THE UNIVERSITY of WISCONSIN MADISON

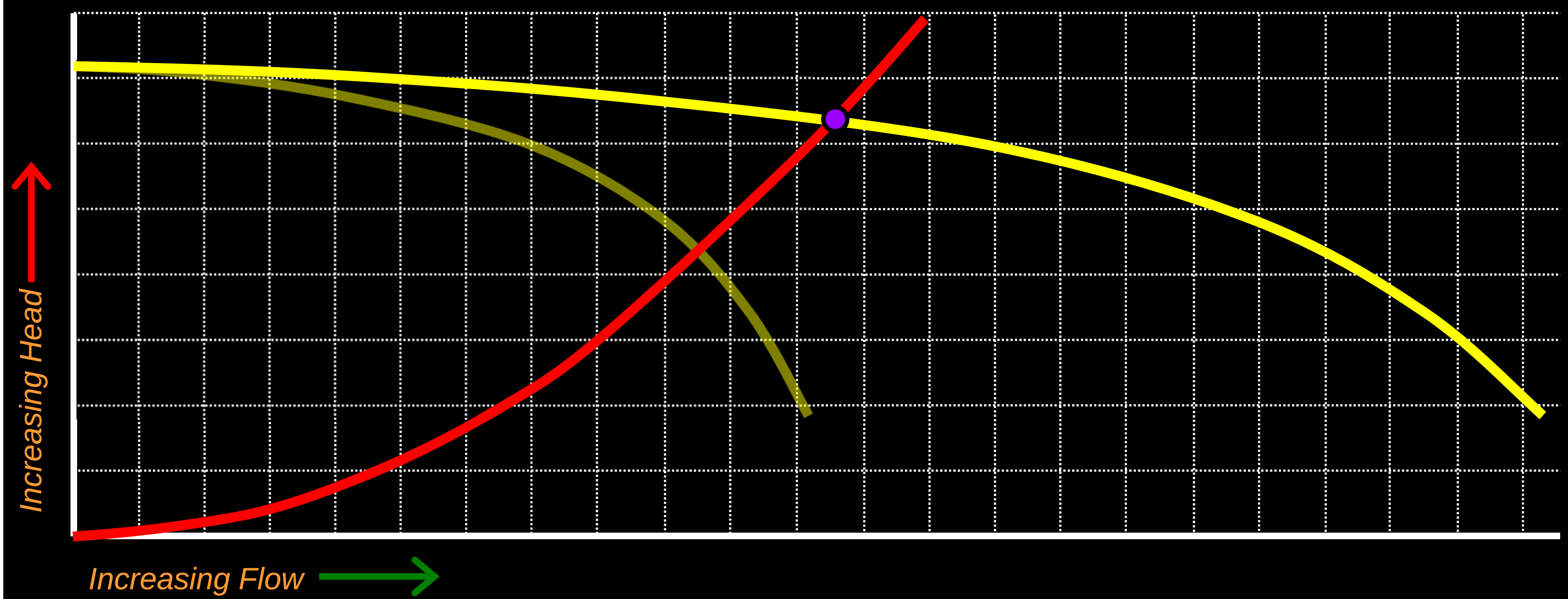
Central Plants

Tab 19-3

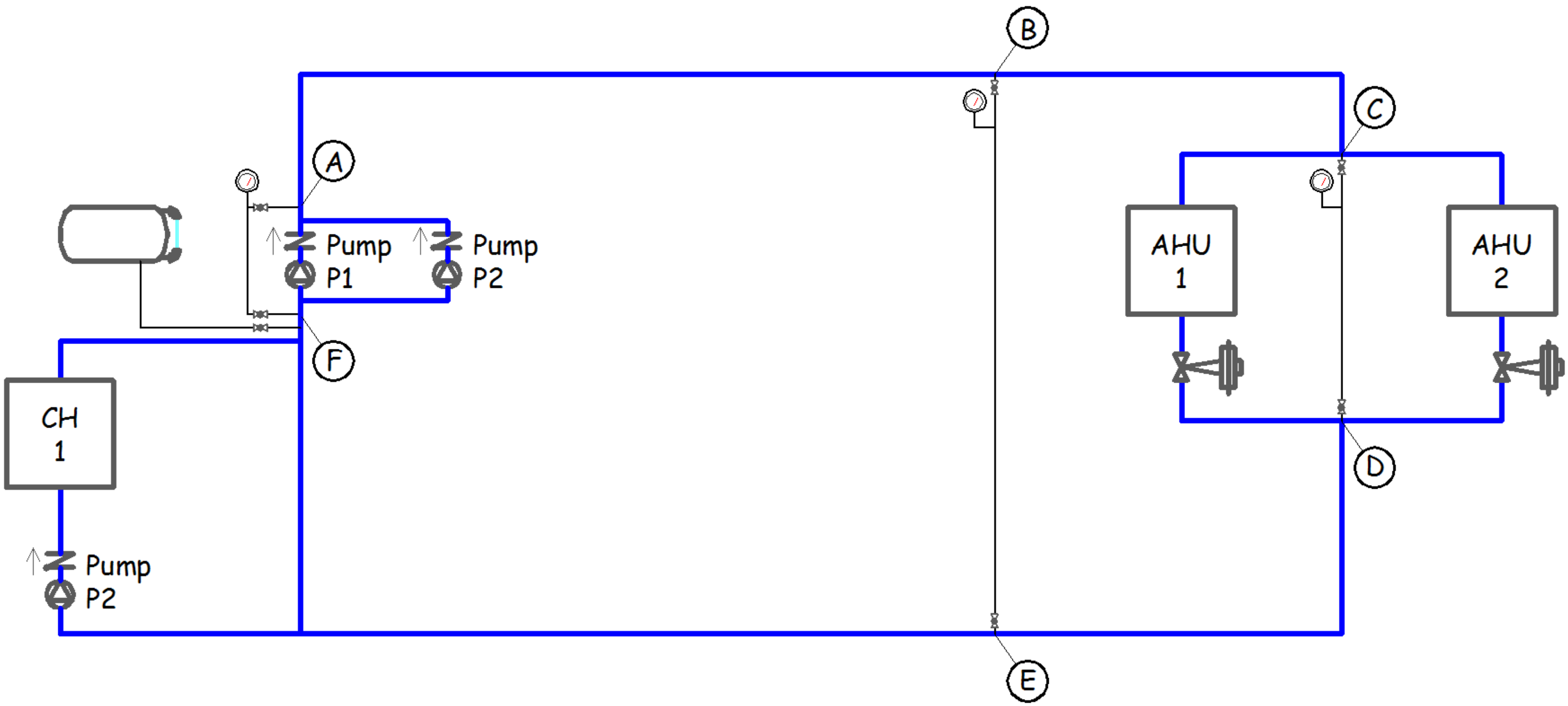
Pump Interactions and the Affinity Laws

Presented By:
David Sellers, Senior Engineer
Facility Dynamics Engineering

Parallel Pumps

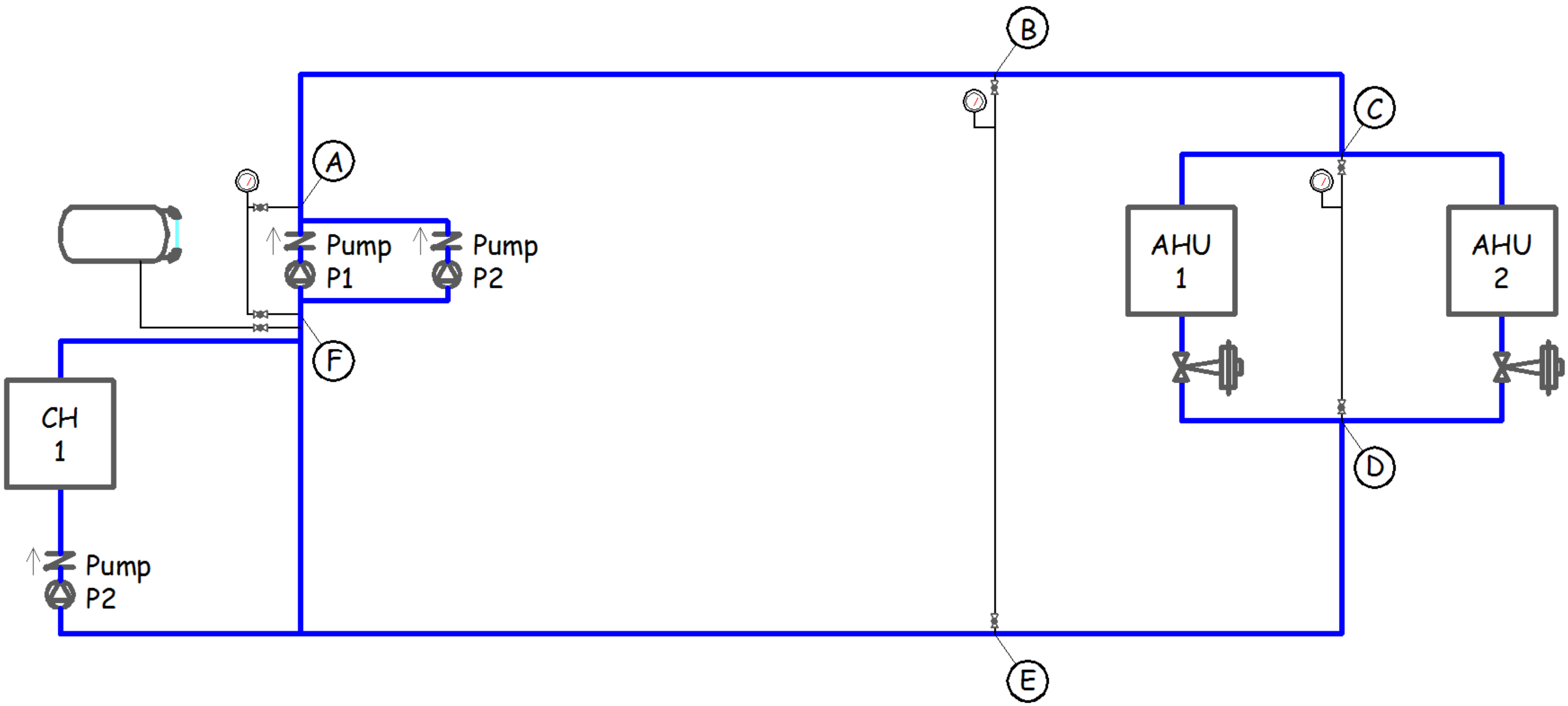


If both pumps are operating at the same speed and one fails, the operating point shifts down the system curve to the point where the single pump curve crosses it; typically more than 50% of the original flow but at less head



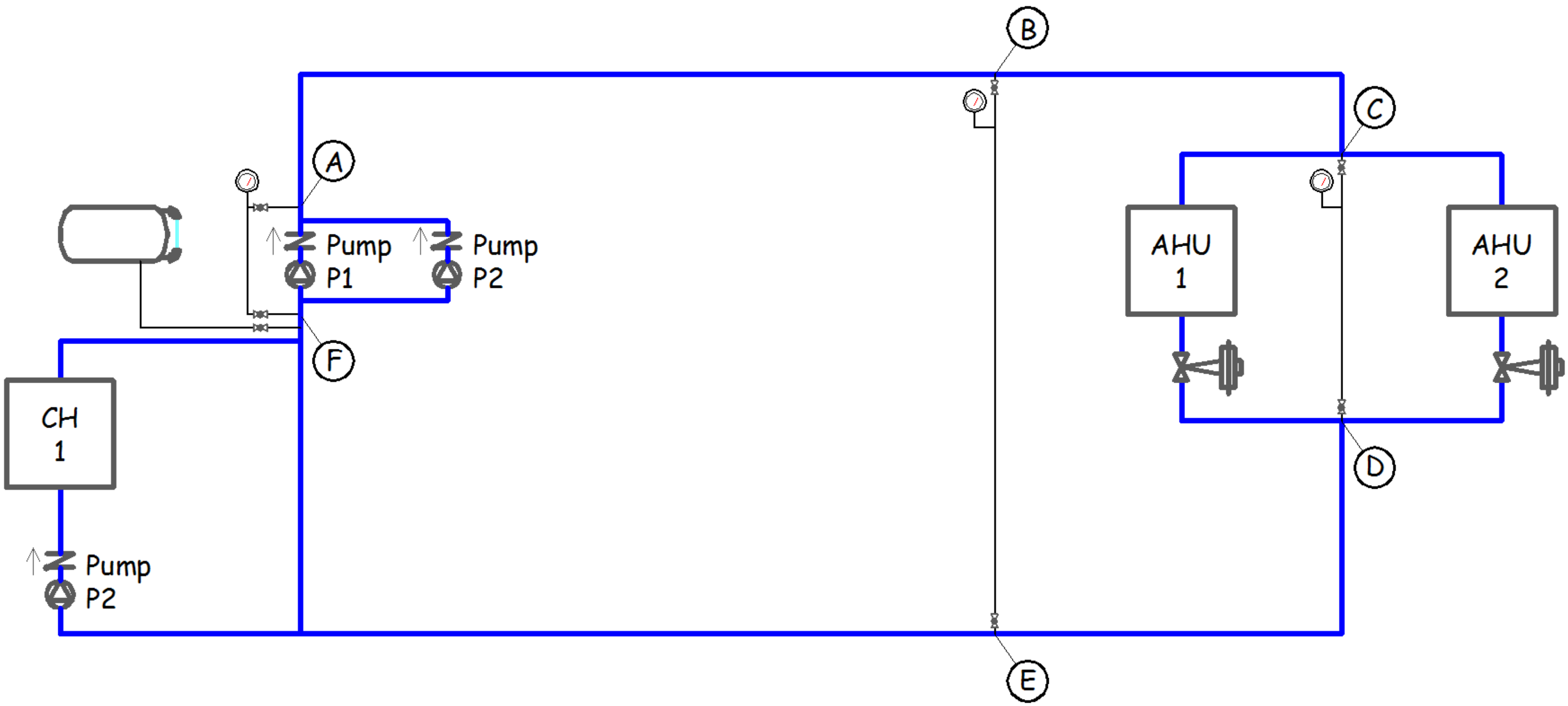
- Assume the pumps are 100% redundant

What should the logic be, specifically, to operate the pumps on a lead/lag basis?



- Assume the pumps are 100% redundant

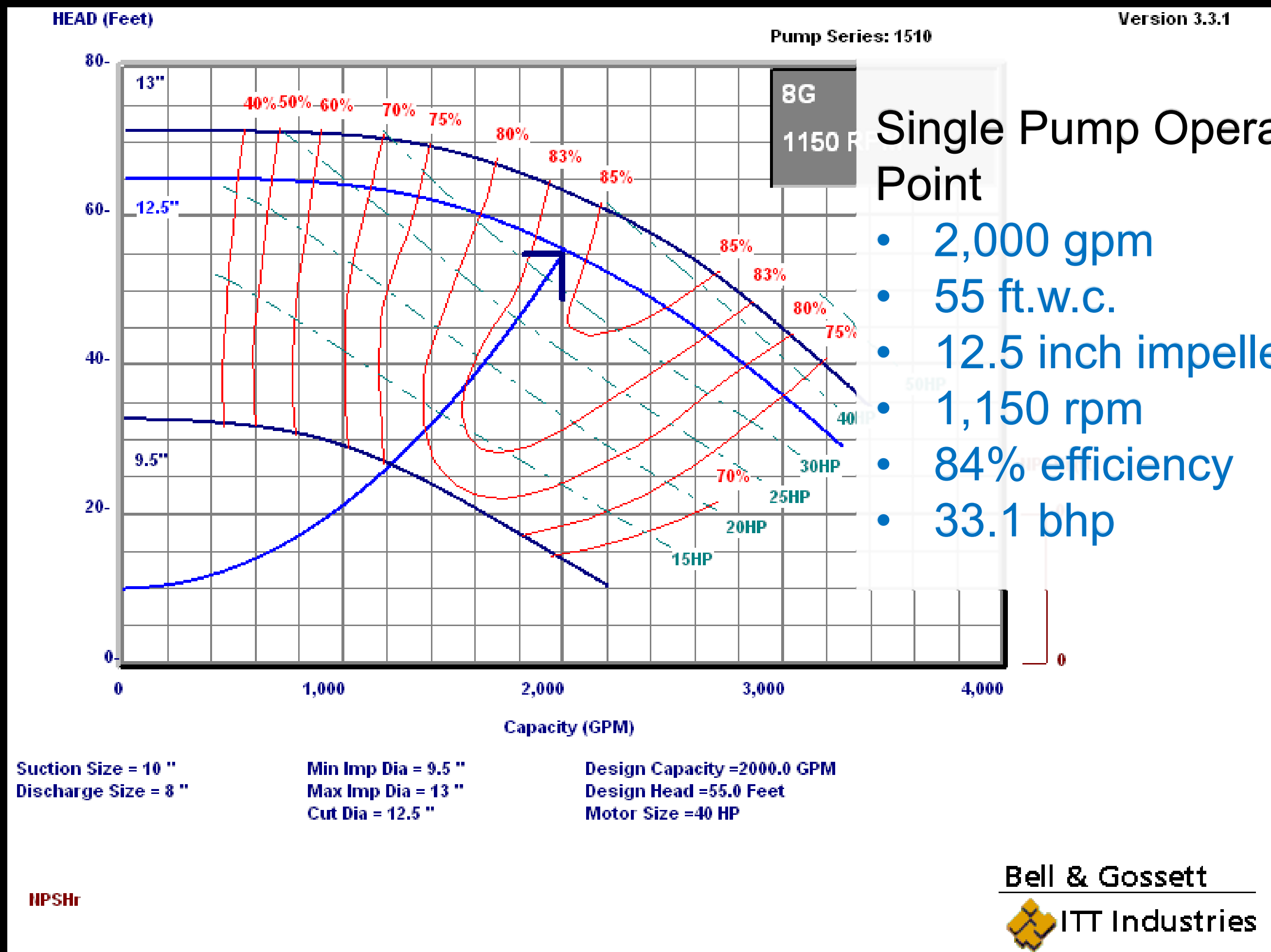
  Is there any problem with running one pump and starting the other pump if a failure is detected?



- Assume the pumps are 100% redundant

  Will running two pumps at reduced speed save energy relative to running one pump at full speed?

One Pump Operating Point

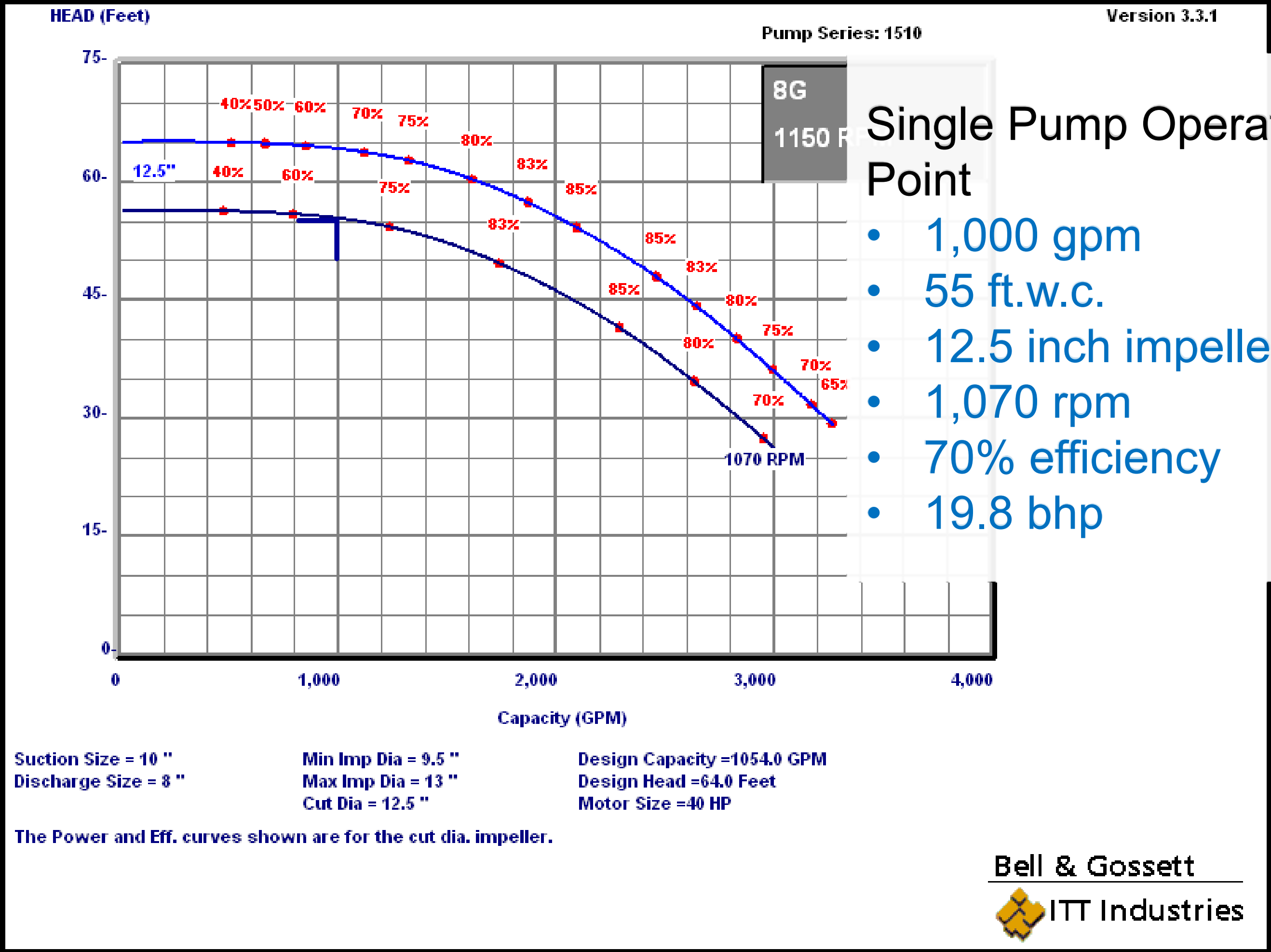


Single Pump Operating Point

- 2,000 gpm
- 55 ft.w.c.
- 12.5 inch impeller
- 1,150 rpm
- 84% efficiency
- 33.1 bhp

Two Pumps Doing What One Could Do

Each Pump Moves Half the Flow at the Design Head



Single Pump Operating Point

- 1,000 gpm
- 55 ft.w.c.
- 12.5 inch impeller
- 1,070 rpm
- 70% efficiency
- 19.8 bhp

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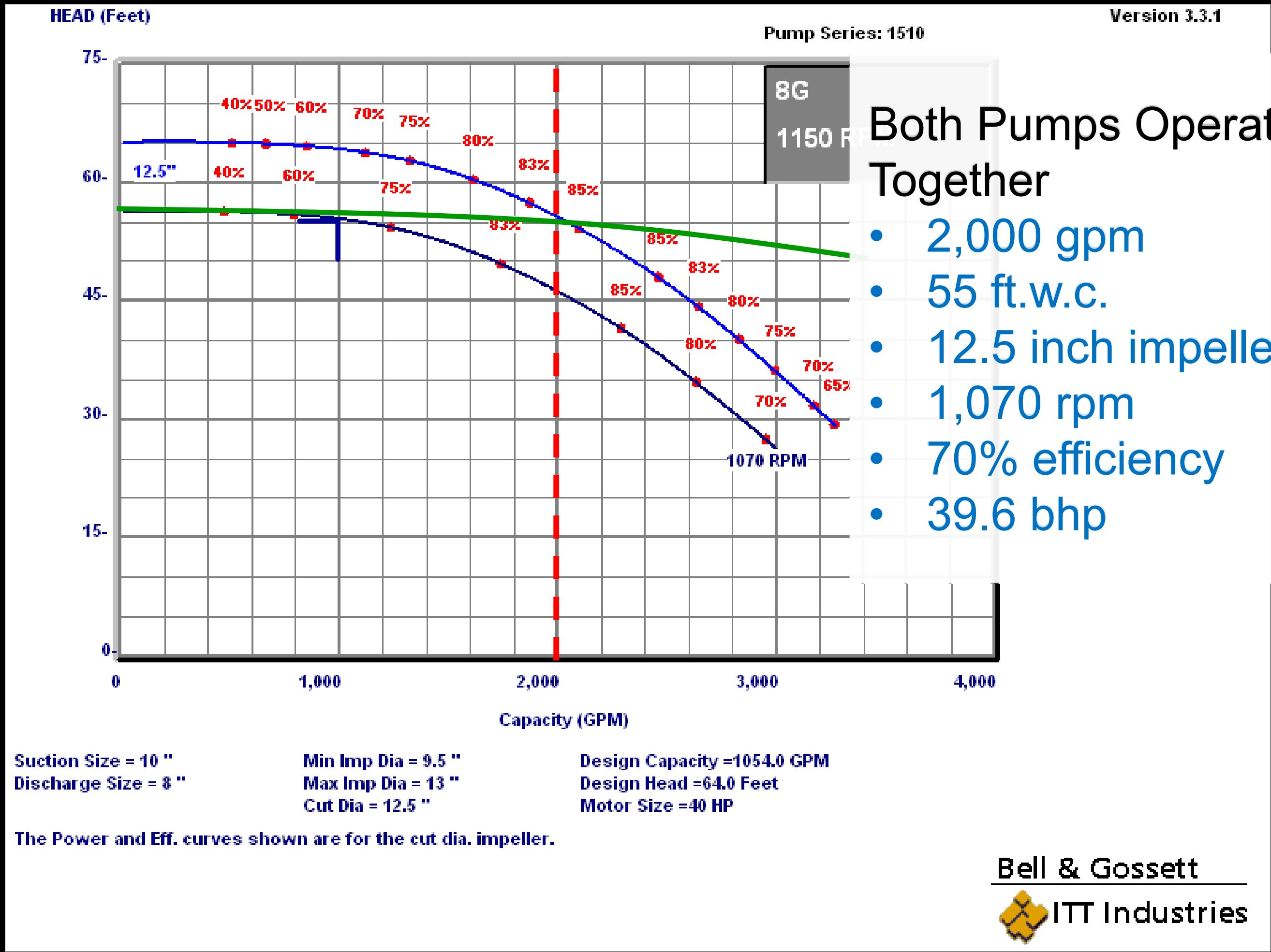
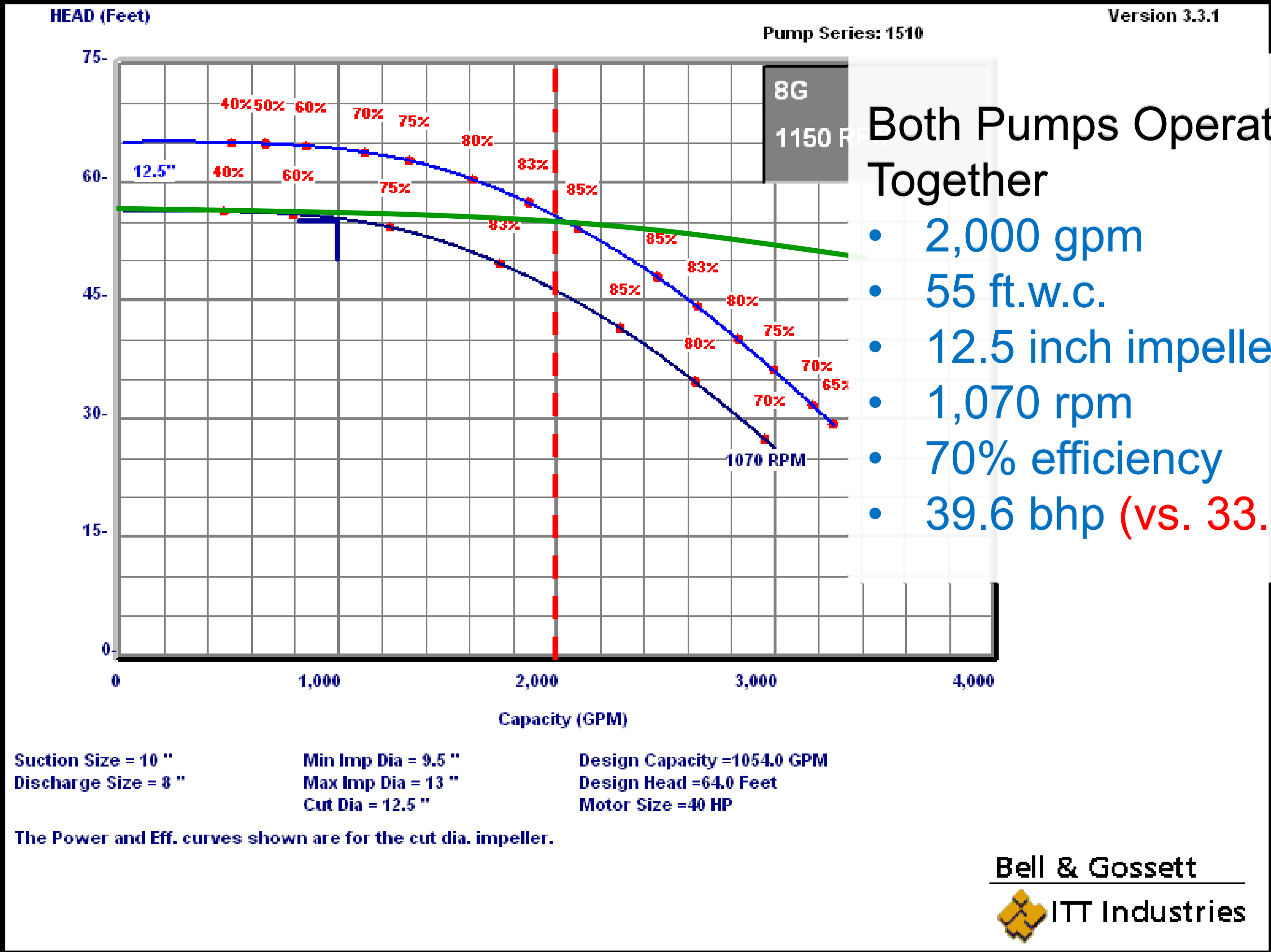


Both Pumps Operating Together

- 2,000 gpm
- 55 ft.w.c.
- 12.5 inch impeller
- 1,070 rpm
- 70% efficiency
- 39.6 bhp

Two Pumps Doing What One Could Do

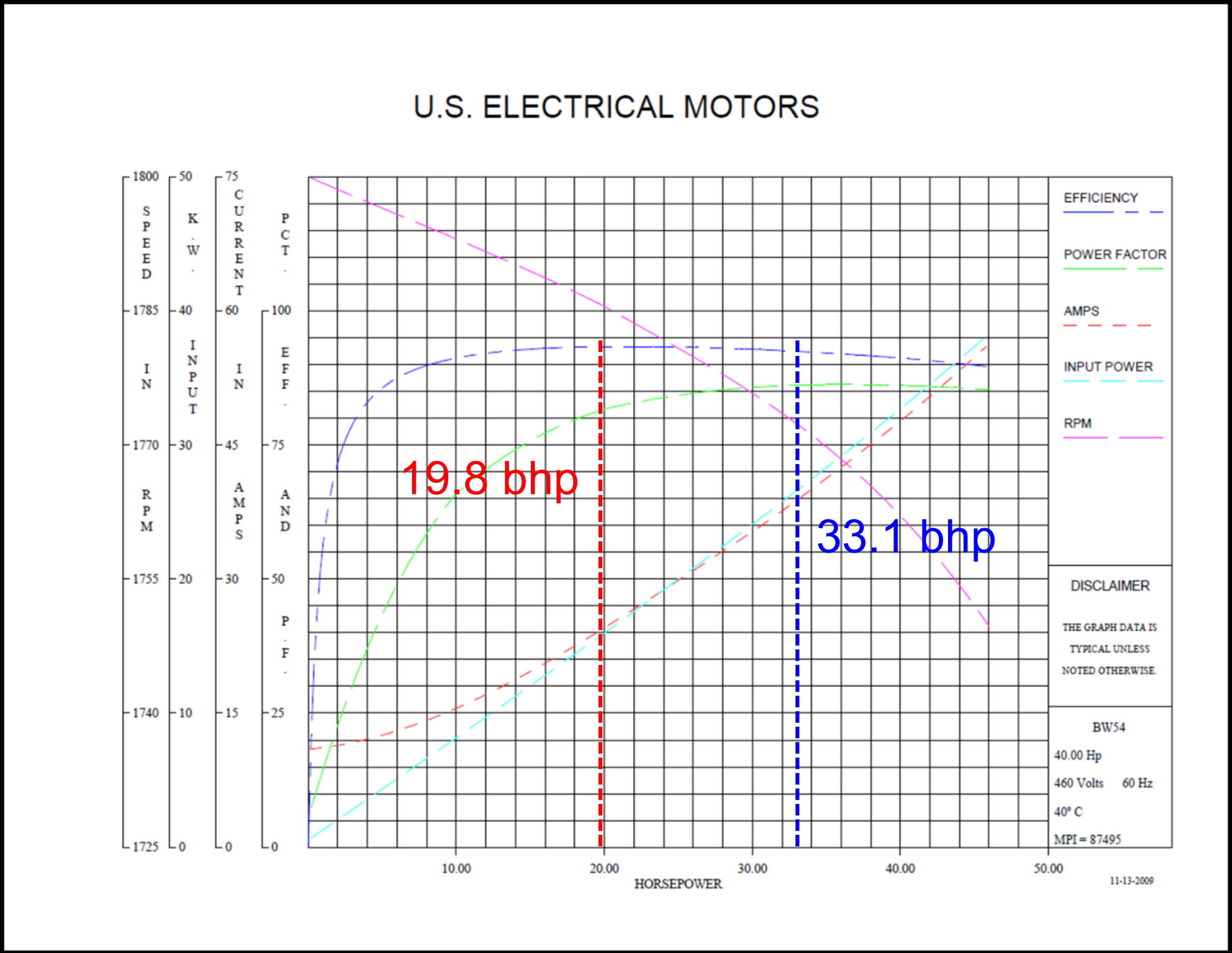
Each Pump Moves Half the Flow at the Design Head



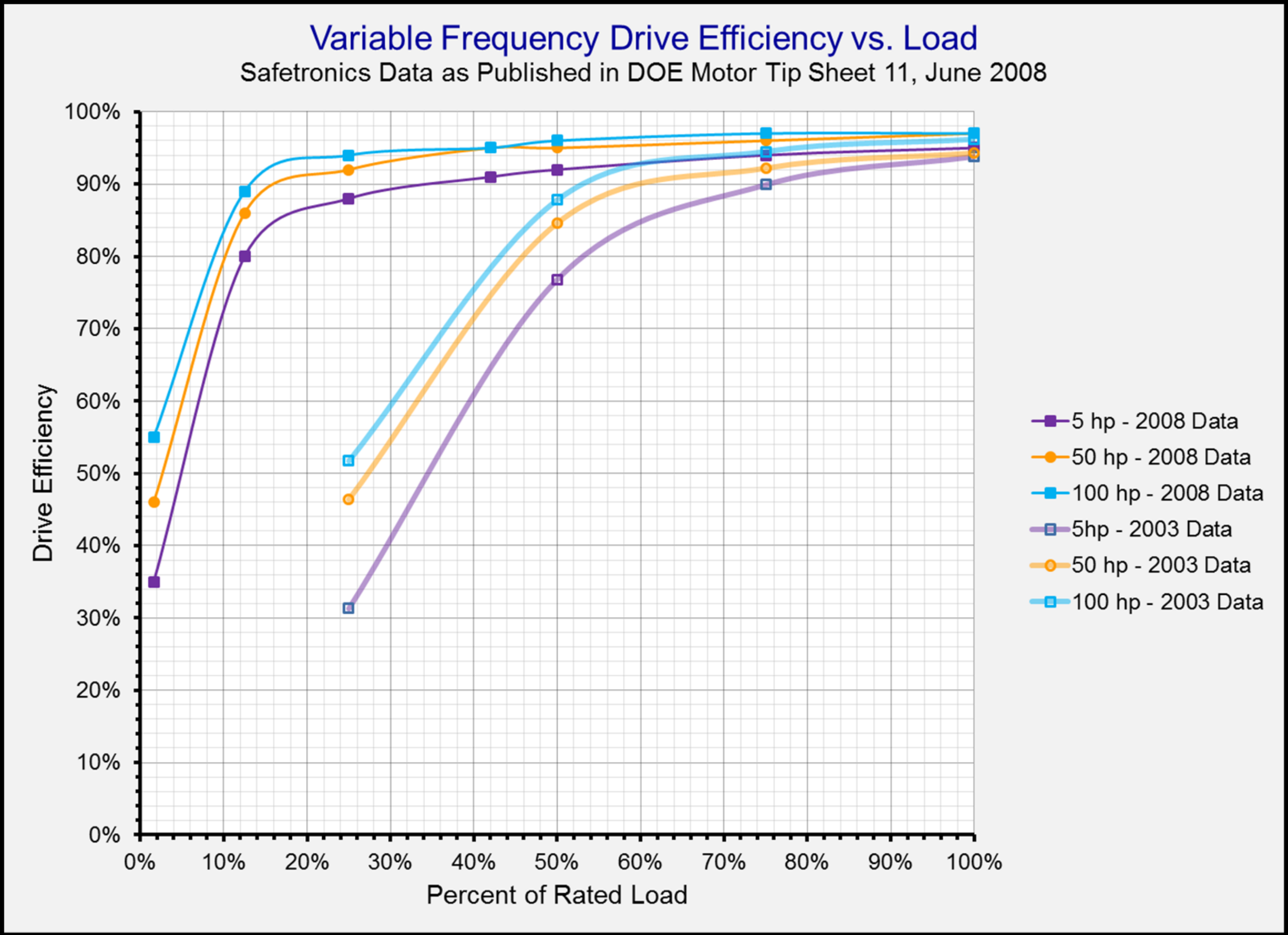
Both Pumps Operating Together

- 2,000 gpm
- 55 ft.w.c.
- 12.5 inch impeller
- 1,070 rpm
- 70% efficiency
- 39.6 bhp (vs. 33.1)

The Motor Efficiency Changed

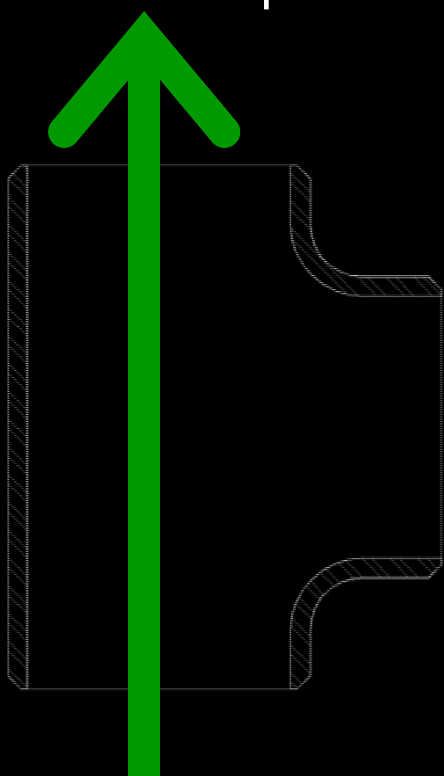


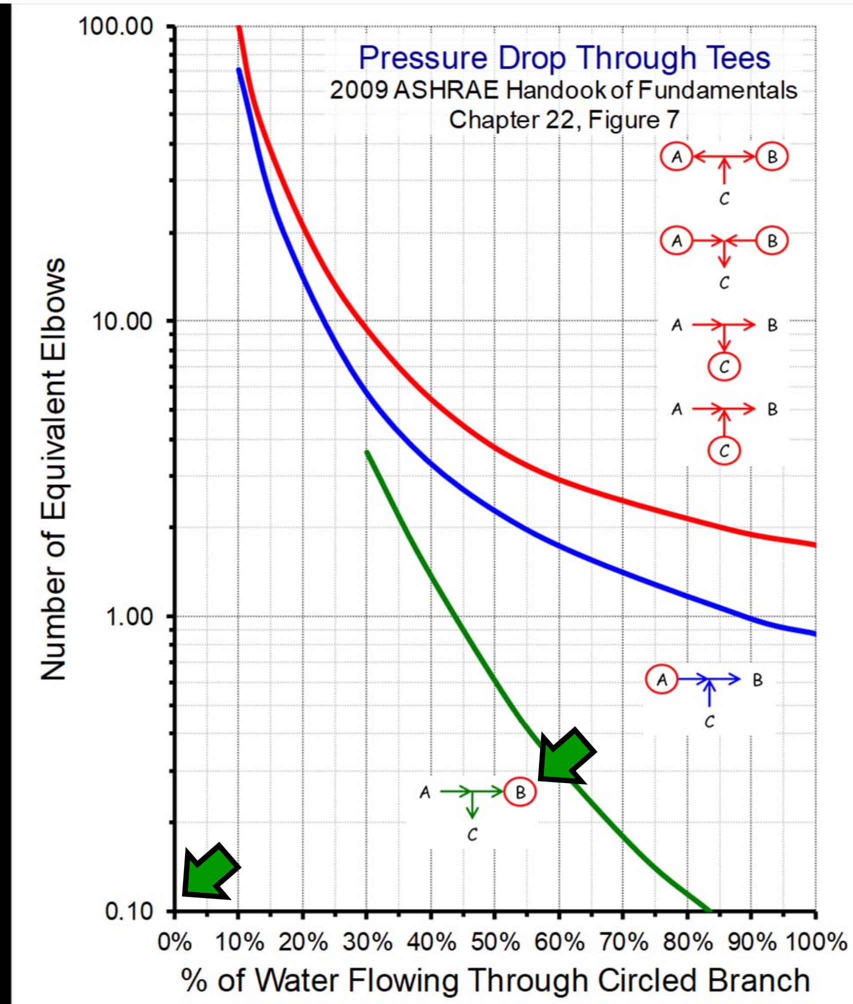
The Drive Efficiency Changed



The Fluid Mechanics Changed

One Pump





Notes:

1. Chart is based on straight tees (i.e., branches A, B, and C are the same size).
2. Pressure loss in desired circuit is obtained by selecting the proper curve according to illustrations, determining the flow at the circled branch, and multiplying the pressure loss for the same size elbow at the flow rate in the circled branch by the equivalent elbows indicated.
3. When the size of an outlet is reduced, the equivalent elbows shown in the chart do not apply. Therefore, the maximum loss for any circuit for any flow will not exceed 2 elbow equivalents at the maximum flow occurring in any branch of the tee.
4. Top curve is average of 4 curves, one for each circuit shown.
5. Data from Giesecke and Badgett 1931, 1932.

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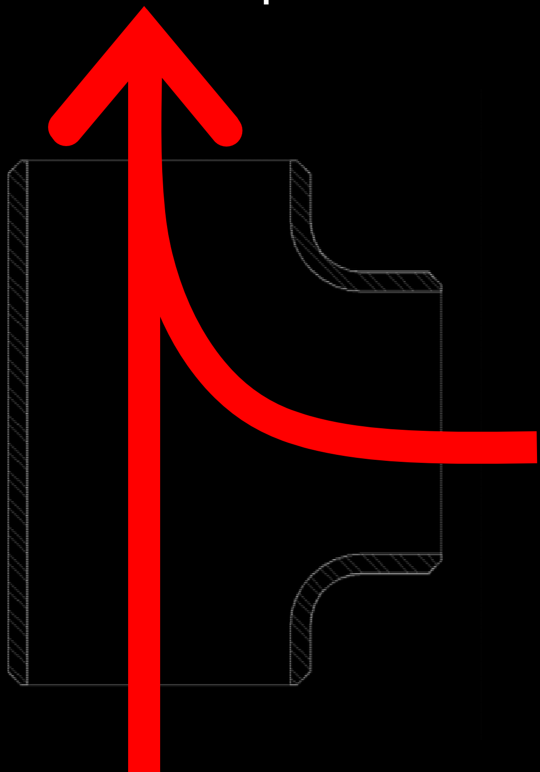
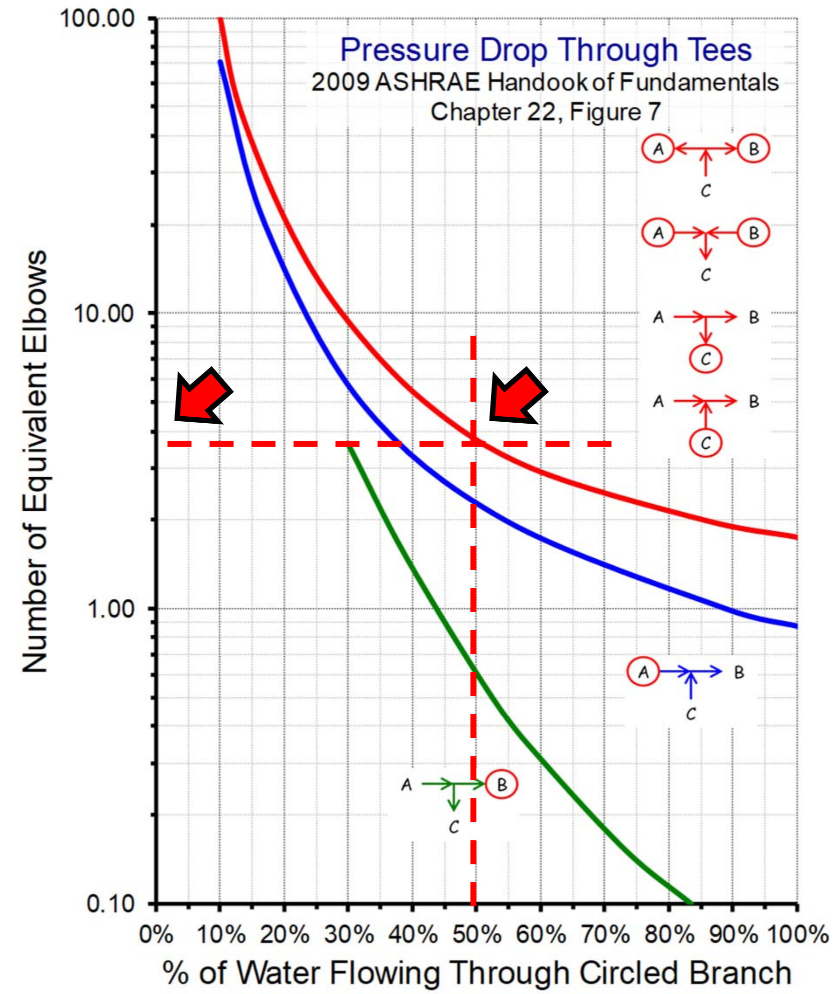
One Pump





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The Bottom Line

You're Still Doing the Same Amount of Work

But probably not as efficiently

$$kW = \left(\frac{Flow \times Head}{3{,}960 \times \eta_{Pump} \times \eta_{Motor} \times \eta_{Drive}} \right) \times \frac{.746\ \text{kw}}{\text{hp}}$$

Where:

kW = Power into the motor and its drive system

$Flow$ = Flow rate in gallons per minute

$Head$ = Pump head in feet water column

3,960 = A units conversion constant

η_{Pump} = Pump efficiency

η_{Motor} = Motor efficiency

η_{Drive} = Drive efficiency

$\frac{.746\ \text{kw}}{\text{hp}}$ = kW to hp conversion constant

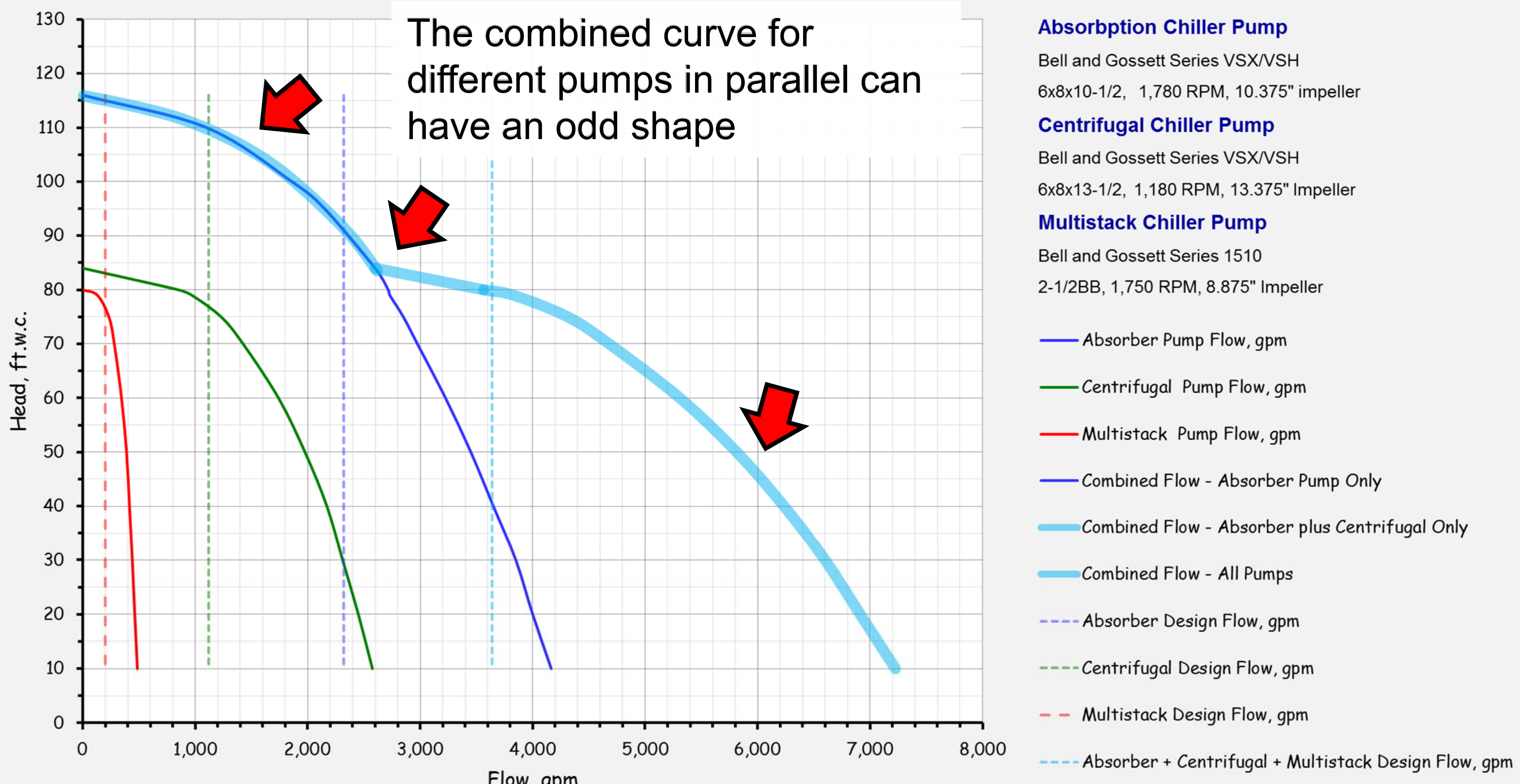
What About Running Two Tower Fans at Half Speed vs. One at Full Speed?

Same Question for These Towers?

Same Question for These Towers?

Different Size Parallel Pumps

System Dynamics can be Complex as Pumps Interact

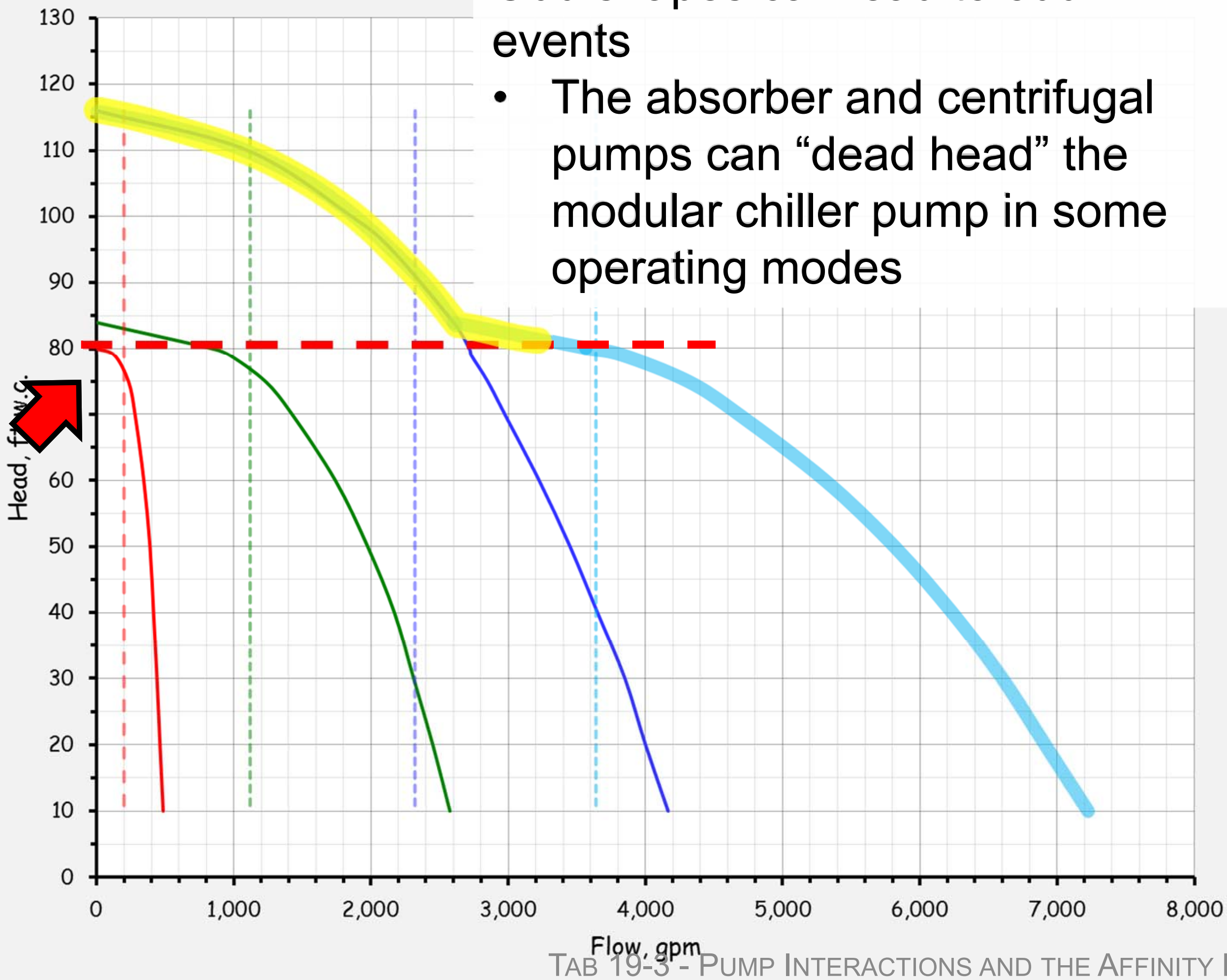


Different Size Parallel Pumps

System Dynamics can be Complex as Pumps Interact

Odd shapes can lead to odd events

- The absorber and centrifugal pumps can “dead head” the modular chiller pump in some operating modes



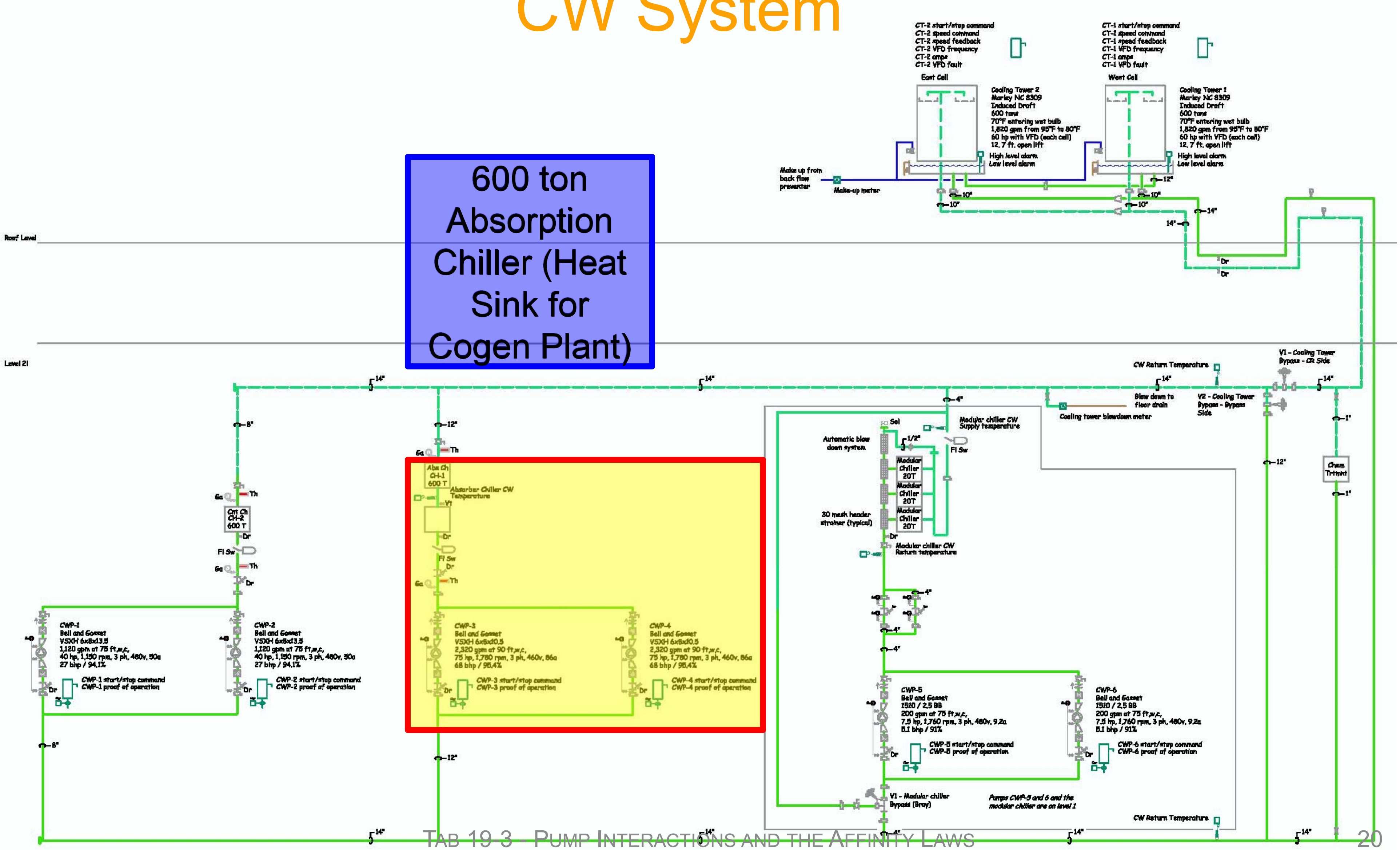
Absorbption Chiller Pump
Bell and Gossett Series VSX/VSH
6x8x10-1/2, 1,780 RPM, 10.375" impeller

Centrifugal Chiller Pump
Bell and Gossett Series VSX/VSH
6x8x13-1/2, 1,180 RPM, 13.375" Impeller

Multistack Chiller Pump
Bell and Gossett Series 1510
2-1/2BB, 1,750 RPM, 8.875" Impeller

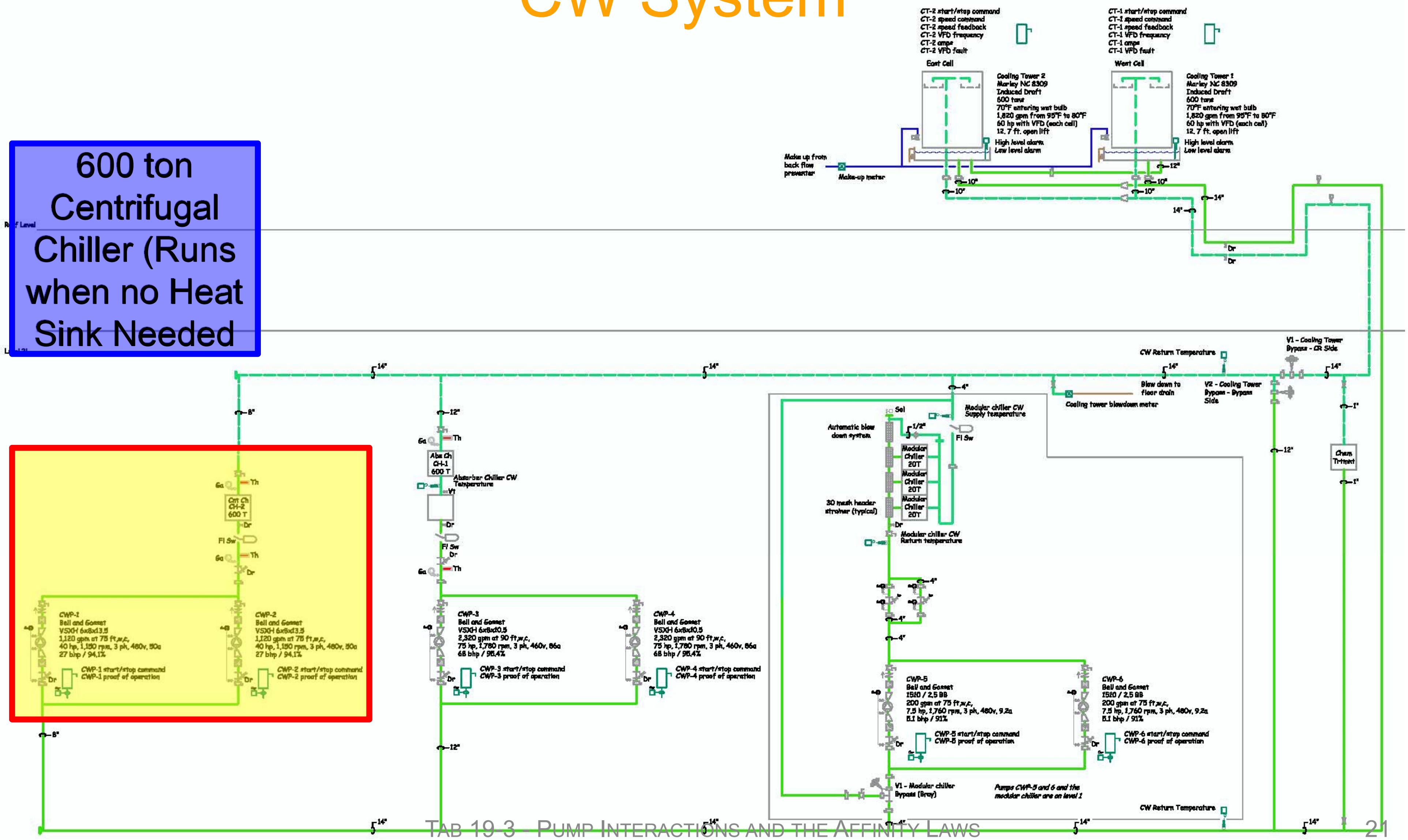
- Absorber Pump Flow, gpm
- Centrifugal Pump Flow, gpm
- Multistack Pump Flow, gpm
- Combined Flow - Absorber Pump Only
- Combined Flow - Absorber plus Centrifugal Only
- Combined Flow - All Pumps
- Absorber Design Flow, gpm
- Centrifugal Design Flow, gpm
- Multistack Design Flow, gpm
- Absorber + Centrifugal + Multistack Design Flow, gpm

Multi Pump Constant Volume CW System



Multi Pump Constant Volume CW System

600 ton Centrifugal Chiller (Runs when no Heat Sink Needed



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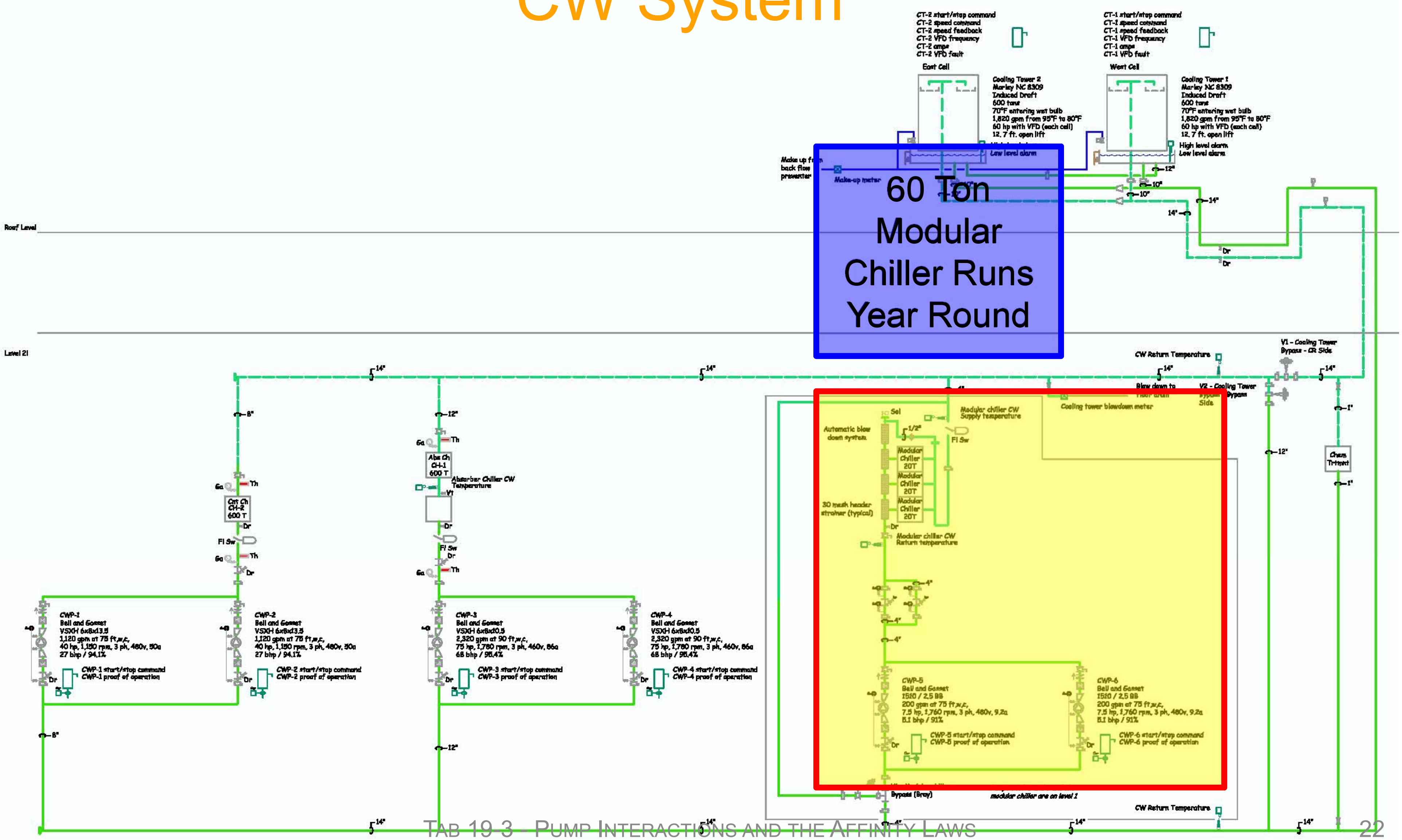

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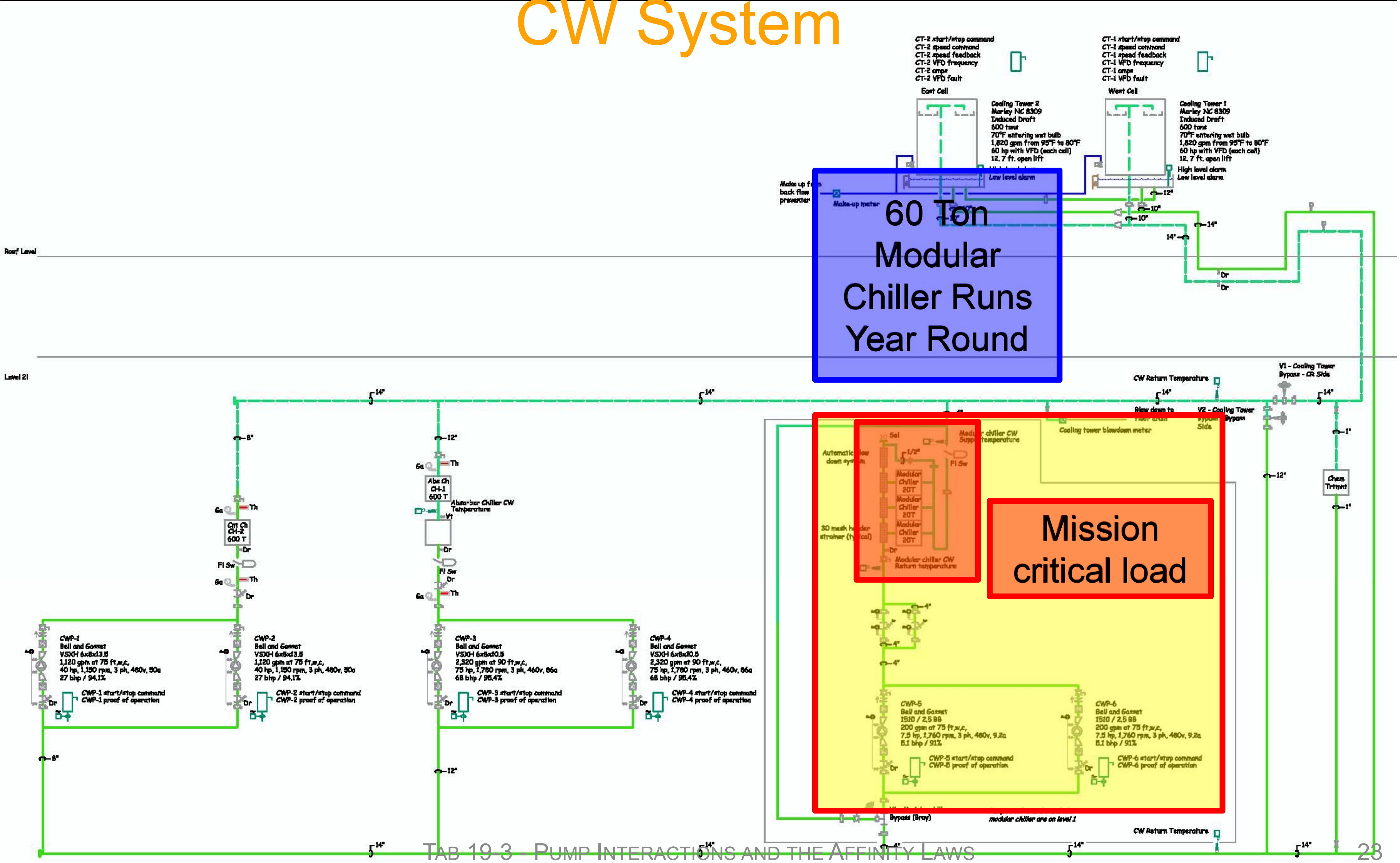

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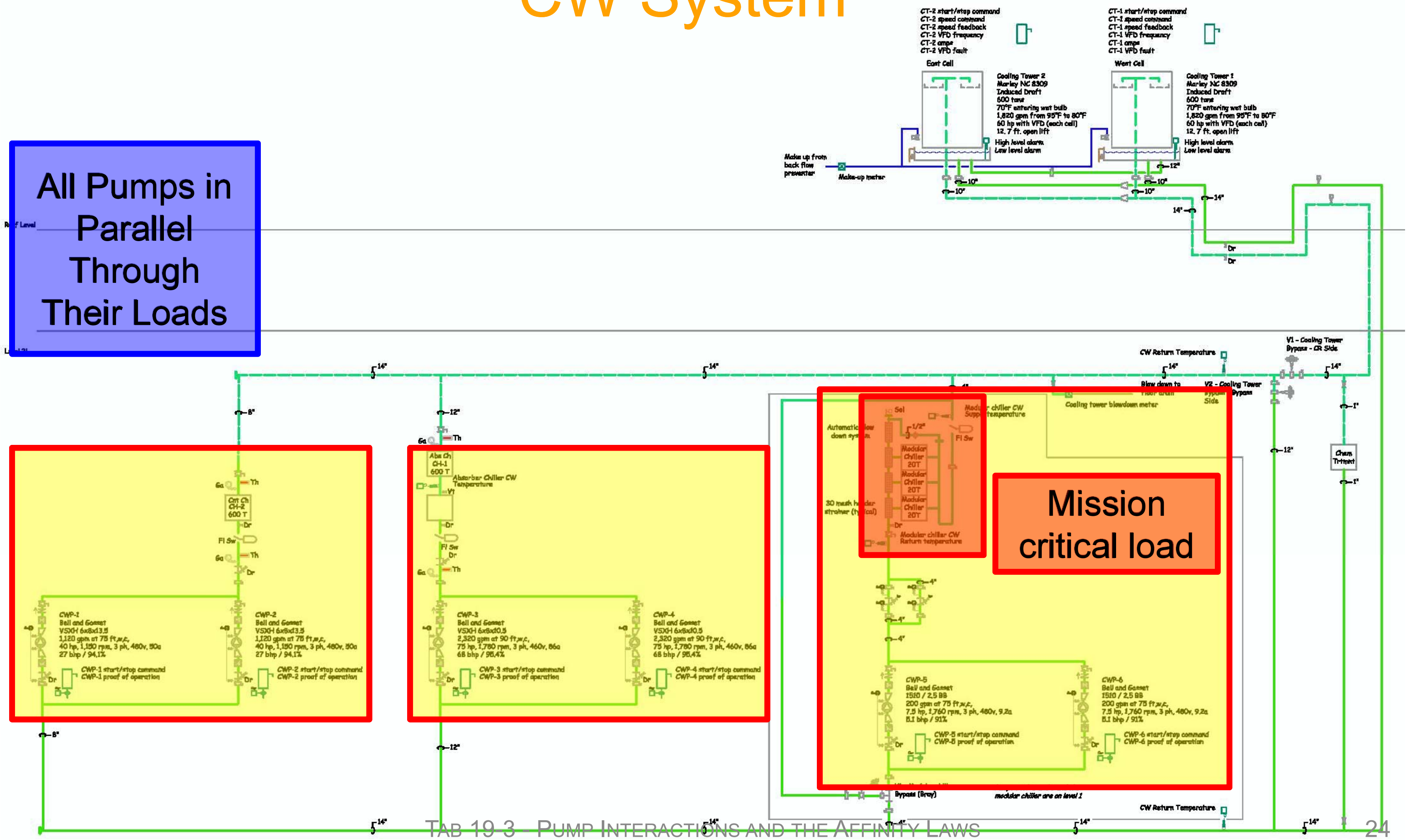
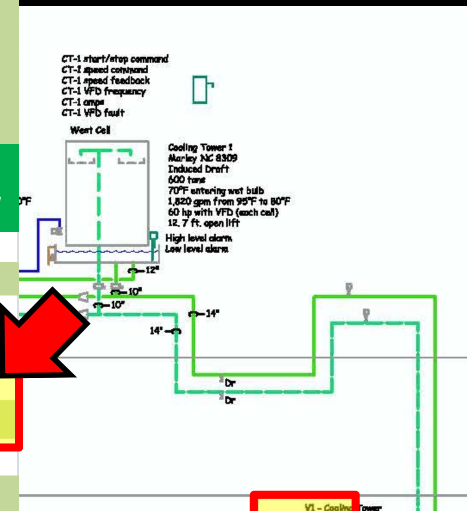
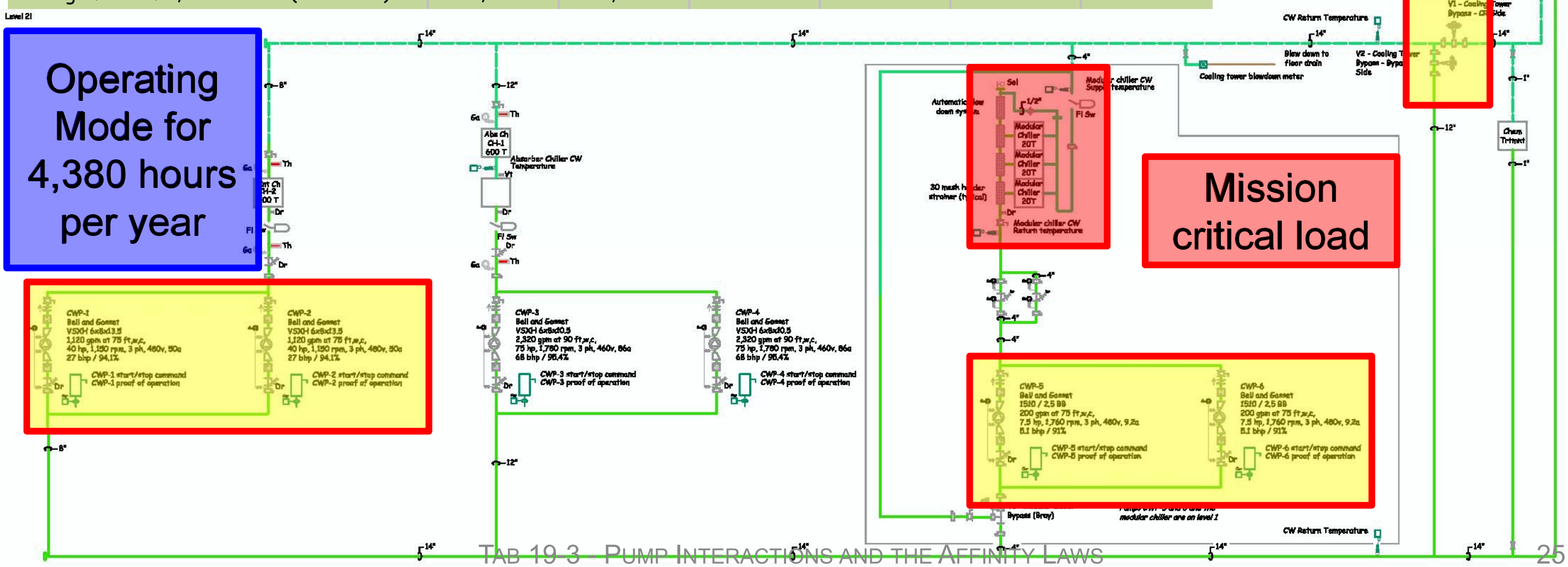


Multi Pump Constant Volume CW System

Test Data Summary						
Design Targets	Total Flow, gpm					
Centrifugal Chiller	1120					
Absorption Chiller	2320					
Modular Chiller	200					
Absorber plus Centrifugal Chiller	3440					
Absorber plus Modular Chiller	2520					
Centrifugal plus Modular Chiller	1320					
All Chillers	3640					
Test Mode (V2 at 100% = Full Cooling Tower Bypass)	Total Flow, gpm	Target	% of Target	Centrifugal % Design Flow	Absorber % Design Flow	Modular % Design Flow
Testing Mode: M.S. Stand-Alone (V-2 0%)	205	200	103%			103%
Testing Mode: M.S. (V-2 100%)	235	200	118%			118%
Testing Mode: M.S. & Abs (V-2 0%)	2,510	2,520	100%		101%	80%
Testing Mode: M.S. & Abs (V-2 100%)	2,740	2,520	109%		112%	70%
Testing Mode: M.S. & Cent (V-2 0%)	1,475	1,320	112%	116%		88%
Testing Mode: M.S. & Cent (V-2 100%)	1,625	1,320	123%	132%		88%
Testing Mode: M.S, Abs & Cent (V-2 0%)	3,183	3,640	87%	92%	93%	0%
Testing Mode: M.S, Abs & Cent (V-2 100%)	4,045	3,640	111%	118%	110%	85%





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