Emergency Zone Planning for a City Distribution Gas Network

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Abstract

This paper reviews how to define Emergency Zones in a City Distribution Gas Network. City Gas Operators need to consider aspects of emergency management, risk and vulnerability of their gas networks. As part of an Emergency Response Plan, natural gas operators need to understand the exact steps to be followed if an emergency should occur. The specific circumstances of any incident will determine what emergency response is most appropriate. In most incidents, gas operators will have to determine how to isolate the emergency impact area.

By using Hydraulic Gas Pipeline Network Simulators and Geographical Information System (GIS), city gas planners can increase their Emergency Preparedness and Emergency Management by pre-defining an Emergency Planning Zone (EPZ). An EPZ is a hydraulically isolated area, which is a region that can be fully shut off to prevent feeding flammable gas into a pipeline incident while maintaining the flow to the maximum number of customers or critical customers, such as hospitals. These incidents include leaking pipes, pipe ruptures, earthquakes or other natural disasters. The size of an EPZ usually has a maximum customer count to minimize the service interruption to an acceptable level. An EPZ will also need to be updated, as the city expands over time, on a regular basis.

City Gas Distribution System

A Gas Distribution System is a connected pipeline network that transports natural gas from multiple gas supplies such as pipeline inter-connects, city gate stations or regulator stations to the end-user customers. A typical gas distribution network consists of high/medium/low pressure pipes, service lines to deliver gas, valve stations for routing or isolating gas flow, pressure regulator stations to reduce pressures, flow control stations to regulate gas flow, pipe fittings to join pipe discontinuities, metering stations to measure inlet gas and customer meters to monitor the end users consumption. High pressure International, Inter-state and Intra-state transmission pipelines move gas across states, countries, city boundaries, and then enter city gas distribution at city border gate stations. Typically, gas is pressure regulated, processed and odorized before entering city border gate stations. Within the city, gas travels through several pressure level pipes to different regions in the city. At the final legs, service pipes connected to mains receive gas for the end-users.

Valve requirements by Federal Regulations

An Emergency Planning Zone is usually isolated by sectionalizing valves or isolation locations. Sectionalizing valves for distribution pipelines shall be installed and maintained at strategic points on the pipeline system at intervals which will permit sections of the line to be isolated. Sectionalizing valves for transmission pipelines shall conform at a minimum to the transmission pipeline valve spacing requirements in 49 C.F.R. 192.179 (1), except that for new installations in locations that are classified as Class 1 or Class 2 in the Federal Regulations, the valve spacing shall conform to the Class 3 requirements. Within the boundaries of cities and villages, or in the vicinity thereof, sufficient additional valves shall be provided and other appropriate steps taken to provide means for promptly turning off the gas and rapidly reducing the pressure in any section of pipe in the event of a pipeline failure or other emergency.

(1) United States, Code of Federal Regulations, 49 C.F.R. Part 192 – Transportation of Natural and Other Gas By Pipeline: Minimum Federal Safety Standards

Distribution System Sectionalizing Valve Requirements

Each operator of a distribution pipeline installed shall ensure that the pipeline contains sectionalizing valves in sufficient numbers and spacing to adequately facilitate the safe and reliable operation of the distribution system under both normal and emergency operating conditions in accordance with 49 C.F.R. 192.181.

The Federal Regulation states:

1. Each high-pressure distribution system must have valves to be spaced so as to reduce the time to shut down a section of main in an emergency. The valve spacing is determined by the operating pressure, the size of the mains, and local physical conditions.
2. Each regulator station controlling the flow or pressure of gas in a distribution system must have a valve installed on the inlet piping at a distance from the regulator station sufficient to permit the operation of the valve during an emergency that might preclude the access to the station.

Most local regulations are more stringent than their corresponding Federal regulations. On valve spacing, some local regulations require "in determining the number and spacing of sectionalizing valves, a pipeline operator shall ensure that the maximum number of customers to be affected by an emergency shutdown shall not exceed **500 customers**. In addition, the operator shall consider the volume of gas that could be released to the atmosphere and the response time capabilities of the operator in addition to the Federal requirements." According to AGA (American Gas Association) 2005 survey, gas companies used from **500** to **40,000** affected customers as guideline when defining emergency sectionalized zones. There is not a uniform maximum allowable customer count adopted by the gas industry. In the same AGA survey, one company said **10,000** customers per isolation are manageable. On valves ahead of regulator stations, one local regulation requires "A valve shall be installed upstream of each regulator station for use in an emergency to stop the flow of gas. These valves are to be installed at a safe distance from the station, but no more than **500 feet** from the regulator station. The distance for the valve location can be greater than 500 feet if physically impractical to install closer."

Factors used in Evaluating Sectionalizing Valves

Valves should be located within each distribution system to reduce the time to shut-down a segment of the system in an emergency. To determine the locations of these valves, the following common factors are used to evaluate:

1. Operating pressure of the distribution system
2. Volume of gas that could be released to the atmosphere
3. Size of area and population density between valves required to isolate the area
4. Accessibility of the valve locations
5. Minimum number of personnel required to shutdown and restore the area
6. Other means and availability of required equipment to control the flow of gas in the event of an emergency
7. Amount and type of customers, such as hospitals, schools, commercial and industrial loads, etc., that will be affected
8. Response time capabilities of the operator
9. Logical System Boundaries or Natural Boundary such as rivers
10. Single or dual feed area
11. Location Class, high-density area

Maintenance of EPZ's and Sectionalizing Valves

The operator will then need to apply the considerations above, and shall determine whether the number and/or spacing of its valves meets the requirement to adequately facilitate the safe and reliable operation of the distribution system under both normal and emergency operating conditions.

Whenever the sectionalizing of valves results in a defined EPZ having more than the maximum allowable customer count being affected in an emergency shutdown, the operator needs to analyze whether additional valves need to be installed in order to reduce the number of customers affected to be below the maximum allowable customer count. EPZ's will have to be re-evaluated and redefined as the system changes over time.

Required sectionalizing valves shall be maintained in accordance with the requirements of 49 C.F.R. 192.747. All of the sectionalizing valves necessary for the safe operation of the system must be inspected and maintenance performed to assure location, access and operating ability at intervals not exceeding 15 months but at least once each calendar year. Each operator must take prompt remedial action to correct any valve found inoperable, unless the operator designates an alternative valve.

Information needed to Define EPZ

When defining an EPZ, it is not only to identify an isolation area, but also to ensure such isolation of one part of the system is possible while maintaining gas flow into all other parts of the system at acceptable conditions, such as minimum delivery pressures and minimum design flow rates.

A Geographical Information System (GIS) can only provide system map and house counts, but it can not be used to perform flow analysis or check hydraulic isolation. Never the less, it is still very important to start with a GIS system or a database containing key attributes to establish a hydraulic distribution gas network model. The numbers of pipes, valves and regulators for a typical gas distribution network are usually very large, which makes it impossible to build a model manually. Some of the advanced gas pipeline simulation software packages do support direct import from GIS (such as ESRI shape files) or databases (such as Intergraph Oracle database). Typical GIS minimum attributes needed to automatically build a hydraulic network model are illustrated in the following Table:

Type	Attributes
Nodes	Name, X, Y, Elevation
Pipes	Name, Upstream Node Name (or X, Y), Downstream Node Name (or X ,Y), pipe internal diameter, pipe length
Valves	Name, Upstream Node Name (or X, Y), Downstream Node Name (or X ,Y), Valve Size
Regulators	Name, Upstream Node Name (or X, Y), Downstream Node Name (or X ,Y), Regulator Size

Once a hydraulic model is built, the system needs to be categorized into High Density Areas and Other Areas, based on Class locations as defined in the following table.

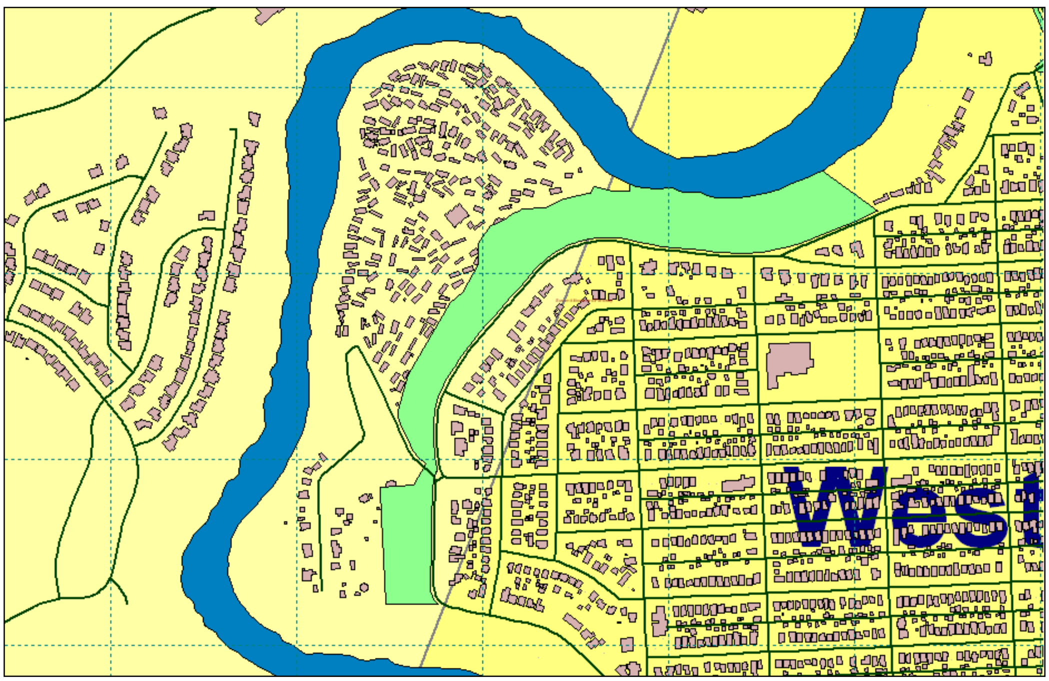
Development within the class location unit	Class designation
10 or fewer dwelling units It is intended to cover areas such as wasteland, deserts, mountains, grazing land, farmland, and sparsely populated areas.	Class 1
One or more of the following: Class 2 a) 11 to 45 dwelling units; b) a building occupied by 20 or more persons during normal use; c) a small, well-defined outside area occupied by 20 or more persons during normal use, such as a playground, recreation area, outdoor theatre, or other place of public assembly; or d) an industrial installation, such as a chemical plant or a hazardous substance storage area, where release of the service fluid from the pipeline could cause the industrial installation to produce a dangerous or environmentally hazardous condition. It is intended for fringe areas around cities and towns, industrial areas, ranch or country estates, etc.	Class 2
46 or more dwellings It is intended to reflect areas such as suburban housing developments, shopping centers, residential areas, industrial areas and other populated areas not in Location Class 4.	Class 3
A prevalence of buildings intended for human occupancy with 4 or more stories above ground This location class includes areas where multistory buildings are prevalent, and where traffic is heavy or dense and where there may be numerous other utilities underground.	Class 4

Notes:

1) A "class unit" is an onshore area that extends 200 meters on either side of the centerline of any continuous 1.6 km length of pipeline
2) Each dwelling unit in a multiple-dwelling-unit building shall be counted separately.
3) If it is likely that there will be future development in the class location assessment area sufficient to increase the class location designation, consideration shall be given to using the higher class location designation.
4) Consideration shall be given to designating class location assessment areas that contain buildings intended for human occupancy from which rapid evacuation may be difficult, such as hospitals or nursing homes, as Class 3 locations.

* For more details, please refer to C.F.R. 192.5 or CSA Z662-03 4.3.2.2 (Canadian Standards Association).

It will be much easier to sectionalize if a hydraulic model can be imposed on a GIS map. The graph below is an example of a Central Business District showing low pressure pipelines, natural boundaries and buildings.

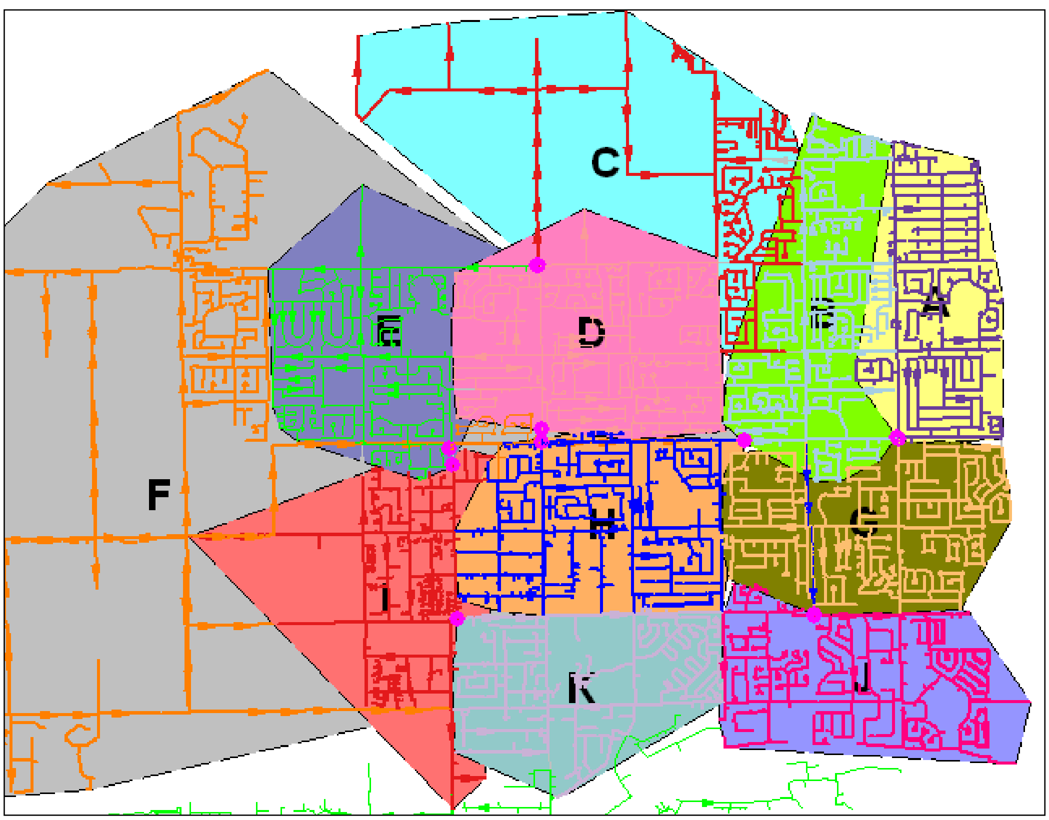


City Gas Operators often limit the size of an EPZ to a maximum number of city blocks in high-density areas. Isolation of sections, in high-density areas or class 4 locations, is usually achieved by valves. In regions where the population is less than the maximum allowable count and a non Class 4 location, isolation may be done at pressure reducing stations. In other local systems, isolation may be achieved using methods other than valving (such as squeezing-off or stop-off fittings.)

Hydraulic Simulator needed to Define EPZ

Most of the hydraulic simulators can perform flow analysis adequately. However, not all simulators are advanced enough to provide the following essential features to define hydraulic isolation areas. These essential support features include:

1. GIS as background map and direct import for model building
2. Locating hydraulic isolation elements
3. Graphically define regions by add/remove
4. Provide house counts within a defined region
5. Flow Path Tracking feature to display the distribution of gas; where the gas is flowing from and going to
6. Tracing the upstream pressure reduction stations or supply sources
7. Display defined regions with color coding
8. Display different pressure systems with color coding
9. Taking the entire region out-of-service or in-service to conduct flow analysis
10. Locating low pressure locations, preferably coloring pressure changes before and after for comparison



EPZ Flow Analysis

For each EPZ defined, the engineer will have to perform Flow Analysis to confirm that the isolation of this part of the system can maintain a pre-defined design peak hour gas flow (or a reduced percent of the design peak hour flow) into all other parts of the system at acceptable minimum pressure levels.

Steps for Flow Analysis are as followed:

1. Identify Critical EPZ's, these are usually isolation areas when shut down will leave adjacent EPZ's dependent on back feeds from other areas
2. Perform Flow Analysis by taking the identified EPZ out-of-service (isolated)
3. Determine if the pre-defined design peak hour flow can be maintained
4. Determine the maximum system flow rate while the EPZ is out-of-service
5. Mark the lowest pressure and location
6. If needed, recommend valve requirements, system improvements or operational alternatives
7. Update EPZ maps and isolation valve locations

About The Authors

Jen Jo (JJ) Wang joined Gregg Engineering at the beginning of 1999. He graduated from the University of Houston in 1982 with a Master of Science in Mechanical Engineering. Since his graduation, Mr. Wang has worked for various major U.S. gas pipeline companies, including Tennessee Gas Pipeline, NGPL Pipeline and Enron in the areas of gas pipeline modeling and simulation, compressor research, gas measurement, SCADA, system optimization, fuel management and gas control. Mr. Wang is currently the General Manager of Technical Services within Gregg Engineering, responsible for managing all real time, automation and optimization solution implementations, as well as engineering consulting projects.

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