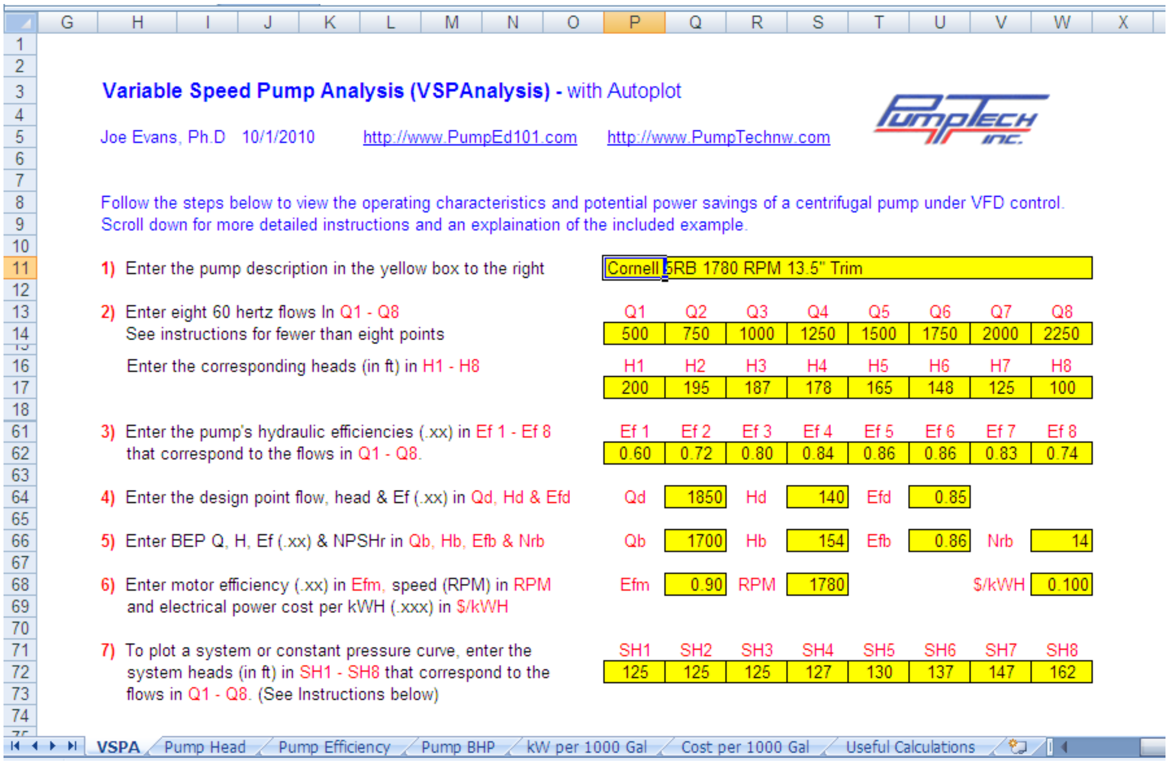
Variable Speed Pump Analysis

Joe Evans, Ph.D http://www.PumpEd101.com

When selecting a pump for variable speed operation, a number of conditions must be evaluated. For example, will the performance curve allow the range of operation required by the application? Will the frequency range be large enough to allow stable operation? What is the hydraulic efficiency from minimum to maximum flow? What level of power savings can be expected? These are some of the important questions that arise during the pump selection process and there are several others.

Over the past twenty years, I have written a number of white papers that address variable speed pump selection. I have also developed several spread sheets that provide a graphical view of a pump's performance when operating under VFD control. My most recent excel program, "VSPAnalysis", combines the information provided by several of the other spreadsheets into a single, user friendly, version. It can also be used with other variable speed controllers such as adjustable magnetic couplings. When used in conjunction with "VFPPA" (see my October 2010 P&S article), it will provide just about everything you need to know when evaluating simplex and multiplex pumps for operation in a variable speed application. Both are available for download at the "Pump Sizing, Selection & Testing Tools" page of my website (www.PumpEd101.com).

Figure 1 is a screenshot of the data entry tab of VSPAnalysis. If you scroll down below the data entry area, you can view detailed instructions and an overview of the example that is included. The overview explains the information that is presented in the other tabs. The data required includes pump flows and corresponding heads, hydraulic efficiency at each flow point, design point information, BEP point information, motor information and utility charges. You can also enter the static and friction heads at each flow point for generation of a system curve. The Pump Head, Pump Eff, Pump BHP, kW per 1000 gal and Cost per 1000 gal tabs show the variable frequency curves from 30 to 60 hz with data labels that are specific to the tab name. The Useful Calculations tab provides automatic calculations for Specific Speed (Ns), Suction Specific Speed (Nss) and several BEP and Design Point calculations. If you enter impeller eye diameter, it will also calculate Suction Energy (SE). You can add other calculations if you wish.


Variable Speed Pump Analysis (VSPAnalysis) - with Autoplot

Joe Evans, Ph.D 10/1/2010 http://www.PumpEd101.com http://www.PumpTechnw.com

Follow the steps below to view the operating characteristics and potential power savings of a centrifugal pump under VFD control.
Scroll down for more detailed instructions and an explaination of the included example.

1) Enter the pump description in the yellow box to the right: Cornell 5RB 1780 RPM 13.5" Trim

2) Enter eight 60 hertz flows In Q1 - Q8
See instructions for fewer than eight points
Enter the corresponding heads (in ft) in H1 - H8

3) Enter the pump's hydraulic efficiencies (.xx) in Ef 1 - Ef 8 that correspond to the flows in Q1 - Q8.

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
500	750	1000	1250	1500	1750	2000	2250
H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**
200	195	187	178	165	148	125	100
Ef 1	**Ef 2**	**Ef 3**	**Ef 4**	**Ef 5**	**Ef 6**	**Ef 7**	**Ef 8**
0.60	0.72	0.80	0.84	0.86	0.86	0.83	0.74

4) Enter the design point flow, head & Ef (.xx) in Qd, Hd & Efd — Qd 1850, Hd 140, Efd 0.85

5) Enter BEP Q, H, Ef (.xx) & NPSHr in Qb, Hb, Efb & Nrb — Qb 1700, Hb 154, Efb 0.86, Nrb 14

6) Enter motor efficiency (.xx) in Efm, speed (RPM) in RPM and electrical power cost per kWH (.xxx) in $/kWH — Efm 0.90, RPM 1780, $/kWH 0.100

7) To plot a system or constant pressure curve, enter the system heads (in ft) in SH1 - SH8 that correspond to the flows in Q1 - Q8. (See Instructions below)

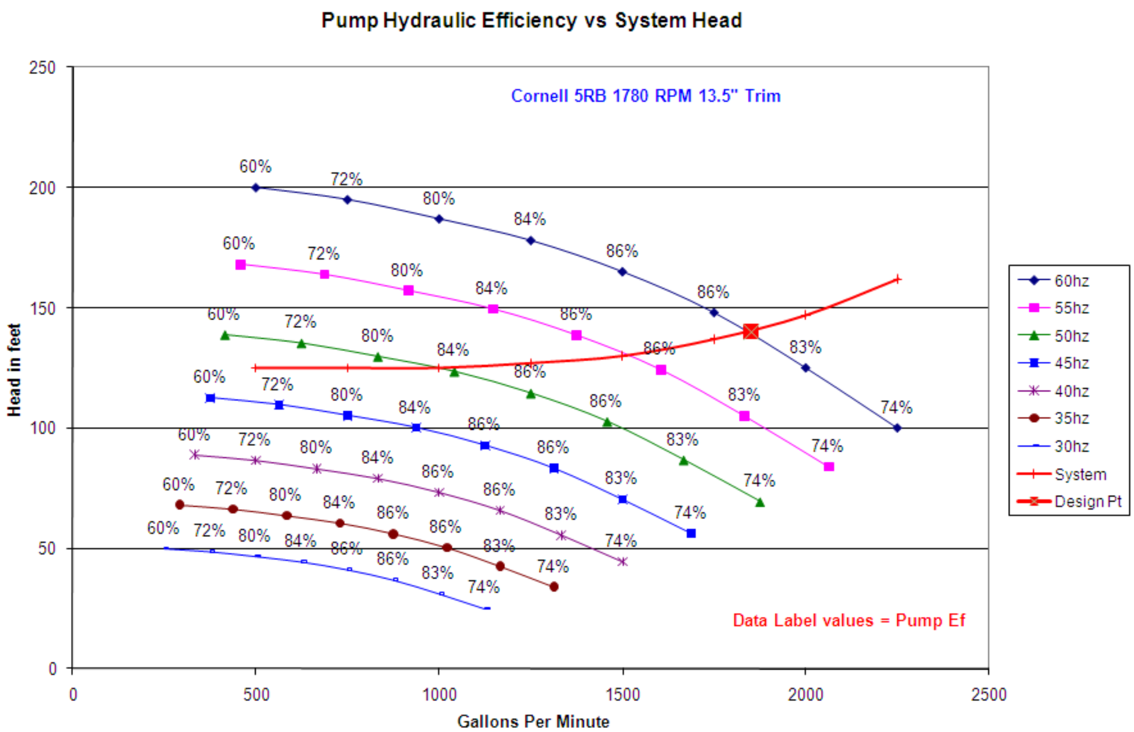
SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8
125	125	125	127	130	137	147	162

VSPA / Pump Head / Pump Efficiency / Pump BHP / kW per 1000 Gal / Cost per 1000 Gal / Useful Calculations

In the example, we are evaluating a pump that must meet a range of flow from 1000 to 1850 GPM at the system heads shown in Step 7.

Figure 2 is representative of the charts shown by the Pump Head through Cost per 1000 gal tabs. The one shown is pump hydraulic efficiency versus system head across the range of flow. It also shows the slope of the efficiency isomers as pump speed (hz) is reduced and how they intersect the system curve.

This particular pump has a hydraulic efficiency of 85% at the design point (full flow) and maintains an efficiency of approximately 84 % at minimum flow. Intermediate flows peak at 86%. This represents an excellent range of efficiency and will have a large impact on energy savings and the cost of operation. The slope of the efficiency isomer is also important. At 1000 GPM the efficiency of the 60 hz curve is 80%. But, at the reduced speed required by the system curve, efficiency increases to almost 84% due to the leftward migration of the 1250 GPM efficiency point.



Tabs 3 through 6 show the same system curve, frequency curves and design point. The difference is the data label values. The Pump Head and Pump BHP tabs show the head produced and BHP required at various flow and frequency points. For the example BHP ranges from 34 Hp to 76 HP across the range of flow. It also shows a 25 BHP reduction at 1000 GPM versus control valve operation. The kW and Cost per 1000 Gal tabs show the power and cost per thousand gallons pumped. The cost per 1000 gallons pumped ranges from 0.051 to 0.057 cents. All of the tabs show an operating range of 10 hz from minimum to maximum flow. This is more than adequate to provide stable operation and reduce hunting and over reaction to flow changes.

Figure 3 shows the information that is automatically calculated in the Useful Calculations tab. This is a work in progress and changes based upon the input I receive. The left hand column shows the calculations for Specific Speed, Suction Specific Speed and Suction Energy. Entry of the impeller eye diameter is required to calculate Suction Energy. Unlike Specific Speed, Suction Specific Speed and Suction Energy vary with a change in speed.

This is due to the change in NPSHr. The calculator uses the generally accepted equation shown at the bottom of the column to estimate the change in NPSHr as speed is decreased. See my February 2010 P&S article for a detailed description of Suction Specific Speed and Suction Energy. The right hand column shows several calculations at BEP and the Duty Point.

Useful Calculations

General		**BEP**	
Specific Speed (Ns)	1679	Pump Efficiency	86.0%
		Pump BHP	76.9
Suction Specific Speed (Nss)**		kW per 1000 Gallons Pumped	0.62
60hz	10140	Cost per 1000 Gallons Pumped	$0.062
55hz	9816		
50hz	9469	**Design Point**	
45hz	9103		
40hz	8712	Pump Efficiency	85.0%
35hz	8283	Pump BHP	76.9
30hz	7819	kW per 1000 Gallons Pumped	0.57
		Cost per 1000 Gallons Pumped	$0.057
Suction Energy (SE)			
Enter eye diameter in inches	7.2	If eye diamater is not known it can be	
60hz	129957376	estimated as follows:	
55hz	115360936		
50hz	101085255	End Suction - Suction Diameter X 0.9	
45hz	87500427	Split Case - Suction Diameter X 0.75	
40hz	74468732		
35hz	61886397		
30hz	50105418		

** NPSHr estimation at reduced speeds is:
(RPM2 / RPM1)^1.5 = (NPSHr2 / NPSHr1)

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pumps and packaged systems manufacturer and distributor with branches throughout the Pacific Northwest. He can be reached via his website www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.