BUREAU OF INDIAN STANDARD
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भारतीय मानक मसौदा

पम्प हौदी और अन्तर्ग्राही का द्रवचालित डिजाइन — दिशानिर्देश

(IS 15310 *का पहला पुनरीक्षण*)

Draft Indian Standard

HYDRAULIC DESIGN OF PUMP SUMPS AND INTAKES — GUIDELINES

(*First Revision of* IS 15310)

Water Conductor Systems
Sectional Committee, WRD 14

Last Date for Comments:
24/05/2025

FOREWORD
(*Formal clauses of the foreword will be added later*)

The performance of pumps 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 a significant effect on the configuration.

Proper pump intake design takes care of the problems as 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.

This standard was first published in 2003, and this revision has been brought out to bring the standard in the latest style and format of the Indian Standards. Further, the document has been reviewed to incorporate technological advancements and to make necessary editorial corrections.

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, shall be rounded off in accordance with IS 2 : 2022. Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded-off value should be the same as that of the specified value in this standard.

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HYDRAULIC DESIGN OF PUMP SUMPS AND INTAKES — GUIDELINES

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1 SCOPE

This standard lays down 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 TERMINOLOGY

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).

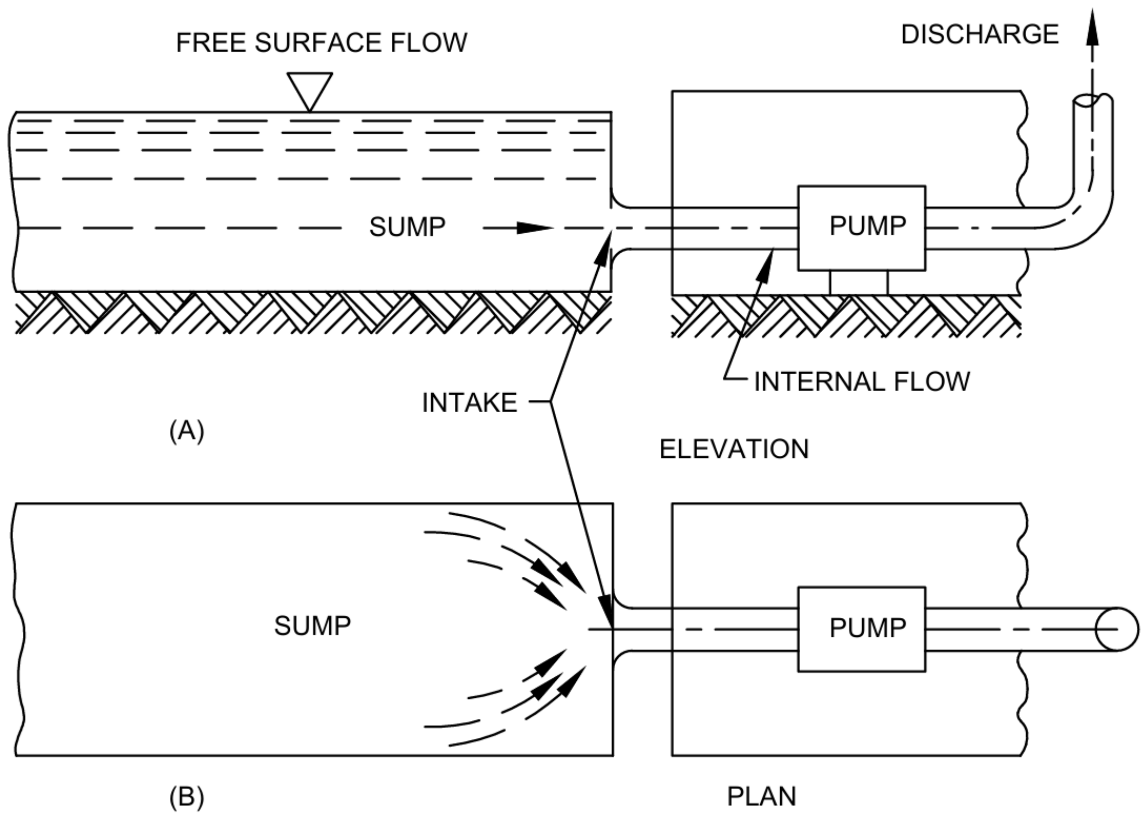


FIG. 1 DEFINITION SKETCH FOR PUMP SUMP AND INTAKE

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)].

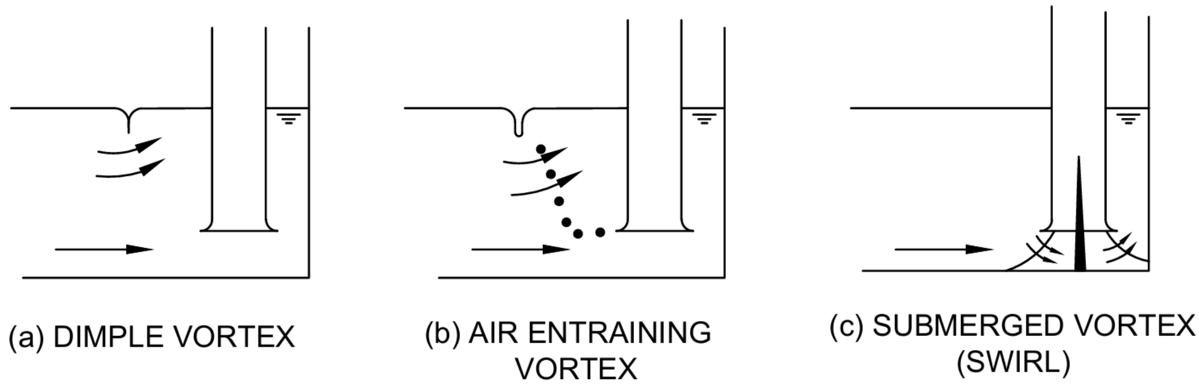


FIG. 2 VORTEX CLASSIFICATION

2.7 Swirling Flow

Flow is 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.

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 topmost point of intake required to prevent air-entraining vortices (*see* Fig. 3).

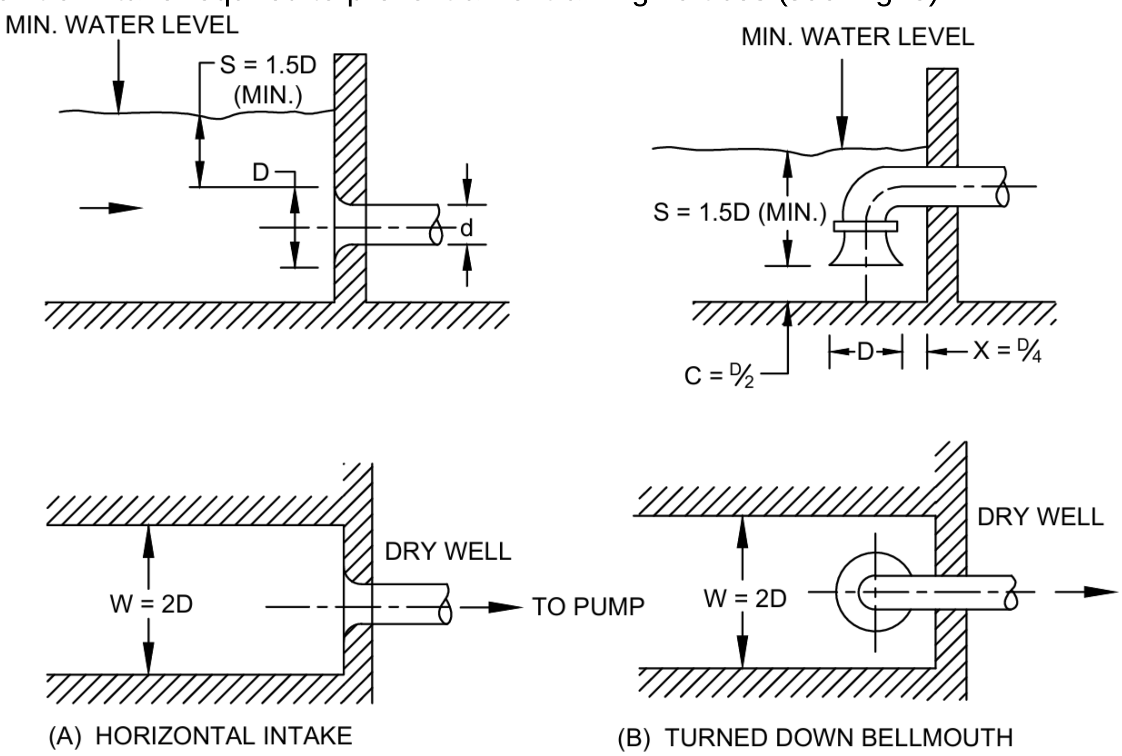
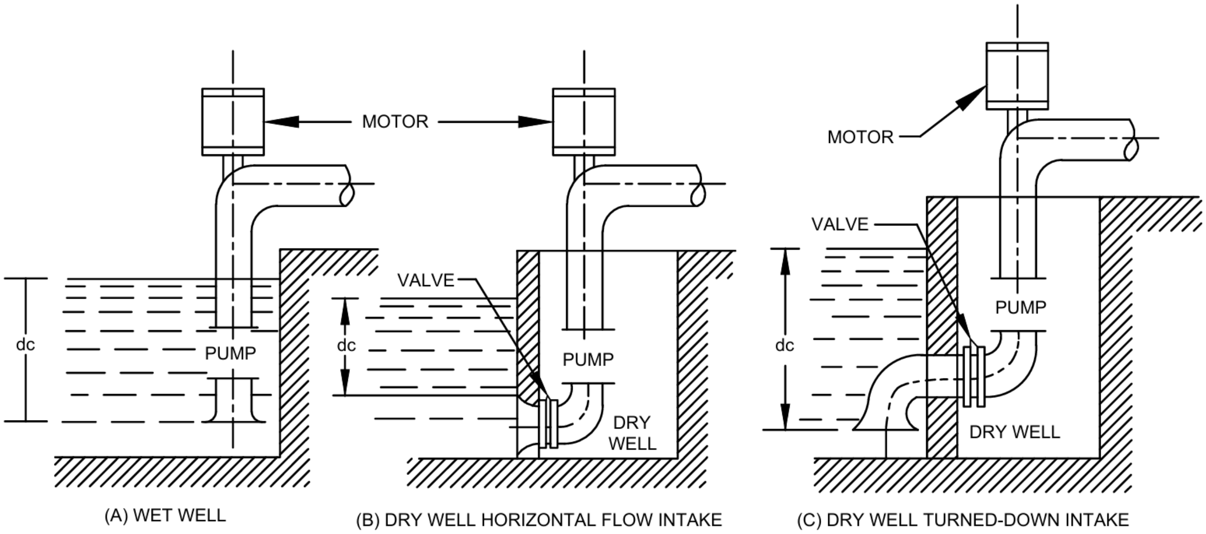


FIG. 3 SUMP DESIGN FOR SINGLE PUMP DRY WELL SUMP

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.



Where, d_c = critical submergence depth.

FIG. 4 WET AND DRY PUMP INSTALLATION

2.9 Minimum Submergence

The depth of submergence over a bell-mouth at the allowable lowest water level.

2.10 Swirl Angle

The swirl angle is defined as

$$\emptyset = arctan\frac{V_t}{V_a}$$

where

V_t = tangential velocity component of swirling flow; and

V_a = axial velocity component of flow in pipeline. This is used to measure the 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 plus the head corresponding to the atmospheric pressure minus the head corresponding to the vapour pressure:

$$NPSH = H_T + \frac{P_O}{P_g} - \frac{P_V}{P_g}$$

where

H_T = total inlet head in cm $(H - h_t)$, *see* Fig 5;

P_O = atmospheric pressure in g/cm^2;

P_V = vapor pressure in g/cm^2; and

P_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).

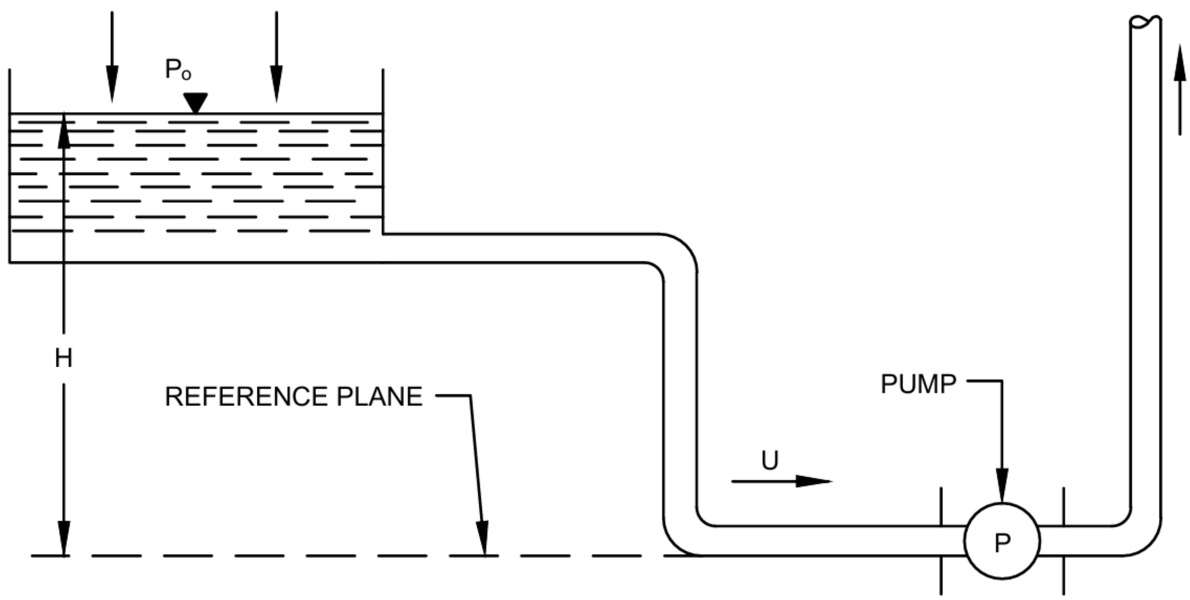


FIG. 5 DIAGRAM TO ILLUSTRATE 'NPSH'

$NPSH = H + \frac{P_O}{P_g} - \frac{P_V}{P_g} - h_t$ (taking into consideration head loss due to friction in suction pipe)

where

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;

h_t = head loss in suction pipeline, cm.

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

4.1 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.

4.2 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 maybe directed in the back wall or turned down through an angle of upto 90° as shown.

4.2.1 *Vertical Entry Pumps*

4.2.1.1 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.

4.2.1.3 The bottom clearance (C) between bellmouth and sump floor shall be kept not less than $\mathrm{D}/2$.

4.2.1.4 Backwall clearance (B) between bellmouth and backwall shall be $\mathrm{D}/4$ to $\mathrm{D}/3$ (Fig. 6a).

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

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

4.2.1.7 *Width*

Width of the pump bay shall be a minimum of $2D$.

4.2.2 *Horizontal Entry Pumps*

4.2.2.1 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).

4.2.2.2 *Channel width*

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

4.2.2.3 *Bottom clearance*

Clearance from bottom (C) for turned down elbow arrangement shall be kept $\mathrm{D}/2$.

4.2.2.4 Clearance with backwall (B) shall be $\mathrm{D}/4$ to $\mathrm{D}/3$ (same as in the case of vertical entry pumps).

4.2.2.5 *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.

$$\text{Minimum water level} = C + S + \text{safety margin}$$

where

C = bottom clearance between sump floor and bell mouth ($\mathrm{C} = \mathrm{D}/2$)
S = submergence ($S \geq 1.5\ \mathrm{D}$)

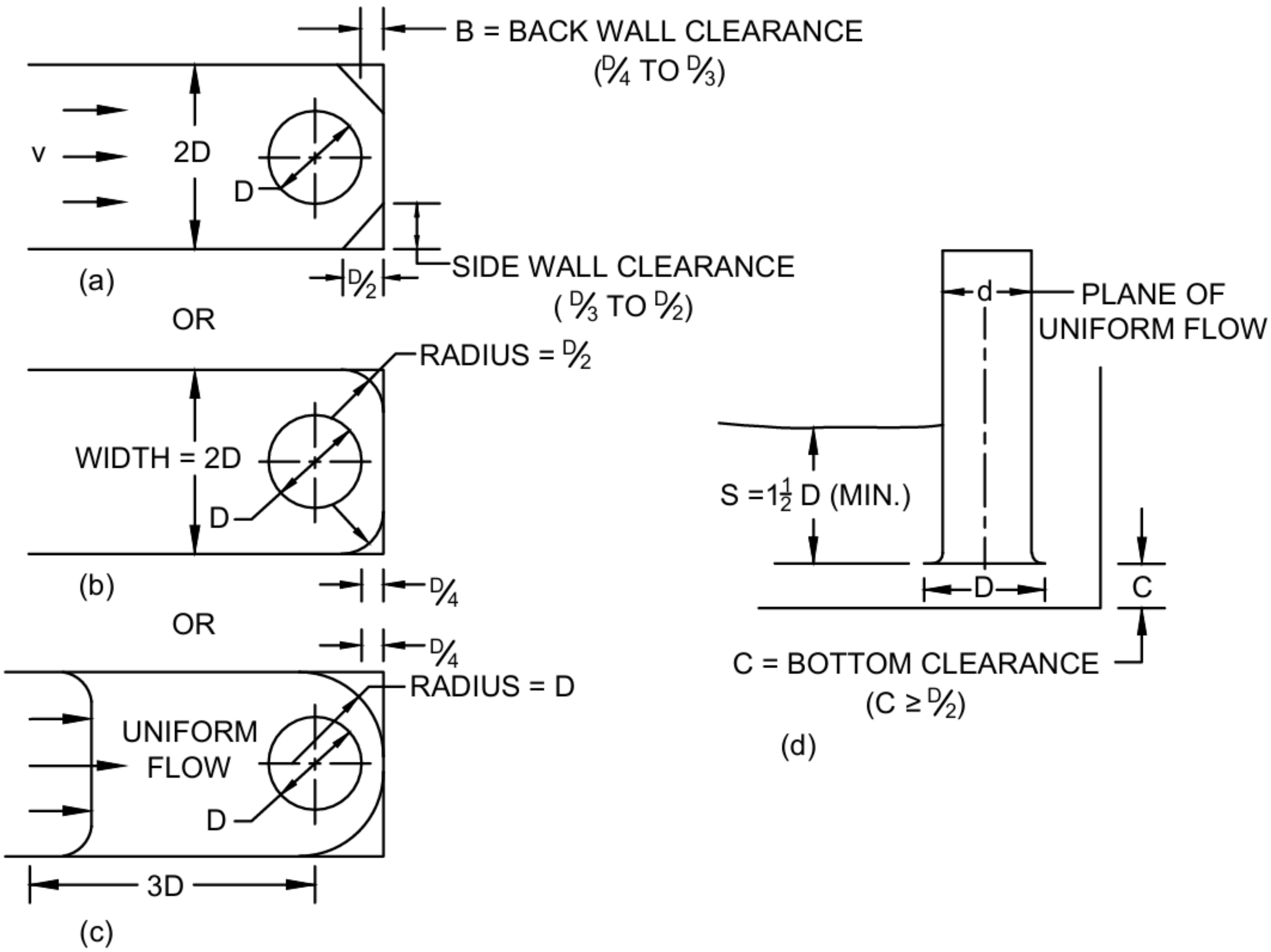


FIG. 6 SUMP DESIGN FOR SINGLE PUMP WET WELL SUMP

4.2.2.6 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).

4.3 Multiple Pump Sumps

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

4.3.1 *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.

4.3.1.1 *Width of pump house*

The width of pump bay is kept minimum $2\ \mathrm{D}$. In case of open sump the minimum width of pump house is $2\mathrm{ND}$ and in case of unitised-pump it is $2\ \mathrm{ND} + (\mathrm{N}-1)\ \mathrm{T}$ where N is number of pumps, D is bell mouth diameter and 'T' is pier wall thickness between two pumps.

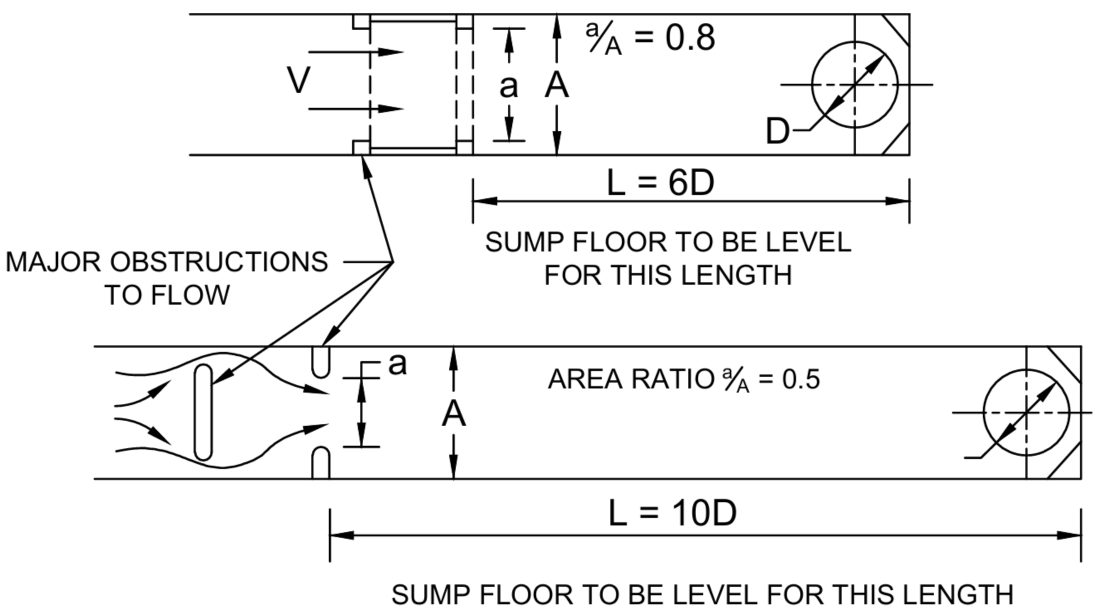


FIG. 7 LENGTH OF APPROACH CHANNEL

4.3.1.2 Center to center distance between pumps shall be kept minimum of $2\mathrm{D}$ for open sump and $2\mathrm{D} + \mathrm{T}$ for unitized sump to provide adequate clearance in pumpbay.

4.3.1.3 Pump inlet velocity in column pipe is generally limited to $3\ \mathrm{m}/s$ and velocity at entry of bell mouth shall not exceed $1.3\ \mathrm{m}/s$.
4.3.1.4 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 $1.2\ \mathrm{m}/s$.

4.3.1.5 *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.

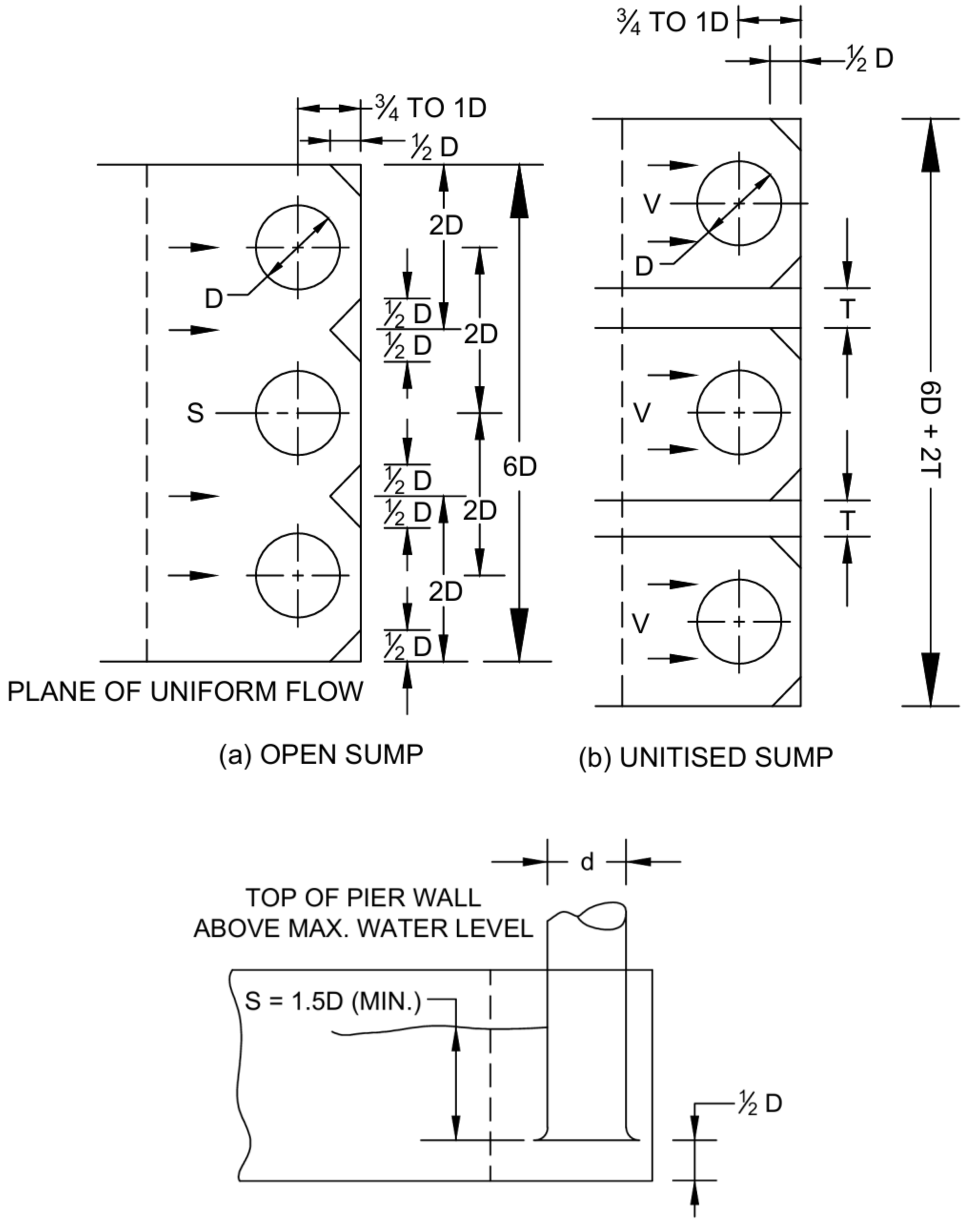


FIG. 8 BASIC SUMP DESIGNS FOR MULTIPLE PUMPS WET WELL ARRANGEMENT