ENERGY WORKFORCE & TECHNOLOGY COUNCIL

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WELL STIMULATION INDUSTRY GUIDELINES

Hydraulic Fracturing with New Technologies and Innovation

DISCLAIMER

This voluntary industry guideline document is offered as general guidance only. Each Member Company must still use its own independent judgement and discretion to implement its operations successfully and develop specific systems that best fit its management structure, product lines, location, and other factors that are unique to the company and the products and services it provides. These guidelines are not meant to be a substitute for applicable laws and regulations, nor do they alter or enhance the obligation of Member Companies to fully comply with federal, state and local law.

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1. GENERAL

1A. Industry Guidelines Introduction

This document outlines the industry guidelines to safely use natural gas as an off-road fuel source while performing hydraulic fracturing services. These industry guidelines apply to all the multitude of different equipment systems and service companies operating such equipment. This document assumes a baseline understanding of the use of natural gas, knowledge of hydraulic fracturing, oil and gas operations, applicable regional and federal laws and guidelines, etc.

1B. Natural Gas Introduction

1. Natural gas is a commonly used fuel around the world, and when managed properly it can be a safe, low emission and cost-effective alternative to heavily refined or processed fuels.
2. The industry guidelines discussed within this document are focused on mitigating risk. These guidelines include properly managing the pressures and temperatures, making releases easily detectable and ensuring adequate setbacks to keep personnel and unclassified equipment away from potentially flammable environments.
3. Natural gas primarily consists of methane, as well as other hydrocarbons, carbon dioxide, and nitrogen. Raw produced natural gas may contain hydrogen sulfide (H2S) i.e. “sour gas”, however fuel-quality natural gas must be “sweet” which means the H2S has been removed. This document only considers non-toxic fuel-quality sweet natural gas.
4. Safe handling of natural gas shall consider its key characteristics:
    a. Natural gas is flammable and can form explosive mixtures with air between its lower and upper explosive limits.
        i. Lower explosive limit (LEL) is 5% gas-to-air mixture
        ii. Upper explosive limit (UEL) is 15% gas-to-air mixture
    b. Natural gas is lighter than air.
        i. Size and location of flammability depend on the leakage rate and the speed and variability of air moving around leak (e.g. wind).

ii. Outdoor open-air environments typically allow for natural dispersion of released natural gas.

c. Natural gas is an asphyxiant and can displace oxygen in an enclosed space.
d. Natural gas is odorless. The addition of odorant (e.g. methyl mercaptan), if feasible, allows for gas leaks to be easily detected by human smell.

1C. Natural Gas Fueled Equipment Introduction

There are different types of prime movers, i.e. devices generating mechanical or electrical power, on a hydraulic fracturing worksite that may use natural gas. They each have different requirements for the natural gas fuel supply and use the gas differently to produce either mechanical or electrical power.

1. Dual Fuel Diesel Engines consume diesel and natural gas at the same time. Diesel engines may be referred to by their EPA compliance level, Tier 2 or Tier 4, which indicate their air quality emission levels and do not directly imply natural gas usage. Dual fuel engines are most commonly used for mechanical power and are directly coupled to a frac pump. Diesel engines may utilize natural gas in their combustion process by one of two means: single-point fumigation or multi-point gas admission.
    a. Fumigation injects a controlled amount of gas into the engine's air intake, so that the fuel energy of the gas introduced decreases the amount of required diesel needed to achieve the same power output. Fuel trains on fumigation-style dual fuel engines typically require gas below 100 psig.
    b. Multi-point injection puts natural gas directly into the cylinder, allowing for more controlled gas usage as compared to fumigation. This style of engine typically requires natural gas above 100 psig to facilitate gas admission into the pressurized air stream.
2. Gas Turbines may use natural gas exclusively as a single fuel source. Natural gas-powered turbines are deployed in a wide range of sizes, may be coupled to a generator or directly to a hydraulic fracturing pump and typically requires above 250 psig fuel.

3. Natural Gas Engines are spark-ignited engines that use natural gas as a single fuel source. Most industrial gas engines can operate with gas pressures below 100 psig fuel.

1D. Sources of Natural Gas

Natural gas used in the oil field most often from three sources, commonly referred to as "Field gas," compressed natural gas or "CNG" and liquified natural gas or "LNG." Each source requires a different equipment package onsite. Regardless of the source, there must be a gas distribution system to safely transport the gas from the source to each individual frac engine, turbine, or generator engine.

1. Field Gas refers to locally produced gas that is piped directly to the wellsite. Due to infrastructure limitations, field gas typically has not yet been fully processed and may contain water, heavy hydrocarbons and/or H2S. As such, field gas most often requires some level of treatment or processing at the wellsite to be usable in the prime mover(s). Processing equipment often creates a byproduct of liquid water, hydrocarbons and/or rich two-phase permeate. Gaseous off-streams that cannot otherwise be managed will require a flare. Field gas is most often odorless when arriving at the wellsite.
2. CNG is fully treated natural gas that is compressed to a high pressure for efficient transportation. Upon arrival at the wellsite, CNG is depressurized and heated in decanting equipment, e.g. Pressure Reduction Systems (PRS), to the required pressure and temperature of the prime mover. Typical CNG systems operate at a 3,600 psig maximum pressure and temperatures between -20°F and 120°F. CNG produces no hydrocarbon byproducts onsite and may be odorized prior to transportation to the wellsite.
3. LNG is fully treated natural gas that is refrigerated below its boiling temperature and loaded into a trailer in liquid form. Upon arrival at the destination, LNG is sometimes transferred to an onsite holding tank, i.e. Queen. From the holding tank, the LNG is returned to gaseous form through heating and/or vaporizing equipment. Typical LNG systems operate around 100 psig and below -200°F. LNG may not be odorized until after vaporization. Unlike Field Gas or CNG, LNG and its vapors are heavier

than air due to the temperature, requiring additional precautions and extended setbacks.

2. PROGRAM REQUIREMENTS

2A. Gas Quality

1. The gas supply should, when possible, be odorized to maximize the chances to detect unplanned releases.
2. Gas quality requirements differ between prime movers and must be understood by gas provider, processer and prime mover owner/operators. The requirements of the prime mover(s) may determine what level of gas treatment is required, if any, to adjust its properties prior to its supply to the prime mover(s). The gas quality, especially field gas, may also vary during operations and this variability must be considered during job planning and while operating to ensure gas quality to the prime mover(s) remains adequate.
3. Liquids (water and/or hydrocarbons) and H2S shall be removed in every application, with adequate means to detect liquids and H2S and isolate gas supply if detected.
4. Adequate separation and/or dryers should be used when necessary.
5. The gas supply shall meet the required pressure and temperature for the specific prime mover(s) being used.

2B. Integrity Programs/Maintenance Requirements

1. An integrity program shall be developed, documented, and managed for all distribution lines and equipment, following equipment OEM requirements and industry best practices, and should include recurring elements such as:
    a. Visual inspections
    b. Leak test
    c. Pressure test
2. Results of such integrity tests shall be documented, and records shall be stored for a reasonable time period.
3. Integrity tests should only be performed by personnel competent to conduct the test.
4. Company policies for equipment maintenance procedures shall be followed.

2C. Standardized Training

1. All natural gas equipment operators and maintenance personnel (internal or contractor) should be trained in:
    a. Natural gas basics including but not limited to:
        i. Natural gas behavior, e.g. pressure vs. temperature, lighter than air
        ii. Flammability, LEL/UEL
    b. Operating procedures for gas-related PPE including personal and portable gas monitors.
    c. Equipment details and procedures applicable to their role and responsibilities.
2. All natural gas equipment operators and maintenance personnel (internal or contractor) should be certified to any applicable local regulations, e.g. Texas RRC Alternative Fuels, and OEM operator programs.
3. All personnel onsite potentially involved with natural gas operations shall be aware of the location of manual and automated safety shutdowns of applicable equipment.

3. EQUIPMENT REQUIREMENTS

3A. Process and Distribution Equipment

1. All equipment used to process and handle natural gas shall be suitable for natural gas and designed for the application with consideration of applicable national, local and industry codes and regulations.
2. Each site should have a schematic available that displays where natural gas lines exist, as well as locations of release points.
3. Equipment designs shall consider pressure ratings, temperature ratings, sizing, class rating of each section, and the type and quantity of risk mitigations in case of component failures.
4. Special considerations made for HDPE ("poly") piping and hoses where ratings change as a function of environmental conditions such as temperatures, etc.
5. Methods and locations to empty or depressurize natural gas lines should consider where personnel commonly work, and any unclassified equipment or electronics may exist.
6. The natural gas equipment shall have adequate filtration to protect prime movers from foreign objects, water and excessive oil.
7. Supply equipment shall have means to manually isolate the primary gas supply source and gas delivery to each prime mover.
8. Components should be appropriately labeled on all-natural gas equipment.

3B. Emergency Shutdowns

1. There shall be device(s) capable of isolating the gas supply from the prime movers. Those devices should be automatically activated in safety critical events with the aid of instrumentation and control system(s) as well as easily accessible and clearly visible push buttons located near or on the gas supply equipment, near or inside the data van, and/or near the egress point of the job location. At a minimum, these critical events shall be detected without the need of human intervention:
    a. Excessive gas pressure delivered to fleet
    b. Major release of natural gas to atmosphere

2. CNG and LNG trailers shall have multiple means to isolate vessels. At least one of those means shall be a minimum of 20 feet away from the hose connections.
3. Any enclosed natural gas-related systems including the supply equipment shall have leak detection tied to an emergency shutdown.

3C. Other Safety Devices

1. A minimum of two personnel working in or around natural gas equipment and lines shall be equipped with personal gas monitors that detect methane (CH4) and hydrogen sulfide (H2S). Such personal monitors must be positioned on the external garment front (Coverall) or (Shirt) and be located within 12 to 18 inches of the face of the user to enable alarm condition to be visible, and heard by the user.
2. If natural gas supply is un-odorized, continuous area monitoring should be considered by means of stationary gas detection and/or devices on personnel working nearby natural gas lines. Natural gas is lighter than air and as such these devices should be located with consideration of wind direction, air movement created by cooling fans, and heat generated by heavy equipment that can interfere with monitoring equipment.
3. Any pressure safety valve shall be mounted within a skidded or trailer mounted system and release to an area away from personnel and ignition sources.
4. Planned natural gas release points shall be at a safe location relative to other equipment and areas with personnel and should be elevated above normal working heights or a minimum of 8 feet above grade.
5. Fire extinguishers should be placed near natural gas supply and processing equipment, and storage vessel(s). The type of fire extinguisher must address the applicable risks, and the size must meet any national, local, or industry codes or regulations.
6. Physical barriers should be used to minimize potential contact between vehicles and natural gas equipment and storage vessels.

3D. Dual Fuel Conversion Kits and Fuel Trains

1. The fuel trains and dual fuel conversion kits (if applicable) on the prime mover, as described in Section 1C, shall comply with the requirements of the manufacturer and all applicable national, local, or industry codes and regulations.
2. The fuel trains and dual fuel conversion kits shall be certified when required by authorities having jurisdiction.

4. PRE-FRAC PLANNING

4A. Introduction

Hydraulic fracturing operations are complex operations that bring together multiple services on location to complete concurrent processes, each with its own inherent risks. The addition of a natural gas fuel distribution system during these multiple operations introduces additional risk that not all parties may be familiar with. Service companies and operators are encouraged to consider the topics below as part of the pre-planning process.

4B. Lease Spacing and Equipment Layout

1. The lease layout for a job utilizing natural gas as a fuel source will include additional considerations beyond a more traditional job using only diesel fuel.
2. Minimum setbacks of gas supply systems shall always be known and adhered to. Non-mobile (e.g. skidded) unclassified equipment shall not be placed within area classifications created by natural gas equipment per NFPA 70E (National Electrical Code). Most natural gas equipment can be moved or re-orientated to modify the area classifications at the well site as required. API recommended practices should also be referenced when defining the safe pad layout.
3. Consideration should be given to the location of the storage vessel and/or gas processing equipment and manifold system or flare along with routing of the distribution lines to each individual piece of equipment, with considerations to:
    a. Easy ingress and egress
    b. Away from other high-traffic activities (e.g. proppant)
    c. Adequate separation to potential ignition sources such as engines to allow for safe dispersion.
    d. A downwind location on lease relative to prevailing winds is ideal. Wind socks installed in appropriate locations help onsite personnel determine wind direction at all times.
    e. Line of sight to visually detect unsafe situations where noise is a factor.

4. Natural gas distribution routing should be planned for paths with as little other activity as possible to minimize risk of potential damage to fuel lines via truck traffic, maintenance activities, iron changeouts or any other on-pad operations.
5. No natural gas equipment or distribution lines shall be enclosed by permanent or temporary structures without validation that all electronics under enclosure meet area classification requirements. Natural gas supply equipment that feature automatic leak detection outlined in section 3B(3) are excluded from this requirement.
6. If applicable, any planned HDPE "poly" piping shall be included in the equipment layout plan. No section of HDPE piping shall be closer than 150 feet from any flare.
7. A monitoring strategy should be put in place for the location that will provide adequate warning to all on-site personnel in the event of a leak. It should be noted that LNG or field gas processed on site (and CNG in some cases) will not have an odorant unless added on location, making a strong monitoring strategy even more important in these cases.
8. A vehicle traffic flow plan shall be developed in conjunction with the equipment layout plan. The traffic flow plan should consider the following:
    a. Minimize interaction between natural gas traffic and other heavy-haul traffic.
    b. Machinery such as forklifts, skid steers, etc. should avoid close proximity to natural gas equipment storage vessel(s).

4C. Multiple Parties Onsite

1. All parties should be aware of what parties and personnel will be onsite. Each party should clearly identify to all other parties:
    a. Company name
    b. Number and type of personnel that will be onsite
    c. The role and responsibility of the party during project
2. The pressure pumper should have ample opportunity to review safety programs of any other party onsite, including but not limited to:
    a. Emergency Response Procedures (ERP's)
    b. Integrity management programs of contractor's equipment
    c. Training program details and certifications of onsite personnel

4D. Hazard Identification/Risk Management (IRP 24) [grid matrix]

1. The company's Emergency Response Procedures (ERP) must be followed in the case of an emergency. The ERP must include required responses to natural gas related emergencies such as a major unplanned gas release or thermal event on natural gas equipment, as well as the actions required on natural gas equipment during non-gas related emergencies including but not limited to thermal events away from natural gas equipment or weather events.
2. A pre-frac hazard identification exercise, specific to the natural gas infrastructure on location, should be completed in advance of the job. The matrix should be reviewed again at the completion of rig up to ensure all hazards have been identified including any unique to the current location. This hazard matrix should form the basis for discussion on the natural gas system at the pre-job safety meeting.
3. Determine a safety action plan during the pre-job safety meeting, before the rig-up. The client representative and third parties should participate in the meeting. During the safety meeting, the service supervisor must gather all those relevant to the job and discuss the following items:
    a. Whether supply gas is odorized or not to determine if leaks may only be detected through active leak detection.
    b. Ensure all gas lines and gas source will be included in the elevated hazard area.
    c. Spot the muster points and identify exit routes.
    d. Determine those crew members who will perform key critical operations on natural gas equipment before evacuating.

5. Rig Up

5A. Verifying Safety Systems

1. Verify final equipment spotting matches site plan developed during pre-frac and/or meets all national, local, and industry-specific applicable codes and regulations.
2. Verify no natural gas equipment or distribution lines are enclosed without area classification compliance of all other devices under the same enclosure.
3. Ensure adequate quantity of 4-gas personal gas monitors for the personnel onsite that are calibrated or bump-tested and have fully charged batteries. Monitors should be serialized and assigned to personnel for tracking purposes in the event of an emergency.
4. Perform applicable tests on area monitoring (if present) as recommended by the manufacturer.
5. All push buttons rigged up per Section 3B must be clearly visible and tested to verify functionality prior to introducing natural gas to the system.
6. The area around the natural gas supply/processing equipment should be clearly marked with signage. A barrier to limit access by unqualified personnel should be considered.

5B. Gas Quality Verification

1. Prior to introducing gas to the prime mover, the prime mover owner/operator shall have the opportunity to review the quality of the final natural gas supply for verification it meets the minimum requirements of the prime mover.

5C. Natural Gas Supply Equipment

1. The natural gas supply equipment shall be grounded or bonded to a grounded piece of equipment. If a site grounding grid is not available, a dedicated grounding rod for natural gas equipment may be installed and used once the proper approvals are received from the operator and local authorities if

applicable. Grounding rods must be installed at an appropriate depth and moisture level to ensure effective operation.

5D. Laying Out Gas Distribution System

1. Only trained and competent personnel should be installing gas distribution system or connecting gas lines to the equipment using the gas (e.g. hydraulic fracturing pumps, generators, turbines, etc.).
2. All gas lines or hoses should be spotted in locations to minimize interaction with foot and vehicle traffic. When interaction is unavoidable, gas lines can be kept separate from traffic with physical barriers such as concrete "jersey barriers."
3. If hard pipe or flexible gas lines must cross vehicle traffic areas, "half-moon" pipes or rated drive-overs shall be used for above-grade gas lines. Buried lines should be properly protected from damage with encasement and/or weight distribution plates.
4. Gas lines located in proximity to frac equipment have risk of damage from the vibratory nature of frac iron while pumping. The lines should either be constructed of a material resistant to such damage, and/or procedures and physical separation should be in place to prevent gas lines from contacting frac iron.
5. Each section of continuously conductive gas line must be properly grounded or bonded to a section that is grounded to prevent generation of static electricity.
6. There must be provisions to safely determine if the distribution system is energized when required.

5E. Introducing Gas to a De-Energized Line

1. Prior to introducing natural gas to the distribution system:
    a. All gas lines shall be visually inspected to ensure each is properly and completely connected with no openings to the atmosphere, including but not limited to all vent valves in closed positions.

   b. Designated personnel shall be notified that the gas system will be energized.
2. A leak check should be done immediately after introducing natural gas to the distribution system. Leak checks must be performed with at least two of the methods described below.
   a. Soap/water mixture, or Snoop
      i. This method localized to each specific potential leak point represents the most reliable method of leak detection.
   b. Human smell test (only if natural gas is odorized)
   c. Portable gas detector with pump-driven air analyzer
3. Leaks may also be detected using these methods, but each has limitations and should not be relied upon to detect leaks.
4. Pressure loss. Pressure drop detected during times with no gas usage by any prime mover onsite (e.g. between hydraulic fraccing stages on dual fuel fleets) may indicate a gas leak but noticeable pressure loss depends on the size and type of the leak and the length of time spent monitoring pressure.
5. Audible hissing of escaping gas. Other potentially loud devices on the wellsite may conceal an audible gas leak.
6. Condensation and/or "frosting" due to gas dropping in temperature as it escapes through a leak. This depends on variables such as temperatures of the outside air and natural gas.

5F. Readiness Checklist

1. A checklist may be used to confirm readiness for initiating operations, including requirements listed in this section 5.

6. Pumping

6A. Recurring Leak Checks

1. Leak checks on the natural gas distribution system should be regularly performed a minimum of twice per day by competent personnel through at least two of the methods described in Section 5E(2).
2. If a leak is found at any time, the natural gas supply shall immediately be isolated by means of manual intervention or the emergency shutdown devices (ESD). The gas lines exposed to the leak shall be de-energized after isolation and prior to fixing any leak.
3. Re-introduction of natural gas to the system after the leak is properly addressed shall follow the procedure in section 5E.

6B. Recurring Visual Inspections

1. Visual inspection of all natural gas lines shall be done at the same or greater frequency as the leak checks, looking for discrepancies such as:
    a. Damaged lines
    b. Disconnected lines
    c. Unplanned contact with vibratory components such as frac iron
2. If such discrepancies are detected, the natural gas supply shall immediately be isolated by means of manual intervention or the emergency shutdown devices (ESD) then de-energized. The section of the line that failed inspection shall be removed and replaced following the procedure outlined in Section 5E.

6C. Connection or Disconnection of Any Line

1. Natural gas lines may need to be connected and/or disconnected during a project for reasons such as:
    a. Removing or replacing a prime mover from active spread
    b. Replacement of damaged natural gas lines

2. A gas line must be de-energized prior to disconnection and connection. Exceptions may be made if the connection device safely allows connection and disconnection without risk of gas release or personal injury.
3. Procedure outlined in Section 5E shall be followed after any gas line is connected during a project.

6D. Known Change to Gas Supply

1. If the supply of natural gas is known to change (e.g. CNG to field gas, between different sources of field gas, etc.), the pressure pumper should be notified and an updated gas sample should be pulled and analyzed to confirm compliance with minimum gas quality specifications.

6E. Two-Way Radio Communication

1. Personnel onsite responsible for natural gas supply and/or distribution shall have a radio connected to the primary frequency as the hydraulic fracturing crew to enable communication between all personnel without delay.

6F. Traffic Onsite

1. The vehicle traffic flow should follow the prescribed plan as developed in the pre-frac planning stage, detailed in Section 4B(8).
2. Unqualified personnel should not enter the area around the natural gas supply/processing equipment.

7. Rig Down

7A. Preparation

1. Verify natural gas equipment has been isolated from the source and all gas lines have been de-energized prior to initiating rig down procedures.
2. Gas lines should be rigged down prior to frac lines to avoid equipment damage.

7B. Procedure

1. Close the ball valves on each unit and gas source.
2. Purge the gas line with nitrogen when available. If not, shut in supply valve and vent back to source unit and vent to atmosphere.
3. Rig down the gas line for each unit and return the hose to the storage position.
4. Thoroughly clean the area around fuel system components that will be disconnected, preventing dirt and contaminants from entering the fuel system and supply lines.
5. Cap all the hose ends and equipment connection points. It is imperative the gas hoses and gas train are clean and free of debris and liquid.

7C. Post-Mortem Lessons Learned

1. Ensure lessons learned and areas for improvement from the project are documented and communicated to the appropriate parties for executing any applicable corrective actions.

8. Definitions

Lower Explosive Limit (LEL): Minimum ratio of fuel to air that allows for a combustible environment. A lower fuel to air mixture ratio would not be combustible. The LEL number is specific to the fuel.

Upper Explosive Limit (UEL): Maximum ratio of fuel to air that allows for a combustible environment. A higher fuel to air mixture ratio would not be combustible. The UEL number is specific to the fuel.

Dual Fuel Engine: An engine capable of simultaneously consuming two types of fuel, e.g. natural gas and diesel.

Prime Mover: A device that converts fuel to mechanical power.

PPE: Personal protective equipment that mitigates specific injury risks for personnel, represents the last line of defense beyond engineered and procedural risk mitigations. E.g. safety glasses, hard hats, fire retardant clothing, methane detectors, etc.

Field Gas: Natural gas produced nearby that is available for fuel prior to being fully processed.

LNG: Liquid Natural Gas at a temperature below its boiling point.

CNG: Compressed Natural Gas. Natural gas at a pressure at or above 2,400 psig.

ERP: Emergency Response Procedure defines the required actions in response to an emergency.

Personal Gas Monitor: A device that detects gases such as methane and others, designed to be worn by personnel while working in areas that potentially have such gases in the environment.

Portable Gas Monitor: A device that tests for presence of specific gases in the environment, typically by use of a pump to actively draw in surrounding air.

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