Natural Refrigerant Training Summit

Building a Sustainable Workforce

Using P&ID to Further Understand CO2 Transcritical Booster Systems

Andre Patenaude
Emerson / Copeland

NORTH AMERICAN Sustainable Refrigeration Council

NORTH AMERICAN Sustainable Refrigeration Council

Confidence

Delivering the future of CO_2 refrigeration.

Using P&ID to Further Understand CO2 Transcritical Booster Systems

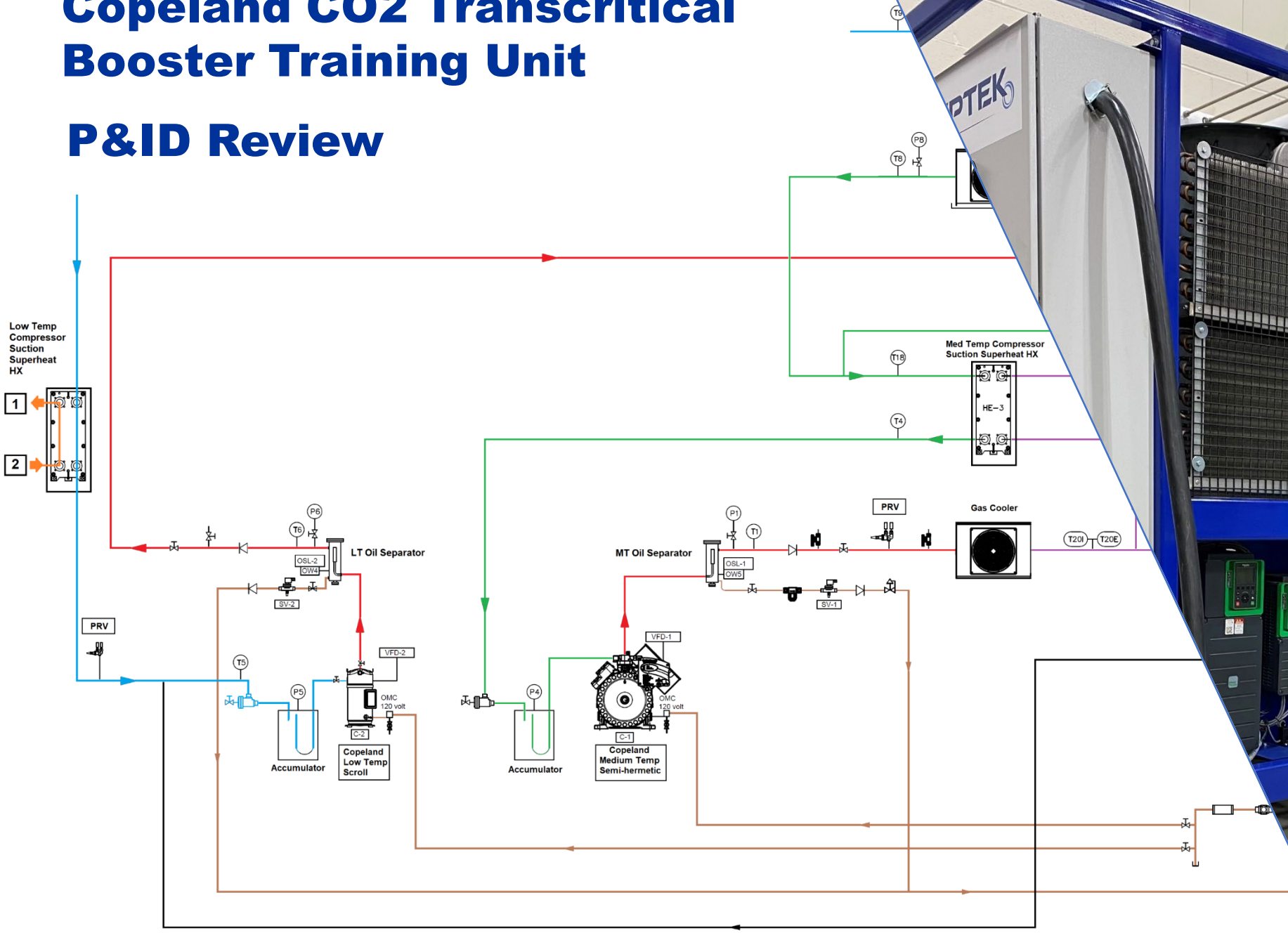
NASRC Natural Refrigerant Summit

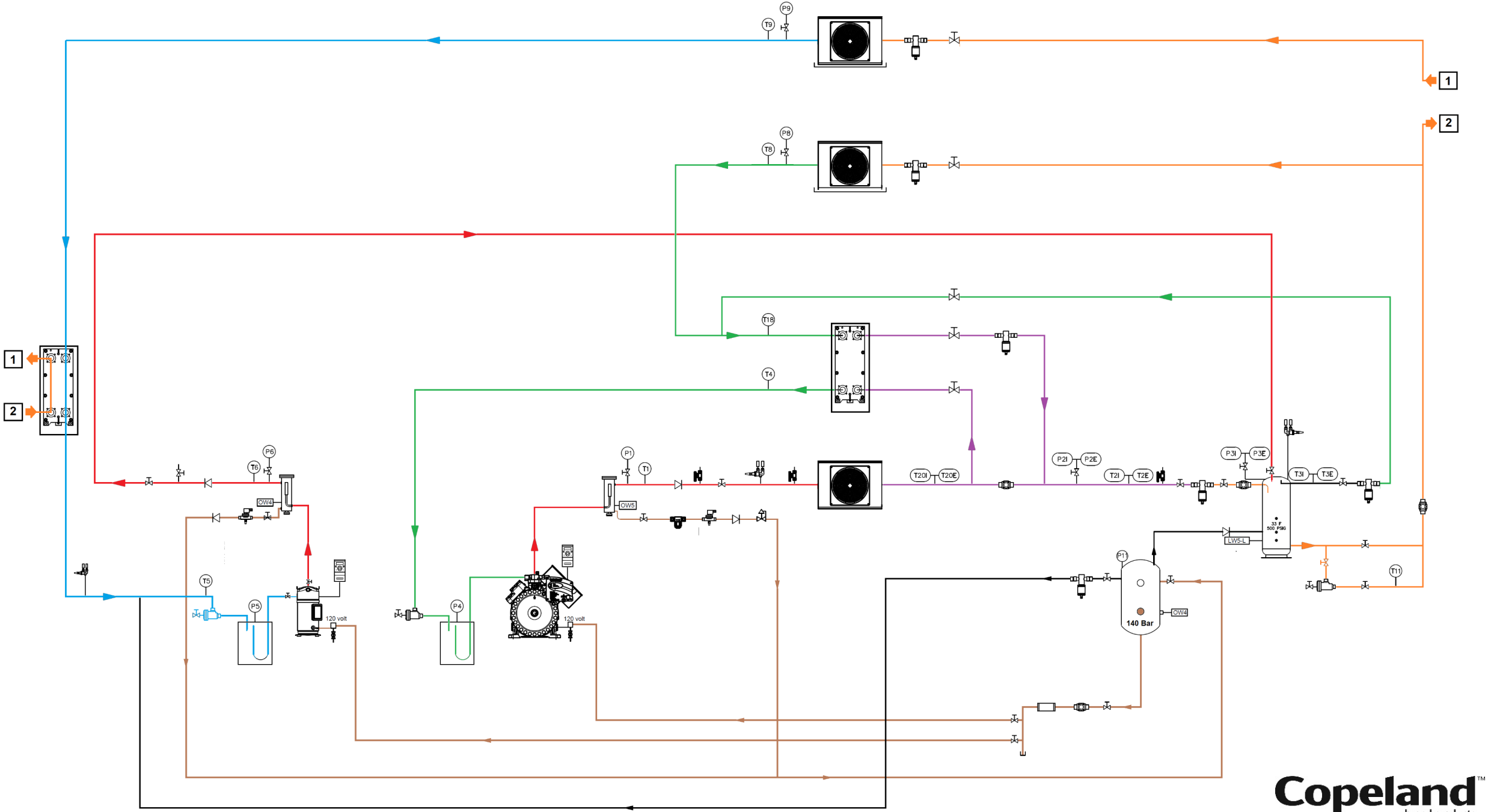
April 4-6, 2023, Irwindale, CA

Copeland

Copeland CO2 Transcritical Booster Training Unit

P&ID Review





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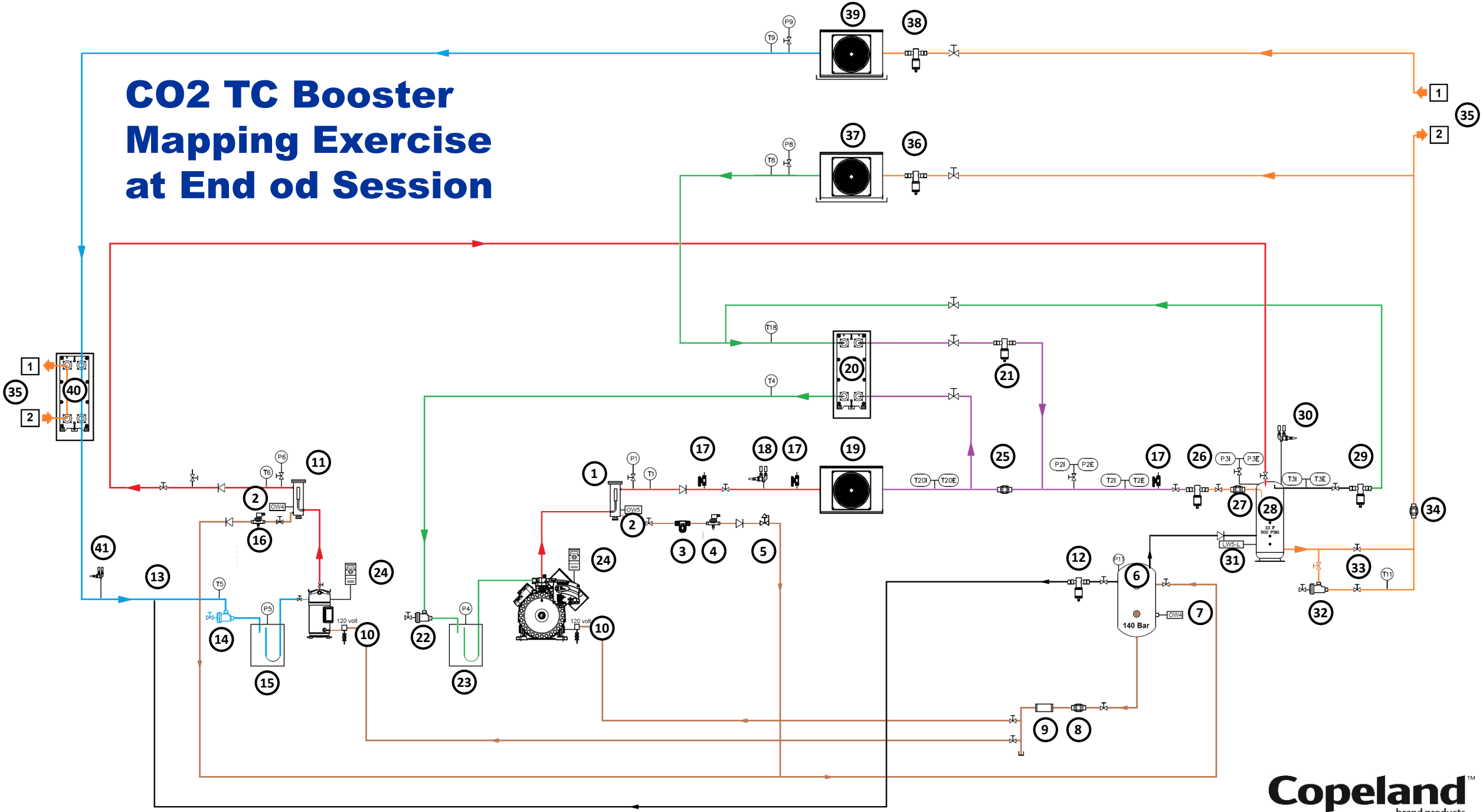
CO2 TC Booster Mapping Exercise at End od Session



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CO2 Transcritical
MT Copeland Semi-hermetic
4MTLS

Low Temp Evaporator
Medium Temp Evaporator
Low Temp Compressor Suction Superheat HX
Med Temp Compressor Suction Superheat HX
HE-3
EV-5
* 50 % CLOSE
Gas Cooler
PRV
LT Oil Separator
MT Oil Separator
Flash Tank
HPV
BGV
Oil Reservoir
140 Bar
Accumulator
Copeland Low Temp Scroll
Accumulator
Copeland Medium Temp Semi-hermetic
OMC 120 volt
VFD-1
VFD-2
C-1
C-2
SV-1
SV-2
EV-1
EV-3
EV-8
OSL-1
OSL-2
OW4
OW5
LW5-L

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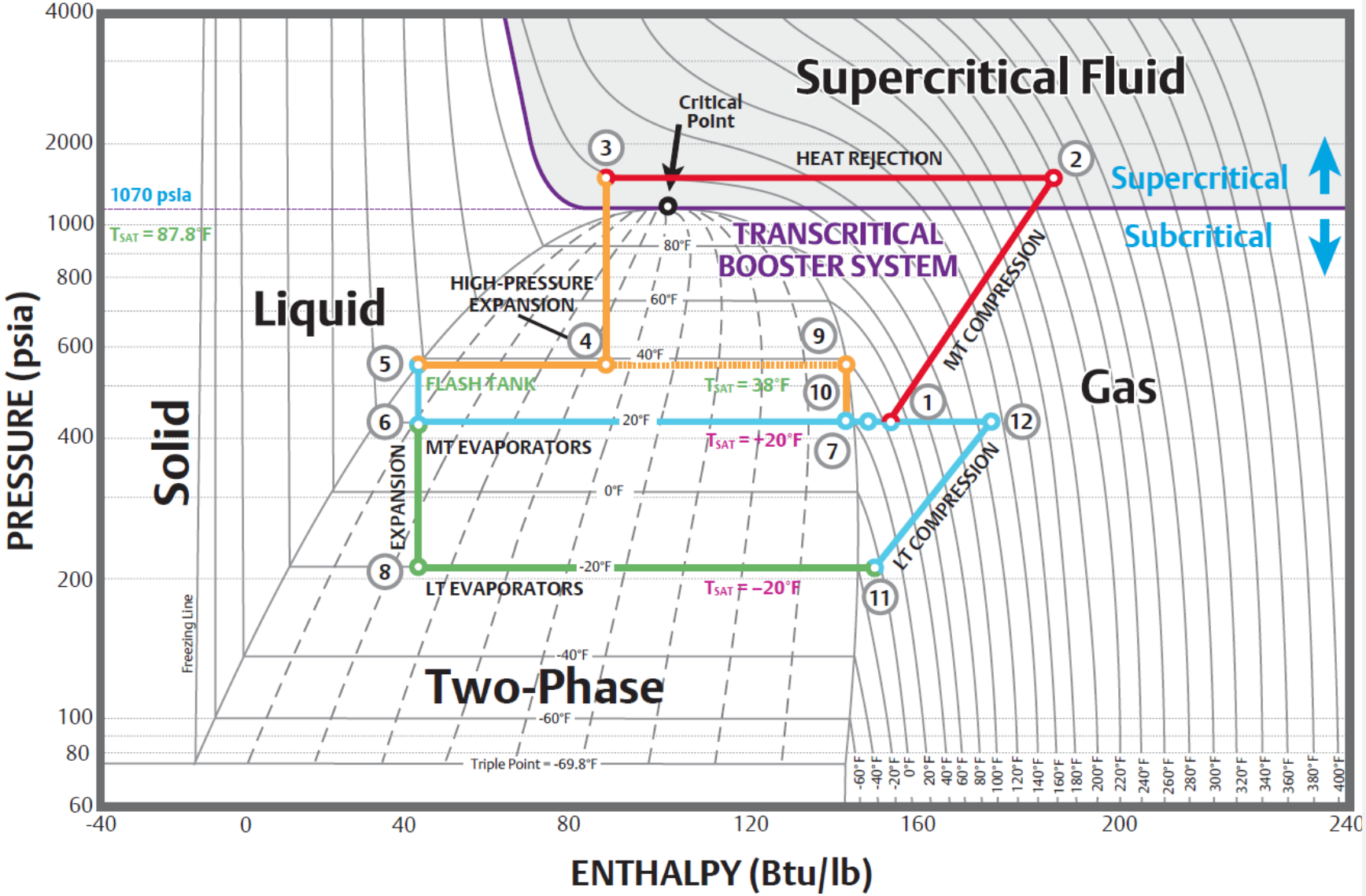
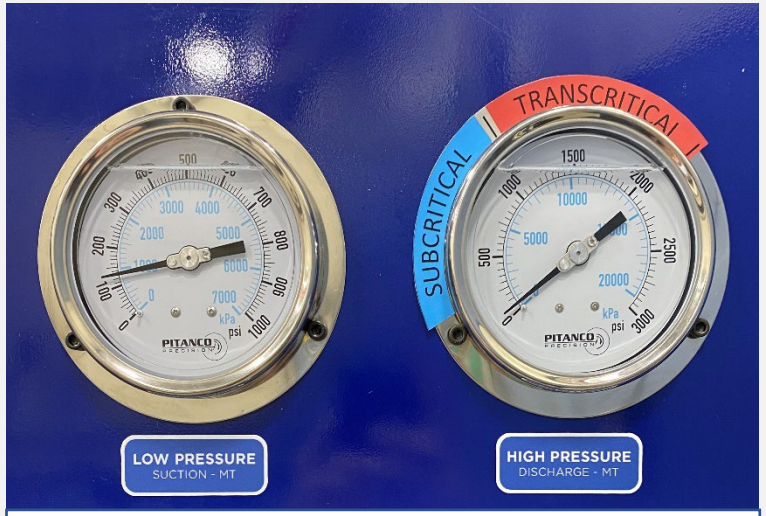
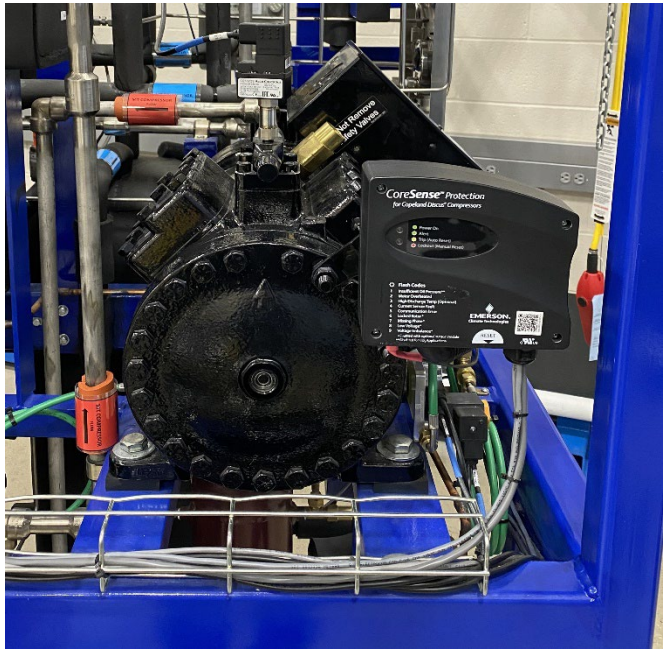
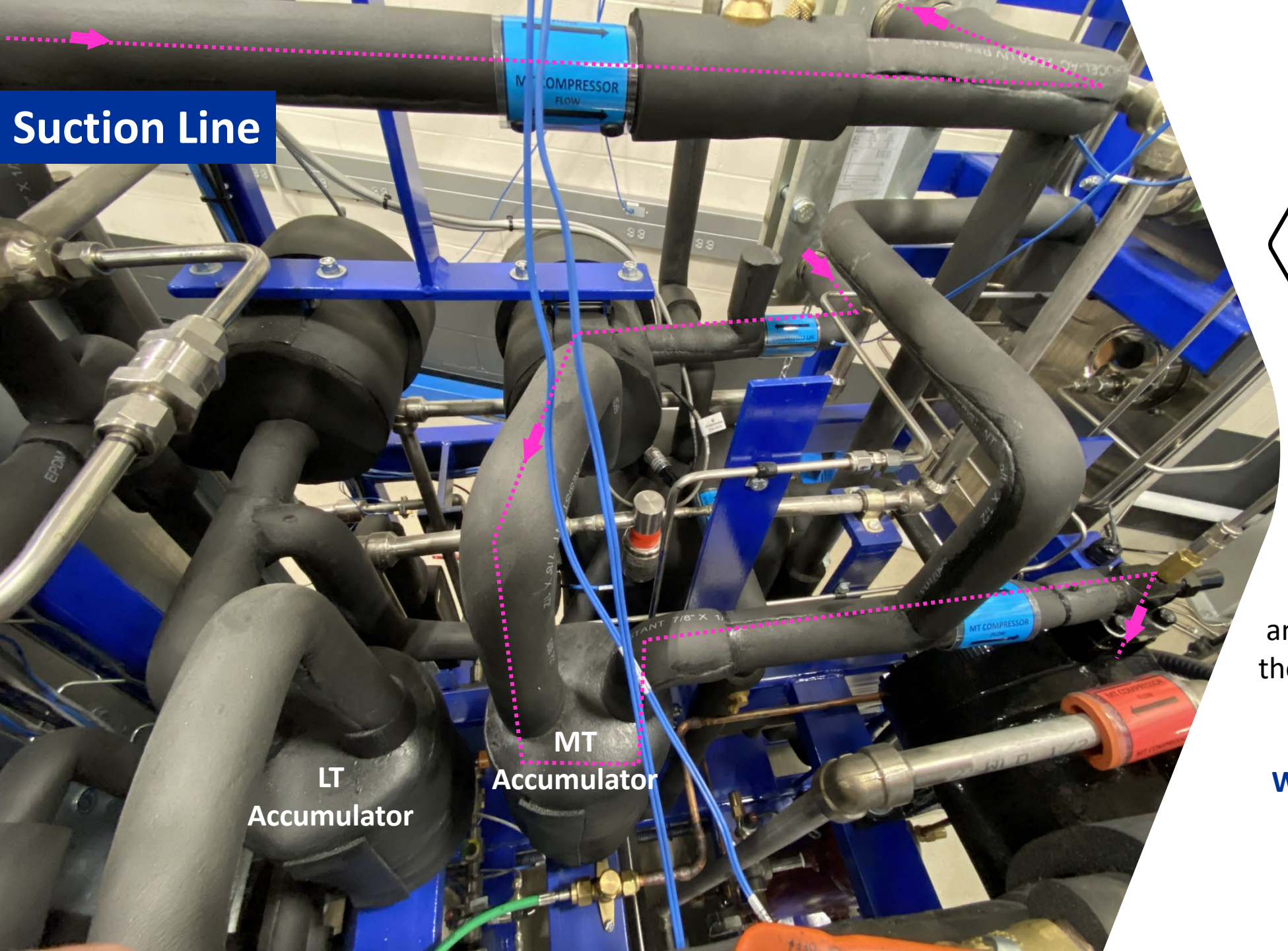

Supercritical Fluid
Critical Point
HEAT REJECTION
Supercritical
Subcritical
1070 psia
T_{SAT} = 87.8°F
TRANSCRITICAL BOOSTER SYSTEM
HIGH-PRESSURE EXPANSION
Liquid
MT COMPRESSION
Gas
FLASH TANK
T_{SAT} = 38°F
MT EVAPORATORS
T_{SAT} = +20°F
EXPANSION
Solid
LT COMPRESSION
LT EVAPORATORS
T_{SAT} = −20°F
Freezing Line
Two-Phase
Triple Point = -69.8°F
PRESSURE (psia)
ENTHALPY (Btu/lb)


SUBCRITICAL
TRANSCRITICAL
LOW PRESSURE
SUCTION - MT
HIGH PRESSURE
DISCHARGE - MT


CoreSense Protection

Discharge Line

Copeland 4MTLS40KE-FSC-C00



Suction Accumulators

are never Insulated
since they use the
ambient heat to help superheat
the return gas to the compressor

For the Trainer;
We Insulated them for Safety,
to Avoid Slipping Danger
Due to Water Dripping
on Training Floor

Copeland Transcritical CO2 Compressors

Copeland 4MTLS Semi-hermetic

4MTLS Series; 4 Cylinders

Description:

- Cooling Capacity
  - 5 to 20HP Models, 40 to 150 MBH
  - 24 to 34HP Models 192 to 310 MBH

Main Characteristics:

- Pressures: Operating 120bar (1740 psig)
- Pressure Relief Valves Ratings
  - 135bar (1958psig)
- Low Sound Level, Vibration & Pulsation
- UL Approved for North America

Speed Range:

- 25Hz to 70Hz (4MTLS40K-15M)
- 30Hz to 70Hz (4MTLS20)
- 30Hz to 60Hz (4MTLS22M-28M)
- CoreSense, Advanced Protection, Preventive Maintenance, Remote Communication

Compressors of same Capacity

Discus 4DH

CO2 4MTLS15

Copeland™ brand products

Copeland™ brand products

Stator Cover

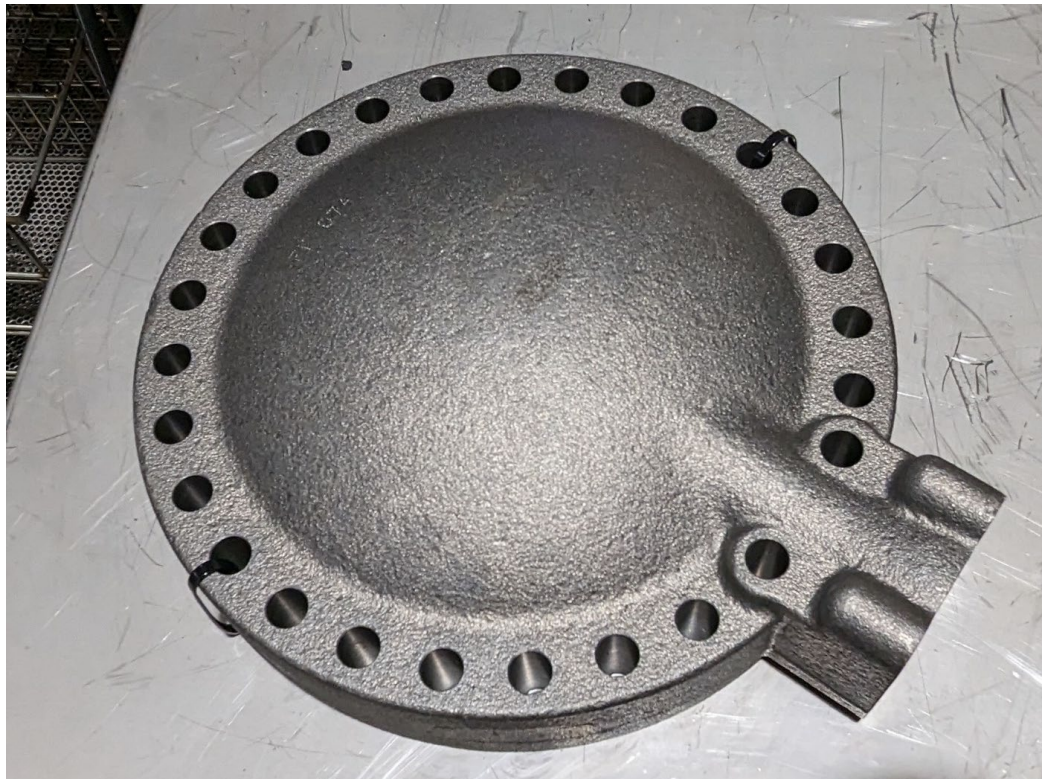
Discus 4DH

005-1832-00

12 bolts

CO2 4MTLS15

505-1218-00



27 bolts

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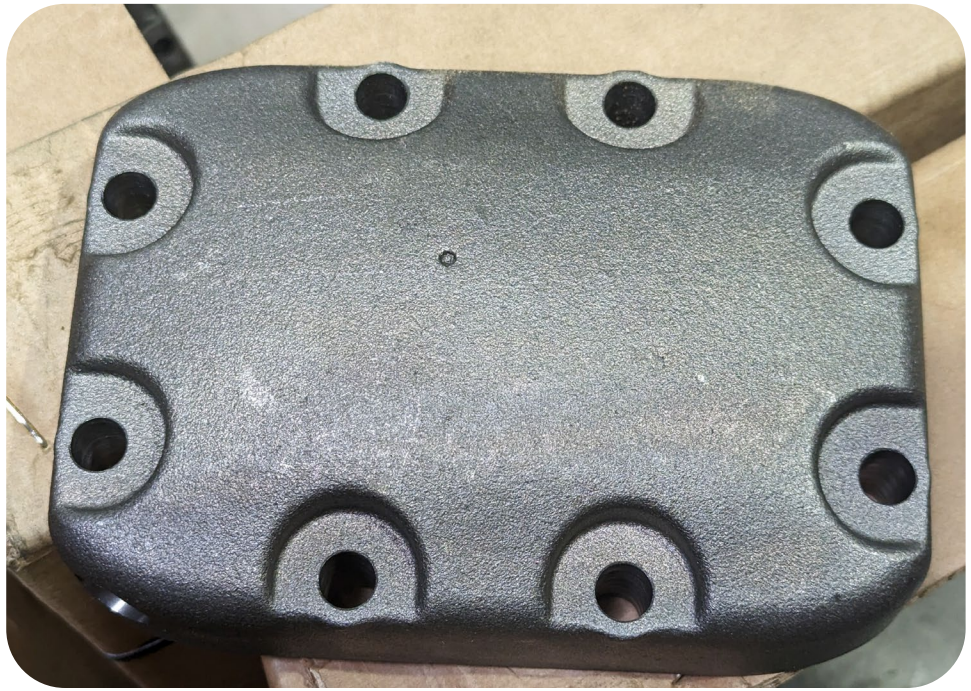
Head Covers

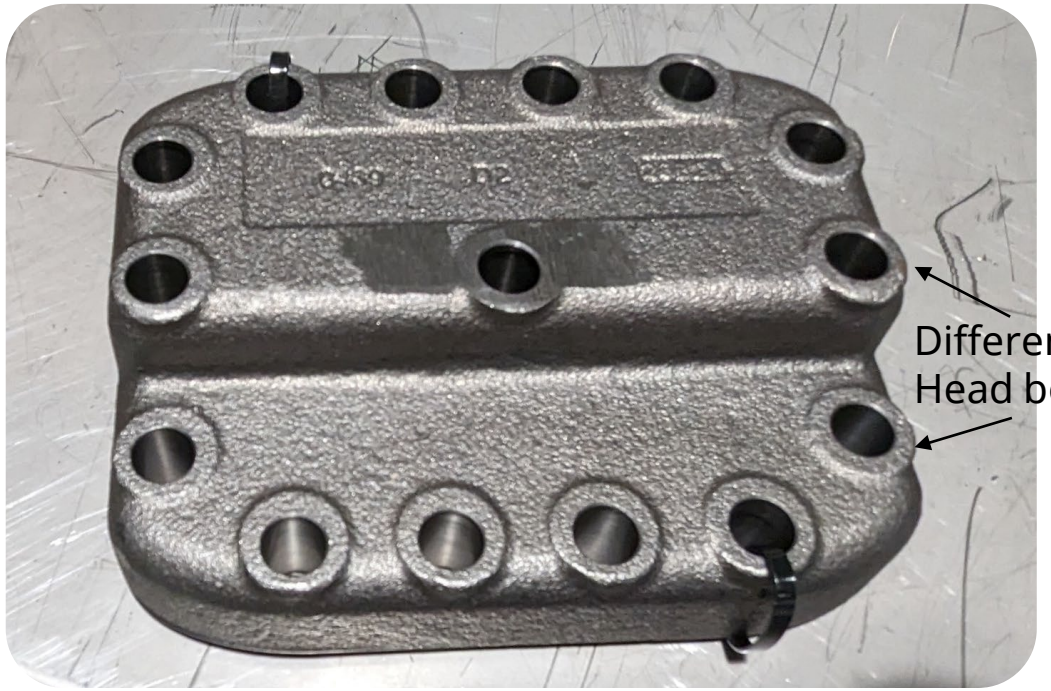
Discus 4DH

002-0433-00



CO2 4MTLS15

002-0439-00



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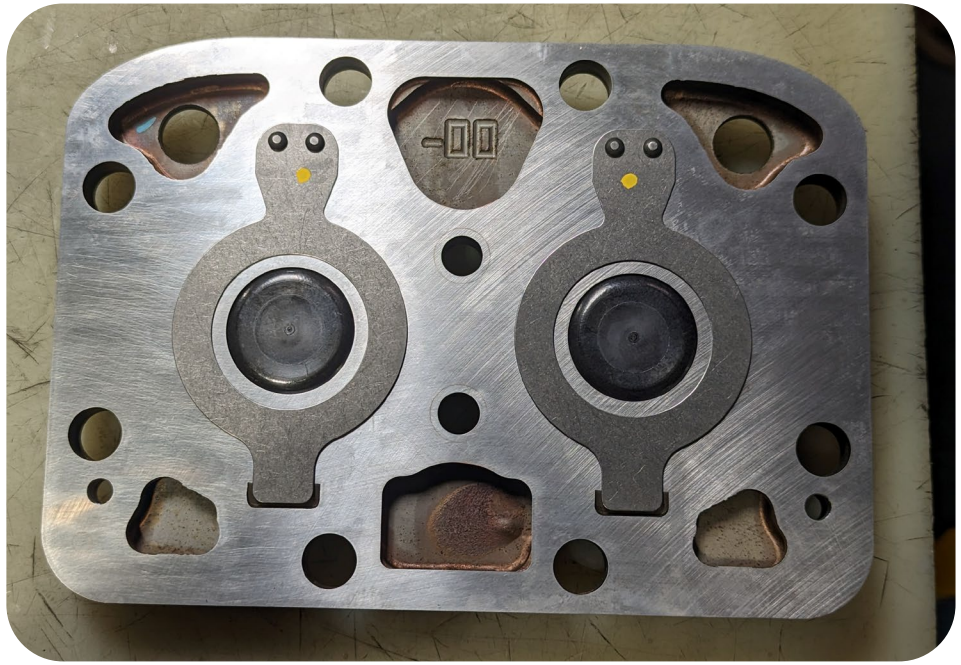
Valve Plates

Discus - 4DH



503-2032-00

CO2 - 4MTLS15

503-1075-00

Note: Discus “puck” design vs. traditional Reed

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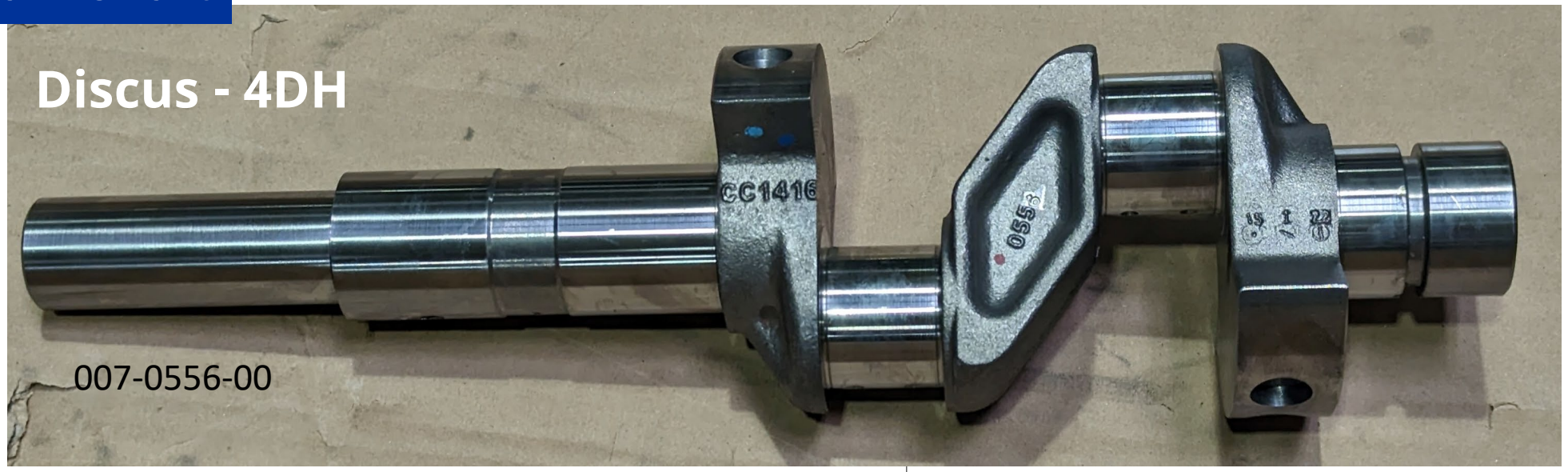
Crankshaft

Discus - 4DH



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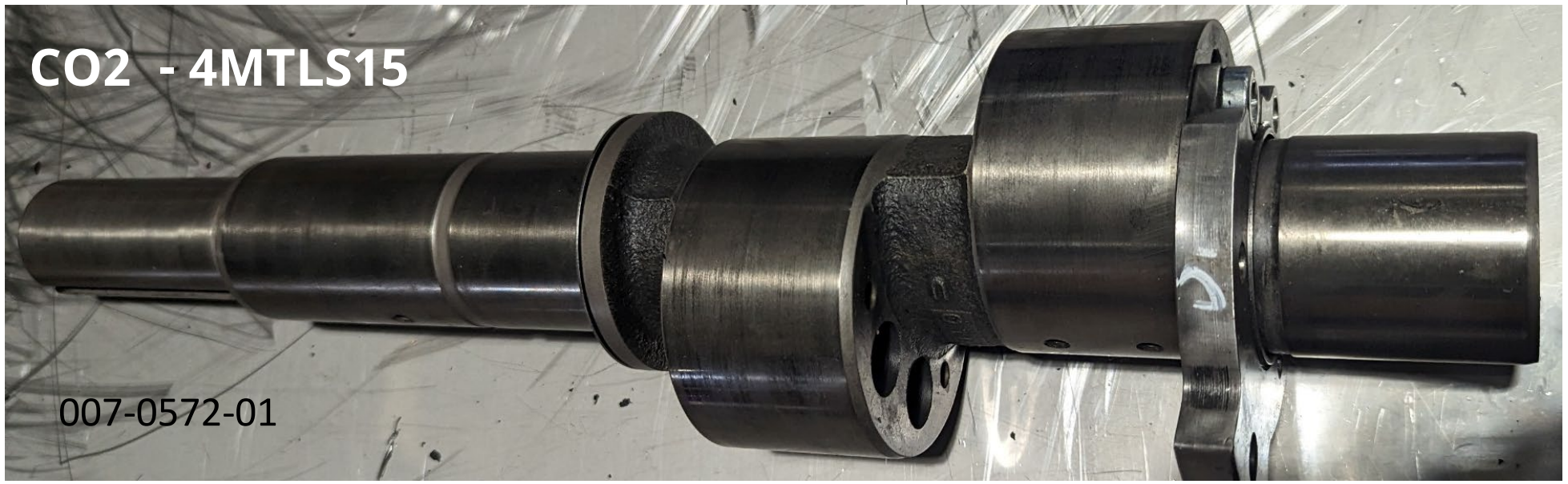
CO2 - 4MTLS15



007-0572-01

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Connecting Rods

Discus - 4DH

Discus
Large Diameter 47mm
Small Diameter 19mm

CO2 - 4MTLS15

CO2
Large Diameter 82mm
Small Diameter 25mm

DU Bearings pressed in each hole

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Wrist Pins

Discus - 4DH

CO2 - 4MTLS15

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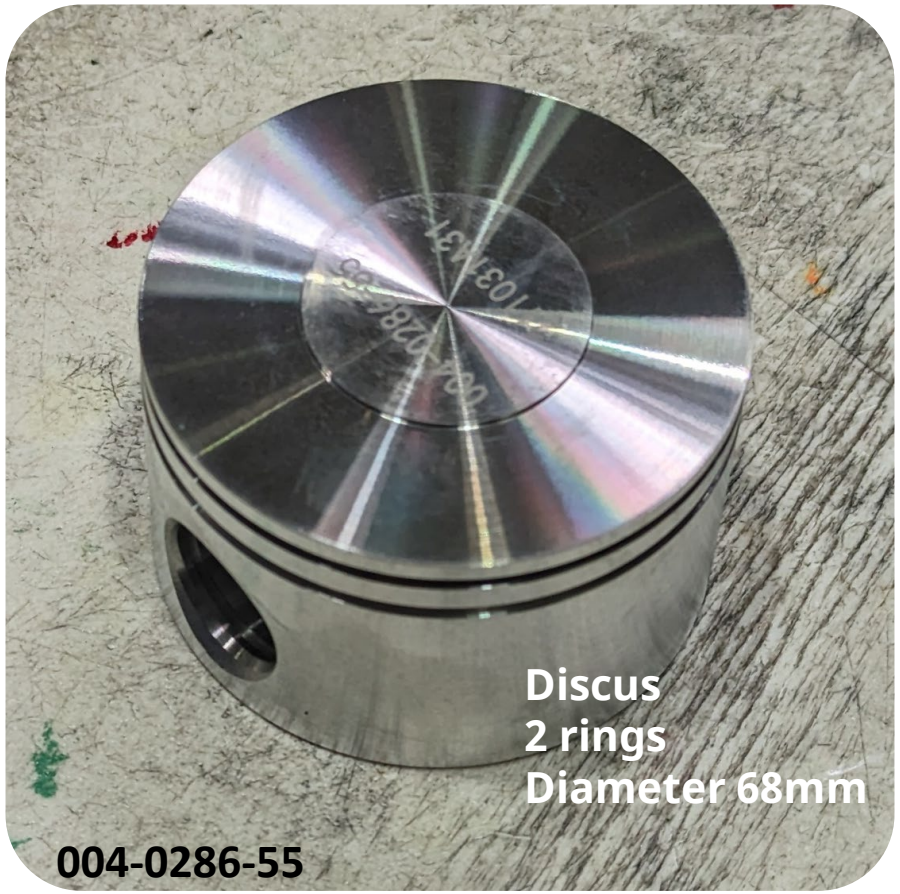
Pistons

Discus - 4DH



CO2 - 4MTLS15

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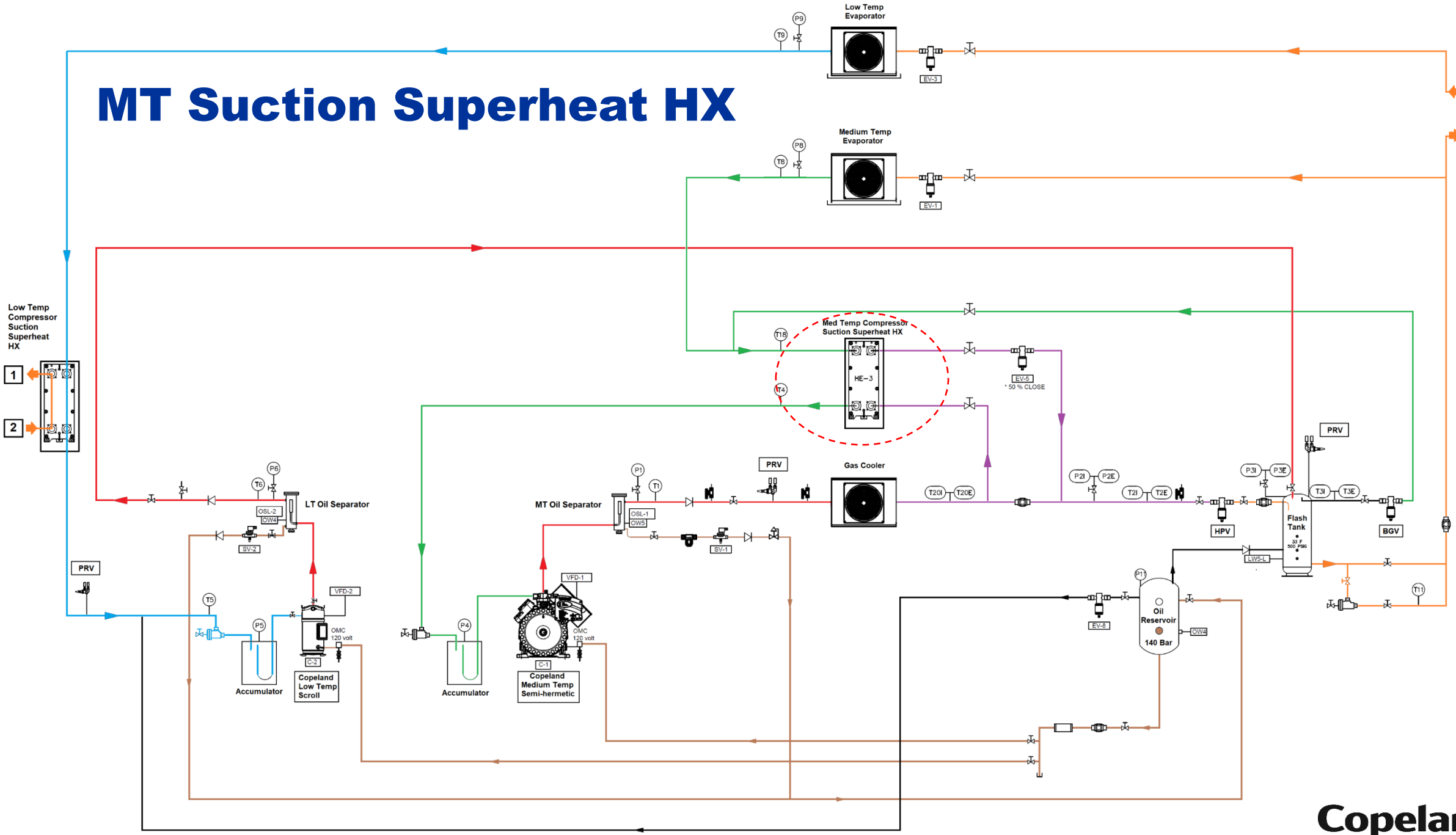
MT Suction Superheat HX



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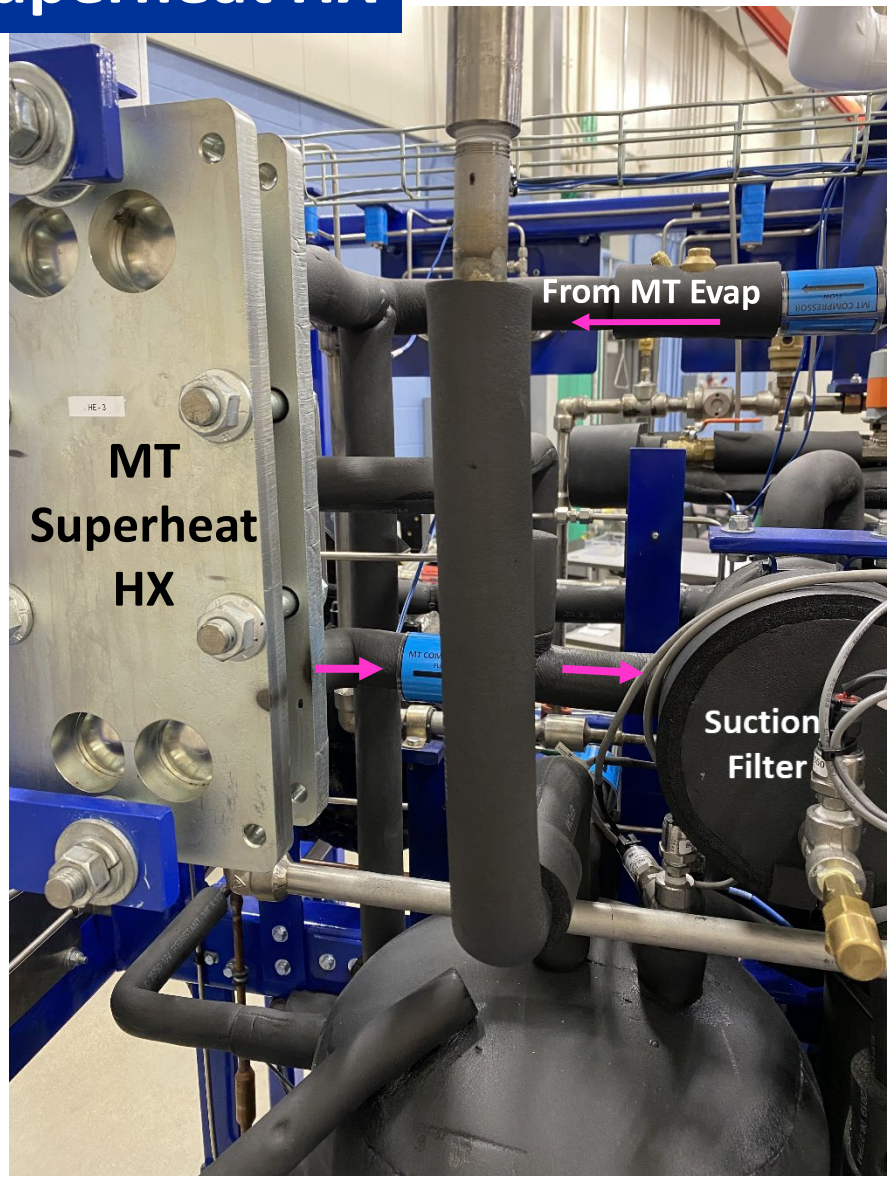
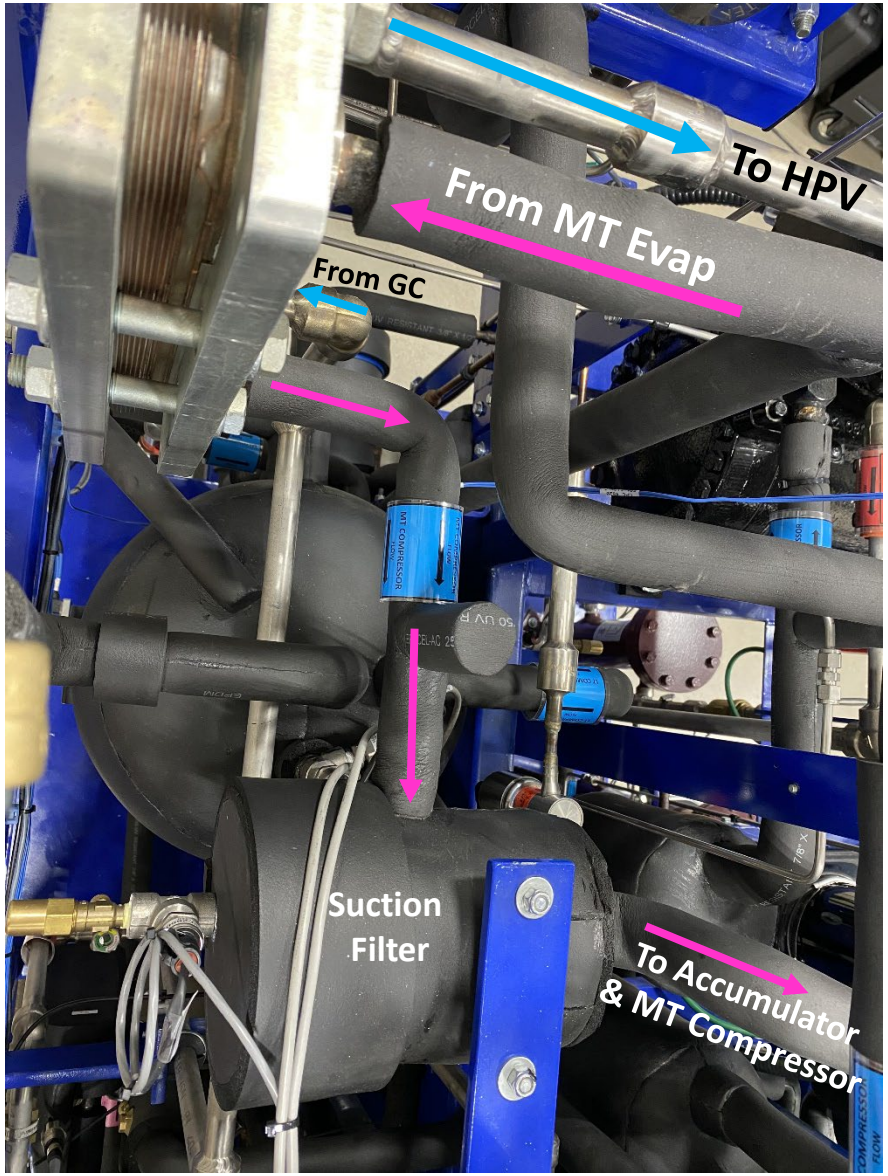
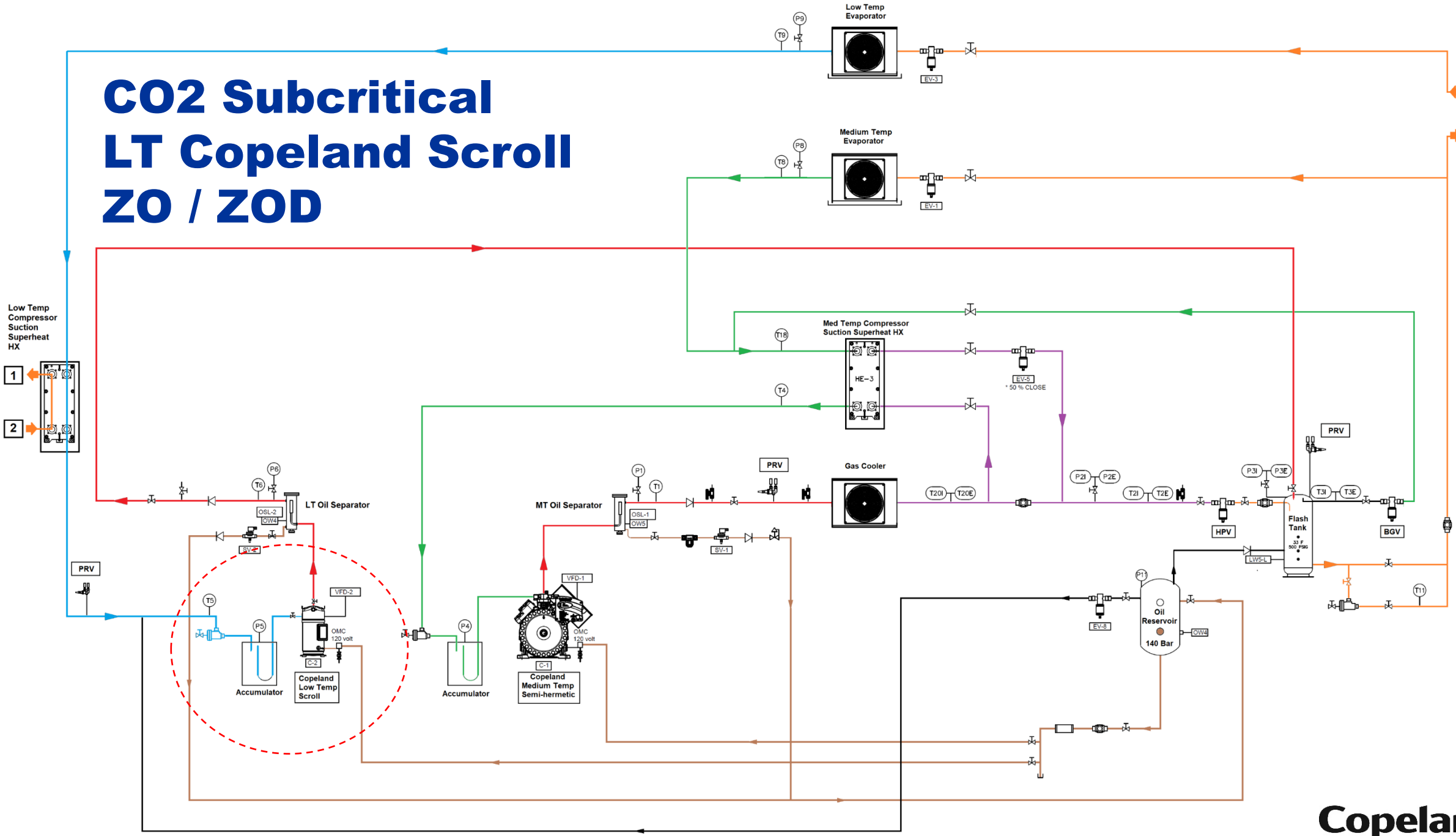
MT Superheat HX





CO2 Subcritical
LT Copeland Scroll
ZO / ZOD



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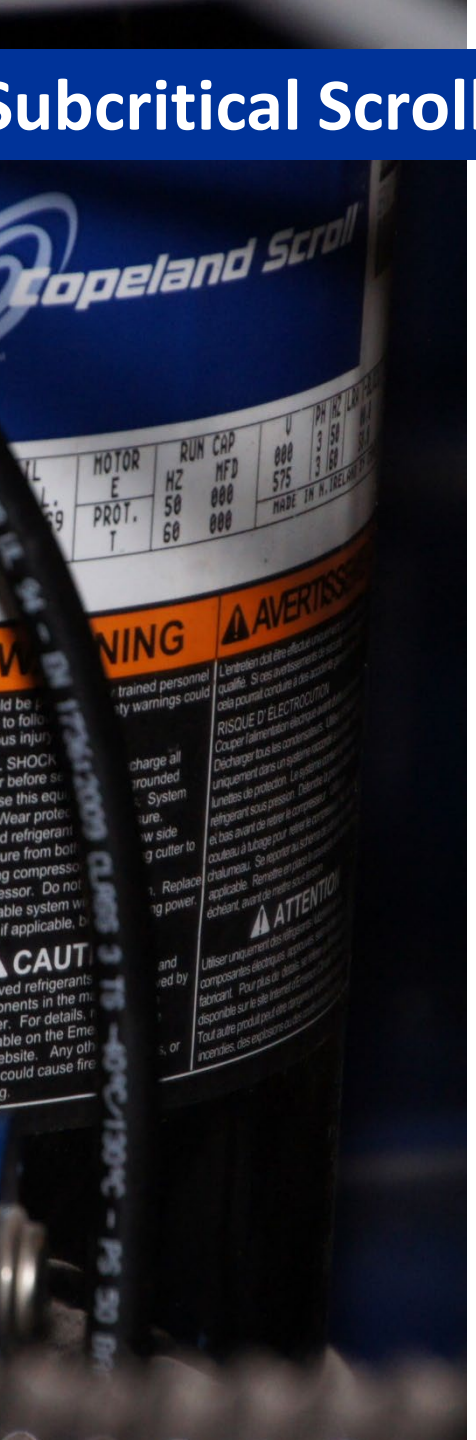
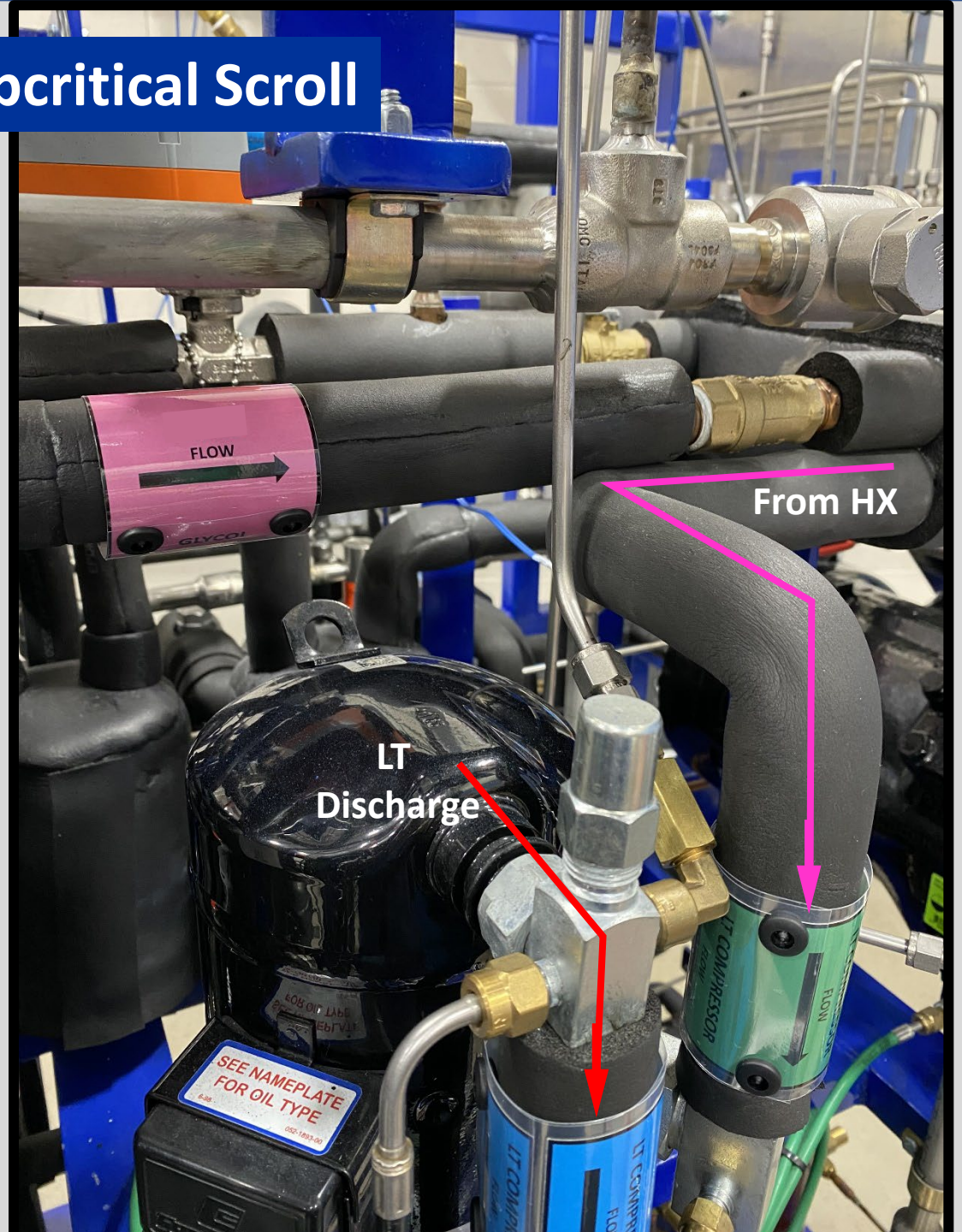
Subcritical Scroll



LT Subcritical Scroll



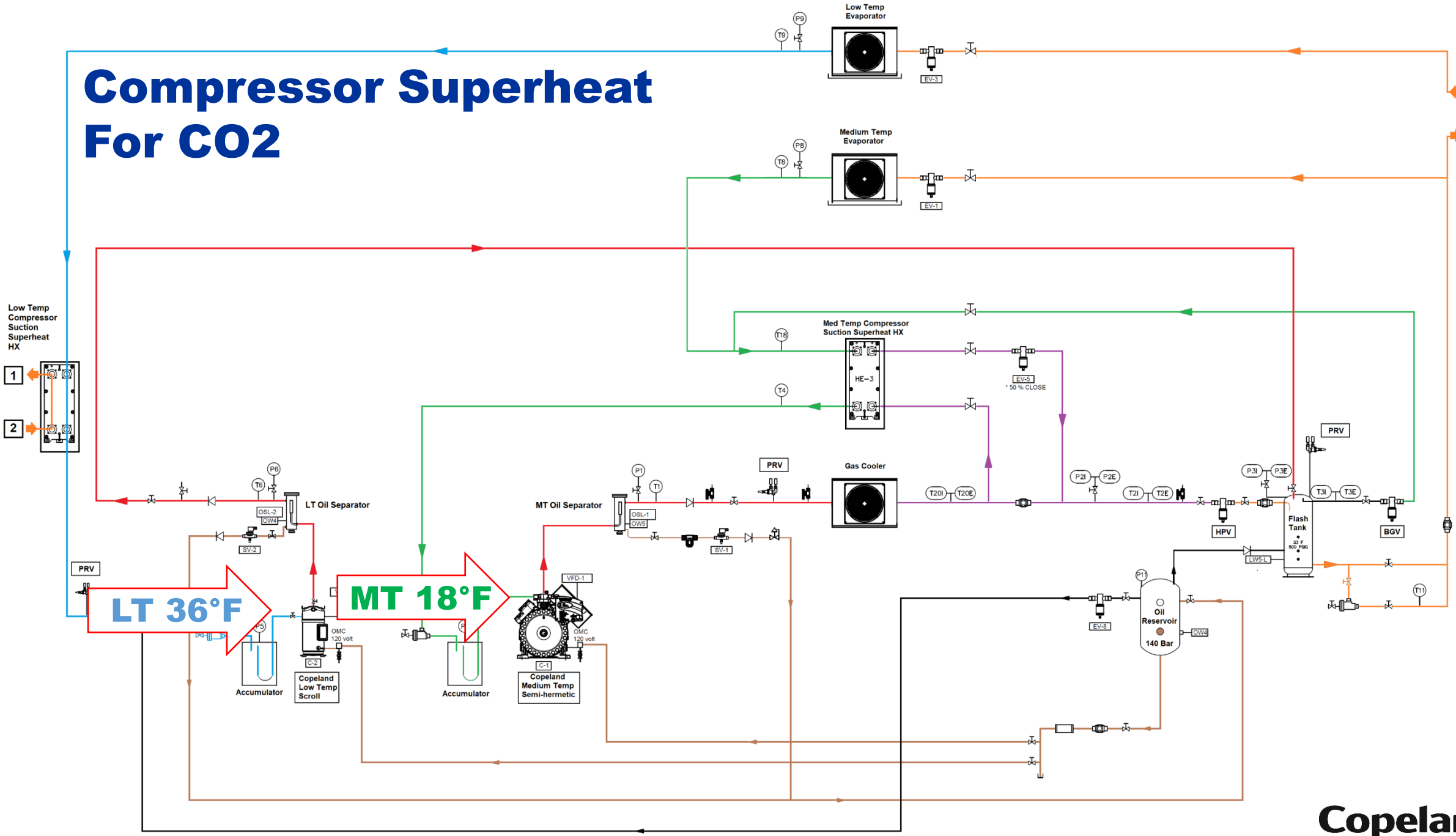
Copeland ZO Scroll Compressors

					Available (60Hz, 50Hz)				
Model	Nominal Horsepower	Displacement	Capacity Btuh	Capacity kW	EER	460V	230V	575V	380V
ZO21K5E	1.5	112 CFH	20,800	6.0	15.4	✓	✓		✓
ZO(D)34K3E	2.0	172 CFH	32,000	9.4	15.4	✓	✓	✓	✓
ZO45K3E	2.5	228 CFH	44,500	13.0	16.5	✓	✓	✓	
ZO58K3E ZO(D)58K3E	3.5	291 CFH	57,000	16.7	16.7	✓	✓	✓	✓
ZO88KCE	5.5	431 CFH	85,300	25.0	16.3	✓	✓	✓	✓
ZO(D)104KCE	6.0	498 CFH	98,500	28.9	16.3	✓	✓	✓	✓

Capacity with R-744 at -31F evap, 14F cascade cond, 5F RG, 14F liquid

- Axial And Radial Compliance For Improved Liquid And Debris Handling
- Low Sound Emission And Vibration
- High Volumetric Efficiency
- Digital Modulation Available Providing 10-100% Capacity
- Maximum Operating Envelop Pressure: Low Side = 229psig
- Maximum Operating Envelop Pressure: High Side = 561psig
- Maximum Standstill Pressure: Low Side = 500 psig (UL)
- Maximum Standstill Pressure: High Side = 500 psig (UL)

Compressor Superheat For CO2



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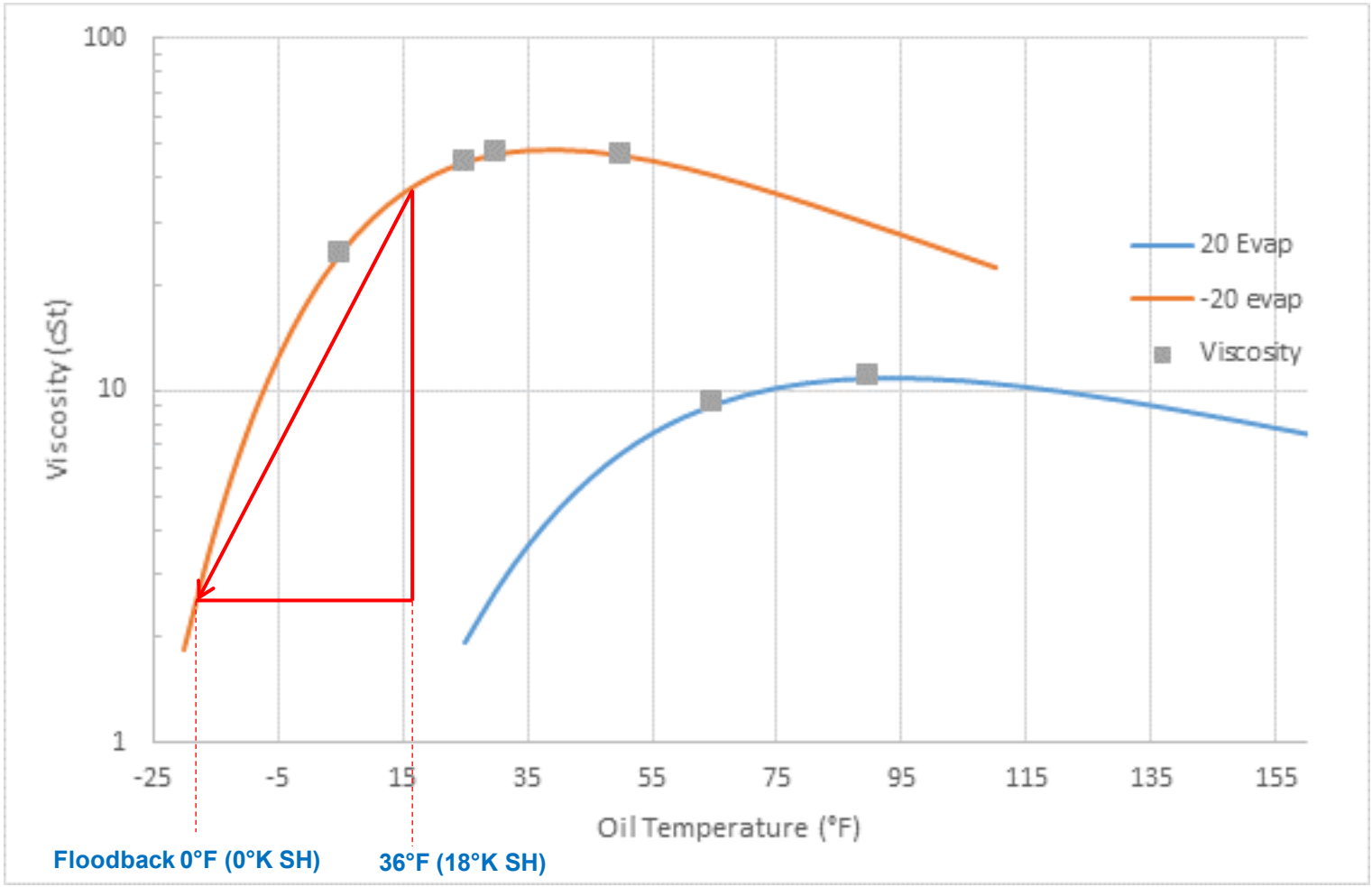
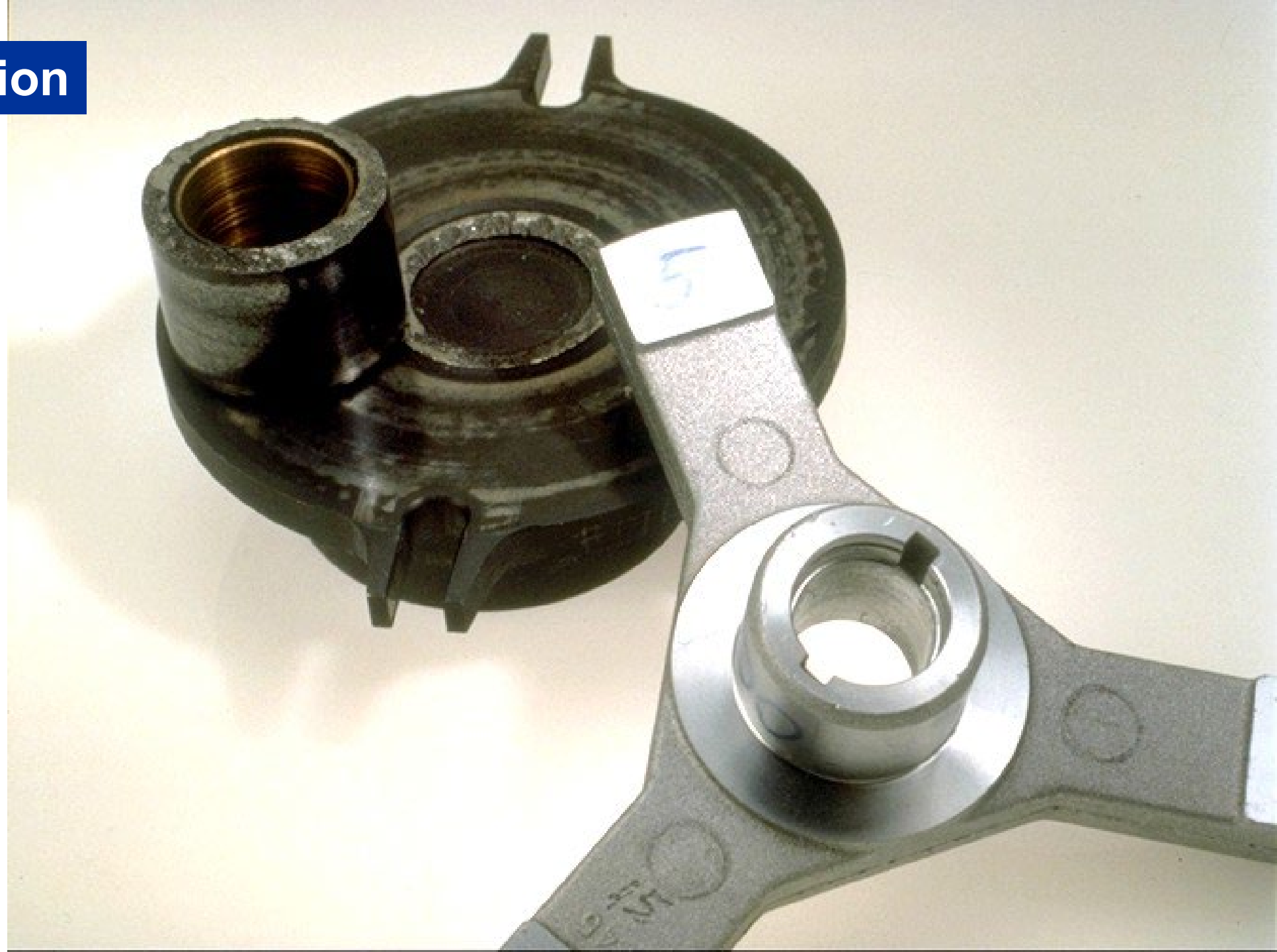
POE Oil Viscosity in CO_2 Vs Suction Superheat

Oil Temp Measured Bottom of Sump



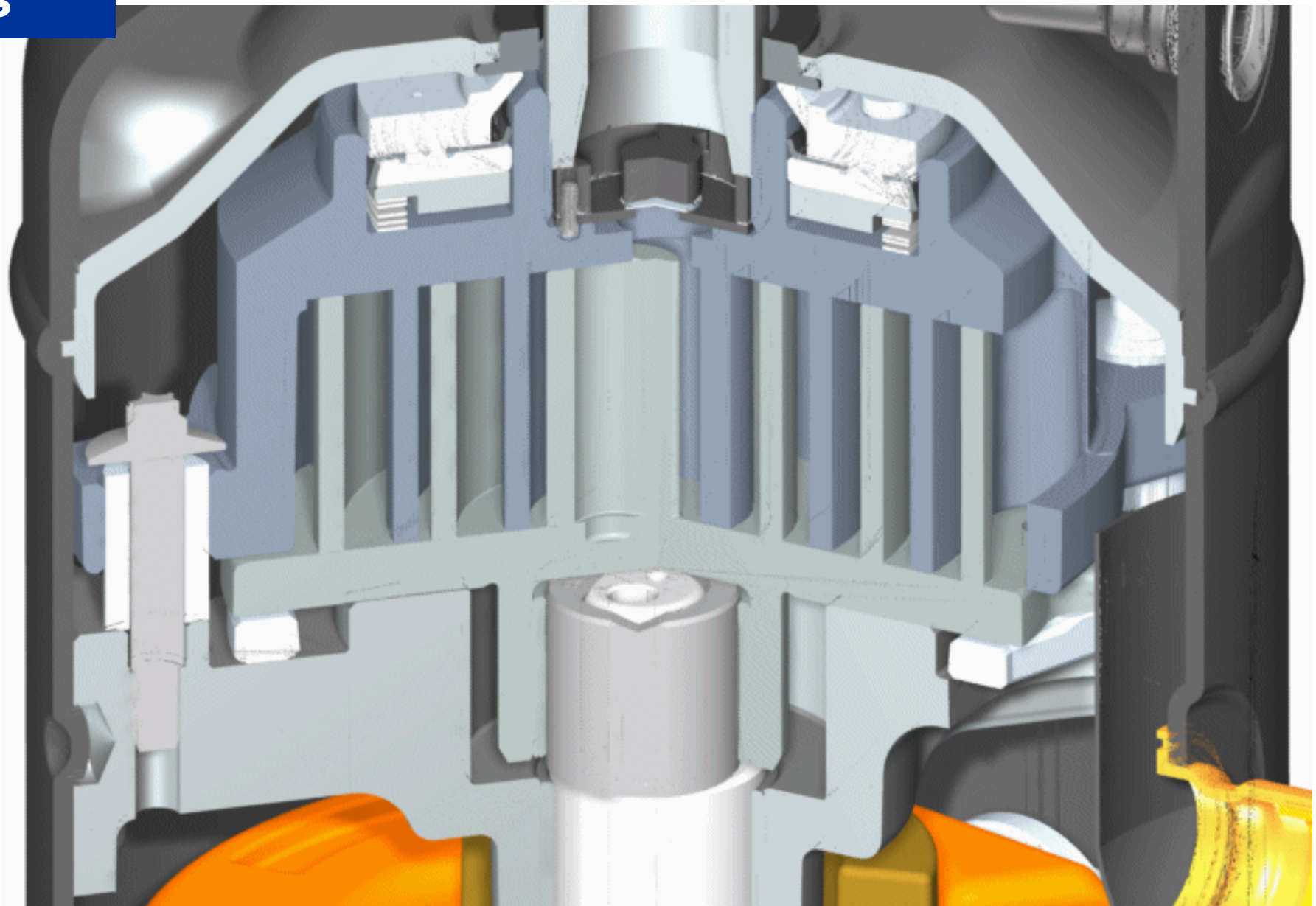
Scroll Drive Bearings
Lack of Lubrication

Lack of Lubrication



Scroll Drive Bearings

Scroll Modulation – How It Works



MT & LT Oil Separator

Low Temp Evaporator
Medium Temp Evaporator
Low Temp Compressor Suction Superheat HX
Med Temp Compressor Suction Superheat HX
HE–3
Gas Cooler
LT Oil Separator
MT Oil Separator
Accumulator
Accumulator
Copeland Low Temp Scroll
Copeland Medium Temp Semi-hermetic
Oil Reservoir
140 Bar
Flash Tank
PRV
PRV
PRV
HPV
BGV
EV-3
EV-1
EV-5
* 50 % CLOSE
EV-8
SV-2
SV-1
OSL-2
OW4
OSL-1
OW5
LW5-L
VFD-1
VFD-2
OMC
120 volt
C-1
C-2
T1
T2E
T2I
T3E
T3I
T4
T5
T6
T8
T9
T11
T18
T20E
T20I
P1
P2E
P2I
P3E
P3I
P4
P5
P6
P8
P9
P11
1
2

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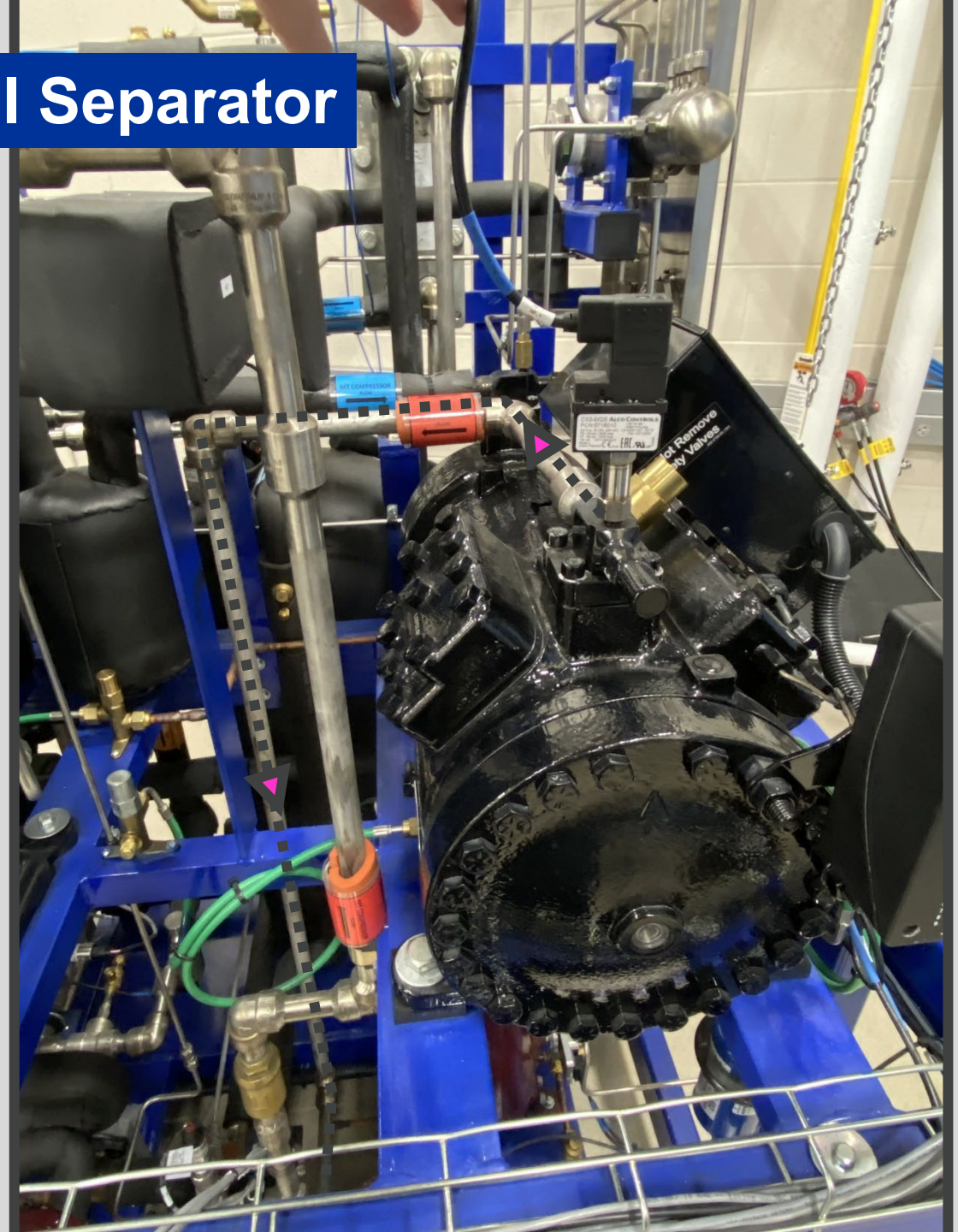
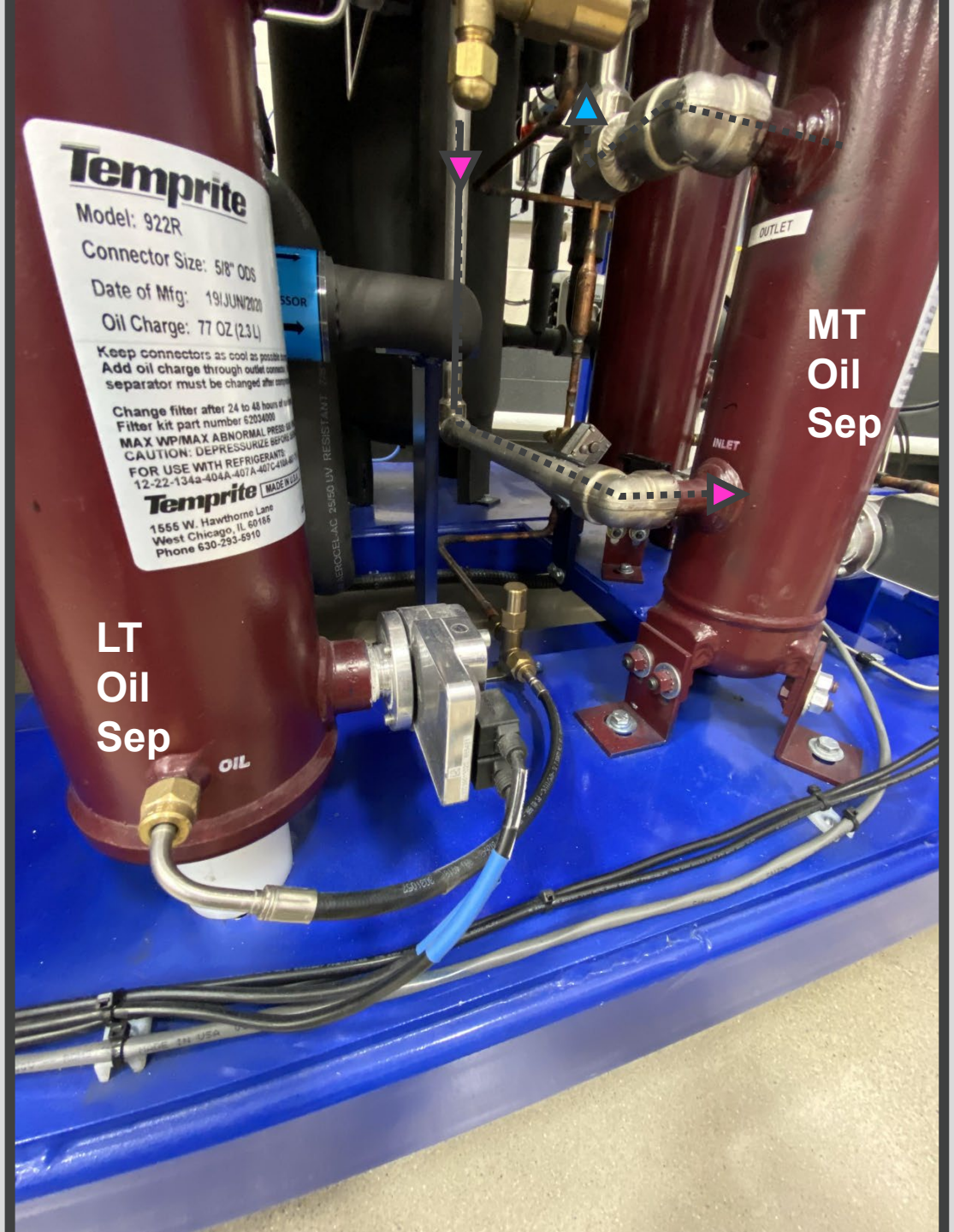
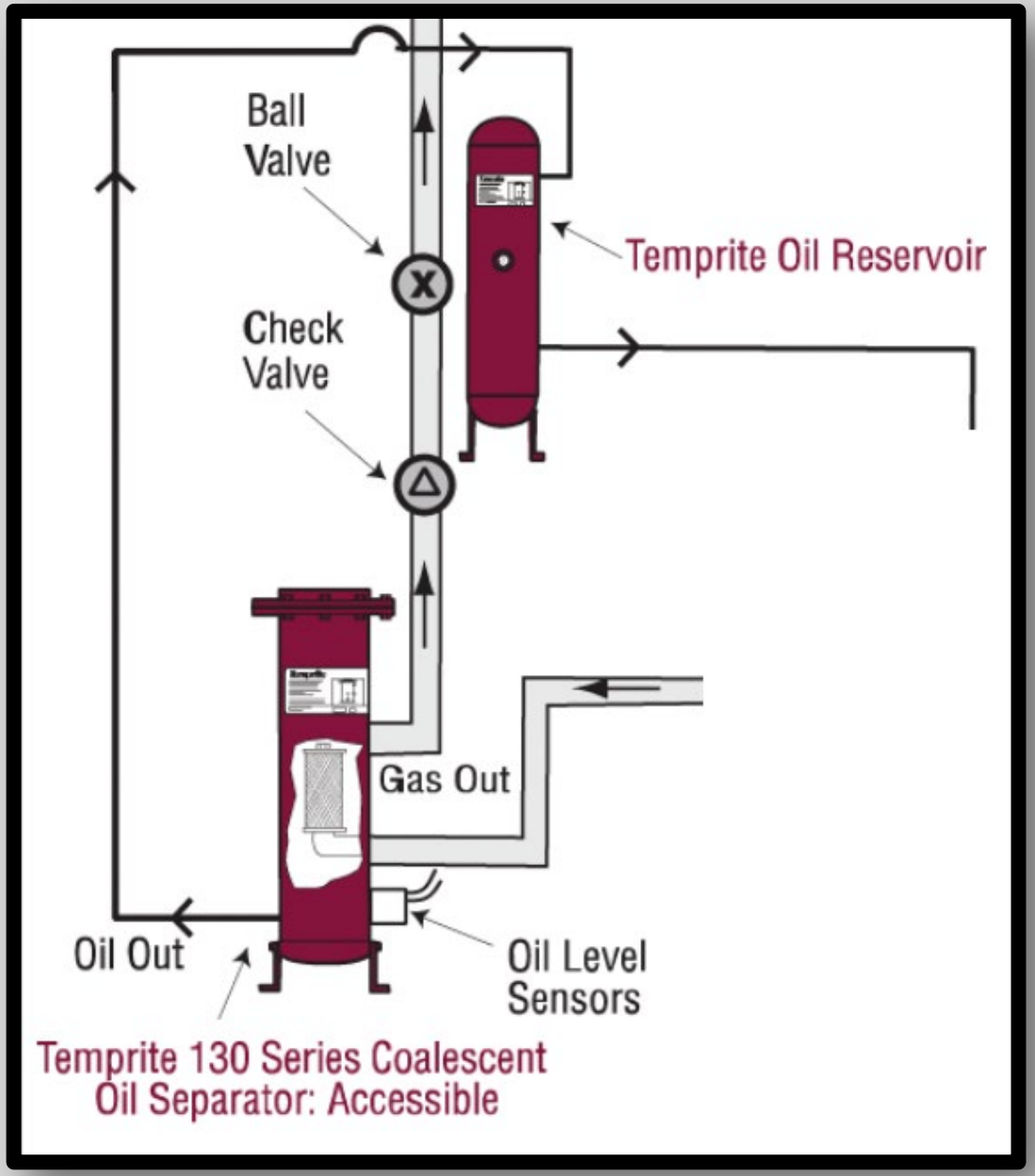
Oil Separator

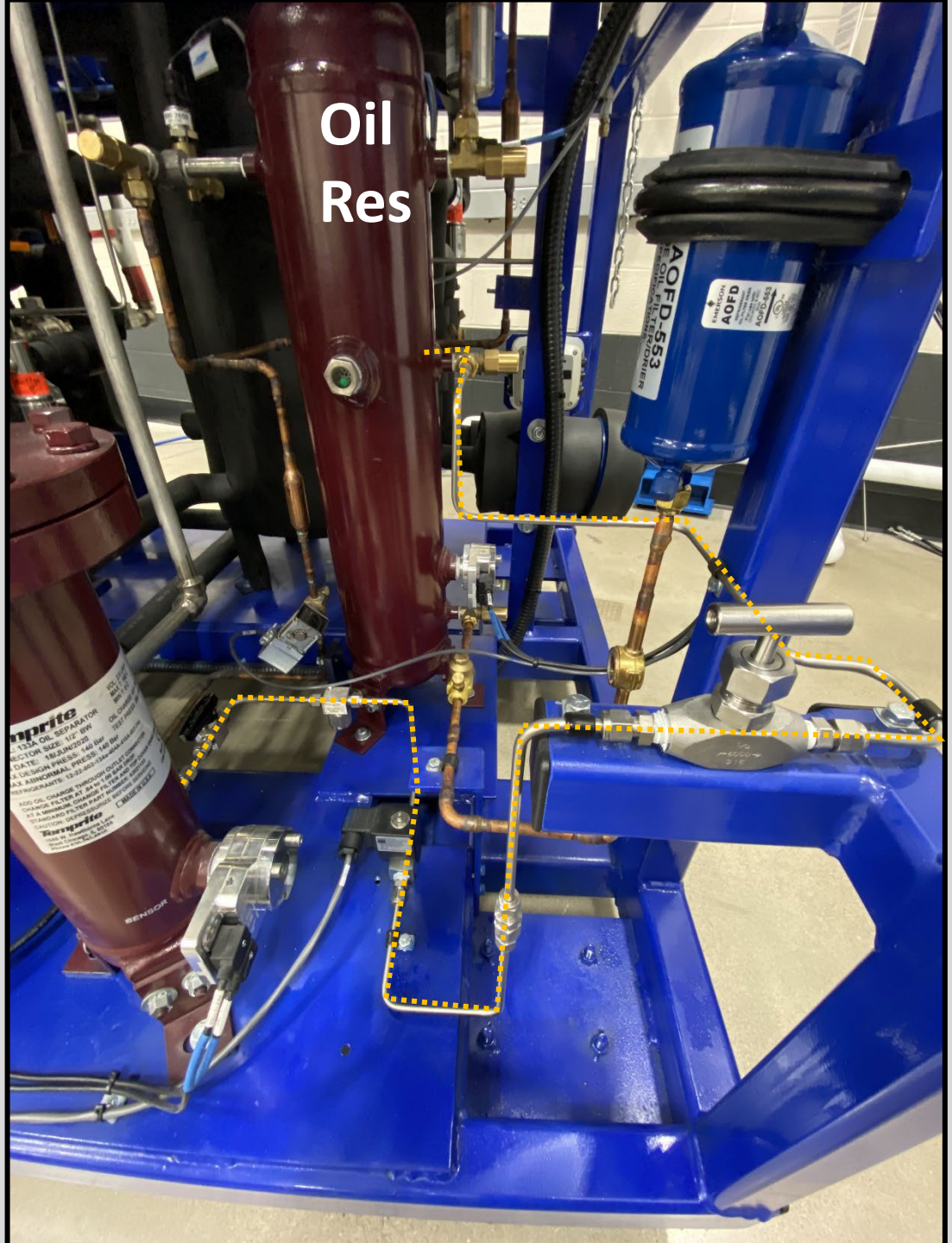




Oil Separator



Oil Separator



Oil Separator

- Suitable for CO_2 Transcritical and subcritical ranges
- Maximum Operating Pressure of 2030 Psig (140 bar)
- **Coalescent oil separators** are used (98.5%⁺ separation efficiency)
- Separates the oil from the refrigerant to;
  - Reduce oil circulated through the system
  - Ensures adequate oil returning to the compressors

Oil Separator

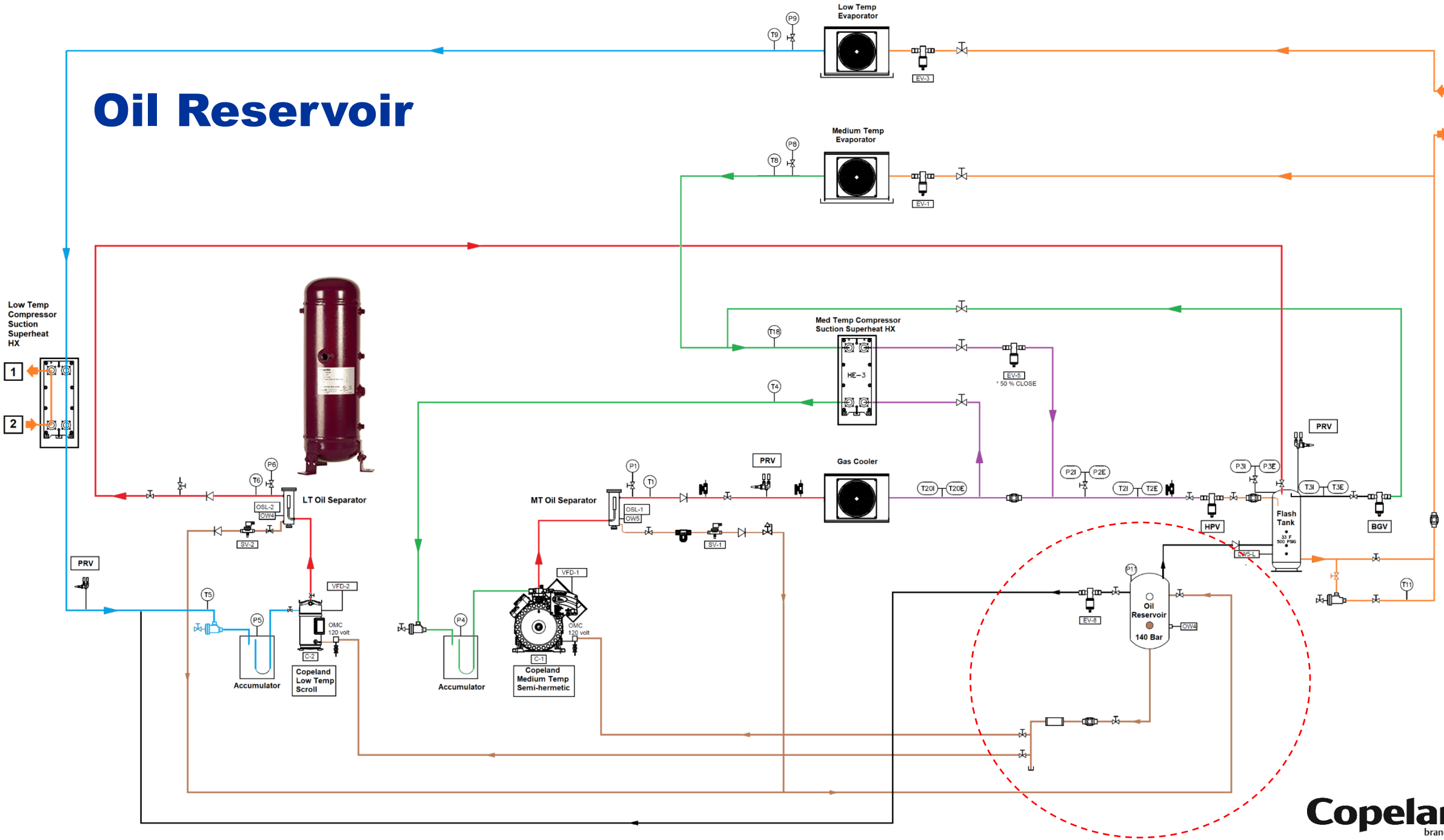
- Removable top for filter replacement
- Uses a glass fibre media for high efficiency rates
- Has the ability to filter out dirt and particulates down to 0.3 microns
- Replace after initial 24 to 48 hours of operation
  - and when pressure drop across the separator exceeds 13 psi (0.9 bar)
- To ensure immediate oil return upon start-up, the oil separators are to be pre-charged with oil (mfg. specs) i.e... Model 133A (20 oz.)

Westermeyer Releases Electronic Oil-Filter Monitor and Oil Strainer for Transcritical CO_2 Systems

February 24, 2023 COMMERCIAL REFRIGERATION NORTH AMERICA

Westermeyer Industries displayed its newly released **RDP-01T Differential Pressure Monitor**

Oil Reservoir



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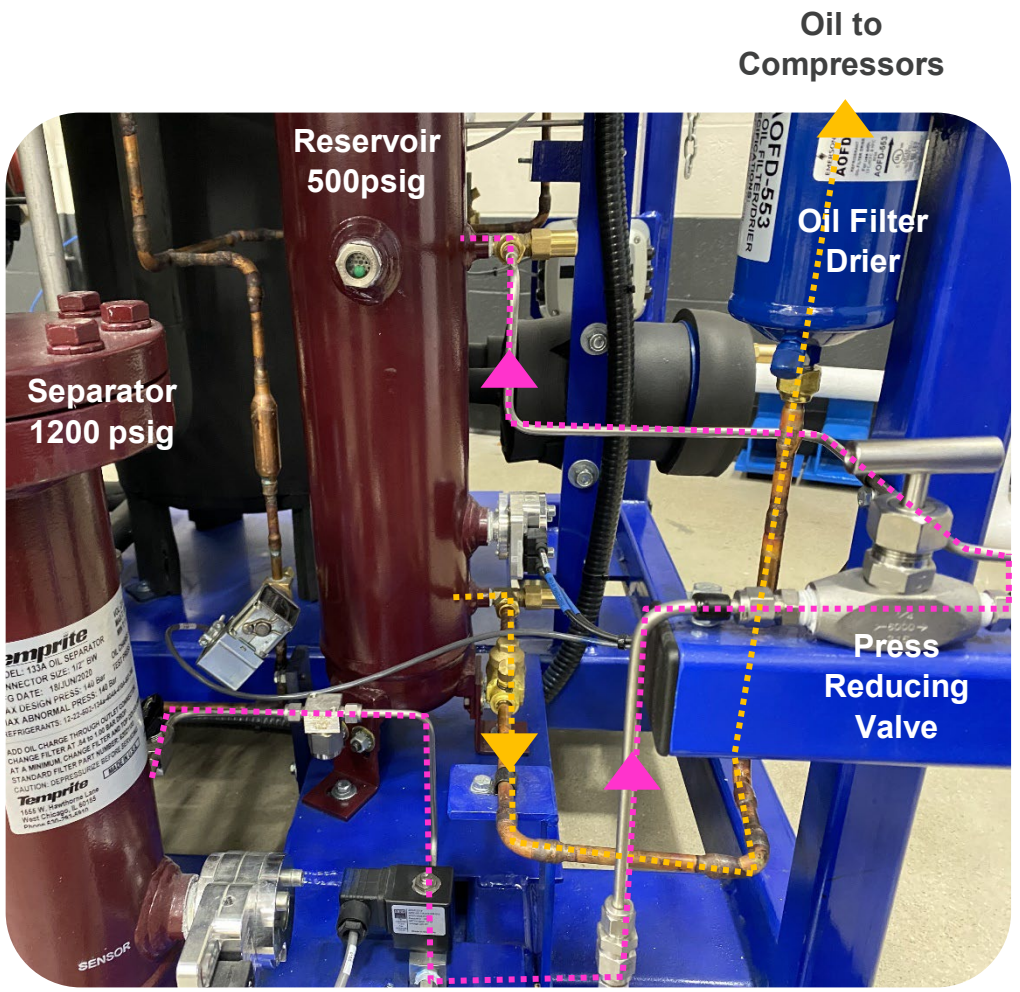
Oil Reservoir

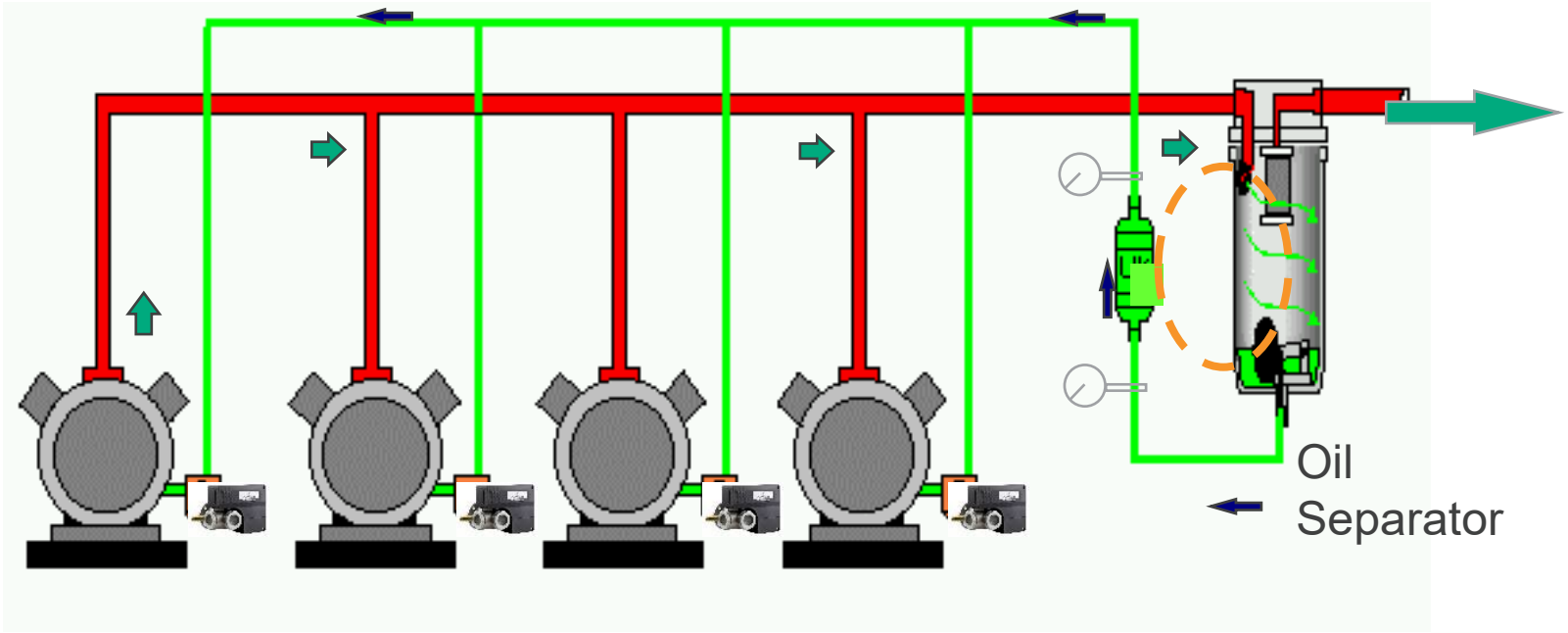
- To improve the control of oil return, oil from both separators are sent to a common oil reservoir
- From the reservoir, oil returned to the compressors becomes a function of pressure difference
- Each compressor has it's own oil monitoring, balancing and alarming system as previously mentioned i.e....(OMB, OM5, OW5 ....)
- The oil reservoir is to be pre-charged with oil (mfg. specs) i.e... RES 7 (68 oz. (min.) – centre of bottom sight-glass)
- Pressure reducing valve is used from the Transcritical oil separator due to the higher discharge pressure
  - Oil supply pressure must be higher than the crankcase pressures of all compressors



Oil Filter Drier

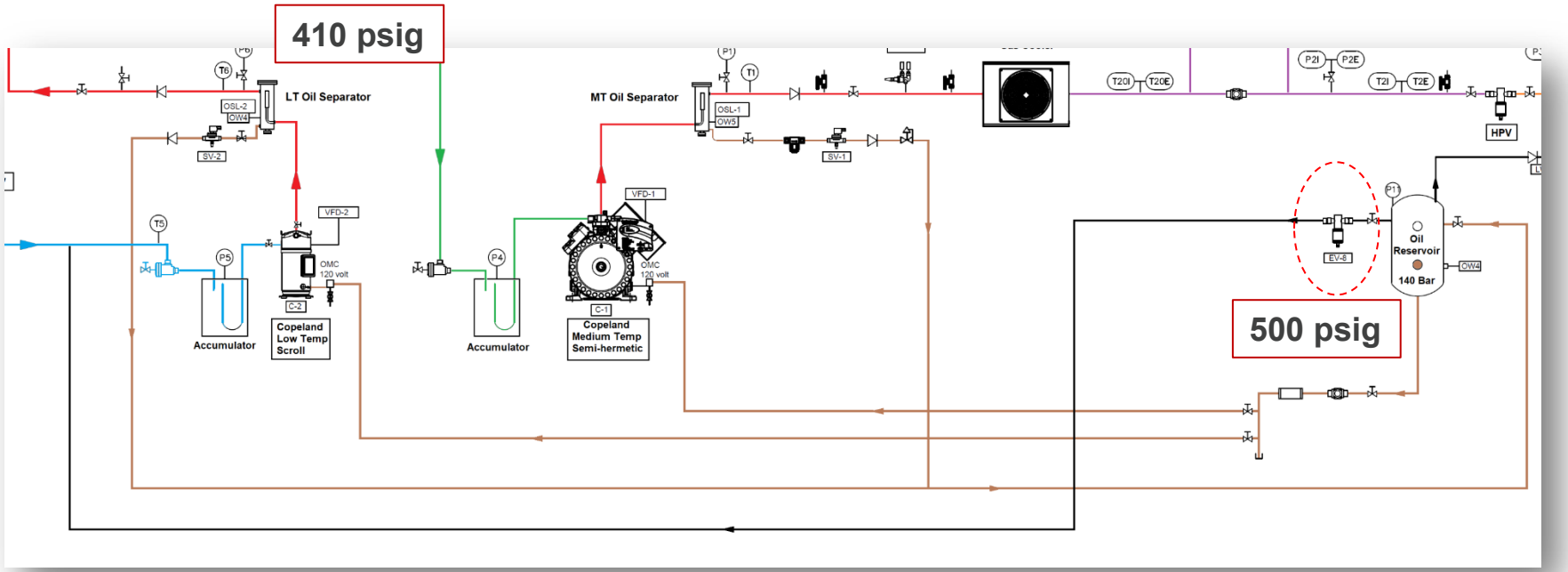
AOFD 553 - Emerson

- 100% Molecular Sieve For Moisture
- Removal in POE Oils while Fully
- Protecting the Oil Additives
- 3 Micron Filtration For Optimum
- Compressor Protection
- 3 / 8 “ SAE Connections



Oil Reservoir Pressure Reducing Valve

- When Low Temp Oil Separator operating at 410psig need to purge excess oil into the oil reservoir which is at 500psig, this valve opens temporarily to drop the pressure in the reservoir below 400 psig for the oil to oil from LT Oil Sep to oil Reservoir



Oil Reservoir Level Control Emerson OW5

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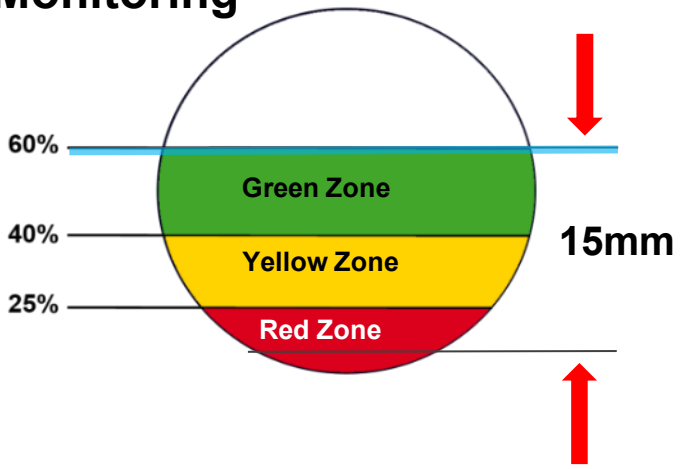
Oil Watch

Compressor Oil Level Controls
Emerson OMC, OM5

Emerosn Hall-effect

Hall-effect Sensor
3 Zone Level Monitoring



LEDs	Status / Function	Function	Alarm
●	Oil Level in green zone (60 - 40%)		
● ●	Oil Level in green zone (60 - 40%)	Injection, delay 10s	
●	Oil Level in yellow zone (40 - 25%)	Injection	
● ●	Oil Level in red zone (25 - 0%)	Injection	Yes, delay 120s

OM5

OMC

SPDT output contacts for external connection

- Alarms, status lights, compressor off control

Uses a reverse Hall-effect sensor

- Uses a float to sense oil level
- Sealed semi-conductor device
  - non-contact, wear free
  - sealed – contaminate proof
- Immune to vibration, debris and water
- Debris retention magnet for reliable control

Oil Level Contol

Adapter

LED Display

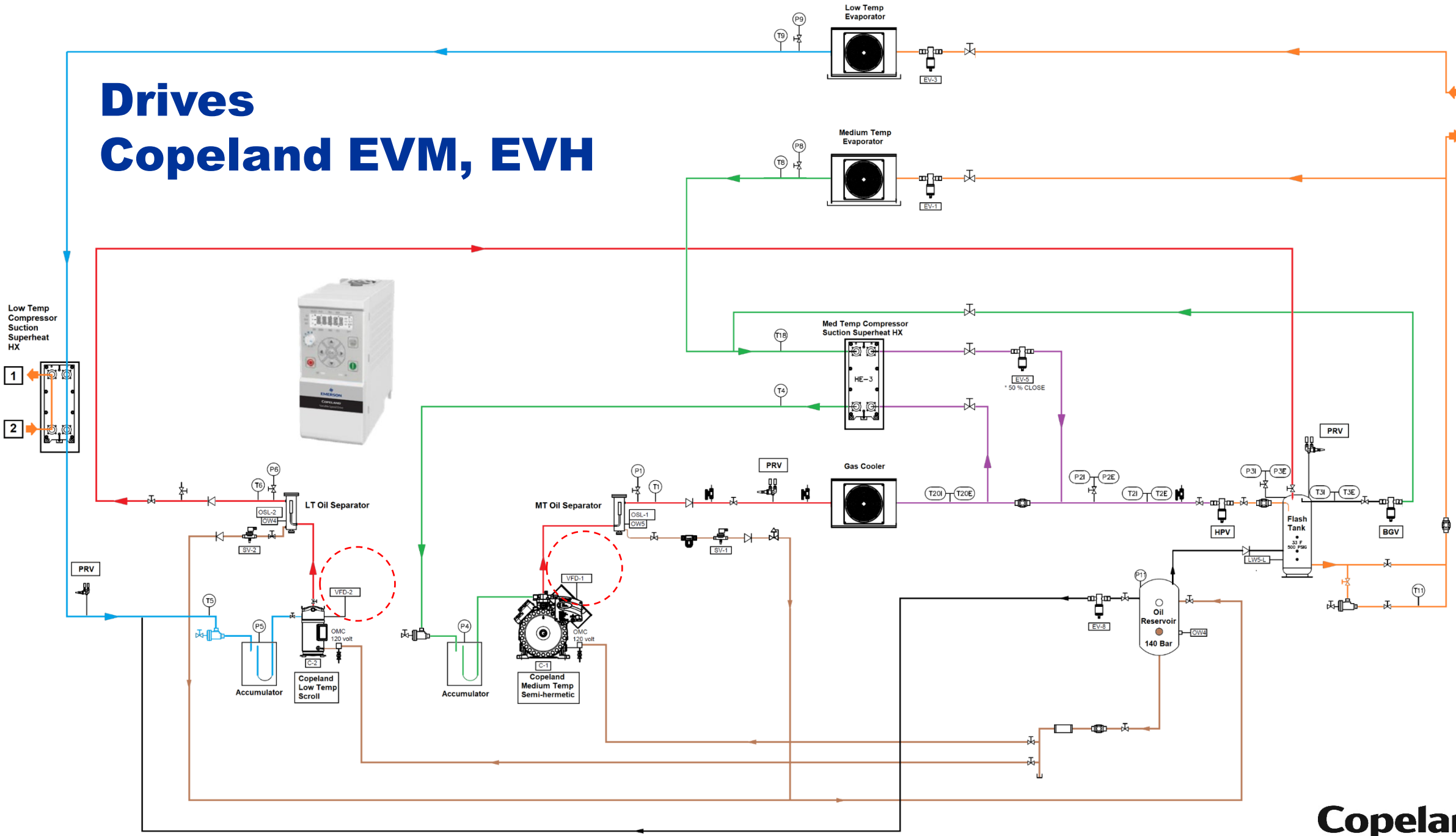
Power Green

Fill Yellow

Alarm (low oil) - Red

Subcritical Scroll	Subcritical Scroll	Transcritical 4MTL(S)	Transcritical 4MTL(S)	
				
OMC MOP 1885 psig 130bar *MOPD* *100bar* 1450psig	OMB-JB1 MOP 870psig 60bar *MOPD* *24bar* *350psig*	OMB-JB1 MOP 870psig 60bar *MOPD* *24bar* *350psig*	OMC MOP 1885 psig 130bar *MOPD* *100bar* 1450psig	OM5 MOP 1885 psig 130bar *MOPD* *100bar* 1450psig

Drives
Copeland EVM, EVH



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Where Can You Add a VFD?

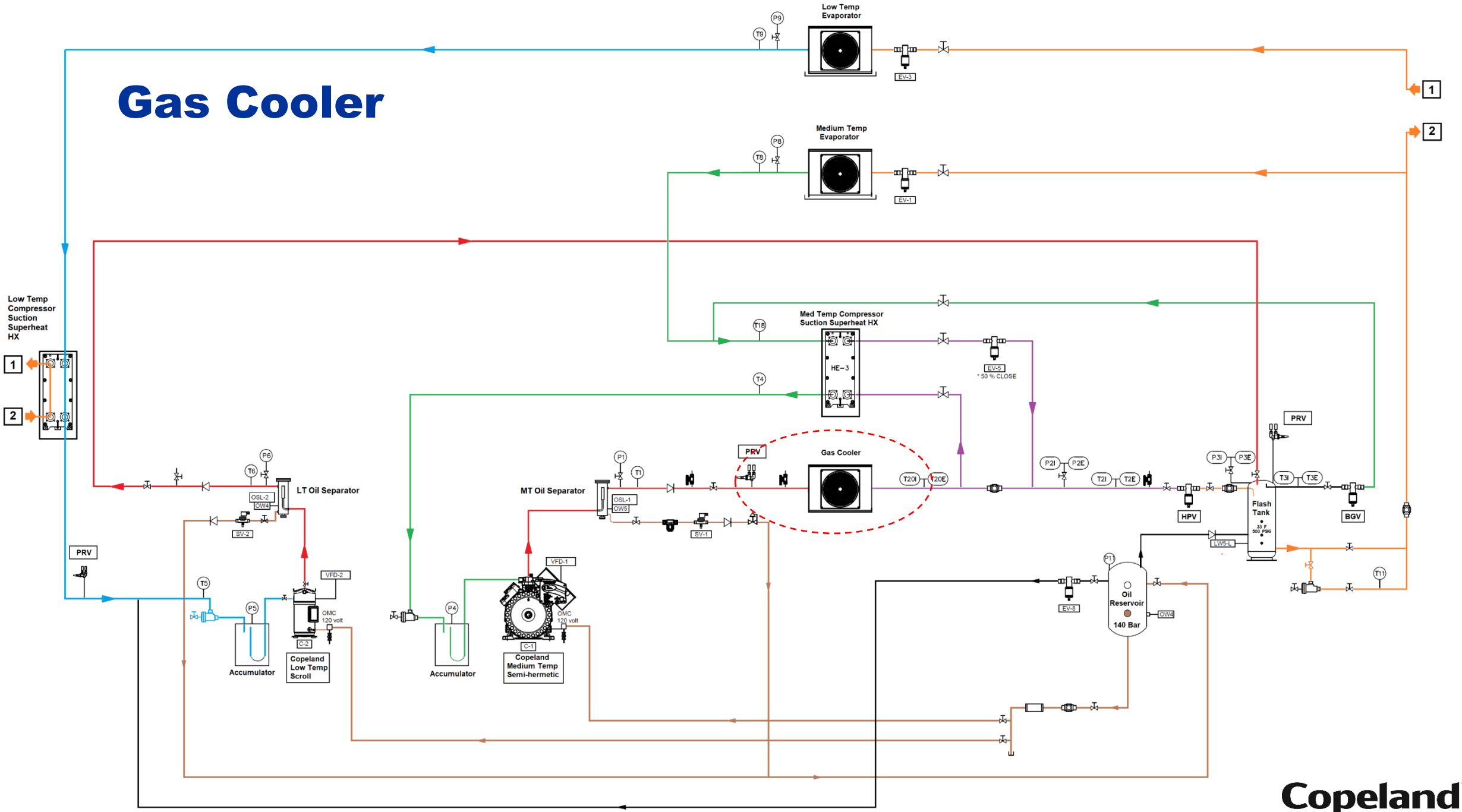
Fans
Evaporator
Condenser
Exhaust

Fixed Speed Compression
Scroll
Semi-Hermetic
Screw
(including non-Copeland brands)

Variable Speed Compression
Scroll
Hermetic Recip

Circ. Pumps

Gas Cooler



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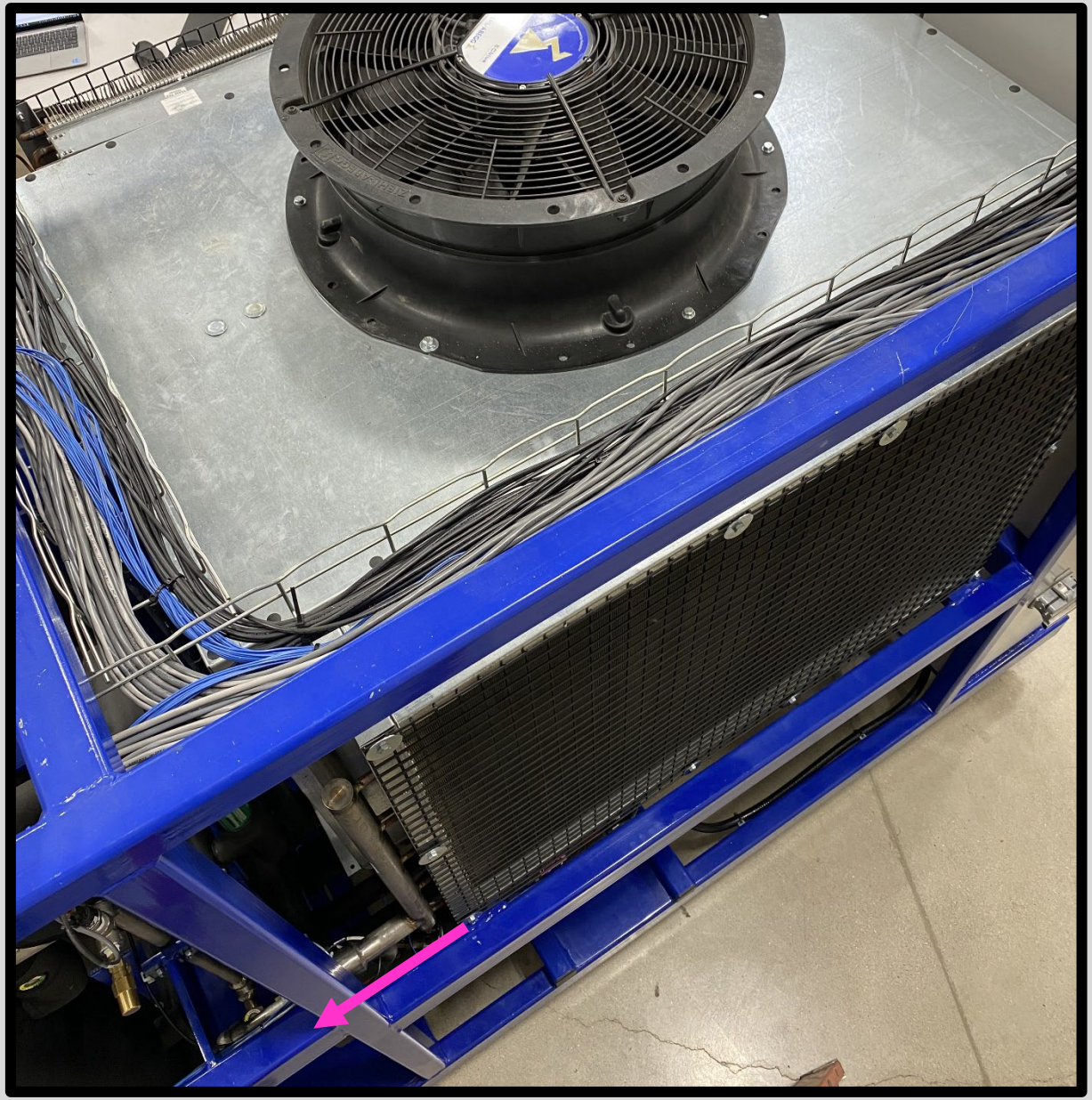
Gas Cooler



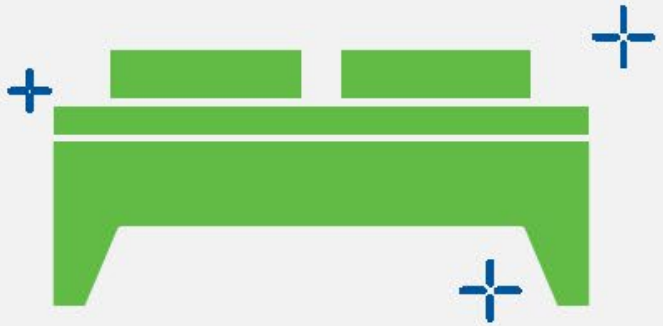
Gas Cooler

2

GAS COOLER

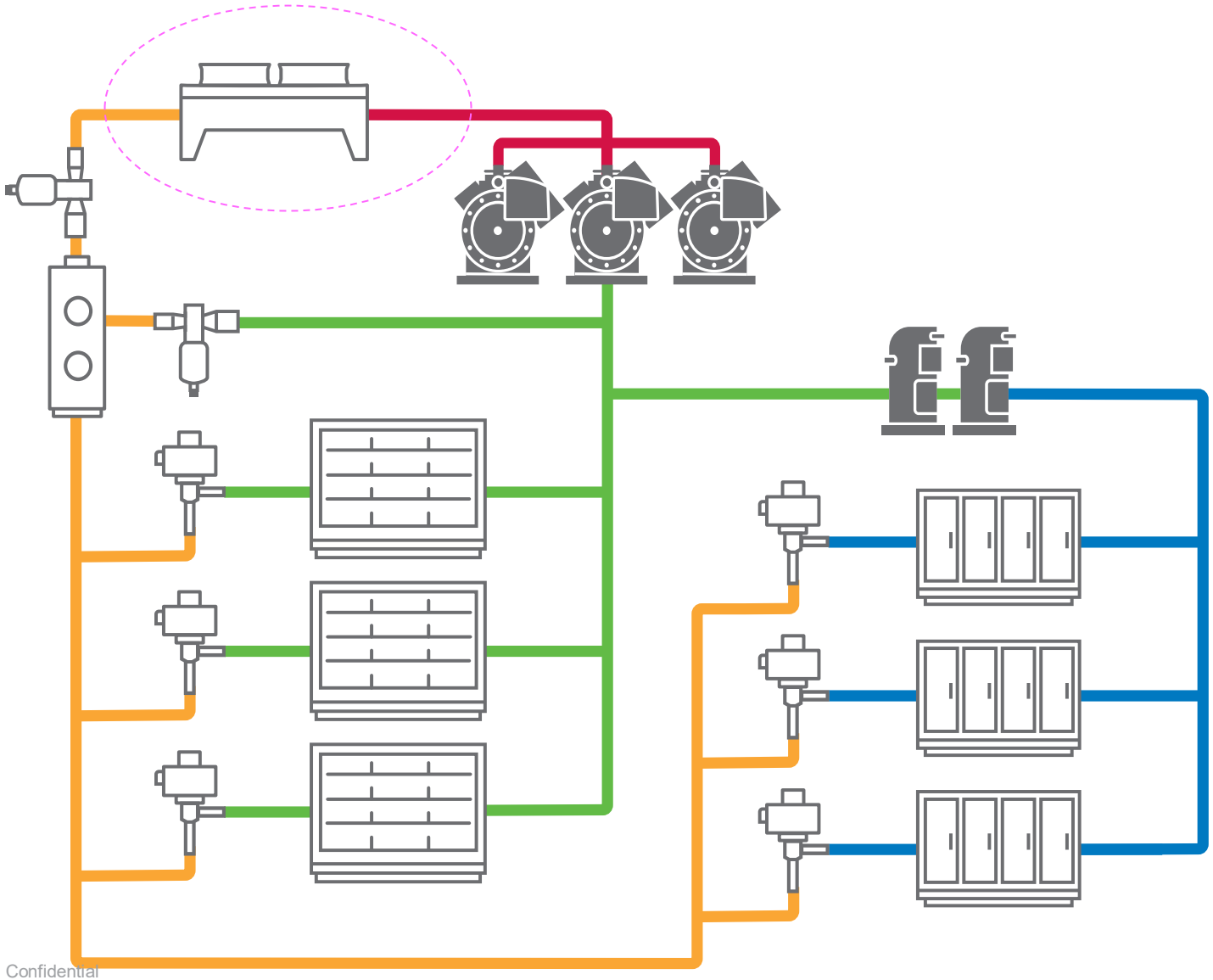
The gas cooler (aka condenser), typically located on the roof, is integral to a CO_2 TCB system's design.

- Must be sized to handle the system's total heat of rejection from MT compressors at an installation location's design conditions
- Typically designed with variable speed fan motor control
- Can include adiabatic cooling pads to improve system efficiencies in warm ambient climates



GAS COOLER/CONDENSER

CO_2 Transcritical Booster Systems Gas Cooler

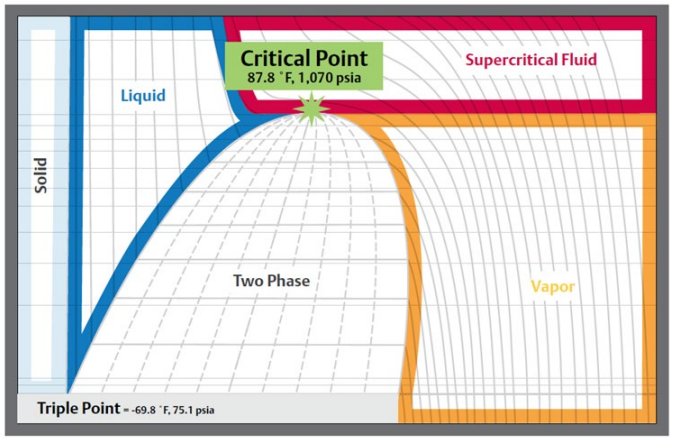


Transcritical Mode (AKA Supercritical)

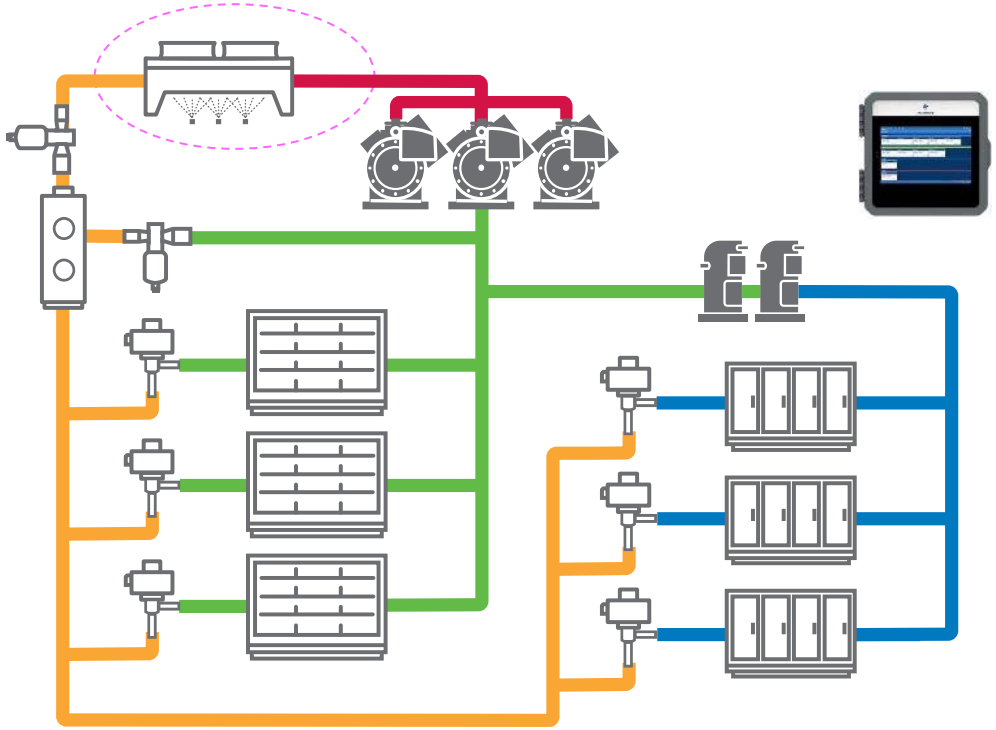
- > 75F Ambient
- **5 to 7°F TD**

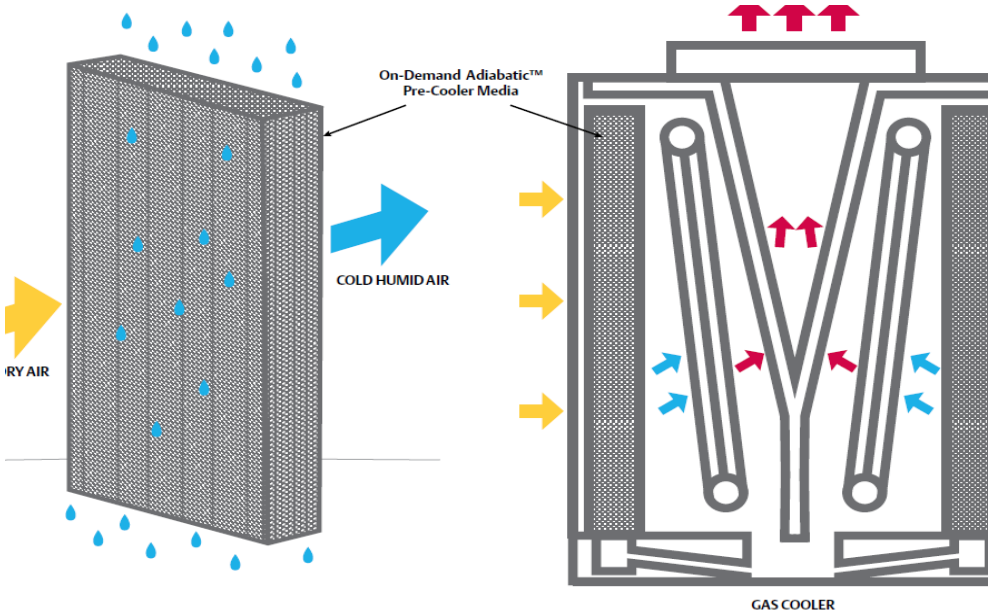
Subcritical Mode

- <75°F Ambient
- **10 to 13°F TD**



CO_2 Transcritical Booster System Condenser / Gas Cooler





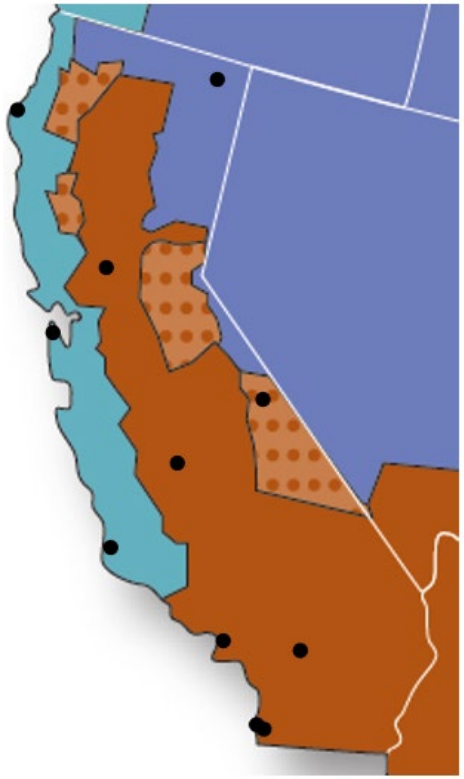
4694 hrs TC Mode

Hot-Dry 3B Climate Zone		Max Temp	25F Bin	30F Bin	35F Bin	40F Bin	45F Bin	50F Bin	55F Bin	60F Bin	65F Bin	70F Bin	75F Bin	80F Bin	85F Bin	90F Bin	95F Bin	100F Bin	105F Bin	110F Bin	115F Bin	Total Hours
Dry Gas Cooler	PALM SPRINGS, CA	114.8	0	0	0	12	168	449	816	653	1063	905	860	967	498	851	536	570	227	178	7	8760
Adiabatic	PALM SPRINGS, CA	81.6	0	0	0	12	168	560	1448	1762	2421	1822	514	53	0	0	0	0	0	0	0	8760
			Subcritical operation										Transcritical operation									

567 hrs TC Mode

% Time Operating in Transcritical Mode
(aka Supercritical Operation)

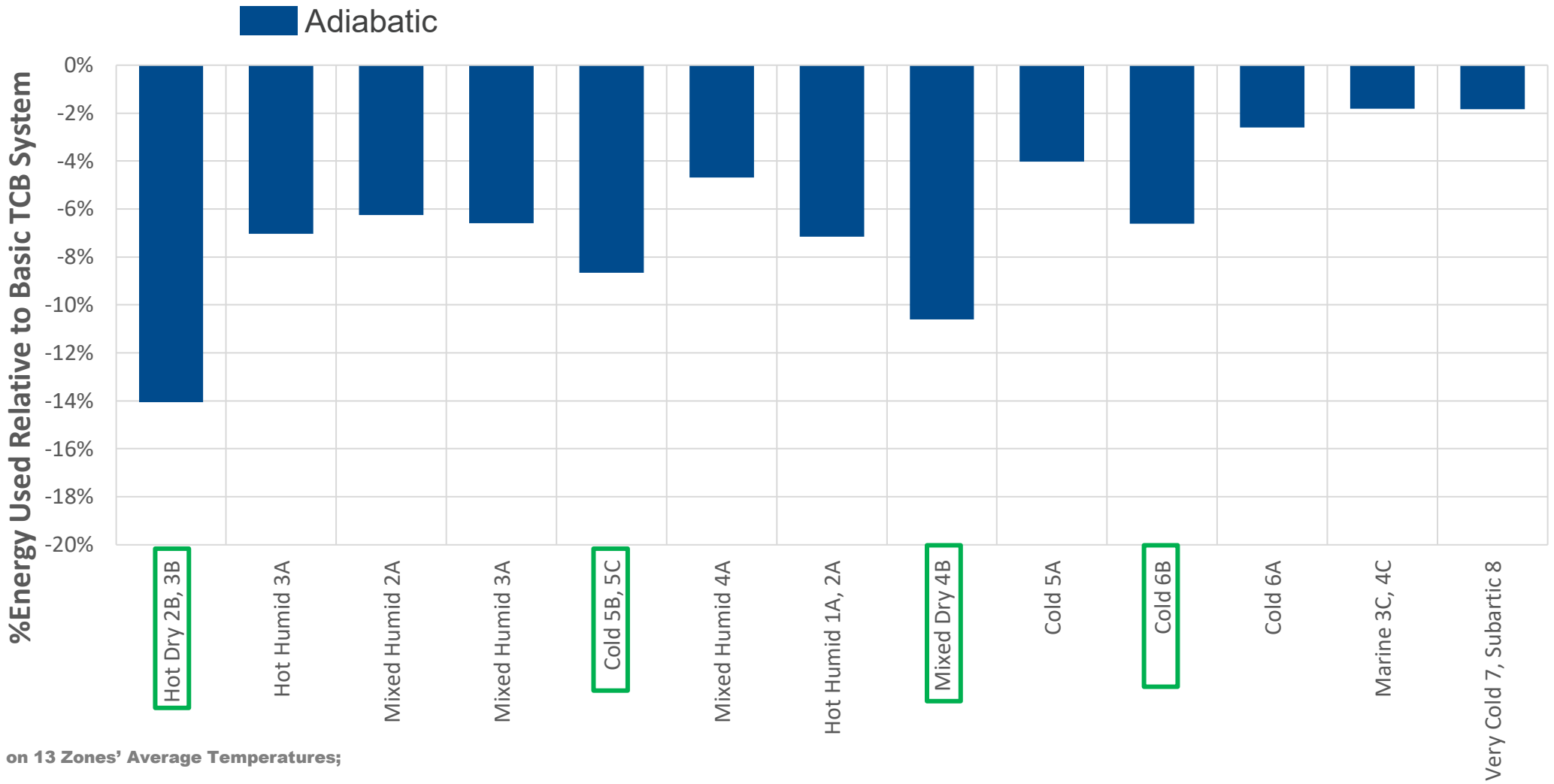
California
6 Zones



City	ASHRAE	IECC	%TC Dry GC	%TC Adi GC
San Diego	Hot Dry	3B	10%	0.5%
Sacramento	Hot Dry	3B	22%	0%
Los Angeles	Hot Dry	3B	5%	0%
Palm Springs	Hot Dry	3B	54%	6.5%
Fresno Yosemite	Hot Dry	3B	30%	0%
San Francisco	Marine	3C	2%	0%
Santa Maria	Marine	3C	4%	0%
Bishop	Mixed Dry	4B	25%	0%
Arcata	Marine	4C	0.1%	0%
Alturas	Cold	5B	13%	0%

Assumptions: ≥ 75 °F Ambient = Supercritical operation dry gas cooler
≥ 72 °F Ambient = Water flow adiabatic gas cooler

Percent of Energy Saving vs. Basic TCB Systems

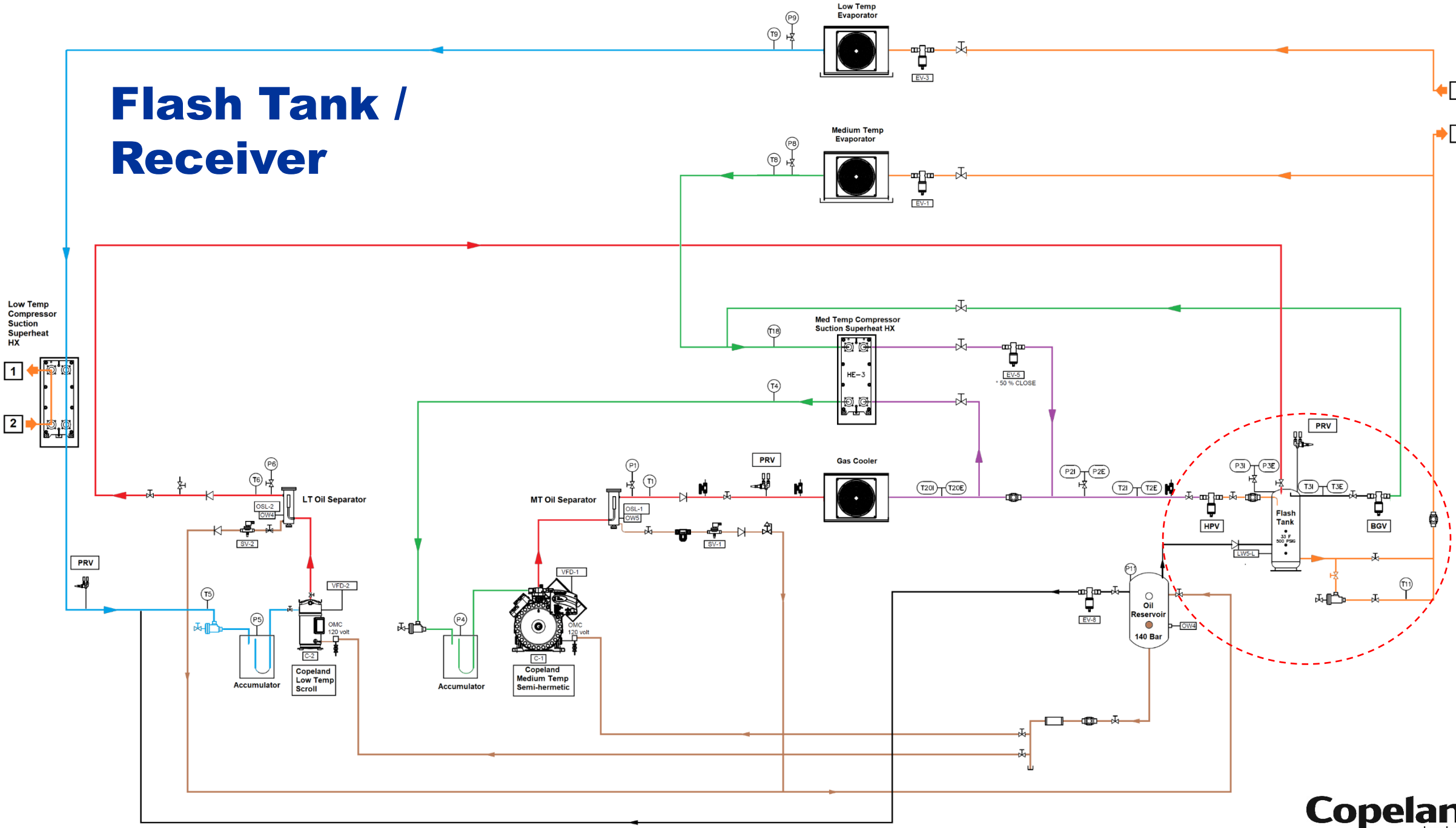


Charts Based on 13 Zones' Average Temperatures;

Weather Data: NREL TMY3 data, EES Software, 400MBH MT +18SST, 100MBH LT -20F

Climate Zones with Lower Average Relative Humidity Show Better Energy Reduction With Adiabatic Gas Coolers than with Parallel Compression…

Flash Tank / Receiver



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Flash Tank / Receiver

- 30 to 40F = 476 to 553 pisg
- Sizing is Key
- Level Management
- Insulated Flash Tank
- Insulated Liquid Lines

Stable Flash Tank pressure is the key to smooth performance year round

Pressure Relief Valves

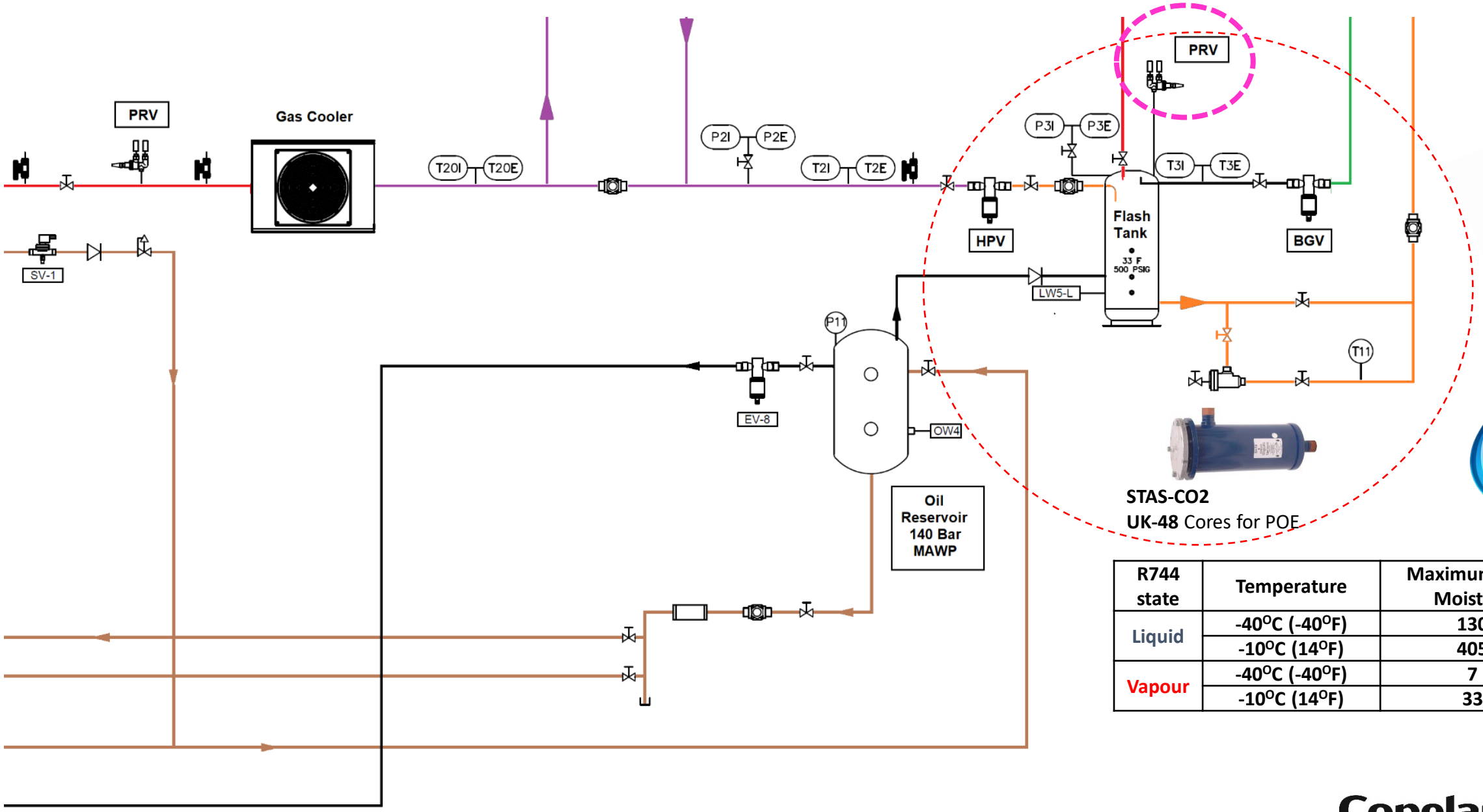
Typical PRV Setting For Supermarket

- **Discharge; 1600psi (110bar)**
- **Flash Tank / Liquid Line; 650psi (45bar)**
- **MT Suction; 650psi (45bar)**
- **LT Suction; 500psi (35bar)**

After a few releases, most PFVs will drift from setpoint, causing early relief.

- Changing PFV to protect against early release will saveCO2, system issues and and keep customer happy

Flash Tank



STAS-CO2
UK-48 Cores for POE

R744 state	Temperature	Maximum ppm Moisture
Liquid	-40°C (-40°F)	130
	-10°C (14°F)	405
Vapour	-40°C (-40°F)	7
	-10°C (14°F)	33

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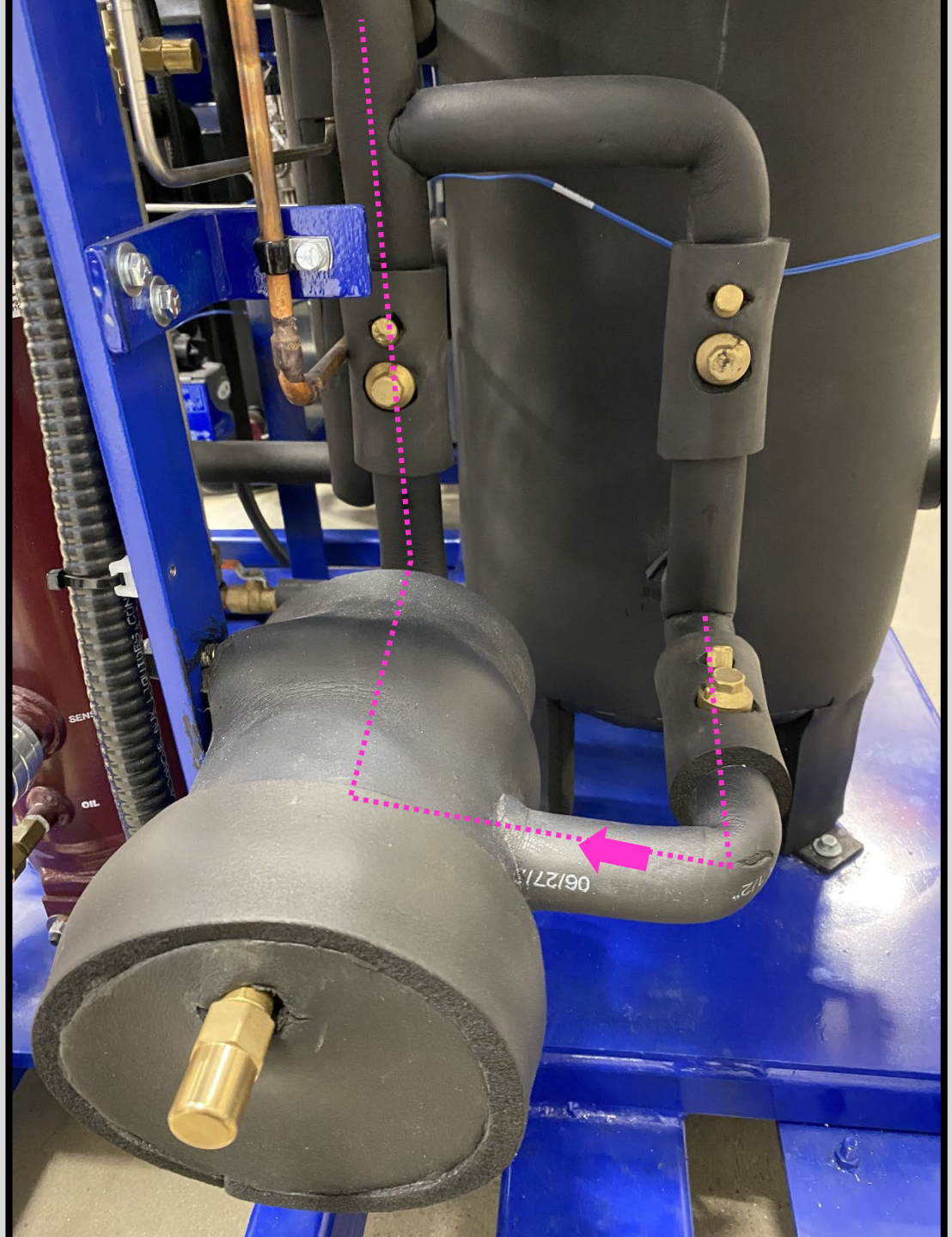
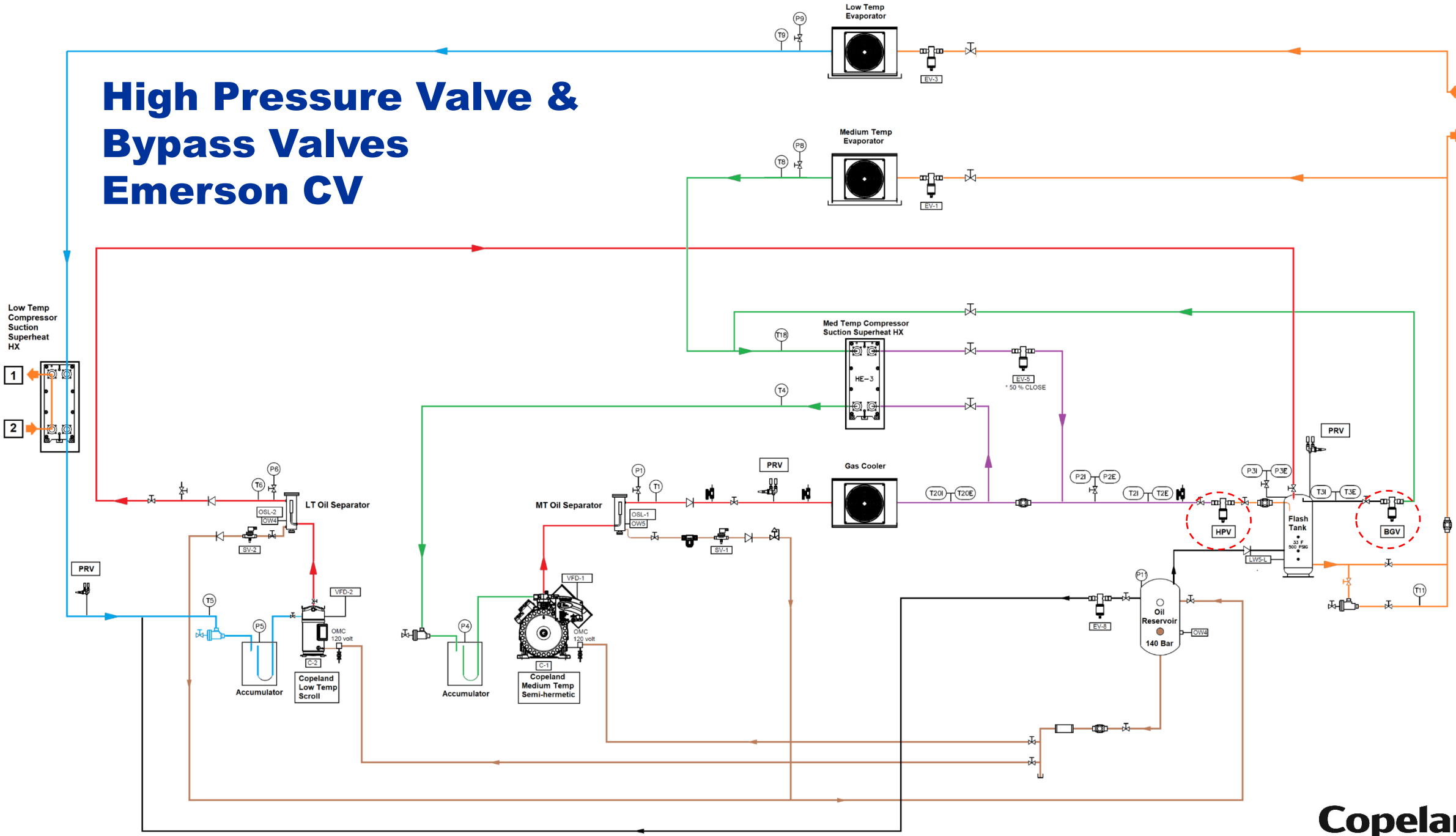
Liquid Line Filter Drier

Installed at the Bottom of the Flash Tank



Dry Ice,
if Liquid is left in drier shell when opening

High Pressure Valve & Bypass Valves Emerson CV



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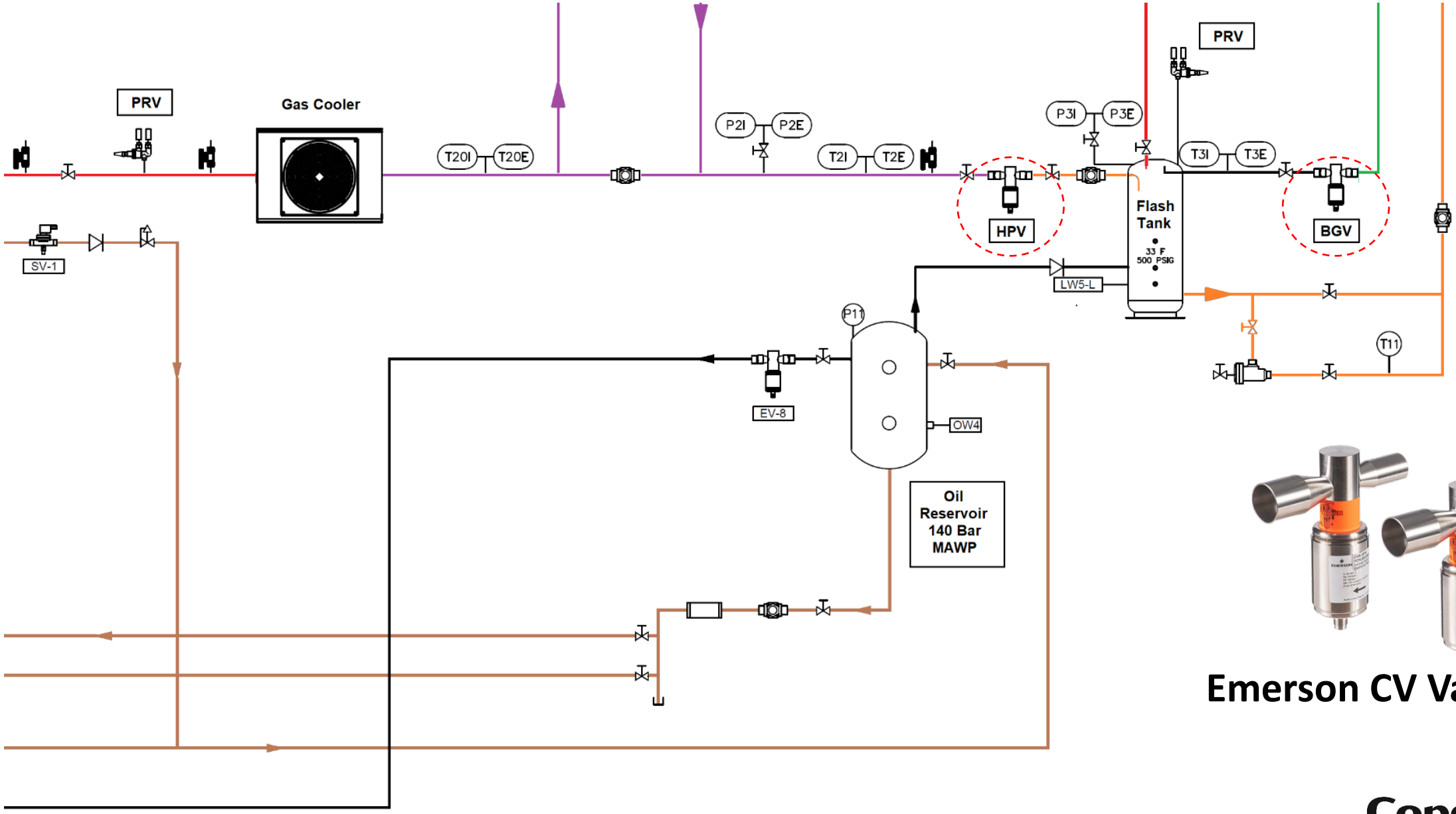
High Pressure Valve & Bypass Valve



Emerson CV Valves

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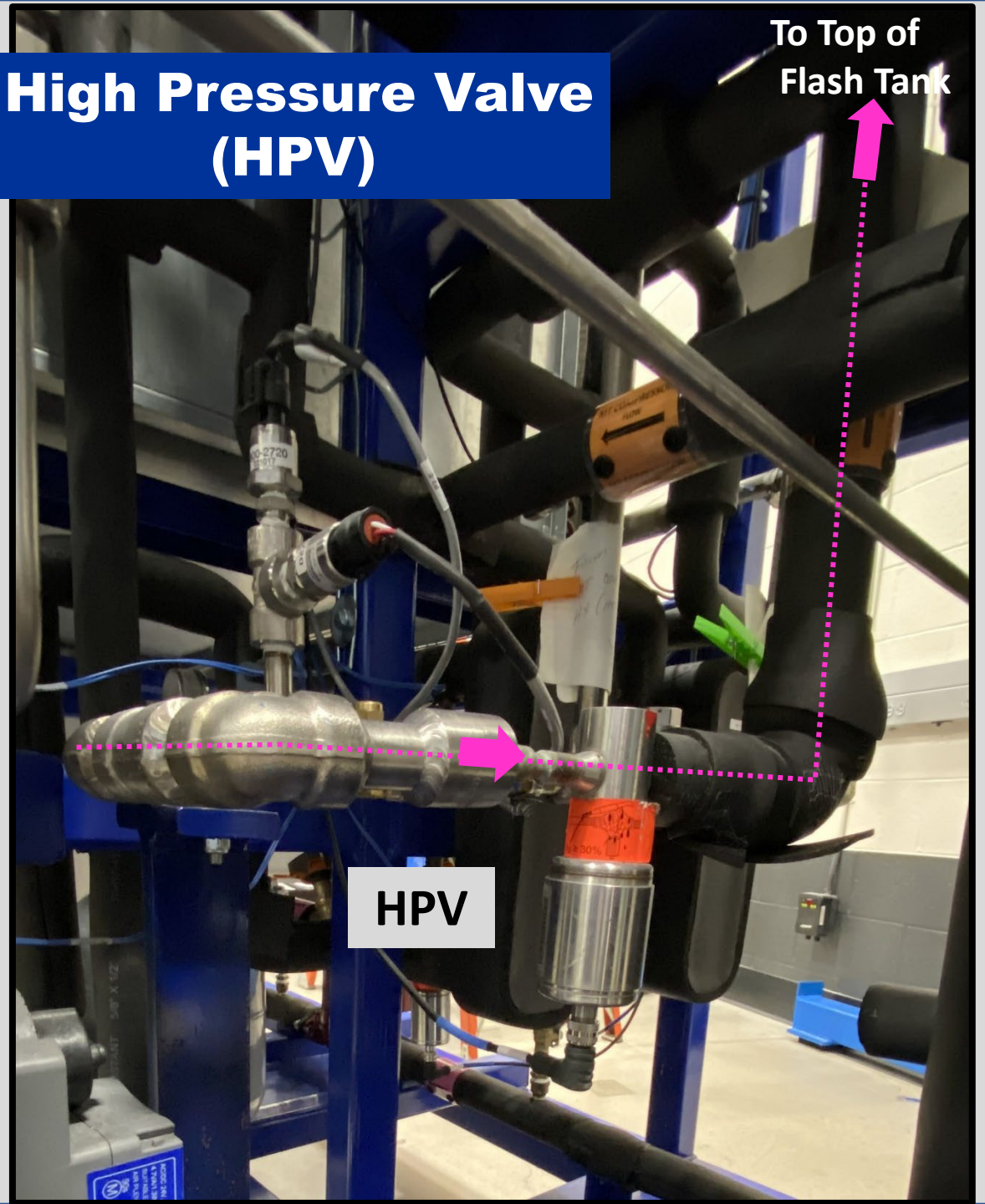
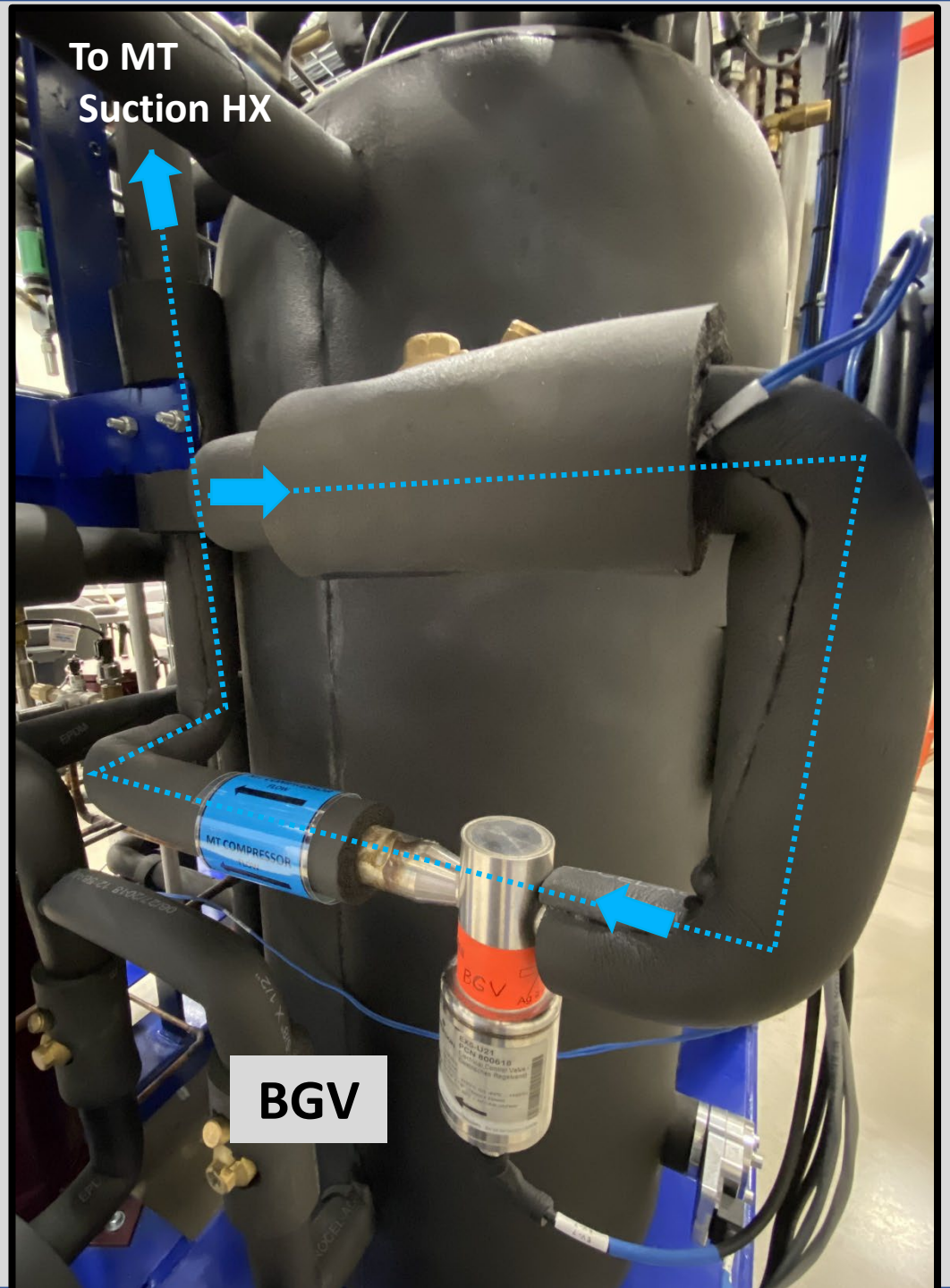
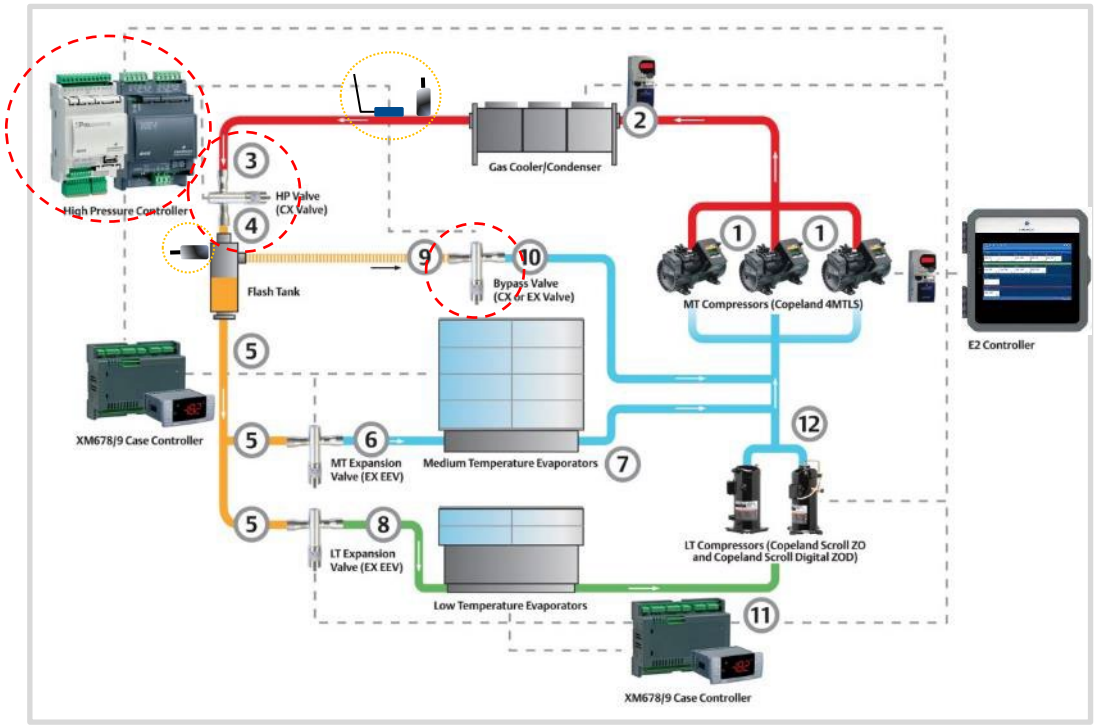
High Pressure Valve (HPV)



Bypass Gas Valve (BGV)



CO_2 High Pressure Controller



Inputs

1. Gas Cooler Out Pressure
2. Gas Cooler Out Temp.
3. Flash Tank Pressure
4. Capacity Demand Input

Subcritical Operation

- Maintains Subcooling In Condenser

Transcritical Operation

- Ignores Subcooling Control & Controls Gas Cooler Pressure

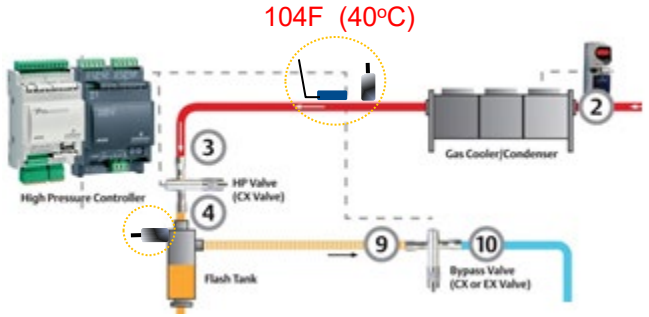
Transient Operation

- Avoids Hard Switch In Either Sub or Transcritical To Evade Effects of Rapid CO2 Density Change

High Pressure Valve (HPV) & Bypass Valve (BPV)

–The Control Point In Both The Valves Is Flash Tank Pressure
– If Pressure Is > Set Point, The HPV Throttle & BPV Opens
– If Pressure Is < Set Point. The HPV Opens & BPV Throttles

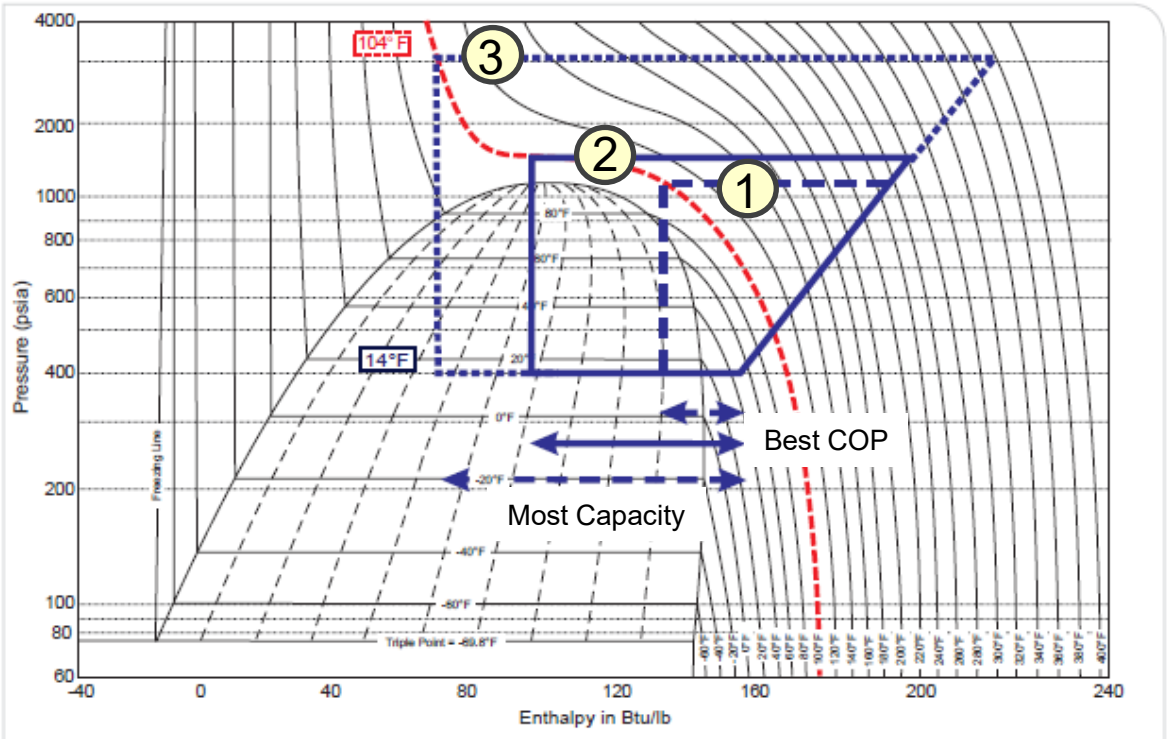
Three Examples Same Evaporator Conditions



Optimal GC Pressure In TC Mode Only	②	
30	1088	75
31	1111	76.6
32	1147	79.1
33	1182	81.5
34	1218	84
35	1253	86.4
36	1288	88.8
37	1324	91.3
38	1359	93.7
39	1400	96.5
40	1430	98.6
41	1465	101
42	1501	103.5

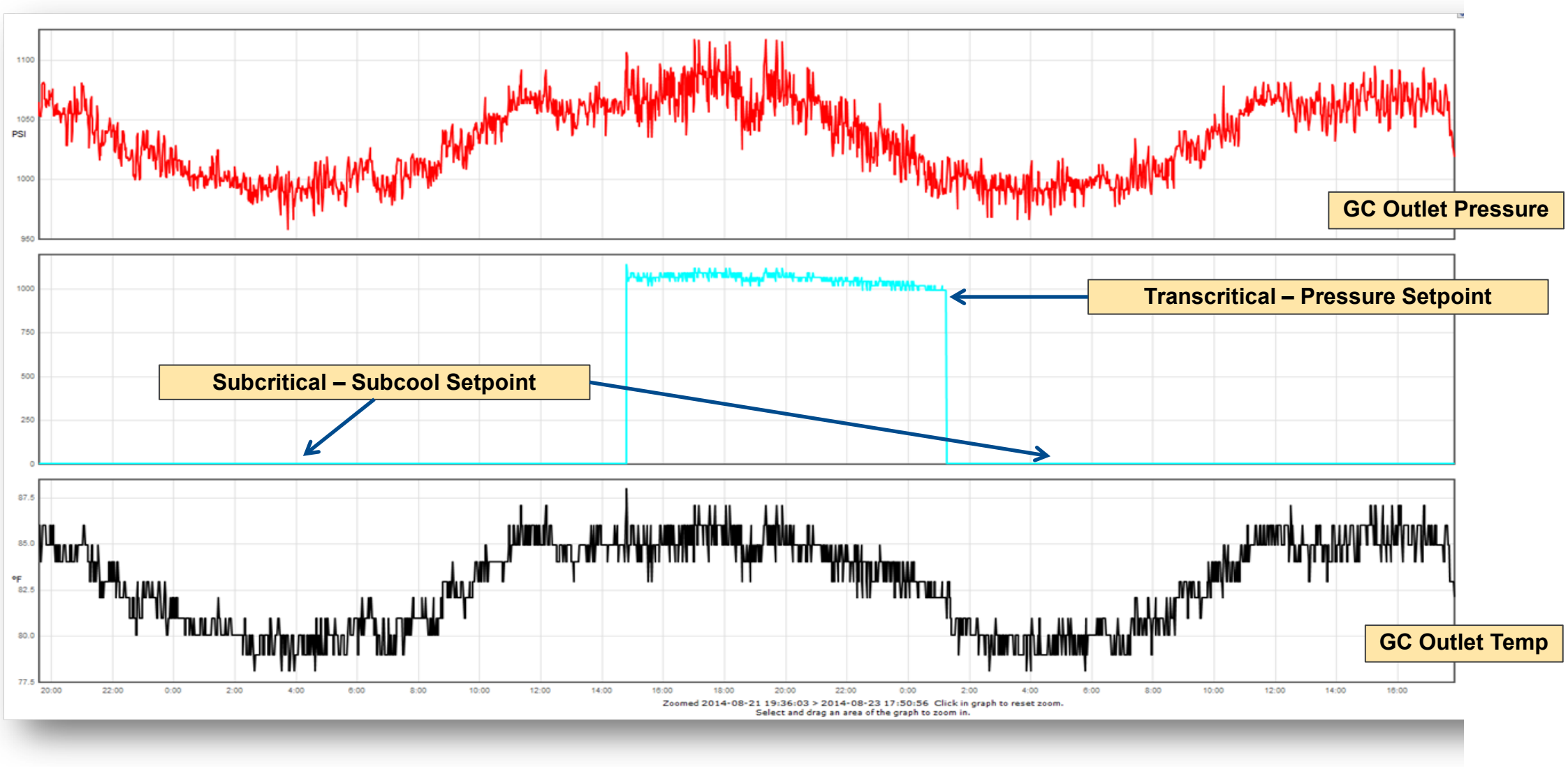
2: Optimal pressure for gas cooler outlet temperature

COP= Heat Energy Removed (BTU) / Power Input

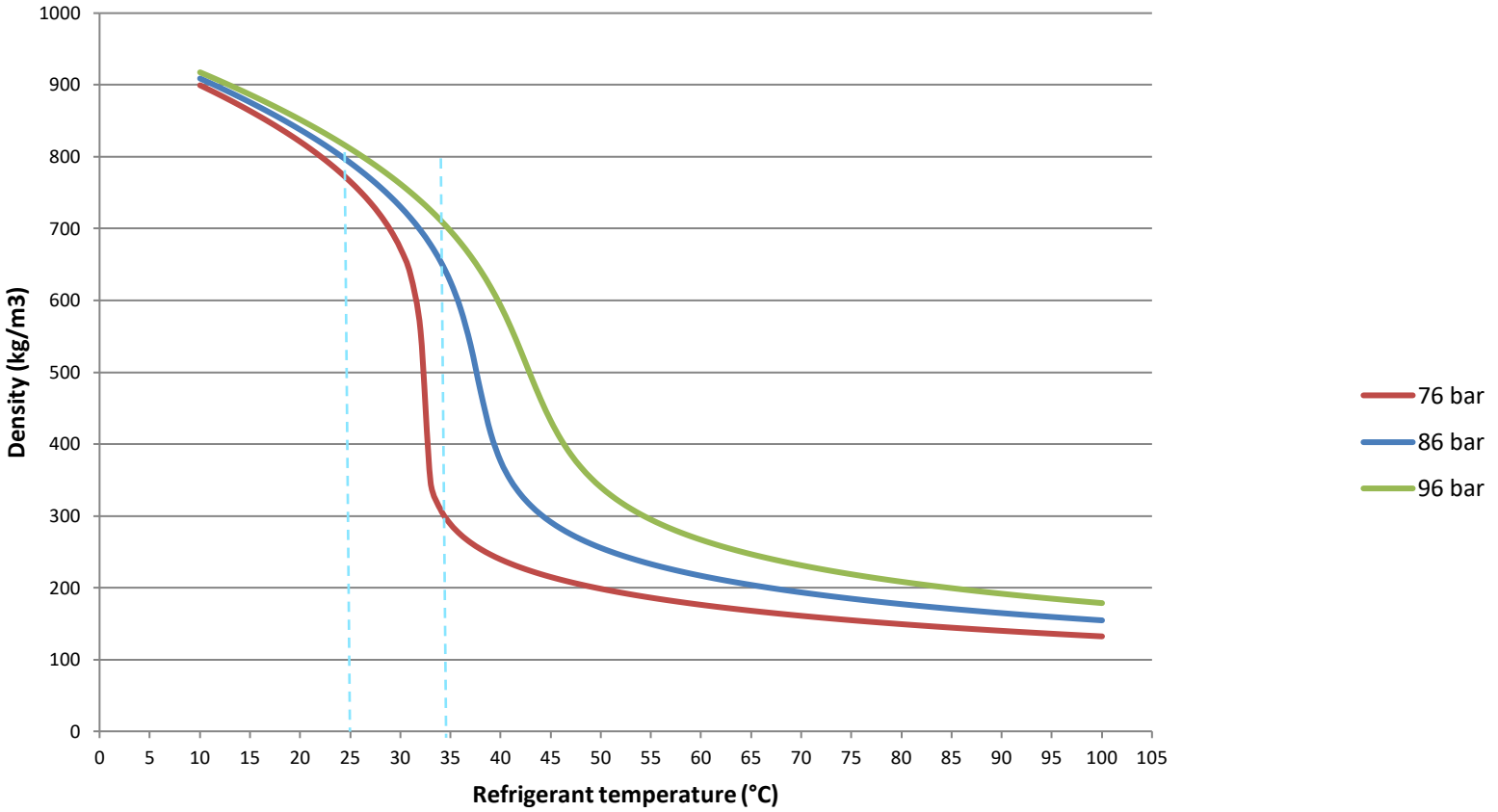


For each example , R744 exits the gas cooler at 104°F. This exit temperature is a function of the size of the gas cooler and the ambient temperature, in the same way as condensing temperature is a function of the size of the condenser and the ambient temperature.

Transcritical Mode



CO2 Density (kg/m3)



The design of the gas cooler pressure regulating valve is very sensitive, as the refrigerant density changes rapidly between 25 and 35°C.(77F & 95F) The proper selection of the expansion valve therefore requires checking different operating points.

Evaporators EEV
Emerson “CV” or “PM”

Low Temp Evaporator
Medium Temp Evaporator
Low Temp Compressor Suction Superheat HX
Med Temp Compressor Suction Superheat HX
HE–3
EV-5
* 50 % CLOSE
Gas Cooler
PRV
LT Oil Separator
MT Oil Separator
Accumulator
Accumulator
Copeland Low Temp Scroll
Copeland Medium Temp Semi-hermetic
OMC 120 volt
Oil Reservoir 140 Bar
Flash Tank
HPV
BGV

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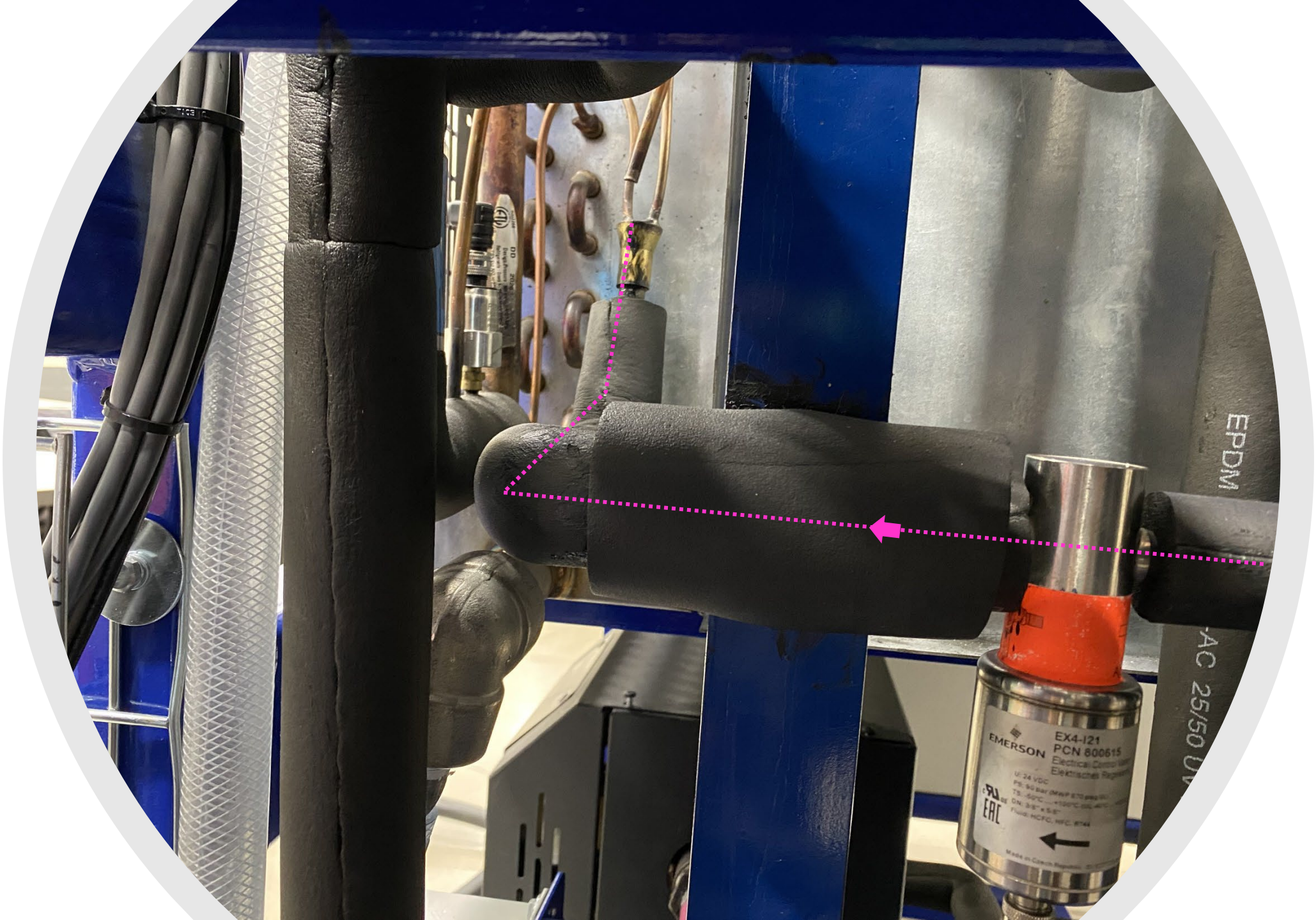
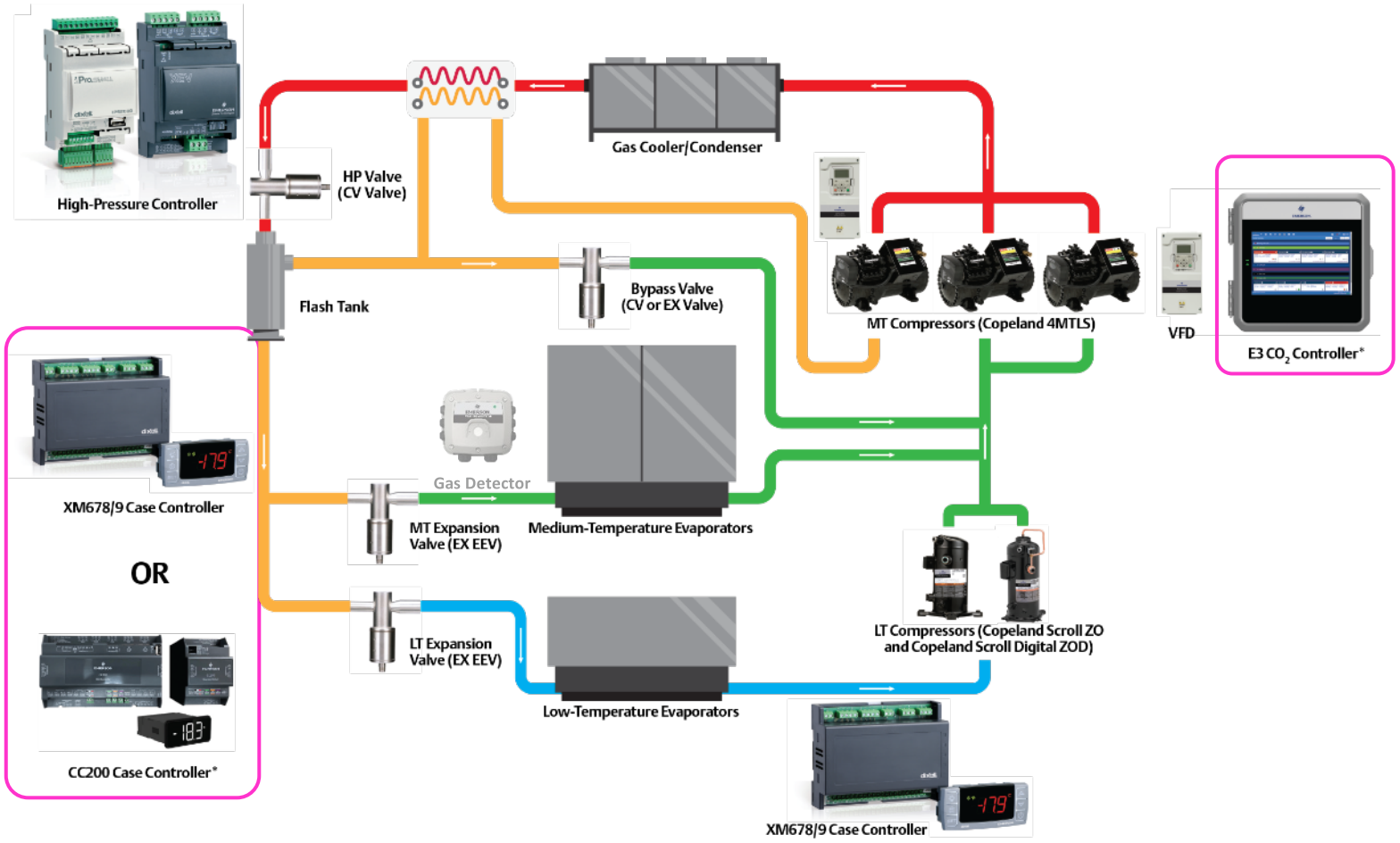
EEV



EEV


CEPTEK
Low Temp Evaporator
Medium Temp Evaporator
Training Unit
CO2
Climate.Emerson.com
EMERSON
STANLEY

Supervisory & Case Controls



*Launching soon

E3 Supervisory Controls

Simplified and Intuitive User Interface

- *Intuitive Navigation*
- *Increased Visibility:*
- *Priority Actions:*
- *Fast Response:*
- *Mobile-Optimized:*
- *Secure Data:*

Supervisory Control

E3 with CO2 Application

CC200 Case Controls

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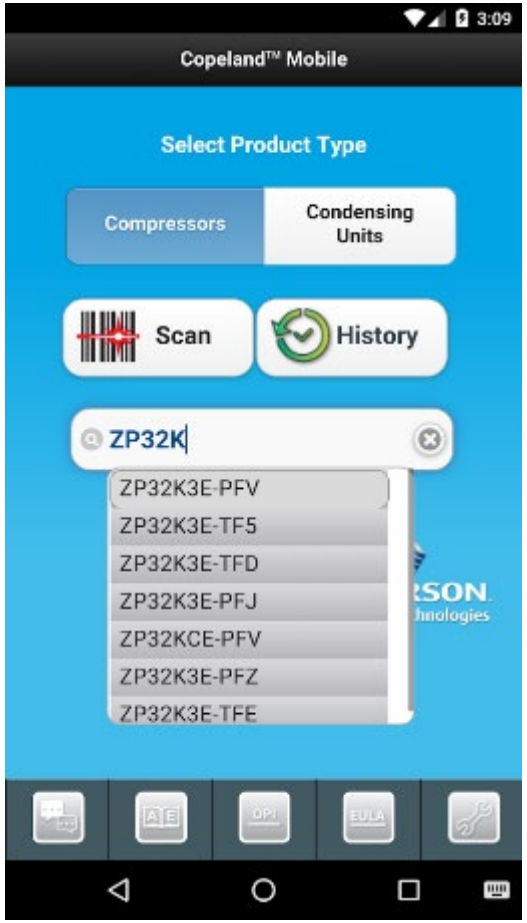
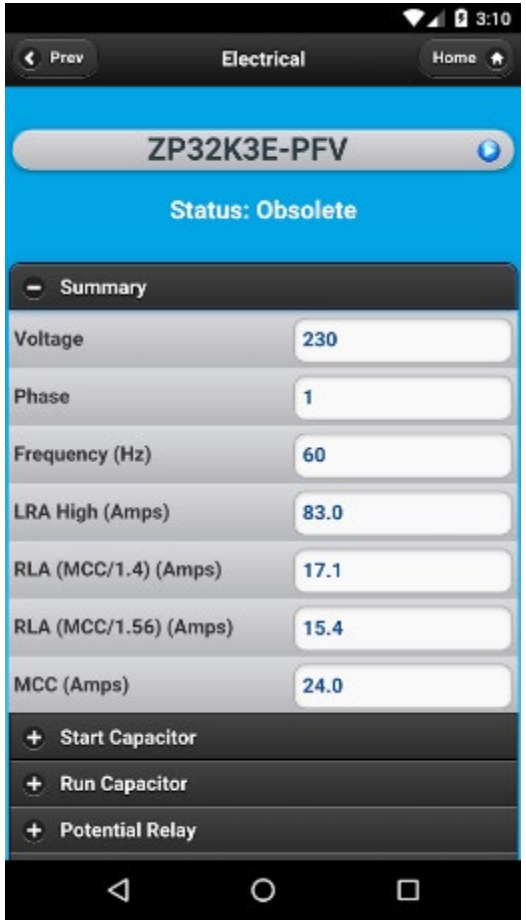
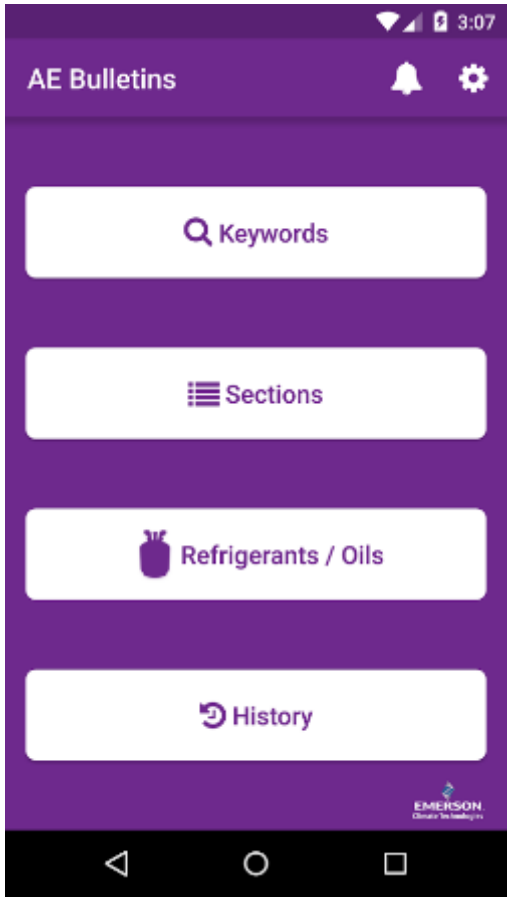
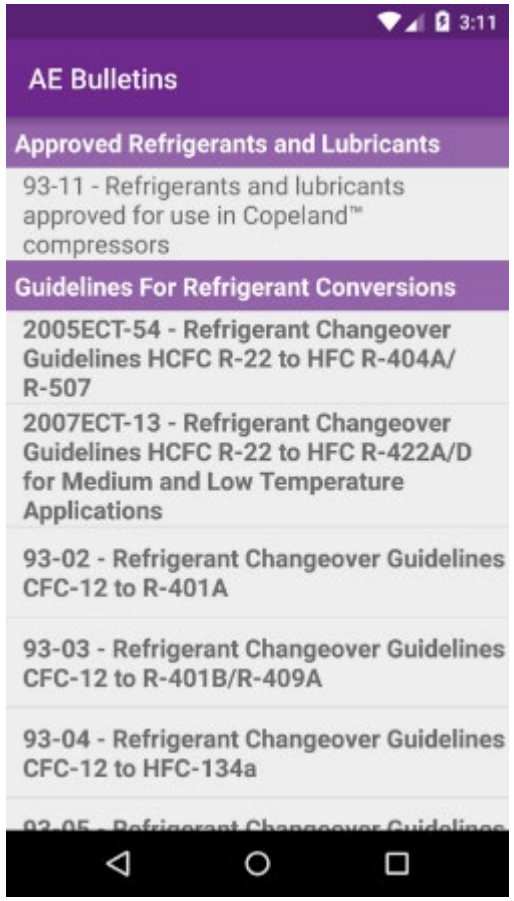
Copeland Mobile

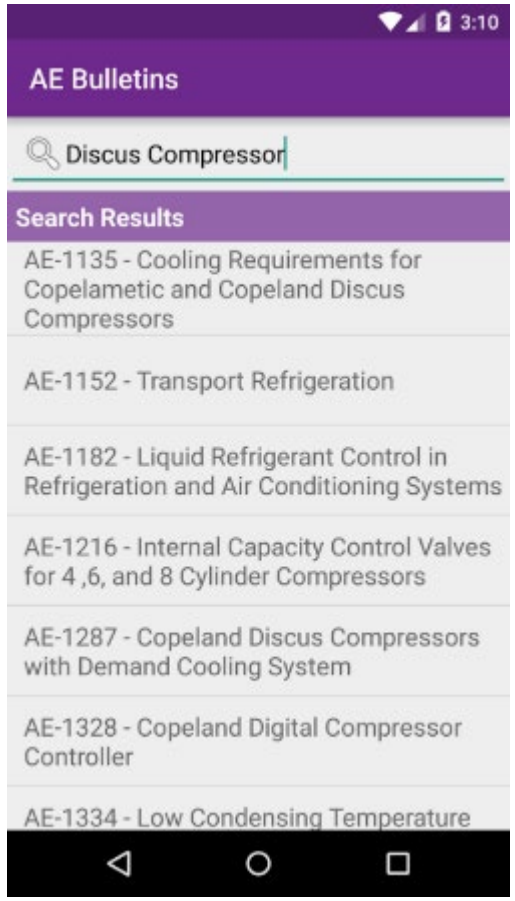




AE Bulletins – App, OPI, PSS, CPID,







Let's go Check out The Unit!

Thank you!

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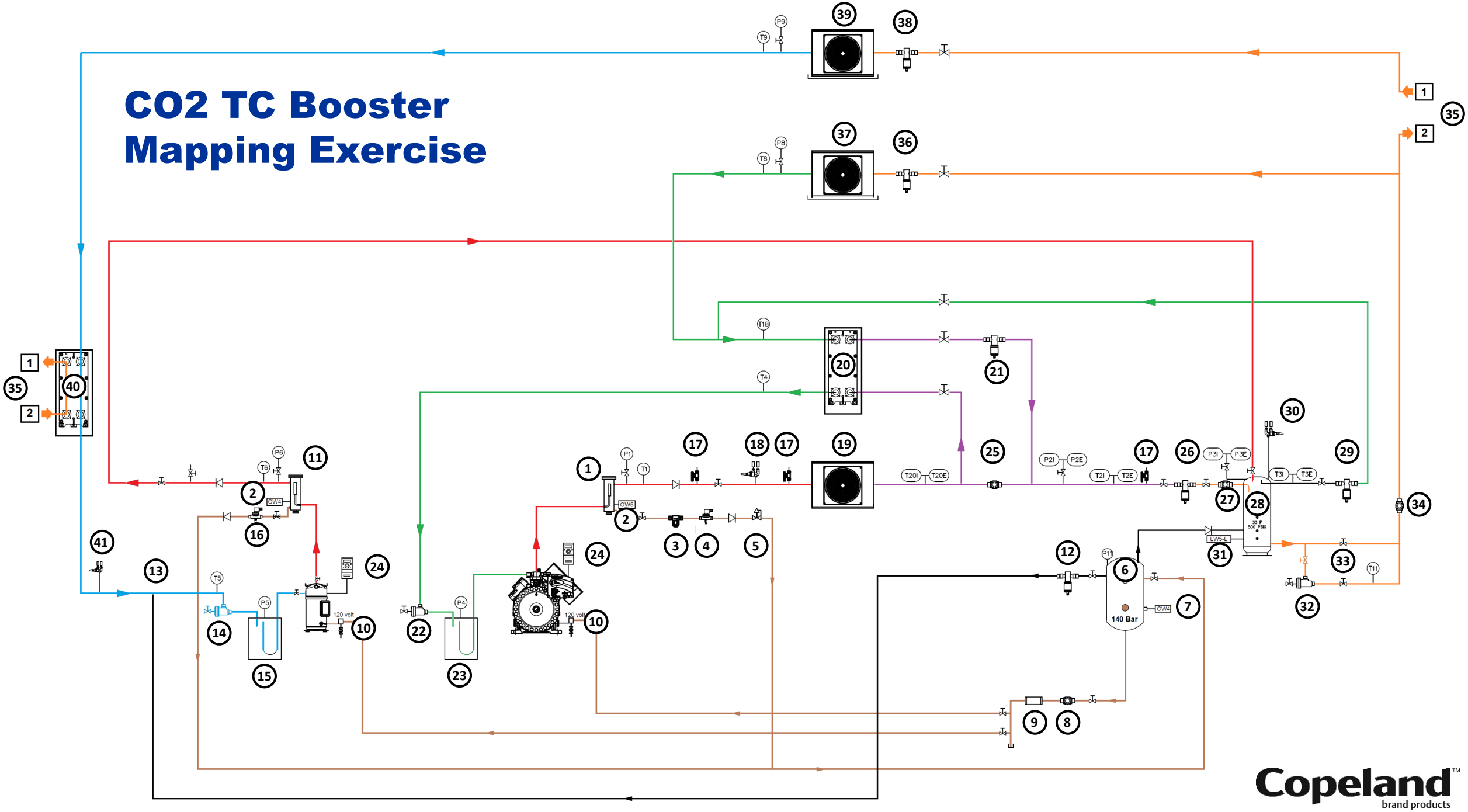
CO2 TC Booster Mapping Exercise



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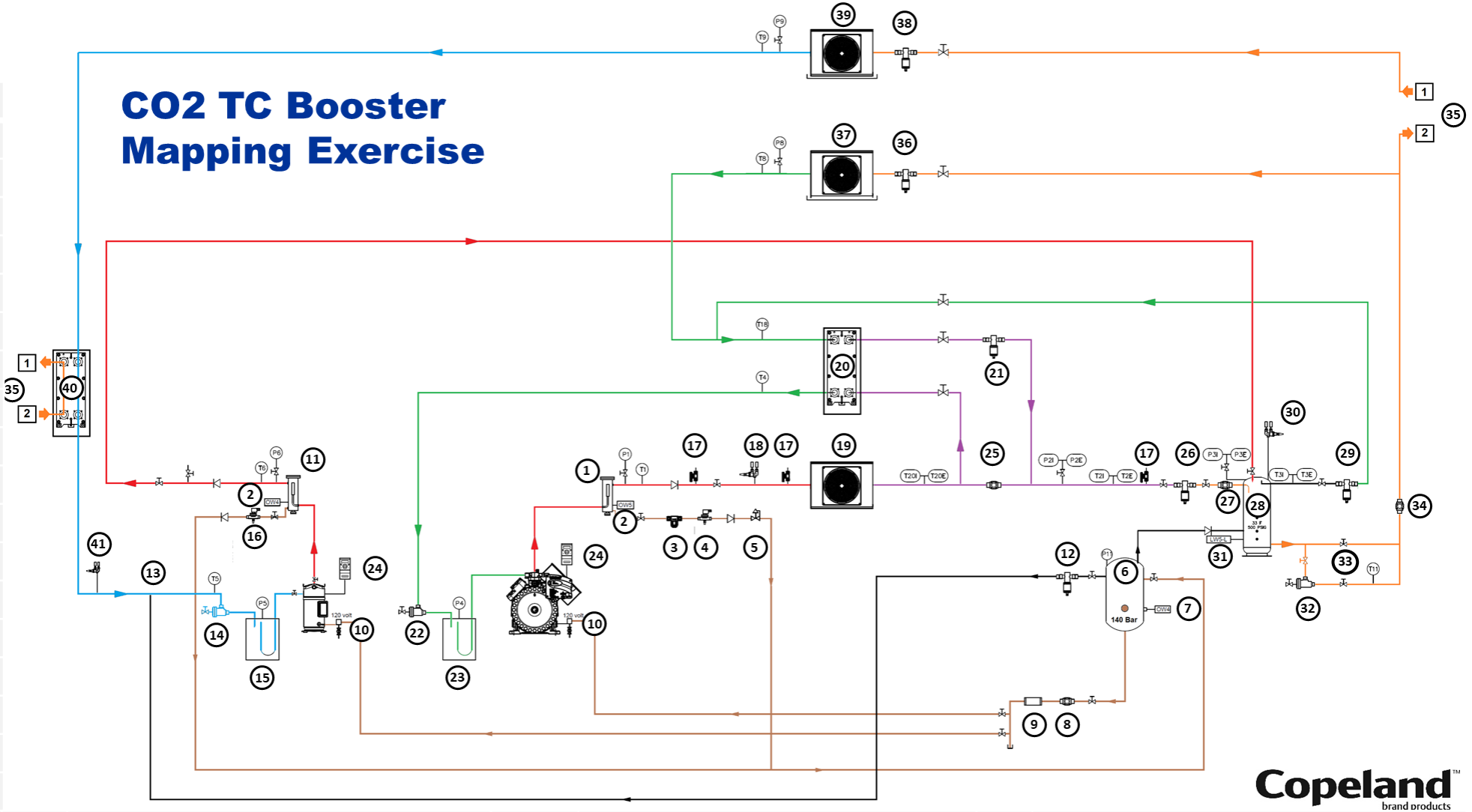
Identify all Components

CO2 TC Booster Mapping Exercise



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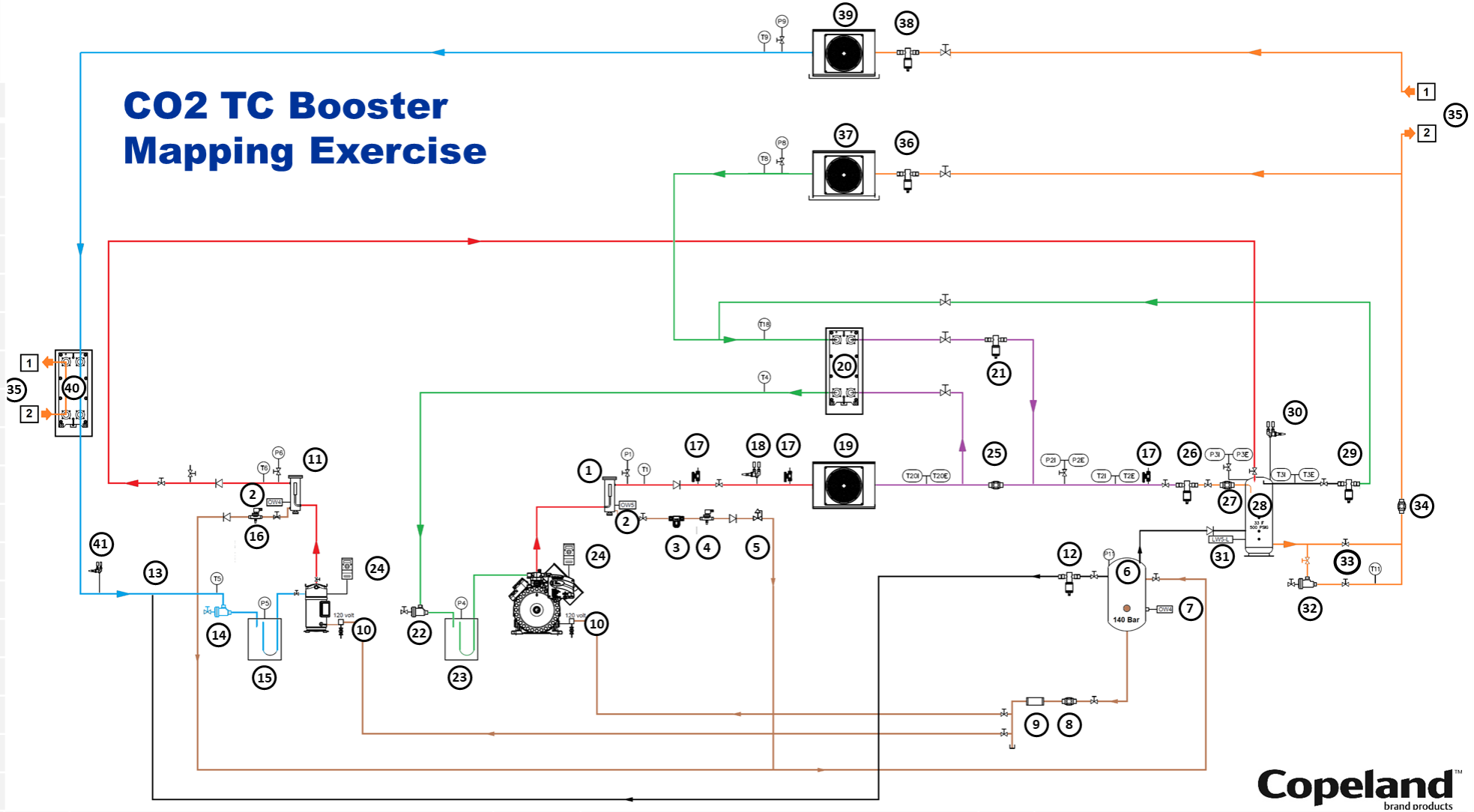
22		28		34		40		
23		29		35		41		

Identify all Components

-	MT Copeland 4MTLS Compressor
-	LT Copeland Scroll Compressor
1	MT Oil Separator
2	Oil Level Control; MT Oil Separator
3	Oil Line; MT Press. Reducing Valve
4	Oil line, MT Solenoid Valve
5	Outlet Pressure Reg, MT Oil Line
6	Oil Reservoir
7	Oil Reservoir, Oil Level Control
8	Oil Line Sight Glass
9	Oil Line Filter Drier
10	Oil Level Regulator for Compressor
11	LT Oil Separator
12	Reservoir Press. Reducing Valve
13	Oil Reservoir Press. Release Point
14	LT Suction Filter
15	LT Suction Accumulator
16	LT Sep. Outlet Oil Solenoid Valve
17	Access Valve MT High Side



18	PRV for MT Discharge Line	24	Variable Speed Drive	30	PRV for Flash Tank	36	EEV for MT Evaporator
19	Gas Cooler	25	Sight Glass Gas Cooler Out	31	Low Liquid Level Control for Flash Tank	37	MT Evaporator
20	MT Suction Heat Exchanger	26	High Pressure Valve (HPV)	32	Liquid Line Filter Drier	38	EEV for LT Evaporator
21	Flow Reg Valve for MT Suction HX	27	Sigh Glass at outlet of HPV	33	Shut Off Valves to Change Drier Core	39	LT Evaporator
22	MT Suction Filter	28	Flash Tank / Receiver	34	Liquid Line Sight Glass	40	Liquid to LT Suction HX
23	MT Suction Accumulator	29	Bypass Gas Valve (BGV)	35	Inlet & Outlet if Liquid to LT Suction HX	41	PRV for LT Suction

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To receive an electronic training certificate:

1. Scan or visit nasrc.org/session-surveys
2. Provide your name and email at the end of the survey

Please Note: *You will not receive a certificate unless you share your name on the survey form.*

Using P&ID to Further Understand CO2 Transcritical Booster Systems

Presenter Name: Andre Patenaude

Emerson / Copeland

Natural Refrigerant Training Summit

CO_2 Training Unit Walk Around

Building a Sustainable Technician Workforce

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