Using Pipeline Pump-Down Techniques To Lower Gas Line Pressure Before Maintenance

Executive Summary

Operators of natural gas pipeline systems routinely reduce line pressure and discharge gas from pipeline sections to ensure safe working conditions during maintenance and repair activities. Typically, operators block the smallest possible linear section of the pipeline and depressurize it by venting gas to the atmosphere. In 2004, an estimated 12 billion cubic feet (Bcf) of methane was vented to the atmosphere during routine maintenance and pipeline upsets.

Using pump-down techniques to lower gas line pressure before performing maintenance and repair activities is an effective way to reduce emissions and yield significant economic savings. Pipeline pump-down techniques involve using in-line compressors either alone or in sequence with portable compressors. Using in-line compressors is almost always justifiable because there are no capital costs, and payback is immediate. The cost-effectiveness of also using a portable compressor to increase gas recovery, however, depends greatly on site-specific factors and operating costs.

Another alternative is to install an ejector. An ejector is a venturi nozzle that uses high-pressure gas as motive fluid to draw suction on a lower pressure gas source, discharging into an intermediate pressure gas stream. The ejector can be installed on vent connections up and down stream of a partly closed valve, or between the discharge and suction of a compressor which creates the necessary pressure differential.

Regardless of the pump-down technique selected, emission reductions are directly proportional to how much pipeline pressure is reduced before venting occurs. On average, up to 90 percent of the gas in the pipeline can be recovered for sale instead of being emitted. Pipeline pump-down techniques are most economical for larger volume, higher pressure gas lines and work most effectively for planned maintenance activities and cases in which sufficient manifolding exists to connect a portable compressor.

Many Natural Gas STAR Partners have realized significant economic savings by using pump-down techniques. In 2004, Natural Gas STAR transmission Partners saved a total of 4.1 Bcf of gas using pump-down techniques. Based on a value of gas saved of $7.00/Mcf, that equals more than $28 million saved.

Technology Background

Natural gas transmission, distribution, and production companies transport methane and other light hydrocarbons via pressurized gas pipelines. These pipelines can require repairs or maintenance throughout their lifetime as a result of interior and exterior corrosion, gasket and weld leaks, failures of defective materials, and damage caused by external factors. Pipeline repairs fall into four general categories:

★ Class 1 non-emergency repairs that do not involve complete service interruption.

★ Class 2 non-emergency repairs that require complete service interruption.

★ Class 3 emergency repairs that require complete service interruption.

★ Class 4 large-scale projects where new pipe is being

Economic and Environmental Benefits

Method for Reducing Natural Gas Losses	Volume of Natural Gas Savings (Mcf)[a]	Value of Natural Gas Savings ($)			Implementation Cost ($)	Payback (Months)[b]		
		$3 per Mcf	$5 per Mcf	$7 per Mcf		$3 per Mcf	$5 per Mcf	$7 per Mcf
Pump down gas pipelines before maintenance	200,000 per year	$600,000 per year	$1,000,000 per year	$1,400,000 per year	$98,757	2	2	1

General Assumptions:
[a] Based on experiences reported annually by Natural Gas STAR Partners, which varied considerably. Factors impacting the volume of gas saved and the cost of implementation include pipeline length and pressure, compressor type, and number of locations or pump-down instances. Data includes both in-line and portable compressor reported results.
[b] Payback period for in-line compressors is immediate because there are no capital costs.

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(Cont'd)

run parallel to existing pipe and require service interruption.

Pipeline repairs and maintenance activities typically require depressurizing the pipeline to remove gas from the affected section of pipe and ensure safe working conditions. One approach to depressurization is to block off the impacted pipeline segment and vent the gas in that segment to the atmosphere. Alternatively, operators can use pump-down techniques to lower the gas-line pressure before venting. Pump-down techniques are the preferable alternative because they make more gas available for sale and reduce methane emissions.

In implementing pipeline pump-down techniques, operators can use two types of compressors to reduce pipeline pressure: in-line compressors and portable compressors. Depending on the situation, operators can use in-line compressors alone or with portable compressors.

- ★ **Using in-line pipeline compressors to draw down the pressure within their compression ratio limits.** Typically, in-line pipeline compressors have compression ratios of up to 2 to 1. By blocking the upstream valve of the targeted line segment while continuing to run the downstream compressor, the pipeline pressure can be reduced to approximately 50 percent of the working line pressure. The compressor can then be shut down and the line segment fully blocked. Lowering the line pressure by one-half is often sufficient to safely install sleeves over damaged line. This type of line pump-down process should be done only in a manner consistent with safety management policies.

- ★ **Using a portable compressor to further lower the line pressure.** Operators can also consider using portable compressors to achieve additional reduction beyond what in-line compressors can provide. Portable compressors can have up to a 5 to 1 compression ratio. When used in combination with an in-line compressor, portable compressors can lower line pressure by up to 90 percent of its original value without venting. Portable compressors can be used safely only when the downstream block valve is sufficiently manifolded. Again, safety policies should be strictly followed when using a portable compressor.

Although a portable compressor can recover an additional 40 percent of the original pipeline gas for sale, it is most appropriately used during planned maintenance, such as Class 1 and 2 repairs. This is because of the difficulty of renting or leasing a unit, mobilizing it, and depressurizing the line in a timely and cost-effective manner during an emergency. Portable compressors also are more easily justified when multiple sections of pipeline are taken out of service, either as a single project or as a set of serial repairs.

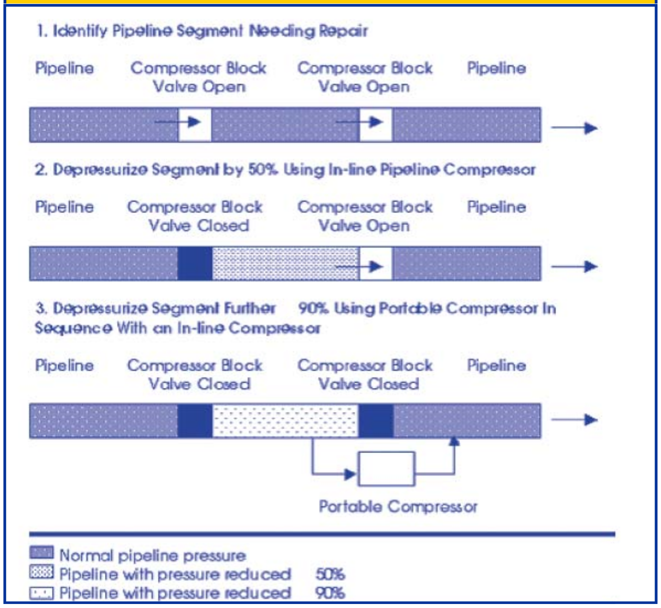
Exhibit 1 summarizes which pump-down techniques are applicable for the different classes of pipeline repair.

Exhibit 2 illustrates the basic sequence of events for depressurizing a pipeline segment.

Exhibit 1: Applicability of Pipeline Pump-Down Techniques

Repair Class	Pump-Down Technique	Description of Applicability
Class 1	In-line and Portable	These techniques can be used most extensively for Class 1 and Class 2 because such repairs primarily involve non-emergency situations and planned maintenance.
Class 2		
Class 3	In-line only	Class 3 typically involves emergency repairs with significant urgency to return the pipeline to service, leaving no time to mobilize a portable compressor.
Class 4	In-line only	Class 4 projects can be vast, with new pipe being run parallel to existing pipelines. Opportunities exist for recovering gas from the old lines during startup of the new line, but must be coordinated very carefully because of the size of the projects.

Exhibit 2: Sequence of Depressurization Events



Economic and Environmental Benefits

Companies can realize significant environmental and economic benefits by using downstream in-line and portable compressors to lower gas-line pressure before performing maintenance and repair activities. Potential savings include:

- ★ Recovery and sale of natural gas that would have been vented to the atmosphere. In the case of production pipelines, the gas stream might also contain valuable heavy hydrocarbons.
- ★ Reduction of methane emissions.
- ★ Reduction of nuisance odor and noise.
- ★ Elimination or significant reduction of hazardous air pollutant (HAP) emissions, primarily benzene, toluene, ethyl benzene, and xylene (BTEX).

Decision Process

When gas pipelines require maintenance or repair, companies can either:

- ★ Vent gas in the damaged section of pipeline to the atmosphere.
- ★ Recover as much of the pipeline gas as possible.

Step 1: Estimate the quantity and value of gas that in-line compressors can recover.

Depending on the compression ratio of the downstream in-line compressor(s), up to 50 percent of gas in the line can be recovered at minimal or no cost to the operator. Exhibit 3 provides calculations that operators can use to determine the total amount of gas in the pipeline segment and the amount and value of gas that can be recovered using the in-line compressor(s).

Step 2: Verify technical feasibility of using a portable compressor.

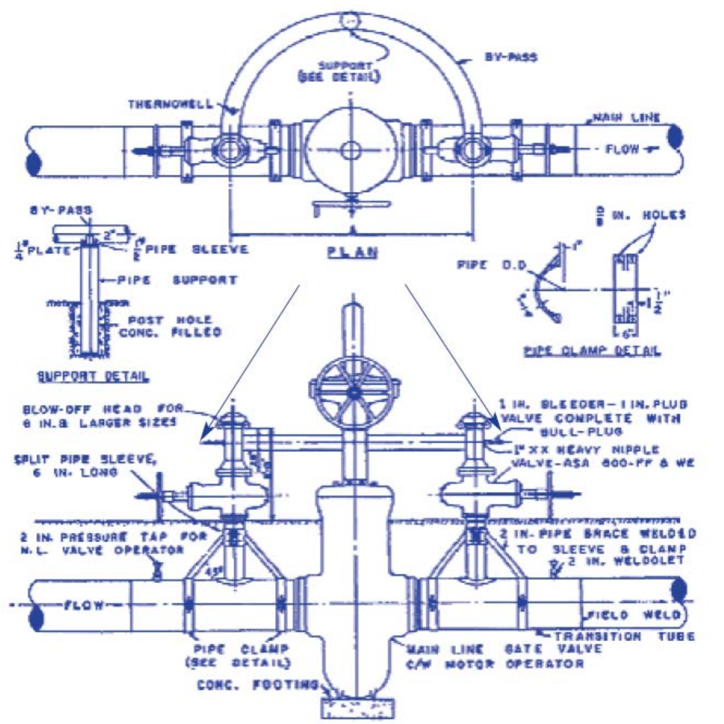
After calculating the potential volume of pipeline gas recoverable by an inline compressor, the operator should determine if the mechanical capability exists to use a portable compressor.

A portable compressor can further reduce the line pressure by moving up to 40 percent of the remaining original gas volume to the pressurized side of the block valve; however, using a portable compressor is only possible if the compressor can physically connect to the pipeline. Exhibit 4 illustrates a typical gas pipeline manifold. At a minimum, proper portable compressor connections should include bleeder valves upstream and downstream of a mainline block valve. The minimum size of bleeder valves

Exhibit 3: Gas Savings from Use of the In-line Compressor

Given:	
L I P Ri	= Pipeline length between block valves (miles) = Pipeline interior diameter (feet) = Pipeline operating pressure (psig) = In-line compressor compression ratio
(1)	**Calculate: M = Amount of Gas in Pipeline**
M	= L x (5,280 ft/mile) x π x (I / 2)^2 x (P +14.65 psig) / 14.65 psig
(2)	**Calculate: Ni = Gas recoverable using an in-line compressor**
Ni	= M - (M/Ri)
(3)	**Calculate: Vi = Value of gas recovered using an in-line compressor**
Vi	= Ni x $7/Mcf

Exhibit 4: Gas Pipeline Block-valve Manifold System



Source: *Gas Engineers Handbook*

depends on the size of the portable compressor. A technical representative from the portable compressor leasing or manufacturing company can specify manifolding requirements for specific units.

Step 3: Determine the appropriate-sized portable compressor for the project.

Selecting an appropriately sized portable compressor is best done with the assistance of a leasing company or manufacturer's technical representative who can recommend a portable compressor that satisfies the project requirements (e.g., amount of gas, discharge pressure requirements, schedule).

Step 4: Check the availability and cost of purchasing or leasing a portable compressor.

Companies considering a portable compressor are often faced with the question of whether to rent or purchase the unit. A limited number of portable gas compressors are available for rent, and rental companies typically prefer long-term leases. If the continual use of portable compressors for line pump-down activities is planned, companies might want to consider purchasing a portable gas compressor. Even then, availability and internal cost remain important considerations. Exhibit 5 shows the wide cost ranges for several operating scenarios.

- ★ **Other purchasing considerations.** In addition to the purchase price, other capital expenditures include taxes and administrative costs, installation costs, and freight costs. Installation costs are often site specific. One vendor indicated these costs could be as low as $3,886 or as high as $19,430 for a small compressor (i.e., less than 100 horsepower), and can range from $19,430 to $77,718 for a large unit (i.e., more than 2,000 horsepower). Freight costs are also site-specific, ranging from $7,900 to $13,170 for small units and $26,300 to $39,500 for larger units. All these cost factors should be included in the total purchase price of the compressor and when calculating the annualized cost of a compressor. Vendors indicated the lifetime of compressor units ranged between 15 to 20 years if properly maintained.

- ★ **Other leasing considerations.** Leased compressors also have similar installation and freight costs. Leasing prices are usually on a monthly basis. One vendor indicated that monthly rental expenses were approximately 3 percent of the purchase price. Another vendor provided a rental price based on the horsepower of the compressor. These rental prices ranged from $15 per horsepower per month for large compressors to $20 per horsepower per month for small compressors.

Exhibit 5: 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.

Maximizing the benefits of this investment requires coordinating planned maintenance activities to lower the compressor's mobilization or demobilization costs. Such coordination is especially important for maintenance conducted on smaller, lower pressure gas lines because margins diminish as the volume of potentially recoverable gas is reduced.

Step 5: Estimate the operating costs associated with using a portable compressor.

Operating costs include fuel/energy, maintenance, and labor costs. Natural gas is the fuel most frequently used to operate compressors. Vendors indicated that fuel usage ranged from 7,000 to 8,400 Btu per brake horsepower per hour. Maintenance costs range from $5 to $12 per horsepower per month depending on the compressor's size.

Seven Steps to Evaluate the Use of In-line and Portable Compressors:

- Step 1: Estimate the quantity and value of gas that in-line compressors can recover.
- Step 2: Verify technical feasibility of using a portable compressor.
- Step 3: Determine the appropriate-sized portable compressor for the project.
- Step 4: Check the availability and cost of purchasing or leasing a portable compressor.
- Step 5: Estimate the operating costs associated with using a portable compressor.
- Step 6: Calculate the volume and value of the gas recovered by a portable compressor.
- Step 7: Evaluate the economics of using a portable compressor in sequence with an in-line compressor.

In most cases, however, the maintenance costs are included in the rental price.

Step 6: Calculate the volume and value of the gas recovered by a portable compressor.

The gas available for recovery using the portable compressor is a function of the amount of gas remaining in the pipeline section being repaired. Since the in-line compressor already has reduced the gas volume, the portable compressor works with the reduced volume.

The recovery of gas is governed by the compression ratio. The volume of portable compressor-recovered gas is equal to the volume of gas in place minus the volume of gas divided by the compression ratio. The gross value of the recoverable gas using the portable compressor is the amount of gas in Mcf multiplied by the gas price in $/Mcf. These calculations are shown in Exhibit 6.

Exhibit 6: Calculating Gas Savings from Using a Portable Compressor

Given:	
M Ni Rp Vi	= Gas originally available for recovery (Mcf) = Gas recovered using an in-line compressor (Mcf) = Portable compressor compression ratio = Value of gas recovered from in-line compressor ($)
(1)	**Calculate: Np = Gas recovered using a portable compressor**
Np	= Ni - (Ni/Rp)
(2)	**Calculate: Vg = Value of gas recovered using a portable compressor**
Vg	= Np x $7/Mcf

Step 7: Evaluate the economics of using a portable compressor in sequence with an in-line compressor.

The net value of recovering gas from the pipeline section being repaired can be determined by subtracting the cost (i.e., operating costs, leasing costs, or annualized costs) from the value of gas recovered using the unit. Operators can effectively reduce the cost of using a portable compressor by planning and executing multiple projects in succession. The total value of gas recovered by the in-line compressor and the portable compressor is the sum of the two valuations. The total economic evaluation includes subtracting the costs of this procedure. Exhibit 7 shows this valuation procedure.

Exhibit 7: Calculating Total Economic Benefit of Using a Portable Compressor in Sequence with an In-line Compressor

Given:	
Vi Vg Vcf Vcl Vcm Vci Vcs Vcp Vct CR I N	= Value of gas recovered using in-line compressor ($) = Value of gas recovered using a portable compressor ($) = Cost of fuel, see Step 5 = Cost of labor = Cost of maintenance, see Step 5 = Capital cost of installation, see Step 4 = Capital cost of freight, see Step 4 = Purchase cost of compressor, see Step 4 = Cost of taxes and administration = Capital recovery factor (Where CR = $[I \times (1+I)^n] / [(1+I)^n-1]$) = Interest rate = Number of years in contract period (rental) or lifetime (purchase)
(1)	**Calculate: Vcr = Cost of capital investment recovered over the duration of the compressor contract period**
Vcr	= (Vci + Vcs + Vcp + Vct) x CR
(2)	**Calculate: Vc = Total costs associated with a portable compressor**
Vc	= Vcf + Vcl + Vcm +Vcr
(3)	**Calculate: Vp = Net value of recovered portable gas**
Vp Vp Vp	= Net value of portable recovered gas = Value of portable recovered gas - operating cost ($) = Vg - Vc
(4)	**Calculate: Vt = Total value of recovered gas**
Vt Vt Vt	= Total value of in-line and portable recovered gas = Total value of in-line recovered gas + net value of portable recovered gas = Vi + Vp

Sample Gas Recovery Scenario

Sample Scenario Using Portable Compressor

A company's 30-inch exterior diameter (28.5-inch interior diameter) pipeline operating at 600 pounds per square inch (psig) requires a blow down prior to maintenance at various 10 mile stretches. The downstream in-line reciprocating compressors have a compression ratio of 2 to 1 and can be safely used to draw down line pressure. A leased portable compressor with an effective 8 to 1 compression ratio operating at 1,000 horsepower is available at $31,000 per month (including maintenance costs) and can be manifolded to one of the block-valve systems. The portable compressor can remove approximately 416 Mcf per hour and consumes 7,000 Btu per horsepower per hour. The maintenance crew can

Methane Content of Natural Gas

The average methane content of natural gas varies by natural gas industry sector. The Natural Gas STAR Program assumes the following methane content of natural gas when estimating methane savings for Partner Reported Opportunities.

Production	79 %
Processing	87 %
Transmission and Distribution	94 %

install and operate the compressor at no additional cost to the company. Freight costs to transport the portable compressor from the rental company to the user total $19,000. The blowdown and maintenance will be done an average of 4 times per month. The portable compressor will be leased for a 12-month period.

To determine the benefits associated with using the portable compressor in combination with the in-line compressor, an operator used the following steps to calculate the net value of the recoverable gas. First, the operator calculated the total amount of gas available for recovery.

Exhibit 8: Total Volume of Gas Available for Recovery

Total gas available for recovery for each 10 mile stretch:

= 10 miles x 5,280 feet per mile x (π x (2.375 feet)^2 ÷ 4) x ((600 psig + 14.65) ÷ 14.65 psig) x 1 Mcf per 1,000 cf

Then the operator calculated the volume and value of gas recoverable using the in-line compressor.

Exhibit 9: Net Savings Associated with Using the In-line Compressor

Amount of gas recoverable per action using the in-line compressor:

= 9,814 Mcf - (9,814 Mcf ÷ 2.0 in-line compression ratio)
= 4,907 Mcf recovered per action using in-line compression

Value of gas recovered per action using the in-line compressor:

= 4,907 Mcf x $7.00 per Mcf
= $34,349 per action

Annual value of gas recovered assuming 4 actions per month:

= $34,349 x 4 per month x 12
= $1,648,752

Next, the operator calculated the volume and gross value of gas recoverable using a portable compressor.

Exhibit 10: Gross Savings Associated with Using the Portable Compressor

Gas available to be recovered using the portable compressor:

= Total gas available - gas recovered by in-line compressor
= 9,814 Mcf - 4,907 Mcf
= 4,907 Mcf recoverable gas available for portable compressor

Gross value of the gas recoverable per pump-down using a portable compressor:

= gas recoverable using portable compressor x value of gas
= [4,907 Mcf - (4,907 Mcf ÷ 8 portable compression ratio)] x $7.00 per Mcf
= $30,056

Gross value of the recoverable gas during a 12-month period, assuming an average of 4 pump-downs per month:

= $30,056 x 4 x 12
= $1,442,688

The operator also needed to account for fuel, maintenance, and freight costs associated with the portable compressor.

Exhibit 11: Costs Associated with the Portable Compressor

To calculate the fuel costs, the operator first needed to determine how many hours the compressor would be operating and based on those hours, the amount of fuel used for each 10-mile stretch:

Hours the portable compressor will operate to remove the volume of gas:
= gas recoverable using portable compressor ÷ rate of compressor
= (4,907 Mcf - (4,907 Mcf ÷ 8 compressor ratio)) ÷ 416 Mcf per hour
= 10 hours

Fuel used, assuming natural gas has a heat content of 1,020 Btu/scf:
= 7,000 Btu/hp/hour x 1,000 hp x 10 hours ÷ 1,020 Btu/scf ÷ 1,000 scf/Mcf
= 69 Mcf for each 10-mile stretch

Fuel costs assuming four 10-mile stretches per month:
= $7.00 per Mcf x 69 Mcf x 4
= $1,932 per month

Lease and maintenance costs
= $31,000 per month

Freight Cost
= $19,000

Total cost of using the portable compressor during a 12-month period:
= fuel costs + lease and maintenance cost + freight costs
= 12 x ($1,932 + $31,000) + $19,000 = $414,184

Subtracting the portable compressor costs from the savings yields the net savings associated with using a portable compressor.

Adding net savings from the in-line and portable compressors yields the total net savings for this scenario.

Exhibit 12: Net Savings Associated with Using the Portable Compressor

Total net value of the recovered gas during a 12-month lease using the portable compressor:
= $1,442,688 - $414,184
= $1,028,504

Exhibit 13: Net Value of Savings from Entire Recovery Scenario

Net value of the recovered gas from the entire scenario (in-line + portable)
= $1,648,752 + $1,028,504
= $2,677,256

Lessons Learned

Using pump-down techniques to depressurize the pipeline during planned maintenance activities allows companies to economically recover 50 percent to 90 percent of the vented natural gas. Partners offer the following lessons learned when using in-line and portable compressors to recover pipeline contents:

- Always perform in-line compressor pipeline pump-downs as part of a planned maintenance program. Even when portable compressors are not used, in-line compressors can reduce venting emissions.

- Incorporate in-line compressor pump-downs into emergency procedures. Although it is more difficult to perform pipeline pump-downs during emergencies (e.g., repairing leaking pipelines) than during planned maintenance, emergency pump-downs still can generate substantial gas and cost savings.

- Partners can maximize gas and cost savings by using portable compressors intensively, making repairs or upgrades on multiple segments of line taken out of service in turn. Check portable compressor availability and sizes when planning operations. Availability of portable compressors can be limited in isolated areas.

- Manifold at least one of the two mainline block valves to accommodate portable compressors.

- If possible, calculate the economics of recovering natural gas before planned maintenance activities. This ensures the cost-effectiveness of the activities.

- Include reductions in methane emissions realized through this approach in Natural Gas STAR Program annual reports.

Nelson Price Indexes

In order to account for inflation in equipment and operating & maintenance costs, Nelson-Farrar Quarterly Cost Indexes (available in the first issue of each quarter in the *Oil and Gas Journal*) are used to update costs in the Lessons Learned documents.

The "Refinery Operation Index" is used to revise operating costs while the "Machinery: Oilfield Itemized Refining Cost Index" is used to update equipment costs.

To use these indexes in the future, simply look up the most current Nelson-Farrar index number, divide by the February 2006 Nelson-Farrar index number, and, finally multiply by the appropriate costs in the Lessons Learned.

Case Study: One Partner's Experience

In 1998, Southern Natural Gas Company saved 32,550 Mcf using pump-down compressors to evacuate pipelines. The company used compressors at one location three times per year at an estimated total cost of $68,100 at 2006 costs. The company estimated saving nearly $228,000 in recovered product, using $7/Mcf as the value of gas no longer being vented. Subtracting pump-down costs from the value of gas saved, the company achieved net savings of $159,900. In this case, the estimated payback period for the portable compressor was approximately 4 months.

Case Study: One Partner's Experience

One Partner reported saving more than 8 MMcf during a 55-month period using an ejector installed on a pipeline bleeder. Typical methane emissions reductions can be estimated as 700 Mcf per year for one ejector installed to evacuate 2 miles of 18-inch out-of-service pipeline from 600 to 50 psig, using 200 feet of 1-inch piping connections, once per year.

This practice requires an adjacent operating pipeline with vent connections on both sides of a block valve or compressor, in close proximity to the pipeline being taken out of service and depressurized.

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