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मल जल व्यवस्था तंत्र में सहाय अंग संरचनाओं की रीति संहिता

भाग 5 ज्वारभाटा गिरावट

Indian Standard

CODE OF PRACTICE FOR ANCILLARY STRUCTURES IN SEWERAGE SYSTEM

PART 5 TIDAL OUTFALLS

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Water Supply and Sanitation in Building Sectional Committee had been approved by the Civil Engineering Division Council.

Whenever in a sewerage system ancillary structures like manholes, flushing tanks, inverted syphons, pumping stations and pumping mains, tidal outfalls, etc are provided these should be properly designed. This part of the standard on ancillary structures in sewerage system provide guidance for design and construction of tidal outfall. The other parts of the standard are:

Part 1 Manholes (*first revision*)

Part 2 Flushing tanks (*first revision*)

Part 3 Inverted syphons (*first revision*)

Part 4 Pumping stations and pumping mains (rising mains)

Indian Standard

CODE OF PRACTICE FOR ANCILLARY STRUCTURES IN SEWERAGE SYSTEM

PART 5 TIDAL OUTFALLS

1 SCOPE

1.1 This standard (Part 5) specifies requirements on philosophy, location, design, construction and equipment for installation of tidal outfalls used in sewerage system for economic disposal of waste water into the sea.

2 REFERENCES

2.1 The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 PHILOSOPHY OF INSTALLING TIDAL OUTFALL

3.1 The underlying philosophy being safe and economic disposal of waste without any significant detrimental effect on the receiving water that would impair its beneficial use.

3.2 In the engineering analysis of tidal outfall disposal of waste water, following aspects shall be considered :

a) Protection of public health,

b) Avoidance of nuisance conditions,

c) Aesthetic requirements,

d) Influence on marine flora and fauna,

e) Economic of reclamation, and

f) Overall economics of outfall disposal system.

4 DESIGN CONSIDERATIONS

4.0 Principle and Objectives

4.1 The function of a tidal outfall is to discharge waste water to the sea after pre-treatment which includes grit removal and mechanical treatment, up to a distance from the shore to ensure the dilution, dispersion and natural purification so as to reduce the concentration of harmful organisms and chemicals present in waste water to the acceptable levels in inshore water used for fisheries, recreational purposes etc.

4.2 Water Quality Criteria

4.2.1 The desired inshore water quality will depend upon the local usage of the receiving water for bathing, fishing, shell fishery and recreational activities.

4.2.2 Faecal (Enteric) bacteria are found in sewage and waste water in large numbers. They can readily be detected when dispersed in sea water and are used as indicator for detecting the presence of pathogenic organisms and chemicals even if they are found in much smaller concentrations in waste waters.

4.2.3 The length of the sea outfall should be sufficient to ensure enough dilution and dispersion characteristics such that conditions in receiving water may satisfy certain specified water quality criteria in accordance with IS 2490 (Part I) : 1981.

4.2.4 Formation of surface sticks, which are caused by greasy material in waste water should be minimized by ensuring rapid dilution.

4.2.5 Quality of receiving water should be related to recreational use. The waste water discharge should not detract from visual aesthetic quality of water.

4.3 Fisheries

Shell fishes and certain other fishes are susceptible to the effects of pollutants discharged in the sea, and may be destroyed by bacterial infection, toxic substances, or siltation of suspended in their feeding ground and also the spawning ground for fish may be affected deleteriously by such conditions. Most of the marine life existing on sea bed which settle to sea bottom. Mobile organisms tend to avoid such regions. Sudden release of certain waste may give rise to acute toxic conditions in marine environment, depletion of dissolved oxygen which in acute cases may result in the mass deaths of fishes by asphyxiation.

4.4 Pre-treatment

4.4.1 To protect the outfall system against blockages to minimize visual pollution, it is desirable to pretreat and control the discharge of waste water.

4.4.2 The following are the desirable functions to:

a) Remove grit;

b) Remove debris, namely rags and plastics from flow;

c) Disintegrate floatable material such as faecal matter, to ensure rapid dispersion in the sea;

d) Remove greasy materials; and

e) Provide further treatment, i.e., sedimentation, if so required, generally avoided.

4.4.3 During installation of pre-treatment head-works, environmental considerations should be taken care of and precaution should be taken regarding noise, odour, safety and appearance.

4.4.4 The economic balance between the degree of pre-treatment on land and the length of the outfall is one of the major design consideration. Generally a long outfall with limited pre-treatment is found to be economical and favourable.

4.5 Diffuser Systems

4.5.1 Requirements of the optimum discharge location for dispersion is necessary to select a suitable diffuser array of single or multiple ports along final length of outfall. Careful hydraulic analysis of flow diversion to the ports in the diffuser manifold and the overall head loss within the complete outfall system should be checked to ensure that beaches used for bathing, boating, sports are not polluted by smell, solids and slicks. It is necessary to achieve some initial dilution before final discharge. Initial dilution for given water depths, sea water density, waste water density, discharge pipes diameter and ambient current velocity can be found out readily by *in-situ* tracer tests.

4.5.2 While designing elements of outfall disposal system that is dispersion and dieoff, initial dilution, diffuser system and outfall pipe care should be taken to determine the effects of seawater entering the outfall system at low flows.

4.6 Nature of Discharge

4.6.1 Components of domestic waste water are prone to quick degradation in sea water. The combination of degradation and dilution renders waste harmless in the salt water environment. In the natural process of growth and decay, sufficient quantity of oxygen is usually available in waste water. Ultra violet light from sun acts as disinfecting agent in killing bacteria, while currents and turbulence enhance dilution and sedimentation takes place over a wide area. Where decomposed material once again enters the lower level food chain.

4.6.2 Substances resistant to degradation (that is non-degradable) in the sea environment shall be checked if discharged continuously or in large quantities. This situation may arise at places where waste water consists of combined effluents of domestic and industrial discharges. Among all pollutants the most noxious and non-degradable which have the tendency to bio-concentrate (that is bio-magnificate) in marine environment are halogenated organic compounds, mercury, lead, arsenic, cadmium, hydrocarbons, oils and systhetic substances. For their tolerance limits *see* IS 2490 (Part 1) : 1981.

4.7 The outfall structures discharging waste water should be at a sufficient distance from intakes supplying process or cooling water for industrial use, or from the vicinity of fish farming installations to prevent contamination.

4.8 In the design of outfall structures as far as possible the advantage of self-purification that is natural degradation shall be availed. The parameters concerned are biochemical oxygen demand and suspended solids, the nutrient elements like, nitrogen and phosphorous.

4.9 The magnitude of waste water flow depends on the type of existing sewerage system whether combined or separate (that is, foul sewage and surface water). Designed flow can be found out as per IS 2951 (Parts 1 and 2) : 1965. While designing and deciding about the size of outfall structure, nature of discharge, existing flows along with provision for increases as a result of variation in population and seasonal variations, shall be by gravity if sufficient head is available otherwise pumping can be adopted. If pumps are used, generator shall be installed to prevent flooding in the event of power supply failure (*see* also IS 5600 : 1970).

5 INVESTIGATIONS AND RECORDS

5.1 Uptodate hydrographic charts and records shall be collected to get information about water depths, nature of sea bed, obstructions, velocities at desired positions. This data is normally utilized for preliminary analysis.

5.2 Geological maps and records shall be made available from concerned departments (that is, Geological Survey of India), giving details of boreholes, drillings, nature of sea bed, nature of bed expected to carry outfall structure and presence of slips, faults etc.

5.3 Oceanographic records giving details about past behaviour of waves over a specified period shall be obtained from the department of oceanography.

5.4 Tidal information and current records give broad picture of tidal current activity and continuous records of at least one year shall be made available and studied to find tidal variations.

5.5 Other Possible Effects on Currents

5.5.1 *Littoral Drift*

The direction and trend of the littoral drift may in course of time affect the currents near the shore, and past records over as long a period as possible should be investigated. Extensive littoral drift may alter conditions in the immediate vicinity of the outfall construction and in extreme cases it may undermine pipe structure also. As far as possible aerial photograph giving littoral drift and coastal morphology shall be made available.

5.5.2 *Fresh Water Discharge from Heavy Rains Inland*

Serious interference with normal tidal currents may be caused by the discharge into an estuary of large quantities of fresh water due to abnormal heavy rains inland. These discharges may also carry a heavy load of agriculturally derived nutrient which can create eutrophic effects in estuary with poor flushing characteristics.

5.5.3 *Groynes, Training Walls or Other Works in the Vicinity*

Particular attention should be paid to the position of existing or contemplated groynes or other works which may either cause the scour of the current to undermine the outfall pipe or may cause the beach to fill up and smoothen the outlet. If the sewer outfall is above beach level, it may itself act as a groyne and affect the stability of the beach.

5.6 Meteorological Records

5.6.1 The direction and force of wind have a direct influence on local conditions. Sometimes the combination of wind and tide may result in abnormally high or low tidal levels in the area. All historical and continuous records should be obtained from meteorological department.

5.7 Local Information

5.7.1 Local knowledge and experience of boatmen, fishermen and others with regard to exceptional tides, tidal bores, wind effect and any other peculiarities of the locality should always be taken into consideration.

6 DETAILED STUDIES

6.1 Tidal Information

6.1.1 *Tide Table*

An essential preliminary to the design of a tidal sewer outfall in a tide-table for the locality when the tide tables for the locality of the proposed outfall are not available, it is not always safe to interpolate figures between the two nearest available tide-tables, as tide levels and time may vary considerably in short distances.

6.1.2 *Tidal Records*

In the absence of a tide-table, records of time and height of tides covering at least one year should be obtained. If the proposed site is an estuary, the appropriate river authority might have full tidal records which could be made available; otherwise fresh tidal observations should be made. For this purpose a recording tidegauge should be installed as near as practicable to the site of the proposed outfall, in a position where it is sheltered from abnormal weather conditions and where there is enough water to prevent the float grounding on the floor of the chamber. Continuous records should be calculated from the following observations:

a) Mean low water (springs),

b) Mean high water (springs),

c) Mean low water (neaps),

d) Mean high water (neaps), and

e) Mean tidal level.

In addition, the highest and lowest recorded tide levels in the district should be ascertained.

6.2 Tidal Currents

6.2.1 The fullest possible information regarding the tidal currents is necessary before deciding on the location of a sewer outfall into tidal waters. Some information and guidance may be obtained from the local river authority and local laymen. However, precise survey data may usually be required.

6.2.2 *Observation of Tidal Currents*

6.2.2.1 *Observation by floats*

The wastewater from outfall usually rises to the sea surface before being carried away by the tidal current for lateral and deep dispersion. Wind direction and strength may affect the current, particularly at or near the water surface. So it is essential to supplement the information obtained as above by a series of careful float observations at the proposed point of discharge, and the results of the observations properly interpreted.

6.2.2.2 *Period of observation*

Although some idea of behaviour of tidal currents can be obtained by float observation taken over one complete lunar cycle of tides but observations should be taken over as long a period a possible including times when the most undesirable conditions, particularly on-shore winds, exist. The observations to be of real value, should be taken over for at least one year.

6.2.2.3 *Intervals of release of floats*

Floats shall be released from the site of outlet of the proposed outfall at regular intervals of time covering a complete cycle of tide, preferably commencing at high water. The release of floats at one hour intervals can give quite reliable information on the trend of the currents, but the interval may have to be reduced if the first observations taken, show such action to be necessary.

6.2.2.4 Movement can be monitored by small marker devices designed to float virtually submerged but still be visible from a boat. Suitable drift-card can be made from coloured plastics material to float on edge and just submerged. These drifters are released in quite large numbers.

6.2.2.5 Pole or stick floats are intended to integrate the water movement over a depth corresponding to their length. These floats are just submerged and fitted with a light weight identification flag. Measurements at greater depths can be made by drouge device, which may carry a radar reflector supported by line beneath a buoyant marker unit.

6.2.2.6 All types of floating devices are affected by wind. So it is preferred to calibrate their performnace with respect to a soluble water-tracer namely Dye.

6.2.2.7 Observations of float positions can be made by any one of the following:

a) Sextant method,

b) Two theodolites method, and

c) Electric methods.

It is always better to consult surveyor before carrying out above observations.

6.2.2.8 Time interval of readings should be about 15 minutes if feasible. After all float observations have been taken, they should be grouped together and plotted taking account of wind draft, soundings, survey map, and land marks. The information gained from current studies will give idea about the preliminary outfall discharge point to be selected.

6.2.3 *Observations by Jelly Bottles*

The use of jelly bottles for observations of tidal currents involves dropping a bottle containing hot liquified jelly into the sea. The direction and speed of the current are found by noting the angle at which the jelly solidifies.

6.2.4 *Observation by Other Methods*

Other methods, such as current meters, drop cards, dyes are now being used. Radio active tracers may be used for current observation under expert supervision. In case of current meters, recording instruments are available for continuously measuring current speed and direction at a point in the sea. Data can be recorded on magnetic tape in a form which can be transferred to computer.

6.3 Dilution and Dispersion

6.3.1 *General*

There is a wide range of field studies which can contribute information relevant to outfall design. Some are demanding in time and resources and even if completed successfully, may not necessarily provide values of the diffusion parameters which are significantly different from those selected from literature, in relation to the short-term behaviour of sewage in the sea. Careful thought should be given therefore, to the relevance of the measurements which are being proposed and the ultimate aims of the investigation. There are two main situations to consider first, where discharge is proposed into an area, as there is no existing sewage discharge and secondly, where an existing outfall can be used as a source of sewage to study aspects of local dispersion performance. In some cases, it is necessary to differentiate between the effects of two or more sources of sewage by the use of added tracer substances.

6.3.2 *Dye Dispersion Studies*

Reference has been made to the use of dyes to calibrate the performance of floats and drougues (**6.2.2.6**). Measurements may be extended to determine rates of horizontal and vertical mixing (diffusion coefficients). Dye concentration is measured in a fluorometer, the dye being made to fluorescence in ultra-violet light. Ideally, dye should be continuously injected, after preliminary dilution, at the proposed outfall location over full tidal cycles. Continuous measurements of dye concentration at several depths are required along straight traverse lines through the dye plume between known starting and finishing points. Each set of transverses through the plume is then corrected for drift to some mean time (usually that associated with the point of maximum concentration) and a synoptic plot obtained of dye concentration. The diffusion rate can then be estimated from the area enclosed by contours of particular concentration levels at various positions. Care in handling concentrated dye solutions is essential to prevent false readings due to contamination. The behaviour of the particular dye used should be checked with respect to photochemical decay and absorption on particular matter.

6.3.3 *Other Tracer Materials*

Fluorescent dyes are the most suitable tracers for general purpose use, but other substances may be used in special cases. Radioactive tracers are particularly suitable for surveys where concentration is measured *in situ*, although specialized detection equipment is required, involving the employment of qualified radiochemists to handle the tracer in concentrated form. Bacterial tracers are available, which can be detected after dilution by serveral orders of magnitude more easily than can dyes or radioactivity. However, as this method entails discrete samples being taken for analysis, the technique is more applicable to studies of the long-term fate of sewage in the sea.

6.3.4 *Bacteriological Studies*

Where waste water is already being discharged to the sea in the neighbourhood of the proposed new outfall, it is useful to examine spatial and temporal distributions of indigenous sewage bacteria in the nearshore water. Samples collected at regular intervals from fixed stations can be analysed for coliform bacteria or faecal coliform and the results examined statistically to find correlations between bacterial counts and environmental parameters such as tidal state, wind velocity, sea state and solar radiation. The results may also indicate the presence of other sources of sewage bacteria such as storm overflows or polluted river discharges.

6.3.5 *Bacterial Mortality*

A parameter of considerable importance to the prediction of the fate of sewage in the sea is the rate of mortality. Although many factors are probably involved in reducing bacterial counts in sea water, there is considerable evidence to show that sunlight is the most important controlling influence. The effectiveness of a particular level of solar radiation depends on the depth to which the light can penetrate the water column. In clear sea water, this may be several metres, but if the water is highly turbid, as is often the case in estuaries or at sea during storms, the depth of penetration may be only a few centimetres. Salinity and temperature are also parameters of relevance to the inactivation of bacteria as they survive considerably longer in fresh water than in salt water under otherwise similar conditions. Measurements of turbidity, salinity and temperature should be included therefore in water quality surveys.

The rate of bacterial mortality in sea water is described by the T period, which is the time required for 90 percent of bacteria to die off T periods should be locally determined but can vary at the same site between less than 1 hour to over 48 hours.

6.3.6 *Model Studies*

The complexity of combining the dispersion and decay processes affecting patches of diluted sewage of various ages requires the use of computer models. A good degree of realism may be obtained by using a hydrodynamic model to estimate the pattern of tidal currents over a whole area; they should be calibrated and validated from field measurements. These results can then be used in dispersion models, calibrated from dilution, dispersion and decay studies, to study several options under a variety of conditions.

6.4 Biological Studies

Possible effects of domestic sewage on marine flora and fauna can be examined in two ways: by *in situ* monitoring and comparison of conditions in polluted and similar control areas, or by toxicity tests in the laboratory using samples of domestic sewage diluted with sea water.

The procedures adopted by the relevant authority for the control of trade effluents within the drainage area of a tidal outfall should have regard to the effect of such discharges on the marine environment. Where the discharge of trade effluents to the outfall is permitted, tests of acute or chronic toxicity to selected marine organisms may be desirable.

Where *in situ* monitoring is to be carried out, controlled observations should be made:

a) at the site of the outfall before its construction, to provide a basis for direct comparison with studies made after the outfall is brought into use; and

b) at a control site in the vicinity which exhibits similar characteristics to the outfall site but should be unaffected by the new discharge. This control site would enable variations in marine flora and fauna unrelated to the new discharge to be observed.

The physical nature of the sea bed will indicate whether particular material is likely to settle or be resuspended. Quantitative estimates should be made of the abundance and diversity of species present and seasonal variations determined.

Where outfalls discharge to estuaries or other semi-enclosed bodies of water, it may be necessary to estimate the effects of additional nutrients on the growth of plants and the consequent effects on concentrations of dissolved oxygen.

6.5 Geophysical Investigations

6.5.1 *General*

Information should be obtained on the configuration and surface structure of the sea bed along the line of the proposed outfall. Subsequently, cores can be drilled from the sea floor to provide information on the geological nature of the sub-strata.

6.5.2 *Sea Bed Profiling*

Detailed information on the distribution of water depth, or bathmetry, may be obtained by echo-sounding surveys along known transit lines, the spacing between successive lines being dependent on the details required. Topographical features of the sea bed can be mapped using side-scan sonar equipment which also reduces the number of transit lines required to survey a given area. Seismic reflection profiling would determine the vertical extent and type of material beneath the sea bed. Low-frequency pulses of acoustic energy are used to penetrate up to 60 m below the sea bottom.

6.5.3 *Off-shore Site Investigations*

When a feasible line for the outfall has been established, the composition of the bed material should be examined in more detail.

Within the surface zone and in shallow water further offshore, this can be done by divers using hand probes or jetting equipment to test the resistance to penetration. Samples of bed material can also be obtained by divers. In deeper water, it may be necessary to use grabs or corers operated from survey vessels. Corers operating by gravity or under pneumatic pressure can provide samples which can be examined for particle size and shear strength. However, corers may only be of limited value and full borehole investigations should be undertaken, where tunnel construction is under consideration. Geological information is essential to the selection of construction method, whether the outfall is to be supported on piles, buried in a trench, or constructed in a tunnel. Both cost and feasibility of a particular method of construction are dependent on the nature of sub-strata.

7 LOCATION

7.1 All hydrographic and geophysical information obtained should be considered in reaching a decision about the location of the new outfall. Some of the original options will probably have been rejected during the course of the initial studies; it is likely that the final choice will be concerned with outfall length and method of construction. Ideally, predicted performance should be compared with criteria required for adjacent recreational areas. Wherever possible, the outfall pipe should be burried beneath the fore-shore to protect its exterior coating from wave damage.

The amenity value of local recreational beaches should be taken into account in deciding the position and length of a sea outfall and the site of any associated headworks. The location and design of any storm overflows, and levels at which they are set to operate, should not be overlooked. It is important to ensure that visible solids, identifiable as of sewage origin, are not discharged. The time taken for water to travel from the seaward end of the outfall to the shore in unfavourable wind conditions should be determined. The degree of dilution which is likely to be achieved in the minimum transit time should be estimated.

7.2 Initial Dilution

Dilution performance and distribution of outlet ports should be calculated for all tidal conditions and compared with a demand curve relating dilution to the distance of offshore; there is no justification for requiring high initial-dilution performance at points remote from recreational areas.

7.3 Tidal Conditions

Data on tidal currents should be examined to ensure that minimum dilution criteria will be satisfied at all states of tide. In some cases, where slack-water conditions persist for a significant part of the tidal cycle, it may be necessary to consider storing sewage during this critical period. Similarly, storage sewage during this critical period may be required during the lower half of the tidal cycle at sites where the tidal range is large and the water line recedes several kilometres across the foreshore at low water. If possible, however, storage should be avoided, to discourage the establishment of anaerobic conditions.

Residual movements of water in the longshore direction should be deduced and related to the time that sewage will remain in a particular area. The effects between layers of water at different depths should be determined.

7.4 Levels and Slope of Foreshore

Full information should be obtained as to the slope of the foreshore and its relation to the level of the shore and of the outfall sewer. The portion of the outfall on the foreshore should have as great a fall as possible and where practicable, should extend beyond low water marks of spring tides. Dilution and dispersal are considerably affected by the depth of water at the point of discharge. This, therefore, should be so chosen to give the greatest practicable depth of disharge.

7.5 Secondary Dilution

Appropriate rates of horizontal and vertical diffusion should be determined and applied to the estimation of secondary dilution during successive tidal cycles after discharge.

7.6 Effects of Wind

Winds from certain quarters are likely to give rise to worst-case conditions at shore. Estimates should be made of water quality in such cases and these compared with the average conditions predicted. Although wind-induced movement of water is likely to reduce the transit of polluted water between the outfall and the shore, it will increase the rate of vertical mixing, thus enhancing dilution.

7.7 Geological Information

Very careful investigation should be made over the whole length of the proposed outfall, and outfall of the ground underlying the pipe. If serious erosion or accretion of the foreshore is taking place in the neighbourhood, all available records should be consulted as to the yearly rate and if this shows any effect on tidal currents should be considered. If the bottom is very soft or subject to slips, the site should be avoided, if possible. The underlying geological strata should also be investigated. Advice on this may be obtained from the 'Geological Department'.

7.8 Environmental Effects

An assessment should be made of the long term ecological effects of discharging sewage at a particular location. Particular attention should be given to local fisheries. Controls should be applied to the discharge of toxic substances (*see* **4.6.2**).

8 PRE-TREATMENT

8.1 Except in the case of discharge well out to sea or into a strong offshore current, coarse visible solids should be removed so as to eliminiate any asthetic objection to the outfall. This can be achieved by the use of coarse screen, a grit settlement facility, comminutors, disintegrating pumps or screens. The screenings should be either completely removed incenerated and returned to sewage. Where discharge takes place into a tidal estuary, or into the sea close to the shore, and depending on the dilution and tidal currents, it may be necessary to remove suspeneded solids before discharge. This is carried out in sedimentation tanks similar to those used for the primary treatment of sewage at inland treatment works.

8.2 Purpose of Setting up Pre-treatment Unit

8.2.1 The prime purpose of setting up pre-treatment unit is to remove the amount of suspended-solids or particles discharged to sea up to a size to ensure easy dispersion and bio-degradation by natural process.

8.2.2 Following are the objectives of pre-treatment unit:

a) to safe gurard the fine screening operation at penstock ;
b) to achieve minimum maintenace ;
c) to ensure a long operational life of outfall system ; and
d) It shall not cause offence to local residents.

8.3 Disposal of screenings should be done by burial, tipping on land or incineration in closed chambers after dewatering.

8.4 The sludge from primary settling tank shall be treated locally by anaerobic digestion. If volume and nature of sludge permits, then it can be dumped into the sea without treatment, considering marine flora and fauna.

9 DESIGN OF OUTFALL FACILITY

9.1 Storage Tanks and Outfall Sewers

9.1.1 The capacity of storage tanks and outfall sewers will depend upon two factors:

a) the period of time when crude discharge from outfall is not permissible; and
b) the amount of waste-water to be stored before the tanks are allowed to overflow.

9.1.2 Discharge from storage tank and outfall sewer shall be controlled by valves or penstocks operated manually, electrically, hydraulically, or by compressed air. The openings and closing of valves and penstocks may be controlled automatically by timing device or by float operated contacts actuated by water level. Timing devices can be designed to correspond to approximately to the tidal cycle. An alternative means of operation should always be provided for use in an emergency. The choice of method of operation depends on the head of waste water to be controlled, the size and weight of the valve gate, the availability of particular power source and man-power at site.

9.1.3 Following provisions should be made in design of storage tanks and outfall sewers:

a) adequate means of dealing with sludge which settles out during any period of detention;
b) the isolation of tanks for cleaning and repair purposes and the consequent provision of spare capacity;
c) the discharge of storm sewage if in excess of the design capacity without causing surcharge conditions in the incoming sewers;
d) adequate access for inspection and renewal of mechanical part;
e) adequate ventilation requires particular attention where the ventilation provided to prevent the accumulation of flammable and toxic gases such as methane, carbon monoxide; and
f) adequate marking of external features where the amenities of the foreshore could be affected. Care should be taken to control offensive odours and to preserve amenity of area.

9.1.4 *Number and Type of Valves*

The outlets from storage tanks or sewers should be controlled by either values or penstocks and, except in the smallest schemes, more than one penstock should be provided, with adequate provision for isolation to enable repairs and maintenance to be carried out.

9.1.5 *Location*

The invert of the valve or penstock should be below the level of the bottom of the tank.

9.2 Penstock Chambers

9.2.1 *Size and Location*

The objects of a penstock chamber are to provide room not only for operation but also for the easy cleaning and repair of the penstock and its operating mechanism. Access to the chamber should, therefore, be sufficient to allow for the removal of the largest components of the penstock in the event of replacement being required. Grooves for stop planks are sometimes provided on the upstream side of the penstock so that the sewage flow can be held up temporarily to enable small repairs to be carried out on the penstock. In order to prevent exceptionally high tides overflowing and possibly damaging the land around the chamber, a screw-down cover in a properly secured frame may be necessary [*see* IS 11625 :1986 and IS 11639 (Part 1) : 1986].

9.3 Hydraulic Design Aspects

9.3.1 The hydraulic design of an outfall makes a vital link between the many preliminary investigation and the final engineering solutions.

9.3.2 The physical and hydraulic characteristics of an outfall may be used to calculate the performance of the outfall's diffuser, in terms of flow distribution and head loss, and overall head loss of the outfall, at all design discharges. It can be done with the aid of computer programme also. In this process internal velocities to prevent internal sedimentation and jet velocities to prevent sea water intrusion shall be predicted. Since it is a cyclic design process some design optimization is required to be achieved.

9.3.3 Calculations should be done to check the need of valves or other devices to be located on the diffuser ports to prevent saline intrusion. The diffuser ports situated above sea bed should be so designed as to prevent them from being caught up by fishing nets or hooked by ships anchors.

9.4 Outfall Pipe

9.4.1 *Sizes*

The outfall pipe requires to be large enough to discharge, within the permissible period, the whole contents of any storage tanks plus the maximum inflow for that period. It should be noted that the rate of discharge will depend on :

a) the hydraulic gradient between the level in the storage tanks and the level of the tide;
b) the gradient of the pipe where it is free flowing;
c) the diameter of the pipe; and
d) velocity of flow in pipe.

The size of the pipe should be calculated on that basis.

9.4.2 *Dispersal of Discharge*

Where large volumes of waste water are to be dealt with, consideration should be given to the dispersal of flow by jets or multiple outlets providing as wide an angle of discharge as possible. The design of sewerage scheme may be simplified and costs may be reduced by discharging the waste water to two or more different points of outfall. This may avoid the necessity of deep excavation, and possibility of pumping.

9.4.3 *Point of Discharge*

The length of the outfall pipe will vary with the particular site conditions. The seaward end of an outfall, wherever practicable, should be carried down below low water level. If, on a very flat beach, a considerable length of the pipe has to be below the beach level it may mean that the wastewater will have to be pumped through the outfall pipe. Different considerations will apply in the case of surface-water outfall or storm sewage overflow pipes. The former may be discharged high up the beach, but the latter should be extended to low water level, if at all practicable (*see* IS 5600 :1970 for sewage pumping).

10 CONSTRUCTION

10.1 Types of Outfall and Methods of Installation

There has been considerable development in sea bed pipeline construction techniques in recent years. It is desirable that the expertise of both construction contractor and designer should participate throughout the design process, if the most economic solution is to be adopted. Such a combination of skills may be difficult to achieve since a sea outfall project will require an extensive survey and investigation stage before any detailed proposals can be put forward and costed. When tenders are invited for the construction of the outfall, the results of the various marine investigations should be made available to tenderers, who should be encouraged to put forward alternative offers, based on proven or adequately researched construction techniques.

10.1.1 *Piped Outfalls Constructed Without Excavation* [*see* Fig.1(a)].

This is an outfall where the pipe and diffuser section is laid entirely on or above the sea bed. It may be constructed in a variety of materials and is placed by the bottom tow, float and sink, or *in situ* construction methods. The diffuser section is generally a continuation of the outfall pipe, with a stepped area reduction, along which circular discharge ports are cut into the pipe. In designing this type of outfall, most careful considration should be given to its protection against drag from ships' anchors and trawled fishing gear.

10.1.2 *Piped Outfalls in Trench* [*see* Fig.1(b)]

This is a common type of outfall where the pipe is shallowly buried, and in which the diffuser section consists of a number of short riser pipes linked to discharge ports just above the sea bed. Construction techniques are similar to the sea bed type described in **10.1.1**, except that the pipe is laid into a pre-dredged or excavated trench which is subsequently backfilled with bed materials, rock or concrete. If backfilled with granular material, the stability of the pipe (particularly if emptied for inspection) in the backfill material should be evaluated, especially in a surf zone. Clearly, these outfalls are well protected, and hydraulically may be considered similar to tunnelled outfalls with very short riser pipes.

10.1.3 *Tunnelled Outfalls*

There are two types of tunnelled outfalls as follows:

a) Tunnelled outfalls with the diffuser risers connected to the tunnel soffit [*see* Fig.1(c)], and

b) Tunnelled outfalls with the diffuser risers connected to the tunnel invert [*see* Fig.1(d)].

Under normal discharge conditions, when the entire outfall system is full of fresh water, the hydraulic behaviour of both types is the same. However, their behaviour under sea water intrusion conditions is significantly different with less risk using type (b) above.

There are a number of sub-classifications in which a tunnelled outfall may terminate in a sea bed pipe diffuser section, or the diffuser section of any type may take the form of two or more separate arms. The need for a multi-port diffuser should not be assumed, as there are circumstances where its added design and operational complications are unnecessary.

10.2 Materials

10.2.1 The material selected for a particular outfall pipe will depend on the diameter and length for construction and installation methods.

10.2.2 For the method of installations described in **11.2** to **11.7**, use long length of pipe and suitable materials including steel, concrete, G.R.P. (Glass Reinforced Plastic) pipes, P.V.C., composite material and polyethylene pipes.

10.2.3 *Steel Pipes*

Steel pipes corrode rapidly in sea water and needs to be protected externally as well as internally by suitable coatings. These coatings may be composed of coal-tar, enamel and G.R.P. layer. Cathodic protection may be provided (*see* IS 8062 :1976) by the use of sacrificial anodes or the impressed current anode system (*see also* IS 6631 :1972, IS 3589:1981 and IS 4310 :1967).

Exterior coating of concrete is provided to add extra weight and is applied over a steel wire mesh to ensure resistance against mechanical damage and corrosion.

10.2.4 *Concrete Pipes*

These should conform to IS 458 : 1988. Concrete is resistant to attack by sea water but can be damaged by

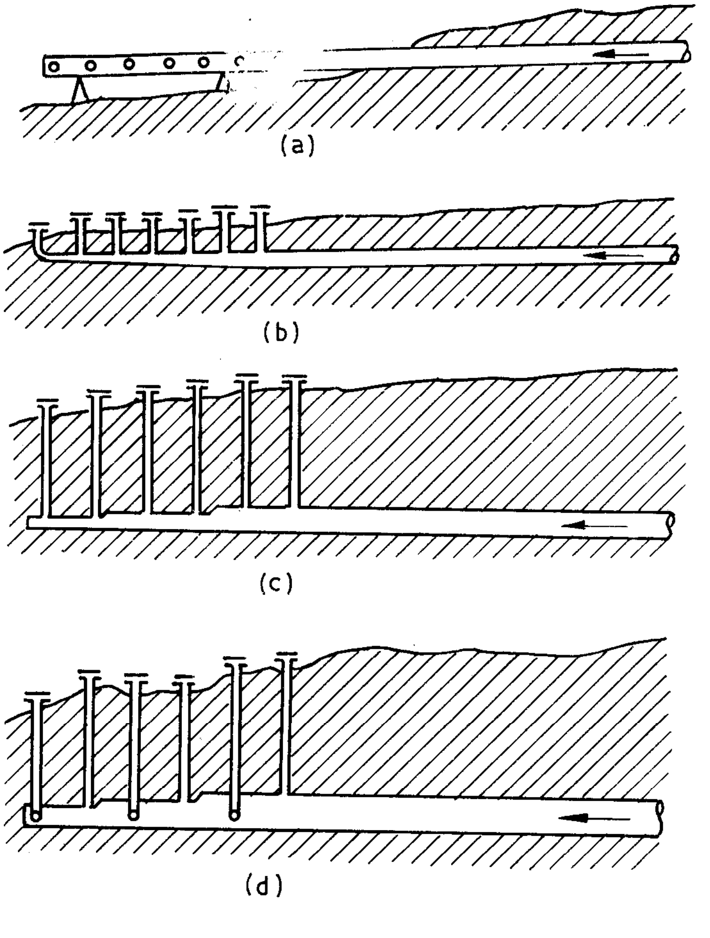

FIG. 1 FOUR MAIN TYPES OF OUTFALL AND DIFFUSER CONFIGURATION

acids and wastes containing high concentrations of sulphur compounds. Acid resistant cement is used for lining. This should be reinforced and have spigot and socket joints. Proper lining at least 150 mm should be applied to protect pipe line from abrasion and impact of waves. Prestressed concrete pipes can also be found advantageous and shall conform to IS 784 :1978.

10.2.5 *G.R.P. (Glass Reinforced Plastics) Pipes*

These pipes should conform to IS 12709 :1989. They have advantage of resisting corrosion but require proper anchorage and additional weight for anchorage and protection against abrasion.

10.2.6 P.V.C. (Polyvenyl Chloride) pipes shall conform to IS 4984 : 1978. These pipes are light weight and require additional weight for anchorage and protection against wave impact, though they provide good resistance against corrosion.

10.2.7 *Asbestos-Cement Pipes*

These are alternative material pipes under certain suitable conditions. These should conform to IS 6908 : 1975.

10.2.8 *Composite Material*

Steel cylinder, reinforced concrete pipes provide good anchorage, enough resistance against waves impact and abrasion. It is found very suitable for marine environment if coated externally by some suitable coating material. These pipes should conform to IS 1916 1963.

11 METHODS OF INSTALLATION

11.1 General

A number of construction methods are available for the installation of marine outfalls. The method most appropriate to any given situation should be determined after considering the following:

a) Length and diameter and the stresses to be imposed on the outfall arising from pulling, bending, pressure tests, intermediate supports on land and at sea, the forces imposed by waves, currents, water depth and sea bed movement;

b) Type of internal and external coatings and weight coating, including feasibility of application, particularly at joints, and stresses imposed on coatings;

c) Depth of water and the sea bed profile along the proposed outfall route;

d) Geology of the sea bed and the underlying strata, foundation stability, depth and method of burial (e.g. predredging, post lay trenching, imported cover), stability and maintenance of predredged trenches;

e) General hydrographic regime and physical characteristics of the inshore waters including such factors as currents, waves and tides;

f) Location and availability of onshore construction areas and facilities;

g) Contractors, expertise; and

h) Shipping movement over outfall route and work area, and related problems of anchor dragging and interference with construction method.

11.1.1 The methods of constructing outfalls are basically variations of one or more of the following:

a) bottom pull;

b) lay barge;

c) reel barge;

d) float and lower;

e) sectional outfalls;

f) tunnelled outfalls.

Methods (a) to (d) invariably involve constructing the outfall at a location remote from its final position. Temporary stresses imposed in these cases will usually be much greater than those in the permanent condition. With methods (a) to (e), a temporary cofferdam construction through beach and foreshore will usually be required for excavation purposes to a point at or below low water, where floating, dredging or trenching equipment can be deployed.

11.2 Bottom Pull Method

11.2.1 The bottom pull method (*see* Fig. 2) is the most common method of outfall construction. Typically, pipe strings are assembled on a construction site, in line with the proposed route, and inspected and tested prior to being pulled into the sea.

11.2.2 A barge equipped with heavy duty winches is anchored seaward of the offshore end of the outfall and is used to pull the pipeline from the construction site. Successive strings are joined on until the complete

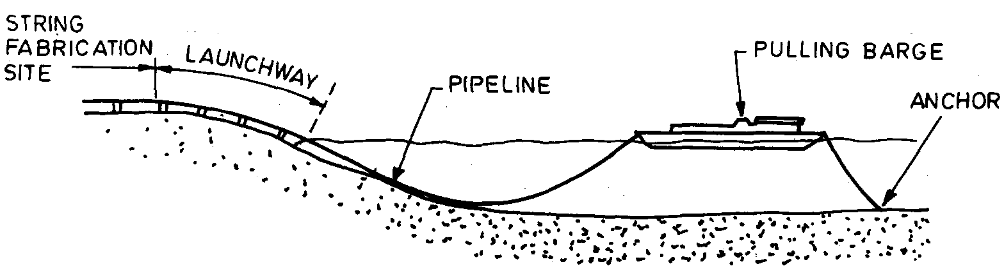

FIG. 2 BOTTOM PULL METHOD

length is in its final position.

11.2.3 This method is usually associated with welded steel pipe which has the advantage of inherent strength and longitudinal flexibility and can have a continuous concrete weight coating for protection and stability. However, prestressed concrete and HDPE or MDPE pipelines have also been installed by this method.

11.2.4 The pulling capacity installed should not be less than the total negative buoyancy of the outfall as designed, for stability in the prevailing wave and current regime. The temporary pulling stress and the available pulling capacity is a function of the required to be in line with the outfall can be pulled out with the outfall.

11.3 Lay Barge Method

The lay barge method (shown in Fig. 3) involves the jointing of pipe lengths on a barge equipped with a launching ramp, down which the pipeline is fed in stages as the barge moves progressively away from the shore.

11.3.1 The individual pipes are coated on land and transported to the lay barge in batches, as required. The draft of the barge and the sea conditions determine the distance offshore at which it can commence laying. The inshore section is pulled to the land with winches and then the barge moves offshore using its own anchors, which are progressively moved offshore with tugs.

11.4.1 This method is used for small diameter steel, plastics or flexible armoured pipelines and, if required, concrete collars can be attached as the pipe enters the water for increased stability.

11.4.2 While purpose built vessels are used for offshore oil and gas flowlines, small and less sophisticated barges can be utilized for laying plastics and flexible outfalls in the shallower inshore areas.

11.4.3 This method has particulars application for constructing outfalls to small coastal towns.

11.5 Float and Lower Method

In sheltered coastal area and inland lakes, outfalls can be floated to the required location and lowered into position (*see* Fig. 5).

11.5.1 The outfall is assembled onshore, preferably in one length, at a site that can be remote from the final location. It is then manoeuvred into the water and lifting slings from a number of launch pontoons attached at the required centres. The outfall is raised clear of the sea bed using the winches on the launch pontoons and towed to its required location. The launch pontoons are then anchored and the outfall lowered into its final position using the winches in a pre-determined sequence

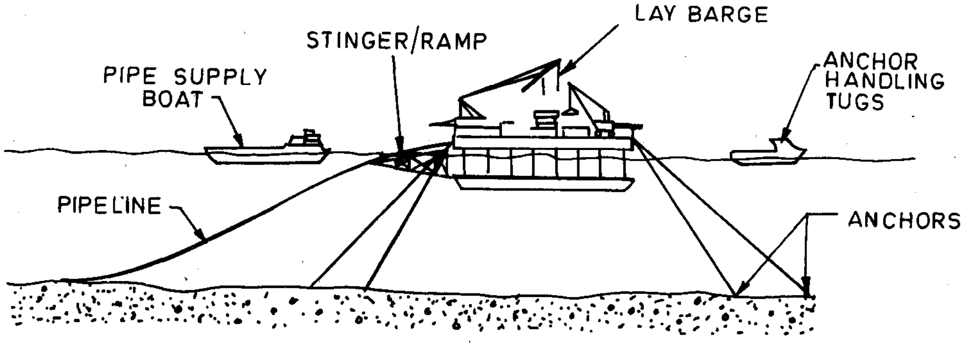

FIG. 3 LAY BARGE METHOD

11.3.2 This method is associated with laying long lengths of offshore pipelines in an ocean environment, and is normally considered to be uneconomical for machine outfalls. However, in sheltered waters, a simple shallow draft barge can be utilized for laying either steel, HDPE or MDPE outfalls.

11.4 Reel Barge Method

The reel barge method of laying submarine pipelines (*see* Fig. 4) involves coiling a continuous length of pipe onto a large diameter reel or turntable. The pipe is then laid from the barge, through a straightener, and down a ramp on to the sea bed. As the barge progresses along the required route, the reel unwinds and the pipeline is laid in-position.

11.5.2 Steel, PVC and polyethylene outfalls can be installed by this method. Concrete collars are normally attached to PVC and polyethylene outfalls to provide sufficient weight for stability. But for steel, continuous concrete weight coating or collars can be utilized. For short lengths of outfall in shallow water, it may be feasible to design the line to float without pontoons and to be lowered into position by controlled flooding.

11.6 Sectional Outfall Methods

There are several methods of installing sectional outfall, the essential feature being that the outfall is built by jointing individual pipes at the sea bed. The procedure is heavily dependent upon divers, but is applicable to all types of pipe as little or no temporary stress condition is imposed.

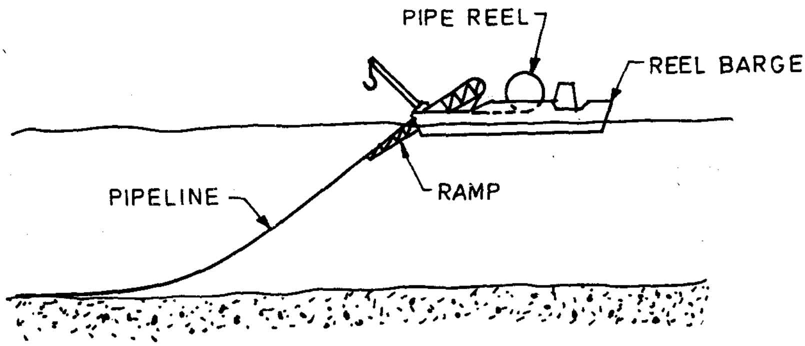

FIG. 4 REEL BARGE METHOD

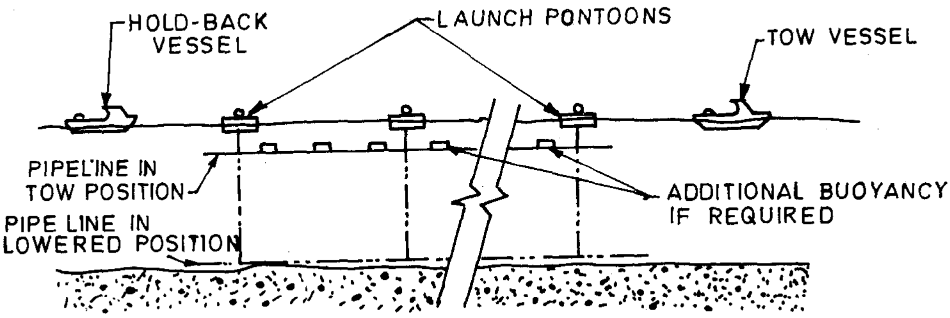

FIG. 5 FLOAT AND LOWER METHOD

11.6.1 At its simplest, conventional small diameter pipes can be laid, one at a time, in a trench on the sea bed or on a suitably prepared granular bed, using a small crane barge and joined together by divers. The joints are normally of the rubbering type, but with additional restraining devices, to prevent the joints opening after installation.

11.6.2 For larger diameter outfall, say 1 500 mm and above, individual pipes can be lowered to the sea bed from a crane barge of self-elevating platform and supported to in a purpose made framework. This framework, which is controlled from the support vessel under the direction of a diver, allows vertical and transverse adjustment of the pipe position. By adjusting the longitudinal position, the new pipe can be inserted into the previously laid pipes and the joint completed.

11.6.3 Very large multiple outfalls can be installed by the immersed tube method. The outfall is formed from a number of sections which are assembled on a slipway or in a dry-dock and floated to their required location. Each section is then lowered onto a prescreeded granular bed or concrete foundation pads. After adjusting its position on the sea bed, an initial seal is made to the preceding section using hydraulic rams or hydrostatic pressure before continuing on to the next section. The final joints between each section are completed from inside the outfall after it has been dewatered.

11.7 Tunnelled Outfalls

Tunnelled outfall construction is not usually considered for outfalls less than 1 600 mm diameter unless:

a) Local physical circumstances preclude the sea bed outfall previously described; or

b) The movement of the sea bed is so great as to endanger the long-term stability of the outfall.

11.7.1 Submarine tunnels are ideally constructed from a single shaft located on shore and through impermeable materials such as still homogeneous clays or sound rock. Other sea bed materials, faults and fissures can be tunnelled through using modern chemical grouting, with or without compressed air, but the cost implications can be considerable.

11.7.2 The tunnel is normally lined with *in situ* reinforced concrete or precast concrete segments, to support the excavation and improve the hydraulic characteristics.

11.7.3 At the offshore end, the outfall has to be connected to the sea bed through either a series of vertical shaft or a single shaft from which a diffuser section is laid on the sea bed. These shafts can be formed by drilling from the sea to the tunnel using a self-elevating platform or floating equipment. Alternatively, the shafts may be raised from inside the tunnel, finally breaking out to the sea bed using explosive charges.

12 OPERATION AND MAINTENANCE

12.1 A long sea outfall should be designed to operate efficiently with minimum maintenance. The velocity in the outfall system should be sufficient to achieve self-cleansing velocities to obviate the build up of settled particles. A flushing regime should be incorporated in the design to ensure that velocities are sufficiently high to scour the invert of the pipe.

In the normal circumstances, a well designed outfall should give satisfactory service without routine attention. Evidence of a build-up of sediment within the outfall may be observed by increases in the head required to maintain discharge at a given tidal state. If there is a marked decrease in the retention period in the outfall at a given rate of flow, the installation should be monitored regularly as regards hydraulic performance. Physical checks should be made regularly at 6 to 12 month intervals over the first 2 or 3 years of an outfall's life, and every 2 or 3 years thereafter.

12.2 The full route of the pipe should be inspected by engineering divers to note any signs of damage or other unsatisfactory conditions. Particular attention should be given to the following:

a) Abrasion of the outer protective coating;

b) Undermining of the bed by erosion of bed materials;

c) Excessive growths of marine organisms; and

d) The conditions of the outlet ports.

12.3 The report should describe any remedial work required and this should be carried out at the earliest opportunity before the nostile environment further attacks the outfall fabric.

ANNEX A

(*Clause* 2.1)

LIST OF STANDARDS REFERRED

IS No.	*Title*
458 : 1988	Precast concrete pipes (with or without reinforcement)
784 : 1978	Prestressed concrete pipe (including fittings) (*first revision*)
1916 : 1963	Steel cylinder reinforced concrete pipes
2490 (Part 1) : 1981	Tolerance limits for industrial effluents discharged into inland surface waters : Part 1 General limits (*second revision*)
2951 : 1965	Recommendations for estimation of flow of liquids in closed conduits :
(Part 1) : 1965	Head loss in straight pipes due to friction resistance
(Part 2) : 1965	Head loss in valves and fittings
3589 : 1981	Electrically welded steel pipes for water, gas and sewage
4310 : 1967	Weldable steel pipe fittings for marine purposes
4984 : 1987	High density polyethylene pipes for potable water supplies; sewage and industrial effluents (*third revision*)
5600 : 1970	Sewage and drainage pumps
6631 : 1972	Steel pipes for hydraulic purposes
6908 : 1975	Asbestos cement pipes and pipe fittings for sewerage and drainage
8062 : 1976	Code of practice for cathodic protection of steel structures :
(Part 1) : 1976	General principles
(Part 2) : 1976	Underground pipelines
(Part 3) : 1977	Ship's hull
(Part 4) : 1979	Galvanic protection of dock-gates, caissons, piers and jetties
11625 : 1986	Criteria for hydraulic design of penstocks
11639 (Part 1) : 1986	Criteria for structural design of penstocks : Part 1 Surface penstocks
12709 : 1989	GRP pipes for water supply and sewerage

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