Pump Curve Accuracy

Introduction:

What are the attributes that make one pump selection software package superior to another? Aside from all the bells and whistles, the key to a superior pump selection program is the ability to accurately reproduce the manufacturers’ performance curves and to place the pumps that can meet the customer’s needs on a selection list. This includes not only the flow versus head performance curves, but also the efficiency and power curves.

Figure 1 shows a detailed manufacturer’s pump curve. It includes the flow versus head performance curves as well as isometric curves for efficiency, power, and NPSHr. These curves accurately represent the performance of the indicated pump in accordance with the ANSI/HI 1.6-2000 Centrifugal Pump Tests standard. If you had to size a pump for a system with design conditions of 600 U.S. GPM at 39 feet of head, and you were evaluating this particular pump, you could feel confident in knowing that this pump, with a 10” impeller would successfully fill the bill. It is important that the pump selection and evaluation process accurately reflect the manufacturers published pump curve to aid the customer in evaluating the pump for their application. As we will see, the key to generating accurate curves is in the method with which the pump performance data is saved and displayed.

All pump manufacturers have paper curves representing the performance of their pumps, and most also have these curves available in pdf format. However, in order for a software program to understand and use this pump performance data, these curves must first be converted into a form which can be read by a software program. We call this the digitization of the pump curve. There are various methods of digitizing performance curves, but what happens when these curves are translated into a functioning piece of software whose intention is to compile and evaluate a list of viable pumps meeting some selection criteria? As you will see, the accuracy of this translation can be critical to the pump selection and evaluation process.

So how are these curves digitized? Well, there are several ways to accomplish this, all of which involve obtaining data points from the pump manufacturers. These points can either be extracted from the published paper curves, or gathered directly from the manufacturers. One simple method is to take several points along the performance curve, and perform a polynomial regression analysis. This results in a polynomial expression describing the performance curve which can be saved and used in a pump selection program. The original data points are then discarded, and the pump performance data is now represented solely by an equation. Depending on the shape of the original published curve, this polynomial expression may or may not be an accurate representation. A second, more robust method is to collect as many data points as is necessary to accurately fit the shape of the published performance curve, and use these saved data points to represent the original published curve in the pump selection program. A numerical analysis can then be performed on these points such that a curve is drawn which precisely represents the original published curve.

PUMP-FLO® utilizes the most robust method for digitizing pump curves. In generating these curves, PUMP-FLO® offers three key factors that other pump selection programs do not:

- PUMP-FLO® has the ability to define and save as many data points as is necessary to ensure complete accuracy when representing the performance curve’s geometry.
- PUMP-FLO’s proprietary algorithm forces the drawn curve to go through every single data point entered which ensures the curves accurately match the manufacturer’s published data.
- PUMP-FLO’s algorithms have the capability to provide the most accurate efficiency and power curves.

Performance Curves:

First, look at an example which illustrates the problems associated with the simple polynomial regression method of curve digitization. The following curves depict flow versus head and since they are the primary search parameters, it is crucial that these points match up with the performance curve provided by the manufacturer. In figure 2a, we have a performance curve from a major pump manufacturer displayed in black. On top of that in pink, we have overlaid the curve which was generated by a pump selection tool using a simple polynomial regression.
Notice that performance curves with anomalies are not well represented. Figure 2b shows the same graphs zoomed in on the anomalies. As you can see, a polynomial regression has a tendency to smooth out the anomalies like those shown in this figure. The consequences of this curve characterization can be minor, or they can be significant. Depending on where these deviations occur, this may affect placement on a selection list. Certain pumps may be selected which cannot actually meet the design criteria. In addition, if your pump is performing in areas where the polynomial regression curve deviates from the manufacturer's published performance curve, you will get erroneous energy usage figures and operating costs.

Now, look at the same performance curve with an overlay of the pump curve generated by PUMP-FLO®. The proprietary PUMP-FLO® regression forces the curve to pass through every single data point collected. It then smooths the curve to provide clean, accurate pump performance curves which end users can use with confidence in their various piping system analyses.
From Figures 3a and 3b, the PUMP-FLO® method results in a curve which much more accurately represents the actual performance curve. Flow and head are not significantly overstated or understated at any point in the curve range.

Even the best numerical analysis techniques cannot predict anomalies between data points. If the performance curve you are trying to digitize has these types of dips or abnormalities, it is imperative that you are able to collect enough data points in and around that range. As a minimum, you would want to have data points collected at the edges and at the peak (or valley) of the anomaly. Ideally, you might want to add a couple more points in between. The advantage that you get with PUMP-FLO® is that you have the flexibility to define as many points as is necessary to accurately describe the entire range of the pump curve, anomalies included.

Power and Efficiency Curves:

In addition to the standard flow versus head pump curves, many manufacturers also include curves for pump efficiency, and pump power. It must be stressed that pump efficiency and pump power are functions of each other. The formulas for calculating efficiency and power are:

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\text{bhp} = \frac{QH\rho}{247000\eta} \quad \text{and} \quad \eta = \frac{QH\rho}{247000\text{bhp}}
\]

Where: 
- bhp = brake horsepower
- \(\eta\) = pump efficiency
- Q = Flow rate (gpm)
- H = total head (ft)
- \(\rho\) = fluid density (lb/ft\(^3\))

Power is calculated with efficiency as a parameter, and vice versa. So in order to reproduce accurate and trustworthy results, it follows that one set of data must be gathered from the pump manufacturer, and the other set of data must be calculated. When generating curves, it is not accurate to try to collect and reproduce both sets of data from the manufacturer. This would leave open the possibility of errors where a customer might select a flow, head and efficiency from the graph, perform a hand calculation of the corresponding power, and find that the calculated power does not match up with the power shown on the graph. For this reason, only one set of empirical data, efficiency or power, is taken from the manufacturer. The other value must be calculated.
Another area where PUMP-FLO® is going to give superior results is in the digitization of pump efficiency and power data from the manufacturer. PUMP-FLO® utilizes various techniques to digitize the curves based on what data is available from the manufacturer. Our most frequently used algorithm provides highly accurate efficiency and power data.

Now look at our previous manufacturer’s performance curve, and see the effect digitizing can have on power and efficiency curve generation. In Figure 4a, we have the manufacturer’s performance and efficiency curves with an overlay of another pump selection software maker’s curves. Notice the efficiencies are well off the mark, particularly in and around the 70%+ operating range. Not only are the iso efficiency curves misaligned, but the percentages do not match up with the published curve at all. The pump’s overall efficiency is overstated by up to 3%. If your customer was to download these performance curves (Figure 4a in black) from your technical literature, and your salesperson were to present the performance curves (Figure 4a in pink) from your internal pump selection software, there’s no way this customer is going to able to tell that these are one and the same pump. This introduces confusion and a lack of confidence in the pump performance data to the customer. In Figure 4b, we have the manufacturer’s performance and power curves with an overlay of the other pump selection software’s curves. The power curves start off tracking well, which we would expect, since those data points are taken directly from the manufacturer. However, notice that the flow range has been severely limited on the 30 hp and 50 hp curves. They do not even extend anywhere close to run out. Once again, if your customer has downloaded the black curves, and your salesperson is presenting the pink curves, the salesperson is not going to be able to properly size a motor because of the lack of information.

There are two serious engineering issues which arise due to the inaccuracies of these curves. The first relates to the efficiency errors. For example, let us say you run this pump with an 11” impeller at its best efficiency flow rate of 1800 US GPM for one year, and let us assume your utility costs are $0.15 per kWh. Overstating the efficiency by only 2 percentage points will, over the course of a year, increase the operating costs of this pump by almost $1500. With the increase in energy audits throughout the industry, particularly within government agencies and municipalities, this type of an inaccuracy is bound to come to light and cast doubt on the validity of the manufacturer’s pump performance data.

The second issue is with respect to the power curves. The truncated power curves shown in the figure above do not extend to run out flow rates. This is important because pump motors are most often sized to the non-overloading power on the design curve, which is frequently at run out. If the customer cannot tell what the power is at run out flow rates, then they will not be able to properly size a motor.

Once again, look at the same performance curves with an overlay of the curves generated by PUMP-FLO®. In Figure 5a, we have the manufacturer’s performance and efficiency curves with an overlay of PUMP-FLO’s curves. Note that the iso efficiency curves are dead-on at every single point in the graph, and the efficiency is never overstated. In figure 5b, PUMP-FLO’s power curves also track extremely well with the manufacturer’s, given that they are calculated power curves, and more importantly, the endpoints at the run out flow rates are dead-on. In addition to unmatched pinpoint accuracy of curves, PUMP-FLO® also generates an additional horsepower curve above the top impeller diameter based on manufacturers’ data. This allows you to see how close you are to requiring the next higher size motor.
Having a pump selection program which accurately represents your pump’s actual performance is a necessity. The Hydraulic Institute only allows a few percentage points of variation between test data and actual performance. Having variability or inaccuracies in your digitized pump curves can only compound the errors, and as a manufacturer, liability is an issue. PUMP-FLO’s treatment of your head versus flow data, efficiency data, and power data is engineered to be the best in the business. You will not find a more accurate representation of your pump performance data than what the PUMP-FLO® line of products provides.

Figure 5a: Efficiency curves with PUMP-FLO overlay

Figure 5b: Power curves with PUMP-FLO overlay

- Manufacturer’s Published Performance Curves
- PUMP-FLO’s Proprietary Regression
- Manufacturer’s Power Curves
- PUMP-FLO’s Power Curves

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