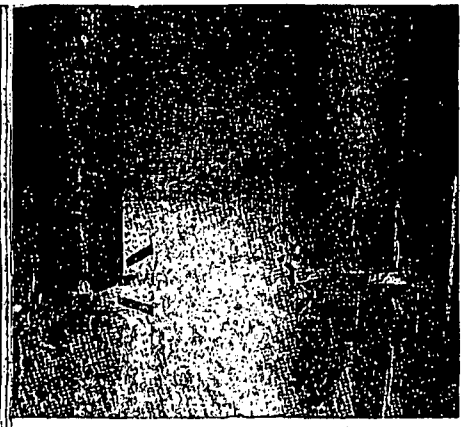
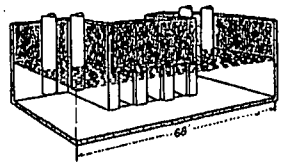
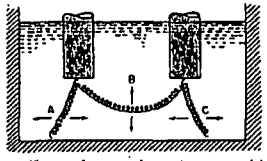


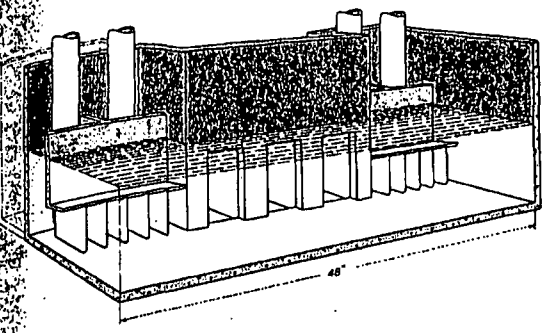
1 Model of pump intake has flow-indicating flags mounted on transparent Lucite floor. They can be seen from below



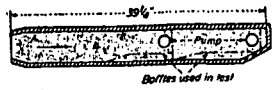
2 Proposed installation of prototype before model tests were conducted



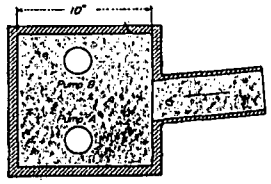
3 Types of vortex formation at model suction bell. Prototype is similar



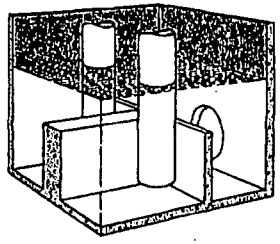
4 Final model arrangement of proposed setup shown in Fig. 2. Model tests reveal troubles that would be met with first design if it were built as originally planned



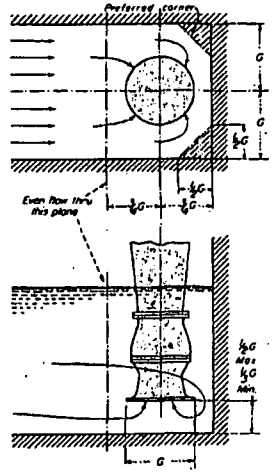
5 Arrangement for second model test described in the text of this article



6 Original arrangement of the third model test that was made by author



7 Corrected arrangement of intake in Fig. 6. Model tests showed faults



8 Preferred installation for one pump when intake model tests aren't made

Rid Vertical-Pump Intake Design of Guess With Model Tests

Field experience with intake models shows you can study an entire installation in miniature and obtain results that will hold for the prototype. Here are details of several actual tests, their results, and the design thinking that was developed from them

By A BRKICH, *Development Engineer, Cameron Engrg Dept, Ingersoll-Rand Co*

► CHANNELS GUIDING WATER to vertical pumps greatly affect their performance and dependability. Single-pump intakes are relatively simple. But multi-pump installations need considerable thought during intake design, especially where capacity of existing facilities is increased by inserting more pumps into a given space.

Intake studies must be reasonably accurate because construction expense is great. Savings made by over-simplification of the intake can hardly be justified if they produce harmful hydraulic conditions that increase frequency of pump repairs. Best, if not the only way of predicting installation performance, is duplication with a model. Cost is justified by assurance of successful operation of the full-size installation.

Suction Conditions. *Good operation* requires that flow in suction bell be evenly distributed across inlet area. This is obtained only by proper design of components influencing it. One of the most important is the flow pattern.

Poor flow can lead to hydraulic instability at suction bell in form of a strong vortex that tends to wander in a periodic manner, causing varying pressure distribution with uneven flow to impeller. Outward signs are vibration, cavitation, worn bearings and others. These may be continuous or periodic, depending on disturbance. In severe cases pump column bolts fail, probably from fatigue.

Another form of hydraulic unbalance occurs when high channel velocities or obstructions cause flow to enter only one side of bell. Disturbance is usually of constant magnitude but effects are as bad as those above.

Model Tests. You can consider channel flow pattern the result of two independent influences. One is pattern *established by flow from channel* inlet to pumps. Superimposed on it are local vortices induced about each pump by impeller rotation. Channel flow is the most important in hydraulic-stability studies and deserves much consideration.

Sharp corners, abrupt turns and asymmetry cause channel-flow disturbances. In model tests we can replace pumps with pipes having suitably shaped inlets, and obtain reliable results.

Intake Problem. Hydraulic losses are never a consideration because velocities in intake are low. Prevention of eddies and vortices in channel that disturb flow at inlet bell is the problem to solve. You may do this by changing channel design to eliminate disturbances or by isolating them in areas where they do no harm.

Scale factors from 1/12 to 1/16 give models of convenient size. They permit easy reproduction of construction details with a flow pattern large enough to be clearly evident.

Model capacity to use is debatable. For exact hydraulic similarity, forces acting on elements at similar points in the two flows must have the same ratio to each other. Reynolds number compares inertia and friction forces, or R = inertia forces/friction forces = VL/u, and $Q_m = Q(L_m/L)\ (u_m/u)$, where Q = flow capacity, L = characteristic length, u = kinematic viscosity, m = values pertaining to model, V = characteristic velocity.

Froude number compares inertia and gravity forces, or F = inertia forces/gravity forces = $(V^2/L)/g$, and $Q_m = Q(L_m/L)^{5/2}$, where g = acceleration due to gravity.

Since viscous or frictional forces are secondary in these studies, Reynolds number is usually ignored. Froude number is essentially an expression for centrifugal forces for an element traveling in a curved path. So with a model operating at Q_m, any vortices present are dynamically like those in prototype, particularly if water surface is free.

Model capacity is increased slightly to compensate for stabilizing effect of its smaller dimensions. If channel design is correct, velocities can be substantially increased without disturbing flow if other limitations like hydraulic jump are not exceeded.

Flow Indicators. Small metallic flags, made of 0.005 in. brass shim stock mounted about suction bell, make good flow indicators in model having a Lucite floor, Fig. 1. By observing flow from below model with mirrors, pattern is clearly evident. Total angular movement and direction of any flag permit a more exact evaluation of flow stability at any point. Photographs are easily taken.

Test Examples. Fig. 2 is an installation difficult to analyze without a model. Four large pumps were to be used in new building—two in each bay. Lack of space caused a crowded arrangement.

Model tests immediately showed that the large quantity of water emerging from the sluice gates impinged against the facing wall, creating a strong flow distortion. Abrupt 90-deg turn ahead of pumps aggravated this condition. Average velocities around pumps appeared low, but lack of guides allowed disturbances to reach pumps and set up vortices. Fig. 3 shows vortices observed during tests with various combinations of pumps and sluice gates.

With Froude number same as in prototype, vortices were not persistent. But they had the objectionable feature of wandering appreciably. Because of high bell clearances and large area behind them, rotating bodies of water under pumps with vortices A and C moved about whenever disturbing influences from the sluice gates reached them. This would cause hydraulic unbalance of impellers in prototype. Resulting vibration reduces pump operating life. Water surface gave no sign of conditions below.

At increased capacities, vortices became more positive, showing flow pattern was unsound, needed correction. Rearrangement showed improvement was made by bringing wall behind pump forward until there was a clearance of one-fourth suction-bell diameter with pumps one-half a bell diameter above floor. Magnitude of vortices A and C was reduced while holding them firmly in position under the bells. Vortex B was eliminated entirely.

Fig. 4 shows final arrangement. It has a flow pattern completely different from the original. Front wall prevents disturbances from reaching pumps. Tunnels with their sloping ceilings

(*Continued on page* 192)