

**BELL SYSTEM PRACTICES**  
**Outside Plant Construction**  
**and Maintenance**

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## **PRESSURE TESTING**

### **PNEUMATIC RESISTANCE OF CABLES**

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#### **1. GENERAL**

1.01 This section discusses the behavior of gas in cables and the relationships that exist between gas flow, pressure drop, and pneumatic resistance of cables maintained under pressure.

#### **2. CABLE STRUCTURE**

2.01 Depending upon the type and make-up of cable, from 50 to 70 per cent of the volume inside the sheath is air space through which gas can flow. The conductors divide this space into many small gas channels some of which are through the porosities in the paper or pulp insulating material.

2.02 The structural characteristics of a cable determine the number, size and shape of the gas channels and this, 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 gas 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 gas. Cables containing coaxials or 13 or 16 gauge paper insulated conductors present considerably less resistance to flow than do cables containing only small gauge conductors, such as 24 or 26 gauge. Pneumatic resistance is the yard stick which is used to compare the flow characteristics of one cable to that of another.

### 3. BASIC CABLE

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

3.02 If this cable were twice as long (other factors remaining unchanged) it would deliver gas only half as fast or at the rate of one-half cubic foot per hour.

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

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

### 4. TOTAL PNEUMATIC RESISTANCE

4.01 From the discussion in Part 3, it can be seen that the volume of gas 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 gas can be expressed as follows:

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

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

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

Where  $P$  is the pressure drop in pounds per 1000 feet of cable,  
 $F$  is the volume of flow in cubic feet per hour measured at atmospheric pressure,

$R$  is the total pneumatic resistance of the cable expressed in units of pneumatic resistance as determined by test.

4.02 The above relationship is similar to Ohm's law for an electrical circuit, considering that the pressure ( $P$ ) is the electromotive force in volts, the flow ( $F$ ) is the current in

amperes and the total pneumatic resistance (R) is the total electrical resistance of the circuit in ohms.

4.03 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.

4.04 A knowledge of the total pneumatic resistance of a cable is useful in predicting the effects of a junction of different type cables on gradient shape when analyzing pressure graphs, and in the proper selection of cables to form circular gas sections on multi-cable routes in order to minimize junction effects. Total resistance is used in continuous flow systems to determine the rate of gas loss for a leak and the expected improvement in gradient shape and values of pressure at various points in the system which would result from the clearance of a leak. Total resistance is also of value when determining the rate of gas consumption and the volume of gas required when cylinders of gas are connected to a cable to maintain pressure during the period of sheath openings.

## 5. UNIT PNEUMATIC RESISTANCE

5.01 From the statement in Paragraph 3.04, it can be seen that the volume of gas which will flow through a cable increases with increase in cross-sectional area and that 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 two halves act in parallel, each delivering half the total volume of gas. 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 This 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 the area of a cable one inch in diameter outside the sheath.

$$R = \frac{r}{d^2}$$
$$r = R_d^2$$

Where **d** is the outside diameter of the cable in inches,  
**R** is the total pneumatic resistance of the cable,  
**r** is the unit or specific resistance of each unit of area of the cable.

5.04 Tests indicate that for practical purposes, cables of similar core construction, such as all 19 gauge quads, have about the same unit resistance, regardless of diameter.

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.

5.05 The unit resistance of a cable is a measure of the tightness of the core and speed of flow of gas through the cable. A high value of unit resistance indicates a tight core and a slow cable in respect to gas flow. A low value of unit resistance indicates a loose core and a fast flow cable.

5.06 A knowledge of unit resistance is of value in predicting the rate at which a pressure disturbance travels in a cable and the things which depend upon this rate, such as steepness of gradient slope, time required for charging and for gradient stabilization, build-up time in flash testing, and contactor operating time after the occurrence of a leak.

5.07 If it is necessary to determine the "unit" resistance of cables that are not listed in this section, it can be done by first finding the total pneumatic resistance as covered in Part 6.

## 6. TESTS TO DETERMINE TOTAL PNEUMATIC RESISTANCE

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

6.02 For example, assume that the pneumatic resistance of a cable, CA-140, containing 68 pairs 16 gauge and 70 quads 19 gauge is to be determined. A 1200-foot section of cable is available and gas 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:

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

$$F = \frac{88 \text{ cubic feet}}{6 \text{ hours}} = 14.7 \text{ cu. ft. per hour}$$

$$R = P/F = \frac{6}{14.7} = .41 \text{ Total pneumatic resistance}$$

6.03 The detailed procedure to be followed in making pneumatic resistance tests on cables is covered in another series of the Bell System Practices. When the pneumatic resistance of a cable not listed in the tables in Part 7 is desired, the matter should be referred to the engineer.

## 7. PNEUMATIC RESISTANCE VALUES FOR DIFFERENT CABLES

7.01 The approximate pneumatic resistance values as determined by test for various cables are given in the following tables. Values for exchange type cables are given in Table 1; values for a number of toll cables are given in Table 2.

**TABLE NO. 1**

### Pneumatic Resistance Values per 1000 Feet

#### Exchange Type Cable

Number of Pairs	* 19 Gauge ENB or equivalent		22 Gauge		24 Gauge		26 Gauge	
	Total Pneu. Resist.	Unit Pneu. Resist.	Total Pneu. Resist.	Unit Pneu. Resist.	Total Pneu. Resist.	Unit Pneu. Resist.	Total Pneu. Resist.	Unit Pneu. Resist.
	R	r	R	r	R	r	R	r
2,121	—	—	—	—	—	—	1.3	9.0
1,818	—	—	—	—	—	—	1.6	9.0
1,515	—	—	—	—	—	—	1.8	9.0
1,212	—	—	—	—	1.5	8.0	2.2	9.0
909	—	—	1.0	6.5	1.9	8.0	3.0	9.0
606	—	—	1.5	6.5	2.5	8.0	4.5	9.0
455	.7	5.0	1.8	6.5	—	—	—	—
404	.8	5.0	2.0	6.5	4.0	8.0	6.0	9.0
303	1.0	5.0	3.0	6.5	5.0	8.0	7.5	9.0
202	1.5	5.0	4.0	6.5	8.0	8.0	11.5	9.0
152	2.0	5.0	5.0	6.5	10.0	8.0	15.0	9.0
101	3.0	5.0	7.5	6.5	13.0	8.0	20.0	9.0
76	4.0	5.0	10.0	6.5	16.0	8.0	25.0	9.0
51	6.0	5.0	15.0	6.5	20.0	8.0	40.0	9.0
26	10.0	5.0	25.0	6.5	40.0	8.0	50.0	9.0
16	15.0	5.0	40.0	6.5	50.0	8.0	80.0	9.0
11	20.0	5.0	50.0	6.5	60.0	8.0	90.0	9.0

\* 19 Gauge DNB or equivalent types have approximately the same pneumatic resistance as 19 gauge toll cable of the same total number of pairs.

TABLE NO. 2

CADwg. No. or Spec.	Total Pneu. Resist. R	Cable Data	Cable Make-up										Coaxials	
			Wire Conductors											
			Quads					Pairs					Wires	Size
			10	13	16	19	22	13	16	19	22	24	19	.270
CA-1	.65				148	1	—	6						
CA-2	.48			12	124	—	—	6						
CA-6	.48			42	70	1	—	6						
CA-45	1.39			19										
CA-58	.44				208	1		6						
CA-140	.41				70	—	—	68						
CA-469	1.01	S.P.T.*			32									
CA-470	.57	S.P.T.			48									
CA-471	.87	S.P.T.			37									
CA-543	3.99	S.P.T.			12									
CA-587	2.68				61									
CA-593	2.01	S.P.T.			19									
CA-598	3.22				16									
CA-617	1.41	S.P.T.			32	—	—	—	61					
CA-660	1.15	S.P.T.							91					
CA-701	.80	S.P.T.			52(S)**									
CA-705	2.61				12	42								
CA-707	1.55				27									

\* S.P.T. = Short Pair Twist. All others have long pair twist.

\*\* (S) = Metallic shield in or over core.

TABLE NO. 2 (Continued)

CADwg. No. or Spec.	Total Pneu. Resist. R	Cable Data	Cable Make-up													
			Wire Conductors									Coaxials				
			Quads					Pairs					Wires	Size		
			10	13	16	19	22	13	16	19	22	24	19	.270	.375	
CA-726	1.20					64										
CA-801	.48					98	—	—	4							
CA-803	.60	S.P.T.				44										
CA-818	.45	S.P.T.				61										
CA-842	2.33	S.P.T.									44(S)					
CA-852	2.09	S.P.T.									44					
CA-912	2.22	S.P.T.									61					
CA-948	2.59	S.P.T.				16										
CA-961	1.53	S.P.T.				27										
CA-994	.63	S.P.T.														
CA-995	.37	S.P.T.									131(S)					
CA-1002	.87					95(S)										
CA-1030	.28	S.P.T.				75										
CA-1056	2.30	S.P.T.				44(S)	—	—	—	—	505					
CA-1060	1.46	S.P.T.									37					
											70					

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TABLE NO. 2 (Continued)

CADwg. No. or Spec.	Total Pneu. Resist. R	Cable Data	Cable Make-up												
			Wire Conductors								Coaxials				
			Quads					Pairs				Wires	Size		
			10	13	16	19	22	13	16	19	22	24	19	.270	.375
CA-1062	.89	S.P.T.				64									
CA-1063	.41	S.P.T.				52									
CA-1064	.78	S.P.T.				44									
CA-1066	.70	S.P.T.				44(S)									
CA-1070	1.46	S.P.T.								70(S)					
CA-1091	1.65	S.P.T.				24									
CA-1191	.36	S.P.T.				84									
CA-1198	.84	S.P.T.				21	—	—	—	3	4	—	—	6	
CA-1208	.47	S.P.T.				48	—	—	—	3	4	—	—	6	
CA-1215	.63	S.P.T.								3	—	—	—	8	
CA-1250	.50	S.P.T.				54	—	—	4	—	—	—	6	—	6
CA-1264	.40	S.P.T.					2	—	—	8	—	—	8	—	8
CA-1264	.55	Lepeth					2	—	—	8	—	—	8	—	8
CA-1267	.38	S.P.T.				10	—	—	—	—	—	—	8	—	8
CA-1283	.42	S.P.T.				40	—	—	—	—	—	—	8	—	8
CA-1304	.30	S.P.T.				68	—	—	8	—	—	—	8	—	8
CA-1322	.41	S.P.T.				76	—	—	—	—	—	—	8	—	8
CA-1324	.41	S.P.T.				2	—	—	8	42	—	—	8	—	8

TABLE NO. 2 (Continued)

CADwg. No. or Spec.	Total Pneu. Resist. R	Cable Data	Cable Make-up												
			Wire Conductors										Coaxials		
			Quads					Pairs					Wires	Size	
			10	13	16	19	22	13	16	19	22	24	19	.270	.375
CA-1328	.49	S.P.T.				32	—	—	8	—	—	—	8	—	8
CA-1357	.43	S.P.T.				24	—	—	4	202	—	—	6	—	6
CA-1357	.62	S.P.T.				21	—	—	4	—	—	—	6	—	6
CA-1359	.42	S.P.T.				80	—	—	4	—	—	—	—	—	—
CA-1400	.37	S.P.T.				36	—	—	4	—	—	—	8	—	8
3432	.46				19	56	—	—			101				
3568	.09				—	—	—	—	18						
3757 (7402)	.07				3	10	—	—	—	6	18				
3593	.32				7	18	—	—	—	6	18				
3776	.16					18	37	—	—	—	—	18			
3810	.40				3	30	—	—	—	—	18				
3890	.65					8	48	—	—	—	—	26			
3948	.69						19	56							
3965	.16						7	140	1						
3987	.52						30	—	—	—	1				
4031	.83						19	56	—	—	—	51			
4061	.62						56	41	1						
							12	46	1						

TABLE NO. 2 (Continued)

CADwg. No. or Spec.	Total Pneu. Resist. R	Cable Data	Cable Make-up											
			Wire Conductors									Coaxials		
			Quads					Pairs					Wires	Size
			10	13	16	19	22	13	16	19	22	24	19	.270
4240	.51				27	27	1	—	—	154				
4250	.46				42	64	1							
4251	.72				33	56	1							
4334	.70					75	1							
4439	.46				33	71	1							
4475	.46				19	93	1							
4476	.51				16	85	1							
4491	.50				37	33	1	—	—	51				
4537	.42				48	60	1	—	6					
4554	.76				27	64	1							
4722 (CA-4)	.41				27	99	1	—	6					
4723	.52				33	85	1	—	6					
4744	.37				19	114	1	—	6					
4795	.33				16	90	1	—	6	—	—	174		
4824	.23				7	13	1							
4838	.89				3	19	1							
4849	1.51					14	1							
4857	.44					12	124	1	—	6				
4885	.42					27	165	1						