

Odor Intensity Monitoring, Odorization Methodology, Renewable Natural Gas and Hydrogen Blending

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Odorization History

Sadly, odorization of combustible gas in the USA resulted from a tragic gas explosion at the London School on March 18, 1937 in New London, Texas. Two hundred ninety-four people, mostly children, died on this day. Additional related deaths were recorded in the days afterward. Combustible gas was not required to be odorized at the time. Oil well drilling in the area was very active and producers had been flaring unwanted wet gas. Local businesses began the practice of tapping into the wet gas lines and using the wet gas for heating and cooking purposes since the wet gas was considered worthless by the producers. The school followed suit and tapped into a local wet gas line. Unfortunately, an improper fitting connection allowed un-odorized wet gas to leak into the school. It is reported that for several days prior to the explosion the children and teachers complained about having headaches and not feeling well. It is believed a shop teacher started an electric tool which provided an ignition source for the combustible gas mixture.

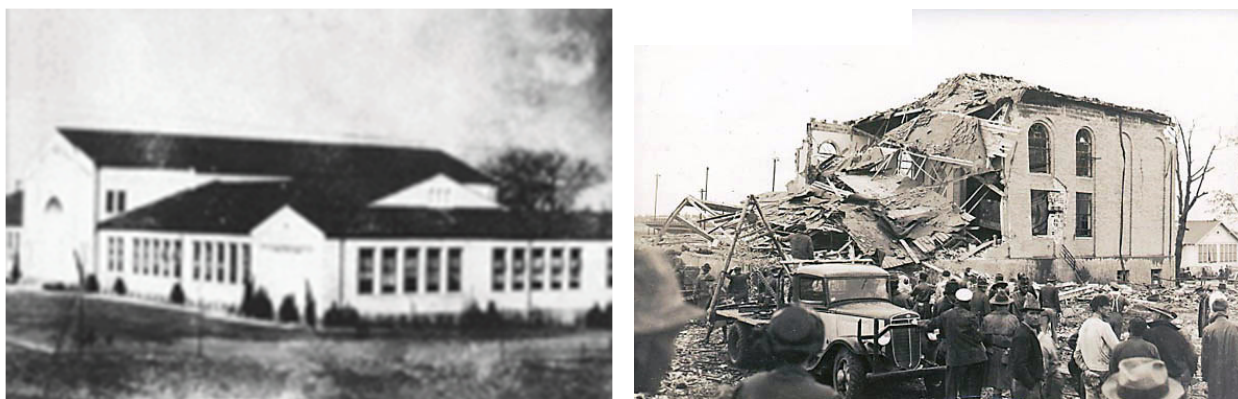


Figure 1. New London, TX, school before and after the explosion

A recent newscast video covering the disaster may be viewed using the following link:

<https://www.kvue.com/article/news/history/america-worst-school-disaster-texas-85-years-ago-this-week/269-d828bbc8-b543-4a7e-bdbf-a91926e98ae0>

The direct responses in Texas to the explosion were two-fold and addressed both **safety and liability**:

1. Combustible gas for distribution and consumption shall be odorized. The Texas Legislature, within weeks after the explosion, mandated that thiols (mercaptans) be added to natural gas. Today, odorization of combustible gas in pipelines in the USA is regulated by Title 49, Part 192.625 of the Code of Federal Regulations (49 CFR Part 192.625) under the Department of Transportation (DOT). Subparts (a), (e) and (f) specifically address odorization methodology. Several states have additional codes in place to further supplement the federal regulation. International regulations have been adopted for the same purpose – to provide a safety agent within combustible gas such that a person with a normal sense of smell, sniffing an adequate but safe concentration, should readily detect the perceived intensity of the odor as that of a gas leak.

2. Installation of facilities which can affect public safety shall be the responsibility of qualified and licensed individuals. The Texas Legislature, in an emergency session after the explosion, enacted the Engineering Registration Act (now known as the Texas Engineering Practice Act) which further resulted in the formation of state boards of Professional Engineers in all USA states and the National Board of Professional Engineers with their respective engineering societies. Internationally, standardization of practices is exemplified in the International Organization for Standardization (ISO).

Odorization Regulations

A combustible gas pipeline operator shall first and foremost be familiar with, understand, and comply with all applicable odorization regulations for their location and infrastructure. It is to be understood that 49 CFR 192.625 or any related state, local or similar international regulation does not define a combustible gas pipeline operator's odorization program. The language of 49 CFR 192.625 and similar regulations is performance or results oriented and it gives the combustible gas pipeline operator the decision-making power to implement a program that is both effective and practical. International regulations are more dynamic than 49 CFR 192.625 as they may vary by country and there may be far more borders involved which places more emphasis on custody transfer. European regulations provide a good example of this. A key resource is Marcogaz, <https://www.marcogaz.org/>, which represents the European gas industry on all technical aspects of the gas system's full value chain. International Standard ISO/TR 16922 (2022) pertains to Natural Gas Odorisation. Marcogaz's GI-OD-09-04 (2020) tabulates, per country:

- Legal Section
- Odorization Control Section
- Odorization Plants (Odorizers) Section
- Gas Chromatographic Analysis at Odorization Plants
- Odorization Plants Section (Biomethane Injection)
- Olfactory Level Section
- Odorants Concentrations Section
- Updating References (date references)

Odorization Monitoring Program

In general, an odorizer should be closely monitored for injection rate or odorant usage, combustible gas samples should be analyzed, odor intensity (odor concentration threshold and / or odor intensity level) and odorant concentration tests shall be periodically performed at selected points throughout the downstream distribution system and customer leak calls should be monitored. An odorization monitoring program should include but not be limited to:

1. Compliance to national, federal, state, local or international regulations and company policy.
2. Record keeping.
3. Operations & Maintenance (O&M) documentation.
4. Odor intensity (odor concentration threshold and / or level) monitoring if applicable.
5. Operator qualification and training.
6. Odorant concentration monitoring.
7. Customer leak calls.
8. Customer service personnel sniff tests.

Odor concentration threshold monitoring directly addresses 49 CFR 192.625 and is of critical importance. International regulations may or may not require odor intensity level or odor concentration threshold as mentioned. Hereafter, an odor intensity level or odor concentration threshold test instrument will be referred to as a gas dilution apparatus in accordance with test standards language as found in the ASTM International (<https://www.astm.org/>) standard ASTM D6273-14, “Standard Test Methods for Natural Gas Odor Intensity”. ASTM D6273-14 documents relevant terms and test procedures using a gas dilution apparatus for both odor intensity level and odor concentration threshold.

An odorization monitoring program is essential given the miles of distribution mains and service pipelines involved. In the US, there are presently approximately 2.4 million miles of distribution pipeline. (Source: PHMSA).

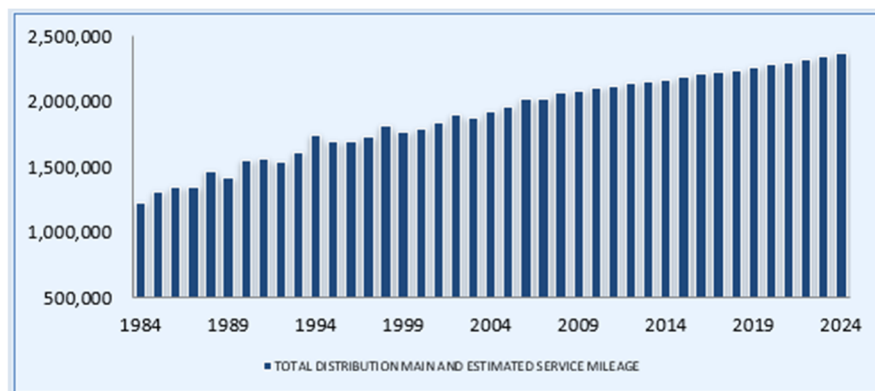


Figure 2. US Total Distribution Main and Estimated Service Mileage

Record Keeping

Accurate record keeping is vitally important and shall be maintained. The records should be neat, up-to-date, and readily available for reference or inspection. Records should include details including but not limited to:

1. Odor Concentration Threshold / Odor Intensity Level Monitoring – Date, time, location, gas dilution apparatus used, test operator’s name, test results and any action items.
2. Odorant Concentration Monitoring – Date, time, location, test method used, instrumentation references, test results and any action items.
3. Customer Leak Calls – Tracking by number of calls, location, frequency, time of year and pipeline status.
4. Equipment Specifications – Manufacturer’s specifications for all gas dilution apparatus, odor monitoring devices, gas analyzers and odorizers.
5. Equipment Maintenance and Calibration – Records of all inspections, calibrations, maintenance and modifications.
6. Odorant – Amount purchased, date purchased, date and amount transferred to an odorizer, date and reading of all storage tanks or odorizer liquid levels, injection rates and the Certificate of Analysis for each batch of odorant purchased.
7. Operator Qualification and Training – Relevant information about operator or service personnel qualifications and training.
8. Safety – Relevant information pertaining to either personnel or public safety issues.

Operations and Maintenance (O&M) Documentation

Processes and procedures should be documented for reference and control. Company specific requirements regarding odorization should be included. Sections should include operator qualification and training, customer leak calls, customer service personnel sniff tests and public safety awareness programs among others.

Odor Intensity Monitoring

Odor intensity monitoring, as included in the odorization requirements set forth in 49 CFR 192.625, is addressed primarily in subparts (a), (e) and (f) which basically state:

- (a) Combustible gas in a distribution line must contain a natural odorant or be odorized so that at a concentration in air of one-fifth the lower explosive limit, the gas is readily detectable by a person with a normal sense of smell.
- (e) Equipment for odorization must introduce the odorant without wide variations in the level of odorant.
- (f) To assure the proper concentration of odorant in accordance with this section, each operator must conduct periodic sampling of combustible gases using an instrument capable of determining the percentage of gas in air at which the odor becomes readily detectable.

It must be stressed that employing an instrument that uses a person's normal sense of smell shall be used for odor intensity monitoring as required by 49 CFR 192.625 subpart (f). A person with a normal sense of smell, sniffing an adequate but safe concentration, should readily detect the perceived intensity of the odor as that of a gas leak. Odorant concentration shall not be used to verify the odor intensity is readily detectable.

International regulations are not necessarily olfactory based and may be based on odorant concentration analysis alone.

Regardless of regulation, safety is implemented by the perceived odor intensity. As such, gas source quality and consistency are key requirements for perceived odor intensity as varying consistency from multiple sources and compositions may significantly contribute to odor masking and odor fade, thus making the perceived odor intensity ineffective and unsafe. Therefore, it is highly recommended that olfactory tests be performed to verify distribution perceived odor intensity, even if odorant concentration analysis alone is specified in the respective regulation.

49 CFR 192.625 (a)

Of key interest in subpart (a) are the lower explosive limit (LEL), the definition of readily detectable and a normal sense of smell.

LEL

The lower explosive limit (LEL) of combustible gas in a pipeline can be determined analytically using chromatographic analysis of the components and then calculated using Le Chatelier's Mixing Rule. A generalized description of the mixing rule is:

$$\text{LEL} = 100 / [\% \text{gas1} / \text{LEL}_{\text{gas1}} + \% \text{gas2} / \text{LEL}_{\text{gas2}} + \% \text{gas3} / \text{LEL}_{\text{gas3}} + \dots] \quad \% \text{ gas in air} \quad (\text{Equation 1})$$

Example for 80 % methane, 10 % ethane, 10 % propane:

$$\text{LEL} = 100 / [80/5.0 + 10/2.9 + 10/2.0] = 4.1 \% \text{ gas in air} \quad (\text{Equation 2})$$

Alternatively, the operator may choose a conservative value lower than that for methane alone taking into account variations in the composition of the combustible gas. The LEL of methane is considered to be 5.0 % gas in air (reference Gas Processors Association publication GPA 2145). One fifth that LEL is 1.0 %. The April 2017 AGA Odorization Manual includes additional information and an embedded Excel link to aid in LEL calculation for alkanes. For monitoring at elevation, the effects on LEL are minor and generally ignored.

Readily Detectable

The definition of readily detectable is subjective but may be considered that intensity at which a person with a normal sense of smell would be prompted to take immediate action.



Figure 3. Readily Detectable

Normal Sense of Smell

Odor intensity test operators should be tested and selected for a normal sense of smell with respect to odorant. A normal sense of smell can and will be affected by various factors which include but are not limited to fatigue, smoking, recent eating, sickness, medications, cologne or perfume, age, gender and olfactory fatigue. It is stressed that mercaptans will quickly cause olfactory fatigue and adequate time must be permitted between odor intensity tests. A typical time between test locations is 45 – 60 minutes.

49 CFR 192.625 (e)

Of key interest in subpart (e) are the equipment for odorization and without wide variations in the level of odorant.

Odorizers

There are several types of odorizers available for vaporizing odorant into a combustible gas stream. These odorizers include but are not limited to Injection, Bypass, Wick and Hybrid variations. Their selection and use is highly usage dependent. A distribution system may be composed of a variety of odorizer types.

Odorants

The odorant's ability to odorize the gas stream and be readily detectable are dependent on several factors including but not limited to:

1. Odorant type and blend.
2. Odor fade.
3. Odor masking.
4. Odorizer performance.
5. Pipeline status – new, repaired, hydrostatic pressure testing, purging, etc.
6. Combustible gas flow – low, high, dead ends.
7. Peak shaving – propane, hydrogen gas.
8. Combustible gas composition – conventional, shale, RNG, hydrogen blending.
9. Pipeline material type and age – steel, plastic.
10. Pipeline distillates, oxidation.
11. Soil absorption.

The most common US commercial blends of odorant are Spotleak[®] and Scentinel[®]. In Europe, THT and TBM are commonly used, along with blends. A sulfur free odorant, GASODOR[®] S-FREE, can be used to reduce the corrosive effects of sulfur. Ethyl Mercaptan is most commonly used for propane.

Odorant Introduction

To achieve the requirement of introducing odorant without wide variations in the level of odorant, an odorizer should be closely monitored for injection rate or odorant usage, combustible gas samples should be analyzed, and odor intensity tests shall be periodically performed throughout the downstream distribution system.

Quantitative sulfur and / or other combustible gas stream component analysis can be performed both in the lab and / or on-site. Pipeline operations may require portable and / or application specific instrumentation such as when pickling or purging.

To control the odorant level and limit the odorant level variations, a control loop with monitoring feedback is typically established and maintained. The complexity of such control loops will vary with demands of the odorization system. A simplified version of a control loop is shown below:

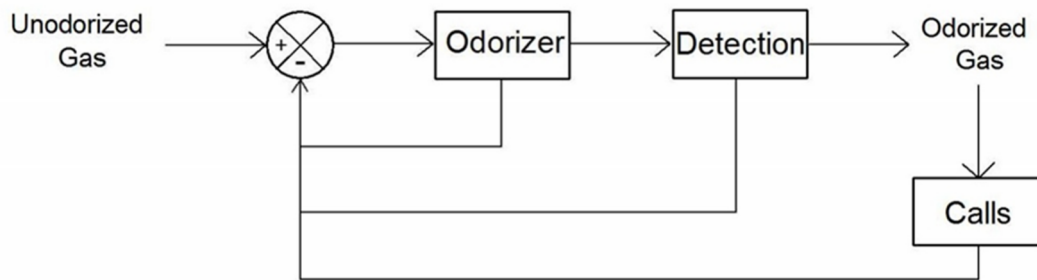


Figure 4. Odorant Monitoring and Control

Monitoring feedback will include but not be limited to:

1. Injection rate.
2. Gas sample sulfur analysis
3. Odor intensity monitoring
4. Customer leak calls
5. Service reports

Combustible Gas Stream Analysis

Titration, analyzers and chromatographs are lab grade instruments employed for analyzing combustible gas stream components and composition, for both gases and liquids. ASTM, EPA and international test standards are typically referenced. A variety of detectors are used, including lead acetate tapes, chemiluminescence, flame photometric and electrochemical technologies. These detector technologies provide for total sulfur calculations and in many cases for complete component separation. Concentrations can generally be displayed in a variety of forms from grains, parts per million and pounds of odorant per gas volume. These instruments can be configured for laboratory use where samples are brought in or placed directly on the pipeline for real-time calculations. Analysis of hydrogen blends requires special consideration for accurate results. Several communications packages are available for transfer of information directly to a centralized gas controller.

A variety of manufacturers offer Titrators, Analyzers and Chromatographs which include but are not limited to:

- Chromatotec
- Del Mar Scientific
- Galvanic Applied Sciences Inc.
- Agilent / Hewlett Packard
- Atlas Analytical
- Perkin – Elmer
- Spectra – Physics
- Yokogawa

Portable Devices

Low-cost field devices are available for spot checking the gas stream for mercaptans. Their accuracy is less than that for analyzers, but they respond quickly and are valuable for “go / no go” field work such as purging operations. Other portable devices are available for multi – gas, O₂, CO₂, H₂S, H₂ or CH₄ analysis. Similarly, they offer less accuracy than analyzers but are generally smaller, faster, and lower cost.

Length of Stain or Detector Tubes, also known as stain tubes, are one-time use devices made of sealed glass tubes containing a chemical sorbent that changes color upon exposure to the selected compound in the test gas sample.

Electrochemical Odorant Sensors, such as the Odor Handy Plus from Axel-Semrau and the Ex Tec OD4 by Sewerin, are hand-held electronic sulfur detection instruments sensitive to mercaptans or tetrahydrothiophene (THT). They respond within a few minutes and are more accurate than stain tubes. They are useful during pipeline operations such as pickling and purging where the odorant levels are monitored during operations until nearly complete and then odor intensity is monitored.

Specialized Portable and Fixed Devices and Instruments

Portable and field installed devices and instruments shall have the proper and necessary safety, environmental and hazardous use certifications for the application as required. The area’s hazardous safety rating shall be known and understood. A hot work permit may be required. These devices and instruments include but are not limited to:

- Multi – gas instruments used for RNG / Landfill analysis
- Hydrogen Detectors used for detecting hydrogen gas leaks
- Personal Safety Monitors used for real-time personnel safety
- Natural Gas Detectors

Natural Gas Detector advances in detection technology have made low power, long life products available for permanent installation in homes, businesses, and high consequence locations. Natural gas detectors can supplement odor intensity monitoring and are recommended for low / no flow locations where supplemental odorization is not practical and when soil absorption may lead to odor fade. Furthermore, they offer 24 / 7 leak detection monitoring during times when a person is not physically present. Most models connect to a network, typically provided by Advanced Metering Infrastructure

(AMI) or WiFi, thus providing remote alerts and notifications to home and business owners or optionally emergency services. New York City has adopted Law 157 requiring the installation of natural gas detectors and Consolidated Edison's pilot program has installed over 250,000 detectors to date. The program is expected to save lives and money due to the increased public safety and reduced liability. The National Transportation Safety Board (NTSB) presently has about 37 Recommendations for natural gas detectors and their Residential Natural Gas Leak Detection video is available at: <https://www.youtube.com/watch?app=desktop&v=w7bC329QejE>

Shale Gas, Renewable Natural Gas (RNG) and Hydrogen Injection

Shale gas and RNG are special odorization cases as they differ from odorization for conventional natural gas, primarily due to differences in composition. Hydrogen injection presents no significant odorization challenges if following the rule of thumb range of 5 – 20 % hydrogen gas in the combustible gas stream. Of particular interest is the recent growth of hydrogen injection, especially in Europe.

Shale Gas

Shale gas has a composition very similar to conventional natural gas and with fewer problematic unwanted components than bio methane or RNG. Odor masking and odor fade are of primary concern.

RNG



Used with permission, AGA American Gas, July 2019

Figure 5. RNG on the Rise

RNG presents more of an odorization challenge as there are more components that may interfere with odorization and RNG usage is on the rise. RNG is created from biomass, typically by anerobic digestion or thermal gasification to produce raw biogas, followed by clean-up / upgrading to produce pipeline quality natural gas. RNG end use applications include but are not limited to:

- Transportation Fuel (Renewable Fuel Standard credits in the US)
- Peak Shaving / Blending
- Local Power Generation
- Local Heating
- Energy Storage

Biomass sources include dairy farms, landfills, wastewater treatment plants, municipal solid waste, forest waste and organic waste (agriculture and food). Biogas, created from biomass, can contain many compounds and components undesirable for inclusion into a pipeline. Landfills particularly can produce a large number of components, some possibly hazardous. Landfill gas shall be cleaned up and upgraded to pipeline gas quality prior to being tested for odor intensity using a gas dilution apparatus. The quality and safety of any monitored combustible gas for odor intensity measurements shall be understood and implemented. After cleaning up, the biogas can be considered bio methane. Bio methane must then be further upgraded (additional components removed) to be considered RNG. A biomass utilization graphic is illustrated below:

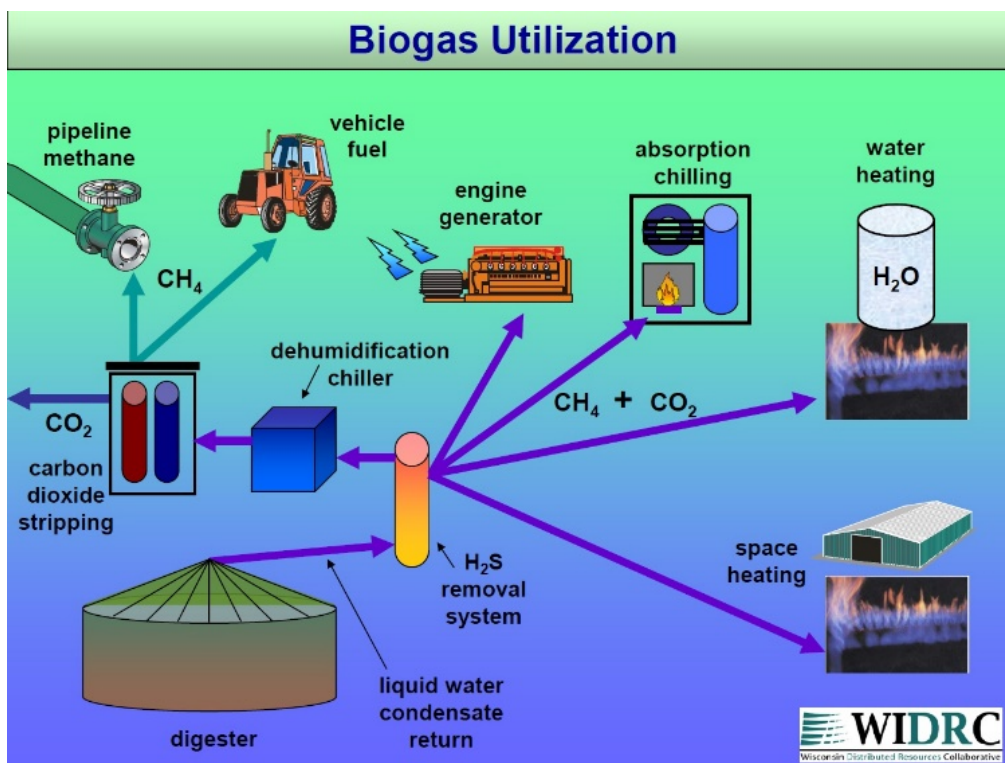


Figure 6. Biogas Production and Utilization

Some typical components found in raw biogas are:

- | | |
|--|------------------|
| • Methane | CH ₄ |
| • Water | H ₂ O |
| • Hydrogen Sulfide | H ₂ S |
| • Carbon Dioxide | CO ₂ |
| • Oxygen | O ₂ |
| • Carbon Monoxide | CO |
| • Hydrogen | H ₂ |
| • Siloxanes | |
| • Aldehydes, Ketones, VOCs | |
| • Metals (Mercury, Arsenic, Lead) | |
| • Ammonia, Amines | |
| • Bacteria, Microbes & MIC (Microbially Induced Corrosion) | |
| • Many others | |

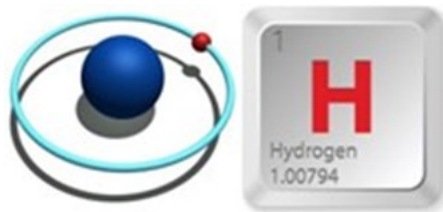
There are several considerations for producing RNG:

- Biogas must be cleaned up, especially with Landfills, and Upgraded
- Local Gas Processing / Delivery / Storage logistics
- Pipeline Interconnection Issues
- Odor Masking, Odor Fade due to unwanted components
- Biogas Clean-up, Upgrade, Storage and Disposal Costs
- Legal Concerns, Tariffs, Hazardous Waste
- Wobbe Index, Heating Value, LEL, End Use Compliance
- Source Gas Stability

After clean-up and upgrading, RNG will generally have very similar specifications and characteristics to pipeline quality natural gas. Odor masking and odor fade need special attention as the components of RNG may interact with the odorant and / or mask the odor.

Hydrogen Gas Injection

Hydrogen gas injection is growing, especially in Europe, where renewable interest is high, and logistics make it difficult to expand the gas grid. Hydrogen gas injection into natural gas lowers the carbon footprint and increases energy storage capacity. Hydrogen based fuel cells and vehicles are expanding in the market. Hydrogen is either transported / piped to an injection site or produced locally, typically via electrolysis.



Shutterstock

Figure 7. Hydrogen

Hydrogen production is classified by “color”:

Green: Green hydrogen is made by using clean electricity from surplus renewable energy sources such as solar or wind power to electrolyze water.

Blue: Blue hydrogen is produced mainly from natural gas, using a process called steam reforming which brings together natural gas and heated water in the form of steam. The output is hydrogen – but also carbon dioxide as a by-product. That means carbon capture and storage (CCS) is essential to trap and store this carbon.

Grey: This is currently the most common form of hydrogen production. Grey hydrogen is created from natural gas or methane using steam methane reformation but without capturing the greenhouse gases made in the process.

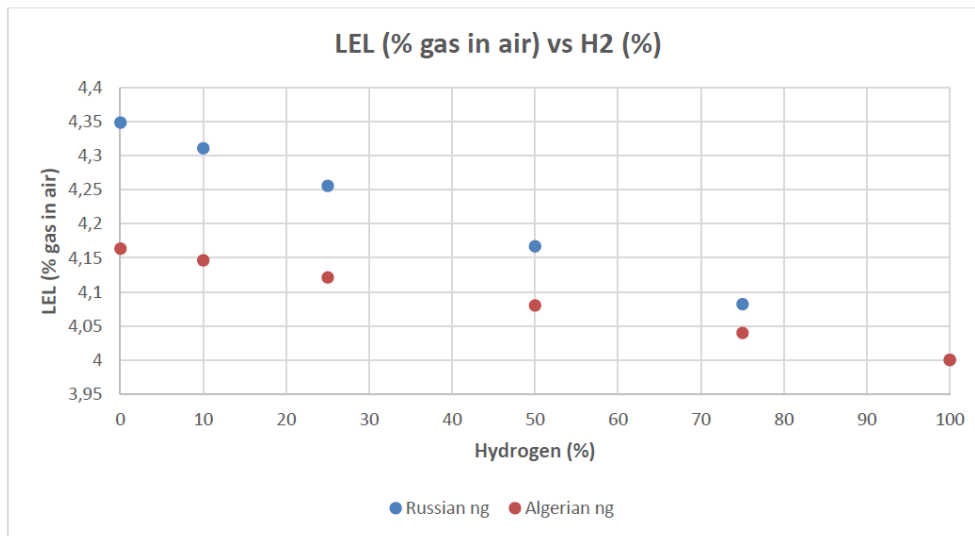
Black and Brown: Black coal or **Brown** lignite coal is used in the hydrogen-making process via gasification. These are opposite of green hydrogen in the hydrogen spectrum and are the most environmentally damaging.

Pink: Pink hydrogen is generated through electrolysis powered by nuclear energy. Nuclear-produced hydrogen can also be referred to as **Purple** or **Red** hydrogen.

There are several considerations for implementing hydrogen gas injection. These include but are not limited to:

- Hydrogen is explosive from 4 – 76 % gas in air
- A hydrogen flame is almost invisible and burns very hot (4000 ° F)
- Delivery, Storage and Infrastructure
- Injection percentage is typically 5 – 20 % for operational compliance
- Hydrogen is extremely small and light weight (lighter than natural gas)
- Hydrogen may leak through welds and threads in steel pipe
- Bulk leakage of hydrogen in PE pipe – low pressure usage typical
- Risk of hydrogen gas pockets by leaks and under low flow conditions
- Wobbe Index, Heating Value, LEL, End Use Compliance
- Hydrogen leak detector

Most notable is the explosive range and possible risk of forming pockets of hydrogen gas. Specialized materials may be required for hydrogen processing. A 5 – 20 % hydrogen gas in natural gas / RNG is a rule of thumb only. Actual samples and measurements should be performed for validation but most other aspects of odorization and operations may not need to change. Variations in LEL due to hydrogen mixing are relatively minor are shown in the following graph from Marcogaz:



Data calculated in reference to atmospheric conditions: pressure of 101,3 kPa and temperature of 20°C.

Figure 8. Hydrogen Gas Blend LEL vs Percent Gas in Air

49 CFR 192.625 (f)

Of key interest in subpart (f) are each operator must conduct periodic sampling and using an instrument (gas dilution apparatus) capable of determining the percentage of gas in air at which the odor becomes readily detectable.

Periodic Sampling

Periodic sampling intervals will vary depending on the combustible gas pipeline's status. Factors which affect the status include but are not limited to: distribution system spread, customer density, high consequence areas, pipeline maintenance, pipeline installation and the combustible gas pipeline operator's prior experience with odorization in their system. Periodic sampling intervals may vary from hours to weeks and will be location specific. Periodic sampling intervals should generally be uniformly spaced in time. Test locations for periodic sampling should be selected based on the status and characteristics of the distribution system. Both indoor and outdoor locations should be considered. Outdoor locations should be protected from wind during the tests and awareness of interfering odors from nearby sites (odor masking) should be considered. Potential locations include but are not limited to:

1. System end points.
2. Public buildings (hospitals, schools, etc.).
3. High consequence areas.
4. City gate stations.
5. Pipeline maintenance and repair segments.
6. Regulator or meter stations.
7. Customer meters.
8. No or low flow pipeline segments.

Gas Dilution Apparatus

A gas dilution apparatus for odor intensity monitoring shall be used for compliance. Gas dilution apparatus are typically designed to be compatible with the ASTM D6273-14. D6273-14 details two test methods. The most common and required method, odor concentration threshold, determines the percent gas in air level at which a person with a normal sense of smell first determines the odor is readily detectable as that of gas. This is referred to as the **Readily Detectable Level (RDL)**. The second method, odor intensity level, evaluates a pre-determined percent gas in air mixture for odor intensity and the gas dilution apparatus operator then judges the mixture using either Absent, Barely Detectable, Readily Detectable, Strong, Very Strong / Obnoxious or similar descriptors. International regulations employ similar descriptions using the Sales Scale. Both test methods may be used for the same test point. Immediate action shall be taken for test results not meeting 49 CFR 192.625, state regulations, international regulations or the limits defined by the combustible gas pipeline operator.

Higher values of the RDL are sometimes mistakenly viewed as being better or more desirable. Higher values obtained for the RDL actually indicate a lower concentration of odorant with a tendency to under odorize. Conversely, lower values of the RDL indicate a higher concentration of odorant and a tendency to over odorize. Very low values of the RDL will increase the number of customer leak calls. For example, assuming a combustible gas pipeline is filled with 100 % methane, one-fifth the LEL would be 1.0 % gas in air. A typical range at which the gas could be readily detectable can be 0.4 – 0.7 % gas in air. It is the responsibility of the combustible gas pipeline operator to establish and document an acceptable range that is in compliance with international, federal (49 CFR 192.625) and possibly with more stringent state and regional regulations.

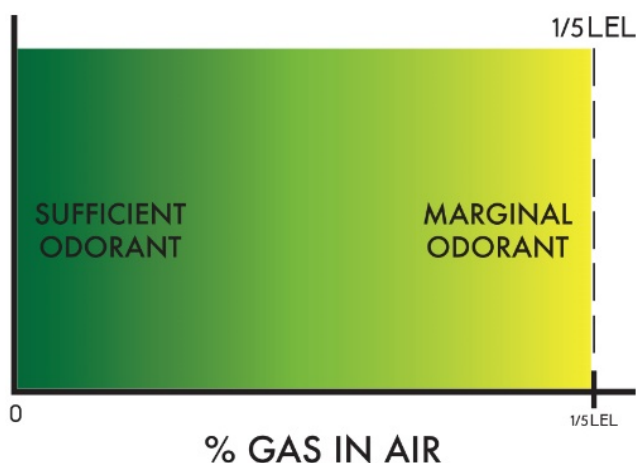


Figure 9. RDL in % Gas vs Odorant Level

A gas dilution apparatus generally works by mixing an operator-controlled flow of combustible gas with fresh air. The mixture is delivered to an exhaust port or chamber designed for evaluation (“sniffing”) by the operator. During the test, an operator should only briefly sniff the exhaust as repeated exposure to mercaptans will quickly lead to olfactory fatigue. It is recommended that the gas dilution apparatus operator follow the manufacturer’s operating instructions. The percent gas in air readout or display may be blanked out during the test to not influence the operator’s judgement. All gas dilution apparatus require periodic calibration as defined by the manufacturer. The operator should be trained and qualified personnel. A typical gas dilution apparatus block diagram is shown below:

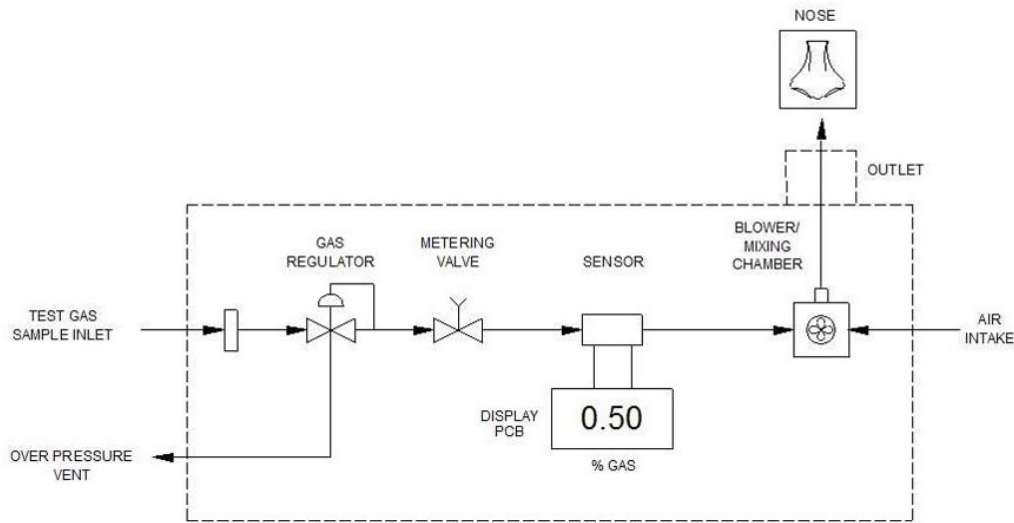


Figure 10. Typical Gas Dilution Apparatus Block Diagram

Special care is needed when connecting to a combustible gas test point as most gas dilution apparatus are low pressure instruments and are typically calibrated at inches of water column inlet pressures. An external cut regulator may be required. Measurements at elevation must be understood and accounted for as the air thins approximately 3 % for every 1000 feet of elevation increase. The combustible gas test sample shall be safe for the operator to sniff. Landfill (or any suspect) gas should be analyzed, cleaned up and upgraded prior to odor intensity monitoring.

Commercially produced gas dilution apparatus in the US, in chronological release date order, are the Bacharach *Odorometer*, Heath Consultants Incorporated *ODORATOR*, YZ Systems *DTEX* and the Heath Consultants Incorporated *ODORATOR 2*. The Bacharach *Odorometer* and Heath's *ODORATOR* are now discontinued but mentioned for support reasons.

Bacharach - *Odorometer*



The rate of gas flow reads out on the flowmeter on the right side of the panel. A glass float is provided for the range of 0.04% to 0.4%, and a stainless-steel float is provided for the range of 0.1% to 1.2%. The calibration chart applies to gases with a density of 0.620 and a chart on the inside of the cover door shows the correction factors to be used for gases of other densities.



Heath Consultants Incorporated - *ODORATOR*



The *ODORATOR* incorporates a mass flow sensor and a digital display. The *ODORATOR* mixes natural or propane gas with air in concentrations from zero to approximately 2% for natural gas or 1% for propane. Correction charts are included for both correcting and interpolating the instrument's readings over its full measurement range and when used at elevation.



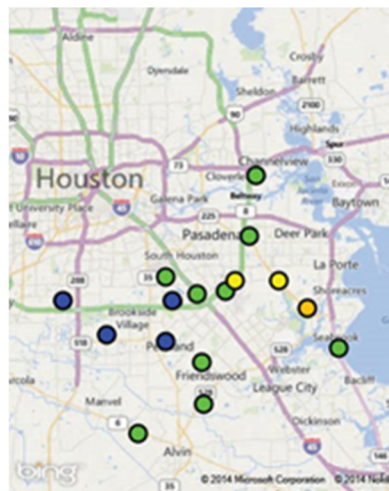
YZ Systems - *DTEX* Odorant Detection System



DTEX was the first microprocessor-based gas dilution apparatus for conducting odorant detection tests. It assists the user in quantifying the odorant level in natural gas with menu driven, step-by-step instructions. *DTEX* features on-board test and location data storage.

Reporter software is a data management tool that allows the operator to securely store test details electronically, such as odorant levels, locations, time and date, important notes and instrument errors.

Heath Consultants Incorporated - *ODORATOR 2*



The *ODORATOR 2* is the first microcontroller based GNSS (GPS) audit system. It contains on-board sensors to automatically correct raw readings for accuracy, actual test location pressure and actual test location temperature. Models support either natural gas (methane) or propane.

OdorSeer and OdorSeer Remote are PC software that supports custom configuration of the instrument and via its secure database provides readings mapping, data analysis, reporting tools and the import / export of remote field test data for ease of data integration and management.

Supplementary Information

The American Gas Association, in April 2017, released a complete update to their Odorization Manual for the natural gas industry. The Odorization Manual provides a wide scope and detailed guidance information submitted by highly knowledgeable and experienced industry professionals. It is strongly recommended to purchase and reference this manual.

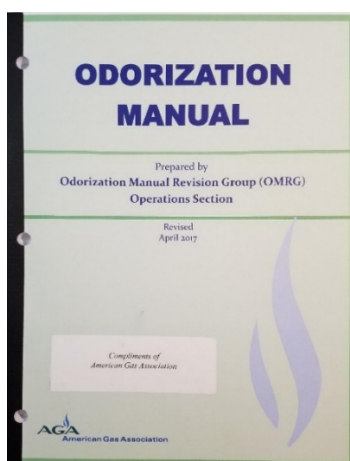


Figure 11. 2017 AGA Odorization Manual

Conclusion

The huge task of insuring that a proper odorization program has been implemented and maintained involves information gathering from several sources. There is no one piece of information that allows one to see the effectiveness of an odorization program but a combination of pieces to complete the picture. In the world today, critical attention must be focused on odorization programs to protect life, property and ensure **PUBLIC SAFETY**. Odor in a combustible gas leak is the public's primary leak indicator and without this warning the public would be in serious danger in the event a leak goes unnoticed. A properly documented and maintained odorization program will provide positive support in the event of litigation or regulatory review.

References

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