Maintenance of Centrifugal Pumps

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ABSTRACT

At first sight, a centrifugal pump seems to be one of the simplest machine. In practice however, it is capable of posing an enormous spectrum of different problems. Occasionally one comes across problems that seems to defy everything, we know about centrifugal pumps. The selection of the right pump for the right job is very important and results in minimum maintenance of pumps. But this calls for knowledge of not only what happens within the pump but also what happens behind and beyond the pump. Therefore it has to be a joint effort between the hydraulic expert and the process specialist . Selection of the right pump itself rewards. Start up, operating problems, maintenance cost etc. are minimized. The intention of this paper is to put forward some of the less understood factors of centrifugal pumps which are nevertheless of greatest importance in making of correct choice and right maintenance, obviating disappointment or expenses.

INTRODUCTION

The problems of centrifugal pumps can be grouped under three classes: Real hydraulics problems, Real mechanical problems and unreal hydraulic problems. The real hydraulics problems are those in which the pump is unable to function according to the specifications of capacity, head and efficiency. This may be due to faults in the pump or in the pump driver assembly. Certain hydraulics problems such as capitation can cause the second class of real problems such as mechanical break down. Real mechanical problems display such symptoms as noise, vibrations, excessive heating, lead to hydraulic malfunction, through which the pump fails to meet its performance requirements.

The unreal problems are usually hydraulic in nature and generally result from faulty piping layout and faulty testing procedure. Unfortunately, correcting such problems is often more expensive than correcting those of the first two classes because of difficulty in diagnosis.

Important reimperatives on maintenance

Proper maintenance does not start with repairs of worn out spare parts, but right at the time of selection and instillation. Following certain fundamental rules will help obtain the most reliable service, the least expensive maintenance and the longest possible life from the centrifugal pumps (Fig. 1).

Selection

- Do not oversize pumps. This leads to uneconomical operation and generally narrows the safe operation range of capacities.
- Do not try to select pumps with excessively low NPSH(R)
- Do not falsify real available NPSH, trying to keep margin up your sleeve. This leads to selection of pumps with excessively high suction specific speed and high minimum flows.
- Do not use mechanical seal when packing is more than adequate for the intended service.

Installation

- Do not use suction elbows in a plane parallel to shaft. place them in the plane perpendicular to the shaft.
- Do not use the casing as an anchor for the piping.
- Do provide adequate flow, pressure and temperature instrumentation for each pump.
- Pump and driver alignment must be rechecked under normal operating conditions.

Operation

- Do not operate pumps below the recommended minimum flow (Fig. 1).

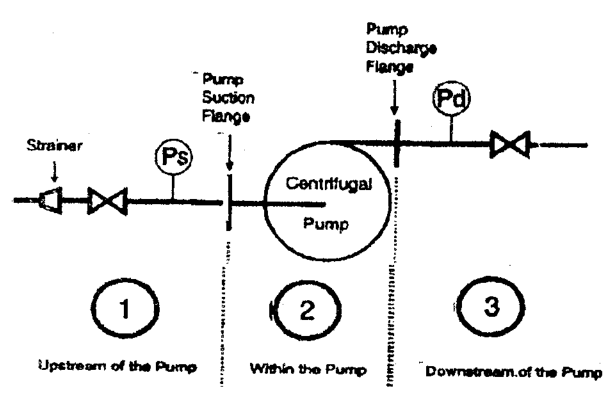


Fig. 1: Potential areas of concern when hydraulic performance declines

- Do not throttle the pump suction to reduce its capacity.
- Do not run two pumps in parallel when a single pump can carry the reduced system load.
- Do not stop a pump while it is cavitating. Reestablish normal operation first and then stop the pump if you have to.
- A pump handles liquids. Keep air out.
- Do not run a pump if excessive noise or vibration occurs.
- Do run spare pumps occasionally to check their availability.
- Don't stop leakage from stuffing box completely. Some leak is necessary to lubricate and cool packing.

Maintenance

- Do not open pumps for inspection unless factual circumstantial evidence warrants it.
- Do not overlubricate the bearings.
- Packing stuffing boxes in an art. Do not assign this task to inexperienced personnel.
- Do not tighten stuffing box glands excessively. Let enough leakage flow to cool and lubricate packing.
- Do monitor the pressure drop across suction strainer. An excessive pressure drop indicates clogging and may reduce available NPSH to a dangerous degree.
- Do keep an adequate stock of spares parts.
- Always use original equipment manfacturers spares.
- Do check concentricity of all parts of the rotor before reassembly.

Effects of pump running away from BEP

The pump has to be selected and operated at or near its best efficiency point. Overexpectation may lead to overloading of the motor, cavitations and increased vibrations. Operating the pump at part capacity may lead to increased loading on the bearings thereby increasing bearing temperatures, increased vibrations and noise. That is, performance of the pump can be monitored by its behaviour, mistakes and temperature. So we have to monitor the pump behaviour (Fig 2).

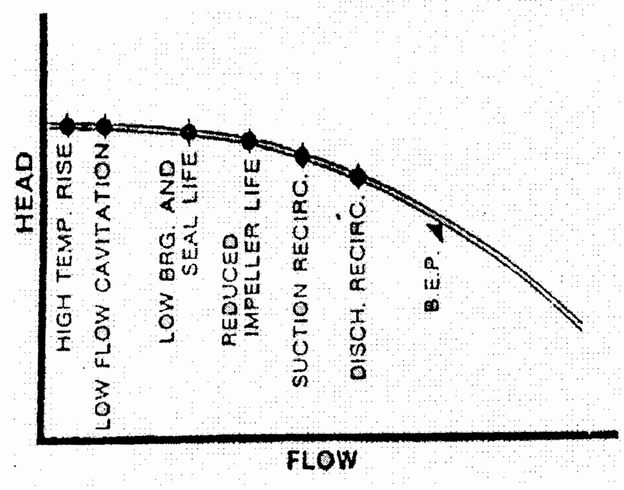


Fig. 2: Head vs. flow curve illustrating point of of events which adversely affect pump operation.

Checklist of troubles

1. Fails to deliver liquid
2. Does not develop enough pressure
3. Loses prime after starting
4. Vibrates
5. Stuffing box leaks excessively
6. Seal leaks excessively
7. Bearings have short life.
8. Delivers less liquid than expected
9. Shape of Q-H curve differs from original
10. Consumes too much power.
11. Is noisy
12. Packing has short life.
13. Seal has short life.
14. Pump overheats and seizes

Major problems and solutions

Pump consumes too much power

System head is less than pump head, Specific gravity is more, Viscosity is more, Misalignment, Foreign matter in impeller, Rotating part rubbing in stationary part, Shaft bend, Gland too tight.

Delivers less liquid than expected

System head is more than pump head, less driver speed, air trapping in suction, clogging in suction pipe, more clearance between impeller and wear ring, NPSH(A) less than NPSH (R).

Bearings have short life

Improper balancing of rotor assembly, misalignment, water contaimination in lubricant, lack of lubrication, excessive lubrication, inferior quality of lubricant.

Pump is noisy

Cavitations, bearing worn out, misalignment, pump running close to shut off, improper balancing of rotor.

Pump vibrates

Improper foundation, misalignment, improper piping support cavitations.

Troubles due to improper installation, assembly and machining or testing

Pump develops less head and consumes less power over its whole working range, while efficiency remains unaltered (Fig 3).

The most common cause for such behaviour is a deformed impeller casting. Two other possibilities are rotational speed lower than specified, or an undersized impeller.

Head falls of rapidly with an increase in flow rate while shutoff head is practically unchanged. Such a curve indicates the reduced throat area of the volute (Fig 4).

Test flow rate is lower than rated by a constant amount at any given head. This curve results from excessive leakage through the wear rings. Usually such curve indicates that the rights are worn and need replacement. A worn wear place and/or worn impeller vanes are indicates when this curve applies to a pump with semi-open impeller (Fig 5).

Head, capacity, efficiency and horse power are all lower over the entire curve. Excessive clearances in the wear rings or between the impeller vanes and wear plates (Fig 6).

Reduced head and efficiency but horse power unchanged. Due to rough water ways in the impeller and/or casing (Fig 7).

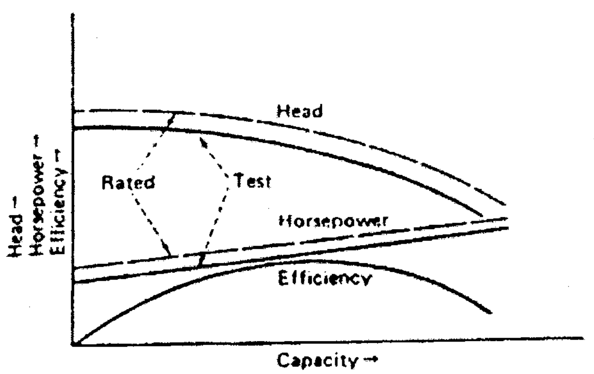


Fig. 3: Impeller diameter too small

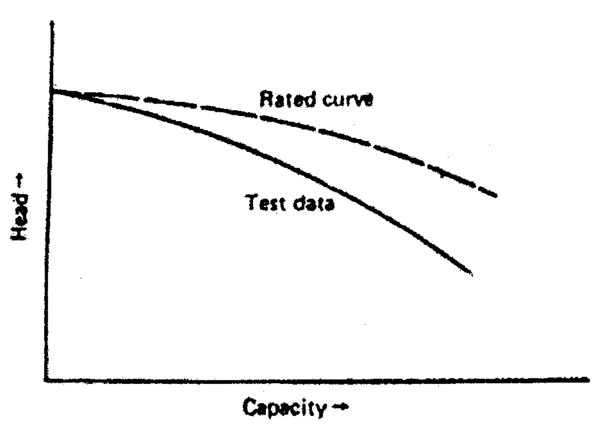


Fig. 4: Obstruction or reduced throat.

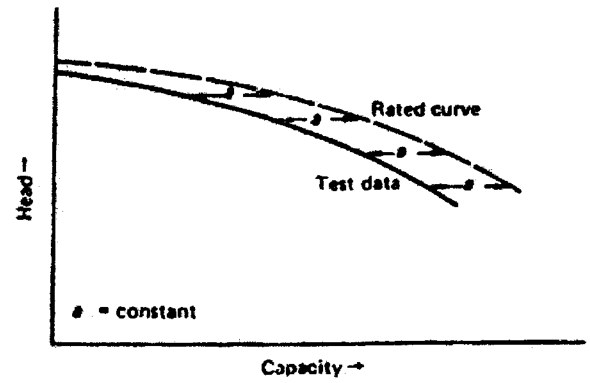


Fig. 5: Leakage through wear rings

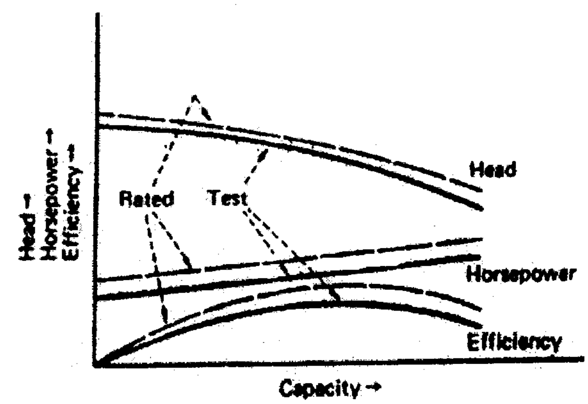


Fig. 6: Excessive leakage through wear rings

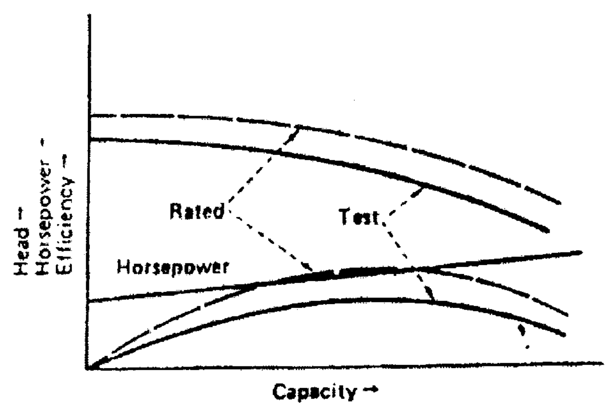


Fig. 7: Rough waterways in casing or impeller

Head./capacity curve correct but low efficiency causes increased horse power. Due to mechanical losses resulted from tight packing or seal, excessive hydraulic pressure on a seal or packing, faulty bearing, misaligned parts, misaligned pump and driver, bent shaft, operation near critical speed, deformation of casing by piping or base plate stress. Curve breaks of earlier than specified due to insufficient NPSH (A) (Fig 8).

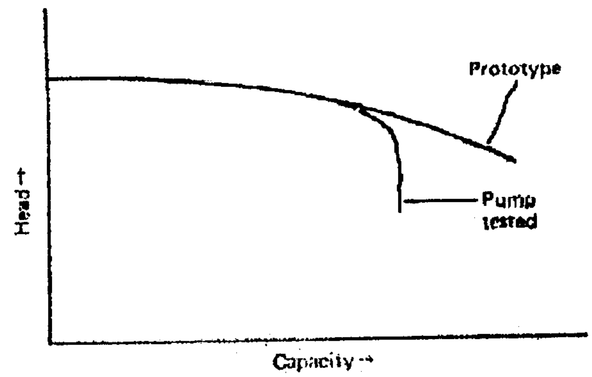
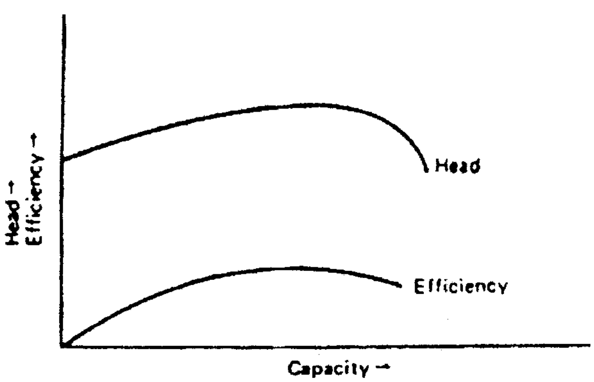


Fig. 9: Insufficient net positive suction head



Pressure head developed by the pump increases with an increase in flow rate. This occurs when the impeller is mounted inversely on the shaft and it some times happens when the pump rotates in the wrong direction (Fig. 9).

Effects of oversizing pumps

The system head curve is developed by plotting total system head (static and friction loss) as the flow varies from zero to maximum. System head curve analysis helps define the operating relationship between the pump head and the system head., Efficient and trouble free operation depends on a close match of pump curve and system curve, otherwise pumps may be picked that are improperly sized and do not run at the conditions for which they are selected./purchased.

At design flow of 350 cum/hr, the engineer calculates the head as 32m, Erroneously believing that using a safety factor will ensure his reaching, D, he adds 12m, to obtain total head of 45 m. Assuming the user needs a pump to operate 350 cum/hr, and 45m, pump manufacturer selects a pump with curve A,B,C (Fig. 10). The pump curve intersects the system head curve at BEP-Best Efficient Point.

However, the actual system curve (Fig. 11) is E.D,C and the pump will run at C rather than B, because with discharge valve fully open, pump seeks equilibrium with the system and operates at the intersection of pump curve and system head curve. At point C, the pump will produce a flow of 480cum/.hr. Not only the user is getting different conditions than he wants, he is also operating at a less efficient point on the pump curve and spending more on energy (Fig. 12).

To get 350cum/hr, the valve is gradually closed, steepening the system head curve. The pump produces 350 cum/hr and 45 m. But head at 350 cum/hr is 32 m.The pump thus produces 45m and 350 cum/hr but delivers only 32 m and 350cum/hr to the system. The additional head 12m, is thus wasted across the valve as heat and noise. The effects of over sizing the pumps

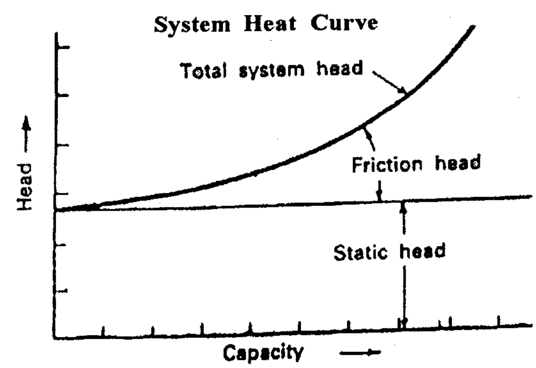


Fig. 10:

A pump operating in a system must develop a total head, which is made up of several components.

1. Static Head	Static Head
2. Difference in pressure	" "
3. Friction loss in Pipes, Valves etc	Friction Loss
4- Entrance & exit losses	" "
5. Differecne in Velocity Heads	" "

If the sum of total static head and of the frictional losses for a series of assumed flows is plotted against flow, the resulting curve is called the system head curve. Super impose the H-Q curve of the pump on the system head curve and the intersection will indicate the flow that will be delivered to the system.

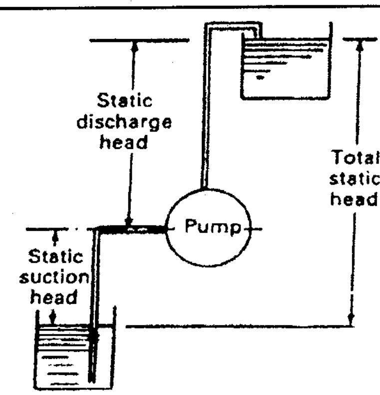


Fig. 11

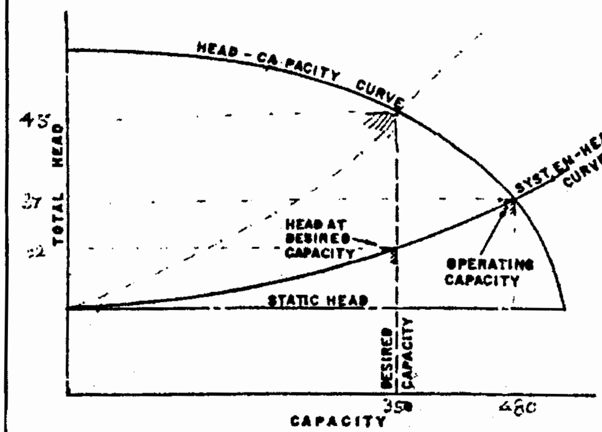


Fig. 12 Effect of oversizing a pump

are 1. operation at excess capacity requires greater NPSH (R) 2. High pressure drop through foot valve, 3. cavitation leading to efficiency drop and premature failure of rotor. 4. Greater power consumption 5. High initial purchase cost 6. Internal loading and hydraulic radial thrust and 7. vibration and dehydration. The solutions are 1. Reduce impeller dia 2. Reduce speed and 3. Go for new correct sized pump. Excessive throttling pump stock pumps leads to dehydration due to high velocity, vibrations, greater internal radial load reducing life of rotating element. Hence, the pumps are not to be operated for extended periods, less than 1/4th of BEP capacity.

How pumps get oversized ?

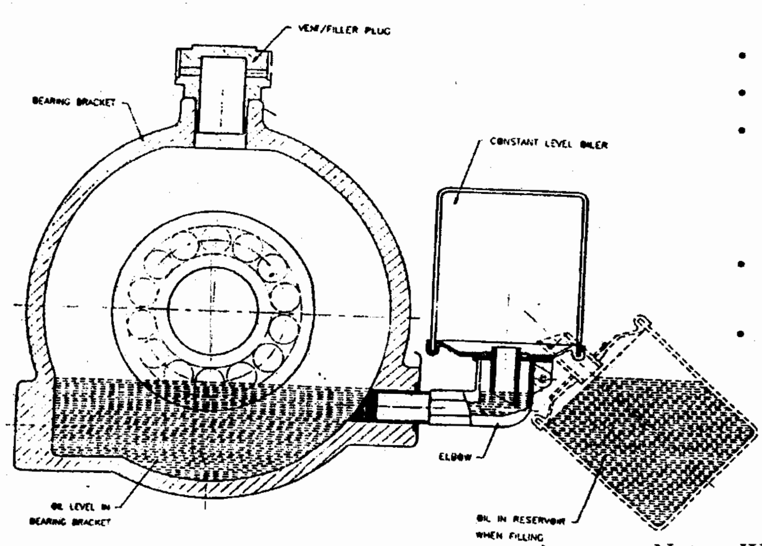
The most common reason pumps are over sizes is "Why take chance getting it wrong?"Design engineers are paranoid of selecting a pump unable to achieve the head required, to achieve the required system flow rate. When selecting a pump, it is prudent to include a safety margin to ensure the pump can accommodate unforeseen system changes that typically occur during the design, construction and operation of the piping system. The safety margin can be thought of as pump insurance and like any insurance, it has a premimum that must be paid. The more the pump is oversized, the higher the premum. The important thing when determining the safety margin in pump selection is to choose the right amount of insruance and know what you are paying for.

Bearing Life

The B-10 life of antifriction bearings used in ANSI and API pumps is supposed to be 24000 and 4000 hrs, respectively. What this means is that 90% of the bearings should still be serviceable after approximately 3 years for ANSI pumps and 5 years for API pumps. In practice, this is not what happens. When one talks to maintenance people who do keep records, one finds that on the average, the life expectancy of the bearings falls short by as much as 50% or more. This is not because the pump manufacturers do not know how to size the bearings or too optimistic and cut corners. It happens generally because of one or two reasons (Fig. 13).

1. The actual load on the bearings exceeds the predicted load or
2. The load which the bearings can carry falls short of the basic bearing load rating because of bearings environment conditions

The first can be caused by a variety of problems such as pump misalignment, excessive forces and moments excerted on the pump by the piping, pump cavitations, operation below recommended minimum flows, poor suction piping etc. The second stems from lack of lubricants, water contamination of lubricants, inadequate cooling, excessive cooling, Of this list, water contamination in the lubricant is probably the greatest



- Remove the vent plug
- Tilt the reservoir as shown in the figure
- Fill oil through the hole left by the vent plug, until oil appears in vertical section of the elbow connecting bearing bracket and reservoir.
- Fill up the reservoir and snap it back in to position
- Fix the vent plug back.

Note:- Whenever the oil level comes down in the reservoir refilling has to be done only in the reservoir not in the BRG bracket.

Fig. 13 Procedure of Oil Filling

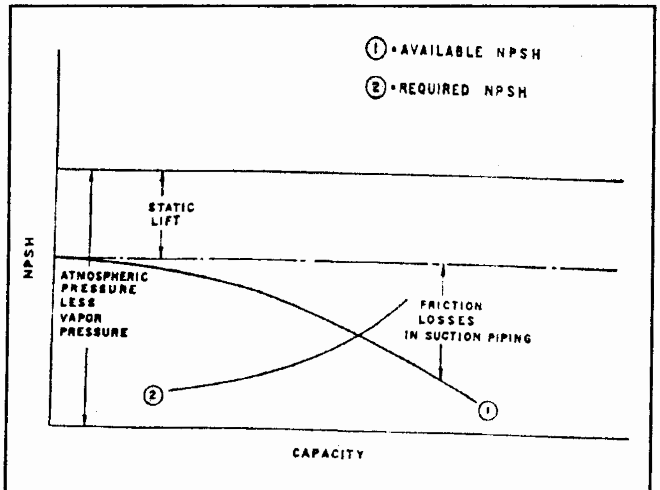


Fig. 14 Available and required NPSH

and most frequent offender Fig. 14. As little as 0.002 % water contamination will reduce bearings life by a dramatic 48%.

There is no question that education of pump users in the proper lubricating practices is the only way to reduce the failure rate attributable to bearings.

Should suction or discharge valve to be throttled?

It is never recommended to throttle the pump suction in order to reduce the capacity, as the effect is to change the pump head-capacity curve through cavitations and operation in the so called break. The pump efficiency is seriously affected in such operation built most important of the ill effects are the erosion and premature destruction which are caused by a cavitation which would reduce capacity as drastically as desired.

Case Study-1

The twin pumps

Two identical pumps (Fig. 14) installed side by side, to transfer liquid from same source in to 'the same pressurized container. Each pump provided separate suction and discharge pipe. Two pumps never operated simultaneously. While one ran, other served as a stand by. Everything about these two systems seemed to be identical except that one pump performed perfectly and second one with great noise and vibration. The troublesome pumping was system dismantled several times but nothing wrong could be found out. The successful pump loop had a 2 inch discharge with a reducer connecting directly to a 1 1/2 inch pipe line. However the troublesome loop had a 6 feet 2 inch pipe connected to pump discharge and only after this length, pipe line was reduced to 1 1/2 inches. When 2 inch dia was replaced with 1 1/2 inch pipe, the problem causing pump operated satisfactorily.

Up to a certain flow rate, the NPSH (R) increases approximately as the square of the flow. Above this capacity, it starts to increase at a much faster rate. In this case the frictional losses in the pipe line constituted a very significant part of the total head, against which each of these pumps had to operate. In the discharge line, that consisted exclusively 1 1/2 inch, the resistance to flow was adequately high. This kept the total head well above the critical pumping head. This in turn limited the flow rate to well below critical capacity. In the other pipe line, however, the reduced resistance of the 2 inch dia pipe section, brought down the total head well below the critical head. This increased the NPSH (R) of the pump well above the NPSH(A). Consequently cavitation developed within the pump. This in turn, gave rise to the noise and vibration.

Case Study-2

Head in storage tank

The pump transferred fuel from a storage tank to oil delivery truck (Fig. 15). Whenever the oil level was low i.e. when the NPSH (A). is less, the pump operated satisfactorily. However, when the storage tank is full i.e. when the NPSH(A) is more, operated with extreme noise and vibration.

The total head against which a pump is operated is defined as the difference between the total head existing at pump outlet and the total head available at inlet. In this particular application, the discharge head tends to be practically constant. This means that an increase in

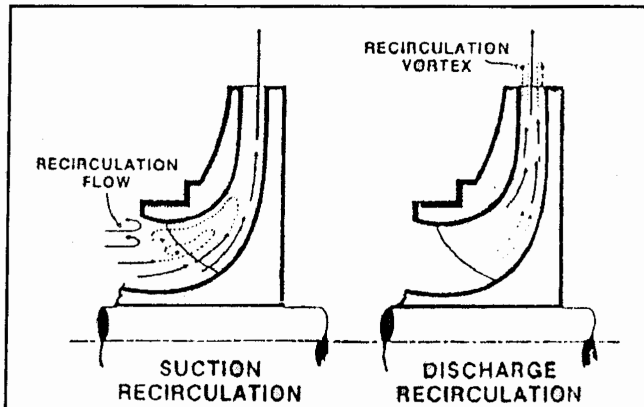
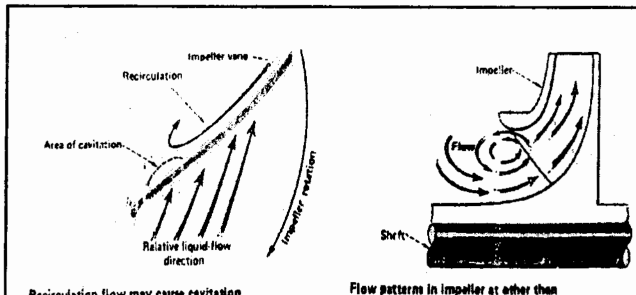


Fig. 15



Recirculation flow may cause cavitation

Flow patterns in impeller at other than best-efficiency-point conditions

Fig. 16

the suction automatically reduced the total head against which the pump has to operate.

When the storage tank is full. the pump operated well below the critical head. This however meant that the pump delivered a flow rate significantly higher than the critical capacity. However the flow meter installed in the pipe line and the measurement of time required to fill the truck, indicated that the rate was well below the critical capacity. There seemed no solution to this puzzle.

The most important factor that determines the NPSH(R) of a pump at a given speed is the rate of flow through the impeller. The flow rate through the impeller is usually grater than that through the pipe line owing to leakage through the wear rings. However if a wear ring is missing, this short circuits the impeller discharge to the impeller eye. In such case, the flow through the impeller may easily be 30% to 40% higher than the flow through pipe line. In this case, this would have brought the total flow, through impeller, well above the critical flow rate, The pump was opened and the front wear ring was found to be missing. A new wear ring was installed in the casing and solved the problem.

Case Study-3

Two identical slurry pumps, installed side by side, to pump bauxite slurry d from same source. Each pump provided separate suction and discharge pipe. Two pumps were operated simultaneously. Everything about these two system seemed to be identical except that one pump performed perfectly and second one with areat noise, vibration. And leading frequent failure of the shaft and faster worn out of impeller and wear plates. The troublesome pumping was system dismantled several times but nothing wrong could be found out.

Since, pumps are identical running for same duty conditions, customer claimed free replacement. As one pump was giving satisfactory operation. The problematic pump was reconditioned with new spares and put back into operation. After a particular period of time, customer reported again the shaft breakage. When the problem was attended by the Service Engineer during third time, he could see the pump operator throttling the suction valve for varying the flow. And the service engineer concludes the problem. He noticed in the successful pump, the discharge valve is provided near the pump discharge i.e. in a reachable position. In the problematic pump, the discharge valve was provided at a grater distance which the operator could not reach and ha had to go to first floor to control it. Since the suction valve was provided in a reachable position, the operator controlled the flow with suction valve without knowing the effect of this operation. When the suction valve was kept fully open and discharge valve was used to control the flow, the problematic pump started giving satisfactory performance as that of the successful pump.

It is never recommended to to throttle the pump suction in order to reduce the capacity, as the effect is to change the pump head-capacity curve through cavitations and operation in the so called break. The pump efficiency is seriously affected in such operation but most important of the ill effects are the erosion and premature destruction which are caused by a cavitation which would reduce capacity as drastically as desired.

Maintenance schedule

Every month

Bearings : Check temperatures, causes of hot bearing are: Sleeve, not enough lubrication, antifriction too much lubricant. Change oil if necessary.,

Every three to four months

Bearings: Inspect and clean, drain lubricant from bearings and housings and clean with suitable cleaner.

Every six months

Stuffing Box: Watch for excesive leakage of sealing liquid. Inspect packing for wear and damage. Replace if defective. Check position of lantern rings.

Sleeves: Examine for trueness, scoring and wear.

Pump & Driver: Check alignment. Re-align if necessary. Examine piping supports and lock for strains on pump caused by poorly supported pipe.

Every year

Impeller: impeller for wear from abrasion, corrosion, and cavitations. Cavtiations is the pitting from hammering effects of recondensing vapor bubbles.

Casing: Check similarly, If impeller is badly worn, look for scale and forign matter.

Wearing Surfaces: Check clearances between stationary and rotary parts, foot valves. Strainers. Inspect for cavitations and obstructions.

Ten reasons to buy OEM spares

- You get the parts that is made to fit your pump and not a part that is almost right"
- The parts are manufactured under rigid quality control techniques to original design specifications and tolerance.
- The materials are properly developed to specifications that ensure consistent quality.
- The parts, pumps and your application are backed by the company's knowledgeable sales and technical support personnel.
- Critical parts are hydraulically tested to ensure

trustworthy application.

- It allows to forge a strong relationship with the OEM for the best all round service.
- It allows OEM to develop and maintain a database on the equipment, which can be used for trouble shooting, future upgrades and accurate reordering of parts.
- By supporting the OEms, you enable them to conduct more extensive research and development, thereby improving their products, customer services and pricing for yourself.
- Using non-OEM parts can avoid the pump warranty
- Using non OEM parts can, in critical applications, pose a safety hazard.

CONCLUSION

The site conditions including the quality of the maintenance personnel as well as the availability of operating instructions with the maintenance personnel is equally important. In addition to this, long shut down periods due to nonavailability of power/raw materials etc, have to be carefully assessed and suitable preventive measures taken. Static corrosion is very often more harmful and leads to serious problems. Aging and clogging of the piping and strainers are also common during such times and are overlooked. It is needless to mention that for any machine, preventive and routine maintenance is mandatory for its successful operations.

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