Methane Savings from Compressors

Lessons Learned from the
Natural Gas STAR Program

Anadarko Petroleum Corporation and the
Domestic Petroleum Council

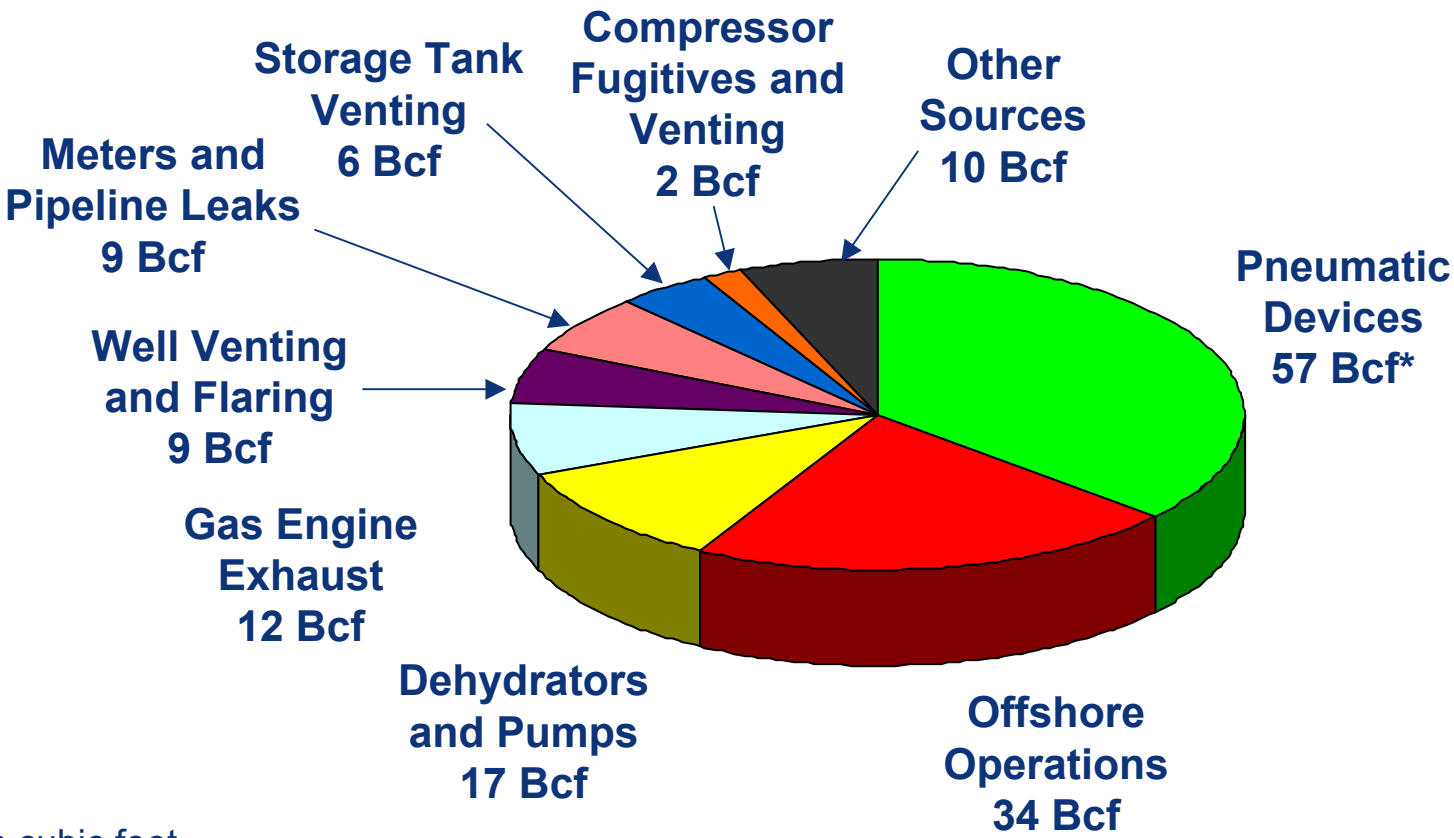
Producers Technology Transfer Workshop
College Station, Texas
May 17, 2007

epa.gov/gasstar

Compressors: Agenda

- Methane Losses from Reciprocating Compressors
- Methane Savings through Economic Rod Packing Replacement
- Is Rod Packing Replacement Profitable?
- Industry Experience – Northern Natural Gas
- Low Emission Packing
- Discussion

Methane Emissions from Natural Gas Production Sector (2005)

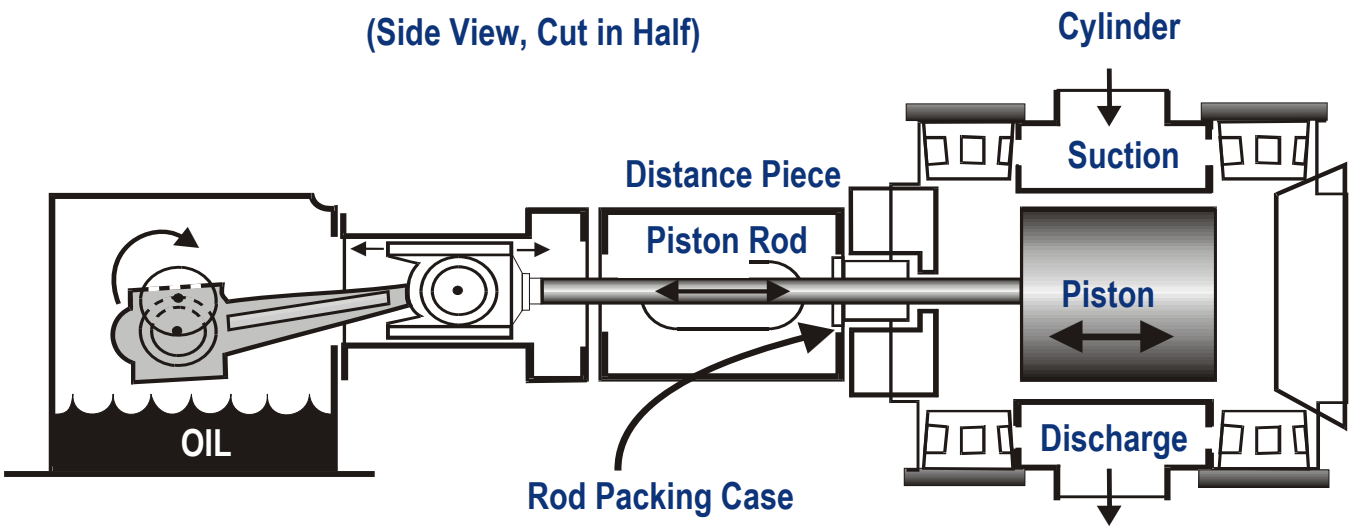


*Bcf = billion cubic feet

EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2005.* April, 2007. Available on the web at: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissions.html
Natural Gas STAR reductions data shown as published in the inventory.

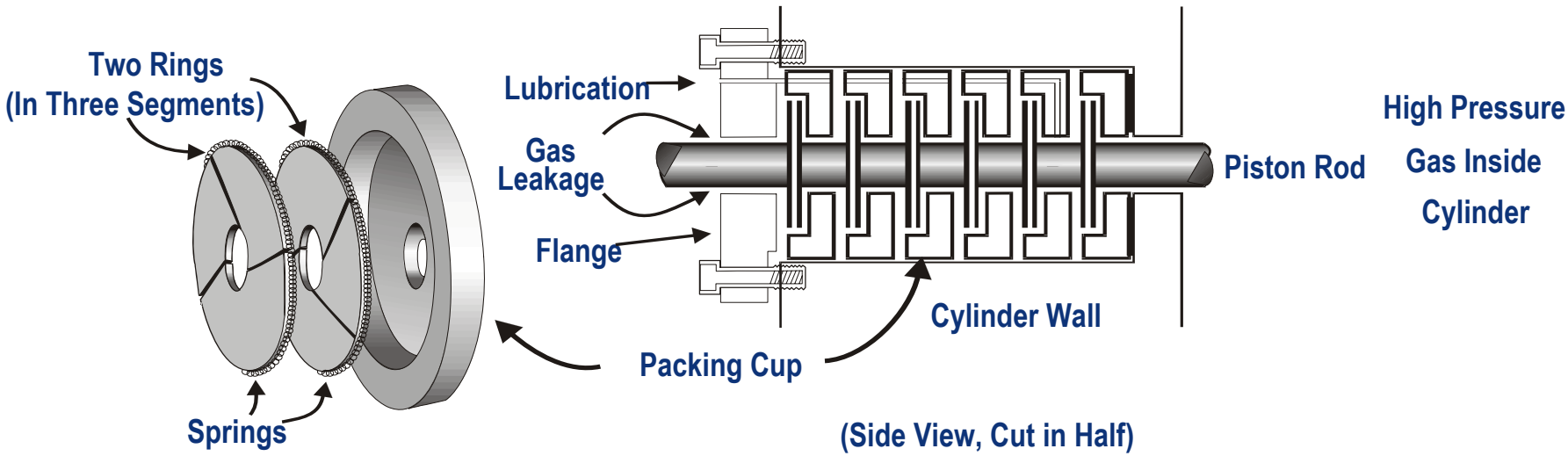
Methane Losses from Reciprocating Compressors

- 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 ($\leq$ 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

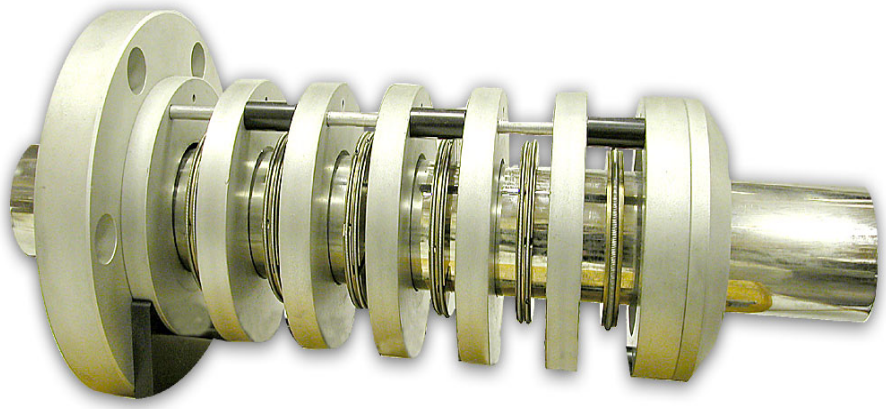
PRCI/ GRI/ EPA. *Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations*

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: $ 675 to $ 1,100
    (with cups and case) $ 2,100 to $ 3,400
  - Rods: $ 2,500 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

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

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

One year payback

$$ER = \frac{\$11{,}070 \times 1.1 \times 1{,}000}{(8{,}000 \times \$7)}$$
$$= 217 \text{ scf per hour}$$

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

Leak Reduction Expected (cf/hour)	Payback (year)
32	1
17	2
12	3
9	4

Rod and Rings

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

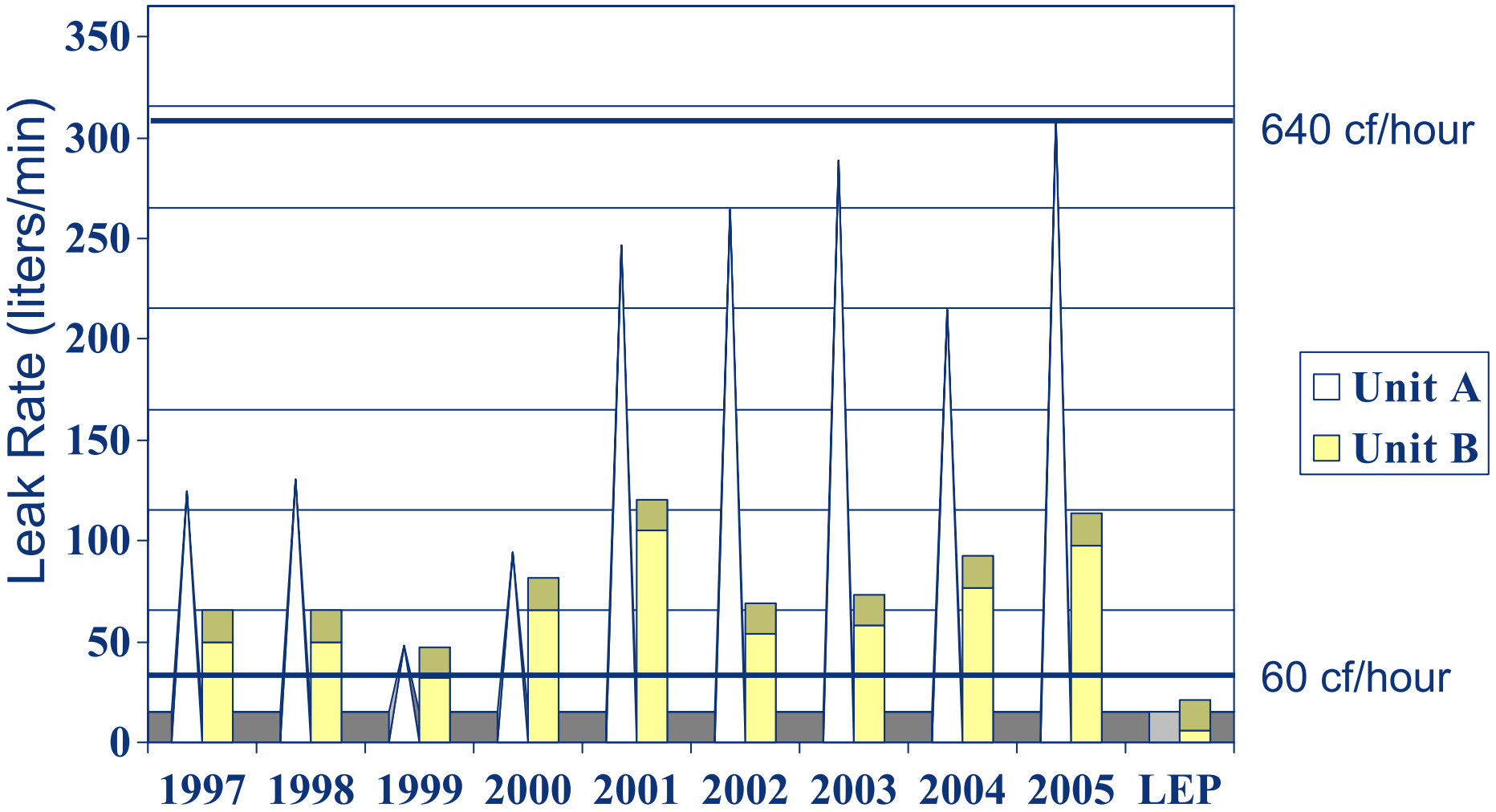
Leak Reduction Expected (cf/hour)	Payback (year)
217	1
114	2
79	3
62	4

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

Northern Natural Gas - Leakage Rates



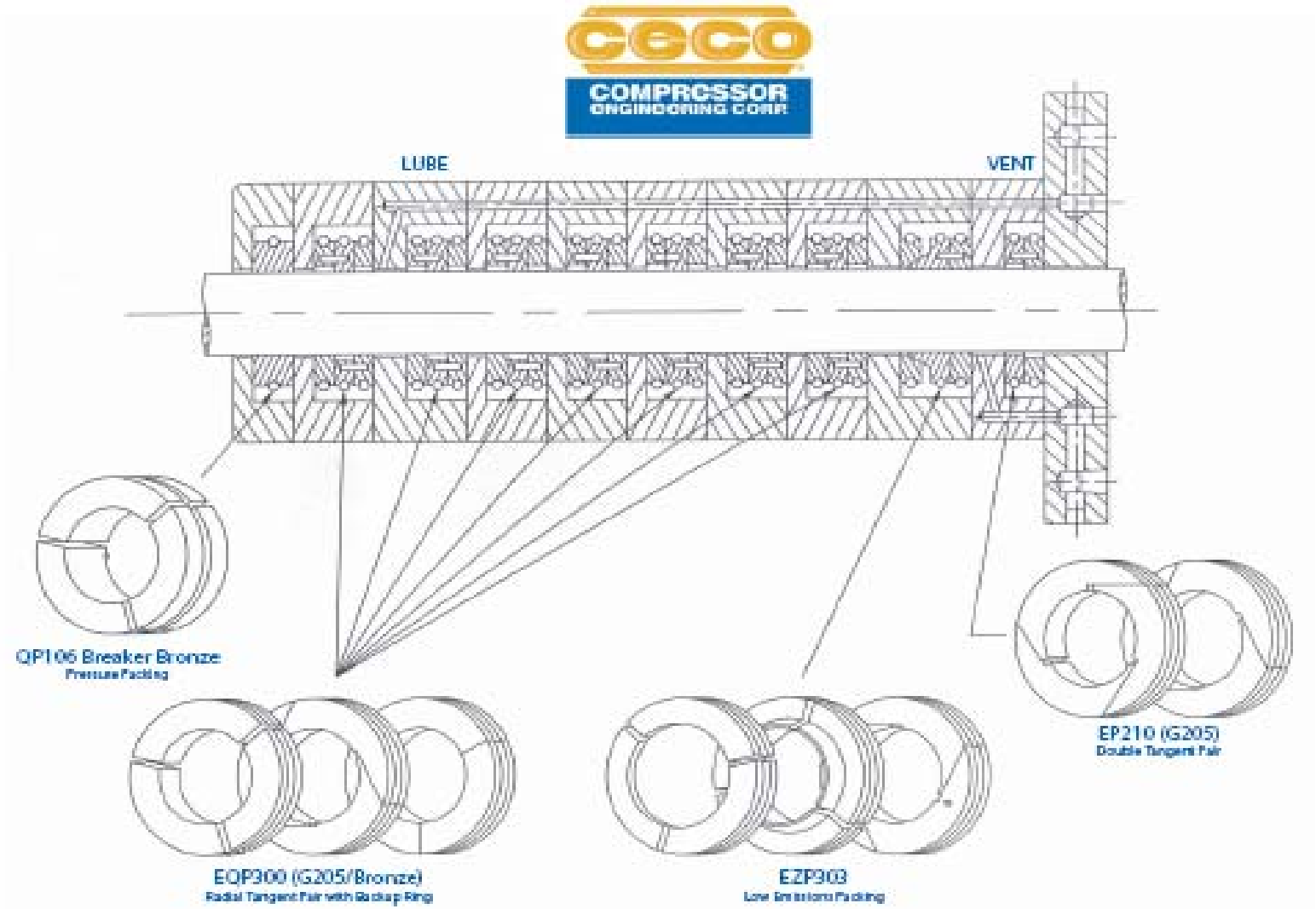
Northern Natural Gas Packing Leakage Economic Replacement Point

- 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 1440 minutes/day= 2,600 scf/day
  - 2,600/1000 = 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

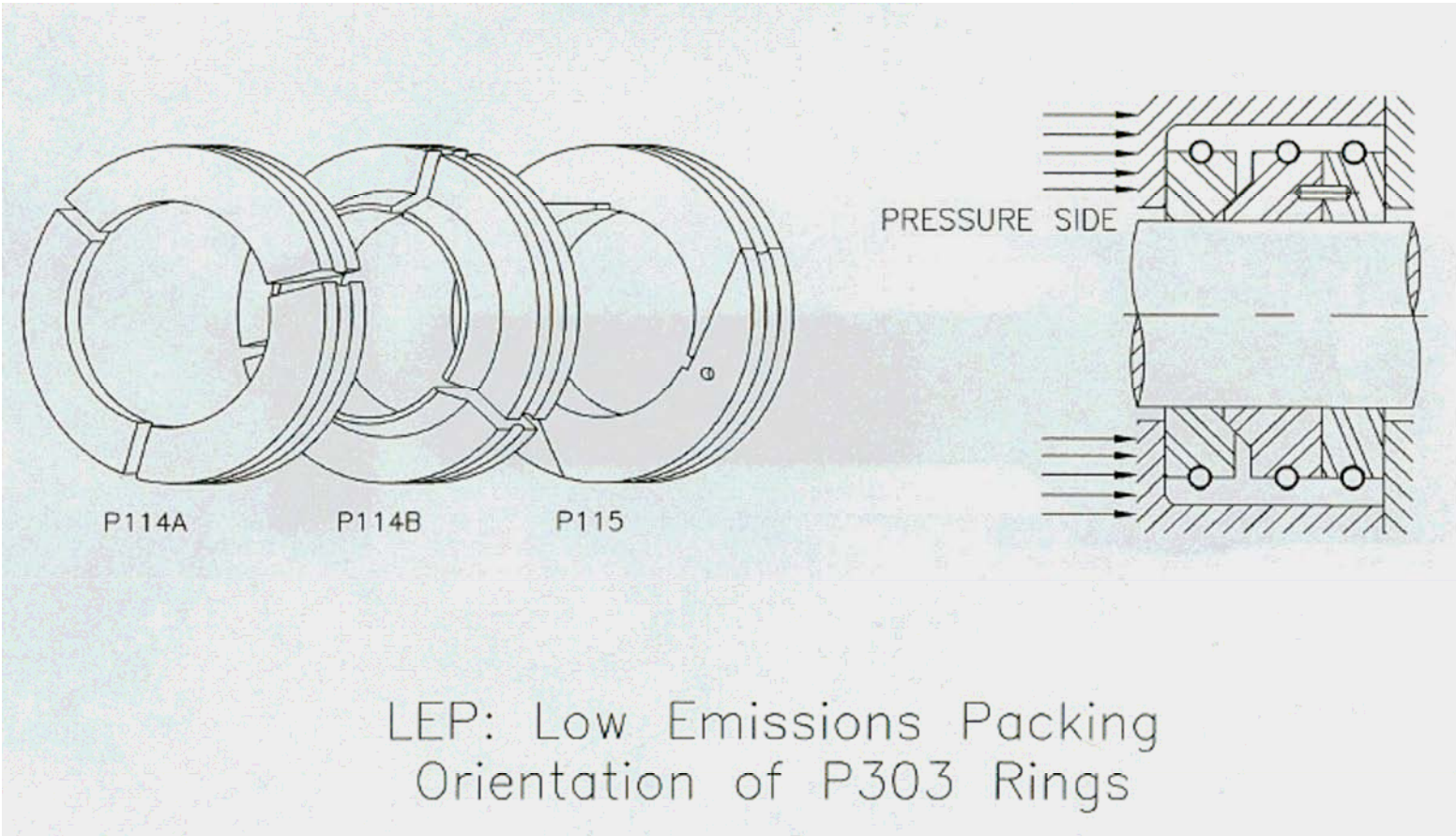
Low Emission Packing

- 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



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 an practices
- Actual costs and benefits
- Leased compressors
  - Control over rod packing type and maintenance?