Methane to Markets

Reducing Methane Emissions from Compressors: Economic Rod Packing Replacement

IAPG & US EPA Technology Transfer Workshop

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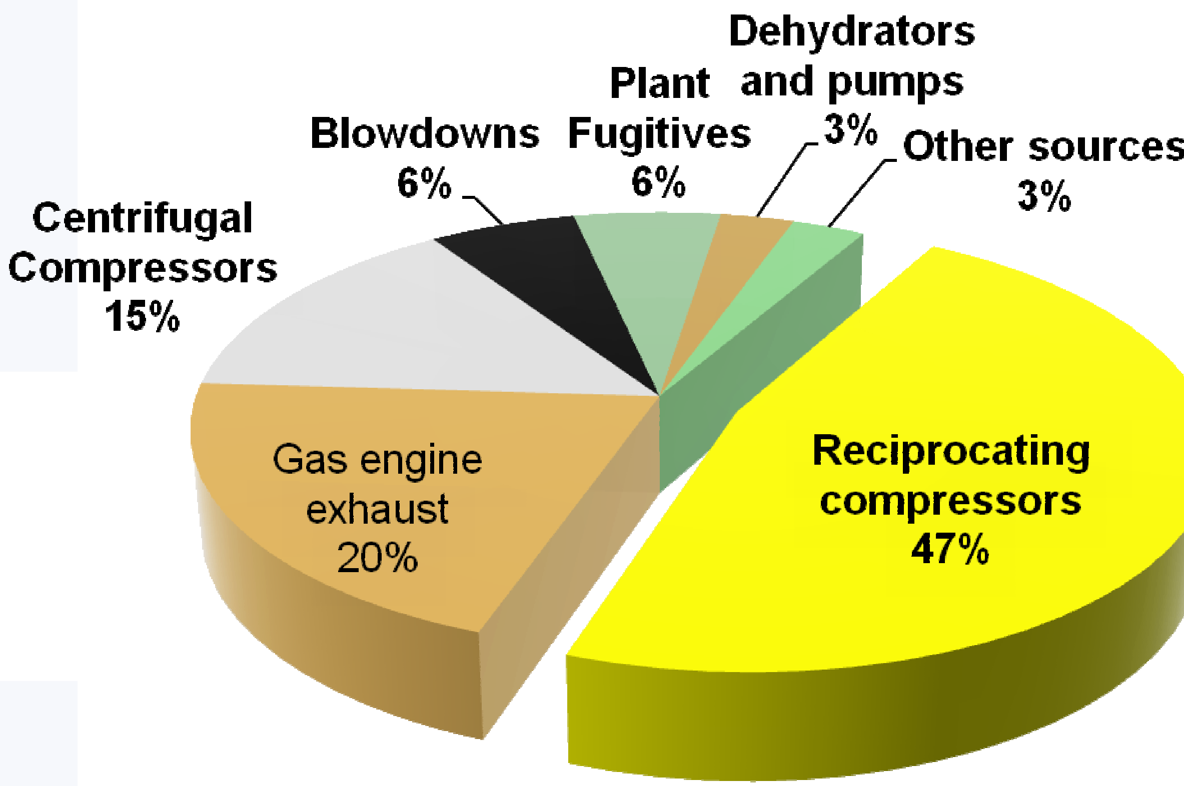
U.S. Processing Sector Methane Emissions

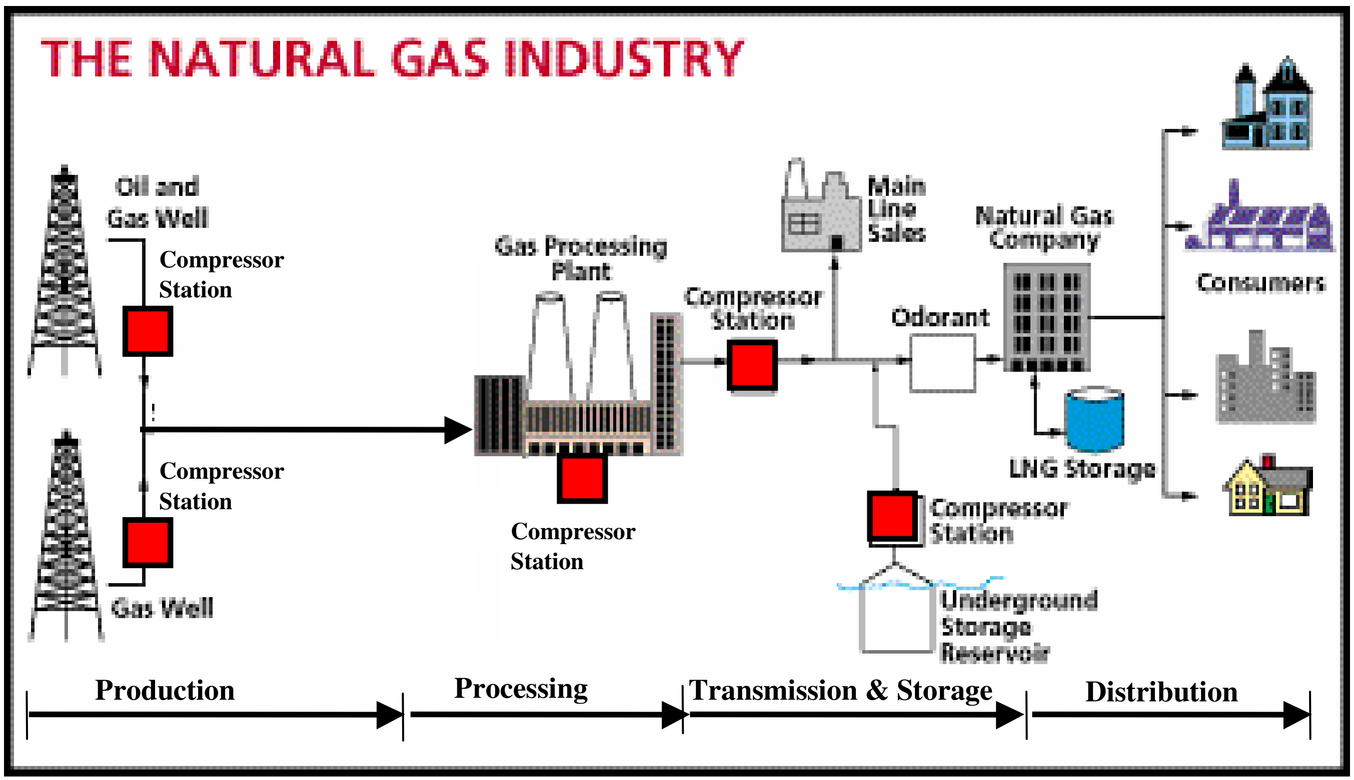


EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2006.* April, 2008. Available on the web at: epa.gov/climatechange/emissions/usinventoryreport.html

Note: Natural Gas STAR reductions from gathering and boosting operations are reflected in the production sector.

Compressor Methane Emissions What is the problem?

- It is estimated that methane emissions from compressors in the natural gas industry account for about one fourth of all methane emissions from the natural gas industry



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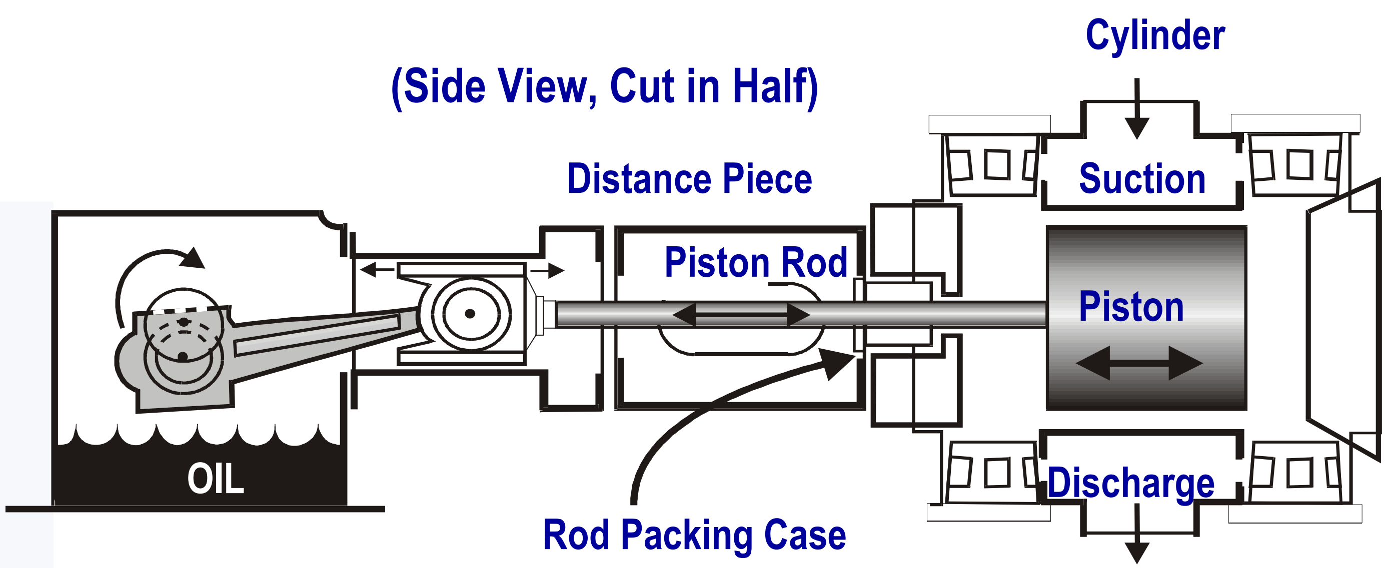
Methane Savings from Compressors: Agenda

- Reciprocating Compressors
  - Methane Losses
  - Methane Savings
  - Industry Experience
- Discussion

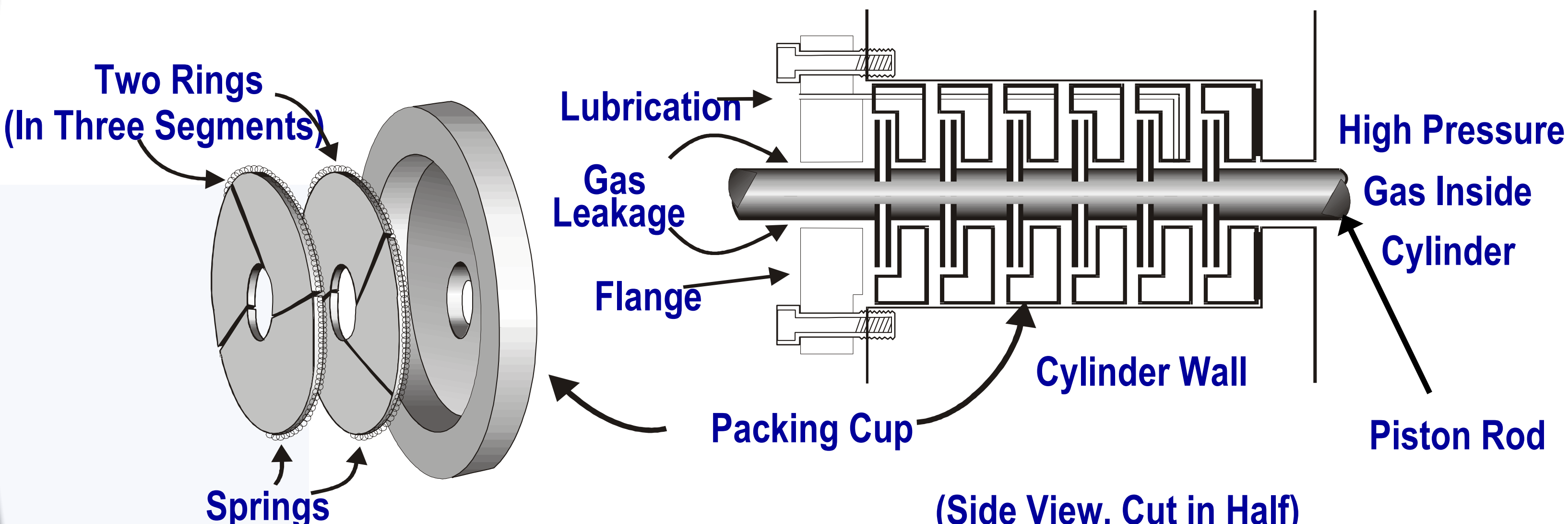
Methane Losses from Reciprocating Compressors

- Reciprocating compressor rod packing leaks some gas by design
  - Newly installed packing may leak 1,70 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



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Impediments to Proper Sealing

Ways packing case can leak

- Nose gasket (no crush)
- Packing to rod (surface finish)
- Packing to cup (lapped surface)
- Packing to packing (dirt/lube)
- Cup to cup (out of tolerance)

What makes packing leak?

- Dirt or foreign matter (trash)
- Worn rod (0,0015 mm/mm ∅)
- Insufficient/too much lubrication
- Packing cup out of tolerance (≤ 0,051mm)
- Improper break-in on startup
- Liquids (dilutes oil)
- Incorrect packing installed (backward or wrong type/style)

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Methane Losses from Rod Packing

Emission from Running Compressor	2,80	m^3/hour-packing
Emission from Idle/Pressurized Compressor	4,11	m^3/hour-packing
Leakage from Idle Compressor Packing Cup	2,24	m^3/hour-packing
Leakage from Idle Compressor Distance Piece	0,96	m^3/hour-packing

Leakage from Rod Packing on Running Compressors				
Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (m^3/hour)	1,98	1,78	4,25	0,68

Leakage from Rod Packing on Idle/Pressurized Compressors				
Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (m^3/hour)	1,98	N/A	4,16	0,62

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

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Steps to Determine Economic Replacement

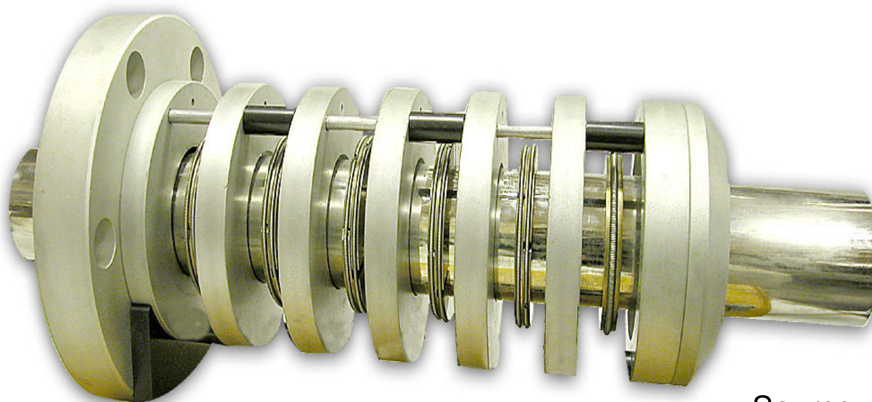
- Measure rod packing leakage
  - When new packing installed – after worn-in
  - Periodically afterwards
- Determine cost of packing replacement
- Calculate economic leak reduction
- Replace packing when leak reduction expected will pay back cost

Cost of Rod Packing Replacement

- Assess costs of replacements (US$)
  - A set of rings: / (with cups and case) / Rods:

A set of rings:	$ 135	to	$ 1.080
(with cups and case)	$ 1.350	to	$ 2.500
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 (m^3/hour) = $$\frac{CR \times A/P \times 1{,}000}{(H \times GP)}$$

Where:

CR = **Cost of replacement (US$)**

A/P = **Capital recovery factor at interest *i* and *n years recovery period***

H = **Hours of compressor operation per year**

GP = **Gas price (US$/thousand cubic meter)**

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Economic Replacement Threshold

- Example: Payback calculations for new rings and rod replacement

CR = \$1.620 for rings + \$9.450 for rod
CR = \$11.070

H = 8.000 hours per year

GP = \$70,63/Mm³ (US\$ 2/mcf)

A/P @ i = 10% , n = 1 year = 1,1

A/P @ i = 10% , n = 2 years = 0,576

Two year payback:

$$ER = \frac{\$11.070 \times 0{,}576 \times 1.000}{\left(8.000 \times \$70{,}63\right)}$$

$$= 11{,}28 \text{ stdm}^3 \text{ / hour}$$

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 with new rings

Rings Only

Rings: $1.620
Rod: $0
Gas: $70,63/Mm^3
Operating: 8.000 hours/year

Leak Reduction Expected (m^3/hour)	IRR (%)
2,27	74
1,70	52
1,42	40
1,13	28

Rod and Rings

Rings: $1.620
Rod: $9.450
Gas: $70,63/Mm^3
Operating: 8.000 hours/year

Leak Reduction Expected (m^3/hour)	IRR (%)
12,74	58
9,91	42
7.08	24
5,66	14

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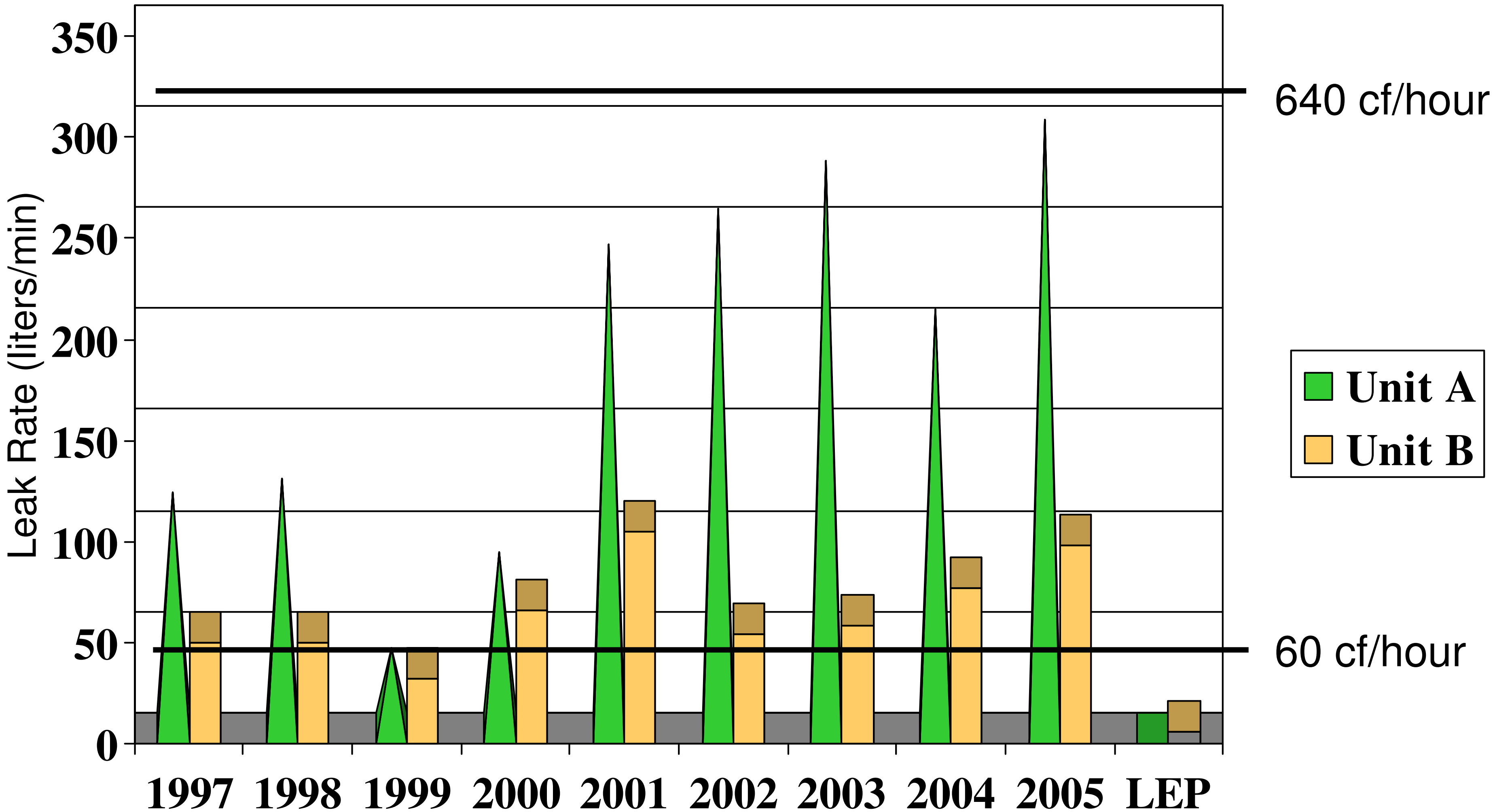
Industry Experience – Northern Natural Gas

- Monitored emission at two locations
  - Unit A leakage as high as 0,301 liters/min (640 cf/hour)
  - Unit B leakage as high as 105 liters/min (220 cf/hour)
- Installed Low Emission Packing (LEP)
  - After 3 months, leak rate showed zero leakage increase

Northern Natural Gas - Leakage Rates



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Case Study: Partner Packing Leakage Economic Replacement Point

- Approximate packing replacement cost is US$3.000 per compressor rod (parts/labor)
- Assuming gas at US$70,63/Mm3 ($2/Mcf):
  - 50 liters/minute =
  - 50 x 60 minutes/hour= 3.000 liters/hr
  - 3.000 x 24/1.000 = 72 m^3/day
  - 72 x 365 days= 26.280 m^3/year
  - 26.280/1.000 x $70,63/$Mm^3$ = $1,900 per year leakage
  - This replacement pays back in <2 years

Industry Experience – Natural Gas Star Partner

A physical leak measurement study was performed to quantify current gas losses and determine leak reduction potential for a 4 cylinder natural gas compressor.

- Actual leak rate: 76.3 m^3/h (668 Mm^3/year)
- Methane content of leakage flow: 78%
- Potential methane savings: 59.5 m^3/h (522 Mm^3/year)
- Implementation cost (rods and packing): US$ 56.000[1]
- Savings (@ US$ 70,63/Mm^3): US$ 37.000/year
- Payback: 19 months

1: Price considering US$ 7.500 per rod and US$ 2.500 per set of packing for each of the four cylinders with installation cost of US$4.000 per cylinder

Emissions from reciprocating compressors

Anticipated emissions:

- **Typical gas compression station: 3 x 3-stage 1.100 hp, 60 kg/cm^2 compressors**
- **Typical emissions:**

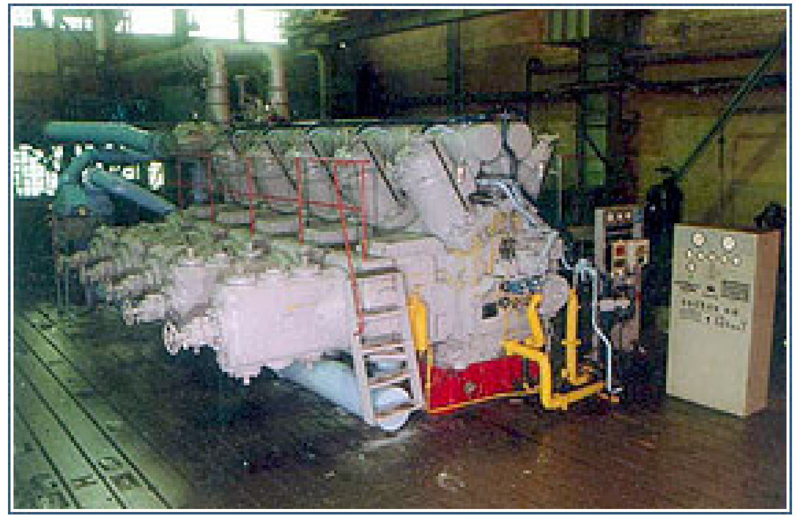
  50 Mm^3/year / compressor for total of 150 Mm^3 of gas emitted per station
- **Emissions affected by:**

  - Rod / packing material

  and construction

  - Maintenance frequency

  - Rotation speed



Mitigation Option:

Optimize frequency for replacing worn rod / packing rings

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Low Emission Packing

- Low emission packing (LEP) overcomes low pressure to prevent leakage
- 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

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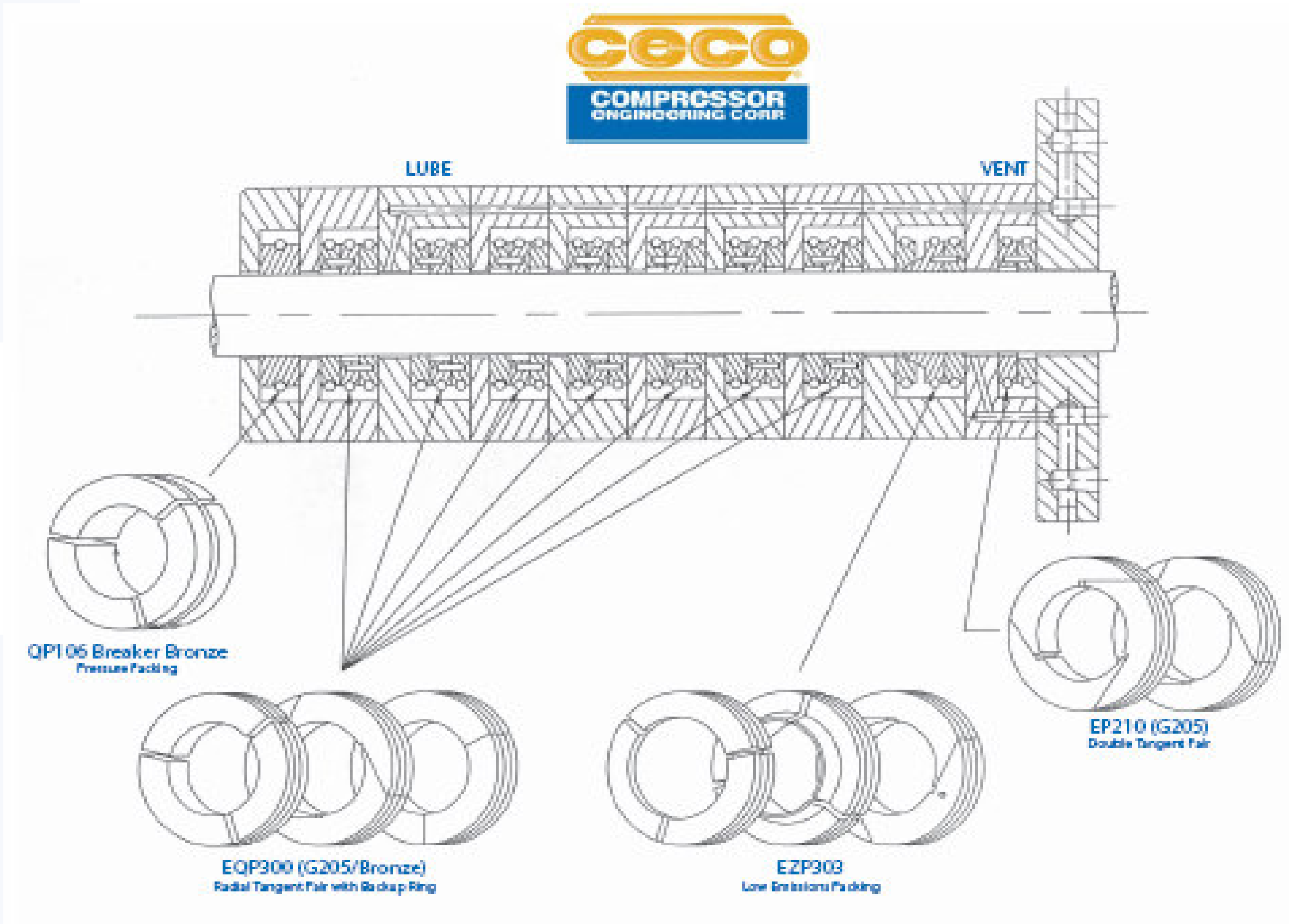
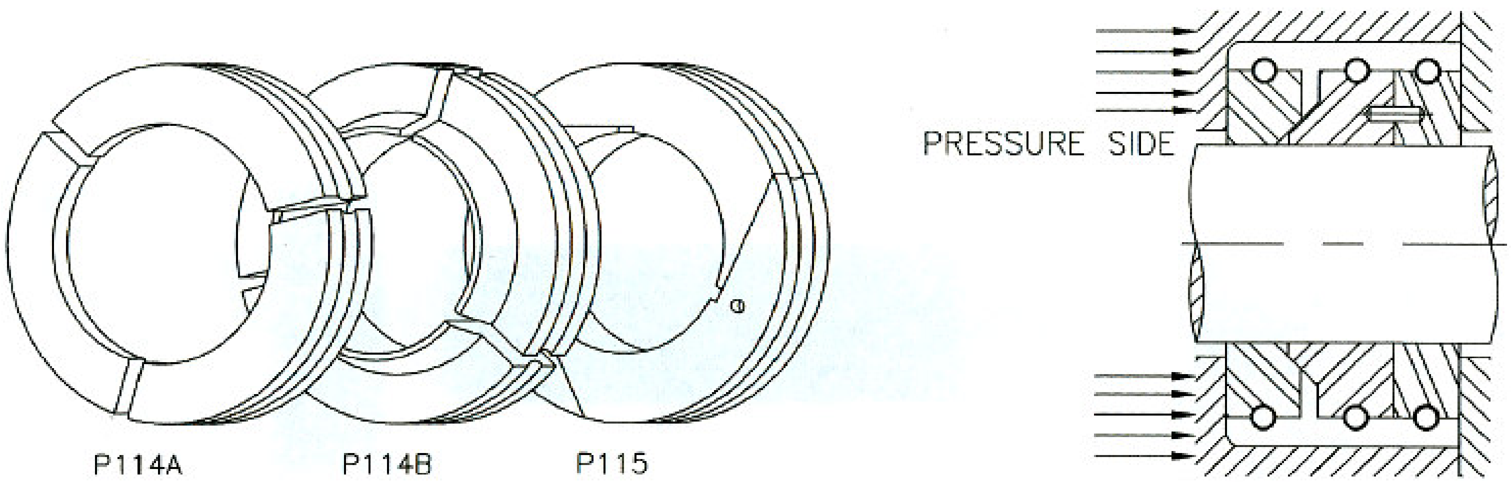
LEP Packing Configuration



Orientation in Cup



LEP: Low Emissions Packing
Orientation of P303 Rings

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Reasons to Use LEP

- Upgrade is inexpensive
- Significant reduction of greenhouse gas are major benefit
- Refining, petrochemical and air separation plants have used this design for many years to minimize fugitive emissions
- With gas at US$ 70,63/Mm3 (US$2/Mcf), many packing case leakage LEP applications are cost - effective.

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Discussion

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