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High Performance Buildings

Danfoss

Oil Management Solutions for Manifolding Scroll Compressors for Refrigeration Systems

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Danfoss (Tianjin) Ltd, Commercial Scroll Compressors

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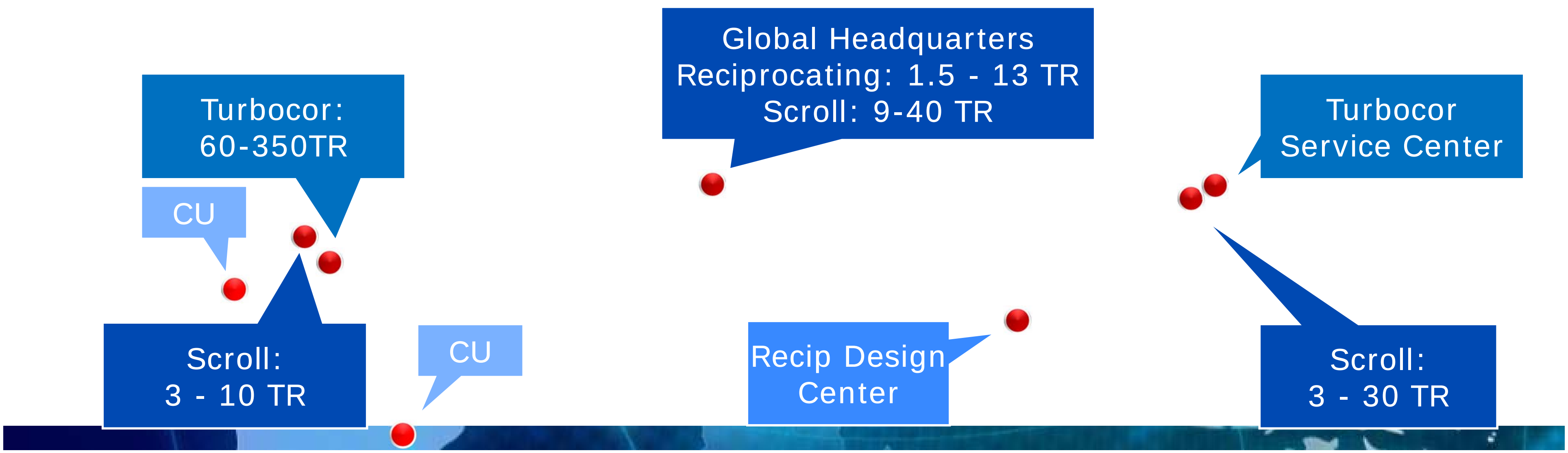
Danfoss Commercial Compressors

- Leading compressor and condensing unit Research & Development and manufacturing since 1971
- Focused on commercial air conditioning, heating and refrigeration applications
- Manufacturing in four continents: Europe, NAM, LAM, Asia
- Leading the market in commercial inverter compressor solutions



Compressors Platforms

	<10TR - 35 kW	8TR-40TR 28-140 kW	> 40TR-140 kW
Danfoss AC Scrolls	**H** (HRH, HLJ, HCJ, HRP, HLP, HCP)	**S** (SH, SZ, SM, SY, WSH)	**Tandem, Trio**
Danfoss MT, LT Refrigeration	**MTZ / MT (recip.)** **MLZ, LLZ (scroll)**	**MLZ, LLZ Tandem**	

Danfoss Inverter Compressors	**VTZ (recip.)** **VRJ (scroll)**	**VSH, VZH**	**Tandem**	**Turbocor**

Oil Management Solutions for Manifolding Scroll Compressors for Refrigeration Systems

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    - Oil Return to one Compressor
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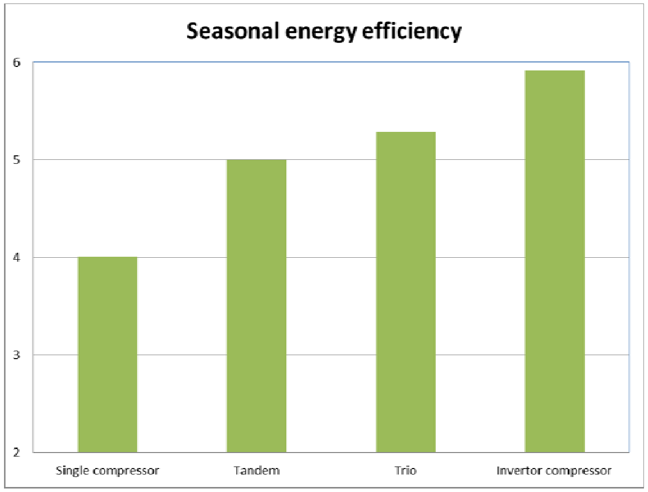
Manifolding Introduction

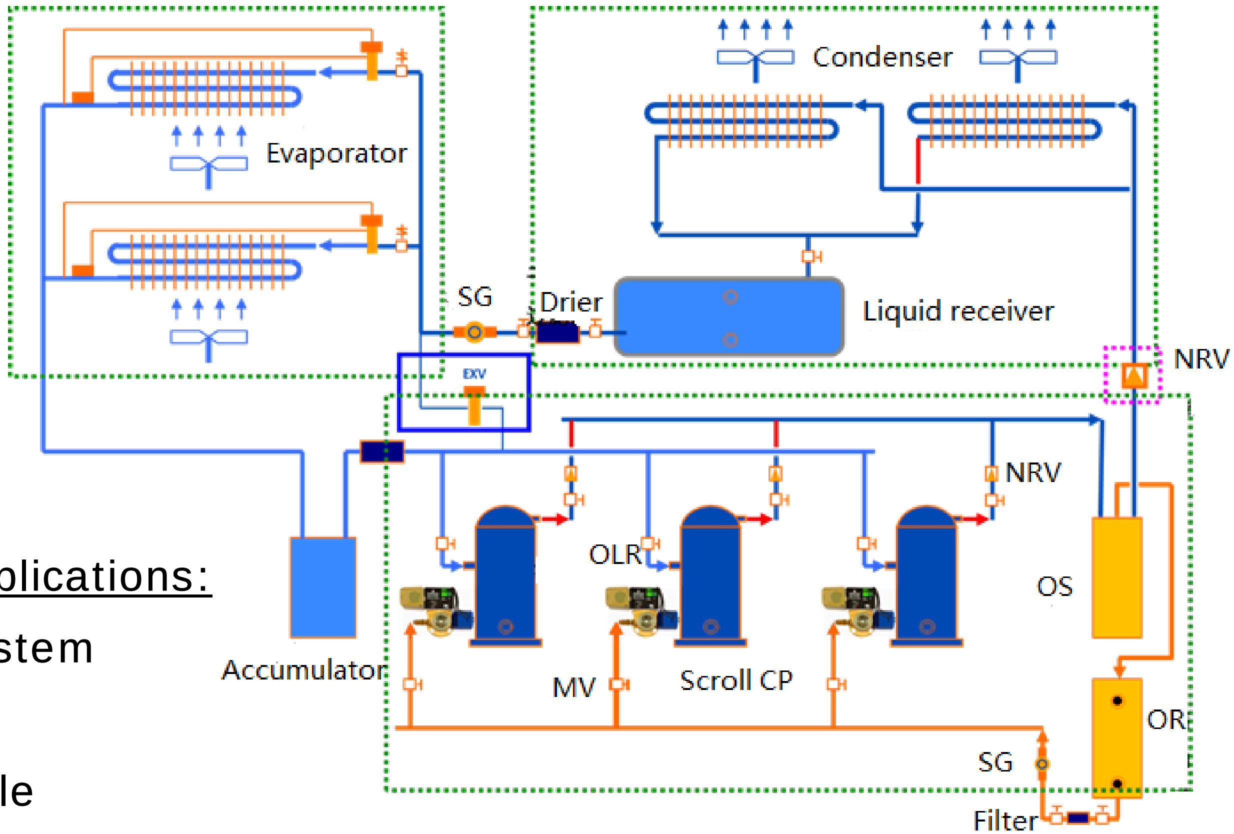
A manifolding compressor system is a unit of 2 or more compressors connected in parallel

Benefits:

- Scaling up system capacity
- Capacity modulation – higher seasonal efficiency of the system
- Lower starting load
- Back-up



Manifolding Introduction

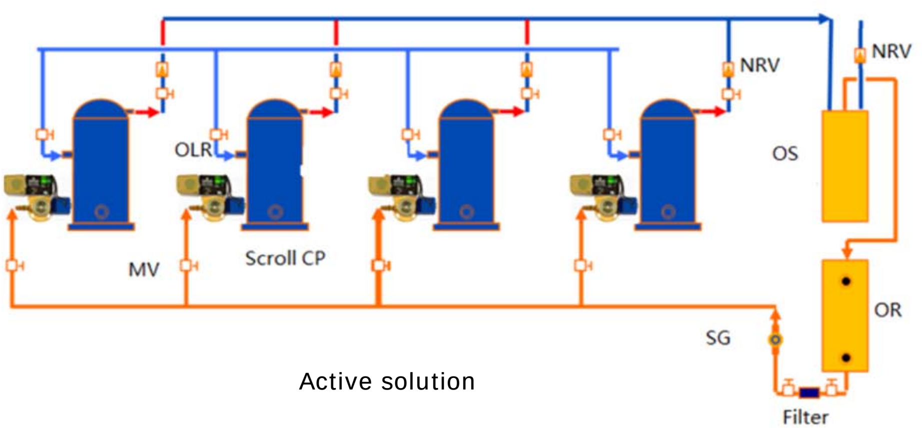


Typical manifolding applications:

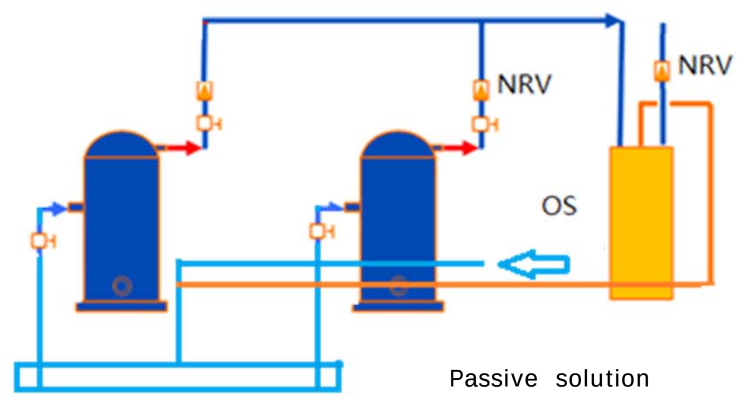
- Big refrigeration system
- Multiple cold rooms
- System with multiple evaporators

Manifolding Introduction

- Oil management solutions:
- Active Solution
  - Oil level is regulated by oil level control device (oil level regulator) – higher reliability at higher cost
- Passive Solution
  - Oil level is maintained by proper piping design for good balance – cost effective yet robust solution



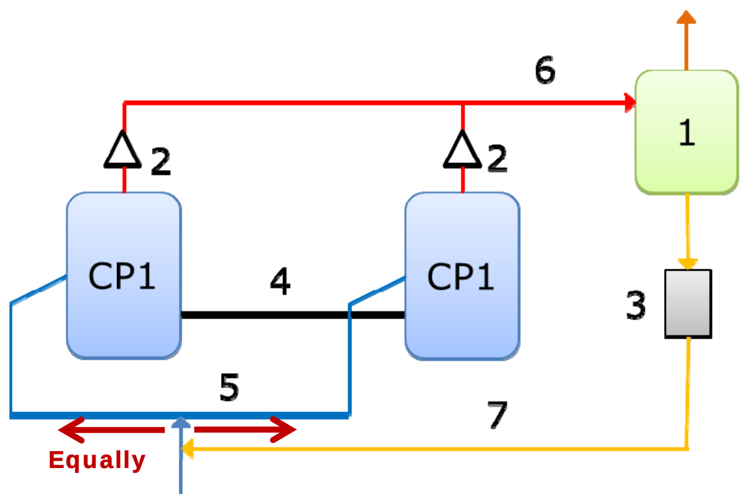
Active solution



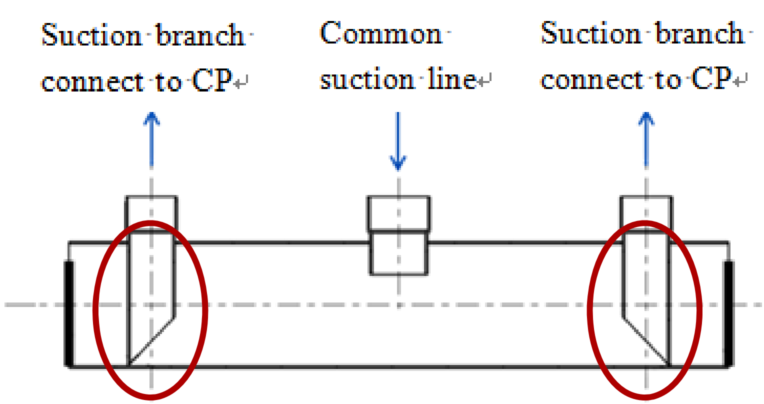
Passive solution

Passive Oil Management Solutions 1 - Oil Return to Common Suction

- 2 compressors one common oil separator
- Symmetric design
- Compressors as close as possible

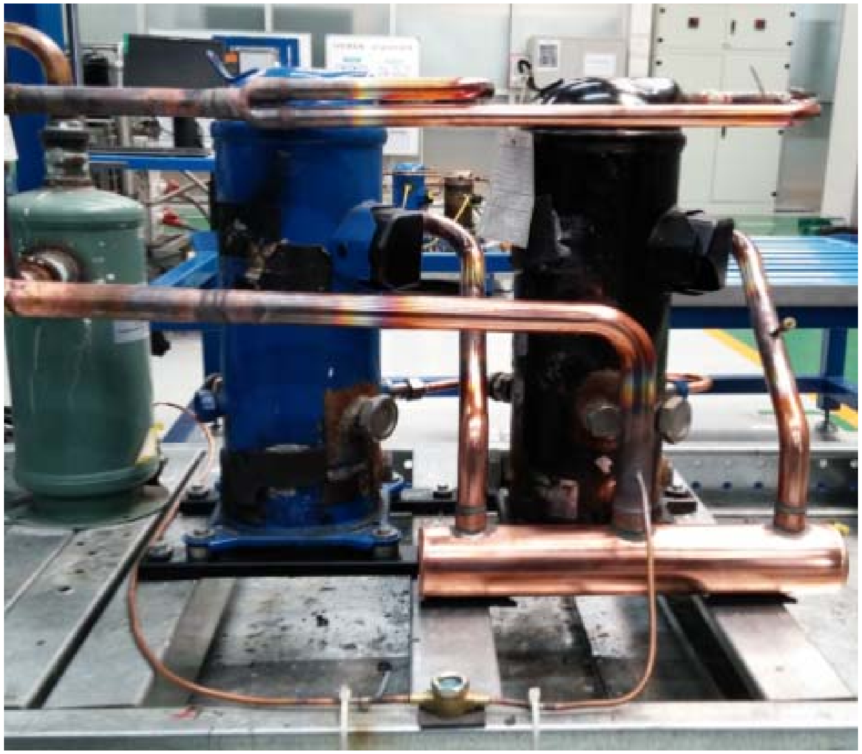


Schematic of oil return to common suction:
1. OS; 2. NRV; 3. Oil filter; 4. OBL; 5. Suction line;
6. Discharge line; 7. Oil return line



Cross-section of suction header

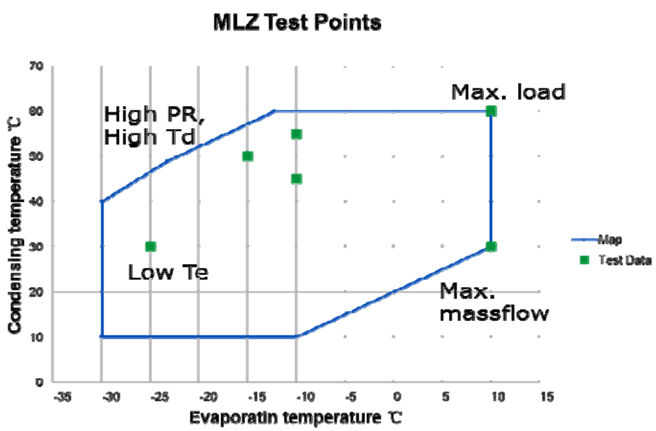
Passive Oil Management Solutions 1
- Oil Return to Common Suction



Oil return to common suction test

- Even tandem with Danfoss refrigeration scroll compressors
- Oil separator – filter type with float ball valve
- OBL is at the same level as oil sight glass
- Smaller OBL size → less contribution to gas equalization

Passive Oil Management Solutions 1 - Oil Return to Common Suction



- Low cost
- Symmetric design
- Strict OBL size selection and suction header design
- Efficient OS for single running and both running

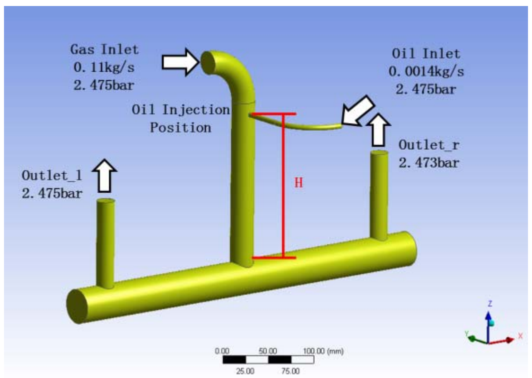
Table 2: Test result for oil return to common suction line

Condition (°C) (Tevap/Tcond)	Running Compressor (CP)	Running CP oil level (oil level in SG)	Standby CP oil level (oil level in SG)
-10/45	Single	3/4	Bottom~1/3
	Both	Full/Full	-
-10/55	Single	3/4	1/4~1/3
	Both	Full/Full	-
-25/30	Single	4/5~Full	1/4~1/3
	Both	Full/Full	-
10/30	Single	1/2	1/4~1/3
	Both	(1/2)/Full	-
-15/50	Single	3/4~Full	1/4
	Both	Full/Full	-
10/60	Single	1/3~4/5	1/3~1/2
	Both	Full/Full	-

Oil level can be guaranteed under both part-load and full-load operating.

Passive Oil Management Solutions 1
- Oil Return to Common Suction

- Oil injection position (H) influence on oil balancing



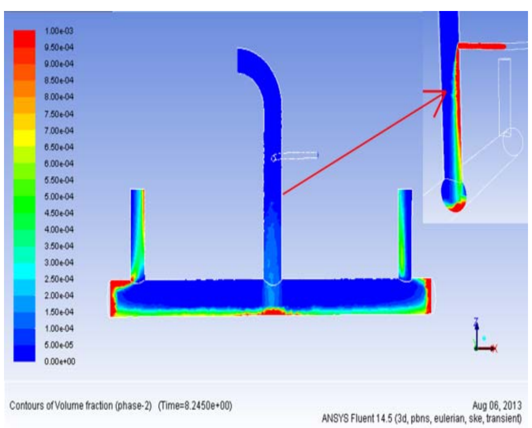


Table 2: Simulation result for oil return to common suction line

Height (mm)	147	100	60
Oil Return left (mass flow g/s)	0.729	0.75	0.809
Oil Return right (mass flow g/s)	0.648	0.632	0.593
Oil Return Difference (mass flow g/s)	0.081	0.117	0.216
Oil Distribution Difference %	5.79%	8.36%	15.40%

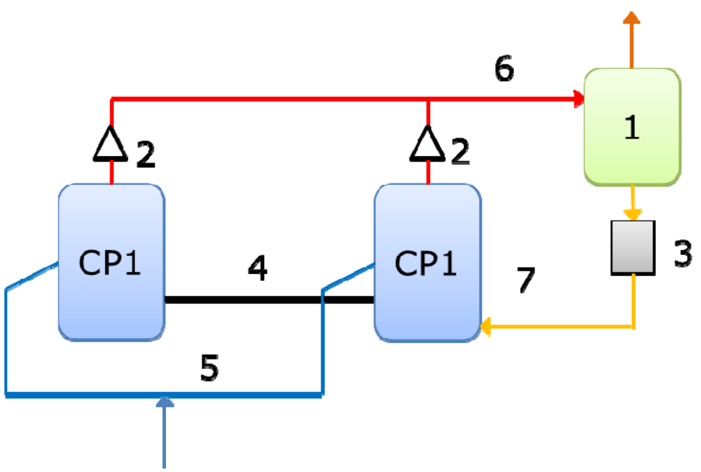
Table 3: Test result for oil return to common suction line

Condition (°C) (Tevap/Tcond/SH/SC)	Suction Difference@ Oil return position A (H =64mm)	Suction Difference@ Oil return position B (H=147mm)
-10/45/11.0/0	0.54~0.76kPa	0.16~0.21kPa
-25/30/11.1/0	0.46~0.57kPa	0.36~0.44kPa

H should be at least 5 times diameter of the common suction line.

Passive Oil Management Solutions 2
- Oil Return to one Compressor

- Low cost
- Strict OBL size selection and suction header design
- Additional port on the compressor's crankcase
- Efficient OS for single running and both running



Schematic of oil return to compressor:
1. OS; 2. NRV; 3. Oil filter; 4. OBL; 5. Suction line; 6. Discharge line; 7. Oil return line

Passive Oil Management Solutions 2
- Oil Return to one Compressor

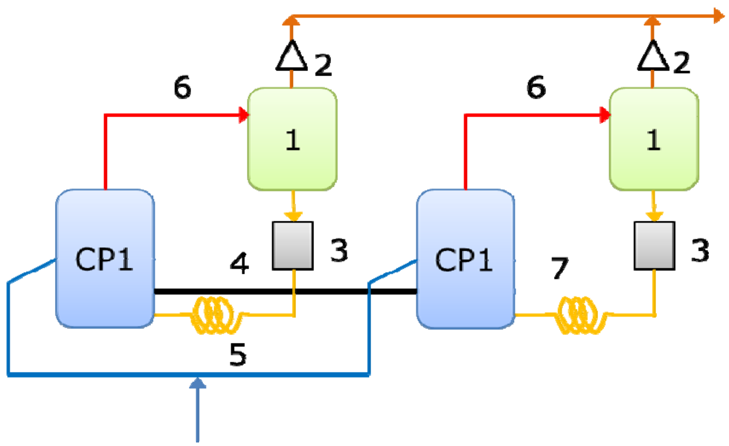
Table 4: Test result for oil return to compressor

Condition (°C) (Tevap/Tcond)	Running Compressor (CP)	Running CP oil level (oil level in SG position)	Standby CP oil level (oil level in SG position)
-10/45/11.0/0	Single	Bottom/Full	Bottom
	Both	Bottom/Full	-
-25/30/11.0/0	Single	Bottom~1/2	Bottom
	Both	Bottom/Full	-
0/50/11.0/0	Single	2/3~Full	Bottom
	Both	(1/4)/Full	-
10/30/11.0/0	Single	Bottom	Bottom
	Both	Full/Full	-

Test result:

- Oil level is acceptable
- Oil balancing is not as good as solution 1
- Additional oil return port is needed on compressor's crankcase

Passive Oil Management Solutions 3 - Individual Oil Return



Schematic of individual oil return
1. OS; 2. NRV; 3. Oil filter; 4. OBL; 5. Suction line; 6. Discharge line; 7. Oil return line with a capillary tube

- Higher cost
- More accessories
- Less strict requirement of symmetrical pipework
- Less requirement for OS efficiency for part load operation

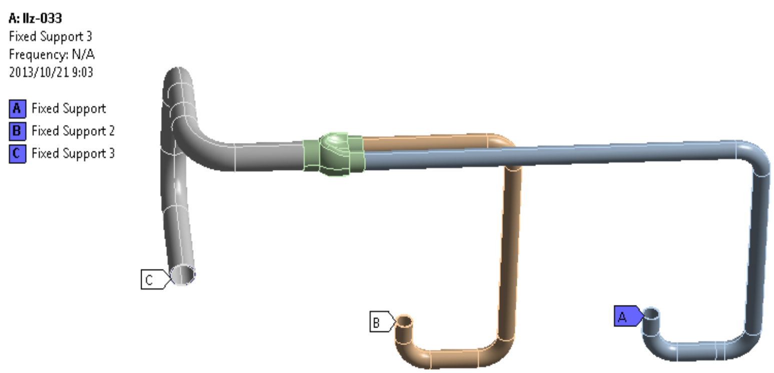
Table 5: Test result for individual oil return

Condition (°C) (Tevap/Tcond)	Running Compressor (CP)	Running CP oil level (oil level in SG position)	Standby CP oil level (oil level in SG position)
-10/45/11.0/0	Single	1/2	Bottom
	Both	Full/Full	-
-10/55/11.0/0	Single	1/4~3/4	Bottom
	Both	Full/Full	-
-25/30/11.0/0	Single	1/2~Full	Bottom
	Both	Full/Full	
10/30/11.0/0	Single	1/4	Bottom
	Both	Full/Full	-
10/60/11.0/0	Single	1/4	Bottom
	Both	Full/Full	-
-10/45/11.0/0	Single	1/2	Bottom
	Both	Full/Full	-

Oil level can be guaranteed under both part-load and full-load operating.

Vibration Simulation

- First round FEA



Discharge pipe model for the first round FEA

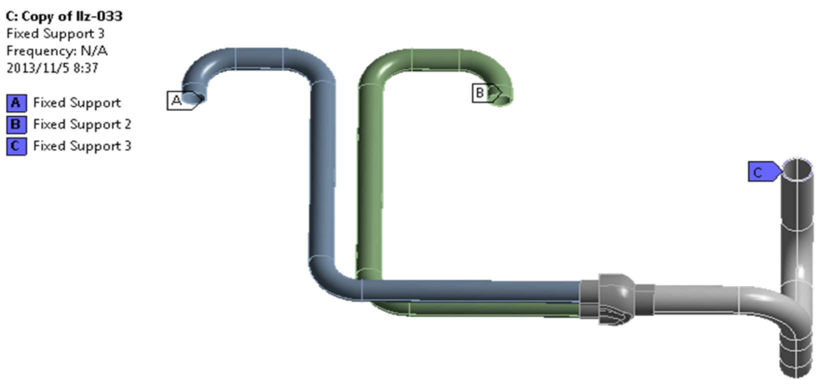
The first mode of natural frequencies is 48~49Hz, which is very close to the actual rotating speed of a motor, which will cause piping resonance, leading to fatigue failure.
Therefore a modification to discharge pipe is required in order to shift the mode away from operating frequency.

Table 6: Test result for the first round of study

Natural Frequencies, Hz		Difference		Mode match
Experiment	Calculations	Absolute	Relative	
48.2	49.3	1.1	2%	Yes
87.7	83.7	-4	5%	Yes
93.1	91.8	1.3	1%	Yes
129.9	129.8	-0.1	0%	Yes
160.4	153.1	-7.3	5%	Yes
192.6	188.3	-4.3	2%	Yes

Vibration Simulation

- Second round FEA



Discharge pipe model for the second round FEA

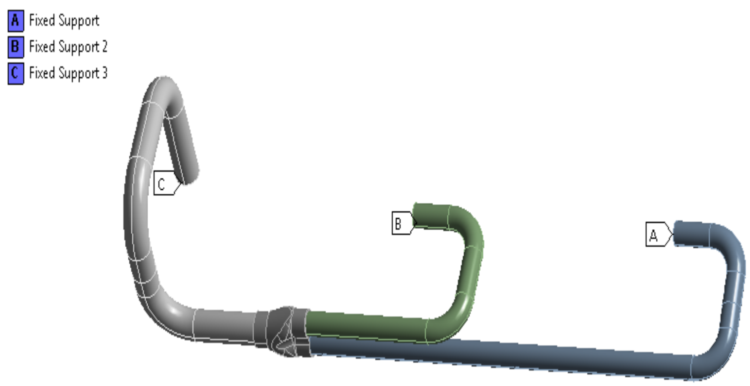
Table 7: Test result for the second round of study

Natural Frequencies, Hz		Difference		Mode match
Experiment	Calculations	Absolute	Relative	
57.4	58.7	1.3	2%	Yes
94.1	100.5	6.4	7%	Yes
113.7	134.4	20.7	18%	Yes
140.2	156.5	16.3	12%	Yes
-	172.1	-	-	-

By reducing the cantilever effect of the piping the stiffness was increased, shifting the natural frequency to higher values.
But as the mode gets closer to 60Hz, application in some regions becomes risky.

Vibration Simulation

- Third round FEA



Discharge pipe model for the third round FEA

After optimization, the orientation of compressors was modified by 90 degrees allowing even higher level of stiffness enhancement.
All the natural frequency modes were pushed away from 50/60Hz range.

Table 8: Test result for the third round of study

Natural Frequencies, Hz		Difference		Mode match
Experiment	Calculations	Absolute	Relative	
107.8	125.0	17.2	16%	Yes
136.8	156.5	19.7	14%	Yes
160.7	185.5	24.8	15%	Yes

The FEA simulation results match with test results very well, it shows a feasible way to use FEA to predict the piping design for engineering.

Conclusion

- Solution 1 – oil return to common suction is recommended
- The height of oil injection position to header should not be less than 5 times the diameter of the common suction line
- The lower the gas velocity inside a suction header the better pressure equalization in two compressors
- FEA modal analysis can help with initial piping design, by finding NF modes distribution as well as their approximate values. The real values can be confirmed during the test

Table 9: Comparison of three passive solutions

Items	Solution 1 – oil return to common suction	Solution 2 – oil return to compressor	Solution 3 – individual oil return
Long/short circuit	**Long**	Long	Long
Reliability	**Good**	Good	Good
Cost	**Low**	Low	High
Standard Compressor	**Yes**	No	Yes
Application	**Even tandem**	Even tandem	Even, uneven & multiple compressors more than two

Thank you
for your attention!

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