Reciprocating Compressor Rod Packing

Lessons Learned from the
Natural Gas STAR Program

Chevron Corporation,
New Mexico Oil and Gas Association,
Texas Oil and Gas Association

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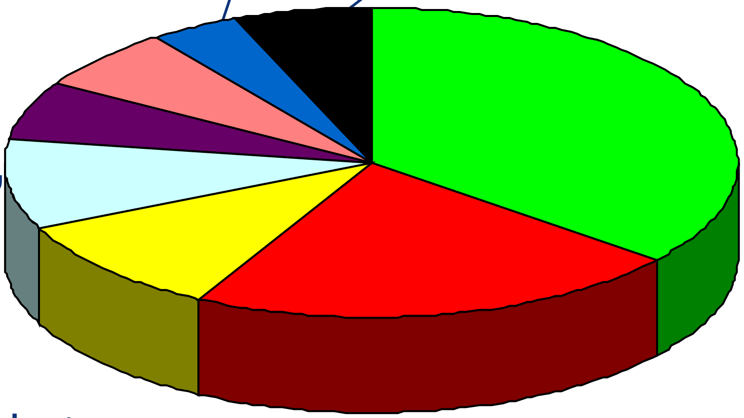
epa.gov/gasstar

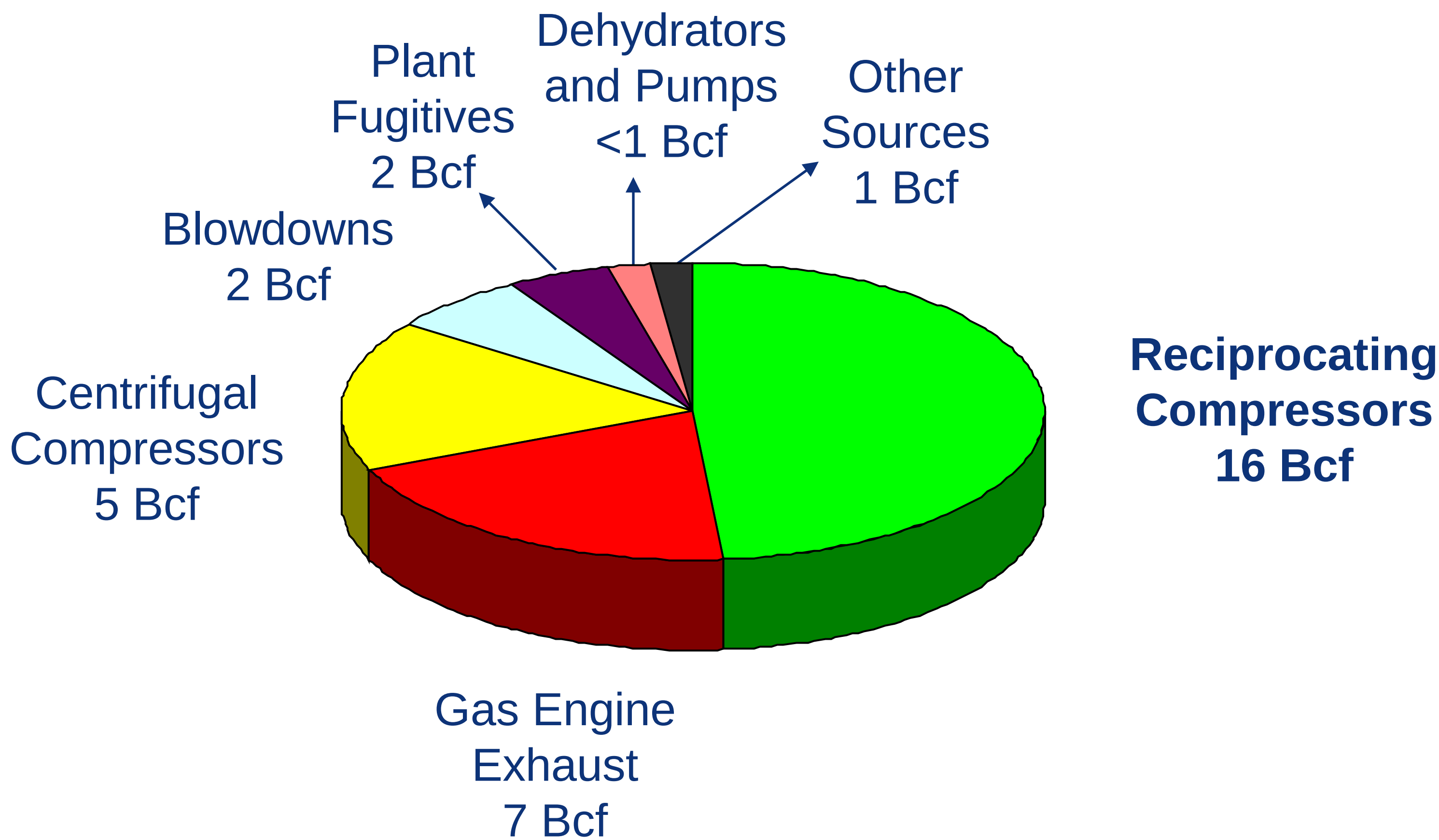
Industry Emissions: Production, Gathering, and Boosting



Source: 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.

2006 Processing Sector Methane Emissions

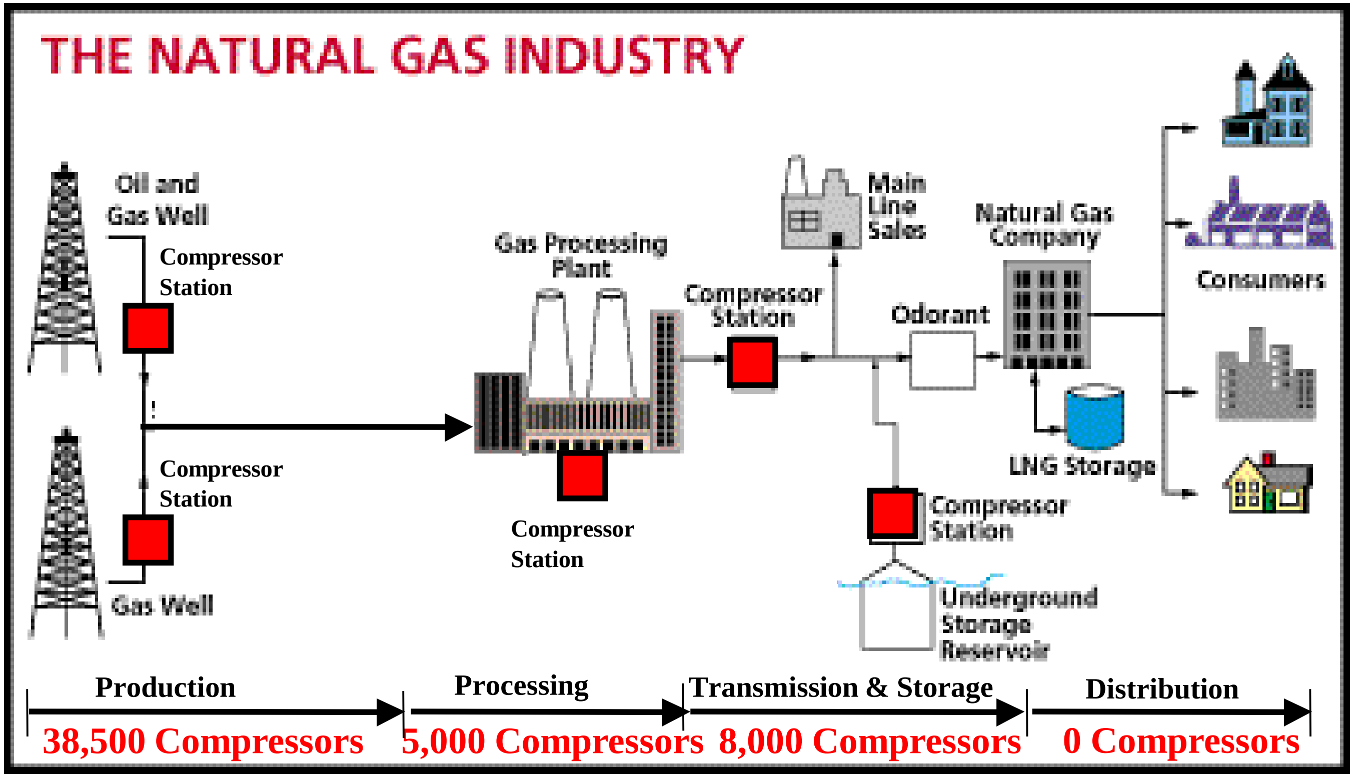


EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2006.* April, 2008. Available on the web at: epa.gov/climatechange/emissions/usinventoryreport.html

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

Compressor Methane Emissions
What is the problem?

- Methane emissions from the ~51,500 compressors in the natural gas industry account for 89 Bcf/year or about 24% of all methane emissions from the natural gas industry

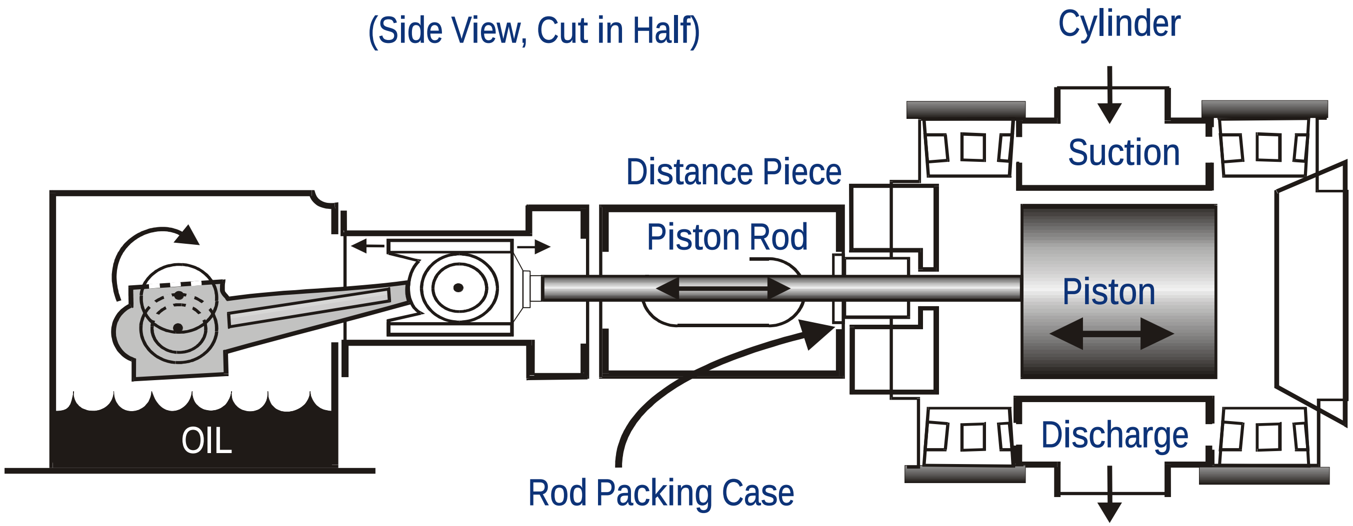


Methane Savings from Compressors: Agenda

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

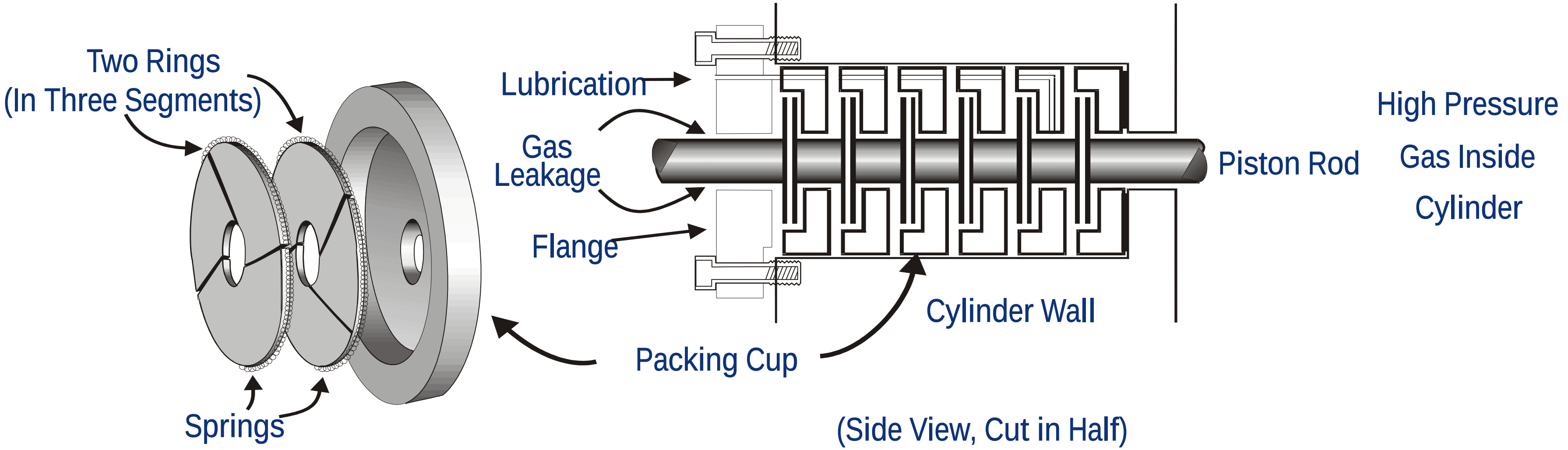
Methane Losses from Reciprocating Compressors

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



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 (.0015”/per inch dia.)
- Insufficient/too much lubrication
- Packing cup out of tolerance (≤ 0.002”)
- 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	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

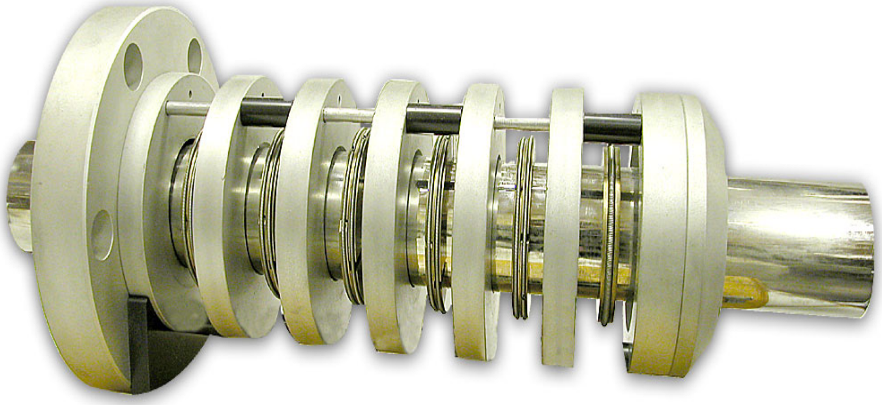
PRCI/ GRI/ EPA. *Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations*

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: $ 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 (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)**

Economic Replacement Threshold

- Example: Payback calculations for new rings and rod replacement

CR = $1,620 for rings + $9,450 for rod
= $11,070
H = 8,000 hours per year
GP = $7/Mcf

One year payback

$$ER = \frac{\$11{,}070 \times 1.1 \times 1{,}000}{\left(8{,}000 \times \$7\right)}$$

$$= 217 \text{ scf per hour}$$

DF @ i = 10% and n = 1 year

$$DF = \frac{0.1(1+0.1)^1}{(1+0.1)^1 - 1} = \frac{0.1(1.1)}{1.1-1} = \frac{0.11}{0.1} = 1.1$$

DF @ i = 10% and n = 2 years

$$DF = \frac{0.1(1+0.1)^2}{(1+0.1)^2 - 1} = \frac{0.1(1.21)}{1.21-1} = \frac{0.121}{0.21} = 0.576$$

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: $7/Mcf
Operating: 8,000 hours/year

Leak Reduction Expected (cf/hour)	Payback (months)
55	7
29	12
20	18
16	22

Rod and Rings

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

Leak Reduction Expected (cf/hour)	Payback (months)
376	7
197	13
137	18
108	22

Based on 10% interest rate
Mcf = thousand cubic feet

Industry Experience – Northern Natural Gas

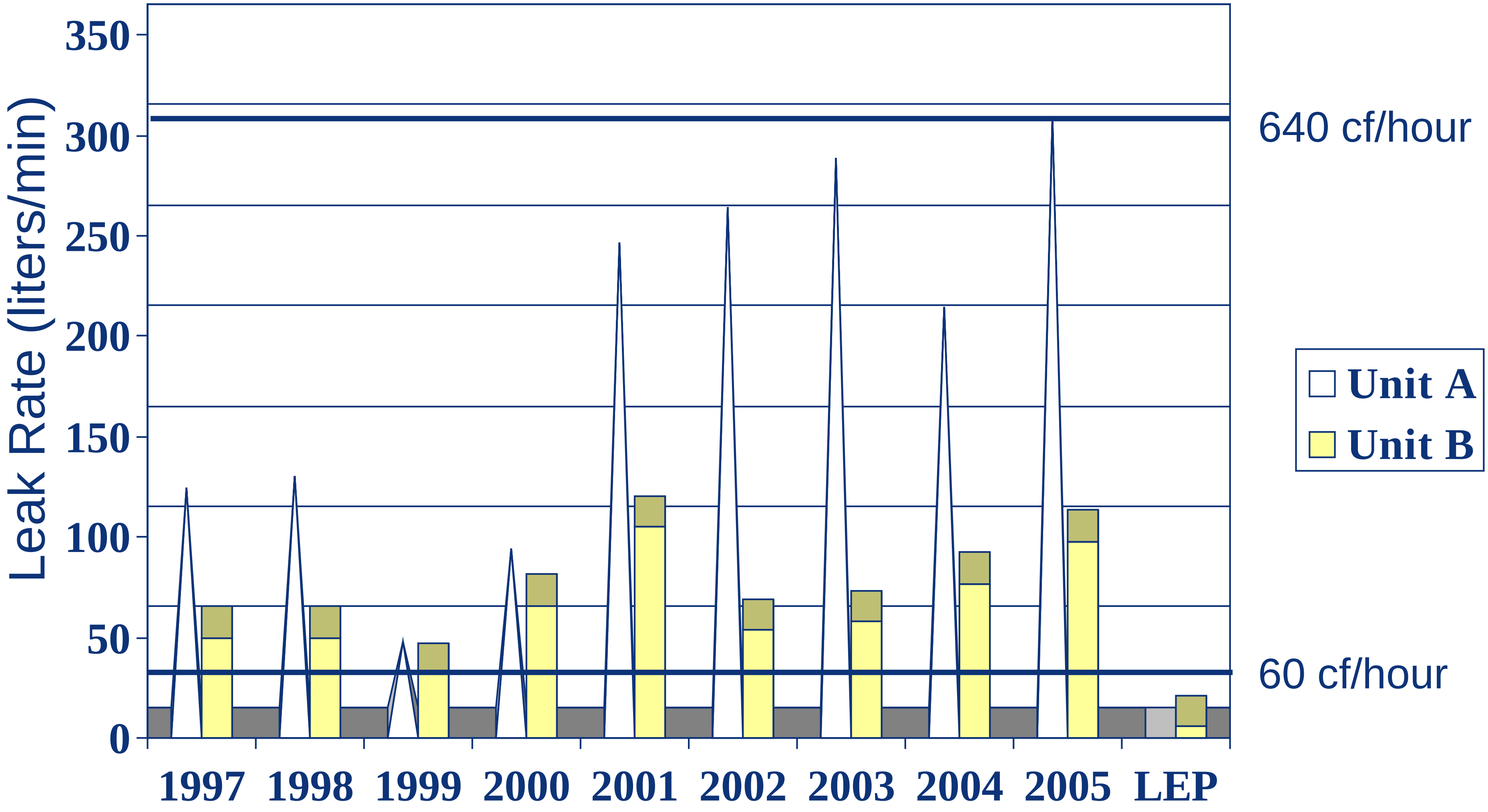
- Monitored emission at two locations
  - Unit A leakage as high as 301 liters/min (640 cf/hour)
  - Unit B leakage as high as 105 liters/min (220 cf/hour)
- Installed Low Emission Packing (LEP)
  - Testing is still in progress
  - After 3 months, leak rate shows zero leakage increase

Industry Experience – Occidental

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

Source: Occidental

Northern Natural Gas - Leakage Rates



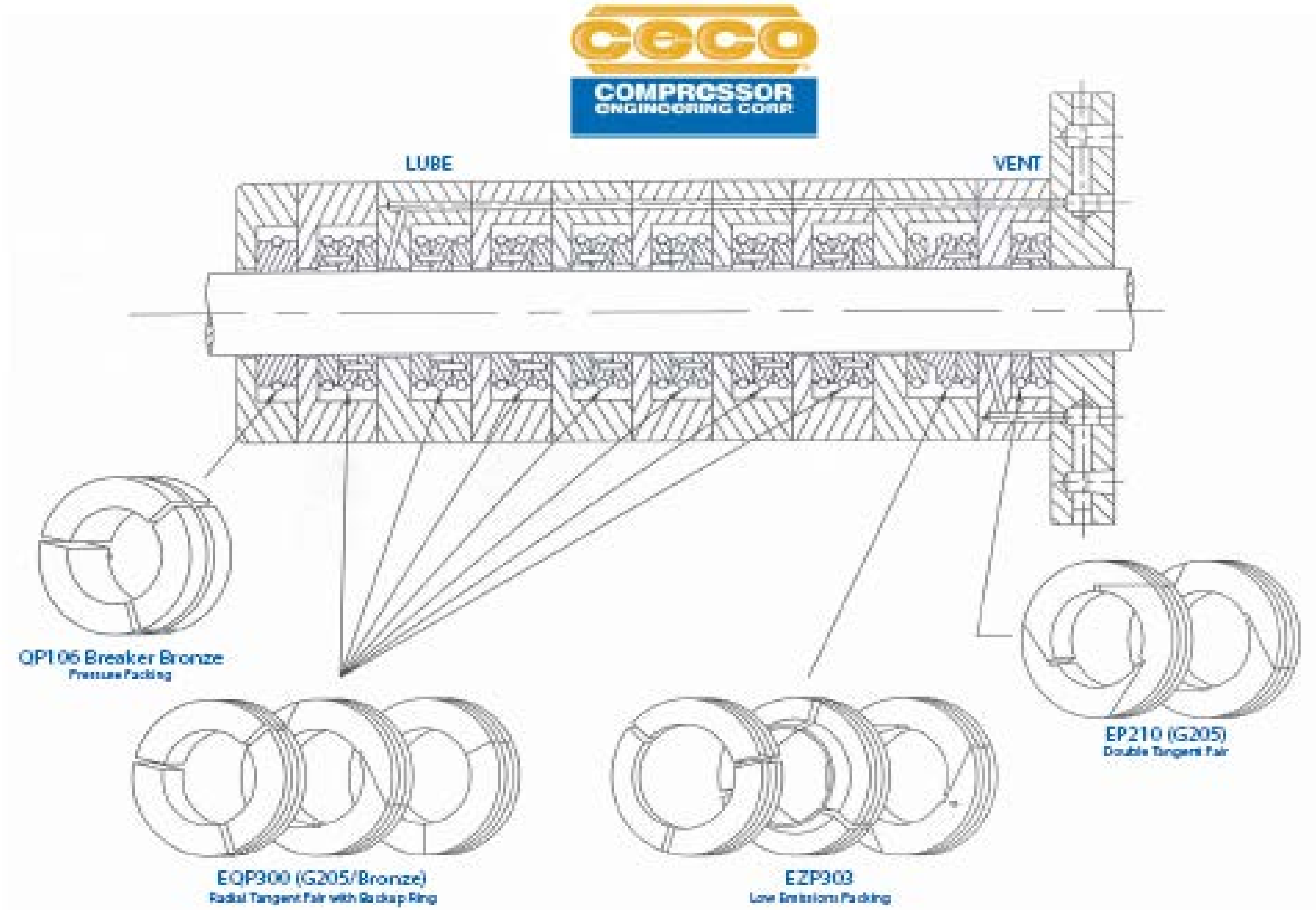
Northern Natural Gas Packing Leakage Economic Replacement Point

- Approximate packing replacement cost is $3,000 per compressor rod (parts/labor)
- Assuming gas at $7/Mcf:
  1 cubic foot/minute = 28.3 liters/minute
  - 50 liters/minute/28.316 = 1.8 scf/minute
  - 1.8 x 60 minutes/hour= 108 scf/hr
  - 108 x 24/1000 = 2.6 Mcf/day
  - 2.6 x 365 days= 950 Mcf/year
  - 950 x $7/Mcf = $6,650 per year leakage
  - This replacement pays back in <6 months

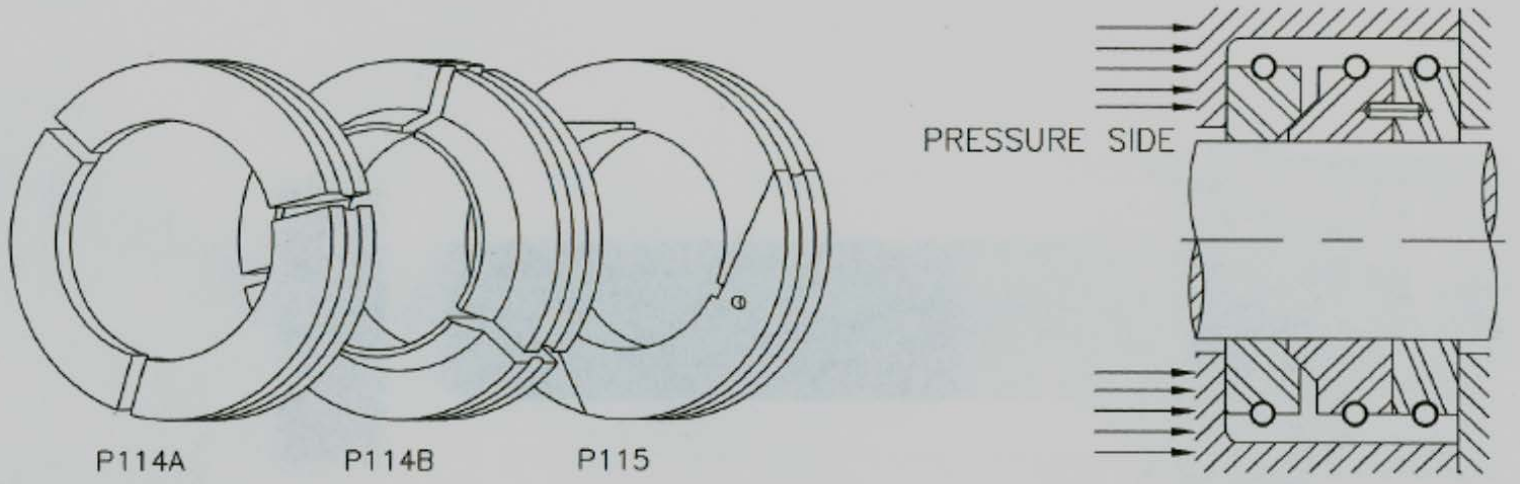
Low Emission Packing

- 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

LEP Packing Configuration



Orientation in Cup



LEP: Low Emissions Packing
Orientation of P303 Rings

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 $7/Mcf, packing case leakage should be identified and fixed.

Discussion

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