Recommendations For Vertical Pump Intakes

BY: HERMAN GREUTINK

LOCATION

A vertical turbine, mixed flow or axial flow pump's location in a sump is critical to good performance. Figures 1 and 2 provide good design criteria for sump layout. These criteria are based on a maximum bell entrance velocity of 6 ft/s. However, because bell diameters vary from manufacturer to manufacturer, these ratios must be adjusted to accommodate the differences.

According to the U.S. Army Corps of Engineer's design guide, "For satisfactory pump performance based on research and prototype experience, recommended submergence, S, should be 1.25 D or greater, and the dimensionless flow ratio through the individual pump should not exceed a value of 0.40 for:

$Q/\sqrt{gD^5}$

where

Q= discharge, cfs

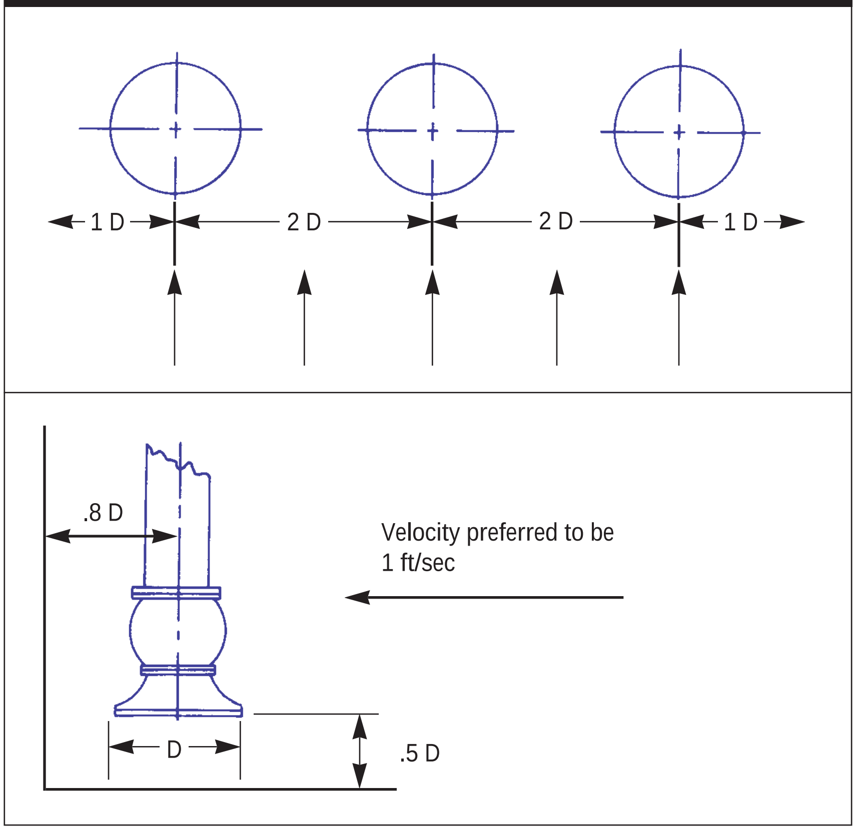
D= pump bell diameter, ft

g= acceleration due to gravity, 32.2 ft/s^2

Submergences that are less than, and flow rates that exceed the above limits were investigated, and more complex designs were required for satisfactory hydraulic performance."

The recommendation of 1.25 D minimum submergence is suitable for storm water and flood control pumps (provided a vortex supressor beam is used as illustrated by Figure 2); however, for continuous service pumps a submergence of 1.75 D is recommended. If the submergence is less than these values, the bell diameter must be enlarged. For instance, to meet a 1.25 D submergence value, the bell diameter should be enlarged to produce an average entrance velocity of 3.3 ft/sec. This velocity may be a bit conservative, but the cost of enlarging the diameter is low and the benefits are tangible.

FIGURE 1



VORTICES

If a vortex still occurs after you have followed the above guidelines, it is not generally difficult to alleviate. It takes very little energy to form a vortex; therefore, it takes very little energy to get rid of it!

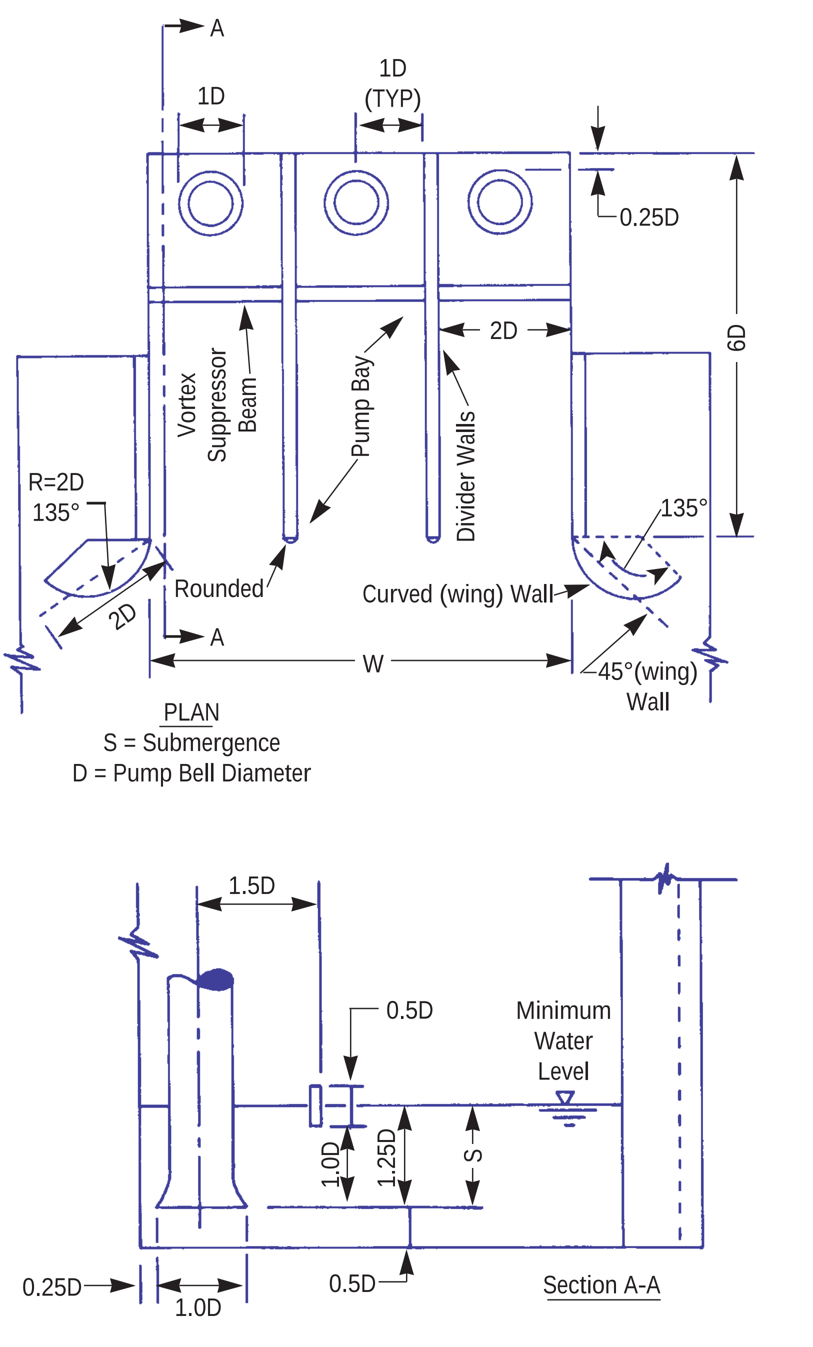
Submerged vortices, however, can be troublesome. These vortices will touch the floor and/or wall of an intake. They are the result of swirling masses of water next to or under the pump and are not continuous. Although submerged vortices sound like cavitation due to the lack of net positive suction head (NPSH), the noise created by a vortex comes and goes as the vortex comes and goes. To mitigate submerged vortex formation, apply the following strategies:

- Place a cone under the bell.
- Employ splitters.
- Fill-in intake corners.
- Use diffuser screens.

HIGH VELOCITY

As a rule, high velocity to a pump in the intake and/or at the bell leads to reduced life of the pump. For a given head and capacity, today's pumps operate at approximately double the speed of the pumps in use before the

FIGURE 2



1960's. The net result of these higher speeds is a drastically increased frequency of pump repairs. Slowing down continuous service pump speeds may be more expensive initially but the long-run savings on maintenance will more than compensate for the increased pump costs.

A high velocity stream aimed at or near the pump could also be a source of premature failure. A fluid force of this nature should be diffused by piling, screens or walls in front of the conduit outlet. Figure 3 provides a simplified depiction of distances required to diffuse a high velocity flow out of a conduit.

The breakup of jet streams can be achieved by baffles as shown in Figure 4. This configuration also promotes better distribution to multiple pumps.

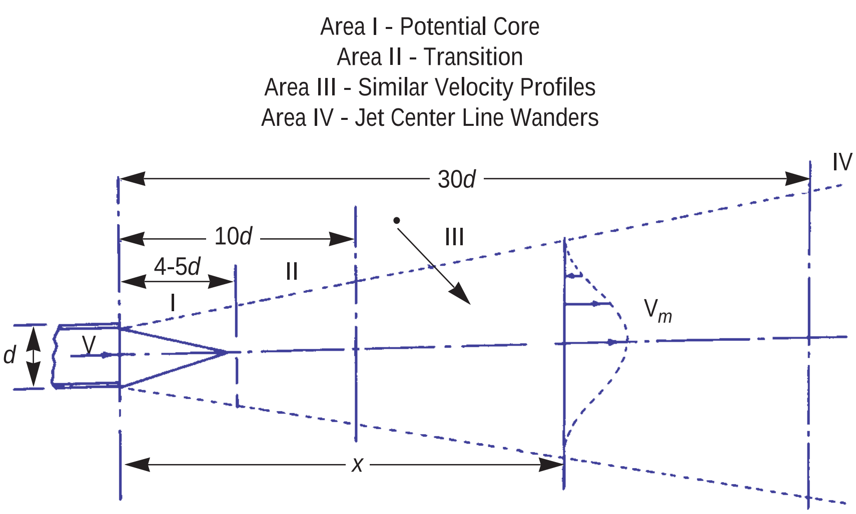
DIVIDING WALLS

Because short dividing walls are not recommended, they are not pictured in any of the figures. (Figure 1 shows no dividing wall while Figures 2 and 4 show long dividing walls.) With multiple pump stations, the front of the short walls can propagate vortices when one or more pumps are out of service. So it is better to have no walls than short walls. Long walls provide easy support for the pumps, as well as drainage for individual pump sumps when stop logs are used.

INTAKE TESTS

When guidelines such as those published by the Hydraulic Institute and the British Hydro-mechanics Research Association (BHRA) cannot be followed, model intake tests should be performed, especially for pumps larger than 50,000 gpm. ■

FIGURE 3

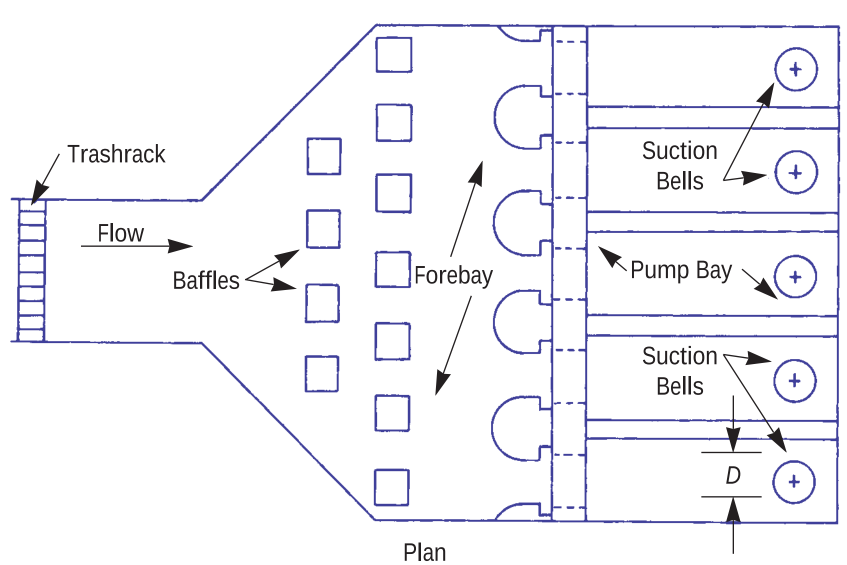


Up to about 30 times diameter d, the formula

$$\frac{V_m}{V} = 6.5 \times \frac{d}{x}$$ is used to determine V_m

V and V_m (ft/sec.), d and x (ft.)

FIGURE 4



Plan

D = Suction bell diameter, ft.

U.S. Army Corps of Engineer's Design Instructions for Flood Control Pumps

REFERENCES

1. U.S. Army Corps of Engineers, Engineering Technical Letter No. 1110-2-313 "Hydraulic Design Guidance for Rectangular Sumps of Small Pumping Stations with Vertical Pumps and Ponded Approaches."
2. Prosser, M. J. "The Hydraulic Design of Pump Sumps and Intakes." British Hydromechanics Research Association.
3. Hydraulic Institute Standards, 14th Edition

Herman Greutink is vice president and technical director for Johnston Pump Company in Brookshire, TX.

Intake Design

The function of the intake, whether it be an open channel or a tunnel having 100 per cent wetted perimeter, is to supply an evenly distributed flow of water to the suction bell. An uneven distribution of flow, characterized by strong local currents, favors formation of vortices and with certain low values of submergence, will introduce air into the pump with reduction of capacity, accompanied by noise. Uneven distribution can also increase or decrease the power consumption with a change in total developed head. There can be vortices which do not appear on the surface, and these also may have adverse effects.

Uneven velocity distribution leads to rotation of portions of the mass of water about a centerline called vortex motion. This centerline may also be moving. Uneven distribution of flow is caused by the geometry of the intake and the manner in which water is introduced into the intake from the primary source.

Calculated low *average* velocity is not always a proper basis for judging the excellence of an intake. High *local* velocities in currents and in swirls may be present in intakes which have very low *average* velocity. Indeed, the uneven distribution which they represent occurs less in a higher velocity flow with sufficient turbulence to discourage the gradual build-up of a larger and larger vortex in any region. Numbers of small surface eddies may be present without causing any trouble.

The ideal approach is a straight channel coming directly to the pump. Turns and obstructions are detrimental since they may cause eddy currents and tend to initiate deep-cored vortices.

Water should not flow past one pump to reach the next if this can be avoided. If the pumps must be placed in line of flow, it may prove necessary to construct an open front cell around each pump or to put turning vanes under the pump to deflect the water upward.

All possible streamlining should be used to reduce the trail of alternating vortices in the wake of the pump or of other obstructions in the stream flow.

The amount of submergence for successful operation will depend greatly on the approaches to the intake and the size of the pump. While specific design is generally beyond the scope of the pump manufacturer's responsibility, he may comment while the intake layout is still preliminary if he is provided with the necessary intake drawings reflecting the physical limitatons of the site.

Complete analysis of intake structures is best accomplished by scale model tests.

Subject to the qualifications of the foregoing statements, Figs. 68, 69, & 70 have been constructed for single and simple multiple pump arrangements to show suggestions for basic sump dimensions. They are for pumps normally operating in the capacity range of approximately 3,000 to 300,000 gpm. Since these values are composite averages from a great many pump types and cover the entire range of specific speeds, they must not be thought of as absolute values but rather as basic guides subject to some possible variations. For pumps normally operating at capacities below approximately 3,000 gpm, refer to Sump or Pit Designs (small pumps) page 114.

All of the dimensions in Figs. 68, 69 & 70 are based on the rated capacity of the pump at the design head. Any increase in capacity above these values should be momentary or very limited in time. If operation at an increased capacity is to be undertaken for considerable periods of time, the maximum capacity should be used for the design value in obtaining sump dimensions.

The Dimension C is an average, based on an analysis of many pumps. Its final value should be specified by the pump manufacturer.

Dimension B is a suggested maximum dimension which may be less depending on actual suction bell or bowl diameters in use by the pump manufacturer. The edge of the bell should be close to the back wall of the sump. When the position of the back wall is determined by the driving equipment or the discharge piping, Dimension B may become excessive and a "false" back wall should be installed.

Dimension S is a minimum for the sump width for a single pump installation. This dimension can be increased, but if it is to be made smaller, the manufacturer should be consulted or a sump model test should be run to determine its adequacy.

Dimension H is a minimum value based on the "normal low water level" at the pump suction bell, taking into consideration friction losses through the inlet screen and approach channel. This dimension can be considerably less momentarily or infrequently without excessive damage to the pump. It should be remembered, however, that this does not represent "submergence." Submergence is normally quoted as dimension H minus C. This represents the physical height of water level above the bottom of the suction inlet. The actual submergence of the pump is something less than this, since the impeller eye is some distance above the bottom of the suction bell, possibly as much as 3 to 4 feet. For the purposes of sump design in connection with this chart, it is understood that the pump has been selected in accordance with specific speed charts, Figs. 57, 58, 59, and 60, the submergence referred to herein having to do only with vortexing and eddy formations.

Dimensions Y and A are recommended minimum values. These dimensions can be as large as desired but should be limited to the restrictions indicated on the curve. If the design does not include a screen, dimension A should be considerably longer. The screen or gate widths should not be substantially less than S, and heights should not be less than H. If the main stream velocity is more than 2 feet per second, it may be necessary to construct straightening vanes in the approach channel, increase dimension A, conduct a sump model test of the installation, or work out some combination of these factors.

Dimension S becomes the width of an individual pump cell or the center-to-center distance of two pumps if no division walls are used.

On multiple pump installations, the recommended dimensions in Figs. 68, 69 and 70 also apply as noted above, and the following additional determinants should be considered:

Fig. 71a. Low velocity and straight-line flow to all units simultaneously is the first recommended style of pit. Velocities in pump area should be approximately one foot per second. Some sumps with velocities of 2 feet per second and higher have given good results. This is particularly true where the design resulted from a model study. Not recommended would be an abrupt change in size of inlet pipe to sump or inlet from one side introducing eddying.

Fig. 71b. A number of pumps in the same sump will operate best without separating walls unless all pumps are always in operation at the same time, in which case the use of separating walls may be beneficial. If walls must be used for structural purposes, and pumps will operate intermittently, leave flow space behind each wall from the pit floor up to at least the minimum water level, and the wall should not extend upstream beyond the rim of the suction bell. If walls are used, increase dimension S by the thickness of the wall for correct centerline spacing. Round or "ogive" ends of walls. NOT recommended is the placement of a number of pumps around the edge of a sump with or without dividing walls.

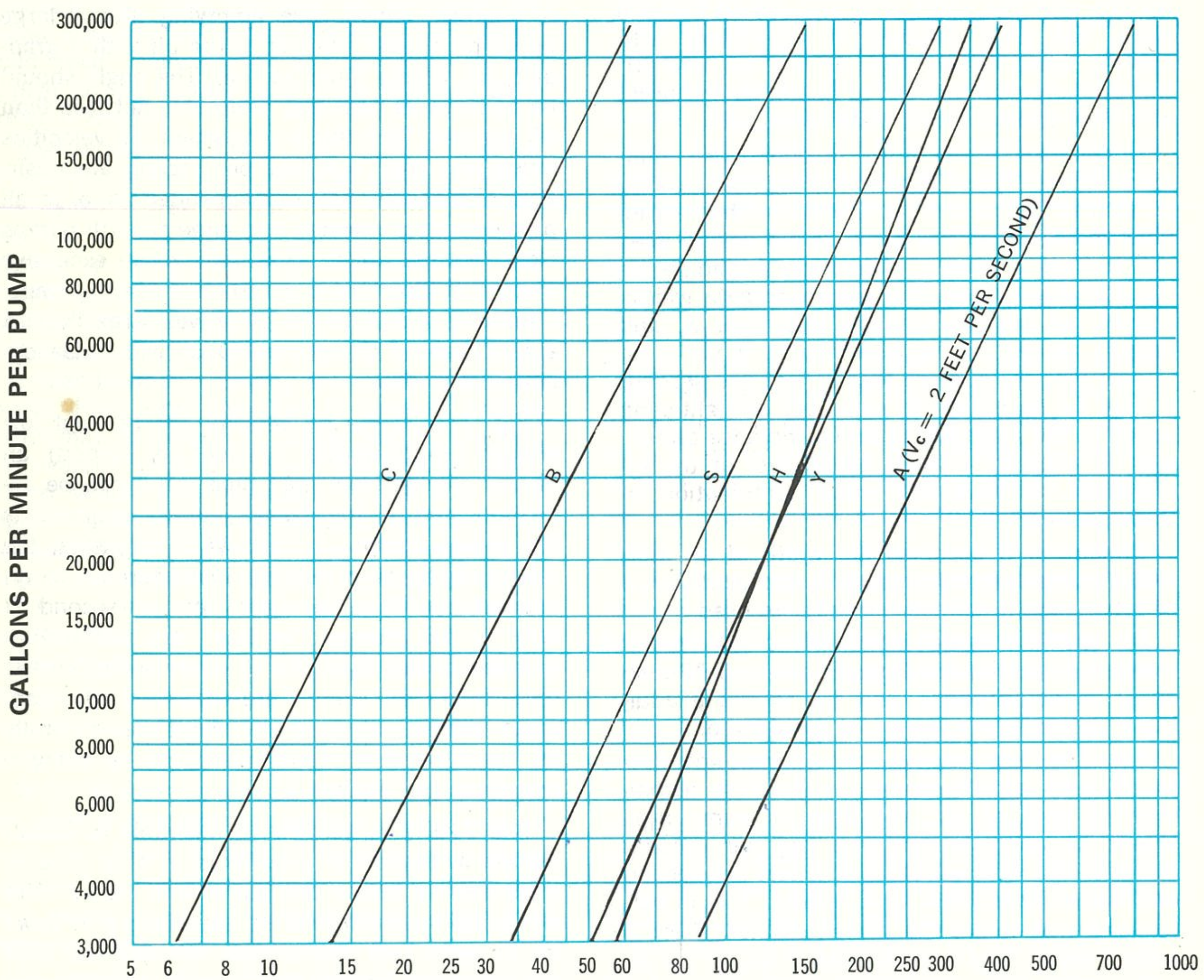
Fig. 71c. Abrupt changes in size from inlet pipe or channel to pump bay are not desirable. A relatively small pipe emptying into a large pump pit should connect to the pit with a gradually increasing taper section. The angle should be as large as possible, preferably not less than 45 degrees. With this arrangement, pit velocities much less than one foot per second are desirable. Especially not recommended is a small pipe directly connected to a large pit with pumps close to the inlet. Flow will have excessive change of direction to get to most of the pumps. Centering pumps in the pit leaves large "vortex areas" behind the pumps which will cause operational trouble.

Fig. 71d. If the pit velocity can be kept low enough (approximately one foot per second), an abrupt change from inlet pipe to pit can be accommodated if the length equals or exceeds the values shown. As ratio W/P increases, the inlet velocity at p may be increased up to an allowed maximum of eight feet per second at W/P = 10. Pumps "in line" are not recommended unless the ratio of pit to pump size is quite large, and pumps are separated by a generous margin longitudinally. A pit can generally be constructed at much less cost by using a recommended design.

Fig. 71e. It is sometimes desirable to install pumps in tunnels or pipe lines. A drop pipe or false well to house the pump with vaned inlet ell facing upstream will be satisfactory in flows up to eight feet per second. Without the inlet ell, the pump section bell should be positioned at least two pipe (vertical) diameters above the top of the tunnel, not hung into the tunnel flow, especially with tunnel velocities two feet per second or more. There should be no signs of air along the top of tunnel. It may be necessary to lower the scoop or insist on minimum water level in vertical well.

Note: The foregoing statements apply to sumps for clear liquid. For fluid-solids mixtures refer to the pump manufacturer.

SUMP DIMENSIONS VERSUS FLOW



RECOMMENDED SUMP DIMENSIONS IN INCHES

Fig. 68 SUMP DIMENSIONS VERSUS FLOW

See explanatory notes in Text under Intake Design.

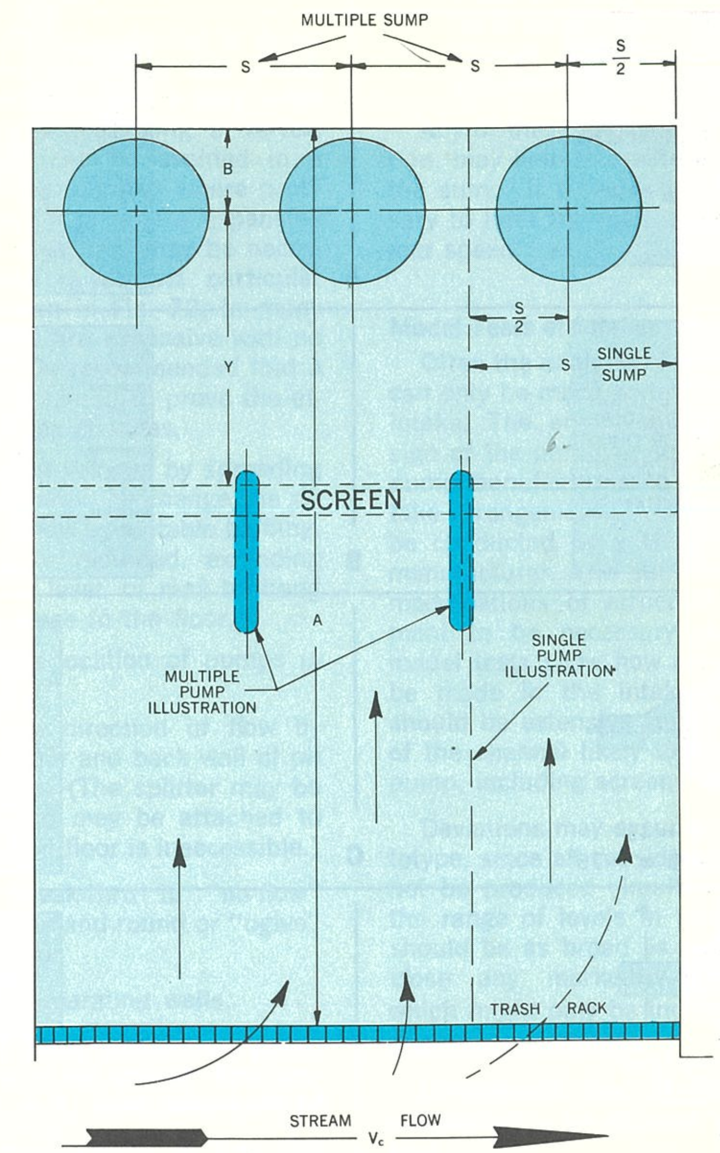


Fig. 69 SUMP DIMENSIONS VERSUS FLOW

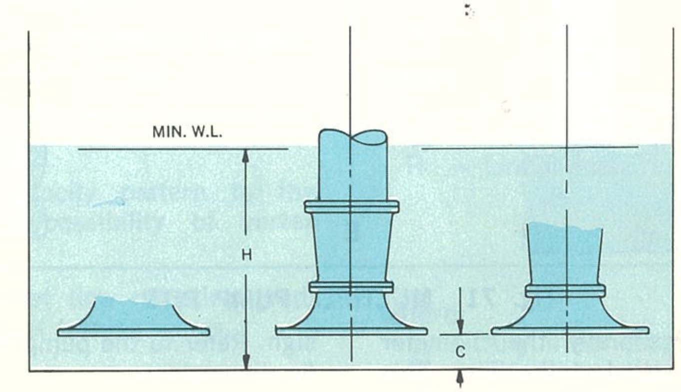
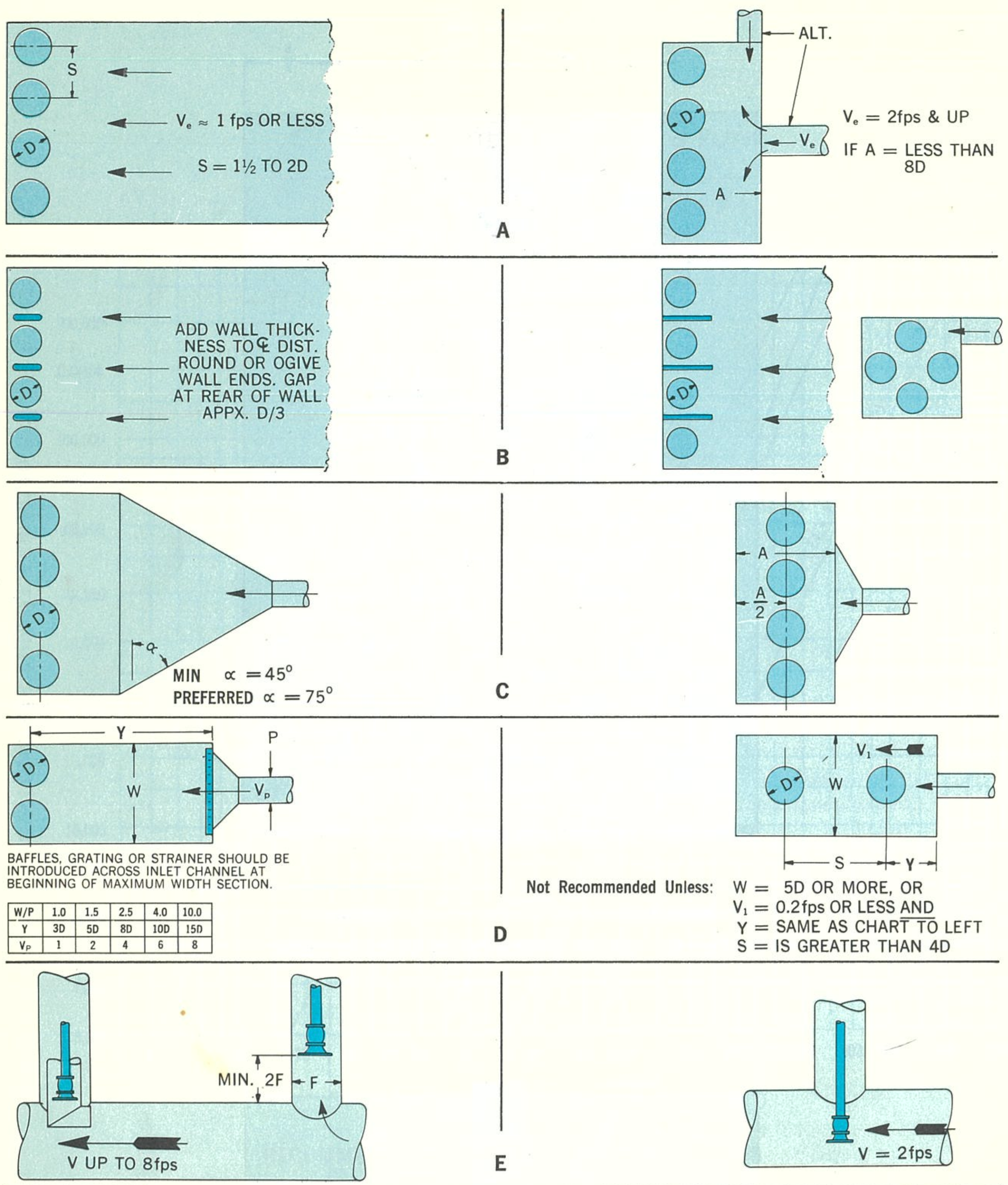


Fig. 70 SUMP DIMENSIONS



W/P	1.0	1.5	2.5	4.0	10.0
Y	3D	5D	8D	10D	15D
V_P	1	2	4	6	8

Fig. 71 MULTIPLE PUMP PITS

The Dimension D is generally the diameter of the suction bell measured at the inlet. This dimension may vary depending upon pump design. Refer to the pump manufacturer for specific dimensions.

Note: Figures apply to sumps for clear liquid. For fluid-solids mixtures refer to the pump manufacturer.

centrifugal pumps applications

Correction of Existing Sumps

It is well established that vortexing in pump suction pits is harmful to pumps and intake structures. It is equally true that a very small force will actually begin generating a vortex. While this phenomenon can be avoided in a new design, for existing structures where problems are already apparent or where expansion is required, corrective measures may be necessary. Possible revisions to correct particular sump problems are shown in Fig. 72. In many cases, field modifications are expensive with no guarantee of success. It is recommended that a sump model test be considered to prove the effectiveness of the proposed changes.

Fig. 72a—Reduce inlet velocity by spreading the inflow over a larger area, or change the direction and velocity of inflow by suitable baffling. (The baffle may be floor mounted, extending above the minimum flow level, or may be hung from above, extending close to the floor.)

Fig. 72b—Change the location of pumps in relation to the inflow.

Fig. 72c—Change the direction of flow by adding splitters to the floor and back wall of pit under centerline of pump. (The splitter may be parallel to inlet flow, and may be attached to pump suction bell if the pit floor is inaccessible.)

Fig. 72d—Provide break-thru to "no-flow" bays in multiple pump pits and round or "ogive" ends of separating walls, *or*

Fig. 72e—Eliminate separating walls.

Fig. 72f—Eliminate sharp corners at gates, screens, etc., by filling in for smooth flow contour (fairing).

Fig. 72g—Reduce the velocity of flow and eliminate vortexing by adding bell extension suction plate and splitter to pump bell.

Fig. 72h—Use floating rafts around the pump column to prevent surface vortices.

Fig. 72i—Use large spheres to prevent surface vortices.

Fig. 72j—Improve velocity pattern to the pump to reduce the possibility of vortex formation.

Fig. 72k—Change inlet flow direction gradually by means of parallel turning vanes.

In general:

Keep inlet flow below two ft per second.

Keep flow in pit below one ft per second.

Avoid changing direction of flow from inlet to pump, *or*

Change direction gradually, smoothly, independently.

Any of these alterations, singly or in combination, may help to create a better flow pattern in the sump. If troubles persist, it may be necessary to limit the total flow or change pump size and speed.

Model Tests of Intakes

Often the analysis of a proposed intake design can only be made by use of a scale model of the intake. The engineers responsible for the design of the pumping station should consult with pump manufacturers to establish one or more intake arrangements. A sump model test can then be conducted by a University or by the pump manufacturer. The sump model test may show modifications of structure or baffling arrangement to be necessary, and sometimes sump model tests show how considerable savings can be made in the intake structure. The model should be extensive enough to include all parts of the channel likely to affect the flow near the pump, including screens and gates.

Deviations may occur between model and prototype, since all considerations of similarity cannot be produced simultaneously. Consequently, the range of levels in velocities to be explored should be as broad as possible in order to disclose any markedly unfavorable tendencies which might only be incipient at mathematically analogous conditions.

Comparable flow in the model is generally considered to be obtained at equal Froude numbers.

On this basis,

$$V_m = V_p \times \sqrt{R}$$

where

V_m = Velocity of water in the model
V_p = Velocity of water in the prototype
R = Linear scale ratio of model to prototype

$$\text{Or } \frac{L_m}{L_p}$$

where

L_m = Any linear dimension of the model
L_p = The dimension on the prototype corresponding to any dimension L_m on the model

Several investigators have found better agreement between model and prototype when velocities are equal, than when velocities are in accord with the Froude number. In the present stage of the art, caution suggests that this entire range of velocities be explored in the model test.

Sump or Pit Design (Small Pumps)

The design of sumps for small pumps (less than approximately 3,000 gpm normal discharge capacity per pump) should be guided by the same general principles as outlined.

However, since there is a large variety of geometric configurations for these small units, recommended limiting dimensions, such as shown in Fig. 68-70, cannot be sufficiently generalized and so presented. Where specific pit or sump dimensions are required, the manufacturer's recommendations should be requested.

In addition to the general design principles outlined, for single and multiple pump settings in large sump designs, the following factors are pertinent to the design of small sumps or pits:

Inlet Opening (Pit Type Sumps)

The sump inlet should be below the minimum liquid level, and as far away from the pump as the sump geometry will permit. The influent should not impinge against the pump, jet directly into the pump inlet, or enter the pit in such a ways as to cause rotation of the liquid in the pit. Where required, a distribution nozzle can be used to prevent jetting, and baffling can be used to prevent rotation.

Sump Volume (Pit Type Sumps)

The usable pit volume in gallons should equal or exceed two times the maximum capacity in gpm to be pumped. If units operate on float switch control, pit should be sized to allow no more than three or four starts per hour per pump. These guides generally insure pits of adequate size to dissipate the inflow turbulence and to assure reasonable life of the starting equipment.

Minimum Liquid Level

Minimum liquid level should be adequate to satisfy the particular pump design. The pump manufacturer's specific dimensions should be used.

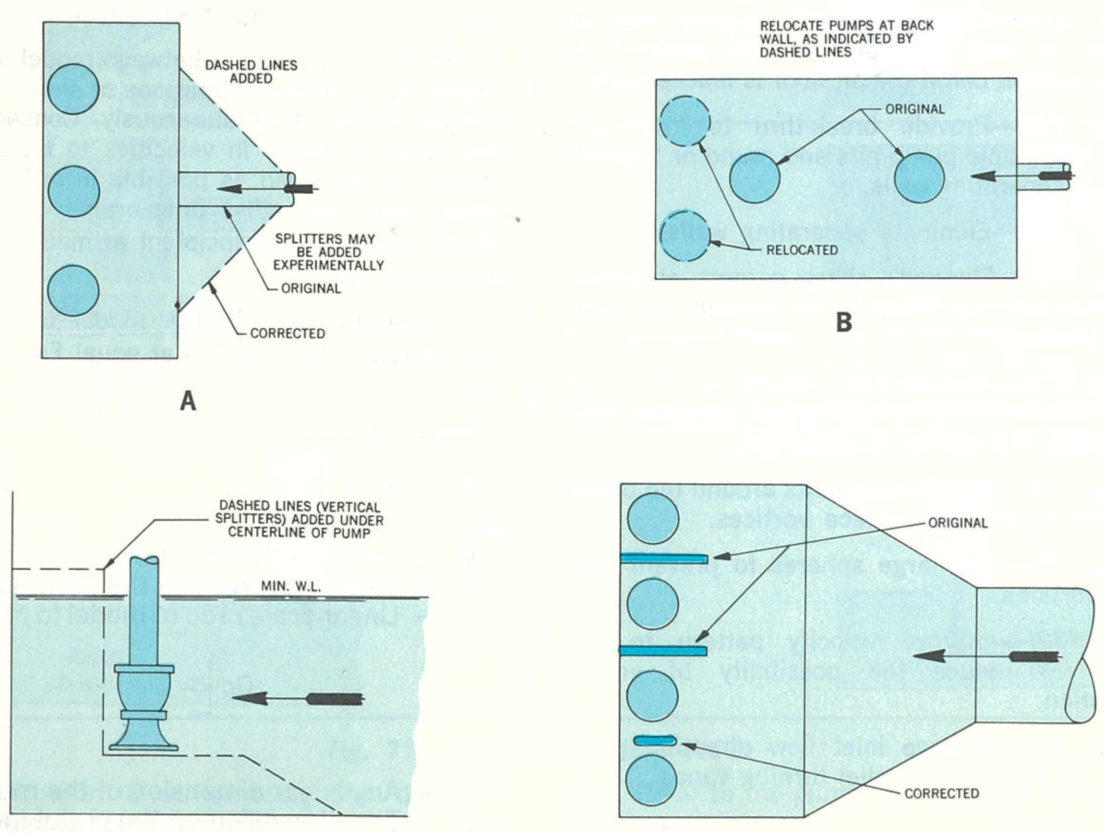
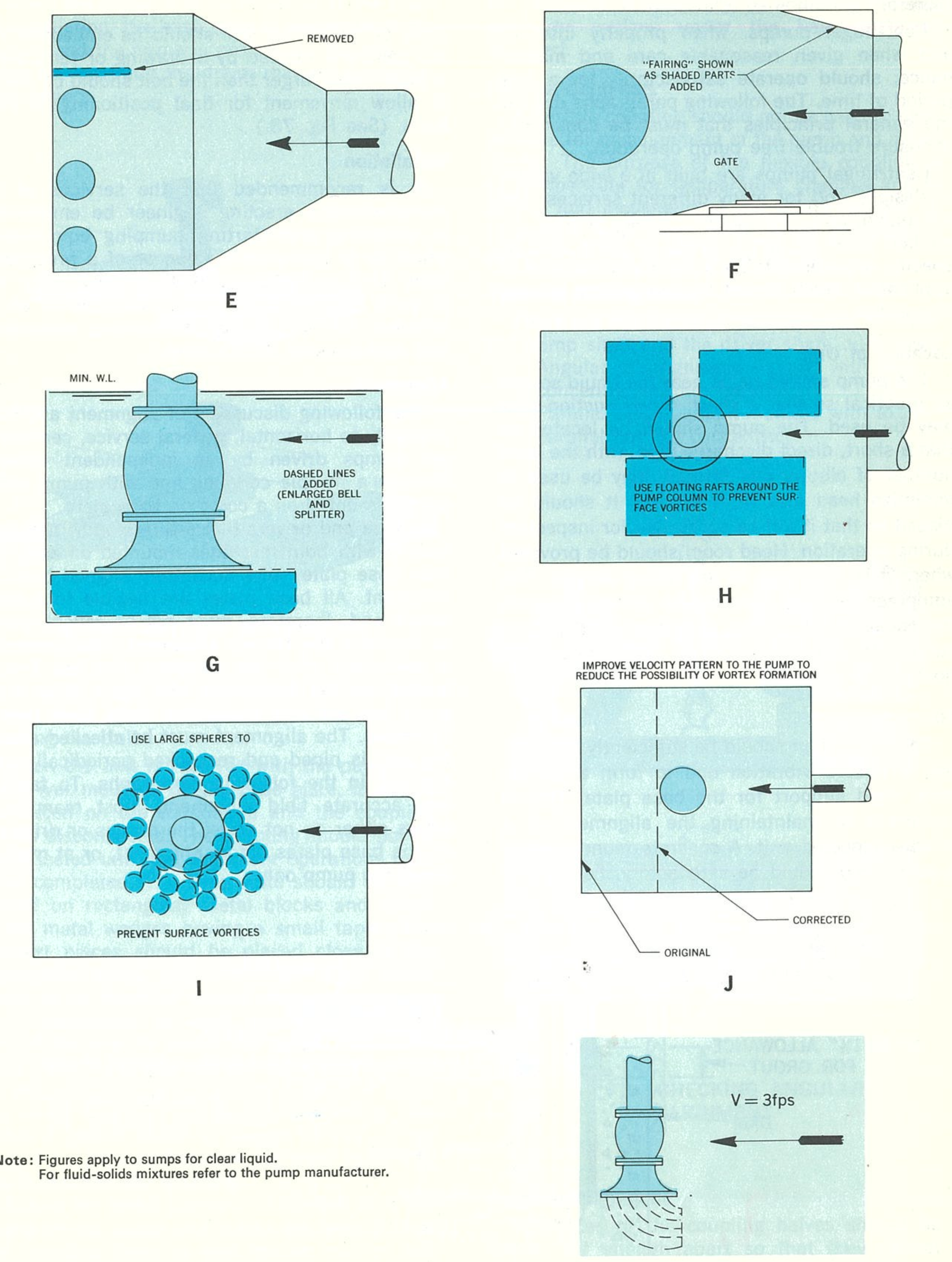


Fig. 72 CORRECTION OF EXISTING SUMPS



Note: Figures apply to sumps for clear liquid.
For fluid-solids mixtures refer to the pump manufacturer.

Fig. 72 CORRECTION OF EXISTING SUMPS, Cont.