A Prcposal for the Standardizatin of NPSH Determination of Pumping Machinery

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Introduction

Back in 1967, this writer presented a paper with the same title to the ASME Cavitation Forum at Chicago, Illinois. The response, in the form of verbal and written discussion, was strongly in favor of such standardization. The 0% head drop, which has not been too popular a criterion in the U.S.A., was recommended in the paper for the determination of minimum required NPSH. It is interesting to note that two years later, Raabe reported (2) in another ASME sponsored cavitation symposium, "The decisive cavitation criterion for European manufacturers of hydraulic machines is the point at which efficiency or head are beginning to drop." From the above, it follows that there is a timely need for the standardization of NPSH determination of pumping machinery on a worldwide basis.

In this paper, we will extend our discussion to include test facilities, test methods and test fluid, in addition to the data interpretation previously presented.

Data Interpretation

Head drop is the criterion most often used to determine required NPSH. Several articles (1) mention that a 3% drop from the non-cavitating head is common industry practice. Other articles (1) have proposed. 5%, 1% or 2%. And for supercavitating inducers, 10% has been used (Fig. 1).

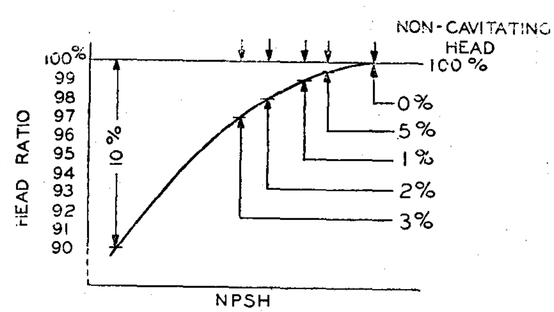

FIG. 1. VARIOUS STANDARDS USED IN DETERMINING THE REQUIRED NPSH

There has been some concern that a safety factor is needed for cavitation prevention. Incipient cavitation or onset of bubble formation can occur without a perceptible drop in head. Since engineering practice generally provides for factors of safety for stress analyses and other determinations of an imprecise nature, why not do the same thing for the cavitation of pumping machinery? In accordance with this line of reasoning, it would be imperative to pick some point before the head starts to drop, rather than a certain percentage of head drop. This would be particularly true for those cases where the head plunges, once it starts to deteriorate. On the other hand an inducer which may have a 5% or even a 10% drop in head, can still be considered to be performing successfully as long as the pump produces a specified capacity without instability.

How to pick a point on the H vs NPSH for the determination of required NPSH, therefore depends a great deal on the application and on the shape of the plot. Pump users and manufacturers could negotiate the applicable values in each individual case. However, a more useful solution, one which benefit both the user and the manufacturer, would be to have a universally accepted standard for the determination of the minimum required NPSH. The author proposes the 0% head drop criterion as the logical choice. In the Head vs. NPSH plot (Fig. 2) the discharge head is held constant while the suction head is reduced. At the critical NPSH the discharge head will drop for most cases, and sometimes will rise first and then drop. I would therefore suggest that a horizontal line be drawn to link all the non-cavitating points. When this line departs from the rising or dropping portion of the curve we have a point of interception, which is the critical NPSH or the required NPSH.

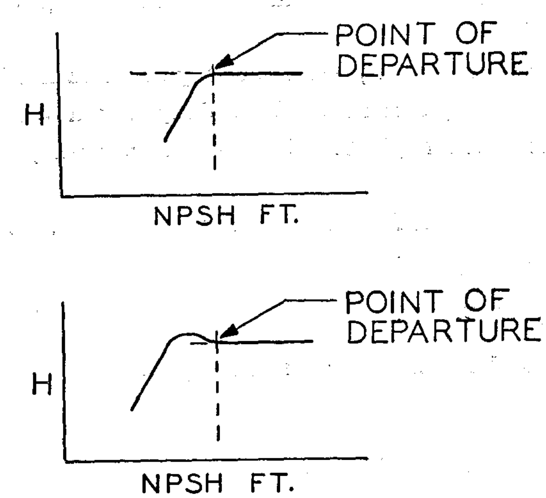

FIG. 2. POINT OF DEPARTURE

In actual laboratory tests a good practice is to hold the liquid temperature and submergence constant so that the suction tank pressure becomes the only variable in the calculation of NPSH. The Head vs. NPSH plot can then be replaced with Head vs. Suction pressure. Use of the critical suction pressure to calculate NPSH eliminates the necessity of an NPSH computation for each reading.

Another good practice is to use a differential pressure gage or manometer to measure H, with one leg connected to the discharge side and the other leg connected to the suction tank. Thus the H reading is constant for the non-cavitating range. By this means, the head drop is really an effective indicator for cavitation, better than either power or efficiency drop, which will be described next.

In the constant capacity method, when the head changes due to cavitation, power and efficiency also change and hence can be used as cavitation indicators. Stepanoff (3) states, "For motor driven pumps a drop of KW input as a measurable cavitation effect gives more accurate readings than the drop of head or efficiency." Those who use a platform scale in conjunction with a dynamometer to measure the input power also claim that the scale beam drop is the first sign of cavitation. However, the writer has conducted several comparative tests from time to time and has been unable to confirm that power drop is more sensitive than head drop.

Granting that power does not respond to cavitation faster than head, there is no reason to agree that efficiency drop should be preferred as a cavitation indicator. Since efficiency cannot be directly measured but must be calculated from two readings, head and power, it is more subject to error.

For the adoption of 0% head drop, the following advantages can be claimed:

1. At 0% head drop, the affinity law is still applicable. So NPSH test data at one speed can be extrapolated to other speeds and from one size to another for geometrically similar designs. Once cavitation begins, flow similarly is destroyed: application of Thoma's law for extrapolation NPSH data under head drop conditions will produce errorous results.

2. For multiple stage pumps, only the first stage suffers head drop. So a 3% head drop in the first stage is equivalent to 1.5% drop for a 2-stage pump, etc. Such adjustment, needed but often neglected, becomes unnecessary for the 0% head drop method.

3. A common measurement for relative success of low NPSH pump designs is provided.

Test Facilities and Methods

There are three typical testing arrangement (Fig. 3)

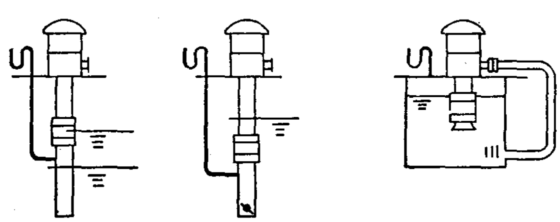

FIG. 3A FIG. 3B FIG. 3C

FIG. 3 NPSH TEST ARRANGEMENT (SHOWN WITH VERTICAL PUMPS)

a) Variable-level method

b) Suction-throttling method and

c) Closed-loop method

In method (a), the pump is supplied from a relatively deep sump in which the liquid level can be varied to establish the desired suction lift. For an application which requires suction lift, this arrangement can nearly duplicate the field operating condition. However, for reasons listed below, this method should only be used when a better arrangement is not available:

1. In this method, the suction pressure cannot be increased at will. When the pump requires a high NPSH, this method may be quite impractical.

2. It probably will be time-consuming and expensive to change the water level. From a test cost standpoint, it becomes desirable to cover as many capacities as possible at each change of water level. A series of such tests will result in a family of curves representing various water levels. When a curve for any suction lift breaks away from the envelope, critical NPSH occurs. The break point by this method is generally not well defined, and a certain percentage of head drop is not applicable to this form of plot.

When enough water level changes are made, it is possible to put together all head readings pertaining to the same capacity to make conventional plot of H-NPSH or H-Suction lift. But the quality of the test data is inferior to that obtained from other test methods.

The suction-throttling method (b) avoids the tedious work of changing water levels without requiring relatively expensive NPSH test equipment. Reduced pressure to the pump suction is created by throttling the valve located in the suction pipe. Depending on the type of valve used, turbulence of various degrees will be produced. The turbulence and the air or gas released will influence the accuracy of the test results, generally on the conservative side.

Method (c) is far superior to the other two for accurate determination of the suction head pressure. The pressure on the closed loop system can be varied by simply increasing or decreasing air pressure in the tank; there is no change in water level and valve setting. High suction lift and high suction head can be simulated this way with great ease.

The chief drawback to method (c) is the cost. It requires a separate test arrangement apart from regular laboratory facilities. This means extra investment and extra floor space. For large pumps, the cost of a storage tank may be prohibitively high.

In designing a closed-loop, one important but rather difficult problem to solve is the size of the suction tank relative to the maximum capacity of the pump to be tested. If the tank is too small, the water temperature will rise too fast to be measured accurately. In addition, there will be excessive bubbles and turbulence in the tank, which will effect the accuracy of the NPSH determination.

Rankin (4) proposed that the tank should have twice the capacity of the pump in gallons per minute. This criterion is very liberal. For example, for a 5000 gpm pump, a cylindrical tank would be about 10′ in diameter and 18′ high. From experience, this writer proposes a 1:2 ratio of tank capacity to pump discharge as the criterion; that is, for a 5000 gpm pump, the minimum tank size would be 2500 gallons.

Adopt Water As the Standard NPSH Liquid

The required NPSH *at the incipient cavitation*, as measured in feet of pumped liquid, is same for all liquids. It follows that any liquid may be used to measure the required NPSH of a pump. However, due to availability and ease of handling, water is by far the most popular liquid used. Petroleum fuel pumping applications are next in importance to water for the pumping industry, yet due to the inherent difficulty in determining NPSH for fuels, all of the NPSH data currently available are taken from water tests. The thermal cavitation criterion indicates that the required NPSH for a pump is less for petroleum fuel than for water. Such indication, however, does not give any degree of comfort to the pump users. Consequently NPSH data for fuel pumps is not diligently sought. A few of the complicated problems in conjunction with NPSH determination with fuel are listed below:

1- True vapor pressure must be used. (5).

2- Since fuel vaporizes progressively, its identity actually changes with time. The vapor bulb, a preferable device to measure vapor pressure, must be refilled for each run (6).

3- A specific test conducted by the writer confirmed a fact familiar to the aircraft pump industry: the rate of vacuum evacuation has a pronounced effect on the cavitation performance (7).

To recognize an existing fact and to establish a common basis for the comparison of relative sucessus of low NPSH pump design, it is proposed that we formally adopt water as its standard test liquid.

Whenever a low NPSH is reported in terms of suction specific speed, it will be understood that the test was made in water, unless specifically noted otherwise.

Summary

For the reasons given in this paper, it is proposed that NPSH determination be standardized, as follows:

1- Use head drop instead of efficiency or power drop or other indications.

2- Use 0% head drop instead of 0.5%, 1%, 3% or other percentages.

3- Use enclosed-loop method as the prefered test arrangement.

4- Adopt water as the standard test liquid.

References

1. Fang, "On the Standardization of NPSH Determination of Pumping Machinery" ASME Cavitation Forum, May 1967.
2. Raabe, "Cavitation Effects in Turbomachinery-European Experiences" Cavitation State of Knowledge, ASME Fluids Engineering and Applied Mechanics Conference, June 1969.
3. Stepanoff, "Cavitation Properties of Liquids," ASME Trans Series A, April 1964.

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