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700.0 Interpretation of Results

701.0 *Introduction*

The graphical presentation of data provides the most effective method of explaining results. Each curve should be identified and dated with the pertinent information such as pump serial number, impeller designation, impeller diameter, speed, and liquid pumped. Field test results are to be compared to the manufacturer's data. An understanding of the definitions of the following terms is essential.

1. Certified test curve
2. Certified curve
3. Published generalized curve

701.1 A certified test curve is a graphical representation of a physical test of a specific pump. Such tests were conducted under specific conditions and acceptance criteria, and were specified and paid for by the purchaser. The details of how the tests were be conducted, the acceptance criteria and the documentation of the results were defined to the purchaser prior to conducting the test. It should be noted that typically only the design point head, flow and efficiency were guaranteed and only within a specific tolerance. All other data is for information only. NPSH required was NOT guaranteed unless made a part of the purchase order and an NPSH required test was not conducted.

701.2 A certified curve is typically a copy of the published generalized curve (see definition below for this term) with the "design point" head and flow conditions noted on the curve. This document is a graphical representation of the contract requirements of the equipment which was supplied. The indicated conditions will be used as the acceptance criteria if the purchaser specified hydraulic tests were to be conducted. These curves are no more than the published generalized curves. During testing, alterations of the impeller diameter and vane entry surfaces may have been required to achieve the design point, contract conditions and fall within the specified acceptance tolerances.

701.3 Published generalized curves graphically represent a composite of a number of pump tests of the pump model indicated. There typically will be variation of the hydraulics actually produced by any specific impeller model and diameter from that which is illustrated on the curve. While the total head developed by the pump will normally be within an 8% tolerance of the specified values (with correspondingly different horsepower requirements), there can be substantially higher variations on certain pumps.

702.0 *Discussion*

702.1 Data obtained under field conditions may not represent a smooth curve. The curve represented by the data will be an average. If the data points deviate significantly from the average curve, investigation of the reasons for these deviations should be made.

702.2 There is a given relationship between horsepower, total head, capacity, and $NPSH_R$ requirements. As a crosscheck on the field test results, one parameter can be compared to the others using the manufacturer's published characteristic curves. If the head and horsepower are known, the capacity can be estimated. If the $NPSH_R$ is known, the capacity at that point can be estimated. If the horsepower is known, the capacity can be estimated. See the characteristic curve (Figure 702.2. 1) for the relationship between these parameters.

702.2.1 The relationship between the Power, total developed head and capacity for a given pump speed and impeller diameter may be expressed more rigorously by:

$$P_w = \frac{s\,Q\,H}{3{,}960\ (eff)} \quad \text{for customary units}$$

$$P_w = \frac{9.81\,s\,Q\,H}{(eff)} \quad \text{for SI units}$$

Where *eff* is the pump efficiency, defined in 605.2

Figure 702.2.1 illustrates the typical graphical performance data presentation of a centrifugal pump. Total head vs. capacity are illustrated for various impeller diameters operating at a fixed speed. $NPSH_R$ vs. capacity is also illustrated.

702.2.2 As speed or impeller diameter change, the total head (H), flow and power will change.

702.2.3 The actual measured test results at different speeds or impeller diameter other than illustrated by the manufacturer's data are to be adjusted per paragraph 606.0 and 607.0 of this document prior to comparing it to the manufacturer's published information.

702.3 Capacity measurements are usually the most difficult to obtain. In some field installations you may not find instrumentation for measurement of capacity. Indirect determination of capacity may be necessary. Changes in a known tank volume being supplied by the pump over a measured period of time may be the only field flow measurement available.

702.4 Head measurement is normally the easiest measurement to accomplish in the field. The differential pressure between the suction and the discharge at positions other than the inlet and outlet flanges of the pump measured with the instruments located at an elevation equal to the pump centerline will be required to be adjusted for elevation, static head, pressure drop due to friction losses and changes in velocity head.

702.5 The accuracy of field performance tests is directly dependent on the accuracy of the head and flow measurements. Pumps with a relatively flat performance curve (A), as illustrated by the solid line curve in figure 702.5.1 require more attention to the precision of the flow measurement to produce a meaningful performance curve. Curves with a steeper slope (B) as illustrated by the dotted line in figure 702.5.1 require attention to a precise head measurement.

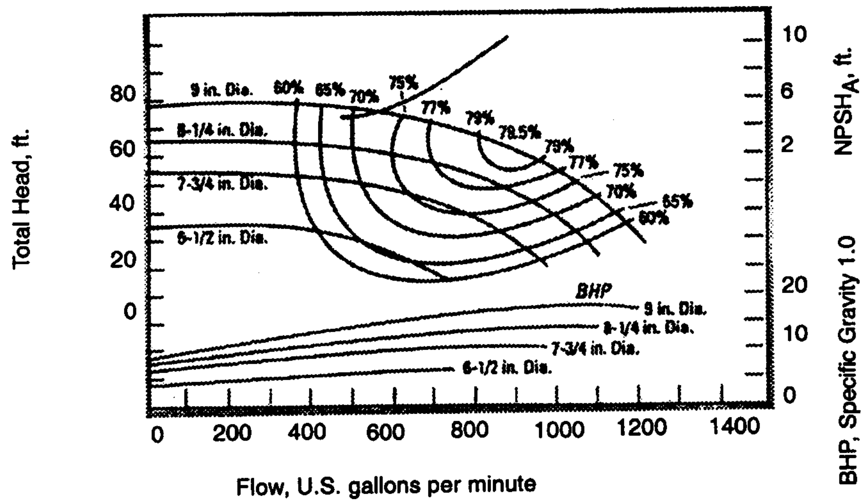

Figure 702.2.1 Typical Pump Performance Curve

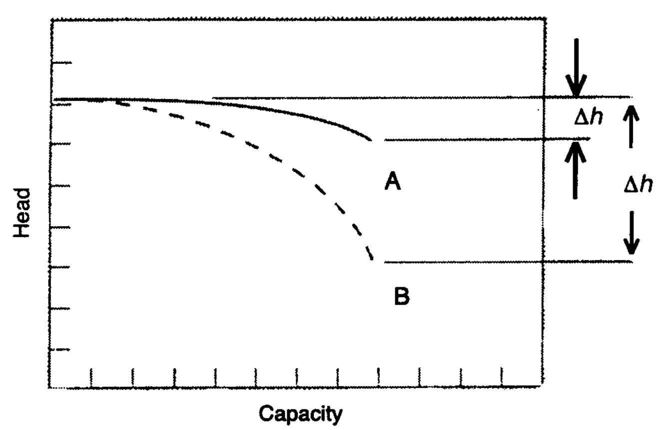

Figure 702.5.1 Capacity Vs. Head Curve

702.6 Comparing the field horsepower vs. flow to the corresponding data from the supplier will help evaluate major discrepancies that may exist in the pump's performance. Measured results will have to be adjusted to compensate for site condition, specific gravity and viscosity before making this comparison. The flat curve (A) in Figure 702.7.1 represented by the solid line would not permit such determination. Other methods would have to be used. The curve with dotted line (B) represents a very steep horsepower curve and would lend itself to indirect flow determination.

702.7 It should be noted that viscosity will affect the performance of a centrifugal pump. The curve in Figure 702.8.1 taken from the Hydraulic Institute Standards shows the effect of viscosity on the performance of a centrifugal pump. Viscosity characteristics of the fluid that is being pumped should be determined.

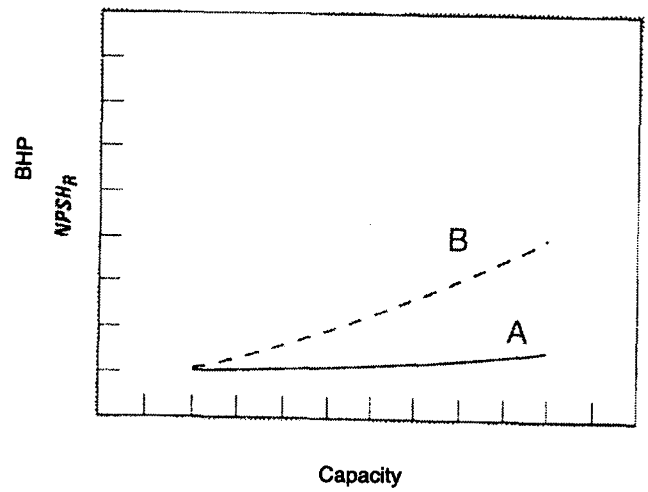

Figure 702.7.1 Capacity Vs. Horsepower Curve

702.8 Specific gravity will also have an effect on performance as shown in Figure 702.8.1. The specific gravity of the fluid must be known.

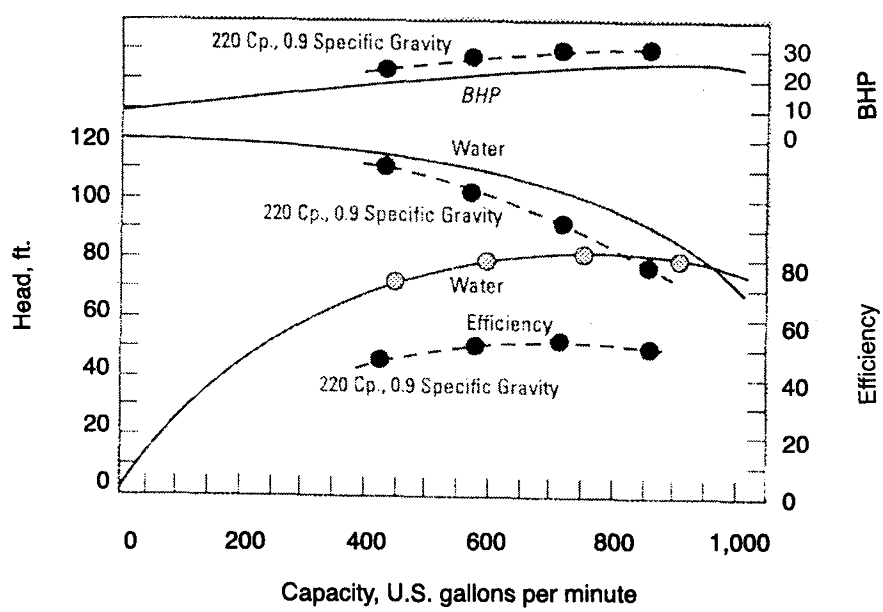

Figure 702.8.1 Typical Pump Curve

702.9 Changes in speed from those specified will affect the pump performance, as illustrated in Figure 702.9.1. Verification of speed is essential at each test point. Manufacturer's published curves illustrating the measured performance test results are adjusted to reflect constant driver speed throughout the range of flows. This speed will be noted on the performance curve. The measured field test results should be adjusted to this common speed using the information in paragraphs 606.0 and 607.0 of this procedure.

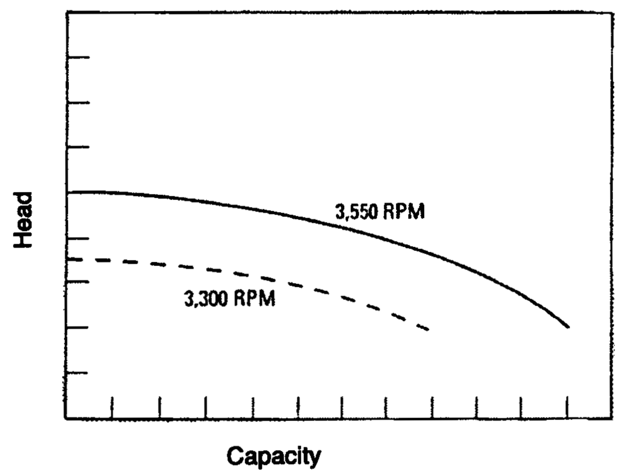

Figure 702.9.1 Capacity Vs. Head Curve with Speed as a parameter

703.0 *Trouble Checklist*

The following tables can be used to identify possible problem areas that can affect performance in centrifugal pumps.

Table 703.0.1 No Liquid Delivered

1. Priming - casing and suction pipe not completely filled with liquid.
2. Speed too low.
3. System head too high. Check the total head (particularly friction loss) or develop system curve.
4. Suction lift too high (suction pipe may be too small or long, causing excessive friction loss). Check with vacuum or compound gauge.
5. mpeller or suction or discharge pipe or opening completely plugged (i.e., valve shut off).
6. Wrong direction of rotation.
7. Air pocket in suction line.
8. Stuffing box packing worn or liquid seal plugged, allowing leakage of air into pump casing.
9. Air leak in suction line.
10. Not enough suction head for hot or volatile liquids. Check carefully as this is a frequent cause of trouble in such service.
11. Impeller key missing.
12. Broken shaft.
13. Pumps not properly vented.

Table 703.0.2 Not Enough Liquid Delivered

1. Priming - casing and suction pipe not completely filled with liquid.
2. Speed too low.
3. System head higher than anticipated. Check total head (particularly friction loss) or develop system curve.
4. Suction lift too high (suction pipe may be too small or long, causing excessive friction loss). Check with vacuum or compound gauge.
5. Impeller suction or discharge opening partially plugged.
6. Wrong direction rotation.
7. Air pocket in suction line.
8. Stuffing box packing worn or liquid seal plugged, allowing leakage of air into pump casing.
9. Air leak in suction line.
10. Not enough suction head for hot or volatile liquids. Check carefully as this is a frequent cause of trouble in such service.

11. Foot valve too small.
12. Foot valve or suction pipe not immersed deeply enough.
13. Mechanical defects:
    a. Impeller clearance too great.
    b. Impeller damaged.
    c. Wrong impeller (i.e., size).
14. Vortexing.
15. Entrained gases in liquid.
16. Impeller key missing.
17. Worn or missing wear rings.
18. Casing wear.

Table 703.0.3 Not Enough Pressure

1. Speed too low.
2. Air or gases in liquid.
3. Impeller diameter too small.
4. Mechanical defects:
    a. Impeller clearance too great.
    b. Impeller damaged.
5. Wrong direction of rotation.
6. Incorrect location of pressure gauge on discharge nozzle or discharge pipe.

Table 703.0.4 Pump Works a While and Then Quits

1. Leaky suction line.
2. Stuffing box packing worn-or liquid seal plugged allowing leakage of air into pump casing
3. Mechanical defects:
    a. Broken shaft.
    b. Broken coupling.
4. Motor stops due to overload trip out.
5. Vortexing or insufficient $NPSH_A$

Table 703.0.5 Noise

1. Insufficient $NPSH_A$
2. Bearings.
3. Foreign object in pump casings.
4. Vortexing.
5. Cavitation.

703.1 *Effects of Cavitation on performance testing:* Centrifugal pumps experience at least two types of cavitation. The first, and most pertinent to this procedure, is cavitation resulting from inadequate margin between the $NPSH_A$ and $NPSH_R$. This will cause a reduction in the pump hydraulic performance as well as, in time, mechanical damage to the pump. The second is cavitation resulting from what is known as "low flow recirculation".

703.2 Cavitation resulting from an inadequate NPSH margin or from too low a flow rate for the pump design must be eliminated before attempting to conduct field-tests which will be compared to the manufacture's data. NOTE: Severe and extended periods of cavitation can damage the pump and should be eliminated. See reference 805.1.

703.2.1 The presence of moderate to severe cavitation can normally be determined by the existence of a crackling sound emanating from the suction side piping of the pump. It is advisable that a good quality mechanic's stethoscope be used to conduct this evaluation.

703.2.2 At flow rates near or below the manufacturer's published or tested NPSH values, the noise of recirculation cavitation may appear, but will not affect performance test results. If cavitation noise disappears at higher flow rates, the cavitation can be attributed to the recirculation phenomena and the test effort continued without any change to the system.

703.2.3 The presence of cavitation may also be determined by a strong axial vibration component that disappears with a larger NPSH margin shown in Figure 703.2.3. A broad band vibration frequency will also typically exist when performing a vibration spectrum analysis of the pump. The greater the cavitation the larger the amplitude of the vibration will exist over the broad band range.

703.3 If the purpose of a field test is to compare the pump performance to the "as new condition" and to the supplier's published or test results, it will be meaningless to proceed without first eliminating the cavitation due to an inadequate NPSH margin.

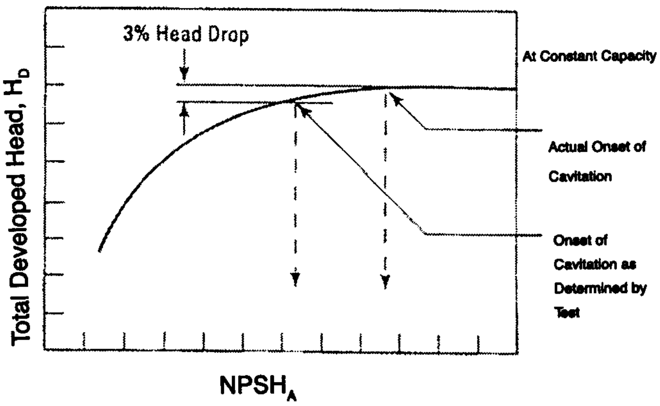

Figure 703.2.3 NPSH on the Pump Curve

703.4 *Reduction and Control of Cavitation Damage* If a given pump has suffered damage from cavitation and it is not possible to increase the $NPSH_A$ or reduce $NPSH_R$ by means of operating at a lower flow, certain things can be done to alleviate or reduce continued damage short of massive modifications such as lowering the pump.

703.4.1 Certain materials have relatively great resistance to cavitation attack. Cast iron and other soft materials are especially prone to damage. It may be possible to replace pump impeller and/ or casing with a material which has a much higher resistance to damage.

703.4.2 After consulting with the manufacturer the leading edge of the impeller vanes can be cut back and perhaps the impeller eye enlarged thereby reducing velocity and its attendant pressure drop. The pump manufacturer should be contacted concerning an alternative impeller pattern that includes these modifications that may still perform with satisfactory head, capacity, and efficiency.

703.4.3 The existing impeller vanes may be sharpened by filing to a narrow leading edge by the manufacturer.

703.4.4 Pre-rotation in the suction piping can be reduced by installation of a simple straightening vane. Care should be taken to insert vanes with a minimum pressure drop.

703.4.5 Impeller inlet vanes and casing can be coated with a resilient, nonmetallic coating material that provides a cushioning effect to the shock waves produced by the collapsing bubbles. Applying such coatings is a special procedure, will probably affect the head/capacity performance of the pump and may not be possible on high-speed units.

703.4.6 For materials near their boiling point the suction line may be cooled to lower the vapor pressure, thereby raising the $NPSH_A$.