Methane Emissions Reduction Opportunities at Natural Gas Compressor Stations

Turkmenistan Symposium on Gas Systems Management: Methane Mitigation

April 26 – 29, 2010, Ashgabat, Turkmenistan

Don Robinson, Vice President
ICF International

Methane to Markets

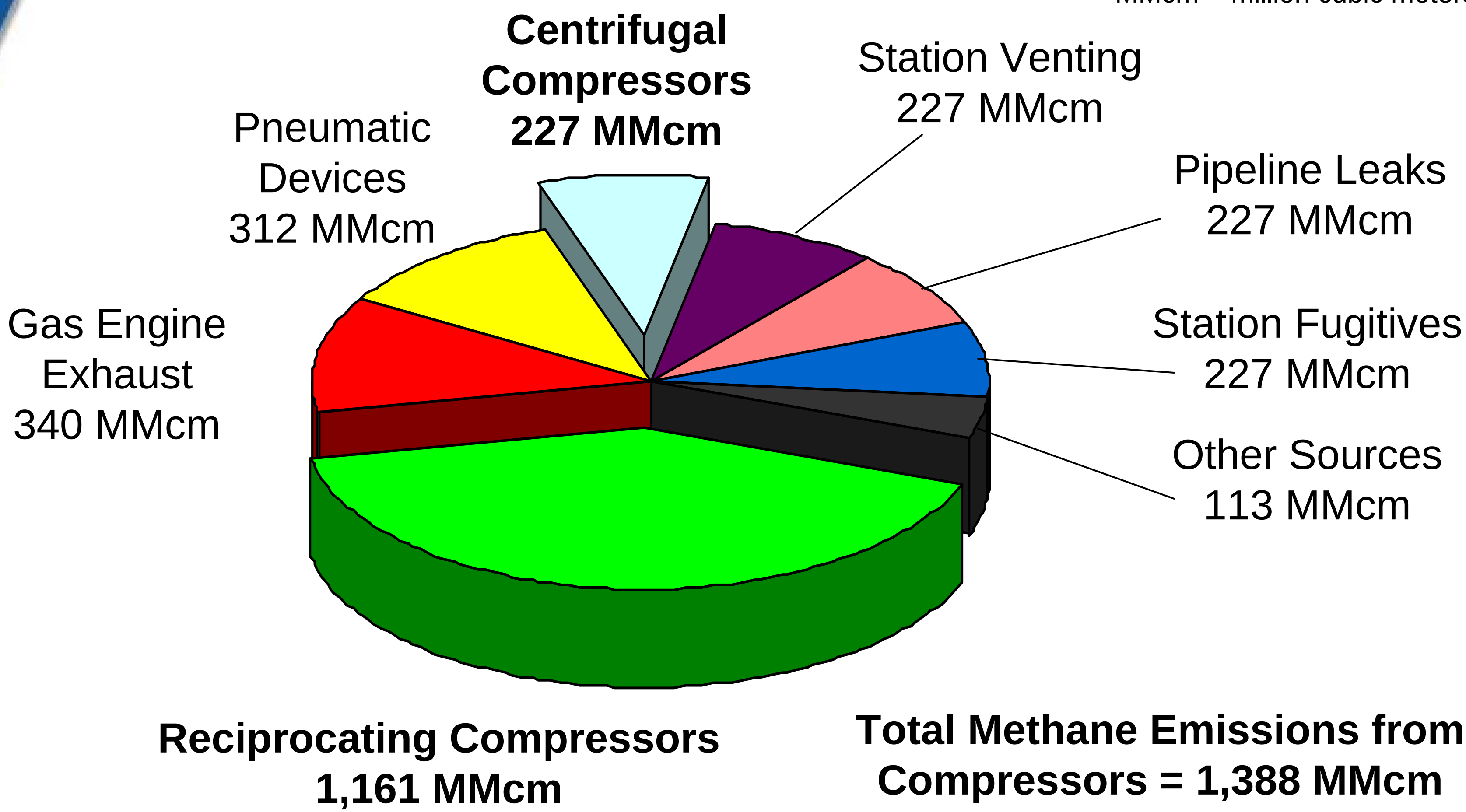
Compressor Seals: Agenda

- U.S. Methane Emissions from Compressor Seals
- Centrifugal Compressor Wet Seals
  - Methane Losses
  - Solutions
  - Economics
  - Industry Experience / More Opportunities
- Reciprocating Compressor Rod Packing
  - Methane Losses
  - Solutions
  - Economics
  - More Opportunities / Industry Experience
- Contacts and Further Information

Methane to Markets

U.S. Methane Emissions from Compressor Seals

*MMcm = million cubic meters

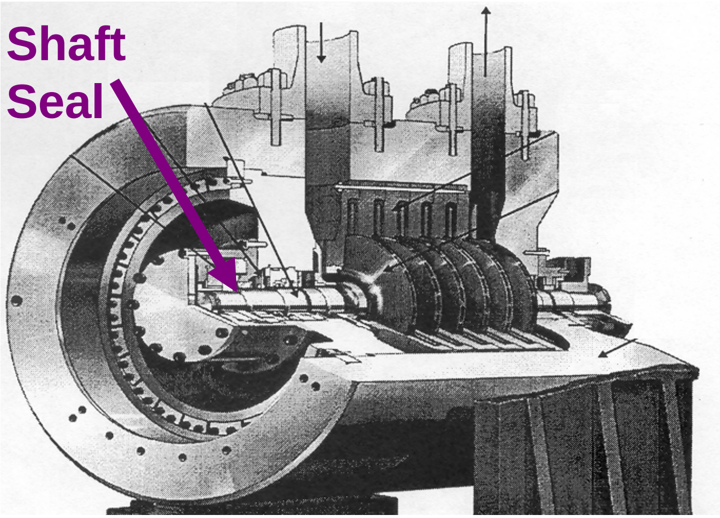


Total Methane Emissions from Compressors = 1,388 MMcm 49% of transmission

EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2007.* April, 2009. Available on the web at: epa.gov/climatechange/emissions/usinventoryreport.html

Methane Losses from Centrifugal Compressors

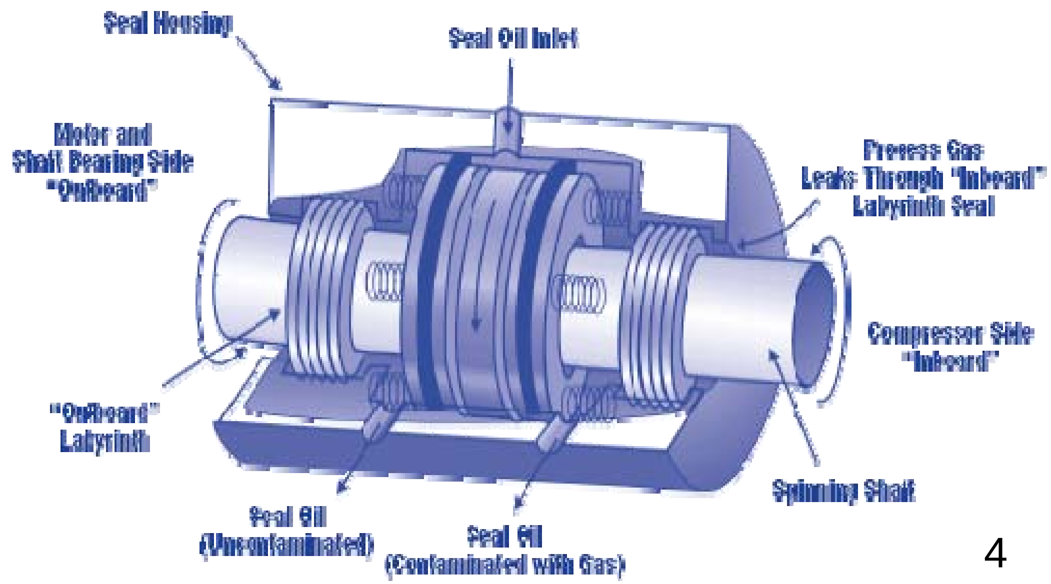
- Centrifugal compressor wet seals leak little gas at the seal face
  - The majority of methane emissions occur through seal oil degassing which is vented to the atmosphere
  - Seal oil degassing may vent 1.1 to 5.7 m^3/minute to the atmosphere
  - One Natural Gas STAR Partner reported emissions as high as 2,124 m^3/day



Centrifugal Compressor Wet Seals

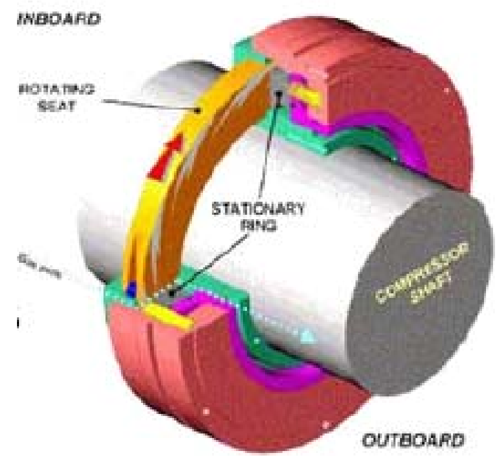
- High pressure seal oil circulates between rings around the compressor shaft
- Oil absorbs the gas on the inboard side
- Little gas leaks through the oil seal
- Seal oil degassing vents methane to the atmosphere

Source: PEMEX

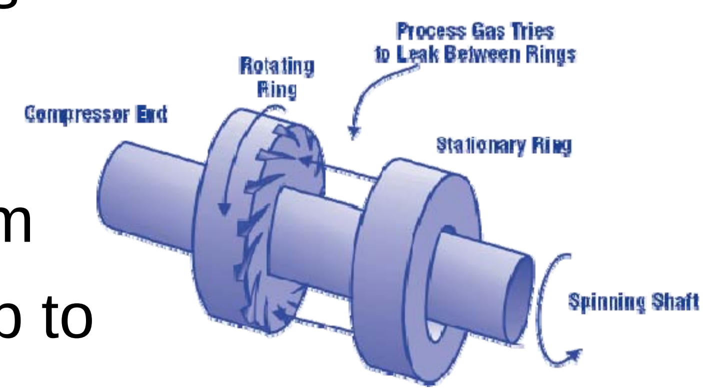


Wet Seals Solution: Dry Seals

- Dry seal springs press stationary ring in seal housing against rotating ring when compressor is not rotating
- At high rotation speed, gas is pumped between seal rings by grooves in rotating ring 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
- Can operate for compressors up to 206 atmospheres (atm) safely



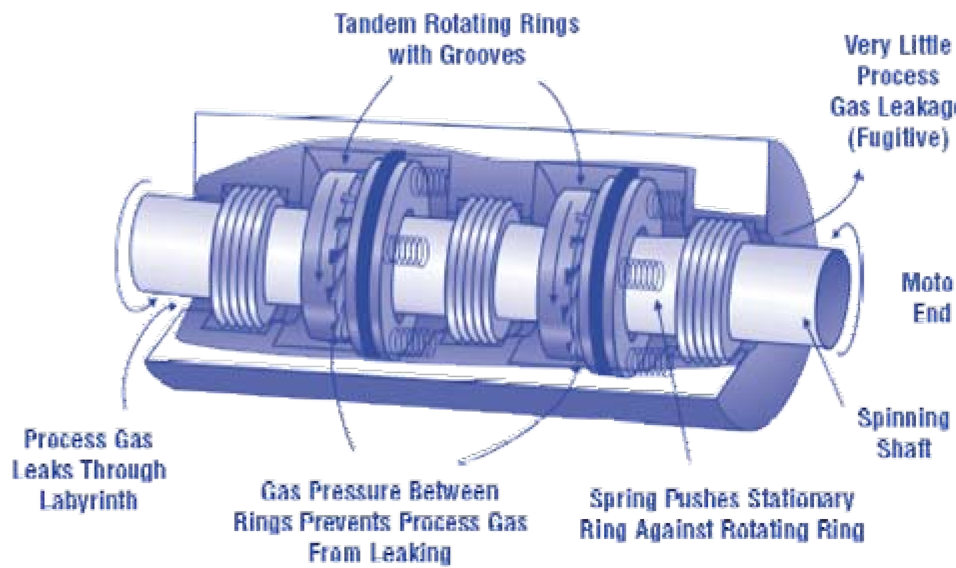
Source: PEMEX



Methane Savings through Dry Seals

- Dry seals typically leak at a rate of only 0.8 to 5.1 m^3/hour (0.01 to 0.09 m^3/ minute)
  - Significantly less than the 1.1 to 5.7 m^3/minute emissions from wet seals
- Gas savings translate to approximately TMT 387,315 to TMT 2,251,215 at TMT 855/Mcm[1]

Source: PEMEX



[1]Mcm = thousand cubic meters

Economics of Replacing Seals

- Compare costs and savings for a 15.2 cm (6-inch) shaft beam compressor

Cost Category	Dry Seal (TMT)	Wet Seal (TMT)
Implementation costs[1]		
Seal costs (2 dry @ TMT 38,475/shaft-inch, with testing)	461,700	
Seal costs (2 wet @ TMT 19,240/shaft-inch)		230,850
Other costs (engineering, equipment installation)	461,700	0
Total implementation costs	923,400	230,850
Annual operating and maintenance	40,185	291,840
Annual methane emissions (@ TMT 855/thousand m^3; 8,000 hours/year)		
2 dry seals at a total of 12 m^3/hour	82,080	
2 wet seals at a total of 168 m^3/hour		1,149,120
Total costs over 5-year period	1,534,725	7,435,650
Total dry seal savings over 5 years		
Savings	5,900,925	
Methane Emissions Reductions (million m^3)	6.4	

[1]Flowserve Corporation (updated costs and savings)

Methane to Markets

NaturalGas EPA POLLUTION PREVENTER

Industry Experience – PEMEX (Mexican Production Company)

- PEMEX had 46 compressors with wet seals at a production site
- Converted three to dry seals
  - Cost TMT 1,265,400/compressor
  - Saves 580,500 m^3 /compressor/year
  - Saves TMT 496,330 /compressor/year in gas[1]
- 2.5 year payback from gas savings alone[1]
- Plans for future dry seal installations

Source: PEMEX

[1]Gas price at TMT 855/Mcm

Industry Experience – Supersonic Gas Injector: TransCanada (Canadian Transmission Company)

- Developed for capturing very low pressure vent gases and re-injection into a high pressure gas stream without the use of rotating machinery
- Savings
  - 113,000 m^3/year of gas savings from one compressor
  - Natural gas worth TMT 96,615/year/unit at TMT 855/Mcm
  - Zero operating cost

Source: TransCanada

Methane to Markets

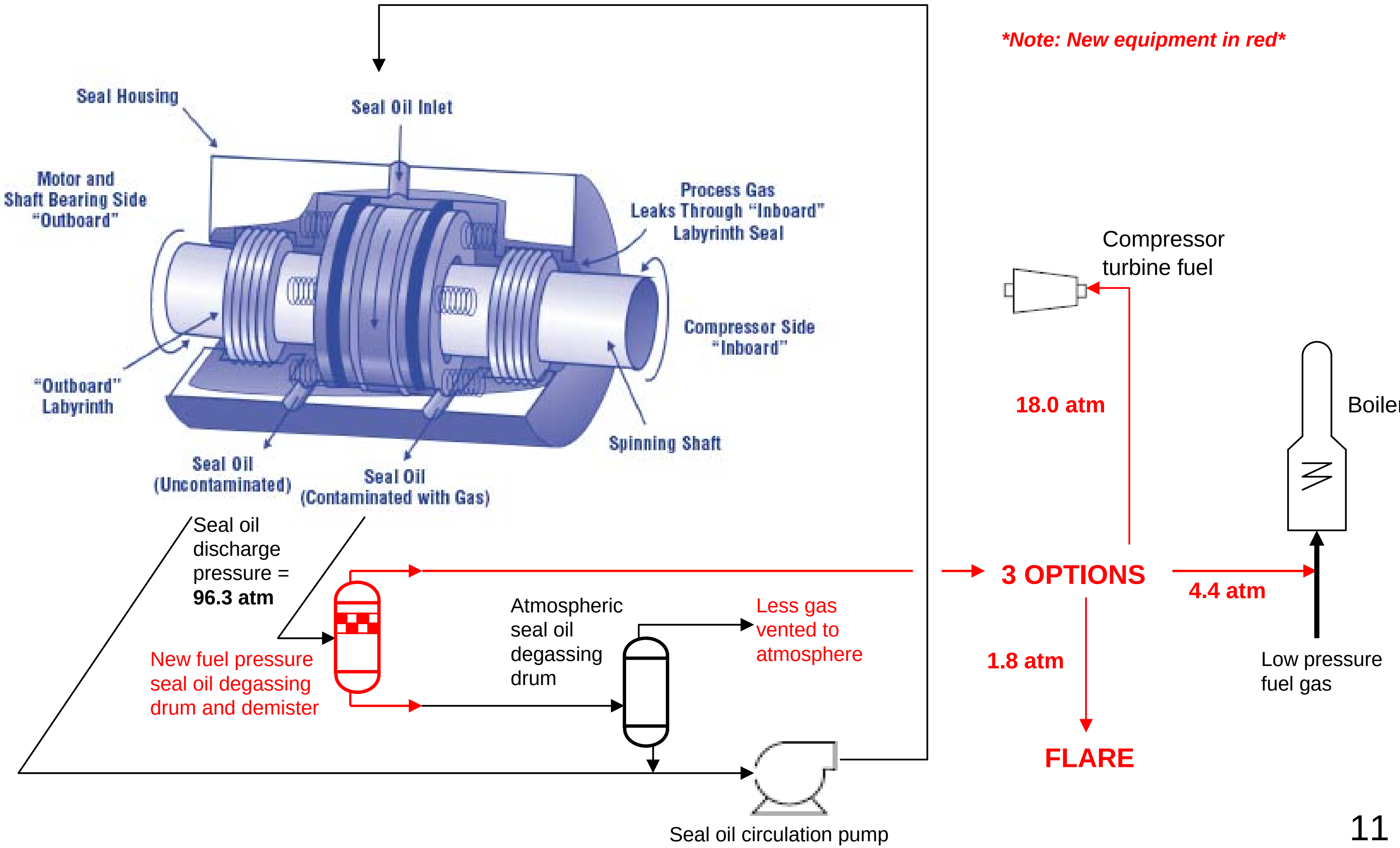
NaturalGas EPA POLLUTION PREVENTER

More Opportunities

- Partners are identifying other technologies and practices to reduce emissions
- One partner degasses seal oil in an intermediate pressure drum, with the gas used:
  - As turbine fuel
  - As low pressure fuel
  - To flare
- Prevents most seal oil gas emissions from venting to atmosphere
- Less expensive capital costs compared to dry seals
- Partner reported emission reductions of 3.1 m^3/minute (110 ft^3/minute) *per seal* when routing gas back to turbine fuel

More Opportunities—cont.

- Partner's seal oil degassing vent recovery and use:



More Opportunities—cont.

- Investment includes cost of:
  - Intermediate degassing drum
  - New piping
  - Gas demister/filter
  - Pressure regulator for fuel gas line
- Project summary:
  - Less capital intensive than dry seals
  - Reduce emissions while also improving site efficiency
  - Positive cash flow after less than a month

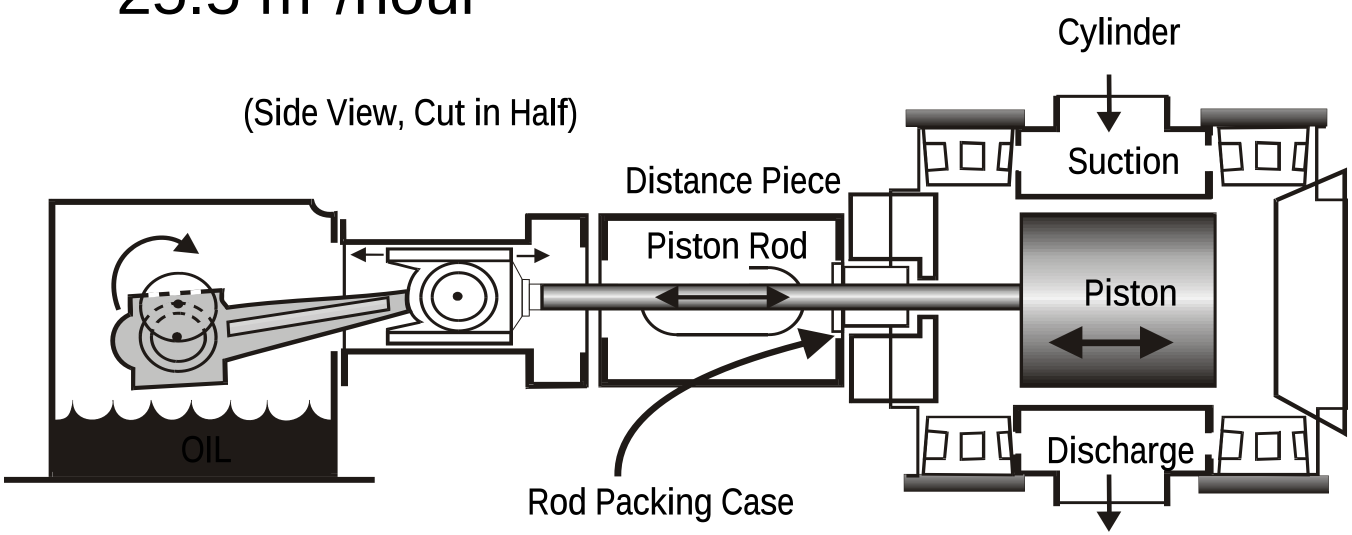
PROJECT SUMMARY: CAPTURE AND USE OF SEAL OIL DEGASSING EMISSIONS			
Operating Requirements	▪Centrifugal compressor with seal oil system ▪Nearby use for low pressure fuel gas ▪New intermediate pressure flash drum, fuel filter, pressure regulator		
Capital & Installation Costs	TMT 62,700[1]		
Annual Labor & Maintenance Costs	Minimal		
Methane saved	1.8 MMcm		
Gas Price per Mcm	TMT 430	**TMT 855**	TMT 1285
Value of Gas Saved	TMT 774,000	**TMT 1,539,000**	TMT 2,313,000
Payback Period in Months	1	**0.5**	0.33

[1]Assuming a typical seal oil flow rate of 14.20 liters/minute (3.75 gallons/minute)

Methane to Markets

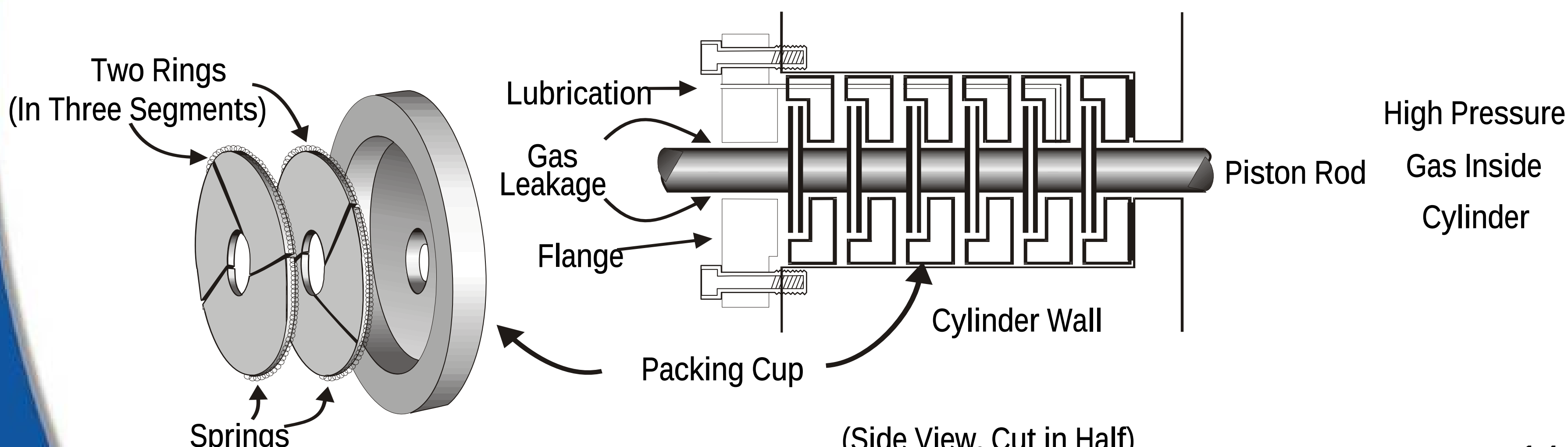
Methane Losses from Reciprocating Compressors

- Reciprocating compressor rod packing leaks some gas by design
  - Newly installed packing may leak 0.3 to 1.7 m^3/hour
  - Worn packing has been reported to leak up to 25.5 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



(Side View, Cut in Half)

Impediments to Proper Sealing

Where packing case can leak

- Nose gasket
- Packing to rod
- Packing to cup
- Packing to packing
- Cup to cup

What makes packing leak?

- Dirt or foreign matter (trash)
- Worn rod (.015 mm/per cm dia.)
- Insufficient/too much lubrication
- Packing cup out of tolerance (≤ 0.05 mm)
- Improper break-in on startup
- Liquids (dilutes oil)
- Incorrect packing installed (backward or wrong type/style)

Methane Losses from Rod Packing

Emission from Running Compressor	24,600	m^3/year-packing
Emission from Idle/Pressurized Compressor	36,000	m^3/year-packing
Leakage from Packing Cup	19,500	m^3/year-packing
Leakage from Distance Piece	8,500	m^3/year-packing

Leakage from Rod Packing on Running Compressors				
Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (m^3/year)	17,300	15,700	37,300	5,900

Leakage from Rod Packing on Idle/Pressurized Compressors				
Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (m^3/year)	17,400	N/A	36,500	5,400

Source: Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations – PRCI/ GRI/ EPA PR-246-9526

Methane to Markets

Solution: Economic Replacement

- Measure rod packing leakage
  - When new packing installed–after worn-in
  - Periodically afterwards
- Determine cost of packing replacement
- Determine economic replacement threshold
  - Partners can determine economic threshold for all replacements
  - This is a capital recovery economic calculation
- Replace packing when leak reduction expected will pay back cost

Economic Replacement Threshold (m^3/hour) =

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

Where:

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

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

Methane to Markets

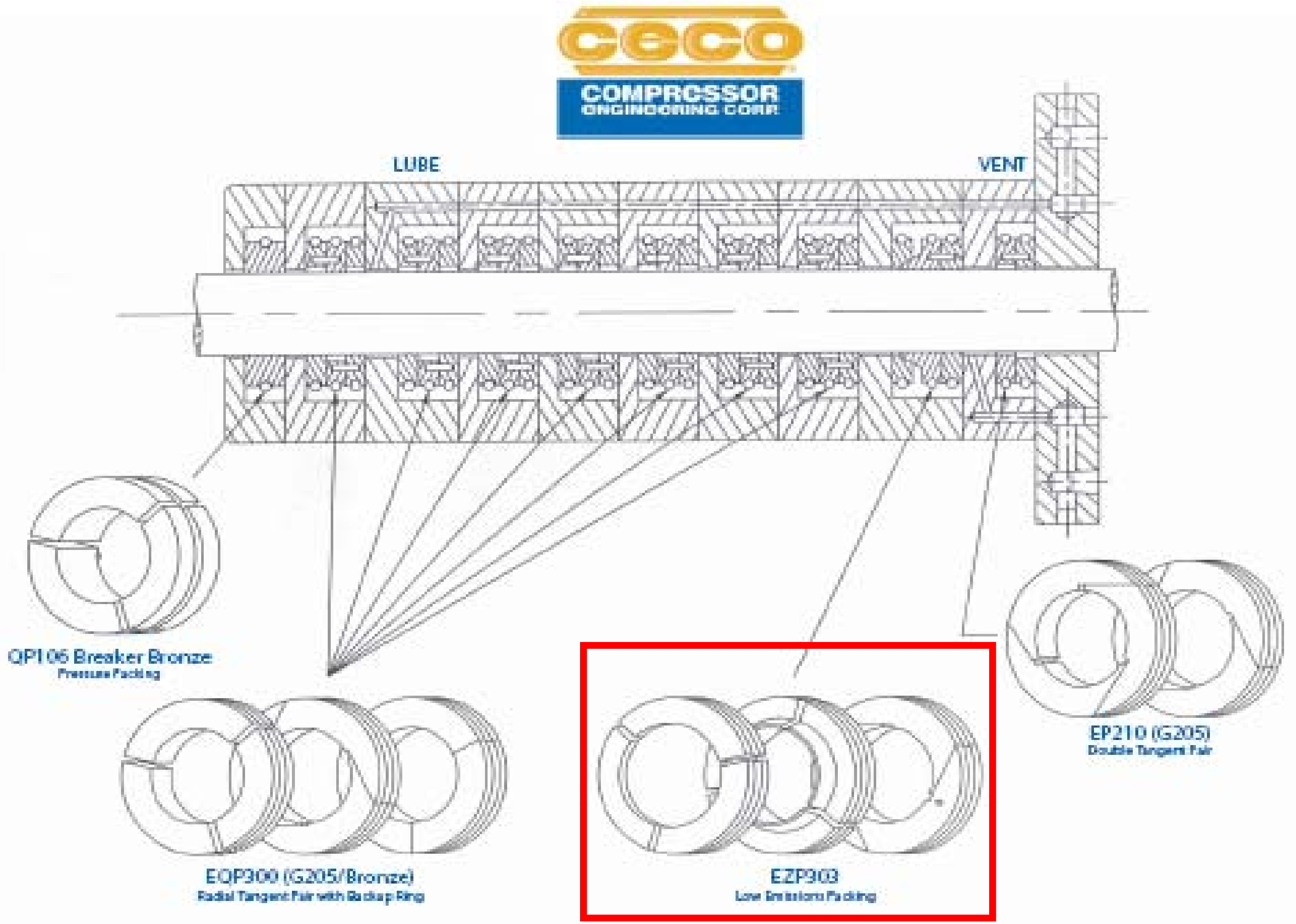
More Opportunities: Low Emission Packing (LEP)

- The side load eliminates clearance and maintains positive seal on cup face
- LEP is a static seal, not a dynamic seal. No pressure is required to activate the packing
- This design works in existing packing case with limited, to no modifications required

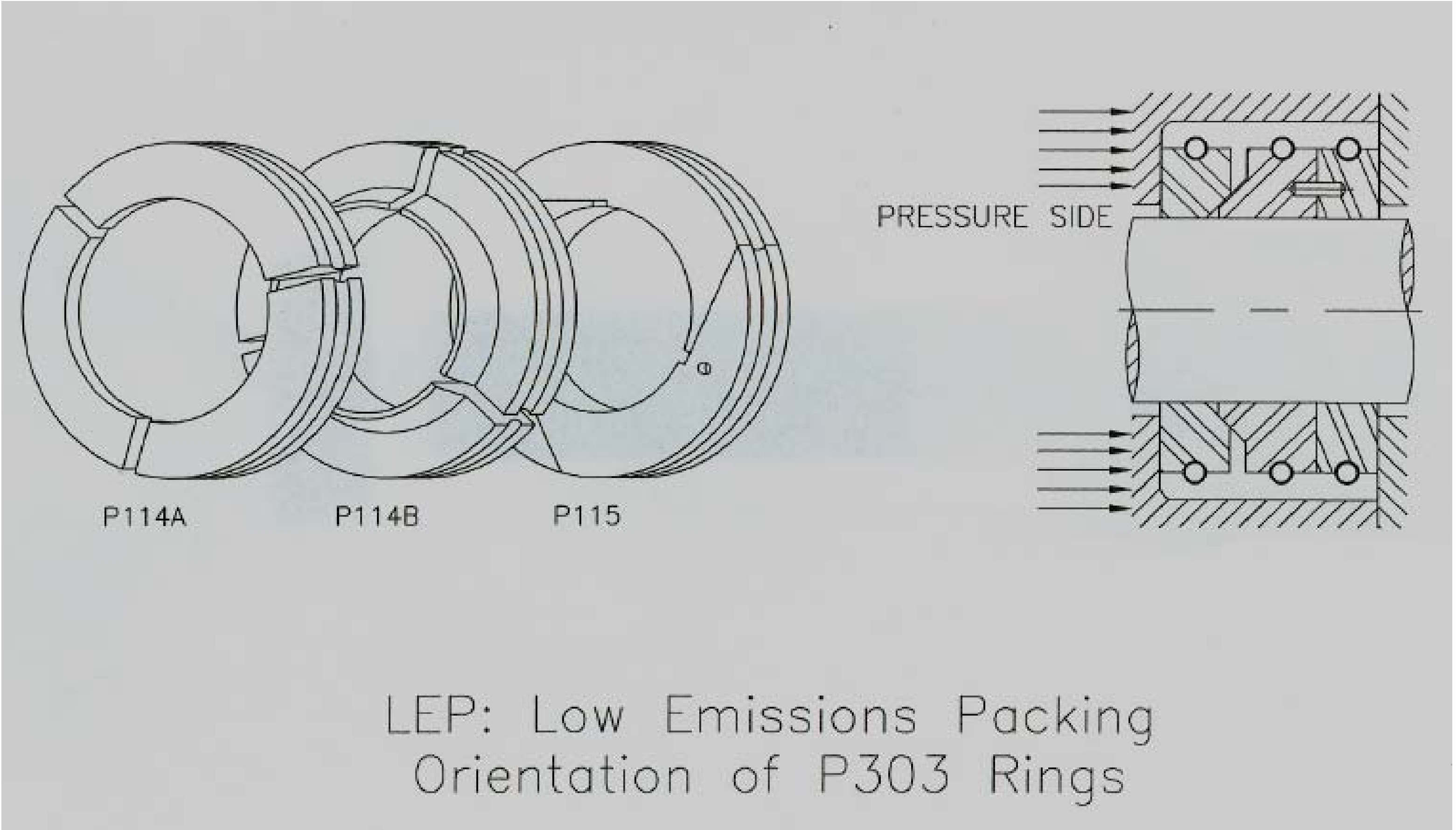
Methane to Markets

NaturalGas EPA POLLUTION PREVENTER

LEP Packing Configuration



Orientation in Cup



Methane to Markets

Industry Experience – Northern Natural Gas (U.S. Transmission Company)

- Monitored emissions at two locations
  - Unit A leakage as high as 301 liters/minute (18 m^3/hour)
  - Unit B leakage as high as 105 liters/minute (6 m^3/hour)
- Installed low emission packing (LEP)
  - Testing is still in progress
  - After 3 months, leak rate showed zero leakage increase

Contact Information and Further Information

- More detail is available on these practices and over 80 others online at: epa.gov/gasstar/tools/recommended.html
- For further assistance, direct questions to:

Roger Fernandez
EPA Natural Gas STAR Program
fernandez.roger@epa.gov
(202) 343-9386

Don Robinson
ICF International
drobinson@icfi.com
(703) 218-2512