## VFPPA – Variable Frequency Parallel Pump Analyzer

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There are several ways to control two identical, parallel pumps operating under variable frequency control in various pumping applications.  One method is to size a single drive to handle both pumps and vary the speed of both synchronously.  A more efficient method uses two drives to control the pumps.  Once one pump reaches its maximum speed, the second pump is brought on line and both are operated at synchronous speeds (like the previous example).  Yet another two drive method keeps one pump at maximum speed and varies the speed of the other.  This example can also be achieved with a single drive and a transfer switch.  When the drive reaches full speed, the switch causes a contactor to operate that pump across the line and the drive is transferred to the second pump.  The downside to this control scheme is that there is no back up drive.

The first example can work if the normal flow is always greater than the maximum flow of one pump.  Otherwise it can be very inefficient.  Examples two and three are better alternatives but which one is the best?  Well, it depends upon the breadth of a pump's hydraulic efficiency and the system conditions in which it is operating.  It is always worth comparing these two control schemes to see which can provide the best operating conditions.  The beta version of VFPPA allows you to compare the hydraulic efficiencies of identical, parallel pumps operating under synchronous or independent speed control.

Figure 1 is a screen shot of the data input tab of VFPPA.  It shows the required data (yellow cells) and the various tabs that are generated.  The "One Pump" tab shows the H/Q curves and hydraulic efficiencies of a single pump at speeds of 45 to 60 Hz.  The "Two Pumps" tab shows the same information for two pumps running at synchronous speeds.  The other tabs show both single and two pump operation at various speeds and are used if a more detailed view is required.  The "Average Efficiency Calculator" and the "Energy Savings Calculator" at the right of the screen are used to determine which control technique is best for a particular pump and application.

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Q12    Vertical Multistage (25HP)

**Variable Frequency Parallel Pump Analyzer (Beta)**

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Follow the five steps below to view the operation of two identical centrifugal pumps under VFD control.
Scroll down to row 77 for more detailed instructions.

1) Enter the pump description in the yellow box to the right    Vertical Multistage (25HP)

2) Enter eight 60 hertz flows In Q1 - Q8  (Cells H20 - O20)
Enter the corresponding heads (in ft) in H1 - H8  (Cells P20 - W20)
(*See instructions below when entering fewer than eight points)

| Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 280 | 271 | 262 | 252 | 240 | 225 | 206 | 182 |

3) To plot a system curve (static), enter the head (in ft)
in SH1 - SH8 (Cells P62 - W62). (See instructions below)

| SH1 | SH2 | SH3 | SH4 | SH5 | SH6 | SH7 | SH8 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 |

4) Enter the pump's hydraulic efficiencies in Ef 1 - Ef 8
(Cells P67 - W67) that correspond to the flows in Q1 - Q8
Enter as a decimal equivalent.  (See instructions below)

| Ef 1 | Ef 2 | Ef 3 | Ef 4 | Ef 5 | Ef 6 | Ef 7 | Ef 8 |
|------|------|------|------|------|------|------|------|
| 25% | 45% | 55% | 60% | 67% | 72% | 78% | 76% |

5) Click on the various tabs to view pump performance.

VFPPA Instructions

**Average Efficiency Calculator**

| Pump 1 Full Speed Flow | 350 |
|---|---|
| Pump 1 Eff @ Full Speed Flow | 78% |
| Pump 2 Flow @ Reduced Speed | 100 |
| Pump 2 Eff @ Reduced Speed | 50% |
| Total Flow | 450 |
| % of Total Flow - Pump 1 | 77.8% |
| % of Total Flow - Pump 2 | 22.2% |
| Average Hydraulic Efficiency Different Speeds | 71.8% |

**Energy Savings Calculator**

| Pump Eff @ Synchronous Speed | 66% |
|---|---|
| Motor Efficiency | 90% |
| Cost / KWh | $0.10 |
| BHP Synchronous Speed | 35.5 |
| Cost / Hr Synchronous Speed | $2.94 |
| BHP Different Speeds | 32.6 |
| Cost / Hr Different Speeds | $2.70 |

Scroll down to row 112 for more detailed instructions
and an explanation of the example provided.

Tabs: VFPPA Data Input | One Pump | Two Pumps | 45-60 Hz Curves | 55 & 60 Hz Curves | 50 & 55 Hz Curves | 45 & 50 Hz Curves

Ready     100%

start   Microsoft Excel - VFP...   10-10 parallel vfd   vfppa - Microsoft Word    12:33 PM

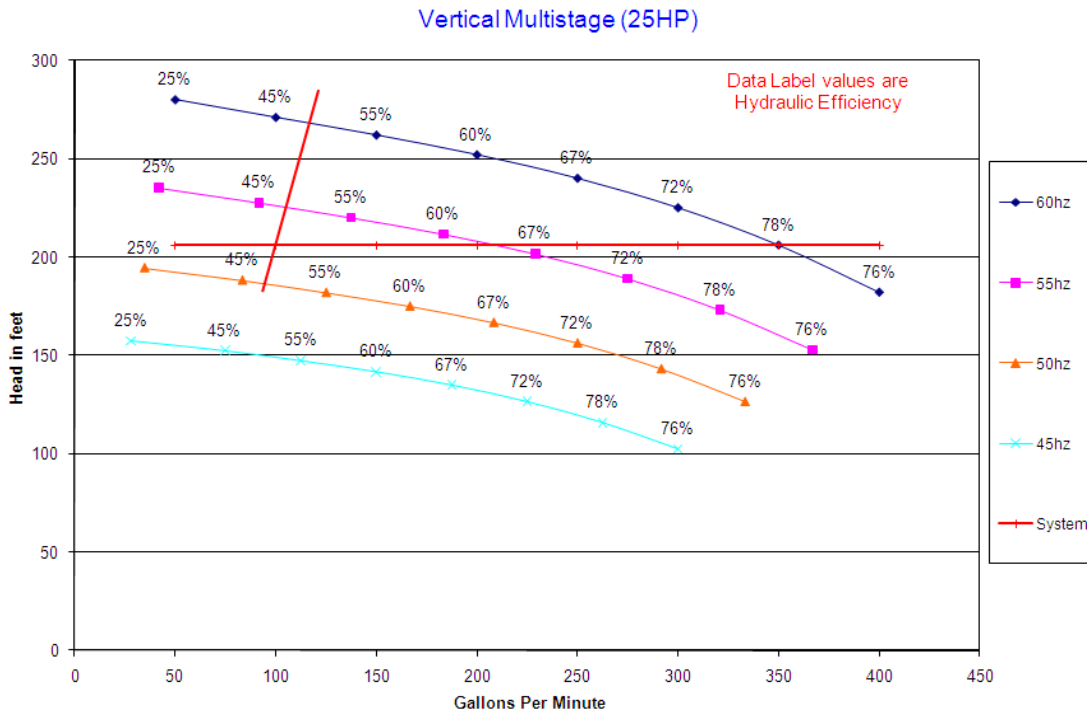## Synchronous Speed Control

The example included with the analyzer is vertical multistage with a BEP flow of 350 GPM and a BEP efficiency of 78%.  The rather flat H/Q curve is typical of this design.  The system curve shows a required static pressure of 206 feet.

Figure 2 is the plot produced in the "Two Pumps" tab and shows the various H/Q curves produced from 45 to 60 Hz under synchronous speed control.  The data labels show the average hydraulic efficiency.  As shown, when both pumps run at full speed (60 Hz) they produce a flow of 700 GPM @ 206' TDH and operate at BEP efficiency (78%).  The black angled line is the operating point of both pumps at single pump maximum flow (350 GPM).  Speed is approximately 54 Hz and efficiency drops to slightly below 60%.  As flow (speed) increases so does the average efficiency of the two pumps.  The red angled line crosses the system curve at 450 GPM at a speed of approximately 56 HZ and efficiency is increased to about 67%.  Let's take a look at individual speed control and compare the two operating efficiencies at 450 GPM.

Vertical Multistage (25HP)
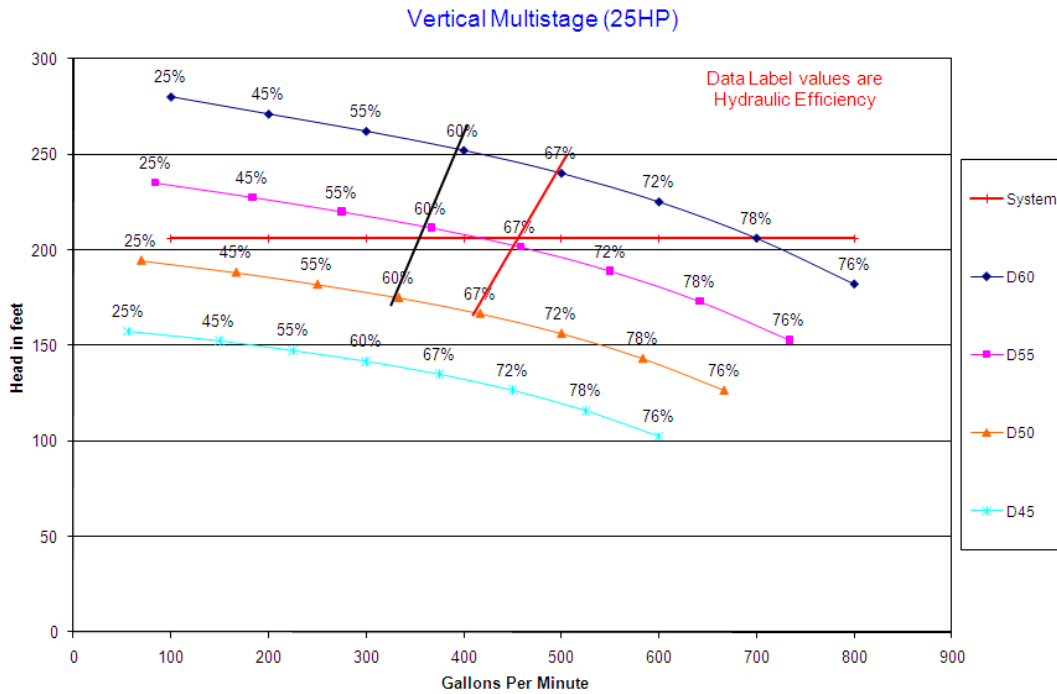
## Individual Speed Control

Figure 3 is the plot produced in the "One Pump" tab. As shown, a single pump operating at 60 Hz will produce a maximum flow of 350 GPM at 78% hydraulic efficiency. Under this control scheme, when the pump reaches maximum flow it is maintained at full speed and the second pump is brought on line at some reduced speed. The red angled line crosses the system curve at 100 GPM at a speed of about 52 Hz. This is the flow that must be provided by the second pump in order



Vertical Multistage (25HP)

to match the 450 GPM flow produced by two pumps running at synchronous speeds. The hydraulic efficiency at this flow point is about 50%.

In order to compare the efficiencies of these two control techniques, the information above is entered into the Average Efficiency Calculator. The calculator requires the flow and efficiency of the pump running at full speed and the flow and efficiency of the pump running at a reduced speed. Upon entry it calculates the % of total flow contributed by each pump and the average hydraulic efficiency of the two pumps. The calculator shows an average efficiency of 71.8% which is about 5% higher than the 67% produced at synchronous speed.

The Energy Efficiency Calculator requires the efficiency of the pumps operating at synchronous speed, the motor efficiency and the cost per KW of power. It calculates the total BHP and cost per hour of operation for each control scheme. As shown synchronous operation requires an additional 2.9 BHP and cost per hour is increased by 24 cents.

If you were to compare the efficiencies of the two control techniques at 400 GPM, individual control would trump synchronous control by about 6 percentage points and at 500 GPM it will still have a 1 point advantage. As flow increases to 600 GPM the two efficiencies get closer but individual control is still higher by about 0.3 percentage points. This trend continues until flow reaches 700 GPM and both control techniques operate at 78%.

For this particular pump, individual speed control is the best control choice. For others, synchronous control may work equally as well or even better. It will depend upon the application and the efficiency range. When three or more pumps are operated in parallel, individual speed control should still be compared, however, it will have less of an impact as more pumps are brought on line. For example, when the second pump is brought on line and operated synchronously, each pump will initially operate at 50% of its BEP flow. But when a third pump is called, each will begin at 66.6% and if a fourth pump is called each will begin at 75% of BEP flow. These increased minimum flows will also result in an increase in average efficiency.

Now, you may be wondering if a savings of $0.24 per hour is worth the trouble. I think that it is - - for several reasons. If the system operates just above one pump flow for extended periods even this small savings will add up over several years of operation. Also, the savings can be much larger as application BHP increases. Finally, it costs you absolutely nothing because both schemes require the same components. Think of it as one small step, that when included with

others, allows the best possible increase in overall efficiency.

The beta version of VFPPA is available for download from the "Pump Sizing & Selection Tools" section of my web site.  The final version will support generation of a system curve that is composed of both static and friction head.  It should be up there early next year.

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