Natural Refrigerant Training Summit

Building a Sustainable Workforce

Using P&ID to Further Understand CO2 Transcritical Booster Systems Presentation Title

Andre Patenaude

Copeland

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 Training Summit

Nov.14-15-16, 2023, St Louis, MO

Andre Patenaude

COPELAND

Official Recognized Provider Attendance Record

Submit to: NATE • attn: Recognized Provider Recorder
2111 Wilson Blvd. Suite 510 • Arlington, VA 22201

Recognized Provider Name Copeland Date _____

Training Location, City & State Plumbers & Pipefitters Local 562 Training Center

Course Name CO2 System Basics / Booster System Ops NATE Course # 1212-0136

NATE Approved Hours 2 Course Hours Total 2

Instructions on filling out this form:

1. If additional sheets are needed, please use copies of this sheet, not blank paper
2. Course name, number and hours must match as submitted and approved by NATE.
3. Records must be received within 60 days to receive credit. Records received after this WILL NOT GET CREDIT.
4. To receive credit, the original roll and all information must be provided. No copies or faxes will be accepted.
5. If handwriting is unclear, credit will not be given.
6. Instructors hours will only be recorded in instructors box at bottom.
7. This record must be used for single-day courses. Multi-day courses use a different form.

Technician Name Please print as it appears on your NATE ID card	**NATE ID #** **Must be included to receive credit**	**Signature**

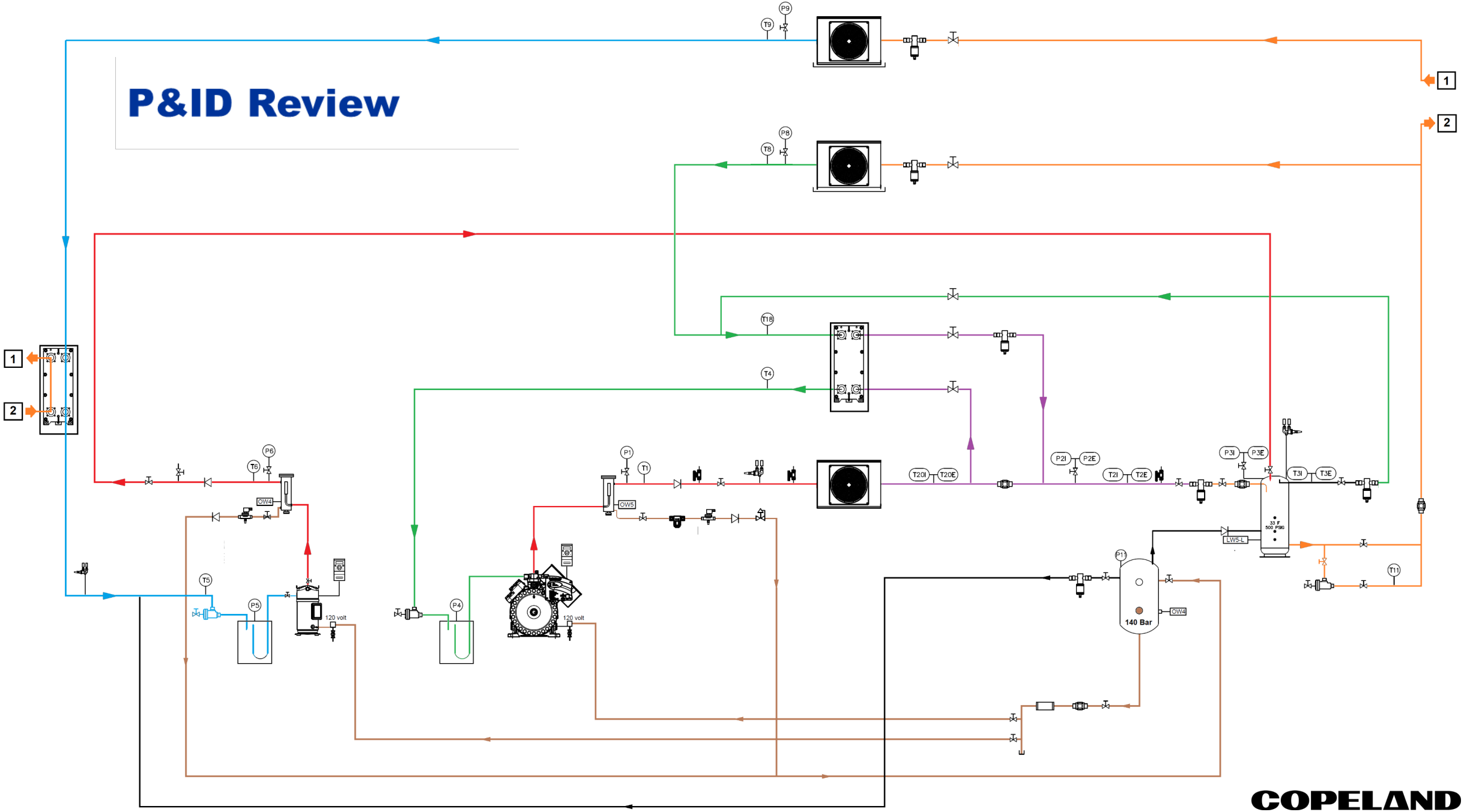
Instructors training credit requires NATE ID #. • Course ID# 1587-0003

Name _____ Date ___/___/___ NATE ID# _____

Signature _____ Email _____

Revised 03.09

P&ID Review



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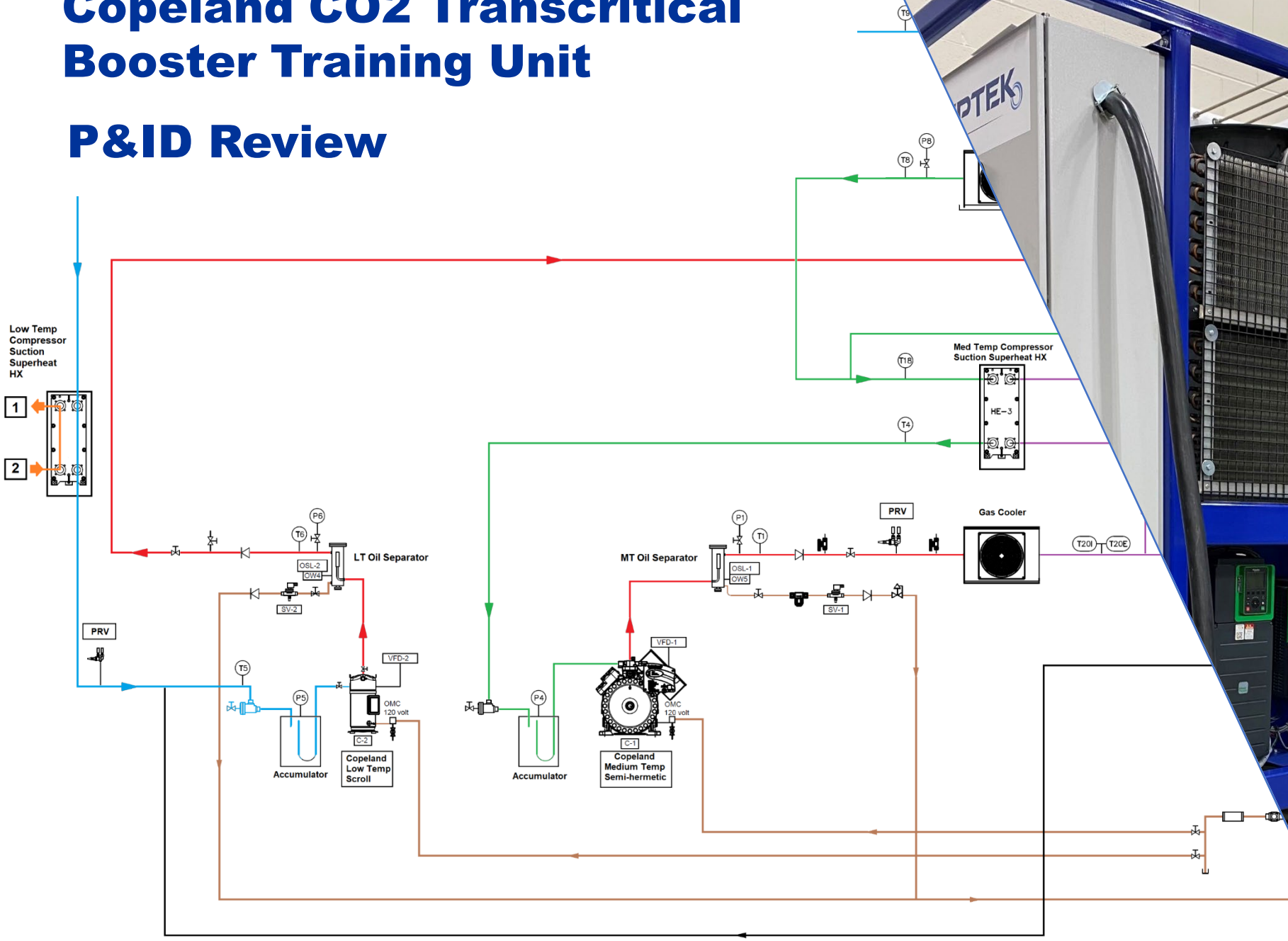
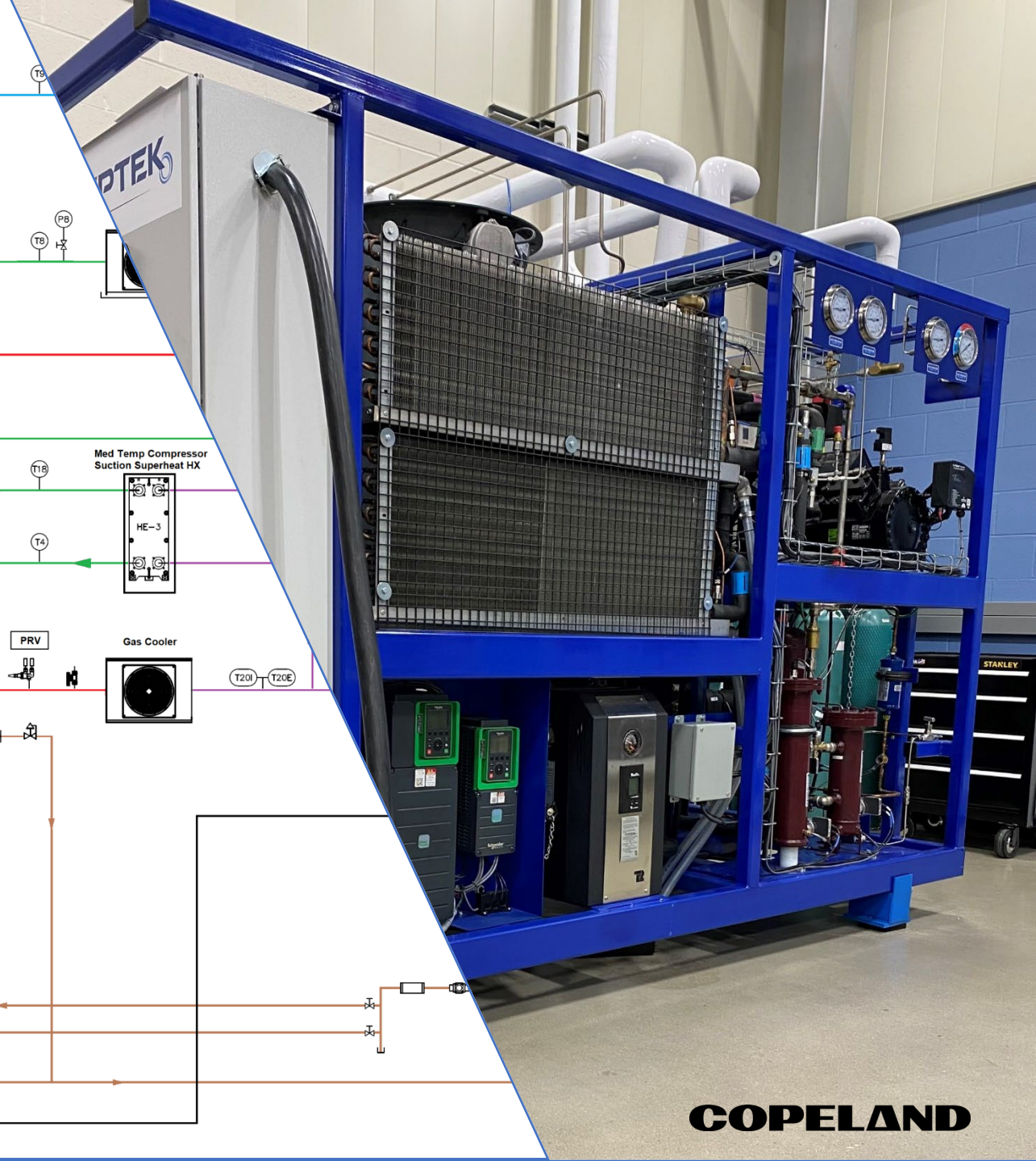
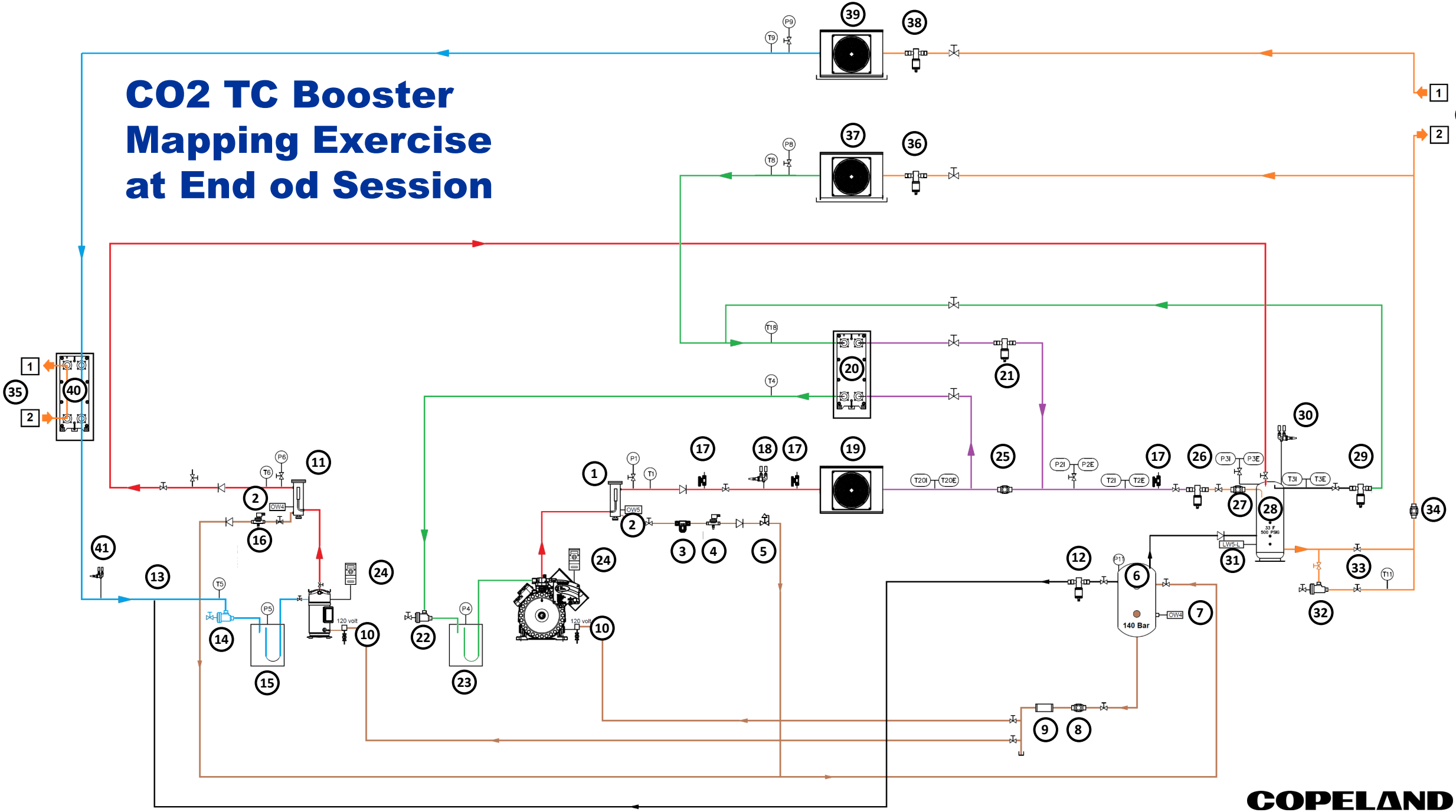
Copeland CO2 Transcritical Booster Training Unit

P&ID Review





CO2 TC Booster Mapping Exercise at End od Session



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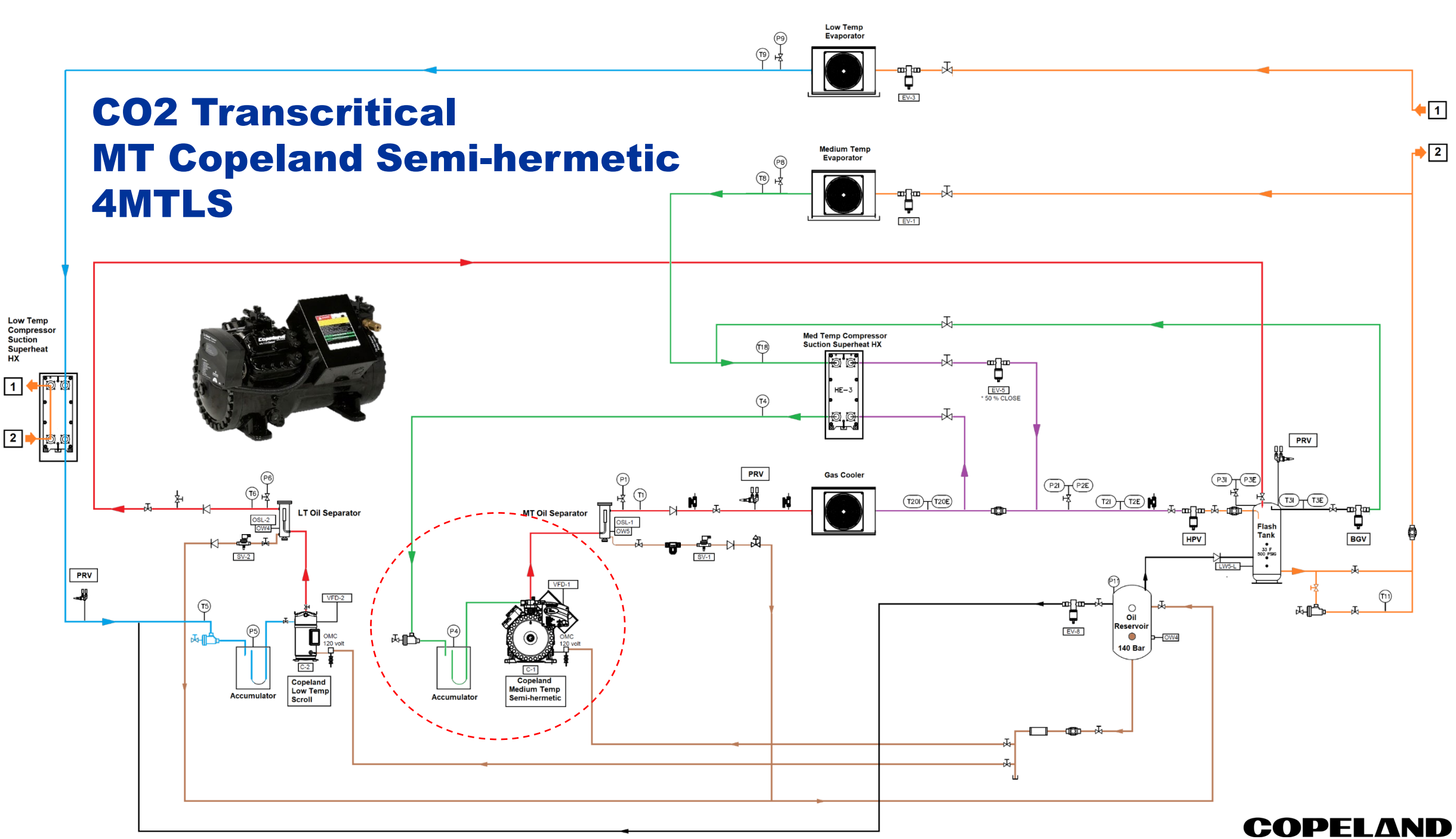
CEPTEK
Training Unit
CO2
Climate.Emerson.com
EMERSON
STANLEY

2

COPELAND

CO2 Transcritical
MT Copeland Semi-hermetic
4MTLS



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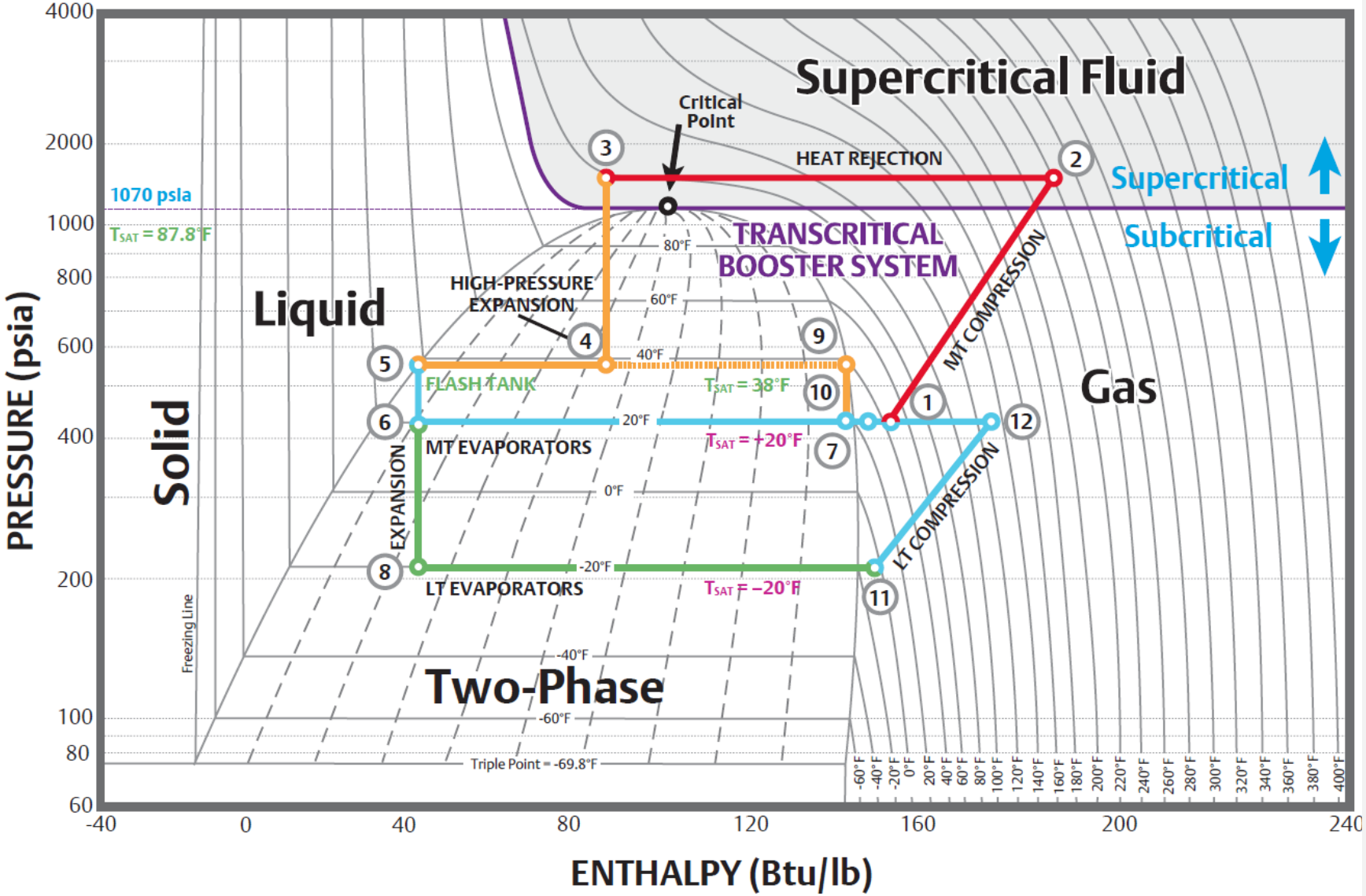
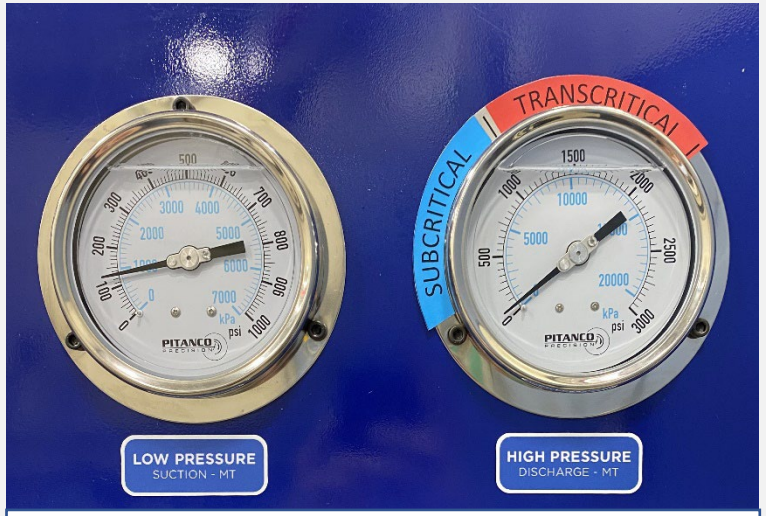
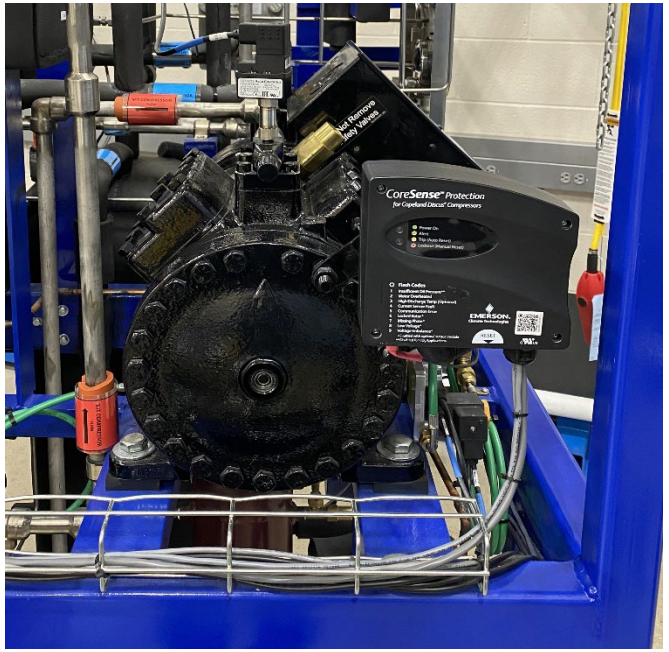

Supercritical Fluid
Critical Point
HEAT REJECTION
Supercritical
Subcritical
TRANSCRITICAL BOOSTER SYSTEM
1070 psia
T_{SAT} = 87.8°F
HIGH-PRESSURE EXPANSION
Liquid
Solid
Gas
MT COMPRESSION
FLASH TANK
T_{SAT} = 38°F
MT EVAPORATORS
T_{SAT} = +20°F
EXPANSION
LT COMPRESSION
LT EVAPORATORS
T_{SAT} = −20°F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


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

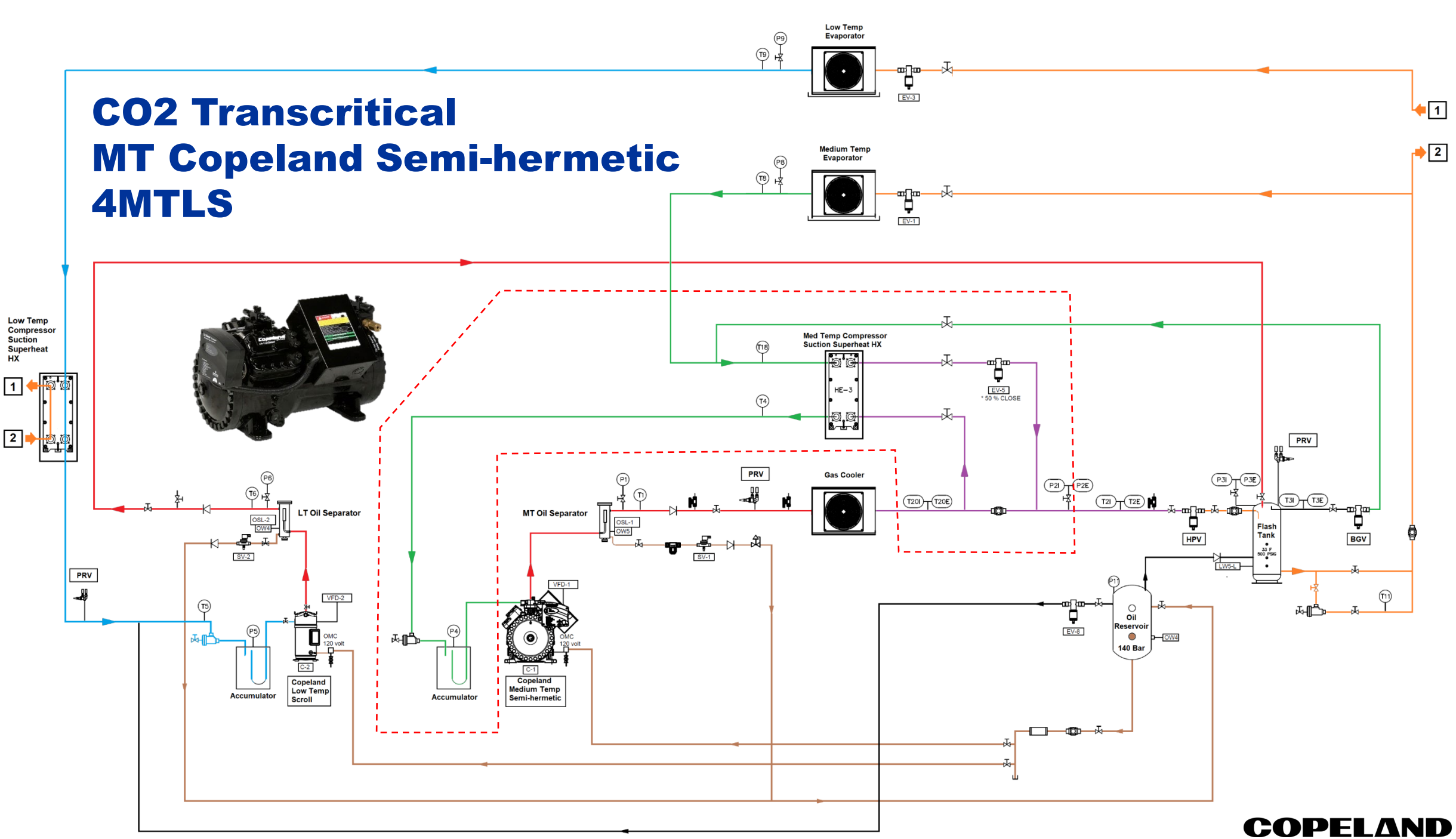

CoreSense Protection

Discharge Line

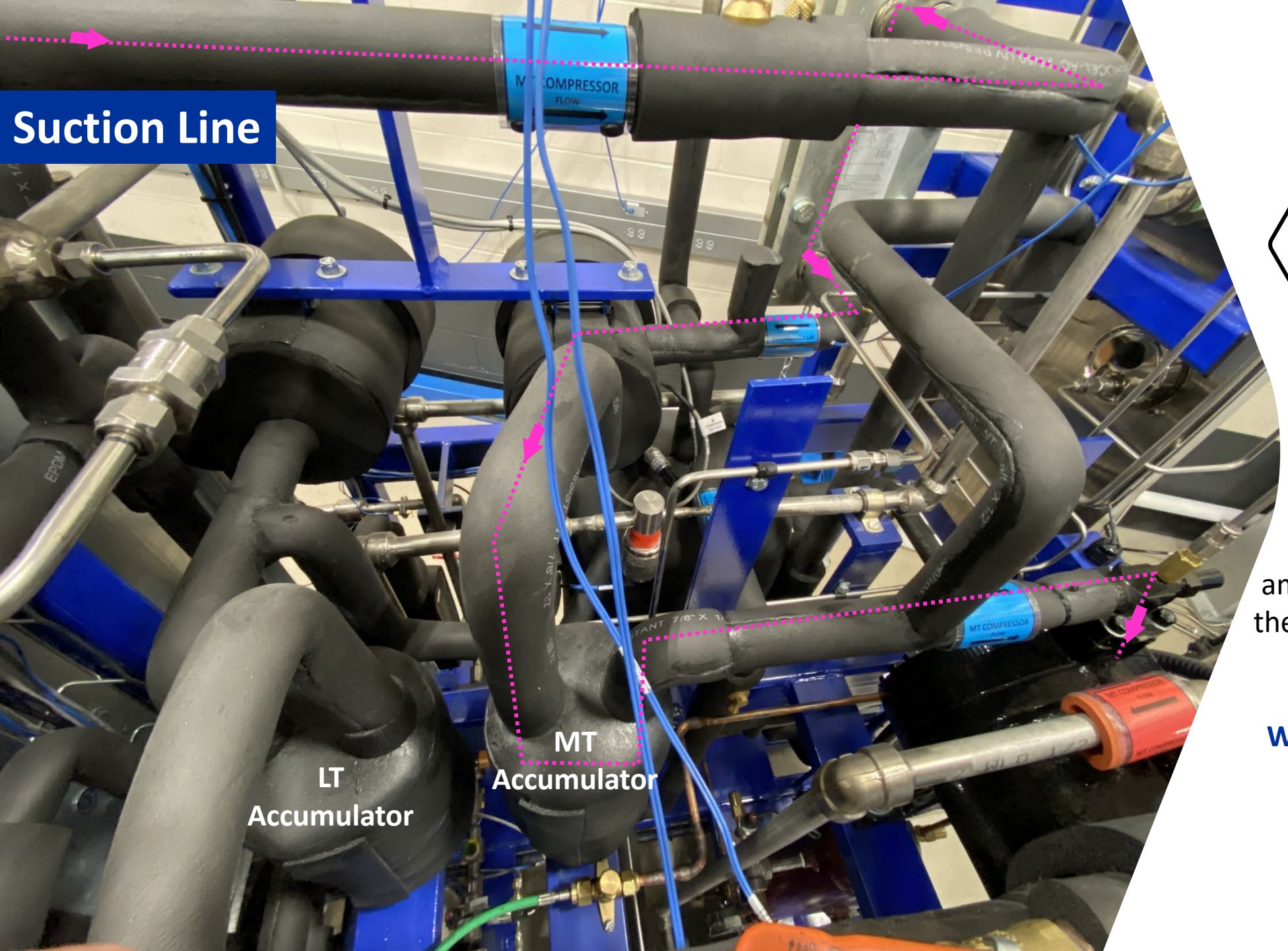
2

Copeland 4MTLS40KE-FSC-C00

CO2 Transcritical
MT Copeland Semi-hermetic
4MTLS



COPELAND



2

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

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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

2

Discus 4DH

CO2 4MTLS15

Stator Cover

2

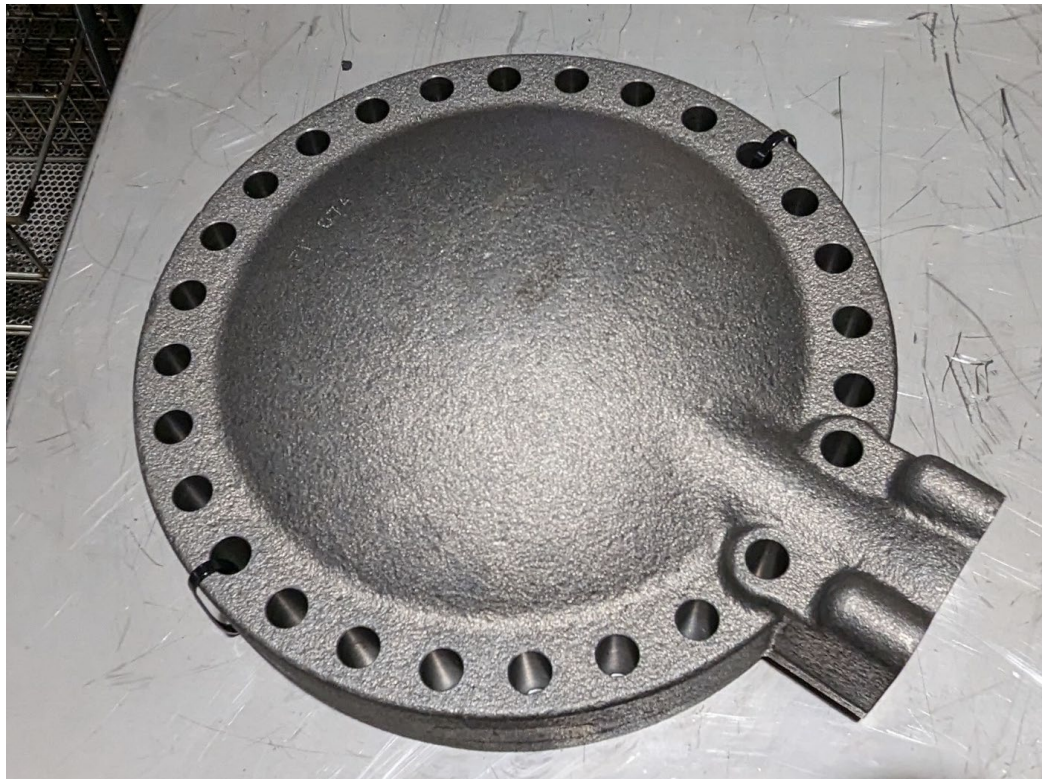
Discus 4DH

005-1832-00

12 bolts

CO2 4MTLS15

505-1218-00

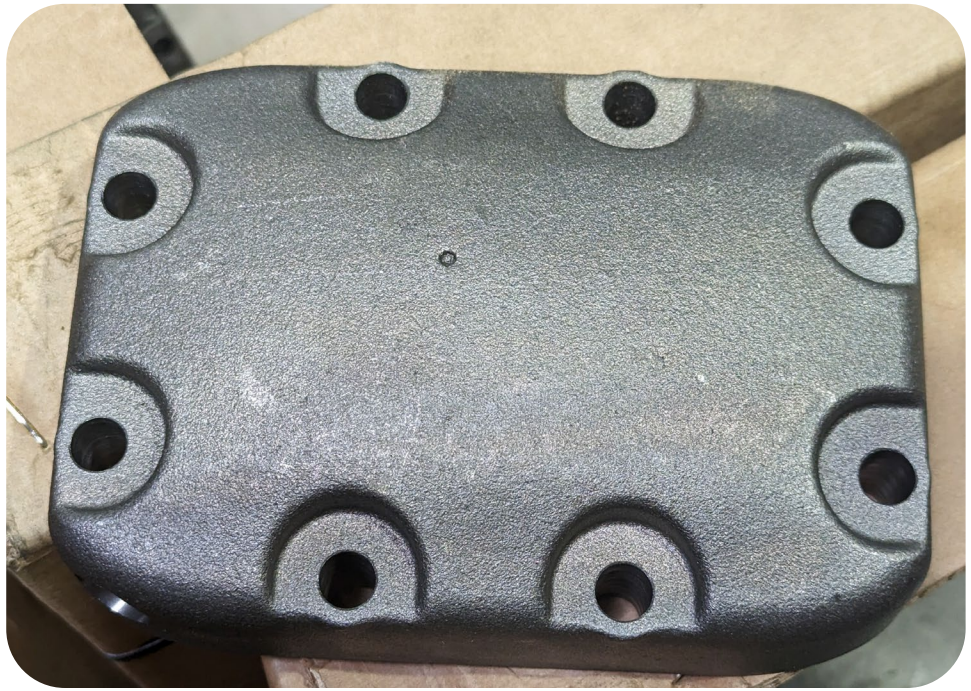


27 bolts

Head Covers

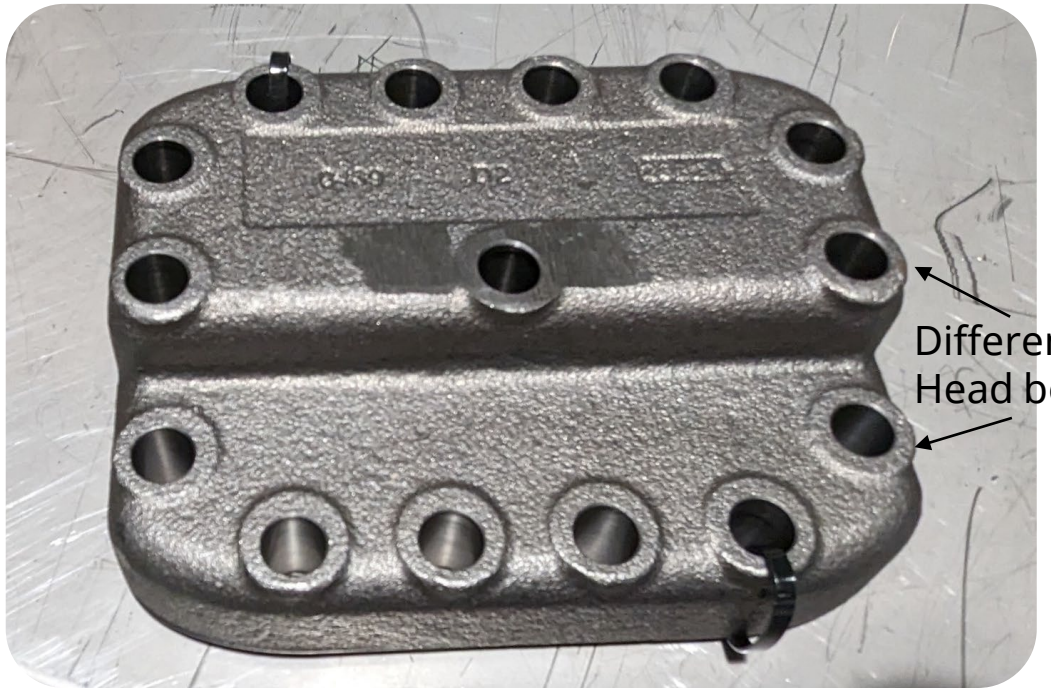
Discus 4DH

002-0433-00



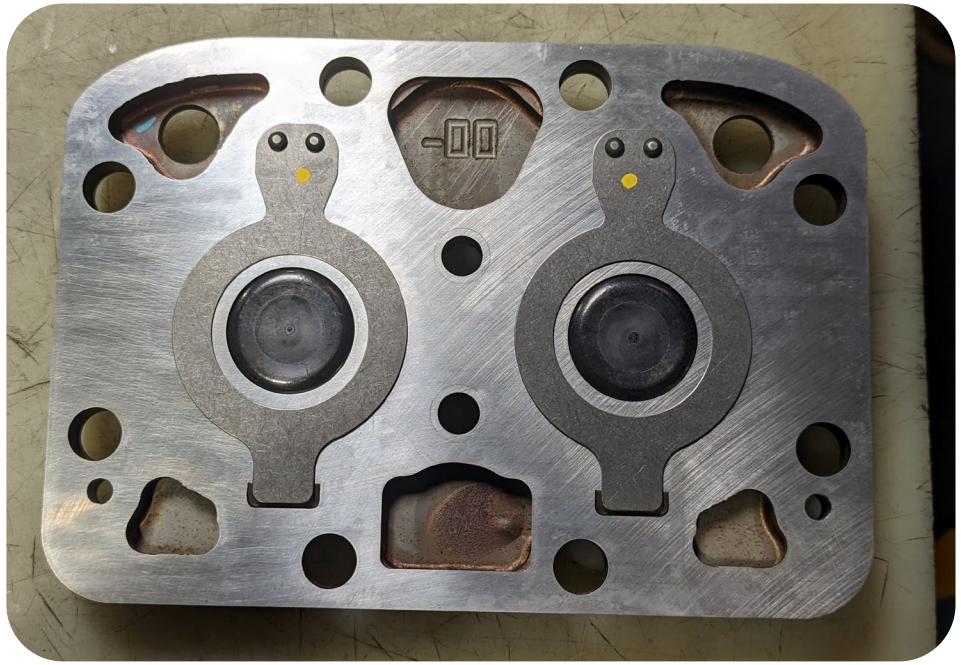
CO2 4MTLS15

002-0439-00



Valve Plates

Discus - 4DH



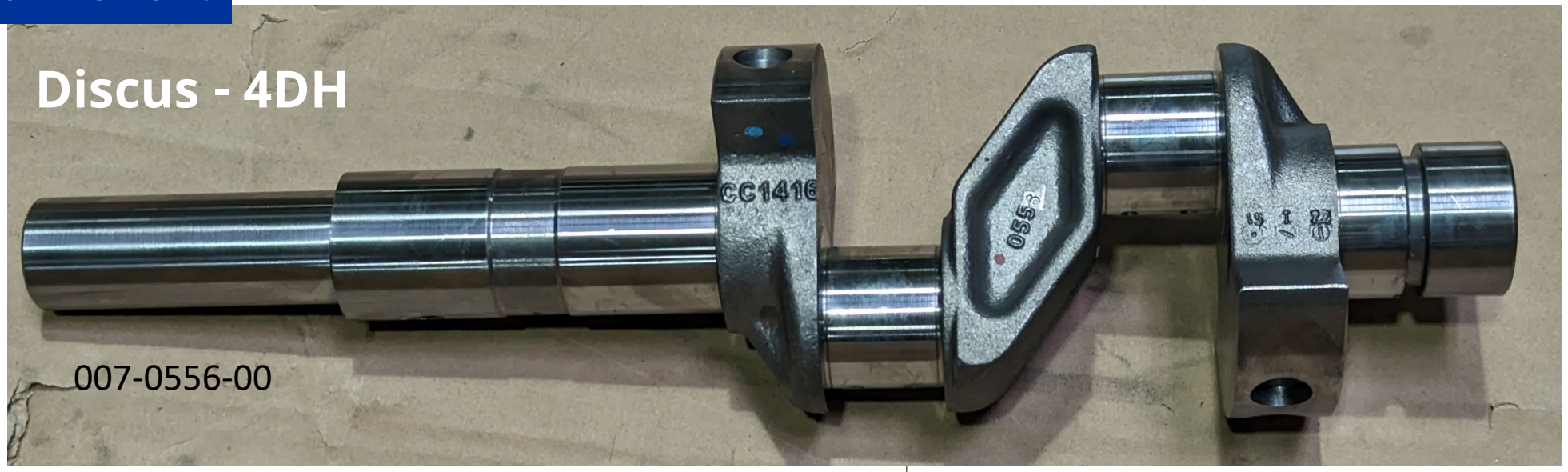
503-2032-00

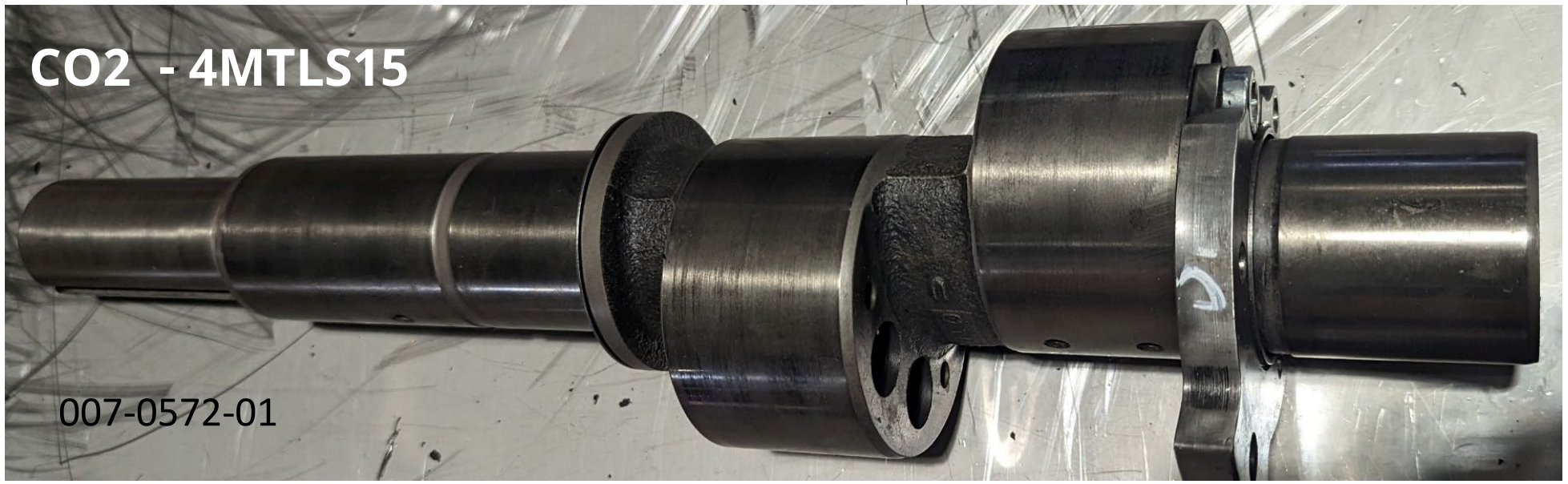
CO2 - 4MTLS15

503-1075-00

Note: Discus “puck” design vs. traditional Reed

Crankshaft





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

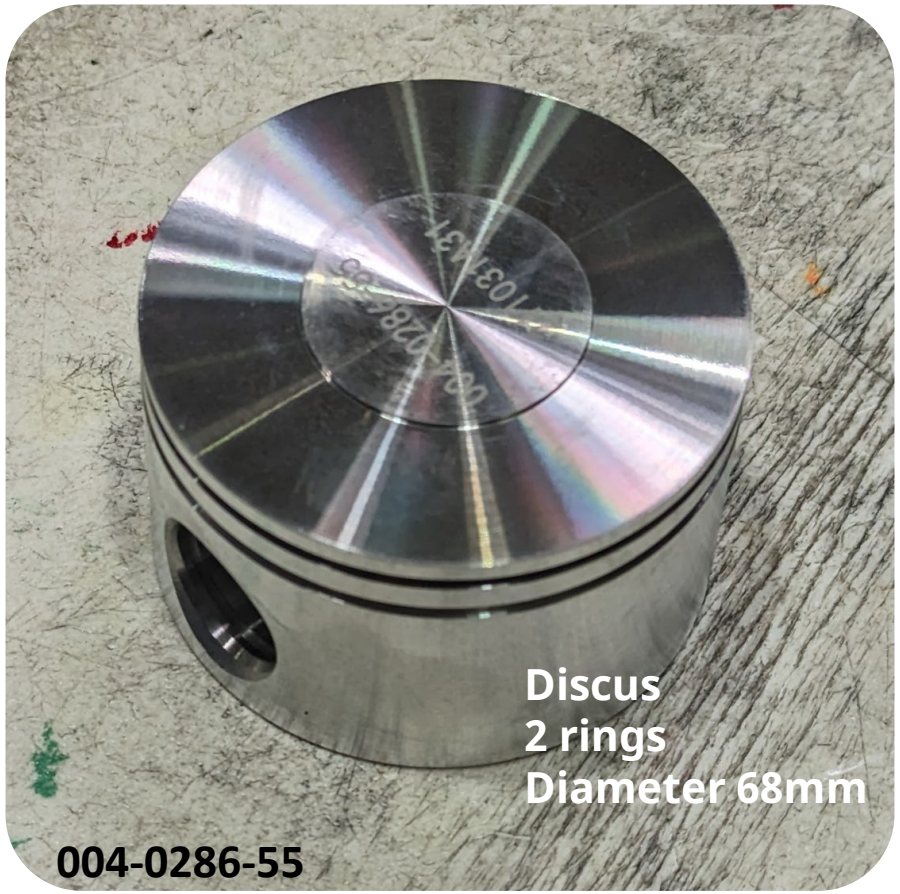
Wrist Pins

Discus - 4DH

CO2 - 4MTLS15

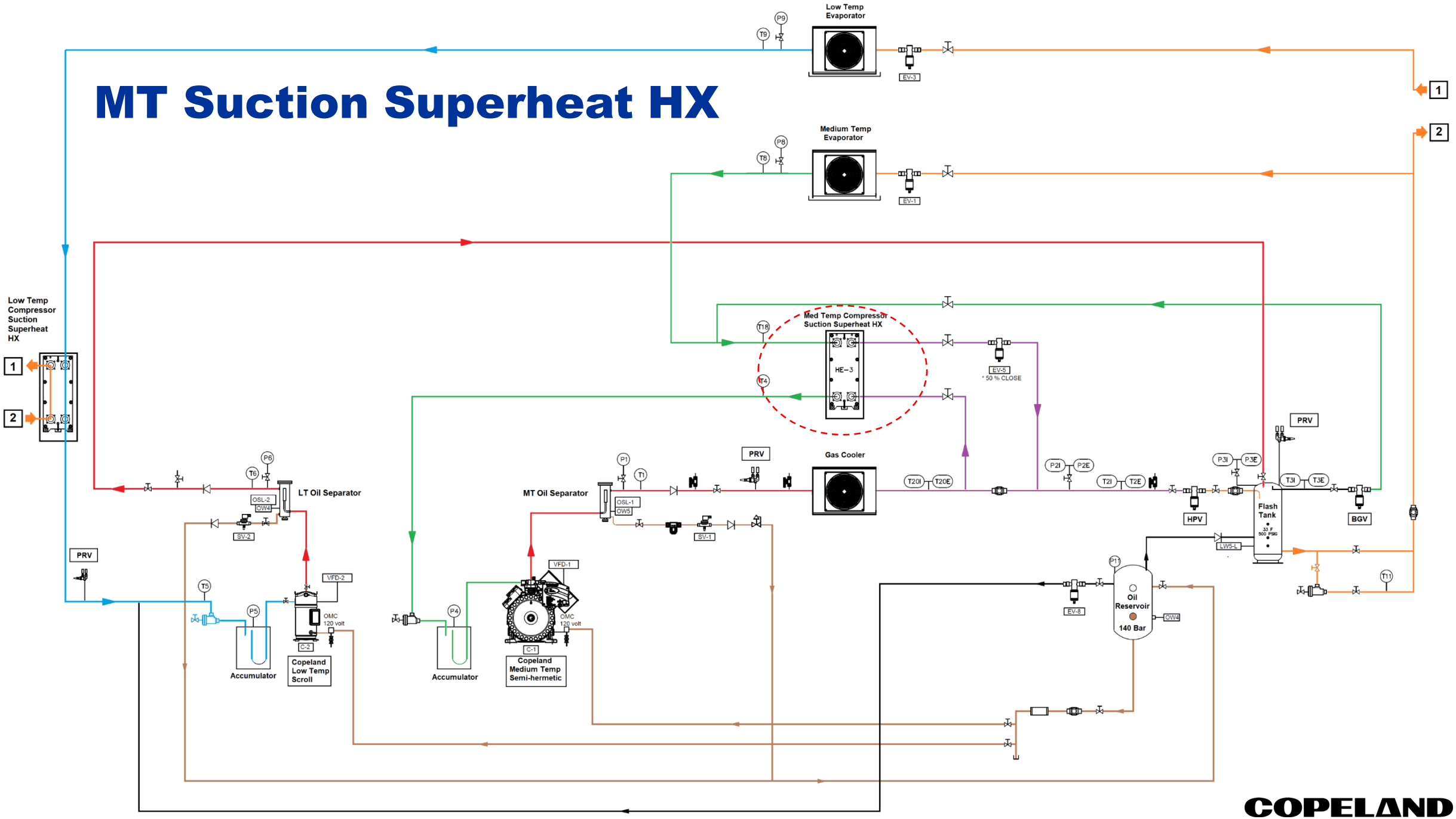
Pistons

Discus - 4DH



CO2 - 4MTLS15

MT Suction Superheat HX



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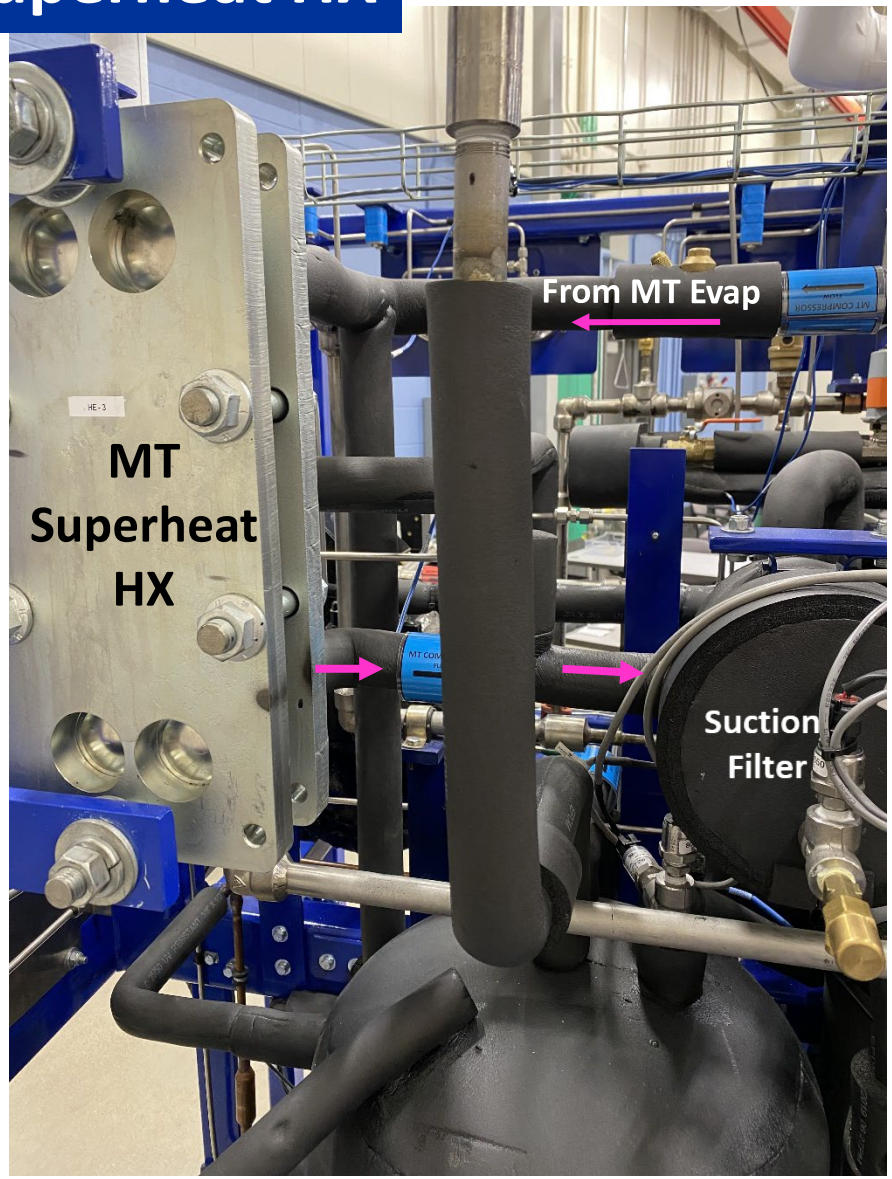
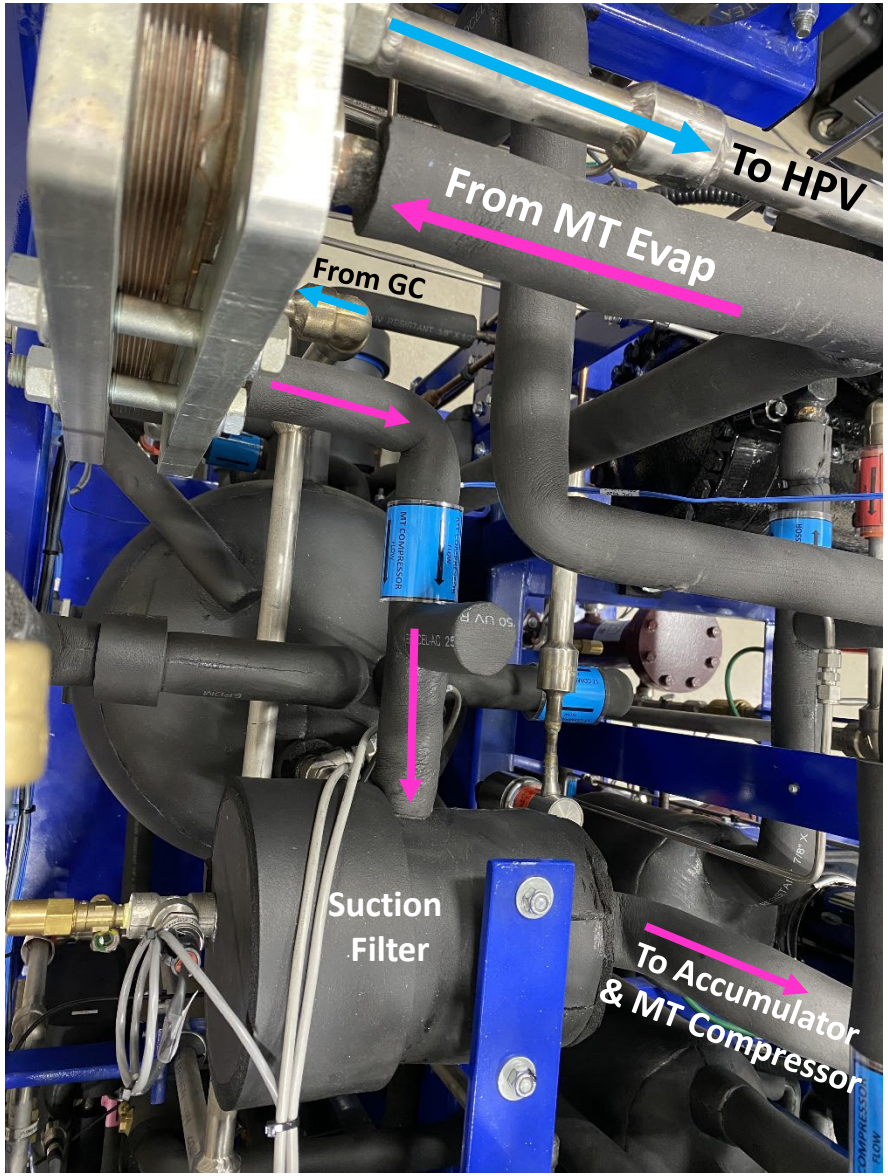
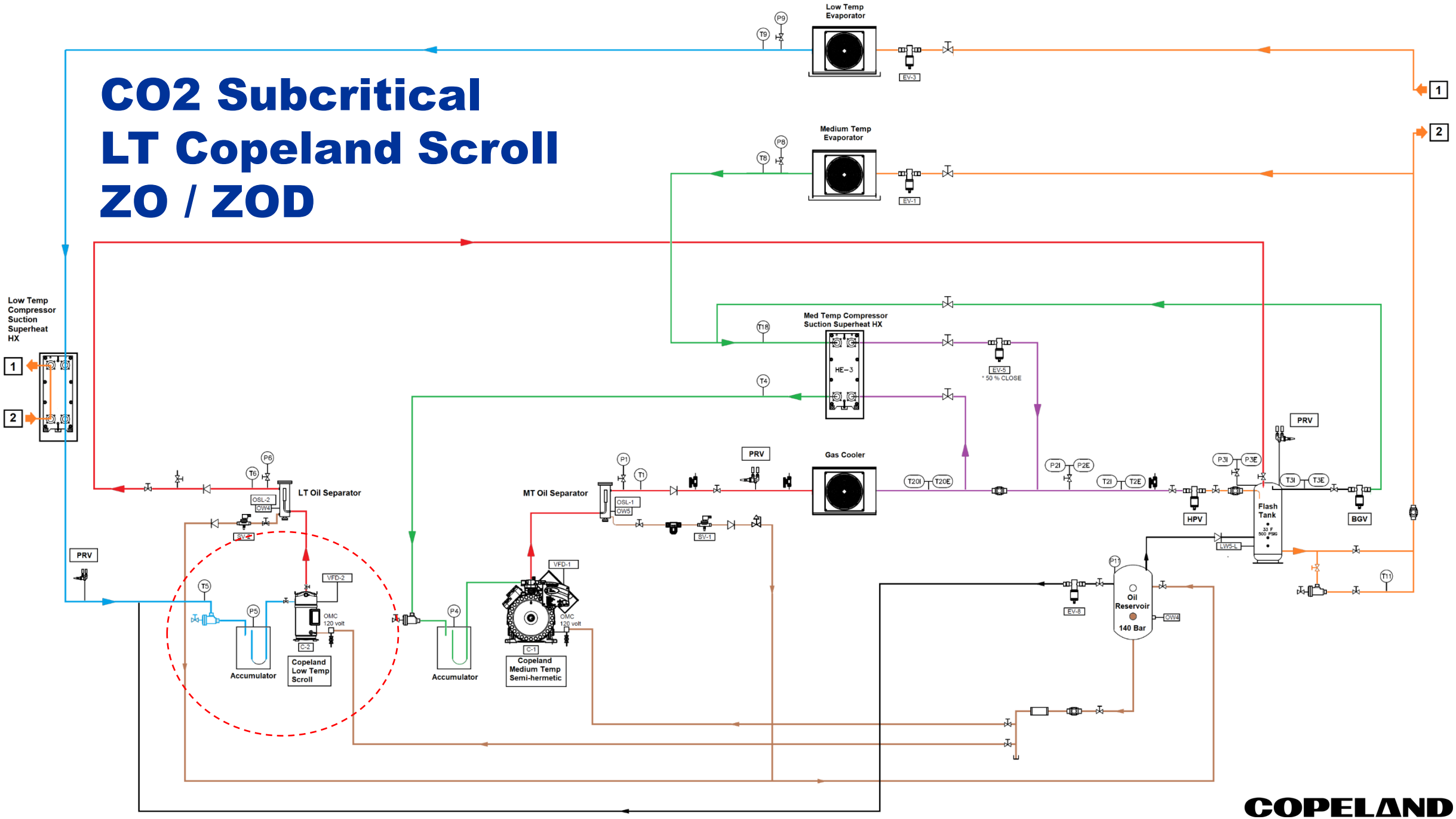
MT Superheat HX





CO2 Subcritical
LT Copeland Scroll
ZO / ZOD



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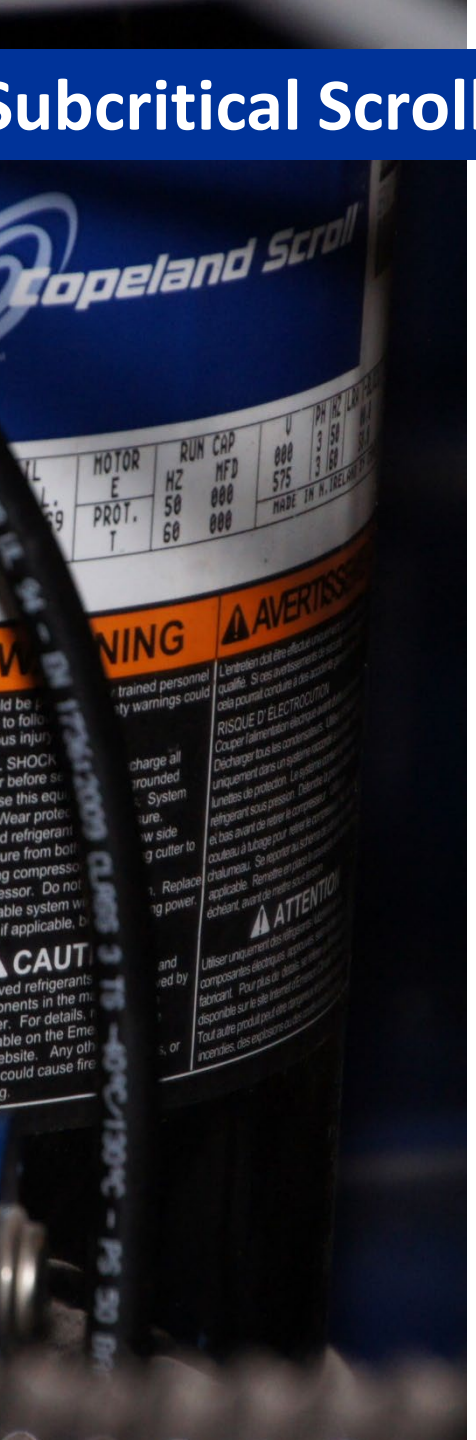
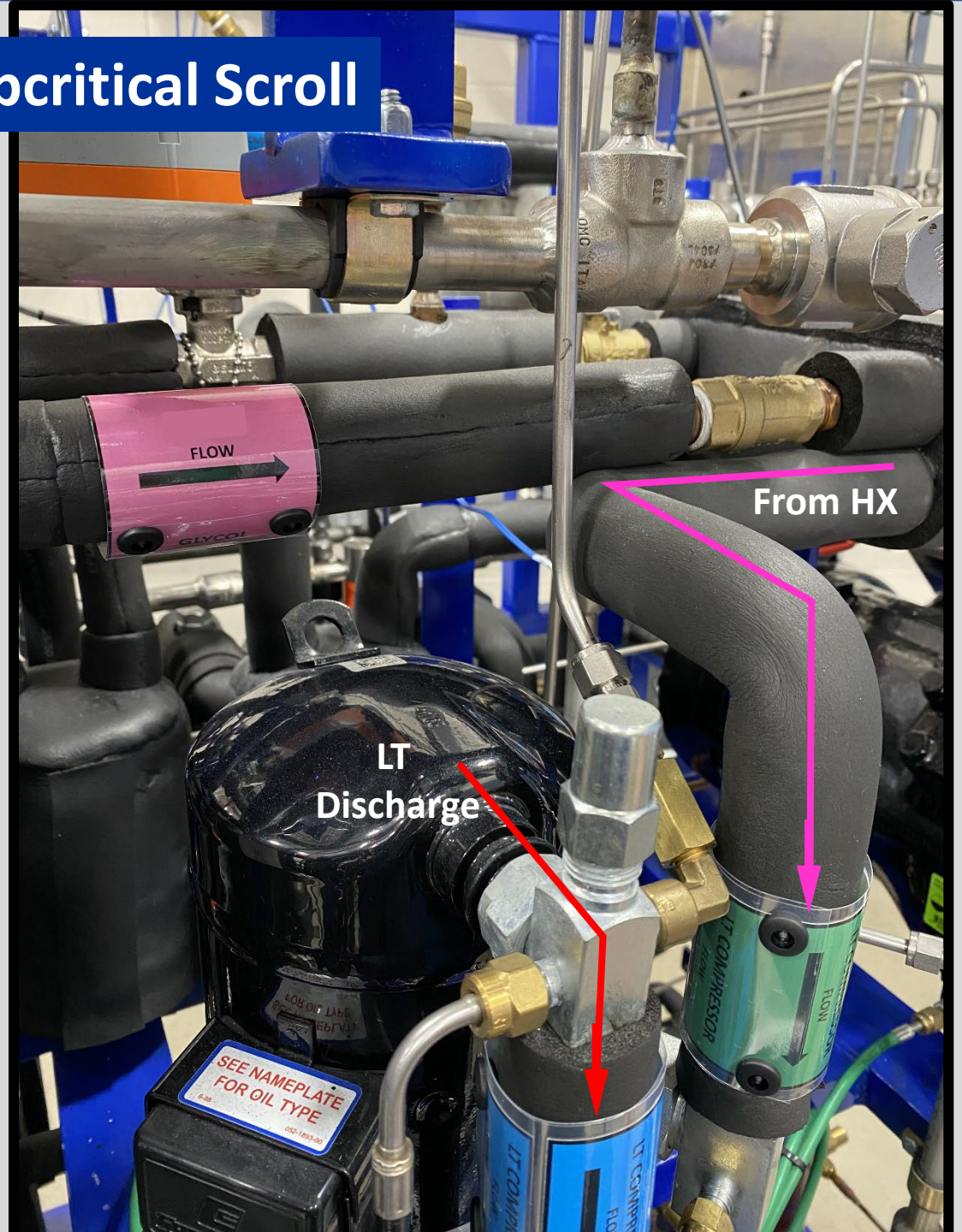
Subcritical Scroll



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)

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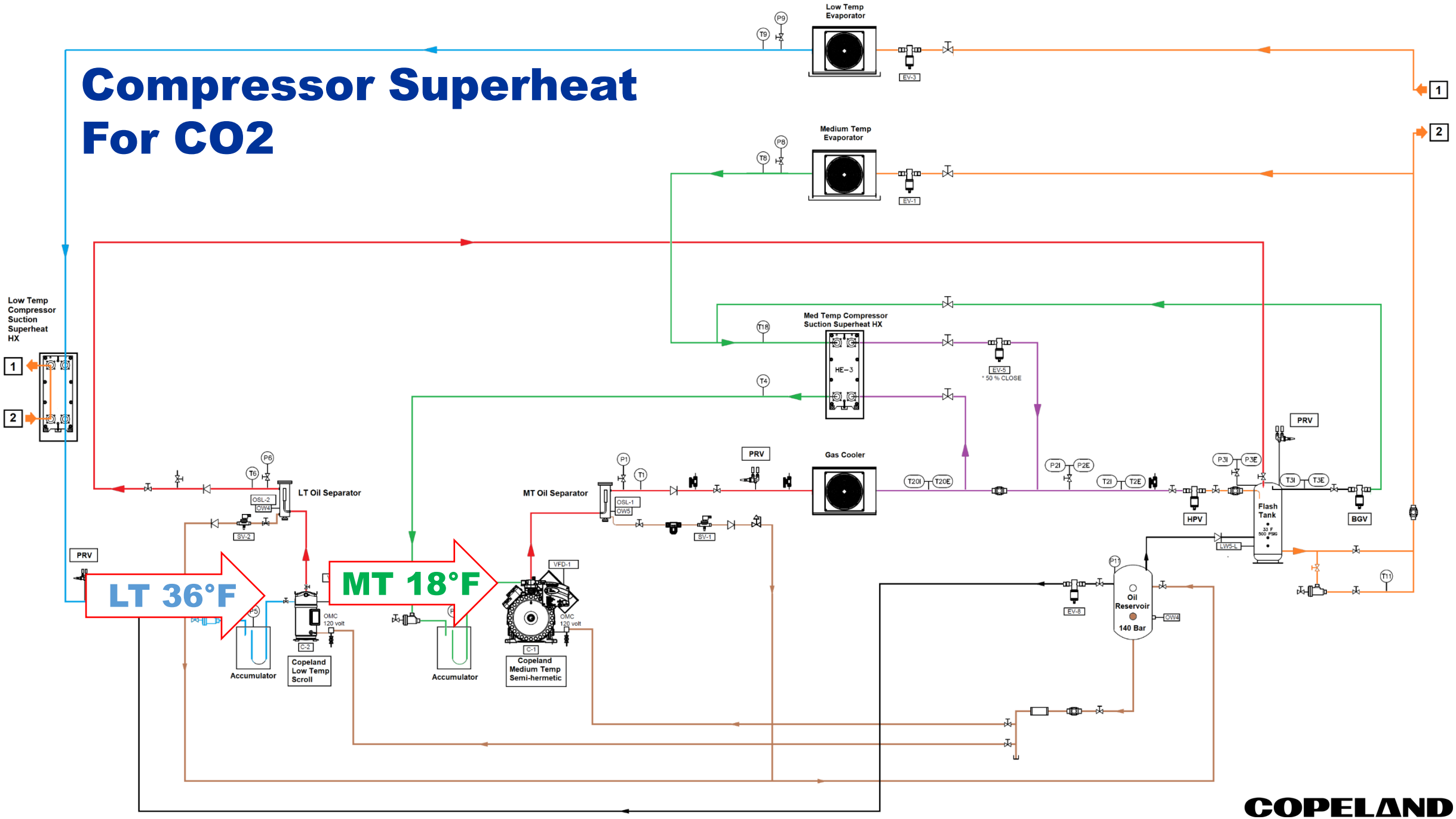
Compressor Superheat For CO2



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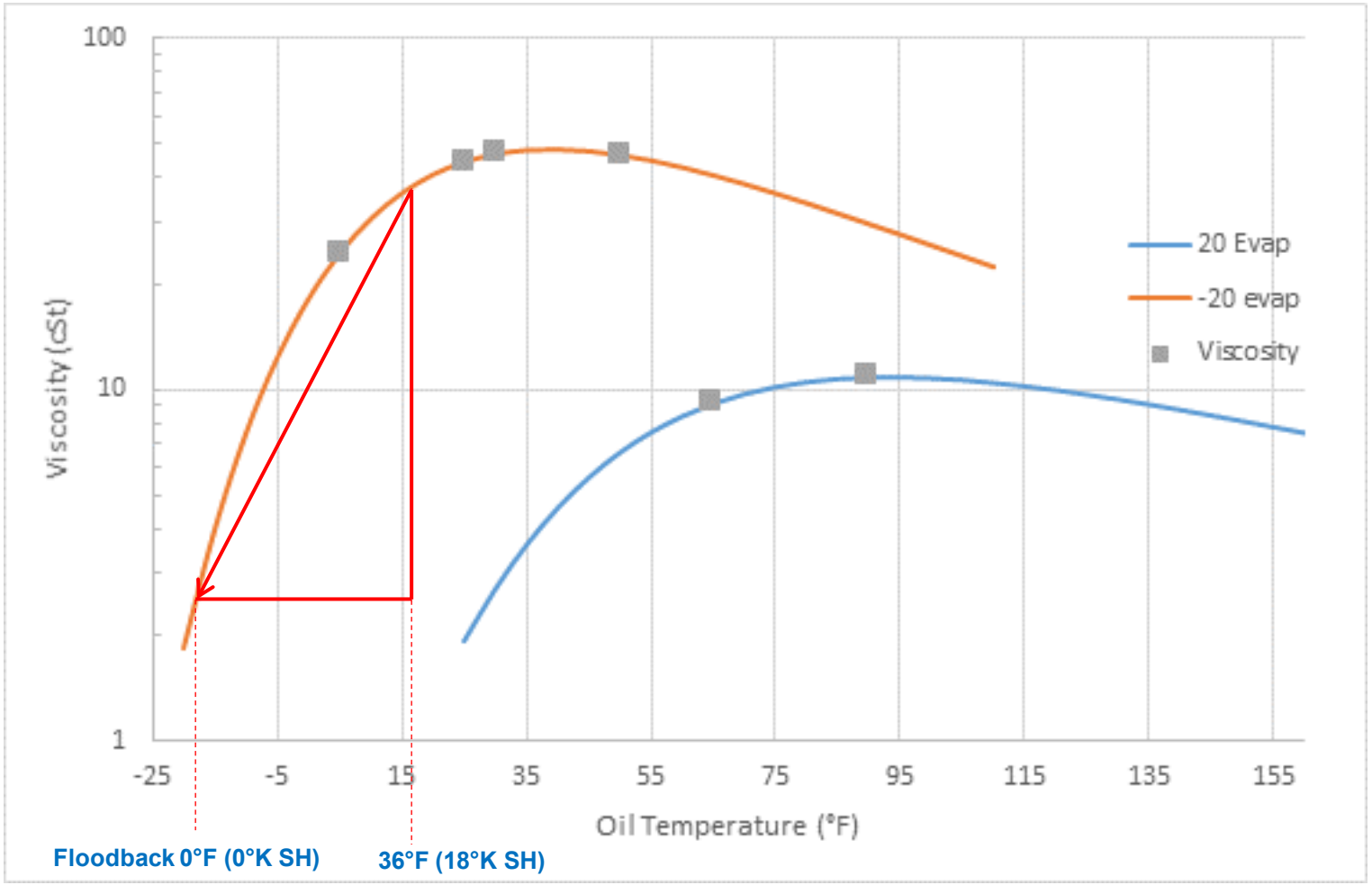
POE Oil Viscosity in CO_2 Vs Suction Superheat

Oil Temp Measured Bottom of Sump



Scroll Drive Bearings
Lack of Lubrication

Lack of Lubrication

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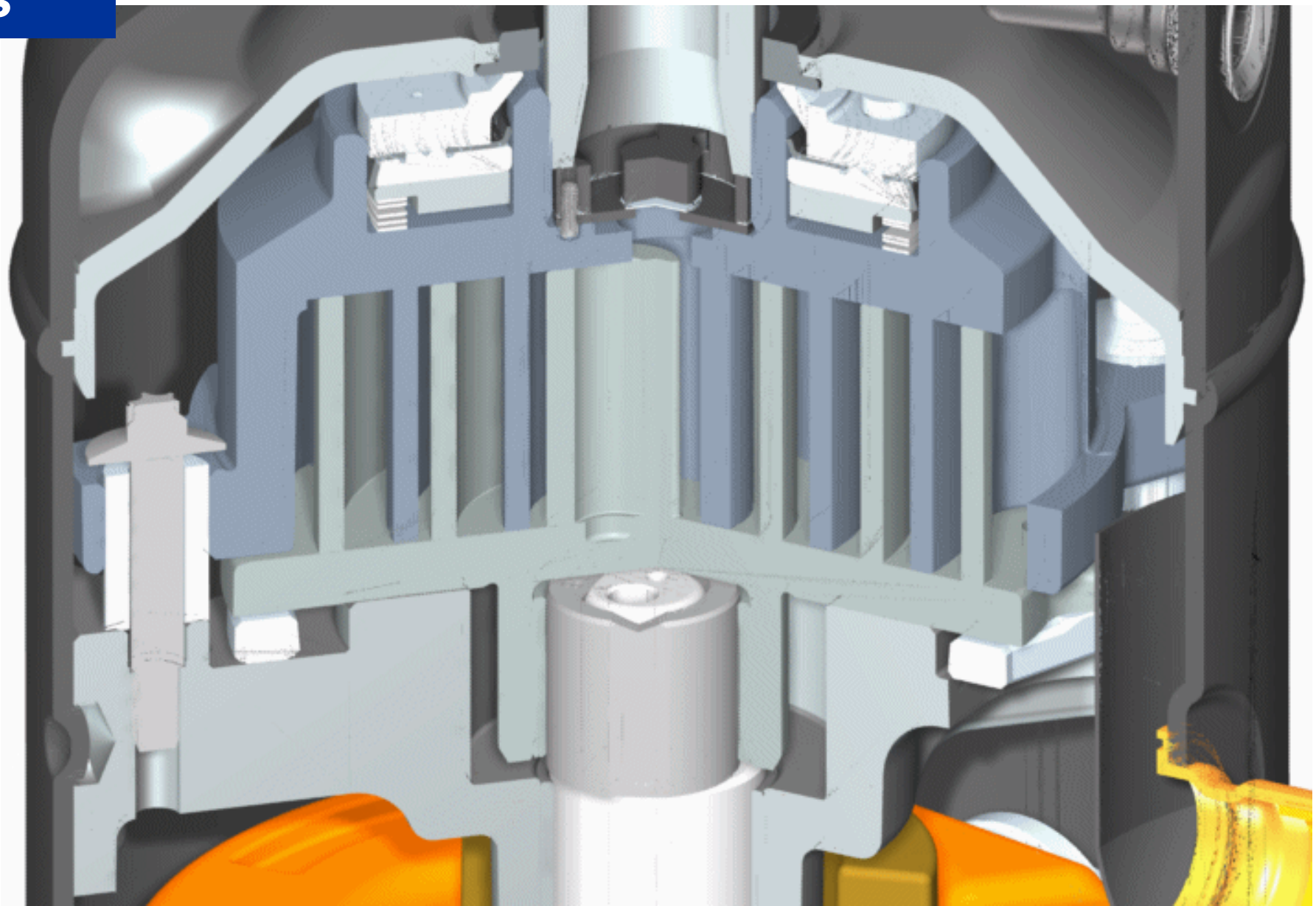
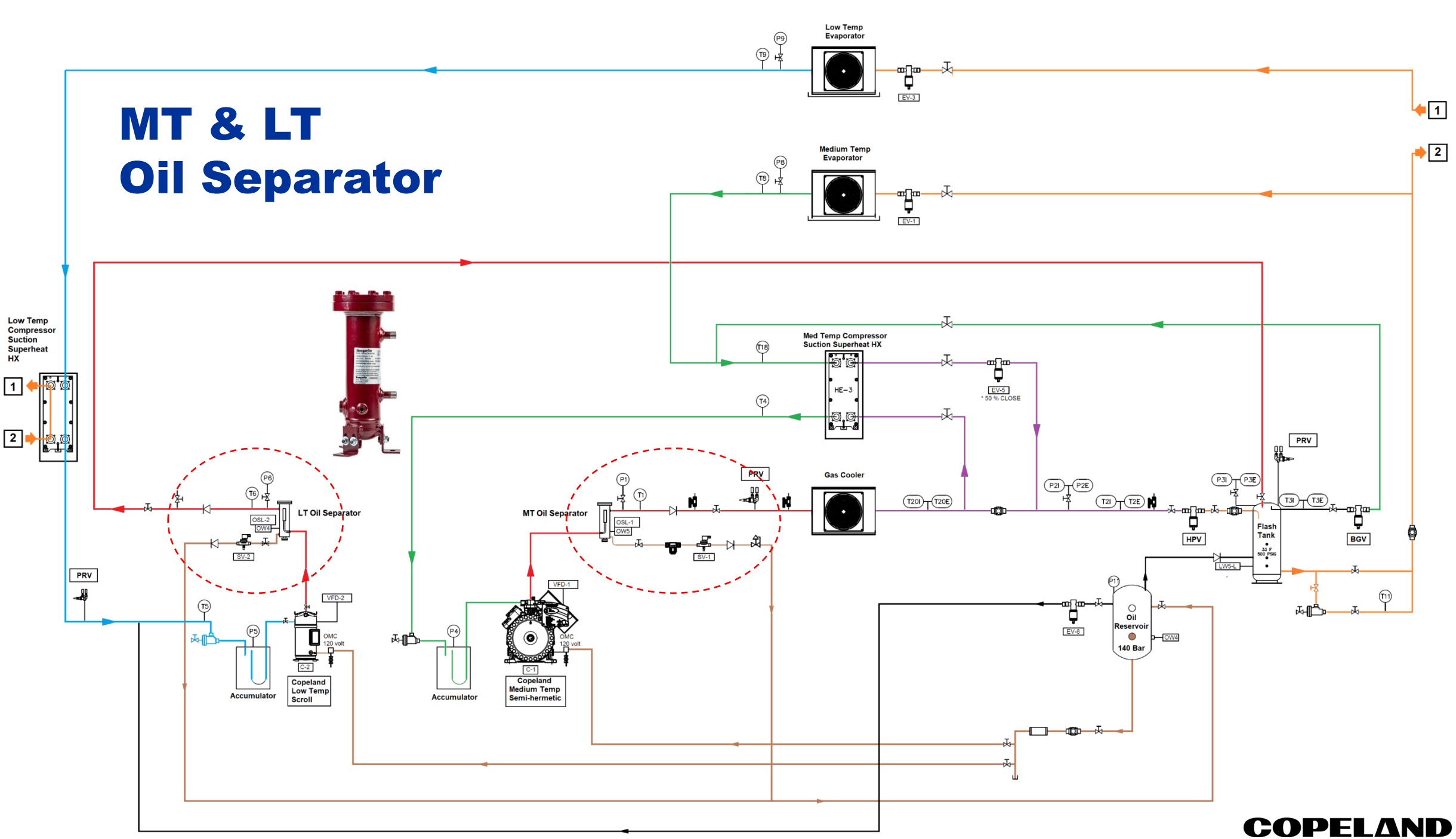
Scroll Modulation – How It Works



MT & LT Oil Separator



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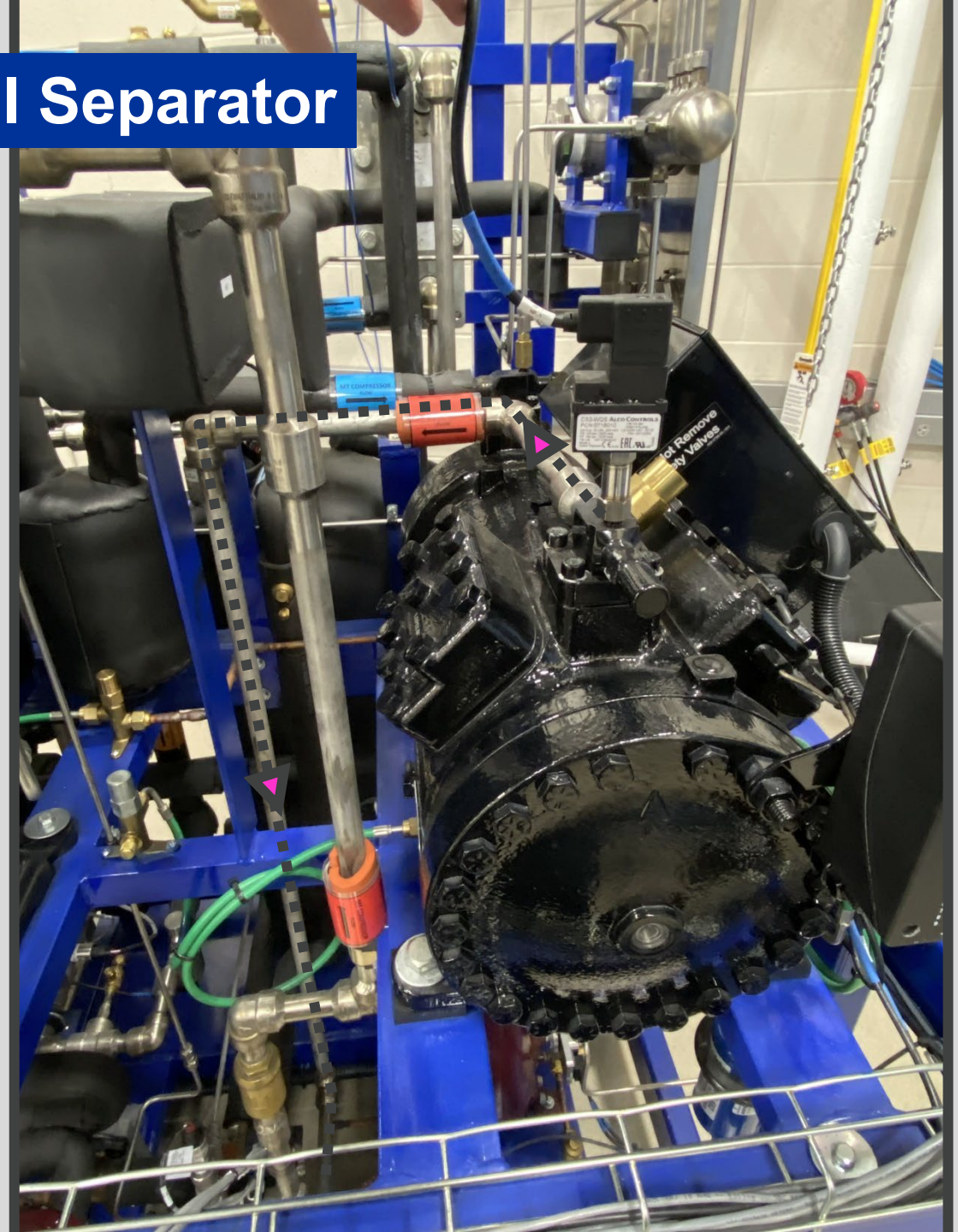
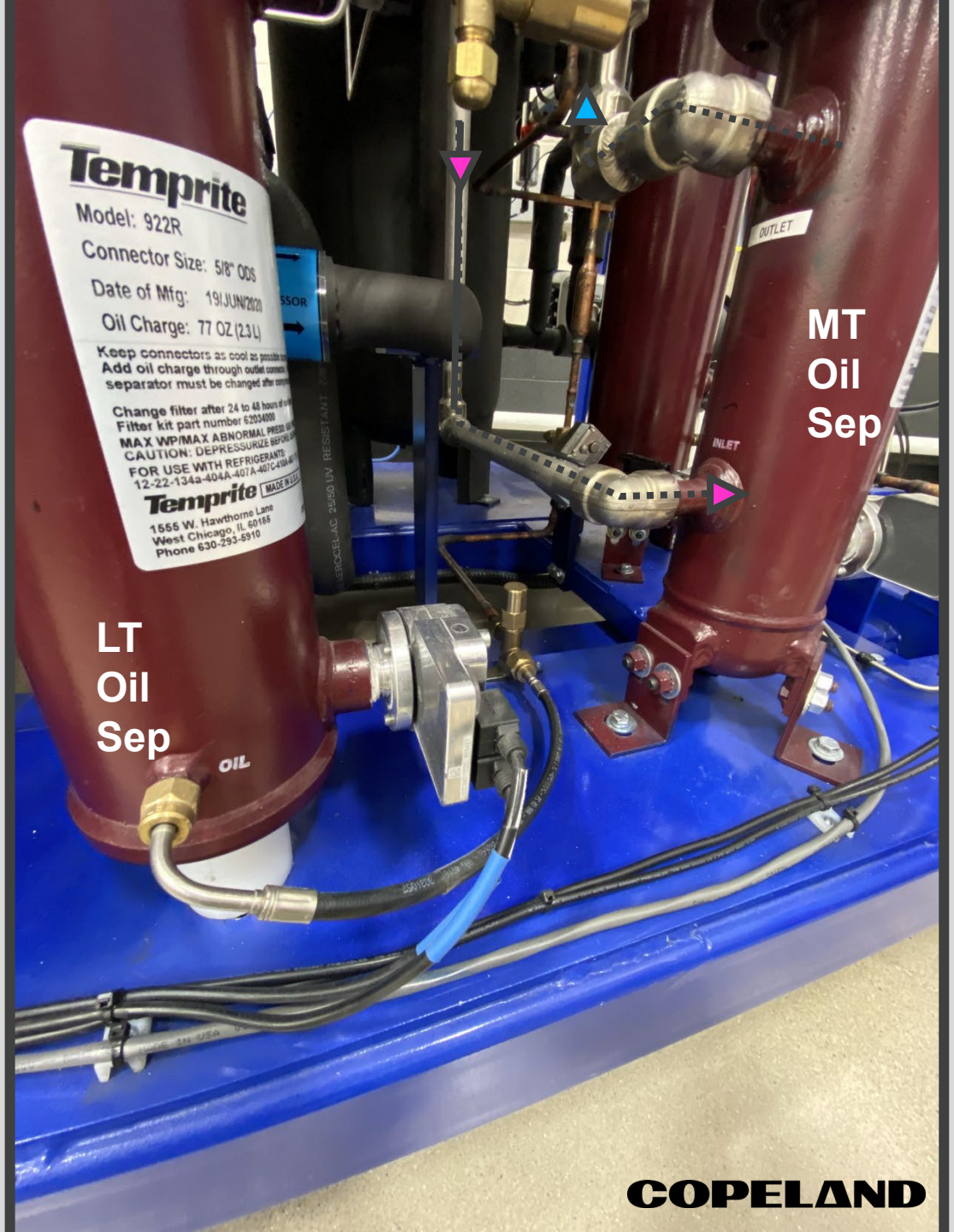
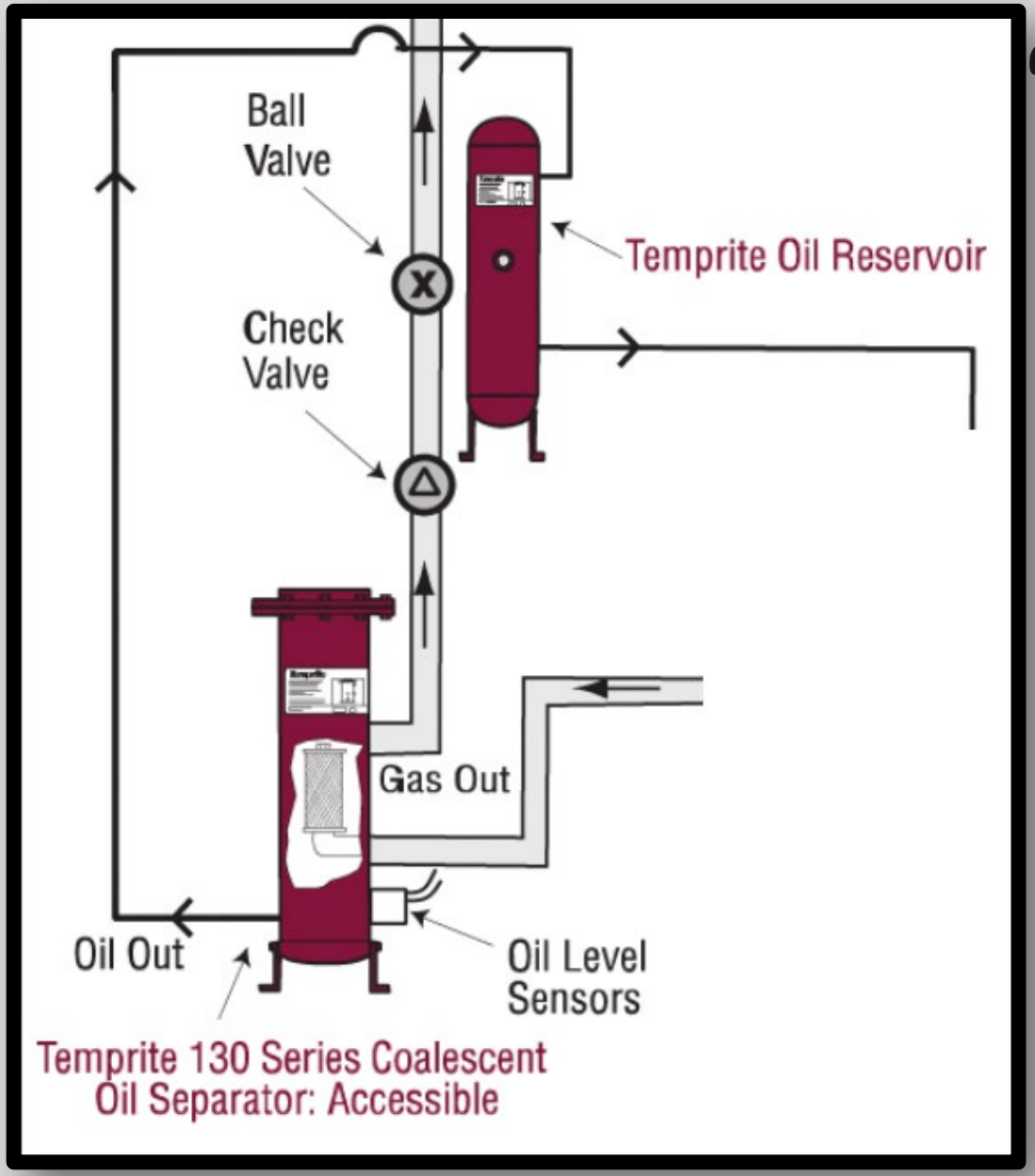
Oil Separator



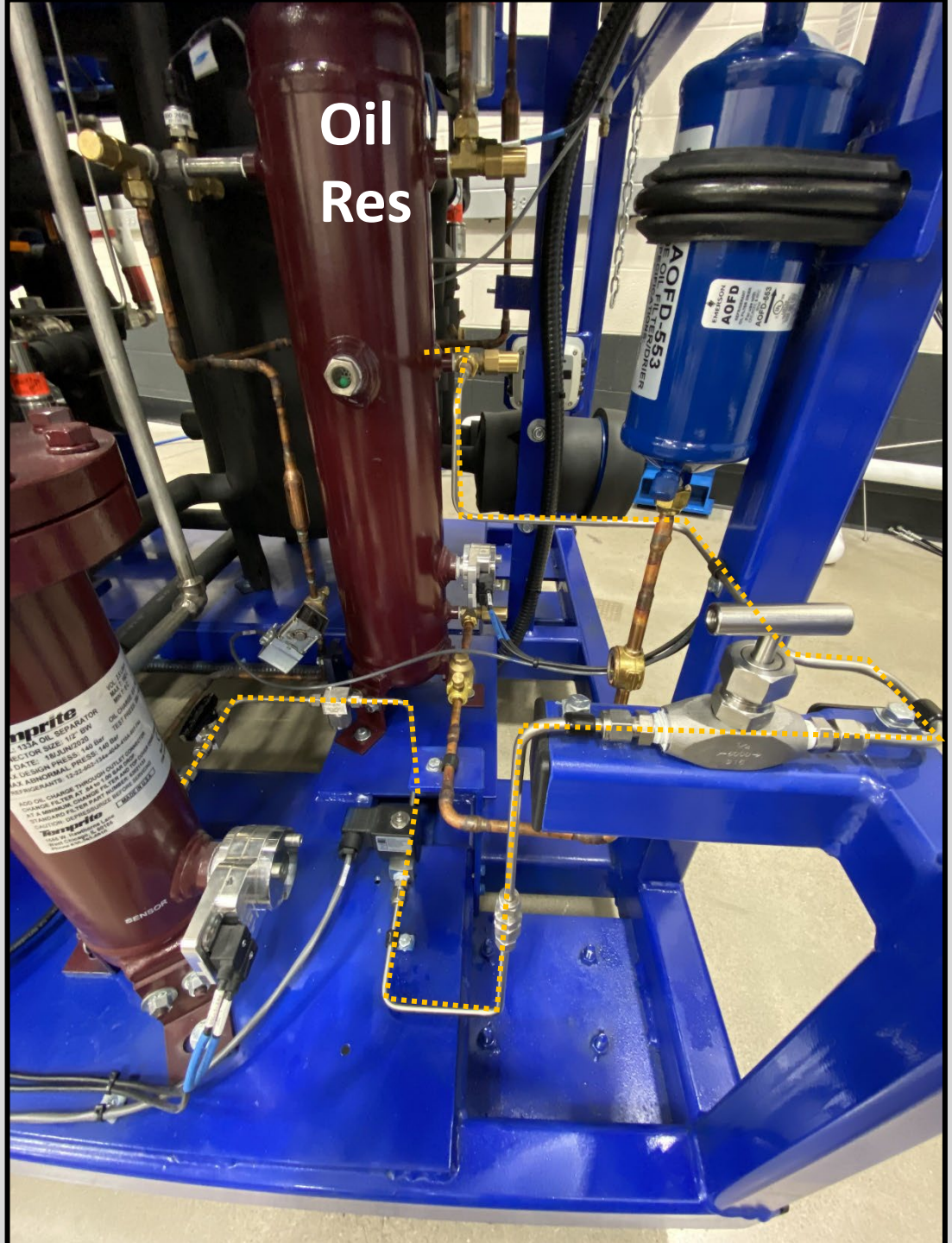


Oil Separator



Temprite 130 Series Coalescent
Oil Separator: Accessible

Oil Separator



2

Oil Separator

2

- 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.)

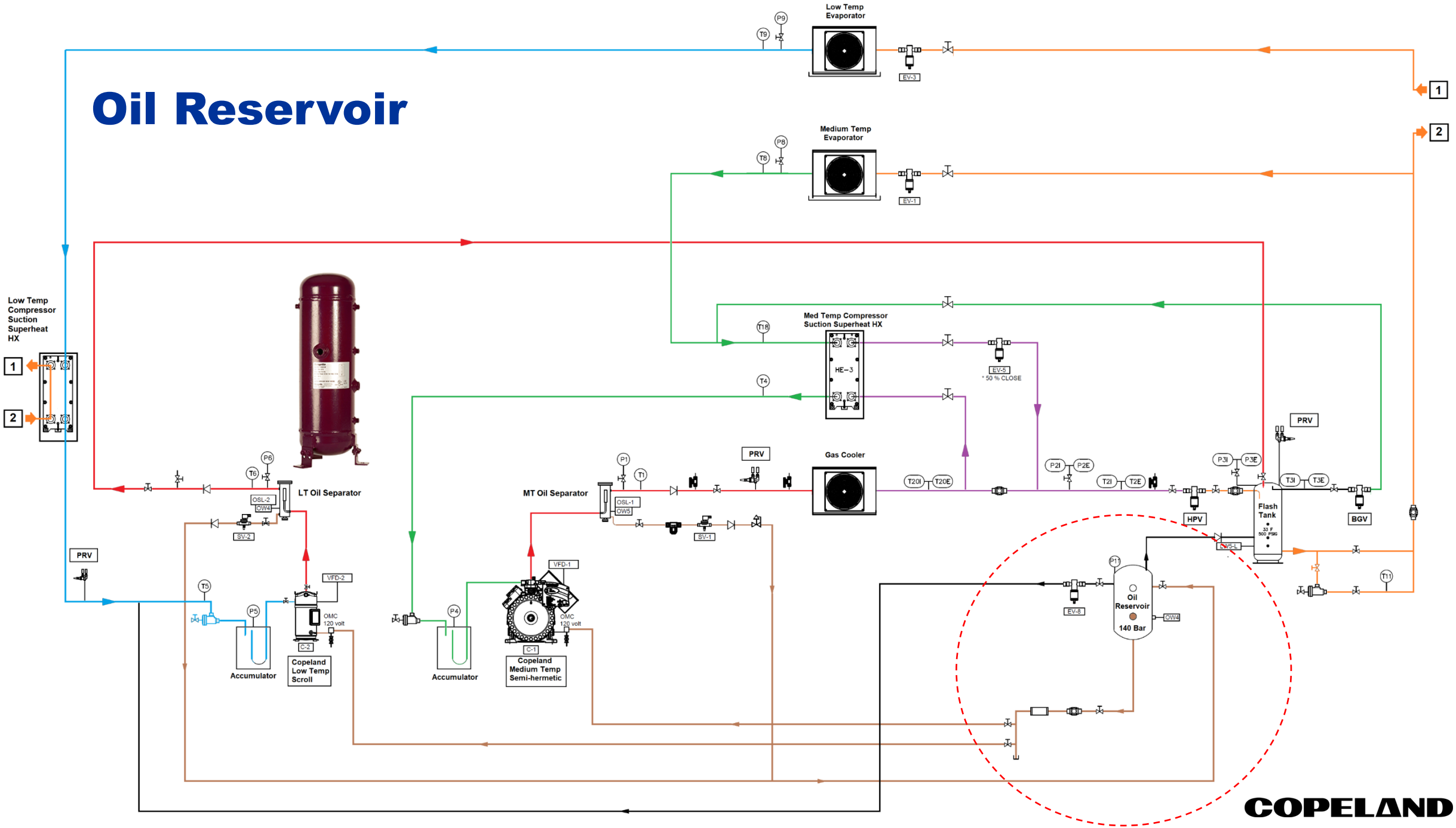
Westermeyer Releases Electronic Oil-Filter Monitor and Oil Strainer for Transcritical CO_2 Systems

February 24, 2023 COMMERCIAL REFRIGERATION NORTH AMERICA

2

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

Oil Reservoir



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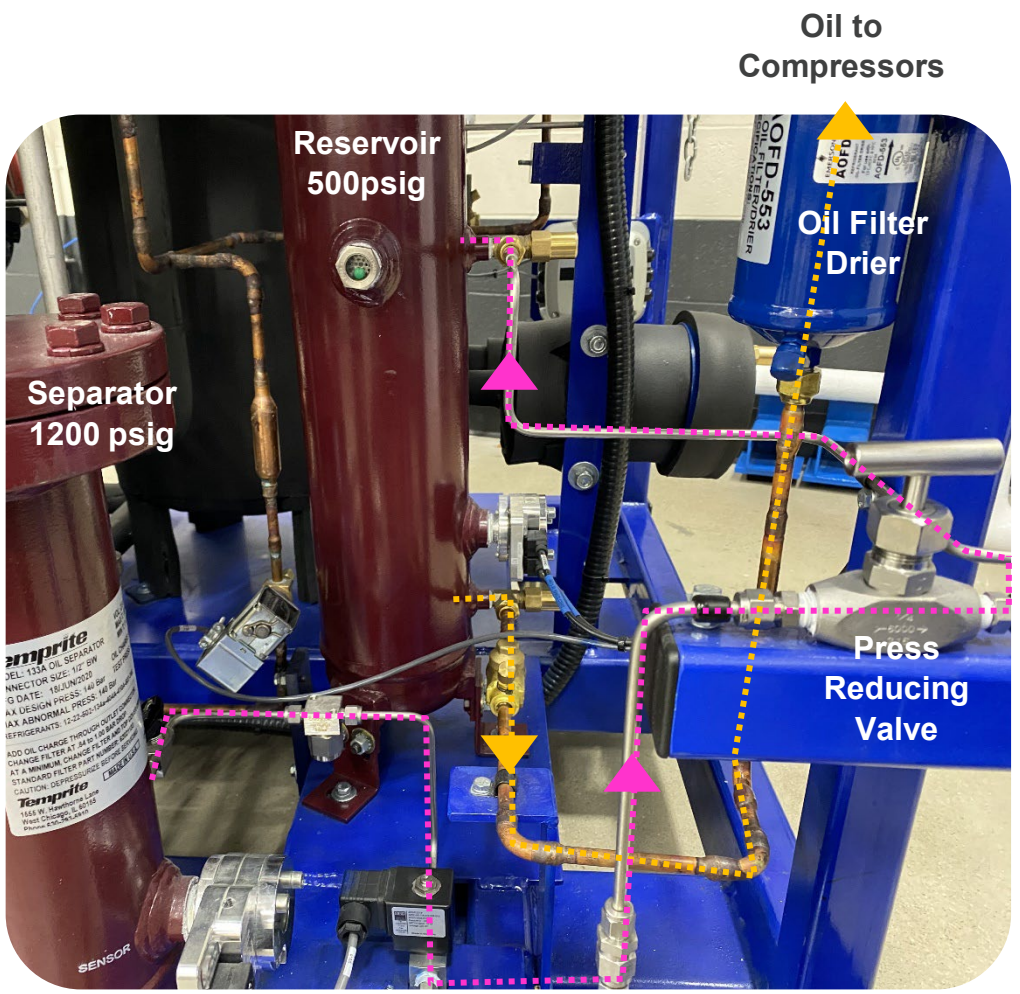
Oil Reservoir

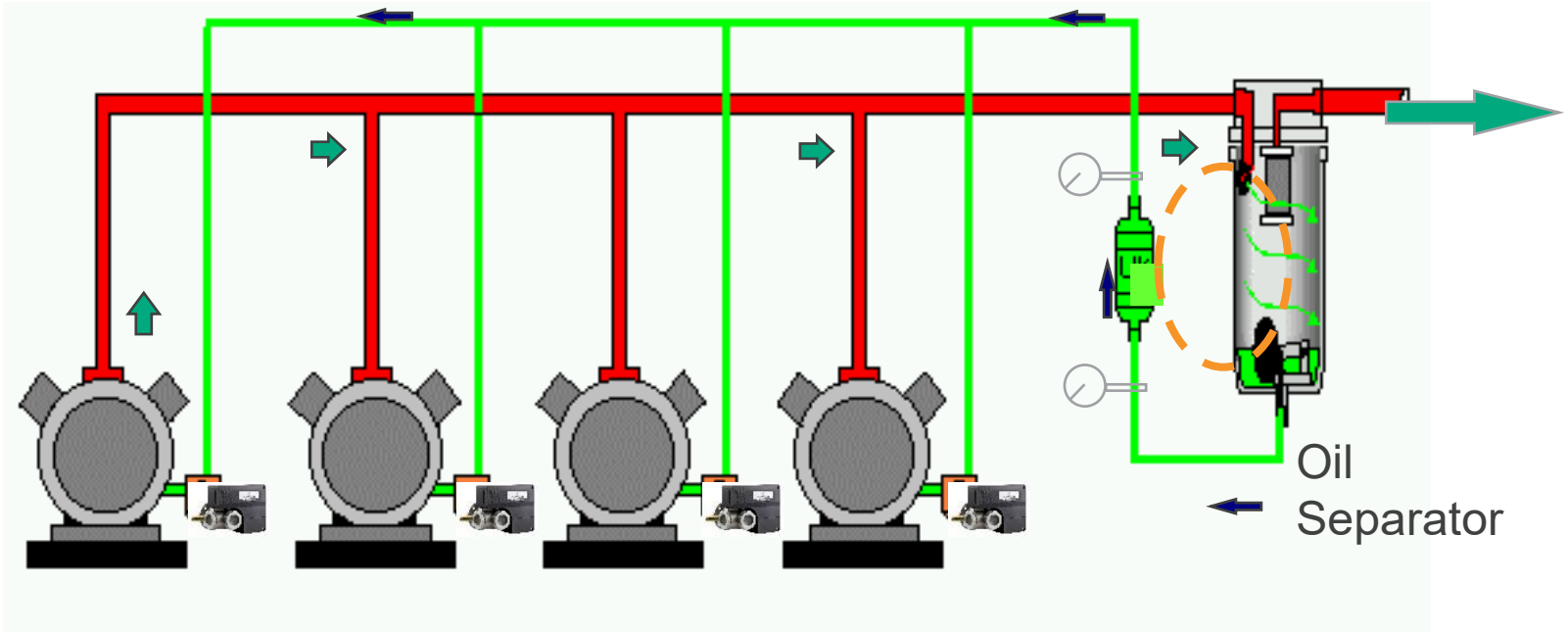
- To improve the control of oil return, oil from both separators are sent to a common oil reservoir
- From the reservoir, oil returned to the compressors becomes a function of pressure difference
- Each compressor has it's own oil monitoring, balancing and alarming system as previously mentioned i.e....(OMB, 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

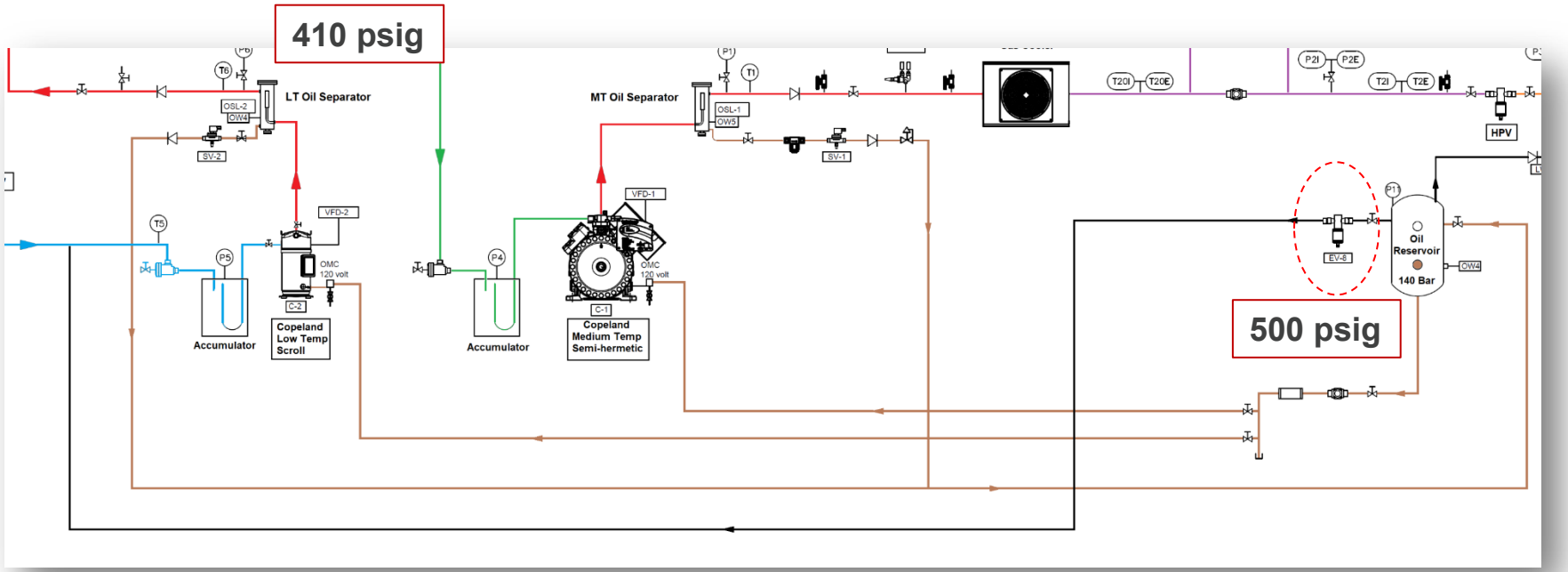
- 100% Molecular Sieve For Moisture
- Removal in POE Oils while Fully
- Protecting the Oil Additives
- 3 Micron Filtration For Optimum
- Compressor Protection
- 3 / 8 “ SAE Connections



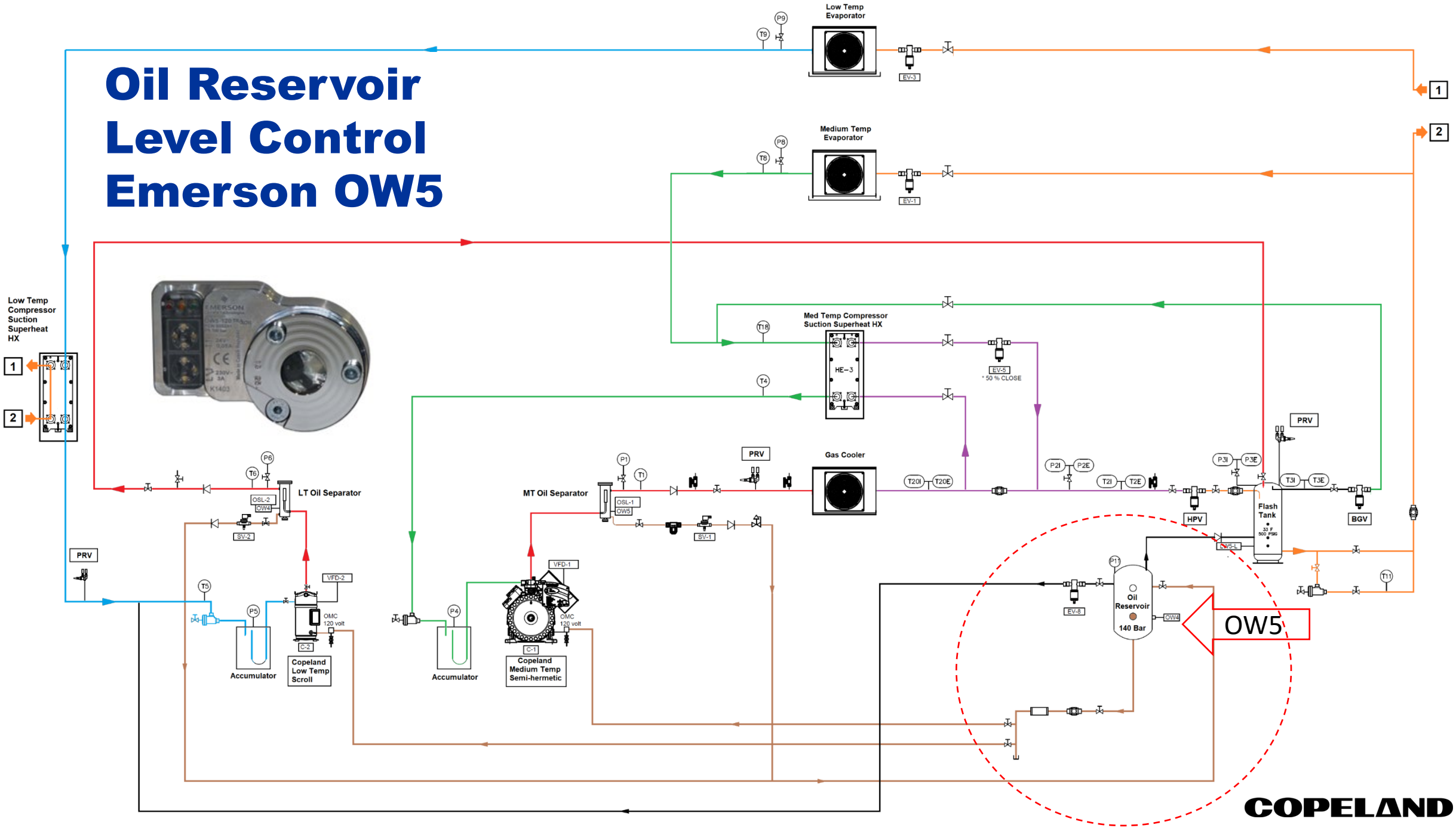
Oil Reservoir Pressure Reducing Valve

2

- 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

2

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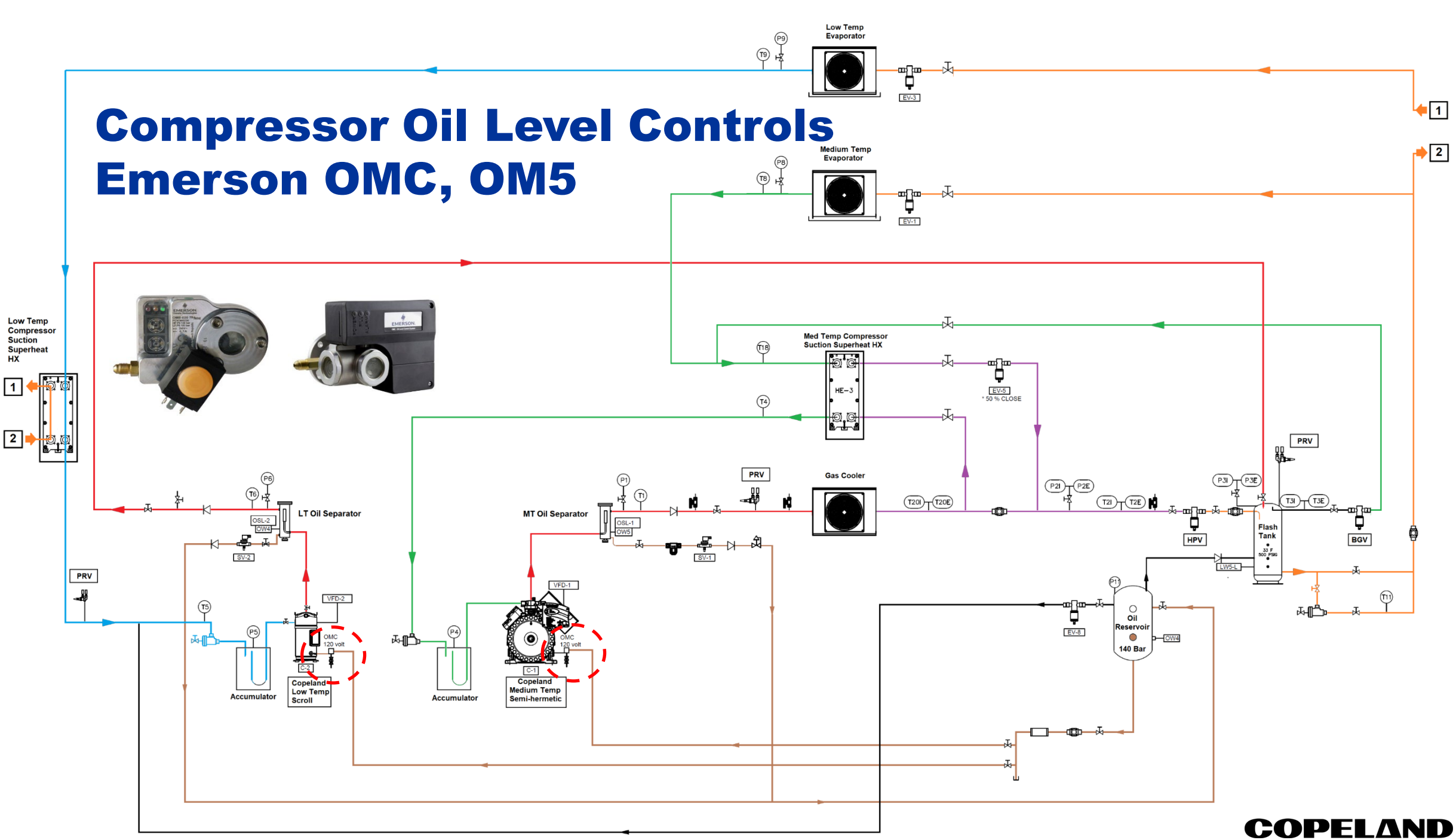
Compressor Oil Level Controls
Emerson OMC, OM5



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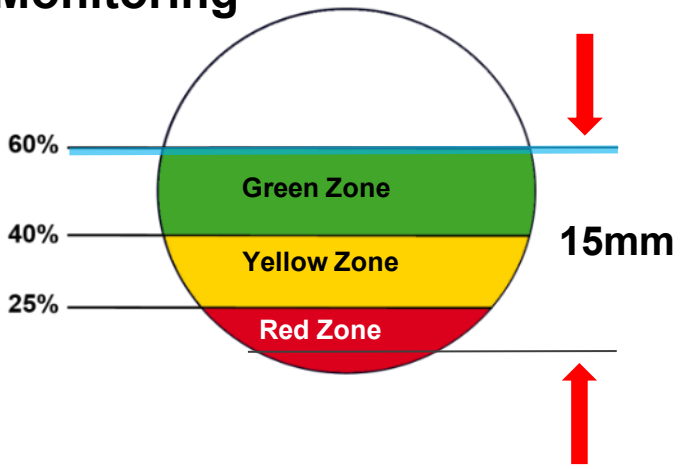
Emerosn Hall-effect

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

OMC
MOP
1885 psig
130bar
MOPD
100bar
1450psig

Subcritical Scroll

OMB-JB1
MOP
870psig
60bar
MOPD
24bar
350psig

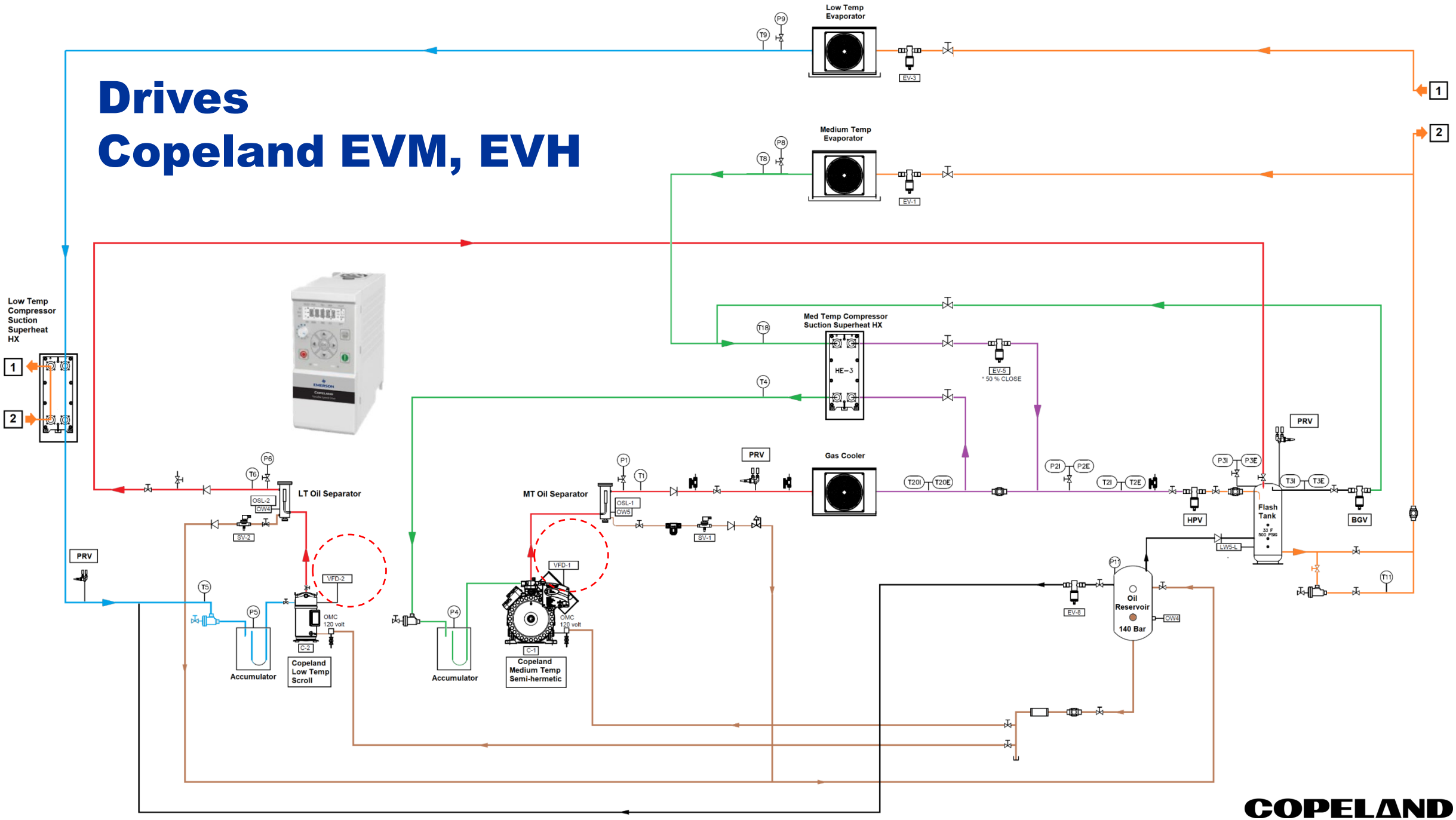
Transcritical 4MTL(S)

OMC
MOP
1885 psig
130bar
MOPD
100bar
1450psig

OM5
MOP
1885 psig
130bar
MOPD
100bar
1450psig

COPELAND

Drives
Copeland EVM, EVH



COPELAND

Where Can You Add a VFD?

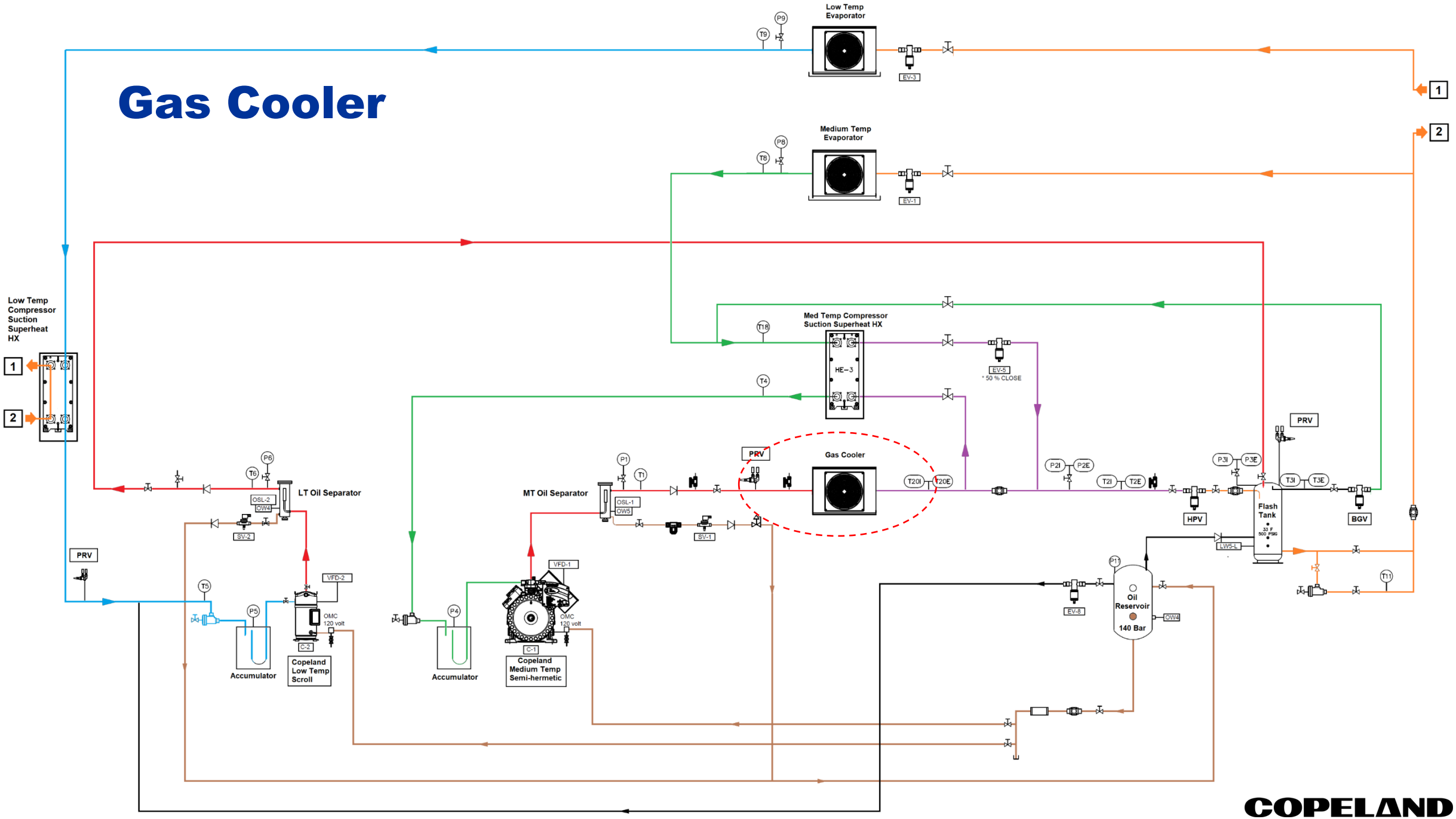
Fans
Evaporator
Condenser
Exhaust

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

Variable Speed Compression
Scroll
Hermetic Recip

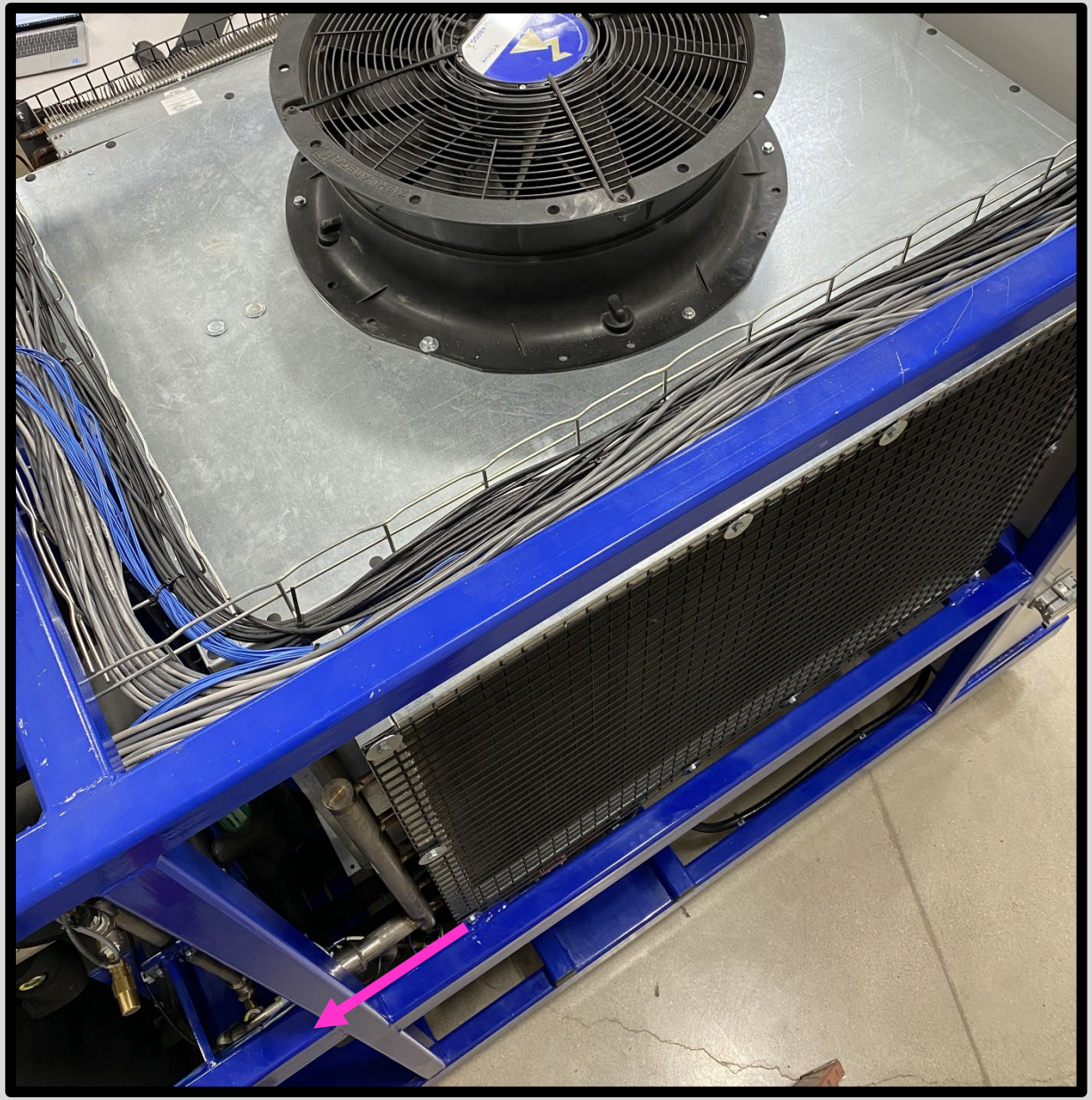
Circ. Pumps

Gas Cooler

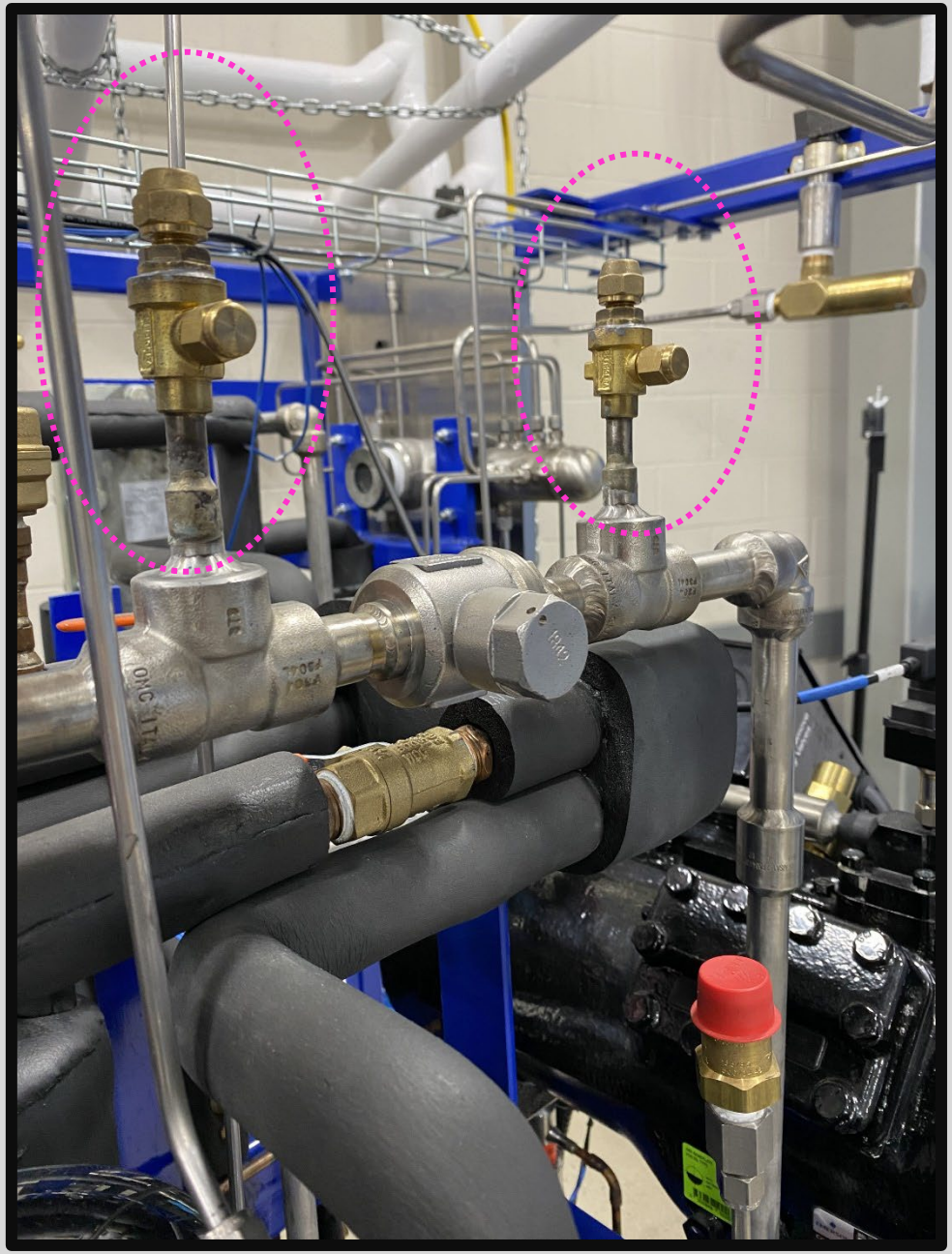


COPELAND

Gas Cooler



Gas Cooler

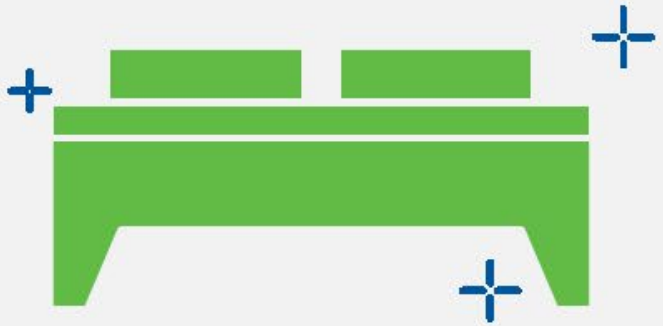


2

GAS COOLER

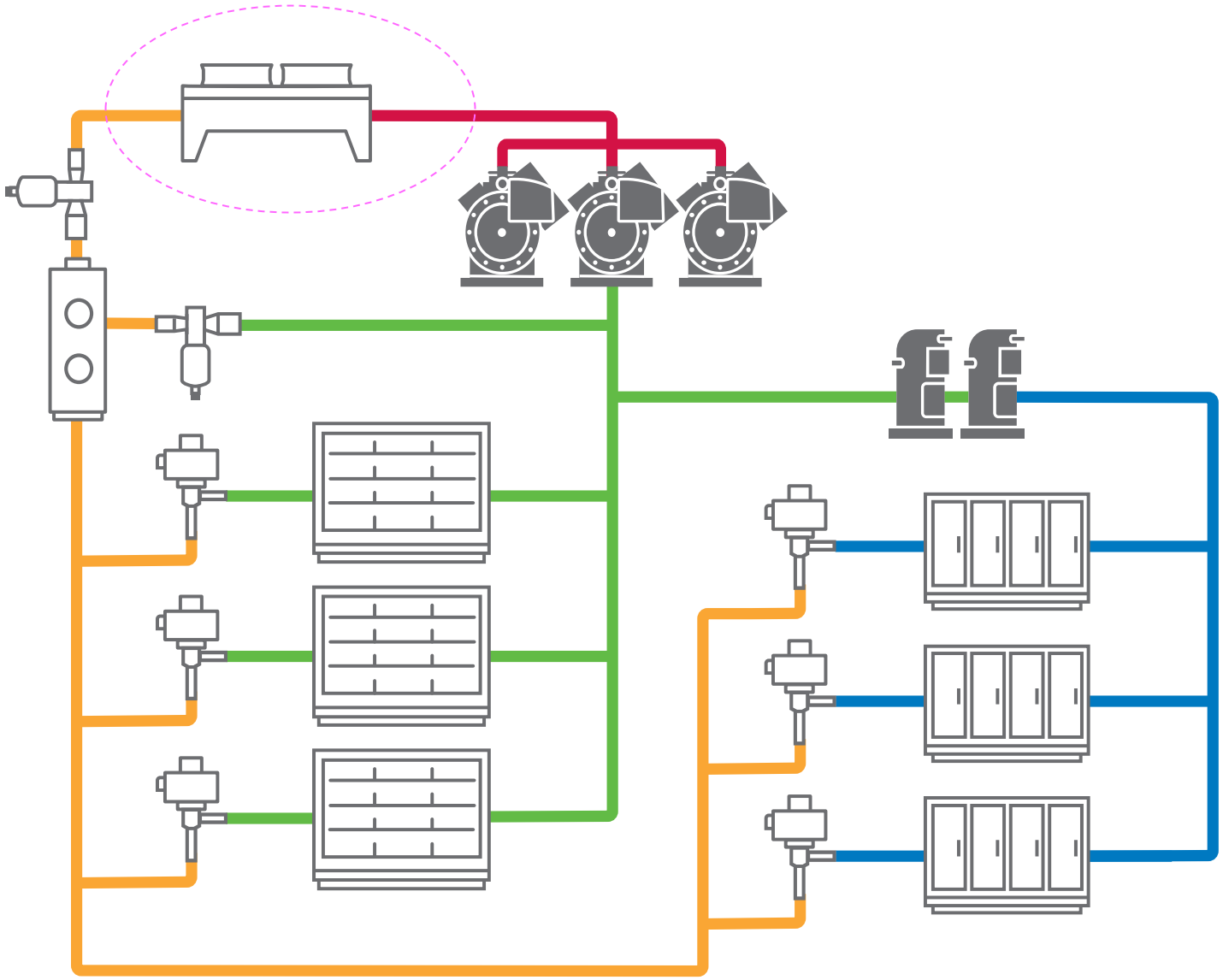
The gas cooler (aka condenser), typically located on the roof, is integral to a CO_2 TCB system's design.

- 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

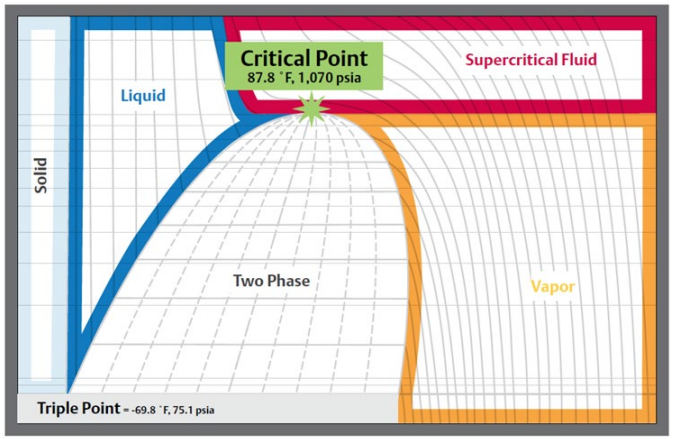


Transcritical Mode (AKA Supercritical)

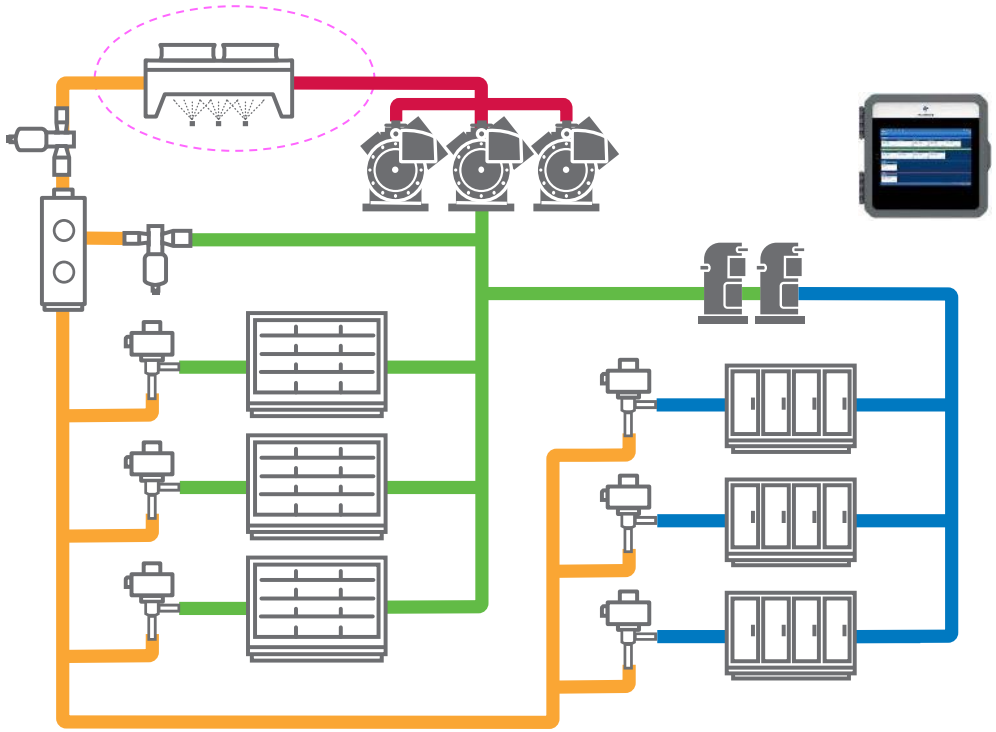
- > 75F Ambient
- **5 to 7°F TD**

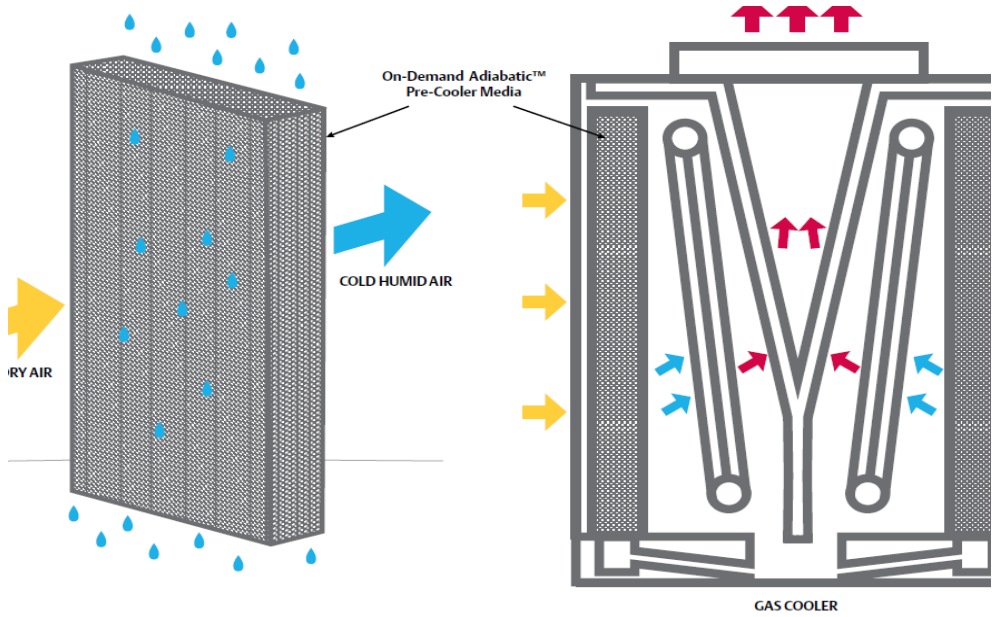
Subcritical Mode

- <75°F Ambient
- **10 to 13°F TD**



CO_2 Transcritical Booster System Condenser / Gas Cooler





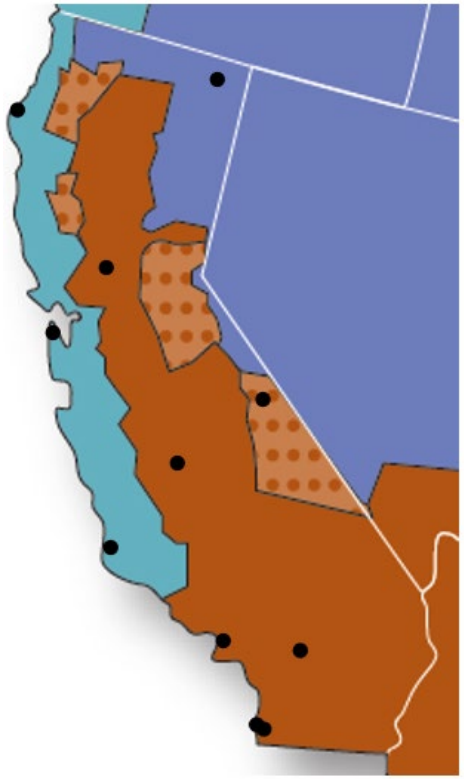
4694 hrs TC Mode

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

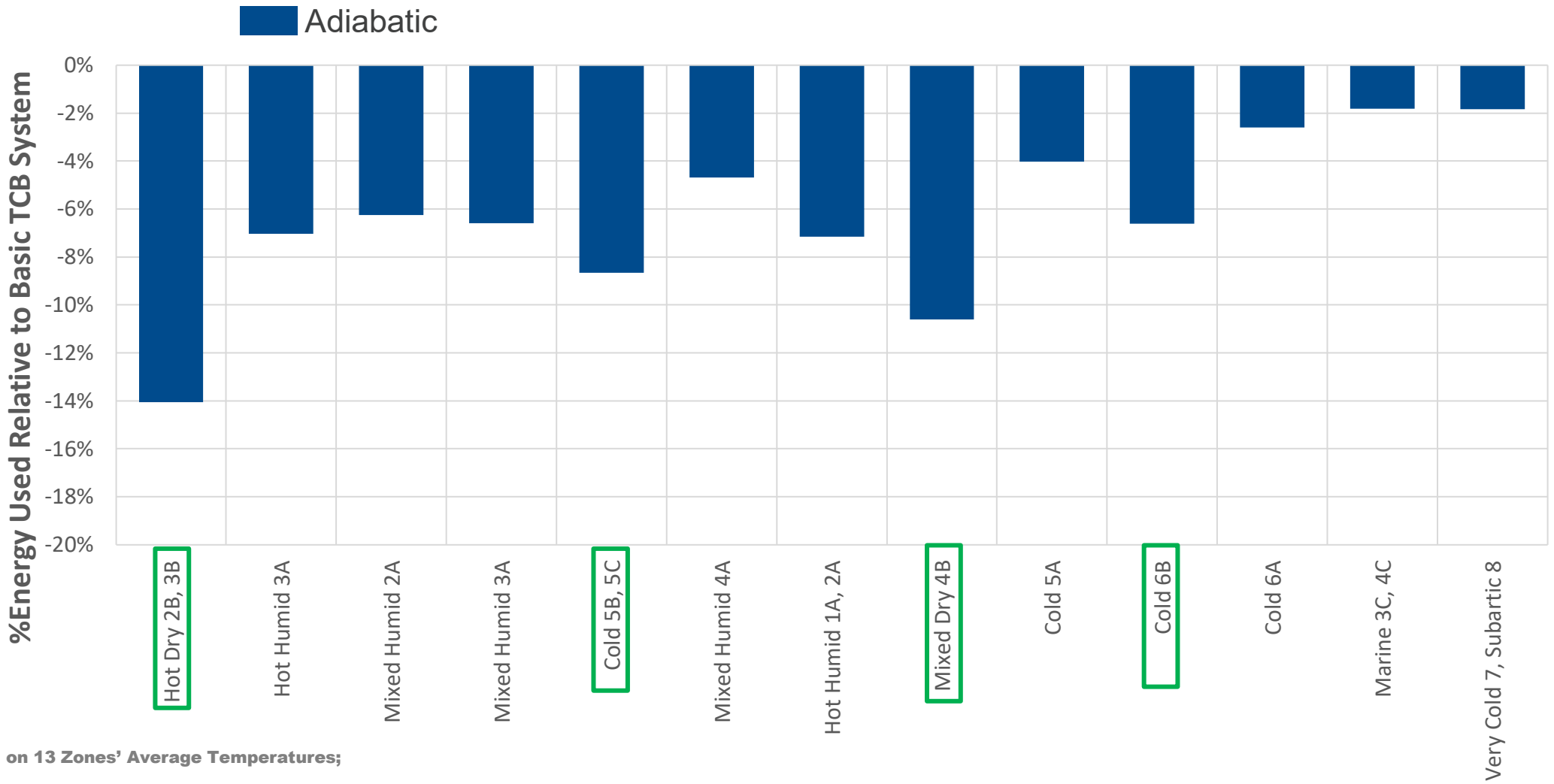


City	ASHRAE	IECC	%TC Dry GC	%TC Adi GC
San Diego	Hot Dry	3B	10%	0.5%
Sacramento	Hot Dry	3B	22%	0%
Los Angeles	Hot Dry	3B	5%	0%
Palm Springs	Hot Dry	3B	54%	6.5%
Fresno Yosemite	Hot Dry	3B	30%	0%
San Francisco	Marine	3C	2%	0%
Santa Maria	Marine	3C	4%	0%
Bishop	Mixed Dry	4B	25%	0%
Arcata	Marine	4C	0.1%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

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

2

Percent of Energy Saving vs. Basic TCB Systems

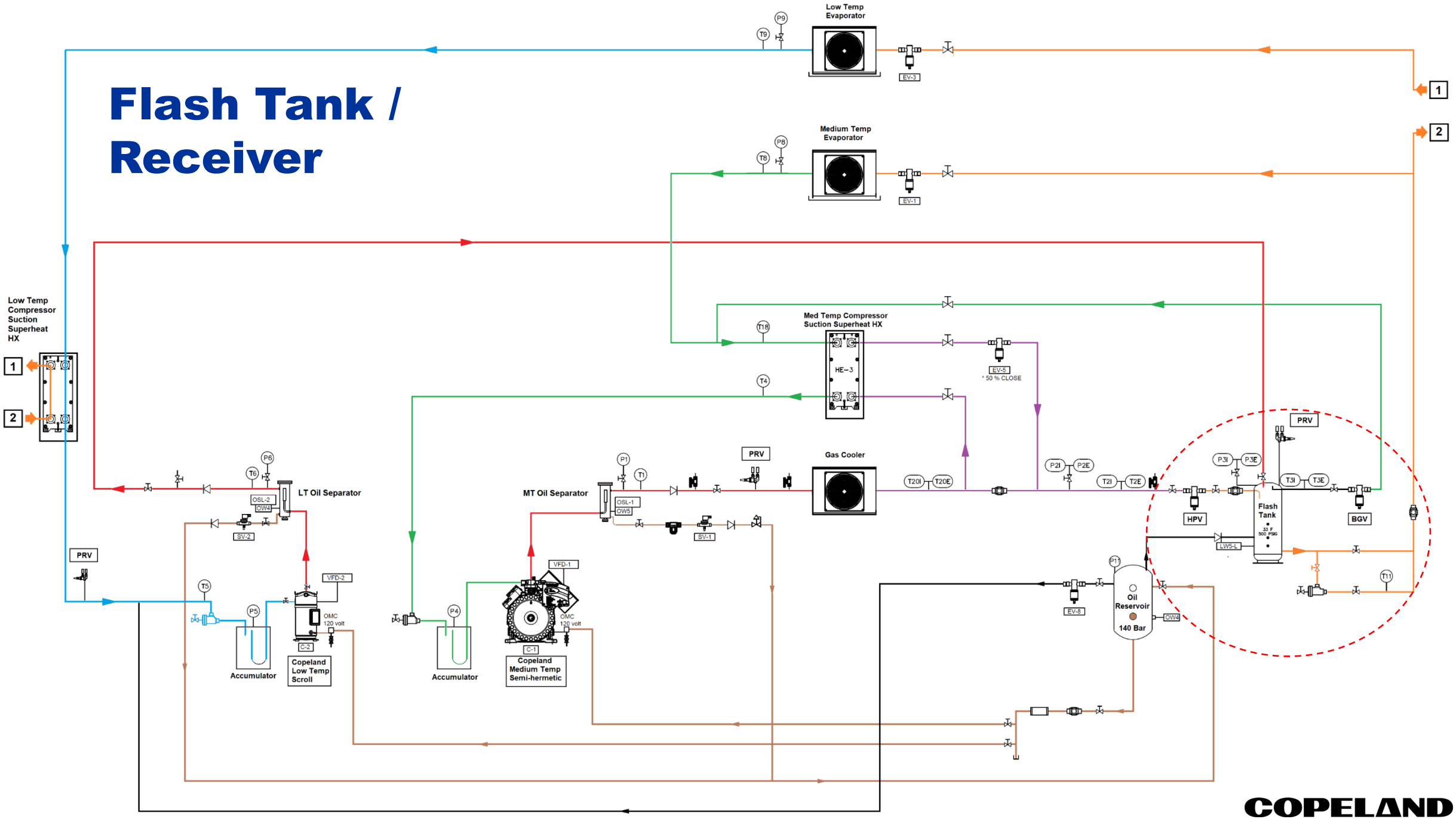


Charts Based on 13 Zones' Average Temperatures;

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

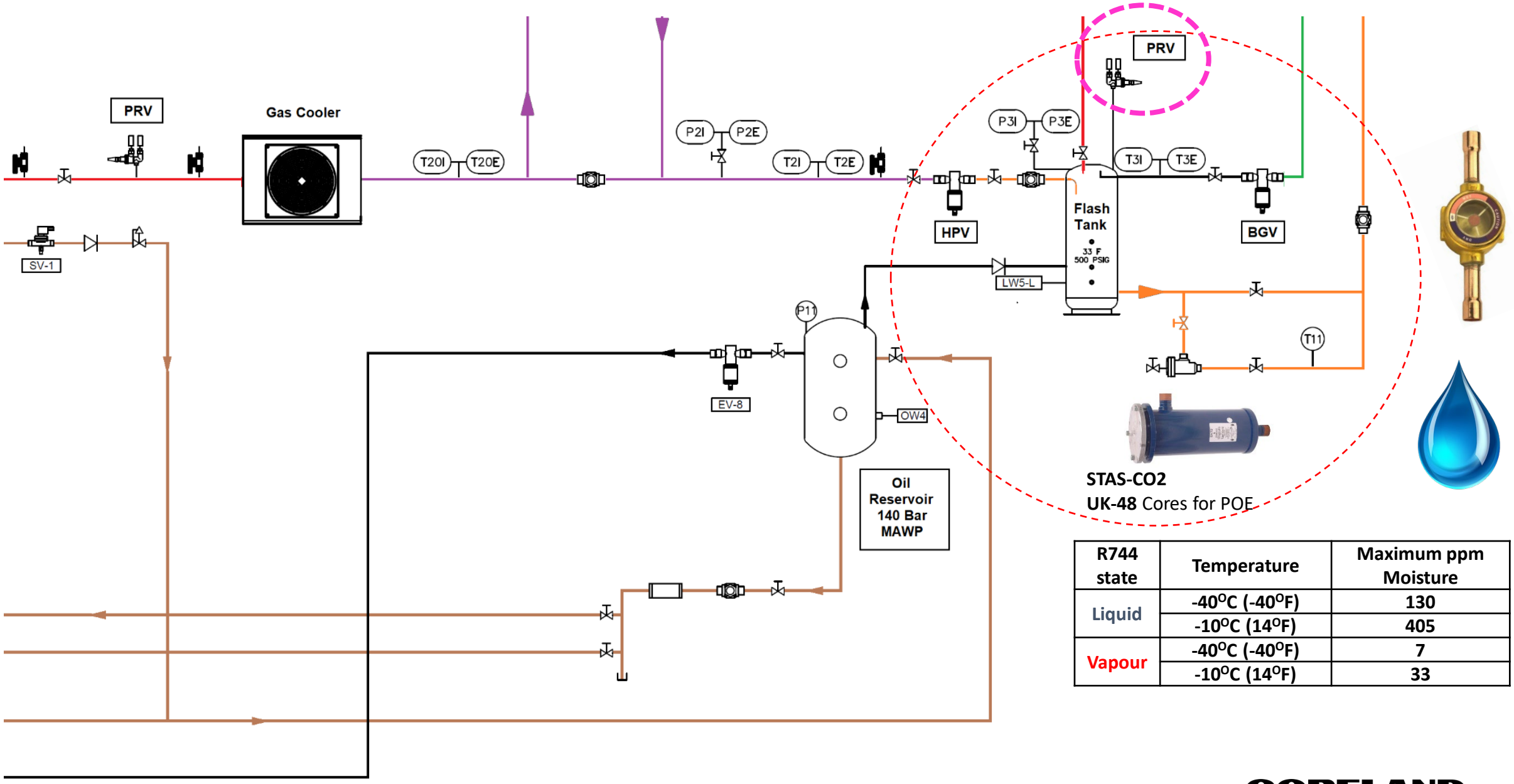
Typical PRV Setting For Supermarket

- **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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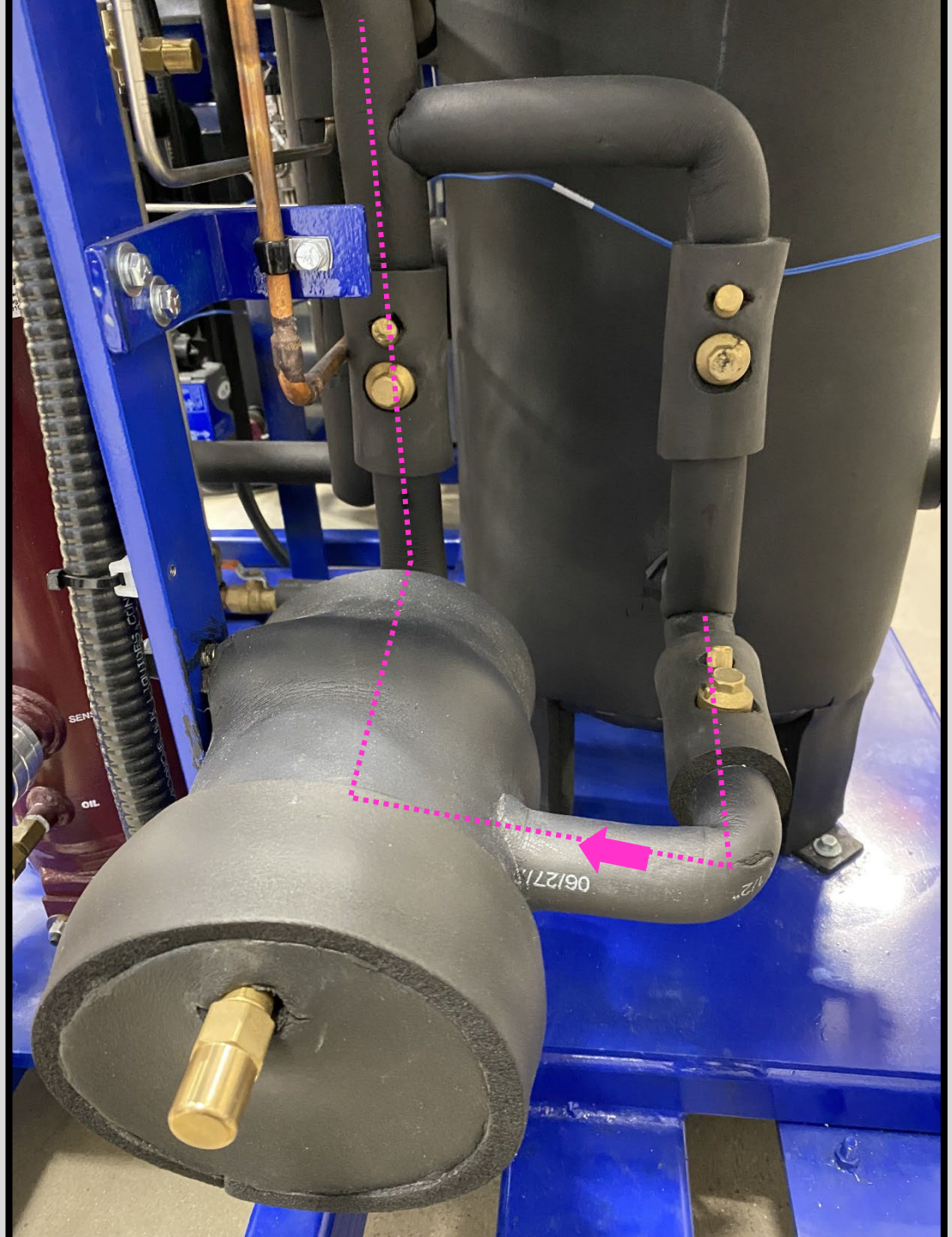
Liquid Line Filter Drier

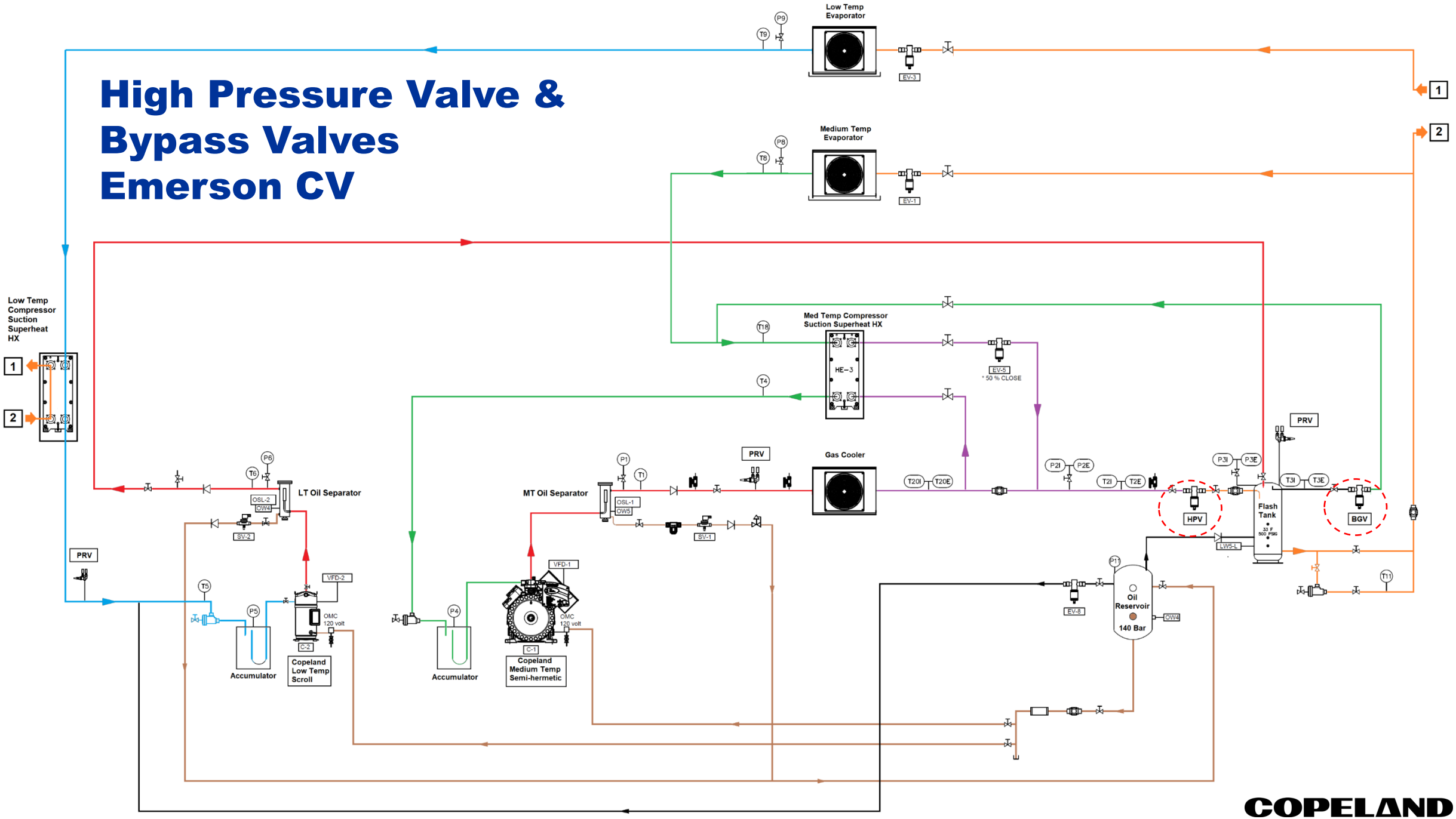
2

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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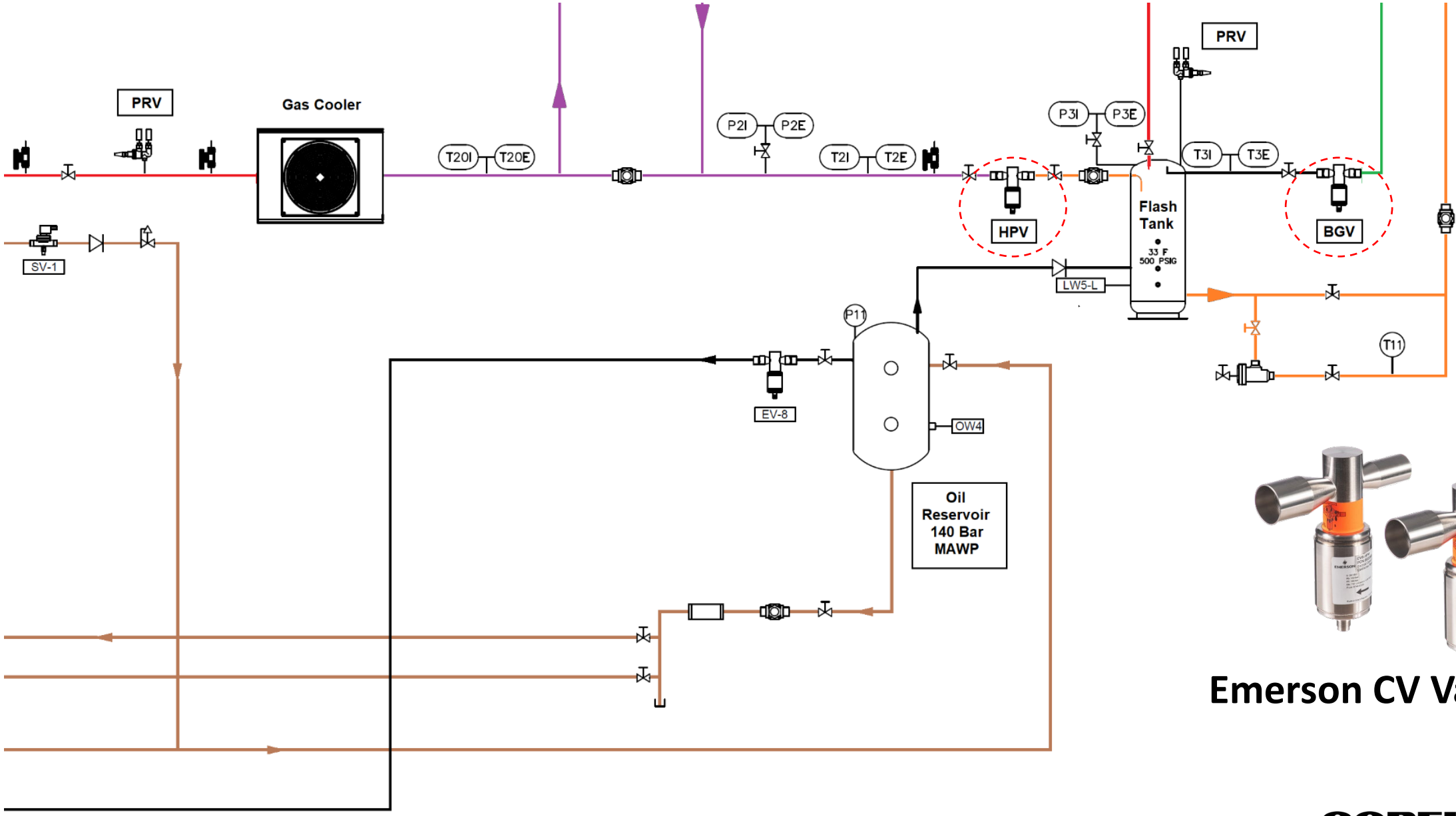
High Pressure Valve & Bypass Valve



Emerson CV Valves

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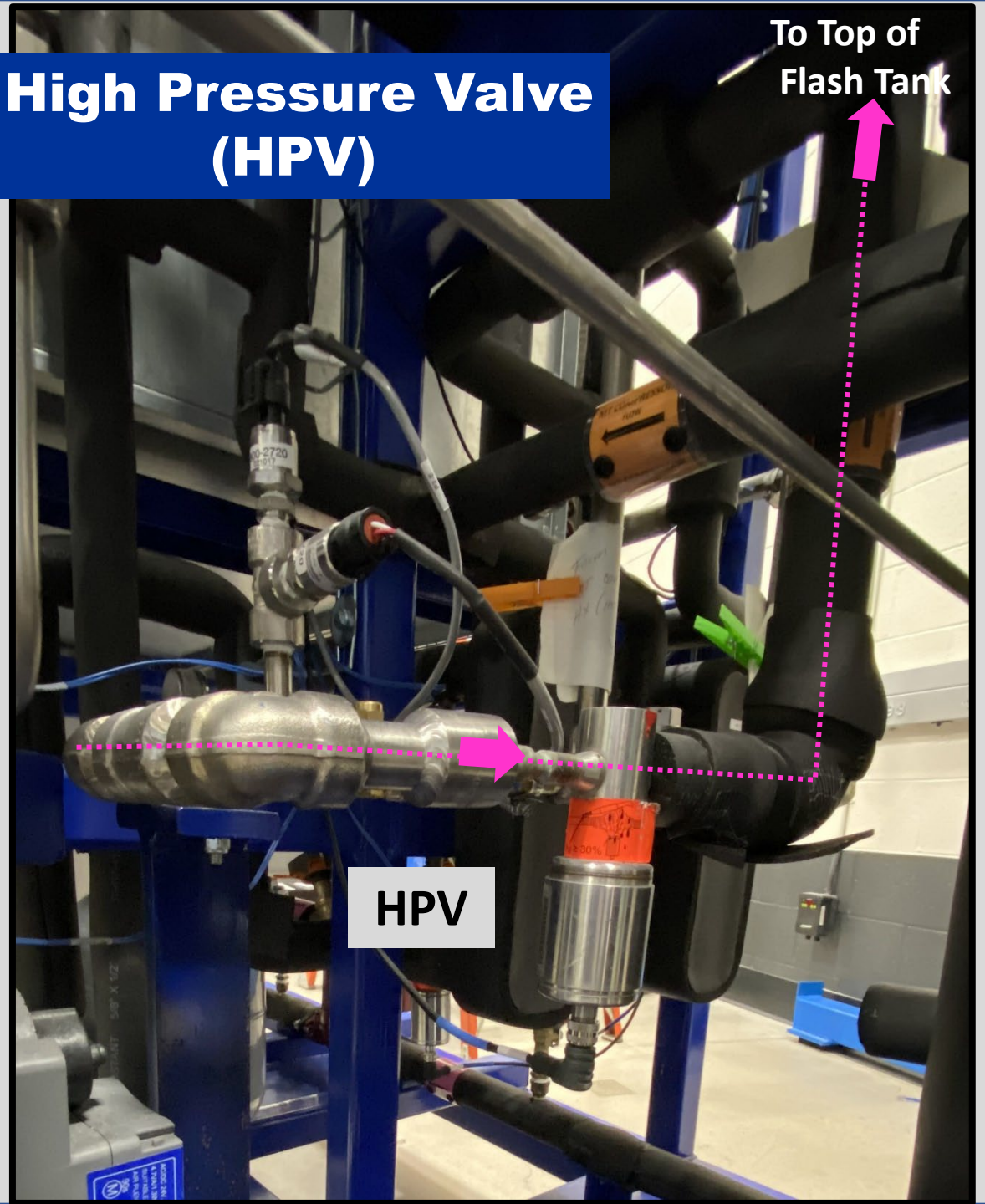
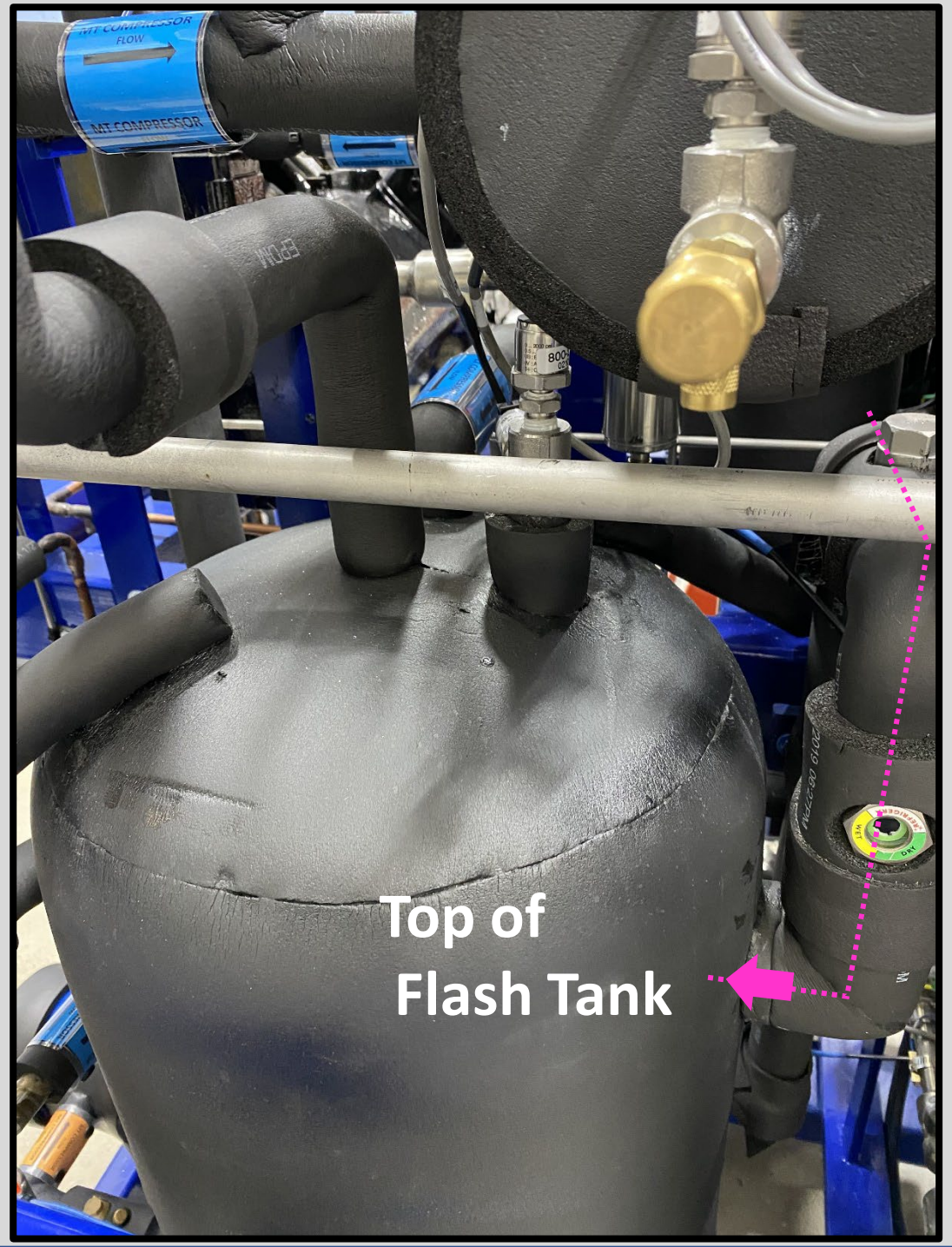
High Pressure Valve (HPV)





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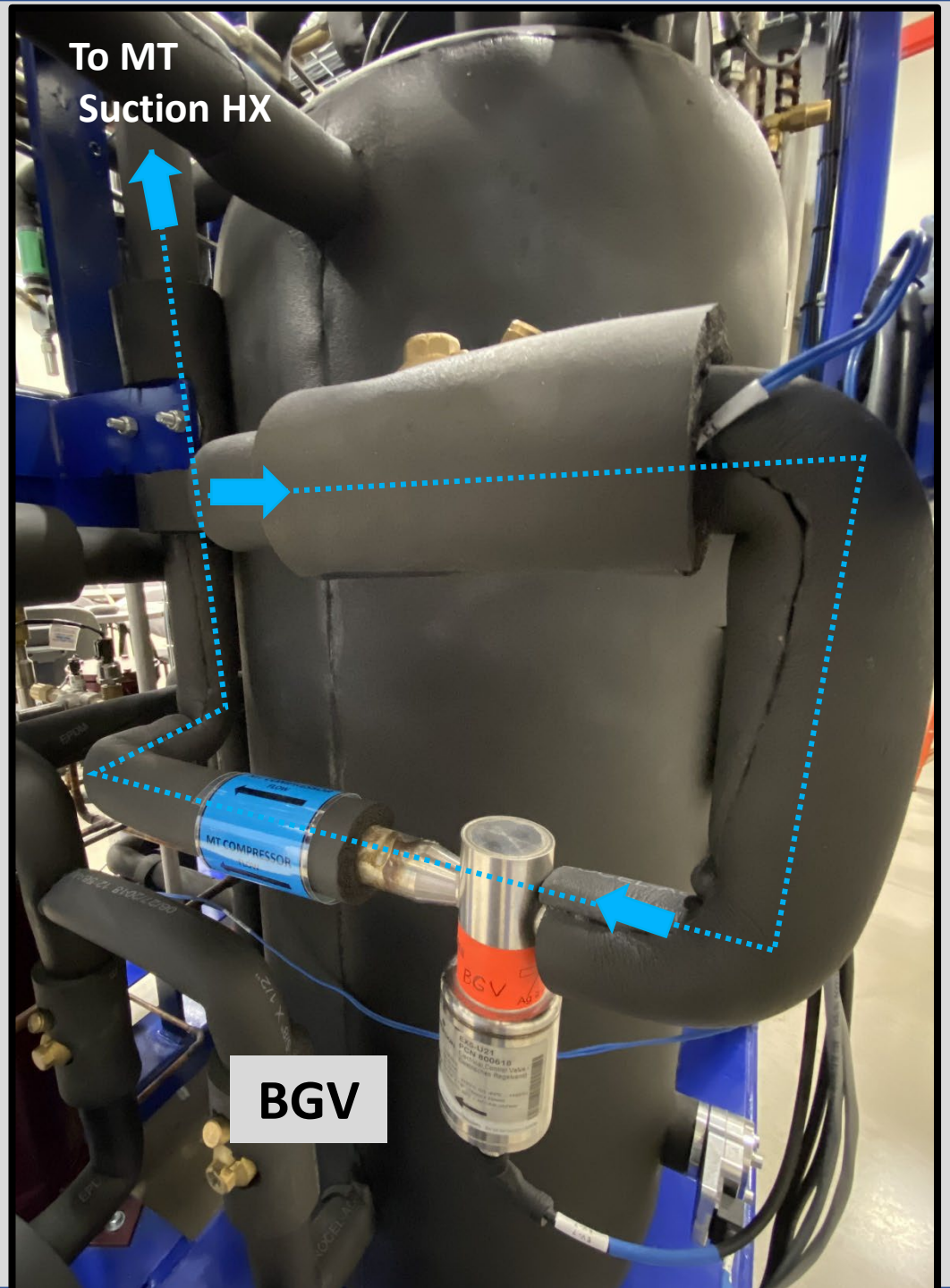
Bypass Gas Valve (BGV)



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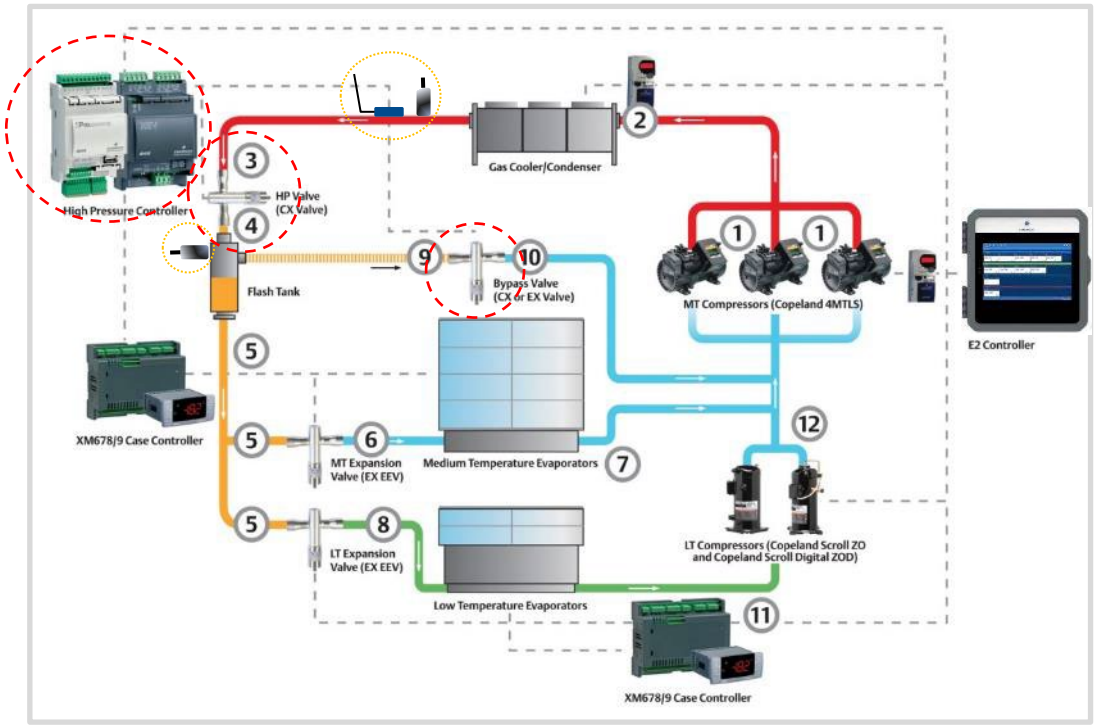
CO_2 High Pressure Controller



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

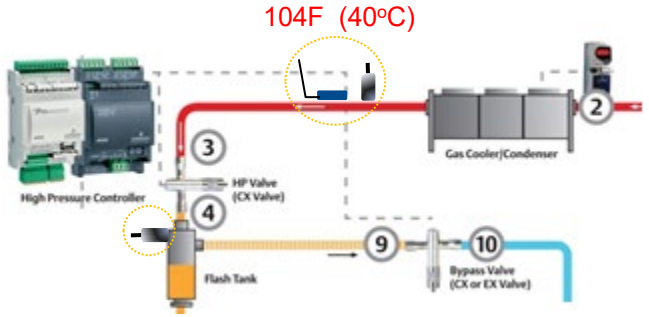
Transient Operation

- 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

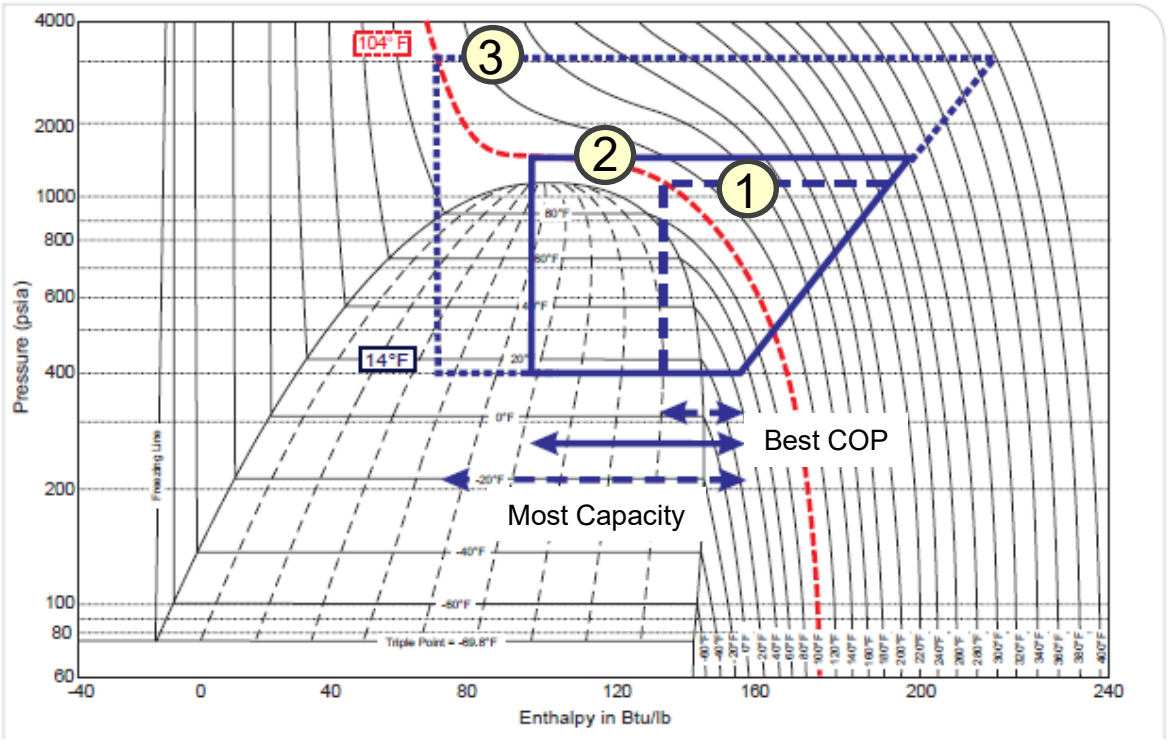
Three Examples Same Evaporator Conditions



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

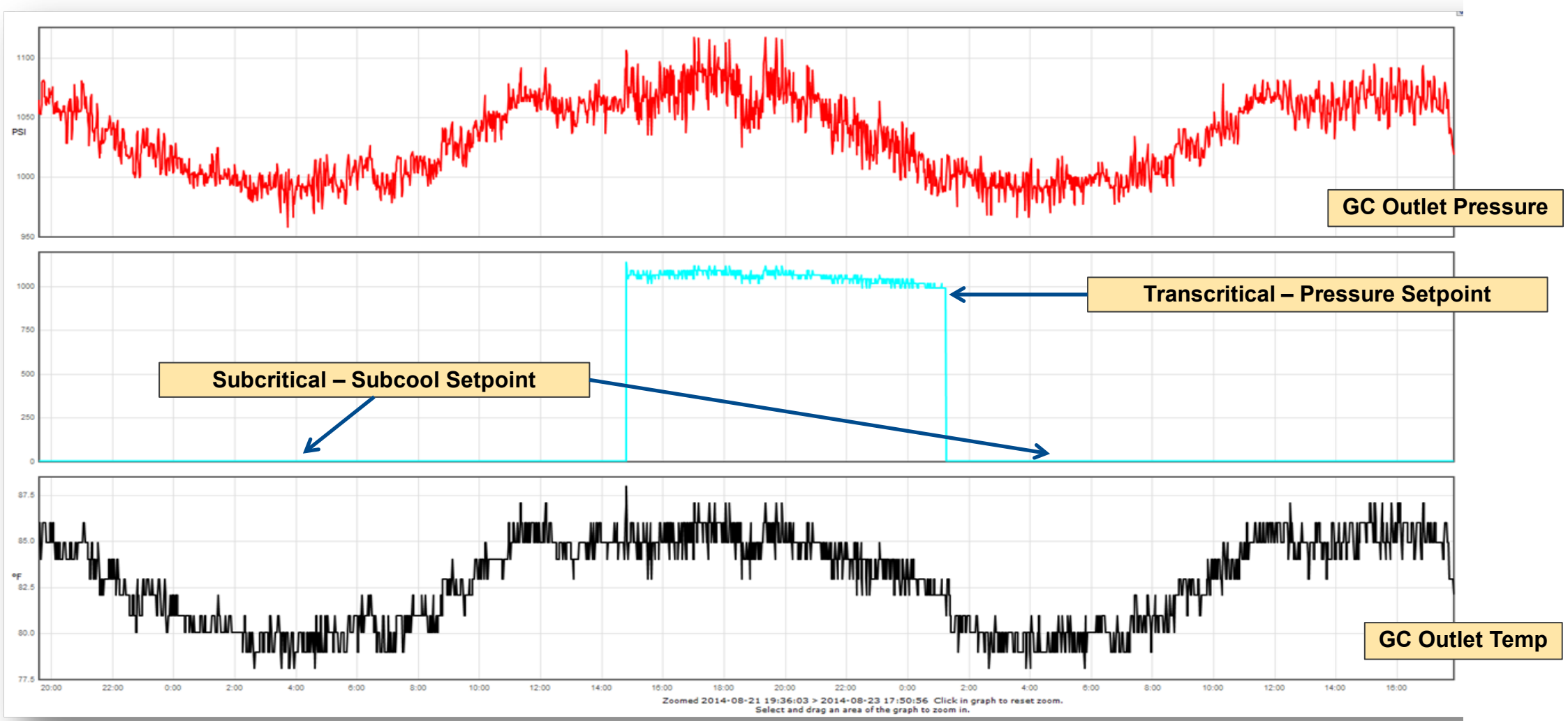
2: Optimal pressure for gas cooler outlet temperature

COP= Heat Energy Removed (BTU) / Power Input

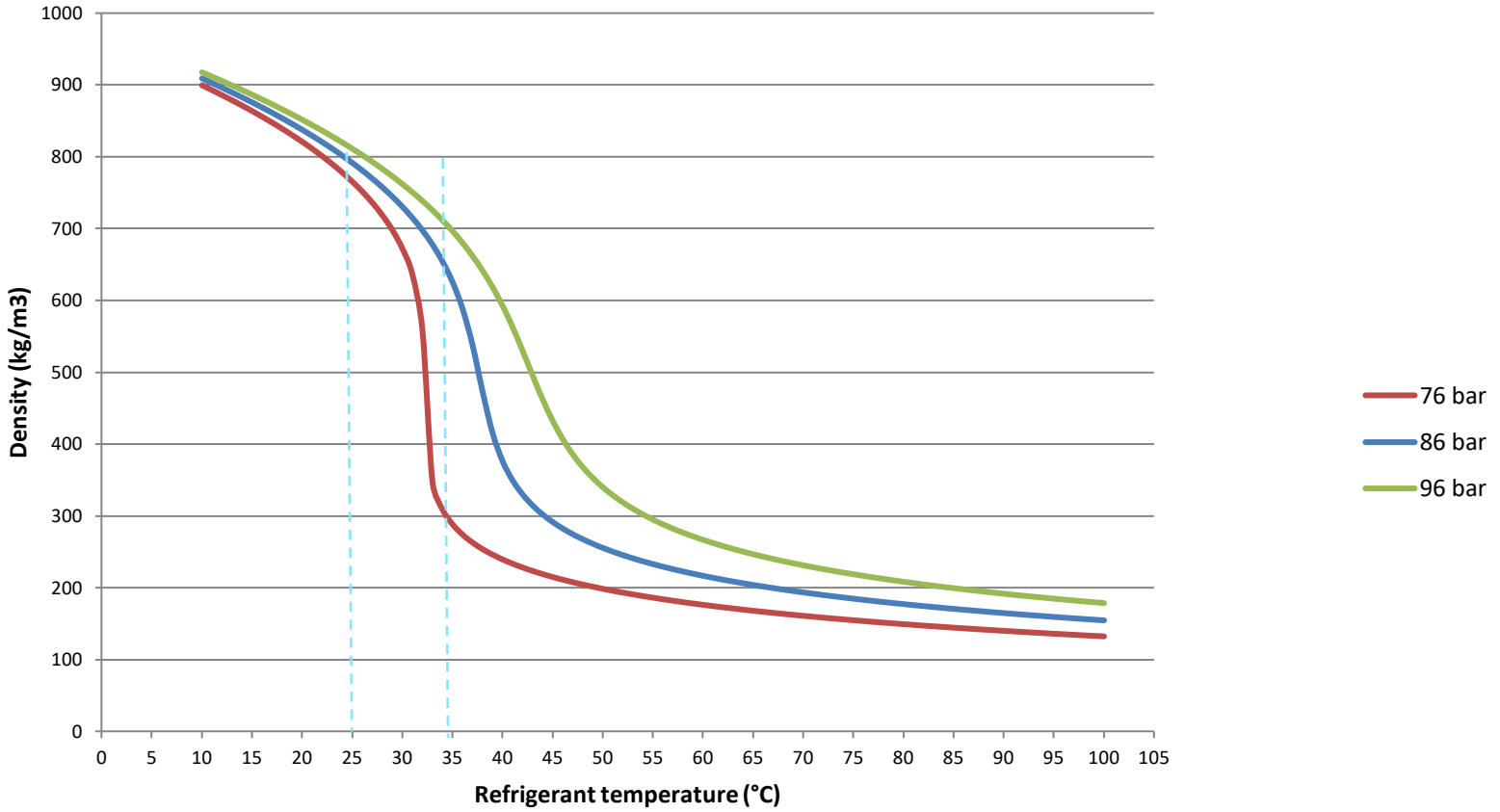


For each example , R744 exits the gas cooler at 104°F. This exit temperature is a function of the size of the gas cooler and the ambient temperature, in the same way as condensing temperature is a function of the size of the condenser and the ambient temperature.

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.

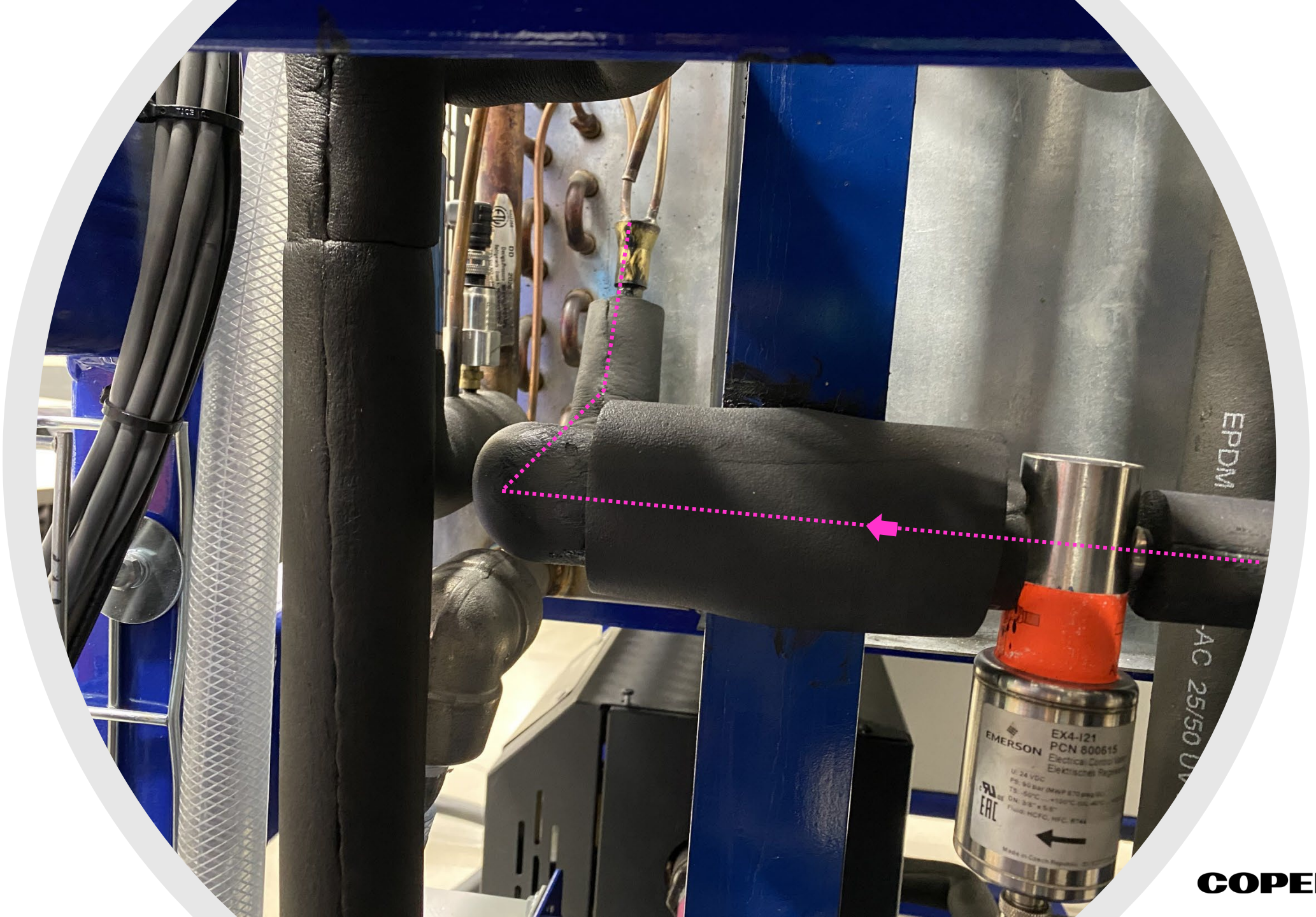
Evaporators EEV
Emerson “CV” or “PM”

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
Flash Tank
HPV
BGV
Oil Reservoir 140 Bar

COPELAND

EEV

2



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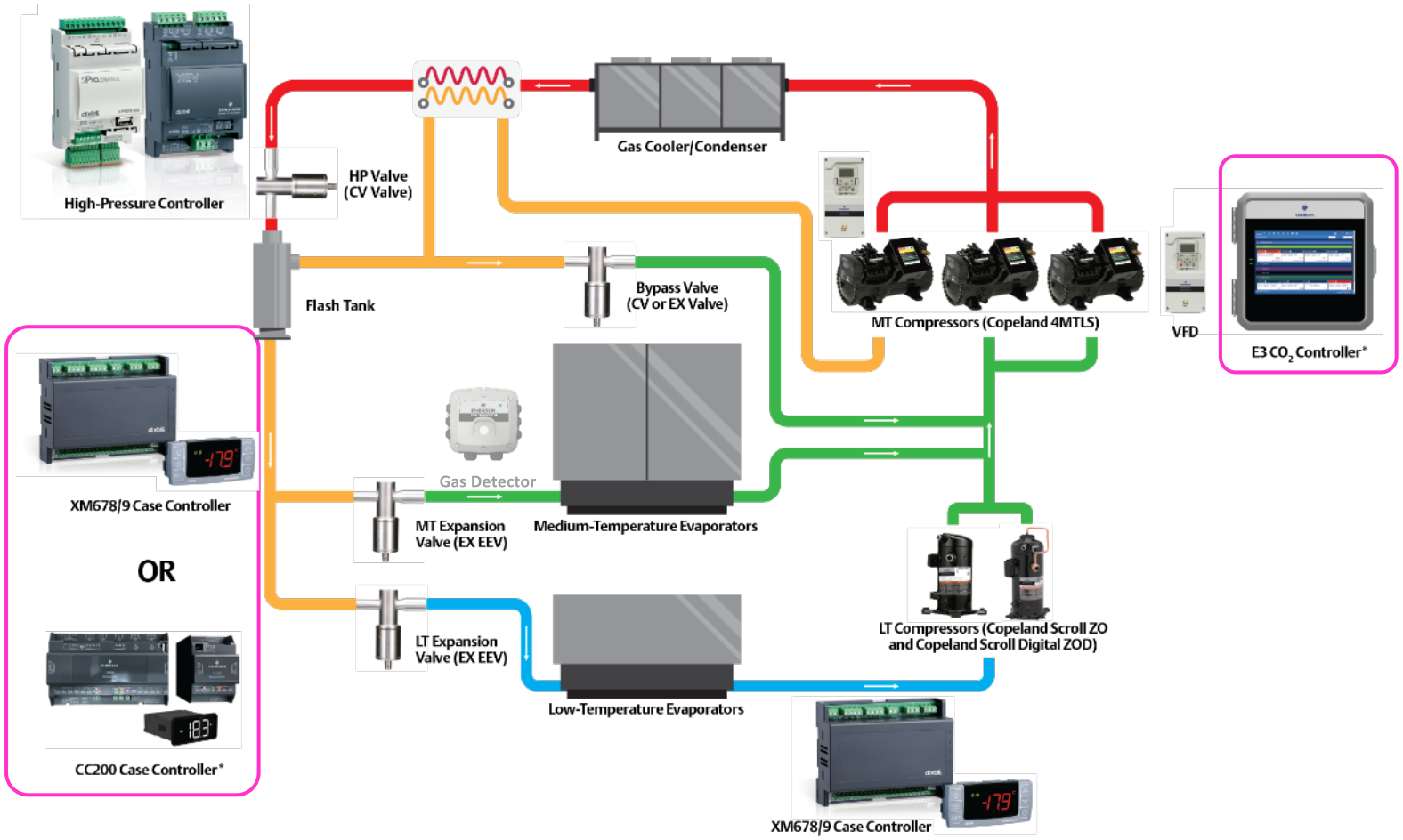
EEV

2

COPELAND

Supervisory & Case Controls



E3 Supervisory Controls

Simplified and Intuitive User Interface

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

Supervisory Control

2

E3 with CO2 Application

CC200 Case Controls

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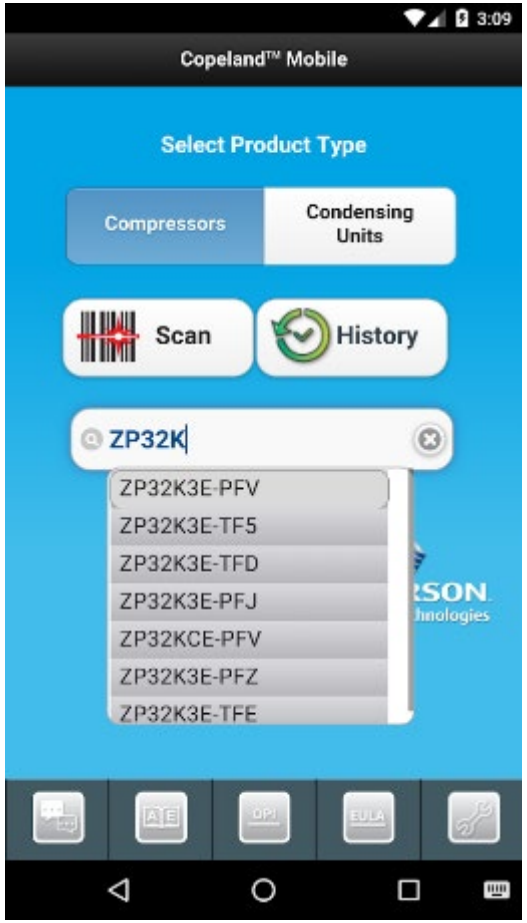
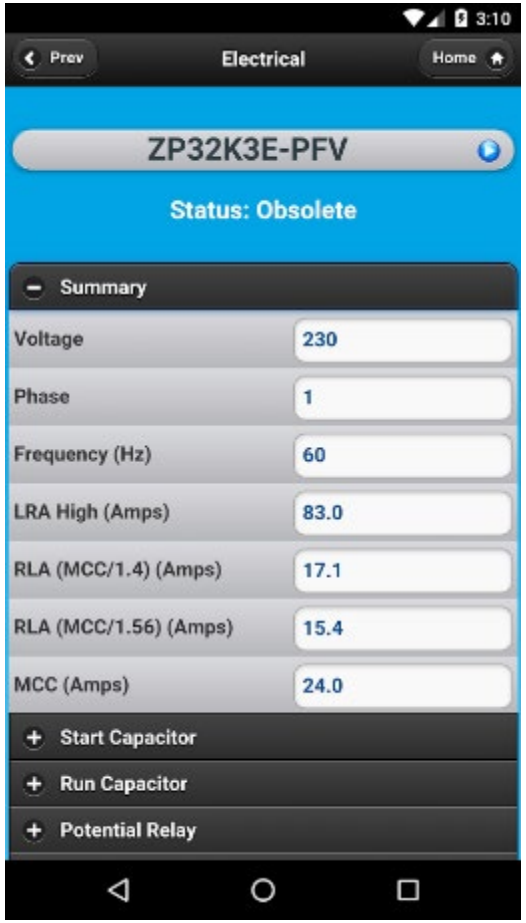
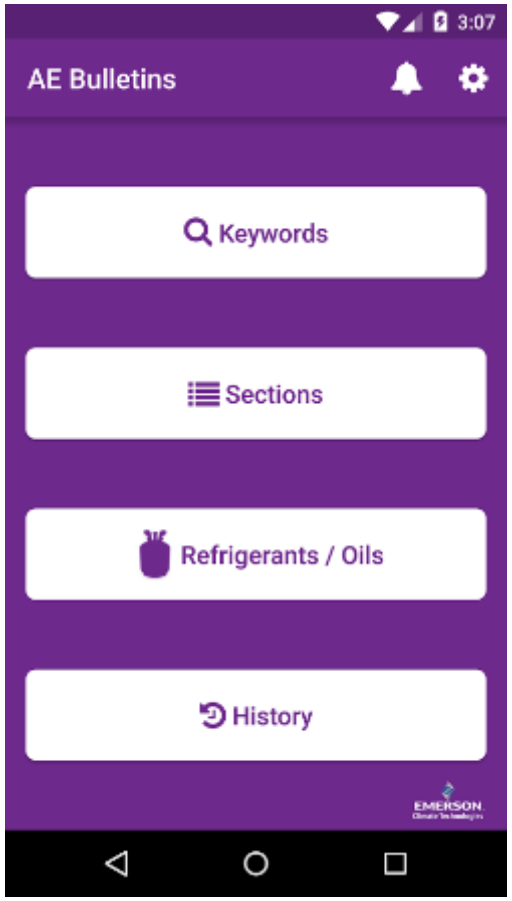
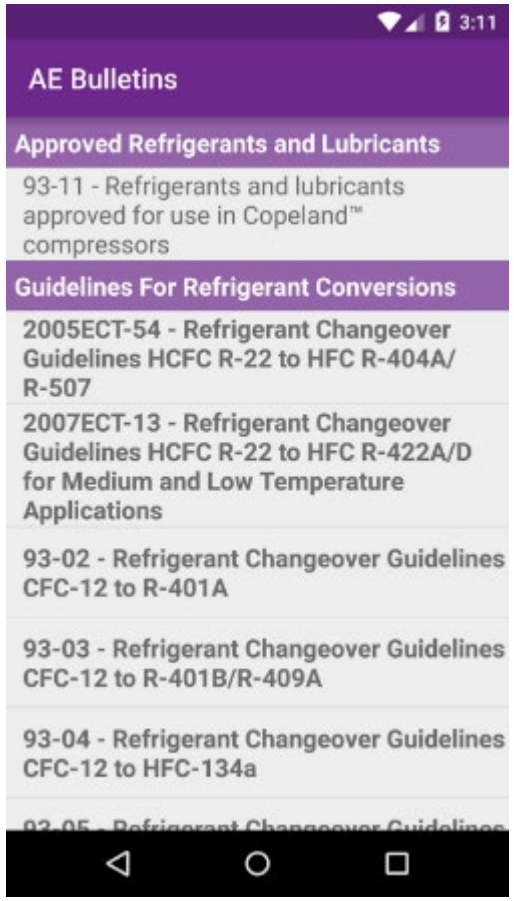
Copeland Mobile

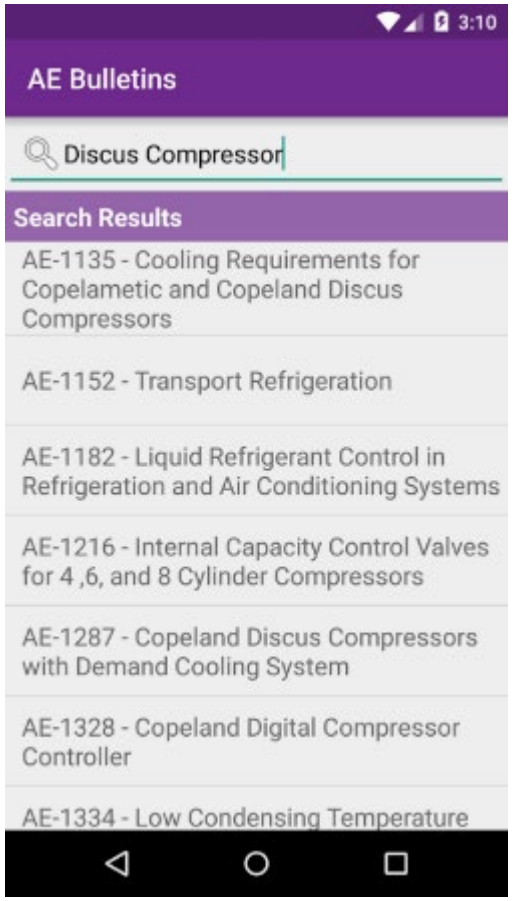




AE Bulletins – App, OPI, PSS, CPID,







COPELAND

Certificate of Completion

is hereby granted to:

_____

In recognition of completing:

Piping & Instrumentation Diagram (P&ID) for CO2 Transcritical Booster Systems

1.5 Course Hours
Granted: November 15, 2023

Share Your Feedback!

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

Andre.Patenaude@Copeland.com
Copeland

NORTH AMERICAN Sustainable Refrigeration Council

Let's go Check out The Unit!

Thank you!

COPELAND

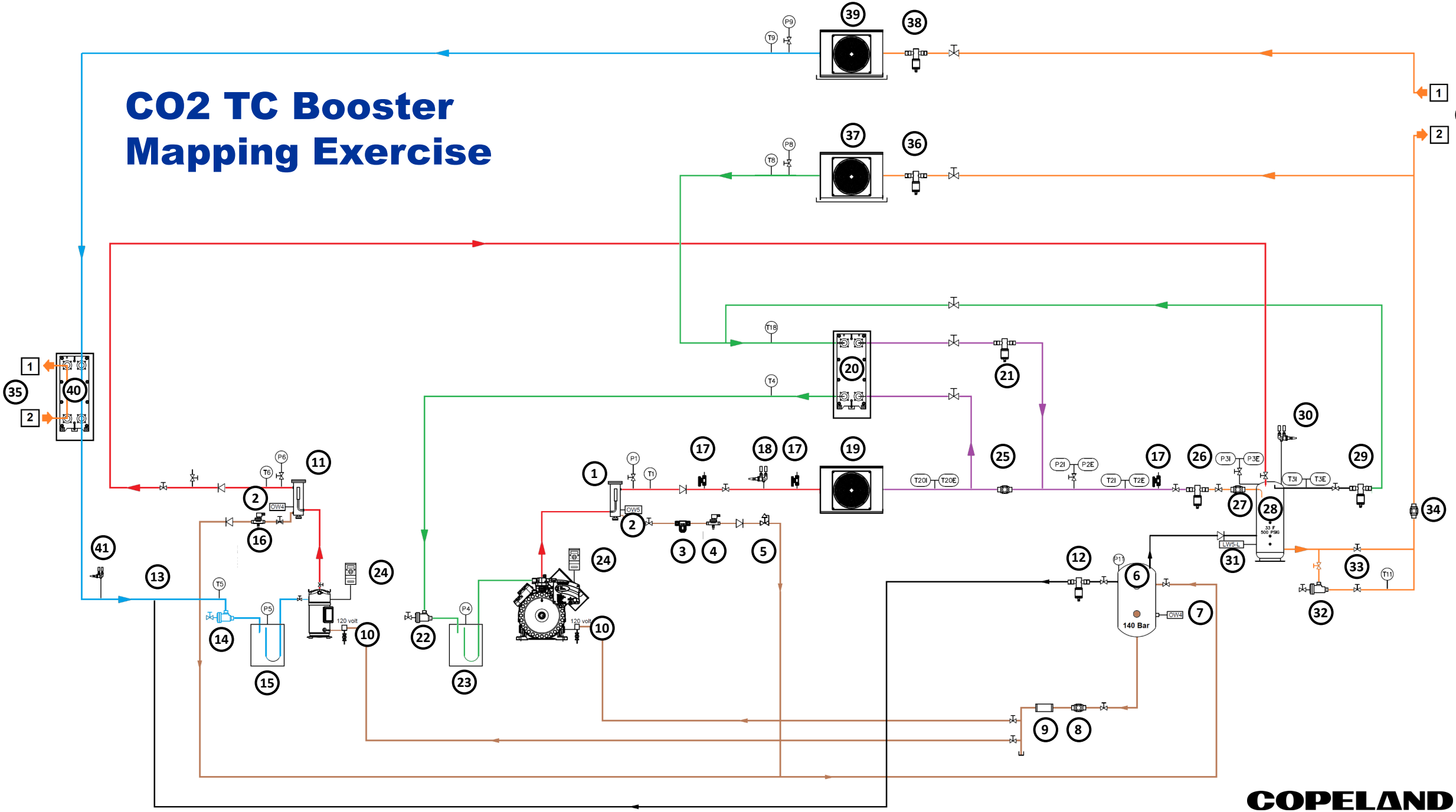
Natural Refrigerant Training Summit

CO_2 Training Unit Walk Around

Building a Sustainable Technician Workforce

COPELAND

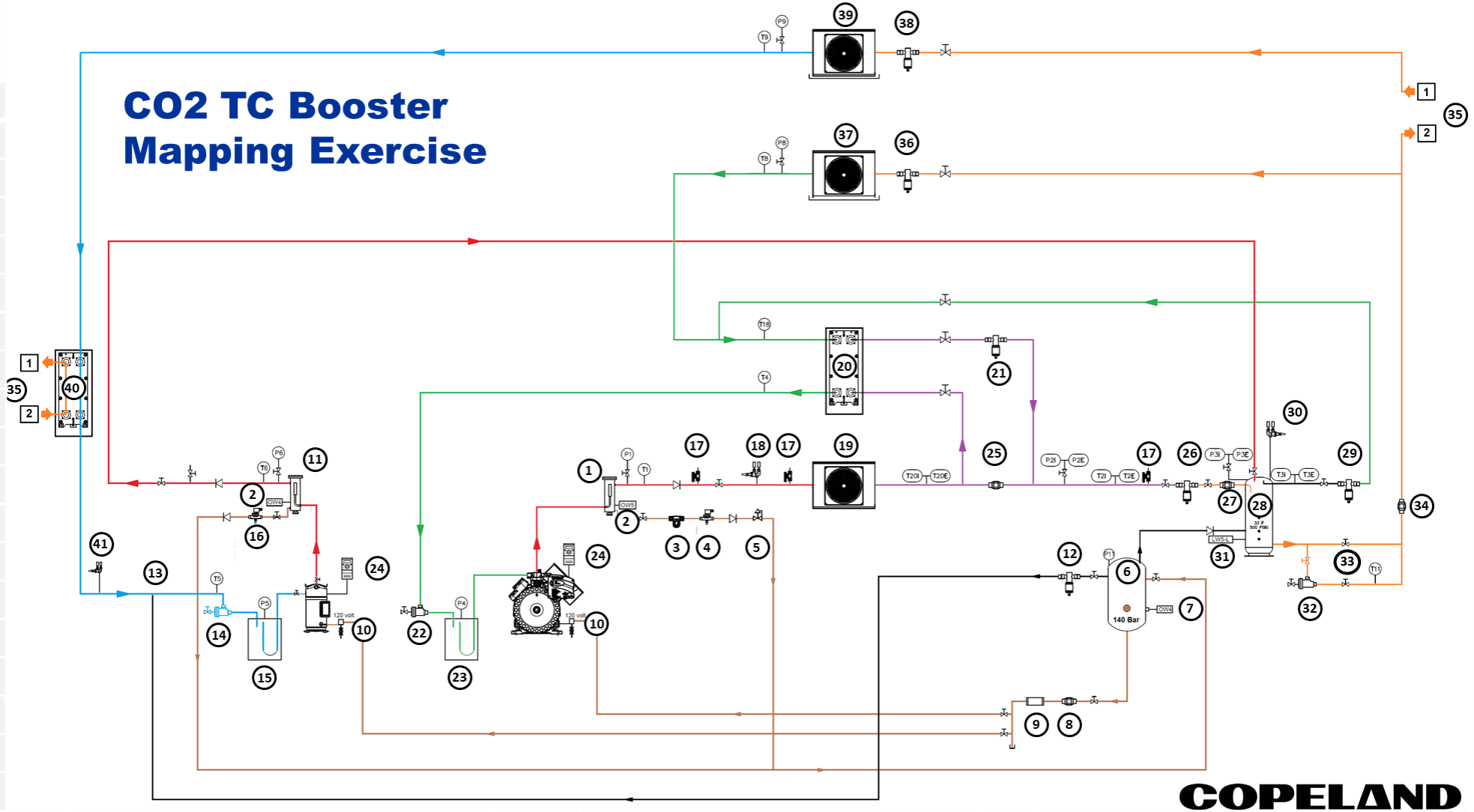
CO2 TC Booster
Mapping Exercise



COPELAND

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