Suction Side Problems - Gas Entrainment

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Multiple symptoms associated with noncondensable suction side gas entrainment, such as loss of pump head, noisy operation, and erratic performance, often mislead the pump operator. As a result, entrained gas is generally diagnosed by eliminating other possible sources of performance problems. To adequately control gas entrainment a user should first be aware of systems most likely to produce gas, and then employ methods or designs to eliminate entrainment into these pumping systems.

ENTRAINMENT VERSUS CAVITATION

The audible pump noise from noncondensable entrained gas will produce a crackling similar to cavitation or impeller recirculation. However, cavitation is produced by a vapor phase of the liquid which is condensable, while noncondensable entrained gas must enter and exit the pump with the liquid stream.

To test for gas entrainment over mild cavitation, run the pump back upon the curve by slowly closing the discharge valve. The noise will diminish if it originated from cavitation and the pump is not prone to suction recirculation. In contrast, with entrained gas, continued performance at this portion of the curve will choke off or gas-bind the pump, causing unusually quiet operation or low flow.

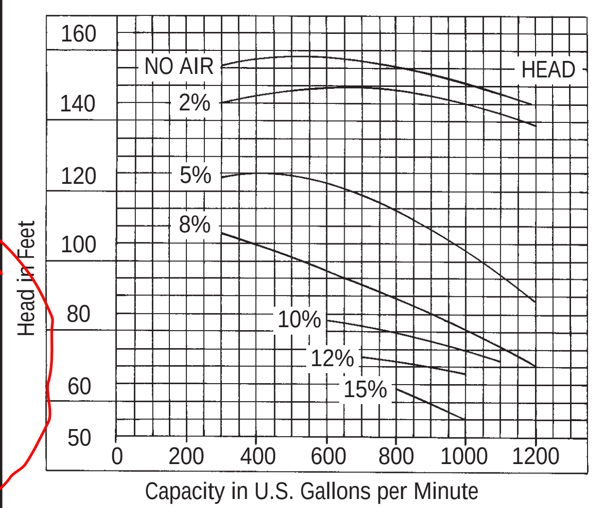
GAS BOUND IMPELLERS

As a process stream containing entrained gas nears the impeller, the liquid pre-rotating from the impeller tends to centrifuge the gas from the process stream. Gas not passing into the impeller accumulates near the impeller eye. As entrained gas flow continues to increase, the accumulating groups of bubbles are pulled through the impeller into the discharge vane area where they initiate a fall in flow performance. The bubble choking effect at the impeller eye produces a further reduction of Net Positive Suction Head Available (NPSHA). At this stage long term damage to the pump from handling entrained gases is generally negligible when compared with the damage due to cavitation. If the process stream gas volume increases, however, further bubble build-up will occur, blocking off the impeller eye and stopping flow (Ref. 1).

A pump in this gas bound state, will not re-prime itself, and the gas, with some portion of the liquid, must be vented for a restart against a discharge head. The effort to restart a gas bound impeller depends on

FIGURE 1. ENCLOSED IMPELLER-ENTRAINED GAS HANDLING PERFORMANCE

The LaBour Company, Inc. Effect on head and capacity of varying quantities of air with water being pumped.

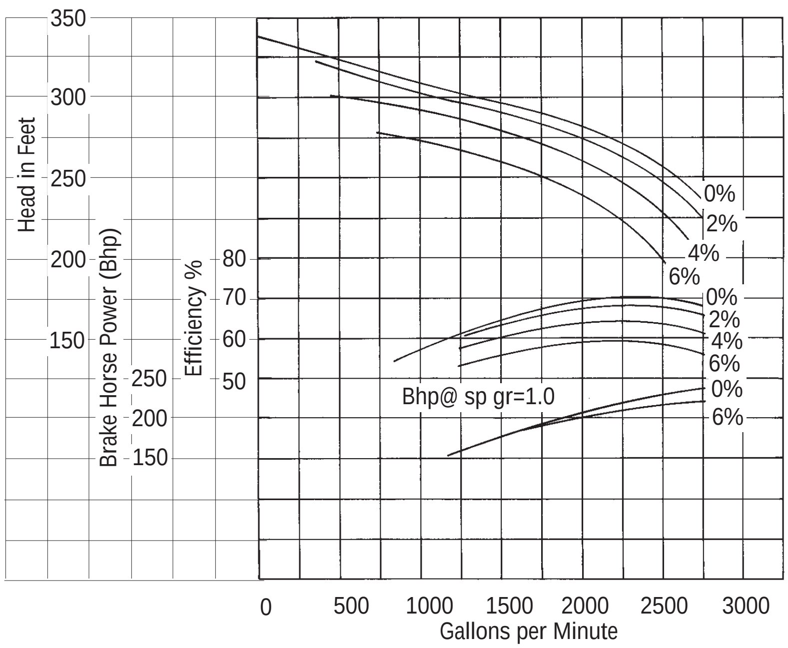


Size: no. 55; Type: SQ. Speed: 1750
Impeller Diameter: 11"

Air quantities given are in terms of free air at atmospheric pressure referred to % of total volume of fluid being handled.

FIGURE 2. OPEN IMPELLER-ENTRAINED GAS HANDLING PERFORMANCE

Gould's Pumps, Inc. Approximate Characteristic Curves of Centrifugal Pump



Size: 6x8-18 Speed: 1780 rpm Impeller Diameter: 17 1/4"

impeller position, type and valving arrangement, among other variables. Degassing is easier to accomplish with a variable speed driver, such as a steam turbine, than with a constant speed electric motor drive. In addition, a recycle line to the suction vessel vapor space is often an effective method for degassing an impeller, since with this arrangement the pump is not required to work against a discharge head. (Ref. 1 describes methods for venting gas on modified pumps that are gas bound.)

As a rule, if the probability of entrained gas exists from a chemical reaction, the inlet piping design should incorporate a means to vent the vapor back to the suction vessel's vapor space or to some other source.

EFFECTS OF ENTRAINED GAS ON PUMP PERFORMANCE

Figures 1 and 2 illustrate the effect of entrained gas on a LaBour enclosed impeller and a Gould's paper stock open impeller. As illustrated by the figures, 2% entrained gas does not produce a significant head curve drop. Note that while the LaBour impeller experiences a 22% head loss at 5% gas volume, the Gould's open impeller experiences a 12% head loss at this volume. Some open impeller paper stock designs can actually handle up to 10% entrained gas because clearance between the case and impeller vanes allows more turbulence in the process fluid, which tends to break up gas accumulation more efficiently than an enclosed impeller with wear rings. In addition, other designs, such as a recessed impeller pump, may handle up to 18% entrained gas. In fact, most standard centrifugal pumps handle up to 3% entrained gas volume at suction conditions without difficulty. (Ref. 2 discusses open impeller pump modifications.)

SYSTEMS PRODUCING ENTRAINED GAS

The most common conditions or mechanisms for introducing gas into the suction line are:

1. Vortexing
2. Previously flashed process liquid conveying flashed gas into the suction piping.
3. Injection of gas, which does not go into solution, into the pumpage.
4. Vacuum systems, valves, seals, flanges, or other equipment in a suction lift application allowing air to leak into the pumpage stream.
5. Gas evolution from an incomplete or gas producing chemical reaction.

If a particular application produces entrained gas or has the potential to do so, the best solution is to eliminate as much entrainment as possible by applying corrective pump system design and/or a gas handling pump. If liquid gas mixing is desired, employ a static mixer on the dis-

FIGURE 3. DEVELOPMENT OF A VORTEX

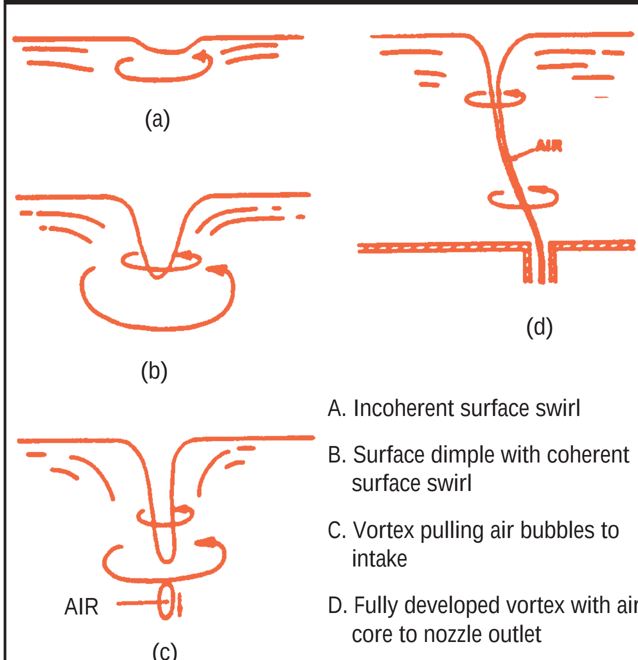


FIGURE 4. "HAT" TYPE VORTEX BREAKER

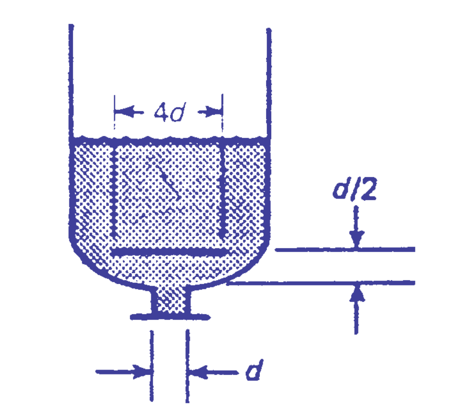
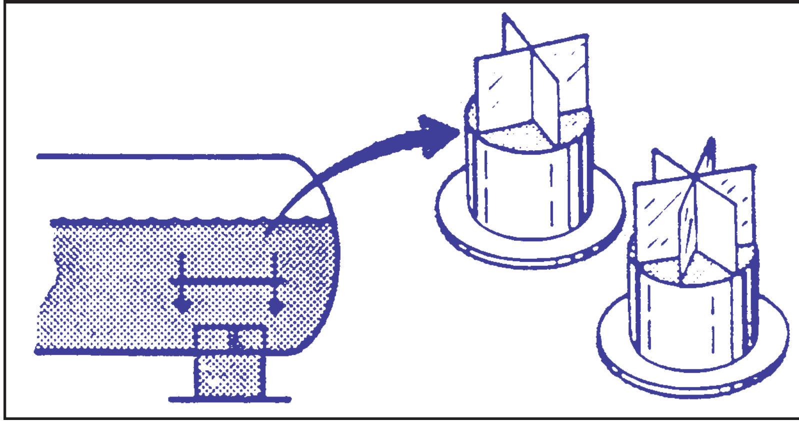


FIGURE 5. "CROSS" TYPE VORTEX BREAKER



charge of the pump. In addition, an anticipated drop in pump head due to an entrained gas situation may be offset by oversizing the impeller.

Of the five aforementioned mechanisms, vortexing is the most common source of entrained gas. Therefore, a user should be especially cautious employing mechanical equipment, such as tangential flash gas separators and column bottoms re-boilers, likely to produce a strong vortex.

VORTEX BREAKER DESIGN

The extent of gas entrainment in the pumped fluid as the result of vortex formation depends on the strength of the vortex, the submergence to pump suction outlet, and the liquid velocity in the pump suction nozzle outlet. Vortices form not only through gravity draining vessel applications, but also in steady state draining vessels, and in vessels under pressure or with submerged pump suction inlets. Vortex formation follows conservation of angular momentum. As fluid moves toward the vessel outlet, the tangential velocity component in the fluid increases as the radius from the outlet decreases. Figure 3 shows various stages of vortex development. The first phase is a surface dimple. This dimple must sense a high enough exit velocity to extend from the surface and form a vortex. (For experimental observations regarding vortex formation see Refs. 3, 4.)

The most effective method to eliminate entrained gas in pump suction piping is to prevent vortex formation either by avoiding vortex introducing mechanisms or by employing an appropriate vortex breaker at the vessel outlet. A "hat" type vortex breaker, illustrated in Figure 4, covers the vessel outlet nozzle to reduce the effective outlet velocity. This design doesn't allow a vortex to stabilize because the fluid surface senses only the annular velocity at the hat outside diameter (OD). In addition, the vanes supporting the hat introduce a shear in the vicinity of the outlet to further inhibit vortex formation. An annular velocity of 1/2 ft/sec at the hat OD produces a viable solution. Variations in hat diameters from 4d to 5d and hat annular openings of d/2 to d/3 are acceptable when annular velocity criteria are met. Annular design velocities of more than 1 ft/sec are not recommended.

"Cross" type breakers, installed above or inserted in vessel nozzle outlets as shown in Figure 5, work for some applications by providing additional shear to inhibit a mild vortex from feeding gas into a nozzle outlet (providing enough submergence is available). However, this design will not stop a strong vortex and will decrease NPSHA. A user should be aware of these limitations.

COLUMN VORTEXING

If a column draw-off pump is erratic and/or nearly uncontrollable, a vortex may be feeding gas into the draw-off nozzle of the pump as illustrated by Figure 6a.

It may be difficult to understand how a pump with 60 ft of vertical suction could be affected by entrained gas, but in this real case example Murphy's law applied twice. First, since the pump system in question has a NPSHA greater than 50 ft, the piping designer employed a smaller suction pipe with a liquid velocity of 10 ft/sec. Second, the column draw-off nozzle was sized according to normal fluid velocity practice. As a result, the tray liquid had an exit velocity of 5 ft/sec with a liquid level 6-in. above the top of the draw-off nozzle and a vortex formed, feeding gas into the draw-off nozzle.

As in the above example, due to a lack of proper submergence, gas is carried into the pump suction piping as a high liquid downward velocity exceeds the upward velocity of a gas bubble.

Many draw-off vortexing problems may be eliminated by proper pump system design or by one of two vortex breaker designs illustrated by Figures 6b and c. The selection of the breaker design may depend on the downcomer arrangement and space limitations. The most effective vortex breaker is the slotted pipe design shown in Figure 6c.

Application of these corrective pump systems designs or installation of an appropriate gas handling pump can solve suction side gas entrainment problems, resulting in a smoother process operation. ■

FIGURE 6. DESIGN MODIFICATIONS FOR A SYSTEM EXHIBITING A LACK OF ADEQUATE SUBMERGENCE AND PROHIBITIVELY HIGH EXIT VELOCITY

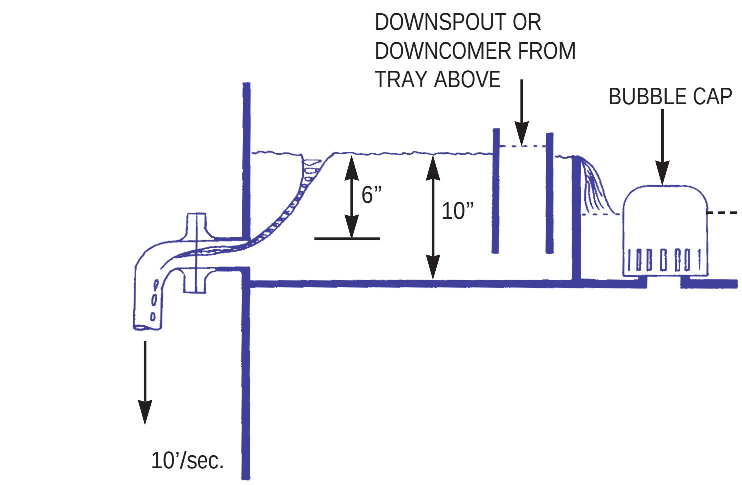


Figure 6a. Tray take off nozzle with vortex from lack of correct submergence and too high exit velocity.

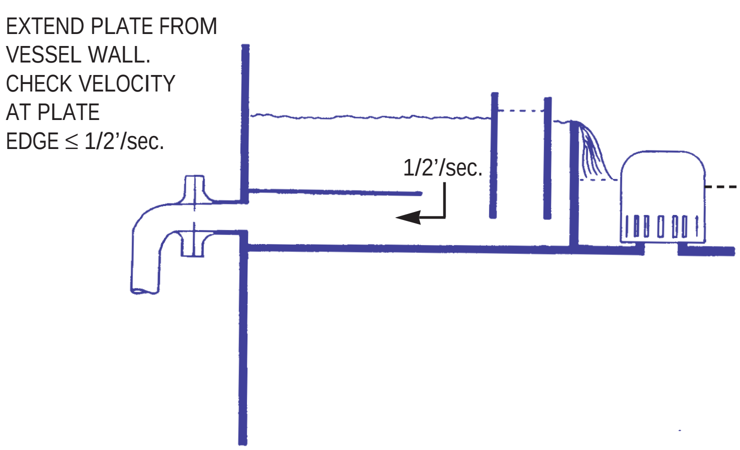


Figure 6b. Plate extension over outlet nozzle lowers high outlet velocity.

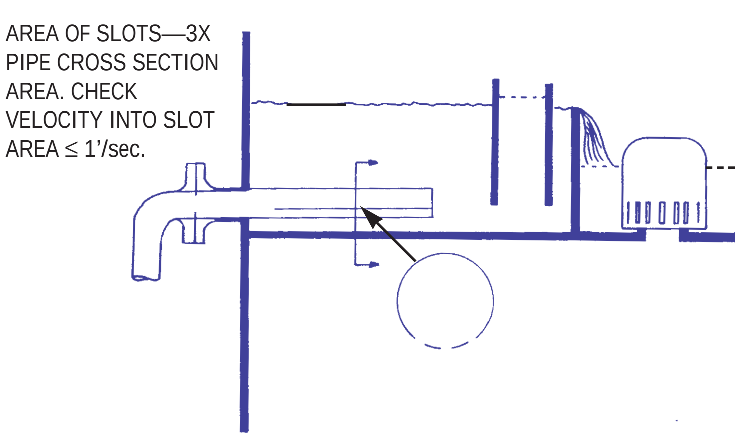


Figure 6c. Slotted pipe vortex breaker.

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