Guidelines for Fuel Gas Line Cleaning Using Compressed Air or Nitrogen

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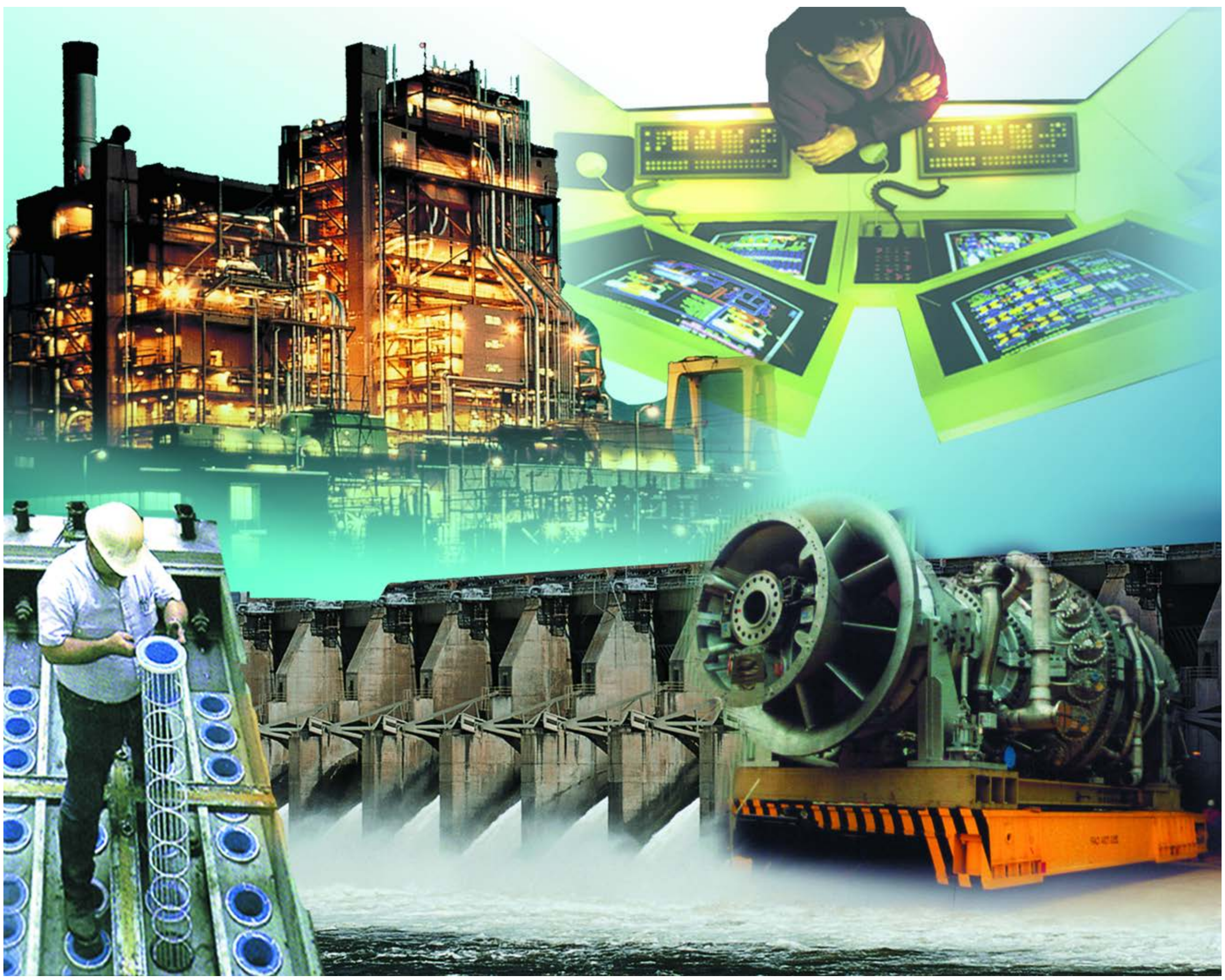

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Technical Update, December 2011

EPRI Project Manager

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THE FOLLOWING ORGANIZATION, UNDER CONTRACT TO EPRI, PREPARED THIS REPORT:

CEC Combustion Safety Inc.

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ACKNOWLEDGMENTS

The following organization, under contract to the Electric Power Research Institute (EPRI), prepared this report:

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This report describes research sponsored by EPRI.

This publication is a corporate document that should be cited in the literature in the following manner:

Guidelines for Fuel Gas Line Cleaning Using Compressed Air or Nitrogen. EPRI, Palo Alto, CA: 2011. 1023628.

PRODUCT DESCRIPTION

This document lays a foundation for helping the industry to better understand common practices, design basis, and issues to consider for performing fuel gas line cleaning using compressed air or nitrogen pneumatic blow processes.

Background

Commissioning incidents related to natural gas piping have caused concern in the power industry. Practices using natural gas blows for cleaning facility-owned natural gas piping systems, prior to putting them into service, have contributed to several significant explosion and fire events. The Electric Power Research Institute (EPRI) worked with industry experts, turbine suppliers and power companies to produce this document in response to the US Chemical Safety Board’s letter of June 28, 2010, requesting EPRI publish technical guidance addressing the cleaning of fuel gas piping supplying gas turbines using inherently safer methods such as pneumatic blows.

Objectives

To provide practical information to conceptually plan pneumatic blow cleaning processes using air or nitrogen, and to provide a basic foundation of knowledge regarding fuel gas piping systems related to the power industry and information about important concepts such as cleaning force ratio momentum factors to optimize the cleaning effect.

Approach

The report includes a description of the basic design elements of gas transmission delivery piping systems, gas yards and gas conditioning systems to provide a foundation of knowledge regarding the arrangement of these systems, components, and how they serve combustion turbine systems. The document next addresses the more common methods of gas line cleaning. The focus of the document is pneumatic processes, including compressed air and nitrogen. Calculation methodologies are provided, along with rules of thumb for these processes, as well as safety considerations and sample project information.

Results

There is a significant body of knowledge regarding pipe cleaning methods, including those related to pneumatic blow processes. These processes have been used successfully in many power facility applications. The reader can apply the concepts in this document to enhance the chances for a successful and safer project.

Applications, Value, and Use

Although natural gas has occasionally been used as the fluid medium for cleaning, pneumatic blowing using compressed air or nitrogen has the benefit of avoiding flammable and potentially explosive fuel/air mixtures near the exhaust of such blows. Given the possible expanded role of natural gas fuel in the future of electrical power generation, this document is a resource for understanding natural gas systems associated with power facilities, and for key insights into reducing risks and hazards associated with fuel gas supply piping cleaning processes. With this document, EPRI has assembled technical guidance to enhance the level of knowledge for cleaning natural gas lines using compressed air or nitrogen as a part of commissioning processes.

Keywords
Natural gas
Fuel line piping
Cleaning force ratio
Pneumatic blows
Pigging
Water jet flushing

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INTRODUCTION

Gas Line Cleaning Incidents in the Power Industry

The electric power industry has faced significant tragedies related to fuel gas systems and natural gas line cleaning during commissioning processes. The most recent and most significant was the Kleen Energy power plant explosion, February 7, 2010. This was a new 620 MW combined cycle plant located in Middletown, Connecticut that was close to completion at the time of the incident. This incident occurred when natural gas ignited as it was being used as a cleaning medium to blow lines free of debris prior to start-up. This incident left 6 people dead and injured more than 50 people. The natural gas pressure used for cleaning was at approximately 650 psig (4,480 kPa). A total of 15 natural gas blows were completed intermittently over about 4 hours through open ended pipes located strategically throughout the site. The gas blow that immediately preceded the incident involved natural gas being released between two heat recovery steam generators (HRSG) in a partially confined area. The large volume of gas, estimated to be about 480,000 standard cubic feet (13,600 m^3), found an ignition source and created a deflagration that devastated the facility.

A similar natural gas blow incident occurred on January 26, 2003 at Calpine's Wolfskill Energy Center natural gas power plant in Fairfield, California. In this case high pressure natural gas at about 630 psig (4,340 kPa) was vented to atmosphere from a piping system to flush it of debris. The natural gas blow was performed in a congested area only about 10 feet (3 m) from the gas turbine building. The gas discharge made for an accumulation near a building overhang. This accumulation of natural gas found an ignition source and made for an explosion that sent debris over the heads of seven people that were present and standing between 80 and 140 feet (24 and 43 m) away from the discharge area. No injuries were reported but windows were shattered a quarter of a mile away.

Another natural gas blow incident was reported in October 2001 during commissioning of fuel gas piping at the Ohio Edison facility in Lorain, Ohio. In this case the cleaning processes included pigging, an air blow, and then a final high pressure natural gas blow. The incident report indicated that a short 3 foot (0.9 m) stack was used to discharge the gas. Shortly after commencing the gas blow, the gas ignited causing a flame to shoot 30 to 40 feet (9 to 12 m) from the stack outlet. Personnel immediately shut off the gas flow to extinguish the fire. No injuries were reported but there was damage to electrical cables.

The US Chemical Safety Board in 2010 conducted research into commissioning practices and found that a significant number of facilities are commissioned with blowing/cleaning processes using compressed air or nitrogen and that this is a safer and preferred practice to using natural gas as a cleaning medium. There are a considerable number of new facilities to be built and commissioned within the United States over the next 20 years. It is anticipated that this document lays a foundation for helping the industry to better understand common practices, design basis, and issues to consider for performing gas fuel line cleaning using compressed air or nitrogen pneumatic blow processes.

What This Document Provides

This document first provides an overview of natural gas systems related to power industry facilities. It attempts to provide a foundation of knowledge beyond that necessary for only understanding cleaning processes. It is intended that with this broader perspective the reader will be more effective in directing, evaluating, and implementing safe and effective cleaning processes for the commissioning of natural gas piping systems.

The document then provides an overview of the more common techniques in use in the industry for fuel gas line cleaning with the understanding that the state of the art of these processes continues to advance. These include pneumatic pipe blowing using air or nitrogen, pigging, and water jet flushing technologies. These additional processes are described from an overview perspective to provide awareness of their application and to provide some basic background. The document's focus is pneumatic pipe cleaning process information and this topic is discussed in the most detail. The term "pneumatic" is used throughout the document to refer to the possibility of using either compressed air or nitrogen for pipe cleaning (recognize that air is 78% nitrogen). The use of more than one cleaning process for servicing an entire piping system is typical. This document provides the reader with an understanding of the important basic elements for conducting safer and more effective pneumatic pipe cleaning. These include a checklist of factors to consider, a description of cleaning force momentum ratio concepts, and rules of thumb and expectations regarding the blow processes including duration of blows, numbers of blows, and methods for evaluating cleaning effectiveness.

This document also provides a framework to develop a cleaning specification that includes "build it clean" concepts. It does not however provide specific tables for determining actual pipe charging conditions, equipment capacity selection tables, or methods for determining particle size or volumetric cleanliness. This kind of detail is not possible for a document of this scope considering all the variables that could exist. Design of the piping networks, the specific sections being cleaned, and the cleaning equipment to be installed as part of the systems operational requirements are site-specific considerations and are also not addressed in this document. This document does not replace the knowledge, experience, or skill that will most certainly be required of the Engineer/Procure/Construct (EPC) and commissioning team.

Modeling fluid flows and velocities makes for the most reliable understanding of whether or not acceptable cleaning force momentums have been achieved. This kind of modeling is somewhat sophisticated and requires specialized software and engineering knowledge to apply correctly. This document does not describe specific modeling software capabilities although it does discuss goals for those applying models in attempting to understand what velocities to solve for and how to configure these models to derive information needed for maximum cleaning effectiveness.

Lessons Learned

The types and methods for cleaning natural gas lines must be considered early in the design stage of any project. With proper planning, pneumatic blows using compressed air or nitrogen can be among the safest and lowest overall cost processes available.

Piping systems need to be constructed with effective cleaning segmentation as an important design consideration. This must include considerations for periodic isolations, branch take-off isolations, and locations for temporary piping take-offs for discharges. Furthermore, these important segmentation design elements need to be verified in the field as the myriad of special field considerations start to occur.

It is also very important that specifications include considerations for contractors to “build it clean” and to “preserve the cleanliness”. This consideration should be an enforced, inspected, and staffed part of every job and become an established culture within the construction contractor’s organization.

2
BASIC DESIGN ELEMENTS OF FUEL GAS PIPING SYSTEMS FOR POWER/UTILITY FACILITIES

Interface with Service Line from Gas Transmission

Before one can begin to effectively understand gas line cleaning and commissioning processes it is important to understand the basic design elements of gas transmission delivery piping systems, gas yards and gas conditioning systems. Hence, this document starts with a description of these systems. The world of gas piping systems for power and utility facilities usually begins with a transmission line at some distance off the property or battery limits. In some cases this line is owned by the generation entity or a subsidiary. However, in most cases this line is owned and operated by a third party entity that provides service to a gas yard somewhere on the plant property. There is some important delineation or demarcation point where a change of custody occurs for the gas. This point could be identified by contract documents a flange or pipe section or at a valve or metering station. This section of piping from the transmission line to the gas yard is usually something that gets designed as per the Code of Federal Regulations Title 49, CFR Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards (see Chapter 3 for information about US Federal DOT and PHMSA guidelines). The sections of piping covered by these standards usually include considerations for corrosion protection and for future line cleaning, (pig receivers and launchers).

Gas Yard and Fuel Conditioning

As shown in the following figure, the fuel gas from the service line passes through the main shut-off valves and, in some cases, through a dew point water bath heater. A pigging receiving station may also be included. A fuel gas compressor may also be required, depending on the final pressure requirements for the gas turbine. If the main transmission line is at high pressure, the gas then flows through pressure regulators to a coalescing filter and then in some cases through an odorant insertion station. Then the gas flows to the turbine gas conditioning skid that may include an additional heater, prior to flowing to the fuel manifolds and control valves at the turbine enclosure.

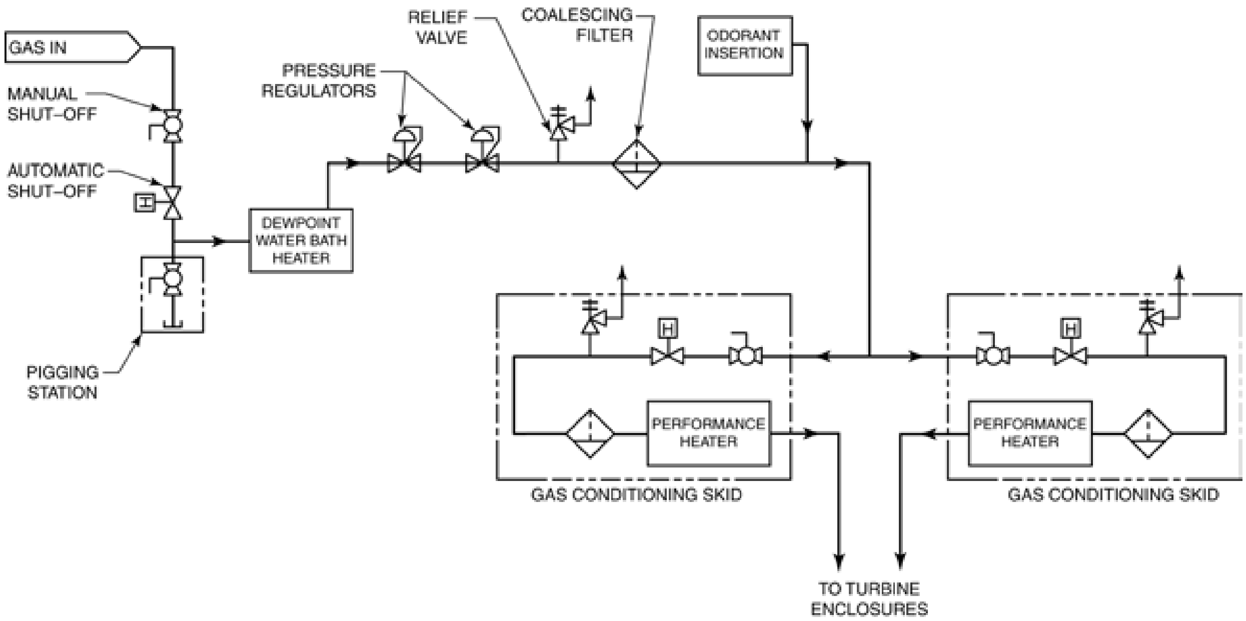


Figure 2-1
Typical Schematic Arrangement of Gas Yard and Fuel Conditioning

This simple schematic is provided for purposes of showing how major fuel gas system components might be inter-related to each other. The “gas conditioning skid” can be complex and can include a series of scrubbers, filters, by-passes, block valves, blend valves, control valves and other components. The conditioning skid can be among the most complex pieces of the entire system to clean; careful planning will need to take place to do this correctly and without damaging equipment.

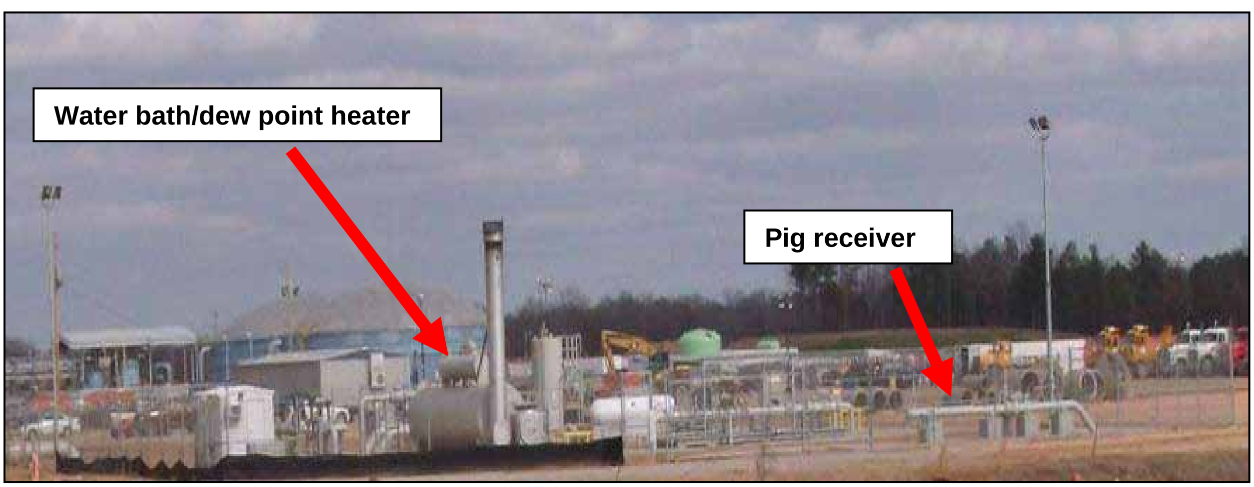


Figure 2-2
Typical Gas Yard for a Combustion Turbine Facility

Main Shut Off

The first place where transmission line gas piping might enter a property is typically called a gas yard. There are usually many shut off valves at a gas yard. Some of these are part of the gas utility or gas transmission company's piping and others are part of the customer's plant piping. The demarcation point is typically the discharge of the gas meter. It's important for the owner of a facility to know and designate which manual valves are designated as the customer's manual shut off valves and which of these would be used in an emergency to isolate the plant. In addition to a manual shut off valve, many sites also have an automatic valve in place that has actuators and can be remotely actuated. Many of the automatic valves are natural gas pressure actuated and have manual hydraulic pump back-up systems. Some have pneumatic or electric actuators. There are many styles of manual shut off valves and automatic valves. It's important that all valves be maintained and function tested periodically.

Figure 2-3
Trunion Mounted Style Ball Valve with Gear Wheel Operator and Position Indicator

Pig Receiver/Launcher

Many gas yards contain a pig receiving/launching station, (pigging station). There are many styles and types of receiving/launching stations. The design of the pigging station is usually commensurate with the design of the piping system and intended pigging that might need to occur. There are federal regulations which require periodic pigging and, since piping regulated by the federal Department of Transportation (DOT) usually is provided up to and into the gas yard, pig receivers are sometimes located in the gas yard. NFPA 56 also addresses safety considerations for the design and operation of pigging stations.

DOT regulations require that all new and replaced transmission piping systems be "designated and constructed to accommodate the passage of instrumented internal inspection devices", except for station piping including "compressor stations, meter stations, or regulator stations" (49 CFR Part 192.150). Most facilities require inspection of the transmission service at some time in their operating life, and smart (instrumented) pigging is the most common method of inspecting transmission piping.

Figure 2-4
Gas Yard Pigging Station Receiver/Launcher

Pressure Regulation & Relief

Interstate transmission pipelines usually operate at much higher pressures than those used within a power facility, although some power plants operate turbines at transmission line pressures. The pressure delivered to the gas yard can be 1,000 psig (6,895 kPa) or more. This gas is usually dropped in pressure through a series of regulators to between 500 and 700 psig (3,450 and 4,825 kPa). In most cases when gas is dropped in pressure some type of overpressure protection is provided for protection in case of a regulator failure. This protection is usually a relief valve or series of relief valves. Understanding the discharges from these relief valves and making sure that the areas surrounding these discharges have the proper electrical hazard classification is important.

The act of reducing the gas pressure drops its temperature. There is about a 1 F drop in gas temperature for every 15 psig drop in pressure (1 C drop in temperature for every 103 kPa drop in pressure). Gas that is very cold can make for cold wet dripping and even icing of piping and components. In cases where the pressure drop is large, hydrocarbons and water vapor can be condensed inside the pipe. Hydrates and liquids inside of gas lines can clog instrument sensing lines. Wet dripping pipe accelerates external corrosion. For all of these reasons, water bath dew point heaters are sometimes provided to increase gas temperatures,

Figure 2-5
Typical Gas Yard Pressure Regulators

Dew Point/Water Bath Heaters

Dew point or water bath heaters are fired heaters that heat the natural gas to prevent it from being too cold (below design conditions) as its pressure is reduced and it is distributed throughout the facility. These heaters can be either before or after the main regulator stations. These heaters are usually shell and tube heat exchangers with a series of small diameter tubes that the natural gas passes through. These tubes are submerged in a bath of heated glycol water. The water bath is usually kept at about 160 to 180 F (71 to 82 C). Typical gas delivery temperature from these heaters is 80 to 120 F (26 to 49 C) depending on the systems design and their placement. Additional heaters are often used for gas turbine performance enhancement and are located on the gas skid closer to the turbine. These can increase the gas temperature to 350 F (177 C) or more in the case of some manufacturers' larger capacity systems (typically over 25 MW).

Figure 2-6
Typical Dew Point/Water Bath Heaters

Odorization Systems

Commercially available natural gas is mostly methane which has no natural odor. Odorant can be added if it is to be a design feature of the facility. Not all facilities use natural gas that is odorized. The odor typically associated with natural gas is a chemical called mercaptan, (a sulfur compound similar to skunk odor). This chemical can be added upstream of the gas yard either in the transmission system or at the gas yard. Odorization must be applied to very carefully controlled specifications. The DOT regulations, Title 49 Part 192.625, have requirements for gas odorization. The concentration of mercaptan is a key gas safety parameter that must be monitored and managed by the provider if it is added. No facility or operations personnel should ever rely on mercaptan as being an effective indicator of the presence or absence of natural gas in the environment. There are many factors which can impact one's sense of smell, especially when it comes to detecting mercaptan.

Mercaptan can be absorbed by new steel pipe and other materials. This phenomenon is called "odor fade". Not all persons are able to detect the odor and there are also conditions which make it less detectable by certain persons, including the aged and those with medical issues such as sinus problems. It's also possible for chronic low levels of mercaptan to desensitize person's sense of smell. This is called "odor fatigue". This means that if someone is exposed to a mercaptan environment, they may not be able to effectively detect it in the future or be able to discern different mercaptan levels. This is one of the reasons that one can never rely on the smell of odorized natural gas for determining its presence or concentration. Instead properly calibrated meters or detectors should always be used to determine its presence or concentration. In some cases, depending on presence of flammable materials in the area, electrical devices such as gas detectors must be intrinsically safe or explosion proof.

Figure 2-7
Gas Odorization System

Filters (Coalescing and Particulate)

Particulate and coalescing filters are an important part of the natural gas piping system. Permanently installed filters are usually located in the main gas distribution system; final filters are located immediately before each gas turbine unit to capture smaller particles. There is then usually an additional strainer of some type inside the turbine enclosure to act as a final stop for gas particulates.

Particulate filters should be a mesh or filter element that traps debris that could cause immediate turbine damage or accumulate and cause corrosion. Turbine manufacturers can provide guidance in this area. Coalescing filters are designed to bring together small liquid droplets to form larger droplets that would then remain within the vessel due to a velocity drop or impingement so they can be drained and removed.

Figure 2-8
Coalescing Filter Installation

Gas Conditioning Skids

Once gas is delivered to a site at a gas yard, reduced in pressure, warmed up, and cleaned it is piped to each conditioning skid to get further specific processing before it is burned in the gas turbine combustors. These skids often contain metering equipment, further pressure regulation, filtering and performance related gas heating systems. A discussion of some of these systems follows.

Metering

Some facilities meter at the gas yard for custody transfer and then again at individual units to allow for an evaluation of performance. Metering is usually with temperature corrected turbine meters, Coriolis effect meters, orifice plates or annubar metering technologies.

Heating for Performance

Many gas turbine systems, particularly those with DLN (dry low NOx) combustors, use natural gas that is heated to over 300 F (149 C) immediately prior to the combustion system to enhance combustor performance, manage fuel characteristics such as calorific density (as measured by Wobbe Index) for active control systems, and improve performance for possibly additional energy recovery and system efficiency. There could be separate turbine combustion system pilot gas lines that are not heated. Heating is done in many ways including with steam shell and tube heat exchangers and electric resistance circulation heaters.

Figure 2-9
Typical Shell and Tube Heater for Heating Natural Gas to Meet Turbine Performance Requirements

Shut off/Flow Control

Some type of remote automatic shut off valve is usually included. These valves are typically pneumatically actuated (instrument air or natural gas) and also usually include a “fail safe” spring return close feature. These are intended to allow for emergency isolation of units.

Relief Valves

In many cases, relief valves are also included at gas conditioning skids. These relief valves serve as a final protection in the case of regulator failures upstream of the skid. These can be full flow capacity or "for fire" sized. The location and orientation of the discharge vents from these is an important consideration.

Final Section of Piping from the Skid to the Turbine Enclosure

In many cases additional protection from pipe contamination is provided by constructing the last section of pipe between the gas conditioning skid and the unit out of stainless steel. This avoids long term issues associated with corrosion that could allow rust and other contamination to pass directly to the combustors.

Turbine Fuel Train Considerations

Once the gas comes into the turbine enclosure there are usually a series of isolation and flow control valves. There are both manual valves for isolation and double block and bleed automatic valves. This usually includes a flow or throttling valve for speed control.

Figure 2-10
Fuel Train Inside Turbine Enclosure

3

REGULATIONS, CODES, AND STANDARDS RELATED TO GAS PIPING FOR POWER PLANTS AND UTILITIES

The following is a summary of relevant regulations, codes, and standards used in the United States for natural gas piping systems that may be associated with power and utility operations. In some cases these documents describe construction and operation of piping systems. In some cases these provide insight into safe cleaning and commissioning activities. The purpose of this section is to make readers aware of these documents as guidance for planning for cleaning and commissioning activities beyond what are provided with this document. The reader should pay particular attention to NFPA 56 which is the newest standard published in August 2011. It forms the core of the only formal flammable gas work practice guidance available in the world today. The documents described below in more detail include the following:

1. Title 49 CFR Part 192, Federal regulations administered by the Pipeline and Hazardous Materials Safety Administration of the U.S. Dept. of Transportation (DOT)
2. ASME B31.1, Power Piping by American Society of Mechanical Engineers
3. NFPA 54, National Fuel Gas Code, by National Fire Protection Association
4. NFPA 56 , Standard for the fire and explosion prevention during cleaning and purging of flammable gas systems
5. NFPA 850, Recommended practice for fire protection for electric generating plants and high voltage direct current converter stations

US Federal Government

DOT 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards

While DOT issues federal regulations, PHMSA is the Pipeline and Hazardous Materials Safety Administration, and its mission is to protect people and the environment from the risks inherent in transportation of hazardous materials by pipeline and other modes of transportation. Their website is www.phmsa.dot.gov.

PHMSA helps to create and administer the parts of the Code of Federal Regulations, (CFR) related to gas transmission pipelines. These are title 49 CFR parts 190 to 199. These regulations generally apply to gas piping systems up to a customer’s connection and line of demarcation, (i.e. custody transfer). It is important that every owner operator understand where DOT regulated piping starts and stops on their property.

Many of the technical requirements for natural gas piping systems are found in Title 49, CFR 192, Transportation of Natural Gas and Other Gas by Pipeline, (minimum safety standards). This provides information on piping materials, components, pipe design, welding, corrosion controls, operations and maintenance, operator qualifications, and pipeline integrity management.

American Society of Mechanical Engineers

The American Society of Mechanical Engineers (ASME) publishes a family of piping standards covering Power Piping, Fuel Gas Piping, Process Piping, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, Refrigeration Piping and Heat Transfer Components and Building Services Piping. Their website is www.asme.org. These documents describe the selection of piping materials, their installation and joining methods, and pressure testing.

B31.1 - 2010 - Power Piping

This code prescribes minimum requirements for the design, materials, fabrication, erection, test, and inspection of power and auxiliary service piping systems for electric generation stations, industrial institutional plants, central and district heating plants to include natural gas piping systems.

The code covers boiler external piping for power boilers and high temperature, high pressure water boilers in which steam or vapor is generated at a pressure of more than 15 psig (103 kPa); and high temperature water is generated at pressures exceeding 160 psig (1,100 kPa) and/or temperatures exceeding 250 degrees F (121 degrees C).

ASME also has a process piping standard (ASME B31.3) which is used by some designers for natural gas and other piping systems design within power facilities.

National Fire Protection Association

The National Fire Protection Association (NFPA) publishes a series of codes and standards. Their website is www.nfpa.org.

NFPA 54 - 2012 National Fuel Gas Code

The National Fuel Gas Code is adopted as law by several states. This document provides requirements for fuel gas piping operating at up to 125 psig (860 kPa). It specifically excludes power plants and electrical utilities from its scope. It covers both natural gas and propane. The document includes sections on piping materials to be used, pipe joining methods, pressure testing, and some information about purging into and out of service. The document does not address pipe cleaning or commissioning operations. After several gas piping incidents, the US Chemical Safety Board asked NFPA to review the document for its effectiveness at addressing safe gas purging practices. Thereafter a tentative interim amendment (TIA) was released in August of 2010. This TIA has a number of key changes that are important to understand for those working within the parameters covered by this documents scope. The TIA is incorporated in the 2012 edition of the document. Whenever reviewing any NFPA consensus codes it's vital to identify and carefully review TIAs that might exist.

NFPA 56 (PS) - 2012 Standard for the Fire and Explosion Prevention During Cleaning and Purging of Flammable Gas Systems

This standard was recently created by NFPA at the request of the US Chemical Safety Board after the Kleen Energy and other related incidents (the US Chemical Safety Board is an independent federal agency charged with investigating industrial chemical accidents). NFPA 56 (PS) was released to the public as a Provisional Standard in August, 2011. Provisional Standards from the NFPA are developed using an expedited process where an emergency condition exists. NFPA 56 is the first Provisional Standard developed by NFPA, and only the second NFPA

Provisional Standard ever developed by any organization in the United States. Provisional standards, within the NFPA's process, immediately enter into the normal revision cycle.

NFPA 56 covers safe work practices for flammable gasses and all natural gas and liquefied petroleum gas systems outside the scope of the national fuel gas code (NFPA 54). NFPA 56 is one of the most directly relevant documents available for the safe commissioning of natural gas piping systems for power and utility operations. Experts collaborating on NFPA 56 agreed on several findings related to fuel gas line cleaning, specifically: (1) "Fluid media for testing or cleaning shall not introduce a flammable atmosphere into or create a fire hazard in the piping system being tested or cleaned;" (2) "Flammable gas shall not be used for internal cleaning of piping;" (3) "Air, inert gas, steam, or water shall be acceptable cleaning media except…[that] …a pig shall be permitted to be used to clean piping systems; "and that (4) "Pig cleaning using flammable gas as the propellant shall utilize a closed system." Refer to NFPA 56 (PS) for details.

In some cases, a system may already be in service or is being expanded. In these cases, safely removing existing flammable gasses and safely purging the piping into and out of service is very important. NFPA 56 provides for safe practices for performing these kinds of activities where there can be risks from releasing flammable gases from venting processes and purging. Also, there are software tools available for dispersion modeling of vented gasses. The US EPA has a software tool (ALOHA) available at no cost from its website that models dispersion of gasses once they are released. One should be sure to completely understand all of the limitations of modeling of this type before making important decisions about the accuracy and use of this kind of information.

It's important for those that are planning this kind of work to understand that besides national consensus standards like NFPA 56 there are also state slaws, rules and regulations that will have to be considered. For example, on July 8, 2011, after the Kleen Energy plant explosion, the State of Connecticut passed a law banning the practice of "using flammable gas to clean or blow the gas piping of an electric generating facility" (see Public Act 11-101, section 1:http/www.cga.ct.gov/2011/ACT/PA/2011PA-00101-R00HB-05802-PA.htm). These kinds of laws may be more stringent than consensus standards.

NFPA 850 - Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

This document covers basic design and construction elements associated with combustion turbine power facilities and convertor or transformer stations. It includes a number of elements regarding fuel systems and includes a TIA 10-2 (tentative interim amendment), issued on 10/20/10 that has a number of important recommendations regarding the cleaning and commissioning of natural gas piping systems for power and utility operations. It also includes specific mention of pipe cleaning methods.

Note that all NFPA Codes, Standards, and Recommended Practices can be viewed, but not copied or printed, at no cost from www.nfpa.org.

4
PIPING SYSTEMS SOURCES OF CONTAMINATION

The best way to avoid extensive pipeline cleaning processes is to avoid contamination. There has been considerable work done to develop clean fabrication and installation processes. This chapter discusses the forms of contamination that are often observed in natural gas piping systems and provides a framework for avoiding them.

The specific types of contamination observed include the following:

a. Iron Oxide (rust)
b. Pipe Mill Scale
c. Welding Slag
d. Other miscellaneous debris
e. Water vapor and free water from hydrotesting or other water based processes including flushing

Iron Oxide Inside of Piping Systems

Iron Oxide is one of the biggest sources of gas piping contamination that must be removed so that it cannot be carried downstream to continually clog filter elements and plant equipment. If enough iron oxide is present during a blow it can appear at the end of the pipe as a large orange or brown plume during initial blows.

Figure 4-1
Iron Oxide and Debris Coming from Pipe

Iron oxide (rust) can occur within new steel piping if it is not carefully managed through the storage and installation process. Moisture can be introduced through weather conditions that could include precipitation. However, even changing temperature conditions where dew point occurs during humid conditions can make for moisture on unprotected pipe and subsequent rusting.

Moisture can also be introduced through hydrostatic pressure testing processes and water jet or water aeration flushing where moisture is not completely removed. Flash rusting is a phenomenon that can occur quickly and spread if steps are not taken to include chemical inhibitors with water-based processes.

It's important to determine how water will be promptly removed and piping protected after water-based processes. Steps usually include some form of pigging to mechanically remove residual water followed by air drying and some type of chemical inhibitor or passivation agent.

Figure 4-2
Inside of Pipe Before and After Water Jet Flush

Photos courtesy of Hydromilling Group

Pipe Mill Scale

Mill scale is formed on the outer surfaces of steel sheets as they are produced by hot rolling steel. These sheets are then converted to piping with the inside of the pipe containing mill scale. Mill scale is formed at a temperature of a minimum of 900 F (482 C), and is composed of mostly iron oxides that are mostly bluish black in color. This material is usually less than a millimeter thick and initially adheres to the steel surface. Any break in the mill scale coating will cause accelerated corrosion of steel exposed at the break. Thus, mill scale helps to prevent corrosion until its breaks off the surface due to some mechanical cause like expansion and contraction of the pipe, temperature changes, and even scouring from fluids at high velocities. Newly installed pipe is vulnerable to this mill scale coming off over time. This is why cleaning processes seek to intentionally remove as much loose scale as possible before start-up.

Pickling, or acid removal of mill scale, is available for carbon steel piping. However, this is usually reserved for smaller sections within specialized applications like lube oil systems. Stainless steel piping is another approach for avoiding mill scale, and many facilities use stainless steel on the final connection to equipment and combustors.

Weld Slag & Spatter

Weld slag is the residue left on a weld bead from the flux. It shields the newly deposited weld metal from atmospheric contaminants that will weaken the weld joint. Spatter is globules of molten metal that are expelled from the joint and then re-solidify on the metal surface.

Welding processes require that two pieces of pipe be first beveled and then brought together so that welding processes can melt adjoining materials and become part of the base metals. This first deposition of weld materials occurs at an area that can be melted through and make for small particles to drop into the pipe during the first pass of the welder called the "root pass". Once the root pass is in place additional layers are placed on the weld to fill in the joint.

Specialized welding processes are usually called out for root passes as are processes to mechanically swab or wire brush joints from the inside after each weld to minimize contamination.

Other Debris

There can be many other materials and conditions inside a pipe that could contaminate a fuel gas system including random debris like welding rods, pieces of gaskets, and even materials completely unrelated to piping system installations like soda cans.

“Build it clean” is a phrase used often when describing processes that are aimed at minimizing contamination. The following are key considerations for “building it clean” processes.

Figure 4-3
Foreign Material Exclusion Covers on Pipe Ends

Design piping with a particular method of cleaning in mind so as to facilitate removal of debris upon installation, including avoidance of unnecessary or inaccessible dead legs, low points and abrupt changes in flow path or diameter, and careful sizing and placement of vents, drains and removable spool pieces, among others. Many of these features are difficult to see and conceptualize on a drawing. In many cases they will need to be implemented under the careful eye of a field piping superintendent at the job site as pipe is being installed.

a. Carefully specifying and monitoring welding techniques and changing the way root passes are installed to minimize protrusion of weld beads and the presence of pipe bore slag.
b. Cleaning individual piping spools upon fabrication or in place as they are installed.
c. Consider chemical rust inhibitors and laying up piping with nitrogen instead of air prior to placing in service.
d. Pickling of critical pipe sections or using stainless steel.
e. Careful removal of moisture and control of piping storage and handling.
f, Careful control of foreign objects on job sites and the use of foreign material exclusion caps on piping sections as they are stored and after they are installed.

Water Vapor or Free Water from Hydrotesting or Other Water-Based Processes

Residual water and water vapors can be present from hydrotesting of piping pressure capabilities or from cleaning processes like water jet flushing. Turbine manufacturers have specifications for maximum water vapor content in fuel gasses. If water and water vapors are not properly removed these too can become sources of contamination which can fail the turbine manufacturer's criteria and cause damage to equipment.

Removing residual water is usually done with a series of pigging, free blows, and or some form of controlled air drying involving the passage of low relative humidity air through the piping systems. Low relative humidity air is usually generated by heating air or using dried compressed air. Compressed air dryer systems are discussed later in this document. These are available as refrigerated dryers and desiccant dryers. Desiccant dryers make for much lower relative humidity air than do refrigerated dryers.

5
FUEL GAS PIPING SYSTEM CLEANLINESS REQUIREMENTS

This chapter provides the reader with insight into what end cleanliness goals are targeted. Although turbine manufacturers typically require power plant owners to meet very specific fuel cleanliness requirements so as not to void warranty requirements, accepting as "clean" the major piping components is a somewhat subjective practice. It is expected that the formal operational cleaning systems in place (like filters and strainers described previously) will prove adequate if the subjective tests described in this section for the new piping systems are completed in a satisfactory manner.

The requirements of the major pipe cleaning processes are usually agreed upon in advance of being performed and witnessed by the turbine manufacturer's site technical representative. The following describes specific combustion turbine contamination issues that designers and operators are trying to avoid.

Combustion Turbine System Component Contamination Issues

The possible issues within combustion turbines that can come from fuel contamination include fuel combustor clogging, injector nozzle wear, and blade particulate impingement. Turbine manufacturers publish overall contaminant loading guidelines where air and fuel contaminants are considered. The design of most systems is for fuel gases to be introduced into combustor cans positioned in a radial pattern around the hot end of the turbine. These combustor cans usually have some number of relatively small holes or nozzles that discharge the gas for it to be ignited. These small holes can become clogged with debris or eroded, compromising performance. Getting into the combustor cans to clean them out can be time consuming. All of this can impact plant performance, reliability, and maintenance costs.

Manufacturer Fuel Cleanliness Requirements

The following table represents data excerpted from manufacturer specification sheets related to fuel cleanliness requirements. These criteria define what is required for the continuous operation of their equipment and speak to the complexity of filtering equipment required for removal of particulates. The cleaner the fuel piping systems at start-up, the more effective and longer lasting the operational filter media should be. Information for finding fuel cleanliness details for gas turbine manufacturers are referenced in the appendix. Manufacturer's guidelines and requirements are subject to change. Always consult with the manufacturer to be sure that the latest guidelines are being used whenever systems that can impact cleanliness are addressed.

Table 5-1
Example of Turbine Manufacturers Fuel Cleanliness Requirements

Manufacturer	Maximum Particle Size (micrometers)	Particle Concentration (ppm, wt)
General Electric	10	28
Mitsubishi	5	30
Pratt & Whitney	10	30
Rolls-Royce	20	NA
Siemens	10	20
Solar Turbines	10	20

Note: always refer to the OEM's specifications for the definitive statement of their technical position regarding fuel cleanliness requirements.

Strike Targets for Cleanliness Evaluation

Cleanliness requirements are usually met by demonstrating that the number and size of impact marks made on a target (a specially configured piece of wood or metal placed in the flow path coming out of the end of the fuel gas line) after a pneumatic blow meet some specified criteria. The acceptance criteria can be somewhat subjective, but is mutually agreed upon between the contractor and other interested parties. For example, parties may agree that cleanliness criteria are met after a minimum of 10 blows where no more visible plume occurred followed by 3 successful target blows where no more than 5 impacts were seen on the strike target material.

Strike targets take many forms. These can be anything from highly polished stainless steel to aluminum, or plywood painted white. There is also much variability in the size and placement techniques. This too is largely an experientially derived trial and error process. In some cases targets have been affixed to the piping system such that the exit jet can impinge after about an 18" (46 cm) distance. Care must be taken to properly address the effects of back pressure, exhaust stream diversion, and the forces transferred to targets, target mounting apparatus and supports.

Interpreting target impacts is more of an art than a science. It's clear when a target has obviously failed. Target runs get progressively cleaner as blows continue. However, there could be random hits that occur after clean blows.

Temporary Piping Issues for Targets

Gas cleaning processes such as pigging and pneumatic blowing usually require considerable use of temporary piping; the extent would be clearly understood once sectional plans are created. This has to be planned in advance and is best accomplished during the design stage. There will be control valves and equipment in the pneumatic piping system that need to be either removed or bypassed prior to the cleaning process. Thermowells need to be removed, instrument lines closed, and discharge piping installed to direct pneumatic blows to safe areas. Temporary piping considerations, especially around blow control valves and discharge piping, need to include the jet or momentum effect of the escaping air or nitrogen coming out of the end of the system. This could require special supports to counter forces to be found at the ends. The sudden shock to piping systems and changes of direction involved in blows can also require that temporary supports be installed intermediately in systems where changes of direction take place, for example.

Figure 5-1
Temporary Piping for Pipe Pneumatic Blow Cleaning Discharge with Target Mounting Bracket and Outline of Where a Target Would Be Mounted

In some cases, temporary piping systems include hoses. This could, for example, be a consideration for air actuated blow valves and connections from compressors. Hose ratings and their coupling systems must have the appropriate pressure ratings and the appropriate connections. Whip checks (safety wires on or around couplings) should always be a part of systems where hoses are in use. Whip checks provide protection in the case of hoses or couplings accidentally coming apart. All temporary piping must be designed according to applicable code requirements. The applicable code is usually ASME B31.1.

6
PNEUMATIC BLOW CONSIDERATIONS AND PLANNING

The focus of this chapter is to make the reader aware of issues related to pneumatic blow cleaning processes using compressed air or nitrogen. Considerations for other pipe cleaning processes including line pigging and flushing (aerated water and water jet) are covered in chapter 9. This chapter introduces concepts such as breaking the entire system down into logical segments, cycle initiation techniques, sequencing of different cleaning and line integrity validation processes, blow cycles and their duration, along with safety issues to consider.

Pneumatic Line Blowing Overview

Pneumatic blow cleaning processes involve the discharge of a high pressure gas, (compressed air or nitrogen) through the piping systems in a series of rapid bursts interrupted by recharge cycles. When considering pneumatic cleaning options there are conditions under which both compressed air and nitrogen have merit. The issues to consider include whether air compressors of suitable capacity are readily available at the site, if storage in the form of a section of pipe, a new out of service boiler or some other suitably rated storage vessel or volume is available, and the system (what segments) are being cleaned.

Steam lines are typically cleaned and blown with steam in a manner analogous to pneumatic blows. The majority of fuel gas line cleaning is accomplished with compressed air blows that is clean and dry. Nitrogen is also available for use and in some cases can offer advantages over compressed air. However, the tradeoff is always the higher cost of nitrogen and the volumes required. Nitrogen also requires additional safety considerations because it is an asphyxiant. Even though air is 78% nitrogen, one full breath of pure nitrogen can render one unconscious or worse, (see www.csb.gov website for Valero or Union Carbide incident case study videos for more information about nitrogen asphyxiation hazards).

Line blowing effectiveness has been identified to be a function of the cleaning force ratio (CFR) that is achieved. Cleaning force momentum is the product of mass flow and velocity that would be moving through the piping system. The fluid momentum of the air or nitrogen near the pipe wall entrains particles at the wall into the fluid flow through aerodynamic forces. It is the goal of the cleaning process to pass a fluid (gas air or nitrogen) through the piping system that generates higher cleaning forces than can ever be achieved from the flow of natural gas during operations. Cleaning force momentum calculations must take into account the density of the medium used and changes in geometry of the piping system as might affect the velocity of the medium during the pneumatic blow process. Care must be taken in establishing the desired flow path, the sequence of blows, and the treatment of dead legs, branches and in-line elements. Example calculations for line blowing processes are presented in the next chapter.

Plant Piping Configuration for Pneumatic Blowing Cleaning Processes

Before any discussion about calculating CFRs, one must understand the basic approach behind splitting the overall piping systems up into logical discrete segments for pneumatic blowing. There are three primary elements that make up a well-planned and executed pipe system cleaning process:

1. Precisely defining the flow path of each blow.
2. Identifying the proper sequence of blows as among the various segments and sizes of piping to be cleaned.
3. Applying appropriate cleanliness criteria establishing the measure of successful cleaning.

The plant piping systems must first be evaluated and divided into logical segments that the planner deems appropriate for the optimal blow paths and sequencing. This is usually done by reviewing P&ID diagrams and mechanical piping layouts of the system while considering the physical piping and equipment relating to the operational cleaning processes. In-line elements and vessels may have to be removed from the flow path using temporary bypass piping or by removal of internals (such as filter elements). The blow process usually begins with larger bore piping in segments determined by the storage capacity of the cleaning medium and the delivery equipment (air compressors or nitrogen systems) capabilities. Upon cleaning the large bore segments, smaller off-take lines that were isolated from the large bore cleaning may be lined up and blown individually, using the clean large bore piping as an additional medium pressure reservoir by blocking in the large bore discharge. Temporary piping for all planned blows should incorporate necessary valving, target holders and other features enabling a more or less continuous process of logically sequenced blows, one leading to the next without intermediate construction work that adds to the cost with extension of rental equipment and personnel. One must also consider risks related to introducing debris into cleaned lines as subsequent blow paths are established. Generally the set up for each blow should be limited to lining up valves and loading target receivers as necessary. There are many factors to consider which will ultimately shape the cost of this commissioning step and how long it will take.

The selection of segments and defining of pressures (starting and ending) and storage will determine the number of compressors, where they are located, and how they are operated. If operating conditions are not optimized recharge cycles (recharging the system pressure back to what is needed to start another blow) and understanding the number of blows can add costly days to the schedule.

Piping Segment Issues to Consider

Blowing usually occurs following the path of the entering natural gas on the site. The first segment in the system can provide challenges because there may not be storage capacity ahead of it for the blow medium. In planning future segments this first segment can serve as a reservoir. However, unless a receiver (tank) is used or unless there is some other means to store air, (like an out-of-service boiler); the first segment can be a challenge. In cases where there is little or no storage, consideration may be given to configuring the blow in the reverse direction towards the feed end of the system for an initial set of blows.

In some cases those responsible for commissioning will have to decide how far back into the system makes sense for cleaning processes and with what cleaning expectations. For example, if the previously described segment was several miles of buried pipe with little or no storage capability conducting a number of blows with any type of system could be a challenge. In this case, pigging or nitrogen pumper trucks could be an alternative to the use of compressed air.

Project Sequencing with Other System Blows and Commissioning Processes

The overall sequence of cleaning and blows for all lines, not just natural gas systems, must also be considered. Other systems such as steam lines, boilers, hydraulic lines, etc. can also be part of cleaning processes. Coordinating all of these minimizes costs and time for the overall project. For example, pressure testing may be with water, (hydrotesting) and may be done for steam lines as well as natural gas lines. Hydrotesting requires that lines be dried after testing. The drying processes will probably include pigging and air blows which could be coordinated with other systems cleaning processes.

Pneumatic Blow Cycles

The number of blows required to achieve a certain cleanliness level cannot be predetermined. Field experience has indicated that this number can be in the 10 to 20 range on the low end to over 100 on the high end depending on many factors including the geometry of the piping system, construction techniques affecting the amount and type of debris and contamination inside piping systems, and the cleanliness levels desired. There are really two things that are occurring during each blow that are important. In one case, the cleaning force momentum is used to break loose and or dislodge materials. The remaining flow volume is used simply to transport these dislodged materials out of the piping systems. In most cases the majority of the cleaning or dislodging takes place with the first few blows. Subsequent blows remove less and make for a diminishing return as the pipe cleaning process continues..

Initiating Blow Cycles

There are two common methods for initiating blow cycles. One is the packing fracture blow method. The other is through the use of a fast opening full port valve. Opening the valve can be either through an actuator or with someone manually opening it depending on the valve size and project needs.

Packing Fracture Initiation Method

The packing fracture initiation method is an alternative to the use of a fast opening blow initiation valve for starting a blow. In this method a rupture plate or packing is placed between a set of flanges. The line upstream of the flanges is pressurized until the packing or plate fails immediately releasing a burst of pressure downstream. This packing or plate is replaced for each blow. The packing or plate is often constructed of a sheet of rubber or multiple sheets of some substrate with known rupture pressure characteristics.

Blow Valve Initiation Method

The blow control valve initiation method involves the use of a dedicated full port, fast acting, valve that is usually a full port ball valve. In some cases special relief valves are also used. This valve must be mounted securely with bracing to prevent it from experiencing movement from the actuator momentum when the valve needs to stop.

There is usually one person put in charge of initiating blows. This person usually also has control of an alarm system and is the single point of communication to lead the blow efforts. There would be a system pressure gauge visible or immediately accessible to this person so that blows can be started and stopped effectively. An alarm must be sounded to clear the area, especially the discharge area, before a blow occurs.

The opening time of valves is a critical factor in achieving the rapid momentum effect that is so important in making for an effective blow. The faster the valve moves the faster the desired flow conditions are established. The recharge rate of the compressors is slow compared to the discharge rate. The use of full port ball valves with an opening time of just a few seconds or less has been found to be effective for pneumatic blowing applications.

When these valves are 18” or larger for example, the valve opening and stopping forces can make for considerable momentum which can shear and fail valve stems. Opening valves this large this fast makes the anchoring of these valves, and all piping, structures and equipment very important. A qualified design professional should be charged with evaluating the dynamic and static forces of the blow and determining appropriate support requirements.

Frequent cycling of large diameter rapid open blow valves could lead to excessive wear. Lubrication and service of these valves might be required during the cleaning process. Continued use of these valves and consistent cycling can lead to seat damage and drag. Increased drag can lead to shear stresses on the valve stem over time and subsequent failure. Given the lead time of these kinds of valves and actuators, and the project delays that replacement or repair of valve failure can cause, many operators choose to have a spare close by.

The selection of actuators and their energy source, (compressed air or nitrogen from cylinders), can also be very important. The actuators in use might require higher pressure than the air system can deliver and possibly at different times than it is available. In many cases this means the use of dedicated compressed gas cylinders to operate these actuators. When using compressed gas cylinders to actuate valves care must be taken not to exceed the allowable pressure rating of the actuator.

Planning Considerations for Pneumatic Blowing Projects

The following are common considerations that should be reviewed when planning a pneumatic blow pipe cleaning project.

Noise/Silencers

Noise can be an important consideration in populated areas. Noise levels from blow discharges and diesel compressors can exceed community nuisance level standards. It is important to use silencers or other appropriate abatement means if noise is an issue. There are several vendors that rent silencers for large flow gas discharges.

Even when silencers are used, hearing protection will probably be required for those working within the area. It is also important that local authorities, including the police and fire departments, be made aware of pneumatic blowing operations and the noise that is generated so that they do not have to respond and disrupt operations for noises that seem unusual to neighbors.

Alarms

Alarms are required by NFPA 56 for pneumatic blow cleaning operations. Alarm systems are required to announce that a blow is about to occur. This will usually be an audible and a visual alarm prior to initiating the blow. All affected employees should be instructed regarding precautions to take when blows are about to occur. For example, being out of the way of discharge ends, and wearing proper personnel protective equipment (PPE), including eye protection, are especially important.

Consideration of Discharge Areas

Discharge areas should be free of personnel or property in the immediate discharge area of the exit jet. The exit jet can extend hundreds of feet from the pipe discharge. In most cases exit jets are turned straight up or directed towards open areas. Many different objects can exit the piping system including small weld slag pellets, flame cutting slag and fabrication leavings, wood, welding rods, nuts and bolts, hand tools, vermin remains and other materials that when propelled at high velocity can be immediately harmful to people and other property within range of the exit trajectory.

Initial blows can also release clouds of fine iron oxide dust from the inside of the system. This visible plume can travel some distance. It is common to have exit discharge areas barricaded off with red caution tape as well as personnel who watch over these areas to keep others away and verify the path of exiting debris.

Instrumentation and Control Systems Damage from Cleaning

Numerous thermowells, gauges, temperature indicators, and sensing lines can be attached to all of the piping throughout the system. Consider these components to prevent their damage and their possibly impeding the cleaning processes using pneumatic blows as well as other cleaning methods. For example, protrusions in the piping systems can stop or damage pigs. Instrument sensing lines can become contaminated and clogged. Control valves and orifice plates can be damaged by high velocity debris. An effective cleaning plan must consider removing some of these components and properly isolating others. It is also important to remember that certain filter, strainer and coalescing elements may need to be changed out early into the initial operating cycles.

Pneumatic Process Safety Considerations

There are many safety considerations for operating high pressure pneumatic systems. The energy contained in a pneumatic system can be substantial. Factors affecting the risk of exposure to hazards include the volume that is stored and its pressure level, among others. Major hazards include sudden ruptures of piping systems due to piping or fitting failures. These kinds of failures could result in projectiles and fragments along with a blast wave.

It is essential that all personnel involved in the conduct of compressed medium blows be fully briefed on the hazards, exclusionary zones, communication protocols, alarms, and emergency procedures relating to the blows.

Personnel near areas of risk like the compressors, blow valves, and or highest pressure areas of storage should be provided with areas of refuge that could offer protection in the case of an incident. Exclusion zones should also be provided for those not directly associated with the project to minimize risks.

One of the first layers of protection is to be sure that all temporary piping and fittings are fabricated in accordance to ASME B31.1 to meet the maximum expected pressure ratings of the systems. The following safety practices should be implemented prior to performing high pressure pneumatic blows and processes.

1. Comprehensive procedures must be created and implemented and written records should be maintained documenting that all personnel involved in the blowing procedures have attended training sessions in which the project procedures and all hazards have been reviewed.
2. Provide areas of refuge for anyone within exclusion zones. Areas of refuge may be needed to provide for substantial shelter.
3. Provide exclusion zones for those not directly associated with the project.
4. Complete a comprehensive review of all temporary equipment and piping including hoses and valves.
5. Consider conducting blows when jobsites are minimally staffed.
6. Consider NDT testing of welds that are in the highest pressure areas that will be critical to the integrity of the system being blown.

7
PNEUMATIC BLOW CALCULATIONS

This chapter presents the concept of cleaning force ratio (CFR) momentum calculation methodologies. These provide a method for understanding when velocity and flow conditions have the most chance for dislodging contaminates and moving them through the piping system. The aim is to provide the reader with the conceptual knowledge required to understand the calculations but does not replace the services of an experienced professional familiar with the detailed requirements for achieving the desired cleanliness results.

Cleaning Force Ratio (CFR) or Momentum Ratio Calculations

Line blowing effectiveness has been identified to be a function of the cleaning force ratio (CFR) momentum that is achieved. Cleaning force momentum is the product of mass flow and velocity that interacts aerodynamically with particulates extending beyond the pipe wall into the moving fluid at the fluid boundary. It is the goal of the cleaning process to pass a fluid (gaseous air or nitrogen) through the piping system with higher cleaning forces than would ever be achieved from the flow of fuel gas through the pipe during peak plant operations. A CFR of greater than one ensures that the momentum achieved during cleaning will exceed the momentum that can be expected during operations. Some turbine manufacturers have provided recommended CFRs of as much as 2. The presumption is that all or nearly all particles remaining attached to the pipe walls after pneumatic blows are unlikely to be dislodged during operations.

The cleaning force momentum ratio calculation is shown below in equation 7-1. It is calculated by taking the mass flow squared times the specific volume of the fuel gas as it will flow during maximum operating conditions. That value is the denominator in the momentum ratio fraction. The numerator is the product of mass flow and specific volume of the cleaning medium during blow conditions. The target or ideal CFR has been identified in several case history publications as having a value of between 1.2 and 2.0. These publications have also presented that CFRs of greater than 1.2, (representing velocities of more than 20% above maximum expected flow conditions), have contributed little to encouraging more substantial cleaning. Providing more than the target flows for higher CFRs often adds to the cost and time required for the project to be completed. Importantly, care must be taken to consider changes in pipe bore size so as to maintain the desired CFR throughout the flow path of the cleaning process.

The following formula represents the calculation described above:

$$CFR = \frac{M(blow)^2 \text{ X } V(Blow)}{M(ref)^2 \text{ X } V(ref)}$$

M(blow) = Mass flow of medium used for blowing (Air), lbm/sec (kg/s)

V(blow) = Specific volume of blow medium (Air) during the blow, ft^3/lbm (m^3/kg)

M(ref) = Mass flow of Natural gas under maximum load conditions lbm/sec (kg/s)

V(ref) = Specific volume of Natural gas under lowest possible pressure to achieve the maximum flow conditions, ft^3/lbm (m^3/kg)

What has to Be Determined?

The following needs to be determined for conducting pneumatic blows for any cleaning project:

a. Identify the starting pressures required to obtain velocities and CFR velocities of over 1.0.
b. The designer must review all of the segments to find the worst case set of velocity conditions for the project regarding air or medium needs. The required velocities, along with medium storage capacity in the system, will drive the capacity and pressure capability of the air compressors or nitrogen sources to be selected.
c. What will the starting pressure be?
d. What will be the end pressure when we will close the blow valve and recharge, (it will usually not be zero, but only some pressure value where desired velocities no longer occur)?
e. What is the configuration/size of the temporary piping including the blow valve?

Approach to Performing the Calculations

The denominator of the CFR fraction will always be known as a function of the plant size and heat rate. The following is an example of how this can be calculated.

Example Plant Facts/Assumptions

1. 5 simple cycle combustion turbine units @ 55 MW each, total of 275 MW capacity. If peak loads or overpowering are larger than the nominal design, use the larger capacity figures.
2. Heat rate: 10,000Btu/kWh, (usually available from the turbine manufacturer).
3. Natural gas heating value: 21,500 Btu per pound, (this can change seasonally and with the site).
4. Specific volume of natural gas at 400 psig (2,760 kPa) = .786 cubic feet per pound (0.0491 cubic meter per kilogram)
5. Assume that the plant design is for 500 psig (3,450 kPa) gas pressure but that full capacity can still be achieved with gas pressure as low as 400 psig (2,760 kPa). This is the "worst case" gas pressure that results in the highest momentum and should be used as part of this calculation.

The following formula (Equation 7-1) represents the calculation we are trying to solve:

$$CFR = \frac{M(blow)^2 \ X \ V(Blow)}{M(ref)^2 \ X \ V(ref)} \qquad \textbf{Equation 7-1}$$

M(blow) = Mass flow of medium used for blowing (Air), lbm/sec (kg/s)

V(blow) = Specific volume of blow medium (Air) during the blow, ft^3/lbm (m^3/kg)

M(ref) = Mass flow of Natural gas under maximum load conditions, lbm/sec (kg/s)

V(ref) = Specific volume of Natural gas under lowest possible pressure to achieve the maximum flow conditions. ft^3/lbm, (m^3/kg)

We will assume that the CFR is 1.2. The following example is illustrated in English units for clarity.

Finding the Denominator

Btu heat input to the plant = 275,000 kw (10,000 BTu/kWh)(1 hr/3,600 seconds)

Btu heat input to the plant = 763,888.9 BTU's per second

Natural gas mass flow = 763,888.9 Btu/second/(21,500 Btu/pound) = 35.5 pounds per second

Natural gas specific volume at 400 psig assumed to be .786 ft^3/lbm

Denominator = $(35.5)^2$pounds/second (.786 ft^3/lbm) = 990.6 pounds-cubic feet/$second^2$

This value remains constant throughout any additional calculations for this segment. We now have the following condition:

$$CFR = 1.2 = \frac{M(blow)^2 \text{ X } V(Blow)}{990.6 \text{ pounds-cubic feet/second}^2}$$

What to Solve For?

The CFR for the example above was assumed to be 1.2. The CFR will generally be estimated for starting purposes to be between 1 and 1.2. There are a number of approaches that can now be taken to solve for various pieces of the equation above.

Solving for Mass Flow for Known CFR

Solving for mass flow and velocity is usually achieved for many places in each segment using pipe flow modeling software, such as AFT-Arrow or Pipeflow software. These software packages allow the user to configure the system with pre-blow conditions including pipe sizes, lengths, end conditions, and air pressure to be released. These velocities and the known conditions along the piping segments would provide mass flow figures that can then be input to the numerator of the equation for the CFR shown above.

These calculation processes are usually done iteratively and the results input to spreadsheets to calculate CFRs for each piping segment in the overall project. The initial starting pressure value identified becomes the beginning storage reservoir (tank or receiver) pressure. The calculation would then be completed again to identify what the pressure is when the velocity degrades to just under a CFR of 1. This provides a possible ending or stopping pressure for the blow since little cleaning would continue to take place below that velocity.

Assumptions for the starting compressed air conditions:

If we input a starting pressure of 60 psig for a 12" line open at the other end, we end up with an estimated average velocity of

$$CFR = 1.2 = \frac{M(blow)^2 \text{ X } V(Blow)}{990.6 \text{ lbm-cubic feet/second}^2}$$

Or $M(blow)^2$ X V(Blow) = 1,188.7 lbm-cubic feet/$second^2$

If the starting compressed air pressure is 60 psig, the density is .381 lbm/ft^3, then the starting specific volume is 2.62 ft^3/lbm

The equation then becomes

$M(blow)^2$ X 2.62 ft^3/lbm = 1,188.7 lbm-cubic feet/$second^2$

$M(blow)^2 =$ 453.7 lbm^2/sec^2

M(Blow) = 21.3 lbm/sec

V(Blow) if the pipe size is 12" = (21.3 lbm/sec)/(.381lbm/ft^3)(.78 ft^2) = 71.6 ft/sec

If we now wanted to understand the stopping pressure, (i.e. the point at which the CFR is below 1), this can be calculated as follows:

$M(blow)^2$ X V(Blow) = 990.6 lbm-cubic feet/$second^2$

$M(blow)^2$ X 2.62 lbm/ft^3 = 990.6 lbm-cubic feet/$second^2$

$M(blow)^2 =$ 378.1 lbm^2/sec^2

M(Blow) = 19.4 lbm/sec

Hence, a starting pressure with a resulting mass flow of 19.4 lbm/sec would indicate where a blow would be stopped because the CFR would be less than 1.

To evaluate this we could for example assume an air pressure of 50 psig. The density of this would be .330 lbm/ft^3, then the starting specific volume is 3.03 ft^3/lbm

The equation then becomes

$M(blow)^2$ X 3.03 ft^3/lbm = 1,188.7 lbm-cubic feet/$second^2$

$M(blow)^2 =$ 392.3 lbm^2/sec^2

M(Blow) = 19.8 lbm/sec

One can see that the target end pressure, yielding a CFR of close to 1 is about 50 psig, (the calculated mass flow of 19.4 is very close to the mass flow of 19.4 that represents a CFR of 1).

Hence, if this were a blow valve-initiated blow, the valve would be closed at about 50 psig and the system again charged to 60 psig for another blow. Remember, this calculation only identifies flows and calculation methods for CFRs. Debris also needs to be transported out of the piping systems so it may be desirable to continue below 50 psig in this case.

Some "Rules of Thumb" for Pneumatic Blow Pipe Cleaning Process Calculations

1. Heat rates for combustion turbines are in the 7,500 to 10,000 Btu/kWh range and can be used to estimate peak gas loads to understand expected operational gas line velocities that can transport pipe contaminants.
2. CFRs for compressed air blows would likely start at about 1.2 and end at about 1.0. Some turbine manufacturers have called for CFRs to be up to 2 as a recommendation. However, remember that exceeding a CFR of 1.2 has been documented to produce little net cleaning. Exceeding a CFR of 1.2 can consume additional resources and time for little benefit. In the case of nitrogen as a medium, the asphyxiation hazard is increased by exceeding a CFR of 1.2 since more nitrogen is released during the blow.
3. Design velocities for natural gas piping systems for utility plants of this type are in the range of 10 to 20 feet per second. Exceeding this for blowing conditions is acceptable and in fact is the objective.
4. In many cases at least 10 blows are conducted on each line segment, depending on many things including the presence of iron oxide (rust) and fabrication techniques.
5. Most pneumatic blows start with less than 80 psig (550 kPa) and continue for 5 to 20 seconds. This is highly dependent on segments, sizes, compressors, piping conditions, and storage.
6. Choked flow conditions achieved anywhere in the piping system (1,126 feet per second) will limit and restrict the flow.
7. Rotary screw air compressor rentals come in two basic configurations, (low pressure oil less machines and high pressure oil sealed machines). Low pressure machines are in the 10 to 150 psig range (6.9 to 1,035 kPa range). High pressure machines are in the 90 to 350 psig range (620 to 2,410 kPa range).
8. Typical machine capacities are from 500 cfm to 1,600 cfm. This is usually expressed by the vendor as scfm, or air capacity at standard conditions, 70F and 14.7 psia (101.4 kPa absolute). You will at some point most likely be considering the mass flow capacity of the machines to estimate how many you need. Most vendors have design staffs with expertise in these areas that can help you make selections. Having spare compressors and or dryers available is an important consideration.
9. There are a number of rental contractors with experience in air blow processes who would typically include dryers, hoses, and regulators.
10. When sizing disconnects, switchgear, or conductors for temporary compressor power remember that starting loads for compressors are larger than steady state loads. Refer to the manufacturer or compressor provider's motor characteristics for these criteria. This can be very different depending on what kinds of starters are provided as part of the rental package and the equipment configuration.

8
COMPRESSED AIR SUPPLY EQUIPMENT CONSIDERATIONS

This chapter provides information about compressed air pneumatic blow equipment and infrastructure systems required. This includes an overview of compressors including capacity considerations and ancillary equipment that might be required like dryers.

Selection Considerations for Compressors

Air compressors come in a number of different basic configurations based on the mechanism by which air is compressed. The most common of these are reciprocating piston units, rotary screw units, and centrifugal blower units. Of the many different types of air compressor technologies available, the most common technology used for compressors related to pneumatic blow line cleaning processes is rotary screw compressors. These are normally rented for specific cleaning projects.

The heart of screw compressors are two interlocking screws that rotate opposed to each other capturing and compressing a small amount of air with each rotation and then pushing this into a collection header system to be released to the load.

Figure 8-1
Rotary Screws Used in Air Compressor System

Rotary screw compressors are available as either oil lubricated/flooded screws or screws that are not sealed/lubricated with oil. In the case of oil lubricated or sealed screws, oil is injected into the screw cavities to aid in sealing. Some of this oil then becomes directly entrained in the discharge stream. The design of the compressor system is to capture and remove most of this oil and return it to be recycled to the process.

Small amounts of oil carry over are usually not problematic for fuel gas piping systems. In many cases natural gas contains some hydrocarbon liquids which will end up deposited inside the piping surfaces over time.

In an oil-free (or "oil-less") design there is no injection of oil and the sealing occurs through close machining tolerances between the screws. These designs usually do not seal as well as oil injection designs. Hence, the maximum pressure capability of oil free designs is usually lower than oil injection designs but may nonetheless prove suitable for this application. If prolonged use of an oil sealed system is planned, the consumption of oil and its potential deposition somewhere in the system should be considered. In the case of gas line cleaning processes, small oil deposits are not harmful. In fact, most natural gas has with it some residual hydrocarbons that may deposit on the pipe walls in the normal course of operating the systems.

Figure 8-2
Typical Rental Screw Compressors Installed at a Job Site

Photo courtesy of Atlas Copco

Capacity Considerations, (Pressure and Flow Ratings)

The issues to be specified when arranging for a rental compressor will need to include the pressure and flow capabilities and the energy source for compression.

Pressure Capabilities

Pressure capabilities will need to be confirmed through the pipe flow analysis and modeling, but in many cases machines capable of up to 150 psig (1,035 kPa) are adequate. Many compressed air blows begin at 60 to 80 psig (415 to 550 kPa) (much less than the normal line pressure of the expected natural gas operating conditions) and then drop to some threshold level above zero during the blow. A recharge of the system then begins before another blow cycle.

Energy Sources and Site Preparation

Most machines are provided with diesel engines for compression power. However, electric motor machines are available from most rental firms if adequate power and disconnects are available on site. In some cases generators can be an option if the configuration warrants this.

If local power connections are utilized the installed equipment will need to comply with NFPA 70 (National Electrical Code). The switch gear and cabling can be a substantial part of the overall equipment needs.

A rule of thumb for estimating power consumption for air compressors is that they consume about 1 horsepower for every 4 cfm of compressed air produced. This figure will at least provide some basis for estimating load requirements until manufacturer data can be obtained.

Flow Capacity

Flow capacity will have to be determined through a detailed analysis of the piping segments to be completed, the order with which they are completed, and the amount of storage available. Planned storage capacity for each blow segment is vital to compressor capacity selection.

The larger the compressor capacity, the shorter the recharge cycles. This has the effect of reducing the overall project time. Velocity and flow modeling calculations will provide starting points.

Storage Capacity of System Considerations

The first segment in a system can be one where there is little or no storage capacity. It is also possible to rent storage tanks or receivers for adding capacity. In some cases consideration is given to having the first blows be in reverse of order of the gas flow. This allows for parts of the balance of the system to be used for storage. As subsequent sections of the piping are blown clean they can be used for storage.

Remember that cleaning force momentum ratio velocity blows are designed to dislodge and entrain contaminants, but then continuing flows transport this debris out the end of the pipe. More storage allows for more transport flow.

A typical blow cycle has the air flow occurring at some optimal cleaning force momentum ratio pressure down to some lower calculated pressure where cleaning forces are no longer occurring. The length of an effective blow in between recharge cycles is impacted by the systems storage capacity. Storage capacity is usually obtained from using sections of piping or boilers/HRSG’s nearby. It is not usually the case that compressed gas accumulators or receivers are rented or made part of the system when some permanent plant device fulfills the purpose of a pressure reservoir.

Air Compressor Ancillary Items

Dryers (Refrigerated and Desiccant) & After-Coolers

Dry air can be an important consideration. Depending on the climate and the humidity present when the project occurs, considerable water can be delivered with the compressed air to the piping systems. Compressed air at 250 psig (1,725 kPa) on an 80% humidity day with an 85 F (29 C) ambient temperature could contain 3 pounds of water for every 100 pounds of air. This water vapor is converted to liquid water when the air is compressed. The exit temperatures near the discharge of the piping systems can be significantly below ambient and below dew point temperatures because of the air expanding in the system as it moves through. The biggest expansion and drop in temperature occurs at the exit end. It is not uncommon to see moisture and frost at the exit end piping. This can even lead to ice crystals being generated and discharged. In some cases this has marked targets and mistakenly indicated remaining debris.

There are two main types of dryers available for rental as well as after coolers. These are refrigerated air dryers and desiccant air dryers. Refrigerated air dryers use commonly available refrigerants to cool one side of a heat exchanger. The compressed air passes through the other side and is reduced in temperature. When the temperature of the air mixture is below dew point the saturated moisture comes out of the air and deposits itself in liquid separators and is drained away.

Dryers are specified by the dew point of the air that they provide. For example, refrigerated dryers for rentals are capable of delivering air down to dew points of about 38F. This means that if the piping you are pneumatically blowing is above 38F none of the moisture in the air will deposit itself on the pipe surface.

Desiccant air dryers are capable of delivering air with dew points as low as -100F. These can be applied to provide air that is capable of absorbing moisture for drying out the inside of piping systems. Desiccant systems consist of a chamber or vessel holding small beads that have an affinity for moisture. As the compressed air passes through and contacts the beads water is absorbed. There are usually at least two vessels or cartridges so that one can be regenerated while the other is loading. Regeneration usually occurs by heating the beads and passing some dry air through. Heating can occur with electric resistance elements, steam, or direct fired air heaters.

After coolers are a means to cool compressed air upon its discharge. There are different styles and types of after coolers. Some of these are water cooled shell and tube heat exchangers using cooling water that could be from cooling towers or city water. These do have the effect of removing some moisture but are not as effective as refrigerated air dryers.

Receivers

Receivers are storage tanks used for compressed air systems. Some compressor equipment rental companies can provide them. Receivers may be needed to store air to provide for an adequate blow reservoir.

Relief Valves

Relief valves are an important safety consideration in pneumatic systems. It is important to understand where they exist and to make sure personnel in proximity to these understand how they operate and that they can discharge at any moment during operations. The discharge vents from relief valves can subject anyone close by to significant discharge velocities and pose a hazard to personnel. Therefore, it is imperative that discharge vent outlets be located in safe non-hazardous locations away from personnel egress areas and ignition sources. The location of relief valve discharges needs to be a part of the hazard review planning for cleaning operations.

Temporary Air Compressor Installation/Operation Considerations

Most compressed air systems used for gas blows use rented compressors. Air compressor rentals and set ups could make for some challenges due to the following:

a. Starting and operating engines in cold weather can be an issue as well as servicing them.
b. Mounting and location considerations, (diesel generators and compressors), must include accessibility for fuel deliveries, topography of the land for getting the compressors delivered and picked up. Precipitation can make roadways less accessible and make for problems moving and or servicing compressors.
c. There will be combustion product discharges from diesel equipment that can be re-entrained into building ventilation systems. This must be considered along with shifting wind directions, stack heights, and topography.
d. Site preparation must include some amount of stabilizing the unit on a flat surface and chocking wheels. It may be appropriate to barricade the units or limit access.
e. Noise may also be a consideration when deciding where to locate units on the site. It is likely that as the job progresses the location of the machine may also be changed.
f. Service capabilities of the rental firm will be important since the rented equipment will be the critical path item for many people conducting the pneumatic blow operations. In most cases compressors are rented such that back-up capacity is available with another unit already on site.
g. In some circumstances compressors on a project, or diesel stationary power engines, will require that union qualified or licensed personnel be present to operate and maintain the equipment on a 24/7 basis. Hence, staffing will always have to be a consideration.

As described in the next chapter, compressed nitrogen supply systems can provide the same performance without some of these considerations.

9

COMPRESSED NITROGEN EQUIPMENT CONSIDERATIONS

Nitrogen pneumatic blows are an alternative to compressed air blows. This chapter describes some of the special considerations when considering nitrogen as a gas source. One of the primary advantages of using nitrogen includes some of the special characteristics of the pumper trucks available and the volume and pressures they can deliver. This can help to provide the right characteristics to get effective cleaning force momentum ratio's in situations where there is not much available volume for storage.

Nitrogen Source Considerations

Nitrogen volumes and pressures required for pneumatic blowing processes are provided through the use of mobile pumper trucks. These systems use a positive displacement pump that moves liquid nitrogen through a high capacity vaporizer and makes high pressure gas available for blowing.

Nitrogen has an advantage that it is dry, whereas compressed air systems may require a dryer to remove moisture. Even with a dryer, compressed air systems cannot get moisture levels as low as nitrogen systems.

Nitrogen systems do carry with them an asphyxiation risk. Even though 78% of every breath we take is nitrogen, one full breath of nitrogen can render one unconscious or worse. Because its presence is not detected by sight or smell it is essential that oxygen detection equipment is in use to protect all personnel present in any area where nitrogen may accumulate, whether by inadvertent leak or by the blow process as designed. Training and informational resources regarding the dangers of nitrogen asphyxiation can be found at www.csb.gov, (see Valero and Union Carbide videos).

The potential for nitrogen asphyxiation increases directly with the amount of nitrogen release. When evaluating required cleaning force ratios, field trials have indicated little to no additional cleaning benefit to exceeding targeted cleaning force ratios (CFRs) of 1.2 to 2.0. Hence, especially considering the cost of nitrogen, it's important to accurately target and then maintain the proper CFR through the process.

Air compressors also have the potential to leave oil residue. Nitrogen systems have no such residue. In most cases some small amount of oil residue, especially considering the small amount of air used for pneumatic blowing, is not an important issue. It's important to consider different air compressor types and discuss oil contamination with vendors when rental equipment is chosen.

Nitrogen systems can react much faster than traditional compressor systems. The timing benefits come about through the following:

a. Less hook ups for utilities.
b. Less recharge time.
c. Pneumatic testing can occur immediately after with the high pressures that are available.
d. Much more mobile to move around and reconnect (since it's sourced from a truck) for getting to extensive networks.

Pumper Truck Gas Discharge Capacity

Pumper truck capacity can range to 3,000 to 15,000 scfm with very high pressures, up to 15,000 psig (103,400 kPa). This technology was derived for the oil industry for well injection and fracturing. A 3,000 gallon liquid nitrogen truck can provide about 225,000 scfh of gas or about 16,000 pounds of gas at standard conditions. Air compressors used for pneumatic blow processes would typically only have capacities of 60,000 to 90,000 scfh.

In any pneumatic blow system, (whether it be steam, natural gas, air or nitrogen), the storage of some volume of gas is important and planning for this gives capacity to the system. The capacity required is related to the volume of piping to be cleaned and storage capacity that is available.

The kind of capacity available from pumper trucks makes a lot of sense for piping systems that are substantial, long, and have minimal storage for the initial segment.

Figure 9-1
Nitrogen Pumper Truck

Photo courtesy CETCO Oilfield Services.

A potential disadvantage may be the total cost to perform the blows using nitrogen. Compressed air blows are often chosen based on cost, despite other advantages of compressed nitrogen. The user must weigh the advantages and disadvantages of each approach.

10
OTHER CLEANING PROCESSES: FLUSHING & PIGGING

This chapter provides an overview of flushing and pigging technologies used for pipe cleaning that can be applied to fuel gas lines. These topics are each introduced and described from an overview perspective.

Water Jet Flushing, Milling, and Aerated Water Blows of Piping Systems

There are a number of water based flushing and blowing processes commonly used for fuel gas line cleaning. These are usually part of a family of processes that are deployed sequentially to get the overall desired cleanliness. These processes include water jetting or milling and aerated water jet flushing.

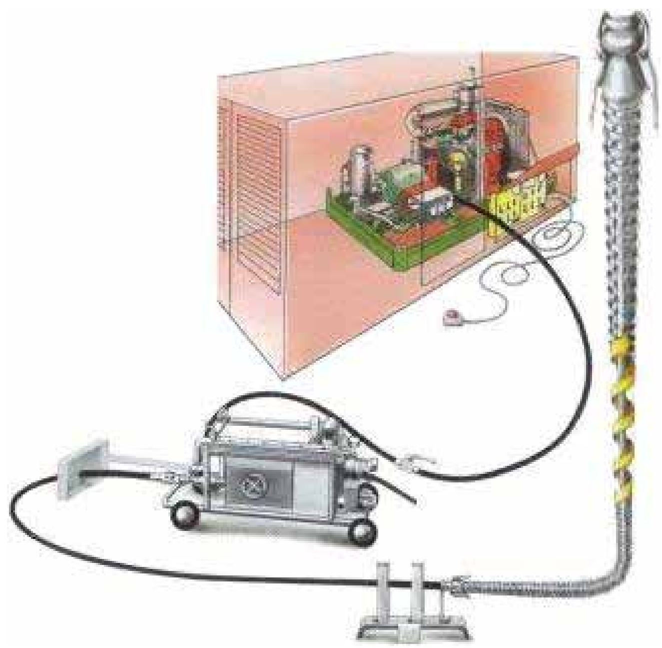


Figure 10-1
Smaller Equipment Layout for Water Jetting

Photo courtesy of Hydromilling Group

Water jet flushing or milling is a process where high pressure water jets connected to special hoses are moved through the piping systems. The jets operate at pressures of 10,000 psig (68,950 kPa) or more and are effective in removing pipe mill scale, weld slag, and rust from the inside of gas lines. The debris is removed and flushed from the system as the jet nozzles head is retracted. Typical water flows are 20 to 40 gpm. Contractors operating these facilities usually provide facilities to collect the water and debris. The water can be disposed of or recycled through the special collection systems provided as a part of the cleaning plan. Contractor equipment for these processes typically includes a trailer to house the control facilities somewhat near the operation and space to locate the pump system skid. Pump system skids can be diesel operated or run from a rental generator. A source of water and space for water and debris collection equipment would also need to be provided.

Aerated water jet flushing is a process where highly aerated water is forced as a slug down a pipe at speeds of 40 to 80 feet per second (12.2 to 24.4 meters per second) to dislodge debris, weld slag, corrosion deposits, and other foreign objects from the pipe.

Contaminants such as chlorides and minerals that could causes issues with piping and related components should be avoided. Water quality should be specified and water quality requirements for flushing should be coordinated with the turbine OEM.

Pigging

Pigging is the process of mechanically moving a specially designed device through a section of pipe for cleaning and other purposes such as pipe inspection. There are many varieties and levels of complexity of pigs. This section focuses on pigs used for cleaning. There are open and closed pigging processes. In an open pigging process a pig is inserted and moved through the system to some end point and then blown out through an open end with debris.

In a closed pigging process the pig and debris settle into a pig receiver. In closed systems there is little release of the compressed air or gas that is used as the energy source to move the pig. This discussion will not address the design elements of receivers and launchers or any particulars regarding their operation but will instead seek to inform the reader regarding the different types of cleaning pigs that are available.

NFPA 56 provides relevant guidance on pigging systems used for gas line cleaning including operational considerations for systems that have been in service.

Pig Types and Cleaning Applicability

The following describes pig types that are commonly used in cleaning processes.

a. Poly Pig. Flexible polyethylene pigs, ideal for applications where the pipeline condition is not well known and the primary requirement is to not block the pipeline.
b. Pin Wheel Pig. Designed to aggressively remove debris such as scale and hard wax from the walls of the pipeline. Hard steel pins burst and scrape debris from the pipe wall.
c. Pressure bypass pig. This type of pig has a pressure relief built into it that allows for a burst of liquid or gas to exit the pig in the direction of flow that move debris and accumulation from in front of it when the pig becomes stuck.
d. Inhibitor spray pig. This type of pig applies a corrosion inhibitor inside the piping system as it moves.
e. Magnetic cleaning pig. This pre-inspection pig removes ferrous metallic debris such as welding rods from a pipeline. It uses strong permanent magnets to collect and hold these materials.
f. Cup pig. These pigs are designed for use in long runs in which wear may be a special concern. They are specified for commissioning of pipelines as an alternative to bi-directional pigs and for separation of different media.

g. Brush pig. The brush pig is a bi-directional cleaning tool that cleans without scraping the interior wall of the pipeline. It uses both metallic and non-metallic brushes.
h. Smart pig. This type of pig has electronic data collection instruments that can find defects and determine pipe wall thicknesses. Some can also be tracked along their path.
i. Gauging pig. This type of pig is used to determine roundness and sag issues in the piping systems.
j. Dual diameter pigs. This pig seals tightly to the internal pipe wall and can be custom produced for any diameter differential.

Pipe runs must be designed initially with pigging in mind to be an effective choice. Temporary launchers and receivers can be installed for the cleaning procedure. Pigs are more commonly used in main transmission and service lines by the gas transmission companies for long lengths of piping.

Figure 10-2
Pipeline Foam Pigs Used for Cleaning and Water Removal

Photo courtesy of Pipeline Pigging Products Inc.

A
APPENDICES

Sample Clean Construction and Pneumatic Cleaning Processes Specifications

Note: The following is meant to serve as a guide to provide a framework for implementing “build it clean” processes and pneumatic compressed air pipe cleaning techniques for gas lines. There are many issues within the context of what is identified here that need to be made specific to the conditions that exist at any particular job site and the plant’s design.

1.0 General

This document provides for the basic natural gas piping system cleaning procedures. These specifications are intended as reference for the owner or commissioning contractor as these processes are implemented. There are several processes described in this document along with “build it clean” recommendations. It is likely that there will be a combination of processes deployed for a given project.

The owner or EPC shall provide a supplement to this document that identifies specific procedures and conditions that meet the site design requirements. The final procedures shall be coordinated with all of the entities on site and involved with the project including but not limited to the upstream facilities.

Individual spool pieces after the final gas conditioning skid to the turbine shall be inspected visually inspected using bore scope technology if necessary to verify that none of this piping is rusted or has any foreign materials or particles inside.

2.0 Safety Plan

The contractor shall establish a detailed safety plan that includes a written hazard analysis plan and mitigation steps that will be in place. This plan shall be created with the assistance of the owner. The contractor’s plan and all anticipated pipe cleaning processes shall be in accordance with NFPA 56, Standard for Fire and Explosion Prevention during Cleaning and Purging of Flammable Gas Piping Systems (available at www.nfpa.org).

3.0 Preservation of Systems

Once piping sections are deemed cleaned and blown the contractor will lay up the piping systems to preserve them using nitrogen gas if no work activities are to occur on the fuel gas systems for more than 10 days after the pressure testing and before the systems are purged into service with natural gas. The contractor shall be responsible for nitrogen safety training and communications to all relevant parties regarding the installation of nitrogen to the systems and the asphyxiation hazards that can occur in turbine enclosures and other areas where ventilation may not be yet operational.

4.0 Minimizing Weld Slag and Fabrication Contaminants (“Build it Clean”)

The following describes welding processes that may be applicable to the installation of gas lines to minimize weld slag deposits. These processes must be verified with the installing contractor to still be able to meet mechanical strength requirements.

a. Apply TIG welding, (gas tungsten arc welding, GTAW) to the tack weld, to at least the first and the second layers of the fuel gas piping.
b. Clean the inside of the piping with wire brushes, swabs, and localized compressed air blows after each weld is deemed complete.
c. In the case of stainless pipe welding the pipe should be filled with argon gas. Stainless line welding processes should not include the insertion of any materials for line sealing (these could be carried downstream to clog the combustor nozzles during commissioning).
d. Immediately after spool pieces are deemed complete and before they are transported for storage or installation they shall have foreign material exclusion covers securely installed.
e. Shop fabricated piping shall be cleaned at the fabricators shop and shall have foreign object exclusion covers installed immediately upon completion. Do not remove temporary exclusion covers until just before installation.

5.0 Cleaning Methods

The following describes gas line cleaning methods that are to be used, as agreed to and designated by the owner and EPC contractor, for various sections of the fuel gas line to be installed. Prior to the start of any cleaning processes the EPC contractor will break the fuel gas piping systems into blocks with recommended processes for each. These processes may include the following.

5.1.1 Pig Cleaning

Pig cleaning processes shall include the installation of temporary launchers and catchers. The contractor's plan shall indicate the style of pigs to be used and their intended sequence. The contractor shall also indicate the need to remove reducers on piping and verify that pig obstacles do not exist during the cleaning processes and that all devices are reinstalled afterwards.

Pig launch and motive force energy is to be by clean and dry compressed air.

If the pigging is to be done with an open pigging system a catcher shall be arranged to minimize the probability of the pig and the debris become uncontrolled projectiles. Catchers are typically constructed with a blind flange that has extended threaded rod that is longer than the length of the pig. The catcher can be retrofit with a hemp bag or some type of mesh to further restrain particulate removed from the pipe.

Valves on the pipe line, which can be obstacles for pigs, shall be removed and replaced with spool pieces. Valves on branch lines shall be tightly closed or blocked with blinds to minimize the chances of air leakage.

Orifices and or other protrusions such as thermowells shall be removed.

The capacity of the compressor for the pigging processes shall be capable of providing a minimum of 200 cfm at 102 psig (705 kPa) maximum pressure.

The contractor shall provide a communication plan for the launcher and catcher operations.

Pig selection, including progressive use of different types of pigs, shall be included in the plan presented to the owner's team. A typical progression might be first a soft sponge type of pig to catch large debris, followed by a hard type pig like a spiral or rubber for stuck foreign materials, and then a hard type final pig to judge the overall cleanliness.

Pig Operational Guidelines

a. The cleaning shall be carried out with all pigs going in the same direction.
b. Confirm the outlet valve of the compressor or air storage system is closed.
c. Insert a pig in the launcher and the head end directed downstream towards the catcher.
d. Turn the compressor on.
e. Communicate with the catcher personnel who are in a barricaded area as per the safety plan to assure that they and the area are ready.
f. Open the air outlet valve of the compressor or storage system and confirm that the air pressure is starting to fluctuate to indicate pig movement.
g. Keep the air pressure below 58 psig (400 kPa) while the pig is being propelled.
h. The operation shall be stopped when the air pressure goes up over 58 psig (400 kPa). This could indicate a stuck pig.
i. A required running pressure is normally 1.5 to 22 psig (10 to 150 kPa) depending on scale conditions and foreign objects encountered.
j. Close the air outlet valve of the compressor or air storage source immediately when the pig arrives at the catcher.
k. Suitable running speeds are usually in the range of 2.5 to 5 feet per second.

5.1.2 Pneumatic Blowing (Air or Nitrogen)

The contractor shall divide the piping system strategically to optimize the cleaning process and present this plan to the owner. The pneumatic blow cleaning plan shall include the following.

The contractor shall conduct pipe flow velocity modeling and cleaning force momentum calculations. These calculations shall provide conditions that make for a cleaning force momentum ratio of over 1 will be achieved through out each of the strategically selected piping sections. These calculations and the pipe flow modeling results shall be provided to the owner as documentation of the cleaning plan. It is generally expected that starting air pressures in the system at the blow initiation point will be 45 to 60 psig (310 to 415 kPa) depending on the system geometry.

If nitrogen is used as the cleaning medium, special considerations will be given to possible asphyxiation hazards. This shall include a section addressing this as required in the safety plan.

The contractor shall identify expected numbers of blows and durations for each section along with an overall plan for timing (number of calendar days start to finish) for the entire cleaning process.

The contractor shall specify the air or nitrogen delivery requirements including the compressor or vaporizer truck size and dryer arrangement (if applicable) to be part of the project. The contractor shall also indicate a proposed site location or locations for where the compressor or nitrogen delivery truck will need to be located so that work can be coordinated. The contractor shall use clean and dry air (where air is used). Plant instrument air is acceptable for us if it is available.

If the contractor intends to use parts of the facility infrastructure for storage, such as boiler drums, this shall be identified.

The contractor will also specify blow initiation methods for the cleaning process as one of the following.

a. Blow valve initiation

   If blow valve initiation is selected the contractor will identify this and identify the type of valve to be used, style of actuator, and methods of securing the valve, and locations where the valve will be installed.

b. Packing fracture initiation

   If packing fracture initiation is selected the contractor will identify this and the expected locations and fracture pressures to be used.

6.0 Pipe Pneumatic Blow Cleaning Guidelines

a. Verify that the temporary hoses are of the proper rating and all are secured and that whip checks are in use.

b. Consideration should be given to avoiding the free discharge of debris and possible projectiles during the blow process.

c. Close all instrument lines and takeoffs such as for pressure gauges to avoid damage.

d. Once temporary air or nitrogen supply piping is connected pressurize the blow valve or the fracture plate, usually in the range of 45 to 60 psig (310 to 415 kPa). However, pipe modeling and cleaning force momentum calculations will drive this.

e. Open the blow valve quickly or pressurize until the fracture plate blows. The pneumatic discharge can cease once the system pressure drops below the calculated target velocity since no more cleaning will be taking place at that time. Carefully managing this will minimize the possible time between blows.

f. Repeat these processes until there is no visible dust or debris discharge and the targets meet goals.

6.1.3 Hydro Water Jet Cleaning

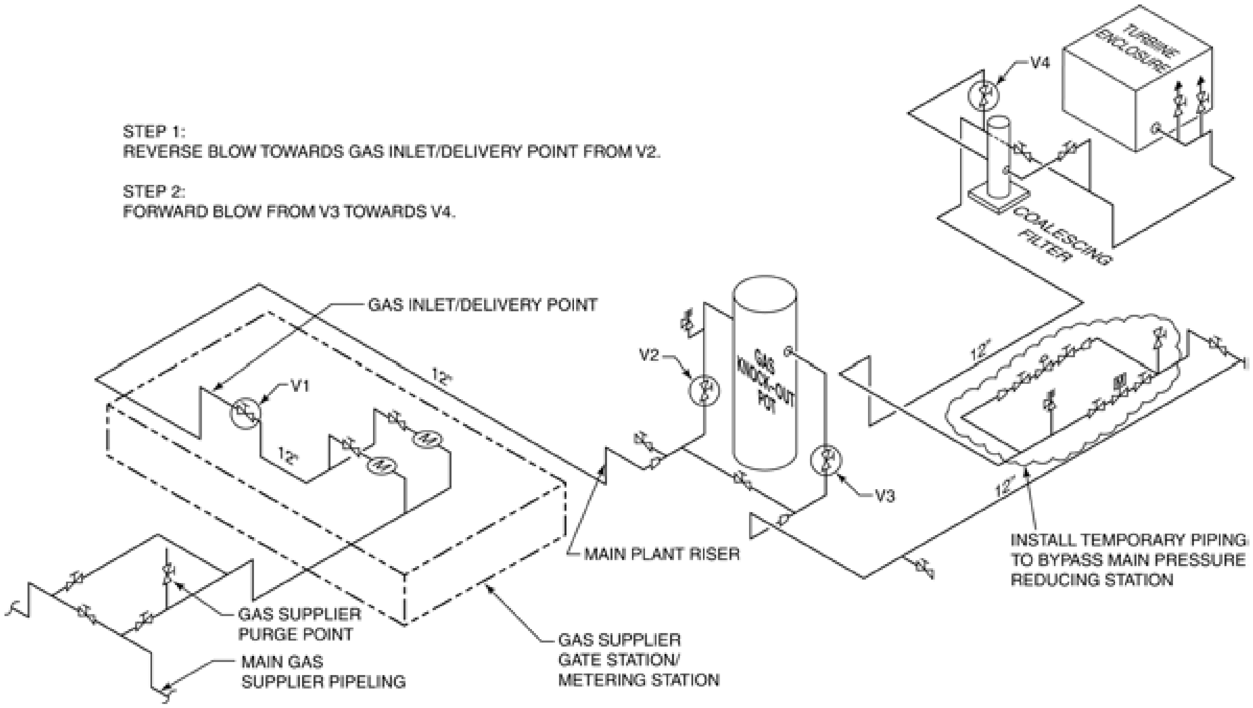
Contractor shall provide a detailed plan that includes strategic section of piping systems and locations of pump system and cleaning hose routes. Contractor to identify proposed cleaning pressures and nozzle sizes for each section. Contractor shall also identify collection and treatment of residual water including disposal for each section of the project.

7.0 Evaluation of Pipe Cleanliness

The owner shall conduct a conference with the commissioning contractor, the EPC contractor, and the turbine manufacturer to reach a mutual cleanliness goal. This shall include some evaluation of targets installed in the pneumatic discharge from the temporary piping installed. This conference shall determine the type of targets, their method of mounting, and their evaluation.

Targets are generally installed once 5 to 10 blows are completed and there does not appear to be any readily observable debris left in the piping systems. Target evaluations are typically subjective. Criterion often includes the number of apparent impacts or scratches, (depending on the target material).

Sample Project Conceptual Piping Diagram for Cleaning Using Compressed Air Blows



Configuration for pneumatic compressed air blow cleaning

Step 1

Complete reverse blows, (counter the normal fuel flow direction), by installing a blow control valve or packing fracture plate at valve V2. The balance of the system behind valve V2 (towards V4) would provide a storage reservoir of air for the blow.

Note: There is no capability in the piping system at the beginning of the service to accommodate the storage of air to move debris in the normal direction of fuel gas flow.

Procedural Issues:

1. Verify that all fuel sources have been properly isolated using double block and bleed valve arrangements or blanks. Review all required project safety plans.
2. Remove valve V1 and install temporary piping with a discharge end and target mounting bracket.
3. Provide a blow control valve or packing fracture material at valve V2.
4. Connect the compressed air supply such that it fills the system, between V2 and V4, to use that section of piping as a reservoir.
5. Initiate successive blows at valve V2 to discharge air towards the former location of valve V1 out the new discharge piping.
6. After no visible plume or materials exit install a target and evaluate findings on successive target blows.

Step 2

Use newly cleaned pipe section as storage and blow from the gas entrance point valve through the balance of the system towards valve V4.

1. Install a blow control valve or fracture plate at the former position of valve V3.
2. Move the compressed air supply line so that the system can charge the just cleaned section, (between V1 and V3).
3. Reinstall valve V1 at the main gas inlet.
4. Install temporary piping to by-pass the main pressure relief station.
5. Remove valve V4 located just before the unit coalescing filter and install temporary piping that includes a discharge end and target mounting bracket.
6. Initiate successive blows at valve V3 to discharge air towards the former location of valve V4 out the new discharge piping.
7. After no visible plum or materials exit install a target and evaluate findings on successive target blows.

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