Designation: D8000 – 15

Standard Practice for Flow Conditioning of Natural Gas and Liquids[1]

This standard is issued under the fixed designation D8000; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers flow conditioners that produce a fully developed flow profile for liquid and gas phase fluid flow for circular duct sizes 1- to 60-in. (25.4- to 1525-mm) diameter and Reynolds Number (Re) ranges from transition (100) to 100 000 000. These flow conditioners can be used for any type of flow meter or development of a fully developed flow profile for other uses.

1.2 The central single-hole configuration that is derived using fundamental screen theory is referenced as the flow conditioner described herein.

1.3 Piping lengths upstream and downstream of a flow conditioner are considered a critical component of a flow conditioner and constitute the complete flow conditioner system.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4150 Terminology Relating to Gaseous Fuels

2.2 *AGA Standard:*[3]

AGA Report No. 8 Compressibility Factor of Natural Gas and Related Hydrocarbon Gases

3. Terminology

3.1 Refer to Terminology D4150 for general definitions related to gaseous fuels. Definitions specific to this standard follow.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *annuli, n*—ring-shaped object, structure, or region.

3.2.2 *axial symmetry, n*—symmetry around an axis; an object is axially symmetric if its appearance is unchanged if rotated around an axis.

3.2.3 *Reynolds number, n*—dimensionless number used in fluid mechanics to indicate whether fluid flow past a body or in a duct is steady or turbulent.

3.2.4 *velocity profile, n*—variation in velocity along a line at right angles to the general direction of flow.

4. Significance and Use

4.1 Flow conditioners are used for the conditioning of the turbulent flow profile of gases or liquids to reduce the ADD (velocity profile distortion) DEL (turbulence), swirl, or irregularities caused by the installation effects of piping elbows, length of pipe, valves, tees, and other such equipment or piping configurations that will affect the reading of flow measurement meters thus inducing measurement errors as a result of the flow profile of the gas or liquid not having a fully developed flow profile at the measurement point.[4]

5. Flow Conditioner Design Methodology

5.1 *Pipe Flow Profiles*—Almost any description can be prescribed by using the perforated plate utilizing screen theory. That is, any upstream velocity profile, U_1, can be changed to a downstream velocity profile, U_2, with the use of a screen (herein referred to as a flow conditioner) (see Fig. 1).

NOTE 1—The upstream flow profile need not be mathematically defined or even known.

5.1.1 The intent of the screen theory methodology is to suppress or allow flow such that the axi-symmetric distribution of the fluid flow eventually manifests itself into a fully developed state—$g(r)$. Separating the pipe flow into annuli and

[1] This test method is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.12 on On-Line/At-Line Analysis of Gaseous Fuels.

Current edition approved Sept. 15, 2015. Published October 2015. DOI: 10.1520/D8000–15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the American Gas Association, 400 N. Capital St., NW, Washington, DC 20001, www.techstreet.com/aga.

[4] Per various Coriolis Flow Meter manufacturer statements: A Coriolis Flow Meter reportedly does not require flow conditioning, therefore this ASTM standard does not apply.

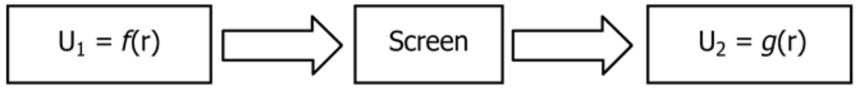


FIG. 1 Pipe Flow Profile

correlating the openness of each annulus in terms of an effective beta ratio of that annulus with respect to a discretized reference fully developed velocity flow profile is then done to have the resultant velocity flow profile fully developed [or some chosen function, $g(r)$] . The annuli and accompanying nomenclature are defined in Fig. 2.

5.1.2 For a screen, the relationship between the downstream U_2 and upstream U_1 velocities can be shown to follow the relationship between sudden enlargements and contractions (the flow conditioner holes) as a fully developed state by using Equation X (Karnik and Erdal). This equation relates the pressure drop of the holes considered as sudden enlargements and the designer can use as many annuli (n) as they wish. The user of this practice is cautioned that manufacturing difficulty increases with the number of annuli chosen. It is also recommended that the downstream velocity relationship (function, equation) be that which is of a fully developed state.

5.1.3 *Step 1*—Choose a downstream velocity function. For pipeline flow measurement, all flow meters are on a baseline against a fully developed flow profile. It is recommended that a function replicating the fully developed state be used at the chosen Reynolds number.

5.1.3.1 In this case, a power law flow profile is chosen such as Eq 1:

$$\frac{U_r}{U_{\max}} = \left(1 - \frac{r}{R}\right)^{\frac{1}{n}} \quad or \quad \frac{U_y}{U_{\max}} = \left(\frac{y}{R}\right)^{\frac{1}{n}} \tag{1}$$

where:

U_r = velocity at location, r;
U_{max} = maximum velocity at pipe center line;
r = r location;
R = r at pipe wall; and
n = 1/friction factor.

5.1.3.2 In terms of U_{ave} and U_{max} (at pipe center line), we obtain:

$$U_{ave} = U_{\max}\left[\frac{2n^2}{(n+1)(2n+1)}\right] \tag{2}$$

where:
values for U_{ave} and U_{max} are in Table 1.

5.1.4 *Step 2*—Choose an overall flow conditioner pressure loss coefficient that is suitable for the intended flow requirements. Note that the overall effectiveness or isolating capability of the flow is a very strong function of the pressure loss. The relationship between effectiveness and pressure drop is indicated in Fig. 2. Eq 4 can be used to accomplish this.

$$K_0 = \frac{\Delta P_0}{\frac{1}{2}\rho U_{ave}^2} \tag{3}$$

5.1.5 *Step 3*—Pressure drop of each ring (i).

$$\frac{U_i}{U_{ave}} = \frac{U_{\max}}{U_{ave}}\left(\frac{Y_i}{R}\right)^{\frac{1}{n}} \tag{4}$$

5.1.6 *Step 4*—Plug all terms into flow conditioner pressure drop coefficient Eq 5.

$$K_0 = \frac{0.7(1 - \lambda_i)}{\lambda_i^2} + \left[\frac{1 - \lambda_i}{\lambda_i}\right]^2\left[\frac{U_i}{U_{ave}}\right]^2 \tag{5}$$

5.1.7 *Step 5*—Equate Eq 6 for each hole size and number of holes for each ring.

$$\lambda_i = \frac{n\left(\frac{\pi}{4}\right)a^2}{\pi(R_{i+1}^2 - R_i^2)} \tag{6}$$

where*:*

λ_i = porosity of ring, i;
n = number of holes in ring, i;
a = area of each hole; and
R_x = r at x.

5.2 *Flow Conditioner Qualification Pipe Flow Profiles*—To comply with the requirements of this practice, the flow conditioner shall be shown to provide a state of flow within the pipe that resembles the fluid flow characteristics of a straight piece of pipe not shorter than 200 inside pipe diameters. This

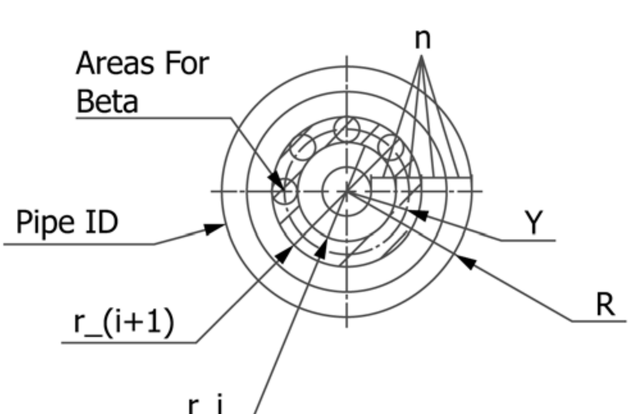


FIG. 2 Annuli and Nomenclature

TABLE 1 U_{ave} and U_{max}

n	U_{ave}/U_{max}	U_{max}/U_{ave}
1	0.333	3
2	0.533	1.875
3	0.643	1.56
4	0.711	1.41
5	0.758	1.32
6	0.791	1.26
7	0.816	1.22
8	0.836	1.19
9	0.851	1.173
10	0.865	1.155

shall be shown when installed downstream of any piping installation effect in any pipe length chosen.

5.2.1 This requirement ensures that specific flow meter type and flow conditioner peculiarities are avoided.

5.2.2 The mean normalized velocity profile shall resemble that of the "SE" flow profile to within ±2 % at any location within the pipe. The "SE" profile is as shown in Fig. 4.

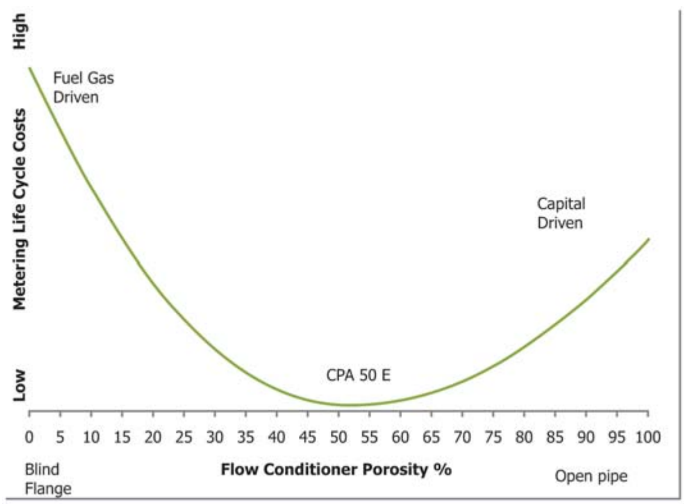


FIG. 3 Flow Conditioner Effectiveness as a Function of Pressure Loss

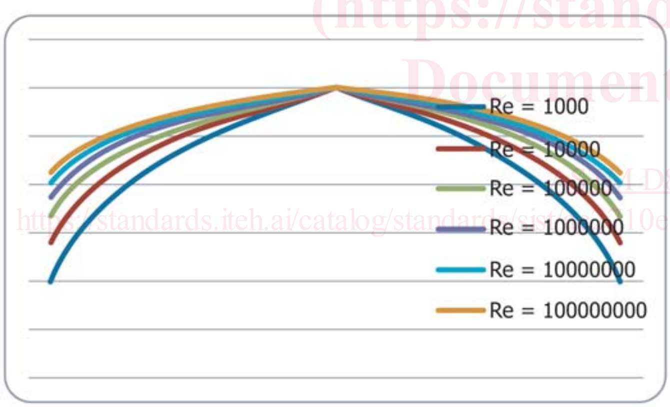


FIG. 4 Power Law Velocity Profiles

5.3 *Configuration Information*—Orders for material under this practice should include the following, as required, to describe the material adequately:

5.3.1 The nomenclature used to specify a flow-conditioning device is the following (9 in. (23 cm) not included in the description):

[NPS] [AA] [BB] [CC ANSI Rating] [Material Type]

5.3.2 The terms for a complete description are:

5.3.2.1 *AA = Nominal Pipe Size (NPS)*

(1) NPS does not refer to the pipe outside diameter up to NPS 12-in. (30.5-cm) pipe. For NPS 14-in. (35.5-cm) and larger pipe sizes, NPS corresponds to pipe outside diameter.

(2) In 90 % of applications, NPS will correspond with a published pipe schedule. In applications that exceed NPS 30 in. (76 cm), actual pipe inside diameters are used more than schedules. This may be due to difficulty meeting pressure containment requirements with published pipe schedules in larger pipe sizes. In some instances [even if smaller pipe sizes; NPS 16-in. (40.6 cm) and smaller], the pipe inside diameter may not correspond with a published pipe schedule. Flow conditioners can be manufactured to any pipe inside diameter.

(3) Standard weight pipe and Schedule 40 are equivalent in all sizes to NPS 10-in. (25.4-cm) pipe from NPS 12- to 24-in. (25.4- to 61-cm) standard weight pipe having a wall thickness of 0.375 in. (1 cm). Extra strong weight pipe and Schedule 80 are equivalent to NPS 8-in. (20-cm) pipe from NPS 8- to 24-in. (20- to 61-cm) extra strong pipe having a wall thickness of 0.500 in. (1.3 cm). Extra, extra strong pipe has no corresponding schedule number.

5.3.2.2 *BB = Flange Type*

(1) Flange application and flow conditioner type—There are many different flange types used in the measurement industry. Flange type specification is required (see Table 2).

TABLE 4 ANSI Rating

ANSI Class Designation	Nominal Pressure Class	Approximate Cold Working Pressure Rating[A]
150	PN 20	290 psi (2000 kPa)
300	PN 50	725 psi (5000 kPa)
400	PN 68	986 psi (6800 kPa)
600	PN 100	1450 psi (10 000 kPa)
900	PN 150	2175 psi (15 000 kPa)
1500	PN 250	3625 psi (25 000 kPa)
2500	PN 420	6091 psi (42 000 kPa)

[A] Not to be used in lieu of standards compliant pressure calculations for wall thicknesses and strength requirements. For temperature ranges from -20 to 100°F (-28.8 to 37.7°C).

5.3.2.3 *CC = Schedule or Actual Pipe Inside Diameter*—See Table 3.

5.3.2.4 *American National Standards Institute (ANSI) Rating = Pressure Class*

(1) ANSI rating—Pressure class rating or PN (pressure nominal). This information is required to size the flow conditioner to the pressure rated flange properly (see Table 4).

5.3.2.5 *Material Type = Steel Type*—The flow conditioner can be made of any type of material. The material of manufacture shall be stated on the purchase order. The most common flow conditioners are of stainless steel construction and these materials can be seen in Table 5.

5.3.2.6 *Ring No.* = only applies to ring-type joint (RTJ) applications (see Table 6).

6. Flow Conditioner Markings

6.1 *Markings*—All plates will have the following markings etched or mechanically placed upon the outer flange edge:

6.1.1 ANSI rating;

6.1.2 Temperature range;

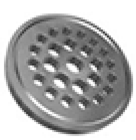
6.1.3 Manufacturer model identification;

6.1.4 Size, that is, NPS XX Sch. XX;

6.1.5 Material, that is, 304ss;

6.1.6 Country of manufacture;

TABLE 2 Flange Type

Flange Type	Flow Conditioner	Description	Nomenclature
Raised Face 	Type A Raised Face (RF)	Compressed between two raised face flanges in meter tube with thin flange—most popular—requires meter tube to be rolled to remove flow conditioner.	FOE (flange on end)
Raised Face 	Wafer	Compressed between two raised face flanges in meter tube with full width flange—least popular—does not require meter tube to be rolled to remove flow conditioner.	FWO (full width option)
Pinned in Pipe 	Pinned	Flanges are replaced by a threadolette and set screw. Used where conventional tube bundles are to be retrofitted.	TBR (tube bundle replacement)
Ring-Type Joint (RTJ) 	RTJ	Compressed between two RTJ flanges in meter tube.	RTJ (ring-type joint)
Ring-Type Joint (RTJ) 	RTJ Insert	The flow conditioner is inserted into a counter bore machined into the meter tube RTJ flange.	RIS (ring-type joint insert style)

6.1.7 Serial number and identification of plate by use of a combination of the purchase order number and number of the plate in the specific purchased lot in the following order; purchase order number XXXX, followed by plate number XX, out of total number of the lot XX as shown in Example 1.

6.1.7.1 *Example 1*—Purchase order 1234 that has ordered three plates on this order will have the following number for the first plate in the lot: 123431; but, if there is only one plate in this example order, then the number would be 123411, thus, the format: [order number] + [plate number out of the lot] + [total number of plates in the lot];

6.1.8 Flow (see Fig. 5);

6.1.8.1 Top indication (see Fig. 6); and

6.1.9 Heat number [using Material Test Report (MTR)].

6.1.10 The customers paint over the flow conditioners and cannot see the labeling on the flow conditioner—top indication recovery is paramount.

6.1.11 While the holes are being machined, a top indication will be machined as follows:

6.1.11.1 A 1/8-in. (3.155-mm) diameter cutting tool will side cut into the flange of the flow conditioner to a depth of 1/8-in. (3.155-mm) as shown in Fig. 6. To avoid orientation confusion, there shall be a 1/8-in. (3.155-mm) notch that will be top dead center (tdc). Place new top indication as such "Top ↑notch↑" as shown in Fig. 6.

6.2 *Bore Scope Marking*

6.2.1 To provide a second level of identification, the flow conditioner type can be machined into the downstream face of the flow conditioner as indicated in Fig. 7.

6.2.2 The order of indication shall be: NPSXX_Sch XX.

7. Installation Distances

7.1 *Markings*—To provide the best flow conditions possible, the flow conditioner shall be installed carefully. The flow conditioner shall not be installed in distances less than shown in Fig. 8.

TABLE 3 Schedule or Actual Pipe Inside Diameter

Nominal Pipe Size		Schedule	Inside Diameter	Flange Thickness
Outside Diameter (in.)	Number	Wall Thickness Designation		
1			1.185	0.125
1.315			1.097	0.125
	40	Std	1.049	0.125
	80	XS	0.957	0.125
	160		0.815	0.125
		XXS	0.599	0.125
1 1/4			1.530	0.125
1.660			1.442	0.125
	40	Std	1.380	0.125
	80	XS	1.278	0.125
	160		1.160	0.125
		XXS	0.896	0.125
1 1/2			1.770	0.125
1.900			1.682	0.125
	40	Std	1.610	0.125
	80	XS	1.500	0.125
	160		1.338	0.125
		XXS	1.100	0.125
			0.850	0.125
			0.600	0.125
2			2.245	0.125
2.375			2.157	0.125
	40	Std	2.067	0.125
	80	XS	1.939	0.125
	160		1.689	0.125
		XXS	1.503	0.125
			1.251	0.125
			1.001	0.125
2 1/2			2.709	0.125
2.875			2.635	0.125
	40	Std	2.469	0.125
	80	XS	2.323	0.125
	160		2.125	0.125
		XXS	1.771	0.125
			1.525	0.125
			1.275	0.125
3			3.334	0.250
3.500			3.260	0.250
	40	Std	3.068	0.250
	80	XS	2.900	0.250
	160		2.626	0.250
		XXS	2.300	0.250
			2.050	0.250
			1.800	0.250
4			4.334	0.250
4.500			4.260	0.250
			4.124	0.250
	40	Std	4.026	0.250
	80	XS	3.826	0.250
	120		3.626	0.250
			3.500	0.250
	160		3.438	0.250
		XXS	3.152	0.250
			2.900	0.250
			2.650	0.250
6			6.407	0.250
6.625			6.357	0.250
			6.187	0.250
	40	Std	6.065	0.250
	80	XS	5.761	0.250
	120		5.501	0.250
	160		5.189	0.250
		XXS	4.897	0.250
			4.625	0.250
			4.375	0.250
8			8.407	0.250
8.625			8.329	0.250
			8.187	0.250
	20		8.125	0.250
	30		8.071	0.250
	40	Std	7.981	0.250
	60		7.813	0.250
	80	XS	7.625	0.250
	100		7.439	0.250
	120		7.189	0.250
	140		7.001	0.250
	160		6.813	0.250
			6.625	0.250
			6.375	0.250
10			10.482	0.250
10.750			10.420	0.250
			10.312	0.250
	20		10.250	0.250
	30		10.136	0.250
	40	Std	10.020	0.250
	60		9.750	0.250
	80	XS	9.564	0.250
	100		9.314	0.250
	120		9.064	0.250
			9.000	0.250
	140		8.750	0.250
	160		8.500	0.250
			8.250	0.250
			7.750	0.250
12			12.438	0.250
12.750			12.390	0.250
	20		12.250	0.250
	30		12.090	0.250
		Std	12.000	0.250
	40		11.938	0.250
		XS	11.750	0.250
	60		11.626	0.250
	80		11.376	0.250
			11.250	0.250
	100		11.064	0.250
			11.000	0.250
	120		10.750	0.250
	140		10.500	0.250
			10.250	0.250
	160		10.126	0.250
14			13.688	0.250
14.000			13.624	0.250
			13.580	0.250
			13.562	0.250
	10		13.500	0.250
			13.438	0.250
	20		13.376	0.250
			13.312	0.250
	30	Std	13.250	0.250
	40		13.126	0.250
			13.062	0.250
		XS	13.000	0.250
	60		12.814	0.250
			12.750	0.250
	80		12.500	0.250
	100		12.126	0.250
	120		11.814	0.250
	140		11.500	0.250
	160		11.188	0.250
16			15.670	0.250
16.000			15.624	0.250
	10		15.500	0.250
	20		15.376	0.250
	30	Std	15.250	0.250
	40	XS	15.000	0.250
	60		14.688	0.250
	80		14.314	0.250
	100		13.938	0.250
	120		13.564	0.250
	140		13.126	0.250
	160		12.814	0.250
18			17.670	0.250

TABLE 3 *Continued*

Nominal Pipe Size		Schedule	Inside Diameter	Flange Thickness
Outside Diameter (in.)	Number	Wall Thickness Designation		
18.000			17.624	0.250
	10		17.500	0.250
	20		17.376	0.250
		Std	17.250	0.250
	30		17.126	0.250
		XS	17.000	0.250
	40		16.876	0.250
	60		16.500	0.250
	80		16.126	0.250
	100		15.688	0.250
	120		15.250	0.250
	140		14.876	0.250
	160		14.438	0.250
20			19.634	0.375
20.000			19.564	0.375
	10		19.500	0.375
	20	Std	19.250	0.375
	30	XS	19.000	0.375
	40		18.814	0.375
	60		18.376	0.375
			18.250	0.375
	80		17.938	0.375
	100		17.438	0.375
	120		17.000	0.375
	140		16.500	0.375
	160		16.064	0.375
24	10		23.500	0.500
24.00	20	Std	23.250	0.500
		XS	23.000	0.500
	30		22.876	0.500
			22.750	0.500
	40		22.626	0.500
			22.500	0.500
			23.564	0.500
			22.250	0.500
	60		22.064	0.500
	80		21.564	0.500
	100		20.938	0.500
	120		20.376	0.500
	140		19.876	0.500
	160		19.314	0.500
30			29.500	0.750
30.00	10		29.376	0.750
		Std	29.250	0.750
	20	XS	29.000	0.750
	30		28.750	0.750
	40		28.500	0.750
			28.250	0.750
			28.000	0.750
			27.750	0.750
32			31.500	0.750
32.000	10		31.376	0.750
		Std	31.250	0.750
	20	XS	31.000	0.750
	30		30.750	0.750
	40		30.624	0.750
			30.500	0.750
			30.250	0.750
			30.000	0.750
			29.750	0.750
36			35.500	1.000
36.000	10		35.376	1.000
		Std	35.250	1.000
	20	XS	35.000	1.000
	30		24.750	1.000
	40		34.500	1.000
			34.250	1.000
			34.000	1.000
			33.750	1.000

7.2 *Minimum Meter Run Distances*—Any distance longer than indicated will result in higher quality flow profiles (see Table 7).

7.3 In bi-directional metering applications, identical meter run distances will increase the chance of pulsation-induced meter run harmonics that can be detrimental to proper meter operation.

7.4 *Pressure Drop Determination*

7.4.1 Let:

$$k = 0.52 \frac{(1 - \beta^2)}{\beta^2} \quad (7)$$

$$\Delta p = \frac{k \rho U^2}{2} \quad (8)$$

where:

Δp = recovered pressure loss across the flow conditioner [lb/in.^{2} (Pa)];
k = pressure loss coefficient (experimentally determined);
ρ = fluid density, kg/m^3;
U = fluid velocity, m/s; and
K = dimensionless pressure drop coefficient.

7.5 *k Values*

7.5.1 *Low Reynolds Number Turbulent Pipe Flow (Inertial Flow)*—See Fig. 9.

7.5.2 *High Reynolds Number Turbulent Pipe Flow (Inertial Flow)*—See Fig. 10.

7.5.3 *High Viscosity Fluids Laminar Low Reynolds Number Flow (Frictional Flow):*

7.5.3.1 For high viscosity fluids, an additional viscosity adjustment factor is installed into the pressure-drop equation. These values shall be experimentally determined. L. P. Martinez provides a very useful overview of low Reynolds number *k* factor determination with comparisons between previous estimations.

7.5.3.2 In the absence of test results availability, we propose the following estimation for lack of a better method presently available.

(1) The pressure-drop *k* factor results are extrapolated to extend to very low Re and to obtain the results in Table 8.

7.6 *Pressure-Loss Examples*

7.6.1 *Methodology*—The methodology used to determine the pressure losses as a result of fluid movement past the flow conditioner is the following typical pressure-loss approach:

$$\Delta P = k \frac{1}{2} \rho v^2 \quad (9)$$

where:

k = head loss coefficient—experimentally determined and confirmed by NRTC = 1.5 to 1.7;
ρ = density via AGA Report No. 8; and
v = mean fluid flow velocity.

7.6.2 *Density*—Using a typical composition of 93 % methane, 3 % ethane for the AGA 222 Report No. 8 calculation results in the following examples in Table 9.

7.6.3 *Pressure Loss*

7.6.3.1 Using the following equation [and measurements of 65 and 100 ft/s (20 and 30.5 m/s)]: