

**PRESSURIZATION CHARACTERISTICS OF
POLYETHYLENE - INSULATED AND - JACKETED
TELEPHONE CABLES**

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The Insulated Power Cable Engineers Association

283 Valley Road Montclair, N.J. 07042

Area Code 201 Phone 744-3786

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INTRODUCTION

As polyethylene telephone cable lines increase in length, maintenance costs mount and demands for service reliability become more exacting, the trend toward gas pressurization of cables gains momentum.^{1,2} This is readily understandable when it is realized that pressurization keeps water out of a cable, provides a warning signal when jacket damage has occurred or a leak has developed at a joint, and assists in location of the point of pressure loss.

Pressurization systems commonly used in telephone cable installations are of the "continuous flow" variety. Gas, usually dry air or dry nitrogen, is fed into one end of a cable at a fixed pressure and expelled to the atmosphere at a remote end. The characteristics of any given cable with respect to movement of gas through the cable's flow path by differential pressure is identified by the pneumatic resistance of the cable. Values of pneumatic resistance are useful in evaluating differences in pressure gradients with length when cables of different sizes are connected in a system, in locating leaks and in planning pressurization facilities.

To obtain full benefits of pressurization some users require that some cables be shipped pressurized to make certain that jackets are free of defects prior to installation. As polyethylene is permeable to gases, it is necessary to have knowledge of the rate of gas pressure drop due to gas diffusion for various cables in order to differentiate between loss of pressure due to permeability and pressure drop due to jacket defects.

This publication discusses pneumatic resistance and permeability with respect to theory, methods of calculations and typical values (or patterns of values) from measurements made on cable produced circa 1963 by representative manufacturers.

¹Pressurization of Telecommunication Cables: Part 1—Principles of Gas Pressurization. J. R. Walters, J. F. Keep and J. F. Craggs. The Post Office Electrical Engineers' Journal, January 1963. London, England.

²Continuous Flow Gas Pressure Systems—Theory and Application to Telecommunication Cables. Information Bulletin No. 31—External Plant. Commonwealth of Australia. Postmaster-General's Department Headquarters, Engineering Division.

PART I PNEUMATIC RESISTANCE¹

THEORY AND FORMULAE

The characteristics of any given telephone cable with respect to movement of gas through the cable's flow path by differential pressure is identified by the pneumatic resistance of the cable. Pneumatic resistance is defined by the relationship:

$$R = \frac{P}{F}$$

where:

- R = pneumatic resistance,
 P = pressure drop in lbs/in.²/unit length (in feet) of cable,
 F = flow in standard* cubic feet per hour (scfh).

Example:

Pneumatic resistance of a given cable may be determined as follows:

- (a) Introduce gas under a constant pressure† into one end of a length of cable whose length is known.
- (b) Measure the rate of air flow at the open end of the cable length in cubic feet per hour.
- (c) Compute pneumatic resistance. An example is given:

Gas supply pressure = 10 psig
 Cable length = 1100 feet
 Flow for 4 hours = 70 cubic feet

$$P = \frac{10 \text{ lb}}{1.1 \text{ thousand feet}} = 9.1 \text{ pounds per 1000 feet}$$

$$F = \frac{70 \text{ cubic feet}}{4 \text{ hours}} = 17.5 \text{ cubic feet per hour}$$

$$R = \frac{P}{F} = \frac{9.1}{17.5} = 0.52 \text{ pneumatic resistance}$$

* For the purpose of this discussion a standard cubic foot of gas is considered to be a cubic foot of dry gas at atmospheric pressure (14.7 lb/in²) and a temperature of 23 C (73.4 F).

† While pressures of 9 to 12 psig are customarily used, it is understood that as much as 20 psig has been used with no apparent damage to the cable.

¹A Method of Analysis of Pneumatic Resistance Data for Polyethylene-Insulated Telephone Cables. W. D. Parker. IEEE Conference Paper CP 63-1053, 1963.

MEASUREMENT PROCEDURE

The apparatus used is shown schematically in Figure 1-1. Measurements were made on various lengths of aerial cable and on direct burial cable.

Aerial cable consists of twisted pairs of polyethylene-insulated conductors assembled into a cable core and covered with a nonhygroscopic tape. Over the tape is a corrugated aluminum or copper shield and an outer polyethylene jacket.

Direct burial cable is similar to aerial cable but has an inner polyethylene jacket between the core covering tape and the shield.

Dry filtered air at a regulated pressure of 9 psig was supplied to the flow path of the cable through a fitting over the polyethylene jacket of single-jacketed cable and over the inner jacket of double-jacketed cable at the outer end of the cable on the reel. From the inner end of the cable length air was conducted by similar means through a flow meter and a gas consumption meter. Mercury manometers were used to measure input pressure and back pressure. Back pressure was observed to be imperceptible. The flowmeter was used to indicate stabilization of exit flow, and volume of flow in cubic feet was measured by means of the gas consumption meter. Time of stable flow and consumption meter readings at the beginning and the end of the measuring interval were recorded for use in calculation of rate of flow.

DATA

Measurements were made by five cable manufacturers on representative samples from their production. Data reported from these measurements are recorded graphically as follows:

Figure 1-2 — Size 19 Awg aerial cable
 Figure 1-3 — Size 22 Awg aerial cable
 Figure 1-4 — Size 19 Awg direct burial cable
 Figure 1-5 — Size 22 Awg direct burial cable

A different symbol is used to indicate values reported by each of the five manufacturers.

A number alongside a plotted point indicates the number of times the value represented by the point was recorded.

On each graph the solid line is the "line of best fit", drawn from the equation for pneumatic resistance in terms of pair count. By definition it is that line which makes a minimum the sum of squares of the deviations from the line of the plotted values of pneumatic resistance from a known pair count.²

The broken lines are 95 percent confidence limits on the solid line. If the solid line is used to predict the value of pneumatic resistance for a cable of known pair count, these confidence limits give the limits between which the prediction has a 95 percent chance of being correct.²

²The statistical reference for the foregoing is Industrial Experimentation (book), K. A. Brownlee, Chemical Publishing Company, Inc., New York, 1952, pp.61-65.

EQUATIONS

The derived equations of pneumatic resistance in terms of pair count for the respective cable types and conductor sizes are:

Type of Cable	Awg Size	log R =
aerial	19	1.5733-1.1643 log PC
"	22	1.3282-0.5084 log PC
direct burial	19	1.2741-0.7362 log PC
" "	22	2.0554-0.7612 log PC

where:

R = pneumatic resistance
PC = pair count

The straight line relationship is significant at the 0.1 percent level in each instance. In other words, the probability of linearity of the pneumatic resistance—pair count relationship is 99.9 percent.

The equations and charts are based on products of the various manufacturers at the time the cable was produced and tested. They should be more realistic than anything previously available. Any changes in design, materials, processes and related areas by any manufacturer could change the equations and charts but would not necessarily adversely affect the utility of the cable.

ANALYSIS OF DATA

Values of R for compatible constructions, that is, with corrugated shields or with smooth jackets over the core covering tapes, were grouped according to conductor size for analysis and formed the bases for several meaningful observations.

1. For cables of homogeneous capacitance, sheath design and conductor size, R varies with pair count in a straight line relationship with negative slope on log-log coordinates. (Figures 1-2, 1-3, 1-4 and 1-5.)
2. Values of R are randomly distributed with respect to manufacturer. R for any given cable is likely to lie at any point within appropriate confidence limits. The negative slope of the R-pair-count line varies directly with conductor size, being more pronounced with larger conductors. (Figures 1-2 vs 1-3 and Figures 1-4 vs 1-5.)
 - a. A plausible explanation is that R of the cable comprised of larger conductors, with their larger interstitial spaces, is affected relatively more by cross-sectional core geometry and relatively less by conditions existing at the core periphery. Gas flow characteristics may also be a factor.

3. The best estimate of the R-pair-count relationship is the solid line of the equation as shown. Equal linear deviations above and below such a line represent equal percent deviations. If the line of equal arithmetic deviations is considered more useful, it may be located as passing through points of mean scalar difference between the broken lines and parallel to those lines.
4. Variability of R for any given pair count is greater than 22 Awg cables than for 19 Awg cables. (Figures 1-3 and 1-5 vs 1-2 and 1-4.)
 - a. Effects of the smaller interstitial spaces may be magnified by effects of variability of pair twist, stranding and cabling.
5. Additional indication of greater sensitivity of pneumatic resistance, R, of No. 22 Awg, is the relatively lower level of R for aerial cables with their shields directly over the core-covering tapes. (Figure 1-3 vs Figure 1-5.)
 - a. The relatively more rigid core-covering tapes and the rigid and corrugated shields would be expected to provide relatively larger flow paths at the core peripheries.

COMMENTS

Telephone cables are designed and manufactured to meet predominant exacting electrical requirements, and pneumatic properties are incidental.

The cables for which values of R were determined for this study were taken from stock and represent production circa 1963. Cable design, for optimum electrical properties, is dynamic, and changes in core assembly may be made to enhance electrical properties, with incidental effects, one way or another, on pneumatic properties. Such incidental effects may exist in the data under consideration, but no effort has been made to isolate them.