# Pipeline Maintenance Best Practices

Lessons Learned from the
Natural Gas STAR Program

SGA Environmental Round Table

Charlotte, North Carolina

June 25 - 27, 2008

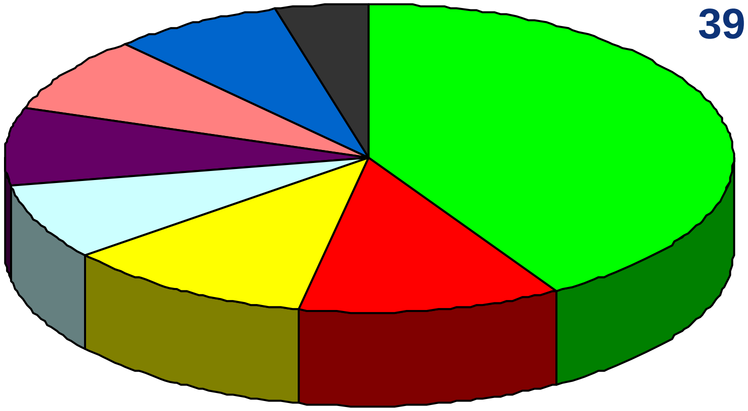
epa.gov/gasstar

# Pipeline Maintenance Agenda

- Methane Losses
  - What are the sources of emissions?
  - How much methane is emitted?
- Methane Recovery
  - Hot Taps
  - Pipeline Pumpdown
  - Composite Wraps
  - Additional Partner Reported Opportunities
- Discussion

# 2006 Transmission Sector Methane Emissions

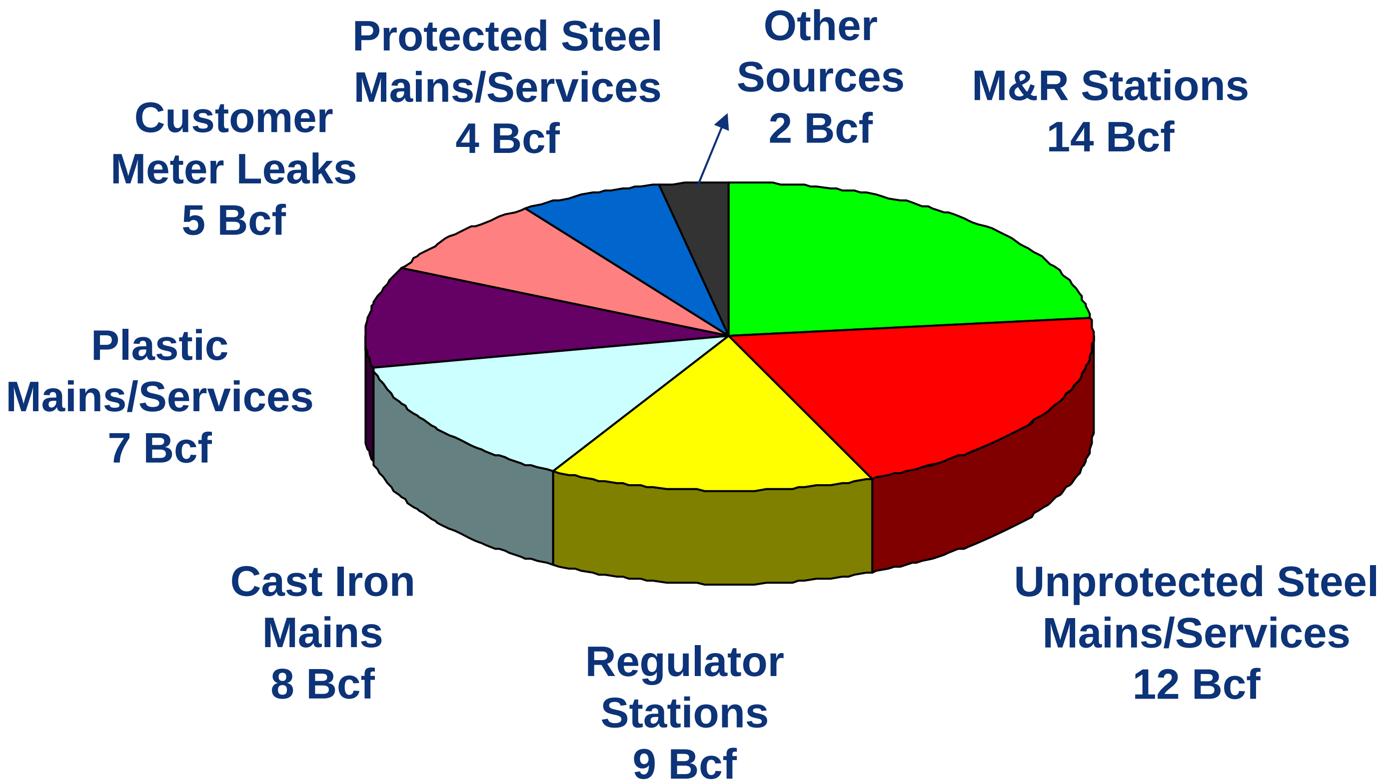
- Pipeline leaks can occur through internal and external corrosion, material defects, joint and fitting defects, and third party damage




EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2006.* April, 2008. Available on the web at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html
Natural Gas STAR reductions data shown as published in the inventory.

# 2006 Distributions Sector Methane Emissions

- Older cast iron and unprotected steel pipelines contribute the majority of emission of pipeline related emissions

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Natural Gas STAR reductions data shown as published in the inventory.

# What is the problem with current practices?

- Methane gas leaks are invisible, unregulated, and go unnoticed
- Methane vented in preparation for pipeline maintenance/new connections
- Smallest possible linear section of pipeline is blocked in and depressurized to the atmosphere
- “Hot work” may require purging pipeline with inert gas
- These practices results in methane emissions
  - Loss of Sales
  - Service disruption and customer inconvenience
  - Costs of evacuating the existing piping system

# Hot Taps

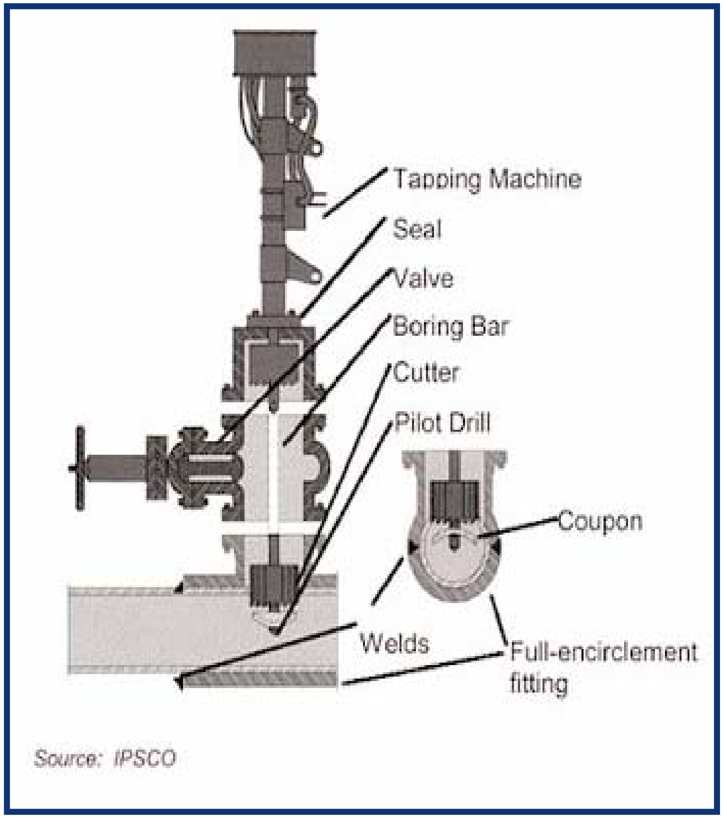
Connecting Pipelines without Disruption

Certified Williamson Industries Technician performing a hot tap with a 760 Tapping Machine as part of a 12" Stopple application.

Source: Williamson Industries Inc.

# What are Hot Taps?

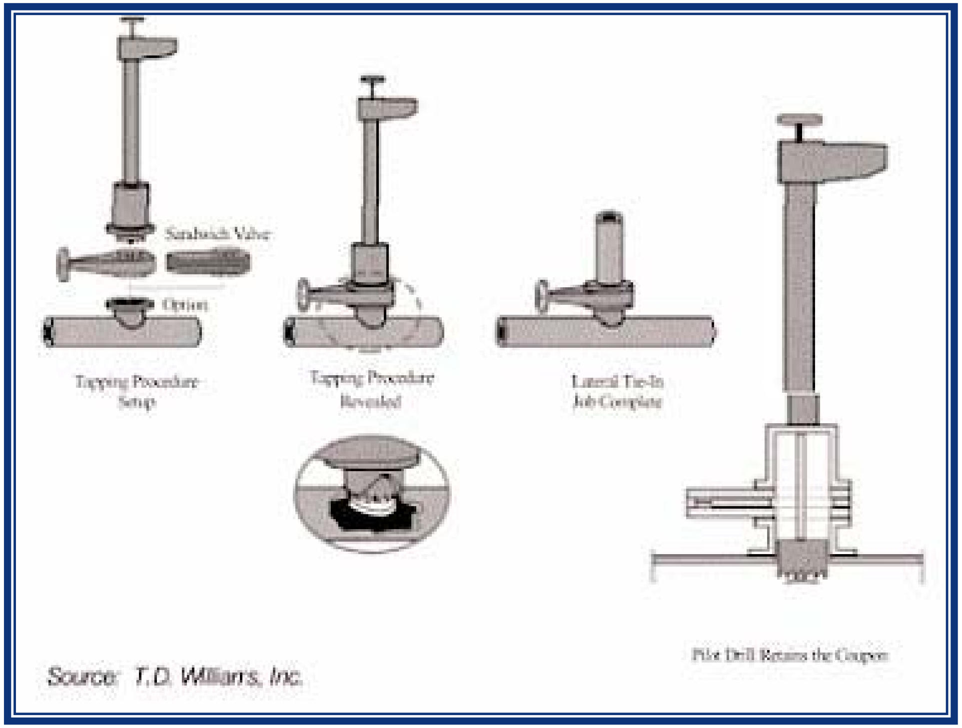
- New branch connection while the pipeline remains in service
  - Attach a branch connection and valve to the main pipeline
  - Cut-out a section of the main pipeline wall through the valve to connect the branch to the main pipeline
- Current technology has improved reliability and reduced complications
- Hot tapping can be used to add connections to a wide range of pipelines
  - Transmission pipelines
  - Distribution mains




*Schematic of Hot Tapping Machine*

# Hot Tapping Procedure

- Connect fitting and permanent valve on the existing pipeline
- Install hot tapping machine on the valve
- Perform hot tap and extract coupon through the valve
- Close valve and remove hot tapping machine
- Connect branch line




Source: T.D. Williams, Inc.

# Hot Tap Benefits

- Continuous system operation – shutdown and service interruptions are avoided
- No gas released to the atmosphere
- Avoided cutting, realignment and re-welding of pipeline sections
- Reduced planning and coordination costs
- Increased worker safety
- No gas outages for customers

# Hot Tap Economics

- Determine physical conditions of existing line
- Calculate the cost of a shutdown interconnect
- Hot tap expenses
- Estimated annual hot tap costs
  - For hypothetical scenario
- Estimated annual hot tap savings
  - For hypothetical scenario
- Economic analysis of hot tap vs. shutdown

# Determine physical conditions of existing line

- Maximum operating pressure (during hot tap)
- Type of pipe material
- Condition of parent pipeline (internal/external corrosion and wall thickness)
- Emergency valve location for isolation in case of accidents
- Working space evaluation (desired tap diameter, location of other welds, obstructions, etc.)
- Check if the line is looped

# Calculate Cost of Shutdown Interconnect

- Given: A pipeline company requires numerous shutdown or hot tap connections as follows --

| | | | | |
|---|---|---|---|---|
| **Pipeline diameter (D) = 4 inches** | 4 | 8 | 10 | 18 |
| **Pipeline pressure (P) = 350 psig** | 350 | 100 | 1,000 | 200 |
| **Isolated pipeline length (L), miles** | 2 | 1 | 3 | 2 |
| **Annual taps** | 250 | 30 | 25 | 15 |

- Volume of natural gas lost

- $V_g = \dfrac{D^2 * P * \left[ L / 1{,}000 \right] * 0.372}{1{,}000} = \dfrac{4^2 * 350 * \left[ 2 * 5{,}280 / 1{,}000 \right] * 0.372}{1{,}000}$

= 22 Mcf * $7/Mcf = $154

# Calculate Cost of Shutdown Interconnect (cont'd)

- Volume of purge gas (assumed to be nitrogen)

$$V_{pgas} = \frac{\left(\frac{D^2 * L}{183}\right)}{1{,}000} * 2.2 = \frac{\left(\frac{4^2 * 2 * 5{,}280}{183}\right)}{1{,}000} * 2.2 = 2 \text{ Mscf}$$

  - Given:
    - Cost of natural gas ($C_g$) = $7/Mscf
    - Cost of nitrogen ($C_{pgas}$) = $8/Mscf
  - Value of gas lost by shutdown interconnects (Including purge gas)
- Cost = $C_g + C_{pgas} = V_g * P_g + V_{pgas} * P_{pgas}$
  = (22 * 7) + (2 * 8)
  = $170 for each 4 inch pipeline shutdown interconnect

# Hot Tap Expenses

- Calculate the cost of a hot tap procedure
  - Cost of the hot tap equipment purchase and O&M cost of hot tapping contract
  - Purchase costs for small tapping machines vary from $17,287 to $30,122
  - Most companies find it economical to contract out large jobs

| Connection Size | Capital Costs ($) | | Contracting Service Cost ($) | Equipment O&M Cost ($/yr) |
|---|---|---|---|---|
| | Machine[1] | Material | | |
| Small Taps (<12") | 17,287 – 30,122 | -- | -- | 724 – 7,235 |
| Large Taps (>12") | 130,963 – 261,927[2] | 2,619 – 11,944[2] | 1,447 – 5,788 | -- |

**[1] Hot tap machines can last from 5 to 40 years. A company can perform as many as 400 small taps per year.**

**2 Most companies will find it more economical to contract out large jobs, and would not therefore incur these costs.**

**Note: Cost information provided by Hot Tap manufacturers and contractors. Prices only provided for most economic options. Updated 2006**

# Estimated Annual Hot Tap Costs

- Given (annual program):
  - Equipment cost per small tap machine = $23,704
  - Operations and Maintenance (O&M) cost per machine = $3,979
  - Number of small hot tap machines = 2
  - Contract Services cost per large tap = $3,618
  - Number of contracted taps = 15 (all taps 12 inches and larger)

- Total equipment cost = $23,704 * 2 = $47,409
- Total O&M cost = $3,979 * 2 = $7,959
- Contract Service cost = $3,618 * 15 = $54,263

# Estimated Annual Hot Tap Savings

- Evaluate the gas savings benefits of hot tapping

| Estimated Annual Gas Savings for the Hypothetical Scenario | | | | | | |
|---|---|---|---|---|---|---|
| Tap Scenario | Annual Tap Number | Natural Gas Savings | | Nitrogen Purge Gas Savings | | Total Gas Savings |
| Pipeline | | Per tap Mscf | Annual Mscf | Per tap Mscf | Annual Mscf | $ |
| 4” pipeline, 350 psig, 2 mile line | 250 | 22 | 5,500 | 2 | 500 | 42,500 |
| 8” pipeline, 100 psig, 1 mile line | 30 | 13 | 390 | 4 | 120 | 3,690 |
| 10” pipeline, 1,000 psig, 3 mile line | 25 | 589 | 14,725 | 19 | 475 | 106,875 |
| 18” pipeline, 200 psig, 2 mile line | 15 | 255 | 3,825 | 41 | 615 | 31,695 |
| Total Annual | 320 | | 24,440 | | 1,710 | 184,760 |

# Economic Analysis of Hot Tap vs. Shutdown

- Compare the options and determine the economics of five year hot tapping program (320 taps/yr)

| Economic Analysis of Hot Tap Versus Shutdown | | | | | | |
|---|---|---|---|---|---|---|
| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| Capital Cost, $ | (47,409) | 0 | 0 | 0 | 0 | 0 |
| Contract Service Cost, $ | 0 | (54,263) | (54,263) | (54,263) | (54,263) | (54,263) |
| O&M Cost, $ | 0 | (7,959) | (7,959) | (7,959) | (7,959) | (7,959) |
| Total Cost, $ | (47,409) | (62,222) | (62,222) | (62,222) | (62,222) | (62,222) |
| Natural Gas Savings, $ | | 171,080 | 171,080 | 171,080 | 171,080 | 171,080 |
| Inert Gas Savings, $ | | 13,680 | 13,680 | 13,680 | 13,680 | 13,680 |
| Net Benefit, $ | (47,409) | 122,538 | 122,538 | 122,538 | 122,538 | 122,538 |
| Payback (months) | | | | | | 5 |
| IRR | | | | | | 258 % |
| NPV[1] | | | | | | $417,107 |
| [1]Net Present Value (NPV) based on 10% discount rate for 5 years | | | | | | |

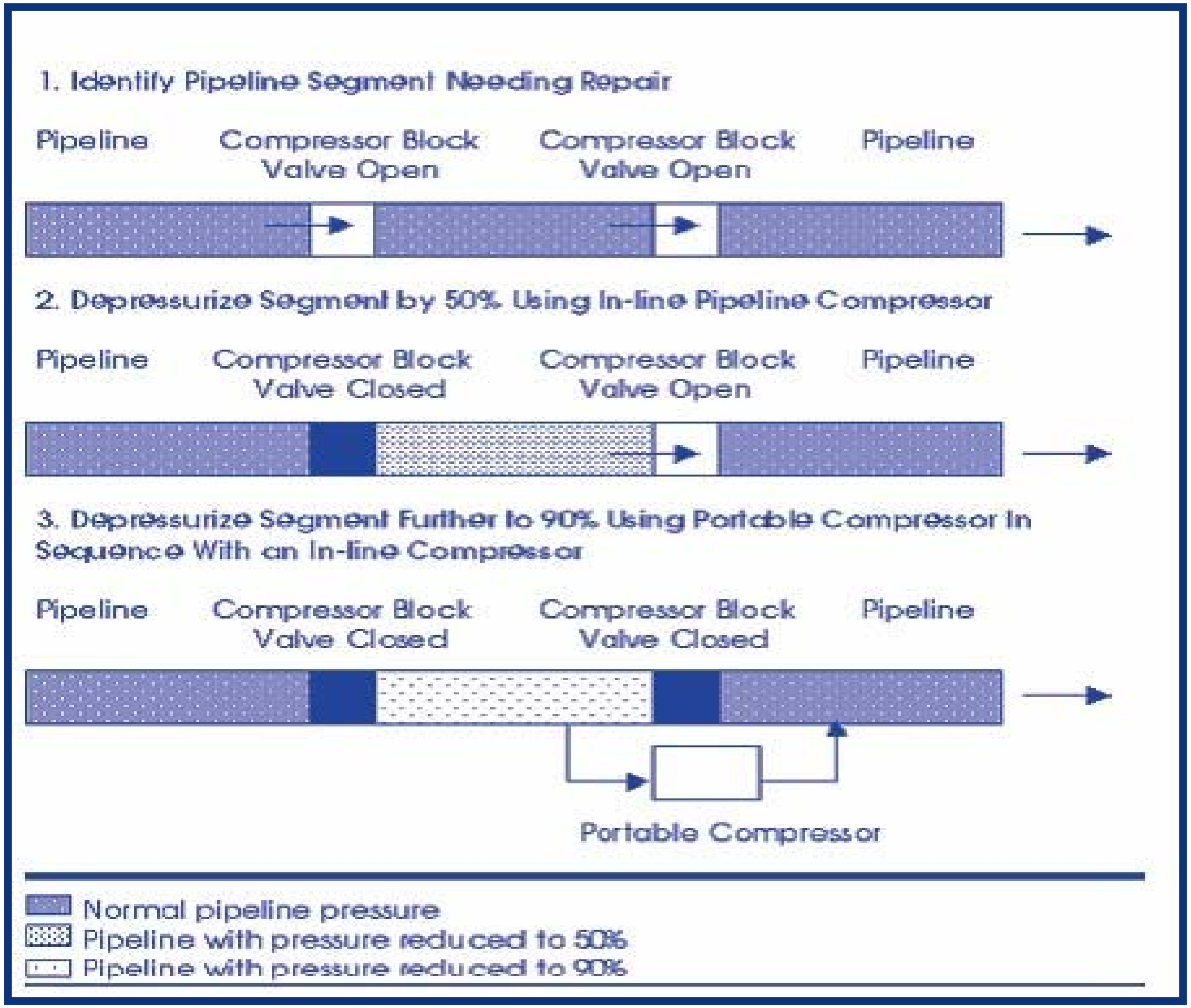
# Methane Recovery by Pipeline Pumpdown

- Most applicable to large pipelines operating at high pressures
- Use In-Line compressors to “pull down” the pressure to minimum suction pressure
- Use portable compressor to “pull down” pressure even further
- Cost is justified by immediate payback in gas savings
- About 90% of gas usually vented is recoverable

# Pipeline Pumpdown Technique

- In-line Compressor
  - Typically 2:1 compression ratio
  - By blocking upstream valve, the pressure in the pipeline is reduced to safe limits for maintenance
- Portable Compressor
  - Typically 5:1 compression ratio
  - Can be used in conjunction with in-line compressors to reduce pressure in pipeline section
  - Cost-justifiable only when multiple sections of pipeline are being serviced
  - Distribution mains generally do not contain a large enough volume of gas to justify the use of portable compressors

# Sequence of Depressurization Events



# Economics of Pipeline Pumpdowns

- Calculate gas vented by depressurizing pipeline
- Calculate gas saved with in-line compressors
- Calculate gas saved with portable compressor
  - Consider cost of a portable compressor
- Calculate annual savings

# Calculate Gas Vented by Depressurizing Pipeline

- Estimate the quantity and value of gas that in-line compressors can recover
  - **Given:**
    - Pipeline isolated length (L) = 10 miles
    - Pipeline interior diameter (I) = 2.375 feet
    - Pipeline operating pressure (P) = 600 psig
    - In-line compressor compression ratio (Ri) = 2
  - **Gas vented in depressurizing pipeline**

M = L*(5,280 ft/mile) * (π * I2/4) * (P/14.65 psig) * (1 Mscf/1,000cf)

M = (10*5,280) * (π*2.3752)/4 * (600+14.65)/14.65 * 1/1,000)

M = 9,814 Mscf

# Calculate Gas Saved using In-line Compressors

- Amount of gas recoverable per action using an in-line compressor

  Ni = M – (M/Ri) = 9,814 – (9,814/2) = 4,907 scf

- Value of gas recovered per action using an in-line compressor

  Vi = Ni * $7/Mscf = 4,907 * $7 = $34,349

- Annual value of gas recovered assuming 4 actions per month

  = $34,349 * 4 * 12 = $1,648,752

# Calculate Gas Saved using Portable Compressors

- Given:
  - Portable compression ratio (Rp) = 8
  - Rate of compressor = 416 Mscf / hour
- Gas available for recovery

  = M – Ni = 9,814 – 4,907 = 4,907 Mscf
- **Gas saved using a portable compressor**

  Np = Ni – (Ni / Rp) = 4,907 – (4,907 / 8) = 4,294 Mscf
- **Value of gas recovered using portable compressor[1]**

  Vg = Np * $7/ Mscf = 4,294 * 7 = $ 30,056 * 4 * 12 = $ 1,442,688

[1] Because cost of operating portable compressor is high, assume portable compressor is used for 4 pipeline pumpdowns per month.

# Consider Costs of a Portable Compressor

- Estimate the costs associated with using a portable compressor
  - Fuel costs (mostly natural gas) (Vcf) ~ 7,000 – 8,400 Btu per brake horse power per hour
  - Maintenance costs (Vcm) ~ $5 - $12 per horsepower per month
  - Labor costs (Vcl)
  - Taxes and administrative costs (Vct)
  - Installation costs (Vci)
  - Freight costs (Vcs)

# Portable Compressor Costs – Capital Costs

| Portable Compressor Purchase and Lease Cost Range* | | | | | |
|---|---|---|---|---|---|
| 1,000 PSIG – High Flow | | 600 PSIG – Medium Flow | | 300 PSIG – Low Flow | |
| Purchase | Lease | Purchase | Lease | Purchase | Lease |
| $3 - $6 million | $77,000 - $194,000 per month | $1.0 - $1.6 million | $31,000 - $46,000 per month | $518,131 - $777,197 | $15,000 - $23,000 per month |
| *Based on assumptions that purchase cost does not include cost of freight or installation and that lease cost is 3 percent of purchase cost | | | | | |

# Cost of a Portable Compressor – Operating and Maintenance Costs

- Fuel used by compressor per 10 mile isolated length, per month

  = 69 Mscf

- Fuel costs assuming one 10-mile isolated lengths, per month = $7/Mscf * 69 Mscf

  = $483 per month

- **Total cost of using the portable compressor during a 12 month period**

  = fuel costs + lease and maintenance costs + freight costs

  = 12 * ($483 + $31,000) + $19,000

  = $ 396,796

# Calculate Annual Savings

- Gross value of gas recoverable during a 12-month period, **In-line Compressor**

  $= V_g * 1 * 12 = 34,349 * 4 * 12 = \$ 1,648,752$

- Gross value of gas recoverable during a 12-month period, **Portable Compressor**

  $= V_g = N_p * \$7/ \text{Mscf} = 4,294 * 7$

  $= \$ 30,056 * 4 * 12$

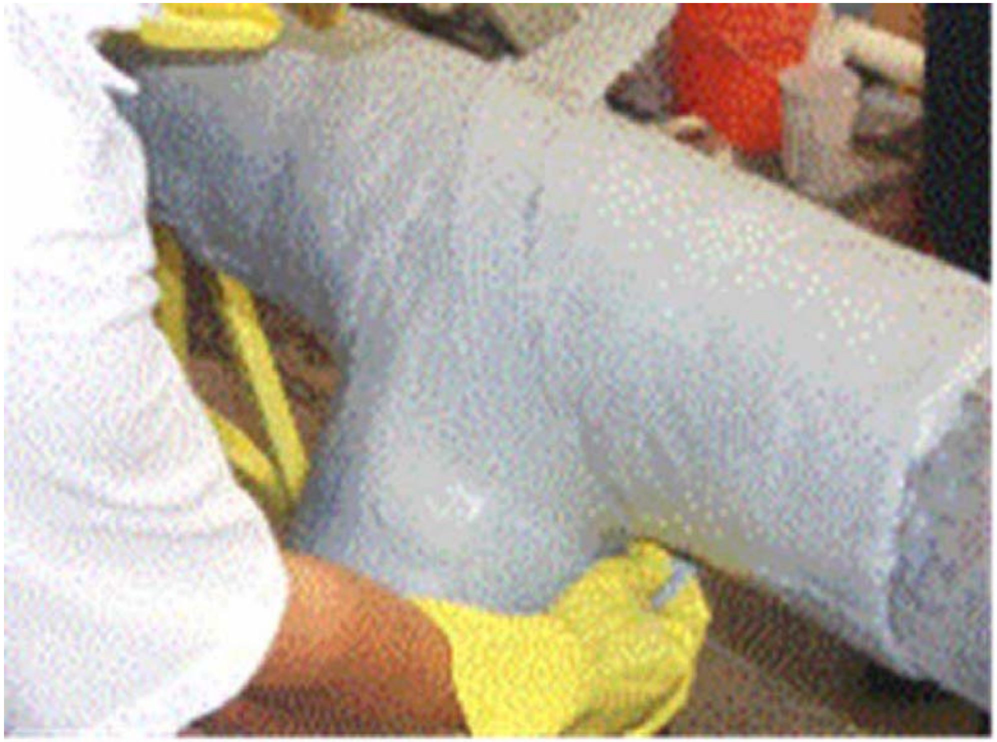
  $= \$ 1,442,688$

- **<u>Net Savings</u>** associated with using **both In-line and Portable Compressor**

  $= \$ 1,648,752 + (\$ 1,442,688 - \$ 396,796)$

  $= \$ 2,677,256$

# Composite Wrap



Source: Armor Plate

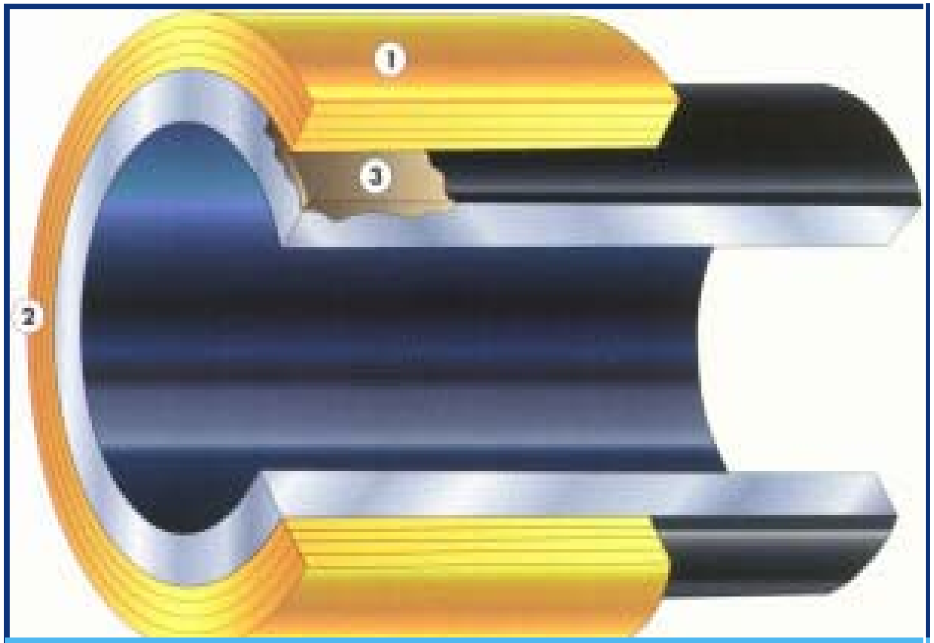
Permanent On-Line Pipeline Repair Technology

# What is Composite Wrap?

- Non-leaking pipeline defects can only be fixed in one of three ways, per Department of Transportation (DOT) regulations:
  - Cut out damaged segment and replace with new pipes
  - Install a full-encirclement steel split sleeve over the damaged area
  - Install a composite sleeve over the damaged area
- Composite Wrap Advantages:
  - Can be performed without taking pipeline out of service
  - Repair is quick and less costly than replacement or sleeve options
  - Eliminates venting associated with replacement

# Composite Wrap. What is it?

1) A high-strength glass fiber composite or laminate
2) An adhesive or resin bonding system
3) A high-compressive-strength load transfer filler compound
4) Replaces lost hoop strength



Source: Clock Spring® Company L. P.

# Composite Wrap Installation

- After excavation and pipe preparation
  - External defects filled with filler
  - Composite wrap wound around pipe with adhesive or laminating agents
  - Typically 2” of wrap must extend beyond damage
  - Excavation site refilled after mandated curing time
- Reducing pressure improves quality of repair

# Economics of Composite Wrap

- Calculate associated costs
  - State assumptions
  - Calculate labor cost
  - Calculate equipment cost
  - Calculate indirect costs
- Calculate Natural Gas Savings

- Compare options

# Calculate Associated Costs: Assumptions

- Given:
  - Need to repair a 6” non-leaking defect on a 24” pipeline, operating at 350 psig; assume 16 hours to complete the project[1]. Assume cost of engineering management is 25% cost of field labor.
- $C_{labor}$ = cost of labor

  *Hourly rate of field labor category*

  | | |
  |---|---|
  | Operator | = $ 46/hr |
  | Pipeliner | = $ 42/hr |
  | Apprentice | = $ 28/hr |

- $C_{equip}$ = cost of equipment

  *Cost of individual equipment*

  | | |
  |---|---|
  | Composite Wrap Kit | = $ 1,087/kit |
  | Backhoe | = $ 45/hr |
  | Sandblasting equipment | = $ 12/hr |
  | Pipeline coatings (5% composite kit) | = $ 54 |

[1]Partner supplied information. Updated to 2006 costs.

# Labor Costs

- Given:
  - $C_{indirect}$ = indirect costs such as field inspection crew, permits, etc. (assume 50% of total equipment and labor cost)

- Calculate cost of labor
  - $C_{labor}$ = Engineering management cost + Field labor cost

    Field labor cost = hourly rate * time-length of project

    = ($ 46 + $ 42 + $ 28) * 16

    = $ 1,856

    Engineering Management cost = 0.25 * $ 1,856 = $ 464

    $C_{labor}$ = $ 464 + $ 1,856 = $2,320

# Equipment and Indirect Costs

- Calculate cost of equipment
  - $C_{equip}$ = Cost of consumable materials (composite wrap kit and coatings) + Cost of renting/using equipment on site

    = $ 1,087 + $ 54 + ($ 45 * 16) + ($ 12 * 16)

    = $ 2,053
- Calculate indirect costs
  - $C_{indirect}$ = Cost of permits, inspection services, right-of-way, etc.

    = 0.5 * ($C_{labor}$ + $C_{equip}$) = 0.5 * ($ 2,320 + $ 2,053)

    = $ 2,186
- Calculate total cost of repair
  - Total Cost of Repair = $C_{labor}$ + $C_{equip}$ + $C_{indirect}$

    = $ 2,320 + $ 2,053 + $ 2,186

    = $ 6,559

# Calculate Natural Gas Savings

- Given:
  - D = inside diameter of pipeline (inches)
  - L = length of pipeline between shut-off valves (feet)
  - P = Pipeline pressure
  - $P_{natural\ gas}$ = Current natural gas market price ($7/Mcf)
  - $V_{natural\ gas}$ = Volume of natural gas emissions

- $$V_{natural\ gas} = \frac{D^2 * P * (L/1000) * 0.372}{1,000}$$

  $$= \frac{24^2 * 350 * (52,800/1,000) * 0.372}{1,000}$$

  $$= 3,960 \text{ Mcf}$$

- Value of natural gas = $V_{natural\ gas} * P_{natural\ gas}$

  = 3,960 * $7/Mcf

  = $27,720

# Comparison of Options – Pipeline Replacement vs. Composite Wrap

Given: 24" diameter operated at 350 psig, with 10 miles between shut-off valves

| | 6" Defect | | 234" Defect | |
|---|---|---|---|---|
| | Composite Wrap Repair | Pipeline Replacement | Composite Wrap Repair | Pipeline Replacement |
| Natural Gas Lost | 0 | 3,960 | 0 | 3,960 |
| Purge Gas (Mcf) | 0 | 199 | 0 | 199 |
| Number of Composite Wrap Kits | 1 | 0 | 20 | 0 |
| Cost of Natural Gas Lost | $0 | $27,720 | $0 | $27,720 |
| Cost of Purge Gas | $0 | $1,592 | $0 | $1,592 |
| Labor | $1,720 | $4,350 | $3,440 | $6,525 |
| Equipment and Materials | $1,142 | $3,520 | $22,833 | $6,950 |
| Indirect Costs | $1,886 | $3,148 | $13,136 | $5,390 |
| Total Cost of Repair | $4,748 | $40,330 | $39,409 | $48,177 |
| Most Economical Option | X | | X | |

# Composite Wrap Lesson Learned

- Proven permanent repair for external defects
- Temporary repair for internal faults
- In-service pipeline repair methodology
- Ideal for urgent and quick repair
- Avoid service disruptions
- Cost-effective
- Trained but not skilled crafts persons required
- Specialized welding and lifting equipment not required
- Minimizes access concerns
- No delays awaiting metal sleeve
- Cathodic protection remains functional

# Additional Partner Reported Opportunities

- Install excess flow valves
- Insert gas main flexible liners
- Cast iron joint sealing robot (CISBOT)

Source: ConEd

# Install Excess Flow Valves

- **What is the Problem?**
  - Gas line breaks from ground movement or third party damage can release gas to the atmosphere
- **Partner Solution**
  - Installing excess flow valves that shut off gas flow in response to the high-pressure differential
- **Methane Savings**
  - Based on 1 valve activation a year on a 50 psig, ½ inch service line
- **Applicability**
  - All gas service lines

**Methane Savings**

15 Mcf/yr

**Project Economics**

| | |
|---|---|
| Project Cost | > $10,000 |
| Annual O&M Costs | < $100 |
| Payback | > 10 yr |

# Insert Gas Main Flexible Liners

- **What is the Problem?**
  - Cast iron and unprotected steel piping have the highest leakage factors
- **Partner Solution**
  - Using flexible plastic inserts where replacement is unfeasible reduces losses
- **Methane Savings**
  - Based on retrofitting 1 mile of cast iron main and 1 mile of unprotected steel service lines
- **Applicability**
  - Cast iron and unprotected steel pipelines

**Methane Savings**

225 Mcf/yr

**Project Economics**

| | |
|---|---|
| Project Cost | $1,000 - $10,000 |
| Annual O&M Costs | < $100 |
| Payback | < 1 yr |

# Cast Iron Joint Sealing Robot (CISBOT)

- Robotic system inserted into live
  15- to 31-cm diameter cast iron distribution lines to seal leaking joints with an anaerobic sealant
- No service disruption and minimal excavation

CISBOT

Source: ConEdison

# Discussion

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