

SUBSCRIBER LOOP CHECKING GENERAL CONSIDERATIONS

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1. GENERAL

1.01 This section provides a general description of the J94024 Loop Checking System and the factors considered in the basic design.

1.02 Other practices in this series are listed below.

AB22.090.11 — Subscriber Loops — Factors Affecting Insertion Loss

AB22.090.12 — Loop Checker Generator — Determination of Output Shape

AB22.090.13 — Loop Checker Generator — Application to Non-Loaded Loops

AB22.090.2, AG15.211 — Application of the Loop Checking System

AB22.090.3, AG15.212 — Preparation of Loop Checker Distance Zone Map

2. FACTORS AFFECTING LOOP LOSS

2.01 The transmission loss of a properly designed and constructed loop is a function of frequency, and of the length, resistance, and

loading of the loop.* The loss of nonloaded loops having a fixed amount of bridged tap increases with increasing frequency, resistance, and length. The loss of loaded loops (for frequencies below cutoff) also increases with increasing frequency and resistance, but is relatively independent of the length.

The preceding discussion suggests that these parameters must be known and accounted for when utilizing transmission loss as a criterion in determining whether or not a loop has been properly designed, constructed and assigned. The length parameter is, however, only applicable to nonloaded loops.

2.02 In Section AB22.090.11 the effects of loop irregularities on transmission loss are discussed in some detail. Loop irregularities are defined, for present purposes, as variations from the design rules. Different loaded-loop irregularities effect the loss below 3 KC in different ways. The nature of these effects is such that a transmission loss measurement at a single frequency, or even at a number of discrete frequencies, probably would not always show whether or not a loaded loop conforms in all respects with the design rules.

2.03 Nonloaded loops are generally expected to have one type of irregularity (excess bridged tap). Excess bridged tap increases the loop loss over the whole transmission band but has a more pronounced effect at the higher frequencies. Thus, a single frequency measurement, preferably above 1 KC, will probably indicate this type of irregularity.

2.04 Sections AB22.075.1 and AB22.075.2 prescribe certain rules for the design of subscriber loops. The purpose of the rules in regard to transmission is to provide a satisfactory grade of transmission performance in a given

* This is covered in some detail in Sections AB22.090.11, AB22.090.12, and AB22.090.13. In particular, see Figs. 1, 2, 13, and 14.

central office area based on a statistical distribution of loop losses. If the rules are followed, satisfactory transmission performance should result; if they are not followed, the performance probably will be substandard. Of course, the loops can be designed to the rules and yet be constructed improperly, or the subscribers can be assigned to the loops erroneously. In these cases, the performance is also usually substandard.

2.05 One way of determining whether or not transmission is substandard would be to measure the transmission performance of loops in such a way as to indicate violation of the design rules. This is the philosophy followed in the design of the loop checker equipment.

3. BASIC EQUIPMENT DESIGN

3.01 Section AB22.090.11 outlines the effect of loop parameters and irregularities on the transmission loss of loops. Design of equipment to be used for determining whether or not loops have been properly designed and constructed must include consideration of these factors. The purpose of this section is to show how the basic features of the loop checker equipment evolved from such consideration.

3.02 Basic to the design of the loop checker equipment was recognition of the fact that probably the most feasible system would be one incorporating a relatively complex generator installed at the central office and a simple, easily operated measuring device to be used at the subscriber end of the loop.

3.03 Different loaded-loop irregularities affect the transmission loss at different portions of the transmission band. Since measurement at discrete frequencies would not reliably detect these irregularities, the decision was made to use a swept band of frequencies. The band between 1 KC and 3 KC was chosen since this band appeared to be reasonably sensitive to most types of irregularities.

3.04 The measurement procedure followed when using the loop checker equipment should be as simple as possible. A GO-NO GO or PASS-FAIL type of measurement fulfills this objective. However, this is a difficult measure-

ment to make using a swept band of frequencies since the loop has a loss vs. frequency shape and, hence, the received power varies with frequency. One way to eliminate this varying received power as much as possible is to shape the output power vs. frequency of the generator to compensate for the loop loss vs. frequency shape. That is, as the loop loss increases with frequency the generator out-put-power increases with frequency. This produces a fairly flat received-power spectrum at the subscriber end of the loop. Of course, different loops have different loss vs. frequency characteristics. The shaping had to be designed to produce a flat output at the subscriber end of loops which are designed and constructed to the limits of the rules. These loops are called limiting loaded loops. A limiting loaded loop is defined as one which has been designed with the maximum amount of bridged tap and end section, and which has load spacing meeting the requirements. The discussion of Section AB22.090.12 shows that all such loops, regardless of length or resistance, have a transmission loss vs. frequency shape that is substantially the same over the band from 1 KC to 3 KC. Thus, if the output power of the generator is increased with frequency the same as the limiting loaded loop loss increases with frequency, the received level at the subscribers end of this loop will be approximately flat across the frequency band. The loop checker generator output power is shaped in this manner.

3.05 The level shaping discussed above was designed for use on loaded loops because loaded loops can have many types of irregularities which become more evident when using a swept band of frequencies. However, the shaped output must also be applicable to the measurement of nonloaded loops. Nonloaded loops usually will only have the irregularity of excess bridged tap. This excess bridged tap adds loss at all frequencies and is fairly easy to detect. Occasionally a nonloaded loop may have one load which was placed erroneously. The resultant cutoff would be detected since the loss at the higher frequencies would be greater than that of a good nonloaded loop. Section AB22.090.13 describes the use of the shaped output for the measurement of nonloaded loops.

3.06 As discussed in Section AB22.090.12, the loss of properly designed loops increases with resistance and is about 0.5 db for each 100 ohms increase in loop resistance. This parameter is accounted for in the measuring device by including a potentiometer and DC current-measuring circuit which are used to adjust the sensitivity for the resistance of any loop.

3.07 The loss of properly designed nonloaded loops increases with length. This is discussed in some detail in Section AB22.090.13 where it is shown that the "allowed" * 2KC loss of nonloaded loops increases about 0.25 db for each 1 KFT increase in length. Thus, the measuring device must incorporate an adjustment which will compensate for this added loss by increasing the sensitivity on longer loops.

The loss of loaded loops does not increase appreciably with length. Therefore no variable adjustment for length need be made for loops over 18 KFT long, i.e., loops which should be loaded.

4. DESCRIPTION OF THE LOOP CHECKER EQUIPMENT

4.01 Considerations of the preceding sections culminated in the design of the loop checker equipment. The equipment consists of the Loop Checker Generator and the Loop Checker (referred to in the preceding section as the measuring device).

4.02 24A Loop Checker — (See Fig. 1)

4.021 The Loop Checker is described in specification J94024A and is shown on SD-99706-01. It is a small, one-transistor transmission measuring set which receives operating power from the central-office battery over the loop. It is bridged on the subscriber loop near the main station. The main station can remain on the loop if it is in the on-hook condition. During the test the Loop Checker provides the termination on the loop.

4.022 The face of the meter is divided into two regions; a green and a yellow region. The boundary between the two regions is marked "ZERO." The face is printed with db markings

* The term "allowed" is defined in Section AB22.090.13.

at the one and two db points or both sides of "ZERO." A small dot is also printed on either side of "ZERO." These dots are used in calibration of the Loop Checker at the Loop Checker Generator.

4.023 The sensitivity of the Loop Checker can be adjusted for the resistance and length of the loop. For the former, a push button is depressed while measuring DC current, and the "ZERO SET" dial is rotated until the meter needle is on "ZERO." When this has been done the Loop Checker has been adjusted for the loop resistance.

4.024 The "ZERO SET" dial is marked in kilohms from 0 to 1.5. These markings represent the loop resistance when the loop is connected to a central office having nominal 400-ohm, 48 volt talking-battery supply. Thus, when this dial is adjusted to null for the DC current, an approximate measurement of the loop resistance is obtained from the dial reading.

4.025 The length sensitivity adjustment is provided by a length potentiometer. The "LENGTH" dial is marked in even kilofeet from 0 to 18, and full clockwise is marked "OVER 18" for those loops greater than 18 kilofeet long which should be H-88 loaded. Other loading systems will be covered later (Paragraph 6.02).

4.026 The Loop Checker has two sets of terminals. The first called "TEL" is used to connect a 1011B handset, or equivalent, to the Loop Checker. The handset is used to dial the generator test line and to monitor the received test tone. The second set of terminals, called "LINE," is used to connect the Loop Checker to the loop.

4.027 The Loop Checker is polarity sensitive. Hence, a reversing switch is incorporated to reverse the polarity of the line terminals if it has been connected incorrectly to the loop.

4.028 Two push buttons are mounted on the face of the Loop Checker. When both push buttons are normal, the "LINE" and "TEL SET" terminals are connected together to form a through path in the Loop Checker. The handset terminates the loop in this condition. When the "ZERO SET" push button is depressed, the

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loop is terminated in about a 5-ohm resistor and the current adjustment is made. When the "MEAS" push button is depressed the loop is terminated in a 900-ohm resistor and the received level of the test tone is measured. There is also a high-impedance connection from the "TEL" terminals to the "LINE" terminals for monitoring the tone at a reduced level during the "MEAS" condition.

4.029 The Loop Checker will measure between -7.3 dbm and -19.5 dbm into its 900-ohm resistive load with ± 0.7 db accuracy. The sensitivity of the set depends on the settings of the "LENGTH" and "ZERO SET" potentiometers. Table 1, attached, lists the power requirements, in dbm, into 900 ohms necessary to have the meter needle read on the "ZERO" mark for various potentiometer setting combinations.

4.03 24B Loop Checker Generator —
 (See Fig. 2)

4.031 The Loop Checker Generator is described in specification J94024B and is shown on SD-99707-01. The generator is a completely electronic sweep-frequency oscillator, sweeping recurrently between 1 KC and 3 KC in about six seconds. The return from 3 KC to 1 KC is about 0.5 seconds. The generator output as a function of frequency, shaped in accordance with the discussion of Paragraph 3.04 is shown in Fig. 2 of Section AB22.090.12. A test-line circuit (SD-98100-01) is used with the generator to provide ringing trip, supervision, and time out where required.

4.032 The output impedance of the generator is 900 ohms. The generator is capable of serving up to ten simultaneously connected lines. A jack also provides a flat swept band at a reduced level (-8.7 dbm) which is used to test the Loop Checker. This flat output must be externally amplified if it is to be used for other purposes.

4.033 The generator shaped-output power is set such that the Loop Checker needle reads on "ZERO" or stays in the green region when measuring a loop. Thus the output-power setting depends on the losses of these loops and

on the sensitivity characteristics of the Loop Checker. Table 1 shows that the Loop Checker requires -13.8 dbm to read on "ZERO" when the length dial is set to "OVER 18" and the resistance dial is set to 1 kilo-ohm. The 2 KC loss of the 1000-ohm loaded loop (from Section AB22.090.12) is 9.8 db. Thus the generator output power must be $-13.8 + 9.8 = -4.0$ dbm into 900 ohms at 2 KC for the Loop Checker to read at least on "ZERO."

4.034 The value given above for generator output power is based on the assumption that the generator is directly connected to the bare loop. Actually the generator is connected to the loop through the central office switching equipment, and the transmission loss of this equipment must be compensated for. Simplification of results obtained in an earlier study provides the following estimates of office loss: 0.7 db for those offices having less than 20,000 lines; 1.2 db for those offices having over 20,000 lines. It is recommended that measured values be used wherever possible, however. The generator output power must also be increased to offset effects of other parameter variations. This will be discussed in the next section. For present purposes, the adjustment required is estimated to be about 0.8 db.

4.035 Consideration of the compensating adjustments results in the 2 KC power requirements for the generator given below.

CENTRAL OFFICE SIZE (Lines)	2 KC OUTPUT POWER (dbm into 900 ohms)
Under 20,000	$-4.0 + 0.7 + 0.8 = -2.5$
Over 20,000	$-4.0 + 1.2 + 0.8 = -2.0$

The mechanics of level setting are covered in BSP Sections in the A Series.

4.04 The Loop Checker equipment is designed to give a PASS-FAIL indication of the design and construction of a loop. When a loop has a FAIL reading this means that one or more loop-design or assignment rules have been violated. The work involved in determining which rules have been violated may be considerable, possibly involving record searching, physical

checking, and further testing. Obviously, if the Loop Checker FAILS a loop which has in fact been designed and constructed according to the rules, this added work is wasted. A few erroneous readings are possible because of the statistical nature of the many factors entering into the measurement. One objective in the design of the equipment has been to minimize the probability of giving a FAIL reading on a good loop. Naturally, one result of this objective is the increased probability of PASSING a loop which violated the rules. These loops, however, will be marginal loops on the borderline between good and slightly substandard.

4.05 Loops having the same resistance and length have different losses depending on their gauge make-up, location of bridged tap, etc. These variations have been taken into account in setting the "allowed" loop losses shown in Sections AB22.090.12 and AB22.090.13.

4.06 Other factors which have statistical distributions and which affect the measurement are equipment accuracy, central-office transmission loss, central-office battery voltage and resistance, and the knowledge of the loop length. In Paragraph 5 the effects of these factors are considered in some detail with the result that an added margin of 0.8 db is derived which is used in setting the generator output-power level. This added margin will prevent FAILING more than a negligible number of marginal loops.

5. MARGINS INCLUDED FOR PARAMETER VARIATIONS

5.01 The intent in the use of the Loop Checker equipment is to very rarely FAIL a properly designed and constructed loop. Thus, margins must be provided to account for the variations from nominal of the parameters which affect the measurement. Of course, adding margins to achieve this goal increases the probability of PASSING a loop which has slight irregularities, but this is not considered to be serious.

5.02 The quantities which may vary from nominal, and would therefore affect the measurement of the loop, are as follows:

1. Generator output.
2. Sensitivity of the Loop Checker.
3. Central-office battery and resistance.
4. Central-office transmission loss.
5. The estimated loop length may differ from the true length.

5.03 The required system accuracy of the combined generator output power and Loop Checker sensitivity is ± 0.73 db about nominal. This variation is assumed to be normal with a σ of 0.24 db.

5.04 The Loop Checker was designed to measure the loop resistance when the loop was connected to a central office having nominal 48-volt battery and 400-ohm battery-supply resistance. The DC current as a function of loop resistance for these conditions is shown on Fig. 3. Variations in battery supply voltage and resistance from nominal will produce variations from the curve. The more critical condition is high battery voltage and low supply resistance. The reason for this is that the Loop Checker interprets the resulting higher current as a lower-resistance loop, and the current sensitivity is adjusted such that the allowed loss for the loop is decreased. A supply voltage of 51 volts maximum and a battery-supply resistance of 360 ohms minimum is assumed to represent the worst case. On this basis, the apparent loop resistance will be about 80 ohms lower than the nominal-loop resistance (as measured using 49 volts and 400 ohms). The corresponding allowed loss difference is about 0.4 db. The variation is assumed normal with a σ of 0.13 db.

5.05 It is assumed that the estimate of the loop length, by whatever means acquired, will be within 2 KFT of the true length. The corresponding error amounts to a 0.5 db difference in loss from true length. Again, normality is assumed with a σ of 0.17 db.

5.06 The level of the generator will be initially set to take into account the approximate mean of the central-office transmission loss in

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which it is located, discussed earlier in the section). However, this loss will vary about the mean, and this variation is assumed normally with $\sigma = 0.14$ db.

5.07 The summary of the standard deviations for the quantities affecting the measurement of the received generator power are:

QUANTITY	σ
Generator Power and Loop Checker Accuracy	0.24 db
Loop DC Current	0.13 db
Length Estimate	0.18 db
Central Office Loss	0.14 db
Combined Standard Deviation (Root Sum Square Basis)	0.35 db

Multiplying the combined σ by 2.33 (99% point) and rounding off yields a margin of 0.8 db. Adding this 0.8 db margin to the nominal output power of the generator implies that the Loop Checker equipment should not FAIL a marginal loop more than a negligible percentage of the time. A marginal loop is one that is correctly designed and constructed but that is approaching a limiting loop.

6. LIMITATIONS

6.01 The Loop Checker equipment is designed for use in central offices having nominal 48-volt battery and 400-ohm battery supply resistance. This restricts its use to No. 1 and No. 5 X-Bar and SXS offices only. Modifications necessary to permit use of the equipment in panel office areas are now under study.

6.02 The equipment is further designed for use on nonloaded or H-88 loaded cable only. It will, however, work satisfactorily on H-44 loaded loops if the length dial is set to the 10 KFT position rather than the "OVER 18" position. This is discussed in Section AB22.090.12. It should perform satisfactorily on loops containing no more than about 10% rural or urban wire if the wire is not wet during measurements.

6.03 Laboratory computations indicate that the equipment can be used on loops containing open wire. For loops over 18 KFT long, the equipment will probably detect the presence of more than 18 KFT of nonloaded cable in the loop if the length dial is set to 18 KFT rather than to "OVER 18." This implies that all loops over 18 KFT long containing open wire must have transmission loss no greater than 18 KFT nonloaded cable loops. This length setting will ordinarily pass -2 db effective-loss loops. The length-dial setting should be set to the actual length for those loops containing open wire whose total length is less than 18 KFT long. The use of the Loop Checker equipment on open wire loops is not completely satisfactory since it was designed for cable. However, it will indicate when a rural subscriber is receiving worse transmission than the poorest urban subscriber.

6.04 The measurement of the transmission performance of the loop is based on the allowed losses of the bare loop. Thus any devices in the loop which add loss or change the battery feed resistance or voltage, may make the use of the equipment ineffective. These devices may include key sets, PBX equipment, long-line equipment, or off-hook party line telephones. On-hook telephones do not affect the measurement.

TABLE 1

Power in dbm into 900 ohms Required at Line Terminals of Loop Checker
to Have Meter Needle Read on Zero

		LENGTH Dial Setting — KFT										
		0	2	4	6	8	10	12	14	16	18	Over 18
ZERO SET Dial Setting — kilo-ohms	0.	-7.3	-7.8	-8.3	-8.8	-9.3	-9.8	-10.3	-10.8	-11.3	-11.8	-8.8
	0.2	-8.3*	-8.8	-9.3	-9.8	-10.3	-10.8	-11.3	-11.8	-12.3	-12.8	-9.8
	0.4	-9.3	-9.8	-10.3	-10.8	-11.3	-11.8	-12.3	-12.8	-13.3	-13.8	-10.8
	0.6	-10.3	-10.8	-11.3	-11.8	-12.3	-12.8	-13.3	-13.8	-14.3	-14.8	-11.8
	0.8	-11.3	-11.8	-12.3	-12.8	-13.3	-13.8	-14.3	-14.8	-15.3	-15.8	-12.8
	1.0	-12.3	-12.8	-13.3	-13.8	-14.3	-14.8	-15.3	-15.8	-16.3	-16.8	-13.8
	1.2	-13.3	-13.8	-14.3	-14.8	-15.3	-15.8	-16.3	-16.8	-17.3	-17.8	-14.8
	1.4	-14.3	-14.8	-15.3	-15.8	-16.3	-16.8	-17.3	-17.8	-18.3	-18.8	-15.8
	Full*	-15.0	-15.5	-16.0	-16.5	-17.0	-17.5	-18.0	-18.5	-19.0	-19.5	-16.5

* Full means the full clockwise rotation of the ZERO SET Dial.



Fig. 1 - 24A Loop Checker

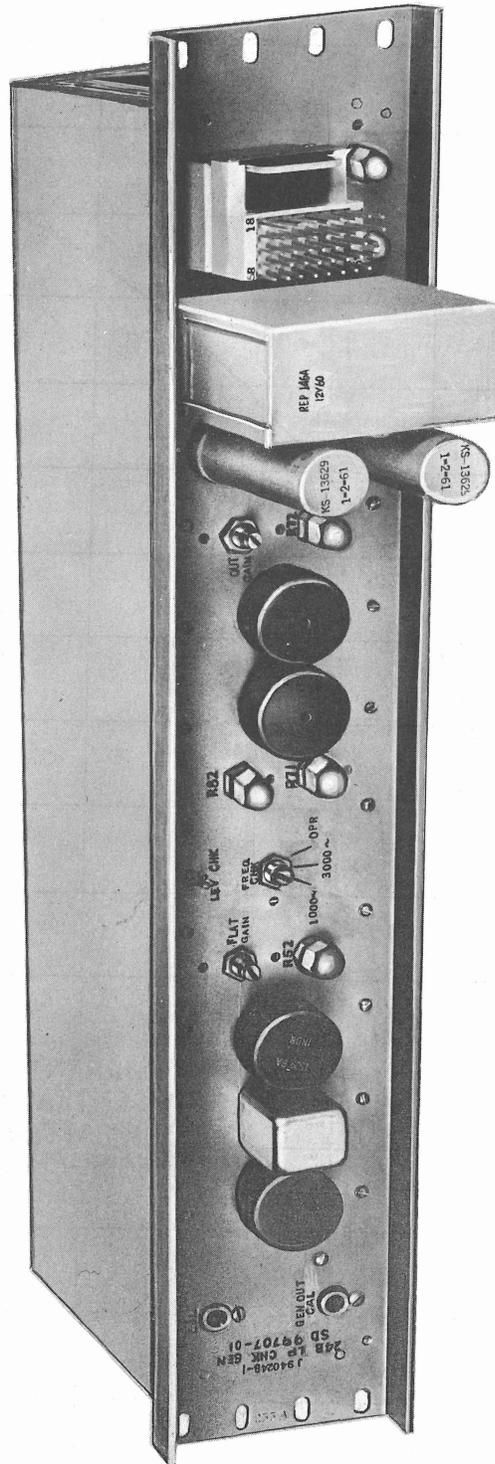


Fig. 2 - 24B Loop Checker Generator

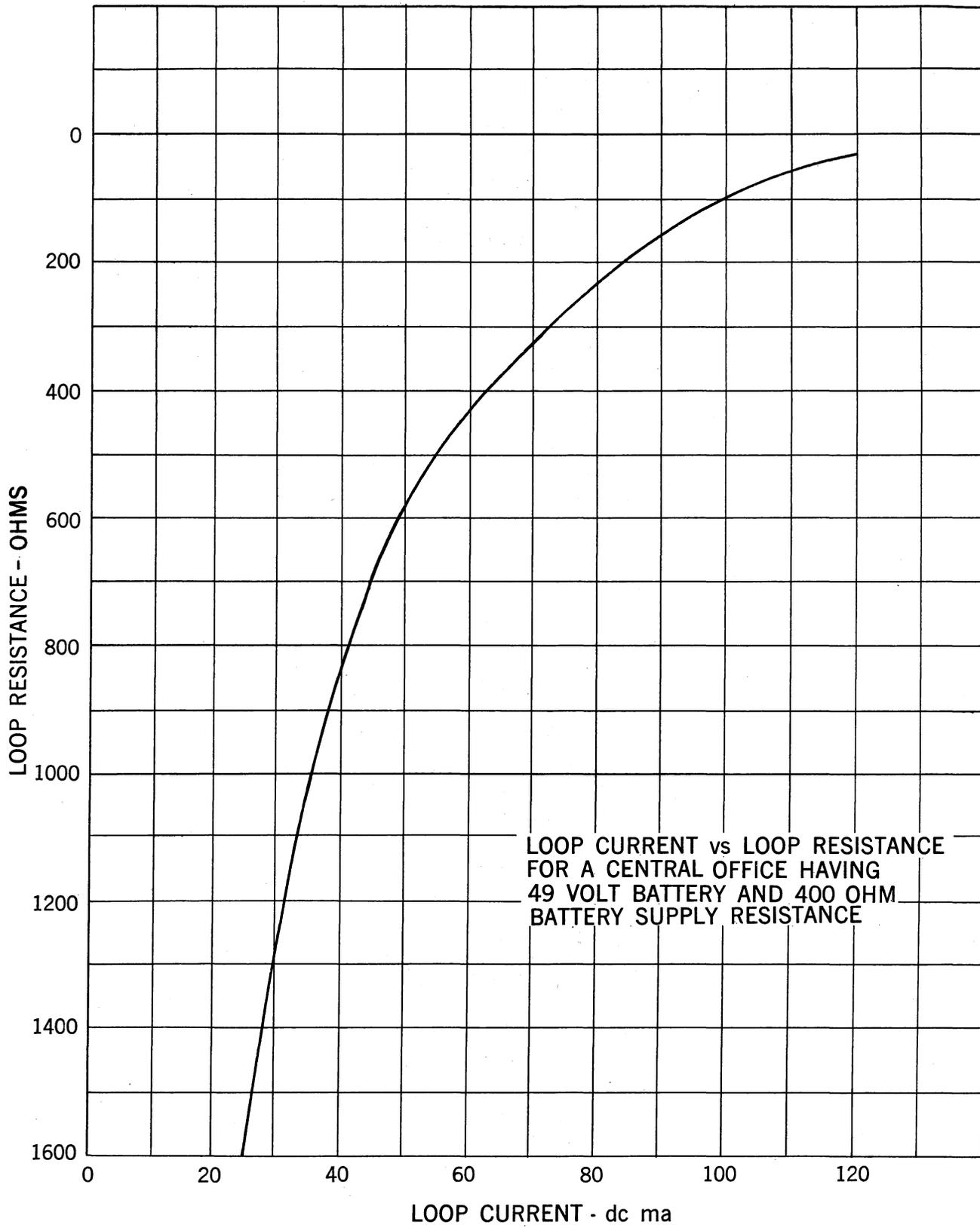


Fig. 3