Pumping Configurations and DeltaPValve® Savings

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Introduction

In order to investigate pump energy savings from different pumping configurations and delta T (ΔT) performance criteria, a generic campus system serving four buildings was created and evaluated using Pipe-Flo hydraulic modeling software. The total building cooling coil capacity is 1,000 tons, with an actual diversified campus peak load of 800 tons. The central plant contains two 400 ton chillers to meet the design load for this analysis. Three different system pumping configurations were analyzed: a constant speed primary system, primary-secondary system with constant speed primary pumps and variable speed secondary pumps, and a variable speed primary system.

Model Inputs

The load was distributed throughout the four buildings at 15%, 20%, 40%, and 25%. Four different load conditions were simulated for each system configuration: design load (800 tons), 75%, 50%, and 25%. A ΔT profile for typical systems is shown in Table 1, based on facility surveys and operator feedback. Improved ΔT results achieved through precision control in DeltaPValve® systems are also shown in Table 1, derived using coil selection software and a specific coil evaluated through part load conditions. The Ideal Coil curve is referenced from the 2016 ASHRAE Handbook, HVAC Systems and Equipment, Chapter 13-2.5, Figure 24, “Chilled-Water Coil Heat Transfer Characteristic”.

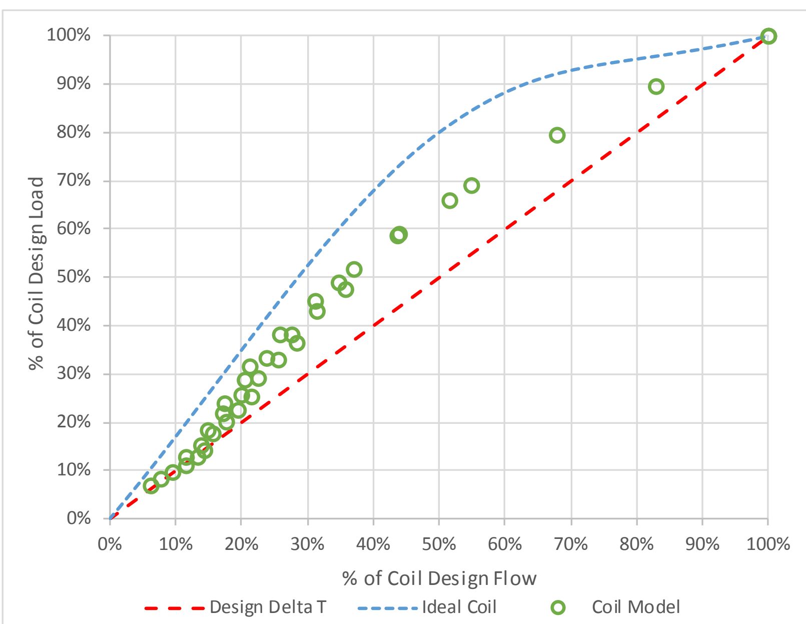


Figure 1: Coil Performance Results

The required flow rate to satisfy the load conditions with the given ΔT is calculated by:

$$Flow\ (GPM) = \frac{24 * Load\ (Tons)}{\Delta T\ (°F)}$$

Each chiller is assumed to have a 15 ft pressure drop at design flow (800 GPM) with a 2nd order curve fit for flow rate vs. pressure drop calculated by the modeling software. Each building is assumed to have a 20 PSID pressure drop at design flow, also with a calculated 2nd order curve fit. This is a general representation of a typical building and incorporates coils, tees, elbows, isolation valves, control valves and other fittings.

A minimum differential pressure of 5 PSID was specified for all control valves for pump selection and energy calculations. A case using 3 PSID minimum was also considered for non-DeltaPValves for an additional point of reference.

All piping lengths between buildings and pumps/ chillers is consistent for each system layout however, additional piping for more pumps, headers, and a bypass is added at appropriate lengths when required.

Table 1: Model Inputs for Load, Delta T, and Flow Rate

Building 1 (15%)

					DeltaP Valve		Typical Valve	
			Load (Tons)	%Flow	Flow (GPM)	Delta T (F)	Flow (GPM)	Delta T(F)
ARI Load	ARI Time	Design	150		300.0	12.0	300	12
100%	1%	80%	120	66%	198.3	14.5	240	12
75%	42%	60.0%	90	46%	137.1	15.8	216	10
50%	45%	40.0%	60	30%	89.1	16.2	160	9
25%	12%	20.0%	30	16%	48.3	14.9	90	8

Building 2 (20%)

					DeltaP Valve		Typical Valve	
			Load (Tons)	%Flow	Flow (GPM)	Delta T (F)	Flow (GPM)	Delta T(F)
ARI Load	ARI Time	Design	200		400.0	12.0	400	12
100%	1%	80%	160	66%	264.4	14.5	320	12
75%	42%	60.0%	120	46%	182.8	15.8	288	10
50%	45%	40.0%	80	30%	118.8	16.2	213	9
25%	12%	20.0%	40	16%	64.4	14.9	120	8

Building 3 (40%)

					DeltaP Valve		Typical Valve	
			Load (Tons)	%Flow	Flow (GPM)	Delta T (F)	Flow (GPM)	Delta T(F)
ARI Load	ARI Time	Design	400		800.0	12.0	800	12
100%	1%	80%	320	66%	528.8	14.5	640	12
75%	42%	60.0%	240	46%	365.6	15.8	576	10
50%	45%	40.0%	160	30%	237.6	16.2	427	9
25%	12%	20.0%	80	16%	128.8	14.9	240	8

Building 4 (25%)

					DeltaP Valve		Typical Valve	
			Load (Tons)	%Flow	Flow (GPM)	Delta T (F)	Flow (GPM)	Delta T(F)
ARI Load	ARI Time	Design	250		500.0	12.0	500	12
100%	1%	80%	200	66%	330.5	14.5	400	12
75%	42%	60.0%	150	46%	228.5	15.8	360	10
50%	45%	40.0%	100	30%	148.5	16.2	267	9
25%	12%	20.0%	50	16%	80.5	14.9	150	8

Constant Speed Primary System

Layout

System layout for the constant speed primary system is shown in Figure 2. It consists of two chillers and two constant speed primary pumps connected in parallel. Three-way control valves are represented in each building on the return side by the paired valves, i.e. valve 1 & 2, valve 3 &4, etc. Pumps were selected to satisfy the 5 PSID minimum differential pressure at the hydraulically remote location at the design load condition.

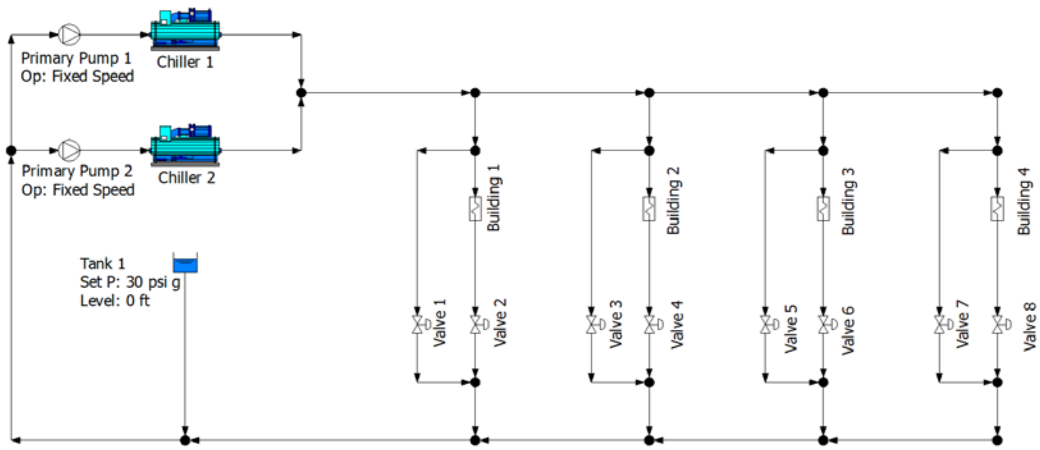


Figure 2: Constant Speed Primary System Layout

Results

Results for the constant speed primary system are shown in Table 2 including the required pumping power for each load condition as well as the pump energy over a year with the projected AHRI run time. The total cost to operate the primary pumps per year is also shown with an assumed blended electric rate of $0.10 per kWh. The required pumping power is the same for each load condition because of the constant pump speed and 3-way control valve configuration.

Table 2: Results for Constant Speed Primary System

		Constant Primary			
			Load (Tons)	Pump (HP)	Energy (kWh)
AHRI Load	AHRI Time	Design	1,000		
100%	1%	80%	800	42.1	2,750
75%	42%	60.0%	600	42.1	115,505
50%	45%	40.0%	400	42.1	123,755
25%	12%	20.0%	200	42.1	33,001
				Total kWh/yr	275,011
				$/kWh	$0.10
				$/yr	$27,501

Primary-Secondary System

Layout

System layout for the primary-secondary system is shown in Figure 3. It consists of two primary pumps and two chillers connected in parallel, as well as two secondary pumps connected in parallel. The primary pumps are constant speed while the secondary pumps are variable. There is a hydraulic decoupler between the primary and secondary systems to hydraulically separate the two pumping loops. The primary pumps were selected by closing the secondary system and allowing all chilled water to flow through the decoupler. The secondary pumps were selected by closing the primary system and setting the valve to the max design load condition while satisfying the minimum DP condition (5 PSID) at the hydraulically remote location (Building 4).

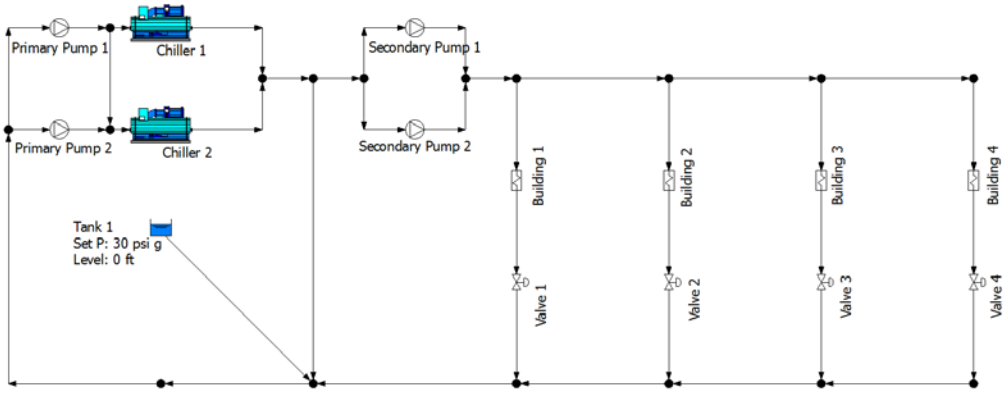


Figure 3: Primary-Secondary System Layout

Results

Results for the primary secondary system are shown in Table 3 including the required pumping power, energy, and electrical cost per year. One chiller, one primary pump, and one secondary pump were able to satisfy the load for the 25% and 50% load DeltaPValve® scenarios.

Table 3: Results for Primary-Secondary System

ARI Load	ARI Time	Design	Load (Tons)	Typical 5 PSID Pump (HP)	Typical 3 PSID Pump (HP)	DeltaP-Valve Pump (HP)	Typical 5 PSID Energy (kWh)	Typical 3 PSID Energy (kWh)	DeltaP-Valve Energy (kWh)
			1,000						
100%	1%	80%	800	44.6	42.7	31.7	2,912	2,789	2,069
75%	42%	60.0%	600	36.6	34.9	20.0	100,415	95,641	54,740
50%	45%	40.0%	400	25.6	24.3	9.7	75,376	71,319	28,525
25%	12%	20.0%	200	9.8	9.8	6.7	7,688	7,690	5,225

	Typical 5 PSID	Typical 3 PSID	DeltaP-Valve
Total kWh/yr	186,391	177,440	90,560
$/kWh	$0.10	$0.10	$0.10
$/yr	$18,639	$17,744	$9,056
$/yr savings	$0	$895	$9,583
Savings %	0.00%	4.80%	51.41%

Variable Speed Primary System

Layout

The system layout for the variable speed primary system is shown in Figure 4. This system configuration is identical to the constant speed layout, except the three-way control valves are replaced with two-way control valves and a header was added between the two primary pumps. The pumps were selected to satisfy the minimum DP condition (5 PSID) at the hydraulically remote location (Building 4) at design load. A minimum flow bypass is also added to address chiller minimum flow rates.

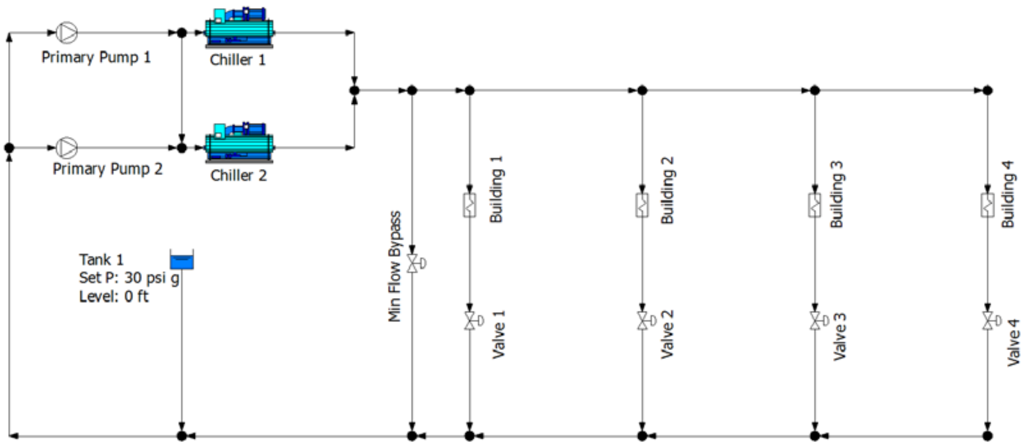


Figure 4: Variable Speed Primary System

Results

Result for the variable primary system layout are shown in including the required pumping power for each load condition with typical performance and a 5 PSID setpoint, typical performance and a 3 PSID setpoint, and DeltaPValve® performance with a 5 PSID setpoint. The required flow rates for the typical and DeltaPValve® systems for each load condition are shown in Table 1. Because of the increased ΔT performance and subsequent decrease in required flow rate to satisfy the load, the pumping power for the DeltaPValve® scenario is substantially less than when achieving the typical performance with standard control valves. One chiller and one primary pump are able to satisfy the 25% load condition for both the typical and DeltaPValve® cases, as well the 50% load condition for the DeltaPValve® case.

Table 4: Results for Variable Primary System

AHRI Load	AHRI Time	Design	Load (Tons)	Typical 5 PSID Pump (HP)	Typical 3 PSID Pump (HP)	DeltaP Valve Pump (HP)	Typical 5 PSID Energy (kWh)	Typical 3 PSID Energy (kWh)	DeltaP Valve Energy (kWh)
			1,000						
100%	1%	80%	800	41.5	39.0	25.3	2,710	2,545	1,655
75%	42%	60.0%	600	31.5	29.1	10.5	86,423	79,948	28,923
50%	45%	40.0%	400	15.0	13.2	4.5	44,199	38,867	13,281
25%	12%	20.0%	200	5.5	4.7	1.8	4,308	3,665	1,395

	Typical 5 PSID	Typical 3 PSID	DeltaP Valve
Total kWh/yr	137,640	125,025	45,254
$/kWh	$0.10	$0.10	$0.10
$/yr	**$13,764**	**$12,503**	**$4,525**
$/yr savings	$0	$1,261	$9,239
Savings %	0.00%	9.16%	67.12%

Discussion

In terms of minimizing pump energy, variable primary systems are the most favorable configuration of the three types considered. Hydraulic profiles for this system configuration are shown in Figure 5, and present a comparison of standard vs. DeltaPValve® operation at both full load and part load (50%) conditions. It is evident that there is a substantial decrease in pump power when DeltaPValves are used in place of typical valves, as a lower flow rate, and subsequent pump head pressure, is required to satisfy the same load conditions.

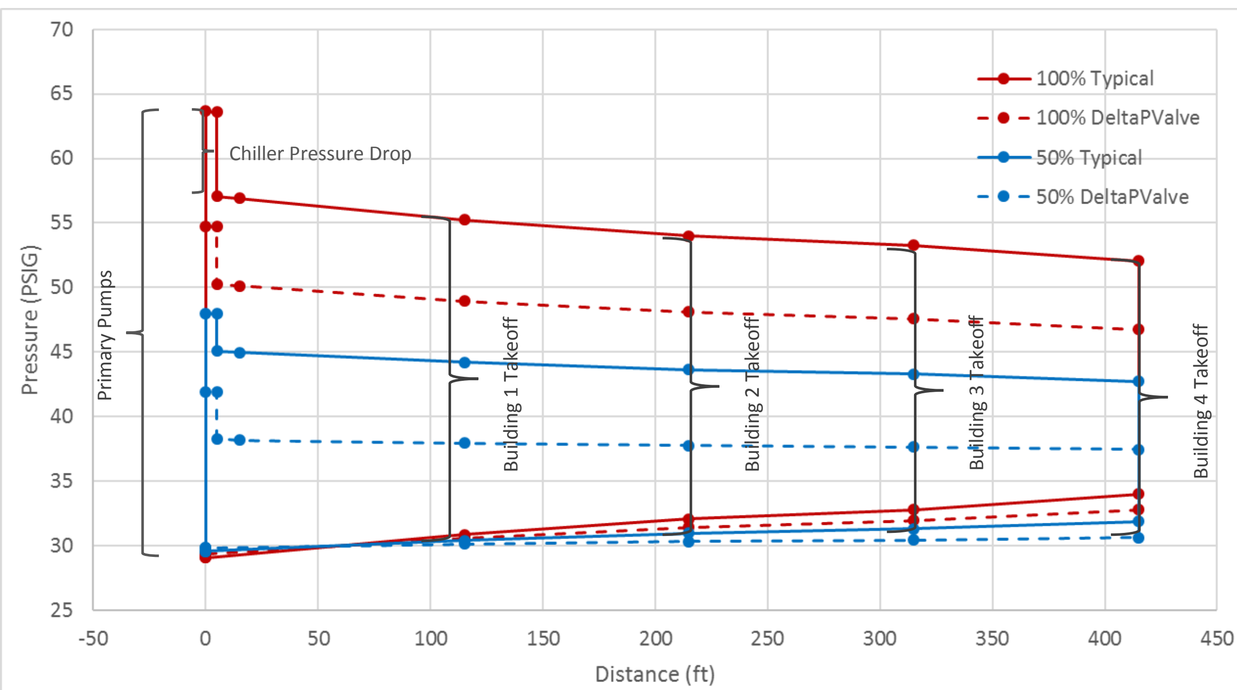


Figure 5: Hydraulic Profiles for Variable Primary System

When comparing electrical energy consumption and cost to operate pumps for a chilled water system, the use of DeltaPValves to maximize system performance and achieve high coil delta T has a much larger impact on overall efficiency than the pumping configuration. Table 5 highlights the benefit of high ΔT and resulting reduction in required flow from precision control, as it far outweighs a decrease in the differential pressure setpoint. DeltaPValve® systems can provide 150% more energy savings than a system with lower differential pressure setpoints, even in an efficient variable primary flow system.

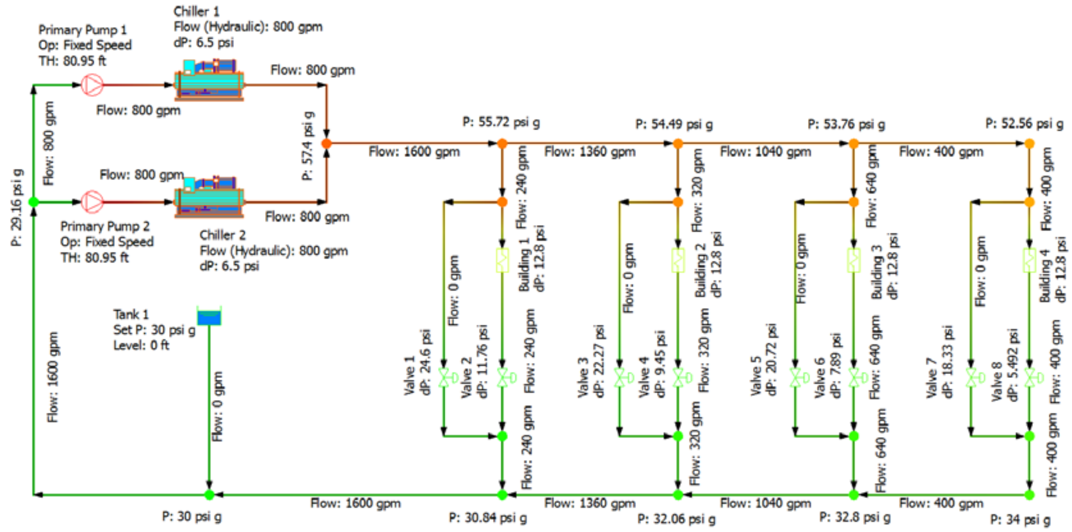
Table 5: Energy and Savings Summary

	Constant Primary	Primary Secondary			Variable Primary		
	Typical	Typical	Typical 3 PSID	DeltaP-Valve	Typical	Typical 3 PSID	DeltaP-Valve
Total kWh/yr	275,011	186,391	177,440	90,560	137,640	125,025	45,254
$/yr	$27,501	$18,639	$17,744	$9,056	$13,764	$12,503	$4,525
$/yr Savings	$0	$8,862	$9,757	$18,445	$13,737	$14,998	$22,976
Savings %	0.0%	32.2%	35.5%	67.1%	50.0%	54.5%	83.5%

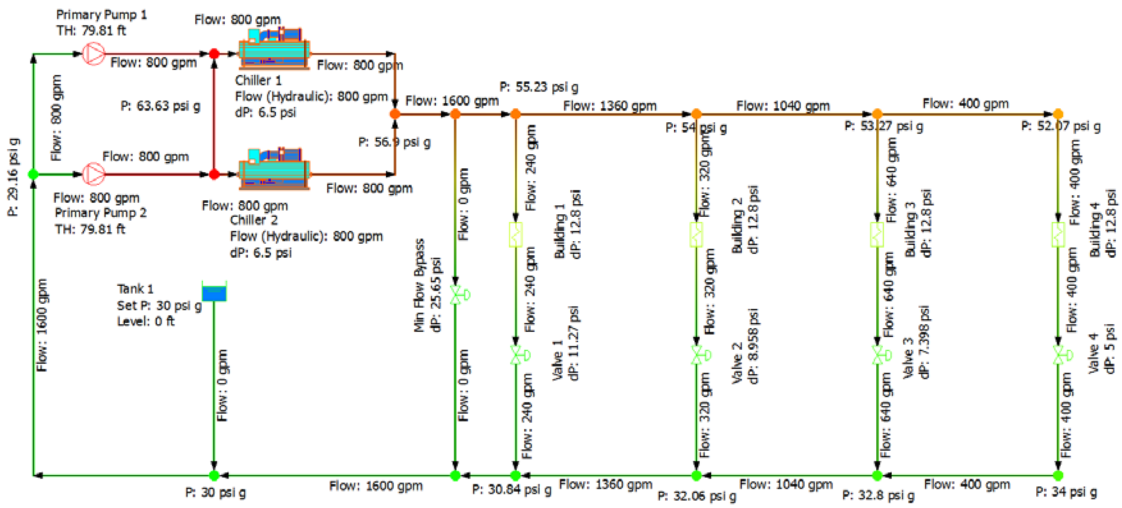
While pumping configurations garner a lot of attention when it comes to efficiency opportunities, the real opportunity lies in addressing the cooling demand at system coils. A properly operating variable primary flow system is more efficient than a primary-secondary configuration, but precision flow control provides the best conditions for coils to operate as intended by maximizing the heat transfer with the least amount of chilled water. There are also additional impacts from precision control not addressed in this analysis, including a reduction in peak load and chiller efficiency with higher return water temperatures.

Appendix A: Operating Conditions

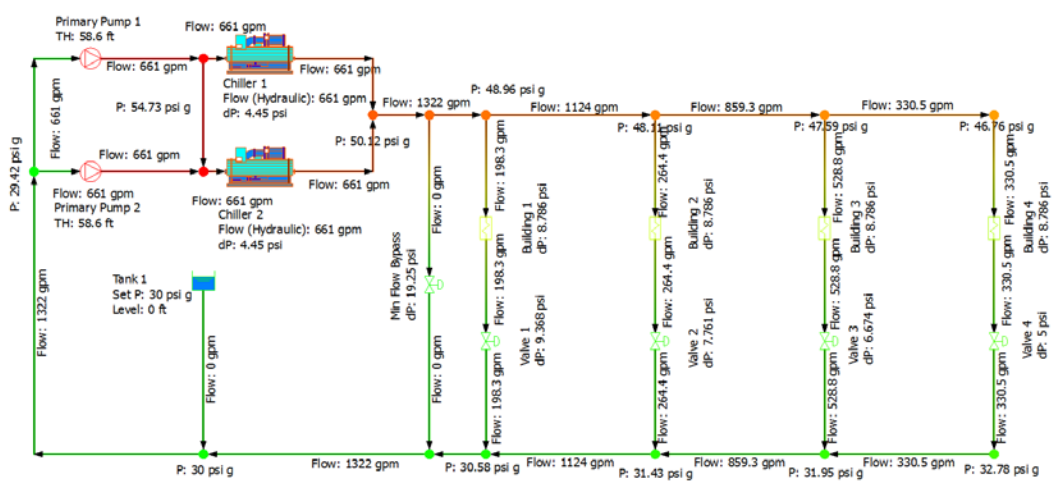
Constant Speed



Variable Speed

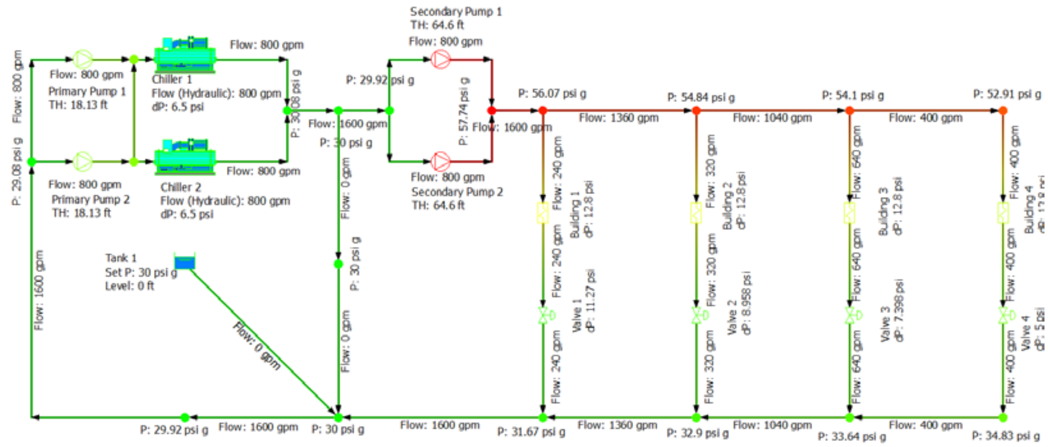


100% Typical Valve

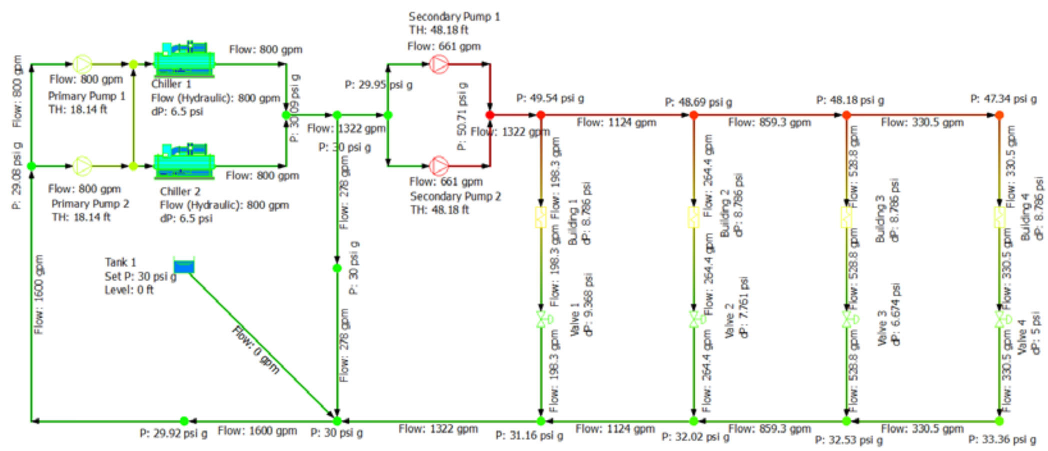


100% DeltaPValve

Primary-Secondary



100% Typical Valve



100% DeltaPValve