Methane Savings from Compressors

Lessons Learned from the
Natural Gas STAR Program

DCP Midstream and the Gas Processors Association

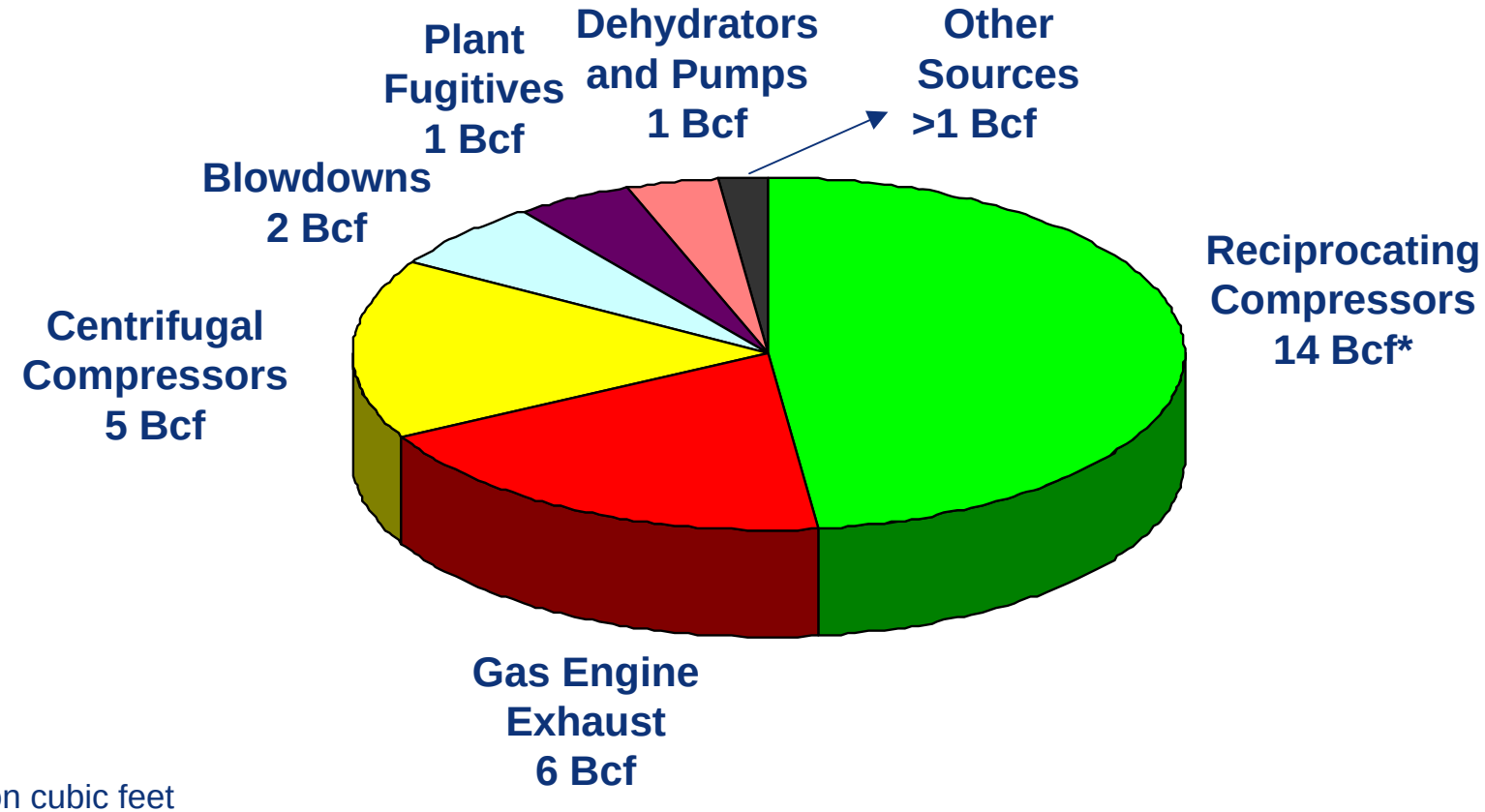
Processors Technology Transfer Workshop
Houston, Texas
April 24, 2007

epa.gov/gasstar

Compressors: Agenda

- Methane Losses from Reciprocating Compressors
  - Methane Savings through Economic Rod Packing Replacement
    - Is Rod Packing Replacement Profitable?
    - Industry Experience – Occidental
- Methane Losses from Centrifugal Compressors
  - Methane Savings through Dry Seals
    - Is Wet Seal Replacement Profitable?
    - Industry Experience – PEMEX
  - Finding More Opportunities
- Discussion

Methane Emissions from Natural Gas Processing Sector (2005)

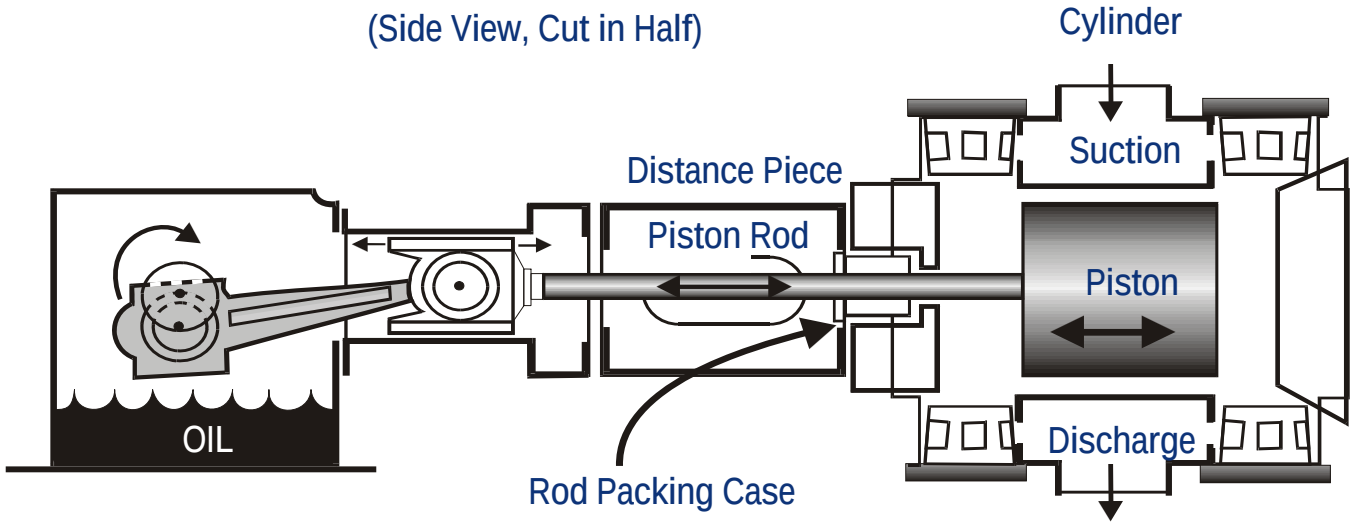


*Bcf = billion cubic feet

EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2005.* April, 2007. Available on the web at: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissions.html
Natural Gas STAR reductions data shown as published in the inventory.

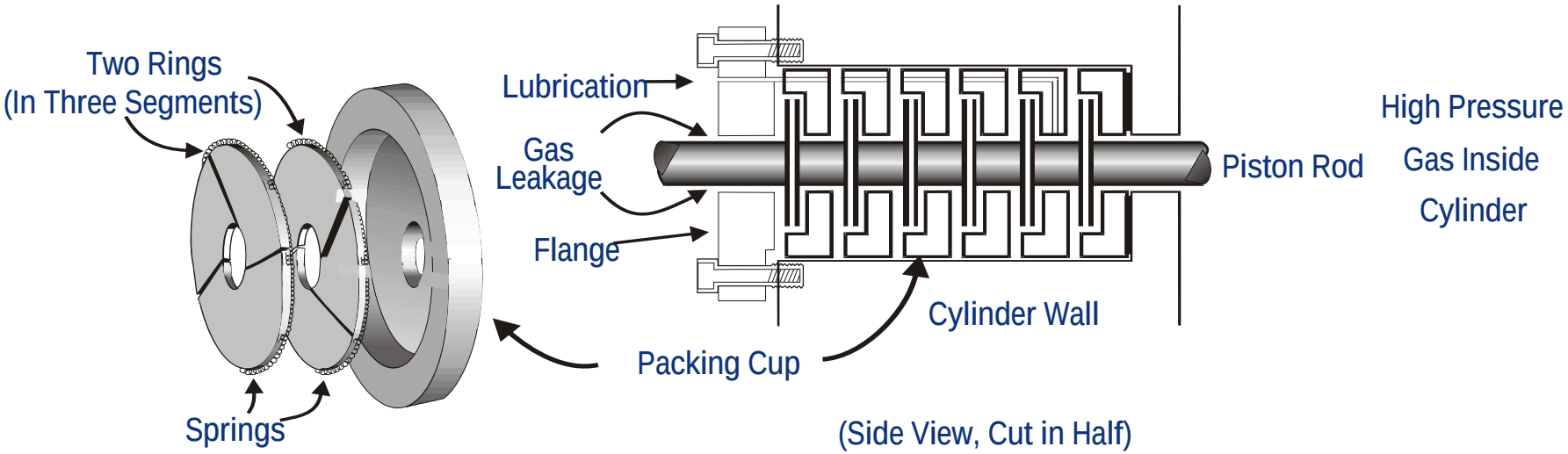
Methane Losses from Reciprocating Compressors

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



Reciprocating Compressor Rod Packing

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



Methane Losses from Rod Packing

Emission from Running Compressor	99	cf/hour-packing
Emission from Idle/Pressurized Compressor	145	cf/hour-packing
Leakage from Idle Compressor Packing Cup	79	cf/hour-packing
Leakage from Idle Compressor Distance Piece	34	cf/hour-packing

Leakage from Rod Packing on Running Compressors				
Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (cf/hour)	70	63	150	24

Leakage from Rod Packing on Idle/Pressurized Compressors				
Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (cf/hour)	70	N/A	147	22

PRCI/ GRI/ EPA. *Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations*

Methane Savings Through Economic Rod Packing Replacement

- Assess costs of replacements
  - A set of rings: $ 675 to $ 1,100
    (with cups and case) $ 2,100 to $ 3,400
  - Rods: $ 2,500 to $13,500
    - Special coatings such as ceramic, tungsten carbide, or chromium can increase rod costs
- Determine economic replacement threshold
  - Partners can determine economic threshold for all replacements

Economic Replacement Threshold (cf/hour) = $\frac{CR * DF * 1{,}000}{(H * GP)}$

Where:

CR = Cost of replacement ($)
DF = Discount factor (%) at interest *i*
H = Hours of compressor operation per year
GP = Gas price ($/thousand cubic feet)

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

Is Rod Packing Replacement Profitable?

- Measure initial leakage rate
  - i.e. leakage expected with new rings
- Periodically measure leakage increase

Rings Only

Rings: $1,620
Rod: $0
Gas: $7/Mcf
Operating: 8,000 hours/year

Leak Reduction Expected (cf/hour)	Payback (year)
32	1
17	2
12	3
9	4

Rod and Rings

Rings: $1,620
Rod: $9,450
Gas: $7/Mcf
Operating: 8,000 hours/year

Leak Reduction Expected (cf/hour)	Payback (year)
217	1
114	2
79	3
62	4

Based on 10% interest rate
Mcf = thousand cubic feet

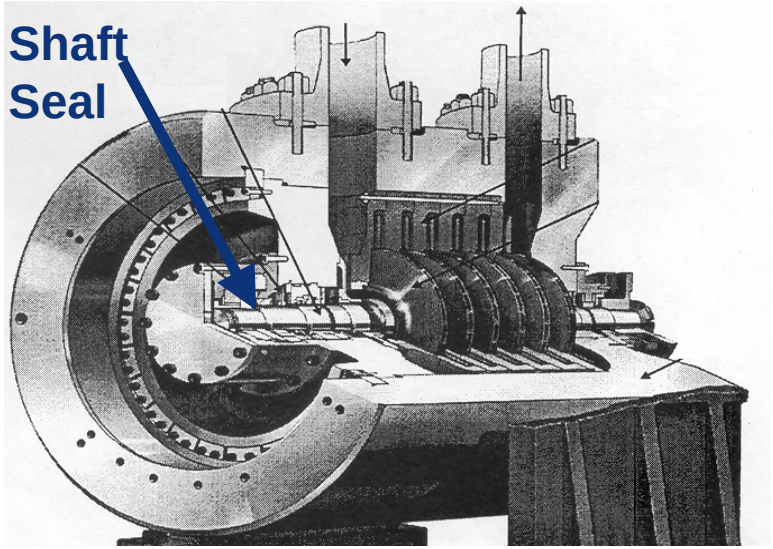
Industry Experience – Occidental

- Occidental upgraded compressor rod packing at its Elk Hills facility in southern California
- Achieved reductions of 400 Mcf/day/compressor
- Saving 145 MMcf/year
- Payback in under 3 years

Source: Occidental

Methane Losses from Centrifugal Compressors

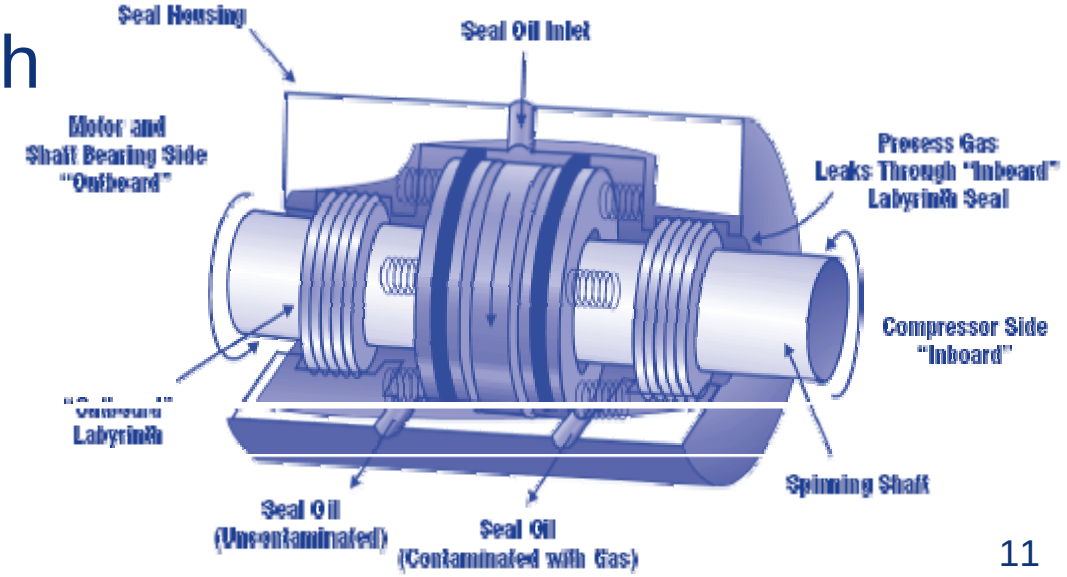
- Centrifugal compressor wet seals leak little gas at the seal face
  - Seal oil degassing may vent 40 to 200 cubic feet per minute (cf/minute) to the atmosphere
  - A Natural Gas STAR Partner reported wet seal emissions of 75 Mcf/day (52 cf/minute)



Centrifugal Compressor Wet Seals

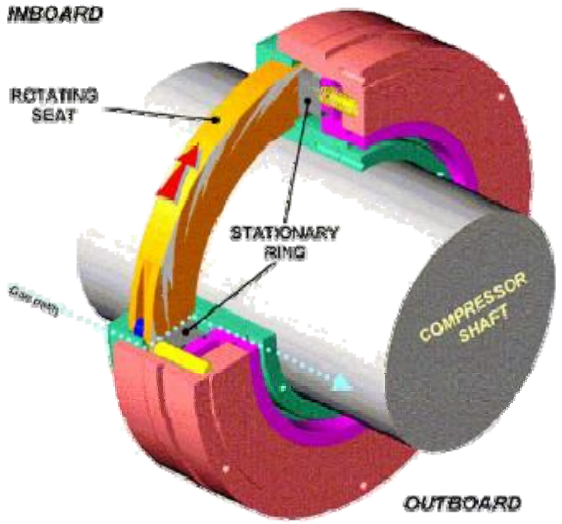
- High pressure seal oil circulates between rings around the compressor shaft
- Oil absorbs the gas on the inboard side
- Little gas leaks through the oil seal
- Seal oil degassing vents methane to the atmosphere

Source: PEMEX

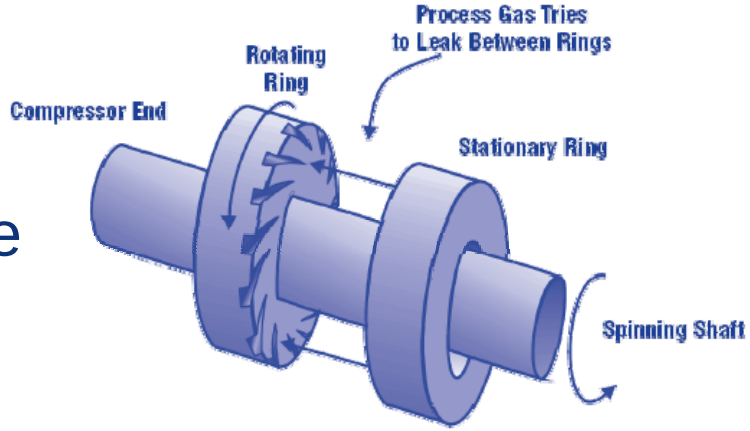


Natural Gas STAR Partners Reduce Emissions with Dry Seals

- Dry seal springs press the stationary ring in the seal housing against the rotating ring when the compressor is not rotating
- Sealing at high rotation speed pump gas between the seal rings creating a high pressure barrier to leakage
- Only a very small volume of gas escapes through the gap
- Two seals are often used in tandem
- Can operate for compressors up to 3,000 pounds per square inch gauge (psig) safely



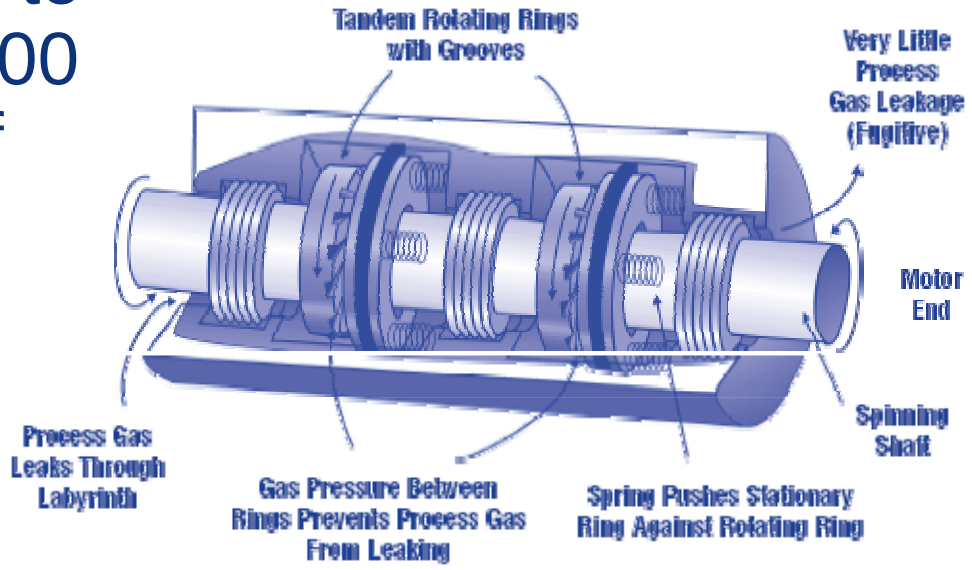
Source: PEMEX



Methane Savings through Dry Seals

- Dry seals typically leak 0.5 to 3 cf/minute
  - Significantly less than the 40 to 200 cf/minute emissions from wet seals
- Gas savings translate to approximately $112,000 to $651,000 at $7/Mcf

Source: PEMEX



Economics of Replacing Seals

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

Cost Category	Dry Seal ($)	Wet Seal ($)
Implementation Costs[1]		
Seal costs (2 dry @ $13,500/shaft-inch, with testing)	$162,000	
Seal costs (2 wet @ $6,750/shaft-inch)		$81,000
Other costs (engineering, equipment installation)	$162,000	$0
Total implementation costs	$324,000	$81,000
Annual Operating and Maintenance	$14,100	$102,400
Annual Methane Emissions (@ $7/Mcf; 8,000 hours/year)		
2 dry seals at a total of 6 cf/minute	$20,160	
2 wet seals at a total of 100 cf/minute		$336,000
Total Costs Over 5-Year Period	$495,300	$2,273,000
Total Dry Seal Savings Over 5 Years		
Savings	$1,777,700	
Methane Emissions Reductions (Mcf; at 45,120 Mcf/year)	225,600	

[1] **Flowserve Corporation (updated costs and savings)**

Is Wet Seal Replacement Profitable?

- Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hours/year
  - Net present value = $1,337,769
    - Assuming a 10% discount over 5 years
  - Internal rate of return = 129%
  - Payback period = 10 months
    - Ranges from 3 to 11 months based on wet seal leakage rates between 40 and 200 cf/minute
- 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 – PEMEX

- PEMEX had 46 compressors with wet seals at its PGPB production site
- Converted all to dry seals
  - Cost $444,000/compressor
  - Saves 20,500 Mcf/compressor/year
  - Saves $126,690/compressor/year in gas
- 3.5 year payback from gas savings alone

Source: PEMEX

Finding More Opportunities

- Partners are identifying other technologies and practices to reduce emissions
  - BP-Indonesia degasses wet seal oil to fuel gas pressure, capturing emissions as fuel
    - Reduces expensive implementation costs of replacing with dry seals
  - TransCanada is researching the use of an ejector to recover dry seal leakage
    - Compressor discharge to suction
    - Application to TransCanada compressors would save 538 MMcf/year
    - Negligible operating costs

Discussion

- Industry experience applying these technologies and practices
- Limitations on application of these technologies an practices
- Actual costs and benefits
- Leased compressors
  - Control over rod packing type and maintenance?