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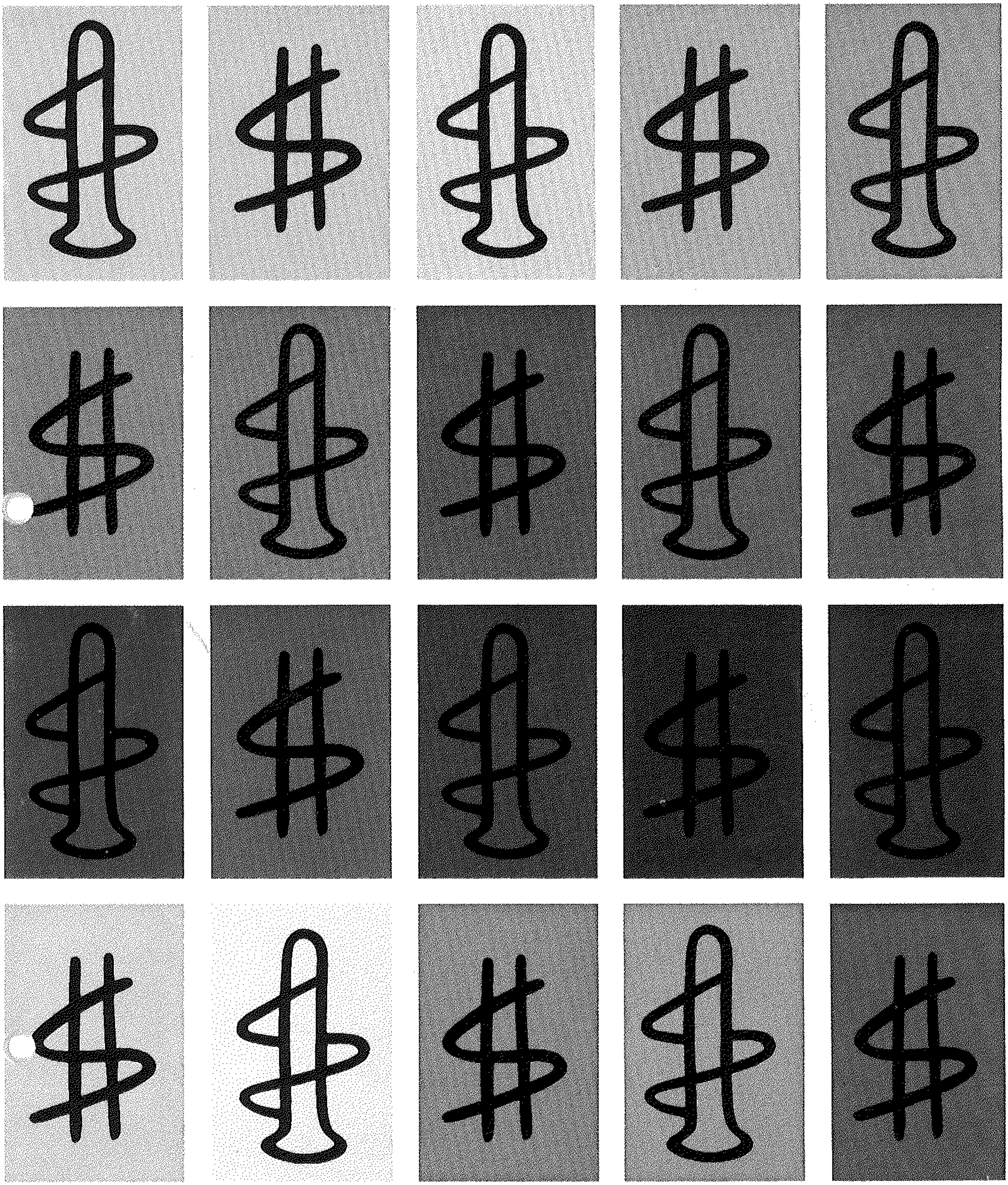
pumpworld



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The cost-saving inducer.
The Worthington inducer has become synonymous with dollar savings. When low pressures and high temperatures make npsh a critical problem, the inducer pulls extra fluid into the impeller, improving suction performance and reducing npsh requirements of the pump across its normal operating range. Systems can be designed with smaller components without compromising performance – and smaller components mean lower system costs. The Worthington inducer cuts operating costs as well. Improved suction performance makes possible the use of higher speed pumps which generally operate at higher efficiencies. An article on the technology and application benefits of the modern-day inducer begins on page 5.

The inducer: An advanced suction impeller design helps reduce cost of pump and plant.

By Martin Grohmann

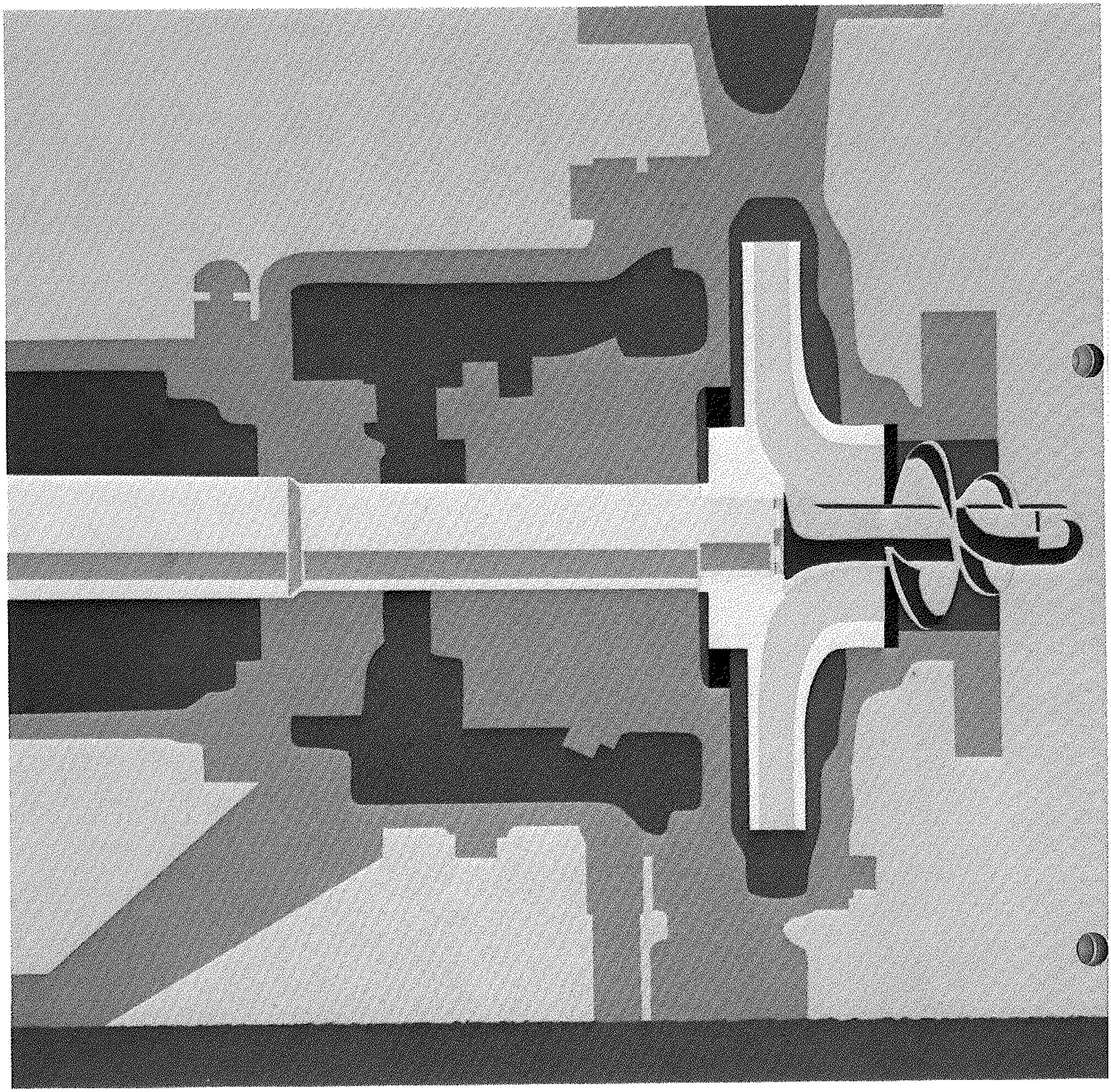

Figure 1 — Inducer/impeller arrangement on a single-stage horizontal pump.

For economy, process plant designers like to use high-speed centrifugal pumps: either the smaller single-stage horizontal, or the shorter vertical design. These smaller pumps save machinery, energy and capital costs. Unfortunately, pumps with these qualifications have inherently higher npsh requirements, and so the call has gone out for pumps—and impellers—with the lowest possible npshr (net positive suction head required).

At the limits of conventional impeller performance, Worthington's inducer works to meet these stringent requirements. By use of this advanced suction impeller design, npshr of the pump can be reduced to half its initial value—a benefit applicable to every type and size of centrifugal pump impeller.

This article reviews the technology and application benefits of the modern-day inducer. For a look at some of the exhaustive research behind this technological accomplishment, conducted by Worthington operations in Austria, Italy, the United States and Canada, see *Pumpworld*, Vol. 2/No. 1 (1976).

The inducer is an axial type impeller or propeller shaped like a male conveyor screw, which is placed in the eye area of a conventional impeller. Both inducer and impeller are set on the same shaft and rotate at the same speed. The inducer itself has a low npshr. It generates enough head to provide suction pressure for the conventional impeller, thus avoiding problems of cavitation where npsh available is low.

The inducer can be placed directly ahead of the impeller as shown in Figure 1, or a diffuser can be added between inducer and conventional impeller, improving the part-load operation.

Pressure distribution determines npshr.
In order to explain the basic action of an inducer, the npsh value of an impeller must be understood. Figure 2 indicates pressure distribution of the liquid just ahead of the impeller and in it. Assume the liquid is approaching the impeller at atmospheric pressure. Each impeller vane can be compared with the wing of an airplane, where an overpressure is generated at the lower side and an underpressure on the upper side. Such a low-pressure area also exists on the suction side of the impeller vane.

The entering liquid flows into the low-pressure area first, before head is generated by the centrifugal action. The pressure drop between a spot just *ahead of* the entrance edge, and the region of the lowest pressure just *behind* the entrance edge, represents the npsh requirements of the impeller. This pressure drop, or npsh value, must always be less than the difference between atmospheric pressure and vapor pressure, in order to have liquid rather than gas bubbles around the impeller vanes.

If the pressure distribution of a streamline looks like the dotted line in Figure 2, it is evident that for part of the streamline, the prevailing pressure is below the vapor pressure; cavitation will occur in this region. An impeller can absorb only limited cavitation, so for best operation the pressure distribution in an impeller should always be like the solid line.

In many applications the liquid may enter with less than atmospheric pressure, or the vapor pressure may be quite high. Consequently, the allowable pressure drop of the entering liquid down to the vapor pressure becomes too small to comply with the npsh requirement of a conventional impeller. The pressure distribution with a conventional impeller—like the dotted line in Figure 2—would be in the cavitation region, and would damage the pump in short order. This problem is solved by adding the inducer, which has such a low npshr that even in cases like these, pressure along the streamline never drops below the vapor pressure.

Inducer provides pressure boost.
Figure 3 shows the pressure distribution in an inducer and the associated conventional impeller. Liquid enters with suction pressure (or atmospheric pressure). Because of the small pressure drop at the inducer entrance, pressure never gets below vapor pressure. The inducer subsequently generates enough head to provide adequate suction pressure for the conventional impeller.

In spite of the large pressure drop at the conventional impeller inlet, the streamline never again approaches vapor pressure, avoiding any vaporization in the impeller. By increasing the generated head of the inducer, a large safety margin between the vapor pressure and the lowest pressure in the impeller can be achieved.

Basically, the inducer is a very small booster pump, lifting the suction pressure to a sufficient level for the main conventional impeller. With this design, the booster pump and main pump are incorporated into one casing and mounted on a single shaft.

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How does an inducer work?

We have already compared an impeller with an airplane wing. An inducer represents a high-speed airplane with thin wings with a small incidence. Therefore, the low-pressure generation on the upper side of the wing—the npsh value—is small. Flat airfoil profiles with low incidence are acceptable because an inducer needs to generate only a small head, as shown in Figure 4.

On the other hand, an impeller must generate high heads, so it needs thicker vanes with a large incidence. The conventional impeller can be compared with a low-speed airplane with a high lift coefficient—or high npsh value—as shown in Figure 5.

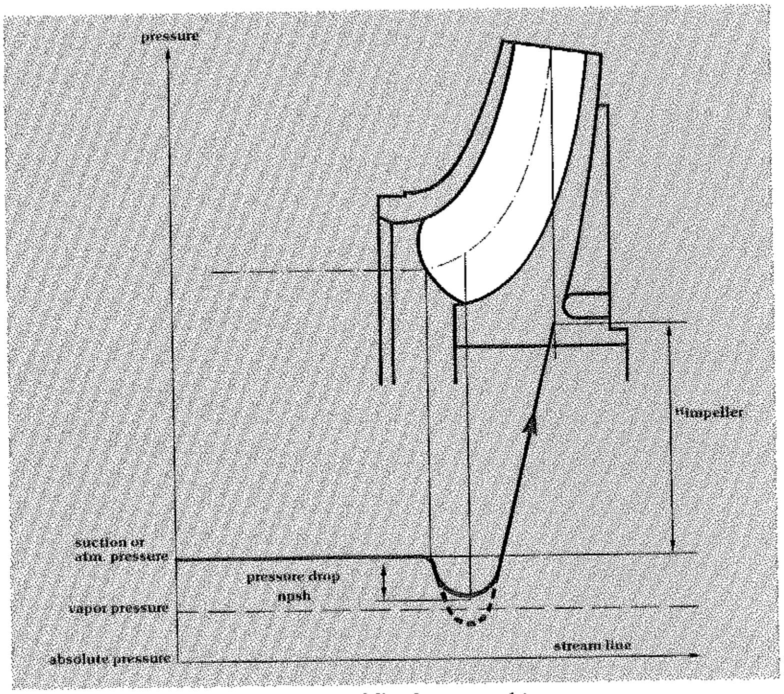


Figure 2 — Pressure distribution of fluid approaching and entering the impeller.

Inducer/impeller combination has advantages of both.

The impeller and the inducer are designed with quite different assumptions. Each has certain advantages and disadvantages, but when the impeller and inducer are applied together, the disadvantages cancel out, and the advantages reinforce each other. Figure 6 shows the design assumptions for the impeller and inducer alone, and for the combination. Total head generation and efficiency are high, like a conventional impeller, but the combination also retains the low npsh value.

As shown in Figure 3, the inducer contributes some head to the total requirement, but only 5% or less. The efficiency of an inducer is, of course, lower than an impeller, but since such a small percentage of the total head is generated at this lower efficiency, overall efficiency of the pump doesn't change much. Overall bhp is not increased, and no power penalty has to be taken into account.

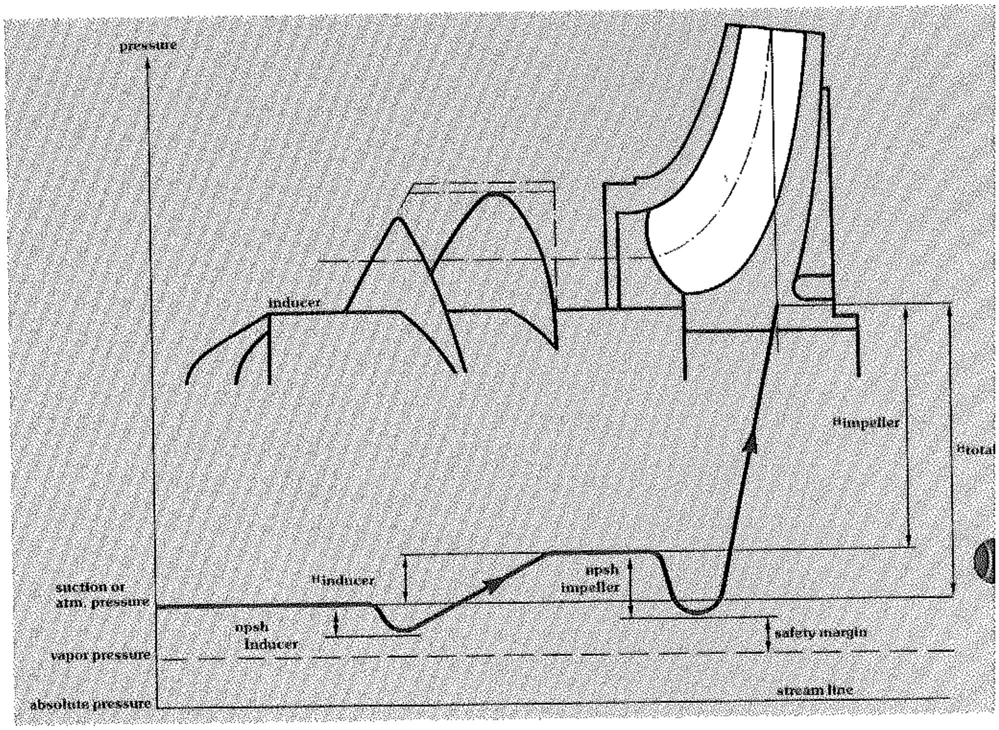


Figure 3 — Pressure distribution in inducer/impeller combination.

Use of diffuser vanes.

As mentioned before, the inducer can be placed just ahead of the main be used between inducer and impeller. In either case it is evident that the inducer exit must match the impeller inlet. This isn't easily done. In fact, Worthington pump companies in Europe and North America devoted some ten years of research to optimizing inducer design and matching inducers to impellers. Vane profiles and loadings, velocity profiles at entry and exit of an inducer, head distribution in the inducer, capacity matching, vane angle matching, and many other points were studied.

Each inducer generates a certain pre-rotation for the impeller, which can be avoided by providing diffuser vanes between inducer and impeller. As the pre-rotation of the inducer becomes larger with reduced capacity, diffuser vanes are a definite advantage for pumps which will often operate at capacities considerably below design.

Use of diffuser vanes is also related to the classification of the pump. A single-stage overhung pump can't use them because the overhung portion of the shaft would be too long, decreasing mechanical reliability. In a multi-stage vertical pump, however, where the shaft can easily be extended and supported between impeller and inducer if necessary, the provision of diffuser vanes is simple and expedient.

Cavitation.
The inducer is inherently able to withstand problems associated with cavitation. When vaporization occurs at the inducer inlet, the liquid is vaporized into a lot of small bubbles which will eventually collapse, but as the inducer is designed for a very small and steady pressure rise all along its vanes, the bubble implosions are spread over the entire vane length. As a result, there is no big shock. The inducer continues to run smoothly, and vibration and erosion do not occur. In a conventional impeller, on the other hand, the bubbles would be collapsing along a very small portion of the vane length, as the pressure rise is quite sudden and steep. Consequently, the impeller vibrates and heavy erosion can be expected.

NPSH performance.
When npsh of a conventional impeller is compared with capacity, the result is a fairly smooth, continuous curve falling from the higher capacity to the lower one, Figure 7. An inducer's curve falls steeply at high capacities and levels off abruptly at lower capacities. The range of operation for the inducer should, of course, always be in the left-hand, flat part of the npsh curve, to avoid intersection between npsha and the steep rising part of the curve. Shifting the steep part of the inducer curve as far right as possible, to provide the maximum area of flat operation, is one of the capacity-matching problems which were investigated in the research program.

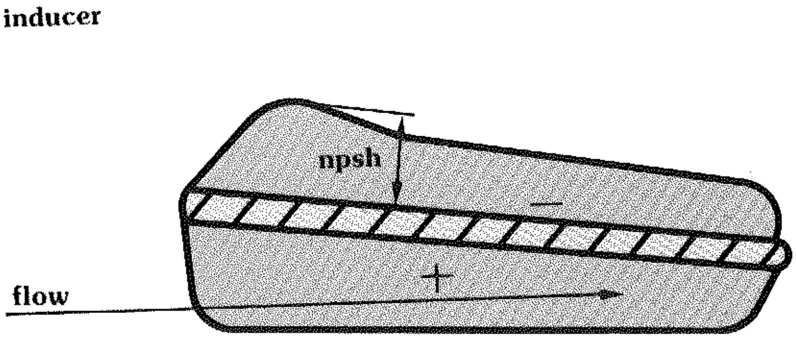


Figure 4 — Airfoil profile of a typical inducer: flat, with low incidence.

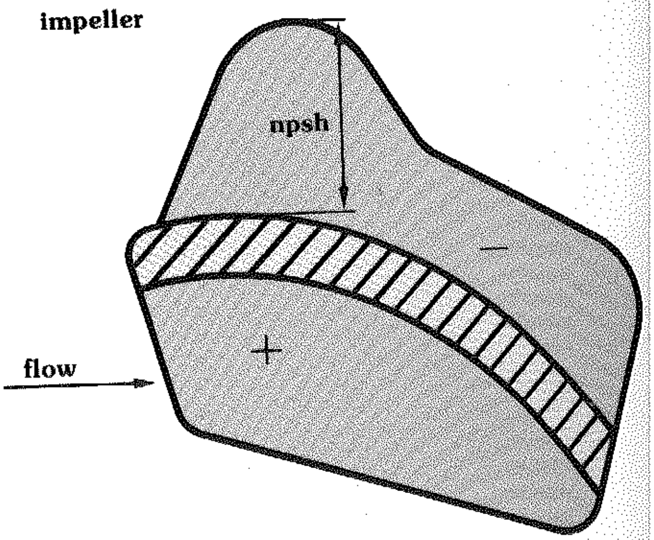


Figure 5 — Airfoil profile of impeller: high, with large incidence.

	head	npsh	Eff.
impeller	high	high	high
inducer	low	low	low
impeller + inducer	high	low	high

Figure 6 — Design assumptions for impeller, inducer, and the combination.

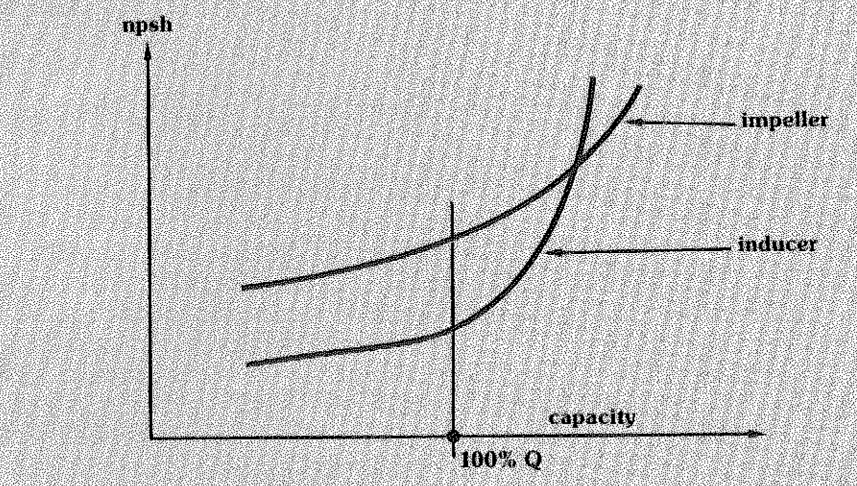


Figure 7 — Characteristic NPSH curves of impeller and inducer.

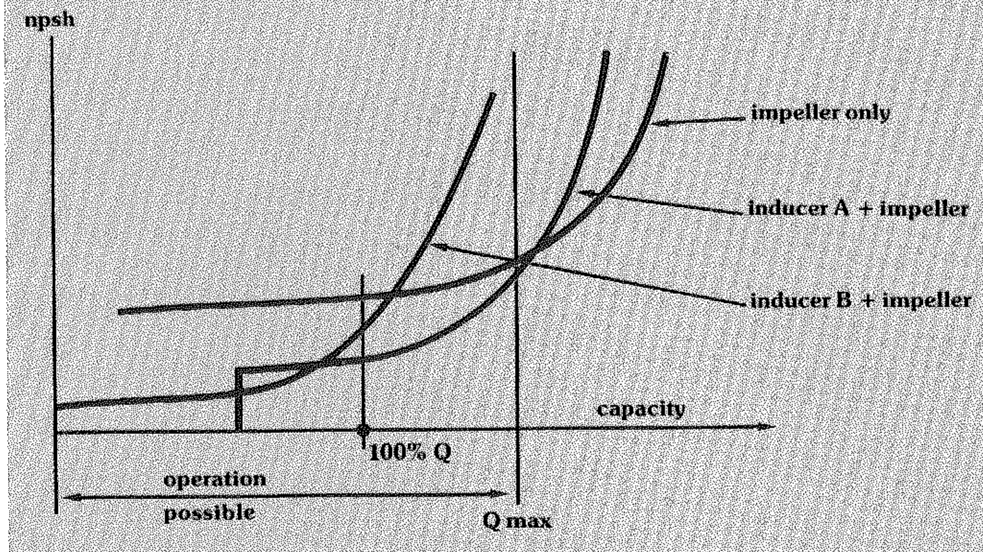


Figure 8 — Two inducer designs provide optimized operation in several capacity ranges.

Another consideration: the inducer tends to show a region of rough operation at low capacities. The onset of unstable operation can be controlled by the design of the inducer vanes, and the degree of pre-rotation to the conventional impeller. Two inducer designs are therefore provided for each impeller, to form a combination optimized according to the range of operation, as shown in Figure 8. Before the application engineer can properly select an inducer pump, the minimum continuous capacity operation must be known.

Two big advantages.

The design considerations we've discussed result in two main advantages for the pump user:

- Low npshr, allowing a smaller, higher speed, lower horsepower pump, saving pump, energy and capital costs.
- Smooth and safe operation, even under conditions which would conventionally lead to cavitation.

These two important improvements to conventional impeller technology permit new pump applications and have resulted to date in such specific advantages as the routine application of shorter vertical can pumps and high-speed pumps with fewer stages. Here are some of the ways inducers are extending the range of successful pump operation.

One-pump LPG handling.

Liquefied petroleum gas is usually stored at a temperature close to vaporization, so the available suction pressure to the first-stage impeller is essentially only the head of liquid in the storage tank. As the inducer's npshr is in the same range as the depth of the tank sump, an inducer pump can strip the LPG tank completely. A conventional pump would require a separate stripping device to empty the tank.

Handled entrained air.
Liquids with high air or gas content often cannot be handled by a conventional impeller, as the gas or air is separated out on the suction side of the impeller vanes, causing the impeller to lose suction (see "Entrained air problems" in this issue). As we've seen, an inducer raises the pressure at the impeller inlet, so the separation doesn't occur. Liquids with about 50% gas content by volume have been pumped successfully.

High-speed pumps.
Where npsha in the plant was too small for a single-stage, high-speed horizontal pump with conventional impeller, the system designer previously had to apply a multi-stage, low-speed horizontal pump or a high-speed vertical can pump. Both solutions resulted in much higher machinery, installation and plant costs. A single-stage, high-speed inducer pump can comply with the low npsh requirement. Figure 9 shows the resultant space and energy savings; the smaller, simpler pump costs less into the bargain.

Shorter can pumps.
In a vertical condensate pump, the "can" setting is determined by the static suction head requirement of the first impeller. As an inducer needs half the npsh of a conventional impeller or even less, the can setting can be reduced to half that of a conventional can pump. Shorter can settings result in much lower plant costs, and the shorter pump has a relatively stiffer lineshaft, reducing deflection and extending operating life.

The past and future inducer.
The inducer is not as new as it seems. In the 1920's, Worthington's Oscar [illegible]er was granted the first inducer patent for a double-suction impeller with an inducer on each side. This development was too advanced for the period, and was overlooked and then forgotten.

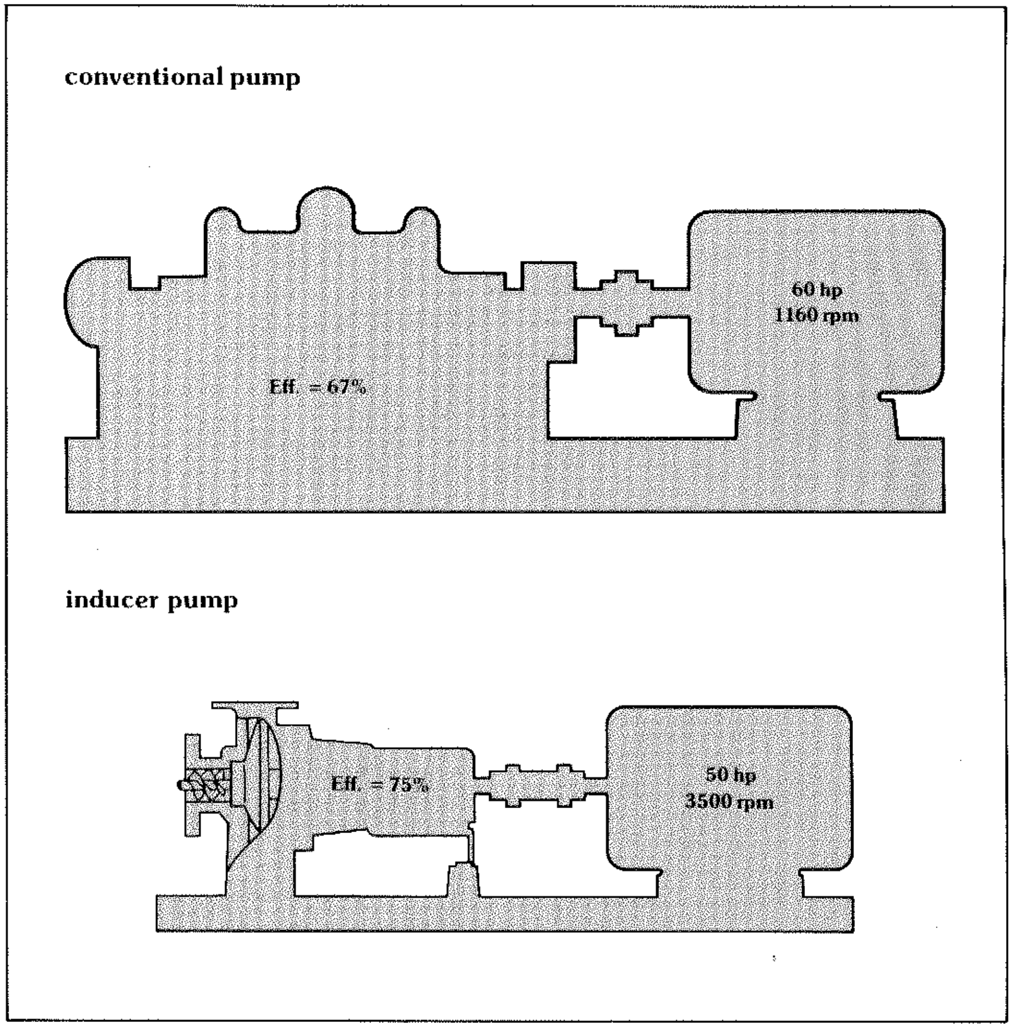


Figure 9 — The inducer-equipped pump, shown below, saves space and pumping power for the same service conditions and NPSHR.

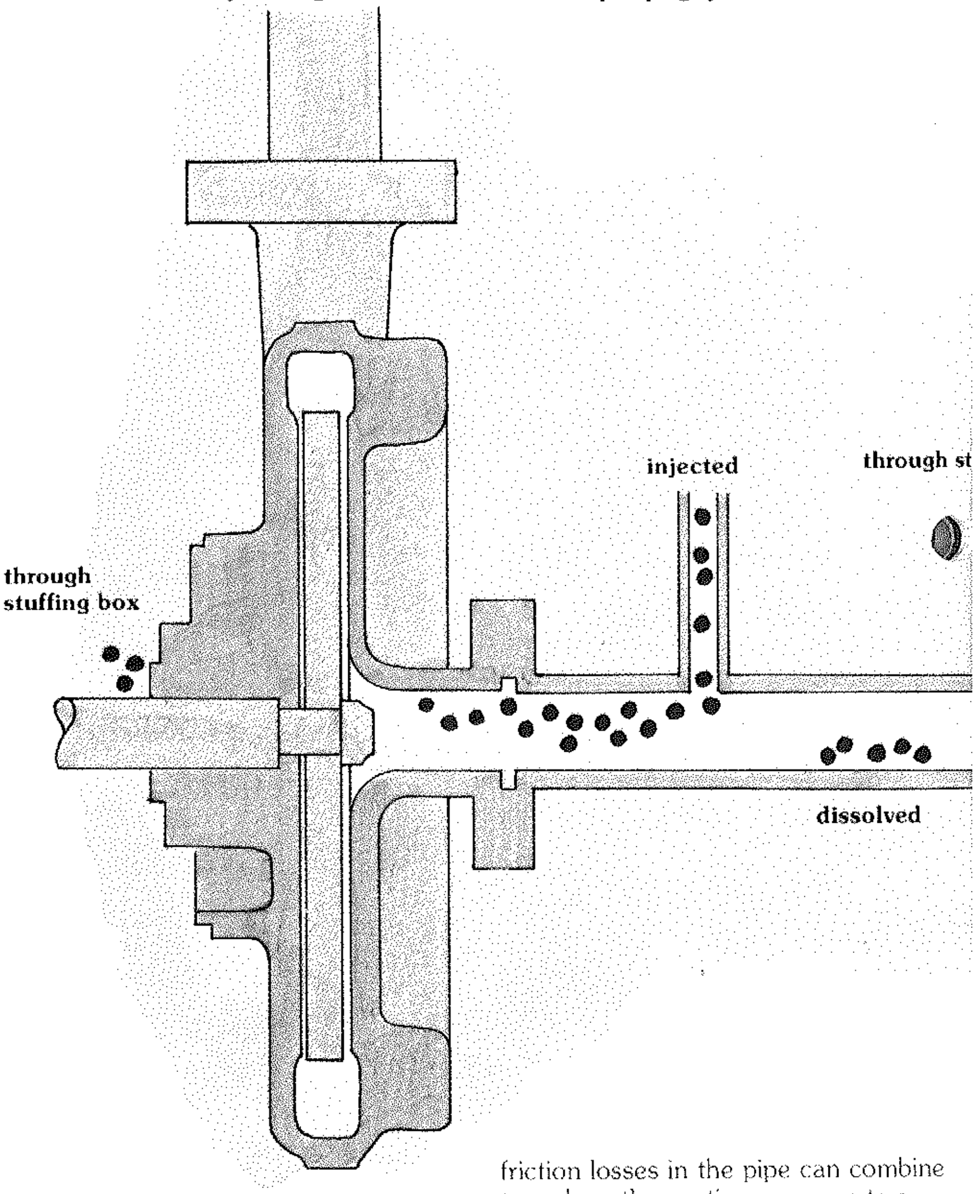
After World War II, the old invention was rediscovered and used on high-speed fuel pumps for aerospace applications. Worthington's inducer achieved commercial application in the 1960's. Since then, inducer-equipped horizontal and vertical pumps have been supplied for such services as boiler feed, refinery, petrochemical, liquid gas and protein mixture. Inducer pumps are operating successfully all over the world.

Inducer-equipped pumps not only reduce overall costs of the pump and the installation, but increase the reliability and safe operation of the entire plant. The inducer pump represents a real advance in pumping technology: a lead into the future.

Centrifugal pumps and entrained air problems.

By John H. Doolin

Figure 1 — Some of the ways air or gas becomes entrained in a pumping system.



In a centrifugal pump that handles water or other liquids, the centrifuge effect tends to separate any air or gas that is entrained and lets it accumulate near the eye of the impeller. The effect of entrainment on centrifugal pump performance is not very clearly understood by many pump users. This article discusses the problem and looks into how entrainment can often be minimized and what should be done in cases where some entrainment is unavoidable.

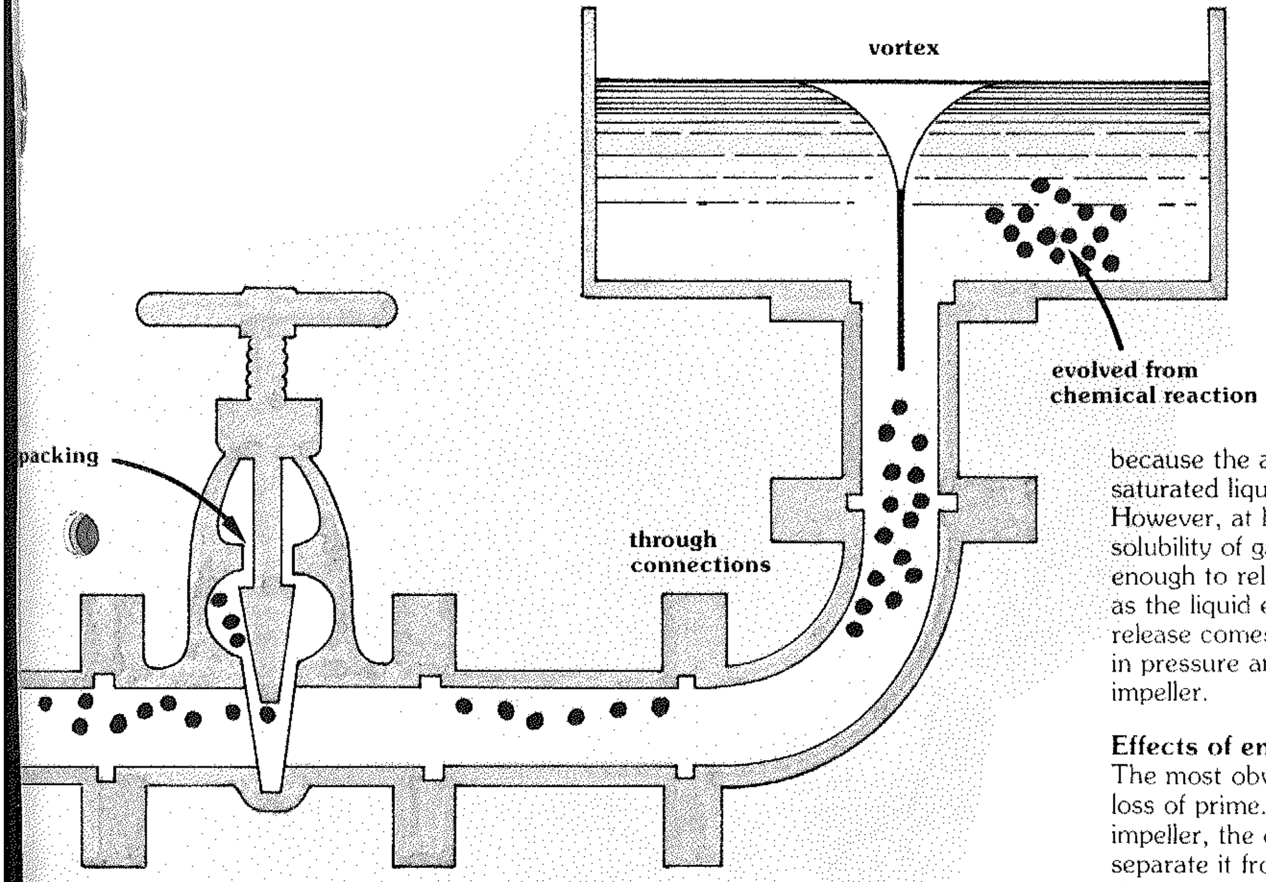
Air is not condensable. It must enter the pump with the liquid or from an external source and must leave the pump, with the liquid, as a separate entity.

Sources of gas.
Probably the easiest and most obvious way for air to get into a pump is by means of a vortex at the inlet to the suction pipe. This vortex or whirlpool is the familiar type that one sees when emptying a bathtub, and it occurs when the pipe inlet is relatively close to the water surface and the inlet velocity is high. The position of the inlet pipe makes little difference. A vortex can form when the inlet pipe opens vertically down, horizontally, or vertically up as shown in Figure 1.

To prevent a vortex from forming, the first step is to keep the pipe inlet well submerged. If this is not possible—because a tank is being stripped dry, for instance—baffles around the opening can keep the vortex out. A horizontal baffle extending in all directions around the inlet works best; its diameter should be five times as large as the inlet pipe diameter (Figure 2). With a baffle of this size, the liquid creeps rather than swirls.

Sucking air through pipe joints can also be a problem. In many installations the pump is higher than the surface level of the entering liquid, so the entire suction pipe is under a partial vacuum. Actually, even when the intake level is several feet above the pump, velocity head and friction losses in the pipe can combine to reduce the suction pressure to a point where it becomes a partial vacuum. It is therefore important to make all pipe joints and fittings airtight. The most frequent offenders are usually pipe unions, or union-type connection on hose lines. All threaded or flanged connections should be made up with pipe compound to keep them airtight. Valve stems are also common causes of air intake. The valve-stem packing should be tightened until it becomes difficult to turn the handle.

Jack Doolin is Director of Product Development for the Standard Pump Division of Worthington Pump Corporation (USA).



Most centrifugal pumps are designed so the stuffing box is exposed to pump suction pressure. This is done because suction pressure is usually easier to seal against than the relatively high discharge pressure. However, when the suction is not under pressure but a vacuum, the problem is not to keep liquid from leaking out but to keep air from leaking in.

To do this with dry packing is impractical. For proper operation, pump packing needs a controlled leakage of liquid to cool and lubricate it. When the suction pressure is a vacuum, the liquid must be injected into the stuffing box seal cage connection under about 15 psi pressure. This liquid cools and lubricates the packing, and the forced out-leakage keeps air from leaking in.

In various processes, it is necessary to inject air or gas, frequently CO_2, into the liquid being pumped. This should be done on the discharge side of the pump if at all possible, but sometimes the injection must take place in the tank from which the pump takes suction, or directly in the suction pipe. In such cases, the amount of injection should be within the limits described later.

Gas evolved from a chemical reaction should also be limited. If possible, the reaction should be allowed to proceed to completion and the gas allowed to escape before the liquid enters the pump. Gas that has dissolved from the atmosphere is seldom a problem because the amount of gas in a saturated liquid is usually small. However, at low temperatures the solubility of gas in liquid may be high enough to release fairly large quantities as the liquid enters the pump. This release comes from the local reduction in pressure and agitation by the impeller.

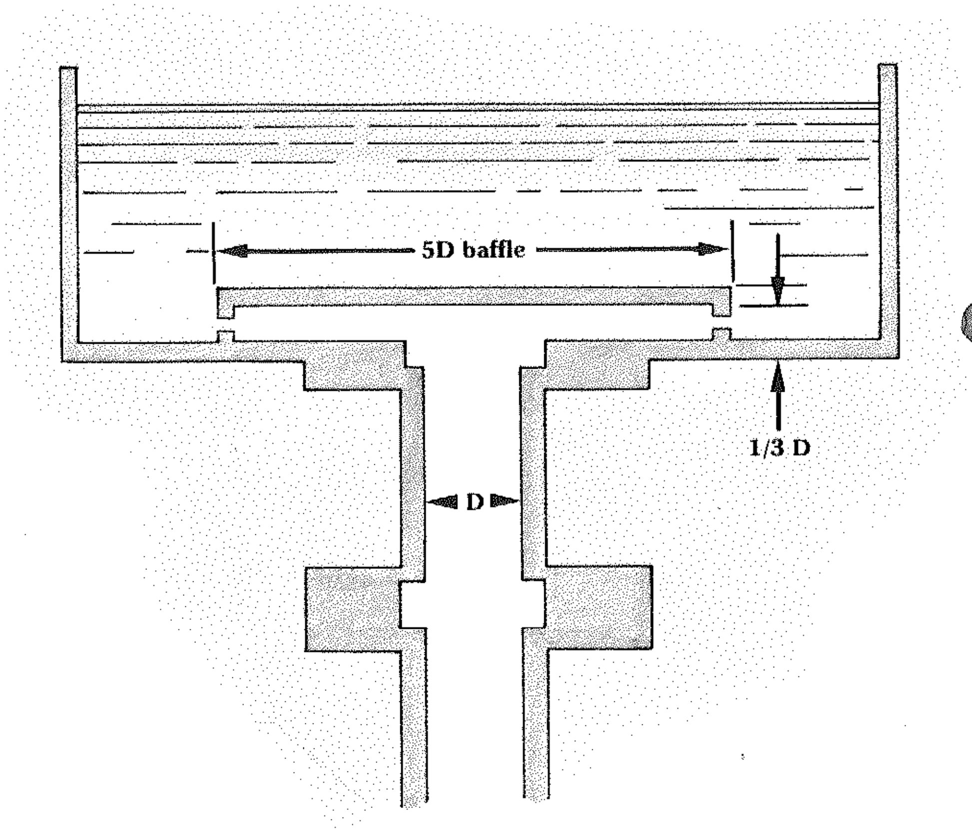
Effects of entrained gas on the pump. The most obvious effect is the complete loss of prime. As a bubble enters the impeller, the centrifuge effect tends to separate it from the liquid and keep it at the impeller eye; however, the flow of liquid past the bubble has a drag effect that tends to carry the bubble through the impeller.

Normally, the drag effect will carry along a reasonable amount of gas. But when the gas volume becomes large or the liquid flow is small (such as when operating near shutoff), the drag effect of the liquid is reduced, and gas accumulates in the impeller eye. Eventually, the accumulation of gas prevents the passage of any more liquid, and the pump becomes gas-bound. Once this happens, the pump will not normally reprime itself. It must be shut down, the gas vented off or evacuated, and then the pump must be restarted.

Even when a pump manages to carry a reasonable amount of gas without losing prime, its head and capacity output suffer. Consider a pump handling water with 5% gas by volume. The specific gravity of the mixture is approximately 0.95, and so the pressure developed will be somewhat reduced, as with any low-specific-gravity fluid. Similarly, the output capacity in terms of the liquid phase will be reduced by the volume of gas. (The effect is actually not quite as simple as this analysis, but the reasoning does help explain the causes of lower output.)

Noise is another effect of air in centrifugal pumps—however, in many cases, this effect is the least important. Where the noise itself is not objectionable, for its own sake it can usually be ignored, since the damage to the pump will be negligible. Unlike cavitation, where vapor bubbles collapse completely, air bubbles do not. The hammer effect of liquid on metal is thus cushioned.

Figure 2 — Best dimensions for baffle.



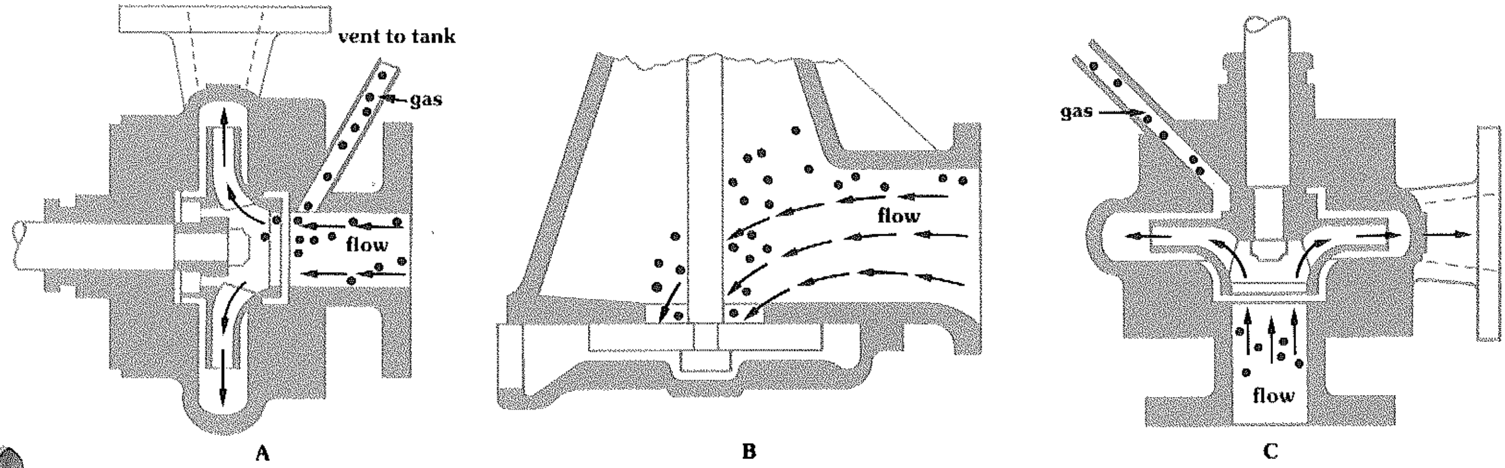
Venting may help.
The impeller position and the use of venting can have a profound effect on the ability of a pump to handle gas without becoming gas-bound. In the normal position, with the axis of the impeller horizontal (Figure 3A), gas sometimes accumulates in the impeller eye. Venting the top of the casing has no effect, since the gas bubble cannot get to the vent. Only by venting the pump close to the top of the impeller eye can the gas escape and the pump reprime itself. Of course, the vent is only effective when pump suction pressure is higher than the pressure at the point to which the outlet of the vent is connected.

Venting is considerably improved by mounting the impeller vertically upward (Figure 3B). In this position, the pump is practically self-venting and is extremely unlikely to become gas-bound. However, the input liquid level must be above the pump, so that any gas that collects can rise back up the suction pipe.

Mounting the impeller vertically downward makes the pump very difficult to vent and extremely susceptible to gas binding (Figure 3C). Since the impeller opens downward, the pump cannot be vented through the impeller eye. However, if the impeller has hydraulic balance holes through to the back, these can sometimes be used to relieve the gas so that it can escape through vents in the back of the casing.
Of course, the best way to handle gas entrained in liquid is to control its entrance in the first place, rather than venting to remove it later. But if the gas cannot be prevented from entering, judicious venting can be of considerable help in some applications and may be worth trying. If venting does not give the desired result, pump modifications or special types of pumps may be necessary.

Effect on typical characteristic curve.
Figure 4 shows a typical system of head/capacity curves. The top curve represents a liquid that is free of gas. When as little as 1% gas by volume is

Figure 3 — Best way to vent pump depends on position of impeller.



entrained and goes through the pump (rather than being vented), the head and capacity are noticeably reduced. In addition, the curve can no longer be carried to shutoff because at low capacity the pump becomes gas-bound.

As the percent of gas is increased, the head and capacity are reduced further, and the minimum capacity gets to be a larger and larger value. Finally, a percentage is reached beyond which the pump will not operate at all—not even at the higher capacities.

Therefore, if it appears that entrained air or gas is going to be a problem, it is better to go to a pump with an impeller of larger diameter rather than to a pump with a larger suction nozzle. Incidentally, when analyzing a problem of this nature, the gas volume must be measured under pump suction conditions. A given volume of gas under atmospheric conditions expands when the pump suction is under vacuum. Consistent evaluation can therefore only be made by relating the gas volume to suction pressure.

It is important that the true suction pressure be determined. In an existing system, this can best be done by direct measurement. In a system not yet built, the pressure will have to be calculated.

Pump modifications.

So far we have discussed centrifugal pumps of conventional design. However, there are several special pump modifications that enable a pump to handle greater amounts of air.

One modification is based on a patented diverging impeller design. That is, the impeller width at the inlet or eye is smaller than the width at the periphery or O.D. To quote the manufacturer, "There is a greater area at the discharge than at the inlet, so that the material pumped cannot enter fast enough to replace the ejected liquid, and a vacuum space is formed between the blades." Air or gas enters the vacuum space between the blades and passes through the pump.

In a second patented arrangement, the outside diameter of the impeller is cut on a 45-degree angle, as shown in Figure 5. The angle-cut imparts a helical motion to the liquid, which traps the gas in the center of the main flow stream and carries it through the casing. This enables the pump to handle greater amounts of gas without losing prime, and to handle gas at lower capacities.

The primary advantage of the design is that it can be applied as a modification to almost any centrifugal pump and hence is readily available. Even with this design, however, a loss in head and capacity must be expected when handling entrained gas.

Special pumps.

Going beyond the relatively simple pump modifications, a variety of special pumps inherently handles much greater amounts of gas without great difficulty.

The first of these—the self-priming centrifugal—has an impeller that agitates the air and liquid mixture. A stripper or tongue, located close to the outside diameter of the impeller, deflects some of this mixture up into a settling chamber where the air separates. The air-free liquid is then recirculated to the impeller to pick up more air.

In effect, the pump can handle 100% air (which it does during the priming cycle). However, it is still subject to the same head and capacity reductions as a standard centrifugal. Also, self-priming pumps tend to be bulky because of the extra suction and discharge chambers, and in stainless steel they can be quite costly.

Another special design is the jet pump. This is a combination ejector and centrifugal pump in series. The ejector can handle any amount of gas, which then combines with the primary stream of fluid and enters the centrifugal pump impeller. At this point, the limitations of all centrifugal pumps control the action of the impeller, but the combination of ejector and pump can handle more gas than the pump alone. This is because the ejector compresses the gas before it enters the impeller.

A third design—the water ring or water piston vacuum pump—has a ring of water that revolves in an elliptical path. The chief use of this pump is to prime centrifugal pumps, and the effect is the same as if a vacuum pump were put at the end of the vents shown in Figure 3A.

Summary of recommendations.

In general, air or gas is undesirable in a centrifugal pump and should be excluded if at all possible. If a limited amount of gas is handled, then caution must be used in selecting a pump. Most standard centrifugal pumps can handle 3% gas without difficulty. Many can handle more than this, but with varying degrees of uncertainty. Where more than 7% gas must be handled, a self-priming or other special pump should be used unless the excess gas can be vented off before it reaches the pump.

In any case, whichever type is used, the pump should be selected as close to its best efficiency capacity as possible—with an allowance in the form of a larger impeller then being made for reductions in head and capacity due to the gas.

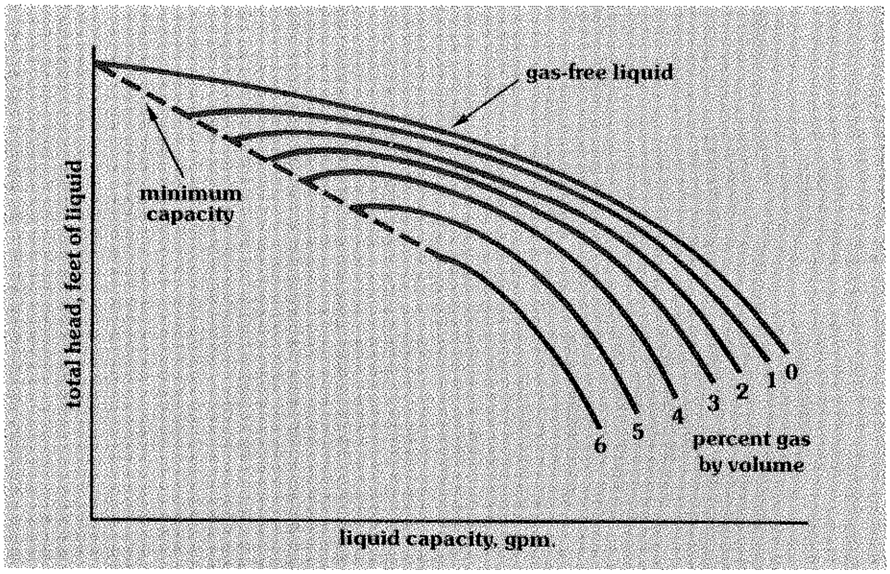


Figure 4 — Effect of various amounts of entrained gas on pump characteristics.

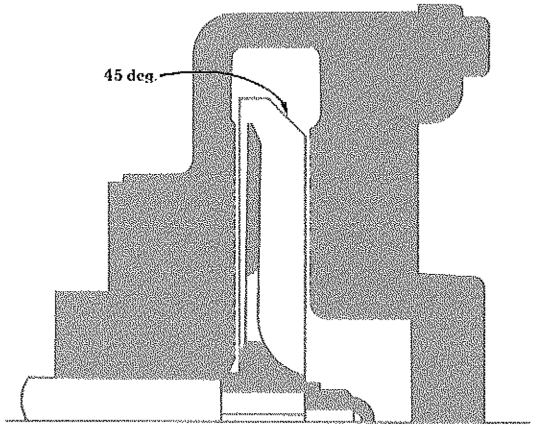
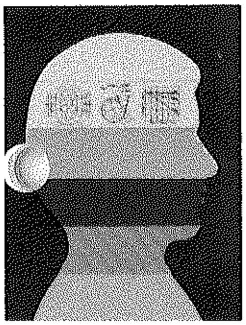


Figure 5 — Angle-cut impeller carries gas through the casing.



pump refresher

Basic hydraulics: More characteristics of liquids.

Part 6

In the last issue we looked at viscosity, the property of a fluid which causes it to offer resistance to shear stress. A number of other properties or characteristics of commonly handled fluids may also have significant effects which must be considered in connection with a pumping system.

Specific gravity.
Specific gravity is a relative measure of fluid's density as compared with water.

The specific gravity of water at 60° F is 1.0. If the density of the fluid is greater than water, its specific gravity will be greater than 1. For example, concentrated salt brine may have a specific gravity of 1.2, which means its density is 20% greater than water. Another example is sulfuric acid, which can have a specific gravity less than 1. Gasoline has a specific gravity of 0.72, kerosene 0.80, and lubricating oil 0.90.

Vapor pressure.
The best way to understand vapor pressure is to consider a container which is completely closed and half filled with liquid (Figure 1). If the other half of the container is completely evacuated of air, a portion of the liquid will vaporize and fill the upper half of the container with vapor. If we measure the pressure of the vapor in the upper half of the container, by definition, that pressure is equal to the vapor pressure of the liquid at that liquid temperature.

Vapor pressure is measured in pounds per square inch absolute (psia) and is generally a function of the temperature of the liquid. The curve shown in Figure 2 is a plot of the vapor pressure of water as a function of temperature. At 60° F, the vapor pressure of water is approximately 0.3 psia. At what we commonly refer to as the boiling point of water, 212° F, the vapor pressure is equal to atmospheric pressure, 14.7 psia.

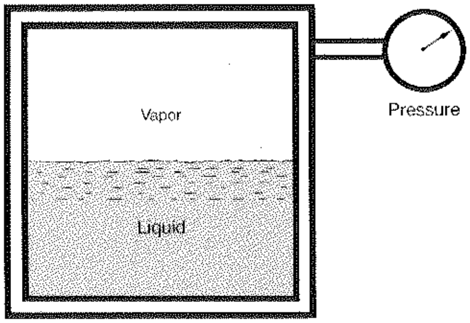


Figure 1 — Vapor pressure.

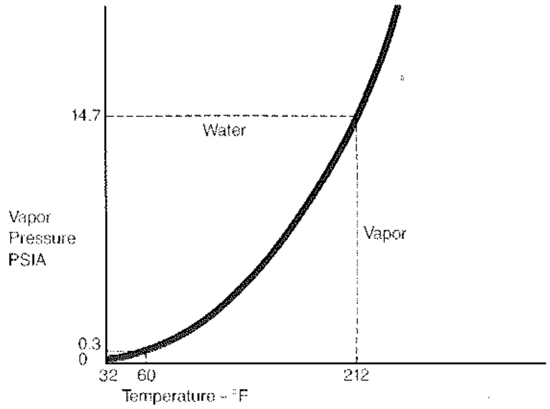


Figure 2 — Vapor pressure of water as a function of temperature.

Other liquids have vapor pressure characteristics different from water. The table in Figure 3 shows the vapor pressure of a variety of liquids at 60° F.

Entrained solids.
Another factor that influences the characteristics of liquids is the amount and type of solids entrained in the liquids handled. A simple example is dirty river water. In this case, the solids in the water have a negligible effect on normal pumping characteristics. In many cases, however, the nature and concentration of materials entrained in the liquid may have a substantial effect on the liquid characteristics and therefore on the pumping system and the application of pumps.

As concentrations of solids increase, the solids can affect other characteristics of the liquid. For example, the specific gravity may change. If the percentage of solids carried by the liquid is fairly high, the average density, or average weight of the fluid, can rise to as high as 1.2 or 1.3, Figure 4.

Vapor Pressure at 60 F in psi absolute	
ammonia	110
propane	105
butane	26
pentane	7
kerosene	3
water	0.3

Figure 3 — Vapor pressures of common fluids to 60° F.

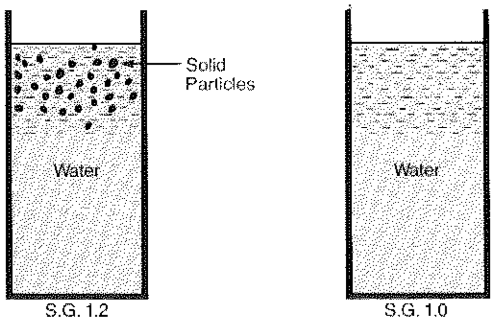


Figure 4 — Effect of entrained solids.

In heavy concentrations, mixtures of solids and liquids are called "slurries". Slurries not only have higher specific gravities, but the viscosity of the fluid may be increased considerably because of the solids content.

The size and type of solids carried by the liquid can also be important. In an extreme case, stringy solids such as rags would have little effect on viscosity or specific gravity and little abrasive effect. Nevertheless, their clogging action could bring the whole system to a standstill as shown in Figure 5.

Entrained gas.
Most liquids carry small amounts of air or other gases completely dissolved in the liquid. This has little effect on fluid flow or pumping requirements. In some processes and in some installations, however, more significant amounts of air or gas are introduced into the liquid, either intentionally as part of the process or accidentally by vortexes or air leaks on the suction side of the pump. The

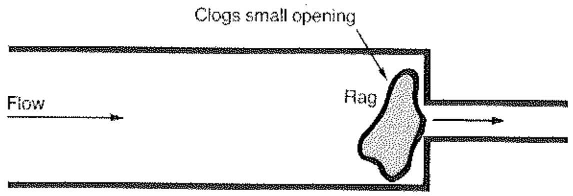


Figure 5 — Effect of stringy material.

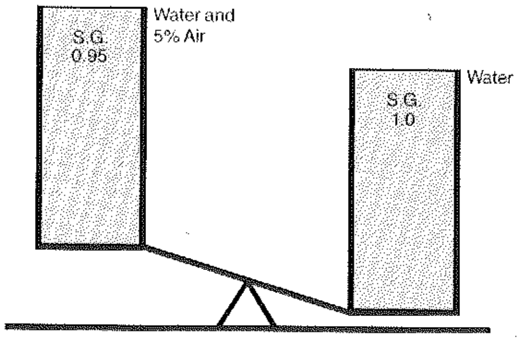


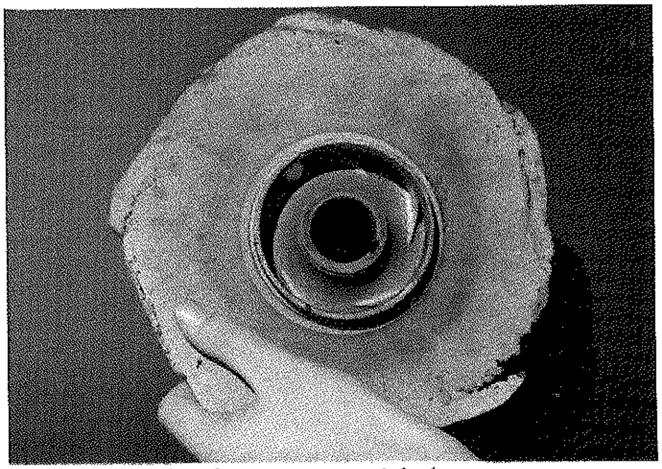
Figure 6 — Effect of entrained air.

effect of air or gas entrained in the liquid becomes significant when gas exceeds about 1% of the total volume of the mixture.

The primary effect of entrained gas is to change the specific gravity of the liquid. For example, if water, with a specific gravity of 1, has entrained in it 5% air with a very low specific gravity, the result is a mixture of air and water with a specific gravity of about 0.95, Figure 6. (Another article in this issue, "Centrifugal pumps and entrained air problems," goes into more detail on this common pumping system problem.)

Corrosive properties.
The corrosive nature of liquids is a highly important consideration. Corrosion characteristics generally have little effect on fluid flow or the hydraulics associated with pumping. However, they can have a severe effect on the life of the system—drastically abbreviating it in some cases. When corrosive fluids are to be handled, extreme care must be given to the selection of proper materials of construction.

Dirty river water has little effect on normal pumping characteristics unless the percentage of solids is high.



Proper materials selection is essential when corrosive fluids are to be handled.

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