IS 15310 (2003): Hydraulic Design of Pump Sumps and Intakes - Guidelines [WRD 14: Water Conductor Systems]

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पंप की हौदी और अन्तर्गाही मुख का जलीय डिजाइन—मार्गदर्शी सिद्धान्त

Indian Standard

HYDRAULIC DESIGN OF PUMP SUMPS AND INTAKES — GUIDELINES

ICS 93.160

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Intake Structures Sectional Committee, WRD 11

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Intake Structures Sectional Committee had been approved by the Water Resources Division Council.

Performance of pump is influenced to a considerable extent by the flow conditions at the intake. Swirls and air entraining vortices affect pump performance, causing considerable noise, vibration, cavitation damage, increased suction losses and reduction in efficiency. Large flow swirl intensities increase the frictional losses which reduce the available net positive suction head (NPSH) of the pumps. The swirls can also cause pre-rotation at the impeller inlet, particularly in the case of vertical turbine pumps where impeller is very near to the sump bottom, it may lead to shock losses at the entry resulting in the pump operating at off-duty point affecting the cavitation characteristics of the pump. Site constraints also have significant effect on the configuration.

Proper pump intake design takes care of problems referred above. Though pump sump and intake are designed as per general guidelines actual design and measures for its smooth functioning are finalized through model studies.

The composition of the committee responsible for formulation of this standard is given in Annex A.

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 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

HYDRAULIC DESIGN OF PUMP SUMPS AND INTAKES — GUIDELINES

1 SCOPE

This standard stipulates the guidelines for initial hydraulic design of pump sump and intake structures from approach channel up to its entry into suction pipe of the pump.

2 DEFINITIONS

2.1 Pump Sump

A lined excavation generally of a simple geometric shape adjacent to the pump intake. When the intake is directly adjacent to a river or reservoir, the area immediately upstream of the intake section is termed 'forebay' (*see* Fig.1).

2.2 Pump Intake

The structure between the pump sump or forebay and the pump itself is termed as pump intakes. Generally pump intake is in the form of bell mouth, suction bowl and column pipeline. The intake can be horizontal or vertical or inclined. In some cases, the intake is part of pump itself (*see* Fig. 1).

2.3 Pumpbays

In case of multiple pump installations the pumps are usually separated from each other by separating walls (piers). Individual pump chamber is then called as pumpbay.

2.4 Dimple Vortex

A free surface vortex making a dimple on the free surface without air entrainment (*see* Fig. 2 a).

2.5 Air Entraining Vortex

A vortex which enters an intake from the free surface with intermittent or continuous air entrainment (*see* Fig. 2 b).

2.6 Submerged Vortex (Swirl)

A vortex which enters the intake from a solid flow boundary with submerged vapour core (*see* Fig. 2 c).

2.7 Swirling Flow

Flow usually caused by large scale rotation in the bulk of the fluid in the sump which is then amplified as the flow converges into the intake.

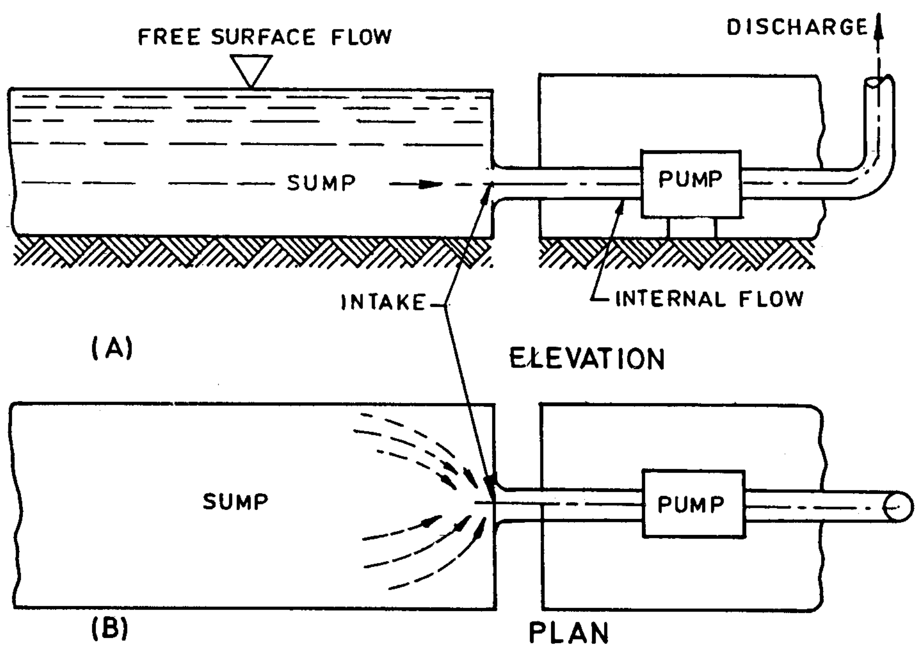


FIG. 1 DEFINITION SKETCH FOR PUMP, SUMP AND INTAKE

2.8 Critical Submergence

2.8.1 *Critical Submergence for Horizontal Intakes*

It is the minimum vertical depth from the surface of water in the pump sump to the top most point of intake required to prevent air entraining vortices (*see* Fig. 3).

2.8.2 *Critical Submergence for Vertical Intakes*

It is the minimum depth from the water surface to the pump intake to prevent entry of air and formation of vortices as indicated in Fig. 4.

2.9 Minimum Submergence

The depth of submergence over a bellmouth at the allowable lowest water level.

2.10 Swirl Angle

The swirl angle is defined as

$$Ø = \arc\tan \frac{V_t}{V_a}$$

where

V_t = tangential velocity component of swirling flow; and

V_a = axial velocity component of flow in pipeline. This is used to measure intensity of swirling flow in the pump intake.

2.11 Net Positive Suction Head (NPSH)

Net positive suction head (NPSH) is the total inlet head

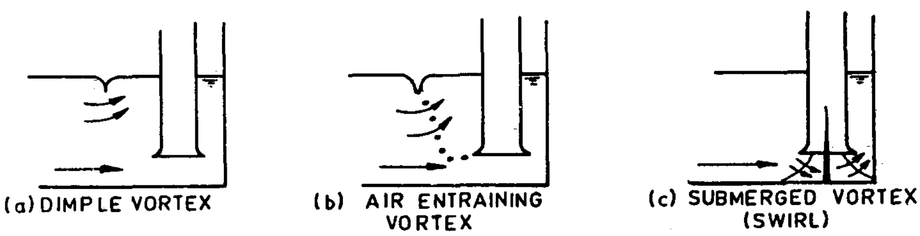


FIG. 2 VORTEX CLASSIFICATION

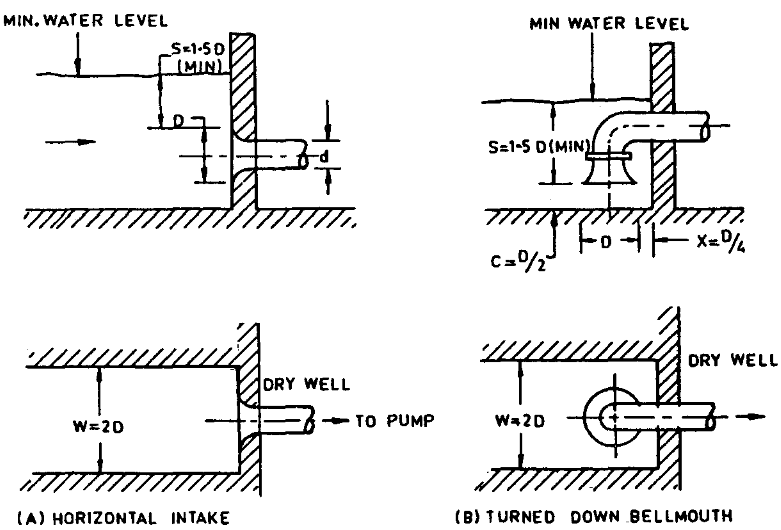


FIG. 3 SUMP DESIGN FOR SINGLE PUMP DRY WELL SUMP

plus the head corresponding to the atmospheric pressure, minus head corresponding to the vapour pressure:

$$NPSH = H + \frac{P_o}{\rho_g} - \frac{P_v}{\rho_g}$$

where

H = total inlet head in cm,

P_o = atmospheric pressure in g/cm^2,

P_v = vapour pressure in g/cm^2, and

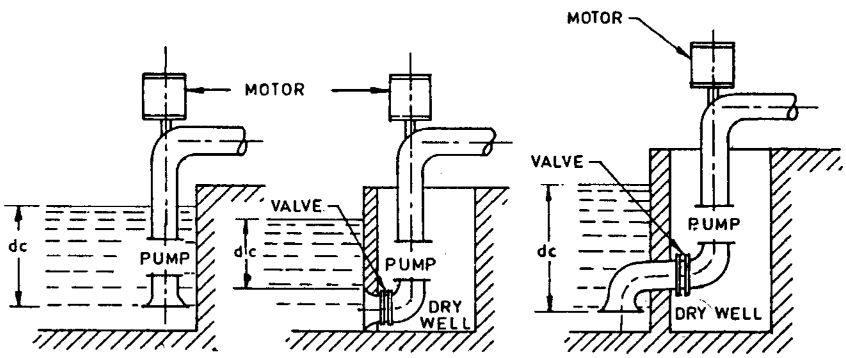
ρ_g = density of water in g/cm^3.

NOTES

1. NPSH and inlet head are measured/taken from a reference plane (Fig. 5.).

2. The inlet head used includes velocity head based upon the average inlet velocity.

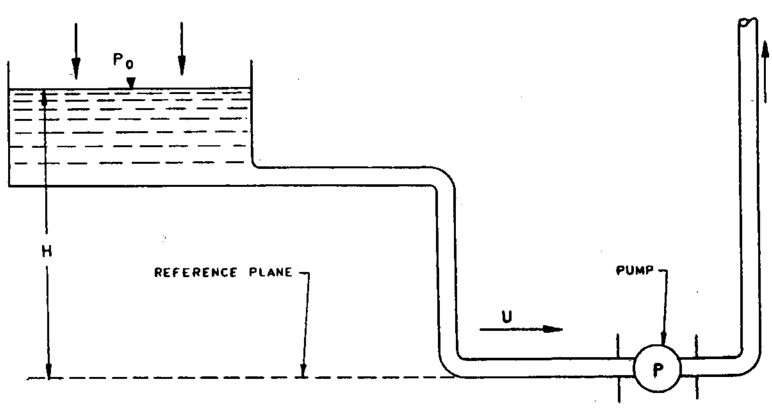
3. Reference plane is the horizontal plane through the center of the circle formed by the external points of the impeller blades (*see* fig.5).



(A) WET WELL (B) DRY WELL HORIZONTAL FLOW INTAKE (C) DRY WELL-TURNED-DOWN INTAKE

dc : Critcal Submergence Depth

FIG. 4 WET AND DRY PUMP INSTALLATION



$$NPSH = H = \frac{P_o}{\rho_g} - \frac{P_v}{\rho_g} - h_f$$

H = vertical height of the water surface in the sump above the datum. Thus if the water surface is below the datum, 'H' is a negative quantity;

P_o = atmospheric pressure, g/cm^2;

ρ_g = density of water;

P_v = water vapour pressure; and

h_f = head loss in suction pipeline cm.

FIG. 5 DIAGRAM TO ILLUSTRATE 'NPSH'

3 TYPES OF PUMP INTAKES

The position and location of pump intake generally depends upon the source of water available for pumping and the proximity of the plant to the source of water. The pump intakes may be broadly classified as :

a) pump intakes placed in source of water, and
b) pump intakes placed away from source of water.

4 STANDARD DESIGN

4.0 General

Standard design of sump mainly depends upon rated flow per pump to be handled for irrigation, power plant, industrial project, sewerage system, etc. This will in turn govern the type and number of pumps required.

The following aspects shall be considered for a good sump design:

a) Even flow distribution;
b) Ideal flow condition in each pump bay with respect to swirl and vortex formation and prevention of pre-rotation;
c) Independent pump operation;
d) Use of screens in pump bays for arresting all trash and floating material; and
e) Provision of gates to isolate pump bay for maintenance, etc.

For satisfactory pump operation the flow into suction pipe intake has to be evenly distributed across the area and this can be achieved by proper design of sump components. Sharp corners, abrupt turns and non symmetry should be avoided.

While designing the sump, prevention of eddies and vortices in the channel and pump bays and the condition of the flow approaching inlet of bell is important.

4.1 Single Pump Sumps

A pump can be installed in a wet or a dry well. A vertical turbine pump suspended in a wet well and a similar pump in a dry well is shown in Fig. 4. In a dry well the bellmouth may be directed in the back wall or turned down through an angle of upto 90° as shown.

4.1.1 *Vertical Entry Pumps*

4.1.1.1 Figure 4 shows basic design for wet well sump for a vertical pump. All the dimensions are given in terms of bell mouth diameter (D), which is generally taken as 1.5 to 1.8 times pump column pipe diameter.

4.1.1.2 *Side wall clearance*

The clearance between side wall and bellmouth shall be maintained between D/3 and D/2.

4.1.1.3 The bottom clearance (C) between bellmouth and sump floor shall be kept not less than D/2.

4.1.1.4 Backwall clearance (B) between bellmouth and backwall shall be D/4 to D/3 (Fig. 6a).

4.1.1.5 The upstream flow distribution shall be uniform within a distance at 3 D from pump centerline (Fig. 6c).

4.1.1.6 The sharp corner shall be avoided or shall be either blanked or given fillet of radius as shown in Fig. 6a, 6b and 6c.

4.1.1.7 *Width*

Width of the pump bay shall be minimum 2 D.

4.1.2 *Horizontal Entry Pumps*

4.1.2.1 Figure 3 and Fig. 4b show the general layout for dry well sump with a horizontal entry to the pump. This configuration is usually adopted when reliability is the prime requirement, since the pump is accessible at all times for maintenance. All the dimension are given in terms of bell mouth diameter(D), which is generally taken as 1.5 to 1.8 times pump column pipe diameter (d).

4.1.2.2 *Channel width*

The channel width shall be 2D (same as in the case of vertical entry pumps)

4.1.2.3 *Bottom clearance*

Clearance from bottom (C) for turned down elbow arrangement shall be kept D/2.

4.1.2.4 Clearance with backwall (B) shall be D/4 to D/3 (same as in the case of vertical entry pumps).

4.1.2.5 *Minimum water level (MWL)*

The minimum water level is decided by external factors such as level of the incoming pipe culvert, NPSH requirements of the pump, etc. Considering these factors, water level should be kept as low as possible to reduce the cost of civil engineering works.

Minimum water level = $C + S$ + safety margin

where

C = bottom clearance between sump floor and bell mouth ($C = D/2$)

S = submergence ($S \geq 1.5\ D$)

4.1.2.6 Straight length of approach channel in pump bay shall be upto 10 D downstream of major obstructions to flow path (for example, gate structure, bridge piers, etc) for example, screen. However, model tests are advisable for determining the exact length of approach channel (*see* Fig.7 for details).

4.2 Multiple Pump Sumps

Wet well pumps are the commonly used pump in multiple pumps sumps.

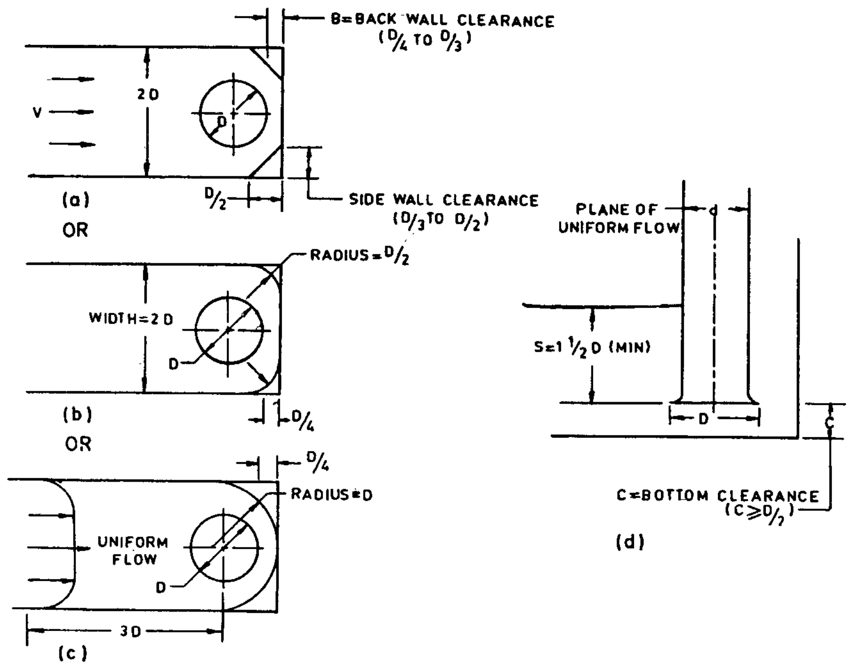


FIG. 6 SUMP DESIGN FOR SINGLE PUMP WET WELL SUMP

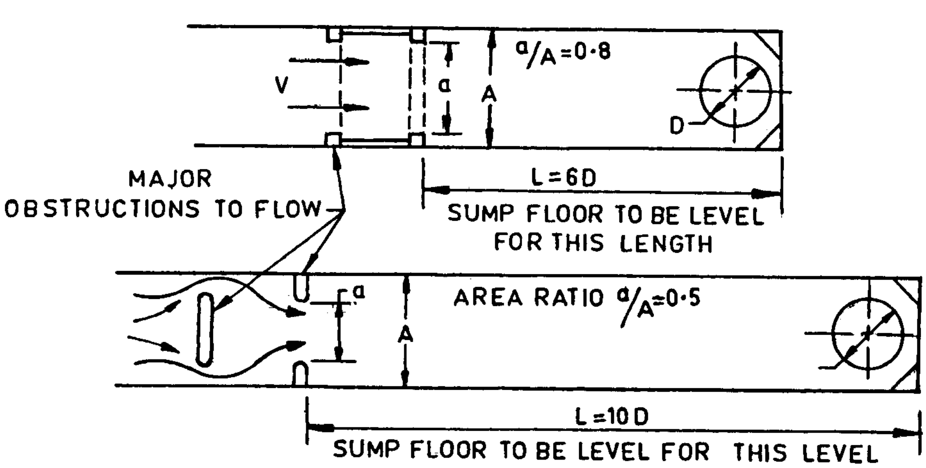


FIG. 7 LENGTH OF APPROACH CHANNEL

4.2.1 *Wet Well Pump Installation*

Figure 8 shows alternate ways of installing pumps in a sump. The arrangement shown in Fig. 8a is used where uniform steady flow occurs just upstream of the intakes. However, if the approach flow is less uniform than ideal, the arrangement shown in Fig. 8b is preferred.

4.2.1.1 *Width of pump house*

The width of pumpbay is kept minimum 2 D. In case of open sump the minimum width of pump house is 2 ND and in case of unitised pump it is 2 ND+(N−1)T where N is number of pumps and 'T' is pier wall thickness between two pumps.

4.2.1.2 Center to center distance between pumps shall be kept minimum of 2D for open sump and 2·D + T for unitized sump to provide adequate clearance in pumpbay.

4.2.1.3 Pump inlet velocity in column pipe is generally limited to 3 m/s and velocity at entry of bell mouth shall not exceed 1.3 m/s.

4.2.1.4 Approaches to the sump are shown in Fig.7 for open and unitised sump. Velocity of the flow of a channel conveying water to sump should not be greater than 1.2 m/s.

4.2.1.5 *Piers*

In the case of multiple pump arrangements, the piers are erected between two pumps to avoid interference of one pump on the other and to cater for structural requirements of pump house. As a thumb rule, the length of piers can be taken as 10 D where D is bellmouth diameter. The nose of the pier should be smooth, preferably semicircular. Piers also help in straightening the flow approaching pump bell.

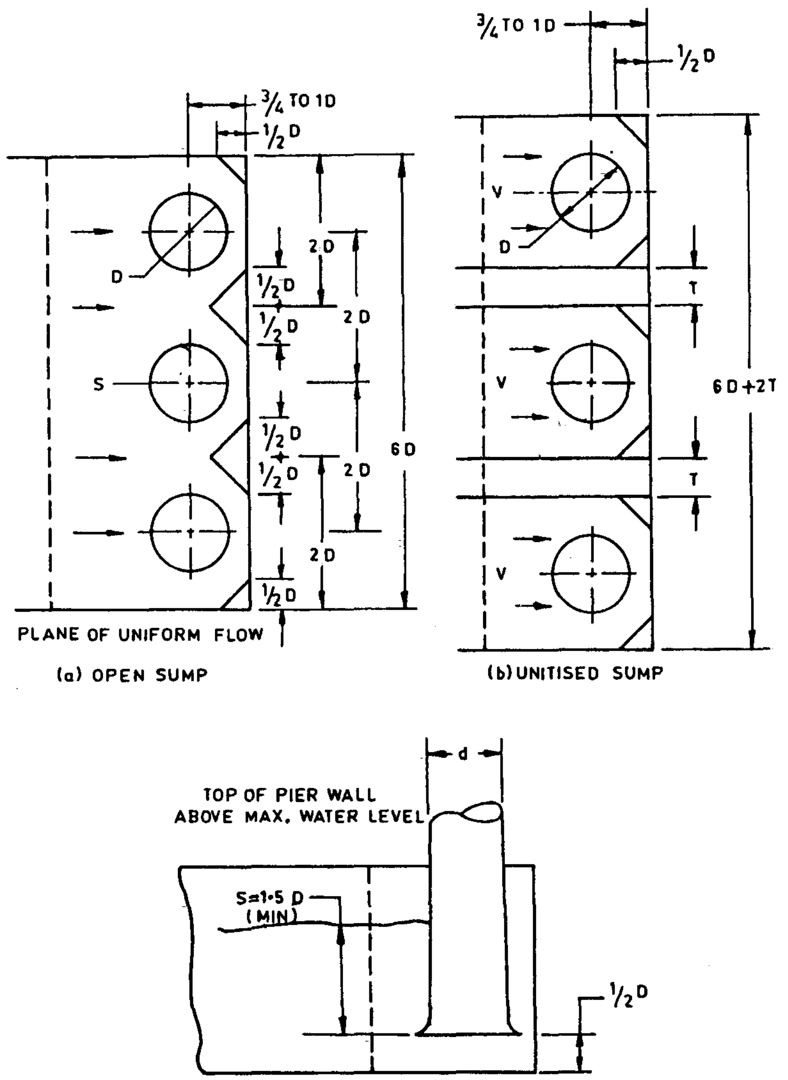


FIG. 8 BASIC SUMP DESIGNS FOR MULTIPLE PUMPS WET WELL ARRANGEMENT

4.2.1.6 The maximum divergence for the forebay side walls with respect to forebay center line should be limited to 20 degrees and the maximum slope at bottom to be not more than 10 degrees to avoid separation of flow. The velocity in the pump bays should not be more than 0.3 m/s.

4.2.1.7 Screens should be provided at the inlet of each pump bay in order to arrest all trash and floating material and straighten the flow.

5 MODEL STUDY

To finalize a pump sump and intake design for any application, hydraulic model studies on a geometrically similar model are advisable to study flow conditions, cavitation, vortex formation, efficacy of antivortex devices, etc. However, to make minimum alterations in the model during experimental studies to achieve satisfactory flow conditions, it is essential to have initially some intake design for that application based on some guidelines/thumb rules, according to which a model can be constructed for initial studies.

5.1 As a thumb rule the capacity of the sump may be based on the detention period. A detention period of 7 to 10 minutes depending on the rate of flow of a single pump or multiple pumps may be a reasonable value.

6 ANTI-VORTEX/SWIRL DEVICES

Various expedients (anti-vortex/anti-swirl devices) need to be evolved first with Froudian velocity through intake if the flow conditions are observed with occurrence of swirls and vortices. The efforts should be made to minimise pre-rotation.

The type of expedients generally adopted are flow guide baffle wall, breast walls, floating rafts, grid walls, anti-swirl cones, splitter vanes, etc. However, the most suitable or optimum suitable device can be finalised through trial runs on the model and the solution may vary from case to case.

The effectiveness of the anti-vortex device shall be verified for flow velocities higher than Froudian, and upto the actual velocity, that is, prototype velocity, as may be considered necessary.

ANNEX A

(Foreword)

COMMITTEE COMPOSITION

Intake Structures Sectional Committee, WRD 11

Organization	*Representative(s)*
Central Water Commission, New Delhi	SHRI K. S. BHATIA (***Chairman***)
Bharat Heavy Electricals Ltd, New Delhi	SHRI B. SENGUPTA SHRI P. SINHA (*Alternate*)
Central Board of Irrigation and Power, New Delhi	DR A. S. CHAWLA SHRI A. N. BHARGAVA (*Alternate*)
Central Design Organization, Nasik	SUPERINTENDING ENGINEER (G.O.) SUPERINTENDING ENGINEER (GATES) (*Alternate*)
Central Electricity Authority, New Delhi	SHRI A. K. JAIN SHRI NEERAJ KUMAR (*Alternate*)
Central Inland Capture Fisheries Research Institute, Kolkata	DR MANIRANJAN SINHA SHRI V. V. SUGUNAN (*Alternate*)
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Indian Pump Manufacturers Association, Mumbai	SHRI S. L. ABHYANKAR SHRI R. G. PADALKAR (*Alternate*)
Irrigation Department, Government of Punjab, Punjab	CHIEF ENGINEER (RSDD) DIRECTOR (T&P) (RSDD) (*Alternate*)
Irrigation Design Organization and Research Institute, Roorkee	CHIEF ENGINEER (PHD) SUPERINTENDING ENGINEER (*Alternate*)
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Narmada Water Resources and Water Supply Department, Gujarat	OFFICER ON SPECIAL DUTY (1) UNDER SECRETARY (Wm) (*Alternate*)
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BIS Directorate General	SHRI S. S. SETHI, Director and Head (WRD) [Representing Director General (*Ex-officio*)]

Member Secretary
SHRIMATI ROSY DHAWAN
Joint Director (WRD), BIS

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