United States
Environmental Protection
Agency

Research and Development

Risk Reduction
Engineering Laboratory
Cincinnati, OH 45268

EPA/600/SR-95/041 March 1995

EPA

Project Summary

Improvements in Pump Intake Basin Design

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Pump intake basins (or wet wells or pump sumps) designed in accordance with accepted criteria often pose many operation and maintenance problems. This report summarizes field surveys of 3 trench-type pump intake basins representative of 29 such basins that have been in satisfactory service for nearly 3 decades, large-scale (1:4) model studies made at the ENSR Consulting and Engineering hydraulic laboratory in Redmond, WA and at Montana State University in Bozeman, MT, and a full-scale basin study made at Fairbanks Morse Pump Corporation plant in Kansas City, KS. Field studies of three small, round pump inlet basins are also included. A considerable part of the report is devoted to recommended procedures and rules for intake basin design. The effectiveness of cones and vanes in reducing swirling (pre-rotation) is also reported, together with means for reducing or eliminating vortexing.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Background

Head-capacity curves for pumps are obtained by the manufacturer from a single pump operating in a semi-infinite pool with no nearby walls or floors and no stray currents. Hence flow into the pump suction is symmetrical with no vortices or swirling. Pumping station designers rely on these curves to define the operating conditions for pumps. But various constraints (size, cost, and storage time, for example) often require both the walls and the floor to be at a distance to the pump intake no greater than the diameter, D, of the intake. Consequently, flow toward the intake cannot be fully symmetrical and may not develop into symmetrical velocities in the throat of the intake.

Water usually enters a pump sump from a pipe or an open channel. Velocity is reduced as the flow expands in the basin, and, because rapidly expanding flow is unstable, localized rotation occurs and can develop into severe swirling. In many traditional or common designs (see Hydraulic Institute Standards [1]) the row of pumps is positioned normal to the inlet pipe so that the flow to all the pumps except the center one is asymmetrical. In some designs the incoming flow must make a 90° turn to reach the pumps. Unless the approach distances in both designs are long enough (a distance difficult to quantify), the water will be swirling before it reaches the pump intake. Swirling can, in fact, occur if the flow distribution toward the pump intake is even slightly off-center. Using traditional designs is no guarantee that the pumps will perform to the manufacturer's curves. Model studies to improve pump performance have been required even when traditional designs have been faithfully followed.

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Asymmetrical flow to an intake is likely to produce an asymmetrical velocity distribution in the throat. Such dissymmetry creates an excessive load on one side of the impeller, and stresses on shafts, bearings, and couplings. It can cause rough operation, vibration, and loss of head and capacity. Swirling changes the angle of attack on the impeller blade and also reduces head and capacity. Swirling in the approach can degenerate into vortices. Vortices also form as liquid separates from walls or floors. The pressure in the core of a vortex is reduced and can cause noisy operation and vibration. When a vortex is severe, it results in cavitation that quickly erodes metals.

Results and Discussion for Trench-Type Pump Intake Basins

a) General

A design that largely avoids asymmetrical flow to the intakes is shown in Figure 1. Note that both plan and cross-section views are symmetrical. The water jet from the inlet spreads and the velocity is diminished somewhat before the jet strikes the rear wall and returns, thereby setting up a recirculation pattern above the trench. Velocities along the floor of the trench are very small and water tends to enter the pump inlet more or less uniformly from all sides. Swirling is almost always within acceptable bounds and can be virtually eliminated by cones and/or vanes. Of course, vortices can form due to the proximity of walls and floors. But floor vortices can be eliminated with cones and diminished by vanes at the pump intake. Wall vortices can be diminished by vanes. In any event, vortices in trench designs are not more severe than they are in traditional designs.

b) Variable Speed Pumping

Trench-type intake basins are suitable for both variable speed and for constant speed pumps. In variable speed pumping, the objective is to match the pump output to the inflow so that no storage is needed. Therefore, the volume of the basin is of no consequence, and the only concerns are that the cross-section above the trench be large enough to accommodate the recirculation pattern, and that the length be great enough to accommodate the inlets and allow sufficient space around machinery for maintenance access. The water level is used to regulate the speed of the pumps (2) , and the normal operating water level is confined between the invert and the soffit of the inlet pipe (for variable speed pumping only).

c) Constant Speed Pumping

In constant speed pumping, the pumps are turned on and off, so some storage capacity is required while pumps are off. To avoid overheating motors by frequent starts and stops, the storage capacity is often rather large, and if the basin were to contain all the storage, it might have to be large, deep, and costly. However, by sloping the approach pipe from some upstream point at a downward gradient of 2% to the pump inlet basin over a distance of, for example, 70 m (200 ft), a normal operating water level fluctuation of 1.2 m (4 ft) can be obtained between low water level at the invert of the inlet and high water level at the upstream point. The storage in the pipe augments that in the basin. By making the pipe larger, the storage can be increased while the velocity down the approach pipe is limited to produce no more than a weak hydraulic jump when the flowing water contacts the level water surface somewhere between the upstream point and the invert of the inlet pipe. The report contains a table that provides acceptable flow rates versus approach pipe size. The sloping approach pipe has another unique advantage: it eliminates the cascade that occurs in traditional designs when the water level is below the inlet pipe. These cascades drive bubbles deep into the pool below, and pump intake currents often capture them and draw them into the pump with devastating effects on the capacity, head, and efficiency of the pump. In the trench-type inlet basin, air bubbles are not introduced into the sump.

d) Solids-Bearing Waters

Many waters (raw water, storm water, and sewage) contain solids that settle rapidly in traditional designs as the scouring velocity in the intake pipe falls to very low levels in the approach to the pumps. These solids can change the hydraulic characteristics of the basin appreciably, and if any organic material is present, can emit noxious and corrosive gases. Such solids can be removed from traditional sumps only with great expense and difficulty, and designs for solids-bearing waters are addressed in the Hydraulic Institute Standards (1) with the statement "Figures apply to sumps for clear liquids. For fluid-solids mixtures refer to the pump manufacturer."

In contrast, an enormous advantage of trench-type pump inlet basins is the ease and speed of cleaning them. Solids can be swept from trench-type basins in a few minutes at almost no expense and without manual labor. If the inflow is small, water for cleaning can be stored in the upstream pipe by shutting off all pumps. The sluice gate is adjusted to pass about 80% to 85% of the last pump's capacity. When enough water has been stored, all pumps are turned on at full capacity. As the water level in the basin drops, water running down the ogee spillway accelerates to supercritical velocity and forms a hydraulic jump that progresses rapidly downstream from the toe of the spillway, under the upstream pumps, and then to the last pump. All solids are swept up by the jump and carried to the last pump. During cleaning, the last pump is always operated at full speed, but because of the air entrained in the jump, it can only discharge about 85% of its normal capacity. By controlling the sluice gate opening, the jump can be made to go downstream at any desired velocity. Cleaning is normally accomplished in a minute or less after the jump forms at the bottom of the spillway.

Conclusions

The trench-type pump intake basin is eminently successful as has been demonstrated both with models and in the field over nearly three decades with pump sizes ranging from 63 L/s (230 m^3/h or 1,000 gpm) to 4.7 m^3/sec (17,000 m^3/h or 75,000 gpm). No such sump has ever required retrofitting, and no pump installed in one has failed to perform satisfactorily. The authors prefer this type over all others wherever applicable. But unless the designer has had experience with installations of larger sizes in trench-type sumps, this design should not be universally applied to pump sizes larger than 1,900 L/s (6,800 m^3/h or 30,000 gpm) without design-specific testing.

The full report was submitted in fulfillment of Contract No. CR-817937 by the Department of Civil Engineering, Montana State University, Bozeman, MT, under sponsorship of the U.S. Environmental Protection Agency

References

1. Hydraulic Institute. Hydraulic Institute Standards for Centrifugal, Rotary and Reciprocating Pumps, 14th Ed., Parsippany, NJ 1983.
2. Sanks, R. L. et. al., Pumping Station Design, Butterworth Heinemann, Newton, MA, 1989.

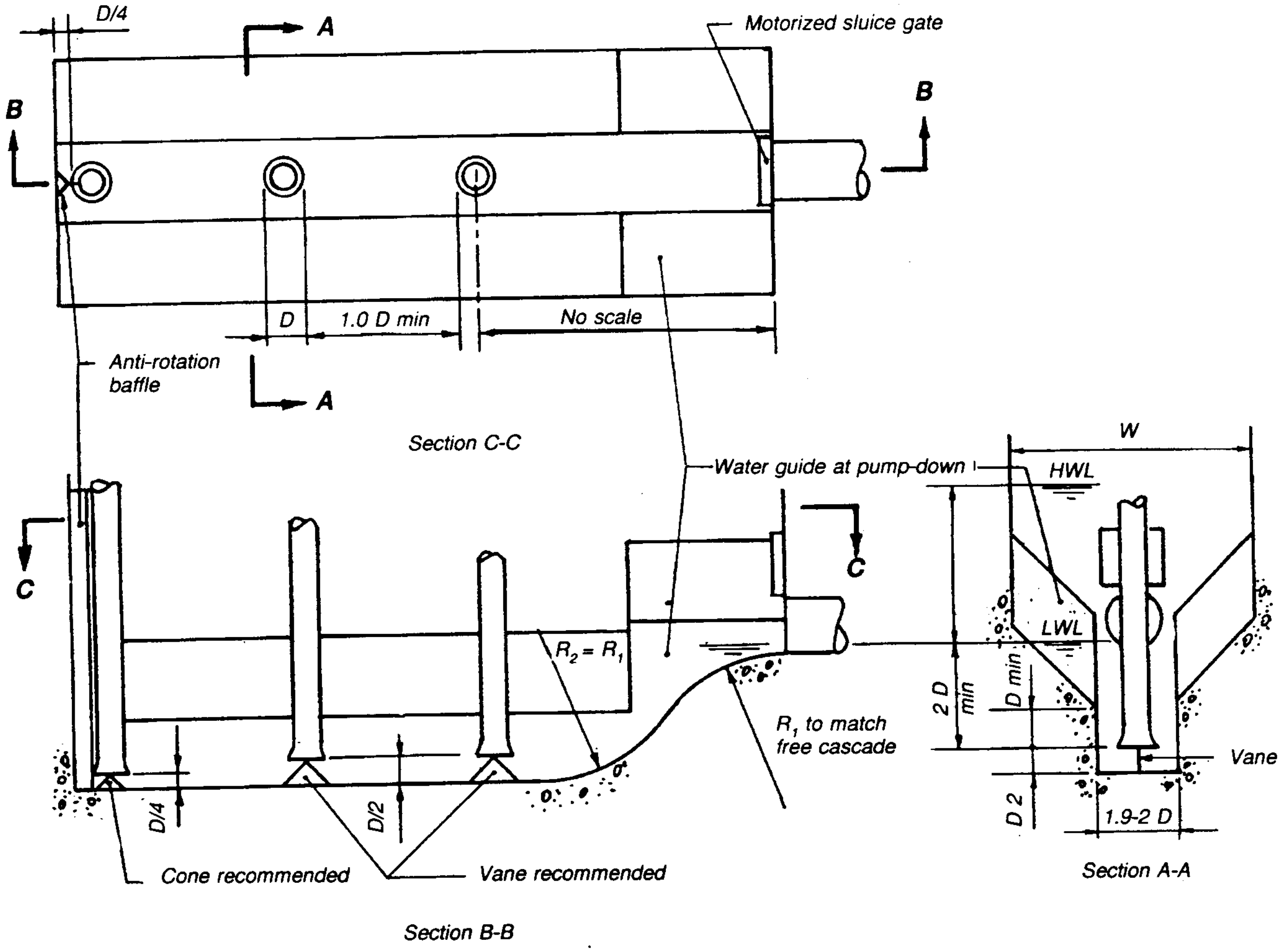

Figure 1. Rectangular sump for constant speed pumping and solids-bearing water. For variable speed pumping, high water level is at the top of the pipe. For clear water, omit the ogee spillway. Pumps can be column or dry-pit types or, with modifications, submersible.

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The complete report, entitled "Improvements in Pump Intake Basin Design," (Order No. PB95-188090; Cost: $19.50, subject to change) will be available only from:

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