Pumps (and Piping)

Design, Performance and Commissioning Issues

Parallel Pumps and Pump/Motor Interactions

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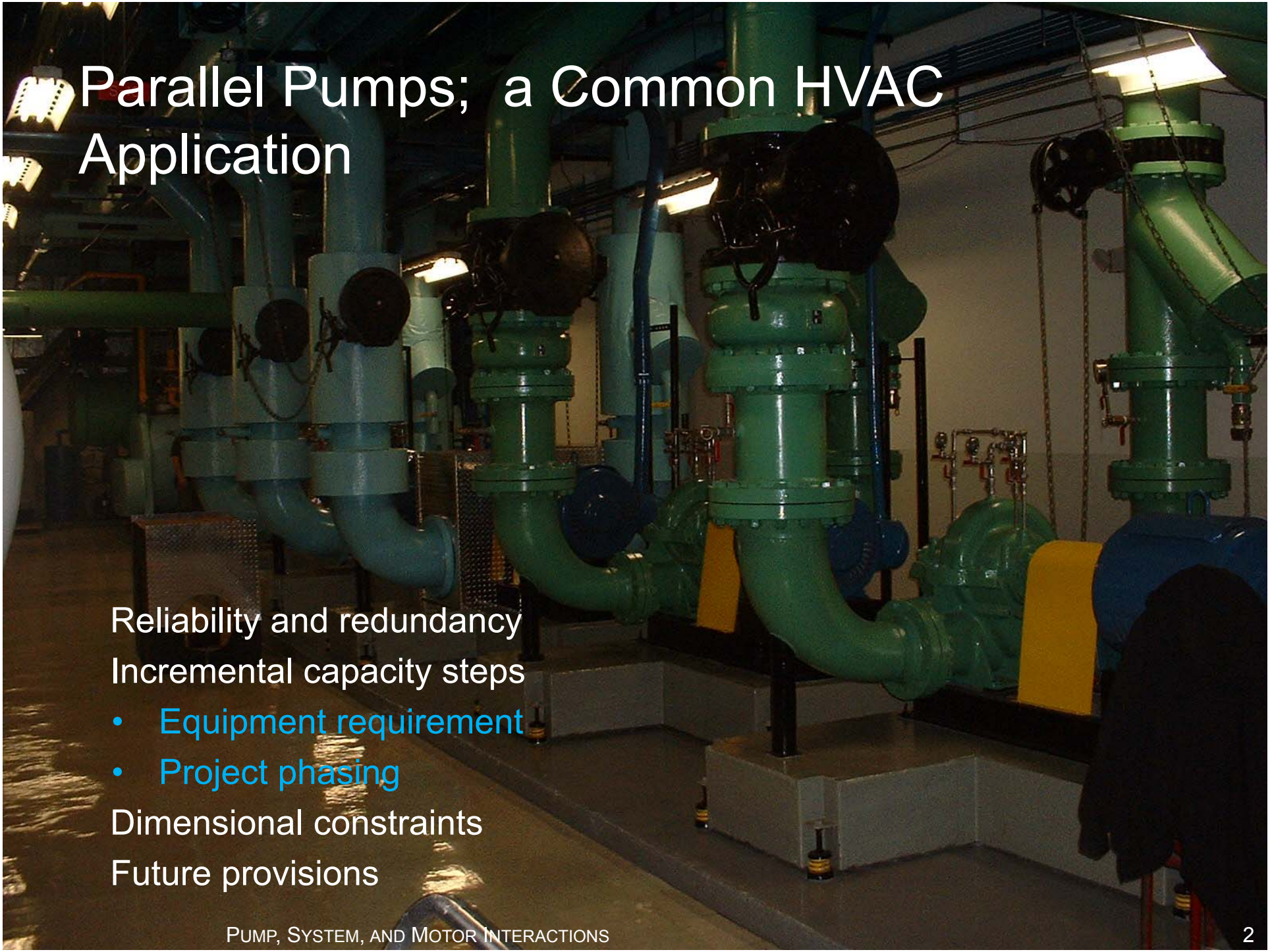
Parallel Pumps; a Common HVAC Application



Reliability and redundancy

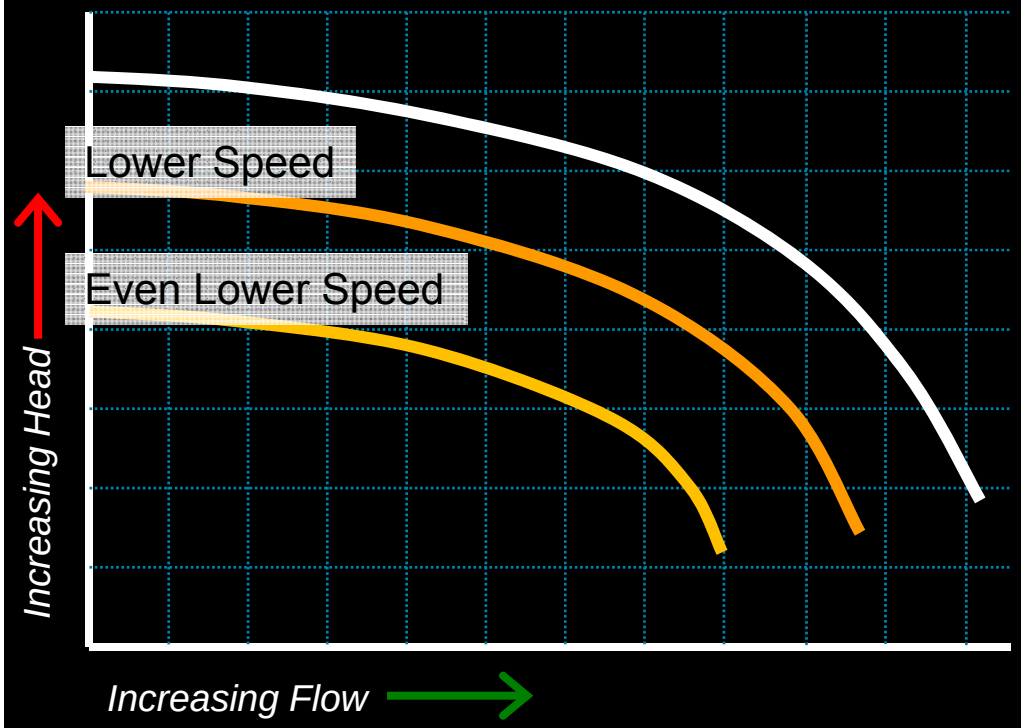
Incremental capacity steps

- Equipment requirement
- Project phasing

Dimensional constraints

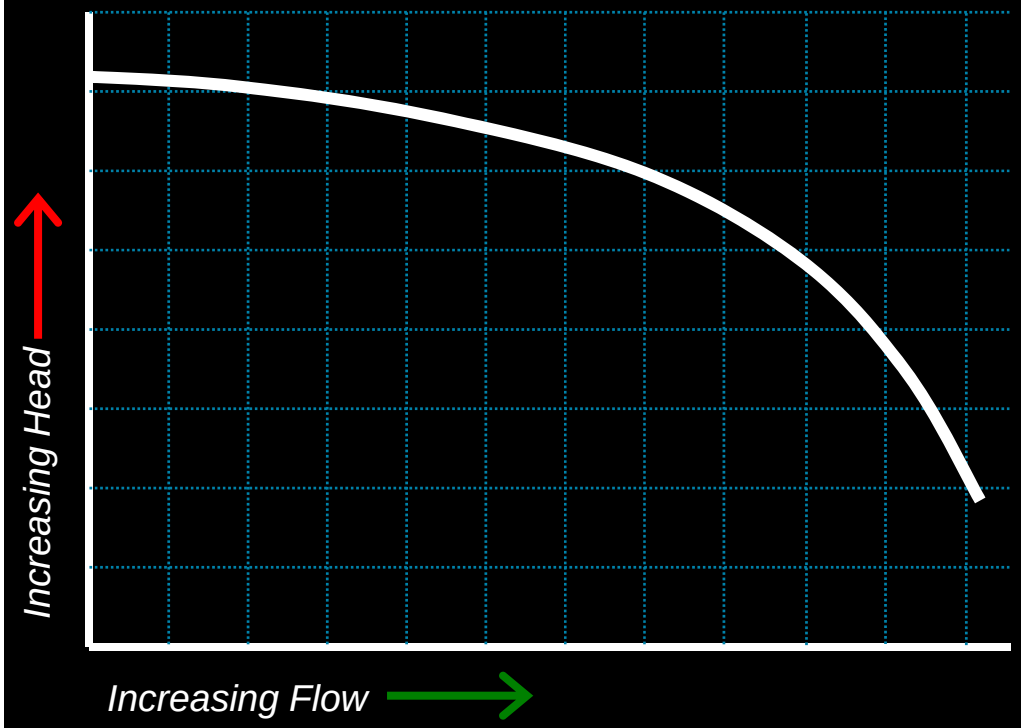
Future provisions

Parallel Pumps



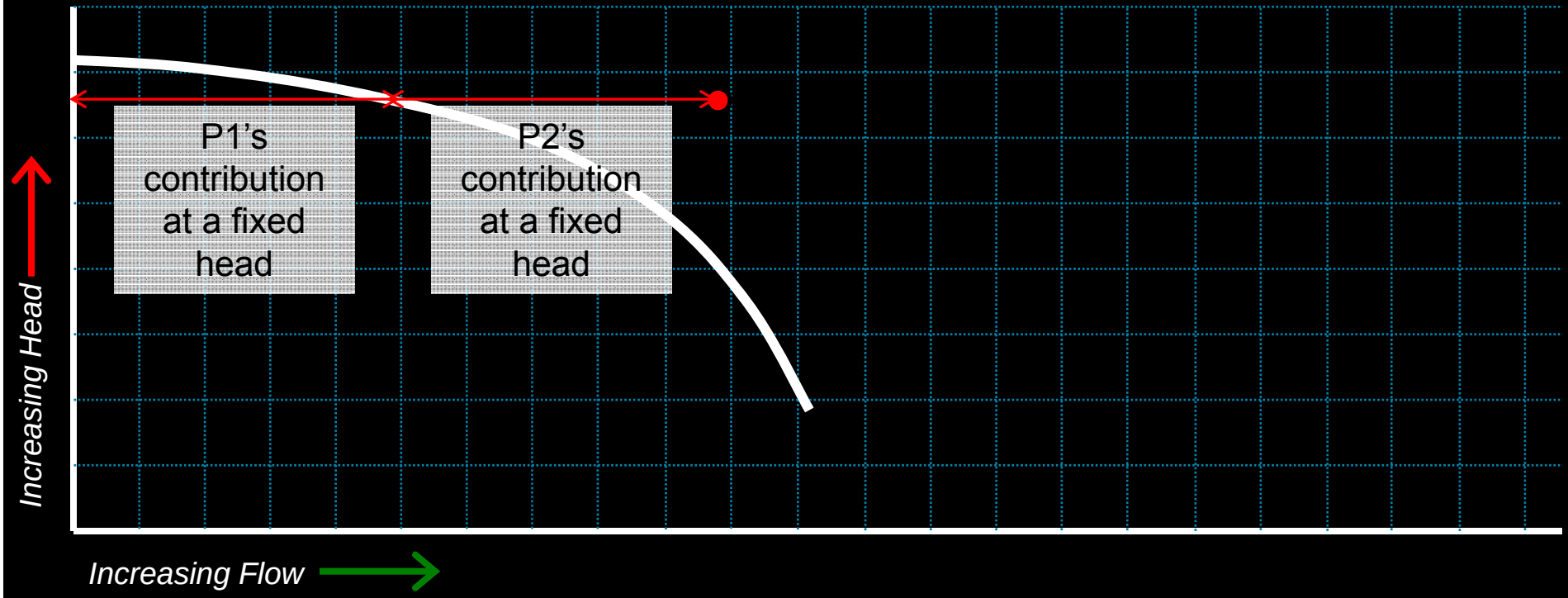
Start with the curve for a single pump at a number of speeds

Parallel Pumps



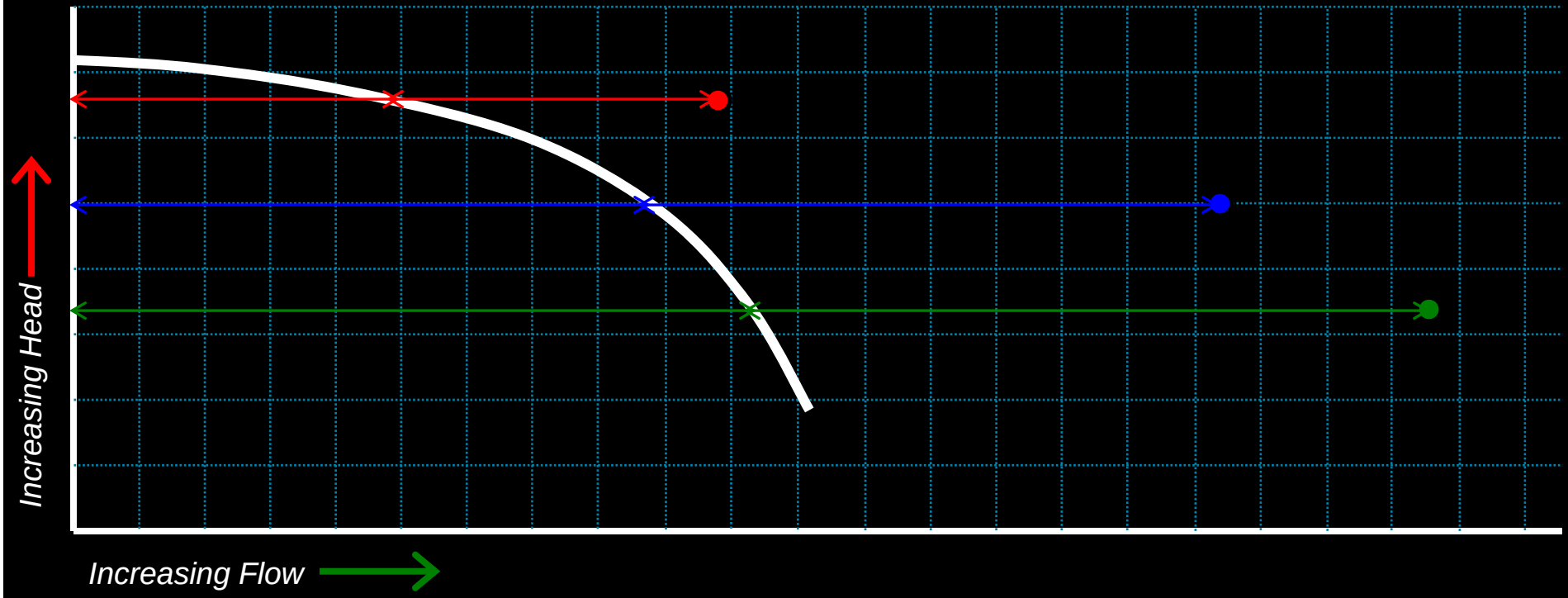
Focusing on the full speed curve …

Parallel Pumps



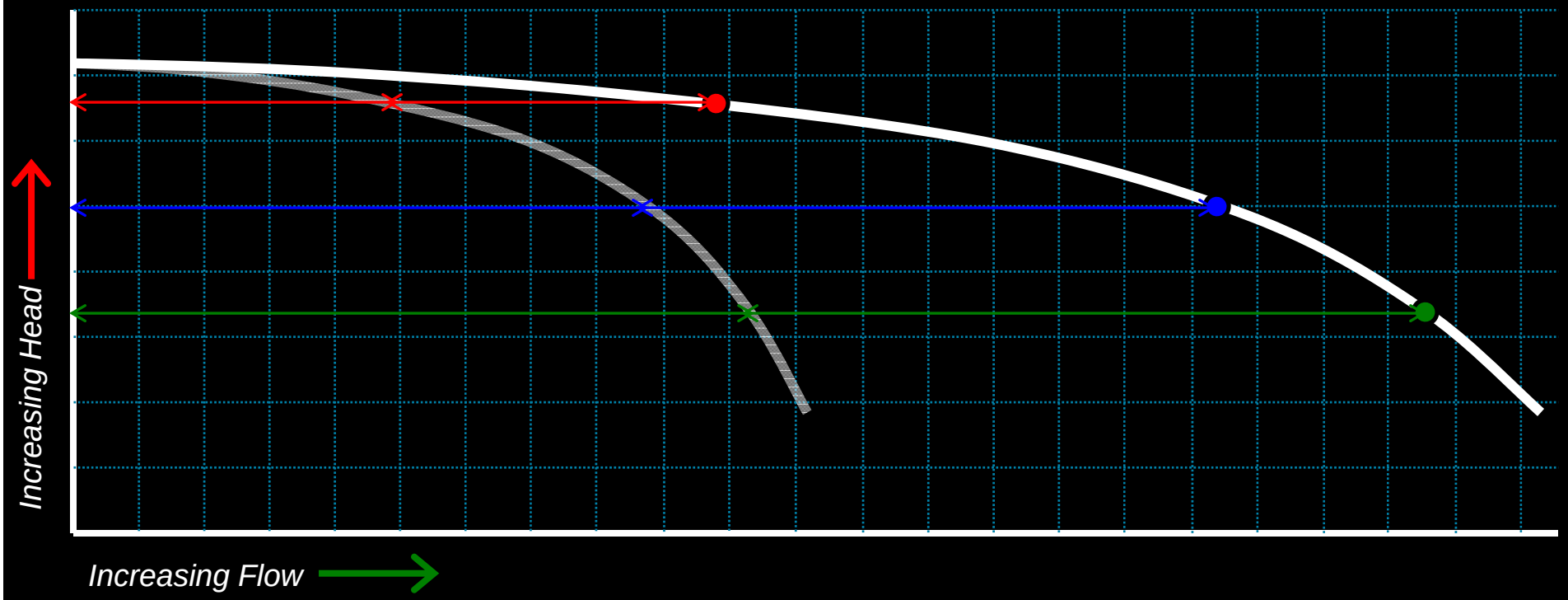
Construct the curve for the same pump at the same speed operating in parallel by doubling the flow at different heads

Parallel Pumps



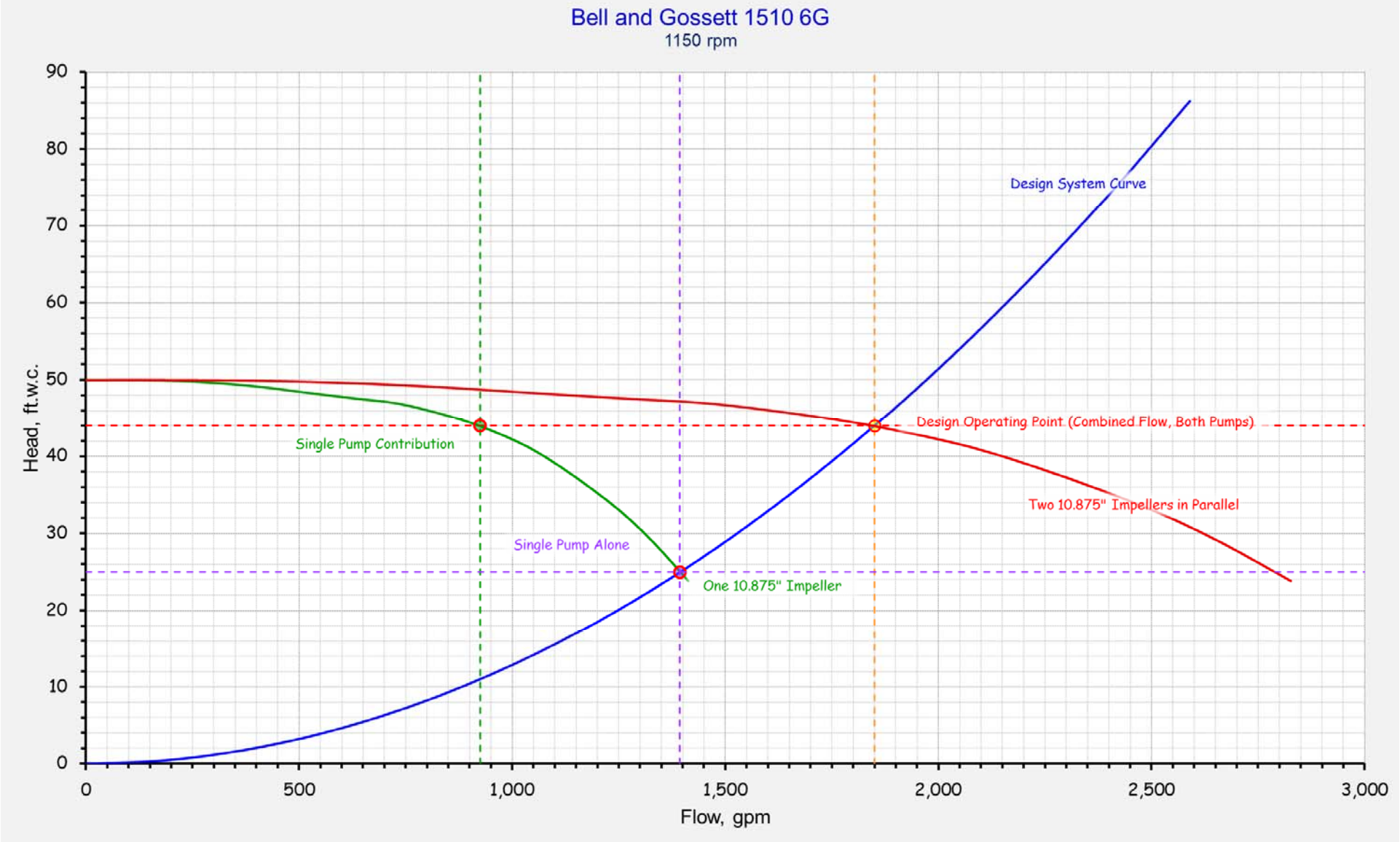
Construct the curve for the same pump at the same speed operating in parallel by doubling the flow at different heads

Parallel Pumps

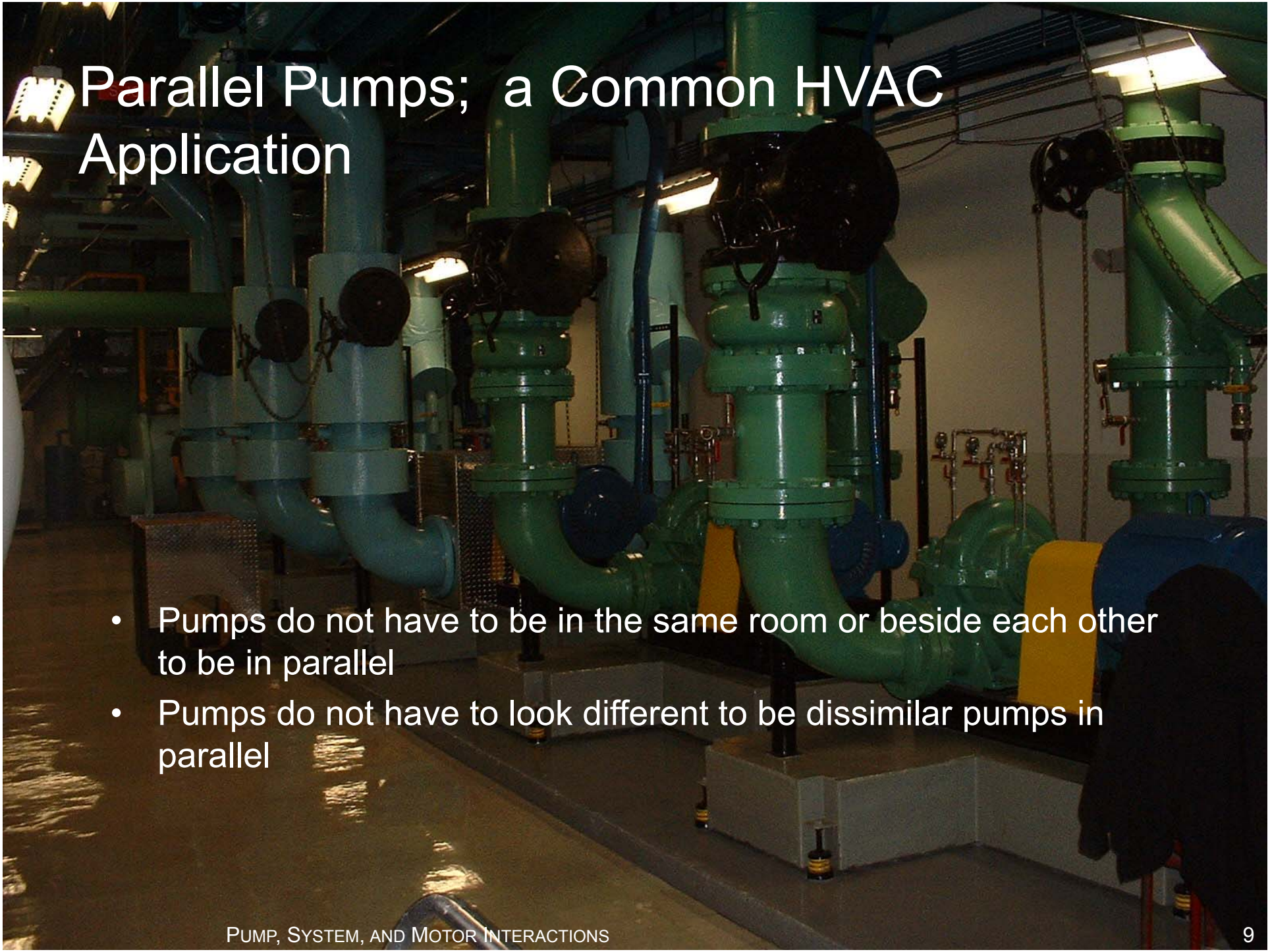


Construct the curve for the same pump at the same speed operating in parallel by doubling the flow at different heads

Parallel Pumps – The Benefits of Digital



Parallel Pumps; a Common HVAC Application



- Pumps do not have to be in the same room or beside each other to be in parallel
- Pumps do not have to look different to be dissimilar pumps in parallel

Applying Centrifugal Loads to Induction Motors

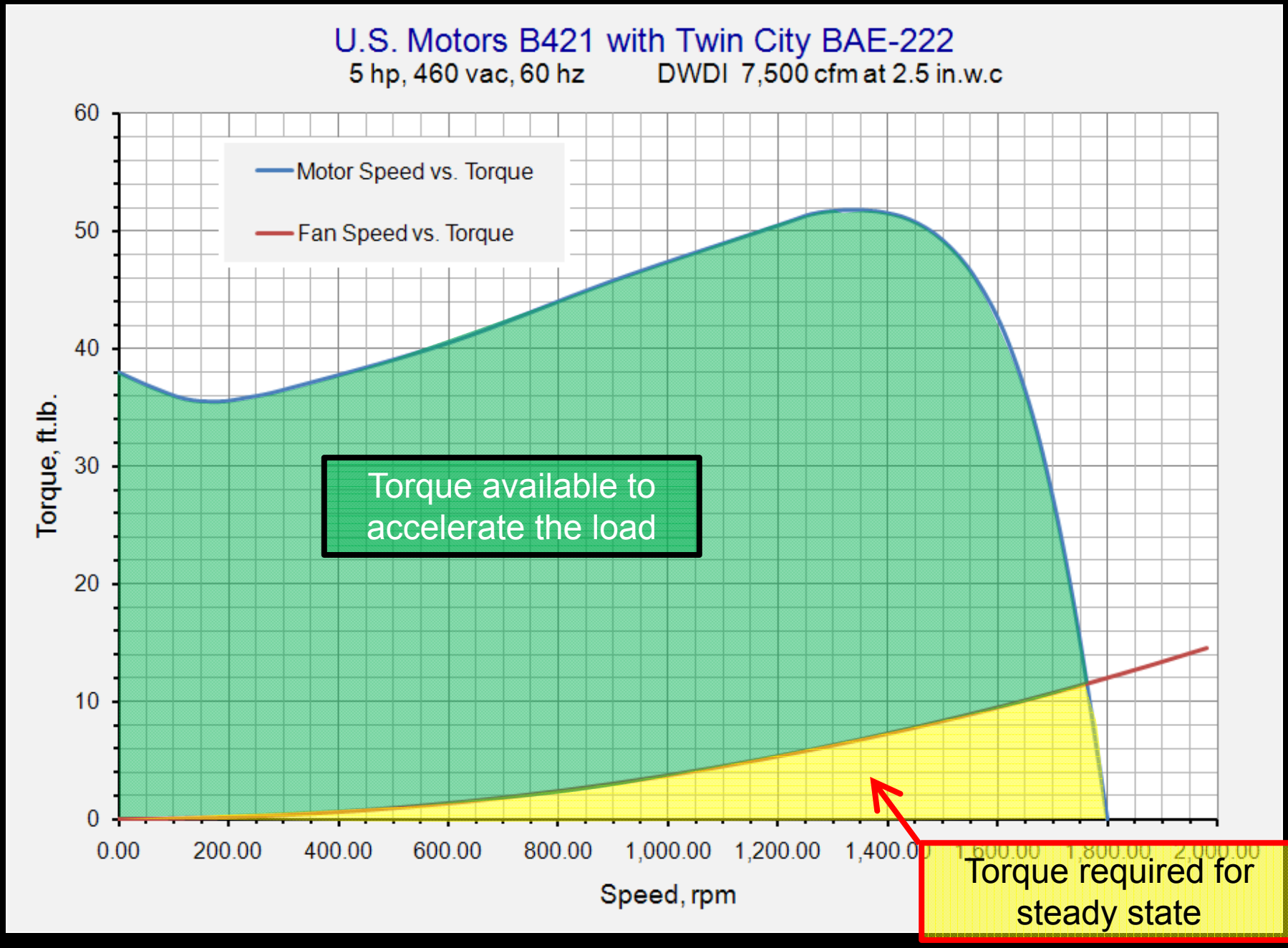
Centrifugal loads like pumps and fans extract power as a function of torque and speed

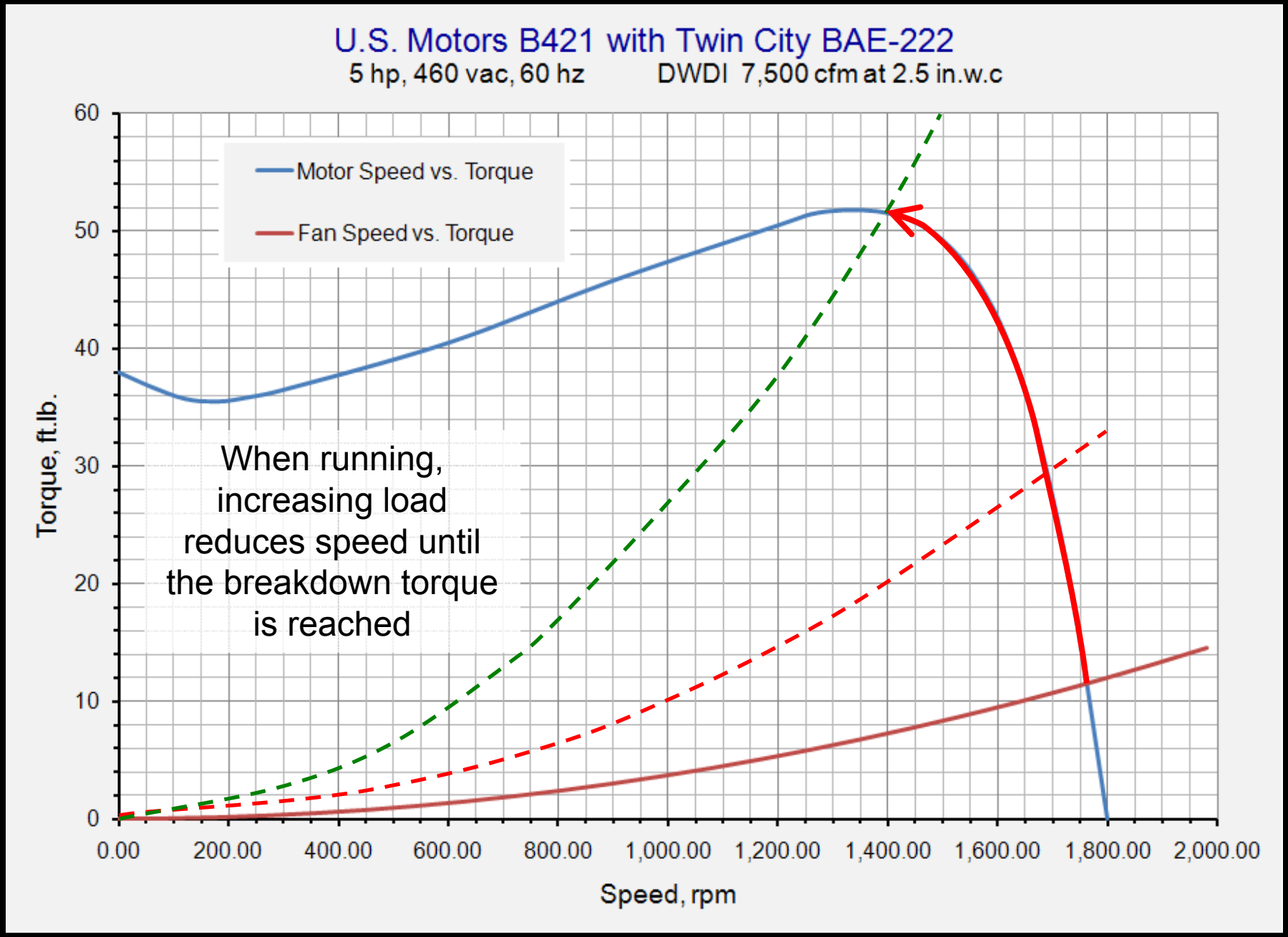
- Requirements at the design operating point are a function of the pump or fan design
- Requirements at other points can be projected based on the affinity laws

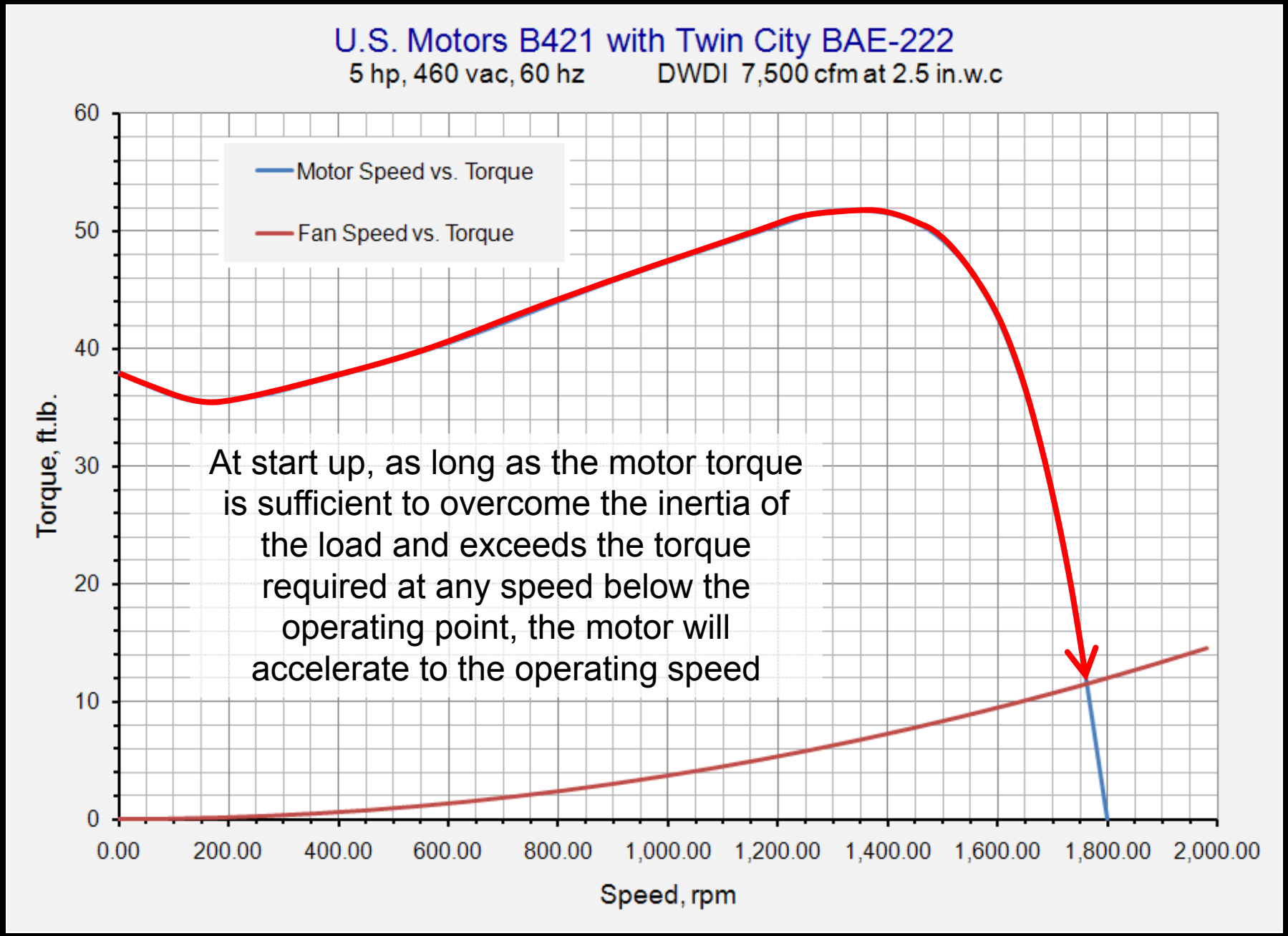
Induction motor horse power is a function of torque and speed

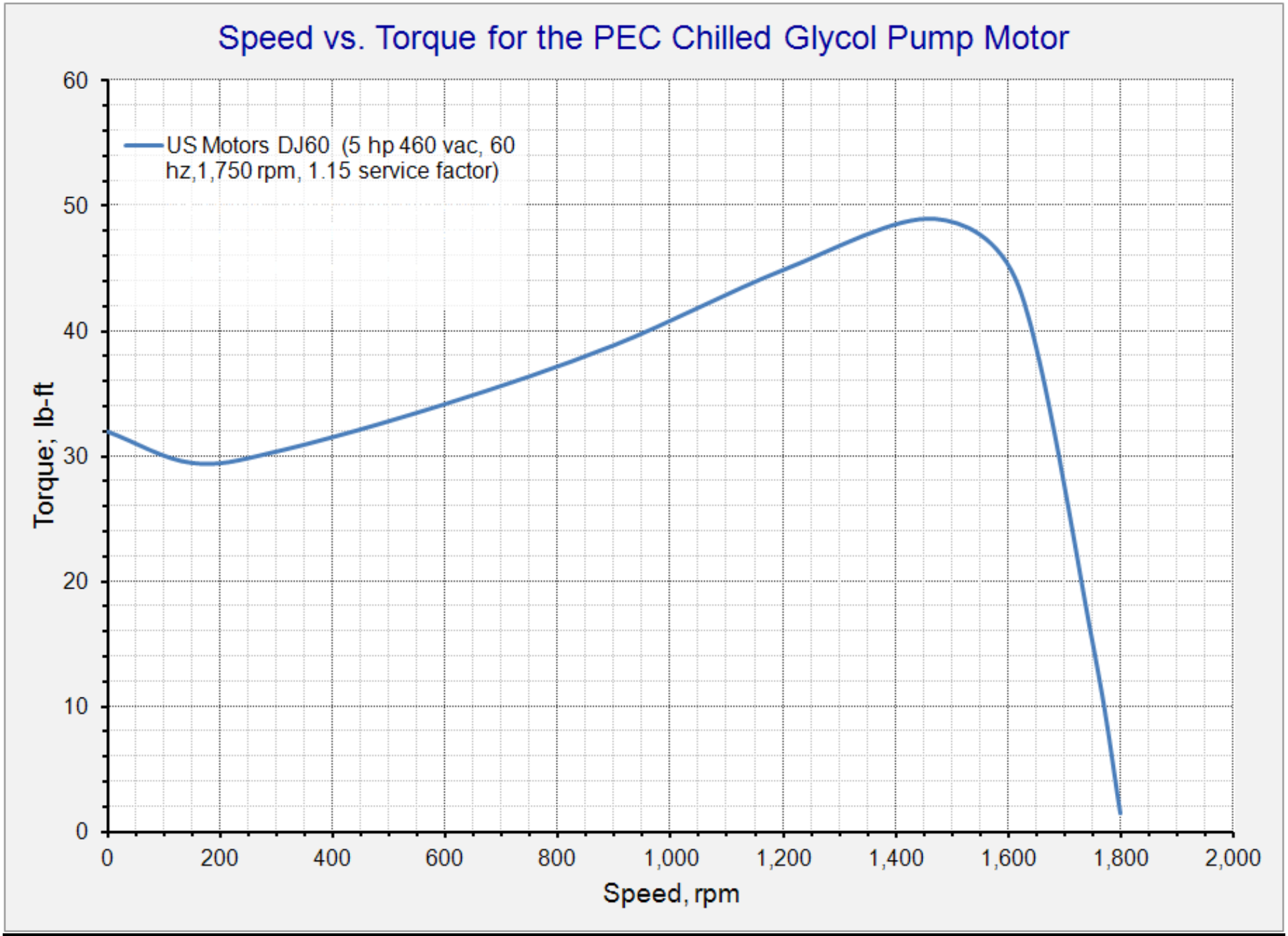
- Relationship is a function of motor design
- Relationship depicted on the torque-speed curve

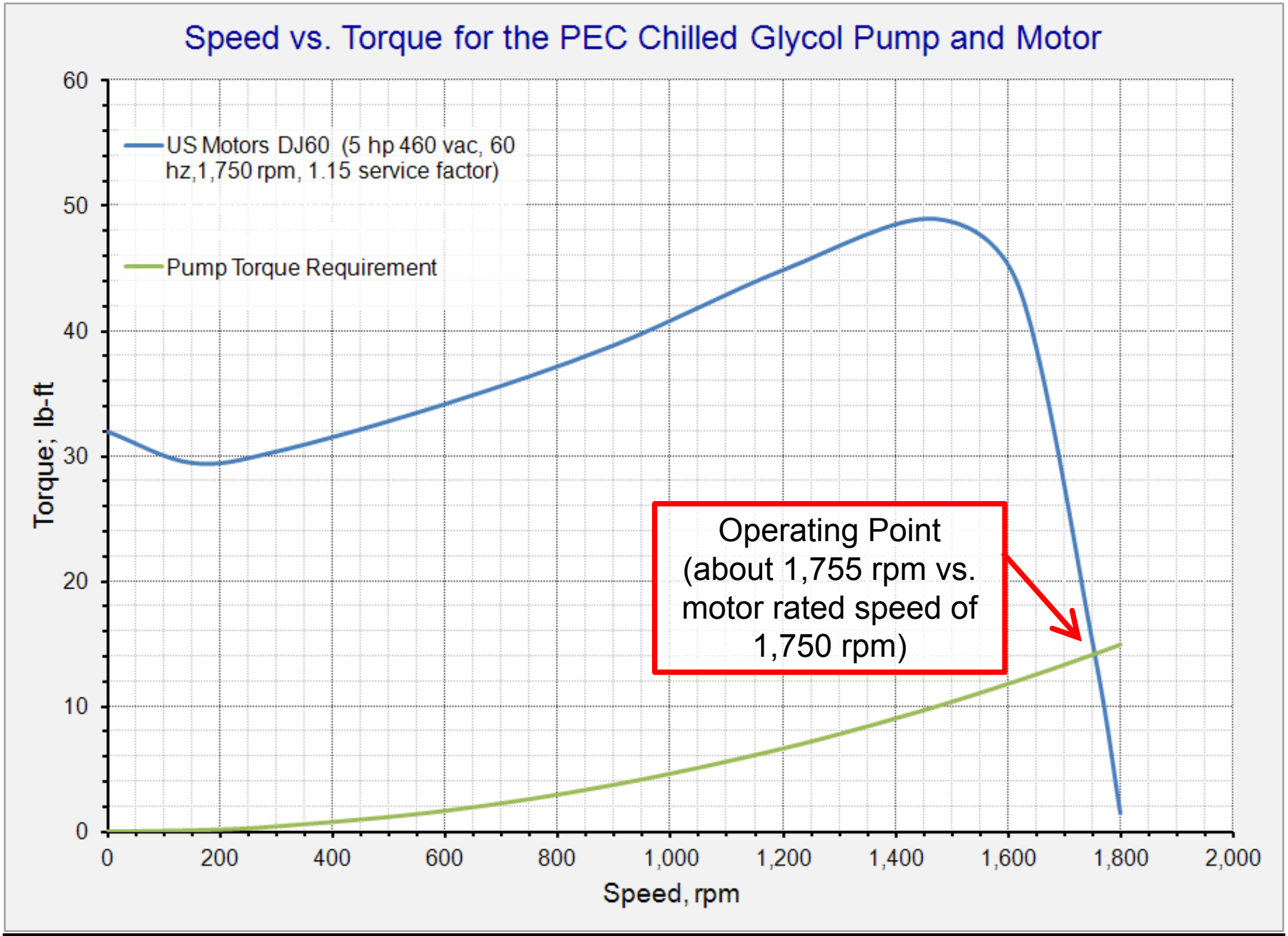
$$torque_{Speed\ ?} = torque_{FullSpeed} \times \left(\frac{rpm_{Speed\ ?}}{rpm_{FullSpeed}} \right)^2$$

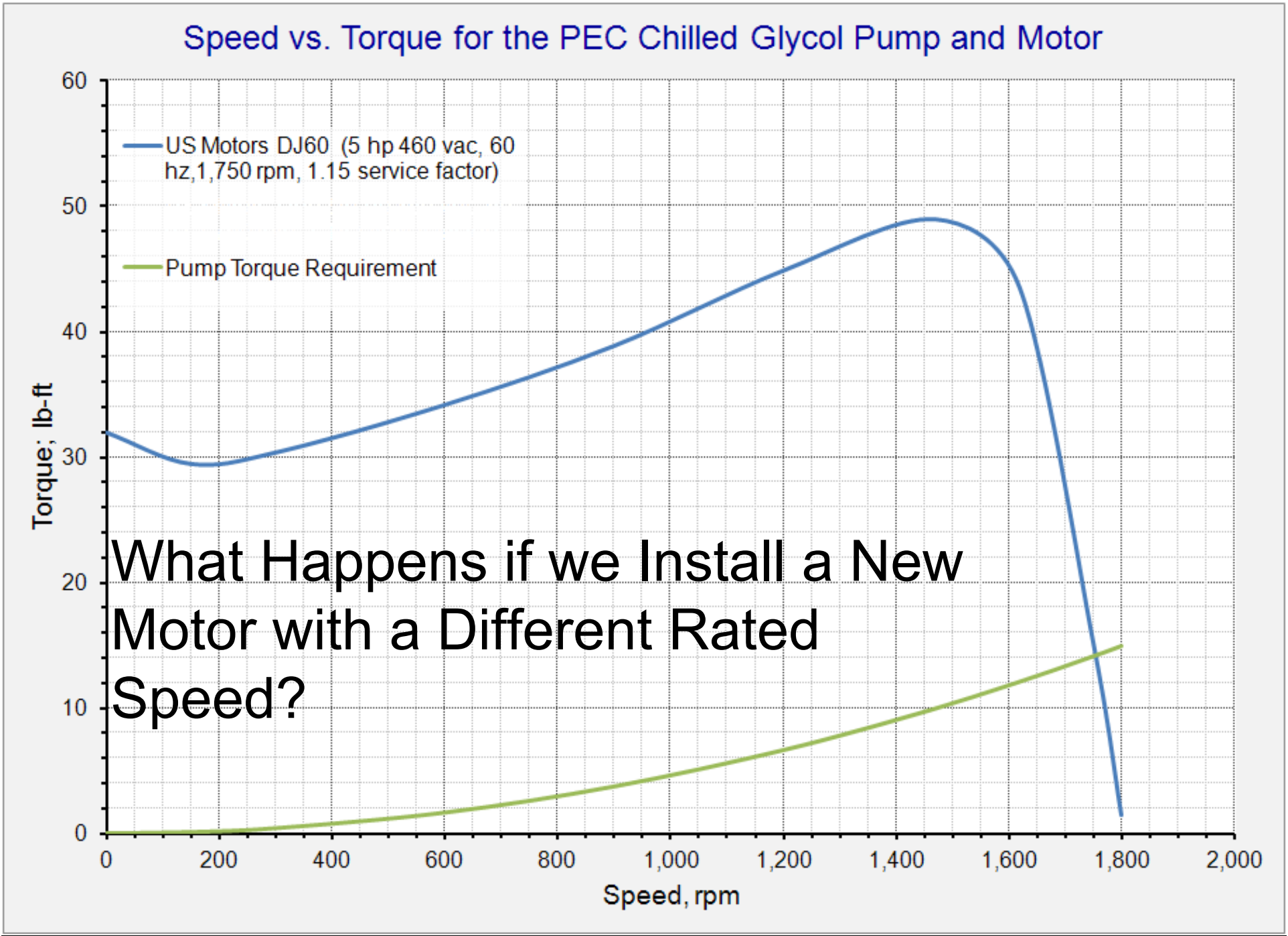

U.S. Motors B421 with Twin City BAE-222
5 hp, 460 vac, 60 hz
DWDI 7,500 cfm at 2.5 in.w.c
Motor Speed vs. Torque
Fan Speed vs. Torque
Torque, ft.lb.
60
50
40
30
20
10
0
0.00
200.00
400.00
600.00
800.00
1,000.00
1,200.00
1,400.00
Speed, rpm
Torque available to accelerate the load
Torque required for steady state


U.S. Motors B421 with Twin City BAE-222
5 hp, 460 vac, 60 hz
DWDI 7,500 cfm at 2.5 in.w.c
Motor Speed vs. Torque
Fan Speed vs. Torque
When running, increasing load reduces speed until the breakdown torque is reached
Torque, ft.lb.
60
50
40
30
20
10
0
0.00
200.00
400.00
600.00
800.00
1,000.00
1,200.00
1,400.00
1,600.00
1,800.00
2,000.00
Speed, rpm


U.S. Motors B421 with Twin City BAE-222
5 hp, 460 vac, 60 hz
DWDI 7,500 cfm at 2.5 in.w.c
Motor Speed vs. Torque
Fan Speed vs. Torque
At start up, as long as the motor torque is sufficient to overcome the inertia of the load and exceeds the torque required at any speed below the operating point, the motor will accelerate to the operating speed
Torque, ft.lb.
0
10
20
30
40
50
60
0.00
200.00
400.00
600.00
800.00
1,000.00
1,200.00
1,400.00
1,600.00
1,800.00
2,000.00
Speed, rpm


Speed vs. Torque for the PEC Chilled Glycol Pump Motor
US Motors DJ60 (5 hp 460 vac, 60 hz,1,750 rpm, 1.15 service factor)
Torque; lb-ft
Speed, rpm
0
10
20
30
40
50
60
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000


Speed vs. Torque for the PEC Chilled Glycol Pump and Motor
US Motors DJ60 (5 hp 460 vac, 60 hz,1,750 rpm, 1.15 service factor)
Pump Torque Requirement
Operating Point (about 1,755 rpm vs. motor rated speed of 1,750 rpm)
Torque; lb-ft
Speed, rpm
0
10
20
30
40
50
60
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000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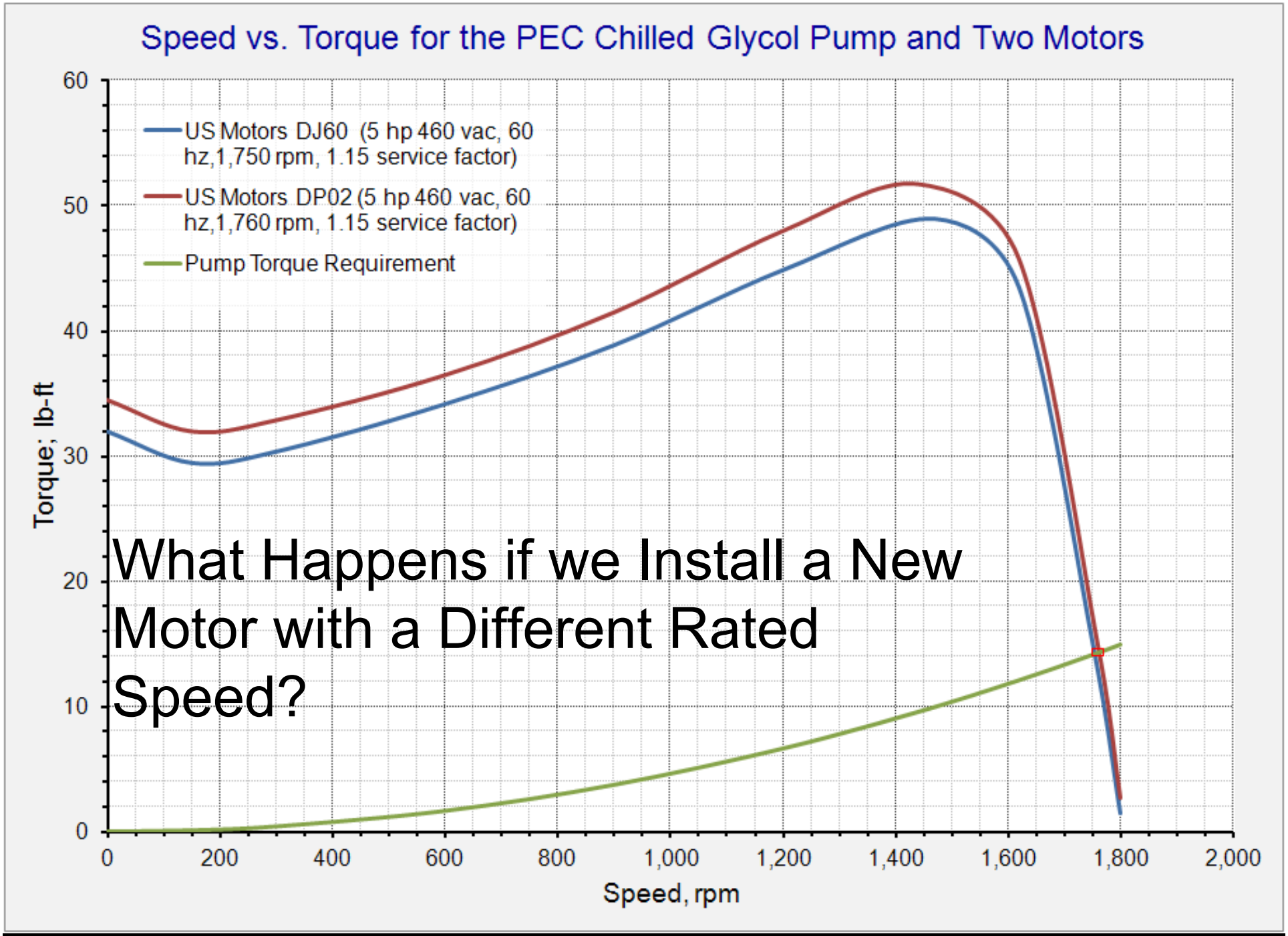
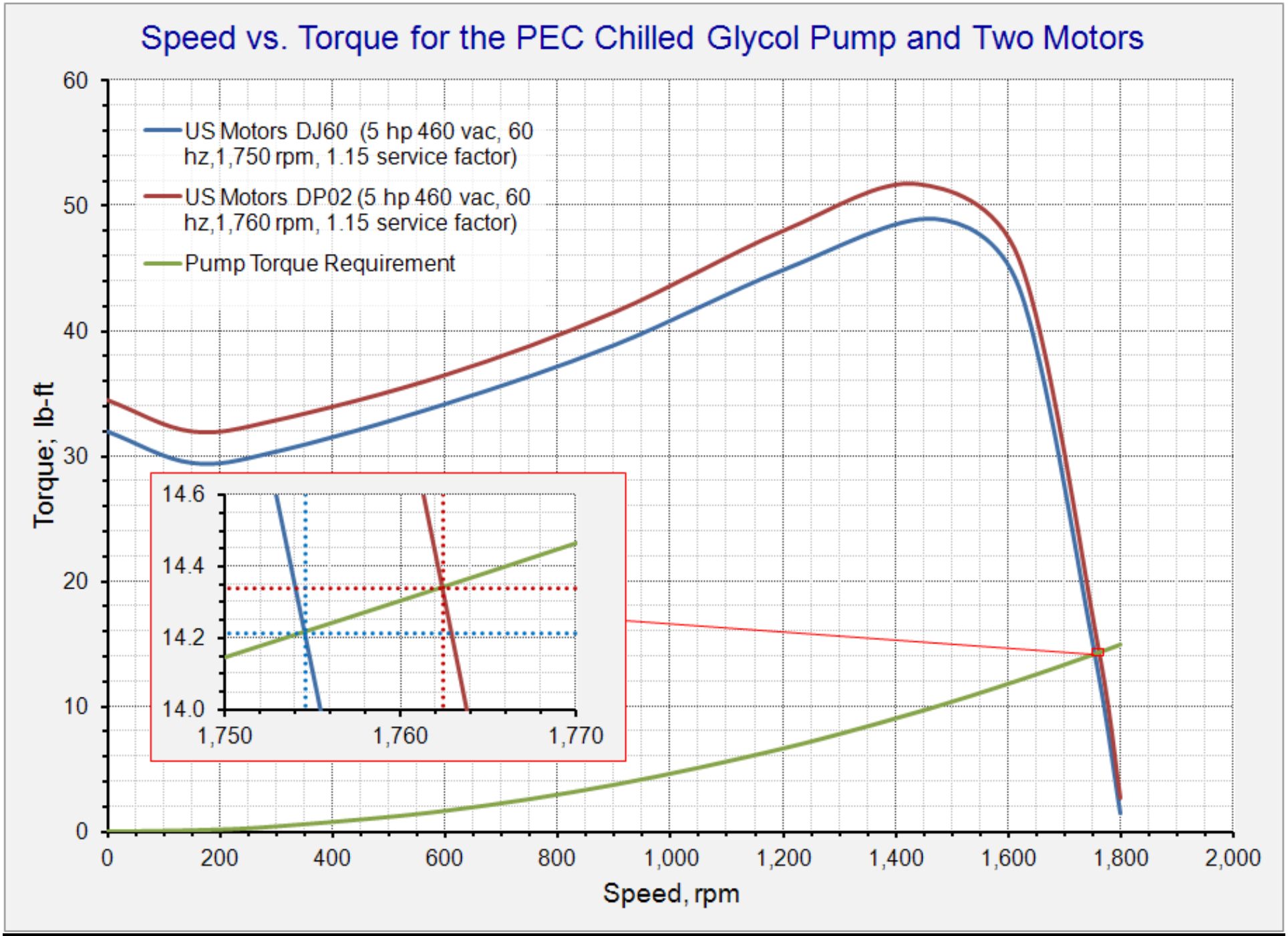
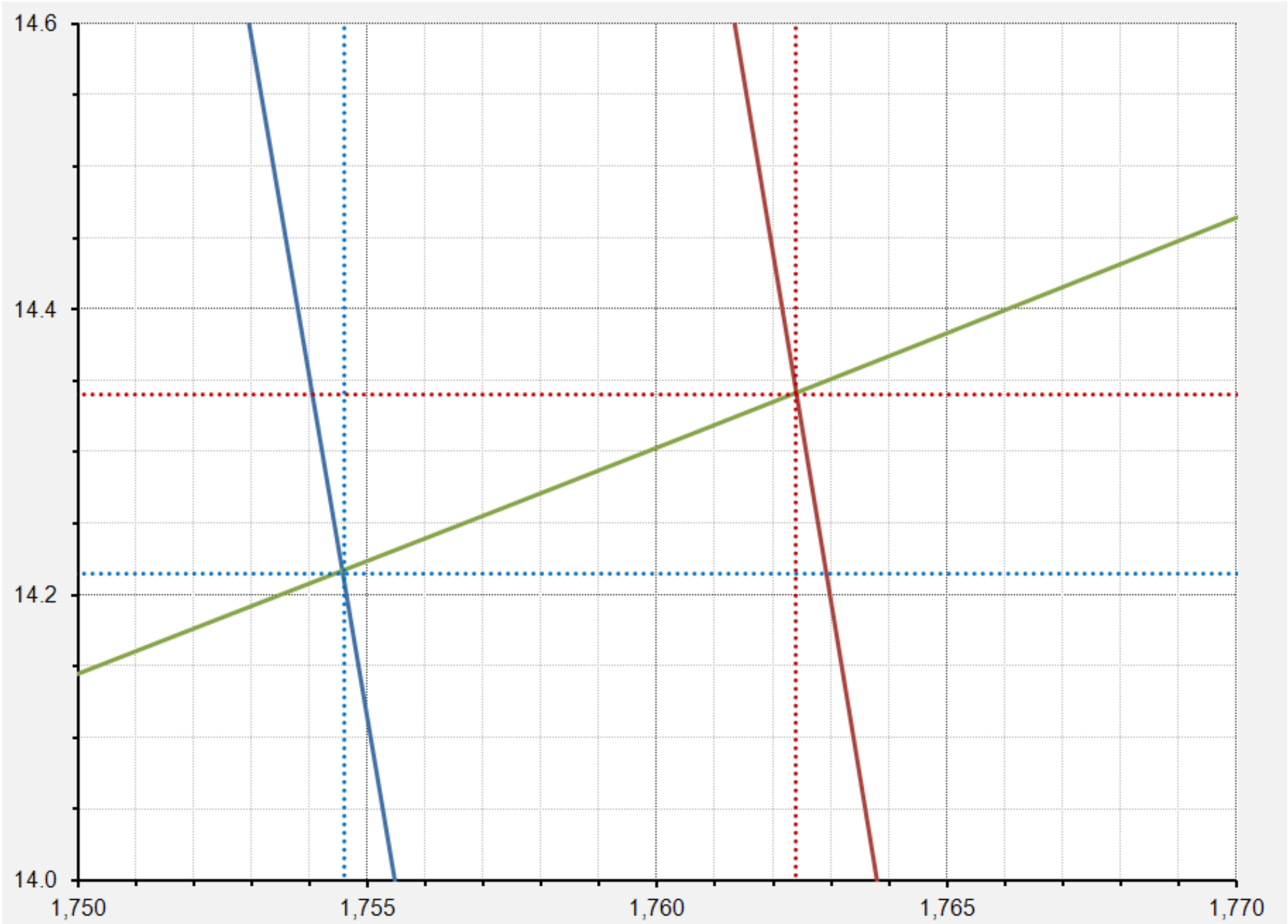
Pump Torque Requirement
Torque; lb-ft
0
10
20
30
40
50
60
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Speed, rpm
What Happens if we Install a New Motor with a Different Rated Speed?


Speed vs. Torque for the PEC Chilled Glycol Pump and Two Motors
US Motors DJ60 (5 hp 460 vac, 60 hz,1,750 rpm, 1.15 service factor)
US Motors DP02 (5 hp 460 vac, 60 hz,1,760 rpm, 1.15 service factor)
Pump Torque Requirement
Torque; lb-ft
0
10
20
30
40
50
60
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Speed, rpm
What Happens if we Install a New Motor with a Different Rated Speed?


Speed vs. Torque for the PEC Chilled Glycol Pump and Two Motors
US Motors DJ60 (5 hp 460 vac, 60 hz,1,750 rpm, 1.15 service factor)
US Motors DP02 (5 hp 460 vac, 60 hz,1,760 rpm, 1.15 service factor)
Pump Torque Requirement
Torque; lb-ft
Speed, rpm
0
10
20
30
40
50
60
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
14.6
14.4
14.2
14.0
1,750
1,760
1,770


14.6
14.4
14.2
14.0
1,750
1,755
1,760
1,765
1,770

Energy Cost Associated with the Shift in Operating Point

Pump full speed bhp	4.75	Based on original CHW pump selection
Pump full load motor speed	1,755	rpm (from the DJ60 curve at design hp)
Pump design torque	14.22	$lb\text{-}ft_{Force}$
Speed at new motor balance point	1,762	rpm (read from chart)
Torque at new motor balance point	14.34	lb-ft (read from chart)
bhp at new operating point	4.81	hp
Increase from original bhp	0.06	hp
	0.05	kW
Increased kWh	405	kWh per year (round the clock operation)
Increased $	$61	per year ($0.15/kWh electrical cost)

Energy Cost Associated with a Motor Efficiency Improvement

Original bhp required	4.75	hp
Efficiency improvement	1.5%	
hp savings	0.07	hp
kW savings	0.05	kW
Anticipated Savings kWh	477	kWh per year (round the clock operation)
Anticipated Savings $	$72	per year ($0.15/kWh electrical cost)

The Bottom Line if you Don't Pay Attention to Rated Speed

What you thought you would save

- 477 kWh per year
- $72 per year ($0.15/kWh electrical cost)
- 7.2 year simple payback

What you actually save

- 72 kWh per year
- $11 per year ($0.15/kWh electrical cost)
- 46.1 year simple payback