Methane Losses from Compressors

Lessons Learned
from Natural Gas STAR

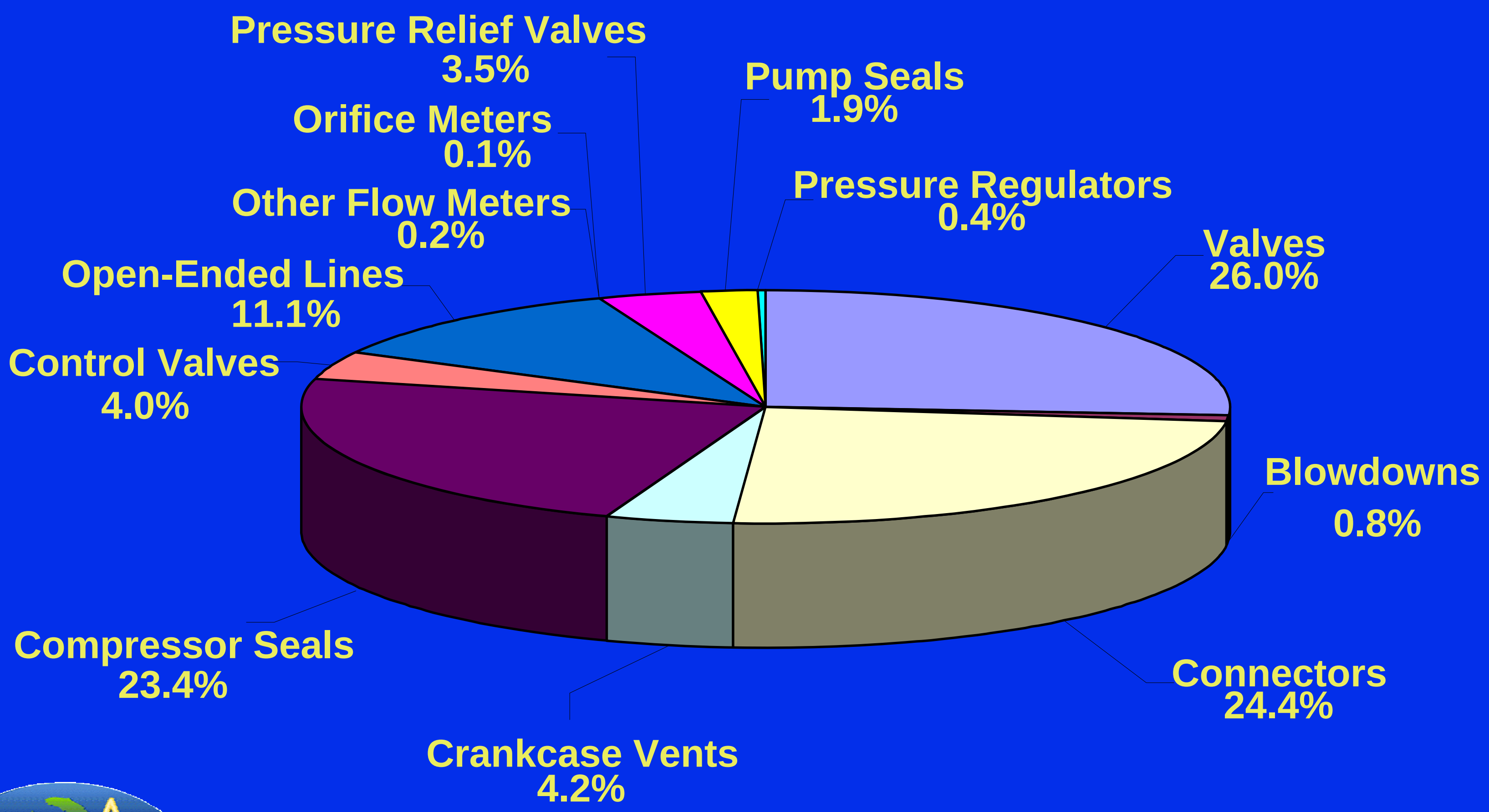
Producers Technology Transfer Workshop

Marathon Oil and
EPA's Natural Gas STAR Program
Houston, TX
October 26, 2005

Compressors: Agenda

- Methane Emissions
- Reciprocating Compressors
- Centrifugal Compressors
- Directed Inspection and Maintenance (DI&M)
- Discussion Questions

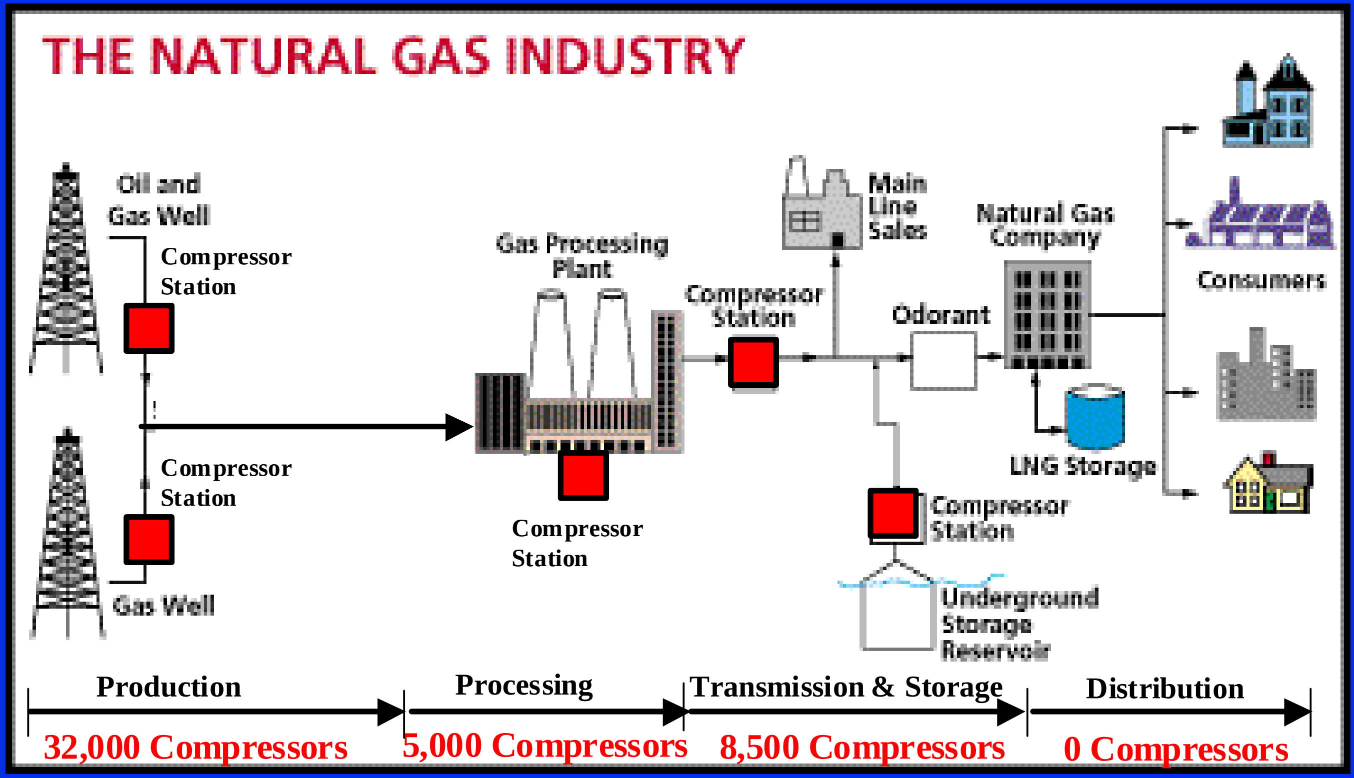
Natural Gas Losses by Equipment Type



Clearstone Engineering, 2002

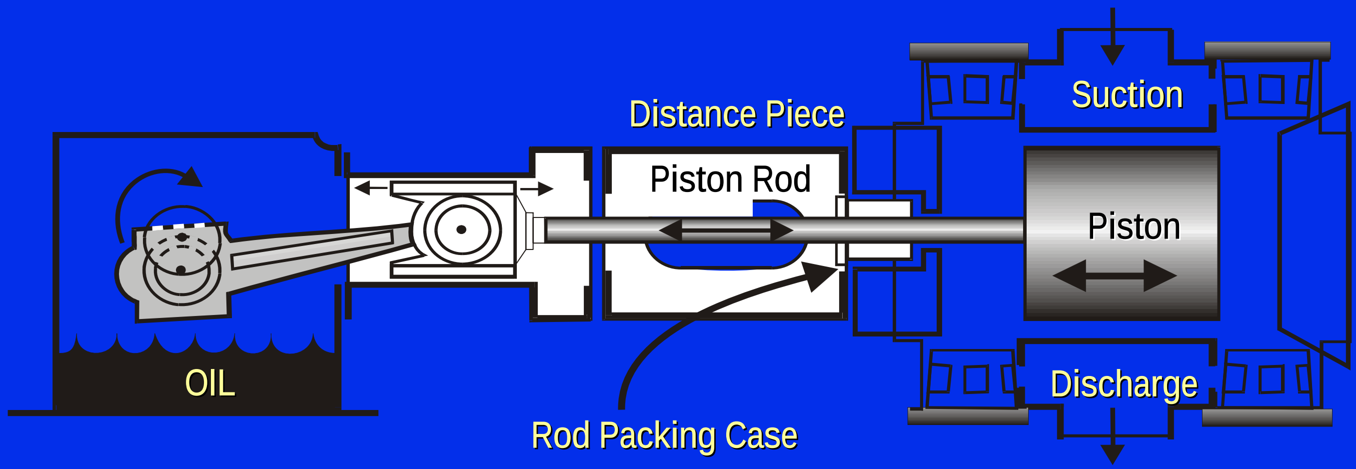
Compressor Emissions
What is the problem?

- ✫ Fugitive emissions from compressors in all sectors are responsible for approximately 86 Bcf/yr
- ✫ Over 45,000 compressors in the natural gas industry



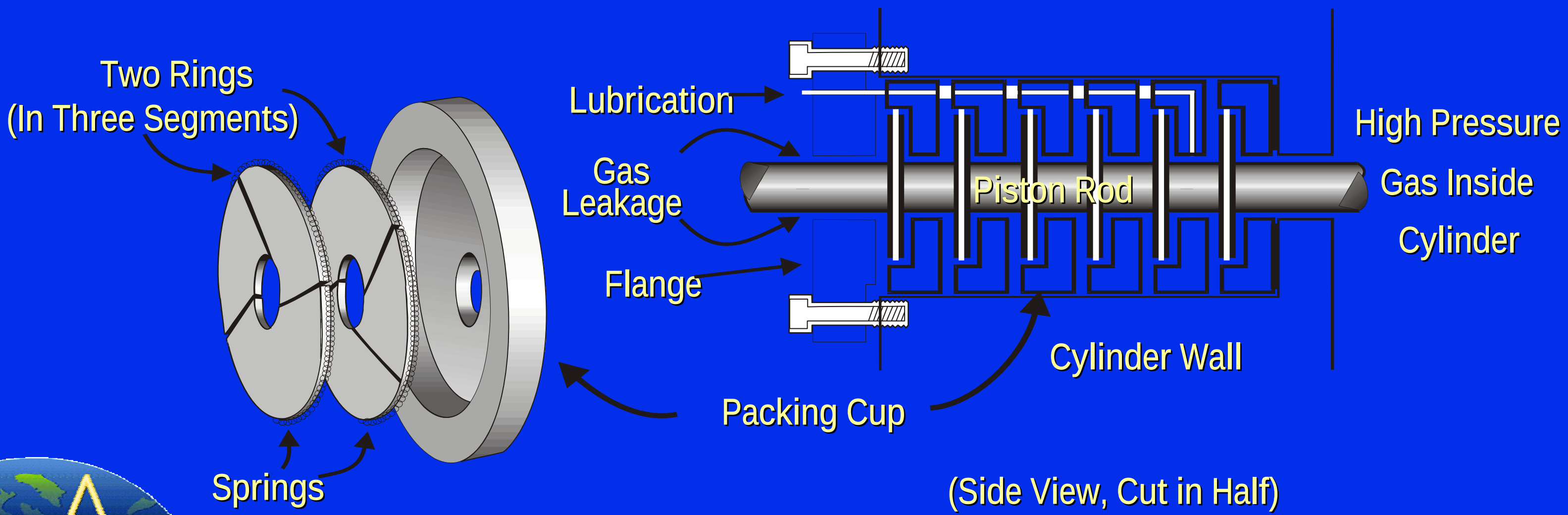
Methane Losses from Reciprocating Compressors

- Reciprocating compressor rod packing leaks some gas by design
  - **Newly installed packing may leak 60 cubic feet per hour (cf/h)**
  - **Worn packing has been reported to leak up to 900 cf/h**



Reciprocating Compressor Rod Packing

- A series of flexible rings fit around the shaft to prevent leakage
- Leakage still occurs through nose gasket, between packing cups, around the rings and between rings and shaft



Methane Losses from Rod Packing

Emission from Running Compressor	870	Mcf/year-packing
Emission from Idle/Pressurized Compressor	1270	Mcf/year-packing
Leakage from Packing Cup	690	Mcf/year-packing
Leakage from Distance Piece	300	Mcf/year-packing

Leakage from Rod Packing on Running Compressors

Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (Mcf/yr)	612	554	1317	210

Leakage from Rod Packing on Idle/Pressurized Compressors

Packing Type	Bronze	Bronze/Steel	Bronze/Teflon	Teflon
Leak Rate (Mcf/yr)	614	N/A	1289	191

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

Methane Recovery Through Economic Rod Packing Replacement

- Assess costs of replacements
  - A set of rings: $ 500 to $ 800
    (with cups and case) $1500 to $2500
  - Rods: $1800 to $10000
    - Special coatings such as ceramic, tungsten carbide, or chromium can increase rod costs
  - Determine economic replacement threshold
  - Partners can determine economic threshold for all replacements

$$\text{Economic Replacement Threshold (scfh)} = \frac{CR * DF * 1{,}000}{(H * GP)}$$

Where:

CR = Cost of replacement ($)
DF = Discount factor (%) @ interest *i*
H = Hours of compressor operation per year
GP = Gas price ($/Mcf)

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

Is Rod Packing Replacement Profitable?

- Periodically measure leakage increase

Rings Only

Rings:	$1,200
Rod:	$0
Gas:	$3/Mcf
Operating:	8,000 hrs/yr

Leak Reduction Expected (scfh)	Payback Period (yrs)
55	1
29	2
20	3
16	4
13	5

Rod and Rings

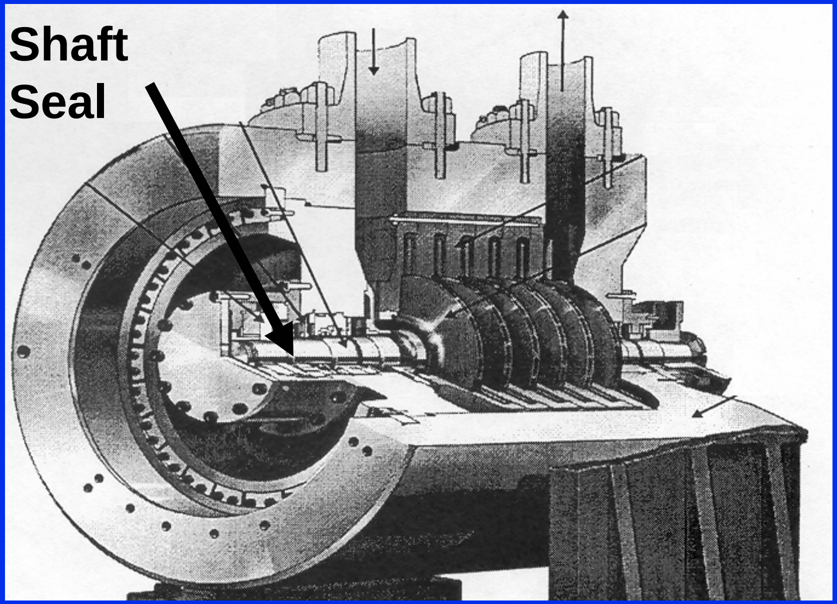
Rings:	$1,200
Rod:	$7,000
Gas:	$3/Mcf
Operating:	8,000 hrs/yr

Leak Reduction Expected (scfh)	Payback Period (yrs)
376	1
197	2
137	3
108	4
90	5

Based on 10% interest rate
Mcf = thousand cubic feet, scfh = standard cubic feet per hour

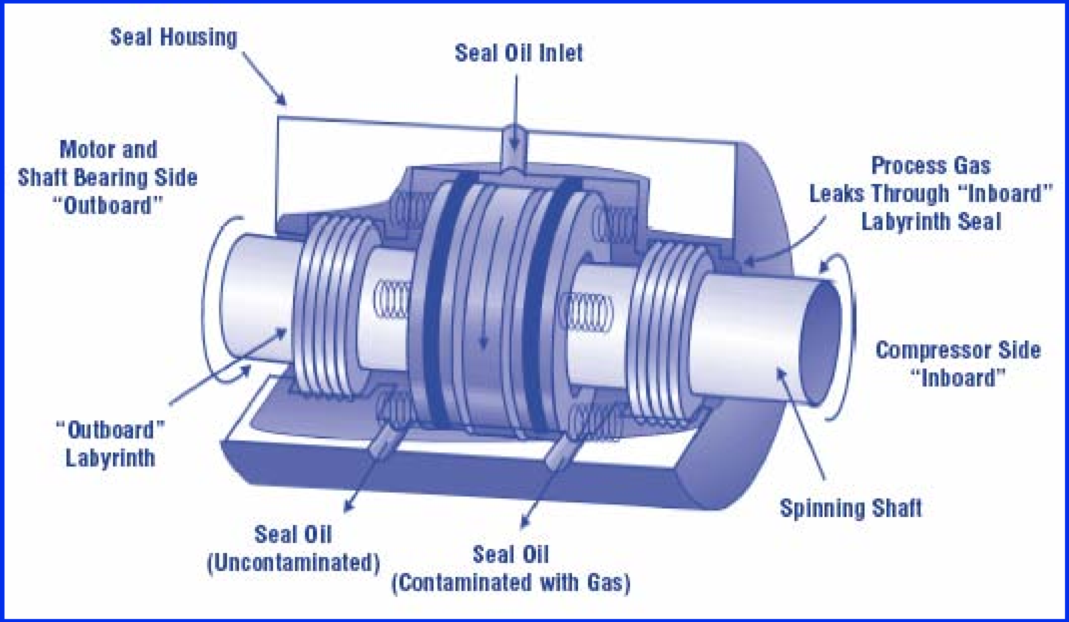
Methane Losses from Centrifugal Compressors

- Centrifugal compressor wet seals leak little gas at the seal face
  - **Seal oil degassing may vent 40 to 200 cubic feet per minute (cf/m) to the atmosphere**
  - **A Natural Gas STAR partner reported wet seal emissions of 75 Mcf/day (52 cf/m)**



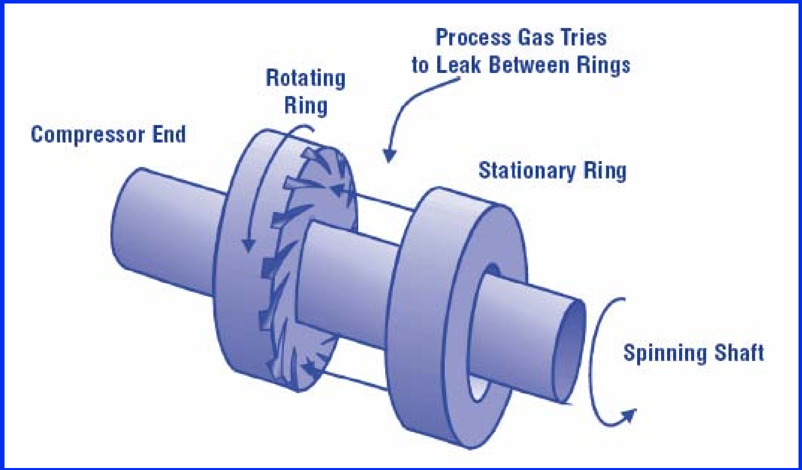
Centrifugal Compressor Wet Seals

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



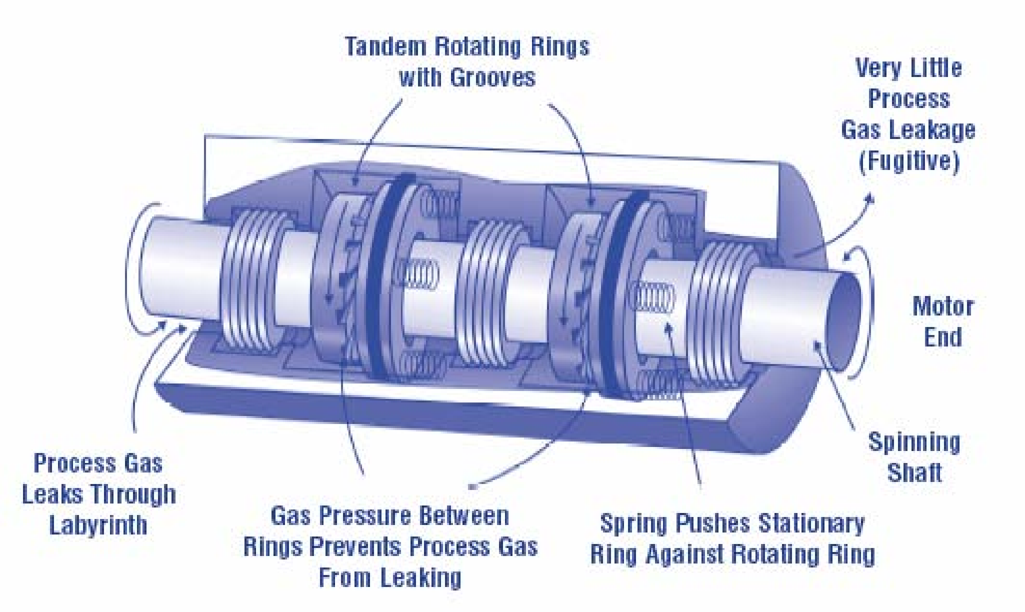
Gas STAR Partners Reduce Emissions with Dry Seals

- Dry seal springs press the stationary ring in the seal housing against the rotating ring when the compressor is not rotating
- At high rotation speed, gas is pumped between the seal rings 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 3,000 psig safely



Methane Recovery with Dry Seals

- Dry seals typically leak at a rate of only 0.5 to 3 cf/m
  - **Significantly less than the 40 to 200 cf/m emissions from wet seals**
- Gas savings translate to approximately $49,000 to $279,000 at $3/Mcf



EPA POLLUTION PREVENTER

Other Benefits with Dry Seals

- Aside from gas savings and reduced emissions, dry seals also:
  - **Lower operating cost**
    - **Dry seals do not require seal oil make-up**
  - **Reduced power consumption**
    - **Wet seals require 50 to 100 kiloWatt per hour (kW/hr) for ancillary equipment while dry seals need only 5 kW/hr**
  - **Improve reliability**
    - **More compressor downtime is due to wet seals with more ancillary components**
  - **Eliminate seal oil leakage into the pipelines**
    - **Dry seals lower drag in pipelines (and horsepower to overcome)**

Economics of Replacing Seals

- Compare costs and savings for a 6-inch shaft beam compressor

Cost Category	Dry Seal ($)	Wet Seal ($)
Implementation Costs		
Seal costs (2 dry @ $10,000/shaft-inch, w/testing)	120,000	
Seal costs (2 wet @ $5,000/shaft-inch)		60,000
Other costs (engineering, equipment installation)	120,000	0
Total Implementation Costs	240,000	60,000
Annual O&M	10,000	73,000
Annual methane emissions[4] (@ $3.00/Mcf; 8,000 hrs/yr)		
2 dry seals at a total of 6 scfm	8,640	
2 wet seals at total 100 scfm		144,000
Total Costs Over 5-Year Period ($):	333,200	1,145,000
Total Dry Seal Savings Over 5 Years:		
Savings ($)	811,800	
Methane Emissions Reductions (Mcf) (at 45,120 Mcf/yr)	225,600	

Flowserve Corporation

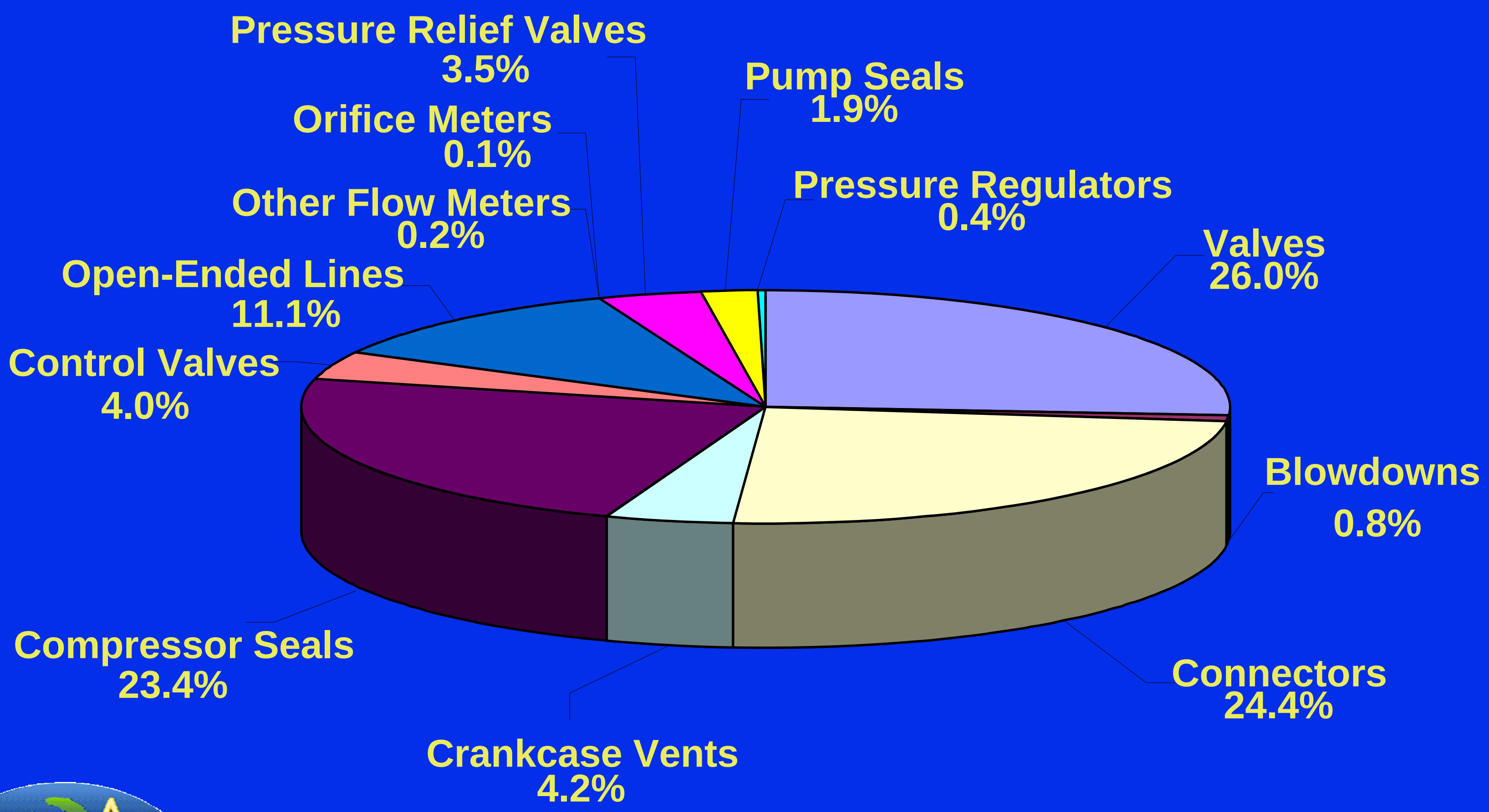
Is Wet Seal Replacement Profitable?

- Replacing wet seals in a 6 inch shaft beam compressor operating 8,000 hr/yr
  - **Net Present Value = $531,940**
    - **Assuming a 10% discount over 5 years**
  - **Internal Rate of Return = 86%**
  - **Payback Period = 14 months**
    - **Ranges from 8 to 24 months based on wet seal leakage rates between 40 and 200 cf/m**
- Economics are better for new installations
  - **Vendors report that 90% of compressors sold to the natural gas industry are centrifugal with dry seals**

Directed Inspection and Maintenance at Compressor Stations

- What is the problem?
  - **Gas leaks are *invisible*, *unregulated* and *go unnoticed***
- STAR Partners find that valves, connectors, compressor seals and open-ended lines (OELs) are major sources
  - **About 40 Bcf methane emitted per year from OELs**
  - **About 10 Bcf methane emitted per year from compressor seals**
- Facility fugitive methane emissions depend on operating practices, equipment age and maintenance

Natural Gas Losses by Equipment Type



Clearstone Engineering, 2002

How Much Methane is Emitted?

Summary of Natural Gas Losses from the Top Ten Leakers[1]				
Plant No.	Gas Losses From Top 10 Leakers (Mcf/d)	Gas Losses From All Equipment Leakers (Mcf/d)	Contribution By Top 10 Leakers (%)	Percent of Plant Components that Leak
1	43.8	122.5	35.7	1.78
2	133.4	206.5	64.6	2.32
3	224.1	352.5	63.6	1.66
4	76.5	211.3	36.2	1.75
Combined	477.8	892.84	53.5	1.85

[1]Excluding leakage into flare system

How Can These Losses Be Reduced?

- Implementing a Directed Inspection and Maintenance (DI&M) Program

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What is a DI&M Program?

- Voluntary program to identify and fix leaks that are cost-effective to repair
- Outside of mandatory LDAR
- Survey cost will pay out in the first year
- Provides valuable data on leakers

Screening and Measurement

Summary of Screening and Measurement Techniques		
Instrument/ Technique	***Effectiveness***	***Approximate Capital Cost***
Soap Solution	* *	$
Electronic Gas Detectors	*	$$
Acoustic Detection/ Ultrasound Detection	* *	$$$
TVA (FID)	*	$$$
Bagging	*	$$$
High Volume Sampler	* * *	$$$
Rotameter	* *	$$
Infrared Detection	* * *	$$$

Cost-Effective Repairs

Repair the Cost Effective Components

Component	Value of Lost Gas[1] ($)	Estimated Repair Cost ($)	Payback (Months)
Plug Valve: Valve Body	12,641	200	0.2
Union: Fuel Gas Line	12,155	100	0.1
Threaded Connection	10,446	10	0.0
Distance Piece: Rod Packing	7,649	2,000	3.1
Open-Ended Line	6.959	60	0.1
Compressor Seals	5,783	2,000	4.2
Gate Valve	4,729	60	0.2

Hydrocarbon Processing, May 2002
[1]Based on $3/Mcf gas price

How Much Gas Can Be Saved?

- Natural Gas STAR Lessons Learned study for DI&M at compressor stations estimates
  - **Potential Average Gas Savings ~ 29,000 Mcf/yr/compressor station**
  - **Value of gas saved ~ $87,000 / compressor station (at gas price of $3/Mcf)**
  - **Average initial implementation cost ~ $26,000 / compressor station**

Discussion Questions

- To what extent are you implementing these opportunities?
- Can you suggest other opportunities?
- How could these opportunities be improved upon or altered for use in your operation?
- What are the barriers (technological, economic, lack of information, regulatory, focus, manpower, etc.) that are preventing you from implementing these practices?