Lessons Learned

From Natural Gas STAR Partners

REDUCING EMISSIONS WHEN TAKING COMPRESSORS OFF-LINE

Executive Summary

Compressors are used throughout the natural gas system to move natural gas from production and processing sites to customer distribution systems. When compressors are off-line, methane can leak from a number of sources, the amount depending on system pressurization. In a depressurized system, methane emissions result from the "blowdown," or venting of the high-pressure gas left within the compressor and from continued leakage of unit isolation valves. In a fully pressurized system, methane can leak from the closed blowdown valve and the compressor rod packings.

Natural Gas STAR partners have found that simple changes in operating practices can save money and significantly reduce methane emissions. Keeping compressors pressurized when they are off-line for operational reasons achieves immediate payback—there are no capital costs and emissions are reduced by avoiding "blowdown." Two additional options further reduce methane emissions. Connecting the blowdown vent lines to the fuel gas system allows normally vented gas to be used while the compressor is off-line. A static seal can be installed on a pressurized compressor's rods to eliminate rod packing leaks during shutdown. Benefits of these practices include fewer bulk gas releases, lower leak rates, and lower fuel costs, with a payback in most cases of less than a year.

Action (Reduce Compressor Emissions by:)	Net Volume of Gas Saved (Mcf/year)	Net Value of Gas Saved ($/year)[2]	Cost of Implementation($)	Payback[3]
Option 1: Keeping pressurized	4,400	13,200	0	Immediate
Option 2: Keeping pressurized and Routing Gas to Fuel	+1,345[1]	+4,035[1]	1,250	4 months
Option 3: Keeping pressurized and Installing Static Seal	+1,200[1]	+3,600[1]	3,000	10 months

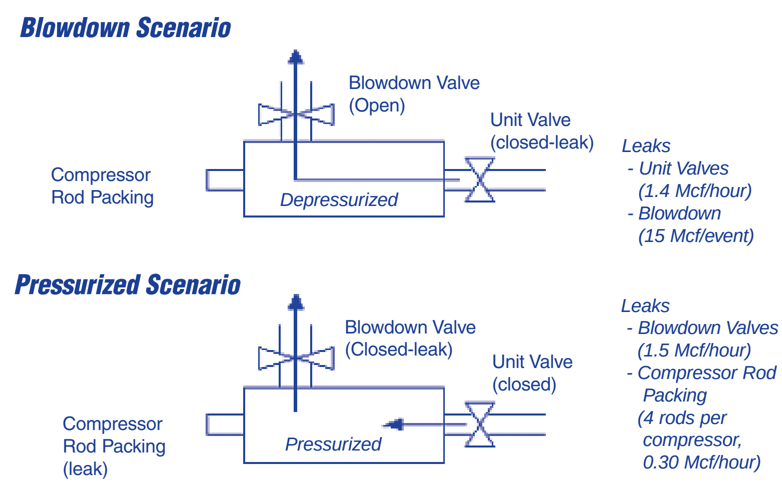
[1] Incremental over base
[2] Value of gas = $3.00/Mcf
[3] 10 percent discount rate

This is one of a series of Lessons Learned Summaries developed by EPA in cooperation with the natural gas industry on superior applications of Natural Gas STAR Program Best Management Practices (BMPs) and Partner Reported Opportunities (PROs).

Technology Background

Compressors used throughout the natural gas system are cycled on- and off-line to meet fluctuating demand for gas. Maintenance and emergencies are other occasions compressors are taken off-line. Standard practice is to "blow down," or vent the high pressure gas left in the compressor when it is taken off-line. While the compressor is blown down, leakage continues from the unit isolation valves. When a compressor is fully pressurized, methane can leak from the closed blowdown valve and the compressor rod packings (see Exhibit 1).

Exhibit 1: Compressor Diagram



The number of times a compressor is blown down for operational purposes depends on its operational mode. Some compressors are base loaded, meaning they operate most of the time, and might be blown down only three times per year. Down time for these compressors averages 500 hours per year. Other compressors operate in peak load service, coming on line as demand increases and higher pipeline pressures are required, and dropping off the system as market demand decreases. These compressors can be off-line on average 40 times per year, for approximately 4,000 hours.

The ratio of base load compressors to peak load compressors varies widely between pipeline companies because of different operating strategies, system configurations, and markets. On some pipelines, 40 percent of the compressors might be base loaded; on others, 75 percent might operate in a base load mode.

The largest source of methane emissions associated with taking compressors off-line is from the blow down or venting of gas remaining within the compressor (i.e., depressurizing the system). On average, a single blowdown will result in the release of approximately 15 Mcf of gas to the atmosphere.

Unit isolation valves are another source of methane emissions from off-line compressors. These large valves isolate the compressor from the pipeline and can leak significant amounts of methane between the high pressure pipeline and atmospheric pressure. A typical leak rate for unit valves is 1,400 scf per hour (scfh). Although unit valves are periodically maintained to reduce leaks, their inaccessibility results in increasing leakage between scheduled maintenance.

Other sources of emissions from off-line compressors are the compressor rod packings and blowdown valves. Seals on compressor piston rods will leak during normal operations, but this leakage increases approximately four fold (to about 75 scfh per rod, or 300 scfh per four-cylinder compressor) when a compressor is idle and fully pressurized, that is, not blown down. Leaks occur through gaps between the seal rings and their support grooves, which are closed by the dynamic movement of the piston rod and lubricating oil (see EPA's *Lessons Learned: Reducing Methane Emissions from Compressor Rod Packing*). Blowdown valves also leak from pressurized systems at a typical rate of 150 scfh.

Natural Gas STAR partners have significantly reduced methane emissions from compressors taken off-line for operational reasons by applying one or more of the following three measures:

1. Keep compressor pressurized. Avoid compressor blowdown emissions by keeping compressors fully pressurized. This will substantially reduce the leak rate from 1,400 scfh at the unit valve to approximately 450 scfh from the blowdown valve and rod packings. With no facility modifications required, this is the best measure for all compressors whenever possible.

2. Keep pressurized and route gas to fuel. Connecting the blowdown vent lines to the fuel gas system allows the normally vented gas to be used when taking a compressor off-line. Once the pressures between the fuel system and the compressor are equalized, the compressor "floats" at the fuel gas pressure (typically 100-150 pounds per square inch (psi)). Leakage from the compressor packings and blowdown vent is reduced to about 125 scfh. Leaks across the unit valves into the compressor continues to feed the fuel system via the vent connection.

3. Keep pressurized and install a static seal. A static seal on the compressor rods eliminates rod packing leaks during shutdown when the compressor is kept pressurized. A static seal is installed on each rod shaft outside conventional packing. An automatic controller activates when the compressor is shutdown to wedge a tight seal around the shaft; the controller deactivates the seal on start-up. Leakage occurs only from the blowdown valve at about 150 scfh when at system pressure.

Economic and Environmental Benefits

Natural Gas STAR partners can achieve substantial environmental and economic benefits by taking simple steps to avoid blowing down, or depressurizing, off-line compressors whenever possible:

- ★ **Fewer Bulk Gas Releases:** By not depressurizing off-line compressors, operators can save 15 Mcf each time the compressor is taken off-line. Assuming base load units are blown down three times per year and peaking units 40 times, between 45 Mcf and 660 Mcf can be saved annually.
- ★ **Lower Leak Rates:** Keeping compressors fully pressurized avoids significant leaks across the unit valves of 475 Mcf per year for base load units and 3,800 Mcf per year for peak load units.
- ★ **Lower Fuel Costs:** Routing compressor gas to the fuel system uses fuel gas that otherwise would have been vented from compressors, thus decreasing fuel costs.

Decision Process

Operators can easily and cost-effectively reduce methane emissions from compressors off-line by following the four steps below:

Step 1: Identify blowdown alternatives. Three options, described in the Technology Background section, are available when taking compressors off-line for operational reasons:

- ★ **Option 1, keeping compressor pressurized**
- ★ **Option 2, keeping compressor pressurized and routing gas to fuel**
- ★ **Option 3, keeping compressor pressurized and installing a static seal**

The best option for all compressors is to simply avoid depressuring whenever possible. Options 2 and 3 provide additional gas savings when used in conjunction with Option 1. Option 2 can be used when taking compressors off-line for maintenance or emergency reasons; bleeding off gas in the compressor to the fuel system prior to blowing down the compressor can reduce emissions and save money.

Step 2: Calculate quantity and value of methane emissions. The total methane emissions from compressors taken off-line and blown down is the sum of the losses from venting the compressor and the losses across the unit valves for the period of time the compressor is depressurized. The key inputs for calculating the total losses per compressor per year include:

- ★ The number of blowdowns per year (B).

★ The pressurized compressor's volume between unit isolation valves (V). The volume of gas vented per blowdown depends on the compressor's cavity volume, the piping between isolation valves, and the pressure. Using Henry's Law (volume is inversely proportional to pressure or $P_1V_1 = P_2V_2$) this can be calculated directly. (The EPA default is 15 Mcf per blowdown.)

★ The duration of the shut-down periods (T).

★ The leakage rate at the unit valves (U). Unit valve leaks can be measured at the blowdown vent using hand-held measuring devices. Leak rates generally increase since the last maintenance of the valves. A default of 1,400 scfh is used in this analysis.

Total emissions (TE) are calculated as: TE = BV + TU. The total value (TV) or cost of these emissions is TE times the price (P) of gas or TV = TE x P.

Most of this information is easily accessible from operating records and nameplate specifications, or can be estimated. Exhibit 2 presents two sample calculations of losses, one for a base load compressor and one from a peak load compressor.

Exhibit 2: Sample Calculations

Assumptions:	Base Load	Peak Load
No. of blowdowns/year	3	40
Volume of compressed gas (scf)	15,000	15,000
Hours off-line/year	500	4,000
Unit valve leak rate (scfh)	1,400	1,400
Sample 1: Baseload Compressor		
Total Emissions	= (3 x15 Mcf) + (500 hours x 1.4 Mcf/h) = 745 Mcf/year	
Total Value	= 745 Mcf/year x $3.00/Mcf = $2,235 per year	
Sample 2: Peak Load Compressor		
Total Emissions	= (40 x 15 Mcf) + (4,000 hours x 1.4 Mcf/h) = 6,200 Mcf/year	
Total Value	= 6,200 Mcf/year x $3.00/Mcf = $18,600 per year	

Step 3: Calculate the costs for each alternative. The costs of each alternative include the capital investment, the incremental operations and maintenance (O&M) costs, and the off-line leak rate associated with the option. The costs of each option are summarized below.

- **Option 1, keep the compressor fully pressurized.** This option has no capital or O&M costs. When instituted, leakage occurs at the compressor rod packing (300 scfh per compressor) and at the blowdown valve (150 scfh), totaling approximately 450 scfh when the compressor is fully pressurized.
- **Option 2, keep pressurized and connect the compressor to the fuel gas system.** This option involves adding piping and valves to bleed gas from an idle compressor into the compressor station's fuel gas system. Facility modification costs range between $900 and $1,600 per compressor. Major determinants of cost are the size of the compressor, the number of fittings, valves, and piping supports, size of piping, length of piping, and whether an automatic analyzer is installed. Once the pressure in the compressor equilibrates with the fuel line pressure, leakage from compressor rod packings falls to about 50 scfh and from the blowdown valve to about 75 scfh, totaling 125 scfh.
- **Option 3, keep pressurized and install a positive static seal on compressor rods.** While technically feasible and compatible with either, Option 3 is not cost-effective when used in conjunction with Option 2 (because leak rates are significantly lower when floating the compressor at the lower fuel line pressures). Static seals cost about $500 per rod, plus $1,000 for an automatic activation controller for the entire compressor, totaling $3,000 per four-rod compressor. With leakage from the compressor rod packing virtually eliminated, the only remaining leakage is from the blowdown valves, approximately 150 scfh.

Exhibit 3 shows the costs associated with these options. Off-line leakage is the sum of leaks from compressor rod packings and the blowdown valve, annualized using the duration of hours off-line in Exhibit 2.

Step 4: Conduct economic analysis. Once the quantity and value of methane emissions and the costs of each alternative have been estimated, conduct an economic analysis. One straightforward way to evaluate the

Exhibit 3: Capital Costs and Leak Rates of Alternatives			
	Option 1 Keep Pressurized	Option 2 Keep Pressurized and Tie to Fuel Gas	Option 3 Keep Pressurized and Install Static Seal
Capital	None	$1,250/compressor	$3,000/compressor
Off-line Leakage			
Baseload	225 Mcf/yr $675	63 Mcf/yr $189	75 Mcf/yr $225
Peak Load	1,800 Mcf/yr $5,400	500 Mcf/yr $1,500	600 Mcf/yr $1,800
Note: Baseload scenario assumes compressor is off-line 500 hour/year; peak load scenario assumes compressor is off-line 4,000 hours/year. Gas cost=$3.00/Mcf.			

economics is through a discounted cash flow analysis, in which the first year costs of each option are compared against the discounted value of the net amount of gas saved.

For Option 1, savings are the difference between quantity of methane emissions (calculated in Exhibit 2) and off-line leakage that occurs when the compressor is kept fully pressurized (calculated in Exhibit 3). Savings for Options 2 and 3 derive from further reducing the net gas leakage in Option 1 by making facility changes.

Exhibit 4 presents the estimated savings of Options 1 and the incremental savings from implementing Option 2 and 3 in addition to Option 1. Option 1 demonstrates an immediate payback with no investment required. For Option 3, incremental savings in a base load mode do not recover the facility investment in a five-year period. Further, the incremental savings of installing the piston rod seals in addition to fuel gas system tie-in (Option 2) are not economically attractive for either base load or peaking mode.

Exhibit 4: Economic Comparison of Options						
	Option1 Keep Pressurized		Option 2 Keep Pressurized and Tie to Fuel Gas		Option 3 Keep Pressurized and Install Static Seal	
	Base	Peak	Base	Peak	Base	Peak
Net Gas Savings(Mcf/yr)	520	4,400	+207	+1,345	+150	+1,200
Dollar Savings/yr[1]	$1,560	$13,200	$621	$4,035	$450	$3,600
Facilities Investment	0	0	$1,250	$1,250	$3,000	$3,000
Payback[2]	Immed	Immed	3 yrs	4 mos	None	10 mos.
IRR[3]	>100%	>100%	41%	323%	Negative	118%

[1] Assuming value of gas $3.00/Mcf
[2] 5 year life and 10 percent discount rate
[3] 5 year life (not including annual O&M costs)

Implementation Tips

Listed below are tips that Natural Gas STAR partners use to evaluate options and reduce emissions from off-line compressors:

★ Operators generally conduct total station maintenance turnarounds every 12 to 18 months, overhauling unit isolation valves and making major modifications such as fuel gas tie-ins. Toward the end of an operating cycle between turnarounds, unit valves, blowdown valves, and compressor rod packing likely experience maximum leakage rates.

★ Safety can become an issue when maintaining gas pressure on idle compressors causes increased rod packing leakage. Installing a static seal on compressor rods eliminates this leakage.

★ Depressuring off-line compressors to fuel gas is effective only where there is sufficient fuel demand to consume the gas at the rate of unit isolation valve leakage (estimated 1.4 Mcf/h).

★ Maintain the tightness of unit isolation valves. Tight sealing unit isolation valves would eliminate 90 percent of annual emissions from typical shutdown and blowdown practices. However, repairs are expensive in terms of both valve materials and labor and emissions from shutting down and depressuring the entire station to access these valves.

Case Study: One Partner's Experience

With growing interest in increasing savings and reducing gas leakage, Company A investigated several practices to help reduce leakage from compressor rod packing. During the period when compressors were taken out of service, the company tied the compressor to the fuel gas system. At this lower compressor cylinder pressure, the leakage through rod packing cases and blowdown valves was reduced considerably. For 3,022 compressor cylinders (a total of 577 compressor units) operating 40 percent of the time, the total gas savings amounted to 1.58 billion cubic feet per year.

Lessons Learned

Partners will find that significant emissions reductions and cost saving will result from avoiding routine compressor blowdown, and, where applicable, eliminating or rerouting leakage. Savings accrue from retained product or displacement of fuel gas. The principal lessons learned from Natural Gas STAR partners are:

- ★ Avoid depressuring whenever possible. Large immediate savings can be realized at no cost by keeping off-line compressors pressurized.
- ★ Educate field staff about the benefits of avoiding blowdowns.
- ★ Identify shut-down schedule for compressors to determine whether it operates in base or peak load. Use this information to conduct economic analysis of Options 2 and 3.
- ★ Develop a schedule for retrofitting compressors with fuel gas routing systems installing a compressor rod static seal, where justified economically.
- ★ Record reductions at each compressor.
- ★ Reductions in methane emissions should be included in annual reports submitted as part of the Natural Gas STAR Program.

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