FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

July 30, 2013

Melanie Bachman, Esq.
Acting Executive Director
Connecticut Siting Council
Ten Franklin Square
New Britain, CT 06051

RE: **DOCKET NO. NT-2010** – Reopenng of Final Decisions Pursuant to C.G.S. § 4-181(a)(b) for Jurisdictional Natural Gas-Fired Electric Generating Facilities Under C.G.S. § 16-50i(a)(3) and C.G.S. § 16-50k(a) Limited to Council Consideration of Changed Conditions and the Attachment of Conditions to the Certificates and Declaratory Rulings Consistent with the Findings and Recommendations in the Final Report Issued by the Kleen Energy Plant Investigation Review Panel (Nevas Commission) and the Findings and Recommendations in the Executive Report Issued by the Thomas Commission

Dear Ms. Bachman:

As the Council is aware, Bridgeport Fuel Cell Park, LLC, an affiliate of FuelCell Energy, Inc. ("FCE"), sold the assets of the Bridgeport fuel cell park project (the "Project") to Dominion Bridgeport Fuel Cell, LLC ("DBFC"). FCE, as general contractor and agent of DBFC, respectfully submits the following information in accordance with the Council's March 17, 2011 Fuel Cell Decision and Order ("Order"). Through an administrative oversight, notice was inadvertently not provided 15 days prior to fuel pipe cleaning at the Project site. FCE apologizes for this oversight. Measures have been put in place to assure that such an oversight will not happen again.

Information provided below corresponds to the numbered checklist provided in the Order.

1. No natural gas was used in the pipe cleaning procedure.

2. (a) Nitrogen was used in the pipe cleaning procedure.

(b) No known hazards, other than the typical hazards associated with natural gas pipe cleaning, were observed or occurred.

(c) – (e) The attached Electric Power Research Institute ("EPRI") Guidelines fore Fuel Gas Line Cleaning Using Compressed Air or Nitrogen, Document No. 1023628, Updated December, 2011 was used in the natural gas pipe cleaning procedure. Regulations, codes and standards followed during the procedure include (i) US DOT 192 Minimum Federal Safety Standards, (ii) ASME

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B31.1 – 2010 – Power Piping, (iii) NFPA 54 – 2012 National Fuel Gas Code, (iv) NFPA 56 – 2012 Standard for Fire and Explosion Prevention Duing Cleaning and Purging of Flammable Gas Systems, (v) NFPA 850 – Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations, (vi) the EPRI Guidelines.

(f) Personnel performing the work were (i) FuelCell Energy, Inc. and (ii) AZ Corporation. FCE is in the business of selling, installing, maintaining and operating fuel cell power plants and routinely performs this type of work. AZ Corporation is FCE's subcontractor performing civil, electrical and mechanical work. AZ Corporation has performed fuel cell installations in Connecticut for FCE in the past and has an impeccable safety record. AZ's qualifications are attached hereto.

(g) The work performed was overseen by FCE's and AZ's in-house engineers and also by Dominion Bridgeport Fuel Cell's in-house mechanical engineer, who is experienced in power industry practices. The Bridgeport fire marshal and Bridgeport building inspector have performed numerous inspections on the Project to date and have been advised of all aspects of the Project.

(h) Unfortunately, notice of the pipe cleaning operations was not provided to state agencies listed in General Statutes § 16-50j(h). Administrative procedures have been put in place to ensure that this oversight does not happen again.

3. As provided in 2(c) – (e) above, all listed codes and standards were complied with during the cleaning operation.

4. Attached hereto please find a copy of FCE's Emergency Response/Safety Plan for the construction phase of the Bridgeport Project Site. Emergency response documents for the operational phase of the project, including a Hazard and Operability Analysis, Risk Management Plan and Fire Hazard Analysis, are still being prepared.

5. No invoices have been received to date.

6. Site construction is not yet complete, but FCE will notify the Council in writing when it is. The first DFC3000 plant is anticipated to be fuel enabled during the first week of August, with the commencement of testing and commissioning to follow. Two to three days prior to fuel enabling the plant, the natural gas pipes will be air purged and filled with natural gas. A copy of the air purging procedure is attached.

7. As the Council is aware, the Project has been transferred to Dominion Bridgeport Fuel Cell, LLC. Until commercial operation of the Project,

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the entity responsible for management and operation of the Project during construction remains FuelCell Energy, Inc.

8. Not applicable.

If you have any questions with respect to the foregoing or any of the attachments, please contact the undersigned. Thank you for your consideration.

Respectfully submitted,

FUELCELL ENERGY, INC.
On behalf of
DOMINION BRIDGEPORT FUEL CELL, LLC

By: ______________________
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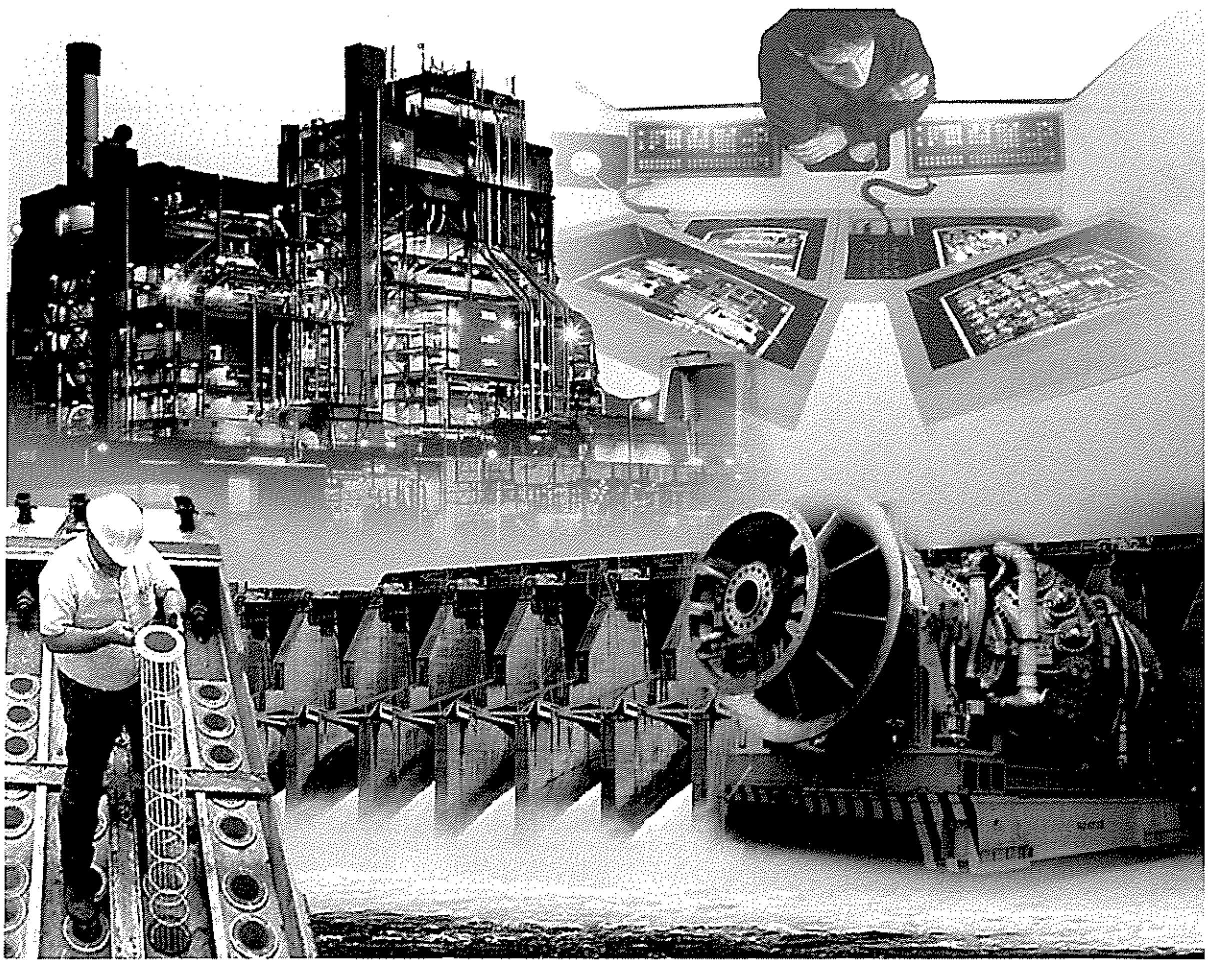
ELECTRIC POWER RESEARCH INSTITUTE

Guidelines for Fuel Gas Line Cleaning Using Compressed Air or Nitrogen

1023628



Guidelines for Fuel Gas Line Cleaning Using Compressed Air or Nitrogen

1023628

Technical Update, December 2011

EPRI Project Manager

D. Grace

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

CEC Combustion Safety Inc.

This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

ACKNOWLEDGMENTS

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

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Principal Investigator
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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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1
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.

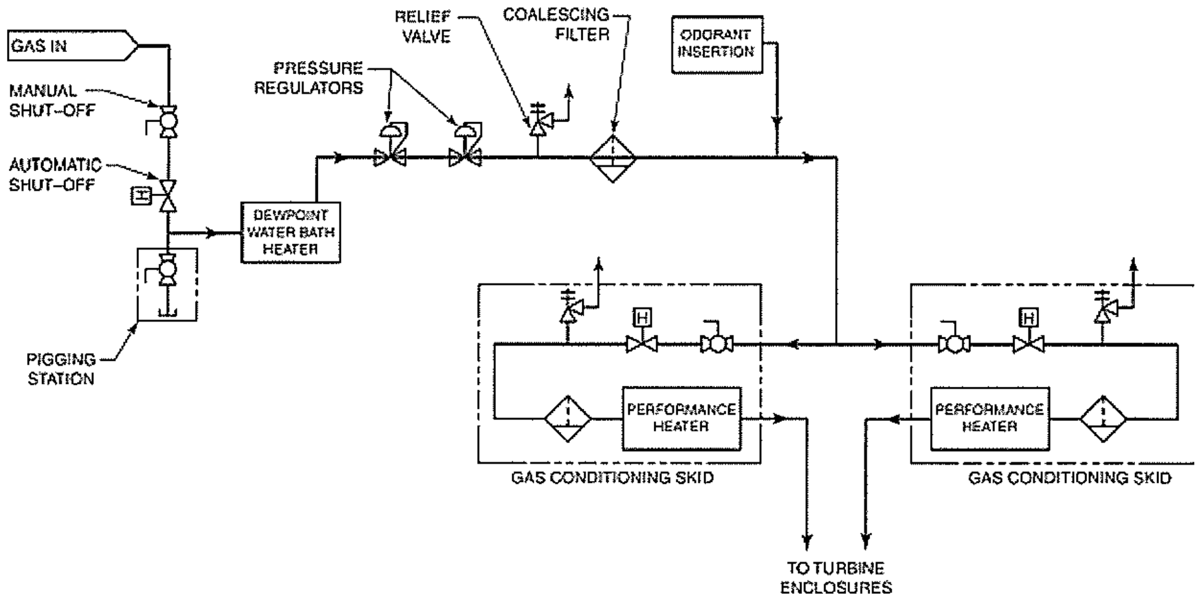


Figure 2-1
Typical Schematic Arrangement of Gas Yard and Fuel Conditioning

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.

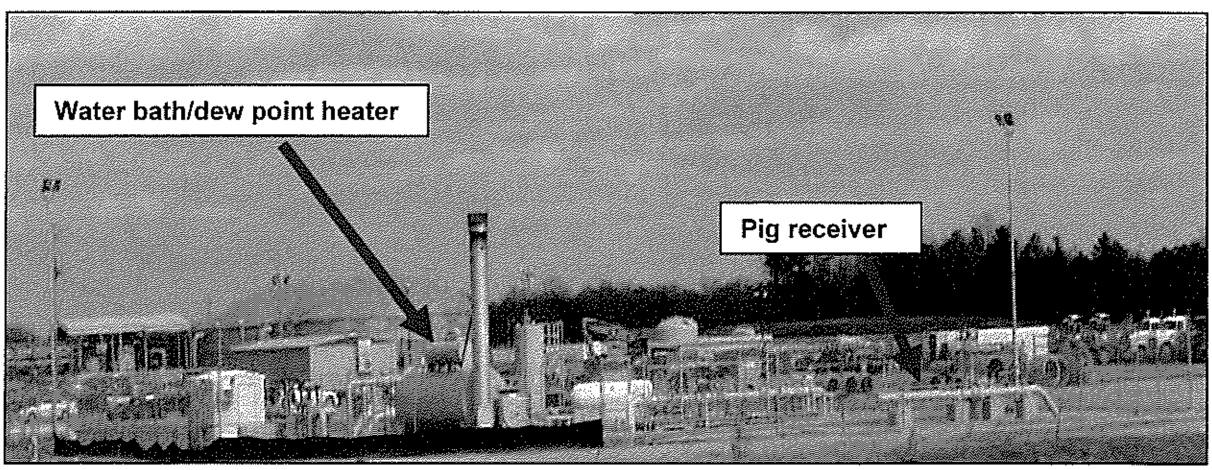


Figure 2-2
Typical Gas Yard for a Combustion Turbine Facility

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.

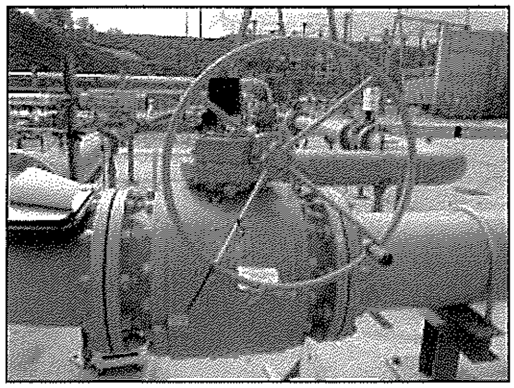


Figure 2-3
Trunion Mounted Style Ball Valve with Gear Wheel Operator and Position Indicator

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,

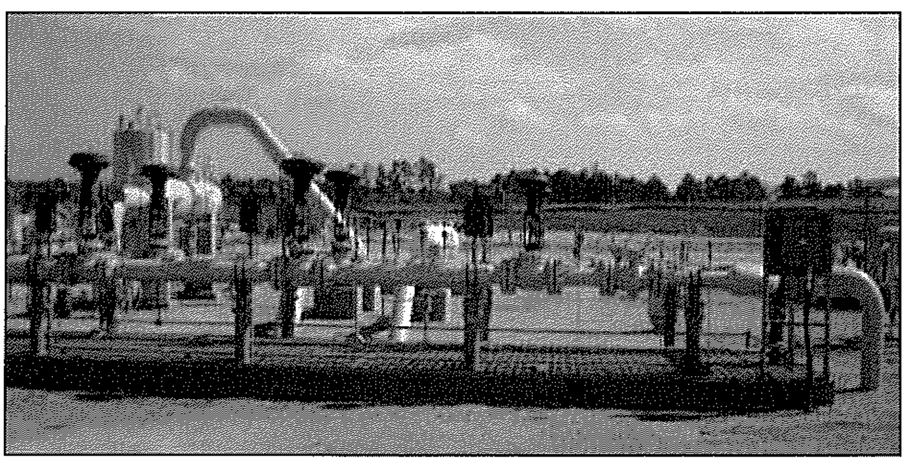


Figure 2-5
Typical Gas Yard Pressure Regulators

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).

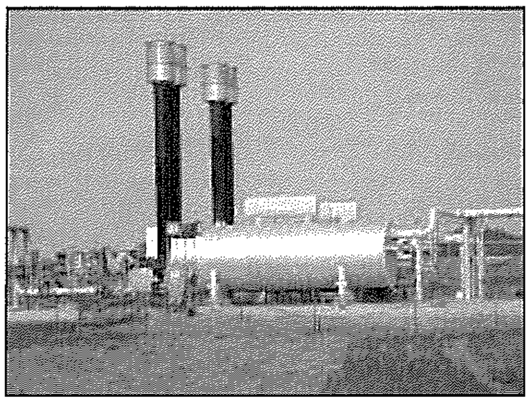


Figure 2-6
Typical Dew Point/Water Bath Heaters

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.

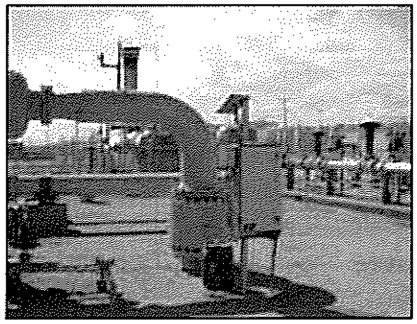


Figure 2-7
Gas Odorization System

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.

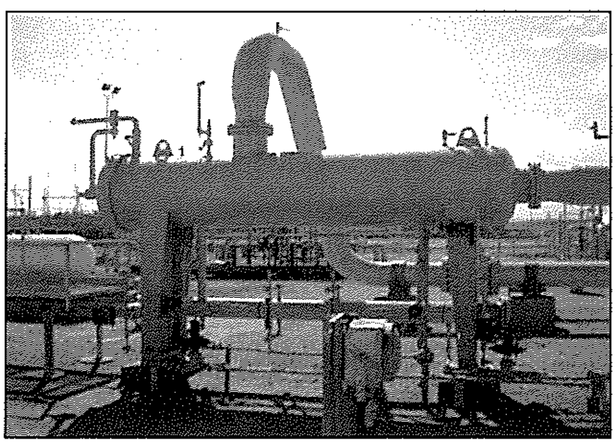


Figure 2-8
Coalescing Filter Installation

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.

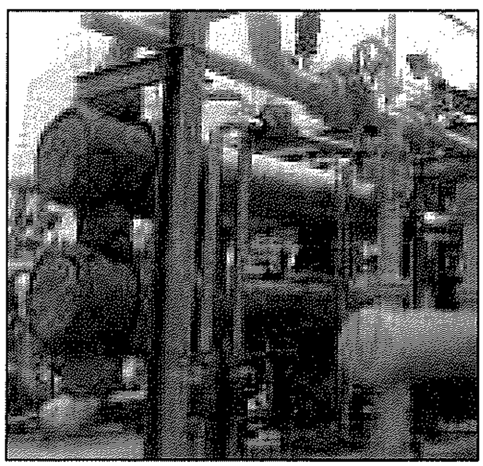


Figure 2-9
Typical Shell and Tube Heater for Heating Natural Gas to Meet Turbine Performance Requirements

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.

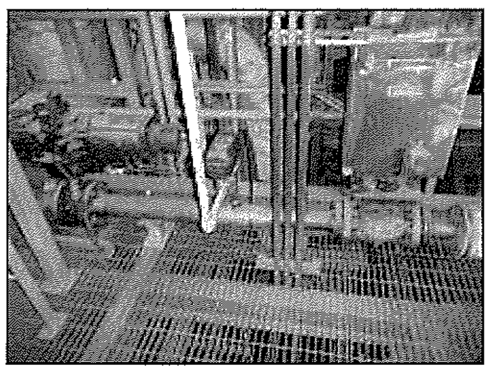


Figure 2-10
Fuel Train Inside Turbine Enclosure

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.

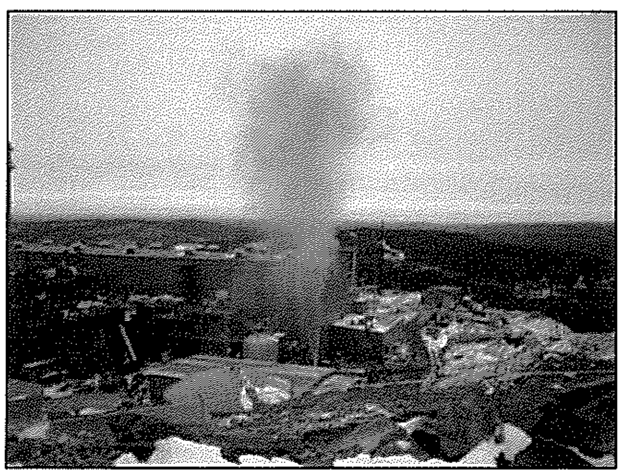


Figure 4-1
Iron Oxide and Debris Coming from Pipe

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.

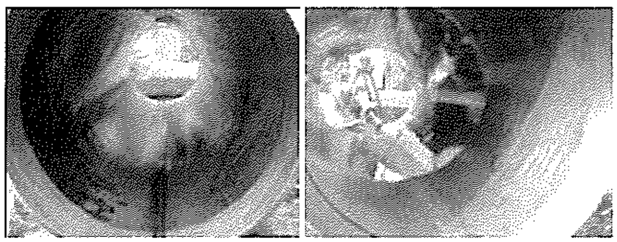


Figure 4-2
Inside of Pipe Before and After Water Jet Flush

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.

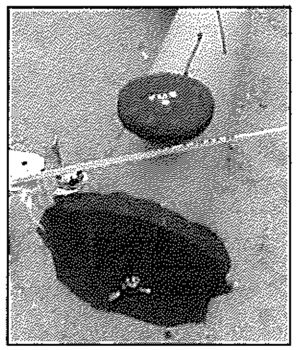


Figure 4-3
Foreign Material Exclusion Covers on Pipe Ends

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.

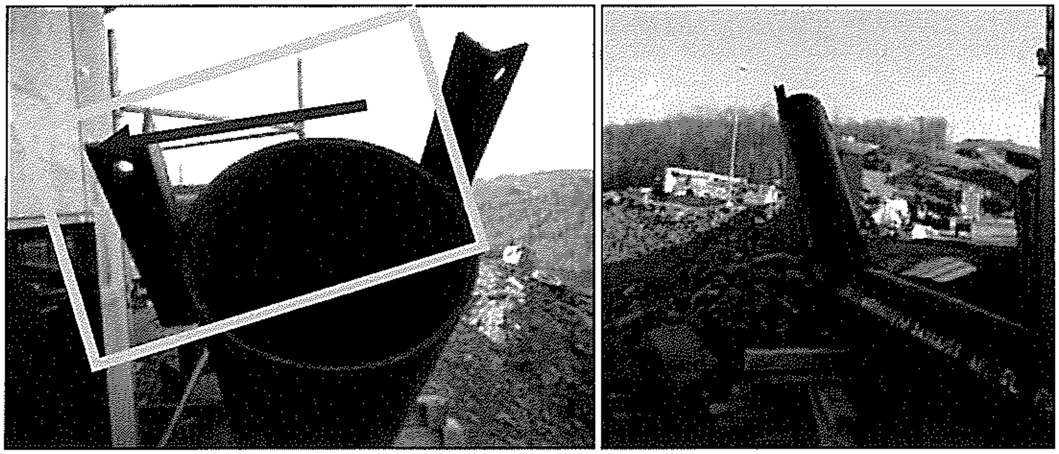


Figure 5-1
Temporary Piping for Pipe Pneumatic Blow Cleaning Discharge with Target Mounting Bracket and Outline of Where a Target Would Be Mounted

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:

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

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:

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

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

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

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.

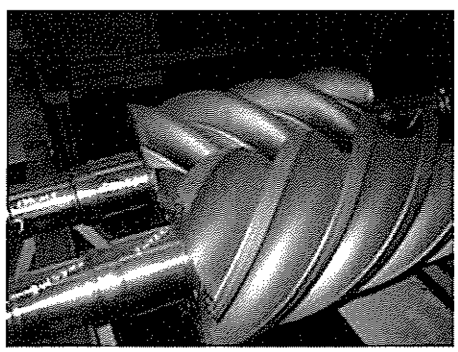


Figure 8-1
Rotary Screws Used in Air Compressor System

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.

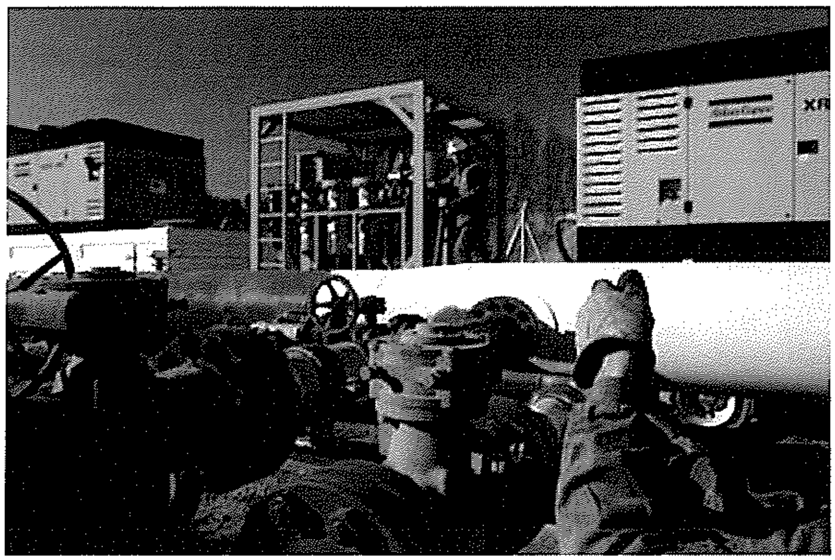


Figure 8-2
Typical Rental Screw Compressors Installed at a Job Site

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.

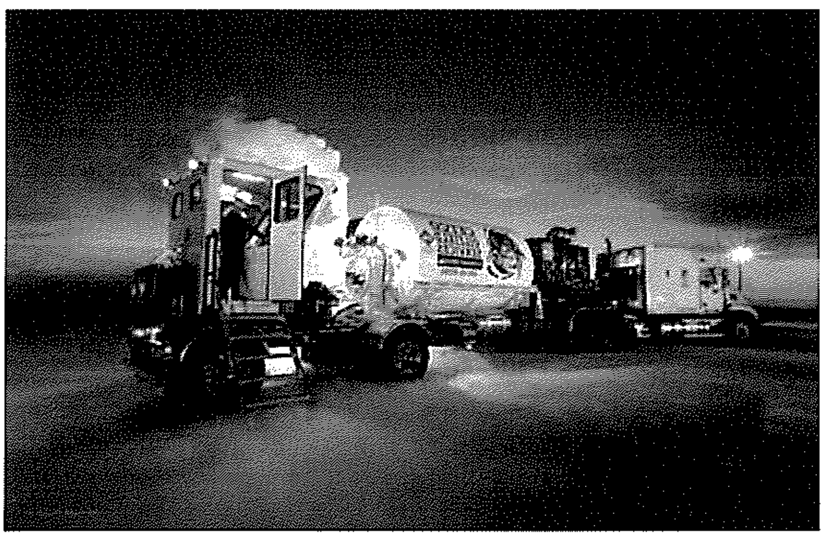


Figure 9-1
Nitrogen Pumper Truck

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.

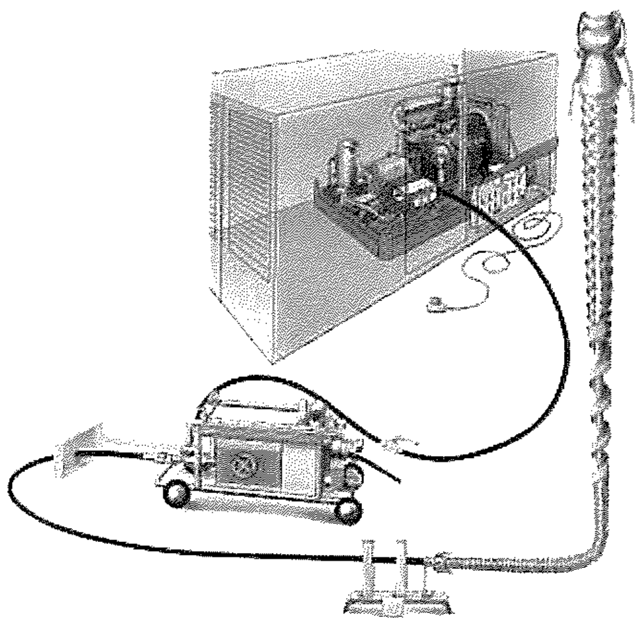


Figure 10-1
Smaller Equipment Layout for Water Jetting

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.

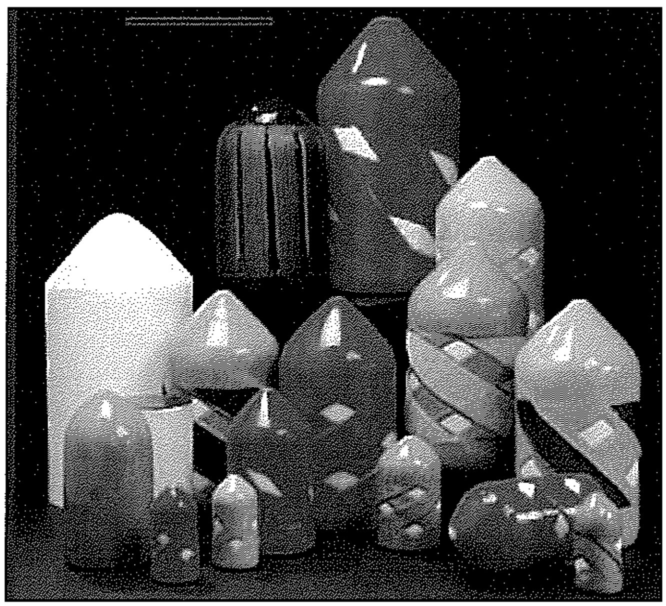


Figure 10-2
Pipeline Foam Pigs Used for Cleaning and Water Removal

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

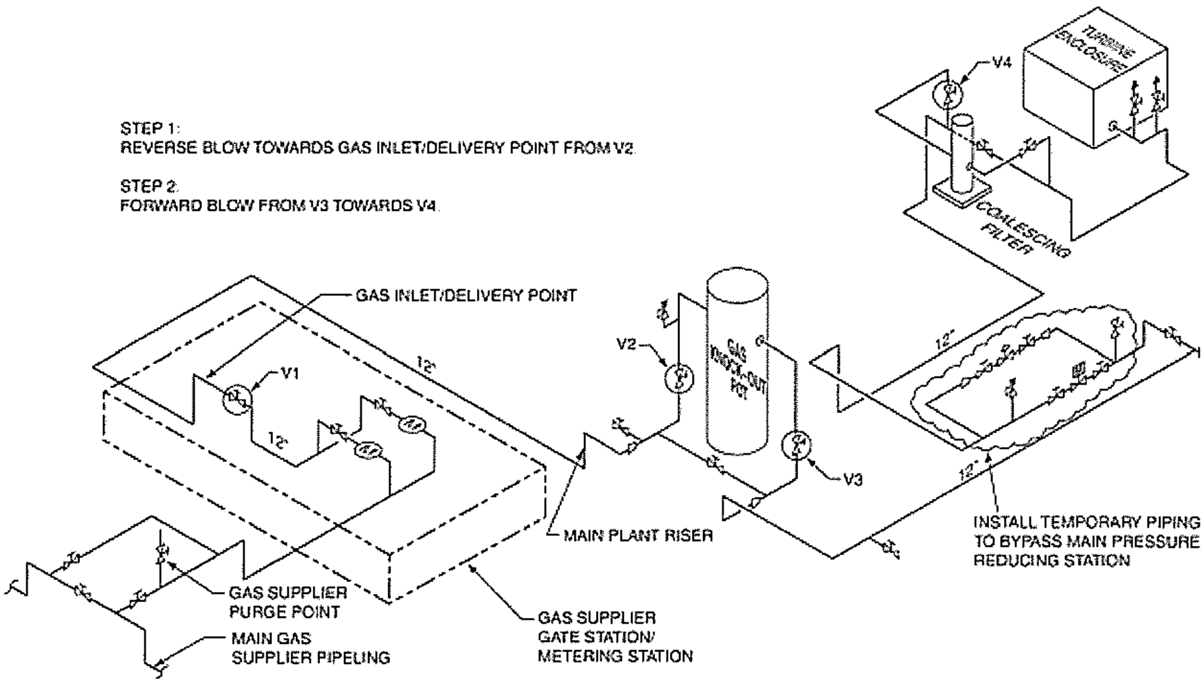
Contractor shall provide a detailed plan that includes strategic section of piping systems and locations of pump system and cleaning hose routes. Contractor to identify proposed cleaning pressures and nozzle sizes for each section. Contractor shall also identify collection and treatment of residual water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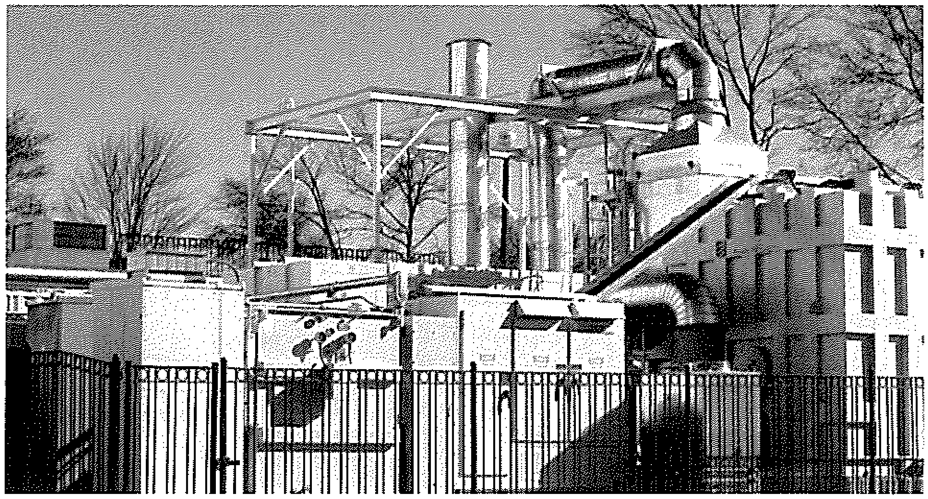

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

Response to Request for Proposal • February 27, 2013
FuelCell Energy • Bridgeport Fuel Cell Park

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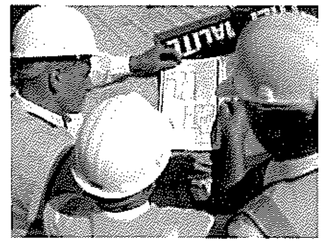
Risk Analysis & Safety Specification Development



A/Z Corporation has a goal of zero accidents and zero injuries with work tasks designed to minimize or eliminate hazards to personnel, processes, equipment, and the general public. A project-specific risk analysis will be conducted for the Bridgeport Fuel Cell Park Project. Using the project-specific risk analysis, the project management team will lead the analysis to document potential exposures that may impact the work, surrounding facilities, equipment, workers, or the public at large. The preliminary analysis for the Bridgeport Fuel Cell Park Project includes items such as, but not inclusive of:

- Existing building interferences
- Client security
- Impact to client occupied spaces
- Impact to client and public traffic patterns
- Potential client facility disruptions
- Overhead and underground utility locations
- Personnel working at elevated locations
- Mechanical, electrical and piping tie-ins and interferences
- Heavy material movement
- Steel erection
- Crane setup and critical lifts

Safety Management System

The Bridgeport Fuel Cell Park Project will have a safety management system in place that outlines the policies, processes, instruction, and documentation that will serve to establish the culture of safety and understanding for all tiers involved on the project. The following components will be part of the systematic approach:

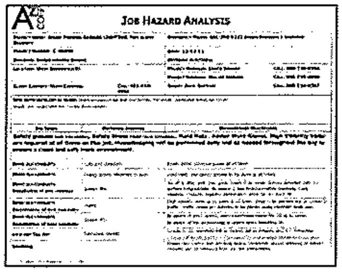
Project-Specific Safety Plan

A/Z will develop, communicate, and implement a written project-specific safety plan. The goal of the safety plan is to assist the A/Z project management team in meeting their responsibilities to provide a safe work environment and to aid in developing a program to eliminate accidents, injuries, and property damage. The safety plan will also identify foreseeable project-specific hazards and list A/Z's mitigation and control of such hazards. As the safety plan is meant to be a living document, A/Z will amend the safety plan to address any new hazards that were not addressed in the initial safety plan, but are later identified during the course of performing work at the Bridgeport Fuel Cell Park Project. The safety plan is required to be followed by all subcontractor/trade contractors as well.

Contractor Qualification

A/Z has established requirements pertaining to contractor safety. A/Z requires an EMR of 1.0 or less and also evaluates other safety performance criteria such as OSHA Recordable Incident Rates, OSHA inspections and citations, and Corporate Safety Program Manuals. Information and prequalification forms are transformed into an electronic data tracking system that is updated on an annual basis.

Job Hazard Analysis (JHA)


JOB HAZARD ANALYSIS

For all work that is to be performed, each subcontractor/trade contractor will create a JHA for the portion of their scope of work that will be reviewed and approved by A/Z before permitting the work to begin. The JHA will be a comprehensive evaluation of the work activity broken down into basic job steps, hazards identified for each step and contain hazard controls measures for each hazard identified. A/Z will keep all JHAs in a bound notebook in an easily accessible location or in electronic form for the length of the project. JHA's will be updated as necessary as the work progresses throughout the project and conditions change. JHA's will be reviewed with applicable employees prior to the start of work at each occurrence and when updates are made and this training will be documented. A sample training matrix is attached to this document for your review.

Daily Safe Plan of Action

Because the Construction site is ever evolving and changing environment from day to day, each subcontractor/trade contractor Field Lead will develop and document a daily hazard analyses to be signed by all personnel for the work they will be performing that day. Hazards may include not only the work that they are performing, but also identify any hazardous work being performed by others that their employees need to be made aware of. This document will be updated and changed as conditions or hazards change throughout the day. This document will be turned into the A/Z project team at the end of the day.

Communication

Orientation: A/Z will develop a project-specific safety orientation for all workers, including subcontractors/trade contractors and other individuals performing work at the site. Orientation training will address all components identified in the project-specific safety plan. The orientation will be completed prior to allowing workers to start on-site.

Preconstruction Safety Meeting: Prior to starting work on the Bridgeport Fuel Cell Park Project, A/Z's Senior Project Manager will lead a preconstruction safety meeting. The meeting will include as attendees the A/Z field supervisory staff that will be primarily responsible for management of workers and crafts, supervisory personnel from major subcontractors/trade contractors, A/Z's Safety Coordinator, and the owner and its representatives. The primary purpose of this meeting is to introduce the A/Z project management team personnel; subcontractors/trade contractors and owner personnel to the A/Z project-specific safety plan and to have A/Z's Senior Project Manager demonstrate an understanding of the project conditions and safety requirements.

Project Safety Communication: A/Z requires subcontractors/trade contractors to implement a policy for ongoing safety communication during the project. It is essential to keep safety in the forefront by communicating the importance of safety on a regular basis. This will be accomplished through the use of daily safety huddles, toolbox meetings, weekly subcontractors/trade contractors meetings, and/or other such initiatives.

Safety Representatives

Project Safety Coordinator: The designated project Safety Coordinator will possess conformance with all FuelCell Energy, University of Bridgeport, and A/Z confidentiality requirements, strict adherence to business ethics and practices, and a continual demonstration of professionalism throughout the Bridgeport Fuel Cell Park Project. The primary roles and responsibilities include, but are not limited to, the following:

- Thorough knowledge of OSHA regulations and requirements.
- Strong diplomatic skills in coordinating with field staff and ensuring safety of all students, faculty, visitors, and contractor personnel.
- Maintaining a full-time on-site presence to conduct audits, job hazard analyses, incident investigations, corrective action, safety meetings, toolbox talks, collaboration with A/Z and subcontractor/trade contractor Project Managers and Superintendents.
- Provide safety report detailing health and safety issues utilizing Predictive Solutions software; attend meetings with the project management team.

Safety Audits / Inspections

Utilizing Predictive Solutions Software, A/Z's Safety Coordinator will conduct and document regular safety inspections (minimum weekly) of the work areas and practices, and those of all subcontractors/trade contractors. Documentation of inspections will be readily available for review on the project site. A/Z will immediately correct any hazardous or otherwise noncompliant conditions identified and maintain documentation of the corrective action. Safety inspection information will be reviewed with owner and its representatives at least on

Incident Investigations

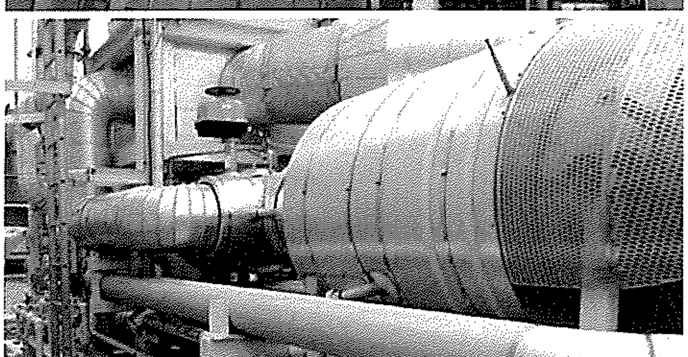
All accidents and significant near misses will be investigated by the Project Superintendents and Safety Coordinator. Copies of the incident reports will be provided to the owner and its representatives, and it will also be reviewed with subcontractor/trade contractor management by the A/Z's Senior Project Manager during weekly project meetings.

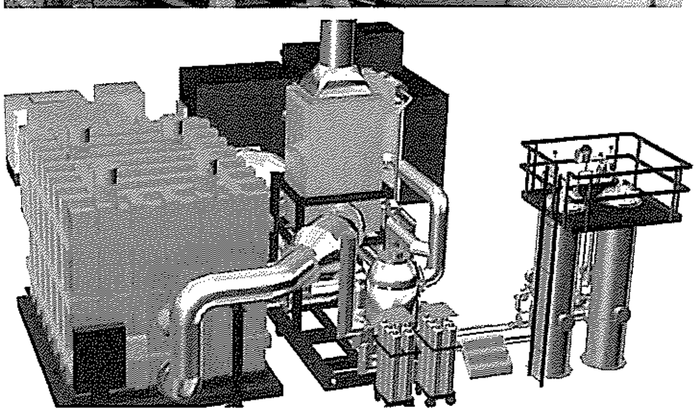
All incidents will be investigated within four hours of occurrence and an incident report filed immediately following the occurrence. If there is insufficient information to answer all questions, the incident will be reported anyway. The missing information will be provided to the owner and its representatives when it becomes available. Corrective actions will be implemented immediately.

Accountability Plan

An accountability plan will be developed, communicated, and implemented for the Bridgeport Fuel Cell Park Project. This plan will include disciplinary procedures to be utilized for noncompliance with safety requirements. Violations may result in work stoppage and progressive enforcement action pursuant to the terms of the subcontractors/trade contractor's contract with A/Z. If violations are severe or repetitive, the subcontractor/trade contractor may be removed from the project and prohibited from working at A/Z projects in the future.

Experience Highlights





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CCSU Fuel Cell Power Plant

Fuel Cell Energy, Inc. (FCE) selected A/Z to lead the design and construction of a 1.4 MW fuel cell power plant for Central Connecticut State University (CCSU), which will be the largest of its kind at any New England university. The CHP solution will be located next to East Hall on CCSU's New Britain Campus where the Department of Facilities Management is located. A/Z and its design partner are responsible for integrating a FCE DFC1500 fuel cell power plant into the campus while minimizing interruption to existing utility services. The unit will be tied into the water and sanitary sewer connections at East Hall as well as campus gas, electrical, and steam utilities. The locally manufactured plant, which features ultra-low emissions and low operating noise, is expected to save CCSU approximately $100,000 in energy costs.

Client Reference:
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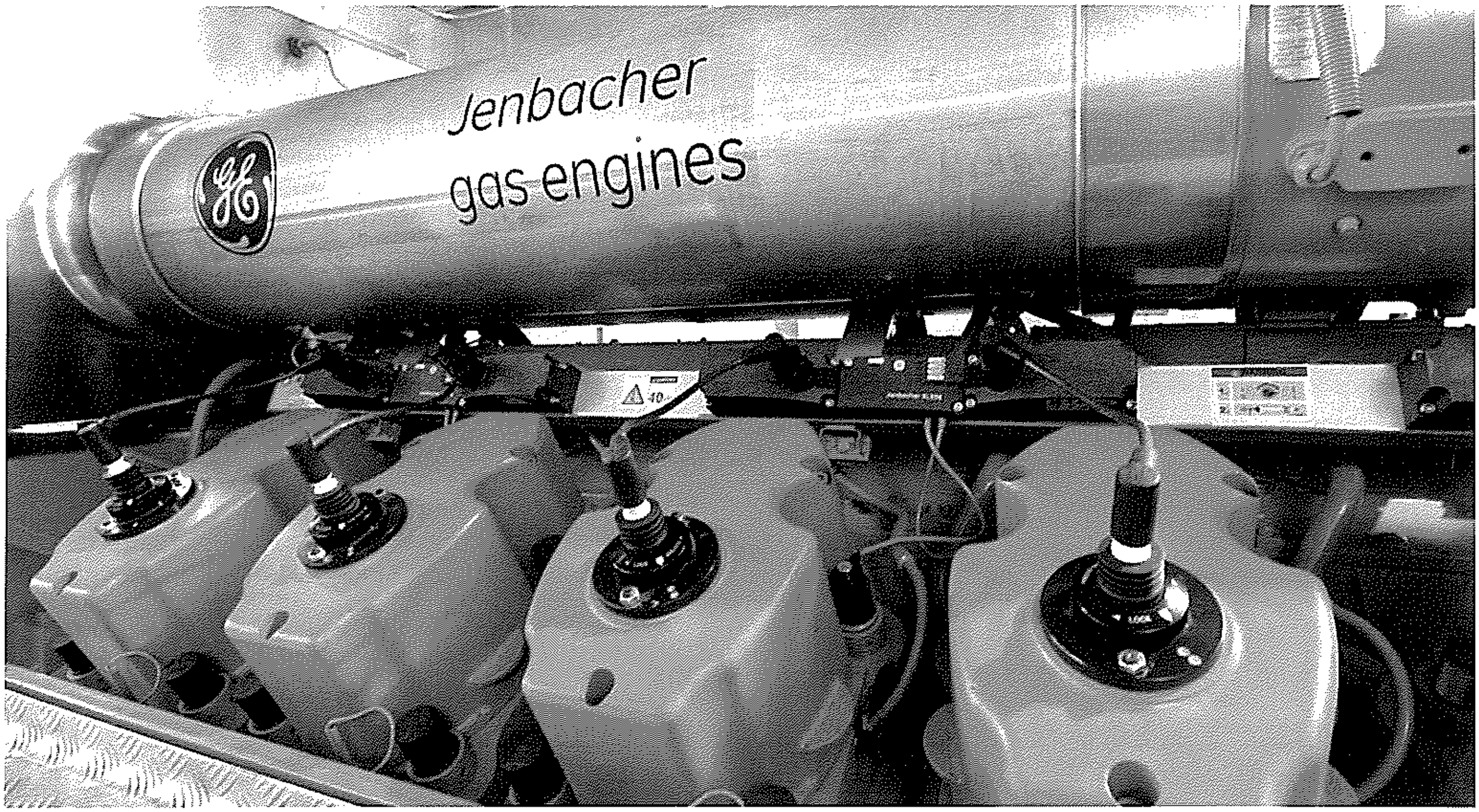

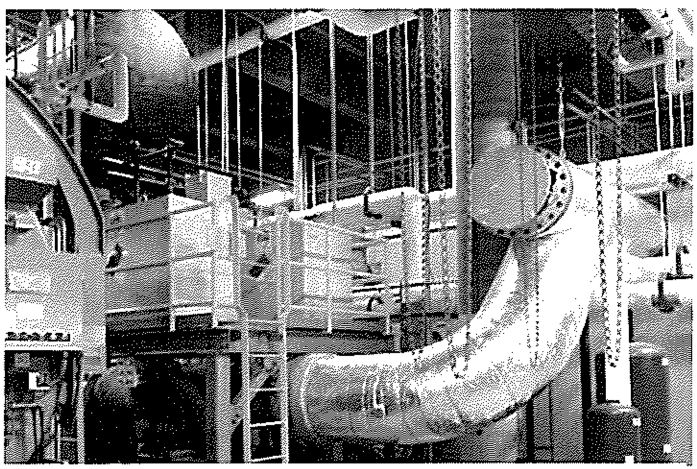

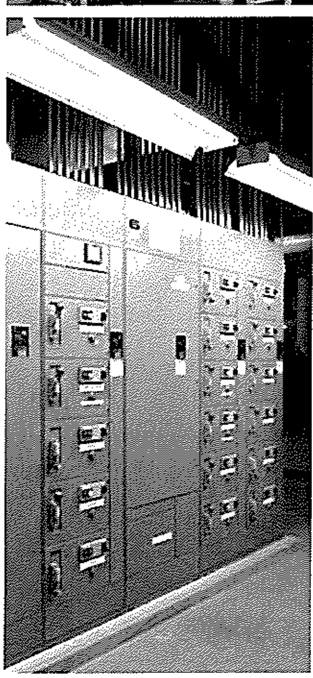

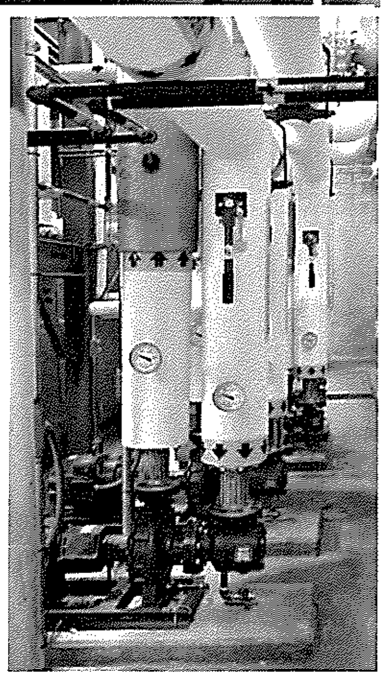

WESLEYAN UNIVERSITY

CHP Facility

The CHP Facility Project at Wesleyan University involved the installation of a combined heat and power system composed of a reciprocating engine as the prime mover, a 22,000 pound, 2.3 MW Jenbacher generator, a waste heat recovery steam generator, and ancillary support equipment. The multi-phase project required the coordination of multidisciplinary construction personnel towards the installation all CHP and distribution equipment while maintaining electrical service to the active campus. Barriers were placed to divert foot traffic around the site footprint on the active campus, ensuring the safety of students and faculty. Extensive civil work was required, including the trenching, excavation, and backfill necessary for the equipment pads and underground steam piping installations. Numerous critical connections to the turbine and associated equipment were completed to provide electrical and heating service throughout the Wesleyan University campus, including the installation of all conduit, cable, high pressure steam, jacket water, aftercooler water, lube oil piping, sub-metered gas piping, breaching, and double-wall central utility plant stack. The successful coordination of construction activities has resulted in a reliable source of energy for the university with the capacity to fulfill over 80% of the campus' requirements.

Client Reference:
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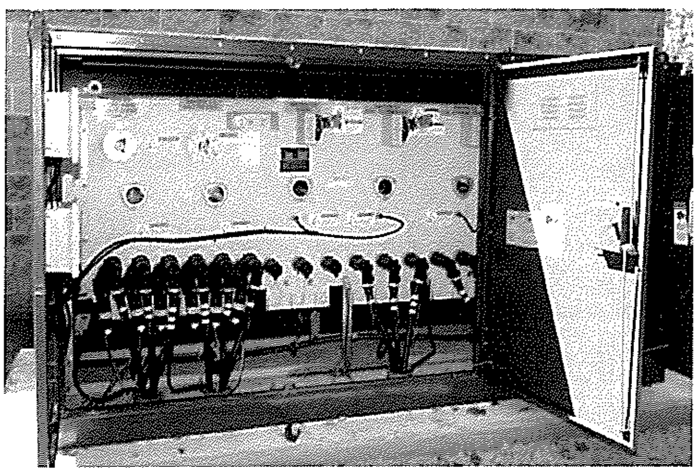

Campus Electrical Distribution Upgrade

The University of Bridgeport's medium voltage electrical distribution system was upgraded in a phased approach over a number of years. The project includes replacement of the entire existing 5 kV system with a modern 15kV system including switchgear, cabling, and transformation. A/Z worked extensively with University personnel to establish precise scheduling and logistics for a series of coordinated shutdowns that would be necessary for the execution of the project. This planning was crucial to the successful completion of the upgrades without interruption to electrical service at the campus. For Phase 1, AZ performed civil and electrical work to install two new 15 kV loop systems. A/Z was responsible for furnishing and installing nine pad-mounted SF6 G&W gas switches, pad-mounted transformers, and approximately 36,000 feet of 2/0 awg, 15 kV cable. A/Z performed all cable installation, splices, and terminations. The distribution system upgrades involved a combination of load break elbows and dead break elbows, including Raychem terminations and splices. A/Z also removed all abandoned cable as part of the project. Phase 2 built upon the system installed during Phase 1. Most of the remaining 5 kV campus transformation enabled the majority of the campus to utilize the new 15 kV infrastructure. The scope of work primarily involved the removal of existing transformers replaced at different locations with new 13.8 kV units to meet current and future power needs. A/Z also performed civil work including excavation and backfill, concrete for new ductbanks, substation improvements, and the installation of safety bollards at all new transformers.

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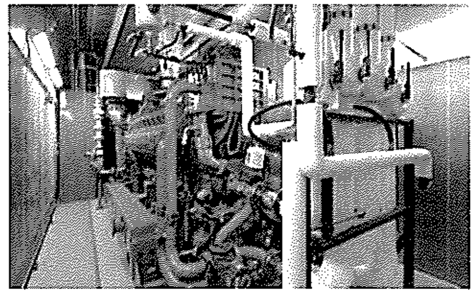
AZ CORP

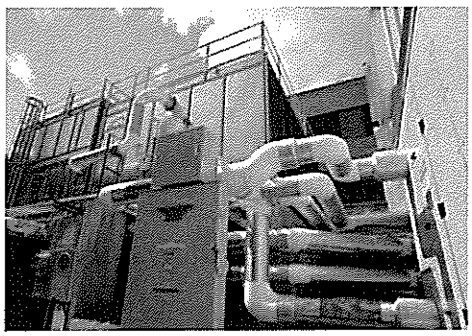
Combined Heat and Power (CHP) Facility • Middlesex Hospital

MIDDLESEX HOSPITAL

Middlesex Hospital selected A/Z to provide specialty construction services for the installation of a CHP system at their busy primary facility in Middletown, Connecticut. The hospital, which provides inpatient, outpatient, diagnostic, emergency, and rehabilitation services to an area of 250,000 residents, presents unique challenges for A/Z's project team. A/Z will draw upon an extensive background in performing infrastructure upgrades within operational healthcare facilities to ensure continuous utility service to Middlesex Hospital throughout construction. In addition to the electrical and mechanical scopes of work required to install the 2.1 MW Cummins generator and other CHP components, A/Z will support the essential commissioning and testing of the system in conjunction with the OEM.



CCHP Tri-Generation Facility • Boston Scientific



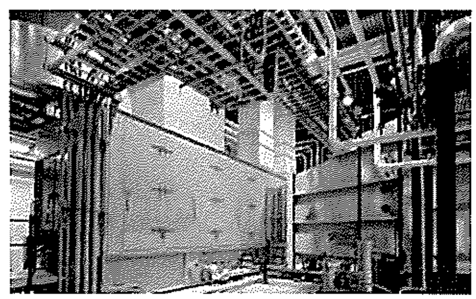
Boston Scientific

A/Z partnered with Dresser Rand to provide general construction, mechanical, and electrical services for the Boston Scientific. The project included a packaged CCHP system, which is comprised of a natural gas internal combustion engine generator with the associated heat recovery steam generator and absorption chiller as well as the applicable emissions control and system control panel. The project team was responsible for the installation of extensive utility piping including condenser water from adjacent cooling towers, chilled water from the CCHP facility's absorption chiller to a header tie-in at the existing chiller mechanical room within the existing facility, and hot water from the exhaust heat exchanger within the unit to a header tie-in at the boiler mechanical room within the existing facility. The CCHP Facility Project also included the electrical connections for the equipment such as feeders, current transformers, potential transformers, and control wiring.

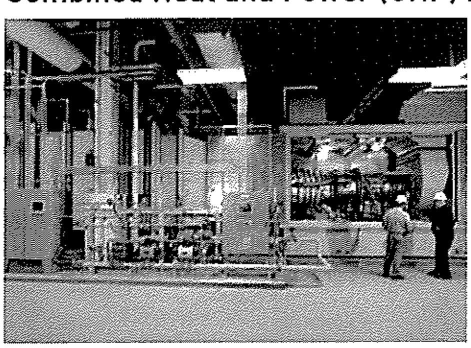
Combined Heat and Power (CHP) Facility • Pfizer, Inc.

Pfizer

A/Z provided general and specialty construction services for the CHP Facility Project, an initiative that included multiple construction phases to expedite the project schedule and avoid operational disruption to Pfizer's Groton, CT campus. The first phase included the excavation and foundation work for the CHP facility. The scope of work for this phase encompassed excavation, rock removal, grade preparation, dewatering, and placement of the building foundation. The second phase included the construction of the standalone CHP facility. The final phase of the project encompassed the installation of all associated CHP equipment: a Solar Mars 100, 10 MW dual-fuel combustion gas turbine, a gas compressor, a heat recovery steam generator, an exhaust scrubber system, a continuous emissions monitoring system, a redundant DeltaV distributed control system, and a medium-voltage paralleling switchgear.



Combined Heat and Power (CHP) Facility • Foxwoods Resort Casino



FOXWOODS RESORT ✦ CASINO

The CHP Facility Project encompassed the installation of two 7.5 MW gas combustion turbines, coupled with two heat recovery steam generators with a combined capacity of 170,000 pounds of steam at 125 psig. The project posed challenging logistics that were successfully planned for and overcome by the project team: the casino and hotel areas remain occupied on a 24/7 basis, which made the continuity of utility services a necessity throughout the project. Additionally, the central utility plant into which the CHP equipment was to be installed is located on the second floor of the facility; the pair of gas turbines were carefully rigged into an opening in the side of the facility. A/Z was responsible for the installation of all owner-supplied equipment including two turbines, HRSG units, breaching, BlackStar generator, ammonia system, selective catalytic reduction units, transfer switches, synchronization gear, and dry-type transformers.

Corporate & Industry Overview

Our Mission

A/Z is committed to being a recognized leader in the delivery of architectural/engineering, construction, operations, and facility maintenance services to the industries we serve. We will achieve this goal by remaining dedicated to these core values:

- ***Integrity***...is absolute in the delivery of services;
- ***Accountability***... at all times with our actions;
- ***Collaboration...*** for the mutual benefit of all.

Our Company

A/Z Corporation is a privately held, industry-leading engineering, construction, operations, and integrated facility maintenance services provider. Our mission is to provide the highest levels of quality and value to the clients we support in a wide range of technology-driven industries. This is a commitment that our firm has upheld for more than 45 years through the efforts of our dedicated team members and our unique combination of in-house resources. We understand what it takes for modern businesses to thrive in a fast-paced marketplace, and we are here to support our clients by understanding and adapting to their needs.

We serve a continuously expanding geographic area of operations throughout the Northeast with strategically positioned offices in the region. Today, we have three regional offices in addition to our corporate office in North Stonington, CT. The regional offices are located in Hartford, CT; Westborough, MA; and King of Prussia, PA. Our team members take a highly collaborative approach to our clients' projects and programs, employing the latest technological solutions and industry best standards. Responsiveness and accountability are central to our goal of earning and sustaining the confidence of our clients.

2011 & 2012 TOP WORK PLACES Hartford Courant FOXCT

A/Z's strongest asset by far is the strength of our team members, and we pride ourselves on the ability to recruit and retain some of the industry's most talented individuals. This is reflected in our recognition as a Top Workplace in a statewide study conducted by human resources consultant Workplace Dynamics for 2011 and 2012. A/Z's skilled professionals undergo continuous training with our firm, and they are enabled and ready to do "Whatever it Takes" for our clients and their projects. This level of dedication from A/Z's team is a key attribute of how we earned the reputation as a highly customer-centric organization.

Our Services

We provide our industry-leading services to our clients via a wide range of delivery platforms. The foundation to all of these platforms is our customer-centric approach, which allows us to be flexible and accountable with the services we offer. A/Z uses a dynamic approach that makes best use of the strengths of our professionals, which can be specifically tailored to each undertaking. This qualifies us to offer our clients a variety of staffing and project team options. We have the capability and leadership to manage technically complex projects and programs through every phase: concept, design development, construction, operations, and beyond. Today, A/Z is typically providing services under the following delivery options:

Professional Services

- Design & Engineering
- Preconstruction & Procurement
- Construction Management
- Design/Build
- Integrated Project Delivery (IPD)
- Owner Representation
- Traditional General Construction

Specialty Services (Self-Perform Capability)

- Civil, Structural, & Architectural
- Mechanical Piping
- Thermal Protection
- Electrical & Instrumentation
- Telecommunications & Security
- Integrated Facilities Management (IFM)
- Operational Support Services

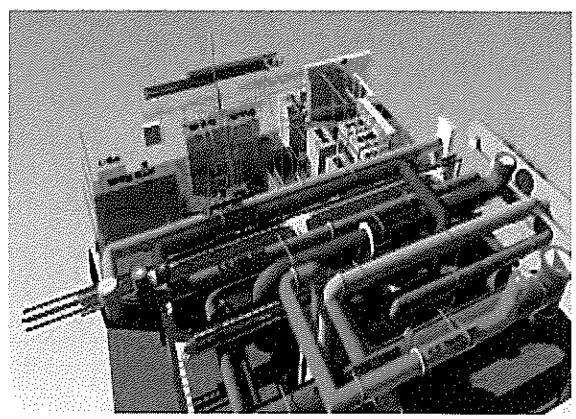
Financial Strength

We have remained a steadfast employer and member of the local business community. Our audited financial statement is available for review upon request. According to the Construction Financial Management Association (CFMA) rating system, A/Z is proud to be classified as a best-in-class financial performer. Our bonding company Travelers, rated A+ in Best's Key Rating Guide, supports all of A/Z's bonding needs as a federally insured surety. They provide A/Z with bonding up to $150 million. Over the past two years, A/Z has successfully managed over $400 million of work-in-place.

Sustainability Commitment

In addition to this financial stability, we also recognize how important it is to our clients to partner with companies that share their commitment to sustainable and environmentally responsible operations. A/Z constantly seeks to adopt proven practices, and we work closely with our clients to minimize the impact of our efforts on our surroundings and the long-term preservation of the environment. We are a certified member of the U.S. Green Building Council and Green Building Initiative (Green Globes). We boast a team of professionals who undergo frequent training in support of the success of our environmental stewardship practices.

Our Proven Technology



While our approach to each undertaking is custom-tailored to our clients' goals, our team members are consistently supported by the latest technology platforms and best practices to enhance collaboration and efficiency. Currently, A/Z can electronically submit all project documentation to our clients. We also support complete Building Information Modeling (BIM) in all disciplines, assemblies, and systems. A/Z also utilizes proven online solutions to facilitate and enhance our procurement process as well through a web-based application. This allows for the rapid and secure transfer of files with our approved subcontractors without the expense of individual reproductions. Today, we can manage all of our project documentation in a real-time digital environment. A few of the industry-standard software suites that we use include:

Our Commitment to Safety

A/Z has developed a culture that promotes an injury-free environment and provides the safest workplace possible for our employees, subcontractors, clients, and others who enter or work near our construction sites. Our belief is that effective contractor safety programs enhance projects. Additionally, we realize that successful management with life safety and stringent environmental controls require defined objectives, strong adherence to fundamental principles, and clearly defined procedures that the team can successfully implement.

A/Z's team is committed to work in partnership with our clients to exceed safety and environmental objectives, ensuring the identification and mitigation of any anticipated hazards.

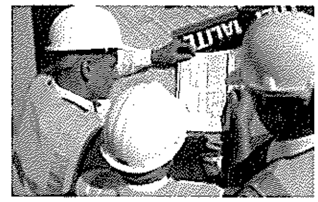
Our dedication to the safe execution of all projects begins with a goal of zero incidents. To this end, we provide a safety-focused, trained, and experienced team for every project. A/Z's core project team members maintain their 30-hour OSHA training certification or equivalent. Additionally, all subcontractors are evaluated prior to contract award by examining their safety programs, OSHA citation record, Lost Time Incident Rate (LTIR), Total Recordable Incident Rate (TRIR) and their Experience Modification Rate (EMR).

Any and all subcontractors that we manage are evaluated prior to contract award by examining their safety programs, OSHA citation record, Lost Time Incident Rate (LTIR), Total Recordable Incident Rate (TRIR) and their insurance Experience Modification Rate (EMR). Failure to meet acceptable standards on any one of these criteria gives cause for careful, close examination. All subcontractors are required to file a safety plan as part of their bid documents and to appoint a safety coordinator to represent and train their employees as well as conduct periodic site inspections. Those requirements are in addition to local, state, and federal safety standards and regulations, including the Occupational Safety and Health Act (OSHA).

To ensure our safety commitment, our project management teams are complemented by dedicated in-house safety representatives utilizing the latest in safety inspection technology. We use *Predictive Solutions* to collect safety-related observations, ultimately allowing our safety team to record inspection results and corrective actions from the field into a database. This allows our team the opportunity to trend our safety performance in a real-time application.

A/Z's 2012 Experience Modification Rate (EMR) at **0.66** sits far below the industry average of 1.0. Our current Recordable Incident Rate (IR) and Lost Workday Incident Rate (LWIR) are also significantly lower than the industry averages at 2.09 and 0.52, respectively. These statistics are exceptional considering the fact that we employ over 400 active, full-time personnel including 275 trades personnel. Additionally, A/Z projects have undergone five OSHA site inspections during the past five years resulting in zero citations.

Our Approach to Safety



A primary part of attaining these safety results is the consistent level of effort that we commit to developing strong safety plans for each project. At the start of each engagement, our core project team members and safety personnel conduct a comprehensive risk analysis. This analysis documents potential exposures that have the potential to impact the work, surrounding facilities, equipment, owner employees, or contractor personnel if not proactively managed. The items that are encompassed by this investigation can include:

- Client security and operational requirements.
- Hazardous analysis of existing conditions.
- Overhead and underground utility locations.
- Areas of elevated work and confined space.
- Mechanical, electrical, and piping tie-ins and interferences.
- Heavy material movement and rigging.

These efforts form the foundation from which a project-specific safety plan will be developed. The plan will incorporate both client-specific safety and security requirements as well as A/Z's proven EH&S protocol. By identifying foreseeable hazards and our mitigation/control practices for such hazards, our project management team will have an important tool with which to eliminate accidents, injuries, and property damage. It is very important for this safety plan to serve as a living document throughout the duration of the project; as the project progresses, the safety plan will be amended in collaboration with client EH&S representatives to address any emerging hazards.

A/Z's project management team shares the responsibility of administering our safety plan in collaboration with our Safety department. These team members communicate closely throughout the duration of the project, and they meet regularly to discuss current site conditions, work activities, and potential hazard mitigation.

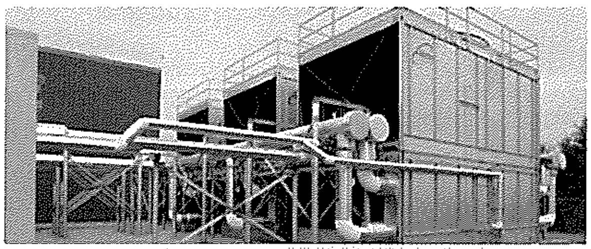
The project-specific safety plan will be implemented for all A/Z personnel as well as our subcontractors. Additionally, we will also employ a number of other best practices and procedures as appropriate, such as:

- Job Hazard Analysis (JHA): For all work that is to be performed, each subcontractor contractor will create a JHA for their scope of work that will be reviewed and approved by A/Z before permitting the work to begin. The JHA will be a comprehensive evaluation of the work activity broken down into basic job steps, hazards identified for each step, and hazard controls measures.
- Daily Safe Plan of Action: Because the construction site is constantly changing, each subcontractor Field Lead will develop and document a daily hazard analysis to be signed by all personnel for the work they will be performing that day.
- Safety Audits/Inspections: A/Z's Safety Coordinators equipped with mobile Predictive Solutions software will conduct and record regular inspections of all work areas and practices. Any non-compliant conditions will be immediately corrected and documented.

These practices and others that will be detailed in our project-specific safety plan are designed to comprehensively address and mitigate potential safety hazards before they can have an impact on any personnel or the project. They are built from our commitment of tailoring our safety practices to the specific needs and potential hazards of every project that we undertake.

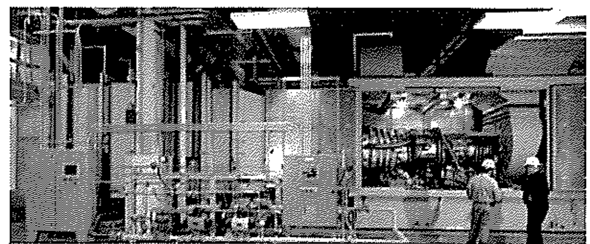
Industry Overview

We understand the utility requirements of our clients, and have a proven track record supporting highly complex utility installations and upgrades. Our team is well-versed in the industry's complex requirements related to life safety, code compliance, and associated MEP manufacturer's installation requirements. Whether implementing utility infrastructure within active campuses or working within highly sensitive operational central utility plants, our expertise and experience allow us to meet the unique needs of today's utility marketplace. The following is a sampling of the facilities and systems with which we possess a strong, proven expertise:



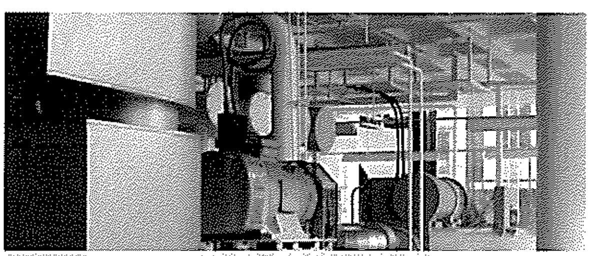
HVAC & Chillers

HVAC systems can be very complex and require the integration of boilers, chillers, air handling units (AHU), pumps, and control systems to allow them to work simultaneously and efficiently. Building Management Systems (BMS) and process control systems ensure operational parameters are maintained within tolerance and compliance with applicable regulatory agency requirements and accepted industry best-practices such as cGMP, JHACO, ASHRAE, and ASHE to name a few. A/Z can provide a single-source solution to support a wide range of assignments including routine maintenance, existing equipment energy analysis, equipment upgrades, and major capital project initiatives.



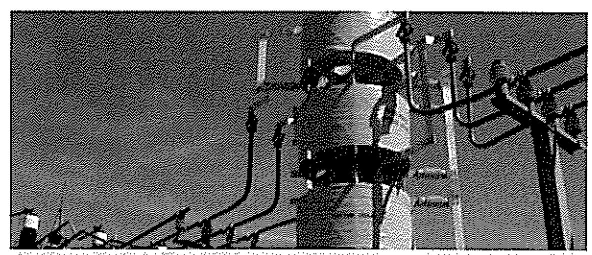
Combined Heat & Power

Combined Heat and Power (CHP), also known as cogeneration, and CCHP, known as trigeneration, has tremendous potential to reduce operating costs and dependence from local utility providers. Our CHP plant installations reduce carbon footprint and annual energy costs as well as improve power system reliability. We have partnered with leading original equipment manufacturers (OEMs) to provide cost-effective solutions for successful CHP and CCHP projects. By carefully evaluating our clients' current and future energy usage, we can offer recommendations on optimizing energy strategies within mission critical sites.



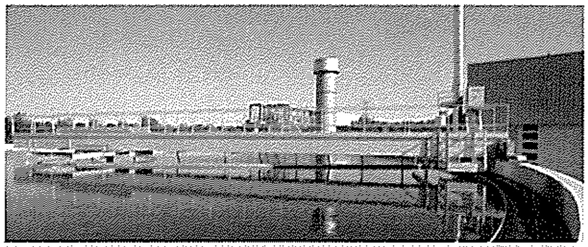
Central Utility Plants

Continuous, reliable utility service is a standard expectation for the clients we service. A/Z has the technical expertise to provide a full range of services, from constructing new utility plants to integrating new, efficient technologies within existing plants. We will bring cost effectiveness and efficiency to the programs we support with a commitment towards environmental responsibility and life safety.



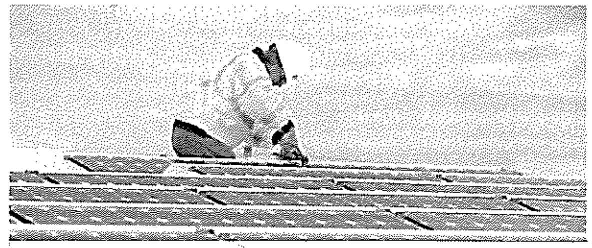
Power Distribution & Substations

Our experience in power distribution and substation construction at voltages up to 69 kV, affords us the experience and resources to upgrade, maintain, and repair critical power distribution systems. This experience spans medium voltage cable installation, splicing, and terminations. Our technicians are trained with all major splice and termination manufacturers. In addition, we are an MVPower Certified Contractor, allowing us to offer 20-year warranties. In addition, A/Z coordinates the entire process of rigging, setting, and testing distribution equipment, from duct banks and equipment pads, to vaults, ground grids, and final witness testing.



Waste & Wastewater Treatment

It's essential that water/wastewater treatment facilities and the associated distribution systems provide effective, reliable service to the businesses and communities they serve. For over two decades, A/Z has provided crucial construction services for municipal and private facilities, including controls, pumping, and metering stations, lift stations, piping distribution, filtration plant upgrades and high purity watering systems. Our team handles on-site trade management and system installations, including water/wastewater treatment solutions that support both regulatory compliance and environmental responsibility. Our ability to serve as a single-source for most installations and upgrade programs ensures that field performance and quality rest with a proven service provider.



Alternative Energy Solutions

Environmental responsibility and utility cost have become a primary focus within the industry today. A/Z continues to embrace technology accelerators that can support carbon footprint reduction and utility usage efficiencies. Today, A/Z is supporting many organizations with sustainable facility solutions that include CHP, renewable energy, fuel cells, solar technology, specialty equipment replacement for energy optimization, and lighting retrofits. Our team has supported primary owners and developers as well as energy supply companies (ESCOs) with alternative energy-saving programs.

Emergency Service

Business, productivity, and client satisfaction depend on uninterruptable utility services, and it's essential that outages and unplanned shutdowns are managed efficiently – regardless of the environment they impact. Our in-house self-perform capabilities allow us to react quickly to any situation, and the ability to deliver comprehensive, effective emergency standby solutions. Whether it's restoring power, HVAC, steam, or water service, we understand utility procedures and protocols, and are committed to partnering with our clients to rapidly deploy effective solutions.

Outage Support

Whether it's a scheduled event or an unplanned shutdown, A/Z has the resources and experience to respond quickly to any outage situation. We can rapidly mobilize teams of licensed electricians, certified welders, pipefitters, insulators, carpenters, and laborers to ensure our clients' facilities are back online fast. We also offer project managers, engineers, and safety personnel to assist our clients during high-risk periods. With our 3D BIM modeling capabilities, CPM scheduling, and procurement services, we can assist in pre-planning so that scheduled outages run without impact or surprises.

EMERGENCY REPONSE PLAN

Bridgeport Fuel Cell Park

Located at:
1366 Railroad Avenue
Bridgeport, CT

Plant Owner: Dominion Bridgeport Fuel Cell, LLC
120 Tredegar Street
Richmond, VA 23219

Contract Operations / Maintenance: FuelCell Energy, Inc.
3 Great Pasture Rd.
Danbury, CT 06813

Core Plan prepared by FuelCell Energy, Inc.

A current copy of this Plan is to remain in an accessible location on-site at all times.

CONTENTS

1. GENERAL

The Bridgeport Fuel Cell Park ("BFCP") Project is an innovative, nominal 15 MW hybrid generating facility that comprises two prime mover technologies to generate high efficiency and ultra clean electricity. The Project will consist of five of FuelCell Energy's ("FCE") 2.8 MW Direct Fuel Cell ("DFC")®3000 power plants integrated with an ORMAT Energy Converter ("OEC") based on the Organic Rankine Cycle ("ORC"). The Project will utilize the excess thermal energy from the fuel cell power plant exhaust to produce an additional 930 kW (nominal) of zero emissions electrical output through the OEC.

The Project will deliver Connecticut Class I renewable power to the United Illuminating ("UI") electric distribution system in Bridgeport, Connecticut for ultimate sale to the Connecticut Light and Power Company ("CL&P") pursuant to an executed long-term power purchase agreement. The facility is to be constructed in accordance with the September 24, 2010 approval of the Connecticut Siting Council.

The facility is designed as an unmanned, fail-safe system. In the event of any upset condition, whether safety or equipment related, the integrated system will engage in an emergency shutdown ("ESD") procedure that will isolate either the specific equipment experiencing the condition or the entire facility, based on the nature of the event.

The system will isolate the fuel supply utilizing dual block valves contained either at the site battery limits and / or on each specific DFC3000 (or in the case of the OEC the motive fluid). The equipment will purge the fuel train with nitrogen and open tie breakers located at the utility grid interface (switchgear) should the situation require electrical isolation as well. FCE's Global Technical Assistance Center ("GTAC"), the regional service team lead, and local service technician will automatically be notified of the change in operational states and will dispatch emergency response crews and / or regional service personnel as necessary as further described below.

2. PLANT SAFETY AND SECURITY

2.1. Construction

2.1.1. Safety Policy and Manual

FCE will address site security and personnel safety as the highest priority ensuring a safe and healthy work environment. Minimum safety requirements and policies have been identified and will be provided and enforced on any level of organization on or performing work at the facility (see Appendix A).

In addition, any subcontractor will be required to provide, adhere to, enforce, and report on their own safety policies and practices. Such policies, procedures and / or handbook will be provided to FCE prior to contract execution for FCE's review and consideration.

2.1.2. Site Supervision

FCE will provide construction and safety managers to be present during any work being performed on site at any time. FCE's management will perform as an additional on-site expert witnessing, inspecting, and enforcing all safety policies and practices.

Further, any subcontractor will be required to have a site safety supervisor on site at all times that any work is being performed. The safety supervisor is responsible for all subcontractor personnel's adherence to all required and prudent policies and practices. The supervisor is to be responsible for:

- Enforcing safety policies and practices,
- Providing safety orientation for any new personnel onsite,
- Daily safety "toolbox" meetings covering daily activities and associated risks by trade,
- Recording the daily safety meetings,
- Weekly safety status meetings and discussion topics,
- Performing and reporting on weekly safety audits,
- Maintaining a daily personnel attendance log (discussed further, later in this plan),
- Site walks with FCE's safety and construction managers on request, and
- Monthly formal reports including labor hours worked, incidents (including near misses, recordable events, and reportable events) along with a detailed description of corrective actions, audit results, and a summary of any site walks that occurred during that period.

At any time, FCE or subcontractor's safety or construction management personnel can, should, and will enforce a stop work directive to correct any safety infractions.

2.1.3. Security

The entire perimeter of the facility will be fenced by a semi-permanent chain link fence with privacy screening. The gates will be closed and locked overnight and any time when site work is not actively being engaged in. Further, whenever work is not being performed on site, a full time security guard will be present to further dissuade any loss, damage, or vandalism during the construction phase.

2.2. Operation

As stated above, the plant is designed as an unmanned facility. The perimeter of the facility will be secured utilizing an 8' decorative fence per direction from the City of Bridgeport. Four (4) vehicle gates and two (2) man gates will allow for equipment and personnel access to the facility. Each gate will be locked by both an FCE and Bridgeport Fire Marshal specified knox locks at all times when the site is unmanned. In addition, site lighting will be provided, automated and available 100% of the time and four (4) cameras will monitor and record all on-site activity.

3. PROJECT SAFETY FEATURES

3.1. Construction

FCE will coordinate with local emergency personnel including the fire and police departments. At any time there is a major equipment delivery, the police department will be notified and contracted to manage and, as required, control local traffic. Prior to bringing or making natural gas available at the facility, FCE will coordinate with the local fire department, provide training regarding the facility equipment and facility safety features, a tour, and description of how the facility will respond should a fire, smoke, or volatile gas release be detected and what additional activities emergency responders can or should perform to further ensure their safety.

3.2. Operation

The certifications and associated safety systems and protocol require multiple levels of security. The system includes multiple flame, temperature, smoke, and gas detectors in addition to a host of operational parameters and instrumentation that can and would identify any upset, emergency, or grid instability condition (please see Appendix B). As stated previously, the system is designed as an unmanned facility and therefore no manual interaction in any foreseeable situation would be required. FuelCell Energy's products are installed globally in locations where manual interaction would not be possible despite its proximity to the general population (such as resorts and casinos). In no cases has on-site facility interaction been required. In addition, this facility considers, is being designed to, meets, and exceeds the requirements imposed by the Environmental Protection Agency ("EPA") Risk Management Protocol ("RMP").

4. COMMUNICATIONS

4.1. Local Emergency Responders

911 is to be contacted and notified immediately in any emergency threatening personnel safety or wellbeing occurring at the facility at any time.

For non-emergency local responders can be contacted as follows:

- Bridgeport Hospital.......................................203.384.3000
- Bridgeport Fire Department...........................203.337.2070
- Bridgeport Police Department.......................203.581.5100

4.1.1. Construction *(prior to December 31, 2013)*

During any and all construction activities, all personnel must be accounted for. All personnel, regardless of purpose, activity, or duration of the site visit, are required to sign in, participate in a safety briefing, and sign out as they leave the facility. The sign in sheet is to be located in the main construction trailer and managed by the site safety manager at all times.

For communication and coordination in emergency situations, the general contractor will perform mass communications regarding emergency situations in the following manner.

1) Should the situation present itself where work needs to be halted as quickly as possible without an immediate safety concern or issue (such as lightning in the area), an air horn will be sounded once signaling to the site personnel that tools and equipment should safely stowed and all personnel should report to the construction trailer for further instructions.

2) Should a situation present itself where imminent danger is likely or a situation requiring immediate evacuation, the horn will be blown three consecutive times indicating that all personnel should drop their tools and equipment and evacuate the facility immediately and report to the designated evacuation area for roll call against the daily sign in sheet.

Following any site emergency, issue, or incident, the following individuals should be notified in the following order.

Site Care and Custody:
Individual...Eric Hermann
Company..AZ
Title..Senior Project Manager

Contact 860.334.8335

Site Management:
Individual ....Kirk Arneson
Company ....FCE
Title ....Senior Project Manager
Contact 203.733.5892

Site Owner:
Individual ....Brian Wright
Company ....Dominion
Title ....Director Project Manager
Contact 804.382.2521

4.1.2. Operation *(following December 31, 2013)*

Any visits during the operational phase will be coordinated through FCE's customer service manager or if planned or unplanned maintenance is required, through FCE's GTAC organization. In all cases GTAC will maintain a list and be in contact with all personnel on site during their visit or operation. In the event an emergency situation or issue is identified by such on-site personnel, the following individuals / organizations will be notified in the following order.

Site Operations and Maintenance:
Individual ....GTAC
Company ....FCE
Title ....Shift Lead
Contact 800.326.3052

Site Operations Manager:
Individual ....John Wolfe
Company ....FCE
Title ....Customer Service Manager
Contact 203.830.5726

Site Owner:
Individual ....Bob Sauer
Company ....DBFC
Title ....Station Director
Contact ....[ADD PHONE NUMBER]

4.2. Local Officials

It is not anticipated that any additional correspondences beyond those associated with permitting, reviews, inspections, and approvals would be required with local officials. Should a situation present itself where notification may be found to be necessary the Bridgeport Building Department can be contacted at 203.576.7225.

4.3. State Officials

Correspondences between state officials and project personnel are expected to be minimal and controlled. No correspondences associated with emergency response would be expected except as otherwise identified in the project's EPA RMP and / or requirements as defined in the site Spill Prevention, Control, and Countermeasure ("SPCC") plan.

4.4. Neighbors

In any situation where daily construction or operational activities would be perceptible, interfere, interrupt or impact the operation of the adjacent neighbors in any way they will be notified in advance of such activity and coordinated with (such as soil compaction, abnormal noise generation, hazardous activities). In the case of emergency situations that may in any way impact them or their property, they will be contacted immediately following the communication with the local responders (911) and prior to coordinating with the facility contact list (defined in paragraphs 4.1.1 and 4.1.2 above) in the instance where they may deem action required per their specific emergency response plan.

AKDO:
Individual .... Chris Nartowicz
Company .... AKDO
Title .... Facilities Manager
Contact 203.814.8273

Dari Farm:
Individual .... Rich Corraro
Company .... Dari Farms
Title .... General Manager
Contact 203.384.0820

Appendix A – FCE Safety Policies

Contractor will plan and conduct the work to safeguard persons and property from injury and will direct performance of work in compliance with reasonable safety and work practices and with applicable federal, state and local laws, rules, and regulations including but not limited to "Occupational Safety and Health Standards" promulgated by the U.S. Secretary of Labor. Work in areas adjacent to electrically energized facilities and/or operating natural gas facilities shall be performed in accordance with said practices, laws, rules, and regulations.

Contractor will enforce adherence to FCE's Safety Policies attached herein and Contractor's own Health and Safety policies. Contractor shall halt any work proceeding in an otherwise unsafe manner. Contractor shall provide their Safety Policies and Handbooks for FCE's reference and will be required to have a full time on site safety manager monitoring and reporting any deviations from either FCE's or the Contractor's policies or procedures.

As part of FCE's continued efforts to provide a safe and healthy workplace it is required that all activities are performed in accordance with all applicable regulatory requirements. While impossible to foresee all potential circumstances; the below list of Environmental, Health and Safety requirements constitutes the basic elements to be followed with while working with or for FCE.

- SIGN IN: All individuals who are not direct employees of FCE must sign in/out at the office on each day that they are on site.

- ACCIDENT, ILLNESS & INJURY: All accidents and injuries occurring on the premises shall be reported immediately to FCE's Construction Manager in charge of the work being performed.

- CHEMICAL RELEASE OR SPILL: Any planned or unplanned spill or release of chemicals on this site, regardless of volume, must be immediately reported to the Construction Manager.

- COMPRESSED GAS MANAGEMENT: The management and use of compressed gas is to be performed in accordance with OSHA standard 29CFR 1910.0101 "Compressed Gasses, General Requirements."

- CONFINED SPACES: All work in "confined spaces" is to be managed in accordance with OSHA standard 29CFR 1910.146.

- CRANE HOIST & SLING SAFETY: The operation of cranes and hoists is to be performed in accordance with OSHA standard 29CFR 1910.179; and the use of slings is to be in accordance with OSHA standard 29CFR 1910.184.

- ELECTRICAL SAFETY: All work involving electricity is to be performed in accordance with OSHA standards 29CFR 1910 Subpart S "Electrical Safety"; 1910.269 "Electric Power Generation, Transmission & Distribution; and NFPA 70E-2004 "Electrical Safety In The Workplace" as applicable.

- EYE PROTECTION: During all times that ANY work is being performed anywhere on the facility all personnel at the facility must be wearing eye protection.

- FALL PROTECTION: All work performed at heights of six feet or greater must be provided with at least one form of fall protection that will either prevent a fall from occurring, or properly arrest a person once the fall event has occurred. However, platforms, or other surfaces designed primarily for walking, shall be provided with an approved guardrail system when they are either; >4' above the adjacent floor or ground level, or, above dangerous equipment (conveyor belts, chemical baths, exposed rebar, etc...) regardless of height. In all cases, work at height must be performed in accordance with OSHA standards 29CFR 1910.23, 132, and 503.

- HAND & PORTABLE POWER TOOL SAFETY: Hand and portable power tools are to be used in accordance with OSHA standard 29CFR 1910 Subpart P

- HAZARD COMMUNICATION; RIGHT to KNOW: 29CFR OSHA standard 29CFR 1910.1200: Employees shall not be exposed to Hazardous Chemicals without first receiving training on the associated physical and health hazards and the measures needed to protect the employee from these hazards.

    - FCE utilizes green on white Target Organ Labels identifying the Name and the Physical & Health hazards of a material; these labels shall be used for all containers not otherwise adequately labeled by the manufacturer.
    - Hazardous materials brought on site shall be labeled and a Material Safety Data Sheet (MSDS) supplied to the Environmental Health and Safety (EHS) Department prior to working with the chemical.
    - An MSDS station detailing all chemicals currently onsite is available for review.

- HAZARDOUS MATERIALS: FCE is to be notified in advance of all hazardous materials to be brought on site. STORAGE use and off-site transportation of these materials shall be performed in accordance with applicable requirements of the Connecticut General Statutes, the Regulations of Connecticut State Agencies and Titles 29 (OSHA), 40 (EPA), 49 (DOT) of the Code of Federal Regulations.

- HOT WORK PERMIT SYSTEM: As part of our overall Fire Prevention Program, FCE utilizes a formal "Hot Work Permit" program. Hot work is any operation that introduces a potential ignition source, which in the presence of combustible or flammable materials can result in a fire. HOT WORK includes but is not limited to operations such as brazing, cutting, grinding, soldering, torching and, welding. The use of a Hot Work Permit is required for all hot work operations outside of designated hot work areas. Hot work can be performed without a permit only in areas specifically designated and posted as a "Hot Work" area

- LADDER SAFETY: The use of ladders is to be done in compliance with the following OSHA standards:
  - 29CFR 1910.25 - PORTABLE WOOD LADDERS
  - 29CFR 1910.26 - PORTABLE METAL LADDERS
  - 29CFR 1910.27 - FIXED LADDERS
  - 29CFR 1910.29 - MANUALLY PROPELLED MOBILE LADDER STANDS & SCAFFOLDS

- LOCKOUT TAGOUT PROGRAM: All servicing and maintenance of equipment is to be performed in accordance with the requirements of OSHA standard 29CFR 1910.147 or 269 as applicable. These standards require locking out all potential energy sources prior to the performance of work.

- PERSONAL PROTECTIVE EQUIPMENT: In accordance with OSHA standard 29CFR 1910.132-138 and Subpart I, work is to be performed using all necessary PPE. Hazard Assessments and Training in the use of required PPE are to be performed and documented prior to performance of work. PPE shall be removed before leaving the work area and disposed of according to waste management procedures to ensure that contaminants are not spread to personnel, through the facility(s), and/or to the environment.

- POWERED INDUSTRIAL TRUCKS: Forklifts and other industrial lift trucks are to be operated only by personnel trained in accordance with OSHA standard 29CFR 1910.178.

- POWERED PERSONAL LIFT TRUCKS: Powered personal lift trucks are to be operated only by personnel trained in accordance with OSHA standard 29CFR 1910.67 and 29CFR 1926.453.

- SAFETY DEVICES: Equipment safety devices are not to be removed, bypassed or otherwise modified without review and approval by FCE.

- SCAFFOLDING: All use of scaffolding shall be in accordance with the following OSHA standards:

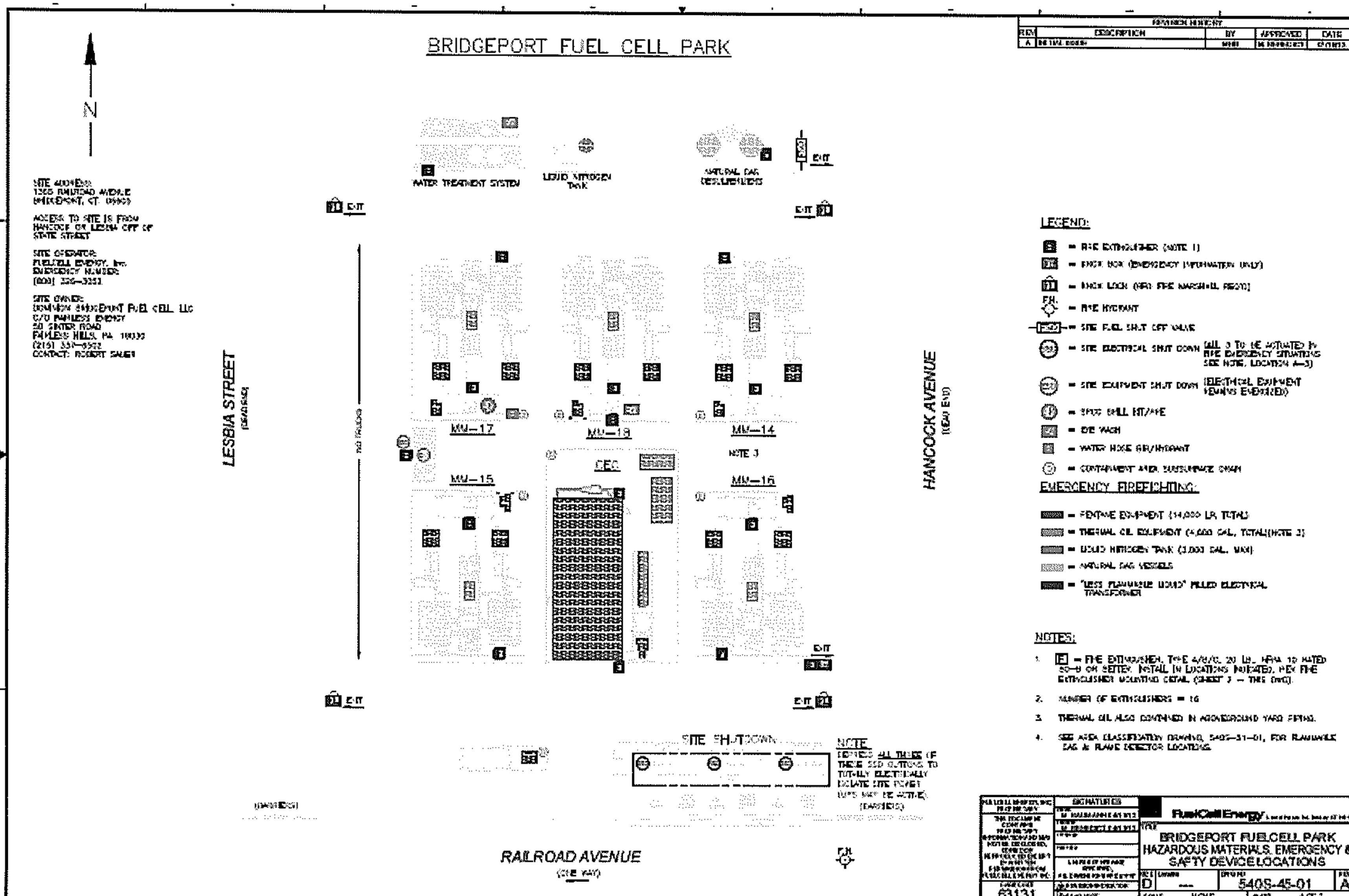
    - 29CFR 1910.28 – "Safety Requirements for Scaffolding"
    - 29CFR 1910.29 – "Manually Propelled Mobile Ladder Stands & Scaffolds"

- STORMWATER POLLUTION PREVENTION: In accordance with the Connecticut Department of Environmental Protection (CTDEP) "General Permit for the Discharge of Stormwater Associated with Industrial Activity"; activities which will directly or indirectly release hazardous or non-hazardous materials into the storm water system are not permitted.

- WASTE MANAGEMENT: FCE is to be notified in advance of all waste to be generated. Under state and federal rules, FCE, as the site operator, is the "Generator" of all waste generated/created on our site(s). As such, FCE is responsible for the proper Management, Storage, Transportation and Disposal of all wastes generated at our site(s). This is to be done in accordance with all applicable requirements of the Connecticut General Statutes, the Regulations of Connecticut State Agencies and Titles 29 (OSHA), 40 (EPA) and 49 (DOT) of the Code of Federal Regulations.

- WORKING ALONE: Working alone can introduce additional hazards not necessarily present during the course of performing work with other personnel. The biggest risk in working alone is during the occurrence of an incapacitating injury to the lone employee; a lack of timely medical attention could exacerbate the injury leading to greater harm. To prevent this, tasks must be assessed for hazards before assigning the employee(s) to perform them alone. If hazards do exist, either periodic monitoring, assignment of additional personnel, or re-scheduling of the work must be done. Further, it is important that task limitations be clear in order that new hazards are not introduced during any work performed alone.

Appendix B – Safety Device Location Survey


BRIDGEPORT FUEL CELL PARK
N
WATER TREATMENT SYSTEM
LIQUID NITROGEN TANK
NATURAL GAS DESULFURIZERS
EXIT
LESBIA STREET
(DEAD END)
HANCOCK AVENUE
(DEAD END)
RAILROAD AVENUE
(ONE WAY)
MW-17
MW-18
MW-14
MW-15
MW-16
CEC
NOTE 3
SITE SHUTDOWN
NOTE:
LEGEND:
= FIRE EXTINGUISHER (NOTE 1)
= FIRE HYDRANT
= SITE FUEL SHUT OFF VALVE
= EYE WASH
EMERGENCY FIREFIGHTING:
= NATURAL GAS VESSELS
NOTES:
2. NUMBER OF EXTINGUISHERS = 16
3. THERMAL OIL ALSO CONTAINED IN ABOVEGROUND YARD PIPING.
FuelCell Energy
BRIDGEPORT FUELCELL PARK
HAZARDOUS MATERIALS, EMERGENCY &
SAFTY DEVICE LOCATIONS
540S-45-01
A
D
NONE
63131

ENGINEERING · CONSTRUCTION · OPERATIONS · MAINTENANCE

46 Norwich Westerly Road
P.O. Box 370
North Stonington, CT 06359

800.400.2420 Phone
860.445.3599 Fax
a-zcorp.com

Job Title: Bridgeport Fuel Cell Park - Gas Line Purging

Date of Analysis: July 2nd, 2013

Reviewed By: Matthew Cirish (A/Z Safety Coordinator)

Approved By: Fuel Cell Energy

Job Location: Fuel Cell Energy Park – 1501 State St. Bridgeport, CT

Job Description:
The following is a basic sequence of events procedure for the safe purging of the air in the new natural gas piping from hand valve HV600 on the gas meter pad to the hand valves located at each module (HV667, HV668, HV669, HV670, HV671).

Important Notes:

- Prior to the venting procedure taking place all above grade and below grade gas piping will have been tested and signed off on.
- Desulfurizer Vessels will be loaded with carbon media per FCE procedure 6.12.2 prior to purging process starting and the gas supply being energized.
- Confirm that SCG has energized the gas piping up to HV-600. This can be verified @ PIT600.

Personal Protective Equipment:

- A/Z Issued Class E Hard Hat
- Eye Protection (Safety Glasses)
- Safety Toed Boots
- Hand Protection
- Face Shield

Roles and Responsibilities: A/Z Safety Department

1) **Training:**
   a) Crew Members whose duties fall within the scope of this standard shall be provided with training that is consistent with the scope of their job activities.
   b) Training shall include hazards of flammable gas, hazards of any compressed gas used for cleaning or purging, safe handling practices of flammable gas and compressed gas as applicable, emergency response procedures and equipment, and company policy.
   c) Personnel training shall be conducted by a competent person (A/Z Safety Coordinator) knowledgeable in the subject matter and shall be documented.
2) **Emergency Response:** In the event of an emergency while working on the Project site, the emergency phone number is 911 from any phone. All site personnel will be evacuated to a pre-determined location (Lesbia Street). Emergency response planning will follow in accordance with 29 CFR 1910.38(a). The Bridgeport, CT Fire Department will be utilized to respond to emergency situations.

3) **Pre-Emergency Planning:** Another task in emergency planning efforts will be to designate appropriate emergency escape routes and safe places of refuge for the site activity areas. These designations may change on a daily basis due factors such as wind direction, the type and extent of emergency situation warranting the need for evacuation, among others. The Safety Coordinator or Supervisor will identify any changes in escape routes and refuge points and will discuss with crew members.

The following situations would classify as emergency situations:

Fire/Explosion: The potential for human injury exists. Toxic fumes or vapors are released. The fire could spread on site or off site and possibly ignite other flammable materials or cause heat-induced explosions. The use of water and/or chemical fire suppressants could result in contaminated run-off.

Spill or Release of Hazardous Materials: The spill could result in the release of flammable liquids or vapors, thus causing a fire or gas explosion hazard. The spill could cause the release of toxic liquids or fumes in sufficient quantities or in a manner that is hazardous to or could endanger human health.

Medical Emergency: Overexposure to hazardous materials, direct exposure with a chemical, trauma injuries (broken bones, severe lacerations/bleeding, burns), eye/skin contact with hazardous materials, loss of consciousness, cold stress (hypothermia), heat stress (heat stroke), heart attack, respiratory failure, and allergic reaction.

4) **Procedures to Account for Site Personnel:** Accounting for personnel will be accomplished through the requirement that all personnel on site sign in and out each day with the A/Z site management team. During an emergency, personnel will immediately evacuate the work area and proceed to the muster points.
5) **Rescue and Medical Duties:** A physician-approved first aid kit, an eyewash station, and Class ABC fire extinguishers will be readily available on site. Only adequately trained site personnel will be authorized to participate in emergency rescue operations.
6) **Activation of Emergency Response Procedures:** Emergency services will be notified immediately in the event of an emergency by DIALING 911 from any phone. The Safety Coordinator will notify A/Z's PM and Fuel Cell Energy and Dominion Representative(s) after emergency services have been called. A list of these contacts is provided:

Local Agencies:
Ambulance: 911
Fire: Bridgeport, CT- 911 (203) 576-7660
Police: Bridgeport, CT - 911 (203) 576-8126
Hospital: Bridgeport Hospital 267 Grant Street Bridgeport, CT (203) 384-3000

A/Z Personnel:
Project Manager: Eric Herrman (860) 334-8335
Site Superintendent: Peter Noonan (860) 608-1283
Safety Coordinator: Matt Cirish (860) 213-3411
Corporate, Health and Safety Manager: Edwin Jones (860) 625-8839

7) **Fire Control:** Smoking/Tobacco products ARE NOT allowed anywhere within the Bridgeport Fuel Cell Park (BFCP) Construction Project. No Hot Work activities or any vehicles or machines will be utilized during procedure.

8) **Emergency Recognition and Prevention:** Because unrecognized hazards may result in emergency incidents, it will be the responsibility of the A/Z PM, SS, SC through daily site inspections and employee feedback (weekly safety meetings, and job safety analyses) to recognize and identify all hazards that are found at the site. These may include:

- Chemical Hazards
- Materials at the site
- Materials brought to the site
- Physical Hazards Fire/explosion
- Slip/trip/fall
- Electrocution
- IDLH atmospheres
- Excessive noise
- Cold
- Heat
- Ecological
- Mechanical Hazards Heavy equipment
- Stored energy system
- Pinch points
- Electrical equipment
- Vehicle traffic
- Environmental Hazards Electrical Storms
- High winds
- Heavy Rain/Snow
- Temperature Extremes (Heat/Cold Stress)

Supervisor

1) Planning:

*Hazards

- Lack of Communication
- Non-compliance
- Energized Equipment
- Pressurized Fluid
- Nitrogen Cylinders / Unit
- Flammable and / or Toxic Atmosphere
- Unauthorized Work

*Controls

- Inform the crew members of Lockout / Tagout
- Plan the work involving personnel responsible for preparation (such as isolation, depressurization, draining, venting, flushing) of the equipment / system to be purged.
- Ensure the equipment / system to be purged is positively isolated from all sources of energy (hydraulic, pneumatic, electrical etc.)
- Use proper locks and tags for isolation
- Ensure the equipment / system is depressurized and content is drained safely.
- Arrange the adequate Nitrogen cylinders / unit considering the volume to be purged.
- Ensure the deployment of Nitrogen unit inside the plant does not create any hazard for the facility.

Crew Members

2) Purging

*Hazards

- Lockout / Tagout
- Plan the work involving personnel responsible for preparation (such as isolation, depressurization, draining, venting, flushing) of the equipment / system to be purged.
- Ensure the equipment / system to be purged is positively isolated from all sources of energy (hydraulic, pneumatic, electrical etc.)

- Use proper locks and tags for isolation
- Ensure the equipment / system is depressurized and content is drained safely.
- Arrange the adequate Nitrogen cylinders / unit considering the volume to be purged.
- Ensure the deployment of Nitrogen unit inside the plant does not create any hazard for the facility.

*Controls

- Ensure the tools (such as N2 unit, pump, hose, coupling, and pressure gauges etc.) to be used are free from defect.
- Ensure the N2 supply hoses and couplings are rated for the required service and pressure.
- Stay away from the pressurized N2 hose and coupling to avoid cold burn in case of leak.
- Barricade the area and post warning notice.
- Calculate the amount of N2 required for the volume to be purged.
- Keep a close watch on the N2 supply flow meter.
- Ensure the disposal of purged volume to a safe location such as flare or vent.

Gas Line Purging Procedure: Information Notes: The following is a basic sequence of events procedure for the safe purging of the air in the new natural gas piping from hand valve HV600 on the gas meter pad to the hand valves located at each module (HV667, HV668, HV669, HV670, HV671).

1.) Prior to the venting procedure taking place all above grade and below grade gas piping will have been tested and signed off on.
2.) Desulfurizer vessels will be loaded with carbon media per FCE procedure 6.12.2 prior to purging process starting and the gas supply being energized.
3.) Confirm that SCG has energized the gas piping up to HV-600. This can be verified @ PIT600.
4.) Danger tape with an information tag will be installed around a 30ft perimeter radius from all purging locations.
5.) No hot work or electronic devices will be allowed within the 30ft taped off perimeter radius.
6.) All workers involved in this work will attend a pre procedure briefing where this procedure will be reviewed.
7.) All workers involved in this procedure will have personal gas monitors on their persons at all times.
8.) All testing instruments will be calibrated and verified prior to being put into service.

Nitrogen Purge from Gas Train to Desulfurizer Tanks:

1) Verify that all of the following hand sample valves are closed and securely capped.
    - HV-662
    - HV-600A
    - HV-603
    - HV-664
    - HV-602A
    - HV-613
    - HV-665
    - HV-602B
    - HV-653
    - HV-673
    - HV-672
    - HV-624
    - HV-682
    - HV-674
    - HV-676
    - HV-690
    - HV-691
    - HV-692

2) The following hand valves will be locked out prior to the new gas service being energized by SCG. Pancakes/Spectacle Blinds will be installed downstream from the listed plant fuel inlet valves.

46 Norwich Westerly Road
P.O. Box 370
North Stonington, CT 06359

800.400.2420 Phone
860.445.3599 Fax
a-zcorp.com

- HV-677 – Desulfurizer piping @ 600-FL-6-1
- HV-667 – MM-17
- HV-668 – MM-18
- HV-669 – MM-14
- HV-670 – MM-15
- HV-671 – MM-16

3) Close or verify closed, HV-660 and HV-659.
4) Verify that HV-656 and 657 have been orientated such that vessel A is the lead vessel and vessel B is the lag vessel. This can be verified by observing the position indicators.
5) Close or verify closed the following hand valves.
   - HV-613
   - HV-653
   - HV-664
   - HV-665
   - HV-639
6) Remove plug from HV-624 open valve to verify zero pressure. Close valve and reinstall plug.
7) Open or verify that HV-640 is open.
8) Install sampling purge tee on HV-672.
9) Run tubing from HV-673 to the discharge side of the sampling tee.
10) Connect the sampling instrument to the purge tee fitting and verify its set to analyze percent O2.
11) Open HV-672 and HV-673.
12) Connect hose form HV-714 – N2 supply valve to HV-600A. Confirm regulator PCV-710 is backed out and PI-710 reads zero.
13) Open HV-714 and adjust PCV-710 until PI-710 reads 20psi.
14) Verify the following hand valves are open.
   - HV-686
   - HV-683
   - HV-685
   - HV-689
   - HV-684
   - HV-688
   - HV-687
15) Open XV-605A and XV605B.
16) Open HV-600A to allow nitrogen to flow thru both desulfurizers in series and then out HV-640.
17) Monitor the gas analyzer installed at HV-672 for oxygen concentration, continue to flow nitrogen until the gas analyzer is reading less than 2% oxygen.
18) When the analyzer measures less than 2% Oxygen, close HV-640 and allow nitrogen pressure in the desulfurizer vessels to build to 20psi as indicated on PT-601.
19) Allow pressure to remain in vessels for 10 minutes then open HV-640 to bleed pressure to 1psi. Repeat this pressurization process 2 more times.
20) Close HV-640 and HV-600A.
21) Remove the plug in HV-624, open valve and verify zero pressure.
22) The desulfurizer vessels are now Nitrogen purged.

Nitrogen Purge of Piping from Desulfurizer Tanks to Plants

1) A sampling purge tee will be installed @ each plant on the following purge valves.
   - HV-674 – MM-14
   - HV-676 – MM-15
   - HV-690 – MM-16
   - HV-691 – MM-17
   - HV-692 – MM-18
2) Connect the sampling instrument to the purge tee and tubing from the discharge side of the purging tee to a safe location.

3) Open HV-660.
4) Open HV-677, HV-679, and HV-678.
5) Open HV-600A allowing nitrogen to flow into the desulfurizer tanks.
6) Open all the vent valves @ the plants per above list and HV-681 and HV-680. Flow should now exit at all the valves and the sampling flow tees at each plant.
7) The monitoring of the venting will be in the following order.
    - MM-14
    - MM-15
    - MM-16
    - MM-17
    - MM-18
8) Monitor the gas analyzer for oxygen concentration starting at MM-14, continue to flow N2 until the analyzer is reading less than 2% oxygen. When less than 2% is achieved close the vent valve. The gas analyzer can now be installed @ MM-18 and this step can be repeated at each plant in the order listed above.
9) When all 5 plants have been successfully purged close HV-600A
10) Shut-off nitrogen supply valve HV-714.
11) Back out nitrogen regulator to drop N2 pressure.
12) Remove the nitrogen hose between HV-714 and HV-600A and replace plugs in valves.
13) Depress the E stop buttons to close XV-605A and XV-605B.
14) Close HV-660.
15) Nitrogen Purge is now complete.

Fuel Flow and Pressure Purge of Desulfurizer Vessels

1) Install purge tee between HV-672 and HV-673.
2) Close HV-660.
3) Verify that HV-659 is closed.
4) Verify all the following valves are closed.
    - HV-613
    - HV-613A
    - HV-653
    - HV-653A
    - HV-664
    - HV-664A
    - HV-665
    - HV-665A
    - HV-639
    - HV-640
    - HV-602A
    - HV-602B
5) Reset the E Stop switches to open valves XV-605A and XV-605B.
6) Slowly open up HV-600 to allow gas to flow.
7) Check pressure on PT-601 should be approximately 21psi but not greater than 28psi.
8) Close HV-600 and check pressure on PT-601, pressure should hold steady.
9) Wait for 1 minute than open HV-600 again.
10) Open HV-640 to begin fuel purging of the vessels.
11) Monitor the gas analyzer for methane concentration @ HV-673. Continue to flow until analyzer reading is greater than 90%. The instrument should be operational and set to analyze 0-100% Methane.

12) Close HV-640 and allow fuel pressure to stabilize to a set point of 21psi as observed on PT-601.
13) Close HV-600.
14) Allow pressure to remain in vessels for 10 minutes, and then open HV-640 to bleed off the pressure and then close HV-640.
15) Repeat the above pressurization / depressurization process 2 more times.
16) Close HV-640.
17) Open HV-600 so vessels are pressurized to 21psi.
18) Desulfurizer vessels are now fuel purged.
19) Remove gas analyzer and purge tee fitting from HV-672 and HV-673.
20) Close HV-673.
21) Open HV-672.

Fuel Purge of Gas Supply Lines to Each Plant's Isolation Valve

1) A sampling purge tee will be installed @ each plant on the following purge valves.
    - HV-674 – MM-14
    - HV-676 – MM-15
    - HV-690 – MM-16
    - HV-691 – MM-17
    - HV-692 – MM-18
2) Connect the sampling instrument to the purge tee and tubing from the discharge side of the purging tee to a safe location.
3) The plants will be purged in the follow order.
    - MM-14
    - MM 15
    - MM 16
    - MM 17
    - MM 18
4) Connect the gas analyzer to the purge tee fitting @HV-674 (MM14) The instrument should be operational and set to analyze 0-100% Methane.
5) Open the following hand valves.
    - HV-660
    - HV-677
    - HC-678
    - HV-679
    - HV-676
    - HV-674
    - HV-690
    - HV-691
    - HV-692
6) Monitor the gas analyzer for methane concentration at the discharge of HV-674 at MM-14, continue to flow gas until the analyzer is reading greater than 90% methane. When greater than 90% is achieved close HV-674. The gas analyzer can now be installed @ MM-18 and this step can be repeated at each plant in the order listed below.
    - MM-14
    - MM 15
    - MM 16
    - MM 17
    - MM 18
7) Depress the E Stop button to close XV-605A and XV-605B.
8) Close HV-600 and install LOTO Devices.

9) Fuel Purging is now complete.

10) Perform a final walk-down of the entire fuel system to verify that all sample valves have been closed and plugged. The following valves shall be checked.

- HV-600A
- HV-662
- HV-603
- HV-664
- HV-664A
- HV-613
- HV-613A
- HV-665
- HV-665A
- HV-653
- HV-653A
- HV-624
- HV-602A
- HV-602B
- HV-682
- HV-674
- HV-676
- HV-690
- HV-691
- HV-692

11) Verify the following valves are closed.

- HV673
- XV-605A
- XV-605B

12) Verify that HV-672 and HV-600 are open.

13) Leave LOTO on the following valves.

- HV-667
- HV-668
- HV-669
- HV-670
- HV-671

Attendant Responsibilities:

1) During all venting and purging to atmosphere, an attendant shall be posted at the perimeter of the danger taped area with an LEL meter.

2) The attendant's responsibilities shall be to ensure;

- That no unauthorized vehicle or pedestrian traffic enters the restricted area.
- To monitor the atmosphere along the perimeter using an LEL meter.
- To communicate with the person performing the purging/venting of the system.

I have read and understand the above procedure:

Name: Date:

AZ CORP

Gas Line Purging Safety Validation Checklist

To be completed by Competent Person.

	YES	NO	NOTES
Has a purging – Job Hazard Analysis been completed?			
Have all fuel line sources been identified?			
Have all fuel lines not required for the purging operation been secured and locked out?			
Are line blanks or blinds required to safely isolate fuel lines, fittings, and gauges?			
Is the purging discharge line located *outside* away from personnel, equipment & buildings? If No, a written Gas Purging Plan should be developed.			
Could high pressure discharge direct gases or foreign objects towards personnel, equipment, and buildings?			
Is inert gas being used as the purging medium?			
If yes will oxygen levels be monitored to maintain adequate concentration between 19.5% and 23.5%?			
Will purging operation involve a flammable gas?			
Will the flammable gas purged settle into low areas where there are uncontrolled ignition sources?			
Has the written Gas Purging Plan been communicated to and approved by the local authority having jurisdiction?			
Have all non-essential personnel been evacuated to a safe location from the purging operations?			
Are reliable combustible gas meters being used to sample for gas concentrations?			
Have employees using the combustible gas meters been trained on their use?			
Have the combustible gas meters been properly calibrated and tested per the manufacturer specifications?			
Have all employees been specifically trained in safe procedures for the gas purging operations?			
Is a temporary hose or line required to direct the purged gas to safe locations outside of the building?			
Has emergency response personnel (Fire Department, EMS, etc.) been notified of the gas purging activities planned?			
Are additional ventilation sources required to maintain gas concentrations within acceptable levels?			
Have all potential ignition sources been isolated, de-energized and locked-out?			

COMPLETED BY:	DATE: