Reducing Emissions from Compressor Seals

Lessons Learned from Natural Gas STAR

Transmission Technology Transfer Workshop

Duke Energy Gas Transmission
Interstate Natural Gas Association of America (INGAA) and
EPA's Natural Gas STAR Program

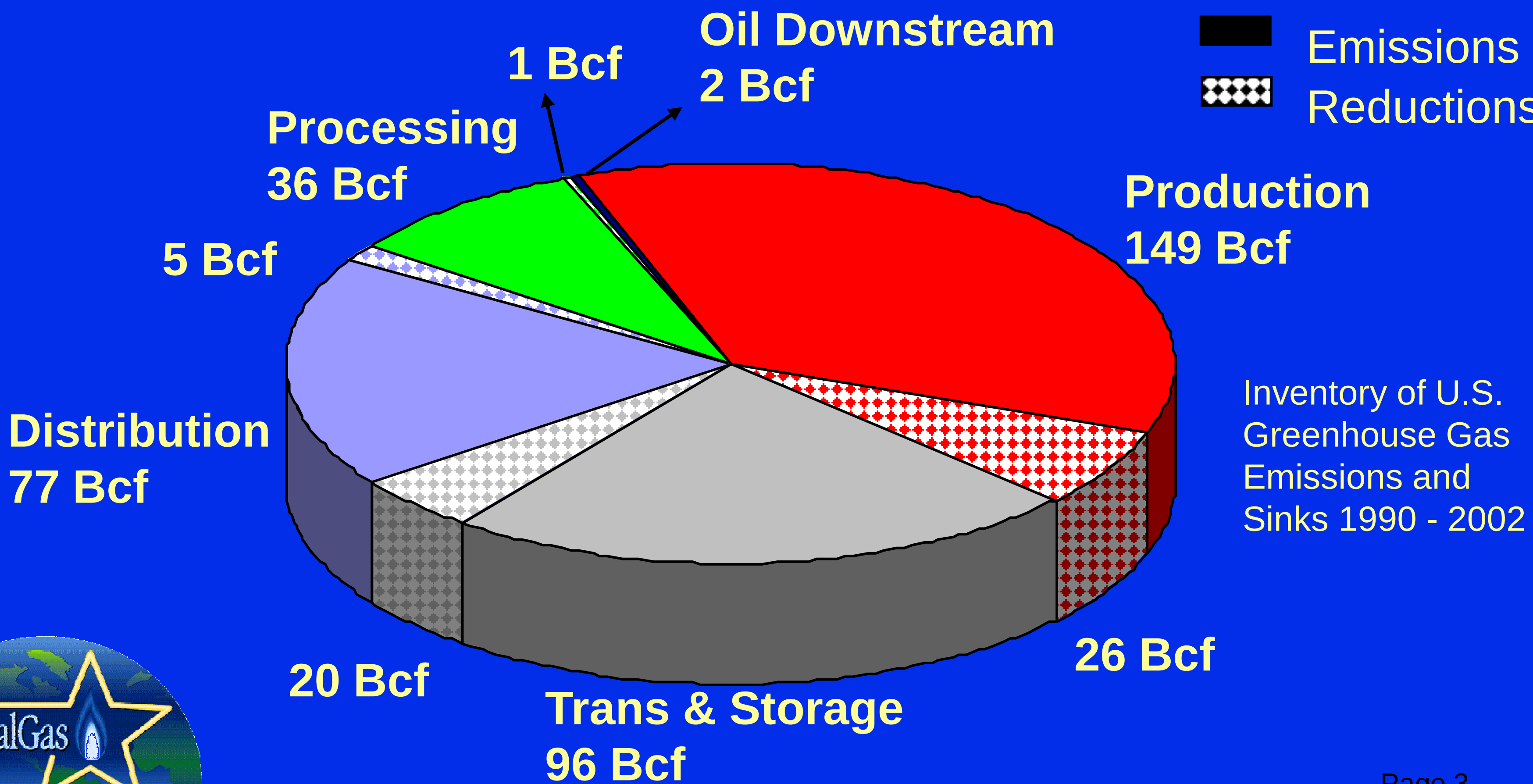
September 22, 2004

Compressor Seals: Agenda

- Methane Losses
- Methane Recovery
- Is Recovery Profitable?
- Industry Experience
- Discussion Questions

Methane Losses from Transmission and Storage

- Transmission and storage sector responsible for 96 billion cubic feet (Bcf) in methane emissions

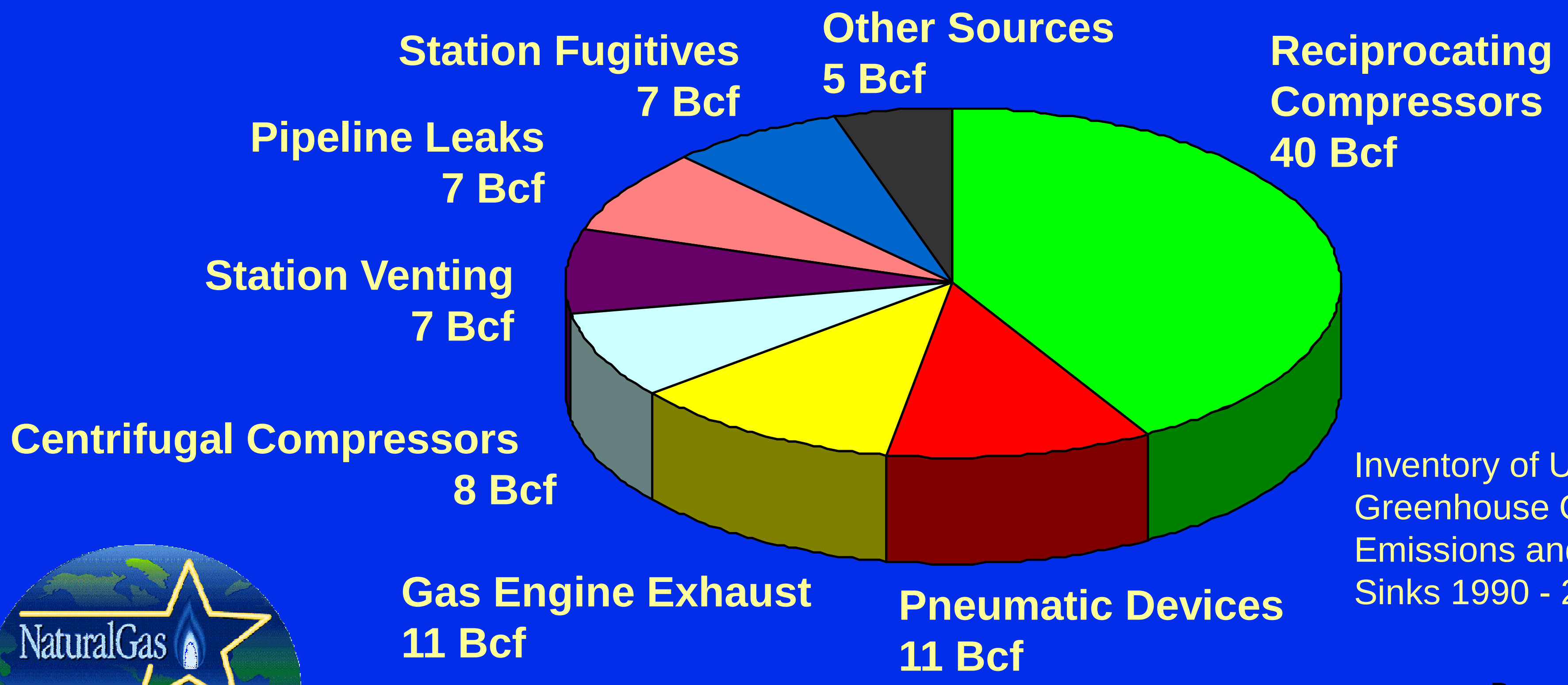


Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2002

Reducing Emissions, Increasing Efficiency, Maximizing Profits

Methane Losses from Compressor Seals

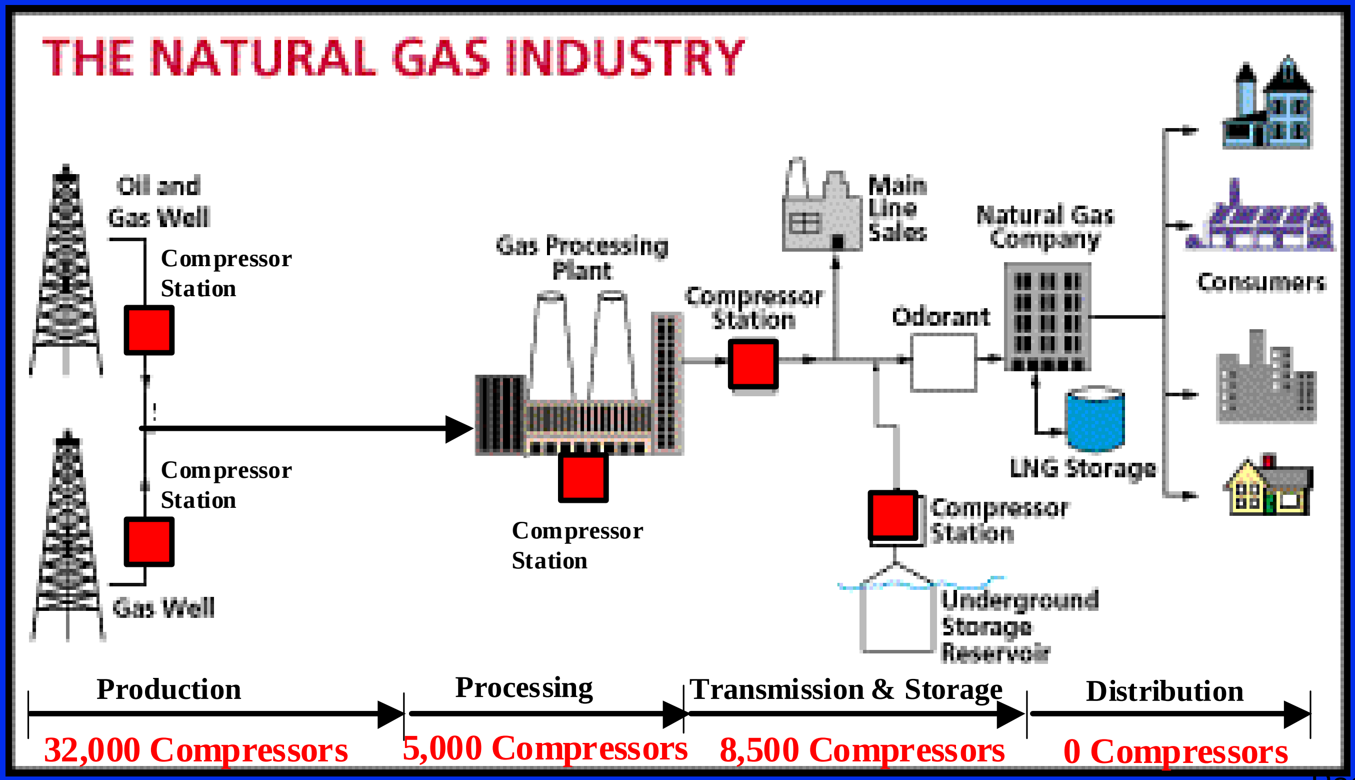
- Compressor seals contribute 50% of transmission and storage emissions
  - **40 Bcf from reciprocating compressors**
  - **8 Bcf from centrifugal compressors**



Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2002

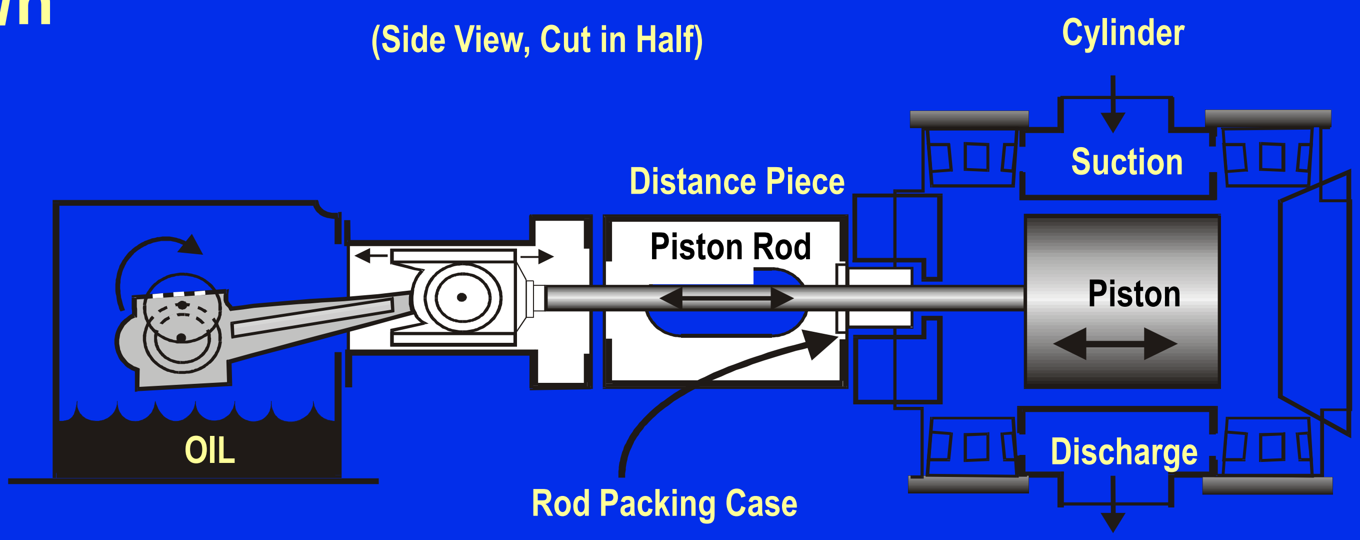
Compressor Seals
What is the problem?

- Compressor seals account for 13% of natural gas industry emissions
  - **Over 45,000 compressors in the natural gas industry**
  - **Over 8,500 compressors in gas transmission sector**



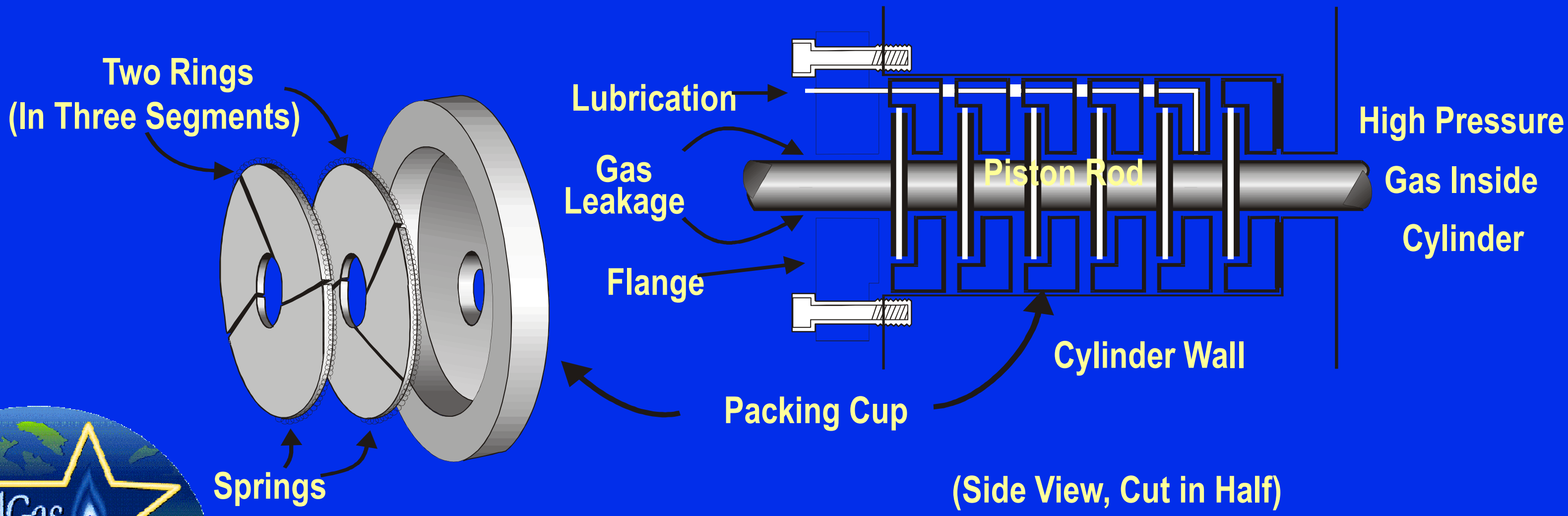
Methane Losses from Reciprocating Compressors

- Reciprocating compressor rod packing leaks some gas by design
  - **Newly installed packing may leak 60 cubic feet per hour (cf/h)**
  - **Worn packing has been reported to leak up to 900 cf/h**



Reciprocating Compressor Rod Packing

- A series of flexible rings fit around the shaft to prevent leakage
- Leakage still occurs through nose gasket, between packing cups, around the rings and between rings and shaft



Reducing Emissions, Increasing Efficiency, Maximizing Profits

Gas STAR Partners Reduce Emission with Economic Rod Packing Replacement

Decision Process

Monitor and record baseline packing leakage and piston rod wear

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Compare current leak rate to initial leak rate to determine leak reduction expected

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Assess costs of replacements

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Determine economic replacement threshold

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Replace packing and rods where cost-effective

Methane Recovery Through Economic Rod Packing Replacement

- Step 1: Monitor and record baseline leakage and rod wear
  - **Establishing baseline leak rates and monitoring rod wear can help to track leakage and evaluate economics**

- Step 2: Compare current leak rate to initial leak rate to determine leak reduction expected
  - **Leak Reduction Expected (LRE) = Current Leak Rate (CL) – Initial Leak Rate (IL)**
  - **Example: The current leak rate is measured as 100 cf/h, the same component leaked 11.5 cf/h when first installed**

LRE = 100 cf/h – 11.5 cf/h
LRE = 88.5 cf/h

Methane Recovery Through Economic Rod Packing Replacement

- Step 3: Assess costs of replacements
  - **A set of rings: $ 500 to $ 800**
    (with cups and case) $1500 to $2500
  - **Rods: $1800 to $3500**
- Step 4: Determine economic replacement threshold
  - **Partners can determine economic threshold for all replacements**

$$\text{Economic Replacement Threshold (scfh)} = \frac{CR * DF * 1{,}000}{(H * GP)}$$

Where:

CR = Cost of replacement ($)
DF = Discount factor (%) @ interest i
H = Hours of compressor operation per year
GP = Gas price ($/Mcf)

$$DF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Is Recovery Profitable?

- Step 5: Replace packing and rods when cost-effective
  - **Example:**

Rings Only

Rings:	$1,200
Rod:	$0
Gas:	$3/Mcf
Operating:	8,000 hrs/yr

Leak Reduction Expected (scfh)	Payback Period (yrs)
55	1
29	2
20	3
16	4
13	5

Rod and Rings

Rings:	$1,200
Rod:	$7,000
Gas:	$3/Mcf
Operating:	8,000 hrs/yr

Leak Reduction Expected (scfh)	Payback Period (yrs)
376	1
197	2
137	3
108	4
90	5

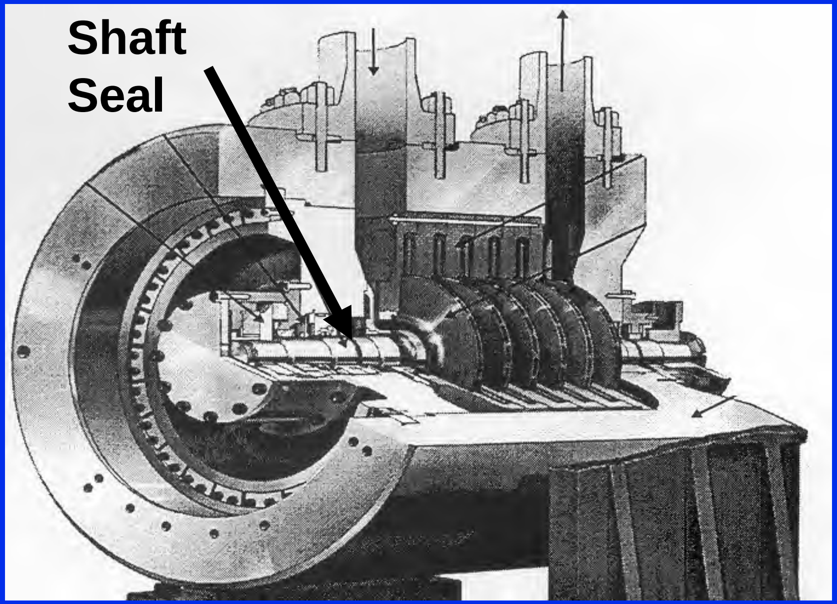
Based on 10% interest rate
Mcf = thousand cubic feet, scfh = standard cubic feet per hour

Industry Experience

- One partner reported replacing worn rod packing rings on 15 compressor units
- Estimated gas savings of 7,000 Mcf or $21,000 @ $3/Mcf
- Cost including materials and labor of $17,000
- Payback period of less than one year

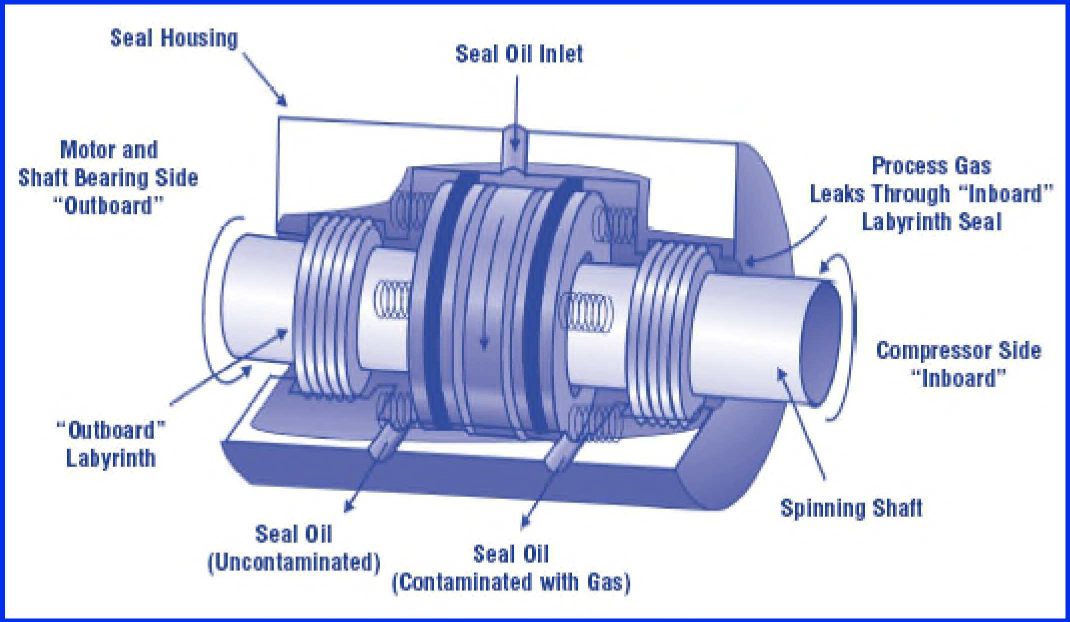
Methane Losses from Centrifugal Compressors

- Centrifugal compressor wet seals leak little gas at the seal face
  - **Seal oil degassing may vent 40 to 200 cubic feet per minute (cf/m) to the atmosphere**
  - **A Natural Gas STAR partner reported wet seal emissions of 75 Mcf/day (52 cf/m)**



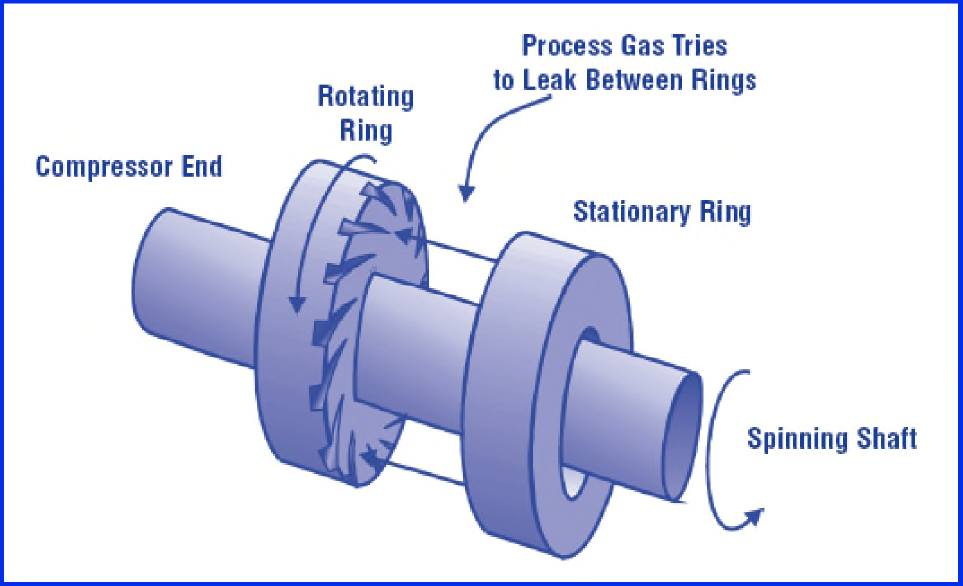
Centrifugal Compressor Wet Seals

- High pressure seal oil is circulates between rings around the compressor shaft
- Gas absorbs in the oil on the inboard side
- Little gas leaks through the oil seal
- Seal oil degassing vents methane to the atmosphere



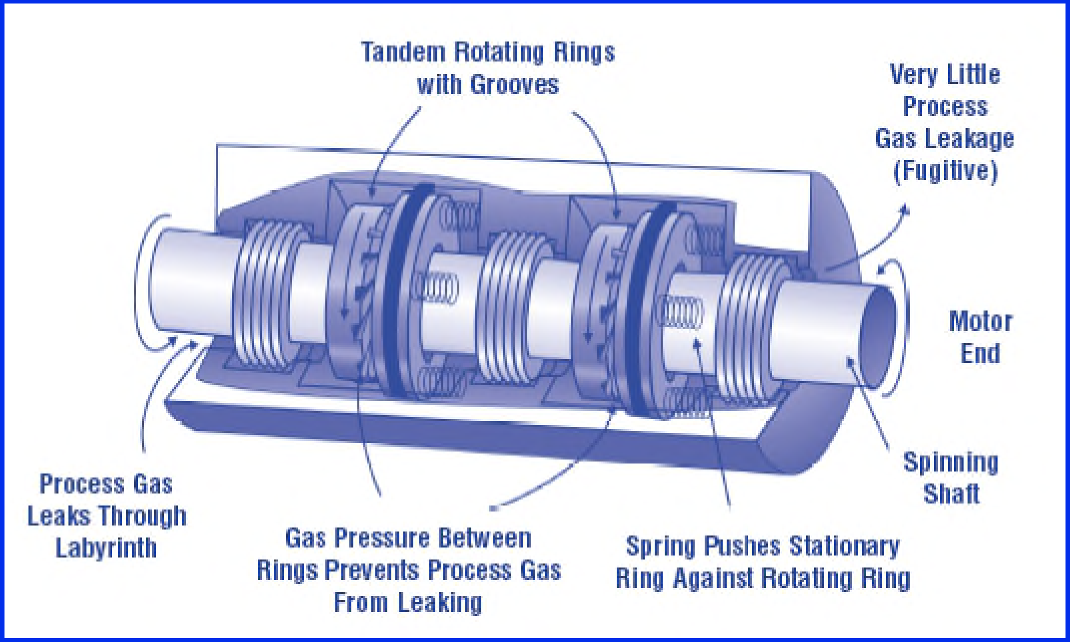
Gas STAR Partners Reduce Emissions with Dry Seals

- Dry seal springs press the stationary ring in the seal housing against the rotating ring when the compressor is not rotating
- At high rotation speed, gas is pumped between the seal rings creating a high pressure barrier to leakage
- Only a very small amount of gas escapes through the gap
- 2 seals are often used in tandem



Methane Recovery with Dry Seals

- Dry seals typically leak at a rate of only 0.5 to 3 cf/m
  - **Significantly less than the 40 to 200 cf/m emissions from wet seals**
- These savings translate to approximately $48,960 to $279,360 in annual gas value



Other Benefits with Dry Seals

- Aside from gas savings and reduced emissions, dry seals also:
  - **Lower operating cost**
    - **Dry seals do not require seal oil make-up**
  - **Reduced power consumption**
    - **Wet seals require 50 to 100 kiloWatt hours (kW/hr) for ancillary equipment while dry seals need only 5 kW/hr**
  - **Improve reliability**
    - **More compressor downtime is due to wet seals**
  - **Eliminate seal oil leakage into the pipelines**
    - **Dry seals lower drag in pipelines (and horsepower to overcome)**

Gas STAR Partners Reduce Emissions with Dry Seal Replacement

Decision Process

Identify candidates for wet seal replacement

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Estimate savings of dry seal retrofit

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Determine costs for conversion to dry seals

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Compare costs to savings

Decision Process to Replace Seals

- Step 1: Identify candidates for replacement
  - **Dry seals are routinely used for compressors operating up to 1,500 pounds per square inch (psi), up to 400º Fahrenheit**
- Step 2: Estimate savings from a dry seal
  - **Gas savings between 34 to 196 cf/m**
  - **Other dry seal benefits ≈ $63,000/yr**

1. Reduced seal power losses = $13,900
2. Reduced oil pump/fan losses= $4,000
3. Increased pipeline flow efficiency = $26,600
4. Reduced oil losses = $3,500
5. Reduced O&M, downtime = $15,000

Decision Process to Replace Seals

- Step 3: Determine dry seal conversion costs
  - **Dry seals cost $5,000 to $6,000 per inch of shaft diameter or $8,000 to $10,000 for tandem seals**
  - **Beam compressors require two seals, one at each end**
  - **Overhung compressors require one seal at the inboard end**

Decision Process to Replace Seals

- Step 4: Compare costs and savings for a 6-inch shaft beam compressor

Cost Category	Dry Seal ($)	Wet Seal ($)
Implementation Costs		
Seal costs (2 dry @ $10,000/shaft-inch, w/testing)	120,000	
Seal costs (2 wet @ $5,000/shaft-inch)		60,000
Other costs (engineering, equipment installation)	120,000	0
Total Implementation Costs	240,000	60,000
Annual O&M	10,000	73,000
Annual methane emissions[4] (@ $3.00/Mcf; 8,000 hrs/yr)		
2 dry seals at a total of 6 scfm	8,640	
2 wet seals at total 100 scfm		144,000
Total Costs Over 5-Year Period ($):	333,200	1,145,000
Total Dry Seal Savings Over 5 Years:		
Savings ($)	811,800	
Methane Emissions Reductions (Mcf) (at 45,120 Mcf/yr)	225,600	

Flowserve Corporation

Is Recovery Profitable?

- Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hr/yr
  - **Net Present Value = $531,940**
    - **Assuming a 10% discount over 5 years**
  - **Internal Rate of Return = 86%**
  - **Payback Period = 14 months**
    - **Ranges from 8 to 24 months based on wet seal leakage rate**
- Economics are better for new installations
  - **Vendors report that 90% of compressors sold to the natural gas industry are centrifugal with dry seals**

Industry Experience

- One Gas STAR partner replaced a wet seal with a dry seal and reduced emissions by 97%
- Dry seal leaked 2 Mcf/d versus wet seal emissions of 75 Mcf/d

Discussion Questions

- To what extent have you replaced rod packing or seals in your reciprocating and centrifugal compressors?
- How can the Lessons Learned study be improved upon or altered for use in your operation(s)?
- What are the barriers (technological, economic, lack of information, regulatory, etc.) that are preventing you from implementing this technology?