Too many flammable gas fires & explosions - upstream/midstream

- *NFPA 56 is an answer!*

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1.0 Introduction

The Marcellus and Utica shale plays have resulted in considerable recent press regarding what regulations apply to piping systems including gathering lines[1]. The thousands of wells that will be drilled and that now are in process will see hundreds of miles of gas pipelines, compressor stations and midstream processing plants put into service. Much of the overall safety focus appears to be regarding long term integrity issues surrounding where gas pipelines pass through populated communities or population centers. This is obviously important and vital for ensuring public safety. Events like the 2010 [2]San Bruno pipeline fires and explosions are still relatively fresh in the minds of regulators and the public. However, there are accidents and injuries that occur almost every day involving workers associated with the production of this gas and the infrastructure that is required to make it useful. The information contained in this paper focuses on protecting the safety of these workers.

The oil and gas industry has the highest number of explosions and fires of any private industry in the United States[3]. The only industry (not private) to have more fire and explosion fatalities than oil and gas in 2013 was firefighting[4], which had 42. This was only because of a tenfold increase from 2012, driven by several disasters such as the Yarnell Hill wildfires in Arizona that claimed the lives of 19 firefighters.

An analysis of public information regarding 77 incidents (related to wells, pipelines, compressor stations, tank batteries, and gas plants), within the past 4 years, showed a total of 42 deaths and 87 injuries (see Table 2.1). This means that, on average, every two and a half explosion/fire incidents claimed a life and injured 3. Given the fact that there was an average of about 20 incidents per year for this period, it means that there were 8 deaths and 22 injuries on an annual basis from explosion/fire incidents from August 2010 to August 2014. In the past few months, preliminary data indicates that this is not slowing down.

This analysis did not consider the economic impact of these incidents. There was little available meaningful information on economic impact. However, it's clear that the average well incident costs millions of dollars in direct damage and lost opportunity. Well incidents during the study period nearly equaled the total number of incidents for the other four categories of events combined (see Figure 2.1).

If you are not familiar with the oil and gas industry, you may want to first read a supplementary document prepared and included in Appendix A 6.0, "Oil & Gas Industries Operations 101, (Upstream/Midstream)" to gain some perspective. This document provides key insights into Upstream/Midstream flammable gas related activities and issues.

This paper's research included an assessment of the incidents by the types of operations involved, (wells/drilling, gathering pipelines, compressor stations, tank batteries and gas plants), the cause (if given), whether or not there was a combustion event, and casualties/injuries.

Finally, this paper reports key recommendations that can be applied by upstream and midstream producers and contractors to minimize explosions and fire risks to protect workers. NFPA 56 (Standard for Fire & Explosions Prevention during the Cleaning and Purging of Flammable Gas Piping Systems) is one of the tools that can help control these risks. Extensive excerpts are included in this paper along with suggestions on how they can be applied. More answers can be found in additional information contained in a number of different API Recommended Practices (RP's). A number of these has also been provided in the appendices to this document. Finally, some of the answers to this problem lie in preventing pressure vessel/piping integrity events. For answers to this issue, the industry is invited to look to the National Board of Boiler and Pressure Vessel Inspectors for help. Their standards and codes along with training programs are already in widespread use in the downstream oil and gas industries. All of these answers together can provide a sound basis for anyone looking to develop programs for protecting workers in the upstream/midstream industries from fire and explosion risks.

2.0 Description of the Incident Data Reviewed

The incidents reviewed, (see Appendix A8.0 for links to data), were identified from Google searches for gas well/drilling, pipeline, compressor station, tank battery and gas plant fires and explosions along with NAICS, (North American Industry Classification System) searches in OSHA's, (Occupational safety and Health Administration), accident database. The incidents that were reviewed come from a 4 year period beginning in about August 2010 through August 2014.

One of the criteria for selecting events to assess was that they needed to be related to upstream or midstream operations. Many gas transportation pipeline incidents were not included because they appeared to be existing systems unrelated to recent or active drilling programs (although in some cases this was hard to discern accurately from the descriptions given in the media).

The information presented in this paper did not include the names of the companies that were listed in any of the publically available sources. This information (owners or operators) was found to conflict in a number of cases among the different sources.

The categories used for the type of incidents included the following:

> ***Wells/drilling****: This category attempted to include issues related to drilling but in most cases not completion or production. This means that incidents related to fracking and or related hydraulic piping systems were usually not included in this category.*
>
> ***Pipeline/Piping****: This category included both gathering line incidents and those piping and pressure vessel related incidents that had to do with fracking fluids, drilling fluids, hydraulic and/or compressed air systems.*
>
> ***Compressor Stations****: These were primarily incidents related to compressors and/or the surrounding equipment at a compressor station.*
>
> ***Tank Batteries****: These were incidents related to brine and oil collection tank systems. Most of these were related to post-drilling operations related to off-loading and or maintenance.*
>
> ***Gas Plants****: These incidents were related to on-going gas plant midstream processing operations.*

2.1 Fires, Explosions, and Combustion Events

It is important to note that some consider there to be levels of severity for fires. Many in the oil and gas industry often refer to two types of combustion events: flash fires and fires. The definition of a flash fire from API, (American Petroleum Institute), RP 99 Flash Fire Risk Assessment for the Oil and Gas Industry, is as follows:

"A fire that spreads rapidly by means of a brief flame front through a diffuse fuel, such as gas or the vapors of an ignitable liquid, without the production of damaging pressure."

The analysis of incidents conducted for this paper considered all fires as combustion events and made no distinction in the level of severity. It is not consoling to the man in the burn unit to tell him that his permanent injuries were only due to a "flash fire" versus a real "fire" fire. In the writer's opinion, all combustion events must be treated with the same level of emphasis.

Fire or combustion related event incidents were the largest single cause of fatalities and injuries for each of the categories. In fact, all of the incidents related to compressor stations, tank batteries, and gas plants were combustion related. Combustion (fire incidents) were also responsible for 81% of the events overall.

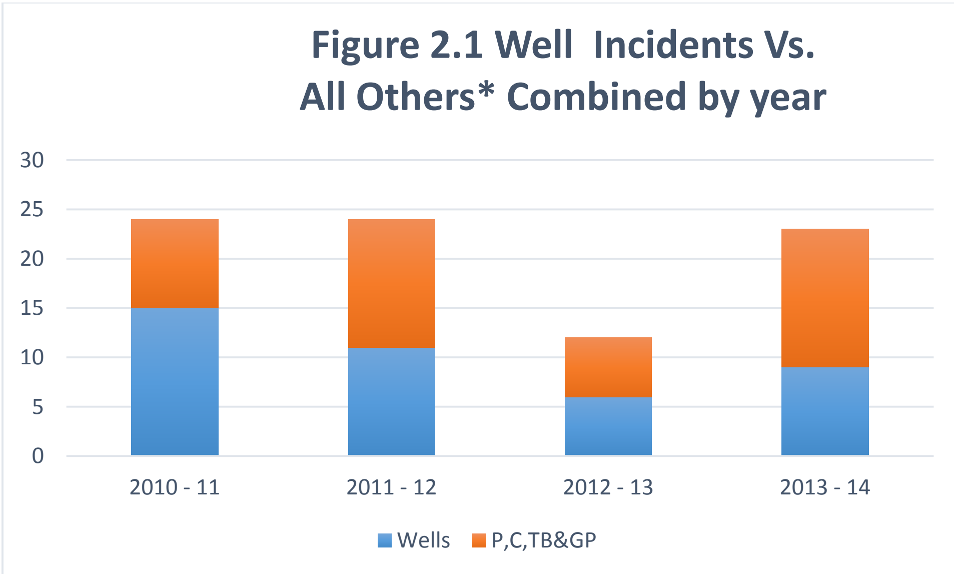
It is for this reason that many of the recommendations that are made revolve around controlling the release of flammable gases and minimizing risks surrounding known flammable gas release events.

2.2 Pressure Vessel/Piping Integrity

There are many reasons that people are injured and killed within this industry. This assessment focused only on explosions and fires. It is important to remember that every explosion does not result in a fire. In some cases, blowouts don't ignite. In other cases, explosions can be the result of drilling or fracking fluid overpressures with non-combustible fluids. In fact, 16 of the 84 incidents examined, (19% of the events), did not involve a combustion (fire). This included 4 of the 12 pipeline/piping incidents and 12 of the 41 well-related incidents.

Two categories of events contained all of the PV/PI incidents. These were wells/drilling and pipeline/piping. None of the other three categories (compressor stations, tank batteries, or gas plants) had PV/PI incidents in the data set examined.

The non-combustion related pipeline/piping explosions, (related to pressure vessel and piping integrity issues – PV/PI), were deadlier (on a fatality per event basis) than the fire events. PV/PI events for pipeline/piping were 33% of the total number of events, but 66% of the pipeline/piping related fatalities. The non-combustion (PV/PI) related well events were 29% of the total and accounted for a proportional number (31%) of fatalities in this category.



*P,C,TB,GP: Pipelines/piping, compressor stations, tank batteries, and gas plants

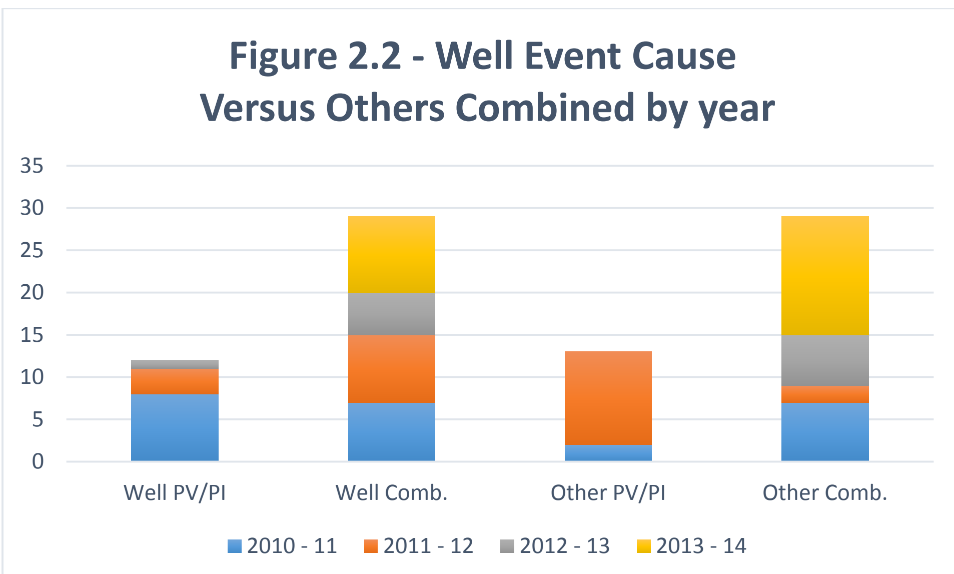


Table 2.1 Events, Fatalities, and Injuries by Type for 2010-2014*

	Comb. Event	*PV/PI Event*	*Total Events*	*Comb. Dead*	*PV/PI Dead*	*Total Dead*	*Comb. Hurt*	*PV/PI Hurt*	*Total Hurt*
Wells	**29**	**12**	**41**	**18**	**8**	**26**	**42**	**2**	**44**
Pipelines	**8**	**4**	**12**	**2**	**4**	**6**	**14**	**1**	**15**
Compressors	**14**	**0**	**14**	**1**	**0**	**1**	**21**	**0**	**21**
Tank Batteries	**12**	**0**	**12**	**8**	**0**	**8**	**4**	**0**	**4**
Gas Plants	**5**	**0**	**5**	**1**	**0**	**1**	**3**	**0**	**3**
Totals	**68**	**16**	**84**	**30**	**12**	**42**	**84**	**3**	**87**

*Notes: PV/PI – Pressure Vessel/Piping Integrity

Table 2.2 Total Events by Type for 2010-2014

	Wells	**Pipelines**	**Compressors**	**Tank Batteries**	**Gas Plant**	**Totals**
2010-11	**15**	**2**	**1**	**5**	**1**	**24**
2011-12	**11**	**6**	**6**	**1**	**0**	**24**
2012-13	**6**	**2**	**3**	**0**	**2**	**13**
2013-14	**9**	**2**	**4**	**6**	**2**	**23**
Totals	**41**	**12**	**14**	**12**	**5**	**84**

Table 2.3 Fatalities by Type for 2010-2014

	Wells	**Pipelines**	**Compressors**	**Tank Batteries**	**Gas Plant**	**Totals**
2010-11	**10**	**2**	**0**	**6**	**1**	**19**
2011-12	**8**	**2**	**1**	**1**	**0**	**12**
2012-13	**5**	**2**	**0**	**0**	**0**	**7**
2013-14	**3**	**0**	**0**	**1**	**0**	**4**
Totals	**26**	**6**	**1**	**8**	**1**	**42**

Table 2.4 Fatalities and Injuries by Type for 2010-2014

	Wells	**Pipelines**	**Compressors**	**Tank Batteries**	**Gas Plant**	**Totals**
2010-11	**22**	**3**	**1**	**7**	**1**	**34**
2011-12	**13**	**9**	**18**	**2**	**0**	**42**
2012-13	**18**	**5**	**3**	**0**	**3**	**29**
2013-14	**17**	**4**	**0**	**3**	**0**	**24**
Totals	**70**	**21**	**22**	**12**	**4**	**129**

3.0 Key Findings/Recommendations

1. A renewed emphasis should be placed on flammable gas hazard management programs for all upstream and midstream activities. This should include internal risk management programs and a new focus program for OSHA. About 80% of the incidents reviewed involved a combustion event (including all of the compressor station, gas plant, and tank battery events along with 66% of the pipeline/piping and 71% of the well incidents). Many of the incidents reviewed appeared to have involved releases of flammable gases related to operational or maintenance activities. In many cases, these activities were planned and releases were intentional.

2. Tools that can serve as the basis for internal programs include the following. A summary of these and relevant excerpts that apply to flammable gas safety are included in the appendices to this document.
   NFPA 56, (National Fire Protection Association), Standard for Fire & Explosions Prevention during the Cleaning and Purging of Flammable Gas Piping Systems
   API RP 54, American Petroleum Institute, (Recommended Practice), Recommended Practice for Occupational Safety for Oil & Gas Well Drilling Operations
   API RP, 55, Oil & Gas Processing Plant Operations Involving Hydrogen Sulfide
   API RP 74, Recommended Practice for Occupational Safety for Onshore Oil & Gas Operations
   API RP 92U, Underbalanced Drilling Operations
   API RP 99, Flash Fire Risk Assessment for the Upstream Oil & Gas Industry
   API 505, Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities

3. A renewed emphasis should be placed on pressure vessel/piping integrity (PV/PI) design, installation, operation, and maintenance. This should include internal risk management programs and a new focus program for OSHA. This is especially the case with temporary piping for drilling and completion operations. A significant number of incidents and a disproportionate number of deaths were attributable to PV/PI Incidents.

   Internal programs that included the following elements would serve to minimize risks.
   a. Training of all staff and personnel on fitting identification, ratings, pressure relief valves, inspection of piping systems to be installed, and pressure testing systems prior to putting them into service.
   b. Conducting regular inspection programs of piping systems and pressure vessels.
   c. Creating contractor mechanical integrity programs that include validation of inspection and testing prior to systems being placed into service.
   d. Initiating a self-inspection certification or subject matter expert program for pressure vessel/pressure piping design and reviews directly at well drilling sites.

4. The industry and its insurers should consider more heavily engaging the ASME, (American Society for Mechanical Engineers), National Board of Boiler and Pressure Vessel Inspectors, (www.nationalboard.org) or API training and certification programs. The NBBI has long served as the world's leading authority for the boiler and pressure piping industry especially as it relates to power generation. The group has a large number of certified piping and pressure vessel

inspectors and ready protocols that can be deployed to assist the oil and gas industry. In addition, many major oil companies with downstream operations utilize the self-inspection and certification programs available through ASME, NBBI, and or API. All of these organizations have many training programs and certifications available for those upstream/midstream operators that want to address the piping and pressure vessel integrity issue. It's time for this kind of expertise to be at the well pad given all the pressure vessels and piping that now appears at these sites to support hydraulic fracking.

5. OSHA should consider changing the way that incidents are reported and categorized. In some cases, OSHA's emphasis or focus programs are not being served because of how "Struck By" incidents are reported. Shrapnel and pressure pulses from explosions have been reported as "Struck By"" and count as a root cause just as being hit from overhead by a dropped hammer. More accurate reporting with additional segmentation of causes could better reveal and emphasize areas of need.

4.0 Types of Activities Responsible for the Greatest Flammable Gas Safety Risks

The following describes oil and gas well development and servicing activities that can involve the release of flammable gases. These activities are examples of where NFPA 56 and API RP's (recommended practices) can help to reduce risks of flammable gas combustion and PV/PI events.

1. **Well Drilling**

   There are several normal operations related to drilling that make for flammable gas safety risks. These include assembling and disassembling flare lines from drilling operations. In some cases, explosion and fire risks are also increased when drilling operations occur using compressed air or an air/water mist on the drill bit during the formative stages of the development of a well. Drilling operations include special fluids (muds) on the drill bit downhole at some point to control unexpected releases. Flare lines usually exist to take unexpected combustibles that may be encountered to be safely consumed. NFPA 56 has guidance for safe practices when these flare lines are disconnected for movement or disassembly of the rig to minimize the potential for flammable gases to be released and ignited from this piping. Purging these lines with nitrogen, as directed in NFPA 56, could be an important safety step when installation, commissioning and/or maintenance occurs.

   In abnormal operating situations, unexpected releases can occur at any time. API RP's referenced in this document describe in detail to the planning for contingencies, the proper use of fire retardant clothing, and the control of ignition sources.

2. **Well completion**

   Well completion often involves the flow and flow-back of fracking fluids and gases through piping systems and separators. These fluids are often at high pressures and can often contain flammable gases. There have been a number of incidents where injuries have occurred because of the high pressures used and mechanical integrity issues. In other cases, gases were released from vents or tank openings that ignited. Installation, commissioning, and maintenance of this piping all create circumstances where NFPA 56 has procedures to enhance safety. API RP's referenced in this document also provide valuable guidance for minimizing these risks.

3. **<u>Putting Wells Into production and local processing equipment</u>**

   Piping from wellhead Christmas trees to local processing equipment including separators, heaters, thermal treaters and or metering stations is another opportunity where proper purging into or out of service according to NFPA 56 guidelines can enhance safety. This equipment, along with storage tanks at the site for brine and residual oils/liquids, all require periodic servicing. Hence, the safety of purging their interconnecting lines and this equipment out of service and back into service can be enhanced with NFPA 56 processes and API RP's.

4. **<u>Service and maintenance of compressor stations</u>**

   The installation and servicing of compressor stations requires them to be purged into and out of service. NFPA 56 processes can enhance the safety of these processes. The API RP's referenced also refer to a number of gas release planning and ignition control processes that can reduce compressor systems risks.

5.0 Review of NFPA 56 Applicability to Oil & Gas Industry

After several tragic events in 2009 related to natural gas explosions, the US Chemical Safety Board (www.csb.gov), asked several standards making organizations to engage volunteer experts in an attempt to help. The National Fire Protection Association (www.NFPA.org), was one of these groups. The world changed on August 10, 2010, when a new standard, NFPA 56, (Standard for Fire and Explosion Prevention during Cleaning and Purging of Flammable Gas Piping Systems) was officially adopted. I am proud to have been one of the people who had the opportunity to work on this committee to formulate the standard.

I have assembled comments below that, in my opinion, point to how and why NFPA 56 applies to the well development and gas processing industries. I have also then summarized some of the key points from the standard that I think those in this industry should understand. I would encourage those involved in the design, installation and or operation of well-related gathering lines, compressor stations, and fracking operations to get the standard and read it for themselves.

The title of this paper says, "NFPA 56 is an answer". Surely it is not the only answer. The appendix to this document contains additional information that can be used for minimizing fire and explosion risks including excerpts from a number of API (American Petroleum Institute) RP's (Recommended Practices) identified for this effort by David Miller, (API Director of Standards). These documents contain many additional helpful elements that are specific to the oil and gas industry that should be considered in any comprehensive fire and explosion risk abatement program.

The following are excerpts from NFPA 56 and comments I have prepared regarding these sections.

> ***1.1.1* Applicability.*** *This standard shall apply to fire and explosion prevention during cleaning and purging activities for*

new and existing flammable gas piping found in electric generating plants and in industrial, institutional, and commercial applications.

Comment: I consider the development of oil and gas wells to be an industrial application. Webster's definition of industrial is consistent with this interpretation.

1.1.1.1 Coverage of piping systems shall extend from the point of delivery to the gas-consuming equipment isolation valve.*

Comment: I consider the point of delivery in this case to be a well head. I consider the gas-consuming equipment to be anything downstream of the wellhead.

***1.1.2 Non-application of Standard.** This standard shall not apply to the following items:*
*(1)*Piping systems covered by NFPA 2*
*(2)*Piping systems covered by NFPA 54*
*(3)*Piping systems covered by NFPA 58*
*(4)*LP-Gas (including refrigerated storage) at utility gas plants (see NFPA 59)*
*(5)*LNG facilities covered by NFPA 59A*
(6) LP-Gas used with oxygen for cutting, welding, or other hot work
*(7)*Vehicle fuel dispensers*
(8) Commissioning and maintenance of appliances or equipment
(9) Vent lines from pressure relief valves
(10) Systems regulated by U.S. Department of Transportation (DOT) 49 CFR 191 and 192

Comment: It is my understanding that most of the gathering lines are not in (DOT) 49 CFR 191 and 192 because they are not near population centers. Hence, this would mean that all of those piping systems **are not currently exempt** from NFPA 56.

What are some of the other key things this standard contains related to the gas well development business?

Before discussing some of the other key issues in NFPA 56 that relate to the oil & gas industry, it's important to discuss some concepts that you might not be familiar with.

Purging is performed to free a gas conduit of gas or air or a mixture of both. This concept leads to purging things out of service and purging things into service. For example, purging something out of service would be taking something that was operating, venting off the pressure and then removing the residual gas and replacing it with an inert substance like nitrogen. If done correctly, this makes it safe to open up and work on without a flammability or explosion risk. Purging something into service would be taking something that had air, and then moving the air out with nitrogen. If done correctly, this prevents a flammable mixture from being formed when gas is brought into the piping system or device. This minimizes the flammability or explosion risk.

Cleaning piping systems in the oil and gas industry is usually done with pigging. NFPA 56 stresses closed pigging systems when gas is used to move pigs and never the use of free gas blows for cleaning.

The following are eight key additional points that are included in NFPA 56 that should be considered along with some comments regarding each point.

1. **Retroactivity**

The standard clearly applies to sites and installations built before the standard was published.

> ***1.3.1*** *Unless otherwise specified, the provisions of this standard shall apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard.*
>
> ***1.3.2*** *The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction and only where it is clearly evident that a reasonable degree of safety is provided.*

Comment: In my opinion, the biggest impact of the retroactivity clause is related to operational issues regarding taking piping systems and pieces of equipment safely into and out of service. This would include maintenance operations where things have to be isolated and gas vented off, purging, and then re-introduction of gas to put the systems back into service.

2. New Construction and possible retrofit issues.

Most EPC (engineer, procure & construct) contractors would be following these codes. However, there could be instances where the requirements for the documentation portions such as pressure testing records, are not well conceived at this time.

> ***4.1 Piping System Construction.*** *Flammable gas piping systems shall be constructed in accordance with ASME B31.1, Power Piping; ASME B31.3, Process Piping; or NFPA 54, National Fuel Gas Code, as applicable.*

Comment: Review all of the requirements of these codes for new installations or major retrofits that are occurring. It is important to be sure that important commissioning related issues are being handled correctly and are well documented with regards to procedures like pressure testing of piping. In this design phase, that it is also important to consider things like purge points where gas can be safely vented to relieve pressure and introduce nitrogen.

3. Extensive cleaning and purge procedures will be required.

Detailed procedures will need to be developed for handling cleaning and purging procedures for new and existing facilities. There is an extensive list of considerations and requirements for these procedures as indicated below.

> ***4.3* Cleaning and Purging Procedures.*** *Written cleaning and purging procedures shall be developed and implemented by a competent person.*
>
> ***4.3.1**** *The written procedure for each cleaning and purging activity shall address as a minimum the following items:*
> ***(1)*** *Scope of Work & Site Specific Purge Procedure Development*
> *a. Cleaning and Purging Method*

b. Piping & Instrument Diagrams (PID's)
c. Chemical & Physical Properties of Flammable Gas, Purge Media & Discharge Gas
d. Determination of purge end-point introducing flammable gas, inert gas, or air
e. Assessment and Control of Purge Inlet & Discharge Locations
f. Temporary Piping System Design
g. Personal Protective Equipment (PPE)
h. Training & Qualifications
i. Management Review & Approval
j. Restoration of Service
k. Target Design, Launcher/Receiver Venting Review for Pigging Operations
l. Regulatory Permits
m. Evaluation of Engineering Controls to Limit Potential Unintended Ignition of Gases (controlled oxidation, "flaring")
n. Written stand-down instructions to stop activity in a controlled manner
o. Hazards

(2)* *Environmental Conditions & Work Locations*
a. Establish and Clearly Identify Exclusion Zones where flammable gas-air mixtures are likely to exist
b. Limit Access for Personnel Not Directly Involved With Purge Operations
c. Assessment of Potential for Gas Migration (Building Openings, Adjacent Structures)
d. Prohibition of Hot Work within Exclusion Zones
e. Lock Out / Tag Out
f. Impact of Environmental Conditions (Wind Speed, Direction, Temperature, Barometric Pressure) on Purge Operations
g. Vehicular & Air Traffic, if Applicable
h. Topography
i. Noise Control / Monitoring

(3) *Communication Plans*
a. Pre-Job Briefings
b. Work Permits
c. Roles & Responsibilities
d. Emergency Response Plan
e. Facility Alarm, Alert & 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 & Grounding Considerations
b. No Smoking or Spark Producing Work within Exclusion Zones
c. Elimination of Hot Work within Exclusion Zone
d. Static Electricity Ignition Sources at Discharge Point

(5) *Pre-Purge Piping System Assessment*
a. Assessment of Piping System for Trapped Liquids, Pyrophoric Solids, and other Flammable / Combustible Deposits Within the Piping System
b. Ensure that the Piping System is Properly Isolated
c. Limiting site conditions that impact the safety of the activity

(6)* *Purge Monitoring and Instrumentation*
a. Ensuring that Monitoring Instruments are Appropriate for Gas Being Purged
b. Training
c. Calibration
d. Monitoring Frequency & Reporting
e. Appropriate selection of Sample Point(s)
f. General atmosphere checks in vicinity of purge gas release

<u>Comments</u>: Consider developing a corporate-wide template approach for implementing a checklist type of system that can document and confirm cleaning and purge jobs as they occur. It is recommended that you consider one form or process for non-routine events and another for routine events.

4. Development of detailed cleaning and purging procedures
Detailed plans and procedures for cleaning and purging will need to written, well documented and made available on the jobsite and shall include names of the primary developer and team members.

4.6 Documentation.
4.6.1 *Cleaning and purging procedures shall be documented and available at the job site.*

<u>Comments</u>: This process will require a culture change in many organizations. The strong documentation makes for a meaningful chain of accountability.

5. Written safety validations of procedures
Written safety validations, of the plans referenced above, will be required each time the plans are used. The safety validation review will also need to document the persons who created it.

4.6.2 *The safety validation documentation shall include the following:*
(1) Names, company names and addresses of the primary developer and other principal team members responsible for the safety validation
(2) Name, company name and address of the principal operational personnel representing the plant owner or operator
(3) Date of preparation and any applicable modification dates
(4) The completed safety validation in accordance with Section 4.4
(5) Any procedures related to the safety validation and any limiting conditions identified in the management of change assessment required in Section 4.5

<u>Comment</u>: This step provides others who may not be intimately associated with the specific task, a chance to provide fresh input and to validate the thinking of the group that prepared the plans.

6. Record retention issues
Purging, cleaning and safety validation plans must be kept for 2 years. Training documentation must be kept for 5 years.

Comment: Some organizations have developed on-line web based approaches for having documents stored on a central server so that they can be easily referenced and immediately available on a sustainable basis.

7. Management of change

Management of change issues need to be integrated into gas purging tasks and plans as indicated below.

> ***4.5* Management of Change.*** *Written procedures to manage change to process materials, technology, equipment, procedures, and facilities shall be established and implemented.*
> ***4.5.1*** *The management-of-change procedures shall ensure that the following issues are addressed prior to any change:*
> *(1)The technical basis for the proposed change*
> *(2)The safety and health implications*
> *(3)Whether the change is permanent or temporary*
> *(4)Modifications to cleaning and purging procedures*
> *(5)Employee training requirements*
> *(6)Authorization requirements for the proposed change*

Comment: This is a review of existing management of change procedures to evaluate how adequately they address gas line cleaning and purging issues. This step causes you to be aware of subtle changes that can make a difference when it comes to safety.

8. Training

There are considerable training requirements for all staff. Sites should have a process for providing training and certification of competent persons related to this topic and for personnel who would be participating in purge operations.

> ***5.1 Training.*** *Persons whose duties fall within the scope of this standard shall be provided with training that is consistent with the scope of their job activities.*
> ***5.1.1*** *Such 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.*
> ***5.1.2*** *Personnel training shall be conducted by a competent person knowledgeable in the subject matter and shall be documented.*
> ***5.1.3*** *Training records shall be maintained for a period not less than 5 years from the date of completion of the activity.*

Comment: Consider developing staff that are subject matter experts who can lead training processes along with a qualification program for all of those that participate in purges. Include elements of knowledge transfer validation and hands on skill transfer in all of the training programs. A part of this program should also include general awareness training for everyone on site even including contractors that might be doing unrelated work.

6.0 Specific Example of How applying "Tools" Could Help to Minimize Explosion and Fire Risks

There is often very limited information contained in internet searches related to incidents and in some cases the information is preliminary. However, in some cases, especially from OSHA logs, information about root causes of incidents is suggested from narratives about what happened. The following represents such a case and along with information from NFPA 56 that if applied might have prevented the incident or minimized its severity.

Incident #1: **July 7th, 2013, Doddridge W. Virginia, Well Pad Explosion Incident (2 Dead – 5 others injured)**

The producer provided the following reasons for an incident that occurred at one of their sites in their July 31, 2013 letter to the West Virginia Department of Environmental Quality, (appendices A 5.0). Each of these causes was reviewed in the context of NFPA 56 guidance. Comments related to each from this review are presented below.

Cause #1: The presence and accumulation of gas from storage tanks on location. NFPA 56, Section 4.3.1 2A, calls for the establishment and clear identification of exclusion zones where flammable gas-air mixtures are likely to exist. It's possible that the NFPA 56 plan required for gas handling activities may have called out a need for an exclusion zone near these tanks and precautions given the likelihood of gas accumulation.

Cause #2: Weather conditions exacerbating the accumulation of said gas. NFPA 56, Section 4.3.1 2F, calls for the impact of environmental conditions (wind speed & direction, temperature, barometric pressure, etc.) to be considered when creating a purging plan.

Cause #3: A concentration of heavier than air methane hydrocarbons in the gas mixture. NFPA 56, Section 4.3.1, 1C, calls for chemical and physical properties of flammable gas, purge media, and discharge gas to be considered. Calling this out and forcing a discussion may have identified this as a possible problem.

Cause #4: An apparent ignition source near the C&R quad-plex skid pump NFPA 56, Section 4.3.1 4, B, Calls for a careful review of ignition sources including no smoking or spark producing work within exclusion zones.

Appendices

A1.0 Tools that can Reduce Explosion & Fire Risks

The "tools" proposed for reducing explosion and fire risks are in the form of standards and recommended practices that you may have never heard of or have forgotten about. Unfortunately, there is not one tool that resolves all of the issues. As the title of this presentation says, NFPA 56 is an answer (or" tool") for abating flammable gas risks in the oil and gas industry. It is also the only standard that the author could find that speaks specifically to flammable gas piping safety processes.

However, NFPA 56 is not the only answer. There is valuable information to be presented about API, (American Petroleum Institute) Recommended Practices as well. Information is presented in these appendices that contains partial (excerpted) information that the author chose to affirm the relevance and value of these concepts. Readers are encouraged to obtain and read NFPA 56 and all of the API RP's referenced in the development of a specific flammable gas hazard safety program. The author also provided some comments and insights with the excerpts that might be helpful in this review.

Review of Additional Relevant Industry Guidelines & Sources of Information

1. **API Recommended Practices**
2. **IADC, International Association of Drilling Contractors Publications**
3. **49 cfr 191/192, (Federal Department of Transportation Guidelines)**

A 2.0 Review of API Recommended Practices Relevant to Flammable Gas Safety Issues

There are a total of five API RP's that were referenced. These RP's were suggested by David Miller, Director of Standards for API. His efforts are greatly appreciated and were vital for enhancing this paper's findings and net benefit to readers.

A 2.1 API RP 54 Recommended Practice for Occupational Safety for Oil & gas Well Drilling and Servicing Operations

Comment: The following were excerpts from the document that appeared to be relevant to ignition source control and or flammable gas hazard abatement.

6. Operations

6.1.15 On land locations, vehicles not involved in the immediate rig operations should be located a minimum distance of 100 feet (30.5 m) from the wellbore or a distance equal to the height of the derrick or mast (including attachments), whichever is greater. Appropriate safety measures should be taken where terrain, location, or other conditions do not permit this spacing.

6.1.16 The rig substructure, derrick, mast, and other equipment as appropriate, shall be grounded to prevent accumulation of a static charge.

6.4.1 Unnecessary engines and motors that are not critical to the operation should be shut down during kill operations.

6.4.13 Pressure testing of the blowout prevention equipment system shall be conducted prior to drilling out any string of casing except conductor pipe or drive pipe. Drilling operations shall not proceed until blowout prevention equipment is tested and determined to be serviceable.

7. Fire Prevention and Protection

7.1.2 Smoking shall be prohibited at or in the vicinity of operations that constitute a fire hazard. Such locations should be conspicuously posted with a sign, "NO SMOKING OR OPEN FLAME," or equivalent.

7.1.3 Smoking shall be permitted only in areas designated for smoking.

7.1.4 Change rooms and other buildings where smoking is permitted should be located in areas designated safe for smoking.

7.1.5 Matches and all smoking equipment should be left in areas designated safe for smoking.

7.1.6 No source of ignition should be permitted in an area where smoking has been prohibited, unless it is first determined safe to do so by the supervisor in charge or his designated representative.
7.1.7 Potential sources of ignition should be permitted only in designated areas located at a safe distance from the well- head or flammable liquid storage areas.
7.1.8 Only safety-designed (non-open flame) heaters shall be permitted on or near the rig floor, substructure, or cellar. The safety features of these heaters shall not be altered.
7.1.9 Equipment, cellars, rig floor, and ground areas adjacent to the well should be kept free from oil & gas accumulations that might create or aggravate fire hazards.
7.1.10 Combustible materials such as oily rags and waste should be stored in covered metal containers and the covers kept in place.
7.1.11 Natural gas or liquefied petroleum gas shall not be used to operate spray guns or pneumatic tools.

10. Drilling and Well Servicing Rig Electrical Systems10.3.1 Area classifications determine the type of and maintenance requirements for electrical equipment on drilling and well servicing rigs under normal operating conditions. When special service operations are being performed, the recommendations for electrical installations under the conditions of service should be followed. See API RP 500 and RP 505 for details of various area classifications.

Note: Adequate ventilation as used in this section is for the prevention of fire and explosion. It is considered adequate if it is sufficient to prevent accumulation of significant quantities of vapor-air mixtures in concentrations over 10% of the lower explosive limit. See NFPA 30: Flammable and Combustible Liquids Code (1993), for additional details. See API RP 500 for discussion of methods for achieving adequate ventilation. Enclosed areas (rooms, buildings, or spaces) that are provided at least one (1.0) cubic foot of air volume flow per minute per square foot of floor area, but at least six (6) air changes per hour, can be considered as adequately ventilated. The ventilation rate can be accomplished by either natural or mechanical means. See API RP 500 for additional information on ventilation verification and classification of areas.

11. Pumping Units

11.1 Discharges of oil or gas to the atmosphere should be to a safe area, preferably on the downwind side of the well and a minimum of 100 feet (30.5 m) from the wellhead, open flame, or other sources of ignition. At locations where this recommendation may be impractical, appropriate safety measures should be implemented.

13. Wireline Service

13.9 Swabbing

13.9.1 While swabbing operations are being conducted, all engines, motors, and any other possible sources of ignition not essential to the operation should be shut down.
13.9.2 When swabbing, the swabbing line should be packed off at the surface so that fluids are routed through a closed flow system to the maximum extent possible.
13.9.3 Swabbing operations should be conducted during daylight hours.
The swabbing unit should be positioned upwind of any swab tanks or pit.

14. Stripping and Snubbing

14.1.1 Gasoline engines and other possible sources of ignition should be located at least 100 feet (30.5 m) from the well-bore during snubbing operations. At locations where this recommendation may be impractical, appropriate safety measures should be implemented.

14.2.9 Snubbing operations should not be performed while welding is being done in the immediate vicinity of the wellhead.

15. Drill Stem Testing

15.2.1 The operator's representative in charge should hold a pre-job meeting with the crew and other involved personnel to review responsibilities for the operations to be performed.

15.2.2 Any engine within 100 feet (30.5 m) of the well (within 35 feet of the well for offshore) should not be operated during the drill stem testing operations without having a heat and spark arresting system for the exhaust.

15.2.3 Measures should be taken to exclude unauthorized personnel from the area during drill stem testing operations.

16. Acidizing, Fracturing, and Hot Oil Operations

16.1.3 All trucks and tanks should be located a minimum of 100 feet (30.5 m) upwind from the wellhead, or equivalent safety measures should be taken where terrain, location, or other conditions do not permit. At locations where this recommendation may be impractical, appropriate safety measures should be implemented.

16.1.5 When used, recording equipment should be located a safe distance from the wellhead and discharge line.

16.1.6 When pumping flammable fluids, all blending equipment used should be grounded and all equipment unloading sand into the hopper should be bonded to the blending equipment.

16.1.10 Personnel not directly involved in the operations should remain beyond a designated minimum distance during all pressure testing and pumping operations.

18. Gas, Air or Mist Drilling Operations

18.3.17 When drilling with natural gas, a spinning rope instead of chain should be used in making up drill pipe (tool joint) connections to minimize the danger of ignition caused by mechanical sparks.

18.5 Minimizing Sources of Ignition

18.5.1 Unauthorized personnel should be excluded from the location.

18.5.2 The rig substructure should be adequately ventilated either by dependable natural circulation or by use of fans.

18.5.3 Generator houses, bunk houses, and the clothing change house should be located at least 100 feet (30.5 m) from the wellbore or equivalent safety measures should be taken.

18.5.4 All automobiles should be parked at least 100 feet (30.5 m) from the wellbore or equivalent safety measures should be taken.

18.5.5 Rig engine(s) should have a heat and spark arresting system for the exhaust.

18.5.6 Each gas or gasoline-fueled engine used in gas drilling operations should be equipped with a low-tension ignition system.

18.5.7 Possible sources of ignition (electric power tools, appliances, open fires, two-way radios, etc.) should be permitted only in designated areas. Only safety-designed heaters should be permitted on or near the rig floor.

A 2.2 API RP 55, recommended Practice for Oil and Gas Processing Plant Operations Involving Hydrogen Sulfide

Comments: The scope of this document was intended for operations where Hydrogen Sulfide is deemed to be present. Although H_2S is a flammable gas, it presents a much more specialized case than the typical natural gas (methane mixture) that represents the cases investigated for this document.

The API RP 55 document identifies a number of elements important to a hazardous gas program that may be applicable to methane related hazards as well. These include sections such as the following:

1. Training, Chapter 5 (includes information about minimum training content, training supervisory personnel, refresher training, visitors and non-frequent visitors, supplemental or advanced training for certain groups and qualifications for instructors).
2. Chapter 5 also provides training record retention requirements. This is something that is included in NFPA 56 as well as record retention requirements for safe work plans.
3. Extensive information is given concerning the nature of portable detection equipment to be used. The information provided is much more in depth than what is provided in NFPA 56.
4. Chapter 7 provides extensive information about safe work plans. The document also covers in detail many elements of contingency planning including recommended contact phone numbers, recommended drills, and immediate action plans. Much of this information could parallel or be applied to methane related flammable gas hazard program training.

A 2.3 API RP 74 Recommended Practice for Occupational Safety for Onshore Oil and Gas Production Facility

Comments: This document describes many general safety requirements for gas production facilities. It is a somewhat complimentary document to API RP 54, (Recommended Practice for Occupational Safety for Oil and Gas Well Drilling and Servicing Operations). This API RP is the only one found that had some direct references to purging of piping systems.

1. Most of this document contains generally helpful information regarding ignition sources and standard lockout/tag-out requirements.
2. Section 9.4.1.3 "5. Purge air from the well and associated equipment using hydrocarbons or other acceptable means" is a statement included for well initial start-up procedures.

This statement is somewhat problematic as using a hydrocarbon could provide for oxygen into a piping system to be combined with flammable gasses make for dangerous conditions. In fact, the US Chemical Safety Board has recommended on numerous occasions that purging with natural gas be prohibited. In my opinion, purging with an inert gas such as nitrogen would make for a safer process.

A 2.4 API Recommended Practice 92U, Underbalanced drilling operations (UBO), reaffirmed April 2013

Comment: Although this standard addresses UBO, it does contain a number of hazard identification and risk analysis requirements that might be used for addressing flammable gas release risks. The requirements for having a safety plan, addressing who should be part of the development team and requiring accountability for that plan are somewhat parallel to NFPA 56.

One of the major differences between this document and NFPA 56 is that many of the safety study requirements are designated as “Should” requirements and not “Shall” requirements. Many similar NFPA 56 statements contain “Shall” statements. Shall statements are mandatory items while should statements are more suggestions.

1. Section 4.4, Safety Studies and Reviews, provides for conducting safety studies and reviews of the proposed operations. This includes HAZID and HAZOP studies.
2. Section 4.4.2.3 (Participants, “the team”), are defined for conducting HAZID and HAZOP studies.
3. Section 4.5 Project Approval is somewhat similar to the NFPA 56 requirements for accountability of purging plans. In the NFPA requirements, there is a need to have responsible parties identify themselves and sign off on the plan.
4. Section 4.5.1.1 calls for an overall project plan to be signed off on by, “a qualified and technically authorized corporate representative.” The representative by his/her signature, will be confirming that all the requirements of this document have been addressed in this plan and that the elements of the plan will be applied during the execution of the plan. The signature will also confirm that appropriate input has been received from qualified technical experts has been obtained when required and that the qualifications of the technical experts are valid.
5. Section 6.2.7 Temporary Piping speaks to many drilling and completions activities. This section, if adopted within many of the drilling and completion operations, is a large part of the answer for PV/PI mechanical integrity incidents.
6. Section 6.2.7.4 states, “Personnel with responsibilities for the various aspects of piping installation and operations shall be determined to be competent to carry out those responsibilities. NFPA 56 uses “OSHA competent person” language for some of its minimum personnel requirements.
7. Both documents reference ASME B31.3. However, API RP 92U goes much further in detailing other aspects of piping integrity requirements related to the intended service.
8. This document requires the certification of the piping system and contains a discussion regarding the constraint of the piping along with traceability of manufacture and components. These things do not exist in NFPA 56.
9. Piping installation and commissioning requirements are extensive within API RP 92U. However, nothing is provided with regards specifically to purging with inert gasses or control of released flammable gas discharges.
10. Section 10.6, Pressure Testing While Commissioning, provides extensive pressure testing requirements for piping systems.

A 2.5 API RP 99, Flash fire risk assessment for the oil and gas industry

<u>Comments</u>: This recommended practice applies to all upstream operations which would include drilling and completion. This document provides tools for addressing matters related to flammable gas releases.

1. According to Section 4.1 Hazard Evaluation, General, "where the potential of flash fires exist, employers shall conduct a risk assessment and utilize controls to mitigate the potential of flash fire injury".
2. This document provides guidance for the application of and policies for where the use of FRC, (fire retardant clothing) can be most useful.
3. This document provides examples of risk assessment techniques such as an explanation of a bowtie model and example worksheets to address where flash fire risks exist.
4. In Figure 2, a "Hierarchy of Controls" diagram is provided. In addressing flammable gas hazard risks for flash fires, an outcome of this kind of analysis could be that NFPA 56 be adopted as an administrative control for some upstream piping operations.

A 3.0 IADC Review

IADC is the International Association of Drilling Contractors. It is the largest and best known trade association representing oil & gas well drilling contractors. The following are comments regarding four safety related documents from IADC and their addressing of flammable gas piping or purging issues.

A 3.1 IADC Rotary Rig Inspection Form

<u>Comment</u>: This is a multi-part tear out form contractors. It is not intended to be a piping safety guide. It provides for common sense items to check for to enhance the safety of drilling rig operations at the job site. It contains 208 questions. This document contains 24 ignition source control and flammable gas hazard recommendations. However, it does not directly address flammable piping or purging issues.

A 3.2 IADC Drilling Rig Best Practices Hazard Recognition Illustrated Workbook

<u>Comment</u>: This is not an official IADC publication but was purchased from their website. This is a simple, easy to use guide for helping staff to recognize obvious drilling rig hazards in the field. It contains a few ignition source control and flammable gas hazard items. It does not directly address flammable gas piping or purging issues.

A 3.3 IADC Health, Safety, and Environmental Reference Guide

<u>Comment</u>: This manual/reference guide is a somewhat comprehensive guide regarding multiple drilling topics. It appears to be aimed towards safety professionals and managers in the drilling industry. Although it does cover hot work, and job safety analysis processes, there is nothing specific about piping, purging and flammable gas hazard issues.

A 3.4 The Oil & Gas Engineering Guide

<u>Comment</u>: This is not an official IADC document but it was purchased from their website. It contains information about the design of piping systems. It does not specifically address issues directly related to purging or flammable gas hazard abatement.

A 4.0 DOT/PHMSA 40 cfr 191/192 Review

Comment: The following are comments and excerpts from 40 cfr 191/192 related to flammable gas and piping systems safety. In addition, this document includes by reference "ASME B31.8 – 2007, Gas Transmission and Distribution Piping Systems". This ASME document contains extensive information about flammable gas piping safety and purging.

> ***§192.605 Procedural manual for operations, maintenance, and emergencies***
> *Each operator shall include the following in its operating and maintenance plan:*
> *(a) General. Each operator shall prepare and follow for each pipeline, a manual of written procedures for conducting operations and maintenance activities and for emergency response. For transmission lines, the manual must also include procedures for handling abnormal operations. This manual must be reviewed and updated by the operator at intervals not exceeding 15 months, but at least once each calendar year. This manual must be prepared before operations of a pipeline system commence. Appropriate parts of the manual must be kept at locations where operations and maintenance activities are conducted.*
> *(b) Maintenance and normal operations. The manual required by paragraph (a) of this section must include procedures for the following, if applicable, to provide safety during maintenance and operations.*
> *(1) Operating, maintaining, and repairing the pipeline in accordance with each of the requirements of this subpart and Subpart M of this part.*
> *(2) Controlling corrosion in accordance with the operations and maintenance requirements of Subpart I of this part.*
> *(3) Making construction records, maps, and operating history available to appropriate operating personnel.*
> *(4) Gathering of data needed for reporting incidents under Part 191 of this chapter in a timely and effective manner.*
> *(5) Starting up and shutting down any part of the pipeline in a manner designed to assure operation within the MAOP limits prescribed by this part, plus the build-up allowed for operation of pressure-limiting and control devices.*
> *(6) Maintaining compressor stations, including provisions for isolating units or sections of pipe and for purging before re-turning to service.*
> *(7) Starting, operating and shutting down gas compressor units.*
> *(8) Periodically reviewing the work done by operator personnel to determine the effectiveness and adequacy of the procedures used in normal operation and main-**PART 192 – TRANSPORTATION OF NATURAL AND OTHER GAS BY PIPELINE: MINIMUM FEDERAL SAFETY STANDARDS** Revision 4/09 – Current thru 192-110 83/154*
>
> *(9) Taking adequate precautions in excavated trenches to protect personnel from the hazards of unsafe accumulations of vapor or gas, and making available when needed at the excavation, emergency rescue equipment, including a breathing apparatus and, a rescue harness and line.*
> *(10) Systematic and routine testing and inspection of pipe-type or bottle-type holders including –*
> *(i) Provision for detecting external corrosion before the strength of the container has been impaired;*
> *(ii) Periodic sampling and testing of gas in storage to determine the dew point of vapors contained in the stored gas which, if condensed, might cause internal corrosion or interfere with the safe operation of the storage plant; and,*

(iii) Periodic inspection and testing of pressure limiting equipment to determine that it is in safe operating condition and has adequate capacity.
(11) Responding promptly to a report of a gas odor inside or near a building, unless the operator's emergency procedures under §192.615(a) (3) specifically apply to these reports.
(12) Implementing the applicable control room management procedures required by §192.631.
(c) Abnormal operation. For transmission lines, the manual required by para-graph (a) of this section must include procedures for the following to provide safety when operating design limits have been exceeded:
(1) Responding to, investigating, and correcting the cause of:
(i) Unintended closure of valves or shutdowns;
(ii) Increase or decrease in pressure or flow rate outside normal operating limits;
(iii) Loss of communications;
(iv)Operation of any safety device; and,
(v) Any other foreseeable malfunction of a component, deviation from normal operation, or personnel error which may result in a hazard to persons or property.
(2) Checking variations from normal operation after abnormal operation has ended at sufficient critical locations in the system to determine continued integrity and safe operation.
(3) Notifying responsible operator personnel when notice of an abnormal operation is received.
(4) Periodically reviewing the response of operator personnel to determine the effectiveness of the procedures controlling abnormal operation and taking corrective action where deficiencies are found.
(5) The requirements of this paragraph (c) do not apply to natural gas distribution operators that are operating transmission lines in connection with their distribution system.
(d) Safety-related condition reports. The manual required by paragraph (a) of this section must include instructions enabling personnel who perform operation and maintenance activities to recognize conditions that potentially may be safety-related conditions that are subject to the reporting requirements of §191.23 of this subchapter.
(e) Surveillance, emergency response, and accident investigation. The procedures required by §§ 192.613(a), 192.615, and 192.617 must be included in the manual required by paragraph (a) of this section.

§192.719 Transmission lines:
Testing of repairs.
(a) Testing of replacement pipe. If a segment of transmission line is repaired by cutting out the damaged portion of the pipe as a cylinder, the replacement pipe must be tested to the pressure required for a new line
§192.725 Test requirements for reinstating service lines.
(e) If air is used for purging, the opera-tor shall insure that a combustible mixture is not present after purging.

A 5.0 Antero Resources Description of Doddridge, W. Va. Incident

ANTERO RESOURCES

Antero Resources
1625 17th Street
Denver, Colorado 80202
Office 303.357.7310
Fax 303.357.7315

July 31, 2013

By e-mail and regular U.S. Mail
Mr. James A. Martin
Chief, Office of Oil and Gas
WV Dept. of Environmental Protection
601 57th Street
Charleston, WV 25304

Re: ***Order No. 2013-52***
Ruddy Alt Pad, Doddridge County, West Virginia

Dear Mr. Martin:

Reference is made to the above captioned order ("Order") which was issued by your office ("OOG") on July 10, 2013. Antero Resources Corporation ("Antero") hereby submits its response to the Order. The numbered responses herein will correspond to the numbered conditions set forth in the Order and restated in this response.

1. Gain control of the activities on the Ruddy Alt pad;

ANTERO RESPONSE: With the aid of local emergency responders and independent contractors, control of the activities at the Ruddy Alt pad following the incident has been accomplished.

2. Submit to OOG a report on or before July 31, 2013 that:

a. Demonstrates a knowledge and understanding as to the cause of the incident on the Ruddy Alt pad;

ANTERO RESPONSE: The causes were:

i. the presence of and an accumulation of gas from storage tanks on location;
ii. weather conditions exacerbating the accumulation potential of said gas;
iii. a concentration of heavier than methane hydrocarbons in the gas mixture; and
iv. an apparent ignition source near the C&R quad-plex skid pump.

b. Demonstrate Antero's ability to safely resume operations on the well pad;

ANTERO RESPONSE: Antero has prepared steps to address each of the causes above and has evaluated these actions with regard to the Ruddy Alt location. We detail those actions in response to item c below and confirm that we will be able to implement each of the proposed actions on the Ruddy Alt pad to allow safe resumption of operations on the pad.

c. Outlines future preventive measures that will safeguard from similar future incidents; and

ANTERO RESPONSE: Antero is undertaking the following measures for all of our future well completion locations:

(i) A minimum three levels of review of the location layout (including all equipment spacing distances to insure distances between potential fuel and ignition sources are maximized and any additional mitigation measures deemed necessary for the specific location are properly considered.

(ii) When conditions warrant, taller cylindrical storage tanks will be used for flowback in lieu of lower profile rectangular tanks to provide highest possible outlet of any gas releases to aid in dispersion of those possible releases.

(iii) All hatches on flowback tanks will be latched to minimize potential for gas releases directly to the atmosphere. Normal releases will be directed to tank top gathering systems for vapors and same will be connected to flares and or combustors. Only emergency relief lines and/or emergency blow down lines will be vented to atmosphere.

(iv) Implementation of a mandatory policy for all personnel on site to wear portable gas monitors unless accompanied on location at all times by personnel with same.

(v) Consideration of fixed gas monitors for each location based on an individual site risk assessment.

(vi) Evaluation and consideration of tank and area ventilation systems for each location based on an individual site risk assessment.

d. Confirm that any possible pollutants were contained on site.

ANTERO RESPONSE: Antero confirms there has been no release of any pollutants on the Ruddy Alt pad, and specifically, there were none associated with the incident in question.

Antero hereby requests that the Office of Oil and Gas authorize us to resume operations on the Ruddy Alt pad.

Respectfully Submitted,

ANTERO RESOURCES CORPORATION

Alvyn A. Schopp,
Vice President – Accounting & Administration

Cc by e-mail only: Rob Pichardo, Esq.
Paul.R.Pichardo@wv.gov
West Virginia Dept. of Environmental Protection, Office of Legal Services

A6.0 Oil & gas well production, completion, gas transportation & processing 101

The following information is provided as a basic reference for those who are not familiar with the oil and gas industry. It is hoped that this information provides a better basis to understand the information presented in this paper.

Gas & Oil well development is first segmented by "onshore versus offshore". This discussion primarily applies to onshore activities. Offshore activities are usually characterized by more extensive safety practices because of the inherent risk in working above water. Hence, NFPA 56 processes deemed to be helpful for onshore activities would also be helpful for offshore activities if they do not already exist.

Another distinction can then be made based on where the gas is at within the wellhead to end user process. For these purposes, the oil and gas industry is generally broken into 3 parts: upstream, mid-stream, and downstream. The upstream industry finds appropriate geological formations, acquires rights, and actually drills the wells. The primary participants are a producer or operator and a host of contractors who provide a portfolio of services to accomplish the task. This is also called the E&P, ENP, or exploration and production part of the business.

Once a well is completed and a well head is installed, the hydrocarbon products are usually sold to a mid-stream company. The mid-stream world consists of all of the piping, compressors, and gas conditioning plants that deliver and, in some cases, modify the product to its end user.

The downstream industry consists of all of the refiners who fractionate or separate the hydrocarbon liquid streams into final end use constituents like gasoline or diesel fuel.

Upstream, exploration and development companies acquire the right to drill wells. Wells are then drilled and cased with pipe and cement through various processes. Once drilling is finished, wells go through a process called, "completion". Completion is the actual stimulation of the well to make commercially significant quantities of hydrocarbons come out of it. Gasses can escape prior to completion during drilling if pockets of gas are encountered, but this discussion seeks to address fracking (the most common and planned completion process in use at this time). Fracking is the hydraulic fracturing of some of the formation and the simultaneous insertion of proppants to hold open small passageways for gas and oil to flow to the surface.

The term hydraulic refers to liquids being forced into the formation under pressure. As hydraulic fracking pressure is, at some point released, flow back of liquids and gasses occurs towards the surface. The first flows are predominantly fracking liquids, (mostly water), with some amount of gas. As this flow back process continues, an ever increasing amount of the returning fluids are gas. Surface processes attempt to separate the liquid and the gas. The gas is then usually directed to vents or to be flared since no commercial connection to utilize the gas would be in place at this time of the well development process.

Once the "completion" process is finished a well is typically shut in with surface mounted wellhead equipment, (referred to as a Christmas tree containing special piping and valves), waiting for connection to production piping, possible local processing equipment, metering facilities and then eventually gathering lines to take the produced gas to a midstream processing plant.

Many gathering lines are today not regulated by the US Federal Department of Transportation (DOT). DOT regulations under PHMSA (Pipeline and Hazardous Materials Safety Administration) apply for many of these piping systems once gas from the well is processed for the first time. This does not usually occur until the gas is collected in gathering lines and taken to a mid-stream processing plant where certain hydrocarbon streams that may have commercial value are separated out.

Produced gas at a well head is usually a high percentage of methane but also usually includes water, brines, and many other gaseous and liquid hydrocarbons. Free liquids and brines are usually removed at the well pad through mechanical separator devices and stored in tank batteries (usually assemblies of parallel tank systems) for sale or disposal.

Pressures underground in some formations are in the 3,000 to 5,000 psig range. Wellhead valve and flow control systems choke or reduce this pressure to about 50 to 80 psig, in many cases, although this can vary by the circumstances and site conditions. Gathering line systems can be hundreds of feet or many miles. They can be 1" plastic pipe to 12" or more steel pipe. They can be from a single well or a complex network collecting from hundreds of wells over many square miles.

Compressor stations help to consolidate flows and provide pressures required to move the gases to mid-stream processing plants. Compressor stations are usually remotely operated unmanned reciprocating units.

This brings us to the mid-stream industry. Mid-stream companies exist to buy and take custody of gas leaving well pad sites from producers. They often install and own the gathering lines, compressor stations, and mid-stream processing plants. Mid-stream piping systems most often begin at a well point of custody transfer or metering station. Mid-stream piping or gathering lines are usually considered to be from this point of custody transfer to a mid-stream processing plant. Once gas or hydrocarbon product leaves the processing gas plant, the piping is usually considered to be distribution piping. Distribution piping usually ties into high pressure transmission piping systems for delivery of primarily methane to commodity markets.

PHMSA (Pipeline Hazardous Materials Safety Act) 40 cfr 191/192 most often regulates piping systems leaving mid-stream processing plants. However, lines coming in, although they may be of similar flow capacity and design, usually fall outside the scope of these regulations. A number of high profile accidents involving these piping systems recently have caused concern. PHMSA is collecting information on these systems and is considering including them within 40 cfr 191/192 scope in the future.

A7.0 Links to Raw Data Sources Used for this Document

	What		**Fat./Inj.**	**Link to story/data**
8/25/2010	Compressor Station	La.	1 Inj.	http://www.katc.com/news/a-natural-gas-compressor-station-exploded-near-shongaloo/
	2010-2011			-
11/3/2011	Compressor Station	Pa.	None	http://breakingenergy.com/2011/11/03/midnight-pennsylvania-explosion-fuels-new-marcellus-gas-safety-c/
	2011-2012			
12/3/2011	Compressor Station	Al.	None	http://nyfriendsofcleanairandwater.blogspot.com/2014_01_01_archive.html
12/6/2011	Compressor Station	Wy.	2 Inj.	http://trib.com/news/state-and-regional/two-suffer-injuries-in-fire-explosions-at-wyoming-natural-gas/article_1e7e73ac-e3a0-563a-bff1-0b6a716457da.html
1/1/2012	Compressor Station	Co.	1 Fat.,2 Inj.	http://www.durangoherald.com/article/20120626/NEWS01/706259928/Blast-at-BP-station-kills-1-hurts-2
3/29/2012	Compressor Station	Pa.	None	http://www.ogj.com/articles/2012/04/cabot-restores-marcellus-shale-gas-production-after-fire.html

7/23/2012	Compressor Station	NJ.	13 Inj.	http://protectingourwaters.wordpress.com/2013/06/01/thirteen-injured-in-williams-compressor-station-explosion-in-new-jersey/
	2012-2013			
3/5/2013	Compressor Station	Ark.	None	http://www.fox16.com/s/d/story/GOhd11nRVU-J5mZhRkyBHQ
3/20/2013	Compressor Station	Pa.	1 Inj.	http://protectingourwaters.wordpress.com/2013/03/20/breaking-gas-compression-station-fire-injures-worker-in-bradford-county/
4/4/2013	Compressor Station	Ok.	None	http://www.newson6.com/story/21895135/witnesses-describe-logan-county-gas-explosion
1/6/2014	Compressor Station	NY.	None	http://www.wbng.com/news/local/Nine-departments-respond-to-blaze-239028421.html
3/14/2014	Compressor Station	W. va.	None	http://www.frackcheckwv.net/2014/03/15/recent-fires-and-explosions-with-natural-gas-in-the-united-states/
5/23/2014	Compressor Station	Ind.	None	http://www.reuters.com/article/2014/05/23/natgas-atlas-energy-fire-indiana-idUSL1N0O91A920140523
7/10/2014	Compressor Station	Pa.	None	http://www.timesleader.com/news/local-news-news/1523876/Susquehanna-County-compressor-station-shut-down-after-morning-fire
	2012-2014			
1/7/2010	Gas Plant	La.	1 Fat.	http://www.kltv.com/story/11787376/one-killed-in-natural-gas-explosion - https://www.osha.gov/pls/imis/establishment.inspection_detail?id=313028326
	2010-2011			
	2011-2012			
11/12/2012	Gas Plant	Ut.	2 Inj.	http://www.deseretnews.com/article/865567222/Explosion-fire-reported-at-Carbon-County-gas-plant.html?pg=all
5/14/2013	Gas Plant	Wa.	1 inj.	http://www.nbcrightnow.com/story/25118246/fire-and-explosion-at-natural-gas-plant-in-plymouth
	2012-2013			
9/21/2013	Gas Plant	W. va.	None	http://chesapeakeclimate.org/wp/wp-content/uploads/2013/07/Factsheet-Dominion-WVA-explosion-Sept2013.pdf
4/23/2014	Gas Plant	Wy.	None	http://www.reuters.com/article/2014/05/01/utilities-williams-de-gas-opal-idUSL2N0NN0J820140501
	2013-2014			

9/20/2010	Pipeline	Tx.	1 Fat.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=314344136
5/28/2011	Pipeline	La.	1 Fat.,1 inj.	http://www.excoresources.com/single-news-release.htm?regid=1570894 - https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200556520
	2010-2011			
11/8/2011	Pipeline	Al.	None	http://spectrabusters.org/2014/01/26/a-36-inch-pipeline-blews-up-in-alabama/
1/11/2012	Pipeline	Tx.	1 Fat.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=316283118
2/7/2012	Pipeline	Tx.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200813327
3/1/2012	Pipeline	Tx.	4 inj.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=315714907
4/6/2012	Pipeline	Tn.	2 inj.	http://en.wikipedia.org/wiki/List_of_pipeline_accidents_in_the_United_States_in_the_21st_century
6/8/2012	Pipeline	Tx.	1 inj.	http://www.oilandgasinjurylawyers.com/blog/2012/06/natural-gas-pipeline-explosion-in-texas-sends-one-worker-to-the-hospital.shtml
	2011-2012			
8/21/2012	Pipeline	Pa.	None	http://stateimpact.npr.org/pennsylvania/2012/08/24/fire-not-explosion-at-susquehanna-drilling-site/
4/11/2013	Pipeline	W. Va.	2 Fat., 3 inj.	http://www.wboy.com/story/21949055/firefighters-working-to-subdue-gas-well-explosion-in-tyler-county-eureka-triad-hunter-magnum-hunter-resources-pipeline
	2012-2013			
2/11/2014	Pipeline	ND.	None	http://bismarcktribune.com/bakken/natural-gas-explosion-reported-near-tioga/article_d4f90b48-9333-11e3-a757-0019bb2963f4.html
8/21/2014	Pipeline	Ok.	4 inj	http://newsok.com/four-are-injured-in-pipeline-fire-near-lindsay/article/5334363
	2013-2014			
7/23/2010	Tank Battery	Pa.	2 Fat.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=314107467
8/20/2010	Tank Battery	Ks.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=201345477
8/27/2010	Tank Battery	Ok.	1 Fat.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=313694390

12/9/2010	Tank Battery	Pa.	1 Fat.,1 inj.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=314110404 - http://www.post-gazette.com/local/north/2010/12/10/One-killed-one-injured-in-Armstrong-County-explosion/stories/201012100140
7/30/2011	Tank Battery	Ok.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200645125
	2010-2011			
6/19/2012	Tank Battery	Ca.	1 Fat.,1 inj.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=202471389
	2011-2012			
	2012-2013			
9/30/2013	Tank battery	Oh.	None	http://www.bizjournals.com/columbus/news/2013/09/30/explosion-damages-rex-energy-well-in.html
9/4/2013	Tank Battery	Ok.	1 Fat.,1 inj.	http://wnow.ddev4.worldnow.com/story/23339000/report-of-oil-field-worker-killed-in-explosion-fire-in-creek-county
1/2/2014	Tank Battery	W. Va.	1 inj.	http://www.frackcheckwv.net/2014/01/04/explosion-at-tyler-county-well-pad-of-jay-bee-oil-gas/
6/22/2014	Tank Battery	Tx.	None	http://www.myfoxdfw.com/story/25838964/oil-tank-battery-fire-started-by-lightning
8/15/2014	Tank Battery	Pa.	None	http://triblive.com/news/allegheny/6625469-74/dispatchers-fire-explosion#axzz3Cjq0CSBj
8/18/2014	Tank Battery	Ok.	None	http://www.tulsaworld.com/homepagelatest/late-night-glenpool-fire-under-investigation/article_f4a2593e-6669-58e6-b4ca-dd04c0d70c49.html?TNNoMobile
	2013-2014			
7/23/2010	Well	Pa.	2 Fat.	http://www.post-gazette.com/local/north/2010/07/23/Indiana-Twp-gas-well-capped-after-explosion-killed-2/stories/201007230145
8/19/2010	Well	Tx.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200813095
9/24/2010	Well	Tn.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200625895
10/30/2010	Well	Tx.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200212843
11/17/2010	Well	La.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200556280
12/1/2010	Well	La.	3 inj.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200556264
12/2/2010	Well	Tx.	4 inj.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200813137

1/4/2011	Well	Wy.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200981124
1/14/2011	Well	Pa.	1 Fat.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=314160847
1/24/2011	Well	Co.	None	http://www.nbc11news.com/news/headlines/Fire_reported_at_Williams_natural_gas_well_114512714.html
3/10/2011	Well	NM.	1 Fat.,2 inj.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200041754
3/16/2011	Well	Tx.	None	http://www.texassharon.com/2011/03/18/devon-energy-gas-well-blowout/
3/31/2011	Well	La.	1 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200556397
4/19/2011	Well	Pa.	None	http://www.naturalgaswatch.org/wp-content/uploads/2011/07/Chesapeake_response_to_EPA.pdf
7/25/2011	Well	ND.	3 inj.	http://bismarcktribune.com/news/state-and-regional/rig-explosion-near-beach-sends-three-to-burn-recovery/article_37c238ca-b6fb-11e0-bf06-001cc4c002e0.html
	2010-2011			
8/29/2011	Well	Wy.	3 Fat.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=200981181 - https://www.starvalleyindependent.com/2011/08/30/explosion-near-glenrock-kills-three/
9/9/2011	Well	Tx.	1 Fat.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=315912972
9/16/2011	Well	ND.	2 Fat., 2 inj.	http://bismarcktribune.com/news/state-and-regional/two-dead-two-injured-in-oil-well-explosion-near-williston/article_a2bfd086-dff7-11e0-86cc-001cc4c03286.html
9/22/2011	Well	Tx.	None	http://eaglefordshale.com/news/karnes-county-well-fire-starts-during-a-hot-oil-treatment/
9/25/2011	Well	Tx.	None	http://www.firehouse.com/news/10460956/texas-oil-well-fire-destroys-trucks-worth-7m
10/28/2011	Well	Tx.	2 inj.	https://www.osha.gov/pls/imis/accidentsearch.accident_detail?id=202126769
1/6/2012	Well	Ok.	None	http://stateimpact.npr.org/texas/2012/01/06/chesapeake-fracking-well-catches-fire-oklahoma/
1/20/2012	Well	Tx.	None	http://stateimpact.npr.org/texas/2012/01/20/explosion-and-fire-at-south-texas-fracking-site/
1/20/2012	Well	Ok.	1 inj.	https://www.osha.gov/pls/imis/establishment.inspection_detail?id=316237411
1/27/2012	Well	NC.	1 Fat.	http://www.pennlive.com/midstate/index.ssf/2012/04/patterson-uti_drilling_company.html
7/16/2012	Well	Oh.	1 Fat.	http://fox8.com/2012/07/16/authorities-respond-to-gas-well-explosion/

	2011-2012			
8/17/2012	Well	W. Va.	3 inj.	http://www.wboy.com/story/19303409/violation-issued-following-well-explosion-in-harrison-county
11/7/2012	Well	La.	2 inj.	http://www.knoe.com/story/20031611/oil-well-explosion-reported-in-tensas-parish
2/15/2013	Well	W. Va.	1 Fat.	http://www.wboy.com/story/21217195/wva-gas-worker-killed-in-eqt-well-pad-blast
3/13/2013	Well	Pa.	None	http://protectingourwaters.wordpress.com/2013/03/15/breaking-wyoming-county-pa-fracking-flowback-blowout-causes-spill-evacuation/
4/5/2013	Well	Tx.	2 Fat., 3 inj	http://www.kcbd.com/story/21895386/2-killed-3-injured-in-oil-well-blowout
7/7/2013	Well	W. Va.	2 Fat., 8 inj	http://www.wboy.com/story/22776291/update-gas-well-fire-injures-5-workers-in-doddridge-county
	2012-2013			-
8/29/2013	Well	Tx.	None	http://www.reuters.com/article/2013/08/30/eog-blowout-texas-idUSL2N0GV23N20130830
9/28/2013	Well	W. Va.	1 inj	http://www.wdtv.com/wdtv.cfm?func=view&section=5-News&item=Gas-Well-Explosion-Sends-One-to-Hospital-in-Helicopter12016
2/11/2014	Well	Pa.	1 Fat., 1 inj	http://www.rkrhess.com/report-on-chevron-well-explosion-in-greene-county-pa/
3/4/2014	Well	Co.	2 Inj.	http://www.denverpost.com/news/ci_25271687/oil-gas-explosion-north-greeley-results-two-minor
3/27/2014	Well	ND.	1 inj	http://oilpatchdispatch.areavoices.com/2014/03/26/officials-investigating-rig-fire-near-watford-city/
4/30/2014	Well	Tx.	2 Fat., 9 inj	http://www.latimes.com/nation/nationnow/la-na-nn-oil-well-explosion-texas-20140430-story.html
6/28/2014	Well	Oh.	None	http://www.herald-dispatch.com/news/briefs/x1116647779/Gas-well-fire-in-eastern-Ohio-forces-evacuations
7/18/2014	Well	Pa.	None	http://www.isssource.com/fire-out-at-pa-gas-well-site/
8/15/2014	Well	Pa.	None	http://www.sharonherald.com/news/article_d5ba1c3a-24eb-11e4-8d3e-001a4bcf887a.html?mode=story
	2013-2014			

A 8.0 John R. Puskar, P.E. Bio

Mr. Puskar is currently the President of Prescient Technical Services in Cleveland, Ohio. Mr. Puskar is a licensed Mechanical Engineer in the State of Ohio and 6 other states. He has a bachelor's degree in Mechanical Engineering from Youngstown State University and an MBA from the Weatherhead School of Management of Case Western Reserve University in

Cleveland, Ohio. Mr. Puskar has been practicing engineering for more than 30 years. He founded and then sold a company which he operated for 28 years that had tested and inspected more than 10,000 fuel systems and combustion systems throughout the world. Mr. Puskar has been retained to investigate and provide opinions on some of the worst recorded fuel and combustion systems disasters known to man. He has developed corporate safety and training programs related to fuels and combustion systems for the world's largest industrial companies included Ford, General Motors, US Steel, Alcoa, and ConAgra. Mr. Puskar has served on several NFPA and ASME standards and codes committees. He is a founding and current member of NFPA 56. Mr. Puskar has presented dozens of papers and is an accomplished author including his new book now in production with John S. Wiley and Sons (released 1/14) titled, "Fuels and Combustion Systems Safety, what you don't know can KILL you".

A 9.0 References

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[3]BLS, Bureau of Labor Statistics, http://www.bls.gov/iif/oshwc/cfoi/cftb0277.pdf

[4]SAFETY, The Drilling Industries Explosion Problem, E&E Publishing, LLC., Mike Soraghan, October 20, 2014.