High and Broad Band Efficiencies in Pumps

by Steve Wilson

While the terms "high efficiency" and "broad band efficiency" are relative and have no real meaning per se, they are terms often used within the pump industry. It should be noted that neither of these terms refer to a benefit. High efficiency is a result of good pump design that may yield the benefits of lower operating costs and less energy consumption at any duty point. This paper will discuss both terms at a basic level. In all cases, unless otherwise noted, efficiency will refer to pump efficiency.

EFFICIENCY

Simply stated, pump efficiency (E_p) is the ratio of output power (water horsepower) (whp) divided by the input power (brake horsepower) (bhp), expressed as a percentage, and can be show as:

$$E_p = \frac{whp}{bhp} \times 100.$$

Efficiency in pumps, as portrayed on pump curves or stated on pump data sheets, is a calculated value based on test results. The amount of work being done is measured, as is the power consumption by the pump and efficiency calculated from those results.

Many factors impact pump efficiency, which has 3 major components:

Mechanical Efficiency

Energy used in bearings, stuffing box and disc friction losses at the wear rings, etc.

Volumetric Efficiency

Accounts for recirculation and turbulence and other losses at glands, etc.

Hydraulic Efficiency

Accounts for friction and shock losses in the flow paths.

Each of the items which detract from the efficiency also detract from the performance of the pump.

Each pump, at design, has the theoretical curve associated with it and its specific speed. The losses internal to the pump detract from the theoretical. This relationship is graphically and simplistically shown in *Figure 1.*

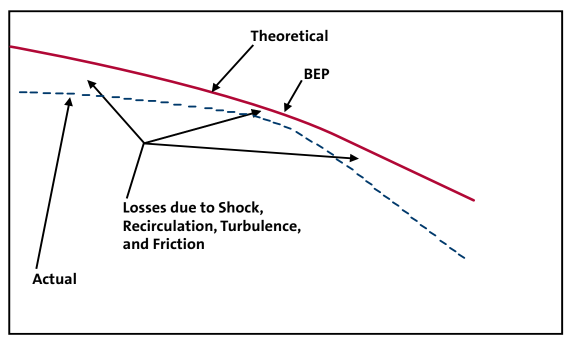

Figure 1. *Actual vs. Theoretical Performance*

As seen in *Figure 1*, the BEP (Best Efficiency Point or Design Point) is that point at which the losses are minimized in total, and the actual curve is closest to that which is theoretically possible. (This will be further discussed later in this paper.) As the pump performs through its range, moving away from the BEP, the amount of these losses change. These losses have been categorized (and again simplified) as Shock (the use of some of the energy to accelerate and decelerate the fluid being pumped); Turbulence (the absorption and use of energy associated with molecules of fluid interacting with other molecules of the fluid); Re-circulation (the failure of fluid to be discharged, but to tend to re-circulate back to the suction or stay within the casing); and Friction (the use of energy as the fluid interacts with the components of the pump. At low flow conditions, friction losses are minimal, but recirculation losses are high; at high flow this is reversed, etc. Thus, the more these losses are reduced, the higher the efficiency.

HOW LOSSES CAN BE MINIMIZED

In order to improve efficiencies, losses must be reduced. A brief discussion of some of the methods employed is given here. This is not meant to be all inclusive.

Shock losses can be minimized by assuring a gradual acceleration and deceleration of the fluids within the pumps. Francis vane impellers may be employed. Assuring that the case and impeller are designed together will also assist in this reduction. Proper attention to the throat area in the casing and much engineering effort is put into this area.

Turbulence losses can be reduced by assuring that flow paths are smooth and as laminar as possible, that internal areas are kept to a minimum size, and that internal designs to not promote turbulence by directing flow inappropriately. One method of reducing recirculation which is generally to be avoided is a sharpening of the cutwater(s) through grinding to a sharp edge. While this will indeed improve efficiencies, the improvement may well vanish shortly after the pumps are put into service and the “knife edge” erodes with fluid passage.

Recirculation losses can be minimized by assuring tight tolerances between the impeller and case at the suction eye (and use of wear rings to keep this tolerance as tight as possible) and minimizing the opportunity for internal recirculation through use of dual (double) volutes. Recirculation losses are also reduced by assuring that the impeller diameter is as large as possible relative to the cutwater (without adding to vane velocity caused erosion and noise).

Friction losses can be reduced through improved casting technologies for smoother finishes, by finishing (matching) surfaces in lieu of leaving them in the “as cast” state, and by reducing the length of the flow path.

In the past decade, great advances have been made in CAD and CAM, in casting technology. In pump design in general, it is now possible that the actual curves perform in excess of the “old” theoretical limits. Nonetheless, the same factors must be considered, regardless of pure numbers.

HIGH EFFICIENCY

It is difficult (or impossible) to state what is meant by high efficiency in a pump. The variety of pump types and intended duties, the specific speeds, pump size, etc., are so varied, that no “cardinal number” can be set that encompasses these circumstances. However, it can be stated that:

- In general, the larger the pump, the higher the attainable efficiency.
- Efficiency should be relative to other, similar, pumps of the same size and type. For example, a 4-inch non clog pump intended to pass 3-inch solids with an efficiency of 80% might be considered to have high efficiency if the other pumps capable of performing the same task had efficiencies of 70% or less even though end suction or split case pumps delivering the same flow rates could be expected to exhibit efficiencies of at least 80%.
- Efficiency is only one aspect of pump performance, and reliability should not be sacrificed for efficiency improvements.
- Typically, when efficiency is discussed, it refers to efficiency at either BEP or a given operating

condition. It does anyone little good to look at a pump with 90% efficiency at design point and hear, "Look how efficient this pump is' if the point of selection is not at that point.

- While efficiency of the pump is important, its impact is best totally evaluated by a study of the system in which it is installed. Moving a pump to its BEP by closing valves and "balancing a system" will indeed improve its efficiency, but the system itself may become even more inefficient or worse, less effective.

BROAD BAND EFFICIENCY

The pump efficiency, as discussed above, will vary as the pump moves away from its BEP in any direction for any reason. At no flow, the efficiency is "0" since no work is being done. This efficiency is expressed on pump curves either through "iso-efficiency lines" or with a separate efficiency curve. The ideal pump would be one that had efficiencies rise rapidly (relative to flow) from shutoff and then stayed high throughout the curve, with the efficiencies staying high through a broad operating range. This can be said to be "Broad Band Efficiency." Such a pump addresses the needs of the "real world" and not only allows selection at a high efficiency point, but will allow efficient operation should conditions either vary or not be as predicted.

Observe the following two curves (*Figures 2A and 2B*) The first pump (*2A*) shows a typical pump curve with relatively decent efficiency at design point and normal efficiency bands.

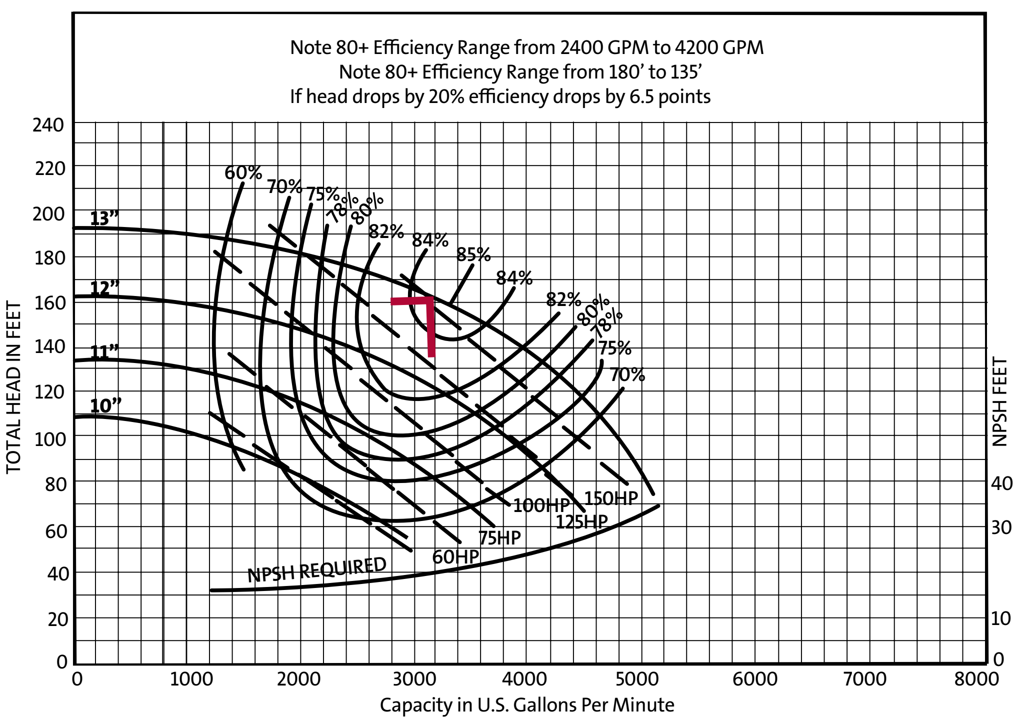

Figure 2A. *Standard Efficiency Bands*

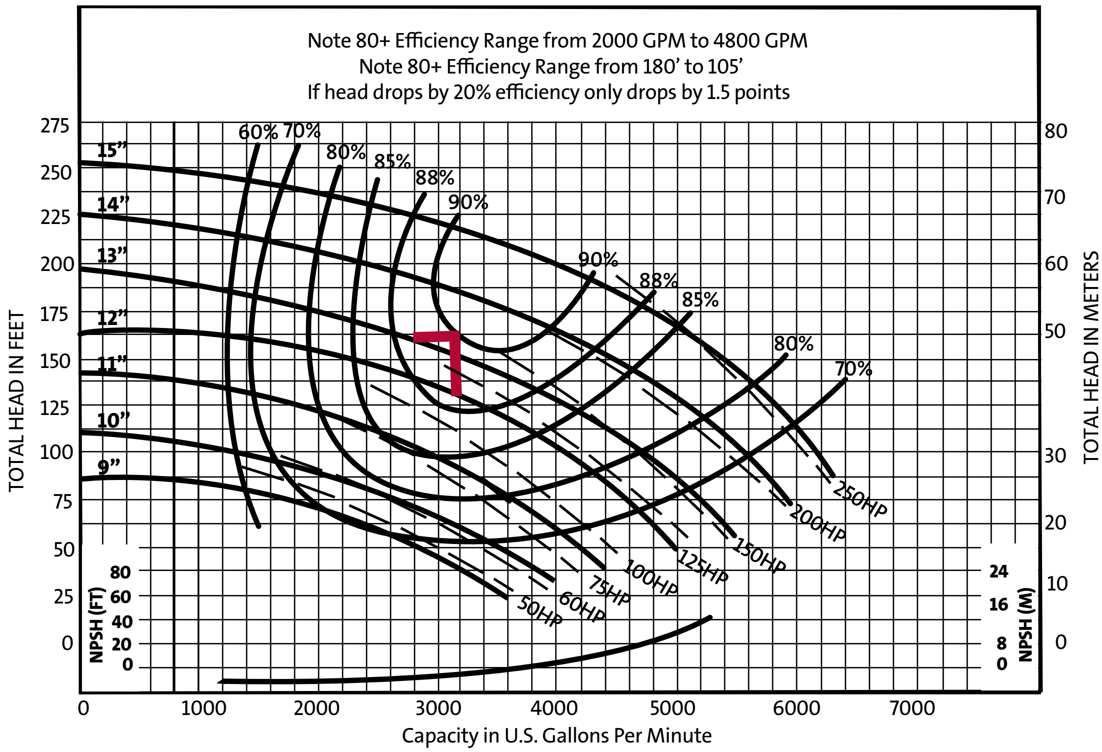

Figure 2B. Broad Efficiency Bands

If the head in the system were to drop by 20% through part loading or actual "as built" differences from design, the head would drop from the 160' design head to (160 x .8) = 128, and the efficiency of the pump in Figure 2A would be reduced from 84.5% to around 78%. Pump (*2B*) exhibits not only higher efficiencies at design (90% vs. the 84.5%), but has a broad band efficiency so that if the head were to drop to the 128' efficiency is maintained at 88%. This pump, in fact, is more efficient at that reduced head than the other pump is at design point.

CONCLUSION

Understanding what is meant by efficiency, high efficiency, and broad band efficiency is valuable in any discussion or study on pump evaluations. It is important to recognize when these terms might come into play so that complete analysis may be accomplished. In addition, it is important to understand what factors are involved in efficiency improvements.

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Being responsible is our foundation
Thinking ahead makes it possible
Innovation is the essence

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