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GRI-94 / 0257.29
EPA - 600/R-96-080l
June 1996

Research and Development

METHANE EMISSIONS FROM THE NATURAL GAS INDUSTRY

Volume 12: Pneumatic Devices

Prepared for

Energy Information Administration (U.S. DOE)

Prepared by

National Risk Management
Research Laboratory
Research Triangle Park, NC 27711

FOREWORD

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GRI-94/0257.29

EPA-600/R-96-080l
June 1996

METHANE EMISSIONS FROM THE NATURAL GAS INDUSTRY, VOLUME 12: PNEUMATIC DEVICES

FINAL REPORT

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RESEARCH SUMMARY

Title	Methane Emissions from the Natural Gas Industry, Volume 12: Pneumatic Devices Final Report
Contractor	Radian International LLC GRI Contract Number 5091-251-2171 EPA Contract Number 68-D1-0031
Principal Investigators	Theresa M. Shires Matthew R. Harrison
Report Period	March 1991 - June 1996 Final Report
Objective	This report describes a study to quantify the annual methane emissions from pneumatic devices, which are a significant source of methane emissions within the gas industry.
Technical Perspective	The increased use of natural gas has been suggested as a strategy for reducing the potential for global warming. During combustion, natural gas generates less carbon dioxide (CO_2) per unit of energy produced than either coal or oil. On the basis of the amount of CO_2 emitted, the potential for global warming could be reduced by substituting natural gas for coal or oil. However, since natural gas is primarily methane, a potent greenhouse gas, losses of natural gas during production, processing, transmission, and distribution could reduce the inherent advantage of its lower CO_2 emissions. To investigate this, Gas Research Institute (GRI) and the U.S. Environmental Protection Agency's Office of Research and Development (EPA/ORD) cofunded a major study to quantify methane emissions from U.S. natural gas operations for the 1992 base year. The results of this study can be used to construct global methane budgets and to determine the relative impact on global warming of natural gas versus coal and oil.
Results	The annual national emission rates for pneumatic devices for each industry segment are as follows: production, 31.4± 65% Bscf; gas processing, 0.60 ± 64% Bscf; and transmission, 14.1 ± 60% Bscf. (Distribution emissions are presented in another report.)

Based on data from the entire program, methane emissions from natural gas operations are estimated to be 314 ± 105 Bscf for the 1992 base year. This is about 1.4 ± 0.5% of gross natural gas production. This study also showed that the percentage of methane emitted for an incremental increase in natural gas sales would be significantly lower than the baseline case.

The program reached its accuracy goal and provides an accurate estimate of methane emissions that can be used to construct U.S. methane inventories and analyze fuel switching strategies.

Technical Approach

Emission rates for pneumatic devices were determined by developing average annual emission factors for devices used in each industry segment and extrapolating these data based on activity factors to develop a national estimate, where the national emission rate is the product of the emission factor and activity factor.

The natural gas industry has two primary types of pneumatic devices that discharge methane: 1) control valves that regulate flow, and 2) gas-actuated block valves. Because each segment of the industry follows its own specific practices regarding "typical" pneumatic device installations, emission factors were developed based on the types of devices observed from site visits.

Emission factor data for the various device types were collected from several sources: measured emissions provided from other studies, manufacturers' data, and data collected from site visits. Data collected during site visits included: the number of each type of pneumatic device, manufacturer and model numbers, operating conditions (e.g., supply gas pressure and supply gas type), and annual device actuation frequency. Equations relating these parameters were developed for the different types of devices to develop an annual emission factor for a generic pneumatic device in each industry segment.

The development of activity factors for each industry segment are presented in a separate report. In general though, the population of pneumatic devices in each industry segment was determined from counts of devices observed during site visits. The national emissions for each industry segment were then based on the product of the emission factor for a generic pneumatic device and the activity factor.

Project Implications

For the 1992 base year, the annual methane emissions estimate for the U.S. natural gas industry is 314 Bscf ± 105 Bscf (± 33%). This is equivalent to 1.4% ± 0.5% of 1992 gross natural gas production. Results from this program were used to compare greenhouse gas emissions from the fuel cycle for natural gas, oil, and coal using the global warming potentials (GWPs) recently published by the Intergovernmental Panel on Climate Change (IPCC). The analysis showed that natural gas contributes less to potential global warming than coal or oil, which supports the fuel switching strategy suggested by IPCC and others.

In addition, results from this study are being used by the natural gas industry to reduce operating costs while reducing emissions. Some companies are also participating in the Natural Gas-Star program, a voluntary program sponsored by EPA's Office of Air and Radiation in cooperation with the American Gas Association to implement cost-effective emission reductions and to report reductions to the EPA. Since this program was begun after the 1992 baseline year, any reductions in methane emissions from this program are not reflected in this study's total emissions.

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1.0 SUMMARY

This report is one of several volumes that provide background information supporting the Gas Research Institute and U.S. Environmental Protection Agency Office of Research and Development (GRI-EPA/ORD) methane emissions project. The objective of this comprehensive program is to quantify the methane emissions from the gas industry for the 1992 base year to within ±0.5% of natural gas production starting at the wellhead and ending immediately downstream of the customer's meter.

This report describes a study to quantify the annual methane emissions from pneumatic devices, which are a significant source of methane emissions within the gas industry. The gas industry has two primary types of pneumatic devices that discharge natural gas: control valves that regulate flow, and gas-actuated isolation (block) valves. Because each segment of the industry follows its own specific practices regarding "typical" pneumatic device installations, emission factors were developed based on the types of devices observed from site visits. Emission factor data were collected from several sources: measured emissions provided from other studies, manufacturers' data, and data collected from site visits.

The population of pneumatic devices in each industry segment was generally determined from counts of devices observed during site visits. The national emission factor for each industry segment was then based on the product of the emission factor for a generic pneumatic device and activity factor.

The annual emissions for pneumatic devices for each industry segment are as follows: production 31.4 ± 65% Bscf; gas processing, 0.60 ± 64% Bscf; and transmission, 14.1 ± 60% Bscf. (Distribution emissions are included in Volume 10 on metering and pressure regulating stations.[1])

2.0 INTRODUCTION

A pneumatic device is a mechanical device operated by some type of compressed gas. In the oil and gas industry, many devices, especially instruments and valves, are powered by natural gas. Some of these devices discharge the power gas (also called supply gas) to the atmosphere.

This report is concerned with all "pneumatic devices," but focuses on devices that release natural gas to the atmosphere, with the exception of gas-powered pumps and gas-powered compressor starters, which are characterized in other parts of the GRI/EPA study.[2,3,4] Also, it is important to note that some pneumatic devices do not emit gas. For example, gas supply regulators and flow measurement devices such as Barton Chart recorders and strip chart recorders are sealed and do not bleed gas to the atmosphere.

The gas industry has two primary types of pneumatic devices that discharge natural gas: 1) control valves that regulate flow, and 2) gas-actuated block valves. Section 3 describes each type of pneumatic device and the methods of data collection used for each type of device.

Section 4 discusses emission factors developed for each type of pneumatic device. Because each segment of the gas industry follows its own specific practices regarding "typical" pneumatic device installations, this section contains separate discussions for each segment of the gas industry: production, gas processing, and transmission and storage. Emissions from pneumatic devices in the distribution segment are characterized in a separate report on meter and regulation station emissions.[1] Section 5 describes activity factors for each segment of the gas industry, and Section 6 provides annual national emissions calculated for each segment of the gas industry.

3.0 PNEUMATIC DEVICE CHARACTERISTICS

This section describes the characteristics of the various types of pneumatic devices used in the natural gas industry, the data collected, and the methods used to extrapolate the data.

3.1 Overview

Pneumatically operated equipment became the standard in the oil and gas industry since electricity was not readily available at remote production sites. Some pneumatic devices are powered by pressurized air from an instrument air compressor. However, the majority of pneumatic instruments and valves in the gas industry are powered by natural gas.

The pneumatic device can be used to move a valve or make a measurement. Most pneumatic measurement devices in the gas industry are sealed and do not emit natural gas unless they have a defect. However, many of these measurement devices send a signal to a control valve that regulates flow and thus controls process variables such as pressure, temperature, flow rate, and level. The controller for the control valve, if powered by natural gas, will discharge methane to the atmosphere. In gas processing and transmission, isolation valves on large pipelines (also called block valves) can be actuated by natural gas, whereas most of the isolation valves in the production and distribution industry segments are operated manually.

Table 3-1 presents the pneumatic device classifications that will be used for the purpose of this report. The function that a control valve affects, such as level, flow rate, temperature, or pressure, usually dictates the type of control device and therefore the controller bleed rate. Pneumatic controllers linked to valves that control process temperature, flow rate, or level (Figure 3-1) bleed gas. The controller bleed rate may be intermittent – alternating between bleeding gas to the atmosphere and not bleeding gas – or

TABLE 3-1. PNEUMATIC DEVICE CLASSIFICATIONS

Valve Information	Pneumatic Controller Information				Pneumatic Positioner[a] Information
Function/Service	**Type of Control**	**Controller Bleed Frequency**	**Controller Bleed Rate (upon valve actuation)**	**Controller Device Design**	**Bleed Status**
Level, Flow Rate, Temperature, or Pressure Control	Snap-acting	Intermittent Stationary Bleed Rate = 0	High rate, discharges full volume of actuator	On-off (Figure 3-10)	N/A
	Throttling	Continuous Non-zero Stationary Bleed Rate	Small to large volume discharged	Orifice-flapper (Figure 3-6)	Continuous or intermittent
	Throttling	Intermittent Stationary Bleed Rate = 0	Small to large volume discharged	Force-balance piston (Figure 3-3)	Continuous or intermittent
Pressure Control	Throttling	No-bleed (discharges to downstream gas line)	No-bleed (discharges to downstream gas line)	Self-contained spring/diaphragm (Figure 3-2)	N/A
Isolation	N/A	Intermittent Stationary Bleed Rate = 0	High rate, discharges full volume of actuator	Piston, rotary vane, or turbine (Figures 3-4, 3-11, 3-12, and 3-13)	N/A

[a] Positioners are optional devices.

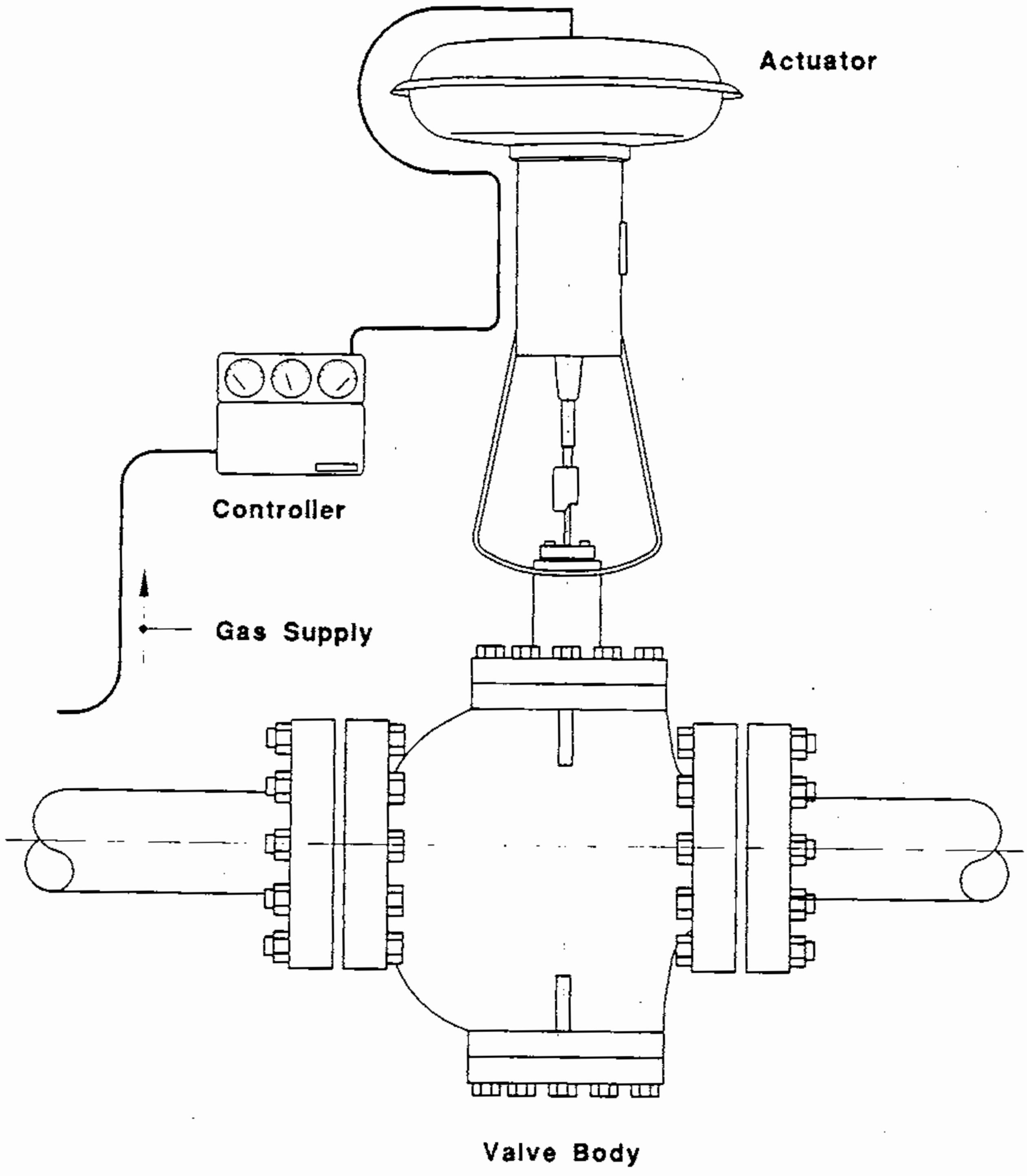


Figure 3-1. Example of a Pneumatic Controller Used for Level, Flow Rate, Temperature, or Pressure Control

the controller may continually bleed gas at various rates (throttling). Pressure controllers may bleed gas to the atmosphere, or may be self-contained (Figure 3-2). Self-contained devices bleed gas from a high-pressure source to a lower pressure source without releasing gas to the atmosphere.

Throttling pneumatic control valves can be equipped with a valve positioner (shown in Figure 3-3), which is a type of mechanical feedback device that senses the actual valve stem position, compares it to the desired position, and adjusts the gas pressure to the valve accordingly. In addition to gas bleeding through the valve controller, the positioner also bleeds gas to the atmosphere.

Isolation valves are used to isolate a segment of pipe or a piece of equipment rather than for process control. An example is shown in Figure 3-4. The valve is either open or closed. Gas is released only when the valve is moved, so the bleed frequency is considered intermittent. This type of operation is fairly infrequent. The bleed rate for these devices varies with the design of the actuator.

Table 3-2 lists the pneumatic devices commonly used in the natural gas industry and whether gas would be emitted in steady-state operation or during the actuation cycle. This table summarizes the bleed modes of the various devices presented in Table 3-1. The pneumatic device bleed modes and classifications are discussed in more detail in the following sections.

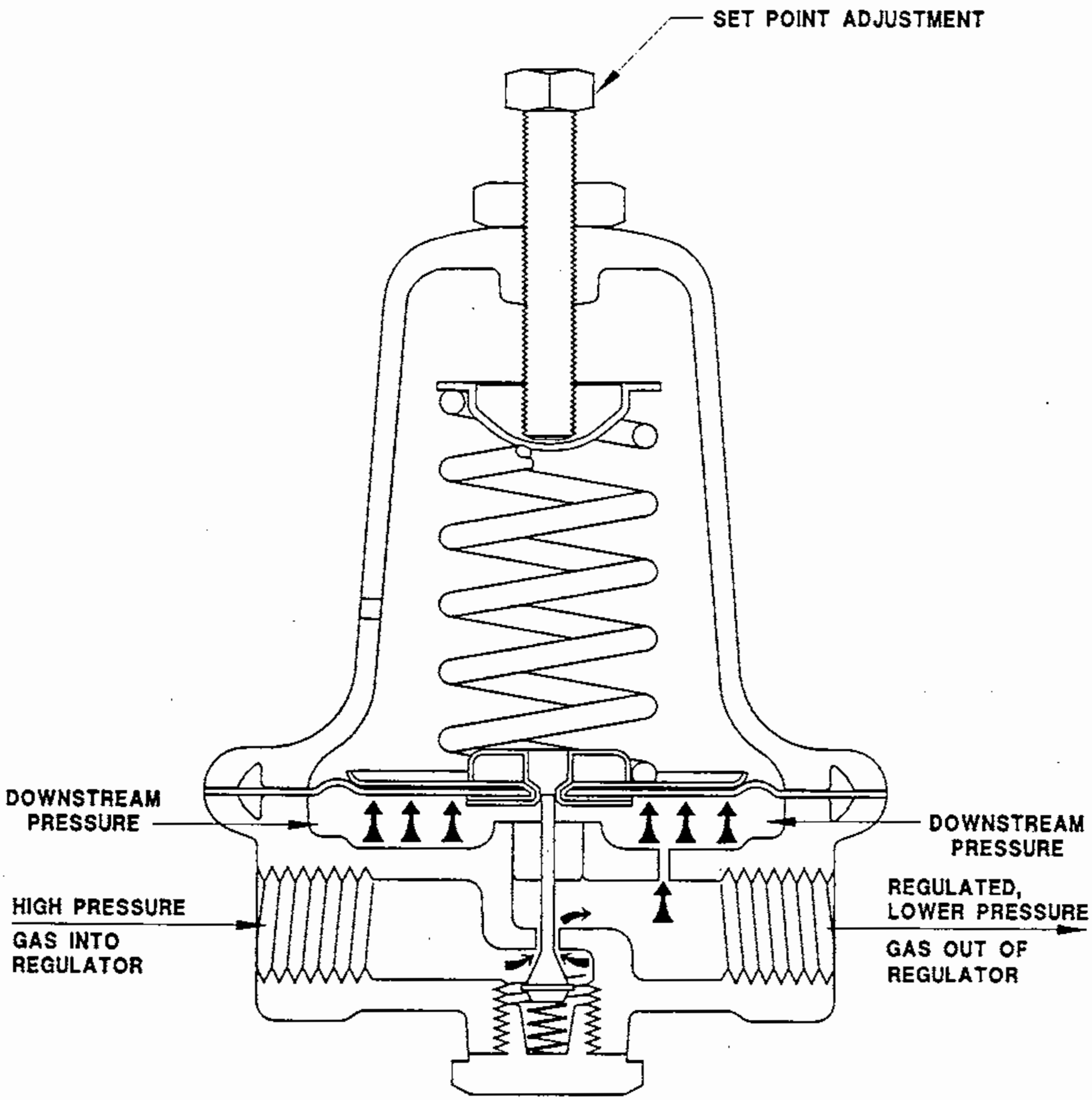


Figure 3-2. Self-Contained, Spring-Loaded Pressure Regulator[5]

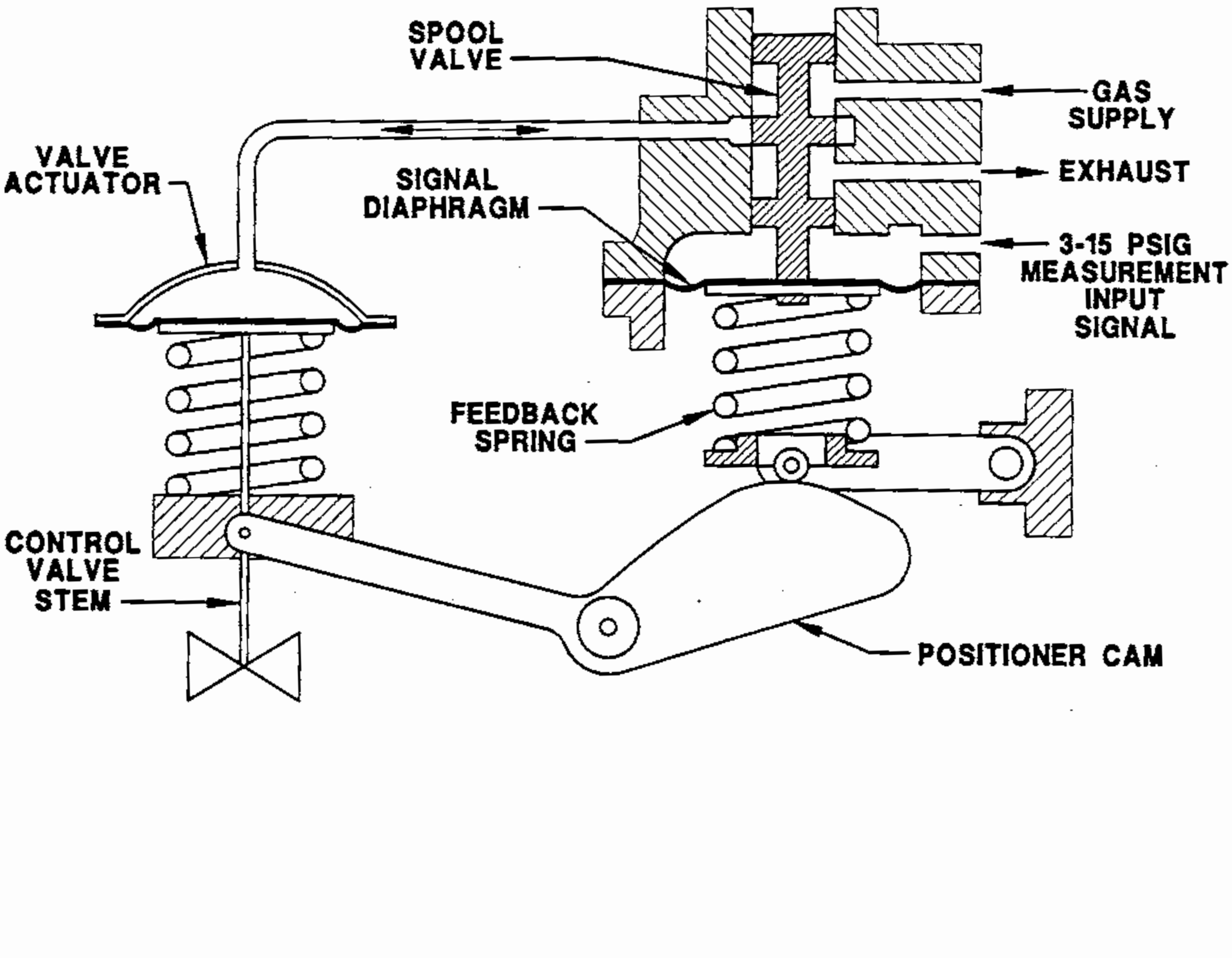


Figure 3-3. Pneumatic Device with Positioner-Force Balance Piston Type[5]

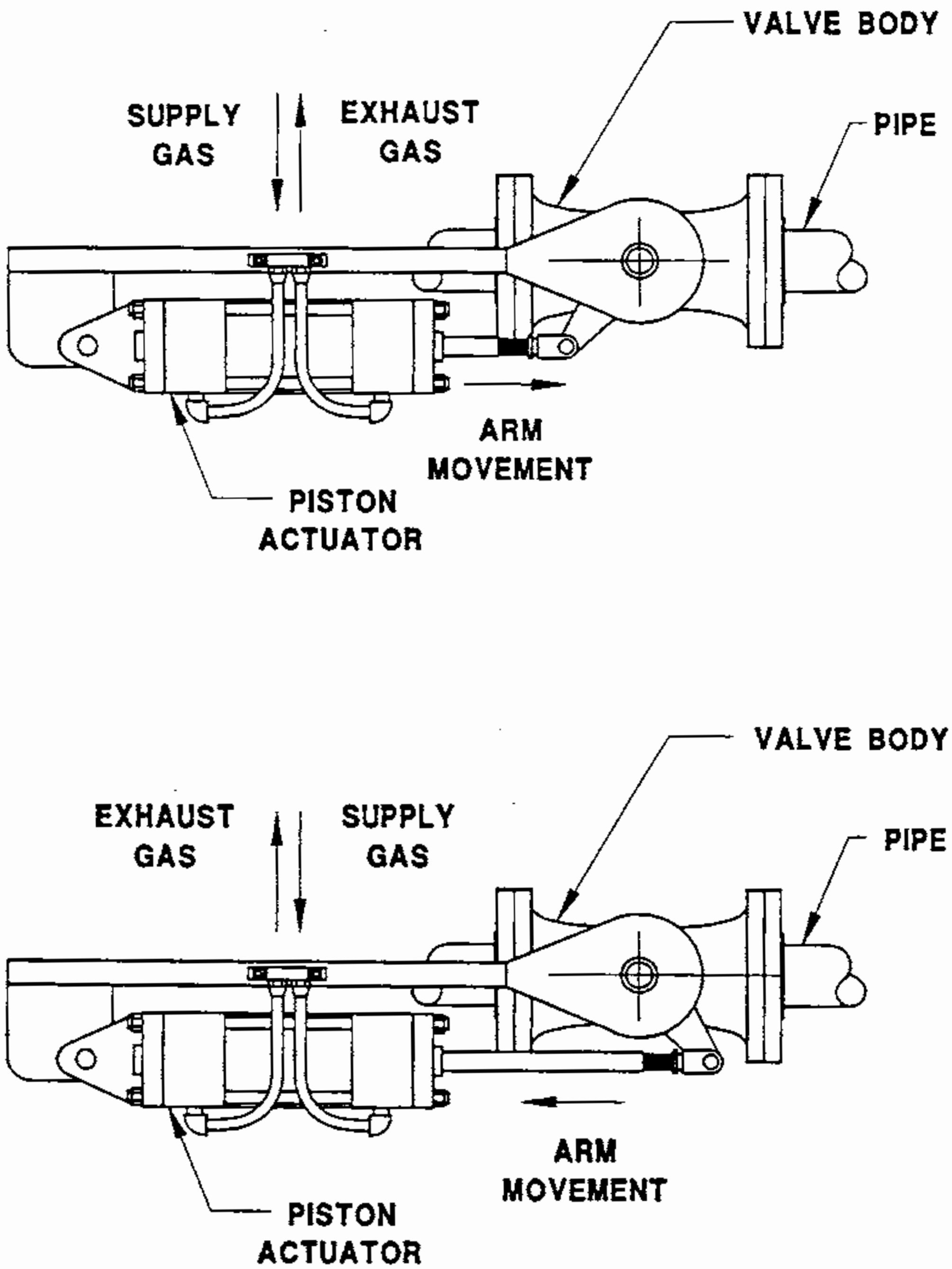


Figure 3-4. Example Isolation Valve - Piston Operator[6]

TABLE 3-2. TYPICAL PNEUMATIC DEVICE BLEED MODES

	Does the Device Bleed During:	
Pneumatic Device Type	**Steady-State Operations?**	**Actuation Cycle (Valve Stroke)?**
Measurement Device		
- Recording	No	No
- Control	No	No
Control Valve (Operator/Actuator)	No	No
Valve Controller		
- Snap-Acting	No	**Yes**
- Throttling		
a. Force Balance	No	**Yes**
b. Orifice/Flapper	**Yes**	**Yes**
Valve Feedback Positioner		
a. Force Balance	No	**Yes**
b. Orifice/Flapper	**Yes**	**Yes**
Self-Contained Pressure Regulators	No	No
Gas-Actuated Isolation Valves	No	**Yes**

3.2 Gas-Actuated Control Valves

3.2.1 Operating Principles

Pneumatic devices (valve controllers) linked to control valves are the largest source of pneumatic emissions in the gas industry. These devices can have two distinct bleed modes: a stationary bleed rate and an actuating bleed rate. The stationary bleed is the rate of gas released when the signal is constant, and the device is not moving. For intermittent bleed pneumatic controllers, the stationary bleed rate is zero. For continuous bleed controllers, the stationary bleed rate is non-zero; it is required to maintain a constant gas supply to the device to provide for a quick response to changes in the controlled process.

When the pneumatic device is moving the control valve, there is an unsteady and different rate of bleed (actuation bleed rate). If the signal is adding pressure to the actuating chamber, the bleed rate drops from the stationary level. If the signal is to release pressure from the actuating chamber, the bleed rate increases above the stationary rate. Actuating bleed rates must be considered over a long period to determine average emissions. Since the rate varies with the frequency of control, the actuating bleed rate is not available from the device manufacturers.

Various parameters such as pressure, temperature, flow rate, and liquid levels are all controlled by opening or closing a control valve in the process line. The necessary elements for controlling a parameter are a parameter measurement device, a valve, a valve controller, and possibly a feedback positioner. For example, Figure 3-5 illustrates a device to control the volume of liquid in a vessel. A level float in the vessel indicates the volume of liquid based on the level measurement. The measurement device sends a weak signal to the controller. The controller receives the weak pneumatic signal and converts it to a stronger pneumatic signal which is sent to the valve actuator to move the valve stem. The flow rate of liquid from the tank is measured and recorded. Each of the elements – measurement, valve, and valve controller – is described in detail below.

Measurement

Weak signals from a measurement device are translated by sealed transmitters into a stronger signal that can physically change valve position, and thus affect flow control. For example, measurement of level using a level float produces a weak mechanical signal that can be used to move the flapper shown in Figure 3-6a. Other measurement media can also serve as the controlling parameter. For example, process flow is typically measured by a drop in pressure across a restriction. The pressure taps on either side of the restriction in the process flow are tied to a diaphragm that deflects when the pressure changes. The deflection of the diaphragm produces a weak mechanical signal that can be used to move the flapper (baffle) shown in Figure 3-6b.

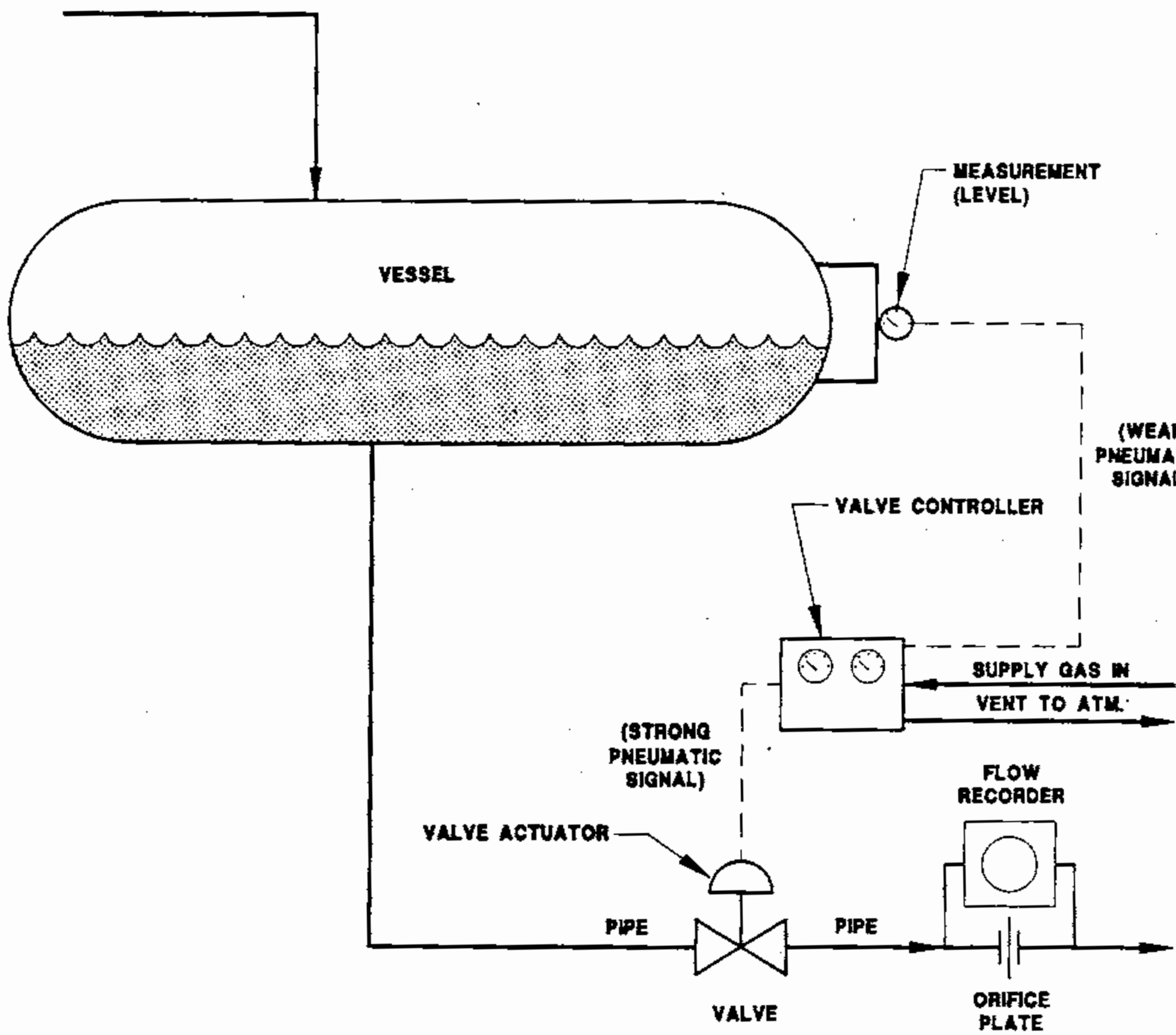


Figure 3-5. Operating Principles

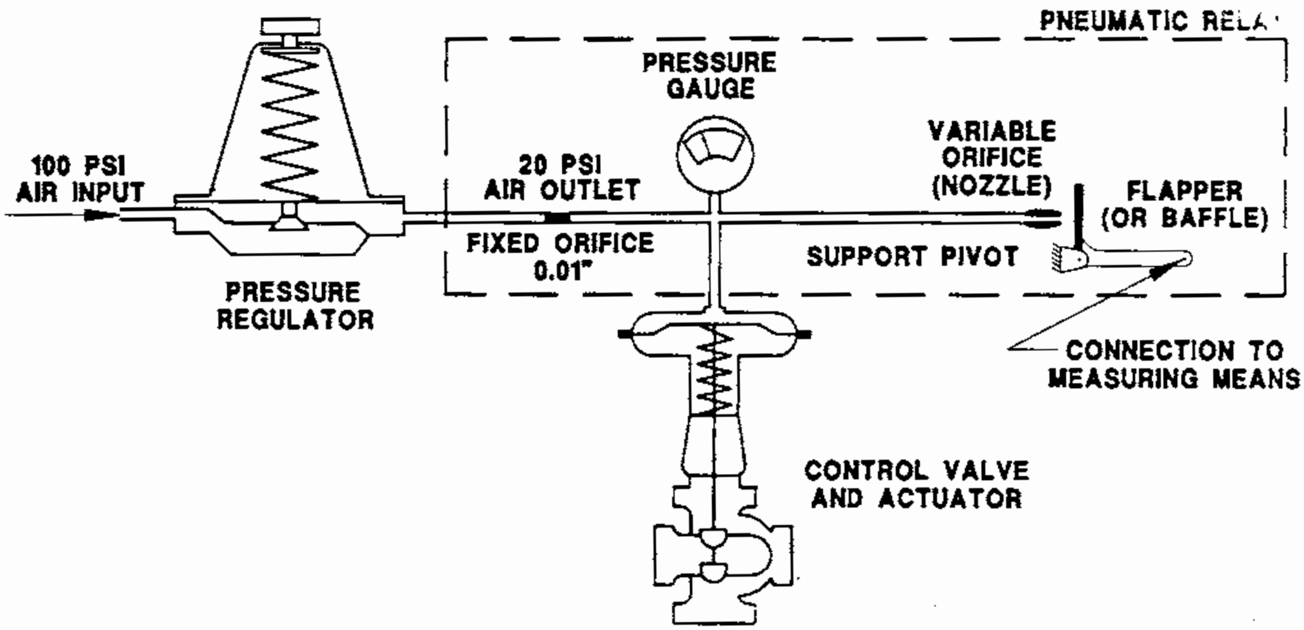


Figure 3-6a. Throttling Continuous Bleed Pneumatic Controller: Orifice Flapper Design[5]

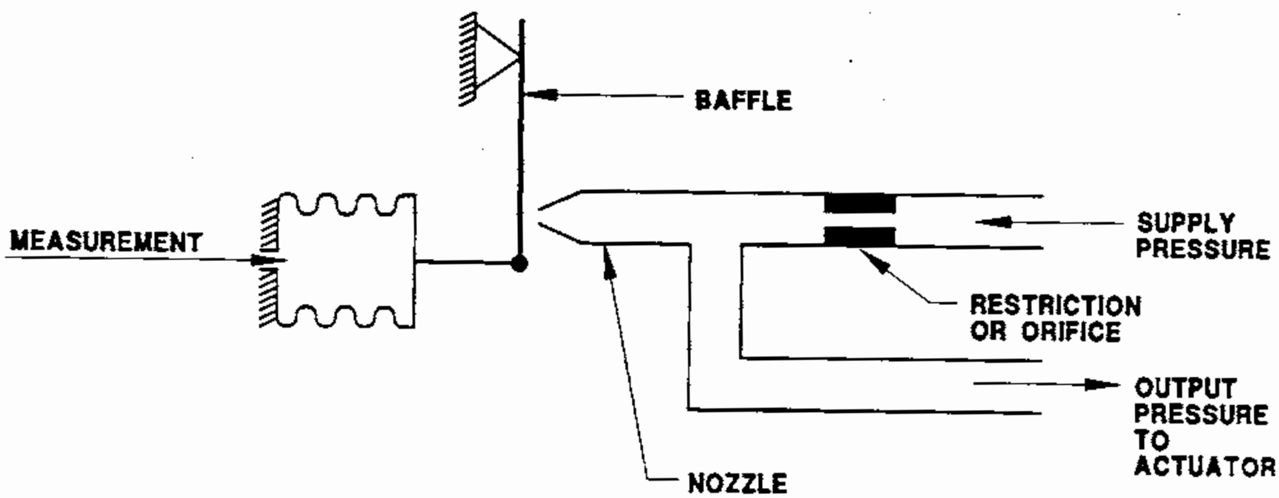


Figure 3-6b. Throttling Continuous Bleed Pneumatic Relay: Orifice Flapper Design[5]

Valve

Flow is regulated by a control valve. The valve operates by moving a valve stem and a valve seat attached to the stem. The movement of the valve seat inside the valve body can then restrict or stop process flow through the valve. The stem can be moved by any force method.

Some valves in the field are moved by small electrical motors; however, a pneumatic device is the most common. In the case of pneumatic actuated valves, the stem is moved by force from the actuator chamber. The actuator chamber is either a diaphragm or a piston device (see Figure 3-7), which deflects or moves because pressure is applied to one side of the chamber. A permanent coiled spring pushes the valve stem in the opposite direction when the pneumatic force is reduced. The valve and valve actuator never bleed directly unless there is a defect. Emissions from such defects are considered fugitive emissions and are considered in the Equipment Leaks[7] report. All actuation gas discharge is emitted back through the valve controller.

Valve Controller

A valve controller is the device that enables a process variable to be changed. The controller device links the valve and the measurement signal to produce a control loop. The controller checks the current measurement of the variable against the desired set point of the variable. If there is a difference, a pneumatic signal is sent to the control valve to open or close the valve. If the measurement matches the set point, equilibrium is maintained and the signal holds a constant level. The controller may bleed at the stationary rate depending on the design.

In the field, the measurement device, valve, and valve controller are often integral. However, the controller is the one element in the measurement/valve/valve-controller loop that discharges gas to the atmosphere. Controllers are highly variable in design. Depending on the design of the controller, the stationary position may or may not

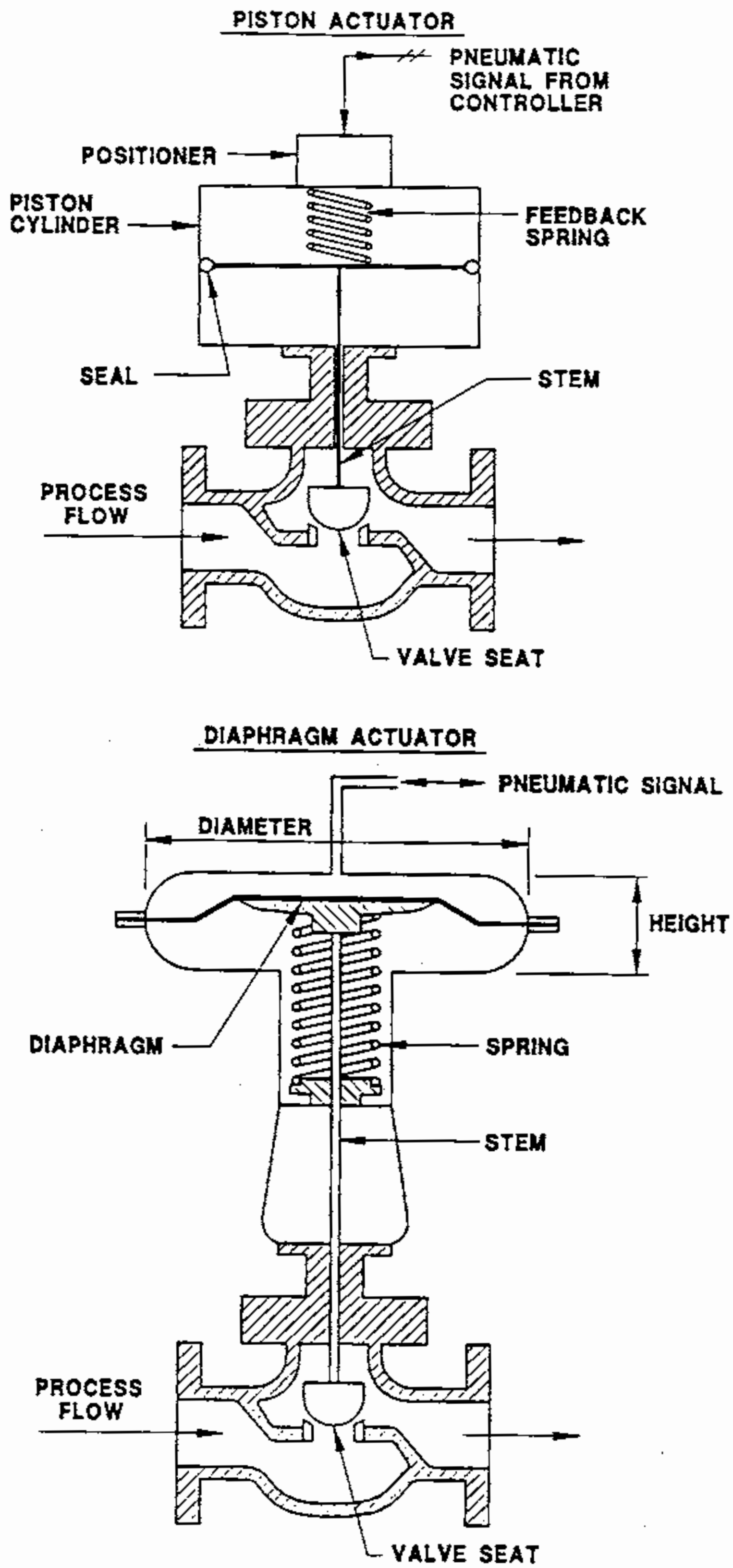


Figure 3-7. Actuator Types[5]

involve a continuous bleed rate. However, the actuation cycle, which is the actual movement or stroke of the valve stem from open to closed and back, always results in the release of gas. This cycle only occurs when the signal changes and control is needed. The frequency of this occurrence will be different for every application.

Pneumatic Relay

The key component of the controller is the pneumatic relay (also called a booster, transmitter, or amplifier). In the simplest case, a controller is only a supply gas regulator and a pneumatic relay. Since the signal from the measurement device is usually weak, it can not produce enough force to open the valve. A controller device amplifies the signal using a higher-pressure supply gas. The supply gas is often taken directly from the produced gas at the field site.

The pneumatic relay is a kind of mechanical amplifier that produces a stronger pneumatic signal. The mechanical amplifier in the controller uses the small force of the measurement deflection to change the supply gas flow path, which alters the resulting downstream supply gas pressure. The change in pressure is a pneumatic signal that is sent to the valve actuator. Controllers may not bleed at all when there is an increasing signal. An increasing signal sends higher-pressure gas into the actuator, deflecting the diaphragm and compressing the spring. When the signal decreases, the controller reduces the pressure on the actuator by releasing gas to the atmosphere.

There are several types of pneumatic relays which, as the main component of the controller, define the type of controller. The most common are throttling and snap-acting. Throttling implies that the valve can be moved to any position proportional to the signal. These devices are most often used for their quick response to system changes or where more precise control is needed.

A simplified drawing of a throttling controller's pneumatic relay shows one method that a pneumatic device may use to change a weak mechanical signal into a stronger pneumatic signal (Figure 3-6b). Basically, the pneumatic device uses a small amount of mechanical force to alter the flow and pressure of a supply gas at higher pressure. This higher pressure stream then becomes the amplified control signal. The higher pressure gas stream is "altered" by being partially diverted through a small orifice that bleeds to the atmosphere. The weak mechanical signal moves a "flapper" that alters the flow of gas out of the orifice. If the flapper is fully extended towards the orifice, the device bleeds at a very low rate, and the pneumatic output is at its highest level. If the orifice is fully open, most of the supply stream bleeds to the atmosphere, and the pneumatic output is at its lowest value. This type of throttling device has a continuous bleed rate, even in the stationary position (no movement of the valve or change of signal) because the orifice opening is not completely closed.

Figure 3-6a shows that a small mechanical force can be used to deflect a flapper arm that covers or uncovers an orifice, changing the gas supply into an amplified measurement signal. Other types of pneumatic relays use a chamber instead of an orifice flapper apparatus. The most common chamber relay is called a "force balance piston device." One example was shown in Figure 3-3, and another is shown in Figure 3-8. This type of device only bleeds when it is out of the neutral position; its continuous bleed rate is zero.

In addition to the primary relay amplifier, many throttling controllers have adjustment devices that allow the operator to alter the set point and response (proportional gain, proportional-integral gain, or proportional-integral-derivative gain), and devices that allow the controller to be reset. These additional devices may also bleed gas, but their rates are steady and are included in the manufacturers' reported total gas consumption rate for the controller. Figure 3-9 shows a device with a proportional set point and reset knob.

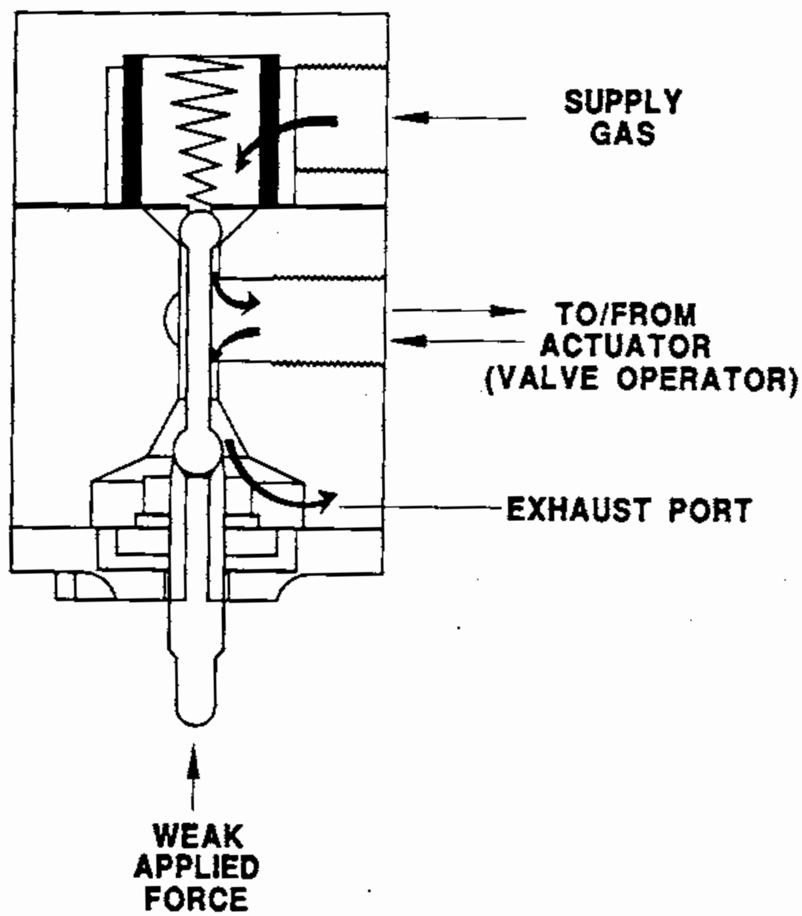


Figure 3-8. Force Balance Piston Device[8]

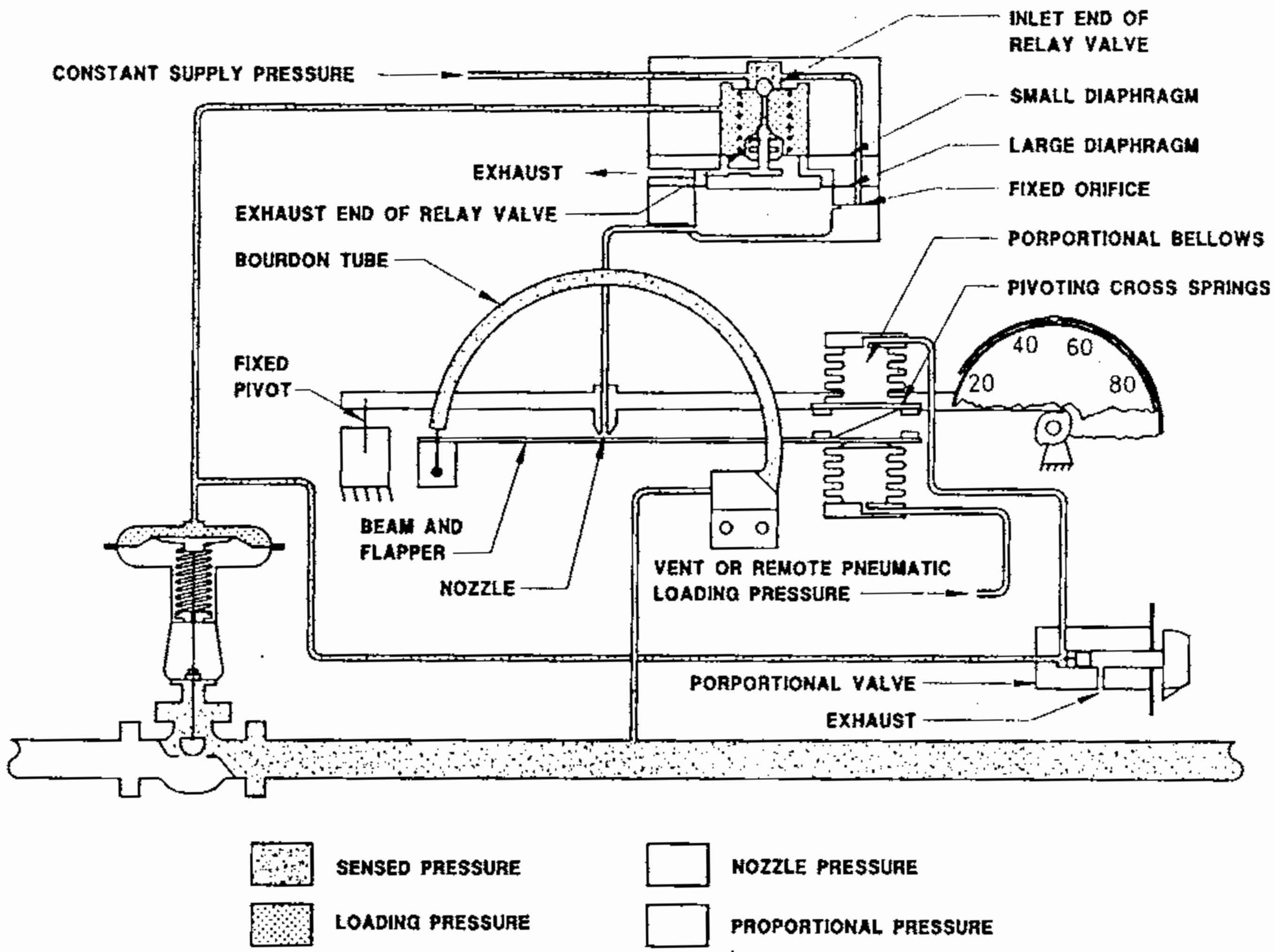


Figure 3-9. Throttling Continuous Bleed Controller with Proportional Adjustment[9]

This knob contains an exhaust port with a continuous bleed line from the actuator diaphragm. These additional bleed locations are typical of proportional controllers.

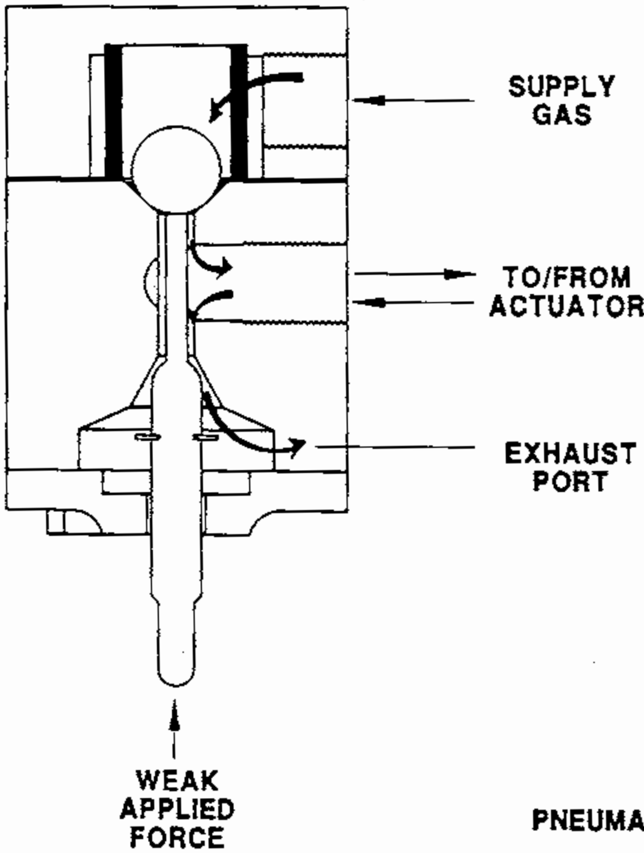
For throttling controllers, manufacturers can design for any desired bleed rate by sizing the orifice flapper or the force balance piston relay. In general, devices with a lower design bleed rate are slower to respond to signal changes, and have longer response times; therefore, some applications that require fast response also require higher bleed rates.

Snap-acting controllers are another type of device common to the gas industry. A snap-acting or "on/off" device is either fully open or fully closed. A snap-acting controller has no continuous bleed, it only bleeds when the actuator is depressured. Figure 3-10 shows two examples of on/off relay devices. As the diagram shows, when the device is on, the full supply-gas pressure is applied to the control valve actuator, and the vent/exhaust line is blocked off. When the device is off, the actuator is vented to the atmosphere and the supply gas is blocked off.

Some controllers have an additional feedback device: a valve positioner that measures, amplifies, and sends a second signal about the position of the valve stem. These positioner devices introduce a second pneumatic relay device to the existing control loop; therefore, a second bleed rate can also be introduced. Positioners are typically used for "slow systems" such as temperature control, where more precise movement of the valve is needed.

Figure 3-3 illustrates a force balance spool relay and the valve positioner that the relay controls. These devices can be easily identified in the field by the positioner arm attached to the valve stem. Only a small percentage of control valves in the gas industry have positioners since this level of fine tuning is not generally required.

ON/OFF SNAP DEVICE



PNEUMATIC SWITCH

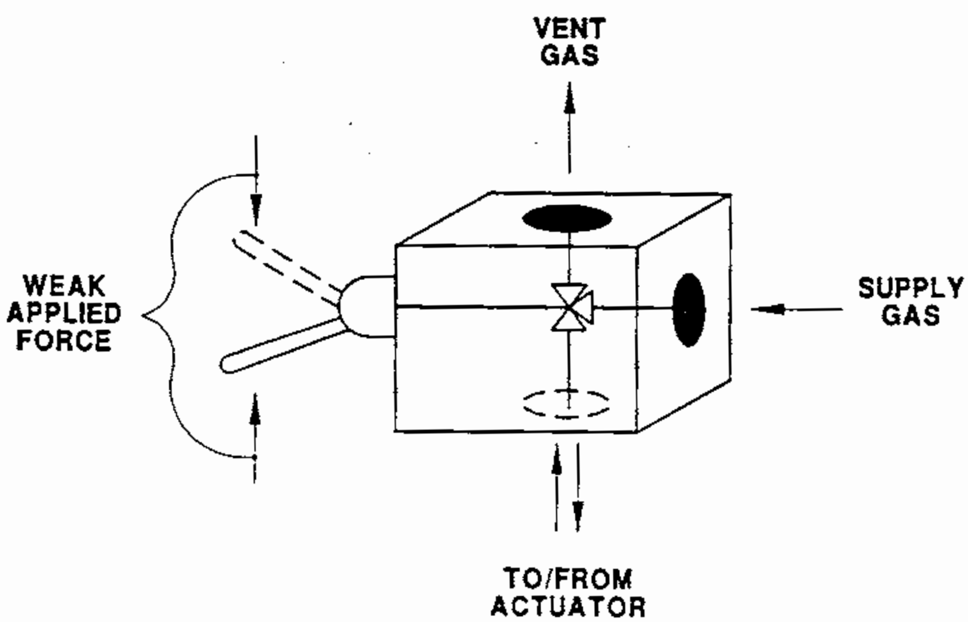


Figure 3-10. On-Off Snap Devices[5]

3.2.2 Data Requirements

As mentioned in the previous section, pneumatic controllers can have two distinct bleed modes, based on the type of relay. There is an actuating bleed rate and a stationary or steady-state bleed rate. The stationary bleed rate occurs when the signal is constant and the valve is not moving; the actuating rate occurs when the valve actuator is depressured. The stationary bleed rate for a device may be zero, depending on its construction. However, every pneumatic controller has a non-zero actuating bleed rate.

The various characteristics that can affect the stationary bleed rate for a production controller are:

1. Basic device type (controller, positioner, self-contained device);
2. Pneumatic relay construction (orifice-flapper versus force balance piston, number of internal control adjustments, such as proportional gain and set point knobs);
3. Device condition (old or worn devices may leak more);
4. Design response time (faster response devices require higher bleed rates); and
5. Supply gas pressure and supply gas type (air produces no methane emissions).

All controller types have an actuation bleed rate. The actuation bleed occurs when the controller moves the valve stem by either releasing pneumatic pressure or applying pneumatic pressure. As the pneumatic pressure is released, the actuator must be vented. The venting occurs through the controller device.

For throttling controllers with continuous bleed rates, the bleed rate will increase above the stationary level so that the actuator can be depressured. For all throttling controllers, actuation bleed rates depend on how far and how often the valve is moved, and must be considered over a long period to determine average emissions.

For snap-acting valves, the actuating bleed depressures the entire actuator to the atmosphere. The actuation bleed rate depends on the size of the device and on how often the valve is moved.

The various parameters that can affect the yearly average actuating bleed rate for a snap-acting or throttling device are:

1. Number of full stroke cycles per year (how often the valve makes a full stroke cycle);
2. Actuating chamber size; and
3. Supply gas pressure.

Based on the characteristics of continuous bleed and intermittent bleed pneumatic devices, the following approach was used to gather pneumatic data from site visits for this report:

1. Basic device type (intermittent versus continuous bleed), the instrument manufacturer, and model number were gathered from several sites by visual inspection;
2. Instrument populations;
3. Supply gas pressure and type; and
4. Field measurements of continuous bleed devices were provided from existing sources.

The bleed rate will vary with the supply gas pressure. The two common signal pressure ranges are: 1) 3 to 15 psig; and 2) 6 to 30 psig.[5] These supply ranges can be easily identified by the gauge dials on the front of the controller box. The 3-15 range will operate at approximately 20 psi gauge; the 6-30 range will operate at about 35 psi gauge.

The site data were combined with manufacturers' data and field measurements (provided from existing sources)[10,11] to produce an annual estimate of emissions for intermittent and continuous bleed actuated controllers.

3.3 Gas-Actuated Isolation Valves

Transmission compressor stations, transmission pipelines, storage stations, and gas plants have large-diameter pipelines, and therefore have large pipeline isolation valves. These valves block the flow to or from a pipeline, and can isolate the facility for maintenance work or in the case of an emergency. The valves are usually actuated remotely by a power source. The valves are so large that manual operation would be extremely slow, and certainly unsuitable in the case of an emergency. The valves are most often actuated pneumatically (by natural gas or compressed air) or by an electric motor.

3.3.1 General Description

Most gas operators on isolation valves discharge gas only when actuated. Once they reach the open or closed position, they do not bleed gas. These valves are actuated infrequently, so their emissions are very intermittent.

The pneumatically actuated isolation valves can generally be divided into two types: 1) displacement operators, and 2) turbine operators. Displacement operators are attached to quarter-turn plug valves or quarter-turn ball valves. These operators use gas pressure (pneumatic force) to move an actuator element in one direction. Sometimes the pneumatic force is applied directly to the actuator element, and sometimes it is applied to oil, so that hydraulic force moves the actuator; in either case, gas is discharged when the valve is actuated. The actuator element is displaced from its original position by the pneumatic or hydraulic force. Displacement operators in the gas industry are of two basic types: 1) rotary vane, and 2) piston.

The rotary vane displacement operator uses natural gas to force a fixed amount of oil from one pressure bottle to another. The oil moves through the vane operator, delivering hydraulic force to the vane, and moving it and the attached valve stem one quarter turn. The oil moving into the bottle forces gas in the top of the receiving pressure bottle to vent to the atmosphere. The most common manufacturer of this type of operator is Shafer Valve Company.[12] Figures 3-11 and 3-12 show a typical pneumatic/ hydraulic rotary vane operator from the Shafer catalogue.

Similarly, Pantex Valve Actuators & Systems, Inc., manufactures a displacement operator that uses natural gas to move a piston.[6] The piston acts on an "arm" or lever that rotates the valve stem. Gas is supplied to one side of the piston and exhausted from the other to move the arm in each direction, either opening or closing the valve. An example of this type of operator is shown in Figure 3-4.

Supply gas for these operators is usually pipeline gas, so pressure varies from site to site. Compressed air can be used if it is available in sufficient volumes. The volume of gas vented depends on the vane or piston displacement size and on the supply gas pressure.

Turbine operators, the second major type of isolation valve operators, are usually attached to gate valves.[13] The turbine operators simply release gas to the atmosphere across a small turbine similar to a gas starter turbine for a reciprocating compressor. The gas spins the turbine blades, and the turbine shaft then turns gears that move the gate valve stem. A turbine operator on a gate valve is illustrated in Figure 3-13.

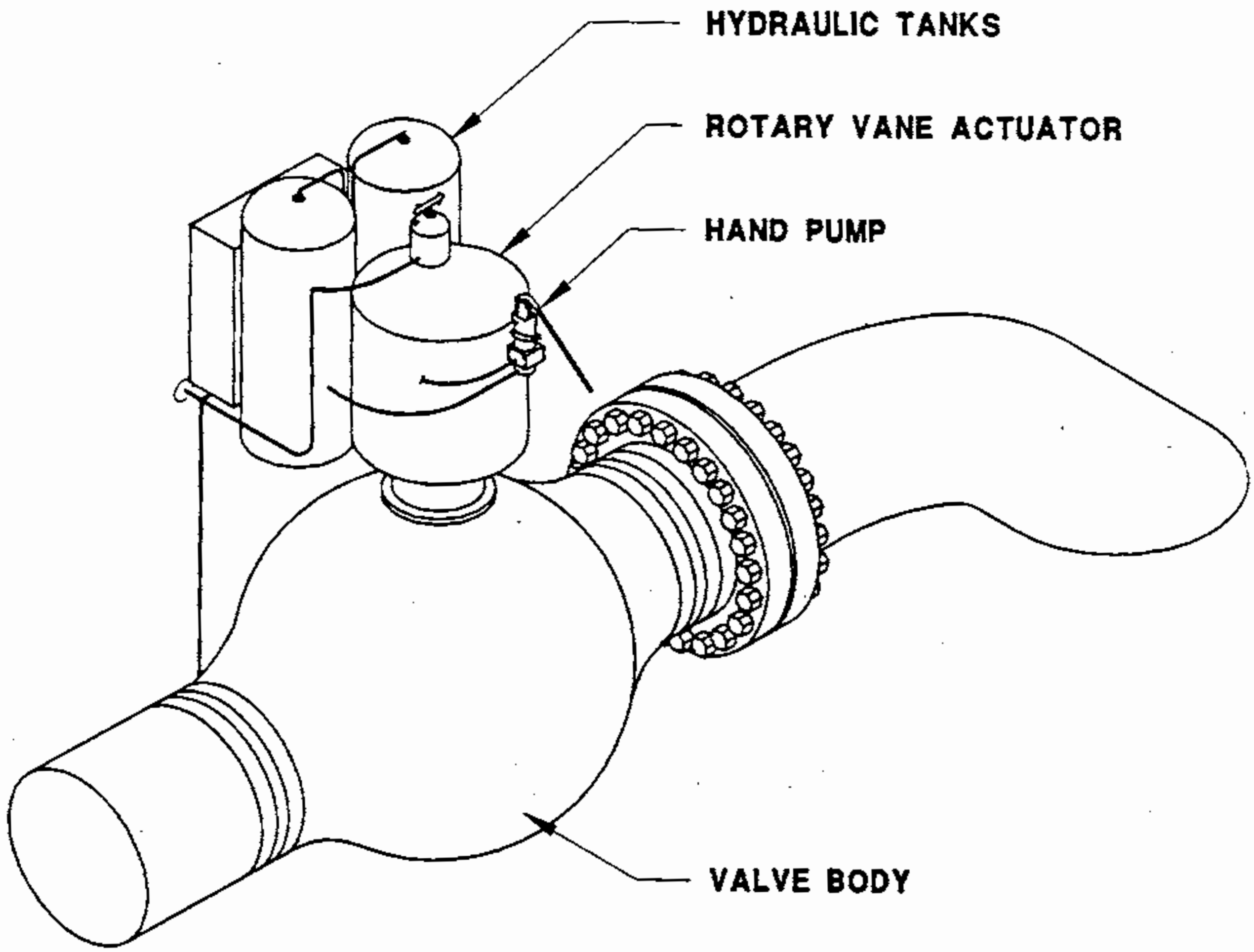


Figure 3-11. Pneumatic/Hydraulic Rotary Vane Operator[12]

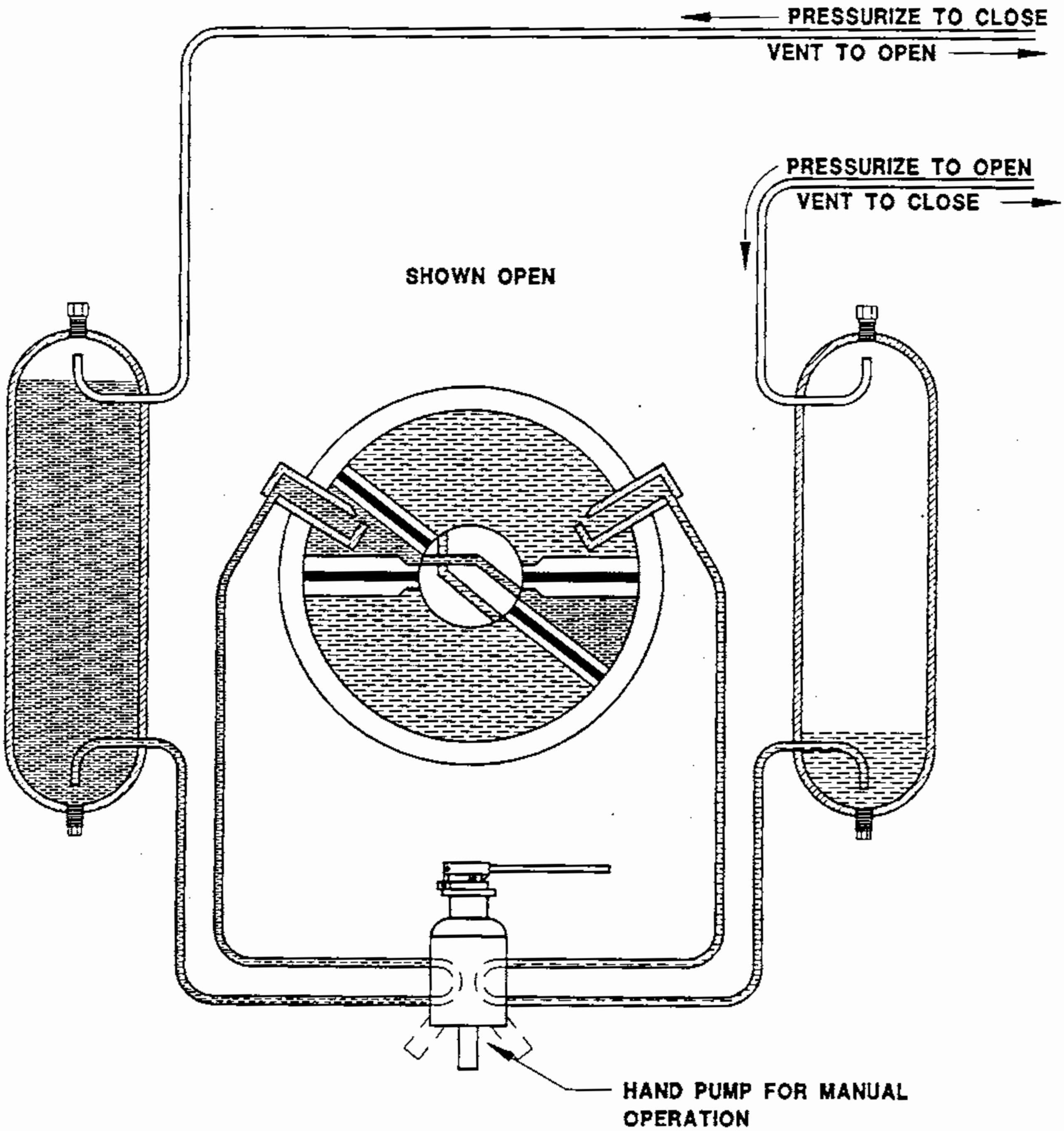


Figure 3-12. Pneumatic/Hydraulic Rotary Vane Operator - Cross Section[12]

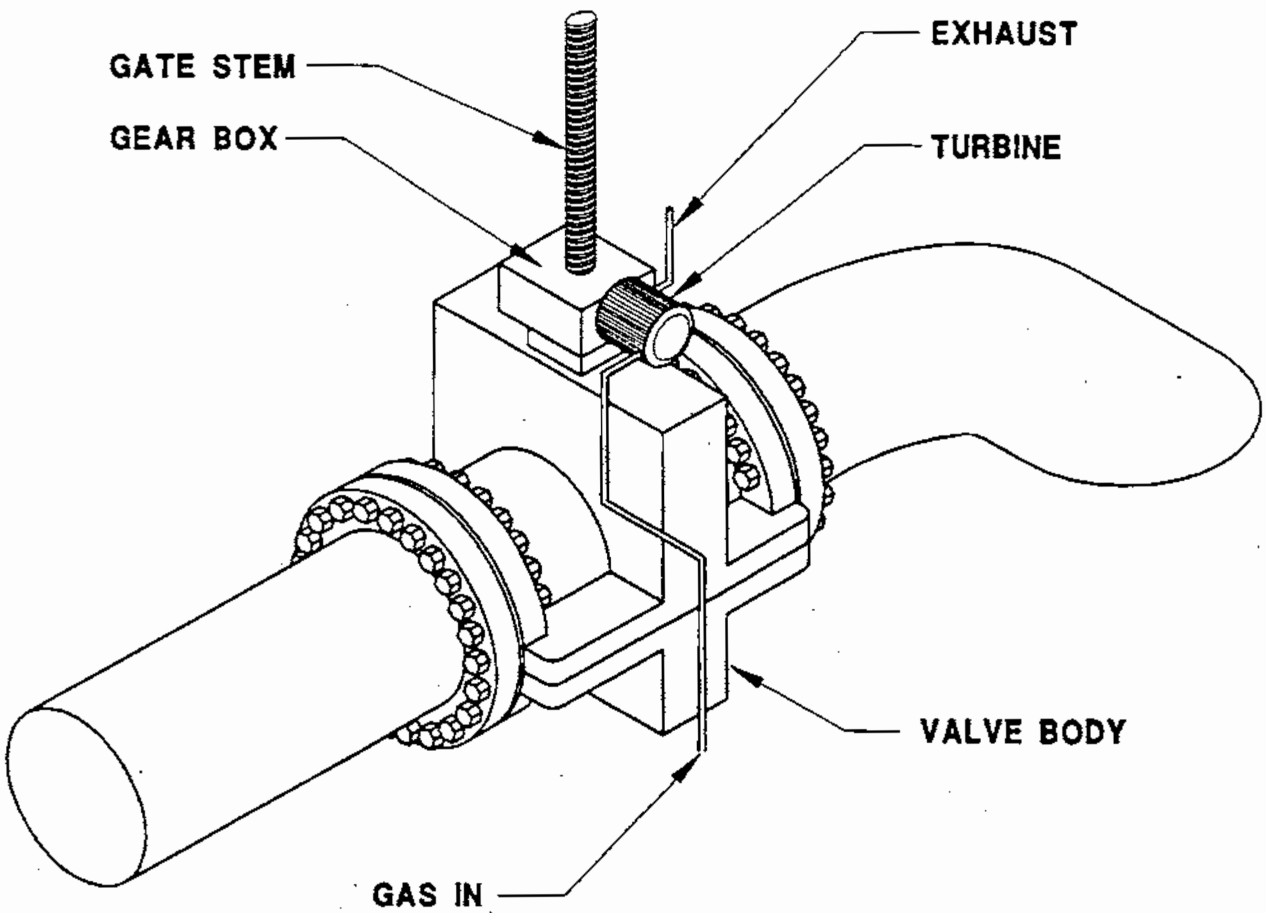


Figure 3-13. Turbine Operator

Pipeline gas is typically used as the supply gas for the turbine devices, so the pressure varies from site to site. The volumes vented depend on the duration of operation to open or close the valve and on the supply gas pressure.

3.3.2 Data Requirements

Based upon the operating principles discussed above, the various characteristics that affect the bleed rate for isolation valve operators are:

1. Basic device type (turbine or displacement);
2. Manufacturer and model number;
3. Supply gas pressure, supply gas type (air produces no methane emissions); and
4. Number of full stroke cycles per year.

The following approach was used to gather pneumatic data for this report from field site visits:

1. During site visits, instrument populations and the instrument manufacturer and model number were gathered from several sites; and
2. Based on observations and interviews, the frequency of operation cycles per year was estimated.

The site data were combined with manufacturers' data and measured data from other studies to produce an emission factor for a typical device type.

3.4 Other Pneumatic Devices

Numerous other devices in the field can bleed methane but do not neatly fit into the categories listed above. Because these devices are rare, or rarely bleed, they were ignored for the purpose of this study. They are listed in this section only for the sake of completeness. Some key examples are:

- Solenoid snap-acting valve controllers;
- Self-contained pressure regulators;
- Pneumatic transmitters; and
- Older flow computers.

The solenoid "snap-acting" controller acts like the pneumatic snap-acting controller, except that its signal is not a weak mechanical signal but an electrical one. The solenoid either opens a valve that puts full supply gas pressure to the top of the valve actuator or closes off that supply and vents the actuator to the atmosphere. Like snap-acting pneumatic relays, it only bleeds when the actuator is depressured. Figure 3-14 shows a diagram of a solenoid relay. These devices are rare since electronic signals are infrequently used in the gas industry.

A common example of a self-contained pressure regulator is the small "gas supply regulator" shown in Figure 3-2. This is a small device that lowers pneumatic gas supply pressure to a desired downstream pressure. These devices are commonly found between pneumatic supply headers and the devices that use the supply gas. Gas supply regulators only bleed if the downstream pressure rises above set-point. Since there are downstream users of the gas, the downstream pressure is almost always lower, so these devices rarely bleed gas. Another common, large, self-contained device is the transmission and distribution pressure letdown regulator (Figure 3-15). These regulators handle the entire gas stream but do not bleed at all. They release actuator pressure to the downstream side and do not bleed to the atmosphere.

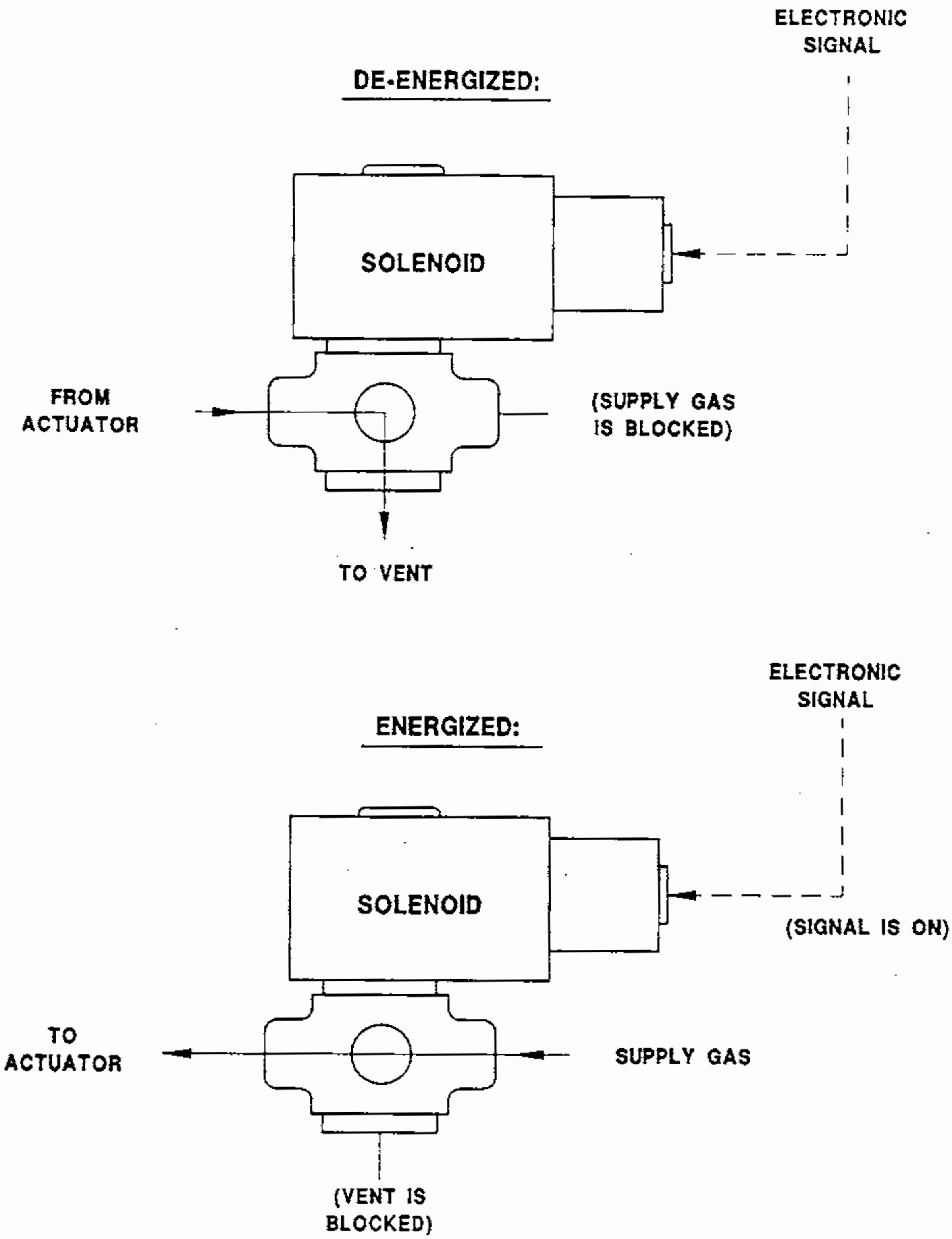


Figure 3-14. Solenoid Relay[5]

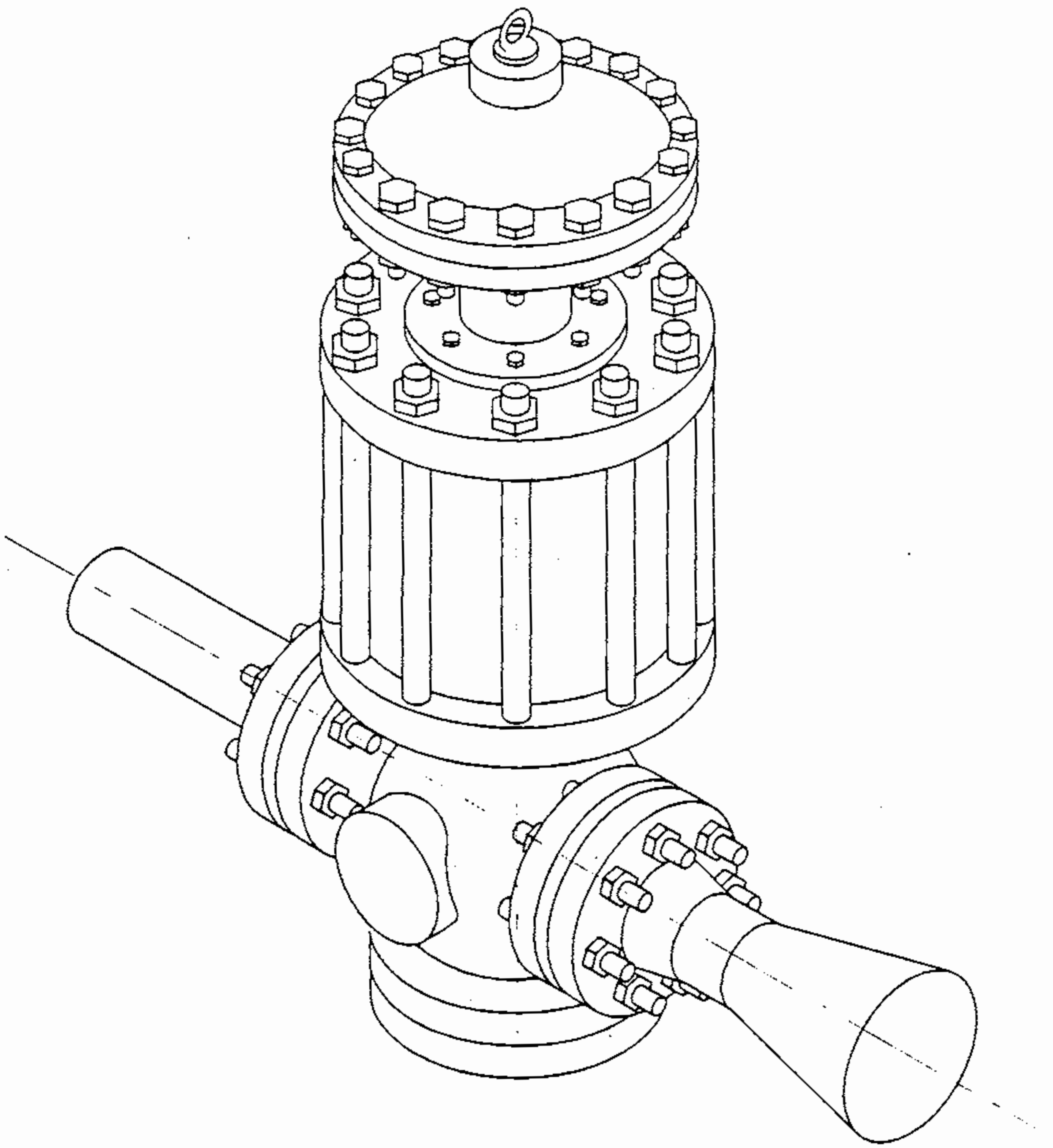


Figure 3-15. Self-Contained Pressure Regulation Valve

The pneumatic transmitters and older flow computers are examples of devices originally installed in older facilities that are out-of-date by today's standards of technology. It is difficult to list, characterize, or group all of the diverse devices in this category. Their total contribution to emissions is considered to be minimal.

4.0 PNEUMATIC DEVICE EMISSION FACTORS

The various segments of the gas industry have different equipment and different standards for using pneumatic devices. Table 4-1 shows the general uses of devices in each segment.

TABLE 4-1. STANDARD USES OF PNEUMATIC DEVICES

	Production	Processing	Transmission	Distribution
Control valves operated by gas?	Yes	Very Few	Yes	Yes
Isolation valves operated by gas?	No	Some	Yes	Some

The following subsections describe the details of pneumatic devices in each segment and the emission factors associated with those devices.

4.1 Production Segment

Valve controllers (pneumatic devices on control valves that regulate flow) are the most common type of pneumatic device in the production segment that discharge gas to the atmosphere. As stated earlier, primary measurement devices, which detect the initial change in the process variable, are sealed and do not directly bleed or exhaust to the atmosphere. In addition, the production pipelines are small, so the isolation valves that exist are manually operated and do not bleed gas.

4.1.1 General Emission Factor Characteristics

Typical production operations include pneumatic valve controllers. Infrequently, production operations may contain valve positioners. There are multiple components (such as set-point adjustment, gain adjustment, and reset knobs) within a controller or positioner that may bleed. These are considered part of the controller device. Certain valves or valve packages may have these emitting elements combined into one field-located box.

The production segment uses both basic types of pneumatic controllers: 1) throttling, and 2) snap-acting. Throttling pneumatic relays of the "force balance piston" type (Figure 3-8) bleed only when they move from the neutral position. They are therefore intermittent emitters and have a stationary bleed rate of zero. Throttling orifice flapper relays (Figure 3-6) bleed continuously, even when the valve is not moving, but their bleed rate varies with the strength of the signal from the process variable. Orifice flapper relays are considered continuous emitters since there is no position where the bleed rate is zero. Snap-acting controllers have a stationary bleed rate of zero and are therefore considered intermittent emitters.

4.1.2 Production Emission Factors

Five sources of information were used to determine the methane emissions from pneumatic devices used in the production segment: the results from a study performed by the Canadian Petroleum Association,[11] manufacturers' data, measured emission rates,[10] data collected from site visits, and literature data for methane composition. Each of these sources is discussed in detail.

Canadian Petroleum Association (CPA) Report

As part of Canada's effort to reduce atmospheric emissions, the Canadian Petroleum Association sponsored a project to quantify methane and VOC emissions in upstream oil and gas operations.[11] Emission measurements from 19 snap-acting pneumatic devices and 16 throttling devices were collected during this study. The results are presented in Table 4-2. The average natural gas emission rate for snap-acting devices was 213 scfd/device ± 57% (90% confidence interval), and the average emission rate for throttling

TABLE 4-2. RESULTS FROM THE CANADIAN PETROLEUM ASSOCIATION PNEUMATIC EMISSION RATE STUDY

Instrument Type	Facility Type	Equipment Type	Quantity Measured	Minimum Flow, scfd	Maximum Flow, scfd	Average Natural Gas Emission, scfd
Snap-Acting Controller	Oil Battery	Group Treater	1	0.0	690	33
		Test Treater	2	172	172	179
		Group Treater	1			14
		Group Treater	2	0.0	>951	226
		Group Treater	2	0.0	>933	59
		Group Treater	2	0.0	>959	140
		Group Treater	2	0.0	573	81
		Group Treater	1	0.0	>1,911	695
		Group Treater	1			12
		Test Treater	2			210
		Test Separator	2	0.0	430	233
		Group Separator	1	0.0	1397	677
		Average Emission for Snap-Acting Controllers				213 ± 57%
Throttling Controller	Oil Battery	Dehydrator	3	0	10	2
		Line Heater	1	55	55	60
		Line Heater	1	11	11	11
		Line Heater	1	31	31	34
		Group Treater	6	7	7	8
		Test Separator	1	529	529	529
		Test Separator	3	9	240	11
		Average Emission for Throttling Controllers				94 ± 152%

devices was 94 scfd/device ± 152%.[11] The CPA report concluded that there was no statistically significant difference between the bleed rates of the snap-acting and throttling controllers.

It should be noted that the CPA report did not distinguish between throttling controllers with intermittent bleed rates and throttling controllers with continuous bleed rates. In addition, only one of the throttling devices actuated while they were measuring it. The measurements recorded for the other throttling devices only represent the stationary or continuous bleed emissions.[14] Therefore, the Canadian measurements are lower than field measurements of similar devices in the U.S., but do agree with the manufacturer's data for similar devices. The CPA measurements were treated as additional data sources and combined with field measurements provided by another source to generate emission factors for intermittent and continuous bleed devices.[10]

Manufacturers' Data

Manufacturers of pneumatic devices may report a "gas consumption" for specific devices based on laboratory testing of new devices. However, the manufacturers indicate that emissions in the field can be higher than the reported gas consumption due to operating conditions, age, and wear of the device.[15,16,17,18] Examples of circumstances or factors that can contribute to this increase include:

- Nozzle corrosion resulting in more flow through a larger opening;
- Broken or worn diaphragms, bellows, fittings, and nozzles;
- Corrosives in the gas leading to erosion or corrosion of control loop internals;
- Improper installation;
- Lack of maintenance (maintenance includes replacement of the filter used to remove debris from the supply gas and replacement of o-rings and/or seals);

- Lack of calibration of the controller or adjustment of the distance between the flapper and nozzle;
- Foreign material lodged in the pilot seat; and
- Wear in the seal seat.

The manufacturers contacted did not have field measurements of devices in service and did not simulate the aging of devices with laboratory measurements, so they could not provided an indication of the expected increase in emissions due to the factors listed above. Since manufacturers' emission rates are based on new devices, actual emission measurements from pneumatic devices in field service, including worn or defective devices, were used as the basis for developing emission factors.[10,11]

Several pneumatic device manufacturers provided information on the gas consumption rates for their continuous bleed devices.[9,16,18,19,20,21,22,23,24,25] Table 4-3 shows the bleed rates for the model series observed during site visits. The manufacturers' reported gas consumption rates represent the gas usage at the specified supply gas pressure for the controller only (unless otherwise noted). Additional emissions may occur from other components of the control loop (i.e., set point exhaust and valve positioner).

For the types of devices listed, gas consumption rates for the controllers can vary from 0 to 2,150 scfd per device. However, the manufacturers indicated that emissions from these devices in field operation may be higher than the reported "maximum." Some manufacturers provided a maximum gas flow rate or delivery capacity that the controller pilot could withstand (4,320 scfd for the Bristol 624II and 8,880 for the Fisher 4100). This flow rate indicates the maximum amount of gas that can be supplied to the control loop. It is possible that some pneumatic devices could continue to operate up to these flow rates, but not above these rates.

The manufacturers' data serve as a sanity check for the field measurements provided by other sources (discussed in the next section). The data reported in Table 4-3 are

TABLE 4-3. MANUFACTURER BLEED RATES FOR CONTINUOUS BLEED PNEUMATIC DEVICES

Manufacturer/ Model	Gas Consumption Rates, scfd		Comments on Specified Rate
	"Minimum"	"Maximum"	
Norriseal 1000 (A)	Model discontinued in the 1960s		No bleed rate information available.
Norriseal 1001(A)	0-10	2,150	Max. bleed rate is not specified by Norriseal. Estimated for 1001 model based on volume of gas required for one complete actuation @ 30 psig supply (provided by manufacturer) and assuming one actuation/min.
Bristol 624, 624 II	72-144	4,320	Min. based on gas consumption of the controller only. Bristol does not manufacture actuators, so they do not specify a gas consumption for the actuator. Max. bleed rate shown is based on the pilot capacity (maximum amount of gas that the controller pilot can accommodate).
Fisher 2400	Model discontinued in 1957		No bleed rate information available.
Fisher 2500	168	1,008	Bleed rate for 35 psig supply pressure. Min. represents the steady state pilot bleed rate (device not actuating). Max. represents gas consumption when the relay is completely open.
Fisher 2900	Model discontinued in 1991		Gas consumption not listed in device brochure, but Fisher representative provided a laboratory measurement of 555 scfd for 35 psig supply pressure.
Fisher 4100	24	1,200 8,880	Bleed rate for 35 psig supply pressure. Min. represents the steady state pilot bleed rate of the controller. Max. represents maximum gas consumption (1200 scfd) and delivery capacity of the controller (8800 scfd).
Invalco AE 155	Model discontinued ~1975		No bleed rate information available.
Invalco CT series	510	960	Minimum bleed rate specified for supply gas pressure of 20-30 psi. Maximum bleed rate shown here is reported by the manufacturer as a typical bleed rate for this device. A retrofit kit is available for this series of devices to reduce the typical bleed rate from 960 scfd to less than 22 scfd.

consistent with emission measurements in the field, in that the manufacturers confirmed that the devices can emit at rates higher than the manufacturers' reported gas consumption rates. In addition, the delivery capacity reported by the manufacturers for some devices serves as an absolute maximum bleed rate. Any measured emission rate higher than the delivery capacity for a given device would indicate an error in the measurement and would justify discarding the measurement.

Directly Measured Emissions for Continuous Bleed Devices

Field measurements of throttling devices with continuous bleed rates were available from companies participating in a separate contractor's program.[10] For these measurements, a contractor connected a flow meter to the supply gas line between the pressure regulator and the controller to measure the gas consumption of the controller. A cumulative flow rate and the current flow (scfh) were recorded and extrapolated to gas consumption per day. The duration of the test depended on the variability of the gas use. For steady operating conditions, one data point was taken for 15-20 minutes. For variable flow rates, several one-hour measurements were taken.

Although the emission measurements were not performed under the direction of this study, the results are believed to be an accurate representation of pneumatic devices in operation in the U.S. natural gas industry. Through interviews with site personnel and the contractor that performed the measurements,[10] the sampling technique, measurement protocol, and equipment calibration procedures were reviewed. Two measurements were removed from the data set because they did not follow the measurement protocol for a single device (in both cases a single emission measurement was reported for an unknown number of devices). The final data set was deemed acceptable by the industry review panel.

After the QA/QC review, the data set contained a total of 41 measurements from a combination of continuous bleed devices from offshore platforms, onshore production sites, and transmission stations. Table 4-4 summarizes the measurements.

TABLE 4-4. MEASURED EMISSION RATES FOR CONTINUOUS BLEED DEVICES

	Production Onshore	Production Offshore	Total Production	Transmission
Number of Measurements	9	9	18	23
Minimum, scfd/device	380	108	108	152
Maximum, scfd/device	2,334	962	2,334	4,215
Average, scfd/device	1,189 ± 39%	556 ± 33%	872 ± 30%	1,363 ± 29%

The use of pneumatic devices in onshore versus offshore production operations is similar. Both use continuous bleed devices primarily for liquid level control in separators. Comparing the average measurements in Table 4-4, the average emission rate for pneumatic devices in offshore operations is much smaller than the emission rate for these devices in onshore operations. However, the offshore emission measurements shown in Table 4-4 are from one company. Therefore, any difference between onshore and offshore device emissions might also be attributed to a company difference. Because most industry reviewers of this study believe that there is no technical reason to divide the data set between onshore and offshore, and additional data were not available to validate a distinction between onshore and offshore, the measurements for these two categories are combined into one emission factor for continuous bleed devices in the production segment.

Continuous bleed pneumatic devices are used for different functions in production versus transmission operations. As mentioned previously, most continuous bleed pneumatic devices in production are used to control the liquid level in separators. In the transmission segment, the same types of devices are used for liquid level control in filter-separators, but are also used for pressure reduction. In addition, the higher pressures and larger pipeline sizes associated with transmission operations require larger actuators and larger valves than are typically found in production, and therefore pneumatic devices used in transmission operations would be expected to result in higher emission rates. For these reasons, separate emission factors were developed for production and transmission.

Comparing the measured emissions for devices in production versus transmission indicates that there is a difference between the industry segments. The combined onshore and offshore production devices have a lower average emission rate of 872 scfd, while transmission devices have an average emission rate of 1,363 scfd. When the Canadian data are included, the production emission factor is 654 $\pm$ 31% scfd/device. The transmission emission factor is unchanged because the Canadian measurements were only from onshore production facilities.

The measured emission rates compare well with the gas consumption ranges provided by the manufacturers, although a direct comparison for all device types can not be made since manufacturer values are not available for all of the models measured. In general, most of the measurements are less than 2,000 scfd (only seven out of the 41 measurements are greater than 2,000 scfd), and all of the measurements are below the reported controller delivery capacities of 4,320 and 8,880 scfd (two devices had emission measurements of 4,215 scfd).

As stated previously, the manufacturers' bleed rates represent laboratory measurements of the gas consumption for new pneumatic devices. In reality, the pneumatic devices in the field have various states of wear and may emit gas at rates higher than the manufacturers' gas consumption data suggest. The measured emissions are in the range of values provided by the manufacturer and are believed to reflect more typical operating conditions for these devices and account for increased emissions due to wear. For the purpose of this report, the measured emissions provided by CPA are combined with the contractor's direct measurements to estimate the emission factor from continuous bleed throttling devices. The resulting natural gas emission factor for the production segment is 654 $\pm$ 31% scfd per continuous bleed device.

Measured Emissions for Intermittent Bleed Devices

Field measurements for intermittent bleed devices, using the same technique described for the continuous bleed devices, were also available from companies participating in this study.[10] Based on the criteria described for continuous bleed devices, measurements for the intermittent bleed devices were reviewed and judged to be acceptable. A total of seven measurements were provided from intermittent bleed devices found in onshore production service. No measurements were available for these types of devices in offshore service or the transmission segment. The average emission rate for the seven devices is 511 scfd ± 36%. The measurements ranged from 211 to 950 scfd/device, as compared to the CPA measurements of similar devices which ranged from 12 to 695 scfd/device (average of 211 scfd from Table 4-2). Combining the 19 measurements from both sources (Canadian and U.S. field measurements) results in a natural gas emission factor of 323 ± 34% scfd/device for intermittent bleed devices in production.

Site Data

For this study, data were collected from a total of 22 sites to establish a count of pneumatic devices for production sites and to determine the fraction of intermittent versus continuous bleed devices at each site. The fraction of each device type was used to scale the emission factor to generate one emission factor for a "generic" pneumatic device. Table 4-5 summarizes the data collected at production sites. For each site, the number of snap-acting devices and the number of throttling devices were collected. Where possible, the manufacturer and model number were recorded for each device.

As discussed in Section 3, throttling devices can be either intermittent or continuous bleed, while snap-acting devices are always intermittent bleed. The number of throttling continuous bleed devices at each site was determined based on the manufacturer and model type of the devices observed. Since these two device types have distinctly different emission rates, the fraction of intermittent bleed versus continuous bleed devices is

TABLE 4-5. SUMMARY OF PRODUCTION SITE DATA

Site	Total Count of Devices	Power Media	Number of Snap-Acting Devices	Number of Throttling Devices[a]	Number of Continuous Bleed Devices[b]
1	136	Gas	114	22	22
2	18	Gas	75	95	29
3	405	Gas	405	0	0
4	68	Gas	48	20	20
5	21	Gas	26	83	21
6	13	Gas	94	534	534
7	3	Gas	999	0	0
8	3	Gas	667	0	0
9	6	Gas	3	3	3
10	14	Gas	0	14	0
11	76	Gas	0	76	76
12	600	Gas	0	600	600
13	107	Air	71	36	25
14	69	Gas	42	27	20
15	13	Gas	8	5	0
16	1	Gas	1	0	0
17	3	Gas	3	0	0
18	4	Air	3	1	0
19	46	Air	6	40	40
20	5	Gas	4	1	0
21	11	Gas	5	42	42
22	31	Gas	0	31	31
TOTALS	4,204		2,574	1,630	1,463
FRACTION BY DEVICE TYPE			Non Continuous Bleed 0.65 ± 43%		Continuous Bleed 0.35 ± 43%

[a] Throttling devices can be either continuous or intermittent bleed.
[b] Continuous bleed devices are a sub-category of throttling devices.

required to develop an emission factor. From the site data, the fraction of continuous bleed devices is 0.35 ± 43%. By difference, the fraction of intermittent bleed pneumatic devices is 0.65 ±43%.

Methane Composition

The percentage by volume of methane in produced natural gas was determined to be 78.8% ± 5%. Details about this value are available in the report, *Methane Emissions from the Natural Gas Industry, Volume 6: Vented and Combustion Source Summary.*[26]

Emission Factor Calculation

The weighted emission factor per device was calculated for production facilities as follows:

$$\text{Weighted Emission Factor} = \left(\text{Fraction of Intermittent Bleed Devices} \times \text{Intermittent Bleed Emission Factor} + \text{Fraction of Continuous Bleed Devices} \times \text{Continuous Bleed Emission Factor}\right) \times \text{Methane Composition} \quad (1)$$

The site data were used to estimate the fraction of intermittent bleed versus continuous bleed devices: 65% ± 43% intermittent bleed and 35% ± 43% continuous bleed (Table 4-5). Table 4-6 summarizes the emission factor terms, where the emission factors for the individual device types (intermittent versus continuous bleed) were based on the field measurements from the United States and Canada discussed previously.

The final result is an average device methane emission factor of 345 scfd/device ± 40% (90% confidence interval), or 126,000 scf/device annually.

TABLE 4-6. PRODUCTION EMISSION FACTOR CALCULATION

Device Type	Fraction of Device Type	Selected Natural Gas Emission Factor, scfd/device
Intermittent Bleed	0.65 ± 43%	323 ± 34%
Continuous Bleed	0.35 ± 43%	654 ± 31%
Methane Emission Factor for Average Device = 345 ± 40% scfd/device		

4.2 Transmission and Storage Segment

The transmission segment is composed of pipelines, compressor stations, and storage stations. Very few pneumatic devices of any type are associated with the pipelines. Within the storage and mainline compressor stations, most of the pneumatic devices are gas-actuated isolation valves and continuous bleed controllers.

4.2.1 General Emission Factor Characteristics

The type of continuous bleed devices in the transmission segment are essentially the same as those in the production segment. The difference is in the use of the devices. In the transmission segment, continuous bleed pneumatic devices are used to regulate pressure on compressors and are sized larger due to the higher pressures in transmission. In production, smaller devices are used primarily to control the liquid level in separators. Since most of the same manufacturers are used, this section will not repeat the discussion from Section 4.1.1.

Isolation valve actuators are predominately found in the transmission segment. Isolation valve actuators emit gas whenever the valve is moved to either the open or closed position. Most compressor stations and storage stations have many valves, since valves are needed to make normal changes in pipeline and equipment flow configurations, as well as to isolate and depressure equipment for maintenance or in case of an emergency. Most sites use natural gas rather than compressed air to actuate these large valves. A large volume of gas is needed to move multiple valves and this requires a large investment in equipment if compressed air is used.

4.2.2 Transmission Emission Factors

Manufacturer and Site Data

The transmission emission factors were determined from information gathered during site visits and from manufacturers' data. The gas-operated devices used in the transmission segment were classified into three categories: continuous bleed devices, isolation valves with turbine operators, and isolation valves with displacement-type pneumatic/hydraulic operators. Devices operating on air were not included in the emission calculation.

The natural gas emission factor for the continuous bleed devices used in transmission is based on measured emissions from these devices at transmission stations (measurement procedure and data quality checks were discussed in Section 4.1.2).[10] As shown in Table 4-4, measured emissions from 23 devices ranged from 152 to 4,215 scfd of natural gas per device, with an average natural gas emission factor of 1,363 $\pm$ 29% scfd/device (497,583 scf/device annually). It should be noted that intermittent bleed devices were not observed at transmission stations.

Data on the following characteristics of isolation valves were gathered at 16 transmission sites:

1. Basic device type (continuous bleed, turbine, or pneumatic/hydraulic);
2. Manufacturer and model number;

3. Supply gas pressure, supply gas type (air produces no methane emissions); and

4. Number of full stroke cycles per year (each cycle consists of two valve movements: open and close).

All of the displacement isolation valves observed at the transmission sites were the pneumatic/hydraulic rotary vane type (Figures 3-11 and 3-12). The number of actuation cycles per year was based on site data. The manufacturer provided the volume of gas used based on the discharge pressure. These values (shown in Table 4-7) were combined to calculate the annual emission factor for each type of displacement-operated isolation valve:

$$EF_{\substack{\text{Displacement-}\\ \text{Operated}\\ \text{Isolation Valve}}} = \frac{\text{Device Gas Usage}}{\text{(scf/psia)}} \times \frac{\text{Discharge Pressure}}{\text{(psia)}} \times \frac{\text{Frequency}}{\text{(cycles/year)}} \times \frac{\text{2 Valve Movements}}{\text{Cycle}} \quad (2)$$

Data provided by Shafer Valve Operating Systems show that the gas usage volumes vary widely, so data on the demographics of various sizes of the rotary-vane-operated valves were gathered from four stations.[27,28] This information is provided in Table 4-7. The total emissions from displacement devices were determined for each site based on the size, actuation frequency, and number of each type of device. An average annual emission factor for this type of device was calculated to be 5,627 ± 112% scf natural gas per device based on the average of the site data.

Due to the diversity of company practices for the few sites which provided data, no direct relationship was established between device count and station size. Therefore, for this emission factor, an average of the four site averages was used, as opposed to an average of all of the individual device measurements. In effect, this weights the measurement by site (transmission station) rather than by device count. Thus, a site with a disproportionately high number of devices is not weighted higher than the other stations.

TABLE 4-7. PNEUMATIC/HYDRAULIC ROTARY VANE ISOLATION VALVE OPERATORS

Site	Supply Gas Pressure, psig	Actuator Size	Gas Usage per Cycle, scf/psi	Number of Devices	Cycles/ Year	Annual Gas Usage, scf/ Device Type
1	935	6.5 x 3.5	0.0042	4	12	383
		6.5 x 3.5	0.0042	1	1	8
		9 x 7	0.0123	1	1	23
		11 x 7	0.022	1	1	42
		14.5 x 14	0.0852	1	1	162
		16.5 x 16	0.1183	3	1	674
		16.5 x 16	0.1183	2	12	5,393
		18 x 8	0.0489	3	1	279
		18 x 8	0.0489	1	12	1,115
		18 x 12	0.0852	1	1	162
		25 x 16	0.318	5	12	36,242
		25 x 16	0.318	1	1	604
		Total Emissions for Site 1 = 45,086 scf Site Weighted Average = 1,879 scf/device ± 54%				
2	935	25 x 16	0.318	4	92	237,496
		25 x 16	0.318	2	64	82,607
		25 x 16	0.318	2	50	64,537
		20 x 16	0.1981	6	5	147,649
		12.5 x 12	0.0482	4	92	1,467
		12 x 12	0.0482	3	5	587
		15 x 8	0.0279	1	6	340
		18 x 8	0.0489	1	6	4,962
		18 x 8	0.0489	1	50	198
		20 x 16	0.1981	1	2	6,031
		20 x 16	0.1981	1	15	14,473
		26 x 36	0.7565	1	36	3,071
		25 x 16	0.318	1	2	19,361
		9 x 7	0.0123	5	5	624
		9 x 7	0.0123	2	2	100
		Total Emissions for Site 2 = 583,803 scf Site Weighted Average = 16,680 scf/device ± 37%				

Continued

TABLE 4-7. (CONTINUED)

Site	Supply Gas Pressure, psig	Actuator Size	Gas Usage per Cycle, scf/psi	Number of Devices	Cycles/ Year	Annual Gas Usage, scf/ Device Type
3	1000	5.5 x 3.5	0.0035	7	15.2	705
		6.5 x 8	0.008	14	15.2	3,224
		9 x 7	0.0123	8	15.2	2,833
		11 x 10	0.0318	1	15.2	915
		12.5 x 10	0.0279	1	15.2	803
		12.5 x 12	0.0482	5	15.2	6,938
		20 x 16	0.1981	3	15.2	17,108
		25 x 16	0.318	12	15.2	109,853
		16.5 x 16	0.1183	9	15.2	30,650
		14.5 x 14	0.0852	1	15.2	2,453
		12.5 x 12	0.0482	1	15.2	1,388
		Total Emissions for Site 3 = 176,870 scf Site Weighted Average = 2,853 scf/device ± 27%				
4	950	12.5 x 12	0.0482	3	12	3,348
		6.5 x 3.5	0.0042	1	12	97
		11 x 10	0.0318	1	12	736
		16 wkm	0.072	2	12	3,507
		Total Emissions for Site 4 = 7,688 scf Site Weighted Average = 1,098 scf/device ± 39%				

AVERAGE DISPLACEMENT DEVICE EMISSION FACTOR = 5,627 ± 112% scf/device

Discharge volumes for the turbine-operated isolation valves depend on the supply gas pressure, the number of full stroke cycles each year (where each cycle consists of two valve movements), and the duration that the turbine operates to complete a valve movement, as follows:

$$EF_{\substack{\text{Turbine-}\\\text{Operatored}\\\text{Isolation}\\\text{Valve}}} = \frac{\text{Device Gas Usage}}{\text{(scf/min)}} \times \frac{\text{Operating Duration}}{\text{(min/operation)}} \times \frac{\text{Frequency}}{\text{(cycles/year)}} \times \left(\frac{\text{2 Valve Movements}}{\text{Cycle}}\right) \quad \textbf{(3)}$$

Information on the approximate turbine motor gas consumption for a given gas pressure was provided by Limitorque Corporation.[13] The manufacturer also provided a typical value for the time required to open or close a valve. Two sites furnished the supply gas pressure, the number of operations per year, and the length of time required to open or close the valve. This information is shown in Table 4-8. Average or typical values (based on information provided by sites or manufacturers) were used for other sites with turbine operators. As with the rotary vane isolation valve emission factor, the emission factor for turbine operated isolation valves was also based on an average of the site data. The resulting annual emission factor for turbine operators is 67,599 ± 276% scf/device.

Methane Composition

The methane composition for the transmission and storage segment was estimated to be 93.4% ± 1.5%.[26]

Emission Factor Calculation

Site data were used to estimate a relative fraction of each type of device found in the transmission segment. Data on turbine and displacement isolation valves were collected from 16 sites. For continuous bleed devices, data for an additional 38 sites were available from a large transmission company participating in this project. Based on the average number of devices at each site, the total number of devices for a typical transmission station and the

TABLE 4-8. MANUFACTURER DATA FOR TURBINE OPERATED ISOLATION VALVES

Site	Supply Gas Pressure, psig	Gas Consumption, scfm	Time/ Operation, sec	Gas Usage, scf/Operation	Cycles/ Year	Annual Natural Gas Emissions, scf/device
1	900-970	500-520	30 120	255 1020	11 1	3,825
2	800	470	180	1410	75	211,500
3 (Typical Values)	800	470	90	705	29	40,890
4 (Typical Values)	800	470	90	705	29	40,890
5 (Typical Values)	800	470	90	705	29	40,890
AVERAGE ANNUAL TURBINE DEVICE EMISSION FACTOR, scf natural gas/device						67,599 ± 276%

fraction of each type of device were determined. Tables 4-9 and 4-10 summarize the site information for each device type.

The annual transmission segment emission factor (scf/site) was determined from the following equation:

$$EF = \left(EF_{\substack{continuous\\bleed}} \times Fraction_{\substack{continuous\\bleed}} + EF_{\substack{turbine\\operators}} \times Fraction_{\substack{turbine\\operators}} + EF_{\substack{displacement\\operators}} \times Fraction_{\substack{displacement\\operators}} \right) \times \%\ methane \quad (4)$$

$$EF = (497{,}584\ scf/device \times 0.32\ cont.\ bleed\ devices/total + 67{,}599\ scf/device \times 0.16\ turbine\ devices/total + 5{,}627\ scf/device \times 0.52\ displacement\ devices/total) \times 0.934\ mol\ methane/mol\ gas$$

$$EF = 162{,}197 \pm 44\%\ scf/device$$

TABLE 4-9. TRANSMISSION DEVICE COUNTS - TURBINE AND DISPLACEMENT DEVICES

Site	Turbine Devices/Site	Rotary Vane Displacement Devices/Site
1	3	26
2	16	62
3	12	34
4	35	0
5	44	0
6	0	11
7	0	17
8	0	35
9	0	69
10	0	6
11	0	18
12	0	4
13	0	50
14	0	2
15	0	0
16	0	0
Average Number of Devices/Site	6.25 ± 94%	20.9 ± 48%
Fraction Device/Site	0.156 ± 94%	0.522 ± 48%
Annual Natural Gas Emission Factor scf/device	67,599 ± 276%	5,627 ± 112%

TABLE 4-10. TRANSMISSION DEVICE COUNTS - CONTINUOUS BLEED

Site	Continuous Bleed Devices/Site	Site	Continuous Bleed Devices/Site
1	39	28	11
2	16	29	11
3	4	30	32
4	3	31	9
5	4	32	12
6	1	33	4
7	1	34	21
8	4	35	12
9	6	36	3
10	2	37	15
11	2	38	3
12	127	39	11
13	18	40	10
14	4	41	44
15	22	42	3
16	3	43	3
17	4	44	9
18	4	45	12
19	4	46	4
20	1	47	26
21	1	48	2
22	1	49	7
23	15	50	11
24	92	51	11
25	3	52	15
26	6	53	6
27	1	54	1

Average Number Devices/Site	12.9 ± 69%
Fraction of Device/Site	0.32 ± 69%
Annual Natural Gas Emission Factor, scf/device	497,583 ± 29%

4.3 Gas Processing Segment

The gas processing segment (gas plants) uses compressed air to power the majority of pneumatic devices within the plant. Of the nine gas plants visited for this study, only one used natural gas-powered, continuous bleed devices in the plant. Approximately one-half of the plants visited had natural gas-driven pneumatic controllers for the isolation valves on the main pipeline emergency shut-down system for the plant or for isolation valves used for maintenance work on specific sections of the plant. All of the other sites used compressed air to power their pneumatic continuous bleed devices and isolation valves.

Unlike the production and transmission industry segments, a mix of pneumatic devices was not observed at each gas processing site. Instead, the gas plants visited generally used only one type of natural gas powered pneumatic device throughout the plant. Stratification by device type could not be determined, so emissions were calculated on a site basis rather than a device type basis.

Manufacturers' and Site Data

The same type of devices used in the transmission segment are also commonly used in the gas processing segment – continuous bleed throttling devices, displacement-operated isolation valves, and turbine-operated isolation valves. For the sites where specific information was provided, emission calculations were based on that information. However, for some sites, the information provided included little more than the type of actuator, supply gas pressure, and an estimate of the number of operations. In these cases, average values from the transmission segment were used to complete the calculations. The site data with the emission estimates are shown in Table 4-11. The technique used to develop emission factors for each site is discussed separately.

TABLE 4-11. GAS PROCESSING SITE EMISSION ESTIMATES FOR NATURAL GAS

Site	Device Type	Number of Devices	Operations/ Year	Displacement/ Device, scf	Annual Natural Gas Emissions scf/Site
1	Continuous Bleed (Fisher)	2	Continuous	497,584	995,168 ± 29%
2	Isolation (Fisher)	3	12	214,675	644,025 ± 29%
3	Air	--	--	--	--
4	Isolation (Turbine)	25	1	780	19,500 ± 112%
5	Isolation Piston Type (Rotary Vane)	7 18	12 1	48	1,206 ± 49%
6	Isolation (Turbine & Pneumatic/ Hydraulic-type Rotary Vane)	1 16	1 12	660 2,716	44,115 ± 68%
7	Air	--	--	--	--
8	Air	--	--	--	--
9	Air	--	--	--	--
		Total			1,704 Mscf ± 21%
		Average (for gas sites)			341 Mscf/gas site ± 103%

Site 1: Continuous bleed devices, such as those used in the transmission segment, were observed at this site. Since the application of these devices is similar to the transmission segment, the annual emission factor of 497,584 scf per device (based on 1,363 scfd/device from Table 4-4) was used.

Site 2: Fisher devices were used to operate isolation valves at this site. Information on the bleed rate for the specific device type was provided by the site.

Site 4: Manufacturer's data from Limitorque were used to estimate emissions for the turbine operators observed at this site.[13] The plant provided the supply gas pressure of 400 psig, and a typical actuation time of 1.5 minutes was used (based on manufacturer data).

Site 5: Piston-type isolation valve operators were found at only one site; information for the specific device types were provided by Pantex, the manufacturer.[6] Table 4-12 lists the manufacturer's data for the model types identified at this site. The weighted average annual emission factor for this type of device was determined to be 48 scf/device ± 49%.

Site 6: For the pneumatic/hydraulic-type rotary vane devices observed at this site, the emission factor was based on the average volume of natural gas released per actuation for the devices presented in Table 4-7. Manufacturer's data from Limitorque, based on a supply gas pressure of 350 psig, were used to estimate the emissions for the turbine operator at this site.

Methane Composition

The percentage of methane in gas used in gas processing plants was determined to be 87.0% ± 5%. Details about this value are available in the GRI/EPA report, *Methane Emissions from the Natural Gas Industry, Volume 6: Vented and Combustion Source Summary*.[26]

TABLE 4-12. GAS USE INFORMATION FOR PANTEX DEVICES (PISTON DISPLACEMENT ISOLATION DEVICES)

No. Devices	Piston Diameter (in.)	Stroke Length (in.)	Gas Usage (acf/stroke)	Annual Gas Consumption[a] (scf/device)
6	8.0	20	0.5818	512
2	3.0	4	0.0164	4.8
1	3.5	4	0.0222	3.3
2	2.0	4	0.0073	2.1
5	8.0	16	0.4654	341
1	2.5	8	0.0227	3.3
1	6.0	16	0.2618	38.4
2	6.0	12	0.1964	57.6
	Annual Site Gas Consumption, scf			965
	Weighted Annual Average per Device, scf			48.1

[a] Gas consumption calculated based on supply pressure of 250 psig, an average of 4.1 operations per year, and two strokes (open and close) per operation.

Emission Factor Calculation

The gas processing emission factor was calculated according to the following equation:

$$EF = K \times \frac{\sum_{i=1}^{n} \text{Annual Site Emissions, scf Natural Gas}}{n} \times \%\ \text{methane} \qquad (5)$$

where:

K = fraction of sites that use natural gas rather than air (0.556 ± 59%)

n = number of sites operating devices with natural gas

Assuming that the sites surveyed are representative of the United States, the average emission rate for sites using natural gas was adjusted based on the ratio of sites using gas-operated devices to the total number of sites surveyed. The annual gas processing methane emission factor of 165 Mscf/site ± 133% was calculated as shown:

EF = 0.556 ± 59% gas sites/total sites surveyed × 341 ± 103% Mscf/gas site × 0.87 ± 5% mol methane/mol gas

EF = 165 ± 133% Mscf/site

4.4 Distribution Segment

The pneumatic devices in the distribution segment primarily consist of pressure reduction throttling valves at meter and pressure regulation (M&R) stations. The actuators and controllers for these valves are generally gas powered, but may or may not bleed gas to the atmosphere, depending on their design. Emissions from these devices were measured as part of the tracer campaign for M&R stations and included in the M&R station emission rates.[1] Distribution pneumatic emissions are therefore excluded from this report.

Isolation valve actuators at distribution M&R stations are usually manually or motor-operated. There were so few pneumatic operators on isolation valves that this emission source is considered negligible.

5.0 PNEUMATIC DEVICE ACTIVITY FACTORS

Pneumatic device activity factors are discussed in detail in Volume 5 on activity factors.[29] The techniques used to develop pneumatic device activity factors for the various industry segments are summarized in this section. For each industry segment, the activity factor corresponds to the emission factor units presented in Section 4. That is, a count of pneumatic devices is used for the production and transmission segments, while the number of gas plants is used for the gas processing segment.

5.1 Production Segment

The total number of pneumatic devices in the U.S. production segment was determined from regionalized site data. The number of pneumatic devices at each site were weighted based on the number of gas wells and the marketed gas production at each site. The site data were extrapolated by the number of gas wells and the marketed gas production within each region. In production, the resulting count of pneumatic devices nationally is 249,000 ± 48%.

5.2 Gas Processing Segment

The activity factor for gas processing is based on the number of gas processing plants reported annually by the *Oil and Gas Journal*. For the base year 1992, the U.S. activity factor for gas processing is 726 gas plants.[30] A confidence bound of ± 2% was assigned based on engineering judgement.

5.3 Transmission and Storage Segment

The number of natural gas-operated pneumatic devices in the transmission and storage segment was calculated based on the average number of devices per station multiplied by the total number of transmission and storage stations nationally using the following equation:

$$AF = \frac{\text{Average Number of Devices}}{\text{Station}} \times \text{Number of Stations} \tag{6}$$

The average number of pneumatic devices per station is the sum of the average number of turbine devices per site, the average number of rotary vane displacement devices per site, and the average number of continuous bleed devices per site. Using the numbers shown in Tables 4-10 and 4-11, the average number of pneumatic devices per site is 40 ± 37%. Therefore, the pneumatic device activity factor for transmission stations is:

AF = (6.25 ± 94% turbine devices/site
+ 20.9 ± 48% rotary vane devices/site
+ 12.9 ± 69% continuous bleed devices/site)
× 2,175 ± 8% stations

AF = (40 ± 37% devices/station) × (2,175 ± 8% stations)

AF = 87,206 ± 38% pneumatic devices

The activity factor includes only pneumatic devices operated by natural gas. Mechanical, electrical, and air-operated devices were excluded from the site counts and are therefore excluded from the national activity factor.

6.0 NATIONAL EMISSION RATE

National emission rates from pneumatic devices for each industry segment were calculated by multiplying the emission factor by the activity factor:

$$\text{National Emission Rate} = \text{Emission Factor} \times \text{Activity Factor} \qquad (7)$$

Table 6-1 presents the final results of the emission rate calculations for each industry segment.

TABLE 6-1. EMISSION RATE RESULTS

	Methane Emission Factor	Activity Factor	Annual Emission Rate
Production	125,925 ± 40% scf/device	249,111 ± 48% devices	31.4 ± 65% Bscf
Gas Processing	165 ± 133% Mscf/site	726 ± 2% sites	0.12 ± 133% Bscf
Transmission	162,197 ± 44% scf/device	87,206 ± 38% devices	14.1 ± 60% Bscf

Based on these results, pneumatic devices contribute a total of 45.6 ± 48% Bscf of methane for 1992.

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APPENDIX A

Source Sheets

P-4

PRODUCTION SOURCE SHEET

SOURCES:	Various Equipment (wells, heaters, separators, dehydrators, compressors)
COMPONENTS:	Pneumatic Devices
OPERATING MODE:	Normal Operation
EMISSION TYPE:	Unsteady, Vented
ANNUAL EMISSIONS:	31.4 Bscf $\pm$ 65%

BACKGROUND:
Most of the pneumatic devices in the industry are valve actuators and controllers that use natural gas pressure as the force for valve movement. There is a large population of pneumatic devices throughout the gas industry. Gas from the valve actuator is vented to the atmosphere during every valve stroke, and gas may be continuously bled from the valve controller pilot as well.

EMISSION FACTOR: **125,925 scf per average device $\pm$ 40%**

(This was adjusted for the production methane fraction of natural gas at 78.8 mol%.)

Pneumatic devices (valve controllers) linked to control valves are the largest source of pneumatic emissions in the production segment. There are two types of devices with distinct bleed modes: intermittent and continuous. Intermittent bleed devices emit methane to the atmosphere only when the control valve actuates; when the device is not moving the bleed rate is zero. Continuous bleed devices emit methane both when the valve actuates and when the device is not moving. An emission rate for a generic pneumatic device combines the bleed rates of the two types of devices, weighted by the population of the device types as follows:

$$EF_{avg.\ pneum.\ device} = (Fraction_{intermittent} \times EF_{intermittent} + Fraction_{continuous} \times EF_{continuous}) \times \%\ methane$$

where:

$$Fraction_{intermittent} = 0.65 \pm 43\%$$
$$Fraction_{continuous} = 0.35 \pm 43\%$$
$$\%\ Methane = 78.8\ mol\ \% \pm 5\%$$

Emissions for intermittent and continuous bleed devices were based on measured data provided by a Canadian study and U.S. field measurements from a separate contractor's program. The average measured emissions for intermittent and continuous bleed devices are 323 $\pm$ 34% and 654 $\pm$ 31% scfd/device, respectively. The fraction of each type of device was determined from site visits.

Therefore the average annual emission factor for a generic pneumatic device is:

$$EF_{avg.\ pneumatic\ device} = 125{,}925 \pm 40\%\ scf/device$$

EF DATA SOURCES:

1. *Methane Emissions from the Natural Gas Industry, Volume 12: Pneumatic Devices* (1) establishes the important emission-affecting characteristics.

2. Site visit device counts establish the fraction of continuous bleed versus intermittent bleed devices for multiple sites.
3. The Canadian Producers Association (CPA) determined an average emission factor per device based on 19 measurements.
4. An independent contractor provided 18 measurements of pneumatic devices in onshore and offshore production services.

EF PRECISION:

Basis:

EF accuracy is based on error propagation from the spread of site device counts and measured emission rates.

ACTIVITY FACTOR: 249,111 pneumatic controllers ± 48 %

The average count of devices per equipment type was determined from multiple site visits. The ratios for the number of devices per gas well and the number of devices per marketed gas production were compiled by region. The regional values were summed to give national device counts based on well counts and marketed gas production. These values were averaged to give the final national device count of 249,111.

AF DATA SOURCES:

1. *Methane Emissions from the Natural Gas Industry, Volume 5: Activity Factors* (2) establishes the methodology for extrapolating the site data to a national count.
2. Site visit device counts, well counts, and production rates establish the number of devices per well and the number of devices per gas production.
3. Total regional gas well counts and 1992 marketed gas production rates are from A.G.A. *Gas Facts* (3).
4. The oil wells that market gas were calculated by this report and *World Oil* (4). Total oil wells for 1992 are reported as 602,197 by the *Oil & Gas Journal* (5). The active oil wells that market gas are determined by multiplying the total national active wells by the fraction that market gas. The fraction is determined from a Texas Railroad Commission database (6) on oil leases and gas disposition from those leases; an analysis that shows the percent of oil leases that market the associated gas in Texas is 34.7%.

AF PRECISION:

Basis:

1. The accuracy for the devices per well and devices per gas production rate are calculated from the spread of site data collected for each region (a total of 36 sites).
2. The accuracy for wells that market gas are based on the spread of data from the Texas Railroad Commission database.

ANNUAL METHANE EMISSIONS: 31.4 Bscf ± 65 %

The national annual emissions were determined by multiplying an emission factor for an average pneumatic device by the population of devices in the production segment.

125,925 scf × 249,111 devices = 31 Bscf

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T-4

TRANSMISSION AND STORAGE SOURCE SHEET

SOURCES:	Various Equipment (vessels, compressors, piping)
OPERATING MODE:	Normal Operation
EMISSION TYPE:	Unsteady, Vented
COMPONENTS:	Pneumatic Devices
ANNUAL EMISSIONS:	14.1 Bscf ± 60%

BACKGROUND:

The transmission segment is comprised of compressor stations, pipelines, and storage stations. There are essentially no pneumatic devices associated with the pipelines. Within the storage and compressor stations, most of the pneumatics are gas-actuated isolation valves, and there are a few continuous bleed controllers.

Meter-only stations do not have venting pneumatics. Meter and regulation (M&R) stations do have regulating pneumatic controllers (the pressure regulator valves), but all of the M&R station pneumatic emissions are counted in the fugitive calculation for M&R stations and so are not included in this sheet.

The continuous bleed controllers in transmission compressor stations are used for liquid level control in filter-separators and pressure reduction. The higher pressures and large pipe diameters associated with transmission operations require larger actuators and valves than typically found in production, resulting in larger emissions than similar devices in production.

Within the storage and mainline compressor stations, most of the pneumatic devices are gas-actuated isolation valves. These valves block the flow to or from a pipeline and can isolate the facility for maintenance work or in the case of an emergency. Therefore, the isolation valves are actuated infrequently and their emissions are intermittent.

EMISSION FACTOR: **162,197 scf/device ± 44%**

(This was adjusted for the transmission methane fraction of natural gas at 93.4 mol%.)

The average pneumatic device emission factor was determined from a compilation of information from several sites. Counts of devices per site were taken during Radian site visits. The devices were classified into three categories: continuous bleed valves, isolation valves with turbine operators, and isolation valves with displacement operators. The emission factor was determined based on the following equation:

$$EF_{\text{pneumatic devices}} = (EF_{\text{cont bleed valves}} \times \text{Fraction}_{\text{cont. bleed valves}} + EF_{\text{turbine operators}} \times \text{Fraction}_{\text{turbine operators}} + EF_{\text{displacement operators}} \times \text{Fraction}_{\text{displacement operators}}) \times \%\ \text{methane}$$

Listed below are the average fraction of devices for each of the three valve categories:

$$\text{Fraction}_{\text{cont bleed valves}} = 0.32 \pm 69\%$$
$$\text{Fraction}_{\text{turbine operators}} = 0.16 \pm 94\%$$
$$\text{Fraction}_{\text{displacement operators}} = 0.52 \pm 48\%$$

Emissions from continuous bleed pneumatics in the transmission segment were measured by an independent contractor. The average emission factor, based on 23 measurements, is 1,363 scfd/device ± 29% (497,584 scf/device).

For the isolation valves with turbine operators, the emission factor depends on the gas usage for a given supply gas pressure, the time required to complete one movement of the valve, and the number of operations per year. The annual emission factor is then:

$$EF_{turbine\ operators} = \text{Gas Usage (scf/min)} \times \text{Operating Duration (min/operation)} \times 2\ \text{(operations/cycle)} \times \text{Frequency (cycles/year)}$$

$$EF_{turbine\ operators} = 67{,}599 \pm 276\%\ \text{scf/device}$$

The equation for isolation valves with displacement operators is similar:

$$EF_{displacement\ operators} = \text{Gas Usage (scf/psia)} \times \text{Supply Pressure (psia)} \times 2\ \text{(operations/cycle)} \times \text{Frequency (cycles/year)}$$

$$EF_{displacement\ operators} = 5{,}627 \pm 112\%\ \text{scf/device}$$

EF DATA SOURCES:

1. *Methane Emissions from the Natural Gas Industry, Volume 12: Pneumatic Devices* (1) establishes the important emission-affecting characteristics of transmission pneumatic devices.
2. Device counts from 16 compressor and storage stations establish the fraction of turbine valve operators, and displacement valve operators. Counts from a total of 54 stations were used to establish the fraction of continuous bleed devices.
3. The emission factor for the continuous bleed valves was based on 23 field measurements.
4. Gas usages for the turbine valve operators were provided by Limitorque. Operating duration and frequency were estimated based on information from two transmission stations.
5. Gas usages for the displacement valve operators were provided by Shafer Valve Operating Systems. Supply pressure and frequency of operation were estimated based on information from four transmission stations.

EF ACCURACY:

Basis:

1. EF accuracy is based on error propagation from the combination of site information and measured data.
2. It was assumed that the manufacturers' data are completely accurate.

ACTIVITY FACTORS: 87,206 pneumatic devices ± 38%

The number of gas operated pneumatic devices in the transmission and storage segment was calculated based on the average number of devices per station and multiplied by the total number of transmission and storage stations nationally. The average number of devices per site was determined to be 40 ± 37%. The total count of transmission compression facilities is 2,175, based on 1,700 compressor stations, 386 UG storage stations, and 89 LNG storage stations.

AF DATA SOURCES:

1. The number of transmission compressor stations was compiled from 1992 Fossil Energy Commission Form No. 2: Annual Report of Major Natural Gas Companies (2).

2. The number of underground storage facilities is taken directly from A.G.A. *Gas Facts*: "Number of Pools, Wells, Compressor Stations, and Horsepower in Underground Storage Fields." Data from base year 1992 were used (3).
3. The number of liquefied natural gas storage facilities was summed from A.G.A. *Gas Facts*, "Liquified Natural Gas Storage Operations in the U.S. as of December 31, 1987 (4)." The table lists 54 complete plants, 32 satellite plants, and 3 import terminals for a total of 89 facilities.
4. The number of devices per site is based on the total number of devices observed during site visits.

AF ACCURACY: 38%

Basis:

1. Extremely tight confidence limits are expected due to the well documented and reviewed numbers published in A.G.A. *Gas Facts* and FERC forms. A 10% confidence bound was assigned to the number of compressor stations and a 5% confidence bound was assigned to the number of storage stations.
2. The confidence bound on the number of devices per station was determined based on the spread of site data.

ANNUAL METHANE EMISSIONS: 14.1 Bscf ± 60 %

The annual emissions were determined by multiplying an emission factor per device (corrected for the methane composition) by the population of pneumatic devices in the transmission segment.

$$162{,}197 \text{ scf/device} \times 87{,}206 \text{ devices} = 14.1 \text{ Bscf}$$

REFERENCES

1. Shires, T.M. and M.R. Harrison. *Methane Emissions from the Natural Gas Industry, Volume 12: Pneumatic Devices.* Final Report, GRI-94/0257.29 and EPA-600/R-96-080l, Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

2. Department of Energy. *FERC Form No. 2: Annual Report of Major Natural Gas Companies.* OMB No. 1902-0028, Department of Energy Federal Energy Regulatory Commission, Washington, DC, December 1994.

3. American Gas Association. *Gas Facts:*. 1993 Data, Arlington, VA, 1994.

4. American Gas Association. *Gas Facts:*. 1991 Data, Arlington, VA, 1992.

GP-6
GAS PROCESSING SOURCE SHEET

SOURCES:	Various Equipment (vessels, compressors, piping)
COMPONENTS:	Pneumatic Devices
OPERATING MODE:	Normal Operation
EMISSION TYPE:	Unsteady, Vented
ANNUAL EMISSIONS:	0.1 Bscf ± 133%

BACKGROUND:

The gas processing segment uses compressed air to power the majority of the pneumatic devices within the plant, although some devices may be powered by natural gas. Many plants use gas driven pneumatic controllers on isolation valves for emergency shut-down or maintenance work.

The same type of devices used in the transmission segment are also commonly used in the gas processing segment — continuous bleed throttling/regulating valves, displacement operators, and turbine operators.

EMISSION FACTOR: 165 Mscf per average plant ± 133%

(This was adjusted for the gas processing methane fraction of natural gas at 87 mol%.)

The average device gas emission factor was determined from a combination of vendor information on device emission rates and device counts from several sites. The average emission factor was calculated using the following equation:

$$EF_{avg.pneum.device} = K \times \frac{\sum_{i=1}^{n} (\text{Annual Site Emissions, scf Natural Gas})}{n} \times \%\ \text{Methane}$$

K	=	fraction of sites that use natural gas rather than air (0.56 ± 59%)
n	=	number of sites operating with natural gas

Each term in this equation was determined from site specific information. The summation of the site specific data was then adjusted based on the number of sites with gas operated devices versus the total number of sites surveyed. The site results are shown in the following table.

Site	Device Type	Number of Devices	Operations/ Year	Annual Displacement/ Device, scf	Displacement/ Site, scf
1	Throttling (Fisher)	2	Continuous	497,584	995,168 ± 29%
2	Isolation (Fisher)	3	12	214,675	644,025 ± 29%
3	Air	--	--	--	--
4	Isolation (Turbine)	25	1	780	19,500 ± 112%
5	Isolation (Rotary Vane)	7 18	12 1	48	1,206 ± 49%
6	Isolation (Turbine & Rotary Vane)	1 16	1 12	3,376	44,115 ± 68 %
7	Air	--	--	--	--
8	Air	--	--	--	--
9	Air	--	--	--	--
TOTAL					1,704 Mscf ± 21%
Average (for gas sites)					341 Mscf ± 103%

EF DATA SOURCES:

1. *Methane Emissions from the Natural Gas Industry, Volume 12: Pneumatic Devices* establishes the important emission-affecting characteristics.
2. Site visit device counts establish the number of continuous bleed devices, turbine operators, and displacement operators for each site.
3. The emission factor for continuous bleed devices was estimated using data provided by one site and measurements for transmission pneumatic devices.
4. Gas usages for the displacement operators were provided by Pantex Valve Actuators and Systems and Shafer Valve Operating Systems. The number of devices, supply gas pressure, and operating frequency were based on site information.
5. Gas usages for the turbine operators were provided by Limitorque Corp. Operating duration, frequency, and supply gas pressure were based on site information.

EF ACCURACY:

Basis:
1. EF accuracy is based on error propagation from the spread of data for the nine sites visited.
2. It was assumed that the manufacturers' data are completely accurate.

ACTIVITY FACTOR: 726 gas processing plants ± 2%

The activity factor for the gas processing segment was taken from published information from the year 1992.

AF DATA SOURCES:

1. The number of gas processing plants was taken from the *Oil and Gas Journal* (2).

AF PRECISION:

Basis:

1. AF accuracy is based on engineering judgement.

ANNUAL METHANE EMISSIONS: 0.12 Bscf ± 133%

The annual emissions were determined by multiplying an average site emission factor (adjusted for the methane composition) by the total number of gas processing sites.

$$165 \text{ Mscf/site} \times 726 \text{ sites} = 0.12 \text{ Bscf}$$

REFERENCES

1. Shires, T.M. and M.R. Harrison. *Methane Emissions from the Natural Gas Industry, Volume 12: Pneumatic Devices.* Final Report, GRI-94/0257.29 and EPA-600/R-96-080l, Gas Research Institute and U.S. Environmental Protection Agency, June 1996.

2. Bell, L. "Worldwide Gas Processing," *Oil and Gas Journal*, July 12, 1993, p. 55.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/R-96-0801	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Methane Emissions from the Natural Gas Industry, Volumes 1-15 (Volume 12: Pneumatic Devices)		5. REPORT DATE June 1996
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) L. Campbell, M. Campbell, M. Cowgill, D. Epperson, M. Hall, M. Harrison, K. Hummel, D. Myers, T. Shires, B. Stapper, C. Stapper, J. Wessels, and *		8. PERFORMING ORGANIZATION REPORT NO. DCN 96-263-081-17
9. PERFORMING ORGANIZATION NAME AND ADDRESS Radian International LLC P.O. Box 201088 Austin, Texas 78720-1088		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 5091-251-2171 (GRI) 68-D1-0031 (EPA)
12. SPONSORING AGENCY NAME AND ADDRESS **EPA, Office of Research and Development Air Pollution Prevention and Control Division Research Triangle Park, NC 27711**		13. TYPE OF REPORT AND PERIOD COVERED Final; 3/91-4/96
		14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES EPA project officer is D. A. Kirchgessner, MD-63, 919/541-4021. Cosponsor GRI project officer is R. A. Lott, Gas Research Institute, 8600 West Bryn Mawr Ave., Chicago, IL 60631. (*)H. Williamson (Block 7).

16. ABSTRACT The 15-volume report summarizes the results of a comprehensive program to quantify methane (CH4) emissions from the U.S. natural gas industry for the base year. The objective was to determine CH4 emissions from the wellhead and ending downstream at the customer's meter. The accuracy goal was to determine these emissions within +/-0.5% of natural gas production for a 90% confidence interval. For the 1992 base year, total CH4 emissions for the U.S. natural gas industry was 314 +/- 105 Bscf (6.04 +/- 2.01 Tg). This is equivalent to 1.4 +/- 0.5% of gross natural gas production, and reflects neither emissions reductions (per the voluntary American Gas Association/EPA Star Program) nor incremental increases (due to increased gas usage) since 1992. Results from this program were used to compare greenhouse gas emissions from the fuel cycle for natural gas, oil, and coal using the global warming potentials (GWPs) recently published by the Intergovernmental Panel on Climate Change (IPCC). The analysis showed that natural gas contributes less to potential global warming than coal or oil, which supports the fuel switching strategy suggested by the IPCC and others. In addition, study results are being used by the natural gas industry to reduce operating costs while reducing emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Prevention	13B
Emission	Stationary Sources	14G
Greenhouse Effect	Global Warming	04A
Natural Gas		21D
Gas Pipelines		15E
Methane		07C

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 85
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
National Risk Management Research Laboratory
Technology Transfer and Support Division
Cincinnati, Ohio 45268

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