Case Study
Zero Leakage Compressor Seals

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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.
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

- **No Inert gas is supplied** to secondary seal to prevent inert gas in recovered gas.

- **75%** of the leak gas goes to primary vent.
- **25%** of the leak gas goes from secondary seal to secondary vent (atmosphere).

- **25% of TOTAL LEAK GAS IS LOST!!**
  - Periodic make up required
  - Emission of high GWP gas to ATM.

- **LEAK GAS TO PRIMARY VENT**
- **PRIMARY VENT GAS BOOST UP**
- **REFRIGERANT GAS RECOVERED TO SYSTEM**
- **LEAK GAS FROM SECONDARY SEAL**
- **REFRIGERANT GAS TO SECONDARY VENT (ATM)**
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: CO2

✓ CO2 is condensable gas

Distiller

- CO2-Refrigeration gas mixture is supplied to distiller
- Distilled refrigeration gas is recovered at bottom of distiller
- Distilled CO2 is recovered at top and recycled as secondary seal gas.

Existing

Liquefied Refrigeration gas

CO2-ref. Gas mixture

Feed Gas

Top Vapor (CO2)

(99.99% purity)

Bottom Liquid

New (Distillation)

Zero leak

25% loss of total leak gas

(99.99% recovery)
New Recovery System

Recovered CO2
Recycled as secondary seal gas

Separation Gas

CO2 leak gas from secondary seal

CO2-Ref. gas mixture from primary vent

Primary Seal Gas

Recovered refrigerant
Recovery rate : 99.99%

Distillation separation unit

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

- **Test Gas**: R134a + CO2
- **Distiller pressure**: 7.0 barg
- **Temperature**: -46 degC (Top)
  30 degC (Bottom)
Test Results

**Refrigerant Recovery Rate**

- R134a content in CO2 at top: \( \leq 30 \text{ ppm} \)
- R134a Recovery Rate = more than 99.99%

**Traced CO2 in Recovered Refrigerant**

- CO2 Content in bottom refrigerant
  - 40ppm (less than expected)

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**Table: Actual Measurement vs Calculation by PRO/II**

<table>
<thead>
<tr>
<th>Gas Composition</th>
<th>Actual Measurement</th>
<th>Calculation by PRO/II</th>
</tr>
</thead>
<tbody>
<tr>
<td>R134a</td>
<td>40.8%</td>
<td>49.2%</td>
</tr>
<tr>
<td>CO2</td>
<td>50.8%</td>
<td>50.8%</td>
</tr>
</tbody>
</table>

**Graph: R=9.24 Temp in Clumn**

- Temperature in NTP & Column Bottom temp.
- Gas Composition Feed: R134a-50.8%, CO2-49.2%
- Feed gas flowrate kg/hr: 14.3
- Feed gas temp. °C: 25.8
- Column top press. barG: 6.9
- Reflux ratio: 9.24
- Column Bottom temp. °C: 31.0
- R134a Content at top of Column: <30-30ppm (17ppm)
- CO2 content at bottom of Clumn: 40ppm (0.30%)

**Diagram: R134a content at top gas**

- Graph showing temperature and pressure distribution across the columns.
- Temperature in °C & Column Top press. barG.
- Reflux ratio: R134a content at top gas.
- CO2 content at bottom of Clumn: 40ppm (0.30%)
Applicable Refrigerant for Distiller with CO2

CO2 saturate temp. -46 degC @ 8 barA.

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

× Low temp. Refrigerant
× Mixture Refrigerant
## Case Study (R134a Case)

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

(*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
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.