Reducing Methane Emissions from Centrifugal and Reciprocating Compressors

Seminar with Russian Independent Oil and Gas Producers on Methane Mitigation Technologies and Strategies

October 4, 2010, Moscow, Russia

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Methane to Markets

NaturalGas EPA POLLUTION PREVENTER

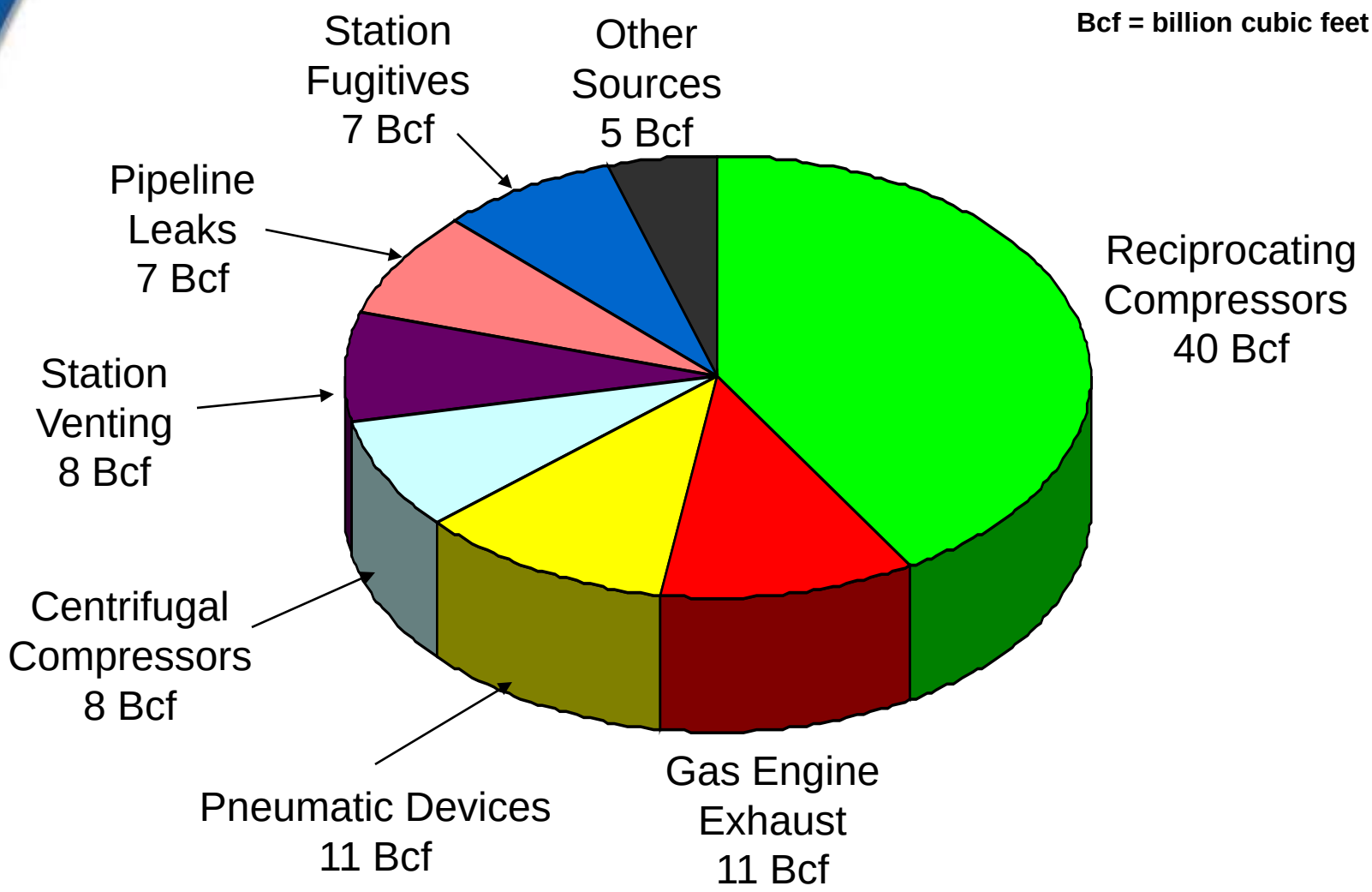
Compressor Seals: Agenda

- 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

2008 Transmission Sector Methane Emissions (97 Bcf)

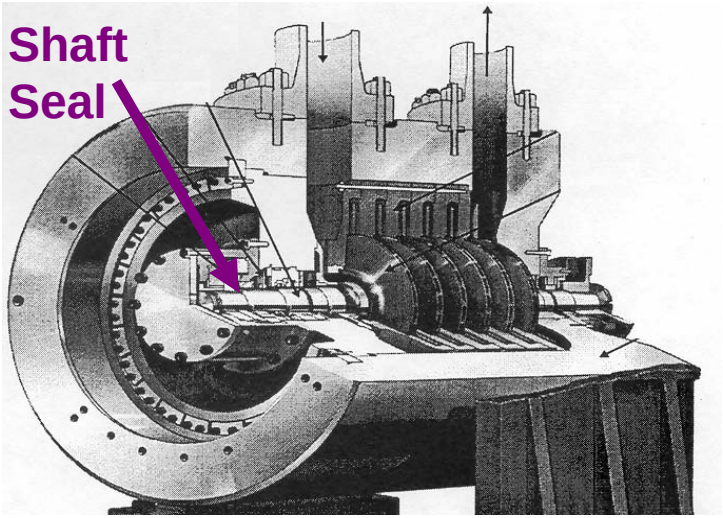
Bcf = billion cubic feet



EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2008.* April, 2010. Available on the web at: epa.gov/climatechange/emissions/usinventoryreport.html.

Methane Losses from Centrifugal Compressors

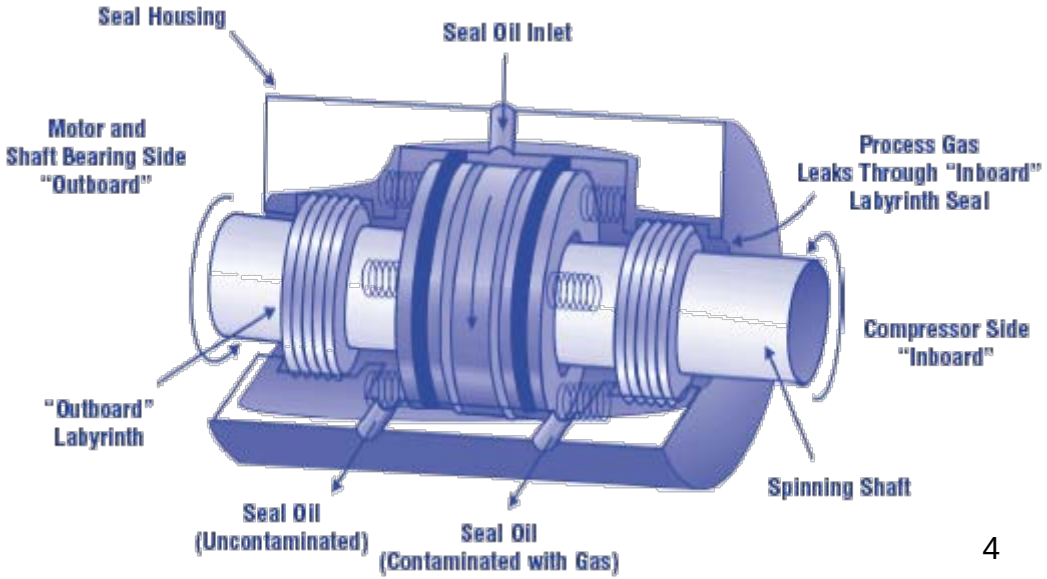
- Centrifugal compressor wet seals leak little gas at the seal face
  - The majority of methane emissions occur through seal oil degassing which is vented to the atmosphere
  - Seal oil degassing may vent 1.1 to 5.7 m^3/minute to the atmosphere
  - One Natural Gas STAR Partner reported emissions as high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



Centrifugal Compressor Wet Seals

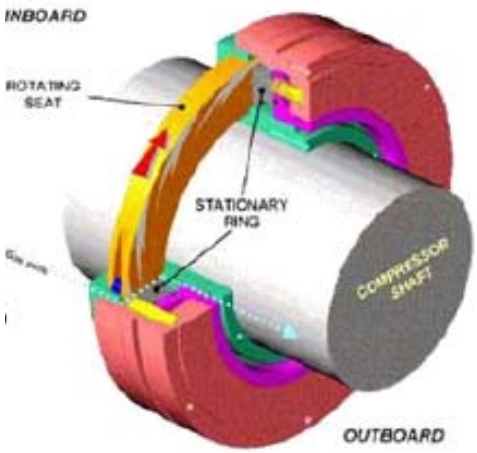
- High pressure seal oil circulates between rings around the compressor shaft
- Oil absorbs the gas on the inboard side
  - Little gas leaks through the oil seal
  - Seal oil degassing vents methane to the atmosphere

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



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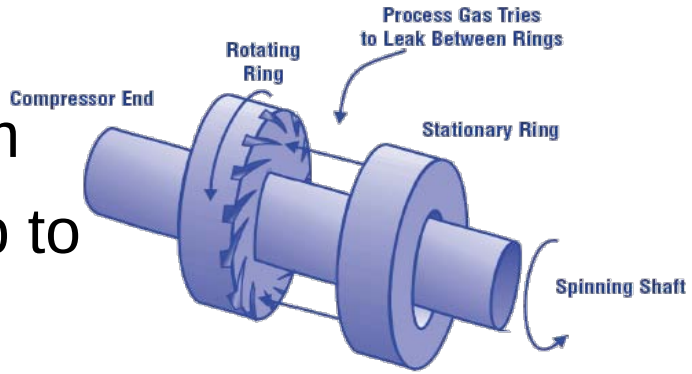
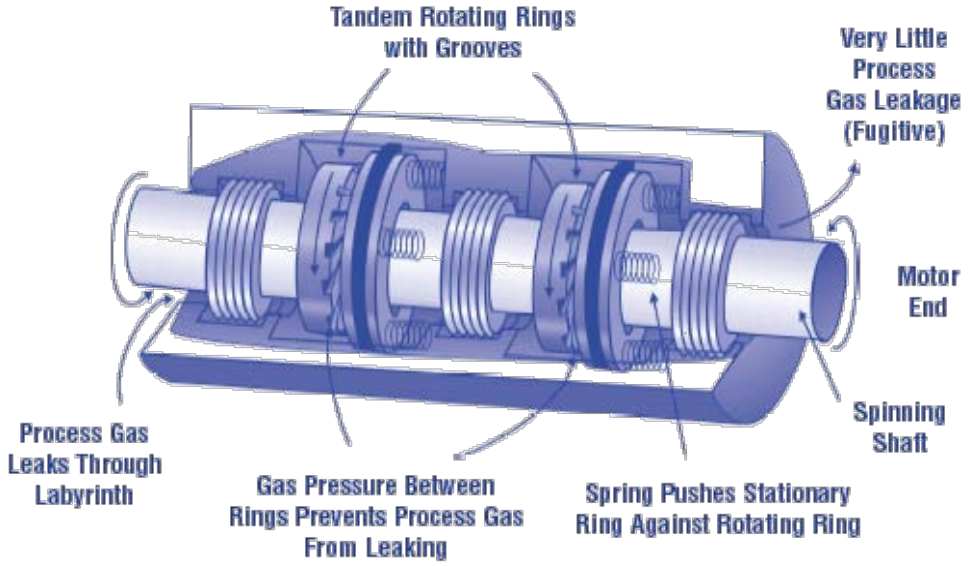


Methane Savings through Dry Seals

- 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 RUB 5,000,000 to RUB 30,000,000 at RUB 11,360/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 (RUB)	Wet Seal (RUB)
Implementation costs[1]		
Seal costs (2 dry @ RUB 414,720/shaft-inch, with testing)	4,976,640	
Seal costs (2 wet @ RUB 207,390/shaft-inch)		2,488,680
Other costs (engineering, equipment installation)	4,976,640	0
Total implementation costs	9,953,280	2,488,680
Annual operating and maintenance	433,150	3,145,730
Annual methane emissions (@ RUB 11,360/thousand m^3; 8,000 hours/year)		
2 dry seals at a total of 12 m^3/hour	1,090,560	
2 wet seals at a total of 168 m^3/hour		15,267,840
Total costs over 5-year period	12,119,030	18,217,330
Total dry seal savings over 5 years		
Savings	6,098,300	
Methane Emissions Reductions (million m^3)	6.24	

[1]Flowserve Corporation (updated costs and savings)

Methane to Markets

Industry Experience – PEMEX (Mexican Production Company)

- PEMEX had 46 compressors with wet seals at a production site
- Converted three to dry seals[1]
  - Cost RUB 13,639,680/compressor
  - Saves 580,500 m^3 /compressor/year
  - Saves RUB 6,594,480 /compressor/year in gas[1]
- 2.1 year payback from gas savings alone[2]
- Plans for future dry seal installations

Source: PEMEX

[1]All data based on Partners' experiences and represented in U.S. economics, converted to Russian currency.
[2]Gas price at RUB 11,360/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 RUB 1,283,680/year/unit at RUB 11,360/Mcm
  - Zero operating cost

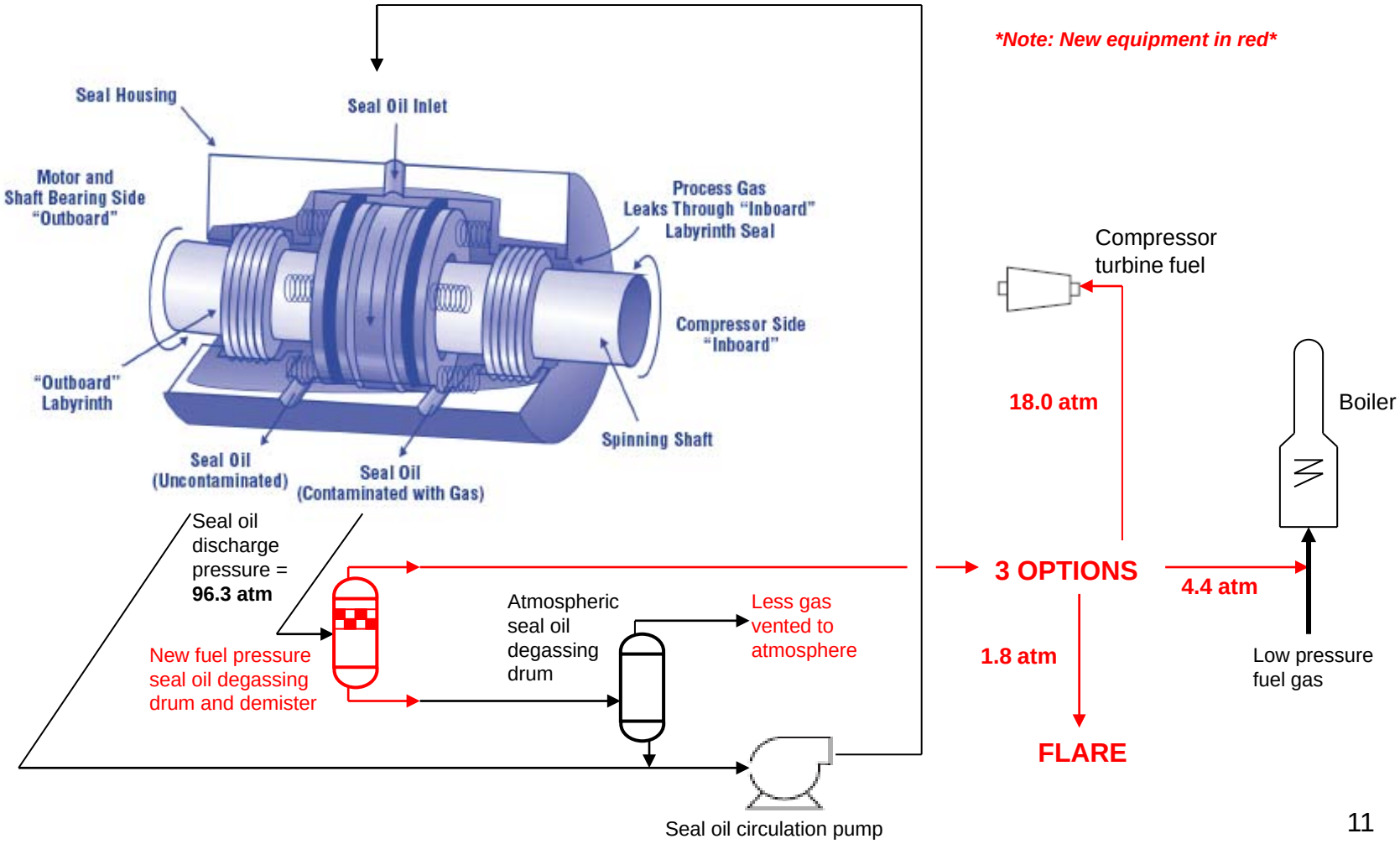
Source: TransCanada

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	RUB 675,840[1]		
Annual Labor & Maintenance Costs	Minimal		
Methane saved	1.8 MMcm		
Gas Price per Mcm	RUB 5,680	**RUB 11,360**	RUB 17,040
Value of Gas Saved	RUB 10,224,000	**RUB 20,448,000**	RUB 30,672,000
Payback Period in Months	0.8	**0.4**	0.3

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

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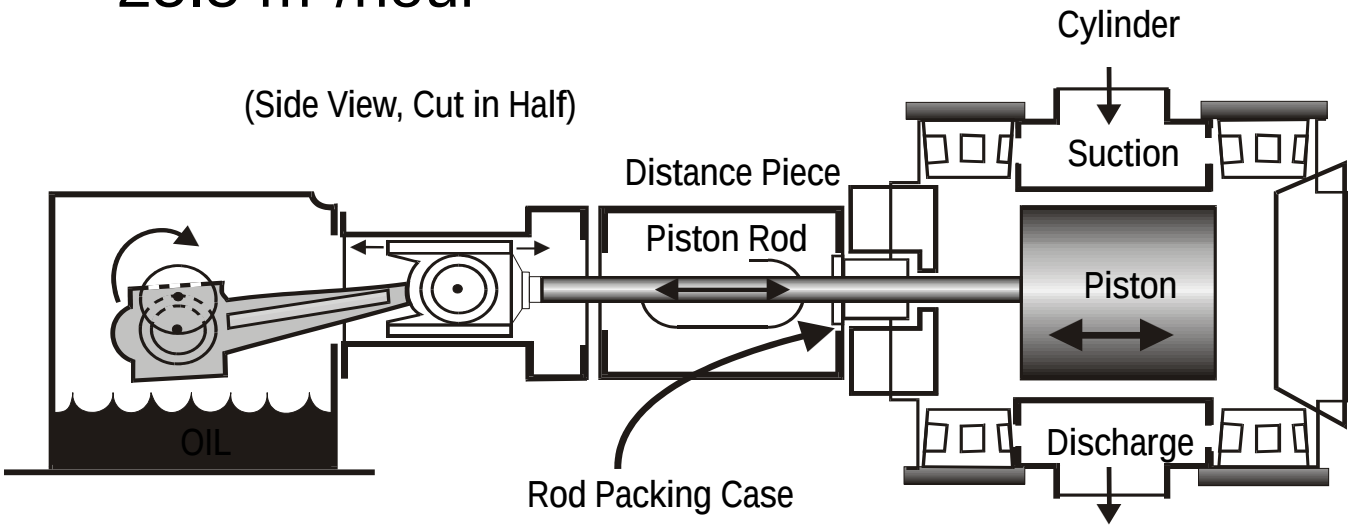
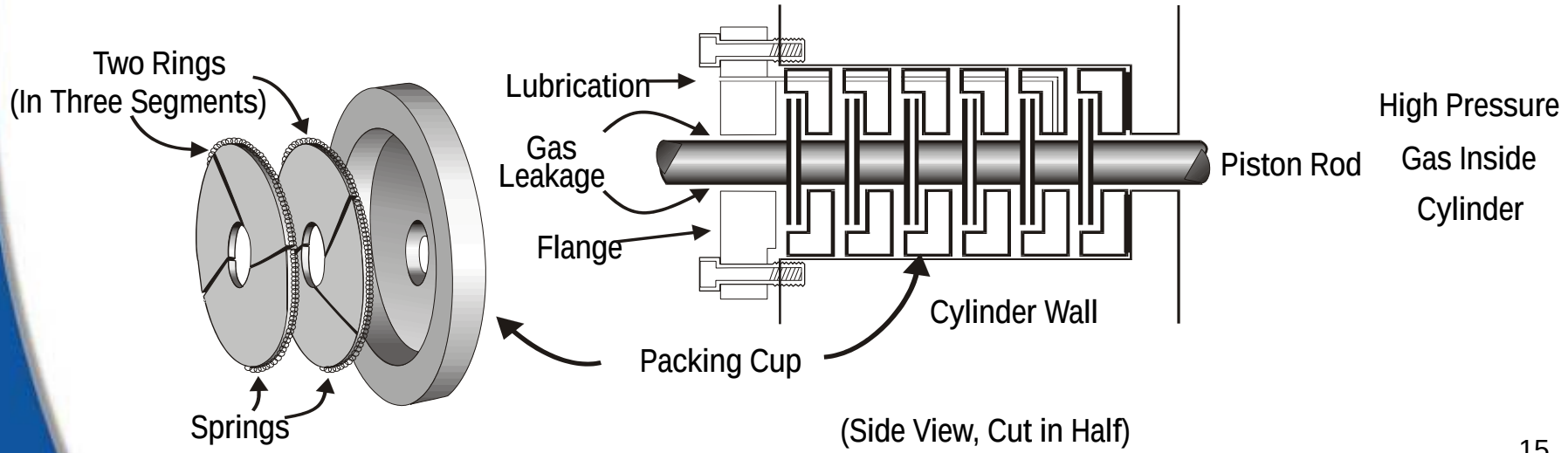
Methane Losses from Reciprocating Compressors

- 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



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

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

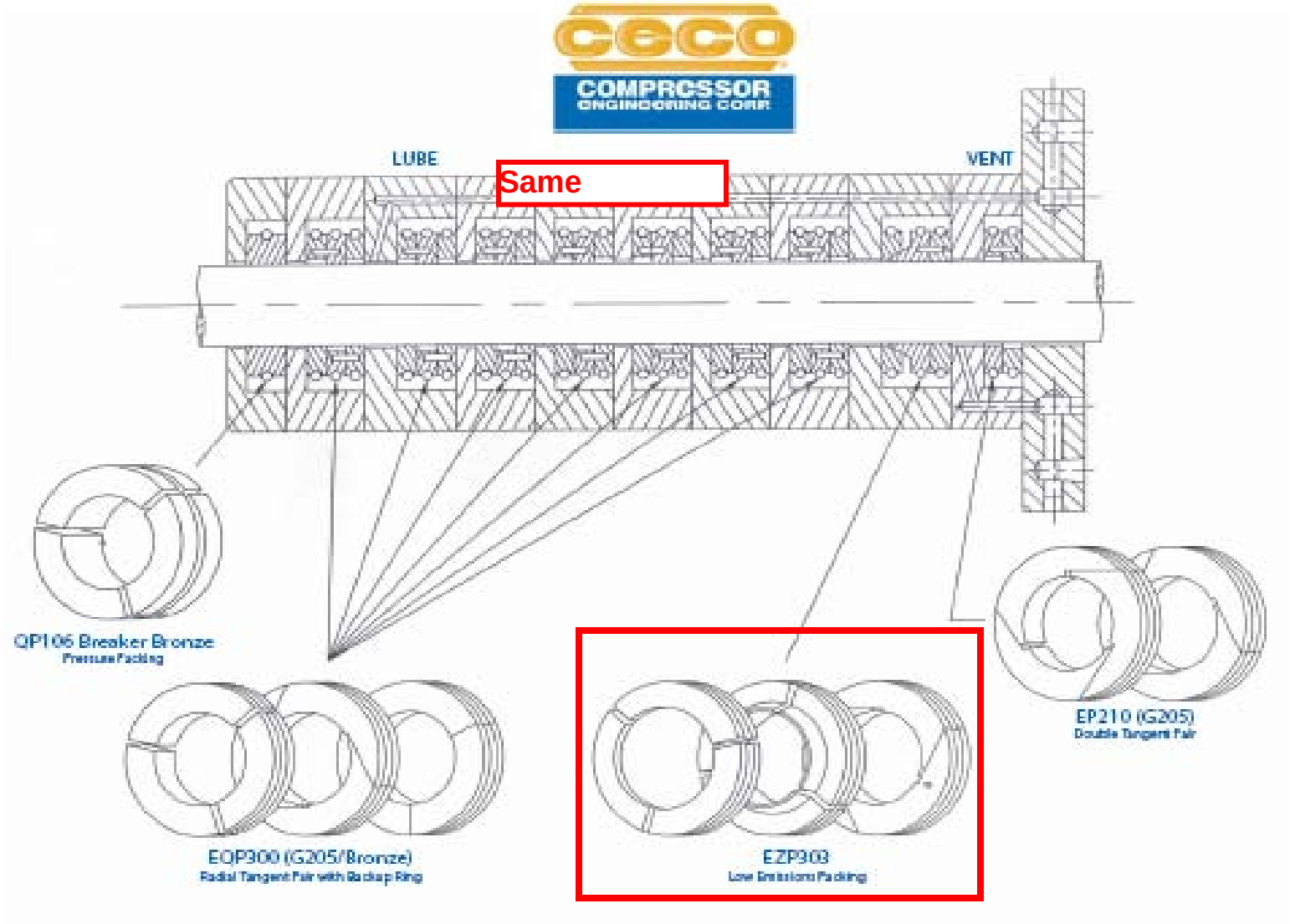
$$DF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

More Opportunities: Low Emission Packing (LEP)

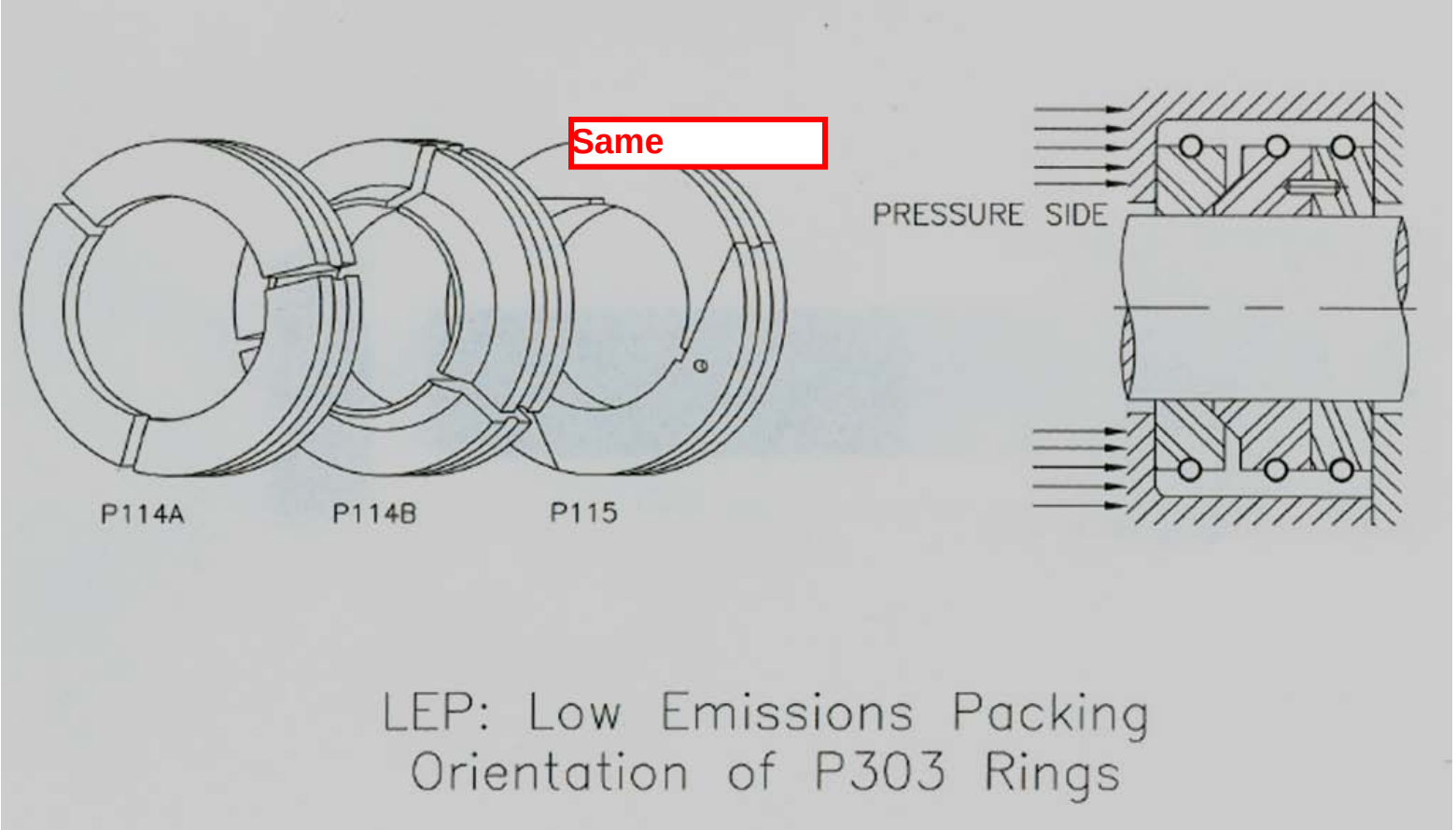
- The side load eliminates clearance and maintains positive seal on cup face
- LEP is a static seal, not a dynamic seal. No pressure is required to activate the packing
- This design works in existing packing case with limited, to no modifications required

Same

LEP Packing Configuration



Orientation in Cup



Reasons to Use LEP

- Upgrade is inexpensive
- Significant reduction of greenhouse gas is major benefit
- Refining, petrochemical, and air separation plants have used this design for many years to minimize fugitive emissions

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

Methane to Markets

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:

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