Indian Standard

CODE OF PRACTICE FOR DESIGN, INSTALLATION, OBSERVATION AND MAINTENANCE OF UPLIFT PRESSURE PIPES FOR HYDRAULIC STRUCTURES ON PERMEABLE FOUNDATIONS

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 25 February 1972, after the draft finalized by the Instrumentation Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 In hydraulic structures on permeable foundations water stored percolates below the foundation of the structure thereby causing uplift pressures. The pressure gradient acting along the direction of flow is a critical design parameter at the exit end of the structure. Design of the structure involves calculation of these pressures and gradients on the basis of certain assumptions. In these cases, therefore, actual observations of these pressures during actual operation become important. This standard has, therefore, been prepared to cover installation of instruments for observation of uplift pressures at the contacts of the structures and the foundation soils. Pressure measurements at depths in the foundation soil and pore pressure measurements in earth and masonry dams using piezometers are being covered in a separate standard which is under preparation.

0.3 The theory of ground water movement is based on Darcy's law for laminar flow which postulates that flow velocity is linearly proportional to the energy gradient and that the flow may be characterized by a potential function satisfying the following equation:

$$\frac{\delta^2\phi}{\delta x^2} + \frac{\delta^2\phi}{\delta y^2} + \frac{\delta^2\phi}{\delta z^2} = 0$$

where

ϕ = velocity potential

$= k\ (z + p/w)$ + a constant

where

k = permeability of the medium,

z = height of the point under consideration above a datum,

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p = residual pressure of water at the point, and

w = unit weight of water.

0.3.1 With a number of simplifying assumptions for ease of mathematical analysis, the residual pressure at any point in the medium may be computed analytically for mathematically elementary boundary geometries, utilizing potential flow theory and suitable conformal transformations.

0.3.2 The assumptions generally made for facilitating theoretical calculations are the following:

a) The sub-soil medium is uniform, homogeneous and isotropic and there are no layers of differing permeabilities within the medium;

b) The soil medium is completely saturated;

c) The flow is laminar throughout, enabling application of Darcy's law and potential flow theory;

d) The temperature of the soil medium and the flowing water is constant;

e) Seepage flow along the bottom profile by passing the soil medium does not occur anywhere; and

f) Only two dimensional analysis is to be made ignoring all end-effects.

0.4 But the assumptions mentioned in **0.3.2** are generally not valid for practical structures. Sometimes values of residual pressures and exit gradient are obtainable from electrical analogs of the structure and the medium which may include effects of non-homogeneity, non-isotropicity, stratification and end-effects. However, even these experimentally obtained values may not be realistic enough, due to the hydraulic properties of the soil medium with its variations from point to point which can never be accurately assessed in its totality and simulated in the analog. The analog could at best be only a gross approximation of the prototype built usually with meagre data.

0.5 Therefore, it becomes essential to install pressure pipes on the structure itself with two objects in view; firstly to act as tell-tales watching the stability of the structure, and to predict any undesirable developments, and secondly, to investigate if the actual pressures at various points on the structure are in conformity with those assumed for purposes of design. A systematic record of their observations, apart from its scientific value, will be as necessary for the maintenance of structures as a record of usual sub-surface soundings and probings.

0.6 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers design, installation, observation and maintenance of uplift pressure pipes provided for hydraulic structures resting on permeable foundations. This is essentially a system for measurement of uplift pressures at the contacts of the structures and the foundation soils.

1.1.1 The principles, however, may also be applied to other structures (such as spillway aprons, head regulators, pump houses on lift channels and other appurtenant structures) resting on permeable foundations, where uplift pressures and excessive exit gradients are likely to develop.

2. GENERAL

2.1 In hydraulic structures on permeable foundations, water stored upstream of the structure percolates below the foundations of the structure due to the difference of head, H, between the upstream and downstream water levels (*see* Fig. 1). Consequently at intermediate points, such as at A on the foundation bottom profile, residual pressures P develop, and they act upwards tending to lift the structure, thereby reducing its stability. In order to design the structure safe against such uplift pressures, it becomes necessary to compute the residual pressure at a number of salient points, and provide sufficient dead weight of the structure itself to counteract the same.

2.2 The pressure gradient or the force of water acting along the direction of flow is a critical design parameter at the exit end of the hydraulic structure indicated as point B in Fig. 1. If at this end, the upward force of water due to the exit gradient is in excess of the effective weight, the surface soil will be lifted up followed by progressive dislodgement of soil particles, and may result in the undermining of the foundation soil called ' piping ', and ultimate failure of the structure itself. This exit gradient should be within design limits dependent on the foundation soil at the exit end of the structure.

3. LOCATION OF PRESSURE-TAPPING POINTS

3.1 The location of the pressure-tapping points in any structure shall be planned with great care and thought. The stratigraphy of the sub-soil,

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*Rules for rounding off numerical values (*revised*).

especially the presence of clay beds and other geological and design features, shall be duly considered together with the foundation profile of the structure.
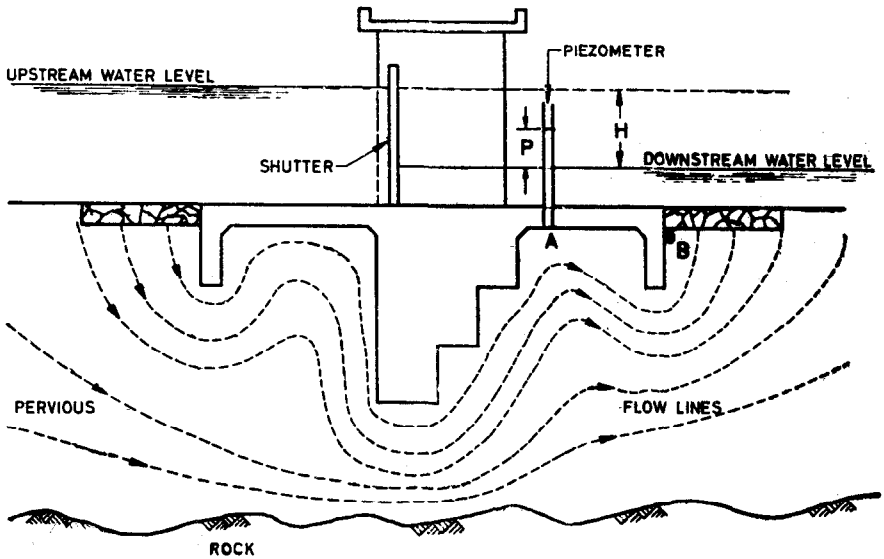

FIG. 1 HYDRAULIC STRUCTURE ON PERMEABLE FOUNDATION

3.2 The pressure points may be divided into three groups:

    a) along and immediately beneath the horizontal or sloping floors,

    b) at different points along the deep vertical cut-offs, and

    c) at different depths in the sub-soil.

3.2.1 A comprehensive arrangement of pressure-tapping points under a typical structure is indicated in Fig. 2.

3.2.2 Tapping points suitable under the horizontal floor are the upstream and downstream ends, immediately upstream and downstream of each vertical cut-off and other intermediate points at regular intervals. These will give uplift pressures at the selected points beneath the floor, a knowledge of which is helpful for watching the safety of the work.

3.2.3 Along the faces of the deep vertical cut-offs the tapping points shall be placed or driven, as found feasible, close against the upstream and downstream faces at suitable depths. The tapping points so located enable

a correct determination of the effect of the depth and spacing of vertical cut-offs and of the stratification of the sub-soil on uplift pressures.

3.2.4 In the sub-soil the tapping points shall be located at suitable depths and intervals under the pervious as well as impervious floors with due regard to stratification. The pressures at these points will give the normal distribution of pressure, away from the zone of distortion due to vertical cut-offs of the structure.

3.2.5 In order to compute the exit gradient, there shall be pressure tappings at the bottom of the vertical cut-off at the downstream end of the structures as indicated in Fig. 2.
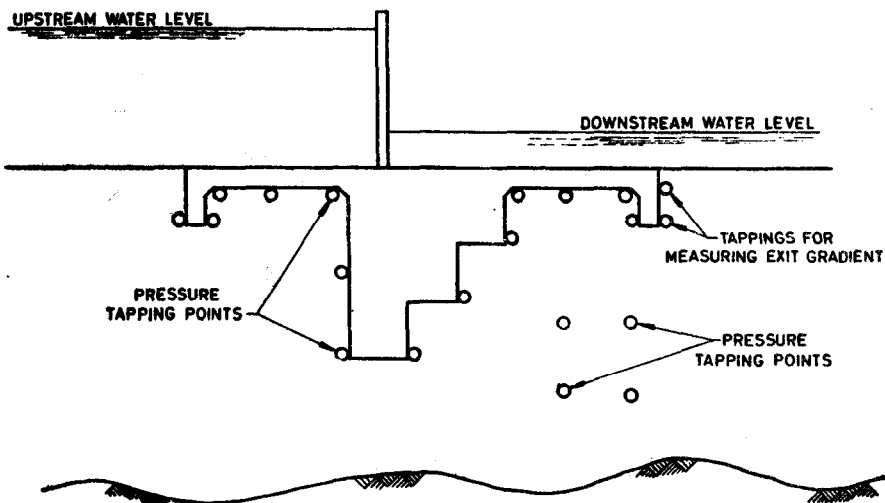

FIG. 2   LOCATION OF PRESSURE-TAPPING POINTS

3.2.6 Pressure-tapping points shall be located along the abutments of the structure and at a number of intermediate sections between the abutments at suitable intervals dependent upon the importance of the structure. A minimum of three intermediate sections of pressure-tapping shall be provided.

4. DESIGN OF FILTER POINTS AND PRESSURE PIPES

4.1 Brass-filter points of 50-mm inner diameter and of 100-cm length each shall be placed at suitable selected points (see Fig. 2) and they shall be connected by 40-mm G. I. pipes to suitable stand pipes located on the superstructure for measurement of water level. All connections shall be leak proof. The filter point shall be fitted with a driving point at one end

and a threaded blind pipe of 50-mm diameter and 75-mm length at the other. In between and around the filter point shall be a 100 cm long, 500-micron wire gauze strainer to serve as the filter (*see* Fig. 3).
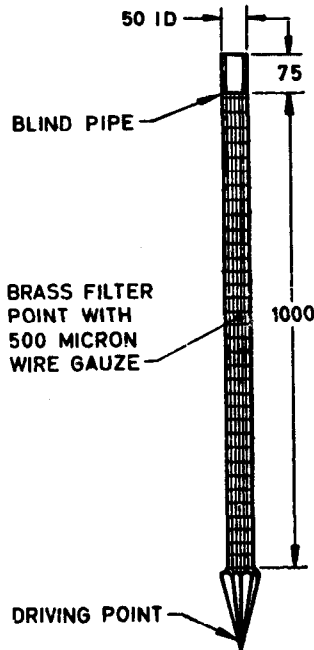
All dimensions in millimetres.

FIG. 3 FILTER POINT

4.2 These filter points shall be laid horizontal where excavation permits. Otherwise they shall be driven down to proper level. Where the depth is too great or when the soil is hard and liable to cause damage to the filter points in driving, the filter point and the connecting blind pipe may be inserted in a bore hole of 100-mm diameter.

4.3 It may not always be necessary to provide graded filter material around the filter points, as required for relief wells, since no flows through the filter points are expected, except during the short periods when change of water level occurs, and during washing operations to remove any choking-up. If graded filters are desired from the point of view of very fine sub-soil material or of the existence of a high probability of choking-up

of the pressure pipes, graded filter material may be provided around the filter points, as for relief wells, in accordance with IS : 5050-1968*.

4.3.1 If graded filters become necessary but the provision of such graded filters becomes costly, as an alternative, porous tube piezometers in which a porous ceramic tube acts as a filter tip may be provided.

NOTE — Details regarding porous tube piezometers will be covered in a separate standard.

5. PRECAUTIONS FOR PRESSURE PIPE

5.1 During the installation of pressure pipes the properties of soil around the tip, should be observed, particularly when the tips are located in soil with different properties and permeabilities recorded. This may be of help in subsequent analysis and interpretation of observations.

5.2 A damaged filter point shall not be used. If one is damaged during driving it shall be replaced with a good one.

5.3 Where necessary, especially in bored installations, a clay seal of minimum 1·5 m may be provided immediately above the filter point to provide effective closing around the periphery of the connecting pipe.

5.4 When more than one pipe are driven at the same place to different depths, they shall be spaced not closer than 30 cm. This will avoid any direct connection between any two filter points that may occur during driving or extraction operations.

5.5 The horizontal piping between the filter point and the observation point on the superstructure shall be slightly inclined downwards in the direction of the filter point to avoid any possible air lock.

5.6 During erection, the ends of all pipes shall be kept closed by caps to avoid foreign matter findings its way into the pipes making observation of water level unreliable, if not impossible.

5.7 All vertical pipes shall be kept dead vertical and no kink of any sort shall be allowed. Failure in this requirement may make it impossible to lower the bell sounder or the thermometer to the right place for observations.

5.8 Each pressure-tapping point shall be given a distinct number and that number shall be marked on the filter point and on each length of connecting pipe. These distinctive numbers shall be stamped on the caps at the end of the stand pipes and on the masonry or concrete platform where they are located.

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*Code of practice for the design, construction and maintenance of relief wells.

5.9 Pipes from the filter points shall be led to piers or abutment walls to enable water level readings to be taken throughout the year. Points directly under a pier or abutment wall shall be connected to the observation platform by a single vertical length of piping. But those away from piers and abutment walls shall be connected by horizontal lengths of piping. These latter shall be placed well below the lowest pressure level that is likely to occur at the respective points. Otherwise no observations will be possible during certain water level conditions, when the observations stand pipe will be dry.

5.10 Each pipe shall be tested to see that the filter point is not choked. If any choking has occured anywhere in the pipe line, it' shall be removed by using compressed air or pressure water under pressure by jetting through the pipe, flowing out through the filter point.

5.11 Each vertical stand pipe shall be provided with a screw cap to avoid bird nests and tampering.

5.12 All the piping including the stand pipes shall be coated with a good quality anti-corrosive paint.

6. OBSERVATIONS

6.1 The observations given in **6.1.1 to 6.1.6** for pressure data shall be made simultaneously.

6.1.1 Upstream and downstream water levels shall be read from water level gauges suitably fixed.

6.1.2 Shade temperature shall be read by means of an accurate maximum-minimum thermometer.

6.1.3 The temperature of river water at a suitable depth below water surface where temperature is approximately constant shall be read. The surface temperature of river water is influenced by atmospheric temperature, and only at a depth of 1·5 to 2·0 m below the water surface, the temperature appears to remain approximately constant. This is the temperature to be observed, only by a maximum-minimum thermometer, and not by an ordinary thermometer, since its readings will be affected by the varying temperature in the upper two metres of water during its withdrawal after reading.

6.1.4 The temperature of sub-soil water shall be read in a few selected observation pipes. These temperatures may be read by long distance recording electrical thermometers, preferably of the automatic recording type.

6.1.5 The water levels in all the stand pipes shall be read by means of a bell sounder lowered into the pipe by a steel tape or by electrical devices. The bell sounder is an accurate, reliable, simple and cheap device. It

consists of a solid brass rod about 90 mm long and 20 mm in diameter ending in an inverted cup of 30 mm diameter (*see* Fig. 4). A swivel is screwed on to the upper end to which the steel tape is attached. The length of the sounder below the zero of the tape shall be measured carefully and added to each reading of the tape to get the true depth from the top of the stand pipe to the water level within the pipe. The moment the cup of the sounder hits the water surface within the pipe, a definite ' plop ' can be heard, a sound which cannot be mistaken or drowned even in the roar of any discharging water through the hydraulic structure. For exact reading, the cup is moved up and down and the precise position where the ' plop ' occurs is read to an accuracy of 2 mm. From the previously known reduced levels of the tops of the stand pipes, the reduced levels of the water within the stand pipes are obtained by subtracting the measured depths.

6.1.6 The depths of sediment on the upstream and downstream floors and if possible the soil characteristics of the sediment shall be observed. Depths of sediment may be measured by sounding.

6.2 For purposes of interpretation, it is recommended that for a filter, laid horizontal, the centre of the filter length will be the position of the pressure point to which the reading in the connecting stand pipe relates. If there is a drop of pressure along the length of the filter the pressure point should be at the farthest position along the direction of flow. Similarly in a vertical filter the pipe reading should refer to the top or bottom end of the filter, whichever is f rthest downstream along the direction of flow and has the lowest pressure. Thus, at the upstream end of the structure, the reading should refer to the bottom of the filter and at the downstream end to the top.

6.3 The frequency of observations will depend on local requirements. For investigation of a particular problem, the observations will have to be rather frequent, but for watching the stability of a structure, once a week for the key-points and once a fortnight for other points shall be enough. Daily observations shall be made during periods when daily water level changes are equal to more than 10 cm.

7. TIME LAG

7.1 When there are large fluctuations in upstream and downstream water levels, for instance during rising or falling floods or when the river supply is being ponded up to feed supplies into the canals, the results are likely to be influenced by time lag. A rise in the upstream level will give relatively lower readings and *vice versa*. When water levels are taken at regular intervals, due allowance shall be made for such time lag.

NOTE — The time lag of the pressure point should be assessed for each uplift pressure pipe after initial saturation of the sub-soil and at periodical intervals. This can be done by filling the stand pipe with water and measuring the time for the water level to drop down to a constant level. The time lag for this purpose may be defined as the

time taken for the water level in the pipe to drop down by 50 percent of the increase obtained by filling the pipe with water. This test shall be performed when water levels on the upstream and the downstream are almost steady. The time lag should be measured as an average of three such trials.

7.2 A sudden rise in downstream level will give relatively lower pipe readings and *vice versa.*

7.3 In a rising flood, when both upstream and downstream levels are rising, the pressure pipes will read relatively low. In a falling flood, when both the upstream and downstream levels are falling, they will read high.
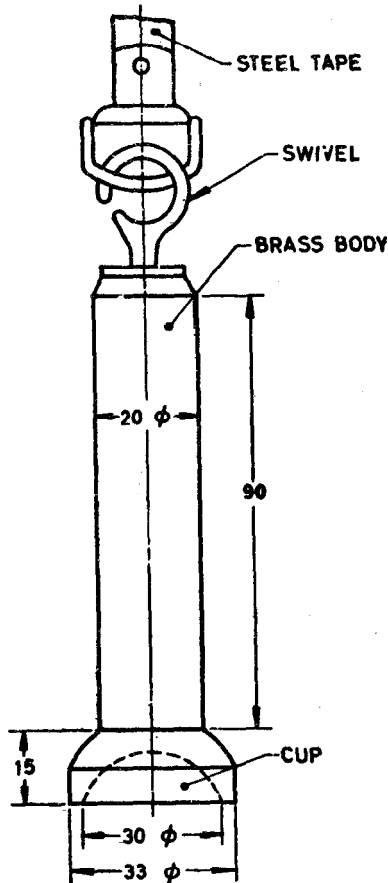
All dimensions in millimetres.

FIG. 4 BELL SOUNDER

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7.4 The response to any variation in head due to change in the upstream or downstream levels is almost instantaneous throughout the structure, but as the rate of movement of sub-soil water is very slow, the water in the pressure pipes takes some time to deplete or recuperate corresponding fall or rise in the pressures. Systematic and comprehensive tests shall be done during the course of operation of the hydraulic structure to enable fixing of the actual amount of time lag.

8. RECORD OF OBSERVATIONS

8.1 The observations shall be recorded suitably in registers or forms.

8.2 The record of observations shall consist of the following:

a) Date of observation;

b) Upstream water level (metres);

c) Downstream water level (metres);

d) Total head, H, that is, difference between upstream and downstream levels (metres);

e) Maximum and minimum shade temperatures ($°C$);

f) Temperature of river water ($°C$);

g) Temperature of water in selected pipes ($°C$);

h) Depths of sediment on upstream and downstream floors (metres);

j) Water levels in all pipes (metres);

k) Residual pressure in each pipe, P, that is, difference between water level in stand pipe and downstream river water level (metres); and

m) Velocity potential percentage, $\phi = (P/H) \times 100$.

8.2.1 The form shown in Appendix A should be used for recording observations.

8.3 For purposes of analysing the observations, pipes are grouped by 'lines', that is, pipes on a single section from upstream to downstream of the hydraulic structures.

8.4 Record in Registers

8.4.1 One page of the register shall be earmarked for one line. Sufficient pages shall be reserved consecutively for each line to admit of all observations for that line being recorded consecutively for a period of, say, one year.

8.4.2 The registers shall be maintained in duplicate, one for permanent record in the office of origin and the other for periodical despatch to any central organization where these data are scrutinized and analysed. These

registers shall be printed on standard forms and made available to the various observation stations for uniformity of record.

8.5 Record in Forms — When forms are used for recording observations, separate forms shall be used for each line of uplift pressure pipes. These forms may be bound in pads of 50 or 100 sheets. Observations shall be recorded in duplicate on these forms at site. These forms with recorded data may be detached from the pad; one copy of the form shall be filed suitably in the office and the other sent as expeditiously as possible to the agency analysing the data.

8.6 For the purposes of ready reference, the data collected and recorded as explained in **8.2** to **8.5** shall be plotted as graphs. Properly plotted graphs will give a quick visual idea of the behaviour of different pipes at any time of the year and will bring to light any special features or abnormalities. For a given pressure point, ϕ (P/H) remains constant for any structure provided the temperature of the flowing water and the nature and depth of sediment or scour on the upstream or downstream pervious floors do not alter. The function ϕ should, therefore, form the basis for plotting, as any variation in this value from the normal will connote damage unless this variation can be explained by temperature and sedimentation. The dates of observation should be plotted on the X-axis and the variable factors on the Y-axis. The variable factors are ϕ , river temperature, sub-soil temperature, H, downstream water level, depths of sediment or scour at the pervious floors, upstream and downstream. These graphs shall be kept plotted up to date for all the key points, so that any unfavourable developments in the sub-soil can be discovered as soon as they occur.

9. MAINTENANCE OF PRESSURE PIPES

9.1 Each year before the onset of monsoon, each pressure pipe shall be tested for any choking-up and cleared, if necessary, by water jetting. The time lag shall be measured for each pipe at required intervals and compared with the initial time lag (*see* Note under **7.1**).

9.2 All missing screw caps on the tops of stand pipes shall he replaced with their original numbers stamped.

9.3 The top levels of the stand pipes shall be checked up by an accurate levelling instrument, if any subsidence of levels is suspected to have occured.

9.4 The stand pipes shall be annually painted with good quality anticorrosive paint, taking care to see that the original pipe numbers are not obliterated.

A P P E N D I X   A

(*Clause* 8.2.1)

REGISTER OF UPLIFT PRESSURE PIPE OBSERVATIONS

Name of river:

Name of hydraulic structure:

<div style="border:1px solid;">

Give sketch of cross-section, along the line of pipes, of the structure (as illustrated in Fig. 2) showing details indicated in Note overleaf.

</div>

Name of observer:

Date of observation:

Approximate time of observation............h to............h

Upstream water level: (m)

Downstream water level: (m)

Head, $H =$ (m)

Shade temperature,   maximum: °C   minimum: °C

River water temperature: °C

Depth of sediment on upstream pervious floor: (m)

Depth of sediment on downstream pervious floor: (m)

Line No.   Total width of *pucca* floor:

Pipe No.	Distance from Upstream End of *Pucca* Floor	Reduced Level of Bottom of Pipe	Reduced Level of Bend of Pipes, if Any
(1)	(2)	(3)	(4)

Pipe No.	Reduced Level of Top of Pipe, m	Pipe Water Temperature, °C	Depth to Water in Pipe m	Reduced Level of Water in Pipe, m	P m [see 8.2 (k)]	$\phi = (P/H) \times 100$		Remarks
						Designed	Observed	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

NOTE — Following features may be shown on the sketch:

a) Foundation profile;

b) Uplift pipes with their number (reduced levels of bottoms and tops of pipes, bends, if any, distance from upstream end of *pucca* floor; and

c) Stratification of the substrata.

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