Methane to Markets

Cross-Sector Methane Emission Reduction Opportunities

Advancing Project Development in India through Public Private Partnerships

22 – 23 February, 2007

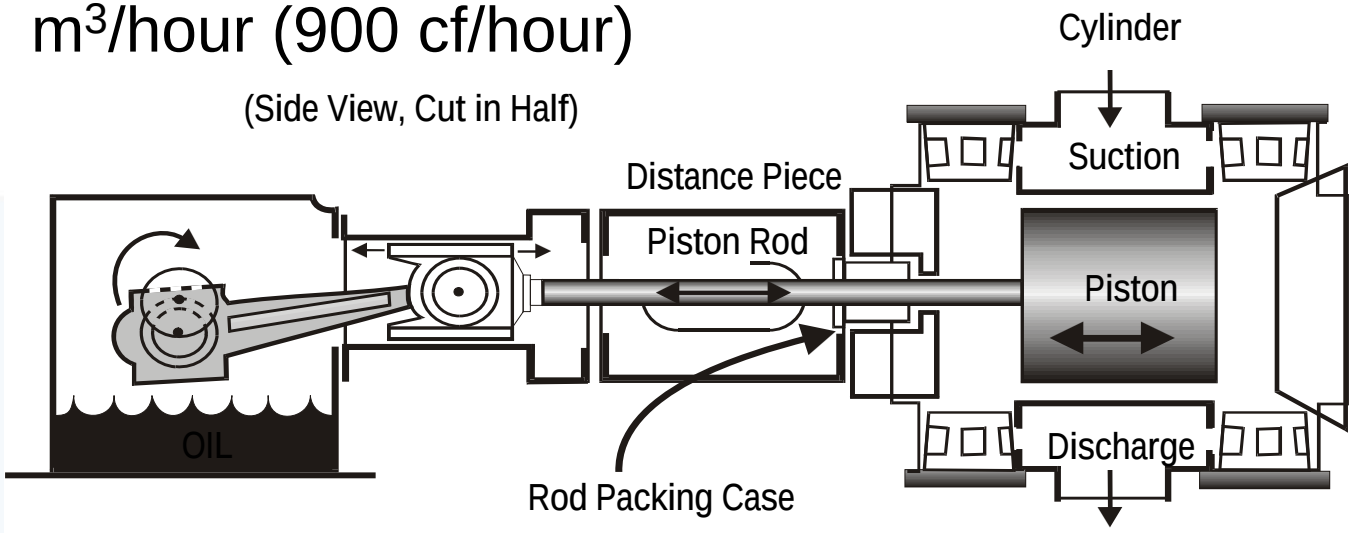
Methane to Markets

Agenda

- **Methane Losses from Reciprocating Compressors**
- Methane Losses from Centrifugal Compressors
- Methane Emission Savings with Directed Inspection and Maintenance (DI&M)
- Discussion Questions

Methane Losses from Reciprocating Compressors

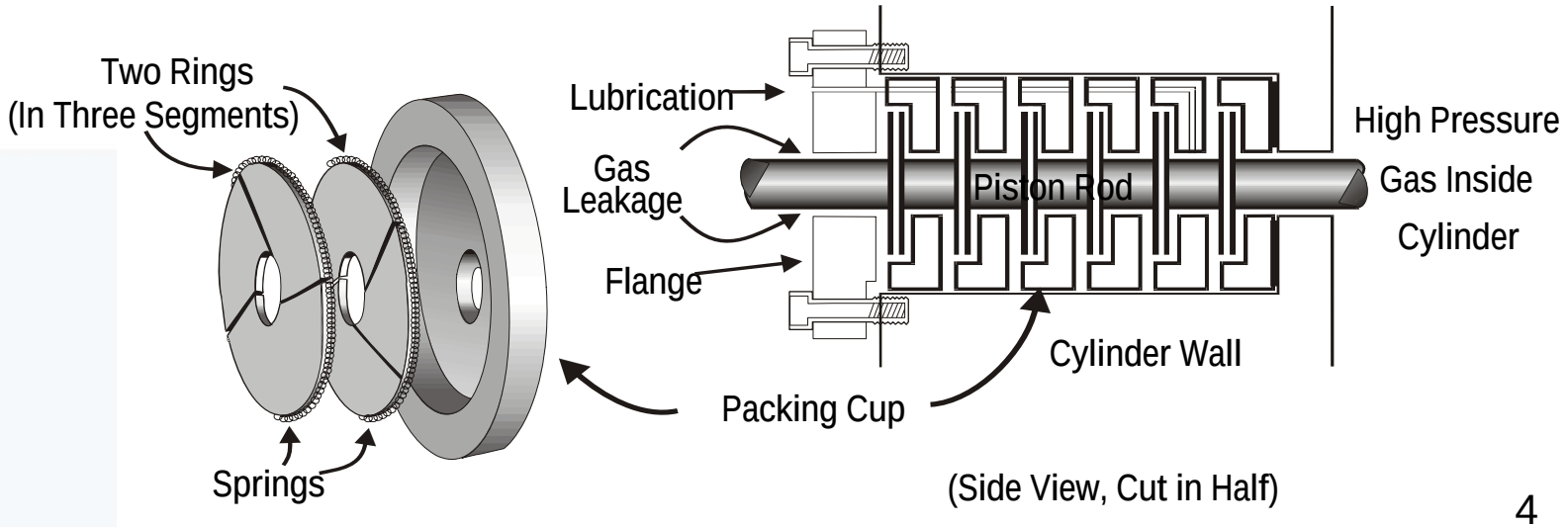
- Reciprocating compressor rod packing leaks some gas by design
  - Newly installed packing may leak 1.7 cubic meters per hour (60 cubic feet per hour)
  - Worn packing has been reported to leak up to 25.5 m^3/hour (900 cf/hour)



cubic meters = m^3, cubic feet = cf

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

35 cubic feet is about 1 cubic meter

Methane Savings Through Rod Packing Replacement

- Assess costs of replacements (U.S. costs)
  - A set of rings: $675 to $1,080
    (with cups and case) $2,025 to $2,500
  - Rods: $2,430 to $13,500
    - 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

Economic Replacement Threshold (m^3/hour) = $\frac{CR * DF * 1{,}000}{(H * GP)}$

Where:

CR = Cost of Replacement ($)
DF = Discount factor (%) at interest *i*
H = Hours of compressor operation per year
GP = Gas price ($ per thousand cubic meter)

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

Is Rod Packing Replacement Profitable?

- Periodically measure leakage increase

Rings Only[1]

Rings:	$1,200
Rod:	$0
Operating:	8,000 hours per year

Leak Reduction Expected (m^3/hour)	Payback[2] (years)
1.3	0.5
0.7	1
0.3	2
0.2	3

Rod and Rings[1]

Rings:	$1,200
Rod:	$7,000
Operating:	8,000 hours per year

Leak Reduction Expected (m^3/hour)	Payback[2] (years)
10.0	0.5
5.1	1
2.7	2
1.9	3

1 - All costs and revenues are represented in U.S. economics

2- Gas price of $7/Mcf ($250/thousand m^3)

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Project Summary for India

- Replace reciprocating compressor rod packing

Project Description: Replace rods and rings on a reciprocating compressor	
Methane Saved:	24,500 cubic meters per year (865 Mcf per year)
Sales Value[1]:	$2,600
Capital and Installation Cost[2]:	($10,000) for rods and rings
Operating and Maintenance Cost[2]:	($50) per year
Payback Period:	4 years

1 – Gas price in India $3/Mcf ($106/thousand m^3)

2 – All costs have been converted to an Indian basis using the methodology described in *US Natural Gas STAR program success points to global opportunities to cut methane emissions cost-effectively*, Oil and Gas Journal, July 12, 2004

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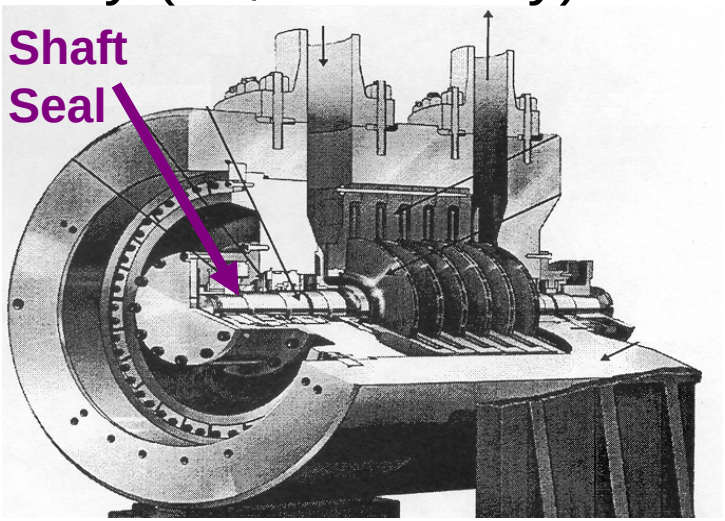
- Methane Losses from Reciprocating Compressors
- **Methane Losses from Centrifugal Compressors**
- Methane Emission Savings with Directed Inspection and Maintenance (DI&M)
- Discussion Questions

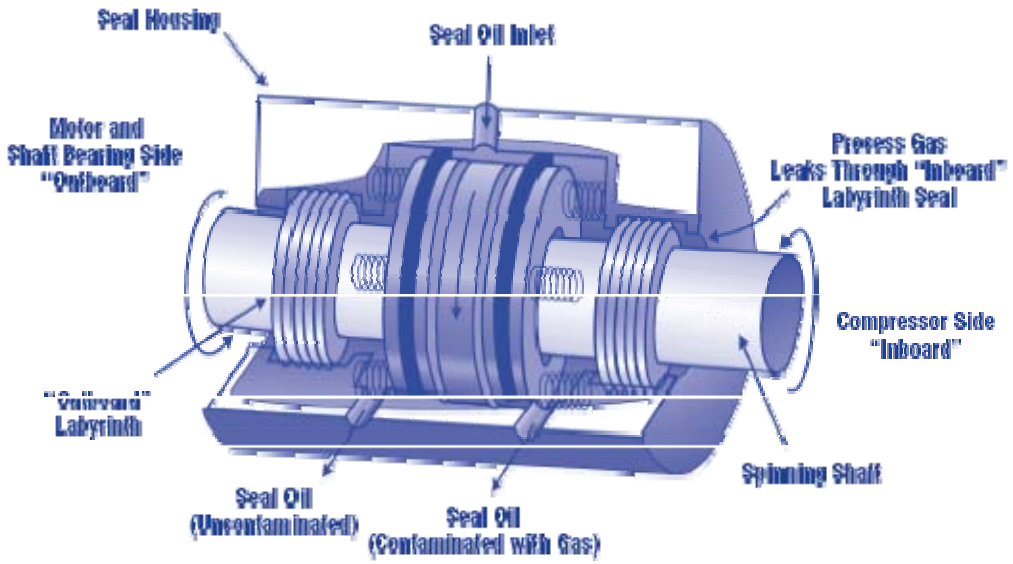
Methane Losses from Centrifugal Compressors

- Centrifugal compressor wet seals leak little gas at the seal face
  - Seal oil degassing may vent 1.1 to 5.7 m^3/minute (40 to 200 cf/minute) to the atmosphere
  - A U.S. company reported wet seal emissions of 2,124 m^3/day (75,000 cf/day)



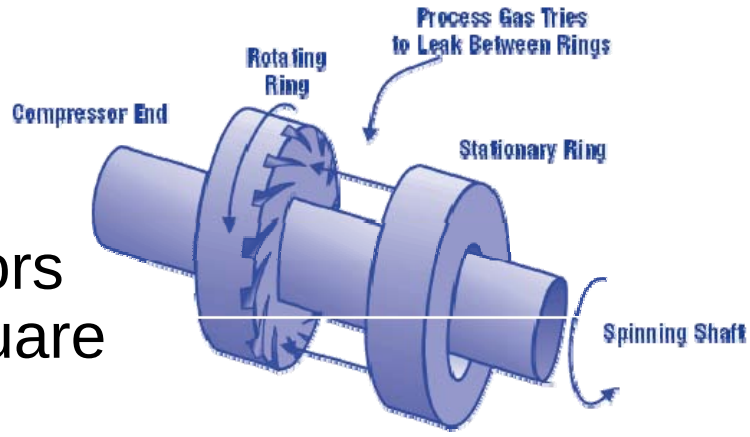
Centrifugal Compressor Wet Seals

- High pressure seal oil 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



Reduce Emissions with Dry Seals

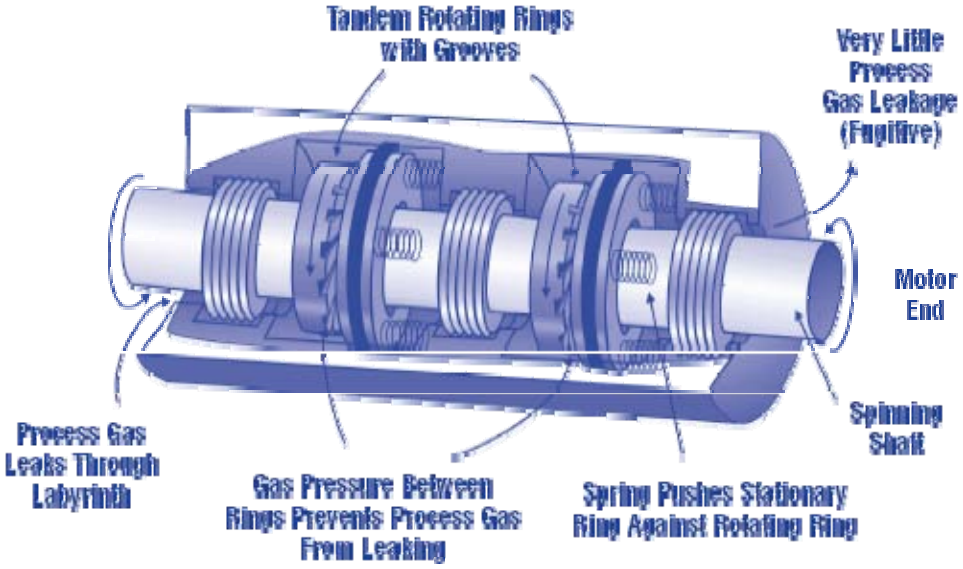
- Dry seal springs press the stationary ring in the seal housing against the rotating ring when the compressor is not rotating
- At high rotation speed, gas is pumped between the seal rings creating a high pressure barrier to leakage
- Only a very small amount of gas escapes through the gap
- 2 seals are often used in tandem
- Can operate for compressors up to 3,000 pounds per square inch gauge (psig)* safely



* 3,000 psig = 205 atm

Methane Savings through Dry Seals

- Dry seals typically leak at a rate of only 0.8 to 5.1 m^3/hour (0.5 to 3 cf/minute)
  - Significantly less than the 1.1 to 5.7 m^3/minute (40 to 200 cf/minute) emissions from wet seals
- Gas savings translate to approximately $112,000 to $651,000 at $7/Mcf ($250/thousand m^3)



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Economics of Replacing Seals

- Compare costs and savings for a 15 centimeter (6-inch) shaft beam compressor

Cost Category	Dry Seal ($)	Wet Seal ($)
Implementation Costs[1]		
Seal costs (2 dry at $10,000 per shaft-inch, with testing)	$162,000	
Seal costs (2 wet at $5,000 per shaft-inch)		$81,000
Other costs (engineering, equipment installation)	$162,000	$0
Total Implementation Costs	$324,000	$81,000
Annual Operation & Maintenance	$14,100	$102,400
Annual Methane Emissions (8,000 hours per year)		
2 dry seals at a total of 0.2 m^3 per minute	$20,160	
2 wet seals at a total of 2.8 m^3 per minute		$336,000
Total Costs Over 5-Year Period	$495,300	$2,273,00
Total Dry Seal Savings Over 5 Years		
Savings	$1,777,700	
Methane Emissions Reductions (1,300,000 m^3 per year)	6,500,000	

1 – All costs and revenues are represented in U.S. economics.

2 – Gas price $7/Mcf ($250/thousand m^3)

Is Wet Seal Replacement Profitable?

- Replacing wet seals in a 15 centimeter (6 inch) shaft beam compressor operating 8,000 hours per year
  - Net Present Value = $1,216,000
    - Assuming a 10% discount over 5 years
  - Internal Rate of Return = 125%
  - Payback Period = 10 months
    - Ranges from 4 to 16 months based on wet seal leakage rates between 1.1 and 5.7 m^3/minute (40 and 200 cf/minute)
- Economics are better for new installations

Methane to Markets

Project Summary for India

- Replace centrifugal compressor wet seals with dry seals

Project Description: Replace wet seals with dry seals for a 15 centimeter (6-inch) shaft beam compressor

Methane Saved:	1,300,000 cubic meters per year (45,120 Mcf per year)
Sales Value[1]:	$135,000
Capital and Installation Cost[2]:	($395,000)
Operating and Maintenance Cost[2]:	($600) per year
Payback Period:	3 years

1 – Gas price in India $3/Mcf ($106/thousand m^3)

2 – All costs have been converted to an Indian basis using the methodology described in *US Natural Gas STAR program success points to global opportunities to cut methane emissions cost-effectively*, Oil and Gas Journal, July 12, 2004

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Methane to Markets

What is the Problem?

- Natural gas leaks are *invisible* and *go unnoticed*
- US companies find that valves, connectors, compressor seals, and open-ended lines (OELs) are major sources
  - Estimated natural gas leaks in India

Production:	136 million m^3	4.8 Bcf/year
Processing:	193 million m^3	6.8 Bcf/year
Transmission:	329 million m^3	11.6 Bcf/year

Sources:

1 – EPA. *Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases 1990-2020* (EPA Report 430-R-06-003)

2 - US Natural Gas STAR program success points to global opportunities to cut methane emissions cost-effectively, Oil and Gas Journal, July 12, 2004

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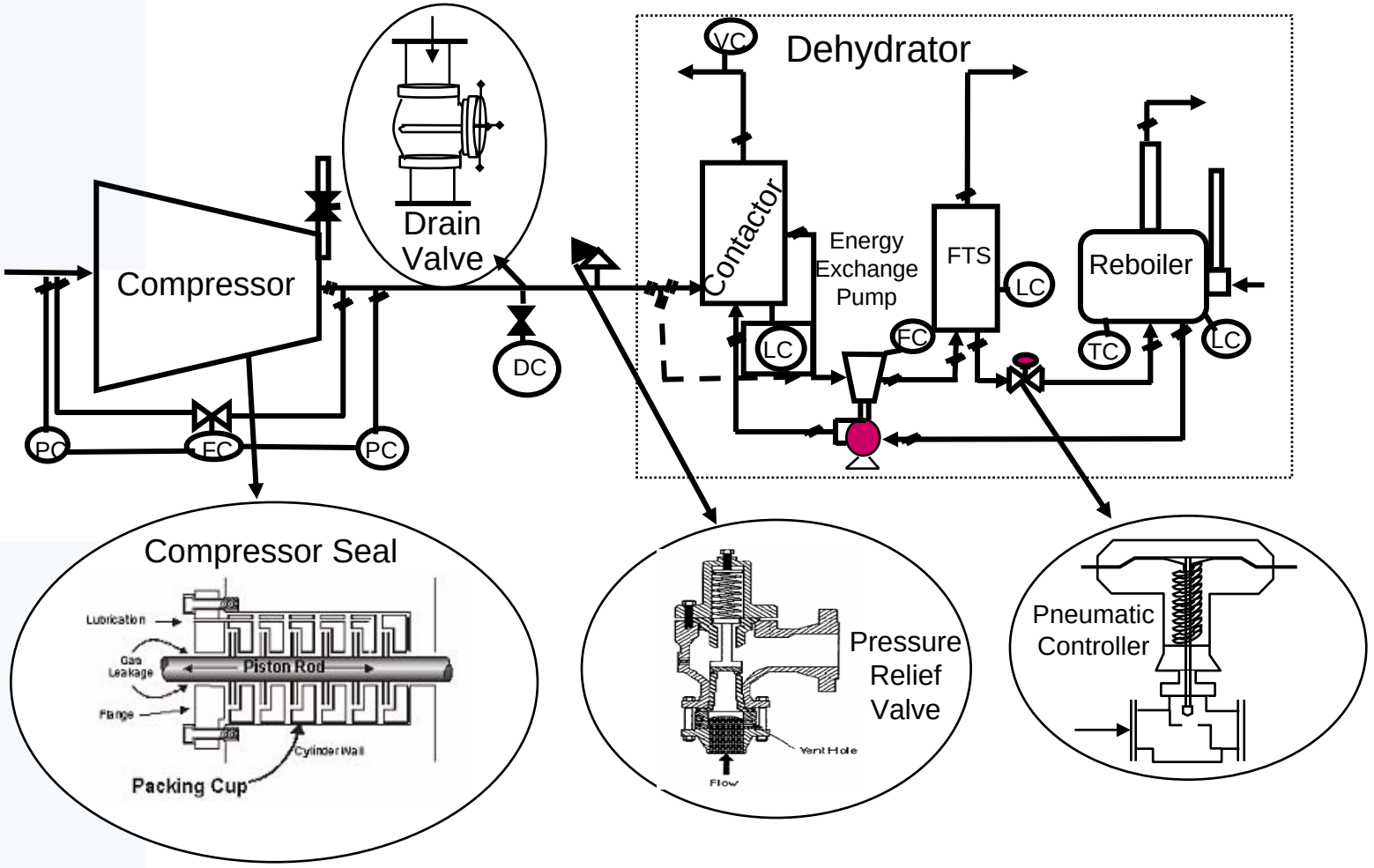
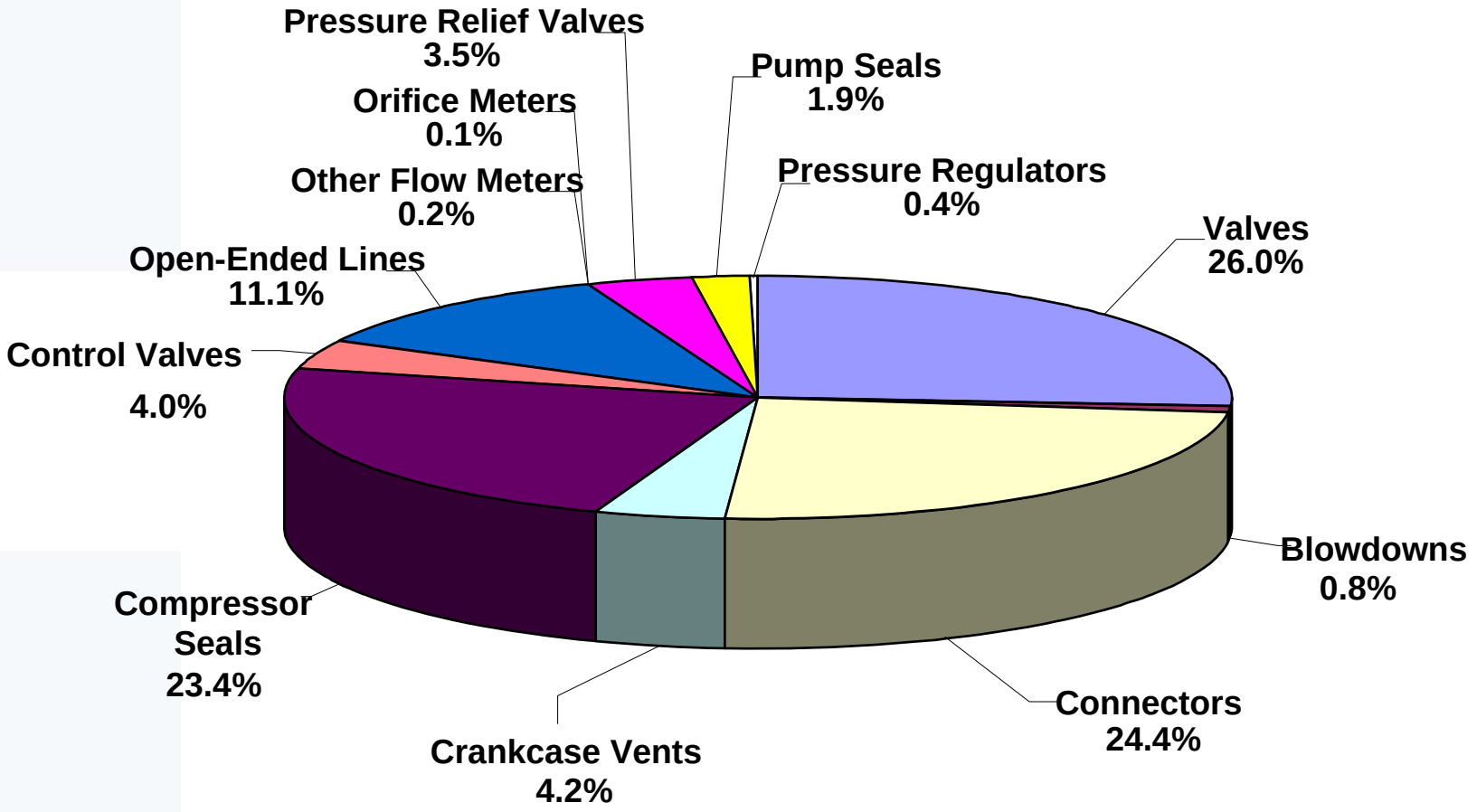
What are the Sources of Emissions?



Distribution of Losses from Equipment Leaks by Type of Component



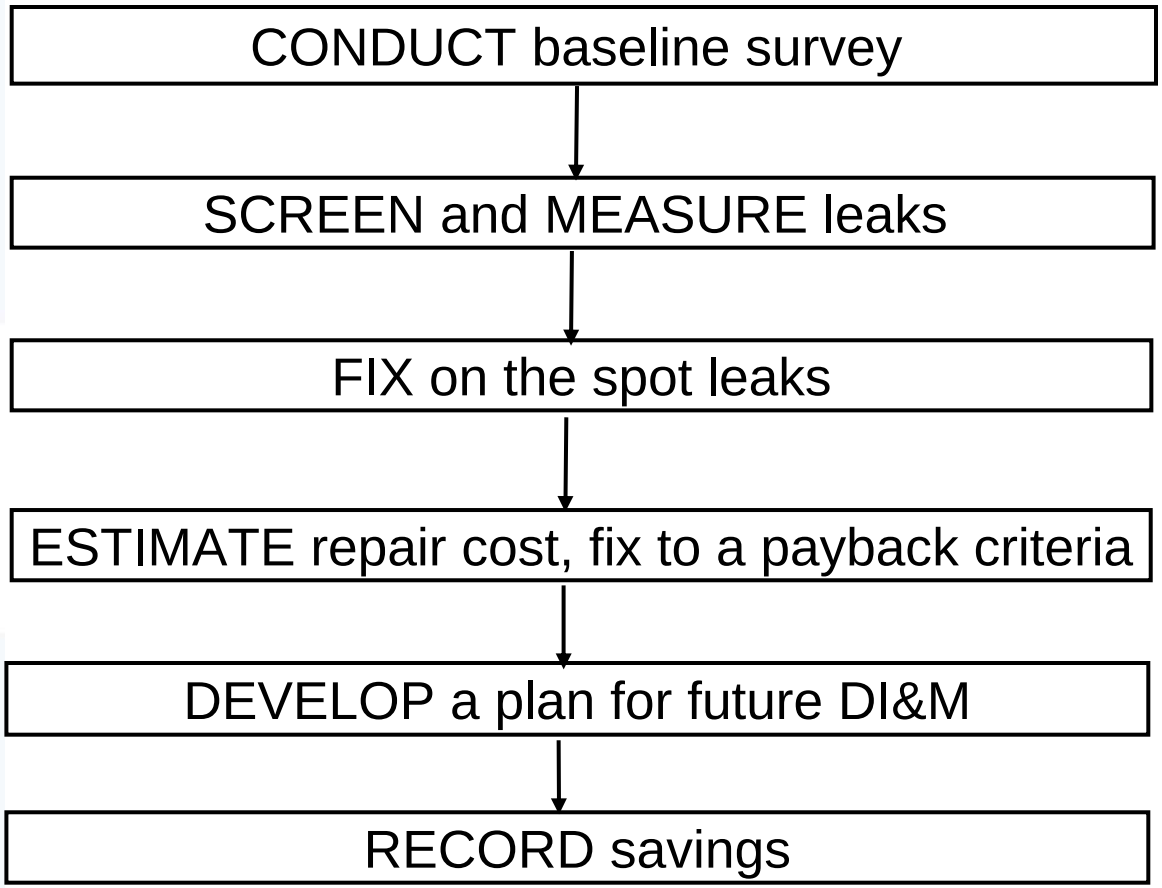
Source: Clearstone Engineering, 2002

Methane Recovery: Directed Inspection & Maintenance (DI&M)

- Fugitive losses can be reduced dramatically by implementing a DI&M program
- Directed Inspection and Maintenance
  - Voluntary program to identify and fix leaks that are cost effective to repair
  - Choice of leak detection technologies
  - Provides valuable data on leakers with information of where to look
  - Strictly tailored to company's needs

Infrared Leak Imaging Camera

How Do You Implement DI&M?



How Do You Detect the Leaks?

- Screening - find the leaks
  - Soap bubble screening
  - Electronic screening (sniffer)
  - Toxic Vapor Analyzer (TVA)
  - Organic Vapor Analyzer (OVA)
  - Ultrasound Leak Detection
  - Acoustic Leak Detection
  - Infrared Leak Detection/Imaging

Toxic Vapor Analyzer

Acoustic Leak Detection

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How Do You Measure the Leaks?

- Evaluate the leaks detected - measure results
  - High Volume Sampler
  - Toxic Vapor Analyzer (correlation factors)
  - Rotameters
  - Calibrated Bag
  - Engineering Method

Leak Measurement Using a High Volume Sampler

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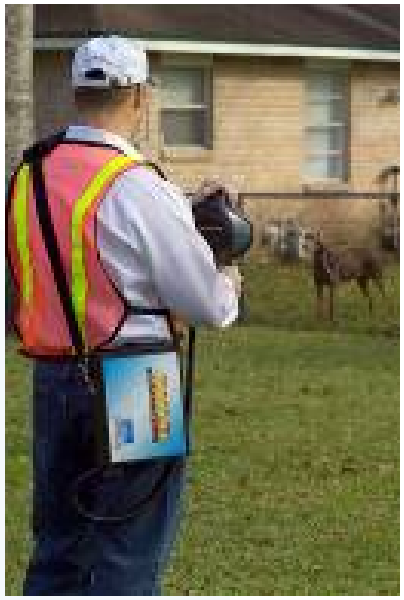
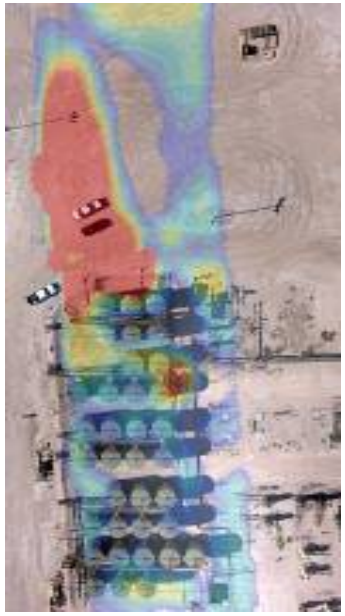
DI&M by Remote Leak Detection

- The trick has always been finding those few leaking needles in the haystack of components
- Real-time detection of gas leaks
  - Quicker identification & repair of leaks
  - Screen hundreds of components an hour
  - Easily screen inaccessible areas





Remote Sensing and Leak Detection Video

- Techniques to find fugitive leaks with new technology and equipment

5 minutes

Available for download at www.epa.gov/gasstar

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Cost-Effective Examples

Average Repair Cost for Equipment at Compressor Stations		
Component Description	Type of Repair	Average Cost[1] ($)
Flange – 6 inch	Change Gasket	$371
OEL on Valve	Grease	$56
Gate Valve	Teflon Repack	$50
Pressure Relief Valve – 1 inch	Replace	$1,238
Rod Packing	Pull Packing Case and Rods to Change Rings, Rework Packing Case	$3,219
Union	Tighten	$12
Source: Indaco Air Quality Services, Inc., 1999, Cost Effective Leak Mitigation at Natural Gas Transmission Compressor Stations.		

1 – All costs and revenues are represented in U.S. economics.

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Project Summary for India

- Directed Inspection and Maintenance Program

Project Description: Begin a DI&M Program and compressor stations

Methane Saved:	833,000 cubic meters per year (29,413 Mcf per year)
Sales Value[1]:	$88,200
Baseline Survey Cost[2]:	($400)
Total Repair Cost[2]:	($31,800) per year
Payback Period:	4 months

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DI&M - Lessons Learned

- A successful, cost-effective DI&M program requires measurement of the leaks
- A high volume sampler is an effective tool for quantifying leaks and identifying cost-effective repairs
- A relatively small number of large leaks contribute most of a compressor station's fugitive emissions
- The business of leak detection is changing dramatically with new technology

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Discussion Questions

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