5429 Harding Highway
Building 500
Mays Landing, NJ 08330
Phone: 609-837-8099
Fax: 609-837-8030

DCO Energy

9121 W. Russell Road
Suite 117
Las Vegas Nevada 98148
Phone: 866-614-6575

February 12, 2014

Connecticut Siting Council
Ten Franklin Square
New Britain, CT 06051
Attn: Melanie Bachman, Esq.

RE: Petition No. 1067
Docket No. NT-2010
Hartford Hospital Fuel Cell Project
19 Jefferson Street, Hartford, CT 06103

Dear Ms. Bachman:

On July 30, 2013, The Connecticut Siting Council issued to Hartford Steam Company (HSC) a declaratory ruling in favor of HSC's Petition No. 1067 that no Certificate of Environmental Compatibility and Public Need be required for the installation of a 1.4MW Fuel Cell at the Hartford Hospital. DCO Energy LLC has been engaged as the EPC Contractor for the installation of the Fuel Cell. DCO, on behalf of HSC, hereby submits this package to demonstrate compliance with portions of Docket No. NT-2010. Information provided below corresponds to the numbered items provided in the Order:

1. *The use of natural gas as a fuel system cleaning medium during fuel cell construction, installation or modification shall be prohibited.* **Confirmed**

2. *Submit the following information to the Council 15 days prior to any fuel pipe cleaning operations related to fuel cell construction, installation, or modification:*
   a. *Identification of the cleaning media to be used;* **Nitrogen**
   b. *Identification of any known hazards through use of the selected cleaning media;* **Nitrogen poses a potential threat of asphyxiation by displacing the oxygen in air. Material Safety Data Sheets for the cleaning medium will be issued to all personnel working with and around the cleaning medium.**
   c. *Description of how known hazards will be mitigated, including identification of any applicable state or federal regulations concerning hazard mitigation measures for such media;* **Proper ventilation will be established and maintained, and air quality will be continuously monitored in the area of all personnel.**
   d. *Identification and description of accepted industry practices or relevant regulations concerning the proper use of such media;* **The Electric Power Research Institute (EPRI) document "Guidelines for Fuel Gas Cleaning using Compressed Air or Nitrogen" was utilized as a guide for the Hartford Hospital Fuel Cell Project's gas cleaning procedures. This document is attached for reference. In addition, the project cleaning procedures are in accordance with the codes and standards listed in Item 3 of this letter.**
   e. *Provide detailed specifications (narratives/drawings) indicating the location and procedures to be used during the pipe cleaning process, including any necessary*

worker safety exclusion zones; **The pipe cleaning process will be performed in two phases. The first phase will cover the interconnecting piping from the point of connection to Connecticut Natural Gas to the FuelCell Energy (FCE) equipment. The second phase will cover the piping located within the FCE equipment skids. The approved procedures detailing the steps for each phase are identified as "AZ-062, Natural Gas Pipe Cleaning Procedure", "AZ-061, Gas Line Purging Procedure" and "FCE-004, Pre Start-up System Fill Procedures". A copy of these procedures are enclosed**

f. *Identification of the contractor or personnel performing the work, including a description of past project experience and the level of training and qualifications necessary for performance of the work;* **This work is being supervised by DCO and performed by AZ Corporation (AZ) and FCE. DCO designs, builds, owns, operates and maintains power generating facilities and is the EPC Contractor for this project. AZ Corporation is contracted by DCO to perform the construction of the plant, and is performing the cleaning and purging of the Phase 1 interconnecting piping. FCE is the supplier of the DFC1500B Module and BOP equipment, and is contracted by DCO to perform startup of the Fuel Cell package. FCE's start up team is comprised of in house engineers and technicians that perform this work on all of their equipment. DCO Energy has an industry leading safety record in the construction, start up and operation of gas fired energy facilities. Both AZ and FCE have safely installed and started up numerous fuel cell installations in the State of Connecticut.**

g. *Contact information for a special inspector hired by the Certificate Holder who is a Connecticut Registered Engineer with specific knowledge and experience regarding electric generating facilities or a National Board of Boiler and Pressure Vessel Inspector and written approval of such special inspector by the local fire marshal and building inspector;* **Joseph Ventre, P.E. has been designated as the special inspector for this project. Mr. Ventre is a licensed Professional Mechanical Engineer with over 39 years of experience. The local Fire Marshall. Captain Roger S. Martin, and Building Official Michael Fuschi have been notified of Mr. Ventre's appointment. Mr. Ventre's phone number is 609-837-8007.**

h. *Certification of notice regarding pipe cleaning operations to all state agencies listed in General Statutes § 16-50j(h) and to the Department of Consumer Protection, Department of Labor, Department of Public Safety, Department of Public Works, and the Department of Emergency Management and Homeland Security.* C**ertified letters have been issued to each department listed above. A summary checklist is enclosed for reference.**

3. *Compliance with the following codes and standards, as adopted and amended by the Department of Public Safety and/or the Authority Having Jurisdiction, during fuel cell construction, installation or modification, as applicable:*
    a. NFPA 54 (2009 edition);
    b. NFPA 54 Temporary Interim Amendment 09-3 (August 25, 2010);
    c. NFPA 853 (2010 edition); and

d. *ASME B31.* **All listed codes and standards have been and will continue to be adhered to during the construction and startup of this fuel cell.**

4. *Submit a copy of an Emergency Response/Safety Plan within 90 days of the date of this decision that includes, but is not limited to the following:*
   a. *A description of the results of any simulated emergency response activities with any state and/or local emergency response officials;* **HSC to discuss with local officials following completion of the facility.**
   b. *Details of any facility site access system;* **The facility is being integrated into the existing Cogeneration Plant that is manned at all times. The fuel cell will be secured by fencing and gates that will be locked except for periods of inspection or maintenance. Only authorized personnel will have access**.
   c. *Establishment of an emergency responder/local community notification system for on-site emergencies and planned construction-related activities that could cause community alarm. The system shall include notification to the following: local emergency responders, city or town officials, state legislators, and local residents that wish to participate.* **Enclosed is the HHFC Emergency Action Plan, Attachment J to the Project Execution Plan.**

5. *The facility owner/operator shall remit timely payments associated with annual assessments and invoices submitted by the Council for expenses attributable to the facility under Conn. Gen. Stat. §16-50v.* **HSC to comply.**

6. *If applicable, the facility owner/operator shall provide the Council with written notice of the completion of site construction and the commencement of site operation.* **HSC to provide written notice upon completion.**

7. *If the facility owner/operator is a wholly owned subsidiary of a corporation or other entity and is sold/transferred to another corporation or other entity, the Council shall be notified of such sale and/or transfer and of any change in contact information for the individual or representative responsible for management and operations of the facility within 30 days of the sale and/or transfer.* **Understood**

8. *The facility owner/operator shall provide the Council with not less than 30 days written notice that the facility plans to cease operations.* **Understood**

If you should have any questions or require additional information, please don't hesitate to contact me at 609-209-1069 or ddrury@dcoenergy.com.

Very Truly Yours,
DCO Energy

Daniel J. Drury, P.E.
DCO Startup Manager

cc: Andrew O. Why, P.E.
Carl Lockhart
Derek Rudd, P.E., HSC
Jim Elsner, HSC
Joe Ventre, P.E., Smart Engineering
siting.council@ct.gov

Enclosures:
AZ-061, Gas line Purging Procedures
AZ-062, Natural Gas Pipe Cleaning Procedure
FCE-004 Pre-Startup System Fill Procedures
EPRI, "Guidelines for Fuel Gas Cleaning using Compressed Air or Nitrogen"
Hartford Hospital Fuel Cell Project Emergency Action Plan
Checklist of Certified Letters issued to State Agencies

DCO Energy

Hartford Hospital Fuel Cell Project

Petition No. 1067

AZ-061

Gas Line Purging Procedures

DCO Energy

100 Lenox Drive, Suite 100
Lawrenceville, NJ 08648

Phone: 6095122339
Fax: 6092190799

SUBMITTAL NO. AZ-061
PACKAGE NO: AZ

TITLE: Natural Gas Pipe Purging Procedure
PROJECT: Hartford Hospital Fuel Cell
DRAWING:
STATUS: NEW
BIC: SE

REQUIRED START: 1/27/2014
REQUIRED FINISH: 2/3/2014
DAYS HELD: 0
DAYS ELAPSED: 10
DAYS OVERDUE: 3

RECEIVED FROM		SENT TO		RETURNED BY		FORWARDED TO	
AZ	MJM	SE	JV	SE	JV	AZ	MJM

Revision No.	Description / Remarks	Received	Sent	Returned	Forwarded	Status	Sepias	Prints	Drawing Date	Held	Elapsed
001	Natural Gas Pipe Purging Procedure	1/27/2014	1/27/2014	2/3/2014	2/4/2014	RRS	0	0		0	8
	This submittal was originally packaged as AZ-057 and issued on January 27, 2014 to Andy Larkin. It is now being re-issued under a new submittal number to match AZ's numbering sequence.										
002	Revision #1 Purging Procedure	2/5/2014	2/6/2014	2/6/2014		RRS	0	0		0	1
003	Gas Line Purging Procedures	2/6/2014	2/6/2014			NEW	0	0		0	0
	Rev. 3 Submission includes typographical revisions per Dan Domenic's suggestion.										

IP-06.04 ATTACHMENT "A"

Field Procured Materials Service Submittals

Vendor/Subcontractor Submittal Initiation

Project Name:	HHFC	Project Number:	77-264	Company Name:	A/Z Corp.
DCO Submittal Number	AZ-061- Rev.-1	Submittal Date:	2/5/2014	Contact Information:	Mark Maulucci Jonathan NcNaught
Plant Equip ID:	NA	Install Spec/DWG Ref:	2302200	AZ #	230200-007 - Rev.-1
Cost Impact:	NO	Schedule Impact:	NO		

Submission Type:

Submittal:	Requirement:	Document Type:
Sub-Contractor	Specified	Catalog Cuts
Materials	As Equal	Test Reports
Manufacturer	Substitutions	O&M Manuals
Professional Services	Shop Drawing	Calculations
		Permits
		Warranties
		Other (Describe Below)

Submittal Description: Gas Line Purge Procedure

Justification For Use:

Attachments:

DCO Submittal Response

DCO Response: No Exceptions Taken / Make Corrections Noted / Revise & Resubmit / Resubmit Certified

Submittal Response:

Potentially Impacts Basis of Design: YES NO

Response By:	Date:	Peer Review:	Date:
Engineer of Record:	Date:	Other:	Date:
[signature]	2/6/14	[signature]	

ATTENTION

If at any point in the submittal process it is determined that the submittal response results in or requires a code review/interpretation, a modified engineering calculation, a change to an engineered drawing/specification, or an addition to an engineering drawing or specification, the submittal must be routed to the EOR for disposition.

Submittal

Spec Section Title: Mechanical

Package No: 230200

No: 007

Title: Gas Line Purging Procedure

Project: Hartford Hospital Fuel Cell

Job: C-5-7588

Status: For Approval

Required Start: 2/6/2014

Required Finish: 2/10/2014

Received From:	Sent To:	Returned By:	Forwarded To:
A/Z Corporation	DCO Energy	DCO Energy	A/Z Corporation

Revision No:	Description	Received	Sent	Returned	Forwarded	Copies Sent:	Status
1	Gas Line Purging Procedure	2/5/2014	2/5/2014			1	
0		1/30/2014	1/30/2014	2/3/2014	2/3/2014	0	Revise and resubmit

A/Z CORPORATION

APPROVED ☐
APPROVED AS NOTED ☐
NOT APPROVED ☐
REVISE AND RESUBMIT ☐
REVIEWED ☒

REVIEW IS FOR GENERAL CONFORMANCE WITH THE DESIGN CONCEPT AND CONTRACT DOCUMENTS MARKING OR COMMENTS SHALL NOT BE CONSTRUED AS RELIEVING THE SUBCONTRACTOR SUPPLIER FROM COMPLIANCE WITH THE PROJECT PLANS AND SPECIFICATIONS NOR DEPARTURES THERE FROM. THE SUBCONTRACTOR /SUPPLIER REMAINS RESPONSIBLE FOR DETAILS AND ACCURACY, FOR CONFIRMING AND CORRELATING ALL QUANTITIES AND DIMENSIONS FOR SELECTING FABRICATION PROCESSES FOR THE TECHNIQUES OF ASSEMBLY, AND FOR PERFORMING THIS WORK IN A SAFE MANNER AND IN ACCORDANCE WITH ALL APPLICABLE CODES.

DATE 2-5-14 BY [signature]

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: Hartford Hospital Fuel Cell – Purging of Gas Piping to Skid # 2 – Rev-2

Date of Analysis: February 5, 2014

Reviewed By: Steven Galbo (A/Z Safety Coordinator)

Approved By: DCO Energy, LLC

Job Location: Hartford Hospital Co-Generation Facility Hartford, CT

Smart Engineering, LLC

Checked for conformance with the design concept & conformity with information given in the contract documents.

- [x] NO EXCEPTIONS TAKEN
- [ ] MAKE CORRECTIONS NOTED
- [ ] REVISE AND RESUBMIT
- [ ] RESUBMIT CERTIFIED

Signature: DO Date: 2/6/14

Job Description:

The following is a basic sequence of events procedure for the safe purging of the air in the new natural gas piping in accordance with NFPA 56 & NFPA 54 from hand valve V-0200 at the CNG gas train to the valve tagged V-0100. An additional valve tagged V-0400 will be installed prior to V-0100 for the purging procedures.

Important Notes:

- Prior to the venting procedure taking place all of the gas piping will have been tested, cleaned and signed off on.
- Confirm that CNG has energized the gas piping up to their last hand valve (V-0200) @ the Contractor tie point.

Personal Protective Equipment:

- A/Z Issued Class E Hard Hat
- Eye Protection (Chemical Splash Goggles)
- Safety Toed Boots
- Hand Protection
- Face Shield
- Hearing protection
- LEL Meters

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.

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 (DCO Trailer @ Retreat Ave). Emergency response planning will follow in accordance with 29 CFR 1910.38(a). The Hartford, 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 to 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) **Notifications:** All Contractors working on site including DCO Energy, LLC, HSC, and Hartford Hospital Fire Marshall shall be notified prior to the commencements of this procedure.
6) **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.

7) **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, DCO Energy and Hartford Hospital Representative(s) after emergency services have been called. A list of these contacts is provided:

Local Agencies:
Ambulance: 911
Fire: Hartford, CT- 911 (860) 757-4500
Police: Hartford, CT - 911 (860) 757-4000
Hospital: Hartford Hospital 80 Seymour Street Hartford, CT (860) 545-5000

A/Z Personnel:
Sr. Mechanical Project Manager: Mark Maulucci (860) 625-8607
Site Foreman: Mauricio Munoz (860) 319-6287
Safety Coordinator: Steven Galbo (860) 941-0458
Corporate, Health and Safety Manager: Edwin Jones (860) 625-8839

DCO Energy LLC:
Construction Project Manager: Andy Why (609) 847-1172
Site Manager: Gerry Zeman (609) 209-3469

8) **Fire Control:** Smoking/Tobacco products ARE NOT allowed anywhere within the Hartford Hospital Fuel Cell Construction Project. No Hot Work activities or any vehicles or machines will be utilized during procedure. All electrical power to devices within a 30ft radius will be de-energized and LOTO.

9) **Work Stand-Down Procedure**: The foreman shall brief all personal the instructions below regarding valve closures to be acted upon in the event of a call for "Stand-Down" during the nitrogen or the gas purge.

- In the case of a stand-down call during the N2 purging phase closing V-0300 will stop the flow of N2 in all downstream piping to skid # 2. In the case of a stand-down call during the gas purging phase closing V-0200 will stop the flow of natural gas in all downstream piping to skid # 2.

10) **Emergency Recognition and Prevention:** Because unrecognized hazards may result in emergency incidents, it will be the responsibility of the A/Z PM, A/Z foreman and A/Z safety coordinator 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 V-0200 at the gas meter assembly to V-0100. FCE start-up technicians will be responsible to perform the purging of the gas piping from V-0100 to skid # 2 thru the desulfurizer tanks and back to skid # 2.

1.) Prior to the venting procedure taking place all gas piping will have been tested, cleaned and signed off on.
2.) Confirm that CNG has energized the gas piping up to V-0200.
3.) Danger tape with an information tag will be installed around a 30ft perimeter radius from all purging locations. Tubing will be installed into the purge tee on the following purge valve and terminated approximently10ft above grade.

    - V-0400

4.) All non-essential personnel are prohibited from entering the cordoned-off areas or elevated platforms above temp piping discharge points during the procedures.
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 (LEL's) 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 V-0100:

1) The following hand valves will be locked out prior to the new gas service being energized by CNG.
    - V-0200
    - V-0100
2) verify that V-0200 is closed and LOTO is installed.
3) verify that V-0100 is closed and LOTO is installed.
4) Close or verify V-0101 is closed and PI-0100 is installed.
5) Install sampling purge tee on V-0400.
6) Run temp tubing from the purge tee on V-0400 to 10ft above grade.
7) Connect gas analyzer to the purge tee and turn on.
8) Connect N2 hose to V-0300 and open.
9) Open N2 cylinder and adjust regulator so piping is pressurized to 20psi.
10) Open V-0400 and monitor the gas analyzer for oxygen concentration, continue to flow nitrogen until the gas analyzer is reading less than 2% oxygen.
11) When the analyzer measures less than 2% Oxygen, close V-0400.
12) Close V-0300, remove N2 hose and install plug.
13) The gas piping is now nitrogen purged.

2) Verify V-0300 is closed,

Gas Purge from Gas Train to V-0100:

1) verify V-0100 is closed and LOTO is installed.
2) and verify plug is installed.
3) Install sampling purge tee on V-0400.
4) Run temp tubing from the purge tee on V-0400 to 10ft above grade.
5) Connect gas analyzer to the purge tee and turn on.
6) Open V-0400.
7) Remove LOTO from V-0200.
8) Open V-0200 to energize piping with natural gas.
9) Monitor the gas analyzer for methane concentration, continue to flow natural gas until the gas analyzer is reading greater than 90% methane.
10) When the analyzer measures greater than 90% Methane, close V-0400.
11) Remove purge tee from V-0400 and install plug.
12) Close and install LOTO on V-0200.
13) The gas piping is now purged with natural gas.

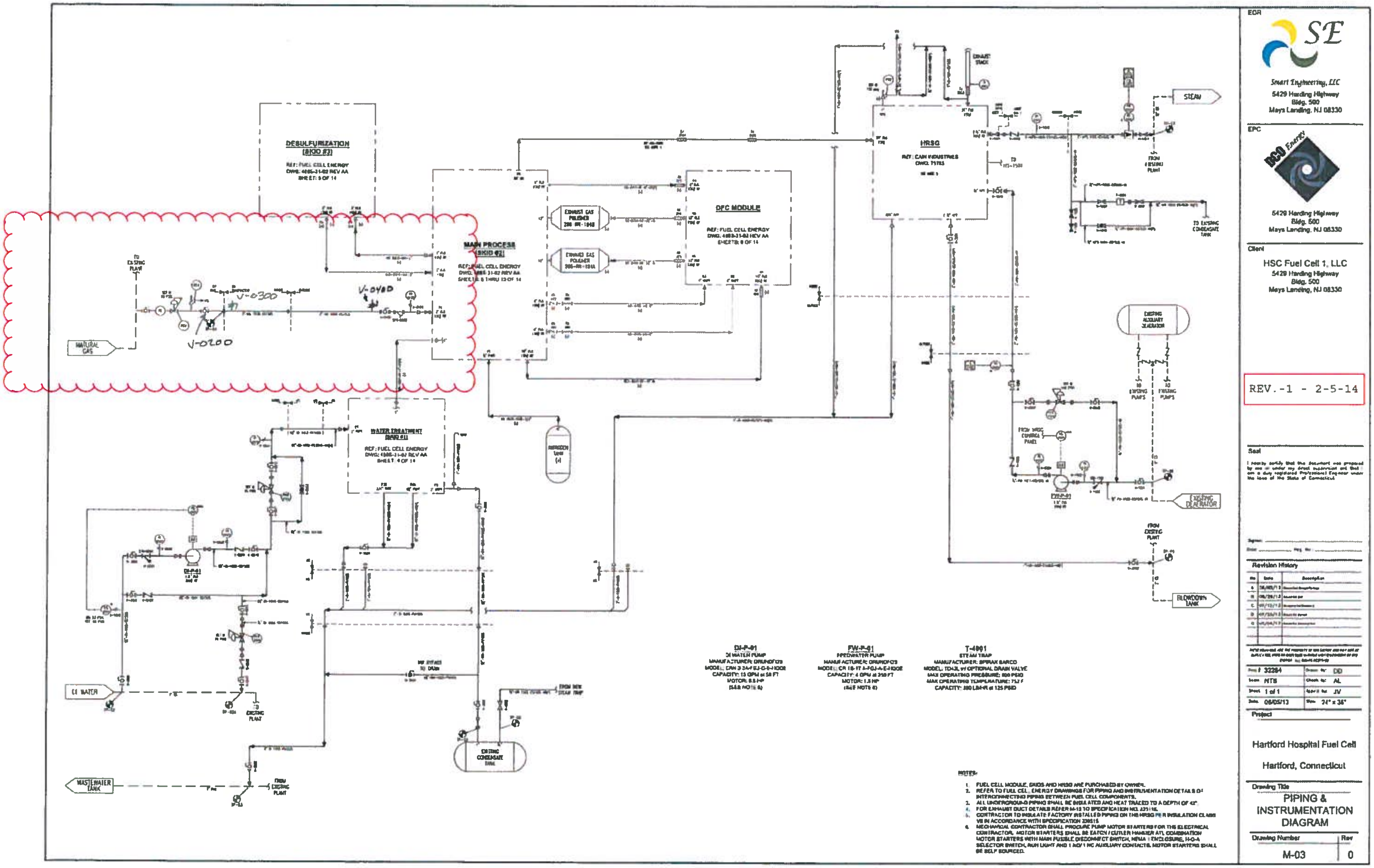
2A) Verify V-0400 is closed

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

800.400.2420 Phone
860.445.3599 Fax
a-zcorp.com

I have read and understand the above procedure:

Name:	**Date:**


EOR
SE
Smart Engineering, LLC
5429 Harding Highway
Bldg. 500
Mays Landing, NJ 08330
EPC
DCO Energy
5429 Harding Highway
Bldg. 500
Mays Landing, NJ 08330
Client
HSC Fuel Cell 1, LLC
5429 Harding Highway
Bldg. 500
Mays Landing, NJ 08330
REV.-1 - 2-5-14
Seal
Revision History
Proj # 32284
Scale NTS
Sheet 1 of 1
Date 06/05/13
Drawn by DD
Check by AL
Size 24" x 36"
Project
Hartford Hospital Fuel Cell
Hartford, Connecticut
Drawing Title
PIPING & INSTRUMENTATION DIAGRAM
Drawing Number M-03
Rev 0
DESULFURIZATION (SKID #3)
MAIN PROCESS (SKID #2)
DFC MODULE
HRSG
WATER TREATMENT (SKID #1)
EXHAUST GAS PULSER
NATURAL GAS
V-0300
V-0200
V-0400
STEAM
EXISTING AUXILIARY DEAERATOR
EXISTING DEAERATOR
BLOWDOWN TANK
EXISTING CONDENSATE TANK
DI WATER
WASTEWATER TANK
DI-P-01
FW-P-01
T-4001
STEAM TRAP
NOTES:
1. FUEL CELL MODULE, SKIDS AND HRSG ARE PURCHASED BY OWNER.
2. REFER TO FUEL CELL ENERGY DRAWINGS FOR PIPING AND INSTRUMENTATION DETAILS OF INTERCONNECTING PIPING BETWEEN FUEL CELL COMPONENTS.
3. ALL UNDERGROUND PIPING SHALL BE INSULATED AND HEAT TRACED TO A DEPTH OF 42".
4. FOR EXHAUST DUCT DETAILS REFER M-13 TO SPECIFICATION NO. 231116.
5. CONTRACTOR TO INSULATE FACTORY INSTALLED PIPING ON THE HRSG PER INSULATION CLASS VII IN ACCORDANCE WITH SPECIFICATION 230715.
6. MECHANICAL CONTRACTOR SHALL PROCURE PUMP MOTOR STARTERS FOR THE ELECTRICAL CONTRACTOR. MOTOR STARTERS SHALL BE EATON / CUTLER HAMMER ATL COMBINATION MOTOR STARTERS WITH MAIN FUSIBLE DISCONNECT SWITCH, NEMA 1 ENCLOSURE, H-O-A SELECTOR SWITCH, RUN LIGHT AND 1 NO / 1 NC AUXILIARY CONTACTS. MOTOR STARTERS SHALL BE SELF SOURCED.

Material Safety Data Sheet

Nitrogen

Section 1. Chemical product and company identification

Product name	:	Nitrogen
Supplier	:	AIRGAS INC., on behalf of its subsidiaries 259 North Radnor-Chester Road Suite 100 Radnor, PA 19087-5283 1-610-687-5253
Product use	:	Synthetic/Analytical chemistry. Liquid – cryogenic coolant.
Synonym	:	nitrogen (dot); nitrogen gas; Nitrogen NF, LIN, Cryogenic Liquid Nitrogen, Liquid Nitrogen
MSDS #	:	001040
Date of Preparation/Revision	:	**1/14/2011.**
In case of emergency	:	1-866-734-3438

Section 2. Hazards identification

Physical state	:	Gas. [NORMALLY A COLORLESS GAS: MAY BE A CLEAR COLORLESS LIQUID AT LOW TEMPERATURES. SOLD AS A COMPRESSED GAS OR LIQUID IN STEEL CYLINDERS.]
Emergency overview	:	WARNING! GAS: CONTENTS UNDER PRESURE. Do not puncture or incinerate container. Can cause rapid suffocation. May cause severe frostbite. LIQUID: Extremely cold liquid and gas under pressure. Can cause rapid suffocation. May cause severe frostbite. Do not puncture or incinerate container. Contact with rapidly expanding gases or liquids can cause frostbite.
Routes of entry	:	Inhalation
Potential acute health effects		
Eyes	:	Contact with rapidly expanding gas may cause burns or frostbite. Contact with cryogenic liquid can cause frostbite and cryogenic burns.
Skin	:	Contact with rapidly expanding gas may cause burns or frostbite. Contact with cryogenic liquid can cause frostbite and cryogenic burns.
Inhalation	:	Acts as a simple asphyxiant.
Ingestion	:	Ingestion is not a normal route of exposure for gases. Contact with cryogenic liquid can cause frostbite and cryogenic burns.
Medical conditions aggravated by over-exposure	:	Acute or chronic respiratory conditions may be aggravated by overexposure to this gas.

See toxicological information (Section 11)

Section 3. Composition, Information on Ingredients

Name	CAS number	% Volume	Exposure limits
Nitrogen	7727-37-9	100	Oxygen Depletion [Asphyxiant]

Section 4. First aid measures

No action shall be taken involving any personal risk or without suitable training.If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus.It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation.

Eye contact	:	Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention immediately.
Skin contact	:	None expected.
Frostbite	:	Try to warm up the frozen tissues and seek medical attention.
Inhalation	:	Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.
Ingestion	:	As this product is a gas, refer to the inhalation section.

Section 5. Fire-fighting measures

Flammability of the product	:	Non-flammable.
Products of combustion	:	Decomposition products may include the following materials: nitrogen oxides
Fire-fighting media and instructions	:	Use an extinguishing agent suitable for the surrounding fire. Apply water from a safe distance to cool container and protect surrounding area. If involved in fire, shut off flow immediately if it can be done without risk. Contains gas under pressure. In a fire or if heated, a pressure increase will occur and the container may burst or explode.
Special protective equipment for fire-fighters	:	Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions	:	Immediately contact emergency personnel. Keep unnecessary personnel away. Use suitable protective equipment (section 8). Shut off gas supply if this can be done safely. Isolate area until gas has dispersed.
Environmental precautions	:	Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.
Methods for cleaning up	:	Immediately contact emergency personnel. Stop leak if without risk. Note: see section 1 for emergency contact information and section 13 for waste disposal.

Section 7. Handling and storage

Handling	:	High pressure gas. Do not puncture or incinerate container. Use equipment rated for cylinder pressure. Close valve after each use and when empty. Protect cylinders from physical damage; do not drag, roll, slide, or drop. Use a suitable hand truck for cylinder movement. Never allow any unprotected part of the body to touch uninsulated pipes or vessels that contain cryogenic liquids. Prevent entrapment of liquid in closed systems or piping without pressure relief devices. Some materials may become brittle at low temperatures and will easily fracture.
Storage	:	Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Cylinder temperatures should not exceed 52 °C (125 °F). For additional information concerning storage and handling refer to Compressed Gas Association pamphlets P-1 Safe Handling of Compressed Gases in Containers and P-12 Safe Handling of Cryogenic Liquids available from the Compressed Gas Association, Inc.

Section 8. Exposure controls/personal protection

Engineering controls : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits.

Personal protection

Eyes : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.

When working with cryogenic liquids, wear a full face shield.

Skin : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Respiratory : Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

The applicable standards are (US) 29 CFR 1910.134 and (Canada) Z94.4-93

Hands : Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.

Insulated gloves suitable for low temperatures

Personal protection in case of a large spill : Self-contained breathing apparatus (SCBA) should be used to avoid inhalation of the product.

Product name	
Nitrogen	Oxygen Depletion [Asphyxiant]

Consult local authorities for acceptable exposure limits.

Section 9. Physical and chemical properties

Molecular weight : 28.02 g/mole

Molecular formula : N2

Boiling/condensation point : -195.8°C (-320.4°F)

Melting/freezing point : -210°C (-346°F)

Critical temperature : -146.9°C (-232.4°F)

Vapor density : 0.967 (Air = 1) Liquid Density@BP: 50.46 lb/ft3 (808.3 kg/m3)

Specific Volume (ft ^{3}/lb) : 13.8889

Gas Density (lb/ft ^{3}) : 0.072

Section 10. Stability and reactivity

Stability and reactivity : The product is stable.

Hazardous decomposition products : Under normal conditions of storage and use, hazardous decomposition products should not be produced.

Hazardous polymerization : Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Toxicity data

Other toxic effects on humans : No specific information is available in our database regarding the other toxic effects of this material to humans.

Specific effects

Carcinogenic effects : No known significant effects or critical hazards.

Mutagenic effects : No known significant effects or critical hazards.

Reproduction toxicity : No known significant effects or critical hazards.

Section 12. Ecological information

Aquatic ecotoxicity

Not available.

Environmental fate : Not available.

Environmental hazards : No known significant effects or critical hazards.

Toxicity to the environment : Not available.

Section 13. Disposal considerations

Product removed from the cylinder must be disposed of in accordance with appropriate Federal, State, local regulation.Return cylinders with residual product to Airgas, Inc.Do not dispose of locally.

Section 14. Transport information

Regulatory information	UN number	Proper shipping name	Class	Packing group	Label	Additional information
DOT Classification	UN1066 UN1977	NITROGEN, COMPRESSED Nitrogen, refrigerated liquid	2.2	Not applicable (gas).		**Limited quantity** Yes. **Packaging instruction** **Passenger aircraft** Quantity limitation: 75 kg **Cargo aircraft** Quantity limitation: 150 kg
TDG Classification	UN1066 UN1977	NITROGEN, COMPRESSED Nitrogen, refrigerated liquid	2.2	Not applicable (gas).		**Explosive Limit and Limited Quantity Index** 0.125 **Passenger Carrying Road or Rail Index** 75
Mexico Classification	UN1066 UN1977	NITROGEN, COMPRESSED Nitrogen, refrigerated liquid	2.2	Not applicable (gas).		-

"Refer to CFR 49 (or authority having jurisdiction) to determine the information required for shipment of the product."

Section 15. Regulatory information

United States

U.S. Federal regulations : **TSCA 8(a) IUR**: Partial exemption
United States inventory (TSCA 8b): This material is listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: Nitrogen
SARA 311/312 MSDS distribution - chemical inventory - hazard identification:
Nitrogen: Sudden release of pressure

State regulations : **Connecticut Carcinogen Reporting**: This material is not listed.
Connecticut Hazardous Material Survey: This material is not listed.
Florida substances: This material is not listed.
Illinois Chemical Safety Act: This material is not listed.
Illinois Toxic Substances Disclosure to Employee Act: This material is not listed.
Louisiana Reporting: This material is not listed.
Louisiana Spill: This material is not listed.
Massachusetts Spill: This material is not listed.
Massachusetts Substances: This material is listed.
Michigan Critical Material: This material is not listed.
Minnesota Hazardous Substances: This material is not listed.
New Jersey Hazardous Substances: This material is listed.
New Jersey Spill: This material is not listed.
New Jersey Toxic Catastrophe Prevention Act: This material is not listed.
New York Acutely Hazardous Substances: This material is not listed.
New York Toxic Chemical Release Reporting: This material is not listed.
Pennsylvania RTK Hazardous Substances: This material is listed.
Rhode Island Hazardous Substances: This material is not listed.

Canada

WHMIS (Canada) : Class A: Compressed gas.

CEPA Toxic substances: This material is not listed.
Canadian ARET: This material is not listed.
Canadian NPRI: This material is not listed.
Alberta Designated Substances: This material is not listed.
Ontario Designated Substances: This material is not listed.
Quebec Designated Substances: This material is not listed.

Section 16. Other information

United States

Label requirements : GAS:
CONTENTS UNDER PRESURE.
Do not puncture or incinerate container.
Can cause rapid suffocation.
May cause severe frostbite.
LIQUID:
Extremely cold liquid and gas under pressure.
Can cause rapid suffocation.
May cause severe frostbite.

Canada

Label requirements : Class A: Compressed gas.

Nitrogen

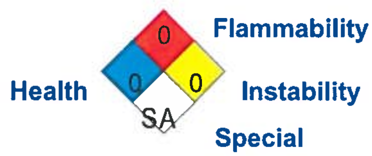
Hazardous Material Information System (U.S.A.) :

Health	0
Flammability	0
Physical hazards	0

liquid:

Health	3
Fire hazard	0
Reactivity	0
Personal protection	

National Fire Protection Association (U.S.A.) :



liquid:

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

Material Safety Data Sheet

1. MATERIAL AND COMPANY IDENTIFICATION

Material Name : **Natural Gas**
Uses : Gaseous fuel for domestic and non-domestic uses.

Manufacturer/Supplier : **Shell Energy North America (US), L.P.**
Two Houston Center
909 Fannin
Plaza Level 1
Houston, TX 77010
USA
MSDS Request : 713-767-5400

Emergency Telephone Number
Spill Information : 877-504-9351
Health Information : DOMESTIC NORTH AMERICA 800-424-9300
INTERNATIONAL, CALL 703-527-3887

2. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Identity	CAS No.	Concentration
Natural gas	8006-14-2	100.00 %

Contains Methane, CAS # 74-82-8
Contains Propane, CAS # 74-98-6
Contains Ethane, CAS # 74-84-0
Contains Butane, CAS # 106-97-8
Contains hydrogen sulphide, CAS # 7783-06-4.

3. HAZARDS IDENTIFICATION

Emergency Overview

Appearance and Odour : Colourless. Gas. Typical gas smell due to addition of odouriser to allow the detection of product leaks..

Health Hazards : Vapours may cause drowsiness and dizziness. High gas concentrations will displace available oxygen from the air; unconsciousness and death may occur suddenly from lack of oxygen. Exposure to rapidly expanding gases may cause frost burns to eyes and/or skin.
Safety Hazards : Extremely flammable. May form flammable/explosive vapour-air mixture. Electrostatic charges may be generated during handling. Electrostatic discharge may cause fire.
Environmental Hazards : Not classified as dangerous for the environment.

Health Hazards
Inhalation : High gas concentrations will displace available oxygen from the air; unconsciousness and death may occur suddenly from lack of oxygen.Exposure to high gas/vapour concentrations may

	lead to narcotic or anaesthetic effects that may impair judgement or lead to central nervous system depression.Breathing of high vapour concentrations may cause central nervous system (CNS) depression resulting in dizziness, light-headedness, headache and nausea.
Signs and Symptoms	: Breathing of high vapour concentrations may cause central nervous system (CNS) depression resulting in dizziness, light-headedness, headache, nausea and loss of coordination. Continued inhalation may result in unconsciousness and death. H2S has a broad range of effects dependent on the airborne concentration and length of exposure: 0.02 ppm odour threshold, smell of rotten eggs; 10 ppm eye and respiratory tract irritation; 100 ppm coughing, headache, dizziness, nausea, eye irritation, loss of sense of smell in minutes; 200 ppm potential for pulmonary oedema after >20-30 minutes; 500 ppm loss of consciousness after short exposures, potential for respiratory arrest; >1000ppm immediate loss of consciousness, may lead rapidly to death, prompt cardiopulmonary resuscitation may be required. Do not depend on sense of smell for warning. H2S causes rapid olfactory fatigue (deadens sense of smell). There is no evidence that H2S will accumulate in the body tissue after repeated exposure.
Environmental Hazards	: Not classified as dangerous for the environment.

4. FIRST AID MEASURES

General Information	: Vaporisation of H2S that has been trapped in clothing can be dangerous to rescuers. Maintain respiratory protection to avoid contamination from the victim to rescuer. Mechanical ventilation should be used to resuscitate if at all possible.
Inhalation	: Remove to fresh air. Do not attempt to rescue the victim unless proper respiratory protection is worn. If the victim has difficulty breathing or tightness of the chest, is dizzy, vomiting, or unresponsive, give 100% oxygen with rescue breathing or CPR as required and transport to the nearest medical facility.
Skin Contact	: If persistent irritation occurs, obtain medical attention.
Eye Contact	: If persistent irritation occurs, obtain medical attention.
Ingestion	: In the unlikely event of ingestion, obtain medical attention immediately.
Advice to Physician	: Treat symptomatically. Hydrogen sulphide (H2S) - CNS asphyxiant. May cause rhinitis, bronchitis and occasionally pulmonary oedema after severe exposure. CONSIDER: Oxygen therapy. Consult a Poison Control Center for guidance.

5. FIRE FIGHTING MEASURES

Clear fire area of all non-emergency personnel.

Flash point	: -187.8 °C / -306.0 °F
Upper / lower Flammability or	: >= 5 %(V)

Explosion limits		
		<= 15 %(V)
Auto ignition temperature	:	583 °C / 1,081 °F
Specific Hazards	:	Forms flammable mixture with air. If released, the resulting vapours will disperse with the prevailing wind. If a source of ignition is present where the vapour exists at 5-15% concentration in air, the vapour will burn along the flame front toward the source of the fuel.
Suitable Extinguishing Media	:	Shut off supply. If not possible and no risk to surroundings, let the fire burn itself out.
Unsuitable Extinguishing Media	:	Do not use water in a jet.
Protective Equipment for Firefighters	:	Wear full protective clothing and self-contained breathing apparatus.

6. ACCIDENTAL RELEASE MEASURES

Avoid contact with spilled or released material. For guidance on selection of personal protective equipment see Chapter 8 of this Material Safety Data Sheet. See Chapter 13 for information on disposal. Observe all relevant local and international regulations.

Protective measures	:	Remove all possible sources of ignition in the surrounding area. Evacuate all personnel. Do not breathe fumes, vapour. Do not operate electrical equipment. Avoid contact with skin, eyes and clothing. Ventilate contaminated area thoroughly. Shut off leaks, if possible without personal risks. Remove all possible sources of ignition in the surrounding area and evacuate all personnel. Attempt to disperse the gas or to direct its flow to a safe location for example by using fog sprays. Take precautionary measures against static discharge. Ensure electrical continuity by bonding and grounding (earthing) all equipment. Monitor area with combustible gas meter.
Additional Advice	:	Notify authorities if any exposure to the general public or the environment occurs or is likely to occur.

7. HANDLING AND STORAGE

General Precautions	:	Take precautionary measures against static discharges.
Handling	:	Avoid contact with skin, eyes and clothing. Extinguish any naked flames. Do not smoke. Remove ignition sources. Avoid sparks. The inherent toxic and olfactory (sense of smell) fatiguing properties of hydrogen sulphide require that air monitoring alarms be used if concentrations are expected to reach harmful levels such as in enclosed spaces, heated transport vessels and spill or leak situations. If the air concentration exceeds 50 ppm, the area should be evacuated unless respiratory protection is in use.
Storage	:	Keep away from sources of ignition - No smoking. Keep container tightly closed and in a cool, well-ventilated place. Cleaning, inspection and maintenance of storage tanks is a specialist operation, which requires the implementation of strict procedures and precautions. These include issuing of work

permits, gas-freeing of tanks, using a manned harness and lifelines and wearing air-supplied breathing apparatus.
Prior to entry and whilst cleaning is underway, the atmosphere within the tank must be monitored using an oxygen meter and explosimeter.

Product Transfer : Earth all equipment.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Occupational Exposure Limits

Material	Source	Type	ppm	mg/m3	Notation
Methane	ACGIH	TWA	1,000 ppm		
Ethane	ACGIH	TWA	1,000 ppm		
Propane	OSHA Z1	PEL	1,000 ppm	1,800 mg/m3	
Propane	OSHA Z1A	TWA	1,000 ppm	1,800 mg/m3	
Propane	ACGIH	TWA	1,000 ppm		
Butane	ACGIH	TWA	1,000 ppm		
Hydrogen Sulphide	ACGIH	TWA	10 ppm		
Hydrogen Sulphide	ACGIH	STEL	15 ppm		
Hydrogen Sulphide	OSHA Z1A	TWA	10 ppm	14 mg/m3	
Hydrogen Sulphide	OSHA Z1A	STEL	15 ppm	21 mg/m3	
Natural gas	ACGIH	TWA	1,000 ppm		

Exposure Controls : The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Select controls based on a risk assessment of local circumstances.
Appropriate measures include: Adequate explosion-proof ventilation to control airborne concentrations below the exposure guidelines/limits.

Personal Protective Equipment : Personal protective equipment (PPE) should meet recommended national standards. Check with PPE suppliers.

Respiratory Protection : If engineering controls do not maintain airborne concentrations to a level which is adequate to protect worker health, select respiratory protection equipment suitable for the specific conditions of use and meeting relevant legislation. Check with respiratory protective equipment suppliers. Where air-filtering respirators are unsuitable (e.g. airborne concentrations are high, risk of oxygen deficiency, confined space) use appropriate positive pressure breathing apparatus. Where respiratory protective equipment is required, use a full-face mask. All respiratory protection equipment and use must be in accordance with local regulations.
Respirator selection, use and maintenance should be in accordance with the requirements of the OSHA Respiratory Protection Standard, 29 CFR 1910.134.

Hand Protection	Not normally required. Suitability and durability of a glove is dependent on usage, e.g. frequency and duration of contact. Always seek advice from glove suppliers. Personal hygiene is a key element of effective hand care. Gloves must only be worn on clean hands. After using gloves, hands should be washed and dried thoroughly. Application of a non-perfumed moisturizer is recommended. If contact with liquefied product is possible or anticipated, gloves should be thermally insulated to prevent cold burns.
Eye Protection	Chemical splash goggles (gas-tight monogoggles) and face shield with chin guard.
Protective Clothing	Skin protection not ordinarily required beyond standard issue work clothes.
Monitoring Methods	Monitoring the oxygen content of the air is often the best means of ensuring safety. There are substantial risks if the concentration of oxygen in the atmosphere varies from the normal (20.8%) under normal atmospheric pressure.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	Colourless. Gas.
Odour	Typical gas smell due to addition of odouriser to allow the detection of product leaks..
Initial Boiling Point and Boiling Range	-161.5 °C / -258.7 °F
Flash point	-187.8 °C / -306.0 °F
Upper / lower Flammability or Explosion limits	>= 5 %(V) <= 15 %(V)
Auto-ignition temperature	583 °C / 1,081 °F
Density	420 g/cm3 at -165.5 °C / -265.9 °F Liquid methane at boiling point.
Water solubility	0.08 g/l at 25 °C / 77 °F
Vapour density (air=1)	Typical 0.58

10. STABILITY AND REACTIVITY

Stability	Stable under normal use conditions.
Conditions to Avoid	Heat, flames, and sparks. May form explosive mixture on contact with air.
Materials to Avoid	Strong oxidising agents.
Hazardous Decomposition Products	Hazardous decomposition products are not expected to form during normal storage.

11. TOXICOLOGICAL INFORMATION

Basis for Assessment	Information given is based on product data, a knowledge of the components and the toxicology of similar products.
Acute Oral Toxicity	LD50 > 5000 mg/kg , Rat
Acute Dermal Toxicity	LD50 > 5000 mg/kg , Rat
Acute Inhalation Toxicity	LC50 >20 mg/l / 4 h, Rat Breathing of high vapour concentrations may cause central

		nervous system (CNS) depression resulting in dizziness, light-headedness, headache and nausea.
Skin Irritation	:	Not expected to be a hazard.
Eye Irritation	:	Not expected to be a hazard.
Respiratory Irritation	:	Not expected to be a respiratory irritant.
Sensitisation	:	Not a skin sensitiser.
Mutagenicity	:	Not considered a mutagenic hazard.
Carcinogenicity	:	Components are not known to be associated with carcinogenic effects.
Reproductive and Developmental Toxicity	:	Not a developmental toxicant.
Additional Information	:	High gas concentrations will displace available oxygen from the air; unconsciousness and death may occur suddenly from lack of oxygen. H2S has a broad range of effects dependent on the airborne concentration and length of exposure: 0.02 ppm odour threshold, smell of rotten eggs; 10 ppm eye and respiratory tract irritation; 100 ppm coughing, headache, dizziness, nausea, eye irritation, loss of sense of smell in minutes; 200 ppm potential for pulmonary oedema after >20-30 minutes; 500 ppm loss of consciousness after short exposures, potential for respiratory arrest; >1000ppm immediate loss of consciousness, may lead rapidly to death, prompt cardiopulmonary resuscitation may be required. Do not depend on sense of smell for warning. H2S causes rapid olfactory fatigue (deadens sense of smell). There is no evidence that H2S will accumulate in the body tissue after repeated exposure.

12. ECOLOGICAL INFORMATION

Information given is based on product data, a knowledge of the components and the ecotoxicology of similar products.

Acute Toxicity	:	Practically non toxic: LC/EC/IC50 > 100 mg/l (to aquatic organisms)
Mobility	:	Contains volatile components. Evaporates extremely rapidly from water or soil surfaces.
Persistence/degradability	:	Inherently biodegradable. Oxidises rapidly by photo-chemical reactions in air.
Bioaccumulation	:	Does not bioaccumulate significantly.

13. DISPOSAL CONSIDERATIONS

Material Disposal	:	Do not discharge into areas where there is a risk of forming an explosive mixture with air.
Local Legislation	:	Disposal should be in accordance with applicable regional, national, and local laws and regulations. Local regulations may be more stringent than regional or national requirements and must be complied with.

14. TRANSPORT INFORMATION

US Department of Transportation Classification (49CFR)

Identification number	UN 1971
Proper shipping name	Natural gas, compressed
Class / Division	2.1

IMDG

Identification number	UN 1971
Proper shipping name	NATURAL GAS, COMPRESSED
Class / Division	2.1
Marine pollutant:	No

IATA (Country variations may apply)

Identification number	UN 1971
Proper shipping name	Natural gas, compressed
Class / Division	2.1

15. REGULATORY INFORMATION

The regulatory information is not intended to be comprehensive. Other regulations may apply to this material.

Federal Regulatory Status

Comprehensive Environmental Release, Compensation & Liability Act (CERCLA)

Natural Gas ()	Reportable quantity: 100 lbs
Natural gas (8006-14-2)	Reportable quantity: 100 lbs
Methane (74-82-8)	Reportable quantity: 100 lbs
Propane (74-98-6)	Reportable quantity: 100 lbs
Ethane (74-84-0)	Reportable quantity: 100 lbs
Hydrogen Sulphide (7783-06-4)	Reportable quantity: 100 lbs

Clean Water Act (CWA) Section 311

Hydrogen Sulphide (7783-06-4)	Reportable quantity: 100 lbs

SARA Hazard Categories (311/312)
Immediate (Acute) Health Hazard. Fire Hazard. Sudden Release of Pressure Hazard.

SARA Extremely Hazardous Substances (302/304)

Hydrogen Sulphide (7783-06-4)	Reportable quantity: 100 lbs
Hydrogen Sulphide (7783-06-4)	Threshold Planning Quantity: 500 lbs

State Regulatory Status

California Safe Drinking Water and Toxic Enforcement Act (Proposition 65)

This material does not contain any chemicals known to the State of California to cause cancer, birth defects or other reproductive harm.

New Jersey Right-To-Know Chemical List

Natural gas (8006-14-2)	Listed. Listed. Listed. Listed. Listed. Listed. Listed. Listed.
Methane (74-82-8)	Listed. Listed. Listed.
Propane (74-98-6)	Listed.
Ethane (74-84-0)	Listed.
Hydrogen Sulphide (7783-06-4)	Listed.
Butane (106-97-8)	Listed.

Pennsylvania Right-To-Know Chemical List

Natural gas (8006-14-2)	Listed.
Methane (74-82-8)	Listed.
Propane (74-98-6)	Listed.
Ethane (74-84-0)	Listed.
Hydrogen Sulphide (7783-06-4)	Environmental hazard. Listed.
Butane (106-97-8)	Listed.

16. OTHER INFORMATION

MSDS Version Number : 2.0

MSDS Effective Date : 11/23/2009

MSDS Revisions	:	A vertical bar (|) in the left margin indicates an amendment from the previous version.
MSDS Regulation	:	The content and format of this MSDS is in accordance with the OSHA Hazard Communication Standard, 29 CFR 1910.1200.
MSDS Distribution	:	The information in this document should be made available to all who may handle the product.
Disclaimer	:	The information contained herein is based on our current knowledge of the underlying data and is intended to describe the product for the purpose of health, safety and environmental requirements only. No warranty or guarantee is expressed or implied regarding the accuracy of these data or the results to be obtained from the use of the product.

DCO Energy

Hartford Hospital Fuel Cell Project

Petition No. 1067

AZ-062

Natural Gas Pipe Cleaning Procedure

DCO Energy

100 Lenox Drive, Suite 100
Lawrenceville, NJ 08648

Phone: 6095122339
Fax: 6092190799

SUBMITTAL NO. AZ-062
PACKAGE NO: AZ

TITLE: Natural Gas Pipe Cleaning Procedure
PROJECT: Hartford Hospital Fuel Cell
DRAWING:
STATUS: NEW
BIC: SE

REQUIRED START: 1/27/2014
REQUIRED FINISH: 2/3/2014
DAYS HELD: 0
DAYS ELAPSED: 10
DAYS OVERDUE: 3

RECEIVED FROM		SENT TO		RETURNED BY		FORWARDED TO	
AZ	MJM	SE	JV	SE	JV	AZ	MJM

Revision No.	Description / Remarks	Received	Sent	Returned	Forwarded	Status	Sepias	Prints	Drawing Date	Held	Elapsed
001	Natural Gas Pipe Cleaning Procedure	1/27/2014	1/27/2014	2/3/2014	2/4/2014	MCN	0	0		0	8
	This submittal was originally packaged as AZ-057 and issued on January 27, 2014 to Andy Larkin. It is now being re-issued under a new submittal number to match AZ's numbering sequence.										
002	Rev. 1 Gas Pipe Cleaning Procedure	2/5/2014	2/6/2014			NEW	0	0		0	1

IP-06.04 ATTACHMENT "A"

Field Procured Materials Service Submittals

Vendor/Subcontractor Submittal Initiation

Project Name:	HHFC	Project Number:	77-264	Company Name:	A/Z Corp.
DCO Submittal Number	AZ-062- Rev.-1	Submittal Date:	2/5/2014	Contact Information:	Mark Maulucci Jonathan NcNaught
Plant Equip ID:	NA	Install Spec/DWG Ref:	2302200	AZ #	230200-008 - Rev.-1
Cost Impact:	NO	Schedule Impact:	NO		

Submission Type:

Submittal:	Requirement:	Document Type:
Sub-Contractor	Specified	Catalog Cuts
Materials	As Equal	Test Reports
Manufacturer	Substitutions	O&M Manuals
Professional Services	Shop Drawing	Calculations
		Permits
		Warranties
		Other (Describe Below)

Submittal Description: Gas Line Cleaning Procedure

Justification For Use:

Attachments:

DCO Submittal Response

DCO Response: No Exceptions Taken / Make Corrections Noted / Revise & Resubmit / Resubmit Certified

Submittal Response:

Potentially Impacts Basis of Design: YES NO

Response By:	Date:	Peer Review:	Date:

Engineer of Record:	Date:	Other:	Date:
[signature]	2/6/14	[signature]	2/6/14

ATTENTION

If at any point in the submittal process it is determined that the submittal response results in or requires a code review/interpretation, a modified engineering calculation, a change to an engineered drawing/specification, or an addition to an engineering drawing or specification, the submittal must be routed to the EOR for disposition.

Submittal

Spec Section Title: Mechanical

Package No: 230200

No: 008

Title: Gas Line Cleaning Procedure

Project: Hartford Hospital Fuel Cell

Job: C-5-7588

Status: For Approval

Required Start: 2/6/2014

Required Finish: 2/10/2014

Received From:	Sent To:	Returned By:	Forwarded To:
A/Z Corporation	DCO Energy	DCO Energy	A/Z Corporation

Revision No:	Description	Received	Sent	Returned	Forwarded	Copies Sent:	Status
1	Gas Line Cleaning Procedure	2/5/2014	2/5/2014			1	
0		1/30/2014	1/30/2014	2/3/2014	2/3/2014	0	Revise and resubmit

A/Z CORPORATION

- APPROVED ☐
- APPROVED AS NOTED ☐
- NOT APPROVED ☐
- REVISE AND RESUBMIT ☐
- REVIEWED ☒

REVIEW IS FOR GENERAL CONFORMANCE WITH THE DESIGN CONCEPT AND CONTRACT DOCUMENTS MARKING OR COMMENTS SHALL NOT BE CONSTRUED AS RELIEVING THE SUBCONTRACTOR SUPPLIER FROM COMPLIANCE WITH THE PROJECT PLANS AND SPECIFICATIONS NOR DEPARTURES THERE FROM. THE SUBCONTRACTOR /SUPPLIER REMAINS RESPONSIBLE FOR DETAILS AND ACCURACY. FOR CONFIRMING AND CORRELATING ALL QUANTITIES AND DIMENSIONS FOR SELECTING FABRICATION PROCESSES FOR THE TECHNIQUES OF ASSEMBLY. AND FOR PERFORMING THIS WORK IN A SAFE MANNER AND IN ACCORDANCE WITH ALL APPLICABLE CODES.

DATE 2-5-14 BY [signature]

A/Z CORP

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: Hartford Hospital Fuel Cell – Cleaning of Gas Piping to Skid # 2 – Rev. - 1

Date of Analysis: February 4, 2014

Reviewed By: Steven Galbo (A/Z Safety Coordinator)

Approved By: DCO Energy, LLC

Job Location: Hartford Hospital Co-Generation Facility Hartford, CT

Smart Engineering, LLC

Checked for conformance with the design concept & conformity with information given in the contract documents.

☒ NO EXCEPTIONS TAKEN
☐ MAKE CORRECTIONS NOTED
☐ REVISE AND RESUBMIT
☐ RESUBMIT CERTIFIED

Signature: DO Date: 2/6/14

Job Description:

The following is a basic sequence of events procedure for the safe cleaning of the new natural gas piping from hand valve V-0200 at the CNG gas train to V-0100. The strainer and the spool to Skid # 2 will be removed for this Procedure.

Important Notes:

- Prior to the cleaning procedure taking place all of the gas piping will have been pressure tested and signed off on.
- Nitrogen will be utilized to perform the cleaning blow for this piping.

Personal Protective Equipment:

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

Attendant Responsibilities:

1) During the blowing procedure an attendant shall be posted at the perimeter of the danger taped area.
2) The attendant's responsibilities shall be to ensure;
   - That no unauthorized vehicle or pedestrian traffic enters the restricted area.
   - To communicate with the person performing the blowing of the system.

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 any compressed gas used for cleaning, safe handling practices of 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 (DCO Trailer @ Retreat Ave). Emergency response planning will follow in accordance with 29 CFR 1910.38(a). The Hartford, 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 to 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:

   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) **Notifications:** All Contractors working on site including DCO Energy, LLC, HSC, and Hartford Hospital Fire Marshall shall be notified prior to the commencements of this procedure.
6) **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.
7) **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, DCO Energy and Hartford Hospital Representative(s) after emergency services have been called. A list of these contacts is provided:

   Local Agencies:

Ambulance: 911
Fire: Hartford, CT- 911 (860) 757-4500
Police: Hartford, CT - 911 (860) 757-4000
Hospital: Hartford Hospital 80 Seymour Street Hartford, CT (860) 545-5000

A/Z Personnel:
Sr. Mechanical Project Manager: Mark Maulucci (860) 625-8607
Site Foreman: Mauricio Munoz (860) 319-6287
Safety Coordinator: Steven Galbo (860) 941-0458
Corporate, Health and Safety Manager: Edwin Jones (860) 625-8839

DCO Energy LLC:
Construction Project Manager: Andy Why (609) 847-1172
Site Manager: Gerry Zeman (609) 209-3469

8) **Fire Control:** Smoking/Tobacco products ARE NOT allowed anywhere within the Hartford Hospital Fuel Cell Construction Project.
9) **Work Stand-Down Procedure**: The foreman shall brief all personal the instructions below regarding valve closures to be acted upon in the event of a call for "Stand-Down" during the nitrogen blow.
    - In the case of a stand-down call during the N2 blowing closing V-0300 will stop the flow of N2.

10) **Emergency Recognition and Prevention:** Because unrecognized hazards may result in emergency incidents, it will be the responsibility of the A/Z PM, A/Z foreman and A/Z safety coordinator 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

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

800.400.2420 Phone
860.445.3599 Fax
a-zcorp.com

- 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) N2 Blowing

*Hazards

- Lockout / Tagout
- Plan the work involving personnel responsible for preparation (such as isolation, depressurization, draining, venting, flushing) of the equipment / system to be blown.
- Ensure the equipment / system to be blown 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

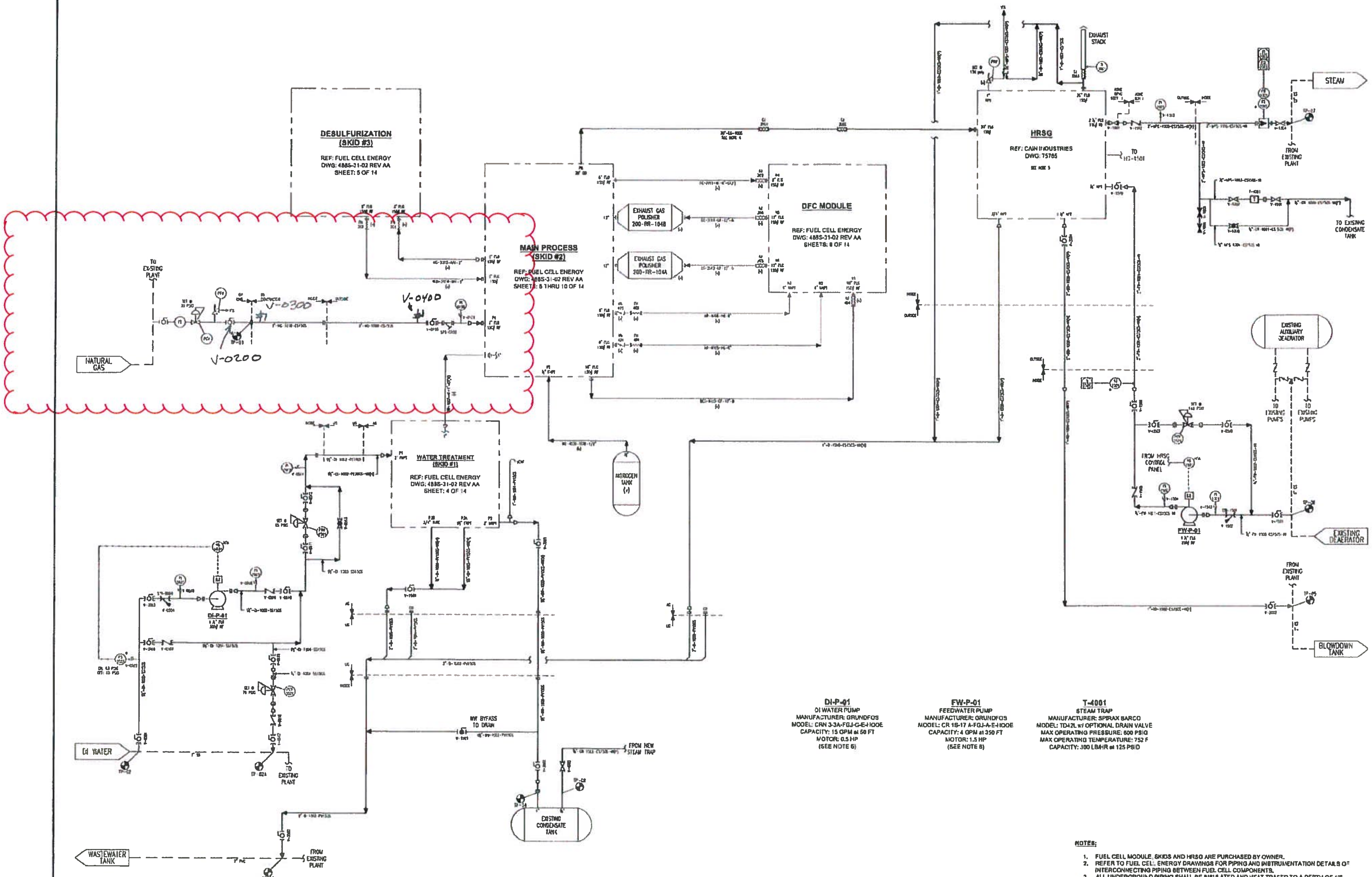
- Ensure the tools (such as N2 tank, hose, coupling, and pressure gauges etc.) to be used are free from defect.
- Ensure the N2 supply hoses and couplings are rated for the required service and pressure.
- Barricade the area and post warning notice.
- Ensure the disposal of purged N2 volume is to a safe location.

Gas Line N2 blowing Procedure: Information Notes: The following is a basic sequence of events procedure for the safe N2 blowing / cleaning of the new natural gas piping from hand valve V-0200 at the gas meter assembly to V-0100.

1.) Prior to the cleaning procedure taking place all gas piping will have been tested and signed off on.
2.) Confirm that V-0200 is closed and LOTO installed.
3.) Confirm that V-0100 is closed
4.) A 100 gallon receiver will be utilized for additional volume of N2 to perform the blow.
5.) A 1" HP hose will be connected from the tank to V-0300.
6.) Valve V-0300 will be opened.
7.) A flanged adapter 3" x 1" with a short piece of 1" CS pipe will be installed on the discharge side of V-0100 to increase velocity.
8.) White tack mat will be placed on the slab below the discharge point of V-0100 as a target for the blow.
9.) Danger tape will be installed around a 30ft perimeter radius from the discharge location.
10.) All non-essential personnel are prohibited from entering the cordoned-off areas during this procedure.
11.) All workers involved in this work will attend a pre procedure briefing where this procedure will be reviewed.
12.) The receiver and piping will be charged to 60psi thru V-0300, pressure verified by gauge on N2 receiver.
13.) Hand Valve V-0100 shall now be fully opened to allow the blow until pressure drops to 45psi.
14.) The target shall be inspected and replaced with a clean target.
15.) Steps 12 thru 14 shall be repeated until the target shows no signs of debri.
16.) At this time the 3" x 1" spool can be removed from V-0100 and the strainer and additional spool can now be installed to skid # 2.
17.) Strainer and additional piping spool will be hand cleaned and inspected prior to installation into the system.
18.) LOTO on valve V-0200 will remain in place until gas purge procedure is performed.
19.) At this time the piping is cleaned and secured for the purging operations.

I have read and understand the above procedure:

Name:	Date:



DI-P-01
DI WATER PUMP
MANUFACTURER: GRUNDFOS
MODEL: CRN 3-3A-FGJ-G-E-HQQE
CAPACITY: 15 GPM at 50 FT
MOTOR: 0.5 HP
(SEE NOTE 6)

FW-P-01
FEEDWATER PUMP
MANUFACTURER: GRUNDFOS
MODEL: CR 1S-17 A-FGJ-A-E-HQQE
CAPACITY: 4 GPM at 350 FT
MOTOR: 1.5 HP
(SEE NOTE 6)

T-4001
STEAM TRAP
MANUFACTURER: SPIRAX SARCO
MODEL: TD42L w/ OPTIONAL DRAIN VALVE
MAX OPERATING PRESSURE: 600 PSIG
MAX OPERATING TEMPERATURE: 752 F
CAPACITY: 300 LB/HR at 125 PSID

NOTES:

1. FUEL CELL MODULE, SKIDS AND HRSG ARE PURCHASED BY OWNER.
2. REFER TO FUEL CELL ENERGY DRAWINGS FOR PIPING AND INSTRUMENTATION DETAILS OF INTERCONNECTING PIPING BETWEEN FUEL CELL COMPONENTS.
3. ALL UNDERGROUND PIPING SHALL BE INSULATED AND HEAT TRACED TO A DEPTH OF 42".
4. FOR EXHAUST DUCT DETAILS REFER M-13 TO SPECIFICATION NO. 235116.
5. CONTRACTOR TO INSULATE FACTORY INSTALLED PIPING ON THE HRSG PER INSULATION CLASS VII IN ACCORDANCE WITH SPECIFICATION 230515.
6. MECHANICAL CONTRACTOR SHALL PROCURE PUMP MOTOR STARTERS FOR THE ELECTRICAL CONTRACTOR. MOTOR STARTERS SHALL BE EATON / CUTLER HAMMER ATL COMBINATION MOTOR STARTERS WITH MAIN FUSIBLE DISCONNECT SWITCH, NEMA 1 ENCLOSURE, H-O-A SELECTOR SWITCH, RUN LIGHT AND 1 NO/ 1 NC AUXILIARY CONTACTS. MOTOR STARTERS SHALL BE SELF SOURCED.

EOR
SE
Smart Engineering, LLC
5429 Harding Highway
Bldg. 500
Mays Landing, NJ 08330

EPC
DCO Energy
5429 Harding Highway
Bldg. 500
Mays Landing, NJ 08330

Client
HSC Fuel Cell 1, LLC
5429 Harding Highway
Bldg. 500
Mays Landing, NJ 08330

REV.-1 - 2-5-14

Seal

I hearby certify that this document was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Connecticut.

Signed: ______
Date: ______ Reg. No: ______

Revision History

No	Date	Description
A	06/05/13	[illegible]
B	06/26/13	[illegible]
C	07/12/13	[illegible]
D	07/22/13	[illegible]
G	08/04/13	[illegible]

Proj #: 32264	Drawn by: DD
Scale: NTS	Check by: AL
Sheet: 1 of 1	App'd by: JV
Date: 08/05/13	Size: 24" x 36"

Project

Hartford Hospital Fuel Cell

Hartford, Connecticut

Drawing Title

PIPING & INSTRUMENTATION DIAGRAM

Drawing Number	Rev
M-03	0

Natural Gas Properties at Actual Operating Conditions

Natural Gas Mass Flow Rate (lbs/hr)	Pressure (psig)	Pressure (atm)	Pressure (psia)	T (°F)	T (R)	$R_{specific}$ (ft^3/in^2I°R)	MW (lb/lb°mol)	Density of Natural Gas (lbs/ft^3)	Specific Volume of Natural Gas (ft^3/lbs)	Velocity Natural Gas (ft/s)
475	15	14.7	30	60	520	0.6561	16.35	0.0871	11.49	30.88

Nitrogen Properties at Actual Operating Conditions

Pressure (psig)	Pressure (atm)	Pressure (psia)	T (°F)	T (R)	$R_{specific}$ [ft^3/in^2I°R]	MW (lb/lb°mol)	Density of Nitrogen [lbs/ft^3]	Specific Volume of Nitrogen [ft^3/lbs)	Velocity of nitrogen blow (ft/s)	Nitrogen Mass flow rate (lbs/hr) when CFR = 1
60	14.7	74.70	70	530	0.3829	28.02	0.368	2.72	16.45	977

Natural Gas Properties

Compound	Methane	Ethane	Nitrogen	Sulfur Dioxide
Molecular Weight (MW)	16.043	30.069	28.013	64.064
Volume Percent	98%	2%	0.2700%	0.0000%

Pipe Properties

Natural Gas Pipe ID (in)	Cross Sectional Area (ft^2)	CFR
3	0.0491	1.2

Nitrogen Blow Stopping Pressure

Stopping Pressure	Pressure (psig)	Pressure (psia)	Density of Nitrogen (lbs/ft^3)	Specific Volume of Nitrogen (ft^3/lbs)	Mass flow rate at stopping pressure
GO	210	224.7	1.107	0.90	1,856
GO	205	219.7	1.082	0.92	1,835
GO	200	214.7	1.058	0.95	1,814
GO	195	209.7	1.033	0.97	1,793
GO	190	204.7	1.009	0.99	1,771
GO	185	199.7	0.984	1.02	1,749
GO	180	194.7	0.959	1.04	1,727
GO	175	189.7	0.935	1.07	1,705
GO	170	184.7	0.910	1.10	1,682
GO	165	179.7	0.885	1.13	1,659
GO	160	174.7	0.861	1.16	1,636
GO	155	169.7	0.836	1.20	1,613
GO	150	164.7	0.811	1.23	1,589
GO	145	159.7	0.787	1.27	1,564
GO	140	154.7	0.762	1.31	1,540
GO	135	149.7	0.738	1.36	1,515
GO	130	144.7	0.713	1.40	1,489
GO	125	139.7	0.688	1.45	1,463
GO	120	134.7	0.664	1.51	1,437
GO	115	129.7	0.639	1.56	1,410
GO	110	124.7	0.614	1.63	1,382
GO	105	119.7	0.590	1.70	1,354
GO	100	114.7	0.565	1.77	1,326
GO	95	109.7	0.541	1.85	1,297
GO	90	104.7	0.516	1.94	1,267
GO	85	99.7	0.491	2.04	1,236
GO	80	94.7	0.467	2.14	1,205
GO	75	89.7	0.442	2.26	1,172
GO	70	84.7	0.417	2.40	1,139
GO	65	79.7	0.393	2.55	1,105
GO	60	74.7	0.368	2.72	1,070
GO	55	69.7	0.343	2.91	1,033
GO	50	64.7	0.319	3.14	996
STOP	45	59.7	0.294	3.40	956
STOP	40	54.7	0.270	3.71	916
STOP	35	49.7	0.245	4.08	873
STOP	30	44.7	0.220	4.54	828
STOP	25	39.7	0.196	5.11	780
STOP	20	34.7	0.171	5.85	729
STOP	15	29.7	0.146	6.83	675
STOP	10	24.7	0.122	8.22	615
STOP	5	19.7	0.097	10.30	549

LEGEND

- Original Data from Spreadsheet
- Data from Plans/Specs
- Data from AAL Gas Analysis Report
- Data from AZ Procedure
- Data from N2 MSDS included with AZ Procedure

Material Safety Data Sheet

Nitrogen

Section 1. Chemical product and company identification

Product name	:	Nitrogen
Supplier	:	AIRGAS INC., on behalf of its subsidiaries 259 North Radnor-Chester Road Suite 100 Radnor, PA 19087-5283 1-610-687-5253
Product use	:	Synthetic/Analytical chemistry. Liquid – cryogenic coolant.
Synonym	:	nitrogen (dot); nitrogen gas; Nitrogen NF, LIN, Cryogenic Liquid Nitrogen, Liquid Nitrogen
MSDS #	:	001040
Date of Preparation/Revision	:	**1/14/2011.**
In case of emergency	:	1-866-734-3438

Section 2. Hazards identification

Physical state	:	Gas. [NORMALLY A COLORLESS GAS: MAY BE A CLEAR COLORLESS LIQUID AT LOW TEMPERATURES. SOLD AS A COMPRESSED GAS OR LIQUID IN STEEL CYLINDERS.]
Emergency overview	:	WARNING! GAS: CONTENTS UNDER PRESURE. Do not puncture or incinerate container. Can cause rapid suffocation. May cause severe frostbite. LIQUID: Extremely cold liquid and gas under pressure. Can cause rapid suffocation. May cause severe frostbite. Do not puncture or incinerate container. Contact with rapidly expanding gases or liquids can cause frostbite.
Routes of entry	:	Inhalation
Potential acute health effects		
Eyes	:	Contact with rapidly expanding gas may cause burns or frostbite. Contact with cryogenic liquid can cause frostbite and cryogenic burns.
Skin	:	Contact with rapidly expanding gas may cause burns or frostbite. Contact with cryogenic liquid can cause frostbite and cryogenic burns.
Inhalation	:	Acts as a simple asphyxiant.
Ingestion	:	Ingestion is not a normal route of exposure for gases. Contact with cryogenic liquid can cause frostbite and cryogenic burns.
Medical conditions aggravated by over-exposure	:	Acute or chronic respiratory conditions may be aggravated by overexposure to this gas.

See toxicological information (Section 11)

Section 3. Composition, Information on Ingredients

Name	CAS number	% Volume	Exposure limits
Nitrogen	7727-37-9	100	Oxygen Depletion [Asphyxiant]

Section 4. First aid measures

No action shall be taken involving any personal risk or without suitable training.If it is suspected that fumes are still present, the rescuer should wear an appropriate mask or self-contained breathing apparatus.It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation.

Eye contact	:	Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention immediately.
Skin contact	:	None expected.
Frostbite	:	Try to warm up the frozen tissues and seek medical attention.
Inhalation	:	Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention immediately.
Ingestion	:	As this product is a gas, refer to the inhalation section.

Section 5. Fire-fighting measures

Flammability of the product	:	Non-flammable.
Products of combustion	:	Decomposition products may include the following materials: nitrogen oxides
Fire-fighting media and instructions	:	Use an extinguishing agent suitable for the surrounding fire. Apply water from a safe distance to cool container and protect surrounding area. If involved in fire, shut off flow immediately if it can be done without risk. Contains gas under pressure. In a fire or if heated, a pressure increase will occur and the container may burst or explode.
Special protective equipment for fire-fighters	:	Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions	:	Immediately contact emergency personnel. Keep unnecessary personnel away. Use suitable protective equipment (section 8). Shut off gas supply if this can be done safely. Isolate area until gas has dispersed.
Environmental precautions	:	Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.
Methods for cleaning up	:	Immediately contact emergency personnel. Stop leak if without risk. Note: see section 1 for emergency contact information and section 13 for waste disposal.

Section 7. Handling and storage

Handling	:	High pressure gas. Do not puncture or incinerate container. Use equipment rated for cylinder pressure. Close valve after each use and when empty. Protect cylinders from physical damage; do not drag, roll, slide, or drop. Use a suitable hand truck for cylinder movement. Never allow any unprotected part of the body to touch uninsulated pipes or vessels that contain cryogenic liquids. Prevent entrapment of liquid in closed systems or piping without pressure relief devices. Some materials may become brittle at low temperatures and will easily fracture.
Storage	:	Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Cylinder temperatures should not exceed 52 °C (125 °F). For additional information concerning storage and handling refer to Compressed Gas Association pamphlets P-1 Safe Handling of Compressed Gases in Containers and P-12 Safe Handling of Cryogenic Liquids available from the Compressed Gas Association, Inc.

Section 8. Exposure controls/personal protection

Engineering controls : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure to airborne contaminants below any recommended or statutory limits.

Personal protection

Eyes : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.

When working with cryogenic liquids, wear a full face shield.

Skin : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Respiratory : Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

The applicable standards are (US) 29 CFR 1910.134 and (Canada) Z94.4-93

Hands : Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.

Insulated gloves suitable for low temperatures

Personal protection in case of a large spill : Self-contained breathing apparatus (SCBA) should be used to avoid inhalation of the product.

Product name	
Nitrogen	Oxygen Depletion [Asphyxiant]

Consult local authorities for acceptable exposure limits.

Section 9. Physical and chemical properties

Molecular weight	:	28.02 g/mole
Molecular formula	:	N2
Boiling/condensation point	:	-195.8°C (-320.4°F)
Melting/freezing point	:	-210°C (-346°F)
Critical temperature	:	-146.9°C (-232.4°F)
Vapor density	:	0.967 (Air = 1) Liquid Density@BP: 50.46 lb/ft3 (808.3 kg/m3)
Specific Volume (ft^3/lb)	:	13.8889
Gas Density (lb/ft^3)	:	0.072

Section 10. Stability and reactivity

Stability and reactivity : The product is stable.

Hazardous decomposition products : Under normal conditions of storage and use, hazardous decomposition products should not be produced.

Hazardous polymerization : Under normal conditions of storage and use, hazardous polymerization will not occur.

Section 11. Toxicological information

Toxicity data

Other toxic effects on humans : No specific information is available in our database regarding the other toxic effects of this material to humans.

Specific effects

Carcinogenic effects : No known significant effects or critical hazards.

Mutagenic effects : No known significant effects or critical hazards.

Reproduction toxicity : No known significant effects or critical hazards.

Section 12. Ecological information

Aquatic ecotoxicity

Not available.

Environmental fate : Not available.

Environmental hazards : No known significant effects or critical hazards.

Toxicity to the environment : Not available.

Section 13. Disposal considerations

Product removed from the cylinder must be disposed of in accordance with appropriate Federal, State, local regulation.Return cylinders with residual product to Airgas, Inc.Do not dispose of locally.

Section 14. Transport information

Regulatory information	UN number	Proper shipping name	Class	Packing group	Label	Additional information
DOT Classification	UN1066 UN1977	NITROGEN, COMPRESSED Nitrogen, refrigerated liquid	2.2	Not applicable (gas).		**Limited quantity** Yes. **Packaging instruction** **Passenger aircraft** Quantity limitation: 75 kg **Cargo aircraft** Quantity limitation: 150 kg
TDG Classification	UN1066 UN1977	NITROGEN, COMPRESSED Nitrogen, refrigerated liquid	2.2	Not applicable (gas).		**Explosive Limit and Limited Quantity Index** 0.125 **Passenger Carrying Road or Rail Index** 75
Mexico Classification	UN1066 UN1977	NITROGEN, COMPRESSED Nitrogen, refrigerated liquid	2.2	Not applicable (gas).		-

"Refer to CFR 49 (or authority having jurisdiction) to determine the information required for shipment of the product."

Section 15. Regulatory information

United States

U.S. Federal regulations : **TSCA 8(a) IUR**: Partial exemption
United States inventory (TSCA 8b): This material is listed or exempted.

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: Nitrogen
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: Nitrogen: Sudden release of pressure

State regulations : **Connecticut Carcinogen Reporting**: This material is not listed.
Connecticut Hazardous Material Survey: This material is not listed.
Florida substances: This material is not listed.
Illinois Chemical Safety Act: This material is not listed.
Illinois Toxic Substances Disclosure to Employee Act: This material is not listed.
Louisiana Reporting: This material is not listed.
Louisiana Spill: This material is not listed.
Massachusetts Spill: This material is not listed.
Massachusetts Substances: This material is listed.
Michigan Critical Material: This material is not listed.
Minnesota Hazardous Substances: This material is not listed.
New Jersey Hazardous Substances: This material is listed.
New Jersey Spill: This material is not listed.
New Jersey Toxic Catastrophe Prevention Act: This material is not listed.
New York Acutely Hazardous Substances: This material is not listed.
New York Toxic Chemical Release Reporting: This material is not listed.
Pennsylvania RTK Hazardous Substances: This material is listed.
Rhode Island Hazardous Substances: This material is not listed.

Canada

WHMIS (Canada) : Class A: Compressed gas.

CEPA Toxic substances: This material is not listed.
Canadian ARET: This material is not listed.
Canadian NPRI: This material is not listed.
Alberta Designated Substances: This material is not listed.
Ontario Designated Substances: This material is not listed.
Quebec Designated Substances: This material is not listed.

Section 16. Other information

United States

Label requirements : GAS:
CONTENTS UNDER PRESURE.
Do not puncture or incinerate container.
Can cause rapid suffocation.
May cause severe frostbite.
LIQUID:
Extremely cold liquid and gas under pressure.
Can cause rapid suffocation.
May cause severe frostbite.

Canada

Label requirements : Class A: Compressed gas.

Nitrogen

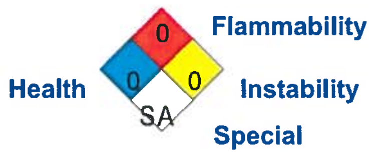
Hazardous Material Information System (U.S.A.) :

Health	0
Flammability	0
Physical hazards	0

liquid:

Health	3
Fire hazard	0
Reactivity	0
Personal protection	

National Fire Protection Association (U.S.A.) :



liquid:

Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above-named supplier, nor any of its subsidiaries, assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

DCO Energy

Hartford Hospital Fuel Cell Project

Petition No. 1067

FCE-004

Pre-Startup System Fill Procedures

FuelCell Energy

Smart Engineering, LLC

Checked for conformance with the design concept & conformity with information given in the contract documents

☒ NO EXCEPTIONS TAKEN
☐ MAKE CORRECTIONS NOTED
☐ REVISE AND RESUBMIT
☐ RESUBMIT CERTIFIED

Signature: [signature] Date: 2/12/14

TECHNICAL SERVICE BULLETIN

Pre-Start Up Fuel System Fill

Date Posted: 11/06/2012
Series: DFC1500B, DFC1500B5 **Plants Affected: All DFC1500B Units**

SUMMARY:

Manual(s) Affected: 20322
This document covers the initial fill of fuel into the fuel cell desulfurizers and fuel system at time of commissioning.
Current/Changed Condition: FCE has to have received Certificate of Mechanical Completion for the installed plant, and plant has yet to have been operated.

CATEGORY: 7

1. As Soon As Possible
2. Next Scheduled Shutdown
3. Next Schedule Maintenance
4. Cold Shut Down
5. Plant De-Energized
6. At Operator Convenience
7. **As Per Identified Time**

Pre-Start Up Fuel System Fill Requirements:

Safety (PPE) (as appropriate for ***each*** participant)	As required by federal, state, local and site regulations and procedures. Lock Out/Tag Out Equipment Safety Glasses Portable Personal gas monitor Monitor/Detector (LEL, O2) (FCE p/n 8107-002) – ***Calibrated, for each FCE employee performing work*** Portable Fire Extinguisher, Type A,B,C
Plant Status	Energized and capable of being Enabled
Parts	None
Consumables	Liquid Nitrogen Dewar , (1) 160 liter liquid (3600 scf gas) minimum capacity Roll of yellow and black "CAUTION" tape. 12" long tie wraps
Non-Standard Tools & Equipment	N2 Purge Kit (FCE p/n 2700) Portable Personal gas monitor(s) (LEL, O2) (FCE p/n 8107-002) – ***Calibrated immediately prior to this procedure*** *(cited above)* RKI model GX-2012 5 channel Gas Analyzer Instrument, w/ 0-100% methane and 0-40% Oxygen measuring capabilities – ***Calibrated immediately prior to use.*** Gas Analyzer Instrument 'Purge Tee Fitting' and flow discharge tubing (larger diameter than analyzer sample tubing, 25') Safety Cones and/or barricades, as determined by local site layout Temporary 'NO SMOKING' signs (min. 2)
Required Reference Documents (available on Master Control)	DFC1500B P&ID: 488S-31-02 (units MB-7+); 483S-31-02 (units MB-1 – MB-6) MSDS-036 (Nitrogen) MSDS-037 (Natural Gas)
Personnel	2

TECHNICAL SERVICE BULLETIN

Pre-Start Up Fuel System Fill

Date Posted: 11/06/2012
Series: DFC1500B, DFC1500B5 **Plants Affected: All DFC1500B Units**

Purging with Nitrogen and filling the fuel system with Natural Gas prior to startup

THIS PROCEDURE HAS BEEN PREPARED IN ACCORDANCE WITH THE REQUIREMENTS OF NFPA 56 (PS). THIS ENTIRE PROCEDURE MUST BE READ IN FULL AND UNDERSTOOD EACH AND EVERY TIME PRIOR TO PERFORMING ANY FUEL GAS PURGING ACTIVITIES.

NFPA 56 (PS) requires that the written procedure for cleaning and purging activities shall at a minimum address approximately fifty items outlined in Section 4.3 of the Code. A matrix is provided in the appendix that describes the location within this procedure where discussion or consideration of each item is located.

I. Brief Procedure Narrative

This procedure is written to comply with the requirements of NFPA 56 (PS). Accordingly, there are very specific requirements which must be carefully followed. Specific training is required to perform this procedure and preparatory work is required prior to the day the procedure is to be performed. The procedure includes the following tasks:
Administration:

- Procedure Safety Validation
- Management Approval
- Training Requirements
- Documentation Requirements
- Management of Change

Preparation:

- Verification of Installation Completion and leak tightness demonstration, including review of documentation
- Pre-Procedure Briefing
- Consideration of Site Specific Conditions
- Required Communications

Procedure:

- Technicians prepare themselves and desulfurizer vessels to be purged
- Desulfurizer vessels are purged with nitrogen
- Piping downstream of the desulfurizer vessels are purged with nitrogen
- Desulfurizer vessels are purged with fuel gas
- Piping downstream of the desulfurizer vessels are purge with fuel gas.

II. Administrative Requirements

A. Procedure Safety Validation

This procedure has successfully passed a process safety review in the form of a "what-if/checklist" analysis. The what-if/checklist analysis review included representatives of the following disciplines:

- Product Engineering (Process Design Engineering, Systems Integration Engineering, Electrical Engineering, Instrumentation and Control Engineering, Operations Engineering)
- Project Management
- Field Service

The most recent process safety review session was conducted on 10/11/2012. The safety validation has met the requirements of Sections 4.4 and 4.6 of NFPA 56 (PS). The Safety Validation document is on file on FuelCell Energy's documentation retention system (Master Control) as Document TSB-1500B5-079.

B. Management Approval

This fuel gas purging procedure, prepared in accordance and in compliance with the provisions of NFPA 56 (PS), has been safety validated and all issues resolved and is management approved by FuelCell Energy, Inc.

__01__, approved by:	(signature on MC file attachment)__	____________________
Revision	Michael Riddell, VP/Chief Engineer	Date

C. Training Requirements

Personnel performing this procedure shall be current with the following training:

- Hazard Communication, EHS Training Module #0122
- Compressed Gas Management, EHS Training Module #0003
- Ladder Safety, EHS Training Module #0010
- Portable Fire Extinguishers, EHS Training Module #0006
- Personal Protective Equipment, EHS Training Module # 0201
- Lockout/Tagout, EHS Training Module #0093 and/or #0094
- FCE Field Service Plant Qualification Procedure sign-off, AD.611 (Sr. Technician)
- Fuel Gas Purging (this procedure)

It is the responsibility FCE field service Team Lead to check and verify the current status of personnel training prior to assigning technicians to perform this procedure.

D. Documentation Requirements

A written copy of the latest revision of this procedure is to be available on site every time this procedure is performed. It is the responsibility of the senior technician conducting the procedure to verify prior to conducting the procedure that the field service team has a written copy of the *latest* revision of this procedure posted to Master Control.
This procedure and the safety validation must be retained for a minimum of 2 years following its use. Non-current revisions of this procedure and its safety validation are retained in a Master Control Archive vault.
Training records for personnel performing this procedure shall be retained for a minimum of 5 years following use of this procedure. Training records are maintained by the FCE Environmental Health and Safety Department for the requisite retention period.

E. Management of Change

Changes to this procedure are to be updated through the Technical Publications Document Change Request (DCR) process that resides on the FCE Service System Database. FCE product manuals are normally updated on a recurring 6 month basis, and non-safety-critical procedure changes will be incorporated at such time. Should any safety-critical changes be required between 6 month manual updates, such updates will be issued service bulletins. ALL procedure changes (with the exception of editorial corrections that do not affect procedure safety) shall be safety validated and management approved. The management of change process shall in all respects comply with all requirements of NFPA 56 (PS) section 4.5.

III. Preparation

A. Pre-Procedure Briefing (tailgate meeting)

The senior technician shall conduct a pre-job briefing prior to executing this procedure. The briefing shall include all on-site FCE personnel, and representatives of other parties (owner, contractors, occupants) present potentially impacted by the procedure. The briefing shall include discussion of the following items at a minimum:

- **FCE Individual roles and responsibilities:**
    - The Senior tech shall monitor the process and process area throughout the procedure. The Senior tech shall "roam" the exclusion area and surrounding areas for the presence of flammable gas and issue and 'watch' or 'stand-down' instructions as required.
    - The Junior tech will perform the physical tasks.

TECHNICAL SERVICE BULLETIN

Pre-Start Up Fuel System Fill

- **Work Stand-down procedure:**
  - The senior tech shall describe exact instructions regarding specific nitrogen or flammable gas valve(s) to be closed in the event of a call for "Stand-down."
  - It is to be clear that any affected person may call for a "Stand down" for any reason of perceived danger and it is to be immediately executed without question.
  - In the case of a stand down call, activation of any of the MBOP E-stop buttons will automatically close XV-205A and XV-205B, stopping purge gas flow (whether nitrogen or fuel) into the desulfurizers and downstream piping. An E-stop button should be activated in the process of evacuating all personnel from the affected area.
- **Site Specific Considerations and Exclusion Zone,**
  - Any site specific considerations and exclusion zones, as determined in Section III B, shall be reviewed.
- **Prohibition of Hot Work:**
  - The senior tech shall provide clear notification that all hot work shall be prohibited within the exclusion zone and beyond to a radius of 35' horizontally from the point immediately below SP-203 for the entire duration of the procedure. All contractors in the vicinity of purging procedure are to be so informed. For the purposes of this procedure, ***hot work*** is to include any use of potentially sparking equipment or processes, including any use of electric tools that are not specifically approved for use in hazardous (potentially explosive) atmospheres.
  - The senior tech shall be sure arrangements have been made to have the specified fire extinguisher available and on site.
- **PPE and MSDSs.**
  - The senior tech shall review all MSDSs and PPE requirements for the procedure. Personal LEL monitors are used as PPE and general warning system throughout this procedure ***by each FCE employee performing work***. It is to be discussed and understood that workers executing this procedure must not rely on smell for flammable gas detection, as gas purged from the system will be odorless.

B. Site-specific Considerations

Note: *This procedure is written such that the inert and flammable gases used in this procedure are all either discharged directly out from the standard-located, hard-piped Skid 3 vent stack discharge termination (SP-203), or through temporary hose discharging in the vicinity of this point. In consideration of the valve and line sizes and gas pressures used in this procedure, it has been predetermined that the SP-203 location is "safe" for all envisioned normal conditions. This predetermination is based on the maximum possible flammable gas flow out from the SP-203 as well as the lighter-than-air density of natural gas fuel. Computational Fluid Dynamics (CFD) modeling has validated the "safe location" designation of SP-203 for much greater flows than are possible out from the discharge valve used in this procedure.*

Prior to conducting this procedure the effect of site-specific conditions shall be evaluated for their potential impact on the safety of this procedure.

- **Inlet Customer Fuel Piping:**
  - The FCE Installation Manual (Document # 20321) requires that the fuel system undergo an inspection and static pressure test (section 6.4) prior to installation mechanical completion signoff. As part of that procedure, the installation contractor is to complete a pressure test report (subsection 6.4.2) and submit such to FCE project management. The senior technician in charge of performing this procedure is to obtain a copy of the pressure test report and confirm acceptable system leak tightness prior to the commencement of gas purging activities.
  - The FCE Installation Manual also requires that the utility fuel line is Certified as ready for use (Document #20321, Section 5.30, step #1.) Prior to the opening of the customer fuel valve to the fuel cell power plant, verification of this Certification needs to be established by on-site FCE personnel (contact FCE project management for Certification). In addition, it needs to be established if such certification or other verification, covers the span of piping from the customer's meter up to the point of the fuel cell skid interconnection. The form of such verification(s) will vary for each installation location, but could take the form of a signed and dated completed purge procedure from the installation contractor or utility, or, if possible with available piping connections, an on-site metered verification of the contents of the interconnection piping (preferred). Acceptable content piping contents would be either less than 2% Oxygen, or greater than 90% methane. Since the configuration of each installation is different, this procedure cannot detail the procedure for obtaining a sample of the gas interconnection piping contents, but such procedure should be consistent with all principals outlined in this procedure. ***This procedure must not be performed if the internal contents of the interconnection piping cannot be established.***
- **Buildings in the vicinity of fuel discharge point:**
  - If there are adjacent buildings of equal or greater height than the discharge vent, then wind conditions must be assessed prior to starting the procedure. If wind conditions are

moderate to significant, and the purge discharge vent is down-wind of the building, then the procedure must be postponed until the wind subsides

- Proximity of building openings to the vent stack must be determined. Under no circumstances shall the vent stack be situated less than 15 feet from a building door or window, or 25 feet from a building air intake.

- **Wind Characteristics:**
    - Generally, only wind of consistent direction of greater than 20 miles per hour directly toward a receptor of concern is a concern for this purge procedure, and then only for receptors elevated above grade.

- **Work / Personnel in Vicinity:**
    - Notwithstanding all of the above, NFPA 56 (PS) and this procedure require that an exclusion zone be established during purge operations wherein all work activities and non-participating personnel are to be excluded. To the extent possible, it is preferred that no other work activities are being conducted within the entire fuel cell power plant limits. However, if this is not practicable, a smaller but strictly enforced exclusion zone is to be established where required. It is the responsibility of the senior FCE tech performing this procedure to establish, maintain and enforce the exclusion zone throughout the duration of this procedure.

- **Minimum Exclusion Zone Limits:**
    - The established exclusion zone shall be marked off with caution tape, safety cones and/or barricades throughout the duration of the procedure. The minimum extents of the exclusion zone shall be as follows:
        - Skid 2, Fuel train side
        - Skid 1 double doors
        - Minimum 10' (15' preferred) radius around the location on the ground immediately below SP-203

- **Senior Tech Responsibility:**
    - As part of these considerations of site specific conditions, the senior FCE tech performing this procedure has both the authority and the responsibility to cancel, postpone, delay or stop the procedure at any time if such site-specific conditions are judged to present a risk of accident. Included in these site specific conditions are unfavorable wind conditions, electrical storms, nearby activities that are judged to present a hazard and others.

C. Required Communications

Before the day on which the procedure will be executed, the senior technician in charge of performing the procedure must complete the following:

- Identify and record the names and contact information for all parties which require notification of flammable gas purging activities. Table 1 (Contact Information and Notification Log) in the appendix shall be used to record this data.
- Contact the site owner and inform them of FCE's intention to conduct flammable gas purging operations.
- Determine if any work permits are required. If any work permits are required, such shall be pursued through or with the knowledge and assistance of FCE management (project manager, customer service representative or field service supervisor.)

On the day that the procedure will be executed, the senior technician shall use Table 1 (Contact Information and Notification Log) to make and record the following notifications:

- Immediately prior to the start of this procedure the site owner, affected site occupant(s), and all site contractors present shall be notified of the purging activity.
- At the completion of purging activities, all parties notified at the start of the purging activities shall be notified that the purging has been completed. A record of such notifications shall be made in Table 1, complete with time and name of person(s) notified.
- If FCE has been instructed to inform other parties in addition to site owner/occupants such pre- and completion-notifications shall also be made and recorded in Table 1.

IV. Procedure:

A. Preparation

1. FCE senior tech shall establish that site specific emergency procedures and contacts are known and validated.
2. Local site conditions shall be considered per the guidance provided in Section III.B of this procedure. Of primary and paramount concern if the acceptability of the **Inlet Customer Fuel Piping** (refer to requirements outlined in Section III B.) Other local site conditions to be considered are installation layout, vicinity work operations, wind and weather conditions and worker assignments.
3. Perform pre-job briefing. Briefing shall be conducted by senior FCE technician and shall include all on-site FCE personnel as well as representatives of all parties potentially affected by the procedure. FCE tech in charge shall communicate all emergency procedures to the briefing participants including "stand-down" instructions for both inert gas and fuel gas purging operations. MSDSs are to be

reviewed as well as the relevant gas properties tabulated in the Appendix. Each FCE employee shall have his/her calibrated gas monitor on their person.

4. Safety glasses shall be worn by all involved personnel throughout all steps of this procedure.
5. An exclusion zone is to be established per the guidance provided in Sections IIIB that may extend beyond the physical boundaries of the fuel cell plant. The zone is to be demarcated with caution tape as well as safety cones and/or barricades as required by local site conditions. No personnel other than the two assigned FCE personnel performing this procedure are to be allowed inside the exclusion zone. During the performance of this procedure there is to be absolutely no ignition sources (smoking, hot work, etc.) allowed within the exclusion zone. The senior FCE technician performing this procedure and who is in charge of monitoring the process and the surrounding area shall continuously patrol the limits of the exclusion zone to enforce this exclusion zone during the conduct of the procedure.
6. There is never to be any smoking within the DFC1500B fuel cell plant boundaries. Additional, temporary NO SMOKING signs are to be posted outside of the exclusion zone limits.
7. All exclusion zone personnel shall equip themselves with their personal gas monitor. Be sure monitor has a valid calibration. Turn on instrument and allow it to warm up. Set to oxygen scale (if required). Secure to belt.
8. Prior to the start of any on-site work, verify that all pre-job notifications and approvals as may be required have been made or obtained, as discussed in the *Required Communications* Section III C, above.
9. Verify that a fire extinguisher is available with close proximity outside the exclusion zone.
10. Verify that the power plant is shut down.
11. Verify that the fuel system is fully operational; that the system is ready for use, leak tested and fully commissioned.
12. Verify that all of the following sample valves are closed and securely capped: HV-237 (skid 2), HV-264, HV-213, HV-265, HV-253, HV-223, HV-243 (skid 2), and HV-249 (skid 2). Also confirm that the flow meter calibration valves, HV-235 and HV-236, are aligned for normal operation - closed and capped.
13. Verify that the customer fuel supply to the plant is closed (off).
14. Verify that customer fuel supply valve has no locks/tags for other than on-site FCE personnel. If not already LOTO'd by FCE on-site personnel, LOTO customer fuel supply valve now. All upstream fuel valves to system should either be open or unlocked and able to be opened.
15. Sr. field service tech shall verify LOTO by all FCE on-site personnel.
16. Locate the customer fuel supply fuel pressure gauge downstream of the customer fuel supply valve and note pressure indication. Locate PI-201 on Skid 2, check to verify that the gauge block valve (HV-201) is open, and note pressure indication. If either gauge indicates any positive pressure (greater than 0 psig), then perform the customer fuel supply valve leak test in step 17. If no pressure is indicated on either gauge, skip to step 18.

17. If a positive pressure is indicated on either the customer fuel supply pressure gauge or PI-201, leak check the customer fuel shutoff valve as follows:
    a. Remove the cap from HV-237 and install a hose line onto the HV-237 outlet. Route the discharge line to a safe location distant from working personnel.
    b. Open HV-237 and release the contained gas between the customer fuel supply shut off valve and the automatic plant shutoff valves, XV-205A/B. Monitor PI-201 and observe it drop to zero psig.
    c. When PI-201 drops to zero psig, immediately close and cap HV-237. Now, observe the customer fuel supply pressure indicator which should also indicate zero psig.
    d. Wait for 5 minutes and then again note the pressure readings on both the customer fuel supply pressure indicator and on PI-201. Both gauges should not indicate any positive pressure.
    e. If any of the observations are other than as described above, STOP procedure and contact the FCE project management associate assigned to the project.
18. Verify that the power plant control system is operational (enabled) in order to allow overriding and opening of electrically actuated valves.
19. Lockout/Tagout the following Valves: HV-252, HV-220, HV-273 and HV-285.
20. Senior field service technician shall verify proper valve LOTOs for previous step.
21. Close or verify closed HV-260 and HV-261.
22. Reposition, or verify correctly positioned HV-256 and HV-257 such that vessel flow arrangement is vessel A is lead vessel and vessel B is lag (second) vessel. Refer to the valve position indicators. Both indicators should indicate flow paths in the shape of a normal capital 'L'.
23. Senior tech shall verify correct positioning of valves HV-260, HV-261, HV-256 and HV-257.
24. Close or verify closed HV-213, HV-253, HV-264, HV-265 and HV-239.
25. Remove cap from HV-223 and open to release any contained pressure. When discharge flow has stopped (if any), close valve and replace cap.
26. Verify HV-201 on PI-201 (skid 2) is open.
27. Open HV-240.
28. Insert a sample hose line of sufficient length several feet into the desulfurizer vessel vent discharge opening and then run the line all the way down to the ground so that the line can be connected to the portable gas analyzer instrument (with 0-40% oxygen concentration measurement capabilities – ***NOT*** your personal gas monitor) and can still be placed onto the ground. ***(NOTE: the expanded metal screen over the vent discharge scarf cut will require that a short length of some ¼" O.D hose be used to insert through the screen opening. Insert 2' of hose into vent pipe end.)*** Secure the hose to the vent stack using tie wraps in a manner such that the hose will not fall out of the vent stack

and that the hose is not kinked or pinched closed. Instrument should be turned on and allowed to warm up per manufacturer's instructions.

29. Connect the N2 purge kit to the nitrogen source. Be sure the regulator adjustment is backed all the way out.
30. Remove the cap from HV-237. Connect the N2 purge kit hose end to HV-237.
31. Sr. Tech shall confirm that correct sample valve (HV-237) is being used to introduce nitrogen into the desulfurizers.
32. Open the N2 supply isolation valve. Adjust the N2 regulator to 12 psi.

B. Nitrogen flow and pressure purging of Desulfurizer Vessels

Note: *When using nitrogen, the "watch" level shall be any breathing area ambient concentration of oxygen that falls to below 20%. At the onset of a "watch" condition, the senior FCE tech shall inform all affected parties in the vicinity while continuing to carefully monitor for further depleted oxygen levels.*

A "stand down" order shall be made if ambient concentration of oxygen reach 19.5% or lower.

> **NOTE:** ***For a "stand down" order, depress any one of the MBOP E-stop buttons in the process of exiting the affected area. Be aware that should a worked actually go down when performing nitrogen purging, that under NO CIRCUMSTANCES should another worker go to their assistance. The correct, best and safest action for BOTH parties is to stop the flow of nitrogen.***

33. On the HMI Screen, force open XV-205A and XV-205B.
34. Verify again that HV-240 is open.
35. Open HV-237 to allow nitrogen to flow through both desulfurizers in series and then out HV-240. Flow noise should be apparent as nitrogen enters the vessels.
36. Do not readjust nitrogen purge kit regulator under flowing conditions – it may read less than 12 psig.
37. Monitor the gas analyzer instrument for oxygen concentration at the desulfurizer vent stack discharge location. Continue to flow nitrogen until the gas analyzer measured reading is less than 2% oxygen.
38. When <2% oxygen has been achieved, close HV-240 and allow the nitrogen pressure in the desulfurizer vessels to stabilize at 12 psig, as can be observed at PI-201 on skid 2.
39. If any valve realignment is required other than what is specifically described in this procedure (e.g. HV-239 needed to be closed) in order to develop the specified pressure in the vessels, then repeat the nitrogen flow purge (steps 35 – 39).

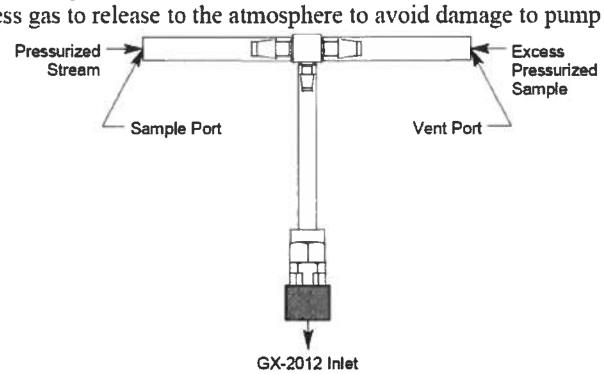
40. Allow pressure to remain in vessel for 2 minutes, then open HV-240 to bleed off pressure to zero psig (or to minimum pressure achievable.)
41. Repeat pressurization – hold – depressurization process 2 more times. (NOTE: if any delay is encountered [e.g., lunch break, off-site call, etc.] during these pressure purge steps (38 – 41), then a repeat of the flow purge, including gas composition end point determination [steps 35 - 37], followed by the pressure purges [steps 38 – 41]).
42. Close HV-240, then close HV-237. Sr. Tech is to confirm both valves are closed.
43. Remove cap on HV-223, open briefly to test for any accumulated pressure and then reclose valve and replace cap. Release of gas due to accumulated pressure means that either or both HV-260 and/or HV-261 are positioned incorrectly and that steps 21 – 44 must be repeated.
44. Desulfurizer vessels are now nitrogen purged.
45. Remove gas analyzer sampling hose from desulfurizer vessel vent stack discharge location.

C. Nitrogen purge of air heater and DFC fuel train fuel lines

46. Install a sampling purge tee fitting on the discharge from HV-277. A purge tee prevents the overpressurization of the gas analyzer equipment and is required to prevent damage to the instrument. A depiction of a purge tee fitting, obtained from the instrument operator's manual, is provided below. When using the purge tee fitting, it is important that the discharge line out of the fitting is of sufficient inside diameter to prevent excessive pressure build up in the fitting.

Purge Tee Fitting

The 17-4430RK-01 purge fitting is used to detect gas levels in a pressurized gas stream from a pipeline or vessel being purged. The sample port of the purge fitting is inserted into the flowing gas. and the vent port will allow any excess gas to release to the atmosphere to avoid damage to pump or sensors.



47. Run a tubing line from the discharge side of the sampling purge tee fitting up to a safe location. The discharge line MUST be larger than the sample line to the instrument in order to prevent overpressurization of the instrument due to backpressure in the discharge line. Acceptable locations to

run the discharge hose line are either up to the desulfurizer vent stack discharge location or to the normal air heater fuel line vent discharge point (the HV-276/277 discharge point). The hose length should be sufficiently long such that after the purge tee fitting is disconnected from HV-277, the fitting can be relocated to HV-243 without having to relocate the discharge end of the hose. Affix the discharge hose securely to prevent it from dropping. Connect the instrument to the purge tee fitting. Instrument should be operational and set to analyze percent O2.

48. All operators must still have personal gas monitors on person.
49. Open HV-261.
50. Open HV-280.
51. Open HV-276.
52. Open HV-237 allowing nitrogen to again flow into the desulfurizers.
53. Open and hold open HV-277. Flow should now exit through the valve and sampling flow tee. Note: keep distance from gas discharge, as nitrogen gas is a simple asphyxiant that displaces air and therefore reduces oxygen concentration where it is present. Pay attention to your personal gas monitor and heed any alarms for deficient oxygen (< 19.5%).
54. Monitor the gas analyzer instrument for oxygen concentration at the HV-277 discharge location. Continue to flow nitrogen until the gas analyzer measured reading is less than 2% oxygen. (Note: Based on a nitrogen dewar gas production capacity of 400 scfh, the purge nitrogen purge should not take more than a minute or two.)
55. When <2% oxygen has been achieved, allow HV-277 to spring close and then close HV-276.
56. Close HV-237.
57. Remove the purge tee from HV-277 discharge. Remove cap from HV-243 and relocate the purge tee fitting to HV-243. (Note: the discharge tubing running from the purge tee fitting should still be routed to the safe location, as described in step 48.)
58. Open HV-243.
59. Open HV-237. Flow should now exit through the valve and the sampling purge tee fitting.
60. Monitor the gas analyzer instrument for oxygen concentration at the HV-243 discharge location. Continue to flow nitrogen until the gas analyzer measured reading is less than 2% oxygen. (Note: Based on a nitrogen dewar gas production capacity of 400 scfh, the purge nitrogen purge should not take more than a minute or two.)
61. When <2% oxygen has been achieved, close HV-243. Remove purge tee fitting.
62. Allow desulfurizer vessels to pressurize to at least 5 psi or more.
63. Close HV-237.
64. Shut off nitrogen supply valve.

65. Back out nitrogen regulator to drop nitrogen pressure.
66. To remove nitrogen purge kit hose connection from HV-237, first loosen and wiggle connection on valve while paying attention for evidence of leakage, so as to ensure that HV-237 has been closed tightly. Remove hose and replace cap on HV-237.
67. On the HMI remove forces on XV-205A and XV-205B (unless immediately proceeding to fuel purge of desulfurizer vessels.)
68. Nitrogen purging is complete.

D. Fuel flow and pressure purge of desulfurizer vessels

69. Prepare for desulfurizer vessels to be purged with fuel as follows:
    a. All techs are to equip themselves with their personal LEL monitor. Secure to belt. Turn on instrument and allow it to warm up. Set to LEL scale (if req'd.)
    b. If this fuel purge step is not immediately following the previous nitrogen purge step by the same personnel, then the absence of oxygen in the desulfurizer vessels must be established by measurement using the calibrated gas analyzer (< 2% oxygen) before proceeding. If the contents inside desulfurizers cannot be established to be <2% O2, then the previous outlined nitrogen purge must be re-performed.

       EXCEPTION: If the duration of the procedure lapse is short (coffee or lunch break) and the site has been secure (workers not present and fuel valve remains LOTO), then the presence of 5 psi on PI-201 can be used as evidence of sufficient air purge with nitrogen.
    c. Insert a sample hose line of sufficient length several feet into the desulfurizer vessel vent discharge opening and then run the line all the way down to the ground so that the line can be connected to the portable gas analyzer instrument (with 0-100% methane concentration measurement capabilities – ***NOT*** your personal gas monitor) and can still be placed onto the ground. ***(NOTE: the expanded metal screen over the vent discharge scarf cut will require that a short length of some ¼" O.D hose be used to insert through the screen opening. Insert 2' of hose into vent pipe end.)*** Secure the hose to the vent stack using tie wraps in a manner such that the hose will not fall out of the vent stack and that the hose is not kinked or pinched closed. Instrument should be turned on and allowed to warm up per manufacturer's instructions.
    d. IMPORTANT: When performing the fuel purge with the gas analyzer sampling from the desulfurizer vent stack, do not allow the instrument to analyze using the 0-100% LEL scale. 100% LEL represents only 5% methane in air and the sensor will be overwhelmed and damaged if it is allowed to analyze LEL when sampling essentially pure fuel gas in an oxygen deficient atmosphere. Use 0-100% methane scale. Refer to instrument operation manual.
    e. Close HV-261. Verify HV-260 is closed.
    f. Verify closed HV-213, HV-253, HV-264, HV-265, HV-239 and HV-240.

TECHNICAL SERVICE BULLETIN

Pre-Start Up Fuel System Fill

g. On the HMI force open or verify open XV-205A and XV-205B.

70. During the fuel gas purging operations that follow, it is the responsibility of the senior FCE field service tech to monitor the area for the (unlikely) possible presence of flammable concentrations of fuel gas. This is to be done using the tech's personal gas monitor. This monitoring is to be accomplished by "roaming" the area(s) that would be most likely to have an elevated fuel gas concentration. During such monitoring activities, a "watch" order shall be issued for a measured concentration greater than 25% LEL, and a "STAND DOWN" order shall immediately be ordered for any measured concentration of 50% LEL or greater.

    NOTE: In the case of a STAND DOWN order, any MBOP E-Stop button should immediately be activated stopping fuel gas flow into the desulfurizers and downstream piping as all personnel are evaluated from the area.

71. Double check again that the gas analyzer being used for purge end point determination (not the personal gas meters) is properly set to the 0-100% methane scale and the LEL scale is off.
72. Slowly crack open, then fully open the customer gas supply valve.
73. Read and note pressure on PI-201. Pressure should read in the vicinity of 12.5 pisg, and NOT above 14.5 psig.
74. Close customer gas supply valve and immediately again view PI-201. Pressure should hold steady at previous reading.
75. Wait at least 1 minute (this it to assure that if vessel pressure relief valves were opened as a result of the rapid in rushing of fuel, that they have an opportunity to reseat.)
76. Open customer gas supply valve again. Pressure at PI-201 should not change. If pressure readings at PI-201 do not behave as described above, contact process engineering.
77. Open HV-240 to begin fuel purging of vessels.
78. Monitor the gas analyzer instrument for methane concentration at the desulfurizer vent stack discharge location. Continue to flow fuel until the gas analyzer measured reading is greater than 90% methane.
79. Close HV-240 and allow the fuel pressure in the desulfurizer vessels to stabilize at PCV-201 set pressure. Observe set pressure at PI-201 on skid 2.
80. Either close customer fuel supply valve or move HV-256 to the neutral position to shut off fuel to the desulfurizers.
81. Allow pressure to remain in vessel for 2 minutes, then open HV-240 to bleed off pressure.
82. Close HV-240.
83. Repeat pressurization – hold – depressurization process 2 more times.
84. Close HV-240 a final time.

85. Open fuel to vessels (customer fuel valve and HV-256 aligned to direct fuel to vessel A) to allow vessels to pressurize up to set pressure.
86. Observe pressure on PI-201. Pressure should be approximately 12.5 psig.
87. Desulfurizer vessels are now fuel purged.
88. Remove gas analyzer sampling hose from desulfurizer vessel vent stack discharge location.

E. Fuel purge of air heater and DFC fuel train fuel lines

89. Install a sampling purge tee fitting on the discharge of HV-277. A purge tee fitting prevents the overpressurization of the gas analyzer equipment and is required to prevent damage to the instrument.
90. Run a tubing line from the discharge side of the sampling purge tee fitting up to a safe location. The discharge line MUST be larger than the sample line to the instrument in order to prevent overpressurization of the instrument due to backpressure in the discharge line. Acceptable locations to run the discharge hose line are either up to the desulfurizer vent stack discharge location or to the normal air heater fuel line vent discharge point (the HV-276/277 discharge point). The hose length should be sufficiently long such that after the purge tee fitting is disconnected from HV-277, the fitting can be relocated to HV-243 without having to relocate the discharge end of the hose. Affix the discharge hose securely to prevent it from dropping. Connect the instrument to the purge tee fitting. Instrument should be operational and set to analyze 0-100% methane (not LEL).
91. Open HV-261.
92. Open HV-280.
93. Open HV-276.
94. Open and hold open HV-277. Flow should now exit through the valve and sampling flow tee.
95. Monitor the gas analyzer instrument for fuel concentration at the HV-277 discharge location. Continue to flow fuel until the gas analyzer measured reading is greater than 90% methane.
96. Allow HV-277 to spring close and close HV-276.
97. Remove the purge tee fitting from HV-277 discharge. Replace any removed piping at HV-277.
98. Remove cap from HV-243 and relocate the purge tee to HV-243.
99. Open HV-243. Flow should now exit through the valve and sampling purge tee.
100. Monitor the gas analyzer instrument for methane concentration at the HV-243 discharge location. Continue to flow fuel until the gas analyzer measured reading is greater than 90% methane.
101. Close HV-243.
102. Remove purge tee fitting.
103. Replace cap on HV-243.

104. On the HMI remove forces on XV-205A and XV-205B.
105. Shut off customer fuel supply valve and LOTO.
106. Fuel purging is complete.
107. Perform a final walkdown of the entire fuel train to verify that all sample valves have been closed and that their caps have been securely installed. Such valves include:
    - HV-237
    - HV-264
    - HV-213
    - HV-265
    - HV-253
    - HV-223
    - HV243
    - HV-249
    - HV-235 (2" valve on skid 2, with pipe cap)
    - HV-236 (2" valve on skid 2, with pipe cap)
108. Double check the position indicators on XV-205A and XV-205B to verify the valves are closed.
109. Remove LO/TO on valves HV-252, HV-220 and HV-273.
110. Remove all tools and equipment and clean area as required.

Appendix:

NFPA 56 (PS) Purge Procedure Required Considerations Matrix

NFPA 56 (PS) Section 4.3.1 Procedure Item for Consideration	Location where addressed
(1) Scope of work and site-specific purge procedure development	
(a) Cleaning and Purging Method	Procedure Sections A, B, C, and D. All steps.
(b) Piping & Instrument Diagrams (P&IDs)	Cited as required reference document at beginning of procedure.
(c) Chemical & Physical Properties of flammable gas, purge media, and discharge gas	A description of the relevant properties of both natural gas fuel and nitrogen inert purge gas is provided in the Appendix. MSDSs references are cited as required r
(d) Determination of purge end point introducing flammable gas, inert gas, or air	Purge into service end points have been determined for both inert and fuel gas and are provided in Procedure steps 27, 29, 43, 60, 63, 75 and 79.
(e) Assessment and control of purge inlet and discharge locations	Purge inlet points for both inert and fuel gas are standardized for this product and are provided in Procedure steps 21 and 58.
(f) Temporary piping system design	Secured vent hose from small diameter sample valves to a specific safe location is specified
(g) Personnel protective equipment (PPE)	Safety glasses, personal gas monitor. Both are cited in PPE section at front of this procedure and in specific steps of the procedure.
(h) Training and qualifications	Specified in Section II, *Training Requirements*
(i) Management review and approval	Specified in Section VII, *Management Approval*
(j) Restoration of Service	Not applicable. This is a purge into service procedure.
(k) Target design, launcher / receiver venting review for pigging operations	This topic is not applicable. No cleaning pigs are used in this procedure.
(l) Regulatory permits	No regulatory permits are known to be required by this procedure.
(m) Written stand-down instructions to stop activity in a controller manner	Discussed in Section III, Pre-Procedure Briefing.
(n) Hazards	Hazards are discussed throughout procedure, in MSDSs in Appendices as well as in Purge Gas

	Relevant Properties outline in the Appendices.
(2) Environmental conditions and work locations	
(a) Establishment and clear identification of exclusion zones where flammable gas-air mixtures are likely to exist	Sections III and IV.
(b) Limited access for personnel not directly involved with purge operations	Section IV.
(c) Assessment of potential for gas migration (building openings, adjacent structures)	Section IV.
(d) Prohibition of hot work within exclusion zones	Section III.
(e) Lockout / tagout	Procedure Steps 14 and 87.
(f) Impact of environmental conditions (wind speed and direction, temperature, barometric pressure) on purge operation	Section IV.
(g) Vehicular and air traffic, if applicable	Section IV. (Air traffic is N/A).
(h) Topography	Section IV.
(i) Noise control / monitoring	Gas discharges from this process are through a maximum 1" diameter valve into a 3" diameter vent header. Noise levels are not anticipated to be problematic and duration of purging activities is relatively short.
(3) Communication plans	
(a) Pre-job briefing	Procedure step 3 and Required Communications Section, V
(b) Work permits	
(c) Roles and responsibilities	
(d) Emergency response plan	
(e) Facility alarm, alert and warning systems	
(f) General facility notification prior to start of purge operations	
(g) General facility notification at the conclusion of purge operations	
(h) Notification of regulatory authorities as required (local emergency responders, utility operators, community officials, environmental authorities, etc.)	
(4) Control of ignition sources	
(a) Bonding and grounding considerations	All equipment is bonded and grounded per code.

(b) No smoking or spark-producing work within exclusion zones	Section III and IV.
(c) Elimination of hot work within exclusion zone	Sections III and IV.
(d) Static electricity ignition sources at discharge point	Discharge point is a high point and the flammable gas is a lighter-than air gas; personnel are not in the immediate vicinity of the flammable gas discharge; vent pipe is grounded and further protected with metallic screen.
(5) Pre-purge piping system assessment	
(a) Assessment of piping system for trapped liquids, pyrophoric solids, and other flammable or combustible deposits within the piping system	Done previously as part of installation and commissioning.
(b) Ensuring that the piping system is properly isolated	Procedure provides clear, detailed valve lineup.
(c) Limiting site conditions that impact the safety of the activity	Other plant specific operations that could impact safety of activity are not enabled. Non-plant specific activities are limited by administrative control (exclusion zone.)
(6) Purge monitoring and instrumentation	
(a) Ensuring that monitoring instruments are appropriate for gas being purged	Specified in equipment list.
(b) Training	Section II.
(c) Calibration	Equipment list at beginning of Procedure.
(d) Monitoring frequency and reporting	Section III and Procedure step 58.
(e) Appropriate selection of sample point(s)	Procedure steps 20, 36, 57 and 71.
(f) General atmosphere checks in vicinity of purge gas release	Section III and Procedure step 58.

TECHNICAL SERVICE BULLETIN

Pre-Start Up Fuel System Fill

Relevant Properties of Purge Gases

Property \ Purge Gas	Nitrogen Gas	Natural Gas
State at Standard Temperature and Pressure (STP)	Gas	Gas
Density (Specific Gravity) at STP	Very near air (SG ~ 1.0)	Significantly lighter-than-air (0.6)
Flammability Characteristic	Non-flammable	Extremely Flammable
Detection	Cannot be detected by senses. Odorless, colorless. Monitor oxygen concentration to avoid potentially hazardous atmosphere.	Colorless, odorless gas. Pipeline supplies are odorized to smell like rotten eggs, however, odor cannot be relied on for detection in purging operations. Gas may be "deodorized" by industrial equipment and olfactory function can easily be overwhelmed and desensitized.
Flammability Range	Not Applicable	4.5% - 15% in air
Stability / Reactivity	Stable	Stable, mixes w/ air to form flammable atmosphere
Health Hazards	Simple asphyxiant – displaces oxygen	Simple asphyxiant – displaces oxygen
Physical Hazards	Pressurized gas	Pressurized gas. Explosive if mixed with air and ignited.
Composition	100% nitrogen	> 93% methane (CH_4)

TECHNICAL SERVICE BULLETIN

Pre-Start Up Fuel System Fill

Table 1

Contact Information & Notification Log

Site Name:______________________________

Date:____________

FCE employee making notifications:______________________________________

Affected Party	Party Name (list)	**Verified** Phone Number (enter no.)	Pre-Notification Time/Person	Completion-Notification Time/Person
Site Owner				
Site Occupant 1				
Site Occupant 2				
Site Contractor 1				
Site Contractor 2				
Gas Utility				
Local Fire Dept.				
Local Ambulance				

Minimum Required Notifications: Site Owner, affected site occupants & all contractors present.

Shaded cell: Notification normally not required, unless if directed by AHJ or permit

Drury, Dan

Subject: FW: HHFC Natural Gas Cleaning & Purging
Attachments: TSB-1500B5-079_R1.doc

From: Warren, Aaron [mailto:AWarren@fce.com]
Sent: Tuesday, February 11, 2014 12:18 PM
To: Drury, Dan; Why, Andy; Zeman, Gerry
Subject: FW: HHFC Natural Gas Cleaning & Purging

FYI

Aaron Warren | Project Manager
Direct: 203.205.2054 Cell: (917) 209-3715 | AWarren@fce.com

FuelCell Energy, Inc. | 3 Great Pasture Rd | Danbury, CT 06810
www.fuelcellenergy.com

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

From: Benedict, Mark
Sent: Tuesday, February 11, 2014 9:54 AM
To: Warren, Aaron
Cc: Brown, Benjamin; Ibanez, Stephen; Hoffman, Valerie
Subject: RE: HHFC Natural Gas Cleaning & Purging

Aaron,

I revised the document to incorporate comments 3, 4 and 8 below.

Regarding comment number 1, FCE offers the following guidance.

The 35' radius exclusion zone recommendation is a severely conservative separation distance, especially at grade level, that can be relaxed using engineering judgment for site specific conditions. This is supported by the following facts:

- The hazardous area classification demarcation for the SP-203 pressure safety vent pipe is an 11' radius about SP-203and discharges at 18 feet above grade. The basis for that radius is the maximum possible flow through the 2" x 3" pressure safety valve due to an upstream regulator full-open failure during operation. Far less gas flow is possible through the smaller HV-239/HV-240 maintenance valves that are further restricted by a downstream flow orifice.
- The pre-startup fuel system fill will result in only limited releases of gases from SP-203, which is 18' above grade. The gases released from SP-203 are either inert or lighter than air and will have a strong buoyant force on them causing them to rapidly rise and disperse in the atmosphere. Gas accumulation at outdoor installations at grade level is not plausible.
- Although FCE does not feel it necessary to have the street closed down, for a still very conservative execution of the procedure, it may be decided that it would be appropriate to barricade the sidewalk for those durations of the procedure that involve any discharge out of SP-203.

Mark Benedict, P.E. | Principal Engineer
Direct: 203.830.7429 | mbenedict@fce.com

FuelCell Energy, Inc. | 3 Great Pasture Rd | Danbury, CT 06810
www.fuelcellenergy.com

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

From: Drury, Dan [mailto:ddrury@dcoenergy.com]
Sent: Thursday, February 06, 2014 11:31 AM
To: Warren, Aaron
Cc: Why, Andy; Zeman, Gerry; Ventre, Joe; Larkin, Andrew; Domenic, Dan
Subject: FW: HHFC Natural Gas Cleaning & Purging

Aaron,
We have submitted the Technical Service Bulletin TSB-1500B5-079 Rev. 1 that you sent us in response to our RFI #009 to our Engineer or Record, and have received the attached response. In order to clarify the comments and our expected course of action, please see the below list:

1. Page 5, Prohibition of Hot Work – FCE, please address the 35' exclusion zone requirement as it pertains to the site-specific conditions. On the north side of the site, 35' from SP-203 lands into an active roadway and crosses a public sidewalk. FCE needs to determine if this requirement will be met or waived at this location.
2. Page 7, Minimum Exclusion Zone Limits – The temporary site fencing, as well as the exclusionary zone referenced above will satisfy this requirement. I reviewed this with the Engineer, no revision to the submission is necessary.
3. Page 9, Step 12 – FCE, please confirm that HV-235 & HV-236 should be included with this section, and add a notation as such.
4. Page 9, Step 16 – FCE, please correct typo identified
5. Page 10, Step 19 – No comment necessary, please disregard question mark.
6. Page 10, Step 24 – No comment necessary, please disregard notation.
7. Page 11, Step 36 – No comment necessary, please disregard question mark.
8. Page 17, Step 107 – Please update this list to include HV-235 & HV-236.

As discussed with you, we are asking FCE to mark up and resubmit this document so that our EOR can approve without exceptions and we can then include this with our submission to the CT Siting Council. Hand-written notes or accompanying clarifications will be fine, we are not looking for a revision to the Technical Bulletin from FCE at this time. We appreciate your attention to turning this around quickly so we can provide the required notice to the Council and maintain our project schedule.

If you have any questions please feel free to contact me.

Thanks

Daniel J. Drury, P.E. - Project Engineer
DCO Energy, LLC
100 Lenox Drive
Suite 100

Lawrenceville, NJ 08648
Tel. 609-896-3111 | Direct. 609-512-2280 | Fax. 609-882-4129
ddrury@dcoenergy.com | www.dcoenergy.com

From: Hiller, Brittany
Sent: Thursday, February 06, 2014 9:07 AM
To: Drury, Dan
Cc: Why, Andy; Zeman, Gerry; Larkin, Andrew; Ventre, Joe; Domenic, Dan
Subject: RE: HHFC Natural Gas Cleaning & Purging

Please see attached submittal review for FCE-004. Status is MCN.

Thanks,

Brittany Hiller
Project Document Control
DCO Energy
5429 Harding Highway
Bldg. 500
Mays Landing, NJ 08330
Phone: 609-837-8024
Fax: 609-837-8030
bhiller@dcoenergy.com | www.dcoenergy.com

DCO Energy

Hartford Hospital Fuel Cell Project

Petition No. 1067

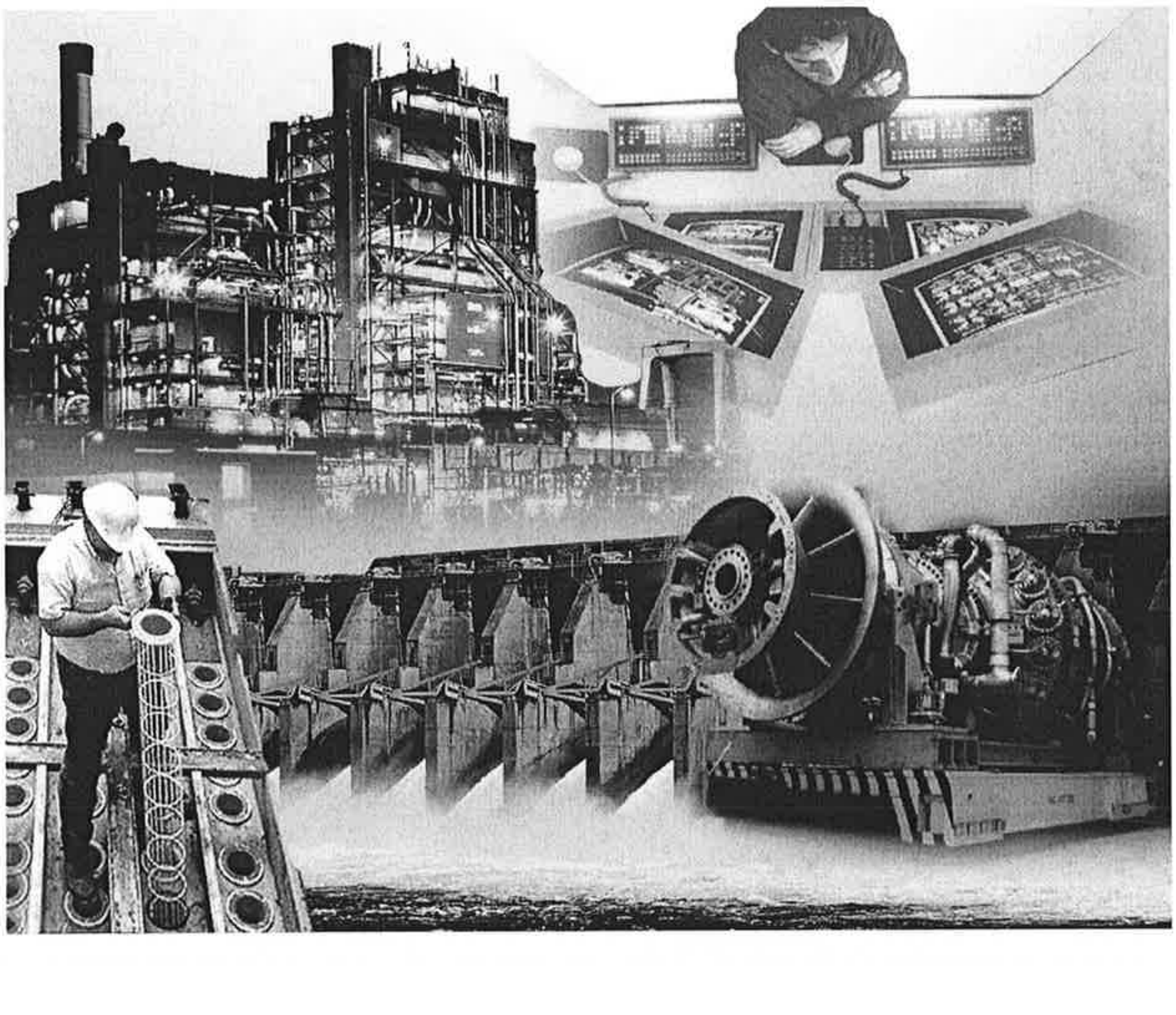
EPRI

Guidelines for Fuel Gas Cleaning using Compressed Air or Nitrogen

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

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

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:

CEC Combustion Safety Inc.
11699 Brookpark Road
Cleveland, OH 44130

Principal Investigator
J. Puskar, P.E.

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

CONTENTS

LIST OF FIGURES

LIST OF TABLES

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.

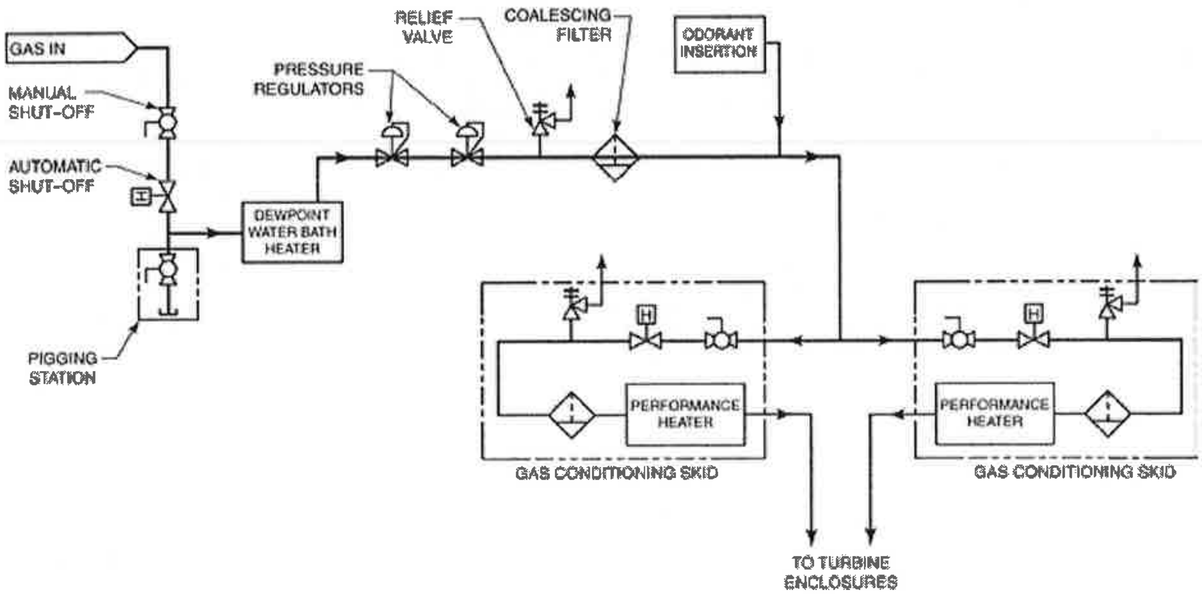


Figure 2-1
Typical Schematic Arrangement of Gas Yard and Fuel Conditioning

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.

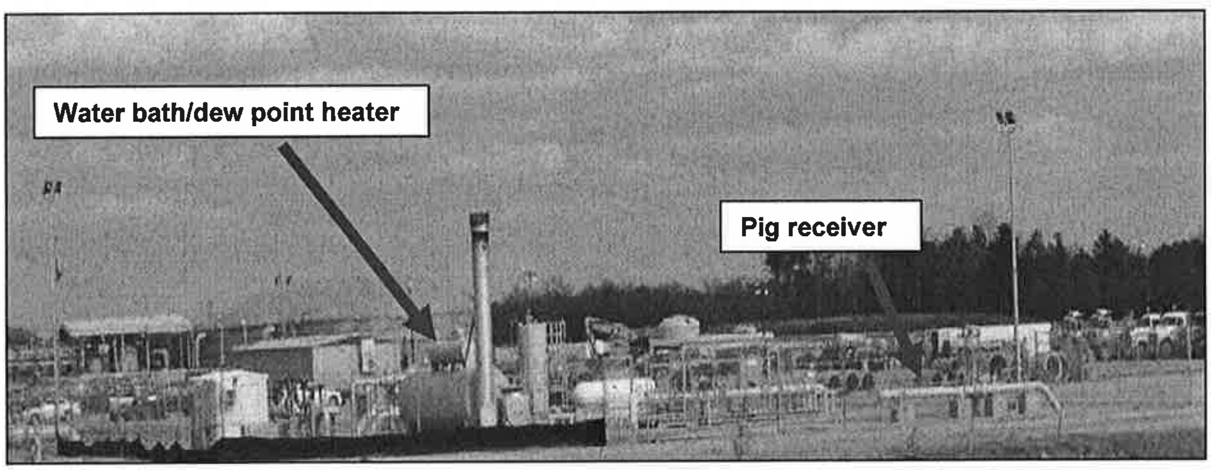


Figure 2-2
Typical Gas Yard for a Combustion Turbine Facility

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.

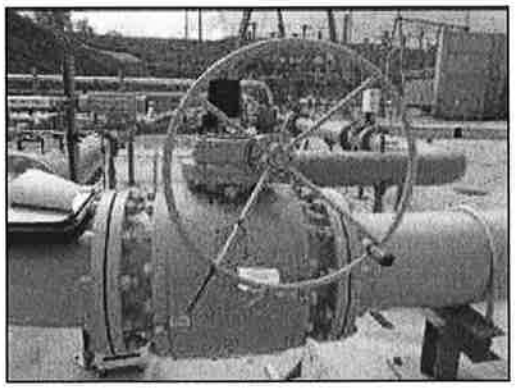


Figure 2-3
Trunion Mounted Style Ball Valve with Gear Wheel Operator and Position Indicator

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.

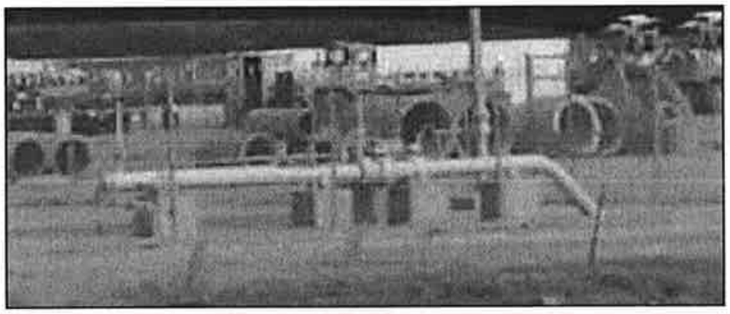


Figure 2-4
Gas Yard Pigging Station Receiver/Launcher

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,

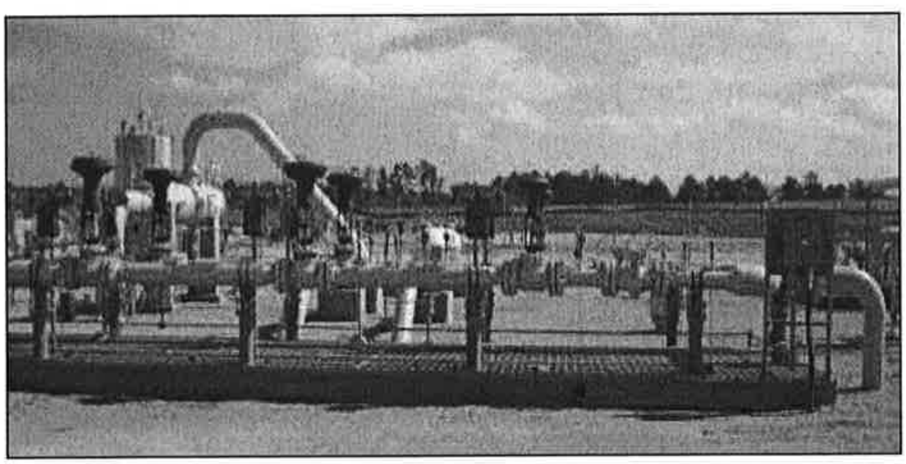


Figure 2-5
Typical Gas Yard Pressure Regulators

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).

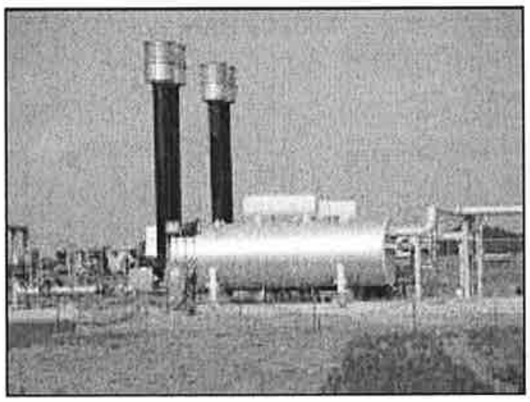


Figure 2-6
Typical Dew Point/Water Bath Heaters

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.

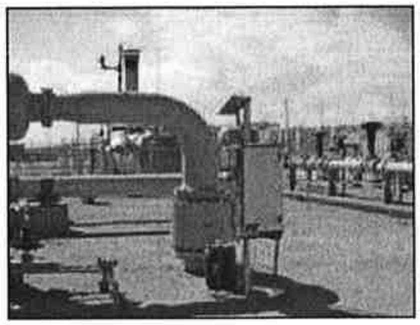


Figure 2-7
Gas Odorization System

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.

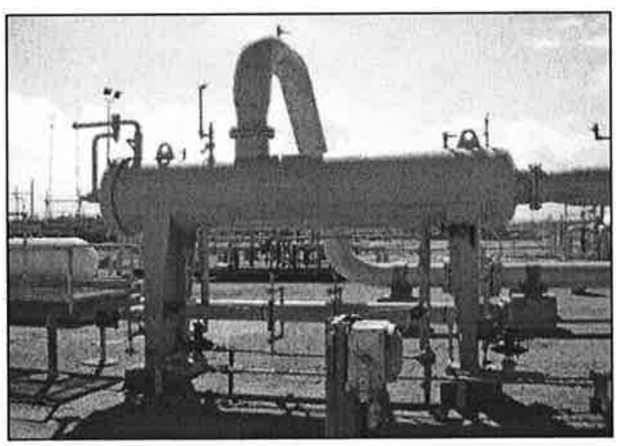


Figure 2-8
Coalescing Filter Installation

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.

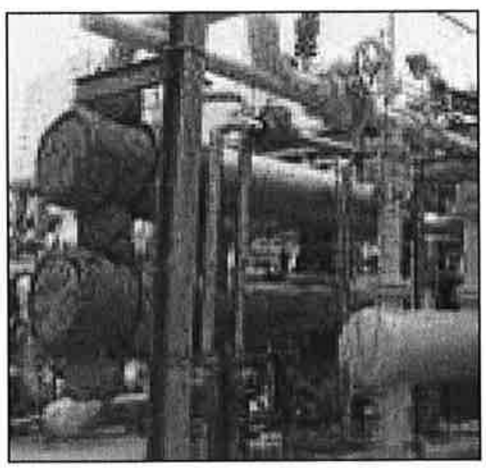


Figure 2-9
Typical Shell and Tube Heater for Heating Natural Gas to Meet Turbine Performance Requirements

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.

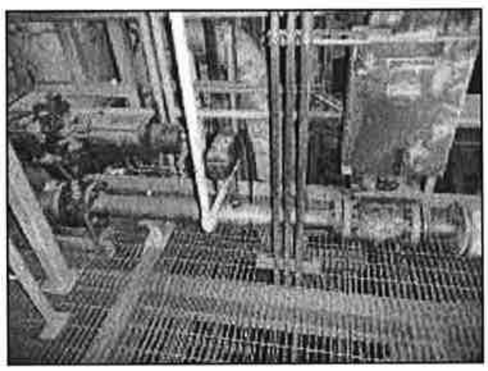


Figure 2-10
Fuel Train Inside Turbine Enclosure

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.

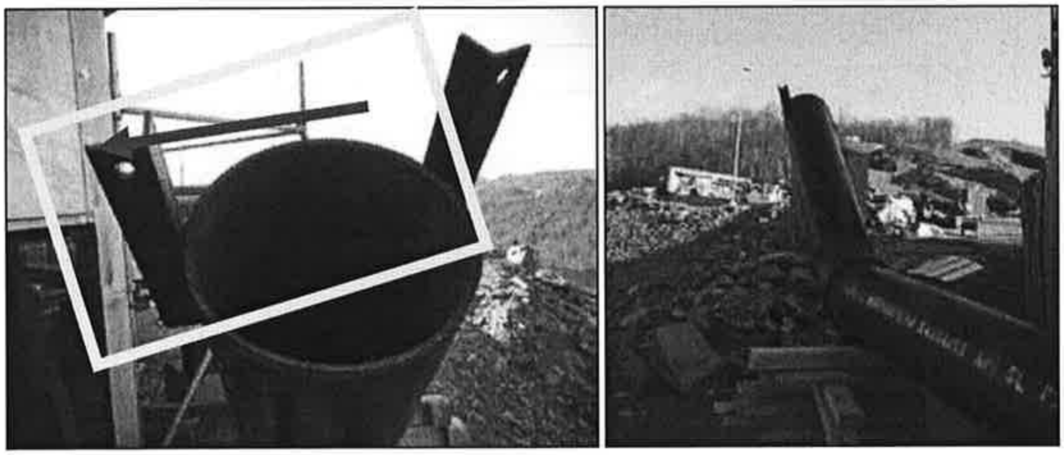


Figure 5-1
Temporary Piping for Pipe Pneumatic Blow Cleaning Discharge with Target Mounting Bracket and Outline of Where a Target Would Be Mounted

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:

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

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:

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

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

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

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

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

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

Finding the Denominator

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

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

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

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

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

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

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

What to Solve For?

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

Solving for Mass Flow for Known CFR

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

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

Assumptions for the starting compressed air conditions:

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

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

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

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

The equation then becomes

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

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

M(Blow) = 21.3 lbm/sec

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

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

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

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

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

M(Blow) = 19.4 lbm/sec

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

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

The equation then becomes

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

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

M(Blow) = 19.8 lbm/sec

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

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

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

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

8
COMPRESSED AIR SUPPLY EQUIPMENT CONSIDERATIONS

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

Selection Considerations for Compressors

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

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

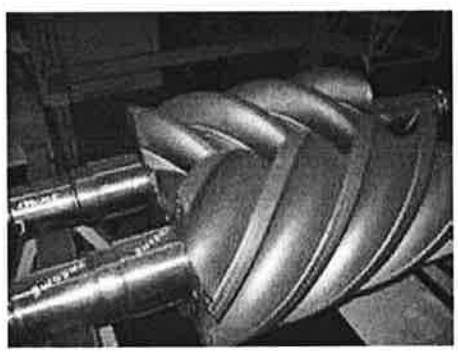


Figure 8-1
Rotary Screws Used in Air Compressor System

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

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

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

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

Photo courtesy of Atlas Copco

Capacity Considerations, (Pressure and Flow Ratings)

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

Pressure Capabilities

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

Energy Sources and Site Preparation

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

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

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

Flow Capacity

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

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

Storage Capacity of System Considerations

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

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

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

Air Compressor Ancillary Items

Dryers (Refrigerated and Desiccant) & After-Coolers

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

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

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

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

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

Receivers

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

Relief Valves

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

Temporary Air Compressor Installation/Operation Considerations

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

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

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

9

COMPRESSED NITROGEN EQUIPMENT CONSIDERATIONS

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

Nitrogen Source Considerations

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

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

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

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

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

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

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

Pumper Truck Gas Discharge Capacity

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

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

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

Figure 9-1
Nitrogen Pumper Truck

Photo courtesy CETCO Oilfield Services.

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

10

OTHER CLEANING PROCESSES: FLUSHING & PIGGING

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

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

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

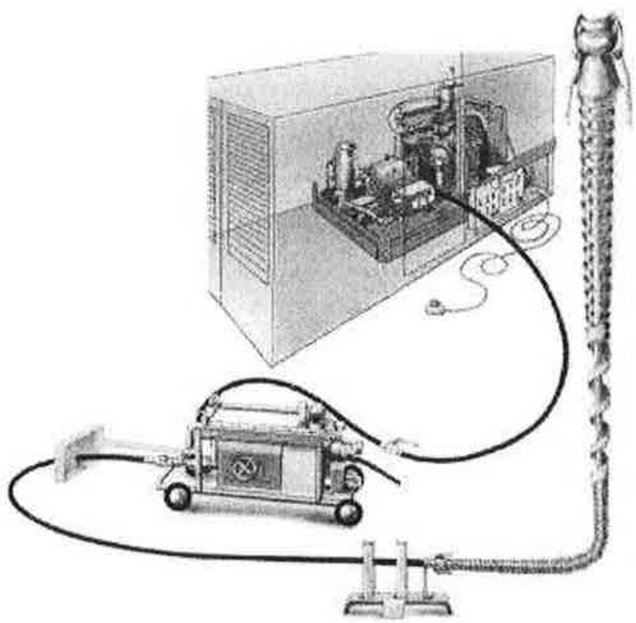


Figure 10-1
Smaller Equipment Layout for Water Jetting

Photo courtesy of Hydromilling Group

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

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

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

Pigging

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

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

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

Pig Types and Cleaning Applicability

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

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

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

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

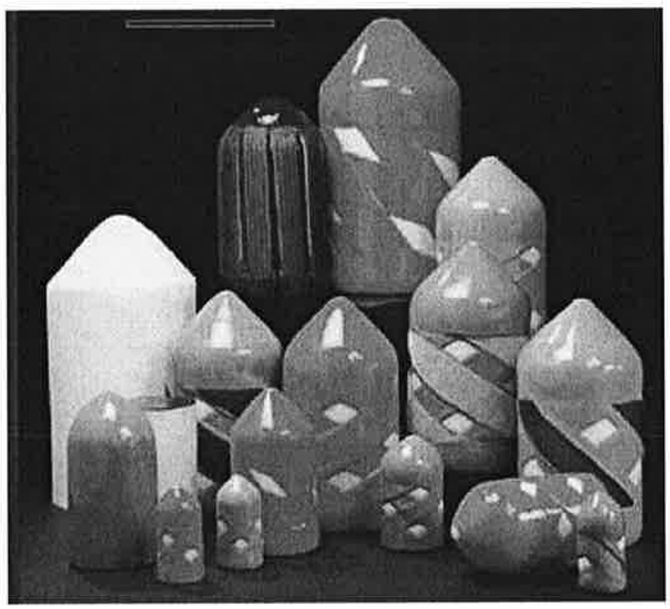


Figure 10-2
Pipeline Foam Pigs Used for Cleaning and Water Removal

Photo courtesy of Pipeline Pigging Products Inc.

A
APPENDICES

Sample Clean Construction and Pneumatic Cleaning Processes Specifications

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

1.0 General

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

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

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

2.0 Safety Plan

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

3.0 Preservation of Systems

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

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

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

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

5.0 Cleaning Methods

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

5.1.1 Pig Cleaning

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

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

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

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

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

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

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

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

Pig Operational Guidelines

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

5.1.2 Pneumatic Blowing (Air or Nitrogen)

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

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

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

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

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

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

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

a. Blow valve initiation

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

b. Packing fracture initiation

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

6.0 Pipe Pneumatic Blow Cleaning Guidelines

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

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

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

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

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

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

6.1.3 Hydro Water Jet Cleaning

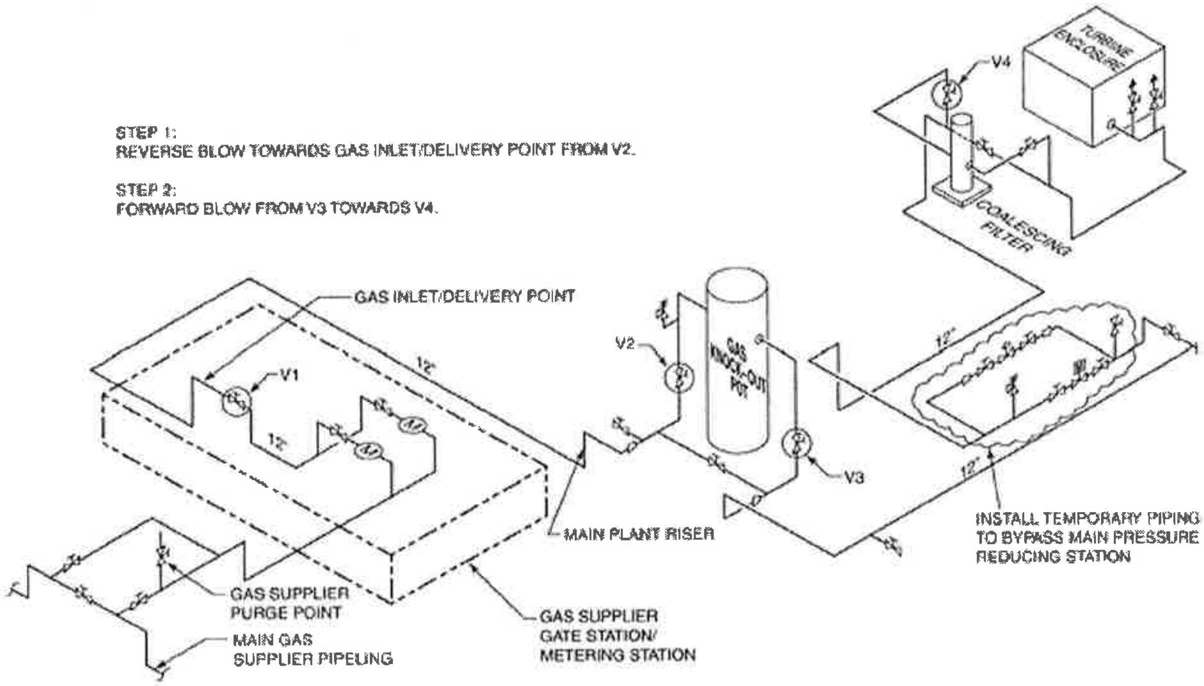
Contractor shall provide a detailed plan that includes strategic section of piping systems and locations of pump system and cleaning hose routes. Contractor to identify proposed cleaning pressures and nozzle sizes for each section. Contractor shall also identify collection and treatment of residual water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

7.0 Evaluation of Pipe Cleanliness

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

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

Sample Project Conceptual Piping Diagram for Cleaning Using Compressed Air Blows



Configuration for pneumatic compressed air blow cleaning

Step 1

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

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

Procedural Issues:

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

Step 2

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

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

Bibliography

1. Solar Turbines Incorporated, Specification No. ES-9-98 Revision AA
2. Pratt & Whitney Specification FR-2
3. Rolls Royce Fuel Gas Specifications
4. GE Energy Recommendations, Fuel System Supply Cleaning for Gas Turbines, GEK 116771 December, 2010
5. Cleaning of Oil & Gas Pipelines, On-Line & Off-Line, by Theo Verluen, N-Spec an activity of Brenntag, copyright 2003 Pigging Products and Services Association.
6. Bechtel Technical Paper, ASME Turbo Expo 2004, Title: Advances in Power Plant Steam Blow Cleaning Analysis, Paul Babel, Alan Veiria, Julie Jarvis, Bechtel Corporation.
7. Boyle Energy Services, commissioning brochure, 2010
8. Natural Gas Power Generation Basic Pipeline Design Requirements, PSIG 0105, Salt Lake City, 2001, Oscar G. Alvarez TGN, Hugo A. Carranza TotalFinaElfGta, Jorge A. Casanova CMS Energy, Carlos A.M. Casares TECPetrol
9. GE Gas Turbine Performance Characteristics, GE Power Systems, GER-3567H
10. GE Power Systems, Experience with Compressed Air Cleaning of Main Steam Piping, GER3636A
11. US Chemical Safety Board, Urgent Recommendations after Kleen Energy Incident, released June 28th, 2010, http://csb.gov/assets/document/KleenUrgentRec.pdf
12. BJ Process and Pipeline Services Brochure, LNG Facility Pre-commissioning Services Experience
13. Enerflo Industries Brochure, Fired and Non-Fired Nitrogen Pumper Truck Services
14. CETCO Oil Field Services, NSC Nitrogen Pumper truck Services
15. Praxair Case Study, Safer Power Plant Start-Ups using Nitrogen, Copyright 2004
16. NFPA 56, www.nfpa.org (National Fire Protection Association)
17. NFPA 54, www.nfpa.org
18. NFPA 850, www.nfpa.org
19. ASME B31, www.asme.org (American Society of Mechanical Engineers)
20. Commissioning of Combined Cycle Power Plants, 2/25/2003, Dan Parker, Start-up Engineer Emeritus, Granite Services, Inc., www.energycentral.com
21. Atlas-Copco air compressors, www.atlascopco.com
22. Water jet flushing, www.hydromilling.com
23. US EPA Website, www.epa.gov
24. GEK 116771, GE Energy recommendations, Fuel Gas Supply Cleaning for Gas Turbines.
25. GEK 110483c revised July 2009, Cleanliness requirements for Power Plant Installation, Commissioning, and Maintenance.
26. Mitsubishi, CG 58366, Cleaning Procedure for GT Fuel Gas Piping
27. www.pipepigs.com, Pipeline Pigging Products Inc., Shannon Kerr
28. AFT Arrow pipe flow modeling software: www.aft.com
29. Pipeflow modeling software: www.pipeflow.com

30. American National Standards Institute, ANSI Essential Requirements: Due Process Requirements for American National Standards, (Annex B: Procedures for the development of a provisional American National Standard (ANS) or a provisional amendment to an ANS, January 2010, www.ansi.org

The Electric Power Research Institute Inc., (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent more than 90 percent of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together... Shaping the Future of Electricity

1023628

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

Hartford Hospital Fuel Cell Project

Petition No. 1067

Emergency Action Plan

Hartford Hospital Fuel Cell
Emergency Action Plan

The operations covered by the DCO HASP have some potential to create emergency situations, such as spills of fuels, hydraulic fluids, contaminated soils and/or contaminated water. Other emergency situations could occur such as fire, explosion, disruption of utility service, natural disaster, and accident or injury to field personnel. This plan has been written to address the procedures that will be followed in the event that such an emergency should occur.

Site Requirements

1. All DCO employees and subcontractor employees shall abide by all emergency instructions given by DCO management.
2. DCO employees and subcontractor employees shall report to DCO management all accidents or occurrences as soon as possible.
3. All subcontractor employees shall report in writing, all accidents or incidents, resulting in injury or damage to property, arising during the course of service, and furnish to DCO a copy of such reports.
4. All subcontractor employees are required to respond to emergency situations as directed by any member of DCO. Employees are expected to cooperate as directed for their own safety.
5. No road may be blocked with any vehicle or material that would interfere with the passage of any emergency vehicle.
6. If an emergency plan is enacted, all personnel will be required to follow the direction of DCO management.

Training

All employees shall be given a copy of this policy and procedure, should they request it. This policy and procedure shall be posted in locations accessible to all employees.

All employees shall receive training to ensure they fully understand the policies and procedures contained herein and can carry out these instructions.

Spill Contingency

Any spills of fuel, hydraulic fluid, soils or water containing hazardous material within a restricted area are to be reported to DCO management immediately. DCO management will then notify the owner’s representative if necessary. Designated spill control personnel will begin spill cleanup procedures as outlined below:

1. Notify DCO management
2. Control area and restrict public access
3. Contain leak
4. Surround area with hay bales and cover with plastic

5. Cleanup the area one section at a time removing only enough hay bales and plastic to gain access to the work area.
6. If it is a liquid spill, use Sorbent to solidify
7. Use shovels or if needed, a backhoe or other equipment to load the spilled material into a container for transport.
8. If necessary, sweep the entire area after removal
9. Remove plastic and hay bales

Fire or Explosion Contingency

In the event of a fire or explosion onsite, DCO management or designee will immediately shut down operations, evacuate the work areas, and notify the local fire department.

DCO management will ensure that access for emergency equipment is provided, and that all combustion (e.g. machinery) has been shut down.

Evacuation of Site Personnel

In the event of an emergency situation where evacuation of the restricted area is necessary, all personnel in the restricted area will evacuate the work area, and assemble at the designated muster area. For efficient and safe site evacuation and assessment of the emergency situation, DCO management will have the authority to initiate proper action if outside services are required. Under no circumstances, will incoming personnel or visitors, other than emergency personnel be allowed to proceed into the restricted area once the emergency situation has been identified.

In the event of a site emergency involving an environmental emergency, event or other occurrence, the following procedure should be followed:

1. An alarm will sound, in the form of three short air horn blasts that will repeat for one minute.
2. If necessary, dial 911 to call for emergency assistance. Stay on the line to answer all questions unless there is a danger to your life or limb.
3. If you will not be endangered, check area for injured fellow employees.
4. If you will not be endangered, shut down all machinery in the area.
5. Proceed to the muster area which will be in front of the job site trailer.
6. Supervisor will make accounting of all employees and report to DCO management.
7. Do not return to regular work or leave your designated area until authorized to do so by your supervisor, or person in charge.

Injury or Illness

Emergency first aid shall be applied on-site as deemed necessary. In cases of a medical emergency, the ambulance squad shall be contacted for transport to the hospital. In non-emergency situations, the individual may be transported to the hospital in a site vehicle. The Emergency Phone Numbers are located in Attachment A.

Accident/Incident Reporting and Investigation

All injuries or illnesses incurred at this site by employees covered by the DCO HASP, regardless of their severity, must be reported to DCO management. Serious injuries or illnesses must be reported to DCO management immediately after their occurrence.

Any accident or incident (other than minor first aid treatment) resulting in an OSHA recordable injury or illness, treatment at a hospital or doctor's office, property damage or a near miss that could have resulted in any of the above, requires that an accident/incident investigation be performed. The investigation will be initiated by DCO management or the first line supervisor of the employee(s) involved, as soon as emergency conditions are under control. The results of the accident investigation are to be documented. A copy of the Accident/Incident Investigation report must be forwarded to DCO management within 24 hours of the occurrence.

DCO management or designee will gather all available information concerning an environmental emergency, event or other occurrence, and promptly communicate such information to the required parties.

Any such communications will, at a minimum specify the following:

- Location, nature, time, and date of the environmental emergency, event, or other occurrence.
- The known or suspected cause of circumstances surrounding and impact of the environmental emergency, event or other occurrence.
- A description of actions taken and to be taken by DCO management in response to the environmental emergency, event or other occurrence.
- Regulatory or other requirements applicable to the circumstances.
- The substance or substances involved including concentrations or amounts involved and the regulatory status of such material.
- The environmental media (air, water, soil) that has been or may be affected by a release or discharge.
- The content of any simultaneous or prior notice provided to any governmental agency.
- Any other information necessary for DCO to continue compliance with state, federal and local laws, regulations, ordinances, permits, approvals, orders or other conditions to ownership, use, and occupancy of the property

Communication

A system using telephones has been established onsite as a means of communication. In the event of a fire, spill, injury, etc. DCO management will be notified immediately. Once an incident has been secured DCO management will notify the owner's representative.

Attachment A

Emergency Phone Numbers

Hartford Hospital Fuel Cell Project

Phone Numbers:

Local Fire Dept:	911
Local Police Dept:	911
Ambulance:	911
National Response Center (Spill):	1-800 424 8802
Poison Control Center:	1-800-955-9119
Hartford Hospital:	860-545-5000
City of Hartford:	860-757-9311

Management/Owner's Representatives:

Site Manager Gerry Zeman	609-209-3469
Project Manager Andy Why	609-847-1172
Safety Director Bobby McGee	609-839-6028

DCO Energy

Hartford Hospital Fuel Cell Project

Petition No. 1067

Checklist of Certified Letters

Issued to State Agencies

Hartford Hospital Fuel Cell Project - DCO Energy, LLC
Petition No. 1067
Checklist of Certified Letters to State Agencies

Agency	Address	Certified Mail Receipt No.	Date Issued	Delivered	Contact	Email Address	Email Issued
The Department of Energy and Environmental Protection	79 Elm Street, Hartford CT 06106-5127	7013-1710-0000-3024-9547	30-Jan-14	3-Feb-14	Daniel C. Esty, Commissioner	deep.webmaster@ct.gov	31-Jan-14
The Department of Public Health	410 Capitol Avenue, PO Box 340308, Hartford CT 06134	7013-1710-0000-3024-9608	30-Jan-14	31-Jan-14	Dr. Jewel Mullen, Commissioner	webmaster.dph@ct.gov	31-Jan-14
The Council on Environmental Quality	79 Elm Street, Hartford CT 06106	7012-3460-0002-9930-7104	30-Jan-14	3-Feb-14	Karl J. Wagener, Executive Director	karl.wagener@ct.gov	31-Jan-14
The Department of Agriculture	165 Capitol Avenue, Hartford CT 06106	7013-1710-0000-3024-9578	30-Jan-14	3-Feb-14	Steven K. Reviczky, Commissioner	CTDeptAg@ct.gov	31-Jan-14
The Public Utilities Regulatory Authority	10 Franklin Square, New Britain CT 06051	7013-1710-0000-3024-9639	30-Jan-14	31-Jan-14	Arthur House, Chairman	pura.information@ct.gov	31-Jan-14
The Office of Policy and Management	450 Capitol Avenue, Hartford CT 06106	7013-1710-0000-3024-9622	30-Jan-14	31-Jan-14	Benjamin Barnes, Secretary of OPM	ben.barnes@ct.gov	31-Jan-14
The Department of Economic and Community Development	505 Hudson Street, Hartford CT 06106	7013-1710-0000-3024-9530	30-Jan-14	31-Jan-14	Catherine Smith, Commissioner	DECD@ct.gov	31-Jan-14
The Department of Transportation	P.O. Box 317546, 2800 Berlin Turnpike, Newington, CT 06131-7546	7013-1710-0000-3024-9592	30-Jan-14	31-Jan-14	James P. Redeker, Commissioner	james.redeker@ct.gov	31-Jan-14
The Department of Emergency Services and Public Protection	1111 Country Club Road, Middletown CT 06457	7013-1710-0000-3024-9561	30-Jan-14	31-Jan-14	Reuben F. Bradford, Commissioner	DESPP.Feedback@ct.gov	31-Jan-14
The Department of Consumer Protection	165 Capitol Avenue, Hartford CT 06106	7013-1710-0000-3024-9523	30-Jan-14	31-Jan-14	William M. Rubenstein, Commissioner	dcp.commissioner@ct.gov	31-Jan-14
Department of Labor	200 Folly Brook Boulevard, Wethersfield CT 06109	7013-1710-0000-3024-9585	30-Jan-14	31-Jan-14	Sharon Palmer, Commissioner	dol.webhelp@ct.gov	31-Jan-14
Department of Public Safety	1111 Country Club Road, Middletown CT 06457	7013-1710-0000-3024-9615	30-Jan-14	31-Jan-14	Leonard C. Boyle, Commissioner	DESPP.Feedback@ct.gov	31-Jan-14
Department of Public Works	165 Capitol Avenue, Hartford CT 06106	7013-1710-0000-3024-9509	30-Jan-14	3-Feb-14	T.R. Anson, Commissioner		
The Department of Emergency Management & Homeland Security	25 Sigourney Street, 6th Floor, Hartford CT 06106	7013-1710-0000-3024-9554	30-Jan-14	3-Feb-14	William P. Shea, Deputy Commissioner	william.shea@ct.gov	31-Jan-14