TANGAIL AGRICULTURAL DEVELOPMENT PROJECT
BRDB/GTZ

MANUAL ON BURIED PIPE IRRIGATION SYSTEMS

Prepared by:

FERENC GEORGI
IRRIGATION ENGINEER

MAY, 1988

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ABBREVIATIONS

BRDB	Bangladesh Rural Development Board
CC	Concrete
cft	cubic foot
cm	centimeter
DTW	Deep Tubewell
ft	foot
GOB	Government of Bangladesh
GTZ	German Agency for Technical Cooperation
h	hour
ha	hectare
kg	kilogram
KSS	Krishi Samabaya Samity (Village Cooperative)
l	liter
LLP	Low Lift Pump
m	meter
mm	millimeter
m^3	cubic meter
NGO	Non Governmental Organisation
PVC	Poly Vinyl Chloride
RCC	Reinforced Concrete
rft	running foot
sec	second
STW	Shallow Tubewell
TADP	Tangail Agricultural Development Project
Tk	Taka
"	inch

Introduction

Buried pipe irrigation systems are still a novelty in Bangladesh, in USA and also India they are since long time widely used for irrigated agriculture. The systems help to increase the command area, makes the water management easier, saves pumping costs and agricultural land otherwise lost to earthern surface irrigation channel.

This manual is meant to be a guide for engineers and technicians to design and construct a non-reinforced low pressure concrete pipe irrigation system under local conditions, with materials and know-how available in Bangladesh.

This booklet is especially dealing with CC pipelines, because at present they are the cheapest pipes available for the purpose. The prices for pipes made of PVC, asbestos cement, steel, etc. are several times higher. If in the next future the Bangladeshi enterpreneurs would produce corrugated hard PVC pipes with a diameter from 6 inch to 10 inch with only a 1/2 mm wall thickness, the situation could change. The factories needs only special extruders and a high enough demand to produce the pipes economically. Corrugated PVC pipes are widely used in Europe for drainage purposes, they are light, easy to transport and can be coiled up. Under ground protected from ultra violet radiation of the sun, they last for ever.

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Chapter 1

Design of concrete pipe irrigation systems

A buried concrete pipe irrigation system has to be designed well, for an efficient water flow required per each outlet to cover the desired command area. On the other hand the cost have to be kept in an economical zone.

If pipelines are too small in diameter the pumping costs will increase, the capacity of the system may be limited.

If pipeline diameter is larger than necessary the costs of the system will be higher.

Higher operating heads allow a higher flow-rate in the system but excessive pipe pressures endanger the safety of the system, which leads to the necessity to use reinforced concrete pipes or other more expensive pipes, like PVC, asbestos cement etc..

Pipeline size and maximum operation head has to be designed to obtain a balanced water distribution and economical operation.

Under normal circumstances most of the design criteria for the pipe irrigation systems in Bangladesh are given:

- Type of watersource DTW, STW, Deep set STW, LLP.
- Size of command area (ha, acres) owned by one KSS.

Recommended size of command area for a pipe irrigation system:

Discharge 2 cusec -> not less than 40 ha (100 acres)
Discharge 1.5 cusec -> not less than 30 ha (75 acres)
Discharge 1 cusec -> not less than 20 ha (50 acres)
Discharge 0.75 cusec -> not less than 15 ha (38 acres)
Discharge 0.5 cusec -> not less than 10 ha (25 acres)

- Discharge of water source (l/s or cusec)
- Form of command area, longish rectangular, square, circular, oval etc..
- Place of watersource related to command area
- Type of command area according to elevations. (High laying, chalas, baids, flats)
- Type of soils (light, medium, heavy)

With the help of the above mentioned datas the decision has to be made how many riser valves (hydrants) are necessary to cover the command area, and how high should be the discharge capacity per riser valve(hydrant).

The following table shows the discharge capacity of various alfalfa valves (hydrants) and size of land which can be irrigated with them.

TABLE 1

SIZE OF ALFALFA VALVE		DISCHARGE CAPACITY		IRRIGABLE AREA	
mm	inch	l/s	cusec	ha	acre
150	6	9.5-19	(1/3)-(2/3)	08-1.6	2-4
200	8	19-28.4	(2/3)-1	1.6-2.4	4-6
225	9	28.4-42.6	1-1.5	2.4-3.2	6-8
250	10	42.6-56.8	1.5-2	3.2-4	8-10

The following tables suggests standards, which were worked out by TADP, for various types of pipe irrigation systems.

TABLE 2 WATER SOURCE DTW OR LLP
Discharge ca 2 cusec (56.8 l/s)

Type of system diameter	Maximum length of pipeline	Number of riser valve	Irrigated area per riser valve	Discharge per riser valve	Total irrigable land
200 mm 8 inch	2440 m 8000 feet	30	1.6 ha 4.0 acres	19 l/s 2/3 cusec	40-48 ha 100-120 acres
225-250 9-10 inch	1770 m 5800 feet	20	2.4 ha 6.0 acres	28.4 l/s 1 cusec	40-48 ha 100-120 acres
300 mm 12 inch	1400 m 4600 feet	12	4.0 ha 10.0 acres	56.8 l/s 2 cusec	40-48 ha 100-120 acres

TABLE 3 WATER SOURCE STW OR DEEP SET STW
Discharge ca (3/4)-1 cusec (21-28.4 l/s)

Type of system diameter	Maximum length of pipeline	Number of riser valve	Irrigated area per riser valve	Discharge per riser valve	Total irrigable land
150 mm 6 inch	854 m 2800 feet	15	1.0 ha 2.5 acre	10.5-14.2 l/s 0.37-0.5 cusec	48 ha 37.5 acres
200 mm 8 inch	610 m 2000 feet	8	1.9 ha 4.7 acre	21-28.4 l/s 0.75-1.0 cusec	15 ha 37.5 acres

For the decision on the number of outlets the following criterias should be taken into consideration:

Very undulated land with lighter soils are indicating more riser valves with a lower discharge. The same applies to a high crop variation scattered over the command area.

Big baids and flats with heavy soils and gentle slops indicate less riser valves with a high discharge.

Naturally, there are variations between the two extremes.

Once the number of outlets is decided, the type of watersource and the size of command area is known, one can choose from the Tables 2 and 3 the type of system which will be constructed.

TABLE 4 NUMBER OF SEPARATE PIPELINES AND NUMBER OF VALVES WHICH ARE IN OPERATION AT THE SAME TIME

Type of system diameter of pipeline	Total discharge	Number of separate pipelines	Number of pipelines in operation	Number of valves in operation at the same time on	
				No	Discharge
200 mm (8 inch)	58.4 l/s 2 cusec	4	3	3	19 l/s 2/3 cusec
225/250 9-10 inch	58.4 l/s 2 cusec	3	2	2	28.4 l/s 1 cusec
250 mm 12 inch	58.4 l/s 2 cusec	2	1	1	56.8 l/s 2 cusec
150 mm 6 inch	21-28.4 l/s (3/4)/1 cusec	3	2	2	10.5-14.2 l/s 0.37-0.5 cusec
200 mm 8 inch	21-28.4 l/s 3/4 cusec	2	1	1	21-28.4 l/s (3/4)-1.0 cusec

1.1 Calculation of the headloss due to friction in the pipeline with the use of Darcy-s equation

$$h_f = \frac{f\ l\ v^2}{2g\ R}\ (m)$$

in which h_f = head loss due to friction in the pipeline in meter (m)

f = coefficient of friction in the pipes, dimension less (-) (see Table 5)

l = length of pipeline in meter (m)

v = velocity of water in the pipeline in meter per second (m/sec)

g = acceleration due to earth gravity in meter per square second (m/sec^2)

g = 9.81 m/sec^2

R = hydraulic radius in meter (m)

$$R = \frac{a}{p} = \frac{a}{d\pi}$$

in which a = area of cross-section of pipeline in square meter (m^2)

and p = wetted perimeter in meter (m)

$$a = \frac{d^2\pi}{4}$$

in which d = diameter of pipeline in meter (m)

π = 3.14 dimension less (-)

and p = $d\pi$

$$\text{also } R = \frac{\frac{d^2\pi}{4}}{d\pi} = \frac{d}{4} \quad \text{(for circular pipes)}$$

$$\text{Therefore} \quad h_f = \frac{2flv^2}{gd} \quad \text{(m)}$$

Discharge capacity or flow rate:

$Q = av$ in cubicmeter per second (m^3/sec)

and $v = \frac{Q}{a}$ in meters per second (m/sec)

TABLE 5 COEFFICIENT OF FRICTION f IN DARCY'S EQUATION FOR CONCRETE PIPES

Diameter of pipe mm	Velocity of water in meter per second				
	0.3	0.6	0.9	1.2	1.4
150 (6")	0.0102	0.0094	0.0090	0.0086	0.0084
200 (8")	0.0087	0.0081	0.0077	0.0073	0.0071
225 (9")	0.0080	0.0074	0.0070	0.0067	0.0064
250 (10")	0.0076	0.0069	0.0067	0.0063	0.0061
275 (11")	0.0071	0.0065	0.0063	0.0059	0.0057
300 (12")	0.0067	0.0062	0.0059	0.0056	0.0054

TABLE 7 FRICTION LOSS (HEADLOSS) FOR CONCRETE PIPES IN METER PER 100 METER PIPELINE

1 feet = 0.305 meter, 1 meter = 3.28 feet

Discharge or Flow rate in liters per second (cusec)	Frictionloss (Headloss) in meter/100 meter					
	Diameter of pipeline					
	150 mm (6")	200 mm (8")	225 mm (9")	250 mm (10")	275 mm (11")	300 mm (12")
9.5 (1/3)	0.38 (15")	0.08 (3.1")	0.04 (1.6")	– –	– –	– –
14.2 (1/2)	0.80 (31.5")	0.18 (7")	0.09 (3.5")	0.06 (2.4")	0.03 (1.2")	– –
18.9 (2/3)	1.32 (51.9")	0.30 (12")	0.16 (6.3")	0.09 (3.5")	0.05 (2")	0.03 (1.2")
28.4 (1)	2.91 (114.5")	0.64 (25.2")	0.34 (13.4")	0.19 (7.5")	0.12 (4.6")	0.09 (3.5")
42.6 (1.5)	– –	1.34 (52.8")	0.72 (28.3")	0.48 (12.1")	0.25 (10")	0.20 (8")
56.8 (2)	– –	– –	1.20 (47.2")	0.69 (27.4")	0.43 (17")	0.33 (13.2")

1.11 Headloss (Friction loss) through riser valves (alfalfa valves) after Michael

TABLE 8

Flow rate in liters per second (cusec)	Headloss in meters of water — Diameter of valve (outlet)					
	150 mm (6")	200 mm (8")	225 mm (9")	250 mm (10")	275 mm (11")	300 mm (12")
9.5 (1/3)	0.02 (0.8")	0.01 (0.4")	– –	– –	– –	– –
14.2 (1/2)	0.05 (2")	0.02 (0.8")	0.015 (0.06")	0.01 (0.04")	– –	– –
18.9 (2/3)	0.09 (3.5")	0.025 (1")	0.02 (0.8")	0.01 (0.4")	0.005 (0.2")	– –
28.4 (1)	0.25 (10")	0.07 (2.8")	0.04 (1.6")	0.03 (1.2")	0.015 (0.6")	0.02 (0.8")
42.6 (1.5)	0.59 (23")	0.15 (6")	0.10 (4")	0.06 (2.4")	0.04 (1.6")	0.03 (1.2")
56.8 (2)	– –	0.28 (11")	0.15 (6")	0.10 (4")	0.075 (3")	0.05 (2")

1.12 Calculation of the Headloss (Frictionloss) in elbows, T-pieces and inlet valves with the use of **Dahlhaus** equation

$$h_b = C_b \; 0.02 \; v^2 \; [m]$$

C_b = Friction Coefficient $\frac{sec^2}{m}$

v = Velocity of water in pipeline [m/sec]

C_b = 4 for riser valve
= 16 for inlet valve
= 8 for a T-piece
= 8 for a 90° elbow

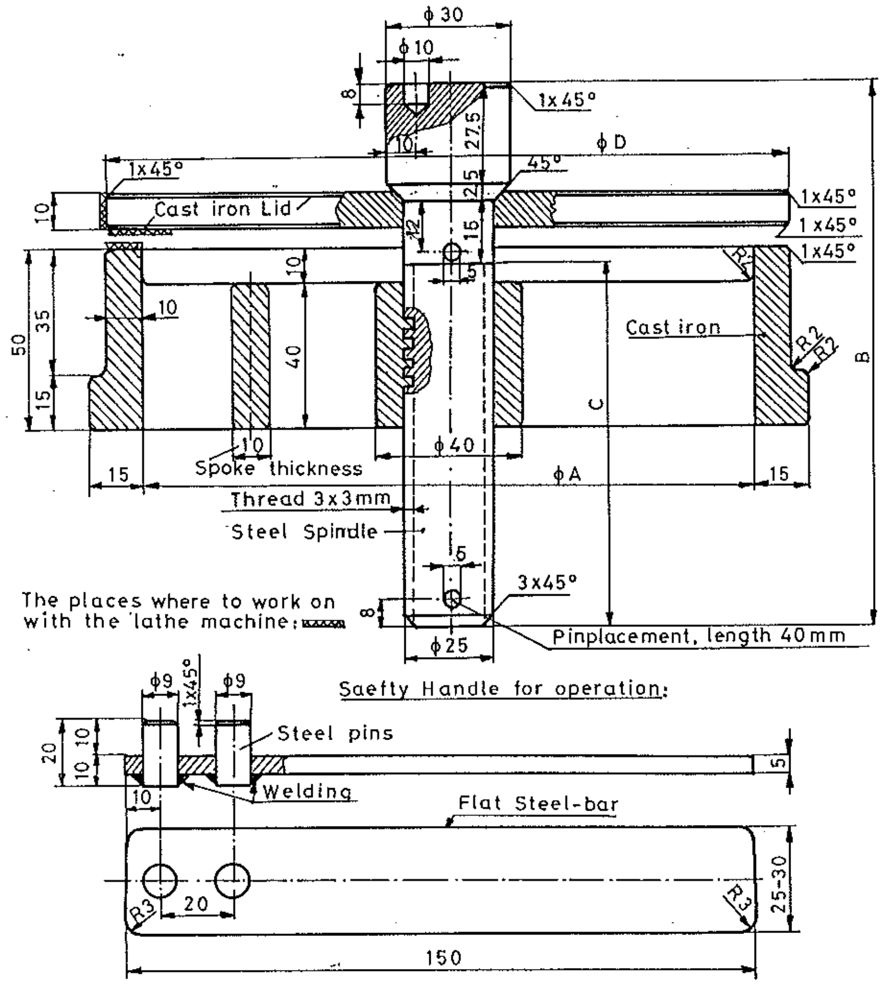
TABLE 9 HEADLOSS THROUGH T-PIECES AND 90° ELBOWS

Flow rate in liters per (l/s)	Headloss in meters of water				
	Diameter of pipe				
	15 cm	20 cm	22.5 cm	25 cm	30 cm
9.5	0.046	0.015	0.009	0.006	0.003
14.2	0.103	0.033	0.020	0.013	0.006
18.9	0.185	0.060	0.037	0.024	0.011
28.4	0.414	0.131	0.082	0.053	0.026
42.6	0.931	0.294	0.184	0.120	0.058
56.8	1.655	0.523	0.326	0.214	0.104

TABLE 10 HEADLOSS THROUGH INLET VALVES

Flow rate in liters per (l/s)	Headloss in meters of water				
	Diameter of inlet valve				
	15 cm	20 cm	22.5 cm	25 cm	30 cm
9.5	0.092	0.030	0.018	0.012	0.006
14.2	0.206	0.066	0.040	0.026	0.012
18.9	0.370	0.120	0.074	0.048	0.022
28.4	0.828	0.262	0.164	0.106	0.052
42.6	1.862	0.588	0.368	0.240	0.116
56.8	3.310	1.046	0.652	0.428	0.216

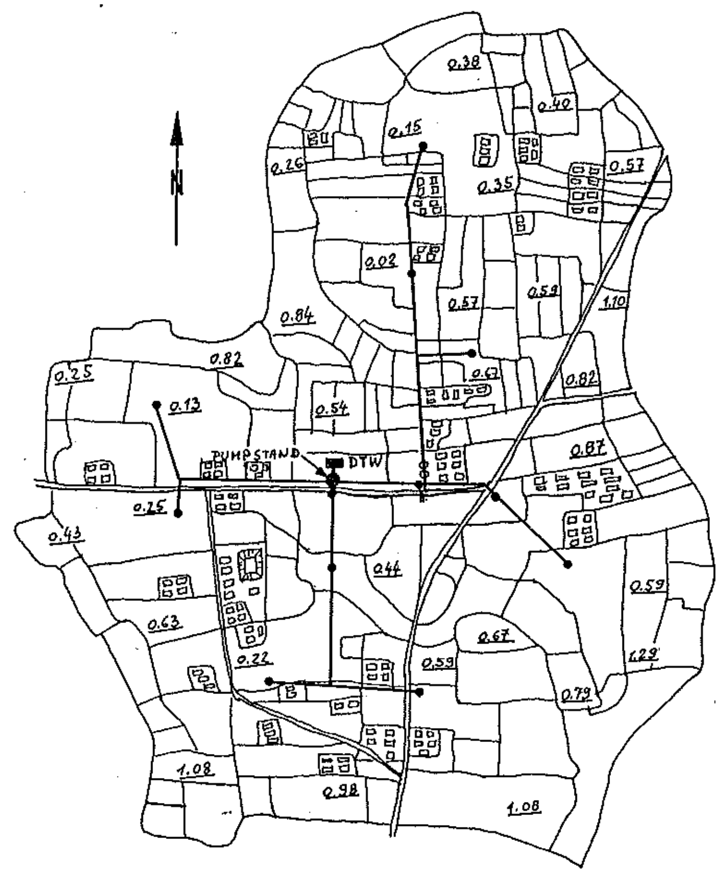
Figure 1: Riser valve (Alfalfa valve)



Valve Size	A (mm)	B (mm)	C (mm)	D (mm)
150 mm	150	150	105	170
200 mm	200	150	105	220
225 mm	225	160	115	245
250 mm	250	160	115	270

All measurements in millimeters !

Figure 2:
PIPELINE ALIGNMENT AND PLACEMENT OF RISER VALVES IN A DTW COMMAND AREA (AS AN EXAMPLE)



INFORMATIONS	SYMBOLS
Command area ca. 50 ha	Riser valve •
Pipeline dia. 300 mm	Pipeline
Riser valve dia. 250 mm	Homesteads
Number of Riser valves 12	Pond
Length of Pipeline 1600 meter	Roads
Overflow-type check 1 No.	Elevation below Top of DTW
	Discharge pipe 0.44 meter

SCALE CA. = 1:7000

1.1.2 Design of riser valves (alfalfa valves)

The riser valve is an essential equipment for the pipe irrigation system. It can be easily manufactured locally from cast-iron with a steel spindle. Every workshop equipped with a lathe machine can produce it. The price of one valve is in the range of 300-500 Taka, depending on the size. They should be designed strong and stardy to enable them to withstand rough handling. Figure 1 shows a design which is proven in field condition.

One can use them with or without rubber gasket. Without gasket minor leakages has to be put up with. For a gasket a short piece of used motorcyle or automobile tube can be used, which has to be stretched over the valve-lid.

It is suggested to design a special handle for opening and closing the riser valves, so that unauthorized persons (like children) cannot open or close them without the handle (see drawing).

The handle for the riser valves should be only in the hand of the linesman of the KSS.

1.2 Placement of riser valves in the command area

When the decision is made on the type of irrigation pipe system constructed on the command area, the number of riser valves is known. They have to be placed on the right spots in the command area. Each riser valve has to be able to irrigate a certain area which belongs to it. The riser valve have to be placed on the nearly highest spot on that particular area.

The farmers of the KSS knows very well which spots are the most suitable ones. Sometimes the spots have to be moved a bit for technical reasons, but still one should involve the farmers in the decision making. So they can identify them selfs with the placement of riser valves.

When the places for outlets are fixed in mutual agreement, the following job is to find the best alignment for the pipelines to connect the riser valves on the shortest and easiest way. (see Figure 2)

1.2.1 Layout of pipeline alignment

The alignment of the pipeline is determined by the spots of the riser valves which have to be served by the pipeline. Naturally, the riser valves have to be connected by the pipeline in such a way to obtain the shortest possible length, to decrease the costs of the pipeline and the headlosses due to friction. (see Figure 2)

The places of the riser valves can be also shifted in some cases, to obtain a layout which is serving all the aspects in an optimal way. It means to weigh all the pros and contras from case to case.

1.2.2 Placement of air vents

Air vents are vertical pipe structures connected on the top of the pipeline. They permit the release of the entrapped air in the pipeline. Big airpockets in the pipeline are a danger for the system. Air can be compressed or expanded by the flow of water in the pipeline and build up a higher pressure or vacuum, which in turn causes the hydraulic hammer (or water hammer). The pipeline can burst on such places. A big water mass in a movement have a high kinetic energy. With a sudden closure of a riser valve that energy has to be destroyed to stop the water movement in the pipeline. Air vents help to do that and protect the system from damage.

Air vents should be installed near the pumpstand, at all high points in the pipeline, at points where there is a downward deflection of more than 10°, and on the end of the pipeline.

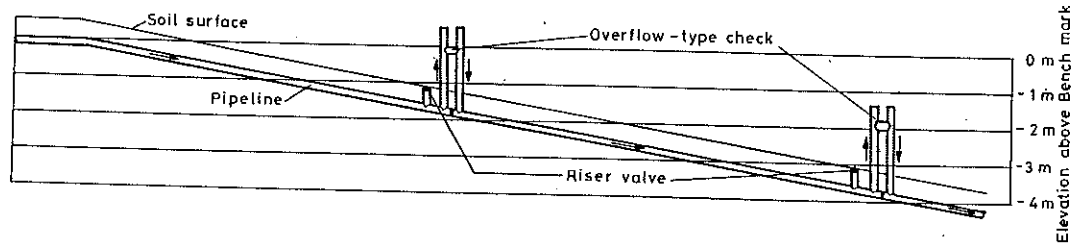
Generally, they should be installed at every riser valve but not more than 150 meters apart, even on straight pipelines with uniform slope.

The cross-section of the vent pipe should not be less than half of the cross-section of the pipeline.

1.2.3 Placement of overflow-type checks

Overflow-type checks are provided to control the flow into branch lines, they are also serving as an air vent.

They should be installed at points where the pipeline makes a downward deflection to a baid or lowland behind the riser valve. On a long downward or upward sloping pipeline at every point which is lower or higher in elevation than 1.5-2.0 meters, to avoid a constant high pressure on the beginning or on the end of the slope. They also help to avoid to fill up long pipelines unnecessarily.



They prevent the necessity to build very high air vents (more than 3m) towards the end of a downsloping or on the beginning of an upwards sloping pipeline. They are practically dividing the pipeline into separate sections.

The overflow-type checks are always constructed from the same diameter of pipes as the pipeline itself. For the headlosses see Table 9 (4 X an elbow).

1.3 Calculation of the required height of the pumpstand, air vents and overflow-type checks, shown in Fig. 1

Given datas for the example:

- Diameter of pipeline, d = 300 = 0.3 meter
- Elevations of ground surface on the pipeline alignment
- Flowrate per riser valve, Q = 56.8 l/sec (2 cusec)
- Distance between riser valves in meters
- Diameter of riser valves d_{rv} = 250 mm
- Diameter of inlet valve d_{iv} = 250 mm
- Ground surface elevations at the riser valves:
  h_o = -0.60 m, h_1 = -0.60 m, h_2 = -1.00 m
  h_3 = -1.00 m, h_4 = -0.30 m, h_5 = -1.00 m

Question: What will be the highest water surface elevation (pressure height) in the pumpstand? In which situation will be that the case? Which riser valve will be in operation?

Logically it looks like, when riser valves 4 is in operation. It is lying on the highest spot on the pipeline alignment and have a long conveyance distance from the pumpstand.

H_4 = Pressure height above Benchmark in the pumpstand

H_4 = h_4 - h_o + Head-loss due to friction in the pipeline from 0 to 4 (see Table 7) + Head-loss through inlet valve (see Table 10) + Head-loss through overflow-type check at 2 (see Table 9, 4 nos. of 90° elbows) + Head-loss through T-piece at 4 (see Table 9) + Head-los through riser valve at 4 (see Table 8).

$$H_4 = -0.30 - (-0.60) + 0.33\frac{116+110+100+90}{100} + 0.428 + 4 \times 0.108 + 0.108 + 0.100$$

$$H_4 = -0.30+0.60+1.373+0.428+0.432+0.108+0.100$$

<u>H_4 = 2.74 m</u>

The same calculation if riser valve 5 is in operation

$$H_5 = h_5 - h_o + 0.33\frac{116+110+100+90+110}{100} + 0.428 + 4 \times 0.108 + 0.108 + 0.100$$

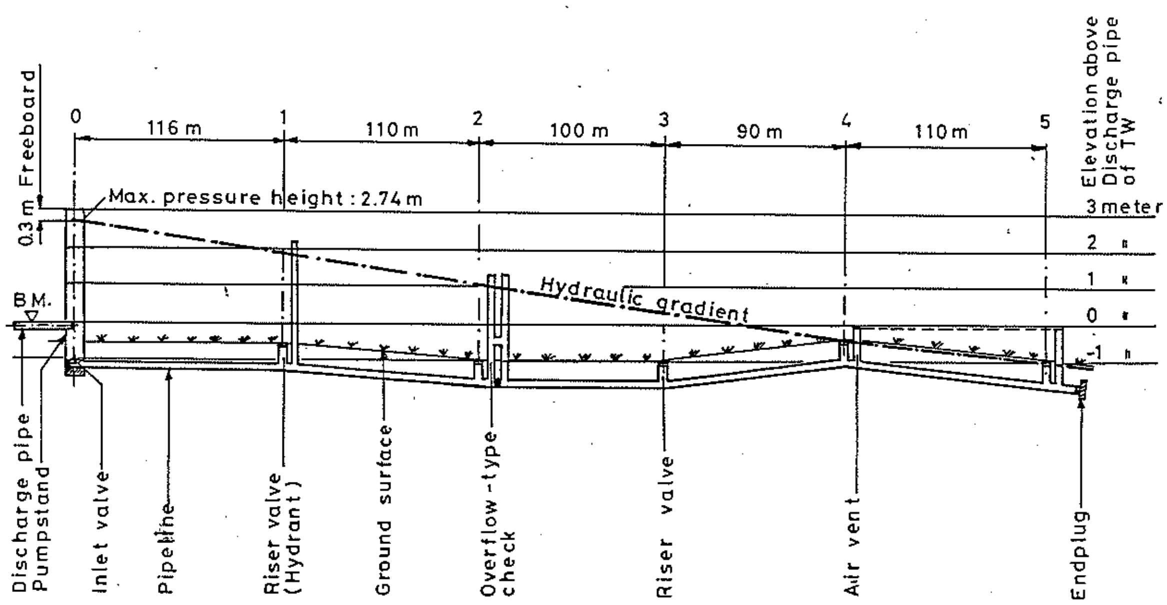
$$H_5 = -1.00-(-0.60)+0.33 \times 5.26+0.428+0.432+0.108+0.100$$

$$H_5 = -0.40 + 1.736 + 0.428 + 0.432 + 0.108 + 0.100$$

<u>H_5 = 2.40 m</u>

The presumption that H_4 will be the highest pressure height in the pumpstand was correct.

The design sketch (Fig. 1) should be drawn with a scale for the length and for the heights.



BM. = Bench mark 0.00 meter

Figure 3 : Design sketch of an example

With the help of the highest pressure height in the pumpstand and the responding riser valve in operation the Hydraulic Gradient can be drawn in the sketch. Now the heights of all air vents and overflow-type check can be extracted from the sketch. The heights should be with the free-board of 0.3 m above the hydraulic gradient.

At the point 5 the pressure head above bench mark is the same as at point 4, when riser valve 4 is in operation, so the air vent should be on the same elevation level.

In the practice it is easy to adjust design errors made about the height of pumpstand and air vents. When pumpstand or air vents are over-flowing during the test of the system, one can extend them with another pipe.

1.4 Selection of pipe size along the pipeline

The costs of low head irrigation pipelines can be reduced considerably with the selection of the pipe sizes according to the need along the pipeline.

A system can be designed with a uniform diameter for the whole system, which makes the design and the production of pipes easier but increases the costs of the system. Before a pipe size can be selected, the following items need to be considered:

- The hydraulic gradient at any point of discharge should be at least 0.30 meters (one foot) above the ground surface. Every type of outlet have a certain headloss. The water has to be delivered to the field.

- The hydraulic gradient should not be below the elevation of the pipeline at any point where water is flowing, otherwise the flow would be cut off.

- At the pumpstand the height of the gradient may be limited due to high pressure.

- The hydraulic gradient will be at the different outlets of different heights. The design has to based on the greatest distance.

- On branch-lines (laterals) base the design on the highest gradient required at the diversion.

- On an overflow-type check draw the hydraulic gradient upstream (towards the pumpstand) from the overflow pipe.

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 vertical drop of the hydraulic gradient. Draw this slope upstream from the proper elevation above the critical hydrant or hydrants (usually which is farthest downstream) and see how it fits in with the limits at points upstream. If necessary, select other sizes and try again.

The diameter of a pipeline can be reduced toward the end to save costs. The available pressure head for the new diameter at the point of reduction is the height of the hydraulic gradient. Where the pipeline deflects downwards for a longer distance, pressure head is gained, the diameter can be reduced.

Branch-lines (laterals) to hydrants can be in some cases reduced.

In any case, at the last hydrant on a pipeline the available pressure head for the distribution of water should not be below 0.3 meters, which is about the optimum.

Note, the headloss through an alfalfa valve is up to 0.15 meters plus the valve lip has to be set 0.10 to 0.15 meters (4-6 inches) below the soil surface to minimize interference with farming operations and to reduce erosion around the valve.

Chapter 2

Concrete Pipes

2.1 Suggested specifications of concrete pipes, joint designs

Due to our experiences in the field we are suggesting biger wall (shell) thicknesses for Bangladesh. We added ca 5% to the wall thickness on the standard specifications for irrigation pipes according to the American Society of Testing Materials (ASTM C118-66T).

The quality of the concrete pipes made locally cannot be kept on the same standard as in USA due to the following reasons:

- Locally available materials like khoa (brick-chips) and sand are from lesser quality. They are using in USA high quality gravel well graded. So, in Bangladesh high quality stone chips are available, but too expensive for the purpose.

- Pipes in USA are made on modern machines well compacted, and casted in Packerhead machines.

- The concrete in USA is mixed according to modern technology in computerized factories.

TABLE 11 PHYSICAL AND DIMENSIONAL REQUIREMENTS FOR CONCRETE IRRIGATION PIPES

Internal diameter mm	Internal diameter inch	Minimum wall (shell) thickness mm	Test Requirements: Internal Hydro static pressure kg/cm²	Test Requirements: Three-Edge Bearing Load kg/linear meter	Working Pressure Head meters	Working Pressure Head feet
150	6	20	3.5	1930	8.5	28
200	8	23	3.5	2000	8.5	28
225	9	25	3.5	2040	8.5	28
250	10	27	3.2	2080	8.5	28
300	12	30	3.2	2230	7.9	26
350	14	33	3.2	2380	7.9	26
400	16	37	3.2	2530	7.9	26

2.2 Casting moulds (vertical shutters) for different pipes

Pipe casting moulds are used in rural areas to produce non-reinforced concrete pipes on the spot where they are needed.

Pipe casting moulds can be made from different materials like, wood, iron sheets, plastic. The length of the pipes are normally 1 m. According to the preferred joint system they can be made for pipes with bellmouth-socket and spigot, Tongue and groove system, or plane end pipes. The durability and easy handling of the moulds depends on the materials used and proper workmanship ot produce them.

Forms with the joint-system bellmouth-socket and spigot and tongue and groove are complicated to make and costly. The esiest moulds to make are to produce plane end pipes.

The cheapest moulds are made by very thin G.I-sheets (thickness 0.5/1.0 mm), with wooden or concrete bases. Before casting the mould have to be clean and have to be coated with used mobil oil. Otherwise the concrete would stick to the mould. Usually with one mould 2-3 pipes can be produced per day. Note that each pipe needs a separate base-plate.

2.3 Pipe spinning gear and spinning forms

In Bangladesh spinning gears are already widely used for the production of reinforced concrete pipes. Small private workshops are using hand driven spinning gears by flat belts or electro motor driven gears.

Common is only, the low quality of the pipes and the relatively high costs. The quality of the pipes depends of the quality of the concrete used and the proper curing of the pipes after making. Poor quality of the khoa used and the poor cement, sand, khoa ratio plus inadequate curing are the reasons for low pipe qualities.

The high costs could be reduced considerably. Reinforcement is not necessary for low pressure pipes, which is about 50% of the costs. Beside that the margin of profit is too high ca. 50% . A transportable hand driven spinning gear, with fanbelt drive can be locally produced for ca. Tk. 40,000.

One gear need 40-60 pipe-forms to produce 60-80 pipes a day with 1.8 m length. The range of pipe diameters from 6 to 12". Note, a pipe with a diameter of 12" and 1.8 m long has a weight of ca. 100 kgs.

2.4 Calculation of the concrete volume for pipelines

$$V = \frac{(do^2 - di^2)\ \pi}{4} = 0.785\ (do^2 - di^2) \quad m^3/rm \text{ or } cuft/rft$$

in which V = Volume of concrete per running meter or rft.

do = Outer diameter of pipe in meter or feet

di = Internal diameter of pipe in meter or feet

π = 3.14

For pipelines which bellmouth socket or socket more material is needed per pipe.

For the jointing material an extra calculation has to be made.

The same applies for foundations etc.

2.5 Suggested concrete mixture ratios by volume for pipe making

a) 1 cement : 2 sand : 4 khoa (brick chips)

100 cft concrete = 18 bags cement + 45 cft sand + 90 cft khoa (brick chips)

b) 1 cement : 2 sand : 3 khoa

100 cft concrete = 21 bags cement + 53 cft sand + 79 cft khoa (brick chips)

1 cubicmeter [$1m^3$] = 35.34 cft

1 cft = 0.0283 m^3

1 bag cement = 1.2 cft by volume

The introduction of wooden measurement box with a volume of 1.2 cft (one bag cement) is recommended. To both sides of the box a long wooden handle can be attached, so two people can easily carry it.

Naturally there could be other mixture ratios with different aggregates. The cement and aggregates should be mixed first dry.

By adding of just sufficient water, the concrete has to be mixed thoroughly to a homogeneous, plastic mass. High water content reduces the quality of the concrete it will be porous less water tight. Masons helpers tends to add to much water to the concrete, it is easier for them to mix it.

When ever possible a hand driven concrete mixer should be used, the initial cost will pay off for the better quality obtained.

2.6 Concrete aggregates

There are various types of concrete aggregates in Bangladesh available.

- Khoa (brick chips) made of bangla or ceramic bricks
- Peagravel
- Stone chips
- Kauchi, minerals in crystalline form available in hilly areas in the forest
- Sylhet sands (very good quality)
- Local sands (medium to good quality)

The decision on the aggregates to be used in a certain project should be made on a costs survey. The price of the aggregate should include the transport costs to the sites where manufacture of the pipes is made.

Generally, the coarse aggregate should be separated into the following sizes ranges:

- 3/8 inch average size; ranging from 1/4 inch to 1/2 inch, for pipes from 6 inch to 12 inch diameter.

- 1/2 inch average size; ranging from 3/8 inch to 3/4 inch, for pipes above 12 inch diameter (pumpstand).

The local sands, peagravel, kouchi are in most of the cases contaminated with clay, silt, organic matter, they are originating from river beds, or hilly areas.

The aggregates should be screened and washed before use.

Near the place which is choosen for pipe production, sufficient water has to be available, for concrete mixing, curing of pipes and washing of the aggregates.

Even the khoa which is normally crahsed by hand on the spot from bricks or brick bits should be screened from dust and washed before use.

2.7 Manufacture of pipes in vertical shutters (casting moulds)

The easiest method to produce CC pipes is to use vertical shutters made of mild steel sheet. The shutters have to be carefully designed and made properly. The outer parts of the shutters are quite trouble free and easy to produce. The inner part of the shutter has to be made of three pieces for the necessity to remove it from inside the ready casted pipe.

The outer and inner part of the shutter have to be circular and they must fit nicely together, for troublefree operation.

Remember that each shutter needs to have 2 baseplates, to enable the production of at least two pipes per day.

The baseplates can be made of wood, castiron, or mild steel.

The shutters should be stiff enough to withstand the pressure applied due to compaction of the concrete. They should not deform and change their circular form, otherwise the stripping of the form from the fresh casted pipe could be difficult.

Before casting, the shutters have to be well brushed with burnt mobile oil, which helps to remove the shutters of the pipes.

The concrete which has to be prepared according to para 2.5 and 2.6, should be filled into the shutter portionwise, each layer has to be compacted carefully with a rod.

After about 4-6 hours the inner part of the shutter can be removed first, 2-4 hours later the outer part of the shutter. Curing should start straightway. (see para 2.9)

After the curing period, the pipes should be properly stacked and stored.

2.8 Manufacture of pipes with the Spinning Gear

The spinning gear is a device which is designed to produce concrete pipes in circular forms (outer forms only). Usual length of the pipes are 6 feet. The hand driven spinning gear is rotating the form with about 300 rotation per minute, when a 9 or 10 inch form is used.

The concrete mixture is shoveled into the form during rotation, the inner surface of the pipe has to be formed and shaped with the help of a T-profiled steelbar, holded on both end by the pipe making masons. The process needs two pipemaking masons, each of them working on one side of the gear simultaniously. The inner diameter of the pipes is given by the circular hole of the form holders.

The compaction of the concrete is done by the centrifugal force, due to rotation. When the pipe is formed a cement sand mixture of 1:1 will be applied into the pipe and with a wet longhandled brush smoothness will be achieved. This final touch gives a sealcoat of 1-2mm thickness to the inner surface of the pipe.

The form with the freshly casted pipe inside is rolled down from the gear on a ramp.

About 6-8 hours after casting, the form can be removed from the pipe. However, the pipe form holders, which are attached on both ends on the form with the help of long on the ends threaded bars and nuts, can be removed just after the casting and used for the next form.

Before use, the forms have to be oiled with used mobil oil, to avoid the sticking of the form to the pipe surface.

Ca. 10 minutes are needed to produce one pipe, the number of forms should be according to the desired output per day.

A pipemaking team should consist the following people:

1 Head Mason (team leader)
1 Assistant Mason
4 Masons Helpers
6 Labourers

4 people are needed to drive the gear.

With the above team with 40-50 forms, 60-80 pipes can be produced per day.

For each pipe diameter different form sizes and form holders are necessary.

For concrete mixture and aggregate consult para 2.5 and 2.6. Curing of pipes see para 2.9.

2.9 Curing of Pipes

Beside the correct cement, sand, gravel and water ratios used for pipe making, quality pipes cannot be obtained without proper curing.

12 to 24 hours after casting or spinning of the pipe, it has to be cured for ca. 21 days.

The best curing method is to immerse the pipes in water, or partially in water and rotate them daily.

Other curing methods:

- Covering the pipes with moist gunny bags and keep them moist.

- Covering the pipes with rice straw and keep them moist.

- Covering the pipes with water hyacinths and keep them moist.

The wind and dry air should be prevented to circulate through the pipes. Important is to keep the concrete moist during the curing period.

2.10 Locally fabricated cc pipes on Packerhead machines

There are local concrete pipe manufacturers with modern Packerhead machines, which are able to produce and supply good quality concrete pipes for irrigation purposes.

Some factories are offering assistance for supervision, pipe installation and transportation. One factory even offers to arrang ena instal a factory at the working site in any part of the country if necessary.

Prices of pipes in Bangladesh (indicative)

Diameter [inch]	Load Bearing [kg/linear meter]	Price per [rft]
4	2395	12
6	2395	16
9	2395	28
12	2395	40

Chapter 3

Construction of buried pipe systems

3.1 Jointing methods of pipes

The joints for non reinforced concrete (CC) pipes are being made in several different ways. (see Figure 4)

- Tongue and groove design
- Bellmouth-socket and Spigot design
- Plane end pipe joints

The surface of the pipes where the jointing will be made should be thoroughly cleaned from dirt with brush and water before the jointing starts. The jointing surfaces of the pipes have to be wetted.

- The jointing of the tongue and groove design should be done the following manner:

  - The groove end of the pipe should point in the direction of pipe laying.

  - The groove has to be filled with mortar (ratio 1:1½; 1:2; 1:2½) and then the tongue end of the next pipe has to be shoved into the groove. About 15 joints back of the pipe laying, a 2-3 inch wide jute braiding (cloth) socked in cement slurry (mix 1:1) have to be bandaged twice around the circumference of the joint gap 15 to 30 minutes later a mortar band of the mixture 1:3 or 1:4 has to be placed around the jute bandage.

- The jointing of the bellmouth-socket and Spigot design should be done the following way:

  - The socket end of the pipe should point in the direction of pipe laying.

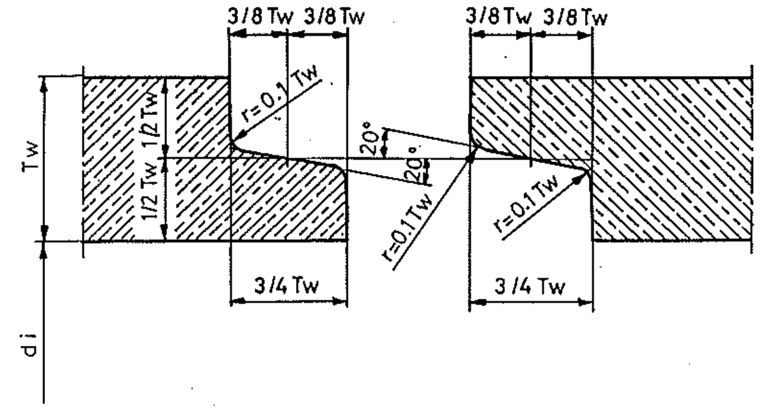
  - The spigot end of the next pipe should be bandaged with jute braiding socket in cement slurry (mix 1:1), one times around the circumference of the spigot, and shoved into the bellmouth socket. Then the bandage has to be pushed into the gap of socket and spigot with a ¼ inch tick bamboo stick.

  Following this, about 6-10 joints back of the pipe laying, a band of mortar (mix 1:3) has to be placed around the joint.

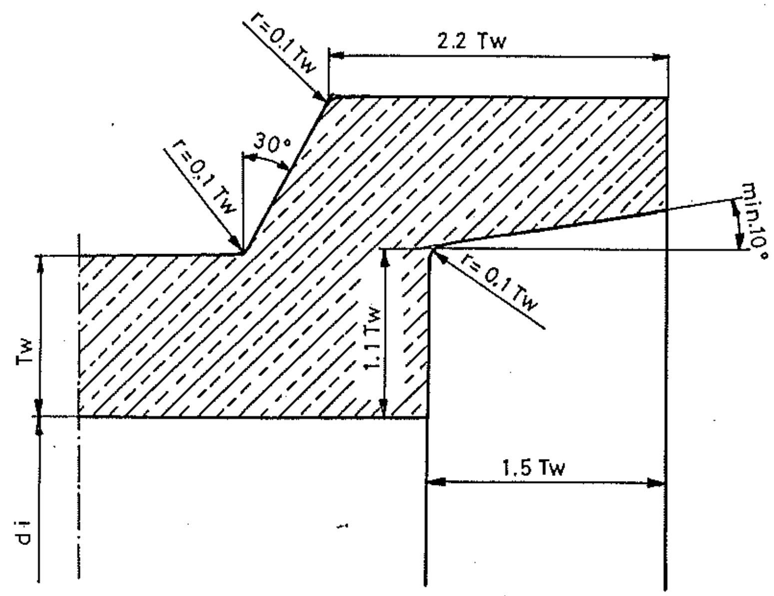
- The jointing of plane end pipes has to be done the following manner:

  - The pipe have to be placed with the plane end on each other without gap in a straight line, a 2-3 inch wide jute braiding (cloth) socked in cement slurry (mix 1:1) have to be bandaged twice around the circumference of the joint gap. 15-30 minutes later a mortar band of the mixture 1:3 or 1:4 has to be placed around the jute bandage.

Figure 4 : Tongue and groove design



Bellmouth - socket and Spigot design



di = Internal diameter of pipe
Tw = Wall - thickness of pipe

3.2 Curing of joints and back-filling of trenches, size of trenches

The curing of the joints is as much important as the curing of the pipes. Joints which are badly cured or not at all, tends to crack (hair-crack), leakages occur. Shortly after the mortar of the bend around the joint get set curing should be started. The easiest method to cure the joints on a pipeline in the trench is to cover the joints and pipes with loose wet soil at least with a foot thickness. If the soil is dry, it can be wetted on the top of the joint from time to time.

Joints on vertical structures like air-vents, pumpstands etc. where the joints cannot be covered with soil, wet gunny bags or jute braiding should be rolled around the joints and kept wet for 2-3 weeks.

The trenches of the pipelines should be covered with soil about 1-1½ above the top of the pipes, latest 12 hour after jointing. If the pipeline is exposed to the sun and hot air during the day it is expanding, during the night the temperature of the air drops, the pipeline is contracting, cracks in the pipeline and joints could occur.

The soil cover on the pipeline keeps the temperature quite constant the extremes are smaller.

The trenches for the concrete pipeline should be so deep that at least 2 feet cover from the top of the pipeline is provided.

The width of the trench should be the diameter of the pipes plus 2 feet. A certain working space for the laying mason has to be provided left and right of the pipeline.

The bottom of the trenches has to be smooth and straight, so the pipes are laying with their full length on the soil.

The places where the joints of the pipes are lying should be cut a small trench about 1 feet wide and 3 inches deep, to provide space for the bellmouth socket and to provide space for the laying mason to work at the joints.

3.3 Construction of pumpstand

For the construction of the pumpstand 3 feet diameter pre-fabricated non-reinforced concrete pipes with 2 feet length are ideal. See pumpstand drawings for different pipeline diameters. (Figures 5,6,7)

Working procedure on pumpstand:

- Mark the center of the pumpstand, 40 cm from the end of the discharge pipe (DTW)

- Brake down the diacharge box (if any) in a circle around center point with a radius of 70 cms.

- Dig a round hole with a radius of 65 cm on center point. For the depth of hole see drawings.

- Dig trenches for the pipelines according to drawings.

Figure 5 :
8" DIA. BURRIED PIPE SYSTEMS PUMPSTAND CONNECTION

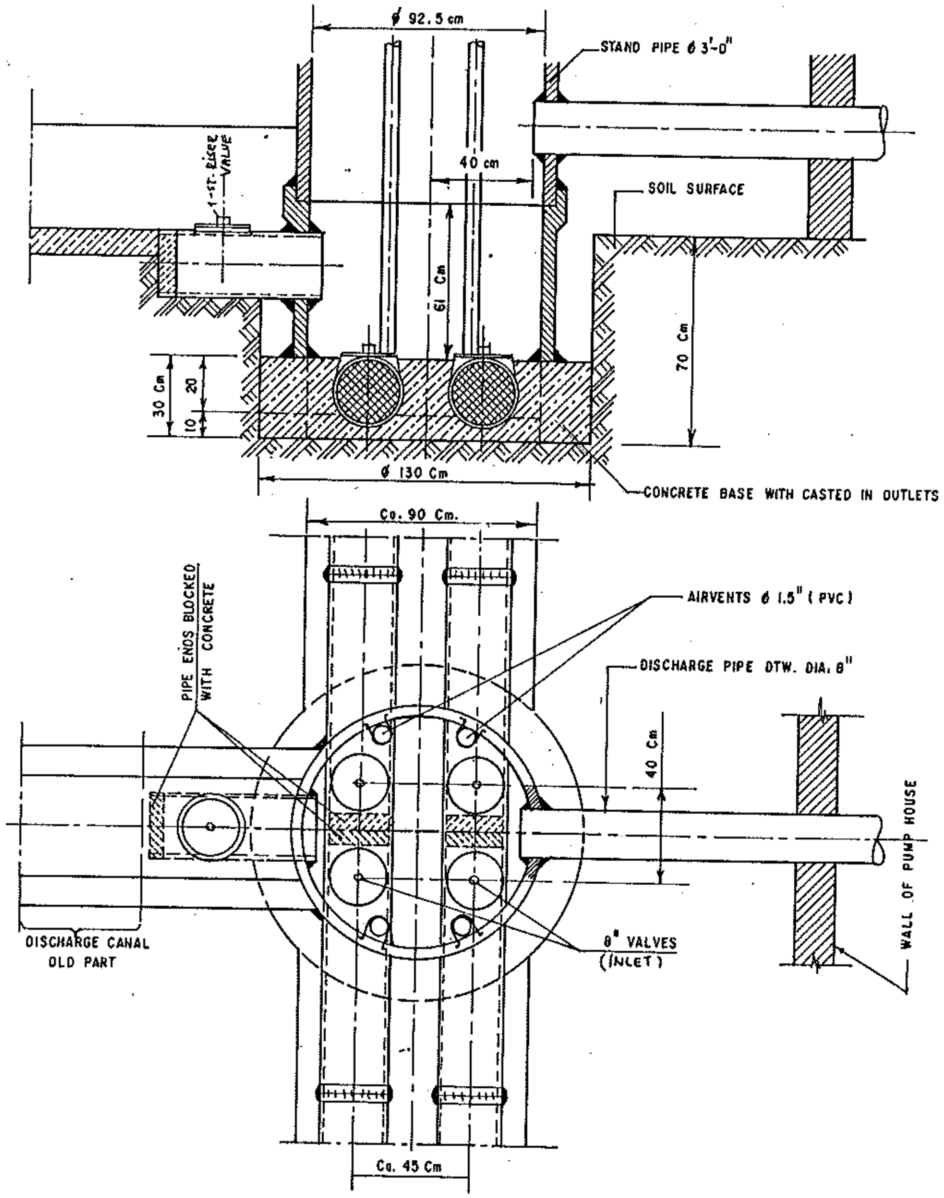


Figure 6: 10" DIA. BURRIED PIPE SYSTEMS PUMPSTAND CONNECTION

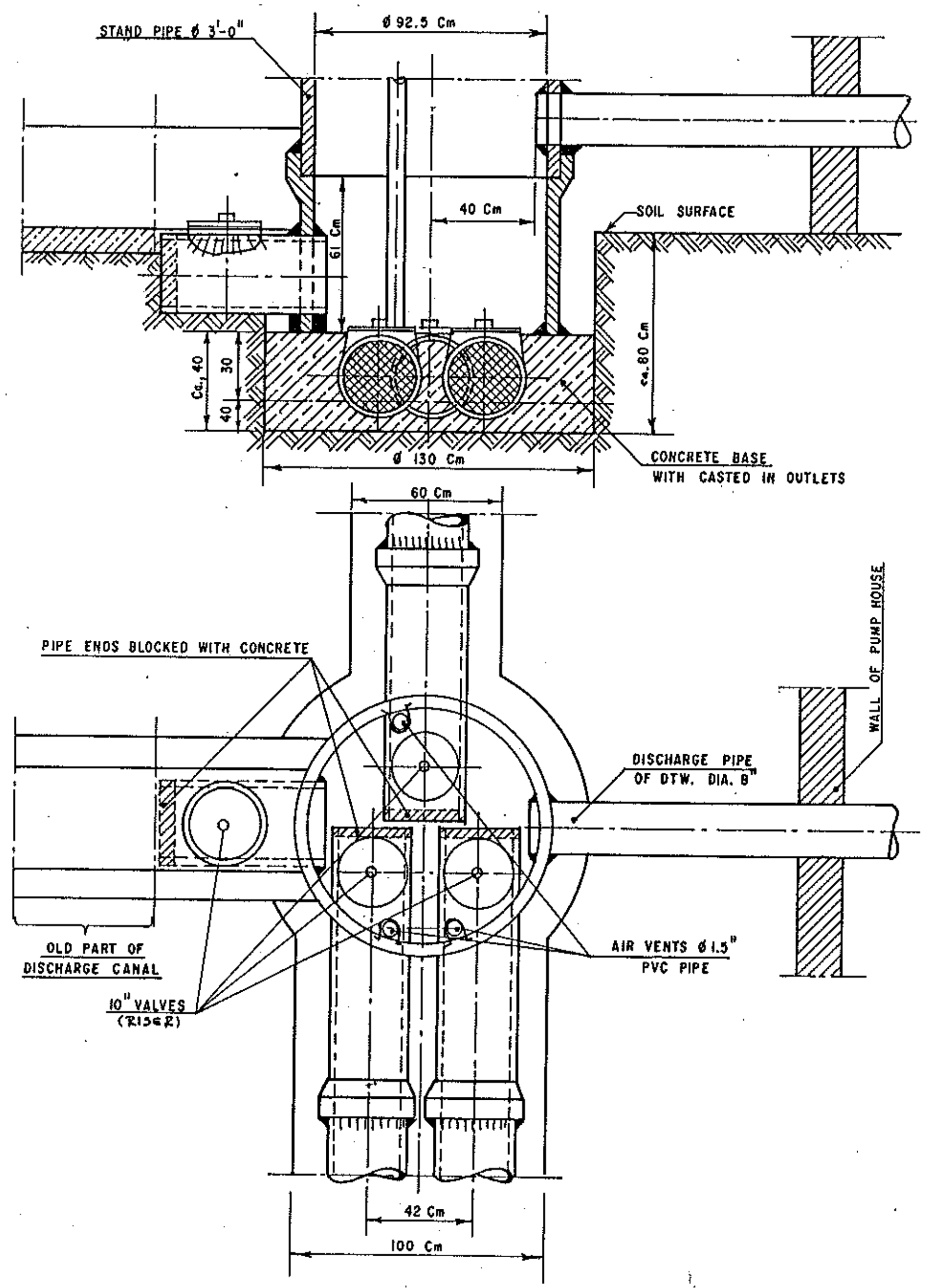
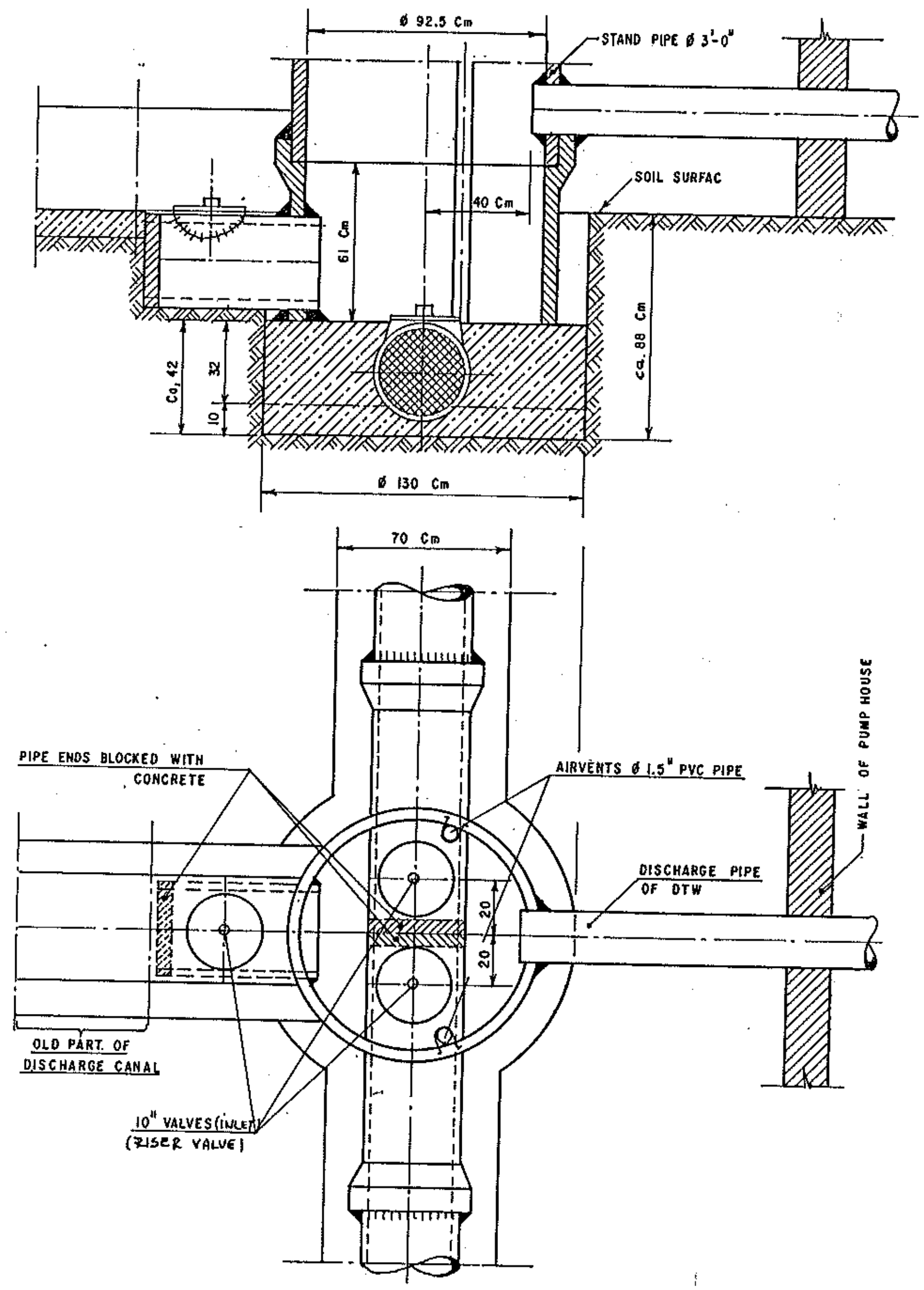


Figure 7: 12" DIA. PUMPSTAND CONNECTION.



- Fill a ca. 10 cm tick concrete layer into the round hole and set the prefabricated pipes, with blocked ends and a casted in alfalfa valve, into the fresh concrete (mixture 1:2:4). Press the pipes ca. 5 cm deep into the fresh concrete. The valve lids should be horizontal.

- When the pipes are laying correctly fill in the rest of the concrete at least a ½ cm below the seat of the valve.

- After 5-6 hours, set the 1st pumpstand pipe of 3 feet diameter (91.5 cm) with mortar on the base, central to the alfalfa valves.

- Fill in and compact soil outside of pumpstand.

- Set the pre-fabricated pipe with alfalfa valve (1st outlet) with blocked end. A hole has to be chiseled into the 1st pipe of pumpstand. The lid of the valve has to be just above the bottom of old discharge channel.

- Extend concrete base of old discharge channel up to the pump stand. Extend site walls of existing diacharge channel up to pumpstand.

- Set the second pumpstand pipe with a hole for the DTW discharge pipe.

- Set the rest of the pumpstand pipes (diameter 3 feet) on the top until required height is reached.

Note: All jointing has to be made according to para 3.1 and 3.2.

3.4 Construction of riser valves (hydrants)

Riser valves should be constructed according to Figure 8 and 10. The alfalfa valves have to be connected to the top of the riser pipe with the help of a prefabricated socket, (see drawing). If bellmouth socket pipes are available for the riser pipes, the alfalfa valves has to be casted with mortar into the bellmouth.

The valve seat should be always **3/8** to **1/2 inch** higher than the top of jointing mortar. For making and curing of joints consult para 3.1 and 3.2.

In the Figures 8 and 10 the pipeline is jointed with prefabricated sockets, the prescribed plane end jointing method in para 3.1 is much more cheaper, if made properly the same quality.

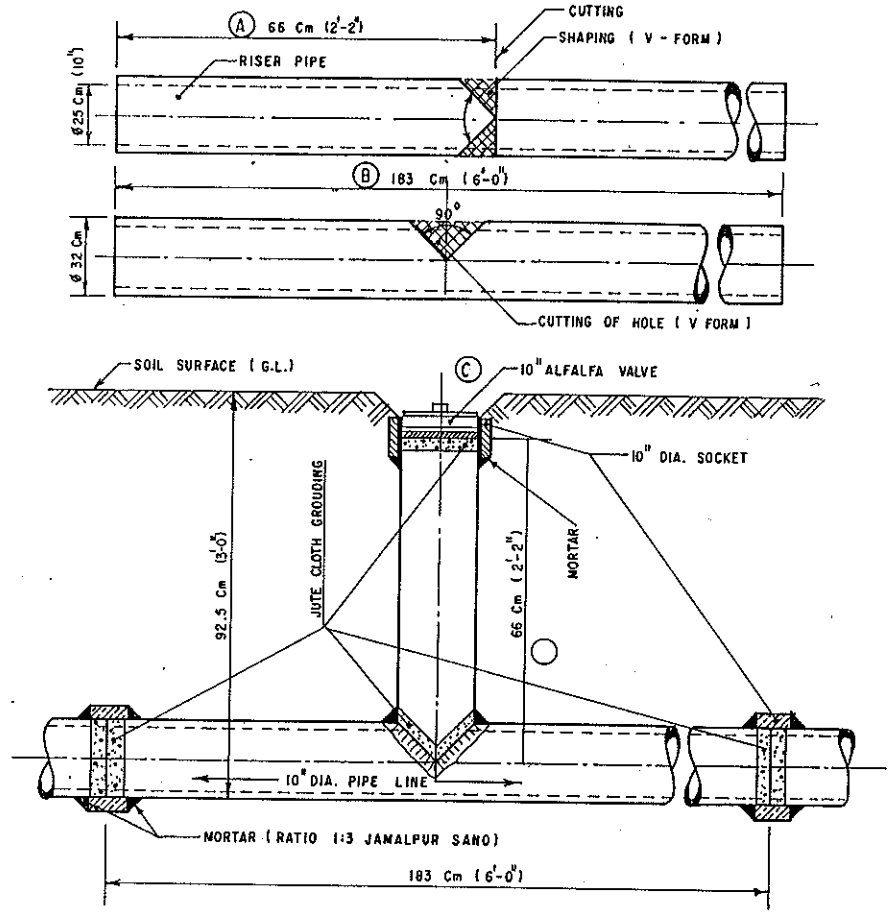
3.5 Construction of air-vents

After the design of a system the height of the air-vents are known. If the diameter of the pipeline is larger (10 or 12 inch) the air-vents can be made with smaller diameter pipes like 6 or 8 inch diameter, to save costs (see para 1.2.2).

For the design and construction of an airvent consult Figure 10.

Note: If the air-vent has to be more than 3 meter (ca. 10 feet) high, it is suggested to put a concrete base around and under the pipeline.

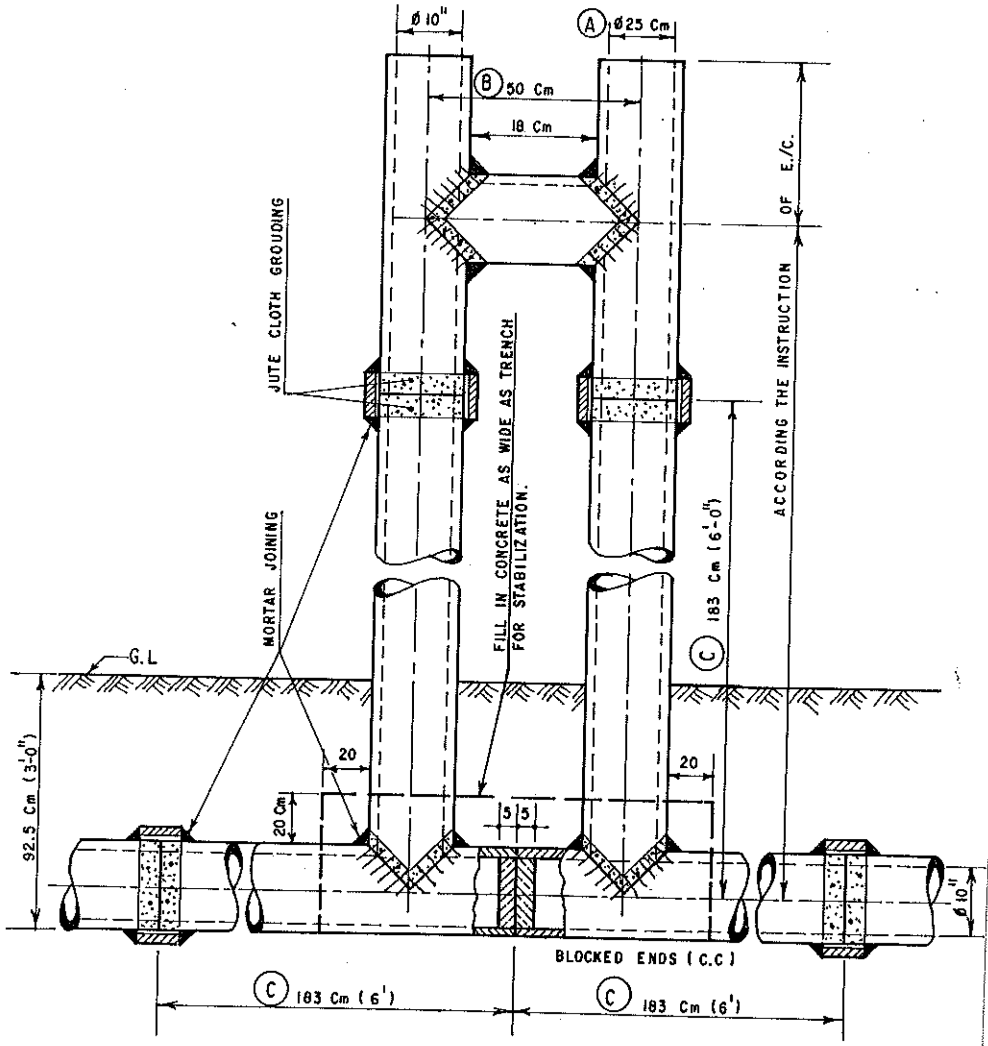
Figure 8: DESIGN OF A RISER VALVE (HYDRANT) FOR 10" BURRIED PIPE IRRIGATION WATER DISTRIBUTION SYSTEMS (SPANNED PIPE)



NOTE : 1) THE SEAT OF THE LID OF ALFALFA VALVE HAS TO BE MINIMUM 1/4" ABOVE SOCKET
2) TOP OF LID (ALFALFA VALVE) Co, 3" BELOW GROUND LEVEL (G.L.)
3) LENGTH OF PIPES RELATED TO SPANNED PIPES

SYSTEM \ MEASUREMENT	A [Cm]	B [Cm]	C [In]
8"	72 Cm	100-110	8"
9"	68 Cm	- " -	8"
12"	60 Cm	- " -	10"

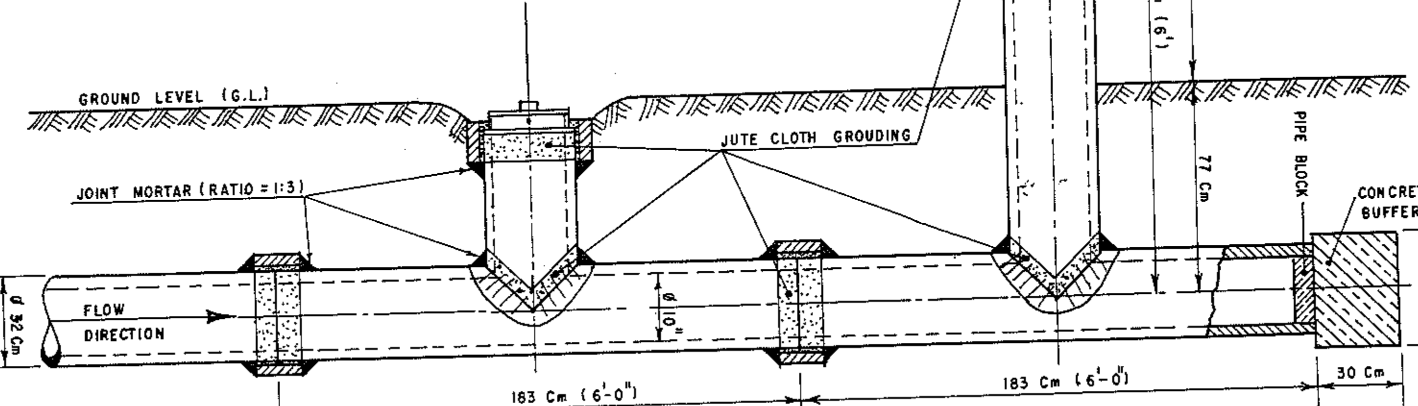
Figure 9: DESIGN OF AN OVERFLOW – TYPE PIPELINE CHECK FOR DIA. 10" BURRIED PIPE IRRIGATION WATER DISTRIBUTION SYSTEM (SPANNED PIPES)



NOTE : 1) THE HEIGHT OF OVERFLOW AND TOTAL HEIGHT OF PIPELINE CHECK, WILL BE GIVEN FROM CASE TO CASE BY ENGINEER IN CHARGE.

MEASUREMENT / SYSTEM	A [Cm]	B [Cm]	C [Cm]
8"	20	45	100 – 110
9"	22.5	48	– " –
12"	30	55	– " –

Figure 10: DESIGN OF AN AIRVENT ON THE END OF A PIPELINE WITH HYDRANT AND CONCRETE BUFFER TO PROTECT THE PIPELINE FROM MOVING DUE TO SURGE



NOTE: 1) THE CONCRETE BUFFER SHOULD BE ANCHORED 1'-0" FOOT (30 Cm) DEEP IN BOTH SITE OF THE TRENCH IN TO THE UNDISTURBED SOIL, TOTAL LENGTH = Ca. 5'-0"

3.6 Construction of overflow-type checks

Overflow-type checks have to be made from the same diameter pipes as the pipeline itself. For the height of overflow from one section of the pipeline into the next consult para 1.2.3.

Higher and havier construction may be on a concrete base under the pipeline.

For design and construction consult Figure 9.

3.7 Checking of pipelines for leaks

After the completion of a pipeline and adequate curing period of joints ca. 3 days, the pipeline has to be tested with the full flow-rate designed for. The testing should last for several hours, to make sure, that possible leaks are detectable along the pipeline. The places where leakages takes place should be marked.

Note: During the pumptest of the pipeline, always the last riser valve on the line has to be open, to obtain the highest pressure in the pipeline. The filled up, or partially filled up trench, should not be flooded by the open riser valve, otherwise the leaks cannot be detected. Make sure that except the one riser valve which is desired to be in operation during the test, all the others are closed.

3.8 Repair of leaks

Once the places, where leakage has been detected, are marked, repairing job can be done. One to two days after testing the soil in the trenches will be dry enough to dig up the spots where leaks are detected. Broken or cracked pipes has to be replaced, new jointings will be required.

Small holes, due to cavity, have to be chiseled free, wetted fillted with mortar and a jute braiding bandage with cement slurry placed around it.

Holes biger than 1½ inch can be repaired to. To prevent the mortar from felling into the pipe, a small piece of very thin metal sheet can be placed inside the pipe under the hole. The metal sheet can be holded with the help of a piece of wire from outside until the mortar is set and dry. Over the patch jute braiding bandage socked in cement slurry should be placed. Joints which are leaking should be done again.

Conclusions

Due to our two years experiences in the field (we installed 30 buried pipe irrigation systems so far) and thanks to the positive response of the farmers towards the innovative system, one can predict a growing demand in the future. The goal should be, that small enterpreneurs will be able to build such systems for farmers cooperatives on demand. The watersources of Bangladesh could be used more efficiently and economically for irrigated agriculture. An economic analysis of TADP's command area development programme has been prepared by Dr. Chowdhury Saleh Ahmed. The benefit cost ratio for buried pipe system is 4.47, which is an encouraging result for the future. It is now up to the GOB and NGO's to promote the system for further development.

List of Workshops

1. Hossain Engineering Works
   6, Nawab Habibullah Road, Near Green Hotel
   Shahbagh, Dhaka. Phone: 501217

   (Alfalfa valves)

2. Jurain Engineering
   Narayanganj Road

   (Spinning gear and forms, Alfalfa valves)

3. Kapils Workshop
   Tangail Town

   (Vertical Shutters, Alfalfa valves)

4. Precision Automobiles and Engineering Works Ltd.
   237/B Tejgaon Industrial Area, Dhaka Phone: 606983

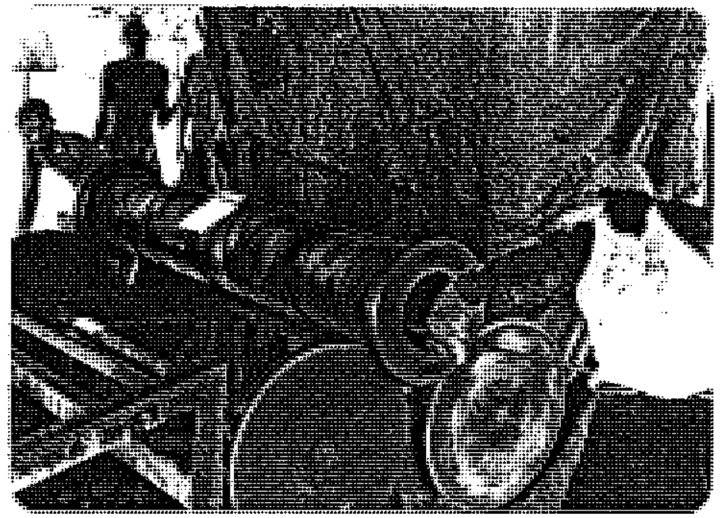
   (Spinning gear and forms, Vertical shutters)

5. Roto Burn and Company Ltd.
   Dhaka-Narayanganj Road, Alibahar
   Phone: 280717, 256560

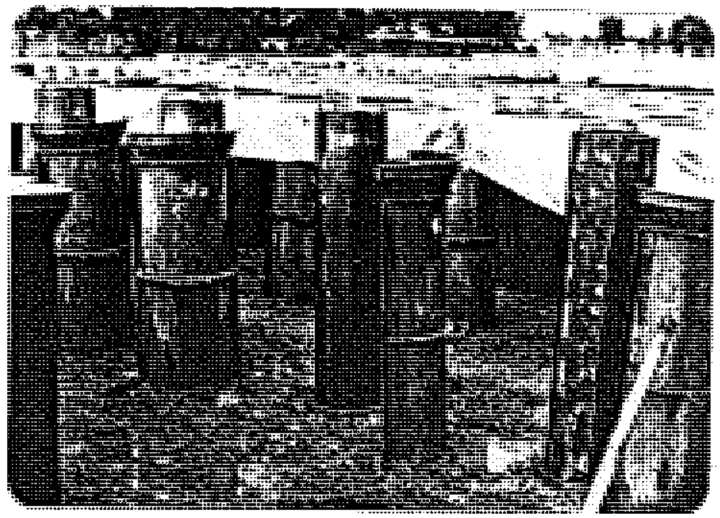
   (RCC pipes and fittings)

6. SMCO Pipe Industries Ltd.
   1/4 Mymensingh Road,
   Paribagh, Dhaka
   Phone: 505009, 508259

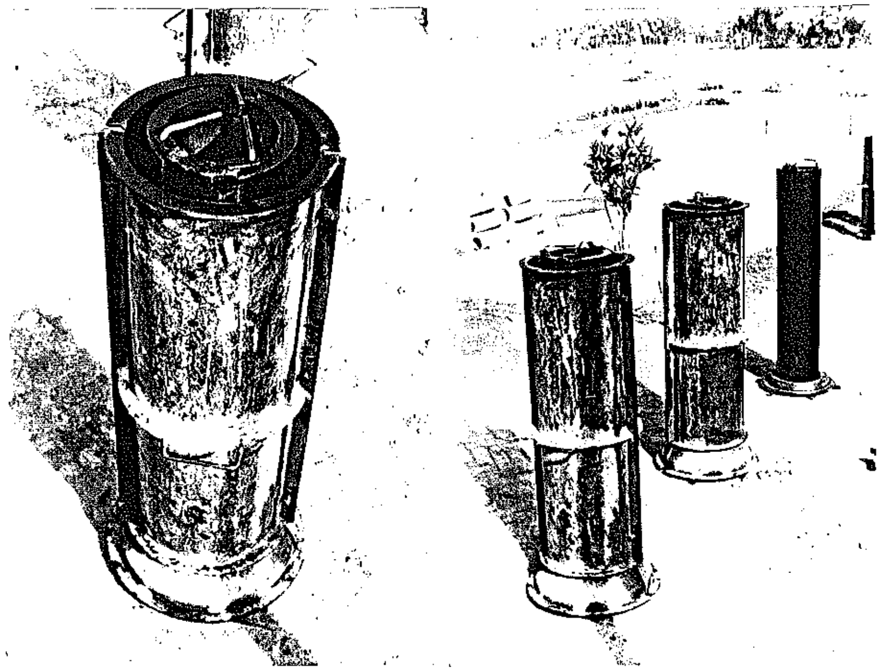
   (CC and RCC pipes on Packerhead machines)



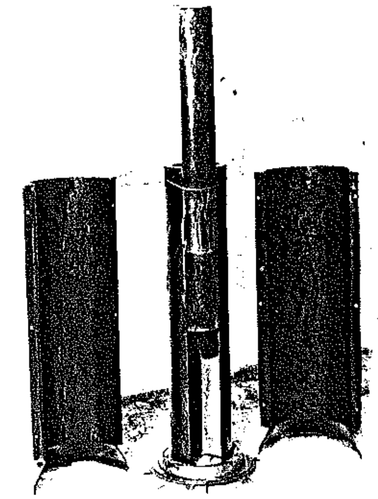
CC Pipe spinning on spinning gear



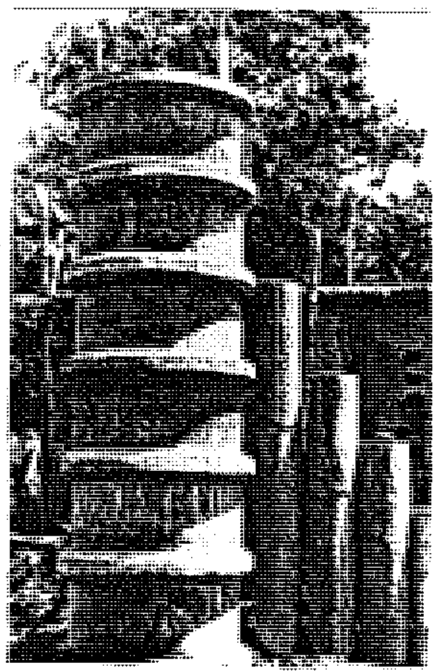
Vertical moulds with baseplate
under the inner mould



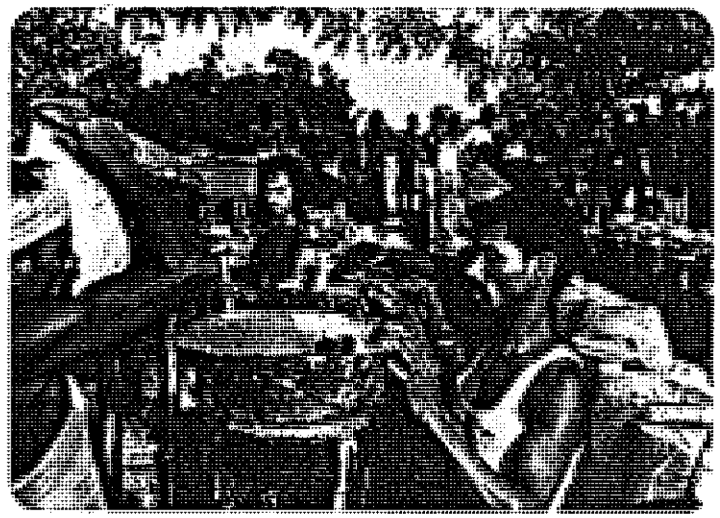
Vertical moulds for bellmouth - socket pipes



outer part, inner part, baseplate

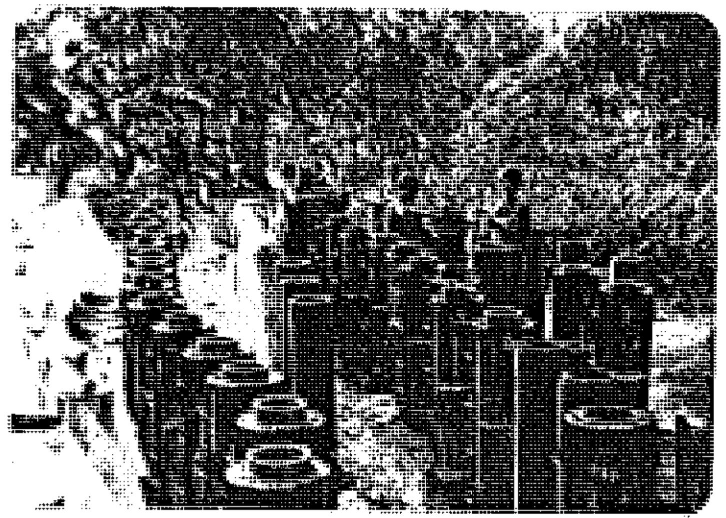


pumpstand (pressure tower)



CC Pipe casting in vertical moulds

CC Pipe casting in vertical moulds



CC Pipe casting in vertical moulds

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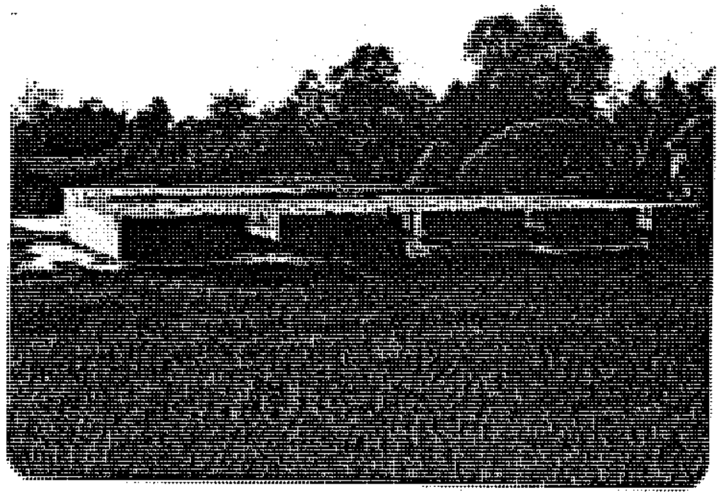
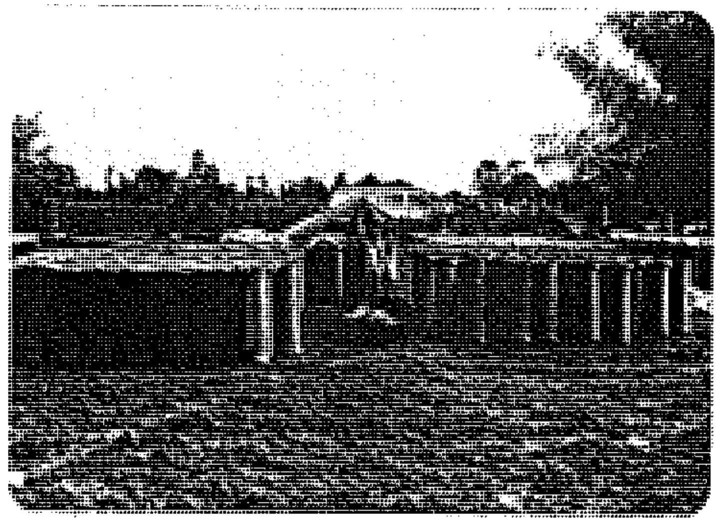
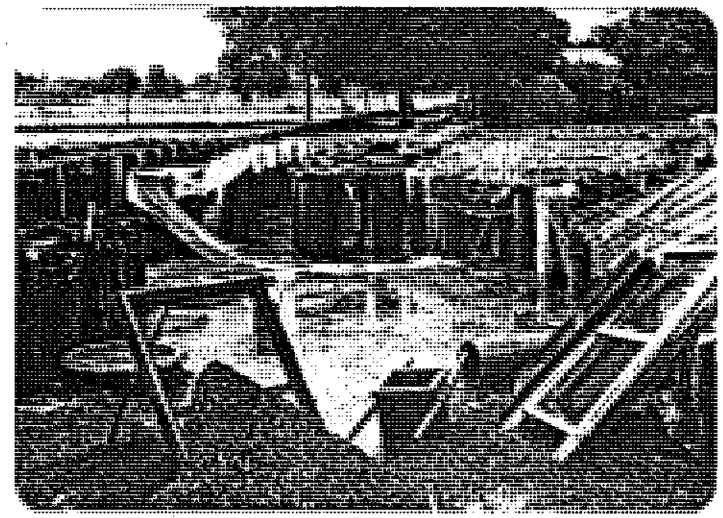


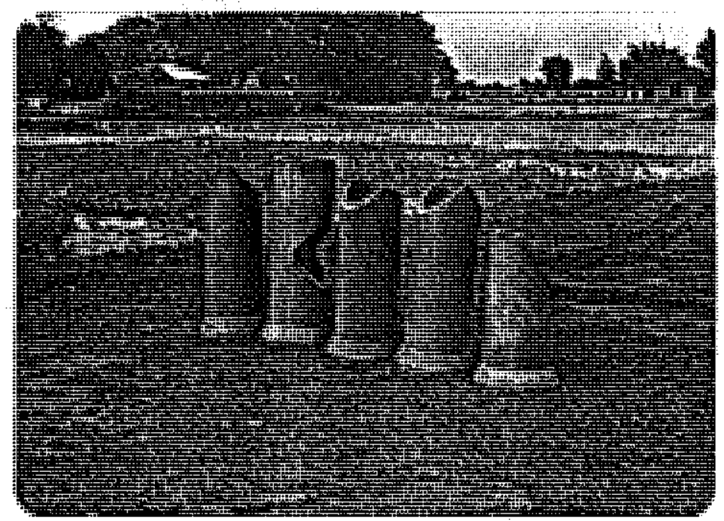
CC Pipe stock yard and curing of pipes



CC Pipe stock yard and curing of pipes

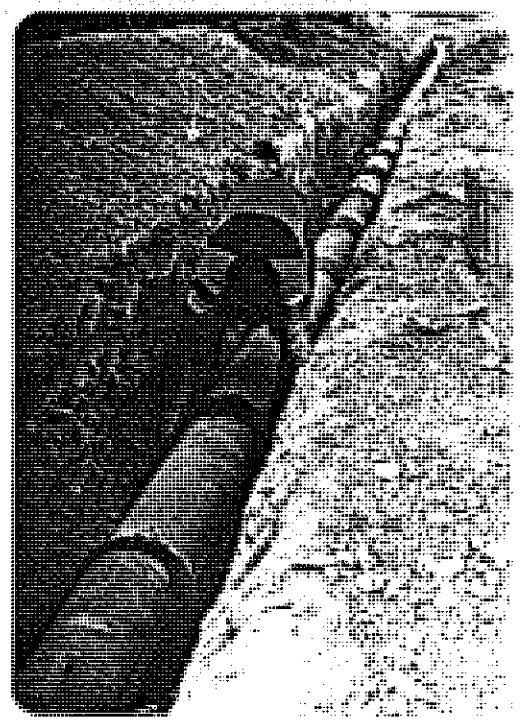


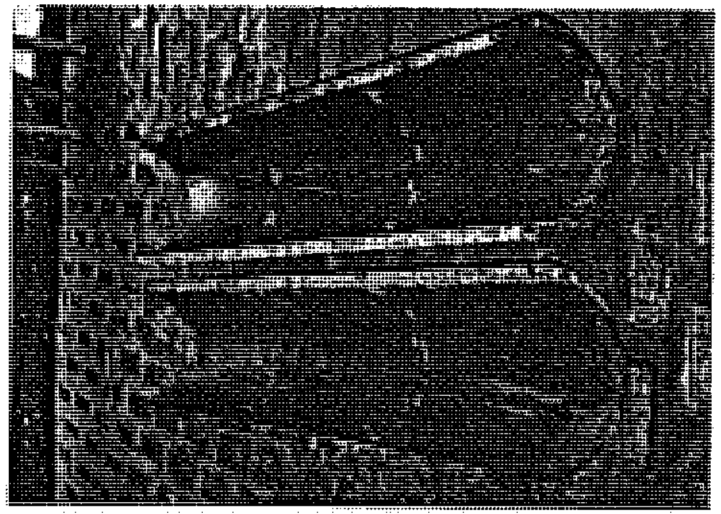
Pipe making place with sieve, measurement box, moulds, ready made pipes



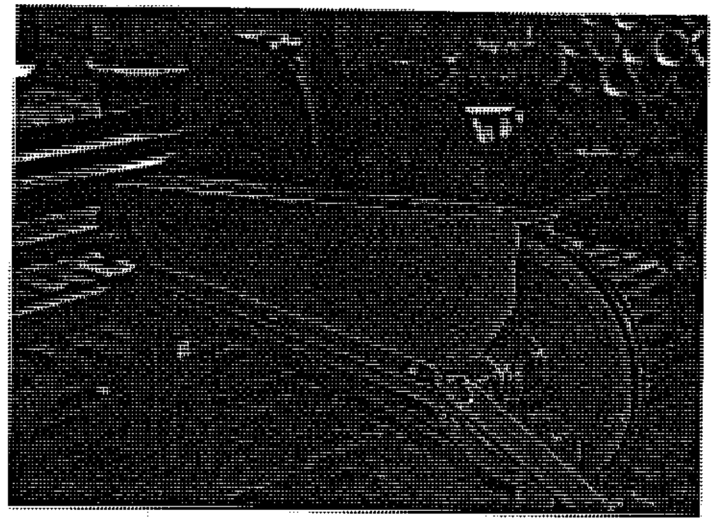
Ready cut pipes for T-s and ellbows


Device for checking of cc pipes for leakages

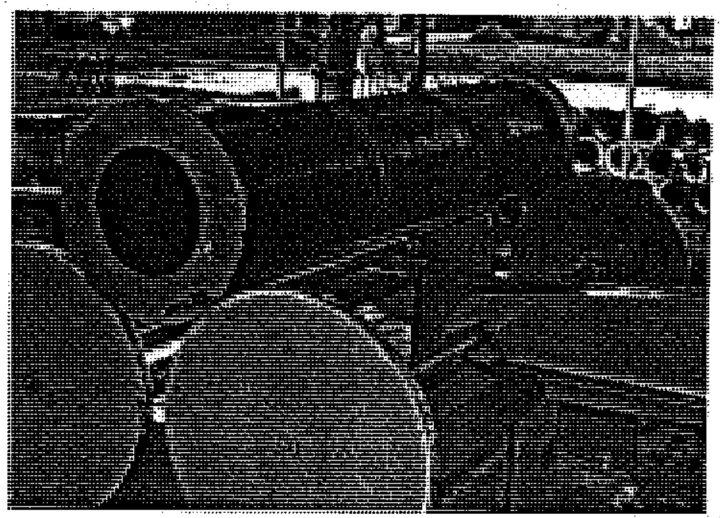

Pipeline laying, jointing



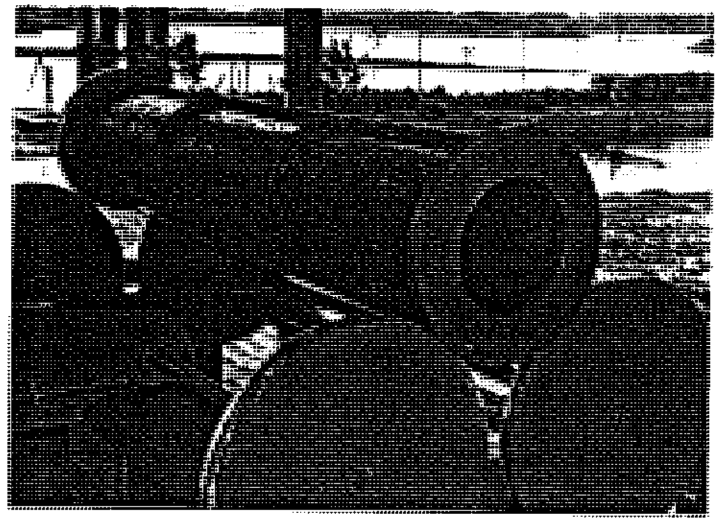
Pipe Forms, two halves have to be bolted together

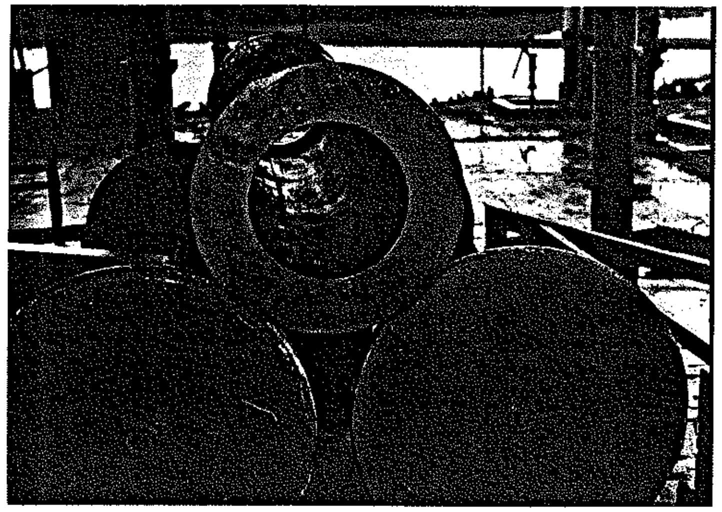


Spinning gear



Spinning gear with pipe form





Spinning gear with a pipe form on it, ready for pipe spinning