A Simple Perspective on Excess Flow Valve Effectiveness in Gas Distribution System Service Lines

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by
Richard B. Kuprewicz
President, Accufacts Inc.
kuprewicz@comcast.net
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Accufacts Inc.
"Clear Knowledge in the Over Information Age"

This report is developed from information clearly in the public domain. The views expressed in this document represent the opinion of the author and not necessarily those of the Pipeline Safety Trust. The author invites all parties to review this paper and develop their own opinions on this very important matter.

Executive Summary

Much activity has occurred in the past decade and heightened discussion is currently occurring regarding the installation of excess flow valves, or EFVs, in gas distribution service lines. Current federal regulation requires a gas distribution company to offer such a device on new or replacement service line installations that operate above 10 psig, with the customer picking up the cost of the installation.[1] This offer program has not resulted in a large percentage of eligible service lines installing this relatively inexpensive safety device for various reasons. As in most issues nowadays, there are extreme positions, emotions, and opinions on the value of such devices, whether they are cost or risk effective, or should be mandated. This paper provides focused technical observations translated in simple terms that should assist the public in making informed decisions on this very important matter. Based on our analysis, we conclude that EFVs should be mandated for all new service line installations and replacements that operate at or above 10 psig.[2]

The Bottom Line Supporting Mandate of EFVs

- Add Little Cost on New or Replacement Service Line Installations
- The Valves are Cheap ($5 - $15/Unit)
- Prevent Many Disasters Associated with Service Lines
- Newer Bleed-by Type Does Not Require Excavation for Reset
- The Current "Offer" System on EFVs is Not Getting Valves Installed
- One Call Education is Not Preventing Many Service Line Failures
- Rise in Gas System Pressures and Greater Use of Plastic Increases Risks of Service Line Disasters

As discussed in this report, EFVs are an important safety device that can cost effectively and significantly reduce the likelihood and consequences of high rate high volume gas releases on distribution service line triggered events that have proved so tragic in past years. Because of population growth across the country, many distribution systems are increasing their operating pressures to meet demand, further increasing the risks of high rate releases (See Figures 1 through 3 on pages 9 and 10). Based on our extensive experience across the U.S., many distribution service line failures resulting in high rate gas releases are initiated by third party damage. While we encourage further regulatory efforts to improve third party damage prevention, especially in the area of enforcement, these

[1] 49CFR192.383, Excess flow valve customer notification requires that the customers of single family residences be offered this safety device on new or replacement service line installations. Ironically, through a gap or loophole in notification procedures, many actual homeowners may never be provided the opportunity or sufficient information to make such an important technical decision.

[2] The limit of present EFV technology requires a minimum operating pressure of 10 psig. There are many technical challenges preventing the application of EFVs in the subcritical flow regime (less than 10 psig).

efforts are not adequate in avoiding service line failures. As discussed in this report, only the installation of EFVs provides sufficient protection of the public from high rate high volume gas releases from all too many service line failures. The time for EFV study is over, and we need to move forward with clear regulatory efforts to mandate installation of EFVs on new service line installations.

Currently the costs of EFVs are not captured in a distribution company's rate base. The majority of costs associated with an EFV (the devices are now only a few dollars per unit), are driven by the engineering evaluation, installation, and future servicing efforts, if any, which may be associated with each installation. This author believes that all costs connected with these mandated safety devices should be included in the distribution company's rate base (including a bona fide rate of return). The total costs of EFVs, in the range of cents or less per MMSCF,[3] are a very small price to pay to insure important infrastructure is prudently safe in an era where gas prices are increasing or swinging at dollar levels because of commodity plays.

Gas Distribution Systems – A Brief Overview

A short description of gas distribution systems is warranted to provide a proper background in the EFV debate and discussion. Gas distribution systems are considerably different in many ways from gas or liquid transmission pipeline systems. The most significant is that distribution systems operate at much lower pressure levels than transmission systems. Lower pressures, and thus lower pipe stress levels, result in distribution pipeline releases acting as leaks with the hole size remaining at the original size for some time, rather than as ruptures.[4] In the U.S., distribution systems consist of network grids of larger pipe supply mains, smaller pipe service lines, and meter assemblies (usually a combined meter and let down pressure regulator in one unit). Gas mains and service lines connected to the mains can run from 10 to several hundred psig pressure depending on the design or operation of the specific system. The service line brings gas from the main (usually in the street) to the meter set/regulator where pressure is further reduced down to that of the low pressure home system which is usually at most a few psig or even lower (i.e., inches of water). The EFV debate deals with the failure risks associated with the service lines that have resulted in much loss of life, usually because gas leaks on the service line have somehow migrated into a building and exploded.

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[3] MMSCF stands for million standard cubic feet. Standard cubic feet, or SCF, is one standard of measurement in the industry and can be easily converted to mass.

[4] Ruptures usually refer to pipe failures such as cracks, corrosion, or punctures associated with high stressed pipelines that go "unstable" and rapidly (in microseconds) propagate down the pipeline, considerably enlarging the initial failure. In distribution systems, certain older plastic pipe can fail as unstable cracks, even at the lower stress levels, enlarging the failure opening, (See OPS Advisory Bulletin ADB-02-07). These low-pressure "brittle-like" plastic pipe crack failures, however, will not "shrapnel" like the high stress very high-energy gas releases associated with steel transmission pipeline rupture failures.

Presently, distribution systems in the U.S. consist of approximately 1.9 million miles of pipe, 1.1 million miles of mains and 0.8 million miles of service lines.[5] Unlike transmission pipelines, distribution systems can be constructed of a variety of different materials. Cast or wrought iron can be found in older systems, while steel or various different plastics have been utilized for many decades. There are also a small percentage of these systems consisting of other metals such as copper. The service lines, the smaller diameter pipes running from the gas mains to the meter/regulator stations, usually consisting of pipe 1 inch or less in diameter to single-family homes, vary in length from a few feet to many hundreds of feet. New service lines are constructed either of steel or plastic. Plastic may be coiled plastic tubing rather then pipe for various reasons. Plastic has cost advantages over steel, especially in the areas of material, installation, and maintenance costs. For example, plastic is usually easier to install via underground boring and doesn't require the additional costs associated with Cathodic Protection (CP) systems that steel services lines may need. Even though the percentage of plastic versus steel service lines varies from region to region, plastic is now the predominant material in new service line installations across the country.

Ownership of service lines, as well as responsibility for leak repair, varies across the U.S. In some states the distribution company owns and is responsible for the service line (usually up to the meter, before gas enters the home). In some states the homeowner owns and is responsible for the service line. In other states the homeowner may own the service line but the gas distribution company is responsible for leak checking the service line periodically. There is considerable diversification across the country on ownership and responsibilities that can leave homeowners confused.

There is also no set design or standard on where to locate service lines or meters (usually a local code issue). Service lines may run considerable distances from the main with the meter/regulator located next to a building (most common). The meter set in some areas may be located near the street with a low pressure supply line (not a service line) running from the meter/regulator to the building. This supply line will be at the lower home system pressure. Pressure in the service line is determined by the pressure on the gas main, or header, it is connected to. Gas main pressures usually do not vary considerably in day-to-day operation. It is worth noting an important risk factor for gas distribution systems. Because of growth demand, many distribution companies are faced with increasing their system pressures to increase gas supply within existing infrastructure. Such a pressure increase raises the risks of high gas rate high volume releases from service line failures. EFVs are safety devices that can quickly activate (in seconds) and shut off gas to avoid high gas volume releases associated with many service line failures.[6]

[5] American Gas Foundation, "Safety Performance and Integrity of the Natural Gas Distribution Infrastructure," January 2005, page 2-1.
[6] The minimum operating pressure of EFVs is currently 10 psig. Most gas service lines operate at pressures above this limit and are candidates for EFV installation.

Service Line Failures

In gas distribution system service line failures the biggest dangers and consequences result when gas releases either migrate or are diverted into buildings or structures that can allow the lighter than air natural gas to accumulate. Such migration can still occur even when a release geysers straight out of the ground above a service line failure site. There are many well-documented cases of gas service line failures that have resulted in serious lose of life and buildings as outside releases seeped into structures via various underground pathways or other ingress points.[7]

Service line failures can take many forms. For either metal or plastic service lines releases can be 1) cracks or minor gaps in the lines, seals, couplings, valves or other joints for various reasons, 2) holes ranging in size from pinhole to larger, or 3) "full-bore" failures where the line is, for all purposes, essentially severed or separated and gas is flowing out of the full internal diameter of the service line. Some cracks can be most difficult to determine, as they can be intermittent because of their tighter nature especially if caused by intermittent loading. Other more serious cracks, mainly for some older plastic pipe, can escalate to a full-bore failure release such as that for the brittle-like plastic failures mentioned earlier. Holes in service lines can be formed from corrosion in metal pipe, punctures from third party damage, rubbing or rock impact, or electrical interference such as arcing and melting of either metal or plastic pipe. Seals can leak with time, or because of poor installation, gas composition changes, or pressure increases, and coupling connections can separate (such as when a excavator pulls on a service line) to mention just some of the more common release scenarios.

EFVs Can Prevent Disasters From

Contractor or Homeowners Digging Through Service Line
Wayward Damage Caused by Boring Tools Such as for Cable or Phone
Downstream Service Line Connections That Fail (i.e., Earth Movement)
Service Line Damage Caused by Poor Locates

Regulations permit some gas leakage on gas distribution systems. No distribution system is without leaks. Gas in distribution systems is odorized to help call attention to leaks. Unfortunately, the unique odor of gas cannot always be reliably depended upon to identify gas releases. Small rate leakage, which does not migrate into structures, may not present major safety problems as gas is lighter than air and for small rate leaks usually dissipates into the air. A prudent pipeline operator will monitor the number and type of leaks, even the small ones, regardless of where they occur in a given area. All leaks need to be properly tracked, monitored, and evaluated as they could suggest a more serious systematic problem that can quickly turn into a much more dangerous situation.

[7] National Transportation Safety Board Publications web page on Pipeline Accidents, http://www.ntsb.gov/Publictn/P_Acc.htm

An acute problem is created when gas does migrate into structures and accumulates. When natural gas mixes with air in the presence of an ignition source (doesn't have to be a flame) a serious explosion with very high blast destructive forces can result. This is an all too demonstrated fact despite the narrow flammability range of natural gas (approximately 5 to 15 vol % in air). All gas leaks transition through the flammability range and the vast majority don't burn or explode. The "trick" is to not generate an ignition point within these limited zones in the "wrong" location. Again, ignition doesn't have to be a flame, and ignition generation or avoidance is seldom under the control of the responder. Static electricity can become an ignition source, for example.

EFVs Won't Help

- In Low Pressure Service Lines
- Slow Leak in Service Line From Corrosion or Minor Damage
- Failure in the Gas Home System Piping
- Appliance Failure
- Earthquake Damage Within the Home

What is an EFV?

EFVs are mechanical devices inserted into gas service lines that permit gas to flow through them with a low pressure drop, but automatically close when a certain, non adjustable flow value (minimum trip flow) is exceeded.[8] EFVs are high precision but simple devices to insure high reliability. Not to make light of the manufacturing process, but EFVs for gas distribution service lines are based on a simple principle that flow forces (flow and pressure are related) across a disk or "poppet" drive against and compress a spring trying to hold the valve open. When the flow forces are high enough, the spring is compressed sufficiently to close the valve. EFVs are of basically two types: positive shutoff or bleed-by.

For positive shutoff EFVs, the poppet latches close at a set spring compression cutting off the gas flow down the service line.[9] Once latched, the valve remains closed regardless of downstream service line conditions. Positive shutoff EFVs must be manually unlatched or reset to the open position once activated. This usually requires that the EFV be dug up in order to reset and return gas service, which can be very time consuming and expensive. Access to the EFV valve may not be easy because they are usually buried and can be located in difficult to reach locations, such as under roadways or sidewalks where the main headers may be situated.

Bleed-by EFVs do not latch when the flow or pressure differential force compresses the spring to seat the disk or poppet closed. A small hole, groove or flow path is drilled

[8] The web site, http://www.gasindustries.com/articles/gisept01b.htm provides an excellent starting point for those seeking additional information on EFVs.

[9] 49CFR192.381(a)(3)(ii)(B) permits a slight leakage of gas through the valve seat of a positive shutoff EFV (not more than 0.4 CFH).

through the disk or poppet to allow the pressure across the closed valve to equalize when the downstream service line break has been repaired and the downstream pressure returned. This pressure equalization path allows a small flow of gas through the closed EFV, but this rate is restricted by federal pipeline regulations.[10] As a matter of reference, a home may utilize approximately 5 to 100 SCFH in a mild but cool climate, 60 °F, (these values will range considerably across the country).[11] The advantage of bleed-by EFVs is that they only require that the source of the excess flow, usually a release, be corrected and the downstream line blocked in to pressure balance the service line across the EFV, automatically resetting the valve to the open position. Bleed-by EFVs avoid the expenses and difficulties associated with digging to get to the EFV to reset the valve once tripped, but allow more gas to bleed through. Most of the EFVs now being manufactured are of the bleed-by type.

The design intent of any EFV is to protect the public from certain major failures of the higher-pressure service line downstream of the EFV and before the regulator/meter set which lowers the gas pressure before it enters a building or home. EFVs are not intended to protect from failures of the lower pressure gas supply system downstream of the regulator. Many locations in the U.S. are permitted to locate their meter set at the edge of large property near the road. In such designs, an EFV will not provide protection for the long low-pressure supply lines (sometimes several hundred feet long) running to the home.

To receive maximum protection from service line failures, an EFV is located on the service line as close as possible to the main. In some cases this is on the main where the service line actually connects into the main (usually on top). In other situations the EFV is actually installed in the run of the service line a little farther downstream of the main as the site permits. It is important to recognize that EFVs are manufactured in certain fixed capacities. There is a fine balance between the valve's capacity, the homeowner's actual gas demand including gas surges and seasonal variations, and the trip setting of the valve, so choosing the right EFV capacity is important. Sufficient gas can release before an EFV activates if an excessively large capacity has been inappropriately selected for a particular installation, preventing the valve from activating. As shown later, given the large increases in gas rate associated with large hole high pressure service line failures, choosing the right EFV capacity should not be a problem for an experienced gas company engineer. It is also a good idea to contact the gas company before adding new major gas demand, such as a new spa heater, after an EFV has been installed. Otherwise the new demand may be sufficient to trip the EFV leaving the homeowner with a real gas shortage. Not all service line leaks that can be dangerous, such as very low rate gas seepages that can still end up seeping and accumulating into a building, are prevented with an EFV. A review of the many NTSB reports on gas distribution system incidences will clearly demonstrate that the vast majority of these tragedies investigated by the NTSB are of the type that could have been prevented by EFVs.

[10] 49CFR192.381(a)(3)(ii)(A) sets a maximum leakage rate for bleed-by EFVs at a maximum of 5% of the manufacturer's specified closure flow rate, up to a maximum of 20 CFH. The 5% maximum usually sets the limit for a home much lower than the 20 CFH.
[11] SCFH is Standard Cubic Feet per Hour.

It is important to note that there are gas distribution systems where an EFV cannot be utilized because of the quality of the gas. Some areas of the country take a significant percentage of their gas directly from gas production wells, bypassing treatment plants. Areas of the country where the distribution system may pass untreated gas with a higher risk of particulates, and especially minor volumes of liquids, can hinder EFV reliability or effectiveness. Minor liquid slugs can gum up or even trip such devices as liquid carries more flow momentum than dry gas on these flow sensitive devices. Current federal regulations appropriately exempt EFVs in service line applications where gas quality could be a problem.[12] It is important to note that quality of gas reasons for exempting the use of EFVs on any particular system should undergo careful review and scrutiny to insure this wavier is not applied abusively. In a related issue, some service lines may need to be blown down periodically to clear them. It is incumbent on operating personnel to recognize the procedures that need to be utilized concerning tripping or reset of EFVs on such systems.

Gas Service Line Releases

Compressibility and flow dynamics of natural gas play an important role in the decision concerning EFVs in service line applications. To understand the release nature of natural gas distribution systems, one must have an appreciation for gas critical flow and subcritical flow. For upstream pressures (the mains) above approximately 10 psig, leaks on service lines will release at a fixed sonic velocity (the critical value) with mass flow highly influenced by the upstream pressure.[13] Sonic velocity is approximately 1400 plus ft/sec which sounds like a large number, but the momentum, mass times velocity, is low compared to the much more destructive and higher momentum releases of gas transmission ruptures (the big crater events). Note, though, that on higher pressure distribution service line failures, gas has been known to “geyser” out of the ground because of the greater momentum.

For natural gas mains and service lines operating at pressures below approximately 10 psig, leaks will flow below sonic velocity. We call this subcritical flow and gas rate of release will be mainly controlled by piping system flow resistance, largely in the service line to the “hole release point.” Subcritical releases are at a much lower leak rate than that for sonic flow. As discussed earlier, both types of flow can still have serious consequences should the gas become trapped or contained. A low-pressure gas line failure (downstream of the regulator) within the home is a subcritical gas flow but these releases are usually trapped within a building and can have very serious consequences (explosions) as they are in a confined space. Though the service line is located outside, a service line failure can result in a portion of the releasing gas migrating into the house via various underground pathways. As you will soon see, even a small percentage of a gas service line release is still a lot of gas. A significant volume of gas can thus enter a house even when gas is

[12] 49CFR192.381(e)
[13] Sonic velocity is set by the gas composition and temperature, which will usually not vary widely for a typical distribution system.

clearly venting or blowing to the atmosphere above the service line leak site. This is especially true for the higher gas flow releases.

To help reach an appreciation for the volume of gas that can be released from a service line, Figures 1 and 2 on pages 9 and 10 plot a running total of the gas released from an unsecured service line during the first hour for various "effective" orifice holes at main pressures of 10 and 100 psig, respectively.[14] Effective orifice means the release was calculated as if it were from an orifice hole of the internal diameter indicated. The actual gas flow may vary slightly from these plots for various minor reasons, but the gas volumes plotted are easily in the ballpark for most service line systems (some systems will flow higher, some lower).[15] Notice how these total gas releases compare to the household consumption of approximately 5 to 100 SCFH mentioned earlier, as well as the rational maximum EFV leakages permitted in federal regulations.

As a sensitivity case, Figure 3, on page 10, plots total gas released as a function of time at various upstream pressures for one hole sized at 0.25 inch, not an uncommon service line damage. It is the nature of distribution gas system operation that the mains will not vary or drop in pressure during service line leaks for quite some time. Response to leak calls and isolation of the damaged service line (either via main isolation, valve shutoff, or line crimping) can take many tens of minutes if not substantially longer. It is clear from these figures that EFVs can play an important role in quickly shutting off gas supply in a wide range of most probable service line damage scenarios. The rationale for installing EFVs becomes even more evident as the pressures or service line sizes increase. Plastic service lines, the most likely material to be utilized in new service line installations, are more susceptible to larger-hole or even full bore damage that results in higher rate gas releases. Plastic is softer, having a lower resistance to impact and cutting than steel.

Conclusions

Based on the release dynamics and general volumes demonstrated in this report, several clear observations and conclusions can be made. The vast majority of gas distribution service lines in this country operate at pressures well above 10 psig with many increasing or expecting to increase their system pressures to meet rising gas demand. Service lines are also most likely to incur damage that results in high gas rate releases. Service line failures thus present a legitimate risk of catastrophic failure from such high rate high volume releases. While the bulk of service line damage that can result in high gas rate release is associated with third party damage, third party damage prevention programs should not be the primary mechanism to avoid the consequences of service line failures.

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[14] These pressures were selected to illustrate the point that released gas can add up quickly for a typical distribution system. There are some distribution systems that operate lower than 10 psig as well as others operating much higher than 100 psig, but many systems operate within the figure ranges.

[15] For example, even at sonic flow at the much higher gas rates, specific system resistance may start to influence release rates. Also, cracks are poorly modeled by orifice calculations.

Only EFVs can serve the effective role to sufficiently prevent many of the high gas rate release incidents associated with service line failures. Clearly, federal regulations should be modified to mandate the use of EFVs on all new service lines, including replacements, operating at 10 psig or greater. Since mandated EFV safety devices will slightly increase the cost of the distribution systems, such costs should be incorporated as a bona fide addition to the system infrastructure and the rate base. All such cost associated with purchasing, installing, maintaining, and replacing, if necessary, as well as "fair return on capital/expenses" concerning EFVs, should be permitted in a rate base authorized for the gas company. Of course, the obligation falls on the gas company to be able to demonstrate and defend that such cost requests are justified, proper, accountable, and auditable to any Public Utility Commission that usually is chartered with approving such cost authorizations.

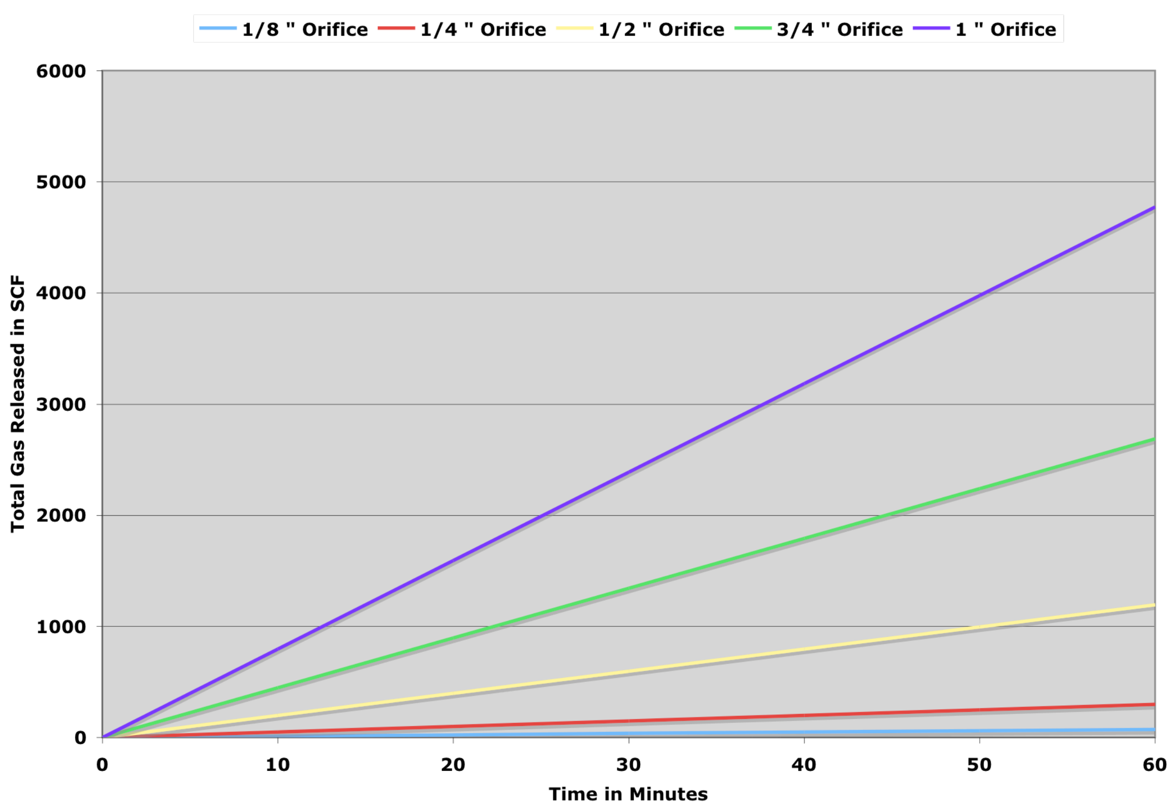

Figure 1 Total Gas Released vs. Time for Various Hole Size, Service Line @ 10 Psig

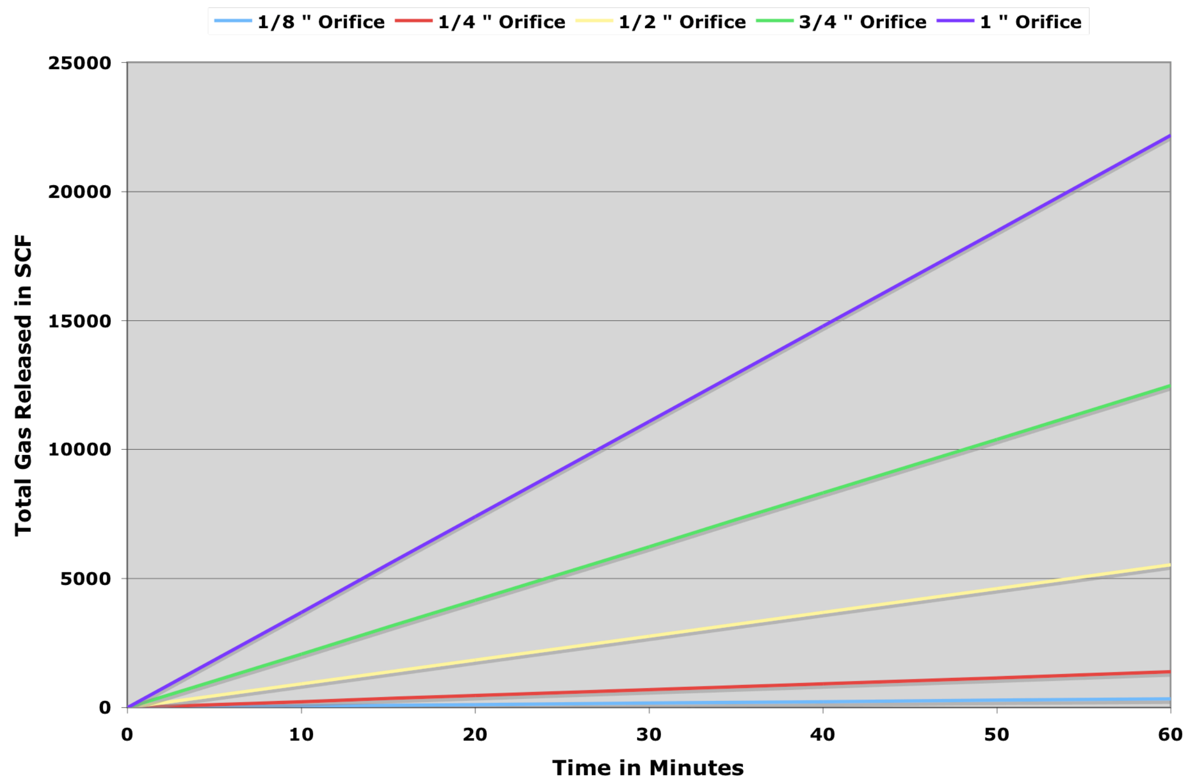

Figure 2 Total Gas Released vs. Time for Various Hole Size, Service Line @ 100 Psig

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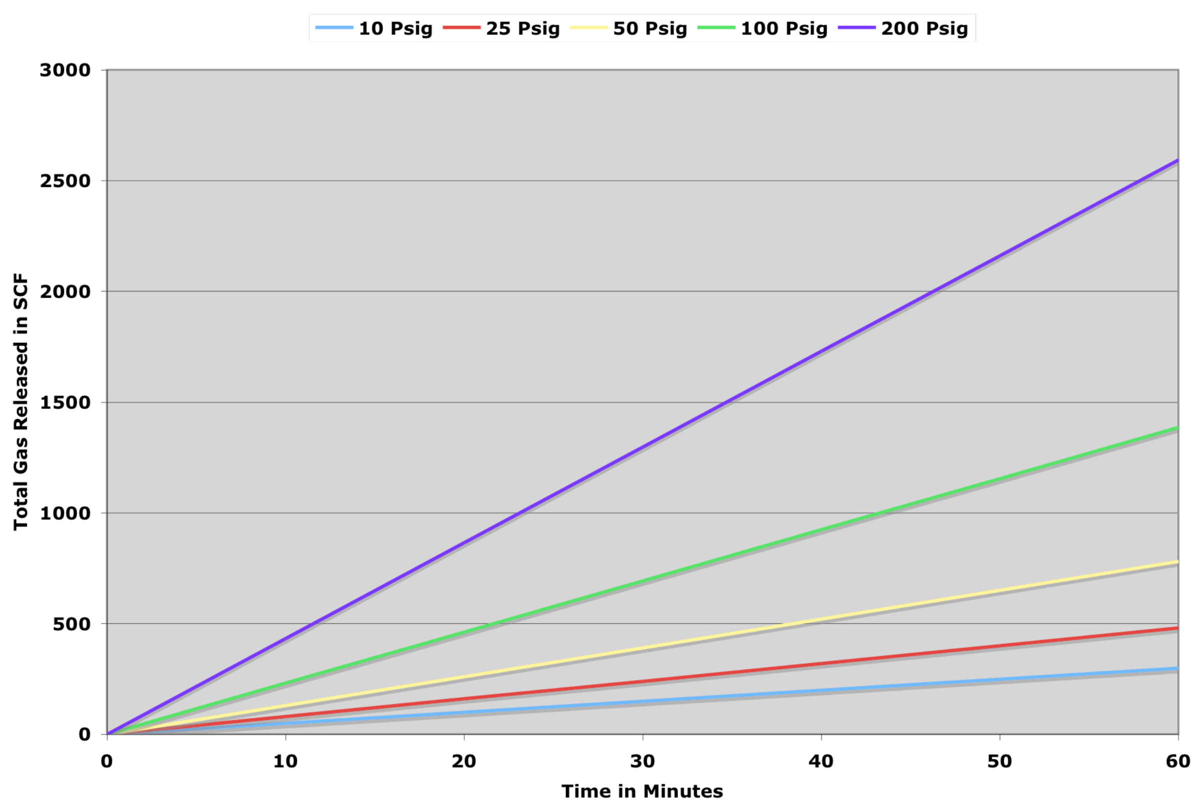

Figure 3 Total Gas Released vs. Time 0.25 inch Hole, Service Line Various Pressures