Manufacturers of Industrial Refrigeration and Gas Compression Equipment

Refrigeration Piping Data Manual

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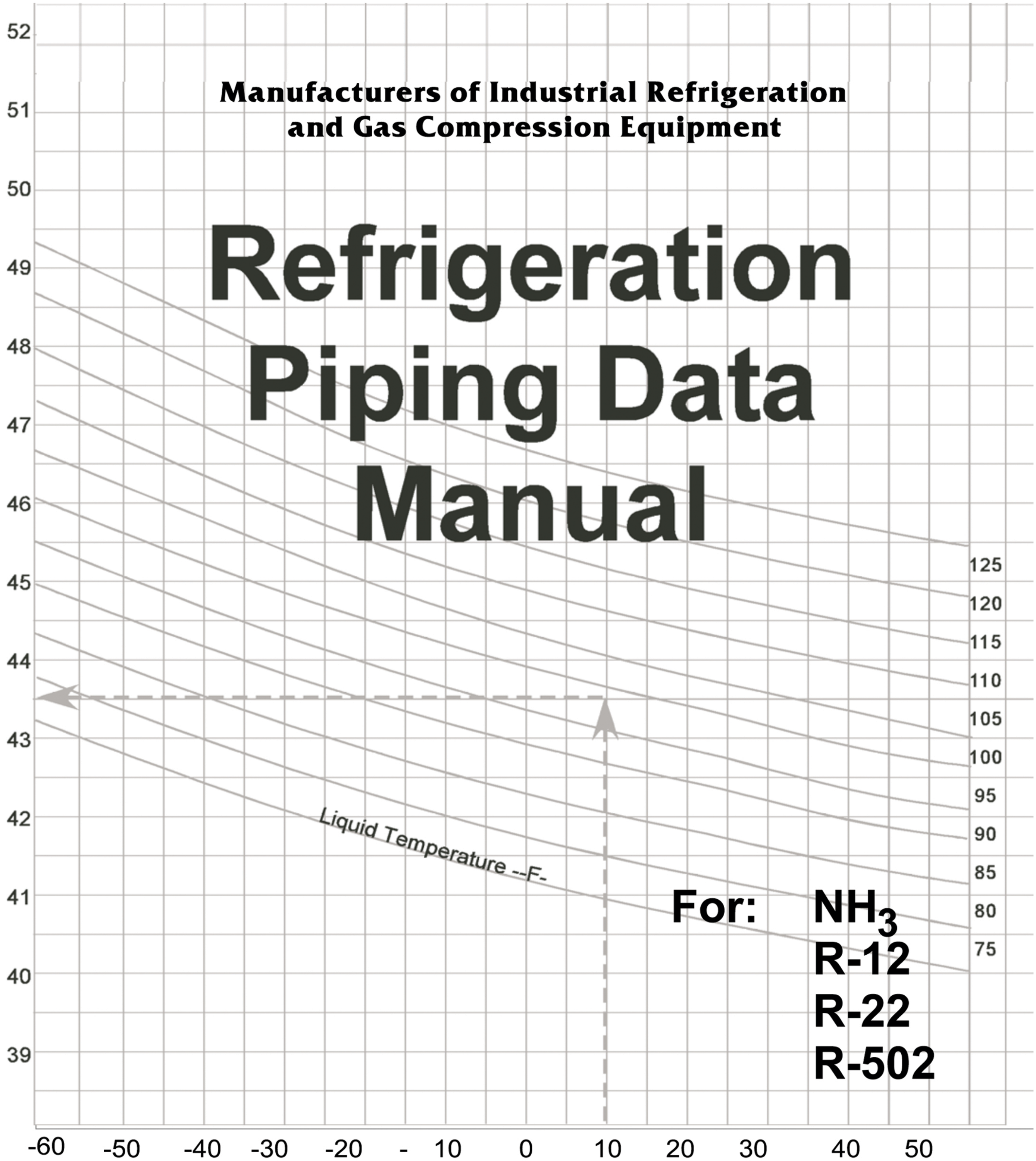

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REFRIGERANT 717 (AMMONIA) PIPING DATA

This section presents useful data for the proper sizing of Refrigerant 717 (Ammonia) piping. Its purpose is not to set design standards, but to provide the latest pipe-sizing information available. It also discusses various factors which determine the allowable pressure drops in different portions of a refrigerant piping system.

Basis of Charts and Tables

The pressure-drop charts given herein for single or high stage applications are based on calculations using the commonly accepted Darcy-Weisbach pressure-drop formula and Darcy friction factors from the Moody Chart (see appendix, Sections A-III and A-IV). Capacity tables for intermediate or low stage applications are based on calculations using Fanning's equation for friction loss.

Pipe Lines. Suction line velocity and pressure drop values are for saturated vapor temperature conditions, and the discharge line values are at pressures corresponding to the condensing temperatures indicated, and superheated to 250 F.

Liquid line velocities and pressure drops are for saturated ammonia liquid at 90 F and can be used with reasonable accuracy for temperatures between 70 F and 110 F.

Valves and Fittings. Pressure losses through refrigerant valves and fittings are given in a table, in the form of "K" factors (velocity heads). These "K" factors are representative, using average values obtained from various tests and manufacturers' ratings. "K" factors vary widely for a given type and size of valve or fitting, depending on the construction or internal design.

For a simplified determination of these pressure drops, "equivalent lengths" of valves and fittings are given in a table. These "equivalent lengths" have been derived, using the "K" factors in conjunction with friction factors taken from the Moody Chart at Reynolds Numbers in the range of normal usage, for both vapor and liquid lines.

"Equivalent lengths" result in a sacrifice of accuracy, depending on the temperature, state and velocity of the refrigerant. "K" factors give more reliable pressure drop data. For greater accuracy, particularly for valves, "K" factors should be obtained from the manufacturer.

Pressure-Drop Limitations (Pipe-Sizing Factors)

Vapor line pressure drops result in an increase in power input to the compressor and a decrease in refrigeration capacity. The most critical line with respect to this is the suction line, as losses in it have the greatest effect on the system. An economic study, involving power input, system capacity, size of system components—evaporator and condenser—and installation cost of pipe and pipe insulation, can best determine the optimum pressure-drop allowance. Experience has shown that the allowable pressure drop for suction lines should decrease with suction temperature. Discharge lines may have a greater pressure-drop, for a specified temperature penalty, than suction lines.

Suction line pressure drop increases the volume of gas to be handled by the compressor, increases the ratio of discharge pressure to suction pressure, and reduces the volumetric efficiency of the compressor. This results in less capacity from a given compressor and more power per ton of refrigeration.

The effect of a particular amount of suction line pressure drop is greater as the suction pressure decreases. Fig. 8 indicates this in showing that a particular pressure drop results in a greater "temperature penalty" at a lower saturation temperature. The result of suction line pressure drop is that the compressor operates from a suction condition corresponding to the actual evaporator temperature minus the temperature penalty.

Larger suction line sizes reduce the pressure drop and, therefore, reduce the compressor capacity required and also the power per ton. However, the larger pipe size increases its cost and also its installation and insulation cost. The best size from an economic consideration can be determined by an economic study with the cost of the various factors available.

Discharge line pressure drop also increases the ratio of discharge pressure to suction pressure and reduces the volumetric efficiency of the compressor. This results in less capacity from a given compressor and more power per ton of refrigeration.

The effect of a particular amount of discharge line pressure drop is less as the discharge saturation temperature increases, but the difference is not very great in the range of saturation temperatures corresponding to usual discharge pressures. Fig. 8 indicates this by showing the relatively small change in "temperature penalty" for a particular pressure drop at the temperatures corresponding to saturation at normal discharge pressures. Fig. 8 also indicates the smaller "temperature penalty" for a given pressure drop in the saturation temperature range corresponding to usual discharge conditions as compared to the range corresponding to usual suction conditions. Because of this, economic considerations usually result in the use of a larger pressure drop as the basis of design for a discharge line than that which would be used for a suction line.

Pressure-drop in the *liquid line* does not affect the system capacity or power input, but flash gas, caused by pressure-drop or liquid-lift, increases the required capacity of the expansion device.

Higher liquid line velocities should be used with caution because of possible stresses due to rapid closing of any liquid valve. Solenoid valves, or solenoid pilot-controlled valves, almost always are rapid-closing.

Basis of Design

Suction lines should generally be selected for a pressure drop of 1 to 3 psi per 100 feet of pipe for temperatures above 20 F. On the other hand, pressure drop should range from 1 to 0.2 psi per 100 feet of pipe at temperatures between + 20 F and — 60 F. In other words pressure-drop allowance should decrease with decreasing suction temperatures.

Discharge lines should generally be selected for a nominal pressure drop between 2 and 5 psi per 100 feet of pipe at any normal condensing temperature.

Liquid lines are sized for low pressure drop to avoid or minimize flash gas.

For sizing of *liquid lines from the condenser to the receiver*, the criterion used is a liquid velocity of 100 ft per minute to simulate sewer-type drainage. Velocities ranging from 75 to 150 ft per minute are commonly used. Factors influencing this line-size selection are elevation difference between the condenser and receiver, the number of restrictions in this line, the diameter of the pipe, whether or not an external gas equalizer will be provided, relationship of condensing temperature to ambient temperature, etc. Where other velocity criteria are used, the line size can readily be selected by the ratio of the velocity used to 100 ft per minute.

For *liquid lines from receiver to system*, the velocity range used is from 100 to 300 fpm, with pressure drop of 2 psi per 100 ft or greater.

The curve showing the relation of change in elevation to the pressure change is based on a constant liquid temperature of 90 F. Where saturated liquid must rise from the receiver to the evaporator, the loss in static head would create flash gas which would further change the characteristics of the temperature-penalty curve. Consequently, for the accurate use of this curve, liquid subcooling should be provided to the extent of the elevation-difference penalty when the liquid column rises upward. Where the receiver is above the evaporator, no subcooling is necessary and credit for the increased pressure may be taken in the selection of the expansion device. (See Figure 6)

Downstream of the expansion device there is a mixture of liquid and flash gas, which involves two-phase flow requiring rather complicated calculations. It has been found from experience that to select a pipe one size larger than that upstream of the expansion device is generally satisfactory.

How to Use Charts

1. Tables 1-A and 1-B permit quick selection of suction lines applicable to the conditions listed.

   Tables 1-A gives suction line capacities (tons) for intermediate or low stage applications. The values in this table are based on 0°F. saturated discharge temperature. For intermediate or low stage suction line capacities at other saturated discharge temperatures, multiply table value by proper line capacity multiplier given in Table A-7 in appendix.

   Table 1-B gives suction line capacities (tons) for single or high stage applications at various saturated temperatures and pressure drops, and at 90°F. condensing temperature. For other condensing (or liquid) temperatures and other pressure-drop limitations, follow steps 3 and 4 below.

2. Table 2 shows discharge line capacities in tons of refrigeration for various pressure drops per 100 ft, and is based on 90 F condensing temperature and + 20 F evaporator temperature. For other condensing (or liquid) temperatures, these capacities are not valid; use the detailed steps outlined below.

   Also shown are liquid-line sizes (1) from the condenser to the receiver, based on 100 ft per min liquid velocity, and (2) receiver to system expansion device, based on a pressure drop of 2.0 psi per 100 ft.

The following steps are used for detailed sizing of ammonia piping:

3. Fig. 2 permits a quick determination of refrigerant-flow rates in lb/(min) (ton) at various evaporating and high pressure liquid temperatures. The total refrigerant-flow rate is determined by multiplying the lb/(min) (ton) from these curves by the system or applicable tonnage.
4. Fig. 3 provides suction and discharge-gas line pressure drops for 100 ft equivalent length of pipe. After finding the total refrigerant-flow rate in lb per min, the pressure drop through any gas line is found by projecting vertically, from the flow rate on the lower scale, to the intersection with the line size to be used. At this intersection, follow the horizontal line to the right and intersect with the vapor temperature line, and then project vertically to the top scale to read the pressure drop.
5. Fig. 4 shows suction and discharge-gas line velocities at various flow rates for different size refrigerant lines. It is read in the same manner as Fig. 3, with the resultant answer in ft per sec velocity.
6. Fig. 5 is used to determine liquid-line velocity and pressure drop. The liquid-flow rate in lb per min, as read on the lower scale, is projected upward to the intersection of a

given pipe size. The velocity in ft per sec can be read at this point and a pressure drop in psi per 100 ft equivalent length can be read on the ordinate scale.

7. Fig. 6 indicates the change in static pressure for a liquid temperature of 90 F at elevations from 0 ft to 50 ft. The elevation difference, read on the lower scale and projected upward to the curve and thence horizontally to the left, will give the change in pressure resulting from elevation difference.
8. Table 3 lists "K" factors (resistance in velocity heads) for commonly-used refrigerant valves and fittings. To determine the actual pressure drop at any given condition of flow, the "K" factor is applied to the nomograph in Fig. 7.
9. Fig. 7 is a nomograph presented for the determination of pressure loss through valves and fittings when the "K" factor and operating conditions are known. A straight line, extending through known values on the "K" factor and velocity scales, gives an intersection with the turning line. A straight line from this intersection is then projected through the desired temperature until it intersects with the scale on the extreme right, giving pressure drop in psi through the valve or fitting.
10. Table 4 lists the nominal "equivalent length" of commonly-used refrigerant valves and fittings. These values may be used in lieu of the "K" factors, for convenience, where less accuracy is required. The equivalent length of all fittings in a line are added to the linear feet of straight run to arrive at a total equivalent length. This length, divided by 100 and multiplied by the pressure drop per 100 feet, will provide the pressure loss throughout the line.
11. Fig. 8 shows the temperature penalty due to pressure drop. The pressure drop read on the left scale, projected to the intersection with the temperature curve will give the temperature penalty due to the pressure drop for saturated liquid or gas as read from the lower scale.

Pulsating Flow

The data provided in the figures and tables above are based on steady-flow conditions. Irregular flow, such as pulsating flow and two-phase flow, which are met in practice, causes an increase in pressure loss beyond that indicated in the given data.

Reciprocating compressors create pulsating flow in both discharge and suction lines. However, because gas density and the pressure-pulsation amplitude are both greater in the discharge line, the added frictional loss due to pulsation is also greater in the discharge line. For the same reasons, the additional pressure loss due to pulsating flow is greater for a single-cylinder compressor than for a multi-cylinder compressor. Pulsation is greater as the compression ratio increases.

The refrigerant piping and other components in the system, such as valves, fittings, condenser, evaporator, etc., attenuate the pulsation, resulting in an energy loss that is only slightly above the frictional loss that occurs when the flow is steady. Use of a muffler in the discharge line, close to the compressor, reduces the friction loss in the line downstream from the muffler. Of course, the frictional loss of the muffler itself must be considered in the system design.

The calculations for these types of flow are complicated, but it has been found that the effects of pulsating flow, where they constitute a problem, can be minimized by selecting the next larger pipe size.

SAMPLE PROBLEM

GIVEN

100 tons refrigeration

10 F evaporator temperature

100 F condensing (liquid) temperature

Piping layout as shown in Fig. 1

Select discharge, liquid and suction lines

Determine compressor operating conditions

SOLUTION

From Fig. 2, the refrigerant flow per ton at 10 F evaporator temperature and 100 F condensing temperature = 0.435 lb/(min)(ton). Refrigerant circulation = 100 tons × 0.435 lb/(min)(ton) = 43.5 lb/min.

DISCHARGE LINE

From Table 2, at 20 F saturated evaporator temperature, 90 F saturated condensing temperature and 2 psi/100 ft pressure drop, a 2½" pipe has a capacity of 140 tons. A 2" size will be tried, although, at the conditions of this problem, it may develop that its pressure drop will appreciably exceed 2 psi/100 ft.

Pressure Drop in Pipe:

From Fig. 3, pressure drop/100 ft. at 43.5 lb/min and 100 F condensing temperature through 2" pipe = 2.3 psi/100 ft.

Pressure drop for 45 ft of pipe = 45/100 × 2.3 = 1.04 psi

From Fig. 4, velocity at 43.5 lb/min and 100 F condensing temperature through 2" pipe = 61 fps

Pressure Drop in Fittings:

Pressure drop for three 2" long-radius welded ells:

From Table 3, K = 0.25

From Fig. 7, Pressure drop = 0.05 psi

3 ells × 0.05 psi = 0.15 psi

Total pressure drop = 1.19 psi

Temperature Penalty:

From Fig. 8, 1.19 psi, 100 F saturation temperature, temperature penalty = 0.35 F

Since this temperature penalty is small, the 2" pipe selection will be used.

LIQUID LINES

Condenser to receiver:

Base selection on velocity in liquid line of 100 fpm.

From Table 2, select 1½" ips.

From Fig. 5, velocity is 1.6 fps = 96 fpm.

Because of gravity flow, no pressure drop need be calculated.

Receiver to expansion valve:

From Fig. 5 for 43 lb/min liquid, select 1" pipe size resulting in 2.0 psi/100 ft pressure drop.

Pressure Drop in Pipe:

Velocity, from Figure 5 = 4 fps = 240 fpm.

Pressure drop for 28 ft of pipe = 28/100 × 2.0 = 0.56 psi

Pressure Drop in Valves and Fittings:

From Table 3, for three standard 1" screwed elbows, K = 1.4; from Fig. 7, pressure drop per ell = 0.10 psi; 3 ells × 0.1 psi = 0.30 psi

From Table 3, for one 1" screwed angle valve, K = 4.3

From Fig. 7, pressure drop for 1" valve at 4 fps = 0.28 psi

Total pressure drop = 1.14 psi

Expansion valve to evaporator:

Size line one size larger than upstream of valve to allow for flash gas, or 1¼".

SUCTION LINE

From Table 1-B, select 3" pipe, which is adequate for 95.3 tons of refrigeration at 1 psi/100 ft pressure drop, 10 F saturated suction temperature and 90 F saturated condensing temperature (interpolated).

Pressure Drop in Pipe:

From Fig. 3, 43.5 lb/min, 3" pipe, at 10 F suction temperature, pressure drop = 1.1 psi/100 ft.

Pressure drop for 27 ft of pipe = 27/100 × 1.1 = 0.30 psi

Pressure Drop in Fittings:

From Fig. 4, velocity at + 10 F suction temperature and 43.5 lb/min for 3" pipe = 105 fps.

For two 3" long-radius welded ells, Table 3, K = 0.23

From Fig. 7, pressure drop for 1 ell = 0.033 psi

For two ells, pressure drop = 0.07 psi

Total pressure drop = 0.37 psi

Temperature penalty:

From Fig. 8, 0.37 psi at 10 F saturation temperature, temperature penalty = 0.40 F

COMPRESSOR SELECTION

Therefore, a compressor must be selected for 100 tons capacity at 10—0.40=9.6 F suction temperature and 100+0.35=100.4 F condensing temperature.

TABLE 1-A. SUCTION LINE CAPACITIES—TONS

(For Intermediate or Low Stage Applications)

Refrigerant and ΔT Equivalent of Friction Drop	Steel IPS	Steel SCH	Suction Lines – Suction Temp F −60	−50	−40	−30	Second Stage Discharge and Liquid Lines
Refrigerant 717 (*Ammonia*)	½	40	0.26	0.38	0.50	0.62	See Table 2
	¾	40	0.55	0.76	1.05	1.30	
	1	40	1.05	1.53	2.00	2.50	
	1¼	40	2.15	3.15	4.10	5.10	
	1½	40	3.4	5.0	6.5	8.1	
	2	40	6.3	9.2	12.0	15.0	
1 F ΔT Per 100 ft Equiv. Length	2½	40	10.3	15.0	19.5	24.3	
	3	40	18.4	26.8	35.0	43.7	
	3½	40	27.3	39.8	52.0	65.0	
	4	40	37.8	55.2	72.0	90.0	
	5	40	68.3	100.0	130.0	162.0	
	6	40	110.0	161.0	210.0	262.0	
	8	40	258.0	376.0	490.0	610.0	

NOTES:

(1) Values based on 0 F saturated discharge temp. For capacities at other saturated discharge temp, multiply table value by proper line capacity multiplier (See appendix, Table A-7).

(2) For other ΔT's and Equivalent Lengths, L_e Line Capacity (Tons)

$$= \text{Table Tons} \times \left(\frac{100}{L_e} \times \frac{\text{Actual } \Delta T \text{ Loss Desired}}{\text{Table } \Delta T \text{ Loss}}\right)^{0.55}$$

(3) For other Tons and Equivalent Lengths in a given pipe size,

$$\Delta T = \text{Table } \Delta T \times \frac{L_e}{100} \times \left(\frac{\text{Actual Tons}}{\text{Table Tons}}\right)^{1.8}$$

(4) For pressure drop (psi) corresponding to ΔT, refer to Refrigerant properties, Table 5.

(5) Size low stage (Booster) discharge lines same as equivalent single stage suction lines (see Table 1-B).

TABLE 1-B. SUCTION LINE CAPACITIES—TONS[1]

(For Single or High Stage Applications)

LINE SIZE[2] (Inches)	Saturated Suction Temperature—F																
	−30			−20			0			20				40			
	Pressure Drop, Psi/100 ft																
IPS	½	1	2	½	1	2	½	1	2	½	1	2	3	½	1	2	3
½	0.44	0.62	0.88	0.50	0.72	1.02	0.65	0.92	1.31	0.82	1.18	1.70	2.40	1.02	1.45	2.06	2.92
¾	0.96	1.37	1.96	1.11	1.58	2.24	1.45	2.06	2.93	1.81	2.60	3.70	5.23	2.25	3.22	4.61	6.52
1	1.92	2.72	3.85	2.13	3.01	4.26	2.74	3.9	5.61	3.5	4.98	7.06	8.70	4.33	6.14	8.84	10.8
1¼	4.8	6.95	9.85	5.43	7.80	11.1	7.07	10.1	14.6	8.99	12.95	18.5	22.8	11.18	16.15	23.1	28.3
1½	7.3	10.5	14.9	8.25	11.9	16.8	10.7	15.5	22.0	14.6	19.7	27.8	34.2	17.1	24.2	34.5	42.6
2	14.1	20.5	29.0	15.9	23.9	32.5	20.9	29.6	42.7	26.4	38.0	53.7	67.1	32.8	46.8	66.7	82.0
2½	22.8	32.6	46.1	25.3	36.1	52.0	33.3	47.7	68.2	42.3	60.2	85.6	105.0	52.5	75.0	106.5	131.0
3	40.1	57.5	81.4	45.1	64.6	91.5	59.1	84.2	121	74.5	106.5	151	187.5	92.5	132	190	233
4	83.5	119	169	93.0	132	186	121	172	244	153	218	305	378	190	269	382	469
5	150	214	303	168	238	341	218	312	443	276	394	555	683	342	485	690	849
6	244	344	487	274	388	550	354	505	715	447	637	900	1110	558	789	1125	1380
8	500	710	1000	560	796	1128	726	1039	1468	920	1308	1850	2270	1135	1615	2295	2810
10	900	1280	1810	1010	1435	2020	1305	1860	2645	1645	2350	3310	4100	2040	2900	4140	5035
12	1450	2050	2900	1625	2310	3280	2100	2780	4280	2675	3820	5410	6600	3325	4685	6670	8200

NOTES: [1] Based on fluid flow at 90 F saturated condensing temperature
[2] Data based on Schedule 40 steel pipe, except that 1″ and smaller are based on Schedule 80

DISCHARGE AND LIQUID PIPING

TABLE 2. DISCHARGE AND LIQUID LINE CAPACITIES—TONS[1]

LINE SIZE[2,3,4] (Inches)	DISCHARGE LINES				LIQUID LINES	
	Temperature 250 F				To Receiver	To System
	Pressure Drop Psi/100 ft				Velocity fpm	Pressure Drop Psi/100 ft
IPS	½	1	2	3	100	2
⅜	—	—	—	—	8.5	11.6
½	1.28	1.85	2.65	3.25	13.6	23.5
¾	2.84	4.03	5.83	7.15	25.2	53.2
1	5.68	8.06	11.6	14.2	42.1	105
1¼	14.7	21.1	30.4	37.2	75.3	225
1½	22.2	31.5	45.0	55.0	103	351
2	43.0	61.4	87.6	107	197	805
2½	68.6	98.5	140	171	280	1280
3	122	174	246	300	432	2270
4	244	351	497	608	745	4630
5	450	638	900	1100	—	—
6	734	1030	1470	1800	—	—
8	1480	2110	3010	3650	—	—

NOTES: [1] Based on fluid flow at 90 F saturated condensing temperature and 20 F saturated evaporating temperature
[2] Data on sizes 2" and over based on Schedule 40 steel pipe
[3] Data on sizes 1" and below based on Schedule 80 steel pipe
[4] Data for discharge line sizes 1¼" and 1½" based on Schedule 40 steel pipe; for liquid line sizes 1¼" and 1½" based on Schedule 80 steel pipe

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VALVES AND FITTINGS K-FACTORS

TABLE 3. "K-FACTORS" (VELOCITY HEADS)[1] FOR VALVES AND FITTINGS

FERROUS VALVES AND FITTINGS[2]

LINE SIZE (Inches) IPS	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL			LONG-RADIUS ELL			TEE, LINE-FLOW			TEE, BRANCH-FLOW		
	Screwed	Flanged	Screwed	Flanged	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded
3/8	21	—	11.0	—	2.5	—	—	—	—	—	0.9	—	—	2.7	—	—
1/2	15	—	8.4	—	2.1	—	—	—	—	—	0.9	—	—	2.4	—	—
3/4	11	—	5.7	—	1.7	—	—	0.9	—	—	0.9	—	—	2.0	—	—
1	9.3	15.5	4.3	5.0	1.4	0.43	0.46	0.73	0.40	0.32	0.9	0.26	0.43	1.8	1.0	1.37
1¼	8.4	12.8	3.5	4.0	1.3	0.40	0.42	0.60	0.37	0.29	0.9	0.24	0.36	1.7	0.90	1.31
1½	7.8	11.5	2.9	3.4	1.2	0.39	0.40	0.52	0.34	0.27	0.9	0.22	0.31	1.5	0.88	1.27
2	7.0	9.9	2.2	2.8	1.0	0.36	0.38	0.40	0.30	0.25	0.9	0.19	0.28	1.4	0.80	1.17
2½	—	9.0	—	2.5	—	0.34	0.37	—	0.27	0.24	—	0.17	0.26	—	0.75	1.13
3	—	8.3	—	2.4	—	0.33	0.36	—	0.25	0.23	—	0.16	0.24	—	0.72	1.10
4	—	7.5	—	2.3	—	0.31	0.35	—	0.22	0.22	—	0.14	0.22	—	0.68	1.05
5	—	7.0	—	2.3	—	0.30	0.34	—	0.20	0.21	—	0.13	0.19	—	0.64	1.01
6	—	6.7	—	2.3	—	0.28	0.32	—	0.18	0.20	—	0.12	0.18	—	0.60	0.98
8	—	6.2	—	2.3	—	0.27	0.31	—	0.15	0.19	—	0.10	0.15	—	0.57	0.93
10	—	6.0	—	2.3	—	0.25	0.30	—	0.14	0.18	—	0.09	0.14	—	0.52	0.90
12	—	6.0	—	2.3	—	0.25	0.29	—	0.13	0.18	—	0.08	0.13	—	0.50	0.88

NOTES: [1] $K = 2gh/V^2$
[2] Based on Schedule 40 pipe

VALVES AND FITTINGS EQUIVALENT LENGTHS

TABLE 4. EQUIVALENT LENGTHS[1] OF VALVES AND FITTINGS

FERROUS VALVES AND FITTINGS[2,3]

LINE SIZE (Inches) IPS	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL			LONG-RADIUS ELL			TEE, LINE-FLOW			TEE, BRANCH-FLOW		
	Screwed	Flanged	Screwed	Flanged	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded
⅜	31	—	16	—	3.7	—	—	—	—	—	1.3	—	—	4.0	—	—
½	29	—	16	—	4.1	—	—	—	—	—	1.8	—	—	4.7	—	—
¾	31	—	16	—	4.7	—	—	2.5	—	—	2.5	—	—	5.6	—	—
1	35	57	16	19	5.3	1.6	1.8	2.8	1.5	1.2	3.4	1.0	1.6	6.8	3.8	5.2
1¼	46	69	19	22	7.1	2.2	2.3	3.3	2.0	1.6	4.9	1.3	2.0	9.2	4.9	7.1
1½	51	76	19	22	7.9	2.6	2.6	3.4	2.2	1.8	5.9	1.4	2.0	9.9	5.8	8.4
2	63	89	20	25	9.0	3.2	3.4	3.6	2.7	2.3	8.1	1.7	2.5	12.6	7.2	10.5
2½	—	101	—	28	—	3.8	4.2	—	3.0	2.7	—	1.9	2.9	—	8.4	13.0
3	—	123	—	36	—	4.9	5.3	—	3.7	3.4	—	2.4	3.6	—	11	16
4	—	155	—	48	—	6.2	7.2	—	4.5	4.5	—	2.9	4.5	—	14	22
5	—	190	—	63	—	8.1	9.2	—	5.4	5.7	—	3.5	5.1	—	17	27
6	—	227	—	78	—	9.5	11	—	6.1	6.8	—	4.1	6.1	—	20	33
8	—	295	—	110	—	13	15	—	7.1	9.0	—	4.7	7.1	—	27	44
10	—	370	—	142	—	16	18	—	8.7	11	—	5.6	8.7	—	32	56
12	—	465	—	173	—	19	22	—	10	14	—	6.2	10	—	39	68

NOTES: [1] $L_e = K(D/f)$
[2] Friction factors (f) determined at "practical" Reynolds Numbers based on 20 F suction lines having pressure-drop of 1.8 psi/100 ft
[3] Based on Schedule 40 pipe

VILTER™ Since 1867

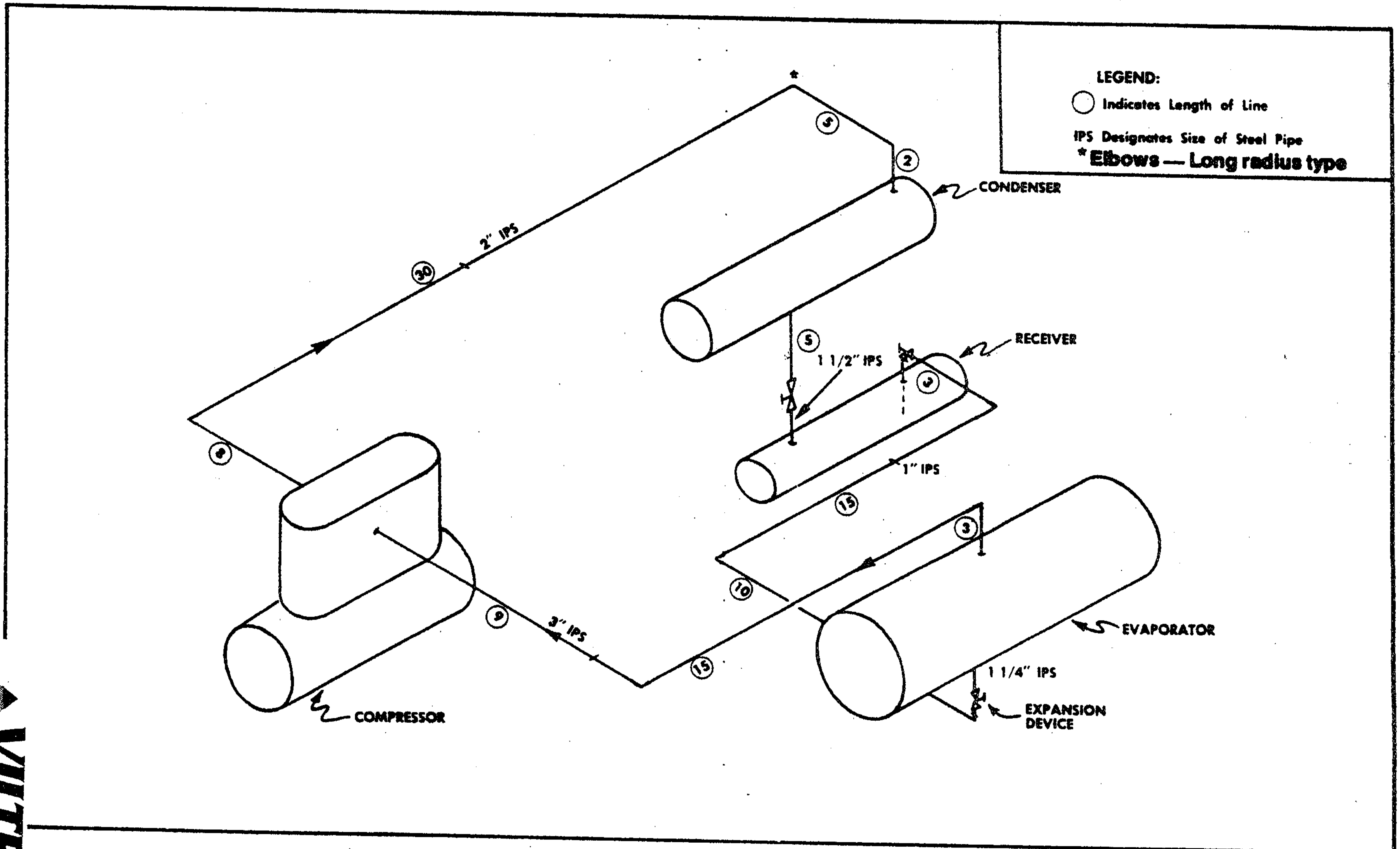


Fig. 1. SCHEMATIC PIPING LAYOUT FOR SAMPLE PROBLEM

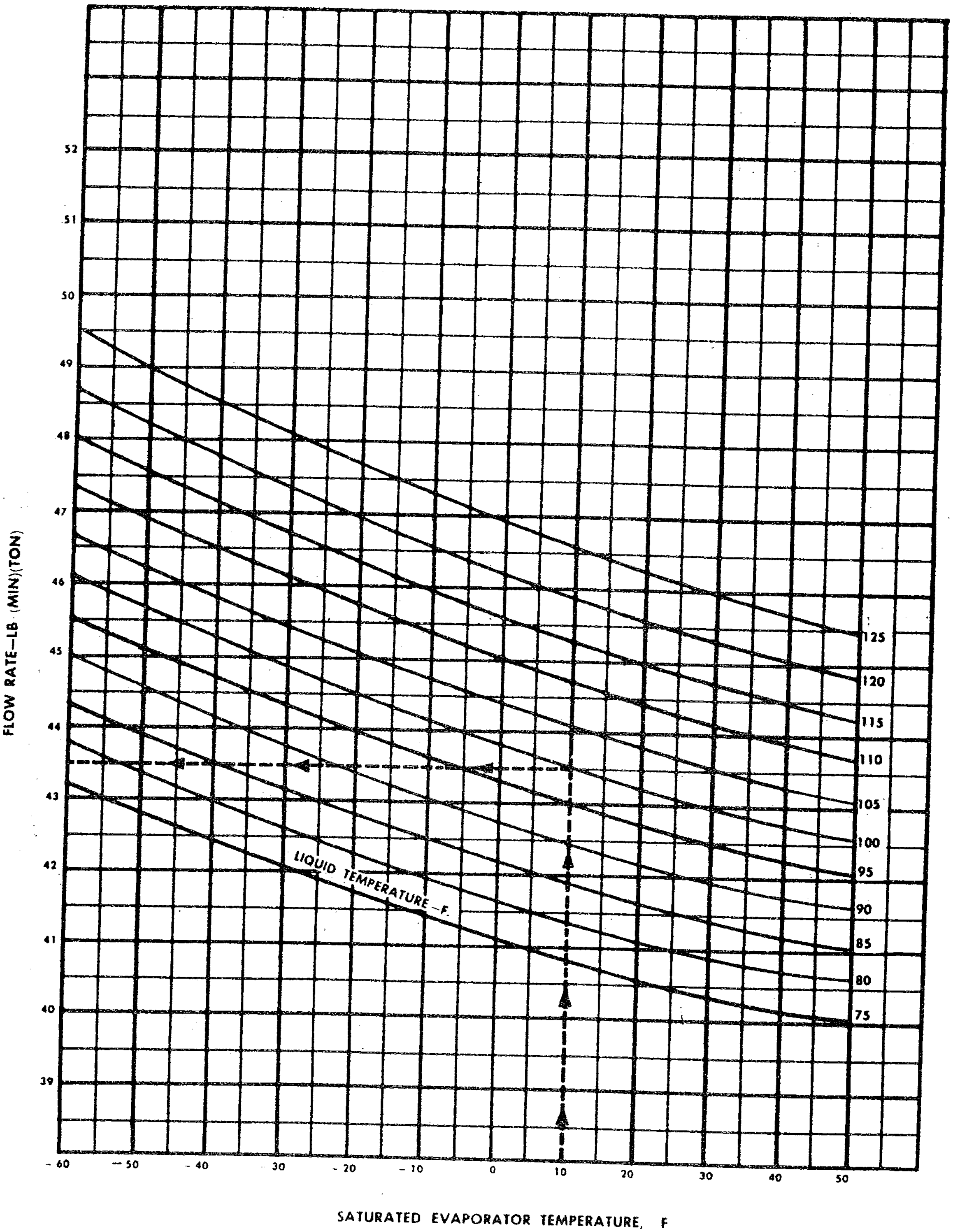


Fig. 2. FLOW RATE PER TON OF REFRIGERATION FOR REFRIGERANT 717

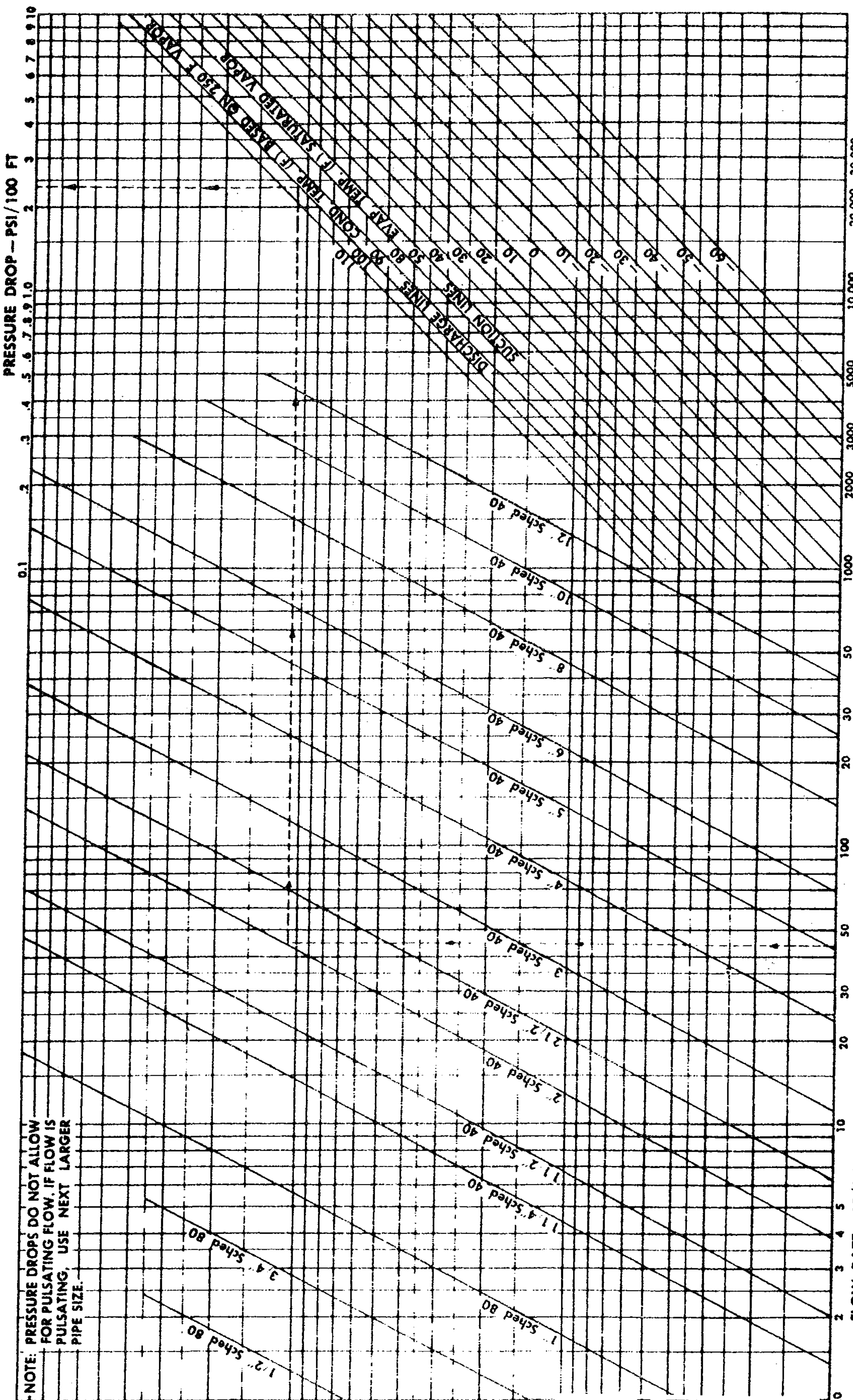


FIG. 3. PRESSURE DROP IN STEEL PIPING FOR REFRIGERANT 717 VAPOR

VILTER Since 1867

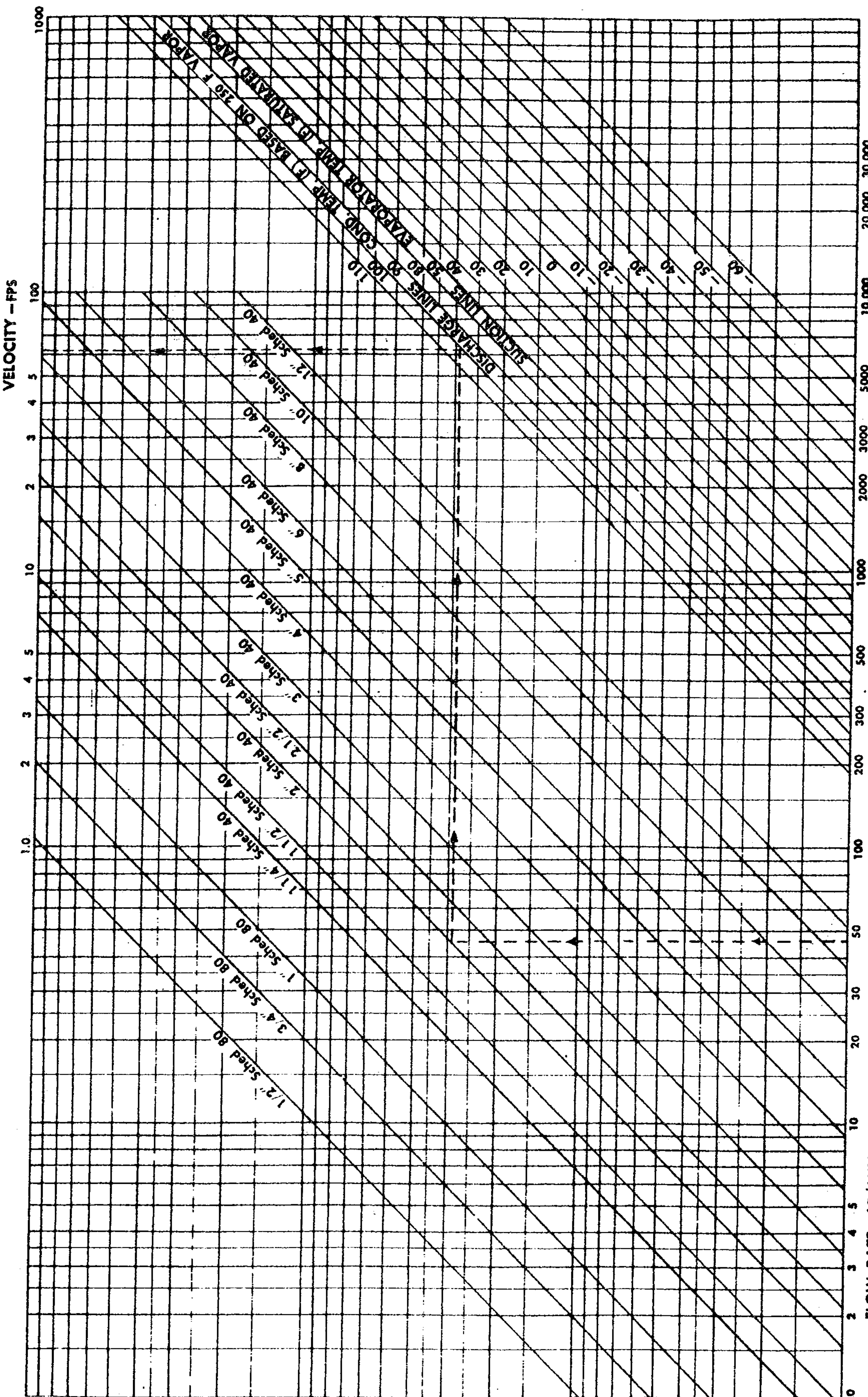


Fig. 4. VELOCITY IN STEEL PIPING FOR REFRIGERANT 717 VAPOR (SUCTION AND DISCHARGE)

VILTER™ Since 1867

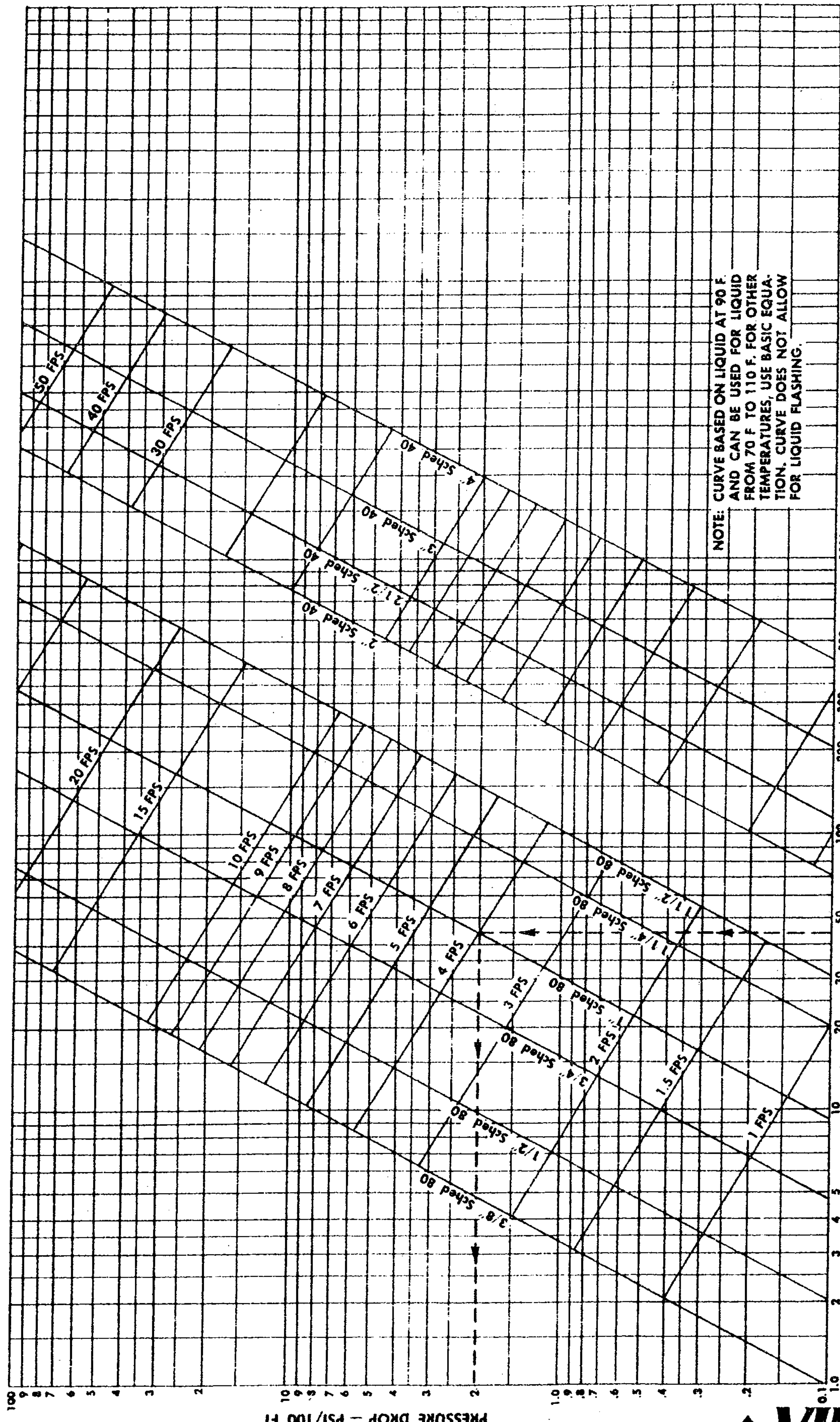


Fig. 5. VELOCITY AND PRESSURE DROP IN STEEL PIPING FOR REFRIGERANT 717 LIQUID

VILTER Since 1867

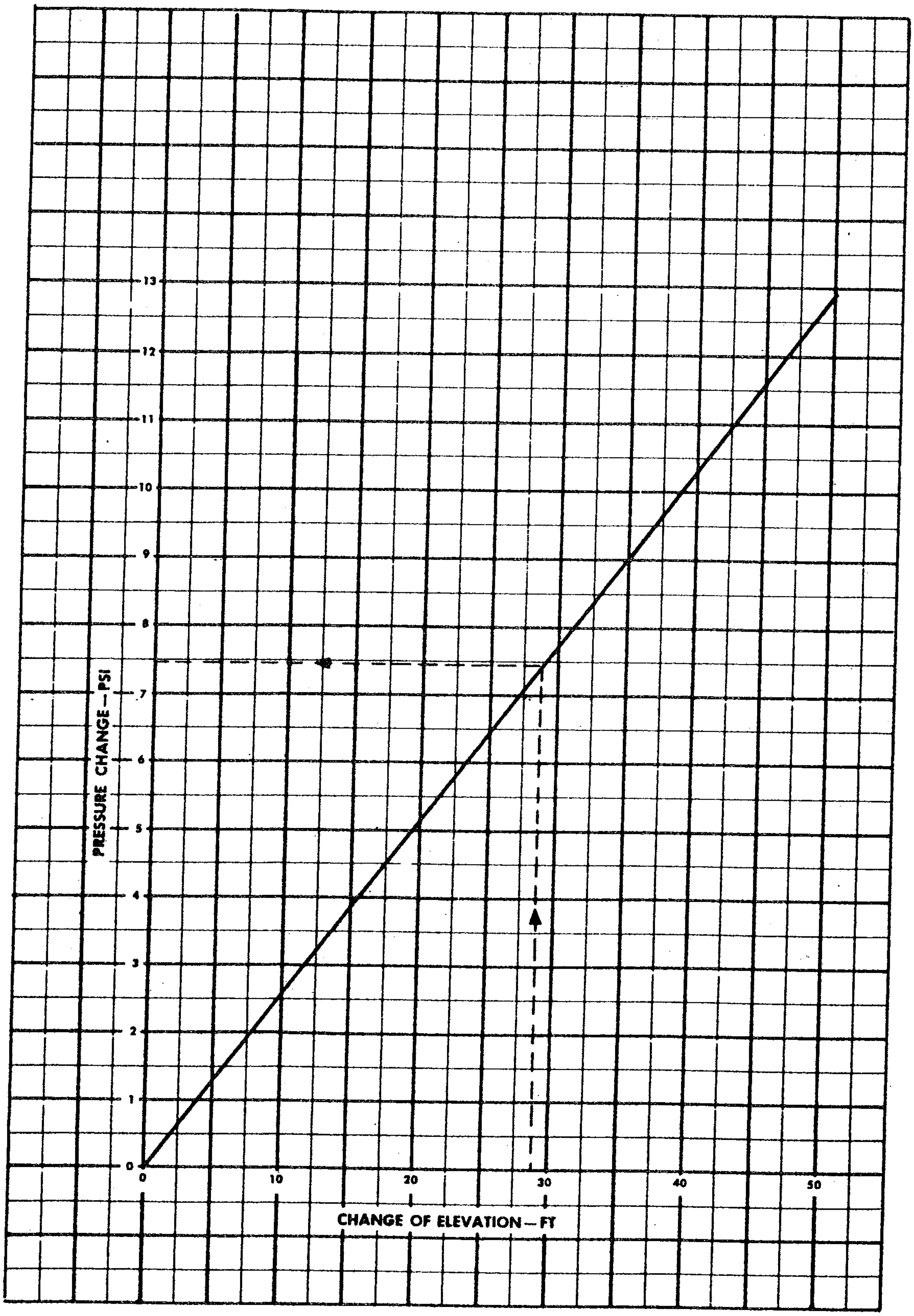


Fig. 6. RELATION OF PRESSURE-CHANGE TO ELEVATION-DIFFERENCE FOR REFRIGERANT 717 LIQUID

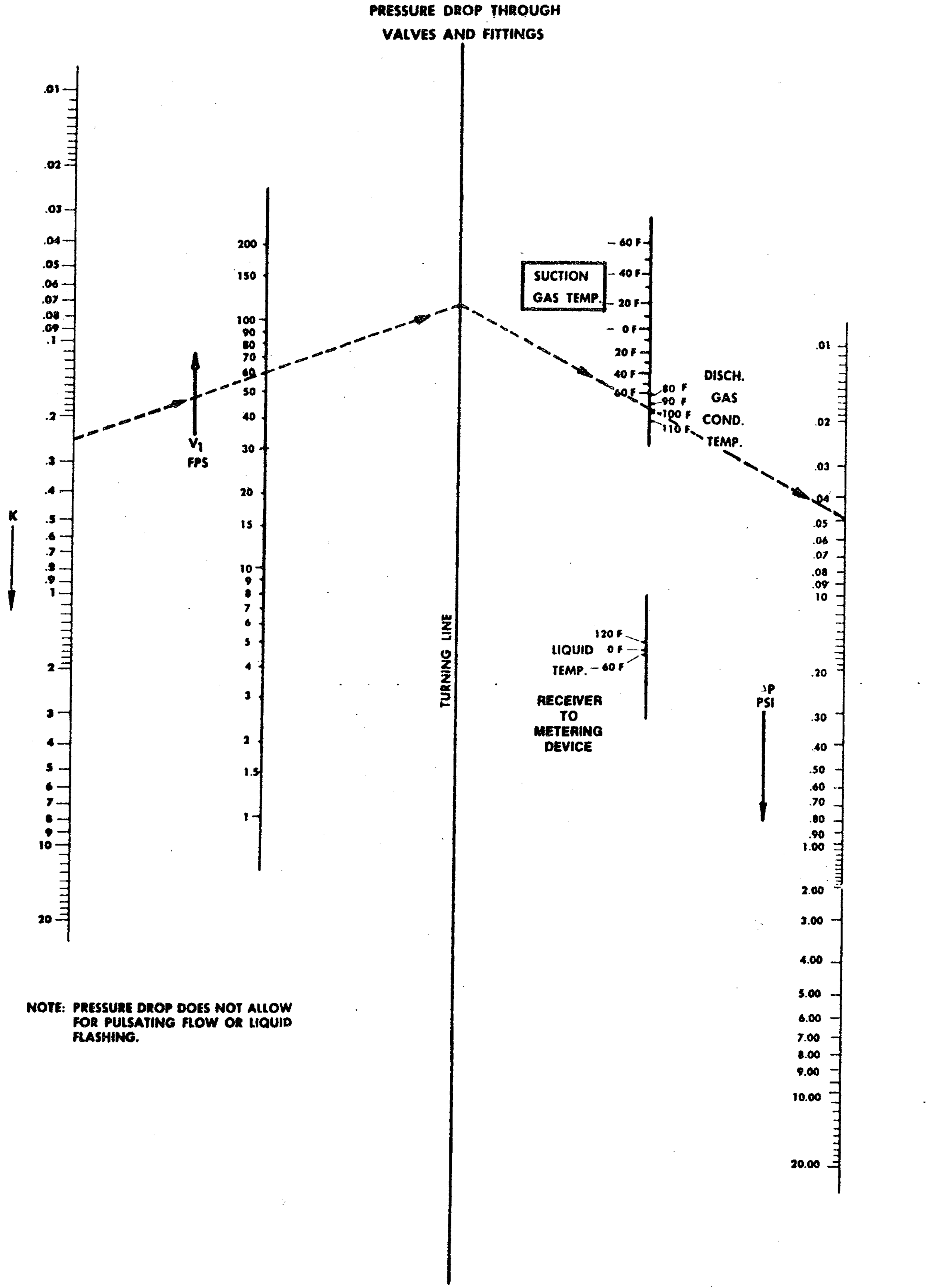


Fig. 7. PRESSURE DROP IN VALVES AND FITTINGS FOR REFRIGERANT 717

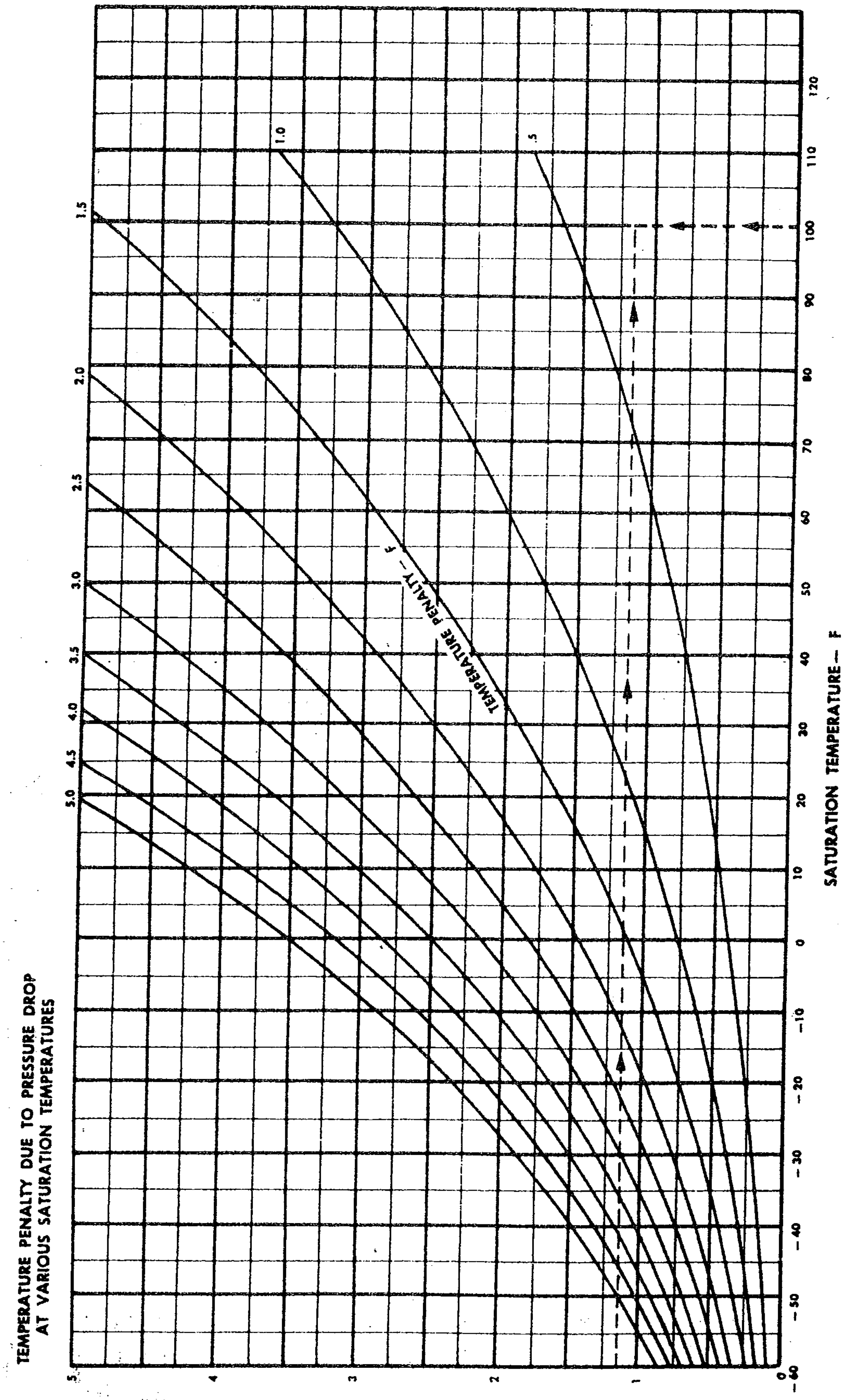


Fig. 8. TEMPERATURE PENALTY DUE TO PRESSURE DROP FOR REFRIGERANT 717

TABLE 5
THERMODYNAMIC PROPERTIES OF REFRIGERANT 717 (AMMONIA)

Temp. — °F	Pressure — Lb. per Sq. In.		Volume — Cu. Ft. per Lb.		Density — Lb. per Cu. Ft.		Enthalpy — Btu per Lb.			Entropy — Btu per (Lb.) (°R)		Temp. — °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
-60	5.55	18.6*	0.02278	44.73	43.91	0.02235	-21.2	610.8	589.6	-0.0517	1.4769	-60
-59	5.74	18.2*		43.37		.02306	-20.1	610.1	590.0	- .0490	1.4741	-59
-58	5.93	17.8*		42.05		.02378	-19.1	609.5	590.4	- .0464	1.4713	-58
-57	6.13	17.4*		40.79		.02452	-18.0	608.8	590.8	- .0438	1.4686	-57
-56	6.33	17.0*		39.56		.02528	-17.0	608.2	591.2	- .0412	1.4658	-56
-55	6.54	16.6*	0.02288	38.38	43.70	0.02605	-15.9	607.5	591.6	-0.0386	1.4631	-55
-54	6.75	16.2*		37.24		.02685	-14.8	606.9	592.1	- .0360	1.4604	-54
-53	6.97	15.7*		36.15		.02766	-13.8	606.2	592.4	- .0334	1.4577	-53
-52	7.20	15.3*		35.09		.02850	-12.7	605.6	592.9	- .0307	1.4551	-52
-51	7.43	14.8*		34.06		.02936	-11.7	604.9	593.2	- .0281	1.4524	-51
-50	7.67	14.3*	0.02299	33.08	43.49	0.03023	-10.6	604.3	593.7	-0.0256	1.4497	-50
-49	7.91	13.8*		32.12		.03113	- 9.6	603.6	594.0	- .0230	1.4471	-49
-48	8.16	13.3*		31.20		.03205	- 8.5	602.9	594.4	- .0204	1.4445	-48
-47	8.42	12.8*		30.31		.03299	- 7.4	602.3	594.9	- .0179	1.4419	-47
-46	8.68	12.2*		29.45		0.03395	- 6.4	601.6	595.2	-0.0153	1.4393	-46
-45	8.95	11.7*	0.02310	28.62	43.28	0.03494	- 5.3	600.9	595.6	-0.0127	1.4368	-45
-44	9.23	11.1*		27.82		.03595	- 4.3	600.3	596.0	- .0102	1.4342	-44
-43	9.51	10.6*		27.04		.03698	- 3.2	599.6	596.4	- .0076	1.4317	-43
-42	9.81	10.0*		26.29		.03804	- 2.1	598.9	596.8	- .0051	1.4292	-42
-41	10.10	9.3*		25.56		.03912	- 1.1	598.3	597.2	- .0025	1.4267	-41
-40	10.41	8.7*	0.02322	24.86	43.07	0.04022	0.0	597.6	597.6	0.0000	1.4242	-40
-39	10.72	8.1*		24.18		.04135	1.1	596.9	598.0	.0025	1.4217	-39
-38	11.04	7.4*		23.53		.04251	2.1	596.2	598.3	.0051	1.4193	-38
-37	11.37	6.8*		22.89		.04369	3.2	595.5	598.7	.0076	1.4169	-37
-36	11.71	6.1*		22.27		.04489	4.3	594.8	599.1	.0101	1.4144	-36
-35	12.05	5.4*	0.02333	21.68	42.86	0.04613	5.3	594.2	599.5	0.0126	1.4120	-35
-34	12.41	4.7*		21.10		.04739	6.4	593.5	599.9	.0151	1.4096	-34
-33	12.77	3.9*		20.54		.04868	7.4	592.8	600.2	.0176	1.4072	-33
-32	13.14	3.2*		20.00		.04999	8.5	592.1	600.6	.0201	1.4048	-32
-31	13.52	2.4*		19.48		.05134	9.6	591.4	601.0	.0226	1.4025	-31
-30	13.90	1.6*	0.02345	18.97	42.65	0.05271	10.7	590.7	601.4	0.0250	1.4001	-30
-29	14.30	0.8*		18.48		.05411	11.7	590.0	601.7	.0275	1.3978	-29
-28	14.71	0.0		18.00		.05555	12.8	589.3	602.1	.0300	1.3955	-28
-27	15.12	0.4		17.54		.05701	13.9	588.6	602.5	.0325	1.3932	-27
-26	15.55	0.8		17.09		.05850	14.9	587.9	602.8	.0350	1.3909	-26
-25	15.98	1.3	0.02357	16.66	42.44	0.06003	16.0	587.2	603.2	0.0374	1.3886	-25
-24	16.42	1.7		16.24		.06158	17.1	586.5	603.6	.0399	1.3863	-24
-23	16.88	2.2		15.83		.06317	18.1	585.8	603.9	.0423	1.3840	-23
-22	17.34	2.6		15.43		.06479	19.2	585.1	604.3	.0448	1.3818	-22
-21	17.81	3.1		15.05		.06644	20.3	584.3	604.6	.0472	1.3796	-21
-20	18.30	3.6	0.02369	14.68	42.22	0.06813	21.4	583.6	605.0	0.0497	1.3774	-20
-19	18.79	4.1		14.32		.06985	22.4	582.9	605.3	.0521	1.3752	-19
-18	19.30	4.6		13.97		.07161	23.5	582.2	605.7	.0545	1.3729	-18
-17	19.81	5.1		13.62		.07340	24.6	581.5	606.1	.0570	1.3708	-17
-16	20.34	5.6		13.29		.07522	25.6	580.8	606.4	.0594	1.3686	-16
-15	20.88	6.2	0.02381	12.97	42.00	0.07709	26.7	580.0	606.7	0.0618	1.3664	-15
-14	21.43	6.7		12.66		.07898	27.8	579.3	607.1	.0642	1.3643	-14
-13	21.99	7.3		12.36		.08092	28.9	578.6	607.5	.0666	1.3621	-13
-12	22.56	7.9		12.06		.08289	30.0	577.8	607.8	.0690	1.3600	-12
-11	23.15	8.5		11.78		.08490	31.0	577.1	608.1	.0714	1.3579	-11
-10	23.74	9.0	0.02393	11.50	41.78	0.08695	32.1	576.4	608.5	0.0738	1.3558	-10
- 9	24.35	9.7		11.23		.08904	33.2	575.6	608.8	.0762	1.3537	- 9
- 8	24.97	10.3		10.97		.09117	34.3	574.9	609.2	.0786	1.3516	- 8
- 7	25.61	10.9		10.71		.09334	35.4	574.1	609.5	.0809	1.3495	- 7
- 6	26.26	11.6		10.47		.09555	36.4	573.4	609.8	.0833	1.3474	- 6
- 5	26.92	12.2	0.02406	10.23	41.56	0.09780	37.5	572.6	610.1	0.0857	1.3454	- 5
- 4	27.59	12.9		9.991		.1001	38.6	571.9	610.5	.0880	1.3433	- 4
- 3	28.28	13.6		9.763		.1024	39.7	571.1	610.8	.0904	1.3413	- 3
- 2	28.98	14.3		9.541		.1048	40.7	570.4	611.1	.0928	1.3393	- 2
- 1	29.69	15.0		9.326		.1072	41.8	569.6	611.4	.0951	1.3372	- 1

* Inches of mercury below one atmosphere

VILTER™ Since 1867

TABLE 5 (Continued)
THERMODYNAMIC PROPERTIES OF REFRIGERANT 717 (AMMONIA)

Temp. – °F	Pressure – Lb. per Sq. In.		Volume – Cu. Ft. per Lb.		Density – Lb. per Cu. Ft.		Enthalpy – Btu per Lb.			Entropy – Btu per (Lb.) (° R)		Temp. – °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
0	30.42	15.7	0.02419	9.116	41.34	0.1097	42.9	568.9	611.8	0.0975	1.3352	0
1	31.16	16.5		8.912		.1122	44.0	568.1	612.1	.0998	1.3332	1
2	31.92	17.2		8.714		.1148	45.1	567.3	612.4	.1022	1.3312	2
3	32.69	18.0		8.521		.1174	46.2	566.5	612.7	.1045	1.3292	3
4	33.47	18.8		8.333		.1200	47.2	565.8	613.0	.1069	1.3273	4
5	34.27	19.6	0.02432	8.150	41.11	0.1227	48.3	565.0	613.3	0.1092	1.3253	5
6	35.09	20.4		7.971		.1254	49.4	564.2	613.6	.1115	1.3234	6
7	35.92	21.2		7.798		.1282	50.5	563.4	613.9	.1138	1.3214	7
8	36.77	22.1		7.629		.1311	51.6	562.7	614.3	.1162	1.3195	8
9	37.63	22.9		7.464		.1340	52.7	561.9	614.6	.1185	1.3176	9
10	38.51	23.8	0.02446	7.304	40.89	0.1369	53.8	561.1	614.9	0.1208	1.3157	10
11	39.40	24.7		7.148		.1399	54.9	560.3	615.2	.1231	1.3137	11
12	40.31	25.6		6.996		.1429	56.0	559.5	615.5	.1254	1.3118	12
13	41.24	26.5		6.847		.1460	57.1	558.7	615.8	.1277	1.3099	13
14	42.18	27.5		6.703		.1492	58.2	557.9	616.1	.1300	1.3081	14
15	43.14	28.4	0.02460	6.562	40.66	0.1524	59.2	557.1	616.3	0.1323	1.3062	15
16	44.12	29.4		6.425		.1556	60.3	556.3	616.6	.1346	1.3043	16
17	45.12	30.4		6.291		.1590	61.4	555.5	616.9	.1369	1.3025	17
18	46.13	31.4		6.161		.1623	62.5	554.7	617.2	.1392	1.3006	18
19	47.16	32.5		6.034		0.1657	63.6	553.9	617.5	0.1415	1.2988	19
20	48.21	33.5	0.02474	5.910	40.43	0.1692	64.7	553.1	617.8	0.1437	1.2969	20
21	49.28	34.6		5.789		.1728	65.8	552.2	618.0	.1460	1.2951	21
22	50.36	35.7		5.671		.1763	66.9	551.4	618.3	.1483	1.2933	22
23	51.47	36.8		5.556		.1800	68.0	550.6	618.6	.1505	1.2915	23
24	52.59	37.9		5.443		.1837	69.1	549.8	618.9	.1528	1.2897	24
25	53.73	39.0	0.02488	5.334	40.20	0.1875	70.2	548.9	619.1	0.1551	1.2879	25
26	54.90	40.2		5.227		.1913	71.3	548.1	619.4	.1573	1.2861	26
27	56.08	41.4		5.123		.1952	72.4	547.3	619.7	.1596	1.2843	27
28	57.28	42.6		5.021		.1992	73.5	546.4	619.9	.1618	1.2825	28
29	58.50	43.8		4.922		.2032	74.6	545.6	620.2	.1641	1.2808	29
30	59.74	45.0	0.02503	4.825	39.96	0.2073	75.7	544.8	620.5	0.1663	1.2790	30
31	61.00	46.3		4.730		.2114	76.8	543.9	620.7	.1686	1.2773	31
32	62.29	47.6		4.637		.2156	77.9	543.1	621.0	.1708	1.2755	32
33	63.59	48.9		4.547		.2199	79.0	542.2	621.2	.1730	1.2738	33
34	64.91	50.2		4.459		.2243	80.1	541.4	621.5	.1753	1.2721	34
35	66.26	51.6	0.02518	4.373	39.72	0.2287	81.2	540.5	621.7	0.1775	1.2704	35
36	67.63	52.9		4.289		.2332	82.3	539.7	622.0	.1797	1.2686	36
37	69.02	54.3		4.207		.2377	83.4	538.8	622.2	.1819	1.2669	37
38	70.43	55.7		4.126		.2423	84.6	537.9	622.5	.1841	1.2652	38
39	71.87	57.2		4.048		.2470	85.7	537.0	622.7	.1863	1.2635	39
40	73.32	58.6	0.02533	3.971	39.49	0.2518	86.8	536.2	623.0	0.1885	1.2618	40
41	74.80	60.1		3.897		.2566	87.9	535.3	623.2	.1908	1.2602	41
42	76.31	61.6		3.823		.2616	89.0	534.4	623.4	.1930	1.2585	42
43	77.83	63.1		3.752		.2665	90.1	533.6	623.7	.1952	1.2568	43
44	79.38	64.7		3.682		.2716	91.2	532.7	623.9	.1974	1.2552	44
45	80.96	66.3	0.02548	3.614	39.24	0.2767	92.3	531.8	624.1	0.1996	1.2535	45
46	82.55	67.9		3.547		.2819	93.5	530.9	624.4	.2018	1.2519	46
47	84.18	69.5		3.481		.2872	94.6	530.0	624.6	.2040	1.2502	47
48	85.82	71.1		3.418		.2926	95.7	529.1	624.8	.2062	1.2486	48
49	87.49	72.8		3.355		.2981	96.8	528.2	625.0	.2083	1.2469	49
50	89.19	74.5	0.02564	3.294	39.00	0.3036	97.9	527.3	625.2	0.2105	1.2453	50
51	90.91	76.2		3.234		.3092	99.1	526.4	625.5	.2127	1.2437	51
52	92.66	78.0		3.176		.3149	100.2	525.5	625.7	.2149	1.2421	52
53	94.43	79.7		3.119		.3207	101.3	524.6	625.9	.2171	1.2405	53
54	96.23	81.5		3.063		.3265	102.4	523.7	626.1	.2192	1.2389	54
55	98.06	83.4	0.02581	3.008	38.75	0.3325	103.5	522.8	626.3	0.2214	1.2373	55
56	99.91	85.2		2.954		.3385	104.7	521.8	626.5	.2236	1.2357	56
57	101.8	87.1		2.902		.3446	105.8	520.9	626.7	.2257	1.2341	57
58	103.7	89.0		2.851		.3508	106.9	520.0	626.9	.2279	1.2325	58
59	105.6	90.9		2.800		.3571	108.1	519.0	627.1	.2301	1.2310	59

TABLE 5 (Continued)
THERMODYNAMIC PROPERTIES OF REFRIGERANT 717 (AMMONIA)

Temp. — °F	Pressure — Lb. per Sq. In.		Volume — Cu. Ft. per Lb.		Density — Lb. per Cu. Ft.		Enthalpy — Btu per Lb.			Entropy — Btu per (Lb.) (°R)		Temp. — °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
60	107.6	92.9	0.02597	2.751	38.50	0.3635	109.2	518.1	627.3	0.2322	1.2294	60
61	109.6	94.9		2.703		.3700	110.3	517.2	627.5	.2344	1.2278	61
62	111.6	96.9		2.656		.3765	111.5	516.2	627.7	.2365	1.2262	62
63	113.6	98.9		2.610		.3832	112.6	515.3	627.9	.2387	1.2247	63
64	115.7	101.0		2.565		.3899	113.7	514.3	628.0	.2408	1.2231	64
65	117.8	103.1	0.02614	2.520	38.25	0.3968	114.8	513.4	628.2	0.2430	1.2216	65
66	120.0	105.3		2.477		.4037	116.0	512.4	628.4	.2451	1.2201	66
67	122.1	107.4		2.435		.4108	117.1	511.5	628.6	.2473	1.2186	67
68	124.3	109.6		2.393		.4179	118.3	510.5	628.8	.2494	1.2170	68
69	126.5	111.8		2.352		.4251	119.4	509.5	628.9	.2515	1.2155	69
70	128.8	114.1	0.02632	2.312	38.00	0.4325	120.5	508.6	629.1	0.2537	1.2140	70
71	131.1	116.4		2.273		.4399	121.7	507.6	629.3	.2558	1.2125	71
72	133.4	118.7		2.235		.4474	122.8	506.6	629.4	.2579	1.2110	72
73	135.7	121.0		2.197		.4551	124.0	505.6	629.6	.2601	1.2095	73
74	138.1	123.4		2.161		.4628	125.1	504.7	629.8	.2622	1.2080	74
75	140.5	125.8	0.02650	2.125	37.74	0.4707	126.2	503.7	629.9	0.2643	1.2065	75
76	143.0	128.3		2.089		.4786	127.4	502.7	630.1	.2664	1.2050	76
77	145.4	130.7		2.055		.4867	128.5	501.7	630.2	.2685	1.2035	77
78	147.9	133.2		2.021		.4949	129.7	500.7	630.4	.2706	1.2020	78
79	150.5	135.8		1.988		.5031	130.8	499.7	630.5	.2728	1.2006	79
80	153.0	138.3	0.02668	1.955	37.48	0.5115	132.0	498.7	630.7	0.2749	1.1991	80
81	155.6	140.9		1.923		.5200	133.1	497.7	630.8	.2769	1.1976	81
82	158.3	143.6		1.892		.5287	134.3	496.7	631.0	.2791	1.1962	82
83	161.0	146.3		1.861		.5374	135.4	495.7	631.1	.2812	1.1947	83
84	163.7	149.0		1.831		0.5462	136.6	494.7	631.3	0.2833	1.1933	84
85	166.4	151.7	0.02687	1.801	37.21	0.5552	137.8	493.6	631.4	0.2854	1.1918	85
86	169.2	154.5		1.772		0.5643	138.9	492.6	631.5	.2875	1.1904	86
87	172.0	157.3		1.744		0.5735	140.1	491.6	631.7	.2895	1.1889	87
88	174.8	160.1		1.716		0.5828	141.2	490.6	631.8	.2917	1.1875	88
89	177.7	163.0		1.688		0.5923	142.4	489.5	631.9	.2937	1.1860	89
90	180.6	165.9	0.02707	1.661	36.94	0.6019	143.5	488.5	632.0	0.2958	1.1846	90
91	183.6	168.9		1.635		0.6116	144.7	487.4	632.1	.2979	1.1832	91
92	186.6	171.9		1.609		0.6214	145.8	486.4	632.2	.3000	1.1818	92
93	189.6	174.9		1.584		0.6314	147.0	485.3	632.3	.3021	1.1804	93
94	192.7	178.0		1.559		0.6415	148.2	484.3	632.5	.3041	1.1789	94
95	195.8	181.1	0.02727	1.534	36.67	0.6517	149.4	483.2	632.6	0.3062	1.1775	95
96	198.9	184.2		1.510		0.6620	150.5	482.1	632.6	.3083	1.1761	96
97	202.1	187.4		1.487		0.6725	151.7	481.1	632.8	.3104	1.1747	97
98	205.3	190.6		1.464		0.6832	152.9	480.0	632.9	.3125	1.1733	98
99	208.6	193.9		1.441		0.6939	154.0	478.9	632.9	.3145	1.1719	99
100	211.9	197.2	0.02748	1.419	36.40	0.7048	155.2	477.8	633.0	0.3166	1.1705	100
101	215.2	200.5		1.397		0.7159	156.4	476.7	633.1	.3187	1.1691	101
102	218.6	203.9		1.375		0.7270	157.6	475.6	633.2	.3207	1.1677	102
103	222.0	207.3		1.354		0.7384	158.7	474.6	633.3	.3228	1.1663	103
104	225.4	210.7		1.334		0.7498	159.9	473.5	633.4	.3248	1.1649	104
105	228.9	214.2	0.02769	1.313	36.12	0.7615	161.1	472.3	633.4	0.3269	1.1635	105
106	232.5	217.8		1.293		0.7732	162.3	471.2	633.5	.3289	1.1621	106
107	236.0	221.3		1.274		0.7852	163.5	470.1	633.6	.3310	1.1607	107
108	239.7	225.0		1.254		0.7972	164.6	469.0	633.6	.3330	1.1593	108
109	243.3	228.6		1.235		0.8095	165.8	467.9	633.7	.3351	1.1580	109
110	247.0	232.3	0.02790	1.217	35.84	0.8219	167.0	466.7	633.7	0.3372	1.1566	110
111	250.8	236.1		1.198		0.8344	168.2	465.6	633.8	.3392	1.1552	111
112	254.5	239.8		1.180		0.8471	169.4	464.4	633.8	.3413	1.1538	112
113	258.4	243.7		1.163		0.8600	170.6	463.3	633.9	.3433	1.1524	113
114	262.2	247.5		1.145		0.8730	171.8	462.1	633.9	.3453	1.1510	114
115	266.2	251.5	0.02813	1.128	35.55	0.8862	173.0	460.9	633.9	0.3474	1.1497	115
116	270.1	255.4		1.112		0.8996	174.2	459.8	634.0	.3495	1.1483	116
117	274.1	259.4		1.095		0.9132	175.4	458.6	634.0	.3515	1.1469	117
118	278.2	263.5		1.079		0.9269	176.6	457.4	634.0	.3535	1.1455	118
119	282.3	267.6		1.063		0.9408	177.8	456.2	634.0	.3556	1.1441	119
120	286.4	271.7	0.02836	1.047	35.26	0.9549	179.0	455.0	634.0	0.3576	1.1427	120

TABLE 6
AMMONIA FLOW RATE
POUNDS/MINUTE/TON REFRIGERATION

Temp. of Suction (°F)	Corres. Suction Pressure (Psig)	Booster Discharge Pressure (Psig)								Condensing Discharge Pressure (Psig)							
		10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220
		Corresponding Discharge Temperature (°F)								Corresponding Discharge Temperature (°F)							
		−8.5	5.5	16.6	25.8	33.8	40.9	47.3	53.2	58.5	63.5	72.6	80.7	88.0	94.6	100.8	106.6
−60	18.6*	.367	.377	.386	.394	.401	.407	.414	.419								
−50	14.3*	.364	.374	.383	.391	.398	.404	.410	.416	.411							
−40	8.7*	.362	.372	.380	.388	.394	.401	.407	.412	.408	.413						
−30	1.6*	.359	.369	.378	.385	.392	.398	.404	.409	.405	.410	.418	.427				
−20	3.6	.357	.367	.375	.382	.389	.395	.401	.406	.402	.406	.415	.423	.431	.438		
−10	9.0	.355	.364	.372	.380	.386	.393	.398	.404	.399	.404	.412	.421	.428	.435	.442	
0	15.7		.362	.370	.378	.384	.390	.396	.401	.397	.401	.410	.417	.425	.432	.439	.446
10	23.8			.368	.375	.382	.388	.393	.398	.394	.398	.407	.415	.422	.429	.436	.442
20	33.5				.373	.380	.386	.391	.396	.392	.396	.404	.412	.419	.427	.433	.440
30	45.0					.378	.383	.389	.393	.390	.394	.402	.410	.417	.424	.431	.437
40	58.6						.382	.387	.392	.388	.392	.400	.408	.415	.422	.428	.435

*Inches mercury below one atmosphere.

TABLE 7
AMMONIA FLOW RATE
CUBIC FEET/MINUTE/TON REFRIGERATION

Temp. of Suction (°F)	Corres. Suction Pressure (Psig)	Booster Discharge Pressure (Psig)								Condensing Discharge Pressure (Psig)							
		10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	220
		Corresponding Discharge Temperature (°F)								Corresponding Discharge Temperature (°F)							
		−8.5	5.5	16.6	25.8	33.8	40.9	47.3	53.2	58.5	63.5	72.6	80.7	88.0	94.6	100.8	106.6
−60	18.6*	16.4	16.9	17.3	17.6	17.9	18.2	18.5	18.8								
−50	14.3*	12.1	12.4	12.7	13.0	13.2	13.4	13.6	13.8	13.6							
−40	8.7*	9.00	9.25	9.45	9.65	9.80	9.98	10.1	10.3	10.1	10.3						
−30	1.6*	6.82	7.00	7.17	7.30	7.44	7.55	7.66	7.76	7.68	7.78	7.93	8.11				
−20	3.6	5.25	5.39	5.51	5.61	5.71	5.80	5.89	5.96	5.90	5.96	6.10	6.21	6.33	6.44		
−10	9.0	4.08	4.18	4.28	4.37	4.44	4.52	4.58	4.65	4.59	4.65	4.74	4.84	4.92	5.00	5.08	
0	15.7		3.30	3.38	3.45	3.50	3.56	3.61	3.66	3.62	3.66	3.74	3.80	3.88	3.94	4.00	4.07
10	23.8			2.69	2.74	2.79	2.83	2.87	2.91	2.88	2.91	2.98	3.03	3.08	3.13	3.19	3.23
20	33.5				2.21	2.25	2.28	2.31	2.34	2.32	2.34	2.39	2.44	2.48	2.53	2.56	2.60
30	45.0					1.82	1.85	1.88	1.90	1.88	1.90	1.94	1.98	2.02	2.05	2.08	2.11
40	58.6						1.52	1.54	1.56	1.54	1.56	1.59	1.62	1.65	1.68	1.70	1.73

* Inches mercury below one atmosphere.

Figures to left of heavy line are based on booster flow-rate of two-stage system with liquid subcooling to within 10°F of intermediate. Figures to right of heavy line are based on single stage.

REFRIGERANT 12 PIPING DATA

This section presents useful data for the proper sizing of Refrigerant 12 (Dichlorodifluoromethane) piping. Its purpose is not to set design standards, but to provide the latest pipe-sizing information available. It also discusses various factors which determine the allowable pressure drops in different portions of a refrigerant piping system.

Basis of Charts and Tables

The pressure-drop charts given herein for single or high stage applications are based on calculations using the commonly accepted Darcy-Weisbach pressure-drop formula and Darcy friction factors from the Moody Chart (see appendix, Sections A-III and A-IV). Capacity tables for intermediate or low stage applications are based on calculations using Fanning's equation for friction loss.

Pipe Lines. Suction line velocity and pressure-drop values are for saturated vapor temperature conditions, and the discharge line values are at pressures corresponding to the condensing temperatures indicated, and superheated to 175 F.

Liquid line velocities and pressure drops are for saturated Refrigerant 12 liquid at 90 F and can be used with reasonable accuracy for temperatures between 70 F and 110 F.

Valves and Fittings. Pressure losses through refrigerant valves and fittings are given in a table, in the form of "K" factors (velocity heads). These "K" factors are representative, using average values obtained from various tests and manufacturers' ratings. "K" factors vary widely for a given type and size of valve or fitting, depending on the construction or internal design.

For a simplified determination of these pressure drops, "equivalent lengths" of valves and fittings are given in a table. These "equivalent lengths" have been derived, using the "K" factors in conjunction with friction factors taken from the Moody Chart at Reynolds Numbers in the range of normal usage, for both vapor and liquid lines.

"Equivalent lengths" result in a sacrifice of accuracy, depending on the temperature, state and velocity of the refrigerant. "K" factors give more reliable pressure drop data. For greater accuracy, particularly for valves, "K" factors should be obtained from the manufacturer.

Pressure-Drop Limitations (Pipe-Sizing Factors)

Vapor line pressure drops result in an increase in power input to the compressor and a decrease in refrigeration capacity. The most critical line with respect to this is the suction line, as losses in it have the greatest effect on the system. An economic study, involving power input, system capacity, size of system components—evaporator and condenser—and installation cost of pipe and pipe insulation, can best determine the optimum pressure-drop allowance. Experience has shown that the allowable pressure drop for suction lines should decrease with suction temperature. Discharge lines may have a greater pressure drop, for a specified temperature penalty, than suction lines.

Suction line pressure drop increases the volume of gas to be handled by the compressor, increases the ratio of discharge pressure to suction pressure, and reduces the volumetric efficiency of the compressor. This results in less capacity from a given compressor and more power per ton of refrigeration.

The effect of a particular amount of suction line pressure drop is greater as the suction pressure decreases. Fig. 11 indicates this in showing that a particular pressure drop results in a greater "temperature penalty" at a lower saturation temperature. The result of suction line pressure drop is that the compressor operates from a suction condition corresponding to the actual evaporator temperature minus the temperature penalty.

Larger suction line sizes reduce the pressure drop and, therefore, reduce the compressor capacity required and also the power per ton. However, the larger pipe size increases its cost and also its installation and insulation cost. The best size from an economic consideration can be determined by an economic study with the cost of the various factors available.

Discharge line pressure drop also increases the ratio of discharge pressure to suction pressure and reduces the volumetric efficiency of the compressor. This results in less capacity from a given compressor and more power per ton of refrigeration.

The effect of a particular amount of discharge line pressure drop is less as the discharge saturation temperature increases, but the difference is not very great in the range of saturation temperatures corresponding to usual discharge pressures. Fig. 11 indicates this by showing the relatively small change in "temperature penalty" for a particular pressure drop at the temperatures corresponding to saturation at normal discharge pressures. Fig. 11 also indicates the smaller "temperature penalty" for a given pressure drop in the saturation temperature range corresponding to usual discharge conditions as compared to the range corresponding to usual suction conditions. Because of this, economic considerations usually result in the use of a larger pressure drop as the basis of design for a discharge line than that which would be used for a suction line.

Liquid line pressure drop results in no direct penalty in capacity or power. It is important that the pressure loss not be such as to produce flash gas. If the pressure loss or liquid lift are such as to result in flash gas, the required capacities of liquid solenoid valves and expansion valves must be increased. Liquid lines cooler than ambient will take in heat and may sweat.

Higher liquid line velocities should be used with caution because of possible stresses due to rapid closing of any liquid valve. Solenoid valves or solenoid pilot-controlled valves, almost always are rapid-closing.

When the liquid is to flow upward in a riser, or when pressure drop may cause flashing, subcooling can be employed to eliminate flash gas in the supply to the expansion valves. Subcooling may make insulation for the liquid line desirable or necessary.

Basis of Design

Suction lines should generally be selected for a pressure drop of 1 to 3 psi per 100 feet of pipe for temperatures above 20 F. On the other hand, pressure drop should range from 2 to 0.2 psi per 100 feet of pipe at temperatures between + 20 F and — 60 F. In other words, pressure-drop allowance should decrease with decreasing suction temperatures.

Discharge lines should generally be selected for a nominal pressure-drop between 2 and 5 psi per 100 feet of pipe at any normal condensing temperature.

Liquid lines are normally sized for a low pressure drop to avoid flash gas. The design conditions most generally accepted are:

a. *Condenser to receiver:* Velocity of 120 fpm or less.

b. *Receiver to system:* Velocity range is generally limited to 300 fpm when a solenoid or snap-acting valve is used. When a snap-acting valve is not employed, velocities somewhat higher than 300 fpm may be employed. Within limits of above velocities, selection on the basis of 2 psi per 100 feet is practiced.

c. *The liquid line between the expansion valve and the evaporator* is often very short, with few restrictions, and may then be the same size as the expansion valve outlet or the evaporator inlet. However, unless it is very short, consideration should be given to the size of this line which will be carrying both gas and liquid. Common practice for relatively short lines, containing a service valve. is to make them one size larger than the liquid line.

How to Use Charts

1. Tables 1-A and 1-B permit quick selection of suction lines applicable to the conditions listed.

   Table 1-A gives suction line capacities (tons) for intermediate or low stage applications. The values in this table are based on 0°F. saturated discharge temperature. For intermediate or low stage suction line capacities at other saturated discharge temperatures, multiply table value by proper line capacity multiplier as given in Table A-7 in appendix.

   Table 1-B gives suction line capacities (tons) for single or high stage applications at various suction temperatures, pressure drops, and at 105°F. saturated condensing temperature. Interpolation may be used between suction temperatures to determine line capacity at a fixed pressure drop. (Do *not* interpolate between pressure-drop columns.) For other condensing temperatures and other pressure-drop limitations, follow the steps outlined below for detailed sizing of lines.

2. Table 2 can be used to determine the capacities of discharge and liquid lines at a specified pressure drop or velocity, as listed. For temperatures other than 105 F condensing and 40 F suction, these capacities are only approximate.

   The following steps are used for detailed sizing of Refrigerant 12 piping:

3. Determine the flow rate, lb/(min) (ton), from Fig. 2. Use saturated evaporator temperature and liquid temperature, disregarding any suction superheating. Total flow equals lb/(min) (ton) times system tonnage.

4. Enter Fig. 3 or Fig. 6, depending on whether the lines are steel or copper, and determine the pressure drop, psi per 100 ft, for the total flow. (Figs. 3 and 6 are used for suction and discharge lines.) The pressure drop through any size line is found by projecting vertically, from the flow rate on the lower scale, to the intersection with the line size to be used. At this intersection, follow the horizontal line to the right and intersect with the vapor temperature line, and then project upward to the top scale to read the pressure drop. Prorate the pressure drop according to the actual length, using either the net length of straight pipe or the straight pipe plus the equivalent length of valves and fittings. If net length of straight pipe is used, determine the pressure drop for valves and fittings from Fig. 10, using appropriate "K" factors from Table 3 and the vapor-line velocity (See Step 5).

5. Using the total refrigerant flow, lb per min, determine the velocity for suction and discharge lines in Fig. 4 or Fig. 7, depending on whether the lines are steel or copper. These charts are read in the same manner as Fig. 3 and Fig. 6.

6. For liquid lines, determine the pressure drop and velocity, using either Fig. 5 or Fig. 8, depending on the type of pipe used. The liquid-flow rate in lb per min, as read on the lower scale, is projected upward to the intersection of a given pipe size. The velocity in ft per sec can be read at this point and a pressure drop in psi per 100 ft equivalent length can be read on the ordinate scale. (The total flow for liquid lines is the same as that in the vapor lines as found in Step 3.) Prorate the pressure drop, using the ratio of actual pipe length versus 100 ft. Valves and fittings in liquid lines are treated in the same manner as outlined in Step 4 for vapor lines.

7. Fig. 9 is used to determine the pressure drop (or gain) in a liquid line when there is an appreciable change in elevation between the condenser or receiver and the evaporator.

8. Fig. 11 is used to determine the temperature penalty for the various refrigerant lines, using the pressure drops determined in the steps above.

Pulsating Flow

Pulsating flow in refrigerant lines causes increased pressure losses beyond those indicated by Fig. 3 and Fig. 6, which are based on steady flow.

Reciprocating compressors create pulsating flow in both discharge and suction lines. However, because gas density and the pressure-pulsation amplitude are both greater in the discharge line, the added frictional loss due to pulsation is also greater in the discharge line. For the same reasons, the additional pressure loss due to pulsating flow is greater for a single-cylinder compressor than for a multi-cylinder compressor. Pulsation is greater as the compression ratio increases.

The refrigerant piping and other components in the system, such as valves, fittings, condenser, evaporator, etc., attenuate the pulsation, resulting in an energy loss that is only slightly above the frictional loss that occurs when the flow is steady. Use of a muffler in the discharge line, close to the compressor, reduces the friction loss in the line downstream from the muffler. Of course, the frictional loss of the muffler itself must be considered in the system design.

SAMPLE PROBLEM

GIVEN

100 tons refrigeration
40 F evaporator temperature
105 F condensing (liquid) temperature
Piping layout as shown in Fig. 1

Select discharge, liquid and suction lines
Determine compressor operating conditions

NOTE: For the purpose of illustration, copper tubing will be assumed throughout. However, for economic or other reasons, good practice might employ all copper, all steel, or some copper and some steel, piping.

SOLUTION

From Fig. 2, at 40 F evaporator temperature and 105 F liquid temperature, the refrigerant flow rate = 4.07 lb/(min) (ton).
Refrigerant circulation = 100 tons x 4.07 lb/(min) (ton) = 407 lb/min.

DISCHARGE LINE

Table 2 indicates 3⅝″ OD copper tube is adequate for 113 tons refrigeration at 2 psi/100 ft.

Pressure Drop in Pipe:

From Fig. 6, 407 lb/min, 3⅝″ OD copper tube, 105 F condensing temperature, pressure drop = 1.6 psi/100 ft.

Pressure drop for 45 ft of pipe = 45/100 × 1.6 = 0.72 psi

Pressure Drop in Fittings:

From Fig. 7, velocity = 40 fps.
From Table 3, 3⅝″ OD long radius ell (sweat fitting) "K" factor = 0.23.
From Fig. 10, pressure drop per ell = 0.11 psi.
Pressure drop for 3 ells = 3 × 0.11 = 0.33 psi
Total pressure drop = 1.05 psi

Temperature Penalty:

From Fig. 11, 1.05 psi, 105 F saturated temperature, temperature penalty = 0.60 F

LIQUID LINES

Condenser to Receiver:

Select line size so that velocity is 120 fpm or less.
Using Table 2, select 3⅛″ OD copper tube. Fig. 8 gives velocity of 1.8 fps = 60 × 1.8 = 108 fpm.
Because of gravity flow, no pressure drop need be calculated.

Receiver to Expansion Valve:

Observe upper velocity limit of 300 fpm in selecting this portion of liquid line.

VILTER Since 1867

Using Table 2, select 2⅛″ OD copper tube. Fig. 8 gives velocity of 4 fps = 240 fpm.

Pressure Drop in Pipe:

From Fig. 8, 407 lb/min, 2⅛″ OD copper tube, pressure drop = 1.25 psi/100 ft.

Pressure drop for 28 ft of pipe = 28/100 × 1.25 = 0.35 psi

Pressure Drop in Valves and Fittings:

From Fig. 8, 407 lb/min, 2⅛″ OD copper tube, velocity = 4 fps.

From Table 3, 2⅛″ OD long radius ell (sweat fitting), "K" factor = 0.25.

From Fig. 10, pressure drop for 3 ells (enter nomograph with 3 × 0.25 = 0.75 combined "K" factor) = 0.10 psi

From Table 3, 2⅛″ OD angle valve (sweat fitting), "K" factor = 2.9.

From Fig. 10, pressure drop for angle valve = 0.40 psi

Total pressure drop = 0.85 psi

Expansion Valve to Evaporator:

As a rule of thumb, increase the line one size after the expansion valve, giving a line size of 2⅝″ OD.

SUCTION LINE

From Table 1-B, select 4⅛″ OD copper tube, which is adequate for 106 tons of refrigeration with a pressure drop of 2 psi/100 ft.

Pressure Drop in Pipe:

From Fig. 6, 407 lb/min, 4⅛″ OD copper tube, 40 F suction temperature, pressure drop = 1.8 psi/100 ft.

Pressure drop for 27 ft of pipe = 27/100 × 1.8 = 0.49 psi

Pressure Drop in Fittings:

From Fig. 7, velocity = 68 fps.

From Table 3, 4⅛″ OD long radius ell (sweat fitting), "K" factor = 0.22.

From Fig. 10, pressure drop per ell = 0.12 psi

Pressure drop for 2 ells = 2 × 0.12 = 0.24 psi

Total pressure drop = 0.73 psi

Temperature Penalty:

From Fig. 11, 0.73 psi, 40 F saturated temperature, temperature penalty = 0.8 F

COMPRESSOR SELECTION

The temperature equivalents of pressure drops in the discharge and suction lines require selecting the compressor to operate at the following conditions:

Discharge temperature = 105 F + 0.6 F = 105.6 F

Suction temperature = 40 F − 0.8 F = 39.2 F

TABLE 1-A. SUCTION LINE CAPACITIES—TONS

(For Intermediate or Low Stage Applications)

*Refrigerant and ΔT Equivalent of Friction Drop**	*Line Size Type L Copper OD*	*Suction Lines — Suction Temp F* −90	−80	−70	−60	−50	−40	−30	*Second Stage Discharge and Liquid Lines*
Refrigerant 12	½								
	⅝								
	⅞				0.2	0.3	0.4	0.5	
	1⅛	0.17	0.24	0.3	0.4	0.6	0.8	1.0	
	1⅜	0.30	0.42	0.6	0.8	1.1	1.4	1.7	
	1⅝	0.47	0.67	0.9	1.2	1.7	2.2	2.7	
2 F ΔT Per 100 ft Equiv. Length	2⅛	1.00	1.40	1.9	2.5	3.5	4.6	5.7	
	2⅝	1.7	2.4	3.3	4.5	6.1	8.0	10.0	
	3⅛	2.8	3.9	5.4	7.3	10.0	13.0	16.2	See Table 2
	3⅝	4.1	5.9	8.2	10.8	15.0	19.5	24.3	
	4⅛	6.0	8.5	11.7	15.6	21.5	28.0	35.0	
	5⅛	10.6	15.1	20.8	27.8	38.5	50.0	62.5	
	6⅛	18.1	25.8	35.4	47.2	65.4	85.0	106.0	

NOTES:

(1) Values based on 0 F saturated discharge temp. For capacities at other saturated discharge temp. multiply table value by proper line capacity multiplier (See appendix, Table A-7).

(2) For other ΔT's and Equivalent Lengths, L_e

Line Capacity (Tons)

$$= \text{Table Tons} \times \left(\frac{100}{L_e} \times \frac{\text{Actual } \Delta T \text{ Loss Desired}}{\text{Table } \Delta T \text{ Loss}}\right)^{0.55}$$

(3) For other Tons and Equivalent Lengths in a given pipe size,

$$\Delta T = \text{Table } \Delta T \times \frac{L_e}{100} \times \left(\frac{\text{Actual Tons}}{\text{Table Tons}}\right)^{1.8}$$

(4) For pressure drop (psi) corresponding to ΔT, refer to Refrigerant properties, Table 5.

(5) Size low stage (Booster) discharge lines same as equivalent single stage suction lines (see Table 1-B).

SUCTION PIPING

TABLE 1-B. SUCTION LINE CAPACITIES—TONS[1]

(For Single or High Stage Applications)

LINE SIZE[2] (inches)		Saturated Suction Temperature—F																			
		−40				−20				0				20				40			
		Pressure Drop, PSI Per 100 Ft																			
IPS	OD	½	1	2	3	½	1	2	3	½	1	2	3	½	1	2	3	½	1	2	3
	½	—	—	—	—	—	—	—	—	—	—	—	0.24	—	—	0.25	0.31	—	—	0.31	0.39
	⅝	—	—	0.20	0.25	—	—	0.28	0.35	—	0.25	0.36	0.45	—	0.32	0.47	0.58	0.28	0.40	0.59	0.74
½		—	—	0.24	0.29	—	0.22	0.32	0.39	—	0.29	0.41	0.51	0.26	0.37	0.53	0.66	0.32	0.46	0.66	0.81
	¾	—	0.23	0.35	0.44	0.22	0.32	0.47	0.59	0.29	0.42	0.62	0.77	0.37	0.54	0.79	0.99	0.47	0.68	1.00	1.23
	⅞	0.25	0.37	0.53	0.67	0.34	0.50	0.73	0.91	0.45	0.65	0.95	1.19	0.57	0.84	1.22	1.51	0.72	1.05	1.54	1.89
¾		0.24	0.35	0.51	0.63	0.33	0.47	0.68	0.83	0.43	0.61	0.87	1.08	0.55	0.78	1.13	1.38	0.69	0.98	1.38	1.70
	1⅛	0.51	0.75	1.10	1.36	0.69	1.00	1.47	1.85	0.91	1.32	1.94	2.42	1.17	1.69	2.47	3.10	1.46	2.14	3.14	3.91
1		0.47	0.67	0.96	1.20	0.63	0.90	1.29	1.58	0.82	1.17	1.67	2.06	1.05	1.51	2.14	2.64	1.30	1.87	2.65	3.27
	1⅜	0.90	1.32	1.92	2.40	1.22	1.77	2.58	3.22	1.61	2.34	3.39	4.22	2.04	2.94	4.30	5.34	2.58	3.74	5.52	6.75
1¼		0.97	1.38	1.99	2.43	1.29	1.85	2.62	3.24	1.68	2.40	3.42	4.22	2.16	3.06	4.35	5.40	2.68	3.81	5.41	6.73
	1⅝	1.44	2.09	3.00	3.78	1.92	2.82	4.10	5.10	2.54	3.68	5.37	6.62	3.25	4.70	6.90	8.46	4.05	6.02	8.65	10.7
1½		1.47	2.09	2.98	3.65	1.94	2.78	3.95	4.87	2.52	3.62	5.12	6.29	3.25	4.59	6.54	8.00	4.00	5.70	8.10	9.83
	2⅛	2.94	4.35	6.30	7.80	4.01	5.80	8.44	10.6	5.28	7.70	11.1	13.8	6.70	9.75	14.2	17.6	8.47	12.3	17.9	22.1
2		2.88	4.05	5.78	7.10	3.80	5.40	7.70	9.5	4.94	7.04	10.0	12.2	6.35	8.95	12.7	15.6	7.87	11.1	15.7	19.3
	2⅝	5.27	7.71	11.2	13.9	7.10	10.4	15.1	18.7	9.44	13.7	19.6	24.5	12.0	17.4	25.4	31.0	15.0	21.9	31.5	39.3
2½		4.52	6.50	9.24	11.4	6.02	8.55	12.2	14.9	7.86	11.2	15.7	19.3	10.1	14.1	20.2	24.7	12.4	17.6	25.0	30.7
	3⅛	8.53	12.4	17.9	22.4	11.3	16.6	23.9	29.9	15.0	21.8	31.4	39.3	19.0	27.8	40.5	49.9	23.8	34.9	50.5	62.6
3		8.02	11.4	16.2	19.9	10.6	15.0	21.6	26.5	13.8	19.6	27.8	34.4	17.6	24.9	35.2	43.5	21.9	30.7	44.3	54.0
	3⅝	12.7	18.4	26.8	32.9	16.9	24.5	35.8	44.4	22.2	32.1	46.7	57.9	28.5	41.2	59.3	74.1	35.6	51.6	75.0	92.0
	4⅛	17.7	25.8	37.4	46.3	23.7	34.6	50.1	62.3	31.4	45.8	65.5	82.0	40.0	57.7	83.5	105	50.3	72.5	106	130
4		16.6	23.8	32.8	41.2	21.8	31.4	44.4	55.5	28.6	40.6	57.2	70.7	36.2	51.8	73.4	90.4	45.0	64.4	91.0	111
	5⅛	32.1	46.3	67.0	83.2	42.7	62.3	90.7	113	56.1	81.3	119	146	71.7	103	150	186	89.7	130	189	233
5		30.0	42.6	60.9	74.6	39.9	56.5	80.3	99.3	51.7	73.6	105	128	65.9	93.0	134	162	81.5	117	165	202
	6⅛	51.2	74.5	108	134	69.4	100	145	180	91.0	131	190	236	115	165	240	300	145	209	300	371
6		48.7	69.0	97.5	121	64.5	91.2	130	159	83.5	118	167	207	106	151	217	264	132	187	265	325
8		99.5	140	199	245	130	186	262	322	170	242	339	422	216	306	435	540	268	381	540	669
10		181	258	361	446	239	338	480	588	310	438	618	759	395	553	788	965	489	689	970	1205
12		290	406	574	706	382	538	765	936	490	695	984	1210	623	882	1260	1550	774	1093	1548	1890

NOTES: [1] Based on fluid flow at 105 F saturated condensing temperature
[2] "IPS" data based on Schedule 40 steel piping "OD" data based on Type L copper tubing

VILTER™ Since 1867

DISCHARGE AND LIQUID PIPING

TABLE 2. DISCHARGE AND LIQUID LINE CAPACITIES—TONS [1]

LINE SIZE [2] (Inches)		DISCHARGE LINES				LIQUID LINES	
		Temperature 175 F				To Receiver	To System
		Pressure Drop Psi/100 ft.				Velocity fpm	Pressure Drop Psi/100 ft
IPS	OD	½	1	2	3	100	2
	½	—	0.33	0.48	0.60	—	—
	⅝	0.42	0.62	0.90	1.13	3.18	4.23
½		0.48	0.70	0.98	1.21	3.20	3.62
	¾	0.73	1.06	1.54	1.92	4.77	7.25
	⅞	1.11	1.62	2.36	2.92	6.61	11.2
¾		1.02	1.46	2.06	2.54	5.90	8.17
	1⅛	2.26	3.30	4.80	6.02	11.2	23.1
1		1.94	2.78	3.96	4.80	9.85	16.1
	1⅜	3.96	5.72	8.25	10.3	17.1	40.0
1¼		3.98	5.72	8.15	9.95	17.5	34.4
	1⅝	6.27	9.10	13.4	16.5	24.3	64.0
1½		5.97	8.45	12.1	14.8	24.1	52.6
	2⅛	13.0	18.8	27.3	34.0	42.3	133
2		11.6	16.6	23.4	29.0	45.7	123
	2⅝	23.1	33.7	48.0	60.2	65.1	236
2½		18.4	26.6	37.4	45.5	65.5	197
	3⅛	36.9	53.6	77.5	95.5	93.0	376
3		32.4	46.2	65.1	80.0	101	350
	3⅝	54.6	79.2	113	140	126	565
	4⅛	76.7	111	160	198	163	795
4		67.1	94.7	135	165	174	712
	5⅛	138	199	288	357		
5		122	172	244	298		
	6⅛	222	320	455	570		
6		195	280	394	480		
8		398	573	810	985		
10		725	1030	1450	1770		
12		1145	1625	2310	2830		

NOTES: [1] Based on fluid flow at 105 F saturated condensing temperature and 40 F saturated evaporating temperature
[2] "IPS" data based on Schedule 40 steel piping except that liquid lines 1½" and smaller are Schedule 80
"OD" data based on Type L copper tubing

VALVES AND FITTINGS K-FACTORS

TABLE 3. "K-FACTORS" (VELOCITY HEADS)[1] FOR VALVES AND FITTINGS

FERROUS VALVES AND FITTINGS[2]

LINE SIZE (Inches) IPS	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL			LONG-RADIUS ELL			TEE, LINE-FLOW			TEE, BRANCH-FLOW		
	Screwed	Flanged	Screwed	Flanged	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded
½	15	—	8.4	—	2.1	—	—	—	—	—	0.9	—	—	2.4	—	—
¾	11	—	5.7	—	1.7	—	—	0.9	—	—	0.9	—	—	2.0	—	—
1	9.3	15.5	4.3	5.0	1.4	0.43	0.46	0.73	0.40	0.32	0.9	0.26	0.43	1.8	1.0	1.37
1¼	8.4	12.8	3.5	4.0	1.3	0.40	0.42	0.60	0.37	0.29	0.9	0.24	0.36	1.7	0.90	1.31
1½	7.8	11.5	2.9	3.4	1.2	0.39	0.40	0.52	0.34	0.27	0.9	0.22	0.31	1.5	0.88	1.27
2	7.0	9.9	2.2	2.8	1.0	0.36	0.38	0.40	0.30	0.25	0.9	0.19	0.28	1.4	0.80	1.17
2½	—	9.0	—	2.5	—	0.34	0.37	—	0.27	0.24	—	0.17	0.26	—	0.75	1.13
3	—	8.3	—	2.4	—	0.33	0.36	—	0.25	0.23	—	0.16	0.24	—	0.72	1.10
4	—	7.5	—	2.3	—	0.31	0.35	—	0.22	0.22	—	0.14	0.22	—	0.68	1.05
5	—	7.0	—	2.3	—	0.30	0.34	—	0.20	0.21	—	0.13	0.19	—	0.64	1.01
6	—	6.7	—	2.3	—	0.28	0.32	—	0.18	0.20	—	0.12	0.18	—	0.60	0.98
8	—	6.2	—	2.3	—	0.27	0.31	—	0.15	0.19	—	0.10	0.15	—	0.57	0.93
10	—	6.0	—	2.3	—	0.25	0.30	—	0.14	0.18	—	0.09	0.14	—	0.52	0.90
12	—	6.0	—	2.3	—	0.25	0.29	—	0.13	0.18	—	0.08	0.13	—	0.50	0.88

NON-FERROUS VALVES AND FITTINGS[3,4,5]

LINE SIZE (Inches) OD	GLOBE VALVE	ANGLE VALVE	SHORT-RADIUS ELL	LONG-RADIUS ELL	TEE, LINE-FLOW	TEE, BRANCH-FLOW
	Flare or Sweat	Flare or Sweat	Flare or Sweat	Flare or Sweat	Flare or Sweat	Flare or Sweat
½	37	12.8	2.5	1.7	0.9	3.5
⅝	28	9.9	2.2	1.5	0.9	3.2
¾	23	7.8	2.0	1.4	0.9	3.0
⅞	19	6.7	1.9	1.3	0.9	2.8
1⅛	15.0	5.0	0.46	0.32	0.43	1.37
1⅜	13.4	4.4	0.42	0.29	0.36	1.33
1⅝	12.0	3.5	0.40	0.27	0.31	1.29
2⅛	10.4	2.9	0.38	0.25	0.28	1.19

NOTES: [1] $K = 2gh/V^2$
[2] Based on Schedule 40 pipe
[3] Based on Type L copper tubing
[4] For screwed valves and fittings, use ferrous K-Factors
[5] For OD sizes above 2⅛", use welded ferruos K-Factors

VALVES AND FITTINGS EQUIVALENT LENGTHS

TABLE 4. EQUIVALENT LENGTHS[1] OF VALVES AND FITTINGS

FERROUS VALVES AND FITTINGS[2,3]

LINE SIZE (Inches) IPS	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL			LONG-RADIUS ELL			TEE, LINE-FLOW			TEE, BRANCH-FLOW		
	Screwed	Flanged	Screwed	Flanged	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded
½	29	—	16	—	4.1	—	—	—	—	—	1.8	—	—	4.7	—	—
¾	31	—	16	—	4.7	—	—	2.5	—	—	2.5	—	—	5.6	—	—
1	35	57	16	19	5.3	1.6	1.8	2.8	1.5	1.2	3.4	1.0	1.6	6.8	3.8	5.2
1¼	46	69	19	22	7.1	2.2	2.3	3.3	2.0	1.6	4.9	1.3	2.0	9.2	4.9	7.1
1½	51	76	19	22	7.9	2.6	2.6	3.4	2.2	1.8	5.9	1.4	2.0	9.9	5.8	8.4
2	63	89	20	25	9.0	3.2	3.4	3.6	2.7	2.3	8.1	1.7	2.5	12.6	7.2	10.5
2½	—	101	—	28	—	3.8	4.2	—	3.0	2.7	—	1.9	2.9	—	8.4	13
3	—	123	—	36	—	4.9	5.3	—	3.7	3.4	—	2.4	3.6	—	11	16
4	—	155	—	48	—	6.2	7.2	—	4.5	4.5	—	2.9	4.5	—	14	22
5	—	190	—	63	—	8.1	9.2	—	5.4	5.7	—	3.5	5.1	—	17	27
6	—	227	—	78	—	9.5	11	—	6.1	6.8	—	4.1	6.1	—	20	33
8	—	295	—	110	—	13	15	—	7.1	9.0	—	4.7	7.1	—	27	44
10	—	370	—	142	—	16	18	—	8.7	11	—	5.6	8.7	—	32	56
12	—	465	—	173	—	19	22	—	10	14	—	6.2	10	—	39	68

NON-FERROUS VALVES AND FITTINGS[2]

LINE SIZE (Inches) OD	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL		LONG-RADIUS ELL		TEE, LINE-FLOW		TEE, BRANCH-FLOW	
	Screwed	Other[4]	Screwed	Other[4]	Screwed	Other[4]	Screwed	Other[4]	Screwed	Other[4]	Screwed	Other[4]
½	40	70	21	24	4.7	4.7	—	3.2	1.9	1.7	5.1	6.6
⅝	39	72	22	25	5.4	5.7	—	3.9	2.3	2.3	6.2	8.2
¾	39	75	23	25	6.2	6.5	2.9	4.5	2.9	2.9	7.1	9.7
⅞	45	78	23	28	7.0	7.8	3.7	5.3	3.7	3.7	8.2	12
1⅛	54	87	25	29	8.1	2.7	4.2	1.9	5.2	2.5	11	8.0
1⅜	64	102	27	33	9.9	3.2	4.6	2.2	6.9	2.7	13	10
1⅝	75	115	28	34	12	3.8	5.0	2.6	8.7	3.0	14	12
2⅛	95	141	30	39	14	5.2	5.4	3.4	12	3.8	19	16
2⅝	—	159	—	44	—	6.5	—	4.2	—	4.6	—	20
3⅛	—	185	—	53	—	8.0	—	5.1	—	5.4	—	25
3⅝	—	216	—	66	—	10	—	6.3	—	6.6	—	30
4⅛	—	248	—	76	—	12	—	7.3	—	7.3	—	35
5⅛	—	292	—	96	—	14	—	8.8	—	7.9	—	42
6⅛	—	346	—	119	—	17	—	10	—	9.3	—	50

NOTES: [1] $L_e = K(D/f)$

[2] Friction factors (f) determined at "practical" Reynolds Numbers based on 40 F suction lines having pressure-drop of 1.8 psi/100 ft

[3] Based on Schedule 40 pipe

[4] Flare, sweat, flanged, etc., and based on Type L copper tubing

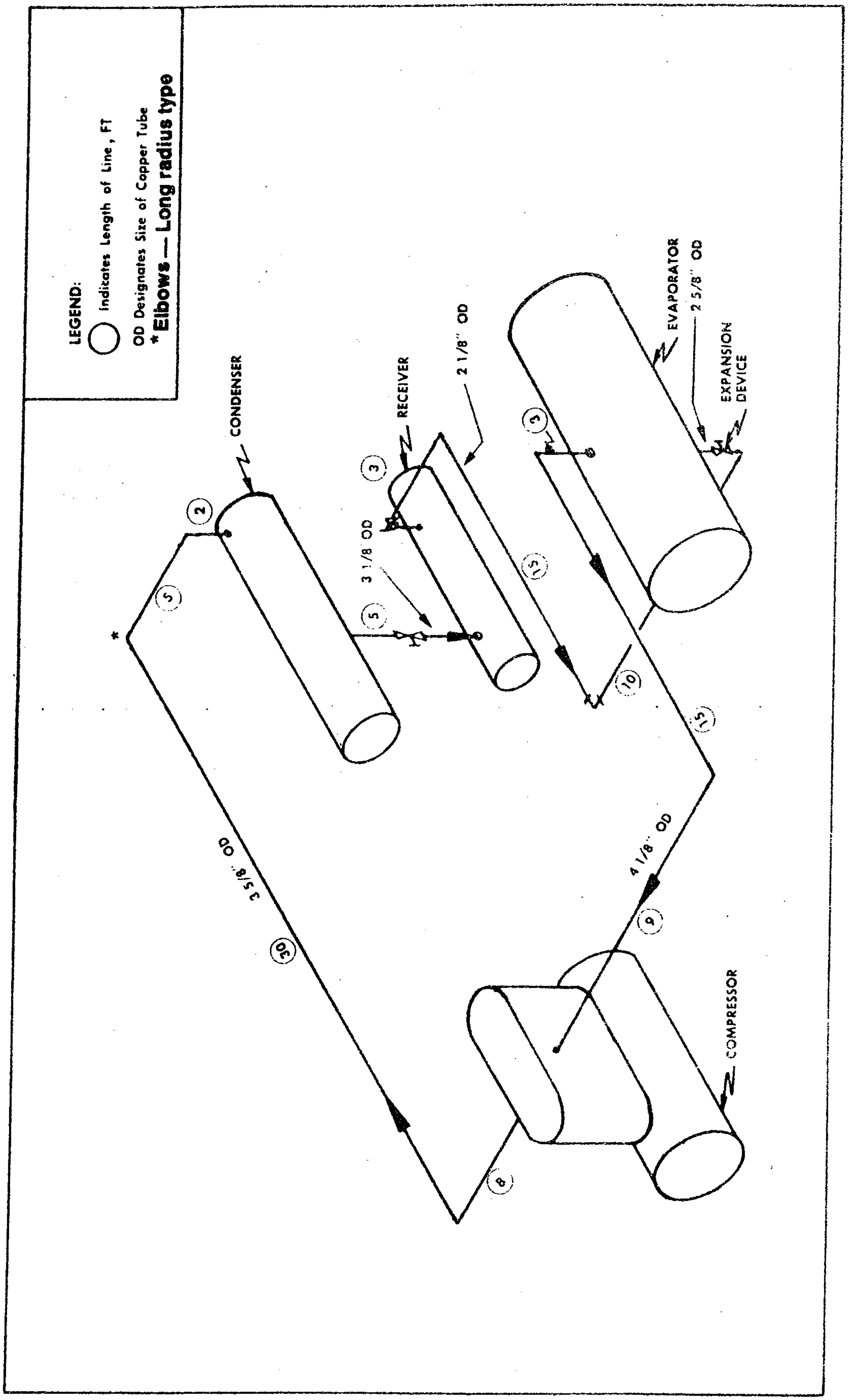


Fig. 1. SCHEMATIC PIPING LAYOUT FOR SAMPLE PROBLEM

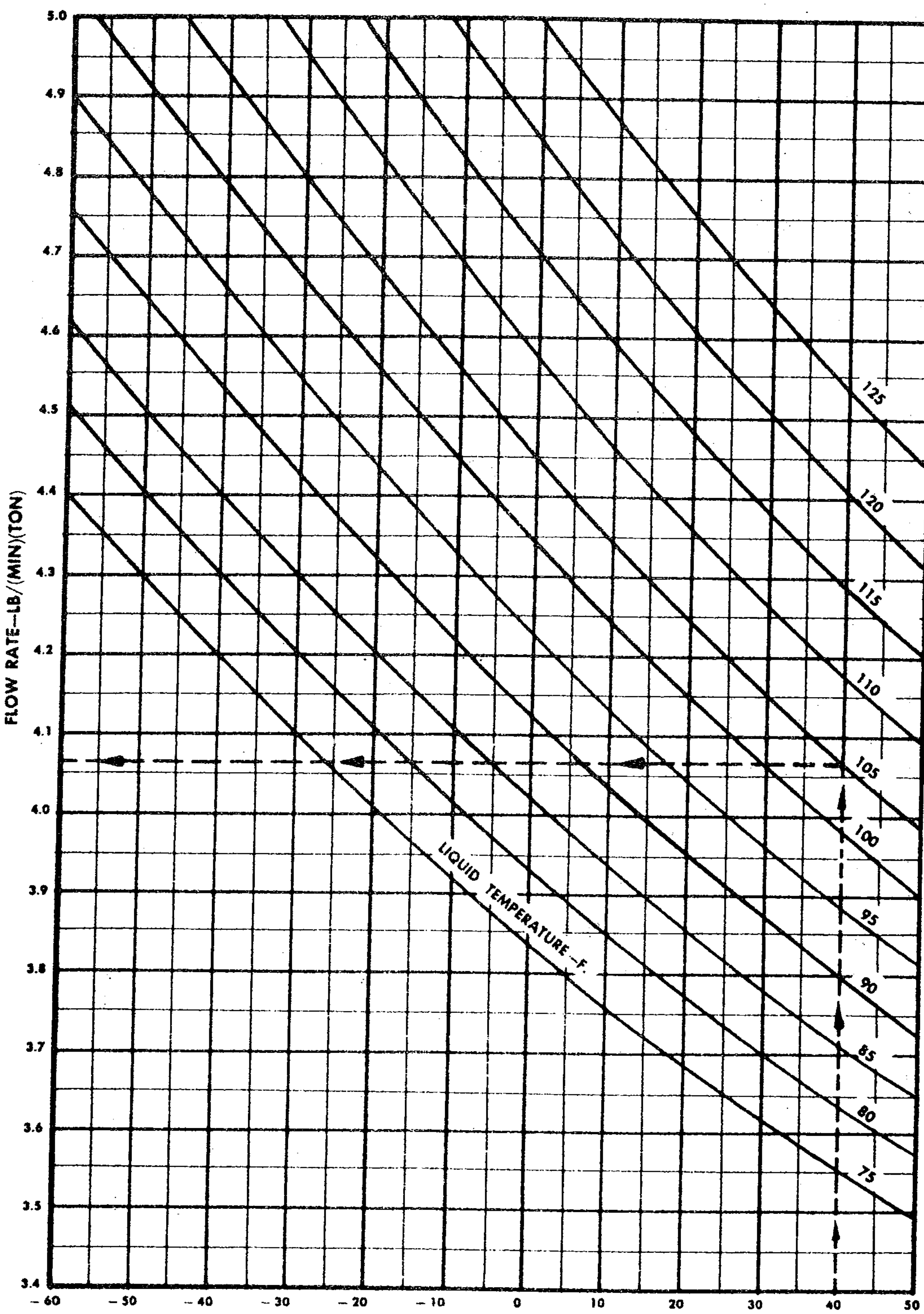


Fig. 2. FLOW RATE PER TON OF REFRIGERATION FOR REFRIGERANT 12

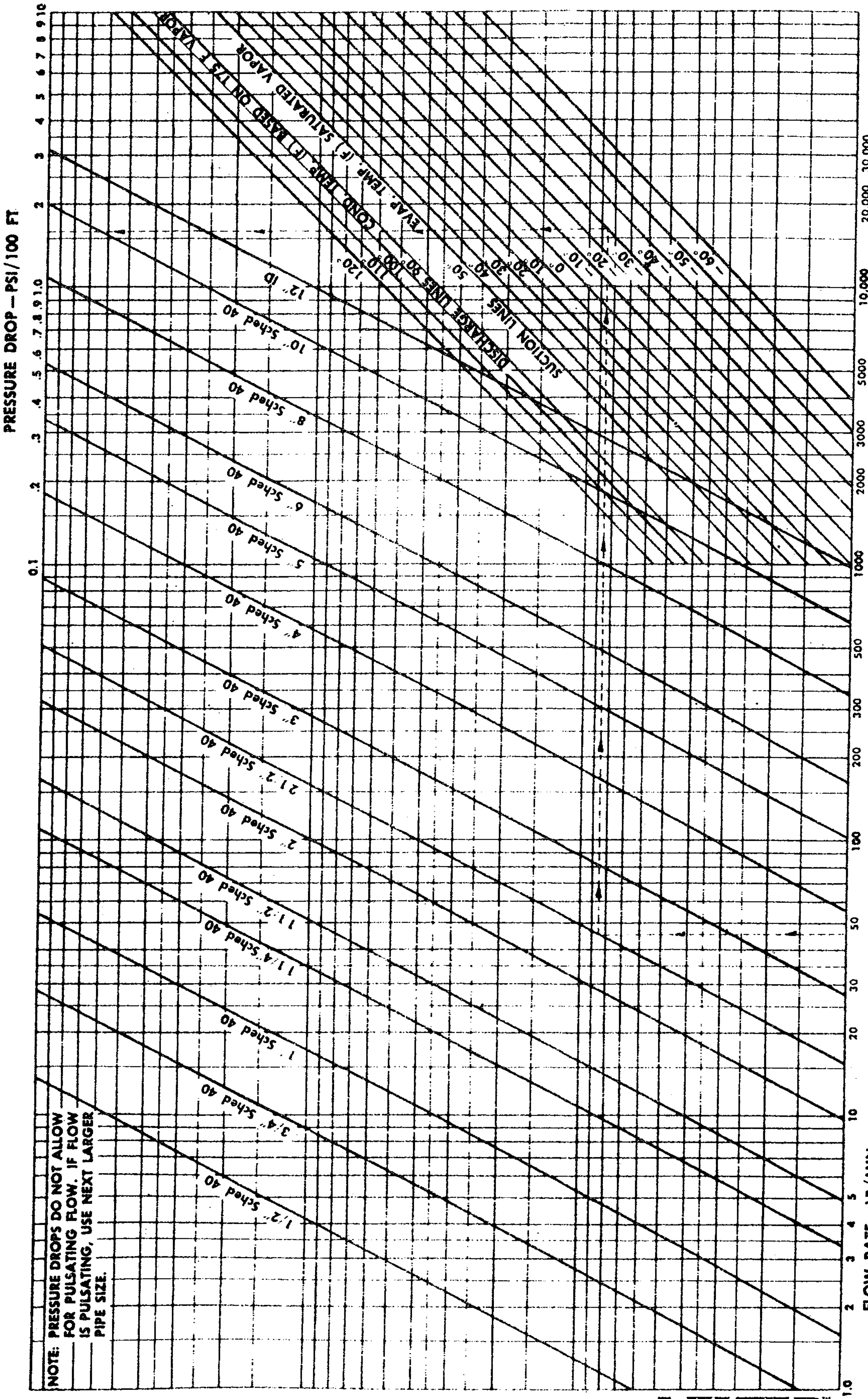


FIG. 3. PRESSURE DROP IN STEEL PIPING FOR REFRIGERANT 12 VAPOR

VILTER Since 1867

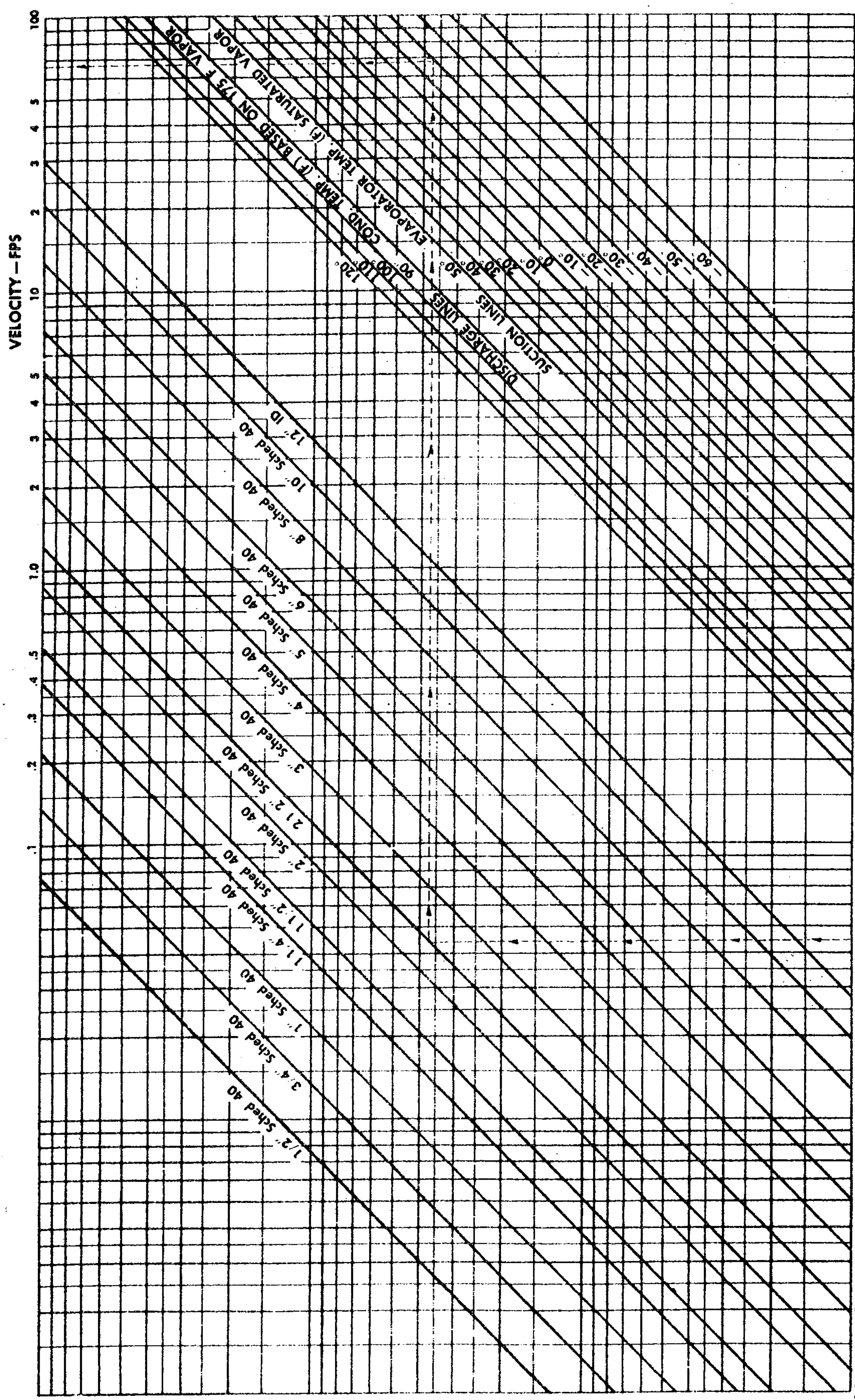


Fig. 4. VELOCITY IN STEEL PIPING FOR REFRIGERANT 12 VAPOR (SUCTION AND DISCHARGE)

VILTER Since 1867

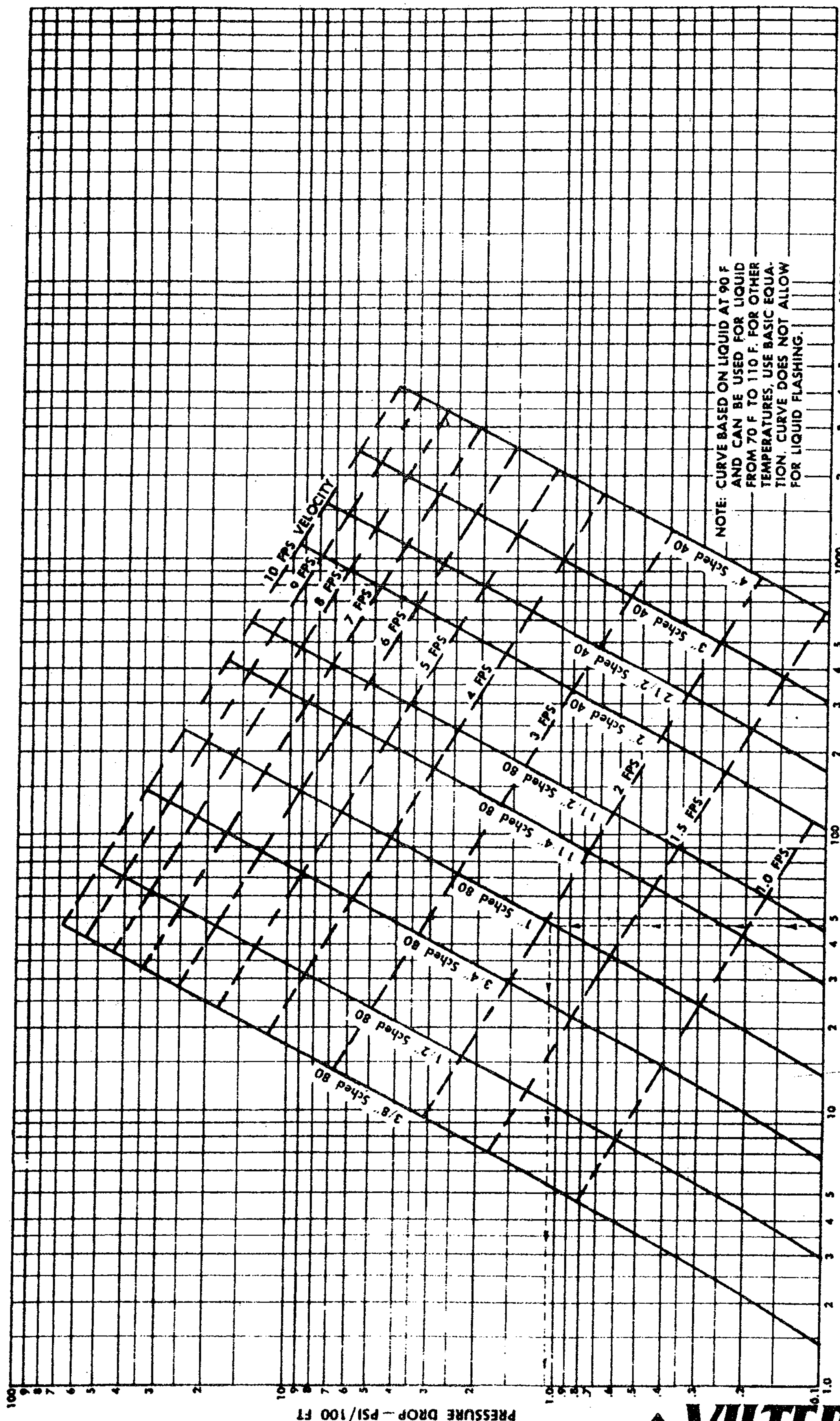


Fig. 5. VELOCITY AND PRESSURE DROP IN STEEL PIPING FOR REFRIGERANT 12 LIQUID

VILTER™ Since 1867

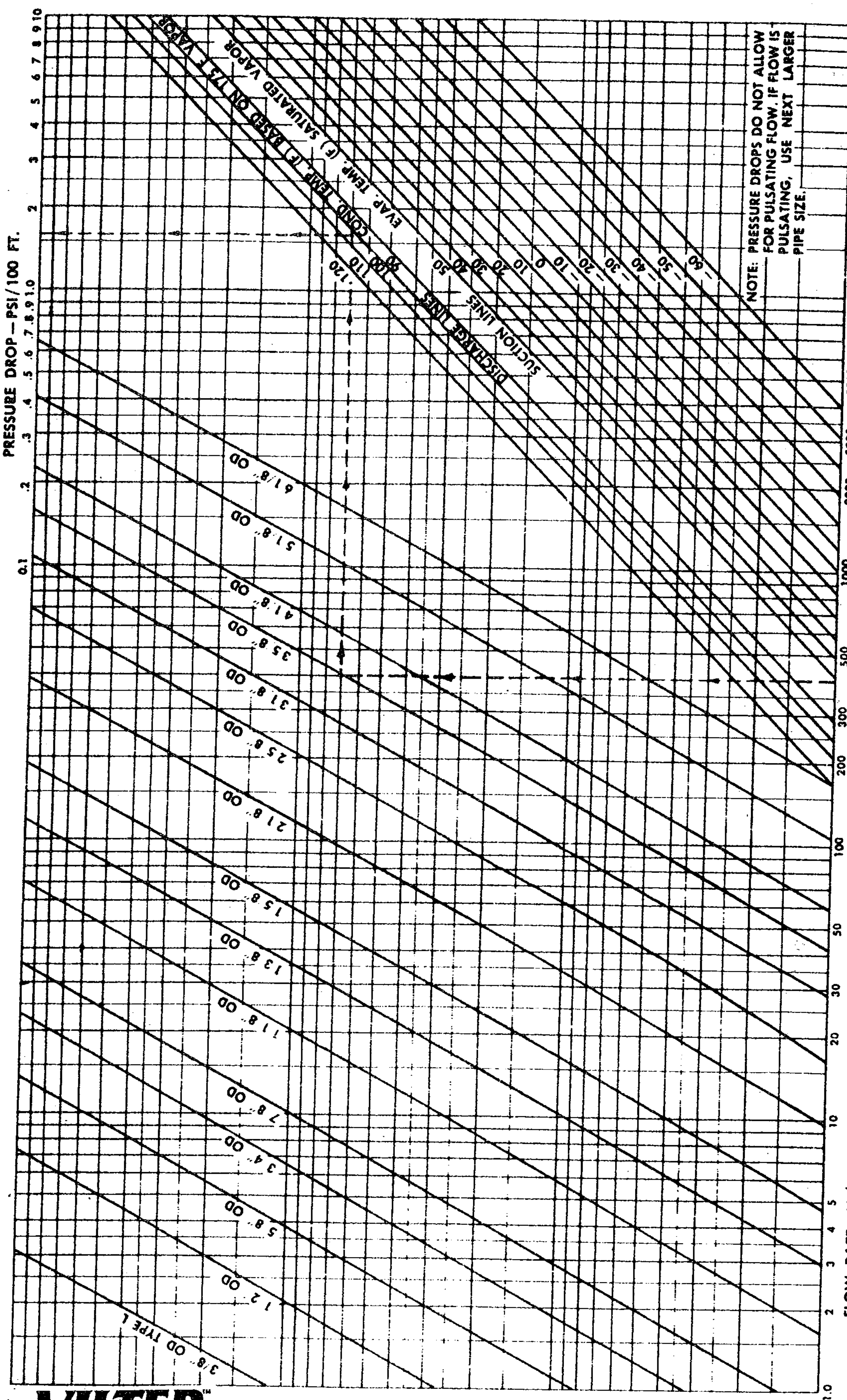


Fig. 6. PRESSURE DROP IN COPPER TUBING FOR REFRIGERANT 12 VAPOR

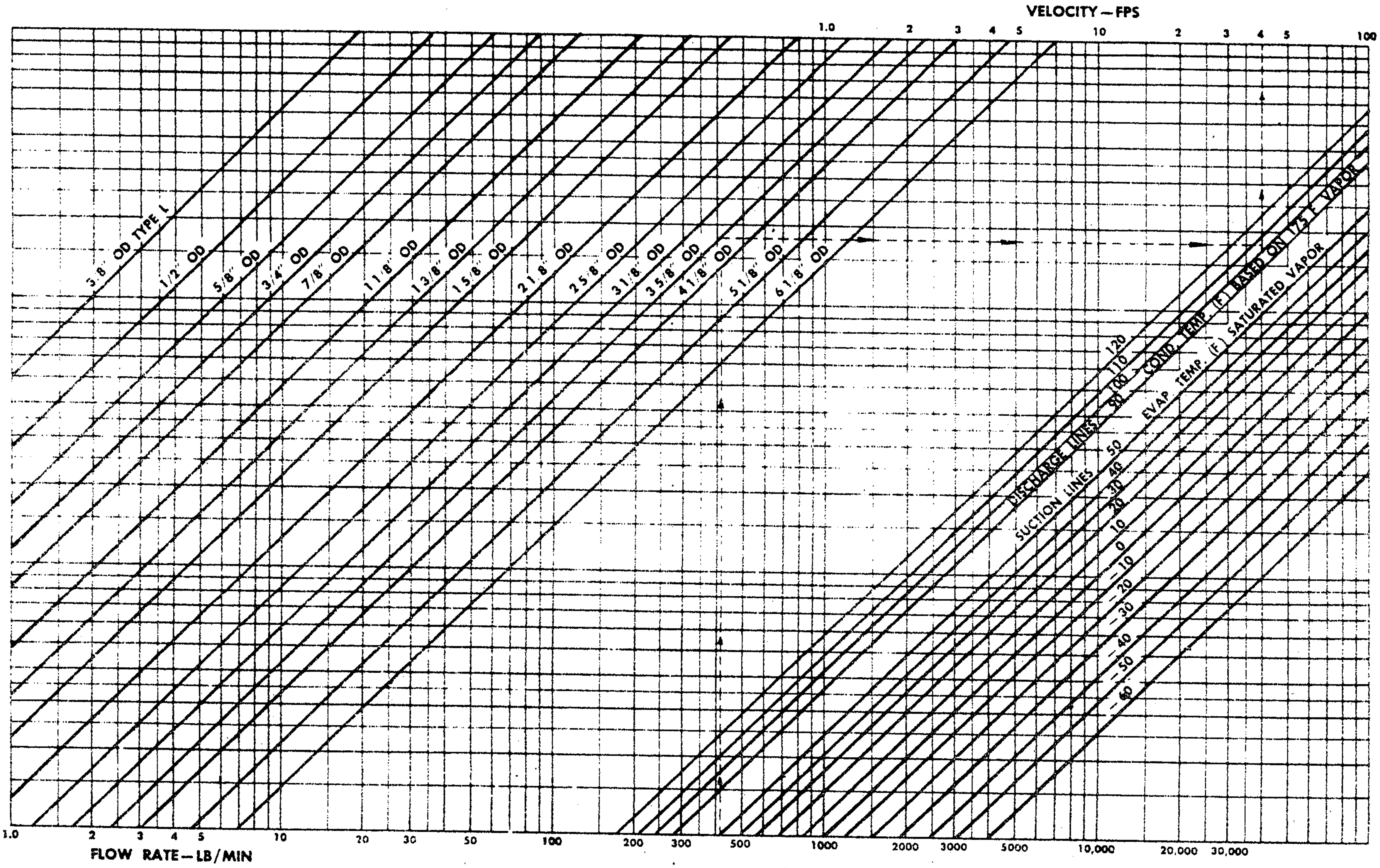


Fig. 7. VELOCITY IN COPPER TUBING FOR REFRIGERANT 12 VAPOR

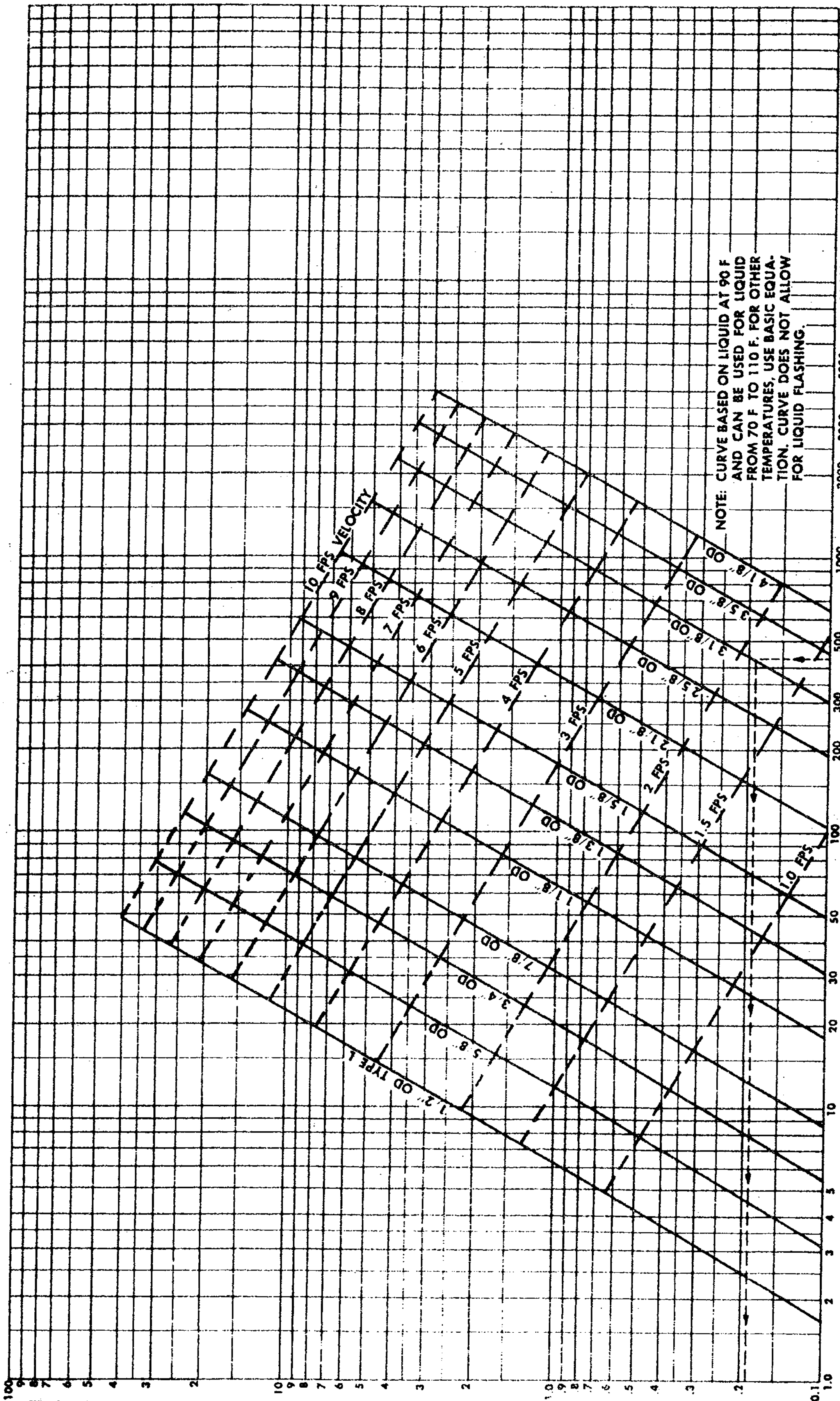


Fig. 8. VELOCITY AND PRESSURE DROP IN COPPER TUBING FOR REFRIGERANT 12 LIQUID

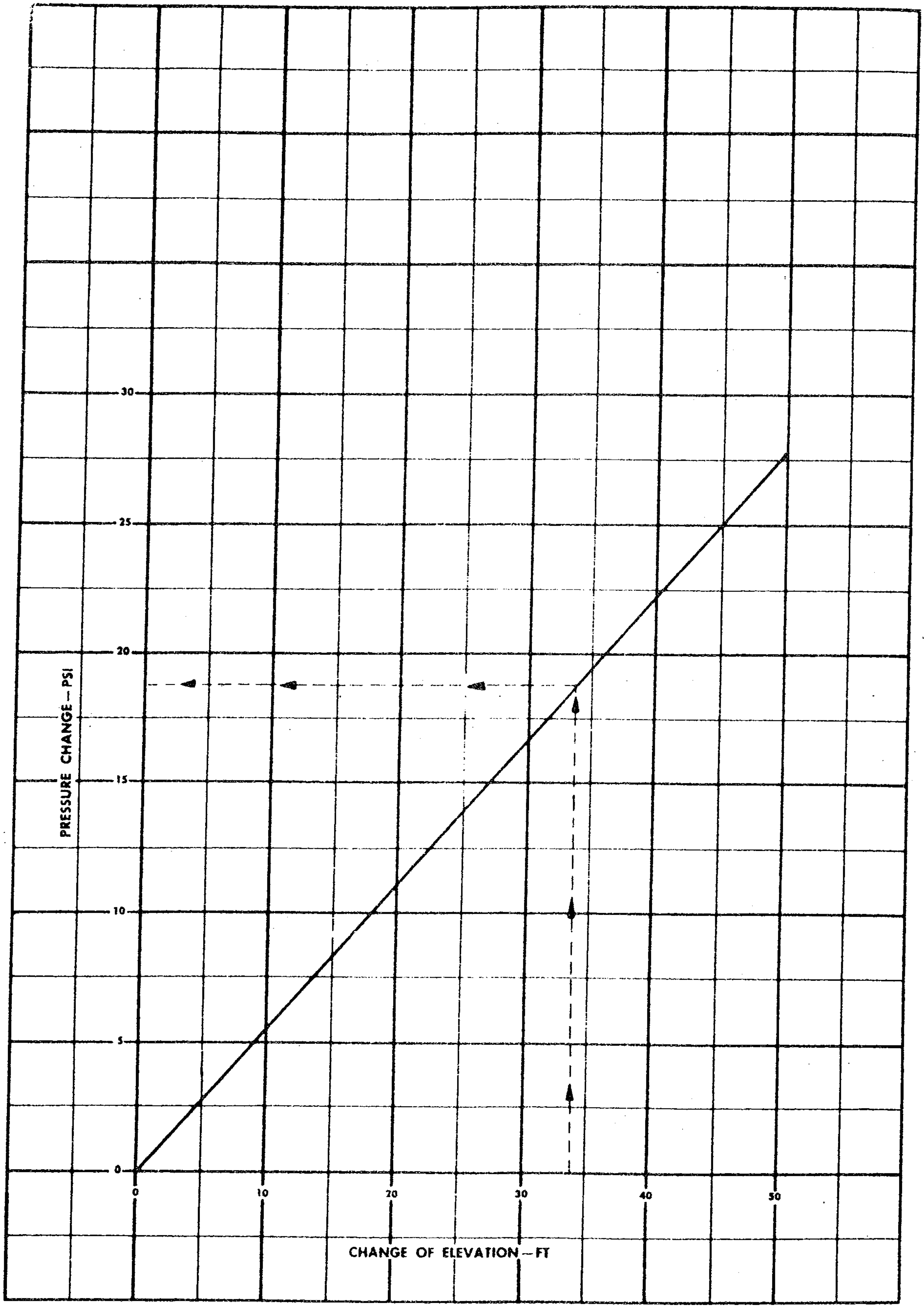
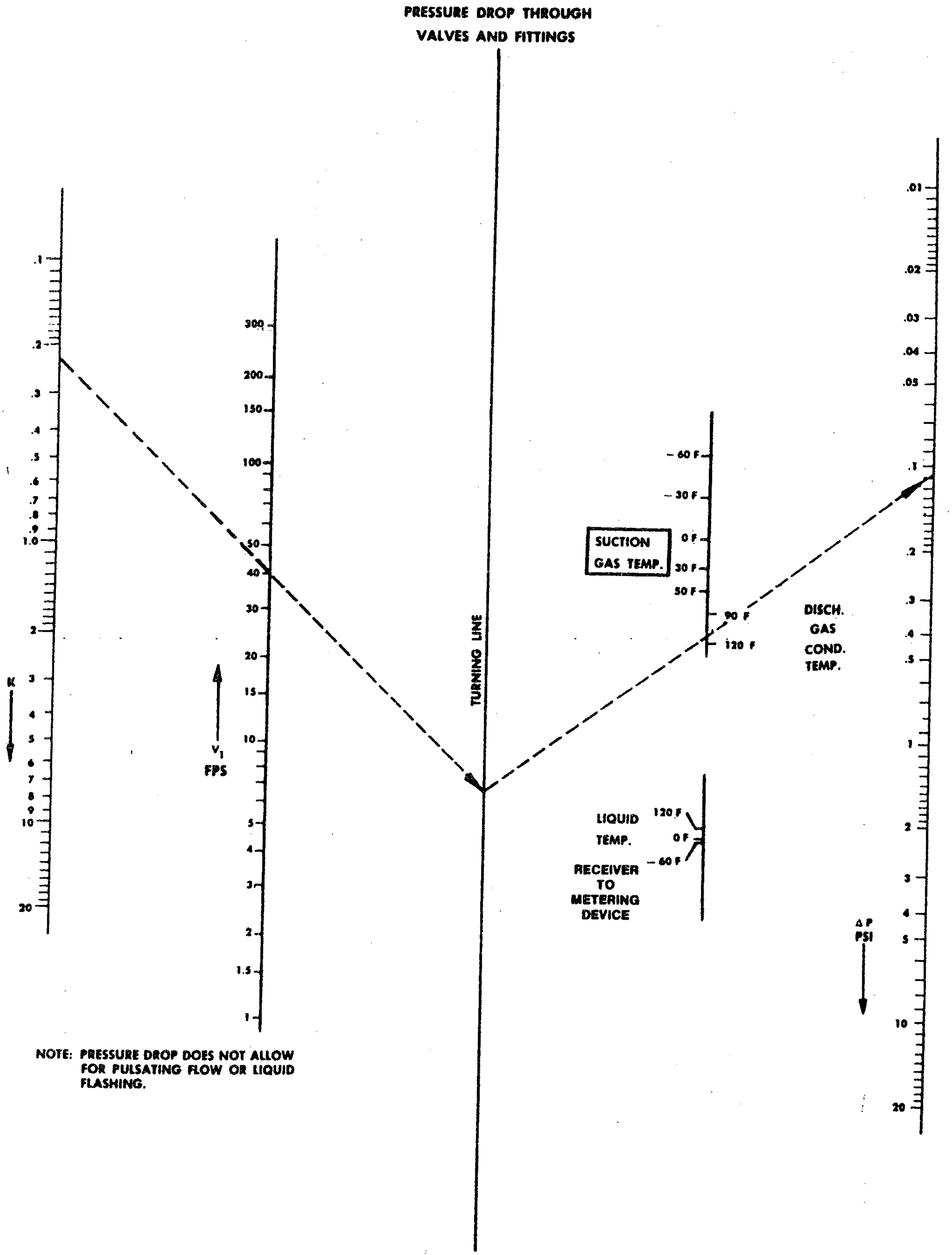


Fig. 9. RELATION OF PRESSURE-CHANGE TO ELEVATION-DIFFERENCE FOR REFRIGERANT 12 LIQUID



NOTE: PRESSURE DROP DOES NOT ALLOW FOR PULSATING FLOW OR LIQUID FLASHING.

Fig. 10. PRESSURE DROP IN VALVES AND FITTINGS FOR REFRIGERANT 12

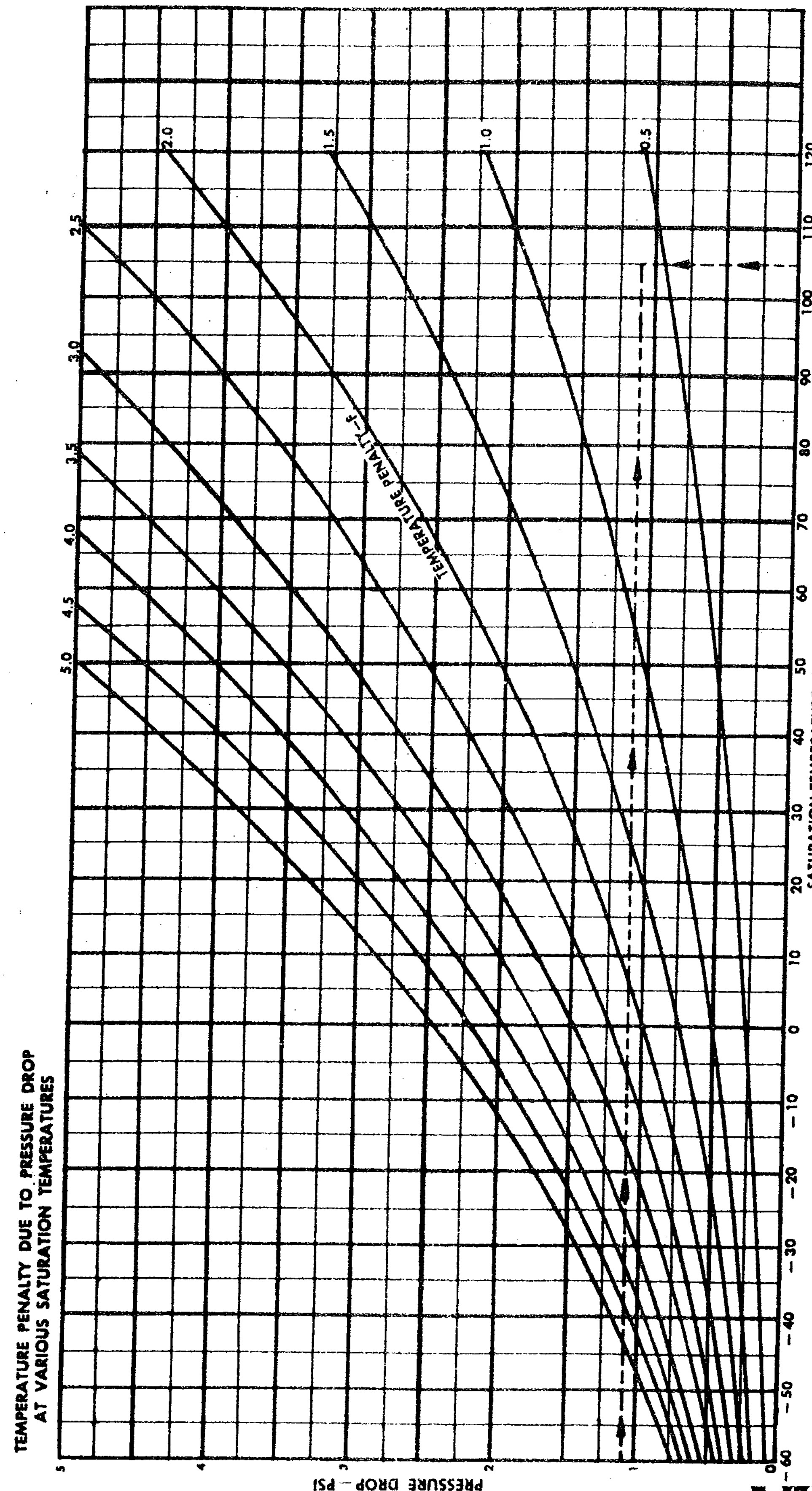


Fig. 11. TEMPERATURE PENALTY DUE TO PRESSURE DROP FOR REFRIGERANT 12

VILTER Since 1867

TABLE 5
THERMODYNAMIC PROPERTIES OF REFRIGERANT 12

Temp. – °F	Pressure – Lb. per Sq. In.		Volume – Cu. Ft. per Lb.		Density – Lb. per Cu. Ft.		Enthalpy – Btu per Lb.			Entropy – Btu per (Lb.) (°R)		Temp. – °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
-85	2.4371	24.9593*	0.010118	13.474	98.830	0.074216	-9.3782	77.289	67.911	-0.023599	0.18267	-85
-80	2.8807	24.0560*	.010164	11.533	98.382	0.086708	-8.3451	76.812	68.467	- .020862	.18143	-80
-75	3.3879	23.0234*	.010211	9.9184	97.930	0.10082	-7.3101	76.333	69.023	- .018156	.18027	-75
-70	3.9651	21.8482*	.010259	8.5687	97.475	0.11670	-6.2730	75.853	69.580	- .015481	.17916	-70
-65	4.6193	20.5164*	.010308	7.4347	97.016	0.13451	-5.2336	75.371	70.137	- .012834	.17812	-65
-60	5.3575	19.0133*	0.010357	6.4774	96.553	0.15438	-4.1919	74.885	70.693	-0.010214	0.17714	-60
-55	6.1874	17.3237*	.010407	5.6656	96.086	0.17650	-3.1477	74.397	71.249	- .007622	.17621	-55
-50	7.1168	15.4313*	.010459	4.9742	95.616	0.20104	-2.1011	73.906	71.805	- .005056	.17533	-50
-45	8.1540	13.3196*	.010511	4.3828	95.141	0.22816	-1.0519	73.411	72.359	- .002516	.17451	-45
-40	9.3076	10.9709*	.010564	3.8750	94.661	0.25806	0.0000	72.913	72.913	.000000	.17373	-40
-38	9.8035	9.9611*	0.010586	3.6922	94.469	0.27084	0.4215	72.712	73.134	0.001000	0.17343	-38
-36	10.320	8.909*	.010607	3.5198	94.275	0.28411	0.8434	72.511	73.354	.001995	.17313	-36
-34	10.858	7.814*	.010629	3.3571	94.081	0.29788	1.2659	72.309	73.575	.002988	.17285	-34
-32	11.417	6.675*	.010651	3.2035	93.886	0.31216	1.6887	72.106	73.795	.003976	.17257	-32
-30	11.999	5.490*	.010674	3.0585	93.690	0.32696	2.1120	71.903	74.015	.004961	.17229	-30
-28	12.604	4.259*	0.010696	2.9214	93.493	0.34231	2.5358	71.698	74.234	0.005942	0.17203	-28
-26	13.233	2.979*	.010719	2.7917	93.296	0.35820	2.9601	71.494	74.454	.006919	.17177	-26
-24	13.886	1.649*	.010741	2.6691	93.098	0.37466	3.3848	71.288	74.673	.007894	.17151	-24
-22	14.564	0.270*	.010764	2.5529	92.899	0.39171	3.8100	71.081	74.891	.008864	.17126	-22
-20	15.267	0.571	.010788	2.4429	92.699	0.40934	4.2357	70.874	75.110	.009831	.17102	-20
-18	15.996	1.300	0.010811	2.3387	92.499	0.42758	4.6618	70.666	75.328	0.010795	0.17078	-18
-16	16.753	2.057	.010834	2.2399	92.298	0.44645	5.0885	70.456	75.545	.011755	.17055	-16
-14	17.536	2.840	.010858	2.1461	92.096	0.46595	5.5157	70.246	75.762	.012712	.17032	-14
-12	18.348	3.652	.010882	2.0572	91.893	0.48611	5.9434	70.036	75.979	.013666	.17010	-12
-10	19.189	4.493	.010906	1.9727	91.689	0.50693	6.3716	69.824	76.196	.014617	.16989	-10
-8	20.059	5.363	0.010931	1.8924	91.485	0.52843	6.8003	69.611	76.411	0.015564	0.16967	-8
-6	20.960	6.264	.010955	1.8161	91.280	0.55063	7.2296	69.397	76.627	.016508	.16947	-6
-4	21.891	7.195	.010980	1.7436	91.074	0.57354	7.6594	69.183	76.842	.017449	.16927	-4
-2	22.854	8.158	.011005	1.6745	90.867	0.59718	8.0898	68.967	77.057	.018388	.16907	-2
0	23.849	9.153	.011030	1.6089	90.659	0.62156	8.5207	68.750	77.271	.019323	.16888	0
2	24.878	10.182	0.011056	1.5463	90.450	0.64670	8.9522	68.533	77.485	0.020255	0.16869	2
4	25.939	11.243	.011082	1.4867	90.240	0.67263	9.3843	68.314	77.698	.021184	.16851	4
6	27.036	12.340	.011107	1.4299	90.030	0.69934	9.8169	68.094	77.911	.022110	.16833	6
8	28.167	13.471	.011134	1.3758	89.818	0.72687	10.250	67.873	78.123	.023033	.16815	8
10	29.335	14.639	.011160	1.3241	89.606	0.75523	10.684	67.651	78.335	.023954	.16798	10
12	30.539	15.843	0.011187	1.2748	89.392	0.78443	11.118	67.428	78.546	0.024871	0.16782	12
14	31.780	17.084	.011214	1.2278	89.178	0.81449	11.554	67.203	78.757	.025786	.16765	14
16	33.060	18.364	.011241	1.1828	88.962	0.84544	11.989	66.977	78.966	.026699	.16750	16
18	34.378	19.682	.011268	1.1399	88.746	0.87729	12.426	66.750	79.176	.027608	.16734	18
20	35.736	21.040	.011296	1.0988	88.529	0.91006	12.863	66.522	79.385	.028515	.16719	20
22	37.135	22.439	0.011324	1.0596	88.310	0.94377	13.300	66.293	79.593	0.029420	0.16704	22
24	38.574	23.878	.011352	1.0220	88.091	0.97843	13.739	66.061	79.800	.030322	.16690	24
26	40.056	25.360	.011380	0.98612	87.870	1.0141	14.178	65.829	80.007	.031221	.16676	26
28	41.580	26.884	.011409	0.95173	87.649	1.0507	14.618	65.596	80.214	.032118	.16662	28
30	43.148	28.452	.011438	0.91880	87.426	1.0884	15.058	65.361	80.419	.033013	.16648	30
32	44.760	30.064	0.011468	0.88725	87.202	1.1271	15.500	65.124	80.624	0.033905	0.16635	32
34	46.417	31.721	.011497	0.85702	86.977	1.1668	15.942	64.886	80.828	.034796	.16622	34
36	48.120	33.424	.011527	0.82803	86.751	1.2077	16.384	64.647	81.031	.035683	.16610	36
38	49.870	35.174	.011557	0.80023	86.524	1.2496	16.828	64.406	81.234	.036569	.16598	38
40	51.667	36.971	.011588	0.77357	86.296	1.2927	17.273	64.163	81.436	.037453	.16586	40

* Inches of mercury below one atmosphere

TABLE 5 (Continued)
THERMODYNAMIC PROPERTIES OF REFRIGERANT 12

Temp. – °F	Pressure – Lb. per Sq. In.		Volume – Cu. Ft. per Lb.		Density – Lb. per Cu. Ft.		Enthalpy – Btu per Lb.			Entropy – Btu per (Lb.) (°R)		Temp. – °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
42	53.513	38.817	0.011619	0.74798	86.066	1.3369	17.718	63.919	81.637	0.038334	0.16574	42
44	55.407	40.711	.011650	.72341	85.836	1.3823	18.164	63.673	81.837	.039213	.16562	44
46	57.352	42.656	.011682	.69982	85.604	1.4289	18.611	63.426	82.037	.040091	.16551	46
48	59.347	44.651	.011714	.67715	85.371	1.4768	19.059	63.177	82.236	.040966	.16540	48
50	61.394	46.698	.011746	.65537	85.136	1.5258	19.507	62.926	82.433	.041839	.16530	50
52	63.494	48.798	0.011779	0.63444	84.900	1.5762	19.957	62.673	82.630	0.042711	0.16519	52
54	65.646	50.950	.011811	.61431	84.663	1.6278	20.408	62.418	82.826	.043581	.16509	54
56	67.853	53.157	.011845	.59495	84.425	1.6808	20.859	62.162	83.021	.044449	.16499	56
58	70.115	55.419	.011879	.57632	84.185	1.7352	21.312	61.903	83.215	.045316	.16489	58
60	72.433	57.737	.011913	.55839	83.944	1.7909	21.766	61.643	83.409	.046180	.16479	60
62	74.807	60.111	0.011947	0.54112	83.701	1.8480	22.221	61.380	83.601	0.047044	0.16470	62
64	77.239	62.543	.011982	.52450	83.457	1.9066	22.676	61.116	83.792	.047905	.16460	64
66	79.729	65.033	.012017	.50848	83.212	1.9666	23.133	60.849	83.982	.048765	.16451	66
68	82.279	67.583	.012053	.49305	82.965	2.0282	23.591	60.580	84.171	.049624	.16442	68
70	84.888	70.192	.012089	.47818	82.717	2.0913	24.050	60.309	84.359	.050482	.16434	70
72	87.559	72.863	0.012126	0.46383	82.467	2.1559	24.511	60.035	84.546	0.051338	0.16425	72
74	90.292	75.596	.012163	.45000	82.215	2.2222	24.973	59.759	84.732	.052193	.16417	74
76	93.087	78.391	.012201	.43666	81.962	2.2901	25.435	59.481	84.916	.053047	.16408	76
78	95.946	81.250	.012239	.42378	81.707	2.3597	25.899	59.201	85.100	.053900	.16400	78
80	98.870	84.174	.012277	.41135	81.450	2.4310	26.365	58.917	85.282	.054751	.16392	80
82	101.86	87.16	0.012316	0.39935	81.192	2.5041	26.832	58.631	85.463	0.055602	0.16384	82
84	104.92	90.22	.012356	.38776	80.932	2.5789	27.300	58.343	85.643	.056452	.16376	84
86	108.04	93.34	.012396	.37657	80.671	2.6556	27.769	58.052	85.821	.057301	.16368	86
88	111.23	96.53	.012437	.36575	80.407	2.7341	28.241	57.757	85.998	.058149	.16360	88
90	114.49	99.79	.012478	.35529	80.142	2.8146	28.713	57.461	86.174	.058997	.16353	90
92	117.82	103.12	0.012520	0.34518	79.874	2.8970	29.187	57.161	86.348	0.059844	0.16345	92
94	121.22	106.52	.012562	.33540	79.605	2.9815	29.663	56.858	86.521	.060690	.16338	94
96	124.70	110.00	.012605	.32594	79.334	3.0680	30.140	56.551	86.691	.061536	.16330	96
98	128.24	113.54	.012649	.31679	79.061	3.1566	30.619	56.242	86.861	.062381	.16323	98
100	131.86	117.16	.012693	.30794	78.785	3.2474	31.100	55.929	87.029	.063227	.16315	100
102	135.56	120.86	0.012738	0.29937	78.508	3.3404	31.583	55.613	87.196	0.064072	0.16308	102
104	139.33	124.63	.012783	.29106	78.228	3.4357	32.067	55.293	87.360	.064916	.16301	104
106	143.18	128.48	.012829	.28303	77.946	3.5333	32.553	54.970	87.523	.065761	.16293	106
108	147.11	132.41	.012876	.27524	77.662	3.6332	33.041	54.643	87.684	.066606	.16286	108
110	151.11	136.41	.012924	.26769	77.376	3.7357	33.531	54.313	87.844	.067451	.16279	110
112	155.19	140.49	0.012972	0.26037	77.087	3.8406	34.023	53.978	88.001	0.068296	0.16271	112
114	159.36	144.66	.013022	.25328	76.795	3.9482	34.517	53.639	88.156	.069141	.16264	114
116	163.61	148.91	.013072	.24641	76.501	4.0584	35.014	53.296	88.310	.069987	.16256	116
118	167.94	153.24	.013123	.23974	76.205	4.1713	35.512	52.949	88.461	.070833	.16249	118
120	172.35	157.65	.013174	.23326	75.906	4.2870	36.013	52.597	88.610	.071680	.16241	120
122	176.85	162.15	0.013227	0.22698	75.604	4.4056	36.516	52.241	88.757	0.072528	0.16234	122
124	181.43	166.73	.013280	.22089	75.299	4.5272	37.021	51.881	88.902	.073376	.16226	124
126	186.10	171.40	.013335	.21497	74.991	4.6518	37.529	51.515	89.044	.074225	.16218	126
128	190.86	176.16	.013390	.20922	74.680	4.7796	38.040	51.144	89.184	.075075	.16210	128
130	195.71	181.01	.013447	.20364	74.367	4.9107	38.553	50.768	89.321	.075927	.16202	130
132	200.64	185.94	0.013504	0.19821	74.050	5.0451	39.069	50.387	89.456	0.076779	0.16194	132
134	205.67	190.97	.013563	.19294	73.729	5.1829	39.588	50.000	89.588	.077633	.16185	134
136	210.79	196.09	.013623	.18782	73.406	5.3244	40.110	49.608	89.718	.078489	.16177	136
138	216.01	201.31	.013684	.18283	73.079	5.4695	40.634	49.210	89.844	.079346	.16168	138
140	221.32	206.62	.013746	.17799	72.748	5.6184	41.162	48.805	89.967	.080205	.16159	140

TABLE 6
REFRIGERANT 12 FLOW RATE
POUNDS/MINUTE/TON REFRIGERATION

Temp. of Suction (°F)	Corres. Suction Pressure (Psig)	Booster Discharge Temperature (°F)						Condensing Discharge Temperature (°F)					
		10	20	30	40	50	60	70	80	90	100	110	120
		Corresponding Discharge Pressure (Psig)						Corresponding Discharge Pressure (Psig)					
		14.64	21.04	28.45	36.97	46.70	57.74	70.19	84.17	99.79	117:2	136.4	157.7
−60	19.01*	3.46	3.60	3.75	3.91	4.09	4.29	4.29	4.51				
−50	15.43*	3.39	3.52	3.67	3.82	4.00	4.19	4.19	4.40	4.64			
−40	10.97*	3.33	3.46	3.60	3.74	3.91	4.08	4.08	4.29	4.52	4.78		
−30	5.49*	3.27	3.39	3.52	3.67	3.82	4.00	4.00	4.20	4.41	4.66	4.94	
−20	0.57	3.21	3.33	3.46	3.60	3.75	3.92	3.92	4.10	4.31	4.54	4.81	5.12
−10	4.49	3.16	3.27	3.39	3.52	3.67	3.84	3.84	4.01	4.21	4.44	4.69	4.98
0	9.15	3.10	3.21	3.34	3.46	3.60	3.76	3.76	3.93	4.12	4.33	4.57	4.85
10	14.64		3.16	3.28	3.40	3.53	3.68	3.68	3.85	4.03	4.23	4.46	4.72
20	21.04			3.22	3.34	3.47	3.62	3.62	3.77	3.94	4.14	4.36	4.61
30	28.45				3.29	3.41	3.55	3.55	3.70	3.87	4.05	4.26	4.50
40	36.97					3.41	3.48	3.48	3.63	3.80	3.98	4.18	4.41
50	46.70						3.43	3.43	3.57	3.72	3.90	4.09	4.31
60	57.74							3.37	3.51	3.66	3.82	4.01	4.22

*Inches mercury below one atmosphere.

TABLE 7
REFRIGERANT 12 FLOW RATE
CUBIC FEET/MINUTE/TON REFRIGERATION

Temp. of Suction (°F)	Corres. Suction Pressure (Psig)	Booster Discharge Temperature (°F)						Condensing Discharge Temperature (°F)					
		10	20	30	40	50	60	70	80	90	100	110	120
		Corresponding Discharge Pressure (Psig)						Corresponding Discharge Pressure (Psig)					
		14.64	21.04	28.45	36.97	46.70	57.74	70.19	84.17	99.79	117.2	136.4	157.7
−60	19.01*	22.4	23.3	24.3	25.3	26.5	27.8	27.8	29.2				
−50	15.43*	16.9	17.5	18.3	19.0	19.9	20.9	20.9	21.9	23.1			
−40	10.97*	12.9	13.4	14.0	14.5	15.2	15.8	15.8	16.6	17.5	18.5		
−30	5.49*	10.0	10.4	10.8	11.2	11.7	12.2	12.2	12.8	13.5	14.3	15.1	
−20	0.57	7.85	8.15	8.46	8.80	9.17	9.58	9.58	10.0	10.5	11.1	11.8	12.5
−10	4.49	6.24	6.45	6.69	6.95	7.25	7.58	7.58	7.91	8.31	8.76	9.25	9.83
0	9.15	4.98	5.16	5.37	5.57	5.79	6.05	6.05	6.32	6.63	6.97	7.36	7.80
10	14.64		4.19	4.35	4.51	4.68	4.88	4.88	5.10	5.35	5.61	5.91	6.26
20	21.04			3.54	3.67	3.81	3.98	3.98	4.14	4.33	4.55	4.79	5.00
30	28.45				3.02	3.14	3.26	3.26	3.40	3.56	3.72	3.92	4.14
40	36.97					2.64	2.70	2.70	2.81	2.94	3.08	3.24	3.41
50	46.70						2.25	2.25	2.34	2.44	2.56	2.68	2.82
60	57.74							1.88	1.96	2.04	2.13	2.24	2.36

*Inches mercury below one atmosphere.

Figures to left of heavy line are based on booster flow-rate of two-stage system with liquid subcooling to within 10°F of intermediate. Figures to right of heavy line are based on single stage.

REFRIGERANT 22 PIPING DATA

This section presents useful data for the proper sizing of Refrigerant 22 (Monochlorodifluoromethane) piping. Its purpose is not to set design standards, but to provide the latest pipe-sizing information available. It also discusses various factors which determine the allowable pressure drops in different portions of a refrigerant piping system.

Basis of Charts and Tables

The pressure-drop charts given herein for single or high stage applications are based on calculations using the commonly accepted Darcy-Weisbach pressure-drop formula and Darcy friction factors from the Moody Chart (see appendix, Sections A-III and A-IV). Capacity tables for intermediate or low stage applications are based on calculations using Fanning's equation for friction loss.

Pipe Lines. **Suction line velocity and pressure-drop values are for saturated vapor temperature conditions, and the discharge line values are at pressures corresponding to the condensing temperatures indicated, and superheated to 200 F.**

Liquid line velocities and pressure drops are for saturated Refrigerant 22 liquid at 90 F and can be used with reasonable accuracy for temperatures between 70 F and 110 F.

Valves and Fittings. **Pressure losses through refrigerant valves and fittings are given in a table, in the form of "K" factors (velocity heads). These "K" factors are representative, using average values obtained from various tests and manufacturers' ratings. "K" factors vary widely for a given type and size of valve or fitting, depending on the construction or internal design.**

For a simplified determination of these pressure drops, "equivalent lengths" of valves and fittings are given in a table. These "equivalent lengths" have been derived, using the "K" factors in conjunction with friction factors taken from the Moody Chart at Reynolds Numbers in the range of normal usage, for both vapor and liquid lines.

"Equivalent lengths" result in a sacrifice of accuracy, depending on the temperature, state and velocity of the refrigerant. "K" factors give more reliable pressure drop data. For greater accuracy, particularly for valves, "K" factors should be obtained from the manufacturer.

Pressure-Drop Limitations (Pipe-Sizing Factors)

Vapor line pressure drops result in an increase in power input to the compressor and a decrease in refrigeration capacity. The most critical line with respect to this is the suction line, as losses in it have the greatest effect on the system. An economic study, involving power input, system capacity, size of system components—evaporator and condenser—and installation cost of pipe and **pipe insulation, can best determine the optimum pressure-drop allowance. Experience has shown that the allowable pressure drop for suction lines should decrease with suction temperature. Discharge lines may have a greater pressure drop, for a specified temperature penalty, than suction lines.**

Suction line pressure drop increases the volume of gas to be handled by the compressor, increases the ratio of discharge pressure to suction pressure, and reduces the volumetric efficiency of the compressor. This results in less capacity from a given compressor and more power per ton of refrigeration.

The effect of a particular amount of suction line pressure drop is greater as the suction pressure decreases. Fig. 11 indicates this in showing that a particular pressure drop results in a greater "temperature penalty" at a lower saturation temperature. The result of suction line pressure drop is that the compressor operates from a suction condition corresponding to the actual evaporator temperature minus the temperature penalty.

Larger suction line sizes reduce the pressure drop and, therefore, reduce the compressor capacity required and also the power per ton. However, the larger pipe size increases its cost and also its installation and insulation cost. The best size from an economic consideration can be determined by an economic study with the cost of the various factors available.

Discharge line pressure drop also increases the ratio of discharge pressure to suction pressure and reduces the volumetric efficiency of the compressor. This results in less capacity from a given compressor and more power per ton of refrigeration.

The effect of a particular amount of discharge line pressure drop is less as the discharge saturation temperature increases, but the difference is not very great in the range of saturation temperatures corresponding to usual discharge pressures. Fig. 11 indicates this by showing the relatively small change in "temperature penalty" for a particular pressure drop at the temperatures corresponding to saturation at normal discharge pressures. Fig. 11 also indicates the smaller "temperature penalty" for a given pressure drop in the saturation temperature range corresponding to usual discharge conditions as compared to the range corresponding to usual suction conditions. Because of this, economic considerations usually result in the use of a larger pressure drop as the basis of design for a discharge line than that which would be used for a suction line.

Liquid line pressure drop results in no direct penalty in capacity or power. It is important that the pressure loss not be such as to produce flash gas. If the pressure loss or liquid lift are such as to result in flash gas, the required capacities of liquid solenoid valves and expansion valves must be increased. Liquid lines cooler than ambient will take in heat and may sweat.

Higher liquid line velocities should be used with caution because of possible stresses due to rapid closing of any liquid valve. Solenoid valves or solenoid pilot-controlled valves, almost always are rapid-closing.

When the liquid is to flow upward in a riser, or when pressure drop may cause flashing, subcooling can be employed to eliminate flash gas in the supply to the expansion valves. Subcooling may make insulation for the liquid line desirable or necessary.

Basis of Design

Suction lines should generally be selected for a pressure drop of 1 to 3 psi per 100 feet of pipe for temperatures above 20 F. On the other hand, pressure drop should range from 2 to 0.2 psi per 100 feet of pipe at temperatures between + 20 F and — 60 F. In other words, pressure-drop allowance should decrease with decreasing suction temperatures.

Discharge lines should generally be selected for a nominal pressure-drop between 2 and 5 psi per 100 feet of pipe at any normal condensing temperature.

Liquid lines are normally sized for a low pressure drop to avoid flash gas. The design conditions most generally accepted are:

a. *Condenser to receiver:* Velocities from about 75 fpm in smaller sizes to 150 fpm in larger sizes are commonly used. Higher velocities may be used where the line is short and direct, or other conditions permit.

b. *Receiver to system:* Velocity range of 100 to 300 fpm, with pressure drop of 2 psi/100 ft or greater.

c. *The liquid line between the expansion valve and the evaporator* is often very short and may then be the same size as the expansion valve outlet or the evaporator inlet. However, unless it is very short, consideration should be given to the size of this line which will be carrying both gas and liquid. Common practice for relatively short lines, containing a service valve, is to make them one size larger than the liquid line.

How to Use Charts

1. Tables 1-A and 1-B permit quick selection of suction lines applicable to the conditions listed.

   Table 1-A gives suction line capacities (tons) for intermediate or low stage applications. The values in this table are based on 0°F. saturated discharge temperature. For intermediate or low stage suction line capacities at other saturated discharge temperatures, multiply table value by proper line capacity multiplier as given in Table A-7 in appendix.

   Table 1-B gives suction line capacities (tons) for single or high stage applications at various suction temperatures, pressure drops, and at 105°F. saturated condensing temperature. Interpolation may be used between suction temperatures to determine line capacity at a fixed pressure drop. (Do *not* interpolate between pressure-drop columns.) For other condensing temperatures and other pressure-drop limitations, follow the steps outlined below for detailed sizing of lines.

2. Table 2 can be used to determine the capacities of discharge and liquid lines at a specified pressure drop or velocity, as listed. For temperatures other than 105 F condensing and 40 F suction, these capacities are only approximate.

   The following steps are used for detailed sizing of Refrigerant 22 piping.

3. Determine the flow rate, lb/(min)(ton), from Fig. 2. Use saturated evaporator temperature and liquid temperature, disregarding any suction superheating. Total flow equals lb/(min)(ton) times system tonnage.

4. Enter Fig. 3 or Fig. 6, depending on whether the lines are steel or copper, and determine the pressure drop, psi per 100 ft, for the total flow. (Figs. 3 and 6 are used for suction and discharge lines.) The pressure drop through any size line is found by projecting vertically, from the flow rate on the lower scale, to the intersection with the line size to be used. At this intersection, follow the horizontal line to the right and intersect with the vapor temperature line, and then project upward to the top scale to read the pressure drop. Prorate the pressure drop according to the actual length, using either the net length of straight pipe or the straight pipe plus the equivalent length of valves and fittings. If net length of straight pipe is used, determine the pressure drop for valves and fittings from Fig. 10, using appropriate "K" factors from Table 3 and the vapor line velocity. (See Step 5.)

5. Using the total refrigerant flow, lb per min, determine the velocity for suction and discharge lines in Fig. 4 or Fig. 7, depending on

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whether the lines are steel or copper. These charts are read in the same manner as Fig. 3 and Fig. 6.

6. For liquid lines, determine the pressure drop and velocity, using either Fig. 5 or Fig. 8, depending on the type of pipe used. The liquid-flow rate in lb per min, as read on the lower scale, is projected upward to the intersection of a given pipe size. The velocity in ft per sec can be read at this point and a pressure drop in psi per 100 ft equivalent length can be read on the ordinate scale. (The total flow for liquid lines is the same as that in the vapor lines as found in Step 3.) Prorate the pressure drop, using the ratio of actual pipe length versus 100 ft.

   Valves and fittings in liquid lines are treated in the same manner as outlined in Step 4 for vapor lines.
7. Fig. 9 is used to determine the pressure drop (or gain) in a liquid line when there is an appreciable change in elevation between the condenser or receiver and the evaporator.
8. Fig. 11 is used to determine the temperature penalty for the various refrigerant lines, using the pressure drops determined in the steps above.

Pulsating Flow

Pulsating flow in refrigerant lines causes increased pressure losses beyond those indicated by Fig. 3 and Fig. 6, which are based on steady flow.

Reciprocating compressors create pulsating flow in both discharge and suction lines. However, because gas density and the pressure-pulsation amplitude are both greater in the discharge line, the added frictional loss due to pulsation is also greater in the discharge line. For the same reasons, the additional pressure loss due to pulsating flow is greater for a single-cylinder compressor than for a multi-cylinder compressor. Pulsation is greater as the compression ratio increases.

The refrigerant piping and other components in the system, such as valves, fittings, condenser, evaporator, etc., attenuate the pulsation, resulting in an energy loss that is only slightly above the frictional loss that occurs when the flow is steady. Use of a muffler in the discharge line, close to the compressor, reduces the friction loss in the line downstream from the muffler. Of course, the frictional loss of the muffler itself must be considered in the system design.

SAMPLE PROBLEM

GIVEN

100 tons refrigeration
10 F evap. temperature
100 F condensing (liquid) temperature
Piping layout as shown in Fig. 1
Select discharge, liquid and suction line sizes
Determine compressor operating conditions

NOTE: For the purpose of illustration, copper tubing will be assumed throughout. However, for economic or other reasons, good practice might employ all copper, all steel, or some copper and some steel, piping

SOLUTION

From Fig. 2, the lb/(min)(ton) at 10 F evaporator temperature and 100 F condensing temperature = 3.08
Refrigerant circulation = 100 tons × 3.08 lb/(min)(ton) = 308 lb/min

DISCHARGE LINE

Table 2 indicates 3⅛" OD copper tube is adequate for 104 tons refrigeration at 2 psi/100 ft.

Pressure Drop in Pipe:

From Fig. 6, pressure drop at 308 lb/min and 100 F condensing temperature through 3⅛" OD = 1.8 psi/100 ft.

Pressure drop for 45 ft. of pipe = 45/100 × 1.8 = 0.81 psi

Pressure Drop in Fittings:

From Fig. 7, velocity at 308 lb/min and 100 F condensing temperature through 3⅛" OD copper tube = 36 fps

From Table 3, for 3⅛" OD long radius ells (sweat fittings) K = 0.23

From Fig. 10. for velocity = 36 fps and K = 0.23, pressure drop per ell = 0.09 psi

3 ells × 0.09 psi = 0.27 psi

Total pressure drop = 1.08 psi

Temperature Penalty:

From Fig. 11, 1.08 psi, 100 F saturated temperature, temperature penalty = 0.40 F

LIQUID LINES

Condenser to Receiver

Select 3⅛" OD liquid line from Table 2 for velocity of approximately 100 fpm.

Because of gravity flow, no pressure drop need be calculated.

Receiver to Expansion Valve:

Using Table 2, select 2 1/8" O.D. pipe size or, from Fig. 8, select 2 1/8" O.D. pipe size for 308 lb/min liquid, resulting in about 0.8 psi actual pressure drop per 100 ft. velocity = 3.2 fps = 192 fpm.

Pressure Drop in Pipe:

Pressure drop for 28 ft. of pipe = 28/100 x 0.8 psi/100 ft. = 0.22 psi

Pressure Drop in Valves and Fittings:

From Fig. 8, 308 lb/min copper tube velocity = 3.2 fps. From Table 3, K = 0.38 for one S.R. sweat ell. Using Fig. 10 with K = 0.38 and 3.2 fps and 100°F. *liquid* temperature, the pressure drop (per sweat ell) is .03 psi x 3 ells = 0.09 psi

Pressure drop for one 2 1/8" flanged angle valve using K = 2.9 from Table 3 and 3.2 fps from Fig. 8, then using Fig. 10 = 0.24 psi

Total Liquid Lines Pressure Drop = 0.55 psi

Expansion Valve to Evaporator:

One size larger than 2⅛", or 2⅝".

SUCTION LINE

From Table 1-B, select 4⅛" OD copper tube, which by interpolation is adequate for 113.8 tons of refrigeration with a pressure drop of 2 psi/100 ft.

Pressure Drop in Pipe:

From Fig. 6, pressure drop at 10 F suction temperature and 308 lb/min for 4⅛" OD = 1.6 psi/100 ft. Pressure drop for 27 ft. of pipe = 27/100 × 1.6. = 0.43 psi

Pressure Drop in Fittings:

From Fig. 7, velocity at 10 F suction temperature and 308 lb/min for 4⅛" OD = 70 fps

Pressure drop for two 4⅛" OD long radius ells (sweat fitting)

From Table 3, K = 0.22

From Fig. 10, pressure drop per ell = 0.10 psi. Pressure drop for 2 ells = 2 × 0.10 = 0.20 psi

Total pressure drop = 0.63 psi

Temperature Penalty:

From Fig. 11, 0.63 psi, 10 F saturated temperature, temperature penalty = 0.7 F

COMPRESSOR SELECTION

Therefore, a compressor must be selected for 100 tons capacity at 10 — 0.7 = 9.3 F suction temperature and 100 + 0.4 = 100.4 F condensing temperature.

TABLE 1-A. SUCTION LINE CAPACITIES—TONS

(For Intermediate or Low Stage Applications)

*Refrigerant and ΔT Equivalent of Friction Drop**	*Line Size Type L Copper OD*	*Suction Lines*							*Second Stage Discharge and Liquid Lines*
		Suction Temp F							
		−90	−80	−70	−60	−50	−40	−30	
	½								
	⅝								
Refrigerant 22	⅞	0.16	0.23	0.31	0.44	0.57	0.75	.094	
	1⅛	0.34	0.48	0.65	0.91	1.19	1.55	1.93	
	1⅜	0.59	0.81	1.12	1.59	2.07	2.7	3.4	
	1⅝	0.93	1.34	1.8	2.5	3.3	4.3	5.4	
	2⅛	1.9	2.8	3.7	5.2	6.8	8.9	11.1	
2 F ΔT Per 100 ft	2⅝	3.5	5.0	6.6	9.4	12.3	16.0	20.0	
Equiv. Length	3⅛	5.5	8.0	10.6	15.0	19.6	25.5	32.0	See Table 2
	3⅝	8.4	12.0	16.0	22.6	29.5	38.5	48.0	
	4⅛	12.0	17.2	22.9	32.3	42.3	55.0	68.8	
	5⅛	21.2	30.6	41.0	57.5	75.0	98.0	122.0	
	6⅛	34.8	50.0	66.5	94.0	123.0	160.0	200.0	

NOTES:

(1) Values based on 0 F saturated discharge temp. For capacities at other saturated discharge temp, multiply table value by proper line capacity multiplier (See appendix, Table A-7).

(2) For other ΔT's and Equivalent Lengths, L_e
Line Capacity (Tons)

$$= \text{Table Tons} \times \left(\frac{100}{L_e} \times \frac{\text{Actual } \Delta T \text{ Loss Desired}}{\text{Table } \Delta T \text{ Loss}}\right)^{0.55}$$

(3) For other Tons and Equivalent Lengths in a given pipe size,

$$\Delta T = \text{Table } \Delta T \times \frac{L_e}{100} \times \left(\frac{\text{Actual Tons}}{\text{Table Tons}}\right)^{1.8}$$

(4) For pressure drop (psi) corresponding to ΔT, refer to Refrigerant properties, Table 5.

(5) Size low stage (Booster) discharge lines same as equivalent single stage suction lines (see Table 1-B).

SUCTION PIPING

TABLE 1-B. SUCTION LINE CAPACITIES—TONS[1]

(For Single or High Stage Applications)

LINE SIZE (inches)		Saturated Suction Temperature—F																			
		−40				−20				0				20				40			
		Pressure Drop—Psi Per 100 ft																			
IPS	OD	½	1	2	3	½	1	2	3	½	1	2	3	½	1	2	3	½	1	2	3
	½	—	—	—	—	—	—	—	—	—	—	—	0.38	—	—	0.39	0.47	—	0.33	0.48	0.59
	⅝	—	—	0.34	0.40	—	—	0.43	0.52	—	0.38	0.55	0.69	0.34	0.48	0.71	0.87	0.41	0.60	0.87	1.09
½		—	—	0.40	0.48	—	0.36	0.49	0.61	0.31	0.45	0.63	0.78	0.40	0.56	0.80	0.96	0.49	0.70	0.99	1.21
	¾	—	0.39	0.56	0.69	0.37	0.52	0.74	0.90	0.46	0.67	0.94	1.17	0.57	0.84	1.21	1.53	0.73	1.16	1.54	1.90
	⅞	0.42	0.61	0.87	1.07	0.53	0.79	1.12	1.41	0.70	1.02	1.46	1.84	0.88	1.28	1.90	2.33	1.13	1.64	2.35	2.93
¾		0.39	0.56	0.79	0.98	0.51	0.73	1.03	1.26	0.65	0.93	1.31	1.62	0.81	1.16	1.64	2.02	0.99	1.42	2.03	2.58
	1⅛	0.83	1.19	1.73	2.16	1.09	1.56	2.29	2.81	1.40	2.02	2.90	3.77	1.78	2.61	3.86	4.72	2.28	3.28	4.80	5.83
1		0.74	1.05	1.50	1.81	0.98	1.38	1.95	2.42	1.25	1.78	2.51	3.12	1.56	2.25	3.18	3.92	1.96	2.72	4.04	4.90
	1⅜	1.45	2.11	3.05	3.89	1.90	2.76	4.14	5.03	2.50	3.61	5.20	6.40	3.16	4.61	6.76	8.20	4.04	5.69	8.35	10.3
1¼		1.53	2.20	3.18	3.86	1.98	2.84	4.05	5.00	2.53	3.74	5.15	6.37	3.21	4.50	6.43	7.97	4.04	5.69	8.05	9.94
	1⅝	2.30	3.38	4.76	5.91	2.96	4.35	6.23	7.77	3.93	5.60	8.10	9.96	4.95	7.17	10.8	12.9	6.23	8.94	13.1	16.2
1½		2.33	3.35	4.76	6.05	3.00	4.35	6.15	7.54	3.93	5.49	7.79	9.52	4.81	6.91	9.65	12.0	6.03	8.47	12.0	14.9
	2⅛	4.79	6.9	10.1	12.4	6.24	9.05	13.2	16.3	8.11	11.7	17.0	21.5	10.3	14.9	22.2	27.0	13.1	19.0	27.1	34.4
2		4.47	6.4	8.95	10.8	5.70	8.19	11.7	14.1	7.37	10.3	14.9	18.4	9.31	13.0	18.7	22.8	11.5	16.4	23.2	28.5
	2⅝	8.30	12.1	17.3	21.6	10.9	15.8	23.1	28.4	14.0	20.6	29.0	38.4	18.0	26.2	39.2	47.0	22.8	32.8	47.0	59.0
2½		7.15	10.1	14.1	17.3	9.1	12.9	18.6	23.0	11.7	16.5	24.0	29.3	14.7	20.9	29.4	38.0	18.2	26.2	37.7	46.3
	3⅛	13.2	19.4	27.7	35.2	17.7	25.2	36.8	45.8	22.6	33.0	47.7	58.3	28.9	41.8	60.0	76.6	35.7	52.9	76.2	94.4
3		12.4	17.9	25.4	31.8	16.1	23.4	34.2	40.4	21.0	29.6	42.0	52.3	26.1	38.0	53.0	64.3	32.5	45.7	65.6	81.2
	3⅝	20.0	28.9	41.3	50.8	25.8	38.1	53.8	67.7	33.7	49.2	70.4	86.2	43.2	62.7	89.0	113	54.6	78.2	114	139
	4⅛	27.4	40.0	57.6	73.6	36.6	52.7	76.3	96.4	47.7	68.5	99.5	125	59.5	87.5	128	160	77.2	112	161	199
4		25.6	36.4	50.5	63.5	32.0	47.1	65.9	81.7	42.7	59.1	84.5	107	53.7	75.5	105	129	64.7	91.7	132	162
	5⅛	50.0	73.7	107	132	66.0	96.5	138	174	89.3	124	180	222	110	159	230	286	135	199	286	357
5		46.4	65.7	92	114	59.3	85.0	121	149	77.4	109	154	189	96.5	133	191	234	118	167	234	291
	6⅛	79.6	117	169	207	105	151	215	272	136	193	284	359	171	251	373	450	218	314	457	573
6		75.0	105	149	180	96	138	195	239	124	176	249	309	156	222	312	396	192	270	397	477
8		156	222	317	392	206	291	410	515	262	373	530	656	331	470	660	820	407	579	827	1010
10		274	396	533	678	365	519	719	890	458	670	920	1120	570	817	1140	1400	718	1020	1420	1740
12		442	606	882	1060	555	810	1140	1420	717	1020	1490	1810	901	1290	1830	2250	1130	1600	2280	2810

NOTES: [1] Based on fluid flow at 105 F saturated condensing temperature
[2] "IPS" data based on Schedule 40 piping "OD" data based on Type L copper tubing

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TABLE 2. DISCHARGE AND LIQUID LINE CAPACITIES—TONS[1]

LINE SIZE[2] (Inches)		DISCHARGE LINES				LIQUID LINES	
		Temperature 200 F				To Receiver	To System
		Pressure Drop, Psi/100 ft				Velocity fpm	Pressure Drop Psi/100 ft
IPS	OD	½	1	2	3	100	2
	½	0.33	0.48	0.69	0.86	2.34	2.89
	⅝	0.59	0.88	1.27	1.63	3.78	5.48
½		0.71	1.00	1.40	1.71	3.81	4.65
	¾	1.05	1.53	2.22	2.74	5.55	9.20
	⅞	1.64	2.36	3.42	4.32	7.85	14.3
¾		1.50	2.09	3.00	3.82	7.05	10.3
	1⅛	3.29	4.71	6.91	8.64	13.4	29.2
1		2.82	4.09	5.75	6.98	11.7	20.2
	1⅜	5.71	8.37	12.1	15.1	20.4	51.5
1¼		5.75	8.21	11.6	13.8	20.9	44.1
	1⅝	8.97	13.1	19.0	23.6	28.9	83.0
1½		8.64	12.4	17.2	21.6	28.8	66.4
	2⅛	19.3	27.2	40.5	49.8	50.4	168
2		16.6	23.6	33.1	41.9	54.6	159
	2⅝	32.9	48.2	68.8	87.0	77.6	296
2½		26.6	39.2	53.2	65.8	77.9	248
	3⅛	53.2	77.1	111	136	111	475
3		47.2	66.4	93.7	116	120	459
	3⅝	79.0	115	165	203	150	742
	4⅛	111	163	232	291	194	984
4		95.0	133	189	232	207	911
	5⅛	199	292	419	522	303	
5		171	239	346	425	325	
	6⅛	316	459	658	823	434	
6		281	409	572	681	471	
8		588	844	1180	1440	815	
10		1020	1430	2040	2490	1280	
12		1640	2320	3300	4080	1840	

NOTES: [1] Based on fluid flow at 105 F saturated condensing temperature and 40 F saturated evaporating temperature
[2] "IPS" data based on Schedule 40 steel piping except that liquid lines 1½" and smaller are Schedule 80
"OD" data based on Type L copper tubing

VALVES AND FITTINGS K-FACTORS

TABLE 3. "K-FACTORS" (VELOCITY HEADS)[1] FOR VALVES AND FITTINGS

FERROUS VALVES AND FITTINGS[2]

LINE SIZE (Inches) IPS	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL			LONG-RADIUS ELL			TEE, LINE-FLOW			TEE, BRANCH-FLOW		
	Screwed	Flanged	Screwed	Flanged	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded
½	15	—	8.4	—	2.1	—	—	—	—	—	0.9	—	—	2.4	—	—
¾	11	—	5.7	—	1.7	—	—	0.9	—	—	0.9	—	—	2.0	—	—
1	9.3	15.5	4.3	5.0	1.4	0.43	0.46	0.73	0.40	0.32	0.9	0.26	0.43	1.8	1.0	1.37
1¼	8.4	12.8	3.5	4.0	1.3	0.40	0.42	0.60	0.37	0.29	0.9	0.24	0.36	1.7	0.90	1.31
1½	7.8	11.5	2.9	3.4	1.2	0.39	0.40	0.52	0.34	0.27	0.9	0.22	0.31	1.5	0.88	1.27
2	7.0	9.9	2.2	2.8	1.0	0.36	0.38	0.40	0.30	0.25	0.9	0.19	0.28	1.4	0.80	1.17
2½	—	9.0	—	2.5	—	0.34	0.37	—	0.27	0.24	—	0.17	0.26	—	0.75	1.13
3	—	8.3	—	2.4	—	0.33	0.36	—	0.25	0.23	—	0.16	0.24	—	0.72	1.10
4	—	7.5	—	2.3	—	0.31	0.35	—	0.22	0.22	—	0.14	0.22	—	0.68	1.05
5	—	7.0	—	2.3	—	0.30	0.34	—	0.20	0.21	—	0.13	0.19	—	0.64	1.01
6	—	6.7	—	2.3	—	0.28	0.32	—	0.18	0.20	—	0.12	0.18	—	0.60	0.98
8	—	6.2	—	2.3	—	0.27	0.31	—	0.15	0.19	—	0.10	0.15	—	0.57	0.93
10	—	6.0	—	2.3	—	0.25	0.30	—	0.14	0.18	—	0.09	0.14	—	0.52	0.90
12	—	6.0	—	2.3	—	0.25	0.29	—	0.13	0.18	—	0.08	0.13	—	0.50	0.88

NON-FERROUS VALVES AND FITTINGS[3,4,5]

LINE SIZE (Inches) OD	GLOBE VALVE	ANGLE VALVE	SHORT-RADIUS ELL	LONG-RADIUS ELL	TEE, LINE-FLOW	TEE, BRANCH-FLOW
	Flare or Sweat	Flare or Sweat	Flare or Sweat	Flare or Sweat	Flare or Sweat	Flare or Sweat
½	37	12.8	2.5	1.7	0.9	3.5
⅝	28	9.9	2.2	1.5	0.9	3.2
¾	23	7.8	2.0	1.4	0.9	3.0
⅞	19	6.7	1.9	1.3	0.9	2.8
1⅛	15.0	5.0	0.46	0.32	0.43	1.37
1⅜	13.4	4.4	0.42	0.29	0.36	1.33
1⅝	12.0	3.5	0.40	0.27	0.31	1.29
2⅛	10.4	2.9	0.38	0.25	0.28	1.19

NOTES: [1] $K = 2gh/V^2$
[2] Based on Schedule 40 pipe
[3] Based on Type L copper tubing
[4] For screwed valves and fittings, use ferrous K-Factors
[5] For OD sizes above 2⅛", use welded ferrous K-Factors

VALVES AND FITTINGS EQUIVALENT LENGTHS

TABLE 4. EQUIVALENT LENGTHS [1] OF VALVES AND FITTINGS

FERROUS VALVES AND FITTINGS[2,3]

LINE SIZE (Inches) IPS	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL			LONG-RADIUS ELL			TEE, LINE-FLOW			TEE, BRANCH-FLOW		
	Screwed	Flanged	Screwed	Flanged	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded	Screwed	Flanged	Welded
½	29	—	16	—	4.1	—	—	—	—	—	1.8	—	—	4.7	—	—
¾	31	—	16	—	4.7	—	—	2.5	—	—	2.5	—	—	5.6	—	—
1	35	57	16	19	5.3	1.6	1.8	2.8	1.5	1.2	3.4	1.0	1.6	6.8	3.8	5.2
1¼	46	69	19	22	7.1	2.2	2.3	3.3	2.0	1.6	4.9	1.3	2.0	9.2	4.9	7.1
1½	51	76	19	22	7.9	2.6	2.6	3.4	2.2	1.8	5.9	1.4	2.0	9.9	5.8	8.4
2	63	89	20	25	9.0	3.2	3.4	3.6	2.7	2.3	8.1	1.7	2.5	12.6	7.2	10.5
2½	—	101	—	28	—	3.8	4.2	—	3.0	2.7	—	1.9	2.9	—	8.4	13
3	—	123	—	36	—	4.9	5.3	—	3.7	3.4	—	2.4	3.6	—	11	16
4	—	155	—	48	—	6.2	7.2	—	4.5	4.5	—	2.9	4.5	—	14	22
5	—	190	—	63	—	8.1	9.2	—	5.4	5.7	—	3.5	5.1	—	17	27
6	—	227	—	78	—	9.5	11	—	6.1	6.8	—	4.1	6.1	—	20	33
8	—	295	—	110	—	13	15	—	7.1	9.0	—	4.7	7.1	—	27	44
10	—	370	—	142	—	16	18	—	8.7	11	—	5.6	8.7	—	32	56
12	—	465	—	173	—	19	22	—	10	14	—	6.2	10	—	39	68

NON-FERROUS VALVES AND FITTINGS[2]

LINE SIZE (Inches) OD	GLOBE VALVE		ANGLE VALVE		SHORT-RADIUS ELL		LONG-RADIUS ELL		TEE, LINE-FLOW		TEE, BRANCH-FLOW	
	Screwed	Other [4]	Screwed	Other [4]	Screwed	Other [4]	Screwed	Other [4]	Screwed	Other [4]	Screwed	Other [4]
½	40	70	21	24	4.7	4.7	—	3.2	1.9	1.7	5.1	6.6
⅝	39	72	22	25	5.4	5.7	—	3.9	2.3	2.3	6.2	8.2
¾	39	75	23	25	6.2	6.5	2.9	4.5	2.9	2.9	7.1	9.7
⅞	45	78	23	28	7.0	7.8	3.7	5.3	3.7	3.7	8.2	12
1⅛	54	87	25	29	8.1	2.7	4.2	1.9	5.2	2.5	11	8.0
1⅜	64	102	27	33	9.9	3.2	4.6	2.2	6.9	2.7	13	10
1⅝	75	115	28	34	12	3.8	5.0	2.6	8.7	3.0	14	12
2⅛	95	141	30	39	14	5.2	5.4	3.4	12	3.8	19	16
2⅝	—	159	—	44	—	6.5	—	4.2	—	4.6	—	20
3⅛	—	185	—	53	—	8.0	—	5.1	—	5.4	—	25
3⅝	—	216	—	66	—	10	—	6.3	—	6.6	—	30
4⅛	—	248	—	76	—	12	—	7.3	—	7.3	—	35
5⅛	—	292	—	96	—	14	—	8.8	—	7.9	—	42
6⅛	—	346	—	119	—	17	—	10	—	9.3	—	50

NOTES: [1] $L_e = K(D/f)$

[2] Friction factors (f) determined at "practical" Reynolds Numbers based on 40 F suction lines having pressure-drop of 1.8 psi/100 ft

[3] Based on Schedule 40 pipe

[4] Flare, sweat, flanged, etc., and based on Type L copper tubing

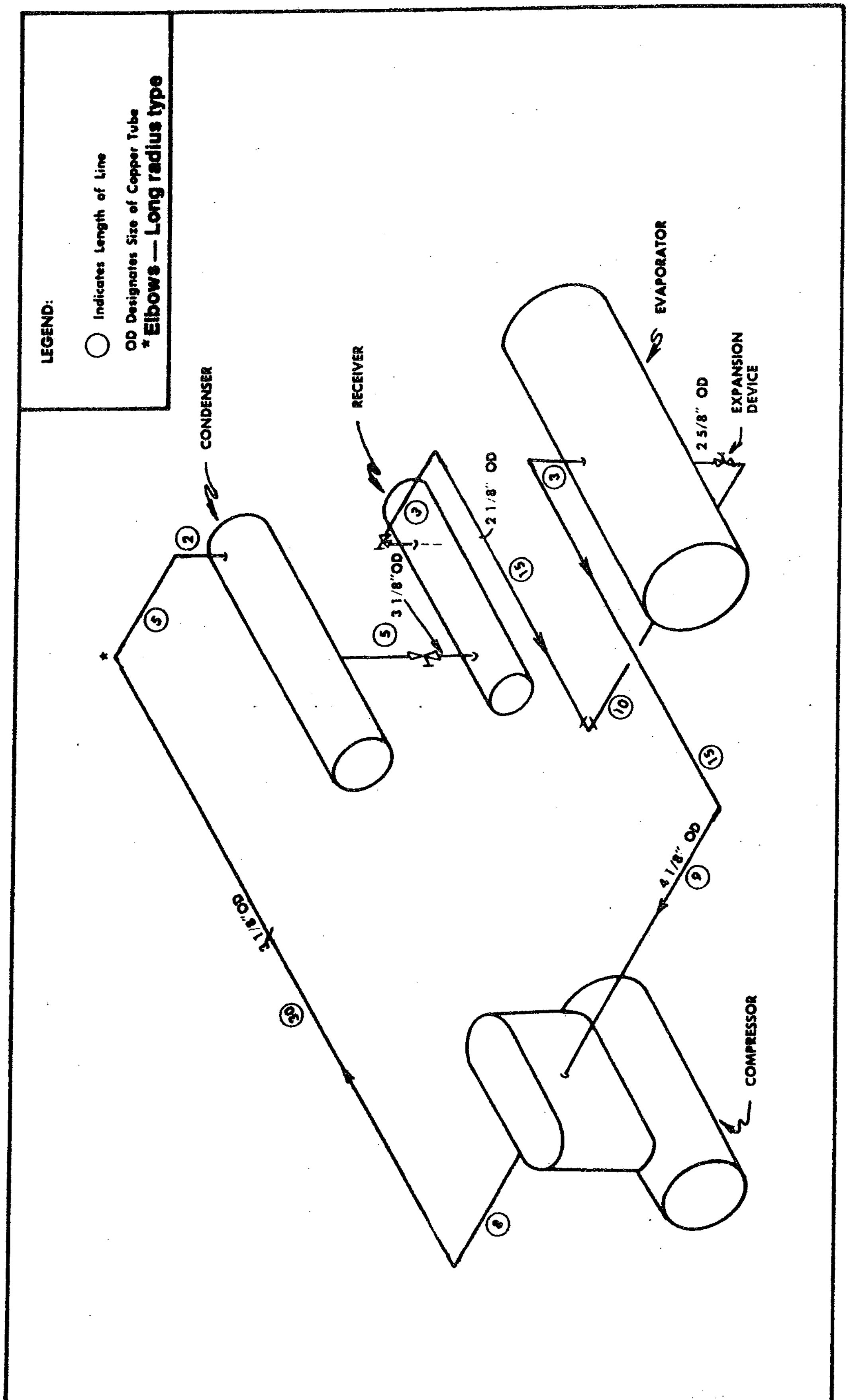

Fig. 1. SCHEMATIC PIPING LAYOUT FOR SAMPLE PROBLEM

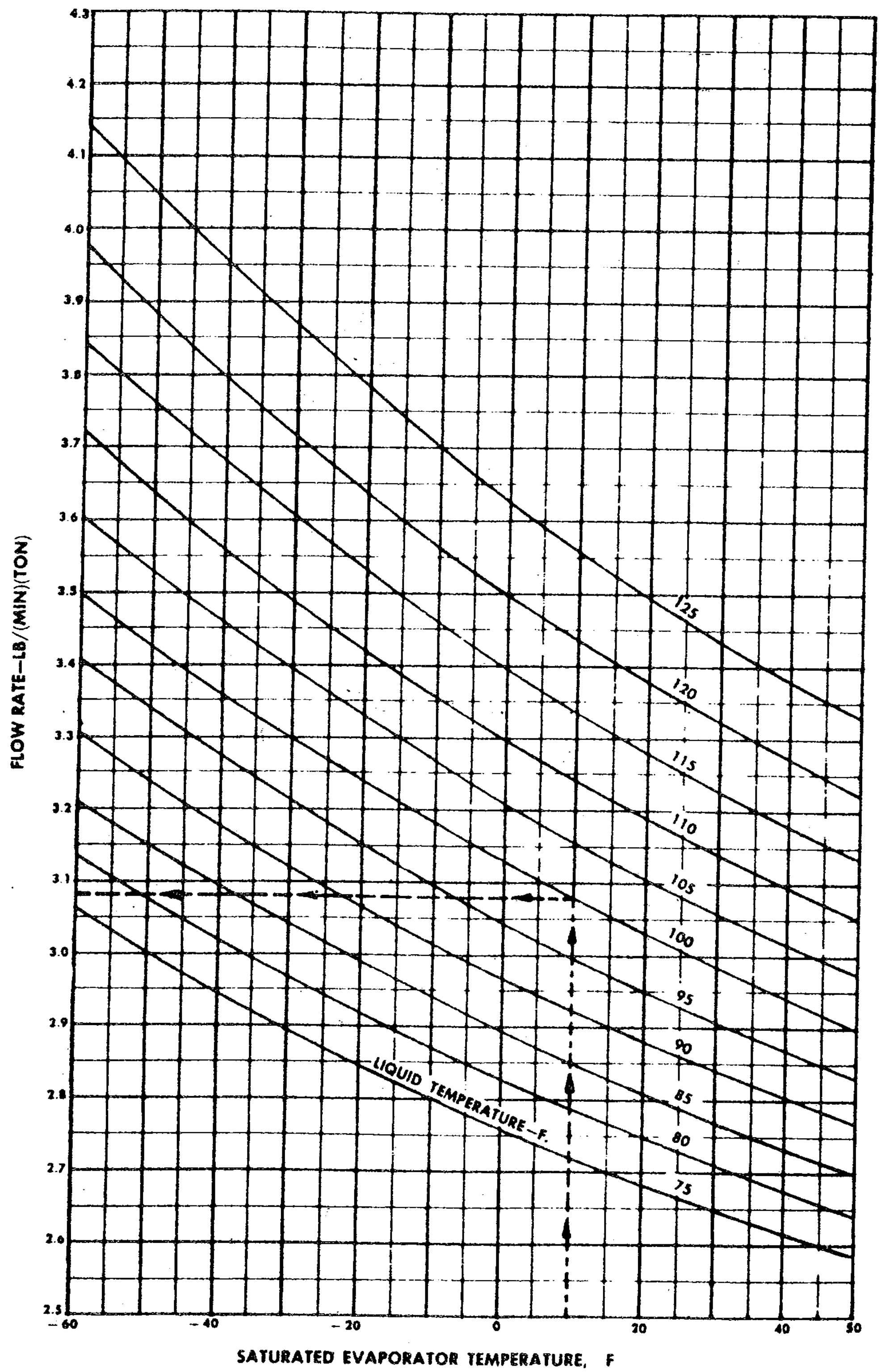

Fig. 2. FLOW RATE PER TON OF REFRIGERATION FOR REFRIGERANT 22

VILTER Since 1867

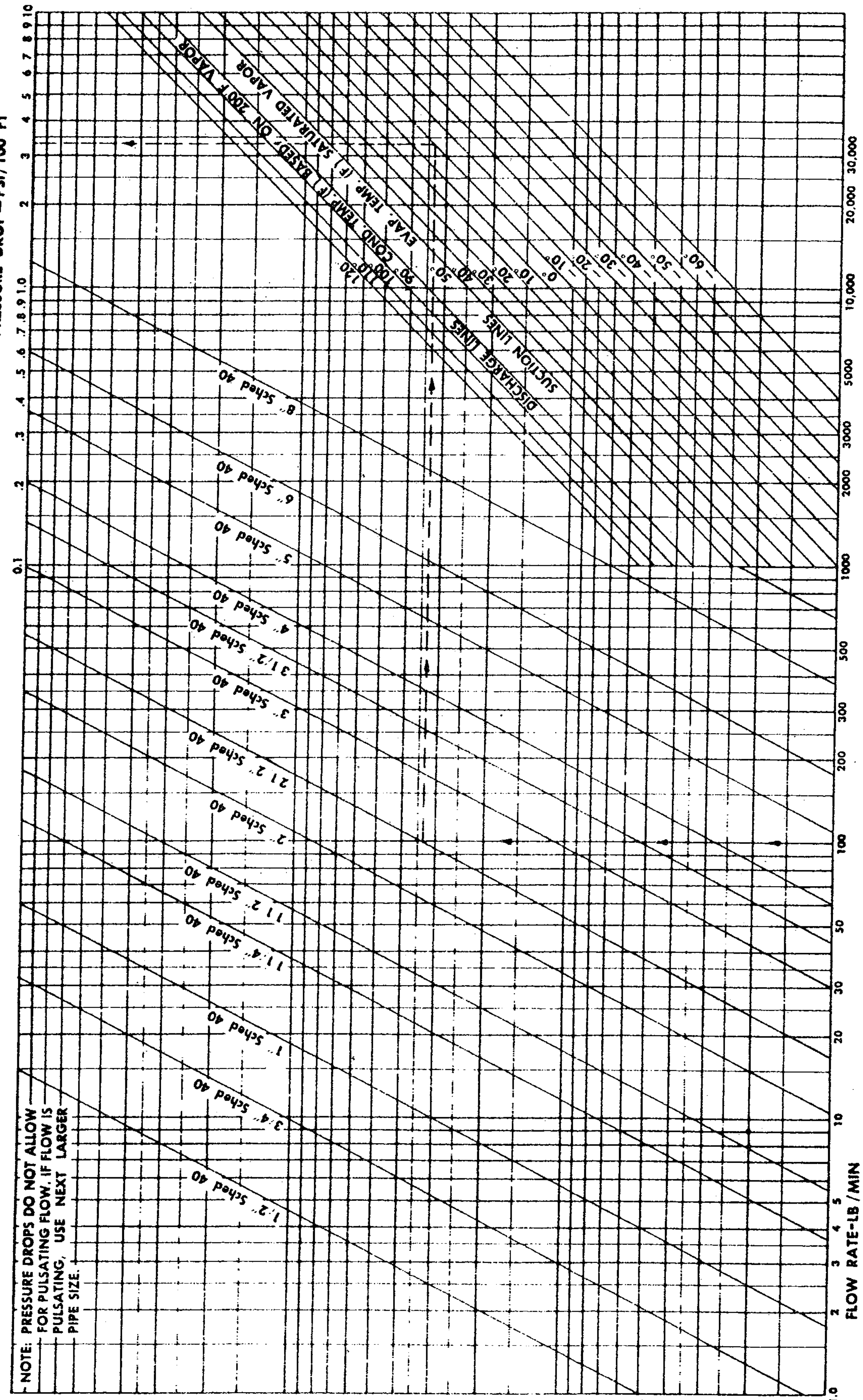

Fig. 3. PRESSURE DROP IN STEEL PIPING FOR REFRIGERANT 22 VAPOR

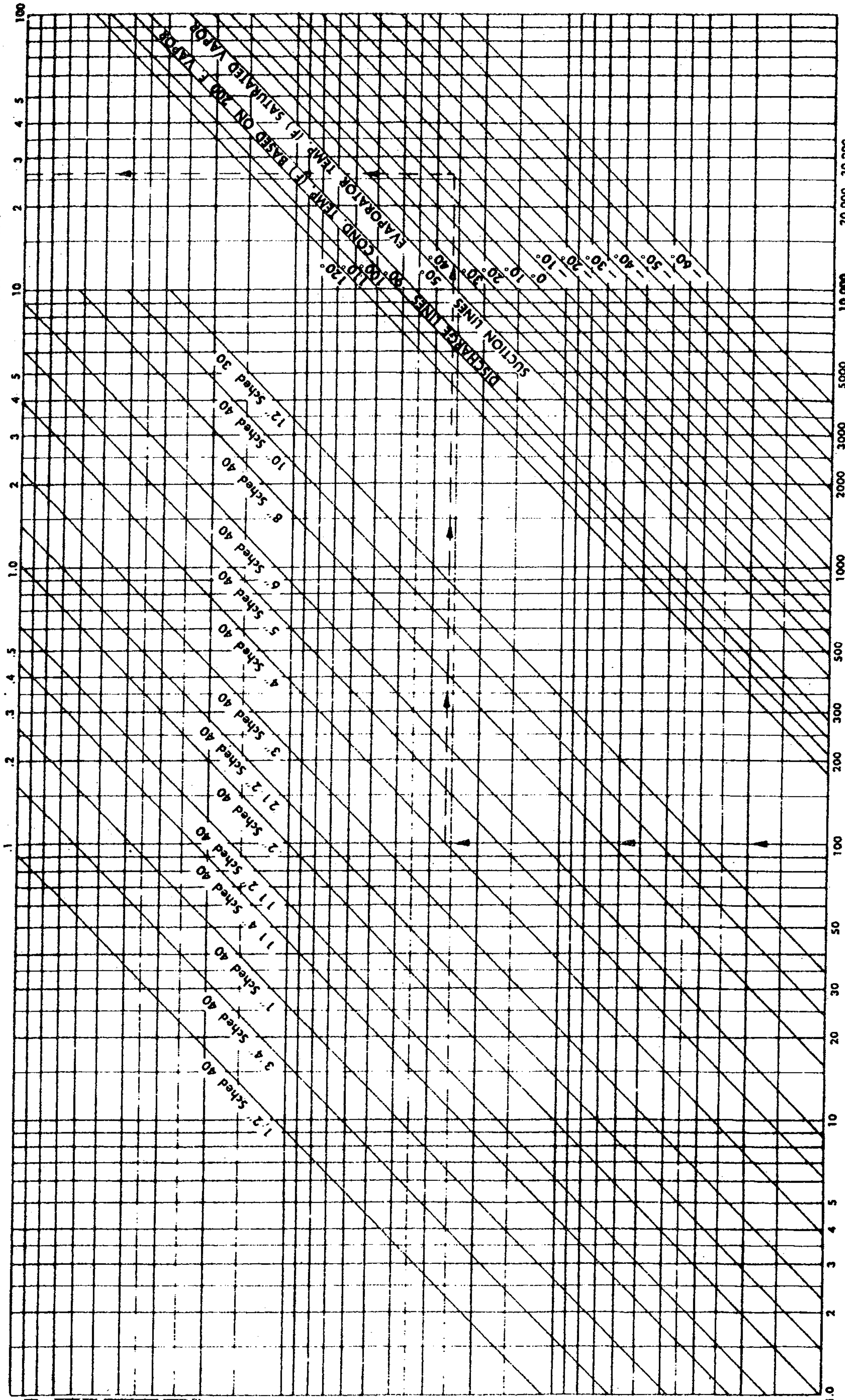

Fig. 4. VELOCITY IN STEEL PIPING FOR REFRIGERANT 22 VAPOR (SUCTION AND DISCHARGE)

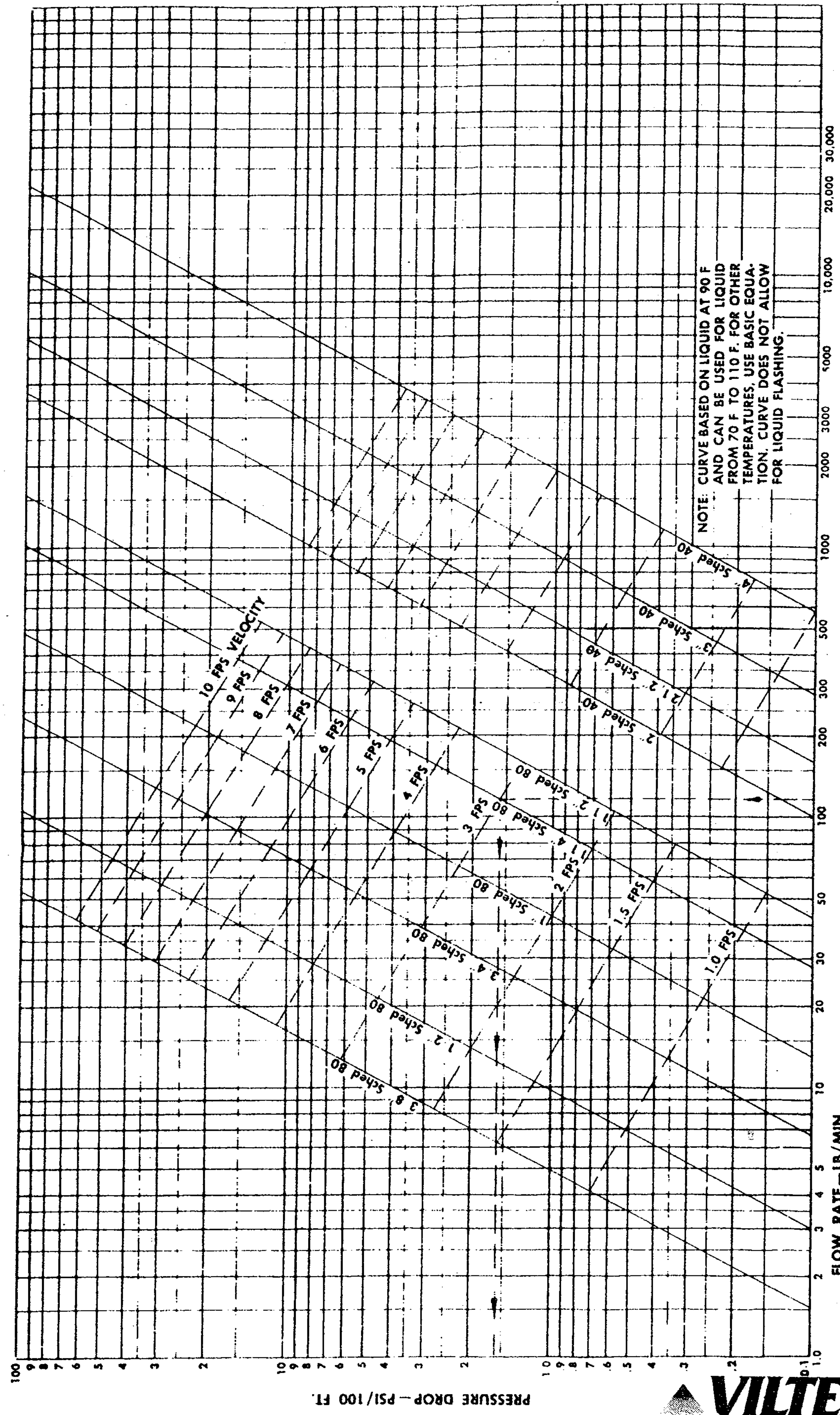

Fig. 5. VELOCITY AND PRESSURE DROP IN STEEL PIPING FOR REFRIGERANT 22 LIQUID

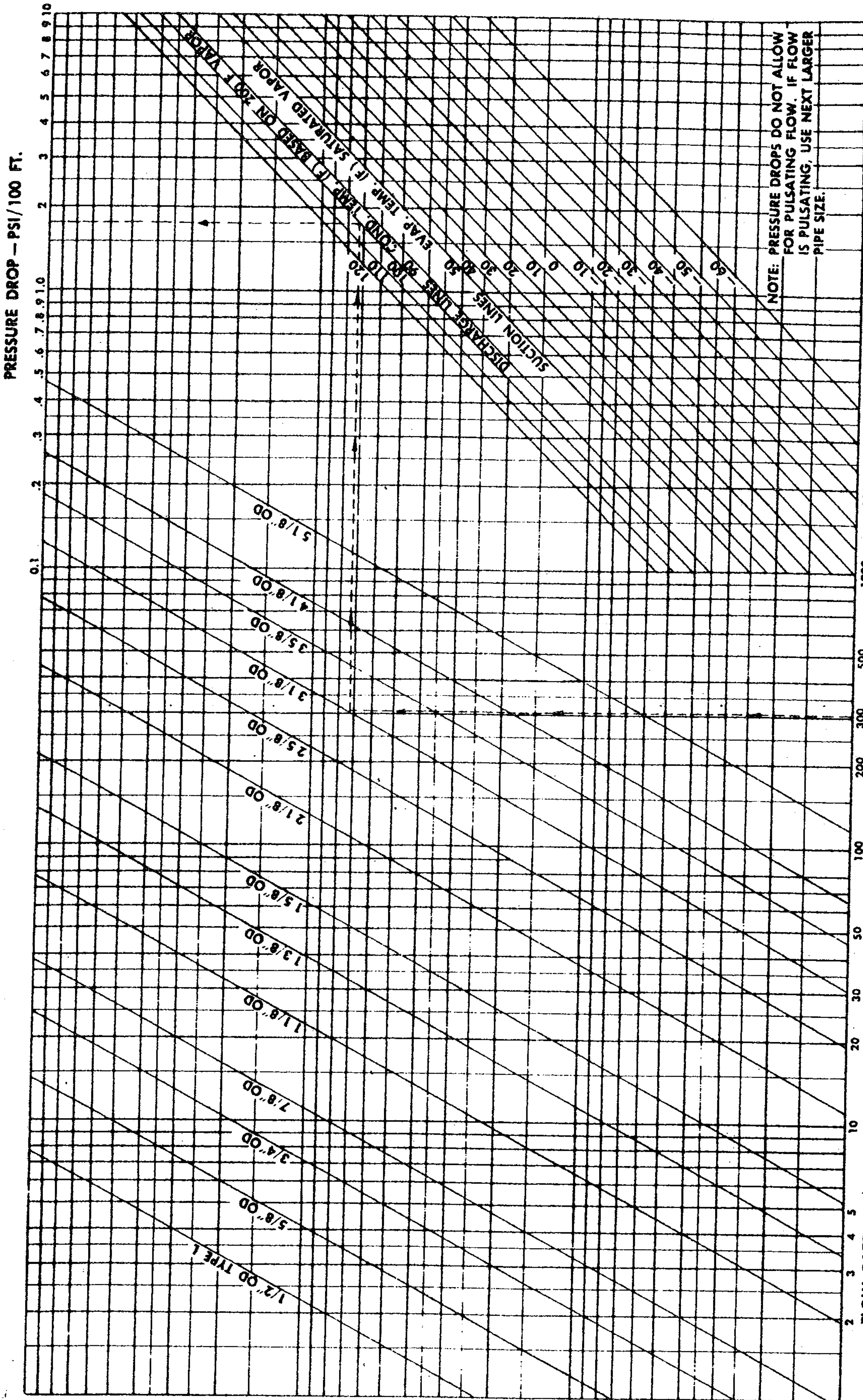

Fig. 6. PRESSURE DROP IN COPPER TUBING FOR REFRIGERANT 22 VAPOR

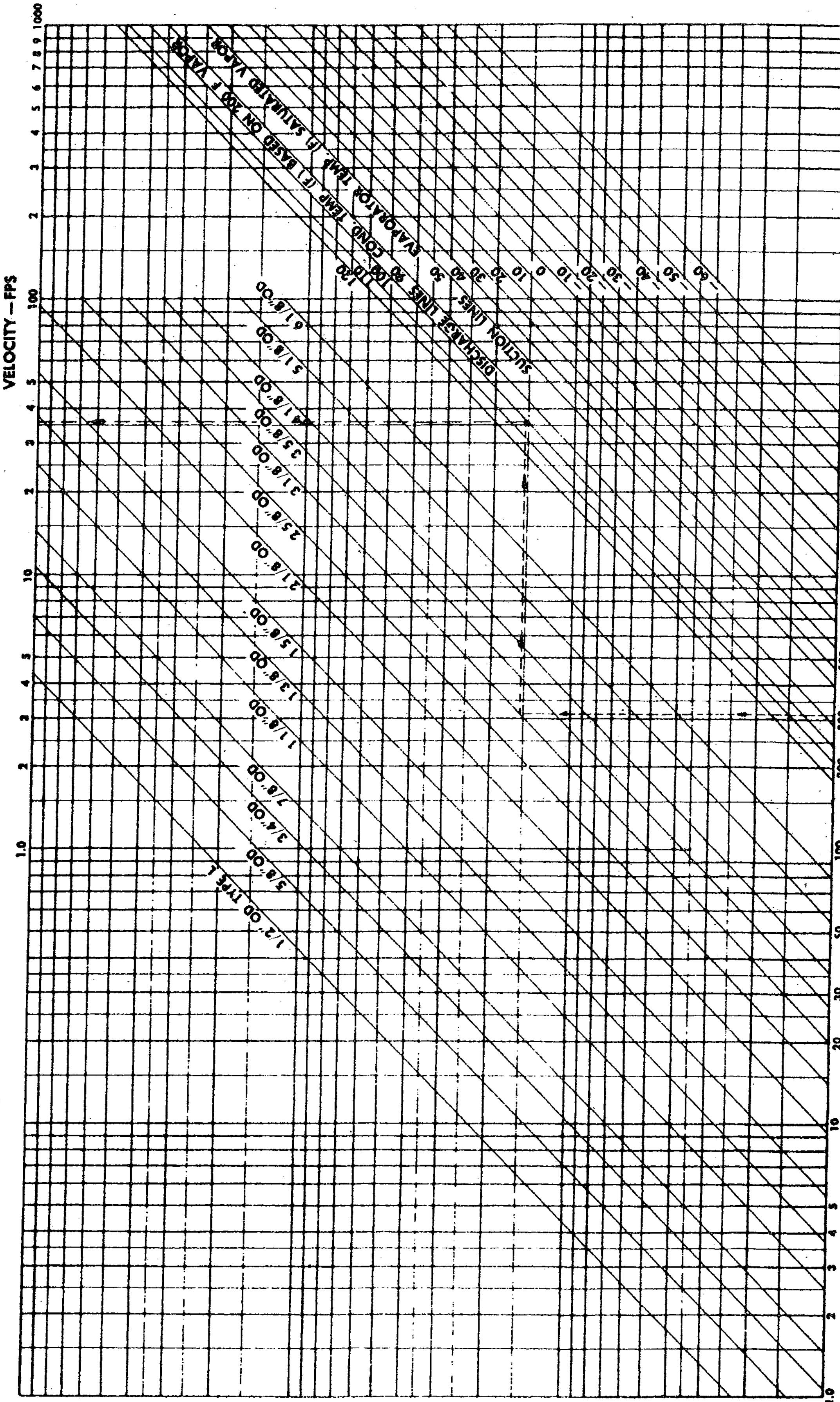

Fig. 7. VELOCITY IN COPPER TUBING FOR REFRIGERANT 22 VAPOR

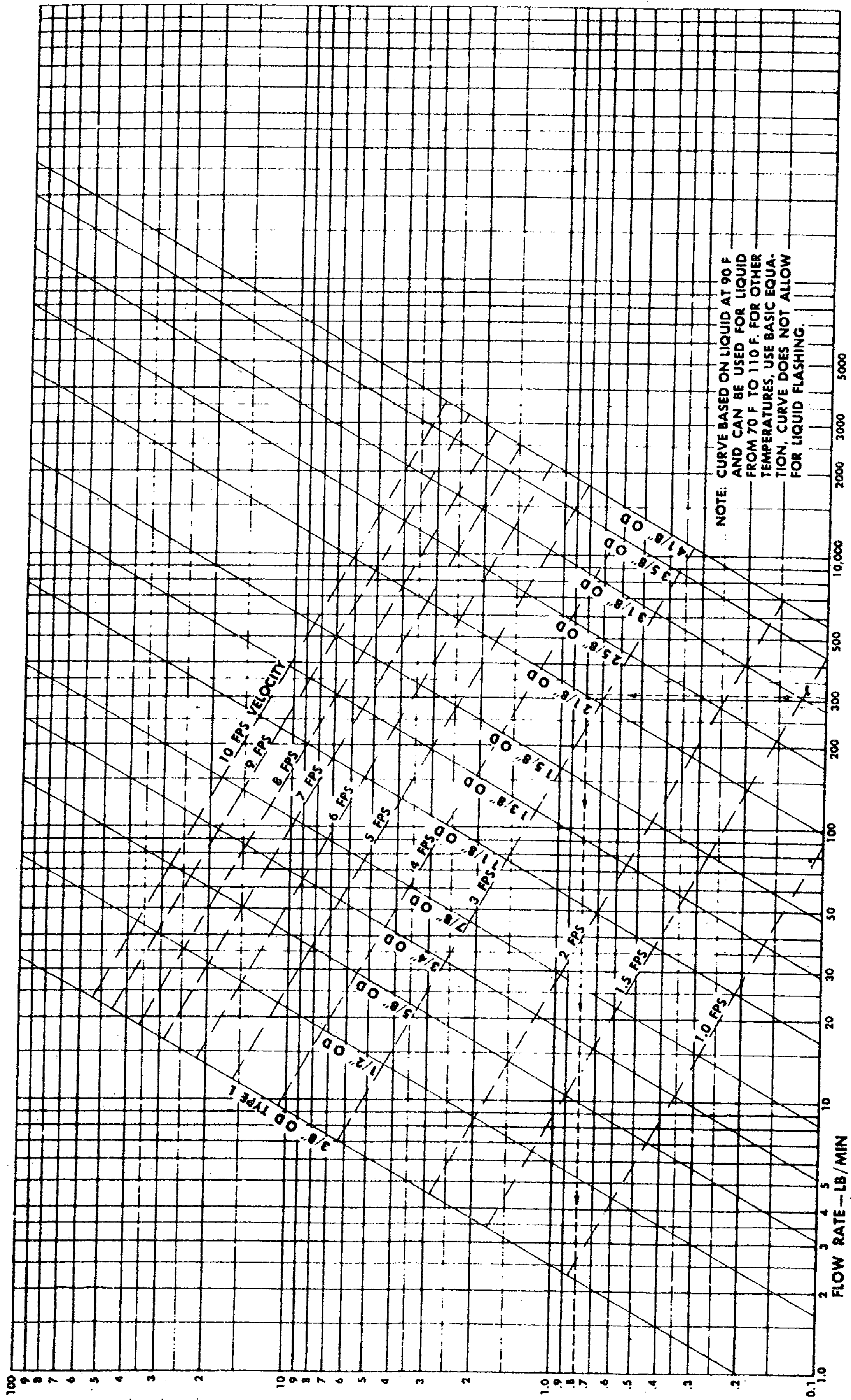

Fig. 8. VELOCITY AND PRESSURE DROP IN COPPER TUBING FOR REFRIGERANT 22 LIQUID

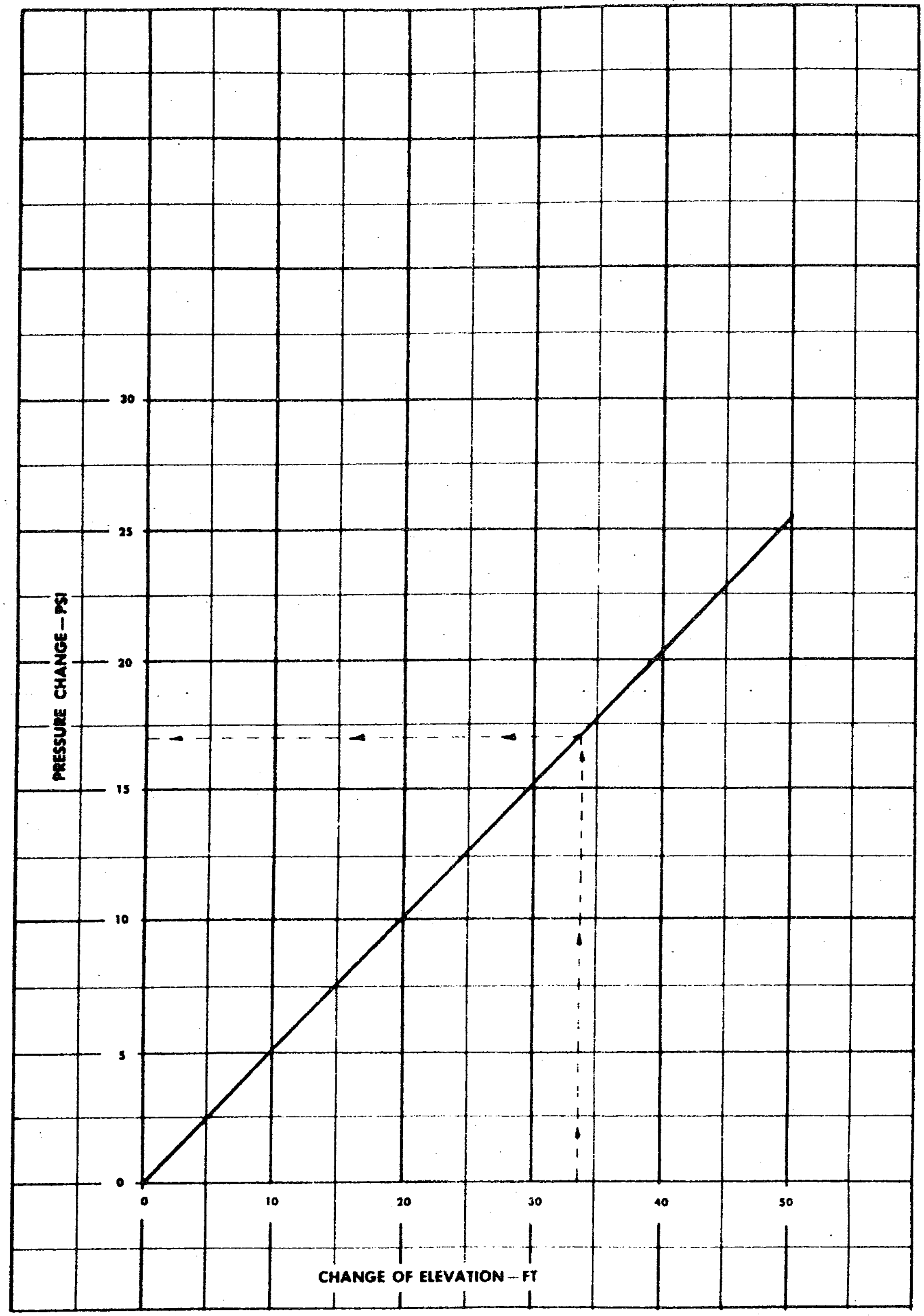

Fig. 9. RELATION OF PRESSURE-CHANGE TO ELEVATION-DIFFERENCE FOR REFRIGERANT 22 LIQUID

VILTER Since 1867

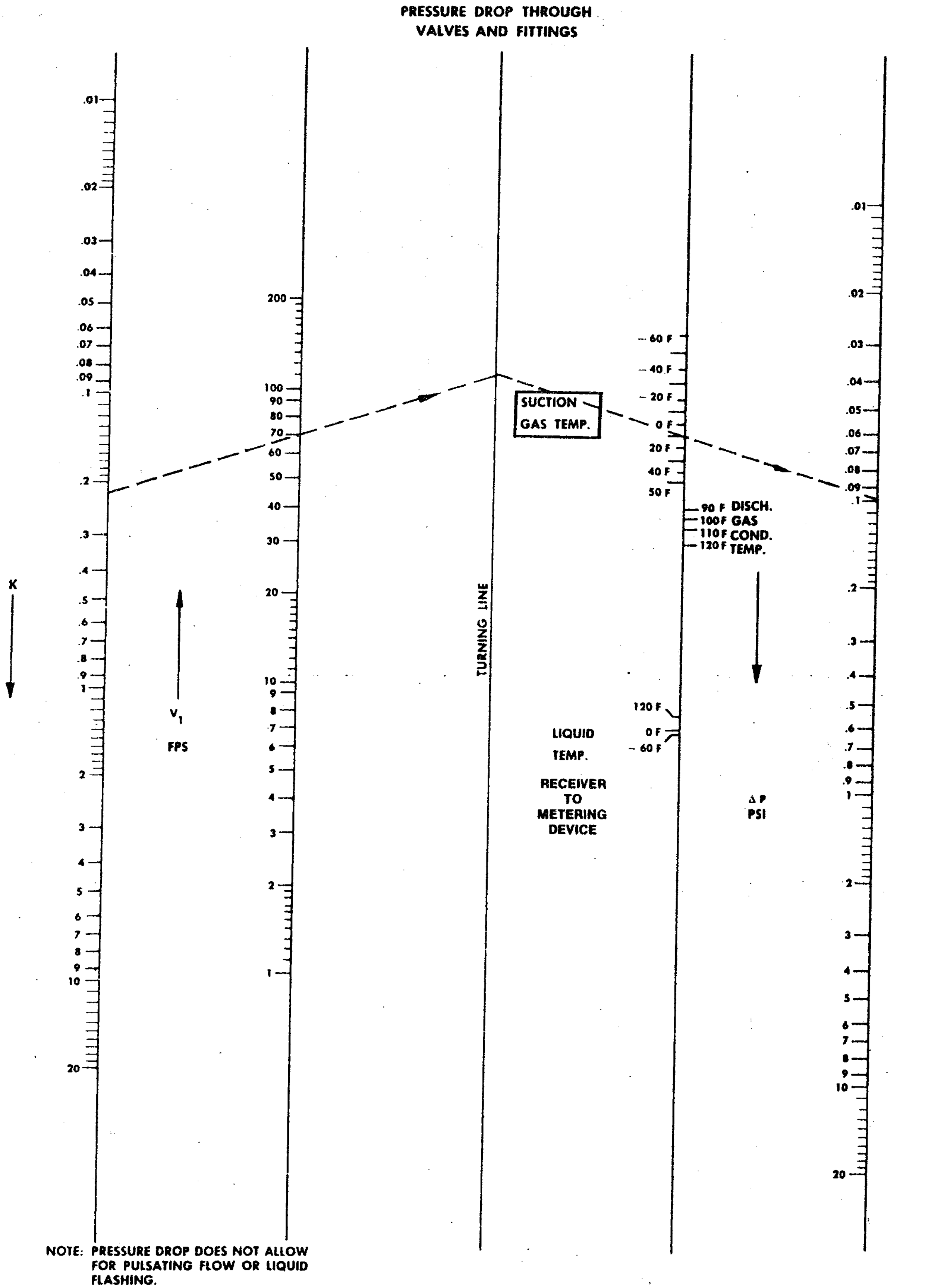

Fig. 10. PRESSURE DROP IN VALVES AND FITTINGS FOR REFRIGERANT 22

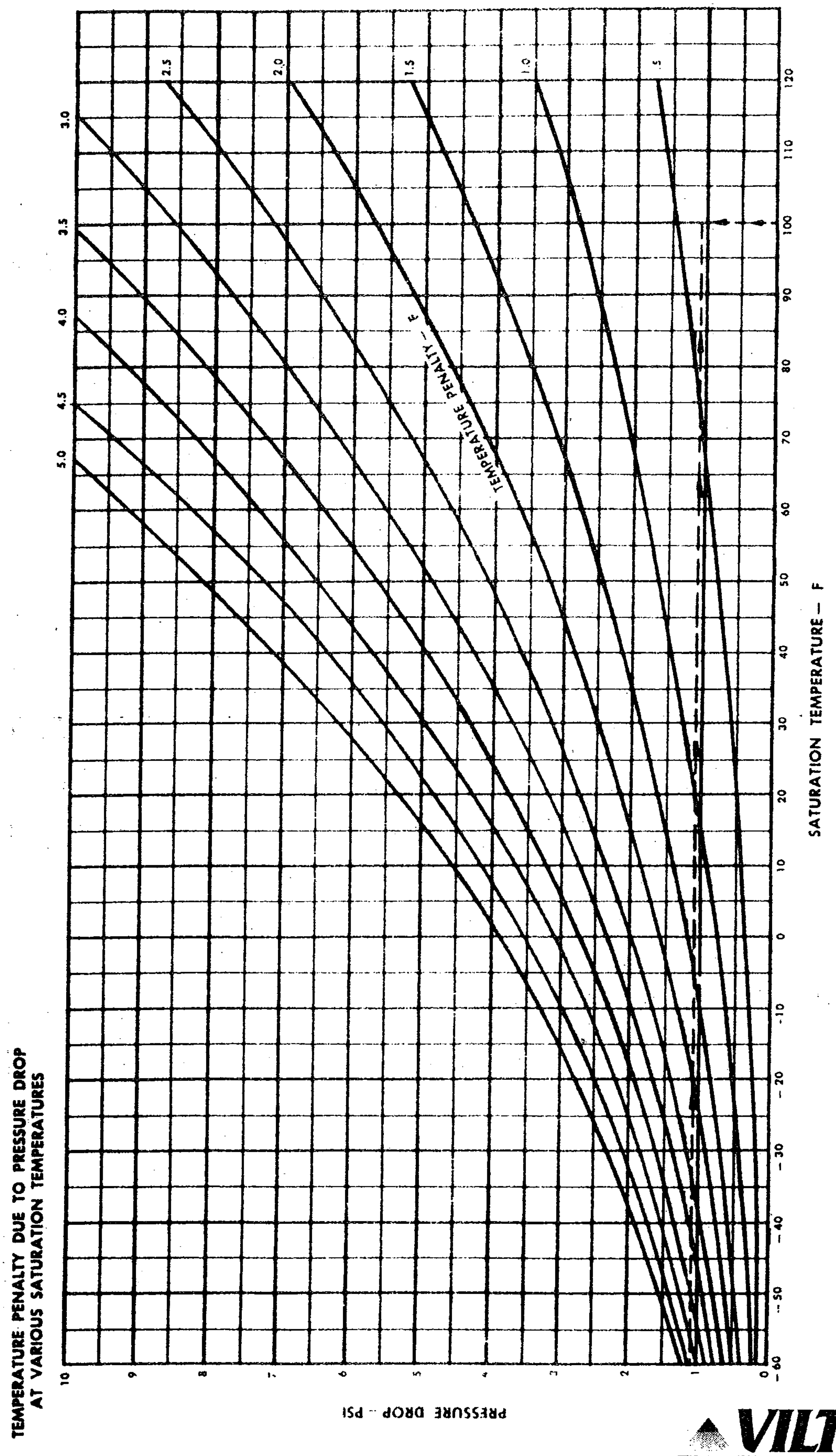

Fig. 11. TEMPERATURE PENALTY DUE TO PRESSURE DROP FOR REFRIGERANT 22

TABLE 5
THERMODYNAMIC PROPERTIES OF REFRIGERANT 22

Temp. – °F	Pressure – Lb. per Sq. In.		Volume – Cu. Ft. per Lb.		Density – Lb. per Cu. Ft.		Enthalpy Btu per Lb.			Entropy – Btu per (Lb.) (°R)		Temp. – °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
−120	1.0954	27.6910*	0.010462	32.280	95.587	0.026124	−19.185	110.205	91.020	−0.05055	0.27388	−120
−115	1.3455	27.1818*	.010511	31.594	95.137	.031652	−18.038	109.646	91.608	− .04720	.27090	−115
−110	1.6417	26.5788*	.010561	26.242	94.684	.038106	−16.886	109.082	92.196	− .04389	.26805	−110
−105	1.9903	25.8689*	.010613	21.930	94.228	.045599	−15.728	108.512	92.783	− .04060	.26533	−105
−100	2.3983	25.0383*	.010664	18.433	93.770	.054252	−14.564	107.935	93.371	− .03734	.26274	−100
−95	2.8731	24.0715*	0.010717	15.578	93.308	0.064192	−13.393	107.351	93.958	−0.03411	0.26025	−95
−90	3.4229	22.9522*	.010771	13.235	92.843	.075557	−12.216	106.759	95.544	− .03091	.25787	−90
−85	4.0562	21.6628*	.010825	11.301	92.376	.088491	−11.031	106.159	95.128	− .02773	.25560	−85
−80	4.7822	20.1846*	.010881	9.6949	91.905	.10315	− 9.838	105.548	95.710	− .02457	.25342	−80
−78	5.1007	19.5361*	.010903	9.1301	91.715	.10953	− 9.359	105.302	95.943	− .02331	.25257	−78
−76	5.4363	18.8528*	0.010926	8.6043	91.525	0.11622	− 8.878	105.053	96.175	−0.02206	0.25174	−76
−74	5.7896	18.1334*	.010949	8.1145	91.335	.12324	− 8.397	104.803	96.406	− .02081	.25092	−74
−72	6.1614	17.3766*	.010972	7.6579	91.144	.13058	− 7.914	104.551	96.637	− .01956	.25012	−72
−70	6.5522	16.5809*	.010995	7.2318	90.952	.13828	− 7.429	104.297	96.868	− .01832	.24932	−70
−68	6.9628	15.7449*	.011018	6.8339	90.760	.14633	− 6.944	104.042	97.098	− .01708	.24855	−68
−66	7.3939	14.8671*	0.011041	6.4621	90.568	0.15475	− 6.457	103.785	97.328	−0.01584	0.24778	−66
−64	7.8463	13.9460*	.011065	6.1144	90.374	.16355	− 5.968	103.525	97.557	− .01460	.24703	−64
−62	8.3208	12.9800*	.011089	5.7891	90.180	.17274	− 5.479	103.264	97.786	− .01337	.24629	−62
−60	8.8180	11.9677*	.011113	5.4844	89.986	.18233	− 4.987	103.001	98.014	− .01214	.24556	−60
−58	9.3388	10.9074*	.011137	5.1989	89.791	.19235	− 4.495	102.736	98.241	− .01092	.24484	−58
−56	9.8839	9.7975*	0.011161	4.9312	89.595	0.20279	− 4.001	102.469	98.468	−0.00969	0.24414	−56
−54	10.454	8.636*	.011186	4.6799	89.399	.21368	− 3.506	102.200	98.694	− .00847	.24345	−54
−52	11.051	7.422*	.011211	4.4440	89.202	.22502	− 3.009	101.929	98.920	− .00725	.24276	−52
−50	11.674	6.154*	.011235	4.2224	89.004	.23683	− 2.511	101.656	99.144	− .00604	.24209	−50
−48	12.324	4.829*	.011261	4.0140	88.806	.24913	− 2.012	101.381	99.369	− .00483	.24143	−48
−46	13.004	3.445*	0.011286	3.8179	88.607	0.26192	− 1.511	101.103	99.592	−0.00361	0.24078	−46
−44	13.712	2.002*	.011311	3.6334	88.407	.27523	− 1.009	100.823	99.814	− .00241	.24014	−44
−42	14.451	0.498*	.011337	3.4596	88.207	.28905	− 0.505	100.541	100.036	− .00120	.23951	−42
−40	15.222	0.526	.011363	3.2957	88.006	.30342	0.000	100.257	100.257	.00000	.23888	−40
−38	16.024	1.328	.011389	3.1412	87.805	.31835	0.506	99.971	100.477	.00120	.23827	−38
−36	16.859	2.163	0.011415	2.9954	87.602	0.33384	1.014	99.682	100.696	0.00240	0.23767	−36
−34	17.728	3.032	.011442	2.8578	87.399	.34992	1.524	99.391	100.914	.00359	.23707	−34
−32	18.633	3.937	.011469	2.7278	87.195	.36660	2.035	99.097	101.132	.00479	.23649	−32
−30	19.573	4.877	.011495	2.6049	86.991	.38389	2.547	98.801	101.348	.00598	.23591	−30
−28	20.549	5.853	.011523	2.4887	86.785	.40182	3.061	98.503	101.564	.00716	.23534	−28
−26	21.564	6.868	0.011550	2.3787	86.579	0.42040	3.576	98.202	101.778	0.00835	0.23478	−26
−24	22.617	7.921	.011578	2.2746	86.372	.43964	4.093	97.899	101.992	.00953	.23423	−24
−22	23.711	9.015	.011606	2.1760	86.165	.45956	4.611	97.593	102.204	.01072	.23369	−22
−20	24.845	10.149	.011634	2.0826	85.956	.48018	5.131	97.285	102.415	.01189	.23315	−20
−18	26.020	11.324	.011662	1.9940	85.747	.50151	5.652	96.974	102.626	.01307	.23262	−18
−16	27.239	12.543	0.011691	1.9099	85.537	0.52358	6.175	96.660	102.835	0.01425	0.23210	−16
−14	28.501	13.805	.011720	1.8302	85.326	.54640	6.699	96.344	103.043	.01542	.23159	−14
−12	29.809	15.113	.011749	1.7544	85.114	.56999	7.224	96.025	103.250	.01659	.23108	−12
−10	31.162	16.466	.011778	1.6825	84.901	.59436	7.751	95.704	103.455	.01776	.23058	−10
−8	32.563	17.867	.011808	1.6141	84.688	.61954	8.280	95.380	103.660	.01892	.23008	−8
−6	34.011	19.315	0.011838	1.5491	84.473	0.64555	8.810	95.053	103.863	0.02009	0.22960	−6
−4	35.509	20.813	.011868	1.4872	84.258	.67240	9.341	94.724	104.065	.02125	.22912	−4
−2	37.057	22.361	.011899	1.4283	84.042	.70012	9.874	94.391	104.266	.02241	.22864	−2
0	38.657	23.961	.011930	1.3723	83.825	.72872	10.409	94.056	104.465	.02357	.22817	0
2	40.309	25.613	.011961	1.3189	83.606	.75822	10.945	93.718	104.663	.02472	.22771	2
4	42.014	27.318	0.011992	1.2680	83.387	0.78865	11.483	93.378	104.860	0.02587	0.22725	4
6	43.775	29.079	.012024	1.2195	83.167	.82003	12.022	93.034	105.056	.02703	.22680	6
8	45.591	30.895	.012056	1.1732	82.946	.85237	12.562	92.688	105.250	.02818	.22636	8
10	47.464	32.768	.012088	1.1290	82.724	.88571	13.104	92.338	105.442	.02932	.22592	10
12	49.396	34.700	.012121	1.0869	82.501	.92005	13.648	91.986	105.633	.03047	.22548	12
14	51.387	36.691	0.012154	1.0466	82.276	0.95544	14.193	91.630	105.823	0.03161	0.22505	14
16	53.438	38.742	.012188	1.0082	82.051	0.99188	14.739	91.272	106.011	.03275	.22463	16
18	55.551	40.855	.012221	0.97144	81.825	1.0294	15.288	90.910	106.198	.03389	.22421	18
20	57.727	43.031	.012255	0.93631	81.597	1.0680	15.837	90.545	106.383	.03503	.22379	20
22	59.967	45.271	.012290	0.90270	81.368	1.1078	16.389	90.178	106.566	.03617	.22338	22

*Inches of mercury below one standard atmosphere.

TABLE 5 (Continued)
THERMODYNAMIC PROPERTIES OF REFRIGERANT 22

Temp. – °F	Pressure – Lb. per Sq. In.		Volume – Cu. Ft. per Lb.		Density – Lb. per Cu. Ft.		Enthalpy Btu per Lb.			Entropy – Btu per (Lb.) (°R)		Temp. – °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
24	62.272	47.576	0.012325	0.87055	81.138	1.1487	16.942	89.807	106.748	0.03730	0.22297	24
26	64.644	49.948	.012360	.83978	80.907	1.1908	17.496	89.433	106.928	.03844	.22257	26
28	67.083	52.387	.012395	.81031	80.675	1.2341	18.052	89.055	107.107	.03958	.22217	28
30	69.591	54.895	.012431	.78208	80.441	1.2786	18.609	88.674	107.284	.04070	.22178	30
32	72.169	57.473	.012468	.75503	80.207	1.3244	19.169	88.290	107.459	.04182	.22139	32
34	74.818	60.122	0.012505	0.72911	79.971	1.3715	19.729	87.903	107.632	0.04295	0.22100	34
36	77.540	62.844	.012542	.70425	79.733	1.4199	20.292	87.512	107.804	.04407	.22062	36
38	80.336	65.640	.012579	.68041	79.495	1.4697	20.856	87.118	107.974	.04520	.22024	38
40	83.206	68.510	.012618	.65753	79.255	1.5208	21.422	86.720	108.142	.04632	.21986	40
42	86.153	71.457	.012656	.63557	79.013	1.5734	21.989	86.319	108.308	.04744	.21949	42
44	89.177	74.481	0.012695	0.61448	78.770	1.6274	22.558	85.914	108.472	0.04855	0.21912	44
46	92.280	77.584	.012735	.59422	78.526	1.6829	23.129	85.506	108.634	.04967	.21876	46
48	95.463	80.767	.012775	.57476	78.280	1.7398	23.701	85.094	108.795	.05079	.21839	48
50	98.727	84.031	.012815	.55606	78.033	1.7984	24.275	84.678	108.953	.05190	.21803	50
52	102.07	87.38	.012856	.53808	77.784	1.8585	24.851	84.258	109.109	.05301	.21768	52
54	105.50	90.81	0.012898	0.52078	77.534	1.9202	25.429	83.834	109.263	0.05412	0.21732	54
56	109.02	94.32	.012940	.50414	77.282	1.9836	26.008	83.407	109.415	.05523	.21697	56
58	112.62	97.93	.012982	.48813	77.028	2.0486	26.589	82.975	109.564	.05634	.21662	58
60	116.31	101.62	.013025	.47272	76.773	2.1154	27.172	82.540	109.712	.05745	.21627	60
62	120.09	105.39	.013069	.45788	76.515	2.1840	27.757	82.100	109.857	.05855	.21592	62
64	123.96	109.26	0.013114	0.44358	76.257	2.2544	28.344	81.656	110.000	0.05966	0.21558	64
66	127.92	113.22	.013159	.42981	75.996	2.3266	28.932	81.208	110.140	.06076	.21524	66
68	131.97	117.28	.013204	.41653	75.733	2.4008	29.523	80.755	110.278	.06186	.21490	68
70	136.12	121.43	.013251	.40373	75.469	2.4769	30.116	80.298	110.414	.06296	.21456	70
72	140.37	125.67	.013297	.39139	75.202	2.5550	30.710	79.836	110.547	.06406	.21422	72
74	144.71	130.01	0.013345	0.37949	74.934	2.6351	31.307	79.370	110.677	0.06516	0.21388	74
76	149.15	134.45	.013393	.36800	74.664	2.7174	31.906	78.899	110.805	.06626	.21355	76
78	153.69	138.99	.013442	.35691	74.391	2.8018	32.506	78.423	110.930	.06736	.21321	78
80	158.33	143.63	.013492	.34621	74.116	2.8885	33.109	77.943	111.052	.06846	.21288	80
82	163.07	148.37	.013543	.33587	73.839	2.9774	33.714	77.457	111.171	.06956	.21255	82
84	167.92	153.22	0.013594	0.32588	73.560	3.0686	34.322	76.966	111.288	0.07065	0.21222	84
86	172.87	158.17	.013647	.31623	73.278	3.1622	34.931	76.470	111.401	.07175	.21188	86
88	177.93	163.23	.013700	.30690	72.994	3.2583	35.543	75.968	111.512	.07285	.21155	88
90	183.09	168.40	.013754	.29789	72.708	3.3570	36.158	75.461	111.619	.07394	.21122	90
92	188.37	173.67	.013809	.28917	72.419	3.4582	36.774	74.949	111.723	.07504	.21089	92
94	193.76	179.06	0.013864	0.28073	72.127	3.5621	37.394	74.430	111.824	0.07613	0.21056	94
96	199.26	184.56	.013921	.27257	71.833	3.6688	38.016	73.905	111.921	.07723	.21023	96
98	204.87	190.18	.013979	.26467	71.536	3.7783	38.640	73.375	112.015	.07832	.20989	98
100	210.60	195.91	.014038	.25702	71.236	3.8907	39.267	72.838	112.105	.07942	.20956	100
102	216.45	201.76	.014098	.24962	70.933	4.0062	39.897	72.294	112.192	.08052	.20923	102
104	222.42	207.72	0.014159	0.24244	70.626	4.1247	40.530	71.744	112.274	0.08161	0.20889	104
106	228.50	213.81	.014221	.23549	70.317	4.2465	41.166	71.187	112.353	.08271	.20855	106
108	234.71	220.02	.014285	.22875	70.005	4.3715	41.804	70.623	112.427	.08381	.20821	108
110	241.04	226.35	.014350	.22222	69.689	4.5000	42.446	70.052	112.498	0.08491	.20787	110
112	247.50	232.80	.014416	.21589	69.369	4.6321	43.091	69.473	112.564	.08601	.20753	112
114	254.08	239.38	0.014483	0.20974	69.046	4.7677	43.739	68.886	112.626	0.08711	0.20718	114
116	260.79	246.10	.014552	.20378	68.719	4.9072	44.391	68.291	112.682	.08821	.20684	116
118	267.63	252.94	.014622	.19800	68.388	5.0506	45.046	67.688	112.735	.08932	.20649	118
120	274.60	259.91	.014694	.19238	68.054	5.1981	45.705	67.077	112.782	.09042	.20613	120
122	281.71	267.01	.014768	.18692	67.714	5.3498	46.368	66.456	112.824	.09153	.20578	122
124	288.95	274.25	0.014843	0.18163	67.371	5.5058	47.034	65.826	112.860	0.09264	0.20542	124
126	296.33	281.63	.014920	.17648	67.023	5.6665	47.705	65.186	112.891	.09375	.20505	126
128	303.84	289.14	.014999	.17147	66.670	5.8319	48.380	64.537	112.917	.09487	.20468	128
130	311.50	296.80	.015080	.16661	66.312	6.0022	49.059	63.877	112.936	.09598	.20431	130
132	319.29	304.60	.015163	.16187	65.949	6.1777	49.743	63.206	112.949	.09711	.20393	132
134	327.23	312.54	0.015248	0.15727	65.581	6.3585	50.432	62.523	112.955	0.09823	0.20354	134
136	335.32	320.63	.015336	.15279	65.207	6.5450	51.125	61.829	112.954	.09936	.20315	136
138	343.56	328.86	.015426	.14843	64.826	6.7374	51.824	61.123	112.947	.10049	.20275	138
140	351.94	337.25	.015518	.14418	64.440	6.9360	52.528	60.403	112.931	.10163	.20235	140

TABLE 6
REFRIGERANT 22 FLOW RATE
POUNDS/MINUTE/TON REFRIGERATION

Temp. of Suction (°F)	Corres. Suction Pressure (Psig)	Booster Discharge Temperature (°F)								Condensing Discharge Temperature (°F)						
		−20	−10	0	10	20	30	40	50	60	70	80	90	100	110	120
		Corresponding Discharge Pressure (Psig)								Corresponding Discharge Pressure (Psig)						
		10.3	16.6	24.1	32.9	43.3	55.2	69.0	84.7	102.5	122.5	145.0	170.1	197.9	228.7	262.6
−70	16.55*	2.25	2.32	2.39	2.47	2.56	2.66	2.77	2.90	2.90						
−60	11.89*	2.22	2.29	2.36	2.44	2.52	2.62	2.73	2.85	2.85	2.98					
−50	6.03*	2.19	2.26	2.32	2.40	2.48	2.58	2.68	2.80	2.80	2.93	3.08				
−40	0.61	2.16	2.22	2.29	2.37	2.45	2.54	2.64	2.75	2.75	2.88	3.02	3.18			
−30	5.02	2.13	2.20	2.26	2.34	2.41	2.50	2.60	2.71	2.71	2.83	2.97	3.12	3.30		
−20	10.30		2.17	2.24	2.30	2.38	2.47	2.56	2.67	2.67	2.78	2.92	3.07	3.24	3.42	
−10	16.60			2.20	2.27	2.35	2.43	2.52	2.63	2.63	2.74	2.87	3.02	3.18	3.36	3.57
0	24.10				2.24	2.32	2.40	2.49	2.59	2.59	2.70	2.83	2.97	3.12	3.29	3.50
10	32.90					2.29	2.37	2.46	2.56	2.56	2.66	2.78	2.92	3.07	3.24	3.43
20	43.30						2.34	2.43	2.52	2.52	2.63	2.75	2.88	3.02	3.18	3.37
30	55.20							2.40	2.49	2.49	2.59	2.71	2.83	2.98	3.14	3.32
40	69.00								2.46	2.46	2.56	2.67	2.80	2.94	3.09	3.26
50	84.70									2.43	2.53	2.64	2.76	2.90	3.05	3.22

*Inches mercury below one atmosphere.

TABLE 7
REFRIGERANT 22 FLOW RATE
CUBIC FEET/MINUTE/TON REFRIGERATION

Temp. of Suction (°F)	Corres. Suction Pressure (Psig)	Booster Discharge Temperature (°F)								Condensing Discharge Temperature (°F)						
		−20	−10	0	10	20	30	40	50	60	70	80	90	100	110	120
		Corresponding Discharge Pressure (Psig)								Corresponding Discharge Pressure (Psig)						
		10.3	16.6	24.1	32.9	43.3	55.2	69.0	84.7	102.5	122.5	145.0	170.1	197.9	228.7	262.6
−70	16.55*	16.2	16.7	17.2	17.8	18.4	19.1	19.9	20.8	20.8						
−60	11.89*	12.1	12.5	12.9	13.3	13.7	14.3	14.9	15.5	15.5	16.2					
−50	6.03*	9.18	9.48	9.73	10.1	10.4	10.9	11.2	11.7	11.7	12.3	12.9				
−40	0.61	7.08	7.28	7.52	7.77	8.04	8.33	8.66	9.02	9.02	9.45	9.90	10.4			
−30	5.02	5.52	5.70	5.85	6.06	6.25	6.48	6.73	7.02	7.02	7.33	7.70	8.08	8.55		
−20	10.30		4.50	4.64	4.77	4.93	5.12	5.31	5.54	5.54	5.77	6.06	6.37	6.72	7.09	
−10	16.60			3.70	3.82	3.95	4.09	4.23	4.42	4.42	4.61	4.82	5.08	5.35	5.65	6.00
0	24.10				3.08	3.19	3.30	3.42	3.56	3.56	3.71	3.89	4.08	4.28	4.52	4.81
10	32.90					2.59	2.68	2.78	2.89	2.89	3.01	3.14	3.30	3.47	3.66	3.88
20	43.30						2.19	2.28	2.36	2.36	2.46	2.58	2.70	2.83	2.98	3.16
30	55.20							1.88	1.95	1.95	2.02	2.12	2.21	2.33	2.46	2.60
40	69.00								1.61	1.61	1.68	1.75	1.84	1.93	2.03	2.14
50	84.70									1.35	1.40	1.46	1.53	1.61	1.69	1.78

* Inches of mercury below one atmosphere

Figures to left of heavy line are based on booster flow-rate of two-stage system with liquid subcooling to within 10°F of intermediate. Figures to right of heavy line are based on single stage.

REFRIGERANT 502 PIPING DATA

Piping data for Refrigerant R-502 is available from several manufacturers. However, since the majority of the information in this section was taken from a Du Pont company bulletin, no changes have been made in changing the "Freon" 502 Du Pont trademark reference to the generic R-502 nomenclature.

Data for the proper sizing of "Freon" 502 refrigerant piping are shown in Table I and in chart form in Figures 1 through 5. The diagrams are not intended to set standards, but to provide pressure drop and velocity data which can assist the design engineer in determining proper pipe sizing for individual applications.

Table 1 gives "Freon" 502 line capacities for single or high stage applications. Values are based on 105°F. condensing temperatures. Multipliers for other condensing temperatures appear under Table 1, footnote number (3).

Basis of Charts

The pressure-drop charts given here are based on calculations using the commonly accepted Darcy-Weisbach formula and Darcy friction factors from the Moody Chart. The calculations and presentation are consistent with those used in the other refrigerant sections of this manual. Tables of "K-factors", equivalent lengths of valves and fittings, and piping dimensions in the other refrigerant sections will also apply to "Freon" 502 calculations.

Refrigerant Flow

For the determination of velocity and pressure drop in refrigerant piping it is necessary to know the refrigerant flow rate.

Figure 1 provides a method for determining refrigerant flow in pounds per minute per ton of refrigeration. It is based on no liquid subcooling and no superheating of the vapor at evaporator conditions. Enter the chart at the appropriate evaporating temperature and move vertically to the design condensing temperature. At this intersection read the refrigerant flow in pounds per minute per ton. Multiply the nominal capacity in tons by this factor and an estimate of pounds flow per minute is obtained. This flow rate is then used to enter the other charts. Refrigerant flow rates calculated by other means and used with the charts in this bulletin may result in incorrect line sizes.

Factors for Selecting Suction Vapor Line Sizes

Compressor suction vapor lines must be sized with the best compromise between minimum pressure drop and adequate velocity for oil return. Pressure drop in these return gas lines will result in loss in compressor or system capacity. On the other hand, systems designed only for minimum pressure drop in the return lines may have velocities too low for the adequate return of oil. Experience to date indicates that the velocity in "Freon" 502 refrigerant return gas lines from systems utilizing suction line heat exchangers should be at least equal to that recommended for Refrigerant 22 refrigerant systems. Adequate oil return has been obtained from all systems designed for Refrigerant 22 and converted to "Freon" 502. In most cases these conversions resulted in slightly higher return gas velocities for "Freon" 502. Care must be exercised in selecting suction line heat exchangers and suction line filters as the higher density of the returning "Freon" 502 gas may result in excessive pressure drop relative to Refrigerant 22.

Factors for Selecting Discharge Vapor Line Sizes

Pressure drop in compressor discharge lines also affects compressor capacity but to a lesser degree than pressure drop in suction lines. Oil movement through these lines is not normally a consideration in their selection. Engineering and economic considerations used in selecting Refrigerant 22 discharge pipe sizes apply to systems utilizing "Freon" 502. In general, it is suggested that discharge lines for "Freon" 502 systems be the same as for Refrigerant 22 systems of equivalent capacity.

Factors for Selecting Liquid Line Sizes

Pressure drop in liquid lines does not adversely affect system capacity or power unless flashing occurs in these lines. The volume flow rate of "Freon" 502 in liquid lines will be from 50% to 100% greater than that in an equivalent Refrigerant 22 system. Figure 4 provides the pressure drop and velocity data for the flow of "Freon" 502 through liquid lines. Pipe size selection for liquid lines between condenser and receiver, and between receiver and evaporator should be based on the same velocity and pressure drop considerations as used for Refrigerant 22. In some instances, this may result in larger liquid lines for "Freon" 502.

How to Use the Charts

1. Determine the flow rate in pounds per minute from Figure 1. With Figure 1 use saturated evaporator temperature and liquid temperature, disregarding any suction superheating. Total flow equals lb/ (min) (ton) times system tonnage.
2. Determine pressure drop, psi per 100 ft, in copper tubing for the suction and discharge lines for the total flow, from Figure 2. The pressure drop through any size line is found by projecting vertically, from the flow rate on the lower scale, to the intersection with the line size to be used. At this intersection, follow the horizontal line to the right and intersect with the vapor temperature line, and then project upward to the top scale to read the pressure drop. Prorate the pressure drop according to the actual length using the straight pipe length plus the equivalent length of valves and fittings (equivalent lengths are listed on pages 10, 30, and 52 of this Manual).
3. Using the total refrigerant flow, lb per min, determine the velocity for suction and discharge lines in Figure 3. This chart is read in the same manner as Figure 2.
4. For liquid lines, determine the pressure drop and velocity, using Figure 4. The liquid-flow rate in lb/min, as read on the lower scale, is projected upward to the intersection of a given pipe size. The velocity in ft per sec can be read at this point and a pressure drop in psi per 100 ft equivalent length can be read on the ordinate scale. (The total flow for liquid lines is the same as that in the vapor lines as found in Step 1.) Prorate the pressure drop, using the ratio of actual pipe length versus 100 ft. Valves and fittings in liquid lines are treated in the same manner as outlined in Step 2 for vapor lines.
5. Figure 5 is used to determine the pressure drop (or gain) in a liquid line when there is an appreciable change in elevation between the condenser or receiver and the evaporator.

TABLE 1
REFRIGERANT LINE CAPACITIES FOR REFRIGERANT 502 (FOR SINGLE OR HIGH STAGE APPLICATIONS)

(Tons of Refrigeration Resulting in a Line Friction Drop (ΔP in psi) per 100 Ft Equivalent Pipe Length as Shown, with Corresponding (ΔT) Change in Saturation Temp.)

Line Size Type L Copper, OD	Suction Lines ΔT = 2 F — Suction Temp, F: −60 ΔP = 0.31	−40 ΔP = 0.94	−20 ΔP = 1.33	0 ΔP = 1.83	20 ΔP = 2.43	40 ΔP = 3.14	Discharge Lines ΔT = 1.0 F ΔP = 3.15 — Saturated Suction Temp: −40	0	40	Liquid Lines* Line Size Type L Copper, OD	Velocity = 100 fpm	ΔT = 1 F ΔP = 3.15
1/2	0.10	0.11	0.15	0.22	0.34	0.49	0.61	0.62	0.78	1/2	1.61	2.40
5/8	0.11	0.15	0.26	0.42	0.63	0.91	1.14	1.27	1.45	5/8	2.58	4.52
7/8	0.23	0.41	0.68	1.09	1.64	2.39	2.98	3.34	3.80	7/8	5.35	12.01
1 1/8	0.46	0.82	1.38	2.20	3.33	4.83	6.02	6.74	7.66	1 1/8	9.13	24.43
1 3/8	0.80	1.44	2.42	3.84	5.80	8.41	10.49	11.74	13.34	1 3/8	13.90	42.71
1 5/8	1.27	2.28	3.83	6.07	9.16	13.29	16.51	18.49	21.01	1 5/8	19.68	67.69
2 1/8	2.65	4.76	7.97	12.63	18.98	27.45	34.03	38.14	43.36	2 1/8	34.23	140.87
2 5/8	4.71	8.44	14.12	22.29	33.50	48.38	59.93	67.18	76.35	2 5/8	52.79	249.43
3 1/8	7.56	13.54	22.58	35.56	53.38	77.02	95.34	107.2	121.5	3 1/8	75.35	398.62
3 5/8	11.30	20.15	33.58	52.83	79.25	114.56	141.4	158.6	180.1	3 5/8	101.9	593.10
4 1/8	15.98	28.47	47.39	74.49	111.78	160.90	199.0	223.1	253.5	4 1/8	132.5	837.24
5 1/8	28.71	51.07	84.85	133.32	199.37	286.92	354.3	397.2	451.2	—	—	—
6 1/8	46.35	82.31	136.77	214.07	319.89	459.97	567.6	636.5	723.1	—	—	—

NOTES:

(1) For Other ΔT's and Equivalent Lengths, L_e Line Capacity (Tons)

$$= \text{Table Tons} \times \left(\frac{100}{L_e} \times \frac{\text{Actual } \Delta T \text{ Loss Desired}}{\text{Table } \Delta T \text{ Loss}}\right)^{0.55}$$

(2) For other Tons and Equivalent Lengths in a given pipe size

$$\Delta T = \text{Table } \Delta T \times \frac{L_e}{100} \times \left(\frac{\text{Actual Tons}}{\text{Table Tons}}\right)^{1.8}$$

(3) Values are based on 105 F condensing temperature. For other condensing temperatures, multiply table tons by the following factors:

Condensing Temp F	Suction Lines	Hot Gas Lines
80	1.20	.83
90	1.12	.91
100	1.04	.97
110	.96	1.02
120	.88	1.08
130	.80	1.16

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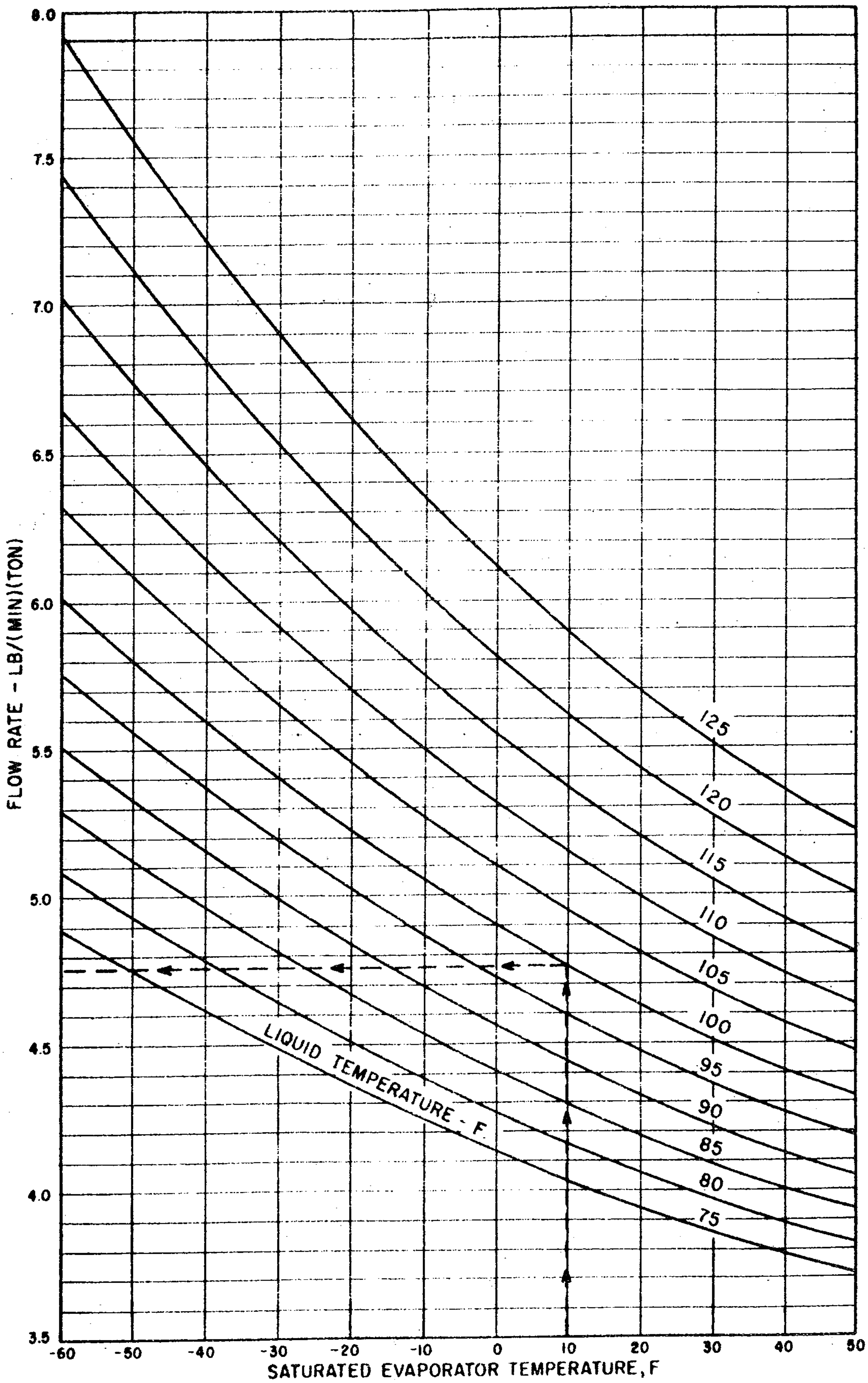

Fig. 1. FLOW RATE PER TON OF REFRIGERATION FOR "FREON" 502

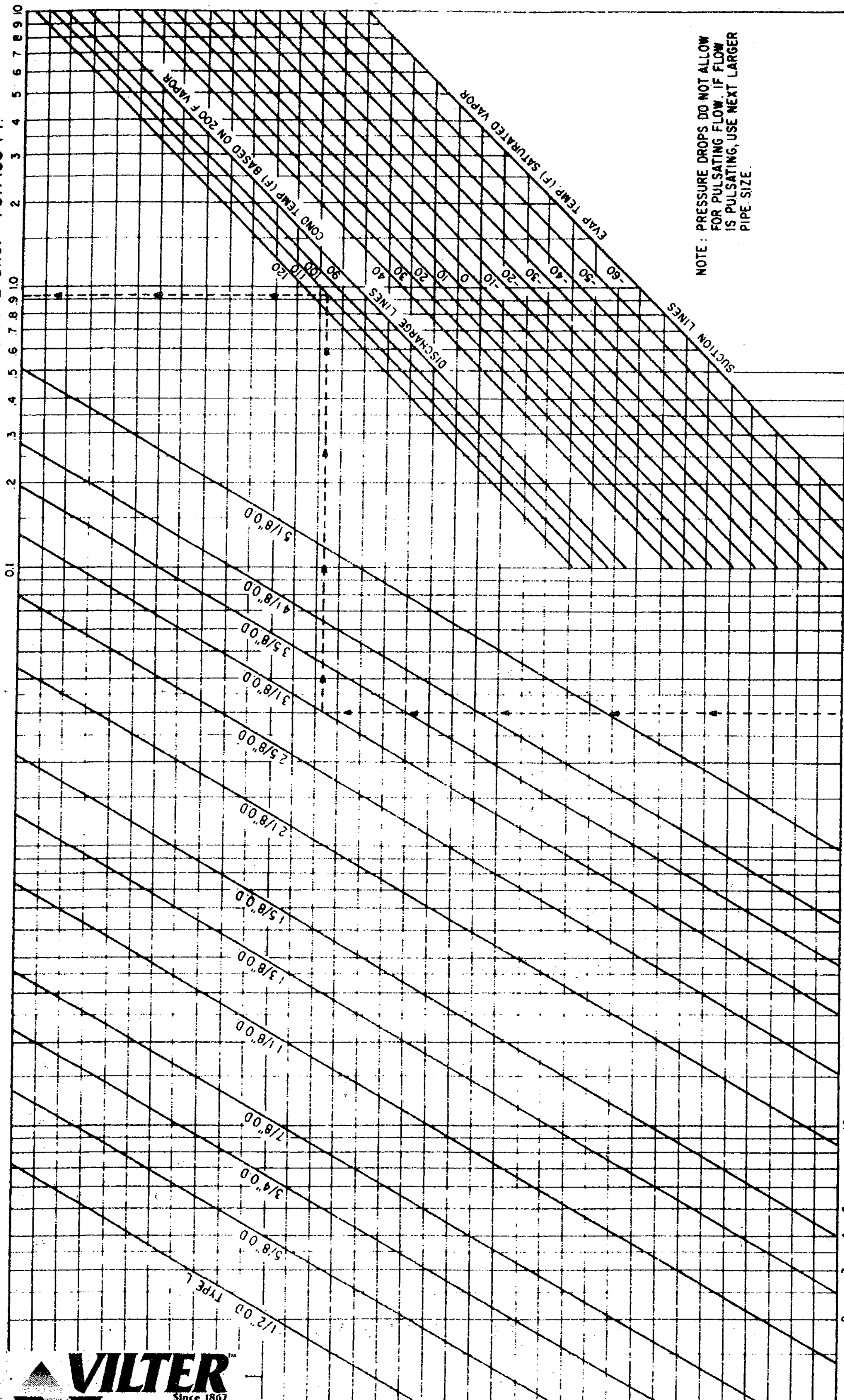

Fig. 2. PRESSURE DROP IN COPPER TUBING FOR "FREON" 502 VAPOR

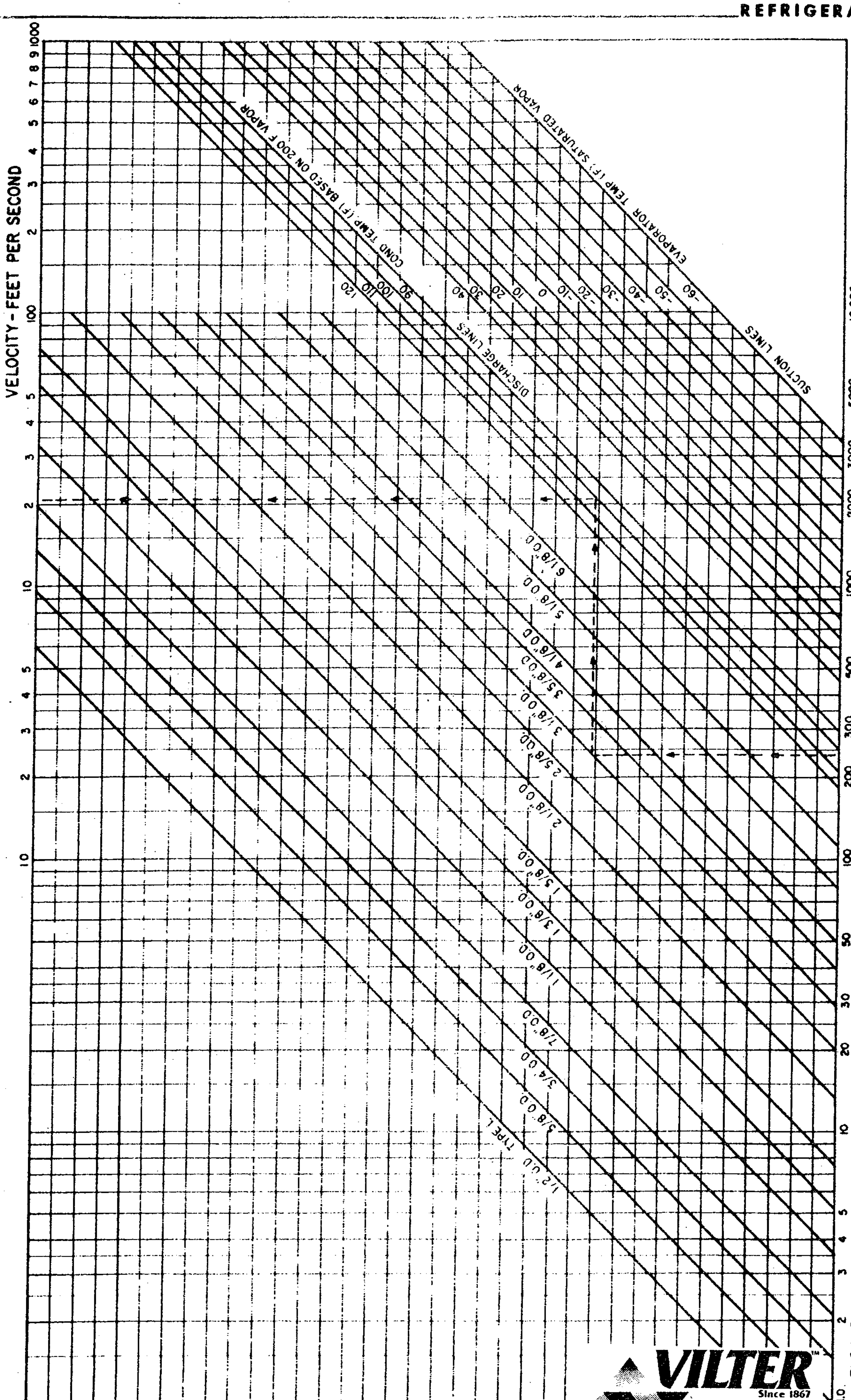

Fig. 3. VELOCITY IN COPPER TUBING FOR "FREON" 502 VAPOR

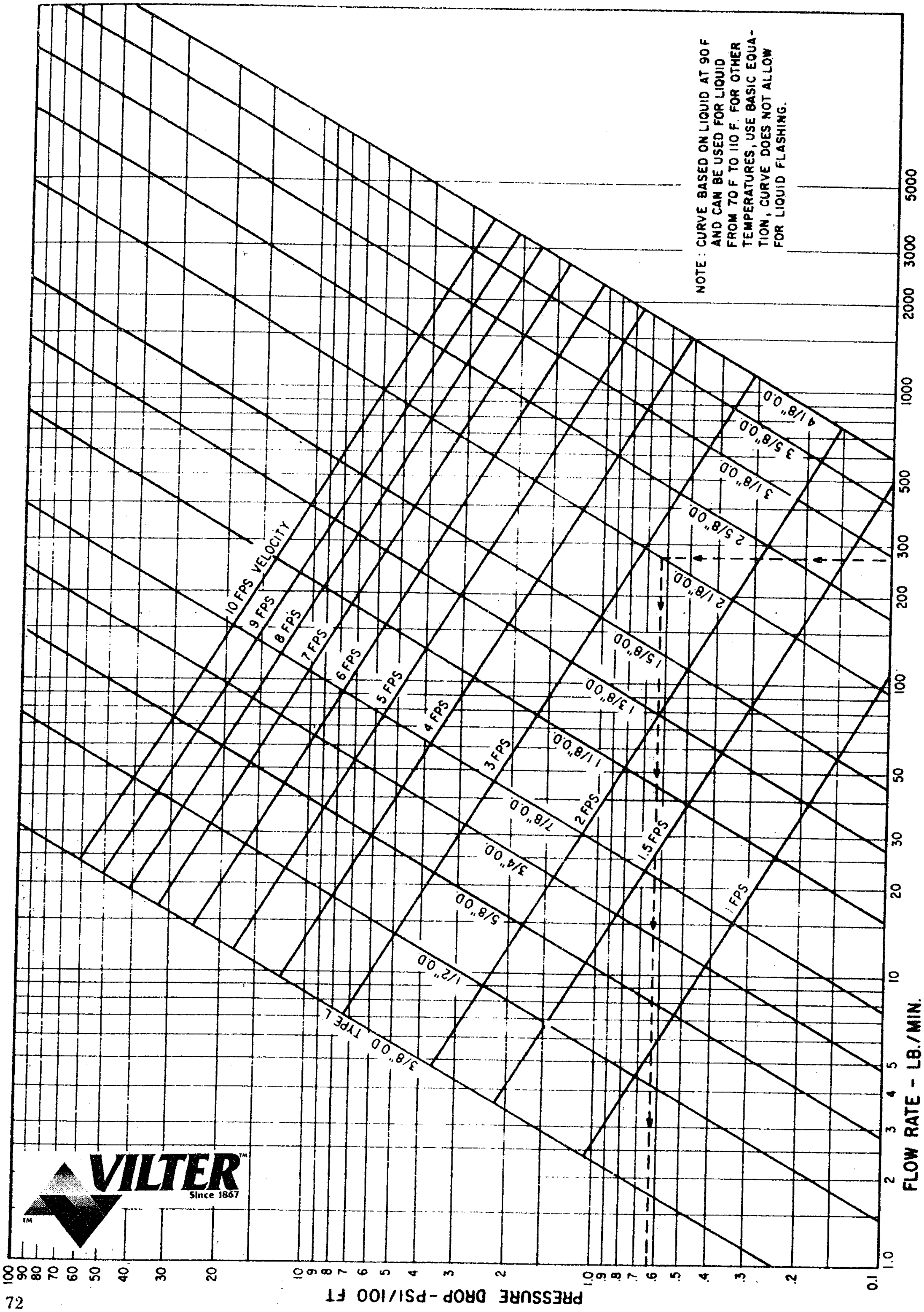

Fig. 4. VELOCITY AND PRESSURE DROP IN COPPER TUBING FOR "FREON" 502 LIQUID

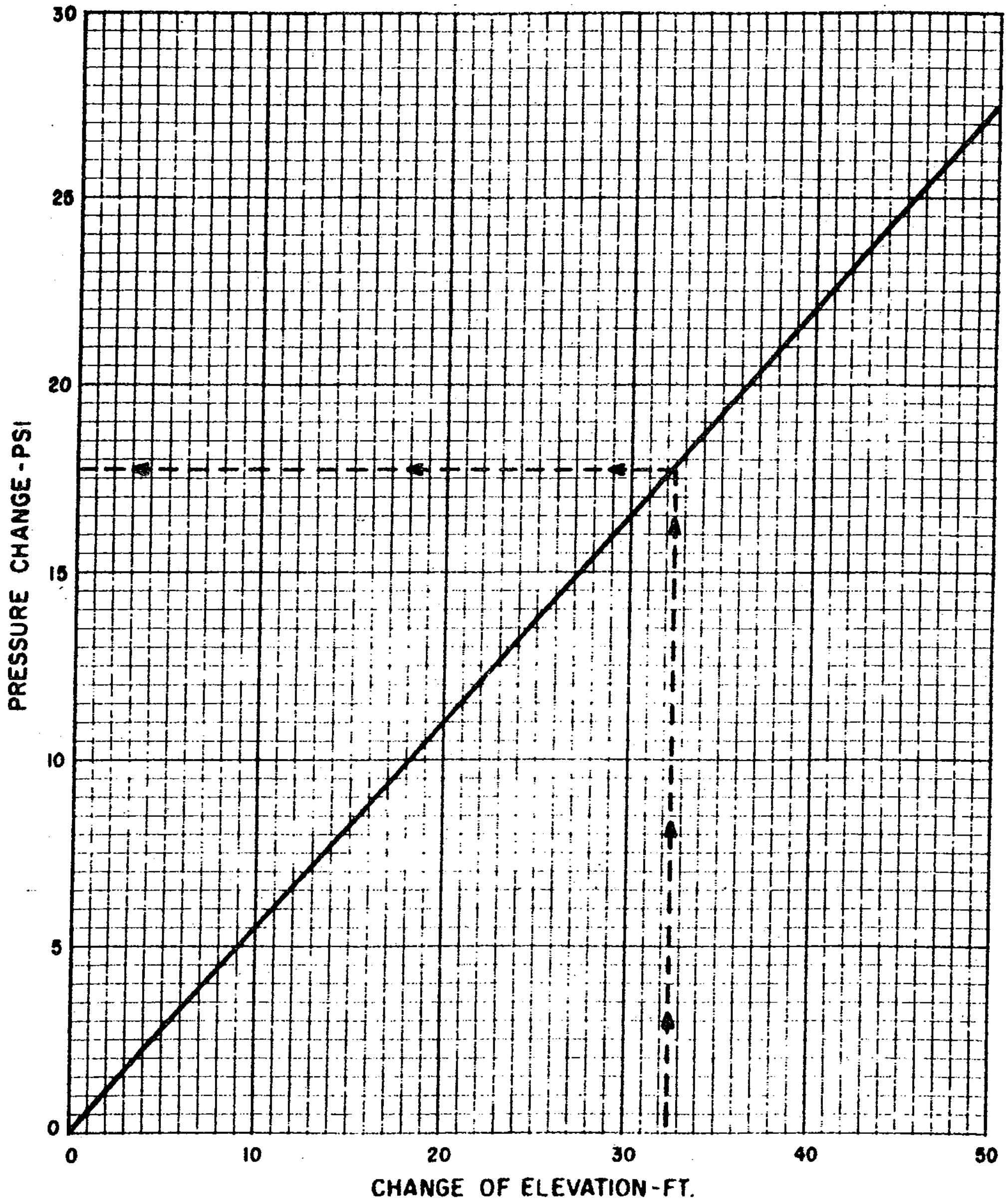

Fig. 5. RELATION OF PRESSURE-CHANGE TO ELEVATION-DIFFERENCE FOR "FREON" 502 LIQUID

TABLE 2
THERMODYNAMIC PROPERTIES OF REFRIGERANT 502

Temp. – °F	Pressure – Lb. per Sq. In.		Volume – Cu. Ft. per Lb.		Density – Lb. per Cu. Ft.		Enthalpy – Btu per Lb.			Entropy – Btu per (Lb.) (°R)		Temp. – °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
-80	6.278	17.14*	0.01036	5.8453	96.55	0.1711	-10.17	80.14	69.97	-0.0254	0.1857	-80
-75	7.318	15.02*	0.01041	5.0696	96.05	0.1973	-8.90	79.53	70.63	-0.0221	0.1846	-75
-70	8.490	12.63*	0.01047	4.4158	95.55	0.2265	-7.65	78.93	71.28	-0.0189	0.1837	-70
-65	9.806	9.96*	0.01052	3.8621	95.04	0.2589	-6.39	78.32	71.93	-0.0156	0.1828	-65
-60	11.28	6.96*	0.01058	3.3910	94.52	0.2949	-5.12	77.70	72.58	-0.0125	0.1819	-60
-55	12.92	3.62*	0.01064	2.9884	94.00	0.3346	-3.85	77.08	73.23	-0.0093	0.1811	-55
-50	14.74	0.04	0.01070	2.6428	93.47	0.3784	-2.57	76.44	73.87	-0.0062	0.1804	-50
-45	16.75	2.06	0.01076	2.3451	92.94	0.4264	-1.29	75.81	74.52	-0.0031	0.1797	-45
-40	18.97	4.28	0.01082	2.0874	92.40	0.4791	0.00	75.16	75.16	0.0000	0.1791	-40
-38	19.92	5.23	0.01085	1.9942	92.18	0.5015	0.52	74.90	75.42	0.0012	0.1788	-38
-36	20.91	6.21	0.01087	1.9060	91.96	0.5247	1.03	74.64	75.67	0.0024	0.1786	-36
-34	21.93	7.24	0.01090	1.8226	91.74	0.5487	1.56	74.37	75.93	0.0037	0.1784	-34
-32	23.00	8.30	0.01093	1.7436	91.52	0.5735	2.07	74.11	76.18	0.0049	0.1781	-32
-30	24.10	9.40	0.01095	1.6687	91.30	0.5993	2.60	73.84	76.44	0.0061	0.1779	-30
-28	25.24	10.54	0.01098	1.5978	91.08	0.6259	3.12	73.57	76.69	0.0073	0.1777	-28
-26	26.42	11.72	0.01101	1.5305	90.85	0.6534	3.64	73.30	76.94	0.0085	0.1775	-26
-24	27.64	12.95	0.01103	1.4667	90.63	0.6818	4.16	73.03	77.19	0.0097	0.1773	-24
-22	28.91	14.21	0.01106	1.4061	90.40	0.7112	4.69	72.75	77.44	0.0109	0.1771	-22
-20	30.22	15.52	0.01109	1.3486	90.18	0.7415	5.21	72.48	77.69	0.0121	0.1769	-20
-18	31.57	16.88	0.01112	1.2939	89.95	0.7729	5.74	72.20	77.94	0.0133	0.1767	-18
-16	32.97	18.28	0.01115	1.2419	89.72	0.8052	6.27	71.92	78.19	0.0145	0.1766	-16
-14	34.42	19.72	0.01117	1.1925	89.49	0.8386	6.80	71.64	78.44	0.0156	0.1764	-14
-12	35.91	21.22	0.01120	1.1454	89.26	0.8731	7.33	71.36	78.69	0.0168	0.1762	-12
-10	37.46	22.76	0.01123	1.1006	89.02	0.9086	7.86	71.07	78.93	0.0180	0.1760	-10
-8	39.05	24.35	0.01126	1.0579	88.79	0.9453	8.40	70.78	79.18	0.0192	0.1759	-8
-6	40.69	26.00	0.01129	1.0172	88.55	0.9831	8.93	70.49	79.42	0.0204	0.1757	-6
-4	42.39	27.69	0.01132	0.9784	88.32	1.0220	9.47	70.20	79.67	0.0215	0.1756	-4
-2	44.14	29.44	0.01135	0.9414	88.08	1.0622	10.00	69.91	79.91	0.0227	0.1754	-2
0	45.94	31.24	0.01138	0.9061	87.84	1.1036	10.54	69.61	80.15	0.0239	0.1753	0
2	47.79	33.10	0.01142	0.8724	87.60	1.1463	11.08	69.31	80.39	0.0250	0.1751	2
4	49.71	35.01	0.01145	0.8402	87.36	1.1902	11.62	69.01	80.63	0.0262	0.1750	4
6	51.68	36.98	0.01148	0.8094	87.12	1.2354	12.16	68.70	80.86	0.0273	0.1749	6
8	53.70	39.01	0.01151	0.7800	86.88	1.2820	12.70	68.40	81.10	0.0285	0.1747	8
10	55.79	41.09	0.01154	0.7519	86.63	1.3300	13.25	68.08	81.33	0.0296	0.1746	10
12	57.94	43.24	0.01158	0.7250	86.39	1.3793	13.80	67.77	81.57	0.0308	0.1745	12
14	60.14	45.45	0.01161	0.6992	86.14	1.4301	14.34	67.46	81.80	0.0319	0.1743	14
16	62.41	47.72	0.01164	0.6746	85.89	1.4824	14.89	67.14	82.03	0.0331	0.1742	16
18	64.75	50.05	0.01168	0.6510	85.64	1.5362	15.44	66.82	82.26	0.0342	0.1741	18
20	67.14	52.45	0.01171	0.6283	85.39	1.5915	15.99	66.50	82.49	0.0354	0.1740	20
22	69.61	54.91	0.01175	0.6066	85.14	1.6485	16.54	66.17	82.71	0.0365	0.1739	22
24	72.13	57.44	0.01178	0.5858	84.88	1.7070	17.10	65.84	82.94	0.0376	0.1738	24
26	74.73	60.04	0.01182	0.5659	84.63	1.7672	17.65	65.51	83.16	0.0388	0.1736	26
28	77.40	62.70	0.01185	0.5467	84.37	1.8292	18.21	65.17	83.38	0.0399	0.1735	28
30	80.13	65.44	0.01189	0.5283	84.11	1.8928	18.76	64.84	83.60	0.0410	0.1734	30
32	82.94	68.24	0.01193	0.5106	83.85	1.9583	19.32	64.49	83.81	0.0422	0.1733	32
34	85.82	71.12	0.01196	0.4937	83.59	2.0256	19.88	64.15	84.03	0.0433	0.1732	34
36	88.77	74.07	0.01200	0.4774	83.33	2.0948	20.44	63.80	84.24	0.0444	0.1731	36
38	91.80	77.10	0.01204	0.4617	83.07	2.1659	21.01	63.44	84.45	0.0455	0.1730	38
40	94.90	80.20	0.01208	0.4466	82.80	2.2390	21.57	63.09	84.66	0.0466	0.1729	40
42	98.08	83.38	0.01212	0.4321	82.53	2.3142	22.14	62.73	84.87	0.0478	0.1728	42

* Inches of mercury below one atmosphere.

TABLE 2 (Continued)
THERMODYNAMIC PROPERTIES OF REFRIGERANT 502

Temp. – °F	Pressure – Lb. per Sq. In.		Volume – Cu. Ft. per Lb.		Density – Lb. per Cu. Ft.		Enthalpy – Btu per Lb.			Entropy – Btu per (Lb.) (°R)		Temp. – °F
t	Absolute P	Gage p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
44	101.3	86.64	0.01216	0.4182	82.26	2.3914	22.71	62.36	85.07	0.0489	0.1727	44
46	104.7	89.97	0.01220	0.4047	81.99	2.4708	23.28	61.99	85.27	0.0500	0.1726	46
48	108.1	93.39	0.01224	0.3918	81.72	2.5524	23.85	61.62	85.47	0.0511	0.1725	48
50	111.6	96.89	0.01228	0.3793	81.44	2.6362	24.42	61.25	85.67	0.0522	0.1724	50
52	115.2	100.5	0.01232	0.3673	81.17	2.7224	25.00	60.87	85.87	0.0533	0.1723	52
54	118.8	104.1	0.01236	0.3557	80.89	2.8110	25.58	60.48	86.06	0.0544	0.1722	54
56	122.6	107.9	0.01241	0.3446	80.61	2.9020	26.16	60.09	86.25	0.0555	0.1721	56
58	126.4	111.7	0.01245	0.3338	80.33	2.9956	26.73	59.70	86.43	0.0566	0.1720	58
60	130.3	115.6	0.01249	0.3234	80.04	3.0918	27.32	59.30	86.62	0.0578	0.1719	60
62	134.3	119.6	0.01254	0.3134	79.76	3.1907	27.91	58.89	86.80	0.0589	0.1717	62
64	138.4	123.7	0.01258	0.3037	79.47	3.2923	28.48	58.49	86.97	0.0600	0.1716	64
66	142.6	127.9	0.01263	0.2944	79.18	3.3968	29.08	58.07	87.15	0.0611	0.1715	66
68	146.9	132.2	0.01268	0.2854	78.88	3.5043	29.67	57.65	87.32	0.0622	0.1714	68
70	151.3	136.6	0.01272	0.2766	78.59	3.6147	30.25	57.23	87.48	0.0633	0.1713	70
72	155.8	141.1	0.01277	0.2682	78.29	3.7284	30.85	56.80	87.65	0.0644	0.1712	72
74	160.3	145.6	0.01282	0.2601	77.99	3.8452	31.45	56.36	87.81	0.0655	0.1711	74
76	165.0	150.3	0.01287	0.2522	77.68	3.9654	32.04	55.92	87.96	0.0665	0.1709	76
78	169.8	155.1	0.01292	0.2446	77.38	4.0890	32.64	55.47	88.11	0.0676	0.1708	78
80	174.6	159.9	0.01298	0.2372	77.07	4.2162	33.24	55.02	88.26	0.0687	0.1707	80
82	179.6	164.9	0.01303	0.2300	76.76	4.3471	33.84	54.56	88.40	0.0698	0.1706	82
84	184.7	170.0	0.01308	0.2231	76.44	4.4819	34.45	54.09	88.54	0.0709	0.1704	84
86	189.8	175.1	0.01314	0.2164	76.13	4.6206	35.06	53.62	88.68	0.0720	0.1703	86
88	195.1	180.4	0.01319	0.2099	75.80	4.7634	35.67	53.14	88.81	0.0731	0.1701	88
90	200.5	185.8	0.01325	0.2036	75.48	4.9105	36.28	52.65	88.93	0.0742	0.1700	90
92	206.0	191.3	0.01331	0.1976	75.15	5.0619	36.89	52.16	89.05	0.0753	0.1698	92
94	211.6	196.9	0.01337	0.1916	74.82	5.2180	37.51	51.65	89.16	0.0764	0.1697	94
96	217.3	202.6	0.01343	0.1859	74.48	5.3789	38.13	51.14	89.27	0.0775	0.1695	96
98	223.1	208.4	0.01349	0.1804	74.15	5.5447	38.75	50.62	89.37	0.0786	0.1693	98
100	229.1	214.4	0.01355	0.1750	73.80	5.7157	39.37	50.10	89.47	0.0796	0.1692	100
102	235.1	220.4	0.01361	0.1697	73.45	5.8921	40.00	49.56	89.56	0.0807	0.1690	102
104	241.3	226.6	0.01368	0.1646	73.10	6.0741	40.62	49.02	89.64	0.0818	0.1688	104
106	247.6	232.9	0.01375	0.1597	72.74	6.2620	41.25	48.47	89.72	0.0829	0.1686	106
108	254.0	239.3	0.01382	0.1549	72.38	6.4560	41.88	47.90	89.78	0.0840	0.1684	108
110	260.5	245.8	0.01389	0.1502	72.01	6.6564	42.52	47.33	89.85	0.0851	0.1682	110
112	267.1	252.4	0.01396	0.1457	71.64	6.8634	43.15	46.75	89.90	0.0862	0.1679	112
114	273.9	259.2	0.01403	0.1413	71.26	7.0775	43.79	46.15	89.94	0.0872	0.1677	114
116	280.8	266.1	0.01411	0.1370	70.87	7.2988	44.43	45.55	89.98	0.0883	0.1674	116
118	287.8	273.1	0.01419	0.1328	70.48	7.5279	45.07	44.93	90.00	0.0894	0.1672	118
120	295.0	280.3	0.01427	0.1288	70.08	7.7649	45.71	44.31	90.02	0.0905	0.1669	120
122	302.2	287.5	0.01435	0.1248	69.68	8.0105	46.36	43.67	90.03	0.0916	0.1666	122
124	309.7	295.0	0.01444	0.1210	69.26	8.2648	47.00	43.02	90.02	0.0926	0.1663	124
126	317.2	302.5	0.01453	0.1173	68.84	8.5285	47.65	42.36	90.01	0.0937	0.1660	126
128	324.9	310.2	0.01462	0.1136	68.41	8.8019	48.29	41.69	89.98	0.0948	0.1657	128
130	332.7	318.0	0.01471	0.1101	67.96	9.0855	48.95	41.00	89.95	0.0958	0.1654	130
132	340.6	325.9	0.01481	0.1066	67.51	9.3798	49.59	40.30	89.89	0.0969	0.1650	132
134	348.7	334.0	0.01491	0.1032	67.05	9.6854	50.24	39.59	89.83	0.0979	0.1646	134
136	357.0	342.3	0.01502	0.09997	66.58	10.003	50.88	38.87	89.75	0.0990	0.1642	136
138	365.3	350.6	0.01513	0.09679	66.09	10.332	51.53	38.13	89.66	0.1000	0.1638	138
140	373.8	359.1	0.01525	0.09368	65.59	10.674	52.17	37.38	89.55	0.1011	0.1634	140

APPENDIX

SECTION A-I

General Statement of Limitations and Assumptions

The charts and tables included in this manual contain the data necessary for proper selection of piping for refrigerating systems using Refrigerant 717 (ammonia), Refrigerant 12 (dichlorodifluoromethane), Refrigerant 22 (monochlorodifluoromethane) or Refrigerant 502 (Azeotrope of R-22 and R-115) over the range of capacities commonly used. In order that they should be applied correctly, the conditions of flow should meet the following requirements:

1. All pipe or tubing referred to is of circular cross-section and it is assumed that the fluid occupies the full cross-section.
2. The fluid is assumed to be all gas or all liquid. The only part of the piping in which a mixture of gas and liquid is considered is in the line between the expansion valve and the evaporator. This line is usually very short, and precise pressure-drop calculations are not normally of much value. A rough means of sizing is given in the "Refrigerant Piping Data" in the first portion of the section on each refrigerant.
3. It is assumed that the condition of the fluid does not change appreciably throughout the section being considered. If the change in temperature or pressure exceeds 10% to 15% of the initial absolute temperature or pressure, an intelligently selected average condition should be used. If there is a rather abrupt change of condition, the piping may be considered in separate sections before and after the point of abrupt change.
4. It is assumed that the rate of flow is reasonably steady. Pulsating flow will result in a greater resistance than if the same average rate occurs at a constant velocity. Normally, even with reciprocating compressors, the multi-cylinder type in current use reduces the pulsation to the point where its influence on pipe size is small or negligible.

SECTION A-II

Nomenclature

h = pressure loss (in feet of the particular fluid), ft

f = friction factor (dimensionless)

L = length of pipe or tube, ft

L_e = equivalent length of pipe for same pressure loss as fitting, ft

D = diameter of pipe or tube, ft

V = velocity (in feet per second) fps

g = acceleration of gravity = 32.17 ft per (sec) (sec)

Re = Reynolds number = $\frac{DV\rho}{\mu}$ (dimensionless)

ρ = mass density of fluid in lb (mass) per cu ft

μ = absolute viscosity of fluid, lb (mass) per (ft) (sec) = 0.000672 x centipoises

K = resistance coefficient for valve or fitting, expressed in velocity heads (dimensionless)

P = pressure loss (in lb per sq in), psi

SECTION A-III

General Equation for Pressure Drop in Pipe

The discussion which follows is applicable to all liquids, and approximately to gases, when the pressure drop is not more than 10 per cent of the initial absolute pressure. Changes in density of gases which result from larger drops in pressure introduce factors which will not be considered. This discussion, so far as it applies to fluids in general, is therefore subject to this limitation.

Consider a straight pipe of internal diameter D in which fluid, of mass density ρ and viscosity μ, is flowing at a mean velocity V. Let the pressure loss in length L be denoted by h.

Certain general laws, based upon observation and experiment, appear to govern fluid friction in pipes and are expressed in all the generally accepted pipe formulas. These laws, briefly stated, are:

1. Frictional loss in turbulent flow generally increases with the roughness of the pipe. When the flow is laminar the frictional loss is independent of the roughness.
2. Frictional loss is directly proportional to the area of the wetted surface, or to πDL.

3. Frictional loss varies inversely as some power of the pipe diameter, or as $\frac{1}{D^x}$.
4. Frictional loss varies as some power of the velocity or as V^n.
5. Frictional loss varies as some power of the ratio of viscosity to density of the fluid, or as $\left(\frac{\mu}{\rho}\right)^r$.

Over a period of years, the various values required for practical application were determined and the well-known pipe-flow formula, known as the Darcy-Weisbach formula, was obtained:

$$h = f\frac{L}{D}\frac{V^2}{2g} \qquad (1)$$

where f is known as the "friction factor" and is dependent upon the roughness of the pipe surface, and the Reynolds number of the fluid, $Re = \frac{DV\rho}{\mu}$.

SECTION A-IV

The Moody Chart

Osborne Reynolds first showed that in pipes two distinct types of flow exist, namely, laminar or streamline flow, and turbulent flow. Furthermore, he found that laminar flow would change over to turbulent flow under certain conditions, with a drastic change in pressure-drop characteristics.

Laminar flow is characterized by parallel flow of all the fluid particles crossing any section of pipe. Experimentally, laminar flow ordinarily exists up to Re values of approximately 2000. For laminar flow the friction factor is practically independent of pipe roughness, and it can be shown both analytically and experimentally that $f = \frac{64}{Re}$.

Turbulent flow exists for values of Re above approximately 3000. It is characterized by flow in random directions within the pipe, with mixing constantly taking place between fast and slow moving portions of the fluid. No completely satisfactory analysis has been made of turbulent flow.

However, thousands of tests have resulted in a rather complete determination of the relationship between friction factor, Reynolds number and pipe roughness. Moody has made an extensive correlation of much of the data. For turbulent flow, it is found experimentally that f is primarily dependent on the relative roughness, and that as Re increases, f tends to become constant for a given pipe roughness.

It is of paramount importance to note that a single graph applies to all fluids, both liquids and gases, all pipe sizes, and that separate friction data are not needed for each particular fluid.

In the range $2000 < Re < 3000$ the flow may be either laminar or turbulent, and theoretical computations in this region may be subject to considerable error. Pipe-size selection should avoid this range, and the velocity ranges in the text provide for this, as well as other considerations.

The chart showing the relation of friction factor to Reynolds number and pipe roughness can be referred to in various places, including the ASRE *Air Conditioning Refrigerating Data Book* and the ASHRAE *Heating, Ventilating and Air Conditioning Guide.*

SECTION A-V

Losses in Valves and Fittings

"K" Factors: It is generally recognized that bends and fittings cause greater pressure losses than straight pipe of equal axial length. These excess losses, over and above skin friction, thus far have eluded rational evaluation. The most generally accepted method of computing the resistance to flow, caused by a valve or fitting, assumes the excess loss to be a direct function of the velocity head, and independent of the friction coefficient:

$$h = K\frac{V^2}{2g} \qquad (2)$$

where K is a proportionality constant, numerical values for which are commonly referred to as "K" factors, and V is the average velocity in the connecting pipe or tube of the same nominal size.

Values of K for valves and fittings are given in the tables in this booklet. Particularly for valves, there is considerable variation in K values among different types and manufacture. If greater accuracy is desired, the manufacturer may be able to give a K value for his product.

Equation (2) may also be written:

$$P = K \frac{V^2 \rho}{(2g)\, 144} \qquad (3)$$

The nomographs given in the text solve this equation for the various refrigerants.

Equivalent Length: Equation (2) is the generally accepted expression for indicating head loss caused by a valve or fitting. It assumes the head loss to be a direct function of the velocity head and independent of the friction coefficient. Also, the loss in straight pipe is as given in equation (1). Since h is the only term on one side of both equations (1) and (2),

$$f \frac{L}{D} \frac{V^2}{2g} = K \frac{V^2}{2g} \qquad (4)$$

$$L = \frac{KD}{f} = L_e \qquad (5)$$

The term L_e is known as the additional "equivalent length", which must be added to the actual straight pipe length to include the resistance of valves or fittings. The value shown in equation (5) for this term includes the friction coefficient. If the "K" value is constant [a] for any given valve or fitting, then the equivalent length will vary with the friction factor, which in turn is a function of the Reynolds number. The equivalent lengths given have been calculated using Reynolds numbers applying to conditions normally used.

[a] This assumption is not strictly justified in light of recent experiments, but "K" is essentially constant over a large range of Reynolds numbers, provided the flow is turbulent. "K" is also affected by the roughness of the pipe leading to and from the valve or fitting. In other words, a given valve installed in rough pipe would not necessarily have the same "K" value as if it were installed in smooth pipe. For practical problems, however, this effect can be neglected.

SECTION A-VI

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SECTION A-VII
Suction and Hot Gas Risers

TABLE A-1.
MINIMUM TONNAGE* FOR OIL ENTRAINMENT UP SUCTION RISERS (TYPE L COPPER TUBING)

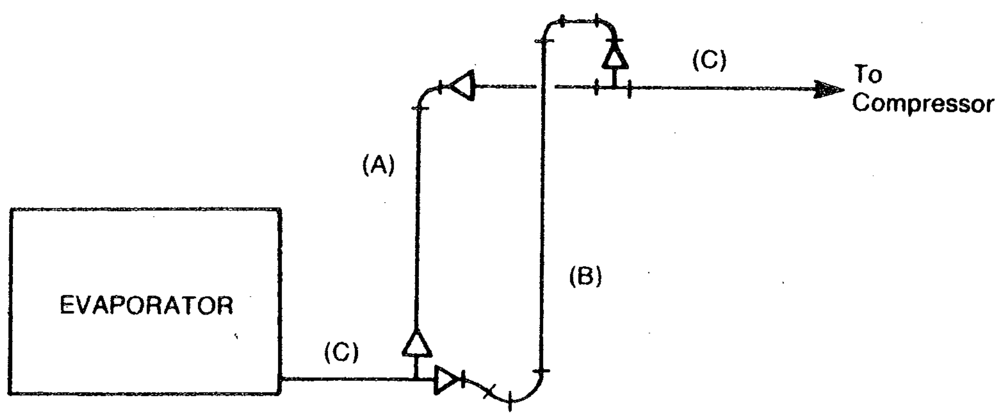
Refrigerant	Sat. Suction Temp, F	Pipe OD											
		½	⅝	¾	⅞	1⅛	1⅜	1⅝	2⅛	2⅝	3⅛	3⅝	4⅛
		Area, Sq. In.											
		0.146	0.233	0.348	0.484	0.825	1.256	1.78	3.094	4.77	6.812	9.213	11.97
R-12*	−40	0.061	0.110	0.182	0.27	0.54	0.91	1.4	2.79	4.78	7.49	10.9	15.1
	−20	.077	.138	.228	.34	.67	1.13	1.75	3.49	5.99	9.36	13.7	19.0
	0	.093	.167	.278	.42	.82	1.38	2.14	4.26	7.32	11.4	16.6	23.2
	20	.112	.201	.332	.50	.97	1.65	2.55	5.1	8.73	13.6	19.9	27.6
	40	.132	.238	.390	.59	1.15	1.94	3.0	6.0	10.3	16.1	23.4	32.6
R-22*	−40	0.09	0.16	0.27	0.41	0.79	1.34	2.1	4.1	7.1	11.1	16.1	22.4
	−20	.11	.20	.33	.50	.96	1.60	2.5	5.0	8.7	13.5	19.6	27.4
	0	.13	.24	.39	.59	1.2	1.96	3.0	6.1	10.4	16.2	23.6	32.8
	20	.16	.28	.46	.70	1.4	2.30	3.5	7.1	12.1	18.9	27.6	38.1
	40	.18	.33	.54	.81	1.6	2.70	4.1	8.2	14.1	22.0	32.1	44.6
R-502†	−60	0.053	0.10	0.16	0.24	0.46	0.78	1.2	2.4	4.1	6.4	9.4	13.0
	−40	.070	.12	.20	.30	.59	1.0	1.5	3.1	5.3	8.3	12.0	16.8
	−20	.084	.15	.25	.38	.74	1.3	1.9	3.8	6.6	10.3	15.0	20.9
	0	.104	.19	.31	.47	.91	1.5	2.4	4.7	8.1	12.7	18.4	25.7
	20	.120	.22	.37	.56	1.1	1.8	2.9	5.7	9.8	15.2	22.2	30.8
	40	.146	.26	.43	.65	1.3	2.2	3.3	6.7	11.4	17.8	26.0	36.1

* Minimum tonnage values are based on the indicated saturation temperatures (SST) with 15 F deg of superheat and 90 F liquid temperature.
• R-12, R-22, reduce or increase table values 1% for 10 F deg less or more superheat.
† For R-502, reduce or increase table values 2% for 10 F deg less or more superheat.
For liquid temperatures other than 90 F, multiply the table values by the corresponding factor listed in the following table:

Liquid Temperature, F		50	60	70	80	90	100	110	120	130	140
Correction	R-12, R-22	1.20	1.15	1.10	1.05	1.00	0.95	0.90	0.85	0.80	0.75
Factors	R-502	1.26	1.20	1.13	1.07	1.00	0.94	0.88	0.82	0.76	0.70

DOUBLE SUCTION RISERS

To return oil in suction lines at reduced loads.



Description and Operation

1. The minimum load riser indicated by (A) is sized so that it returns oil at the minimum possible load.
2. The second riser (B), which is usually larger than riser (A), is sized so that the parallel pressure drop through both risers at full load is satisfactory providing this assures oil return at full load.
3. A trap is introduced between the two risers as shown. During partial load operation, when the gas velocity is not sufficient to return oil through both risers, the trap gradually fills with oil until the second riser (B) is sealed off. When this occurs, the gas travels up riser (A) only and has enough velocity to carry oil along with it back into the horizontal suction main.
4. The fittings at the bottom of the riser must be close coupled so that the oil flooding capacity of the trap is limited to a minimum. If this is not done, the trap can accumulate enough oil on partial load operation to seriously lower the crankcase oil level. Also, larger flood-backs of oil to the compressor occur when the trap clears out on increased load operation.
5. The larger riser (B) forms an inverted trap as it enters the top of the horizontal header. This prevents drainage into this line during periods when this line is "idle" due to minimum loads.
6. Risers (A) and (B) are to be sized using the minimum design velocities as described by ASHRAE for various refrigerants at the system design temperature.
7. The horizontal suction line (C) should be designed according to good suction line practice for minimum pressure drop while maintaining the proper velocity for oil return.

TABLE A-2.
MINIMUM TONNAGE FOR OIL ENTRAINMENT UP HOT GAS RISERS (TYPE L COPPER TUBING)

Refrigerant	Sat. Discharge Temp, F	Pipe OD											
		½	⅝	¾	⅞	1⅛	1⅜	1⅝	2⅛	2⅝	3⅛	3⅝	4⅛
		Area, Sq. In.											
		.146	.233	.348	.484	.825	1.256	1.78	3.094	4.77	6.812	9.213	11.97
R-12*	80	.17	.31	.50	.77	1.51	2.54	3.93	7.84	13.5	21.0	30.7	42.6
	90	.17	.31	.51	.77	1.51	2.54	3.92	7.84	13.5	21.0	30.7	42.6
	100	.17	.31	.51	.77	1.51	2.54	3.92	7.84	13.5	21.0	30.7	42.6
	110	.17	.31	.51	.77	1.50	2.53	3.90	7.81	13.4	20.9	30.5	42.2
	120	.17	.30	.50	.75	1.47	2.49	3.84	7.66	13.2	20.6	30.0	41.6
	130	.17	.30	.49	.72	1.45	2.44	3.77	7.54	12.9	20.3	29.4	40.8
	140	.16	.28	.47	.71	1.38	2.33	3.61	7.20	12.4	19.4	28.2	39.9
R-22*	80	.23	.42	.69	1.04	2.0	3.4	5.3	10.6	18.2	28.3	41.5	57.5
	90	.23	.42	.69	1.04	2.0	3.4	5.3	10.6	18.2	28.2	41.3	57.3
	100	.23	.42	.69	1.03	2.0	3.4	5.3	10.5	18.0	28.1	41.0	56.7
	110	.23	.41	.67	1.02	2.0	3.4	5.2	10.4	17.9	27.9	40.8	56.5
	120	.22	.40	.66	1.00	2.0	3.3	5.1	10.2	17.5	27.4	39.9	55.4
	130	.22	.39	.64	.98	1.9	3.2	5.0	10.0	17.2	26.8	39.0	54.0
	140	.21	.38	.63	.96	1.9	3.2	4.9	9.7	16.7	26.1	38.0	52.6
R-502†	80	.18	.32	.53	.80	1.55	2.7	4.1	8.2	14.1	21.9	32.5	44.3
	90	.17	.31	.51	.77	1.49	2.52	3.92	7.8	13.4	20.9	30.5	42.3
	100	.165	.30	.50	.74	1.44	2.45	3.8	7.55	13.0	20.2	29.5	40.9
	110	.160	.29	.48	.72	1.41	2.38	3.71	7.35	12.7	19.7	28.7	39.8
	120	.154	.28	.46	.69	1.33	2.26	3.52	7.0	12.4	18.7	27.3	37.9
	130	.145	.26	.43	.65	1.27	2.14	3.34	6.62	11.4	17.8	25.9	35.9
	140	.135	.24	.40	.61	1.18	1.98	3.08	6.15	10.6	16.4	24.0	33.3

* Minimum tonnages are based on a saturated suction temperature of +20 F with 15 F deg of superheat at the indicated saturated condensing temperatures with 15 F deg subcooling and actual discharge temperature based on 70% compressor efficiency. For suction temperatures other than 20 F, multiply the table values by the following factors:

Sat. Suct. Temperature	−40	−20	0	+20	+40
Correction Factor	0.85	0.90	0.95	1.0	1.06

† Minimum tonnages are based on a saturated temperature of −20 F. All other conditions are the same as above. For suction temperatures other than −20 F, multiply the table values by the following factors:

Sat. Suct. Temperature	−60	−40	−20	0	+20	+40
Correction Factor	0.87	0.94	1.0	1.08	1.15	1.21

SECTION A-VIII

LINE SIZING FOR LIQUID RECIRCULATION (OVERFEED) SYSTEMS

In the case of liquid recirculation systems, the sizing considerations for the liquid feed lines to the evaporators and the wet return lines to the low pressure receiver are different than conventional systems.

It is necessary to take the overfeed ratio into account to size the feed lines. The TR capacities for conventional liquid lines must be divided by the overfeed ratios in order to obtain the equivalent capacities for liquid feed lines. For example, for a 50 TR ammonia system having a 4 to 1 overfeed ratio, the line should be sized for 4 x 50 = 200 TR duty by normal sizing methods.

Several alternative design methods are used for wet return lines as suggested in Chapter 25 of the ASHRAE Systems Handbook. These are as follows:

1. Use one pipe size larger than indicated for the vapor flow alone.

2. Use a velocity selected for dry expansion reduced by the factor (circulating ratio) – 0.5. This method suggests that the wet return velocity for a 4 to 1 rate of recirculation should be 0.5 that of the acceptable dry vapor velocity.

3. It is also possible to use the tables developed as a result of ASHRAE Research Project RP-107. The final report was made by Messrs. J.B. Chaddock, D.P. Werner and C.G. Papachristou.

When designing wet return lines in which vertical risers are incorporated, consideration should be given to the possibility of liquid holdup. In certain cases it may be necessary to incorporate different arrangements than are employed for conventional suction lines. For those applications where liquid holdup may be a possibility, it may be necessary to employ double risers to handle partial load conditions. Otherwise, it must be recognized that excessive pressure drops may be experienced if liquid holdups exist. In some cases it may be necessary to separate the liquid and transfer it by pumps.

It has been recognized that the conventional practices for estimating pressure drops thru valves and fittings do not apply for wet return connections. The geometry and position of the fittings can have an influence on the pressure drop thru these. Work is being done on this by various researchers, including ASHRAE RP-142 organized by Professor J.B. Chaddock at Duke University. Until more specific information is available, it is advisable to be conservative when selecting and sizing valves and fittings for wet return systems.

SECTION A-IX
Miscellaneous Data

TABLE A-3. VISCOSITY OF REFRIGERANTS

Temperature	(μ in Centipoises)[1]					
	Liquids at Saturation Pressure			Vapors at 1 atmosphere		
F	717	12	22	717	12	22
-40		0.423	0.351		0.0106	0.0105
-20		0.371	0.316		0.0109	0.0109
0		0.335	0.291		0.0113	0.0113
+5	0.250			0.0085		
20	0.240	0.308	0.271	0.0088	0.0116	0.0118
40	0.230	0.286	0.256	0.0093	0.0119	0.0122
60		0.269	0.243		0.0123	0.0126
80	0.210	0.255	0.232		0.0126	0.0130
100	0.200	0.242	0.223	0.0105	0.0129	0.0133
120		0.232	0.214		0.0132	0.0137
140		0.222	0.207		0.0135	0.0141
150				0.0116		
160		0.214	0.201		0.0138	0.0145
180		0.207	0.195		0.0140	0.0148
200		0.200			0.0143	0.0152
220					0.0146	0.0156
240					0.0149	0.0159

[1] Reprinted from 10th Edition, 1957-58, *Air Conditioning Refrigerating Data Book*, by courtesy of The American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Table A-4. STEEL AND WROUGHT IRON PIPE—DIMENSIONS AND PHYSICAL DATA

Nominal Size Inches	Diameter Inches			Thickness of Metal Inches		Transverse Area Square Inches			Lineal Feet per Square Foot of			Lineal Feet Containing 1 Cubic Foot		Weight Per Foot Plain Ends Pounds	
	External	Internal				External	Internal		External Surface	Internal Surface					
		Schedule		Schedule			Schedule			Schedule		Schedule		Schedule	
		40	80	40	80		40	80		40	80	40	80	40	80
⅛	.405	.270	.215	.068	.095	.128	.057	.036	9.434	14.151	17.766	2533.00	3966.4	.244	.314
¼	.540	.364	.302	.088	.119	.229	.104	.072	7.075	10.500	12.648	1383.28	2010.3	.424	.535
⅜	.675	.493	.423	.091	.126	.358	.191	.141	5.658	7.732	9.030	754.32	1024.7	.567	.738
½	.840	.622	.546	.109	.147	.554	.304	.234	4.547	6.132	6.995	473.84	615.0	.850	1.087
¾	1.050	.824	.742	.113	.154	.866	.533	.433	3.638	4.635	5.147	270.02	333.02	1.130	1.473
1	1.315	1.048	.957	.134	.179	1.358	.861	.719	2.904	3.645	3.991	167.25	200.2	1.678	2.171
1¼	1.660	1.380	1.278	.140	.191	2.164	1.496	1.283	2.301	2.768	2.988	96.26	112.25	2.272	2.996
1½	1.900	1.610	1.500	.145	.200	2.835	2.036	1.767	2.010	2.372	2.546	70.73	81.48	2.717	3.631
2	2.375	2.067	1.939	.154	.218	4.430	3.356	2.953	1.608	1.848	1.969	42.91	48.76	3.652	5.022
2½	2.875	2.468	2.323	.204	.276	6.492	4.78	4.238	1.329	1.548	1.644	30.34	33.97	5.793	7.661
3	3.500	3.067	2.900	.217	.300	9.621	7.383	6.605	1.091	1.245	1.317	19.51	21.80	7.575	10.252
3½	4.000	3.548	3.364	.226	.318	12.566	9.887	8.888	0.955	1.077	1.135	14.57	16.20	9.109	12.505
4	4.500	4.026	3.826	.237	.337	15.904	12.730	11.497	.849	0.949	0.998	11.31	12.520	10.790	14.983
5	5.563	5.045	4.813	.259	.375	24.306	19.986	18.194	.687	.757	.793	7.20	7.915	14.617	20.778
6	6.625	6.065	5.761	.28	.432	34.472	28.890	26.067	.576	.630	.663	4.98	5.525	18.974	28.573
8	8.625	7.981	7.625	.322	.500	58.426	50.027	45.663	.443	.479	.500	2.87	3.154	28.554	43.388
10	10.75	10.02	9.75	.366	.500	90.763	78.823	74.662	.355	.381	.391	1.83	1.929	40.483	54.735
12	12.75	12.00	11.75	.375	.500	127.67	113.09	108.43	.300	.318	.325	1.27	1.328	49.562	65.415

Table A-5. COPPER, BRASS OR SEAMLESS-STEEL TUBING—DIMENSIONS AND PHYSICAL DATA[1]

Nominal Size OD Inches	Type	Internal Diameter Inches	Thickness of Metal Inches	Transverse Area Square Inches		Lineal Feet Per Square Foot of Surface		Lineal Feet Containing 1 Cu. Foot	Lineal Feet Containing 1 Gallon	Lineal Feet Occupying 1 Cubic Foot of Space	Weight Per Foot Pounds
				External	Internal	External	Internal				
¼	——	.190	.030 [2]	.049	.028	15.25	20.00	5090.0	681.0	2940.0	.080
⅜	K	.311	.032 [2]	.110	.076	10.45	12.29	1895.0	253.0	1310.0	.134
½	K	.402	.049	.196	.127	7.65	9.50	1135.0	151.0	735.0	.269
	L	.430	.035		.144		8.89	1001.0	133.5		.198
⅝	K	.527	.049	.306	.218	6.10	7.25	660.5	88.0	470.0	.344
	L	.545	.040		.232		7.00	621.0	82.6		.284
¾	K	.652	.049	.539	.333	5.10	5.85	432.5	57.5	267.0	.418
	L	.660	.042		.341		5.79	422.0	56.1		.362
⅞	K	.745	.065	.598	.435	4.36	5.12	331.0	44.0	240.5	.641
	L	.785	.045		.482		4.86	299.0	39.8		.454
1⅛	K	.995	.065	989	.775	3.39	3.84	186.0	24.7	145.9	.839
	L	1.025	.050		.825		3.72	174.7	23.2		.653
1⅜	K	1.245	.065	1.481	1.215	2.78	3.06	118.9	15.8	97.3	1.040
	L	1.265	.055		1.255		3.02	115.0	15.3		.882
1⅝	K	1.481	.072	2.070	1.725	2.35	2.57	83.5	11.1	69.6	1.36
	L	1.505	.060		1.771		2.54	81.4	10.8		1.14
2⅛	K	1.959	.083	3.540	3.000	1.80	1.95	48.0	6.39	40.6	2.06
	L	1.985	.070		3.090		1.92	46.6	6.20		1.75
2⅝	K	2.435	.095	5.400	4.620	1.45	1.57	31.2	4.15	27.6	2.92
	L	2.465	.080		4.760		1.55	30.2	4.01		2.48
3⅛	K	2.907	.109	7.750	6.620	1.22	1.31	21.8	2.90	18.6	4.00
	L	2.945	.090		6.810		1.29	21.1	2.80		3.33
3⅝	K	3.385	.120	10.350	8.96	1.05	1.13	16.1	2.14	13.9	5.12
	L	3.425	.100		9.21		1.11	15.6	2.07		4.29
4⅛	K	3.857	.134	13.320	11.62	.93	.99	12.4	1.65	7.50	6.51
	L	3.905	.110		11.92		.98	12.1	1.61		5.38
5⅛	K	4.805	.160	20.530	18.10	.75	.79	7.95	1.06	7.04	9.67
	L	4.875	.125		18.60		.78	7.75	1.03		7.61
6⅛	K	5.741	.192	29.400	25.80	.62	.67	5.59	.74	4.90	13.87
	L	5.845	.140		26.61		.66	5.41	.72		10.20
8⅛	K	7.583	.271	51.700	44.80	.47	.50	3.22	.43	2.78	25.90
	L	7.725	.200		46.60		.49	3.09	.41		19.29

[1] Conforms to ASA B-9 Code and ASTM Specifications B280-55T and B88-51. [2] Conforms to ASA B-9 Code.

TABLE A-6.
RECEIVER TO CONDENSER EQUALIZING LINE SIZES

Vent Line Size (Nominal Pipe Size) In.	½	¾	1	1¼	1½	2
Max Tons—Refrigerant 12 & 502	35	70	120	200	280	460
Max Tons—Refrigerant 22	50	90	150	260	360	590
Max Tons—Refrigerant 717	50	100	170	310	425	650

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TABLE A-7.
LOW STAGE REFRIGERANT LINE CAPACITY MULTIPLIERS

Sat. Discharge Temp, F	Ammonia	Refrigerant 12		Refrigerant 22	
	Discharge	Suction	Discharge	Suction	Discharge
−30		1.12	0.55	1.09	0.58
−20		1.07	0.70	1.06	0.71
−10	0.77	1.03	0.85	1.03	0.85
0	1.00	1.00	1.00	1.00	1.00
10	1.23	0.96	1.25	0.97	1.20
20	1.45	0.93	1.50	0.94	1.45
30	1.67	0.90	1.80	0.90	1.80

TABLE A-8.
PRACTICAL GAS LINE VELOCITIES FOR VARIOUS REFRIGERANTS (fpm)

Refrigerant	Suction Line	Discharge Line
12, 22, 502	1,200–4,000	2,000–3,500
717 (Ammonia)	500–5,000	3,000–6,000

Velocities indicated are for system design load.

TABLE A-9. CONVERSION TABLE FOR FAHRENHEIT AND CENTIGRADE

Cent.	Temp.	Fahr.	Cent.	Temp.	Fahr.	Cent.	Temp.	Fahr.	Cent.	Temp.	Fahr.	Cent.	Temp.	Fahr.
−73.2	−100	−148.0	−29.3	−21	−5.8	−4.44	24	75.2	20.0	68	154.4	44.5	112	233.6
−67.6	−90	−130.0	−28.8	−20	−4.0	−3.89	25	77.0	20.6	69	156.2	45.1	113	235.4
−62.1	−80	−112.0	−28.2	−19	−2.2	−3.33	26	78.8	21.1	70	158.0	45.6	114	237.2
−59.3	−75	−103.0	−27.7	−18	−0.4	−2.78	27	80.6	21.7	71	159.8	46.2	115	239.0
−56.5	−70	−94.0	−27.1	−17	1.4	−2.22	28	82.4	22.2	72	161.6	46.7	116	240.8
−53.7	−65	−85.0	−26.5	−16	3.2	−1.67	29	84.2	22.8	73	163.4	47.3	117	242.6
−51.0	−60	−76.0	−26.0	−15	5.0	−1.11	30	86.0	23.3	74	165.2	47.8	118	244.4
−50.4	−59	−74.2	−25.4	−14	6.8	−0.56	31	87.8	23.9	75	167.0	48.4	119	246.2
−49.9	−58	−72.4	−24.9	−13	8.6	0	32	89.6	24.4	76	168.8	48.9	120	248.0
−49.3	−57	−70.6	−24.3	−12	10.4	0.56	33	91.4	25.0	77	170.6	49.5	121	249.8
−48.7	−56	−68.8	−23.8	−11	12.2	1.11	34	93.2	25.6	78	172.4	50.1	122	251.6
−48.2	−55	−67.0	−23.2	−10	14.0	1.67	35	95.0	26.1	79	174.2	50.6	123	253.4
−47.6	−54	−65.2	−22.7	−9	15.8	2.22	36	96.8	26.7	80	176.0	51.2	124	255.2
−47.1	−53	−63.4	−22.1	−8	17.6	2.78	37	98.6	27.2	81	177.8	51.7	125	257.0
−46.5	−52	−61.6	−21.5	−7	19.4	3.33	38	100.4	27.8	82	179.6	52.3	126	258.8
−46.0	−51	−59.8	−21.0	−6	21.2	3.89	39	102.2	28.3	83	181.4	52.8	127	260.6
−45.4	−50	−58.0	−20.4	−5	23.0	4.44	40	104.0	28.9	84	183.2	53.4	128	262.4
−44.9	−49	−56.2	−19.9	−4	24.8	5.00	41	105.8	29.4	85	185.0	53.9	129	264.2
−44.3	−48	−54.4	−19.3	−3	26.6	5.56	42	107.6	30.0	86	186.8	54.0	130	266.0
−43.7	−47	−52.6	−18.8	−2	28.4	6.11	43	109.4	30.6	87	188.6	57.3	135	275.0
−43.2	−46	−50.8	−18.3	−1	30.2	6.67	44	111.2	31.1	88	190.4	60.0	140	284.0
−42.6	−45	−49.0	−17.8	0	32.0	7.22	45	113.0	31.7	89	192.2	62.8	145	293.0
−42.1	−44	−47.2	−17.2	1	33.8	7.78	46	114.8	32.2	90	194.0	66.0	150	302.0
−41.5	−43	−45.4	−16.7	2	35.6	8.33	47	116.6	32.8	91	195.8	68.4	155	311.0
−41.0	−42	−43.6	−16.1	3	37.4	8.89	48	118.4	33.3	92	197.6	71.0	160	320.0
−40.4	−41	−41.8	−15.6	4	39.2	9.44	49	120.2	33.9	93	199.4	73.9	165	329.0
−40.0	−40	−40.0	−15.0	5	41.0	10.0	50	122.0	34.4	94	201.2	77.0	170	338.0
−39.3	−39	−38.2	−14.4	6	42.8	10.6	51	123.8	35.0	95	203.0	79.5	175	347.0
−38.8	−38	−36.4	−13.9	7	44.6	11.1	52	125.6	35.6	96	204.8	82.0	180	356.0
−38.2	−37	−34.6	−13.3	8	46.4	11.7	53	127.4	36.1	97	206.6	85.0	185	365.0
−37.6	−36	−32.8	−12.8	9	48.2	12.2	54	129.2	36.7	98	208.4	88.0	190	374.0
−37.1	−35	−31.0	−12.2	10	50.0	12.8	55	131.0	37.2	99	210.2	90.6	195	383.0
−36.5	−34	−29.2	−11.7	11	51.8	13.3	56	132.8	37.8	100	212.0	93.0	200	392.0
−36.0	−33	−27.4	−11.1	12	53.6	13.9	57	134.6	38.4	101	213.8	99.0	210	410.0
−35.4	−32	−25.6	−10.6	13	55.4	14.4	58	136.4	39.0	102	215.6	100.0	212	413.0
−34.9	−31	−23.8	−10.0	14	57.2	15.0	59	138.2	39.5	103	217.4	104.0	220	428.0
−34.3	−30	−22.0	−9.44	15	59.0	15.6	60	140.0	40.1	104	219.2	110.0	230	446.0
−33.8	−29	−20.2	−8.89	16	60.8	16.1	61	141.8	40.6	105	221.0	116.0	240	464.0
−33.2	−28	−18.4	−8.33	17	62.6	16.7	62	143.6	41.2	106	222.8	121.0	250	482.0
−32.6	−27	−16.6	−7.78	18	64.4	17.2	63	145.4	41.7	107	224.6	127.0	260	500.0
−32.1	−26	−14.8	−7.22	19	66.2	17.8	64	147.2	42.3	108	226.4	132.0	270	518.0
−31.5	−25	−13.0	−6.67	20	68.0	18.3	65	149.0	42.8	109	228.2	138.0	280	536.0
−31.0	−24	−11.2	−6.11	21	69.8	18.9	66	150.8	43.4	110	230.0	143.0	290	554.0
−30.4	−23	−9.4	−5.56	22	71.6	19.4	67	152.6	43.9	111	231.8	149.0	300	572.0
−29.9	−22	−7.6	−5.00	23	73.4									

The numbers in the TEMPERATURE column (center column) refer to the temperature either in Centigrade or Fahrenheit, which one desires to convert to the other scale. If converting Fahrenheit to Centigrade, the equivalent temperature will be found in the CENTIGRADE column (left column). If converting Centigrade to Fahrenheit, the equivalent temperature will be found in the FAHRENHEIT column (right column).

VILTER Since 1867

TABLE A-10.
FLOW OF WATER THROUGH SCHEDULE 40 STEEL PIPE

DISCHARGE		PRESSURE DROP PER 100 FEET AND VELOCITY IN SCHEDULE 40 PIPE FOR WATER AT 60°F.															
		Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop	Veloc-ity	Press. Drop
Gallons per Minute	Cubic Ft. per Second	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.	Feet per Second	Lbs. per Sq. In.
		1/8"		1/4"		3/8"		1/2"									
.2	0.000446	1.13	1.86	0.616	0.359												
										3/4"							
.3	0.000668	1.69	4.22	0.924	0.903	0.504	0.159	0.317	0.061								
.4	0.000891	2.26	6.98	1.23	1.61	0.672	0.345	0.422	0.086								
.5	0.00111	2.82	10.5	1.54	2.39	0.840	0.539	0.528	0.167	0.301	0.033						
.6	0.00134	3.39	14.7	1.85	3.29	1.01	0.751	0.633	0.240	0.361	0.041						
												1"		1¼"			
.8	0.00178	4.52	25.0	2.46	5.44	1.34	1.25	0.844	0.408	0.481	0.102						
																1½"	
1	0.00223	5.65	37.2	3.08	8.28	1.68	1.85	1.06	0.600	0.602	0.155	0.371	0.048				
2	0.00446	11.29	134.4	6.16	30.1	3.36	6.58	2.11	2.10	1.20	0.526	0.743	0.164	0.429	0.044		
3	0.00668			9.25	64.1	5.04	13.9	3.17	4.33	1.81	1.09	1.114	0.336	0.644	0.090	0.473	0.043
4	0.00891			12.33	111.2	6.72	23.9	4.22	7.42	2.41	1.83	1.49	0.565	0.858	0.150	0.630	0.071
		2"															
5	0.01114					8.40	36.7	5.28	11.2	3.01	2.75	1.86	0.835	1.073	0.223	0.788	0.104
				2½"													
6	0.01337	0.574	0.044			10.08	51.9	6.33	15.8	3.61	3.84	2.23	1.17	1.29	0.309	0.946	0.145
8	0.01782	0.765	0.073			13.44	91.1	8.45	27.7	4.81	6.60	2.97	1.99	1.72	0.518	1.26	0.241
10	0.02228	0.956	0.108	0.670	0.046			10.56	42.4	6.02	9.99	3.71	2.99	2.15	0.774	1.58	0.361
						3"											
15	0.03342	1.43	0.224	1.01	0.094					9.03	21.6	5.57	6.36	3.22	1.63	2.37	0.755
								3½"									
20	0.04456	1.91	0.375	1.34	0.158	0.868	0.056			12.03	37.8	7.43	10.9	4.29	2.78	3.16	1.28
										4"							
25	0.05570	2.39	0.561	1.68	0.234	1.09	0.083	0.812	0.041			9.28	16.7	5.37	4.22	3.94	1.93
30	0.06684	2.87	0.786	2.01	0.327	1.30	0.114	0.974	0.056			11.14	23.8	6.44	5.92	4.73	2.72
35	0.07798	3.35	1.05	2.35	0.436	1.52	0.151	1.14	0.074	0.882	0.041	12.99	32.2	7.51	7.90	5.52	3.64
40	0.08912	3.83	1.35	2.68	0.556	1.74	0.192	1.30	0.095	1.01	0.052	14.85	41.5	8.59	10.24	6.30	4.65
45	0.1003	4.30	1.67	3.02	0.668	1.95	0.239	1.46	0.117	1.13	0.064			9.67	12.80	7.09	5.85
												5"					
50	0.1114	4.78	2.03	3.35	0.839	2.17	0.288	1.62	0.142	1.26	0.076			10.74	15.66	7.88	7.15
60	0.1337	5.74	2.87	4.02	1.18	2.60	0.406	1.95	0.204	1.51	0.107			12.89	22.2	9.47	10.21
70	0.1560	6.70	3.84	4.69	1.59	3.04	0.540	2.27	0.261	1.76	0.143	1.12	0.047			11.05	13.71
80	0.1782	7.65	4.97	5.36	2.03	3.47	0.687	2.60	0.334	2.02	0.180	1.28	0.060			12.62	17.59
														6"			
90	0.2005	8.60	6.20	6.03	2.83	3.91	0.861	2.92	0.416	2.27	0.224	1.44	0.074			14.20	22.0
100	0.2228	9.56	7.59	6.70	3.09	4.34	1.05	3.25	0.509	2.52	0.272	1.60	0.090	1.11	0.036	15.78	26.9
125	0.2785	11.97	11.76	8.38	4.71	5.43	1.61	4.06	0.769	3.15	0.415	2.01	0.135	1.39	0.055	19.72	41.4
150	0.3342	14.36	16.70	10.05	6.69	6.51	2.24	4.87	1.08	3.78	0.580	2.41	0.190	1.67	0.077		
175	0.3899	16.75	22.3	11.73	8.97	7.60	3.00	5.68	1.44	4.41	0.774	2.81	0.253	1.94	0.102		
																8"	
200	0.4456	19.14	28.8	13.42	11.68	8.68	3.87	6.49	1.85	5.04	0.985	3.21	0.323	2.22	0.130		
225	0.5013	...	...	15.09	14.63	9.77	4.83	7.30	2.32	5.67	1.23	3.61	0.401	2.50	0.162	1.44	0.043
250	0.557	...	...	...	...	10.85	5.93	8.12	2.84	6.30	1.46	4.01	0.495	2.78	0.195	1.60	0.051
275	0.6127	...	...	...	...	11.94	7.14	8.93	3.40	6.93	1.79	4.41	0.583	3.05	0.234	1.76	0.061
300	0.6684	...	...	...	...	13.00	8.36	9.74	4.02	7.56	2.11	4.81	0.683	3.33	0.275	1.92	0.072
325	0.7241	...	...	...	...	14.12	9.89	10.53	4.09	8.19	2.47	5.21	0.797	3.61	0.320	2.08	0.083
350	0.7798			...	...	...	...	11.36	5.41	8.82	2.84	5.62	0.919	3.89	0.367	2.24	0.095
375	0.8355			...	...	...	...	12.17	6.18	9.45	3.25	6.02	1.05	4.16	0.416	2.40	0.108
400	0.8912			...	...	...	...	12.98	7.03	10.08	3.68	6.42	1.19	4.44	0.471	2.56	0.121
425	0.9469			...	...	...	...	13.80	7.89	10.71	4.12	6.82	1.33	4.72	0.529	2.73	0.136
		10"															
450	1.003			...	...	...	...	14.61	8.80	11.34	4.60	7.22	1.48	5.00	0.590	2.89	0.151
475	1.059	1.93	0.054			...	...	...	...	11.97	5.12	7.62	1.64	5.27	0.653	3.04	0.166
500	1.114	2.03	0.059			...	...	...	...	12.60	5.65	8.02	1.81	5.55	0.720	3.21	0.182
550	1.225	2.24	0.071			...	...	...	...	13.85	6.79	8.82	2.17	6.11	0.861	3.53	0.219
600	1.337	2.44	0.083			...	...	...	...	15.12	8.04	9.63	2.55	6.66	1.02	3.85	0.258
				12"													
650	1.448	2.64	0.097			...	...	...	...	...	...	10.43	2.98	7.22	1.18	4.17	0.301
700	1.560	2.85	0.112	2.01	0.047			...	...	...	...	11.23	3.43	7.78	1.35	4.49	0.343
						14"											
750	1.671	3.05	0.127	2.15	0.054			...	...	...	...	12.03	3.92	8.33	1.55	4.81	0.392
800	1.782	3.25	0.143	2.29	0.061			...	...	...	...	12.83	4.43	8.88	1.75	5.13	0.443
850	1.894	3.46	0.160	2.44	0.068	2.02	0.042	...	...	...	...	13.64	5.00	9.44	1.96	5.45	0.497
900	2.005	3.66	0.179	2.58	0.075	2.13	0.047	...	...	...	...	14.44	5.58	9.99	2.18	5.77	0.554
950	2.117	3.86	0.198	2.72	0.083	2.25	0.052			...	...	15.24	6.21	10.55	2.42	6.09	0.613
								16"									
1,000	2.228	4.07	0.218	2.87	0.091	2.37	0.057			...	...	16.04	6.84	11.10	2.68	6.41	0.675
1,100	2.451	4.48	0.260	3.15	0.110	2.61	0.068			...	...	17.65	8.23	12.22	3.22	7.05	0.807
1,200	2.674	4.88	0.306	3.44	0.128	2.85	0.080	2.18	0.042	...	...	...	...	13.33	3.81	7.70	0.948
1,300	2,896	5.29	0.355	3.73	0.150	3.08	0.093	2.36	0.048	...	...	...	...	14.43	4.45	8.33	1.11
1,400	3.119	5.70	0.409	4.01	0.171	3.32	0.107	2.54	0.055					15.55	5.13	8.98	1.28
										18"							
1,500	3.342	6.10	0.466	4.30	0.195	3.56	0.122	2.72	0.063					16.66	5.85	9.62	1.46
1,600	3.565	6.51	0.527	4.59	0.219	3.79	0.138	2.90	0.071					17.77	6.61	10.26	1.65
1,800	4.010	7.32	0.663	5.16	0.276	4.27	0.172	3.27	0.088	2.58	0.050			19.99	8.37	11.54	2.08
2,000	4,456	8.14	0.808	5.73	0.339	4.74	0.209	3.63	0.107	2.87	0.060			22.21	10.3	12.82	2.55
												20"					
2,500	5.570	10.17	1.24	7.17	0.515	5.93	0.321	4.54	0.163	3.59	0.091					16.03	3.94
														24"			
3,000	6.684	12.20	1.76	8.60	0.731	7.11	0.451	5.45	0.232	4.30	0.129	3.46	0.075			19.24	5.59
3,500	7.798	14.24	2.38	10.03	0.982	8.30	0.607	6.35	0.312	5.02	0.173	4.04	0.101			22.44	7.56
4,000	8.912	16.27	3.08	11.47	1.27	9.48	0.787	7.26	0.401	5.74	0.222	4.62	0.129	3.19	0.052	25.65	9.80
4,500	10.03	18.31	3.87	12.90	1.60	10.67	0.990	8.17	0.503	6.46	0.280	5.20	0.162	3.59	0.065	28.87	12.2
5,000	11.14	20.35	4.71	14.33	1.95	11.85	1.21	9.08	0.617	7.17	0.340	5.77	0.199	3.99	0.079	...	...
6,000	13.37	24.41	6.74	17.20	2.77	14.23	1.71	10.89	0.877	8.61	0.483	6.93	0.280	4.79	0.111	...	...
7,000	15.60	28.49	9.11	20.07	3.74	16.60	2.31	12.71	1.18	10.04	0.652	8.08	0.376	5.59	0.150	...	...
8,000	17.82	...	...	22.93	4.84	18.96	2.99	14.52	1.51	11.47	0.839	9.23	0.488	6.38	0.192	...	...
9,000	20.05	...	...	25.79	6.09	21.34	3.76	16.34	1.90	12.91	1.05	10.39	0.608	7.18	0.242	...	...
10,000	22.28	...	...	28.66	7.46	23.71	4.61	18.15	2.34	14.34	1.28	11.54	0.739	7.98	0.294	...	...
12,000	26.74	...	...	34.40	10.7	28.45	6.59	21.79	3.33	17.21	1.83	13.85	1.06	9.58	0.416	...	...
14,000	31.19	...	...	...	...	33.19	8.89	25.42	4.49	20.08	2.45	16.16	1.43	11.17	0.562	...	...
16,000	35.65	...	...	...	...	...	...	29.05	5.83	22.95	3.18	18.47	1.85	12.77	0.723	...	...
18,000	40.10	...	...	...	...	...	...	32.68	7.31	25.82	4.03	20.77	2.32	14.36	0.907	...	...
20,000	44.56	...	...	...	...	...	...	36.31	9.03	28.69	4.93	23.08	2.86	15.96	1.12	...	...

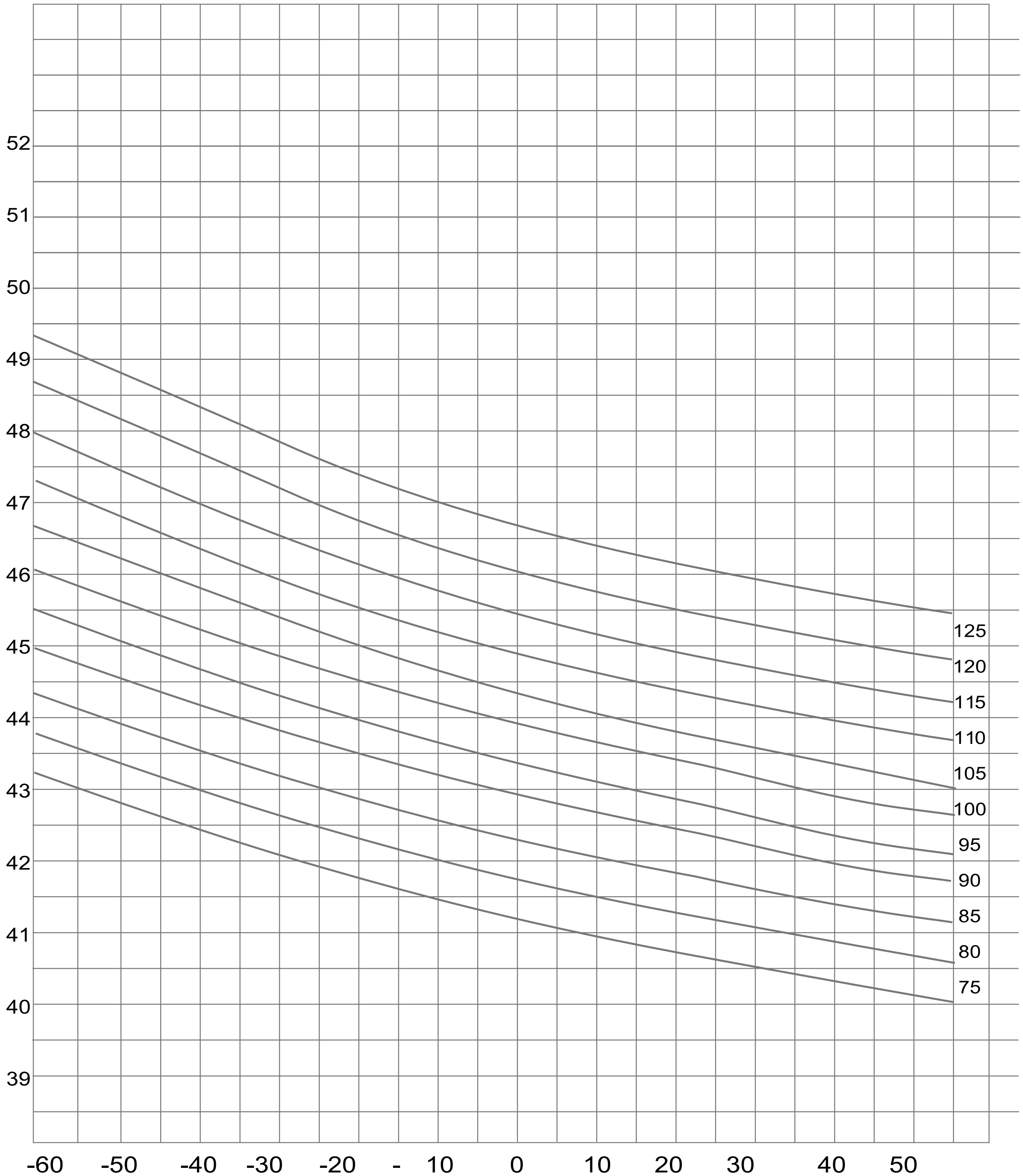
For pipe lengths other than 100 feet, the pressure drop is proportional to the length. Thus, for 50 feet of pipe, the pressure drop is approximately one-half the value given in the table . . . for 300 feet, three times the given value, etc.

Velocity is a function of the cross sectional flow area; thus, it is constant for a given flow rate and is independent of pipe length.

TYPICAL CONVERSION FACTORS (U.S. TO S.I. METRIC)

CONVENTIONAL U. S. UNIT	MULTIPLIED BY CONVERSION FACTOR	GIVES S. I. METRIC	METRIC UNIT SYMBOL
inch	25.40	millimetres	mm
inch	2.54	centimetres	cm
feet	0.3048	metres	m
square feet	0.0929	square metres	m^2
cubic feet	0.02832	cubic metres	m^3
microns (of Hg)	0.133322	pascals (equivalent to newtons per square metre)	Pa N/m^2
pound	0.453592	kilograms	kg
pounds of force	4.448	newtons	N
pounds of force per square inch (p.s.i.)	6.895	kilopascals	kPa
short ton	0.9091	metric tons	t
gallon	3.785	litres	l
gallon	0.003785	cubic metres	m^3
gallons per minute (g.p.m.)	0.06308	litres per second	l/s
gallons per minute (g.p.m.)	0.00006309	cubic metres per second	m^3/s
horsepower (hp)	746.0	watts	W
horsepower (hp)	0.7460	kilowatts	kW
tons of refrigeration	3.5168	kilowatts	kW
revolutions per minute (r.p.m.)	0.104720	radians per second	rad/s
British thermal units (Btu)	1,055.0	joules	J
Btu's per pound	2.326	kilojoules per kilogram	kJ/kg
convection coefficient and u-value (Btu/(hr x ft^2x°F.)	5.678286	watts ÷ (square metres x degrees kelvin)	$W/(m^2 \cdot K)$
temperature level (°F.)	x5/9 (after subtracting 32)	degrees celsius	°C
temperature difference (°F. delta T)	0.555	degrees kelvin	deg K
acres (plant site area)	0.4047	hectares (10,000 m^2)	ha
Btu's per hour	0.293067	watts	W
density (lb./ft^3)	16.0185	kilograms per cubic metre	kg/m^3
feet per second	0.3048	meters per second	m/s

VILTER Since 1867



VILTER®
Since 1867
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Cudahy, WI 53110
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