A Field Perspective on Pneumatic Control and Actuation Systems

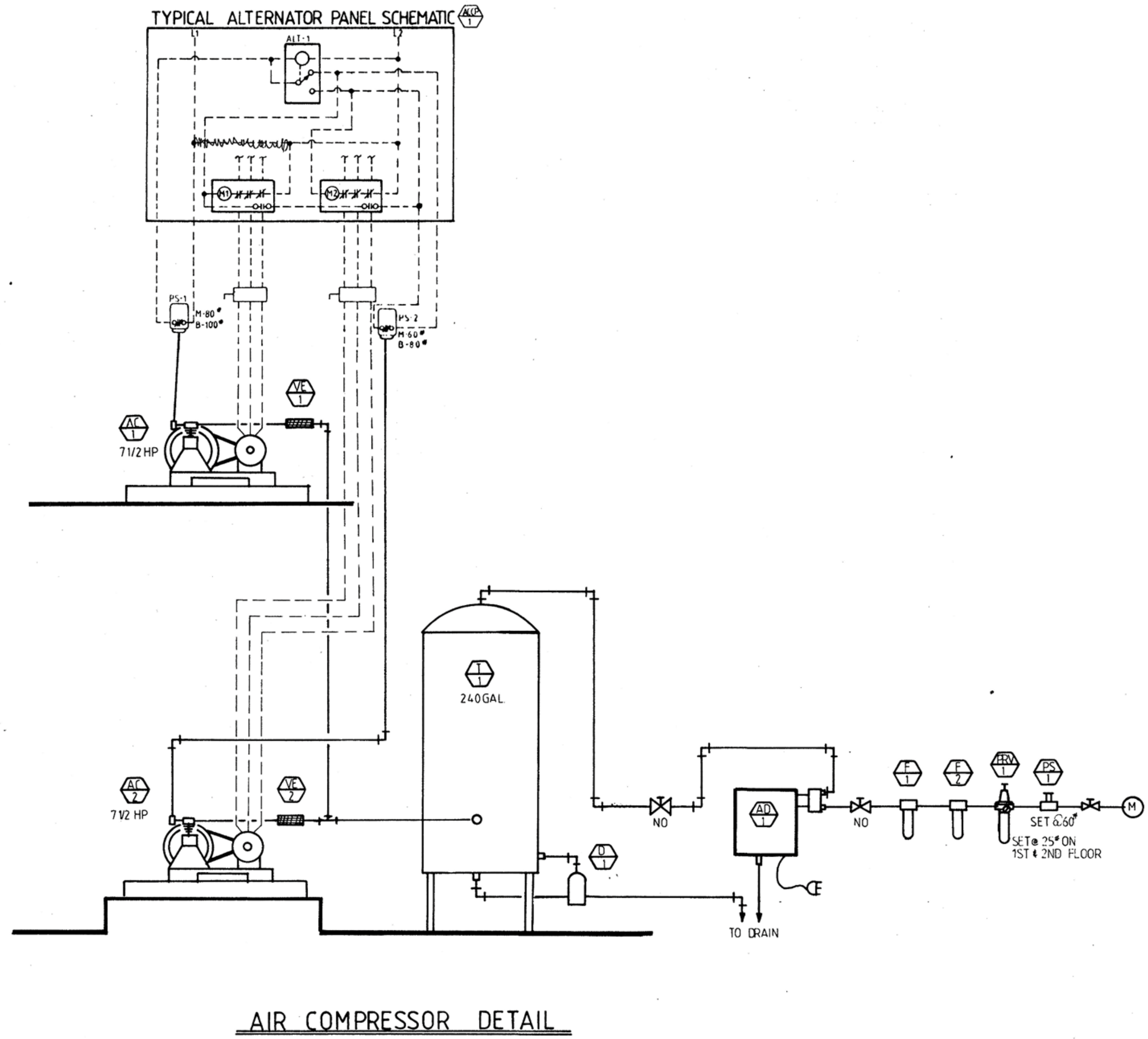
Control Air Systems

Presented By:

David Sellers

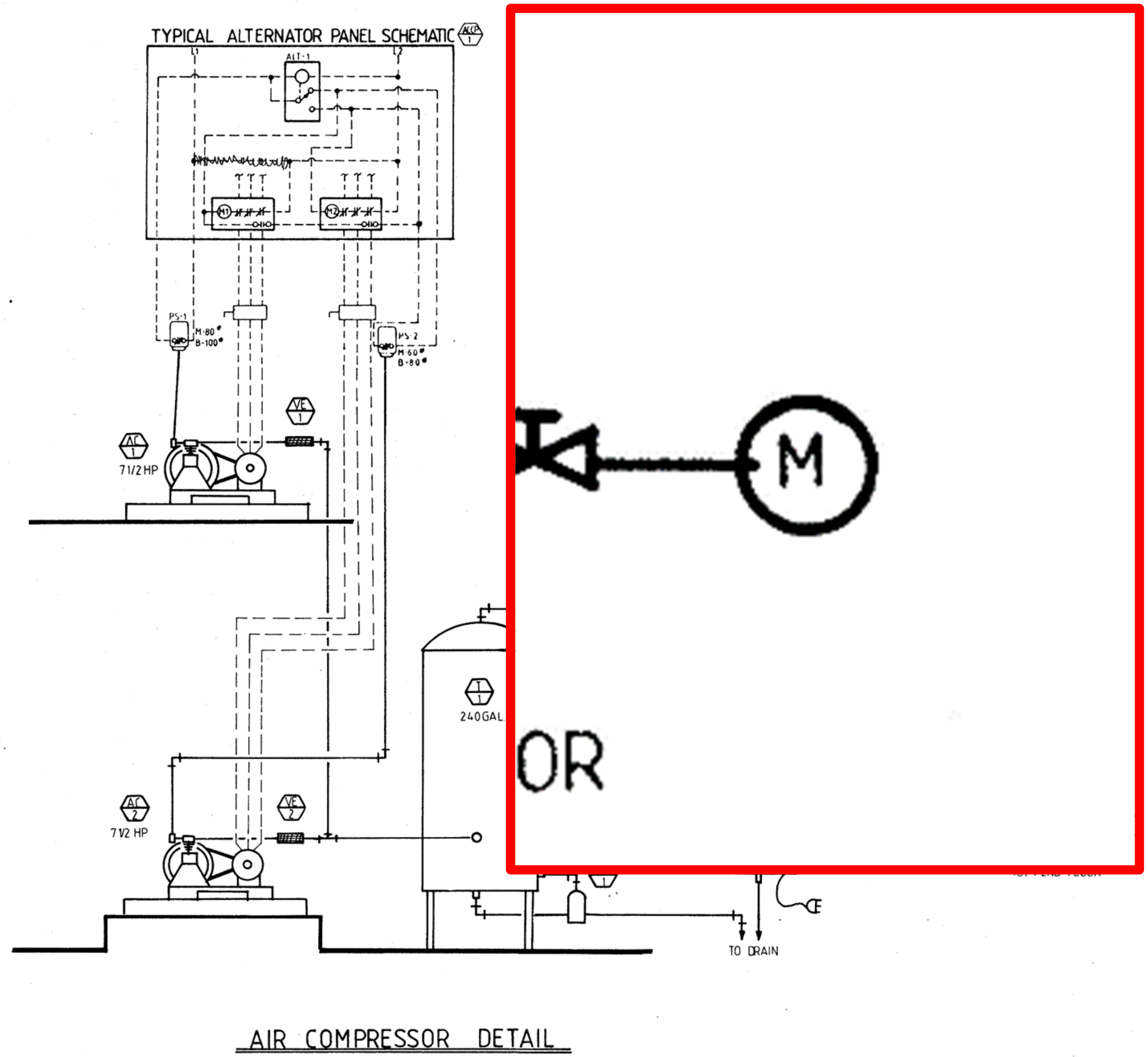
Senior Engineer, Facility Dynamics Engineering

A Typical Pneumatic Air Supply System



A Typical Pneumatic Air Supply System

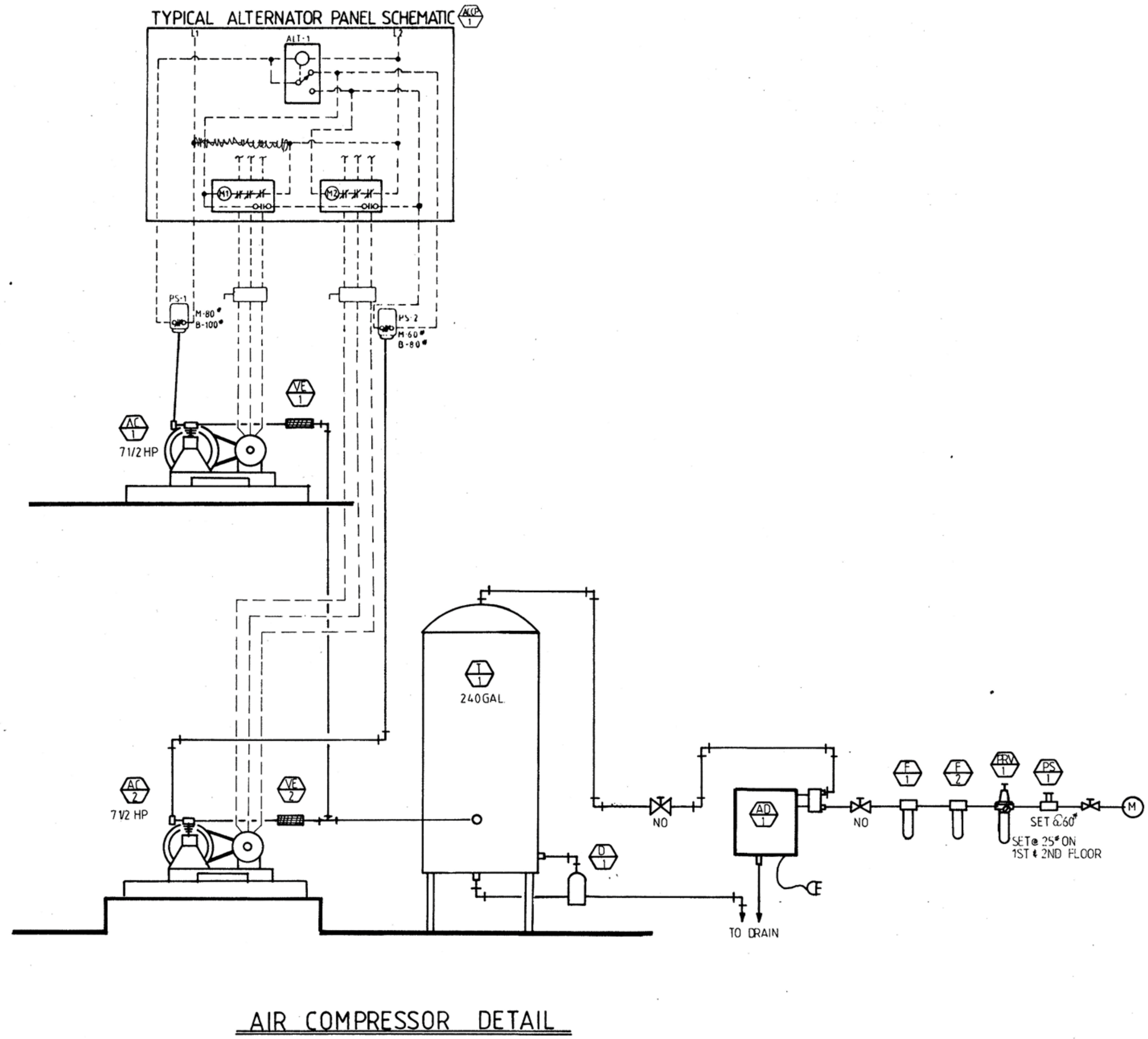
“Main Air”



A Typical Pneumatic Air Supply System

Key Points

1. Pneumatics are truly "plug and play" Jay Santos



Pneumatics are “Plug and Play” Jay Santos

You could use this transmitter …

Pneumatics are "Plug and Play" Jay Santos

You could use this transmitter …

… with this controller …

Pneumatics are "Plug and Play" Jay Santos

You could use this transmitter …

… with this controller …

… and this set point adjuster …

Pneumatics are “Plug and Play” Jay Santos

You could use this transmitter …

… with this controller …

… and this set point adjuster …

… and this interlock …

Pneumatics are “Plug and Play” Jay Santos

You could use this transmitter …

… with this controller …

… and this set point adjuster …

… and this interlock …

… and this final control element ….

Pneumatics are “Plug and Play” Jay Santos

You could use this transmitter …

… with this controller …

… and this set point adjuster …

… and this interlock …

… and this final control element ….

… and it would work just fine

- Physical layer
  - Copper or poly tubing is supported
  - Barbed, compression, soldered, or brazed fittings are supported
- Communications layer
  - 3-15 psig range is standard
  - Anything any range from 0 – 25 psig is supported for signal transmission and sequencing
  - 25 psig power is standard for first tier controllers, 50 psig and higher is supported for distribution and positioning applications and process control

Taking a Look at the “Physical Layer”

- Copper or poly tubing is supported

Taking a Look at the “Physical Layer”

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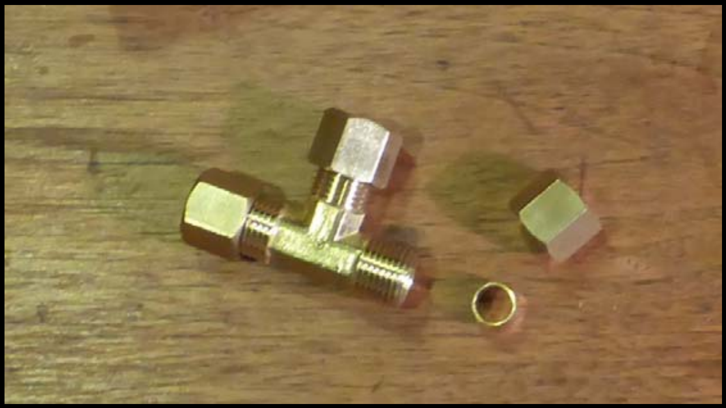

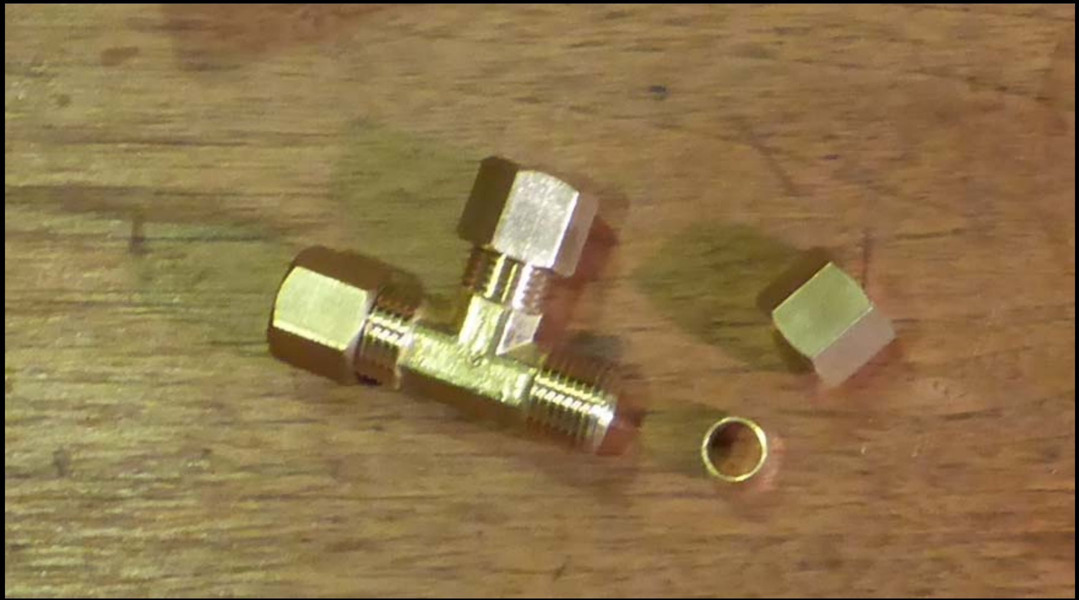

CPChem
PERFORMANCE PIPE™

www.performancepipe.com

Material and Tubing Specifications

Specifications for PLEXCO™ 2600 Instube® Pneumatic Control Tubing

Property	*Test Method*	*Typical Value*
Flame Retardant Compound		
Melt Index	ASTM D 1238	0.6 ± 0.1 g/10 min
Density	ASTM D 792	1.1 ± 0.005 g/cm^3
Tensile Strength – ultimate (20 in./min)	ASTM D 638	> 2000 psi (> 1.8 MPa)
Tensile Elongation – ultimate (20 in./min.)	ASTM D 638	> 600 %
Bending Modulus	ASTM D 747	30,000 ± 5,000 psi (20639 ± 34.5 MPa)
Shore A Hardness	ASTM D 1700	97 ± 3
Shore D Hardness	ASTM D 1700	45 ± 3
Water Absorption	ASTM D 570	5% maximum
Polyethylene Classification	ASTM D 3350	PE 11 or PE 12
Stress-Crack Resistance	ASTM D 1693	> 200 hours non-failure
Brittleness Temperature	ASTM D 745	< -104.8°F (< -76°C)
Pneumatic Instrument Control Tubing		
Burst Pressure	ASTM D 1599	5/32" – > 500 psi (> 3.4 MPa) 1/4" – > 500 psi (> 3.4 MPa) 3/8" – > 500 psi (> 3.4 MPa) 1/2" – > 350 psi (> 3.4 MPa)
Minimum Bend Radius	–	5/32" – 0.50 in. (13 mm) 1/4" – 0.75 in. (19 mm) 3/8" – 1.50 in. (38 mm) 1/2" – 1.88 in. (48 mm)
Maximum Allowable Pulling Load During Installation	–	5/32" – 15 lb. (66 N) 1/4" – 33 lb. (147 N) 3/8" – 76 lb. (338 N) 1/2" – 106 lb. (472 N) 5/32" Twintube – 30 lb. (133 N) 1/4" Twintube – 65 lb. (289 N)
Flammability	UL 94 UL 910	V-2 UL Classified (NFPA 90A)
Flame Propagation	UL 1820	< 5 ft (< 1.5 m)
Smoke Density – Peak Optical Density	UL 1820	< 0.5
Smoke Density – Average Optical Density	UL 1820	< 0.15

NOTICE – This table provides typical physical property information for polyethylene compounds used to manufacture DRISCOPLEX™ 2600 tubing products. It is intended for comparing compounds and tubing. It is not a product specification, and it does not establish minimum or maximum values or manufacturing tolerances for compounds or tubing. The typical property values for compound were determined using compression-molded plaques prepared from compound. Values obtained from tests of specimens taken from tubing can vary from these typical values. Performance Pipe has made every reasonable effort to ensure the accuracy of this information, but this table may not provide all necessary information, particularly with respect to special or unusual applications. This information may be changed from time to time without notice. Contact Performance Pipe to determine if you have the most recent edition.

Taking a Look at Poly Ratings

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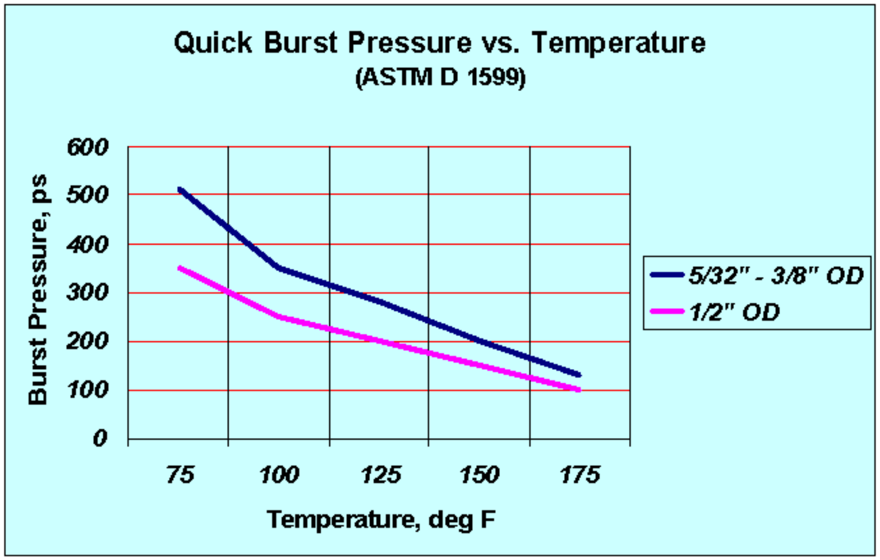


NOTICE - The above chart indicates short term burst pressures as indicated by laboratory tests and does not reflect long term operating burst pressures. No representations of operating burst pressures are expressed or implied.

Taking a Look at Poly Ratings

The Engineering ToolBox

Home www.EngineeringToolBox.com

- **search** is the most efficient way to navigate the Engineering ToolBox!

Plastic Pipes and Maximum Operating Temperatures

ABS, PE, PVC, CPVC, PB, PP and SR - pressure and operating temperatures

Operating Temperature

- is the maximum operating temperatures for plastic pipe materials.

Plastic Pipe Material	Operating Temperature			
	With Pressure		Without Pressure	
	(°F)	(°C)	(°F)	°C)
ABS - Acrylonitrilebutadiene Styrene	100	38	180	82
PE - Polyethylene	100	38	180	82
PVC - Polyvinylchloride	100	38	140	60
CPVC - Chlorinated Polyvinyl Chloride	180	82	180	82
PB - Polybutylene	180	82	200	93
PP - Polypropylene	100	38	180	82
SR - Styrene Rubber Plastic	150	66		

Maximum Short Time Operating Temperature

- for pipes without pressure.

- PVC : 95 °C
- PP : 100 °C
- PE : 95 °C

Heat Distortion Temperature

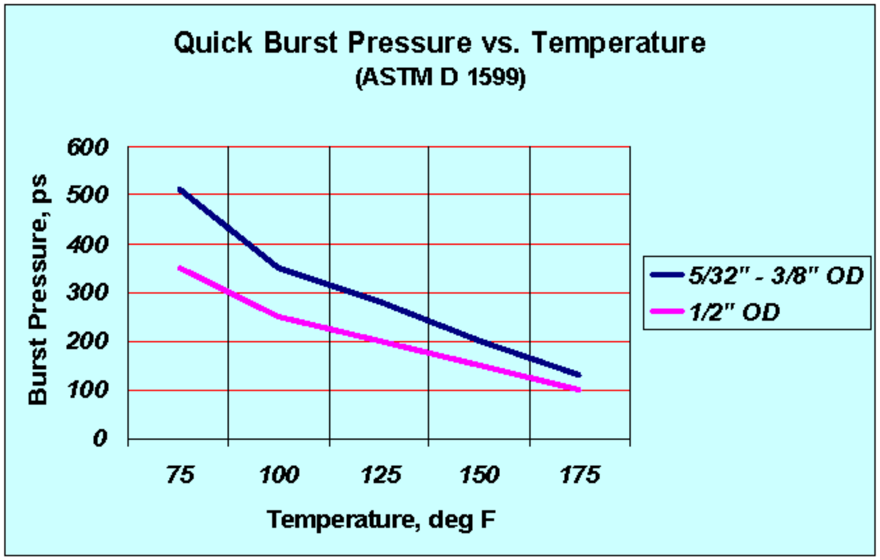
- is the temperature where a test piece of a material placed in a heat medium with a bending load (*18.6 kg/cm²*) applied - reaches a specified deflection.

- ABS: *104 - 106* °C
- PVC: *54 - 80* °C
- HDPE: *43 - 49* °C
- LDPE: *32 - 41* °C
- PP: *57 - 64* °C

Vicat Softening Temperature

- is the temperature where a needle shaped penetrator sinks into a test piece a specified depth when a specified vertical load (*1 kg*) is applied.

- ABS: *102.3* °C
- PVC: *92* °C



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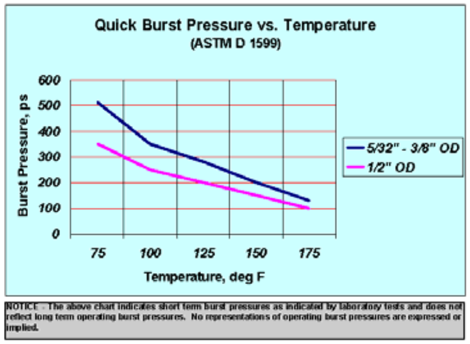

The Same, But Different

- What do these have in common?
- Functionally, what is different about them?

DS1

A Typical Pneumatic Air Supply System

Key Points

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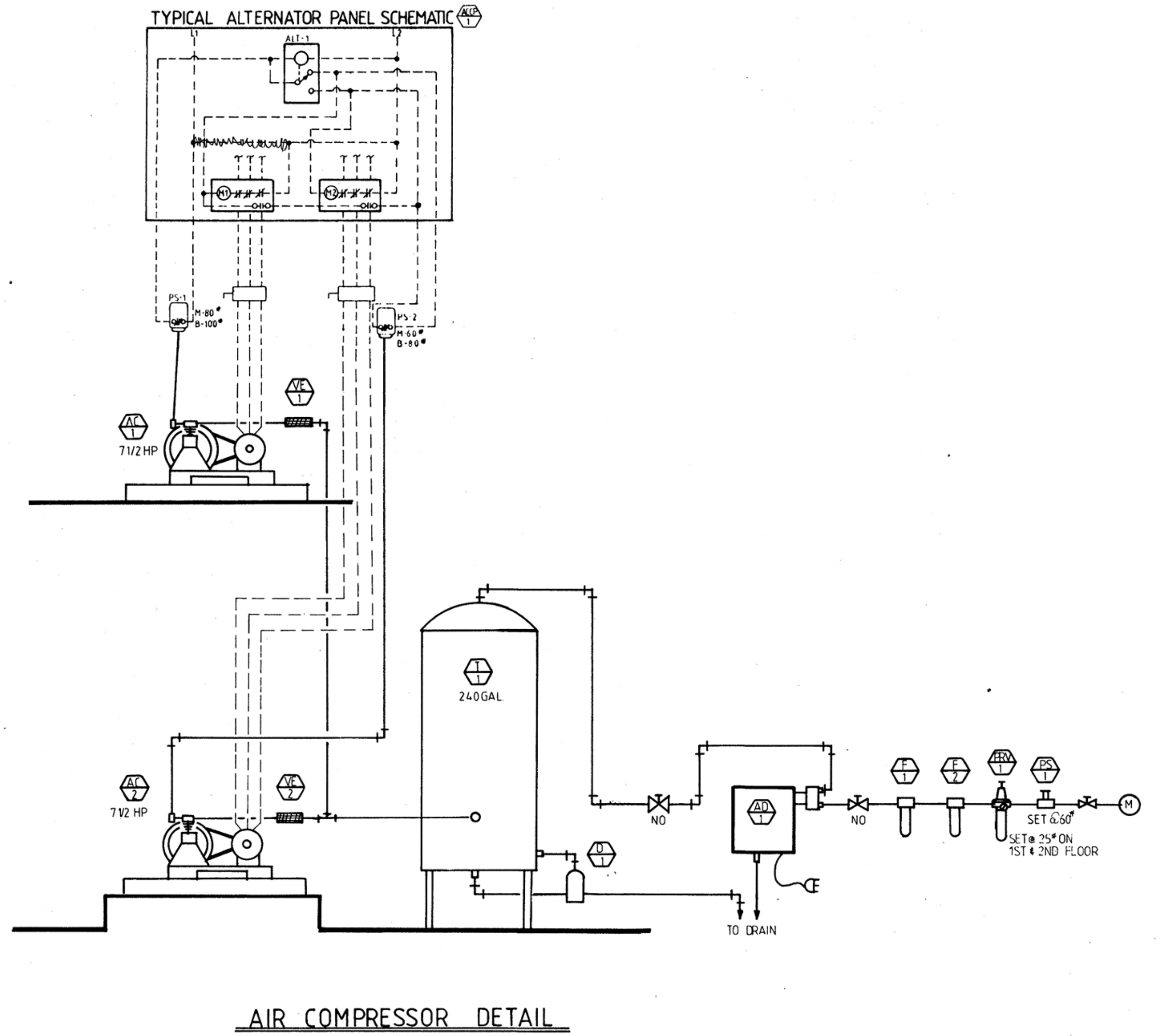


Slide 20

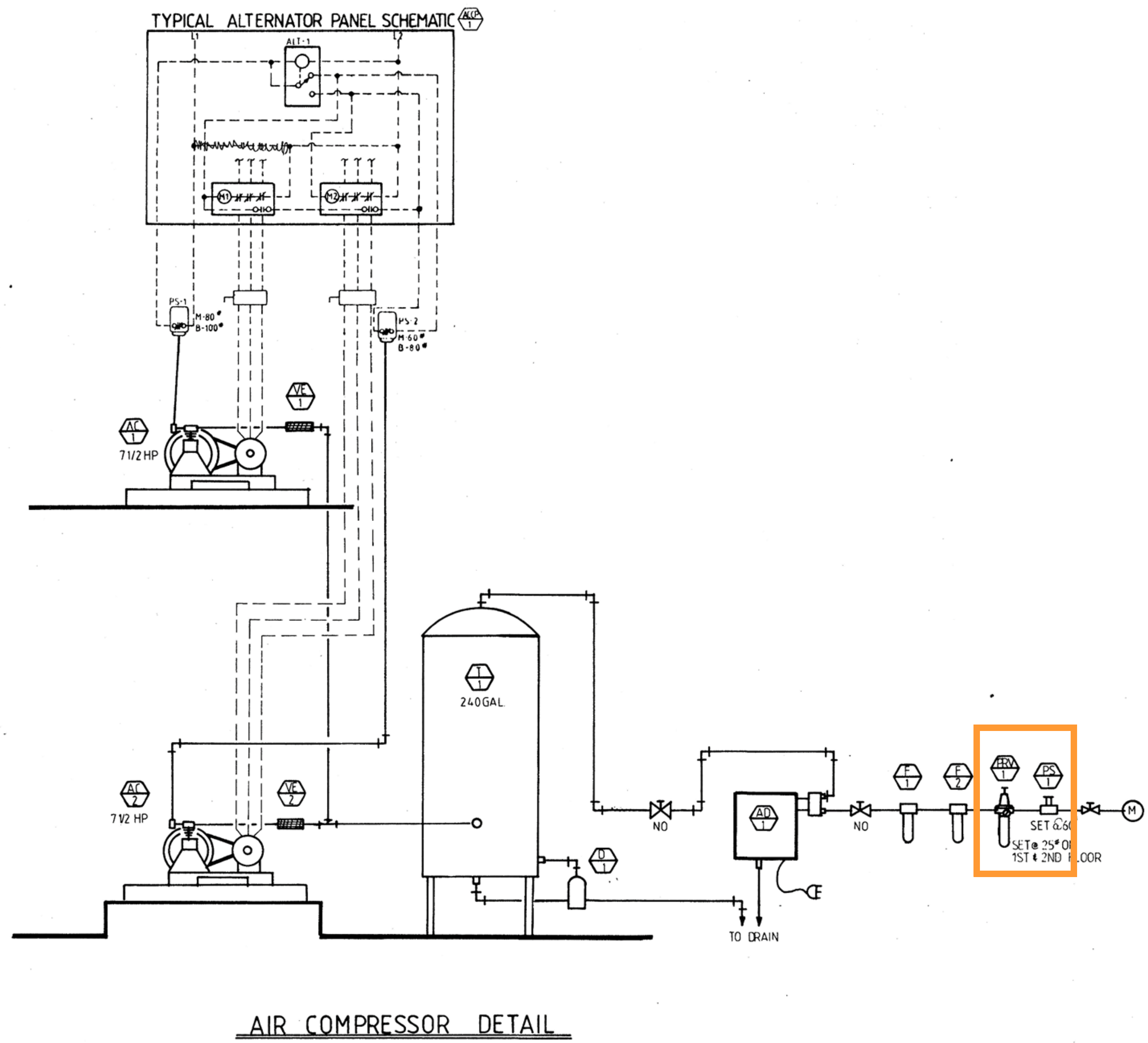
DS1 David Sellers, 6/29/2021

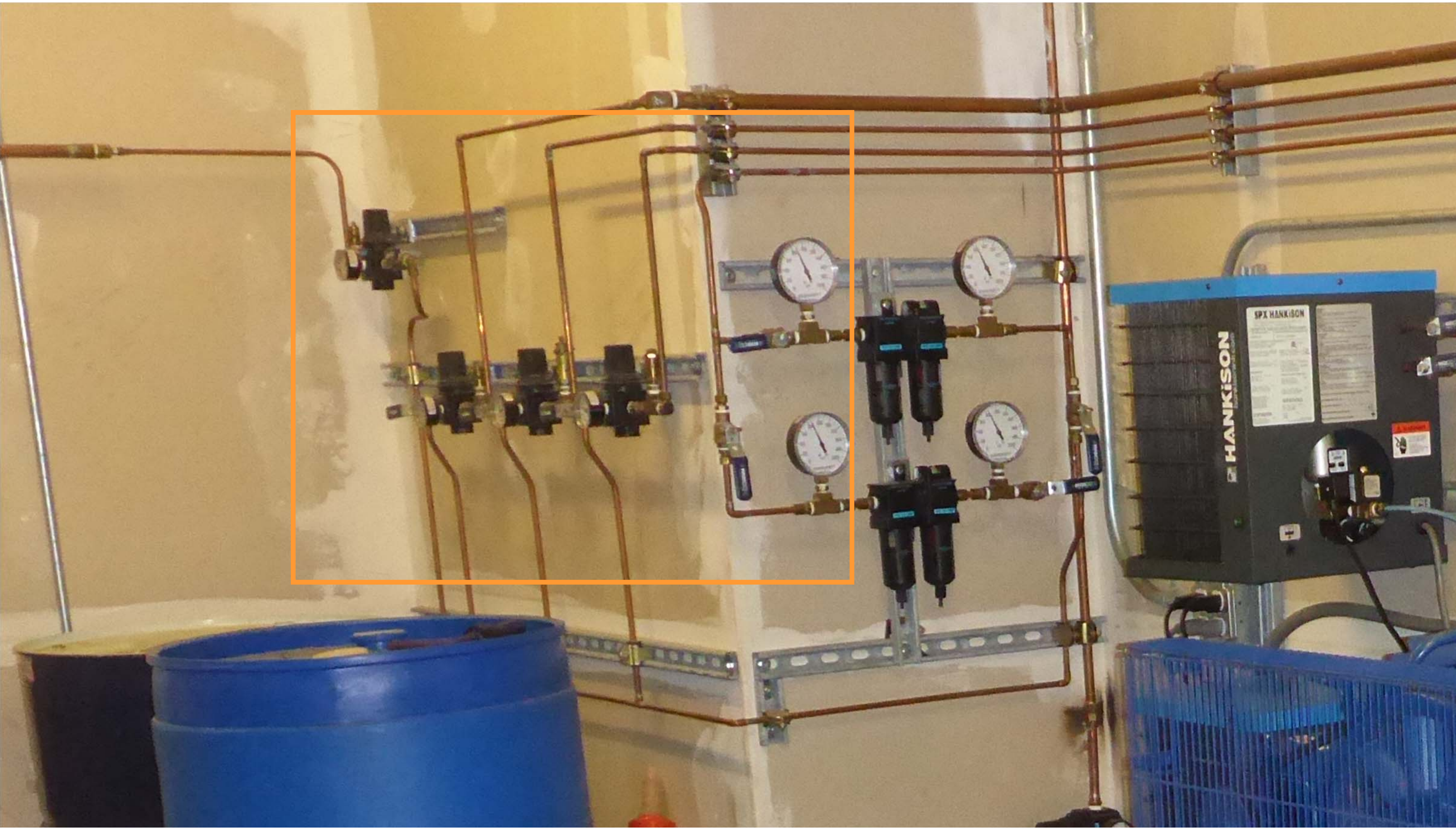

HANKISON
Quincy
Compressor
Climate Control

A Typical Pneumatic Air Supply System

Key Points

1. Pneumatics are truly "plug and play" Jay Santos
2. Pressure regulation is important

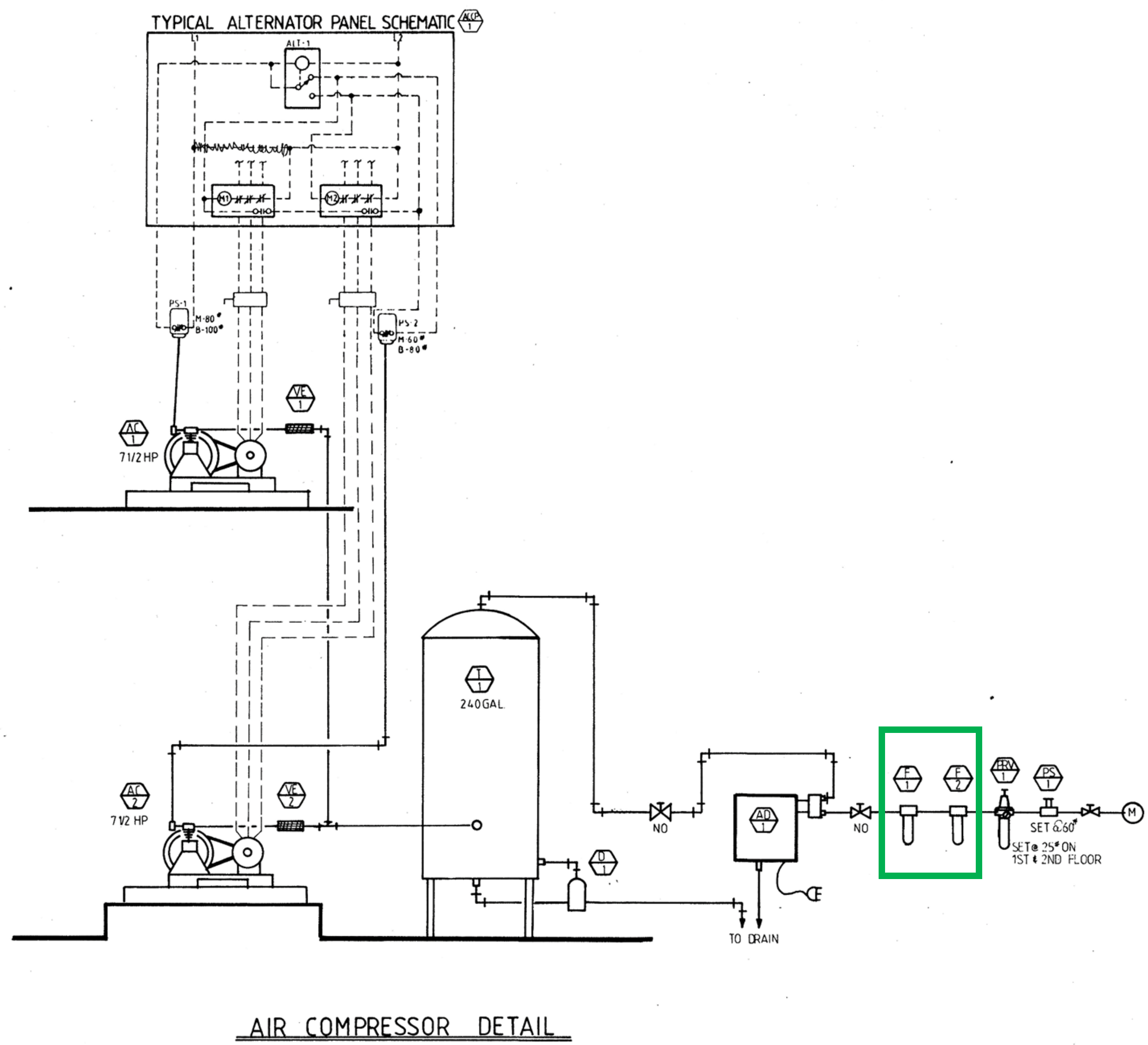


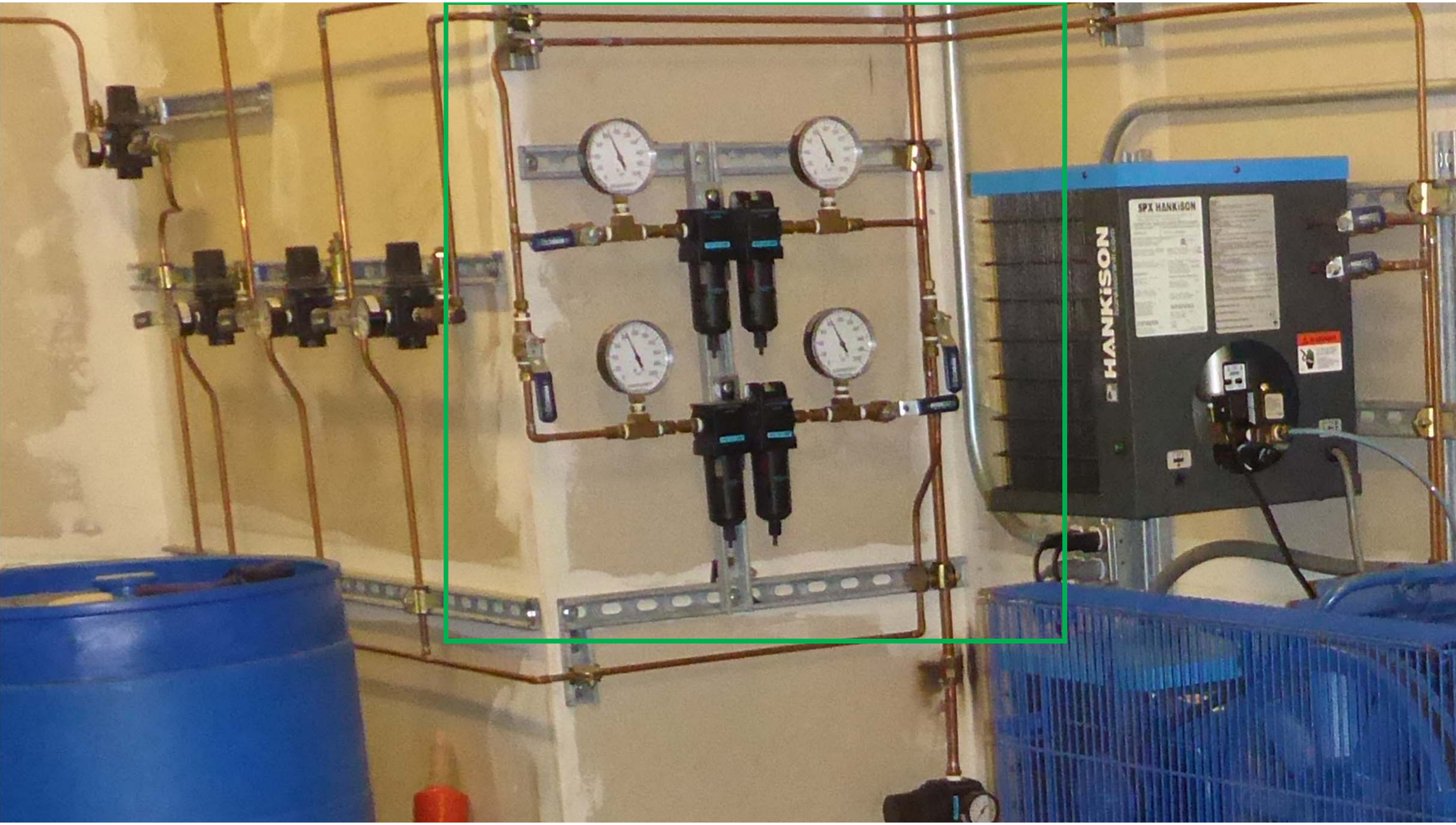

SPX HANKISON
HANKISON

A Typical Pneumatic Air Supply System

Key Points

1. Pneumatics are truly "plug and play" Jay Santos
2. Pressure regulation is important
3. Clean, oil-free air is important




SPX HANKISON
HANKISON

A Typical Pneumatic Air Supply System

Key Points

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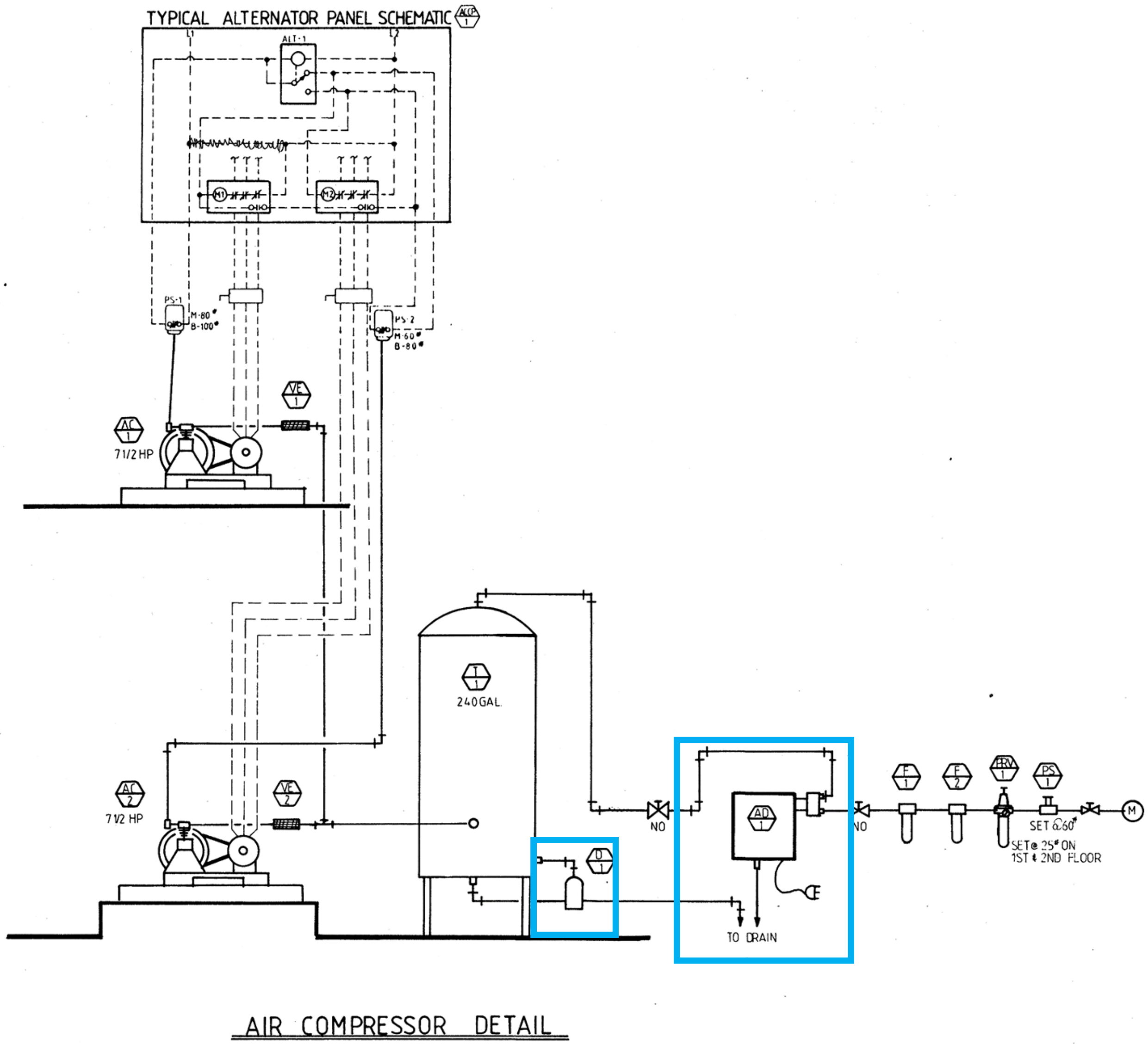
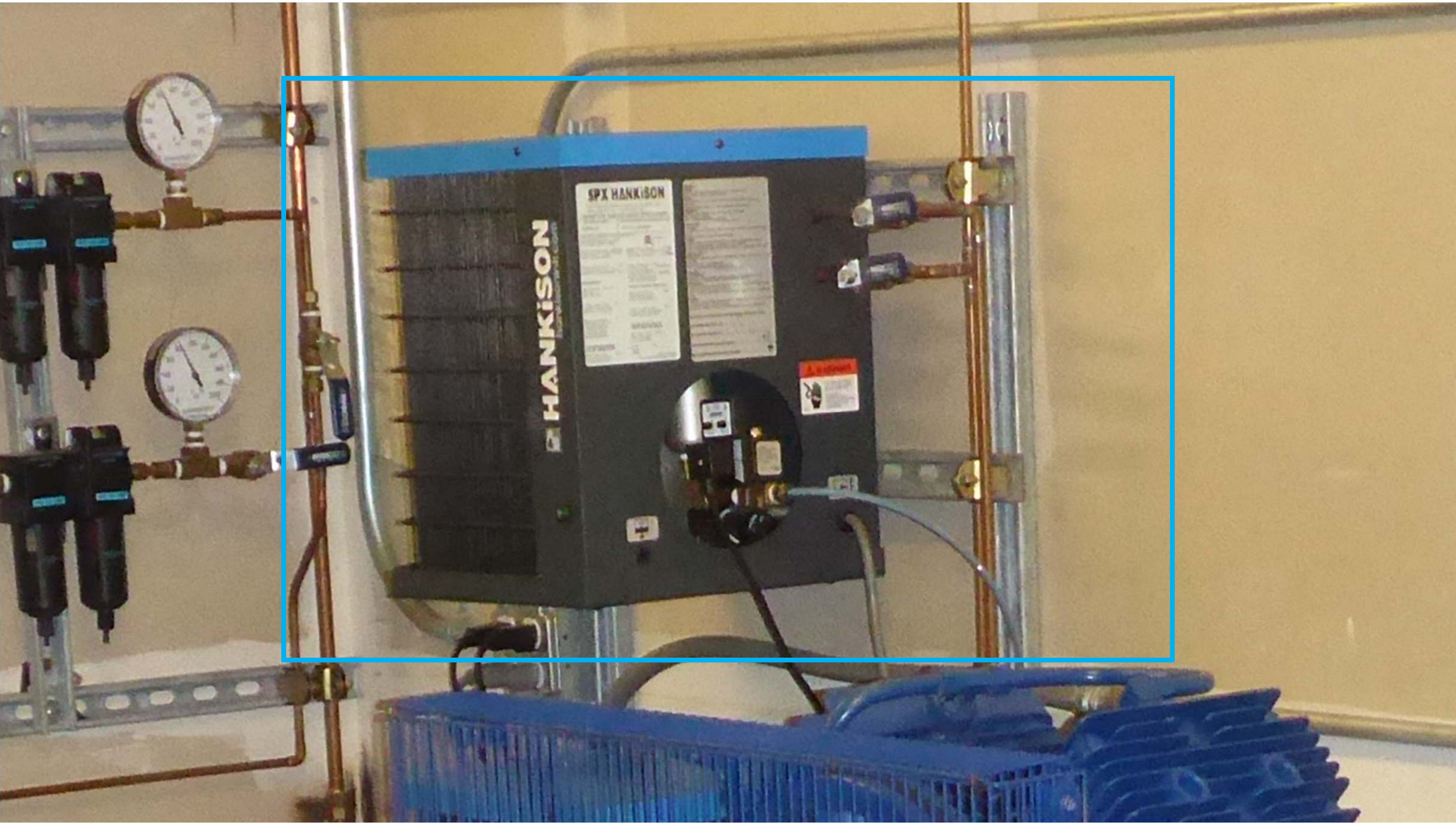
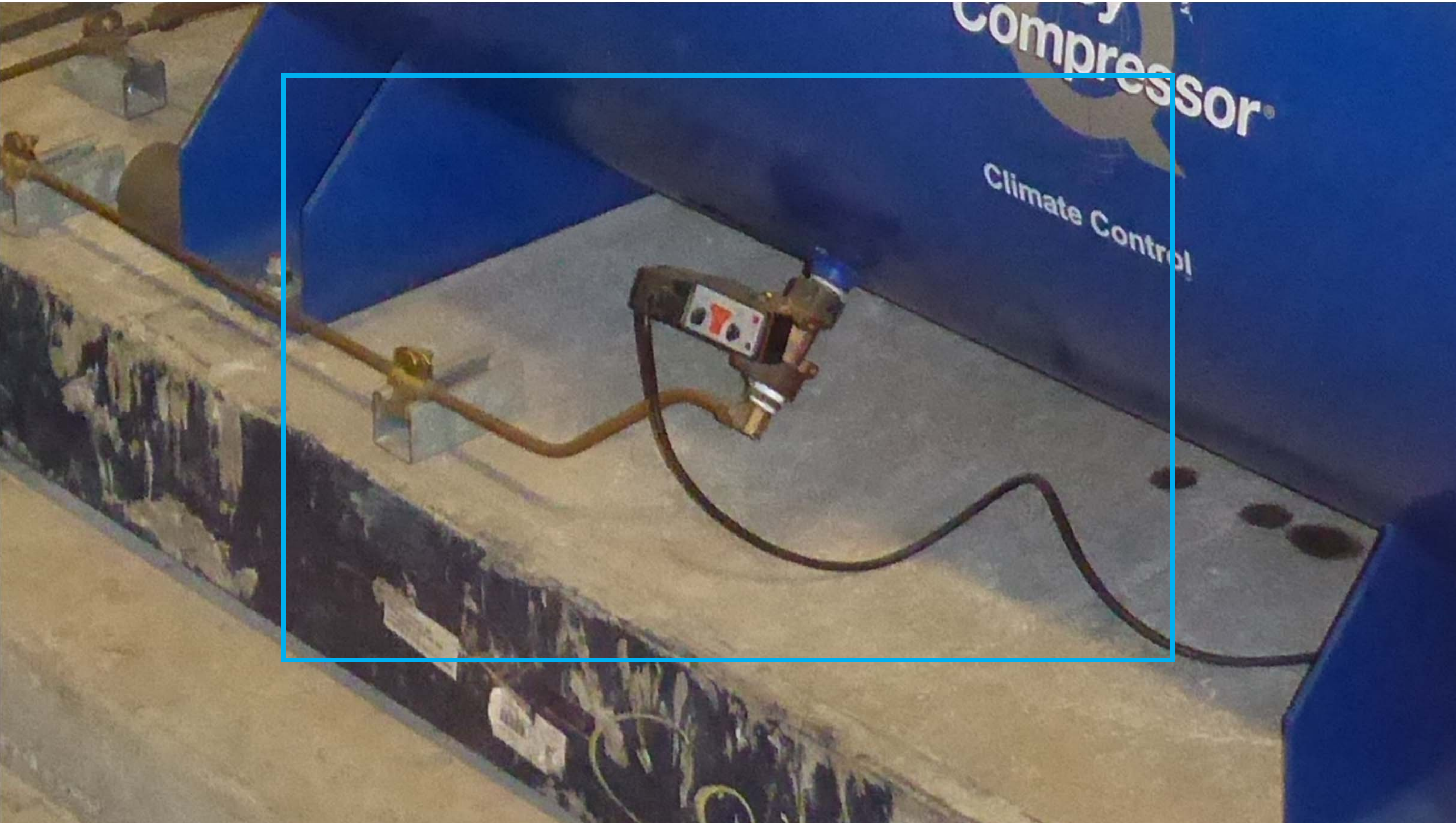
3. Clean, oil-free air is important
4. Dry air is important

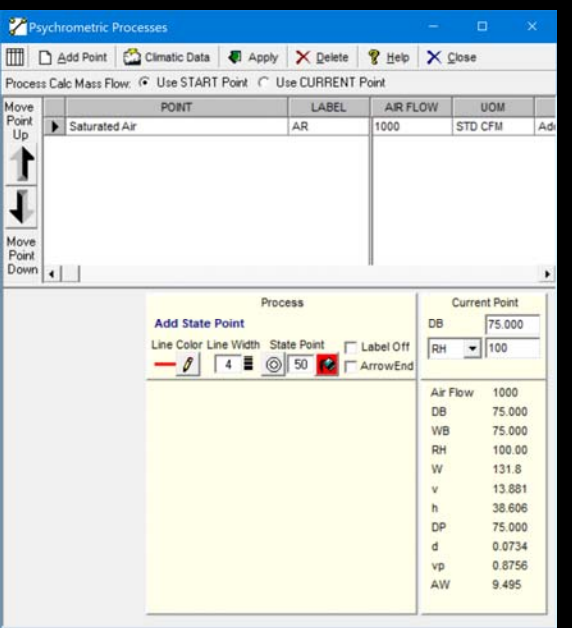



SPX HANKiSON
HANKiSON


Compressor®
Climate Control

Why is there Water in Compressed Air?

Sea Level



Psychrometric Processes
Add Point
Climatic Data
Apply
Delete
Help
Close
Process Calc Mass Flow: Use START Point Use CURRENT Point
Move Point Up
Move Point Down
POINT
LABEL
AIR FLOW
UOM
Saturated Air
AR
1000
STD CFM
Process
Add State Point
Line Color
Line Width
State Point
Label Off
ArrowEnd
4
50
Current Point
DB
75.000
RH
100
Air Flow 1000
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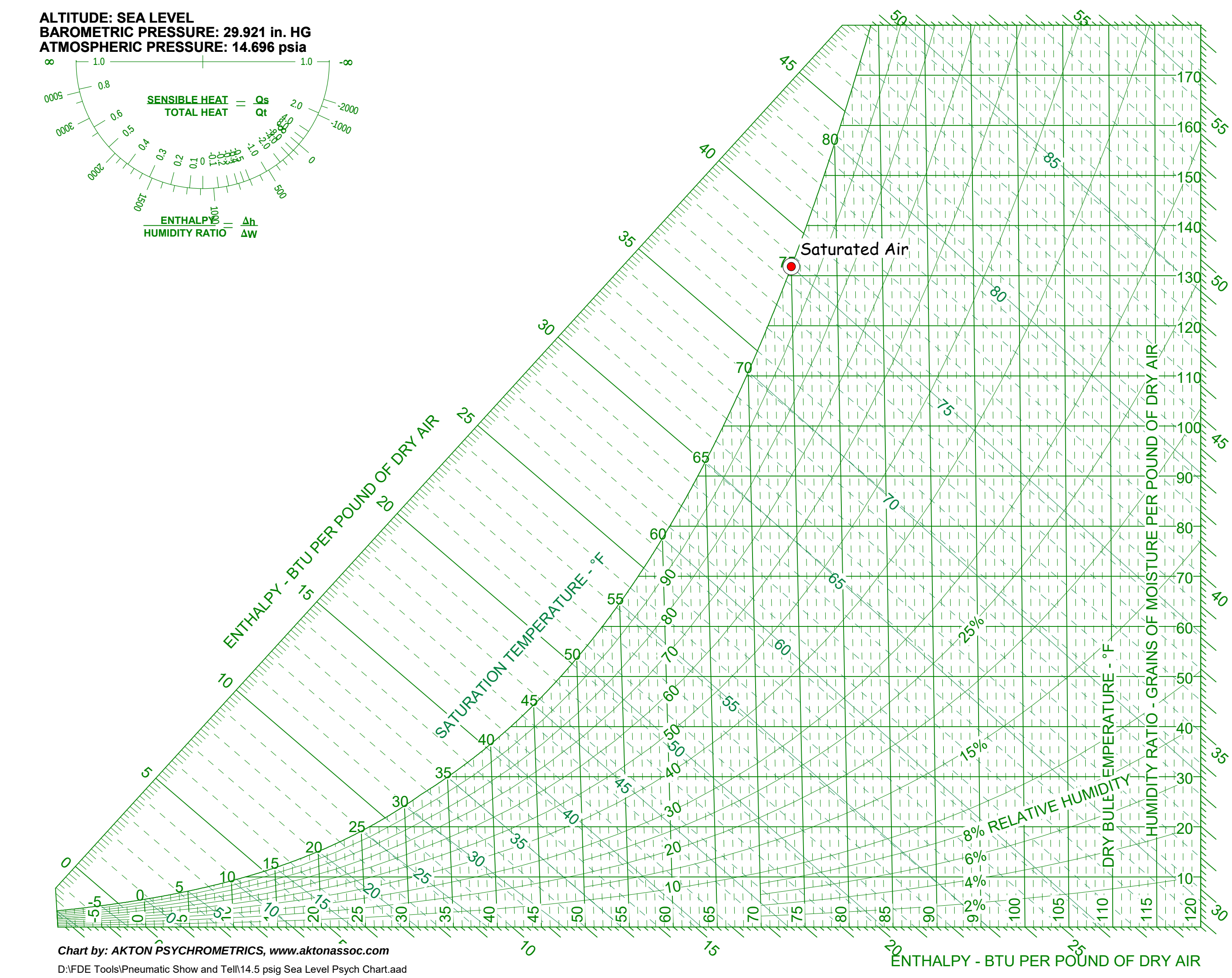
vp 0.8756
AW 9.495



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BAROMETRIC PRESSURE: 29.921 in. HG
ATMOSPHERIC PRESSURE: 14.696 psia
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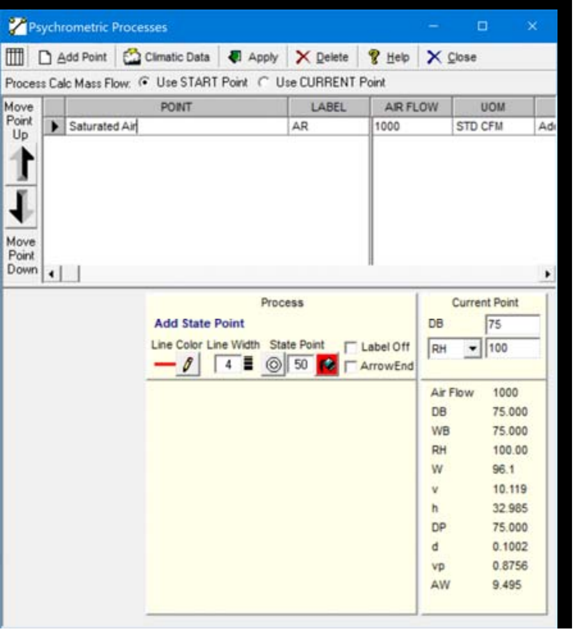
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
Saturated Air
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\FDE Tools\Pneumatic Show and Tell\14.5 psig Sea Level Psych Chart.aad

20 psia



Psychrometric Processes
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Process Calc Mass Flow: Use START Point Use CURRENT Point
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POINT
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AR
1000
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Process
Add State Point
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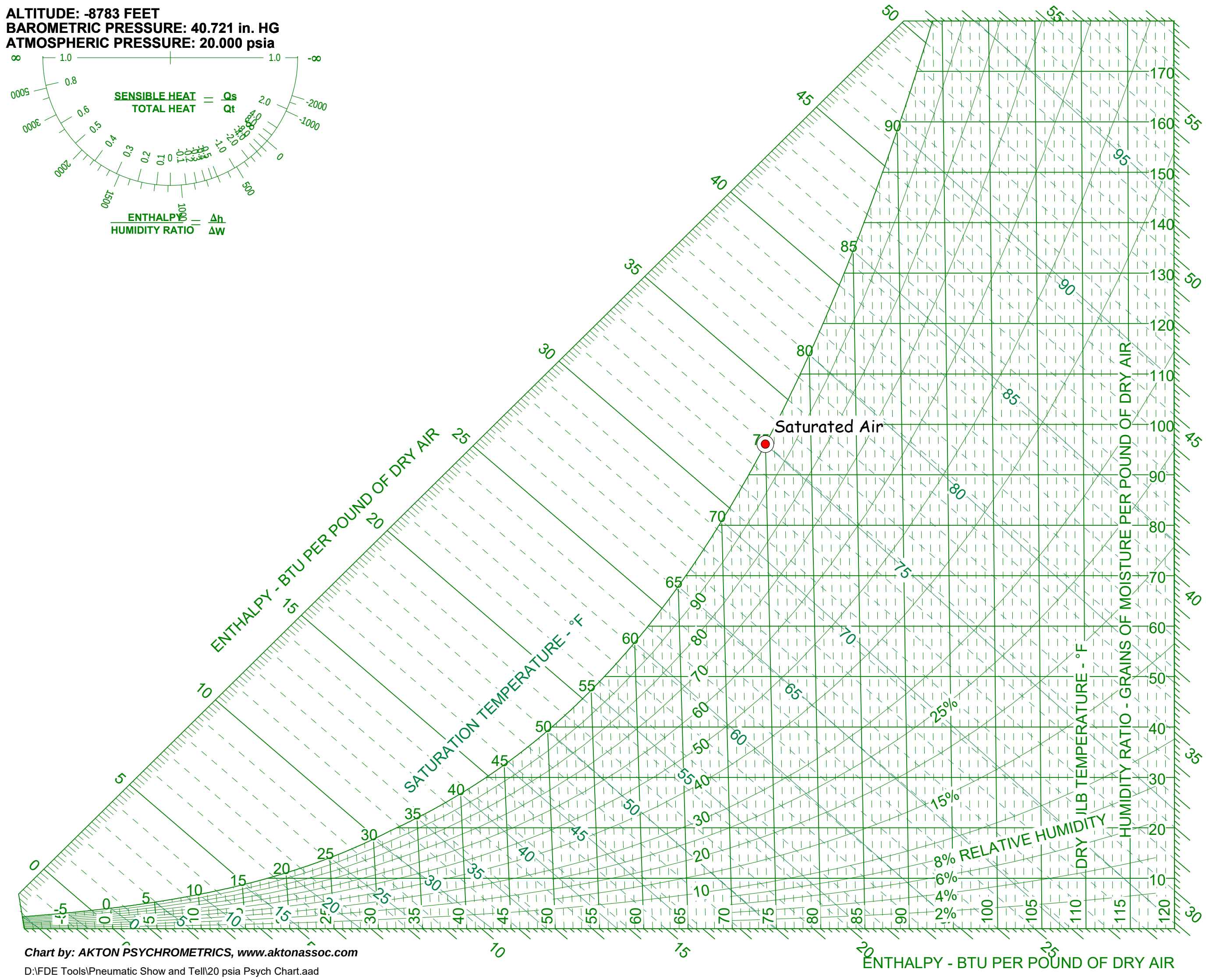
Line Width
State Point
Label Off
ArrowEnd
4
50
Current Point
DB
75
RH
100
Air Flow 1000
DB 75.000
WB 75.000
RH 100.00
W 96.1
v 10.119
h 32.985
DP 75.000
d 0.1002
vp 0.8756
AW 9.495



ALTITUDE: -8783 FEET
BAROMETRIC PRESSURE: 40.721 in. HG
ATMOSPHERIC PRESSURE: 20.000 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
Saturated Air
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
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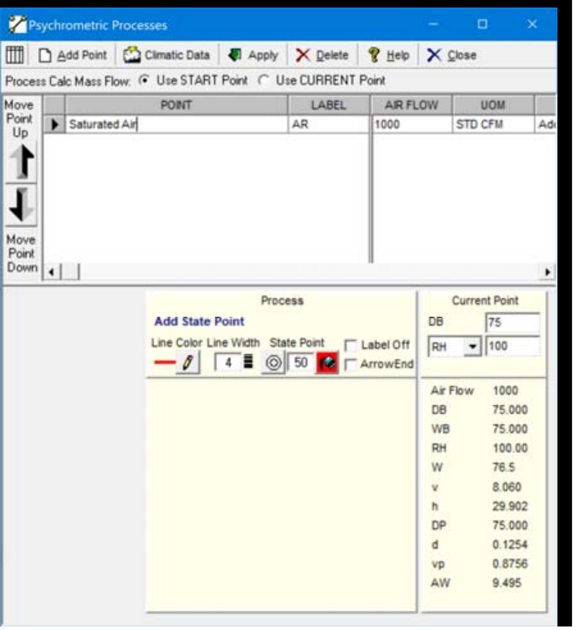
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\FDE Tools\Pneumatic Show and Tell\20 psia Psych Chart.aad

25 psia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STD CFM
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Add State Point
Line Color
Line Width
State Point
Label Off
ArrowEnd
Current Point
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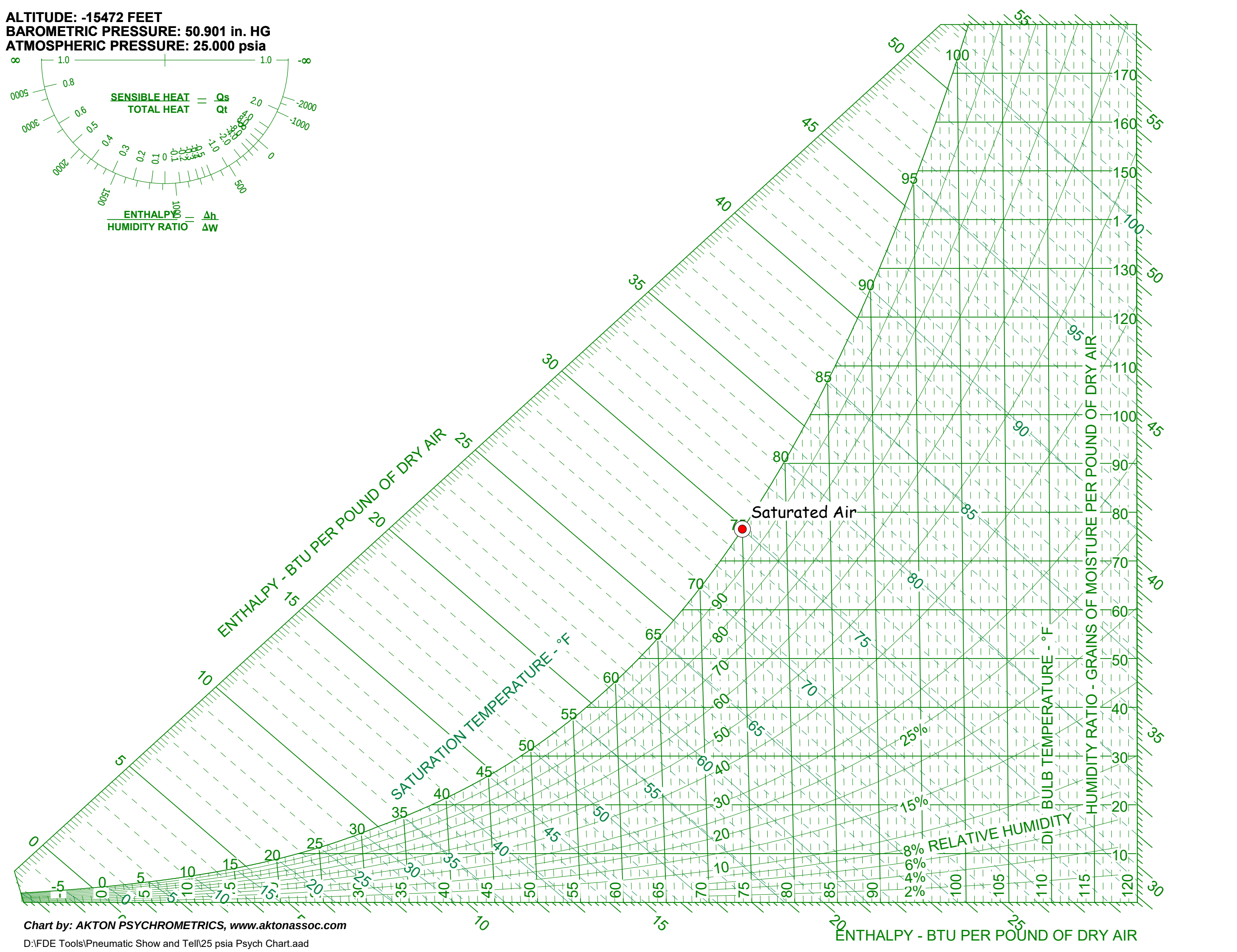
ALTITUDE: -15472 FEET
BAROMETRIC PRESSURE: 50.901 in. HG
ATMOSPHERIC PRESSURE: 25.000 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
Saturated Air
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
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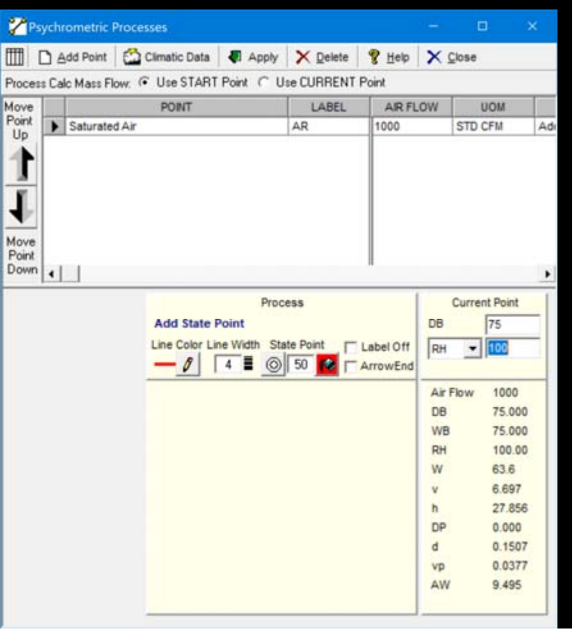
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\FDE Tools\Pneumatic Show and Tell\25 psia Psych Chart.aad

30 psia



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Label Off
ArrowEnd
4
50
Current Point
DB 75
RH 100
Air Flow 1000
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WB 75.000
RH 100.00
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h 27.856
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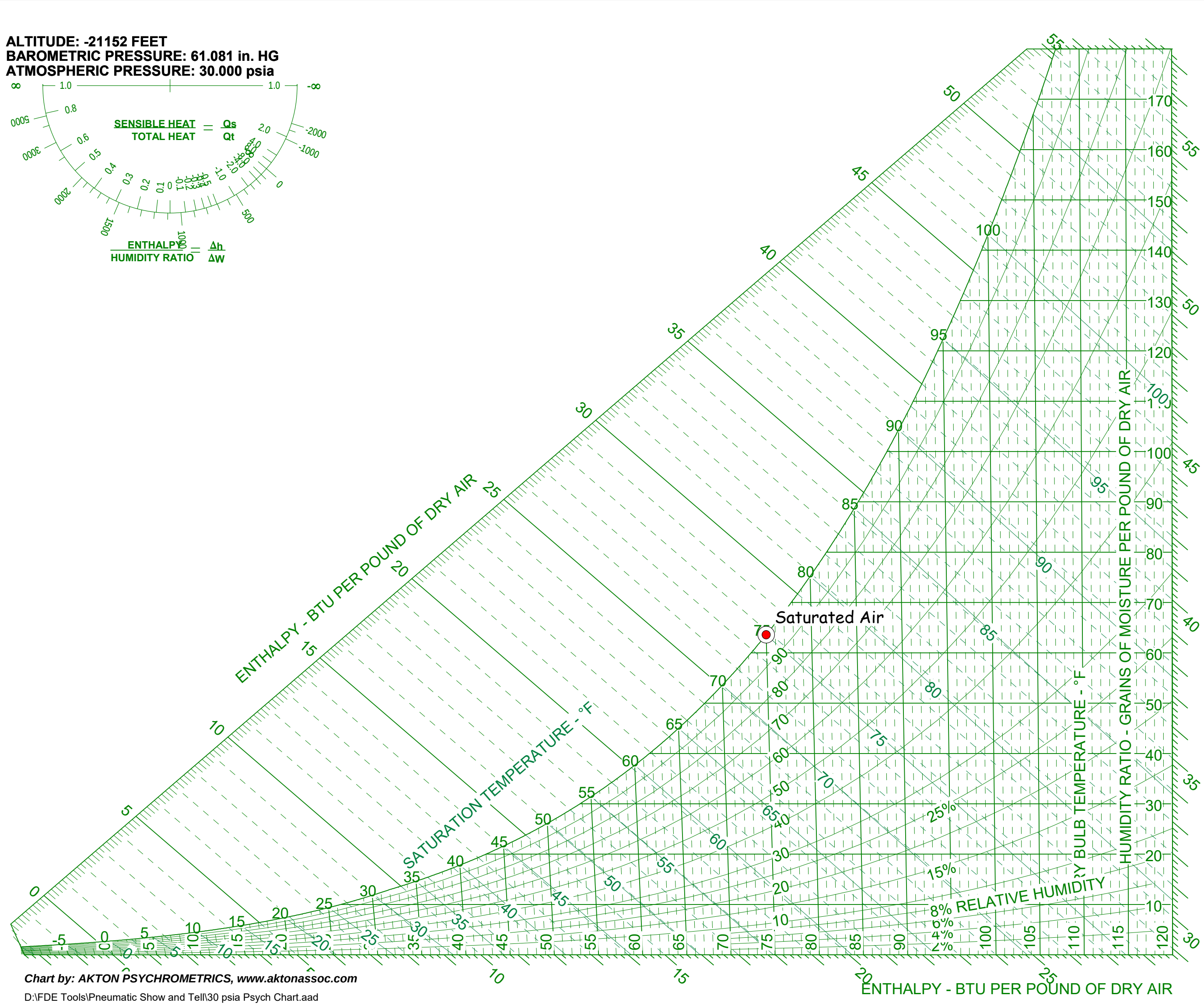
vp 0.0377
AW 9.495



ALTITUDE: -21152 FEET
BAROMETRIC PRESSURE: 61.081 in. HG
ATMOSPHERIC PRESSURE: 30.000 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
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DRY BULB TEMPERATURE - °F
RELATIVE HUMIDITY
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
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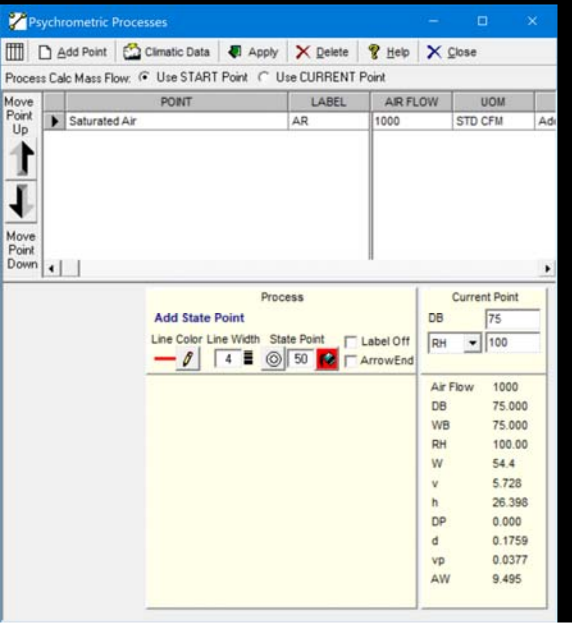
35 psia



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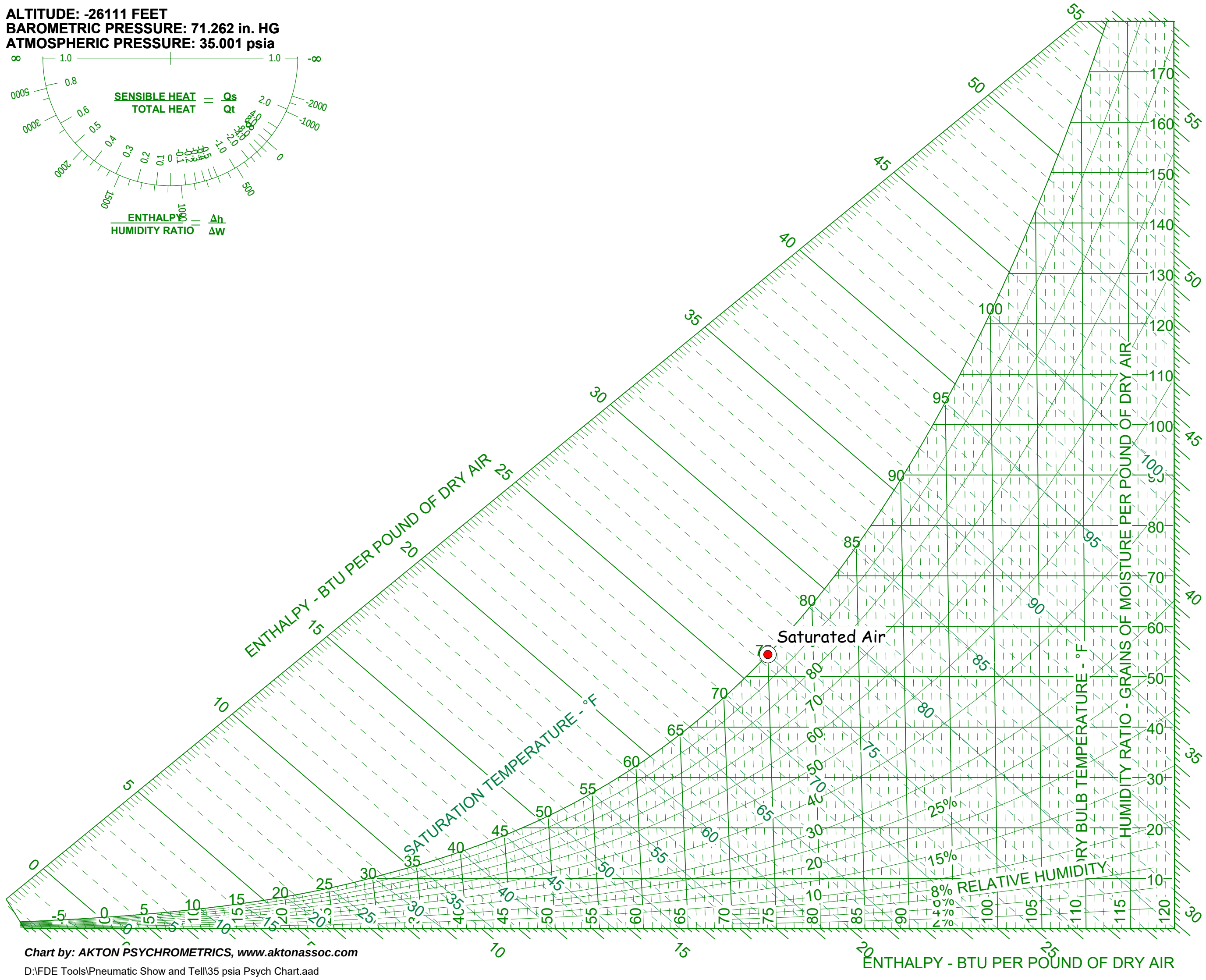
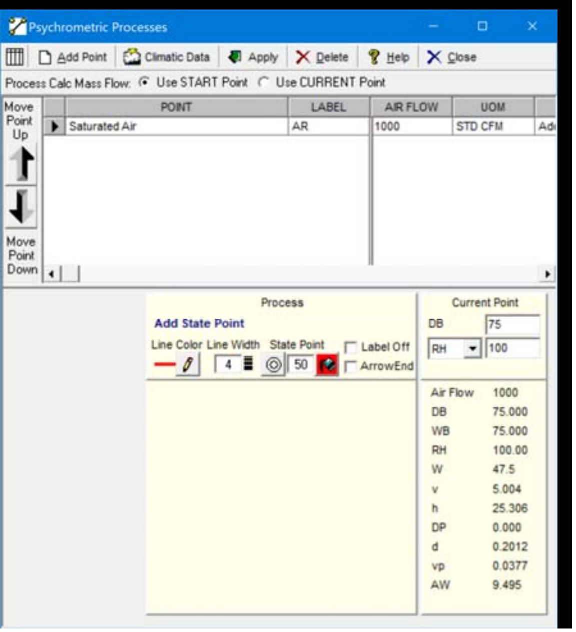
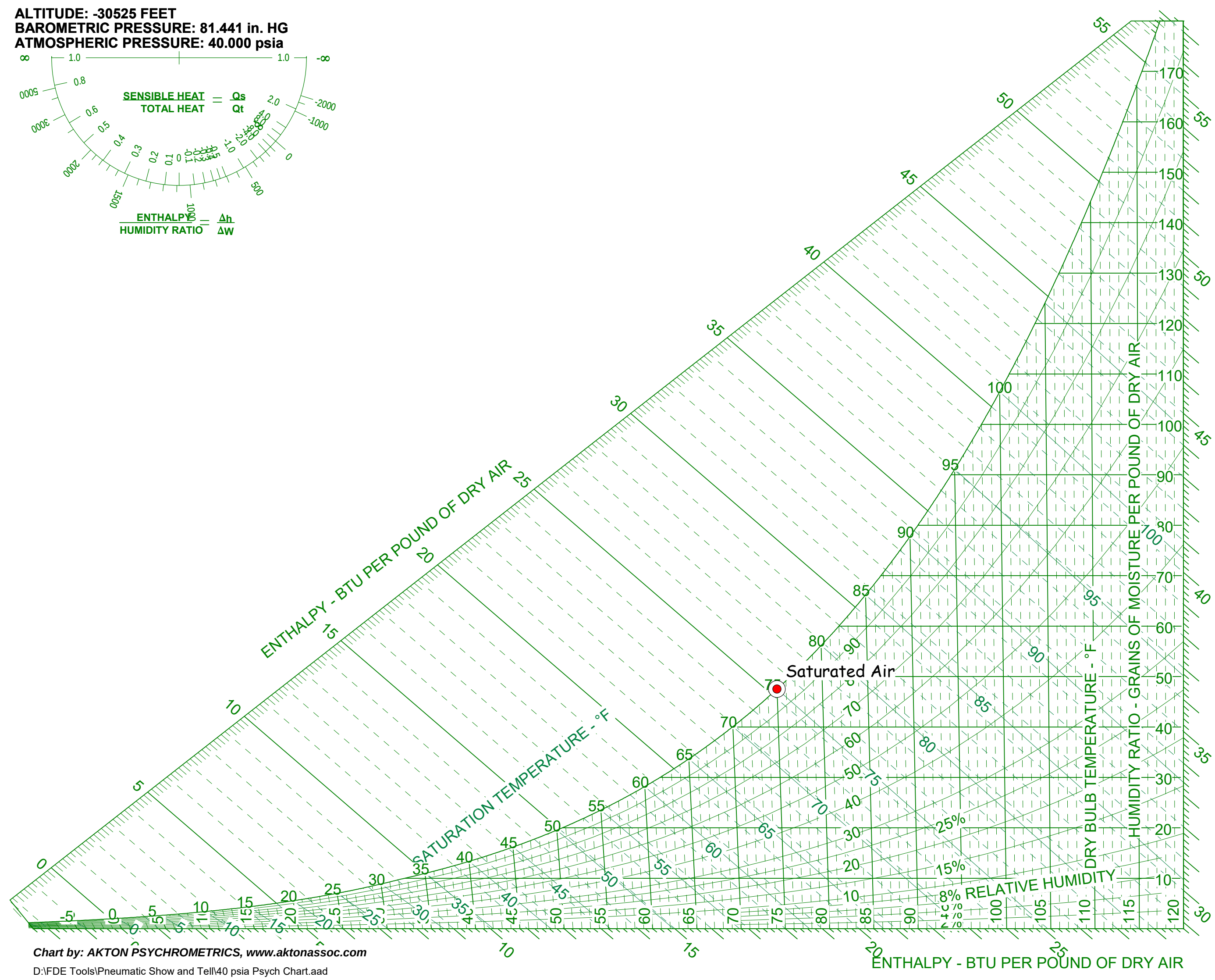
LABEL
AIR FLOW
UOM
Saturated Air
AR
1000
STD CFM
Process
Add State Point
Line Color
Line Width
State Point
Label Off
ArrowEnd
4
50
Current Point
DB
75
RH
100
Air Flow 1000
DB 75.000
WB 75.000
RH 100.00
W 54.4
v 5.728
h 26.398
DP 0.000
d 0.1759
vp 0.0377
AW 9.495

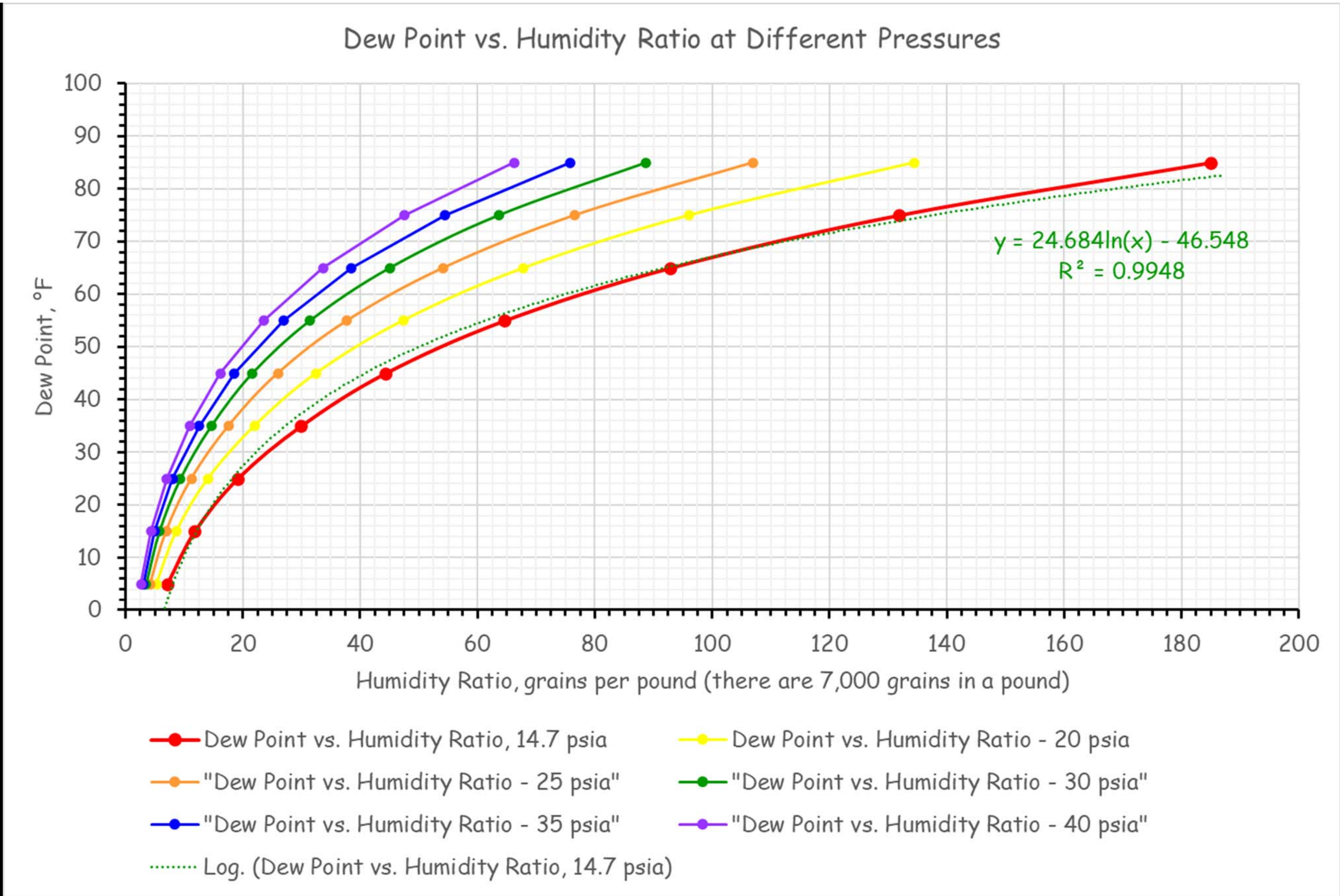


ALTITUDE: -26111 FEET
BAROMETRIC PRESSURE: 71.262 in. HG
ATMOSPHERIC PRESSURE: 35.001 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
Saturated Air
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
ENTHALPY - BTU PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\FDE Tools\Pneumatic Show and Tell\35 psia Psych Chart.aad

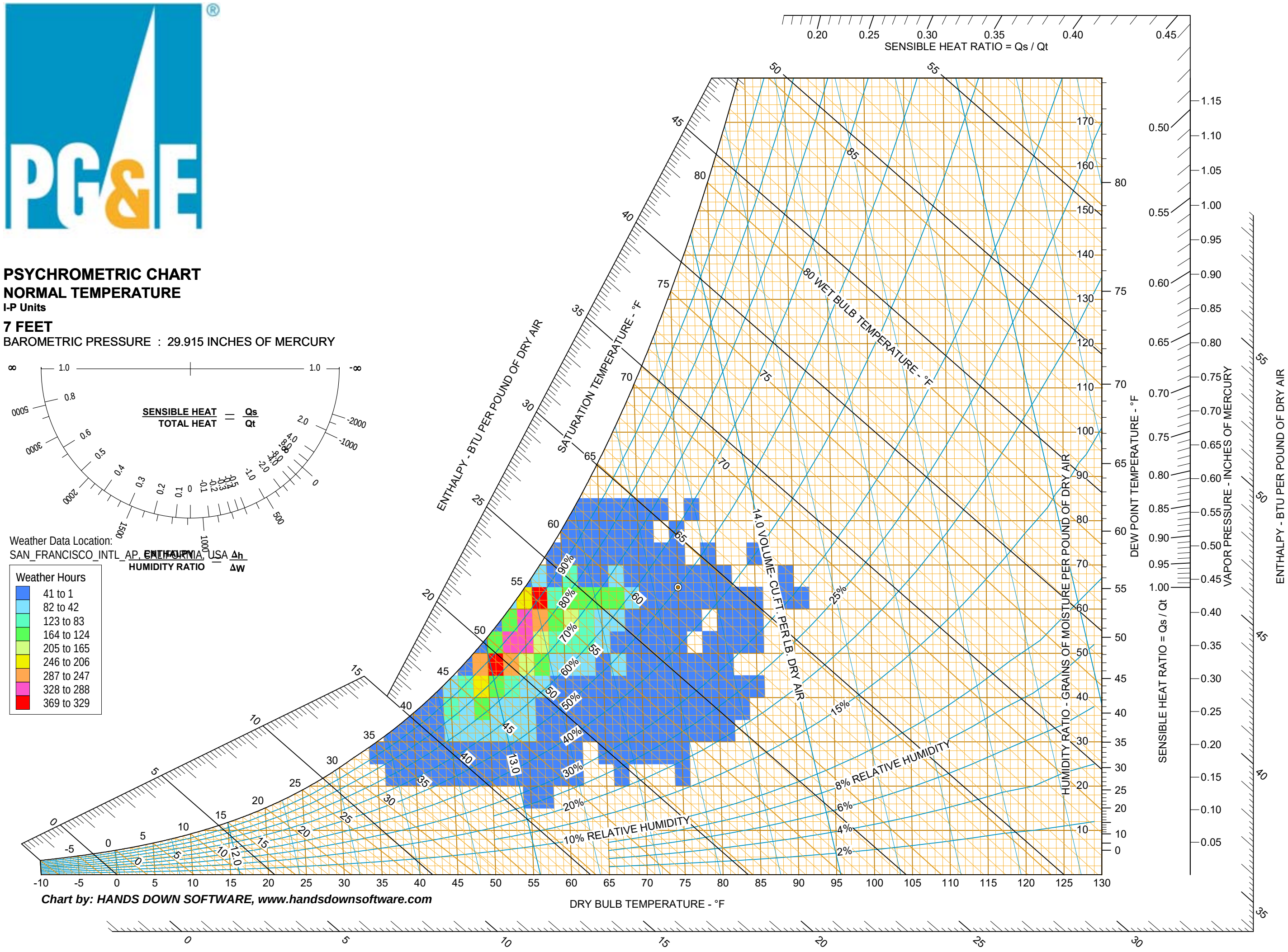
40 psia


Psychrometric Processes
Add Point
Climatic Data
Apply
Delete
Help
Close
Process Calc Mass Flow: Use START Point Use CURRENT Point
Move Point Up
Move Point Down
POINT
LABEL
AIR FLOW
UOM
Saturated Air
AR
1000
STD CFM
Process
Add State Point
Line Color
Line Width
State Point
Label Off
ArrowEnd
Current Point
DB 75
RH 100
Air Flow 1000
DB 75.000
WB 75.000
RH 100.00
W 47.5
v 5.004
h 25.306
DP 0.000
d 0.2012
vp 0.0377
AW 9.495


ALTITUDE: -30525 FEET
BAROMETRIC PRESSURE: 81.441 in. HG
ATMOSPHERIC PRESSURE: 40.000 psia
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
Saturated Air
8% RELATIVE HUMIDITY
25%
15%
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
ENTHALPY - BTU PER POUND OF DRY AIR
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
D:\FDE Tools\Pneumatic Show and Tell\40 psia Psych Chart.aad


Dew Point vs. Humidity Ratio at Different Pressures
Dew Point, °F
Humidity Ratio, grains per pound (there are 7,000 grains in a pound)
y = 24.684ln(x) - 46.548
R² = 0.9948
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
200
Dew Point vs. Humidity Ratio, 14.7 psia
Dew Point vs. Humidity Ratio - 20 psia
"Dew Point vs. Humidity Ratio - 25 psia"
"Dew Point vs. Humidity Ratio - 30 psia"
"Dew Point vs. Humidity Ratio - 35 psia"
"Dew Point vs. Humidity Ratio - 40 psia"
Log. (Dew Point vs. Humidity Ratio, 14.7 psia)

PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
7 FEET
BAROMETRIC PRESSURE : 29.915 INCHES OF MERCURY



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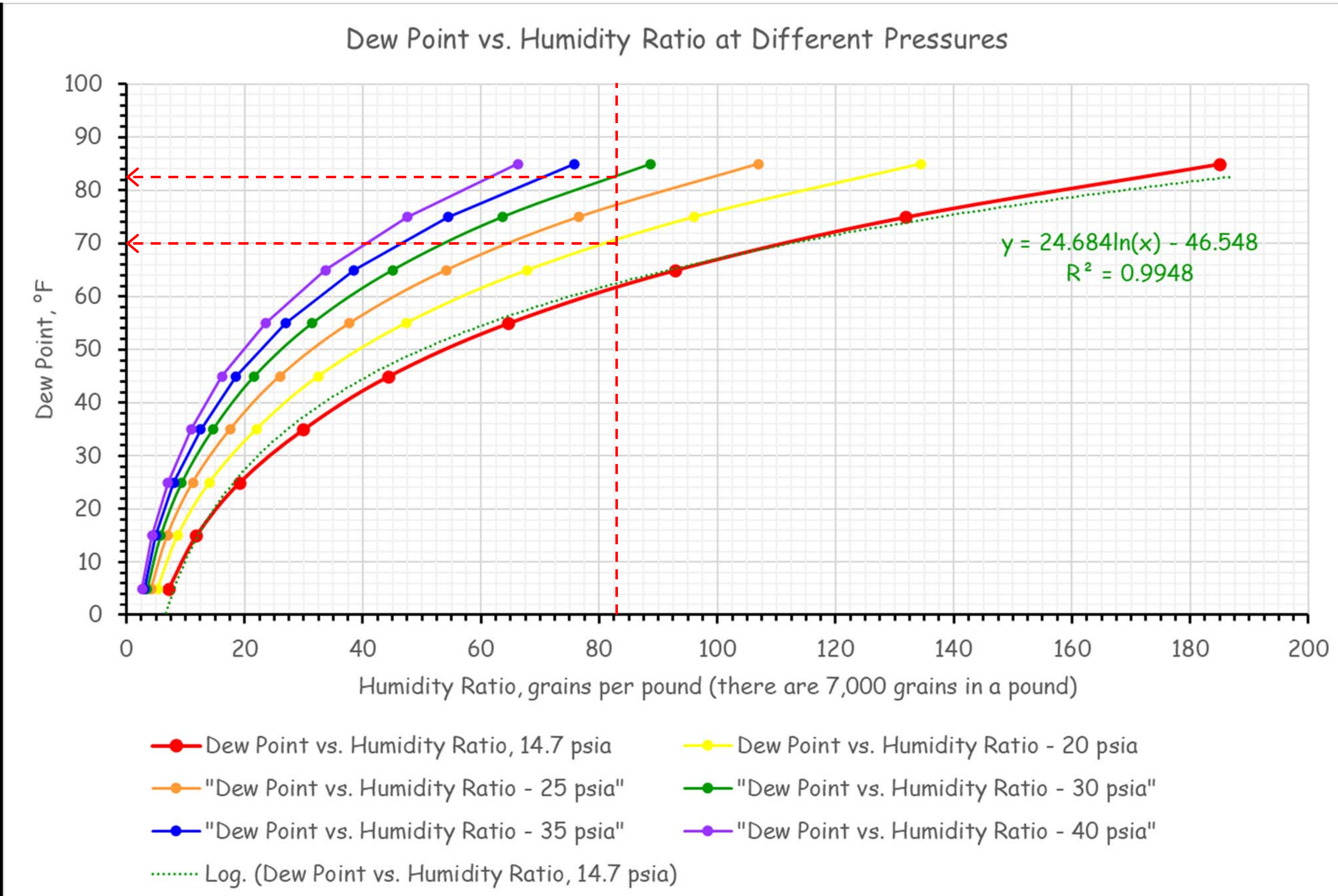
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"Dew Point vs. Humidity Ratio - 40 psia"
Log. (Dew Point vs. Humidity Ratio, 14.7 psia)

PSYCHROMETRIC CHART
NORMAL TEMPERATURE
I-P Units
7 FEET
BAROMETRIC PRESSURE : 29.915 INCHES OF MERCURY

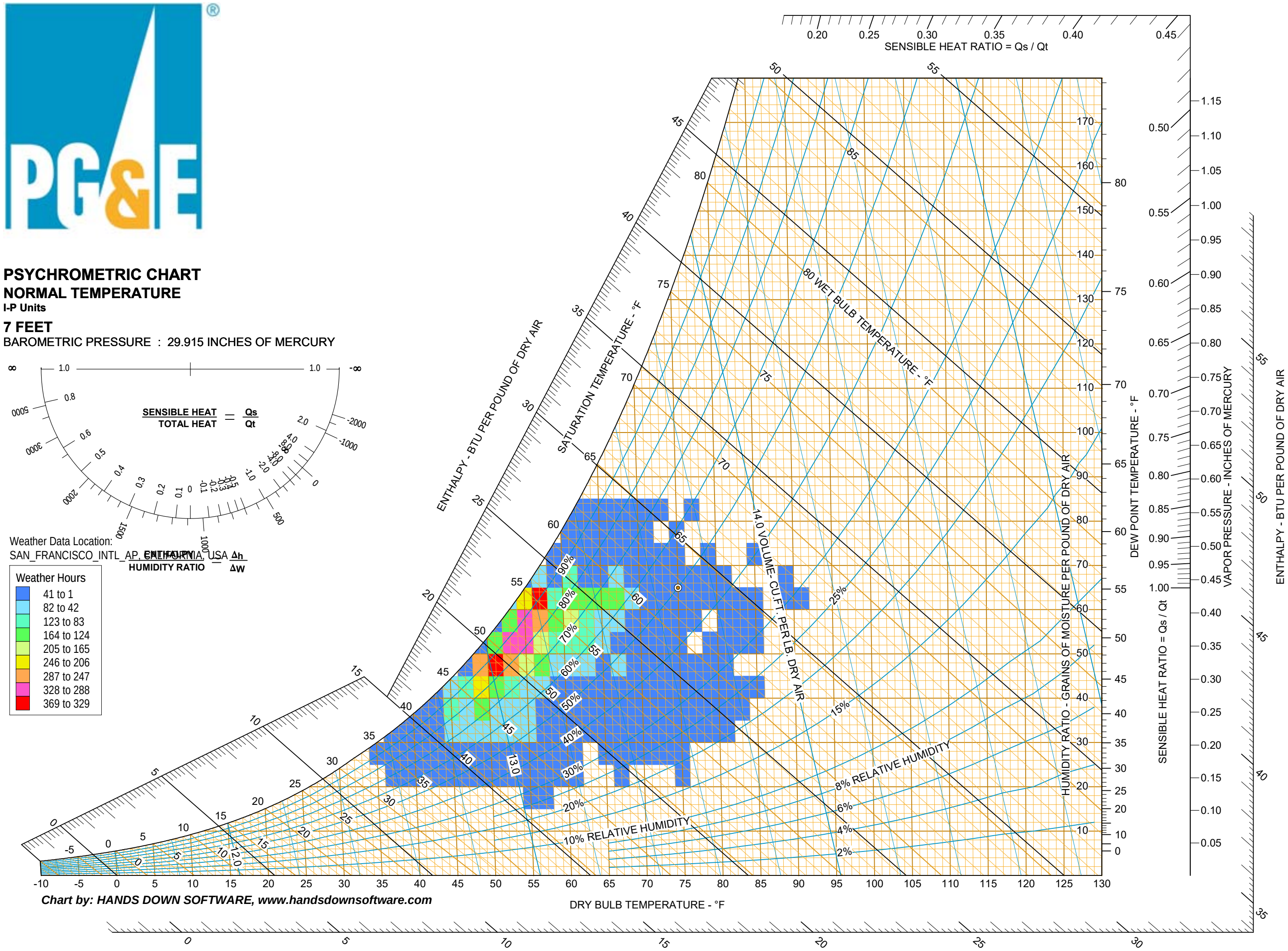

Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

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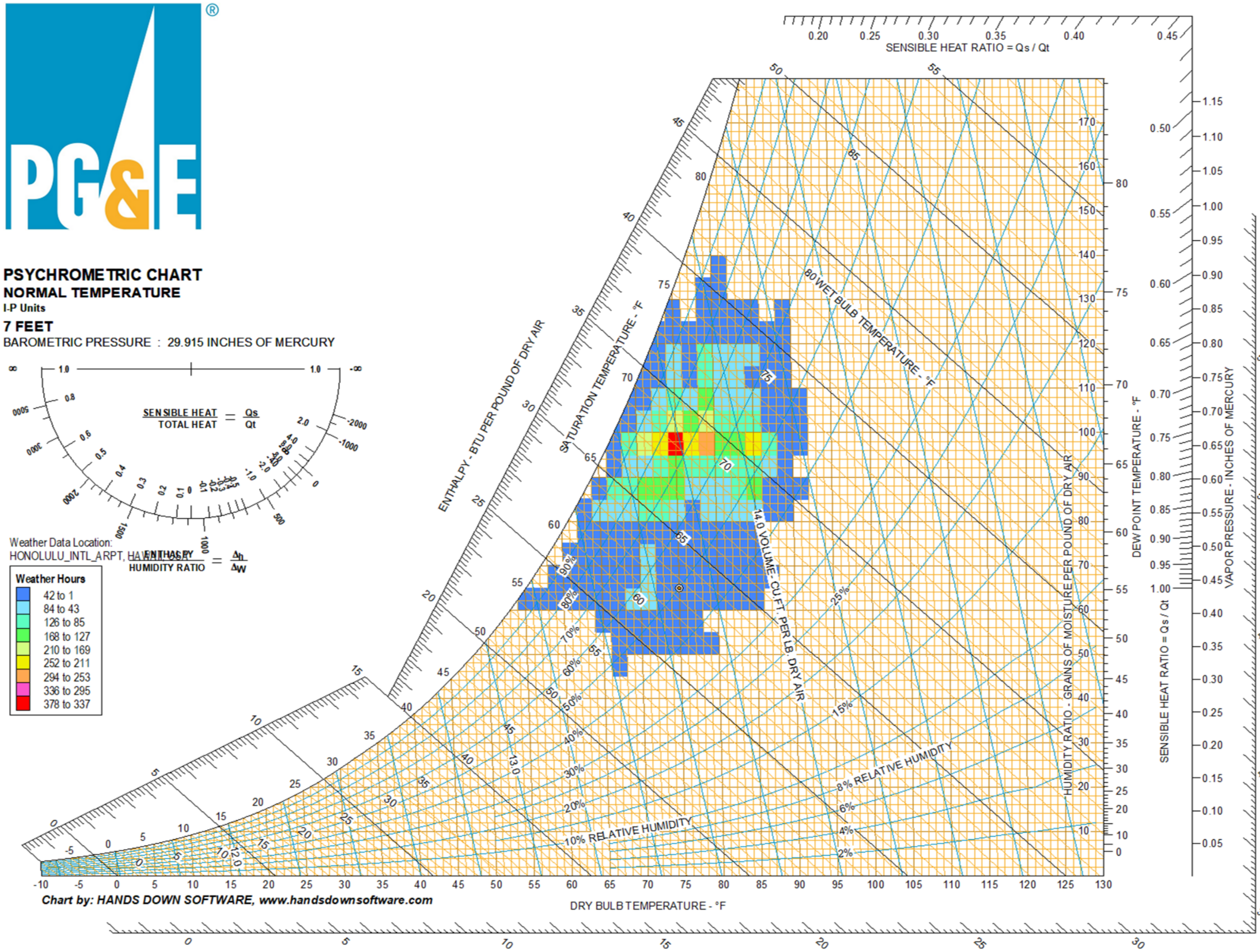
PSYCHROMETRIC CHART

NORMAL TEMPERATURE

I-P Units

7 FEET

BAROMETRIC PRESSURE : 29.915 INCHES OF MERCURY



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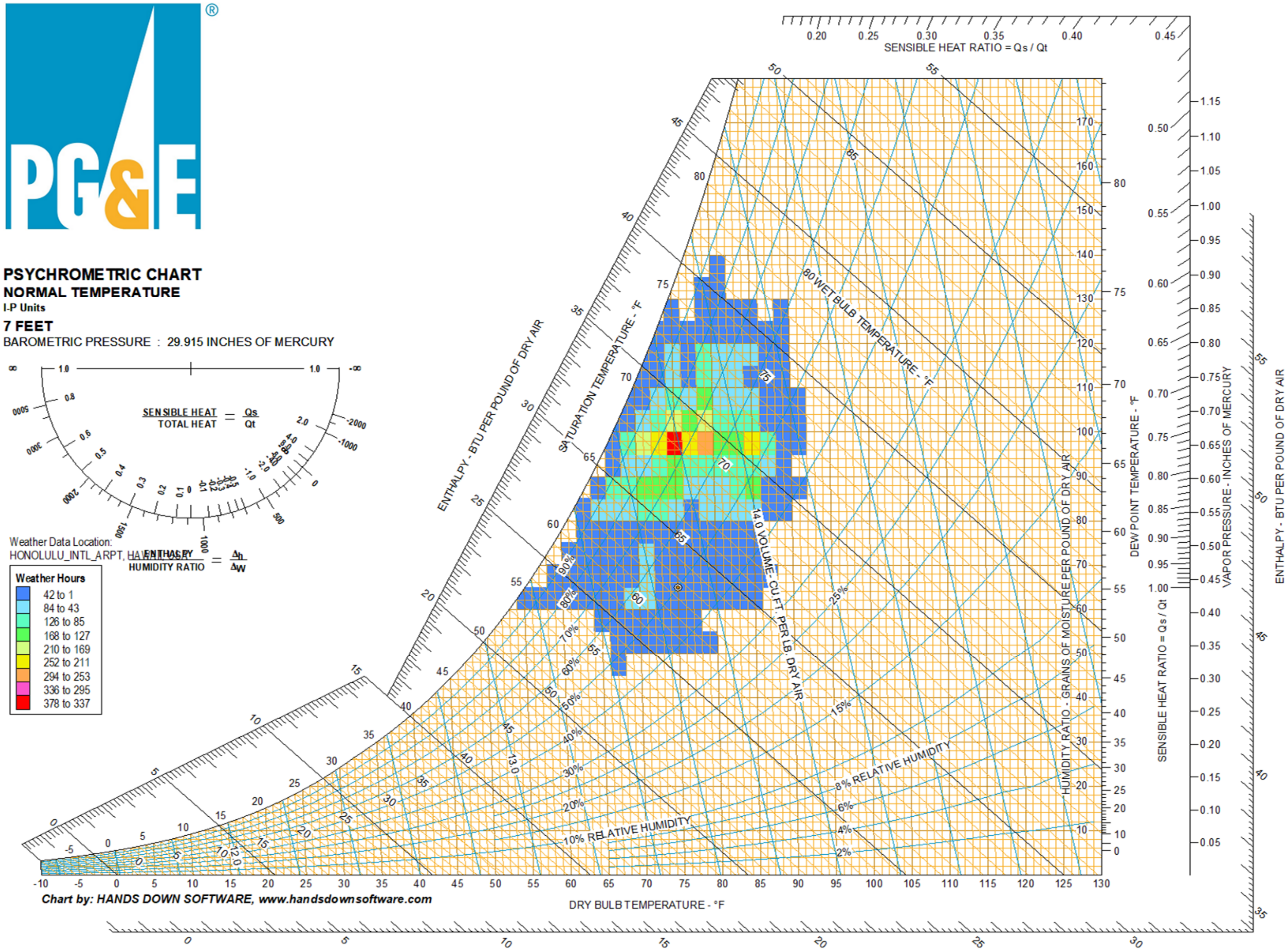
PSYCHROMETRIC CHART

NORMAL TEMPERATURE

I-P Units

7 FEET

BAROMETRIC PRESSURE : 29.915 INCHES OF MERCURY



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You Could Do the Math

The following relationship can be derived from the ideal gas laws by dividing the ideal gas equation for water vapor by the ideal gas equation for air.

$$\frac{p_H}{p - p_H} = w \times \frac{R_H}{R_a}$$

Where:

p_H = The partial pressure of water vapor in the sample in lb/ft^2 absolute.
p = The total pressure of the air and water vapor mixture in the sample in lb/ft^2 absolute.
w = The humidity ratio (humidity ratio is sometimes called specific humidity) in pounds of water per pound of dry air. If it is given in grains per pound, you can convert it to pounds by using the conversion factor of 7,000 grains per pound.
R_H = The gas constant for water vapor (85.8 ft. per°F).
R_a = The gas constant for air (53.3 ft. per°F).

The equations can also be arranged in the following form.

$$w = \frac{R_a}{R_H} \times \frac{p_H}{p - p_H}$$

A special case for saturation.

$$w_s = \frac{R_a}{R_H} \times \frac{p_s}{p - p_s}$$

Where:

p_s = The partial pressure of water vapor in the sample at saturation in lb/ft^2 absolute.

You can also determine the dew point if you know the humidity ratio and the pressure by solving the relationship for the partial pressure of water at saturation and then using a steam table to look up the saturation temperature associated with the partial pressure of water at saturation.

$$w_s = \frac{R_a}{R_H} \times \frac{p_s}{p - p_s}$$

Therefore:

$$w_s \times \frac{R_H}{R_a} = \frac{p_s}{p - p_s}$$

$$\left(w_s \times \frac{R_H}{R_a}\right) \times (p - p_s) = p_s$$

$$p \times \left(w_s \times \frac{R_H}{R_a}\right) - p_s \times \left(w_s \times \frac{R_H}{R_a}\right) = p_s$$

$$p \times \left(w_s \times \frac{R_H}{R_a}\right) = p_s + \left[p_s \times \left(w_s \times \frac{R_H}{R_a}\right)\right]$$

$$p \times \left(w_s \times \frac{R_H}{R_a}\right) = p_s \times \left[1 + \left(w_s \times \frac{R_H}{R_a}\right)\right]$$

You Could Do the Math

The following relationship can be derived from the ideal gas laws by dividing the ideal gas equation for water vapor by the ideal gas equation for air.

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Where:

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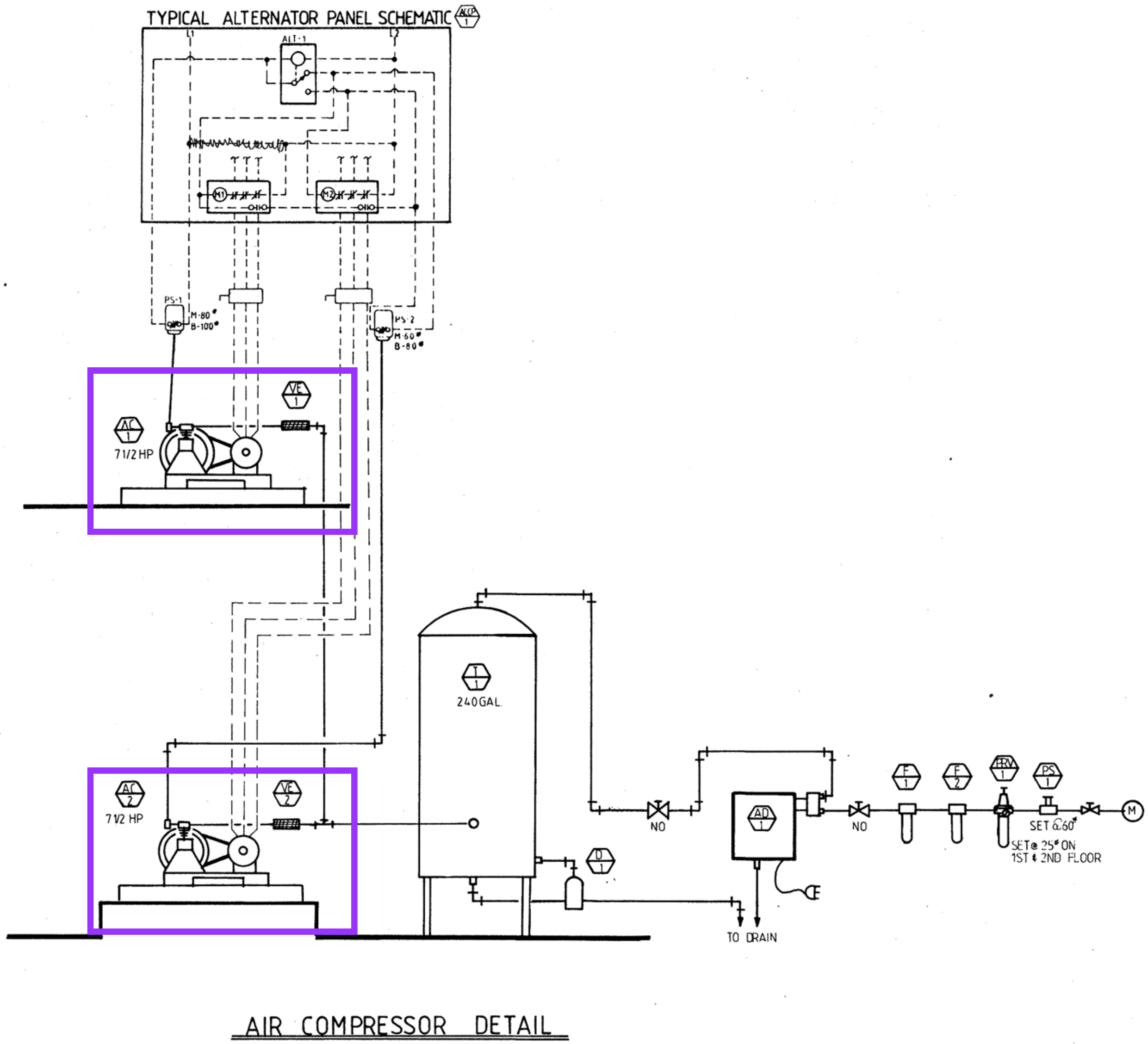
R_H = The gas constant for water vapor (85.8 ft. per°F)

A Typical Pneumatic Air Supply System

Key Points

1. Pneumatics are truly "plug and play" Jay Santos
2. Pressure regulation is important
3. Clean, oil-free air is important
4. Dry air is important
5. Redundancy is important



A Typical Pneumatic Air Supply System

Key Points

1. Pneumatics are truly "plug and play" Jay Santos
2. Pressure regulation is important
3. Clean, oil-free air is important
4. Dry air is important
5. Redundancy is important
6. A tight system is important