ASIA TURBOMACHINERY & PUMP SYMPOSIUM
MARCH 2018 | SUNTEC SINGAPORE

Case Study
Zero Leakage Compressor Seals

Presenter :
Takuya Watanabe

MITSUBISHI HEAVY INDUSTRIES COMPRESSOR CORPORATION

TEES TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION
TEXAS A&M UNIVERSITY

Presenter/Author bios

Takuya Watanabe
Mitsubishi Heavy Industries Compressor Corporation
Engineering & Design Division

He is engaged in design of auxiliary system around compressor and driver since 2005. He received B.S. degree in mechanical engineering from Meiji University in Japan.

Abstract

Dry gas seal is applied to refrigeration compressor. Some of configurations for dry gas seal system are shown in API 617 and 614, however those systems are designed with condition that leak gas from dry gas seal is released to atmosphere or flare system.

In order to minimize emissions and refrigerant make up, this paper introduces the development of new concept of leakage recovery system by distillation column (process patented), and provides verification test results.

Today's presentation

1. Background
2. Tandem Dry Gas Seal Arrangement
3. Existing Recovery System Concept
4. New Recovery System Concept
5. Test of Distillation Unit
6. Applicable Refrigerant & Case Study
7. Conclusions and Recommendations

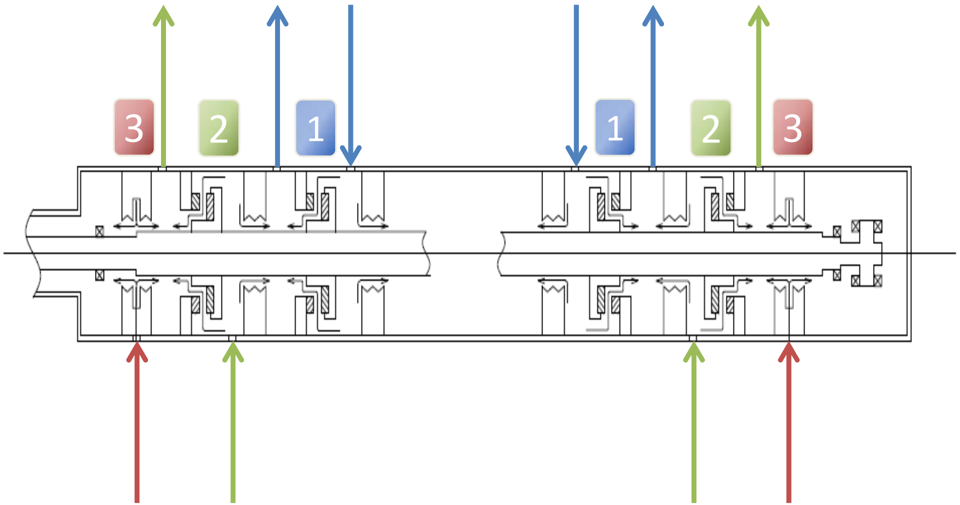
Background

Refrigeration compressors are widely applied to oil & gas industries. Various refrigerant gases, such as R134a that has high GWP (global warming potential) and NH3 that is farmable gas, are used. Dry gas seal is applied to refrigeration API 617 compressors. Some of configurations for dry gas seal system are shown in API 617 and 614, however those systems are designed such that leak gas from dry gas seal is released to atmosphere or flare system.

In order to minimize refrigerant make up or emission, sometimes leak gas from primary seal is recovered from the primary vent line. In this case, secondary seal gas (inert gas) can not be supplied to secondary seal for preventing contamination. Therefore, there is still small leak from secondary seal and recovery rate of refrigeration gas is approximately 75% of total leak gas from primary seal.

In order to achieve “zero leak”, new system with distiller is studied.

Tandem Dry Gas Seal Arrangement



1. PRIMARY SEAL

- Main seal to prevent leak of process gas
- Clean seal gas supplied (using comp. disch. gas)
- Primary vent to flare or safe area
  (Leak seal gas + inert gas)

2. SECONDARY SEAL

- Back up for primary seal
- Inert gas supplied (option for flammable gas)
- Secondary vent to safe area
  (Leak inert gas only)

3. SEPARATION SEAL

- Isolation for dry gas seal and bearing
- Inert gas supplied

Existing Recovery System Concept

LEAK GAS TO PRIMARY VENT

- <u>No Inert gas is supplied</u> to secondary seal to prevent inert gas in recovered gas.

PRIMARY VENT GAS BOOST UP

LEAK GAS FROM SECONDARY SEAL

75 %

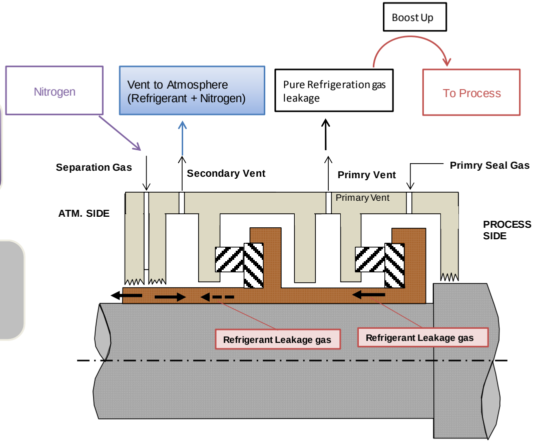
25 %

REFRIGERANT GAS RECOVERED TO SYSTEM

REFRIGERANT GAS TO SECONDARY VENT(ATM)

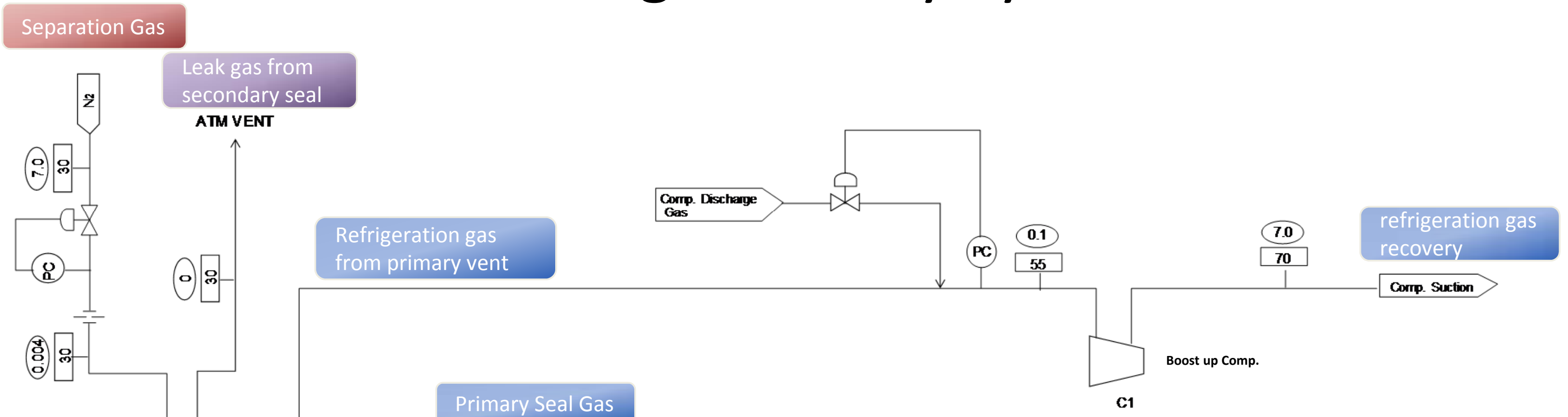
25% of TOTAL LEAK GAS IS LOST !!

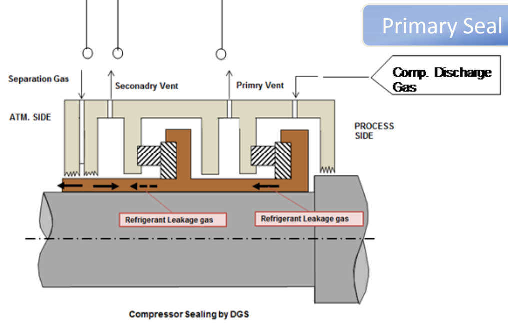
- Periodic make up required
- Emission of high GWP gas to ATM.



Compressor Sealing by DGS

Existing Recovery System





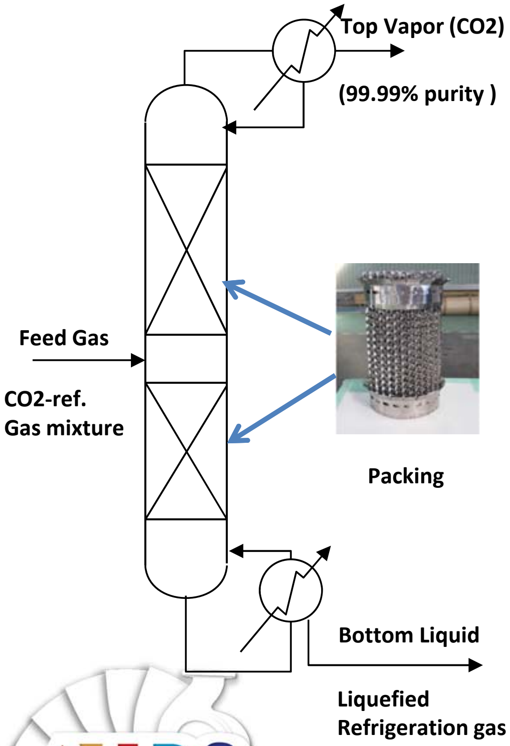
Counter measure for loss from secondary vent

Inert gas supply to secondary seal can prevent refrigeration gas leak to secondary vent.

Difficulty

Inert gas and refrigeration gas are mixed.
Separation of refrigeration gas and inert gas (N2) is difficult

New Recovery System Concept



Secondary Seal Gas : CO_2

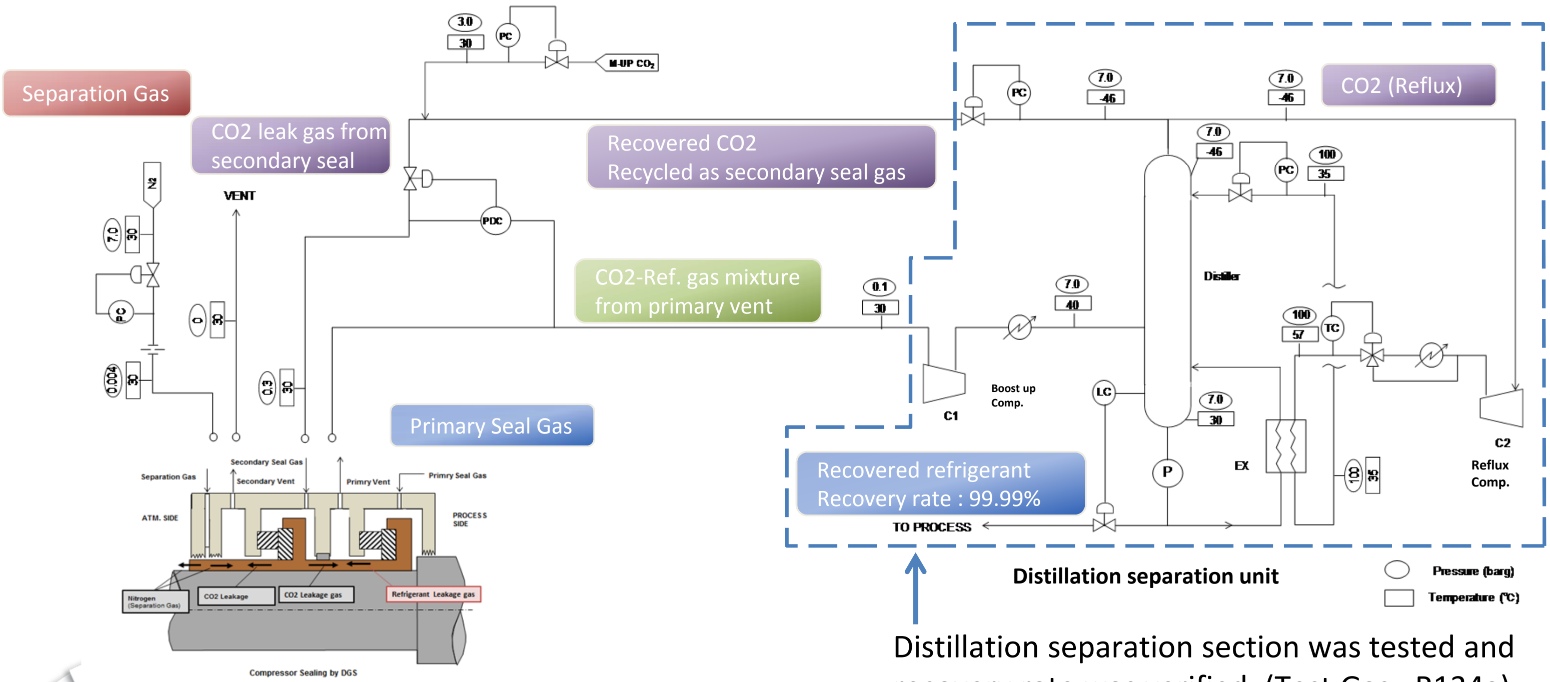
✓ CO_2 is condensable gas

Distiller

- CO_2-Refrigeration gas mixture is supplied to distiller
- Distilled refrigeration gas is recovered at bottom of distiller
- Distilled CO_2 is recovered at top and recycled as secondary seal gas.

Existing	→	New (Distillation)
25% loss of total leak gas		Zero leak (99.99% recovery)

New Recovery System

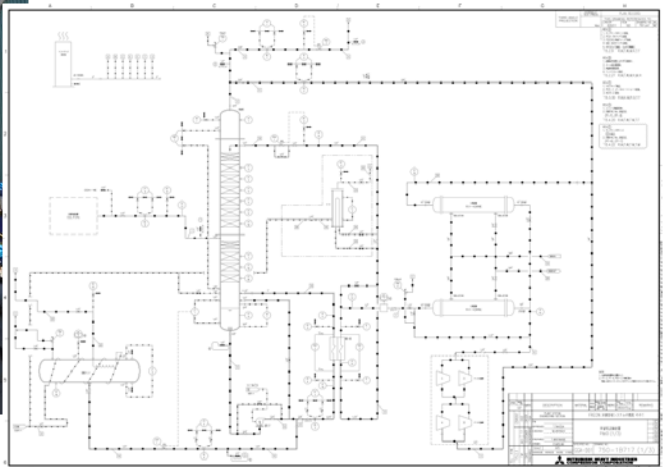


Distillation separation section was tested and recovery rate was verified. (Test Gas : R134a)

Test for Distillation Unit

- **Test Gas : R134a + CO_2**
- **Distiller pressure : 7.0 barg**
- **Temperature : -46 degC (Top)**
  30 degC (Bottom)

Distillation Column Test Unit



Test Loop P&ID

Test Results

Refrigerant Recovery Rate

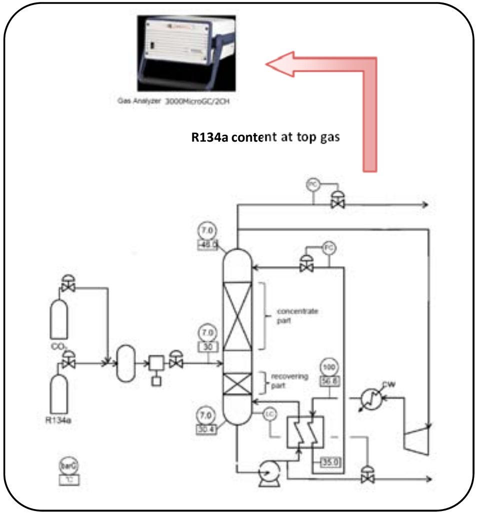
R134a content in CO_2 at top : ≦ 30 ppm

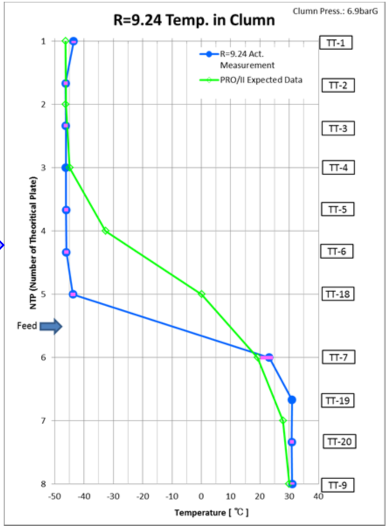
✓ R134a Recovery Rate = more than 99.99 %

Traced CO2 in Recovered Refrigerant

CO_2 Content in bottom refrigerant

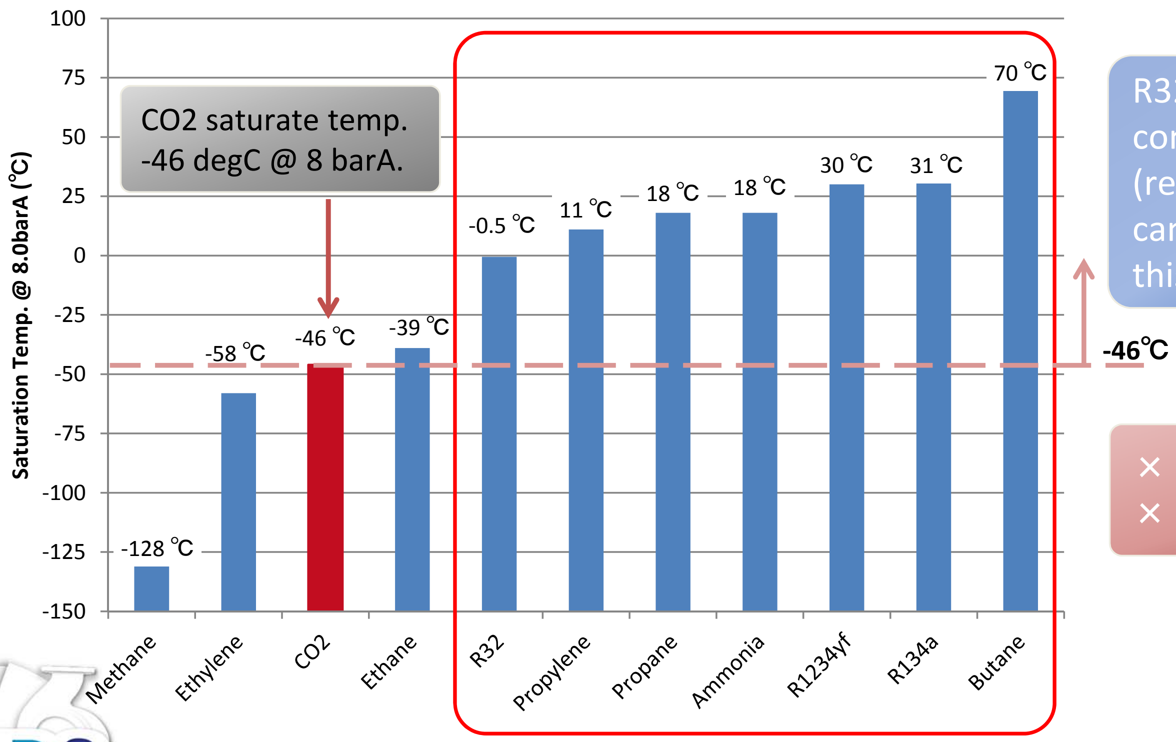
✓ 40ppm (less than expected)





		Actual Measurement	Calculation by PRO/II
Gas Composition		MW:72.56 CO2:50.8% R134a:49.2%	→
Feed gas flowrate kg/hr		14.3	→
Feed gas temp. ℃		25.8	→
column top press. barG		6.9	→
Reflux ratio		9.24	→
Column Bottom temp. ℃		31.0	→
R134a Content at top of Column		<30-30ppm	17ppm
CO2 content at bottom of Clumn		40ppm	0.30%
Temperature ℃	NTP 1	-43.6	-46.3
	1.7	-46.3	-
	2	-	-46.2
	2.3	-46.2	-
	3	-46.2	-44.9
	3.7	-46.1	-
	4	-	-32.6
	4.3	-46.1	-
	5	-43.8	0.1
	6	23.2	19.2
	6.7	23.2	-
	7	-	27.9
	7.3	30.8	-
	8	31.0	30.0

Applicable Refrigerant for Distiller with CO2

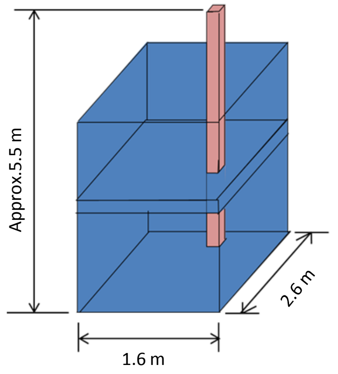


R32 or higher temp. condensable gas (refrigerant gas) can be recovered with this system.

× Low temp. Refrigerant
× Mixture Refrigerant

Case Study (R134a Case)

		Without Recovery (Leak Gas to ATM)	Existing Recovery system (Boost up)	New System (Distillation separation/Recovery)
Distillation		N/A	N/A	Yes
Recovery Rate		0 %	75%	99.99%
Make-up (*1)	R134a	10 ton/year (0.12 Nm3/h per seal)	2.4 ton/year (0.03 Nm3/h per seal)	about 300g /year
	CO2	Not required	Not required	1 ton / year
Utility	E Power	N/A	About 2 kW	About 10 kW
	Nitrogen (separation gas)	Yes	No change	No change
Convert to CO2 Emission. (*2)		13,000 ton/year	3,130 ton/year	53 ton / year



Distillation Unit Size (Reference)

(*1) DGS shaft dia : ϕ100 mm

(*2) R134a GWP : 1300, Electric Power : 0.0006 ton-CO2/kWhr

Without recovery 10 ton/year → Recovery (boost up) 2.4 ton/year → Distiller separation Less than 1 kg/year

AIPS

Advantage and Challenges

Advantage

- Contribution to Environment
  Countermeasure for zero emission and solution for regulation in the future
- No Refrigerant Make Up
  Reducing make up cost and consideration of availability at site is not required.

Challenges

- High Reliability / Availability Requirement
  Reliability / Availability shall be same as refrigeration compressor since it is a part of dry gas seal system. → reflux/boost up comp. shall have stand by comp. (diaphragm comp. is applied)
- Additional Space, Utility (C.W and power) required.
  Additional space and utility requirements are a disadvantage for offshore plant.
- Complexity / process control considerations

Conclusion and Recommendation

- 99.99% leak gas from primary seal can be recovered using distiller.
- Further study will be required to enhancement of Applicability (example: changing the packing type to reduce distiller height, further investigation of suitable gas for secondary seal to reduce reflux comp. press. ratio.)
- As a part of dry gas seal system, the bottle neck of reliability and availability is the rotating machine in distillation unit.