An Introduction to Gas Distribution Systems

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CONTENTS

1. INTRODUCTION. This publication contains instructions and engineering information relating to gas distribution pipe systems, including pressure regulators, valves, meters, and other necessary appurtenances, for the distribution of fuel gas, natural and manufactured, from the point of delivery by the gas supplier to the points of connection with building piping.

2. PURPOSE. The purpose is to furnish a guide for designing new gas distribution systems, for checking the adequacy of designs furnished by gas suppliers, and for analyzing existing systems to determine their adequacy for supplying the demands of proposed additions.

3. SAFETY REQUIREMENTS. The design will include all safety requirements of ANSI B31.8 including guidance for abandoning gas lines. The requirements of ANSI B31.8 are adequate for safety under conditions normally encountered in the gas industry. Requirements for all abnormal or unusual conditions cannot be specifically provided in this publication, nor are all details of engineering prescribed.

4. PRESSURE CLASSES OF DISTRIBUTION SYSTEMS.

4.1 LOW-PRESSURE SYSTEM. In a low-pressure gas distribution system, the gas pressure in the mains and service lines is substantially the same as that delivered to the user's appliances. In such a system a service regulator is not required on the individual service lines.

4.2. HIGH-PRESSURE SYSTEMS. A high-pressure gas distribution piping system operates at a pressure higher than the standard service pressure delivered to the user. In such a system, a service regulator is required on each service line to control the pressure.

5. SYSTEM PLANNING.

5.1 LAYOUT. Gas distribution systems will be planned carefully with due consideration for economy, safety, and uniformity of pressure. The lines will be well-looped within the main area and in all outlying areas whenever practicable and economically feasible to do so. It is not always practicable to loop a supply line to an outlying area and then back into the main system, but in such cases the objectionable effects of dead ends can often be relieved to some extent by looping such line around the area it serves and then back into itself. At large stations it will usually be advantageous to extend the high-pressure line to provide two or more connections with the distributing lines for purposes of uniformity and assurance of adequate pressure.

5.2 LINE LOCATIONS. Gas distribution system lines will never be installed under a building. They will not be laid in the same trench with other utilities to preclude the possibility of leaking gas following along or collecting in other conduits and creating an explosion hazard. For the same reason, gas lines will be above other utilities whenever they cross, if practicable. Gas lines will not be laid under paved streets or in other locations subject to heavy traffic whenever practicably avoidable. Whenever it is necessary to locate gas lines in such locations, the lines will be protected by suitable casing or by burying to a depth to provide at least 2 feet of cover over the top of the pipe. Sufficient clearance must be maintained between plastic mains and steam, hot water, power lines, and other sources of heat, to avoid temperatures in excess of 60 degrees C (140 degrees F) for thermoplastics or 66 degrees C (150 degrees F) for thermo-setting epoxy resin pipe.

5.3 DRIPS. Drips will be installed at all low points in lines transmitting manufactured gas or a mixture of natural and manufactured gas. In lines transmitting natural gas, drips will be installed at the low points immediately following reduction from high pressure to low pressure and at occasional low points throughout the system to provide for blowing out the lines.

5.4 GRADING LINES*.* Gas mains will be buried deep enough to provide at least 2 feet of cover over the top of the pipe. Where manufactured gas is used, the lines will be uniformly graded to drain the low points to prevent the formation of pockets where condensate could restrict the flow of gas. Lines transmitting natural gas need not be graded but may follow the contour of the grounded surface.

5.5 VALUE SPACING IN DISTRIBUTION SYSTEMS. Whether for operations or emergency uses, valves on distribution mains will be spaced as required in the following subparagraphs.

5.5.1 HIGH-PRESSURE SYSTEMS. Valves will be installed in readily accessible locations to reduce the time to shut down a section of a main in an emergency. When determining the spacing of the valves, consideration should be given to the operating pressure and size of the mains and to local physical conditions as well as to the number and type of users or services affected by each potential shutdown.

5.5.2 LOW-PRESSURE SYSTEMS. Valves are required on low-pressure systems only to meet the conditions given in subparagraph 1.6 below.

5.6 LOCATION OF DISTRIBUTION SYSTEM VALVES. A valve will be installed on the inlet piping of each regulator station controlling the flow of pressure of gas in a distribution system. The distance between the valve and the regulator or regulators must be sufficient to permit the operation of the valve during an emergency, such as a large gas leak or a fire in the regulator station. Valves on distribution mains, whether for operating or emergency purposes, will be readily accessible and easily operable during an emergency. Where a valve is installed in a buried box or enclosure, ready access only to the operating stem or mechanism is implied. The box or enclosure will be installed in a manner to avoid transmitting external loads to the main.

5.7 PRESSURE REGULATORS. Pressure regulators are necessary at all points where equipment or design requires reduction in or regulation of pressure. Bypasses around pressure regulators will not be installed unless continuity of service is imperative and the bypass is suitably regulated to prevent possible overpressure of downstream lines.

5.8 CENTRAL REGULATING AND METERING STATION. A central regulating and metering station is generally provided by the gas supplier and is usually located near the entrance to the reservation. When provided by the Owner, all necessary equipment will comply with the requirements of the gas supplier. An enclosure, if required, will be of fire-resistant construction, such as masonry. Adequate provision will be made for ventilation. The design of the enclosure will be coordinated with the using agency and gas supplier. A valve will be installed in the main supply line approximately 100 feet ahead of the station.

5.9 PROTECTION AGAINST ACCIDENTAL OVERPRESSURIZING. Every distribution system and meter and connected facilities will be provided with suitable pressure relieving or pressure limiting devices.

5.9.1 CONTROLLING AND LIMITING PRESSURE IN HIGH PRESSURE GAS DISTRIBUTION SYSTEMS. Each high pressure distribution system or main which is supplied from a source of gas at a higher pressure than the maximum allowable operating pressure for the distribution system will be equipped with pressure regulating devices of adequate capacity designed to meet the pressure, load, and other service conditions under which they will operate or to which they may be subjected. In addition to the pressure regulating devices, suitable protective devices to prevent accidental over-pressurizing must be provided. Suitable protective devices are as follows:

- Spring-loaded relief valves conforming to ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
- Pilot-loaded back pressure regulators used as relief valves and designed so that pilot system or control line failure will open the regulator.
- Weight-loaded relief valves.
- A monitoring regulator installed in series with the primary pressure regulator.

- A series regulator installed upstream from the primary regulator and set to continuously limit the pressure on the inlet of the primary regulator to the maximum allowable operating pressure of the distribution system, or less.
- An automatic shutoff device installed in series with the primary pressure regulator and set to shut off when the pressure on the distribution system reaches the maximum allowable operating pressure, or less. This device must remain closed until reset manually. It should not be used where it might cause an interruption in service to a large number of mains or service lines.
- Spring-loaded diaphragm type relief valves.

5.9.2 CONTROLLING AND LIMITING PRESSURE IN LOWPRESSURE GAS DISTRIBUTION SYSTEMS. Each low-pressure distribution system or low-pressure main supplied from a gas source which is at a higher pressure than the maximum allowable operating pressure for the low-pressure system will be equipped with pressure regulating devices of adequate capacity. Other devices will be designed to meet the pressure, load, and other service conditions under which they will have to operate. In addition to the pressure regulating devices, a suitable protective device to prevent accidental over-pressurizing must be provided and may include:

- A liquid seal relief device that can be set to open accurately and consistently at the desired pressure.
- Weight-loaded relief valves.
- An automatic shutoff device as describe above.
- A pilot-loaded back pressure regulator as described above.
- A monitoring regulator as described above.
- A series regulator as described above.

5.9.3 DESIGN REQUIREMENTS FOR PRESSURE RELIEF AND PRESSURE LIMITING DEVICES. Such devices will:

- Be constructed of materials resistant to atmospheric corrosion externally and gas corrosion internally.
- Have valves and seats designed so they will not stick in positions which prevent the devices from operating properly.
- Be designed and installed for easy maintenance operation to check for leakage, pressure rate actuation, and free valve movement.

5.9.4 TELEMETERING OR RECORDING GAUGES.

5.9.4.1 EACH DISTRIBUTION SYSTEM supplied by more than one district pressure regulating station must be equipped with telemetering or recording pressure gauges to indicate the gas pressure in the district line.

5.9.4.2 ON DISTRIBUTION SYSTEMS SUPPLIED by a single district pressure regulating station, the designer will determine the necessity of installing telemetering or recording gauges in the supply line, taking into consideration the number of buildings supplied, the operating pressures, the capacity of installation, and other operating conditions.

6. MATERIALS AND EQUIPMENT.

6.1 GENERAL REQUIREMENTS. Materials and equipment which will become permanent components of a gas distribution system will be suitable and safe for the conditions in the locality in which they are to be installed. As a minimum, components will meet the safety requirements of Title 49, Code of Federal Regulations, Part 192. To the extent practicable, all materials will meet the requirements of ANSI B31.8 and the approval of the gas supplier. Plastic or steel pipe is preferred for distribution systems. Cathodic protection is mandatory for underground ferrous gas distribution lines. Stations will be provided for testing the cathodic protection system.

6.2 EQUIPMENT SPECIFICATIONS. The designer must *specify* equipment compatible with the system's materials and operating requirements. In every *case*, the safety requirements for equipment in a gas piping system will be comparable with those of the piping components.

6.3 PLASTIC PIPE.

6.3.1 IN VIEW OF THE RAPID PROGRESS of technology in the field of plastic pipe materials, engineers should consult the latest issues of the AGA Plastic Pipe Manual for Gas Service; Title 49, Code of Federal Regulations, Part 192; and the ASTM standards on plastics. In addition, the latest information issued by manufacturers of plastic pipe, or piping components will present in detail the special or specific properties and recommendations related to their products.

6.3.2 PLASTIC PIPING MATERIALS are significantly more resistant to corrosion than metallic piping materials being used for the distribution of natural and other fuel gases. Galvanic corrosion of plastics does not occur since all plastics are nonconductors and are not subject to electrochemical reactions as are metals.

6.3.3 ALL PLASTIC PIPES are significantly lighter than the same size metal pipes. Compared to steel pipe, weight advantage varies from approximately 8 to 1 for polyethylene pipe to about 4½ to 1 for fiberglass pipe; thus it is easier for the construction crews to handle the plastic pipe.

7. MISCELLANEOUS.

7.1 ODORIZATION. A suitable malodorous agent will be injected into any gas which does not possess a natural distinctive odor for the purpose of detecting leaks. Unless the gas in the supply lines has already been odorized by the gas supplier, it will be necessary to provide facilities for injecting a malodorant. A storage tank and controlled device for injecting the odorizing agent at a rate that is proportional to the rate of gas flow, as determined by pressure drop across an orifice, will be required. The point of injection will be on the downstream side of the central regulating and metering station. Recommendations can usually be obtained from gas suppliers for type and quantity of malodorant to use and for suitable injecting equipment.

7.2 LIQUEFIED PETROLEUM GAS (LPG) SYSTEMS.

7.2.1 LIQUEFIED PETROLEUM GASES usually include butane and propane or mixtures of them which can be stored as liquids under moderate pressures of 80-250 psig at ambient temperature.

7.2.2 LPG GAS DISTRIBUTION SYSTEMS will be designed to comply with the requirements of NFPA 58 instead of ANSI B31.8. Polyethylene and fiberglass pipe will not be used in LPG systems.

8. PLANS AND ENGINEERING DATA.

8.1 PLANS. The plans will include a layout drawing showing the entire distribution system and detail drawings clearly showing pipe sizes, the location of gas mains, service connections, details for abandoning gas piping, valves, and regulators. ANSI B31.8 requires that abandoned gas lines be physically disconnected from gas sources. Shutoff valves are not an acceptable means of disconnect

8.2 ENGINEERING ANALYSIS. The engineering analysis will be in diagram form showing all connected loads, flow quantities, pressures, and the location of regulators. A complete set of supporting calculations will be prepared. Notes will be included on or will accompany the diagram to indicate the specific gravity of the gas, the heating value of the gas in Btu's per cubic foot, the base pressure and base temperature at which a cubic foot of gas is defined, the flowing temperature, the normal atmospheric pressure, and such other information as may be pertinent.

8.3 PLASTIC PIPE ENGINEERING CONSIDERATIONS. ASTM D 2513 presents engineering data for thermoplastic pipe, tubing, and fittings intended for fuel gas service. ASTM D 2517 presents engineering data for fiberglass pipe and fittings including adhesives intended for fuel gas service. ASTM D 3350 covers the identification of polyethylene plastic pipe and fittings materials using a cell classification system. The specific plastic material chosen should be thoroughly investigated for the gas service and operating conditions anticipated. It should be adequately resistant to liquids and chemical atmospheres which could be encountered in the gas distribution system and tough enough to withstand the stresses which may be imposed by external as well as internal forces acting on complex piping system configurations.

8.3.1 ENGINEERING DESIGN CONCEPTS for plastics, including plastic pipe, are different from those used when designing with metals. For metals at or near ambient temperature, some considerable fraction of the yield strength is widely used for design purposes. At ambient temperatures, plastics, unlike structural metals, are influenced by the duration of stress as well as by relatively small changes in temperatures. Therefore, design stress levels for plastics are based on long-term strength as measured by plotting stress failure as a function of time at a constant temperature. On a short-term strength basis, design stress levels for plastics would be relatively low. Also, for plastics there is an appreciable increase in strength as temperatures are reduced below design temperatures and an appreciable decrease in strength as temperatures are raised above design temperatures. In fact, at temperatures over 38 degrees & (100 degrees F) there could be significant differences among polyethylenes of the same type and grade. Plastic pipe users should obtain specific stress-temperature data for materials being considered.

8.3.2 IN ADDITION TO the long-term strength, there are other properties which must be considered in selecting a material for fuel gas distribution. These properties include:

(a) Corrosion and chemical resistance.
(b) Aging resistance.
(c) Weatherability.
(d) Strength-temperature relationship.
(e) Toughness.
(f) Permeability.
(g) Flexibility.
(h) Susceptibility to rodent damage.

While all these properties are important and must be considered, only the long-term strength can be defined well enough at the present time to be used as a primary basis for design. However, consideration of the effect of the other properties must be given proper attention in determining suitability for an intended application and an overall factor of safety.

8.3.3 WHEN SELECTING a plastic piping system, the design engineer should relate installation and service requirements with the characteristics of the several plastic systems available. Some of the factors to consider are:

a) *Design pressure levels as a function of required wall thickness.*
b) *Chemicals which may be naturally or unavoidably present or added into the gas system.*
c) *Effects of maximum and minimum ambient temperatures on installation practices, particularly at tie-in points.*
d) *Installation requirements for a flexible type vs. a semi-rigid type material.*
e) *Suitability of material for making plastic to-plastic and plastic-to-metal connections.*
f) *Special design or installation requirements.*
g) *Availability of necessary fittings and tools for fabricating pipe systems in the field.*
h) *Capability and compatibility of material for development of satisfactory operating and maintenance procedures.*

9. GAS DISTRIBUTION SYSTEM DESIGN.

9.1 INTRODUCTION. The design of a gas distribution system will be based on a demand (maximum probable) equivalent to not less than 80 percent of the full (maximum possible) connected appliance load. The actual consumption may never be equal to the maximum probable, but such diversity factor as may exist would serve as a margin of safety if not included in the design. The size of pipe in sections of a distribution system that serves no more than 15 buildings in an isolated area, and in service lines to individual buildings, will be based on the full connected appliance load. In the various gas flow formulas, demand is usually expressed in cubic feet per hour. Because of the variability of the volume of gas with changes in pressure and temperature, reference to definite bases of pressure and temperature is necessary in expressing quantities volumetrically. It is essential that the stated characteristics of the gas, the computations of the connected appliance loads, and the flow formulas used in the design of the pipe system, all be on the same basis. Base conditions are 60 degrees F and 14.73 psia in accordance with AGA Orifice Metering of Natural Gas, Report No. 3.

9.2 FLOW CONDITIONS. There is a pressure loss in pipes roughly proportional to the square of the velocity; and there are at least two distinct flow regimes in pipes, laminar, and turbulent. There is a distinct discontinuity in behavior of fluid when laminar flow rates are exceeded, and a large region for mixed flow behavior (partially turbulent flow) exists between the upper limit of laminar flow and the behavior of pipes in fully developed turbulent flow. The exact transition regions between the various flow regimes are not yet accurately predictable for the various fuel gas piping situations of practical importance. Gas engineering practice has developed practical approximations at working around this inadequately defined area. In only very unusual situations is this lack of exactness of any practical or economic importance.

9.3 DISTRIBUTION SYSTEM DESIGN CRITERIA. The distribution system design engineer rarely designs a totally new system. The design will generally consist of changes to an existing system. Even a new system, unless it is for a complete camp, base or other military facility, has unpredictable loads. The most compelling problem for the distribution system designer is the infrequency of the system operation at or near design capacity.

9.4 FLOW OF NATURAL GAS IN PIPLINES. Plastic pipe has a very smooth and slippery surface. Its frictional resistance is considerably less than that of steel pipe. Therefore, it is often assumed that plastic pipe has significantly more flow capacity than steel pipe. This assumption would be correct under fully turbulent flow conditions, such as those encountered in water service. However, investigation of flows in natural gas distribution systems indicates that the design flows usually fall within the range of only partially turbulent flow (see table 1 for an indication of the typical flow rates in gas distribution systems). In this range, the smooth-pipe flow equations apply all the time to both plastic and steel; therefore, the pipe wall roughness is not a significant factor. Flow formulas found to be satisfactory for sizing steel pipe in natural gas service are recommended for sizing plastic pipe as well. Consideration must, however, be given to differences in inside diameter. In the larger pipe sizes, plastic wall thicknesses are likely to be greater than those of steel pipe.

9.5 DISTRIBUTION SYSTSEM FLOW EQUATIONS.

9.5.1 FULLY TURBULENT FLOW (ROUGH PIPE FLOW LAW). The equation for fully turbulent flow is as follows:

$$Q = (0.4692\,\frac{T_b}{P_b})\left(\frac{({P_1}^2-{P_2}^2)D^2}{GTZL}\right)^{0.5} Log\,(\frac{3.7D}{K}) \qquad (1)$$

9.5.2 PARTIALLY TURBULENT FLOW (SMOOTH PIPE FLOW LAW). Any of the accepted gas flow equations used with steel pipe, such as Mueller, Pole, or the IGT Distribution Equation, can also be used for calculation of plastic pipe flow capacities. Those equations which yield conservative values for steel pipe will also be conservative for plastics. The IGT Distribution Equation is thought to be representative of both steel and plastic for most distribution design situations. It is as follows:

$$Q = \left(0.6643\frac{T_b}{P_b}\right)\left[\frac{{P_1}^2 - {P_2}^2}{TL}\right]^{\frac{5}{9}}\ (D^{\frac{8}{3}})(G^{\frac{4}{9}}\mu^{\frac{1}{9}}) \qquad (2)$$

9.5.3 DEINFITION OF TERMS. The terms used in the flow equations above are:

D = inside pipe diameter, inches

G = specific gravity

L = length of pipe section, feet

P_b = base pressure, 14.73 psia

P_1 = upstream pressure, psia

P_2 = downstream pressure, psia

Q = gas flow rate, MSCFH (thousands of standard cubic feet per hour)

T_b = base temperature, 520 Rankine

T = average temperature of flowing fluid, Rankine

Z = average compressibility factor

μ = viscosity, lb/ft-sec

K = effective roughness of pipe surface, inches

= 0.00006 inch for plastic

= 0.0007 inch for steel

= 0.01 inch for cast iron

9.5.4 USING THE FLOW FORMULAS. Figure 1 may be used to determine whether the rough pipe or smooth pipe flow law should be used. If the flow rate expected is above the curve, then the rough pipe law should be used. If flow rate falls below the curve, then the smooth pipe flow law is applicable. In specific cases where the flow is rather high and a comparison of pressure drop between plastic pipe and steel or cast iron is desired, the following method is suggested:

(a) Determine whether partially or fully turbulent flow formulas are applicable for Figure 1 using the flow and pipe size given in Table 1 below..

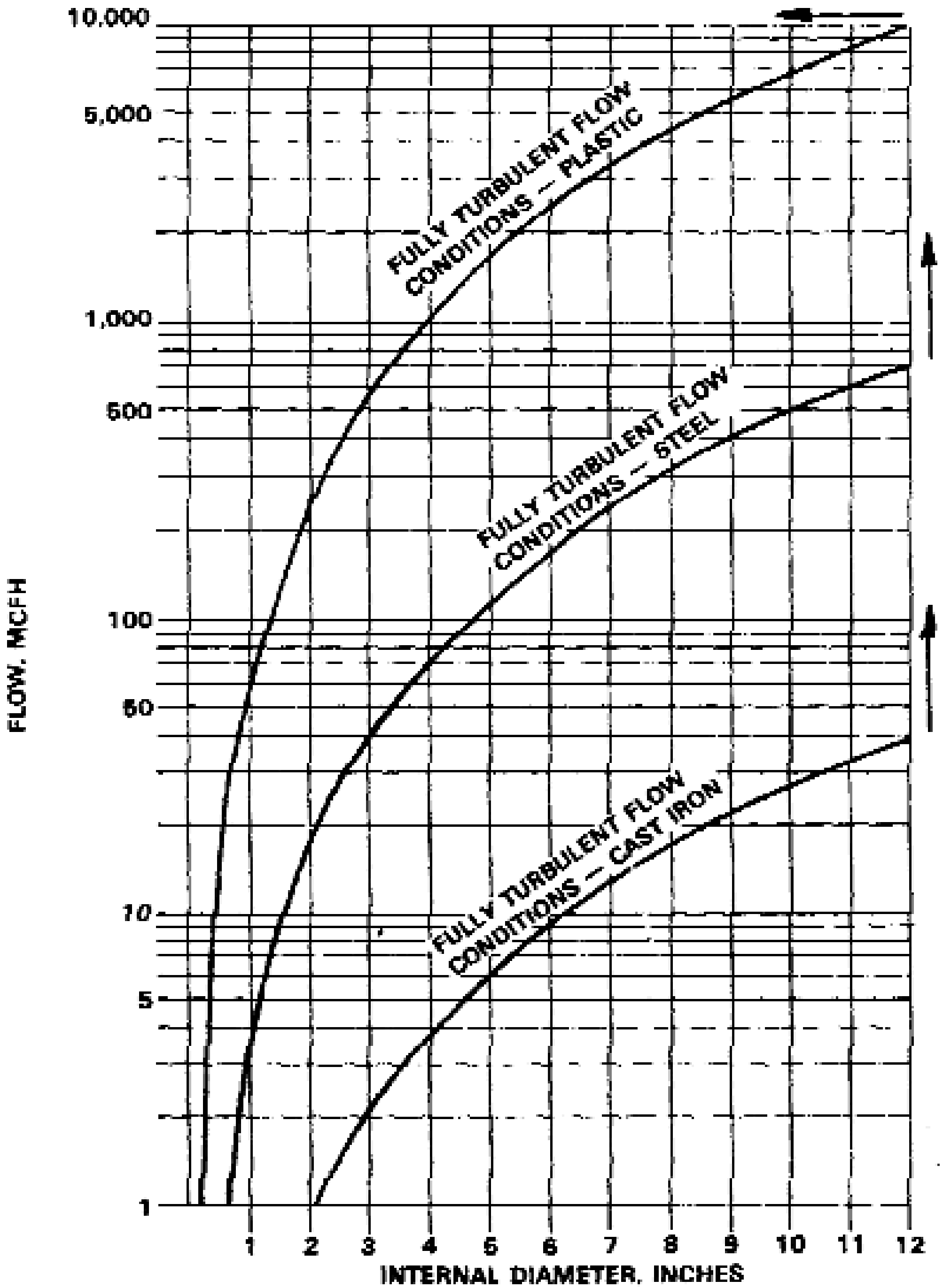
(b) If Figure 1 shows the flow to be in the range where the smooth pipe flow law equation or laminar flow equation (partially turbulent flow) apply for the steel or cast-iron pipe being considered, then there is no advantage for plastic because of reduced pipe surface friction.

(c) If Figure 1 shows that the rough pipe flow law (fully turbulent flow) applies, then there may be some advantage for plastic pipe, depending on relative wall thickness.

Nom Pipe Diameter Inches	Flow Rate, 1000 cu ft per hr
2	17.4
3	43.5
4	81.1
6	163.0
10	555.6

Table 1

Typical maximum flow rates experienced in 60 psi natural gas distribution systems



BASED UPON: IGT DISTRIBUTION EQUATION AND FULLY TURBULENT EQUATION.
K = 0.01 in. FOR CAST IRON, K = 0.0007 FOR STEEL.
K = 0.00006 FOR PLASTIC, G = 0.60, u = 0.0105 CENTIPOISE.

Figure 1

Applicability of partially or full turbulent flow formulas

9.5.5 VERIFICATION OF SYSTEM PRESSURE DROP. It is standard practice for domestic gas suppliers *to* verify or supply system pressure drops for the designer. Upon submittal of the plan for the distribution system, gas suppliers can quickly verify or supply system pressure drops using commercially available slide rule type engineering calculators or prepared computer programs. This service is usually provided at no cost to the designer.