Design Recommendations

PUMP AND PIPE MECHANICAL INSTALLATION GUIDELINES

FLYGT
a xylem brand

Contents

These design recommendations are intended to assist pump station designers, planners, application engineers, consulting engineers, and users of pump stations incorporating Flygt pumps from Xylem. Recommendations for both wet pit and dry pit installations are covered to ensure a reliable installation with minimal noise and vibration. This includes requirements for the fixing of the pump and the connecting pipes, factors affecting sound and noise levels, and recommendations when special considerations should be taken.

Please see pump sump design recommendations for optimal hydraulic conditions. These design recommendations contain the layout and benching details to avoid air entrainment, vorticity, swirl, etc., which can instigate vibrations and noise.

Please consult our engineers to achieve optimum performance and life of the installation. If further anchor bolt analyses are needed, please contact Xylem for a Flygt Engineering Tool, FET, Anchor Bolt Load calculation. The design recommendations are only valid for Xylem equipment. We assume no liability for non-Xylem equipment.

Introduction

Proper installation and anchorage of Flygt pumps and installation accessories is critical to limiting vibration and achieving reliable, trouble free operation. It is important to remember that all piping, fittings, and supports that are mechanically connected to a pump are all part of a single system. Vibrations are unavoidable when a mass, such as a rotor assembly, is turning at high speeds. The rotating mass of a Flygt motor, together with forces from the motor and the hydraulic end, will generate an intrinsic set of disturbance or "excitation" frequencies that are related to the speed of the motor (unbalance and blade pass are the two most important frequencies affecting vibration). When these frequencies coincide with a natural frequency of the system, vibration levels will increase substantially. The likelihood of this occurring is increased for variable speed applications where the pumps can operate over a range of speeds rather than a single constant speed. Most variable frequency drives have the option to exclude certain frequency ranges to avoid regions of high vibrations.

In addition, proper anchorage and support is critical to minimizing vibration. In vertical installations, the tall unsupported mass of the vertical motor exacerbates vibration levels at the upper bearing caused by imbalance, poor installation quality, or hydraulic disturbances – more so than in horizontal installations. Therefore, eliminating system resonances and ensuring high quality installation in vertical Flygt pumps is critical to achieving a smoother running installation.

The following recommendations are consistent with industry standards and are generally accepted as good design practices for concrete anchorage of rotating equipment. These recommendations can be applied to all Flygt pump installations, but specific emphasis is placed on vertical, dry pit installations. Failure to follow these good design and construction practices may result in higher levels of noise and vibration than desired. A licensed civil engineer should be consulted for specific construction design details for each individual installation.

Vibration

Flygt pumps from Xylem are manufactured to be of the highest quality to ensure compliance with ISO vibration test standard 10816-1 and Hydraulic Institute submersible pump test standard 11.6 for factory vibration tests. Although the pump itself can withstand rather high vibration levels (three or four times the actual limit) under running condition without noticeable lifetime reduction, the piping and support structure may suffer and crack if vibration levels are too high. It should be noted that pumps at a standstill are more sensitive to vibrations than when they are operating. To ensure acceptable vibration levels in the field, all parts of the system should be sufficiently stiff and firmly anchored so that the primary disturbances have frequencies below the lowest natural frequency of the system. The following recommendations should be followed to ensure a firmly anchored system:

1. Anchor the piping to the floor or another solid structure (see Piping Support).
2. Anchor the pump firmly to the floor, concrete base or concrete pedestals (see Anchor Recommendations).
3. Concrete pedestals are an integral part of the installation and should be designed to resist vibrations through proper reinforcement and dimensioning (see Concrete Foundations).
4. For extreme vibrations consider attaching a brace to the top of the pump (tall dry installed pumps).

A non-return valve and an air release valve should also be included in the installation. These are omitted for clarity in the drawings.

If weak parts like bellows are used, they must be firmly attached at both sides unless a more advanced soft installation is desired (see Soft Installation Alternative for further recommendations on this type of installation).

Piping support

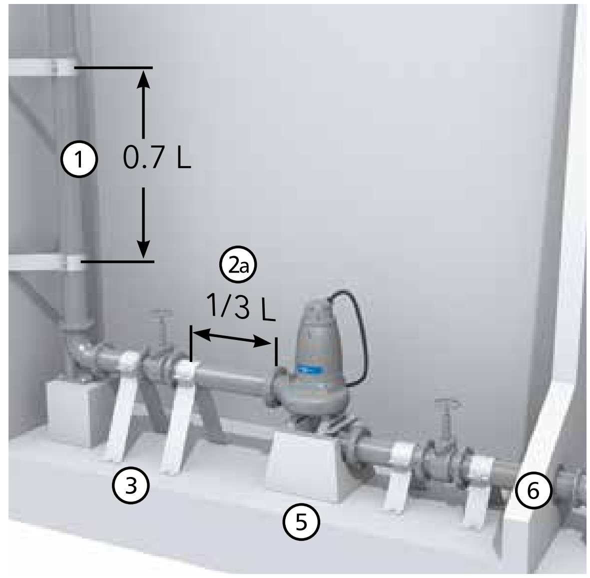
Flygt pumps will generate disturbances that are transmitted to the adjoining pipe and structure through mechanical connection of the piping and the installation structure. Pump speed (imbalance) and blade pass (hydraulic forces) typically are two frequencies at which disturbances can occur. These frequencies can be used to estimate the critical pipe length; i.e. the natural bending frequency of a pipe filled with liquid.

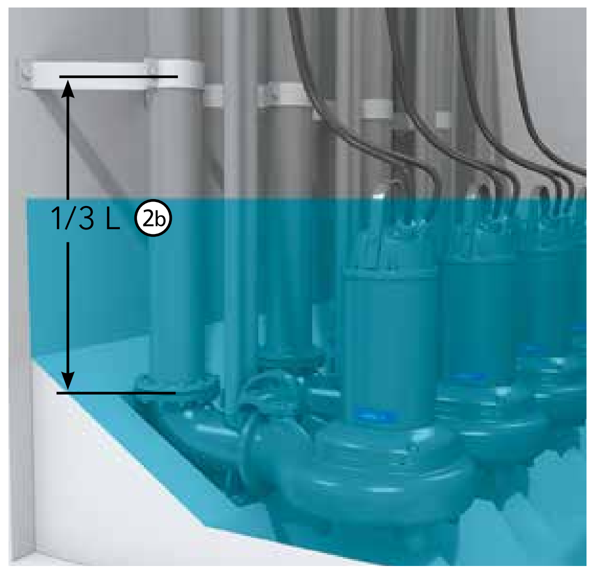
1. Xylem recommends that the distance between pipe supports be set at 70% of the critical length (see Calculation of critical pipe length) for the first mode.

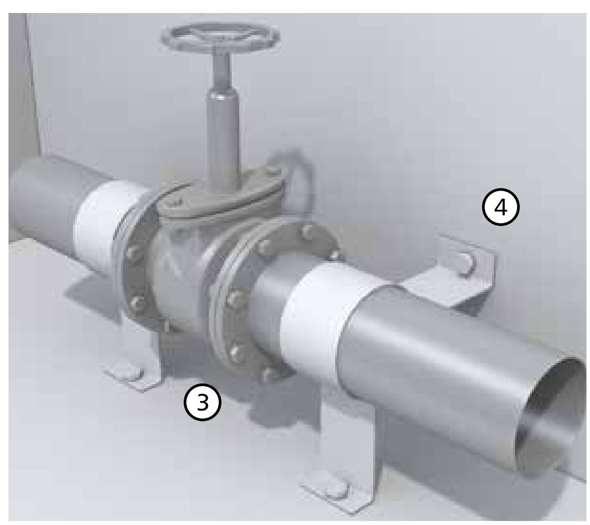
2a. It is also recommended that pipes should have a support located at a distance of 1/3 of the critical pipe length from the pump.

2b. Support can be required in deep sumps; check the critical length.

3. Heavy parts of the piping system, such as valves, must be properly supported. Gate valve, non-return valve (NRV), and pipe up to the NRV should all be supported to allow for the removal of the NRV without loading the adjacent pipe work.
4. Because vibrations are independent of gravity, horizontal supports should be included since they are as essential as vertical supports. Thermal elongation has to be accounted for.
5. The anchorage must be able to safely absorb and withstand the pump shut off pressure thrust load, especially for a long pipe and possible water hammer loads.
6. Piping should be supported by the surrounding structure and not by couplings or pump flanges.







Please ensure that the structure allows easy mounting and removal (details omitted for clarity).

All the pictures above show examples with Flygt pumps

Concrete foundations

1. Concrete pedestals should be reinforced. Reinforcement should mesh with the floor rebar when possible.
2. Pedestal overall height (concrete and grout) should be as low as possible but should allow for proper piping alignment and clearance of suction piping with the floor (see Detail E).
3. Pedestal length and width should be sufficient to meet civil engineering design standard and local codes.
4. Opening between pedestals should allow for proper clearance of the inlet elbow flange at the pump suction.
5. Access to suction elbow and pump mounting bolts should be considered.
6. The foundation and concrete must be of adequate strength to support the weight of the pump with its accessories, plus the weight of the liquid passing through it, and the forces generated by the pump.
7. Consult a registered civil engineer for specific design details.

Anchor recommendations

1. Chemical anchors can be used to anchor Flygt pumps, but the bond can degrade over time and is more elastic than a mechanical anchor. Mechanical cast-in-place anchors meshed with re-bars in concrete are the most robust alternative and are recommended for large dry (vertical) pump installation.
2. The anchor's length required for pre-stressing should be well protected to prevent bonding (heat shrink, wax, or heavy grease) with the concrete or grout.
3. Finally, apply the specified torque in 3 steps – 33%, 66%, and 100% of max torque. At each step, torque all bolts before starting the next step, in an opposing pattern.
4. It is recommended to check the anchor bolt torque for pre-stress relaxation after completion of the initial pump start up test runs. If pre-stress relaxation has occurred, the torque should be re-applied as above. If correction was required after startup test runs, check again after 50 hours of pump operation, and repeat this process every 50 hours of operation until pre-stress relaxation stops.

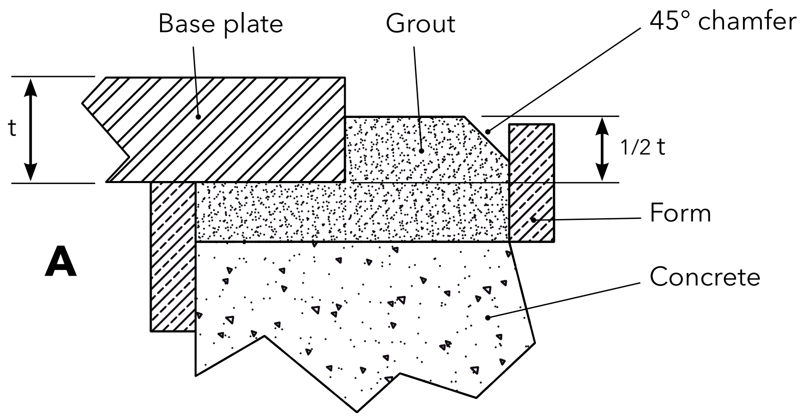
Pump attachment

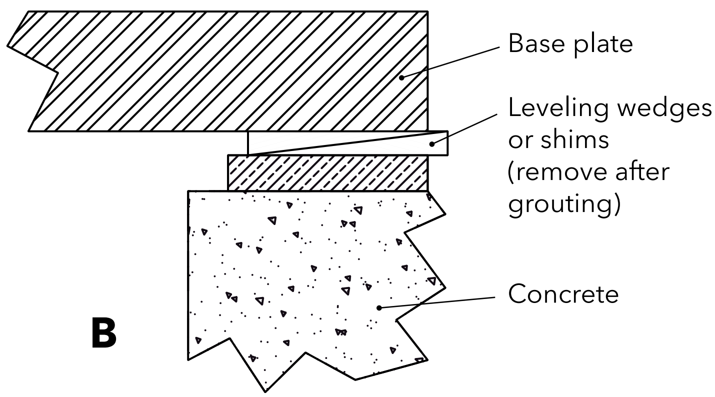
Ensure contact on the entire length of the base to the concrete foundation. Local leveling devices such as washers are not allowed, as this can make the base partly unsupported.

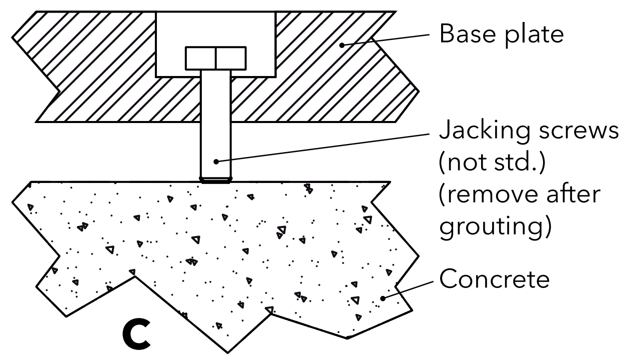
If leveling and grouting is needed:
1. Install and level the mounting plate (or base) only (without the pump) using steel blocks and leveling wedges (see Detail B). Steel blocks, leveling wedges, and anchor bolts should be coated with light oil just prior to leveling and grouting.
2. Pre-stress all anchors (lightly torque) after leveling and prior to grouting. Re-check level prior to grouting.
3. Leveling nuts on the anchors should NOT be used since the anchor will not be properly pre-stressed into the concrete/grout foundation.
4. Leveling shims and blocks should be as small as possible and placed as far as possible from the anchors such that the voids do not impair the grout strength after the shims' removal. An alternate solution would be the addition of threaded holes for jackscrews in the plate (not standard) and use the jackscrews for leveling (see Detail C). Leveling equipment should be removed and the voids filled with grout to allow full support of the mounting plate.
5. Thickness and application of grout should be per the grout supplier's recommendations.
6. The grout around the plate should be poured to approximately ½ of the plate thickness (t) so that some head is developed and the grout will contact all areas under the plate without voids (see Detail A).
7. Blockouts shall be provided at all leveling positions to allow for removal of leveling equipment after grout has cured. Voids should be filled with grout after leveling equipment is removed.
8. A 45 degree chamfer should be located at the final elevation of the grout.

See also Installation, Operation and Maintenace Manual and the dimensional drawings.

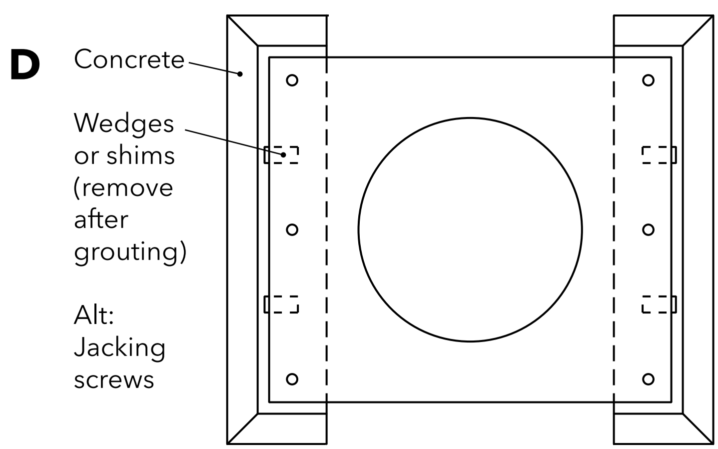
Leveling and grouting details







Concrete foundations for T pump installation



Concrete foundations for T pump installation

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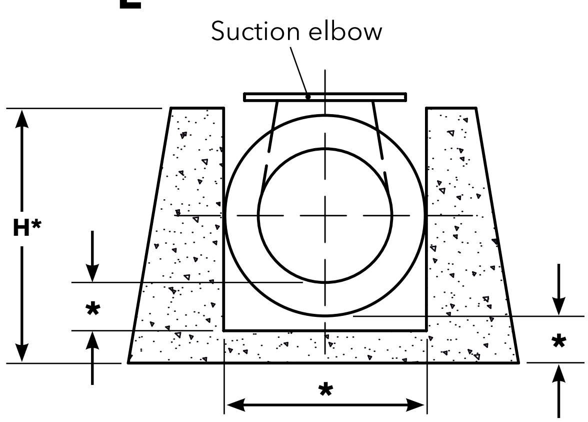
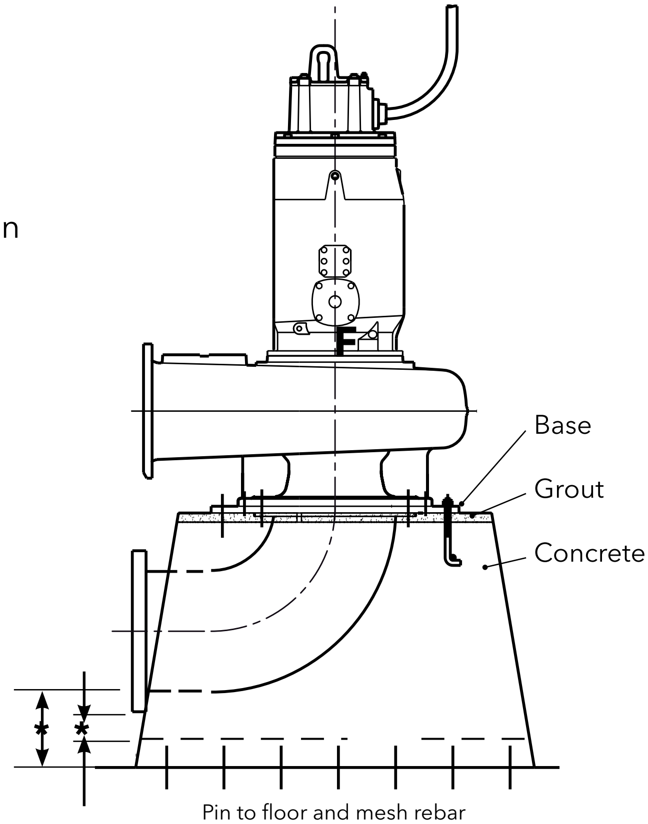


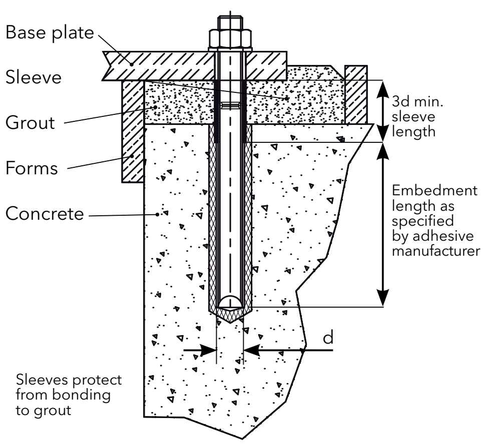
*** =minimum required for piping/elbow installation**



P or Z pump installation using chemical/epoxy anchors ref figure G

T pump installation on a new base (heavy duty) ref figure H and I

G



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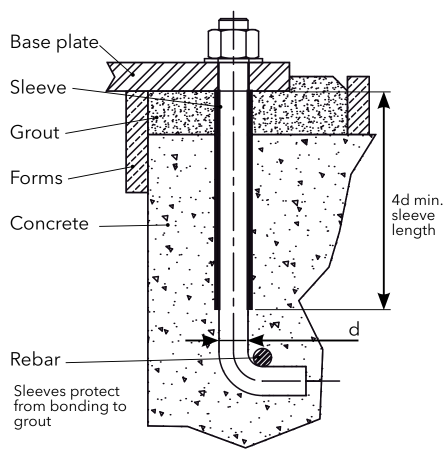

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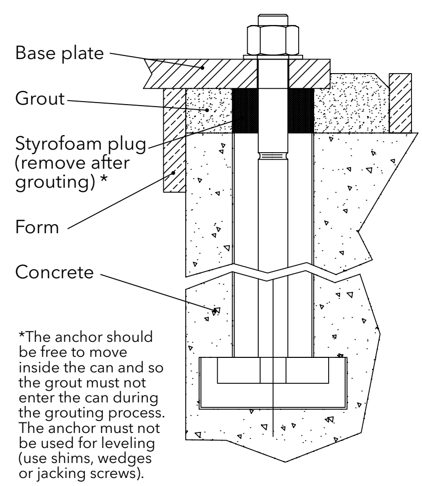


Soft installation alternative

It may be necessary in some cases to explore alternative methods of installation. For example, natural frequencies may exist that make it difficult or impossible to adequately reduce vibration levels. Variable speed applications are far more likely to experience these problems due to the wide range of pump frequencies. If system resonance cannot be resolved by adding stiffness or mass to the system or if resonance is predicted through system analysis, then it may be necessary to modify the pump installation in the following manner:

1. Provide vibration isolation (bellows or flexible joints) at the pump suction and discharge flanges.
2. Provide adequate support of piping immediately adjacent to these joints.
3. Provide a concrete base of at least 2x the mass of the pump and motor.
4. Anchor the Flygt pump firmly to the base.
5. Provide machine feet or rubber carpet between the base and the floor of adequate dimensions.
6. Please note that the force from the fluid pressure has to be supported.

The piping must be well anchored if flexible joints are used. Flexible joints between the pump and pipe can transform pressure fluctuations into disturbances, causing severe vibrations in the piping. Be aware that new modes of motion may occur that have to be handled. Soft installation is difficult to design and proper analyses are vital in order to have a good result. Because of this, Xylem recommends this type of installation only be designed by an experienced civil engineer.

Calculation of critical pipe length (L)

$$L = \sqrt{\frac{k\,\pi^2}{4\,\omega}}\left(\frac{E\left(D_y^4 - D_i^4\right)}{\rho\left(D_y^2 - D_i^2\left(1-\frac{\rho_m}{\rho}\right)\right)}\right)^{1/4}$$

Where:

L = critical pipe length based on natural frequency (ft)

k = $(n + x)^2$ where:

n = mode or order, 1 for first mode

x = 0 if simply support ends
- 0.25 if one end fixed
- 0.50 if both ends fixed
- -0.50 if cantilever beam

ω = frequency (rad/s) e.g. blade pass, motor speed, etc.

E = Young's modulus (psi)

Dy = pipe outer diameter (in)

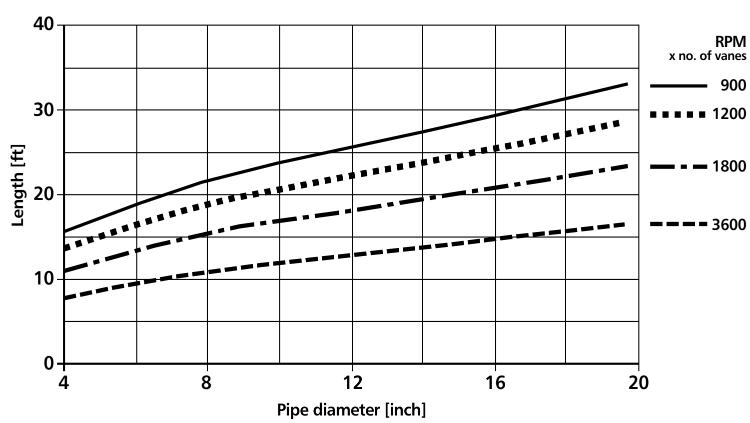
Di = pipe inner diameter (in)

ρ = pipe density (lb/in^3)

ρ_m = density of added mass, e.g. water (lb/in^3)

1 m = 39.36996 inch = 3.28083 ft
1 rad/s = 0.159155 r/s = 9.5493 rpm
1 N/m^2 = $145.04 \cdot 10^{-6}$ PSI
1 kg/m^3 = 0.06243 lb/ft^3 = $36.1273 \cdot 10^{-6}$ $lb/inch^3$

Critical length distance between supports



This graph shows an example with critical lengths for different pipe diameters and RPMs x no. of vanes typical for 60 Hz. The pipe is assumed to be fixed in one end (x=0.25) and densities are assumed as for water and a steel pipe. The pipe wall thicknesses are 4 mm (Dy 4"), 6.3 mm (Dy 8"), 7.1 mm (Dy 12"), 8.8 mm (Dy 16") and 12 mm (Dy 20")

Noise

Sound is the result of pressure changes in the air. Undesirable sound is usually referred to as noise. Pressure changes can be transmitted to the air from a vibrating structure resulting in noise. The better the transmission from the vibrating surfaces to the air, the higher the sound levels will be. Structure borne vibrations can travel some distance before becoming airborne and audible. Liquid born pressure fluctuations can also travel very far before causing the structure to vibrate and generate noise. Consequently, the source of the vibrations causing the noise are not necessarily in the same location as the noise itself.

Sound pressure (Lp) measured in dBA gives more weight to frequencies where the human ear is more sensitive (noted A-weighted). Therefore, dBA is the most appropriate scale of measurement when evaluating noise within a pump room.

The noise from the pump is normally given as the sound power level (Lw). The sound pressure (Lp) in a certain position is determined by distance and positioning of the source together with the acoustical properties of the room. When evaluating the source of pump noise, it is important to remember that disturbances generated from the electrical motor, cavitation, and other flow induced vibrations make important contributions to the sound level.

The recommendations made previously to reduce vibrations are also helpful with respect to noise. The recommendations given below also apply.
Xylem provides guidelines for items 1, 2, 3, and 4 in the Design recommendations for pump stations with large centrifugal wastewater pumps brochure.

1. Operate the pump close to the best efficiency point.
2. Net positive suction head requirements must be met, preferably with a substantial margin.
3. Inlet conditions from the sump and/or suction piping should be well designed from a hydraulic point of view.
4. Fluid induced vibrations in pipes can be held at low levels by avoiding sharp bends, especially if they are located close to valves.
5. Mechanically transmitted vibrations can be diminished by a soft installation as earlier described.
6. Liquid borne pressure fluctuations in the pipe can occur at high head conditions with impellers having a low number of vanes (pulsations due to blade pass). This can be a nuisance in residential areas. It can be decreased by adding pressure pulsation dampers. Please discuss adequate measures with a vibration consultant.

In addition to the above, to reduce the noise in the pump room you may need to implement several of the following measures, all involving recommendations from a vibration consultant:

1. Add acoustic absorption material on the roof and walls to lower the reverberant sound which, apart from very close to the pump, normally dominates.
2. Add acoustic dampening material to the pipes and other sound emitting surfaces to lower the sound pressure level.
3. Add a sound cover or shield around or in front of the pump. Be careful not to inhibit the effectiveness of the motor cooling surfaces.

To reduce the noise transmitted to the environment outside of the pump room you may also need to:

1. Avoid transmittance to the weak parts of the building structure via rigid connections of piping, valves, etc. Use rubber bushings or similar device between piping or supports and weak walls.
2. Avoid open channels, such as ventilation ducts, out of the room with the source of noise.

Noise can never be totally avoided and is also a matter of perception, although well designed stations may keep the noise to acceptable levels.

Noise increases with deviation from best efficiency point, particularly at run out flows.

Explanations

Blade pass frequency
The number of the impeller vanes multipled by the speed frequency of the pump (the frequency of blades passing the outlet).

Harmonics
Harmonics is an integer multiple of the fundamental frequency of a signal. For example, if the fundamental frequency is f, the harmonics have frequency 2f, 3f, 4f, etc.

Young's modulus
A measure of the stiffness of a material.

Material	Young's modulus [ksi]
Steel	3050
Cast iron (ASTM A-48)	1600
Nodular iron	2470
HDPE (High density Polyethylen)	120

Natural frequency
All structures have frequencies that are easily excited, their natural frequencies or resonant frequencies. When you hit a structure with a short pulse that contains all frequencies, the structure will vibrate with its natural frequencies.

System resonance
A small force of a frequency close to the natural frequency of a structure causes very high, often hazardous, vibrations. This phenomena is called resonance.

System engineering

Xylem offers in-depth expertise in the design and execution of comprehensive solutions for water and wastewater transport and treatment. Our know-how and experience are combined with a broad range of suitable products for delivering customized solutions that ensure trouble-free operations for customers. To do this our engineers utilize our own specially developed computer programs, as well as commercially available programs, for design and development projects.

Scope of assistance includes a thorough analysis of the situation and proposed solutions, together with selection of products and accessories.

We also provide hydraulic guidance and assistance for flow-related or rheological issues. Customers turn to us, as well, for analysis of complex systems for network pumping, including calculations for hydraulic transients, pump starts, and flow variations.

Additional services:

- Optimization of pump sump design for our products and specific sites
- Assistance with mixing and aeration specifications and design of appropriate systems
- System simulation utilizing computational fluid dynamics (CFD)
- Guidance for model testing
- Guidance for achieving the lowest costs in operations, service, and installation
- Specially developed engineering software for system design

The range of services is comprehensive, but our philosophy is very simple: There is no substitute for excellence.

Xylem |'zīləm|

1) The tissue in plants that brings water upward from the roots;
2) a leading global water technology company.

We're 12,000 people unified in a common purpose: creating innovative solutions to meet our world's water needs. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. We move, treat, analyze, and return water to the environment, and we help people use water efficiently, in their homes, buildings, factories and farms. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise, backed by a legacy of innovation.

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