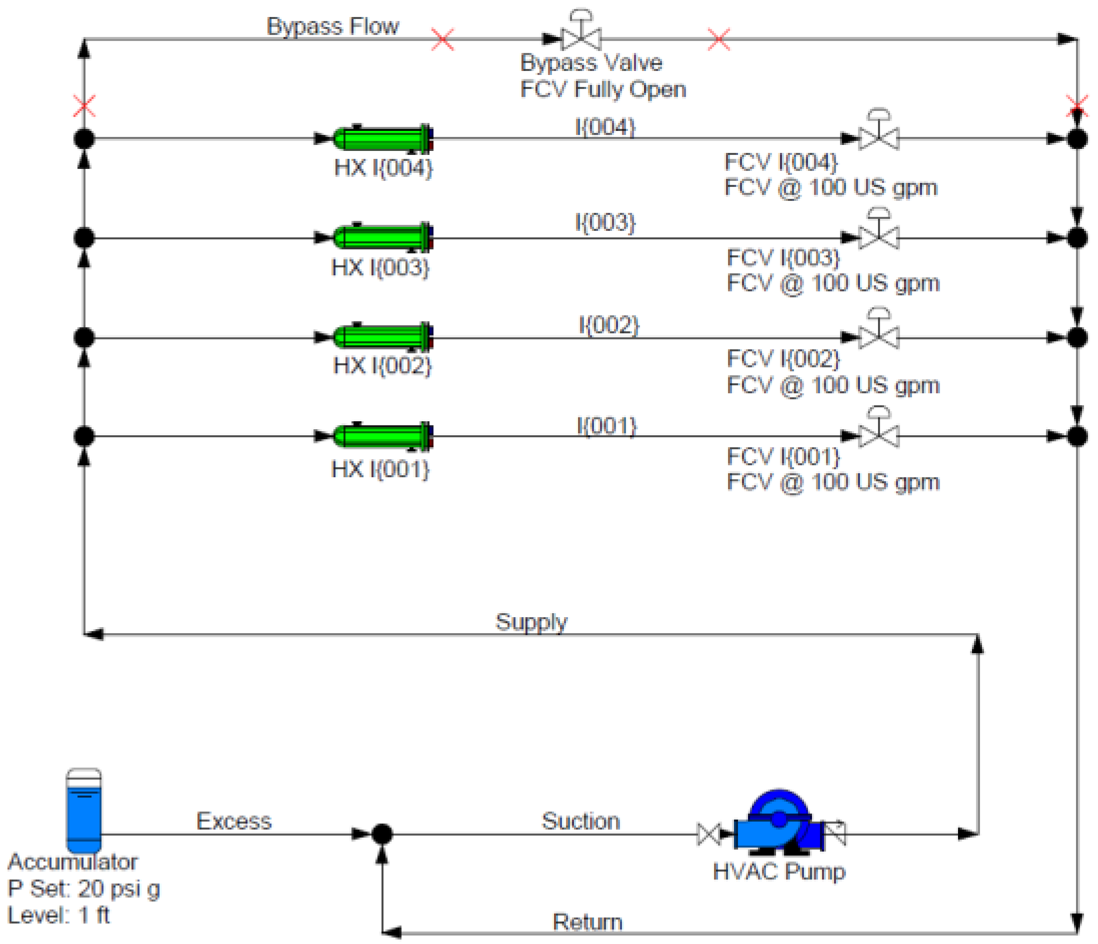
Case Study - Variable Speed Pumps

When designing piping systems in which the system demand varies (for example, a chilled water distribution system with varying loads throughout the year), variable speed pumps may be an effective energy and cost savings option. In these systems, the pump speed can be adjusted to meet the varying demands of the system.

In this example, we will learn how to implement a variable frequency drive pump in a chilled water distribution system. We will be able to see the difference in total pump head, and consequently the difference in power consumption and efficiency when you use a variable speed drive as opposed to a fixed speed drive.

Piping System



In this study we have an HVAC chilled water distribution system. There are multiple draws on the pump anywhere from 12 to 26 gpm per load. The pump was sized for a maximum design load of 400 gpm. The pump selected is a 6x5 split case pump with an 8.5 inch impeller and an 1800 rpm motor. The pipelines were sized for a fluid velocity of 8 ft/sec.

System Operation

This system has a maximum design load of 400 gpm. We will consider various operating scenarios to evaluate the operation of the pump.

The following scenarios are to be evaluated in this example:

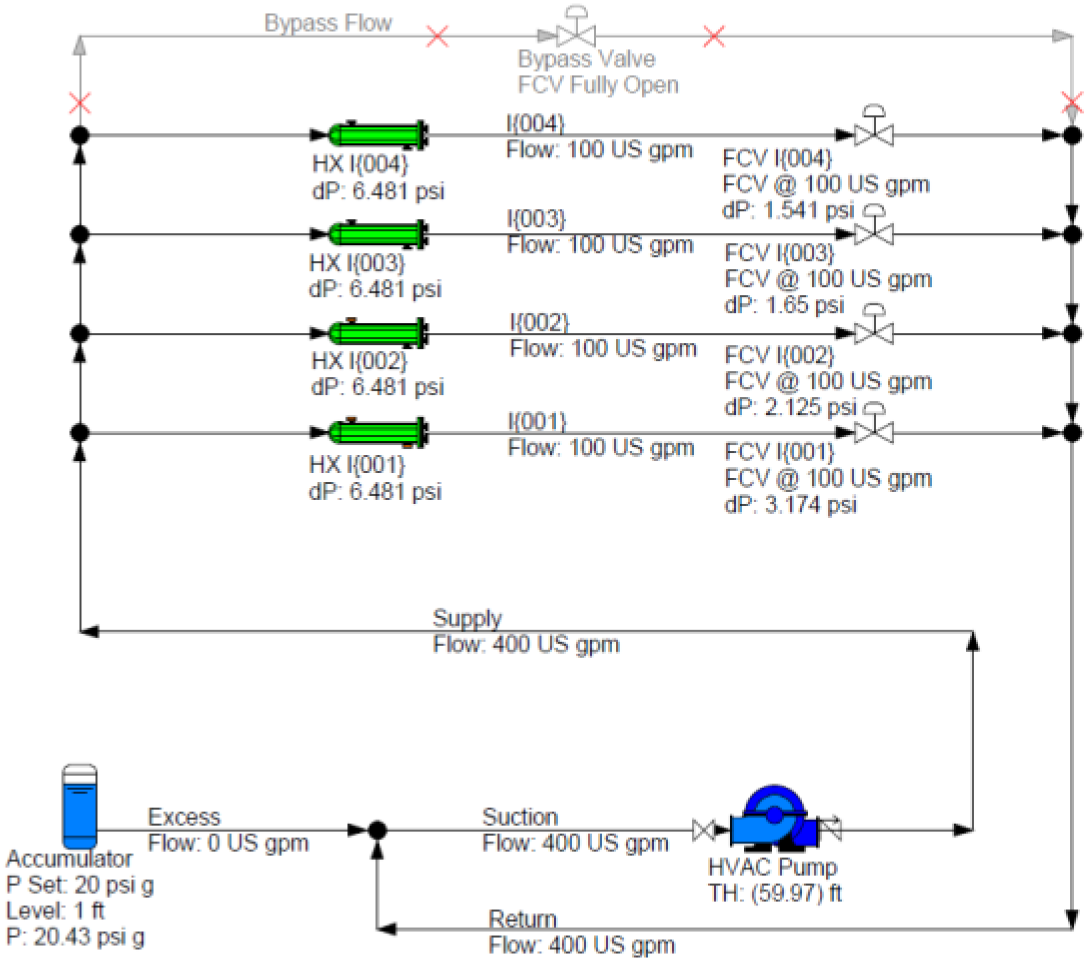
• **Normal Operation**: 90% of maximum design load.

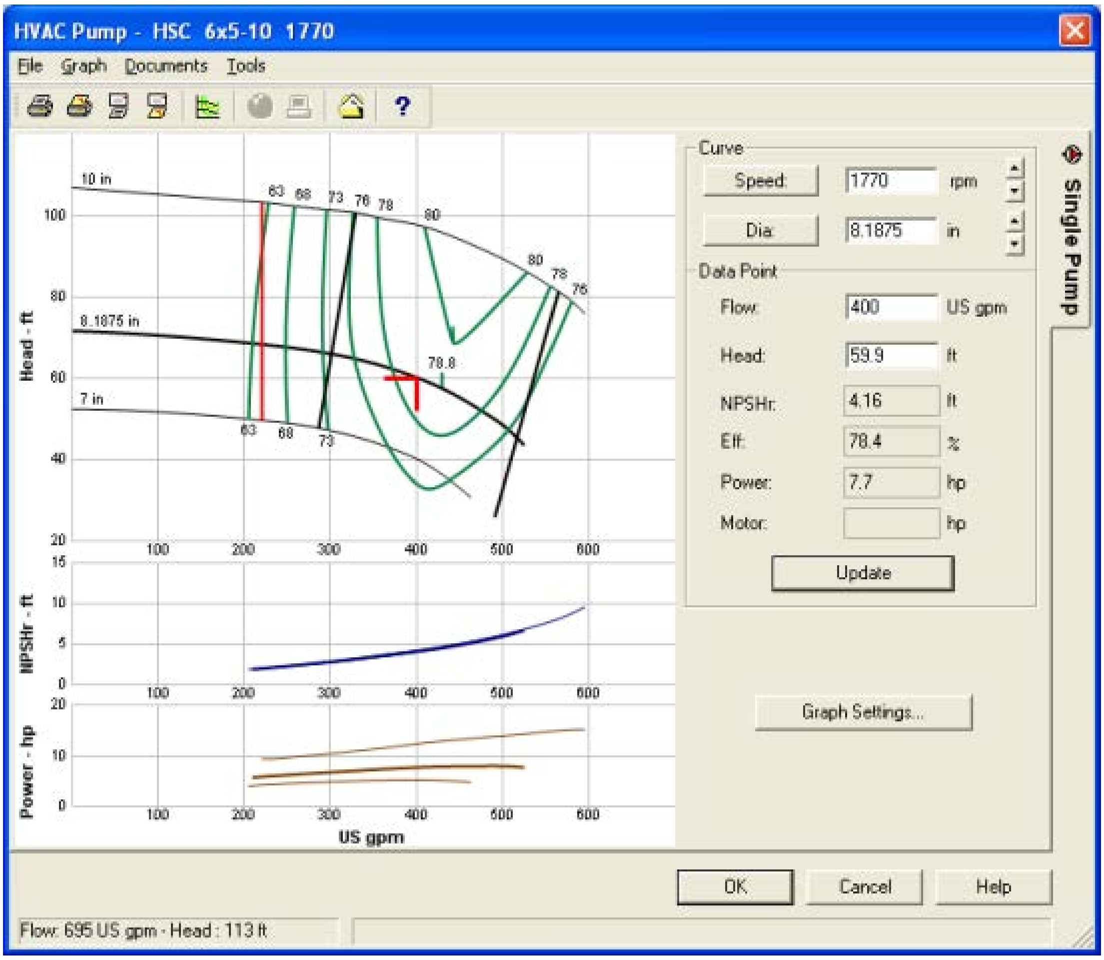
• **Nighttime Operation**: 65% of maximum design load.

• **Shutdown**: Bypass valve maintaining minimum pump flow

Fixed Speed Pump Operation

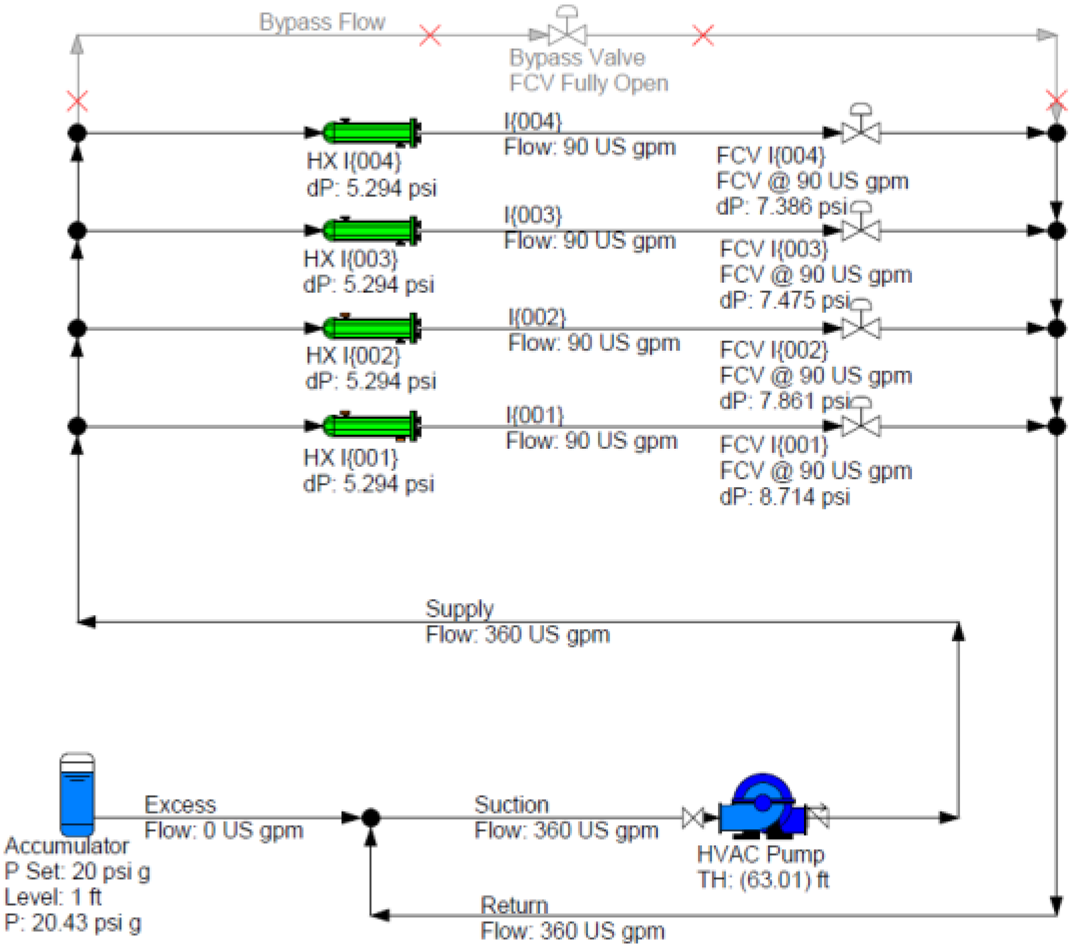
First let's see how the system operates with a fixed speed pump.



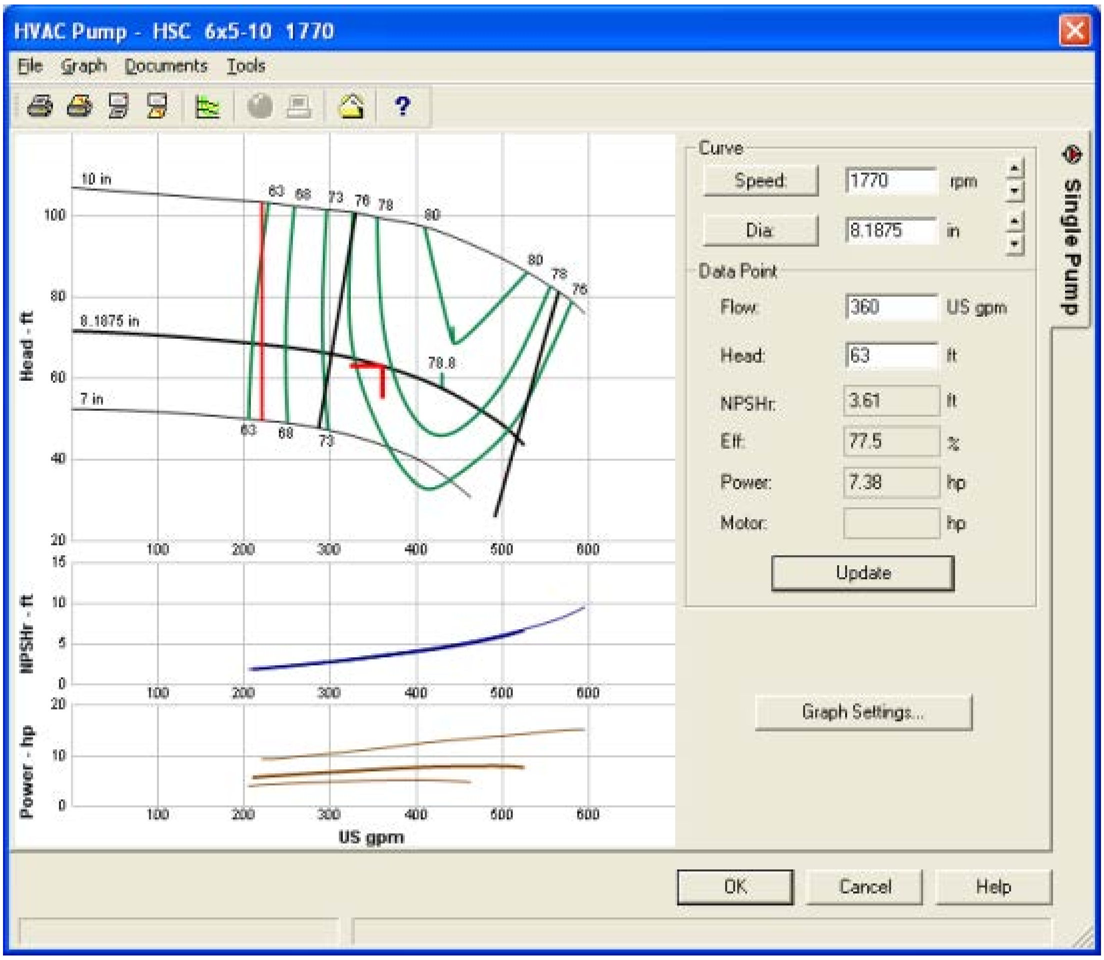


Above is the graph for HVAC Pump.Note the pump's operating point on the graph (the large red knee-shaped mark) and the pump's power and efficiency (7.7 hp at 78.4% efficiency).

Now let's see how the system operates with a fixed speed pump during normal operations.

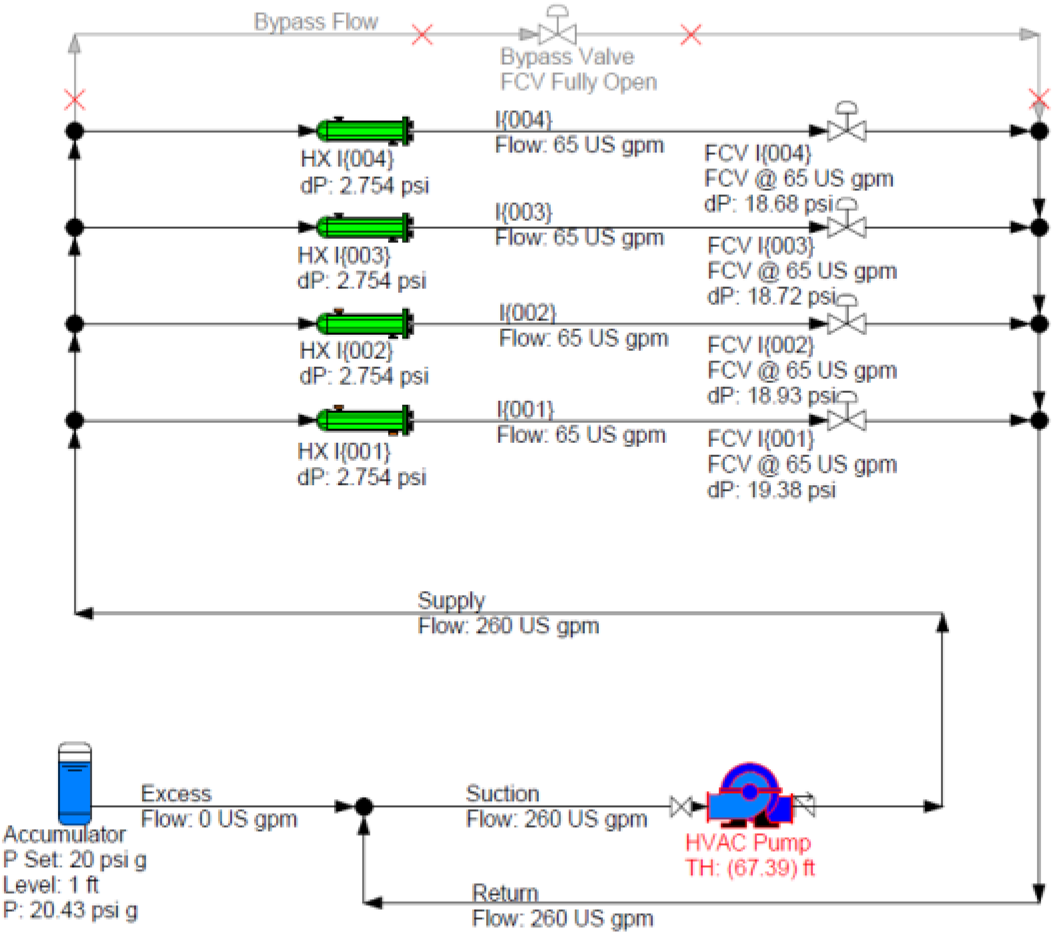


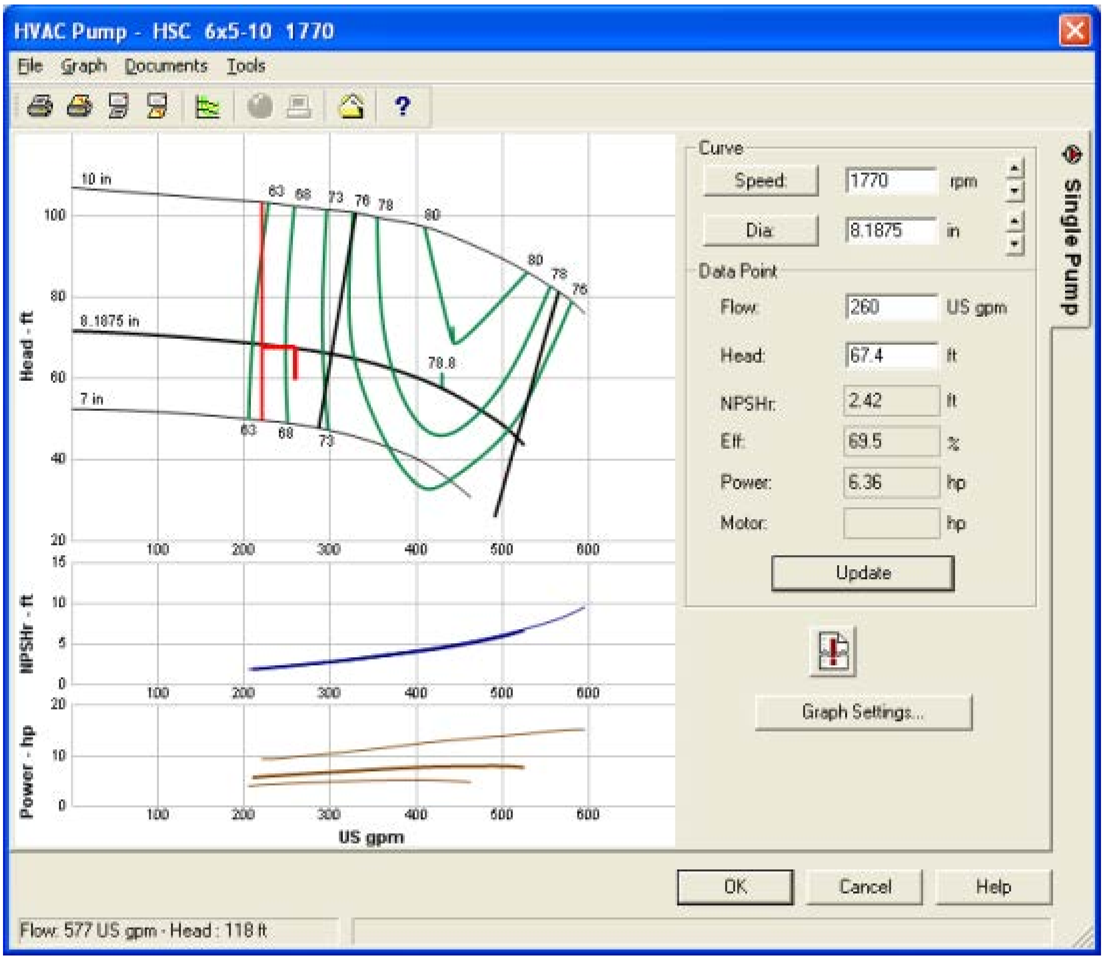
Bypass Flow
Bypass Valve
FCV Fully Open
I{004}
Flow: 90 US gpm
HX I{004}
dP: 5.294 psi
FCV I{004}
FCV @ 90 US gpm
dP: 7.386 psi
I{003}
Flow: 90 US gpm
HX I{003}
dP: 5.294 psi
FCV I{003}
FCV @ 90 US gpm
dP: 7.475 psi
I{002}
Flow: 90 US gpm
HX I{002}
dP: 5.294 psi
FCV I{002}
FCV @ 90 US gpm
dP: 7.861 psi
I{001}
Flow: 90 US gpm
HX I{001}
dP: 5.294 psi
FCV I{001}
FCV @ 90 US gpm
dP: 8.714 psi
Supply
Flow: 360 US gpm
Excess
Flow: 0 US gpm
Suction
Flow: 360 US gpm
Accumulator
P Set: 20 psi g
Level: 1 ft
P: 20.43 psi g
HVAC Pump
TH: (63.01) ft
Return
Flow: 360 US gpm



We can now see how the pump operations have changed.Note the pump's power and efficiency (7.38 hp at 77.5% efficiency). Also, the pump's operating point has moved slightly back on the pump curve.

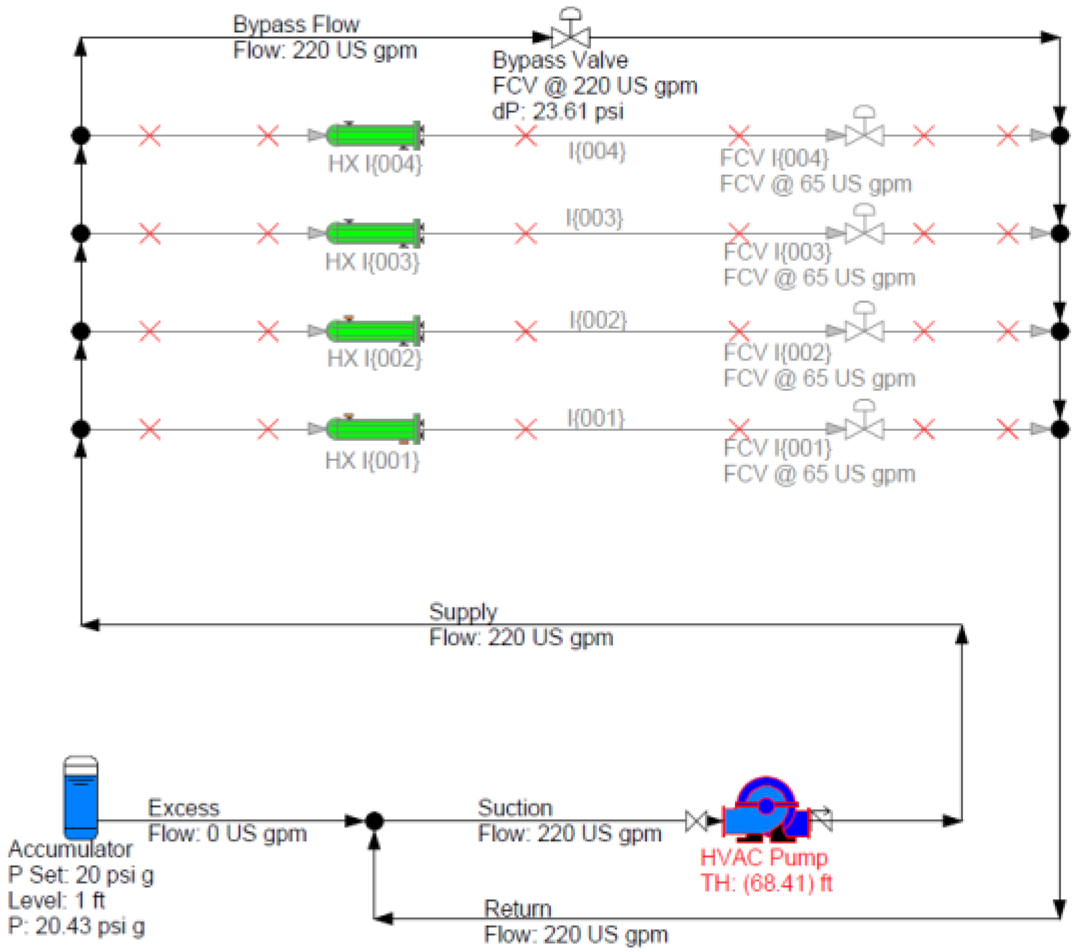
Now we will switch to the fixed speed pump and nighttime operation.


Bypass Flow
Bypass Valve
FCV Fully Open
I{004}
Flow: 65 US gpm
HX I{004}
dP: 2.754 psi
FCV I{004}
FCV @ 65 US gpm
dP: 18.68 psi
I{003}
Flow: 65 US gpm
HX I{003}
dP: 2.754 psi
FCV I{003}
FCV @ 65 US gpm
dP: 18.72 psi
I{002}
Flow: 65 US gpm
HX I{002}
dP: 2.754 psi
FCV I{002}
FCV @ 65 US gpm
dP: 18.93 psi
I{001}
Flow: 65 US gpm
HX I{001}
dP: 2.754 psi
FCV I{001}
FCV @ 65 US gpm
dP: 19.38 psi
Supply
Flow: 260 US gpm
Accumulator
P Set: 20 psi g
Level: 1 ft
P: 20.43 psi g
Excess
Flow: 0 US gpm
Suction
Flow: 260 US gpm
HVAC Pump
TH: (67.39) ft
Return
Flow: 260 US gpm

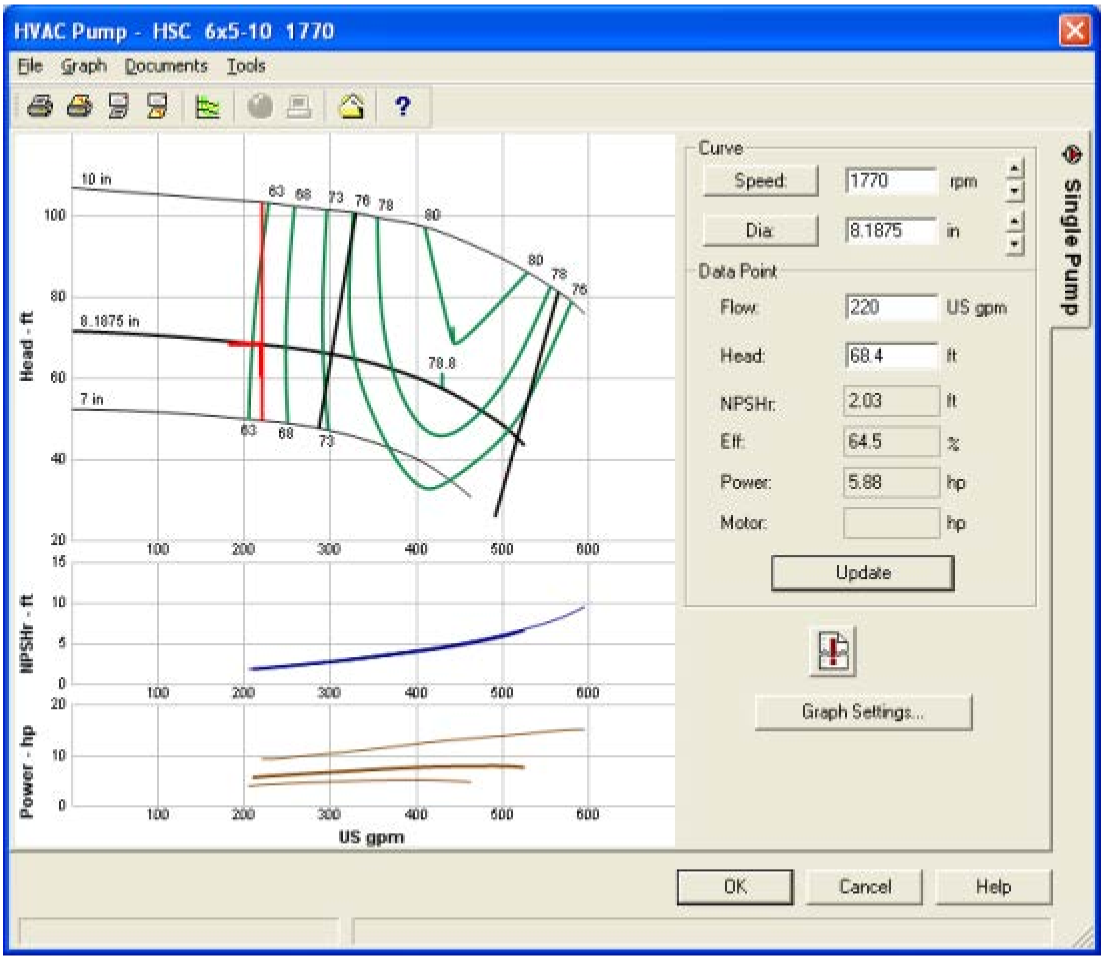


Notice the pump has turned red.This is because the operating point has moved further up the curve and outside of the preferred operating region. The power is at 6.36 hp and the efficiency has dropped to 69.5%.

Lastly, let's take a look at shutdown operations.



Notice that all loads are isolated and the Bypass Valve has been opened enough to keep the pump's minimum flow rate of 220 gpm recirculating.



Note the pump's operating point, power, and efficiency. Power is 5.88 hp and efficiency is down to 64.5%.

With a fixed speed pump, you must change the system resistance in order to meet the changes in the system demands. This is usually accomplished by adjusting control valves. When the system demand decreases, the valves must be throttled down to meet the lower flow rates. This in turn increases the system resistance, and forces the pump to run further back on its curve. This is illustrated in Figure 1 below. Each operating condition runs on a separate system curve, and where that curve intersects the pump curve is the operating point for the pump.

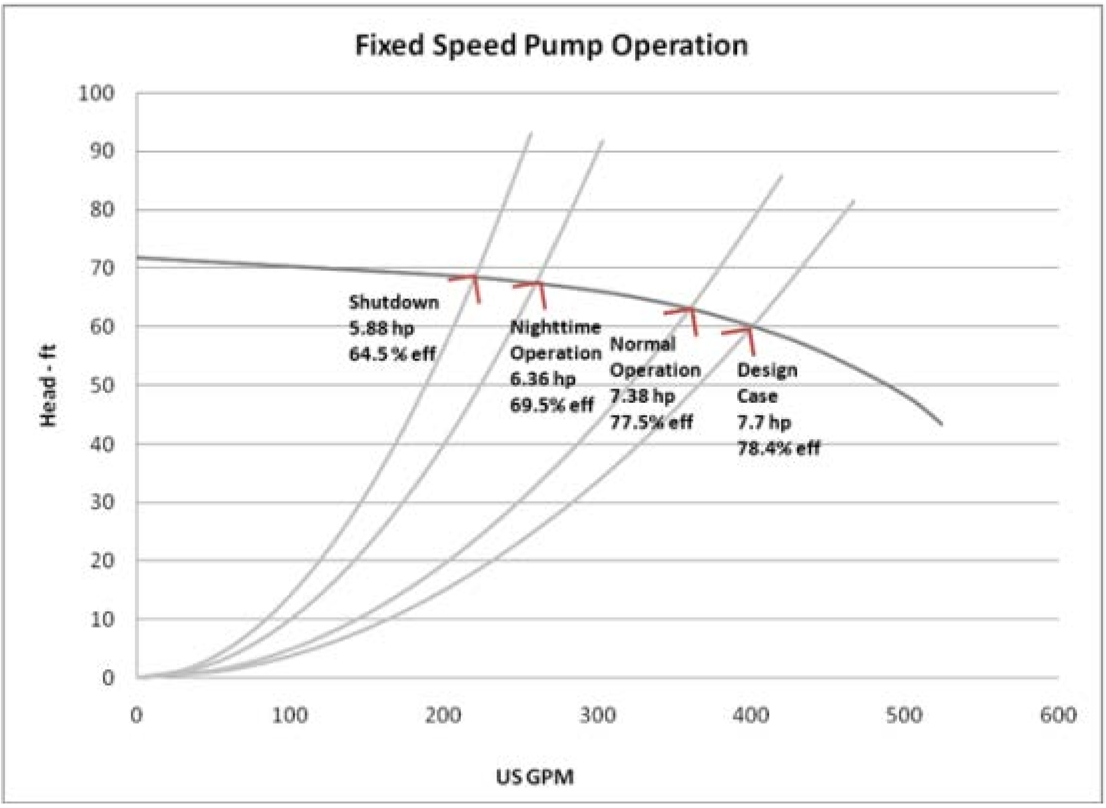
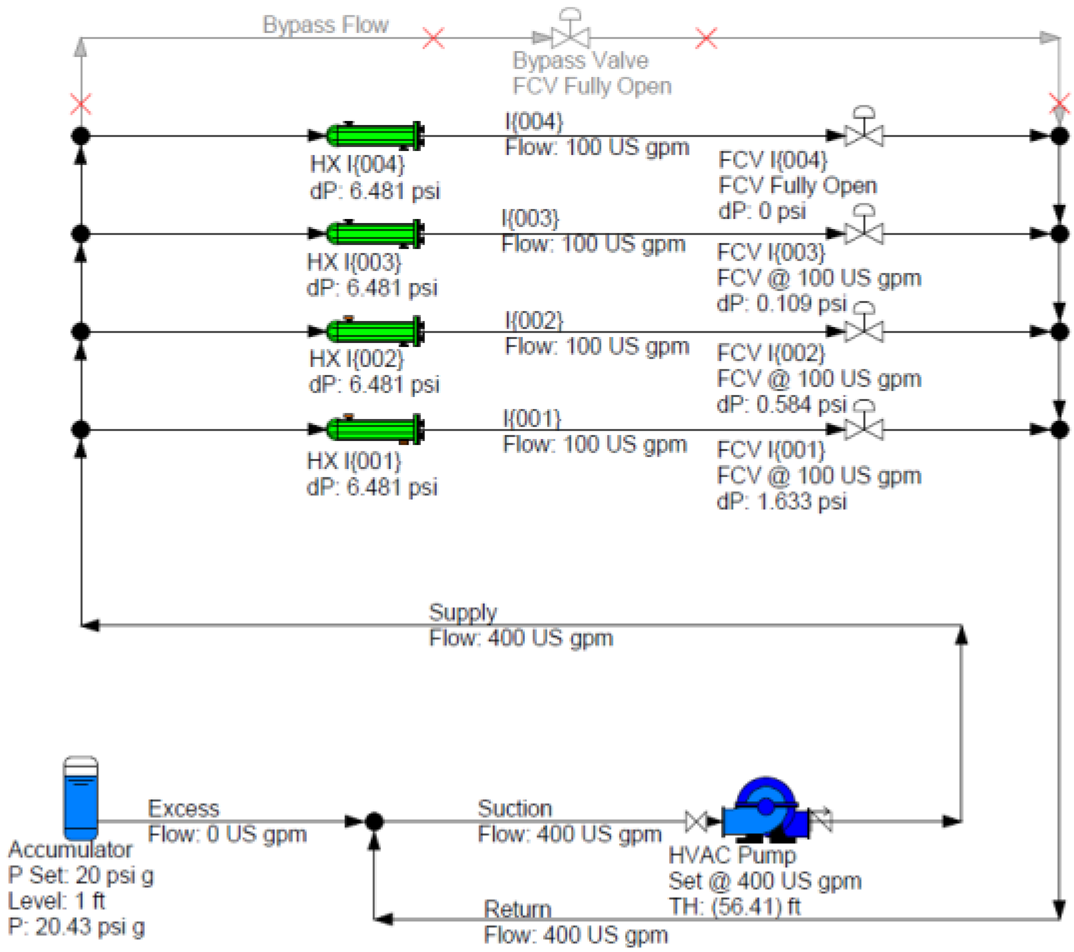


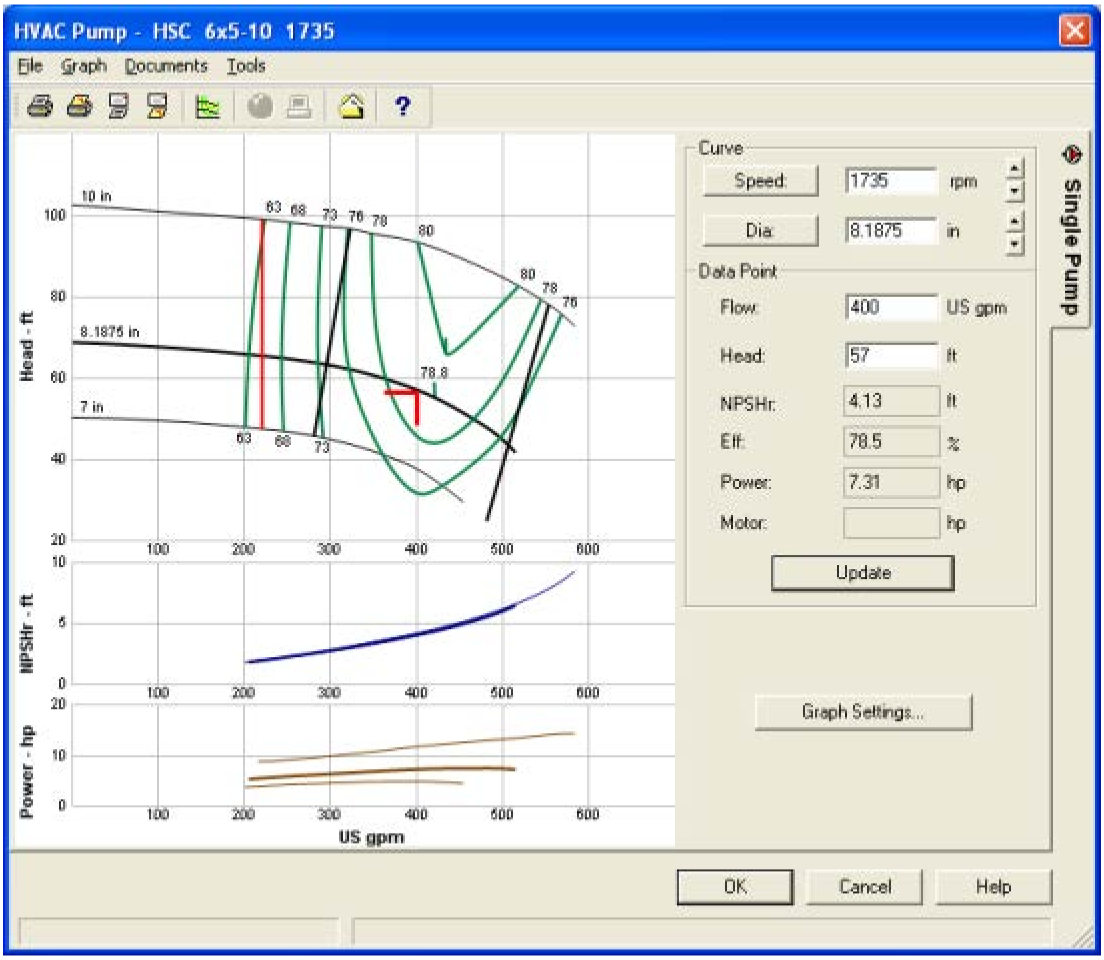
Figure 1 - Fixed Speed Pump Operation

Variable Speed Pump Operation

Now let's see how the system operates with a variable speed pump.

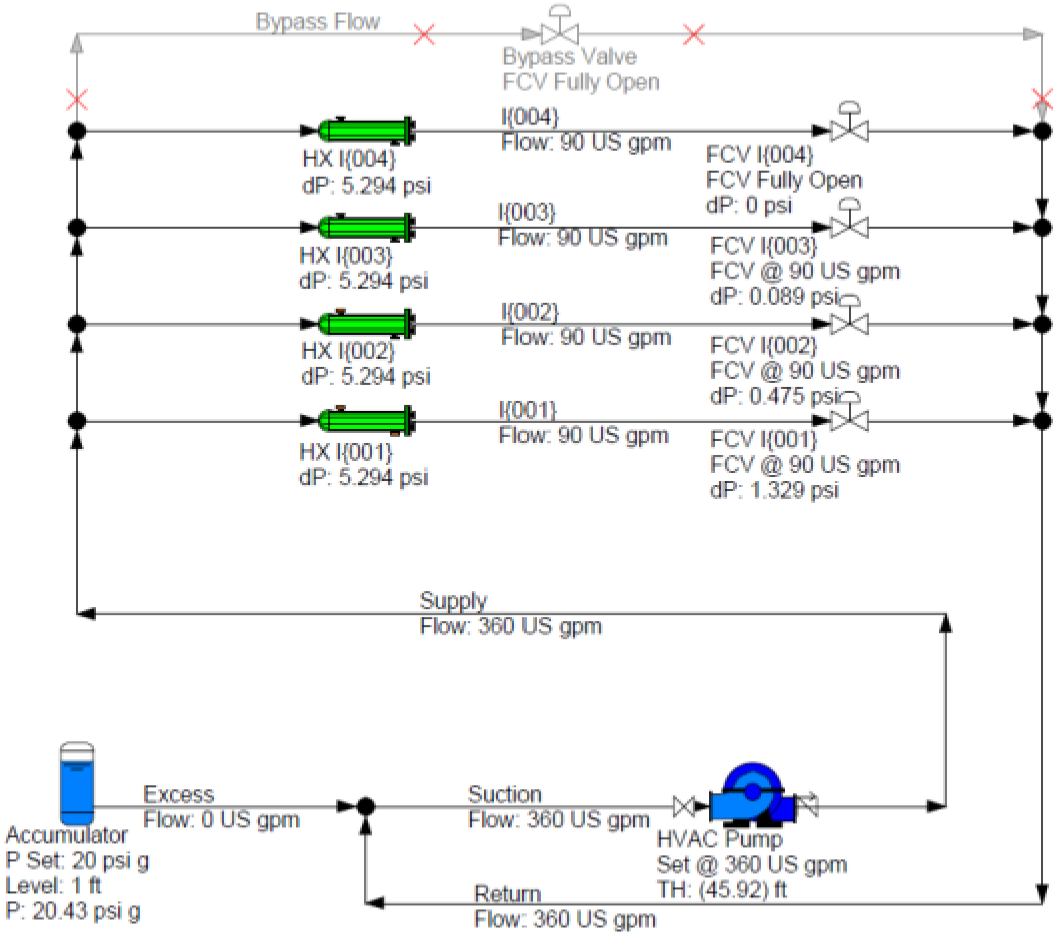


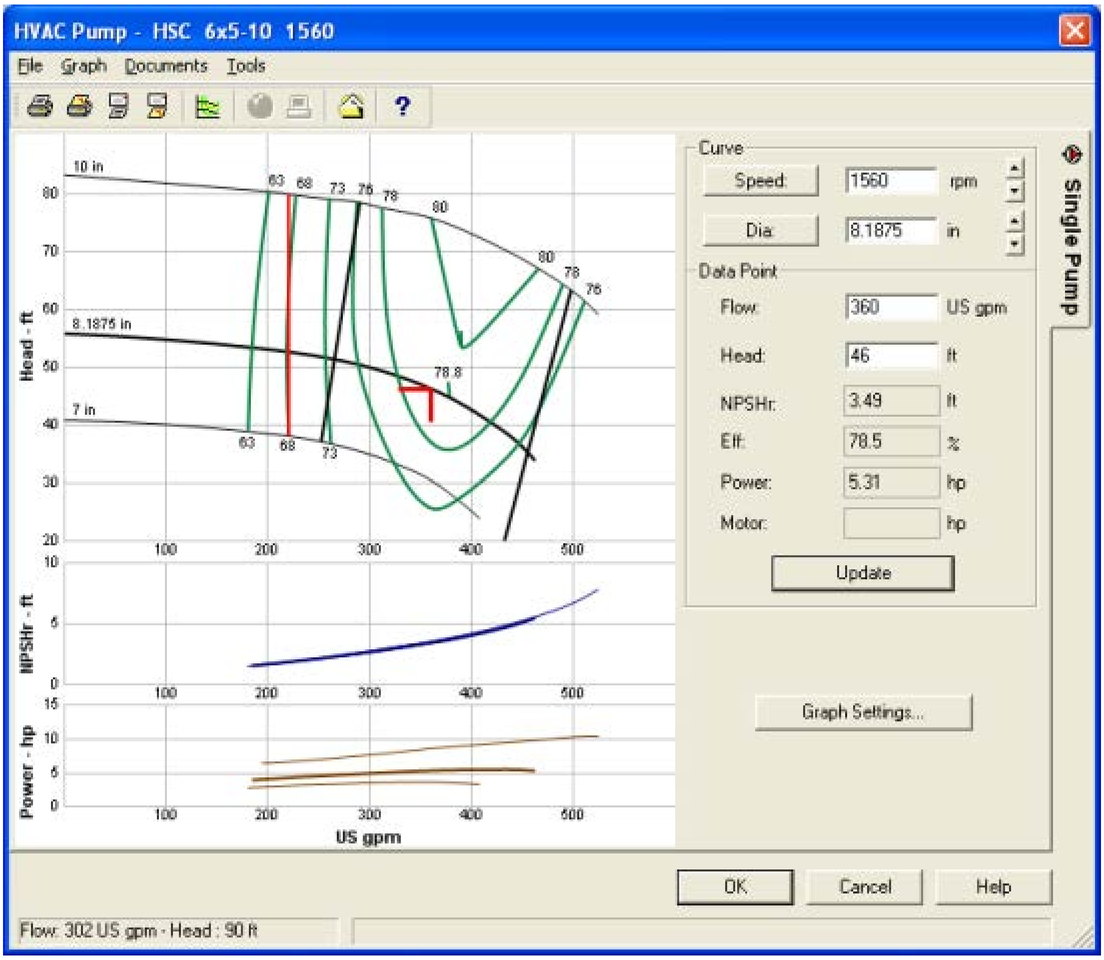
The Lineup Settings for the HVAC Pump have been changed to "Variable speed pump set to" 400 US gpm. In addition, the control valve in the most hydraulically remote loop must be set fully open in order to avoid an overcontrolled situation. The valve which has been set open is FCV I{002}.



Note that the speed of the pump has changed from 1770 rpm to 1735 rpm, and the pump's curve has dropped down to meet the new operating point. Power is 7.31 hp and efficiency is 78.5%.

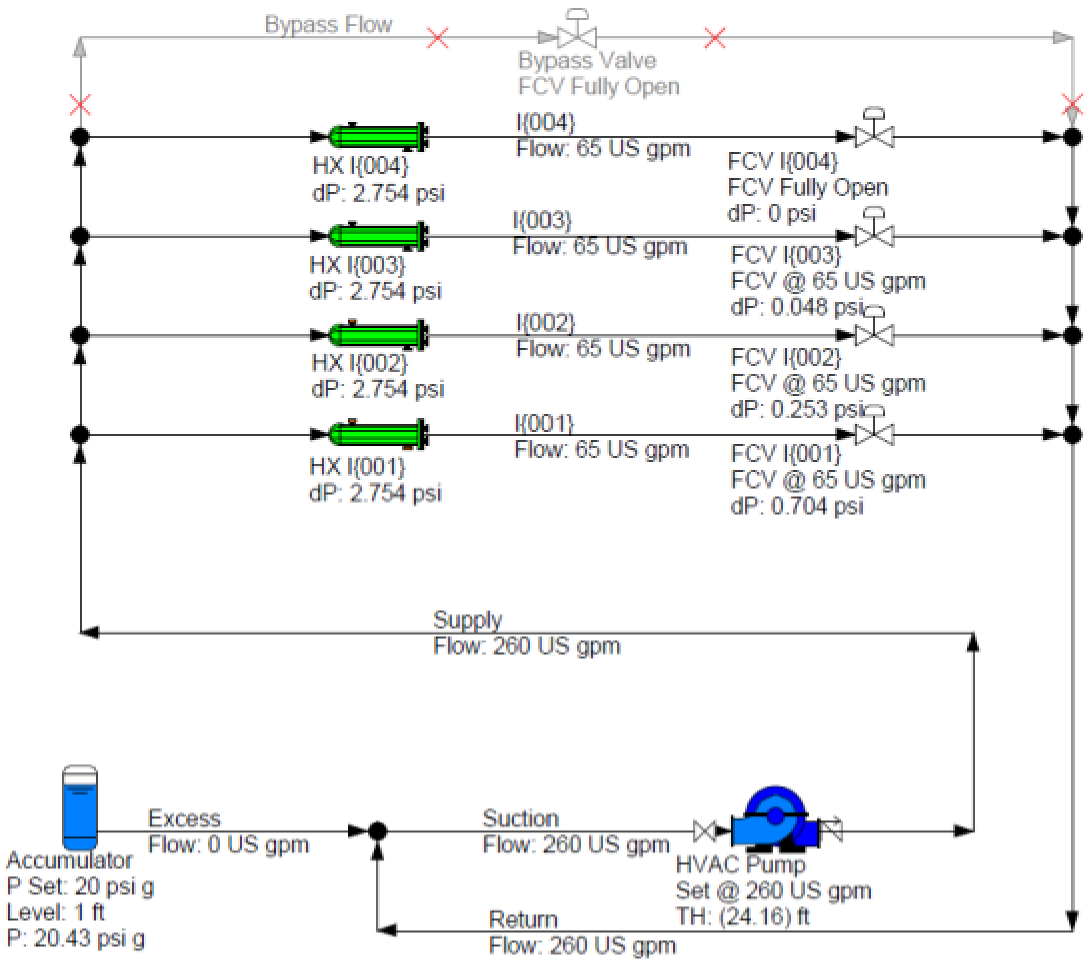
Now let's see how the system operates at normal conditions with a variable speed pump.


Bypass Flow
Bypass Valve
FCV Fully Open
I{004}
Flow: 90 US gpm
HX I{004}
dP: 5.294 psi
FCV I{004}
FCV Fully Open
dP: 0 psi
I{003}
Flow: 90 US gpm
HX I{003}
dP: 5.294 psi
FCV I{003}
FCV @ 90 US gpm
dP: 0.089 psi
I{002}
Flow: 90 US gpm
HX I{002}
dP: 5.294 psi
FCV I{002}
FCV @ 90 US gpm
dP: 0.475 psi
I{001}
Flow: 90 US gpm
HX I{001}
dP: 5.294 psi
FCV I{001}
FCV @ 90 US gpm
dP: 1.329 psi
Supply
Flow: 360 US gpm
Excess
Flow: 0 US gpm
Accumulator
P Set: 20 psi g
Level: 1 ft
P: 20.43 psi g
Suction
Flow: 360 US gpm
HVAC Pump
Set @ 360 US gpm
TH: (45.92) ft
Return
Flow: 360 US gpm

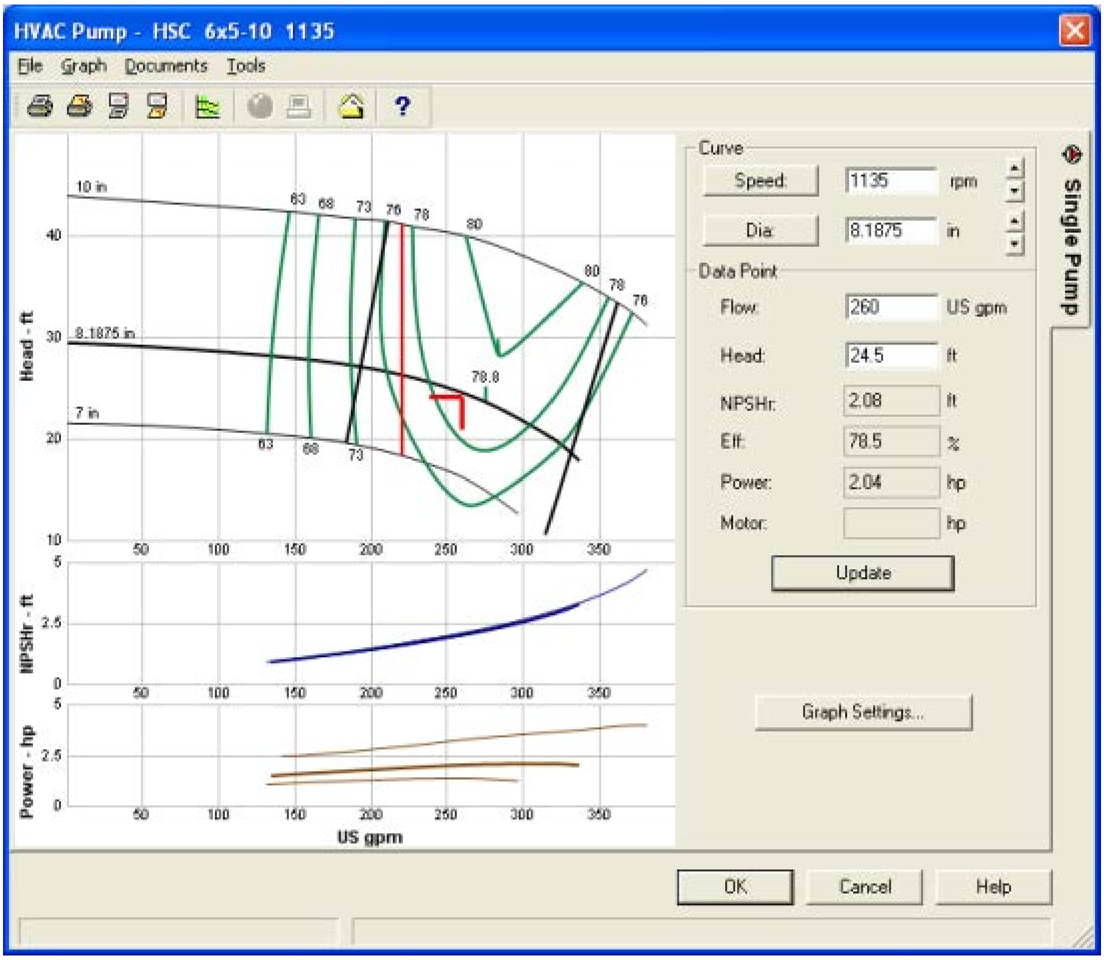


The speed has now dropped to 1560 rpm and the pump curve has dropped accordingly. Power is 5.31 hp and efficiency is 78.5%.

Now we will switch to nighttime operations with a variable speed pump.

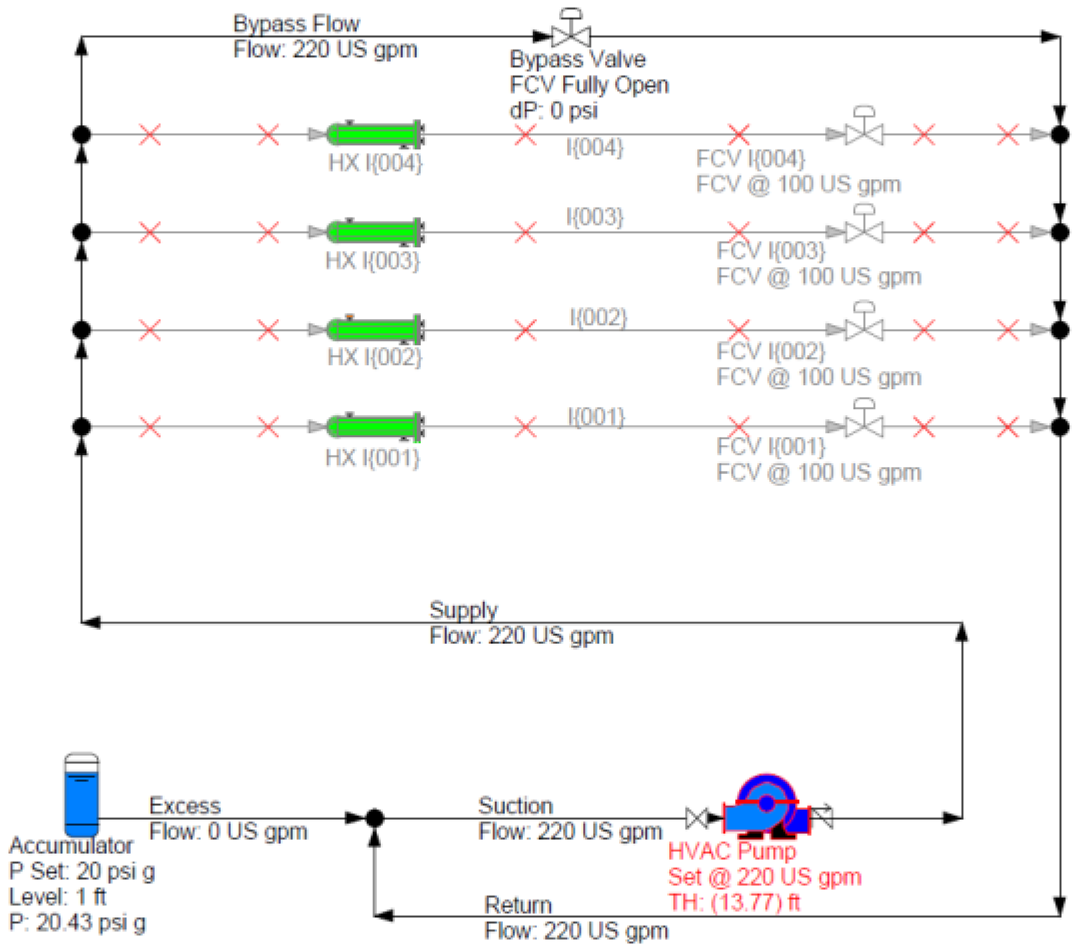


Bypass Flow
Bypass Valve
FCV Fully Open
I{004}
Flow: 65 US gpm
HX I{004}
dP: 2.754 psi
FCV I{004}
FCV Fully Open
dP: 0 psi
I{003}
Flow: 65 US gpm
HX I{003}
dP: 2.754 psi
FCV I{003}
FCV @ 65 US gpm
dP: 0.048 psi
I{002}
Flow: 65 US gpm
HX I{002}
dP: 2.754 psi
FCV I{002}
FCV @ 65 US gpm
dP: 0.253 psi
I{001}
Flow: 65 US gpm
HX I{001}
dP: 2.754 psi
FCV I{001}
FCV @ 65 US gpm
dP: 0.704 psi
Supply
Flow: 260 US gpm
Excess
Flow: 0 US gpm
Suction
Flow: 260 US gpm
Accumulator
P Set: 20 psi g
Level: 1 ft
P: 20.43 psi g
HVAC Pump
Set @ 260 US gpm
TH: (24.16) ft
Return
Flow: 260 US gpm

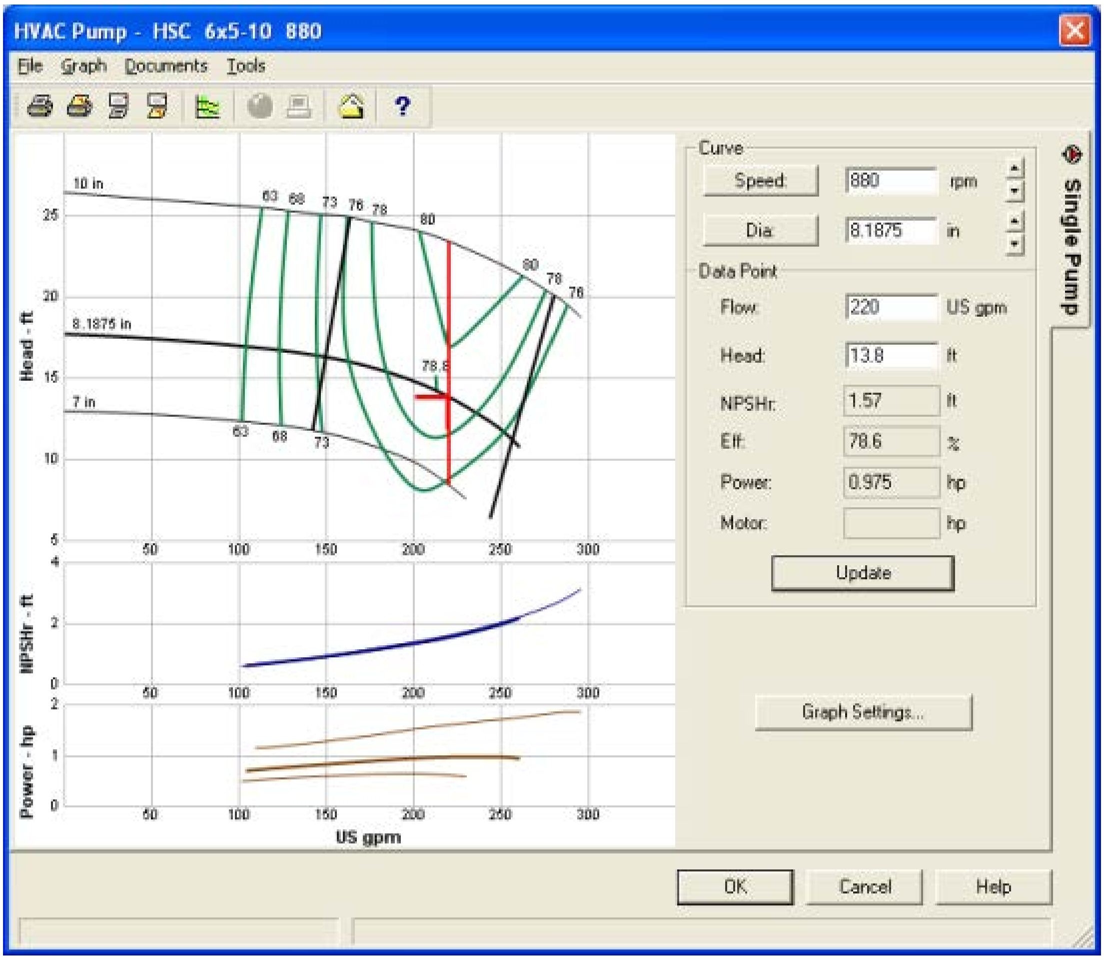


The speed has dropped to 1135 rpm and the pump curve has dropped well below its original design point. Power has dropped drastically to 2.04 hp and efficiency is still high at 78.5%.

The last situation we will look at is the system during shutdown conditions with the variable speed pump.



Bypass Flow
Flow: 220 US gpm
Bypass Valve
FCV Fully Open
dP: 0 psi
HX I{004}
I{004}
FCV I{004}
FCV @ 100 US gpm
I{003}
HX I{003}
FCV I{003}
FCV @ 100 US gpm
I{002}
HX I{002}
FCV I{002}
FCV @ 100 US gpm
I{001}
HX I{001}
FCV I{001}
FCV @ 100 US gpm
Supply
Flow: 220 US gpm
Excess
Flow: 0 US gpm
Suction
Flow: 220 US gpm
Accumulator
P Set: 20 psi g
Level: 1 ft
P: 20.43 psi g
HVAC Pump
Set @ 220 US gpm
TH: (13.77) ft
Return
Flow: 220 US gpm



Notice that the speed has been reduced to 880 rpm. The power is a miniscule 0.975 hp, and the 78.6% efficiency is still almost as high as it was under design conditions.

With a variable speed pump, the pump curve itself is adjusted to meet varying system demands by adjusting the speed according to Pump Affinity Rules. This is illustrated in Figure 2 below. Since the pump continues to run at a high efficiency even during slowdown, this can extend the life of the pump. In addition, the reduced power consumption can provide a substantial savings in operating costs.

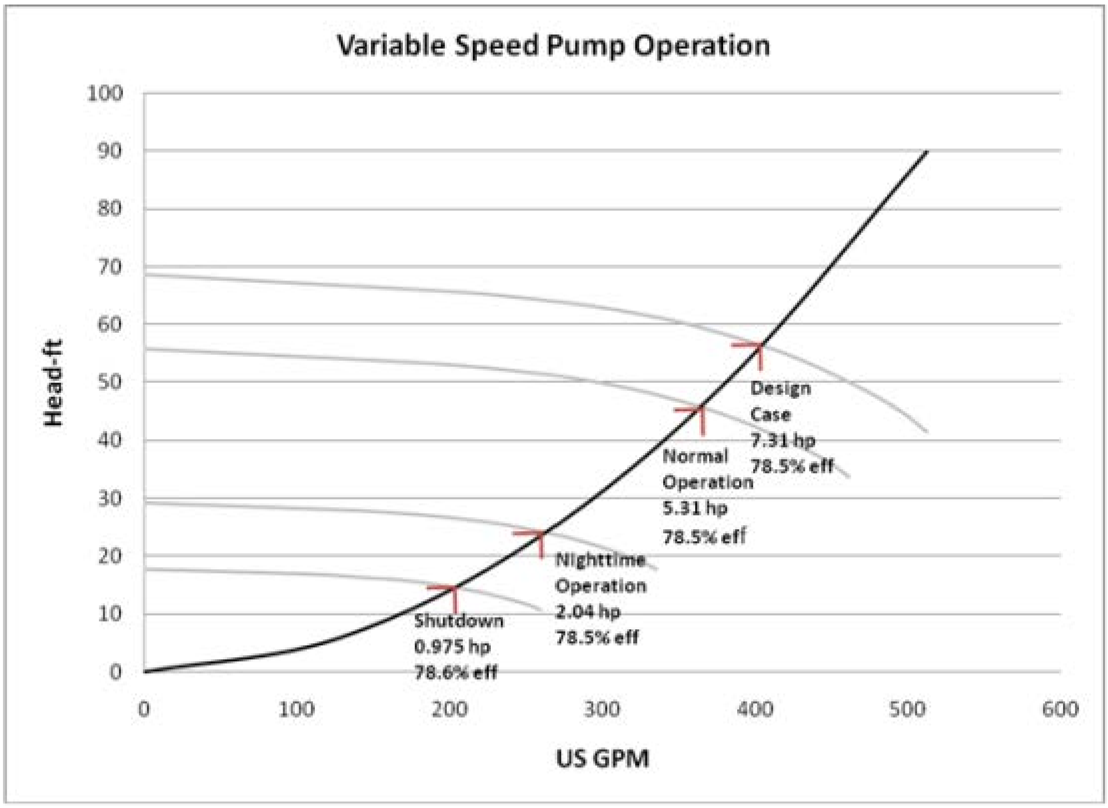


Figure 2 – Variable Speed Pump Operation

Once you have determined that a variable speed drive is feasible, and you have selected the pump from a manufacturer's electronic catalog, it can be modeled in PIPE-FLO by setting the pump to run at a variable speed setting. When a calculation is performed, PIPE-FLO applies the Pump Affinity Rules to determine the speed necessary to meet the new operating point. The speed is calculated using the following equation:

$(H_1/H_0) = (N_1/N_0)^2$ where: **H = pump head in feet N = impeller speed in rpm**

Summary

By using PIPE-FLO's fixed speed and variable speed lineup settings for pumps, you can simulate the operation of the two different types of pumps in your piping system. If you have an existing fixed speed pump, you can model what would happen if you were to change out the motor with a variable frequency drive. In addition, the pump selection module in PIPE-FLO allows you to compare the annual operating costs for both a fixed speed and variable speed pump. In any case, PIPE-FLO gives you the tools you need to make these decisions.