Energy Audit of Pumping System

S L Abhyankar

Generally, the popular perception of audits is that it is a fault-finding exercise. But Quality Audits as per ISO-9000 have brought in a cultural change to this traditional outlook. The author describes here energy, how audits can be performed to improve the operational efficiency of pumping systems. Working of an equipment / facility. He highlights the seven ways to ensure energy efficiency in pumping systems. According to the author both pre-installation measures are as important as post installation steps, both of which cumulatively makes this entire system more and more energy efficient.

Audit

People have known of the concept of audit from the practices in accounting. That audit is a post-event activity or a review activity, investigating the propriety of expenses already incurred. In this practice, audit becomes mostly an exercise in fault-finding.

Quality Audit as per ISO-9000, have brought in a cultural change to this traditional outlook of audits being a post-event, fault-finding activity. By the "Adequacy Audit" concept in ISO-9000, this stage of audit mainly focuses on investigating whether the system as proposed to be installed, and described in the Quality Manual is adequate or proper or not. As against the fault-finding approach, the approach in adequacy audit is to ensure the system to be proper even before installation.

Then in ISO-9000 there are "Compliance Audits" and "Surveillance Audits". During these audits "Non-conformities" are found out. In these audits the approach tends to be the fault-finding approach, yet with an urge for remedies and improvement.

In the case of Energy Conservation in pumping, both approaches – ensuring the system to be energy-efficient, both before and after installation are relevant. The approach also would not be one of fault finding. The approach would be to improve the system to be more energy-efficient.

How Can One Ensure Pumping System To Be Energy-Efficient Before Installation?

In the Standards of Hydraulic Institute, one finds a good summary of 7 Ways to Ensure pumping system to be energy-efficient right from the stage of system-design. It would be good to have them enumerated here.

Design systems with lower capacity and total head requirements. Do not assume these requirements are fixed.

Flow capacity, for example, can be reduced through use of lower velocity in heat exchangers and elimination of open bypass lines. Total head requirements can be reduced by: lowering process static gage, pressure, minimizing elevation rise from suction tank to discharge tank, reducing static elevation change by use of siphons, lowering spray nozzle velocities, lowering friction losses through use of larger pipes and low-loss fittings, and eliminating throttle valves.

Avoid allowing for excessive margin of error in capacity and/or total head. It typically will be less expensive to add pumping capacity later if requirements increase.

Small differences in efficiency between pumps are not as important as knowing and adjusting to the service conditions. Energy savings may be as high as 20% if pumps are sized based on reasonable system heads and capacity requirements. Savings result from operating at a more efficient point on the pump curve, and in some cases, this also avoids the need to throttle pump capacity or operate at a higher capacity than necessary.

Despite the tendency to emphasize initial cost, you will save in the long run by selecting the most efficient pump type and size at the onset.

The choice of a pump depends on the services needed from the pump. Considerations are flow and head requirements, inlet pressure or net positive suction head available, and the type of liquid to be pumped. Maximum attainable efficiency of a centrifugal pump is influenced by the designer's selection of pump rotating speed as it relates to "specific speed." Purchasers need to be aware of this, as well as the decision criteria for determining the type of pump to use.

Use variable-speed drives to avoid losses from throttle valves and bypass lines, except when the system is designed with high static heads.

In such instances, extra concern must be shown when calculating the savings, since the pump affinity laws cannot be used without regard to the change of pump (and motor) efficiency along the system curve. Take care to ensure that the operating point of the pumps remains within the allowable / recommended limits specified by the pump manufacturer.

Use two or more smaller pumps instead of one larger pump so that excess pump capacity can be turned off.

Two pumps can be operated in parallel during peak demand periods, with one pump operating by itself during lower demand periods. Energy savings result from running each pump at a more efficient operating point and avoiding the need to throttle a large pump during low demand. An alternative is to use one variable-speed pump and one constant-speed pump.

Use pumps operating as turbines to recover pressure energy that would otherwise be wasted.

Practically all centrifugal pumps will perform as turbines when operated in reverse. A hydr-aulic power recovery turbine can recover pressure energy when used to drive a generator, or assist the driver of a pump or a compressor.

Maintain pumps and all system components in virtually new condition to avoid efficiency loss.

Wear is a significant cause of decreased pump efficiency. Bearings must be properly lubricated and replaced before they fail. Shaft seals also require consistent maintenance to avoid premature mechanical failures. Most important is the renewal of internal wearing ring clearance and the smoothness of impeller and casing waterways.

How can one ensure Pumping System to be Energy-efficient after Installation?

Maintain like new

The last i.e. the seventh way in 2-7 above is actually a guideline to save energy after installation.

Commissioning Run

Pump is selected, procured and installed against some estimation of the pumping duty. Changes would have happened in the system parameters in the period between the time when the pump specifications were finalized to the time when the pump is installed and commissioned. The first run after commissioning the pump, becomes the right time to review the pump performance, which the pump actually demonstrates vis-à-vis the duty defined in the tender specifications.

Effect of Margins

Pumping duty defined for procurement, i.e. required flow-rate Q, total head, H are derived by estimation. Often, one is more sure of Q. for example, if one wants to neutralise an acid, one is as much sure about Q for alkali to be pumped. It is rather the total head H, which is worked out by estimation. There is tendency to add margins to the value worked out by estimation. But the installed system as may reveal that the margins which were provided during estimation were not needed. In such instance, which is quite common, the pump will demonstrate performance much different from the tender specification this will also have an adverse effect on energy-consumption by the pump. The logic is easy to understand as illustrated in Fig.1.

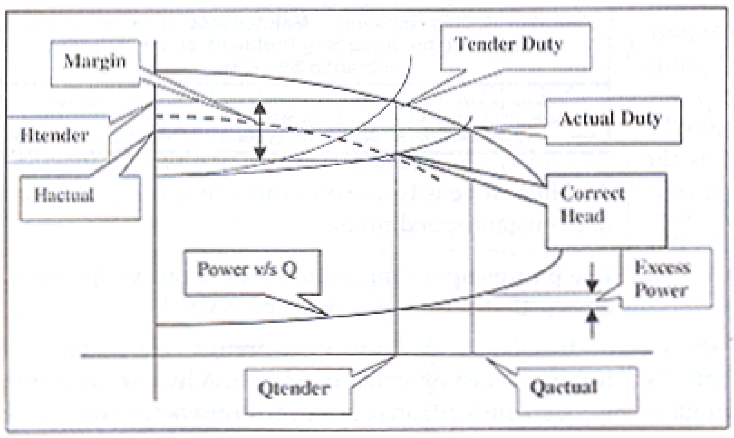


Fig.1. Effect of Margins

Significance of the Margins

Providing margins simply means providing for excess energy consumption. This is so, because, energy consumption is usage of power over number of hours of pumping. Energy consumption will be more, because usage power will be more with margin. Since power (in kW) consumed in pumping is equal to (Rho)*(Q in 1/s)*(H in m)/ 102 / (pump efficiency) / (Motor Efficiency), margins will make either Q being considered more than necessary or H being considered more than necessary. This is precisely the significance of the first of the 7 ways mentioned in HI.

As mentioned above, margin will be provided mostly in specifying the head H. this itself comprises of two components, the static head and the frictional head. Obviously, no margin should be needed for the static head component. Finally it comes to realizing that margins would add only into the frictional head component. This is eminently against the spirit of energy conservation. In providing the margins, it is more the psychology or anxiety that the system should deliver the desired performance.

Resolving the Anxiety

It would help to resolve the anxiety, if one can access what will happen if no margins are provided. It is possible that the system as installed may have higher friction. As shown in Fig. 2, if the actual friction and in turn the actual total head is higher, the pump will deliver less discharge. It is possible that the reduced discharge is still acceptable.

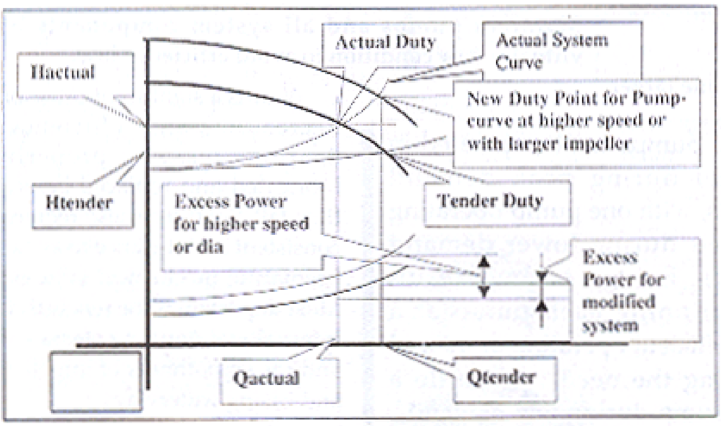


Fig.2 When Margins are not allowed

If the reduced discharge is not acceptable, there would be different options to get the desired discharge.

- System may be modified, say by replacing pipes with pipes of larger diameter. This will reduce the frictional head and in turn will make the system resistance curve flatter as originally estimated.
- Pump speed may be increased.
- Impeller may be replaced with one of larger diameter.

At this point is interesting to note how this option no.3 is provided in API-610. In API-610, it is mandatory that pump-supplier should not offer a model, which satisfies the tender duty only with full diameter impeller. The pump supplier should offer only such model of pump, which will satisfy the tender duty with an impeller diameter less than the full diameter. It is specified that at least 5% head increase should be possible after replacement of impeller.

Margin in power

As shown in Fig. 2 the power input needed by the pump would be more in case of all the 3 options. Most caution is hence needed to check that motor has the capacity to deliver additional power needed in every option.

LCC, The Decision-Making Tool

While all the options do imply some additional capital cost, option no.3 is one with possibly least additional cost. However, option no.1 has the best potential for reducing energy consumption.
All such situations of choosing between options should be resolved by Life Cycle Costing (LCC) approach. An exercise in LCC often reveals that in the total cost of a pumping system over a life, the major cost is incurred on energy-consumption, almost 80%. Hence the option with least cost of energy-consumption often proves the most prudent option.

Benchmarking

Pump-suppliers often tend to compete by quoting higher efficiency to score selling point. It becomes important for the buyers or users to know ”the best attainable efficiency” for a given set of values of Q and H. There have been charts available in handbooks. These charts, as shown in Fig.3 come handy for the users to know the “the best attainable efficiency” for the tender duty.

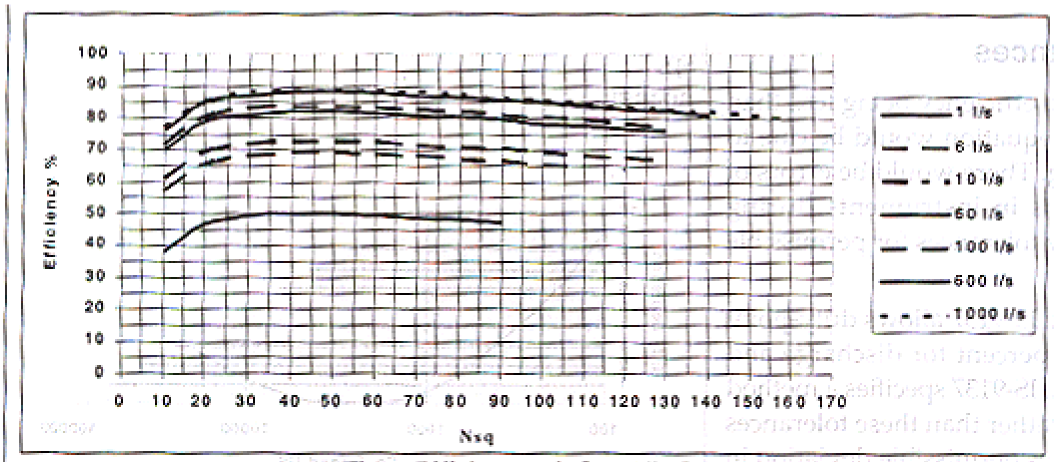


Fig.3. Efficiency v/s Specific Speed

Instead of reading from the Chart of Fig.3, one can get the value of efficiency using the regression equation efficiency = 100*(0.94 – 1/ (13.2*Q)^ 0.32 – 0.29*(0.32 – log(0.047*Nsq)) ^ 2)

In the above equation,

Q shall be in litres per second and
Nsq = n * sqrt (Q / 1000) / H^ 0.75
Where n is rpm and H is in m

BEP and Duty Point

Value of efficiency obtained from the chart or the equation, is appropriate only if the duty point would be the point of best Efficiency (BEP) for the pump. If the duty point is away from BEP, the efficiency at duty point will be less.

There is a recommendation vide clause 2.12 in the 8th edition of API-610, saying, "pumps shall have preferred operating region of 70-120 percent of Best Efficiency capacity of the furnished impeller. Rated capacity shall be within the region 80-110% of Best Efficiency capacity of the furnished impeller."

Safety, reliability, Availability, MTBF and efficiency

For process pumps, the considerations of safety, reliability, MTBF and availability are as important as efficiency. Designers have to strike the best compromise. This would often necessitate a compromise on the value of efficiency.

Deviations and Tolerances

Another reason for pump efficiency being less than the value from the chart or equation would be due to deviations in manufacturing. There would be errors of parallax and of fluctuations in instruments during testing. All standards specify tolerances for permissible deviations.

For example, class C code IS-9137 allows duty-point to be attained within + / -7 percent for discharge and within + / -4 percent for head. IS-9173 specifies a method of evaluating the deviation rather than these tolerances for Q and H. API-610 specifies permissible deviation in head against the nominal Q.

Monogram in HI standards

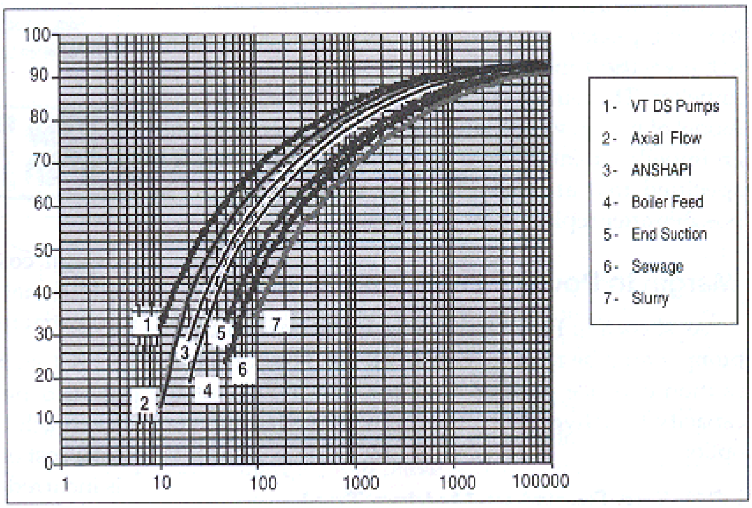
Hydraulic Institute (HI) standards have a monogram, "Estimating efficiency of centrifugal pumps". It is not a single chart as in Fig.3 or a single equation. One has to move across Fig. 1A, 1B and 2. The values of efficiency, especially after applying bilateral deviation as per Fig. 2 therein, turn out to be not competitive with values as per chart in Fig. 3. (See Annexure 1.)

Annexure 1

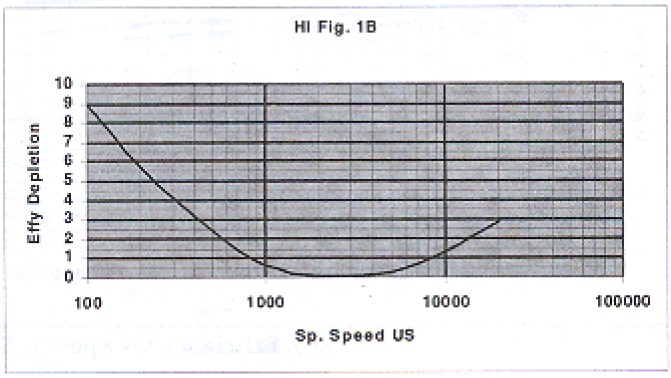
HI Monograph on Estimating Efficiency of Centrifugal Pumps (Curves plotted are by regression analysis done by author)

Step 1.

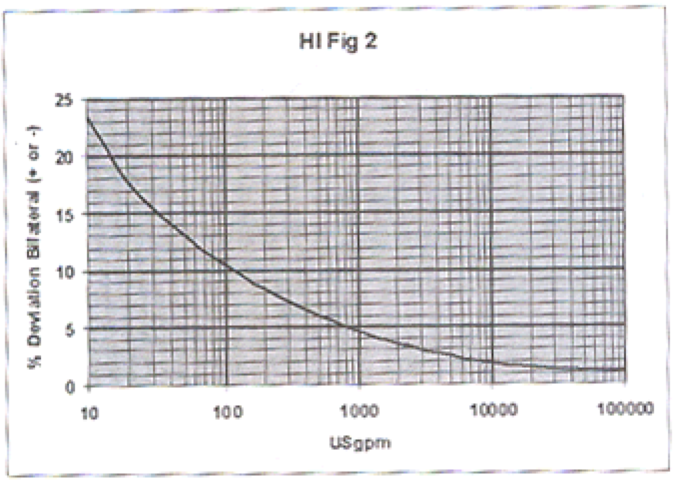
Knowing Q in USgpm and type of pump, find Base Efficiency from Fig. 1A



Step 2. Knowing Q in USgpm, Head in ft and rpm, find Specific Speed in US units. From this find from Fig.1B the depletion in Base Efficiency. Note, for valves of specific speed in the vicinity of 2500, the depletion is negligible.



Step 3. From HI Fig. 2 find possible deviation in efficiency:



Observations

1. Values of maximum efficiency in Col. 14 are fairly close to values of chart efficiency in Col. 9
2. There is a presumption for HI procedure that Suction specific speed shall be 8500 US units. Effect of departure from this value of suction specific speed is not detailed in HI.

Norms for Minimum Efficiency in IS-6595, IS-8034, IS-9079 and IS-14220

The norms were derived from the chart of Fig.3 only. But as norms for 'minimum' efficiency, they had to be and are somewhat less than the values as per Fig. 3. The types of pumps covered are:

IS-6595 Part 1 end suction centrifugal pumps for agricultural purposes to be coupled to engines or motors

IS-8034 Borewell submersible pumpsets and

IS-9079 Part 1End suction electric monoset pumps for agricultural purposes

IS-14220 Open well submersible pumpsets

Although the norms in Part 1 of both IS-6595 and IS-9079 are for pumps for agricultural purposes, they would serve as some benchmark even for end suction process pumps.

Example – Three examples for different types of pumps are illustrated below.

No.	Pump Type	Q in 1/s	Q, Usgpm	Head in m	Head, ft	rpm	Nsq	NsUS
	1	2	3	4	5	6	7	8
1	API	3.785	60	20	65.6168	2900	18.86507	974.3441
2	Boiler Feed, 10 stages	11.355	180	200	656.168	1450	16.33763	843.8067
3	Sewage	56.775	900	40	131.2336	1450	122.1523	6308.927

No.	Chart Effy, Fig.3	Base Effy HI Fig 1A	Depletion HI Fig 1B	Corrected Value	Bilateral Deviation	Maximum Efficiency (HI)	Minimum Efficiency (HI
	9	10	11	12	13	14	15
1	61.37705	52.7	0.738	51.962	12.323	64.285	39.639
2	68.39376	65.53	1.06	62.47	8.58	71.05	53.89
3	76.38608	71.553	0.5207	71.0323	4.856	75.8883	66.1763

Conclusion

Except for IS standards mentioned above, no International standards specify the desired efficiency values for pumps. If they would be available in International standards, these can serve as good benchmarks for any exercise in energy audit and energy conservation in pumping. The chart as in Fig. 3 has been available in text books on pumps and in pump handbook. However values once specified in standards get an inherent credibility of consensus among experts. It will be good if it can so happen. In absence of that people have to rely on charts as in Fig.3 and apply the values judiciously, taking into consideration various factors such as duty point being away from BEP, compromise due to other factors like reliability, MTBF etc. and deviations during manufacturing.

Reference Book:

Chemical Industry Digest
April 2006