VAV Systems

Design, Performance and Commissioning Issues

Load Dynamics – System Side

Instructor:

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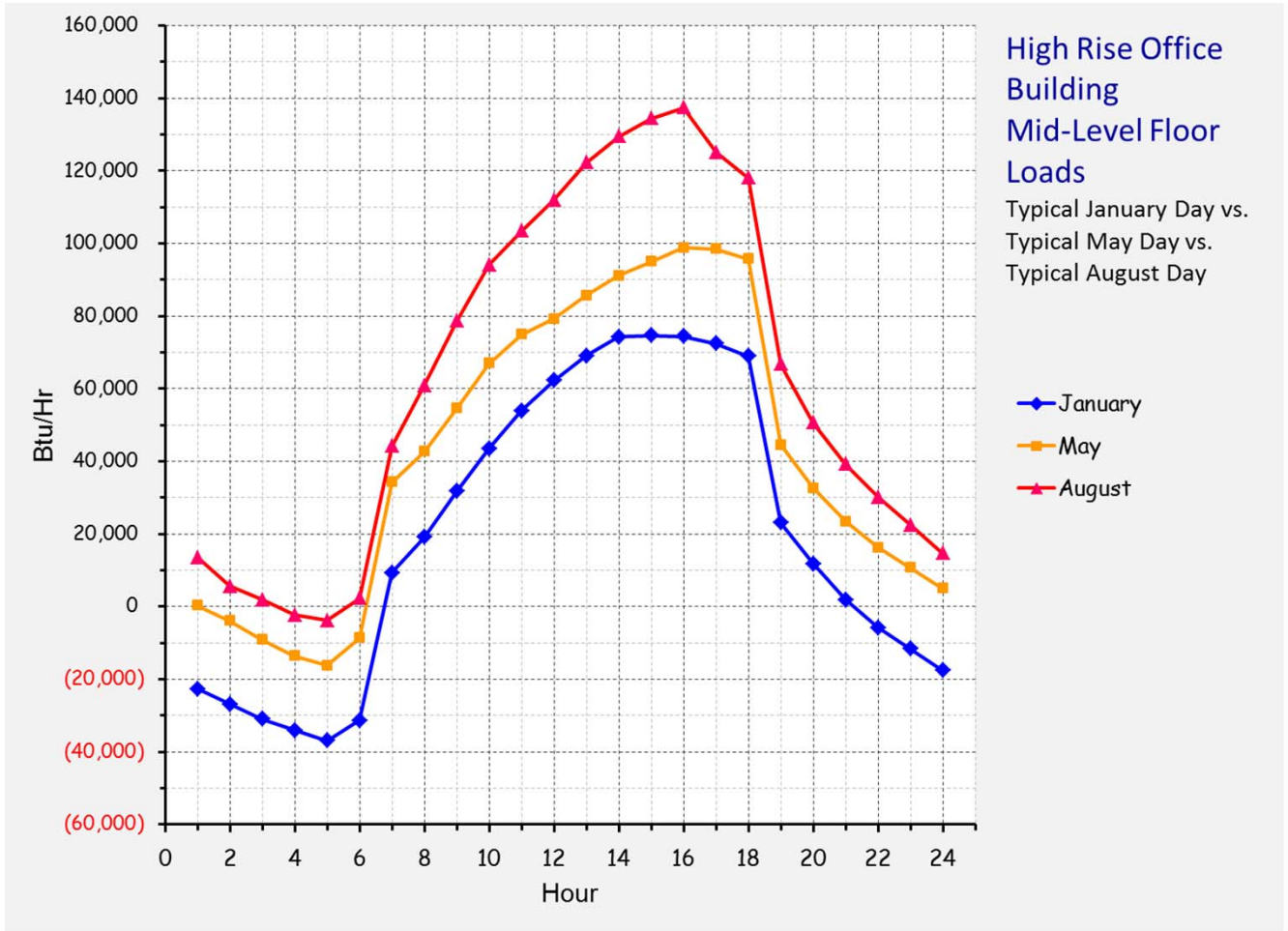
Senior Engineer

Facility Dynamics Engineering

March 7, 2018

Match the System Flow Rate to the Load

Simple in Concept; Challenging in Reality

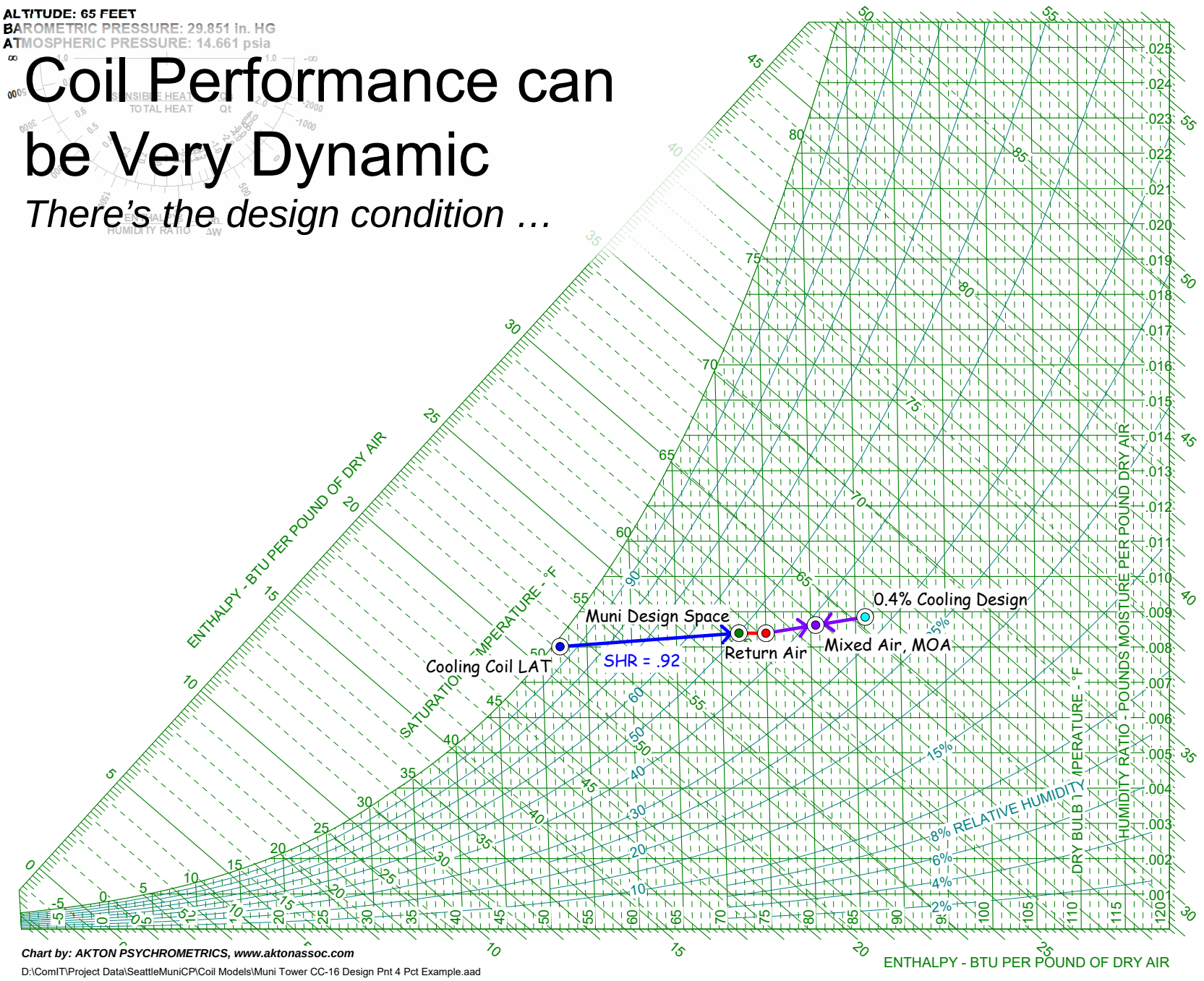


The Cooling Requirements Vary with Time of Day and Time of Year

The Performance of Components Varies with Airflow (which VAV Systems Vary with Load)

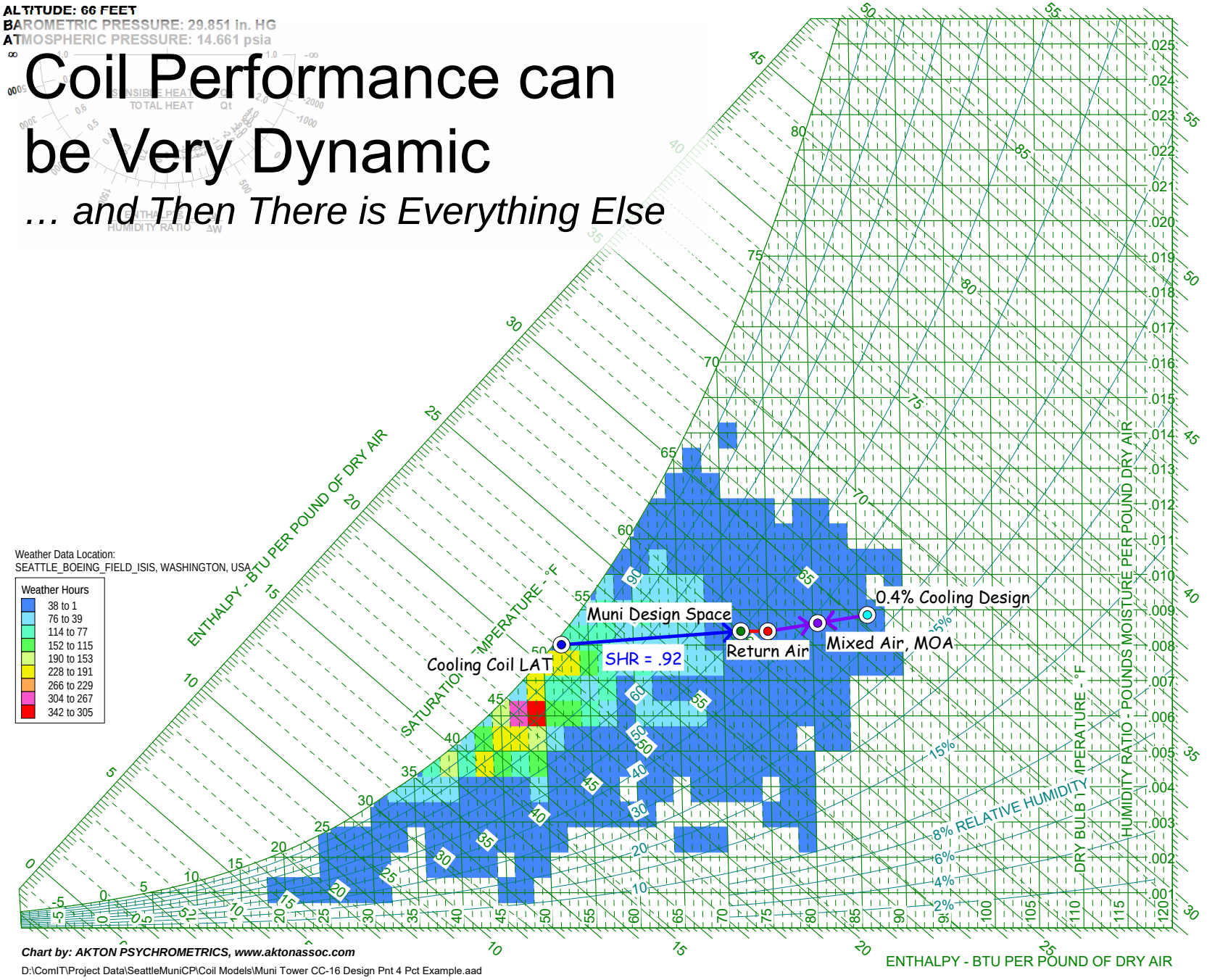
Coil Performance can be Very Dynamic

There's the design condition …

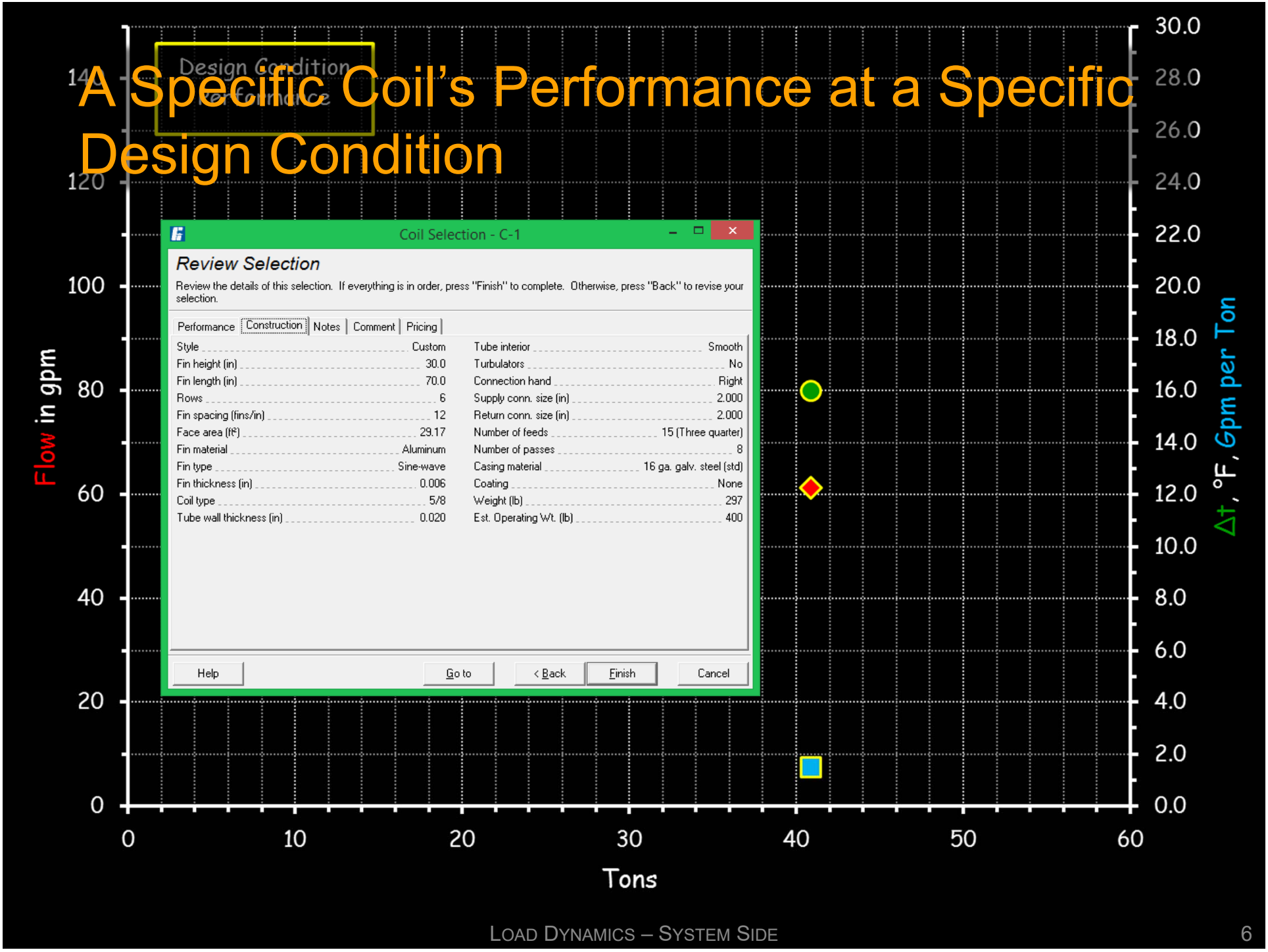


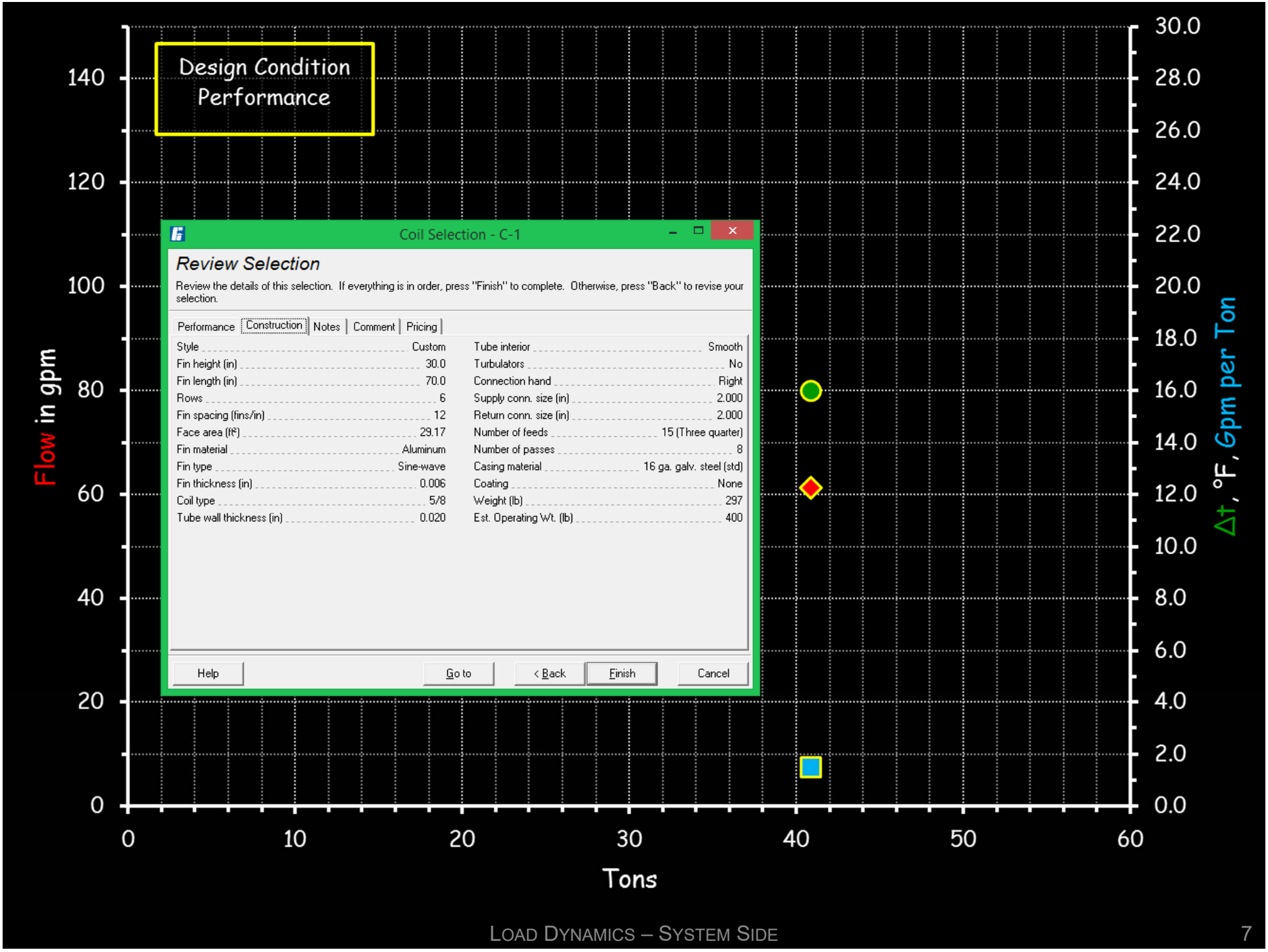
Coil Performance can be Very Dynamic

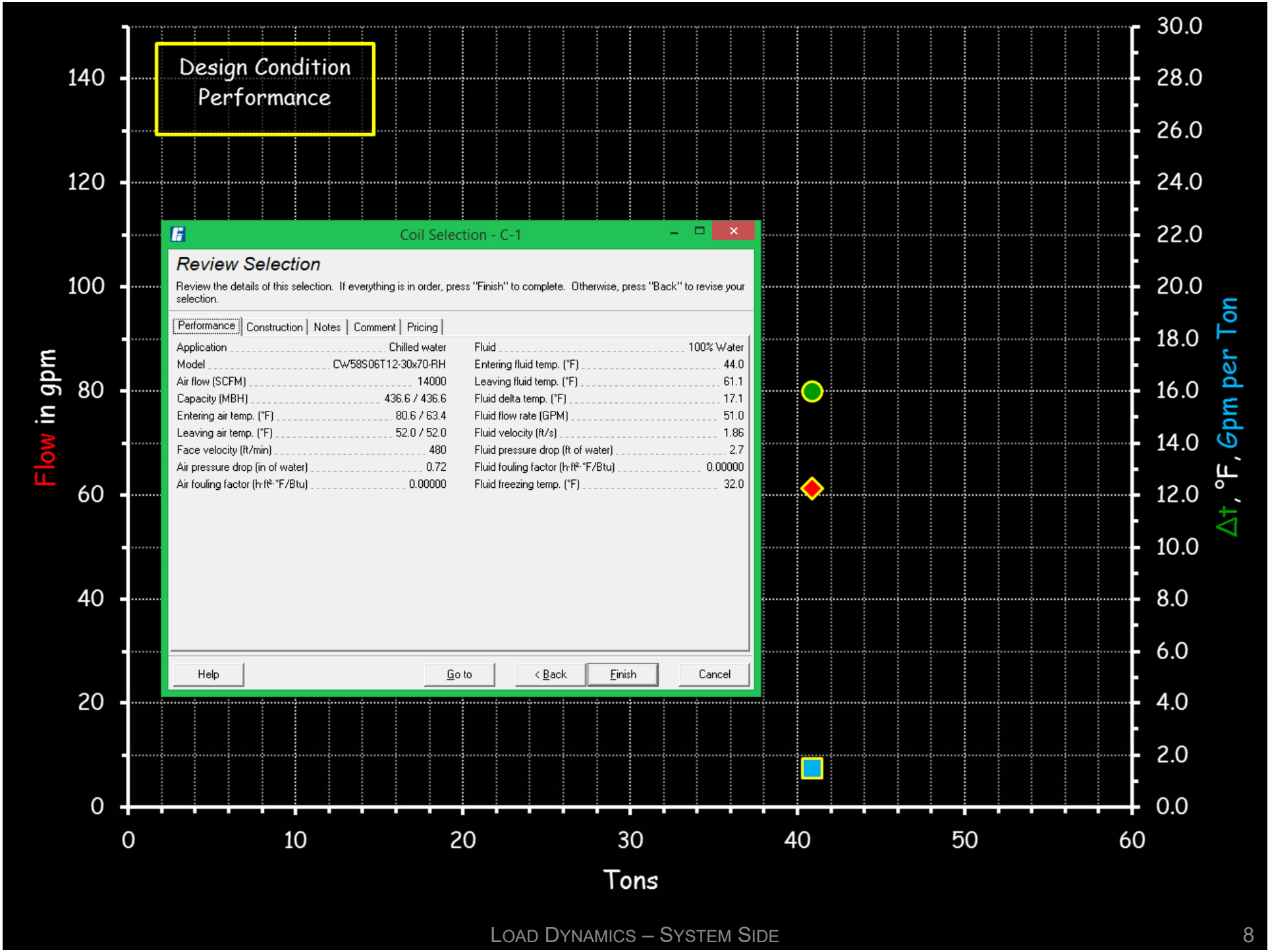
… and Then There is Everything Else



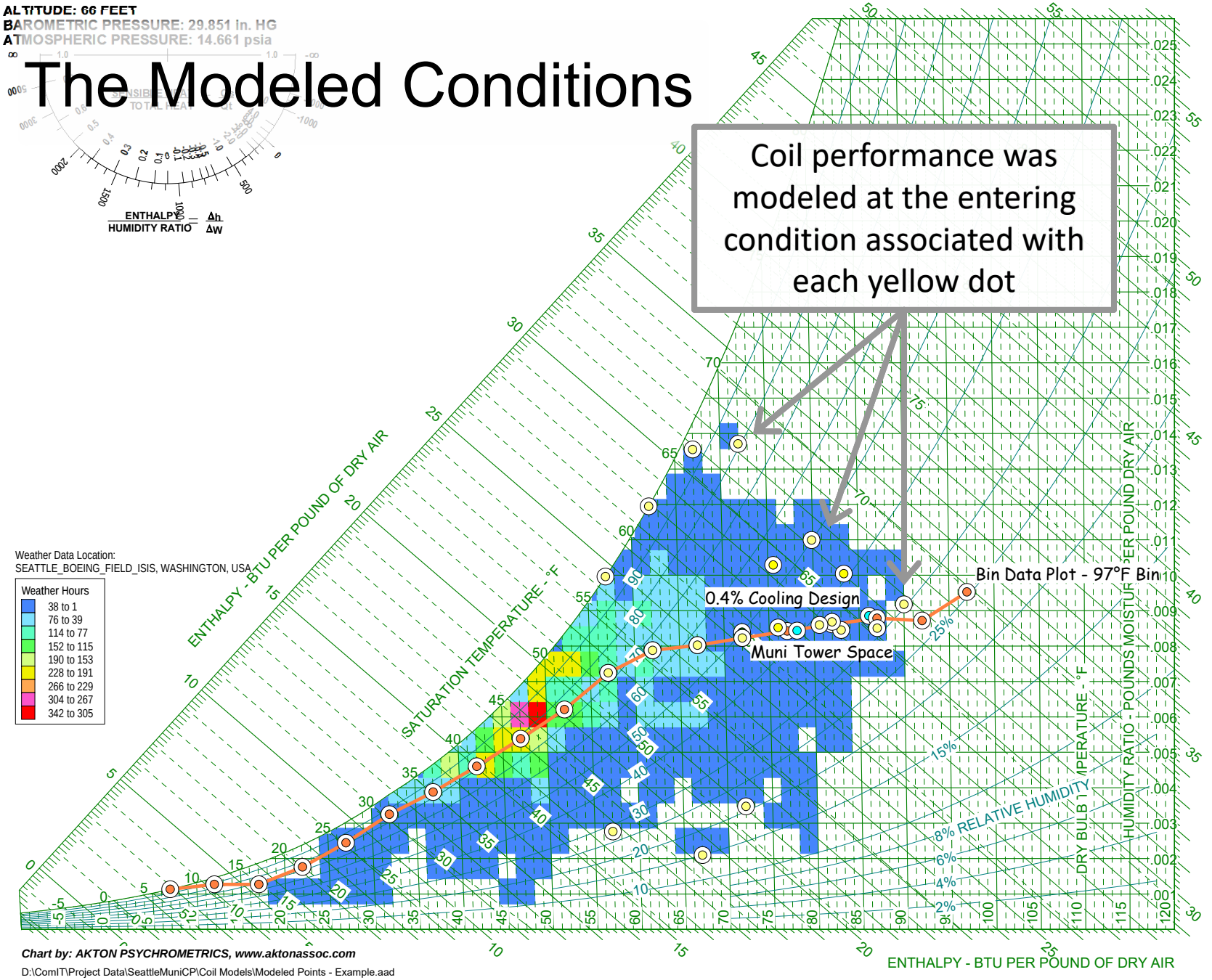
A Specific Coil's Performance at a Specific Design Condition




Design Condition
Performance
Coil Selection - C-1
Review Selection
Review the details of this selection. If everything is in order, press "Finish" to complete. Otherwise, press "Back" to revise your selection.
Performance
Construction
Notes
Comment
Pricing
Style Custom
Fin height (in) 30.0
Fin length (in) 70.0
Rows 6
Fin spacing (fins/in) 12
Face area (ft²) 29.17
Fin material Aluminum
Fin type Sine-wave
Fin thickness (in) 0.006
Coil type 5/8
Tube wall thickness (in) 0.020
Tube interior Smooth
Turbulators No
Connection hand Right
Supply conn. size (in) 2.000
Return conn. size (in) 2.000
Number of feeds 15 (Three quarter)
Number of passes 8
Casing material 16 ga. galv. steel (std)
Coating None
Weight (lb) 297
Est. Operating Wt. (lb) 400
Help
Go to
< Back
Finish
Cancel
Flow in gpm
Tons
Δt, °F, Gpm per Ton
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0

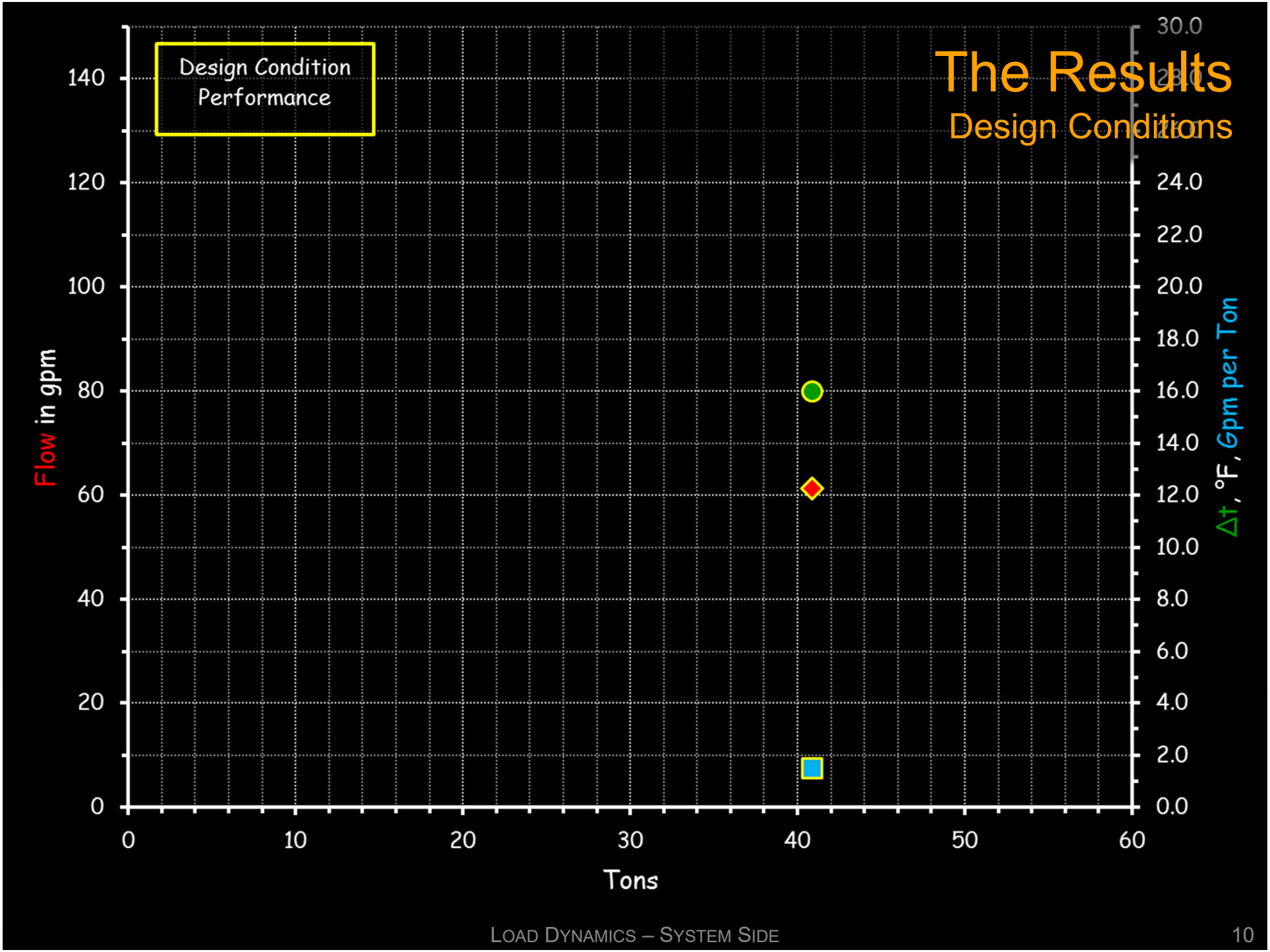

Design Condition
Performance
Coil Selection - C-1
Review Selection
Review the details of this selection. If everything is in order, press "Finish" to complete. Otherwise, press "Back" to revise your selection.
Performance
Construction
Notes
Comment
Pricing
Application Chilled water
Model CW58S06T12-30x70-RH
Air flow (SCFM) 14000
Capacity (MBH) 436.6 / 436.6
Entering air temp. (°F) 80.6 / 63.4
Leaving air temp. (°F) 52.0 / 52.0
Face velocity (ft/min) 480
Air pressure drop (in of water) 0.72
Air fouling factor (h·ft²·°F/Btu) 0.00000
Fluid 100% Water
Entering fluid temp. (°F) 44.0
Leaving fluid temp. (°F) 61.1
Fluid delta temp. (°F) 17.1
Fluid flow rate (GPM) 51.0
Fluid velocity (ft/s) 1.86
Fluid pressure drop (ft of water) 2.7
Fluid fouling factor (h·ft²·°F/Btu) 0.00000
Fluid freezing temp. (°F) 32.0
Help
Go to
< Back
Finish
Cancel
Flow in gpm
0
20
40
60
80
100
120
140
Tons
0
10
20
30
40
50
60
Δt, °F, Gpm per Ton
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0

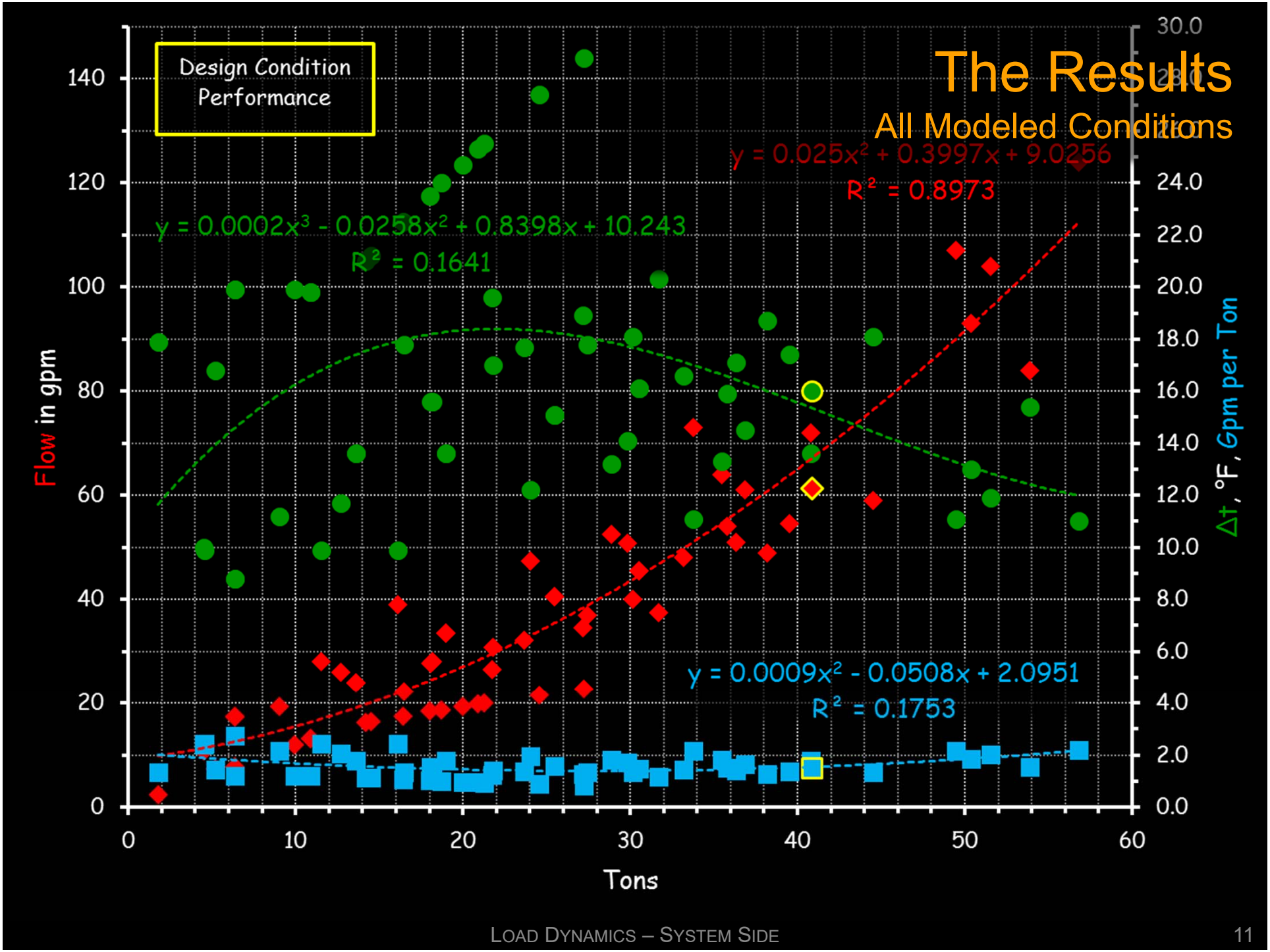
The Modeled Conditions

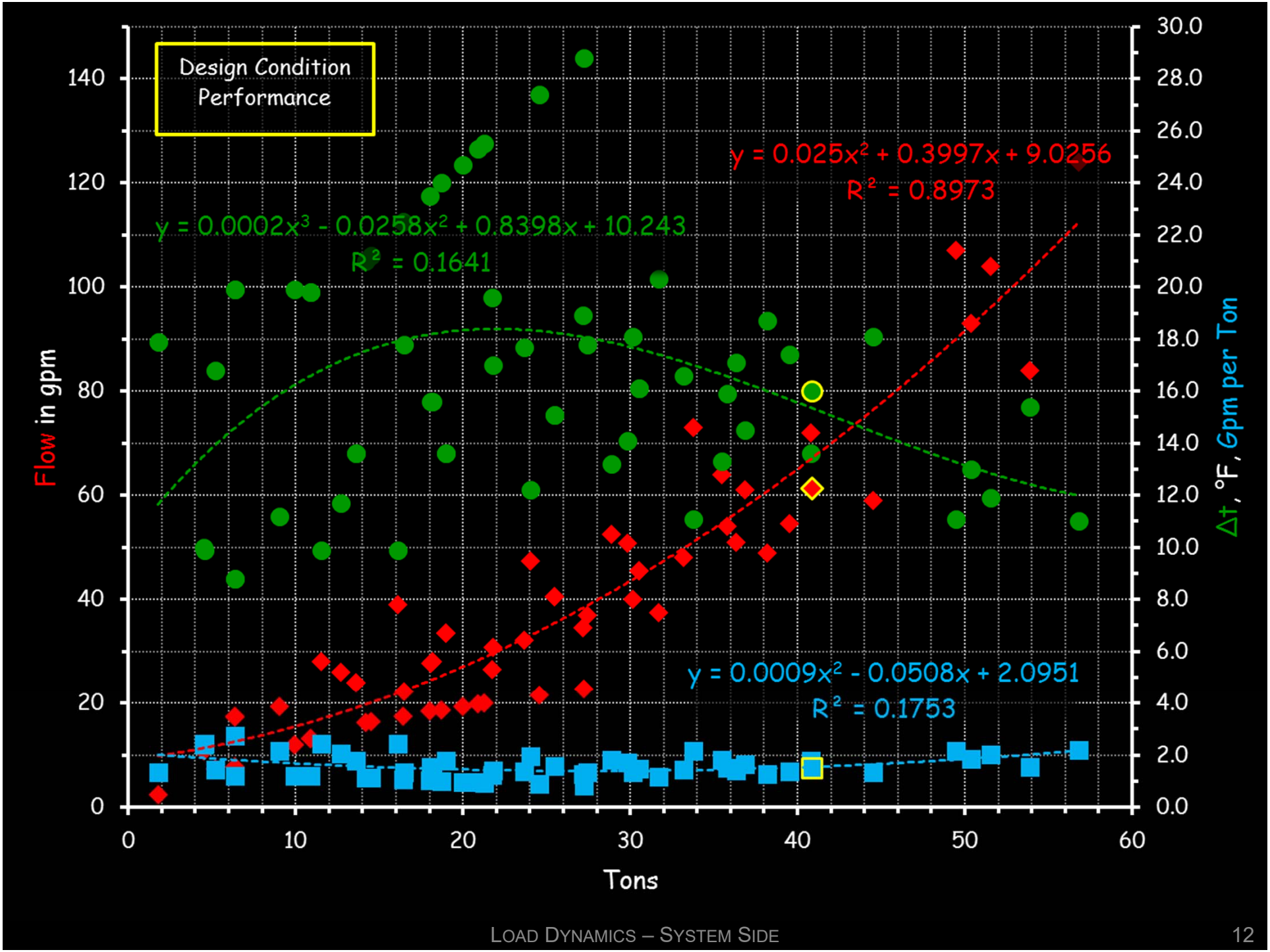


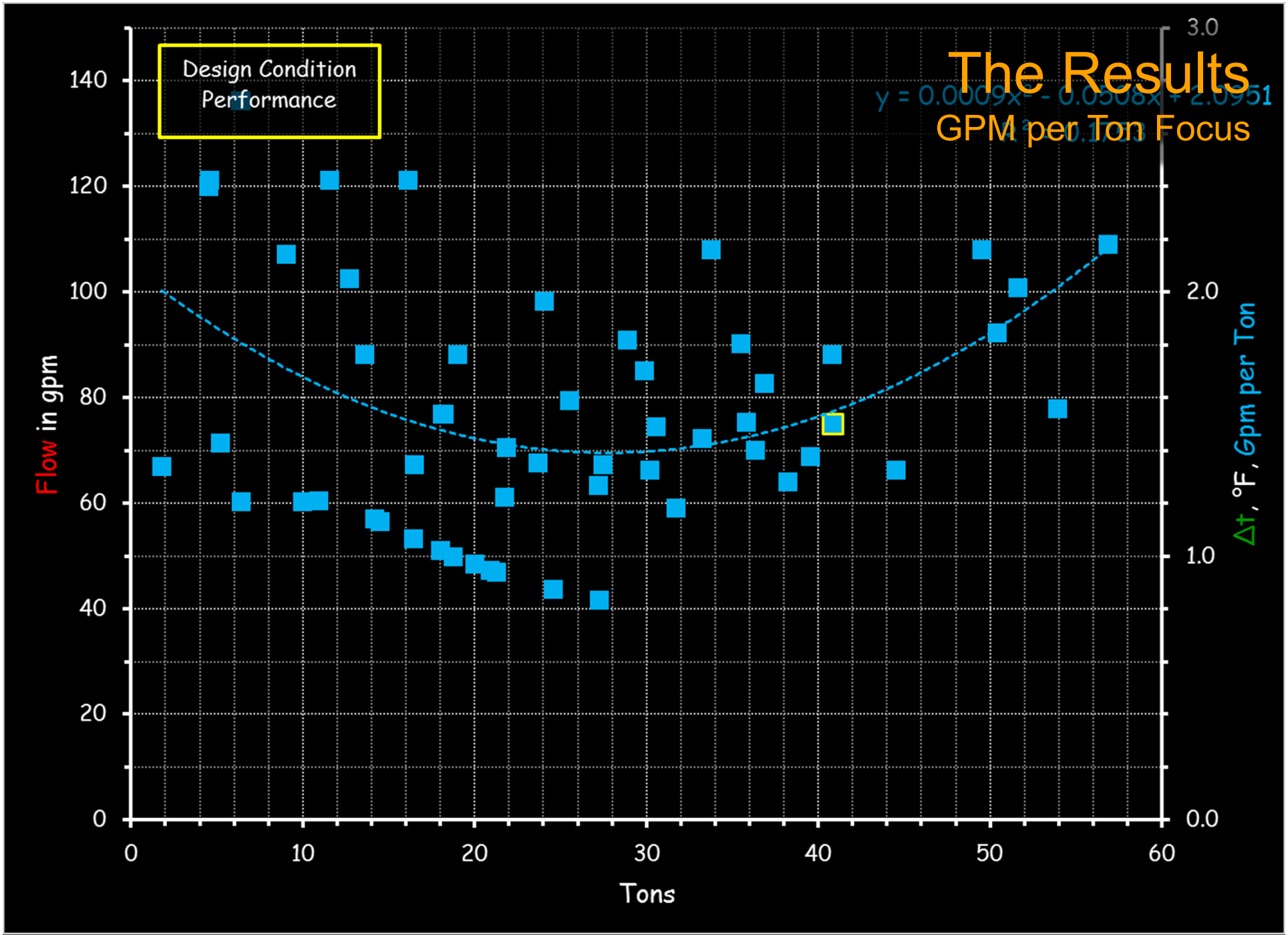
The Results

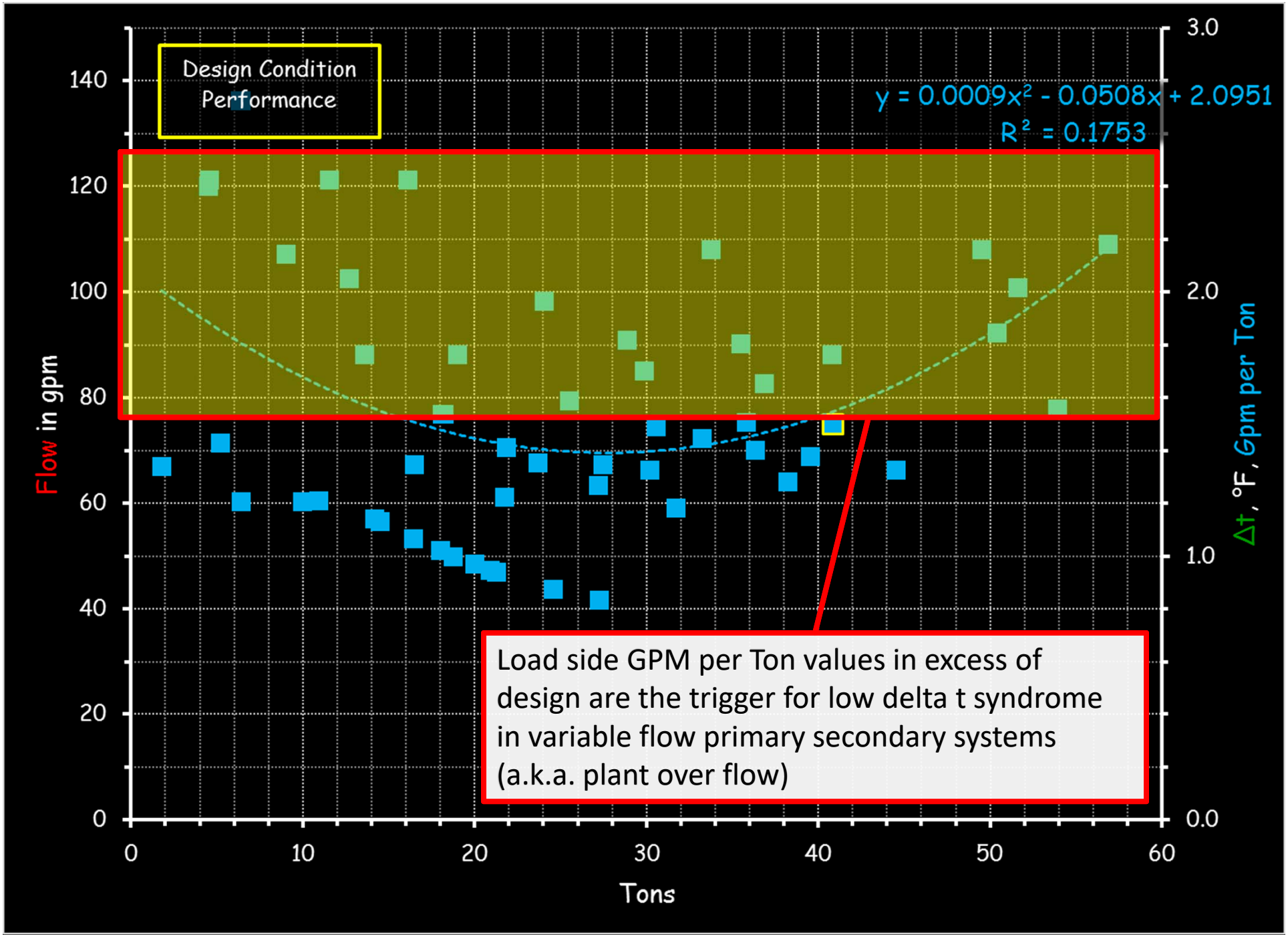
Design Conditions




Design Condition Performance
The Results
All Modeled Conditions
y = 0.025x² + 0.3997x + 9.0256
R² = 0.8973
y = 0.0002x³ - 0.0258x² + 0.8398x + 10.243
R² = 0.1641
y = 0.0009x² - 0.0508x + 2.0951
R² = 0.1753
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
30.0
0
10
20
30
40
50
60

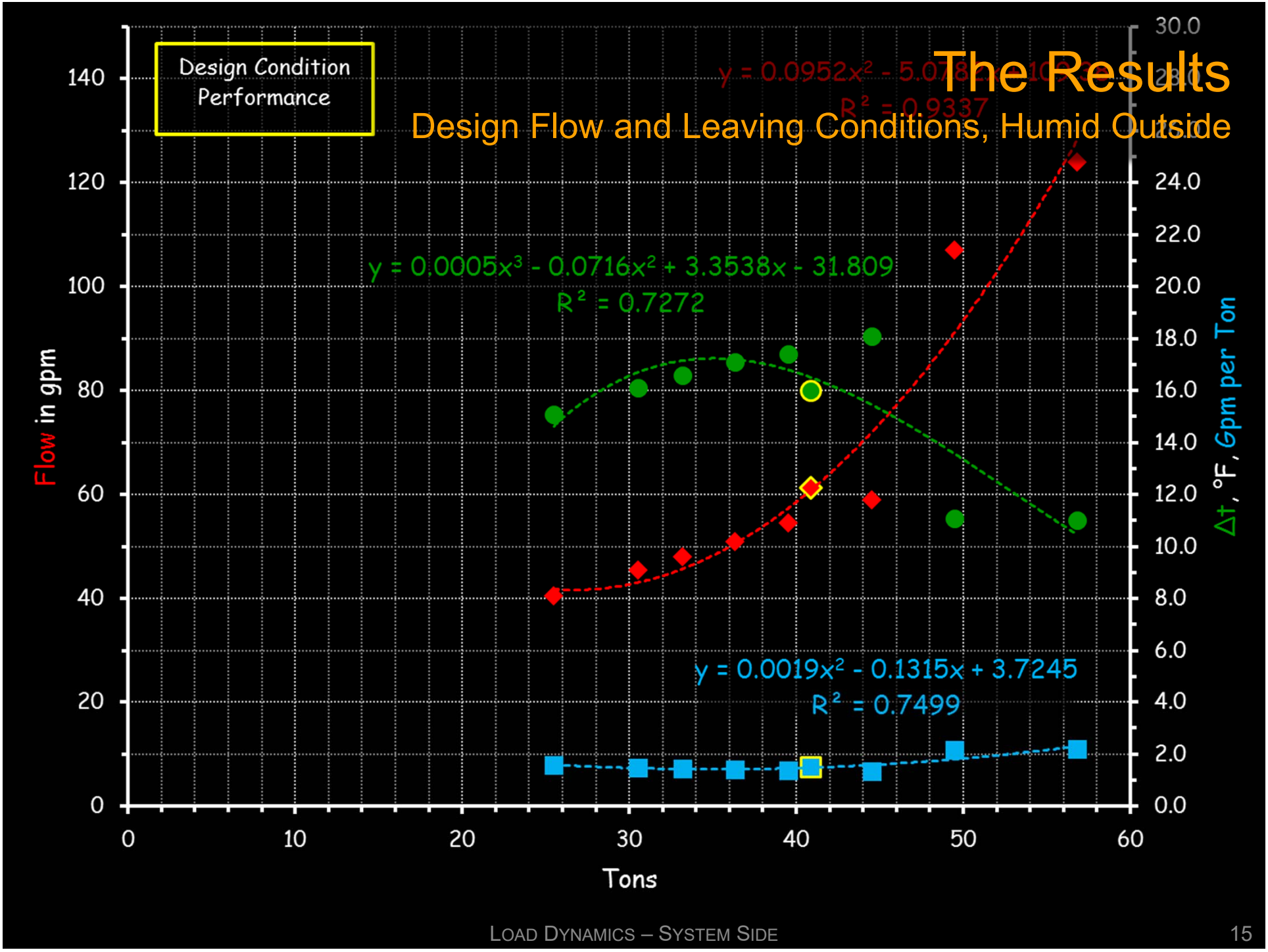

Design Condition
Performance
y = 0.025x² + 0.3997x + 9.0256
R² = 0.8973
y = 0.0002x³ - 0.0258x² + 0.8398x + 10.243
R² = 0.1641
y = 0.0009x² - 0.0508x + 2.0951
R² = 0.1753
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
0
10
20
30
40
50
60


Design Condition
Performance
The Results
GPM per Ton Focus
y = 0.0009x² - 0.0508x + 2.0951
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
1.0
2.0
3.0
0
10
20
30
40
50
60


Design Condition Performance
y = 0.0009x² - 0.0508x + 2.0951
R² = 0.1753
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
1.0
2.0
3.0
0
10
20
30
40
50
60
Load side GPM per Ton values in excess of design are the trigger for low delta t syndrome in variable flow primary secondary systems (a.k.a. plant over flow)

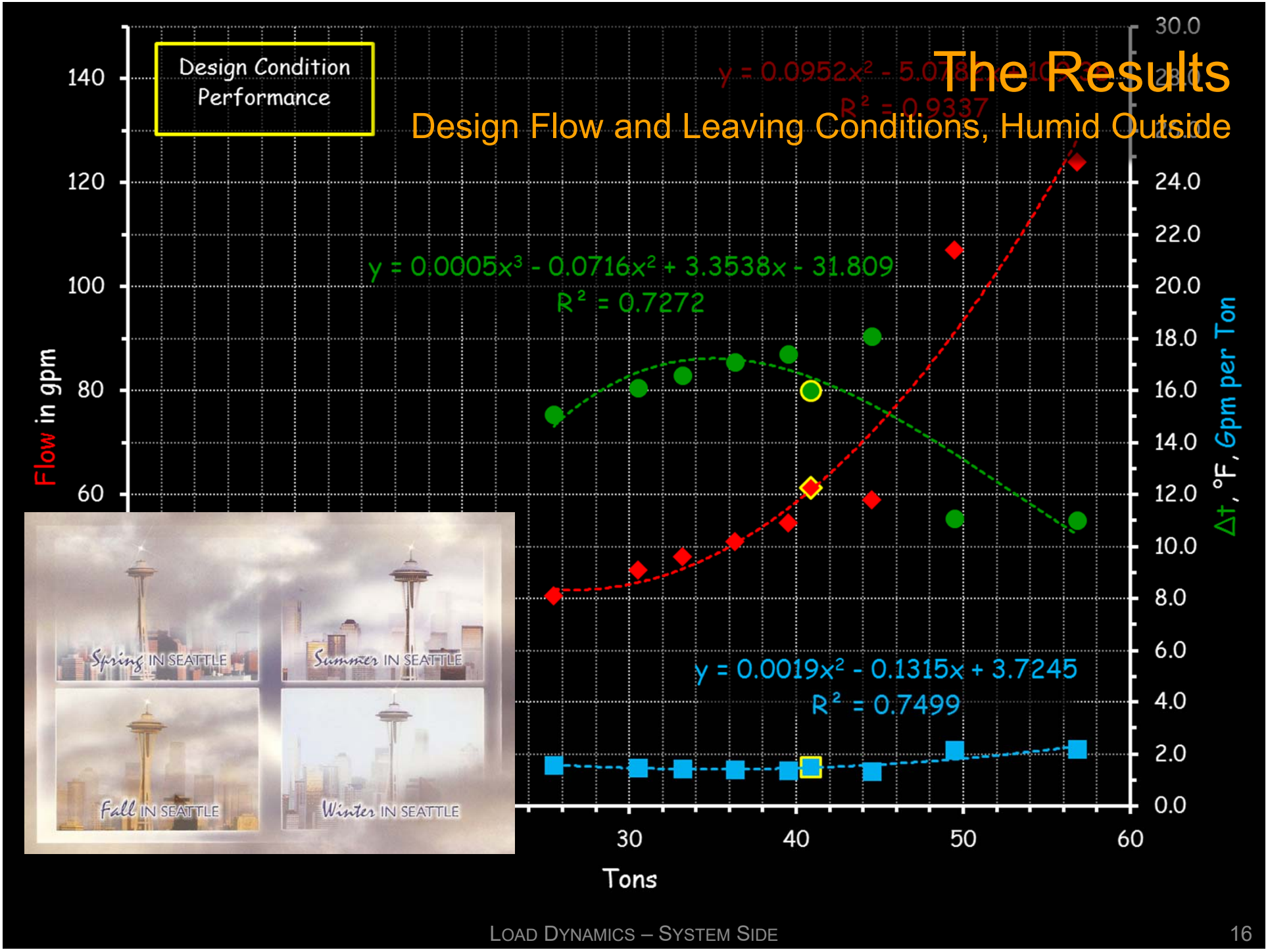
The Results

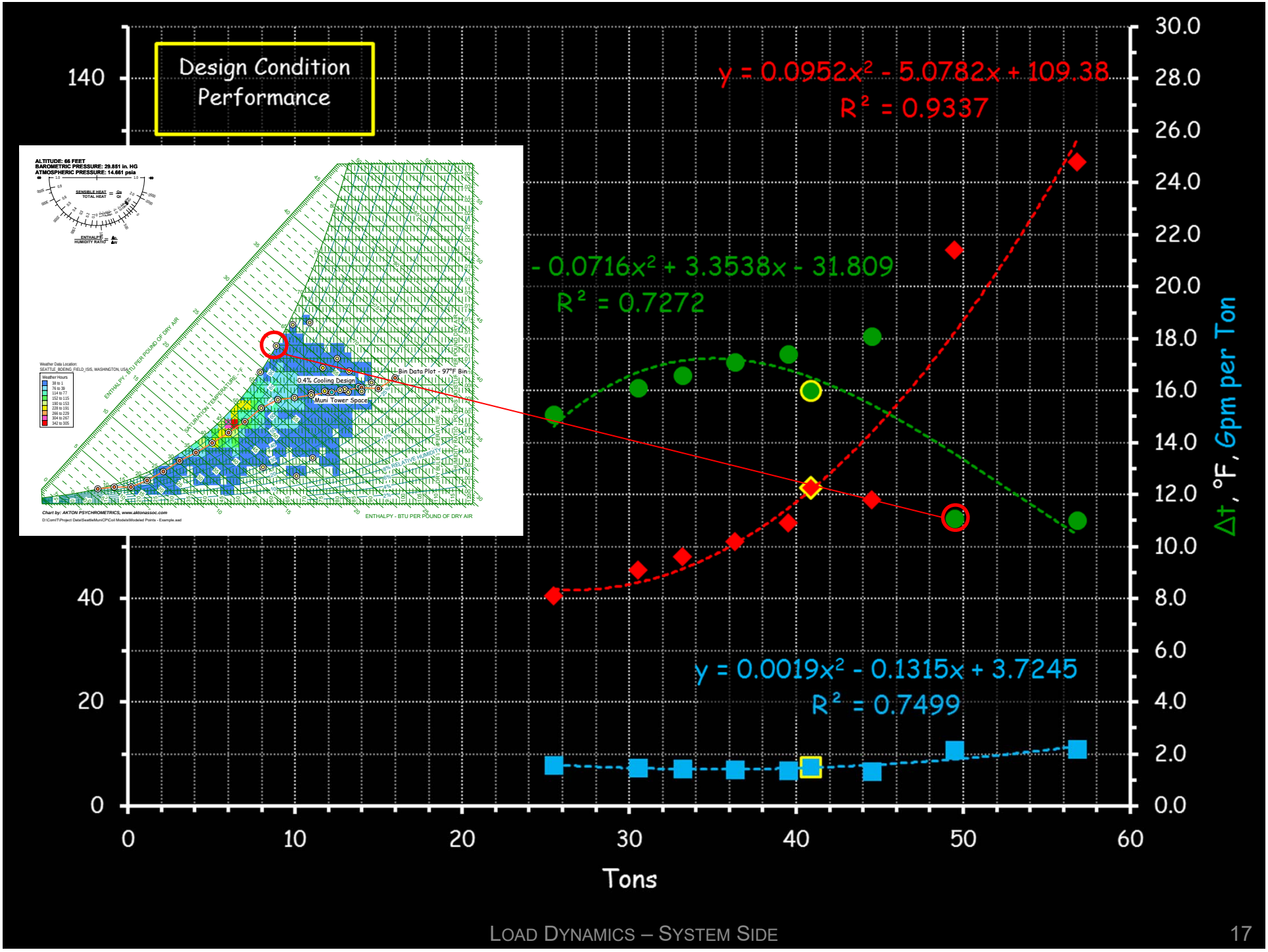
Design Flow and Leaving Conditions, Humid Outside

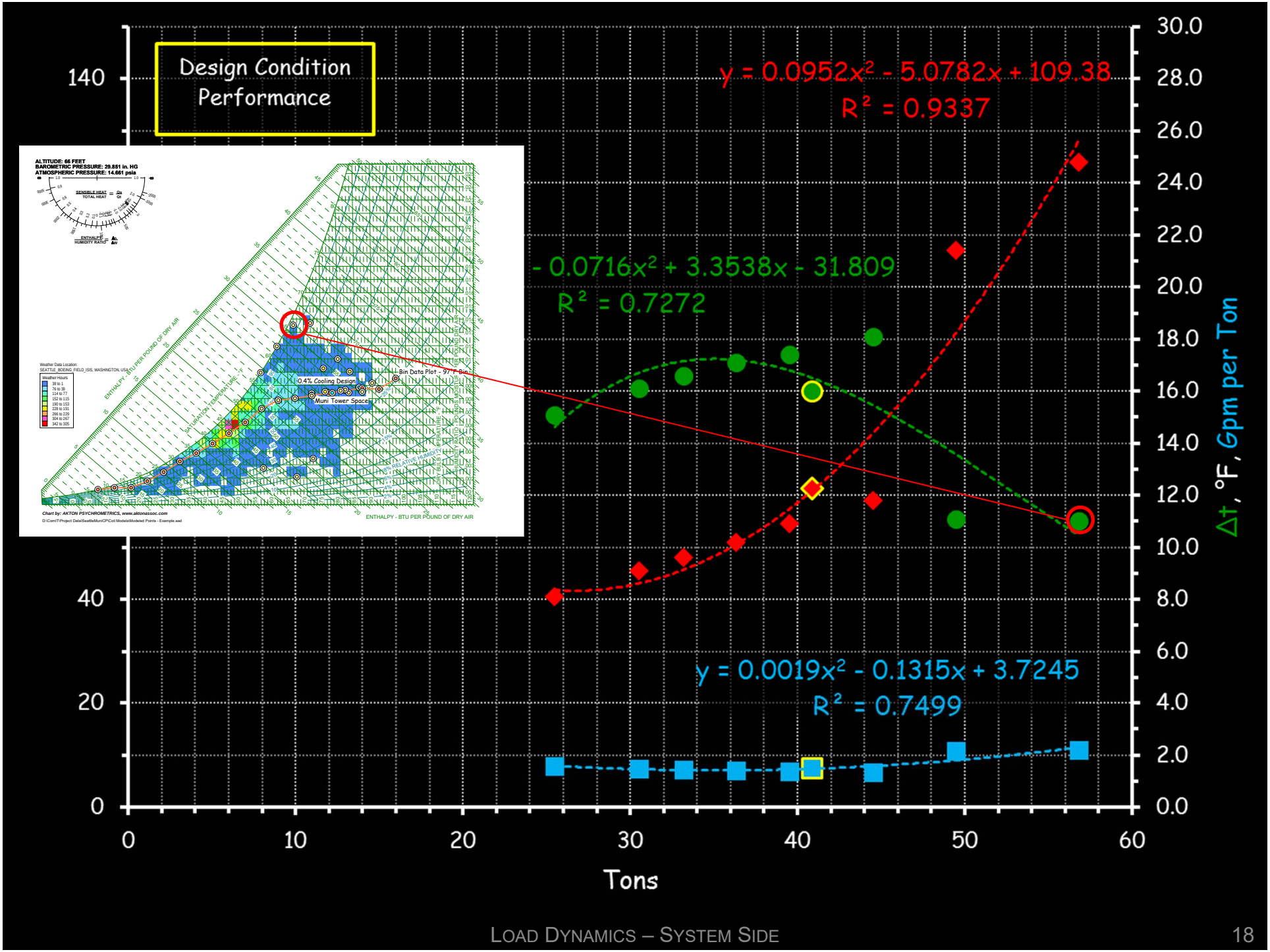


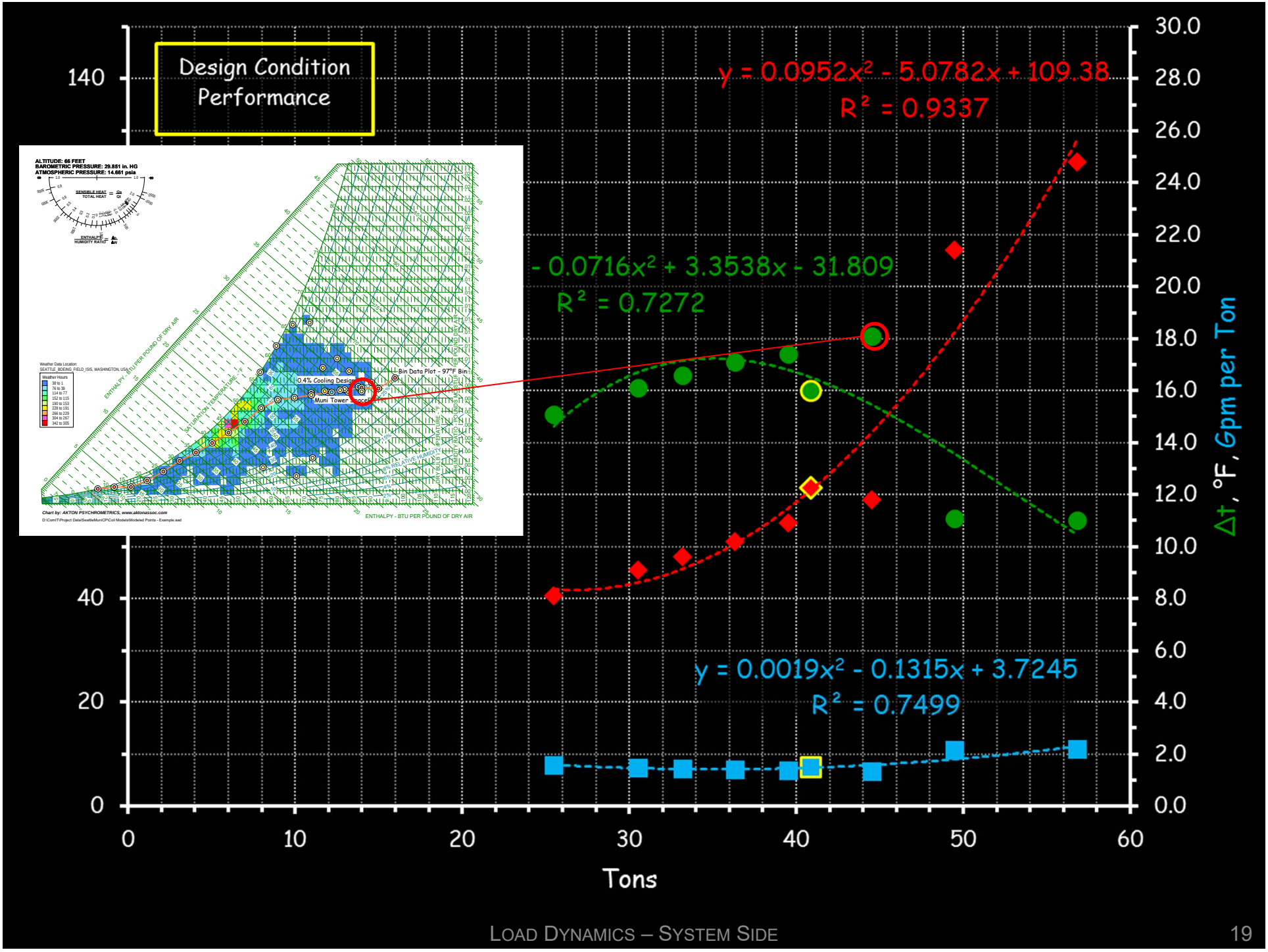
The Results

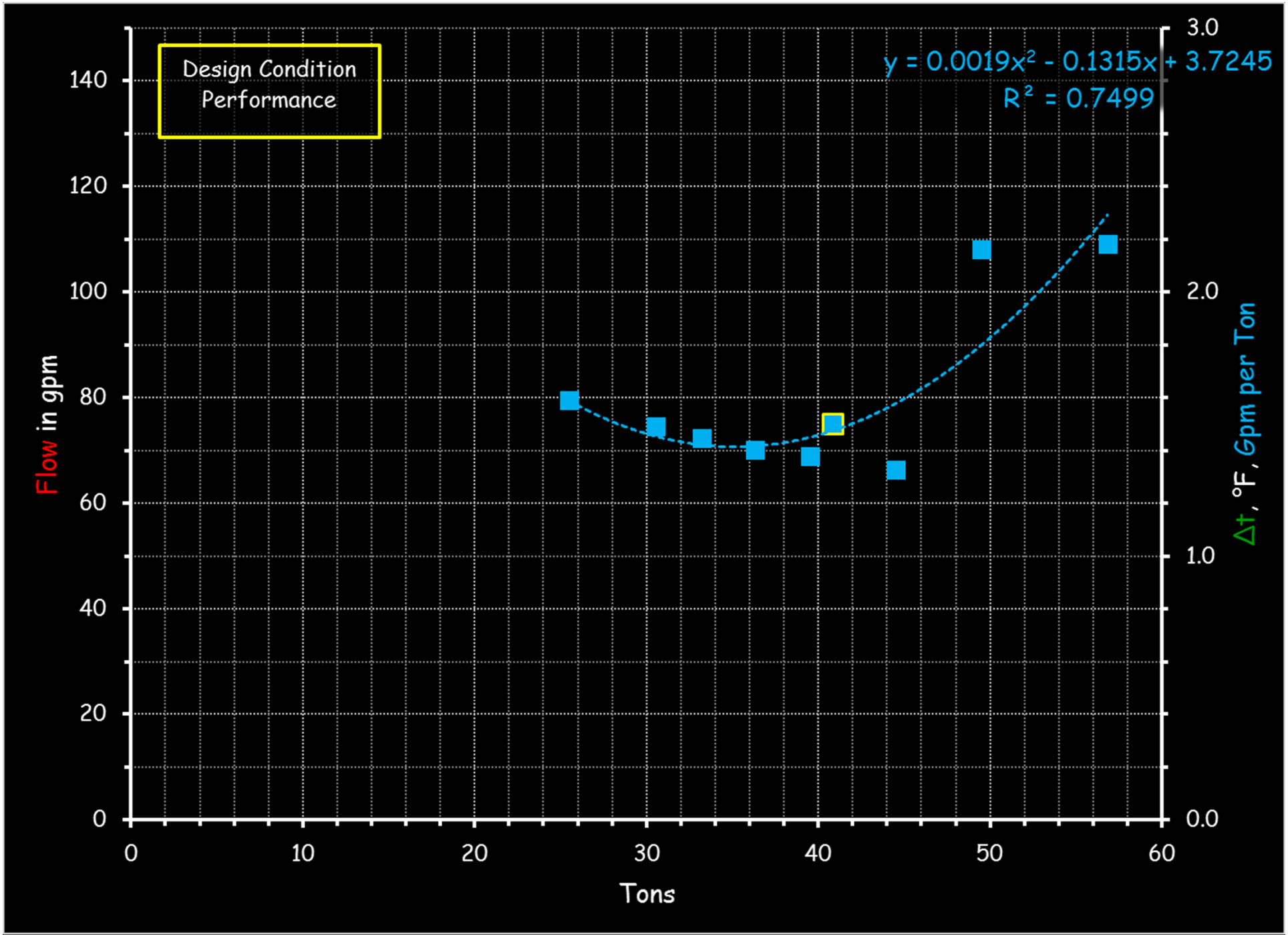
Design Flow and Leaving Conditions, Humid Outside




Design Condition Performance
y = 0.0952x² - 5.0782x + 109.38
R² = 0.9337
- 0.0716x² + 3.3538x - 31.809
R² = 0.7272
y = 0.0019x² - 0.1315x + 3.7245
R² = 0.7499
Δt, °F, Gpm per Ton
Tons
0
10
20
30
40
50
60
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
140
40
20
0
ALTITUDE: 66 FEET
BAROMETRIC PRESSURE: 29.851 in. HG
ATMOSPHERIC PRESSURE: 14.661 psia
Bin Data Plot - 97°F Bin
0.4% Cooling Design
Muni Tower Space
ENTHALPY - BTU PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

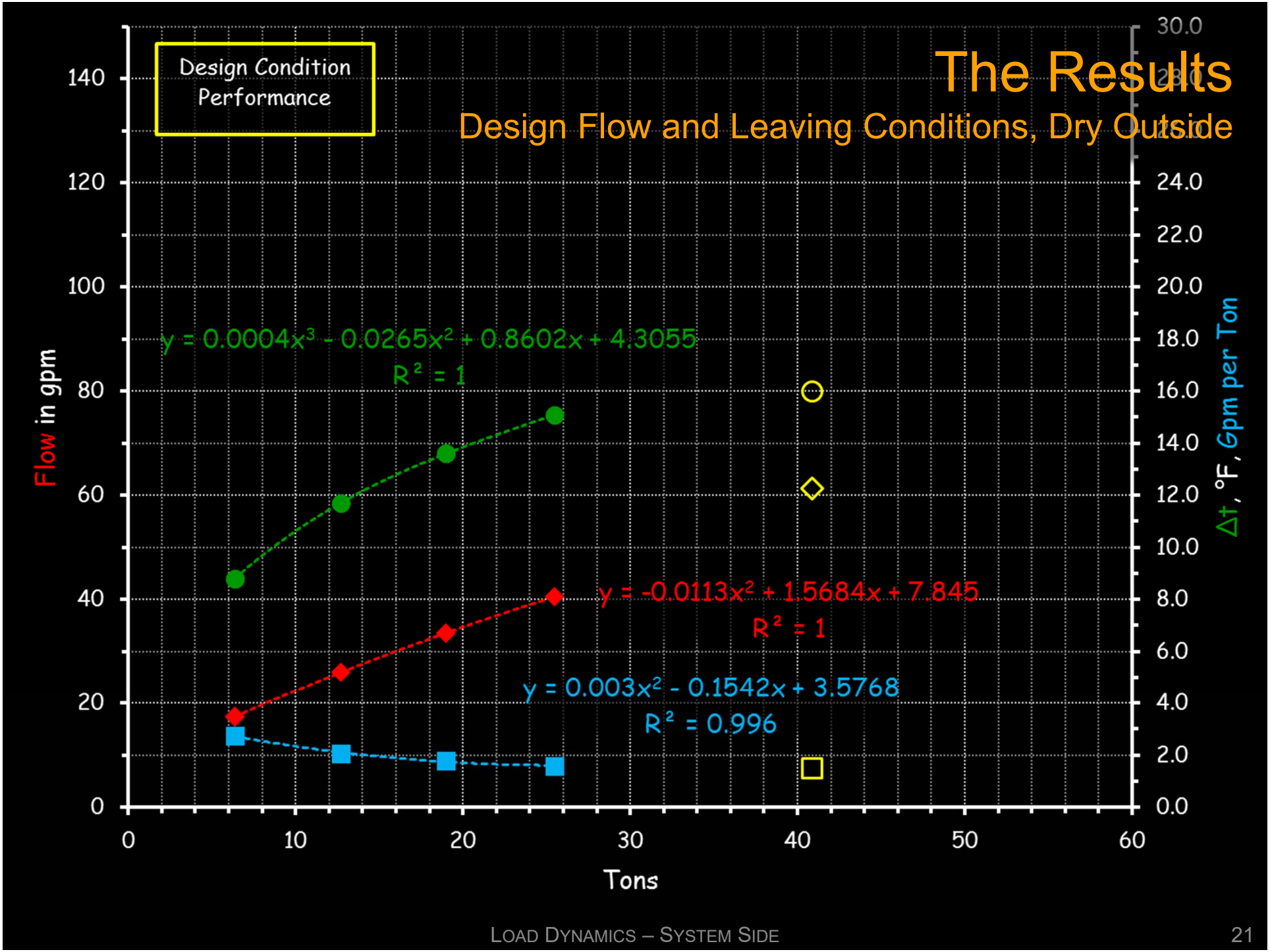

Design Condition Performance
y = 0.0952x² - 5.0782x + 109.38
R² = 0.9337
- 0.0716x² + 3.3538x - 31.809
R² = 0.7272
y = 0.0019x² - 0.1315x + 3.7245
R² = 0.7499
Δt, °F, Gpm per Ton
Tons
0
10
20
30
40
50
60
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
0
20
40
140
ALTITUDE: 66 FEET
BAROMETRIC PRESSURE: 29.851 in. HG
ATMOSPHERIC PRESSURE: 14.661 psia
0.4% Cooling Design
Muni Tower Space
Bin Data Plot - 97°F Dry
ENTHALPY - BTU PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com

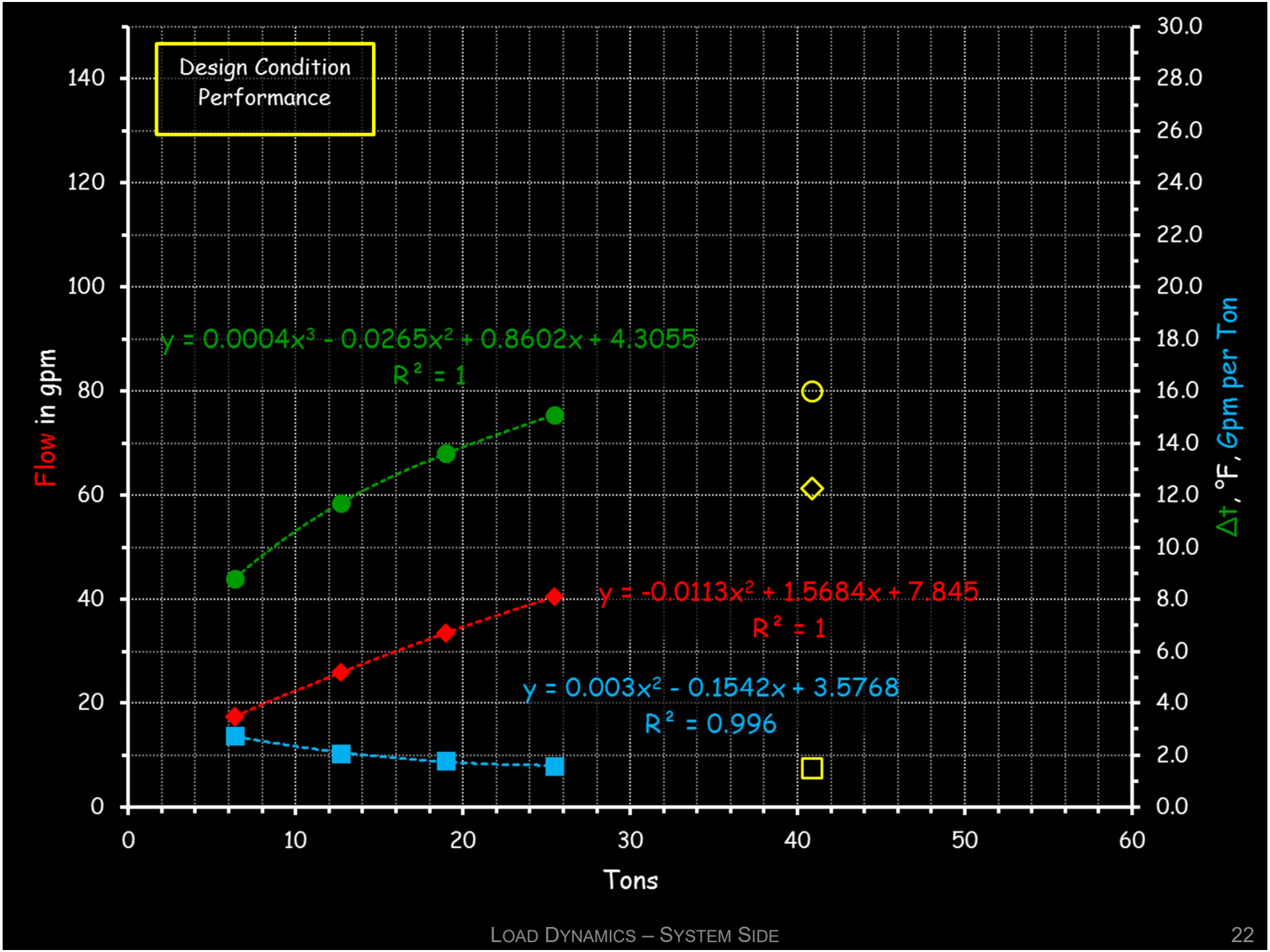

Design Condition Performance
y = 0.0952x² - 5.0782x + 109.38
R² = 0.9337
- 0.0716x² + 3.3538x - 31.809
R² = 0.7272
y = 0.0019x² - 0.1315x + 3.7245
R² = 0.7499
Tons
Δt, °F, Gpm per Ton
0
10
20
30
40
50
60
0
20
40
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
ALTITUDE: 66 FEET
BAROMETRIC PRESSURE: 29.851 in. HG
ATMOSPHERIC PRESSURE: 14.661 psia
Weather Data Location:
SEATTLE, BOEING_FIELD_ISIS, WASHINGTON, USA
Weather Hours
38 to 1
76 to 38
114 to 77
152 to 115
190 to 153
228 to 191
266 to 229
304 to 267
342 to 305
0.4% Cooling Design
Muni Tower Space
Bin Data Plot - 97°F Bin
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\Com\T\Project Data\Seattle\Muni\CP\Coil Models\Modeled Points - Example.asd

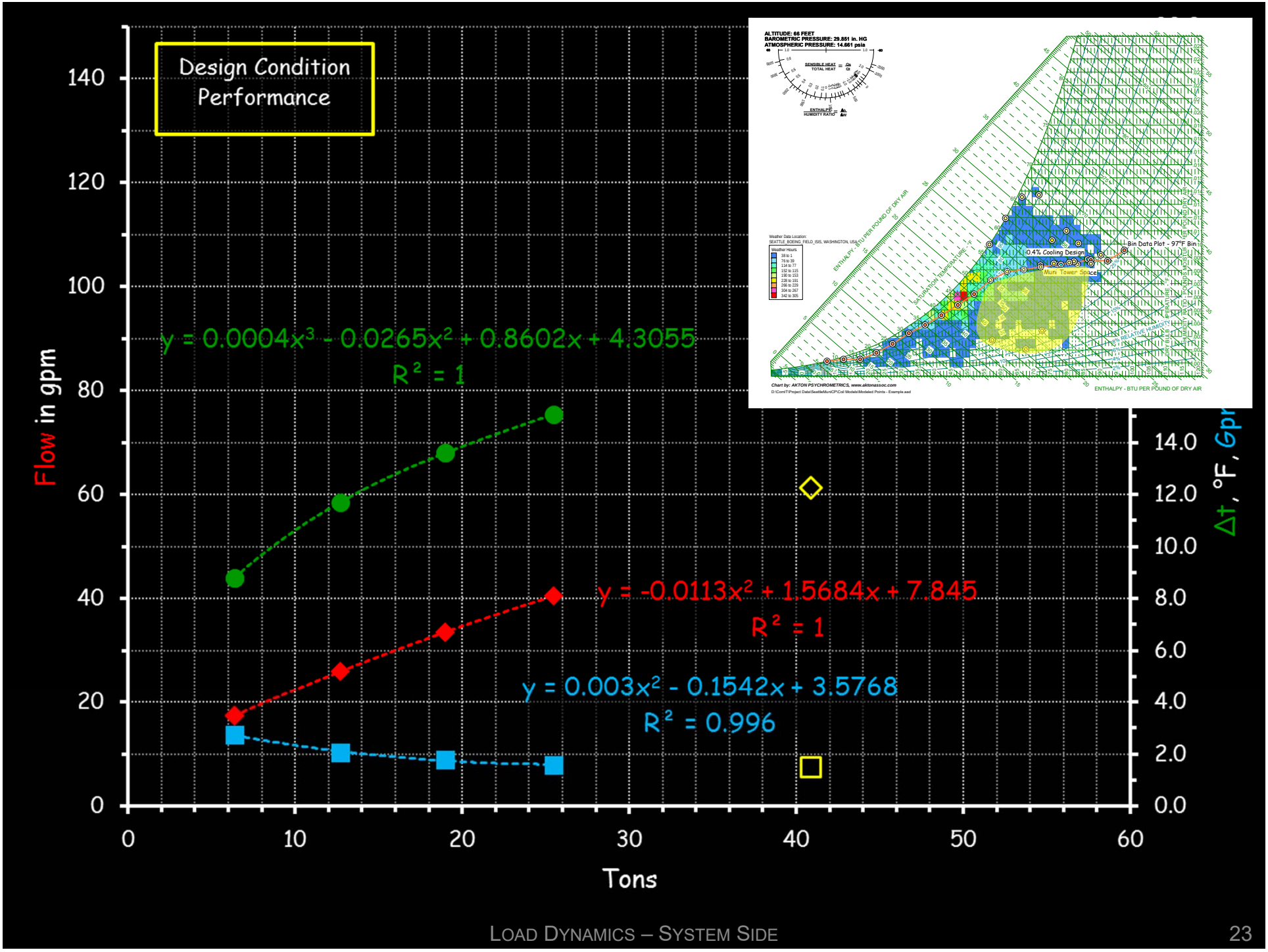

Design Condition
Performance
y = 0.0019x² - 0.1315x + 3.7245
R² = 0.7499
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
1.0
2.0
3.0
0
10
20
30
40
50
60

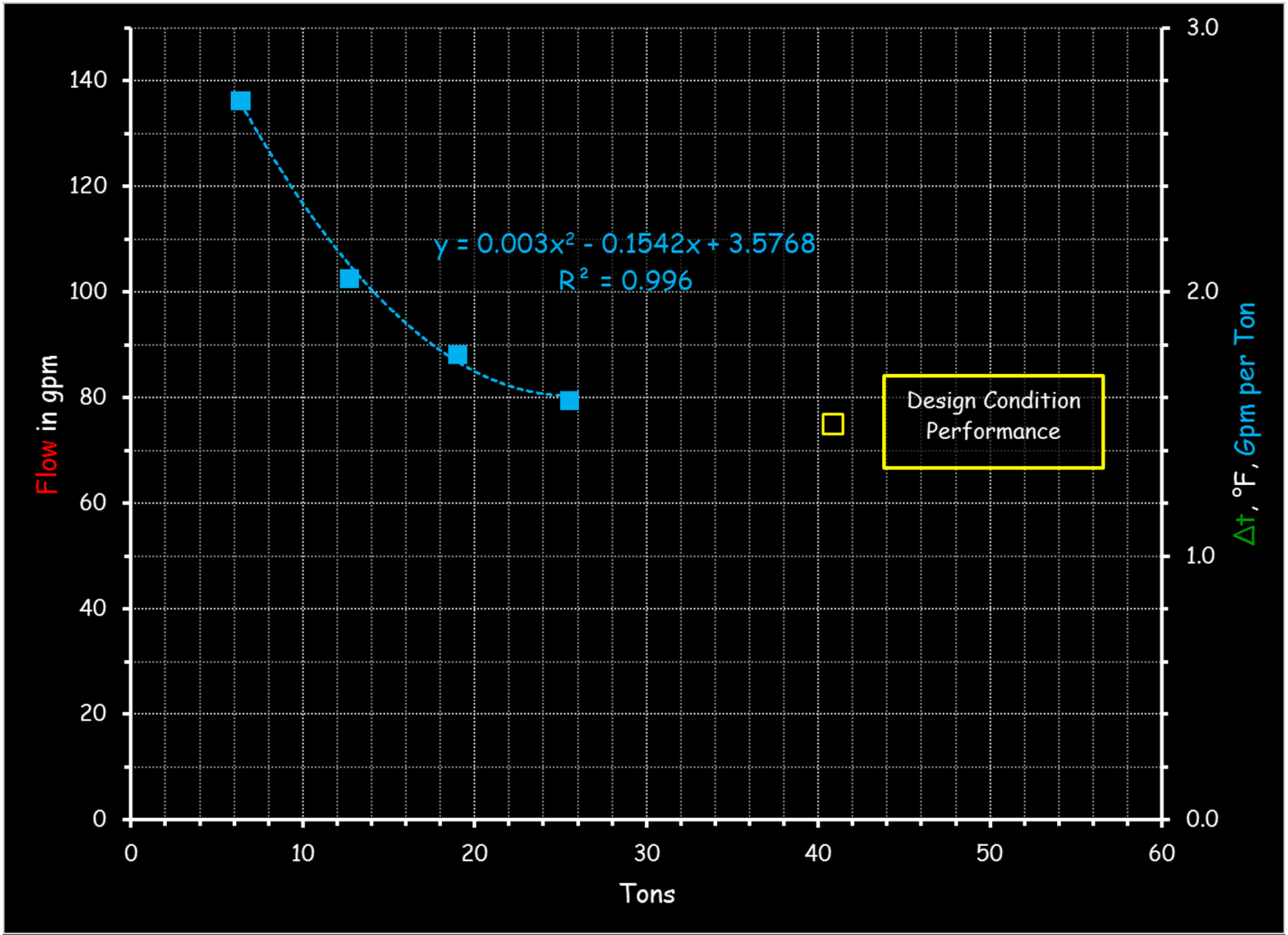
The Results

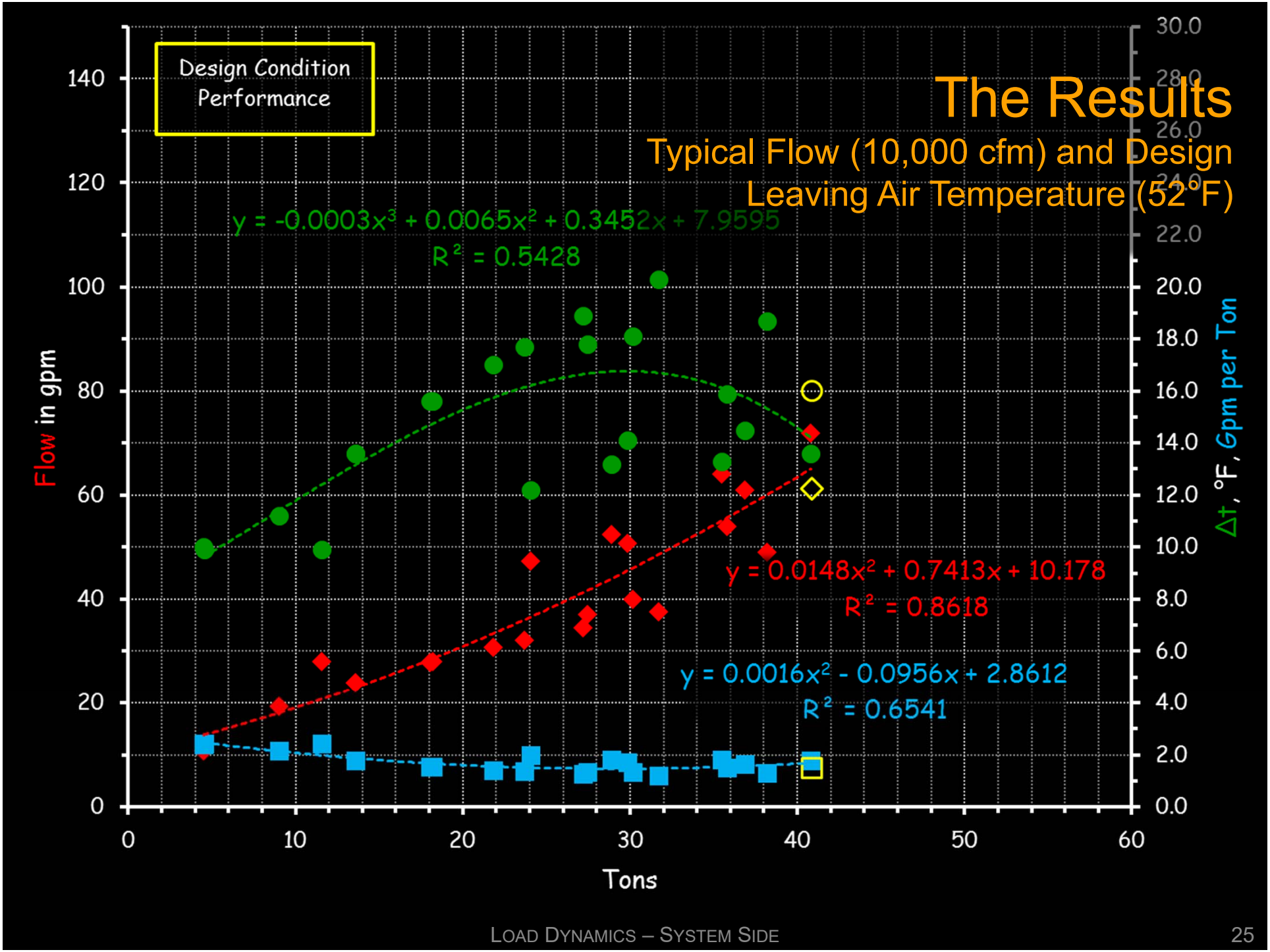
Design Flow and Leaving Conditions, Dry Outside

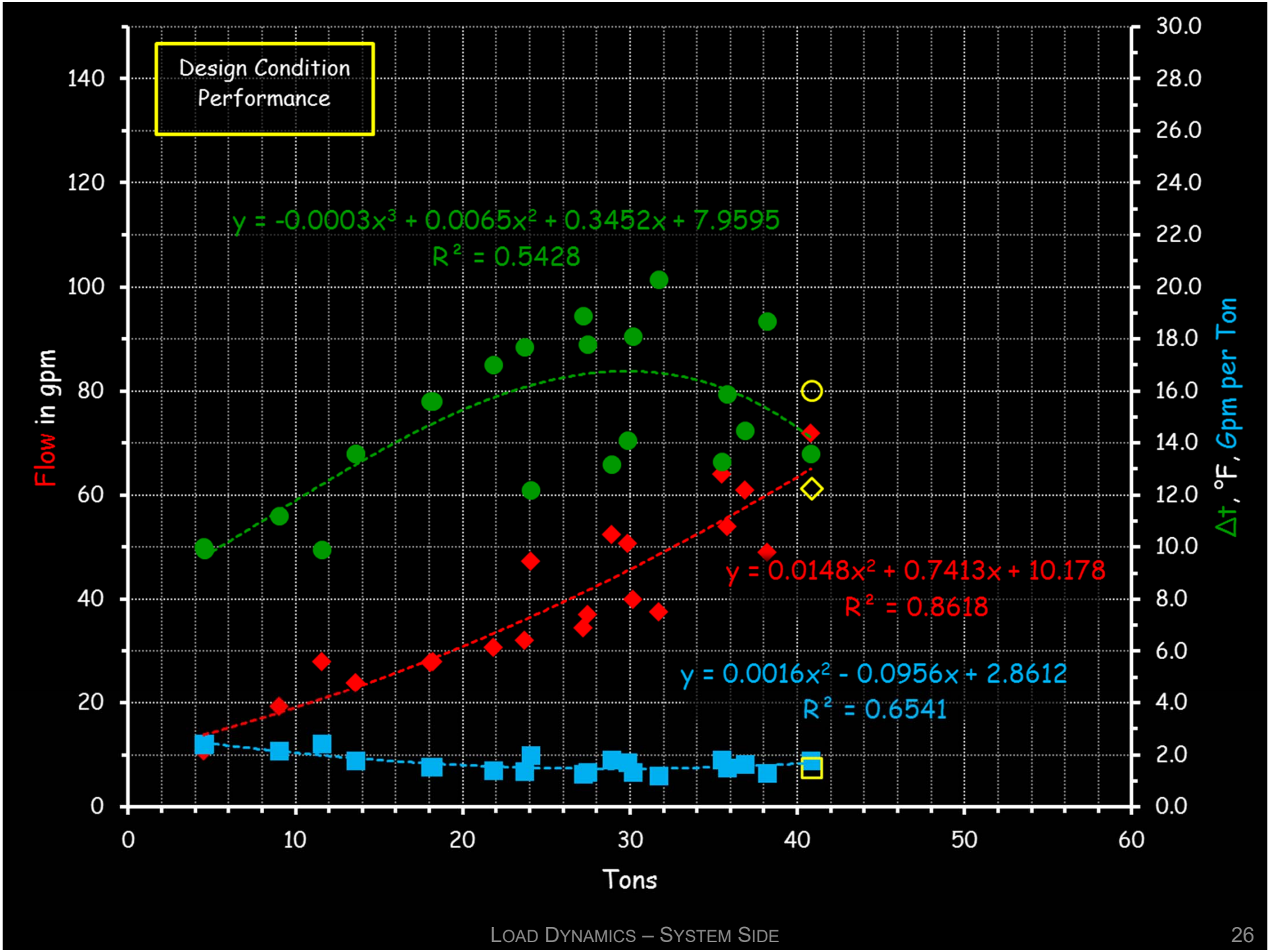


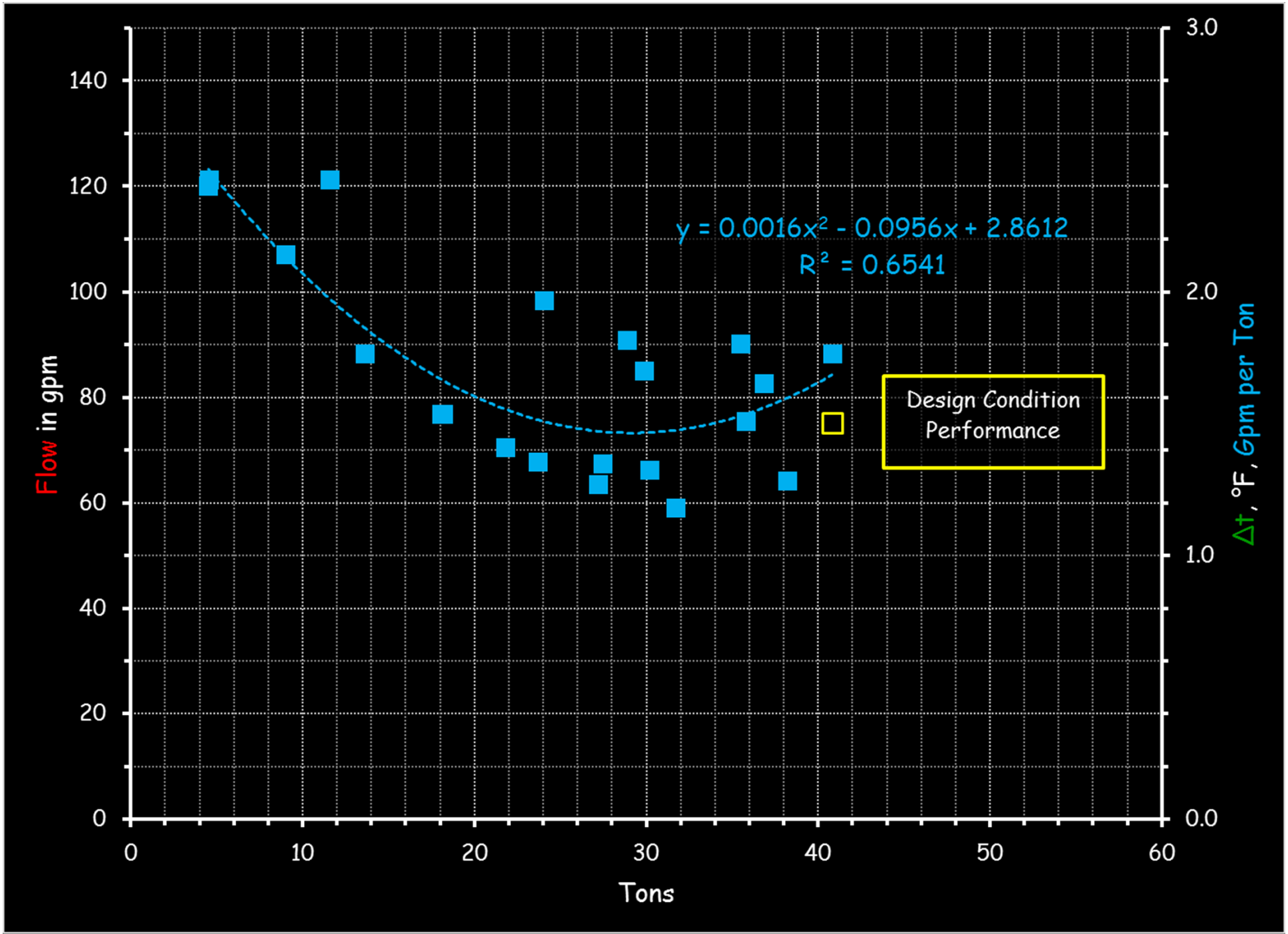

Design Condition
Performance
Flow in gpm
Δt, °F, Gpm per Ton
Tons
y = 0.0004x³ - 0.0265x² + 0.8602x + 4.3055
R² = 1
y = -0.0113x² + 1.5684x + 7.845
R² = 1
y = 0.003x² - 0.1542x + 3.5768
R² = 0.996
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
0
10
20
30
40
50
60

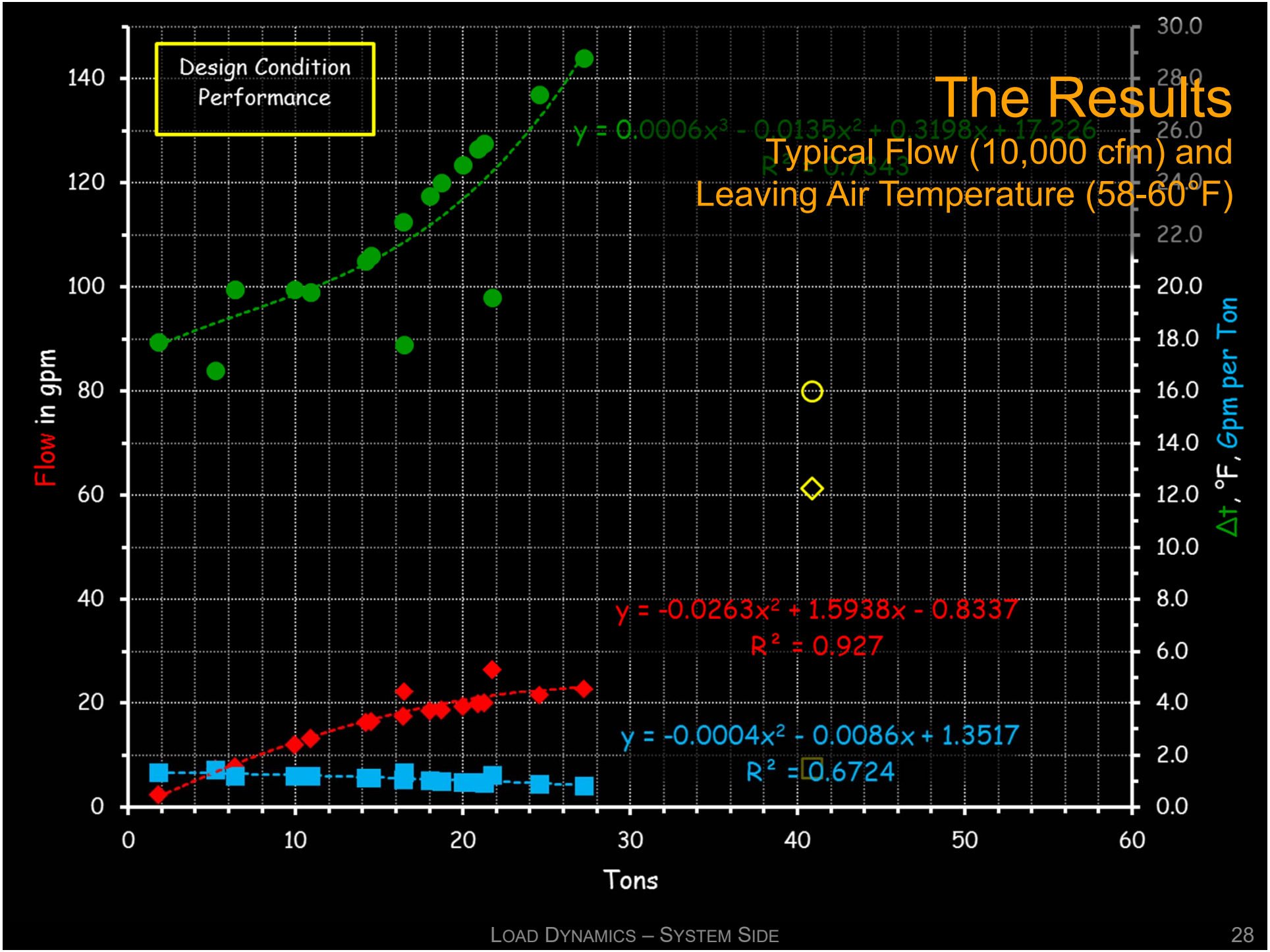

Design Condition Performance
Flow in gpm
Tons
Δt, °F, Gpm
y = 0.0004x³ - 0.0265x² + 0.8602x + 4.3055
R² = 1
y = -0.0113x² + 1.5684x + 7.845
R² = 1
y = 0.003x² - 0.1542x + 3.5768
R² = 0.996
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
ALTITUDE: 66 FEET
BAROMETRIC PRESSURE: 29.851 in. HG
ATMOSPHERIC PRESSURE: 14.661 psia
Bin Data Plot - 97°F Bin
0.4% Cooling Design
Muni Tower Space
ENTHALPY - BTU PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com


Flow in gpm
Δt, °F, Gpm per Ton
Tons
y = 0.003x² - 0.1542x + 3.5768
R² = 0.996
Design Condition Performance
0
20
40
60
80
100
120
140
0.0
1.0
2.0
3.0
0
10
20
30
40
50
60


Design Condition Performance
The Results
Typical Flow (10,000 cfm) and Design Leaving Air Temperature (52°F)
y = -0.0003x³ + 0.0065x² + 0.3452x + 7.9595
R² = 0.5428
y = 0.0148x² + 0.7413x + 10.178
R² = 0.8618
y = 0.0016x² - 0.0956x + 2.8612
R² = 0.6541
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
26.0
30.0

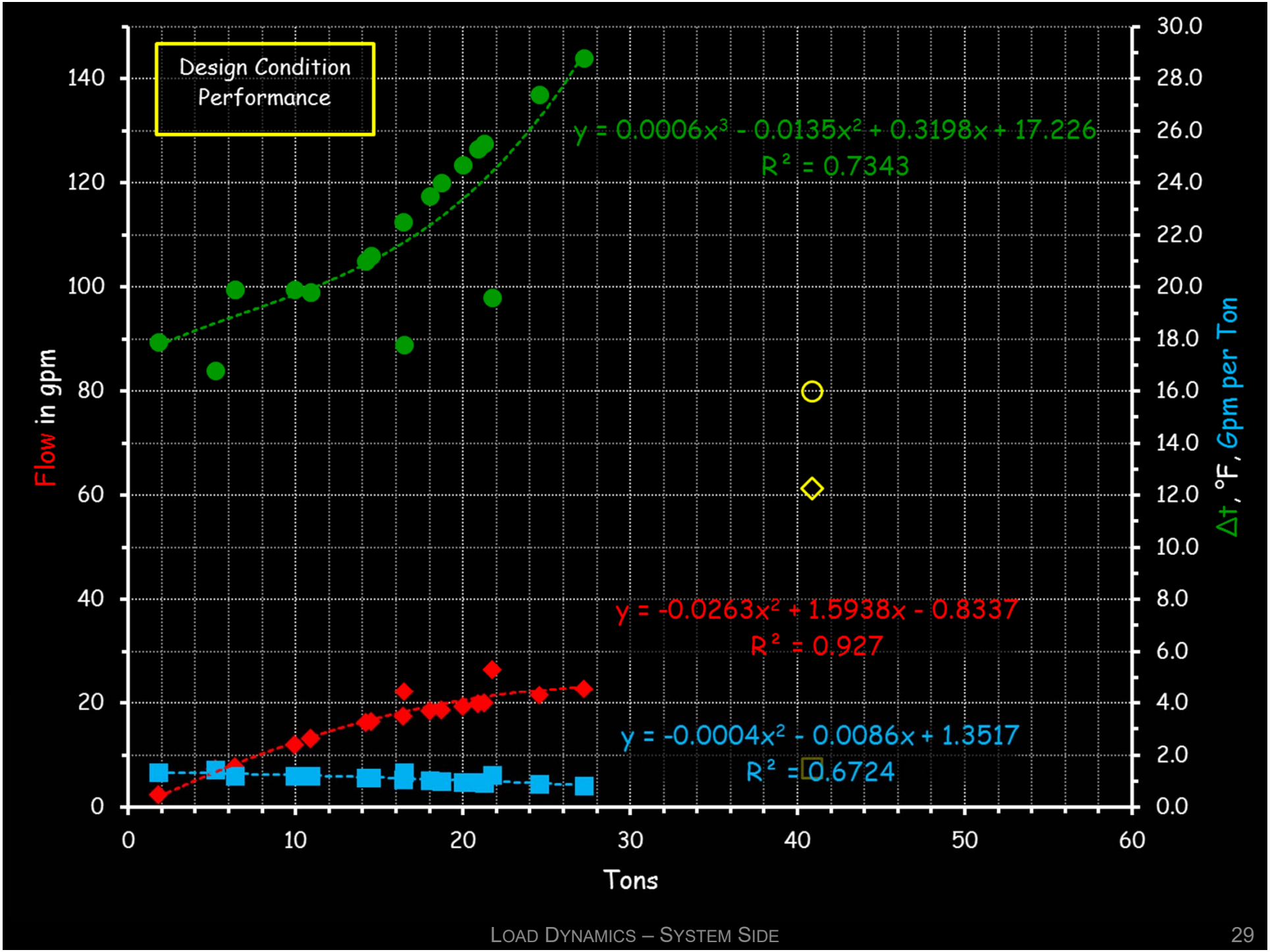

Design Condition
Performance
y = -0.0003x³ + 0.0065x² + 0.3452x + 7.9595
R² = 0.5428
y = 0.0148x² + 0.7413x + 10.178
R² = 0.8618
y = 0.0016x² - 0.0956x + 2.8612
R² = 0.6541
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
0
10
20
30
40
50
60

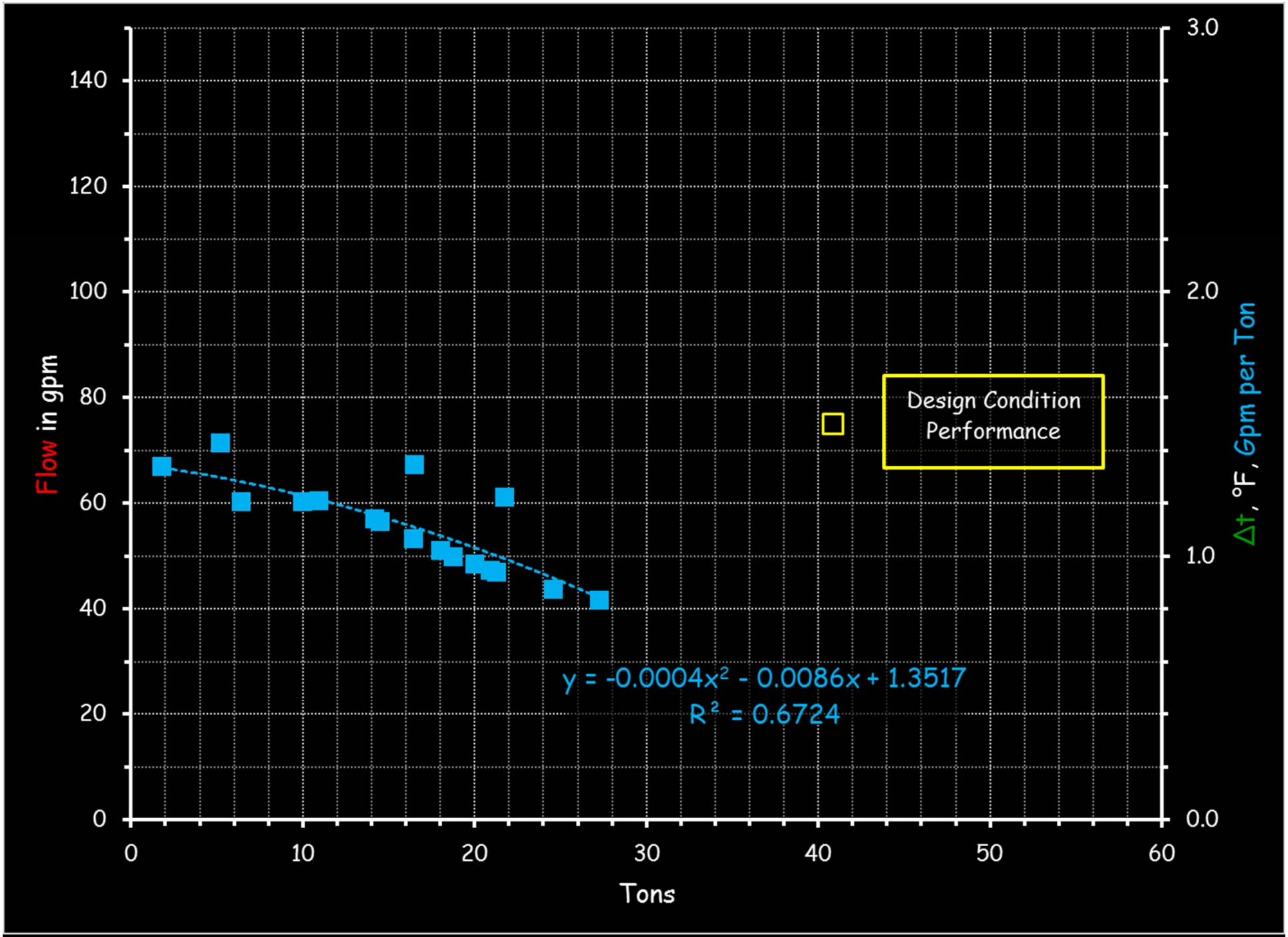

Flow in gpm
Δt, °F, Gpm per Ton
Tons
y = 0.0016x² - 0.0956x + 2.8612
R² = 0.6541
Design Condition Performance
0
20
40
60
80
100
120
140
0.0
1.0
2.0
3.0
0
10
20
30
40
50
60

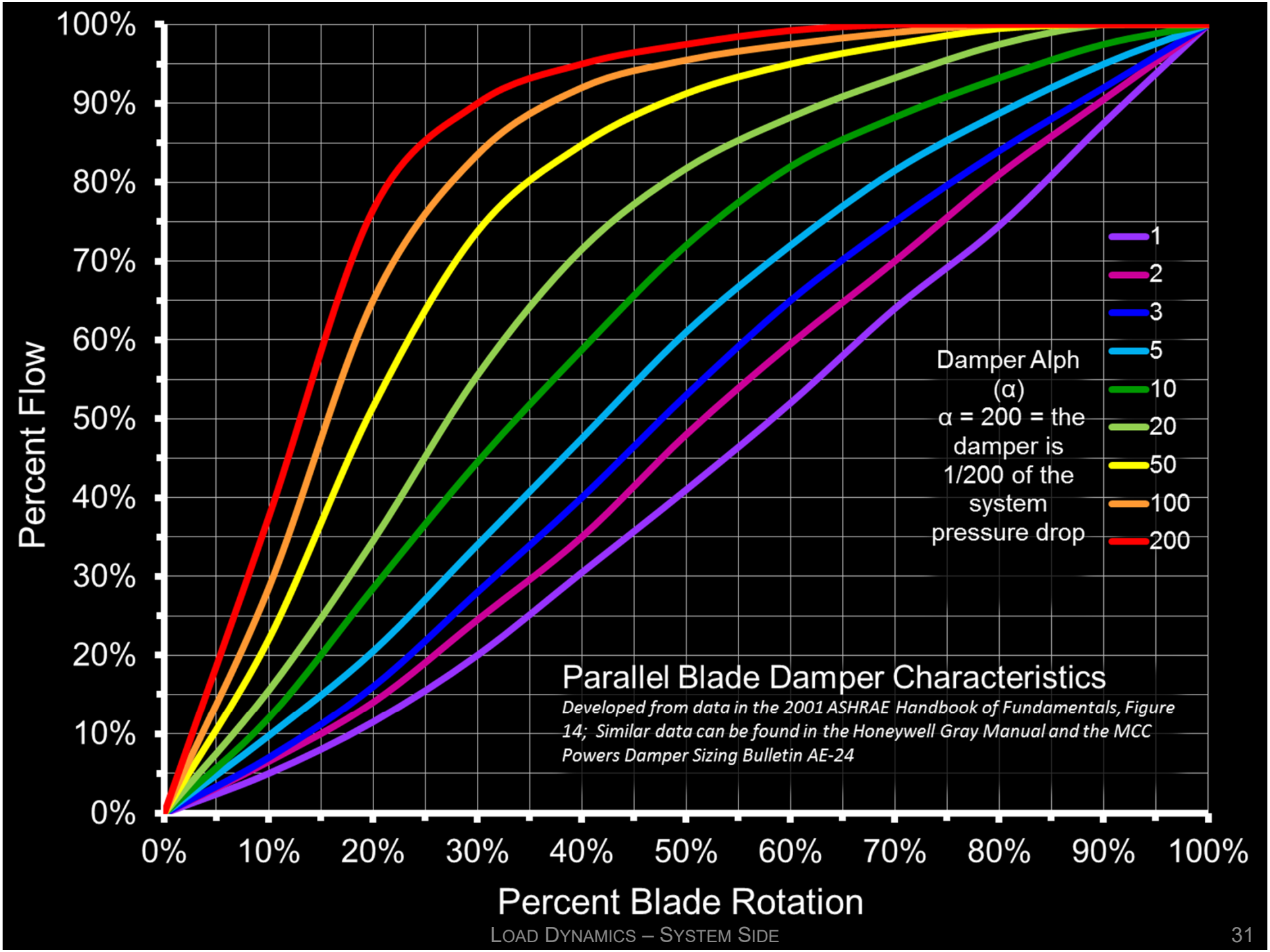


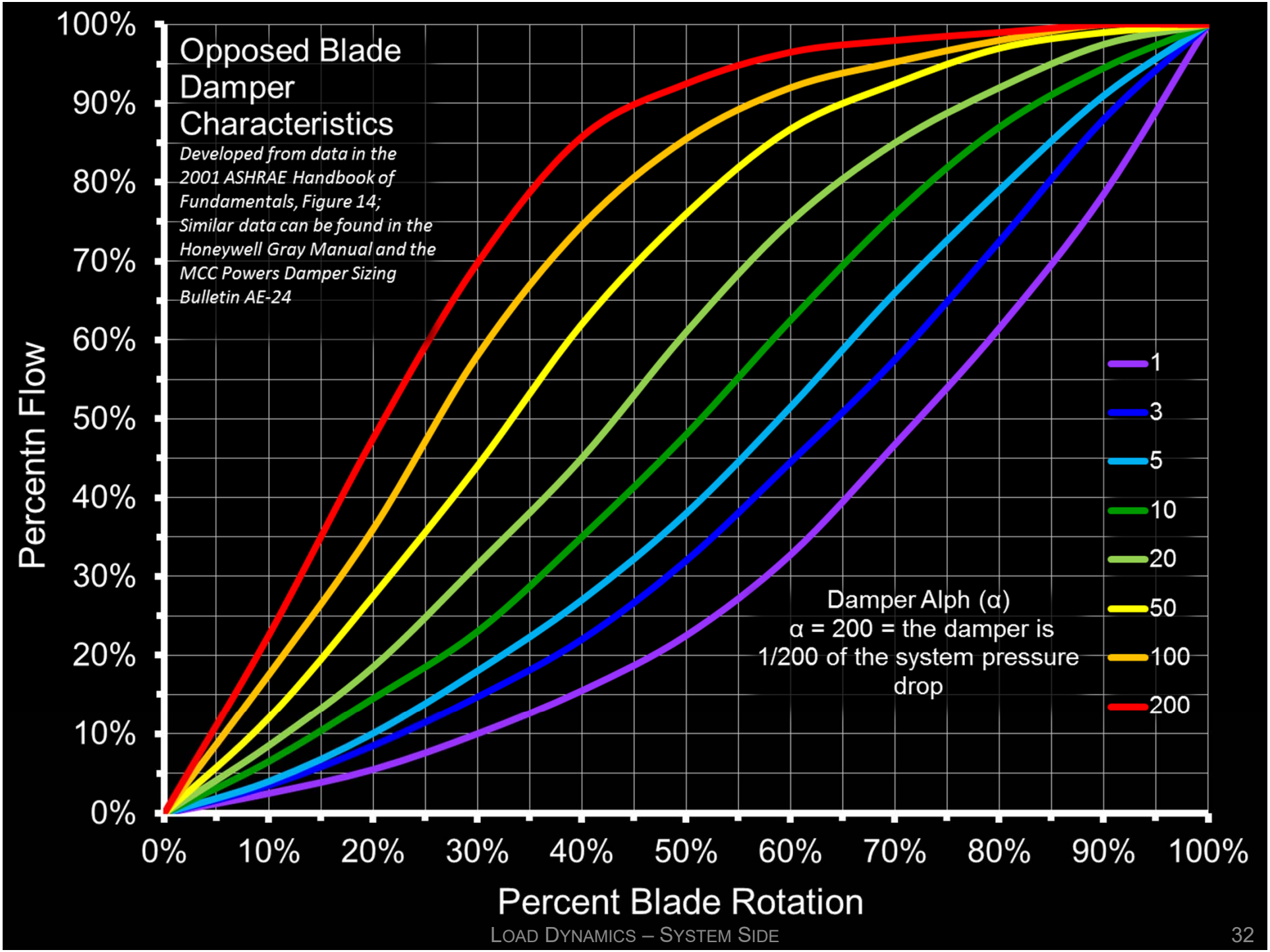
The Results

Typical Flow (10,000 cfm) and Leaving Air Temperature (58-60°F)


Design Condition
Performance
y = 0.0006x³ - 0.0135x² + 0.3198x + 17.226
R² = 0.7343
y = -0.0263x² + 1.5938x - 0.8337
R² = 0.927
y = -0.0004x² - 0.0086x + 1.3517
R² = 0.6724
Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
0
10
20
30
40
50
60

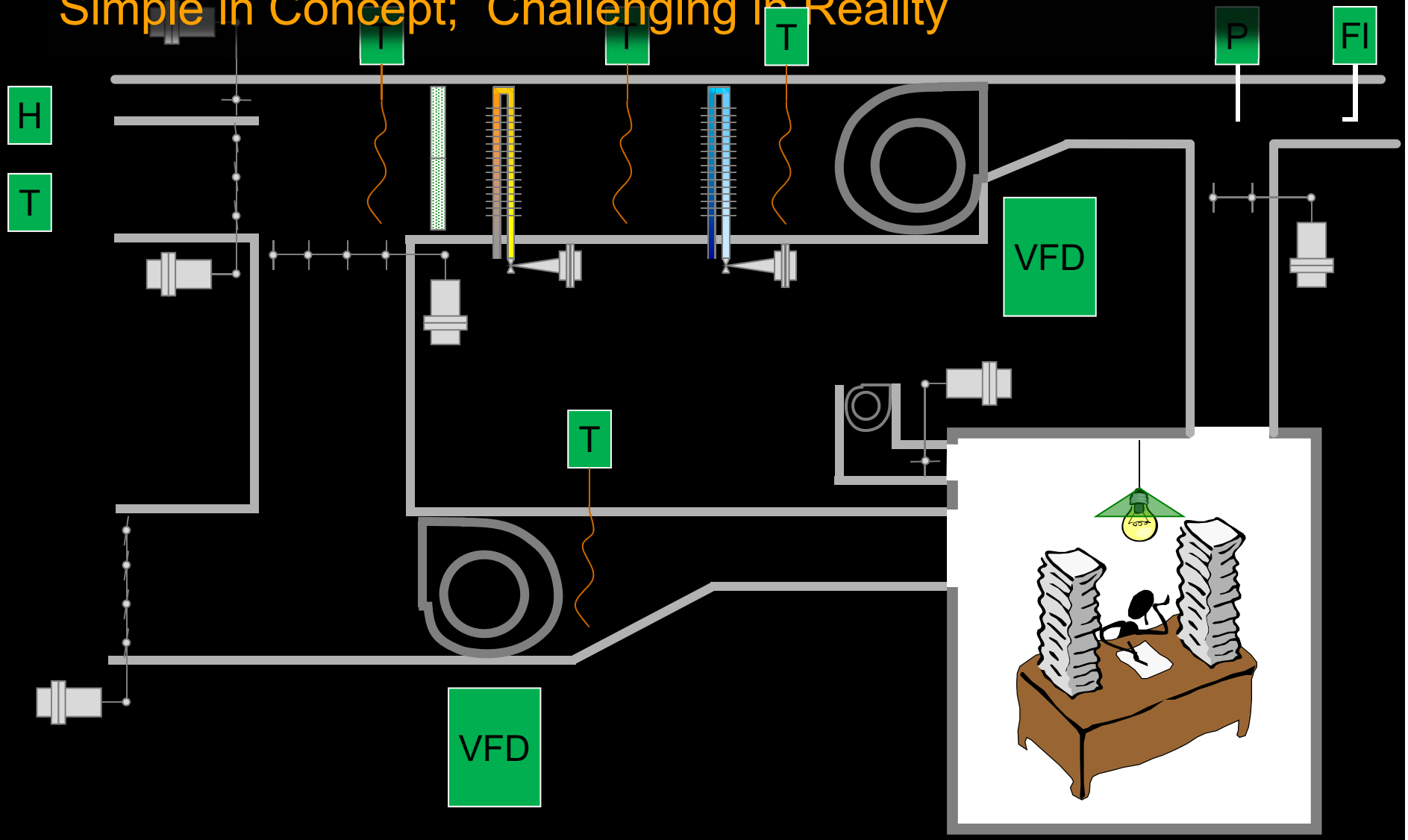

Flow in gpm
Δt, °F, Gpm per Ton
Tons
0
20
40
60
80
100
120
140
0.0
1.0
2.0
3.0
0
10
20
30
40
50
60
Design Condition
Performance
y = -0.0004x² - 0.0086x + 1.3517
R² = 0.6724

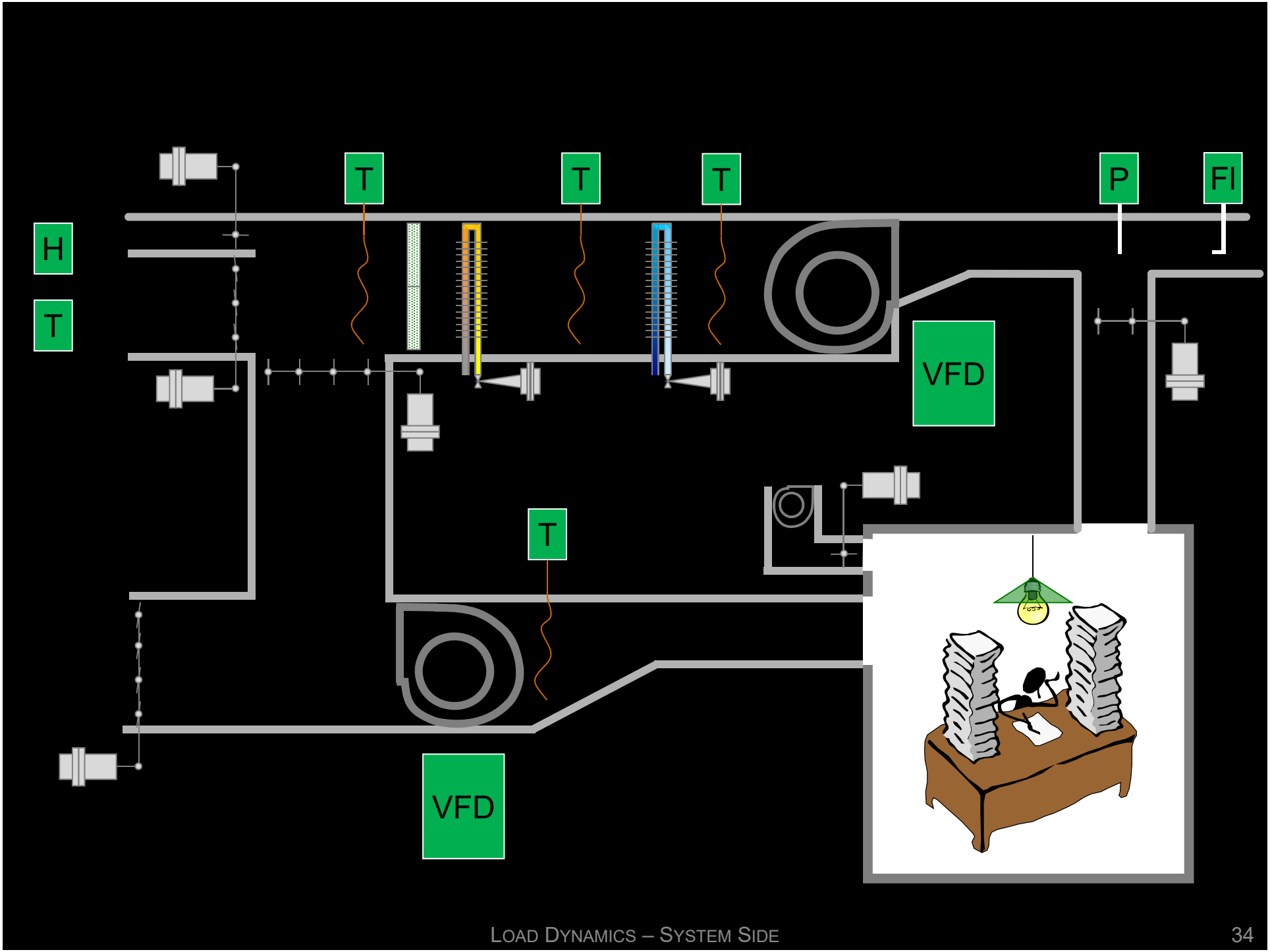

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Flow
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Blade Rotation
Damper Alph
(α)
α = 200 = the damper is 1/200 of the system pressure drop
1
2
3
5
10
20
50
100
200
Parallel Blade Damper Characteristics
Developed from data in the 2001 ASHRAE Handbook of Fundamentals, Figure 14; Similar data can be found in the Honeywell Gray Manual and the MCC Powers Damper Sizing Bulletin AE-24


Opposed Blade Damper Characteristics
Developed from data in the 2001 ASHRAE Handbook of Fundamentals, Figure 14; Similar data can be found in the Honeywell Gray Manual and the MCC Powers Damper Sizing Bulletin AE-24
Percentn Flow
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Blade Rotation
Damper Alph (α)
α = 200 = the damper is 1/200 of the system pressure drop
1
3
5
10
20
50
100
200

Match the System Flow Rate to the Load

Simple in Concept; Challenging in Reality




H
T
T
T
T
P
FI
VFD
T
VFD

Aside from those things, it should not be too hard to get a VAV system to work