



Figure 1. Separator. *Courtesy of the National Fuel Gas Midstream Corporation*

Understanding Natural Gas Compressor Stations

Compressor stations are an integral part of the natural gas pipeline network that moves natural gas from individual producing well sites to end users. As natural gas moves through a pipeline, distance, friction, and elevation differences slow the movement of the gas, and reduce pressure. Compressor stations are placed strategically within the gathering and transportation pipeline network to help maintain the pressure and flow of gas to market.

Components of a Compressor Station

Natural gas enters a compressor station through station yard piping and is passed through scrubbers and filters to extract any liquids and remove solids or other particulate matter that may be in the gas stream (Figure 1). Once the natural gas stream has been cleaned, it is directed through additional yard piping to individual compressors. Computers regulate the flow and number of units that are needed to handle the scheduled system flow requirements. Most compressor units operate in parallel, with the individual compressor units providing the needed additional pressure before directing the gas back into the pipeline with full operational pressure restored. When the required boost in pressure is

very high, several compressor units may be operated in stages (serially) to achieve the desired pressure in stages.

As natural gas is compressed, heat is generated and must be dissipated to cool the gas stream before leaving the compressor facility. For every 100 psi increase in pressure, the temperature of the gas stream increases by 7–8 degrees. Most compressor stations have an aerial cooler system to dissipate excess heat (an “after” cooler). The heat generated by the operation of the individual compressor units is dissipated via a sealed coolant system similar to an automotive radiator.

In wet gas areas, or areas that produce natural gas liquids (NGLs), changes in pressure and temperature cause some of the liquids to drop out. The liquids that drop out are captured in tanks and trucked off site. The liquids captured are referred to as natural gasoline or drip gas, which is often used as a blend in motor gasoline.

Most compressor stations are fueled by a portion of the natural gas flowing through the station, although in some areas of the country, all or some of the units may be electrically powered primarily for environmental or security reasons. Gas-powered compressors may be driven by either conventional piston engines or natural gas turbine

units. There are site design and operational differences, as well as unique air and sound emissions, between these competing compressor engine technologies.

There may be one or more individual compressor units at a station, which can be out in the open, or more often, housed in a building to facilitate maintenance and sound management. Newer units are often housed one per building, but there may be multiple units in one large building. Compressor buildings generally incorporate insulated walls, shielded exhaust systems, and advanced fan technology to dampen sound. Newly constructed compressor buildings may incorporate these features where local, state, or federal regulations require noise mitigation (Figure 2).

Figure 2. Inside compressor building. *Courtesy of the Marcellus Education Team*



Compressor station yards for gathering lines are often larger than transmission line compressors due to multiple pipelines coming into the complex, and in some cases, additional equipment needed to filter and remove liquids from the gas stream (Figure 3). Other components of a compressor complex include backup generators, gas metering equipment, gas filtration systems, and system monitoring and safety controls. There may also be odorization equipment to add mercaptan, which provides the distinctive sulfurous odor to natural gas.

Permitting and Regulatory Framework

Compressor stations are either permitted and regulated at the federal or state level depending on the type of the pipeline the compressor services. For this publication, two basic types of pipeline/compressor systems will be discussed: gathering systems and interstate transmission systems. It should be noted that it is the purpose, not the size of the pipe, that defines whether a pipeline is a gathering or interstate line.

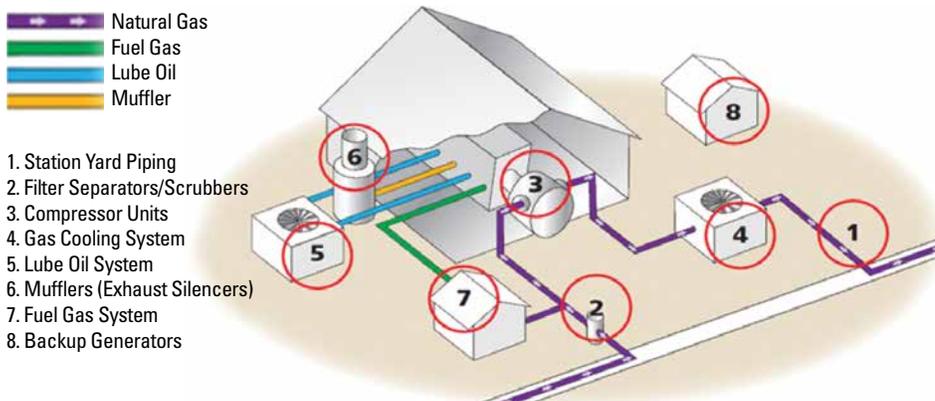
Compressor Stations within the Gathering System

Gathering lines are commonly smaller diameter pipelines (generally in the range of 6 to 20 inches) that move natural gas from the wellhead to a natural gas processing facility or an interconnection with a larger mainline pipeline. Gathering lines are regulated at the state level and compressor stations that

are part of a gathering system are also regulated by the state. In Pennsylvania, the Department of Environmental Protection (PA DEP) is responsible for environmental permitting and regulation during gathering system compressor planning and construction. The Gas Safety Division of the Pennsylvania Public Utility Commission (PA PUC) is responsible for safety oversight during construction and operation of certain Class 2, Class 3, and Class 4 locations. PA PUC regulation includes material and design specifications, on-site inspections, and review of company maintenance and safety procedures.

Natural gas within a gathering system can arrive at a compressor station at a variety of pressures depending on the pressure of the wells feeding the system and the distance gas travels from the wellhead to the compressor. Regardless of the incoming pressure, the gas must be regulated or compressed to transmission pressures (generally 800 to 1,200 psi) before it can enter an interstate transmission system. Because compression requirements can be significant within the gathering system, these compressor systems are generally large facilities consisting of 6 to 12 compressors in several buildings. Many of these gathering system compressor stations are scaled up in size as more wells are drilled in an area, increasing the demand for compression. The permanent land requirements of a gathering system compressor are generally 5 to 15 acres, but they can exceed this, considering slope of land and other factors.

Figure 3. Compression station yard. *Courtesy of Spectra Energy*



Compressor Stations within the Interstate Transmission System

Transmission pipelines are generally wide-diameter (20–48 inches), long-distance pipelines that transport natural gas from producing areas to market areas. These interstate pipelines carry natural gas across state boundaries—in some cases, clear across the country. The Federal Energy Regulatory Commission (FERC) has authority over the location, construction, and operation of interstate pipelines and com-

pressors. The FERC review process includes an environmental review, evaluation of site alternatives, and interfacing with landowners and the public.

Once federally regulated interstate compressor stations become operational, station safety is regulated, monitored, and enforced by the U.S. Department of Transportation (DOT). Within DOT, the Pipeline and Hazardous Materials Safety Administration (PHMSA) is responsible for enforcing proper design, construction, operation, maintenance, testing, and inspection standards.

Interstate transmission lines are regulated at the federal level and compressor stations that are part of an interstate transmission system are also federally regulated. Interstate compressor facilities must generally comply with local and state regulations; however, if there is a conflict, the more stringent regulations will prevail.

Natural gas within an interstate pipeline is generally already pressurized at 800 to 1,200 psi. To ensure that gas continues to flow optimally, it must be periodically compressed and pushed through

the pipeline. Friction and elevation differences slow the gas and reduce the pressure, so compressor stations are placed typically 40 to 70 miles apart along the pipeline to provide a boost in pressure. Because they are only providing a boost in pressure, interstate transmission system compressors are generally smaller facilities compared to gathering system compressors. A typical facility may consist of two compressor units (one that is operational and one that serves as a backup unit) within a single building. The typical permanent land requirement of an interstate compressor is 4 to 5 acres.

Safety Considerations

Compressor stations incorporate a variety of safety systems and practices to protect the public and station employees in the event of an emergency. For example, every station has an emergency shutdown system (ESD) connected to a control system that can detect abnormal conditions such as an unanticipated pressure drop or natural gas leakage (Figure 4). These emergency systems will automatically stop the compressor units and isolate and

Figure 4. Emergency shutdown valve on incoming pipeline. *Courtesy of the Marcellus Education Team*



vent compressor station gas piping (sometimes referred to as a blow down). Regulations require that compressor stations periodically test and perform maintenance on the emergency shutdown system to ensure reliability. It is advisable for landowners, neighbors, and first responders to become familiar with safety systems, testing procedures, and emergency response protocols for compressor stations in their area.

Odorization

Natural gas is a colorless, odorless gas, so an odorant, typically mercaptan, is added to the gas stream as an additional safety mechanism. Odor-

Table 1. Compressor station regulation. The following matrix is provided as a basic overview of compressor station parameters that are regulated and the agencies involved.

	Gathering System Compressors (PA)		Interstate System Compressors (Federal)	
	Agency	Regulation	Agency	Regulation
Air Emissions	PA DEP	Revised GP-5 permit.	EPA and PA DEP	Clean Air Act
Noise Emissions	None*	*Municipalities may have local noise ordinances that would apply to compressor stations within the municipality.		Noise must not exceed a day-night average level of 55 decibels at any preexisting noise-sensitive area (NSA) such as schools, hospitals, or residences.
Erosion and Sedimentation	PA DEP	Chapter 102: erosion and sediment pollution control regulations.	FERC	FERC works in cooperation with county Conservation Districts to implement these regulations.
Siting	PA DEP (limited)	Chapter 105: waterways and wetlands permitting.	FERC	FERC scoping, environmental review, and public input.
Vibration	None		FERC	Companies are required to comply with FERC's rule at 18CFR 380.12(k)(4)(v)(B) to ensure there is no increase in perceptible vibration from the operation.
Operation, Maintenance and Safety	PA PUC	Material and design specifications, on-site inspections, review of maintenance and safety procedures.	US DOT PHMSA	Material and design specifications, on-site inspections, review of maintenance and safety procedures.
Public Input	PA DEP	45-day comment period on proposed general permits.	FERC	Public may submit input on a proposed compressor station during several stages of the FERC review process.
			PA DEP	25 Pa. Code 127.621 25 Pa. Code 127.44

ization of natural gas in Interstate and gathering transmission systems is regulated under Title 49, part 192 of the Federal Code of Regulations, which requires transmission lines in highly populated areas (Class 3 and 4 locations) to be odorized. High-consequence areas are subject to added layers of regulation to ensure public safety. "Class location" is a term used in the regulations to denote the population density surrounding the pipeline. Class location is determined by the number of dwelling units within 220 yards in a sliding mile of the pipeline. Classes 3 and 4 are those locations with 46 or more buildings or a building occupied by 20 or more persons at least 5 days a week for 10 weeks (schools, community centers, etc.). Transportation pipelines in Class 1 and 2 locations—rural areas with fewer than 46 buildings per sliding mile—are exempt from the odorization regulations. On a practical basis, gas that is odorized for a Class 3 or 4 location "upstream" will retain some level of odorant in the gas stream as it travels through Class 1 and 2 areas.

Community and Landowner Considerations

Although some oil and gas leases and pipeline easement agreements may allow the construction of compressor stations on the leased acreage, most compressor station agreements are negotiated as a separate contract with the landowner. When dealing with mineral leases, rights-of-way, or other agreements, it is generally advisable to keep the agreement as narrow as possible and not allow the placement of surface structures—such as compressor stations—within the agreement. By doing this, the landowner may be able to receive additional value from a compressor lease and can concentrate on negotiating terms that are unique to a compressor lease or sale (or avoid it altogether). For example, site location, sound mitigation, traffic, and lighting restrictions may be more important considerations in a compressor site than other agreements. If a compressor station is

already included in a mineral lease or a pipeline agreement, the landowner may want to ask the operator for a surface use agreement to provide guidelines and restrictions for construction of a compressor station; however, this is usually easier to negotiate *before* you have signed a mineral lease. Refer to Penn State Extension publications "A Landowners Guide to Leasing Land in Pennsylvania" and "Negotiating Pipeline Rights-of-Way in Pennsylvania" for more information on mineral leasing and right of way considerations.

Lease or Sell the Site?

Compressor operators may have a preference to own the property rather than lease the acreage where the compressor station is built. Landowners should consider the implications of selling versus leasing their property for a compressor station. Selling the site may alleviate some concerns for landowners such as liability, property taxes, trespass, and site reclamation. Payment for the sale of a site usually occurs up front and in full without the possibility for additional, ongoing payments.

Leasing the property may provide the landowner more control over siting and design considerations of the compressor station. A landowner may require buffers to diminish sound and sight disturbance. Leasing may give landowners more leverage during the construction and operations phases of the compressor station—a midstream company on a lease may be quicker to respond to a landowner from whom they are leasing. Either way, it is important for landowners to consider the agreement and how it may affect their bottom line and lifestyle. Income tax and property tax implications should also be considered in the decision to lease or sell.

Valuation

How much is a site for a compressor station worth? The answer can vary significantly depending on location and the individual landowner's threshold for negotiating terms and conditions of the sale of lease

agreement. If terms are not met, is the landowner willing to compromise? Landowners should consider whether the project will interfere with their land, lifestyle, and/or farming operations. Some items for consideration in negotiating a price might include:

1. The amount of land required
2. The amount of land disturbed (temporary and permanent)
3. The real estate value of the land
4. The impact on the use and value of your remaining acreage
5. Potential interference with agriculture operations
6. Value of recent compressor site leases and sales in your area

Remember, there is no set dollar amount that a landowner must accept, but the value of recent site leases and sales provide a general indication of what the industry is willing to pay for similar agreements in your area.

Clean and Green Program

Clean and Green is a preferential assessment of property tax that encourages the preservation of farm, forest, and open land in Pennsylvania. The Clean and Green law allows the portion of property that is set aside for oil and gas operations to be set aside without penalty that would affect the entire property. The portion of property affected will be subjected to roll-back taxes (up to 7 years and a charge of 6 percent simple interest) and will be assessed at full market value in the future. Landowners enrolled in Clean and Green or any other preservation or conservation program should consider having legal counsel review and amend the agreement stating that the lessor or purchaser assumes payment of any back taxes or penalties assessed as a result of the agreement.

Site Considerations

Site Considerations Compressor station sites have varied widely in the number of acres disturbed during the construction phase and land permanently used during operation.

Figure 5. Compressor station. *Courtesy of the Marcellus Center for Outreach and Research*



(Figure 5). This could range from 3 acres to more than 20 acres per site; an average gathering system compressor site built in the last few years may be 12 to 15 acres, but earth moving, soil stockpiling, and access roads will add to the total disturbed acreage. Landowners may wish to specify a limit on disturbed acres and the amount of land allowed for permanent use. The areas for temporary use or construction rights-of-way should be clearly spelled out in terms of use and the amount of time it is good for (e.g., “temporary” does not have a definition in an agreement until the landowner sets parameters such as 6 months or 1 year).

Sound Emissions

Compressors can generate a significant amount of noise depending on the type of compressor, sound mitigation technologies used, the slope of the land surrounding the compressor, and other factors. Landowners may wish to consider noise as it affects them and their neighbors when negotiating a compressor station agreement. Compressor station operators often incorporate some level of noise mitigation in their site design, but the landowner may want to include minimum standards in their lease or sale agreement.

Currently FERC requires that the noise level can be no greater than 55 decibels day/night average sound level (dBA Ldn) at the closest noise sensitive area (NSA). Noise

sensitive areas would include occupied residences, places of worship, and other locations. This requirement only affects compressor stations that are regulated by FERC, which would include the interstate pipeline system in Pennsylvania, but does not include compressors that are tied into gathering lines. Some municipalities (counties, townships, boroughs) have their own ordinances in place that limit noise. If there is an ordinance in place, consider asking your municipal officials for a copy of the ordinance.

There are no overriding state regulations governing noise emissions from compressor stations in Pennsylvania. If the proposed facility is not under FERC jurisdiction and the municipality does not have a noise ordinance in place, landowners should consider adding minimum standards in their lease/sale agreement. Landowners may also consider future residential development in the area of the proposed compressor site. One consideration is to place a noise restriction at the edge of the compressor site (e.g., no more than 60 dBA Ldn from the edge of the compressor site) rather than a restriction to the closest noise sensitive area.

Air Quality

Most natural gas compressor stations are powered by combustion engines, which vent exhaust emissions into the atmosphere. In 2013, PA DEP implemented stricter emission standards for compressor stations through a revised GP-5. PA DEP has established a comprehensive air emissions reduction program for the natural gas compression and processing operations.

PA DEP has developed a compliance certification form and sample worksheet to assist the regulated industry with the submission of compliance certifications due by March 1 of each year. The US EPA also regulates air emissions from compressor stations under statutes in the Clean Air Act.

Compressor stations can be a potential source of methane emissions. In 2012, EPA estimated that as many as 45 percent of methane emissions in the natural gas transportation and storage sector were from traditional reciprocating compressors (EPA estimated that the transportation and storage sector was responsible for 27 percent of overall methane emissions from the oil and gas industry). To curb methane emissions in the oil and gas

Table 2. Comparative examples of sound levels.

(See extension.psu.edu/business/ag-safety/health/e48)

Sound Levels in dBA	General	Agriculture
0	Threshold of hearing (weakest sound)	
40	Quiet office, library	
50–60	Normal conversation	
55–70	Dishwasher	
74–112		Tractor
77–120		Chainsaw
79–89	Riding mower	
80–105		Combine
81–102		Grain dryer
83–116		Crop dusting aircraft
85–106		Orchard sprayer
85–115		Pig squeals
88–94		Garden tractor
93–97		Grain grinding
110	Leaf blower	
110–130	Rock concert	
125	Jet plane at ramp	

Sources: *Hearing Loss in Agricultural Workers*, National Safety Council, Itasca, IL; League for the Hard of Hearing, New York, NY.

industry, EPA developed the Natural Gas STAR program, which is a flexible, voluntary partnership to encourage oil and natural gas companies to adopt cost-effective technologies and practices to reduce emissions of methane. Many companies within the industry have joined the Gas STAR program and are in the process of implementing methane-reducing practices and technologies. EPA has recently announced the Gas STAR Gold program to recognize facilities that implement a comprehensive suite of protocols to reduce methane emissions. The Gas STAR Gold program is scheduled to launch in 2015.

In addition to any state air quality permit requirements, FERC jurisdictional compressor stations undergo a review under the National Environmental Policy Act (NEPA). The FERC environmental document will address both construction and operational air emissions from the compressor station, as well as soil, site restoration, and visual impacts.

Light and Traffic

Light and traffic in and around compressor facilities can be significant during construction and operation. Traffic is somewhat of an unavoidable issue because equipment, materials, and workers will be traveling to the site every day. A landowner may be able to negotiate a restriction of heavy truck traffic and movement of equipment to and from the site during certain hours (during the overnight hours, for instance).

Sky glow or light pollution is a brightening of the night sky caused by artificial light scattered by small particles in the air such as water droplets and dust. Methods to reduce light pollution include directed lighting and the use of shielded light fixtures so that less light escapes to places where it is not wanted or needed. Directed lighting and shielded light fixtures are points that could be addressed in a site lease/sale agreement.

Soil Mitigation and Site Restoration

Significant soil disturbance and compaction often occurs during construction in the temporary work area surrounding the compressor site. This can result in reduced crop yields on agricultural soils and reduced tree growth on forested soils for several years. Steps should be taken to minimize soil compaction throughout the construction process and to mitigate compaction during restoration. Such steps include using only low-ground-pressure construction equipment and ceasing operations when soils are wet and most susceptible to compactive forces. After replacement of subsoil material and grading of the easement, the entire area should be deep ripped to a depth of 16 inches to loosen the exposed subsoil. The stockpiled topsoil should then be replaced over the easement, again taking steps to avoid compaction. The replaced topsoil should then be loosened by deep ripping to a depth of 16 inches, and on agricultural soils, any rocks brought to the surface should be collected and removed. Recovery of full productivity of agricultural soils can sometimes be accelerated by incorporating compost or manure in the topsoil.

Visual Impact on the Landscape

Compressor sites can often create a lasting visual impact on the landscape once they are built. There are several strategies that can be employed to mitigate these visual impacts and blend a compressor station and related natural gas infrastructure into the landscape. Visual impact considerations can be negotiated into a site lease/sale agreement as one would negotiate value, sound emissions, or any other consideration.

Building Design

Compressor buildings in historic districts and other visually critical areas have been built with design features that mimic surrounding architecture. In rural areas, a compressor building that looks like a barn or other agricultural structure will be less obtrusive than a conventionally built compressor.

Site Location

Some locations naturally lend themselves to visibility such as facilities built on a hill or ridge. Locating a compressor station in a less visible spot or out of direct line-of-sight of neighbors will be less visibly intrusive.

Screening

Mounding soil, solid fencing, and/or planting evergreen trees and shrubs strategically around the facility will help further hide and screen a compressor site from view. These techniques may also help mitigate noise emissions from the site.

Municipal and Zoning Considerations

While the ability of municipalities to apply local zoning ordinances to compressor facilities may be limited and can vary between governmental jurisdictions, there are some aspects of building design and construction where a municipality may have input (either via a local zoning regulation or cooperative agreements with the operator).

Design features such as stormwater runoff from the new facility, building design, lighting, sound emissions, and setbacks from existing buildings are examples of considerations that may be addressed at the local level—again, either through local regulation or cooperative agreements. Municipal officials may also want to consider coordinating and/or participating in emergency response trainings for natural gas compressors and other pieces of infrastructure located within the municipality.

Right of Condemnation or Eminent Domain

Much of this publication discusses issues specific to Pennsylvania. While many of the issues and considerations presented in the publication are universal, important differences regarding the right of condemnation or eminent domain exist between states. In Pennsylvania, the decision to grant a gathering system compressor agreement rests solely with the surface

landowner. Some states (Ohio, for instance) operate under a “common carrier” statute that may allow condemnation of land for the placement of gathering lines and related infrastructure “as necessary and for a public use.” In some cases, compressor stations may fit under this definition (defined state by state) and therefore have the ability to exercise eminent domain for the taking of land to use to build and operate a compressor station.

On the other hand, operators constructing compressor stations as part of the interstate natural gas transmission network are granted the right of condemnation once they receive a “Certificate of Convenience and Public Necessity” after completing the FERC review process. This does not mean that the landowner should not take an active role in negotiating compensation and terms when dealing with the possibility of condemnation. In many cases, a mutual agreement between the landowner and the operator can be reached without going through an eminent domain proceeding. Regardless of the type of facility, landowners and others dealing with compressor station agreements should seek legal advice from an experienced oil and gas attorney in their respective states before signing any agreement.

Extension’s Role

Penn State Extension provides educational resources for landowners and other stakeholders about shale gas development. County extension offices may host an educational workshop, discuss leasing arrangements, or refer you to regulatory or legal specialists.

Although extension educators cannot provide legal advice, they can provide additional insights about leasing and right-of-way considerations.

For more information about Marcellus shale, natural gas development, leasing, and pipeline rights-of-way, visit the Penn State Extension Natural Gas website.

Resources

Publication

Federal Energy Regulatory Commission, “An Interstate Natural Gas Facility on My Land? What Do I Need to Know?” Washington, D.C.: U.S. Government Printing Office, 2009. www.ferc.gov/for-citizens/citizen-guides/citz-guide-gas.pdf.

Websites

Penn State Extension Natural Gas Website: extension.psu.edu/natural-resources/natural-gas

Pennsylvania Department of Environmental Protection (PA DEP) Bureau of Air Quality: www.portal.state.pa.us/portal/server.pt/community/bureau_of_air_quality/14528

Put Our Experience to Work for Your Community

The Penn State Extension Marcellus Education Team strives to bring you accurate, up-to-date information on natural gas exploration and drilling in Pennsylvania. Learn about your rights and choices as a landowner, a businessperson, a local official, or a concerned citizen. Discover the resources available to you.

Visit naturalgas.psu.edu.

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The Agricultural Law Resource and Reference Center is a collaboration between Penn State's Dickinson School of Law and Penn State's College of Agricultural Sciences. Located at both the University Park and Carlisle facilities and funded in part by the Pennsylvania Department of Agriculture, the center is designed to provide the highest-quality educational programs, information, and materials to those involved or interested in agricultural law and policy.

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