means of judging concrete aggregate. This tool is an extremely useful and reliable means of evaluation. Its principal values are : (1) That quick, preliminary esti mates of quality can be made; (2) It provides interpretation and amplification of results of the standard acceptance tests; (3) It is the only reliable means by which any chemical instability or reactive elements can be detected in a new aggregate; (4) That by its means, new aggregates may be quickly evaluated by comparison with other aggregates for which service data are available.

A petrogrpher who can examine aggregate as to its properties which will affect its performance as concrete aggregate can perform a great service to the industry.

For all practical purposes, compensation can be made for deficiencies in some of the desireable properties of concrete aggregate by the use of additional cement, with an appropriate reduction in sand content in the mix. Extra cement will compensate for :

(1) Poorer quality as it may affect strength.

(2) Irregular grading, gaps including a shortage of fines, excessive amounts in one size groups and variable amounts of undersize.

(3) Unfavorable shapes, flats, angular and elongated particles when additional sand is used.

(4) Surfaces that bond less well with mortar.

(5) Dirtiness, perhaps with further reduction in sand.

(6) Variability in these characteristics.

(7) Non-reactive surface coatings.

(8) High water requirement.

(9) Poor quality as through absorption and fine-grained porosity, it may affect durability but only partially.

The necessary amount of extra cement required will vary with :

(1) The degree of imperfection of the aggregate.

(2) The property in which the aggregate is deficient, assuming equal degree, and

(3) The quality of concrete required, includlng the kind of durability

necessary to withstand service environment.

The amount of extra cement required can be determined by test and observation of performance.

Extra cement in the mix will not compensate :

(1) For aggregate elements which are expansively reactive with alkalies in cement, including coatings of opaline material.

(2) For aggregate elements which cause popouts with changing temperature and moisture in surface concrete, since concrete cannot be made that will not absorb and lose moisture to some degree.

Special properties of aggregates favorable to production of concrete pipe are :

(1) Fewer fines passing the 300-micron sieve (US Standard Sieve No. 50) in sand in view of generally higher content. Ten to fifteen percent passing the 300-micron sieve is ample.

(2) Those contributing to good workability and remoldability; such as well-shaped rounded gravel preferable to crushed rock.

(3) Uniformity of all properties, a most important factor.

To be significant, uniformity must be carried to the point that aggregate for each batch, batch after batch, is the same each time they are measured.

Reinforcement : The reinforcement was only assessed by visual means. In some cases, it appears that the material may not be meeting the Indian Standards. The material used by some of the manufacturers was scrap metal which could be of any quality. In many cases, the rod and wire was rusty. It is suggested that some program be initiated to see that the manufacturers are using material that meets the appropriate specifications. No assessment was made as to quantities of reinforcement as to IS : 458.

There is a need to better center the reinforcement cages because during the manufacture of the pipe the reinforcement becomes exposed or nearby exposed. This could be accomplished by using wire ties to hold the reinforcement in position.

CURING

There is a need to change the procedure used in curing concrete pipe. In general, the pipe is left to air dry before it is placed in a water tank to water cure. Large pipe in the water tank is partially exposed. This large pipe may be rotated once a dav to immerse the exposed area and on occasions it may be partially covered with moist gunny bags, but even these may not be kept moist. In some cases, water is occasionally sprayed or splashed on the exposed pipe.

Several simple things can be done to improve curing of the pipe. The ends of the spun pipe can be kept covered with moist gunny bags or with polyethylene sheets to keep the dry air from circulating through the pipe. For hand-made cast pipe, the sand that is placed in the center can be kept moist. After the forms are removed the pipe can be kept wet by total immersion in tanks or by sprinkling or a combination of both if the pipe is too large.

Proper curing is essential to producing good concrete pipe. Concrete properties such as strength, watertightness, wear resistance, and volume stability improve with age as long as conditions are for continued hydration of the cement. The improvement is rapid at early ages but continues more slowly for an indefinite period. Two conditions for such improvement in quality are required ; (1) the presence of moisture and (2) a favorable temperature.

Figure 12, shows the effect of moisture during curing, with different curing methods under different test conditions, on compressive strength. Figure 13, shows the effect of curing temperature on compressive strength of concrete. Figure 12 at page 26 & figure 13 at page 27.

Excessive evaporation of water from newly placed concrete can significantly retard the cement hydration process at an early age. Loss of water also causes concrete to shrink, thus creating tensile stresses at the drying surface. If these stresses develop before the concrete has attained adequate strength, surface cracking may result.

Hydration proceeds at a much slower rate when the concrete temperature is low ; from a practical standpoint there is little chemical action between cement and water when the concrete temperature is near or below freezing. It follows that concrete should be protected so that moisture is not lost during the early hardening period and the concrete temperature is kept favorable for hydration.

Studies have shown that even in an atmosphere of 80 percent relative humidity, the rate of hydration continues to fall as the paste dries out and hydration virtually ceases. For best results, it is necessery to adopt plant and field practices which insure the presence of moisture in the mixture sufficient to hydrate its cement as required to provide the quality of concrete desired.

Concrete can be kept moist (and, in some cases, at favorable temperature) by a number of curing methods that can be classified as follows :

1. Methods that apply additional moisture to the surface of the concrete during early hardening period. These include ponding (immersion in case of pipe), sprinkling, and using wet coverings. Such methods afford some cooling through evaporation, which is beneficial in hot weather.

2. Methods that prevent loss of moisture from the concrete by sealing the surface. This may be done by means of waterproof paper, plastic sheets, liquid membrane—forming compounds, and forms left in place.

3. Methods that accelerate strength gain by supplying heat and moisture to the concrete. This is usually accomplished with live steam.

In the case of concrete pipe, strength is best developed, when suitable mixes and materials are used, by thorugh water curing. Ideally this would include keeping the pipe :

1. Wet inside and outside

2. Free from drafts first 12 hours

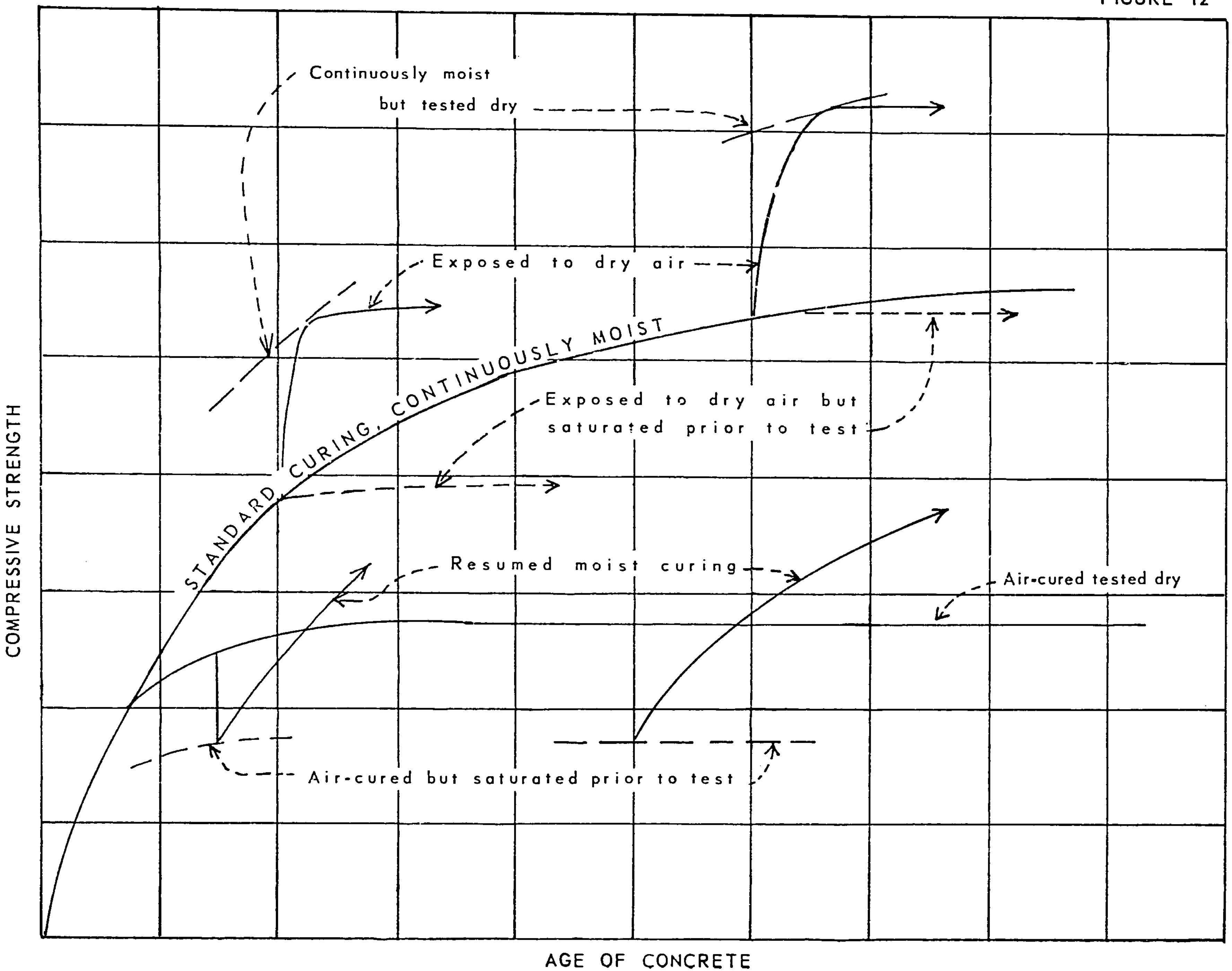
3. Continually wet with moisture on surfaces for 7 days

4. Beginning not earlier than 3 hours after casting, pipe may be warmed with steam for not more than 16 hours at a temperature not exceeding 60 degrees c. (140° F).

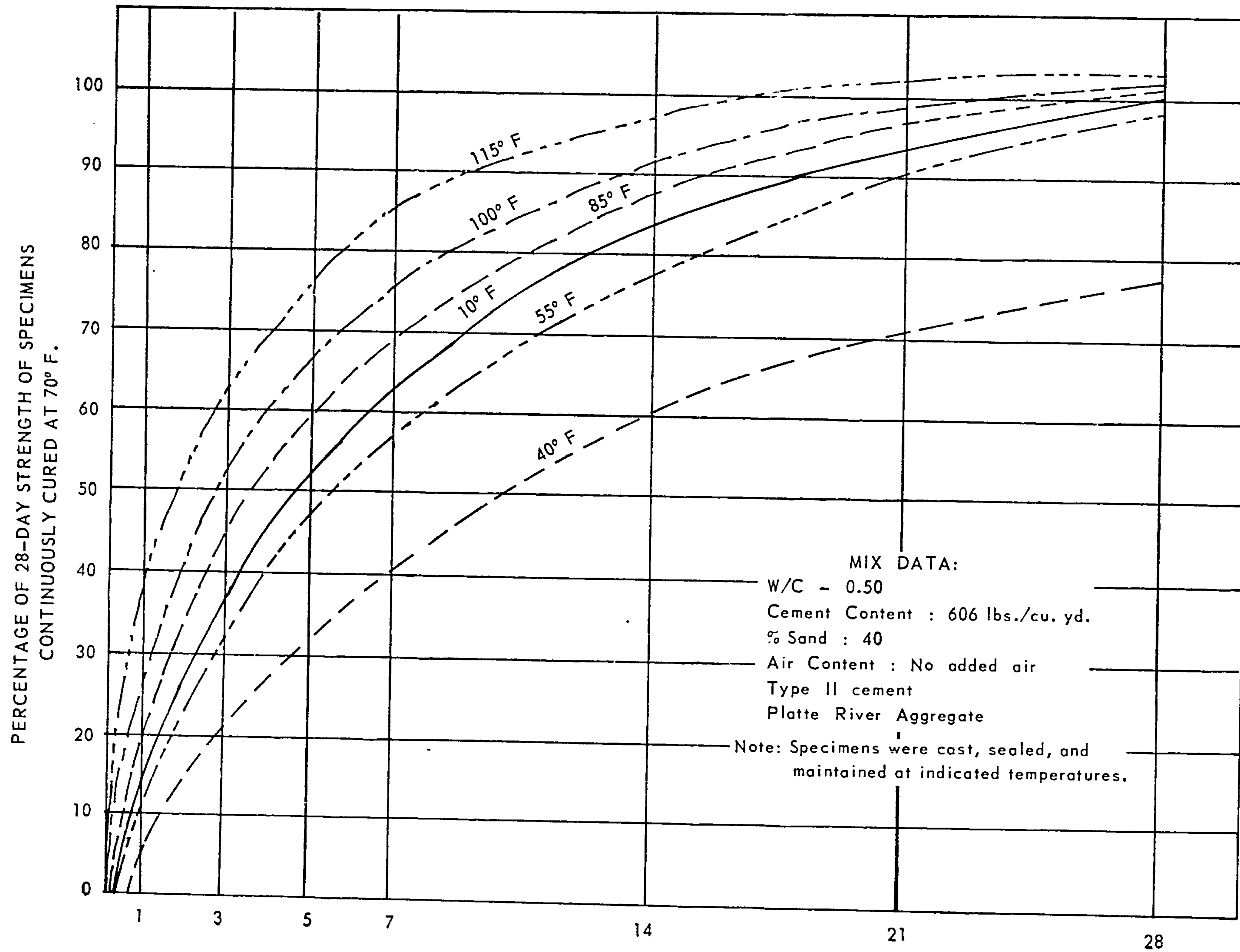
PIPE SIZE, LENGTH AND JOINT DESIGN

Presently, pipe sizes are limited to 152.4-, 228.6-, 304.8-, 381.0, and 457.2-mm (6-, 9-, 12-, 15-, and 18 inch) diameters. It appears that it may be feasible to produce some inbetween sizes. This could result in some cost reduction. For example, suppose from a hydraulics design stand point that a diameter of 254-mm (10-inch) was arrived at, thus a 304.8-mm (12 inch) diameter would have to be selected. The predominant sizes being used are 152.4-, 228.6, and 304.8-mm (6-, 9-, and 12 inch) diameters. Because of smaller sizes being used, it would be better to have the

FIGURE 12



Continuously moist but tested dry
Exposed to dry air
STANDARD CURING, CONTINUOUSLY MOIST
Exposed to dry air but saturated prior to test
Resumed moist curing
Air-cured tested dry
Air-cured but saturated prior to test
COMPRESSIVE STRENGTH
AGE OF CONCRETE



Effect of curing temperature on compressive strength of concrete.

27

following sizes: 152.4-, 203.2-, 254.0-, and 304.8-mm (6-, 8-, 10-, and 12-inch) diameters. This would allow a better selection of pipe for design.

The present length of concrete pipe varies from 1.83 to 2.44 meters (6 to 8 feet). These long lengths present the following problems: 1) breakage during transportation, and 2) large amount of labor that is needed to handle the pipe because of weight. As a result, it appears that it would be feasible to make a pipe that would be about 1 meter (3.28 feet) in length. This item is discussed further in Chapter 10.

The present technique of making a joint is time-consuming because of the type of joint being made, a butt joint with collar. In order to reduce the time required to make a joint it is suggested that the tongue and groove or socket and spigot joint be adopted. With the present manufacturing it would appear that the tongue and groove joint would be the easiest to make. This is discussed further in Chapter 4. The tongue and groove, and socket and spigot design are given in Chapter 9.

Asbestos Cement Pipe

The process used for manufacturing asbestos cement pressure pipe (IS : 1592) is being done in collaboration with Johns-Manville Co. in the the United States, as a result a very good product is being produced. The firms visited, are maintaining good quality control on their products, by continually testing their material and products.

In the manufacture of asbestos cement building pipe (IS :1626) a similar process is used, but with less sophisticated equipment. The pipe that is being produced by the large scale industries appears to be of good quality, whereas the quality of pipe made by the small scale industries is probably not as good. There are two reasons for this differences : (1) the large scale industries start water curing after the initial setting of cement, whereas the small scale industries air dry their pipe for one day, in an open building, before water curing ; and (2) large scale industries probably use a better quality asbestos fiber.

Design, Layout, and Construction

The design and layout of irrigation pipelines appears to be adequate. It is possible that some improvements could be made, but each engineer will have to decide what these improvements will be, based on information in the section that covers design and layout.

There are improvements that can be made in the design of appurtenances which could reduce the cost of such structures. In one State, it was stated that a brick and mortar pump stand costs 5 times more than one made with RCC pipe. Therefore, it is up to each designer to decide what changes he may want to make based on the construction material available and the information provided in this report on appurtenances.

One particular item noted, is the large elaborate main chamber being used to measure pump discharge. A simple pump stand could be used with a different type of measuring device. In appendix I, Methods of Measuring Pipe Flow, several different methods are mentioned on how to measure flow. These methods could be adopted to Indian conditions.

In general, the techniques used in construction were good considering the type of material being used. In Chapter 2, Observations During Visits to Various State, various types of jointing procedures are noted. Of these various methods, it is difficult to say which is the best and easiest to make. This again probably becomes a matter of preference by the individual concerned as long as the joint does not leak :

Care needs to be exercised in making the joint. The area where jointing or banding mortar is to be placed, should be clean and prewetted before any mortar is placed. After the joint is made, proper curing of the joint is necessary. This can be accomplished by placing a wet gunny bag or moist earth over the mortar after it has sufficiently hardend.

Where long sections of pipe are used it is necessary to provide proper support of the pipe. Where the pipe is elevated, for the purpose of making joints, support should be provided in the center of the pipe because the beam strength of the pipe may not be adequate. At one site it was noted that the pipe had cracked in the circumferential direction in the middle due to lack of support (Figure 10, page 16).

The problem of leakage at the joints is probably the result of slight settlement of the pipe, because of improper bedding, which causes cracks in the mortar at the joint. As a result, attention should be given to provide support for the full length of pipe.

CHAPTER 4

Feasibility of Different Pipe

In making a comparison of the feasibility of the different material available for pipelines a number of factors need to be considered. The use of any product is usually dictated to a greater degree by economic considerations. This economic consideration should be based on the life of the material and the cost of maintenance along with the initial cost. As a result, the use of any product in a pipeline system is necessarily related to the economy, based on the annual cost computed over the life of the project.

Technically, any pipe that will convey water could be considered for use in an irrigation system. Therefore the following could be used as a pipeline : nonreinforced concrete pipe, reinforced concrete pipe, asbestos cement pipe, polyethylene pipe, polyvinyl chloride pipe aluminum pipe, and steel pipe. Therefore cost of these various pipe materials is one of the factors that would be considered in the economic evaluation.

In the actual job cost, one is primarily interested in what the total comparative unit cost will be and not any one portion of the unit cost as a comparative cost. The unit cost of any pipeline job can be divided as follows :

1. Cost of trenching;
2. Cost of pipe; which includes transportation and can include breakage during transport and handling of pipe at the job site;
3. Cost of laying; which includes labor and material for joint and involves placing of pipe in the trench, making the joint and curing of joint when applicable;
4. Cost of backfilling;
5. Supervision inspection of work when in progress; and
6. Profit, which would be applicable if a contractor did the job.

Most of the above cost items will vary because there is an interrelationship between them.

The trenching cost will vary with trench size because different pipe material will require different minimum depths of cover, i. e. 152.4—mm (6—inch) diameter nonreinforced pipe requires a 457.2—mm (18—inch) minimum depth of cover, whereas a low head, 1.05 kg/cm^2 (15 p. s. i.), asbestos cement pipe requires 762.0—mm (30—inch) minimum depth of cover.

Pipe cost will vary with type of product selected for use. Tables 1 and 2 at pages 33 & 34 gives a comparison of cost for various pipes.

In looking at the costs of the various pipe material, nonreinforced concrete pipe will be the least expensive to use. Whether the pipe is socket and spigot or tongue and groove will depend on what changes the manufactures can economically make. Basically, the manufacturing of tongue and groove will require the least amount of changes. All that is needed are steel rings that will mold the tongue and groove. As such the forms being used to make reinforced pipe can be used. To make a socket and spigot pipe the present forms would have to be rebuilt and would be suitable only for this one type of pipe. Thus, the manufacturer would be required to have two types of forms.

The cost of laying pipe will vary considerably. The type of pipe used will dictate the amount of labor required to handle the pipe and to make the joint. In addition, the type of joint will dictate the type and amount material needed to make a joint. As an example, a butt end concrete pipe that is 1.8 meters (6—feet) long, requires considerable amount of labor to handle and requires mortar and possibly a collar plus considerable time for making the joint. On the other hand, a socket and spigot pipe, that is 1 meter (3.23 feet) long and of equal diameter as the above pipe, would require much less labor in handling the pipe and only mortar to make the joint with less time involved in making the joint but there would be twice as many joints.

An additional expense that can be incurred is in the labor required in curing mortar joints, whereas an asbestos cement pipe with asbestos cement and rubber gasket would eliminate this expense.

The cost incurred in backfilling will vary with the volume of earth to be placed in the trench and is related to the size of trench.

The expense incurred from supervision should be the same, regardless of the pipe used. The amount of profit allowed should be approximately the same for any type of pipe used, except that it might vary with the speed with which the pipe is installed.

Most of these costs will vary from area to area because of difference in transportation costs, in labour costs, and in material cost. As a result each area will have to make its own cost analysis. The following list gives an indication of cost for trenching, laying and jointing, and backfilling :

Item	*Rates*		
	Minimum Rs/1000CFT[1]	*Maximum Rs/1000CFT*	*Average Rs/1000CFT*
Trenching Cost	25.00	55.20	35.36
Backfilling Cost	12.50	25.00	17.92
Laying and jointing Cost RCC, socket & spigot	*Rs/ft.*	*Rs/ft.*	*Rs/ft.*
9″ dia. (8—foot lengths)	—	—	0.72
12″ dia. ,, ,,	—	—	1.00
15″ dia. ,, ,,	—	—	1.31
18″ dia. ,, ,,	—	—	1.75

(Continued

Butt end with or without Collar			
6″ dia. (6—foot lengths)	—	—	0.56
9″ dia. (6—foot lengths)	0.75	1.16	0.91
12″ dia. (6—foot lengths)	1.03	1.04	1.035
NRCC, Tongue and Groove			
6″ dia. (3—foot length)	—	—	0.42
NRCC, Socket & Spigot			
6″ dia. (3—foot length)	—	—	0.37

[1] CFT = cubic feet

No attempt was made to break these figures in smaller units of cost because the data was not readily available.

The use of some of the material is presently ruled out because of size limitation. The maximum size available in plastic pipe is 200 mm (7.87 inches). Aluminium pipe is available up to 152. 4mm (6 inches). Some of the pipe that is available is ruled out because it is designed for pressures in excess of what is needed, thus making them very expensive. Plastic and asbestos cement pressure pipe is a good example. This type of pipe can be manufactured for lower pressure requirements thereby reducing cost.

In selecting a pipe product consideration should be given to its hydraulic characteristics. In other words, some pipes have lower coefficients of roughness than others. As a result, it may be feasible to select a pipe product of a smaller diameter, with a lower coefficient of roughness, in place of a pipe product of a larger diameter, with a higher coefficient of roughness, and be more economical. This is especially true with large volumes of water.

Presently in India, the only pipe material that will be most feasible to use is the concrete pipe for low head systems. The other pipe material, plastic, asbestos cement, and steel are best suited for high pressure systems. Aluminium pipe is best suited for portable systems which require moderate to high pressures. Some plastic pipe is being used for portable sprinkler pipe. The plastic pipe should not be used for this purpose because it will deteriorate when exposed to ultra violet rays from the sun. Black carbon is used to slow this process down but it will not prohibit the deterioration completely. Therefore, in a relatively short number of years the plastic will become brittle.

The life span of the pipe material mentioned in this report should be at least 50 years, if it is of good quality and properly installed. The only way to determine the life span of the pipe material presently being used in India is to make a survey of the material and determine its condition after so many years use.

Each State Government that is a user of pipe should develop its own total unit cost for each particular pipe material. Where pipe material is being considered, estimates will have to be made for laying and jointing. The manufacturers of these products can provide assistance in making these estimates.

TABLE 1

Cost Comparison of Various Concrete Pipe

Types of Pipe	*152.4—mm (6—inch)*		*228.6—mm (9—inch)*		*304.8—mm (12—inch)*	
	Rs. per ft.	*Rs. per m*	*Rs. per ft.*	*Rs. per m*	*Rs. per ft.*	*Rs. per m*
Reinforced Concrete						
Class NP 2						
Rate Contract						
Range in Cost	1.55—1.86	5.08—6.10	2.05—2.35	6.60— 7.71	3.20—3.70	10.50—12.13
Average Cost	1.69	5.54	2.17	7.12	3.40	11.15
Class NP 2						
Retail Sale						
Range in Cost	1.70—3.00	5.57—9.84	2.05—4.50	6.73—14.76	3.06—6.50	10.02 - 21.30
Average Cost	2.01	6.59	2.52	8.26	4.04	13.25
Collars, for above pipe						
Rate Contract						
Range in Cost	0.95—1.25	Rs./each	1.24—1.65	Rs./each	1.60—2.70	Rs./each
Average Cost	1.08	Rs./each	1.49	Rs./each	2.27	Rs./each
Other pipe						
Hand made, with collar Cost	2.25	7.38	3.50	—	—	—
Hand made, socket and spigot Cost	2.33	7.64	4.80	—	—	—
Spun, socket and spigot						
Cost to governmental agency	1.90	6.23	2.08	6.82	3.18	—
Cost to farmer	1.90	6.23	2.47	8.10	3.75	—
Nonreinforced Concrete						
Butt end						
Hand made	0.66	2.16	0.81	2.64	2.00	6.55
Spun					2.85	9.35
Tongue and Groove						
Spun	1.62	5.32				
Packerhead	2.50	8.20	4.00[1]	13.11		
Socket and Spigot						
Vibrator						
Range in Cost	1.00—1.41	3.28—4.62	1.25—1.89	4.10— 6.20	1.50—2.98	4.92—9.77
Average Cost	1.20	3.84	1.57	5.15	2.24	7.35
Handmade (1:2 Mix)	0.83	2.72	1.33	4.36	1.75	5.74
(1:2½ Mix)	1.75	5.74	2.40	7.87	2.80	9.18
(1:3 Mix)						
Range in Cost	0.67—1.33	4.36	1.00—2.67	3.28— 8.75	1.00 1.50	3.28—4.92
Average Cost	1.00	3.28	1.83	6.00	1.25	4.10
(1:4 Mix)	0.58	1.90	0.75	2.46		—

[1] 10—inch diameter pipe

NOTE : Prices are F.O.R. factory.

TABLE 2

Cost Comparison of Various Other Pipe Material

Type of Pipe	*Pipe Diameter*							
	150 mm (5 91 inches)		*200 mm (7.87 inches)*		*250 mm (9.84 inches)*		*300 mm (11.81 inches*	
	Rs/ft.	*Rs/meter*	*Rs/ft.*	*Rs/meter*	*Rs/ft.*	*Rs/meter*	*Rs/ft.*	*Rs/meter*
Asbestos-Cement.								
Preasure Pipe Class I (5 kg/cm^2) (Is : 1592)								
Pipe without collar	4.68	15.35	6.60	21.65	8.90	29.20	11.86	38.90
Cast iron detachable joint	4.33	14.20	7.74	24.40	10.11	33.20	13.41	44.00
Pipe with cast iron detachable joint (based on 4 meters)	5.76	18.90	8.46	27.75	11.43	37.50	15.22	49.90
Asbestos cement collar	3.04	10.00	4.27	14.00	5.18	17.00	—	—
Pipe with asbestos cement collar (based on 4 meters)	5.44	17.85	7.67	25.15	10.20	33.45	—	—
Low Head								
Low Head Pipe[1]								
Pipe with asbestos cement collar (based on 4 meters)	4.98	16.32	7.00	22.99	9.30	30.53	12.31	40.41
Pipe Diameter	*152.4 mm (6 inches)*				*228.6 mm*	*(9-inch)*		
Building Pipe (non-pressure pipe) IS : 1626)								
Socket and Spigot								
Cost range	2.10-2.89	6.60-9.50			2.90	9.50		
Average Cost	2.60	8.53						
Plastic								
Polyvinyl chloride (PVC) IS: 4985								
Working pressure 4.0 kg/cm^2 (57 psi)[2]	10.09	33.10[4]		13.27	43.20[6]			
Working ,, 8.6 kg/cm^2 (122 psi)	20.45	80.35[4]						
Working ,, 2.3 kg/cm^2 (36 psi)[3]	7.01	22.00[4]						
Polyethylene, high denity (DIN 8074/8075)								
Series I, Working pressure 2.5 kg/cm^2 (36 psi)	8.92	29.25[4]						
Pipe Diameter	*101.6 mm (4 inches)*		*127.0 mm (5 inches)*		*152.4 mm (6 inch)*			
Aluminum								
Plain pipe (fittings not included)[5]	9.00	29.50	12.00	39.40	15.00	49.30		

[1] This type of pipe is not presently made in India. This pipe would have a design pressure requirement of about 1.05 kg/cm^2 (15 psi). The prices are only estimates.

[2] Government prices

[3] Not being made at present, therefore price is an estimate.

[4] Nominal diameter 160 mm. Inside diameter vaties because wall thickness varies with pressure rating.

[5] This pipe will be available with gates (referred to as gated pipe), per gate approximately Rs. 10.00

[6] Nominal diamater 200 mm.

[7] Cast iron ditachable joint (NOTE : Prices may or may not include transport cost.

CHAPTER 5

Design Criteria for Low Head Irrigation Pipelines

For a pipe irrigation system to operate successfully, the pipelines and control structures must be of sufficient size to handle the flow needed without overloading. Pipelines too small in diameter increases pumping costs and may seriously limit the capacity of the irrigation system. On the other hand, pipelines larger than needed add to the cost of a system and may cause uneven flow. Control stands must be high enough to allow sufficient head of water in the pipeline, but stands higher than necessary complicate valve operation and may permit high heads of water to build up, leading to excessive line pressures Therefore, it is important to calculate pipeline sizes and stands heights to give balanced distribution and to help assure trouble free, economical operation.

ELEMENTS TO CONSIDER PRIOR TO DESIGN

Prior to designing a system the following items should be known :

1. Quantity of water available.

2. Type of irrigation (flood irrigation or furrow irrigation).

3. Quantity of water tc be delivered out of each hydrant.

4. Length of run.

5. Width of border strip or area to be irrigated

6. Slopes of ground surface.

Once the foregoing values have been established the system is ready to be designed.

ELEMENTS TO CONSIDER IN DESIGN

Hydrant capacity and type. Sometimes this is not limited by the crop, but by the rate at which water is available.

FLOOD IRRIGATION

Either the alfalfa valve hydrant or the orchard valve hydrant can be used. The former provides the greatest rate of flow. The latter provides a neater hydrant and with some soils less erosion. It is recommended that a hydrant be provided for each strip. Stream sizes should not be so large as to create an erosion problem. If this happens, additional hydrants should be provided for the strip. A "portable hydrant" Figure 16 (at page 50) can be used with metal surface pipe to reduce the number of hydrants needed.

FURROW IRRIGATION

Adequate flow is necessary to maintain proper depth in the furrow. There is seldom reason to provide a flow of less than 0.02 cubic feet per second per furrow Hydrants used for flood irrigation can be adopted to furrow irrigation by using a "portable hydrant" and gated surface pipe, or by a secondary ditch with furrow tubes or siphons. Gated hydrants can be used to irrigate furrows. These are primarily used in vineyards and orchards where it is a practice to irrigate by the furrow method.

HYDRANT SPACING

Furrow irrigated orchards and vineyards, spacing is regulated by tree spacing. Hydrants are put in line with the tree rows and one to four furrows on either side can be served by each hydrant.

FURROW IRRIGATED CROPS

The practice is to plan for flood irrigation since, in most areas, crop rotation is practiced. Most reasonably spaced hydrants for flood irrigation can be adapted to furrow irrigation as mentioned beforehand.

FLOOD IRRIGATION

Spacing of hydrants is normally regulated by cross-slope. Width of strips is normally set so as not to give over 60.7 mm (0.2 foot) elevation difference.

PIPELINE SPACING
FLOOD IRRIGATION

The designer must know the length of run to determine the pipeline spacing. In the United States, pipeline spacing may range in extremes between 30 to 805 meters (100 to 2,640 feet). The most common ranges are between 201 to 402 meters (660 to 1,320 feet) if the slopes are moderate and uniform, and flows of water are adequate.

FURROW IRRIGATION

The most common length of run, in the United States, varies between 67 to 201 meters (220 and 660 feet). With adequate water flows and moderate slopes, there is seldom need for shorter runs.

DESIGN CRITERIA FOR OPEN SYSTEMS

PIPE LINE
SAFETY FACTORS

External load limit—Loads are generally light on this type of installation where there are excessively high fills a safety factor of at least 1.25 should be applied to the certified three-edge bearing test for concrete pipe in computing allowable heights of fill over the pipe. Loads on pipe can be computed according to Indian Standard IS : 783-1959, Code of Practice for Laying of Concrete Pipes.

Pressures—Pipe should pass the hydrostatic test requirements prescribed in the latest applicable Standards or Specifications.

Mortared joints.—The maximum working head in meters (feet) should not be more than one-fourth the certified hydrostatic test pressure as determined by the hydrostatic test.

Rubber Gasket joints.——The maximum working head in meters (feet) should not be more than one-third the certified hydrostatic test pressure as determined by the hydrostatic test.

The maximum working head is defined as the working pressure head plus freeboard and is taken to the center of pipe.

Normally these systems are designed to operate at not more than 9.1 meters (30 feet) head.

FRICTION LOSS

The friction losses for concrete pipe are as follows :

(1) Mortar-jointed pipe, Scobey's concrete pipe formula with $C_s = 0.310$ or Manning's formula $N = 0.013$ can be used.

(2) Rubber gasket jointed pipe, Scobey's concrete pipe formula with $C_s=0.370$ or Mannings formula $N=0.011$ can be used.

(3) Minor losses can be computed in accordance with other listed values in this section:

SELECTION OF PIPE SIZE

Before a pipe size can be selcted, the following items need to be considered :

(1) The hydraulic gradient at any point of discharge should normally be at least 0.30 meters (one foot) above the ground surface (will vary somewhat with type of hydrant or outlet).

(2) The hydraulic gradient should not run below the elevation of the pipe at any point where water is flowing.

(3) At the upstream end, the gradient may be limited by factors such as pressure of the entering water.

(4) The hydraulic gradient will be different for different points of discharge. Always base design on the maximum condition (normally, the greatest distance or the greatest life).

(5) With branching lines, start design downstream on each branch, and work upstream. Above laterals, base design on the highest gradient required on any of the laterals at the diversion (gate) stand.

(6) With an overflow stand system, draw the hydraulic gradient upstream from the overpour lip.

The actual selection of pipe size is made by trial and error. Arbitrarily select a pipe size and determine the loss of head. This loss gives the verticle drop of the hydraulic gradient. Draw this slope upstream from the proper elevation above the critical hydrant or hydrants (usually that farthest downstream) and see how it fits in with the limits at points upstream. If necessary, select other pipe sizes and try them.

STANDS

These are structures formed from vertical sections of pipe, or some-times of concrete cast in place (box stands) or concrete blocks. They may serve as pump stands, gate stands, overflow stands, and float valve stands. In addition they may also function as vents and sand traps. Sometimes, when gates are not required in the stands, they are capped with a smaller vent to above the hydraulic grade line. Float valve stands are used on steeper slopes where the rate of supply can be varied and automatic control offers advantages.

Stands should be placed at each inlet to a concrete irrigation pipe system and at such point as required. They should be designed to :

(1) Avoid entrainment of air

(2) Allow 0.30 to 1.52 meters (one to five feet) of free board

(3) Withstand the pressure within the structure

(4) A height of at least 1.22 meters (four feet) above the ground surface. If visibility is not a factor., they may be lowered if covered or equipped with track guards.

The downward water velocities should not exceed 0.61 meters per second (two feet per second). In no case should such velocity exceed the average pipeline velocity. If the size of the stand is decreased above the pump discharge pipe, the top vent portion should be of such inside cross-sectional area that, if the entire flow of the pump were discharging through it, the average velocity would not exceed 3.05 meters per second (ten feet per second).

PUMP STANDS

Pump stands are used to convey the flow of the pump into the concrete pipe system and to serve functions of other stands. Pump stands can be :

(1) Concrete box stands with vertical sides ;

(2) Non-tapered stands of concrete pipe ;

(3) Tapered stands of concrete pipe, or

(4) Steel cylinder stands mortared to a single piece of concrete pipe riser.

For any of the above types of pump stands in which the pump discharge pipe velocity exceeds three times the outlet pipe velocity, the centerline of the pump discharge pipe should have a minimum vertical offset from the centerline of the outlet pipe equal to the sum of the diameters of the inlet and outlet pipes. The pump discharge may be either through the side of the stand or over the top.

(5) A vent stand may be used in lieu of a pump stand at the entrance to a rubber gasket irrigation pipeline, providing the velocity, direction or turbulence of flow does not prevent the release of entrained air through the vent, and providing the discharge from the pump does not enter through the vent.

Check valves should be used in the pump discharge line wherever the potential backflow from the pipeline would be sufficient to drain the pipeline or damage the pump.

Where the metal pipe runs from the pump to the stand, through the wall of the stand and is mortared into place, a flexible coupling should be used on the pump discharge pipe to keep vibrations from cracking the stand.

A pump stand should not be capped where the well has a tendency to pump sand.

The minimum dimensions of pump stands should be determined by a maximum downwards velocity of 0.61 meters per second (two feet per second). It is desirable to have the diameter of the stand large enough to allow access for repairs.

Refer to Figures 31, 32, 33, and 34 for Structural Drawings (at pages 55, 56, 57 and 58).

OVERFLOW

Overflow stands function both as a check and a drop structure in addition to the usual functions of a stand. As checks, they regulate pressure to maintain constant upstream flow from hydrants or into laterals. As drop structures, they cause a drop in the hydraulic gradient, thus limiting pipeline pressure. This structure is not required on flat area or very slight slopes.

Overflow stands are generally two concrete pipe stands joined together with connections between them at the pipe line elevation, where the gate valve is installed, and at the elevation of the overlip. The upstream stand is essentially a gate stand. The down stream stand is the same diameter as the pipeline.

See Table 3 for Recommended Sizes for Upstream Stand.

Refer to Figures 22, 23, 35, and 36 for Strutural Drawings (at pages 52, 59 and 60).

SAND TRAPS

Sand traps permit the settling out of sand and other suspended material in the water. This keeps such material form settling out in the pipeline where it reduces capacity. Sand traps are suitable for use where the water is delivered into the system by a pump. They must have sufficient cross-section to insure low velocities. The following specifications apply to all sand traps :

(1) Vertical offset of inlet and outlet (preferably up to two times the pipeline diameter).

(2) The bottom at least 600 mm (24 inches) below the invert of the outlet pipe.

(3) Inside diameter such that average vertical velocity does not exceed about 0.076 m/sec (¼ feet/second), and diameter never less than 750 mm (30 inches).

Three horizontal layers of 6.35 to 12.7 mm (¼" to ½") hardware cloth, possibly with 12.7 to 25.4 mm (½" to 1") separations, just below the inlet will make these structures more effective by limiting the "piping" through the flow.

See Table 4 for Recommended Diameters of Sand Traps.

Refer to Figures 18 and 37 for Structural Drawings (at pages 51 and 61).

GATE STANDS

Gate stands prevent high pressure, act as air vents and surge chambers, and control the flow by means of one or more gate valves they contain. They may alse serve as stands for pumps to discharge into, and/or as sand traps

Gate stands are used to regulate the flow into laterals, or where, on a single line, it is desirable to create upstream pressure so that water will flow from hydrants at that point. This is done by partially closing the gate valve —or by closing it all the way if no irrigation is contemplated or if irrigation is completed downstream. If economics allow it, gate valves and capped vents for gate stands can be used, especially where a high stand would be required. This is not desirable where the structure must serve as a sand trap.

Gate stands :

(1) Can serve as vents

(2) Should be of such dimensions that gates are accessible for repair.

See Table 3 for Recommended Sizes of Gate Stands.

Refer to Figures 21 and 38 for Structural Drawings (at pages 52 and 62).

FLOAT VALVE STAND

Float valve stands are used in a series on steep slopes to form a semiclosed pressure in the reach of pipe immediately from it, and such valves release into the stand only as much water as hydrants further down stream are able to take. Thus, by opening and closing, the valve maintains a nearly constant water level in the stand, which is connected directly to the line or lines down stream through which water flows downstream. The downstream pressure is determined by the water surface elevation, and hence by the setting of the float.

When float valves are designed to prevent almost all fluctuation in the water surface elevation, there is a tendency for the valve to "hunt"— —a partial opening and closing occurs that produces a rhythmic variation in flow. This tendency is amplified when float valves are in series. Hunting is prevented by providing for a water surface elevation fluctuation in the stand, between valve – open and valve—closed position, of 150 mm to 300 mm (six inches to one foot), and on other adjustments to the reaction of the float. Thus, the float should be tall relative to its diameter, or there should be linkage between valve and float.

Float stands :

(1) Should be installed at intervals of about 3.05 meters (ten feet) of drop in the line.

(2) Eliminate the need for many high overflow stands

(3) Should have about 600 mm (two feet) of freeboard and 300 mm (one foot) is the minimum.

(4) Should be a minimum of 750 mm (30 inches) in diameter.

The size of float valve required depends upon the head loss available and the friction loss in the valve when wide open under full flow. Table 5 shows various rates of flow through the various valves available in the United States, with valves at wide open position, for various head losses.

Refer to Figure 14 and 39 for on Structural Drawings (at pages 50 and 63).

GRAVITY INLETS

For pipelines into which water flows by gravity from an open ditch, a gravity—inlet structure that may include a sand trap, debris screen, or trash rack is needed to develop full pipe flow and keep trash out. The top should be covered to keep trash from blowing in and to prevent accidents.

Refer to Figures 17, 19, 20, 40, 41, 42, and 43 for Structural Drawings (at pages 51, 64, 65, 66, 67 and 68 to 69).

VENT STAND

These are structures used to relieve pressure release air, and prevent vacuum.

LOCATIONS

Vents should be placed :

(1) At the downstream and of each lateral;

(2) At a design point downstream from any pump stand where the design velocity exceeds 0.30 meters per second (one foot per second)

(3) At points wherever there are changes grade in a downward direction of flow of more than ten degrees

(4) At summits in the pipe line

(5) Immediately upstream from line gates where closure of gate would make this the downstream end of a lateral or line.

The design point in (2) above shall be determined by the equation L=5.9VD for Meteric Units (L=1.76 VD for British Units), where L is the distance downstream in meters (feet) from the air entraining stand, V is the maximum design velocity in meters per second (feet per second) and D is the inside diameter of the pipe in meters (feet).

The maximum height of the vent above the centerline of the pipe line must not exceed the safe working head of the pipeline.

Any stand may substitute for a vent. Vents should be special as necessary for successful seperation at design capacity. A common spacing for vents is about 183 meters (600 feet).

There shall be considered to be opportunity for air entrainment at all gravity inlets and at pump stands where the pump might possibly pump air. When pumping from wells, if there is a downdraft of air into the casing while the pump is in operation, the well shall be considered to pump air. In such case, steel cylinder pump stands should not be used unless

(1) A vent is placed immediately downstream there from, or

(2) The average downward velocity from the pump discharge to the pipeline does not exceed 0.30 meters per second (one foot per second).

STRAIGHT VENT STAND

The cross-sectional area of this type shall be at least one-half the cross-sectional area of the pipeline (both inside diameter measurements).

It should rise to an elevation at least 600 mm (two feet) above the maximum hydraulic gradient. This type of vent stand is not normally used over heights of 4.5 meters (15 feet).

CAPPED VENT STAND

Used where gradients are more than 2.4 meters (eight feet) above ground surface. The bottom of the stand is the same as the vent in Paragraph 3 b. However, at or near the ground surface it is capped over, and a small pipe is extended through the cap to an elevation 600 mm (two feet) above the maximum hydraulic gradient. The cap should have a height of at least one pipe line diameter up from the center line of the pipeline. The small pipe may be steel, sheet metal, or asbestoscement. See Table 6 for recommended Size of pipe Above the Cap, but not less than a 50 mm (two inch) diameter pipe should be used. Extension of the small pipe down into the larger riser is permissible as long as it is at least 50 mm (two inches above the top invert of the pipeline).

AIR VENT AND VACUUM RELIEF VALVES

An air valve may be used in lieu of an open vent except that vent stands at the pump discharge should be open to the atmosphere. The valve outlet should have a 50 mm (two inch) nominal minimum diameter, 50 mm (two inch) outlets should be used for lines of 150 mm (six inch) diameter or less, 75 mm (three inch) outlets for lines of 175 mm to 250 mm (seven inch to ten inch) diameter and 100 mm (four inch) outlets for lines of 300 mm (12 inch) and larger..

Refer to Figure 24, 25, 26, and 44 for Structural Drawings (at pages 53 and 70).

DRAIN VALVES

Drain valves may be provided at low points in lines and at other points as necessary.

Refer to Figure 45 for Structural Drawing (at page 71).

ANCHORS

Abrupt changes in pipeline grade or alignment require either :

(1) A stand of a greater diameter than the pipeline.

(2) An anchor to absorb any axial thrust of the pipeline.

(3) A larger diameter pipe placed horizontally or placed vertically and capped below ground or a capped below ground in-place structure.

An abrupt change shall be considered to be :

(1) An angle of 45° or greater when the maximum working head is under 3.1 meters (ten feet).

(2) An angle of 30° or greater when the maximum working head is between 3.1 meters and 6.1 meters (ten and 20 feet).

(3) An angle of 15° or greater when the maximum working head is 6.1 meters ((20 feet) or more.

Where a vent stand is used in lieu of a pump stand at the entrance to a rubber gasket irrigation pipeline, a suitable anchor should be constructed to resist end thrust.

LINE GATE VALVE

Line gate valves are used to shut off or control flow without the gate valve in a stand. These valves are most useful where stands are high because they make it unnecessary to climb to the top of the stand to turn the valve. In addition, gate valves permit the use of small diameter, special capped vent stands instead of large gate stands. Adjacent vent stands are needed immediately upstream.

Friction losses in wide open gate valves are low, and frequently can be ignored. Table 7 gives approximate losses for wide open valves, which are expressed in "equivalent lengths of straight pipe in feet". Because such losses are small, and since the cost of gate valves increase greatly with size, the question is raised whether a valve somewhat smaller than the pipe can be used. This is best answered by computing the approximate loss of the equivalent pipe size for the particular size of valve being considered.

OUTLETS

Some type of outlet structure or hydrant is necessary in pipelines to deliver water to the land or into some distributing device. Hydrants are risers built from vertical sections of pipe which are saddled over openings in the pipeline and permanently attached to it with a water proof joint. Some kind of valve or gate is installed in the riser to regulate discharge through the hydrant.

ALFALFA VALVES

An alfalfa valve is a screw valve grouted to the top of a pipe riser. A handle and cap plate is attached to threaded rod that moves up or down as the handle is turned. When the valve is closed, the cap plate fits the circular edge of the valve case to make it watertight. When the plate is lifted by turning the handle. water is released from all sides of the valve.

Alfalfa valves are used to distribute water directly to border strips, basins, or stitches. The valve top should be set 75 mm to 100 mm (three to four inches) below the ground surface to minimize interference with farming operations and to reduce erosion from the irrigation stream. Alfalfa valves can be fitted with portable hydrants for connecting to surface pipes.

Where the head is low, riser and valve should be the same size as pipeline so that the entire flow of the pipeline can be released through the valves.

See Table 8 for maximum Design Capacities Recommended for Alfalfa Valve.

Refer to Figures 15 and 46 for Structural Drawings (at pages 50 and 72).

ORCHARD VALVES

Orchard valves are similar to alfalfa valves but have a smaller flow capacity and are so designed that they can be placed at the top of the riser, at the bottom or at most any point between. The preferred location is near the top.

Orchard valves are used instead of alfalfa valves if a smaller flow is acceptable. Because of their lower capacity they are less likely to cause scour around the riser, the top of which should be level with ground surface. It is also possible to place an additional length of pipe that has an opening on one side above the ground line to direct flow from the valve. Portable sheet metal stands or portable hydrants can also be attached to orchard valves to deliver water into surface pipe or ditches.

Table 9 gives Size and Recommended Maximum Capacities for Orchard Valves.

Refer to Figures 27, 28, and 47 for Structural Drawings (at pages 54 and 73).

OPEN POT OUTLETS

In open pot outlets the riser extends above the ground surface for enough for two or more slide-gate tubes to be installed close to the ground line. An orchard valve is placed below the slide gates. This kind of outlet distributes water through the gates to furrows and is used principally in orchard irrigation systems.

Orchard valves regulate flow into the pot, and slide gates regulate flow into individual furrows. Good control can be had by adjusting the orchard valve to keep the water surface only an inch or two above the slide gates. The slide gates are placed inside the pot at ground elevation to minimize erosion of the adjacent soil. Size of the pot depends on the number and size of slide gates to be used. If line pressure is low enough that the pot will not overflow, an orchard valve is not needed in the riser. Then all the flow is controlled at the slide gates.

Table 10 gives maximum design capacities recommended for open pot outlets with orchard valve. Table 11 gives Pot Sizes for Various Sizes and Numbers of Slide Gates.

Refer to Figures 29 and 48 for Structural Drawings (at pages 54 and 74).

CAPPED RISERS OR POT OUTLETS.

In these outlets the top of the pot is capped, the slide gates are installed on the outside of the riser, and an orchard valve is not used. Flow is controlled by adjusting line pressure and by the slide gates. Capped-pot outlets are used only in irrigating orchards and permanent crops where small flows are distributed to the individual furrows. The main advantage of capped-pot outlets is that leaves cannot fall into the pot and clog the slide gates and that an orchard value is not needed. The disadvantages are less control of flow and that, because of the pressure, the jet of water from the slide gate may erode the adjacent soil. Screw valves can be used in place of the slide gates. These valves will break the force of the jet and give a quiet nonerosive flow. Capped-pot outlets can be used where the pressure will not be more than 0.30 to 0.61 meters (one or two feet) above the ground surface.

Table 12 gives Maximum Design Capacities Recommended for Slide Gates for Capped Risers.

Refer to Figures 30 and 49 for Structural Drawings (at pages 54 and 75).

DESIGN CRITERIA FOR SEMICLOSED SYSTEMS

The same basic design criteria applies with the exception that pressure is regulated by float valves.

Float valve systems are used under the same condition as those in effect where overflow stands are used--the flow is *down* a more or less continuous grade. The difference is that each float valve stand regulates the pressure *downstream* from the stand, rather than upstream.

Minimum spacing is such that that the difference in elevation between any two float valve stands should not be less than :

The friction loss per 100 meters (or 1000 feet) of pipe X length of line between stands ÷ 100 (or 1000) + friction loss in float valve when wide open. Friction loss must be expressed as meters (or feet) of water. Table 5 gives friction loss for several float valves.

Maximum spacing is usually every 1.5 to 3.0 meters (five to ten feet) of droppin elevation or not more than 200 meters (660 feet), which ever is less. The water surface in float valve stands, when the gates are wide open, should not be less than 0.30 meters (one foot) above ground surface. Commonly 0.61 to 0.91 meters (two to three feet) above the ground surface is used.

TABLE 3

Upstream Stands for Overflow Stands and Gate Stands

Recommended Sizes

Inside diameter of pipeline		Inside diameter of stands			
		with one gate		with 2 or 3 gates	
mm	inches	mm	inches	mm	inches
152.4 to 254.0	6 to 10	762 0	30	762.0	30
304.8	12	762.0	30	944.4	36
355.6	14	762.0	30	1066.8	42
406.4	16	762.0	30	1066.8	42
457.2	18	762.0	30	1219.2	48
508.0	20	1066.8	42	1371.6	54
609.6	24	1219.2	48	1524.0	60

TABLE 4

Concrete Pipe Sand Traps

Recommended Diameters

Maximum flow	Diameters	
c.f.c.	mm	inches
1.22	752.0	30
1.49	838.2	33
1.77	944.4	36
2.40	1066.8	42
3.14	1219.2	48
3.98	1371.6	54
4.90	1524.0	60

TABLE 5

Rates of Flow in c.f.s. Through Wide Open Float Valves with Head Losses Indicated

Type and size	Head loss in meters (feet) of water					
	(0.15)	(0.30)	(0.61)	(1.52)	(3.05)	(6.10)
	c.f.s.	c.f.s.	c.f.s.	c.f.s.	c.f.s.	c.f.s.
Double disk (balanced) type :						
101.6 mm (4 inch)	0.22	0.31	0.43	0.69	0.97	1.39
152.4 mm (6 inch)	0.52	0.74	1.03	1.66	2.32	3.30
203.2 mm (8 inch)	0.98	1.39	1.97	3.10	3.40	6.25
Single disk (open) type :						
101.6 mm (4 inch)	0.32	0.45	0.64	1.01	1.53	2.18
127.0 mm (5 inch)	0.50	0.71	1.00	1.58	2.10	3.00
203.2 mm (8 inch)	1.28	1.81	2.56	4.05	5.75	8.15

TABLE 6

Size of Pipe Above the Cap for Vent Stand

Pipeline diameter		Suggested pipe diameter above cap	
mm	inches	mm	inches
upto 203.2	upto 8	25.4 to 50.8	1 to 2
254.0 to 355.6	10 to 14	50.8 to 101.6	2 to 4
406.4 to 609.6	16 to 24	101.6 to 152.4	4 to 6

Losses : Friction losses in wide open gate valves are low, and frequently can be ignored. Following are approximations of wide open losses in terms of "Equivalent lengths of straight pipe in feet" that can be used where needed.

TABLE 7

Line Gates, Equivalent Lengths Pipe

Pipe and Valve Size		Equiv. Length of Straight Pipe	
mm	inches	meters	feet
152.4	6	1.22	4
203.2	8	1.52	5
254.0	10	1.83	6
304.8	12	2.13	7
355.6	14	2.44	8
406.4	16	2.74	9
457.2	18	3.35	11
508.0	20	3.66	12
609.6	24	4.27	14

TABLE 8

Alfalfa Valves

Maximum Design Capacities Recommended.

Inside Diameter of Riser		Diameter of Port		Maximum Design Usual Low Head[1]	Capacity High Head[2]
mm	inches	mm	inches	c. f. s.	c. f. s.
152.4	6	152.4	6	0.8	1.6
203.2	8	203.2	8	1.4	2.8
254.0	10	254.0	10	2.2	4.4
304.8	12	304.8	12	3.1	6.3
355.6	14	355.6	14	4.3	8.6
406.4	16	406.4	16	5.6	11.2
457.2	18	457.2	18	7.[illegible]	14.2
508.0	20	508.0	20	8.7	17.5

1 Recommended for minimum erosion with hydraulic gradient one above ground. Assumed 0.5 ft. ponding over valve, $h=0.5$ ft., $Q=0.7A\ 2gh$ where A is the normal port area, h is the loss through the valve, and g is the acceleration due to gravity (32.2 ft/sec^2).

2 Can be used where higher pressures are available (hydraulic gradient 2.5 ft. above ground) and precautions are taken to prevent erosion. (Ponding $=0.5$ ft., $h=2$ ft.)

TABLE 9

Orchard Valves

Size and Recommended Maximum Capacities

Inside Diameter of Riser		Inside Diameter of Pot		Diameter of valve outlet		Approximate Design Capacities	
						Low Head[1]	Higher Head[2]
mm	inches	mm	inches	mm	inches	c. f. s.	c. f. s.
152.4	6	152.4 or 203.2	6 or 8	38.1	1-½	0.04	0.08
152.4	6	152.4 or 203.2	6 or 8	63.5	2-½	0.12	0.23
152.4	6	203.2	8	88.9	3-½	0.23	0.45
152.4	6	254.0	10	152.4	6	0.67	1.34
203.2	8	203.2 or 254.0	8 or 10	127.0	5	0.46	0.93
203.3	8	304.8	12	203.2	8	1.18	2.37
254.0	10	254.0 or 304.8	10 or 12	152.4	6	0.67	1.34
254.0	10	304.8	12	165.1	6-½	0.78	1.57
254.0	10	355.6	14	254.0	10	1.85	3.71
304.8	12	304.8 or 355.6	12 or 14	203.2	8	1.18	2.37
304.8	12	406.4	16	304.8	12	2.67	5.35

[1] Usual design with hydraulic gradient one foot above ground ($Q = 0.6a\sqrt{2gh}$) "a" is nominal port area ; h=0.5 foot.

[2] Higher head design with hydraulic gradient 2-½ feet above ground (h=2.0 ft.).

TABLE 10

Open Pot Outlets with Orchard Valve

For Slide Gates			Maximum Design Capacities Recommended for Orchard Valves				
Diameter of Opening		Maximum Design Capacity	Size (Inside Diameter of riser)		Diameter of Valve Outlet		Usual Design Capacity[1]
mm	inches	c. f. s.	mm	inches	mm	inches	c. f. s.
25.4	1	0.02	152.4	6	38.1	1-½	0.04
38.1	1-½	0.04	152.4	6	63.5	2-½	0.12
50.1	2	0.04	152.4	6	88.9	3-½	0.23
76.2	3	0.015	203.2	8	127.0	5	0.46
101.6	4	0.26	254.0	10	152.4	6	0.56
127.0	5	0.41	254.0	10	165.1	6-½	0.78
152.4	6	0.60	304.8	12	203.2	8	1.18

1 Hydraulic *gradient* one foot above ground surface ($Q = 0.6a\sqrt{2gh}$).
Pot Sizes Recommended for Various Sizes and Numbers of Slide Gates.
Same as Table 11.

TABLE 11

Pot Sizes Recommended for Various Sizes and Number of Slide Gates

mm	inches	
152.4	6	two gates up to 76.2 mm (three inch) diameter
203.2	8	four gates up to 25.4 mm (one inch) diameter. Two gates up to 127.0 mm (five inch) diameter.

(Continued)

254.0	10	four gates up to 50.8 mm (two inch) diameter. Two gates up to 152.4 mm (six inch) diameter.
304.8	12	six gates up to 25.4 mm (one inch) diameter. Four gates up to 50.8 mm (two inch) diameter.
355.6	14	six gates up to 38.1 (1-½ inch) diameter. Four gates up to 76.2 mm (three inch) diameter.
406.4	16	eight gates up to 25.4 mm (one inch) diameter. Four gates up to 101.6 mm (four inch) diameter.

TABLE 12

Maximum Design Capacities
Recommended for Slide Gates for Capped Risers

Diameter of Opening		Usual Design Capacity
mm	inches	c. f. s.
25.4	1	0.02
38.1	1-1½	0.04
50.8	2	0.07
76.2	3	0.15
101.6	4	0.26
127.0	5	0.41
152.4	6	0.60

Maximum Capacity based on the assumption that velocities under 0.91 m/sec (three feet/sec) will not cause excessive erosion.

For pot diameters refer to Table 11.

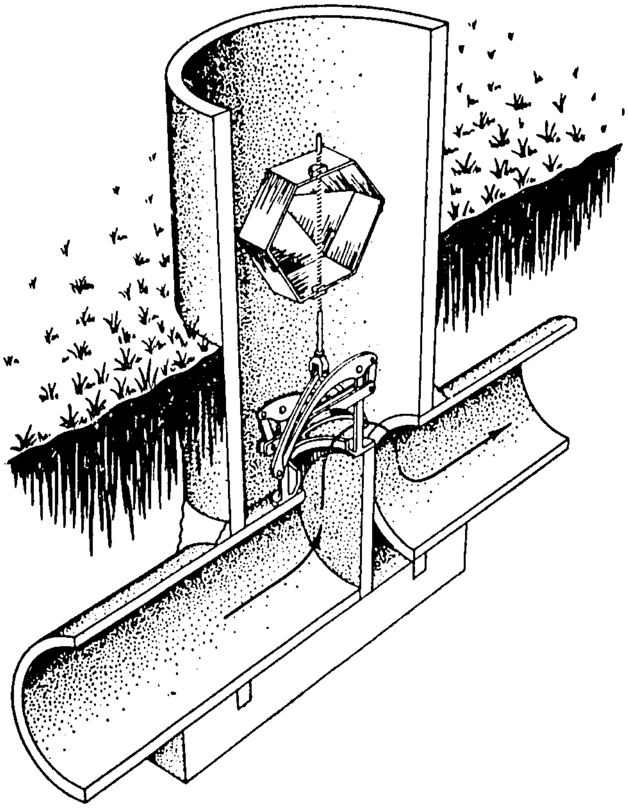


Fig. 14. Section of a float-valve stand

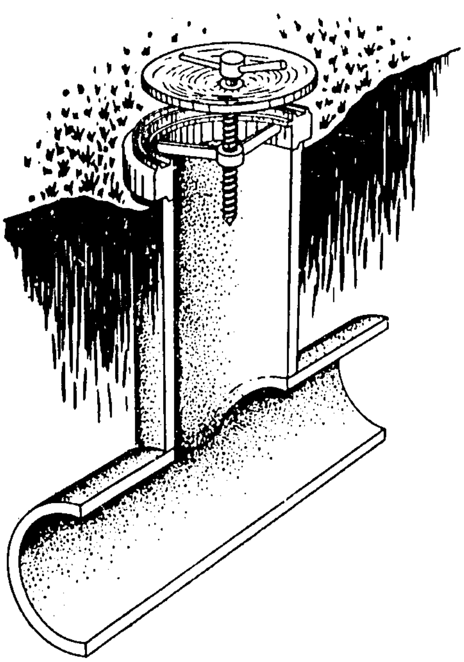


Fig. 15. Section of a alfalfa valve mounted on concrete pipe

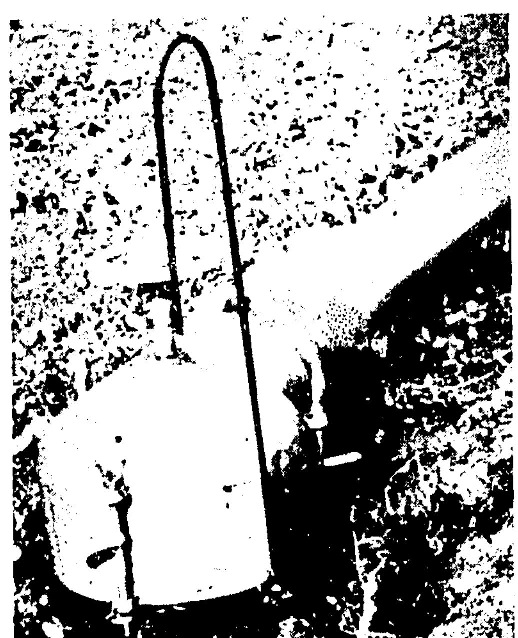


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Fig. 16. Portable hydrant attached to alfalfa valve for gated pipe or surface pipe

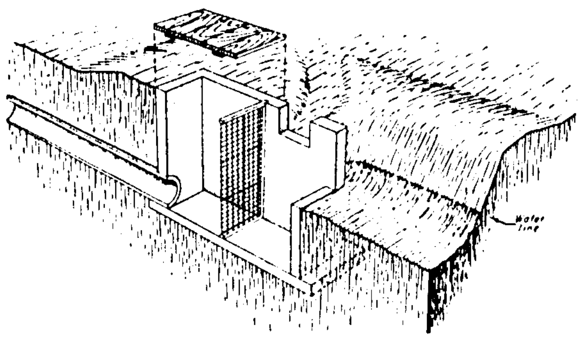

Fig. 17. Gravity inlet for buried low-pressure pipeline

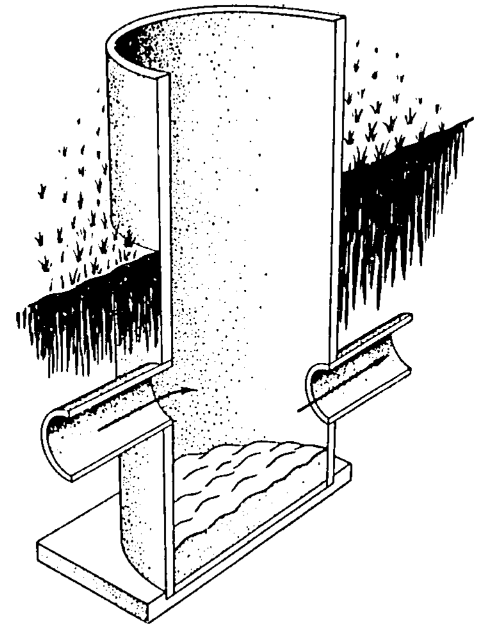

Fig. 18. Typical concrete-pipe sand trap

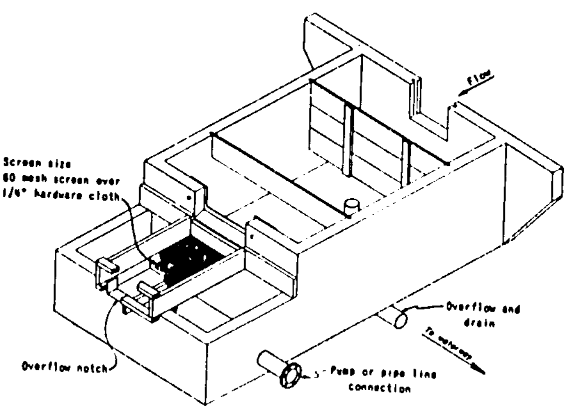

Fig. 19. Typical trash screen

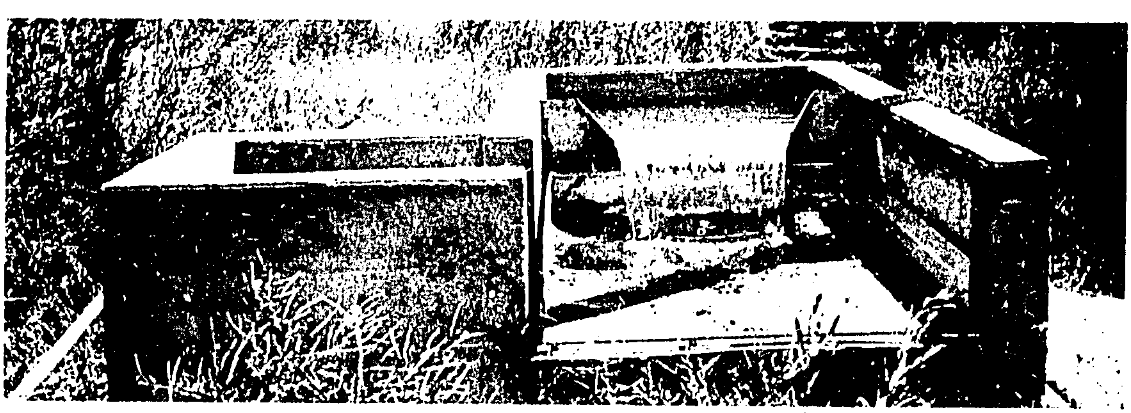

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Fig. 20. Desilting box and trash screen

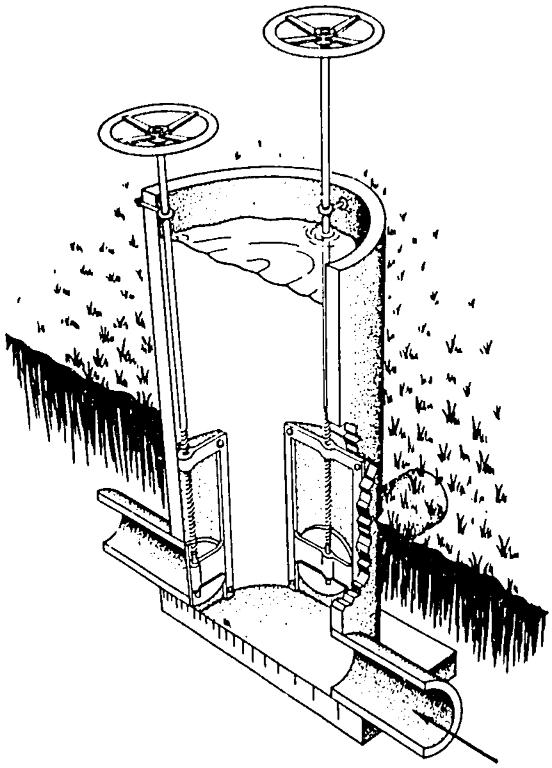


Fig. 21. Section of a concrete-pipe gate stand used to control flow into two laterals

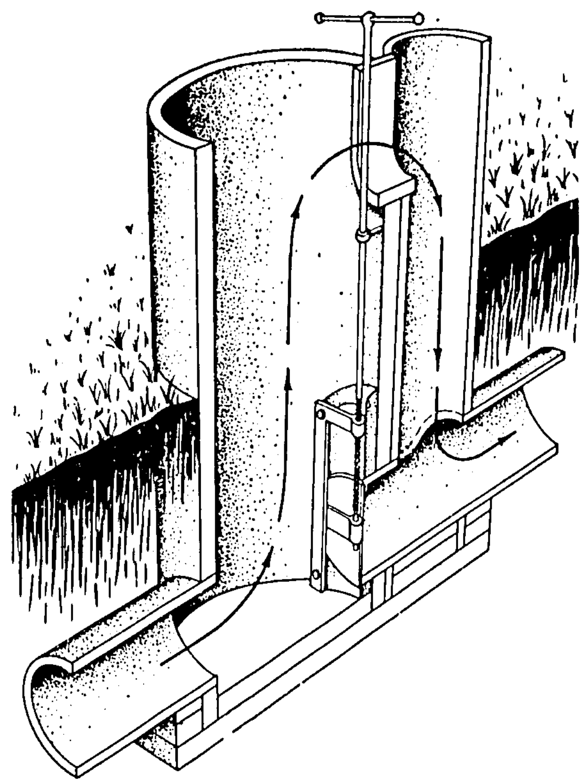
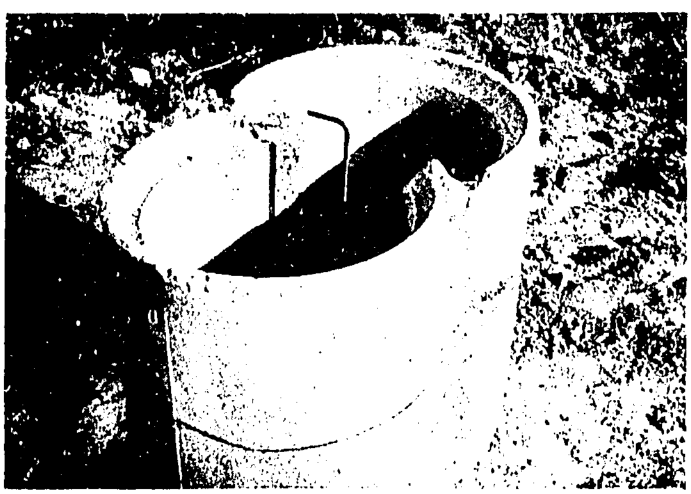


Fig. 22. Section of concrete-pipe overflow stand



IDA-45360

Fig. 23. Concrete-pipe overflow stand

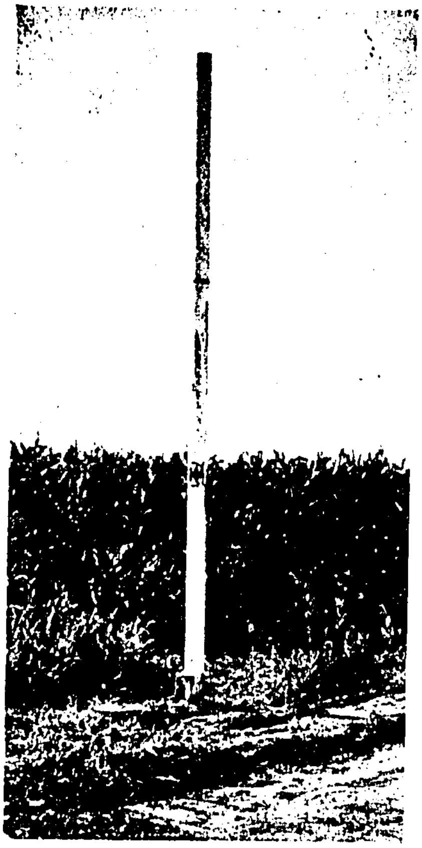


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Fig. 24. Typical capped vent

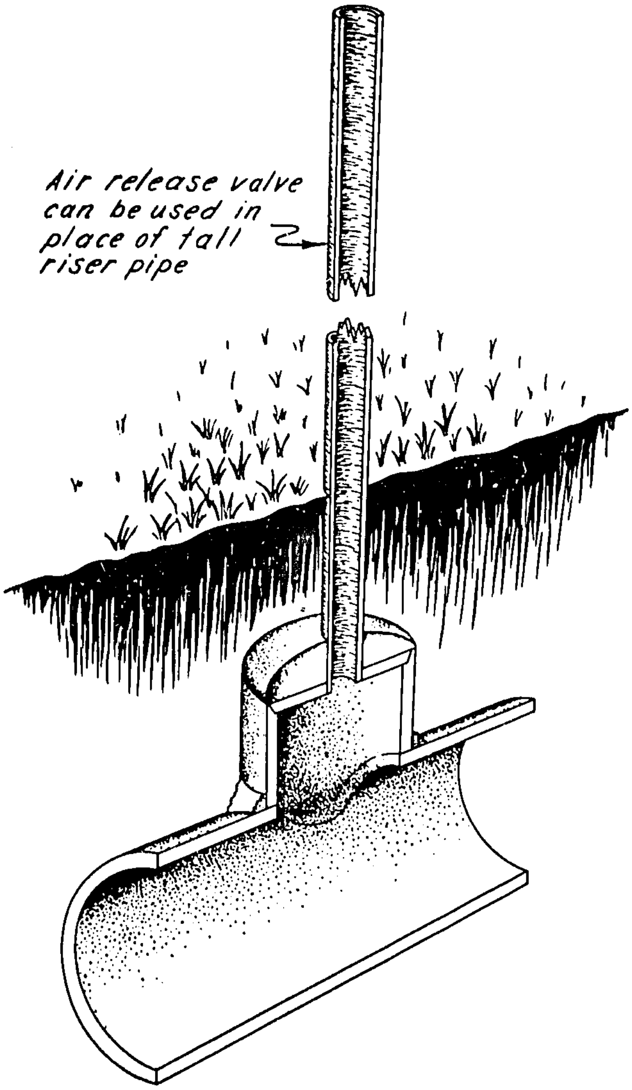


Fig. 25 Section of a capped vent

NEB-2152

Fig. 26. Closeup of air-release valve on right and alfalfa valve on left

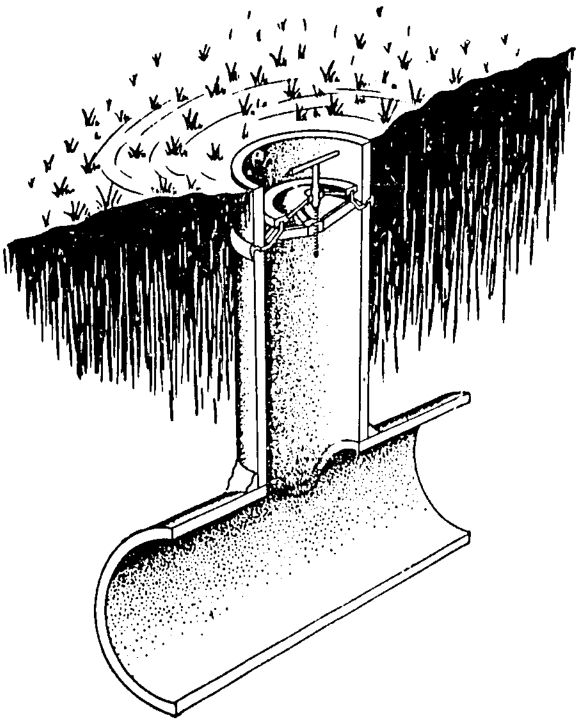


Fig. 27. Section of an orchard valve

Bn-16806

Fig. 28. Orchard valve

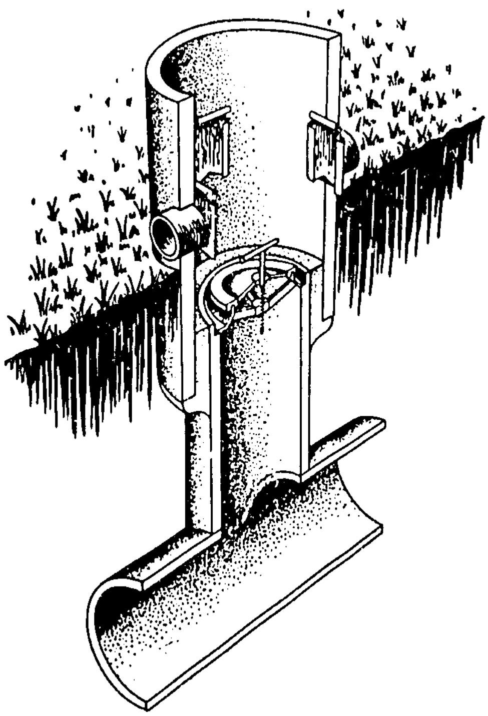


Fig. 29. Open-pot outlet with an orchard valve and slide-gate control

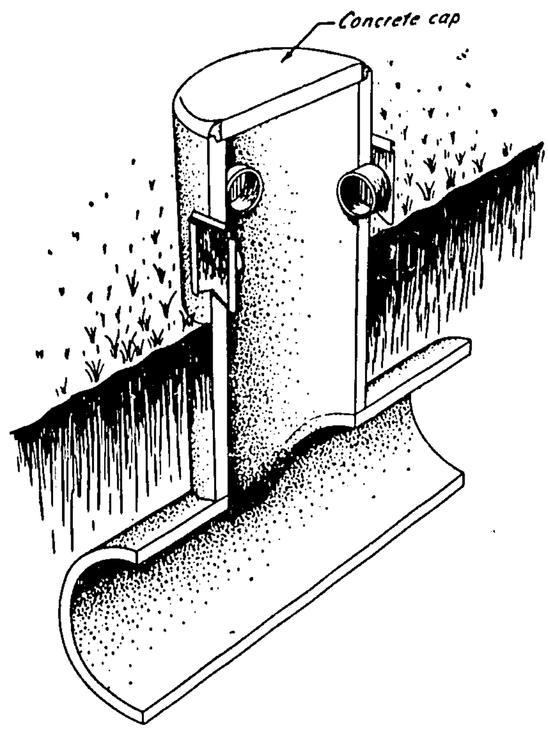
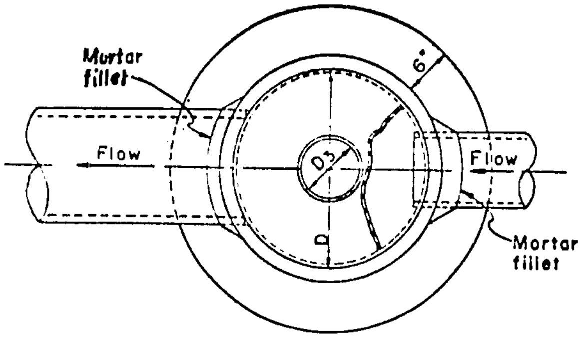
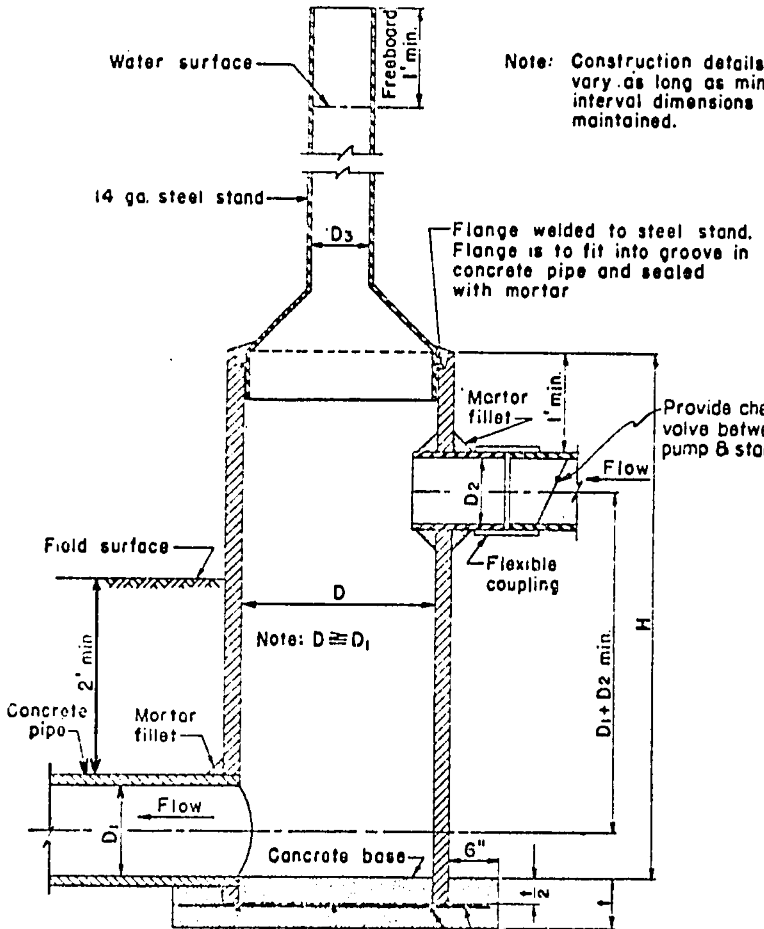


Fig. 30. Section of a capped riser or pot outlet

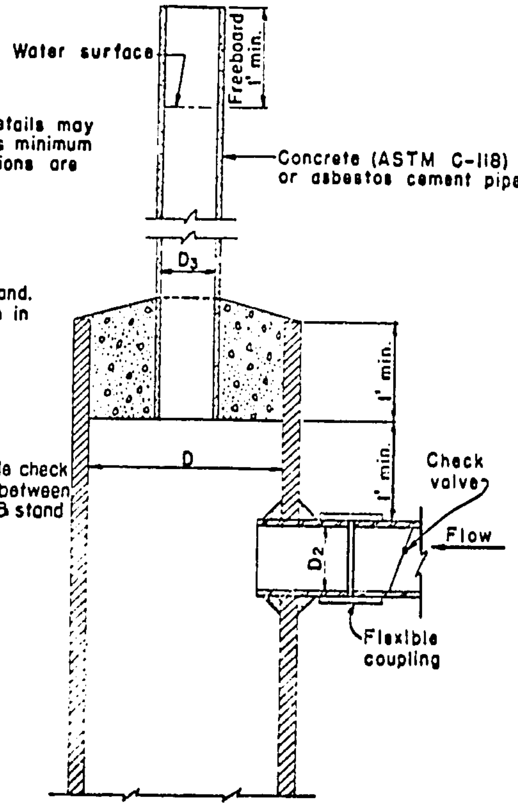


PLAN



℄ CROSS SECTION

Note: Construction details may vary as long as minimum interval dimensions are maintained.



ALTERNATE ℄ CROSS SECTION

Max Q	D	A.S.T.M. Spec.		D_3 Min.	Concrete Base					
					H=10' or less		H=more than 10'		Reinforcing steel	
c.f.s.	In.	No.	Type	In.	t	Cu.yd.	t	Cu.yd.	Size	Length
0.79	12	C-118	Concrete Irrigation Pipe	$3\frac{7}{8}$	4"	.05	6"	.07	—	—
1.07	14			$4\frac{1}{2}$	4"	.05	6"	.08	—	—
1.23	15			$4\frac{3}{4}$	4"	.06	6"	.09	—	—
1.40	16			$5\frac{1}{8}$	4"	.06	6"	.10	—	—
1.77	18			$5\frac{3}{4}$	4"	.07	6"	.11	—	—
2.18	20			$6\frac{3}{8}$	6"	.13	8"	.17	—	—
2.41	21			$6\frac{1}{2}$	6"	.14	8"	.18	—	—
3.14	24			$7\frac{5}{8}$	6"	.16	8"	.22	—	—
3.98	27	C-76	Class II Reinforced Concrete Pipe	$8\frac{5}{8}$	6"	.20	8"	.26	$\frac{3}{8}$	19'
4.91	30			$9\frac{1}{2}$	6"	.23	8"	.30	$\frac{3}{8}$	21'
5.94	33			$10\frac{1}{2}$	8"	.35	8"	.35	$\frac{3}{8}$	22'
7.07	36			$11\frac{1}{2}$	8"	.39	8"	.39	$\frac{3}{8}$	23'
9.62	42			$13\frac{3}{8}$	8"	.50	8"	.50	$\frac{3}{8}$	38'
12.57	48			$15\frac{1}{4}$	8"	.62	8"	.62	$\frac{1}{2}$	46'

NOMENCLATURE

D – Diameter of vertical concrete pipe

D_1 – Diameter of underground pipe

D_2 – Diameter of pump discharge pipe

D_3 – Diameter of stand pipe

t – Thickness of concrete base

H – Height of vertical concrete pipe above top of concrete pipe

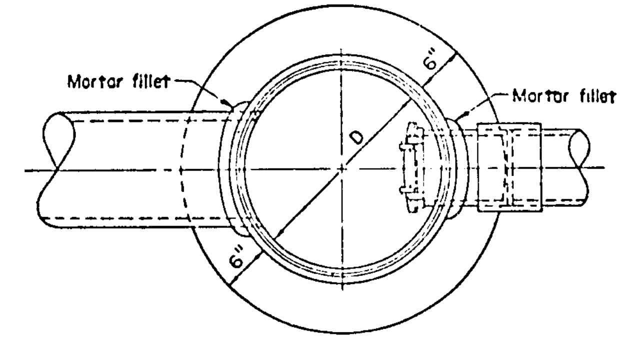
Q – Discharge through structure in c.f.s.

HIGH HEAD TAPERED PUMP STAND FOR CONCRETE PIPE

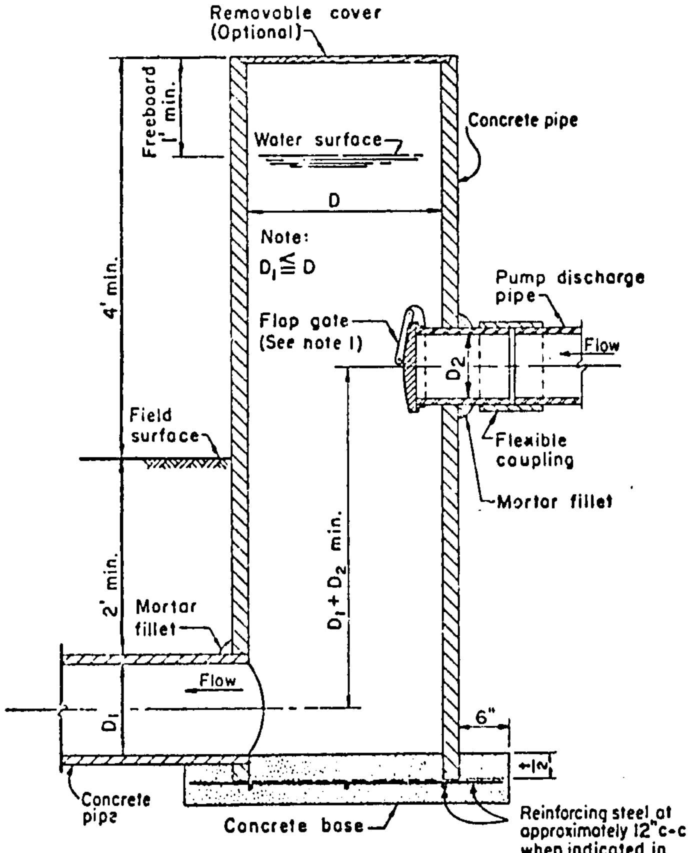
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

12-59 | 5,0-16,199

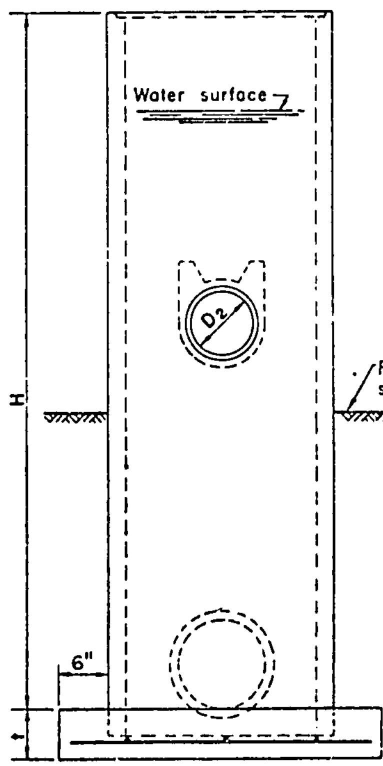
Figure 31



PLAN



℄ CROSS SECTION



ELEVATION

Notes:

1. When D $\leq$ 27" or when D_2 is greater than $1/2$ D eliminate flap gate and use a check valve in pump discharge pipe.

NOMENCLATURE

D - Diameter of vertical pipe

D_1 - Diameter of underground pipe

D_2 - Diameter of pump discharge pipe

t - Thickness of concrete base

H - Height of vertical pipe above top of concrete base

Q - Discharge through structure in cfs.

Max. Q	D	A.S.T.M. Spec.		Concrete Base					
				H=10' or less		H=more than 10'		Reinforcing steel	
c.f.s.	Inches	No.	Type	t	Cu.yd.	t	Cu.yd	Size	Length
0.79	12	C-118	Concrete Irrigation Pipe	4"	0.05	6"	0.07	—	—
1.07	14			4"	0.05	6"	0.08	—	—
1.23	15			4"	0.06	6"	0.09	—	—
1.40	16			4"	0.06	6"	0.10	—	—
1.77	18			4"	0.07	6"	0.11	—	—
2.18	20			6"	0.13	8"	0.17	—	—
2.41	21			6"	0.14	8"	0.18	—	—
3.14	24			6"	0.16	8"	0.22	—	—
3.98	27	C-76	Class II Reinforced Concrete Pipe	6"	0.20	8"	0.26	3/8"	19'
4.91	30			6"	0.23	8"	0.30	3/8"	21'
5.94	33			8"	0.35	8"	0.35	3/8"	22'
7.07	36			8"	0.39	8"	0.39	3/8"	23'
9.62	42			8"	0.50	8"	0.50	3/8"	38'
12.57	48			8"	0.62	8"	0.62	1/2"	46'

HIGH HEAD NON-TAPERED PUMP STAND FOR CONCRETE PIPE

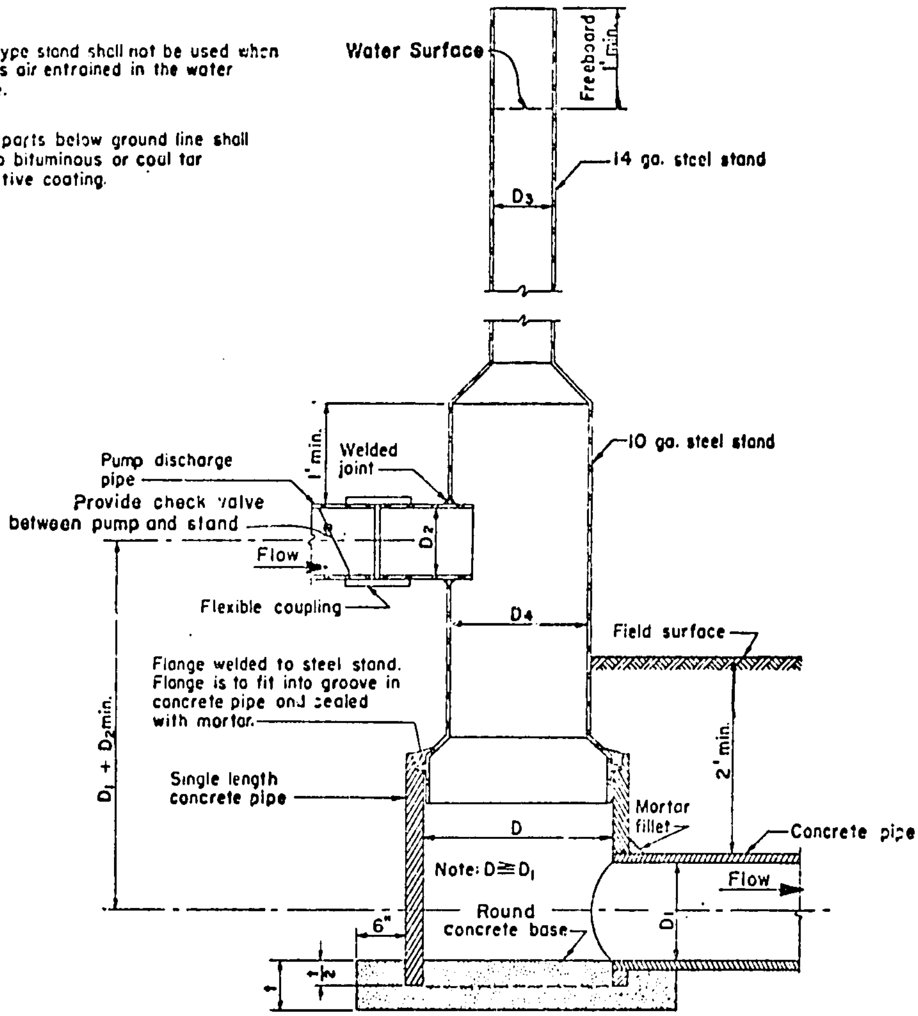
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Compiled	Checked	Date	Drawing No.
		1-64	5,0-19000-27-1

Figure 32

Note: This type stand shall not be used when there is air entrained in the water source.

Metal parts below ground line shall have a bituminous or coal tar protective coating.



℄ CROSS SECTION

Max. Q	Concrete Pipe			Steel Stand				Concrete Base	
	D	A.S.T.M. Spec.		D_4 Min.		D_3 Min.		t	Volume
c.f.s.	Inches	No.	Type	Inches	Gage	Inches	Gage	Inches	Cu. yd.
0.79	12	C-118	Concrete Irrigation Pipe	8 1/2	10	3 7/8	14	4	0.0[illegible]
1.07	14	C-118		10	10	4 1/2	14	4	0.05
1.23	15	C-118		10 5/8	10	4 3/4	14	4	0.06
1.40	16	C-118		11 3/8	10	5 1/8	14	4	0.06
1.77	18	C-118		12 3/4	10	5 3/4	14	4	0.07
2.18	20	C-118		14 1/4	10	6 3/8	14	6	0.13
2.41	21	C-118		14 7/8	10	6 3/4	14	6	0.14
3.14	24	C-118		17	10	7 5/8	14	6	0.16
3.98	27	C-76	Class II Reinforced Concrete Pipe	19 1/8	10	8 5/8	14	6	0.20
4.91	30	C-76		21 1/4	10	9 1/2	14	6	0.23
5.94	33	C-76		23 3/8	10	10 1/2	14	8	0.35
7.07	36	C-76		25 1/2	10	11 1/2	14	8	0.39
9.62	42	C-76		29 3/4	10	13 3/8	14	8	0.50
12.57	48	C-76		34	10	15 1/4	14	8	0.62

NOMENCLATURE

D – Diameter of vertical concrete pipe

D_1 – Diameter of underground pipe

D_2 – Diameter of pump discharge pipe

D_3 – Diameter of upper steel stand pipe

D_4 – Diameter of lower steel stand pipe

t – Thickness of concrete base

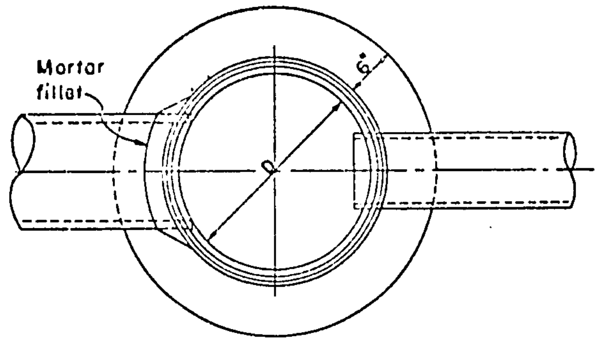
Q – Discharge through structure in c.f.s.

HIGH HEAD STEEL TAPERED PUMP STAND FOR CONCRETE PIPE

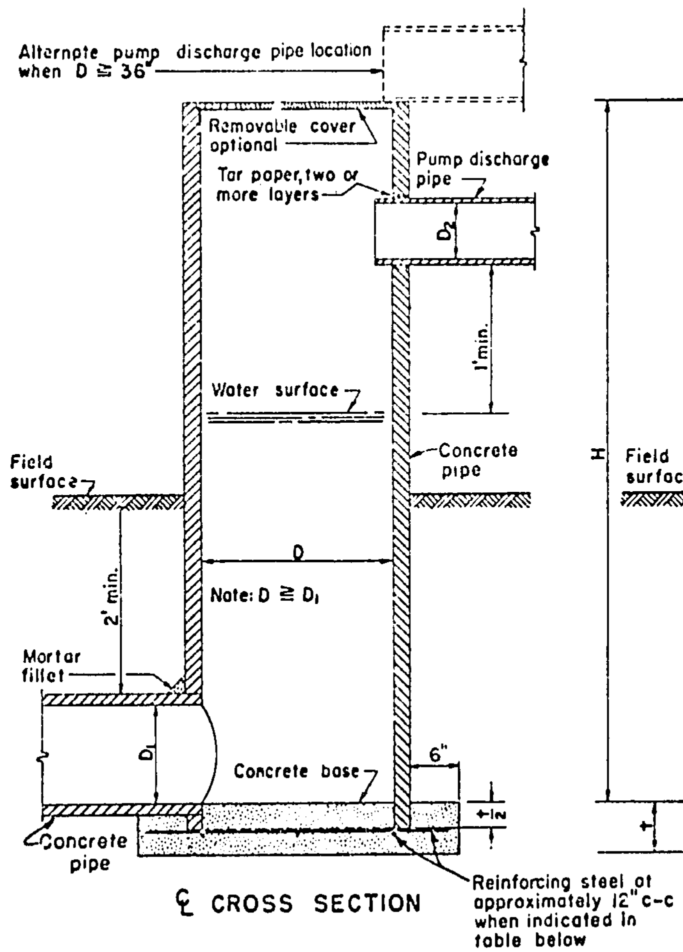
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

1-64 5,0-19000-26-1

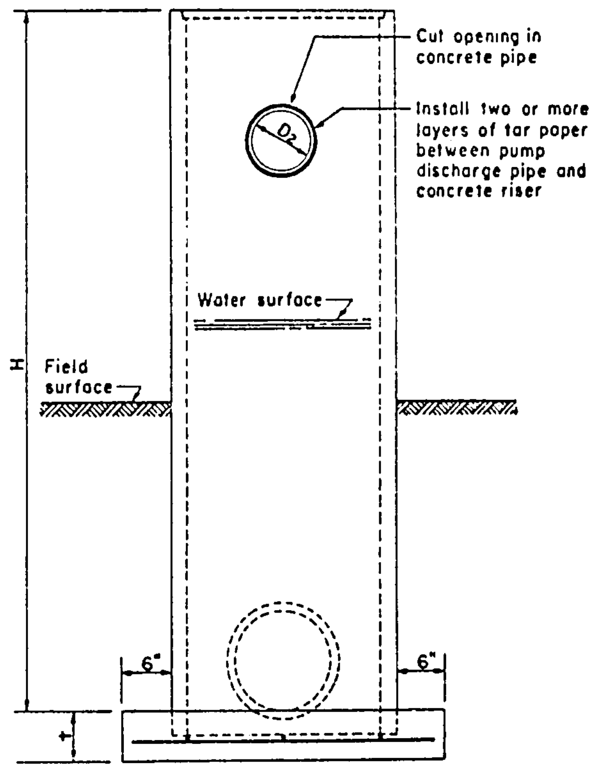
Figure 33



PLAN



℄ CROSS SECTION



ELEVATION

Max. Q		D	A.S.T.M. Spec.		Concrete Base					
					H=10' or less		H=more than 10'		Reinforcing steel	
c.f.s.		Inches	No.	Type	t	Cu. yd.	t	Cu. yd.	Size	Length
0.79		12	C-118	Concrete Irrigation Pipe	4"	0.05	6"	0.07	—	—
1.07		14			4"	0.05	6"	0.08	—	—
1.23		15			4"	0.06	6"	0.09	—	—
1.40		16			4"	0.06	6"	0.10	—	—
1.77		18			4"	0.07	6"	0.11	—	—
2.18		20			6"	0.13	8"	0.17	—	—
2.41		21			6"	0.14	8"	0.18	—	—
3.14		24			6"	0.16	8"	0.22	—	—
3.93		27	C-76	Class II Reinforced Concrete Pipe	6"	0.20	8"	0.26	3/8"	19'
4.91		30			6"	0.23	8"	0.30	3/8"	21'
5.94		33			8"	0.35	8"	0.35	3/8"	22'
7.07		36			8"	0.39	8"	0.39	3/8"	23'
9.62		42			8"	0.50	8"	0.50	3/8"	38'
12.57		48			8"	0.62	8"	0.62	1/2"	46'

NOMENCLATURE

D - Diameter of vertical pipe

D_1 - Diameter of underground pipe

D_2 - Diameter of pump discharge pipe

t - Thickness of concrete base

H - Height of vertical pipe above top of concrete base

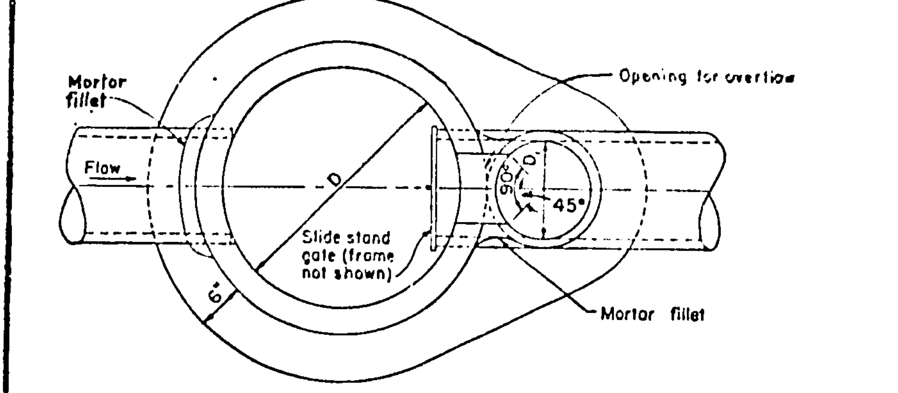
Q - Discharge through structure in c.f.s.

LOW HEAD PUMP STAND
FOR CONCRETE PIPE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

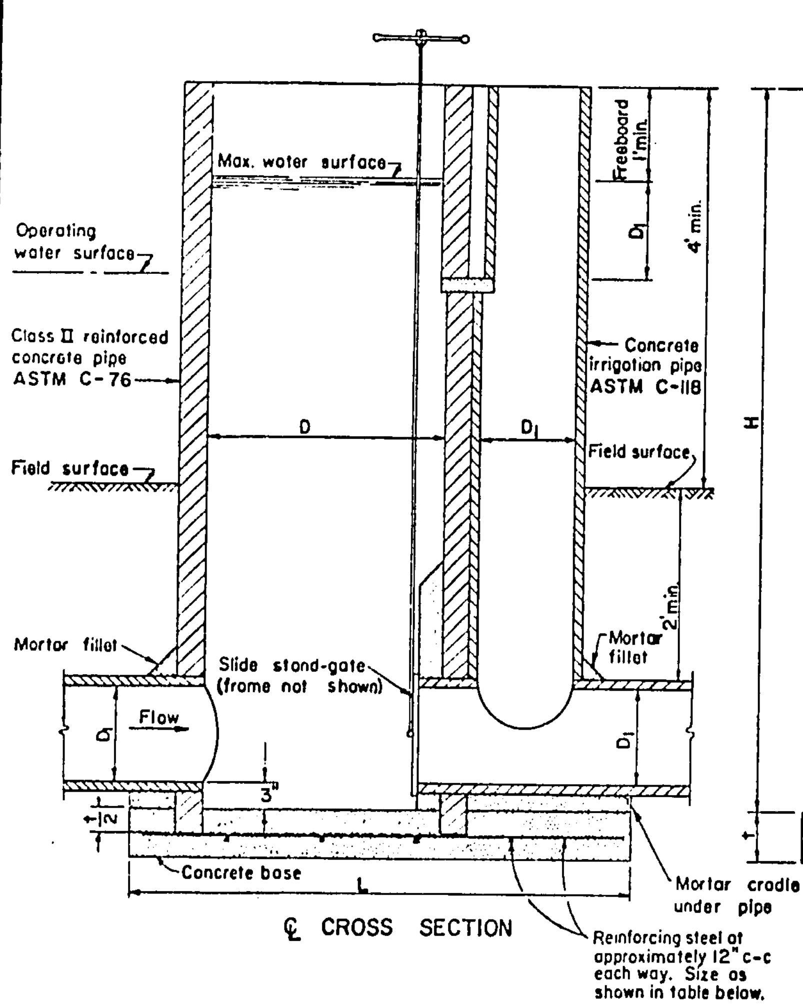
COMPILED	CHECKED	DATE	DRAWING NO.
		1—64	5,0-19,000-25

Figure 34

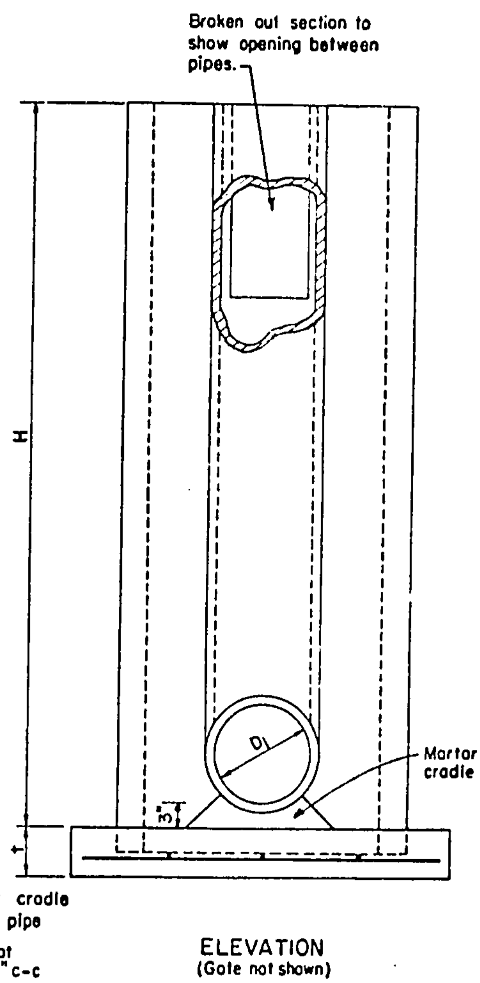


PLAN

NOTE: Provide permanent ladder fastened to stand to provide access to gate wheel.



℄ CROSS SECTION



ELEVATION
(Gate not shown)

TABLE OF DIMENSIONS AND QUANTITIES

D_1	D	Concrete Base						
		L	H=10' or less		H=more than 10'		Reinforcing steel	
			t	volume	t	volume		
Inches	Inches	Feet - Inches	Inches	Cu.yd.	Inches	Cu.yd.	Size	Lgth.ft.
8	30	4'- 10 1/2"	6	0.31	8	0.41	3/8"	24
10	30	5'- 0 1/2"	6	0.32	8	0.42	3/8"	25
12	30	5'- 2 3/4"	6	0.34	8	0.44	3/8"	26
14	30	5'- 5"	6	0.36	8	0.46	3/8"	27
15	30	5'- 6"	6	0.37	8	0.47	3/8"	28
16	30	5'- 7 1/4"	6	0.38	8	0.48	3/8"	29
18	30	5'- 9 1/2"	6	0.39	8	0.50	3/8"	31
20	42	7'- 1 3/4"	8	0.75	8	0.75	3/8"	53
21	42	7'- 3"	8	0.77	8	0.77	3/8"	53
24	48	8'- 1 3/4"	8	0.97	8	0.97	1/2"	64

NOMENCLATURE

D - Diameter of concrete stand pipe
D_1 - Diameter of underground concrete pipe and concrete overflow pipe
H - Height of structure
t - Thickness of concrete base

OVERFLOW GATE STAND for CONCRETE PIPE LINES

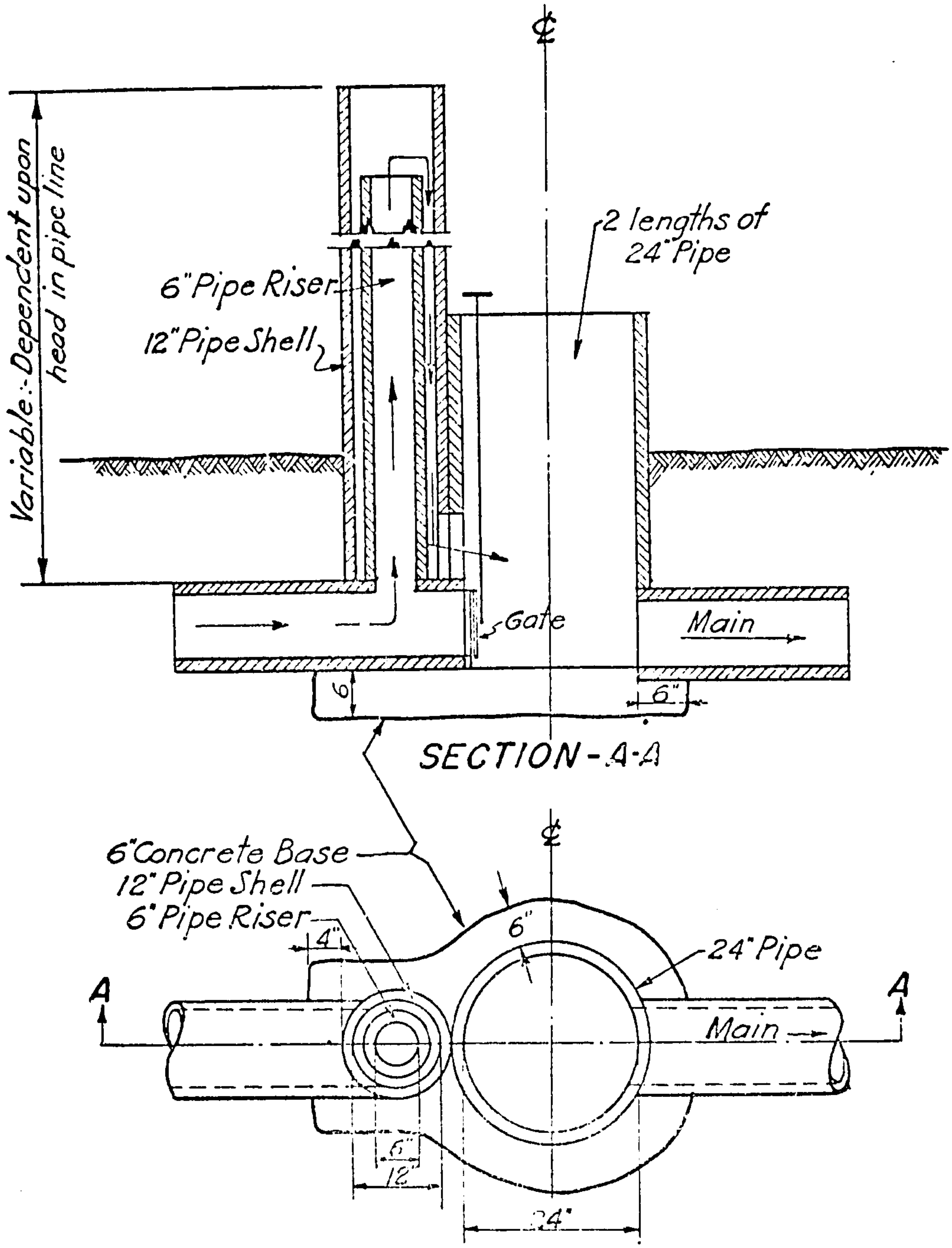
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Compiled	Checked	Date	Drawing No.
		1-64	5,0-19,000-29-1

Figure 35

KING CITY OVERFLOW

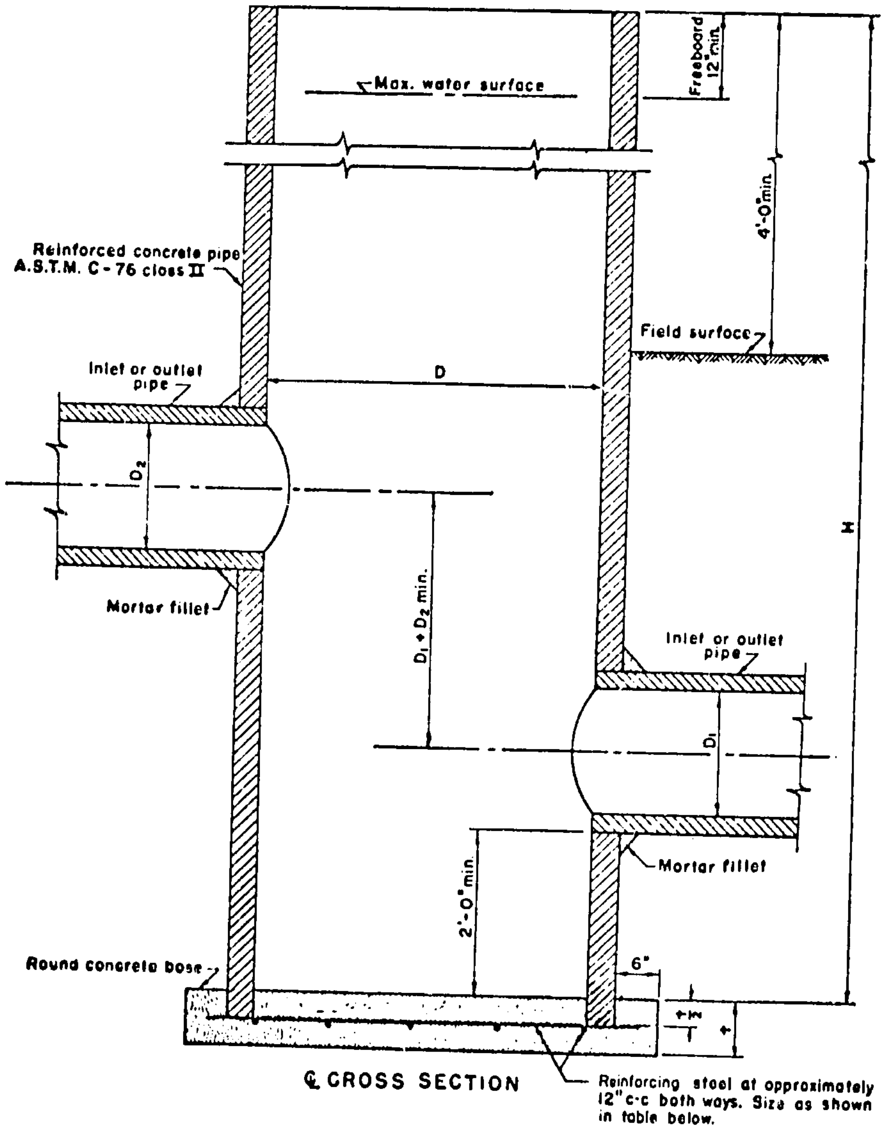
PRESSURE RELIEF



Applicable to pipe lines on moderate slopes
On steep slopes cost of stands and valves is excessive

7-L-Eng-60

Figure 36



NOMENCLATURE

D = Diameter of vertical concrete pipe
D_1 = Diameter of inlet or outlet pipe
D_2 = Diameter of inlet or outlet pipe
t = Thickness of concrete base
H = Height of vertical concrete pipe above top of concrete base
Q = Discharge through structure in c.f.s.

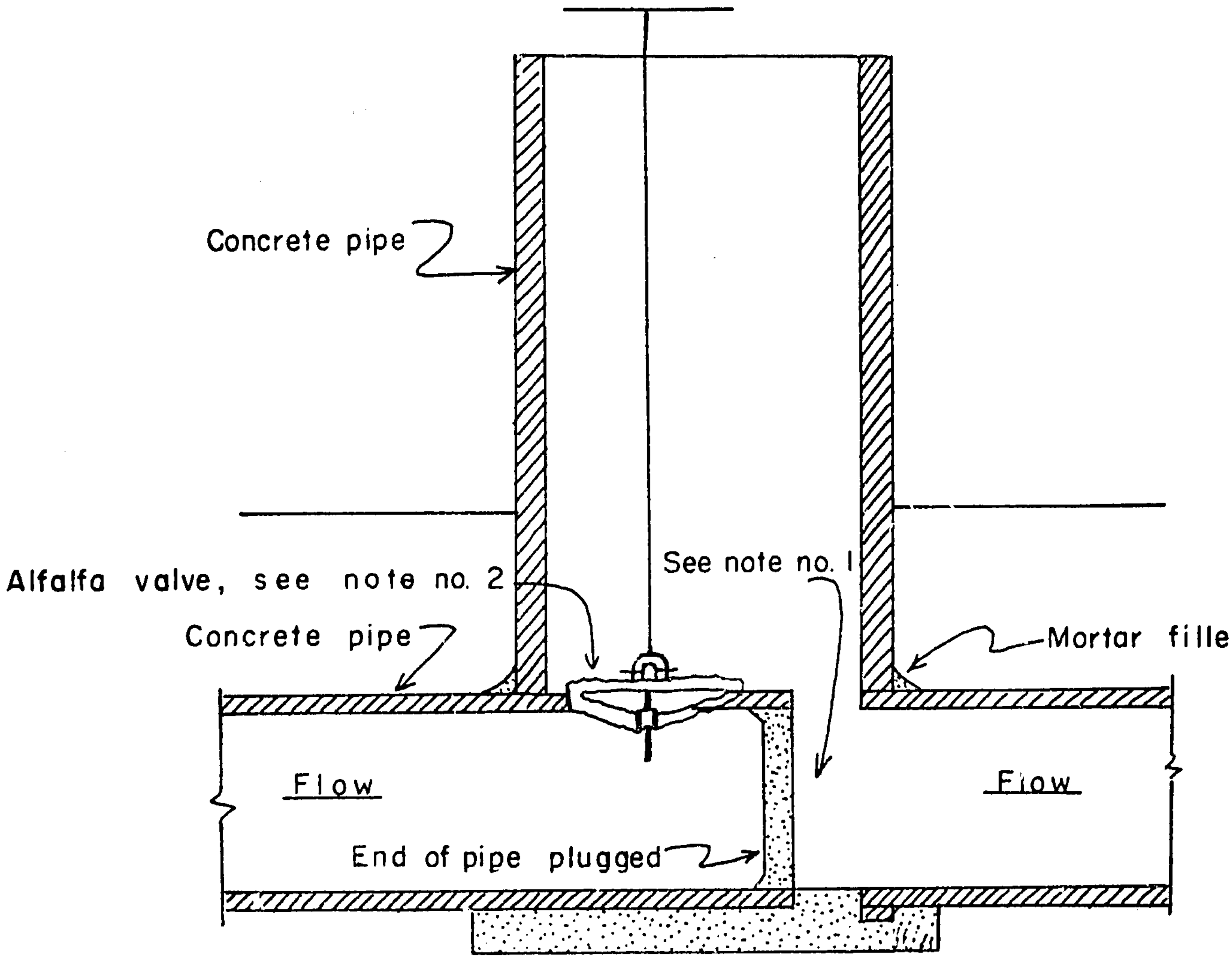
Max. Q	D	Concrete Base					
		H-10' or less		H = more than 10		Reinforcing steel	
c.f.s.	Inches	t	cu. yd.	t	cu. yd.	Size	Length
1.22	30	6"	.23	8"	.30	3/8"	21'
1.49	33	8"	.35	8"	.35	3/8"	22'
1.77	36	8"	.39	8"	.39	3/8"	23'
2.40	42	8"	.50	8"	.50	3/8"	30'
3.14	48	8"	.62	8"	.62	1/2"	46'
3.98	54	8"	.76	8"	.76	1/2"	53'
4.90	60	8"	.91	8"	.91	1/2"	71'

CONCRETE PIPE SAND TRAP FOR CONCRETE PIPE LINE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

1-64 | 5,0-19,000.28-1

Figure 37

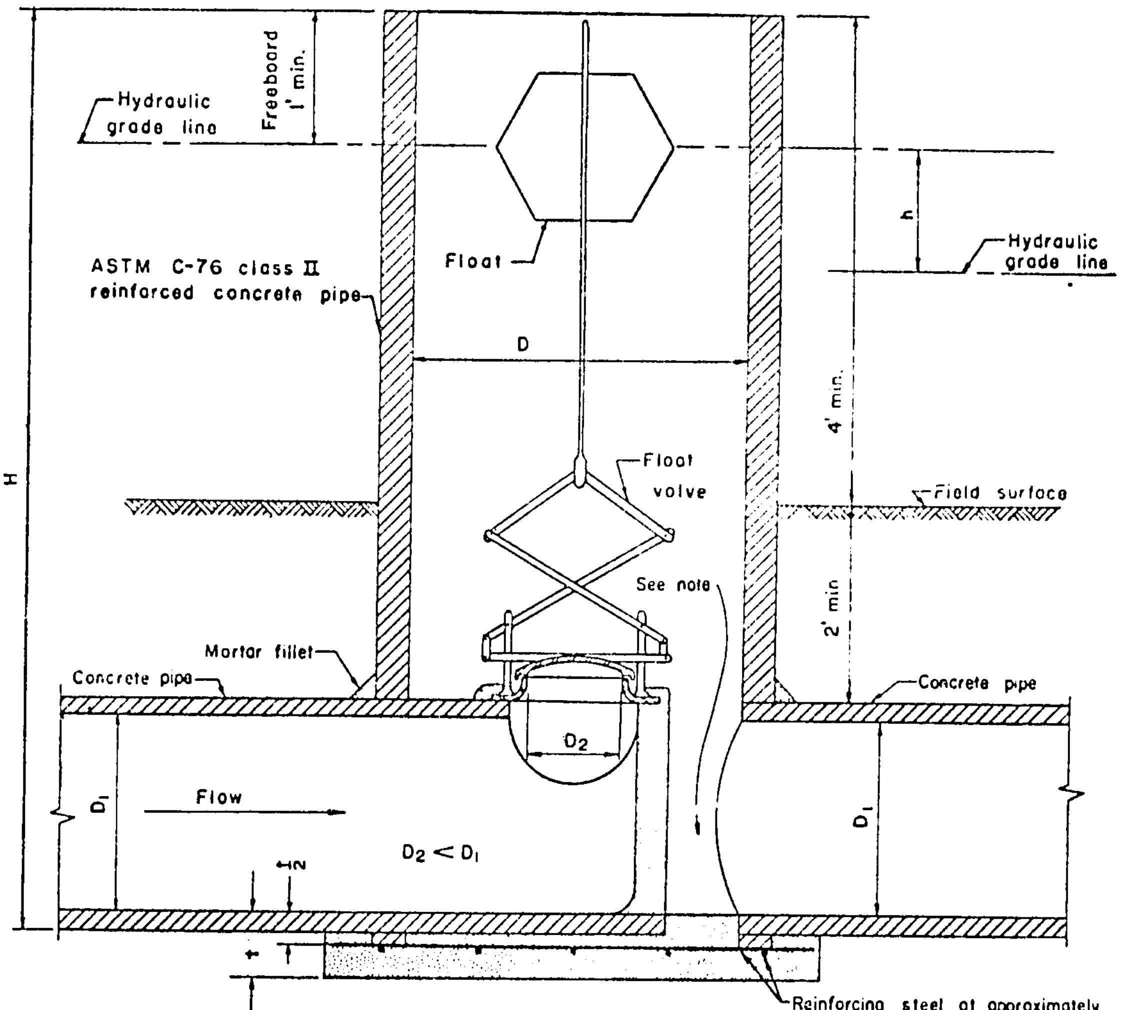


Note No. 1. Provide an inlet area equal to or greater than area of valve :

Note No. 2. Valve should be large enough to carry flow in pipeline.

GATE STAND USING ALFALFA VALVE

Figure 38



℄ CROSS SECTION

Note: 1. Provide an outlet area equal to or greater than the area of the valve (whose diameter is D_2).

D_2 Nominal Inches	Design Flow Capacity* and Stand Diameter							
	h = 0.5'		h = 1.0'		h = 2.0'		h = 5.0'	
	Capacity c.f.s.	D in.	Capacity c.f.s.	D in.	Capacity c.f.s.	D in.	Capacity c.f.s.	D in.
4	0.32	30	0.45	30	0.64	30	1.01	30
5	0.50	30	0.71	30	1.00	30	1.58	30
8	1.28	30	1.81	30	2.56	30	405	30
12	2.87	30	4.07	30	5.75	33	910	42
16	5.12	33	7.24	42	10.23	48	16.17	60

* Valves for single disk (open) type

NOMENCLATURE

D – Diameter of concrete stand pipe

D_1 – Diameter of underground concrete pipe

D_2 – Nominal diameter of float valve

H – Height of stand pipe

t – Thickness of concrete base

h – Difference in head (hydraulic grade lines) between inlet and outlet pipe

TABLE OF QUANTITIES

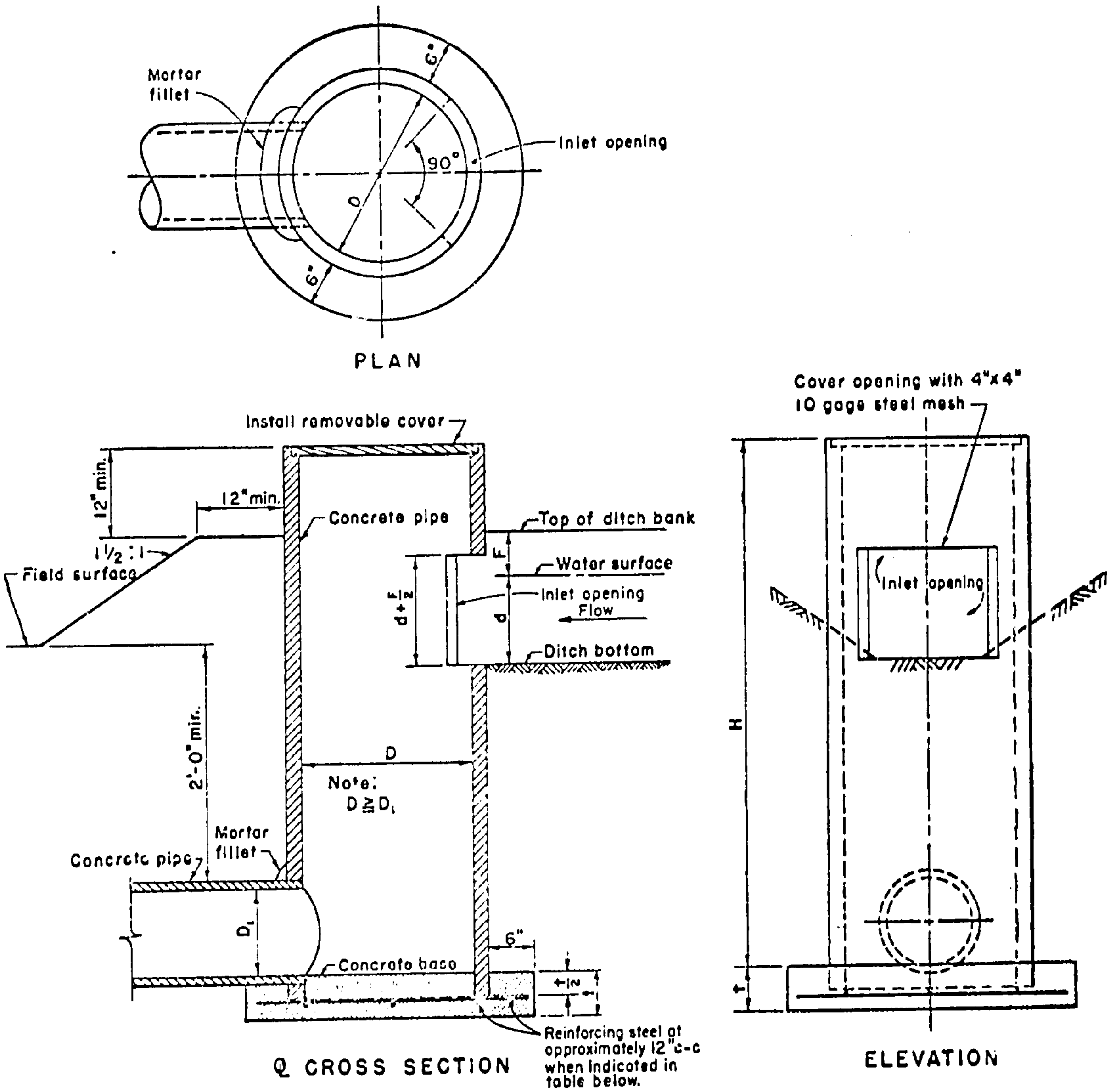
D Inches	Concrete base					
	H = 10' or less		H = more than 10'		Rein. steel	
	t	cu. yd.	t	cu. yd.	size	length
30	6"	0.23	8"	0.30	[illegible]	21'
33	8"	0.35	8"	0.35	[illegible]	22'
42	8"	0.50	8"	0.50	[illegible]	36'
48	8"	0.62	8"	0.62	[illegible]	46'
60	8"	0.91	8"	0.91	[illegible]	71'

NON-BALANCED FLOAT VALVE STANDS for CONCRETE PIPE LINES

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

1-64 5,0-19000-32-1

Figure 39



NOMENCLATURE

d = Depth of water in ditch
F = Freeboard in ditch
D = Diameter of vertical pipe
D_1 = Diameter of underground pipe
t = Thickness of concrete base
H = Height of vertical pipe above top of concrete base
Q = Discharge through structure in c.f.s.

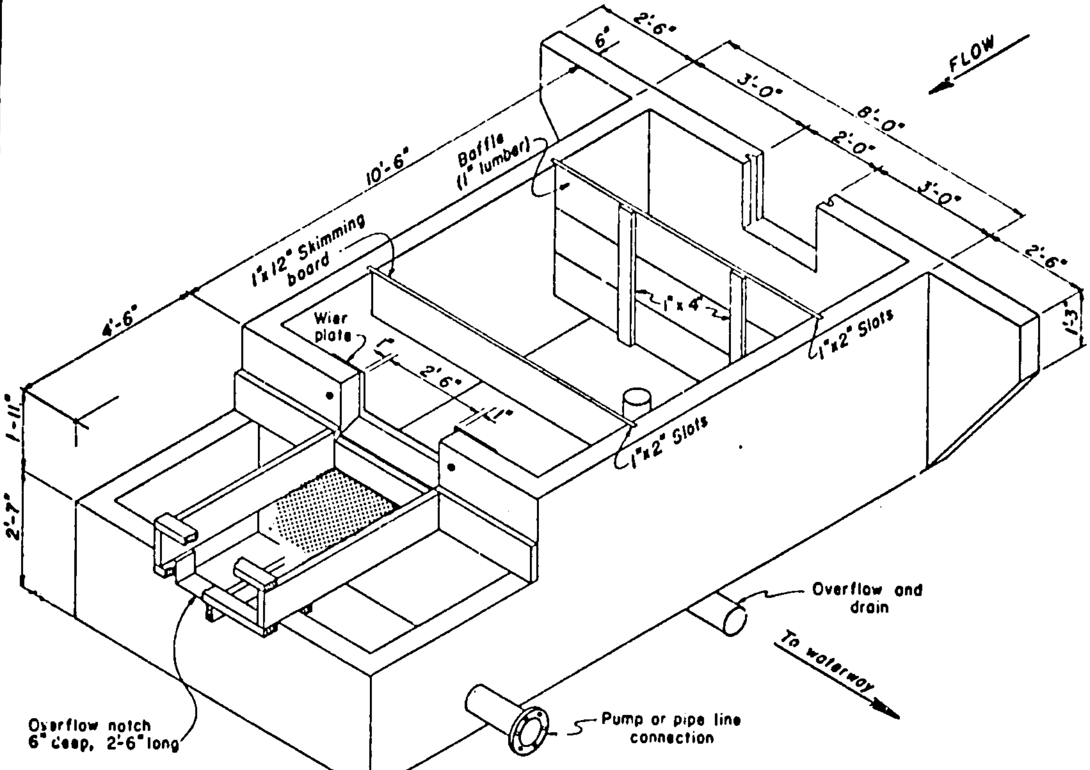
Max. Q	D	A.S.T.M. Spec.		Concrete Base					
				H=10' or less		H=more than 10'		Reinforcing steel	
c. f. s.	inches	No.	Type	t	Cu.yd.	t	Cu.yd.	Size	Length
0.79	12	C-118	Concrete Irrigation Pipe	4"	0.05	6"	0.07	—	—
1.07	14			4"	0.05	6"	0.08	—	—
1.23	15			4"	0.06	6"	0.09	—	—
1.40	16			4"	0.06	6"	0.10	—	—
1.77	18			4"	0.07	6"	0.11	—	—
2.18	20			6"	0.13	8"	0.17	—	—
2.41	21			6"	0.14	8"	0.18	—	—
3.14	24			6"	0.16	8"	0.22	—	—
3.98	27	C-76	Class II Reinforced Concrete Pipe	6"	0.20	8"	0.26	3/8"	19'
4.91	30			6"	0.23	8"	0.30	3/8"	21'
5.94	33			8"	0.35	8"	0.35	3/8"	22'
7.07	36			8"	0.39	8"	0.39	3/8"	23'
9.62	42			8"	0.50	8"	0.50	3/8"	38'
12.57	48			8"	0.62	8"	0.62	1/2"	46'

GRAVITY INLET FOR CONCRETE PIPE

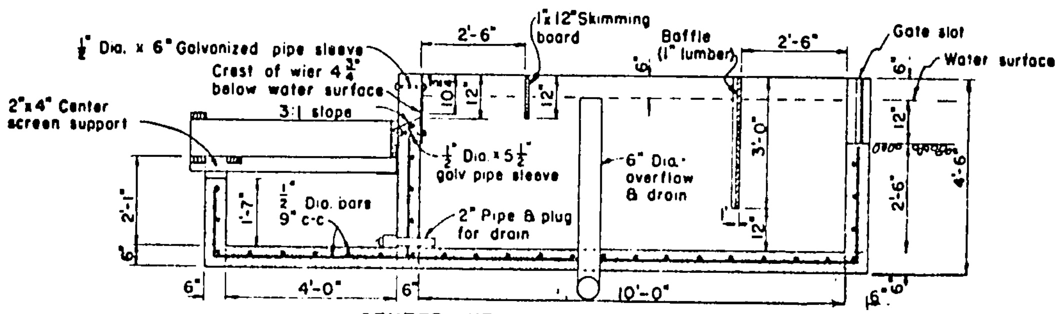
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

1-64 | 5,0-19000-23-1

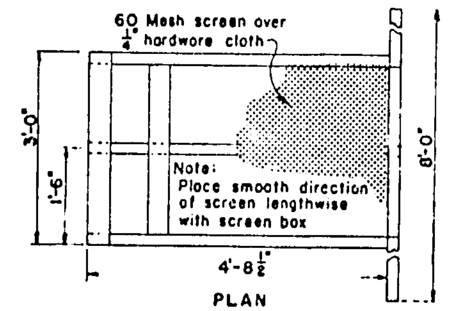
Figure 40



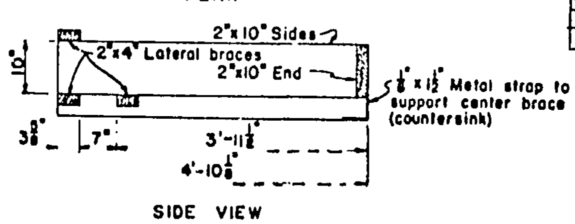
ISOMETRIC



CENTERLINE CROSS SECTION



PLAN



SIDE VIEW

DETAIL OF TRASH SCREEN

TABLE OF QUANTITIES

ITEM	UNIT	QUANTITY
CONCRETE	CU. YDS.	5.7
REINFORCING STEEL	LIN. FT.	883
60 MESH COPPER SCREEN	SQ. FT.	14
1/4" HARDWARE CLOTH	SQ. FT.	14
LUMBER	BD. FT.	71
1/2" GALVANIZED PIPE SLEEVES, 6" LONG	EACH	2
1/2" GALVANIZED PIPE SLEEVES, 5 1/2" LONG	EACH	3
3/8" DIA. GALVANIZED BOLTS, 6 1/2" LONG	EACH	2
3/8" DIA. GALVANIZED BOLTS, 6" LONG	EACH	3
2" DIA. PIPE, 8" LONG	EACH	1
2" PIPE COUPLING	EACH	1
2" PIPE PLUG	EACH	1
6" DIA. PIPE, 3'-6" LONG	EACH	2
6" PIPE ELBOW	EACH	1
1/8" WEIR PLATE	EACH	1
1/8" X 1 1/2" X 12" METAL STRAP	EACH	1

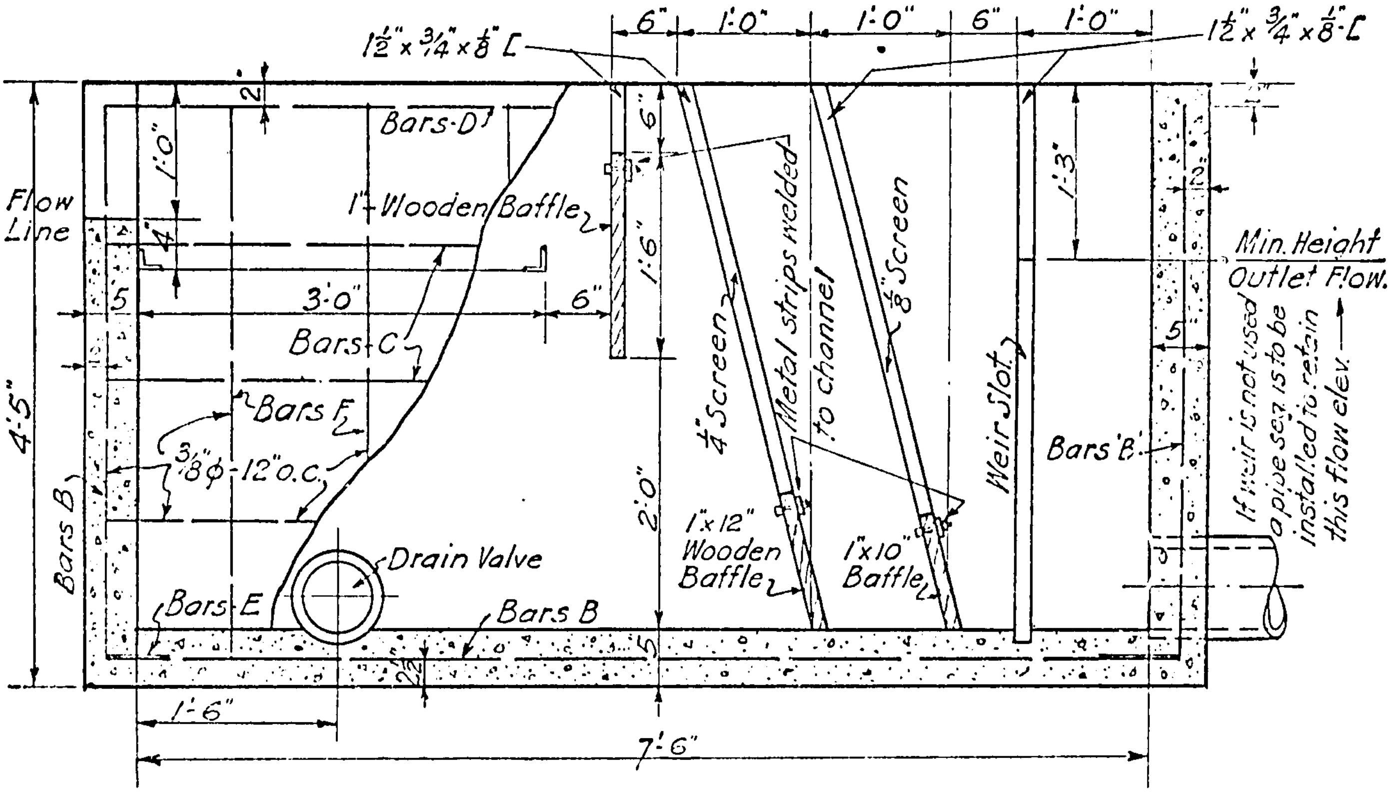
Capacity up to C.fs.

IRRIGATION WATER DESILTING BOX AND TRASH SCREEN

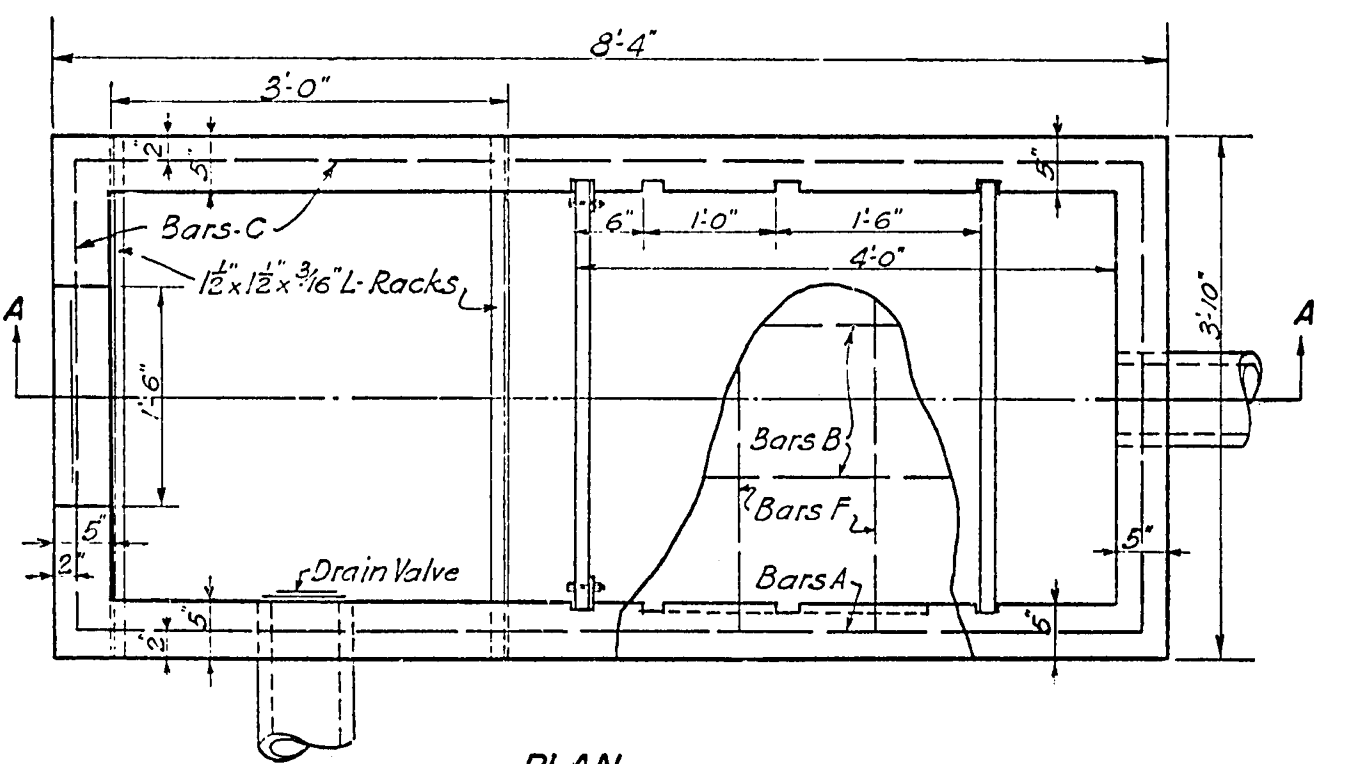
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

1-64 | 5,0-19,000 20-1

Figure 41



SECTION -AA

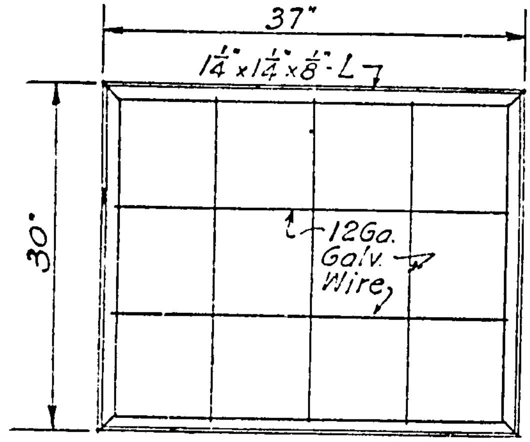


PLAN

SAND TRAP

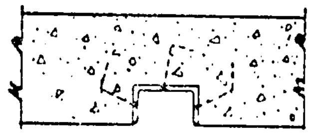
This type of Trap is preferable to Drwg. 7-ID-30a. due to lessened danger of clogging

NOTES:- Concrete in floor slab is to be placed against undisturbed earth
Concrete is to be 2000 lb. concrete maximum size aggregate 1½"
For control and placing of concrete, structure excavation and backfill see Standard Specifications.

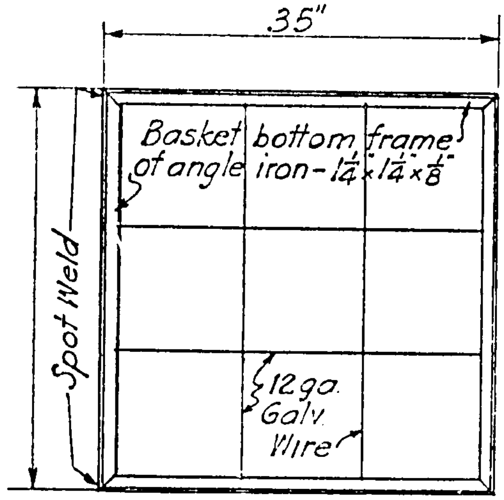


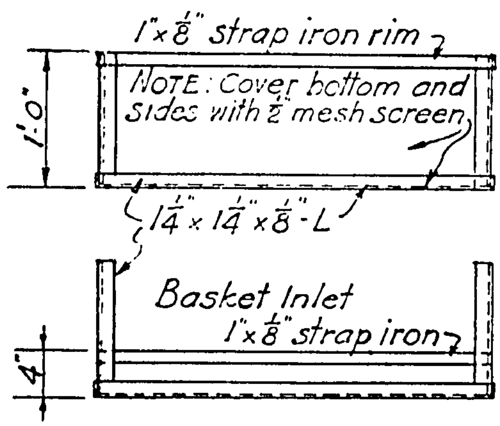
SCREEN FRAME DETAIL

Screen frame for ¼" & ⅛" mesh screens strung with 12 ga. wire. Cut screens to fit inside of frames.



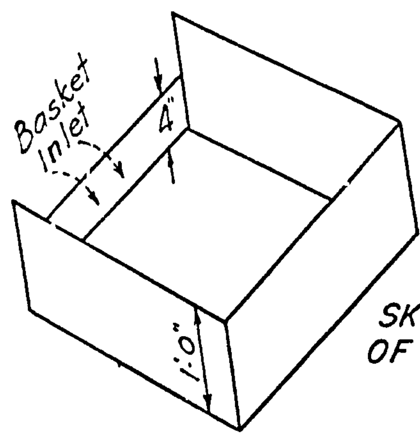
Reinforce slot edges with ch. iron and anchor with nails in concrete





BASKET DETAILS

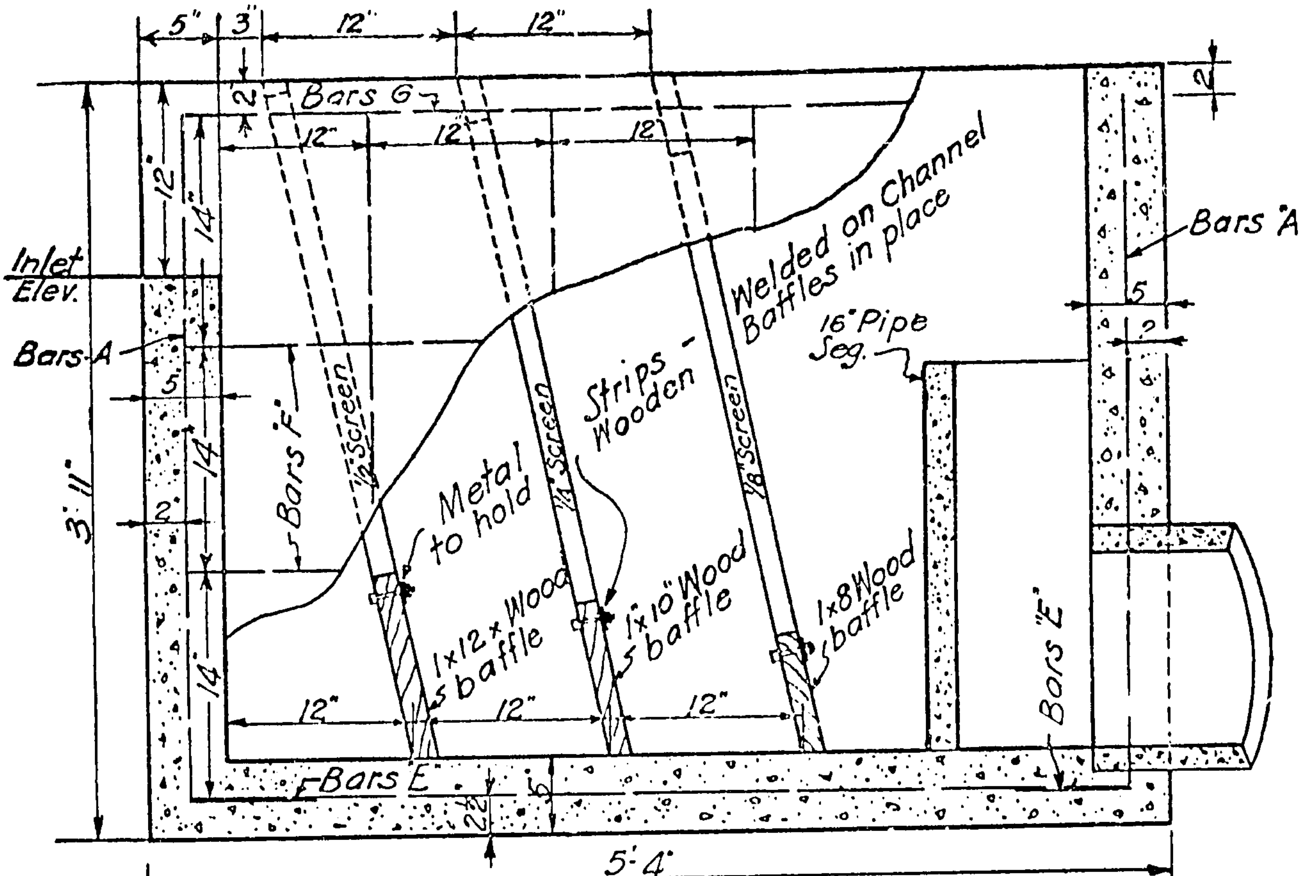
MATERIAL LIST						
NOTE:- All Reinforcing Steel to be ⅜" ϕ Deformed Bars						
TYPE	LOCATION	BENDING DIAGRAM			PCS	LENGTH
A	Floor & Ends	4'-1"	8'-0"	3'-1"	2	16'-2"
B	" "	4'-1"	8'-0"	4'-1"	2	15'-2"
C	Ends & Sides	2'-4"	8'-0"	2'-4"	6	12'-8"
D	" "	10"	8'-0"	2'-4"	2	11'-2"
E	Lower Corners	7"	3'-6"	7"	2	4'-8"
F	Floor & Sides	4'-1"	3'-6"	4'-1"	7	11'-8"
Total amount of steel = 252 lin. ft.						
" " " concrete = 2 cu. yds.						
1¼" x 1¼" x ⅛" L's = 38 lin. ft.						
1½" x 1½" x 3/16" L's = 8 " "						
1" x ⅛" Strap Iron = 12 " "						
1½" x ¾" x ⅛" Channel = 16 " "						
2" x 1" x 3/16" " = 17 " "						
Screens to fit Details.						



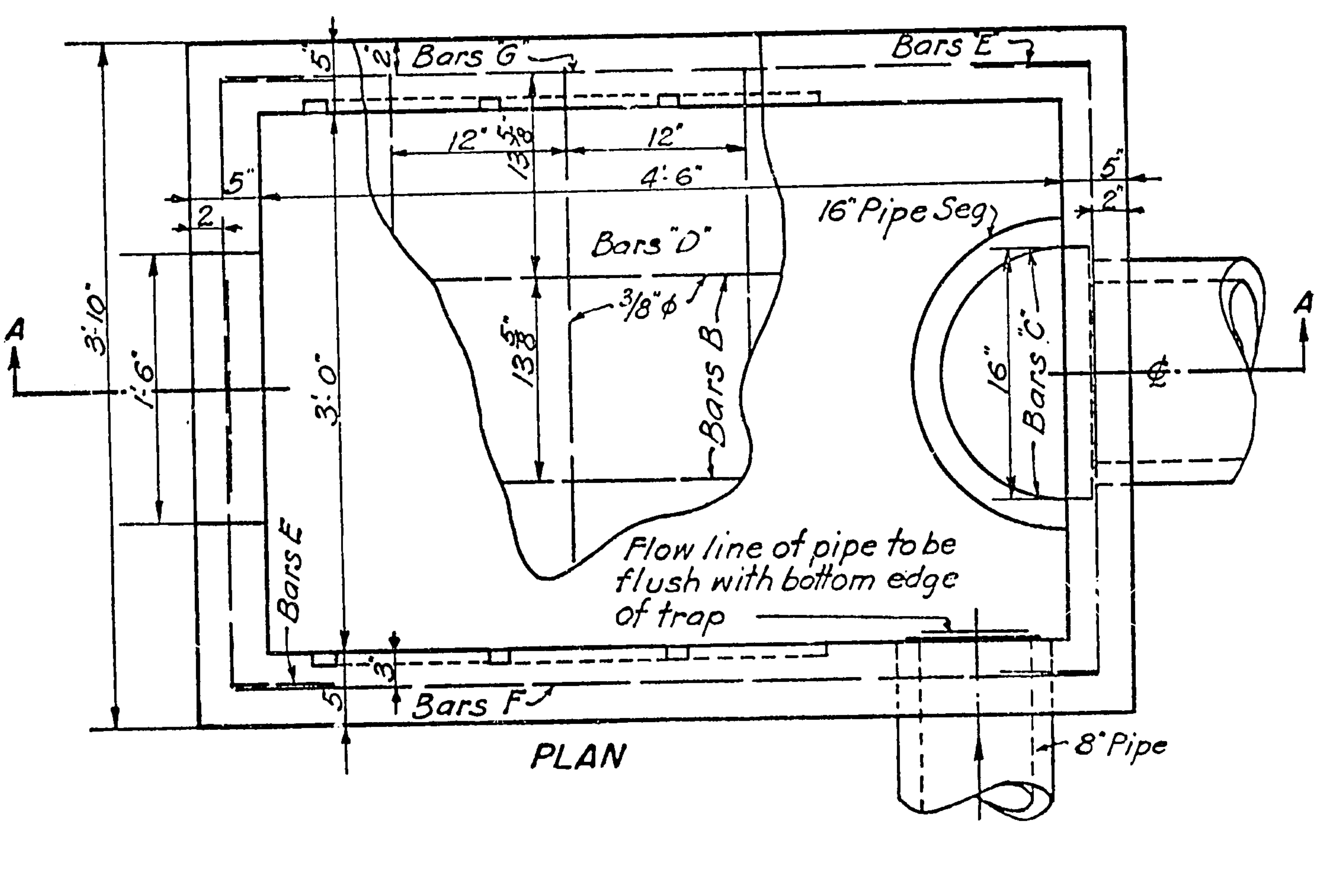
SKETCH OF BASKET

7-L-Eng. 67

Figure 42



SECTION-AA'

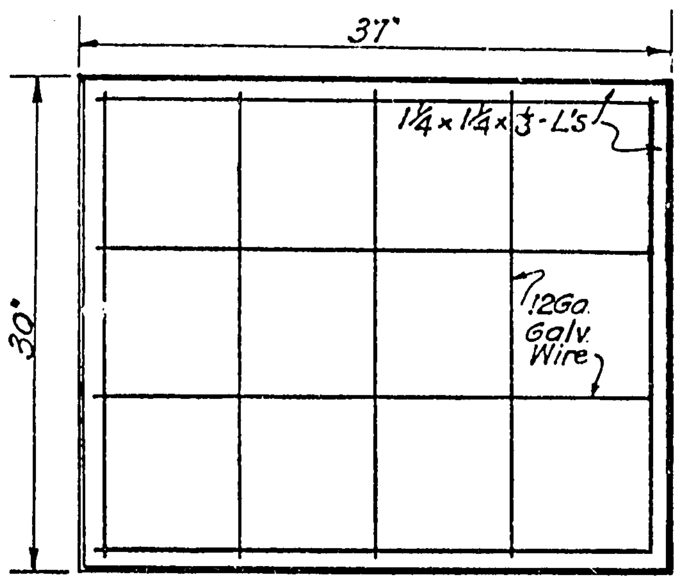


PLAN

MATERIAL LIST					
TYPE	LOCATION	BENDING DIAGRAM	PCS	SIZE	LENGTH
A	Walls	3'-6" ⌊ 5'-0" ⌋ 3'-6"	2	⅜" ø	12'-0"
B	Floor	2'-6" ⌊ 5'-0"	2	"	7'-6"
C	Walls	6" ⌋ [illegible]-6"	2	"	4'-0"
D	Floor	3'-6" ⌊ 3'-[illegible] ⌋ 3'-6"	4	"	10'-6"
E	Floor	6" ⌊ 3'-6" ⌋ 6"	2	"	4'-6"
F	Walls	2'-0" ⌊ 5'-0" ⌋ 2'-0"	4	"	9'-0"
G	Walls	10" ⌊ 5'-0" ⌋ 2'-0"	2	"	7'-10"
Total amount of steel = 150 lin. ft.					
" " " concrete = 1.2 cu. yds.					
1¼" x 1¼" x ⅛" L = 42.0 ft.					
1½" x ¾" x ⅛" Channel = 21.0 ft.					

NOTES

Concrete in floor slab to be placed against undisturbed earth. Concrete to be 2000 lb. concrete maximum size of aggregate 1½ in. For control and placing of concrete, structure excavation and backfill see standard specifications.

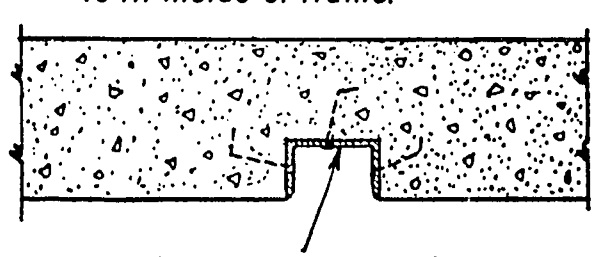


SCREEN FRAME DETAIL

Screen frames for mesh screens strung with 12 ga. wire, cut screens to fit inside of frame.

SAND TRAP

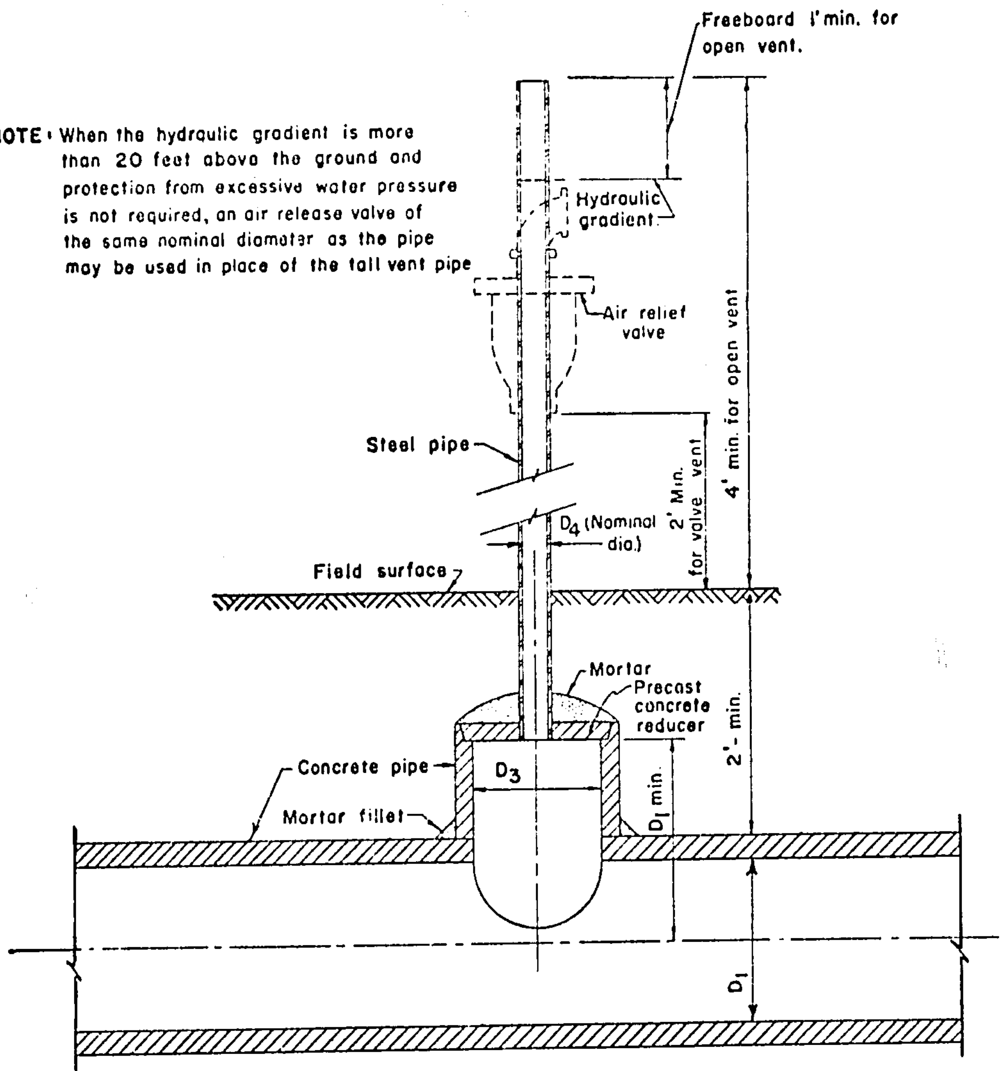
This trap is applicable where available head is limited. Make the baffles of variable height to lessen danger of clogging



Reinforce slot edges with Channel Iron and anchor with nails in concrete

Figure 43

NOTE: When the hydraulic gradient is more than 20 feet above the ground and protection from excessive water pressure is not required, an air release valve of the same nominal diameter as the pipe may be used in place of the tall vent pipe



℄ CROSS SECTION

D_1 Inches	D_3 Min. Inches	D_4 Min. Nominal Dia. Inches
8	6	2
10	8	2
12	10	2
14	10	2
15	12	2
16	12	2 1/2
18	14	2 1/2
20	16	3
21	16	3
24	18	3 1/2

NOMENCLATURE

D_1- Diameter of underground concrete pipe

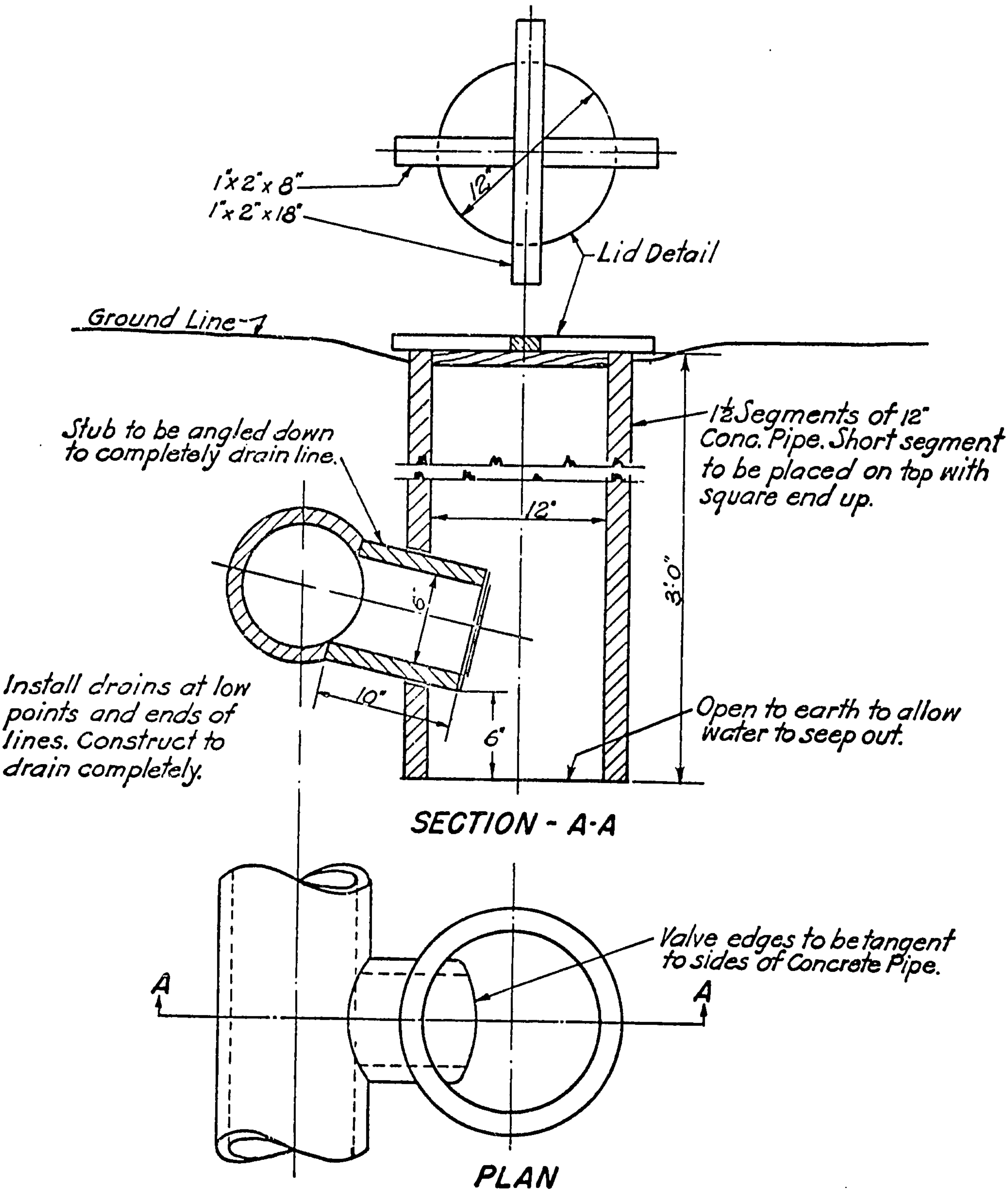
D_3-Diameter of concrete vent pipe

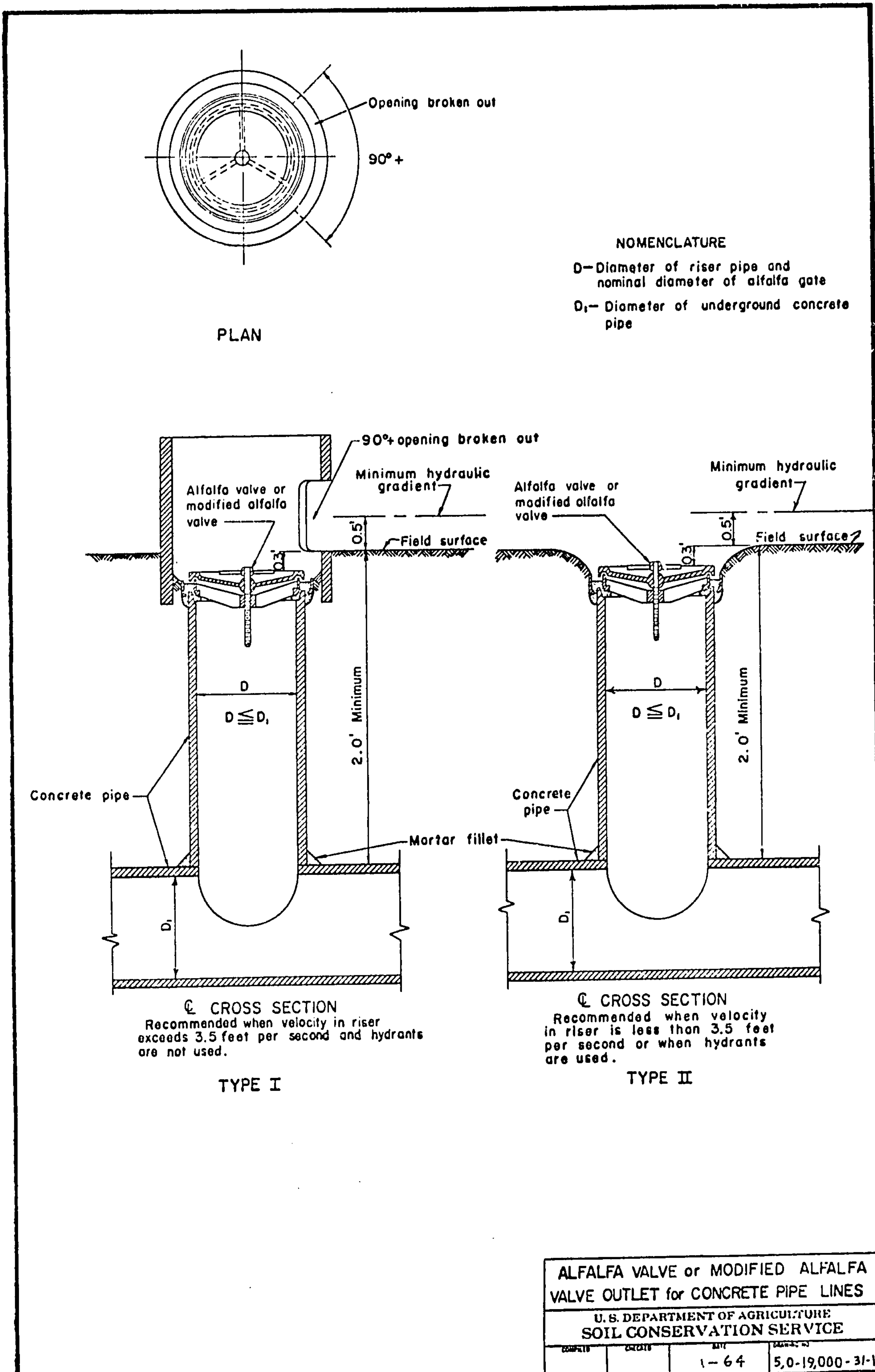
D_4-Diameter (nominal) of steel vent pipe

VENT FOR CONCRETE PIPE LINES			
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE			
		1-64	5,0-19,000-33-1

Figure 44

DRAIN VALVE FOR CONCRETE PIPE





Opening broken out
90°+
PLAN
NOMENCLATURE
D—Diameter of riser pipe and nominal diameter of alfalfa gate
D₁— Diameter of underground concrete pipe
90°+ opening broken out
Minimum hydraulic gradient
Alfalfa valve or modified alfalfa valve
0.5'
0.3'
Field surface
D
D ≦ D₁
2.0' Minimum
Concrete pipe
Mortar fillet
D₁
℄ CROSS SECTION
Recommended when velocity in riser exceeds 3.5 feet per second and hydrants are not used.
TYPE I
Recommended when velocity in riser is less than 3.5 feet per second or when hydrants are used.
TYPE II
ALFALFA VALVE or MODIFIED ALFALFA VALVE OUTLET for CONCRETE PIPE LINES
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
1-64
5,0-19,000-31-1

Figure 46

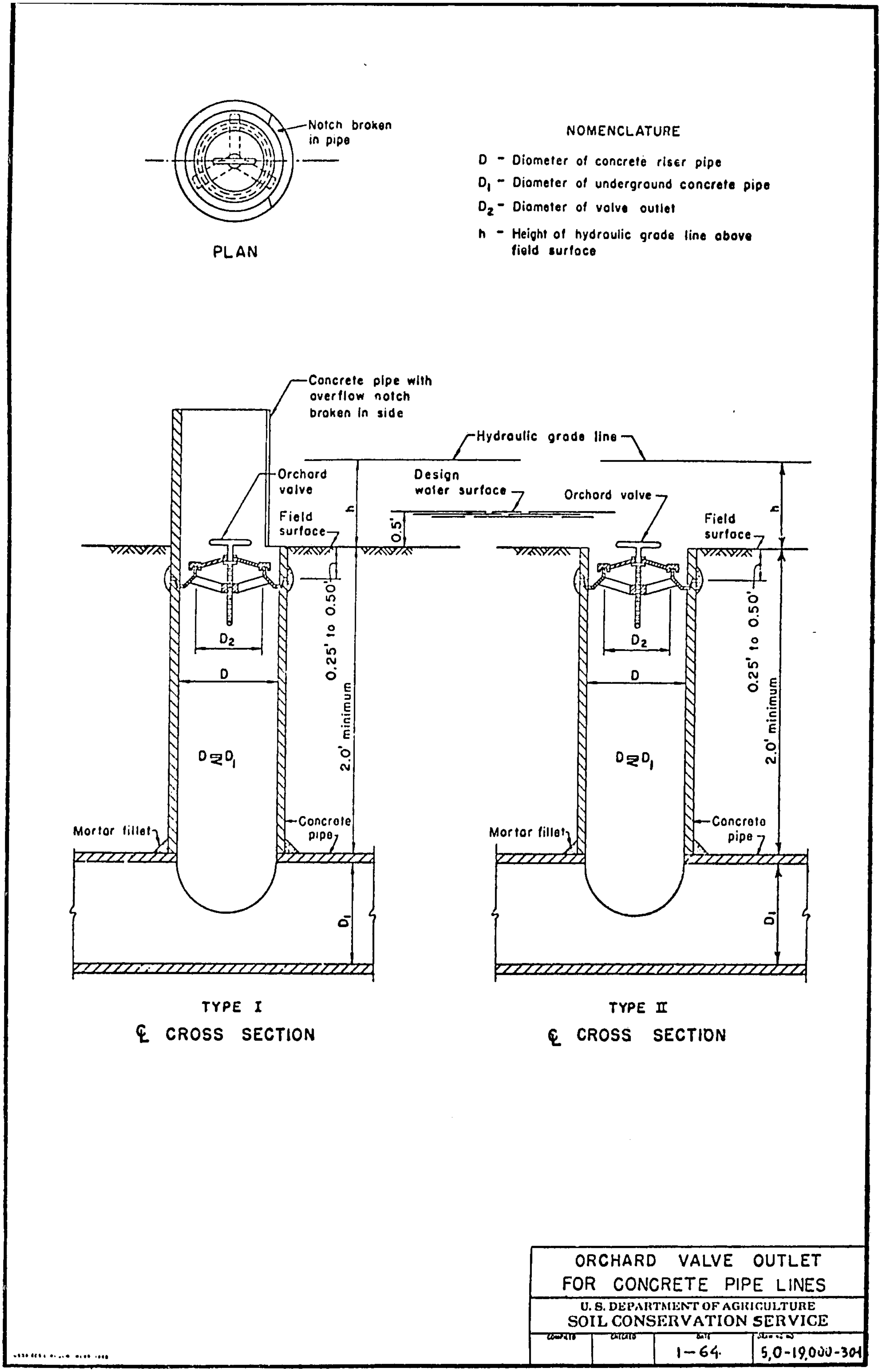

Notch broken in pipe
PLAN
NOMENCLATURE
D - Diameter of concrete riser pipe
D1 - Diameter of underground concrete pipe
D2 - Diameter of valve outlet
h - Height of hydraulic grade line above field surface
Concrete pipe with overflow notch broken in side
Hydraulic grade line
Orchard valve
Design water surface
Orchard valve
Field surface
Field surface
0.5'
h
h
0.25' to 0.50'
0.25' to 0.50'
2.0' minimum
2.0' minimum
D2
D2
D
D
D ≧ D1
D ≧ D1
Mortar fillet
Concrete pipe
Mortar fillet
Concrete pipe
D1
D1
TYPE I
℄ CROSS SECTION
TYPE II
℄ CROSS SECTION
ORCHARD VALVE OUTLET
FOR CONCRETE PIPE LINES
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
1-64
5,0-19,000-301

Figure 47

Standard Drwg. 7-ID-26b
Eng. Divn. SCS. Region 7

DISTRIBUTING STAND FOR PRESSURE SYSTEM OPEN POT OUTET WITH ORCHARD VALVE

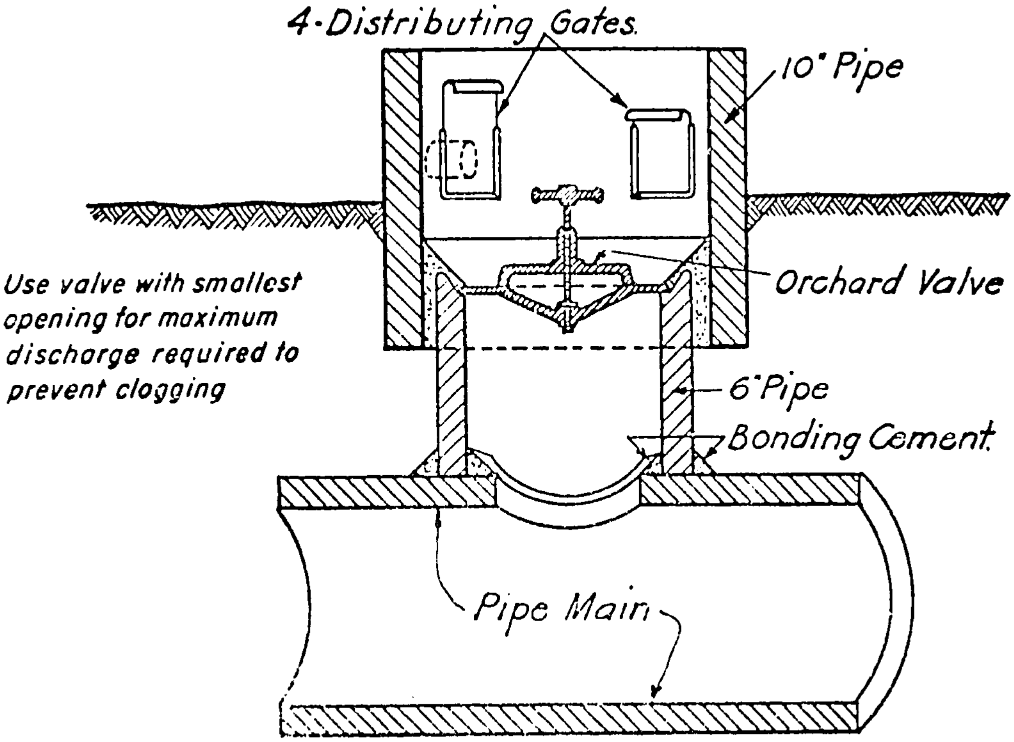
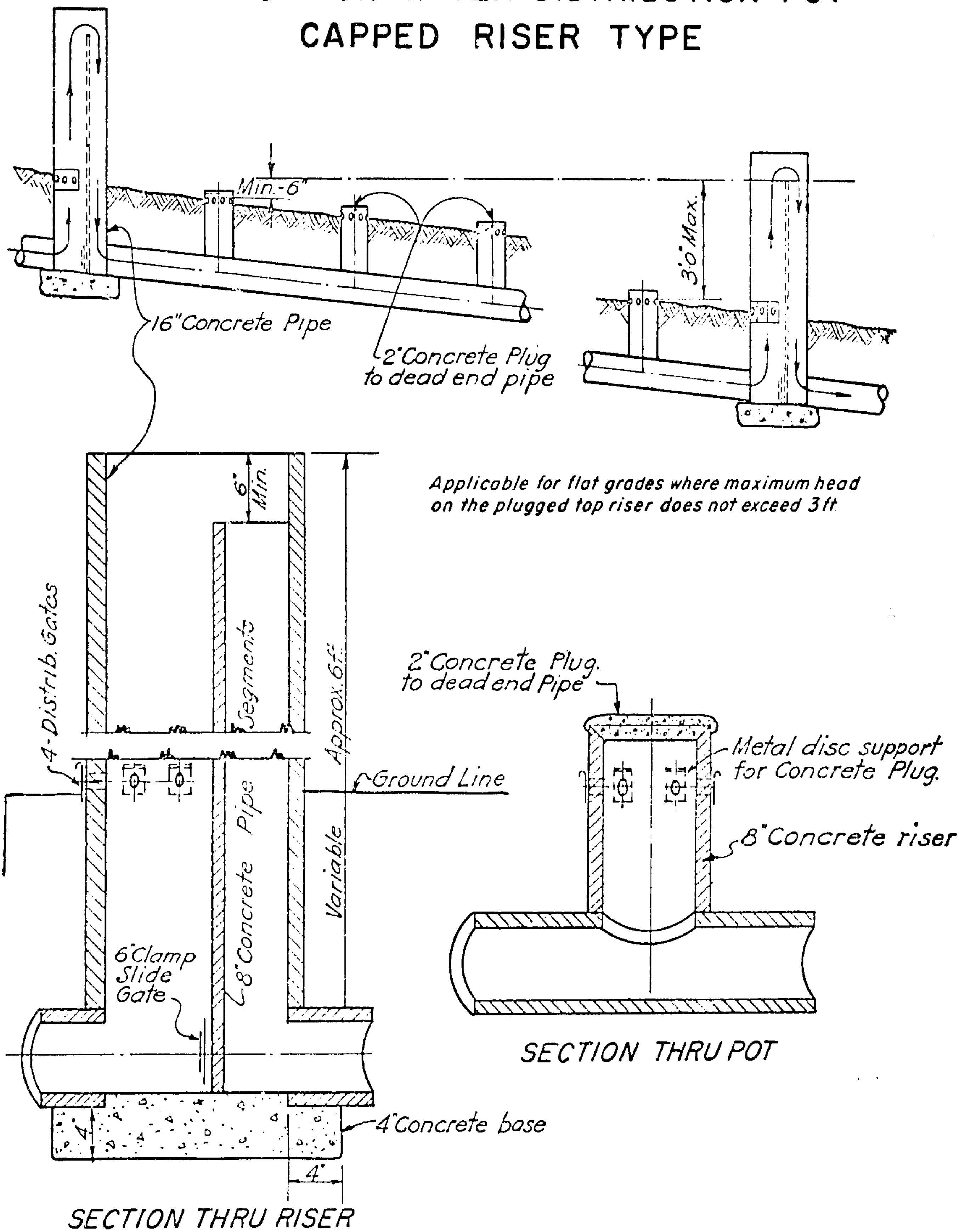


Figure 48

IRRIGATION WATER DISTRIBUTION POT
CAPPED RISER TYPE



Applicable for flat grades where maximum head on the plugged top riser does not exceed 3 ft.

7-L-Eng. 63

Figure 49

CHAPTER 6

Construction Guide for Concrete Irrigation Pipelines

This section covers the installation of concrete pipe only. Pipelines should be constructed in accordance with plans and design with necessary changes being made before beginning construction.

GRADE AND ALIGNMENT

Pipelines should be straight and of uniform gradient from reach to reach or between stands or anchors. This can be controlled by proper excavation of the trench. The alignment and grade for the bottom of the trench should be properly established prior to the excavation of the trench.

EXCAVATION

Trenches should be reasonably straight with bottom reasonably free of undulations and humps. To facilitate economical pipe laying, all trenches should be excavated with vertical sides and a well graded bottom. All excavated material should be deposited on one side of the side of the trench and the pipe placed on the other side.

DIMENSIONS

All pipe should be placed deep enough below the land surface to protect it from hazards imposed by traffic crossings, farm operations, freezing temperatures, or soil cracking. The minimum depth of cover should be 457.2 mm (18 inches) for pipe sizes up to and including 304.8 mm (12 inches) in diameter and for pipelines greater than 304.8 mm (12 inches), the minimum depth of cover should be 609.6 mm (24 inches) in cultivated fields, in loams and coarser textured soils. In heavy soils such as clay the depth of cover should be increased an additional 152.4 mm (six inches), Deeper trenches may be necessary. This requirement should be governed by the usual texture of the soil horizon at the pipe depth rather than by the texture of the surface soil. A lesser depth of cover can be used for rocky area or other local conditions.

The width of trench should be sufficient to permit laying of pipe correctly and for proper bording or finishing of the joints. There should be a minimum clearance of 150 mm (six inches from outside the pipe to the sides of the trench for pipe up to and including 381.0 mm (15 inches) in diameter, and a clearance of from 203.2 to 304.8 mm (eight to 12 inches) on each side for larger pipe.

FOUNDATIONS AND TRENCH BOTTOM

Foundations for pipelines should be firm but should yield slightly and uniformly when pipe is bedded to establish line and grade.

TRENCH IN ROCK OR BOULDERS

If the trench is excavated in rock, boulders, or other hard material the bottom of the trench should be excavated a minimum of 304.8 mm (12 inches) below grade and the trench backfilled with suitable material (sand or similar selected granular material) to the proper grade.

Any filling of this nature should be tamped and compacted to produce a firm foundation.

TRENCH BOTTOM IN UNSTABLE MATERIAL

Where a firm foundation is not encountered, due to soft, spongy or other similarly unsuitable material, all such unstable material under the pipe and for a width of not less than one diameter on each side of the pipe should be removed, and the space backfiled with suitable material (such as coarse sand or fine gravel), properly compacted to provide adequate support for the pipe.

TRENCH IN CLAY OR EXPANSIVE SOILS

Where trenches are excavated in clay soils or those that show evidence of shrinking or swelling, the trench should be excavated 101.6 to 152.4 mm (four to six inches) below grade and brought up to grade with a compacted layer of loam or coarser textured soil or selected granular material. In all clay or expansive soils the pipe should be deep enough so that soil mass surrounding it will not be subject to changes of moisture and temperature.

SUBGRADE AND BEDDING

The bottom of the trench should be graded and prepared to provide a firm and uniform bearing throughout the entire length of pipe. The bottom of the trench should be shaped to fit the lower part of the conduit exterior for a width of at least 50% of the external diameter of the conduit, "Ordinary Bedding" (Load factor = 1.5). All boulders and stones larger than 24.4 mm (inch) should be removed from the subgrade to a depth of 101.6 mm (four inches) below the bottom of the pipe.

WATER IN TRENCH

When water is encountered in the trench it should be removed by draining or pumping. Should water get into the trench before the pipe is laid, the laying of pipe should be postponed until the trench has dried sufficiently to provide a firm foundation for the pipe, or else the mud and softer material should be removed and grade reestablished by back-filling with suitable compacted material.

INSTALLATION OF PIPE IN NEW EMBANKMENT

When non-reinforced pipe it to be installed in new embankment, the embankment should be constructed to a height of 304.8 mm (12 inch) above the grade proposed for the top of the pipe, and for a distance on each side of the pipe of not less than five times the diameter of the pipe. Then the trench should be excavated and the pipe installed according to the recommendations in this section, except that when the pipe is to be installed on a steep slope or at a difficult location, the height of embankment to be constructed in advance of installing the pipe may be varied as directed by the engineer.

For reinforced concrete pipe, the embankment should be built to an elevation over the top of the pipe equal to the external diameter of the pipe, after which the trench can be excavated and the pipe installed.

PLACEMENT

At the time of laying, the prepared trench should be in a reasonably dry condition.

Necessary facilities should be provided for lowering and properly placing the sections of pipe in the trench without damage.

Immediately before placing each section of pipe in final position for jointing, the bedding for the pipe should be made by scraping away or tamping under the body of the pipe and not by wedging or blocking.

The interior of the pipe should be kept free from dirt and other foreign material as the pipe laying progresses, and left clean at the completion of the work. Any pipe which is not in true alignment or which shown any undue settlement after laying or is damaged, should be taken up and relaid.

No pipe should be laid which is cracked, checked, spalled, or damaged beyond specification tolerances, and all such sections of pipe should be permanently removed from the work site.

Curves are allowed with a maximum deflection of five degrees in mortar joints and a maximum of three degrees in rubber gasket pipe, with all joints receiving equal amount of deflection.

JOINTING

MORTAR JOINTS

The pipe along side the trench is tilted into the trench, groove or socket end up. The first section of pipe is laid to grade with the tongue or spigot end pointing in the direction to be followed by the pipe laying. 609.6 mm (24 inches) or larger pipe may be laid with the groove or socket end pointing in the direction to be followed by the pipe laying. After the pipe is set in place, a space should be scraped out, with a pipelayer's trowel, under and immediately in front of the end of each section laid. This space is to be filled with sufficient laying mortar under the tongue or spigot end of each section of pipe laid so that when the bonding mortar is placed, it will connect there with and make a continuous band of mortar around the joint.

In advance of jointing sections of pipe the ends of each section should be washed clean with a wet brush, and immediately prior to placing mortar and jointing the sections, the ends should be thoroughly wetted. The groove or socket end of the next section of pipe is wetted and filled with mortar. This section is then tipped over carefully so as not to dislodge the mortar and the two section of pipe firmly pressed together in such a manner that the groove or socket end of the pipe fits truly and snugly over the tongue or spigot end to which it is to be fitted and so that, mortar is squeezed out from the inner and outer surfaces. Care should be taken so that no mortar falls from the groove or socket end during the abutting operation. Because extruded mortar would reduce flow and increase friction, the inside of the pipe should be wiped smooth of any surplus mortar. In pipe too small for a man to work inside, wiping may be done by dragging a swab or long-handled brush on the inside. This is done after the pipe is placed true to line and grade because any movement there after may cause the joint to leak.

After jointing the pipe, external bands of mortar are placed around all pipe joints. Several sections of pipe should be jointed before banding starts. External bands should never be more than five lengths behind jointing operations.

RUBBER GASKET JOINTS

The first section of pipe laid should be firmly bedded in the center of the trench to establish line and grade with the socket end pointing in the direction to be followed by the pipe laying. Gaskets should be affixed to the pipe not more than 27 hours prior to the installation of the pipe and any loose or improperly affixed gaskets should be removed and replaced to the satisfaction of the engineer. Just before installation, the gasket and the socket end of the pipe are coated with a special gasket soap (usually made from flaxseed) to lubricate the joint for easy assembly and to help seat it. The pipe should be aligned with the previously installed pipe, and shoved together. If, while making the joint, the gasket becomes loose and can be seen through the exterior joint recess when the joint is pulled up to within 25.4 mm (one inch) or closure, the pipe should be removed and the joint remade to the satisfaction of the engineer.

OAKUM (HEMP OR JUTE FIBER) AND MORTAR JOINTS

A closely twisted gasket of Oakum, of the diameter required to support the spigot of the pipe at the proper grade and to make the joint concentric, should be used, The joint packing should be in one piece of sufficient length to pass around the pipe and lap at the top. This gasket should thoroughly be saturated with neat cement grout. The socket of the pipe should be thoroughly cleaned with a wet brush and the gasket laid in the socket for the lower third of the circumference and covered with mortar. The spigot of the pipe should be thoroughly cleaned with a wet brush and inserted in the socket and carefully shoved in. A small amount of mortar should be inserted in the annular space for the upper two-thirds of the circumference. The gasket should be lapped at the top of the pipe and driven into the annular space with a caulking tool.

The remainder of the annular space should then be filled completely with mortar and beveled off at an angle of approximately 45° with the outside of the socket, The finishing of this joint should be at least five joints behind the laying operation.

EXTERNAL BANDS

Immediately in advance of placing external band mortar, the external surface of the pipe sections at the joint should be thoroughly cleaned and wetted to insure proper bonding of the band mortar with the pipe. Care should be exercised to make a union between the band and the mortar which was placed under the joint before the pipe sections were abutted. The band for tongue and groove pipe should not be less than 9 mm (3/8 inch) thick at the pipe joint and should be approximately 100 mm (four inches) wide, overlapping the abutting ends of the pipe sections approximately 45° with the outside edge of the socket.

The edges of the band should adhere to the pipe surface to prevent peeling and should be finished in a workmanlike manner.

LAYING AND BANDING MORTAR

The mortar for the joints should consist of not less than one part Portland cement to two parts of clean, well-graded sand that will pass a 2.36 mm (U.S. No. 8) sieve. The quantity of water in the mixture should be sufficient to produce a soft workable mortar but should in no case exceed 22.7 liters (six U.S. Gallons) per 0.028 cubic meter (one cubic foot) of cement. The consistency of laying mortar should be such as to adhere to the ends of the pipe while being laid and easily squeezed out of the joints when the pipe sections are pressed together. Banding mortar should be plastic and of such consistency that it will readily adhere to the pipe.

Mineral admixtures may be used, but not exceeding one of the following percentages by volume of cement : hydrated line, 5% ; fire clay, diatomaceous earth, or other suitable inert material, 10%.

All mortar should be used within thirty minutes after mixing with water.

JOINT CURING AND BACKFILLING

Openings in all concrete pipelines should be covered to prevent air circulation except when work is actually in progress. Such openings should be kept closed until the pipeline is to be filled with water. The following does not apply when rubber gaskets are used instead of mortar joints.

There should be an initial backfill of soil around the pipe and covering the pipe to a depth of at least 152.4 mm (six inches) for the full width of the trench and not more than seven sections behind the laying. Care should be taken in placing such earth around the pipe to avoid injury to the freshly applied bands.

Mortar joints should be protected from drying out. If the soil used in the initial backfill is not thoroughly moist, a suitable cover over the mortar should be used. This cover can be a layer of kraft paper. An alternate would be to use gunny bags which are kept moist.

If laying ceases for two hours or more, the initial backfill should be brought up to and cover the lasted completed joint. Moist soil provides the best method for curing joints.

Nothing prohibits the complete backfilling while mortar bands are still plastic as long as care is taken. In case complete backfilling is not done at this time, the completion should be delayed at least 20 hours. In placing the backfill the earth should be placed on each side of the line at the same time to avoid displacement or injury to the green mortar joints and bands.

It is desirable to backfill the lines as soon as practical to avoid shrinkage of the joints and bands. Where the backfill is to be flooded to expedite its consolidation, it is absolutely necessary to fill the pipe with water : otherwise, it may float.

Backfilling to a depth of at least 300 mm (one foot) over the crown of the pipe should be made, with moist earth, sand or fine gravel, or similar select granular material. All backfill material should be free from large stones or lumps organic matter, and other unsatisfactory materials.

Backfill should be placed in uniform layers and completely under pipe haunches. Each layer should be carefully and uniformly compacted or consolidated in such a manner so as to completerly fill the voids under the pipe haunches and around the pipe. Large quantities of backfill material should not be dropped on any pipeline until an initial cover of at least 600 mm (two feet) over the top of the pipe has been placed. Uncompacted fill should be mounded over the top of the trench to allow for settlement.

Where the cover over the pipeline will be less than specified, extra fill may be placed over the pipeline to provide the minimum depth of cover if the top width of fill is not less than 3.01 meters (ten feet) and the side slopes are not steeper than six to one.

In expansive or clay soils a loam or coarser textured soil or selected granular material should be used for backfill. This type of backfill should be placed up to at least half the diameter of the pipe. Water should not be turned into the pipeline until all backfilling is completed, and in no case within 24 hours of finishing the pipe joints. Maximum hydrostatic pressure should not be applied to the pipe within three days of finishing the pipe joints.

Openings in Pipelines

All openings cut into concrete pipe for outlets and connections should be full size, within 25.4 mm (one inch) of the inside diameter of the connecting pipe or fittings. Such openings should be avoided. All connections should be cut to fit closely and should be strongly cemented to the pipe with banding mortar, and where possible both the inside and outside of the joint should be brushed smooth. In all cases pipe should be clean and wet before mortar is applied. No pipe spoils, trash, or other obstructions should be left in the pipeline.

CURVES

Curves should not be built into irrigation pipelines. All turns and changes of direction should be made by means of angles sufficiently reinforced or braced to withstand the end thrust of the pipeline due to its expansion and all other stresses due to the change of direction. Whereas a turn exceeds 45° two such angles may be installed, or a section of larger pipe placed vertically may be used as a turn structure. Pipe for use on curves should have one or both ends beveled to fit snugly.

ANCHORS

Anchors should be constructed of either :

a. Concrete poured to fill the space between the pipe and the undisturbed earth at the side of the trench on the outside bends.

b. Soil cement with at least one part of cement to 12 parts of soil of sandy loam or coarser texture, similarly placed and thoroughly tamped.

The anchors should be to the full height of the outside diameter of the pipe and should have a minimum thickness of 150 mm (six inches) and a length in meters (feet) normal to the direction of thrust equal to :

(98 HD Sin $\frac{1}{2}$a)/B-British Units

(1595 HD Sin $\frac{1}{2}$a)/B-Metric Units

where :

H=maximum working head in meters (feet) ;

D—inside diameter of the pipe in meters (feet) ;

B—the allowable passive pressure of the soil (pounds per square foot) ; and

a—the deflection angle of the pipe bend.

The pipe should be clean and wet when placing the anchor to provide a good bond between anchor and pipe. Where adequate soil tests are not available, the allowable passive soil pressure should be considered to be 8009.2 kilograms per cubic meter (500 pounds per square foot). All ends of rubber gasket jointed pipelines should be anchored.

When compacted backfill is used in lieu of an anchor it should be compacted to a density equal to that of the adjacent firm and undisturbed soil for a distance equal to the required anchor length, and for the full height of the pipe.

CONSTRUCTION OF VERTICAL CONCRETE STRUCTURES

All structures should be vertically true. The following details should be adhered to, where applicable :

B. CONNECTIONS TO PIPELINES:

Openings cut into stands for connections to pipelines should be slightly greater than the outside diameter of the connecting pipe. Such opening should be cut either before the structure is placed or after joint mortar has cured sufficiently to prevent damage. All connections should be strongly cemented together with laying mortar and should be clean and wet before the mortar is applied. All exterior joints of vertical structures, wherein irrigation pipe is used, should be bonded in accordance with the procedures suggested for pipelines. Both the inside and outside mortar faces should be brushed or trowled smooth, where possible. The same criteria should apply to the connecting of hydrants or stands on the top of an installed pipeline, except that the openings cut into the pipeline should be within 25.4 mm (one inch) of, but not greater than, the inside diameter of the riser or stand.

PIPE FOR STRUCTURES

All hydrant risers and all stands 600 mm (24 inches) or less in diameter may be constructed of plain concrete irrigation pipe. All stands of diameters greater than 600 mm (24 inches) should be constructed of reinforced concrete pipe or cast-in-or built-in-place.

PLACEMENT

All stands of diameters greater than the pipeline should be connected to and mortared into such stands immediately as they are being laid. Hydrant risers, and stands equal in diameter to the pipeline, or smaller in diameter should be installed after the pipeline has been placed.

BASES OF STANDS

The first section of pipe for stands should be placed on the base of concrete before initial set of that concrete, or the pipe can be placed first and the concrete poured and tamped in around the pipe. Concrete bases of stands should have a diameter at least 250 mm (ten inches) greater than the outside diameter of the stand should be at least 100 mm (four inches) thick for stands not over 450 mm (18 inches) inside diameter or over 3000 mm (ten feet) high above the base; at least 150 mm (six inches) thick for stands up to 750 mm (30 inches) inside diameter and not over 3.66 meters (12 feet) high above the base; and at least 200.0 mm (eight inches) thick for all other stands. After initial set and before final set of the concrete base, water to a depth of 100 to 150 mm (four to six inches) should be carefully poured into the stand, or it should be loosely covered with about 150 m i (six inches) of moist soil.

CAPPED VENT STANDS

The cap, adequately reinforced against internal pressure and any external loads, is mortared into the riser in such manner as to produce a watertight seal. The vent pipe should have a strong watertight connection to the cap, and should be adequately guyed, if necessary, to provide stability.

BANDS

Bands for vertical structures should have a thickness over the joint of ½ the wall thickness of the pipe, and be 100 mm (four inches) wide.

INSPECTION OF FINISHED JOINTS

It should be shown that all pipelines function properly at design capacity. At or below design capacity there should be no objectionable surge or water hammer. To be objectionable there can be either (a) continuing, unsteady delivery of water, (b) damage to the system, or (c) detrimental overflow from vents or stands. Pipelines should be tested for leaks by observing their normal operation any time after a period of two weeks of continuous wetting. All visible leaks should be repaired. Losses for mortar jointed pipelines should not exceed 0.015 m^3/m^2 (0.05 cubic foot per square foot) of inside surface in 24 hours. Losses from rubber gasket lines should not exceed 0.006 m^3/m^2 (0.02 cubic foot per square foot) of inside surface in 24 hours.

CHAPTER 7

Operating Concrete Irrigation Pipelines

The design and construction of concrete pipe irrigation lines is based on the assumption that lines will be properly operated. An irrigation system, like any other item, can give good service only when properly operated and maintained.

KEEP PIPELINES CLEAN

Sand, dirt, and other suspended matter should not be permitted to settle and remain in a pipeline. This especially applies to the low points where such material naturally accumulates. Besides reducing the capacity of the pipeline, constrictions thus caused may develop an abnormal stress on the line.

STANDING WATER IN THE PIPELINE

In filling a pipeline where water is standing in the low points, extreme care must be exercised to avoid excessive pressure due to trapped air.

FILLING CONCRETE PIPELINES

To avoid sudden application of excessive pressures, the pipeline must be filled gradually. Also, this permits the pipeline to adjust to temperature changes.

KEEPING GATES AND VALVES CLOSED

By keeping gates and valves closed, excessive rusting and pitting of seals is avoided.

CHAPTER 8

Problems with Concrete Pipelines

Generally, most concrete pipeline system will operate without giving any trouble. But there are always a few failures, generally of the following types :

1. Development of longitudinal cracks in the pipe, principally in the top or in both top and bottom.
2. Telescoping of sections.
3. Pushing of the pipe into the stands.
4. Development of circumferential cracks.
5. Surging or intermittent flow or water.

The first four types of failure are closely related. The cause of most failures (types 1, 2, and 3), and the prevention of some (type 4) stem from the fact that concrete expands when wet, and contracts when drying. Concrete also is affected by temperatures : it expands when heated, and contracts when cooled.

Circumferential cracks are caused by a drop in the water or soil temperatures, or by drying out of the pipe. The primary cause is low water temperature of surface supplies in winter and early spring. Well waters seldom give trouble. Such cracks may be partially prevented by prestressing the pipe longitudinally. Fortunately this prestressing tends to occur automatically when the pipe, which is laid dry, expands on becoming wet. Longitudinal stress from wetting expansion does not normally remain high for more than a few months to a year, but it continues to offer some protection.

The axial stress set up in pipe by the natural restraint of longitudinal expansion is a partial cause of longitudinal ripping, and also the cause of telescoping and pushing of pipe into structures. The longitudinal rips normally occur within a few days to a week after pipe is laid. Other wetting stresses can occur as a result of change in moisture gradient through a pipe wall, or from a wetter condition around the bottom than around the top of a pipe. Also, stresses can develop as a result of air circulation through a pipe, causing thermal expansion or contraction. Ripping results from a combination of circumferential stresses and longitudinal restraint. The solution to the problem of occasional failures lies not in eliminating wetting expansion, but in keeping it from becoming excessive, and in minimizing moisture gradients around the shell.

Failure from the above causes can be avoided proper laying procedure. First, it involves the by use of *moist* soil for the initial backfill after laying the pipe. This procedure minimizes the circumferential moisture stresseses and takes any excessive peak from longitudinal stress. Another recommended, but seldom practiced, precaution is to minimize air circulation through a line when laying pipe and when the line is not in use. On flat grades this is automatically accomplished because water stands in the lines. On steeper grades the same thing can accomplished by having covers over the stands ; and/or by designing overflow stands so that the pipe is always submerged for a short distance above such stands. Covers should be free to lift up, like a flap valve, if pressures in the stand exceed atmospheric, and should not be absolutely airtight.

As an added precaution against failure, do not lay pipe in extremely hot, extremely cold, or in wet weather.

If pipe should push into structures, this is generally not serious, since it can be remortared to the stand. Procedure is specified so that the pipe can move into the stand and not crush it.

MAKING REPAIRS

Longitudinal compression helps prevent circumferential cracks resulting from temperature drop. If, in making repairs, one or more sections of pipe must be removed, this longitudinal compression can be lost because the two ends of pipe will move together slightly. This can be partially prevented if the line is allowed to dry out as much as possible for several days to a week before repairs are made. To facilitate drying out, remove all water from the line, and open all possible hydrants, gates, and stands to facilitate air circulation. Also, be sure that the sections of pipe used in making repairs are thoroughly dry when they are installed. Backfill with moist soil around the pipe.

SURGES IN PIPELINES

As indicated, surging is one of the common disadvantages of open type system with overflow stands. Air becomes entrained in the water as it overpours the lip into the downstream portion of the overflow stand. This intimate mixture of air and water is carried down into the reach of pipe downstream from the stand, and, because of the turbulence of the flow, the tendency for the air to separate out is minimized. Therefore, after a short interval, the upstream portion-sometimes of this reach of water becomes lighter than the downstream portion—sometimes causing a reversal of hydraulic gradient until the water with entrained air flows back to the stand and the air is dissipated. Thus, forward flow is only in cycles. The pipeline functions at only a fraction of its capacity, and the water is difficult to handle. The following observations have been made with regard to surging :

1. Most trouble occurs at low flows because at near capacity flows there is little, if any, fall of water over the baffles. It may not, however, be possible to open up to full flow because of the surge.

2. When the reach of pipe immediately downstream from the overflow stand causing the entrainment has sufficient grade, the air appears to accumulate gradually along the crown of the pipe and to blow back upstream to the stand. Also, the pipes are often flowing only part full. Thus, in this case, surges do not develop. As yet it cannot be stated wether or not there is a minimum grade above which all air will blow back and prevent trouble.

3. Relief is obtained by placing gate valves in the baffle walls (or between the upstream and downstream portions) of overflow stands and closing these gates only enough to create the pressure necessary for operation of upstream hydrants or laterals. This changes the

hydraulic characteristics of the system. With a straight overflow stand system, each stand keeps upstream heads quite constant so that there is no appreciable upstream change in deliveries (into laterals or out of hydrants). Any water that spills over the baffle is surplus from the upstream deliveries. Thus the far end of a system may have a surplus or a deficiency of water if flow into the system is not exactly correct. Where there are gate valves in the overflow stands baffles, the water levels in the stands will vary with the flow, Thus, upstream deliveries and flow through the baffle gate valves will vary somewhat, and any "errors" in flow into the system will tend to be proportioned throughout. This eases the problem of regulation, but deliveries may not be constant. whether this is an advantage or a disadvantage depends upon individual circumstances.

4. Relief is obtained by placing an airtight cover over the overflow stand in question. This method tends to create a vacuum in the stand, thus inhabiting the entrainment of air. This vacuum affects the hydraulic gradient to the extent that discharge into hydrants and laterals upstream is decreased. The airtight cover may act like a flap valve-seal when there is a vacuum in the stand, but lift for relief if positive pressure should be created. This type system is largely experimental, with breather pipes from the lids extending into the water upstream from the baffles to provide more constant upstream deliveries. It is not recommended as yet.

5. Use of and overflow stand, with a relatively large cross-sectional area of the downpour section, may minimize the trouble. The downward velocity is low, and most of the air may be released before the water gets into the pipe line.

6. Sometimes surge gradually builds up in flowing downstream from reach to reach of pipe. Surge can be dampened by certain irregular spacing of overflow stands. The idea is not, however, generally applicable to farm systems.

CHAPTER 9

Suggested Standards for Concrete Irrigation Pipe

Presently, most of the concrete pipe used by the State Governments is of the reinforced type. This pipe is more expensive than non-reinforced concrete pipe. Thereby, it is desirable to use nonreinforced type of pipe for irrigation lines. A knowledge of certain properties of nonreinforced pipe is useful to the user as an aid in designing better systems.

CHARACTERISTICS OF NON-REINFORCED PIPE

Concrete has peculiarities, as a structural material, that should be recognized. It is strong when a load tends to compress it (it takes high compressive stress). But it is weak when the load tends to pull it apart (tensile stress). Where concrete must withstand appreciable tensile stress, steel reinforcing is embedded in it to take the stress. The pressure of water in concrete pipe creates tensile stress in the shell. External loading, from backfill earth and vehicular traffic over the pipe, creates both compressive and tensile stresses. Therefore, plain concrete irrigation pipe, which contains no reinforcing must be carefully designed and placed so that tensile stresses are never excessive. One might ask-why not use reinforced concrete pipe with steel as a precaution against failure ? Such pipe is made by centrifugal or by vibrating processes that result in an especially dense and strong product. This type is excellent, but considered to be too costly for farm distribution systems in the United States.

In the United States, concrete pipe for irrigation is made by the packer head method that produces it quickly, cheaply, and in quantity. Using this pipe, systems can be designed which operate simply and with good satisfaction. They will withstand considerable abuse when in operation. These facts explain why thousands of kilometers of nonreinforced concrete pipe have been used in the United States As a result, it suggested that such pipe be adopted for use in India. The following Standard is based on ASTM C14, ASTM C118, and ASTM C505[1]/ specifications for concrete pipe.

SUGGESTED PIPE STANDARD FOR NONREINFORCED PIPE

The following standards are suggested for nonreinforced concrete pipe.

SCOPE

This standard applies to nonreinforced concrete pipe to be used for conveyance of irrigation water under low heads, with a tongue and groove joint, socket and spigot joint, or rubber gasket joint.

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[1] See Appendix *E* for title of specifications

MATERIALS

CEMENT

Cement, used should conform to IS : 269 Specification for Ordinary, Rapid-Hardening and Low Heat portland Cement or IS : 455 Specification for Portland Blastfurnace Slag Cement.

AGGREGATES

Aggregates used should conform to IS : 383, Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, except the requirements for gradation do not apply

ADMIXTURES

Slag, pozzalan, fly ash and natural pozzalan can be added to the concrete if needed.

CONCRETE MIXTURE

The concrete should consist of Portland cement, aggregates and water.

Admixtures can be added to replace some of the cement.

The aggregates should be so sized, graded, proportioned, and thoroughly mixed with such portions of cement and water so as to produce a homogeneous mixture of a quality that will produce a pipe that will meet the specified test and design requirements of this standard.

GASKETS

The rubber type compound used in the manufacture of the gaskets should be compounded from natural rubber, synthetic rubber or a mixture of the two fabricated as prescribed in the part on "Gasket Design and Manufacturing Requirements"

PIPE DESIGN AND MANUFACTURING REGUIREMENTS

DESIGN

The minimum standard dimensions should be as given in Table 13 for tongue and groove pipe, Table 14 for socket and spigot pipe and Table 15 for rubber gasket joint pipe.

JOINTS

Pipe units should be manufactured with male and female type joints of a design that will provide proper jointing.

Tongue and Groove.— Design of joint should be as per Figure 50. (Page 96)

Socket and Spigot.— Design joint as per IS : 458, Specifications for Concrete Pipes (With and Without Reinforcement) for Meteric Units or Table 14 and Figure 51 (Pages 97) for British Units.

Rubber Gasket.— The design of the joint can be as follows : The slope on the conic surfaces of the gasket seat on the inside of the female (socket) portion and on the outside of the male (spigot) portion should not be more than 3-1/2° measured from a longitudinal trace on the inside surface of the pipe, The female and/or the male portions should form a proper gasket positioning area or "seat". The joint design should be such that, when the joint has been fully closed and is off center sufficiently to cause the outer concrete surface of the male portion and the inner concrete surface of the female portion to come into contact at some place in the joint periphery, the deformation of the gasket adjacent to that point should not exceed 50% of the stretched diameter for "0" ring gaskets, or 75% of the uncompressed radial thickness for all other types. At the diametrically opposite side, the gasket deformation should not be less than 15% of the stretched diameter for for "0" ring gaskets, or 25% of the uncompressed radial thickness for all other types. "0" ring gaskets are defined as solid gaskets of circular cross-section, Stretched gasket diameters referred to above should be nominal diameters reduced by 0.5% for each 1% of stretch actually used. Refer to Figure 52 for sample design (at page 98).

The joint design should provide for the deflection of each pipe unit by opening one side of the outside perimeter of the joint, wider than the fully closed position, a distance no less than 12.5 mm (½ inch) without reducing its water-tightness.

The joint should be of such design that it will withstand without cracking or fracturing the forces caused by the compression of the gasket, and the required hydrostatic test pressure, In some case, reinforcement is used in the socket portion to prevent cracking or fracturing.

All surfaces of the joint upon or against which the gasket may bear should be smooth, free of spall, cracks, or fractures, and imperfections that would adversely affect performance.

TOLERANCES
TONGUE AND GROOVED PIPE

Variation of the internal diameter should not exceed plus or minus 4.76 mm (3/16 inch) for 150 mm (six inch) pipe, plus or minus 6.35 mm (¼ inch) for pipe having diameters larger than 150 mm (six inch) but not more than 450 mm (18 inch), and plus or minus 7.93 mm (5/16 inch) for larger pipe. The shell (wall) thickness at any point should not be less than the minimum specified in Table 13 by more than 1.59 mm (1/16 inch) for pipe having an internal diameter of 300 mm (12 inches) or less, 2.38 mm (3/32 inch) for pipe having greater than 300 mm (12 inch) diameters but not more than 450 mm (18 inches), and 3.175 mm (1/8 inch) for larger pipe.

Socket and Spigot pipe.— Permissible variations from the dimensions prescribed in Table 16 should not exceed those stated in Table.

Pipe for Rubber Gaskets.— The internal diameter at any point should not be more than 4.76 mm (3/16 inch) or 1-½%, whichever is the greater, less than the nominal internal diameter.

The minimum wall thickness at any point in the pipe barrel should not be more than 5% less than the nominal wall thickness furnished.

The planes formed by the ends of the pipe should not vary from the perpendicular to the longitudinal trace on the inside surface of the pipe by more than 4.76 mm (3/16 inch across the inside diameter of the pipe).

GASKET DESIGN AND MANUFACTURING REQUIREMENTS

FABRICATION

Gaskets should be extruded or molded and cured in such a manner that they will be dense and homogeneous at any cross-section, and have uniform dimensions. They should be free from porosity, blisters, pitting, and other deformations prescribed in the part "Pipe Design and Manufacturing Requirments".

PHYSICAL PROPERTIES OF GASKETS

When tested in accordance with applicable standards, the rubber from which the gaskets are fabricated should have the following physical properties:

Ultimate elongation at break,
percent minimum... 350

Ultimate elongation at break,
after aging, percent of
elongation before aging,
minimum... 80

Hardness, International rubber
hardness deg (see Note) ... 40 to 60

Compression set, percent,
maximum... 25

Water Absorption, percent... 10

Note: Allowable variation ± five from manufacturer's specified hardness.

STRENGTH OF SPLICE

If a splice is used in the manufacture of gasket, the strength should be such that the gasket should withstand 100% stretch over the area including the splice with no visible separation or peeling.

STORAGE

The gasket should be stored in a cool, clean, and shaded place, preferably at 21°C (70°F.) or less and in no case should the gaskets be exposed to direct rays of the sun for more than 72 hours.

CURING OF PIPE

The pipe should be subjected to either one of the two methods of curing described in the following paragraphs or to some other method or combination of methods approved by the purchaser that will give satisfactory results. The pipe should be cured for a long enough time so that the concrete will develope the specified strength requirement in 28 days or less.

STEAM CURING

After the pipe has been made, it should be placed in a curing chamber, free from outside drafts, and cured in a moist atmosphere maintained by the injection of saturated steam vapor for such time and such temperature as may be needed to allow the pipe to meet the test requirements. The curing chamber should be construcred so as to allow the steam to allow the steam to circulate around the pipe.

WATER CURING

Pipe may be water cured by covering with water saturated material or by a system of sprinklers perforated pipe, porous hose, or by any other method that will keep the pipe moist inside and outsied for the time necessary to allow the pipe to meet the test requirements.

PHYSICAL TEST REQUIREMENTS

Test Specimens: Refer to Indian Standard IS : 458-1961, Clause 8, pages 17 and 18 and Clause 9, pages 18 and 19.

Hydrostatic Test Requirements: Maximum hydrostatic test pressures should be as given in Tables 13, 14, and 15, and should be made in accordance with the procedure given in the part on "Test Methods". There should be no leakage of pipe or joints at this pressure when pipes are in straight alignment or in maximum deflected position for rubber gasket jointed pipe. Moisture appearing on the surface of the pipe in the form of patches, or beads of water that result in minor dripping, and slight pinhole spurts, which can be proven to seal and dry up within one week when kept continuously under the prescribed ten-minute test pressure should be considered acceptable.

EXTERNAL LOAD CRUSHING STRENGTH

Test Requirement : External load crushing strength should be as given in Tables 13, 14, and 15, and should be made in accordance with procedure specified in the part of "Test Methods".

Test Acceptance: Refer to Indian Standard IS : 458-1961, Clause 9.3, page 19.

MARKING

Refer to Indian Standard IS : 458-1961, Clause 10, page 20.

FINISH

Refer to Indian Standard IS : 458-1961, Clause 7, page 17.

INSPECTION AND REJECTION

AGE FOR SHIPMENT

Pipe and gaskets should be considered ready for acceptance when they conform to the test requirements and the inspection prescribed in these standards.

INSPECTION

The quality of all materials and the finished pipe and gaskets should be subject to inspection and approval by the purchaser or his representative.

REJECTION OF PIPE

Pipe should be subject to rejection on account of failure to conform to any of the specification requirements or on account of fractures or cracks passing through the shell (wall) of the pipe or end cracks, fractures, and blisters that might interfere with proper jointing or seating of the rubber gasket.

REJECTION OF RUBBER GASKETS

Gaskets which do not conform to the standards specified or which show surface cracking weathering, or other deterioration prior to installation should be rejected. All gaskets should be subjected to inspection.

TEST METHODS

HYDROSTATIC TEST

The hydrostatic test should be made on specimens selected as specified. At the option of the manufacturer, the pipe (1) may be surface dry, (2) may have been completely immersed in water for seven days, or (3) may have been completely soaked from the inside at the working pressure for up to seven days prior to test.

For rubber gasket jointed pipe, test should be made on two or more units of pipe, with gaskets in place, in straight alignment between bulk heads, and secondly on the same units of pipe with the joint between them deflected to creat a position 12.5 mm (½ inch) wider than the fully closed position on one side of the outside perimeter of each joint. No mortar or concrete coatings, fillings or packing other than the gasket itself should be placed in the joint during or prior to, either part of the test.

For other types of pipe the test should be done in the same manner except only one unit of pipe needs to be tested at one time.

Provision should be made to fill the pipe units or unit with water to the exclusion of air. A standardized pressure guage should be connected close to the specimens, and the water pressure brought up to a value of 1/3 the required hydrostatic test pressure for rubber gasket jointed pipe and 0.70 kg/cm² (ten pounds per square inch) for the other types of pipe, in about one minute and held at that pressure for ten minutes. Pressure should then be increased until the required hydrostatic test pressure is reached and held at that pressure for a period of time not to exceed one minute. There should be no leakage from pipe or gaskets when this procedure is followed.

THREE-EDGE BEARING TEST

Refer to Indian Standard IS : 458-1961, Appendix B, page 22.

ABSORPTION TEST

This test is not required for irrigation pipe.

TABLE 13

Physical and Dimensional Requirements for Tongue and Groove, Concrete Irrigation Pipe

Internal Diameter		Minimum Shell (wall) Thickness		Test Requirements: Internal Hydrostatic Pressure on Individual units		Test Requirements: Minimum Three-Edge-Bearing Load		Working Pressure Head[1]	
mm	inches	mm	inches	Kg/cm^2	psi	Kg/linear meter	lbs/linear foot	Meters	Feet
152.4	6	19.050	3/4	3.5	50	1934	1300	8.5	28
203.2	8	22.225	7/8	3.5	50	2008	1350	8.5	28
254.0	10	25.400	1	3.5	50	2083	1400	8.5	28
304.8	12	28.575	1-1/8	3.2	45	2232	1500	7.9	26
355.6	14	31.750	1-1/4	3.2	45	2380	1600	7.9	26
381.0	15	34.925	1-3/8	3.2	45	2455	1650	7.9	26
406.4	16	34.925	1-3/8	3.2	45	2529	1700	7.9	26
457.2	18	38.100	1-1/2	3.2	45	2678	1800	7.9	26
508.0	20	47.625	1-7/8	2.8	40	2752	1850	7.0	23
533.4	21	50.800	2	2.8	40	2827	1900	7.0	23
609.6	24	53.975	2-1/8	2.8	40	2976	2000	7.0	23

[1] Higher pressures may be used up to a maximum of 12.2 meters (40 feet) for 152.4—and 203.2 mm (six and eight inch) diameters, and 10.7 meters (35 feet) for 254.0 and 304.8 mm (ten and 12 inch) diameters, and 9.1 meters (30 feet) for 355.6 through 609.6 mm (14 through 24 inch) diameters. In these cases the strength of the pipe shall be increased to give minimum internal hydrostatic pressures of at least four times the design working pressure when tested as specified in Section.

TABLE 14

Physical and Dimensional Requirements for Socket and Spigot, Concrete Irrigation Pipe 1/2/

Internal Diameter		Thickness of Wall, T		Minimum Taper of Socket[4] T_s	Inside Diameter at Mouth of Socket[3] D_s		Depth of Socket, L_s	
mm	inches				mm	inches	mm	inches
152.4	6	19.050	3/4	1:20	215.900	8-1/2	50.800	2
203.2	8	22.225	7/8	all	279.400	11	57.150	2-1/4
254.0	10	25.400	1	sizes	336.550	13-1/4	63.500	2-1/2
304.8	12	28.575	1-1/8		444.500	15-1/2	63.500	2-1/2
381.0	15	34.925	1-3/8		482.600	19	69.850	2-3/4
456.2	18	38.100	1-1/2		565.150	22-1/4	69.850	2-3/4
533.4	21	50.800	2		660.400	26	69.850	2-3/4
609.6	24	53.975	2-1/8		749.300	29-1/2	76.200	3

Minimum Three-Edge- Bearing Load		Minimum Thickness of Sockets[4]	Internal Hydrostatic Pressure on Individual Units		Working Pressure, Head	
Kg/linear meter	lbs/linear foot		Kg/cm²	Psi	meters	feet
1934	1300	3T/4	3.5	50	8.5	28
2008	1350	all	3.5	50	8.5	28
2083	1400	sizes	3.5	50	8.5	28
2232	1500		3.2	45	7.9	26
2455	1650		3.2	45	7.9	26
2578	1800		3.2	45	7.9	26
2327	1900		2.8	40	7.0	23
2976	2000		2.8	40	7.0	23

[1] See Figure 51 also.

[2] Subject to tolerances in Table 16.

[3] When pipe are furnished having an increase in wall thickness. T, then the diameter at the inside of the socket shall be increased by an amount equal to twice the increase of the wall.

[4] This measurement should be taken 6.35 mm (¼ inch) from the outer end of the socket.

TABLE 15

Physical and Dimensional Requirements for Rubber Gasket, Concrete Irrigation Pipe

Internal Diameter		Minimum Shell (Wall) Thickness[1]		Working Pressure Head[2]		Internal Hydrostatic Pressure on Individual Units		Minimum Mhree-Edge-Bearing Load	
mm	inches	mm	inches	meters	feet	Kg/cm²	psi	Kg/liner meter	lb/liner foot
152.4	6	19.050	3/4	9.1	30	2.8	40	1934	1300
203.2	8	25.400	1	9.1	30	2.8	40	2008	1350
254.0	10	31.750	1-1/4	9.1	30	2.8	40	2083	1400
304.8	12	38.100	1-1/2	9.1	30	2.8	40	2232	1500
381.0	15	47.625	1-7/8	9.1	30	2.8	40	2455	1650
457.2	18	57.150	2-1/4	9.1	30	2.8	40	2678	1800
533.4	21	66.670	2-5/8	9.1	30	2.8	40	2827	1900
609.6	24	76.200	3	9.1	30	2.8	40	2976	2000

1 Thinner walls may be used on pipe units not over 1.22 meters (four feet in length, but the thickness of such walls shall not be less than the internal diameter divided by ten.

2 With the exception of 533.4-and 609.6-mm (21- and 24-inch) pipe, higher pressures may be used up to a maximum of 15.2 meters (50 feet) for 152.4-through 304.8-mm (6-through 12-inch) diameters, and 12.2 meters (40 feet) for 381.0-through 457.2-mm (15-through 18-inch) diameters. In these cases the strength of the pipe shall be increased to give minimum internal hydrostatic pressures of at least three times the design working pressure when tested as specified in Section 10.

TABLE 16

Permissible Variation in Dimensions for Socket and Spigot Pipe

Limits of Permissible Variation in :

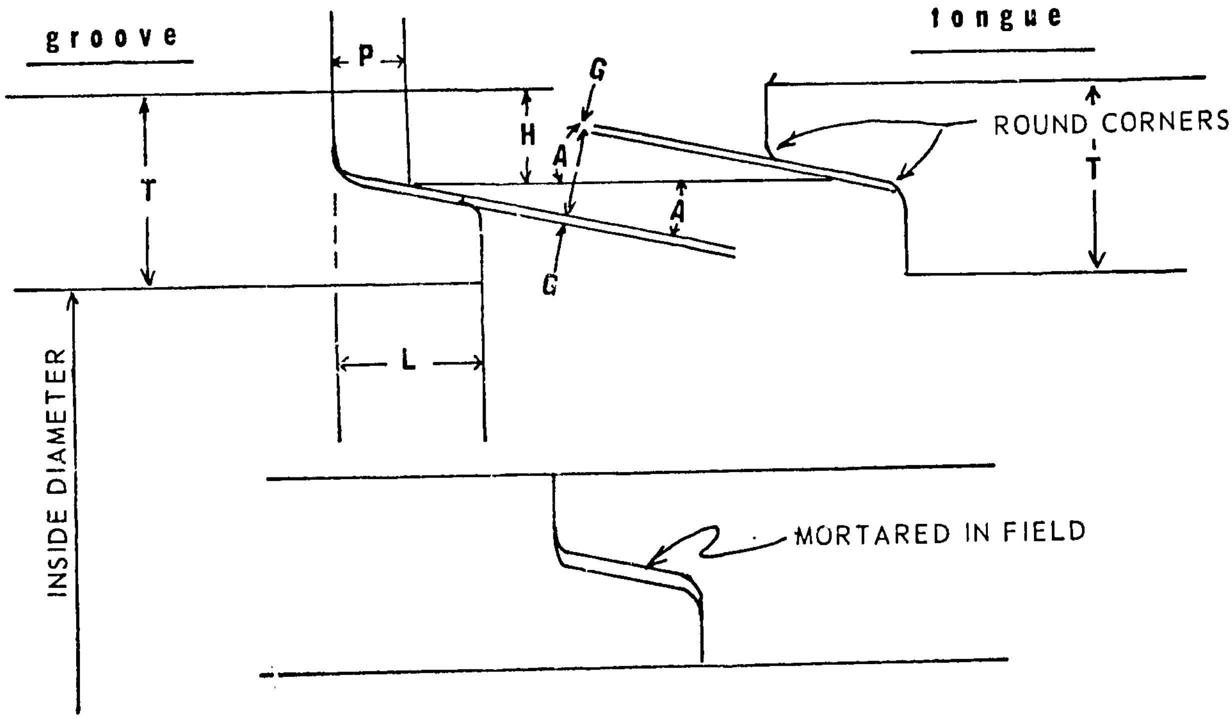
Nominal Size Internal Diameter		Length in		Length of two opposite sides		Internal Diameter pipe or socket		Depth of Scoket		Thickness of barrel	
mm	inches	mm[1] (—)	inches[1] (—)	mm	inches	mm[1]/[2] (±)	inches[1]/[2] (±)	mm[1]/[2] (—)	inches[1]/[2] (—)	mm[1] (—)	inches[1] (—)
152.4	6	6.35	1/4	6.35	1/4	4.76	3/16	6.35	1/4	1.59	1/16
203.2	8	6.35	1/4	7.94	5/16	6.35	1/4	6.35	1/4	1.59	1/16
254.0	10	5.35	1/4	9.52	3/8	6.35	1/4	6.35	1/4	1.59	1/16
304.8	12	6.35	1/4	9.52	3/8	6.35	1/4	6.35	1/4	1.59	1/16
381.0	15	6.35	1/4	11.11	7/56	6.35	1/4	6.35	1/4	2.38	3/32
457.2	18	6.35	1/4	12.70	1/2	6.35	1/4	6.35	1/4	2.38	3/32
533.4	21	6.35	1/4	14.29	9/16	7.94	5/16	6.35	1/4	3.17	1/8
609.6	24	9.52	3/8	14.29	9/16	7.94	5/16	6.35	1/4	3.17	1/8

1 The minus sign (—) alone indicates that the plus variation is not limited ; the plus and minus sign indicate variation in both excess and deficiency in dimension.

2 Socket variation applies to standard strength socket and spigot pipe only.

FIGURE 50

TONGUE AND GROOVE DESIGN

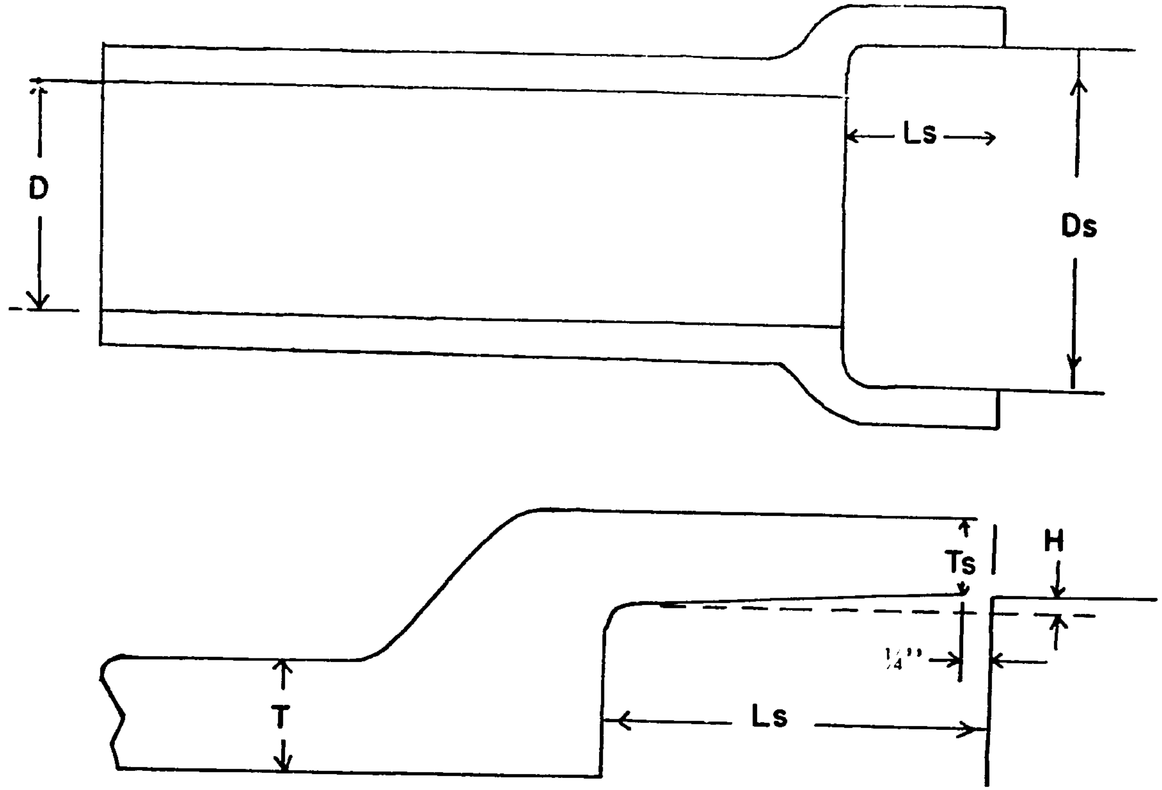


Where :

T = Wall thickness
L = ¾T
P = ½L
H = ½T
G = Varies with pipe diameter – 0.794 mm (1/32 inch) for 152.4 - mm (6 inch) diameter to 3.175mm (1/8 inch) for 609.6-mm (24 inch) diameter pipe.

A = 10 degrees

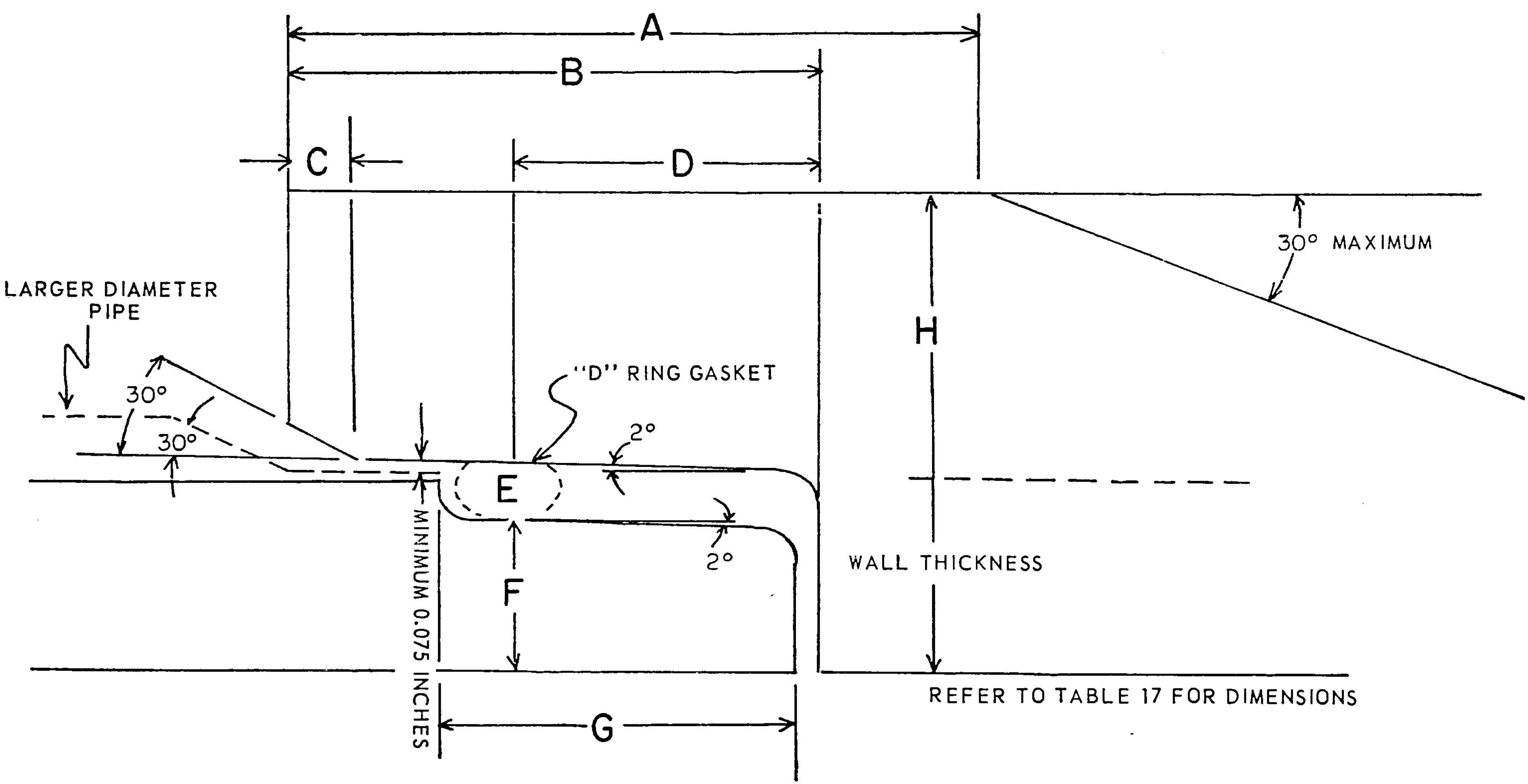
SOCKET AND SPIGOT PIPE DESIGN



REFER TO TABLE 14 FOR DIMENSIONS

FIGURE 51

FIGURE 52



RUBBERGASKET JOINT DESIGN

TABLE 17

Dimensions for Rubber Gasket Joint

Pipe Diameter (inches)	Dimensions (inches)								
	A	B	C	D	E	F	G	H	Gasket Cross-Section
4	4-5/16	2-11/16	5/16	1-35/64	0.301 0.298 0.296	0.875 0.938 1.000	2	1-21/32	15/32
6	4-13/32	2-7/8	6/16	1-21/32	0.321 0.319 0.316 0.314	0.875 0.938 1.000 1.063	2-1/8	1-3/4	1/2
8	4-15/32	3-1/2	13/32	2	0.401 0.399 0.396 0.394	0.938 1.000 1.063 1.125	2-21/32	1-27/32	5/8
10	4-9/16	3-1/2	13/32	2	0.402 0.399 0.395 0.392	0.910 1.000 1.125 1.250	2-21/32	1-15/16	5/8
12	4-5/8	3-1/2	13/32	2	0.402 0.399 0.395 0.392	1.066 1.125 1.250 1.375	2-21/32	2	5/8
15	4-3/4	3-1/2	13/32	2	0.402 0.399 0.397 0.394	1.375 1.500 1.625 1.750	2-3/8	2-1/8	5/8
18	4-15/16	3-1/2	13/32	2	0.402 0.400 0.397 0.395 0.393	1.500 1.625 1.750 1.875 2.000	2-3/8	2-3/16	5/8
21	5-5/16	3-1/2	13/32	2	0.399 0.395 0.391	1.500 1.750 2.000	2-3/8	2-1/4	5/8
24	5-9/16	3-1/2	13/32	2	0.399 0.396 0.392	1.500 1.750 2.000	2-3/8	2-15/32	5/8

Chapter 10

Scope for Introducing New Manufacturing Techniques for Concrete Pipe

In India the primary method used in making concrete pipe is the centrifugal process. This method was developed principally for making reinforced concrete pipe. It has been shown, in India, that this method is adaptable to making nonreinforced pipe, tongue and groove, and socket and spigot pipe.

This process is rather slow, taking about 20 minutes per unit of pipe for the smaller sizes, which are generally 1.8 meters (six feet) long. Generally up to four sections of pipe per unit can be made at one time. This depends on the number of spaces available. As a result, it is difficult to estimate how many meters of pipe can be produced per day. Generally, a figure of 80 units per eight hour-day, of any one size, was given as a production rate. This gives 146.3 meters (480 feet) per day, with the length of pipe being 1.8 meters (six feet). At present, it appears that there is sufficient pipe being made to meet the demand. It takes approximately ten men to make and handle the pipe from one spinning unit. This factor, along with a rather slow production rate and the reinforcement makes for a rather costly pipe. By the elimination of reinforcement, cost of pipe can be reduced. According to most manufacturers, 1/3 of the material cost is in the reinforcement. If the reinforcement is deleted, some of the cost savings will be absorbed by the increase in cement content, needed to improve the quality of the pipe.

The pipe length should be shorter. A length of one meter (3.28 feet) would be a very desirable length. This will mean two times as many joints but improved joint design should compensate for this. With an experienced mason and three helpers 91.4 to 121.9 meters (300 to 400 feet) of the smaller diameter pipe can be installed per day. The shorter length pipe should be easier to handle when laying the pipeline' with less labor required. With the problem of carrying pipe across fields, a shorter pipe will be an additional advantage.

In Chapter 9, Suggested Standards for Concrete Irrigation pipe, several joint designs are being used in the United States and could be also used in India. It is doubtful whether a joint for rubber gaskets can be manufactured with present forms, with the centrifugal method. This type of joint has to be made with rather close tolerances and with a smooth finish to the concrete. This type of joint would be highly desirable in the expansive soils of South India such as the Black Cotton Soil, because of the high shrink-swell problem which can cause cracking of the mortar joint. In India, approximate cost of "0" ring rubber gaskets are as follows for various diameters :

Diameter		Cost each	Diameter		Cost each
mm	inches	Rs.[1]	mm	inches	Rs.
50	1.97	0.12	150	5.91	0.48
80	3.15	0.27	200	7.87	0.75
100	3.94	0.31	250	9.84	1.10
125	4.92	0.41	300	11.81	1.30

[1] Rs. 7.50=$1.00 (1970)

These gaskets are being used with the couplers for asbestos cement pipe. A similar gasket can be used for rubber gasket joints in concrete pipe. In order to implement some of these changes it would be necessary to introduce more modern methods for making concrete pipe. This would require developing equipment in collaboration with some foreign firms or bringing from outside sources and then fabricated in the country.

It would be desirable to introduce the new type of equipment on a limited basis in areas where a special pipe is needed, such as rubber gasket joints in the Black Cotton Soil areas, or where there is a high demand for pipe. The initial cost of such equipment could be quite high.

In the United States, the process used most frequently for manufacturing concrete irrigation pipe is the packerhead method. Other methods being used are the tamping and vibrator methods which are somewhat slower and are used primarily in the manufacture of reinforced or large diameter non-reinforced concrete pipe.

The packerhead method has a high rate of production rates will vary with different designs of machine. The following table gives an idea of what some of the rates of production are :

8-foot (2.44 meter) lengths :

Diameter		Time per pipe
mm	inches	minutes
152.4	6	0.5 to 0.58
304.8	12	1.25 to 1.50
457.2	18	2
609.6	24	2.75 to 3.00
4-foot (1.22 meter) lengths :		
152.4	6	0.66

3-foot (0.91 meter) lengths :

Diameter		Time per pipe unit
mm	inches	minutes
152.4	6	0.33
203.2	8	0.33
254.0	10	0.43
304.8	12	0.50
355.6	14	0.52
381.0	15	0.52

Table 18 following page105, gives a concept of production cost using a packerhead machine and the unit cost per foot of pipe. The figures represent national averages in the United States as closely as could be determined. Table 19 gives production cost of two different manufacturers who use packerhead machines.

TABLE 19

Production Cost of two Manufacturers in the United States

Manufacturer in California, U.S.A.

Tongue and Groove Pipe, Costs per foot

Pipe diameter, inches	Aggregate	Cement	Machine and Labor	Overhead, Office and Other	Selling Cost
6	$ 0.036[1]	$ 0.054	$ 0.09	$ 0.09	$ 0.27
8	0.050	0.076	0.127	0.127	0.38
10	0.069	0.104	0.173	0.174	0.52
12	0.080	0.120	0.20	0.20	0.60

[1] $1.00=Rs 7.50 (1970).

Manufacturer in Texas, U.S.A.

Tongue and Groove Pipe, Costs per foot

Pipe diameter, inches	Aggregate	Cement	Labor	Overhead[2]	Total production cost[3]
12	$0.071	$ 0.099	$ 0.051	$ 0.145	$ 0.366
15	0.092	0.127	0.072	0.197	0.488
18	0.098	0.234	0.080	0.306	0.718

[2] This is equipment depreciation

[3] Administrative cost is not included

Rubber Gasket Pipe, Costs per Foot

Pipe diameter inches	Aggregate	Cement	Steel Wire	Labor	Overhead[2]	Gasket[1]	Total production cost[3]
10	$ 0.091[4]	$ 0.126	$ 0.009	$ 0.052	$ 0.147	$ 0.083	$ 0.508
12	0.116	0.161	0.010	0.063	0.178	0.100	0.628
15	0.159	0.221	0.012	0.093	C.256	0.118	0.859
18	0.184	0.296	0.028	0.118	0.284	0.148	1.058

Size inches	Cost of rubber gasket Dollars[4]
10	0.495 each
12	0.600 each
15	0.715 each
18	0.885 each

[1] Gasket cost.

[2] This is equipment depreciation.

[3] Administrative cost is not included.

[4] $1.00=Rs 7.50 (1970).

In the United States, as well as in other foreign countries, a variety of pipe making machines are available. The cost of such equiptment in the United States, is quite variable and will depend on the range of diameters and length of pipe are to be manufactured.

Listed below are some approximate costs for equipment used to produce concrete pipe :

PACKERHEAD MACHINES :

Range of diameters		Range of Lengths	
mm	inches	meters	feet
101.6 to 381.0	4 to 15	0.61 to 1.07	2 to 3.5
101.6 to 381.0	4 to 15	0.61 to 3.05	2 to 10
101.6 to 685.8	4 to 27	0.91 to 2.45	3 to 8
254.0 tc 1524.0	10 to 60	1.22 to 2.45	4 to 8

Approximate Cost	
Rupees	Dollars
96,000	12,800
221,250	29,500
257,250	34,300
394,500	52,600

TAMPING MACHINES :

Range of diameters		Range of Lengths	
mm	inches	meters	feet
101.6 to 457.2	4 to 18	upto 1.22	upto 4
101.6 to 762.0	4 to 30	upto 1.22	upto 4
203.2 to 944.4	8 to 36	upto 1.83	upto 6
304.8 to 1219.2	12 to 48	upto 2.44	upto 8

Approximate Cost	
Rupees	Dollars
110,250	14,700
127,500	17,000
150,000	20,000
177,750	23,700

VIBRATOR (ONE STATION) :

304 to 1828.8	12 to 72	upto 2.44	upto 8
	212,250	28,300	

In addition to the pipe making machines, some attachments and accessories are needed. The type of attachments needed will depend upon the particular machine. The type and number of accessories needed will depend on the type, size, length, and number of pipe to be produced. Some of the major accessories needed are as follows :

1. **Cores.** The core or inner-form is a cylindrical tube made of cast iron or fabricated steel that forms the inside diameter of the pipe. The cores are available in various diameters, lengths and materials to meet pipe requirement. These are used with the tamped, wet cast, or vibrator processes.

2. **Jackets.** The jackets or outer-form are the determining agent for the external design and shape of pipe and will determine the wall thickness. They are made in either one or two pieces depending on the type of pipe and manufacturing process. These pieces are latched together during the manufacturing and unlatched and stripped (removed) from the pipe in the curing area, brought back to the machine and used again. These are used with all processes.

3. **Bell Shoes or Bell Cores.** These are machined castings that form the inside shape of the female end of the concrete pipe. These are used in the machine tamping process and are attached to the cores.

4. **Tamp Sticks and Tamp Shoes.** The tamp stick physically does the mechanical tamping between the core and jacket. This stick is made from a hard, flexible wood and will vary in size and length dependent on the size of machine and pipe being manufactured. The tamp shoe is a steel casting that is attached to the tamping ends of the stick and is in direct contract with the concrete between the jacket and the core.

5. **Pallets.** The pallets (usually cast iron) are those units which form the male (spigot or tongue) or female (socket or groove) end of the pipe depending on the design of the equipment. They fit and are held within the jacket during the pipe making process and when the jacket is removed, support the pipe and remain under the pipe during the initial curing period. It is important to note that the production rate is related to the number of pallets on hand.

   In addition, there is another pallet that is called the master top pallet which fastens to the concrete pan of the packerhead machine. This pallet forms the ends of the groove or socket of the pipe. In conjuction, a trowel is used to give the ends a good finish. The trowel is shaped to fit the particular socket or groove.

6. **Spigot or Tongue Forming Rings.** These are used to form the male end of the pipe so that the end is dimensionally accurate for proper seating of gaskets. The rings may be equipped with a snap ring to form a groove for some types of rubber gaskets joints.

The total cost of the accessories needed will vary as to type of manufacturing process, number of different sizes to be made, and the production rate. Generally, the cost will range from Rs. 75,000/- to Rs. 112,500/- ($10,000 to $15,000).

In addition, mixers, conveyors or elevators, and skip hoists are needed to provide a continual supply of concrete so as to meet the output capacity of the pipe making equipment.

In Appendix F, there is a list of some of the manufacturers who produce pipe making equipment in the United States. In addition, there are several companies listed who manufacture mixers, conveyors or elevators and skip hoists which can be used with pipe making equipment.

TABLE 18

Production Cost With Packerhead Machines

	Tongue and Groove Pipe					Socket and Spigot Pipe			
Diameter of pipe, inches	6	8	10	12	15	6	8	10	12
Wall thickness, inches	3/4	7/8	1	1-1/8	1-3/8	3/4	7/8	1	1-1/8
Physical Factors :									
Weight per foot, pounds	15.9	24.4	34.5	46.3	70.9	28.4	43.6	61.8	81.2
Feet per ton [1]	126	82	58	43	28	70	46	32	24
Feet per hour [2]	190	190	135	120	115	190	190	135	120
Feet per 8 hour day	1520	1250	1080	960	920	1520	1520	1080	960
Feet per 8 hour day	12.1	18.5	18.6	22.3	32.8	21.7	33.0	33.8	40.0
Labor :									
Employees Required	4	4	4	4	4	4	4	4	4
Labor @$2.00[4] hour/day dollars	64.00	64.00	64.00	64.00	64.00	64.00	64.00	64.00	64.00
Labor per ton, dollars	5.29	3.46	3.44	2.87	1.95	2.95	1.94	1.90	1.50
Labor benefits-20% dollars	1.05	0.69	0.69	0.57	0.39	0.59	0.39	0.38	0.30
Total labor per ton, dollars	6.34	4.15	4.13	3.44	2.34	3.54	2.33	2.28	1.80
Total Costs :									
Concrete[3] ton, dollars[4]	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88	7.88
Labor, dollars	6.34	4.15	4.13	3.44	2.34	3.54	2.33	2.28	1.80
Wearing parts, dollars	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0 50
Cost per ton, dollars	14.62	12.53	12.51	11.82	10.72	11.92	10.71	10.66	10.18
Cost per foot, dollars	0.115	0.15	0.215	0.275	0·3825	0.17	0.235	0.33	0.425

[1] 1 ton equals 2000 pounds

[2] Based on 3-foot length

[3] Mixture :
Cement 1 part
Sand 3 parts

[4] $1.00=Rs. 7.50 (1970)

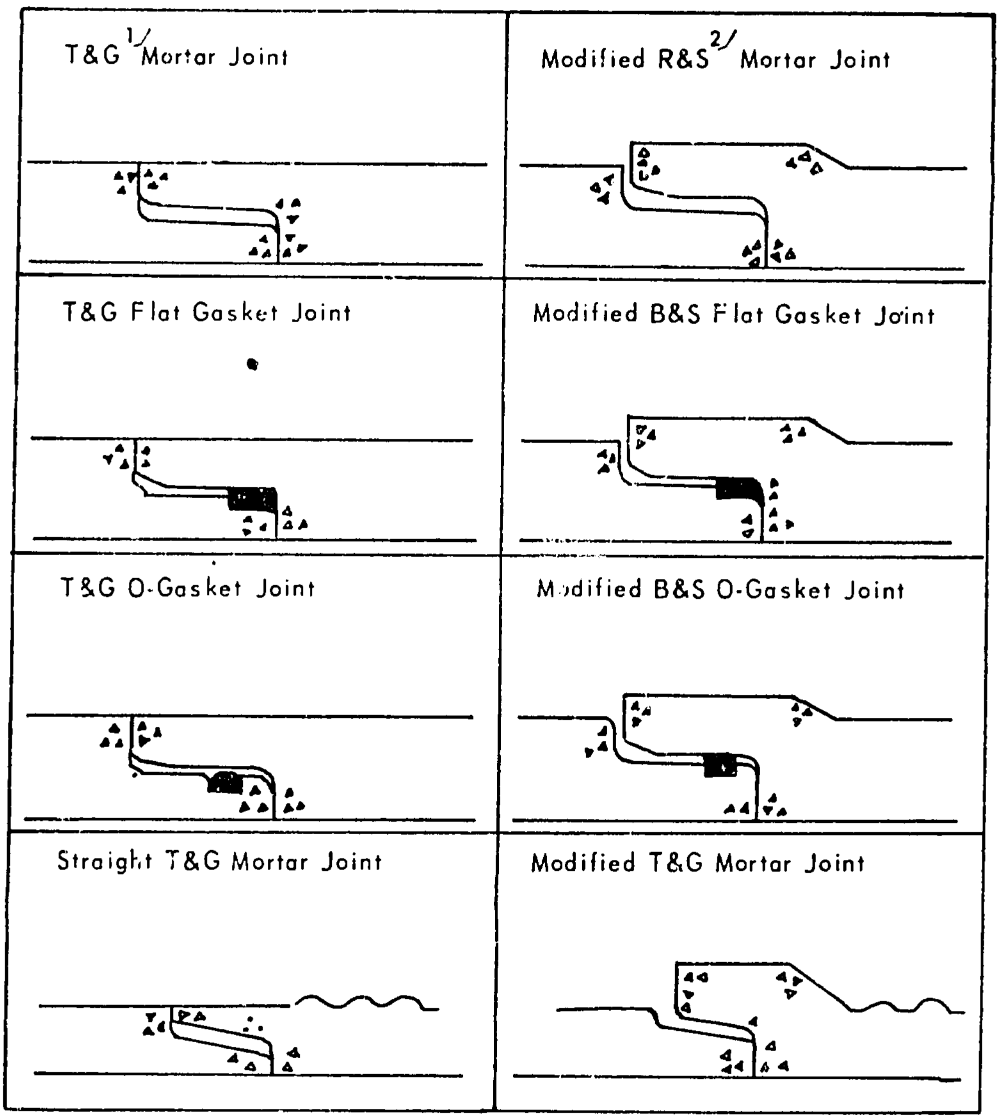
Basic Costs :
Cement per 94 pounds $1.20
Sand per 2000 pounds $2.00
Labor per hour $2.00

Materials Costs per Ton[1]
Cement 500 pounds $6.38
Sand 1500 pounds 1.50
2000 pounds $7.83

NOTE : Figures represent national averages, in the United States, as closely as could be determined.

FIGURE 53

VARIOUS JOINT DESIGNS

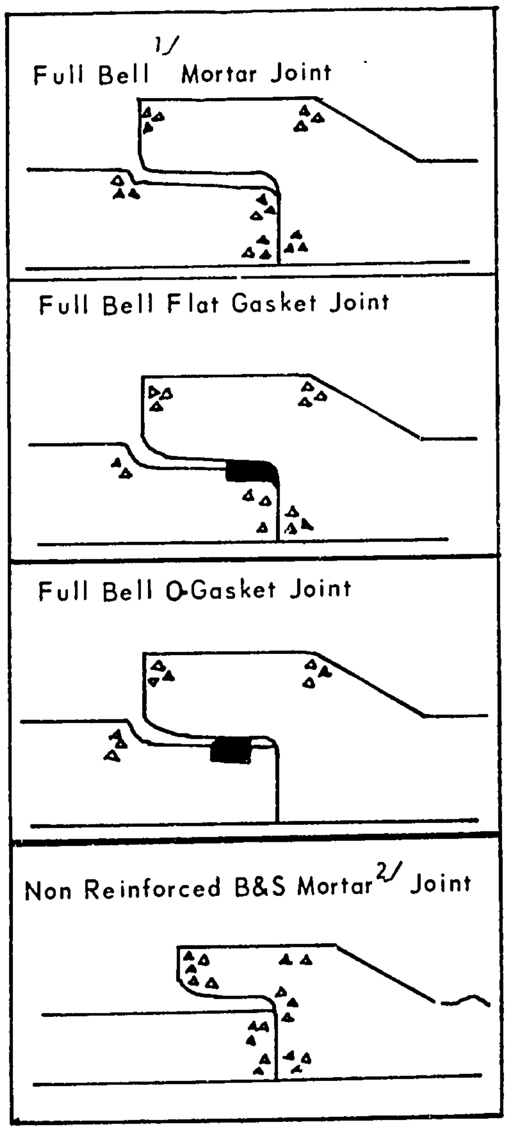


1/ Tongue and Groove

2/ Bell and Spigot or Socket and Spigot

FIGURE 53 (Cont'd)

VARIOUS JOINT DESIGNS (Cont'd)



1/ or Socket

2/ Bell and Spigot or Socket and Spigot

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CHAPTER 11

Design Criteria, Construction Guide, and Material Standards

FOR

PLASTIC TAPE COATED ALUMINUM PIPE,
ASBESTOS CEMENT PIPE,
HIGH PRESSURE UNDERGROUND PLASTIC PIPE,
LOW HEAD UNDERGROUND PLASTIC PIPE, and
STEEL PIPE

The following material was adapted from engineering standards prepared by the U.S. department of Agriculture, Soil Conservation Service for its work. In general, this material should be applicable to Indian conditions. Most of the design criteria for concrete pipelines, for various structures, are applicable in other low head irrigation systems.

Plastic Tape Coated Aluminum Pipe

SCOPE

This standard applies only to buried aluminum pipelines, coated with plastic tape on the exterior surface.

This standard covers (1) the specifications for the aluminum tubing and plastic wrapping to be used, (2) the design criteria, and (3) the minimum installation requirements for the pipeline.

DESIGN CRITERIA

WORKING PRESSURE

The maximum permissible working pressure in the line should be determined by the following equation :

$$P=\frac{2St}{d}$$

Where :

S=527.3 kg/cm² (7500 pounds per square inch)

P=Maximum working pressure in kg/cm² (pounds per square inch)

d=Inside diameter of tube in millimeters (inches)

t=Tube nominal wall thickness in millimeters (inches)

CAPACITY

Design capacity should be based on the following, whichever is greater :

1. The capacity should be sufficient to deliver the volume of water required to meet the peak consumptive use of the crop.
2. The capacity should be sufficient to provide an adequate irrigation stream for all methods of irrigation planned.

For design purposes, the value of "n" in Manning's formula should be considered to be 0.01, except where joints, connections, condition of the pipe, etc. indicate that a higher value is required.

STANDS FOR LOW PRESSURE LINES OPEN TO THE ATMOSPHERE

Stands should be used wherever water enters the pipeline, to avoid entrapment of air, to prevent surge-pressures, collapse due to vacuum failure, and prevent pressure from exceeding the design working stress of the pipe. The stand should be designed to :

1. Allow a minimum of 0.30 meters (one foot) of freeboard. The stand height maximum above the centerline of the pipeline should not exceed the maximum working head of the pipe.
2. Have the top of each stand at least 1.22 meters (4 feet) above the ground surface except for surface gravity inlets which should be equipped with trash racks and covers.
3. Have downward water velocities in excess of 0.61 meters per second (2 feet per second). In no case should

the inside diameter of the stand be less than the inside diameter of the pipeline.

The cross sectional area of stands may be reduced above a point 0.30 meters (1 foot) above the top of the upper inlet but in no case should the reduced cross section be such that it would produce an average velocity of more than 3.05 meters per second (10 feet per second) if the entire flow were discharging through it.

When the water velocity of an inlet pipe exceeds three times the velocity of the outlet, the centerline of the inlet should have a minimum vertical offset from the centerline of the outlet at least equal to the sum of the diameters of the inlet and outlet pipes.

Sand traps, when combined with a stand, should have a minimum inside dimension of 762.0 mm (30 inches) and should be constructed so that the bottom is at least 609.6 mm (24 inches) below the invert of the outlet pipeline. The downward velocity of flow of the water in a sand trap should not exceed 0.076 meters per second (0.25 feet per second). Suitable provisions for cleaning sand traps should be provided. Gate stands should be of sufficient dimensions to accommodate the gate or gates required and should be large enough to make the gates accessible for repair.

Float valve stands should be of sufficient size to provide accessibility for maintenance and to dampen surge.

Construction should be such as to insure that vibration from the pump discharge pipe is not carried to the stand.

VENTS FOR LOW PRESSURE LINES OPEN TO THE ATMOSPHERE

Vents should be designed into the system to provide for the removal of air and prevention of vacuum collapse. They should :

1. Have a minimum freeboard of 0.30 meters (1 foot) above the hydraulic grade line. The maximum height of the vent above the centerline of the pipeline should not exceed the maximum working head of the pipe.

2. Have a cross sectional area at least one half the cross sectional area of the pipeline (both inside measurements) for a distance of at least one pipeline diameter up from the centerline of the pipeline. Above this elevation the vent may be reduced to 50.8 mm (2 inches) in diameter.

3. An air-vacuum release valve may be used in lieu of an open vent. It should have 50.8 mm (2-inch) minimum diameter. 50.8 mm (2-inch) valves should be used for lines 152.4 mm (6-inch) diameter or less, 76.2 mm (3-inch) valves for diameters from 177.8 mm (7 inches) through 2540 mm (10 inches), and 101.6 mm (4-inch) valves for 304.8 mm (12-inch) pipe

4. Vents should be located :

   a. At the downstream end of each lateral.

   b. At summits in the line.

   c. At points where there are changes in grade in a downward direction of flow of more than 10 degrees.

   d. Immediately below the pump stand if the downward velocity in the stand exceeds 0.30 meters per second (1 foot per second).

OUTLETS

Appurtenances to deliver water from a pipe system to the land, a ditch, or any surface pipe system should be known as outlets. Outlets should have a capacity to deliver the required flow, (1) to the hydraulic grade line of a pipe or ditch, or (2) to a point at least 152.4 mm (6 inches) above the field surface.

DRAIN REQUIREMENTS

Stagnant water in aluminum pipe is conducive to corrosion, therefore provisions should be made to completely drain the pipeline. Drainage outlets should be provided at all low points in the system and may either discharge into a dry well or to a point of lower elevation. If these cannot be provided, provisions should be made to empty the line by pumping.

PRESSURE RELIEF, VACUUM RELEASE, AIR RELEASE, AND CHECK VALVES FOR HIGH PRESSURE CLOSED SYSTEMS

A check valve should be installed between the pump discharge and the pipeline where detrimental backflow may occur.

A pressure relief valve should be installed at the pump location when excessive pressures can be developed by operating with all valves closed. Also in closed systems where the line is protected from reversal of flow by a check valve and excessive surge pressures could be developed, a surge chamber or pressure relief valve should be installed. Pressure relief valves should be no smaller than 6.35 mm nominal size for each 25.4 mm of diameter (1/4-inch nominal size for each diameter inch) of the pipeline, and should be set at a maximum of 0.35 kg/cm^2 (5 p.s.i.) above the pressure rating of the pipe.

Pressure relief valves or surge chambers should be installed at the end of the pipeline when needed to relieve surge.

Air release and/or vacuum release/valve should be placed at all summits in the pipeline and at the end of the line when needed to provide a positive means of air release or escape.

Air release and vacuum release valve outlets of at least 12.70 mm (1/2-inch) nominal diameter should be used in lines of 101.6 mm (4-inches) or less in diameter, at least 25.4 mm (1-inch) outlets should be used in lines 127.0-203.2 mm (5-8 inches) in diameter, and at least 50.8 mm (2-inch) outlets in lines 254-0—406.4 mm (10-16 inches) in diameter.

JOINTS AND CONNECTIONS

All connections should be constructed to withstand the working pressures of the line without leakage and leave the inside of the line free of any obstruction which would reduce the line capacity below design requirements. All fittings such as risers, ells, tees, couplings, and reducers should preferably be of similar metal. However, if dissimilar metals are used, proper protection against galvanic corrosion, such as separating dissimilar metals with a rubber or plastic insulator, should be taken. The connection between the pump discharge pipe and the aluminum line should be made with a suitable insulating material such as rubber or plastic.

QUALITY OF WATER

Water quality tests should be made of all aluminum pipeline installations. Copper content in excess of 0.02 p.p.m. will produce nodular pitting and rapid deterioration of the pipe, if water is allowed to remain stagnant.

CONSTRUCTION GUIDE

HANDLING OF PLASTIC COATED TUBING

Tubing should be handled in a manner so as to prevent abrasion to the coating during transportation and handling. It should not be dropped, dragged, or rolled on the ground. If it becomes necessary to move the pipe longitudinally on the ground or in the ditch it should be done in such a manner as not to injure the tubing or coating. When stock-piled the coated tubing should be carefully piled and blocked so as to prevent damage to the coating.

PLACEMENT

All pipe should be placed deep enough below the land surface to protect it form hazards imposed by traffic crossings, farm operations, freezing temperatures, or soil cracking. 0.61 meters (two feet) minimum cover should be provided except in soils subject to deep cracking, where the cover should be a minimum of 0.91 meters (3 feet). Extra fill may be placed over the pipeline to provide the minimum depth of cover if the top width of the trench should be at least 152.4 mm (6 inches) greater than the diameter of the pipe being installed. When trenches are excavated in soils containing rock or other hard materials which might damage the pipe coating materials, they should be excavated deeper than required, and then backfilled to grade with selected fine earth or sand.

INSTALLATION

The line may be assembled above ground or in the ditch taking care to align the joints at time of placement. At each joint, which will be observed during testing for leakage, scoop out sufficient dirt to allow for final coating and taping. Every care should be taken to prevent impact or scuffing against the sides of the trench.

Depending on the type of joint used between lengths of tubing it may be necessary to partially backfill the ditch to hold the tubing in place during testing. If this is done the partial backfill should be on the body of the tubing, but not at the joints. Thrust blocks or anchors should be used at line ends or bends in the line where necessary.

TESTING

Testing the pipe should be accomplished before backfilling. The pipe should be filled with water taking care to bleed the air and slowly build up the pressure to the maximum working pressure, The pipeline should be walked and all leaks repaired before proceeding with backfill. Pipelines should be tested at the working pressure.

It should be demonstrated that all pipelines function properly at design capacity. At or below design capacity there should be no objectionable surge or water hammer. To be objectionable there will be either (1) continuing, unsteady delivery of water, (2) damage to the system, or (3) detrimental overflow from vents, stands, or valves.

BACKFILLING

The initial backfill should be of selected material free from rocks, stones or hard clods. This initial fill should be compacted firmly around the pipe to achieve a soil density equal to or exceeding the natural density of the undisturbed sidewalls of the trench. Care must be taken to avoid deformation or displac · ment of the pipe during this phase of the operation.

When water packing is used the pipeline should be of sufficient depth to insure complete coverage of the pipe after consolidation has taken place.

When water packing is used the pipeline should be filled with water. The initial backfill, before wetting, should be of sufficient depth to insure complete coverage of the pipe after consolidation has taken place.

Water packing is accomplished by adding water in such quantity to thoroughly saturate the initial backfill without inundation. After saturation, the valves should be closed and the pipeline should remain full untill final backfill is made.

The wetted fill should be allowed to dry until firm before final backfill is begun.

Final backfill material should be free of large rocks or boulders, and should be added to the trench in a manner that will leave the fill at ground level after settling.

Any special requirements of the pipe manufacturer should be strictly observed.

CORROSION PROTECTION

All aluminum tubing installed under this guide should be wrapped with a plastic tape for corrosion protection in accordance with the following standard :

1. **Tubing exterior-surface protection.** The surface of the tubing to be coated should be cleansed of all foreign material such as oil, grease, dirt, mud, etc. Any knurls, burrs, or other sharp points should be removed by filing, peening, or wire brushing.

2. **Coating.** The coating that is applied to the tubing should be of a plastic or rubber type material, or both, capable of withstanding the moisture and soil conditions to which it will be subjected on buried aluminum tubing.

   The plastic tape, or combination of plastic tape and other materials used to aid in protecting the tubing and bonding the plastic tape to the tubing should have the minimum physical and electrical properties listed under "Quality of Tape and Bonding Agent," Table 21.

PLASTIC COATING OF FITTINGS AND CONNECTIONS

Where possible, fitting should be coated at a fabricating shop in such a manner as to provide a uniform intimately bonded coating allowing no voids or bridging of coating to metal surface. The surface preparation and the coating materials employed should conform to the minimums set forth under "Corrosion Protection."

Contours or offsets occurring in pipe or fittings of such a magnitude so as to cause "bridging" of the tape coating should be prepared in the following manner :

1. Clean and prepare metal surface as specified under "Corrosion Protection".

2. Prime entire surface to be coated allowing no skips or voids.

3. Wrap with molding or filler tape in manner prescribed by manufacturer of such tape or apply a filler compound to the irregular surface and overwrap with tape. In all cases, primer, molding tape, and filler compound should be compatible and recommended by those manufacturers with whose products they are employed.

FIELD WRAPPING OF JOINTS

Clean and prepare metal surface as prescribed. Remove sufficient overwrap to allow for a minimum of 50.8 mm (2-inch) overlap onto the "inplace" coating. Remove any scuffed or loosely bonded coating material.

Prime entire surface to be coated including the 50.8 mm (2-inch) area of "inplace" coating

Beginning with a "square" or perpendicular wrap, spirally wrap the entire primed area maintaining firm tension and overlap as recommended by the manufacturer. In any case, overlap should not be less than 12.70 mm (1/2-inch) ending with a "square" or perpendicular wrap. Tape should be applied free of voids, folds, or wrinkles.

Where irreqular contours or offsets are encountered that are condusive to "bridging" of the coating to the metal, thereby preventing an intimate voidfree bond, the techniques set forth under "Plastic Coating of Fittings and Connections" should apply.

INSPECTION

After final assembly of the line and taping of the joints and connections, the entire system should be visually inspected for breaks or ruptures in the plastic coating. All breaks or ruptures should be marked and repaired in the following manner :

1. Remove overwrap (if necessary) from the area adjacent to the damage.
2. Trim off scuffed or broken material and brush on a thin film of primer over damaged area and about 50.8 mm (2-inches) beyond, 'onto the undamaged tape. Apply a patch cut to fit the entire primed area. Smooth into place without wrinkles.

The continuity of the plastic coating should be of such quality that all tubing, joints and fitting, after assembly should be capable of passing an inspection test conducted with a spark discharge holiday detector at 1500 volts.

MARKING

Each pipe section should be plainly marked, after wrapping, with the manufacturer's symbol or name, size of pipe, wall thickness and working pressure or class.

MATERIAL STANDARDS

QUALITY OF ALUMINUM TUBING

The tubing should be rigid and composed of aluminum alloys that contain properties and characteristics found suitable for irrigation service by the Sprinkler Irrigation Association (SIA) and the American Society of Agricultural Engineers (ASAE), "Minimum Standards for Irrigation Equipment," approved January 1957.

All alloys used for buried irrigation lines should be clad on the inside of the tubing with an alloy which is anodic to the base alloy to a thickness of at least five percent of the nominal wall thickness of the tubing.

Tubing with nominal wall thickness as listed in column A of Table 20 should be acceptable for all installations where the operating pressure does not exceed 150 psi (10.55 kg/cm^2). The minimum permissible wall thickness of the tubing and the associated maximum permissible working pressures are given in Column B of Table 20. Should tubing be used with wall thickness between the range listed for the pipe size, the maximum working pressure should not exceed that obtained by the equation as shown under Working Pressure on page 116.

TABLE 20

Tube Diameter Inches	Column A: Nominal Wall Thickness, inches Acceptable All Installations to 150 psi working pressure	Column B: Min. Wall Thickness & Assoc. Maximum Working Pressure	
		Inches	Psi
2	.050	.05	150
3	.050	.05	150
4	.050	.05	150
5	.052	.05	150
6	.058	.05	125
7	.064	.05	108
8	.072	.05	94
9	.082	.058	97
10	.094	.058	87
12	.110	.058	73

In cases where tubing six inches and larger in diameter having a wall thickness less than specified in Column A of Table 20 is buried the installer should take all necessary precautions for proper bedding and backfilling of the tubing, as specified in the section on "Back-filling" to prevent damage and partial or complete collapsing of the tubing. In addition adequate safeguards should be taken to prevent negative pressures from causing collapse of the tube under normal service conditions.

TABLE 21

Quality of Tape and Bonding Agent

Minimum Physical Properties

For the Applied Thickness of Plastic Corrosion Preventive Tape

Test Description	Test Method
1. Minimum plastic or plastic and bonding adhesive agent, applied thickness, inches - 0.010	ASTM D1000
2. Breaking strength, lb/in width - 20	ASTM D1000
3. Elongation of plastic coating at break percent - 50 - 300	ASTM D1000

Continued

4. Adhesion to aluminum, oz/in - 22	ASTM D1000
5. Tear test	
Machine direction, lbs. - 4	ASTM D1004
Cross direction - lbs. - 4	ASTM D1004
6. Dielectric Breakdown	
After standard conditions, volts - 7000	ASTM D1000
After water immersion, volts - 6000	ASTM D1000
7. Resistance to impact, cm. - 60	See page 432-A-11
8. Puncture resistance, lbs. - 8.0	See page 432-A-11
9. Salt water resistivity, ohm/ft - 2 x 10^{11}	See page 432-A-12
10. Resistance to abrasion, milligrams - max. 300	See page 432-A-12

Test Methods

RESISTANCE TO IMPACT

Apparatus—The following apparatus shall be required :

1. A steel ball bearing with a diameter of 1-3/8 inches weighing 173.5 ± 1.0 grams
2. A suitable device to release the ball in free-fall.
3. A solid steel plate at least 2 inches by 2 inches by 1/2 inch on which the specimen is placed.
4. A steel roller (See ASTM-D1000, Section 35 (c).
5. An ohmeter.
6. An electrolytic (saturated) solution of cupric chloride in butyl-cellosolve.

TEST PROCEDURE AND RESULTS

A-2-inch by 2-inch specimen shall be placed adhesive side down on the steel plate and the roller passed over it once in each direction at a rate of approximately 2 inches per second. The steel ball shall be droped from 60 cm. on the 10 mil specimens and from 145 cm. on the 20 mil specimens. A few drops of the electrolytic solution shall be applied to the indentation and one of the probes of the ohmeter placed in the solution and the other probe on the steel plate. A puncture occurs if the ohmeter reads 50 megohms or less. Six of ten ball drops must not puncture at specified drop heights in order to pass this test.

PUNCTURE RESISTANCE

Apparatus—The following apparatus shall be required :

1. A cross-head type testing machine which conforms to Section 35a of ASTM D-1000 and is capable of a speed of two inches per minute.
2. A test fixture shown in Figure 54. (at page 119)

TEST PROCEDURE AND RESULTS

Five 1-inch by 3-inch specimens shall be prepared from each 1-inch roll. The testing machine shall be zeroed to compensate for the weight and frictional drag of the test fixture. The specimen shall be placed adhesive side down over the hole in the lower fixture and securely clamped with the clamping device provided. The driven jaw shall move at a rate of two inches per minute. The force required to puncture the specimen shall be recorded in pounds. The average of five tests shall be reported as the puncture resistance.

SALT WATER RESISTIVITY

Apparatus—The following apparatus shall be required :

1. A 10-inch by 13-inch sheet of #20 gage sheet metal.
2. Six pint cans with covers—L.D. Approximately 3.25 inches.
3. Four 1 1/2 volt #6 dry cells.
4. A short circuit jack box containing six circuit jacks.
5. One and one-half pints saturated NaCI solution.
6. An electrometer with appropirate shunt to measure 10^{-3} to 10^{-3} amps.
7. Roller, sealing material, and miscellaneous wire, solder, etc.

TEST PROCEDURE AND RESULTS

Two 4-inch by 13-inch specimens shall be placed adhesive side down on the 10-inch by 13 inch sheet. A roller shall be passed over the specimens untill all air is excluded. The bottoms shall be removed from the pint cans. Three cans shall be evenly spaced bottom side down on each specimen and sealed to the surface of the specimen. The four dry cells shall be connected in series. The 10-inch by 13-inch sheet shall be connected to the negative terminal of the battery bank. Each pint can shall be connected to the positive terminal of the battery bank through a short circuit jack so that an ammeter can be inserted into each individual circuit without interrupting the current flow. Each can shall then be filled 1/4 full with saturated salt solution and the can cover placed on the can to prevent evaporation. The resistivity of the coating in ohms-ft. shall be determined after 15 weeks by measuring the current flowing to each can. The current shall be measured by inserting the electrometer and shunt into the circuit for each can using the short circuit jacks. The resistivity of each sample shall be calculated according to the following formula:

Resistivity (ohm-ft.)

$$= \frac{\text{(Voltage applied in volts) (Area in ft.}^2\text{)}}{\text{(Current in amperes) (Thickness in ft.)}}$$

The average of the six determinations shall be reported as the salt water resistivity.

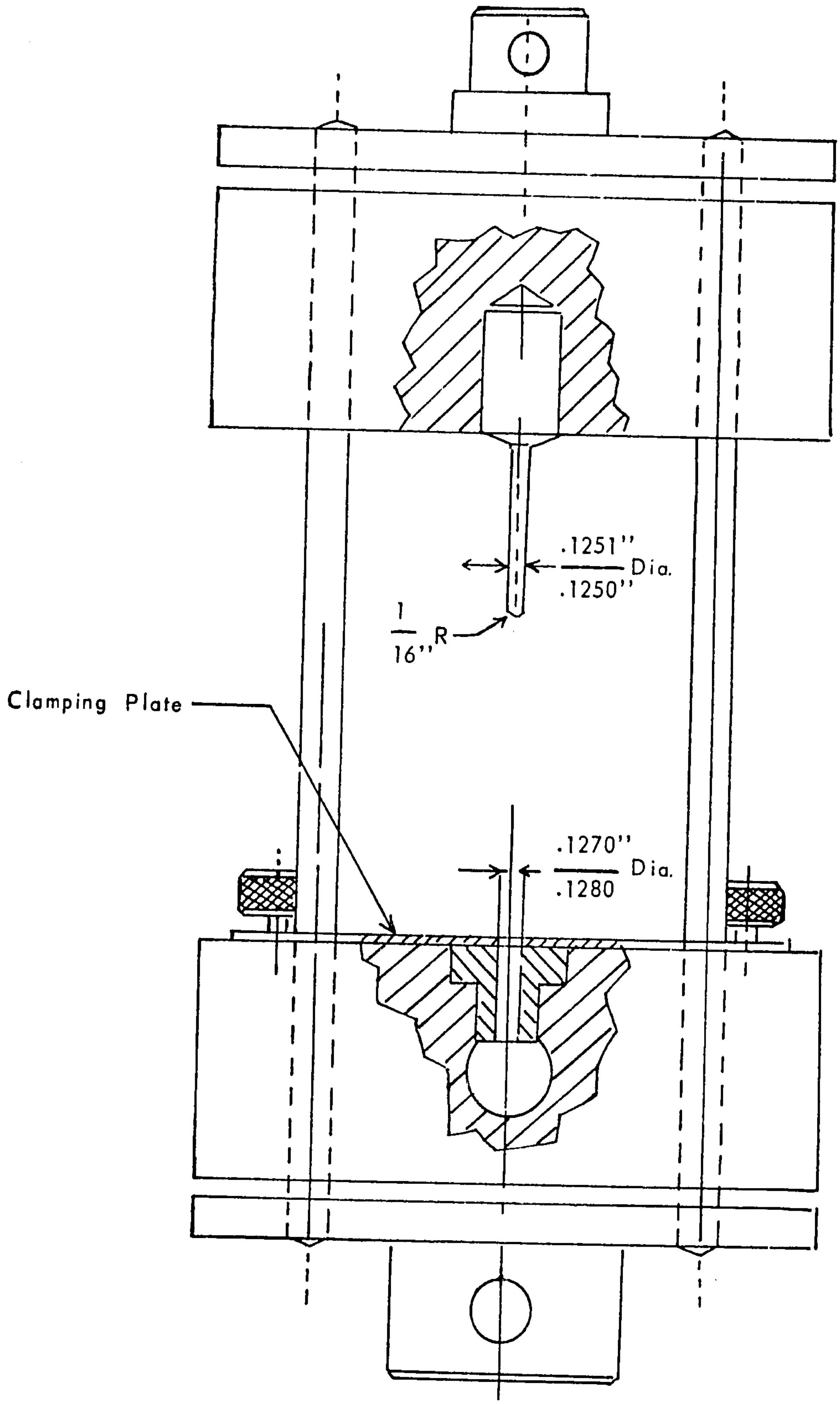
RESISTANCE TO ABRASION

Apparatus—The following apparatus shall be required :

1. Taber abraser, model 140, and parts or equivalent.
2. Analytical balance.
3. A steel roller (See ASTM D-1000, Section 35 (c)..

TEST PROCEDURE AND RESULTS

An approximate 4-inch by 4 inch 2-ply specimen shall be placed adhesive side down to cover the flat specimen plate and the steel roller passed over it once in each direction at a rate of approximately two inches per second. The specimen plate with the attached 2-ply specimen shall be weighed on an analytical balance to the nearest milligram and then placed in the Taber abraser. The abraser wheels covered with fresh NEMA sandpaper strips and loaded at 1000 grams per wheel, shall abrade the specimen for 400 cycles. The specimen plate shall be reweighed to the nearest milligram. The weight loss in milligrams shall be reported as Abrasion Resistance.



PUNCTURE RESISTANT TEST UNIT

Note: Dimensions in inches

Asbestos Cement Pipe

SCOPE

This standard applies to buried asbestos-cement pipelines with rubber gasket joints.

DESIGN CRITERIA

PRESSURE

The maximum design working pressure should be based on a safety factor of no less than 3.0 applied to the certified hydrostatic proof pressure. Hydrostatic test pressures for standard working pressure classifications should be as specified in Table 22.

The minimum acceptable working pressure classification should be 1.05 kg/cm^2 (15 p. s. i.) (Refer to Tables 22, 23, and 24 for minimum physical requirements for Class 15[1] pipe.)

EXTERNAL LOAD LIMIT

A safety factor of at least 1.50 should be applied to the certified 3-edge bearing test in computing allowable heights of fill over the pipe.

CAPACITY

Design capacity should be based on the following, whichever is greater :

1. The capacity should be sufficient to deliver the volume of water needed to meet the peak consumptive use of the crop.
2. The capacity should be sufficient to provide an adequate irrigation stream for all planned methods of irrigation.

FRICTION LOSS

For design purposes, the pipeline friction loss should be no less than that computed by the Hazen-Williams using a roughness coefficient, C_1, of 140.

PRESSURE RELIEF, VACUUM RELEASE AIR RELEASE, AND CHECK VALVES

A check valve should be installed between the pump discharge and the pipeline where detrimental backflow may occur.

A pressure relief valve should be installed at the pump location when excessive pressures can be developed by operating with all valves closed. Also in closed systems where the line is protected from reversal of flow by a check valve and excessive surge pressures could be developed, a surge chamber or pressure relief valve should be installed.

Pressure relief valves should be no smaller than 6.35 mm nominal size for each 25.4 mm of diameter (1/4 inch nominal size for each diameter inch) of the pipeline, and should be set at a maximum of 0.35 kg/cm^2 (5 p. s. i) above the pressure rating of the pipe.

Pressure relief valves or surge chambers

1. These are United States classes of asbestos cement pipe. Presently, no equivalent pipe is being made in India.

should be installed at the end of the pipeline when needed to relieve surge.

Air release and/or vacuum release valves should be placed at all summits in the pipeline and at the end of the line when needed to provide a positive means of air entrance or escape.

Air release and vacuum release valve outlets of at least 12.7 mm (1.1/2 inch) nominal diameter should be used in lines of 101.6 mm (4 inch) diameter or less, at least 25.4 mm (1—inch) outlets in lines of 127—0 to 203—2 mm (5 to 8 inch) diameter, and at least 50.8 mm (2-inch) outlets in lines of 254.0 to 406.4 mm (10 to 16 inch) diameter. Where open stands or vents are used in lieu of valves, the criteria for these structures as specified for non-reinforced concrete irrigation pipelines should be applied.

All pipeline systems using class 15 pipe should be open to the atmosphere.

DRAINING AND FLUSHING REQUIREMENTS

Provisions should be made for draining the pipeline completely where a hazard is imposed by freezing temperatures or drainage is specified for the job.

Where provisions for drainage are required, drainage outlets should be located at all low places in the line. These outlets may drain into dry wells or to points of lower elevation. If drainage cannot be thus provided by gravity, provisions should be made to empty the line by pumping.

A suitable valve should be installed at the distal end of the line when flushing to remove sediment is required.

OUTLETS

Appurtenances to deliver water from a pipe system to the land, a ditch, or any surface pipe system shall be known as outlets. Outletsshould have a capacity to deliver the required flow :

1. To the hydraulic gradeline of a pipe or ditch.
2. To a point at least 152.4 mm (6 inches) above the field surface.
3. To an individual sprinkler or lateral line at the design operating pressure of the sprinkler or lateral line as the case may be.

THRUST CONTROL

Abrupt changes in pipeline grade, horizontal alignment, or reduction in size require an anchor or thrust blocks to absorb any axial thrust of the pipeline.

Where thrust blocks or anchors are used, they should be constructed of concrete or soil cement with at least one part cement to 12 parts soil of sandy loam or coarser texture. Thrust blocks should fill the space between the pipe and the undisturbed earth at the side of the trench on the outside of bends to the full height of the outside diameter of the pipe, should have a minimum thickness of 152.4 mm (6—inches) and a length in meters (feet) perpendicular to the direction, of thrust equal to :

(98 HD Sin 1/2 a)/B—British Units
(1595 HD Sin 1/2 a)/B—Metric Units

Where :

H=maximum working head in meters (feet)

D=inside diameter of the pipe in meters (feet)

B=allowable passive pressure of the soil in kg/m^3 (pounds per square foot), and

a=deflection angle of the pipe bend

CONSTRUCTION GUIDE

PLACEMENT

All pipe should be placed deep enough below the land surface to protect it from hazards imposed by traffic crossings, farm operations, freezing temperatures, or soil cracking. 0.61 meters (two feet) minimum cover should be provided except in soils subject to deep cracking where the cover should be a minimum of 0.91 meters (three feet). Extra fill may be placed over the pipeline to provide the minimum depth of cover if the top width of fill is not less than 3.05 meters (ten feet) and the side slopes are not steeper than six to one.

Where trenches are excavated in soils containing rock or other hard materials, where soils are subject to appreciable swelling and shrinking on wetting and drying, or where the trench bottom is unstable, the trenches should be over-excavated and backfilled with selected materials as needed to provide a suitable base. If water is in the trench, that water should be drained away, and laying the pipe postponed untill a suitable base has been obtained.

The pipe trench should be reasonably straight. The maximum deflection in any one coupling should not exceed five degrees for pipe sizes up to 304.8 mm (12-inches) and three degrees for larger sizes. Short radius curves may be introduced into the alignment by using short sections of pipe and giving each coupling no more than the maximum allowable deflection.

All class 15 pipelines should have a minimum cover of earth of 0.76 meters (two and a half feet) and a maximum cover of 1.22 meters (4-feet). The trench width for installations involving class 15 pipe should be no wider than the pipe diameter plus 457.2 mm (18-inches).

TESTING

Pipelines should be tested for leaks by observing their normal operation any time after the contractor has installed all appurtenances on the pipeline and indicated the pipeline as ready for testing.

The line should be inspected in its entirety while the maximum working pressure is maintained. All visible leaks should be promptly repaired and the line re-tested.

It should be demonstrated by testing that the pipeline will function properly at design capacity. At or below design capacity there should be no objectionable surge or water hammer. To be objectionable there will be continuing unsteady delivery of water, damage to the pipeline, or detrimental discharge from control valves.

MATERIALS STANDARD

PIPE AND COUPLINGS

Asbestos-cement irrigation pipe should be composed of an intimate mixture of Portland Cement or of Portland Blast Furnace Slag Cement or of Portland-Pozzolan Cement, silica and asbestos fiber and should be formed under pressure and thoroughly cured to produce pipe meeting the requirements of these standards.

Coupling sleeves should be made of asbestos cement and should be machined with rubber ring retaining grooves so that when the joint is asssembled a water-tight seal is provided. Assembly of pipe and coupling should provide necessary end separation.

Asbestos cement *pressure* pipe (ASTM C296) in the United States, is classified in accordance with its pressure class, e. g. 100, 150 and 200. Asbestos-cement *irrigation* pipe is classified in accordance with its allowable maximum operating pressure. The four pressure class designations are 15, 25, 75, and 125.

Each standard, random, or short length of pipe and coupling sleeve should by hydrostatically tested by the manufacturer prior to shipment and should have sufficient strength to withstand the internal hydrostatic pressure prescribed in Table 22 when tested in accordance with Section 4 of ASTM C 500 or an equivalent standard.

Each length of pipe in sizes three inches (65.2 mm) through eight inches (203.2 mm) should have sufficient flexural strength to withstand, without failure, the total load prescribed in Table 23, when tested in accordance with Section 7, ASTM C 500 or an equivalent standard.

Asbestos cement pipe should have a minimum crushing strength as indicated in Table 24, when tested in accordance with the crushing test as specified in Section 10 of ASTM C 500 or an equivalent standard. Each length of pipe should be marked with the manufacturer's identification, nominal size, maximum working pressure, and date of manufacture. Each coupling should be marked with the manufacturer's identification, nominal size, and letter "T" to indicate that it has been hydrostatically tested.

GASKETS

The rubber ring gaskets required for proper assembly of pipe and coupling should conform to the manufacturer's dimensions and tolerances. They should equal or exceed the specifications for gaskets in ASTM D 1869 or equivalent standards.

ACCESSORIES

The valves, asbestos-cement or metal fittings etc., should be of adequate capacity and suitable quality to withstand the design pressures and should be installed in accordance with the manufacturer's recommendation to meet the service requirements of the pipeline.

CERTIFICATION AND GUARANTEE

All materials should conform to these minimum requirements and to the tests prescribed in the applicable ASTM Specification or equivalents standard.

The pipe should be certified by the manufacturer for compliance with this standard.

TABLE 22

Applied Hydrostatic Proof Pressures

Working Pressure Classification p. s. i.	Applied Pressure p. s. i.	Size Inches
15# I.P.*	45	3-16
25# I.P.*	75	3-36
75# I.P.*	225	3-36
125# I.P.*	375	3-36
Class 100	350	3-36
Class 150	525	3-36
Class 200	700	3-36

*I. P.—Irrigation Pipe

TABLE 23
Minimum Flexural Strength
Total Applied Load Lbs.

Nominal Size Inches	Working Pressure Classification: Irrigation pipe 15	25	75	125	Class 100	Class 150	Class 200
3	500	300	500	750	755	835	915
4	1000	600	1000	1300	1200	1460	1860
5	1500	900	1500	2000			
6	2000	1300	2000	3300	2800	3700	4900
8	3000	2500	3700	6000	5330	7600	10130

Note : Based on 9-foot span for all sizes - See ASTM C 500, Section 7

TABLE 24
Minimum Crushing Strength
Lbs. Per Lineal Foot

Nominal Size Inches	Working Pressure Classification: 15	Irrigation pipe 25	75	125	Class 100	Class 150	Class 200
3	1500	1500	2300	4400	4600	6700	8800
4	1100	1100	1900	4200	4100	5400	8700
5	1000	1000	1650	4000			
6	1000	1000	1400	3700	4000	5400	9000
8	1200	1300	1650	4000	4000	5500	9300
10	1200	1500	1900	4300	4400	7000	11000
12	1200	1500	2200	4600	5200	7600	11800
14	1200	1500	2600	5000	5200	8600	13500
16	1400	1500	2750	5400	5800	9200	15400
18	1500	1800	2900	5800	6500	10100	17400
20	1800	2000	3100	6500	7100	10900	19400
24	2000	2400	3500	7500	8100	12700	22600
30	2400	3000	4100	9000	9700	15900	28400
36	3000	3600	500	10500	11200	19600	33800

Note : Required loads for other than standard pressure classes can be interpolated.

High Pressure Underground Plastic Pipe

SCOPE

This standard applies to underground pipelines constructed of thermoplastic pipe that are closed to the atmosphere, and are subject to internal pressures up to 22 1 kg/cm² (315 pounds per square inch). This standard covers the design criteria for high pressure irrigation pipelines, the minimum installation requirements for plastic pipelines 25.40 to 304.8 mm (one to 12 inches) in diameter and the standards for the thermoplastic pipe to be used.

DESIGN CRITERIA

WORKING PRESSURE

The pipeline should be designed in such a manner that the maximum working pressure in the line does not exceed the water pressure rating shown in Table 25 for the type and grade of compound used in manufacture of the pipe and for the selected standard dimension ratio (SDR). Pipe having a water pressure rating less than 3.52 kg/cm² (50 pounds per square inch) should not be used.

SOLVENT WELDED JOINTS

The maximum standard dimension ratio for solvent welded thermoplastic pipe should be SDR 26 for 63.50 mm (2 1/2 inch) diameters and smaller, and for larger sizes the minimum wall thickness should be 24.89 mm (0.098 inch).

CAPACITY

The design capacity of the pipeline should be based on which ever of the following criteria is the greater :

1. The capacity should be sufficient to deliver the volume of water required to meet the peak-period consumptive use of the crop or crops to be irrigated.
2. The capacity should be sufficient to provide an adequate irrigation stream for all methods of irrigation planned.

FRICTION LOSSES

For design purposes, friction head losses should be no less than those computed by the Hazen-Williams equation using a roughness co-efficient, CT, equal to 150.

OUTLETS

Such appurtenances as are required to deliver water from the pipeline to an individual sprinkler or to a lateral line of sprinklers or surface pipe located on the ground surface shall be known as outlets. Outlets should have a capacity adequate to deliver the design flow to an individual sprinkler, or to a surface lateral line of sprinklers or surface pipe at the design operating pressure of the sprinkler or lateral line or surface pipe as the case may be.

CHECK VALVES, PRESSURE RELIEF, VACUUM RELEASE, AND AIR RELEASE DEVICES

A check valve should be installed between the pump discharge and the pipeline where detrimental backflow may occur.

A pressure relief valve should be installed between the pump discharge and the pipeline when excessive pressures can be developed by operating with all valves closed. Also in closed systems where the line is protected from reversal of flow by a check valve and excessive surge pressures could be developed, a surge chamber or a pressure relief valve should be installed.

Pressure relief valves or surge chambers should be installed at the end of the pipeline when needed to relieve surge at the end of the line. Pressure relief valves should be no smaller than 6.35 mm nominal size for each 25.4 mm of diameter (1 1/4 inch nominal size for each diameter inch) of the pipeline, and should be set at a maximum of 0.35 kg/cm^2 (five psi) above the pressure rating of the pipe. Air release and/or vacuum release valves should be placed at all summits in the pipeline and at the end of the line when needed to provide a positive means for air entrance or air escape.

Air release and vacuum release valve outlets of at least 12.70 mm (1/2 inch) nominal diameter shall be used in lines of 101.6 mm (four inch) diameter or less, at least 25.4 mm (one inch) outlets should be used in lines of 127.0 to 203.2 mm (five to eight inch) diameter, and no smaller than 50.8 mm (two inch) outlets should be used in lines of 254.0 to 304.8 mm (ten to 12 inch) diameter.

DRAINING AND FLUSHING REQUIREMENTS

Provisions should be made for draining the pipeline completely where a hazard is imposed by freezing temperatures, drainage is recommend by the manufacturer of the pipe, or drainage of the line is specified for the job for any reason. Where provisions for drainage are required, drainage outlets should be located at all low places in the line and air inlets provided at summits to prevent the development of negative pressures. These outlets may drain into dry wells or to points of lower elevation. If drainage cannot be thus provided by gravity, provisions should be made to empty the line by pumping.

Where provisions are needed to flush the line free of sediment, a suitable valve should be installed at the distal end of the pipeline.

CONSTRUCTION GUIDE

JOINTS AND CONNECTIONS

All joints and connections should be constructed to withstand the design maximum working pressure for the pipeline without leakage and should leave the inside of the line free of any obstruction that may tend to reduce its capacity below design requirements.

All fittings, such as couplings, reducers, bends, tees and crossings should be made of material that is recommended for use with pipe and should be installed in accordance with the recommendations of the pipe manufacturer.

Where fittings made of steel or other metals subject to corrosion are used in the line, they should be adequately protected by wrapping with plastic tape or coating with high quality corrosion preventatives. Where plastic tape is used all surfaces to be wrapped should be thoroughly cleaned and then coated with a primer compatible with the tape prior to wrapping.

INSTALLATION REQUIREMENTS

The pipe should be allowed to come to within a few degrees of the temperature that it will have after complete covering prior to any backfilling beyond shading. The pipeline should be installed at sufficient depth below the ground surface to provide protection from hazards imposed by traffic crossing, farming operations, freezing temperatures, or soil cracking. The minimum depth of cover should be :

1. 457.2 mm (18 inches) for pipes 25.4 to 63.5 mm (one to 2 1/2 inches) in diameter.
2. 609.6 mm (24 inches) for pipes 76.2, 88.9, and 101.6 mm (3, 3 1/2, and 4 inches) in diameter.
3. 762.0 mm (30 inches) for pipes 127 mm (five inches) in diameter or larger.

At low places on the ground surface, extra fill may be placed over the pipeline to provide the minimum depth of cover. In such cases, the top width of the fill should be no less than 3.05 meters (ten feet) and the side slopes no steeper than six horizontal to one vertical.

Where rock, hardpan, boulders or any other material which might damage the pipe are encountered, the trench should be undercut a minimum of 101.6 mm (four inches) below final grade. The material used to establish final grade should be sand or fine graded stable soil.

TESTING

The pipeline should be thoroughly and completely tested for pressure strength and leakage before backfill operations are undertaken. The line should be filled with water, taking care to bleed all entrapped air in the process. The pressure should be slowly built up to the maximum design working pressure. The line should be inspected in its entirety while the maximum working pressure is maintained. Where leaks are discovered they should be promptly repaired and the line should be retested. In some cases it may be necessary to partially backfill the line before testing in order to hold the line in place. Where such is the case, the partial backfill should be undertaken in accordance with the provisions specified under Backfilling, covering only the body of the pipe sections and leaving all joints and connections uncovered for inspection purposes.

It should be demonstrated by testing that the pipeline will function properly at design capacity. At or below design capacity, there should be no objectionable surge or water hammer. To be objectionable, there will be continuing unsteady delivery of water, damage to the pipeline, or detrimental overflow from control valves.

BACKFILLING

The pipe should be uniformly and continuously supported. Blocking or mounding not be used to bring the pipe to final grade. The initial backfill should be of selected material free from rocks, stones, or clods greater than approximately 12.7 mm (½ inch) in diameter. The initial fill should be compacted firmly around and above the pipe to achieve a soil density equal to or exceeding the natural density of the undisturbed sidewalls of the trench. Care should be taken to avoid deformation or displacement of the pipe during this phase of the operations.

When water packing is used, pipeline should be of sufficient depth to insure complete coverage of the pipe after consolidation has taken place. Water packing is accomplished by adding water in such quantity as to thoroughly saturate the initial backfill without inundation. After saturation, the valves should be closed and the pipeline should remain full untill final backfill is made. The wetted fill should be allowed to dry until firm before final backfill is begun.

The remainder of the backfill should be placed and spread in approximately uniform layers in such a manner as to completely fill the trench so that there will be no unfilled spaces in the backfill. Final backfill material should be free of rocks or boulders greatethan 76.2

mm (three inches) in diameter and should be added and compacted in a manner that will leave the fill at ground level after settlement has taken place. Rolling equipment should not be used untill a minimum of 457.2 mm (18 inches) of backfill material has been placed over the top of the pipe.

All special requirements of the manufacturer should be strictly observed.

Material Standards

QUALITY OF PLASTIC PIPE

The compound used in manufacturing the pipe should meet the requirements of one of the following materials :

1. **Polyvinyl Chloride** (PVC) as specified in ASTM D 1784. Type I, Grade I; Type I, Grade 2 ; Type II, Grade I or other equivalent standards.

2. **Acrylonitrile — Butadiene-Styrene** (ABS) as specified in ASTM D 1788. Type I, Grade 2 : Type II, Grade 1 or other equivalent standards.

3. **Polyethylene** (PE) as specified in ASTM D 1248. Type II, Grade 3 ; Type III, Grade 2 ; Type III, grade 3 or other equivalent standards.

The pipe should be homogeneous throughout and free from visible cracks, holes, foreign inclusion or other defects. The pipe should be as uniform as commercially practicable in color, opacity, density and other physical properties.

PIPE REQUIREMENTS

The wall thickness should be as determined by the standard dimension ratio (SDR) for a given allowable working pressure applicable to the type and grade of compound used in the manufacture of the pipe, as given in Table 25.

The pipe should meet the following requirements :

1. For IPS[1]/ sized pipe, all the applicable dimensional and quality requirements given in the Commercial Standards and/ or ASTM specification listed in Table 26 or other equivalent standards.

2. PIP[2]/ sized pipe, the dimensional requirements given in Table 27 and 28, and the requirements, with the exception of those concerned with outside diameters and wall thickness, of the applicable Commercial Standards and/ or ASTM specifications listed in Table 26 or other equivalent standards.

Table 25 and 26 should be considered revised to delete or to include additional plastic pipe materials as they are deleted or added to the applicable Commercial Standards and/or ASTM specifications listed in Table 26 or other equivalent standards.

FITTING REQUIREMENTS

Fittings for IPS-sized pipe should meet all the dimensional and quality requirements given in the following applicable ASTM specifications or other equivalent standards :

ASTM D 2464—PVC Fittings Threaded, Schedule 80

ASTM D 2465—ABS Fitings Threaded, Schedule 80

ASTM D 2466—PVC Fittings Socket, Schedule 40

ASTM D 2467—PVC Fittings Socket, Schedule 80

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[1] Outside diameter same as "Iron pipe sizes" (IPS)
[2] Plastic Irrigation Pipe

ASTM D 2468—ABS Fittings Socket, Schedule 40

ASTM D 2469—ABS Fittings Socket, Schedule 80

MARKING

The pipe should be adequately marked. Marking should include the following :

1. Tht nominal pipe size and the size system that applies (IPS or PIP): e.g., 4-IPS or 4-PIP.
2. The type of plastic pipe material in accordance with the designation code; e.g., PVC 1120.
8. The pressure rating in p.s.i. for water at 73.4 degrees F ; e. g., 200 p.s.i.
4. The commercial Standard or ASTM specification designation with which the pipe complies for IPS-sized pipe, or the designation PIP for pipe in this size system ; e.g., CS 256 or PIP.
5. The manufacturer's name (or trademark) and code.

BASIS OF ACCEPTANCE

The acceptability of the pipeline should be determined by inspections to check compliance with all the provisions of the standard with respect to the design of the line, the pipe and appurtenances used, and the minimum installation requirements.

CERTIFICATION AND GUARANTEE

All material should conform to these minimum requirements and to the tests prescribed in the applicable Commercial Standard or ASTM specification or other equivalent standards.

The pipe should be certified by a qualified testing laboratory for compliance with this Material Standard or equivalent standard.

SUPPLEMENT I

Requirements in addition to those in CS-256 or ASTM D 2241 for IPS—OD (outside diameter) pipe.

Wall thicknesses and tolerances for SDR 51 PVC plastic pipe.

Nominal Pipe Size	SDR 51	
	Minimum Wall	Tolerance
Inches	Inch	Inch
5	0.109	+0.020
6	0.130	+0.020
8	0.169	+0.020
10	0.211	+0.025
12	0.250	+0.030

Sustained pressure test conditions for water at 23 degrees C (73 degrees F) for SDR 51 PVC plastic pipe.

Standard Dimension Ratio	Pressure[1] required for test PVC 1120 PVC 1220 PVC 2120	PVC 2116	PVC 2112	PVC 2110
	psi	psi	psi	psi
SDR 51	170	135	115	90

[1] The fiber stresses used to derive these test pressures are as follows :

PVC 1120 — 4200 psi
PVC 1220 — 4200 psi
PVC 2120 — 4200 psi
PVC 2116 — 3360 psi
PVC 2112 — 2800 psi
PVC 2110 — 2300 psi

Some minor adjustments have been made to keep the test pressures uniform to simplify testing.

Burst pressure requirements for water at 23 degrees C (73 degrees F) for SDR 51 PVC plastic pipe.

Standard Dimension Ratio	Minimum burst pressures[1] PVC 1120 PVC 1220 PVC 2120	PVC 2116 PVC 2112 PVC 2110
	psi	psi
SDR 51	260	200

[1] The fiber stresses used to derive these test pressures are as follows :

PVC 1120 — 6400 psi
PVC 1220 — 6400 psi
PVC 2120 — 6400 psi
PVC 2116 — 5000 psi
PVC 2112 — 5000 psi
PVC 2110 — 5000 psi

Some minor adjustments have been made to keep the test pressures uniform so simplify testing.

TABLE 25

Water pressure rating in psi for various types, grades, and standard dimension ratios of non-threaded plastic pipes.

SDR[1]	PVC Materials				ABS Materials			PE Materials		
	PVC 1120 1120 2120	PVC 2116	PVC 2112	PVC 2110	ABS 1316	ABS 1210	ABS 1208	PE 3206 3306	PE 2306	PE 2305
7.0										125
9.0								125	125	100
11.5								100	100	80
13.5	315	250	200	160	250	160	125	80	80	63
17.0	250	200	160	125	200	125	100	63	63	50
21.0	200	160	125	100	160	100	80	50	50	
26.0	160	125	100	80	125	80	63			
32.5	125	100	80	63	100	63	50			
41.0	100	80	63	50	80	50				
51.0	80	63	50		63					

[1]SDR = Standard dimension ratio

SDR = Average outside diameter (inches) for PVC and ABS pipe
Minimum wall thickness (inches)

For solvent welded joints the following limitations will apply :

SDR 32.5 to be used only for 3-inch diameter or larger
SDR 41.0 to be used only for 3½ inch diameter or larger
SDR 51.0 to be used only for 5-inch diameter or larger

SDR = Average inside diameter (inches) for PE pipe
Minimum wall thickness (inches)

TABLE 26

(1) Compound	(2) Type	(3) Grade	(4) Hydrostatic Design Stress	(5) Designation	(6) IPS—sized pipe: Commercial Standard	(7) IPS—sized pipe: ASTM No.
PVC	I	1	2000 p.s.i.	PVC 1120	256	D 2241
PVC	I	2	2000 p.s.i.	PVC 1220	256	D 2241
PVC	II	1	1000 p.s.i.	PVC 2110	256	D 2241
PVC	II	1	1250 p.s.i.	PVC 2112	256	D 2241
PVC	II	1	1600 p.s.i.	PVC 2116	256	D 2241
PVC	II	1	2000 p.s.i.	PVC 2120	256	D 2241
ABS	I	2	1000 p.s.i.	ABS 1210	254	D 2282
ABS	I	3	1600 p.s.i.	ABS 1316	254	D 2282
ABS	I	2	800 p.s.i.	ABS 1208	254	D 2282
ABS	II	1	1250 p.s.i.	ABS 2112	254	D 2282
PE	II	3	500 p.s.i.	PE 2305	255	D 2239
PE	II	3	630 p.s.i.	PE 2306	255	D 2239
PE	III	2	630 p.s.i.	PE 3206	255	D 2239
PE	III	3	630 p.s.i.	PE 3306	255	D 2239

TABLE 27

Outside Diameters of Plastic Irrigation Pipe (PIP)

For ABS and PVC Pipe

Tolerance

PIP Size	Outside Diameter	For Average Measurements	For maximum and minimum: SDR 51, 41, 32.5 26, and 21	For maximum and minimum: SDR 17 and 13.5
inches	inches	inches	inches	inches
4	4.130	±0.009	±0.050	±0.015
6	6.140	±0.011	±0.050	±0.030
8	8.160	±0.015	±0.070	±0.042
10	10.200	±0.015	±0.075	±0.050
12	12.240	±0.015	±0.075	±0.060

TABLE 28

Wall Thickness of Plastic Irrigation Pipe (PIP)

Wall Thickness[1]

PIP Size	SDR 51		SDR 41		SDR 32.5	
	minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
inches	inches	inches	inches	inches	inches	inches
4	—	—	0.101	+0.020	0.127	+0.020
6	0.120	+0.020	0.150	+0.020	0.189	+0.023
8	0.160	+0.020	0.199	+0.024	0.251	+0.031
10	0.200	+0.024	0.249	+0.030	0.314	+0.031
12	0.240	+0.029	0.299	+0.036	0.377	+0.045

[1]The minimum is the least wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirements.

Wall Thickness

PIP Size inches	SDR 26		SDR 21		SDR 17		SDR 13.5	
	Min. inches	Tol. inches	Min. inches	Tol. inches	Min. inches	Tol. inches	Min. inches	Tol. inches
4	0.159	+0.020	0.197	+0.024	0.243	+0.029	0.306	+0.037
6	0.236	+0.028	0.292	+0.035	0.361	+0.043	0.455	+0.054
8	0.314	+0.038	0.389	+0.047	0.480	+0.058	0.604	+0.072
10	0.392	+0.047	0.486	+0.058	0.600	+0.072	0.756	+0.091
12	0.471	+0.056	0.583	+0.070	0.720	+0.086	0.907	+0.109

Low Head Underground Plastic Pipe

SCOPE

This standard applies to underground pipe lines constructed of thermoplastic pipe that are open to the atmosphere, and are subject to internal head pressures between 0 and 15.2 meters (0 and 50 feet) of water.

This standard covers the design criteria for low head thermoplastic irrigation pipelines, the minimum installation requirements for plastic pipelines 101.6 to 381.0 mm (4 to 15 inches) in diameter, and the standards for the thermoplastic pipe to be used.

DESIGN CRITERIA

WORKING PRESSURE

The pipeline should be designed in such a manner that the maximum working head in the line does not exceed 15.24 meters (50 feet) of water.

JOINTS

Any type of joining system that produces a watertight joint having adequate strength for satisfactory service may be used. There should be a minimum of 101.6 mm (4 inches) of overlap between the joint sleeve and the pipe or fittings for clamp type joints. Solvent welded joints should be made with fittings or bells with tapered type sockets. Bell (socket) end pipe or plastic fittings made from the same general type of plastic as the pipe should be used. The minimum overlap for solvent cemented bell end joints shall be 50 percent of the inside diameter of the pipe or 75.2 mm (3 inches), whichever is greater.

CAPACITY

The design capacity of the pipeline should be based on whichever of the following criteria is the greater :

1. The capacity should be sufficient to deliver the volume of water required to meet the peak-period consumptive use of the crop or crops to be irrigated.
2. The capacity should be sufficient to provide an adequate irrigation stream for all methods of irrigation planned.

FRICTION LOSSES

For design purposes, friction head losses should be no less than those computed by the Hazen-Williams equation using a roughness coefficient, Cc, equal to 150.

OUTLETS

Appurtenances to deliver water from the pipe system to the land, to a ditch, or to any surface pipe system shall be known as outlets. Outlets should have a capacity to deliver the required flow to the hydraulic grade line of a pipe or ditch or to a point at least 152.4 mm (6 inches) above the field surface.

STANDS

Stands should be used wherever water enters the pipeline to avoid entrapment of air, to prevent surge-pressures, to avoid collapse due to vacuum failure, and to prevent pressure from exceeding the design working stress of the pipe. Stands should be designed to :

1. Allow a minimum of 0.30 meter (1 foot) of freeboard. The stand height maximum above the centerline of the pipeline should not exceed the maximum working head of the pipe.

2. Have the top of each stand at least 1.22 meters (4 feet) above the ground surface except for surface gravity inlets which should be equipped with trash racks and covers.

3. Have downward water velocities in stands not in excess of 0.61 meters per second (2 feet per second). In no case should the inside diameter of the stand be less than the inside diameter of the pipeline.

The cross sectional area of stands may be reduced above a point 0.30 meters (1 foot) above the top of the upper inlet but in no case should the reduced cross section be such that it would produce an average velocity of more than 3.05 meters por second (10 feet per second) if the entire flow were discharging through it.

When the water velocity of an inlet pipe exceeds three times the velocity of the outlet, the centerline of the inlet should have a minimum vertical offset from the centerline of the outlet at least equal to the sum of the diameters of the inlet and outlet pipes.

Sand traps, when combined with a stand, should have a minimum inside dimension of 762.0 mm (30 inches) and should be constructed so that the bottom is at least 609.6 mm (24 inches) below the invert of the outlet pipeline. The downward velocity of flow of the water in a sand trap should not exceed 0.076 meters per second (0.25 feet per second). Suitable provisions for cleaning sand traps should be provided. Gate stands should be of sufficient dimensions to accomodate the gate or gates required and will be large enough to make the gates accessible for repair.

Float valve stands should be of sufficient size to provide accesibility for maintenance and to dampen surge.

Construction should be such as to insure that vibration from the pump discharge pipe is not carried to the stand.

VENTS AND AIR-VACUUM RELEASE VALVES

Open vents and/or air-vacuum release valves should be designed into the system to provide for the removal of air and to prevent vacuum collapse.

Open vents should have a minimum freeboard of 0.30 meters (one foot) above the hydraulic grade line. The maximum height of the vent above the centerline of the pipeline should not exceed the maximum working head of the pipe in millimeters (feet). These vents should have a cross-sectional area at least one-half the cross-sectional area of the pipeline (both inside measurements) for a distance of at least one pipeline diameter up from the centerline of the pipeline. Above this elevation the vent may be reduced to 50.8 mm (2 inches) in diameter. Air-vacuum release valves should be sized as follows :

Valve outlet size, minimum		Pipeline size	
mm	inches	mm	inches
50.8	2	101.6-152.4	4-6
76.2	3	177.8-254.0	7-10
101.6	4	304.8-381.0	12-15

Open vents and/or air-vacuum release valves should be located :

1. At the downstream end of each lateral.
2. At the summits in the line.
3. At points where there are increases in grade in direction of flow of more than ten degrees.
4. Immediately below the pump stand if the downward velocity in the stand exceeds 0.30 meters (one foot) per second.

DRAINING AND FLUSHING REQUIREMENTS

Provisions should be made for draining the pipeline completely where a hazard is imposed by freezing temperatures, drainage is recommended by the manufacturer of the pipe, or drainage of the line is specified for the job for any reason. Where provisions for drainage are required, drainage outlets should be located at all low places in the line. These outlets may drain into dry wells or to points of low elevation. If drainage cannot be thus provided by gravity, provisions should be made to empty the line by pumping.

Where provisions are needed to flush the line free of sediment, a suitable valve should be installed at the distal end of the pipeline. The pump discharge pipe should be equipped with a check valve where detrimental backflow can occur, or the pump discharge to the stand pipe should be at an elevation above the highest discharge point in the system.

CONSTRUCTION GUIDE

JOINTS AND CONNECTIONS

All joints and connections should be constructed to withstand the design maximum working pressure for the pipeline without leakage and should leave the inside of the line free of any obstruction that may tend to reduce its capacity below design requirements.

All fittings, such as couplings, reducers, bends, tees and crossings should be made of the material recommended for use with the pipe and should be installed in accordance with the recommendations of the pipe manufacturer.

Where fittings made of steel or other metals subject to corrosion are used in the line, they should be adequately protected by wrapping with plastic tape or coating with high quality corrosion preventatives. Where plastic tape is used, all surfaces to be wrapped should be thoroughly cleaned and then coated with a primer compatible with the tape prior to wrapping.

INSTALLATION REQUIREMENTS

The pipeline should be installed at sufficient depth below the ground surface to provide protection from hazards imposed by traffic crossing, farming operations, freezing temperatures, or soil cracking. 762.0 mm (30 inches) minimum cover should be provided except in soils subject to deep cracking where the cover should be a minimum of 944.4 mm (36 inches). The maximum depth of cover for all pipe sizes should be 1.22 meters (4 feet). At low places on the ground surface, extra fill may be placed over the pipeline to provide the minimum depth of cover. In such cases the top width of the fill should be no less than 3.05 meters (10 feet) and the side slopes no steeper than six horizontal to one vertical.

The width of the trench at any point below the top of the pipe should be no wider than is necessary to lay, join and backfill the pipe, and and in no event be more than 609.6 mm (24 inches) wider than the nominal diameter of the pipe.

Where rock, hardpan; boulders or any other material which might damage the pipe are encountered, the trench should be undercut a minimum of 101.6 mm (4 inches) below final grade. The material used to establish final grade should be sand or fine graded stable soil.

TESTING

The pipeline should be thoroughly and completely tested for pressure strength and leakage before backfill operations are undertaken. The line should be filled with water taking care to bleed all entrapped air in the process. The pressure should slowly build up to the maximum design working head of the system. The line should be inspected in its entirety while the maximum working head of the system is maintained. Where leaks are discovered they should be promptly repaired and the line should be re-tested. All leaks should be repaired before proceeding with backfill. In some cases, it may be necessary to partially backfill the line before testing in order to hold the line in place. Where such is the case, the partial backfill should be undertaken in accordance with the provisions specified under Backfilling, covering only the body of the pipe sections and leaving all joints and connections uncovered for inspection purposes.

It should be demonstrated by testing that the pipeline will function properly at system design capacity. At or below design capacity, there should be no objectionable surge or water hammer. To be objectionable, there will be continuing unsteady delivery of water, damage to the pipeline, or detrimental overflow from vents or stands.

BACKFILLING

The pipeline and stand pipes should be filled and maintained at the system design head pressures during the complete backfilling operation. The pipe should be uniformly and continuously supported. Blocking or mounding should not be used to bring the pipe to final grade. The initial backfill should be of selected material free from rocks, stones, or clods approximately greater than 12.7 mm (½ inch) diameter. Water packing should be used whenever possible. In instances where water packing is not possible, the initial fill should be compacted firmly around and above the pipe to achieve a soil density equal to or exceeding the natural density of the undisturbed sidewalls of the trench. Care should be taken to avoid deformation or displacement of the pipe during this phase of the operation.

When water packing is used, the pipeline should be filled with water. The initial backfill, before wetting, should be of sufficient depth to insure complete coverage of the pipe after consolidation has taken place. Water packing is accomplished by adding water in such quantity as to thoroughly saturate the initial backfill without inundation. After saturation, the valves should be closed and the pipeline shall remain full until final backfill is made. The wetted fill should be allowed to dry until firm enough to walk on before final backfill is begun.

The remainder of the backfill should be placed and spread in approximately uniform layers is such a manner as to completely fill the trench so that there will be no unfilled spaces in the backfill. Final backfill material should be free of rocks or boulders qreater than 76.2 mm (3 inches) in diameter and should be added and compacted in manner that will leave the fill at ground level after settlement has taken place. Rolling equipment should not be used until a minimum of 762.0 mm (30 inches) of backfill material has been placed over the top of the pipe.

MATERIAL STANDARD

PLASTIC PIPE

The materials used to make the pipe should meet all the requirements of the following applicable material specifications or other equivalent standards :

Polyethylene Plastic (PE)—ASTM D1248. Type III, Grade 2, and Type III, Grade 3.

Polyvinyl Chloride Plastic (PVC)—ASTM D1784 Type I, Grade I; Type I, Grade 2 ; and Type II, Grade I.

Acrylonitrile-Butadiene-Styrene Plastic (ABS) — ASTM D1788. Type I, Grade I, and Type I, Grade 2.

The pipe should meet the applicable dimensional requirements in Table 29 on the basis of the material selected.

In addition to the above, PVC pipe should meet the requirements of Sections 3(e), 5(a), 5(c), 5(f), 6(a), 6(b), 6(c), 6(g), and 6(h) of ASTM D224 or other equivalent standards where not in conflict with any of the requirements of this low head irrigation piping standard. The dimensions and tolerances should be measured in accordance with the procedures given in ASTM D2122 or other equivalent standards.

In addition to the above, PE pipe should meet the requirements of Sections 3(e), 5(a), 5(b), 5(d), 5(e), 6(a), 6(b), 6(c), 6(d), 6(e) and 6(f) of ASTM D2239 or other equivalent standards where not in conflict with any of the requirements of this low head irrigation piping standard.

In addition to the above, ABS pipe should meet the requirements of Sections 3(e), 5(a), 5(e), 6(a), 6(b), 6(c), and 6(g) of ASTM D2282 of the equivalent standards where not in conflict with any of the requirements of this low head irrigation piping standard. The dimensions and tolerances shall be measured in accordance with proceduse given in ASTM D2122 or other equivalent standards.

MARKING

The pipe should be marked with the following.

1. Type and grade of plastic material.
2. Nominal pipe size.
3. 15.24 meters (50 feet) head.
4. Manufacturers designation.

BASIS OF ACCEPTANCE.

The acceptability of the pipeline should be determined by inspections to check conformance with all the provisions of this standard with respect to the design of the line, the pipe and appurtenances used, and the minimum installation requirements.

CERTIFICATION AND GUARANTEE

The pipe shall be certified by the manufacturer for compliance with this standard.

Table 29

Dimensions of Low Head Plastic Irrigation Pipe

LH — PIP Nominal Size	Inside Diameter Minimum	Inside Diameter Tolerance	Wall Thickness, ABS and PVC Materials	Minimum PE Materials
inch	inch	inch	inch	inch
4	4.000	±0.020	0.065	0.085
6	6.000	±0.025	0.070	0.095
8	8.000	±0.040	0.080	0.120
10	10.000	±0.040	0.100	0.135
12	12.000	±0.040	0.120	0.155
15	15.000	±0.040	0.150	0.200

Steel Pipe

SCOPE

This standard covers the design and installation of buried steel irrigation pipelines and steel irrigation pipelines permanently installed on above-the-ground supports. It is restricted to pipelines not greater than 1219.2 mm (48 inches) in diameter, and does not apply to short pipes used in structures such as siphons, outlets from canals, and culverts under roadways.

DESIGN CRITERIA

WORKING PRESSURE

The pipeline should be designed to meet all service requirements without the use of a working pressure which will produce tensile stresses in the pipe greater than a design stress equal to 50 percent of yield point stress. Design stresses for commonly used steel and steel pipe classes are shown in column two of Table 30.

Table 30

Specification and Grade of Steel	Design Stress 50% Yield Point - psi
ASTM A 283	13,500
Grade B	15,000
Grade C	16,500
Grade D	
ASTM A 570	
Grade A	12,500
Grade B	15,000
Grade C	16,000
Grade D	20,000
Grade E	21,000
AWWA 0202	
Furnace	
butt weld	12,500
Grade A	15,000
Grade B	17,500
Grade X4[2]	21,000

NOTE : Equivalent standards can be used.

In computed tensile stresses in steel pipe, the following items should be considered :

1. The pressure in feet to be delivered at the end of the pipeline.
2. The friction head loss in meters (feet).
3. The elevation differential between the outlet and the inlet of the pipe in meters (feet).
4. Any pressure due to water hammer or surge which may be created by the closure of a valve in the pipeline.

FLOW CAPACITY

The design capacity should be based upon the following, whichever is greater :

1. Capacity to deliver sufficient water to meet the weighted peak consumptive use rate of the crops to be grown.
2. Capacity sufficient to provide an adequate irrigation stream for the methods of irrigation to be used.

MINIMUM WALL THICKNESS

Minimum pipe wall thickness should be as follows :

101.6 through 304 8 mm nominal diameter -1.887 mm less 12.5% (4" through 2" nominal diameter -14 gauge less 12.5%)

355.6 through 457.2 mm nominal diameter - 2.657 mm less 12.5% (14" through 18" nominal diameter - 12 gauge less 12.5%)

508.0 through 609.6 mm nominal diameter - 3.416 mm less 12.5% (20" through 24" nominal diameter - 10 gauge less 12.5%)

660.4 through 914.4 mm nominal diameter - 4.762 mm less 12.5% (26" through 36" nominal diameter - 3/16 inch less 12.5%)

965.2 through 1219.2 mm nominal diameter - 6.350 mm less 12.5% (38" through 48" nominal diameter -1/4 inch less 12.5%)

FRICTION LOSS

For design purposes the pipeline friction loss should be based on that computed with Manning's formula with "n" equal to no less than 0.012 for unlined pipe and no less than 0.010 for lined pipe.

CHECK VALVES, PRESSURES RELIEF, VACUUM RELEASE, AND AIR RELEASE VALVES

Where detrimental backflow may occur, a check valve should be installed between the pump discharge and the pipeline.

A pressure relief valve should be installed at the pump location when excessive pressure can be developed by operating with all valves closed. Also, in closed systems where the line is protected from reversal of flow by a check valve and excessive surge pressures could be developed, a surge chamber or pressure relief valve should be installed close to the check valve on the side away from the pump. Pressure relief valves should be no smaller than 6.35 mm nominal size for each 25.4 mm of diameter (1/4 inch nominal size for each diameter inch) of the pipeline, and should be set at a maximum of 0.35 kg/cm^2 (5 psi) above the safe working pressure of the pipeline.

A pressure relief valve or surge chamber should be installed at the end of the pipeline when needed to relieve surge.

Air release and/or vacuum release valves should be placed at all summits in the pipeline, at the end of the line, and between the pump and check valve when needed to provide a positive means of air entrance or escape.

Air release and vacuum release valve outlets should be at least 12.7 mm (½ inch) nominal diameter when specified for lines of 101.6 mm (4 inch) diameter or less at least 25.4 mm (one inch) outlets for lines of 127.0 to 203.2 mm (five to eight inch) diameter, at least 50.8 mm (two inch) outlets for lines of 254.0 to 406.4 mm (ten to 16 inch) diameter, at least 101.6 mm (four inch) outlets for lines of 457.2 to 711.2 mm 18 to 28 inch) diameter, at least 152.4 mm (six inch) outlets for lines of 762.0 to 914.4 mm (30 to 36 inch) diameter, and at least 203.2 (eight inch) outlets for lines of 965.2 to 1219.2 mm (38 to 48 inch) diameter. For pipelines larger than 406.4 mm (16 inch) diameter, 50.8 mm (two inch) air release valves may be used in place of the sizes indicated above if they are supplemented with vacuum release valves that will provide vacuum release capacity equal to the sizes shown.

DRAINING AND FLUSHING REQUIREMENTS

Provisions should be made for draining the pipeline completely where a hazard is imposed by freezing temperatures or drainage is specified for the job.

Where provisions for drainage are required, drainage outlets should be located at all low places in the line. These outlets may drain into dry wells or to points of lower elevation. If drainage cannot be provided by gravity, provisions should be made to empty the line by pumping.

OUTLETS

Appurtenances to deliver water from a pipe system to the land, to a ditch, or to a surface pipe system shall be known as outlets. Outlets should have capacity to deliver the required flow :

1. To a point at least 152.4 mm (six inches) above the field surface.
2. To the hydraulic gradeline of a pipe or ditch.
3. To an individual sprinkler, lateral line, or other sprinkler line at the design operating pressure of the sprinkler or line, as the case may be.

PIPE SUPPORTS

Irrigation pipelines placed above ground should be supported by suitably built concrete or timber saddles shaped to support the pipe throughout the arch of contact, which should be not less than 90° nor more than 120° as measured at the central angle of the pipe. Where needed to prevent overstressing, ring girder type supports should be used. Support spacing should be such that neither the maximum beam stresses in the pipe span nor the maximum stress at the saddle will result in stresses exceeding the design stress valves.

ANCHORS, THRUSTBLOCKS, AND EXPANSION JOINTS

For above-ground pipelines with welded joints, anchor blocks and expansion joints should be installed at spacings that will limit pipe movement due to expansion or contraction to a maximum of 40 percent of the sleeve length of the expansion coupling to be used. The maximum length of pipeline without expansion joint should be 152.4 meters (500 feet). Above-ground pipelines with rubber gasket type joints should have the movement of each pipe length restrained by steel hold down straps at the pipe supports or by anchor blocks in lieu of normal pipe supports.

Anchor blocks usually will not be required on buried pipelines.

Expansion joints should be installed as needed to limit stresses in the pipeline to the design values.

Thrust blocks should be required on both buried and above ground pipelines at all points of abrupt changes in grade, horizontal alignment, reduction in size. The blocks must be of sufficient size to withstand the forces tending to move the pipe, including those of momentum and pressure as well as forces due to expansion and contraction.

JOINTS AND CONNECTIONS

All connections should be designed and constructed to withstand the working pressure of the line without leakage and leave the inside of the pipeline free of any obstruction that would reduce the line capacity below design requirements. On sloping lines, expansion joints should be placed adjacent to and downhill from anchors or thrust blocks. Where cathodic protection is required, high resistance joints shall be bridged to insure continuous flow of current.

A dielectric connection should be placed between the pump and the pipeline and between pipes with different coatings.

CORROSION PROTECTION

Pipe Interior—Interior protective coatings should be provided where the pH of the water conveyed is 6.5 or lower.

Pipe Exterior—Underground Lines—All pipe exteriors should be provided with full protection against corrosion. Pipe-to-soil potentials from minus 0.85 volt to minus 1.00 volt referred to a copper/copper-sulfate reference electrode should be acceptable evidence of such protection. To meet protection requirements, all pipe should be coated and should be provided with supplementary cathodic protection as specified in Item 2 below.

1. **Criteria for Determining Class of Coating**

   Class A protection coating should be provided when the soil resistivity survey shows either (1) twenty percent or more of the total surface area of the pipeline will be in soil which has a resistivity of 1500 ohm/cm³ or less; or (2) ten percent or more of the total surface area of the pipeline will be in soil which has a resistivity of 750 ohm/cm³ or less. Class B coating should be provided for all other soil conditions.

2. **Cathodic Protection Requirements**

   Supplementary cathodic protection should be provided when the soil resistivity survey shown any portion of the pipeline will be in soil whose resistivity is less than 10000 ohm/cm³ and galvanized pipe is not used. The initial anode installation should be sufficient to provide protection for a minimum of 15 years. The total current required, the kind and number of anodes needed, and the expected life of the protection can be determined as shown below:

a. The total cathode current required can be computed from the formula :

$$I_t = C\frac{A_1}{R_{e1}} + \frac{A_2}{R_{e2}} + \text{— — — —} \frac{A_n}{R_{en}}$$

Where: I_t=total current requirement in ma

A=surface area of pipe in feet²

R_e=soil resistivity in ohm/cm³

C=a constant for a given pipe coating

For design purposes this constant should be considered to be not less than 32 for Class A coatings and not less than 60 for Class B coatings.

b. The kind of galvanic anode to be used is dependent upon the resistivity of the anode bed is :

(a) less than 2000 ohm/cm³ use either zinc anodes ;

(b) between 2000 and 3000 ohm/cm³ use either zinc or magnesium anodes ;

(c) between 3000 and 10000 ohm/cm³ use magnesium anodes

Anodes are not required on pipelines where soil resistivity is greater than 10000 ohm/cm³.

(c) The number of anodes needed to protect the pipeline can be computed by dividing the total cathode current requirements of the pipeline by the current output per anode.

Thus : $N = I_t/I_m$ and $I_m = k/R$

Where : N=number of anodes needed

I_t=total current requirement in ma

I_m=maximum anode current output in ma

K = constant for a given anode
R = soil resistivity of the anod-bed in ohn/cm[3]

d. The expected life of an anode, based on the use of 17 pounds per ampere year for magnesium and 26 pound per ampere year for zinc, can be computed follows :

Magnesium $Y = 58.8W/I_0$
Zinc $Y = 38.2W/I_0$

Where : Y = expected life in years
W = weight of anode in pounds
I_0 = design anode current in ma.

Note : If resistors are used to reduce anode current output in order to increase service life, the number of anodes required should be based on the regulated output of the anode rather than the maximum output, I_m.

3. **Soil Resistivity Determinations.** Preliminary soil resistivity measurements to determine coating requirements and the approximate amount of of cathodic protection needed may be made before the trench is excavated. For this purpose, field resistivity measurements can be made, or samples for laboratory analysis can be taken, at least every 121.9 meters (400 feet) along the proposed pipeline and at points where there is a visible change in soil characteristics. Where-ever a reading differs markedly from a preceding one, additional measurements should be taken to locate the point of change. Resistivity determinations should be made at two or more depths in the soil profile at each sampling station, the lowest depth to be the strata in which the pipe will be laid: The lowest value of soii resistivity found at each sampling station should be used as the design value for that station.

After the pipe trench is excavated, a detailed soil resistivity survey should be made as a basis for final design of the coating and the required cathodic protection. At this time resistivity measurements should be made in each exposed soil horizon at intervals not exceeding 60.910 meters (200 feet). The lowest value of soil resistivity found at each sampling station should be used as the design value for that station. Where design values for adjacent stations differ significantly, additional intermediate measurements should be made.

Pipe Exterior-Above Ground Lines—All pipe installed above ground should be galvanized or should be protected with a suitable protective paint coating, including a primer coat and two or more final coatings.

CONSTRUCTION GUIDE

PLACEMENT-BURIED PIPELINES

Pipe should be laid to the lines and grades as shown on the drawings and/or as staked in the field, and should be placed deep enough below the land surface to protect it from the hazards imposed by traffic crossings, farm operations, freezing temperatures or soil cracking. 0.61 meters (two feet) minimum cover should be provided except in soils subject to deep cracking where the cover should be a minimum of 0.91 meters (three feet). Where necessary to place the pipe at lesser depth, adequate protection should be provided by means of the placement of extra fill over the pipeline, by the use of a fence or other surface barrier, or by the use of extra heavy gauge pipe.

Where trenches are excavated in soils containing rock or other hard material that might damage pipe or coating material, the trenches should be excavated slightly deeper than required and then filled to grade with sand or fine earth.

Coated pipe should be handled so as to prevent abrasion of the coating during transportation and handling and during placement and backfilling of the pipeline. No pipe should be dropped from cars or trucks or allowed to roll down skids without proper restraining ropes. Each section of pipe should be delivered in the field as near as practicable to the place where it is to be installed. When stockpiled it should be neatly piled and blocked with strips between tiers. Where it is necessary to move the pipe longitudinally along the trench, it should be done in such a manner as not to injure the pipe or coating. Pipe should not be rolled or dragged on the ground. If the pipe is supported, as for welding, supports should be of sufficient width and number, and padded if necessary, to prevent damage to the coating.

PLACEMENT-ABOVE GROUND PIPELINES

Concrete, timber or other pipe supports and anchor and thrust blocks should be constructed at the locations and to the dimensions as shown on the drawings and/or as staked in the field. Saddles should be shaped to firmly support the pipe throughout the full arch of contact. At least two layers of felt strips should be placed between the pipe and its support. The felt should cover the entire area of contact between the pipe and the saddle. A graphite lubricant should be placed between the felt strips before the pipe is placed in the saddle.

JOINTS AND CONNECTIONS

Special field joints should be installed in strict accordance with the manufacturer's recommendations. On buried pipelines, high resistance joints between pipe lengths should be electrically bridged with a welded, brazed, or soldered copper wire not smaller than 4/0 gauge of a diameter of 10.0 mm in size. If coated pipe is field welded, special care should be taken to avoid burning the protective coating. After the joints have been welded, they should be covered with a coating equal in quality to that specified for the pipe. Dielectric connections should be placed as specified on the drawings.

TESTING

Underground pipelines should be tested before backfill has been placed over the field joints. Above ground lines may be tested at any time after they are ready for operation.

The pipelines should be filled with water, taking care to bleed air and prevent water hammer. When the line is full, all valves should be closed and the line should be brought up to full design working pressure. All joints should then be carefully inspected for leakage and any visible leaks should be repaired.

It should be demonstrated by testing that all valves, vents, surge chambers and other appurtenances function properly when the pipeline is operated at design capacity. Objectionable surge, water hammer, unsteady delivery of water, damage to the pipeline, and detrimental discharge from control valves are evidence of malfunction.

MATERIAL STANDARDS

PIPE

Pipe should equal or exceed the specifications of the American Water Works Association for "Fabricated Electrically Welded Steel Water Pipe," "Designation AWWA C201, or "Mill-Type Steel Water Pipe," Designation AWWA C202 or other equivalent standards.

STRUCTURAL STEEL

Steel supports and saddles should be fabricated from steel meeting the requirements of ASTM Specifications A36 or equivalent standard.

APPURTENANCES

Standard fittings for the pipe should be used. Elbows, tees, crosses, reducers, gate valves, check valves, air and vacuum release valves, pressure relief valves, and pressure regulators should be of the size and type of material specified and/or shown on the drawings.

CORROSION PROTECTION

INTERIOR COATINGS

When an interior coating is specified, the coating should meet the requirements of one of the following :

1. **Coal-Tar Enamel**—The interior of the pipe should receive a coat of coal-tar primer followed by a hot coat of coal-tar enamel applied either by manual or mechanical means. All material and application should be in accordance with applicable parts of American Water Works Association Specification C203 pertaining to interior coatings or an equivalent standard.
2. **Cement Mortar**—Cement mortar protective coatings may be used when the water to be conveyed has a pH of 5.5 or higher and a sulfate content of 150 ppm or less. Materials and workmanship should be equal to American Water Works Association Specification C205 or an equivalent standard.
3. **Epoxy Resin**—Epoxy resin interior coatings should meet the requirements given in a following section of these specifications for epoxy resin exterior coatings.

EXTERIOR COATINGS

Exterior coatings should be Class A, Class B, or paint as specified for the job.

Class A Coatings—When a Class A coating is required, the coating should meet the requirements of one of the following :

1. **Coal-Tar Enamel**—The outside of the pipe should receive a coat of coal-tar primer followed by a hot coat of coal-tar enamel into which should be bonded an asbestos felt wrapper and finished with a Kraft paper or one coat of water-resistant whitewash. All materials and application should be in accordance with American water Works Association Specification C203 or with other equivalent standards.
2. **Epoxy Resin**—Epoxy resin coatings should have physical characteristics and be applied as follows :

   a. Pipe should be cleaned of all contaminants such as laquer, wax, coal-tar, asphalt, oil or grease.

   b. Pipe should be shot blasted to white metal in accordance with steel structure Painting Council Specification SPPC-SP5-63 using S-170 shot or equivalent or an equivalent standard can be used.

   c. After blasting the pipe surface should be power wire brushed.

   d. The coating should be applied to the clean preheated (232.2° + 246.1°C or 450° +475°F) pipe, using best commercial practice, to a minimum thickness of 0.178 mm (seven mils). The thickness can be determined by using a magnetic thickness gauge. The heat source should not leave a residue on the pipe surface.

   e. The coated pipe should be maintained at or above 218,3°C

(425°F) for a minimum of 20 seconds for full cure. At the end of this time the pipe should be water quenched before a supporting roller comes in contact with the coated surface.

f. All epoxy resin coated pipe should be electrically inspected for holidays using a wet electrode to apply 1000 volts, D. C. across the coating. All imperfections should be repaired.

g. The epoxy resin coating should meet the physical requirements as indicated in the table entitled "Physical Requirements of Class A Cured Epoxy Resin Coating."

Physical Requirements of Class A Cured Epoxy Resin Coating

Test Description	Units	Avg. of Specified Determinations	Tolerance of Average
Hardness	Barcol	10	Min.
Mechanical Shock (Gardner Machines)	Inch lbs.	120	Min.
Therman Shock	Cycles	10	Min.
Heat Resistance 100 hour @ 180°C	Percent	4.5	Min.
Adhesion	Lbs/sq. inch	2000	Min.
Salt Water Resistivity	ohm-ft.	1×10^{10}	Min.

Class B Coatings—When a Class B coating is required, the coating should meet the requirements of one of the following :

1. **Galvanizing**—Pipe should have a zinc coating equal to that specified in the ASTM Designation A 120 or equivalent standard.

2. **Coal-Tar Enamel**—The outside of the pipe should receive a coat of coal-tar primer followed by a hot coat of coal-tar enamel and finished with a Kraft paper or one coat of water-resistant whitewash. All materials and application should be in accordance with American Water Works Association Specification C203 or an equivalent standard, except that the asbestos felt wrapper may be omitted.

3. **Coal-Tar Enamel with Asbestos Felt Wrap** –The outside of the pipe should receive a coat of coal-tar primer followed by a hot coat of coal-tar enamel into which should be bonded an asbestos felt wrapper and finished with a Kraft paper or one coat of water-resistant whitewash. All materials and application should be in accordance with American Water Works Association C203 or equivalent standard, except that the minimum thickness of hot coal-tar enamel applied by pouring and spreading may be 0.794 mm (1/32 inch).

4. **Coal-Tar, Hot Applied Tape and Primer**—All materials and workman-

ship should be in accordance with Federal Specification HHT-30a, August 2, 1967, Tape, Pipe Coating, Coal Tar, Hot Applied, and Primer or an equivalent standard.

5. **Plastic Tape**—Plastic tape coating should be capable of with-standing the moisture and soil conditions to which it will be subjected. All material should be in accordance with Interim Federal Specification L-T-001512 for Type I, standard thickness tape or an equivalent standard, except that the tape coating may be of either rubber material or the specified plastic materials. Application should be as follows :

   a. The surface of the pipe to be coated should be cleansed of all foreign material such as oil, grease, dirt, mud, etc. Any knurls, burrs, or other sharp points should be removed by filing, peening, or wire brushing.

   b. The continuity of the applied plastic coating should be of such quality that all pipe joints, and fittings, after assembly should be capable of passing an inspection test conducted with a spark discharge holiday detector at 1500 volts.

Paint—Unless otherwise specified, all above ground pipelines should be painted as follows :

1. All grease and oil should be removed from the pipe surface by steam cleaning or by solvent cleaning and all dirt, surface rust, and loose scale should be removed by means of wire brushing, flame cleaning, use of rotary abrading tools or by light sand-blasting.

2. To the cleaned pipe there should be applied one priming coat of red lead base paint conforming to the requirements of Federal Specification TT-p-86e, Type I, II or III, or one priming coat of synthetic primer conforming to the requirements of Federal Specification TT-p-636c (1). An equivalent standard can be used.

3. The painting should be completed by the application of two coats of aluminum paint. The aluminum paint should be prepared by mixing aluminum paste conforming to Federal Specification TT-P-320b (1), Type II, Class B with mixing varnish conforming to the requirements of Federal Specification TT-V-81d, Type II, Class B, at the rate of two pounds of aluminum paste per gallon of varnish. The paint should be mixed at the time of use. An equivalent standard can be used.

CATHODIC PROTECTION

Buried steel pipelines, except those constructed with galvanized steel, should be protected with sacrificial galvanic anodes where specified to supplement the protection provided by the pipe coating. The anodes should be of the kind and number as specified for the job and/or as shown on the drawings.

Anode Materials—Anodes can be commercially made magnesium or zinc. Materials and worksmanship should be equal to ASTM Specification B418, or equivalent standard, for zinc.

Each anode should have a full length core with a single stand of insulated copper wire solidly attached to it. The wire should be No. 12 or a diameter of 2. 68 mm or larger. If a header wire is used, the gauge must be sufficient to carry the design current with no more than a 20 millivolt I-R, drop.

All anodes should be commercially packaged and the packaged backfill mix should be of the following proportions by weight.

Zinc —	20 to 30% bentonite, 70 to 80% gypsum
Magnesium—	20 to 25% bentonite, 70 to 75% gypsum, 5% sodium sulfate

Anode Installation—Anodes may be placed either horizontally or vertically. When placed horizontally, they should be at or below the bottom elevation of the pipeline. Vertically placed anodes should have a minimum distance to 0. 91 meters (three feet) between the ground surface and the top of the anode. Anodes should not be placed in fill areas, and magnesium anodes should be placed a minimum distance of 3. 05 meters (ten feet) from the pipeline.

Anodes should be bedded in moist fine clay, clay loam, silt, or silt loam materials. In sandy and gravelly areas fine material should be inported for bedding and for covering the anodes to a depth of 152. 4 mm (six inches). The packaged anodes and the fine textured soil used for bedding and backfill should be thoroughly wetted.

Attachment of Anode to Pipe—The lead wire from the anode, or the header wire for multiple anode installation, should be attached to the pipeline by cadwelding, thermowelding, or other process of equal ability. The area of damaged pipe coating and the weld should then be covered with a coating equal in quality to the specified original pipe coating.

Testing Stations—Testing station facilities should be located and installed as specified for the job and/or as shown on the drawings. Wires at testing stations should be attached to the pipe as specified above for anode lead wires.

CHAPTER 12

Suggested Studies or Evaluations

Studies should be conducted on the following items in order to better facilitate water management :

1. Studies are needed on installed concrete pipelines in order to assist in making necessary improvements to obtain the necessary quality.

2. Field and laboratory studies are needed on the structural and hydraulic characteristics of all nonreinforced concrete pipe in order to establish necessary standards.

3. Further development is needed on irrigation accessories. This includes alfalfa valves and possibly orchard valves and slide or screw gates for stands that will not leak under certain given heads. Additional designs should be developed for portable hydrants, which are used with both plain and gated surface pipe. This will give further flexibility to pipeline systems and can reduce the use of open channels.

APPENDIX A

Agency Representatives and Others Contacted by The Consultant

Central Government

Ministry of Food, Agriculture, Community Development & Cooperation

J.K. Jain, Joint Commissioner, Minor Irrigation
C.G. Desai, Deputy Commissioner, Minor Irrigation
J.S. Bali, Deputy Commissioner, Soil Conservation (Engineering)

Industrial Development, Internal Trade & Company Affairs

Directorate General of Technical Development :
C.D. Anand, Development Officer, Plastic & Plastic Chemical
N.G. Basak, Development Officer, Cement & Asbestos Products

STATES

GUJARAT

Government of Gujarat

V.M. Dave, Chief Engineer (Irrigation) & Joint Secretary
S.L. Patel, Executive Engineer, District Panchayat, Ahmedabad
K.V. Shah, Executive Engineer, Gujarat Tubewell Division II Ahmedabad
S.M. Patel, Professor Agro-Economic Indian Institute of Management, Ahmedabad
A.L. Patel, Executive Engineer, District Panchayat, Masana
K.P. Patel, Deputy Engineer, Mechanical Tubewells
J.R. Vohra, Under Secretary, Irrigation Dept., Ahmedabad
S.A. Mod, Junior Engineer, Office of the Supdt. Engineer, Mechanical
C.H. Vakil, Deputy Engineer, Masana
M.P. Patel, Civil Supervisor

States (*Contd.*)

Private Sector

Rama Shashan, General Manager, Technical
Shri Digvijay Cement Co., Ltd.—Asbestos Products Division, Ahmedabad
J. J. Shaw, Sales Manager, Co., Ltd.,—Abestos Products Division, Ahmedabad
D.P. Shah, Proprietor AlCock Cement & Pipe Concrete Works, Ahmedabad
Natwala P. Shah, AlCock Cement & Pipe Concrete Works, Ahmedabad
Devi Chand Ghulab Das Patel, Suvarnkar Cement and Allied Products, Patan, Dist. Masana
Harilal M. Zaveri, Bharat Pipe Industries, Sidhpur Road, Patan, District Masana
Nathalal D. Zaveri, Bharat Pipe Industries, Sidhpur Road, Patan, District Masana
Krishalal M. Mistry, Bharat Pipe Industries, Sidhpur Road, Patan, District Masana
Jainti Bhai Thakkar, Mukesh Cement Works, Sidhpur, Dist. Masana
Mrs. Sharda Bhain Thakkar, Mukesh Cement Works, Sidhpur, Dist. Masana

HARYANA

Government of Haryana

A.C. Sharma, Joint Director of Agriculture (Soil Conservation & Minor Irrigation), Chandigarh
B.S. Gulhati, Divisional Soil Conservation Officer, Gurgaon
A.K. Malhotra, Executive Engineer, Exploratory Tubewell, Karnal
R.N. Sharma, Asst. Soil Conservation Officer, Narnaul
R.K. Agarwal, Section Officer, Irrigation, Naraingarh, Dist. Ambala
Arjun Singh, Asst. Soil Conservation Officer, Narnaul

Private Sector

Bhagwant Singh, Managing Director, Spun Pipe (India) Pvt. Ltd. Faridabad
R.S. Manik, Director, Spun Pipe (India) Pvt. Ltd. Faridabad
D.D. Aggarwal, Sales Manager, Hyderabad Asbestos, Ballabgarh
Vidur Bhaskar, B.N. Bhaskar & Sons, Faridabad
S.S. Soni, B.N. Bhaskar & Sons, Faridabad

MAHARASHTRA

Private Sector

N.M. Dhuldhyoa, Commercial Manager, Polyolefins Industries, Ltd., Bombay
Harshad Patel, Asst. Sales Manager Polyolefins Industries, Ltd., Bombay
M.S. Khakhar Production Manager, Polyolefins Industries, Ltd., Bombay
K. Ganapathy, Polyolefins Industries Ltd. Bombay

States (*Contd.*)

H.T. Bhavnani, General Manager, Calico Chemicals Plastic Division, Anik, Chembur, Bombay

U.U. Shenoy, Production Engineer, Calico Chemicals Plastic Division, Anik, Chembur Bombay

S. Mitra, Technical Officer, Calico Chemicals Plastic Division, Anik Chembur, Bombay

S.G. Sharma, Planning & Development Officer, Calico Chemicals Plastic Division, Anik, Chembar, Bombay

MYSORE

Government of Mysore

N.P. Jahagirdar, Dy. Director of Agriculture & Project Officer, Regional Pilot Project for Soil & Water Management, Bellary

H. Seshagiri Rao, Agr. Development Officer, Engineering, Bellary

Private Sector

Y.M. Basha, Production Executive, Sri Venkataswara Spun Concrete Pipe Company Bisalahalli, Bellary

PUNJAB

Government of Punjab

G.S. Dhillon, Chief Conservator, Soils, Chandigarh

Karnail Singh, Divisional Soil Conservation Officer, Chandigarh

J.S. Gill, Divisional Soil Conservation Officer, Jullundar

Gurdeep Singh, Asst. Soil Conservation Officer, Chandigarh

Hazara Singh, Asst. Soil Conservation Officer, Moga

J.N. Sharma, Dy. Director of Agricultural & Project Officer Regional Pilot Project for Soil & Water Management, Patiala

Gurbachan Singh, Agricultural Development Officer, Engineering, Patiala

Kulbir Singh, Manager, Punjab State Cooperative Marketing Federation Ltd., Chandigarh

Tirlochan Singh, Manager, Punjab State Cooperative Marketing Federation Ltd., Chandigarh

Laljeet Singh, Processing Expert, Punjab State ,Cooperative Marketing Federation Ltd., Chandigarh

Punjab Agriculture University, Ludhiana

Y.C. Arya, Associate Professor of Agricultural Engineering

States (*Contd.*)

Private Sector

H.S. Mamik, Chandigarh Spun Pipe Co., Chandigarh
D.K. Sharma, 'PRECTO' Chandigarh
Mohinder & Co., Allied Industries, Kurali
C.L. Gupta, Rama Pipe Industries, Sangrur
Vinod Murgai, Landlord, Ferozepur Cant.

TAMIL NADU

Government of Tamil Nadu

N. Sankara Narayana Reddy, Joint Director of Agriculture (Engineering), Madras
P.K. Radhakanth, Divisional Engineer (Agriculture), Madras
Gopal Krishnan, Divisional Engineer (Agriculture), Madras
K. Thandayutham, Divisional Engineer, Thanjavur
S. Savadamuthu, Divisional Engineer (Agriculture), Trichy
C.R. Shanmugham, Divisional Engineer (Agriculture), Coimbatore
R.K. Sivanappan, Professor of Agr. Engineering, Coimbatore
V. Panchapakesan, Asst. Agricultural Engineer, Thanjavur
M.V. Ramanathanam, Asst. Agricultural Engineer, Thanjavur
Srinivasan, Agricultural Supervisor, Vendalur
Dorairaj, Asst. Engineer, Agriculture, Madras
G. Doraisawami, Asst. Agricultural Engineer, Coimbatore
K.M. Nachappan, Asst. Professor, Agr. Engineering, Coimbatore

Private Sector

A. Ramabhadran, General Manager, Waven India, Ltd., Madras
N. Venkataraman, Commercial Manager, Waven India, Ltd., Madras
Albert Van Costen, Engineer, Manager India, Ltd., Madras
A.S. Govindaswamy, Jothi Cement Pipe Works, Madras
Sundramurti, Manager, Jothi Cement Pipe Works, Madras
Krishnamurti, Manager, Jothi Cement Pipe Works, Madras
T. Subramanium, Spun Pipe Company, Thanjavur
M.A. Jamal Mohideen Pappa, Villar, Thanjavur
P.K. Chari, Indian Hume Pipe Co., Srirangam, Trichy
J. Macrae, Sales Manager, Asbestos Cement Company Ltd., Podanur, Coimbatore
V. Sitaram, Works Manager Asbestos Cement Co. Ltd. Podanur, Coimbatore
C.M. Arunachalam, Ajanta Tiles, Coimbatore
Bala Krishnan, P.S.G.B. Sons Estate, Vedapatti, Coimbatore

States (*Contd.*)

UTTAR PRADESH

Government of Uttar Pradesh

S.P. Singh, Director, Tubewell Directorate, Lucknow
P.C. Pramanik, Superintending Engineer, Tubewells, Moradabad
B.D. Rathi, Superintending Engineer, Tubewells, Faizabad
S.P. Garg, Director, Irrigation Research Institute & Research Farm, Roorkee
Amar Singh, Joint Director, Agriculture (Soil Conservation), Lucknow
J.P. Gupta, P.A. to the Director, Tubewell Directorate, Lucknow
A.D.K. Jain, Executive Engineer, Tubewells, Moradabad
Shyam Narain, Executive Engineer, Tubewell Construction, Moradabad
B. P. Hajeley, Executive Engineer, Tubewells, Chandausi
B S. Rai, Executive Engineer, Tubewells, Moradabad
Jia Lal Jain, Executive Engineer, Tubewells, Meerut
Inder Sain, Executive Engineer, Tubewells, Bareilly
Harikrishanlal Dewan, Asst. Engineer, III Tubewells, Meerut
B.N. Agarwal, Asst. Engineer, Tubewells, Meerut
Jaswant Singh, Asst. Engineer, Tubewells, Meerut
M.C. Gupta, Asst. Engineer, Tubewells, Meerut
S.C. Verma, Asst. Engineer, Bareilly
Shaukat Ali, Asst. Engineer, Tubewells, Bareilly
R.D. Singh, Project Officer, Regional Pilot Project for Soil & Water Management, Dohrighat
B. Tripathi, Agricultural Development Officer (Soils), Dohrighat
R. Shahi, Agricultural Development Officer (Eng.) Dohrighat
K.K. Saxena, Agricultural Development Officer (Agronomy), Dhorighat

U. P. Agricultural University, Pant Nagar

D.P. Singh, Vice Chancellor, U.P. Agricultural University
V.S. Raju, Dean, Pant College of Technology
Jaswant Singh, Head of Agricultural Engineering Department
M.S. Misra, Head of Civil Engineering Department
H.S. Chauhan, Professor of Agricultural Engineering
R.A. Rastogi, Associate Professor of Agricultural Engineering
G.B. Johri, Dy. Director, Land Water Development Scheme
C.S. Jaiswal, Asst. Professor
Madan Lal, Asst. Engineer
G.K. Goel, Overseer

States *Contd.*)

Private Sector

Arvind Sharma, Proprietor, Socketed Spun Pipe Co., Rudarpur
Gurbax Singh, Partner, Gurbachan Singh Chadha & Co., RCC Factory, Haldwani
R.B. Patel, Manager, Khurpia Farm of the Kesar Sugar Works, Ltd., Kichha
B.D. Gupta, Proprietor, Himalaya Spun Pipe Manufacturing Co., Meerut
D.D. Gupta, Himalaya Spun Manufacturing Co., Meerut
Mukhtar Hussain, Proprietor, C.C. Pipe Manufacturing Center, Deengarpur, Moradabad
Akhtar Hussain, Proprietor, C.C. Pipe Manufacturing Center, Deengarpur, Moradabad
K.N. Sharma, Proprietor, Rohilkhand Cement Pipes, Pvt. Ltd., Bareilley

WEST BENGAL

Government of West Bengal

M.C. Mukherjee, Commissioner & Secretary, Agriculture, Calcutta
B.N. Sen, Chief Engineer (Agriculture), Calcutta
B.K. Bhattacharjee, Superintending Engineer, Agricultural Irrigation, Calcutta
P.K. Bhattacharya, Superintending Engineer, Agr. Mechanical, Calcutta
D.M. Das, Technical Asst. to Superintending Engineer, Agr. Irrigation, Calcutta
T.K. Chakravarty, Technical Assistant to Suptd. Engineer, Agr. Mechanical, Calcutta
B.K. Banerjee, Executive Engineer, Agr. Irrigation, Calcutta
B. Goswami, Asst. Engineer, 24 Parganas, North I
B. Chakarvarti, Asst. Engineer, Ranaghat
S. Sen, Asst. Engineer, Hooghly I
S. Ghosh, Asst. Engineer, Agr. Mechanical, Chinsara

Private Sector

M. J. Pook, General Manager & Chief Technical Advisor, Premier Irrigation Equipment Ltd., Calcutta
R. Mukerjee, Engineer, Premier Irrigation Equipment Ltd., Calcutta.
S.K. Sur, Sur Industries Corporation, Doltala-Varasat
B. Dutta, B. Dutta & Co., Mithapukar, P.O. Adecongen, Dist. Hoogly

DELHI UNION TERRITORY

Private Sector

N.H. Mirchandani, Manager, Indian Hume Pipe Company, New Delhi
J.P. Desai, Engineer, Indian Hume Pipe Co., Najafgarh

States (*Contd.*)

N.M. Thakur, Manager, Indian Hume Pipe Co., Najafgarh
P.C. Rawal, Manager, Indian Hume Pipe Co., Sarai Rohilla
K.K. Chopra, Engineer, Indian Hume Pipe Co., Sarai Rohilla
N.C. Duggal, Assistant Engineer, Concrete Association of India, New Delhi
P.L. Gulhati, Assistant Engineer, Concrete Association of India, New Delhi

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
NEW DELHI

Leonard J. Saccio, Director
John H. Funari, Dy. Director
Russall O. Olson, Assistant Director, Agricultural Development
Oliver A. Bauman, Dy. Assistanst Director, Agricultural Development
John T. Phelan, Chief, Soil & Water Management Division
Eugene J. Pope, Agricultural Irrigation Engineer
James R. Coover, Soils Advisor
Francis M. Roberts, Resource Inventory Specialist
Donald F. Jones, Agricultural Economist
Glenn L. Ellithorpe, Tubewell Specialist
Stanley Remington, Water Resource Engineer
Ronald H. Pollock, Dy. Chief, Agricultural University Development
A.R. Downie, Chief, Agricultural Production Division
U.S. Madan, Agronomist, Soil & Water Management Division

AHMEDABAD

E.V. Miller, Team Leader, Agricultural Production Project

BANGALORE

Murray P. Cox, Water Management Specialist

BELLARY

D.W. Haslem, Agricultural Engineer
Gerald Kester, Soil Scientist
Eugene W. Shaw, Irrigation Specialist

CHANDIGARH

E. Pershing Vance, Water Management Specialist

States (*Contd.*)

PATIALA

H.Y. Cott, Agricultural Engineer
H.M. Ivory, Agronomist
K.E. Larson, Soil Scientist

LUCKNOW

C.W. Townsend, Water Management Specialist

JABALPUR

Donald J. Minehart, Research Farm Development Advisor

PANT NAGAR

Ralph C. Hay, Agricultural Engineer, Extension
Richard Matsurra, Agronomy Advisor

DOHRIGHAT

A. J. Andresen, Agronomist
C.W. Stewart. Agricultural Engineer
H.R. Sketchlay, Soil Scientist

OTHER AGENCIES
FORD FOUNDATION

D.A. Williams, Program Advisor, Water Management & Development
Tyler Quackenbush, Water Conservation Consultant, New Delhi
Byron. L. Bondurant, Agricultural Engineer, Ludhiana

ROCKEFALLER FOUNDATION

C.R. Pomeroy, Experiment Station Operation Specialist

APPENDIX B

Chronology of Conferences and Travel by the Consultant,

with principal conferess and field advisors from January 7 to May 6, 1970. See Appendix A for complete listing of persons contacted.

Note : Mr. John T. Phelan, Chief, Soil and Water Management Division, USAID., accompanied the consultant in all the major conferences in New Delhi. Mr. U.S. Madan, Agronomist, Soil and Water Management Division, accompanied the consultant in the conferences in New Delhi, Chandigarh, Bombay, Ahmedabad, Madras, Calcutta and Lucknow and toured with him on all field inspections in Punjab, Haryana, Gujarat, Tamil Nadu, Mysore, West Bengal and Uttar Pradesh States.

January 7, Wednesday

Arrived in New Delhi. Met at the airport by John T. Phelan.

January 8, Thursday

Briefings by Dr. Russell O. Olson, O.A. Bauman, John T. Phelan and U.S. Madan of USAID.

Meeting with J.K. Jain, Jt. Commissioner (Minor Irrigation), Ministry of Food, Agriculture, Community Development & Cooperation. J.S. Bali, Dy. Commissioner, Soil Conservation (Engineering) participated in the meeting.

Visited Tyler Quackenbush, Ford Foundation.

January 9, Friday

Met with J.K. Jain, and C.G. Desai, Dy. Commissioners (Minor Irrigation), Ministry of Food, Agriculture, Community Development and Cooperation.

Visited C.R. Pomeroy, Rockefaller Foundation.

Met with C.D. Anand and N.G. Basak, Development Officers, Office of Director General of Technical Development. Mr. Mirchandani, Manager, India Hume Pipe Company was present.

January 12, Monday

Visited irrigation and pipeline system at the Research Farm of Indian Agricultural Research Institute and Water Management Research Laboratory along with Mr. Pomeroy.

January 13, Tuesday

Visited Hume Pipe Company factories at Najafgarh and Sarai Rohilla along with Mr. Mirchandani of India Hume Pipe Company. Also had discussions with Messrs. J.P. Desai, Engineer, K.K. Chopra, Engineer and N.M. Thakur, Manager.

January 14, Wednesday

New Delhi to Chandigarh.

Met Mr. E. Pershing Vance, USAID and Messrs. G.S. Dhillon, Chief Conservator (Soils), Punjab, Karnail Singh and J.S. Gill, Divisional Soil Conservation Officers, Punjab, and Mr. A.C. Sharma, Joint Director of Agriculture (Soil Conservation and Minor Irrigation), Haryana.

January 15, Thursday

At Chandigarh. Accompanied by Messrs. Karnail Singh, and G.S. Dhillon, visited Chandigarh Spun Pipe Co., and had discussions with Mr. H.S. Mamik, Managing Partner. Also visited 'PRECTO' Factory and had discussions with Mr. D.K. Sharma, Proprietor.

Visited tubewells and irrigation pipeline layout at Sadanpur in Naraingarh Tehsil of Ambala District.

Also visited government pipe manufacturing unit III at Patwi. Met Messrs. A. K. Malhotra, Executive Engineer (Irrigation), Haryana and P. K. Agarwal, Section Officer. Mr. A. C. Sharma, Joint Director accompanied.

January 16, Friday

Chandigarh to Ropar and Kurali and back.

Visited N. R. C. C. Pipe Factory of Cooperative Sector at Ropar and Mohinder & Co. Allied Industries at Kurali.

Visited N. R. C. C. pipeline layout for irrigation in village Makauri, Tehsil Ropar and R. C. C. Pipeline layout in Kurali village. Had discussions with Mr. Kulbir Singh, Manager Punjab State Cooperative Marketing Federation Ltd. Met Gurdeep Singh, Assistant Soil Conservation Officer.

Messrs. G. S. Dhillon and Karnail Singh accompanied.

January 17, Saturday

Chandigarh to Patiala via Sangrur.

Visited Rama Pipe Industries (A. C. Pipe factory) and had discussions with C. L. Gupta, Proprietor. Karnail Singh, Divisional Soil Conservation Officer accompanied.

Met H. Y. Cott, H. M. Ivory and K. E. Larson of USAID.

January 18, Sunday

At Patiala.

Visited the Regional Soil and Water Management Pilot Project at Patiala and had discussions with USAID team members and the state officials. Met Messrs. J. N. Sharma, Project Officer and Gurbachan Singh, Assistant Agricultural Officer (Engineering).

January 19, Monday

Patiala to Ludhiana.

Met Mr. Y. C. Arya, Associate Professor, Agricultural Engineering, Punjab Agricultural University and Mr. Byron L. Bondurant, Ford Foundation.

January 20, Tuesday

At Ludhiana

Visited irrigation and pipeline layout system at Punjab Agricultural University farm and had discussions with Professor Arya.

January 21, Wednesday

Ludhiana to Ferozepur and back

Visited N. R. R. C. Pipe Factory at Moga enroute (of Cooperative Sector). Met Mr. Tirlochan Singh, Manager of Cooperative Pipeline factories and Hazara Singh, Assistant Soil Conservation Officer.

Visited the farm of Mr. Vinod Murgai at Ferozepur and irrigation and pipeline system at the farm and had discussions with him. T. Quacksnbush, A. P. Joseph, MFA., Karnail Singh and J. S. Gill accompanied.

January 22, Thursday

Ludhiana to New Delhi.

January 27, Tuesday

At New Delhi

Meeting with J. K. Jain and C. G. Desai.

January 28, Wednesday

New Delhi to Gurgaon, Pataudi, Rewari, Narnaul, Mahendragarh, Dadri, Bhiwani and Rohtak and back.

Visited government tubewells at villages Kanya, Lutafpur and Faizabad and layout of pipeline. Also visited Cooperative Spun Pipe Factory at Narnaul and proposed lift irrigation on Jui Canal near Bhiwani.

Messrs. B. S. Gulhati, Divisional Soil Conservation Officer and R. N. Sharma and Arjan Singh, Assistant Conservation officers accompanied.

February 1, Sunday

New Delhi to Bombay

February 2, Monday

At Bombay. Visited Polyolefin Industries Ltd. factory at Thana and Calico Chemicals Plastics factory at Chambur.

Met Messrs. N. M. Dhuldhoya, Commercial Manager, Harshad Patel, Assistant Sales Manager, M. S. Khakhar, Production Manager and K. Ganapathy of Polyolefins Industries Ltd., and Messrs. H. T. Bhavnani, General Manager, C. S. Shaw, Commercial Manager and U. U. Shanoy, Production Engineer of Calico Chemicals Plastics Division and had discussions with them.

February 3, Tuesday

Visited Mufat Lal Gagal Bai farm Borivillai and the sprinkler irrigation system using P. V. C. Pipeline. M. S. Khakhar, Production Manager of Polyolefin Industries accompanied.

Afternoon—Bombay to Ahmedabad. Met by Messrs. S. L. Patel and K. V. Shah, Executive Engineers and J. R. Vohra, Under Secretary, Irrigation at the airport. Had discussions with S. L. Patel, K. V. Shah and S. M. Patel, Professor of Agro-Economic Faculty, Indian Institute of Management, Ahmedabad.

Met Dr. Elif V. Miller, USAID., and had discussions with him.

February 4, Wednesday

Ahmedabad to Patan, Dist. Masana and back.

Visited R. C. C. Pipeline factories—Survarrkar Cement and Allied Products and Bharat Pipe Industries, Patan, and R.C.C. and N.R.C.C. Mukesh Cement Works at Sidhpur. Met A. L. Patel, Executive Engineer, Dist. Panchyat, S. A. Mod, Junior Engineer. Also met Devi Chand Gulab Das Patel, Harilal M. Zaveri, Nathlal D. Zaveri, Krishalal M. Mistry, Vasindei C. Padhya, Jainti Bhai Thakkar and Mrs. Sharda Bhain Thakkar and discussions with them.

Also visited state tubewell at Moti doi and met C. H. Vakil, Dy. Engineer and M. P. Patel, Civil Supervisor. Messrs. S. L. Patel and K. V. Shah accompanied.

February 5, Thursday

At Ahmedabad

Visited Shri Digvijay Cement Factory Asbestos Products and met Rama Shashan, General Manager (Technical) and J.J. Shaw, Sales Manager. Also visited AlCock Cement and Pipe Concrete Works and met D. P. Shah, Proprietor and Natwa Lal P. Shah. Also visited state tubewells at villages Sarkhay and Bopal. S. L. Patel, K.V. Shah and K.P. Patel, Dy. Engineer, Mechanical Tubewell accompanied.

February 6, Friday

At Ahmedabad

Meeting with V. M. Dave, Chief Engineer (Irrigation), and Joint Secretary. K.V. Shah and S. M. Patel were also present.

Visited Shremjivi Sarvodaya Samudayik Cooperative Farming Society and inspected farms irrigation and pipeline system. This farm had used N. R. C. C. Pipes.

February 7, Saturday

Ahmedabad to New Delhi

February 9, Monday

New Delhi to Madras. Met by P. K. Radhakanth and Gopala Krishnan, Divisional Engineers (Agriculture) and Dorairaj, Assistant Engineer (Agriculture).

Visited Jothi Cement Pipe Works at Vendalur. Met Mr. Sundramurti, Manager and had discussions. Messrs. P. K. Radhakanth, Gopala Krishnan and Dorairaj accompanied.

February 10, Tuesday

At Madras. Visited Jothi Cement Pipe Works and A. C. Factory at Madras. Met A. S. Govindaswamy, Proprietor and Krishnamurti, Manager and had discussions with them.

Also visited Waven India Ltd. Amattur Industrial Estate. Met Ramabhadran, General Manager, N. Venkataraman, Commercial Engineer and had discussions with them. Had a meeting with N. Sankaranarayana Reddy, Joint Director of Agriculture (Engineering) where P. K. Radhakanth, Gopala Krishnan and Dorairaj were also present.

February 11, Wednesday

Madras to Thanjavur via Trichy. Were met by S. Savadamuthu, Divisional Engineer, Trichy and K. Thamdayuthan, Divisional Engineer, Thanjavur. Visited Spun Pipe Company at Thanjavur and met T. Subramanium, Proprietor and had discussions with him. Also visited farm of M. A. Jamal Mohideen Pappa at Vilar village to see the irrigation and pipeline layout system.

Visited handmade pipe factory "Ambrose Fatima R. C. C. Works" at Thanjavur who make hand made N. R. C. C. pipes.
P. K. Radhakanth accompanied.

February 12, Thursday

Thanjavur to Coimbatore via Trichy and Karur.

Visited Indian Hume Pipe Company at Srirangam, Dist. Trichy and met P. K. Chari, Manager. Also visited Kanda Vilas Concrete Works, Karur, Dist. Trichy, who make N. R. C. C. Pipes for irrigation.

Met by C. R. Shanmugham, Divisional Engineer (Agr.) and G. Doraiswami, Assistant Agr. Engineer. P. K. Radhakanth accompanied.

February 13, Friday

At Coimbatore. Met R. K. Sivanappan, Professor, Agricultural Engineering and discussed about pipeline and irrigation distribution system in the District. Accompanied us to P. S. G. R. Sons' Estate at Vedapatti, Dist. Coimbatore where we met Bala Krishnan and went round their farm to see irrigation distribution system.

Visited Asbestos Cement Company Ltd. factory and met J. Macrae, Sales Manager and V. Sitaram, Works Manager.

Also visited 'Ajanta Tiles' factory who make hand made pipes. Met C.M. Arunachalam, Proprietor. Also met K. M Nachappan, Assistant Professor, Agr. Engineering, a 1969 participant to U. S.

February 14, Saturday

Coimbatore to Bangalore. Met by M.P. Cox, USAID.

February 15, Sunday

At Bangalore.

February 16, Monday

Bangalore to Ballary. Mr. M.P. Cox accompanied.

Met with N.P. Jahagirdar, Deputy Director of Agriculture and Project Officer, Seshagiri Rao, Agricultural Development Officer, Engineering, D.W. Haslem, Gerald Kestar of USAID.

Visited Venkateswara Spun Concrete Pipe Company at Bisalahalli-Bellary. Met Y.M. Basha, Production Executive.

February 17, Tuesday

Bellary to Hospet and back. Visited demonstration areas of Regional Pilot project for Soil and Water Management relating to water distribution, leveling, etc.

Also visited Indian Hume Pipe Company, Hospet.

February 18, Wednesday

Bellary to New Delhi.

February 20, Friday

Meeting with J.K. Jain and C.G. Desai, MFA.

February 23, Monday

New Delhi to Calcutta. Met by D.M. Das, Technical Assistant to Superintending Engineer (Agriculture-Irrigation).

Accompanied by M.J. Pook, General Manager and Chief Technical Advisor, visited the factory of Premier Irrigation Equipment Ltd., and discussed about gated pipes and water distribution systems. Also met R. Mukerjee, Engineer of the factory.

February 24, Tuesday

Calcutta to Kalyani and back.

Visited Sur Industries, Corporation Doltala (Varaset) R.C.C. Pipe. Met S.K. Sur, Proprietor of the factory and discussed manufacture of pipe.

Visited state tubewell at Geokhali and layout of pipeline for irrigation. Met B. Goswami and B. Chakarvarti, Assistant Engineers. Messrs. B.K. Bhattacharjee, Superintending Engineer, Agriculture-Irrigation, D.M. Das and B.K. Banerjee, Executive Engineer accompanied.

February 25, Wednesday

Calcutta to Chinsurah and back.

Visited state tubewell at Ilchhoba and laying of R.C.C. pipeline. Visited Messrs. B. Dutta and Co. (Pipe Company) at Mithapukur, Adeconagar, Dist. Hooghly and Met B. Datta, Proprietor and had discussions with him.

B.K. Bhattacharjee, D.M. Das and S. Sen, Assistant Engineer accompanied.

February 26, Thursday

Calcutta to Supuria (Ganges River), Dist. Hooghly and back. Visited water lift system from Ganges River and water distribution for irrigation and discussed the improvements in the system. P.K. Bhattacharya, Superintending Engineer, Agriculture, Mechanical, T.K. Chakarvarty, Technical Assistant and S. Ghosh, Assistant Engineer accompanied.

February 27, Friday

At Calcutta.

Met M.C. Mukherjee, Commissioner and Secretary, Agriculture and discussed improvement in water distribution system.

At this meeting S.N. Sen, Chief Engineer, Agriculture, B.K. Bhattacharya, D.M. Das, T.K. Chakarvarty and B.K: Banerjee were present. Technical conference was held after the above meeting with the Chief Engineer and his staff in Chief Engineer's room.

February 28, Saturday

Calcutta to New Delhi.

March 3, Tuesday

New Delhi to Faridabad and Ballabgarh and back.

Visited Spun Pipe (India) Private Ltd., Faridabad (R.C.C. and N.R.C.C. Pipe factory). Met Bhagwant Singh, Managing Director, R.S. Mamik, Director of the factory and discussed about manufacture of R.C.C. and N.R.C.C. pipes. Also visited Hyderabad Asbestos factory at Ballabgarh, Met D.D. Aggarwal, Sales Manager and A.K. Gupta, Works Manager. Also visited B.N. Bhaskar and Sons factory at Faridabad. Met Vidur Bhaskar and S.S. Soni, Proprietors of the factory and had discussions with them.

March 5, Thursday

Meeting with N.C. Duggal, Assistant Engineer and P.L. Guhati of Concrete Association of India and had detailed discussions regarding manufacture of N.R.C.C. pipe and their program.

March 8, Sunday

New Delhi to Pant Nagar. Met Ralph C. Hay and Richard Matsurra of USAID, and Jaswant Singh and H.S. Chauhan of U.P. Agricultural University, Pant Nagar.

March 9, Monday

At Pant Nagar. Had meeting with V.S. Raju, Dean, Pant College of Technology where Jaswant Singh, H.S. Chauhan, A.A. Rastogi, G.B. Johri of Agriculture Department and R.C. Hay were also present. After the meeting visited laying of pipeline and other structures in the field and also visited Gurbachan Singh Chadha & Co. R.C.C. factory, Haldwani, accompanied by G.B. Johri.

March 10, Tuesday

Visited pipeline system in the Khurpia farm of the Kesar Sugar Works Ltd., Kichha. G.B. Johri accompanied.

Meeting with officers of Agricultural Engineering College.

Also had a meeting with the Vice-Chancellor, U.P. Agricultural University, Pant Nagar where Jaswant Singh and H.S. Chauhan were also present.

March 11, Wednesday

Pant Nagar to Lucknow. Met by Amar Singh, Joint Director, Agriculture (Soil Conservation) and T.N. Srivastava, Chief Conservator of forests, U.P.

March 12, Thursday

Lucknow to Dohrighat. Met C.W. Townsend, USAID enroute to Dohrighat. Had meeting with Messrs. Stewart, Andresen, and Sketchley of USAID.

March 13, Friday

Meeting with Messrs. Stewart, Andresen and Sketchley.

R.D. Singh, B. Tripathi, R. Shahi and K.K. Saxena of the Regional Pilot Project for Soil and Water Management participated in the discussion. Visited Village Level Workers' Training Center proposed as a demonstration plot. Also visited tubewell 113 and its distribution system.

In the afternoon visited tubewell No. 8, Kauri Ram Group, Dist. Gorakhpur and also R.C.C. open channel. Messrs. Stewart, Andresen, R.D. Singh and Shahi accompanied on field visits.

March 14, Saturday

Dohrighat to New Delhi.

March 16, Monday

New Delhi to Moradabad via Meerut.

P.C. Pramanik, Superintending Engineer joined at New Delhi and accompanied on visits to Himalayan Spun Pipe Manufacturing Co., Meerut, Departmental P.C.C. Pipe Manufacturing Plant at Meerut, Tubewell No. 13, Main Canal Group and R.C.C. Channel.

March 17, Tuesday

At Moradabad.

Visited C.C. Slab Manufacturing Plant at Chandausi, Tubewells 68 and 74 of Shahbad group and their water distribution system. Also visited Tubewell No. 83 of Shahbad group where underground pipeline had been laid and also bricklined channel. Tubewell No. 84 of Shahbad group was also visited which was under construction and laying of underground pipeline was in progress.

Had a meeting with Pramanik, Superintending Engineer and his Executive Engineers who accompanied on field visits at Bellary.

In the evening visited P.C.C. pipe manufacturing center, Deengarpur (Moradabad).

March 18, Wednesday

Moradabad to Lucknow via Bareilly. Mr. Parmanik accompanied. Inder Sain, Executive Engineer and S.C. Verma and Shaukat Ali, Assistant Engineers met at Bareilly. Visited Rohilkhand Cement Pipes Pvt. Ltd. Bareilley and Tubewell 23 of Bareilly group at village Hyderabad and R.C.C. semicircular pipe laid for water distribution.

March 19, Thursday

At Lucknow-local holiday.

Had meeting with S.P. Singh, Director. Tubewell Directorate, U.P., Mr. Pramanik., Mr. Rathi, Superintending Engineer, Faizabad, Mr. S.P. Garg, Director, Irrigation Research Institute, Roorkee and J.P. Gupta, P.A. to the Director participated in the discussions. Mr. C.W. Townsend of USAID was also present at the meeting.

March 20, Friday

Lucknow to New Delhi.

APPENDIX C

Bibliography

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3. Peckworth, Howard F., **Concrete Pipe for Irrigation and Drainage,** American Concrete Pipe Association, 1961, Arlington, Virginia 22209.

4. Pillsbury, Arthur F., **Concrete Pipe for Irrigation,** Circular 418, University of California, 1952, (out of print).

5. ____________________, **National Engineering Handbook Section 15, Irrigation ; Chapter 3, Planning Farm Irrigation Systems,** U. S. Department of Agriculture, Soil Conservation Service, U. S. Government Printing Office, 1967, Washington D. C. 20402.

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7. ____________________, **National Engineering Handbook Section 2, Part 1, Engineering Conservation Practices,** U. S. Department of Agriculture, Soil Conservation Service, 1967 with revisions since date of release, Washington, D. C. 20402.

8. ____________________, **Engineering Field Manual for Conservation Practices 1969,** U. S. Department of Agriculture, Soil Conservation Service, 1969, Washington, D. C. 20402.

APPENDIX D

Selected References

1. ______________________, **Agricultural Engineering, A Dictionary and Handbook,** Interstate Printers & Publishers, 1965, Danville, Illinois.

2. ______________________, **Agricultural Engineers Year Book,** Latest Edition, American Society of Agricultural Engineers, St. Joseph, Michigan.

3. ______________________, **Concrete Manual,** Latest Edition, U. S. Department of Interior, Bureau of Reclamation, U. S. Government Printing Office, Washington, D. C.

4. ______________________, **Concrete Pipe Irrigation Systems,** Portland Cement Association, 1960, Skokie, Illinois.

5. ______________________, **Design and Control of Concrete Mixtures,** 11th Edition, Portland Cement Association, 1968, Skokie, Illinois.

APPENDIX E

Specification List

A list of specifications are listed below for various pipe material that have been mentioned in the report or that are applicable.

The specifications from the following organizations are listed ; ASTM (American Society for Testing and Materials), CS (Commercial Standards, prepared by the U. S. Department of Commerce, National Bureau of Standards), IS (Indian Standards Institution), DIN (Standards prepared by West Germany), AWWA (American Water Works Association), SSPC (Painting Council Specifications, USA), and U. S. Government Federal Specifications.

Aluminum Pipe

Minimum Standards for Irrigation Equipment, by the American Society of Agricultural Engineers, approved January 1957, gives specifications for aluminum pipe.

Standards have also been developed by the Sprinkler Irrigation Association in the United States.

ASTM :

D 1000 Testing Pressure Sensitive Adhesive Coated Tapes Used for Electrical Insulation

D 1004 Test for Tear Resistance of Plastic Film and Sheeting

Asbestos Cement Pipe

ASTM :

C 296 Specifications for Asbestos Cement Pressure Pipe

C 500 Testing Asbestos-Cement Pipe

ASTM :

D 1869 Specifications for Rubber Rings for Asbestos-Cement Pipe

IS :

1592, Specifications for Asbestos-Cement Pressure Pipe

1626, Specifications for Asbestos-Cement Building Pipe Gutters and Fittings (Spigot and Socket type)

Concrete Pipe

C 14, Standard Specifications for Concrete Sewer, Storm Drain and Culvert Pipe, (Socket and Spigot)

C 33 Specifications for Concrete Aggregates

C 76 Specifications for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

C 118 Specifications for Concrete Pipe for Irrigation or Drainage, (Tongue and Groove)

C 497 Methods of Test for Determining Physical Properties of Concrete Pipe or Tile

> **Note :** A new procedure has been developed for making absorption test. This procedure gives more reliable results and is given in Appendix H.

C 505 Specifications for Non-reinforced Concrete Irrigation Pipe with Rubber Gasket joints.

IS :

269 Specifications for Ordinary, Rapid-Hardening and Low Heat Portland Cement

383 Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete

455 Specifications for Portland Blast Furnace Slag Cement

458 Specifications for Concrete Pipes (With and Without Reinforcement)

IS :

483 Code of Practices for Laying of Concrete Pipes

Plastic Pipe

ASTM :

D 1248 Specifications for Polyethylene Plastics Molding and Extrusion Materials

D 1784 Specifications for Rigid Poly (Vinyl Chloride) Compounds and Chlorinated Poly (Vinyl Chloride) Compounds

D 1788 Specifications for Rigid Acrylonitrile-Butadiene-Styrene (ABS) Plastics

D 2122 Determining Dimensions of Thermoplastic Pipe

D 2239 Specifications for Polyethylene (PE) Plastic Pipe (SDR-PR)

D 2241 Specifications for Polyvinyl Chloride (PVC) Plastic Pipe (SDR-PR and Class T)

D 2282 Specifications for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR and Class T)

D 2464 Specifications for Threaded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80

D 2465 Specifications for Threaded Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 80

D 2466 Specifications for Socket-Type Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40

D 2467 Specifications for Socket-Type Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80

D 2468 Specifications for Socket-Type Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40

D 2469 Specifications for Socket-Type Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 80

CS :

254 Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR and Class T)

255 Polyethylene (PE) Plastic Pipe (SDR-PR)

256 Polyvinyl Chloride (PVC) Plastic Pipe (SDR-PR and Class T)

IS :

4985 Specifications for Unplasticized PVC Pipes for Portable water supplies
[1] High-Density Polyethylene Pipe.

DIN :

8074/8075 (Specification deals with high-density polyethylene pipe)

Steel Pipe

ASTM :

A 36 Standard Specifications for Structural Steel

[1] Specifications are being developed by the Indian Standards Institute

A 120 Specifications for Black and Hot Dipped Zinc-Coated (Galvinized) Welded and Seamless Steel Pipe for Ordinary Uses

B 418 Specifications for Cast and Wrought Galvanic Zinc Anodes for Use in Saline Electrolytes

AWWA ;

C 201 Fabricated Electrically Welded Steel Water Pipe

C 202 Mill-Type Steel Water Pipe

C 203 Coal-Tar Enamel Protective Coatings for Steel Water Pipe

C 205 Cement-Mortar Protective Lining and Coating for Steel Water Pipe.

Painting Council Specifications :

SSPC-SF 5-63 Steel Structures Painting Council Surface Preparation Specifications

Federal Specifications :

HHT-30a Tape, Pipe Coating, Coal Tar, Hot Applied : and Primer

L-T-001512 Tape, Pressure Sensitive Adhesive, Pipe Wrapping

TT-P-86e Paint Red-Lead-Base, Ready Mixed

TT-P-320c Pigment, Aluminum ; Powder and Paste for Paint

TT-P-636c (1) Primer Coating, Alkyd, Wood and Ferrous Metal

TT-V-81d Varnish ; Mixing, for Aluminum Paint

APPENDIX F

Manufacturers of Pipe Making and Mixing Equipment

Manufacturer	*Type of Equipment*
W. E. Dunn Mfg. Company Holland, Michigan 49423	Packerhead and Mixing
Hydrotile Machinery Company Nashua, Iowa 50658	Packerhead, and Mixing
Praschak Machine Co., P. O. Box 368 Marshfield, Wisconsin 5449	Mixing and Elevating
Quinn Machinery Division of Zeidlers, Inc.	Packerhead, Tamper and Cast, hand made
Waterloo, Iowa 50705 or Boone, Iowa 50036	
Concrete Products Services 500 North Stanwood Road, Columbus, Ohio 43209	Centrifugal and Dri-Cast and Wet Cast (vibrator)
Turmac Inc. 687 North Thompson Street Portland, Oregon 97227	Tamper and Mixing
Hawkeye Concrete Products Co., Mediapolis, Iowa 52637	Vibrator
McCracken Concrete Pipe Machinery Co., P. O. Box 1703 Sioux City, Iowa 51102	Packerhead and Vibrator

APPENDIX G

Manufacturers of Accessories for Irrigation Pipelines, in India

Mohinder & Co. Allied Industries Kurali (District Ropar), Punjab—Manufacturers of Alfalfa Valves, with iron or brass screw (spindle) and in sizes ranging from 4 to 15 inches—slide gates for gate stands are also being made.

[1] Industrial Services and Engineers
57 S. P. Mukherjee Road
Calcutta—26

and

[1] Commercial & Engineering Corporation
138 Canning Street
Calcutta—1.

[1] Both these firms manufacture Tamper Proof Irrigation Valves in various sizes.

APPENDIX H

Supplement to ASTM C 497

The suggested revision of Paragraph 14, Procedure for Boiling Absorption Test, ASTM Specification C497, Tests for Physical Properties of Concrete Pipe, is as follows :

Paragraph 14 (a) **Drying Specimens :**

Specimens shall be dried in a ventilated mechanical convection oven at a temperature of 105 to 113°C (221°—239°F) until two successive weighings at intervals of not less than (6 hours) show an increment of loss not greater than 0.10 percent of the last oven-dry weight of the specimen. Specimens with a wall thickness of 1-1/2" or less shall be dried for a minimum of 24 hours ; specimens with a wall thickness of 1-1/2" to 3" shall be dried for a minimum of 48 hours ; specimens with a wall thickness exceeding 3" shall be dried for a minimum of 72 hours. The last 6 hours of the minimum drying time may be used to determine whether or not the sample had obtained the proper dried weight.

Paragraph 14 (b) **Weighing Dried Specimens**

The oven dried specimens shall be weighed immediately upon removal from the oven where the drying temperature was 105° to 115°C.

Paragraph 14 (c) **Immersion and Boiling**

The dried specimen that has been weighed shall, within 24 hours, be carefully placed (in a suitable receptable that contains clean water at a temperature of 50° to 75°F). Clean water shall be distilled water, rain water, or tap water that is known to have no effect on test results. The water shall be heated to boiling in not less than 1 hour and not more than two hours. Live steam shall not be applied to the water to shorten the pre-boil period until one hour of heating by gas or electricity has been completed. The boiling shall continue for five hours. At the end of the 5 hours boiling period, the heat shall be turned off, and the specimen allowed to cool in the water to room temperature by natural loss of heat for not less than 14 hours or more than 24 hours.

Paragraph 14 (d) **Reweighing Wet Specimens :**

The water cooled specimens shall be removed from the water, placed on an open drain rack, and allowed to drain for one minute. The remaining superficial water shall be removed by quickly blotting the specimen with a dry absorbent cloth or paper. The specimen shall be immediately weighed following blotting.

Paragraph 14 (e) **Scale Sensitivity :**

(Specimens weighing less than 1000 grams shall be weighed to an accuracy of (0.10) percent of the specimen weight. Specimens weighing more than 1000 grams shall be weighed to an accuracy of (one) gram).

Paragraph 14 (f) **Calculations and Reporting** :

The increase in weight of the boiled specimen over its dry weight shall be taken as the absorption of the specimen and shall be expressed as a percentage of the dry weight The results shall be reported separately for each specimen.

APPENDIX I

Methods of Measuring Pipe Flow

This section is from the National Engineering Hand-book, Section 15. Chapter 9, Measurement of Irrigation Water, U. S. Department of Agriculture, Soil Conservation Service. It *should be noted that given rates of flow are in U.S. gallons.*

Pipe Orifices

Pipe Orifices are usually circular orifices placed within or at the end of a horizontal pipe. The head on the orifice is measured with a manometer.

Where the orifice is placed in the pipe, the discharge will not be free, and the head must be measured at points both upstream and downstream from the orifice. For a further discussion of this type of orifice, the reader is referred to King's *Handbook of Hydraulics.*

The pipe orifice more commonly used in measuring irrigation water and the discharge from wells within a range of 50 to 2,000 U. S. gallons per minute has the circular orifice located at the end of the pipe (fig. I-1). The pipe must be level and the manometer, a glass tube, is placed about 24 inches upstream from the orifice. No elbows, valves, or other fittings should be closer than 4 feet upstream from the manometer. The ratio of the orifice diameter to the pipe diameter should be no less than 0.50 nor greater than 0.83. The ratio to be selected, however, must cause the pipe to flow full. The head is measured with an ordinary carpenter's rule.

Discharge through the orifice is computed by use of the formula

$$Q = Ca\sqrt{2gh}$$

where Q = orifice discharge in U. S. gallons per minute

C = coefficient which varies with the ratio of the orifice diameter to the pipe diameters as well as with all the other factors affecting flow in orifices. The value of the coefficient (C) may be taken from figure I-2.

a = cross-sectional area of the orifice in square inches

g = acceleration due to gravity = 32.2 feet per second.

h = head on the orifice in inches measured above its center.

For example, find the discharge from a 5 inch orifice at the end of an 8-inch pipe operating under a head of 25 inches.

Ratio of orifice diameter to pipe diameter $= 5/8 = 0.625$

C from figure I-2—0.63

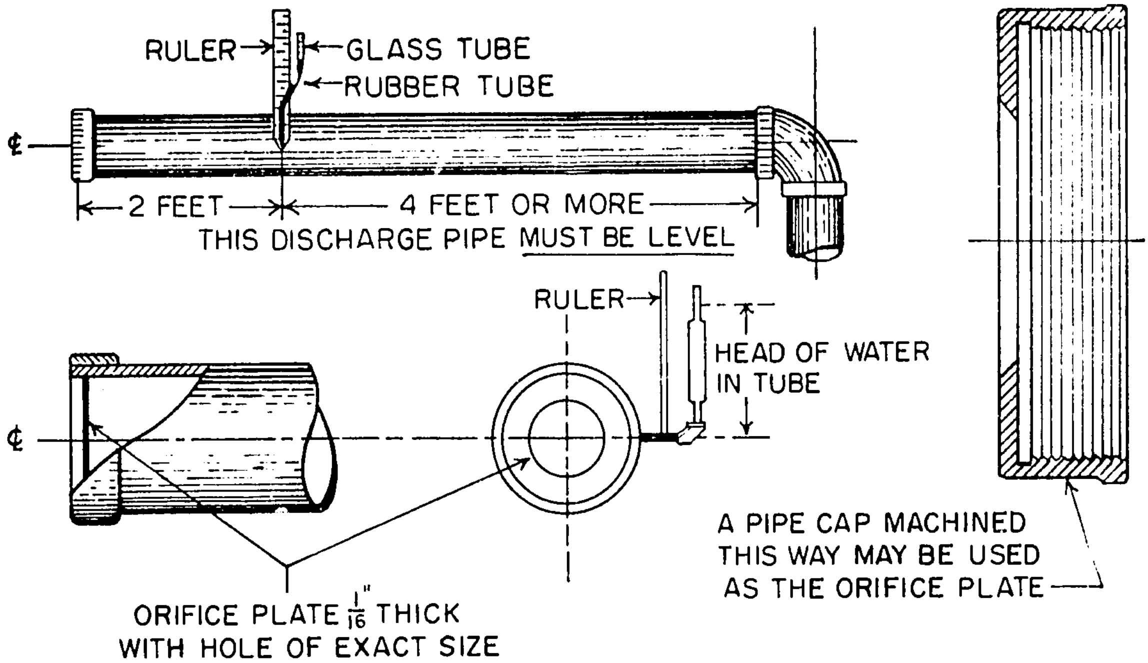

Fig. I—1 Details of a circular pipe orifice located at the discharge end of the pipe

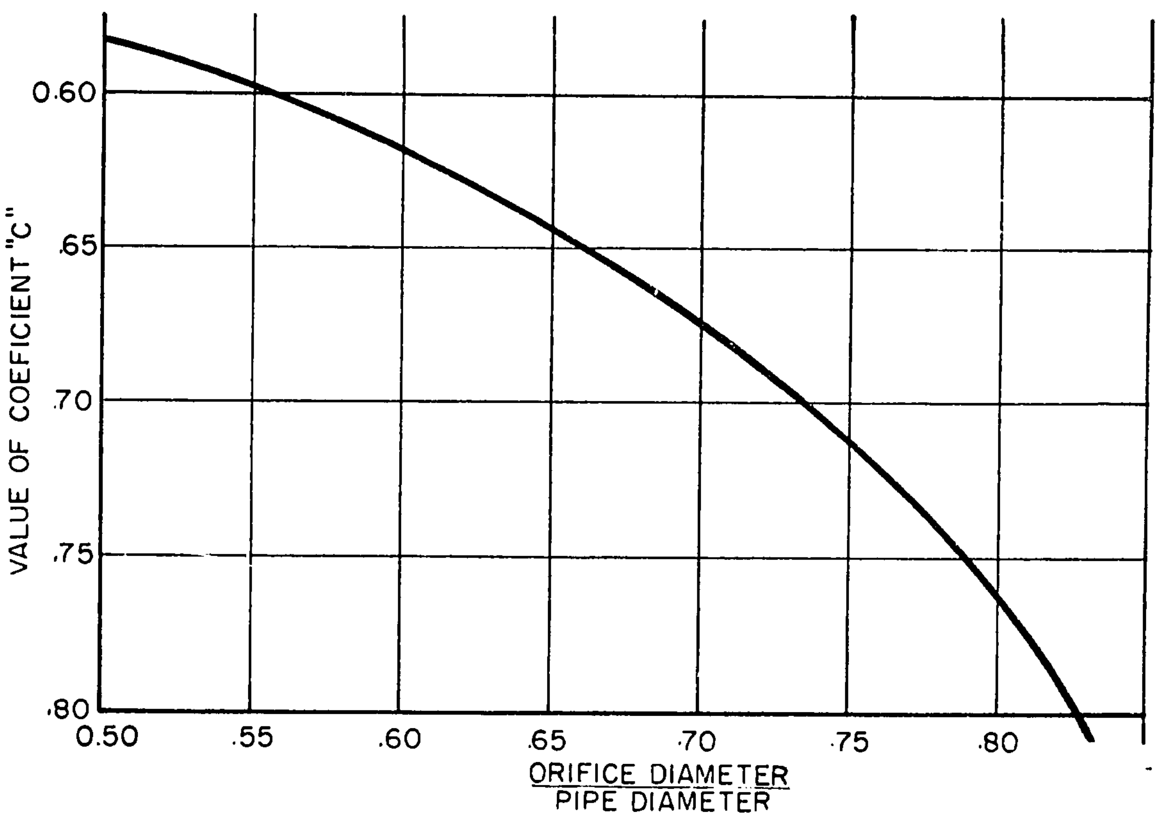

Fig. I—2 Values of the coefficient C for measuring flow from circular pipe orifices based on $Q=CA\sqrt{2gh}$

TABLE I-1

Discharge from circular pipe orifices with free discharge

Head (inches)	3-in orifice		4-in orifice		5-in orifice		6-in orifice		7-in orifice	8-in orifice
	4-in. pipe	6-in. pipe	6-in. pipe	8-in. pipe	6-in. pipe	8-in. pipe	8-in. pipe	10-in. pipe	10-in. pipe	10-in. pipe
	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*
6	108	82	160	150	305	240	408	345		
8	122	94	185	170	350	280	458	395	600	935
10	133	104	205	190	393	316	508	445	666	1040
12	146	114	225	208	430	346	556	490	728	1120
14	157	123	243	224	465	376	599	530	785	1194
16	167	132	257	238	495	402	636	568	838	1266
18	178	140	271	252	524	426	672	604	887	1336
20	187	148	285	266	548	449	708	636	933	1404
22	197	156	299	279	572	470	744	664	979	1471
24	205	164	310	291	596	488	776	692	1022	1529
26	214	171	323	303	620	504	805	720	1064	1585
28	222	177	335	314	644	520	831	747	1104	1641
30	230	183	346	325	668	536	857	773	1143	1697
32	239	189	357	335	692	552	882	799	1181	1753
34	246	195	369	345	715	568	907	824	1218	1809
36	254	200	380	354	737	584	931	847	1251	1865
38	260	205	390	363	759	600	955	867	1281	
40	266	210	401	371	781	616	979	887	1311	
42	272	214	411	380	800	631	1001	906	1341	
44	278	219	420	388	820	645	1023	925	1371	
46	284	224	429	396	837	659	1045	944	1401	
48	290	229	440	405	855	672	1067	963	1431	
50	296	234	448	413	872	686	1089	982	1461	
52	302	238	457	421	888	700	1110	1000	1491	
54	307	243	465	429	904	714	1130	1018	1520	
56	313	248	472	437	919	727	1150	1036	1548	
58	317	252	480	445	934	739	1170	1052	1574	
60	323	257	489	453	948	751	1190	1068	1598	
62	328	262	496	461	961	763	1209	1084		
64	333	266	504	469	974	775	1227	1099		
66	338	271	513	475	988	787	1245	1113		
68	343	275	520	483	1002	799	1263	1127		
70	349	280	525	491	1016	811	1280	1140		

[1] From "Layne Well Water Systems, "Layne and Bowler, Inc., Memphis Tenn., 1951.

a = 19.63 square inches

$Q = Ca\sqrt{2gh}$

$= 0.63 \times 19.63 \times \sqrt{2 \times 32.2 \times 25}$

= 496 U. S. gallons per minute

Table I—1 gives discharge values from various combinations of pipe sizes and orifice sizes for heads up to 70 inches.

VEGTURI METERS

The Venturi meter measures the flow of water in pipes under pressure. It utilizes the Venturi principle in that the flow passing through a constricted section of pipe is accelerted and its pressure head is lowered. The cross-sectional areas of the pipe and the constricteds ection being known, the flow is determined by measuring the drop in presssure head.

A cross section of a Venturi meter showing its component parts is shown in figure I-3. The meter is usually inserted between two flanges in a pipeline. At the upstream end the short, straight, cylindrical part of the meter has the same inside diameter as the pipeline and has a side hole drilled through the wall where a piezometer tube is connected for measuring the static pressure. Following this straight section a conical entrance section leads to the short constricted section or cylindrical throat. This entrance cone has an angle of about 21°. The cylindrical throat section is also provided with a side hole for attaching a piezometer tube. The diameter of the throat is one-fourth to one-half the diameter of the pipeline, A conical exit section with an angle of 5° to 7° follows the throat section and ends at a flange in the pipeline. This long exit cone decelerates the flow as smoothly as possible and restoreas normal pressure in the line. A piezometer tube is sometimes connected in the line immediately below the exit section to measure the overall loss of head through the meter ; however, this measurement is not used in computing the rate of flow through the meter. A loss of head through the meter of 10 to 20 percent may be expected.

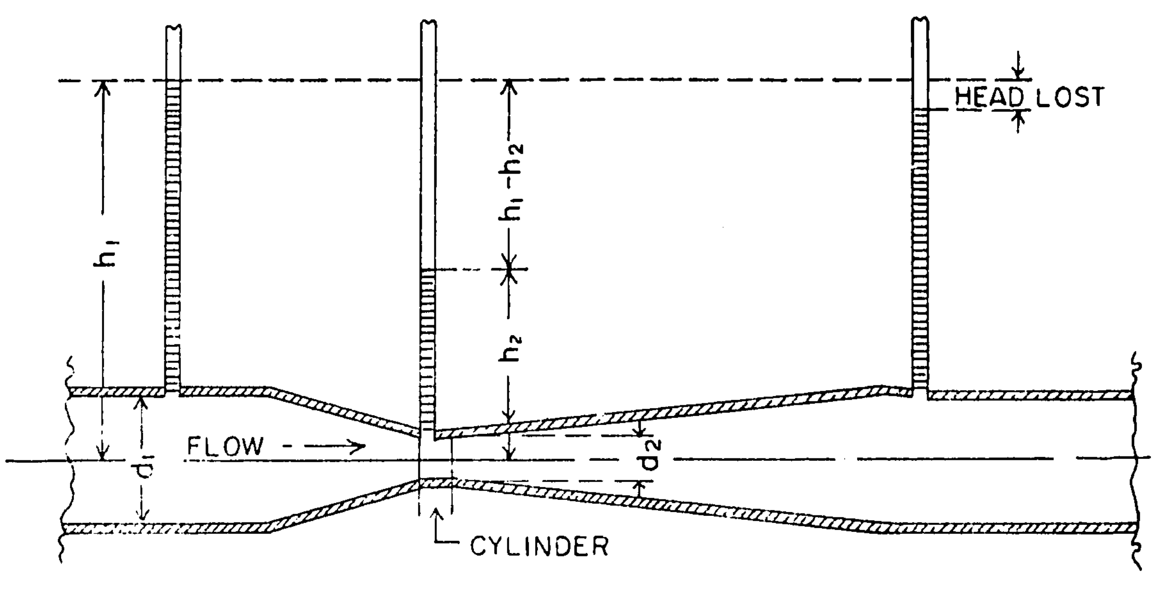

Fig. I-3 Diagram of a Venturi tube

The rate of flow through the meter is computed from the formula

$$Q = CK_2d^2 \sqrt{h_1 - h_2}$$

where Q = rate of flow in cubic feet per second

C = empirical discharge coefficient that may be taken from table 1-2

d_1 = diameter of the entrance section in feet

d_2 = diameter of the throat section in feet

h_1 = pressure head in feet measured above the axis of the meter at the straight entrance section

h_2 = pressure head in feet measure above the axis of the meter at the throat.

K = factor corresponding to the ratio of the throat diameter to diameter of the entrance section.

$$K = \frac{n}{4} \sqrt{\frac{2g}{1 - \left(\frac{d_2}{d_1}\right)^4}}$$

Values of K may be taken from table I-3

Table I-2

Coefficients of discharge (C) for Venturi meters

Diameter of throat (inches)	Throat velocity (feet per second)								
	3	4	5	10	15	20	30	40	50
1	.935	.945	.949	.958	.963	.966	.969	.970	.972
2	.939	.948	.953	.965	.970	.973	.974	.975	.977
4	.943	.952	.957	.973	.975	.977	.978	.979	.980
8	.948	.957	.962	.974	.978	.980	.981	.982	.983
12	.955	.962	.966	.978	.981	.982	.983	.984	.985
18	.963	.969	.973	.981	.983	.984	.985	.986	.986
48	.970	.977	.980	.984	.985	.986	.987	.988	.988

TABLE 1-3

Values of K in formula for Venturi meters

$\frac{d_2}{d_1}$	K	$\frac{d_2}{d_1}$	K	$\frac{d_2}{d_1}$	K	$\frac{d_2}{d_1}$	K	$\frac{d_2}{d_1}$	K
.20	6.31	.33	6.34	.46	6.45	.59	6.72	.72	7.37
.21	6.31	.34	6.34	.47	6.46	.60	6.75	.73	7.45
.22	6.31	.35	6.35	.48	6.47	.61	6.79	.74	7.53
.23	6.31	.36	6.35	.49	6.49	.62	6.82	.75	7.62
.24	6.31	.37	6.36	.50	6.51	.63	6.86	.76	7.72
.25	6.31	.38	6.37	.51	6.52	.64	6.91	.77	7.82
.26	6.31	.39	6.37	.52	6.54	.65	6.95	.78	7.94
.27	6.32	.40	6.38	.53	6.56	.66	7.00	.79	8.06
.28	6.32	.41	6.39	.54	6.59	.67	7.05	.80	8.20
.29	6.32	.42	6.40	.55	6.61	.68	7.11	.81	8.35
.30	6.33	.43	6.41	.56	6.64	.69	7.17	.82	8.51
.31	6.33	.44	6.42	.57	6.66	.70	[illegible]	.83	8.69
.32	6.33	.45	6.43	.58	6.69	.71	7.30	.84	8.89

As an example of the use of this formula, assume a 24-inch pipe diameter, and 8-inch throat diameter, and a drop in pressure head between the entrance and the throat ($h_1—h_2$) of 9.3 feet.

The ratio of the throat diameter (d_2) to the entrance diameter (d_1) = 8/24 = 0.33. Using this ratio in table 1-3, find the ualue of K to be 6.34.

Then

$$Q = CKd_2^2 \sqrt{h_1 - h_2}$$
$$= C \times 6.34 \times 0.667^2 \times \sqrt{9.30}$$
$$= C \times 8.603 \text{ cubic feet per second}$$

Since the value of C will be near unity, the approximate velocity through the throat may be computed as follows :

$$V = \frac{Q}{A} = \frac{8.603}{\pi \times 0.333^2} = 24.6 \text{ feet per second}$$

Using this velocity, the value of C from table I-2 is 0.9805. Thus Q=0.9805x8.603 =8.435 cubic feet per second.

Manufacturers of commercial Venturi meters should be requested to furnish discharge tables or charts for all meters purchased.

IRRIGATION METERS

Meters most commonly used to measure irrigation water are of the velocity type and are installed in canals, flumes, or streams or contained within pipes or conduits up to 6 feet in diameter. When the meters are installed in open channels, the flow must be brought through a pipe or conduit of known cross-sectional area. This pipe or conduit is called a meter tube. The meter placed within the discharge end of this tube.

Irrigation meters essentially consist of a conical propeller connected to a registering head by a gear train. They are operated by the kinetic energy of the flowing water. The propeller is suspended, facing the center of flow, in the pipe, tube, or conduit and is rotated by the flow of water. The speed of the propeller (r.p.m.) is proportional to the average velocity of flow within the tube(ft./sec.), and since the cross-sectional area of the tube is known and remains constant, the propeller speed is proportional to the rate of flow.

The rotating propeller actuates the registering head through the gear train. This head registers total flow on a counter-type clock. The total flow is recorded directly in standard volumetric units such as gallons, cubic feet acre-feet, miner's inch-days, or others.

There are two basic requirements for accurate operations of the meter: (1) The tube must flow full at all times, and (2) the rate of flow must exceed the minimum for the rated range. Meters are given a volumetric calibration test at the factory, and adjustment or recalibration in the field is not normally required.

Irrigation meters of the types described have a number of advantages over other methods of water measurement. Registration is independent of variations in the line pressure or in the rate of flow within the rated range, thus eliminating frequent readings and checks. Since the meters total flow directly, no time-consuming computations are involved, and human errors are eliminated. Automatic totalizer-recording devices are available which may be used with continuous charts and provide permanent records of water use. The principal disadvantages of these meters are their susceptibility to clogging with moss and to vandalism when installed permanently.

Three basic types of irrigation meters are discussed in succeeding paragraphs. These are (1) low-pressure line meters, (2) open-flow meters, and (3) vertical-flow or hydrant-type meters.

Meter valves combine into a single compact unit the functions of irrigation hydrants with those of vertical flow-meters.

Low-pressure-line meters. These are used wherever pipelines are used to distribute irrigation water. They may be installed in new or existing concrete, steel or asbestos-cement pipelines within a range of diameters of 4 to 72 inches. Portable sections of steel pipe with meter installed are available, thus permitting the measurement of water at several locations with one meter. The principal use for low-pressure-line meters is the metering of water delivered to individual farms from lateral lines of an irrigation enterprise. In the smaller sizes, these meters can be used effectively on an individual farm to measure accurately the amount of water applied to a given area, thereby permitting increased efficiency of water use. Figure I-4 shows a low-pressure-line meter installed in a section of steel pipe. Note the straightening vanes installed ahead of the propeller to eliminate turbulence.

Open-flow meters. These are similar to the low-pressure-line meters in construction and are used to meter the flow in open channels gravity-flow, closed-conduit systems. The meter is suspended from a wall or simple support structure into the center of a full-flowing submerged discharge end of a pipe, culvert, or siphon, which serves as the meter tube. The metered section may be round or rectangular. Concrete pipe, corrugated metal pipe, or even long wooden-box structures are satisfactory as meter tubes. Open-flow meters may be installed permanently or may be moved from one location to another

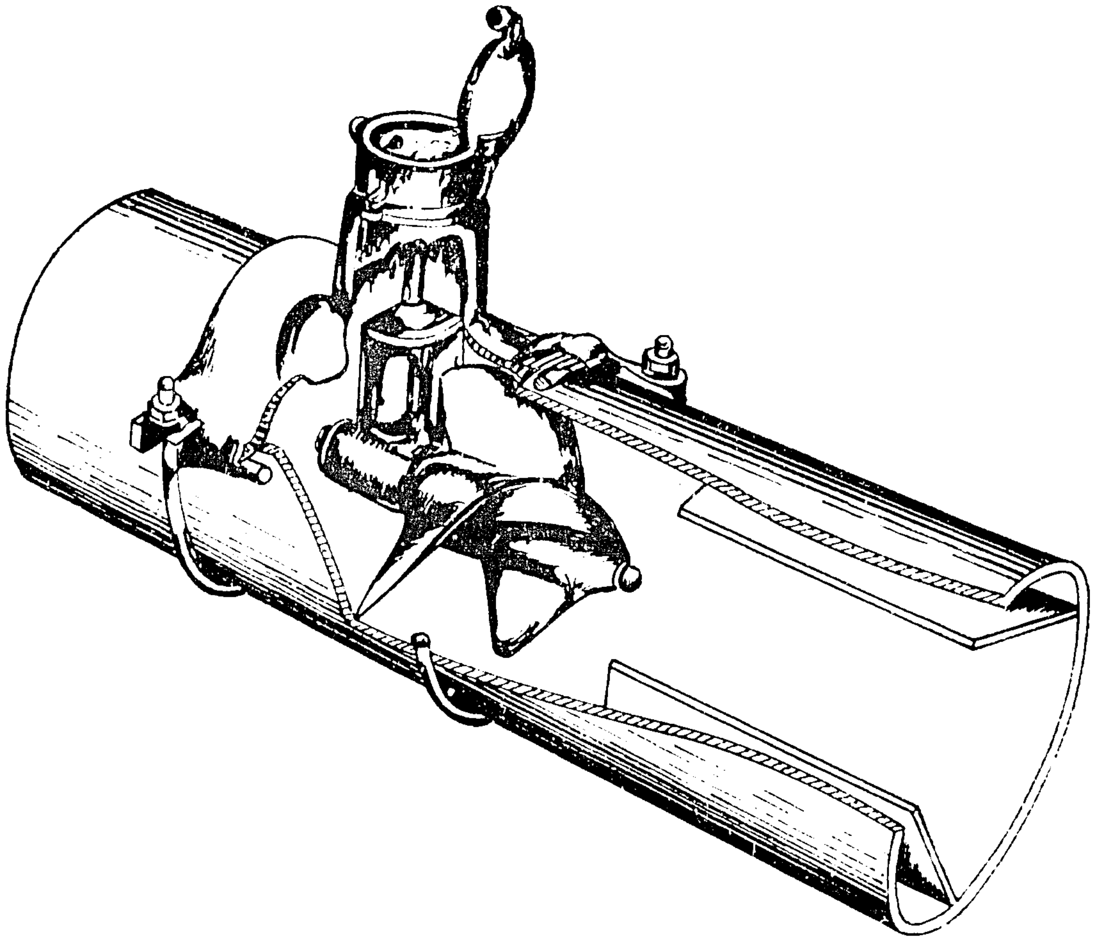

Fig. I-4. A Low-pressure line meter installed in a section of Steel pipe

without interrupting the normal flow of water.

The principal use of the smaller-size meters up to about 42 inches in diameter is to meter the flow at farm turnouts (fig. I-5). The larger sizes are used to meter large volume flow from reservoirs and in main canals and large lateral ditches.

Vertical-flow meters.— These are used to meter the flow of water in vertical pipes (fig. I-6). Their operating principles are identical with those of the other two types of meters, the only difference being the position of the propeller, which is vertical. Water flow unre-stricted in an upward direction through the meter tube, actuates the propeller, and is then deflectted downward by a bonnet or cover to the outside of the tube. The bonnet is designed to provide adequate area for the maximum discharge and to prevent tampering with the propeller.

The principal use for vertical flow meters is the metering of individual farm deliveries where such deliveries are made in gravity flow pipelines and through pipe turnouts.

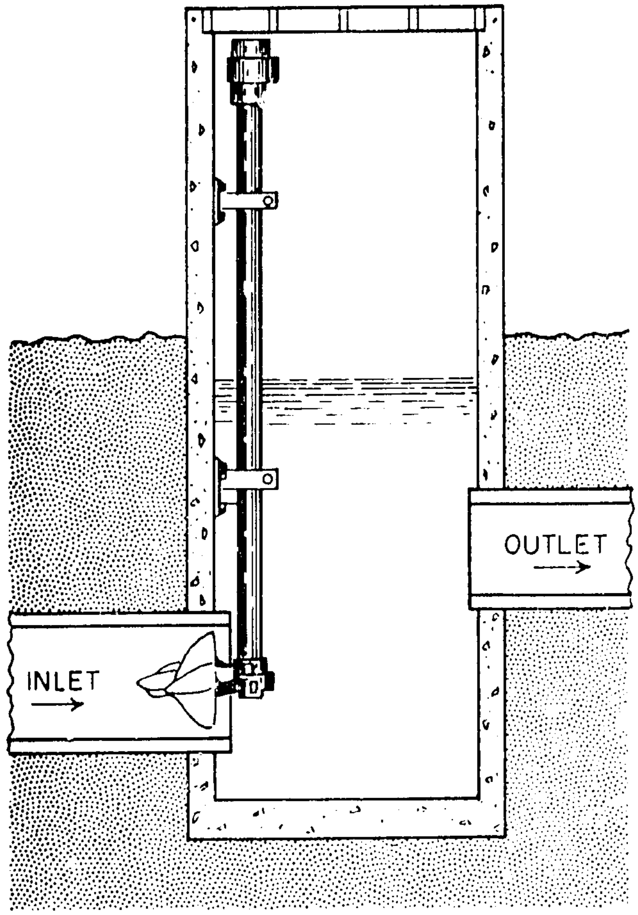

Fig. I-5—An open flow meter installation

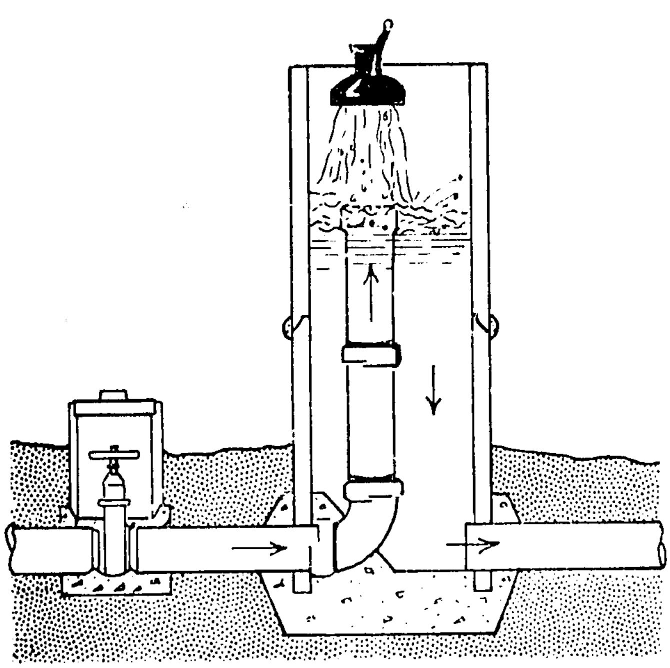

Fig. I-6—Typical-vertical-flow meter installation

Meter valves—Provision is made in these valves for total flow registration at all rates of flow above the minimum rate of flow and for flow control from full capacity to complete shutoff. The rate of flow can be accurately set to that desired by rotating the meter-head assembly. Meter valves are portable and can thus be used on any number of hydrants or pipe turnouts of like diameter up to 12 inches. They may be placed in the open end of any vertical riser discharge pipe.

COORDINATE METHODS

In the coordinate method, coordinates of the jet issuing from the end of a pipe are measured. The flow from pipes may be measured whether the pipe is discharging vertically upward, horizontally, or at some angle with the horizontal. Since the discharge pipe can be set in a horizontal position for measurement purposes, there is no need here for a discussion of flow from pipe in an angular position.

Coordinate methods are used to measure the flow from flowing wells (discharging vertically) and from small pumping plants (discharging horizontally). These methods have limited accuracy owing to the difficulty in making accurate measurements of the coordinates of the jet. They should be used only where facilities for making more accurate measurements by other methods are not available and where an error of up to 10 percent is permissible.

To measure the flow from pipes discharging vertically upward, it is only necessary to measure the inside diameter of the pipe (D) and the height of the jet above the pipe outlet (H) (fig I-7). Table I-4 gives discharge values for pipe diameters up to 12 inches and jet heights up to 40 inches.

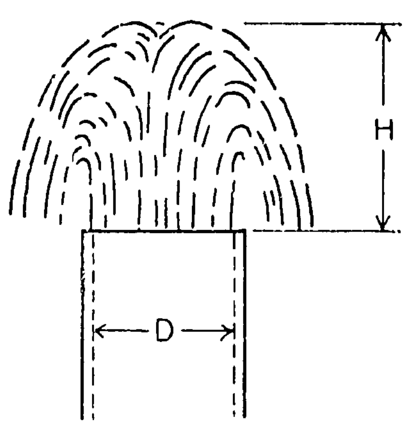

Fig. I-7—Required measurements to obtain flow from vertical pipes

TABLE I-4

Flow from vertical pipes[1]

Jet hieght (inches)	Diameter of pipe (inches)													
	2 Std[2].	3 Std.	4 O.D.[3] Std.		5 O.D. Std.		6 O.D. Std		8 O.D. Std.		10 O.D. Std.		12 O.D. Std.	
	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*		U.S. *G.p.m.*		U.S. *G.p.m.*		U.S. *G.p.m.*		U.S. *G. p. m.*		U.S. *G. p. m.*	
2	28	57	75	86	103	115	137	150	200	215	265	285	330	335
2½......	31	69	95	108	132	150	182	205	275	290	357	385	450	480
3	34	78	112	128	160	183	225	250	340	367	450	490	570	610
3½......	37	86	124	145	183	210	262	293	405	440	555	610	705	755
4	40	92	135	160	205	235	295	330	465	510	660	725	845	910
4½......	42	98	144	173	225	257	320	365	520	570	760	845	990	1060
5	45	104	154	184	240	275	345	395	575	630	840	940	1120	1200
6	50	115	169	205	266	306	385	445	670	730	1000	1125	1370	1500
7	54	125	186	233	293	336	420	485	750	820	1150	1275	1600	1730
8	58	134	202	239	315	360	450	520	810	890	1270	1420	1775	1950
9	62	143	215	254	335	383	480	550	870	955	1360	1550	1930	2140
10	66	152	227	268	356	405	510	585	925	1015	1450	1650	2070	2280
12	72	167	255	295	390	450	565	650	1010	1120	1600	1830	2300	2550
14	78	182	275	320	420	485	610	705	1100	1220	1730	2000	2530	2800
16	83	195	295	345	455	520	655	755	1180	1300	1870	2140	2720	3000
18	89	208	315	367	480	555	700	800	1265	1400	2000	2280	2900	
20	94	220	333	388	510	590	740	850	1335	1480	2100	2420		
25	107	248	377	440	580	665	830	960	1520	1670	2380	2720		
30	117	275	420	488	640	740	925	1050	1690	1870	2650	3000		
35	127	300	455	525	695	806	1000	1150	1820	2020	2850			
40	137	320	490	565	745	865	1075	1230	1970	2160				

[1] Table prepared from discharge curves in Utah Engin, Expt. Sta. Bul. 5, "Measurement of Irrigation Water," June 1955.

[2] Standard pipe.

[3] Outside diameter of well casing.

To measure the flow from pipes discharging horizontally, it is necessary to measure both a horizontal and a vertical distance from some point on the end of the pipe to a similar point in the jet. For convenience, these coordinate are measured from the top of the inside of the pipe to a point on the top of the jet (fig. I-8). These horizontal and vertical distances are called X and Y ordinates, respectively.

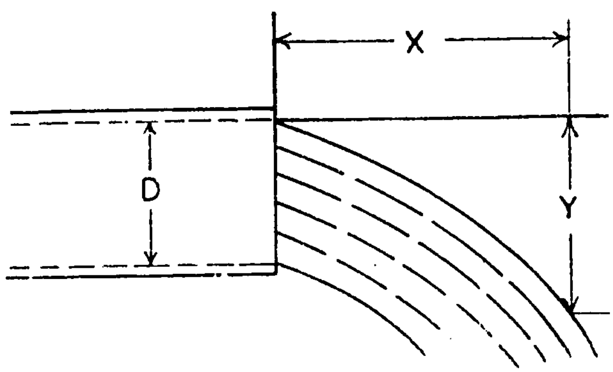

Fig. I-8—Required measurements to obtain flow from horizontal pipes

For reasonably accurate results, the discharge pipe must be level and long enough to permit the water to flow smoothly as it issues from the pipe. Table I-5 gives discharge values for pipe diameters up to 6 inches where the ordinate X is selected to be O, 6, 12, or 18 inches. For pipes flowing less than O.8 full at the end, the vertical distance Y can be measured at the end of the pipe where X=O. Table I-5 is used to obtain the discharge. Table I-5 is also applicable either to conditions of full flow or partial flow.

TABLE I-5

Flow from horizontal pipes[1]

WHEN X=O

Y (inches)	Size of pipe (nominal diameter)				
	2-inch	3-inch	4-inch	5-inch	6-inch
	U. S. *G.p.m.*	U. S. *G.p.m.*	U. S. *G.p.m.*	U. S. *G.p.m.*	U. S. *G.p.m.*
0.20		67.7	180	308	
.30		66.5	175	303	530
.40		65.1	171	298	518
.50		63.6	166	293	506
.60	18.3	62.0	161	287	494
.70	17.6	60.4	156	282	482
.80	16.7	58.4	150	277	470
.90	15.4	55.7	145	271	458
1.00	13.7	53.1	139	265	446
1.20	9.4	46.9	128	251	422
1.40	6.0	40.5	115	237	398
1.60		31.9	102	221	373
1.80		24.0	90	205	347
2.00		17.3	77	187	321
2.20		11.8	64	167	295
2.40		7.3	52	147	270
2.60			41	127	246
2.80			32	108	223
3.00			24	90	200
3.30			13	65	167
3.60				45	137
3.90				29	111
4.20					86
4.50					64
4.80					45

[1] See footnote at end of table.

TABLE I-5

Flow from horizontal pipes[1]—Continued

WHEN X=6 INCHES

Y (inches)	Size of pipe (nominal diameter) 2-inch	3-inch	4-inch	5-inch	6-inch
	U. S. *G.p.m.*	U. S. *G.p.m.*	U. S. *G.p.m.*	U. S. *G.p.m.*	U. S. *G.p.m.*
0.24	177	310	548		
.36	146	274	503	969	1243
.48	126	247	462	857	1113
.60	111	229	435	772	1019
.72	100	215	404	705	947
.84	92	202	377	646	889
.96	85	193	355	606	844
1.08	79	184	337	574	808
1.20	75	175	319	543	772
1.80	60	139	265	449	660
2.40	51	119	229	390	583
3.00	45	105	206	350	525
3.60	40	94	188	314	476
4.20	37	86	169	278	431
4.80	35	79	151	238	386
5.40	32	71	133	193	332
6.00	30	63	116	150	247
6.60	27	50	99	112	
7.20	25	38	83		
7.80	23	29	69		
8.40	20				

WHEN X=12 INCHES

Y (inches)	2-inch	3-inch	4-inch	5-inch	6-inch
.96	157	319	570	1014	
1.08	148	305	548	975	1315
1.20	139	292	530	925	1257
1.80	114	247	444	763	1055
2.40	99	215	395	655	929
3.00	87	193	359	583	844
3.60	79	176	332	530	772
4.20	73	161	305	489	718
4.80	68	149	287	458	673
5.40	63	140	269	426	633
6.00	60	132	256	404	597
6.60	57	126	242	386	574
7.20	54	120	233	368	548
7.80	52	114	224	355	525

[1] See footnote at end of table.

TABLE I-5

Flow from horizontal pipe[1]—Continued

WHEN X=18 INCHES

Y (inches)	Size of pipe (nominal diameter)				
	2-inches	3-inches	4-Inches	5-Inches	6-Inches
	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*	U.S. *G.p.m.*
1.80	166	346	624	1014	1400
2.40	144	305	557	907	1261
3.00	129	274	503	826	1153
3.60	117	251	462	754	1068
4.20	109	233	431	700	992
4.80	101	220	404	655	934
5.40	95	206	382	615	884
6.00	89	197	364	579	839
6.60	84	187	346	548	799
7.20	81	180	332	521	763
7.80	77	172	319	498	732
8.40	75	166	305	476	705

[1] Table for standard steel pipe prepared from data resulting from actual experiments conducted at Purdue Univ. and reported in Purdue Engin. Expt. Sta. Bul. 32, "Measurement of Pipe Flow by the Coordinate Method, "August 1928.

APPENDIX J

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CONCRETE PIPE FOR IRRIGATION

Hundreds of thousands of acres of dry, desolate land are productive today because of irrigation. This land, though naturally rich in plant food elements, could not be profitably farmed without supplemental water.

For centuries irrigation water was conveyed in open ditches, usually unlined. In the late 1800's several far-sighted farmers installed concrete pipe irrigation systems. Performance of these systems has been extraordinary and concrete has become by far the most widely used material for underground pipe systems. Thousands upon thousands of miles of concrete pipelines serve farmers and ranchers in virtually all irrigated regions in North America.

ADVANTAGES OF CONCRETE IRRIGATION PIPE

An irrigation system must be dependable, moderate in cost, and long-lived with little maintenance. Concrete pipe fulfills all these requirements. The advantages of concrete were known to the ancient Romans. They built their aqueducts of concrete and some sections are still capable of carrying water. An enviable performance record.

Many concrete pipe systems have been in service for over half a century. The time-tested performance of concrete pipe is demonstrated in the many irrigated areas of the United States. Concrete irrigation pipe manufactured to ASTM specifications results in a high-quality concrete. The concrete, placed underground with constant moisture and ideal temperature conditions, is subjected to a most favorable environment.

Provides efficiency, economy, convenience. Time and labor costs are greatly reduced with concrete pipe systems. Owners report that one man often can do the work required for a concrete pipe irrigation system, whereas three or four men would be needed to handle an open-ditch system for the same acreage. Hard shovel work is virtually eliminated.

Open ditches often take 3 to 4 percent of the land area out of cultivation. Concrete pipelines permit productive use of almost all the land. In addition, each field is completely accessible to machinery; fields are not isolated by open ditches.

Makes possible irrigation of hilly land. Water delivery to hard-to-reach areas is easier with a concrete pipeline. Pipe can be laid over hills and across valleys, permitting delivery of irrigation water to lands not accessible by open ditches.

Prevents costly water losses. Irrigating with concrete pipe cuts water losses to a minimum. Loss of water from unlined canals and ditches by seepage and evaporation can amount to as much as 60 percent; average loss is around 35 percent, according to the U.S. Department of Agriculture. In areas of limited water supplies, reductions of these losses permit irrigation of additional acres.

Permits close control of water distribution. With concrete irrigation pipe, water can be delivered to any field or any part of a field and the flow can be controlled to the exact amount desired. No part need get too little or too much water.

Requires little maintenance. A properly installed concrete irrigation pipe system greatly reduces maintenance costs and weed control problems encountered in open ditches. Concrete is a strong, durable material—ideal for water conveyance.

WATER SUPPLY AND DISTRIBUTION

Water for irrigation may come from surface supplies originating on the farm or delivered to the farm or from groundwater sources. Surface water supplies available at one location on the farm can be either directly diverted or pumped into a concrete pipe system to distribute water to all the cropland to be irrigated.

Groundwater supplies developed from wells on the farm may be pumped into a concrete pipe system. With a concrete pipe system, wells do not need to be located at the high point of the farm but may be at the location that provides the best water supply.

Methods of applying the water to cropland vary with the type of crops grown, the slope of the land, the soil type, and the available water supply. A study of these factors will provide selection of the most economical irrigation methods and will enable the irrigator to get maximum benefit from the water supply available.

Concrete pipe can deliver water on slopes that could not be irrigated by an open ditch system.

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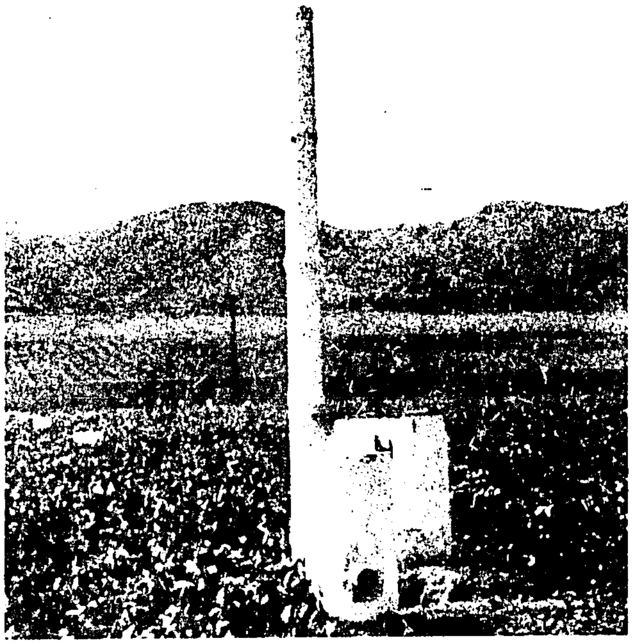


Gate stand, vent, and hydrants of concrete irrigation system. Virtually all the land is productive when irrigated by an underground concrete pipe system.

Furrow irrigation. Underground concrete pipe supplies water to grated surface pipe.

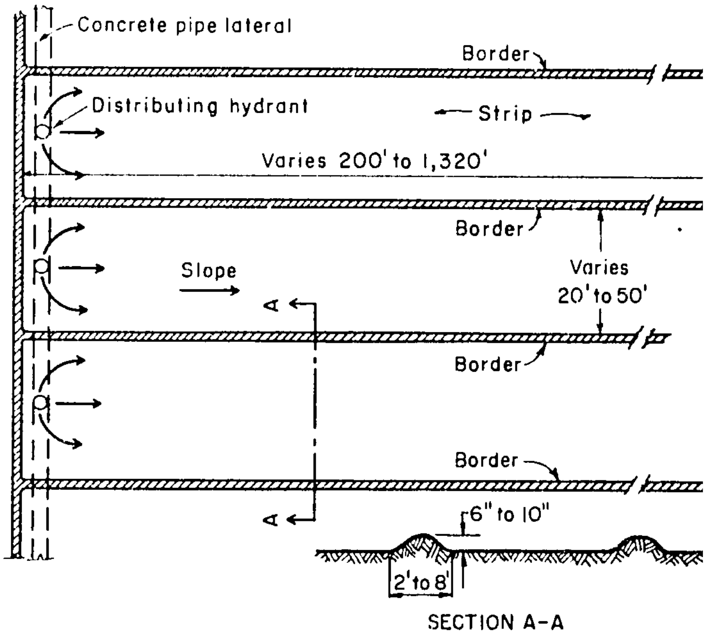


Fig. 1. Typical border and strip layout showing dimensions.

Date palm orchard with basins prepared for irrigation.

Three broad classifications of irrigation are (1) flooding method, (2) furrow method, and (3) sprinkler method.

Flooding method

Irrigation by flooding involves flowing or ponding a sheet of water over the land. Water is delivered to each border or basin area through a concrete pipe lateral and riser equipped with an alfalfa valve. Flooding is controlled by either borders or basins to contain or pond the water. Basins are rectangular areas formed by levees on four sides and are generally used for orchard irrigation. When an orchard is laid out, the land is leveled and the basins formed before the trees are set.

Border irrigation is most commonly used to irrigate alfalfa, small grain, or similar crops. In border irrigation, a sheet of water flows downslope between parallel levees or borders spaced 20 ft. or more apart. (The borders may be closer than 20 ft. for irrigation of pasture land.) They are usually parallel to the side of the field to avoid irregular lengths and corner areas. The land between borders is called a strip. Water is delivered to each strip through a concrete pipe riser and alfalfa valve.

Border irrigation can be used to advantage when crops requiring flooding, such as alfalfa and small grains, are grown in rotation with row crops. Furrows should run in the same direction as the slope to help preserve grading done for the border layout.

Borders are made only high enough to prevent overflowing (Fig. 1). A settled height of 6 to 10 in. is usually sufficient. Borders for alfalfa irrigation are made 5 to 8 ft. wide at the base. Wide borders with sloping sides permit farm machinery to cross over them readily. For irrigated pastures the borders are narrower—usually about 2 ft. wide. Crops can be grown on the borders since water flowing down the slope soaks into the borders.

Furrow method

Furrow irrigation is widely used for row crops. It is also used where flooding would cause the soil to bake and crust or would require heads of water larger than available. Water is absorbed by the land as it flows down small ditches or furrows ranging in length from 100 to 1,500 ft. On tight soils the length of run may be ¼ mile or slightly more. Furrows in sandy or loose soils may be as short as 150 ft.

Three rules should be observed for good furrow irrigation: (1) Space furrows close enough so that wet areas meet. (2) Provide sufficient water for the desired penetration. (3) Limit furrows to a length that will minimize inequalities in water penetration between the upper and lower ends of the field.

Sprinkler method

Sprinkler irrigation has become quite popular because it is suitable for a wide range of topographic conditions and does not require land leveling. However, a detailed economic analysis of the equipment and labor costs, efficient water usage, and land leveling costs should be made. When an underground concrete pipeline operating by gravity flow is used to supply water, a booster pump is incorporated into the system to provide the pressure needed for operation of the sprinkler system. A sprinkler system is also used when soils are too porous for good distribution by surface methods or when the water supply is too small to distribute water efficiently by surface methods.

IRRIGATION WATER REQUIREMENTS

Both the designing engineer and the farmer should know how much water will be required for the production of crops to be grown under irrigation and how much and how often water must be applied. The engineer needs this information to determine the flow of water required at various points in the system. The farmer needs it as a guide to apply the correct amount of water at the proper time. A system designed with inadequate capacity to meet peak crop water demands will result in a reduction of crop yields.

Total water requirements

Irrigation requirements vary with the region of the country, the type of crops grown, the local climatic conditions, and the efficiency of application.

In the arid regions, irrigation crop requirements will be several times the requirements for crops grown in semiarid and more humid regions. Losses from evaporation and plant transpiration are much greater during hot, dry weather and in areas of low humidity. Under such conditions, some crops may use 2 in. or more of water per week. Annual water requirements for small grain crops will be less than for crops like cotton and sugar beets that require a longer period to mature.

Although irrigation water requirements may vary from less than a foot to more than 5 ft. per year, depending on the region and the crops grown, 2 to 3½ ft. will be enough for most crops.

Frequency and amounts of application

The frequency and amounts of irrigation water applied depend on type of crop, stage of growth, soil type, and climatic conditions. Some crops, such as pasture, require frequent applications during the entire growing season. On the other hand, water should not be applied to crops such as cereals and legumes during ripening when grown for seed stock. Root characteristics of crops also are an important factor in determining how often crops need irrigation. Shallow-rooted crops such as vegetables need frequent light applications to maintain moisture in the upper 1 or 2 ft. of soil. Deep-rooted crops such as alfalfa, sugar beets, and cotton require less frequent applications but need more water at each irrigation.

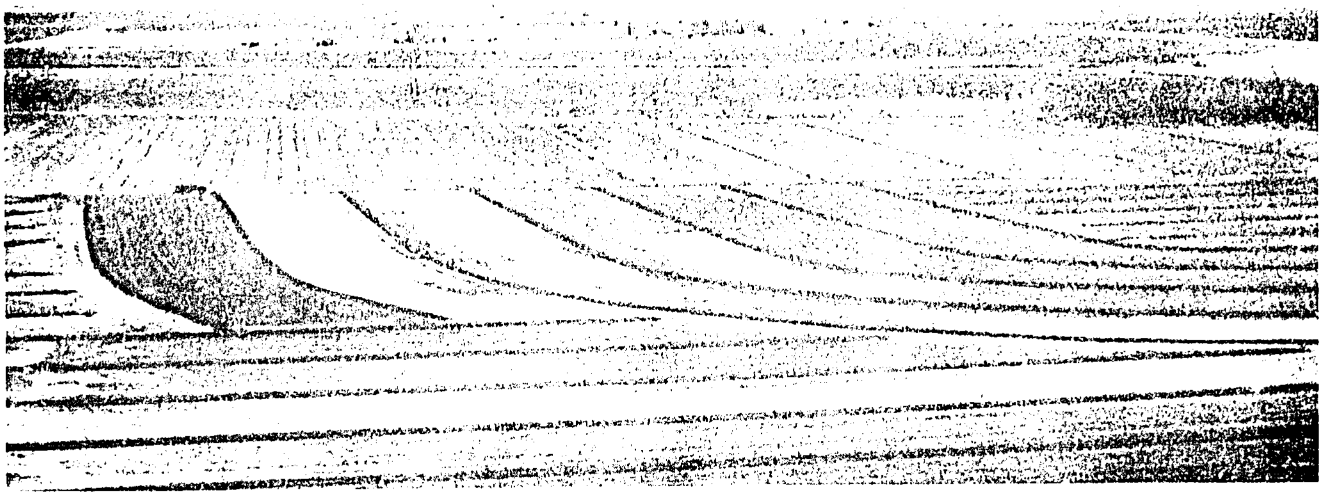
The water-holding capacity of the soil is an important factor in determining amount and frequency of application. Coarse-textured soils have low moisture-storage capacity. Clay soils have high moisture-storage capacity. Therefore, smaller and more frequent applications of water must be made to crops grown on coarse soils than on finer-textured soils. If more water is applied than the soil will hold, waste will occur through runoff and deep percolation.

Table 1 gives the average amount of water needed at each application for various soil and crop conditions. Quantities shown are for average conditions and are based on applications made shortly before crops start to suffer from lack of water. In determining the quantities shown, allowance was made for loss due to evaporation and deep percolation, but not for runoff.

TABLE 1. Recommended Amount of Water to be Applied*

Root Zone	Sandy soil, in.	Loamy soil, in.	Clayey soil, in.
Shallow (less than 2 ft.)	1 to 2	2 to 3	3 to 4
Medium (2 to 3 ft.)	2 to 3	4 to 6	6 to 8
Deep (4 to 6 ft.)	4 to 6	8 to 10	10 to 11

*USDA Bulletin No. 1922, *Practical Irrigation*



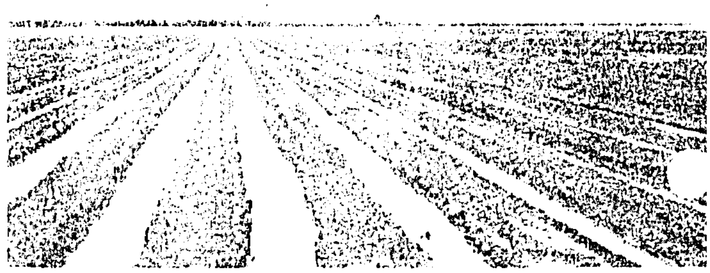
Border irrigation. Parallel, graded borders confine water to increase irrigation efficiency.

Much helpful information on water requirements of different crops can be obtained from college bulletins and textbooks. (See selected references at back of this book.) County agricultural agents, state college extension specialists and Soil Conservation Service offices can also furnish helpful information on farm irrigation water requirements.

INSTALLATION AND OPERATION OF CONCRETE PIPELINES

A concrete pipe irrigation system represents a substantial investment. For best results, the system should be designed by someone experienced in irrigation design. Some pipe producers design and construct irrigation systems. They furnish all labor, materials, and accessories to complete the system according to contract and specifications. Other manufacturers work solely through contractors.

High-quality pipe should be used in construction of irrigation systems. The American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa., has developed standard specifications for concrete pipe for irrigation: Specifications for Concrete Pipe for Irrigation or Drainage, ASTM C118, and Specifications for Nonreinforced Concrete Irrigation Pipe with Rubber Joints, ASTM C505. All concrete pipe used in building irrigation systems should meet the requirements of these specifications. The American Society of Agricultural Engineers has developed a standard entitled Design and Installation of Nonreinforced Concrete Irrigation Pipe Systems, ASAE S261.3. Copies of this standard are available from ASAE, St. Joseph, Mich. 49085. The American Concrete Pipe Association, 1501 Wilson Boulevard, Arlington, Va. 22209, has excellent information available on design, construction, and installation of concrete irrigation systems. Many concrete pipe manufacturers have available copies of these specifications and standards as well as specific information on their products.



Off-season irrigation by furrow method can prove invaluable during the growing season.

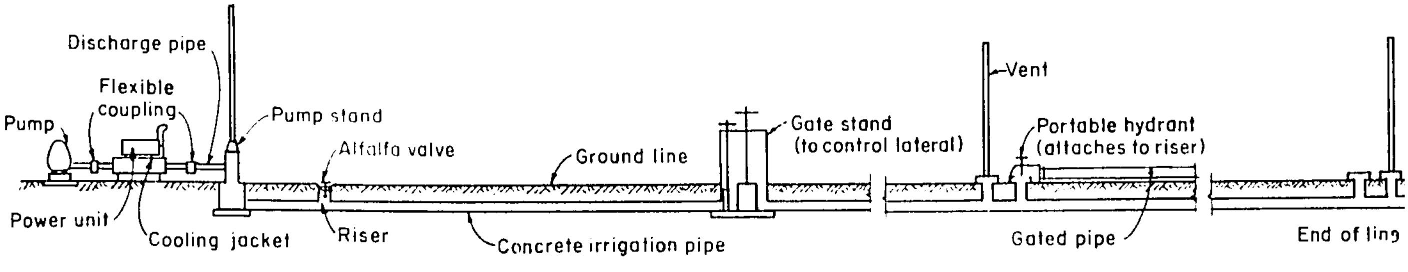
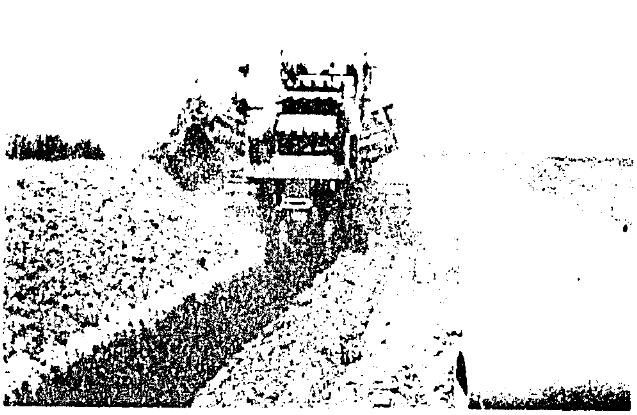
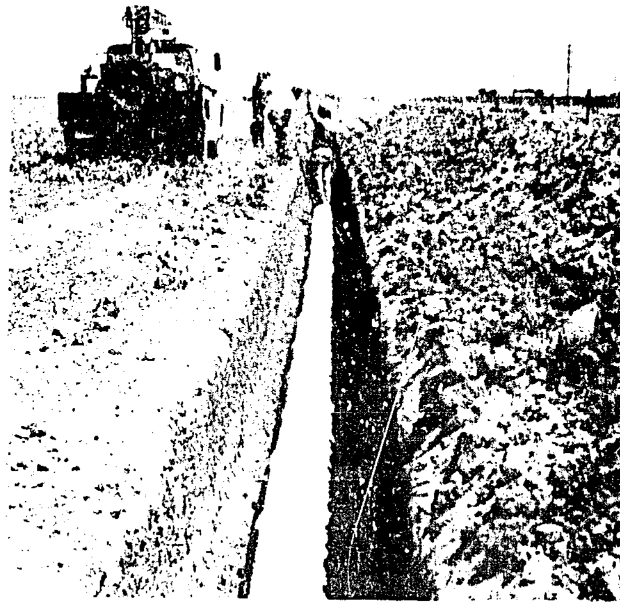


Fig. 2. Elements of an underground concrete pipe irrigation system.



Pipe is distributed even before trench is made when a trencher is used.



A straight, well-graded trench ready for pipe installation. Line and grade of trench should be carefully planned.

Installation

Proper installation of quality concrete pipelines is the key to trouble-free service. The pipe should be carefully placed in a straight trench with uniform grade. The bottom of the trench should be smooth, slightly moist, and firm, with large stones, clods, or other irregularities removed. A thin layer of fine soil or sand may be placed in the bottom of the trench to ensure uniform bedding for the pipe.

When pipelines are to be laid in rocky areas, the trench should be overexcavated and refilled to grade with fine soil or sand. The fill should be properly compacted to produce a firm, uniform foundation.

When pipelines are to be placed in soft, unstable soil, the trench should be overexcavated and backfilled to grade with suitable materials such as gravel, crushed rock, or limestone to provide a stable bedding for the pipe. Excess water in the trench should be removed to ensure proper installation and bedding of the pipe.

Trench depth depends on local soil and climatic conditions. In general, a cover of 2 ft. or more over the top of the pipe has proved satisfactory; in some areas cover as shallow as 18 in. is being used successfully. For economy it is advisable to keep pipe cover to a minimum.

Safe minimum cover may be determined by analysis of the specific soil conditions, pipe size, and section length. Table 2 gives some values for loads transmitted to the pipeline with various depths of cover. The impact factor F_1 should be considered for specific conditions.

TABLE 2. Loads Transmitted to Pipe from 8,000-Lb. Wheel Load,* Pounds per Foot of Length

Cover over top of pipe, ft.	3-ft. pipe length			4-ft. pipe length			6-ft. pipe length		
	Pipe diameter			Pipe diameter			Pipe diameter		
	12 in.	15 in.	18 in.	12 in.	15 in.	18 in.	12 in.	15 in.	18 in.
1.5	1,121	1,282	1,535	894	1,029	1,300	625	720	865
2.0	778	916	1,140	656	791	961	476	556	700
3.0	427	504	645	384	448	559	304	357	458
4.0	260	315	404	238	293	378	140	248	319
ASTM C-118 allowable	1,500	1,650	1,800	1,500	1,650	1,800	1,500	1,650	1,800

Ref: Calculations made using formula and tables in Highway Research Board *Proceedings*, Vol. 26, 1946, page 179.

Formula: $W_p = \frac{1}{L} F_1 C_t P_o$

W_p = pressure on conduit due to surface loads in pounds per linear foot

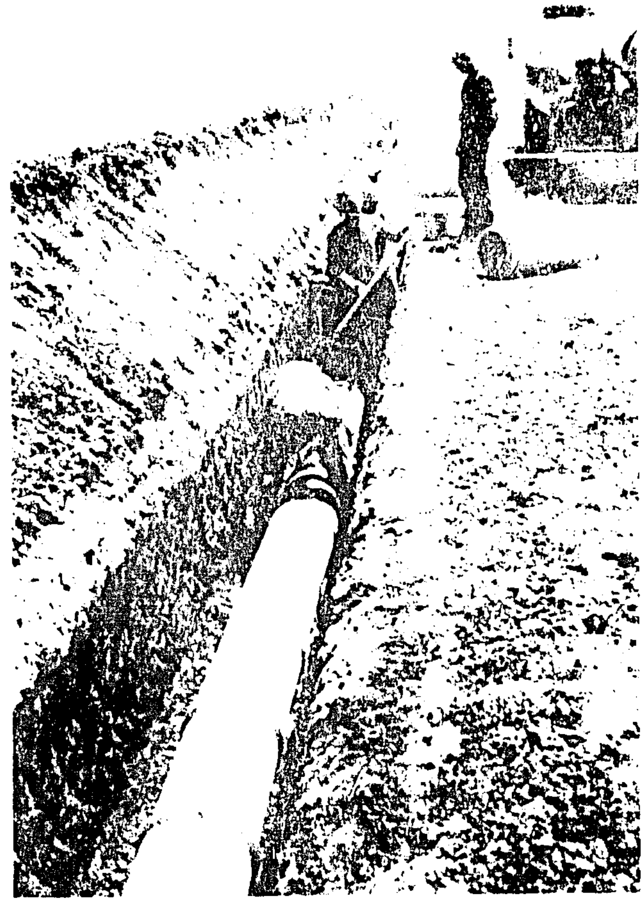
L = length of conduit section

C_t = coefficient from tables by N.M. Newmark (1935) X 4

F_1 = impact factor assumed as 1.0 in above table may vary from 1.5 to 2.0 for moving, heavy loads

*P_o = weight of concentrated surface load, 8,000 lb. used as maximum wheel load in above table

The rubber gasket is placed on the spigot just prior to installation of the pipe. Rubber gasket joint pipe saves labor and equipment.



Installation of mortar joint irrigation pipeline. Truck-mounted mixer and mortar box are convenient to the laying crew.

Rubber gasket pipe joints

Concrete pipe joints are sealed with mortar or rubber gaskets. Flexible joints should be specified in areas with unstable soil or where extreme water temperatures occur. Rubber gaskets have performed extremely well with minimum leakage.

Cost of manufacture is slightly higher for rubber gasket joint pipe due primarily to the closer tolerances that must be maintained. The added cost of rubber gasket joints is partially offset by reduced labor costs because the joints do not need grouting and require less equipment to install.

For details on specifications and installation recommendations for rubber gasketed pipe, refer to ASTM C505, Nonreinforced Concrete Irrigation Pipe with Rubber Joints, American Society of Agricultural Engineers or American Concrete Pipe Association standards, or consult local concrete pipe manufacturers. Rubber gaskets are available in various shapes.

When rubber gasket joint pipe is installed, the gasket is placed on the spigot end of the pipe just before the pipe is placed in the trench. Gasket exposure to sunlight should be kept to a minimum. The gasket and the bell end of the pipe are then coated with a special gasket soap (usually made from flaxseed) to lubricate the joint for easy assembly and to help seal it. The pipe and gasket manufacturers' recommendations for installation should be followed.

Mortar joints

Anyone observing an experienced construction crew in action is impressed with their speed and accuracy in laying concrete pipe with mortar joints. A general technique of installation has been developed that is followed with slight modification by most experienced pipe contractors.

The sections of concrete pipe are first strung along the trench and then tilted into the trench, groove end up. The tongue or spigot end of the first section of pipe is cleaned and wetted with a brush. Sufficient mortar to form the lower section of the outside band or collar is placed in depression at lower side of pipe joint.

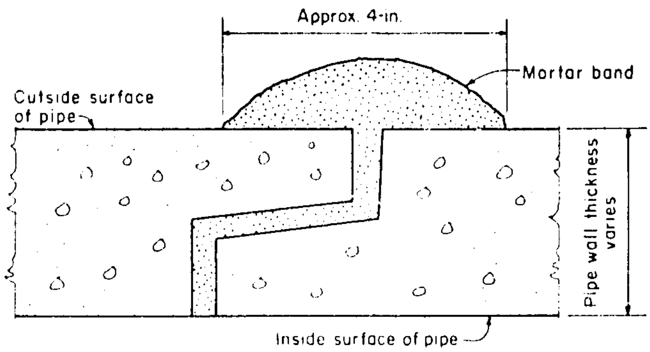


Fig. 3. Details of a mortar joint. The outside mortar band is approximately 4 in. wide. The inside is brushed smooth.

Before backfilling, the bands are wrapped with curing paper or sprayed with curing compound to assure proper curing of the mortar.

The groove or bell end of the next section of pipe is wetted and filled with mortar. This section is then tipped over carefully so as not to dislodge the mortar and is shoved into place to make a snug, tight joint (Fig. 3). Excess mortar will be squeezed out of the joint on both the inside and outside of the pipe. Because extruded mortar would reduce flow and increase friction, the inside of the pipe is brushed smooth of any surplus mortar with a long-handled brush. This is done as soon as the pipe is placed true to line and grade since any movement of the pipe thereafter might result in leaky joints. Another workman places the external band of mortar around the pipe 2 to 5 joints behind the crew laying the pipe.

As soon as the joint is completed, it is covered with curing compound or a layer of fine, moist earth to permit curing of the mortar. If a fine soil covering is used, care should be exercised to not disturb the fresh mortar. All openings in the pipeline are covered to prevent air circulating within the line and drying the interior of the joints too rapidly. The openings are similarly sealed at the end of each day's work.

Backfilling is an efficient operation when done with a small dozer.

Where necessary, the trenches may be completely backfilled within one hour after initial backfill or while mortar band and joint is still plastic. If backfilling is not done while joint mortar is plastic, it should be postponed for at least 24 hours after the pipe are laid. Water should not be turned into the pipelines until backfilling is completed. Nor should water be permitted to flood open trenches as it might raise or float the empty pipeline and cause failure of the joints.

Control structures

The vertical structures along the line (pump stands, division boxes, risers, air release vents, etc.) generally are built of concrete pipe. The pipeline inlet structure develops the full-flow capacity, protects the pipeline from excessive pressure and surge, and filters out trash (Figs. 4 and 5). The stands can also function as air release vents and division boxes.

Vibration from the pump *must not* be transmitted into the pipeline. Pumped water should enter the inlet stand through a flexible coupling. The larger capacity of the stand permits dissipation of the high velocity stream and release of entrapped air before the water enters the pipeline.

When water enters the pipeline from an open ditch, the inlet should be equipped with a trash guard (Fig. 11). The tops of the stands, for pumped or ditch water, should be covered, both as a safety measure and to keep trash from blowing into the pipeline when it is not in use. A sand trap may also be incorporated into the inlet structure if a large quantity of sand is carried in the water.

Vents

Vents are required at all high points in the line, at any abrupt change in grade or direction of the line, directly downstream from any structure that may entrap air, and at the end of the pipeline. Vents are generally installed at points about 500 ft. apart on straight runs. A typical vent is shown in Fig. 12.

Minimum height of the vents should be 4 ft. above the ground surface. At the other extreme, the vent should be as high as necessary to prevent overflow when the pipeline is operating at normal capacity. An air release valve may be substituted for vents in lines not subject to high-pressure surges.

Stands

Several different types of stands are used for flow control. Gate stands, shown in Fig. 8, are used to control the flow of water into laterals or as shutoff gates to increase pressure upstream. These stands may also function as vents and surge chambers. In some installations, in-line gates may be used for the same purpose as the gate stands.

Overflow stands, shown in Fig. 9, should be installed in pipelines down steep grades to prevent excessive pressures in the lower reaches of the lines.

The commonly accepted limit of operating head for irrigation pipelines is 50 ft. for 8-, 10-, and 12-in.-diameter rubber gasket joint pipelines; 40 ft. for 15- and 18-in -diameter rubber gasket joint pipelines; and 25 ft. for mortar joint pipelines.

Gates and valves

The slide gate in the stand shown in Fig. 9 permits straight-through flow when upstream pressure is not required.

A somewhat automatic pressure control by float valve, as shown in Fig. 6, can well be used in some situations. If pressure is increased downstream, the float closes the valve to prevent the passage of unneeded water and thus eliminate the danger of excessive pressure downstream in the pipeline. Float stands

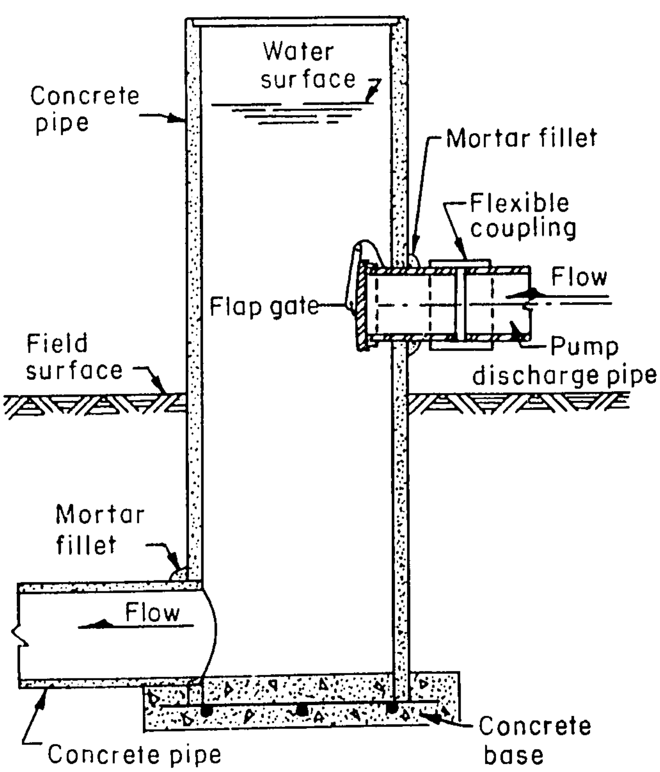


Fig. 4. Detailed section of a pump stand.

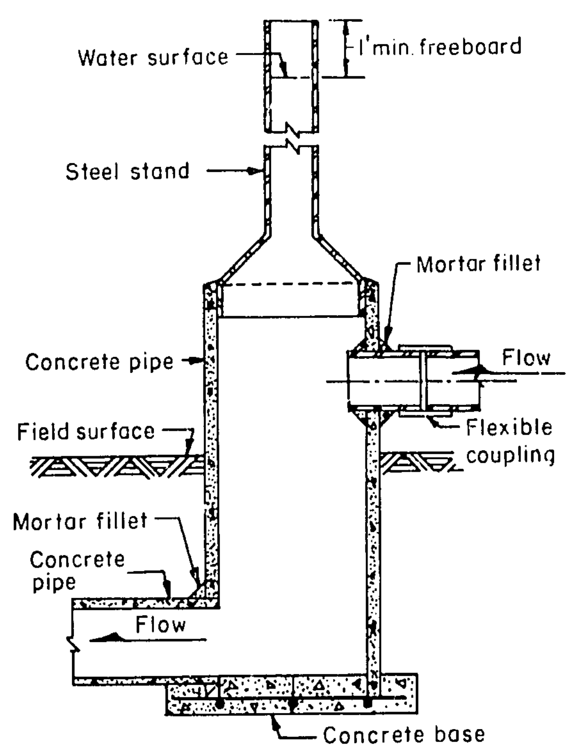


Fig. 5. Detailed section of a high-head tapered pump stand similar to that shown in Fig. 4.

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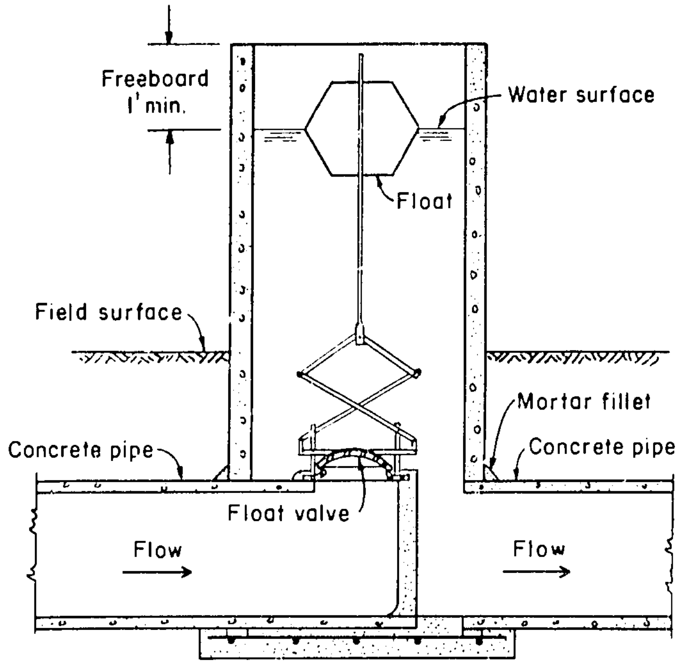


Fig. 6. Section of float valve stand. Pressure and flow are regulated by the float valve.

are usually spaced at intervals of 10 ft. of drop in the pipeline. This type of stand is especially useful in controlling pressure in lines down steep slopes.

Outlet structures are necessary to provide controlled delivery of water to the desired locations. The most common outlets are risers of concrete pipe in the same diameter as the main line that are fitted with gates or valves to regulate flow from the pipeline (Fig. 7).

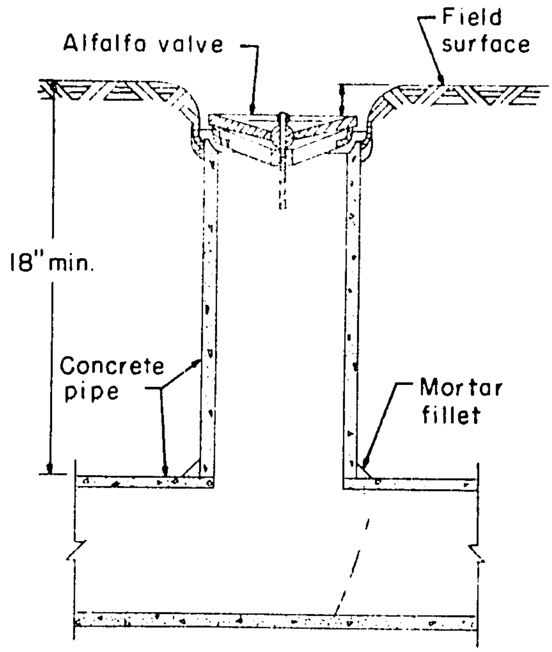


Fig. 7. Section of a typical alfalfa valve installation.

Alfalfa valves are fitted with hydrants to deliver water into gated pipe. An alfalfa valve and riser may also be adapted to provide delivery into the bottom of a concrete-lined ditch. Siphon tubes may then be used to distribute the water into furrows or borders.

Where lesser flow is acceptable and turbulence and scouring are important factors, orchard valves may be substituted for the alfalfa valves. Orchard valves are

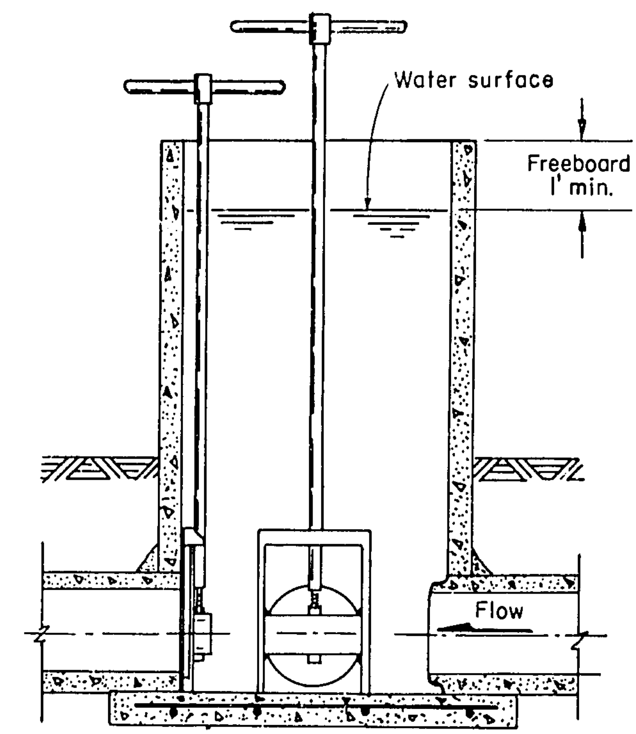


Fig. 8. Detail of a concrete gate stand for diversion to laterals.

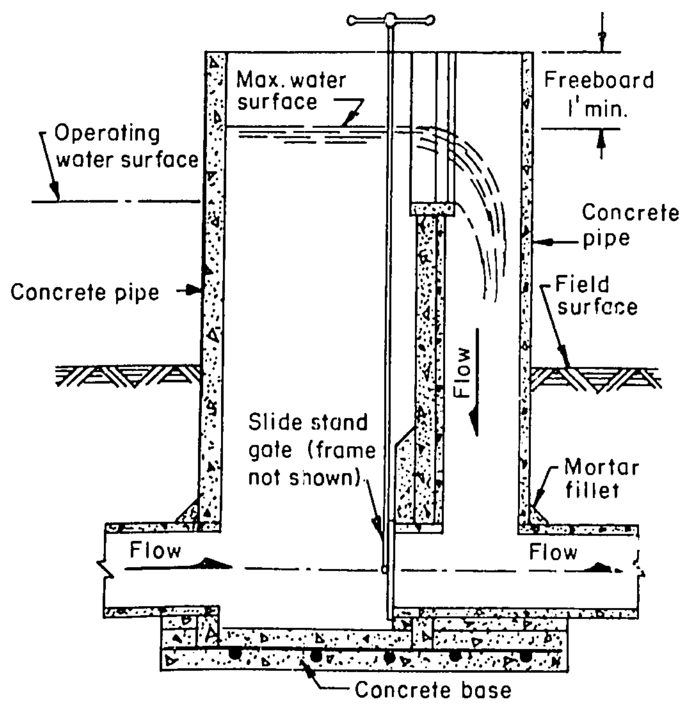
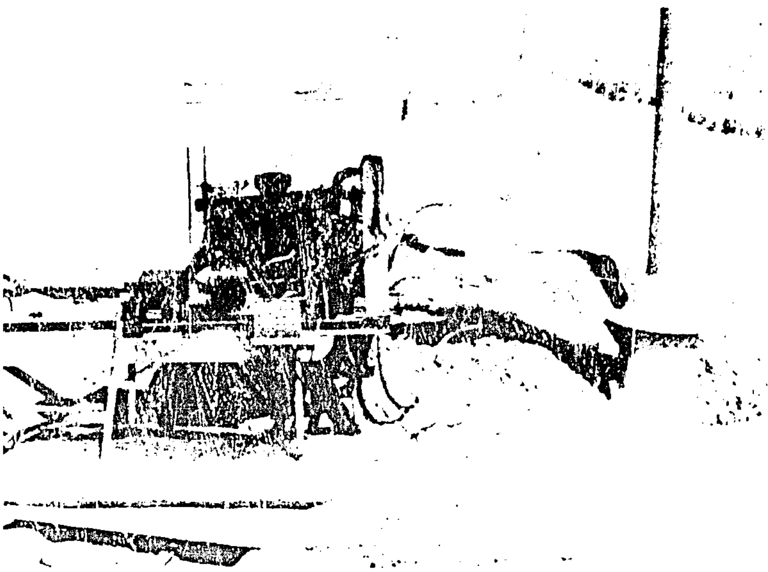
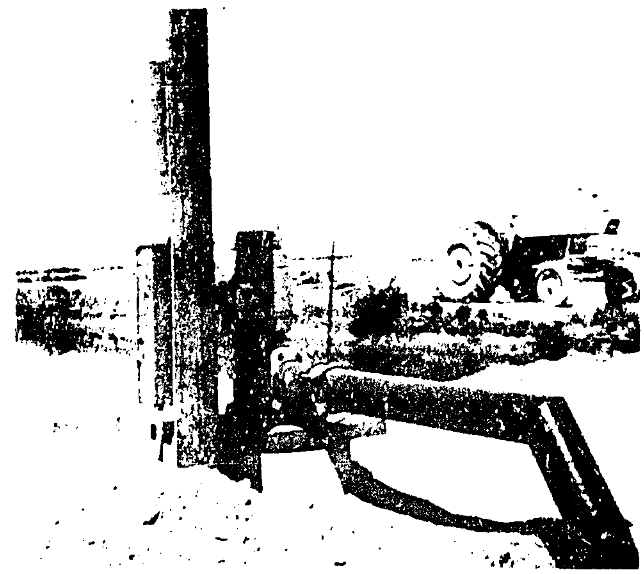


Fig. 9. Section showing details of a concrete pipe overflow gate stand.



Pumping recovered water directly from collection pit into return line. Note the flexible coupling on the pump discharge. This is essential to keep pump vibrations from pumpstand and pipeline.



View of small storage reservoir, sump, screen, and pump into return line.

usually installed just below ground surface as shown in Fig. 10. A hydrant also may be attached to this installation to direct flow into furrows or borders.

Fertilizer application through pipelines

If commercial fertilizers are used in concrete irrigation lines, instructions for protection of the concrete should be secured from the fertilizer manufacturer and followed. Anhydrous ammonia has a softening effect on hard water and causes a precipitation of calcium carbonate; therefore, a phosphate material should be added to counteract this action. After fertilizer has been applied, the irrigation lines should be flushed with water.

If ammonium sulfate is used, concentrations should never exceed 0.1 percent and the lines should be flushed immediately after using.

The application of commercial fertilizers through the medium of the irrigation water has become quite common. However, the above steps should be taken for the protection of concrete irrigation lines.

Water re-use systems

A system for recovering runoff water or tailwater for re-use can be very practical and economical. Typically, re-use system costs are about 25 to 30 percent of the cost of pumping water out of wells.

Concrete pipelines are used for returning the recovered water to the head of the system for redistribution over the field A small storage reservoir to collect waste water runoff can be built and the water pumped back through a pipeline into the irrigation system as the runoff occurs. Often, irrigated land is too valuable to use for irrigation water storage and a sump-type recovery system collects and re-uses the water immediately as runoff occurs.

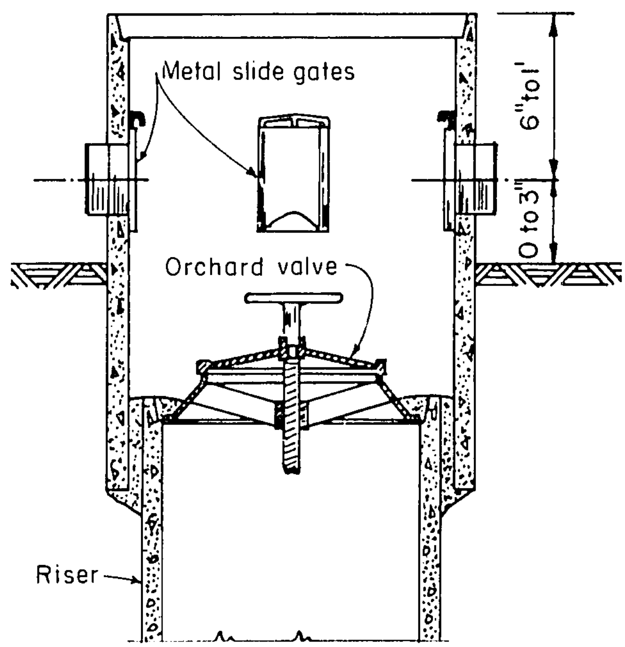


Fig. 10. Section of an open-pot hydrant with orchard valve and slide gate control.

A pit-type system is shown in Fig. 13. The runoff flows into a catch basin, is pumped into the stand, and returned to the head of the irrigation system via the concrete pipeline for re-use. For best performance, the return system should be equipped with some method of screening or filtering the water to keep the pipelines free of silt and debris. Capacity of the return system can be only one-third of the capacity of the main irrigation system. The cost of a water recovery system will be offset in a very few years by the value of the water saved.

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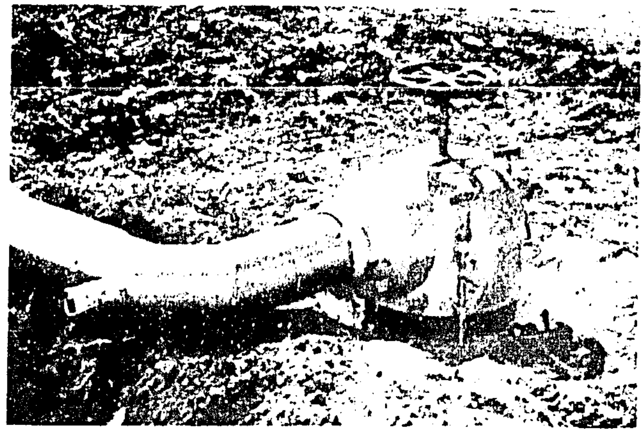
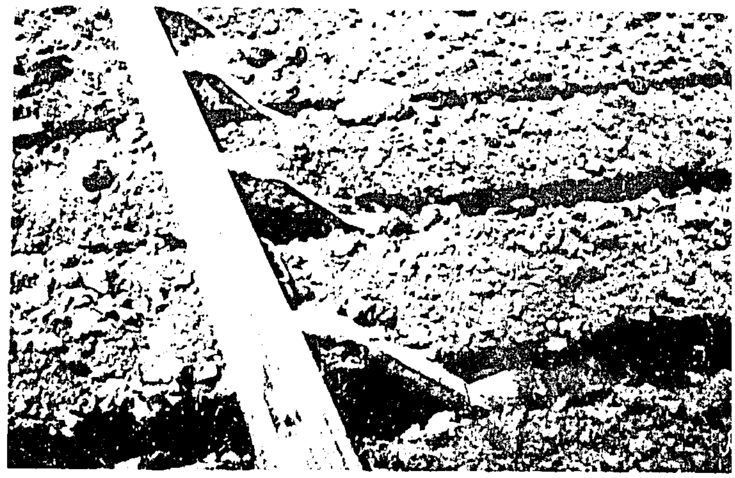
Riser is grouted onto the lateral pipeline.



Close-up of a portable hydrant connection to an alfalfa valve, with gated pipe connected for surface distribution.

An alfalfa valve frame is carefully set on top of the riser and grouted in place. The valve screws into the frame to complete the installation.



A popular method of surface distribution is gated pipe with furrow socks to reduce erosion.

Orchard irrigation from an open-pot hydrant as in Fig. 10.

Maintenance and operation

Proper operation and maintenance are important. The following excellent suggestions have been made by one manufacturer:

"Operate your pipeline carefully. Do not open the gate and let the line fill with a 'bang.' If possible, the evening before you contemplate using the line, 'crack' the valve and let the line fill slowly. This gives the line more time to adjust itself to temperature change. On a hot day, to turn a full head of cool water into a pipeline is poor practice and will lead to trouble later on. Fill your lines slowly.

"Don't pump directly into your pipeline—the vibration may cause joint failure; pump into a surge chamber or standpipe. If the water carries amounts of sand, make provisions for settling it—and removing the sand.

"Your pipeline must have air vents and surge chambers properly installed to protect it from excess pressures. Operate your line under the lowest pressure possible. Air vents are an absolute necessity on the high points in a line to avoid the building up of excess pressures due to entrapped air.

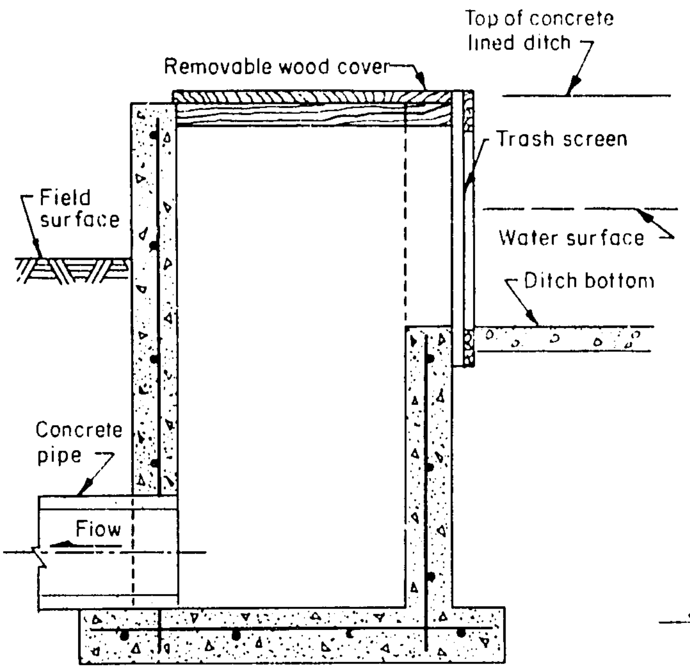


Fig. 11. Section of an inlet structure where water source is a surface ditch or canal.

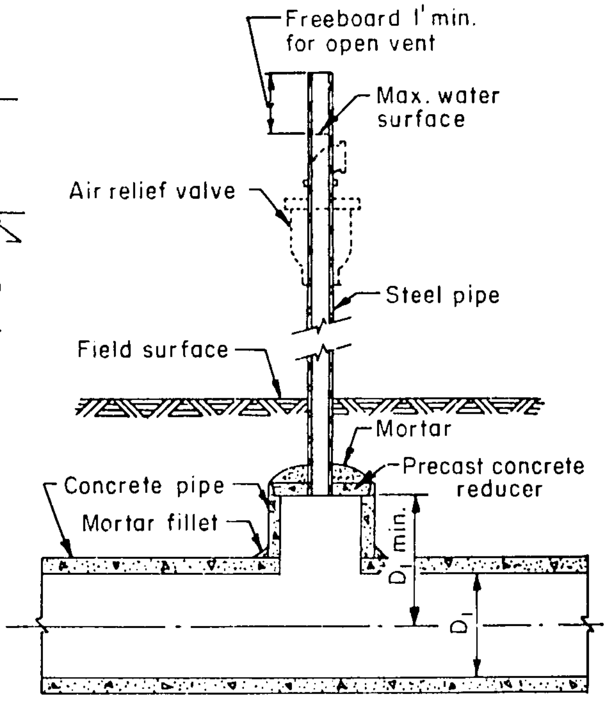


Fig. 12. Section of a typical vent for underground pipelines.

"Open and close all valves and gates gradually to avoid excessive pressure and blowouts.

"Keep valves and gates securely closed when not in use. Do not allow them to stand open. Excessive rusting and pitting of seals is the result of their remaining open. Whether or not you are irrigating, your valves and gates should be operated—all of them—at least once a month."

DESIGNING CONCRETE PIPE IRRIGATION SYSTEMS

A concrete pipe irrigation system must be properly designed to handle efficiently the required flow throughout the system. If pipelines are too small in diameter, pumping costs are increased and the capacity of the system may be seriously limited. On the other hand, pipelines larger than necessary add to the cost of the system and may cause uneven flow. Control stands must be high enough to allow sufficient operating head for the pipeline. Stands higher than necessary complicate valve operation and may permit high heads of water to build up, leading to excessive line pressures (Fig. 14).

Design, not guesswork, must govern the selection of pipeline sizes and gradients. It is important to calculate pipeline sizes and stand heights to give balanced distribution and help assure trouble-free, economical operation. Much valuable assistance can often be obtained from the companies manufacturing concrete pipe.

In designing concrete pipelines for irrigation systems, the designer provides a reasonable factor of safety to protect the system against unexpected conditions. He lays out the system, selects pipe sizes, and designs control structures so that the operating pressures are much lower than the internal bursting pressures of the pipe. Test requirements for internal hydrostatic pressures are higher for small pipe than for pipe of larger diameters. The engineer takes this into consideration in designing pipelines. Thus when using rubber gasket joint pipe having an 8-in. internal diameter, he may design a line with a working head as high as 50 ft. On lines using mortar joint pipe of 18-in. internal diameter, he would not permit working heads of more than 25 ft. and would attempt to limit the working head to 20 ft.

Usually, the designer specifies working heads in the pipelines that are not more than one-quarter to one-fifth the internal bursting pressures of the pipe, as required in the ASTM specifications. When it is necessary to design pipelines with higher heads, concrete pressure pipe is specified. It is seldom necessary to design systems with heads of more than 12 ft. except when the source of water cannot be located at the high point on the farm. Systems are commonly built to operate at heads of 5 to 10 ft.

Before the designer can determine pipeline sizes, he must know the flow required at diversion points and outlets. This is discussed above under "Irrigation Water Requirements." He must know also the head available at each section of pipeline. This depends largely on the lay of the land as determined by a topographic survey.

Another factor that must be taken into account is friction between the flowing water and the walls of the pipeline. This friction resists flow and causes a loss of head. Table 3 shows the feet of head lost due to friction per thousand feet of rubber gasket joint pipeline for a number of pipe diameters and rates of flow. Table 4 shows the losses due to friction in mortar joint pipelines.

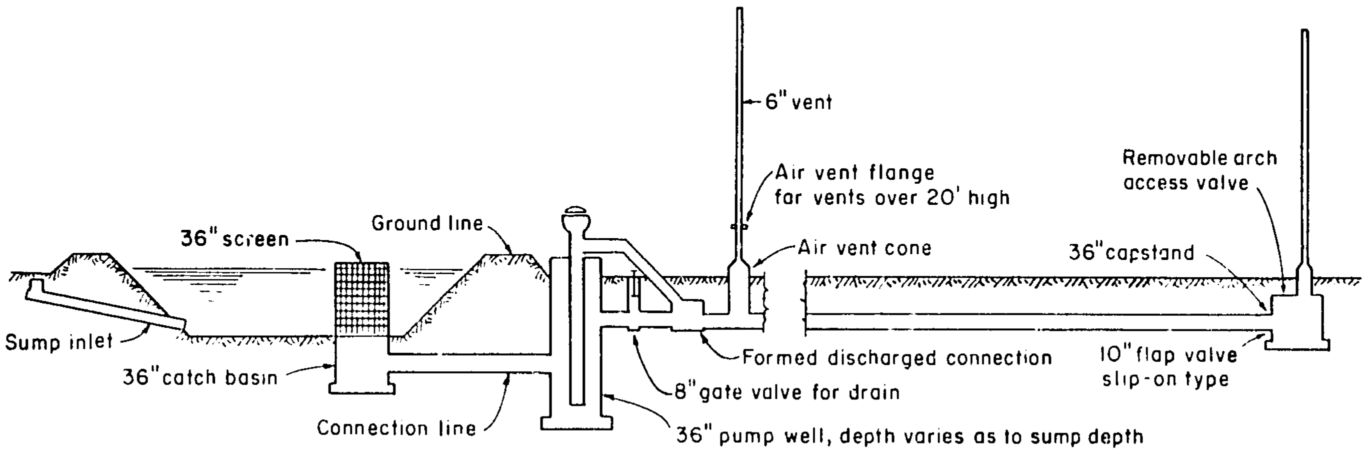


Fig. 13. Elements of a tailwater recovery and water re-use system.

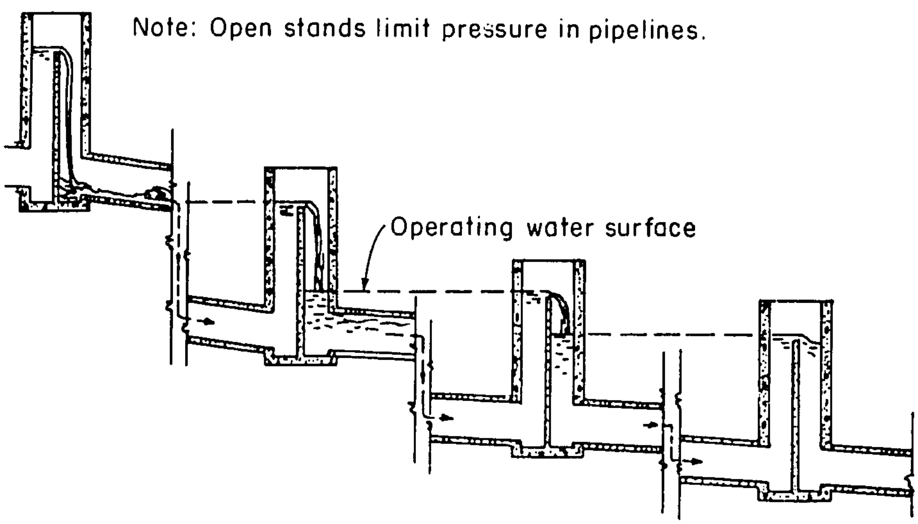


Fig. 14. Profile of a typical open-stand pipe system showing operation of baffle stands.

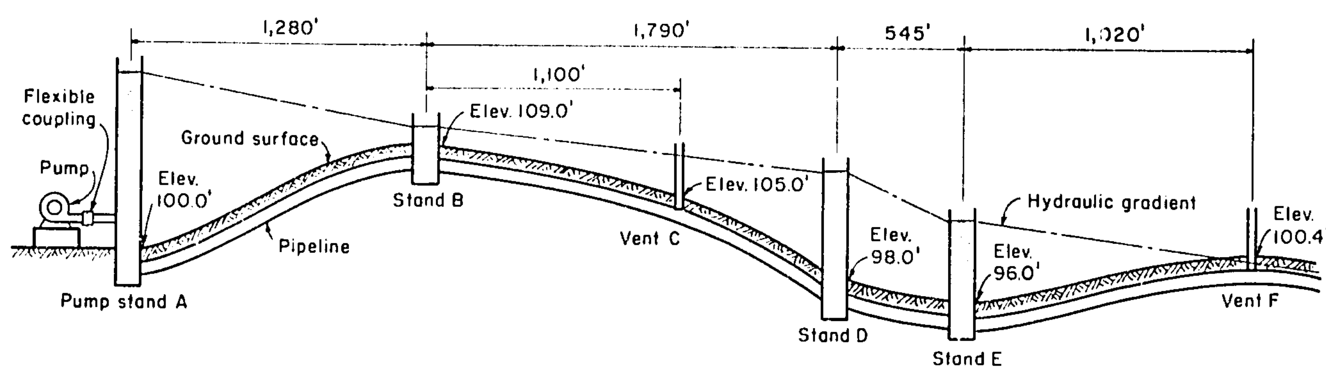


Fig. 15. Profile diagram of a concrete irrigation pipeline in hilly land. Pipe sizes, stand and vent heights, etc., are determined in Examples 1 through 5.

The following examples, based on data from Fig. 15 and Table 3, illustrate how irrigation pipeline systems are designed. Note that the friction loss values in these examples are taken from the table for rubber gasket joint pipe. For mortar joint pipe design. use Table 4.

The hydraulic gradient in Fig. 15 shows the height to which water will rise in open standpipes or vents any place along the line for a given flow. The hydraulic gradient is usually considered to be a straight line connecting the free water surfaces at each end of a uniform section of pipeline between diversion points. Changes in slope, sharp bends, and other factors will cause a shift in the hydraulic gradient and should be considered. The designer should plan the system so that the pipeline flows full and the hydraulic gradient remains above the pipeline to prevent surges and trouble due to entrapped air. Definitions of terms used in the following examples are given on page 21.

TABLE 3. Friction Loss in Rubber Gasket Joint Concrete Pipe in Feet per 1,000 Ft.

Flow: Cubic feet per second	Flow: Gallons per minute	Pipe diameter, in. (d): 6	8	10	12	15	18	21	24	30	36
0.1	45	0.2									
0.2	90	0.8	0.2								
0.3	135	1.8	0.4	0.1							
0.4	180	3.2	0.7	0.2							
0.5	225	5.0	1.1	0.3	0.1						
0.6	270	7.2	1.6	0.5	0.2						
0.7	315	9.9	2.2	0.7	0.3						
0.8	360	12.9	2.8	0.9	0.3	0.1					
0.9	405	16.3	3.5	1.1	0.4	0.1					
1.0	449	20.1	4.4	1.4	0.5	0.2					
1.2	539	29.0	6.4	2.0	0.8	0.2					
1.4	628	39.5	8.7	2.7	1.0	0.3	0.1				
1.6	718	51.5	11.4	3.5	1.4	0.4	0.2				
1.8	808	65.2	14.4	4.5	1.7	0.5	0.2				
2.0	898	80.5	17.8	5.5	2.1	0.7	0.3	0.1			
2.2	987	97.4	21.5	6.7	2.6	0.8	0.3	0.1			
2.4	1,077	115.9	25.6	7.9	3.0	0.9	0.4	0.2			
2.6	1,167	136.1	30.1	9.3	3.6	1.1	0.4	0.2			
2.8	1,257	157.8	34.9	10.8	4.1	1.3	0.5	0.2	0.1		
3.0	1,346	181.2	40.0	12.4	4.8	1.5	0.6	0.3	0.1		
3.2	1,436		45.5	14.1	5.4	1.7	0.6	0.3	0.1		
3.4	1,526		51.4	15.9	6.1	1.9	0.7	0.3	0.2		
3.6	1,616		57.6	17.9	6.9	2.1	0.8	0.4	0.2		
3.8	1,706		64.2	19.9	7.6	2.4	0.9	0.4	0.2		
4.0	1,795		71.1	22.0	8.5	2.6	1.0	0.4	0.2		
4.5	2,020		90.0	27.9	10.7	3.3	1.3	0.6	0.3		
5.0	2,244		111.2	34.5	13.2	4.1	1.6	0.7	0.3	0.1	
5.5	2,469			41.7	16.0	5.0	1.9	0.8	0.4	0.1	
6.0	2,693			49.6	19.1	5.9	2.3	1.0	0.5	0.2	
6.5	2,917			58.2	22.4	6.9	2.7	1.2	0.6	0.2	
7.0	3,142			67.5	25.9	8.0	3.1	1.4	0.7	0.2	
7.5	3,366			77.5	29.8	9.2	3.5	1.6	0.8	0.2	
8.0	3,591			88.7	33.9	10.5	4.0	1.8	0.9	0.3	0.1
8.5	3,815			99.5	38.2	11.9	4.5	2.0	1.0	0.3	0.1
9.0	4,039			111.6	42.9	13.3	5.1	2.3	1.1	0.3	0.1
9.5	4,264				47.8	14.8	5.7	2.5	1.3	0.4	0.1
10.0	4,488				52.9	16.4	6.3	2.8	1.4	0.4	0.2
11.0	4,937				64.0	19.8	7.6	3.4	1.7	0.5	0.2
12.0	5,386				76.2	23.6	9.1	4.0	2.0	0.6	0.2
13.0	5,835				89.4	27.7	10.7	4.7	2.4	0.7	0.3
14.0	6,284				103.7	32.1	12.3	5.5	2.7	0.8	0.3
15.0	6,732				119.1	36.9	14.2	6.3	3.1	1.0	0.4
16.0	7,181					42.0	16.3	7.2	3.6	1.1	0.4
17.0	7,630					47.4	18.2	8.1	4.0	1.2	0.5
18.0	8,079					53.1	20.4	9.1	4.5	1.4	0.5
19.0	8,528					59.2	22.7	10.1	5.0	1.6	0.6
20.0	8,977					65.6	25.2	11.2	5.6	1.7	0.7
22.0	9,874					79.4	30.5	13.6	6.7	2.1	0.8
24.0	10,772					94.5	36.3	16.1	8.0	2.5	1.0
26.0	11,669					110.8	42.6	18.9	9.4	2.9	1.1
28.0	12,567						49.4	22.0	10.9	3.4	1.3
30.0	13,465						56.7	25.2	12.5	3.9	1.5
32.0	14,363						64.5	28.7	14.2	4.4	1.7
34.0	15,260						72.8	32.4	16.1	5.0	1.9
36.0	16,158						81.6	36.3	18.0	5.6	2.1

Computed by Scobey's formula: $H = \frac{33{,}610\,Q^2}{C_s^2 d^{5.25}}$,

C_s = 0.370; d = diameter in inches; and H = friction loss in feet per 1,000 ft.

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TABLE 4. Friction Loss in Mortar Joint Concrete Irrigation Pipe in Feet per 1,000 Ft.

Flow		Pipe diameter, in. (d)												
Cubic feet per second	Gallons per minute	6	8	10	12	14	15	16	18	20	21	24	30	36
0.1	45	0.3	0.1											
0.2	90	1.1	0.2											
0.3	135	2.6	0.6											
0.4	180	4.6	1.0	0.3										
0.5	225	7.2	1.6	0.5										
0.6	270	10.4	2.3	0.7	0.3									
0.7	315	14.0	3.2	1.0	0.4									
0.8	360	18.4	4.1	1.3	0.5	0.2								
0.9	405	23.4	5.2	1.6	0.6	0.3								
1.0	449	28.8	6.4	2.0	0.8	0.4	0.2							
1.2	539	42.0	9.2	2.8	1.1	0.5	0.3	0.2						
1.4	628	56.0	12.5	3.9	1.5	0.7	0.5	0.3						
1.6	718	74.0	16.3	5.1	2.0	0.8	0.6	0.4	0.2					
1.8	808	93.0	20.7	6.5	2.4	1.1	0.8	0.5	0.3					
2.0	898	115.0	25.4	8.0	3.0	1.4	0.9	0.7	0.4	0.2				
2.2	987	140.0	30.8	9.5	3.7	1.6	1.1	0.8	0.4	0.3				
2.4	1,077	165.0	36.5	11.4	4.4	1.9	1.3	1.0	0.5	0.3	0.2			
2.6	1,167		43.0	13.3	5.1	2.3	1.6	1.1	0.6	0.4	0.3			
2.8	1,257		50.0	15.5	5.9	2.6	1.8	1.3	0.7	0.4	0.3			
3.0	1,346		57.3	17.8	6.8	3.0	2.1	1.5	0.8	0.5	0.4	0.2		
3.2	1,436		65.3	20.2	7.7	3.4	2.4	1.7	0.9	0.5	0.4	0.2		
3.4	1,526		73.5	22.8	8.8	3.9	2.7	1.9	1.0	0.6	0.5	0.2		
3.6	1,616		82.5	25.6	9.8	4.4	3.0	2.2	1.2	0.7	0.5	0.3		
3.8	1,706		92.2	28.5	10.8	4.9	3.4	2.4	1.3	0.8	0.6	0.3		
4.0	1,795			31.5	12.2	5.4	3.8	2.7	1.5	0.9	0.6	0.3		
4.5	2,020			39.7	15.3	6.8	4.7	3.4	1.9	1.1	0.8	0.4		
5.0	2,244			49.1	18.8	8.4	5.9	4.2	2.3	1.3	1.0	0.5		
5.5	2,469			59.6	22.8	10.2	7.1	5.0	2.7	1.6	1.2	0.6		
6.0	2,693			70.7	27.1	12.1	8.4	6.0	3.2	1.9	1.4	0.7		
6.5	2,917			82.7	31.8	14.2	9.9	7.1	3.8	2.2	1.7	0.8		
7.0	3,142				36.9	16.5	11.5	8.2	4.4	2.5	2.0	1.0	0.3	
7.5	3,366				42.2	18.9	13.2	9.4	5.1	2.9	2.3	1.1	0.4	
8.0	3,591				48.2	21.5	15.0	10.7	5.8	3.3	2.6	1.3	0.4	
8.5	3,815				54.4	24.3	16.9	12.1	6.5	3.7	2.9	1.4	0.5	
9.0	4,039				61.0	27.2	19.0	13.5	7.3	4.2	3.3	1.5	0.5	
9.5	4,264				68.0	30.3	21.1	15.1	8.2	4.7	3.6	1.8	0.6	0.2
10.0	4,488				75.3	33.6	23.4	16.7	9.0	5.2	4.0	2.0	0.6	0.2
11.0	4,937					40.7	28.3	20.2	10.8	6.3	4.8	2.4	0.7	0.3
12.0	5,386					48.4	33.7	24.0	12.9	7.4	5.8	2.9	0.9	0.3
13.0	5,835					56.8	39.6	28.2	15.2	8.8	6.8	3.4	1.0	0.4
14.0	6,284					65.9	45.9	32.7	17.7	10.2	7.8	3.9	1.2	0.5
15.0	6,732						52.6	37.5	20.3	11.7	9.0	4.5	1.4	0.5
16.0	7,181						60.0	42.7	23.0	13.2	10.2	5.1	1.6	0.6
17.0	7,630						67.7	48.2	26.0	14.9	11.5	5.8	1.8	0.7
18.0	8,079							54.0	29.3	16.8	13.0	6.5	2.0	0.8
20.0	8,977							66.7	35.9	20.7	16.0	7.9	2.5	0.9
22.0	9,874							80.7	43.3	25.1	19.3	9.6	3.0	1.1
24.0	10,772								51.9	28.8	23.0	11.4	3.6	1.4
26.0	11,669								60.8	34.9	27.0	13.4	4.1	1.6
28.0	12,567								70.1	40.4	31.4	15.6	4.8	1.9
30.0	13,465									46.2	36.0	17.9	5.6	2.1
32.0	14,363									53.3	41.0	20.4	6.3	2.4
36.0	16,158									67.1	51.8	25.7	8.0	3.1

Computed by Scobey's formula. In this table C_s = 0.310.

Example 1: The pipeline between pump stand *A* and *B* is to handle 1,526 gpm (gallons per minute). The top of stand *A* is 16 ft. above the ground surface and must have 1 ft. of freeboard. The minimum water elevation in stand *B* is limited to 1 ft. above ground surface. What size line is required?

Solution: The general procedure is to determine the difference between head or water heights at *A* and *B*; then select a pipe size with friction loss nearly equal to this head difference.

Given: ground elevation at pump stand *A* = 100.0 ft. above datum; ground elevation at stand *B* = 109.0 ft.

Find: water surface elevation at *A*:
100.0 + 16.0 (height of stand *A*) − 1 ft. (freeboard) = 115.0 ft.

Find: water surface elevation at *B*:
109.0 + 1.0 = 110.0 ft.

Find: head difference between *A* and *B*:
115.0 − 110.0 = 5.0 ft. (allowable friction loss for 1,280-ft. line).

Find: friction loss per thousand feet of line:

$$5.0 \div \frac{1{,}280}{1{,}000} = 3.9 \text{ ft. per } 1{,}000 \text{ ft.}$$

Enter Table 3 under column "Gallons per minute" with the flow of 1,526 gpm and read across to find the proper pipe size. The 12-in.-diameter pipe has a friction loss of 6.1 ft. and does not meet our requirement of a maximum allowable loss of 3.9 ft. The friction loss for 15-in.-diameter pipe is 1.9 ft. per 1,000 ft., which is well under the maximum. Therefore, in this case 15-in.-diameter pipe is selected.

Friction loss from *A* to *B* is 1.28 × 1.9 = 2.43 ft. Water surface elevation at *A* = 110.0 + 2.4 = 112.4 ft.

Example 2: Four hundred and forty-nine gallons per minute are diverted at *B*, leaving a flow of 1,077 gpm in the 15-in. pipeline between stands *B* and *D*. How high will the water rise in stand *D* under this flow condition if the water elevation in stand *B* is 110.0 ft. as in Example 1?

Solution: For a flow of 1,077 gpm in a 15-in. pipeline, Table 3 shows the friction loss to be 0.9 ft. per 1,000 ft. of line. Since the line between *B* and *D* is 1,790 ft. long, the total friction loss will be 1.79 × 0.9 = 1.6 ft. Therefore, the hydraulic gradient will drop by this amount and the elevation of the water surface in stand *D* will be 1.6 ft. lower than in stand *B*, or at an elevation of 110.0 ft. − 1.6 ft. = 108.4 ft. Since ground elevation at stand *D* is 98.0 ft., a minimum stand height of 108.4 − 98.0 ft. = 10.4 ft. would be required. With 1 ft. allowed for freeboard, stand height requirement is 11.4 ft. The stand would be built 12 ft. high.

Example 3: An air vent is required at *C* because of the high point in the line. What should be the height of the vent pipe to prevent overflowing under the flow conditions previously given?

Solution: The hydraulic gradient from *B* to *C* will drop by an amount equal to the friction loss, or 0.9 ft. per 1,000 ft. of line as determined in Example 2. *B* and *C* are 1,100 ft. apart. Therefore, the hydraulic gradient at *C* will be 0.9 × 1.1 = 1.0 ft. lower than at *B*. The elevation of the hydraulic gradient at *C* will be 110.0 ft. − 1.0 ft. = 109.0 ft. Since the top of the vent must be above the hydraulic gradient to prevent overflowing, the minimum vent height is 109.0 ft. − 105.0 ft. = 4.0 ft. To allow 1 ft. of freeboard, the vent should be 5 ft. high.

Example 4: Stand *E* is to serve both as an overflow stand and a diversion point into a lateral (not shown). Flow in the lateral requires a head in stand *E* of 9.0 ft. above ground surface or a head elevation of 96.0 ft. + 9.0 ft. = 105.0 ft. What size pipe is required for the line between stands *D* and *E* if the flow from *D* to *E* is 1,077 gpm?

Solution: The available head in the line between stands *D* and *E* is the difference between the water heights in the stands, or 108.4 ft. − 105.0 ft. = 3.4 ft. The friction loss equal to this head is 3.4 ÷ 0.545 (distance between *D* and *E*) = 6.2 ft. per 1,000 ft. of line. Entering Table 3 with a flow of 1,077 gpm and a friction loss of 6.2 ft. per thousand gives a required pipeline size of 12 in.

Example 5: Seven hundred and seventeen gallons per minute are diverted to a lateral at *E*, leaving 1,077 − 717 gpm = 360 gpm for the flow in the line between stand *E* and vent *F*. The water elevation in stand *E* is 105.0 ft., as in Example 4. The line is laid 18 in. below ground surface. What should be the line size to permit full flow over the high point?

Solution: Vent *F* prevents siphoning. Therefore, the hydraulic gradient must not drop below the top of the pipeline at the high point if full flow is to occur. Since the pipe is 1.5 ft. below the ground surface, the elevation of the top of the pipeline at the vent is 100.4 ft. − 1.5 ft. = 98.9 ft. The maximum allowable friction loss, *E* to *F*, is therefore 105.0 ft. − 98.9 ft. = 6.1 ft., or 6.1 ÷ 1.02 = 6.0 ft. per 1,000 ft. For the flow of 360 gpm, Table 3 shows that an 8-in. pipe is acceptable because it will have a head loss of only 2.8 ft. per 1,000 ft. A smaller pipeline would cause the hydraulic gradient to drop below the high point in the line and the flow would be broken.

The foregoing examples are intended to illustrate some of the factors that are taken into consideration to provide balanced flow in all parts of the line. The cost of pumping versus the cost of using larger pipe will in some cases govern the choice of pipeline sizes. It is generally good practice to provide a margin of safety in pipeline sizes in order to compensate for slight fouling of the pipeline or unforeseen increases in water requirements.

The examples illustrate only how the proper sizes of pipelines and control structures are chosen. The following problems and solutions, on the other hand, illustrate how designers plan an entire concrete pipe irrigation system that is economical and efficient.

The problems are based entirely on assumed conditions and are simplified for illustrative purposes. In actual practice each field to be irrigated must be designed to fit the particular conditions of that field, taking into account such factors as kind of crop to be grown, water requirement of crop, type of soil, slope of land, whether water is pumped or taken from ditches, and so on.

Problem I

Design a rubber gasket joint concrete pipe irrigation system for a new citrus orchard 660 ft. wide (40 rods) and 1,980 ft. (120 rods) long. (Use Table 3 for head loss due to friction in rubber gasket joint pipe.) Soil is sandy and porous. The experiences of other citrus growers in the locality indicate that a furrow system of irrigation with 4 furrows for each row of trees would be most practical (Fig. 16). Water is to be pumped. Maximum flow of water available is 3.0 cfs (cubic feet per second). The orchard site has a uniform slope or fall of 2 ft. in 660 ft., as shown on plot plan in Fig. 17.

Solution: Because of the porous nature of the soil and the size of the area to be irrigated, the field will be divided into 12 equal-size parcels, each 330 ft. square. Experience in the locality indicates that a flow of 0.02 cu.ft. per second per furrow is necessary to obtain uniform wetting when furrows are 330 ft. long. Trees are set equidistantly apart in 15 rows, each row with 15 trees, in a 330×330-ft. area.

The irrigation flow required for 15 rows of trees with 4 furrows each (one 330×330-ft. field) is $0.02 \times 15 \times 4 = 1.2$ cfs. Since a maximum of 3.0 cfs is available, it would be possible to irrigate $3.0 \div 1.2 = 2\frac{1}{2}$ fields (330×330 ft. each) at one time without working the pump at the maximum. The problem, however, will be solved on the basis of serving two fields.

The size of concrete pipeline required to carry 2.4 cfs is determined by trial from the following facts and from Table 3.

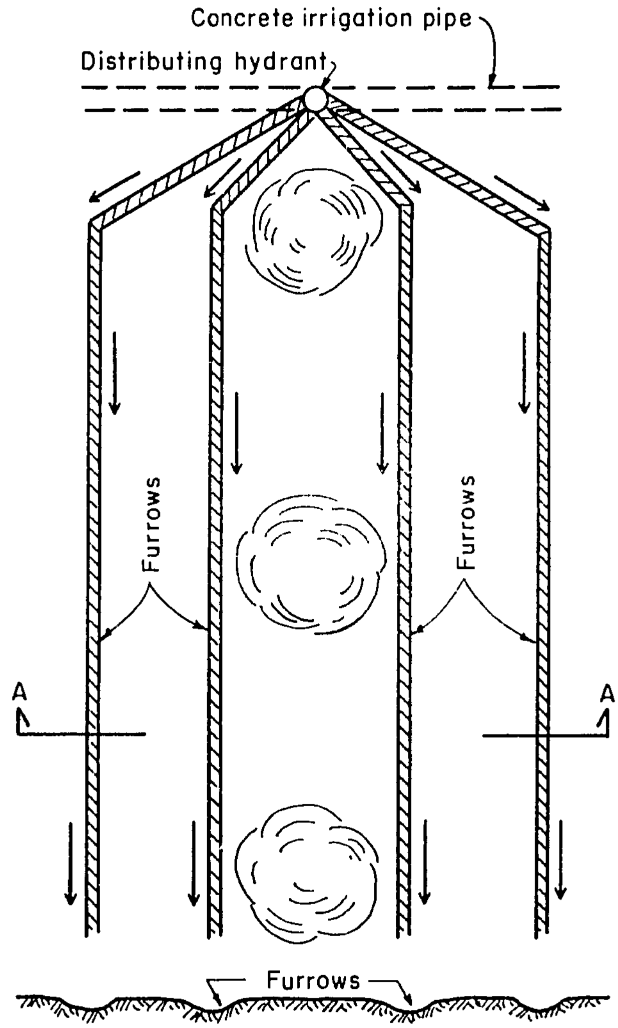


Fig. 16. Furrow system of irrigation with four furrows for each row of trees.

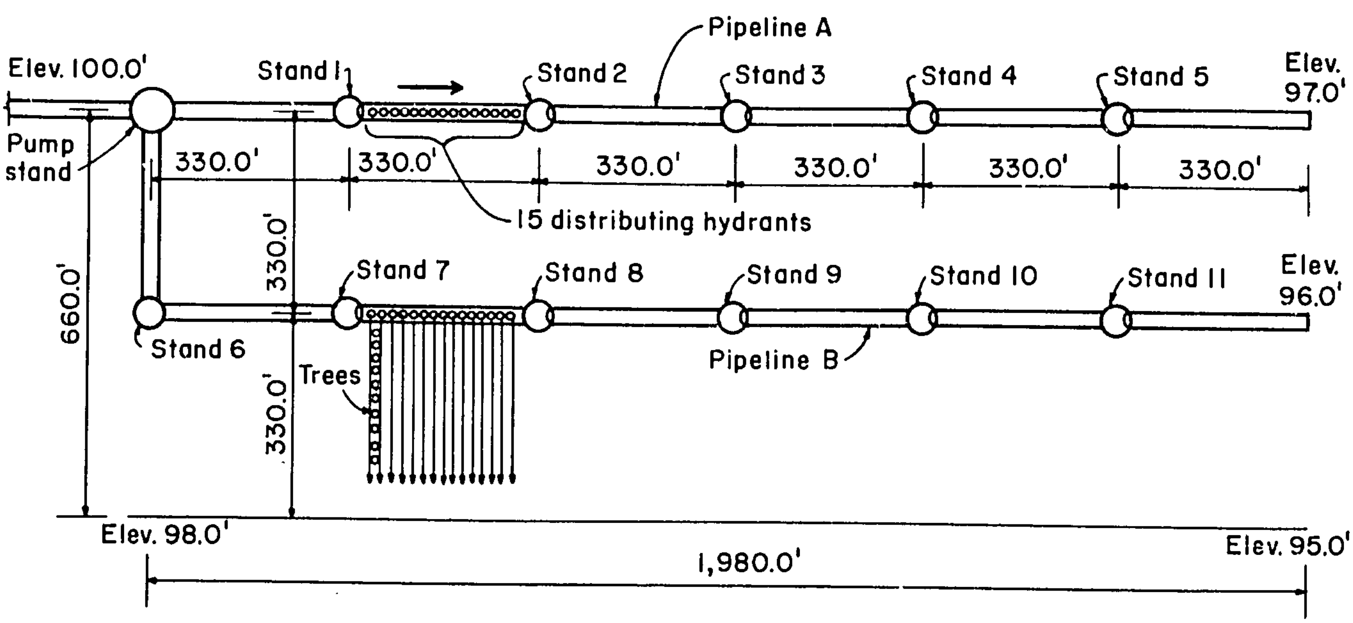


Fig. 17. Layout of area to be irrigated (Problems I and II).

From Fig. 17 we find:

Fall of ground pipeline A = 3 ft.
Fall of ground pipeline B = 4 ft.
Length of line A = 1,980 ft
Length of line B = 2,310 ft.
Length of line A in thousands of feet

$$= \frac{1{,}980}{1{,}000} = 1.98$$

Length of line B in thousands of feet

$$= \frac{2{,}310}{1{,}000} = 2.31$$

From Table 3 we find the friction loss for three different sizes of pipe:

Friction loss in 10-in. pipe = 7.9 ft. per 1,000 ft.
$7.9 \times 1.98 = 15.7$ ft. for pipeline A
$7.9 \times 2.31 = 18.3$ ft. for pipeline B
Friction loss in 12-in. pipe = 3.0 ft. per 1,000 ft.
$3.0 \times 1.98 = 5.9$ ft. for pipeline A
$3.0 \times 2.31 = 6.9$ ft. for pipeline B
Friction loss in 15-in. pipe = 0.9 ft. per 1,000 ft.
$0.9 \times 1.98 = 1.8$ ft. for pipeline A
$0.9 \times 2.31 = 2.1$ ft. for pipeline B

Following is a summary of the facts given and figures calculated for determining the size of concrete pipeline to be used.

Size of pipe, in.	Fall		Loss of head				Height of water in pump stand	
			Line *A*		Line *B*			
	Line *A*, ft.	Line *B*, ft.	Pipe, ft.	Hydrants, ft.	Pipe, ft.	Hydrants, ft.	Line *A*, ft.	Line *B*, ft.
10	3	4	15.7	1	18.3	1	13.7	15.3
12	3	4	5.9	1	6.9	1	3.9	3.9
15	3	4	1.8	1	2.1	1	−0.2	−0.9

(Height of water in pump stand = friction loss in line + loss at distributing hydrants (assume loss of 1 ft.) + rise or − fall of pipeline.)

It is seen that 10-in. pipeline would require relatively high pressures resulting in unreasonable pumping costs. A 12-in. pipeline will deliver the required amount of water at relatively low pressure and at reasonable pumping cost; and it will be adequate for both line A and line B.

If 15-in. pipe is used, the height of water in the pump stand falls below grade (indicated by the negative values in the above table) in both lines A and B. Unless additional flow or pressure head were available, the pipeline would not operate properly for this particular layout; therefore 15-in. pipe is not recommended.

The pump stand must be high enough to take care of the line with the greatest friction loss. (In this problem the height of water in the stand happens to be the same for both lines.)

In determining height of the stands, 1 ft. of freeboard is allowed. Thus the height of the pump stand must be at least 3.9 ft. + 1 ft. = 4.9 ft. In this case, for conservative design, the stand would probably be built 6 ft. high.

The height of the stands will vary from 4 to 6 ft. (Fig. 18). It is not practical to make stands less than 4 ft. high in order to keep out trash and animals.

The system will require 12 gates—two for the pump stand, and one each for all the stands but stand 6, which requires none.

The system will require 180 distributing hydrants, including 180 risers, 180 pots with 4 gates per pot, and 180 orchard valves.

Problem II

Design a concrete pipe irrigation system for an orchard similar to the one described in Problem I, except that water is to be taken from a canal or lateral of fixed head. The surface of the water in the canal is 3 ft. above the surface of the ground at the pipe inlet (Figs. 17, 18, and 19).

Solution: As in Problem I, the flow of water required is 2.4 cfs. Assume 1-ft. loss at the distributing hydrants.

$$\text{Length of line } A \text{ in thousands of feet} = \frac{1{,}980}{1{,}000} = 1.98$$

$$\text{Length of line } B \text{ in thousands of feet} = \frac{2{,}310}{1{,}000} = 2.31$$

Fall in line A = 3 ft.
Fall in line B = 4 ft.

To get the required flow from distributing hydrants, total loss of head must be less than the total available head. Total available head = head at inlet plus the fall in line.

Total available head in line A = 3 ft. + 3 ft. = 6 ft.
Total available head in line B = 3 ft. + 4 ft. = 7 ft.

The total loss of head = loss at hydrants plus friction loss in the pipeline = 1 ft. + the loss in pipeline.

If the total loss of head in line A is to be less than the total head, then 1 ft. plus the friction in pipeline A must be less than 6 ft. (available head). This means that loss of head by pipe friction in line A must be less than 5 ft.

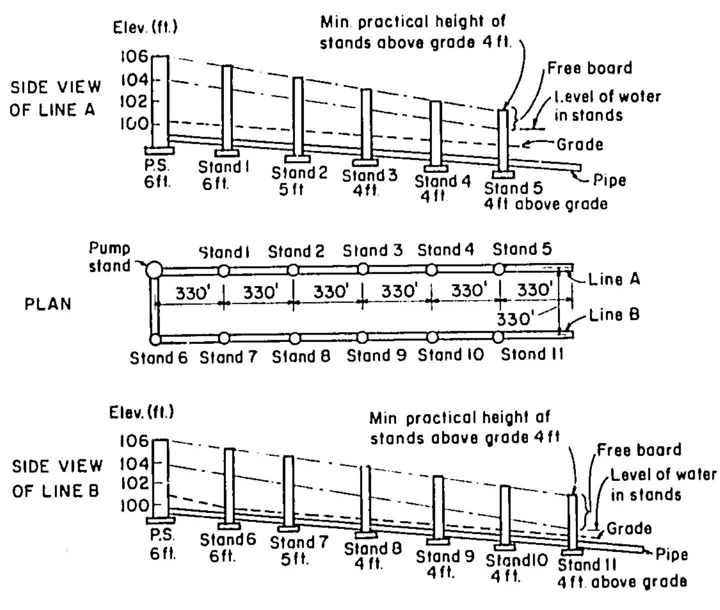
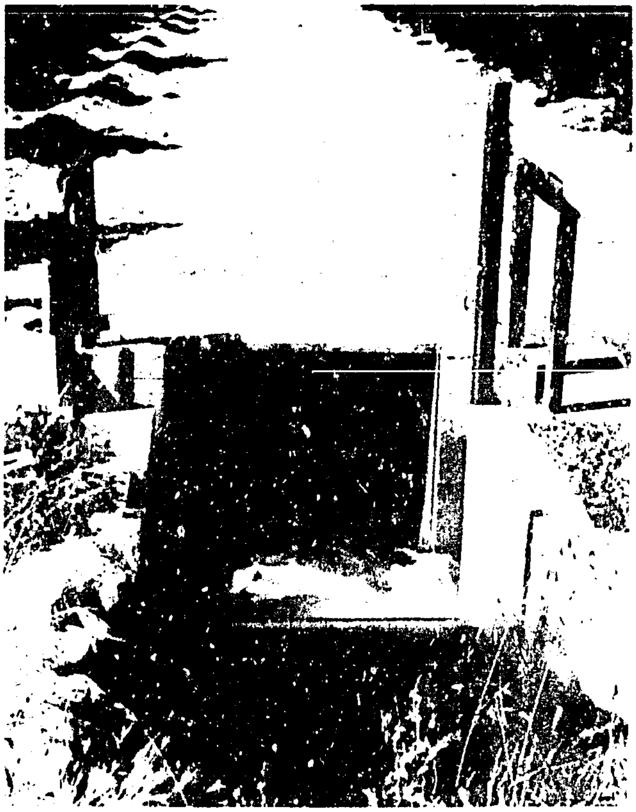


Fig. 18. Pipelines and stands for the system designed in Problem I.



Taking water from an open ditch for a concrete pipe irrigation system (Problem II).

If the total loss of head in line B is to be less than the total available head, then 1 ft. plus the loss of head by friction in line B must be less than 7 ft. (available head). This means that the loss of head by pipe friction in line B must be below 6 ft.

The maximum allowable loss of head friction in 1,000 ft. of pipe is obtained by dividing the total allowable loss of head by the length of pipeline in thousands of feet. Thus, the maximum allowable friction loss in 1,000 ft. of pipe for line $A = 5 \div 1.98 = 2.52$.

The maximum allowable friction loss in 1,000 ft. of pipe for line $B = 6 \div 2.31 = 2.60$.

From Table 3 find the size of pipe that will deliver 2.4 cfs and that will have friction losses less than 2.52 ft. and 2.60 ft. of head for 1,000 ft. of pipeline. In both cases a 15-in. pipeline will be satisfactory.

Since pressure heads at all points of the line are 3 ft. or less, stands 4 ft. high will give at least 1-ft. freeboard. The various control stands will, therefore, be 4 ft. high above grade. Each will have a suitable gate for a 15-in. pipeline. The total number of distributing hydrants will be the same as in Problem I. Each hydrant will consist of a riser pipe, an orchard valve, and a pot with four discharge openings with slide gates.

Attention is called to the fact that under the conditions of this problem it is not possible to increase the head and thereby deliver more water. The pipelines must be designed to carry maximum desired water for any crop anticipated for the field to be irrigated, based on an already established fixed head—in this case 3 ft.

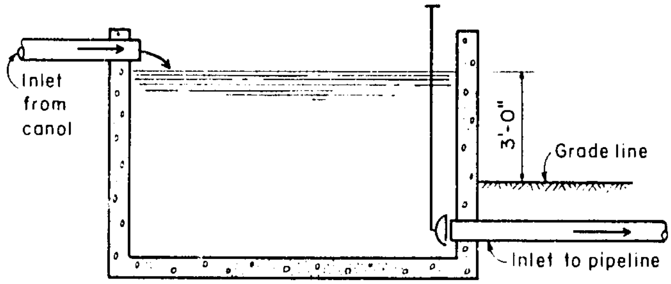


Fig. 19. Cross-section of structure used to control water supply from open ditch to concrete pipe irrigation system. (Problem II).

Problem III

Design a concrete pipe irrigation system for a 40-acre tract of land 1,320 ft.(80 rods) long by 1,320 ft.(80 rods) wide. Border irrigation will be used since alfalfa will be the primary crop grown. The soil is a clay type. The field has a uniform slope or fall of 3 ft. in 1,320 ft., as shown on the plot plan in Fig. 20. The water is to be pumped with a pump supplying 900 gpm or 2.0 cfs.

Solution: Since the field to be irrigated is 1,320 ft. long, it will be convenient to divide it into two equal areas, each 660x1,320 ft. Experience with similar soils in the locality has shown that strips can be made 40 ft. wide and yet be uniformly flooded with water. The 40-acre tract will be laid out as shown in Fig. 20. Only one strip can be irrigated at a time.

The size of concrete pipeline required to carry 2.0 cfs is determined by trial using the following facts obtained from Fig. 20:

Rise of ground, pipeline C = 1 ft.
Fall of ground, pipeline D = 0.5 ft.
Length of line C = 1,320 ft.
Length of line D = 1,980 ft.
Length of line C in thousands of feet

$$= \frac{1,320}{1,000} = 1.32$$

Length of line D in thousands of feet

$$= \frac{1,980}{1,000} = 1.98$$

From Table 3 we find the friction loss for three different sizes of pipe for flow of 2.0 cfs.

Friction loss in 10-in. pipe = 5.5 ft. per thousand.
$1.32 \times 5.5 = 7.3$ ft. for pipeline C
$1.98 \times 5.5 = 10.9$ ft. for pipeline D
Friction loss in 12-in. pipeline = 2.1 ft. per thousand.
$1.32 \times 2.1 = 2.8$ ft. for pipeline C
$1.98 \times 2.1 = 4.2$ ft. for pipeline D
Friction loss in 15-in. pipe = 0.7 ft. per thousand.
$1.32 \times 0.7 = 0.9$ ft. for pipeline C
$1.98 \times 0.7 = 1.4$ ft. for pipeline D

Assume a loss at distributing hydrants with alfalfa valve of 1 ft.

Following is a summary of the facts given and figures calculated for determining the size of the concrete pipeline to be used.

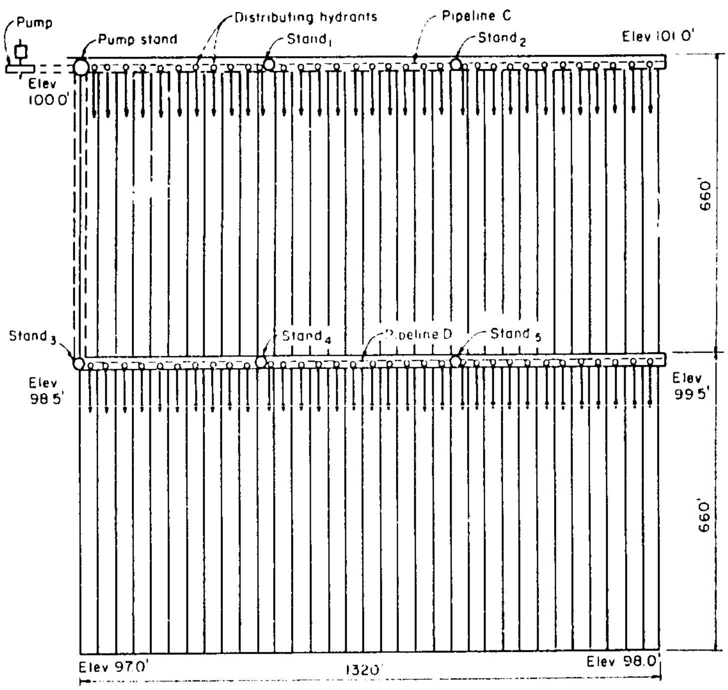


Fig. 20. Layout of area to be irrigated (Problem III).

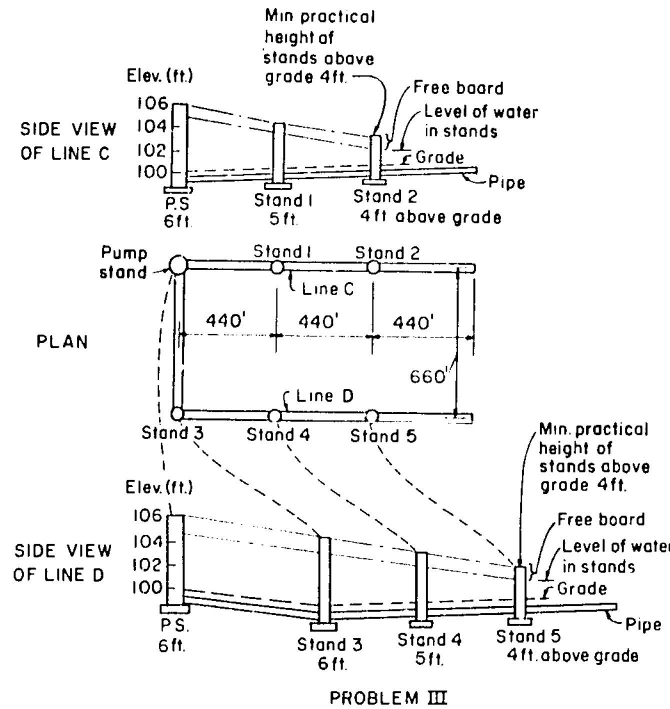


Fig. 21. Pipelines and stands for system designed in Problem III.

Size of pipe, in.	Rise Line *C*, ft.	Fall Line *D*, ft.	Loss of head Line *C* Pipe, ft.	Loss of head Line *C* Hydrants, ft.	Loss of head Line *D* Pipe, ft.	Loss of head Line *D* Hydrants, ft.	Height of water in pump stand Line *C*, ft.	Height of water in pump stand Line *D*, ft.
10	1	0.5	7.3	1	10.9	1	9.3	11.4
12	1	0.5	2.8	1	4.2	1	4.8	4.7
15	1	0.5	0.9	1	1.4	1	2.9	1.9

(Height of water in pump stand = friction loss in line + loss at distributing hydrants + rise or − fall of pipeline.)

A 10-in. pipeline would require relatively high pressures resulting in unreasonable pumping costs. A 12-in. pipeline will deliver the required amount of water at relatively low pressures at a reasonable pumping cost, so 12-in-pipe will be used for both line *C* and *D*. A detailed economic analysis might show a 15-in. pipeline to be more economical in the long run than a 12-in. line when factors such as savings in reduced pumping costs and increased initial investment are considered.

The pump stand must be high enough to take care of the line with the greatest head loss—in this problem, line *D*.

In determining the height of the stands, 1-ft. freeboard is allowed. Thus the pump stand will be 5.7 ft. A stand 6 ft. high will be used. (See Fig. 21.)

Height of stands 1 and 4 is about 5 ft.; stands 2 and 5, about 4 ft.; stand 3, about 6 ft.

The system will require six gates: two for the pump stand, and one each for all stands except stand 3, which requires none.

The system will require 66 distributing hydrants, including one riser and one alfalfa valve for each hydrant.

Problem IV

Suppose it is desired to apply water over the field in Problem III to an average depth of 5 in. How much time will be required to irrigate each strip with water flowing at a rate of 2.0 cfs?

Solution: The depth of application may be calculated from the equation: cfs × number of hours run = average depth in inches × acres. Area of one strip, 40 × 660 ft. = 26,400 sq.ft. = 0.605 acres; therefore, 2.0 × number of hours run = 5 × 0.605 = 3.03. The number of hours run $= \frac{3.03}{2.0} = 1.515$ (approximately 1.5 hours).

DEFINITIONS OF SOME COMMON TERMS USED IN IRRIGATION

Acre-foot. A measurement of water volume. One acre-foot equals the volume of water required to cover an area of 1 acre to a depth of 1 ft. A rule of thumb often used states that 1 cfs running for a period of 12 hours is equal to 1 acre-ft.

Alfalfa valve. A valve to control flow from risers. The opening is equal to the inside diameter of the riser. A ring on the outside of the frame provides a seat and seal for a portable hydrant. See photo and Fig. 7 on pages 9 and 11.

Cfs. Abbreviation for cubic foot per second, which is a measure of the flow of water. One cfs is equal to 449 gal. per minute or, if allowed to flow for 1 hour, 1 cfs would cover 1 acre to a depth of approximately 1 in.

Coefficient of roughness (n **or** C_S). A factor used in hydraulic formulas to express the relative roughness of the interior of the pipe as it affects the flow of water through the pipe (capacity).

Deep percolation loss. Water that percolates downward through the soil beyond the reach of plant roots as a result of inefficient irrigation practices.

Freeboard. The vertical distance above the water surface in vents and stands at operating head provided to allow for unusual or emergency conditions without topping the structure. One-foot freeboard is usually allowed in design of vents and stands.

Head. The difference in elevation between water surfaces at two points along the pipeline or at the source and at the outlet. Energy required to overcome friction in the pipe, bends, and valves can be expressed in feet of head.

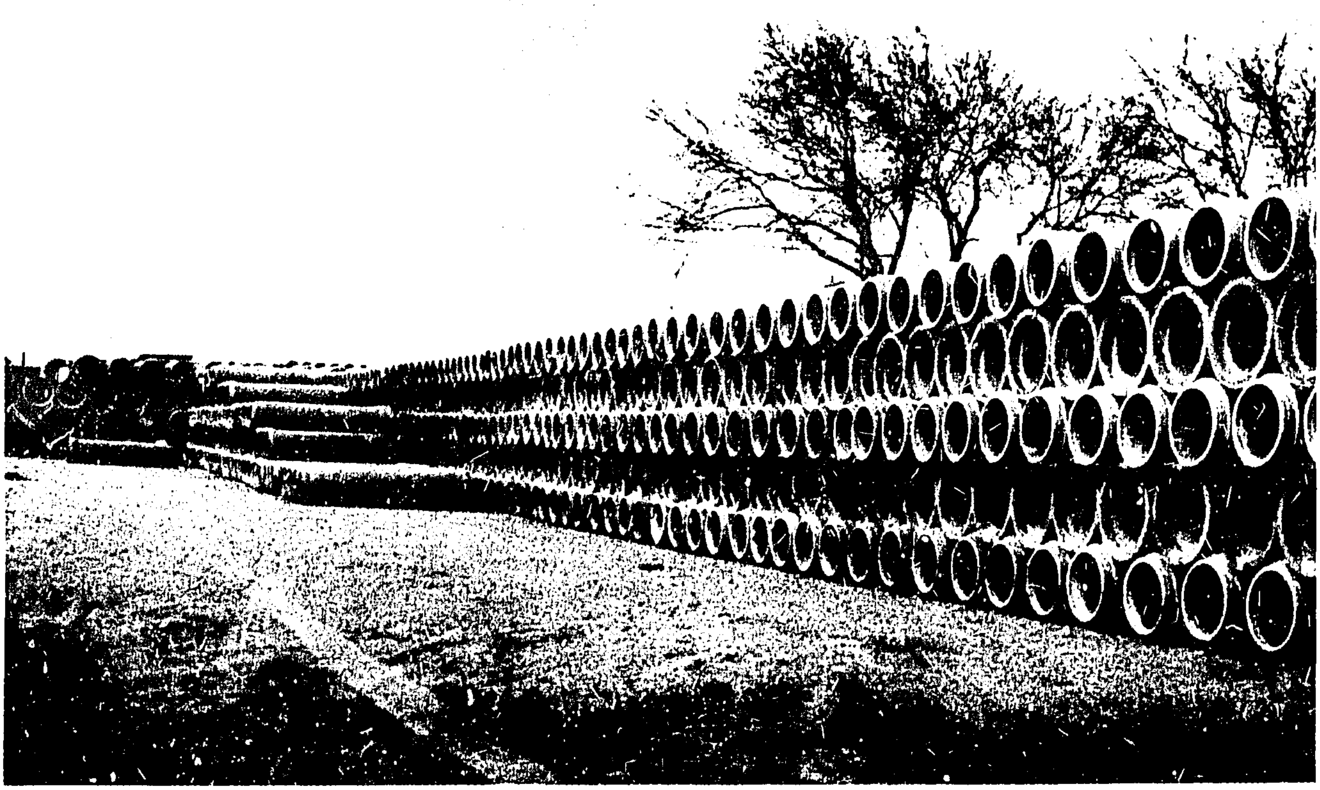
Orchard valve. Similar to alfalfa valve in that a horizontal disc is screwed down onto a seat to control flow. The orchard valve is mounted inside the riser pipe and is smaller in diameter than the riser pipe. The flow capacity is therefore less. See Fig. 10 on page 10.

Portable hydrants. Outlets used for connecting surface pipe to alfalfa valve outlets. See photo on page 11.

Stand. An irrigation structure built from vertical sections of pipe or cast-in-place concrete. It provides an opening to the pipeline into which pump, gate, or float valve can be installed. It may also serve as a vent or sand trap.

Vents. Vertical pipe structures to release air entrapped in the pipeline. Entrapped air must be removed to permit even flow and avoid danger of water hammer. See photo on page 2 and Figs. 2 and 12 on pages 4 and 12, respectively.

Water hammer. The result of a sudden change in the rate of flow causing excessive momentary pressure buildup. Gates and valves should be opened and closed carefully to avoid water hammer and damage to the pipeline.



Carefully stacked pipe in producer's storage area.

SELECTED REFERENCES FOR FURTHER READING

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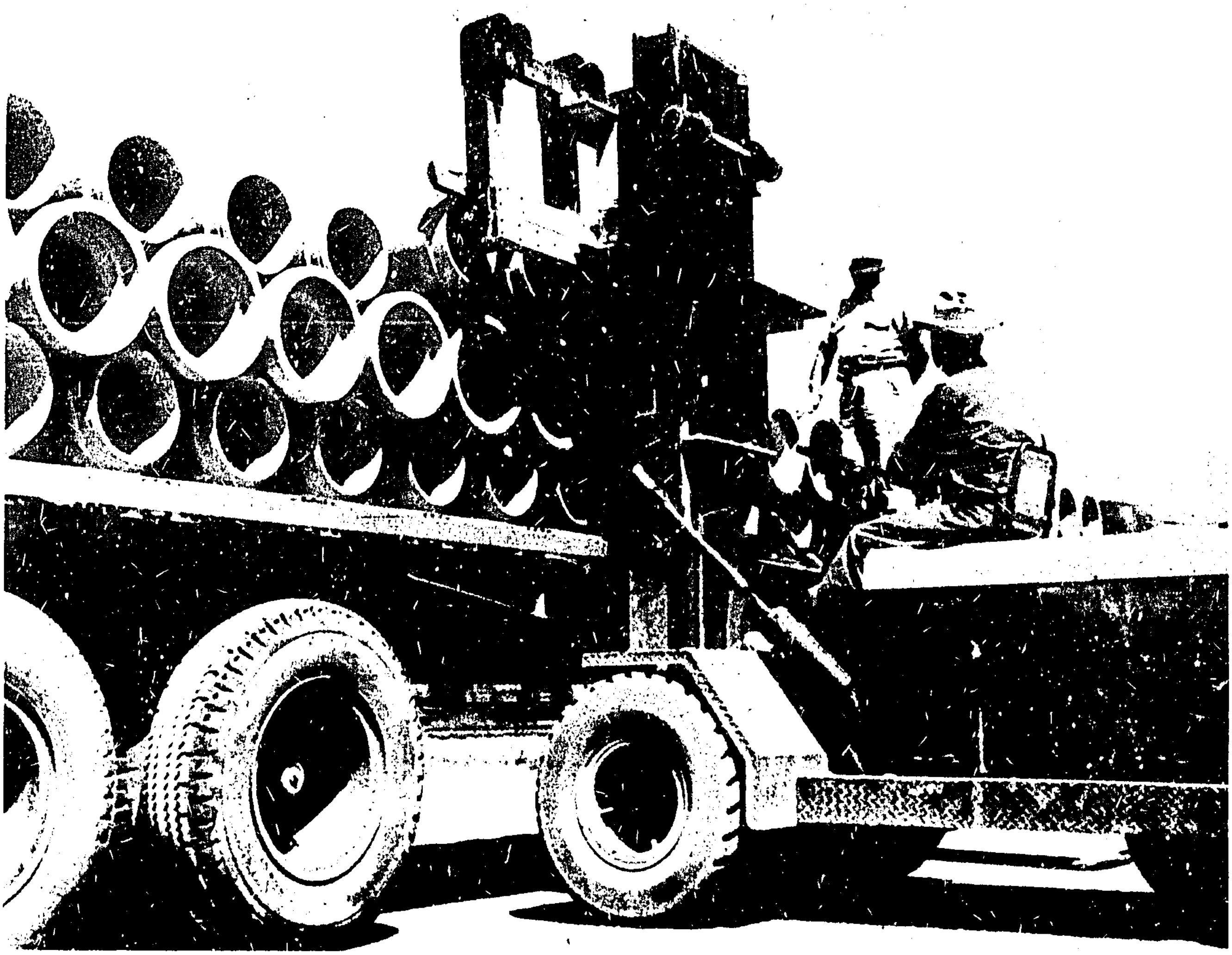
Other good sources of information:

- American Concrete Pipe Association
- Concrete pipe manufacturers
- Irrigation contractors
- Local irrigation districts
- Portland Cement Association
- Soil Conservation Service, U.S. Department of Agriculture
- University extension engineers

Acknowledgments: Fig. 13 and photos on water re-use systems on pages 10 and 13 courtesy of Gibson's Concrete Pipe, Delano, Calif. Figs. *4, 5, 6, 7, 8, 9, 10, 11, 12,* and *14* were adapted from drawings from Soil Conservation Service, U.S. Department of Agriculture.



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