DDS 512-1

DESIGN DATA SHEET

PRESSURE LOSSES OF VENTILATION FITTINGS

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, D.C. 20362-5101

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NAVAL SEA SYSTEMS COMMAND
Washington, D.C. 20362

DDS512-1

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DESIGN DATA SHEET

DEPARTMENT OF THE NAVY, NAVAL SEA SYSTEMS COMMAND

SECTION DDS512-1
PRESSURE LOSSES OF VENTILATION FITTINGS

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DDS512-1-a. References

(a) "Heating, Ventilating and Air Conditioning Equipment Manual," S9512-BS-MMA-010, Naval Sea Systems Command, Department of the Navy, September 30, 1985.

(b) ASHRAE Handbook 1985 Fundamentals, American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Atlanta, GA, 1985.

(c) "HVAC Duct System Design Manual," 2nd Edition, Sheet Metal and Air Conditioning Contractors' National Association Inc. (SMACNA), Vienna, VA, April 1981.

(d) Jorgensen, R., ed., Fan Engineering, 8th Edition, Buffalo Forge Co., New York, NY, 1983.

(e) Duct Size Calculator, Navy # 0938-036-0010, Bureau of Ships, Department of the Navy, October 1, 1968.

(f) Keystone Valve Corp., USA Valve Division Product Catalog, 9700 West Gulf Bank Drive, P.O. Box 40010, Houston, TX, 77040.

DDS512-1-b. **Abbreviations, symbols and subscripts**

1. Abbreviations

aspect ratio	AR
cubic feet per minute	cfm
degrees	deg
feet	ft
feet per minute	fpm
inch	in
inches of water gauge	in wg
minimum	MIN
radius ratio	RR
square feet	ft^2
square inches	in^2
water gauge	wg

2. Symbols

Symbol	Parameter	Unit
A	area	in^2, ft^2
A_1	cross-sectional area of duct or cross-sectional area of slot	ft^2, in^2
A_2	cross-sectional area of bellmouth	ft^2
A_o	cross-sectional area	in^2
b	slot thickness	in
D	diameter	in
D_1	diameter	in
D_2	diameter	in
D_o	diameter	in
d	diameter	ft
E	perpendicular distance between guide vanes	in
F	aspect ratio factor	--
H	duct dimension parallel to axis of the bend	in
K	loss coefficient	--
K_1	loss coefficient for first 90° elbow	--
K_2	loss coefficient for second 90° elbow	--
Ke	loss coefficient for single elbow	--
K_o	loss coefficient for offset	--
K_{Re}	Reynolds number correction loss coefficient	--
L	length or length of trailing edge of vane	ft, in
M	multiplier for elbows with angles other than 90°	--
P	pressure	in wg
p	pressure	in wg

Symbol	Parameter	Unit
Q	air flow rate	cfm
R	free area of armor grating divided by area of duct connected to grating	--
r	radius	in
Re	Reynolds number	--
S	distance between vanes	in
T	grating thickness	in
V	velocity	fpm
W	duct dimension in plane of bend	in
Δ	difference between values or change	--
θ	angle	deg
≥	greater than or equal to	--

3. Subscripts

b	branch
c	common section
d	equivalent diameter
e	equivalent
i	inside
o	outside
s	main
t	throat diameter
v	velocity (pressure)
vf	velocity (pressure) heater face
vs	velocity (pressure) screen face
vt	velocity (pressure) terminal
1b	first branch
2b	second branch

DDS512-1-c. General

1. Pressure losses calculated using the tables and charts in this document are total pressure losses, except where loss coefficients from references (b) and (c) are used. Pressure losses caused by friction must be added to the fitting losses calculated with the loss coefficients from these two sources. Therefore, the lengths of fittings whose loss coefficients are obtained from references (b) and (c) must be added to the length of an adjacent straight duct. Generally, this is accomplished by measuring duct lengths from the center line of one fitting to that of the next fitting. Throughout this document, pressure losses are stated either in inches of water gauge (in wg), or in terms of velocity pressure as follows:

$$p = Kp_v$$

where:

p = total pressure loss, in wg
p_v = velocity pressure, in wg
K = fitting loss coefficient, dimensionless

2. If pressure loss is required in terms of equivalent length of straight duct, it may be obtained by the formula:

$$L_e = 39dK$$

where:

L_e = equivalent length of straight duct, ft
K = fitting loss coefficient, dimensionless
d = diameter of round duct or equivalent diameter of rectangular duct, ft (for more information on equivalent diameter see reference (b))

3. Pressure losses and fitting loss coefficients apply only to fittings proportioned as indicated and installed with sufficient length of duct between them to permit re-establishment of uniform air distribution. Losses and coefficients for fittings of other proportions may be extrapolated with care by the designer.

DDS512-1-d. Screens

1. Total pressure losses given for weather openings and terminals are for fittings without screens. Total pressure losses for waterproof ventilators include the loss caused by screens. If screens are used, the loss for the fitting shall be increased by the following amounts:

1/2-inch mesh (interior location)............... 0.44 p_{vs}
1/2-inch mesh (weather location)............... 1.18 p_{vs}
1/8-inch mesh screen............................ 2.5 p_{vs}
1 1/2-inch wire mesh screen.....................0.25 p_{vs}

where:

p_{vs} = velocity pressure at the face of the screen, in wg

If the face area of the screen is the same as that of the fitting, then $p_{vs} = p_v$. If the two areas are different, then the screen losses given above must be multiplied by:

$$\left(\frac{A_1}{A_2}\right)^2$$

where:

A_1 = area upon which loss of fitting is based
A_2 = face area of screen

DDS512-1-e. Weather openings

1. In all formulas in this section, p_v = velocity pressure developed by the air velocity as measured at the deck openings of the fitting.

2. For openings in the side of a deckhouse, the total pressure loss, p, equals:

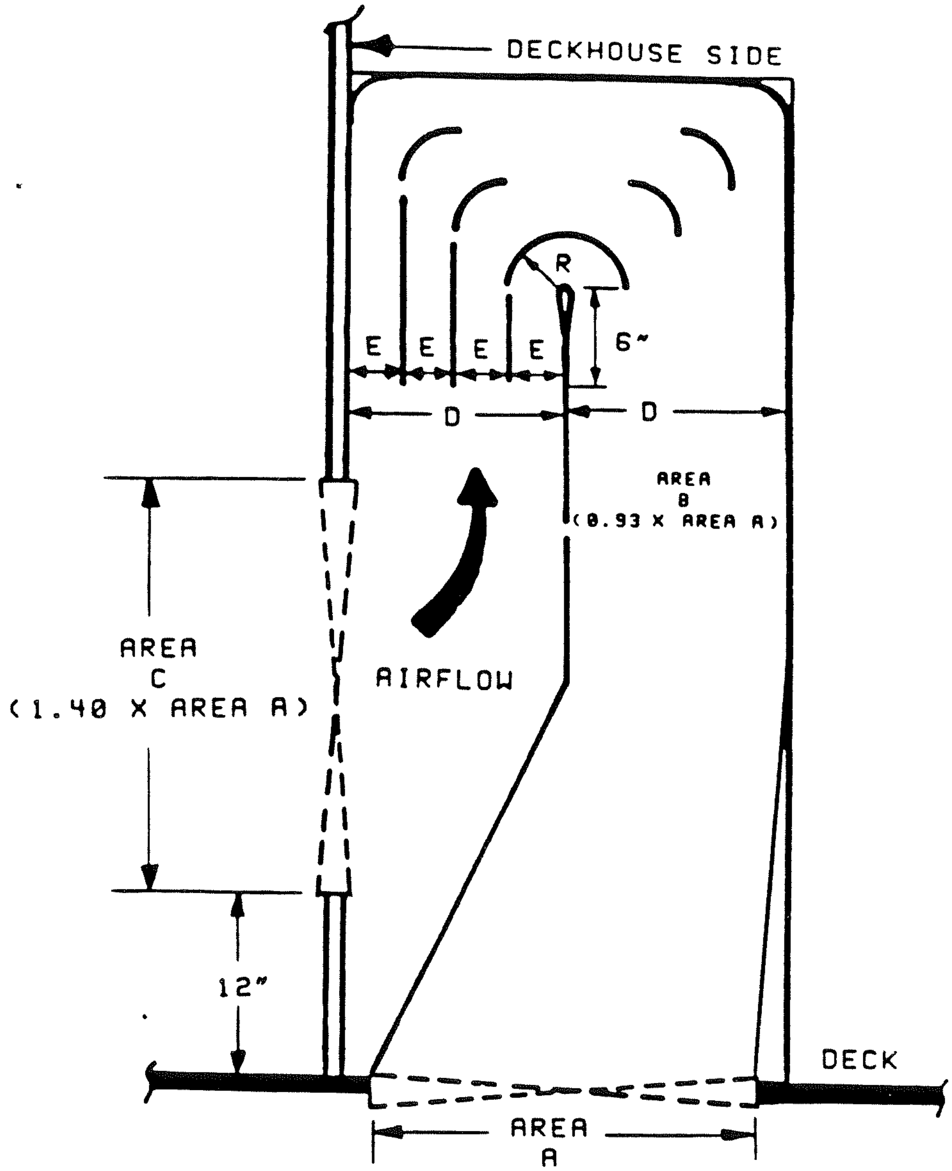
(a) Type A air lift (figure 1)
Loss as supply opening: $p = 2.56\ p_v$
Loss as exhaust opening: $p = 3.01\ p_v$

(b) Type B air lift (figure 2)
Loss as supply opening: $p = 1.70\ p_v$
Loss as exhaust opening: $p = 2.38\ p_v$

3. For Navy standard cowl ventilators (figure 3), the total pressure loss, p, equals:

(a) With splitters
Loss as supply ventilator: $p = 0.53\ p_v$
Loss as exhaust ventilator: $p = 0.65\ p_v$

(b) Without splitters
Loss as supply ventilator: $p = 0.82\ p_v$
Loss as exhaust ventilator: $p = 0.99\ p_v$



D	E and R
Up to 10 in.....	D/3
10-15 in........	D/5
15-21 in........	D/7
21-27 in........	D/5
27-30 in........	D/6

Figure 1. Type A Air Lift for Deck House Side Openings

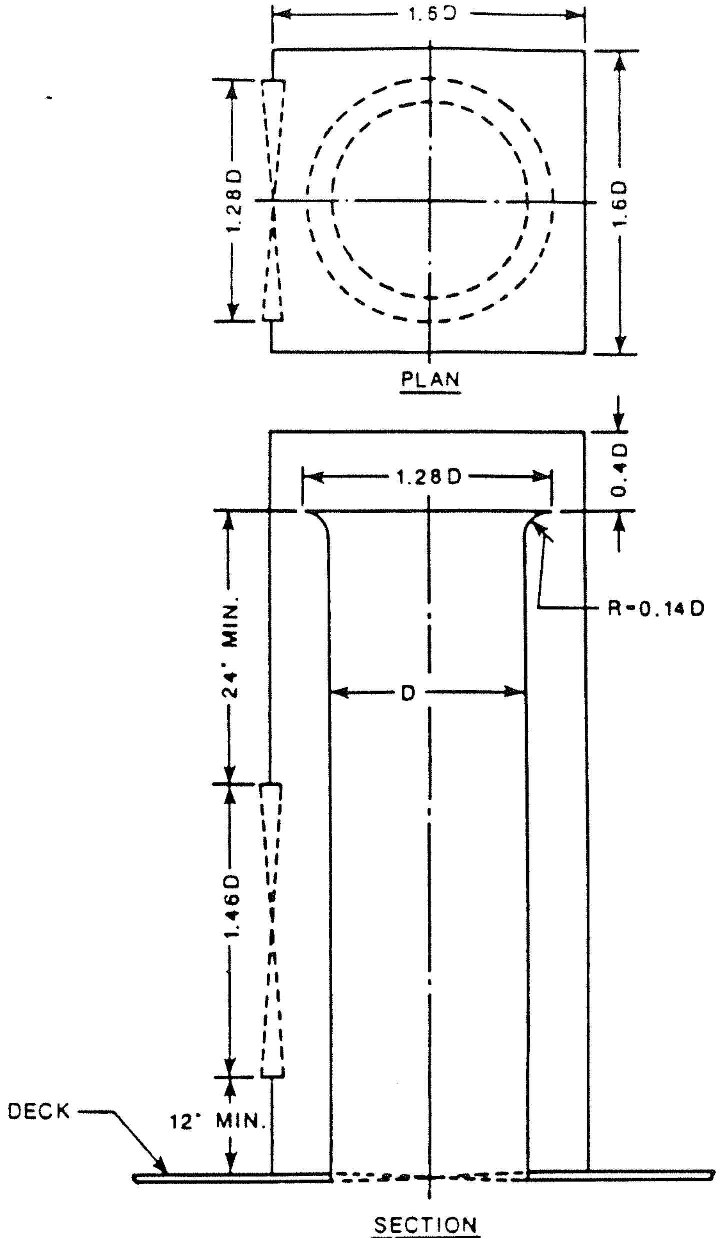


Figure 2. Type B Air Lift for Deck House Side Openings

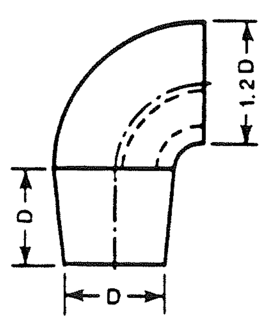


Figure 3. Navy Standard Cowl Ventilator

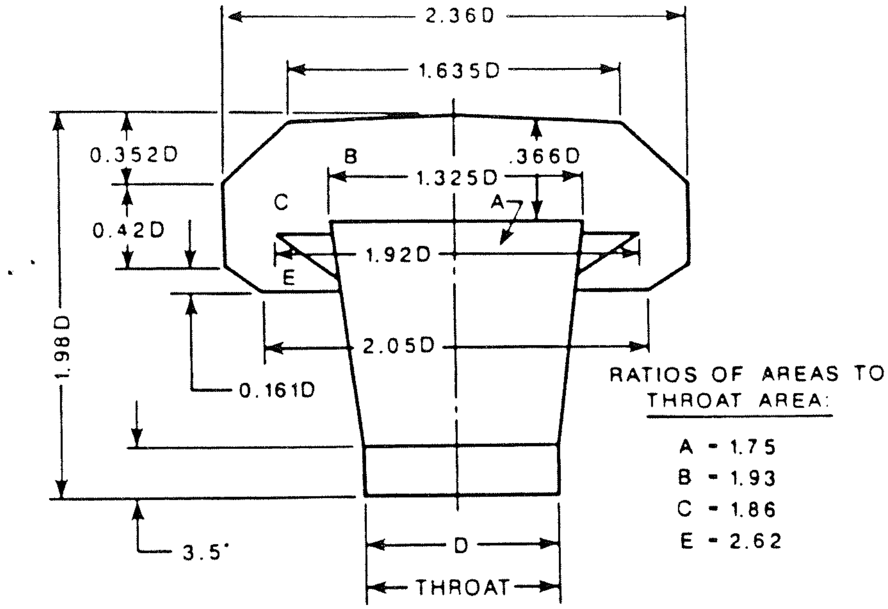


Figure 4. Typical Mushroom Type Ventilator

4. For Mushroom type ventilators (figure 4), the total pressure loss, p, equals:

Loss as supply ventilator: $p = 0.86\ p_v$
Loss as exhaust ventilator: $p = 1.62\ p_v$

5. For Navy standard waterproof ventilators (figure 5), the total pressure loss, p, equals:

$$p = Kp_v$$

where:

K = loss coefficient including 1/2-inch mesh screen (table 1)
p_v = velocity pressure, in wg

6. Pressure losses for standard size ventilators may be read from figure 6. This figure was developed from the data in table 1 and gives pressure losses in inches of water gauge.

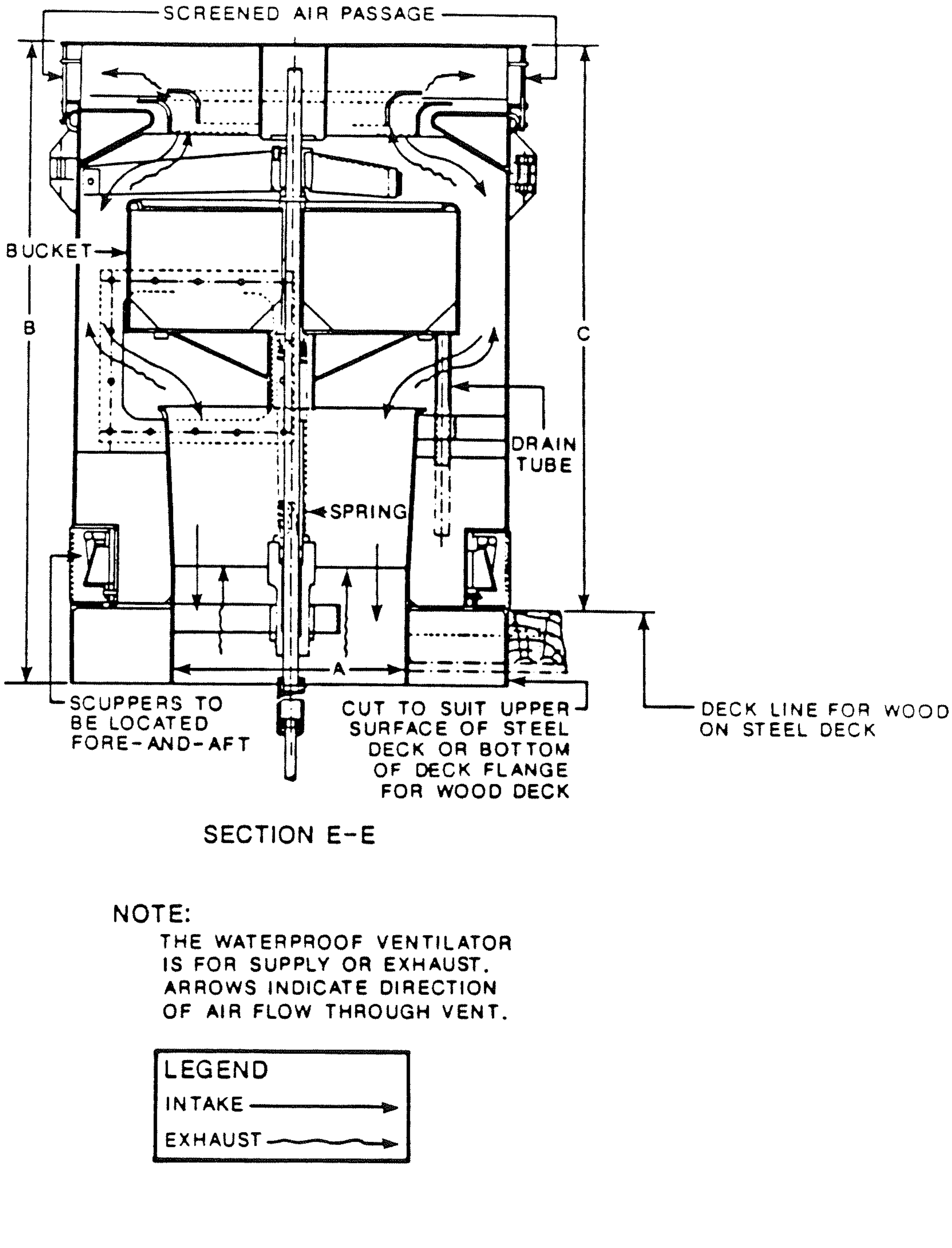


Figure 5. Typical Navy Standard Waterproof Ventilator

TABLE 1. WATERPROOF VENTILATOR PRESSURE LOSS COEFFICIENTS

Size	K (for supply)	K (for exhaust)
15 inches and under	2.80	2.40
16-18 inches	3.08	2.50
19-21 inches	3.55	2.56
22-24 inches	4.00	2.90
25-29 inches	4.34	2.92
30 inches and over	4.80	3.60

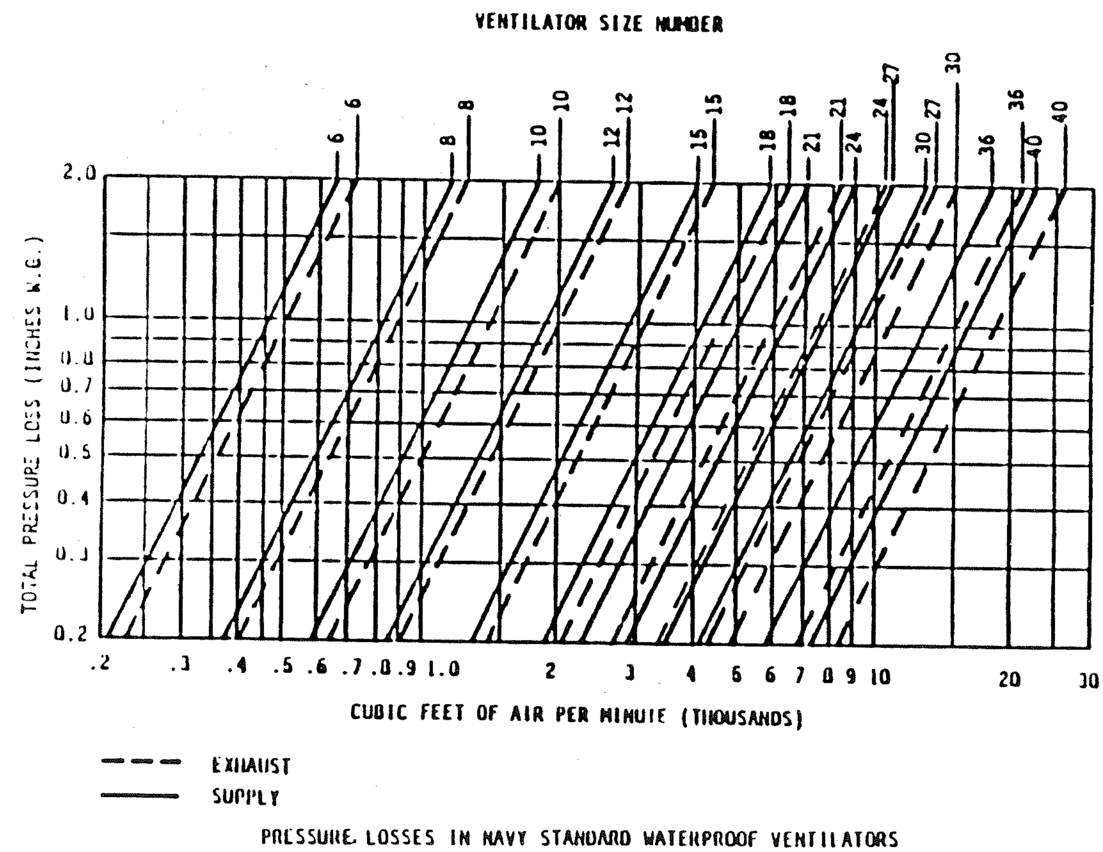


Figure 6. Pressure Losses in Navy Standard Waterproof Ventilators

7. The loss for a gooseneck is the sum of the losses for the component parts for the gooseneck. For example, the loss for an intake gooseneck, which consists of a 180° round elbow (radius ratio = 1.5) and a bellmouth covered with a 1/2-inch mesh screen, will be the sum of the losses for the elbow, bellmouth, and screen.

$$p = 0.8(K_1 + K_2)p_v + 0.10p_v + 1.18 \left(\frac{A_1}{A_2}\right)^2 p_v$$

where:

$0.8\ (K_1 + K_2)\ p_v$ = loss for compound elbow (section h.)

$0.10\ p_v$ = loss for bellmouth (section n.)

$1.18 \left(\frac{A_1}{A_2}\right)^2 p_v$ = loss for 1/2-inch mesh screen (section d.)

and:

K_1 = loss coefficient for first 90° elbow
K_2 = loss coefficient for second 90° elbow
A_1 = cross-sectional area of duct, ft^2
A_2 = cross-sectional area of bellmouth, ft^2
p_v = velocity pressure in duct, in wg

DDS512-1-f. Ducts

1. Friction losses for straight duct, given in inches of water per foot of duct, may be obtained from reference (e).

2. The friction loss for acoustically treated duct (lined with sound-absorbing blanket and perforated sheathing) is to be considered the same as that of untreated duct.

DDS512-1-g. Transition sections

1. Pressure loss of transition sections are based on the geometry of the transition. The pressure loss coefficients presented in this section are applicable only to transitions which result in a change of velocity. While it is known that there is a loss when changing shape only (areas equal), it is negligible and may be disregarded. Note that the included angle of the sides of a converging or diverging transition should not be greater than 30°.

The information in table 2 and table 3 is from reference (b). The frictional losses associated with these duct sections will have to be added to the velocity pressure loss calculated herein. Figures 7, 8, and 9 are from reference (c).

2. Diverging transition in round duct (figure 7)

$$p = Kp_v$$

where:

K = loss coefficient (table 2)

3. Diverging transition in rectangular duct (figure 8).

$$p = Kp_v$$

where:

K = loss coefficient (table 3)

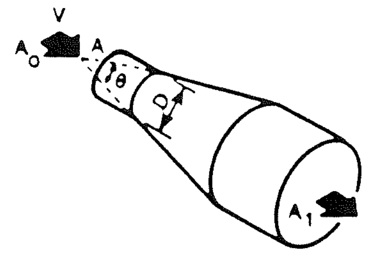


Figure 7. Diverging Transitions in Round Duct

TABLE 2. PRESSURE LOSS COEFFICIENTS FOR DIVERGING TRANSITIONS IN ROUND DUCT

	Loss Coefficient K				
	θ (deg)				
A_1/A_o (in^2)	8	12	16	20	30
2	0.11	0.11	0.14	0.19	0.32
4	0.15	0.17	0.23	0.30	0.46
6	0.17	0.20	0.27	0.33	0.48
10	0.19	0.23	0.29	0.38	0.59
≥16	0.19	0.22	0.31	0.38	0.60

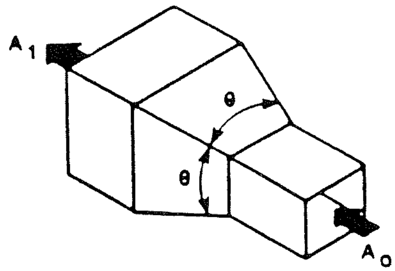


Figure 8. Diverging Transitions in Rectangular Duct

TABLE 3. PRESSURE LOSS COEFFICIENTS FOR DIVERGING TRANSITIONS IN RECTANGULAR DUCT

	K				
	θ (deg)				
A_1/A_o (in^2)	8	10	14	20	30
2	0.14	0.15	0.20	0.25	0.30
4	0.20	0.25	0.34	0.45	0.52
6	0.21	0.30	0.42	0.53	0.63
$\geq$10	0.24	0.30	0.43	0.53	0.64

4. Converging transitions in round and rectangular duct (figure 9)

$$p = 0.05p_v$$

where:

p_v = velocity pressure in small duct, in wg

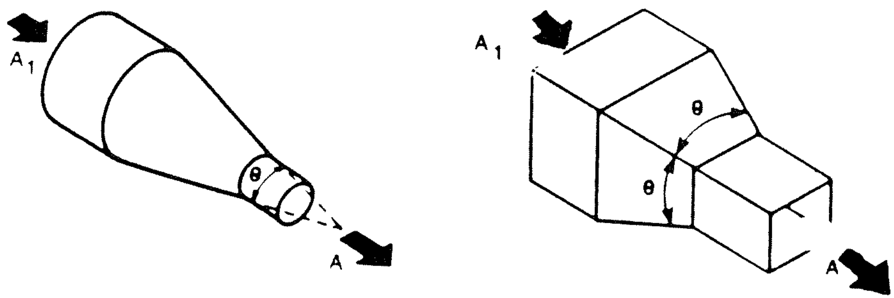


Figure 9. Converging Transitions in Round and Rectangular Duct

DDS512-1-h. Elbows

1. The method for calculating pressure losses in elbows is divided into the following five categories:

(a) Elbows followed by sufficient length of straight duct to permit maximum regain
(b) Elbows at the end of a run of duct
(c) Compound elbows in a run of duct
(d) Vaned elbows
(e) Elbows with no attached duct (natural vents)

The information in tables 4, 5, 6, 7, 8, 9, and 12 is from reference (c). The information in tables 10 and 11 is from reference (b). Therefore, the frictional losses associated with these duct sections will have to be added to the velocity pressure loss calculated. Figures 10, 11, 16, and 17 are from reference (d), figures 12, 13, 14, 15, and 21 are from reference (c), and figures 18 and 20 are from reference (b).

2. All losses for elbows in a run of duct are based on the elbow being followed by a length of straight duct which will allow a normal air flow pattern to be re-established within the duct. This length is generally considered to be equal to 5 times the diameter of a round duct, or for rectangular duct, 5

times the duct dimension in the plane of bend. Where an elbow is followed by less than the required length of duct, the pressure loss coefficient shall be considered the same as the loss coefficient for an elbow at end of a duct, minus one.

3. The duct aspect ratio (H/W) is defined as the ratio of the duct dimension parallel to the axis of the bend to the duct dimension in the plane of the bend (figure 10). The aspect ratio of a rectangular duct affects the pressure loss developed by an elbow. As a result, data is given (in figure 11 from reference (d)) whereby the pressure loss for an elbow with a square cross-section may be corrected to give the pressure loss for an elbow of rectangular cross-section. The notes in figure 11 refer to a radius and curve ratio. A radius ratio (r/W) is defined as the ratio of the centerline radius to the duct dimension in the plane of the bend. A curve ratio (r_i/r_o) is defined as the ratio of the inside radius to the outside radius.

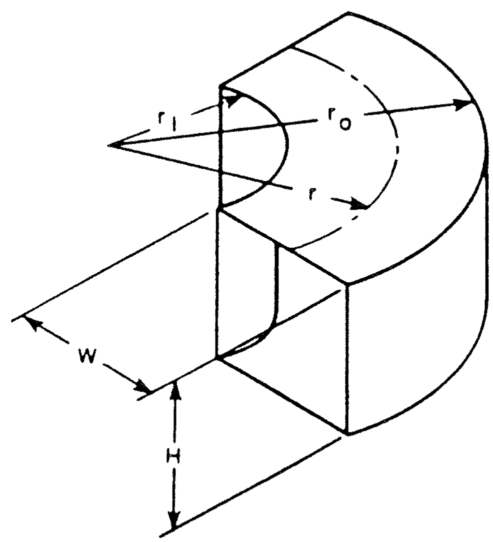


Figure 10. Aspect Ratio

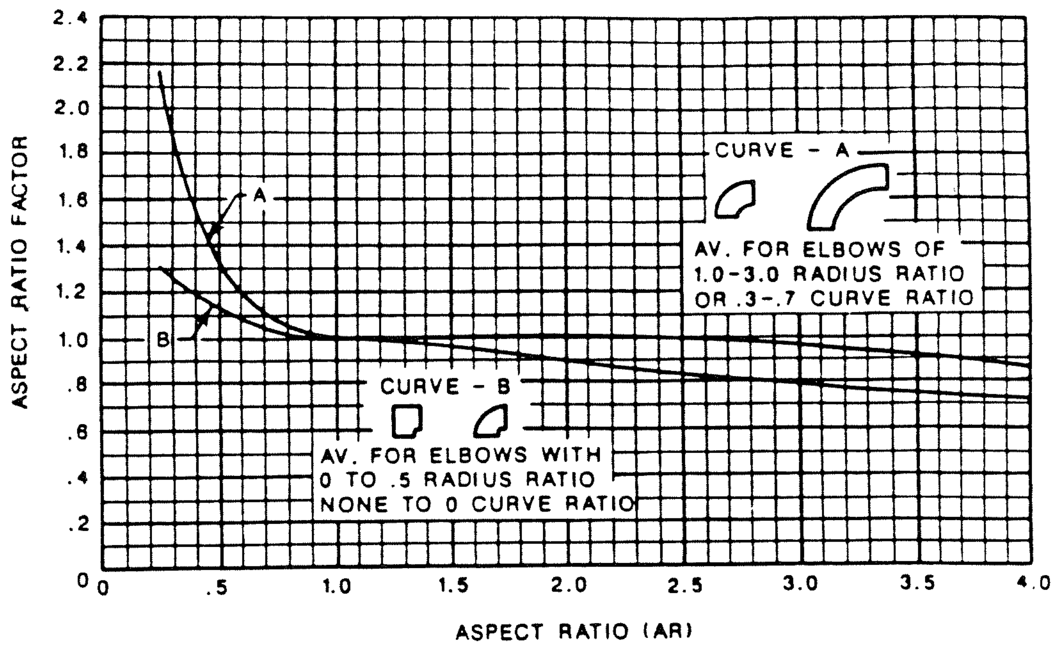


Figure 11. Effect of Aspect Ratio

4. All loss coefficients are stated for 90° elbows. Correction factors for pressure losses developed by elbows of less than or greater than 90° can be found in table 4.

TABLE 4. PRESSURE LOSS COEFFICIENT MULTIPLIERS FOR ELBOWS WITH ANGLES OTHER THAN 90°

θ (deg)	0°	20°	30°	45°	60°	75°	90°	110°	130°	150°	180°
M	0	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40

5. The velocity pressure, p_v, in all equations in this section, is that at the entrance to the elbow unless otherwise specified.

6. Elbows in a run of duct sufficient to allow maximum regain (see DDS512-1-h.2)

(a) Round turn, rectangular duct without splitters (figure 12)

$$p = Kp_v$$

where:

K = loss coefficient (table 5)

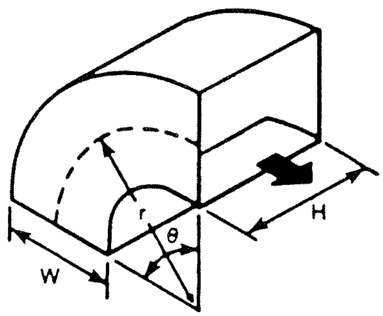


Figure 12. Rectangular Elbows in Run of Duct without Splitters

For round turns without splitters, turbulent flow may be a problem. To determine if it is a problem, check the Reynolds number using the following procedure:

(1) calculate the diameter using:

$$D = \frac{2\ HW}{H + W}$$

where:

D = duct diameter, in
H = duct dimension parallel to the axis of the bend, in
W = duct dimension in the plane of the bend, in

(2) calculate the Reynolds number using:

$$Re = 8.56\ DV$$

TABLE 5. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR 90° ELBOWS WITHOUT SPLITTERS

	Loss Coefficient K										
	H/W										
r/W	0.25	0.5	0.75	1.0	1.5	2.0	3.0	4.0	5.0	6.0	8.0
0.5	1.5	1.4	1.3	1.2	1.1	1.0	1.0	1.1	1.1	1.2	1.2
0.75	0.57	0.52	0.48	0.44	0.40	0.39	0.39	0.40	0.42	0.43	0.44
1.0	0.27	0.25	0.23	0.21	0.19	0.18	0.18	0.19	0.20	0.27	0.21
1.5	0.22	0.20	0.19	0.17	0.15	0.14	0.14	0.15	0.16	0.17	0.17
2.0	0.20	0.18	0.16	0.15	0.14	0.13	0.13	0.14	0.14	0.15	0.15

TABLE 6. PRESSURE LOSS COEFFICIENT CORRECTION FACTORS FOR RECTANGULAR 90° ELBOWS WITHOUT SPLITTERS

	R_e 10^{-4}								
r/W	1	2	3	4	6	8	10	14	≥ 20
0.5	1.40	1.26	1.19	1.14	1.09	1.06	1.04	1.0	1.0
≥0.75	2.0	1.77	1.64	1.56	1.46	1.38	1.30	1.15	1.0

where:

Re = Reynolds number, dimensionless
D = duct diameter, in
V = duct velocity, fpm

(3) using Reynolds number calculated in (2), above, check table 6 to see if a correction is needed for the Reynolds number

(4) if a correction is needed for the Reynolds number, the pressure loss equation becomes:

$$p = K\ K_{Re}\ P_v$$

where:

K = loss coefficient (table 5)
K_{Re} = Reynolds number correction loss coefficient (table 6)

Example: For a duct system with a velocity of 2000 fpm, check the Reynolds number for a 90° rectangular elbow with an aspect ratio of 1.5, a radius ratio of 0.50, H=12 in, and W=8 in.

(1) $D = \frac{2(12)(8)}{12+8} = 9.6$ in

(2) $Re = 8.56(9.6)(2000) = 16.44 \times 10^4$

(3) Checking table 6 for a Reynolds number of 16.44×10^4 and a radius ratio of 0.5, the corresponding correction factor is 1.0, so the pressure loss equation remains unchanged.

(b) Round turn, rectangular duct with splitters (figure 13)

$$p = Kp_v$$

where:

K = loss coefficient (table 7)

(c) Round turn, round duct (figure 14)

$$p = Kp_v$$

where:

K = loss coefficient (table 8)

7. Elbows at discharge end of duct

(a) Rectangular ducts (figure 15)

$$p = Kp_v$$

where:

K = loss coefficient (table 9)

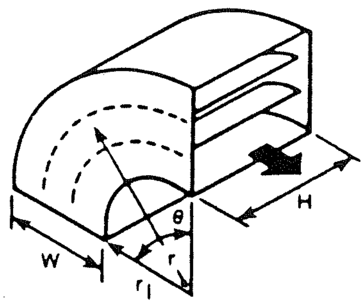


Figure 13. Rectangular Elbow in Run of Duct with Splitters

TABLE 7. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR ELBOWS WITH SPLITTERS

				Loss Coefficient K										
				H/W										
	r_i/W	r/W	r_i/r_o	0.25	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0
One Splitter Vane	0.05	0.55	0.218	0.52	0.40	0.43	0.49	0.55	0.66	0.75	0.84	0.93	1.0	1.1
	0.10	0.60	0.302	0.36	0.27	0.25	0.28	0.30	0.35	0.39	0.42	0.46	0.49	0.52
	0.15	0.65	0.361	0.28	0.21	0.18	0.19	0.20	0.22	0.25	0.26	0.28	0.30	0.32
	0.20	0.70	0.408	0.22	0.16	0.14	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21
	0.25	0.75	0.447	0.18	0.13	0.11	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.15
	0.30	0.80	0.480	0.15	0.11	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12
	0.35	0.85	0.509	0.13	0.09	0.08	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09
	0.40	0.90	0.535	0.11	0.08	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
	0.45	0.95	0.557	0.10	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
	0.50	1.00	0.577	0.09	0.06	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05
				H/W										
Two Splitter Vanes	0.05	0.55	0.362	0.26	0.20	0.22	0.25	0.28	0.33	0.37	0.41	0.45	0.48	0.51
	0.10	0.60	0.450	0.17	0.13	0.11	0.12	0.13	0.15	0.16	0.17	0.19	0.20	0.21
	0.15	0.65	0.507	0.12	0.09	0.08	0.08	0.08	0.09	0.10	0.10	0.11	0.11	0.11
	0.20	0.70	0.550	0.09	0.07	0.06	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.07
	0.25	0.75	0.585	0.08	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
	0.30	0.80	0.613	0.06	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
				H/W										
Three Splitter Vanes	0.05	0.55	0.467	0.11	0.10	0.12	0.13	0.14	0.16	0.18	0.19	0.21	0.22	0.23
	0.10	0.60	0.549	0.07	0.05	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09

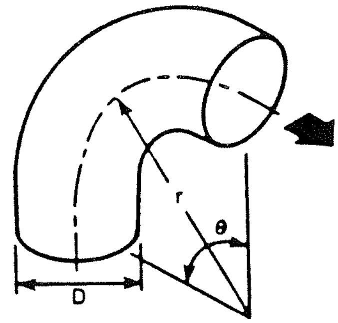


Figure 14. Round Elbow in Run of Duct

TABLE 8. PRESSURE LOSS COEFFICIENTS FOR 90° ELBOWS

r/D	0.5	0.75	1.0	1.5	2.0	2.5
K	0.71	0.33	0.22	0.15	0.13	0.12

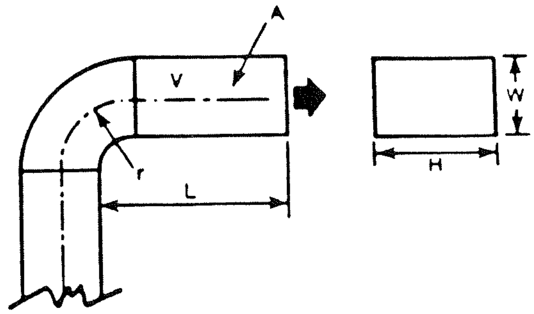


Figure 15. Rectangular or Round 90° Elbows at End of the Duct

TABLE 9. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR OR ROUND 90° ELBOWS AT END OF DUCT

RECTANGULAR

r/W	L/W									
	0	0.5	1.0	1.5	2.0	3.0	4.0	6.0	8.0	12.0
0	3.0	3.1	3.2	3.0	2.7	2.4	2.2	2.1	2.1	2.0
0.75	2.2	2.2	2.1	1.8	1.7	1.6	1.6	1.5	1.5	1.5
1.0	1.8	1.5	1.4	1.4	1.3	1.3	1.2	1.2	1.2	1.2
1.5	1.5	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
2.5	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0

ROUND

L/D	0.9	1.3
K	1.5	1.4

(b) Round ducts ($r/D = 1.0$) (figure 15)

$$p = Kp_v$$

where:

K = loss coefficient (taken from the second part of table 9)

(c) Elbow other than 90^o:

(1) subtract one from the pressure loss coefficient from table 9

(2) multiply the value calculated in (1), by a loss coefficient from table 4

(3) add one to the value calculated in (2)

Example: for a 60^o rectangular elbow, with a length to width ratio of 1.0, and a radius ratio of 1.0:

$$K = (1.4 - 1)\ 0.78 + 1 = 1.31$$

where:

1.4 is from table 9 ($L/W = 1.0$)
0.78 is from table 4

(d) Elbows with splitters:

(1) subtract one from the pressure loss coefficient from table 9

(2) multiply the value calculated in (1) by the ratio of losses, with and without splitters, as given by table 7 and table 5 for an elbow of the same radius and aspect ratio

(3) add one to the value calculated in (2)

Example: for a 90^o rectangular elbow with one splitter, aspect ratio of 0.5, and radius ratio of 1.0:

$$K = (1.4 - 1)\ \frac{0.06}{0.25} + 1 = 1.10$$

where:

1.4 is from table 9 ($L/W = 1.0$)
0.06 is from table 7
0.25 is from table 5

8. Elbows at inlet end of duct

The pressure loss for an elbow at the inlet end of a duct run is equal to, the sum of the loss for an elbow in a run of duct and the inlet loss for an open-end duct inlet (0.95 p_v).

9. Compound elbows in duct

(a) Compound elbows (i.e., two elbows adjacently located in a run of duct) develop a pressure loss which is different from the sum of the pressure losses for the two elbows. The pressure loss coefficients given in this section are for the most common types of compound elbows. Figures 16 and 17 from reference (d) have additional loss coefficients for less common types of compound elbows. RR and AR in figure 16 represent radius ratio and aspect ratio, respectively.

For the formulas in this section:

K_1 = loss coefficient for first turn
K_2 = loss coefficient for second turn
K_o = loss coefficient for the offset
K_e = loss coefficient for single elbow

(1) Two consecutive turns, same angle and plane, either round or rectangular, with a change in direction less than or equal to 90° (figure 18)

$$p = Kp_v$$

where:

$$K = (K_o)K_e$$

See table 10 for values of K_o.

(2) Two consecutive turns, same plane, either round or rectangular, with a change in direction greater than 90° (figure 19)

$$p = 0.8\ (K_1 + K_2)p_v$$

(3) Two consecutive turns, same angle, with planes at right angles (figure 20)

$$p = Kp_v$$

where:

$$K = (K_o)K_e$$

See table 11 for values of K_o

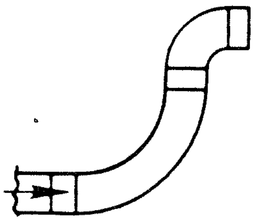
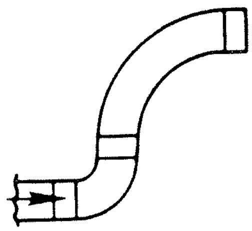
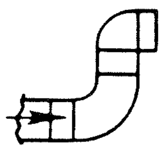
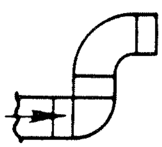
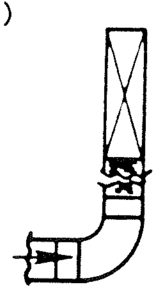
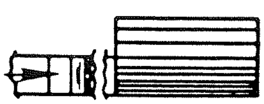
Case No.	First Elbow		Second Elbow		Elbows Only	Elbows Followed By Duct
	RR	AR	RR	AR	ACTUAL	ACTUAL
(1) 	3	4	1.5	4	.372	.276
(2) 	1.5	4	3	4	.242	.264
(3) 	1.5	4	0.5	4	.245	.115
(4) 	0.5	4	1.5	4	.162	.103
(5) 	1.5	4	1.5	.25	.455	.346
(6) 	1.5	.25	1.5	4	.55	.385

Figure 16. Pressure Loss Coefficients for 3 inch by 12 inch Compound Elbows

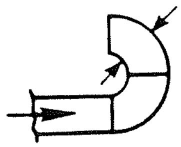
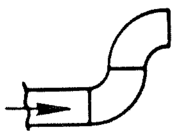
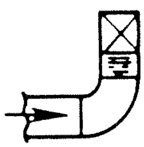
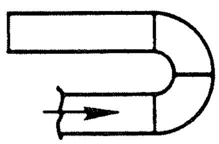
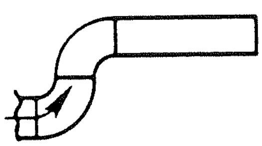
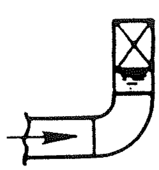
Case No.	Plain Elbows ACTUAL	One Diameter Btw. Elbows ACTUAL	Splitter In Each Elbow ACTUAL
(1) 	1.042	.549	.26
(2) 	.937	1.06	.22
(3) 	.655	.751	.274
(4) 	.43	.314	.15
(5) 	.662	.683	.188
(6) 	.418	.457	.205

Figure 17. Pressure Loss Coefficients for 12 inch by 12 inch Compound Elbows

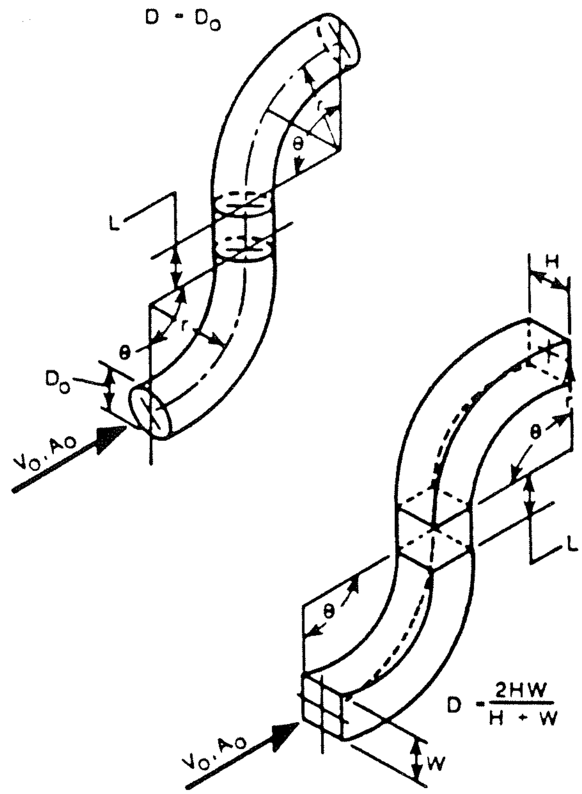


Figure 18. Two Consecutive Turns, Same Angle and Plane, Change in Direction Less than or Equal to 90°

TABLE 10. PRESSURE LOSS COEFFICIENTS FOR THE OFFSET OF TWO CONSECUTIVE TURNS, SAME PLANE, ROUND OR RECTANGULAR

θ (deg)	K_O							
	L/D							
	0	1	2	3	4	6	8	10
15	0.20	0.42	0.60	0.78	0.94	1.16	1.20	1.15
30	0.40	0.65	0.88	1.16	1.20	1.18	1.12	1.06
45	0.60	1.06	1.20	1.23	1.20	1.08	1.03	1.08
60	1.05	1.38	1.37	1.28	1.15	1.06	1.16	1.30
75	1.50	1.58	1.46	1.30	1.27	1.30	1.37	1.47
90	1.70	1.67	1.40	1.37	1.38	1.47	1.55	1.63

θ (deg)	K_O						
	L/D						
	12	14	16	18	20	25	≥40
15	1.08	1.05	1.02	1.00	1.10	1.25	2.0
30	1.06	1.15	1.28	1.40	1.50	1.70	2.0
45	1.17	1.30	1.42	1.55	1.65	1.80	2.0
60	1.42	1.54	1.66	1.76	1.85	1.95	2.0
75	1.57	1.68	1.75	1.80	1.88	1.97	2.0
90	1.70	1.76	1.82	1.88	1.92	1.98	2.0

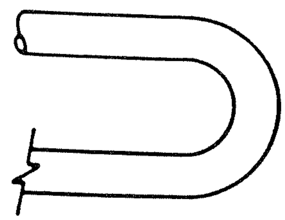


Figure 19. Two Consecutive Turns, Same Plane, Change in Direction Greater than 90°

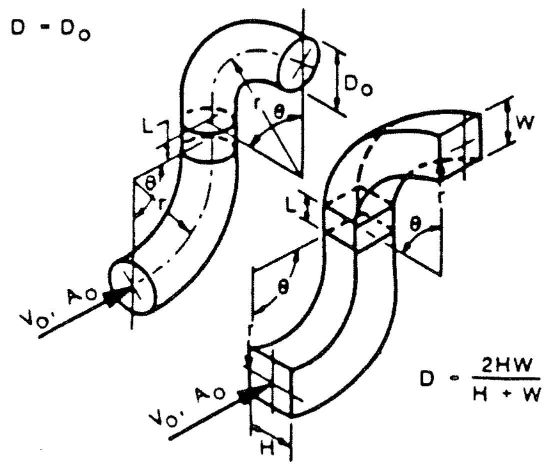


Figure 20. Two Consecutive Turns with Planes at Right Angles

TABLE 11, PRESSURE LOSS COEFFICIENTS FOR THE OFFSET OF TWO CONSECUTIVE TURNS AT RIGHT ANGLES

θ (deg)	K_O						
	L/D						
	0	1	2	3	4	6	8
60	2.0	1.90	1.50	1.35	1.30	1.20	1.25
90	2.0	1.80	1.60	1.55	1.55	1.65	1.80

θ (deg)	K_O					
	L/D					
	10	12	14	20	25	40
60	1.50	1.63	1.73	1.85	1.95	2.[illegible]
90	1.90	1.93	1.98	2.0	2.0	2.0

10. Vaned turns

(a) Vaned turn rectangular duct (figure 21)

$$p = Kp_v$$

where:

K = loss coefficient (table 12)

(b) Vaned turn with rectangular grid attached to round duct (figure 22)

The following pressure loss calculation includes the losses for the grid and for both transitions:

$$p = 1.5\ Kp_v$$

where:

K = loss coefficient (table 12)

11. Elbows with no attached duct

The loss for an elbow with no duct used as a natural vent is:

$$p = Kp_v + 0.95\ p_v$$

where:

K = loss coefficient (table 9)
p_v = velocity pressure in elbow, in wg

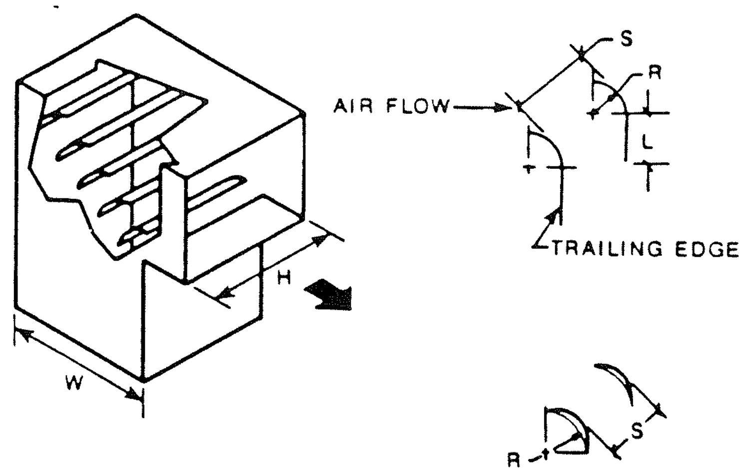


Figure 21. Vaned Turns

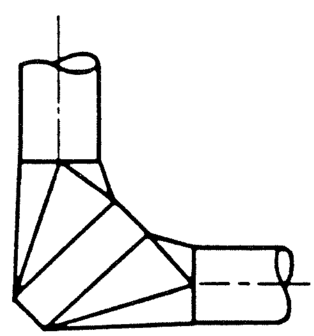


Figure 22. Vaned Turn with Rectangular Grid in Round Duct

TABLE 12. PRESSURE LOSS COEFFICIENTS FOR SINGLE AND DOUBLE THICKNESS VANES IN VANED TURNS

SINGLE THICKNESS VANES

*No.	Dimensions (in)			Loss Coefficient
	R	S	L	K
**1	2.0	1.5	0.75	0.12
2	4.5	2.25	0	0.15
3	4.5	3.25	1.60	0.18

*Numbers are for differentiating between vane sizes only.
**When extension of trailing edge is not provided for this vane, losses are approximately unchanged for single elbows, but increase considerably for elbows in series.

DOUBLE THICKNESS VANES
Loss Coefficient K

*No.	Dimensions (in)		Velocity (V) (fpm)			
	R	S	1000	2000	3000	4000
1	2.0	1.5	0.27	0.22	0.19	0.17
2	2.0	1.5	0.33	0.29	0.26	0.23
3	2.0	2.13	0.38	0.31	0.27	0.24
4	4.5	3.25	0.26	0.21	0.18	0.16

*Numbers are for differentiating between vane sizes only.

DDS512-1-i. **Takeoffs**

1. There are a wide variety of takeoffs employed in a ventilation system, therefore, just a few common types will be covered. Pressure loss information on many other types of takeoffs encountered is available in tables 6-9 and 6-10 of reference (c). The information in tables 13, 15, 16, 17 and 18 and figures 23 through 29 is from reference (c). The information in tables 14 and 19 are from reference (b).

2. Pressure loss coefficients are presented in this section for seven categories of branch takeoff fittings as follows:

(a) Round and rectangular diverging wyes
(b) Round converging wye
(c) Rectangular diverging wye $(A_c \neq A_s + A_b)$
(d) Rectangular converging wye
(e) Rectangular diverging wye, $(A_c = A_s + A_b)$
(f) Rectangular or round wye, $(A_c = A_{1b} + A_{2b})$
(g) Symmetrical wye, dovetail, rectangular

For each type of takeoff

$$p = Kp_v$$

where:

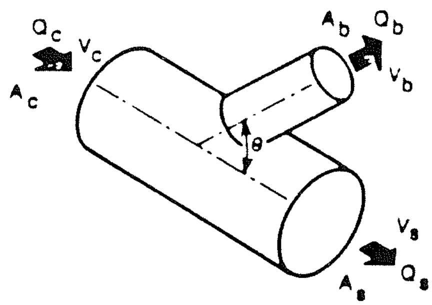
K = loss coefficient

3. Round and rectangular diverging wyes (figure 23)
Table 13 contains pressure loss coefficients for both the duct main and the branch duct connected to round and rectangular diverging wyes. Coefficients are given for takeoff angles of 30°, 45°, 60°, and 90° to the main.

4. Round converging wye (figure 24)
Table 14 contains pressure loss coefficients for both the duct main and the branch duct connected to a round converging wye. Coefficients are given for a takeoff angle of 30°, 45°, and 90° to the main.

5. Rectangular diverging wye (figure 25)
Table 15 contains pressure loss coefficients for both the duct main and the branch duct connected to a rectangular diverging wye.

6. Rectangular converging wye (figure 26)
Table 16 contains pressure loss coefficients for both the duct main and the branch duct connected to a rectangular converging wye.



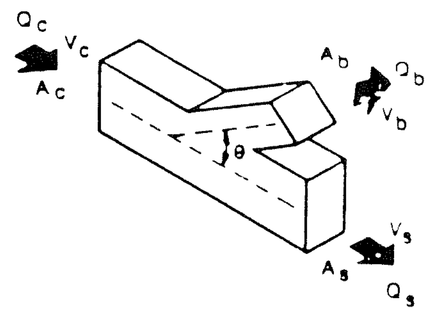


Figure 23. Round and Rectangular Diverging Wyes

TABLE 13. PRESSURE LOSS COEFFICIENTS FOR ROUND AND RECTANGULAR DIVERGING WYES, 30° TO 90°

Main, Loss Coefficient K

V_s/V_c (fpm)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0
K	0.35	0.28	0.22	0.17	0.13	0.09	0.06	0.02	0

Wye θ = 30°: Branch, Loss Coefficient K

A_b/A_c	Q_b/Q_c (cfm)								
(in^2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.8	0.75	0.55	0.40	0.28	0.21	0.16	0.15	0.16	0.19
0.7	0.72	0.51	0.36	0.25	0.18	0.15	0.16	0.20	0.26
0.6	0.69	0.46	0.31	0.21	0.17	0.16	0.20	0.28	0.39
0.5	0.65	0.41	0.26	0.19	0.18	0.22	0.32	0.47	0.67
0.4	0.59	0.33	0.21	0.20	0.27	0.40	0.62	0.92	1.3
0.3	0.55	0.28	0.24	0.38	0.76	1.3	2.0	-	-
0.2	0.40	0.26	0.58	1.3	2.5	-	-	-	-
0.1	0.28	1.5	-	-	-	-	-	-	-

TABLE 13. PRESSURE LOSS COEFFICIENTS FOR ROUND AND RECTANGULAR DIVERGING WYES, 30° TO 90° (Continued)

Wye θ = 45°: Branch, Loss Coefficient K

A_b/A_c	Q_b/Q_c (cfm)								
(in^2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.8	0.78	0.62	0.49	0.40	0.34	0.31	0.32	0.35	0.40
0.7	0.77	0.59	0.47	0.38	0.34	0.32	0.35	0.41	0.50
0.6	0.74	0.56	0.44	0.37	0.35	0.36	0.43	0.54	0.68
0.5	0.71	0.52	0.41	0.38	0.40	0.45	0.59	0.78	1.0
0.4	0.66	0.47	0.40	0.43	0.54	0.69	0.95	1.3	1.7
0.3	0.66	0.48	0.52	0.73	1.2	1.8	2.7	-	-
0.2	0.56	0.56	1.0	1.8	-	-	-	-	-
0.1	0.60	2.1	-	-	-	-	-	-	-

Wye θ = 60°: Branch, Loss Coefficient K

A_b/A_c	Q_b/Q_c (cfm)								
(in^2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.8	0.83	0.71	0.62	0.56	0.52	0.50	0.53	0.60	0.68
0.7	0.82	0.69	0.61	0.56	0.54	0.54	0.60	0.70	0.82
0.6	0.81	0.68	0.60	0.58	0.58	0.61	0.72	0.87	1.1
0.5	0.79	0.66	0.61	0.62	0.68	0.76	0.94	1.2	1.5
0.4	0.76	0.65	0.65	0.74	0.89	1.1	1.4	1.8	2.3
0.3	0.80	0.75	0.89	1.2	1.8	2.6	3.5	-	-
0.2	0.77	0.96	1.6	2.5	-	-	-	-	-
0.1	1.0	2.9	-	-	-	-	-	-	-

TABLE 13. PRESSURE LOSS COEFFICIENTS FOR ROUND AND RECTANGULAR DIVERGING WYES, 30° TO 90° (Continued)

Tee θ = 90°: Branch, Loss Coefficient K

A_b/A_c	Q_b/Q_c (cfm)								
(in^2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.8	0.95	0.92	0.92	0.93	0.94	0.95	1.1	1.2	1.4
0.7	0.95	0.94	0.95	0.98	1.0	1.1	1.2	1.4	1.6
0.6	0.96	0.97	1.0	1.1	1.1	1.2	1.4	1.7	2.0
0.5	0.97	1.0	1.1	1.2	1.4	1.5	1.8	2.1	2.5
0.4	0.99	1.1	1.3	1.5	1.7	2.0	2.4	-	-
0.3	1.1	1.4	1.8	2.3	-	-	-	-	-
0.2	1.3	1.9	2.9	-	-	-	-	-	-
0.1	2.1	-	-	-	-	-	-	-	-

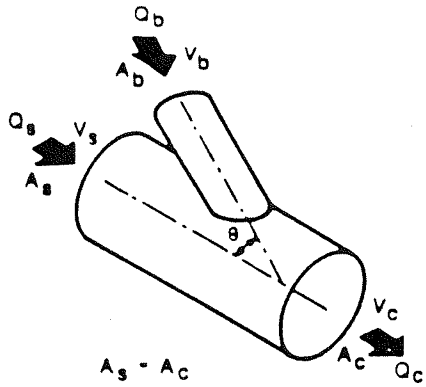


Figure 24. Round Converging Wye

TABLE 14. PRESSURE LOSS COEFFICIENTS FOR ROUND CONVERGING WYE

Wye Θ = 30°

Branch, Loss Coefficient K

Q_b/Q_c (cfm)	A_b/A_c (in^2) 0.1	0.2	0.3	0.4	0.6	0.8	1.0
0	-1.0	-1.0	1.0	-1.0	-1.0	-1.0	-1.0
0.1	0.21	-.46	-.57	-.60	-.62	-.63	-.63
0.2	3.1	0.37	-.06	-.20	-.28	-.30	-.35
0.3	7.6	1.5	0.50	0.20	-.05	-.08	-.10
0.4	14	3.0	1.2	0.59	0.26	0.18	0.16
0.5	21	4.6	1.8	0.97	0.44	0.35	0.27
0.6	30	6.4	2.6	1.4	0.64	0.46	0.31
0.7	41	8.5	3.4	1.8	0.76	0.50	0.40
0.8	54	12	4.2	2.1	0.85	0.53	0.45
0.9	58	14	5.3	2.6	0.89	0.52	0.40
1.0	84	17	6.3	2.9	0.89	0.39	0.27

TABLE 14. PRESSURE LOSS COEFFICIENTS FOR ROUND CONVERGING WYE (Continued)

Main, Loss Coefficient K

Q_b/Q_c (cfm)	A_b/A_c (in^2)						
	0.1	0.2	0.3	0.4	0.6	0.8	1.0
0	0	0	0	0	0	0	0
0.1	0.02	0.11	0.13	0.15	0.16	0.17	0.17
0.2	-.33	0.01	0.13	0.19	0.24	0.27	0.29
0.3	-1.1	-.25	-.01	0.10	0.22	0.30	0.35
0.4	-2.2	-.75	-.30	-.05	0.17	0.26	0.36
0.5	-3.6	-1.4	-.70	-.35	0	0.21	0.32
0.6	-5.4	-2.4	-1.3	-.70	-.20	0.06	0.25
0.7	-7.6	-3.4	-2.0	-1.2	-.50	-.15	0.10
0.8	-10	-4.6	-2.7	-1.8	-.90	-.43	-.15
0.9	-13	-6.2	-3.7	-2.6	-1.4	-.80	-.45
1.0	-16	-7.7	-4.8	-3.4	-1.9	-1.2	-.75

Wye θ = 45°

Branch, Loss Coefficient K

V_b/V_c (fpm)	A_b/A_c (in^2)						
	0.1	0.2	0.3	0.4	0.6	0.8	1.0
0.4	-.56	-.44	-.35	-.28	-.15	-.04	0.05
0.5	-.48	-.37	-.28	-.21	-.09	0.02	0.11
0.6	-.38	-.27	-.19	-.12	0	0.10	0.18
0.7	-.26	-.16	-.08	-.01	0.10	0.20	0.28
0.8	-.21	-.02	0.05	0.12	0.23	0.32	0.40
0.9	0.04	0.13	0.21	0.27	0.37	0.46	0.53
1.0	0.22	0.31	0.38	0.44	0.53	0.62	0.69
1.5	1.4	1.5	1.5	1.6	1.7	1.7	1.8
2.0	3.1	3.2	3.2	3.2	3.3	3.3	3.3
2.5	5.3	5.3	5.3	5.4	5.4	5.4	5.4
3.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0

TABLE 14. PRESSURE LOSS COEFFICIENTS FOR ROUND CONVERGING WYE (Continued)

Main, Loss Coefficient K

V_s/V_c (fpm)	A_b/A_c (in^2) 0.1	0.2	0.3	0.4	0.6	0.8	1.0
0.1	-8.6	-4.1	-2.5	-1.7	-.97	-.58	-.34
0.2	-6.7	-3.1	-1.9	-1.3	-.67	-.36	-.18
0.3	-5.0	-2.2	-1.3	-.88	-.42	-.19	-.05
0.4	-3.5	-1.5	-.88	-.55	-.21	-.05	0.05
0.5	-2.3	-.95	-.51	-.28	-.06	0.06	0.13
0.6	-1.3	-.50	-.22	-.09	0.05	0.12	0.17
0.7	-.63	-.18	-0.3	0.04	0.12	0.16	0.18
0.8	-.18	0.01	0.07	0.10	0.13	0.15	0.17
0.9	0.03	0.07	0.08	0.09	0.10	0.11	0.13
1.0	-0.01	0	0	0.10	0.02	0.04	0.05

Wye θ = 90°

Branch, Loss Coefficient K

Q_b/Q_c (cfm)	A_b/A_c (in^2) 0.1	0.2	0.3	0.4	0.6	0.8	1.0
0	-1.0	-1.0	-1.0	-.90	-.90	-.90	-.90
0.1	0.40	-.37	-.51	-.46	-.50	-.51	-.52
0.2	3.8	0.72	0.17	-.02	-.14	-.18	-.24
0.3	9.2	2.3	1.0	0.44	0.21	0.11	-.08
0.4	16	4.3	2.1	0.94	0.54	0.40	0.32
0.5	26	6.8	3.2	1.1	0.66	0.49	0.42
0.6	37	9.7	4.7	1.6	0.92	0.69	0.57
0.7	43	13	6.3	2.1	1.2	0.88	0.72
0.8	65	17	7.9	2.7	1.5	1.1	0.86
0.9	82	21	9.7	3.4	1.8	1.2	0.99
1.0	101	26	12	4.0	2.1	1.4	1.1

Main, Loss Coefficient K

Q_b/Q_c (cfm)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
K	0	0.16	0.27	0.38	0.46	0.53	0.57	0.59	0.60	0.59	0.55

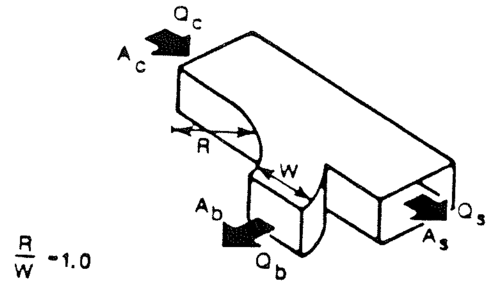


Figure 25. Rectangular Diverging Wye

TABLE 15. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR DIVERGING WYE

Branch, Loss Coefficient K

A_b/A_s	A_b/A_c	Q_b/Q_c (cfm)								
(in^2)	(in^2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.25	0.25	0.55	0.50	0.60	0.85	1.2	1.8	3.1	4.4	6.0
0.33	0.25	0.35	0.35	0.50	0.80	1.3	2.0	2.8	3.8	5.0
0.5	0.5	0.62	0.48	0.40	0.40	0.48	0.60	0.78	1.1	1.5
0.67	0.5	0.52	0.40	0.32	0.30	0.34	0.44	0.62	0.92	1.4
1.0	0.5	0.44	0.38	0.38	0.41	0.52	0.68	0.92	1.2	1.6
1.0	1.0	0.67	0.55	0.46	0.37	0.32	0.29	0.29	0.30	0.37
1.33	1.0	0.70	0.60	0.51	0.42	0.34	0.28	0.26	0.26	0.29
2.0	1.0	0.60	0.52	0.43	0.33	0.24	0.17	0.15	0.17	0.21

TABLE 15. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR DIVERGING WYE (Continued)

Main, Loss Coefficient K

A_b/A_s	A_b/A_c	Q_b/Q_c (cfm)								
(in^2)	(in^2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.25	0.25	-.01	-.03	-.01	0.05	0.13	0.21	0.29	0.38	0.46
0.33	0.25	0.08	0	-.02	-.01	0.02	0.08	0.16	0.24	0.34
0.5	0.5	-.03	-.06	-.05	0	0.06	0.12	0.19	0.27	0.35
0.67	0.5	0.04	-.02	-.04	-.03	-.01	0.04	0.12	0.23	0.37
1.0	0.5	0.72	0.48	0.28	0.13	0.05	0.04	0.09	0.18	0.30
1.0	1.0	-.02	-.04	-.04	-.01	0.06	0.13	0.22	0.30	0.38
1.33	1.0	0.10	0	0.01	-.03	-.01	0.03	0.10	0.20	0.30
2.0	1.0	0.62	0.38	0.23	0.13	0.08	0.05	0.06	0.10	0.20

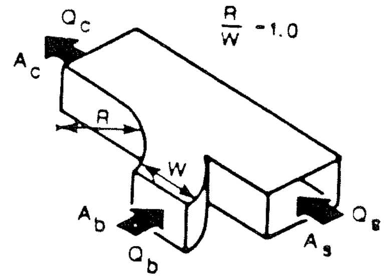


Figure 26. Rectangular Converging Wye

TABLE 16. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR CONVERGING WYE

Branch, Loss Coefficient K

A_b/A_s (in^2)	A_b/A_c (in^2)	Q_b/Q_c (cfm) 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.25	0.25	-.50	0	0.50	1.2	2.2	3.7	5.8	8.4	11
0.33	0.25	-1.2	-.40	0.40	1.6	3.0	4.8	6.8	8.9	11
0.5	0.5	-.50	-.20	0	0.25	0.45	0.70	1.0	1.5	2.0
0.67	0.5	-1.0	-.60	-.20	0.10	0.30	0.60	1.0	1.5	2.0
1.0	0.5	-2.2	-1.5	-.95	-.50	0	0.40	0.80	1.3	1.9
1.0	1.0	-.60	-.30	-.10	-.04	0.13	0.21	0.29	0.36	0.42
1.33	1.0	-1.2	-.80	-.40	-.20	0	0.16	0.24	0.32	0.38
2.0	1.0	-2.1	-1.4	-.90	-.50	-.20	0	0.20	0.25	0.30

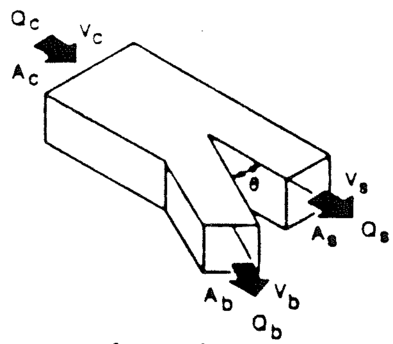
Main, Loss Coefficient K

A_s/A_c (in^2)	A_b/A_c (in^2)	Q_b/Q_c (cfm) 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.75	0.25	0.30	0.30	0.20	-.10	-.45	-.92	-1.5	-2.0	-2.6
1.0	0.5	0.17	0.16	0.10	0	-0.08	-.18	-.27	-.37	-.46
0.75	0.5	0.27	0.35	0.32	0.25	0.12	-.03	-.23	-.42	-.58
0.5	0.5	1.2	1.1	0.90	0.65	0.35	0	-.40	-.80	-1.3
1.0	1.0	0.18	0.24	0.27	0.26	0.23	0.18	0.10	0	-.12
0.75	1.0	0.75	0.36	0.38	0.35	0.27	0.18	0.05	-.08	-.22
0.5	1.0	0.80	0.87	0.80	0.68	0.55	0.40	0.25	0.08	-.10

7. Rectangular diverging wye ($A_c = A_s + A_b$) (figure 27)
Table 17 contains pressure loss coefficients for both the duct main and the branch duct connected to a rectangular diverging wye. As shown in figure 27 the cross-sectional area of the main before the wye is equal to the cross-sectional area of the main (after the wye) plus the branch.

8. Rectangular or round wye, converging or diverging ($A_c = A_{1b} + A_{2b}$) (figure 28)
Table 18 contains pressure loss coefficients for the branch duct connected to a rectangular or round wye, converging or diverging. As shown in figure 28 the cross-sectional area of the main equals the sum of the cross-sectional areas of the branches.

9. Symmetrical wye, dovetail, rectangular, converging or diverging (figure 29)
Table 19 contains pressure loss coefficients for the branch duct connected to a symmetrical rectangular wye, converging or diverging.



θ = 15° to 90°

$A_c = A_s + A_b$

Figure 27. Rectangular Diverging Wye ($A_c = A_s + A_b$)

TABLE 17. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR DIVERGING WYE ($A_c = A_s + A_b$)

Branch, Loss Coefficient K

θ	V_b/V_c (fpm)												
(deg)	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	[illegible]
15	0.81	0.65	0.51	0.38	0.28	0.20	0.11	0.06	0.14	0.30	0.51	0.76	1.0
30	0.84	0.69	0.56	0.44	0.34	0.26	0.19	0.15	0.15	0.30	0.51	0.76	1.0
45	0.87	0.74	0.63	0.54	0.45	0.38	0.29	0.24	0.23	0.30	0.51	0.76	1.0
60	0.90	0.82	0.79	0.66	0.59	0.53	0.43	0.36	0.33	0.39	0.51	0.76	1.0
90	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE 17. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR DIVERGING WYE ($A_c = A_s + A_b$) (Continued)

Main, Loss Coefficient K

θ (deg)	15-60	90				
		A_s/A_c (in²)				
V_s/V_c (fpm)	0-1.0	0-0.4	0.5	0.6	0.7	≥0.8
0	1.0	1.0	1.0	1.0	1.0	1.0
0.1	0.81	0.81	0.81	0.81	0.81	0.81
0.2	0.64	0.64	0.64	0.64	0.64	0.64
0.3	0.50	0.50	0.52	0.52	0.50	0.50
0.4	0.36	0.36	0.40	0.38	0.37	0.36
0.5	0.25	0.25	0.30	0.28	0.27	0.25
0.6	0.16	0.16	0.23	0.20	0.18	0.16
0.8	0.04	0.04	0.17	0.10	0.07	0.04
1.0	0	0	0.20	0.10	0.05	0
1.2	0.07	0.07	0.36	0.21	0.14	0.07
1.4	0.39	0.39	0.79	0.59	0.39	--
1.6	0.90	0.90	1.4	1.2	--	--
1.8	1.8	1.8	2.4	--	--	--
2.0	3.2	3.2	4.0	--	--	--

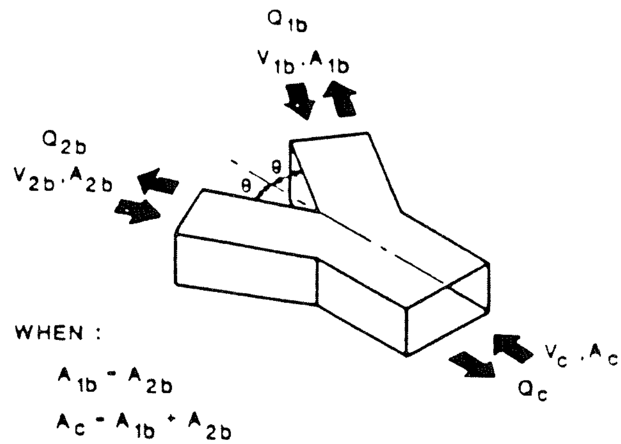


Figure 28. Rectangular or Round Wye, Converging or Diverging ($A_c = A_{1b} + A_{2b}$)

TABLE 18. PRESSURE LOSS COEFFICIENTS FOR RECTANGULAR OR ROUND WYE ($A_c = A_{1b} + A_{2b}$)

Converging

Branch, Loss Coefficients K

θ	Q_{1b}/Q_c or Q_{2b}/Q_c										
(deg)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
15	-2.6	-1.9	-1.3	-.77	-.30	0.10	0.41	0.67	0.85	0.97	1.0
30	-2.1	-1.5	-1.0	-.53	-.10	0.28	0.69	0.91	1.1	1.4	1.6
45	-1.3	-.93	-.55	-.16	0.20	0.56	0.92	1.3	1.6	2.0	2.3

Diverging

Branch, Loss Coefficients K

θ	V_{1b}/V_c or V_c or V_{2b}/V_c												
(deg)	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
15	0.81	0.65	0.51	0.38	0.28	0.20	0.11	0.06	0.14	0.30	0.51	0.76	1.0
30	0.84	0.69	0.56	0.44	0.34	0.26	0.19	0.15	0.15	0.30	0.51	0.76	1.0
45	0.87	0.74	0.63	0.54	0.45	0.38	0.29	0.24	0.23	0.30	0.51	0.76	1.0
60	0.90	0.82	0.79	0.66	0.59	0.53	0.43	0.36	0.33	0.39	0.51	0.76	1.0
90	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

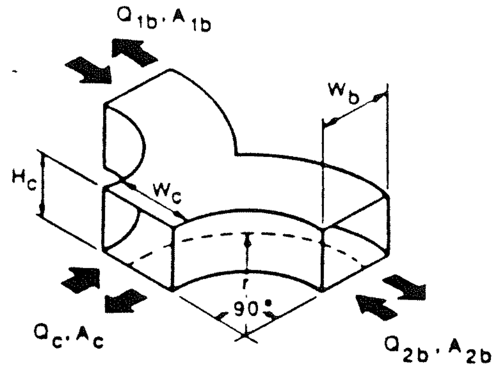


Figure 29. Symmetrical Wye, Dovetail, Rectangular, Converging or Diverging

TABLE 19. PRESSURE LOSS COEFFICIENTS FOR SYMMETRICAL WYE, DOVETAIL, RECTANGULAR

Converging		
A_{1b}/A_c or A_{2b}/A_c	0.50	1.0
K	0.23	0.07

Diverging		
A_{1b}/A_c or A_{2b}/A_c	0.50	1.0
K	0.30	0.25

DDS512-1-j. **Watertight closures**

1. Pressure losses for type R and K watertight closures at the intake in the duct and at the discharge are available from figures 30, 31, 32, 33, 34, and 35, which are reprinted by permission of Keystone Valve Corporation, reference (f). For more detailed physical data on type R and K closures, see NAVSEA drawings 805-1749102 and 805-1749103.

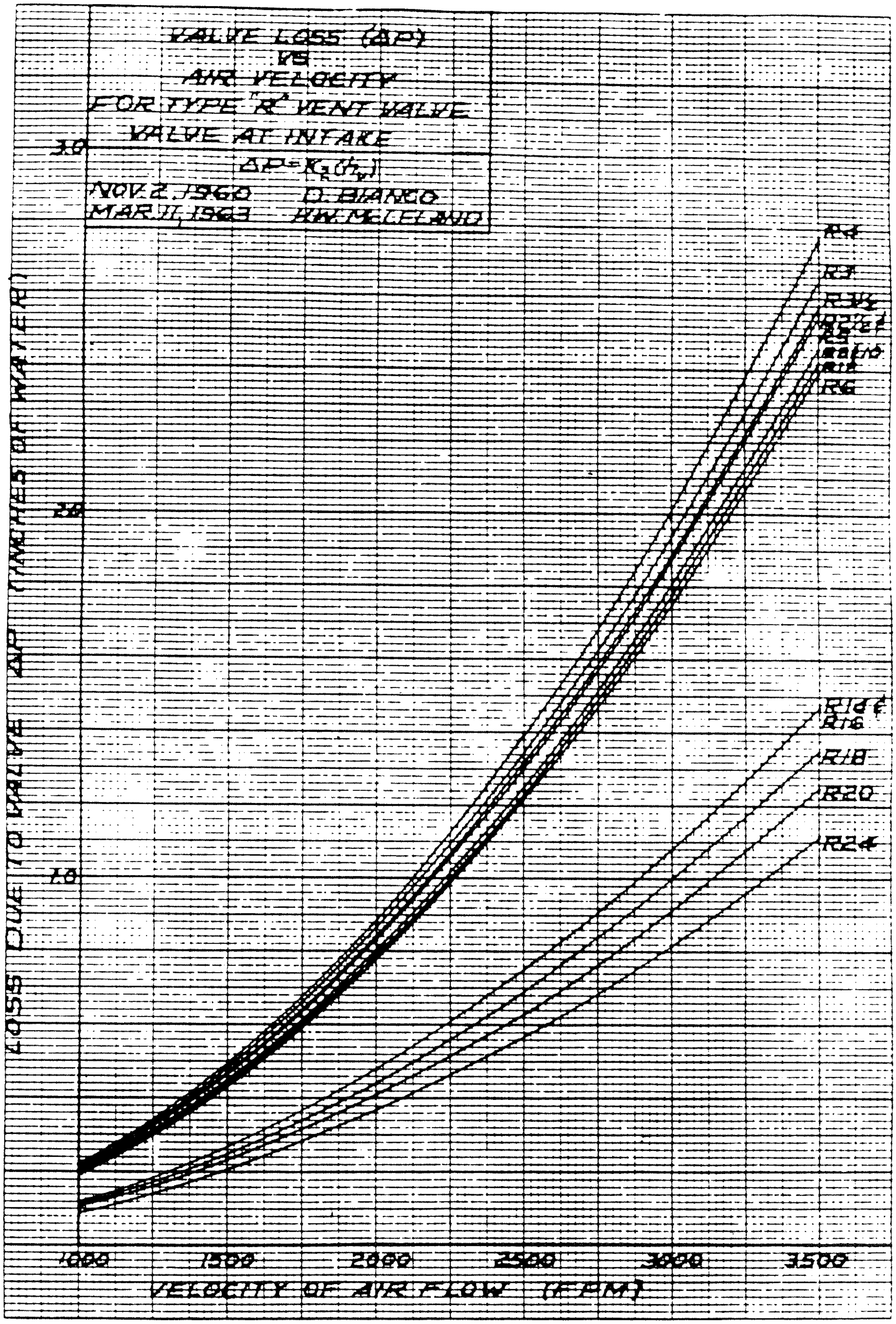


Figure 30. Type R Watertight Closure at the Intake

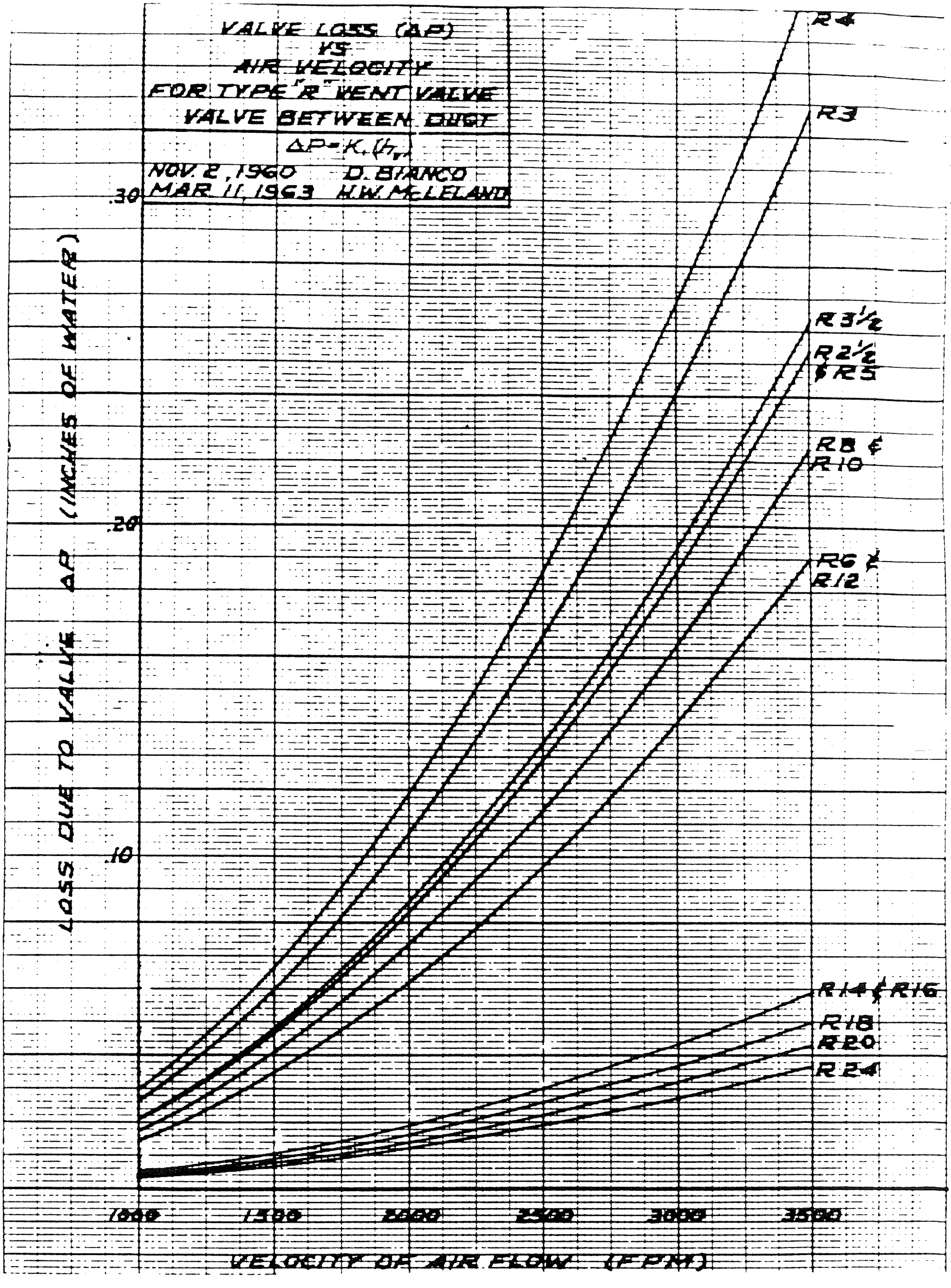


Figure 31. Type R Watertight Closure in the Duct

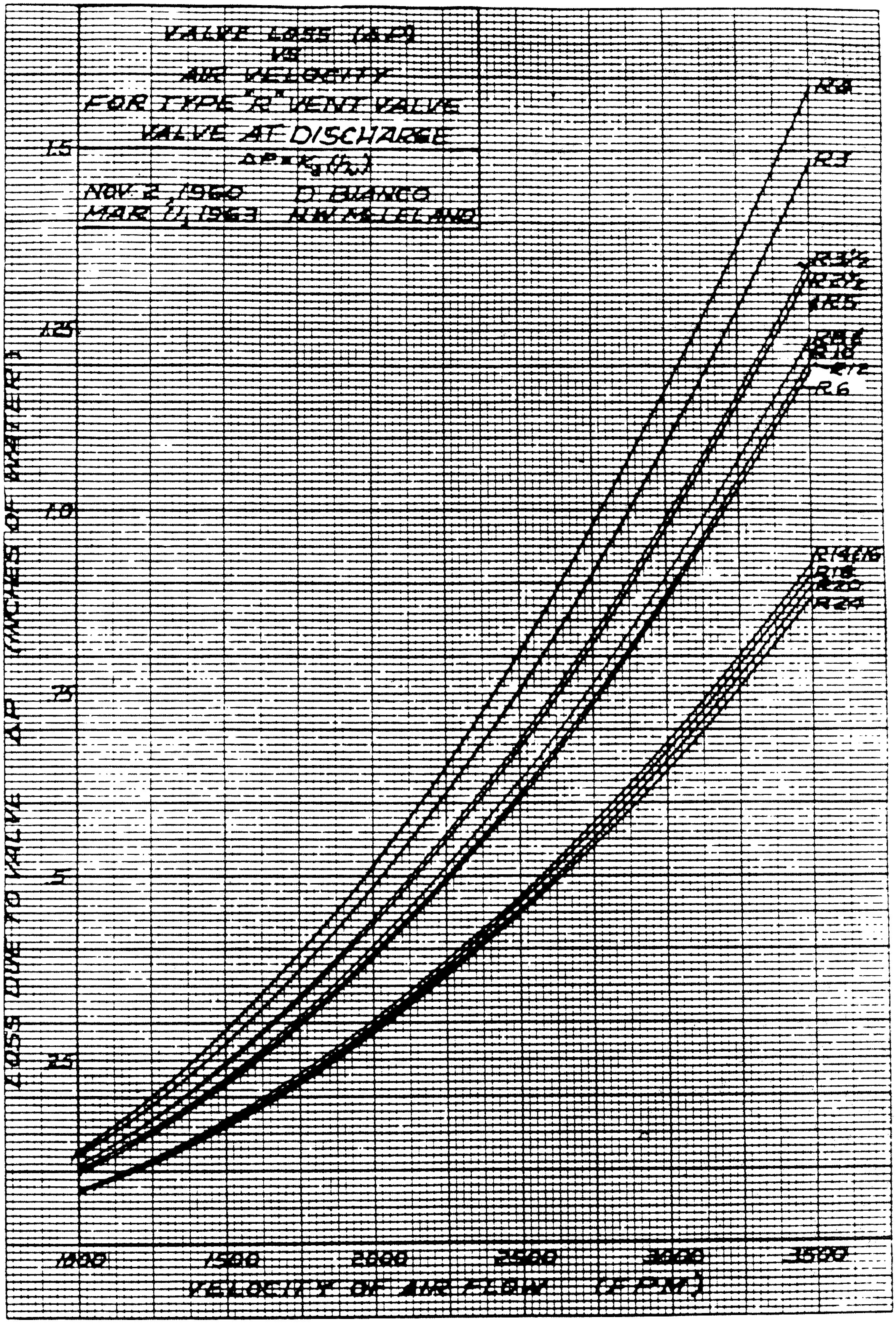


Figure 32. Type R Watertight Closure at the Discharge

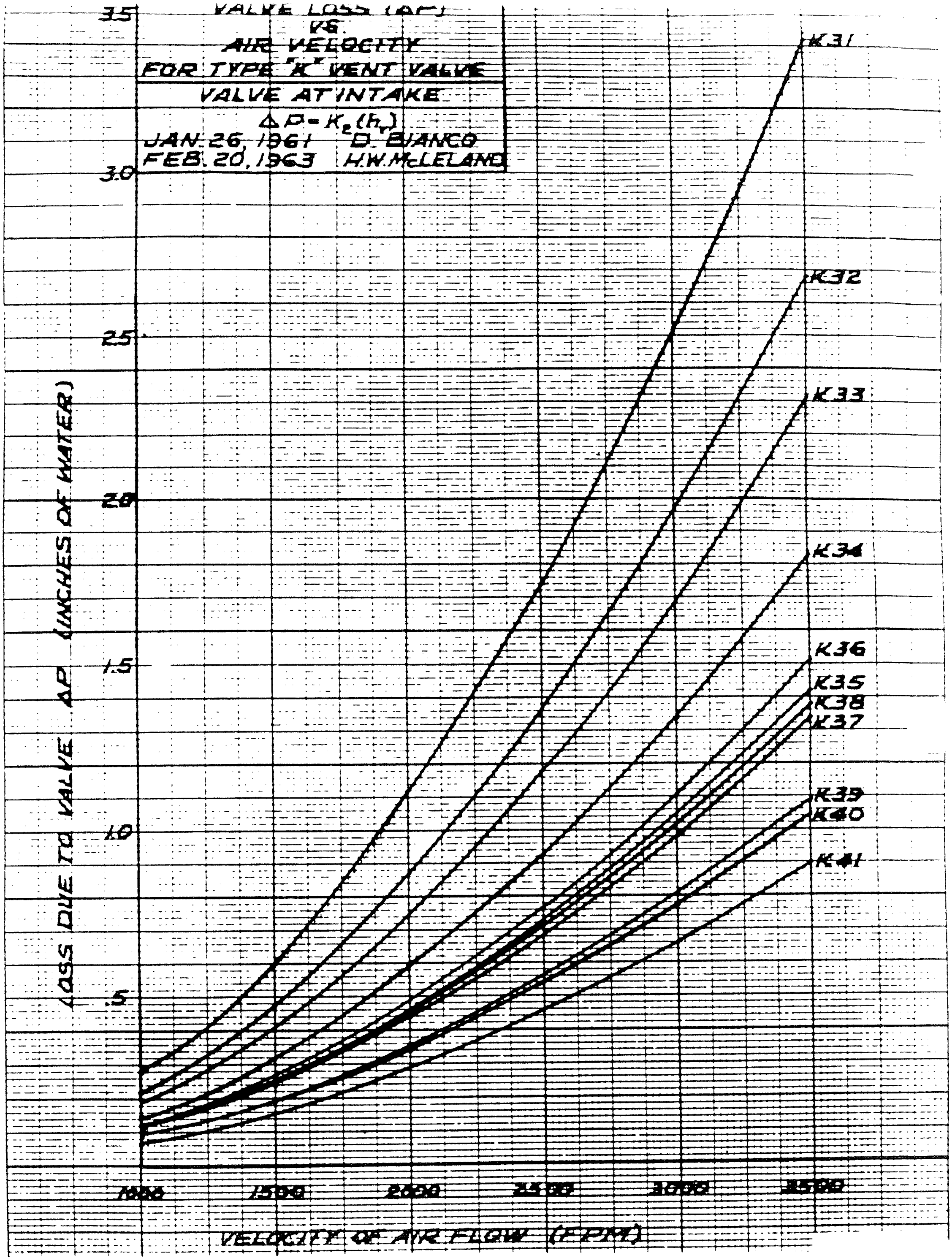


Figure 33. Type K Watertight Closure at the Intake

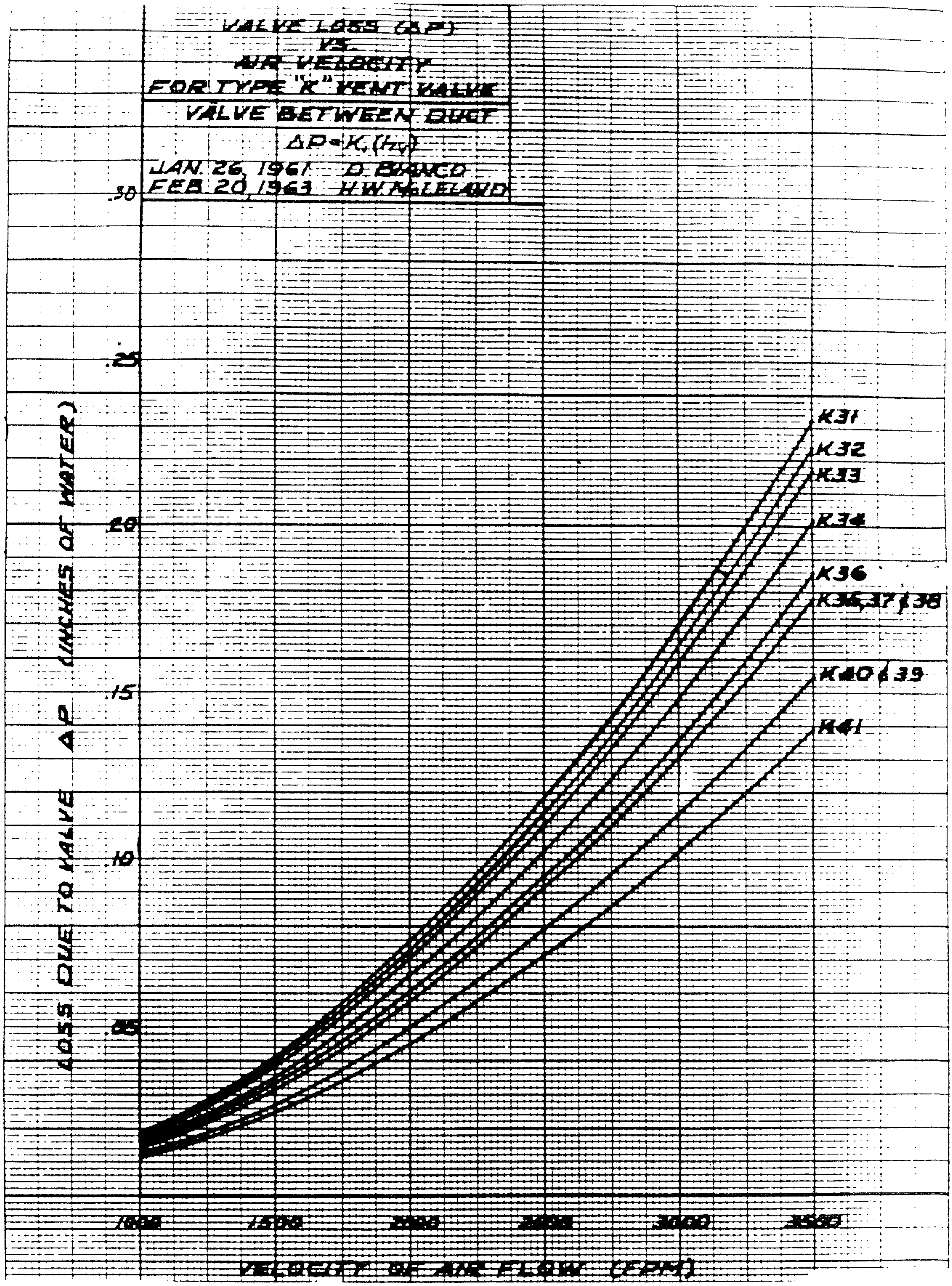


Figure 34. Type K Watertight Closure in the Duct

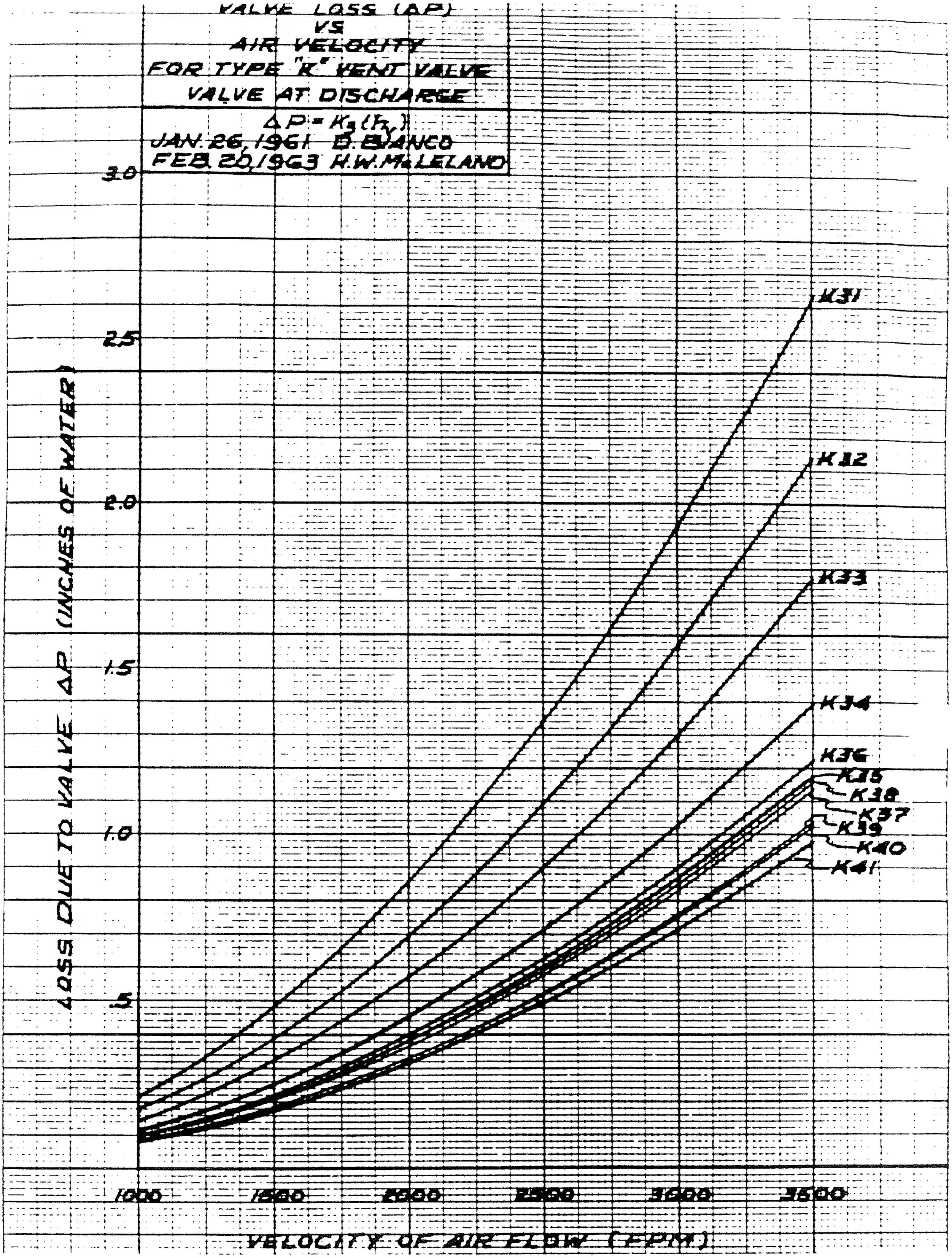


Figure 35. Type K Watertight Closure at the Discharge

DDS512-1-k. **Navy standard ventilation heaters**

1. Pressure losses for Navy standard steam duct heaters are presented in figure 36. The designer must pay close attention to the heater size (21 through 38) and fin spacing (L, M, and H). For more detailed physical data on Navy standard steam duct heaters, see reference (a), chapter 5.

2. Pressure losses for Navy standard electric duct heaters are presented in figure 37 and NAVSEA technical manual S9512-AS-MMA-010/MOD J-106, figure 5. Again the designer must be aware of the various sizes (19 through 38) and fin spacings (L, M, and H). For more detailed physical data on Navy standard electric duct heaters, see reference (a), chapter 5.

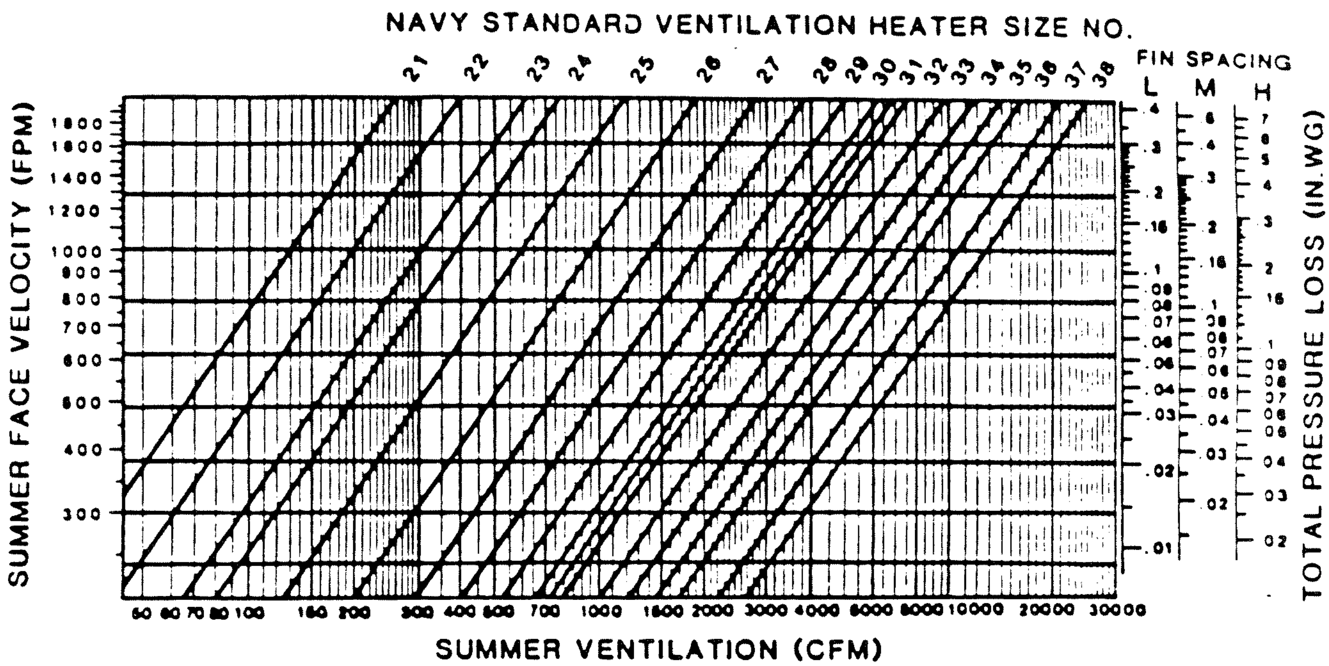


Figure 36. Steam Duct Heater Performance Charts

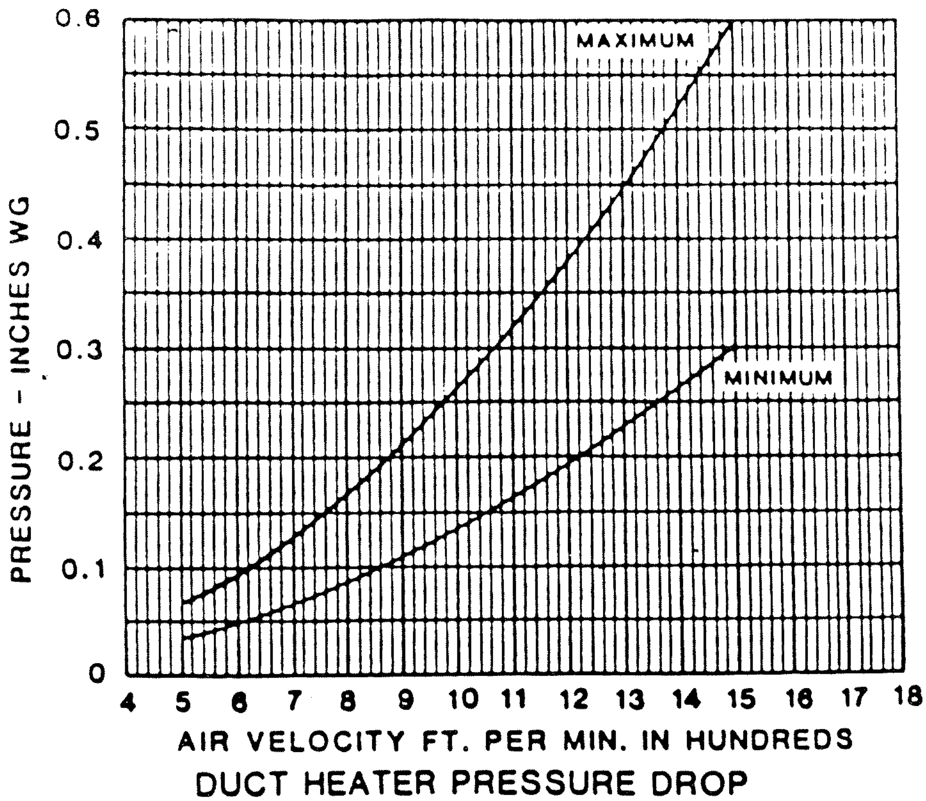


Figure 37. Electric Duct Heater Performance Charts

DDS512-1-l. Navy standard cooling coils

1. Pressure losses for series DW, Navy standard cooling coils can be read in inches of water gauge from figure 38.

DDS512-1-m. Flame arresters

1. Total pressure losses through Navy standard flame arresters with air filter removed can be read in inches of water gauge from figure 39. The air filter pressure loss can be obtained from figure 38 and should be added to that of the flame arrester to find the pressure loss for the device.

DDS512-1-n. Terminals

1. Discharge loss in this section includes the loss of the velocity head of the discharged air. The information in table 20 is from reference (c) and the information in tables 21 and 22 from reference (b).

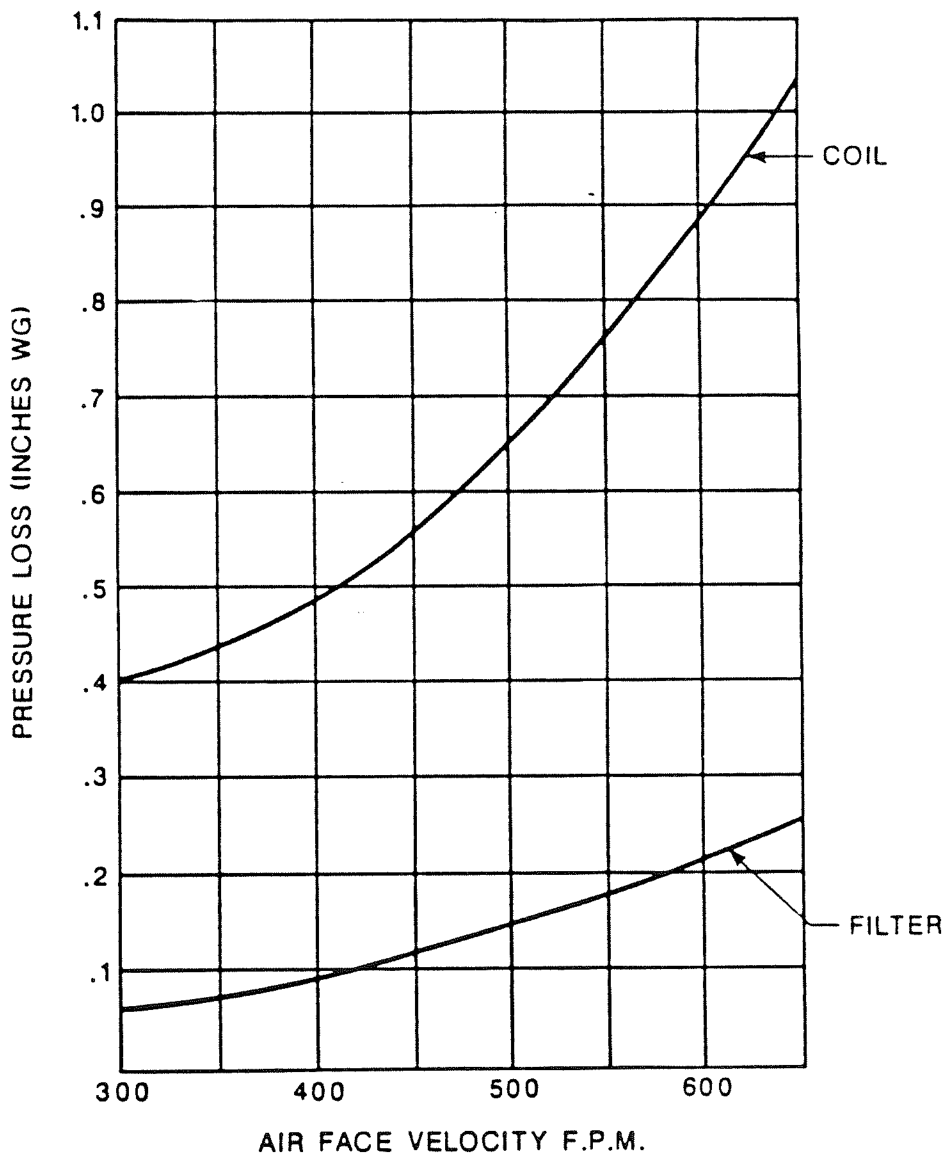


Figure 38. Pressure Loss Coefficient for Cooling Coils and Filters

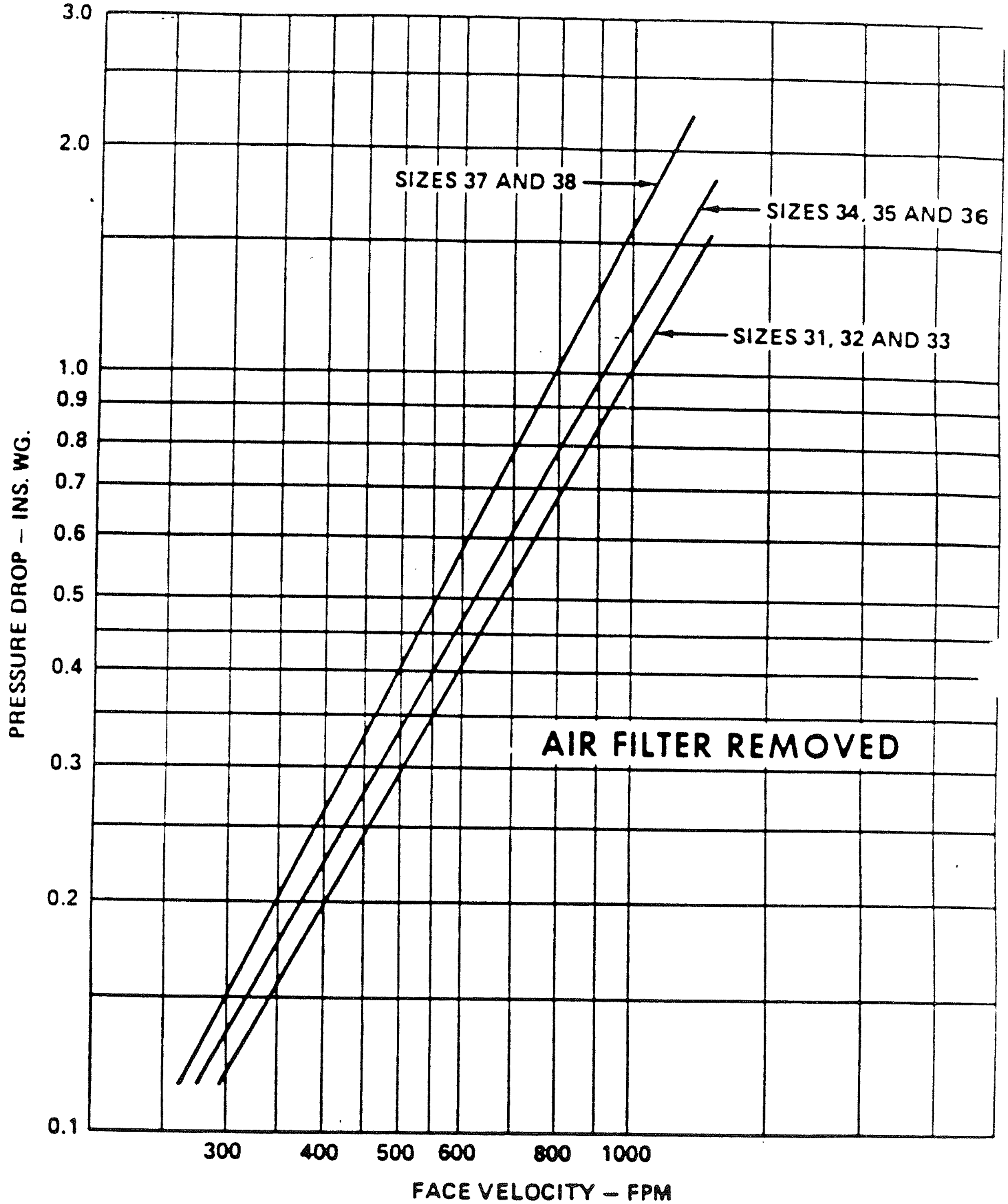


Figure 39. Total Pressure Losses for Flame Arresters

2. Opening in side, top, or bottom of a rectangular duct (figure 40)

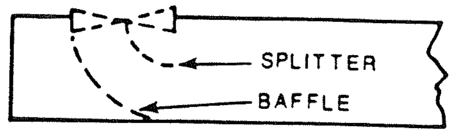


Figure 40. Opening in Rectangular Duct

In the formulas that follow:

p_v = velocity pressure at opening, in wg

F = aspect ratio factor (curve B in figure 11)

The D-dimension is the width of the opening on the side of the duct, and the W-dimension is the other dimension of the opening.

(a) Duct openings without baffles or splitters

Inlet loss: $p = 1.94\ Fp_v$
Discharge loss: $p = 2.92\ Fp_v$

(b) Duct opening with baffle only

Inlet loss: $p = 1.43\ Fp_v$
Discharge loss: $p = 2.92\ Fp_v$

(c) Duct opening with baffle and splitter

Inlet loss: $p = 1.16\ Fp_v$
Discharge loss: $p = 2.10\ Fp_v$

3. Open end of duct (figure 41)

Inlet loss: $p = 0.95\ p_v$
Discharge loss: $p = 1.17\ p_v$

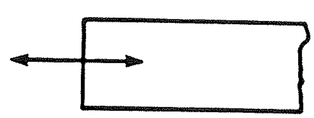


Figure 41. Open End of Duct

4. Straight duct terminating in plate (figure 42)

Inlet loss: $p = 0.87\ p_v$
Discharge loss: $p = 1.17\ p_v$

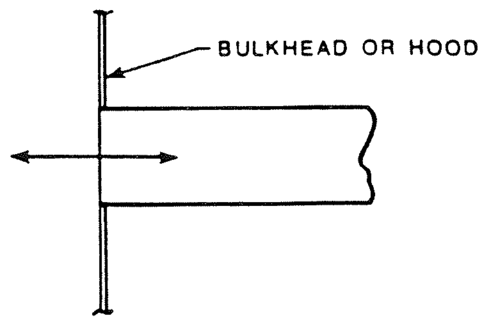


Figure 42. Straight Duct Terminating in Plate

5. Diverging cone at the discharge end of a duct (figure 43)

$p = Kp_v$

where:

K = loss coefficient (table 20)

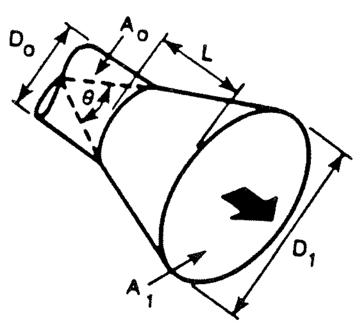


Figure 43. Diverging Cone at the Discharge End of a Duct

TABLE 20. PRESSURE LOSS COEFFICIENTS FOR DIVERGING CONES AT THE DISCHARGE END OF A DUCT

Loss Coefficient K

A_1/A_o (in^2)	θ (deg) 14°	16°	20°
2	0.33	0.36	0.44
4	0.24	0.28	0.36
6	0.22	0.25	0.32
10	0.21	0.23	0.30
16	0.17	0.20	0.27

6. Navy standard bellmouth exhaust terminal (figure 44)

   Inlet loss: $p = 0.10\ p_v$

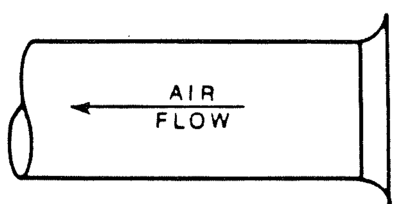


Figure 44. Standard Bellmouth Exhaust Terminal

7. Navy standard type E adjustable supply terminal (figure 45)

   (a) This type of terminal is generally used with a preceding transition in order to reduce or increase the discharge velocity. In such cases, the total pressure loss in the transition should be computed separately as described in subparagraphs DDS512-1-g-2 and DDS512-1-g-3.

   (b) Since the terminal is adjustable, the total pressure loss through this type of terminal will vary from a low value of $p = 1.20\ p_{vt}$ (where p_{vt} is the terminal velocity pressure) when the terminal is oriented (as in figure 45) for straight-through flow, to a high value of $p = 2.33\ p_{vt}$ when the terminal end has been turned

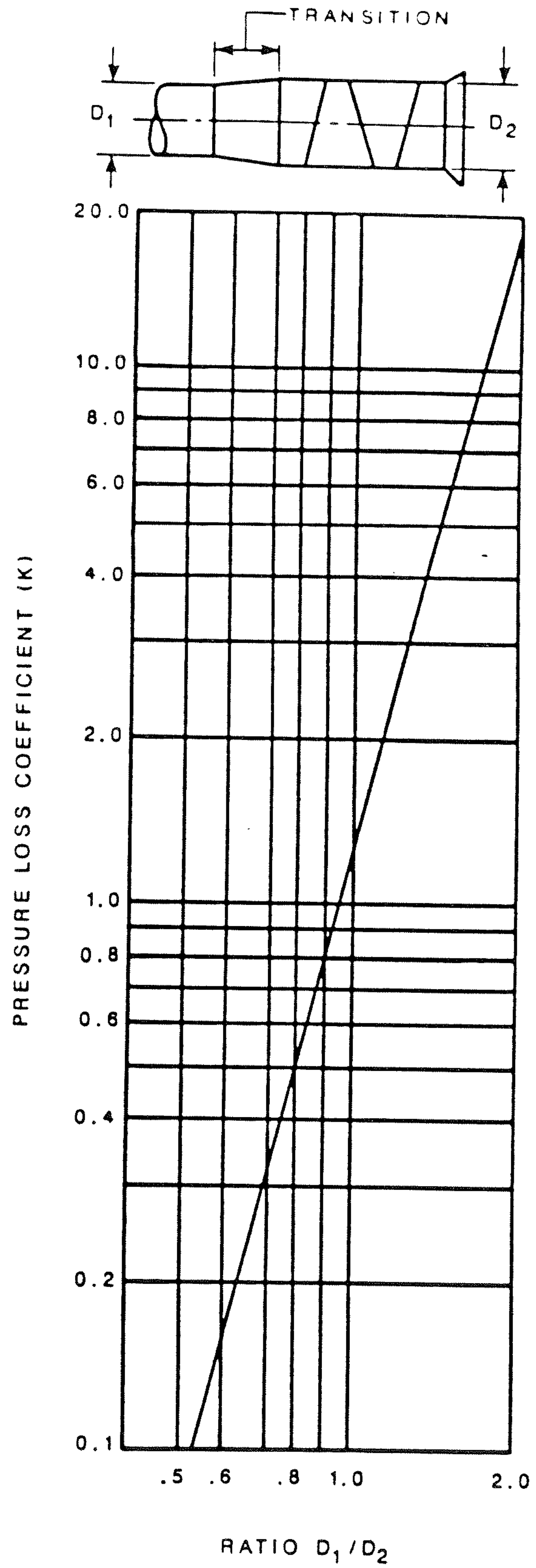


Figure 45. Pressure Loss Coefficients, Type E Terminals (Straight Position)

to 90°.. At times it may be desirable to express the terminal loss in terms of the velocity pressure in duct at the entrance to the transition to the terminal. This loss is:

$$p = Kp_v$$

where:

K = loss coefficient for a terminal in straight position (figure 45)

p_v = velocity pressure at entrance to transition, in wg

10. Slotted openings in supply ducts (figure 46, from reference (b)) are divided into two groups for purposes of calculating the pressure drop through the opening. The pressure loss through the first opening (at the terminal end of a run of duct) should be calculated by utilizing the coefficients in table 21. All successive terminal openings utilize the coefficients in table 22 to calculate the pressure loss. Note that if the supply duct is rectangular the equivalent diameter must be calculated to use table 21 referenced above. In all cases the pressure loss is calculated with the formula:

$$p = Kp_v$$

where:

K = loss coefficient (table 21 or table 22)

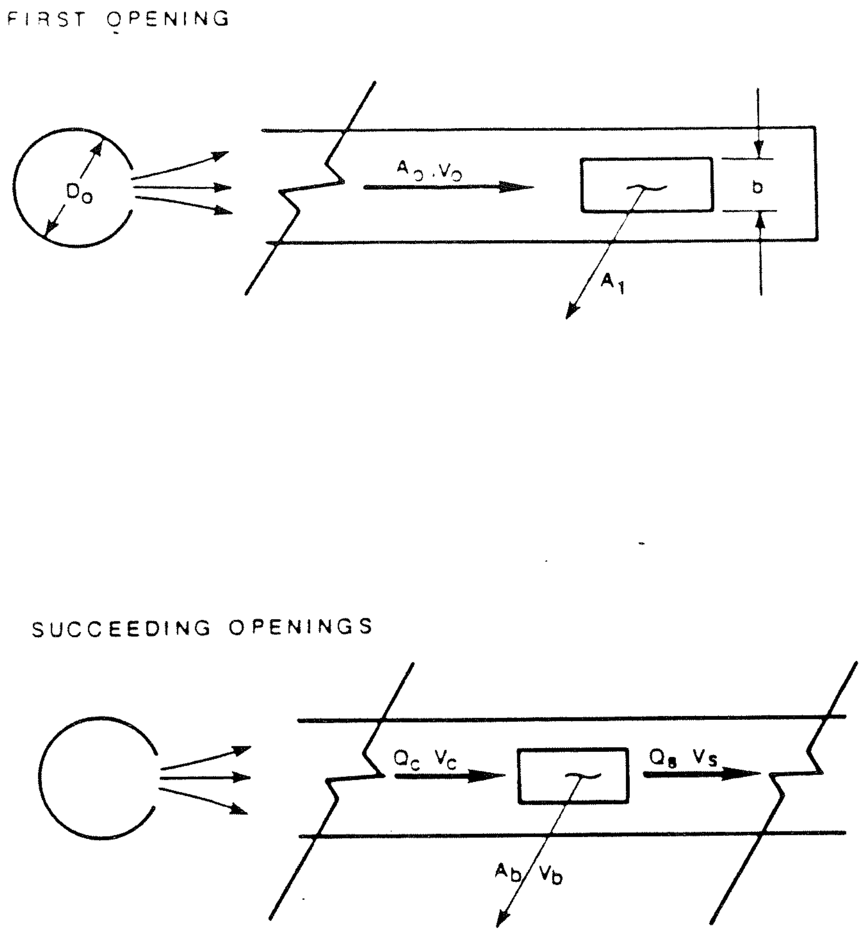


Figure 46. Slotted Ducts First and Succeeding Openings

TABLE 21. PRESSURE LOSS COEFFICIENTS FOR SLOTTED DUCTS FIRST OPENING

Loss Coefficient K

b/D_o	A_1/A_o (in^2) 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.13	253	63	28	16	--	--	--	--
0.26	248	62	28	16	10	7.2	5.4	--
0.38	244	61	27	16	10	7.1	5.4	4.3
0.48	240	60	27	15	9.9	7.0	5.3	4.2
0.62	228	57	26	15	9.6	6.8	5.2	4.1
0.70	220	55	25	14	9.3	6.6	5.1	4.0

Loss Coefficient K

b/D_o	A_1/A_o (in^2) 0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
0.13	--	--	--	--	--	--	--	--
0.26	--	--	--	--	--	--	--	--
0.38	3.6	3.0	--	--	--	--	--	--
0.48	3.5	2.9	2.9	2.6	2.3	--	--	--
0.62	3.4	2.9	2.5	2.2	2.0	1.9	1.7	--
0.70	3.3	2.8	2.4	2.2	1.9	1.8	1.7	1.6

TABLE 22. PRESSURE LOSS COEFFICIENTS FOR SLOTTED DUCTS SUCCEEDING OPENINGS

Loss Coefficient Branch (Opening) K_b

V_b/V_c	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
K_b	1.8	1.7	1.7	1.8	1.9	2.1	2.3	2.6	3.0

Loss Coefficient Main, K_s

V_s/V_c	0.4	0.5	0.6	0.8	1.0
K_c	0.06	0.01	-.03	-.06	-.03

DDS512-1-o. Old applications

This section covers equipment and specific applications presently installed on existing U.S. Navy ships. The equipment and applications will not be found on new construction (post 1987), but are presented herein for use in overhaul design projects where they may be encountered.

Venturi tubes

1. Pressure losses for venturi tubes are based on the following formulas where:

p_v = velocity pressure in duct, in wg
d_d = equivalent diameter of duct, in
d_t = throat diameter of venturi, in

(a) Straight venturi tube

$$p = 0.15\left[\left(\frac{d_d}{d_t}\right)^4 - 1\right] p_v$$

(b) Straight venturi tube with gate valve in throat

$$p = 0.15\left[\left(\frac{d_d}{d_t}\right)^4 - 1\right] p_v + 0.04\left(\frac{d_d}{d_t}\right)^4 p_v$$

(c) 90° elbow venturi tube

$$p = 0.15\left[\left(\frac{d_d}{d_t}\right)^4 - 1\right] p_v + 0.14\left(\frac{d_d}{d_t}\right)^4 p_v$$

(d) 90° elbow venturi tube with gate valve in throat

$$p = 0.15\left[\left(\frac{d_d}{d_t}\right)^4 - 1\right] p_v + 0.21\left(\frac{d_d}{d_t}\right)^4 p_v$$

2. Approximate pressure losses for venturi tubes may be read in inches of water gauge from the curves in figures 47 and 48. These curves have been developed from the formulas listed above and are based on duct velocities from 2,000 to 3,500 fpm.

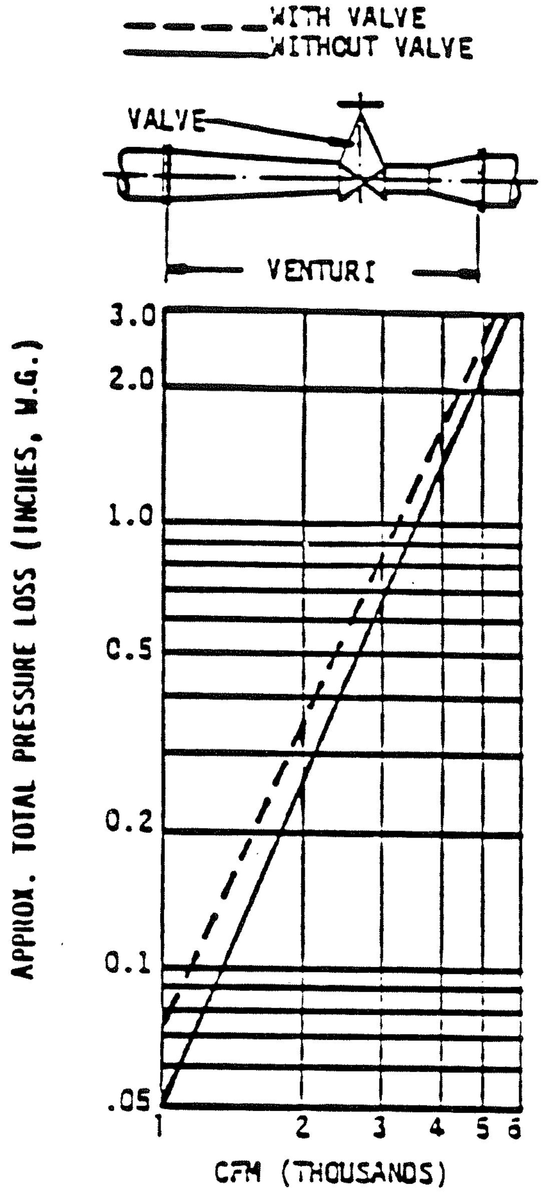


Figure 47. 7 3/4-inch, Straight Venturi, with and without Gate Valve

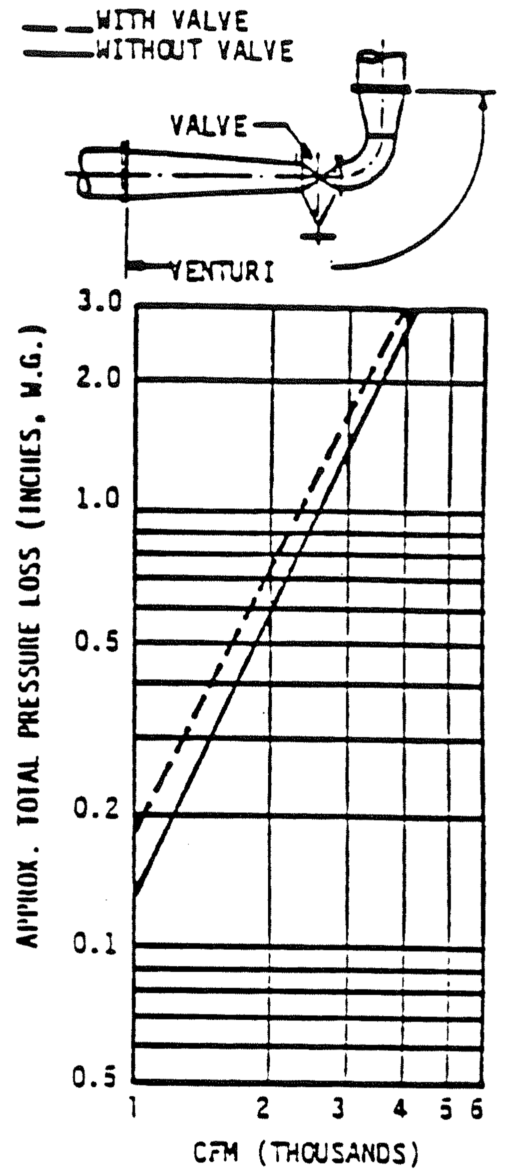


Figure 48. 7 3/4-inch, 90° Elbow Venturi, with and without Gate Valve

Armor gratings (figure 49)

1. The following terms are used in the pressure loss formulas for armor gratings presented in this section:

$R = \frac{\text{free area of armor grating}}{\text{area of duct connected to armor grating}}$

p_v = velocity pressure at face of grating (not the grating holes), in wg

T = grating thickness, in

K = constant depending on length of straight duct, i.e., no elbows or takeoffs, on discharge side of the grating face

Values of K are:

Distance downstream	K
No duct	4.50
6 inches	2.75
12 inches	1.86
18 inches	1.63
24 inches	1.52
36 inches and over	1.40

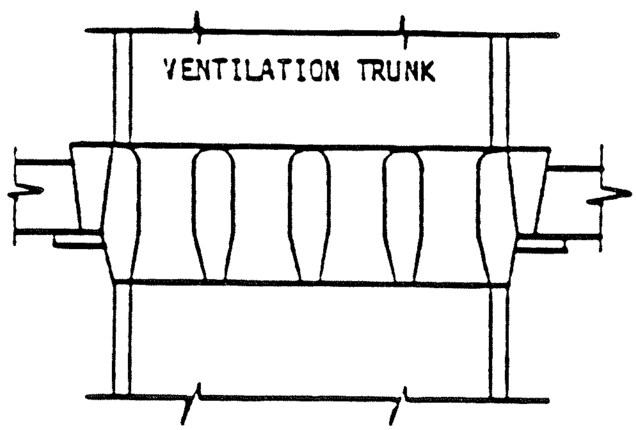


Figure 49. Armor Gratings

2. Total pressure loss through the grating is:

(a) Gratings installed with cones in discharge face, i.e., holes expanding in direction of flow as in figure 49

$$p = K\left(\frac{0.175}{R} + 0.024T\right) p_v$$

(b) Gratings installed with cones in entrance face

$$p = K\left(\frac{0.45}{R} - 0.024T\right) p_v$$

(c) The total pressure loss formulas presented above are for installations with duct on the intake side of the grating. If the intake duct is omitted, the total pressure loss will be increased 0.50 p_v. Example: The total pressure loss for an armor grating with no duct on the intake or discharge will be:

$$p = 4.50\left(\frac{0.175}{R} + 0.024T\right) p_v + 0.50p_v$$

(air flow away from conical face of grating)

or

$$p = 4.50\left(\frac{0.45}{R} - 0.024T\right) p_v + 0.50p_v$$

(air flow toward conical face of grating)

(d) If a bellmouth is fitted to entrance face of grating, add loss for a bellmouth ($0.10p_v$) instead of $0.50p_v$.

(e) The pressure loss through a grating and a 90° vaned turn, installed at least 6 inches beyond discharge side of grating, is less than the sum of the individual losses. This loss may be assumed equal to the sum of the grating loss for a 36-inch straight downstream duct plus the normal vaned turn loss. For example, the loss for an installation that includes a bellmouth on the entrance side, an armor grating with cones installed in entrance face and a vaned turn 1 foot to 6 inches from the discharge face of the grating will be:

$$p = 1.40\left(\frac{0.45}{R} - 0.024T\right) p_v + 0.10p_v + KFp_v$$

where:

K = loss coefficient for vaned turn (table 12)

GENERAL NOTE: Avoid locating fan hub closer than 6 inches from the grating face because it will change the grating pressure loss from that given and will alter fan delivery. If possible, keep fan hub at least 3 feet from the grating to limit noise. Noise level decreases sharply as the distance between hub and grating increases from 6 inches to 3 feet. At approximately 3 feet, the noise level continues to decrease at a slower rate up to 10 feet.

Heaters

1. Frequently, it is desirable to use a duct heater as a supply terminal or as an intake. In other instances, it is necessary that the heater be rotated about its vertical or horizontal axis to fit in a run of duct. In any of these cases, there is a total pressure loss in excess of that heater alone which must be accounted for in the system pressure loss calculations.

2. In the formulas in this section, p_{vf} = velocity pressure at heater face.

3. For a heater which is rotated about its horizontal or vertical axis (figure 50), the pressure loss will be:

$$p = Kp_{vf}$$

where:

K = loss coefficient (table 23)

The coefficients given in table 23 for the condition with turning vanes are based on the following:

(a) The shape of the turning vanes attached to the heater which are normally assumed to be circular arcs of a 2-inch radius.

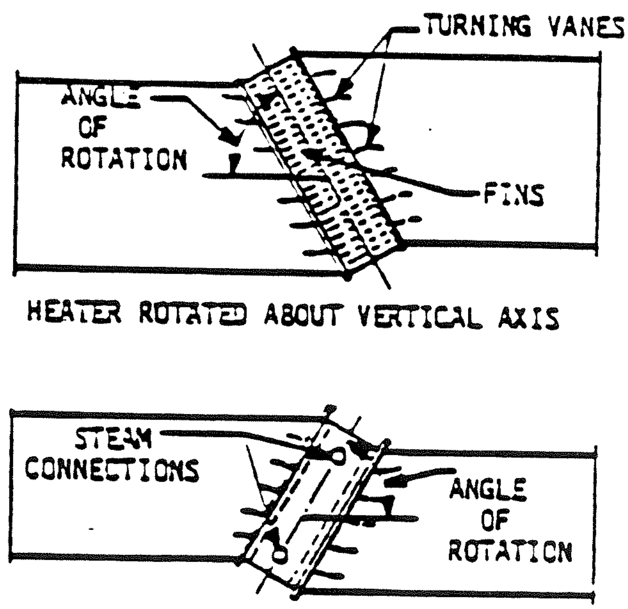


Figure 50. Heater Rotated About Horizontal or Vertical Axis

TABLE 23. PRESSURE LOSS COEFFICIENTS FOR STEAM HEATERS ROTATED ABOUT THE HORIZONTAL AND VERTICAL AXIS

Heater rotated about	Loss Coefficient K														
	Type H					Type M					Type L				
	30°	45°	60°	75°	90°	30°	45°	60°	75°	90°	30°	45°	60°	75°	90°
Horizontal axis (without turning vanes)	4.42	3.46	3.46	--	3.46	3.57	2.39	2.39	--	2.32	3.22	1.93	1.93	--	1.59
Horizontal axis (with turning vanes)	4.13	--	--	--	--	3.39	--	--	--	--	2.85	--	--	--	--
Vertical axis (without turning vanes)	--	5.35	4.05	3.48	3.48	--	3.88	2.64	2.22	2.22	--	3.74	2.28	1.64	1.64
Vertical axis (with turning vanes)	--	3.62	--	--	--	--	2.72	--	--	--	--	2.25	--	--	--

(b) The turning vanes are located on the upstream and downstream sides of the heater, spaced 1.5 inches apart across the face of a heater and rotated about its vertical axis, or 2.5 inches apart across the face of a heater and rotated about its horizontal axis.

4. For a heater used as an intake, the total pressure loss will be:

$$p = Kp_{vf}$$

where:

K = 4.05 for type H heaters
2.66 for type M heaters
2.08 for type L heaters

The above values are correct if the heater is followed by either a straight duct section, oriented parallel to the intake duct, or a converging transition (with a maximum included angle of 60°). The values presented above do not include the total pressure losses for the transitions.

5. The total pressure loss for a heater used as a discharge terminal, which is rotated 45° about its horizontal or vertical axis, has no upstream turning vanes, and no discharge duct is calculated as follows:

$$p = Kp_{vf}$$

where:

K = loss coefficient (table 24)

6. The total pressure loss through a heater installed in 90° elbow (figure 51) will be as listed below:

(a) Type H heater $p = 4.45\ p_{vf}$
(b) Type M heater $p = 3.92\ p_{vf}$
(c) Type L heater $p = 3.30\ p_{vf}$

TABLE 24. PRESSURE LOSS COEFFICIENTS FOR STEAM HEATERS USED AS DISCHARGE

Heater rotated 45° about	Type H	Type M	Type L
Horizontal axis	5.02	3.19	2.77
Vertical axis	5.16	4.09	3.71

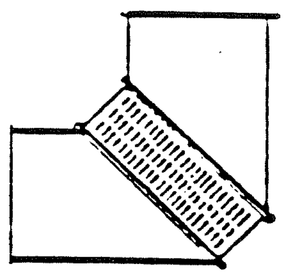


Figure 51. Heater Installed in 90° Elbow

Watertight Closures (figure 52)

1. Pressure losses for type B and C watertight closures are based on the air flow rate through the closure and the direction of air flow. The total pressure loss for each type of fitting can be read in inches of water gauge from figure 52.

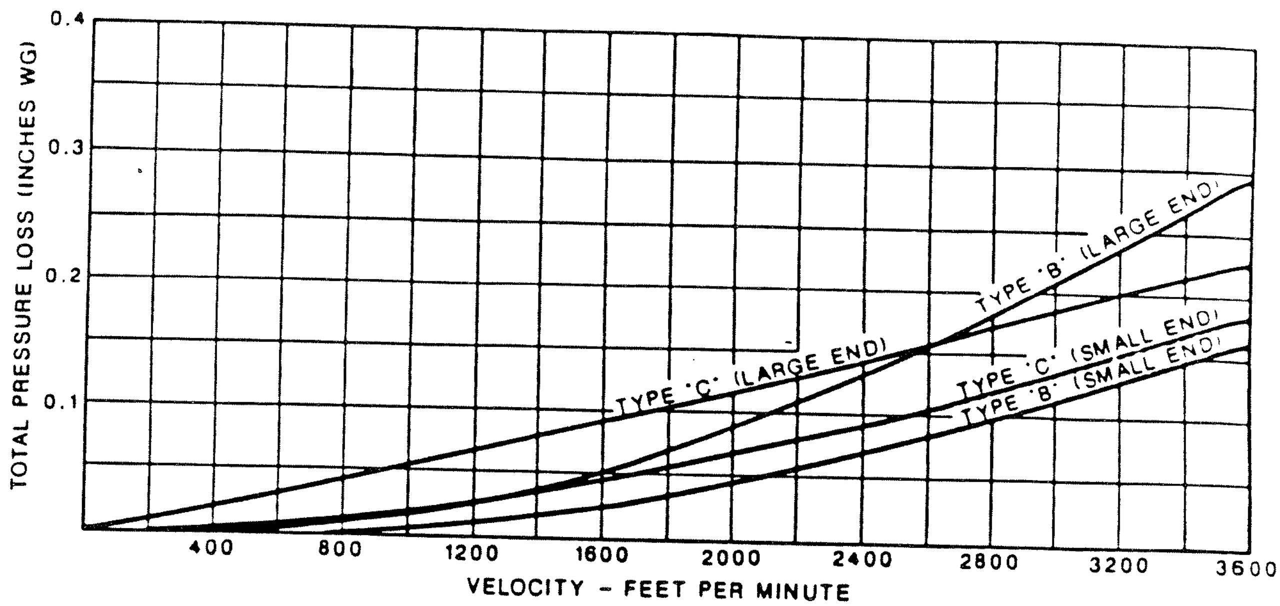


Figure 52. Total Pressure Losses for Watertight Closures (Type B and C)

Navy Standard Diffusing Terminals (figure 53)

1. Total pressure losses for Navy standard diffusing terminals may be read in inches of water gauge from figure 53. If a diffusing terminal is the only terminal of a particular branch, the required total pressure in the duct, two feet upstream of the terminal, is given in figure 53. If 2 or more terminals are required in a branch, see DDS512-2 for method of computation.

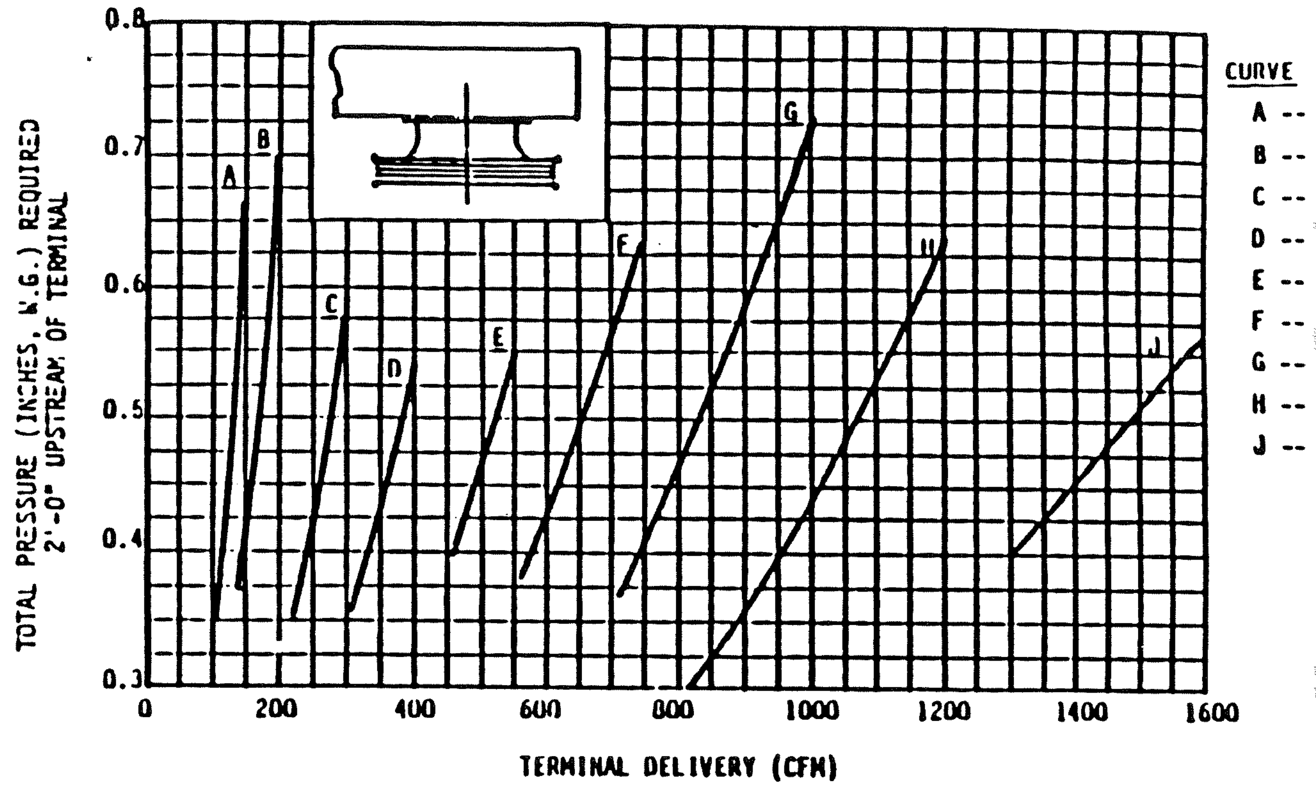


Figure 53. Pressure Requirements for a Single Diffusing Terminal

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