Oil			Percentage		VOC Emissions	
	bbl/year	Number	of Total	of SSE	Uncontrolled	Controlled
	50,000	32	98.2%	95.8%	55.0	9.4
	40,000	51	97.1%	93.2%	44.0	7.5
	30,000	82	95.3%	89.1%	33.0	5.6
	20,000	153	91.2%	79.7%	22.0	3.7
	10,000	377	78.4%	49.9%	11.0	1.9
(SSE)	4,565	753	56.9%	0.0%	5.0	0.9
	Total	1,746	0.0%			

Condensate			Percentage	VOC Emissions	
	bbl/year	Number	of Total	Uncontrolled	Controlled
	10,000	6	99.6%	44.8	7.6
	8,000	7	99.6%	35.8	6.1
	6,000	13	99.2%	26.9	4.6
	4,000	18	98.8%	17.9	3.0
	2,000	28	98.2%	9.0	1.5
(SSE)	1,100	40	97.4%	4.9	0.8
	Total	1563	0.0%		

Dehydator			Percentage	VOC Emissions	
	MMCF/year	Number	of Total	Uncontrolled	Controlled
	400	15	99.0%	15.1	2.6
	300	43	97.2%	11.3	1.9
	200	90	94.2%	7.5	1.3
(SSE)	133	175	88.8%	5.0	0.9
	Total	1563	0.0%		

All Utah O&G Wells (as of 6/5/2013) Summary			
Well Count		Indian Cntry	Non-Indian Cntry.
Oil	4950	2833	2117
Producing	4300	2554	1746
Shut-In	650	279	371
Gas	7777	5834	1943
Producing	6769	5206	1563
Shut-In	1008	628	380
Total	12727	8667	4060
		68.10%	31.90%

	O&G Wells Producing or Shut-In (as of 6/5/2013) Summary			
	Well Count			
	Indian Cntry		Non-Indian Cntry.	
	Uintah	Duchesne	Uintah	Duchesne
Oil	958	1379	337	1402
Gas	5772	28	1	25
Oil & Gas	6730	1407	338	1427
Total	8137		1765	
	82.18%		17.82%	

High-Bleed Pneumatic Devices

Program Description

This strategy to reduce ambient ozone levels by reducing volatile organic compounds (VOCs) within the non-attainment area (NAA) considers changes that industry can make regarding high-bleed pneumatic devices. Colorado Air Quality Control Commission Regulation No. 7 (Reg. 7) may be modified to require that natural gas exploration and production (E&P) and mid-stream facilities within the NAA reduce emissions from high-bleed pneumatic devices by incorporating one or more of the following options:

- Require that new facilities install low- or no-bleed pneumatic devices
- Require that existing facilities retrofit or replace high-bleed pneumatic devices with low- or no-bleed pneumatic devices
- Require that enhanced maintenance be performed on high-bleed pneumatic devices
- Require keeping natural gas actuated device discharge from being vented
- Require using an instrument air system
- Require using solar generated electricity at E&P sites

Many process control devices are used to operate valves that regulate pressure, flow, temperature, and liquid levels. These devices can be operated pneumatically, electrically, or mechanically. Most of the devices used by the natural gas industry are pneumatically operated. Although instrument air is commonly used to power pneumatic devices at gas processing facilities, the majority of natural gas industry pneumatic devices are powered by natural gas.[1] Other uses of pneumatic devices occur with small pumps, compressor motor starters, and isolation shutoff valves.

As part of normal operation, most pneumatic devices emit, or "bleed", gas to the atmosphere either continuously or intermittently. A 2003 Environmental Protection Agency (EPA) study reported that emissions from pneumatic devices are collectively one of the largest sources of methane emissions in the natural gas industry. Estimated annual nationwide methane emissions are approximately 31 billion cubic feet (Bcf) from the production sector, 16 Bcf from the processing sector, and 14 Bcf from the transmission sector.[1] By definition, high-bleed pneumatic devices emit at least 6 standard cubic feet gas per hour (scfh) to atmosphere. The highest bleed rate listed in one source, a table published by the EPA, is 42 cubic feet per hour (cfh).[1] The average bleed rate for high-bleed pneumatic devices in the NAA is 21 cfh.[2] Natural gas is primarily composed of methane, but also contains other compounds including VOCs and hazardous air pollutants (HAPs). Bleed rates of 6, 21, and 42 cfh natural gas represent emission sources of 0.3, 1.1, and 2.1 tons per year (tpy) VOC, respectively, assuming a VOC molar fraction of 7.47 percent, which is representative of the NAA.[2]

Options for Further Consideration

VOC emissions from pneumatic devices within the NAA were 24.8 tons per day (tpd) for the 2006 baseline and have been projected to be 28.6 tpd for the 2010 baseline. These emissions represent 14.0 and 15.1 percent of the total VOC emissions from oil and gas sources in the NAA in 2006 and 2010, respectively.[3] Therefore, emission reductions related to this source category have the potential to be significant. As a result, this strategy has been developed since the draft version was presented at the February 26, 2008 RAQC stakeholder meeting. However, not all options within this strategy have been further developed. This paper presents information for the options that have been further developed.

All stakeholder comments received to date and responses, if ready, are available in a separate document that will be accessible to stakeholders.

Install, Retrofit, or Replace to Low- or No-Bleed Pneumatic Devices
Many companies have reduced natural gas emissions significantly by replacing or retrofitting high-bleed pneumatic devices. Field experience shows that up to 80 percent of all high-bleed devices can be replaced or retrofitted with low-bleed devices.[1] Retrofitting or replacing devices can provide better system-wide performance and reliability, and improve monitoring of parameters such as gas flow, pressure, and liquid level.

Perform Enhanced Maintenance
Up to 20 percent of high-bleed devices can not be retrofitted or replaced with low-bleed devices.[1] For example, very large devices require fast and/or precise responses to process changes which can not be achieved with low-bleed devices. In those cases, natural gas emissions may be reduced by performing enhanced maintenance. Enhanced maintenance includes cleaning, tuning, and repairing leaking gaskets, tubing fittings, and seals. Additional enhanced maintenance includes tuning to operate over a broader range of proportional band and eliminating unnecessary valve positioners.

Air Quality

VOC emissions from pneumatic devices within the NAA were 24.8 tpd for the 2006 baseline. They have been projected to be 28.6 tpd for the 2010 baseline, assuming that regulatory and industry policy and practices do not change.[3] VOC emissions may be reduced by 16.2 tpd if the first and second options presented in this strategy are adopted (low- or no-bleed devices are used instead of high-bleed devices in most instances). If the third option is adopted, VOC emissions would be reduced by an additional 1.3 tpd (enhanced maintenance performed on high-bleed devices that can not be retrofitted or replaced with low- or no-bleed devices).

These emission reduction values are based upon the following assumptions.

- 80 percent of high-bleed devices can be converted to low- or no-bleed devices[1]
- The average bleed rate for low- and no-bleed devices is 1.934 cfh[2]
- Enhanced maintenance will be performed on remaining high-bleed devices (20 percent of original number)
- Enhanced maintenance consists of cleaning, tuning, and repairing leaking gaskets, tubing fittings, and seals
- Enhanced maintenance will reduce emissions from high-bleed devices by 7.5 cfh per device[1]

Health and Welfare Benefits

While health benefits are not quantified here, it is understood that reducing direct emissions of VOCs can reduce ozone and some air toxics. This will reduce the incidence of human health impacts caused by ozone such as pulmonary, cardiovascular, respiratory, and nervous system disease. Because elevated ozone also damages crops, forests, and other natural plant life, all would benefit if emissions are reduced. This strategy would also reduce emissions of methane, which contributes to climate change.

Program Costs

EPA Natural Gas STAR partners have achieved significant savings and emissions reductions through replacement, retrofit, and maintenance of high-bleed pneumatic devices. Most retrofit investments pay for themselves in approximately one year, and replacements in as little as 6 months.[1]

A cost analysis was performed based on assumptions described in the Air Quality section of this paper over a time period of 1 year. Results are shown in the following table. Costs depend on whether high-bleed devices are converted to low- or no-bleed devices by retrofitting, replacing at end-of-service life, or early replacement and also whether or not enhanced maintenance is performed on remaining high-bleed devices.

Option	Cost per Device[1]	Cost with Enhanced Maintenance ($/ton VOC)*	Cost without Enhanced Maintenance ($/ton VOC)*
Retrofit 80 % High-Bleed to Low-/No-Bleed	$500	376	373
Replace 80 % High-Bleed to Low-/No-Bleed at End-of-Life	$250	203	186
Early Replacement 80 % High-Bleed to Low-/No-Bleed	$1350	962	1,007
Perform Enhanced Maintenance on 20% High-Bleed	$176***	NA	409 **

* Reported costs of reducing VOCs are higher than actual costs because the calculations do no include income that will be generated by reduced product (natural gas) loss

** Cost to perform enhanced maintenance without considering other options is $409 per ton VOC reduced

*** The cost per device to perform enhanced maintenance is made up of the cost to reduce the supply pressure ($153) and the cost to repair leaks and retune ($23)

Install, Retrofit, or Replace to Low- or No-Bleed Pneumatic Devices

The EPA reports that one company replaced 70 high-bleed pneumatic devices with low-bleed devices and retrofitted 330 high-bleed devices, which resulted in an emission reduction of 1,405 thousand cubic meters (Mcm) per year. At $105 per Mcm, this resulted in a savings of $148,800 per year. The cost, including materials and labor for the retrofit and replacement, was $118,500. Therefore, the payback period was less than one year.[4]

Early replacement (replacing prior to projected end-of-service-life) of a high-bleed valve with a low-bleed valve is estimated to cost $1,350. Based on $3 per Mcf gas, the payback is estimated to take 21 months. For new installations or end of service life replacement, the incremental cost difference of high-bleed devices versus low-bleed devices is $150 to $250. Based on $3 per Mcf gas, the payback is estimated to take 5 to 12 months.[1]

Perform Enhanced Maintenance

Enhanced maintenance of pneumatic devices, which nominally consists of cleaning, tuning, and repair or replacing leaking gaskets, tubing fittings and seals, is estimated to cost up to $350. Based on $3 per Mcf gas, the payback is estimated to take 0 to 5 months.[1]

RACT Considerations

In conjunction with the first and second option presented in this strategy, the Colorado Air Pollution Control Division (APCD) is proposing to make Reasonably Available Control Technology (RACT) consistent between Reg. 3 and Reg. 7 to address the potential conflict between the regulations on when RACT is triggered. Reg. 3 triggers RACT at permit levels for new sources, whereas Reg. 7 triggers RACT by source category or at 100 tpy (as described in Section II.c.1.a(1)). This could be accomplished by removing Reg. 7 language regarding RACT and other applicable exemptions and instead relying upon existing Reg. 3 language or by making Reg. 7 language consistent with Reg. 3 language. General concepts associated with the presumptive RACT proposal are:

- The regulation should be modified to establish that the APCD will require RACT for all new and modified oil and gas sources
- Wyoming Best Available Technology (BAT) determinations can be used as an example, which will reduce APCD resource impacts to initiate the program. Over time, the APCD would re-evaluate RACT determinations to ensure requirements utilize current control technology. The goal may be a review of each technology and update as needed. All RACT policies would be available on the Web, which would promote consistency.

- RACT determinations can be identified by compiling and maintaining a list in a guidance document, rather than in regulation, so that they can be modified more easily to keep with current technology.
- The APCD may consider developing general permits that would include the relevant RACT determination to streamline the permitting process.
- RACT applies to new and modified sources. The APCD may need to address existing sources to ensure ozone is reduced to National Ambient Air Quality Standards (NAAQS).

Implementation/Administration

This strategy has the potential to significantly increase the number of regulated sources, and has reporting, permitting, and/or compliance assurance impacts to the APCD.

References

[1] US EPA, *Lessons Learned: Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry*
[2] ENVIRON, Buys and Associates, and IPAMS, *Development of Baseline 2006 Emissions from Oil and Gas Activity in the Denver-Julesburg Basin*, February 7, 2008
[3] ENVIRON, Buys and Associates, and IPAMS, *Development of Baseline 2006 Emissions from Oil and Gas Activity in the Denver-Julesburg Basin*, March, 2008
[4] US EPA, *Methods for Reducing Methane Emissions from Natural Gas Systems*, www.coalinfo.net.cn/coalbed/meeting/2203/papers/naturalgas/NG019.pdf

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Options For Reducing Methane Emissions From Pneumatic Devices In The Natural Gas Industry

Executive Summary

Pneumatic devices powered by pressurized natural gas are used widely in the natural gas industry as liquid level controllers, pressure regulators, and valve controllers. Methane emissions from pneumatic devices, which have been estimated at 51 billion cubic feet (Bcf) per year in the production sector, 14 Bcf per year in the transmission sector and <1 Bcf per year in the processing sector, are one of the largest sources of vented methane emissions from the natural gas industry. Reducing these emissions by replacing high-bleed devices with low-bleed devices, retrofitting high-bleed devices, and improving maintenance practices can be profitable.

Natural Gas STAR Partners have achieved significant savings and methane emission reductions through replacement, retrofit, and maintenance of high-bleed pneumatics. Partners have found that most retrofit investments pay for themselves in little over a year, and replacements in as little as 6 months. To date, Natural Gas STAR Partners have saved 36.4 Bcf by retrofitting or replacing high-bleed with low-bleed pneumatic devices, representing a savings of $254.8 million worth of gas. Individual savings will vary depending on the design, condition and specific operating conditions of the controller.

Technology Background

The natural gas industry uses a variety of control devices to automatically operate valves and control pressure, flow, temperature or liquid levels. Control devices can be powered by electricity or compressed air, when available and economic. In the vast majority of applications, however, the gas industry uses pneumatic devices that employ energy from pressurized natural gas.

Natural gas powered pneumatic devices perform a variety of functions in all three sectors of the natural gas industry. In the production sector, an estimated 400,000 pneumatic devices are used to control and monitor gas and liquid flows and levels in dehydrators and separators, temperature in dehydrator regenerators, and pressure in flash tanks. In the processing sector, about 13,000 gas pneumatic devices are used for compressor and glycol dehydration control in gas gathering/booster stations and isolation valves in processing plants (process control in gas processing plants is predominantly instrument air).

Economic and Environmental Benefits

Method for Reducing Natural Gas Losses	Volume of Natural Gas Savings (Mcf/year)	Value of Natural Gas Savings ($/year)			Implementation Cost ($)	Payback (Months)		
		$3 per Mcf	$5 per Mcf	$7 per Mcf		$3 per Mcf	$5 per Mcf	$7 per Mcf
Replacement								
Change to low-bleed device at end of life.	50 to 200	$150 to $600	$250 to $1,000	$350 to $1,400	$210 to $340[a]	4 to 27	3 to 17	2 to 12
Early-replacement of high-bleed unit.	260	$780	$1,300	$1,820	$1,850	29	17	13
Retrofit	230	$690	$1,150	$1,610 per year	$675	12	7	5
Maintenance	45 to 260	$135 to $780	$225 to $1,300	$315 to $1,820	Negligible to $500	Immediate to 8	Immediate to 5	Immediate to 4

General Assumptions:
[a] Incremental cost of low-bleed over high-bleed equipment.

Definition of High-Bleed Pneumatic

Any pneumatic device that bleeds in excess of 6 scfh (over 50 Mcf per year) is considered a high-bleed device by the Natural Gas STAR Program.

In the transmission sector, an estimated 85,000 pneumatic devices actuate isolation valves and regulate gas flow and pressure at compressor stations, pipelines, and storage facilities. Non-bleed pneumatic devices are also found on meter runs at distribution company gate stations for regulating flow, pressure, and temperature.

As part of normal operation, pneumatic devices release or bleed natural gas to the atmosphere and, consequently, are a major source of methane emissions from the natural gas industry. The actual bleed rate or emissions level largely depends on the design of the device.

Exhibit 1 shows a schematic of a gas pneumatic control system. Clean, dry, pressurized natural gas is regulated to a constant pressure, usually around 20 psig. This gas supply is used both as a signal and a power supply. A small stream is sent to a device that measures a process condition (liquid level, gas pressure, flow, temperature). This device regulates the pressure of this small gas stream (from 3 to 15 psig) in proportion to the process condition. The stream flows to the pneumatic valve controller, where its variable pressure is used to regulate a valve actuator.

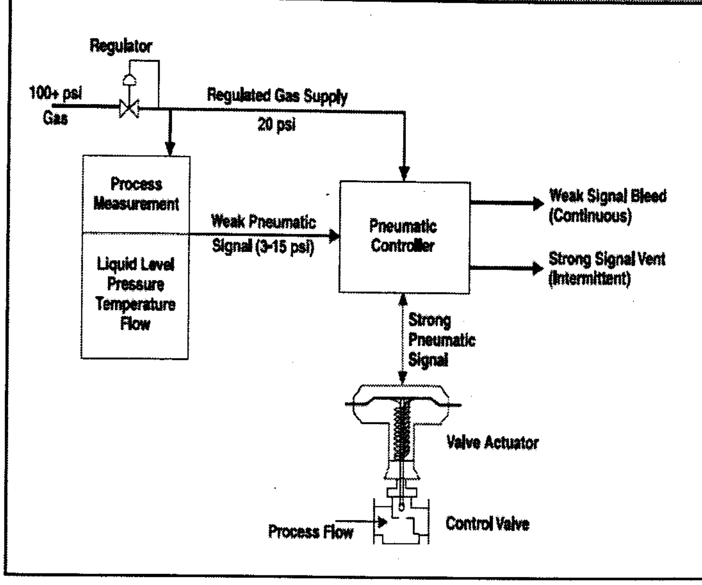
To close the valve pictured in Exhibit 1, 20-psig pneumatic gas is directed to the actuator, pushing the diaphragm down against the spring, which, through the valve stem, pushes the valve plug closed. When gas is vented off the actuator, the spring pushes the valve back open. The weak signal continuously vents (bleeds) to the atmosphere. Electro-pneumatic devices use weak electric current instead of the weak gas stream to signal pneumatic valve actuation.

In general, controllers of similar design usually have similar steady-state bleed rates regardless of brand name. Pneumatic devices come in three basic designs:

★ **Continuous** bleed devices are used to modulate flow, liquid level, or pressure and will generally vent gas at a steady rate;

★ **Actuating or intermittent** bleed devices perform snap-acting control and release gas only when they stroke a valve open or closed or as they throttle gas flows; and

Exhibit 1: Pneumatic Device Schematic



★ **Self-contained** devices release gas into the downstream pipeline, not to the atmosphere.

To reduce emissions from pneumatic devices the following options can be pursued, either alone or in combination:

1. Replacement of high-bleed devices with low-bleed devices having similar performance capabilities.

2. Installation of low-bleed retrofit kits on operating devices.

3. Enhanced maintenance, cleaning and tuning, repairing/replacing leaking gaskets, tubing fittings, and seals.

Field experience shows that up to 80 percent of all high-bleed devices can be replaced with low-bleed equipment or retrofitted. Exhibit 2 lists the generic options applicable for different controller requirements.

In general, the bleed rate will also vary with the pneumatic gas supply pressure, actuation frequency, and age or condition of the equipment. Due to the need for precision, controllers that must operate quickly will bleed more gas than slower operating devices. The condition of a pneumatic device is a stronger indicator of emission potential than age; well-maintained pneumatic devices operate efficiently for many years.

Exhibit 2: Options for Reducing Gas-Bleed Emissions by Controller Type

Action	Pneumatic Types		
	Level Controllers	Pressure Controllers	Positioners/ Transducers
Replacements			
High-bleed with low-bleed	X	X	X (electro-pneumatic)
Retrofits			
Install retrofit kits	X	X	X
Maintenance			
Lower gas supply pressure/replace springs/re-bench	X	X	X
Repair leaks, clean and tune	X	X	X
Change gain setting	X	X	
Remove unnecessary positioners			X

Economic and Environmental Benefits

Reducing methane emissions from high-bleed pneumatic devices through the options presented above will yield significant benefits, including:

★ **Financial return from reducing gas-bleed losses.** Using a natural gas price of $7.00 per thousand cubic feet (Mcf), savings from reduced emissions can range from $315 to $1,820 or more per year per device. In many cases, the cost of implementation is recovered in less than a year.

★ **Increased operational efficiency.** The retrofit or complete replacement of worn units can provide better system-wide performance and reliability and improve monitoring of parameters such as gas flow, pressure, or liquid level.

★ **Lower methane emissions.** Reductions in methane emissions can range from 45 to 260 Mcf per device per year, depending on the device and the specific application.

Decision Process

Operators can determine the gas-bleed reduction option that is best suited to their situation, by following the decision process laid out below. Depending on the types of devices that are being considered, one or more options for reducing pneumatic gas bleed may be appropriate.

Step 1: Locate and describe the high-bleed devices.

Partners should first identify the high-bleed devices that are candidates for replacement, retrofit, or repair. The identification and description process can occur during normal maintenance or during a system-wide or facility-specific pneumatics survey. For each pneumatic device, record the location, function, make and model, condition, age, estimated remaining useful life, and bleed rate characteristics (volume and whether intermittent or continuous).

The pneumatic device's bleed rate can be determined through direct measurement or from data provided by the manufacturer. Direct measurement might include bagging studies at selected instruments, high-volume sampler measurements (see "Directed Inspection and Maintenance at Compressor Stations" Lessons Learned) or the operator's standard leak measurement approach. Operators will find it unnecessary to measure bleed rates at each device. In most cases, sample measurements of a few devices are sufficient. Experience suggests that manufacturers' bleed rates are understated, so measurement data should be used when it can be acquired.

Appendix A lists brand, model, and gas bleed information—as provided by manufacturers—for various pneumatic devices. This is not an exhaustive list, but it covers the most commonly used devices. Where available, actual field data on bleed rates are included.

Step 2: Establish the technical feasibility and costs of alternatives.

Nearly all high-bleed pneumatic devices can be replaced or retrofitted with lower-bleed equipment. Consult your pneumatic device vendor or an instrumentation specialist for availability, specifications and costs of suitable devices. Low-bleed devices can be requested by specifying bleed rates less than 6 standard cubic feet per hour (scfh). It is important to note that not all manufacturers report bleed rates in the same manner, and companies should exercise

Five Steps for Reducing Methane Emissions from Pneumatic Devices:
1. Locate and describe the high-bleed devices;
2. Establish the technical feasibility and costs of alternatives;
3. Estimate the savings;
4. Evaluate the economics; and
5. Develop an implementation plan.

caution when making purchases of low-bleed devices.

Appendix B lists cost data for many low-bleed pneumatic devices and summarizes the compatibility of retrofit kits with various controllers. This is not an exhaustive list, but it covers the most commonly used devices.

Maintenance of pneumatics is a cost-effective method for reducing emissions. All companies should consider maintenance as an important part of their implementation plan. Cleaning and tuning, in addition to repairing leaking gaskets, tubing fittings, and seals, can save 5 to 10 scfh per device. Tuning to operate over a broader range of proportional band often reduces bleed rates by as much as 10 scfh. Eliminating unnecessary valve positioners can save up to 18 scfh per device.

Some high-bleed devices, however, should not be replaced with low-bleed devices. Control of very large valves that require fast and/or precise response to process changes often require high-bleed controllers. These are found most frequently on large compressor discharge, and bypass pressure controllers. EPA recommends contacting vendors for new fast-acting devices with lower bleed rates.

Step 3: Estimate the savings.

Determine the quantity of gas that can be saved with a low -bleed controller, using field measurement of the high-bleed controller and a similar low-bleed device in service. If these actual bleed rates are not available, use bleed specifications provided by manufacturers.

Gas savings can be monetized to annual savings using $7.00 per Mcf and multiplying bleed reduction, typically specified in scfh, by 8,670 hours per year.

Gas Savings = (High-bleed, scfh) — (Low-bleed, scfh)

Annual Gas Savings = Gas Savings (scfh) * 8,760 hrs/yr * 1 Mcf/1000scf * $7.00/Mcf

Step 4: Evaluate the economics.

The cost-effectiveness of replacement, retrofit, or maintenance of high-bleed pneumatic devices can be evaluated using straightforward economic analysis. A cost -benefit analysis for replacement or retrofit is appropriate unless high-bleed characteristics are required for operational reasons.

Exhibit 3 illustrates a cost-benefit analysis for replacement of a high-bleed liquid level controller. Cash flow over a five-year period is analyzed by showing the magnitude and timing of costs (shown in parenthesis) and benefits. In this example, a $513 initial investment buys a level controller that saves 19 scfh of gas. At $7.00 per Mcf, the low-bleed device saves $1,165 per year. Annual maintenance costs for the new and old controllers are shown. The maintenance cost for the older high-bleed controller is shown as a benefit because it is an avoided cost. Net present value (NPV) is equal to the benefits minus the costs accrued over five years and discounted by 10 percent each year. Internal rate of return (IRR) is the discount rate at which the NPV generated by the investment equals zero.

Exhibit 3: Cost-Effectiveness Calculation for Replacement

Type of Costs	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Implementation Costs, $ (Capital Costs)[a]	(513)					
Annual Savings, $ (New vs. Old)[b]		1,165	1,165	1,165	1,165	1,165
Maintenance Costs, $ (New Controller)[c]		(34)	(34)	(34)	(34)	(34)
Avoided Maintenance, $ (Replaced Controller)[c]		70	70	70	70	70
Net Benefit	(513)	1,202	1,202	1,202	1,202	1,202

NPV[d] = $4,042
IRR = 234%

Notes:
[a] Quoted cost of a Fisher 2680 device. Adjusted to 2006 equipment costs. See Appendix B.
[b] Annual savings per device calculated as the change in bleed rate of 19 scfh x 8,760 hrs/hr = 167 Mcf/yr at $7/Mcf.
[c] Maintenance costs are estimated.
[d] Net Present Value (NPV) based on 10% discount rate for 5 years.

Exhibit 4 illustrates the range of savings offered by proven methods for reducing gas bleed emissions. For simplicity, it is assumed that the cost of maintenance of the pneumatic device will be the same before and after the replacement, retrofit, or enhanced maintenance activity.

As seen in Exhibit 4, sometimes more than one option to reduce gas bleed may be appropriate and cost-effective for a given application. For the listed options, please note that the payback period with respect to implementation cost can range from less than one month to two years.

Exhibit 4: Economic Benefits of Reducing Pneumatic Device Emissions

Action	Cost[a] ($)	Bleed Rate Reductions[b] (Mcf/yr/device)	Annual Savings[c] ($/year)	Payback Period (months)	IRR[d] (%)
Replacement					
Level Controllers					
High-bleed to low-bleed	513	166	1,165	6	226
Pressure Controllers					
High-bleed to low-bleed	1,809	228	1,596	14	84
Airset metal to soft-seal	104	219	1,533	<1	>1,400
Retrofit					
Level Controllers					
Mizer	675	219	1,533	6	226
Large orifice to small	41	184	1,288	<1	>3,100
Large nozzle to small	189	131	917	3	>450
Pressure Controllers					
Large orifice to small	41	184	1,288	<1	>3,100
Maintenance					
All types					
Reduce supply pressure	207	175	1,225	3	>500
Repair leaks, retune	31	44	308	2	>900
Level Controllers					
Change gain setting	0	88	616	Immediate	—
Positioners					
Remove unnecessary	0	158	1,106	Immediate	—

[a] Implementation costs represent average costs for Fisher brand pneumatic instruments installed.
[b] Bleed rate reduction = change in bleed rate scf/hr x 8,760 hr/yr.
[c] Savings based on $7.00/Mcf cost of gas.
[d] Internal rate of return (IRR) calculated over 5 years.

The case studies in Exhibit 5 on the next page present analyses performed and savings achieved by two Natural Gas STAR Partners who installed retrofit kits at gas production facilities.

Step 5: Develop an implementation plan.

After identifying the pneumatic devices that can be profitably replaced, retrofitted or maintained, devise a systematic plan for implementing the required changes. This can include modifying the current inspection and maintenance schedule and prioritizing replacement or retrofits. It may be most cost-effective to replace all those devices that meet the technical and economic criteria of your analysis at one time to minimize labor costs and disruption of operation.

Where a pneumatic device is at the end of its useful life and is scheduled for replacement, it should be replaced with a low-bleed model instead of a new high-bleed device whenever possible.

When assessing options for replacement of high-bleed pneumatic devices, natural gas price may influence the decision making process. Exhibit 6 shows an economic analysis of early replacement of a high bleed pneumatic device with a lower bleed device at different natural gas prices.

Exhibit 5: Case Studies on Retrofit To Reduce Gas Leaks at Natural Gas STAR Partner Sites

Study	Implementation Costs ($)	Emissions Reductions (Mcf/yr)	Annual Savings ($/year)	Payback (months)	IRR (%)
Company 1:					
Platform 1	8,988	2,286	16,002	7	177
Platform 2	13,892	3,592	25,144	7	180
Retrofit Liquid-level controllers	5,452	1,717	12,019	6	220
Company 2:					
Per device	702	219	1,533	6	218

Exhibit 6: Gas Price Impact on Economic Analysis

	$3/Mcf	$5/Mcf	$7/Mcf	$8/Mcf	$10/Mcf
Value of Gas Saved	$780	$1,300	$1,820	$2,080	$2,600
Payback Period (months)	29	18	13	11	9
Internal Rate of Return (IRR)	31%	64%	95%	110%	139%
Net Present Value (i=10%)	$1,107	$3,078	$5,049	$6,035	$8,006

Other Technologies

Instrument air, nitrogen gas, electric valve controllers, and mechanical control systems are some of the alternatives to gas powered pneumatics implemented by Partners.

★ **Instrument Air.** These systems substitute compressed, dried air in place of natural gas in pneumatic devices, and thus eliminate methane emissions entirely. Instrument air systems are typically installed at facilities where there is a high concentration of pneumatic control valves and fulltime operator presence (for example, most gas processing plants use instrument air for pneumatic devices). The major costs associated with instrument air systems are capital and energy. Instrument air systems are powered by electric compressors, and require the installation of dehydrators and volume tanks to filter, dry and store the air for instrumentation use. Generally, Partners have found that cost-effective implementation of instrument air systems is limited to field sites with available utility or self-generated electrical power. The Lessons Learned study, "Covert Gas Pneumatic Controls to Instrument Air," provides a detailed description of the technical and economic decision process required to evaluate conversion from gas pneumatic devices to instrument air.

★ **Nitrogen Gas.** Unlike instrument air systems that require capital expenditures and electric power, these systems only require the installation of a cryogenic liquid nitrogen cylinder, that is replaced periodically, and a liquid nitrogen vaporizer. The system uses a pressure regulator to control the expansion of the nitrogen gas (i.e., the gas pressure) as it enters the control system. The primary disadvantage of these systems stems from the cost of liquid nitrogen and the potential safety hazard associated with using cryogenic liquids.

★ **Electric Valve Controllers.** Due to advances in technology, the use of electronic control instrumentation is increasing. These systems use small electrical motors to operate valves and therefore do not bleed natural gas into the atmosphere. While they are reliant on a constant

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.

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 %

supply of electricity, and have high associated operating costs, they have the advantage of not requiring the utilization of natural gas or a compressor to operate.

★ **Mechanical Control Systems.** These devices have been widely used in the natural gas and petroleum industry. They operate using a combination of springs, levers, flow channels and hand wheels. While they are simple in design and require no natural gas or power supply to operate, their application is limited due to the need for the control valve to be in close proximity to the process measurement. Also, these systems are unable to handle large flow fluctuations and lack the sensitivity of pneumatic systems.

Each of these options has specific advantages and disadvantages. Where Natural Gas STAR Partners do install these systems as replacements to gas powered pneumatic devices, they should report the resulting emissions reductions and recognize the savings.

One Partner's Experience

Union Pacific Resources replaced 70 high-bleed pneumatic devices with low-bleed pneumatic devices and retrofitted 330 high-bleed pneumatic devices. As a result, this Partner has estimated a total reduction of methane emissions of 49,600 Mcf per year. Assuming a gas price of $7 per Mcf, the savings corresponds to $347,200. The costs of replacing and retrofitting all the devices, including materials and labor, is $166,300 at 2006 costs, resulting in a payback period of less than one year.

One Partner's Experience

Marathon Oil Company surveyed 158 pneumatic control devices at 50 production sites using the Hi-Flow Sampler to measure emissions. Half of these controllers were identified as non-bleed devices (e.g., weighted dump valves, spring operated regulators, enclosed capillary temperature controllers, non-bleed pressure switches). High-bleed devices accounted for 35 of 67 level controllers, 5 of 76 pressure controllers, and 1 of 15 temperature controllers. Measured gas emissions were 583 scfh total; 86 percent of emissions came from level controllers, with leaks up to 48 scfh, and averaging 7.6 scfh. Marathon concluded that "control devices with higher emissions can be identified qualitatively by sound prior to leak measurement, making it unnecessary to quantitatively measure methane emissions using technologically advanced equipment."

Lessons Learned

Natural Gas STAR Partners offer the following Lessons Learned:

★ Hear it; feel it; replace it. Where emissions can be heard or felt, this is a sign that emissions are significant enough to warrant corrective action.

★ Control valve cycle frequency is another indicator of excessive emissions. When devices cycle more than once per minute, they can be replaced or retrofitted profitably.

★ Manufacturer bleed rate specifications are not necessarily what users will experience. Actual bleed rates will generally exceed manufacturer's specifications because of operating conditions different from manufacturer's assumptions, installation settings and maintenance.

★ Combine equipment retrofits or replacements with improved maintenance activities. Do not overlook simple solutions such as replacing tubes and fittings or rearranging controllers.

★ The smaller orifices in low-bleed devices and retrofit kits can be subject to clogging from debris in corroded pipes. Therefore, pneumatic supply gas piping and tubing should be flushed out before retrofitting with smaller orifice devices, and gas filters should be well maintained.

★ When replacing pneumatic control systems powered by pressurized natural gas with instrument air or other systems, do not forget to account for the savings from the resulting methane emission reductions.

★ Include methane emission reductions from pneumatics in annual reports submitted as part of the Natural Gas STAR Program.

References

Adams, Jim, Norriseal, personal contact.

Burlage, Brian, Fisher Controls International, Inc., personal contact.

Colwell, Chris, Masoneilan, personal contact.

Fisher Controls International, Inc. *Pneumatic Instrument Gas Bleed Reduction Strategy and Practical Application.*

Garvey, J. Michael, DFC Becker Operations, personal contact.

Hankel, Bill, Ametek - PMT Division, personal contact.

Henderson, Carolyn, U.S. EPA Natural Gas STAR Program, personal contact.

Husson, Frank, ITT Barton, personal contact.

Loupe, Bob, Control Systems Specialist Inc., personal contact.

Murphy, John, Bristol Babcock, personal contact.

Radian Corporation. *Pneumatic Device Characterization.* Draft Final Report, Gas Research Institute and U.S. Environmental Protection Agency, January 1996.

Tingley, Kevin, U.S. EPA Natural Gas STAR Program, personal contact.

Wilmore, Martin R., Shafer Valve Company, personal contact.

Ulanski, Wayne. *Valve and Actuator Technology.* McGraw-Hill, 1991.

Appendix A

The following chart contains manufacturer-reported bleed rates. Actual bleed rates have been included whenever possible. Discrepancies occur due to a variety of reasons, including:

- ★ Maintenance.
- ★ Operating conditions.
- ★ Manufacturer vs. operating assumptions.

It is important to note that manufacturer information has not been verified by any third party and there may be large differences between manufacturer-reported bleed rates and those found during operations. Until a full set of information is available, companies should be careful to compare bleed rates in standard units (CFH) when comparing manufacturers and models. During this study we found that manufacturers reported information in a wide range of different units and operating assumptions.

Gas Bleed Rate for Various Pneumatic Devices

Controller Model	Type	Consumption Rate (CFH)	
		Manufacturer Data	Field Data (where available)
High-Bleed Pneumatic Devices			
**Fisher 4100 Series	Pressure controller (large orifice)	35	
**Fisher 2500 Series	Liquid-level controllers (P.B. in mid range)	10-34	44-72
*Invalco AE-155	Liquid-level controller		44-63
*Moore Products—Model 750P	Positioner	42	
*Invalco CT Series	Liquid-level controllers	40	34-87
**Fisher 4150/4160K	Pressure controller (P.B. 0 or 10)	2.5-29	
**Fisher 546	Transducer	21	
**Fisher 3620J	Electro-pneumatic positioner	18.2	
Foxboro 43AP	Pressure controller	18	
**Fisher 3582i	Electro-pneumatic positioner	17.2	
**Fisher 4100 Series	Pressure controller (small orifice)	15	
**Fisher DVC 6000	Electro-pneumatic positioner	14	
**Fisher 846	Transducer	12	
**Fisher 4160	Pressure controller (P.B. 0.5)	10-34	
**Fisher 2506	Receiver controller (P.B. 0.5)	10	
**Fisher DVC 5000	Electro-pneumatic positioner	10	
**Masoneilan 4700E	Positioners	9	
**Fisher 3661	Electro-pneumatic positioner	8.8	
**Fisher 646	Transducer	7.8	
**Fisher 3660	Pneumatic positioner	6	
**ITT Barton 335P	Pressure controller	6	
*Ametek Series 40	Pressure controllers	6	
Low- or No-Bleed Pneumatic Devices			
**Masoneilan SV	Positioners	4	
**Fisher 4195 Series	Pressure controllers	3.5	
**ITT Barton 273A	Pressure transmitter	3	
**ITT Barton 274A	Pressure transmitter	3	
**ITT Barton 284B	Pressure transmitter	3	
**ITT Barton 285B	Pressure transmitter	3	
**Bristol Babcock Series 5457-70F	Transmitter	3	
**Bristol Babcock Series 5453-Model 624 -II	Liquid-level controllers	3	
**Bristol Babcock Series 5453-Model 10F	Pressure controllers	3	
**Bristol Babcock Series 5455 Model 624 -III	Pressure controllers	3	
**ITT Barton 358	Pressure controller	1.8	

Options For Reducing Methane Emissions From Pneumatic Devices In The Natural Gas Industry
(Cont'd)

**ITT Barton 359	Pressure controller	1.8	
**Fisher 3610J	Pneumatic positioner	16	
**Bristol Babcock Series 502 A/D	Recording pneumatic controllers	<6	
**Fisher 4660	High-low pressure pilot	<5	
**Bristol Babcock Series 9110-00A	Transducers	0.42	
Fisher 2100 Series	Liquid-level controllers	1	
**Fisher 2680	Liquid-level controllers	<1	
*Norriseal 1001 (A) (snap)	Liquid-level controller	0.2	0.2
*Norriseal 1001 (A) ('Envirosave')	Liquid-level controller	0	0
*Norriseal 1001 (A) (throttle)	Liquid-level controller	0.007	0.007
**Becker VRP-B -CH	Double-acting pilot pressure control system (replaces controllers and positioners)	0-10	
**Becker HPP-5	Pneumatic positioner (Double-acting)	0-10	
**Becker EFP-2.0	Electro-pneumatic positioner	0	
**Becker VRP-SB	Single-acting pilot pressure control system (replaces controllers and positioners)	0	
**Becker VRP-SB GAP Controller	Replaces pneumatic "gap" type controllers	0	
**Becker VRP-SB-PID Controller	Single-acting pilot pressure control system specifically designed for power plant type feeds (replaces controllers and positioners)	0	
**Becker VRP-SB-CH	Single-acting pilot pressure control system (replaces controllers and positioners)	0	
**Becker HPP-SB	Pneumatic positioner (Single-acting)	0	

Actuator Model	Size	Manufacturer Data	Field Data
*Shafer RV-Series Rotary Vane Valve Actuators	33" x 32"	1,084	
	36" x 26"	768	
	26" x 22"	469	
	25" x 16"	323	
	20" x 16"	201	
	16.5" x 16"	128	
	14.5" x 14"	86	
	12.5" x 12"	49	
	12" x 9"	22	
	11" x 10"	32	
	9" x 7"	12	
	8" x 6.5"	8	
	6.5" x 3.5"	6	
	5" x 3"	6	
Actuator Model	**Size**	**Number of Snap-acting Strokes per CF**	**Number of Throttling Strokes per CF**
**Fisher Valve Actuators	20	21	39
**Fisher Valve Actuators	30	12	22
**Fisher Valve Actuators	34/40	6	10
**Fisher Valve Actuators	45/50	3	5
**Fisher Valve Actuators	46/50	2	3

* Last updated in 1996.
** Last updated in 2001.

Appendix B

Controllers Compatible with MIZER Retrofits	
Type	**Brand/Model Number**
Liquid-level controllers	C.E. Invalco — 215, 402, AE-155
	Norriseal — 1001, 1001A
Pressure controllers	Norriseal — 4300
Suggested Retail Prices for Various Brand Low-Bleed Pneumatic Devices (Estimates Based on Best Information Available at Time of Publication)	
Brand/Model	**Price per Device**
**ITT Barton 335P (pressure controller)	$920
**ITT Barton 273A (pressure transmitter)	$1,010
**ITT Barton 274A (pressure transmitter)	$1,385
**ITT Barton 284B (pressure transmitter)	$1,605
**ITT Barton 285B (pressure transmitter)	$1,990
**ITT Barton 340E (recording pressure controller)	$1,400
**ITT Barton 338E (recorder controller)	$2,800
**Ametek Series 40 (pressure controllers)	$1,100 (average cost)
**Becker VRP-B-CH	$1,575.00
**Becker HPP-5	$1,675.00
**Becker VRP-SB	$1,575.00-$2,000.00
**Becker VRP-SB-CH-PID	$2,075.00
**Becker VRP-SB-CH	$1,575.00
**Becker HPP-SB	$1,675.00
**Mizer Retrofit Kits	$400-$600
**Fisher 67AFR (airset regulators)	$80
**Fisher 2680 (liquid-level controllers)	$380
**Fisher 4195 (pressure controllers)	$1,340
**Bristol Babcock Series 9110-00A (transducers)	$1,535-$1,550
**Bristol Babcock Series 5453 (controllers)	$1,540
**Bristol Babcock 5453 40 G (temperature controllers)	$3,500
**Bristol Babcock Series 5457-624 II (controllers)	$3,140
**Bristol Babcock Series 502 A/D (recording controllers)	$3,000
**Bristol Babcock Series 5455-624 III (pressure controllers)	$1,135
**Bristol Babcock Series 5453-624 II (liquid level controllers)	$2,345
**Bristol Babcock Series 5453-10F (pressure controllers)	$1,440

* Last updated in 1996.
** Last updated in 2001.

United States
Environmental Protection Agency
Air and Radiation (6202J)
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EPA provides the suggested methane emissions estimating methods contained in this document as a tool to develop basic methane emissions estimates only. As regulatory reporting demands a higher-level of accuracy, the methane emission estimating methods and terminology contained in this document may not conform to the Greenhouse Gas Reporting Rule, 40 CFR Part 98, Subpart W methods or those in other EPA regulations.

TABLE 2-4. OIL AND GAS PRODUCTION OPERATIONS AVERAGE EMISSION FACTORS (kg/hr/source)

Equipment Type	Service[a]	Emission Factor (kg/hr/source)[b]
Valves	Gas	4.5E-03
	Heavy Oil	8.4E-06
	Light Oil	2.5E-03
	Water/Oil	9.8E-05
Pump seals	Gas	2.4E-03
	Heavy Oil	NA
	Light Oil	1.3E-02
	Water/Oil	2.4E-05
Others[c]	Gas	8.8E-03
	Heavy Oil	3.2E-05
	Light Oil	7.5E-03
	Water/Oil	1.4E-02
Connectors	Gas	2.0E-04
	Heavy Oil	7.5E-06
	Light Oil	2.1E-04
	Water/Oil	1.1E-04
Flanges	Gas	3.9E-04
	Heavy Oil	3.9E-07
	Light Oil	1.1E-04
	Water/Oil	2.9E-06
Open-ended lines	Gas	2.0E-03
	Heavy Oil	1.4E-04
	Light Oil	1.4E-03
	Water/Oil	2.5E-04

[a]Water/Oil emission factors apply to water streams in oil service with a water content greater than 50%, from the point of origin to the point where the water content reaches 99%. For water streams with a water content greater than 99%, the emission rate is considered negligible.

[b]These factors are for total organic compound emission rates (including non-VOC's such as methane and ethane) and apply to light crude, heavy crude, gas plant, gas production, and off shore facilities. "NA" indicates that not enough data were available to develop the indicated emission factor.

[c]The "other" equipment type was derived from compressors, diaphrams, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, relief valves, and vents. This "other" equipment type should be applied for any equipment type other than connectors, flanges, open-ended lines, pumps, or valves.

TABLE 2-8. OIL AND GAS PRODUCTION OPERATIONS SCREENING RANGES EMISSION FACTORS

Equipment type	Service[b]	≥10,000 ppmv Emission factor (kg/hr/source)[a]	<10,000 ppmv Emission factor (kg/hr/source)[a]
Valves	Gas	9.8E-02	2.5E-05
	Heavy Oil	NA	8.4E-06
	Light Oil	8.7E-02	1.9E-05
	Water/Oil	6.4E-02	9.7E-06
Pump seals	Gas	7.4E-02	3.5E-04
	Heavy Oil	NA	NA
	Light Oil	1.0E-01	5.1E-04
	Water/Oil	NA	2.4E-05
Others[c]	Gas	8.9E-02	1.2E-04
	Heavy Oil	NA	3.2E-05
	Light Oil	8.3E-02	1.1E-04
	Water/Oil	6.9E-02	5.9E-05
Connectors	Gas	2.6E-02	1.0E-05
	Heavy Oil	NA	7.5E-06
	Light Oil	2.6E-02	9.7E-06
	Water/Oil	2.8E-02	1.0E-05
Flanges	Gas	8.2E-02	5.7E-06
	Heavy Oil	NA	3.9E-07
	Light Oil	7.3E-02	2.4E-06
	Water/Oil	NA	2.9E-06
Open-ended lines	Gas	5.5E-02	1.5E-05
	Heavy Oil	3.0E-02	7.2E-06
	Light Oil	4.4E-02	1.4E-05
	Water/Oil	3.0E-02	3.5E-06

[a]These factors are for total organic compound emission rates (including non-VOC's such as methane and ethane) and apply to light crude, heavy crude, gas plant, gas production, and offshore facilities. "NA" indicates that not enough data were available to develop the indicated emission factor.

[b]Water/Oil emission factors apply to water streams in oil service with a water content greater than 50%, from the point of origin to the point where the water content reaches 99%. For water streams with a water content greater than 99%, the emission rate is considered negligible.

[c]The "other" equipment type was derived from compressors, diaphrams, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, relief valves, and vents. This "other" equipment type should be applied for any equipment type other than connectors, flanges, open-ended lines, pumps, or valves.