Vertical Turbine Pump Basin Design

Sump Design:

A thorough examination of this subject is beyond the scope of this session, however there are points that can be addressed in the time allowed. Recommendations in this presentation follow guidelines set forth by the Hydraulic Institute, Section 9.8.

Many sump installations require a multiple pump intake structure. This is common for industrial makeup water, cooling tower applications and fire pumps. The pumps are usually horizontal end suction, split case double suction or vertical turbine pumps.

Cooling Towers In Healthcare

Cooling is especially important in hospitals and medical centers.

- Hospitals require an ambient temperature of 72^{o}, 24/7.
- Patient comfort is top priority.

Turbine Pumps provide:

- Proven pumping option used in healthcare facilities worldwide.
- Low cost dependable solution for pumping condenser water.
- Long life cycle 8 to 12 years.
- Condenser water can be pumped and controlled efficiently.
- Reliable operation with no priming required.

According to the Hydraulic Institute:

Ideally, the flow of water into a pump should be uniform, steady and free from swirl and entrained air. Lack of uniformity can cause the pump to operate away from the optimum design conditions and at lower hydraulic efficiency. Unsteady flow causes the load on the impeller to fluctuate, which can lead to noise, vibration, bearing problems and fatigue failures of pump shafts.

Sump Design:

The design objective for a multiple pump intake is:

- To ensure that each pump is allowed to receive the design flow rate.
- To ensure that the flow is in a straight line as it enters the pump suction.
- Avoid the formation of vortex allowing air to enter the pump and system.

Design Objectives

Specific hydraulic phenomena have been identified that can adversely affect the performance of pumps. Phenomena that must not be present to an excessive degree are:

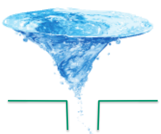
- Submerged vortices
- Free surface vortices
- Pre-swirl magnitude and fluctuation with time
- Non-uniform distribution of velocity in space and time at the impeller eye
- Entrained air or gas bubbles

Vortex Types

Incoherent Surface Swirl

Surface Dimple with Coherent Surface Swirl

Surface Dimple with Coherent Surface Swirl



Fully Developed Vortex Pulling Air Stream Into Intake

Design Objectives

- Avoid cross flow patterns of the intake that create an asymmetric flow pattern approaching any of the pumps.
- Cross-flow velocities should not exceed 50% of the sump entrance velocity.
- Pumps designed for flows exceeding 5,000 gpm must have dividing walls between each pump in the system.

Intake Structures for Clear Liquids

The characteristics of the flow approaching an intake structure are among the most critical considerations for the designer. When determining direction and distribution of flow at the entrance to a pump intake structure, the following must be considered:

Intake Structures for Clear Liquids

- The orientation of the structure relative to the body of supply liquid.
- Whether the structure is recessed from, flush with, or protrudes beyond the boundaries of the body of supply liquid.
- Strength of currents in the body of supply liquid perpendicular to the direction of approach to the pump.
- The number of pumps required and their anticipated operating combinations.

Recommendations for Dimensioning Rectangular Intake Structures

Basic design requirements for satisfactory hydraulic performance of rectangular intake structures include the following:

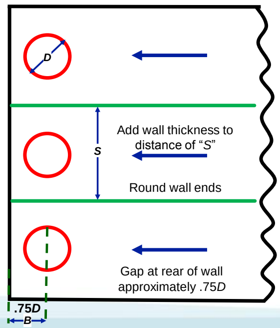
- Adequate depth to limit velocities in the pump bays and reduce the potential for formulation of surface vortices.
- Adequate pump bay width, in conjunction with the depth, to limit the maximum pump approach velocities to 1.5 ft/s, but narrow and long enough to channel flow uniformly toward the pumps.
- Pumps should NOT be lined up in a narrow channel in the direction of the flow path. The final pump in the channel would not receive as much flow as the first pump in the channel.

Design Guidelines
Turbine Pump Concrete Sump

(based on Recommendations from HI 9.8)

- Pump bay inlet velocity should be 1 foot per second (maximum 1.5 foot per second)
- Specify sump dimensions in multiple of pump bell diameters "*D*"
- Dimension "B" between pump centerline and back wall is ".75*D*"
- Inlets for each pump should be minimum "2*D*" between walls
- Sump floor needs "5*D*" from pump centerline to a break or abrupt change
- Angle of sump changes should not exceed 10 degrees
- Distance between the inlet bell and floor should be .3*D* to .5*D*
- Normal low water level is "*S*" minimum pump submergence plus floor clearance
- Low level alarm should be installed

Design Guidelines
Turbine Pump Concrete Sump



- "*D*" dimension is the diameter of the suction bell measured at the inlet.
- Minimum 2*D* for each pump inlet between walls
- "*S*" dimension is 2*D* plus divider wall thickness
- Flow velocity, *V*, not exceed 1½ fps maximum
- Dimension "*B*" should be .75*D* as shown to back wall

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Design Guidelines
Minimum Submergence

(based on Recommendations from HI 9.8)

- Minimum submergence "*S*" is required to prevent strong air core vortices is based in part on a dimensionless flow parameter, the Froude number, defined as:

$$F_D = \frac{V}{(gD)^{0.5}}$$

- Where:
  - F_D = Froude number at *D* (dimensionless)
  - *V* = Velocity at suction inlet = Flow/Area, based on *D*
  - *D* = Outside diameter of bell or inside diameter of pipe inlet
  - *g* = gravitational acceleration

Consistent units must be used for *V*, *D*, and g so that F_D is dimensionless. The minimum submergence *S* shall be calculated from where the units of *S* are those used for *D*.

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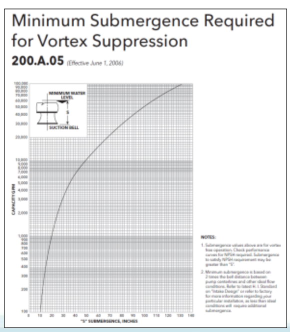
Design Guidelines
Minimum Submergence

- Many pump manufacturers offer minimum submergence "*S*" recommendations



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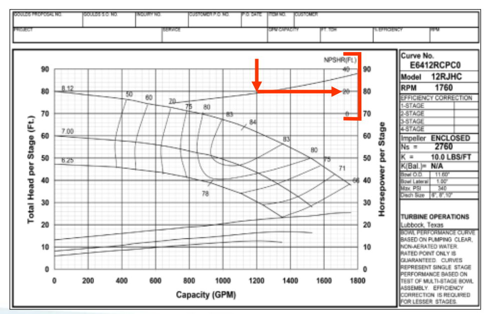
Net Positive Suction Head (NPSH)



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Net Positive Suction Head (NPSH)

NPSH (Net Positive Suction Head) is the total suction head in feet of the liquid being pumped (at the centerline of the impeller eye) less the absolute vapor pressure of the liquid being pumped.

$$NPSHA = h_a - h_{vpa} \pm h_{st} - h_{fs}$$

Where:

h_a = absolute pressure (in feet of liquid being pumped) on the surface of the liquid supply level (if open tank, barometric pressure); or the absolute pressure existing in a closed tank

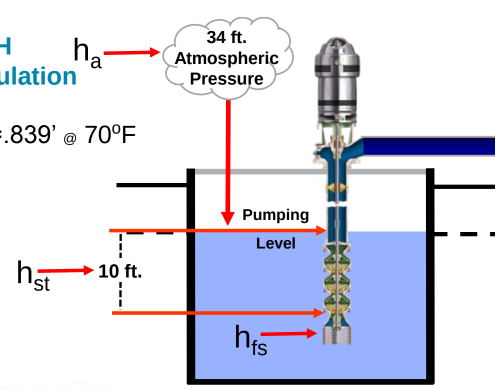
h_{vpa} = the head in feet corresponding to the vapor pressure of the liquid at the temperature being pumped

h_{st} = static height in feet that the liquid supply level is above or below the pump centerline or impeller eye

h_{fs} = all suction losses (in feet) including entrance losses and friction losses through pipe, valves, and fittings, etc.

NPSH Calculation

h_{vpa} = .839' @ 70°F



$$NPSH_A = h_a - h_{vpa} + h_{st} - h_{fs}$$

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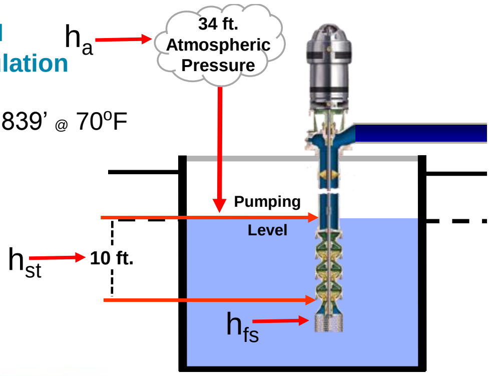
NPSH Calculation

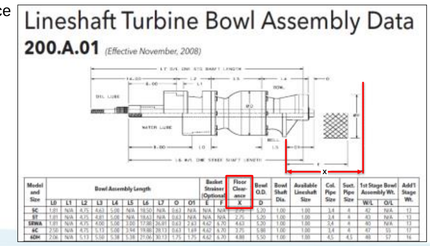
h_{vpa} =.839' @ 70°F



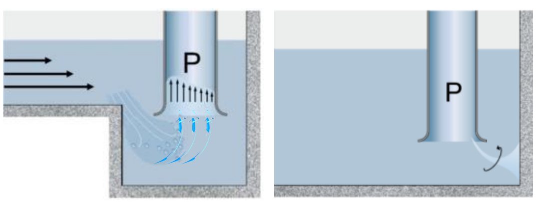
43' = 34' - .839' + 10' - 0'

Design Guidelines Floor Clearance

- The pump manufacturer can make recommendations for floor clearance



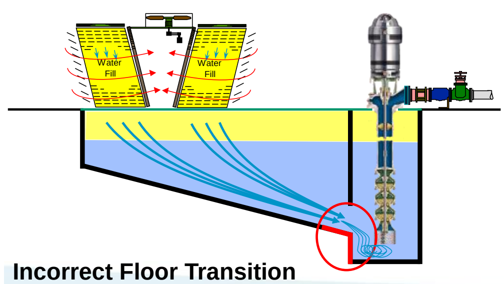
Angle of sump changes should not exceed 10°



Maximum sump velocity of 1 ft per second. Minimum "5D" inlet distance before a sump break. Back wall ".75D" distance to pump center line.

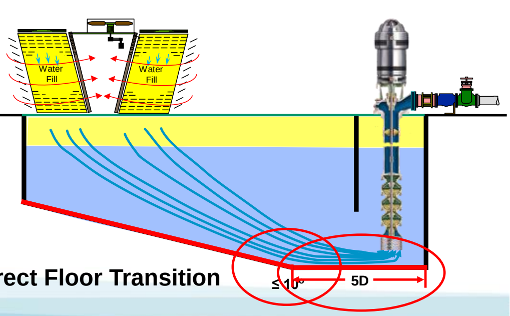
Avoid abrupt changes in inlet sump floor close to pump.

Angle of sump changes should not exceed 10°

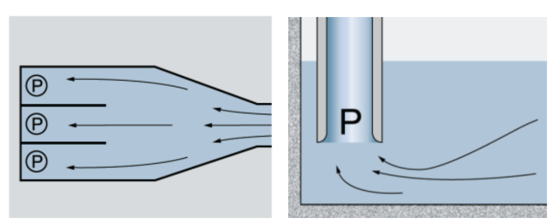


Incorrect Floor Transition

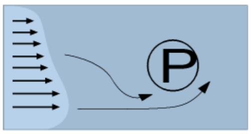
Angle of sump changes ≤ 10°
Distance to change 5D

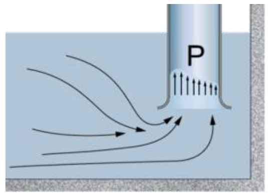


Correct Floor Transition

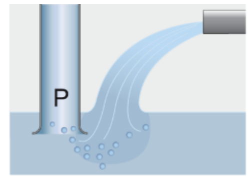


Schematic plan and cross-section view of a pump station with open channels to the pumps.

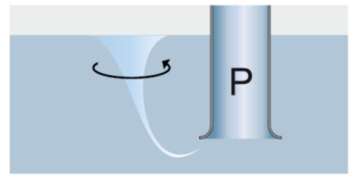




A non-uniform approach inlet flow leads to pre-swirl and uneven velocity into the pump inlet which can overload the motor, reduce pump performance, create noise, vibration and bearing wear.



Entrained air can cause reduction in discharge and loss of efficiency. May require screen and distance.



Strong surface vortex with an air core will result in cavitation, uneven load, noise and vibration. Maximum sump velocity 1 foot per second.

Flow Patterns

The material presented in the following section is provided for the convenience of the intake design engineer in correcting unfavorable hydraulic conditions of existing intakes. None of the remedial measures described herein are part of the standard intake design recommendations provided in H I Standard section 9.8.

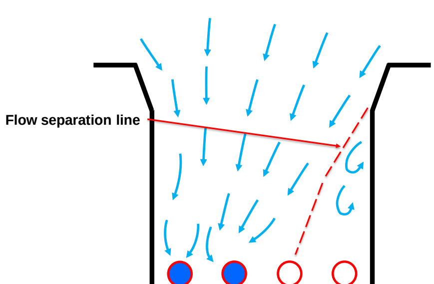
Physical model studies of intake structures and pump suction piping

A properly conducted physical model study is a reliable method to identify unacceptable flow patterns at the pump suction for given sump or suction piping designs and to derive acceptable intake sump or piping designs. As described in H I Section 9.8.4

Open vs. Partitioned Structures

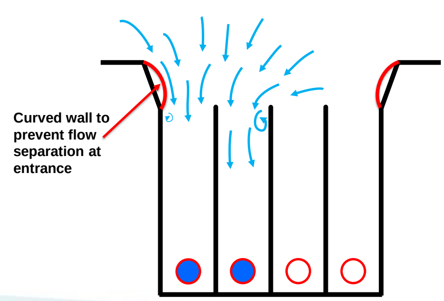
If multiple pumps are installed in a single intake structure, then dividing walls placed between the pumps result in more favorable flow conditions than found in open sumps. Adverse flow patterns can frequently occur if dividing walls are not used. For pumps with design flows greater than 5000 gpm, dividing walls between pumps are required.

Open Sump Flow Patterns

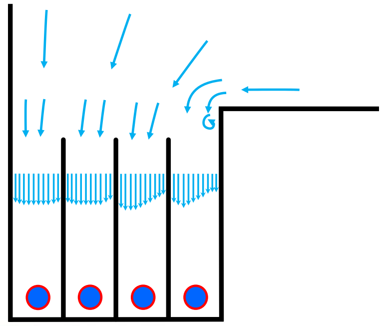


2 Pumps running, no partitions

Partitioned Sump Flow Patterns

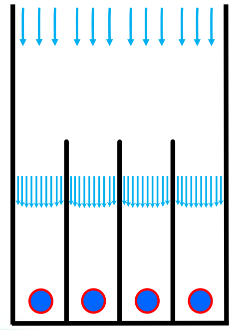


Sidewall Flow Patterns



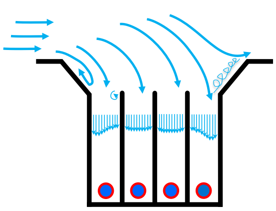
1 wall parallel, 1 wall perpendicular

Straight Line Flow Patterns

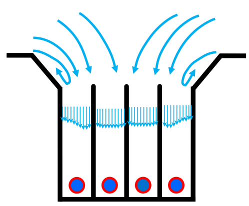


Straight Approach

Wing Wall Flow Patterns

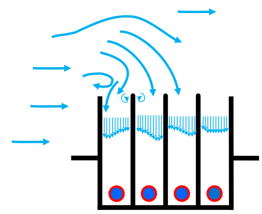


Wing walls, w/crosscurrents

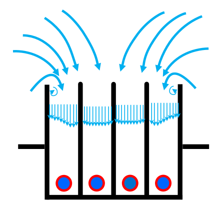


Wing walls, w/no crosscurrents

Non-Wing Wall Flow Patterns

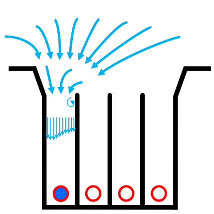


No wing walls, w/crosscurrents

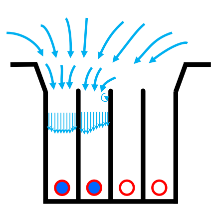


No wing walls, w/no crosscurrents

Multi-Pump Flow Patterns

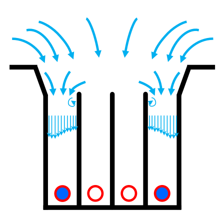


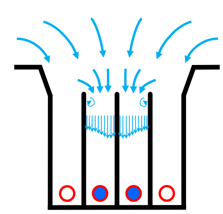
1 Pump Running



2 Pumps Running

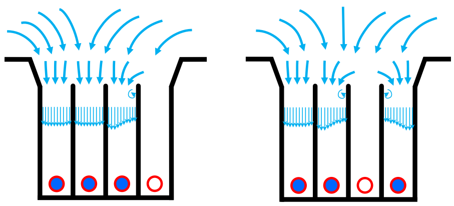
Multi-Pump Flow Patterns





2 Pumps Running

Multi-Pump Flow Patterns

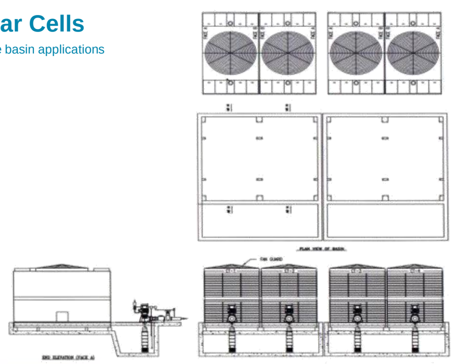


3 Pumps Running

Example Project

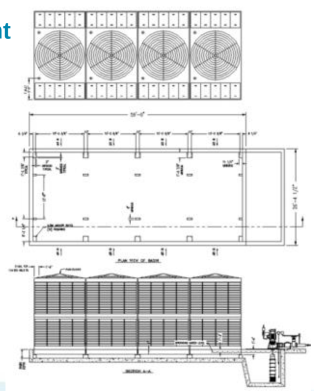
Modular Cells

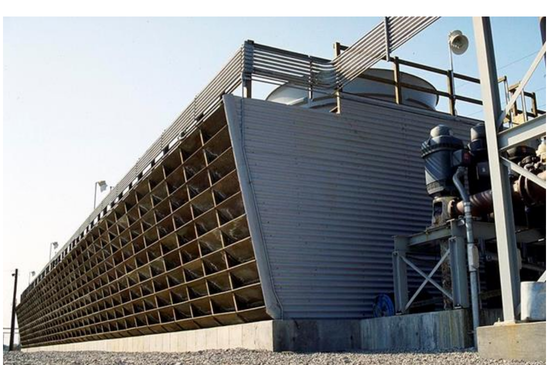
For concrete basin applications

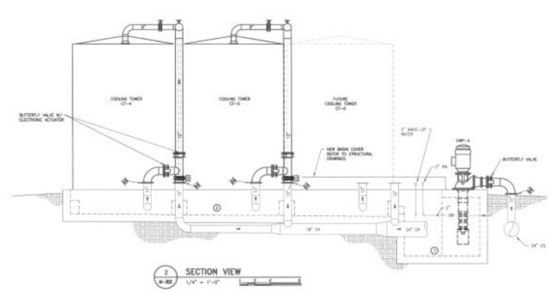


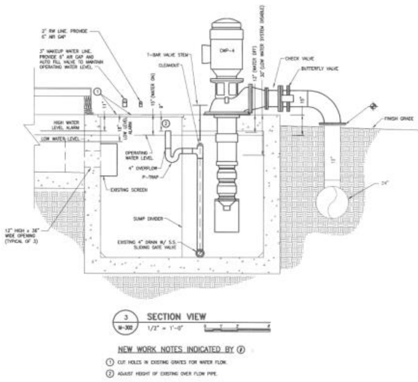
5200 Ton Central Plant

- Concrete cold water basin
- 4 basinless factory modules
- Extends equipment life
- Reduces installation cost and time
- Consistent "CTI" Performance without field testing








SUMP DIVIDER
EXISTING 4" DRAIN W/ S.S. SLIDING GATE VALVE
3
SECTION VIEW
1/2" = 1'-0"
NEW WORK NOTES INDICATED BY
1 CUT HOLES IN EXISTING GRATES FOR WATER FLOW.
2 ADJUST HEIGHT OF EXISTING OVER FLOW PIPE.

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Thank you!