

ENGINEERING  
TOMORROW

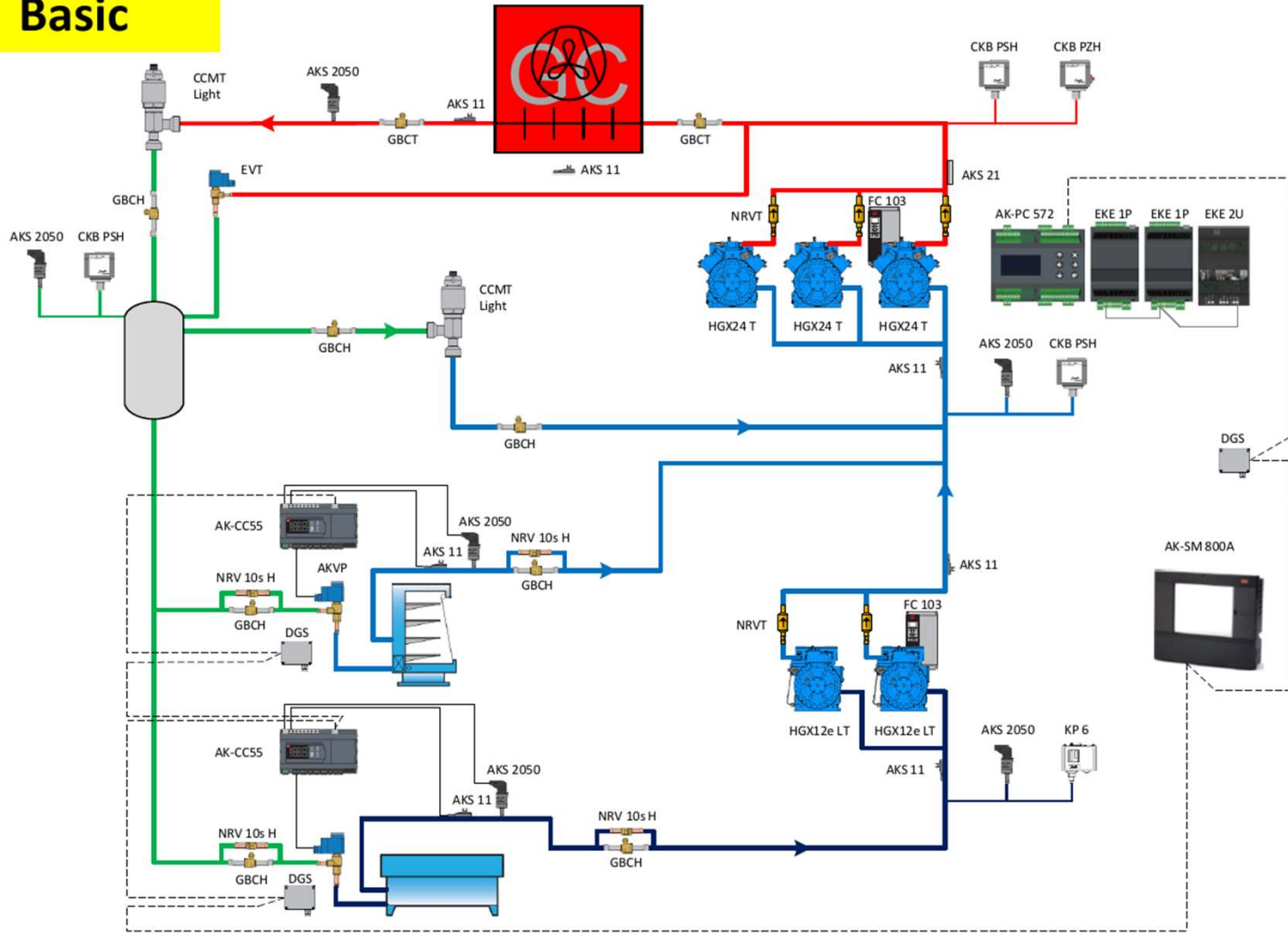


## Danfoss Mobile Training Unit North American Tour – Spring 2023

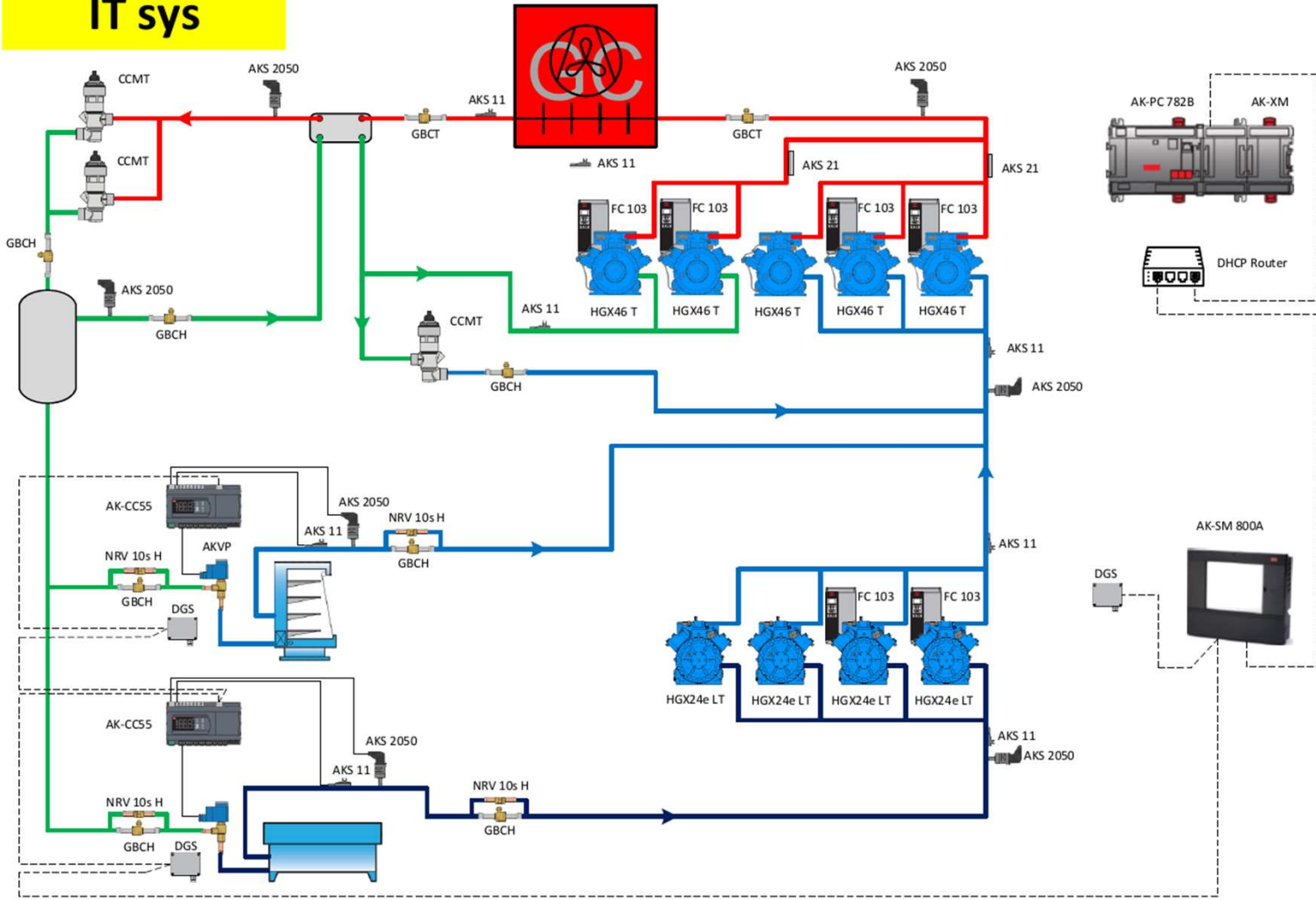
CO<sub>2</sub> Refrigeration System Demonstrations  
AK-PC 782A Controller Training  
CO<sub>2</sub> Multi Ejector Overview

CO<sub>2</sub> Field Service Engineer – John Slattery  
Application Engineer – Dwain P. Mayer

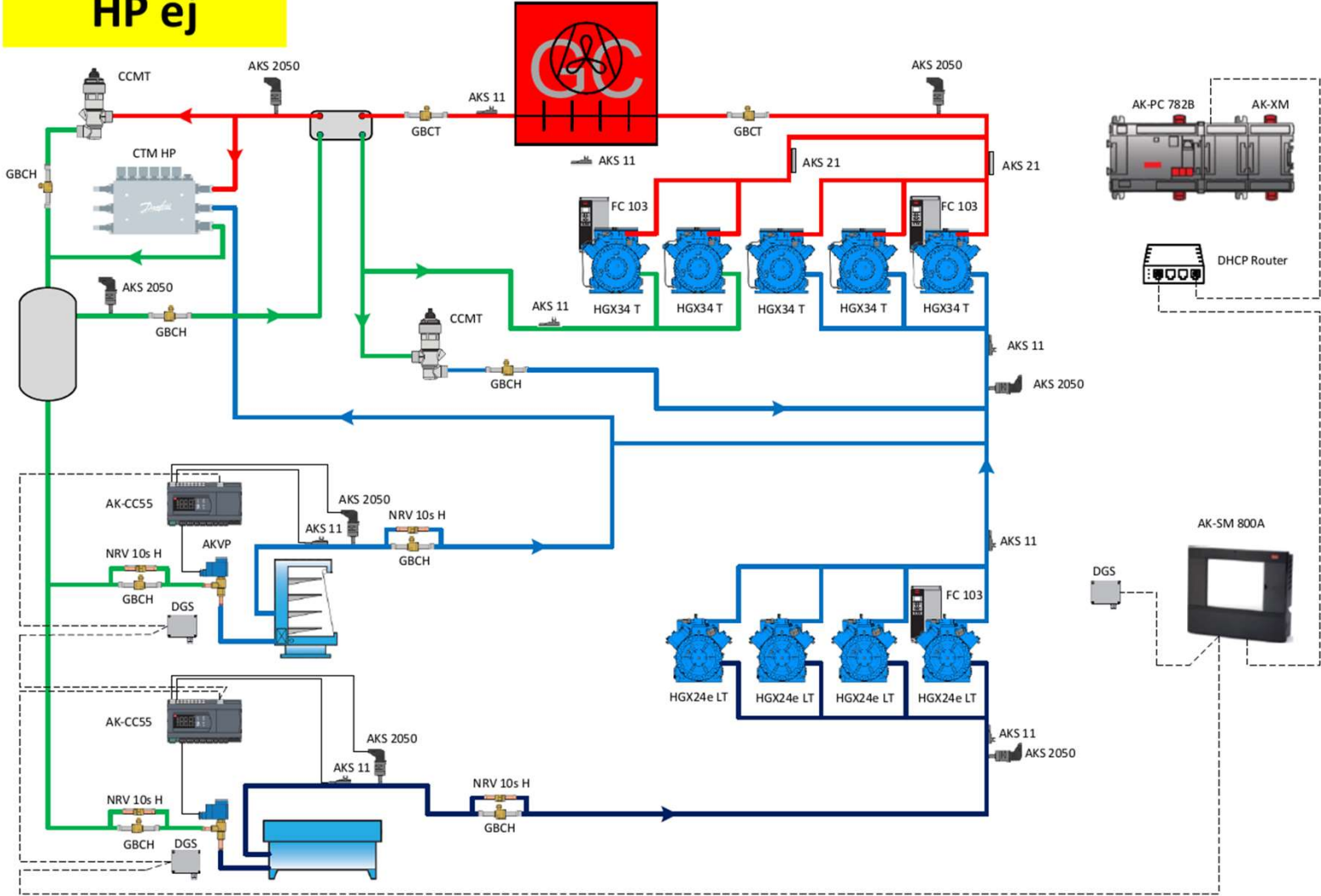
# Basic



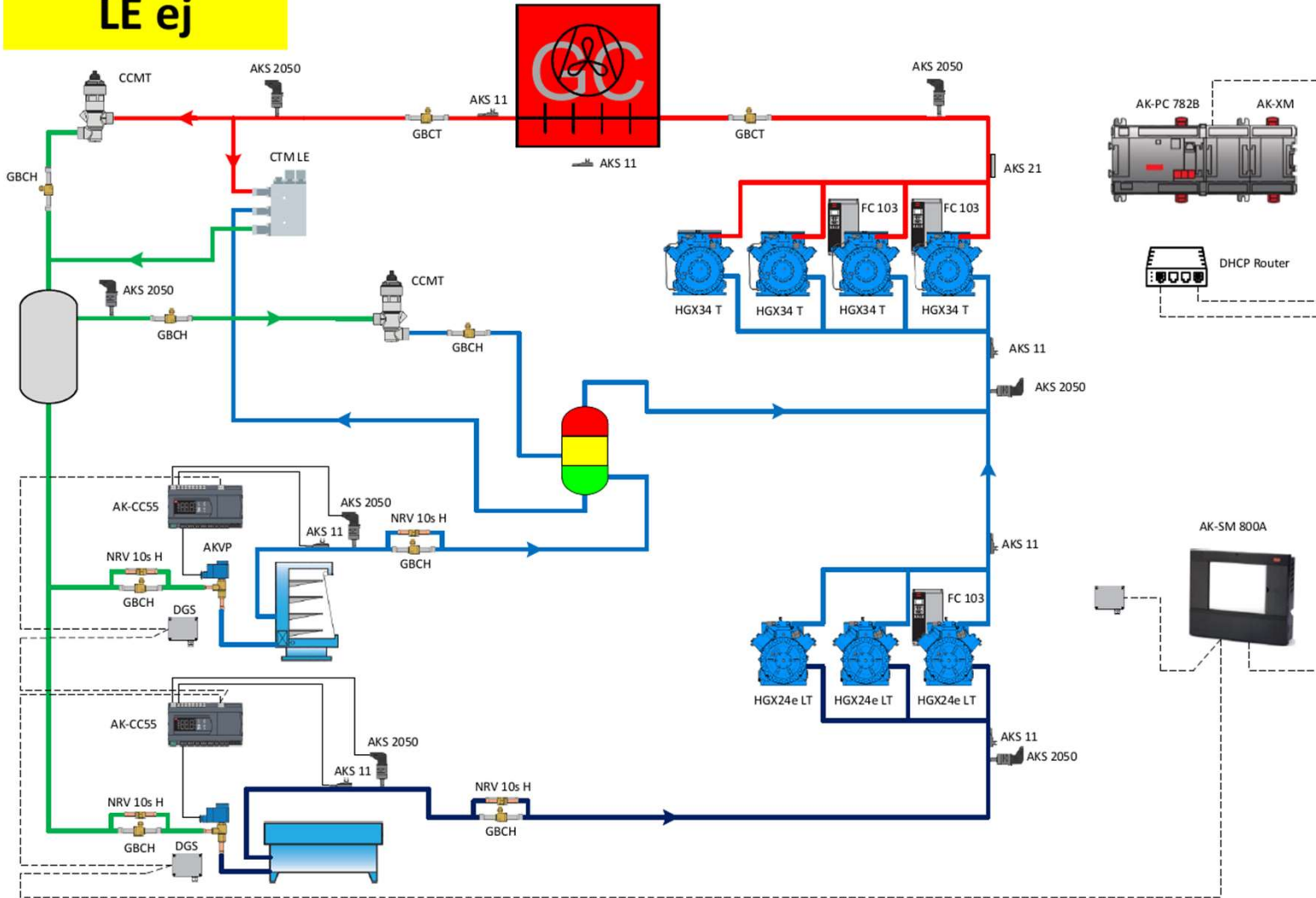
# IT sys



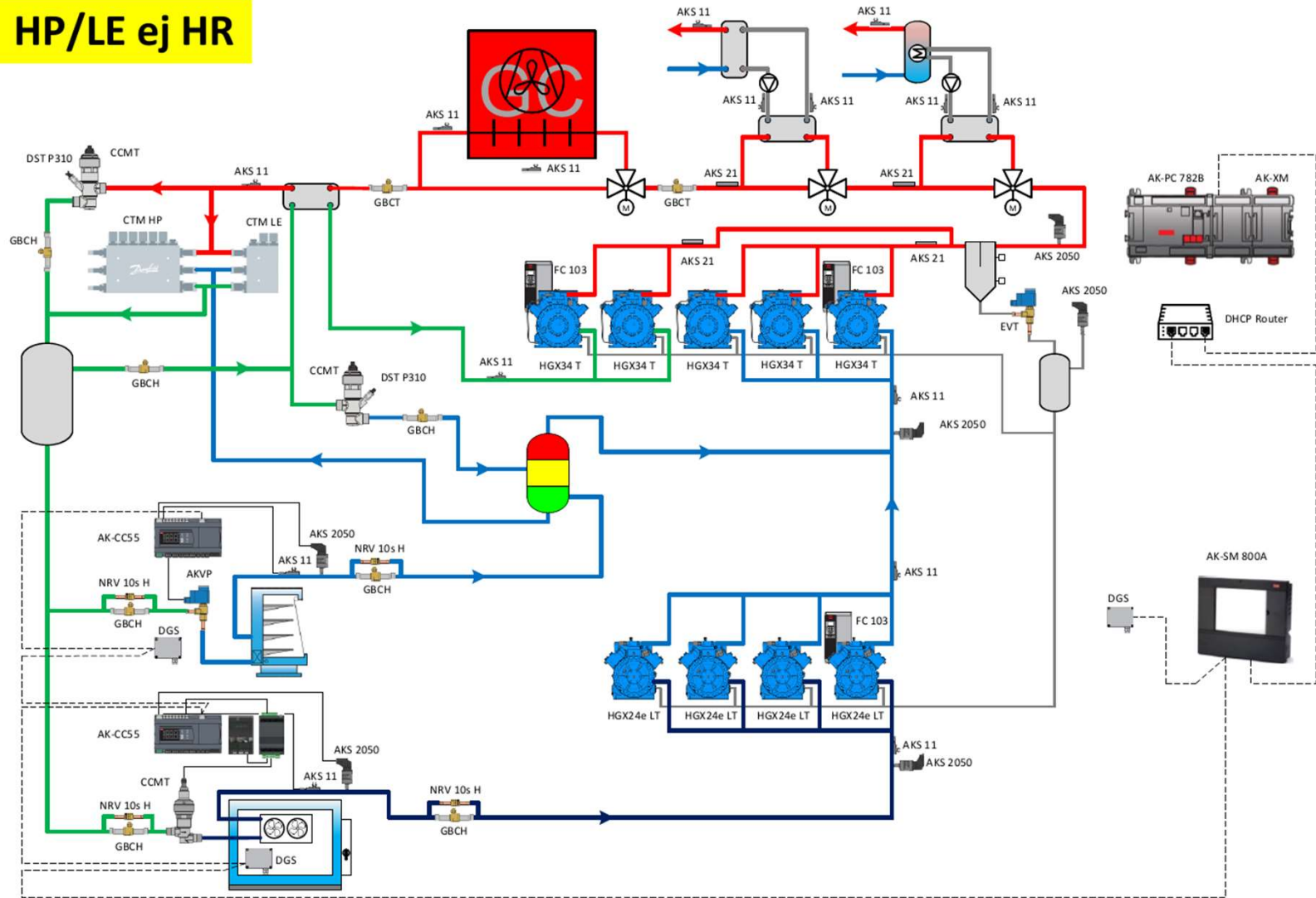
# HP ej



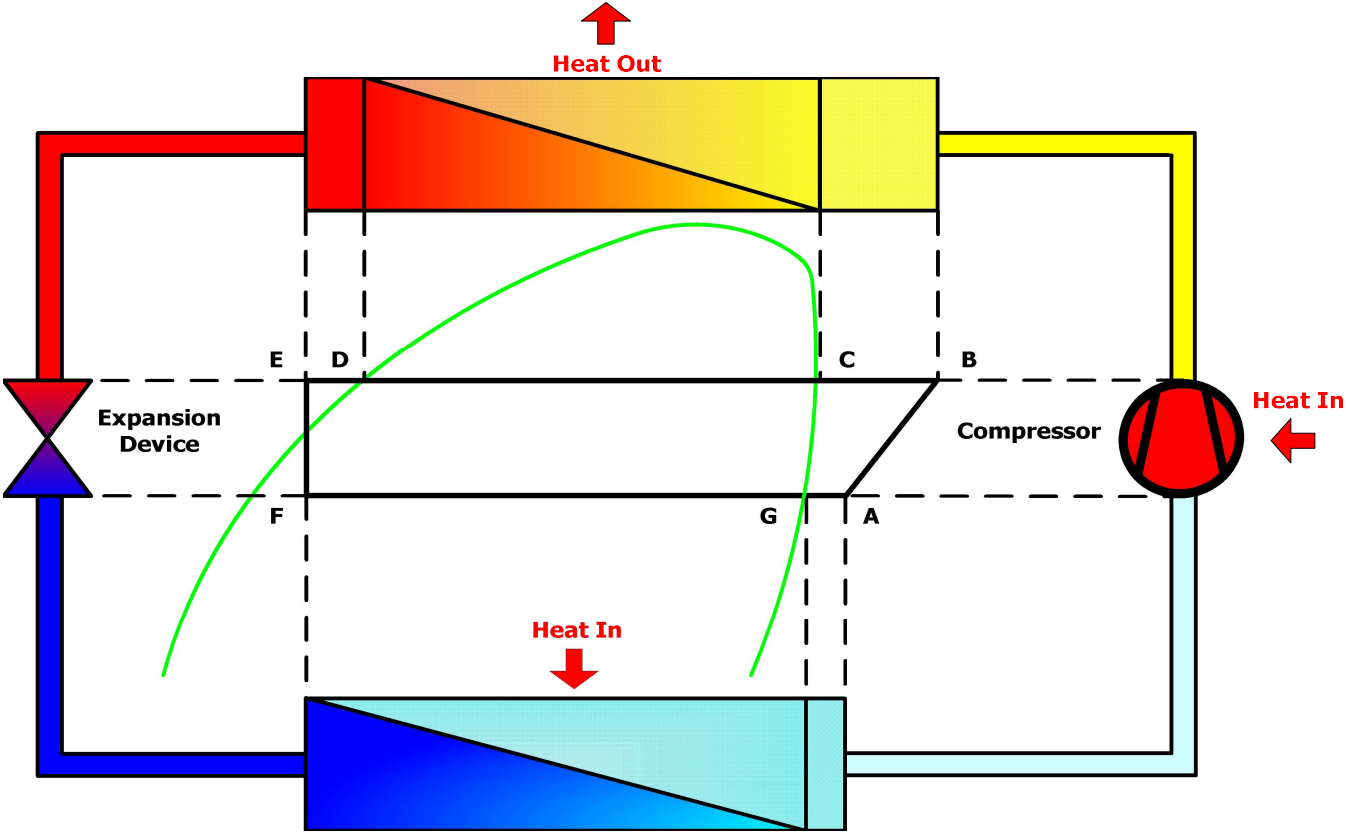
# LE ej



# HP/LE ej HR

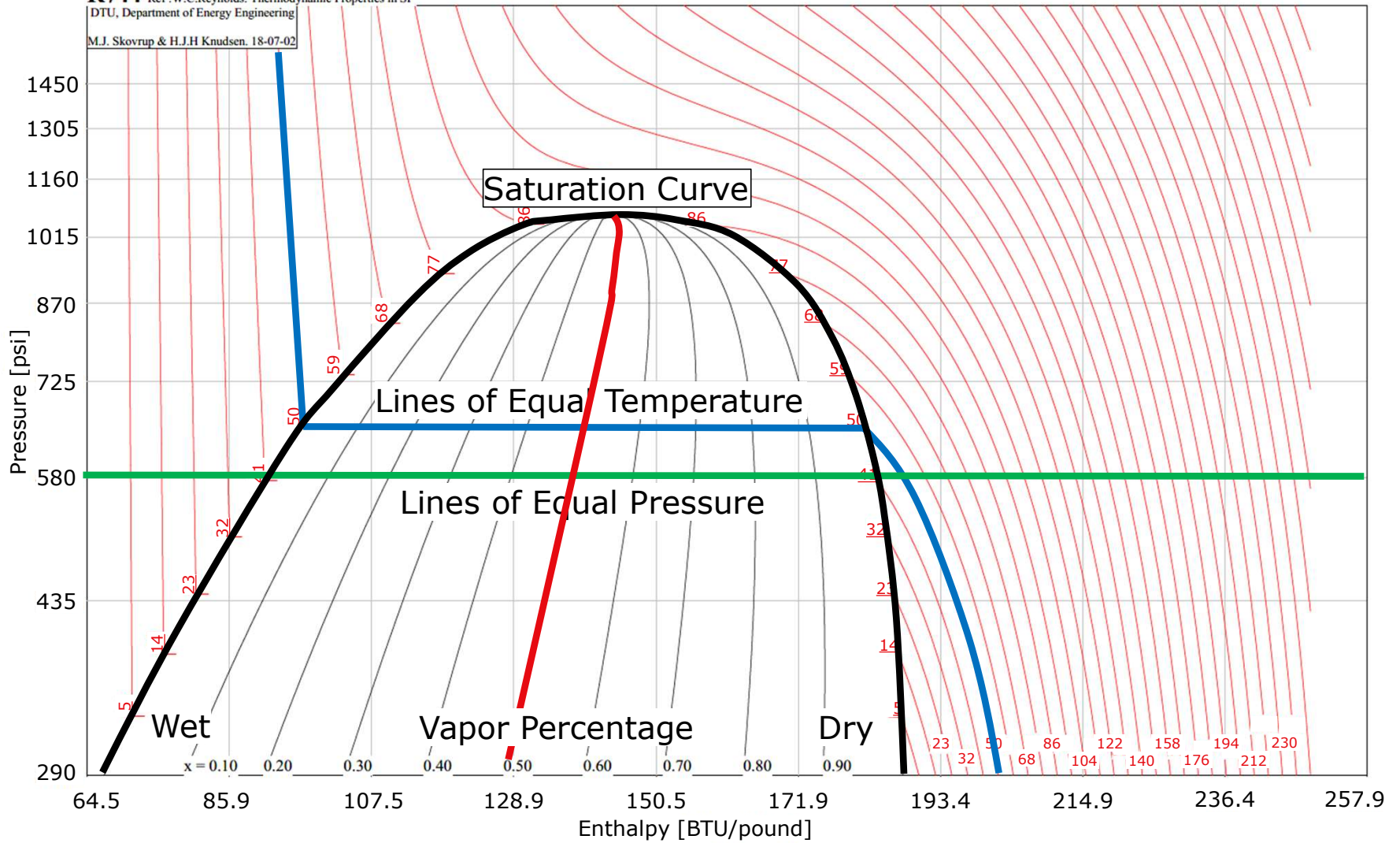


# Basic Refrigeration Cycle



A-B Compression A-B Compression, B-C Desuperheating, C-D Condensing, D-E Subcooling, E-F Re-expansion, F-G Vaporisation, G-A Superheating

**R744** Ref: W.C.Reynolds: Thermodynamic Properties in SI  
 DTU, Department of Energy Engineering  
 M.J. Skovrup & H.J.H Knudsen. 18-07-02

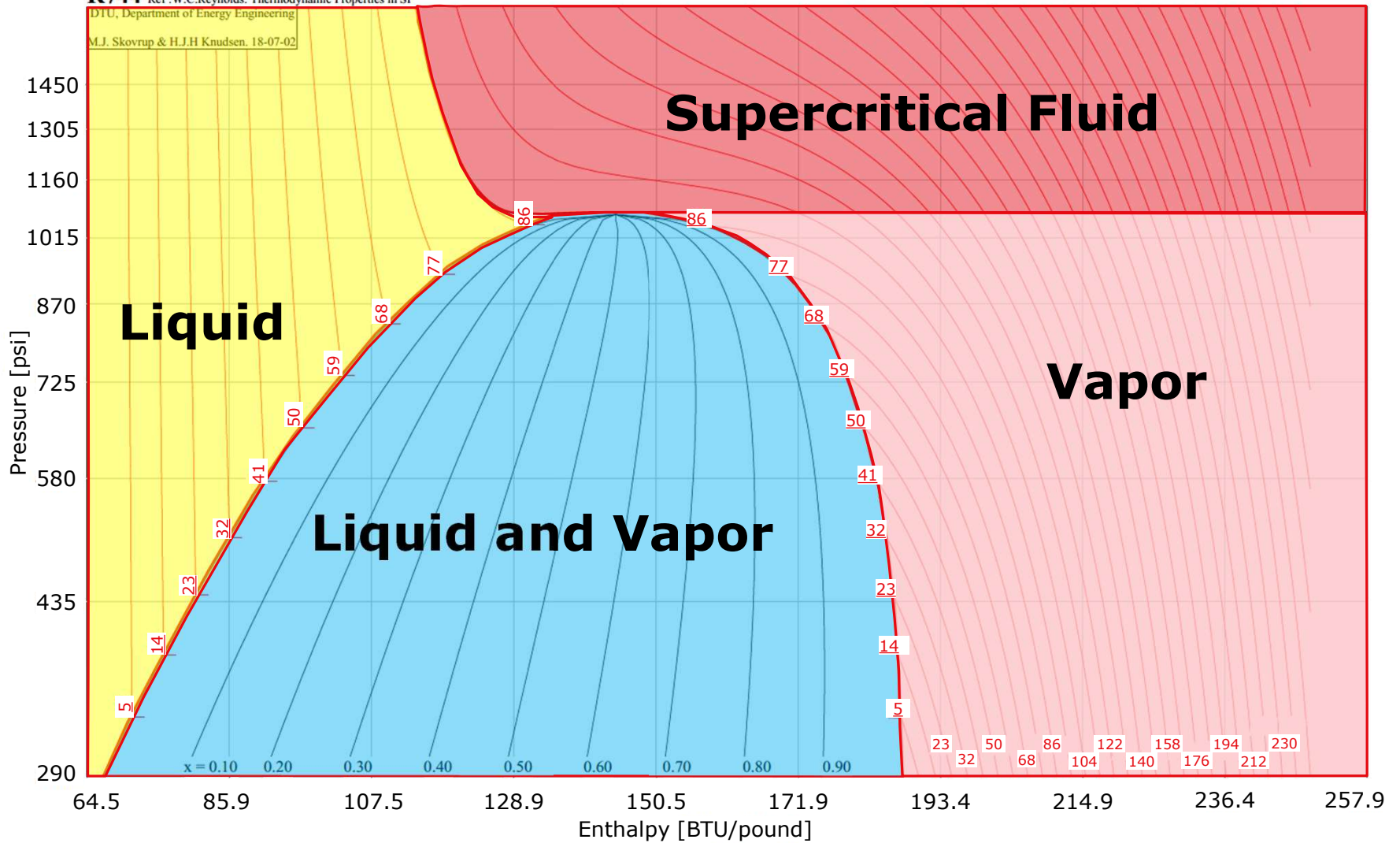




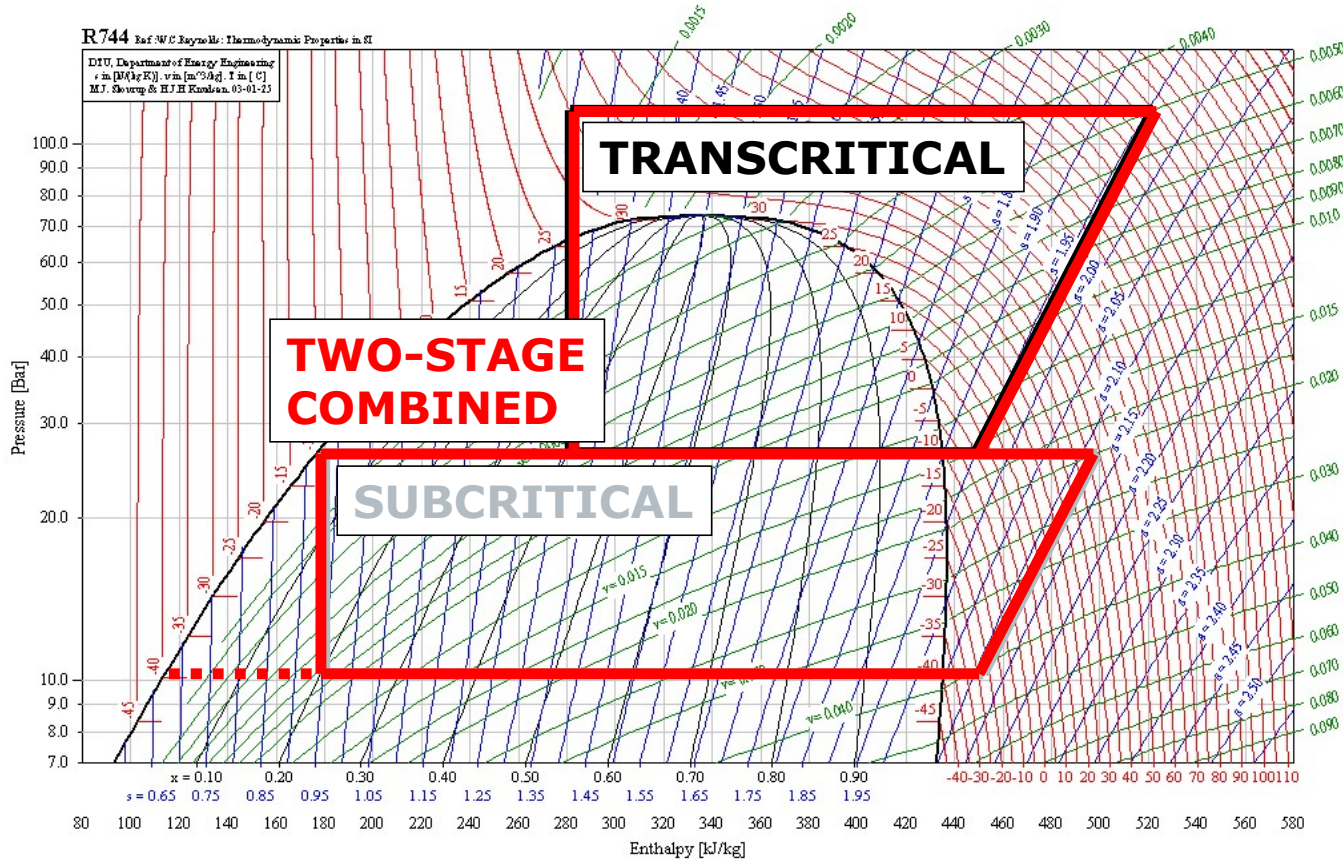
R744 Ref: W.C.Reynolds: Thermodynamic Properties in SI

DTU, Department of Energy Engineering

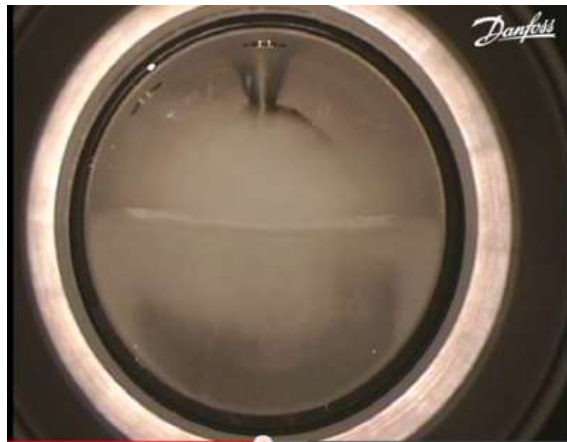
M.J. Skovrup & H.J.H Knudsen. 18-07-02



# Transcritical & Subcritical Cycles



# Transcritical CO2 in Action



Danfoss CO2 Phase Change Video

## Phase Change Video

### CO2 Video

1bar = 14.5psia

10bar = 145.5psia

100bar = 1450psia

140barg = 2044.5psig

-40C = -40F

0C = 32F

40C = 104F

20'C = 68'F

57.2bar-a = 829.6psia

Triple Point

5.2bar-a = 75.4psia

-56.6C = -69.88F

-78.4'C = -109.1'F @  
0psig

Critical Point

73.6bar-a =

1067.4psia

31'C = 88'F

Density @ Critical  
Point

468 kg/m3 = 30lb/ft3

# CALM™ CO<sub>2</sub> Adaptive Liquid Management

## System Control

Pack control:

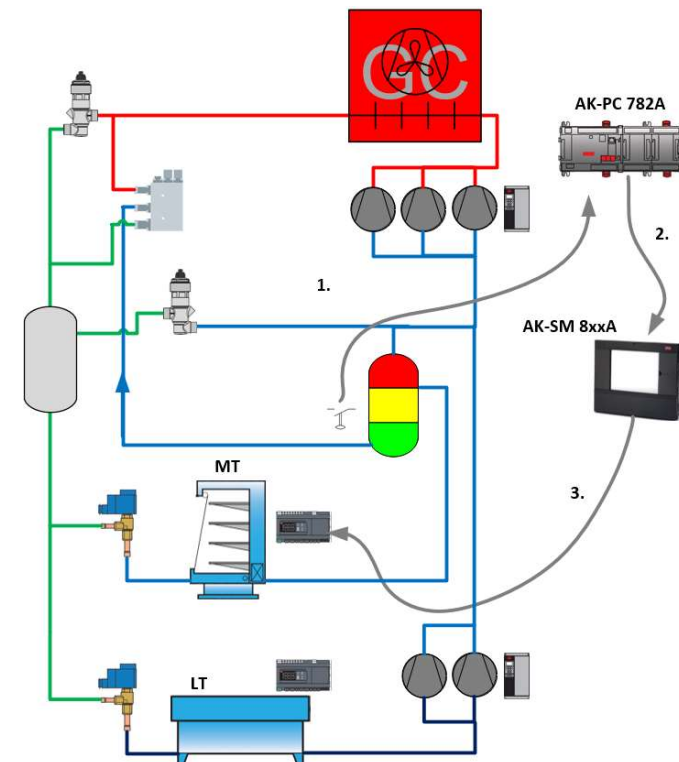
- **Po optimization**

Evaporators control:

- **Modulating thermostat**
- Adaptive SH (MSS)
- Adaptive Liquid Control (ALC)
- Only most loaded evaps will operate either with zero superheat (ALC) or at Minimum Stable Signal (MSS) (depending on settings)

## CALM™ solution

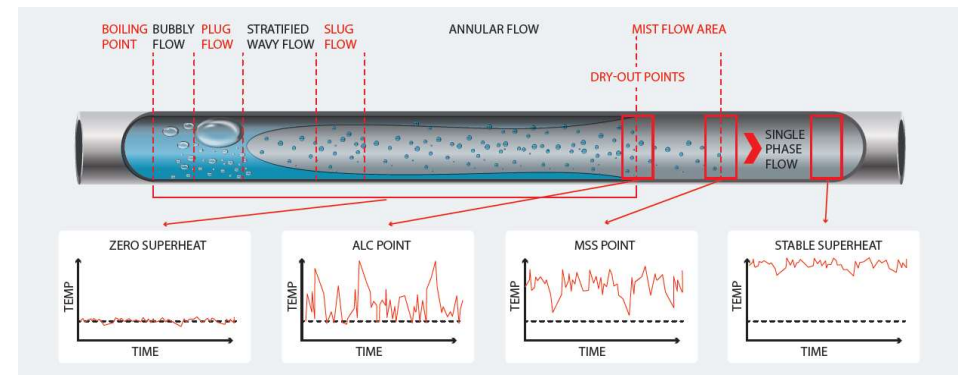
1. High Liquid level switch signal >> AK-PC 782A/B
2. High level status via communication to AK-SM 8xxA
3. CC 55's switch from ALC to MSS superheat control on all MT evaporator controllers



# Evaporator control

- **Stable superheat** can be measured when the superheat is higher than the MSS point.
- **MSS point** (Minimum Stable Signal) can be found on the borderline between the Mist Flow area and the Single-Phase Flow – With MSS control the highest evaporator efficiency is achieved while all liquid is evaporated, and only superheated gas is leaving the evaporator
- **ALC point** (Adaptive Liquid Control point) can be found near the Dry-Out point on the borderline between the Annular Flow area and the Mist Flow area – With ALC the highest evaporator efficiency is realized with droplets of refrigerant leaving the evaporator
- **Zero superheat** can be measured in all parts of the evaporator where fluid exists (until Dry-Out point)

If evaporator was a tube:

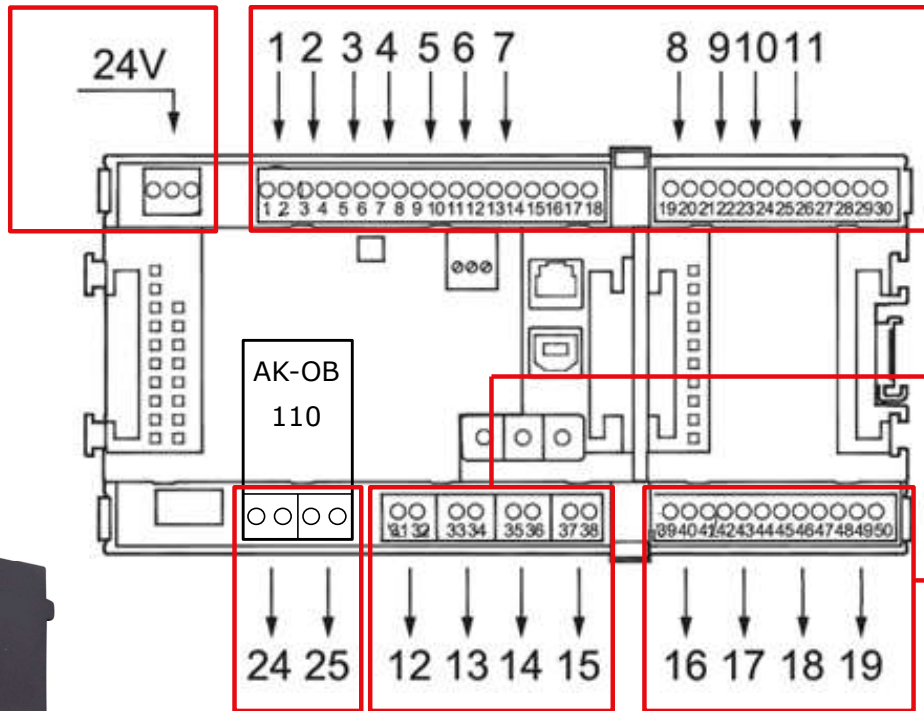


ENGINEERING  
TOMORROW

*Danfoss*

Danfoss AK-PC 782A Hardware

# AK-PC 782A – Hardware



(11) Analog Inputs

- Pressure, Temp
- Digital Inputs

(4) Solid State Relay Outputs

- Pulse Valves (oil)

(4) Standard Relay Outputs

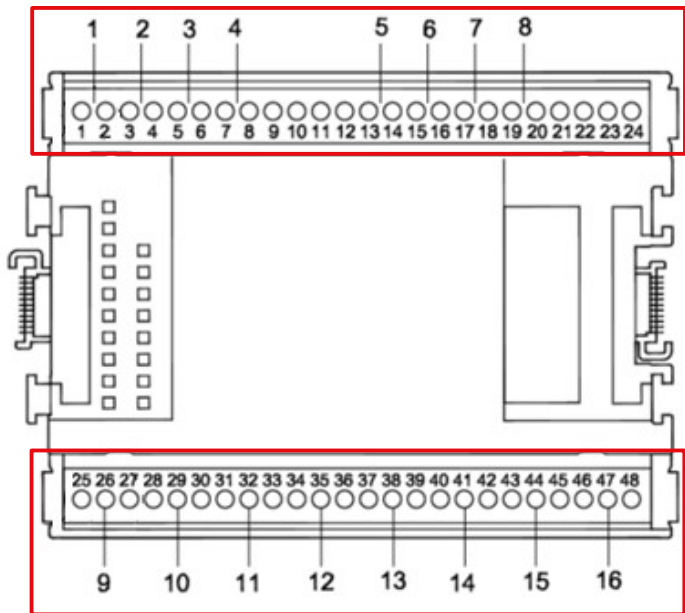
- Compressors, HG Dump

(2) Optional Analog Outputs

- VFD 0-10V Signal



# AK-XM 205 – Hardware

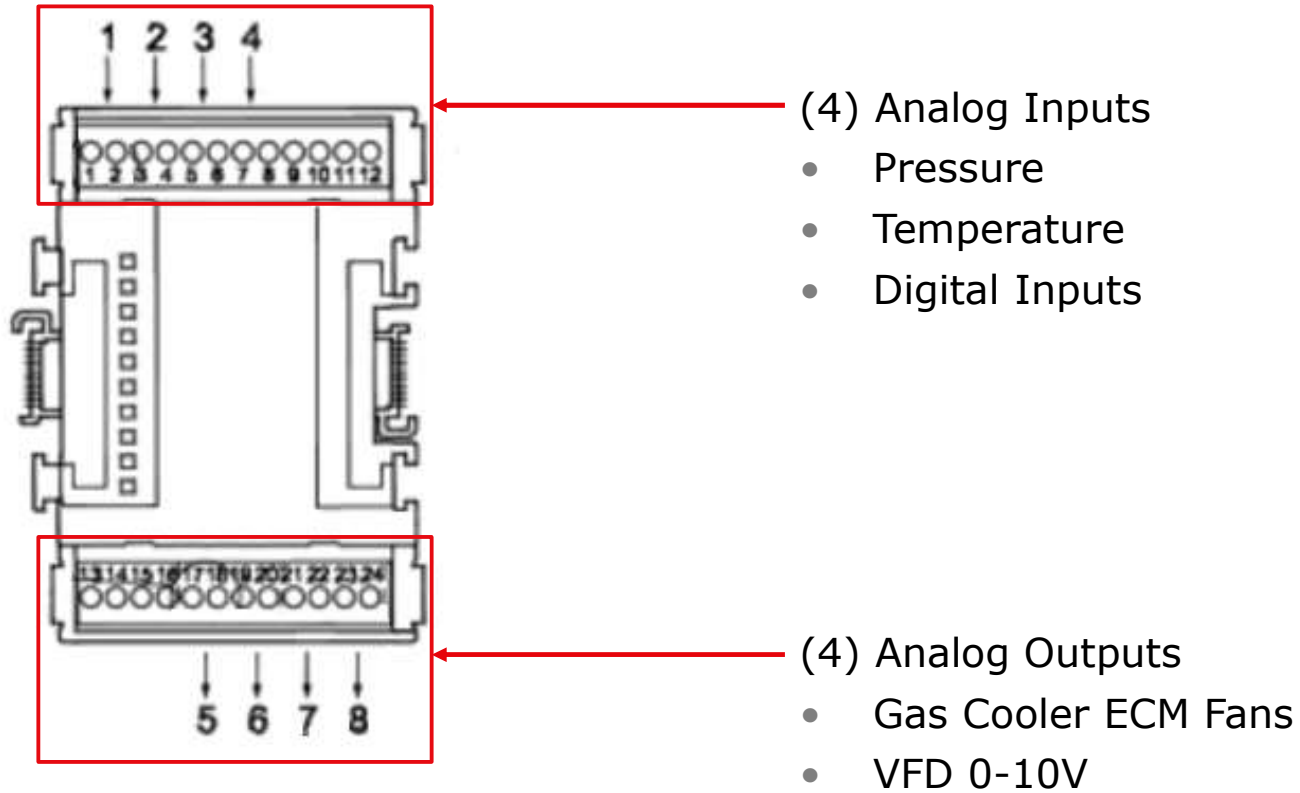


- (8) Analog/Digital Inputs
- Pressure, Temp
  - Safety ON/OFF Inputs

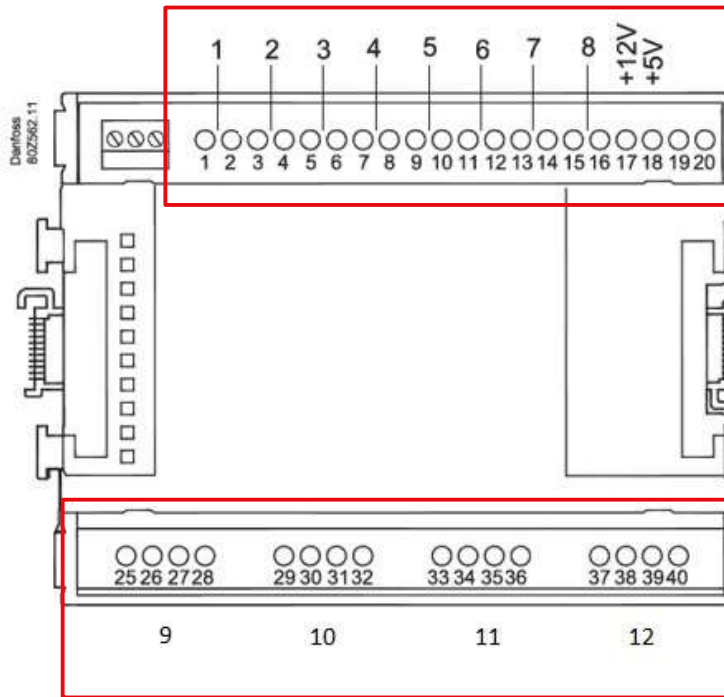
- (8) Relay Outputs
- Compressors
  - Hot Gas Dump
  - Liquid Injection



# AK-XM 103A – Hardware



# AK-XM 208C – Hardware



(8) Analog Inputs

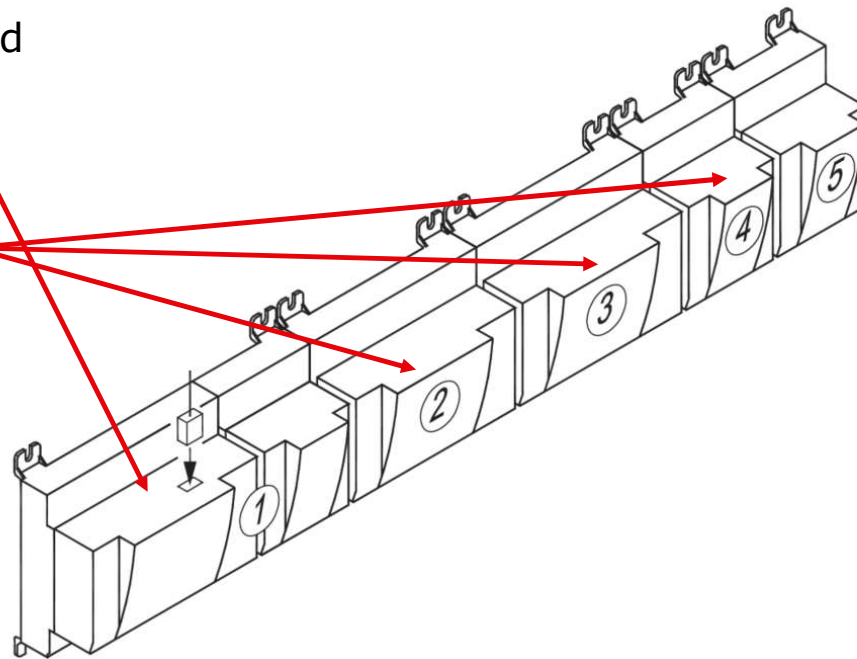
- Pressure
- Temperature
- Digital Inputs

(4) Stepper Valve Outputs

Valve data	
Type	P
ETS 12.5 - ETS 400 KVS 15 - KVS 42 CCMT 2 - CCMT 8 CCM 10 - CCM 40 CTR 20	1.3 VA
CCMT 16 - CCMT 42	5.1 VA
CCMT - 3L/5L/8L	4.0 VA

# AK-PC 782A – Module Arrangement

- AK-PC is considered module #1
- Additional AK2 modules are in sequential order



00:099 UNIT 2 AK-PC 782

I/O configuration

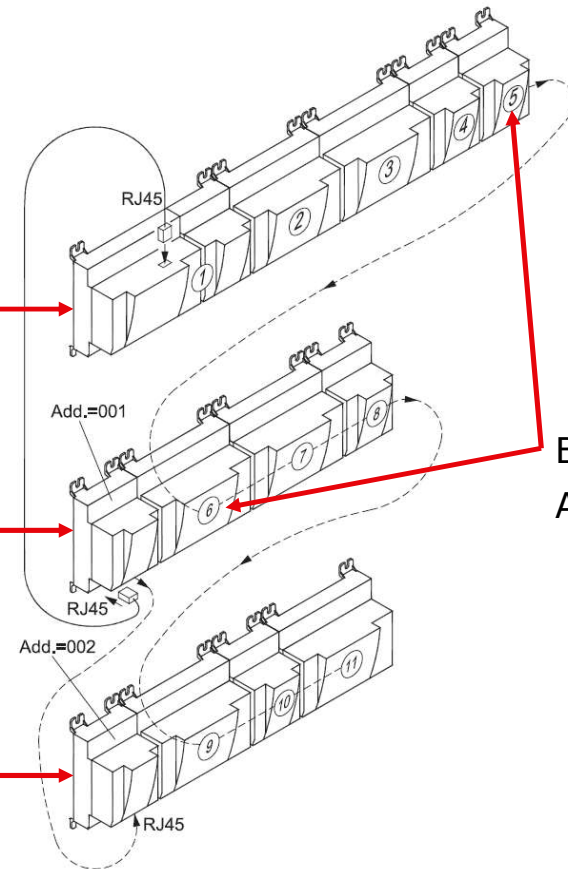
Function	Mod.	Pt	Type
Speed comp. MT-1	1 -	25	0 -10 V
Speed comp. LT-1	1 -	24	0 -10 V
Condenser speed	5 -	8	10- 0 V
HP Control			
Vhp	5 -	5	0 -10 V
Vrec 1	4 -	9	CCM-20
Heat recovery			
Speed hr	0 -	0	0 -10 V
Gen. purpose			
PI-1 Voltage	6 -	5	1 - 5 V
PI-2 Voltage	5 -	6	0 -10 V

# AK-PC 782A – Extended Comms

AK-PC782A (Address 0XX)

AK-CM 102 (Address 001)

AK-CM 102 (Address 002)



Board Numbers  
Are Continuous

A maximum of FIVE AK-CM102 comm modules can be added

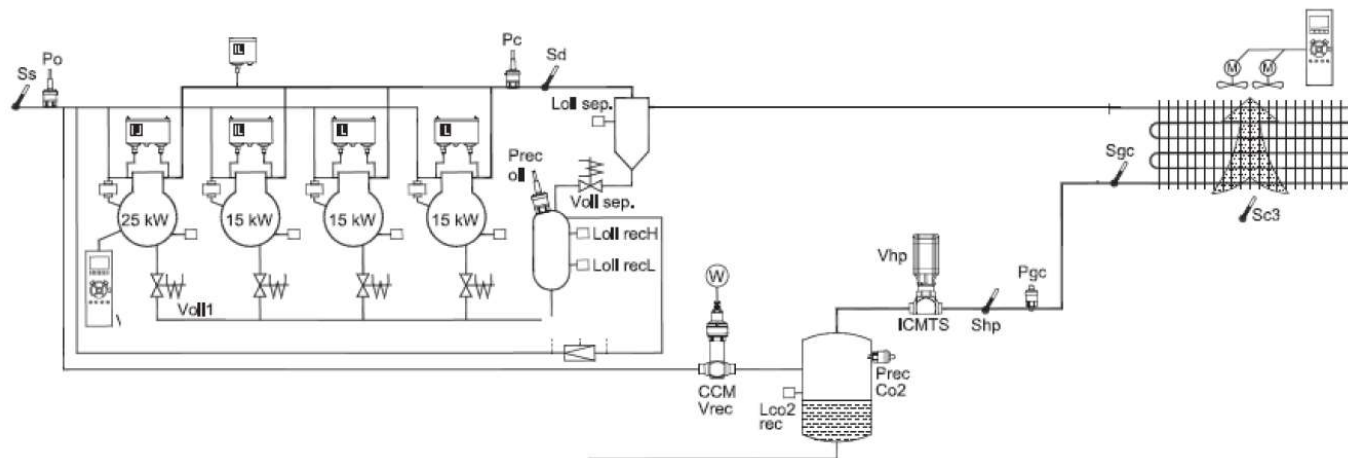
ENGINEERING  
TOMORROW

*Danfoss*

Service Tool (ST500)

# Service Tool AK-ST 500

## Sensor Abbreviations



<b>Po</b>	Suction Pressure	<b>Sgc</b>	Gas Cooler Outlet Temperature
<b>Ss</b>	Suction temp	<b>Sc3</b>	Ambient Temperature
<b>Pc</b>	Condensing Pressure	<b>Prec</b>	Receiver Pressure
<b>Sd</b>	Discharge Temperature	<b>Vrec</b>	Receiver Gas Bypass Valve
<b>Pgc</b>	Gas Cooler Outlet Pressure	<b>Vhp</b>	High Pressure Valve (Gas Cooler Outlet)

# Service Tool AK-ST 500

## Main Screen Features

MT Suction Group



IT Suction Group



Gas Cooler Fan



High Pressure Valve



Ejector Control



Receiver Bypass Valve



Alarm	value	Ref.	Act.%	Status
	17.9 °F	20.0 °F	52	Normal ...
	32.0 °F	34.4 °F	0	Vrec ctrl.
	70.2 °F	65.5 °F	52	Running
	815.0 psi	827.3 psi	0	Normal
	816.6 psi	827.7 psi	27	Normal
	486.3 psi	507.6 psi	57	Normal ...

Ref. = Set Point

Value = Actual

Act.% = Active Capacity

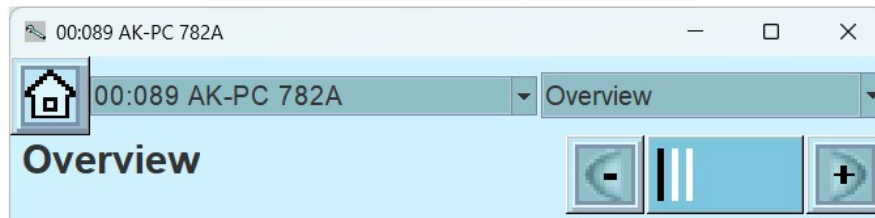
Status = Condition

Alarm = Problem

# Service Tool AK-ST 500

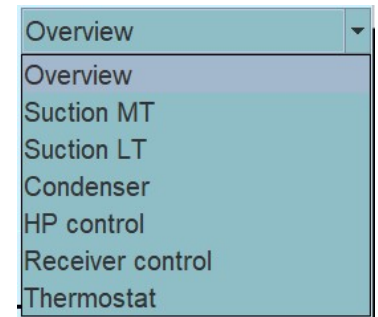
## Main Screen Top/Bottom Icons

Disconnect



System Overview  
Schedules  
Main Switch

Logging  
Alarms  
Configuration



Next/Previous Page




# Service Tool AK-ST 500

## Configuration Screens – Lock/Unlock

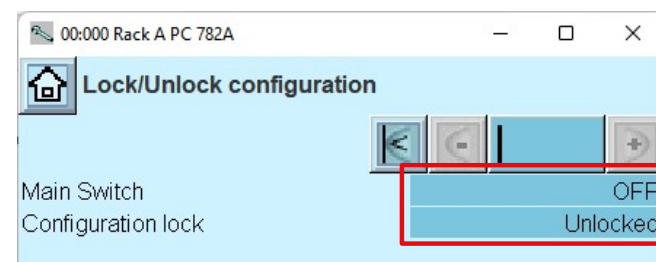
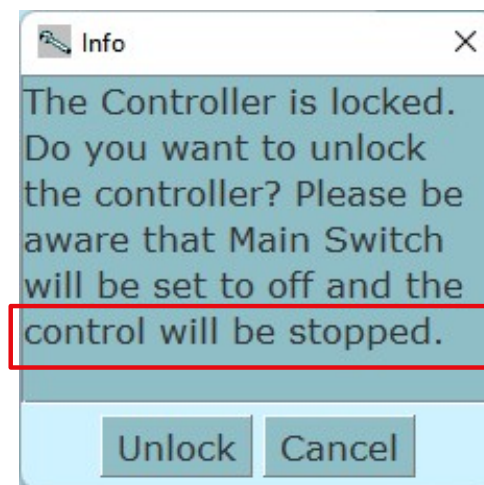
The **Lock/Unlock Configuration** process must be understood to prevent unsafe operating conditions.

Many adjustments can be made while the system is running... BUT

If you see this message, clicking UNLOCK will immediately STOP the rack!

Access the main switch with the  icon on ST500 home screen.

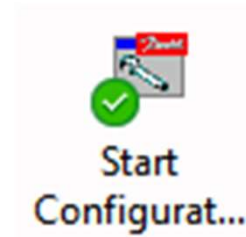
The Main Switch starts/stops all control functions. It must be turned ON to run; turned OFF to stop the rack or make significant configuration changes.



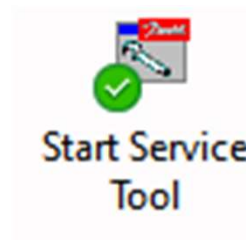
# Service Tool AK-ST 500

After installation of Service Tool AK-ST 500 you will have two icons on your desktop.

**Start Configuration**

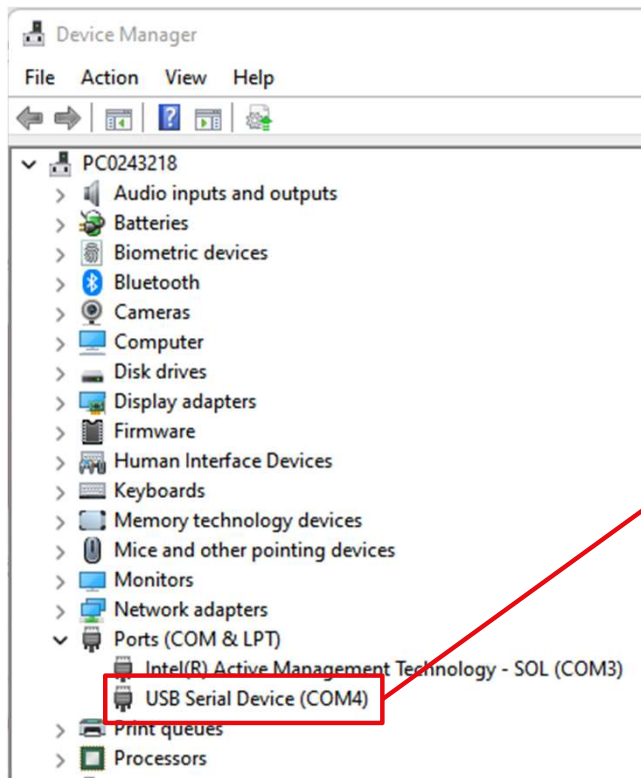


**Start Service Tool**



# Service Tool AK-ST 500

## Comm Port Configuration



1. Connect to an AK-PC 782A controller with a USB A/B cable
2. Go to **Device Manager** on your PC and look at the active comm ports
3. You should see **USB Serial Device** and a comm port number shown. COM4 is the comm port setting for your AK-ST 500 program.

# Service Tool AK-ST 500

## Start Configuration

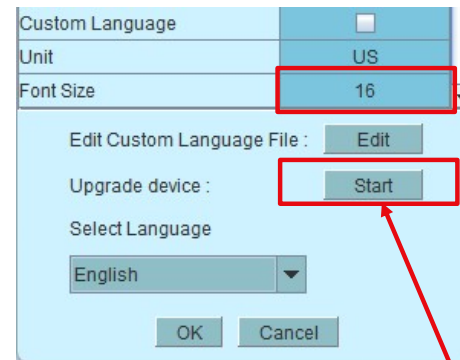
Use **Start Configuration** the first time you start the program or when you need to upgrade a controller.



You will be able to set the comm port when you are connected to a controller.

Check '**Auto logon as SUPV**'

Set units to **US**



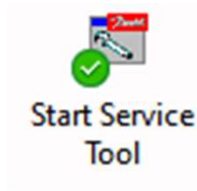
Set **Font Size to 16** or you can set font to Scalable for larger text, but some text fields may be partially hidden.

You can use ST 500 to upgrade software versions in AK-PC 782A controllers. This requires a '.tgz' file that Danfoss will provide if the need for an upgrade arises.

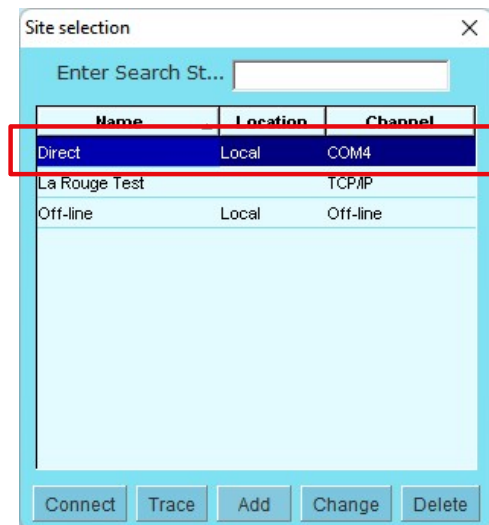
# Service Tool AK-ST 500

## Start Service Tool

Use **Start Service Tool** for daily work



Use **Direct** to connect to a controller using a **USB A/B type printer cable**



USB-A to USB-B



Use **Off-Line** to run simulations of saved controller programs. Saved program have a '.bck' extension.

# Service Tool AK-ST 500

## Input/Output Configuration

The image displays four screenshots of the Service Tool AK-ST 500 I/O configuration interface, each showing a different category of I/O configuration for a training unit (00:089 AK-PC 782A).

**1. Digital outputs configuration:**

Load	Mod.	Pt	Active at
Compressors			
Compressor 1-MT	0	0	ON
Compressor 2-MT	0	0	ON
Compressor 3-MT	0	0	ON
Compressor 1-LT	0	0	ON
Compressor 2-LT	0	0	ON
Liq. inject suction MT	0	0	ON
Comp. running MT	0	0	ON
Oilmanagement			
Oil valve separator 1	0	0	
Fans			
Fan 1	0	0	ON
Gen. purpose			
Liquid Supply Temp	0	0	ON
Oil Supply Temp	0	0	ON
HG Dump Valve	1	14	ON

**2. Digital inputs configuration:**

Alarm / Function	Mod.	Pt	Active at
Compressor 1-MT:			
General safety	0	0	Closed
VSD comp. 1 fault	0	0	Closed
Compressor 2-MT:			
General safety	0	0	Closed
Compressor 3-MT:			
General safety	0	0	Closed
Compressor 1-LT:			
General safety	0	0	Closed
VSD comp. 1 fault	0	0	Closed
Compressor 2-LT:			
General safety	0	0	Closed
Oilmanagement			
Oil sep 1 high level	3	7	Closed
Rec. low liquid level	2	6	Closed

**3. Analog outputs configuration:**

Function	Mod.	Pt	Type
Speed comp. MT-1	0	0	0 - 10 V
Speed comp. LT-1	0	0	0 - 10 V
Condenser speed	0	0	10 - 0 V
HP Control			
Vhp 1	0	0	CCMT-16
Vrec 1	0	0	ETS-100...

**4. Analog inputs configuration:**

Sensor	Mod.	Pt	Type
Po-MT suction pr...	0	0	AKS2050-59
Ss-MT suction gas	0	0	Pt 1000
Sd-MT discharge	0	0	Pt 1000
Po-LT suction pres.	0	0	AKS2050-59
Ss-LT suction gas	0	0	Pt 1000
Sd-LT discharge	0	0	Pt 1000
Ss-LT suction gas	0	0	Pt 1000
Sd-LT discharge	0	0	Pt 1000
Ss-LT suction gas	0	0	Pt 1000
Sd-LT discharge	0	0	Pt 1000
Pc cond. pres.	0	0	AKS2050-159
Oilmanagement			
HP Control			
Pgc	0	0	AKS2050-159
Prec	0	0	AKS2050-59
Sgc temp.	0	0	Pt 1000

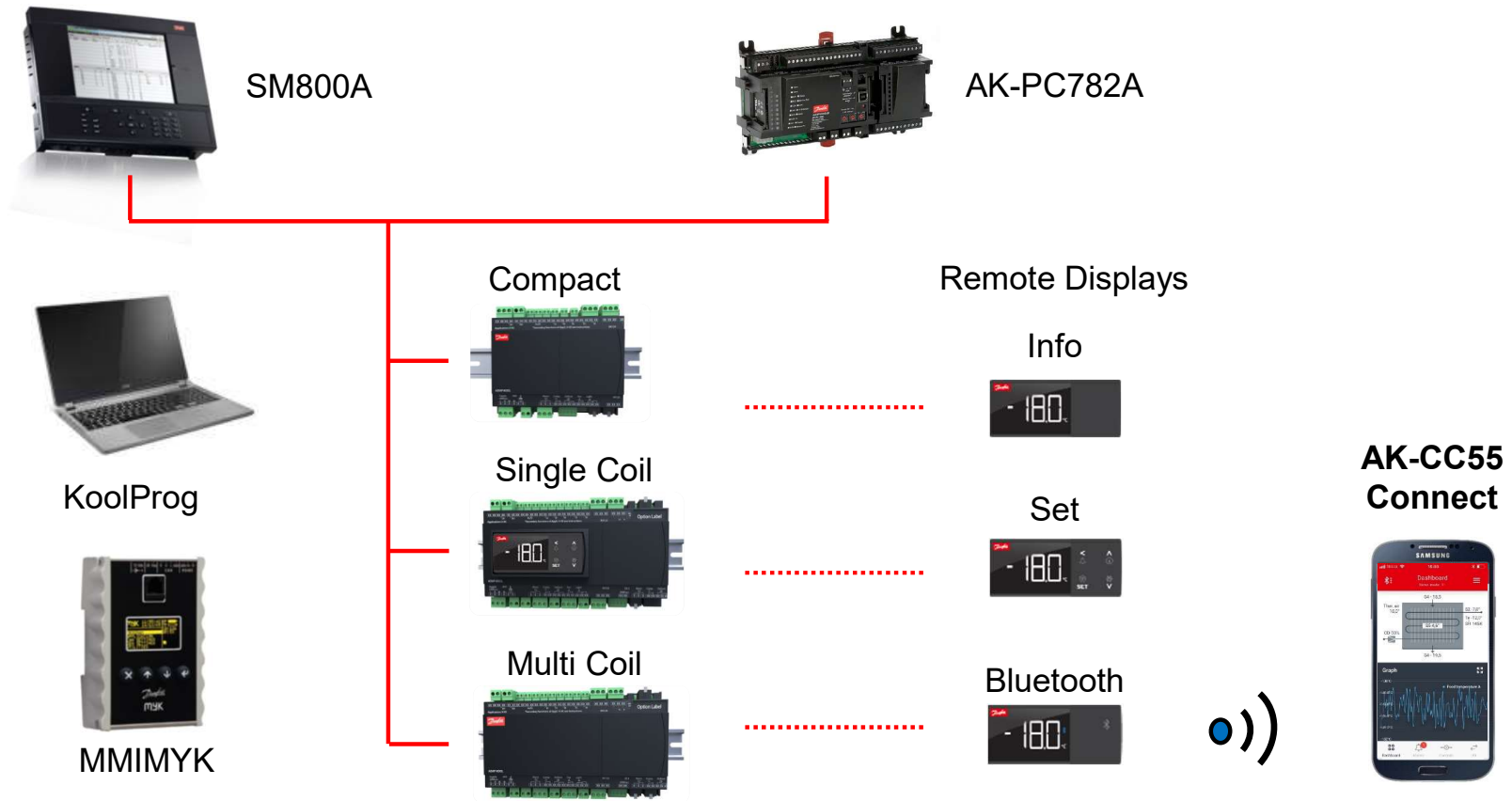
Let's configure the I/O on your training units.

ENGINEERING  
TOMORROW

*Danfoss*

# AK-CC55 Case Controllers

# AK-CC55 Case Controller Ecosystem



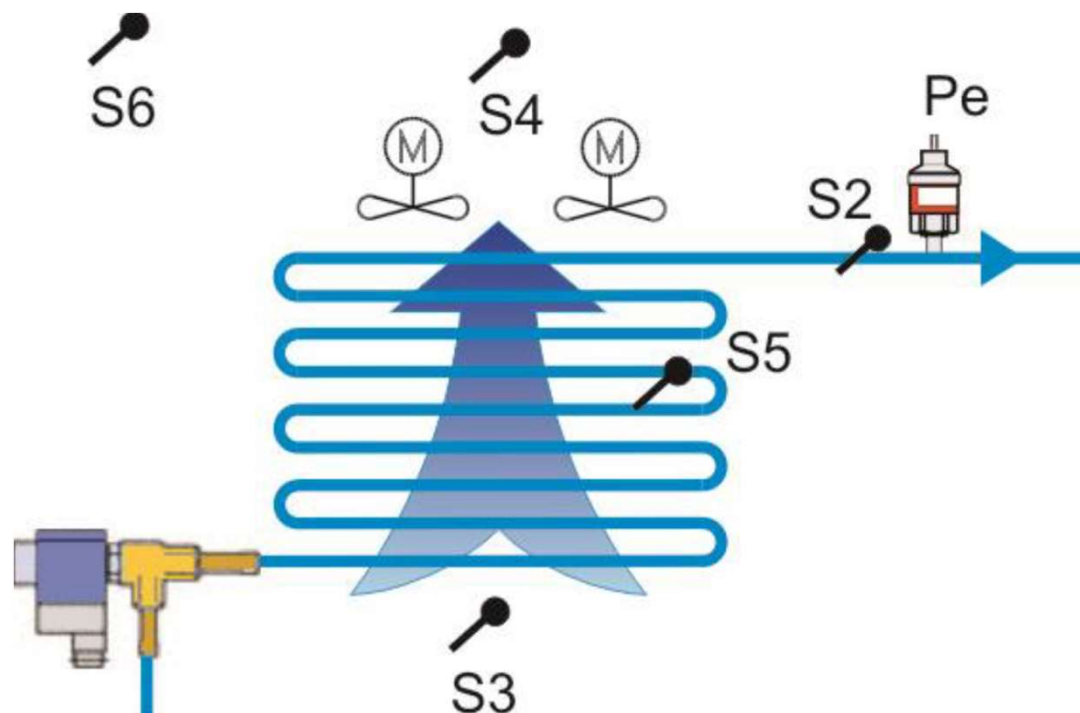


# AK-CC55 Case Controller Product Offerings



	<b>AK-CC55 Compact</b>	<b>AK-CC55 Single Coil</b>	<b>AK-CC55 Multi Coil</b>
Valve	1 x TEV or AKV	1 x AKV	3 x AKV
Digital Output	3	5	4
Digital Input	1	3 (2)	3 (2)
Analog Output	1	1	1
Analog Input	5	6 (7)	6 (7)
Display	1 remote	2 remote 1 remote + 1 Integrated	2 remote
Modbus	Standard	Standard	Standard
LON	-	Opt	Opt
TCP/IP	-	Opt	Opt

## AK-CC55 Sensor Locations



### ID – Description

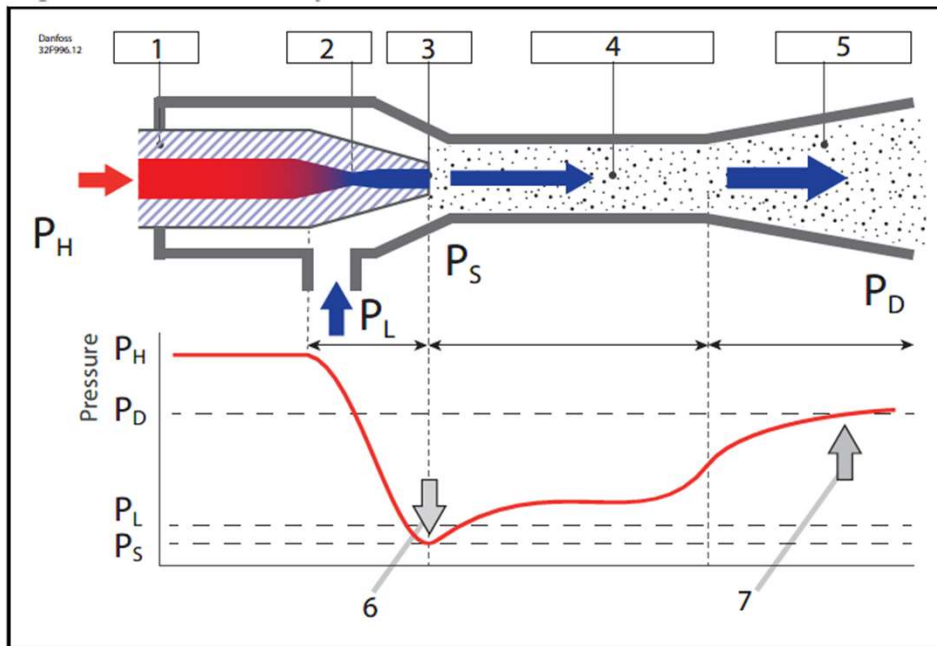
- Pe – Evaporator Outlet Pressure
- S2 – Evaporator Outlet Temperature
- S3 – Return Air Temperature
- S4 – Discharge Air Temperature
- S5 – Coil Temperature (Defrost)
- S6 – Product Temperature

ENGINEERING  
TOMORROW

*Danfoss*

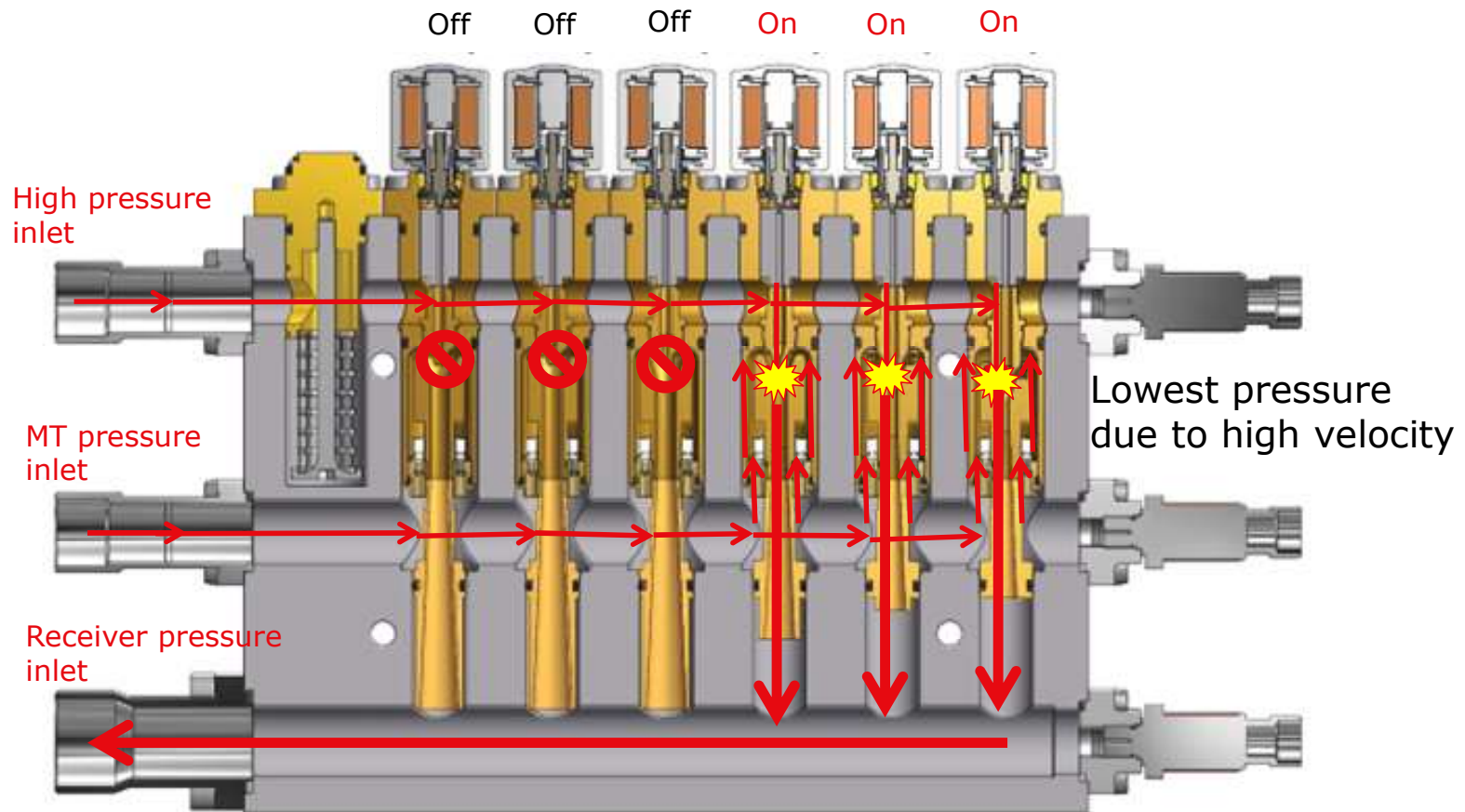
## Ejector Overview

# Working Principal of the Multi Ejector



- |   |   |
|---|---|
| 1 | Nozzle  |
| 2 | Throat  |
| 3 | Exit  |
| 4 | Mixing chamber                                  |
| 5 | Diffuser  |
| 6 | Intake due to pressure differential             |
| 7 | Pressure increase due to reducing flow velocity |

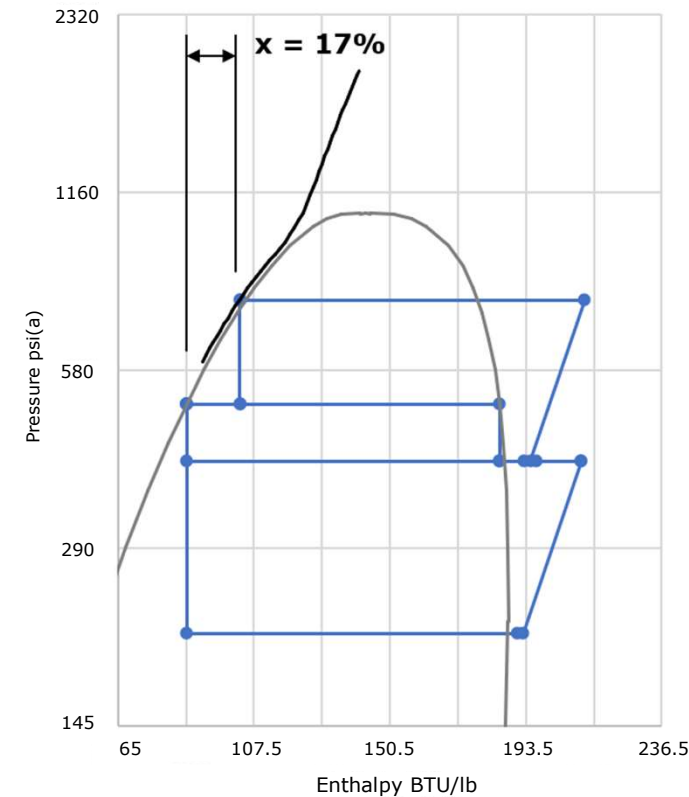
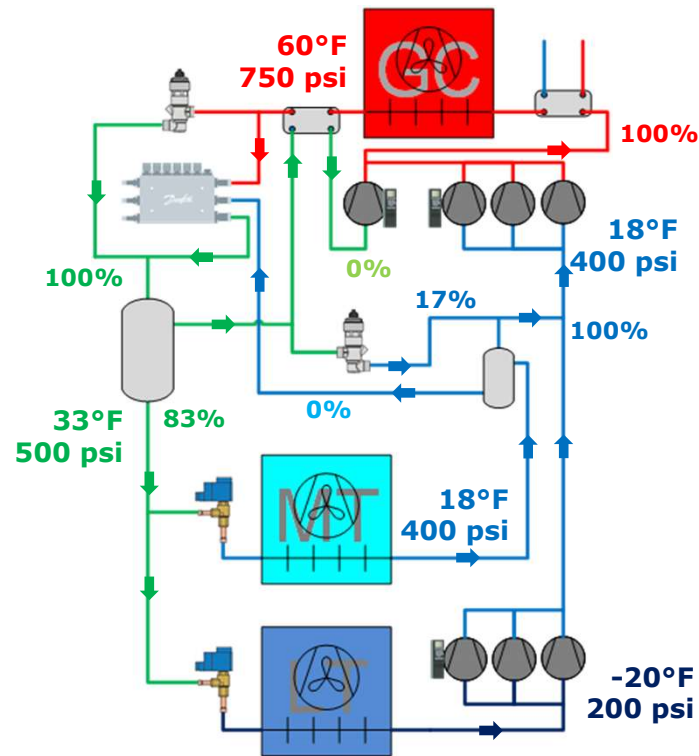
# How does the Multi Ejector work?



# High Pressure Lift Ejector System (HP) Cold Ambient Operation

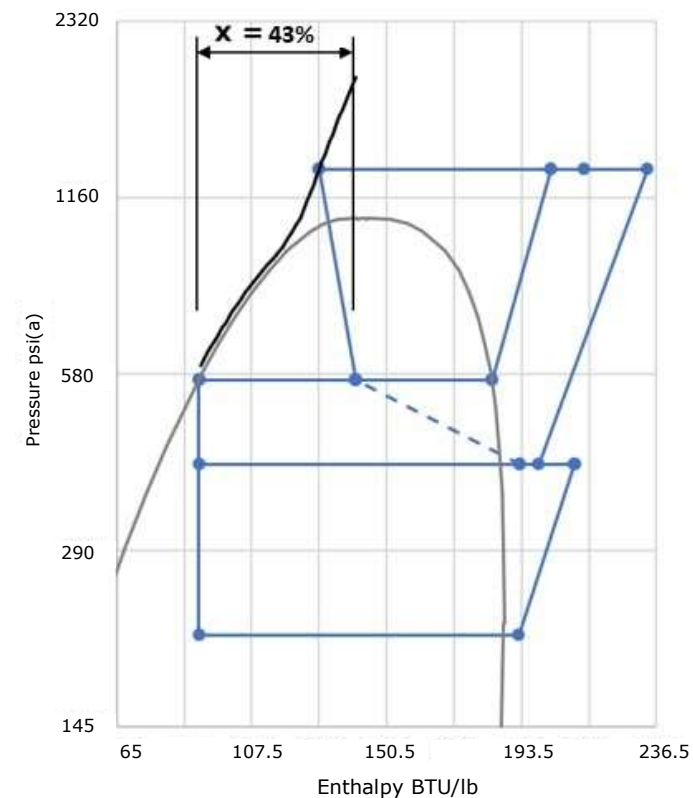
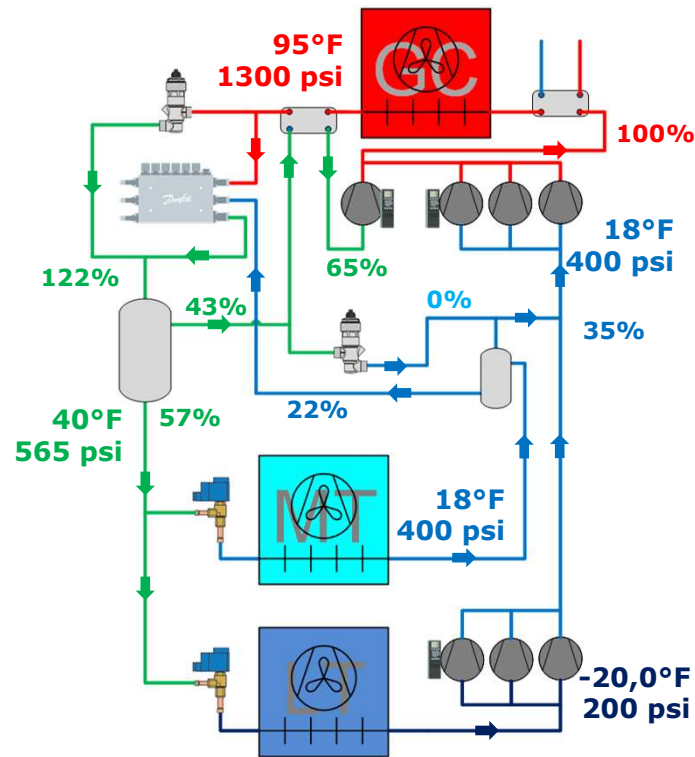
The HP Ejector is the optimal solution for **medium** to **large** commercial refrigeration systems with parallel compressors

- In colder ambient conditions system operates as a standard booster system
- Ejector is simply controlling the high pressure as a high-pressure valve according to the optimal COP Gas Cooler pressure algorithm
- The gas bypass valve control pressure in the receiver releasing flash gas to the MT compressors

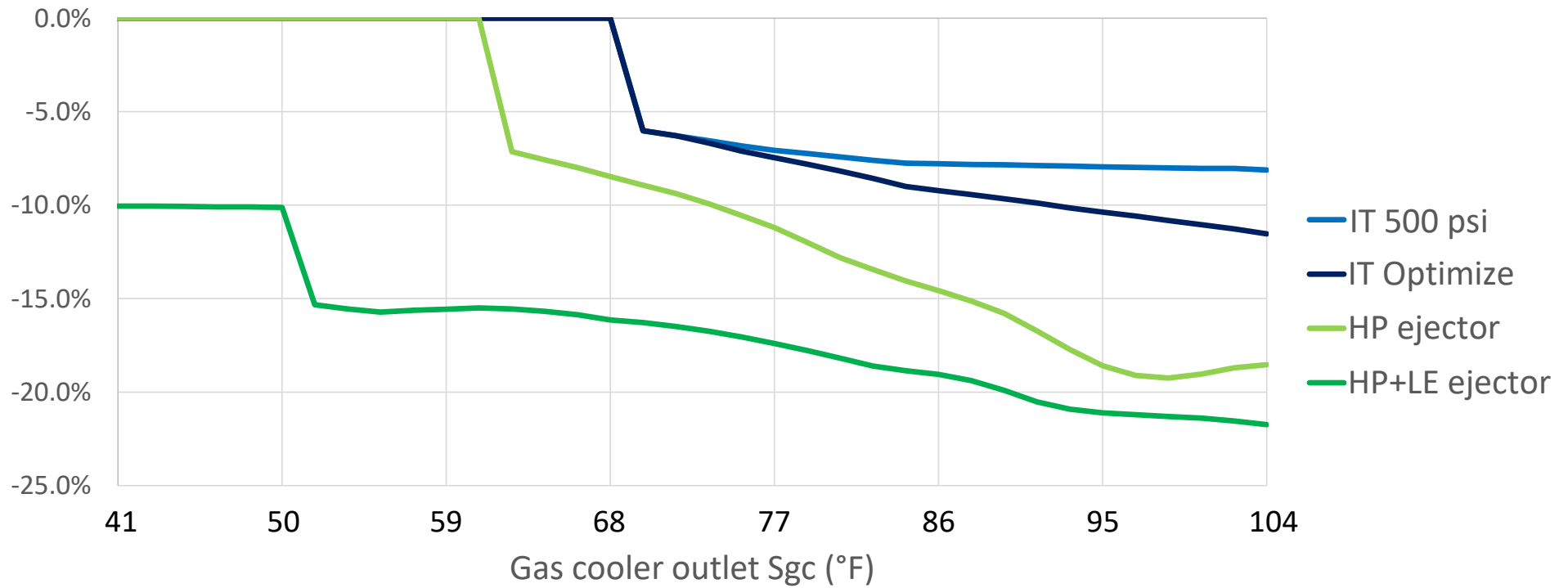


# High Pressure Lift Ejector System (HP) Warm Ambient Operation

- In warmer conditions the optimal temperature and pressure out of the gas cooler (Sgc) is high
- Higher pressure in GC will enable ejector to lift **part of the MT evaporator mass flow** through ejector to the receiver
- Both effects will result in increased mass flow in the receiver enabling the parallel compressors to run
- The gas bypass valve is closed
- The receiver pressure is controlled by the AK-PC 782A/B controller
- We recommend use of the **Optimal Receiver Pressure** function in the controller to provide the best system performance



# Energy Reduction Standard CO<sub>2</sub> Booster System as a Reference







**ENGINEERING  
TOMORROW**