Methane to Markets

Reducing Emissions from Reciprocating and Centrifugal Compressors

International Workshop on Methane Emissions Reduction Technologies in the Oil and Gas Industry

Lake Louise

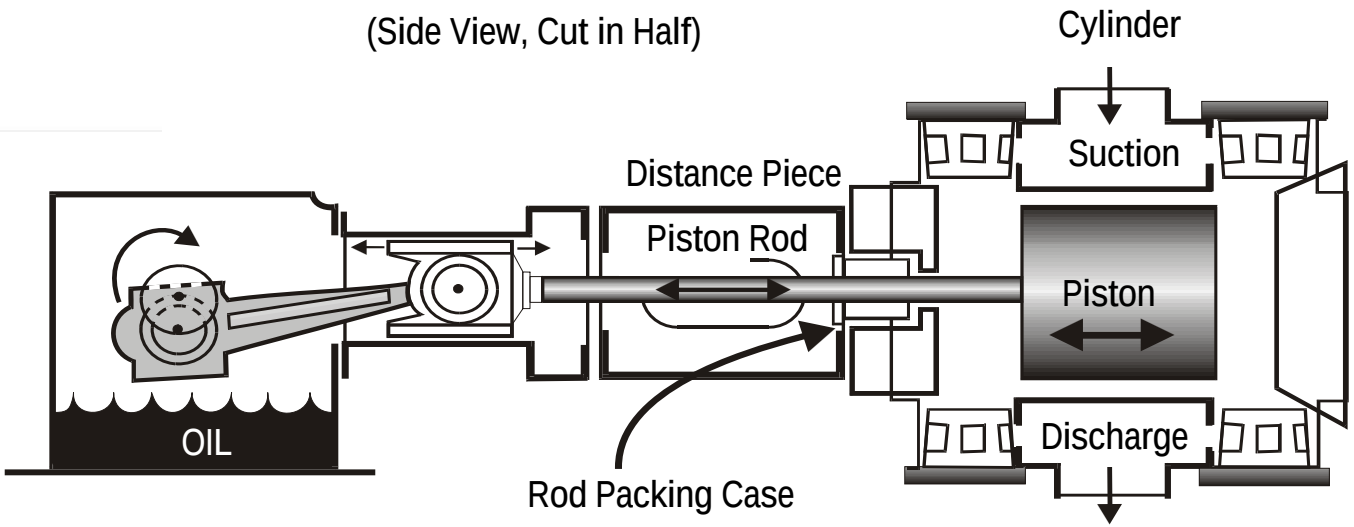
14-16 September 2009

Methane Savings from Compressors: Agenda

- **Reciprocating Compressors**
  - **Methane Losses, Methane Savings, Industry Experience**
- Centrifugal Compressors
  - Methane Losses, Methane Savings, Industry Experience
- Discussion

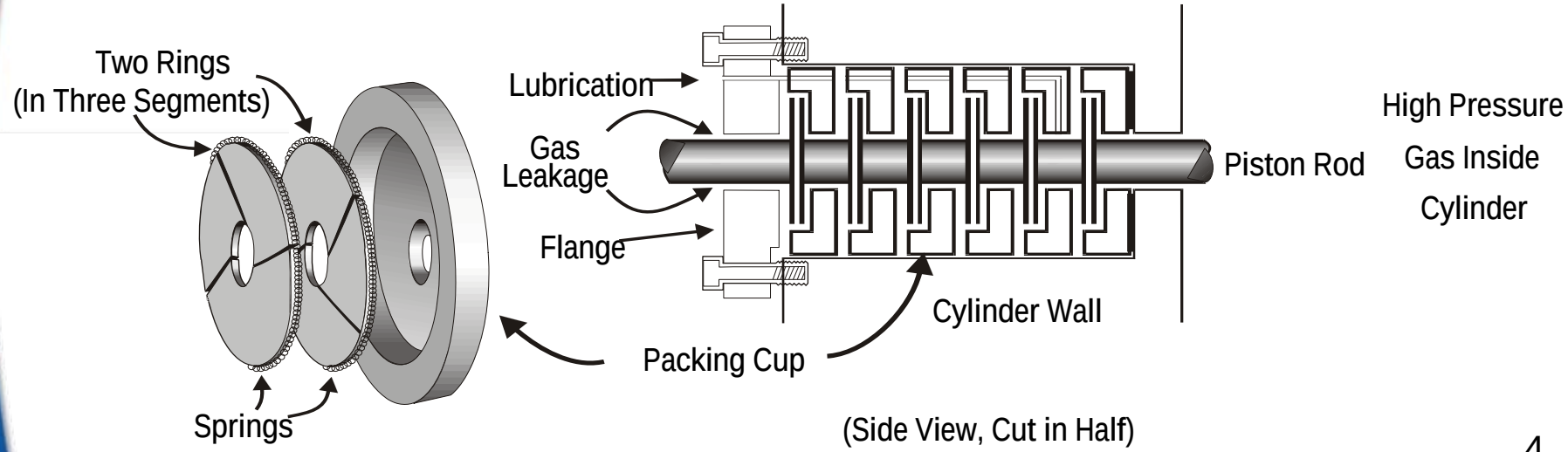
Methane Losses from Reciprocating Compressors

- Reciprocating compressor rod packing leaks some gas by design
  - Newly installed packing may leak 60 cubic feet per hour (cf/hour) (2 m^3/hour)
  - Worn packing has been reported to leak up to 900 cf/hour (26 m^3/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 (3 m^3)/hour-packing
Emission from Idle/Pressurized Compressor	145	cf (4 m^3)/hour-packing
Leakage from Idle Compressor Packing Cup	79	cf (2 m^3)/hour-packing
Leakage from Idle Compressor Distance Piece	34	cf (1 m^3)/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
Leak Rate (m^3/hour)	2	1.8	4.3	0.7

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
Leak Rate (m^3/hour)	2	N/A	4.2	0.6

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

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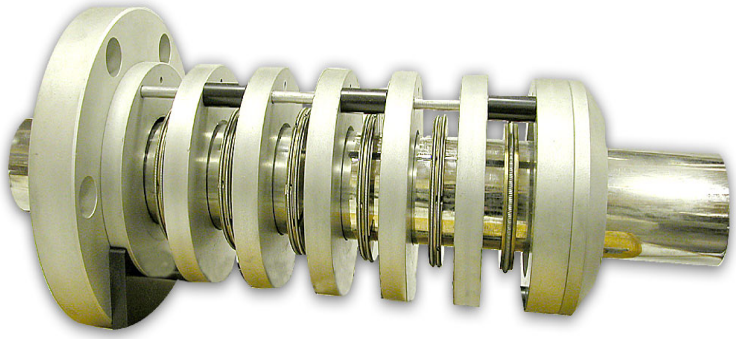
Steps to Determine Economic Replacement

- Measure rod packing leakage
  - When new packing installed – after worn-in
  - Periodically afterwards
- Determine cost of packing replacement
- Calculate economic leak reduction
- Replace packing when leak reduction expected will pay back cost

Cost of Rod Packing Replacement

- Assess costs of replacements
  - A set of rings: $ 1,350 to $ 1,700
    (with cups and case) $ 2,025 to $ 3,375
  - Rods: $ 2,430 to $13,500
    - Special coatings such as ceramic, tungsten carbide, or chromium can increase rod costs



Source: CECO

Calculate Economic Leak Reduction

- Determine economic replacement threshold
  - Partners can determine economic threshold for all replacements
  - This is a capital recovery economic calculation

Economic Replacement Threshold (cf/hour) =

$$\frac{CR * DF * 1{,}000}{(H * GP)}$$

Where:

CR = Cost of replacement ($)

DF = Discount factor at interest *i* =

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

H = Hours of compressor operation per year

GP = Gas price ($/thousand cubic feet)

Is Rod Packing Replacement Profitable?

- Replace packing when leak reduction expected will pay back cost
  - "leak reduction expected" is the difference between current leak rate and leak rate you expect with new rings

Rings Only

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

Leak Reduction Expected		Payback
(cf/hour)	(m^3/hour)	(months)
62	1.8	6
32	0.9	12
22	0.6	18
17	0.5	24

Rod and Rings

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

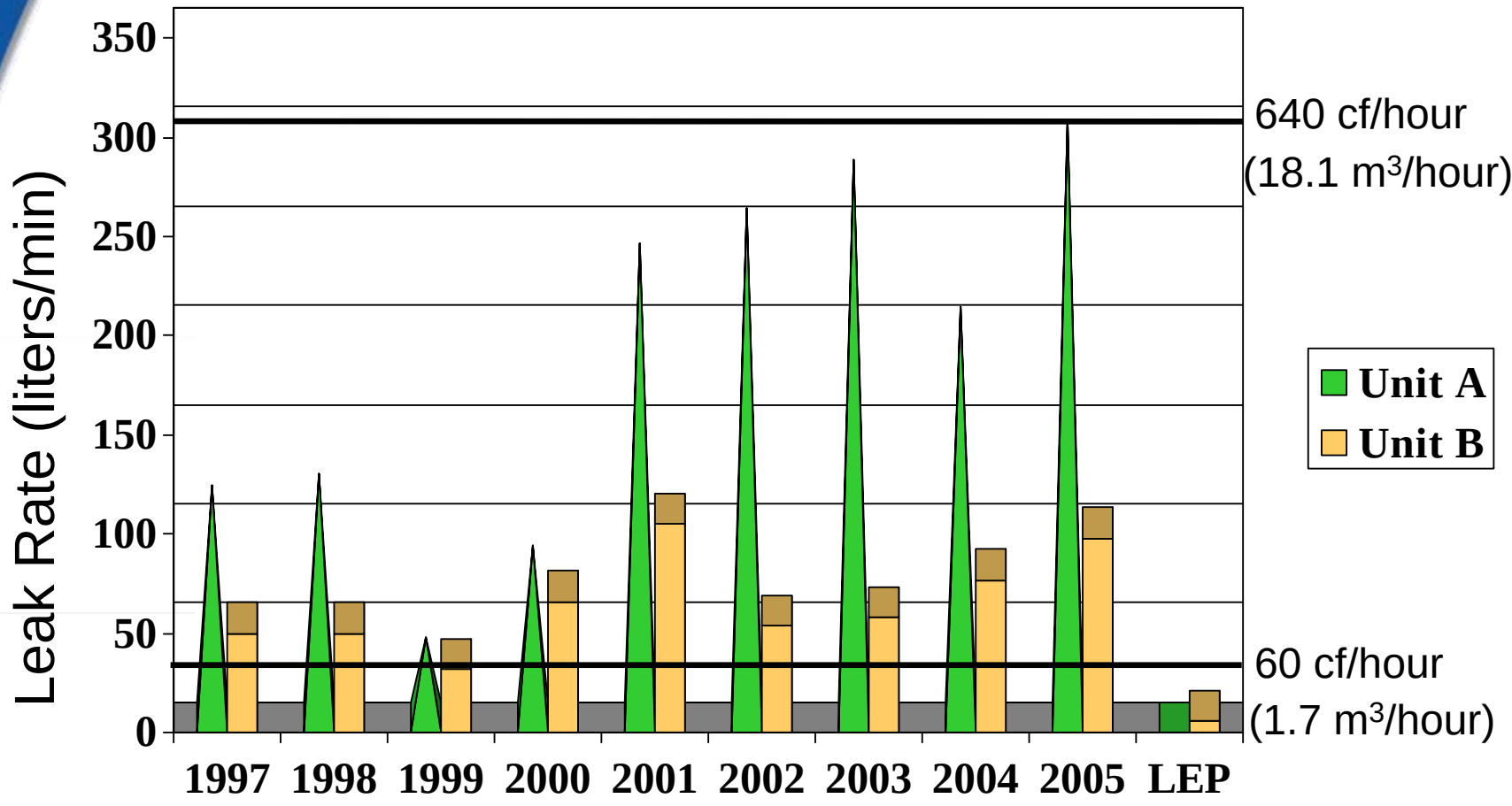
Leak Reduction Expected		Payback
(cf/hour)	(m^3/hour)	(months)
425	12	6
217	6.2	12
148	4.2	18
114	3.2	24

Based on 10% interest rate
Mcf = thousand cubic feet;

Industry Experience – Northern Natural Gas

- Monitored emission at two locations
  - Unit A leakage as high as 301 liters/min (640 cf/hour) (18.1 m^3/hour)
  - Unit B leakage as high as 105 liters/min (220 cf/hour) (6.2 m^3/hour)
- Installed Low Emission Packing (LEP)
  - After 3 months, leak rate shows zero leakage increase

Northern Natural Gas - Leakage Rates



- At a packing replacement cost of $3,000 per compressor rod (parts/labor) and assuming gas at $7/Mcf, this replacement pays back in <6 months

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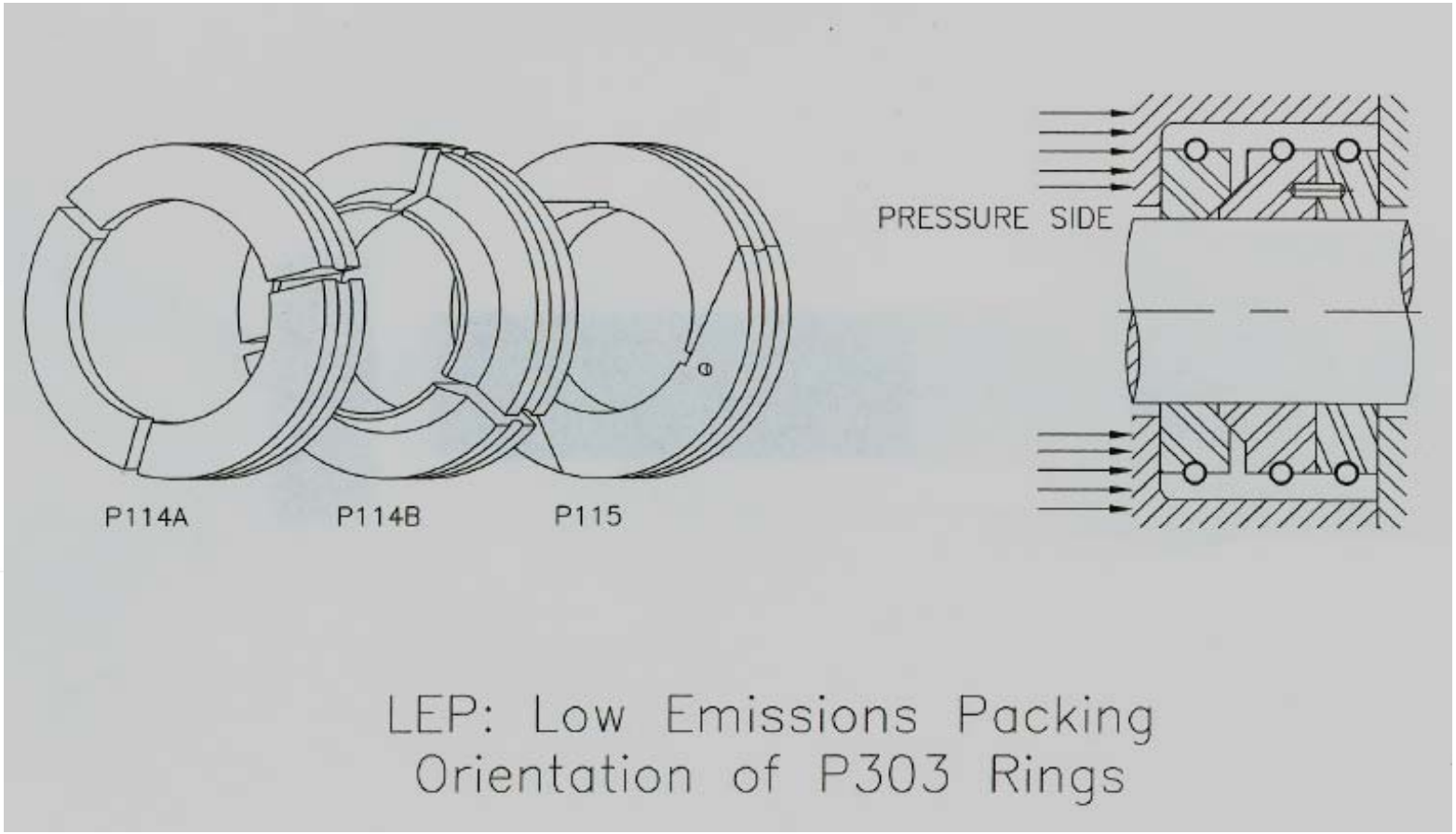
LEP Packing Configuration



Methane Savings from Compressors: Agenda

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- **Centrifugal Compressors**
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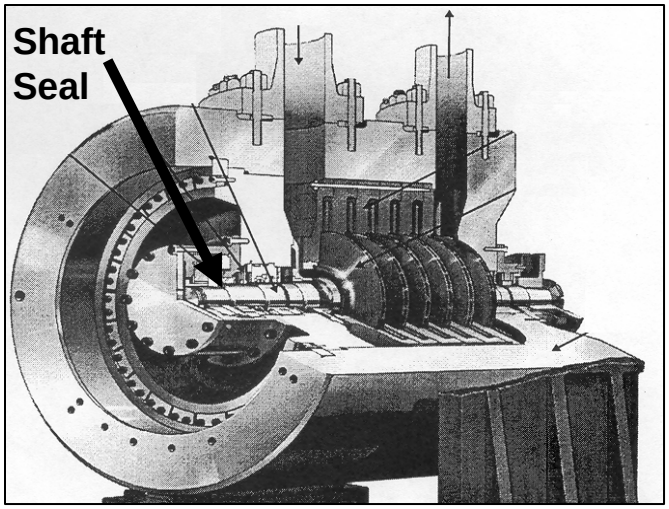
Methane Losses from Centrifugal Compressors

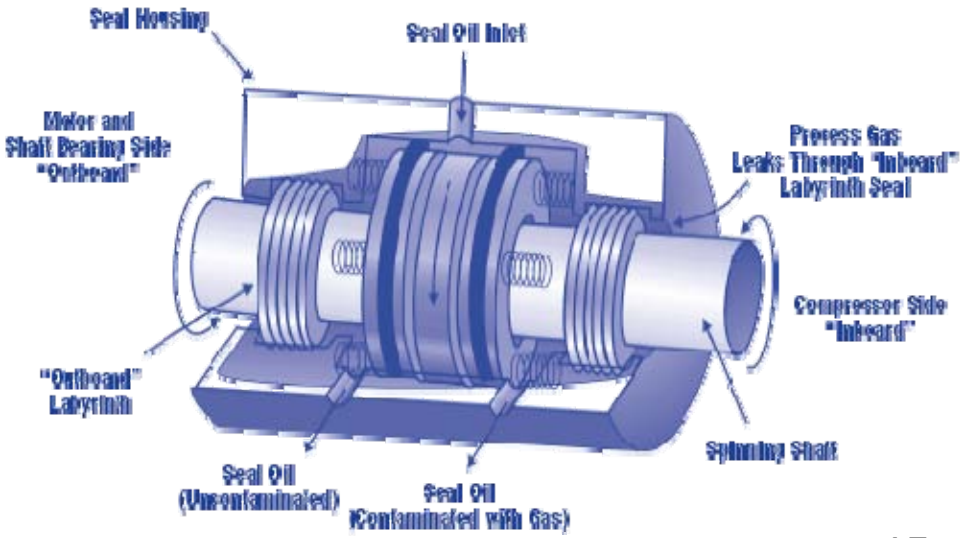
- Centrifugal compressor wet seals leak little gas at the seal face
  - Seal oil degassing may vent 40 to 200 cubic feet per **minute** (cf/minute) (1.1 to 5.7 m^3/minute) to the atmosphere
  - A Natural Gas STAR Partner reported wet seal emissions of 75 Mcf/day (52 cf/minute) (1.5 m^3/minute)



Centrifugal Compressor Wet Seals

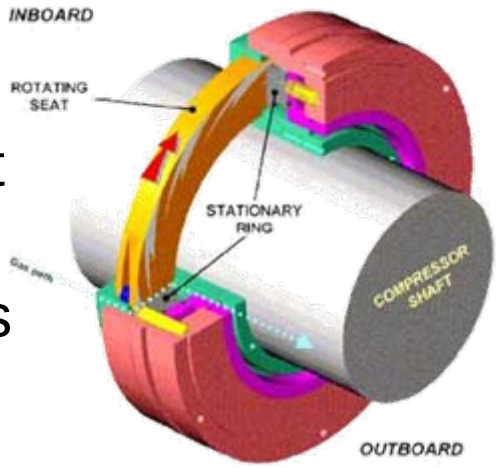
- High pressure seal oil circulates between rings around the compressor shaft
- Oil absorbs the gas on the inboard side
- Little gas leaks through the oil seal
- Seal oil degassing vents methane to the atmosphere

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) (205 atm) safely



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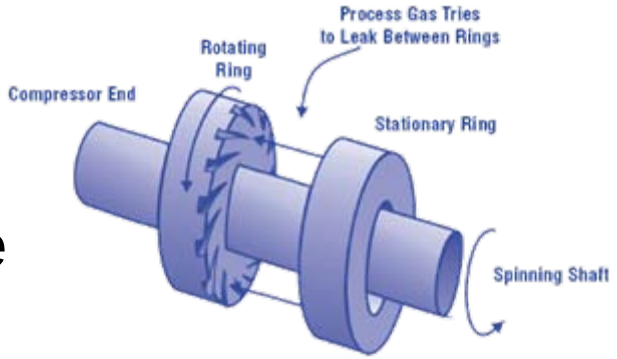

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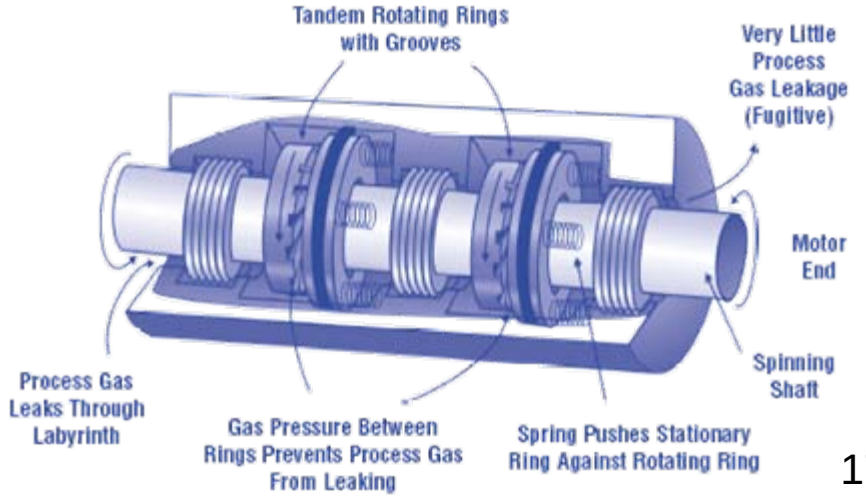
Methane Savings through Dry Seals

- Dry seals typically leak 0.5 to 3 cf/minute (0.01 to 0.1 m^3/minute)
  - Significantly less than the 40 to 200 cf/minute (1.1 to 5.7 m^3) emissions from wet seals
- Gas savings translate to approximately $112,000 to $651,000 at $7/Mcf

Source: PEMEX



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Economics of Replacing Seals

- Compare costs and savings for a 6-inch (15.2 cm) 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 (0.2 m^3/minute)	$20,160	
2 wet seals at a total of 100 cf/minute (2.8 m^3/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)	225,600 (6 million m^3)	

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

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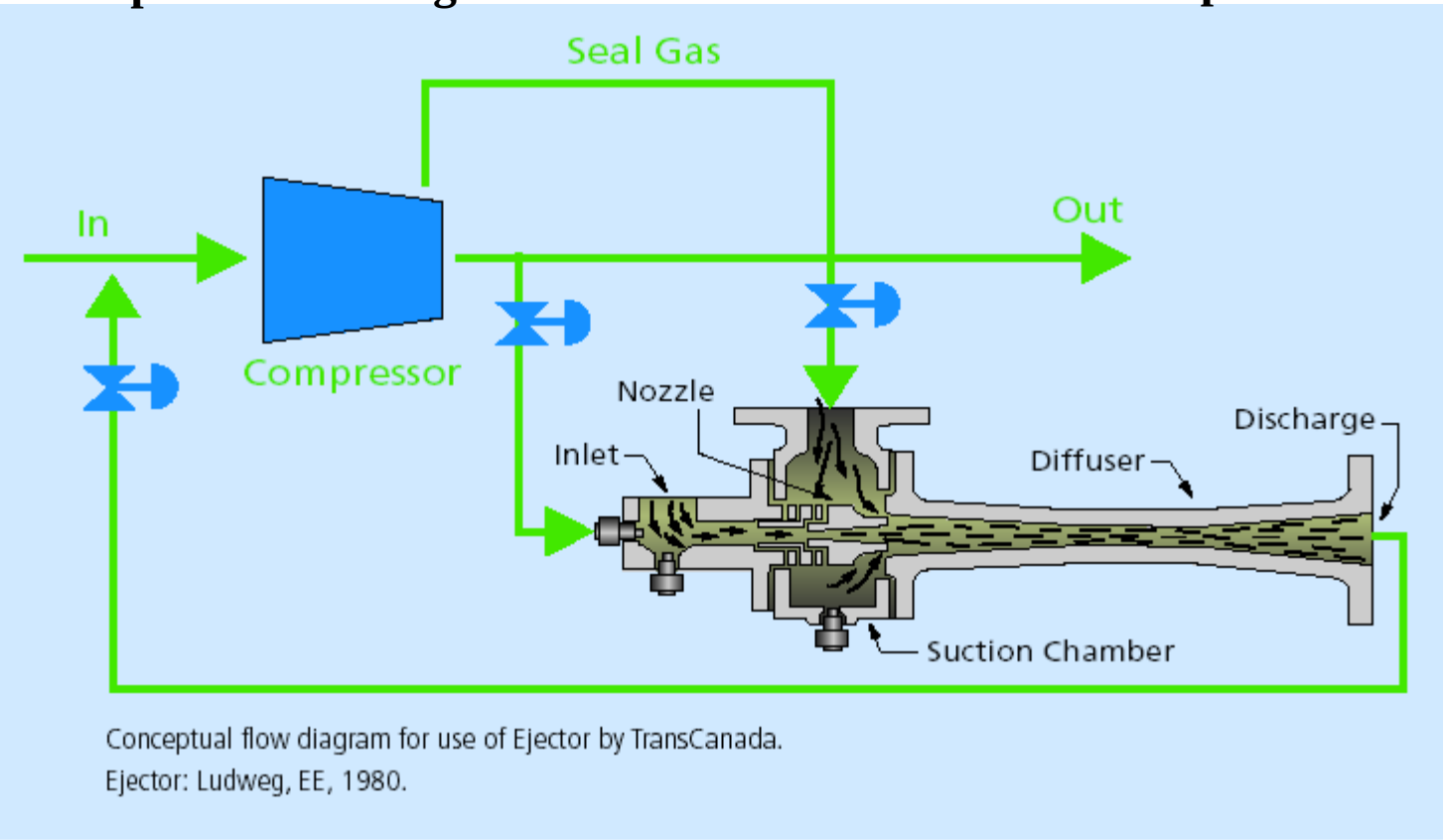
Finding More Opportunities

- Partners are identifying other technologies and practices to reduce emissions
  - TransCanada has successfully conducted pilot studies on the use of an ejector to recover dry seal leakage

Source: TransCanada

Gas-Gas Ejector for Dry Gas Seal Leak Capture

Conceptual Flow Diagram **US & Canadian patent filed**



Source: TransCanada

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Discussion

- Industry experience applying these technologies and practices
- Limitations on application of these technologies and practices
- Actual costs and benefits