CABLE PRESSURE SYSTEM

PNEUMATIC RESISTANCE OF CABLES

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1. GENERAL

1.01 This section covers the behavior of air in cables and the relationships between airflow, pressure drop, and pneumatic resistance of cables maintained under pressure.

1.02 This section is reissued to add and delete certain sizes and gauges of pulp- and plastic-insulated exchange cables. Arrows are used to indicate these changes.

2. CABLE STRUCTURE

2.01 Depending on the type and makeup of cable, from 50 to 70 percent of the volume inside the sheath is air space through which air can flow. The conductors divide this space into many small air channels, some being through the pores in the paper- or pulp-insulating material.

2.02 The structural characteristics of a cable determine the number, size, and shape of the air channels. This action, in turn, controls the pneumatic resistance of the cable. Compared to a pipe where the resistance to low-velocity flow is largely due to the friction between the moving air and the inside surface of the pipe, the resistance of cables is very high.

2.03 Different types of cable vary widely in the amount of resistance they offer to the flow of air. Cables containing coaxials or 13- or 16-gauge, paper-insulated conductors present considerably less resistance to flow than cables containing only small gauge conductors, such as 24- or 26-gauge. Also, cables containing plastic-insulated conductors offer less resistance than comparable cables containing paper- or pulp-insulated conductors. Pneumatic resistance is the yardstick which is used to compare the flow characteristics of one cable to that of another.

3. BASIC CABLE

3.01 In order to compare the flow of air in various cables, it has been found convenient to relate all cables to a basic cable. This basic cable is assumed to be 1000 feet in length, with a diameter over the jacket of 1 inch. The characteristics of this cable are such that if a cylinder of dry air is connected to one end with the regulator set to deliver air at 1 pound of pressure, air will flow continuously from the other end at the rate of 1 cubic foot per hour. By definition, this basic cable has a total pneumatic resistance of 1.0 unit of pneumatic resistance.

3.02 If this cable were twice as long (other factors remaining unchanged), it would deliver air only half as fast, or at the rate of 1/2 cubic foot per hour.

3.03 If the source of dry air were connected to the cable with the regulator set at twice the pressure (other factors remaining unchanged), it would deliver air twice as fast, or at the rate of 2 cubic feet per hour.

3.04 If this cable contained twice the cross-sectional area (other factors remaining unchanged), it would deliver air twice as fast, or at the rate of 2 cubic feet per hour.

4. TOTAL PNEUMATIC RESISTANCE

4.01 As outlined in Part 3, the volume of air which will flow through a cable decreases with increase in length, and increases with increase in pressure. The relationship between pressure, volume of flow, and resistance to the flow of air can be expressed as follows:

$$P = FR \quad (1)$$

$$F = P/R \quad (2)$$

$$R = P/F \quad (3)$$

Where: P = Pressure drop in pounds per 1000 feet of cable

Where: F = Volume of flow in cubic feet per hour measured at atmospheric pressure

Where: R = Total pneumatic resistance of the cable expressed in units of pneumatic resistance, as determined by test.

4.02 Approximate total pneumatic resistance values for a number of different cables have been measured and are given in Part 7. If required, the pneumatic resistance of a type of cable not given in the tables may be determined by test, as described in Part 6.

4.03 A knowledge of the total pneumatic resistance of a cable is necessary for making leak location estimates with the cable pressurization computer, analyzing gradients involving more than one size and gauge of cable, and predicting probable pressure drop as a result of uniformly distributed leakage in a cable system. Total resistance is also valuable for estimating the most effective location for pressure sources and estimating the volume of dry air required where pressure sources are connected to a cable to maintain pressure during a period when the sheath would be open.

5. UNIT PNEUMATIC RESISTANCE

5.01 As mentioned in paragraph 3.04, the volume of air which will flow through a cable increases with increase in cross-sectional area; and when the cross-sectional area is doubled, the rate of flow is doubled.

5.02 In the latter case, the pneumatic resistance of each half is the same; but the halves act in parallel, each delivering half the total volume of air. As a result, the total pneumatic resistance (R) of this cable is only half as much as that of the smaller cable of similar type.

5.03 The relationship between the total pneumatic resistance of a cable and pneumatic resistance of each unit of area can be expressed as follows. For convenience, a unit of area is defined as being equal to an area of a 1 inch, diameter over jacket, cable.

$$R = \frac{r}{d^2} \quad \text{or} \quad r = Rd^2$$

Where: R = Total pneumatic resistance of the cable

r = Unit resistance of each unit of area of the cable.

d = Outside diameter of the jacket in inches. (This does not include any mechanical protection.)

5.04 Refer to Layer 626-200 of the Bell System Practices for the jacket or sheath diameter of the various types of cables.

5.05 Tests indicate that for practical purposes, cables of similar core construction, such as all 19-gauge quads, have about the same unit resistance per unit area. However, the total resistance (R) varies with the number of units of area in the cable. The larger the cable, the less the total resistance will be.

5.06 The unit resistance of a cable is a measure of the tightness of the core and speed of airflow through the cable. A high value of unit resistance indicates a tight core and a slow flow cable. A low value of unit resistance indicates a loose core and a fast flow cable.

5.07 Unit resistance is of value in predicting the rate at which air travels in a cable. Factors affected by this rate are steepness of gradient slope, time required for charging and gradient stabilization, built-up time in flash testing, and time interval before a contactor will operate to indicate the presence of a leak.

5.08 If it is necessary to determine the ***unit*** resistance of cables that are not listed in this section, it can be done by finding the total pneumatic resistance, as covered in Part 6, determining the diameter over the jacket of the cable, and substituting in the formula given in paragraph 5.03.

6. TESTS TO DETERMINE TOTAL PNEUMATIC RESISTANCE

6.01 The total resistance of a cable can be determined by connecting a cylinder of dry air to one end of a length of cable about 1000 feet long so air can flow toward a large opening at the other end. The volume of air delivered in a period of time can be observed on the regulator. The total resistance then is calculated from the relationship R = P/F, which is given in paragraph 4.01.

6.02 For example, assume that the pneumatic resistance is to be determined for a 1200-foot section of CA-140 cable, containing 68 pairs of 16 gauge and 70 quads of 19 gauge. Air is admitted at one end at a regulator pressure of 7.2 pounds. If after 6 hours the cylinder had delivered 88 cubic feet, the total pneumatic resistance of the cable would be as follows:

$$P = \frac{7.2 \text{ lbs}}{1.2 \text{ thousand ft}} = 6 \text{ lbs per 1000 ft}$$

$$F = \frac{88 \text{ cubic ft}}{6 \text{ hr}} = 14.7 \text{ cubic ft per hr.}$$

$$R = P/F = \frac{6}{14.7} = 0.41 \text{ total pneumatic resistance}$$

6.03 The total pneumatic resistance of a ***composite*** cable can be estimated if the total resistance of each of the two parts is known. The formula used to find the total pneumatic resistance of the cable is as follows:

$$R_t = \frac{R_1 R_2}{R_1 + R_2}$$

Where: R_t = Total pneumatic resistance of composite cable.

R_1 = Total pneumatic resistance of one part of a composite cable.

R_2 = Total pneumatic resistance of the second part of the composite cable.

7. PNEUMATIC RESISTANCE VALUES FOR DIFFERENT CABLES

7.01 ♦The pneumatic resistance values as determined by test for various cables are given in Tables A, B, C, D, and E.

Note: The values in Tables A and E may vary as much as 25 percent. The variations in plastic-insulated cables are much greater and may vary as much as 50 percent from those shown in Tables B, C, and D.♦

♦ TABLE A ♦

PAPER OR PULP INSULATED CABLES INCLUDING STEAMPETH AND TUFPULP

NUMBER OF PAIRS	PNEUMATIC RESISTANCE VALUES PER 1000 FEET					
	22-GAUGE (INCLUDING SCREENED)		24-GAUGE		26-GAUGE	
	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE
	R	r	R	r	R	r
3600	—	—	—	—	0.6	9.0
3000	—	—	—	—	0.7	9.0
2700	—	—	—	—	0.8	9.0
2400	—	—	—	—	1.0	9.0
2100	—	—	—	—	1.3	9.0
1800	—	—	0.9	8.0	1.6	9.0
1500	—	—	1.2	8.0	1.8	9.0
1200	0.7	6.5	1.5	8.0	2.2	9.0
* 1100	0.8	6.5	—	—	—	—
900	1.0	6.5	1.9	8.0	3.0	9.0
600	1.5	6.5	2.5	8.0	—	—
400	2.0	—	4.0	8.0	6.0	9.0
300	3.0	6.5	5.0	8.0	7.5	9.0

* Not manufactured with screen.

◆ TABLE B ◆

PLASTIC INSULATED CONDUCTOR CABLE (INCLUDING DUCTPIC)

NUMBER OF PAIRS	PNEUMATIC RESISTANCE VALUES PER 1000 FEET												
	17-GAUGE (ALUM)		19-GAUGE		20-GAUGE (ALUM)		22-GAUGE (INCLUDING SCREENED)		24-GAUGE		26-GAUGE		
	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	TOTAL PNEUMATIC RESISTANCE	UNIT PNEUMATIC RESISTANCE	
	R	r	R	r	R	r	R	r	R	r	R	r	
4200	—	—	—	—	—	—	—	—	—	—	0.6	7.0	DUCTPIC
3600	—	—	—	—	—	—	—	—	—	—	0.7	7.0	
3000	—	—	—	—	—	—	—	—	—	—	0.8	7.0	
2400	—	—	—	—	—	—	—	—	—	—	1.0	7.0	
1800	—	—	—	—	—	—	—	—	—	—	1.3	7.0	
1400	—	—	—	—	—	—	—	—	—	—	—	—	
1200	—	—	—	—	—	—	—	—	—	—	2.0	7.0	
1000	—	—	—	—	—	—	—	—	—	—	—	—	
900	—	—	—	—	—	—	—	—	0.3	1.9	0.6	2.7	
600	—	—	—	—	0.1	1.0	0.2	1.3	0.4	1.9	0.8	2.7	
400	—	—	—	—	0.1	1.0	0.3	1.3	0.6	1.9	1.4	2.7	
300	0.1	0.5	0.1	0.8	0.2	1.0	0.4	1.3	0.8	1.9	1.8	2.7	
200	0.1	0.5	0.2	0.8	0.3	1.0	0.6	1.3	1.2	1.9	2.7	2.7	
150	0.1	0.5	0.3	0.8	0.4	1.0	0.8	1.3	1.7	1.9	3.7	2.7	
100	0.1	0.5	0.4	0.8	0.6	1.0	1.2	1.3	2.5	1.9	5.5	2.7	
75	0.1	0.5	0.5	0.8	0.8	1.0	1.6	1.3	3.4	1.9	—	—	
50	0.2	0.5	0.7	0.8	1.1	1.0	2.4	1.3	5.1	1.9	11.0	2.7	
25	0.4	0.7	1.4	1.0	2.3	1.3	5.1	2.2	11.0	3.5	22.0	5.5	
16	—	—	2.2	1.0	—	—	8.2	2.2	—	—			
11	—	—	3.2	1.0	—	—	12.0	2.2	—	—			
6	—	—	6.0	1.0	—	—	—	—	—	—			