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represents the best available information at hand, devoid of bias toward any particular product or point of view. Individual committees are required to document their deliberations and to invite public comment on draft standards as a part of the process. Responses to public comment are documented and made a part of the record. The results, although not necessarily representing the cutting edge of available technology, do represent the minimum in acceptable performance, and that minimum should be considered when any project is developed. The owner can certainly decide whether the standard should be used, but the engineer has an obligation to inform the owner of the perils faced by nonconformance, including the prospect that (1) the installation may not perform as desired, and (2) warranties may be voided.

This book is complementary to and compatible with these standards, and the presentation in this chapter not only follows ANSI/HI 9.8-1998 but also reflects: (1) experience gained through more than 45 years of designing pumping station wet wells, (2) information developed at the U.S. Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, (3) investigations at Montana State University at Bozeman, ENSR Hydraulic Laboratory in Redmond, Washington, Alden Research Laboratory in Holden, Massachusetts, and northwest hydraulic consultants in Seattle, Washington, and (4) full-scale tests at the Fairbanks Morse Pump Corp. plant in Kansas City—all of which have led to several publications [3, 4, 5, 6, 7].

### *Pump Inlet Conditions*

Undesirable features noted in many sump designs include:

1. A free fall (no matter how short) from the inlet conduit into the sump or pool below with the consequent entrainment of air in the liquid and (with wastewater) the release of odors. The air bubbles, easily captured by currents and carried into the pumps, cause loss of capacity and damage to the equipment. Air discharged into pipes promotes sulfuric acid production, and in unprotected concrete pipes the combination leads to collapsing sewers.
2. Piping with excessive velocities that cause unreasonable headloss and can lead to vibration problems due to turbulence in fittings and valves.
3. Abrupt changes in flow direction upstream from the pump inlet connection. In sumps, abrupt changes usually cause vortices. In intake manifolds and pump inlet piping, abrupt changes in direction may cause flow to become asymmetrical and thus overload pump shafts and bearings. Abrupt changes in flow direction are acceptable when the pump manufacturer (1) supplies the fitting as a part of the equipment, or (2) does not take exception to the presence of the fitting. Pump operation is probably not adversely affected in such circumstances.
4. Sump or inlet piping geometry that permits differential velocities and, thus, rotation of the fluid. With the slightest rotation, the spin increases as the water approaches the pump suction inlet. Swirling in the suction pipe may reduce the local NPSHA in the core to zero and thereby cause cavitation, noise, and rapid wear even though the average NPSHA is adequate. Swirling at the impeller changes the angle of attack of the flow to the impeller blades and shifts the pump curve, often drastically.
5. Horizontal velocities in sumps near the pump inlets that are too high. In general, such velocities should be less than 0.3 m/s (1 ft/s). Actual velocities usually differ greatly from calculated average velocities.
6. Interference between adjacent intakes. Space intakes no closer than 2.5 $D$ c-c (where $D$ is intake bell diameter). Also consider access clearance [1.1 m (42 in.) minimum] between adjacent machines.
7. Discontinuities such as corners without fillets and uneven distribution of currents caused by flow past pier noses that often result in the formation of air-entraining vortices. Although there is usually no surface indication, subsurface vortices may also occur, and they can be very damaging.
8. Stagnant areas in wastewater pumping station wet wells where velocities are too low to prevent the deposition of the putrescible solids in wastewater. Velocities of about 0.3 m/s (1 ft/s) are enough to keep organic solids moving, whereas velocities in excess of 0.5 m/s (2 ft/s) are required to keep grit moving. After organic material and grit are deposited, velocities in excess of 1.6 m/s (5 ft/s) are required to move them with reasonable celerity.

See Section 27-6 for a discussion of wet well failures in which the designer did not follow the above advice.

The water velocity into pump intakes recommended in ANSI/HI 9.8-1998 is given in Table 12-1. However, the authors recommend the velocity be limited to about 1.1–1.2 m/s (3.5–4.0 ft/s). This rec-

- As the source of project information for producing detailed drawings and specifications
- For control of project information and changes
- For cross-checking and final document coordination
- As a means of communication between project disciplines.

P&IDs are also useful (1) as control documents during construction, (2) as aids in personnel training, and (3) for the operation of the facility.

### *Structural Considerations*

At this stage in the process, recommendations from the project geotechnical engineer should be available to the project structural engineer. It is now time to make important decisions regarding construction methods. A detailed station layout is not necessary at this time, but a rough idea of station dimensions and loads is necessary.

Later in the detailed layout stage, the structural engineer should again be consulted about the thickness and placement of walls and slabs, although structural design should not commence until the next stage.

### *Sump Design*

Extreme caution should be exercised in the sump design, particularly as it relates to inlet conditions. A poor design will very likely result in an inability to develop the intended capacity of the pumps, contribute to or cause severe damage to the pumping equipment, and result in shortening the useful life of the station. A comprehensive discussion of sump and pump intake design is located in Sections 12-3 and 12-5 to 12-8. The authors recommend improved self-cleaning wet wells for all wastewater pumping stations.

Details of some successful sump designs for large, moderate-size, and small pumping stations are shown in Sections 17-5, 17-6, and 17-7, respectively, but improved wet well designs as exemplified in Figures 12-3, 12-16, 12-23, and 12-31 should be used instead. The method of construction may influence the sump design, for example, as in the Duwamish Pumping Station where a caisson was used to construct the station substructure. A good sump and inlet design must have the following:

- Minimal turbulence and no influence from the incoming sewer, such as a cascade that might entrain air in the liquid and, therefore, into the pumps and force main. Avoid cascades preferably with an approach pipe (see Section 12-7) or, at worst, a drop pipe or a drop manhole. The entrance velocity into the sump should not significantly exceed 1.1 m/s (3.5 ft/s).
- Conservative values of NPSHA (see Figure 10-13 and text in Section 10-4) obtained by a suitable elevation of the pump relative to the LWL plus suction pipe velocities limited to about 2.4 to 3.4 m/s (8 to 11 ft/s) for keeping headlosses low.
- Suppression of vortices by (a) good geometry, (b) sufficient pump intake submergence as determined by Equation 12-1 (see also Dicmas [5]), and (c) the addition of cones under water pump intakes or flow splitters under wastewater pump intakes and fillets in corners to eliminate or reduce them. (See Figures 12-3, 12-14 to 12-16, and 12-19 to 12-21 for design details.)
- Adequate pump intake velocities for removing solids and, at the same time, for obtaining a good hydraulic environment for the pumps. See Table 12-1, but be aware that the author and editors consider 1.5 m/s (5 ft/s) to be a near-maximum velocity and not a target. All of the pumping stations in Sections 17-5 and 17-6 were designed for a maximum of 1.1 m/s (3.5 ft/s) intake velocity, and they have performed very well.

### *Pipeline Orientation*

The relative positions (vertical as well as horizontal) of the incoming sewer or sewers and discharge pipelines can influence the station layout. However, avoid undue influence in this regard. The principal cost savings in the project are realized by making the pump room and sump layout as efficient as possible, by saving excavation and structure costs, and by the smaller cost of ventilation and lighting. Thus, for the price of a manhole or bend or two, significant cost savings in the pumping station can often be realized. Efficient pump room layout is a key factor in owner satisfaction.

### *Pump Room Layout*

The efficiency of the pump room layout, as suggested previously, has a great effect on the overall cost of the project. Used in this context, *efficient* or *efficiency* means conserving room or structure plan dimensions without sacrificing optimum machine performance or personnel access for operation and maintenance of the equipment. The following are some guiding considerations: