Size of piping for natural gas

Kent, A. D.

Publisher’s version / Version de l'éditeur:
https://doi.org/10.4224/20338337
Technical Note (National Research Council of Canada. Division of Building Research); no. TN-469, 1966-04-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

No. 469

TECHNICAL NOTE

LIMITED DISTRIBUTION

PREPARED BY A. D. Kent CHECKED BY A. G. W. APPROVED BY N. B. H.

DATE April 1966

PREPARED FOR limited distribution

SUBJECT SIZE OF PIPING FOR NATURAL GAS

In the installation of gas burning appliances the choice of the pipe size is often left to the installer who relies upon the municipal or provincial installation code for guidance in his selection of pipe. In Canada an increasing number of provinces are adopting either in whole or in part the Canadian Standards Association (CSA) Standard B149-1962 Installation Code for Gas Burning Appliances and Equipment. As this document is thus being used in Canada for most natural gas installations, it is important that, among other requirements, the pipe sizing data be reliable.

This Note contains the results of an examination of the relationships determining the flow of fluids through pipes with specific application to low pressure natural gas and a critical examination of the capacity table in CSA Standard B149-1962.

1. Equations for Gas Flow

The basic fluid flow equation contained in most text books on fluid flow is the Darcy-Weisbach equation (sometimes known as the Fanning formula) which for turbulent flow is as follows:

$$\Delta p = \frac{f_D L \rho V^2}{2Dg} \qquad \text{- - - (1)}$$

where

Δp = static pressure drop, lb per sq ft

f_D = Darcy-Weisbach friction factor (dimensionless)

L = length of pipe, ft

D = pipe diameter, ft

ρ = density, lb per cu ft

V = velocity, ft per sec

g = acceleration of gravity = 32.2 ft per sec^2.

Since pipe capacity is the product of gas velocity V and the cross-sectional area of the pipe $A = \frac{\pi}{4} D^2$, then in engineering units

$$Q = 380 \sqrt{\frac{d^5 h}{f_D L W}} \qquad \text{- - - (2)}$$

where

Q = discharge capacity, c.f.h.

d = diameter of pipe, in.

h = pressure drop, in. of water

f_D = Darcy-Weisbach friction factor (dimensionless)

L = length of pipe, ft

W = specific gravity of gas (air = 1).

The ASHRAE Guide and Data Book 1965-1966 published by the American Society of Heating Refrigerating and Air-Conditioning Engineers, Chapter 6, p. 91 gives a chart based on the work of L. F. Moody (ASME Transactions, Vol. 66, 1944, p. 671) from which the value of f_D in Equation (2) can be determined graphically, knowing the Reynolds number and the pipe diameter and assuming a value for the absolute roughness of the pipe. In the expression for Reynolds number, $N_{Re} = VD/n$, where n = the kinematic viscosity (0.00019 sq ft per sec for natural gas, assuming a specific gravity of 0.60).

For laminar flow (Reynolds number less than 2000) the factor f_D is independent of surface roughness and equals $64/N_{Re}$. The basic equation for laminar flow thus becomes

$$\Delta p = \frac{0.994\,\mu L V}{D^2} \qquad \text{- - - (3)}$$

where

Δp = pressure drop, lb per sq ft

μ = absolute viscosity
(for natural gas 0.00000806)

L = length, ft

V = velocity, ft per sec

D = pipe diameter, ft.

In engineering units the capacity equation for laminar flow is as follows:

$$Q = 88800 \frac{d^4 h}{L} \qquad \text{- - - (4)}$$

where

Q = discharge capacity, c.f.h.

d = pipe diameter, in.

h = pressure drop, in. water

L = length of pipe, ft.

Equations (2) and (4) are what might be termed the basic equations of fluid flow. From time to time engineers and scientists have attempted to simplify these, particularly the formula for turbulent flow, in order to cover a limited range of conditions for a particular fluid. There are several such equations as well as charts and rapid calculators based on such equations which are used for the determination of discharge capacity of pipes. Among these perhaps the most widely used for natural gas flow are the Huff and Logan equation (ref. 1), the Spitzglass equation (ref. 2), and an AGA equation (ref. 3) as follows:

(a) <u>The Huff and Logan Equation</u>

$$Q = \frac{2331\, h^{0.543}\, d^{2.631}}{s^{0.468}\, L^{0.543}} \qquad \text{- - - (5)}$$

where

Q = discharge, c.f.h.

h = pressure drop, in. water

d = diameter of pipe, in.

s = specific gravity of gas (relative to air at room temperature and 30 in. Hg)

L = length of pipe, ft.

It is noted that the authors depart from the power of 1/2 in the basic formula for the variables h, s, and L. A convenient nomograph is published which simplifies the use of the formula.

(b) <u>The Spitzglass Equation</u>

$$Q = 1910 \sqrt{\frac{d^5 h}{wL(1 + \frac{3.6}{D} + 0.030)}} \qquad \text{- - - (6)}$$

where

Q = discharge of gas, c.f.h.

d = diameter of pipe, in.

h = frictional drop in pressure, in. water

w = specific gravity of gas (air = 1)

L = length of pipe, yd.

(c) The American Gas Association Equation

$$\text{Cu ft per hr} = 1350\sqrt{\frac{(\text{diam, in.})^5 \times (H_2O \text{ press drop, in.})}{1/3\ (\text{Length, ft})\ (\text{gas density})}} \quad - - - (7)$$

Accompanying this equation in the text of "Gaseous Fuels" (3) is a table of pipe capacities for pipes 3/4 in. to 8 in. in diameter for pipe lengths from 15 to 600 ft. The table is based on 0.2-in. pressure drop and specific gravity of gas of 0.60. Agreement between the table and the equation requires that the "diameter" in the formula should be the nominal pipe diameter and not the actual inside diameter, as most equations use. Also the term "gas density" in the formula should read "specific gravity" in order that the table and formula should agree. The AGA text also recognizes the work of Huff and Logan, reproducing the formula and nomograph referred to in (a) above.

2. Comparison of Equations

Table 1 is a comparison of capacities for various pipe arrangements determined from the various equations presented and from the values given in tables in installation codes for natural gas. The table is based on iron pipe sizes from 1/2 in. to 8 in. and three representative lengths have been chosen based on the usual table. The pressure drop assumed is 0.3 in. water column and the specific gravity 0.60 (air at 30 in. Hg. and room temperature = 1). The table includes the capacity values from the present Table 1.1 of the CSA Standard B149-1962 and its American counterpart the ASA Z21.30-1964. The blanks opposite the side heading "Darcy-(ASHRAE)" in the columns for smaller diameter pipes indicate that the product of the gas velocity and the pipe diameter is so low that the resultant Reynolds number is between 2000 and 3000. Under these conditions there may be laminar or turbulent flow or even a fluctuating condition from one to the other which makes the discharge an unknown quantity. The figures in parenthesis opposite the "Darcy-(ASHRAE)" heading are for laminar flow since Reynolds numbers are below 2000 for these conditions.

It is important to note that the capacities given for the Darcy-(ASHRAE) equation (for turbulent flow) are based on the assumption that the pipe is wrought iron or steel, which according to the ASHRAE Guide Table 4, p. 91, has an absolute roughness e of 0.00015 (ft). The Guide roughness figures for drawn metal tubing (less than 0.00001 ft), galvanized iron (0.0005 ft) and for cast steel (0.00085 ft) are several times lower or higher and therefore the f_D factor could vary widely for different materials. For example, for galvanized iron pipes, the relative roughness e/D would be 3.33 times the value for wrought iron or steel, so that for a 4-in. pipe 15 ft long the f_D would be 0.024 instead of 0.021 and the Reynolds number 80300 instead of 86500. Thus the capacity for 0.3 in press drop and 0.60 specific gravity would be 14500 instead of 15600, a decrease of 7 per cent.

The choice of a basis for capacity figures for a document such as CSA B149 is therefore an arbitrary one since no one set of figures can apply to all conditions. From Table 1 it is evident that:

(a) The Huff and Logan equation and the present ASA Z21.30 figures for capacity are in close agreement with one another throughout the range of pipe sizes and lengths, the latter being about 2 to 4 per cent higher. Both sets of figures agree closely with the theoretical figures of the Darcy-(ASHRAE) equation except in the larger pipe sizes where the Darcy values are higher. Both sets of figures are considerably higher than the present B149 figures for the 1/2-, 3/4- and 1-in. pipe sizes but, from 1 1/4- or 1 1/2-in. diameter up, the B149 figures are equal to or higher than these two sets of values especially for the longer pipes. There appears to be an inconsistency of progression in the capacity figures of the present B149 table particularly between the 1-in. and 1 1/4-in. pipe sizes.

(b) The Spitzglass equation gives much the same capacity values as are now used in B149 except slightly lower values than B149 in the smaller diameter pipes and somewhat higher capacities in the larger pipes, the cross-over occurring at about 3-in. pipe diameter regardless of length of pipe.

(c) The AGA equation is a simple formula and, when specific gravity is used in place of gas density in the denominator, provides capacities that appear to agree quite well with other equations. The use of the nominal pipe size instead of the actual inside diameter, however, introduces irregularities that result in inaccuracy since the relationship of nominal size to actual diameter is far from a straight line.

3. Allowance for Valves and Fittings

Regardless of the formula chosen there should be allowance made for the resistance of fittings and valves in any specific piping system, which will reduce the maximum capacity values from those in the table. If neglected, this can lead to a serious error, particularly in a short system using large pipe. For example, a single long sweep elbow in an 8-in. pipe is equivalent to about 14 ft of pipe. If the length of the actual pipe run is only, say 15 ft, the presence of the single elbow will reduce the allowable capacity (for 0. 3-in. water maximum pressure drop) from about 97, 000 to about 66, 200 cu ft per hr, a reduction of roughly one third. This moderate example illustrates why it is inaccurate to use a maximum capacity table such as in CSA B149 or ASA Z21. 30 without some allowance for the fittings, whereas these standards require no additional allowance "for an ordinary number of fittings."

Table 2 (from reference 4) gives the resistance of fittings and valves in terms of equivalent feet of pipe.

These values of equivalent feet are considerably higher than those given in "Gaseous Fuels" (3) for resistance of fittings and valves.

Such a table should accompany the table of maximum allowable capacity to improve the accuracy of the pipe selection and ensure that the limiting pressure drop (usually 0. 3-in. water) is not exceeded. For further accuracy the pipe-capacity table should be accompanied by conversion equations or tables for other pressure drops, other pipe materials, and other specific gravities of the gas being utilized. Since the pressure drop (h) and the specific gravity (s) in the equations have the exponential of roughly 1/2, a minor variation in either of these does not affect the capacity greatly. If a pressure drop of 0. 2 in. or 0. 5 in. is used instead of 0. 3 in. however, the capacity will be considerably changed and appropriate factors should be applied, such as the following based on an exponent of 0. 5.

Pressure Drop, In. Water	Correction Factor (multiply)
0.2	0.82
0.3	1.00
0.4	1.15
0.5	1.29
1.0	1.82

A similar set of correction factors could also be given for specific gravities of gas other than the 0.60 for which Table 1 is prepared, as is already given in CSA B149-1962, p. 25.

With regard to the allowance for different piping materials, the equation only applies to one value of absolute roughness and if it were desirable to take into account the variations in absolute roughness of the various piping materials it would be necessary to have separate tables for each material.

* * * * * *

References

(1) Huff, W. J. and Logan, L. Gas engineering flow formulae and the Reynolds number. American Gas Association Proc. 1935, p. 687.

(2) Spitzglass, J. M. Flow of fluids and frictional resistance in pipes. Armour Engineer, March and May, 1917.

(3) American Gas Association. Gaseous fuels. Edited by L. Shnidman, 1954, p. 62.

(4) Kent's Mechanical Engineers' Handbook, 12th edition (Power Volume). p. 1-34. John Wiley and Sons Inc. 1957.

TABLE 1

PIPE CAPACITY IN CU. FT. PER HR.

For 0.3 in. w.c. press. drop and 0.60 sp. gr. gas

SCHEDULE 40 PIPE

Nominal Pipe Size		½	3/4	1	1¼	1½	2	2½	3	4	5	6	8
Actual I.D., Inches		.622	.824	1.049	1.380	1.610	2.067	2.469	3.068	4.026	5.047	6.065	7.981
Length of Pipe Ft													
30	Darcy-(ASHRAE)	-	145	285	600	915	1830	2870	5190	10700	19700	32200	66200
	Huff & Logan	70	146	274	565	850	1640	2610	4640	9460	17150	27900	57900
	Spitzglass	50	113	229	488	777	1575	2575	4690	9800	18000	29100	59000
	AGA	53	147	302	529	830	1710	2980	4700	9660	16900	26600	54600
	CSA B149	52	120	241	535	850	1780	2760	4700	9700	-	27370	55850
	ASA Z21.30	73	152	285	590	890	1650	2700	4700	9700	-	-	-
150	Darcy-(ASHRAE)	(26)	(82)	-	239	366	727	1160	2150	4370	8060	13350	27700
	Huff & Logan	29	61	114	236	355	685	1090	1940	3950	7150	11650	24200
	Spitzglass	22	51	102	218	347	704	1150	2100	4390	8050	13000	26400
	AGA	24	66	135	236	370	763	1330	2100	4320	7550	11900	24400
	CSA B149	-	-	109	242	380	780	1240	2090	4350	-	12240	25000
	ASA Z21.30	31	64	120	250	380	710	1130	2000	4100	-	-	-
600	Darcy-(ASHRAE)	(7)	(20)	(53)	-	-	328	533	961	2020	3740	6140	12900
	Huff & Logan	14	29	54	111	165	320	510	910	1850	3350	5450	11300
	Spitzglass	11	25	51	109	174	352	575	1050	2190	4000	6500	13200
	AGA	12	33	68	118	185	382	665	1050	2160	3780	5950	12200
	CSA B149	-	-	-	119	192	390	620	1030	2130	-	6000	12480
	ASA Z21.30	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 2*

RESISTANCE OF VALVES AND FITTINGS IN EQUIVALENT FEET OF PIPE LENGTH

Nominal diameter std pipe, in.	Gate valve fully open	Globe valve fully open	Angle valve fully open	Std elbow, or run of tee reduced 50%	Medium sweep elbow, or run of tee reduced 25%	Long sweep elbow, or run of standard tee	Standard tee through side outlet	45° Elbow
1/2	0.4	17	8	1.5	1.4	1.0	3.3	0.8
3/4	0.5	22	11	2.0	1.8	1.4	4.5	1.0
1	0.6	27	14	2.7	2.2	1.7	5.7	1.3
1 1/4	0.8	36	18	3.5	3.0	2.3	7.6	1.7
1 1/2	1.0	43	22	4.3	3.6	2.7	9.0	2.0
2	1.2	55	27	5.5	4.5	3.5	12.0	2.5
2 1/2	1.4	67	33	6.5	5.2	4.2	14.0	3.0
3	1.7	82	41	8.0	6.8	5.2	17.0	3.8
4	2.3	110	53	11.0	9.0	7.0	22.0	5.0
5	2.9	140	70	14.0	12.0	9.0	27.0	6.3
6	3.5	170	80	16.0	14.0	11.0	33.0	7.5
8	4.5	225	120	20.0	17.0	14.0	43.0	10.0

* Extracted from Figure 3, p. 1-34 (4).