NOISE ENGINEERING

CONTROL OF CENTRAL OFFICE NOISE

MEASUREMENT OF BATTERY SUPPLY NOISE

CONTENTS — PAGE

1. GENERAL

1.01 Power plants are potential noise sources in working communications circuits. Therefore, this section provides general engineering information on the characteristics, measurements, evaluation, and considerations for reduction of noise appearing at various points in central office power supply circuits.

1.02 This section is reissued to renumber it into the 870 division of the Plant Series, to retitle it, and to make a few miscellaneous changes.

1.03 With a few exceptions, discharge filters are necessary to meet the "talk" battery objectives given in this section. This section, therefore, discusses filters, their effectiveness under varying load conditions and their application with special emphasis given to decentralized filters.

1.04 This section is one of several related to the general problem of noise arising within central offices. Other sections cover general central office noise engineering considerations and discuss the noise aspects of other specific central office equipments.

1.05 Telecommunications nomenclature attaches somewhat specialized meanings to a number of power plant terms. Appendix 1 defines a number of these as they may be encountered in measurement and evaluation of battery supply noise.

2. ENGINEERING CONSIDERATIONS

A. Battery Plant Noise

2.01 The battery charging apparatus, induction from nearby wiring, noise producing loads supplied by the battery, and occasionally induction from sources outside the telephone plant may produce extraneous noise voltages in power plant batteries and the connected wiring and apparatus. Although the impedance of the power plant is low compared to that of most transmission circuits, it is not always low enough to reduce these extraneous voltages sufficiently to meet noise objectives of individual lines and trunks.

2.02 Rectifiers produce 60-Hz harmonics, while rotating machines may generate other tones. The number of commutator bars and the speed of rotation determine the frequency. These are the major contributors of power plant noise. However, other power apparatus, such as ringing machines and control relays, may add some tones and transients to the noise from the power plant.

2.03 Noise from dc supplies may enter communications circuits as follows:

(a) By way of the dc fed into the talking circuit of subscriber loops or by way of similar dc supplies of talk or signal battery to the transmission path of various trunk circuits.

(b) By way of the filament or plate battery supplied to amplifiers or carrier terminals used in various communications systems.

(c) By induction when a battery supply lead, not closely paired with its ground, lies close to transmission path cabling.

(d) By way of the common impedance provided by the battery supply wiring.

B. Battery Supply Filters in Telephone Plant

2.04 Battery supply filters are for the purpose of keeping noise generated by rectifiers from interfering with transmission. Charge filters, in most cases part of the rectifier, reduce ripple voltages. Discharge filters, located on the load side of the central office power plant, provide talk battery for the more sensitive circuits. These filters also attenuate other noise appearing at the battery bus as it travels via the battery supply wiring to sensitive transmission circuits. The components may vary depending on their use as described below.

2.05 In the usual power plant arrangement with the battery floated across the output of the rectifier, the charge filter consists of a capacitor bridged across the output of the rectifier. These capacitors reduce the source impedance of the power plant and at the same time help reduce noise voltages on the battery bus. As the distance between a load and the rectifier increases, the filter capacitor will be less effective in reducing noise voltages. This is because of the higher impedance of the longer leads. Charge filters may consist of inductors only, or a combination of inductors and capacitors in "L" or "T" configurations. Table A lists several charge filters as provided in the output of typical charging rectifiers.

2.06 Discharge filters, both decentralized and centralized, consist of a series inductor and a large shunt capacitor placed between the battery and the load with the capacitor on the load side of the inductor. Large capacitance values keep the source impedance low. Table B gives representative capacitance and inductance values for some discharge filters encountered in plant.

2.07 In general, discharge filters are installed (a) in the talk battery feed to subscribers loops, (b) in plate and filament battery supply to electron

TABLE A
TYPICAL CHARGE FILTERS

POWER PLANT	RECTIFIER CAPACITY AMPS.	RECTIFIER CAPACITY VOLTS	INPUT INDUCTANCE	TOTAL CAPACITANCE	OUTPUT INDUCTANCE
110-A	30	48	26mH	None	None
110-A	100	48	1mH	17,500μF	0.7mH
111-A*	30	48	20mH	13,000μF	None
111-A†	200	48	0.45mH	32,500μF	0.20mH
301-C&302A‡	1600	24	308mH	273,000μF	None
301-C&302A‡	1600	48	308mH	224,000μF	0.77mH

* J-87233A Rectifier
† J-86295A Rectifier
‡ KS-19212 24 Volt and KS-19215 48 Volt Rectifiers

TABLE B

TYPICAL DISCHARGE FILTERS

SUPPLY VOLTAGE	FULL LOAD CURRENT	RESISTANCE OF INDUCTOR	FULL LOAD INDUCTANCE	TOTAL CAPACITANCE
24	10A	.0118ohm	1.9mH	3500μF
24 & 48	15A	.0118ohm	1.4mH	3500μF
24 & 48	25A	.0118ohm	0.8mH	7000μF
24 & 48	50A	.0052ohm	1.0mH	7000μF
24 & 48	112A	.0035ohm	1.1mH	7000μF
24 & 48	200A	.0023ohm	1.0mH	7000μF
130V	1A	1.15 ohm	350 mH	400μF
130V	25A	.027ohm	14.0mH	2400μF

tubes, and (c) as required in the battery supply leads for other noise sensitive equipment or circuits.

2.08 The centralized discharge filter consists of an inductor and capacitor close to the battey. Centralized filters, because of their location far removed from the noise sensitive equipment they supply, require long battery supply leads. These leads may pick up considerable amounts of noise by both magnetic and electrostatic induction. Also, the impedance of long leads adds to the source impedance, which tends to increase any common impedance crosstalk between circuits supplied by these leads.

2.09 Smaller decentralized filters in, or very close to, the bays containing circuits that require quiet battery avoid the disadvantages of centralized filters. The decentralized filter eliminates the need for long, exposed leads back to the battery location. The actual talk battery leads can be short and confined largely to the bay where they are to be used.

2.10 A fuse in series with the larger filter capacitors protects the power plant and other equipment from damage and guards against possible service interruption if a capacitor should fail by an internal short.

2.11 Figures 1 and 2 show the insertion loss for typical discharge filters. Appendix 2 gives additional details as to the method used and assumptions made in computing the data for these curves. The figures show that these filters are quite effective in the voiceband. Reduced load allows a resonant peak in the vicinity of 50 to 55 Hz to become apparent. This resonance makes the filter virtually lossless below 80 Hz. Because of this, any 60-Hz energy, and to a lesser degree 120-Hz energy, will appear on the load side of these filters at about the same or higher level as on the source side.

3. NOISE MEASUREMENTS

A. General

3.01 Battery plants are only one of several sources of noise in central offices. Therefore, the interpretation of a series of battery supply noise measurements will depend to a considerable degree on the contributions from other central office sources. Further, the coupling paths through the battery supply system, though quite direct, involve large impedance irregularities. These make it difficult to define the relationship between noise measured at a battery source and noise at some point on the transmission path through a central office. When to make and how to interpret battery noise measurements will frequently depend, therefore, on the circumstances in each specific situation. Trouble conditions involving harmonics of 60 Hz or common impedance crosstalk are representative situations that might suggest noise measurements on the battery supply.

B. Test Apparatus

3.02 The 3A noise measuring set, the 4A frequency analyzer, and the 7A carrier frequency noise measuring set are the basic instruments for battery supply noise measurements. These with suitable cords, and the monitoring headphones included with each, should be all that is necessary for measurement and analysis of message circuit noise. The 103-5 and 103-6 layers of the Plant Series include sections

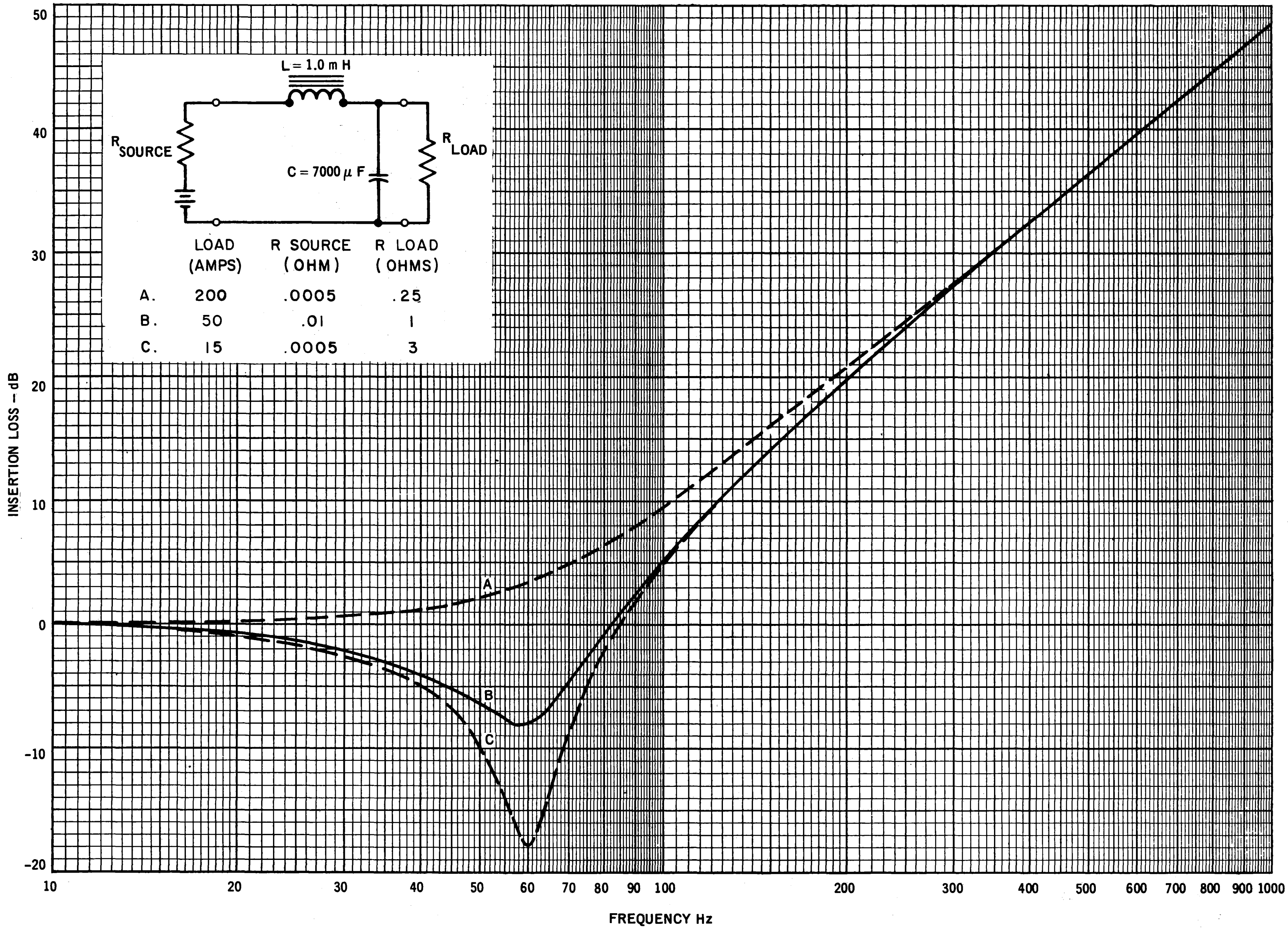

Fig. 1—Insertion Loss of Typical Decentralized Power Filter For 10 to 1000 Hz (SD-95571-01) See Appendix 2

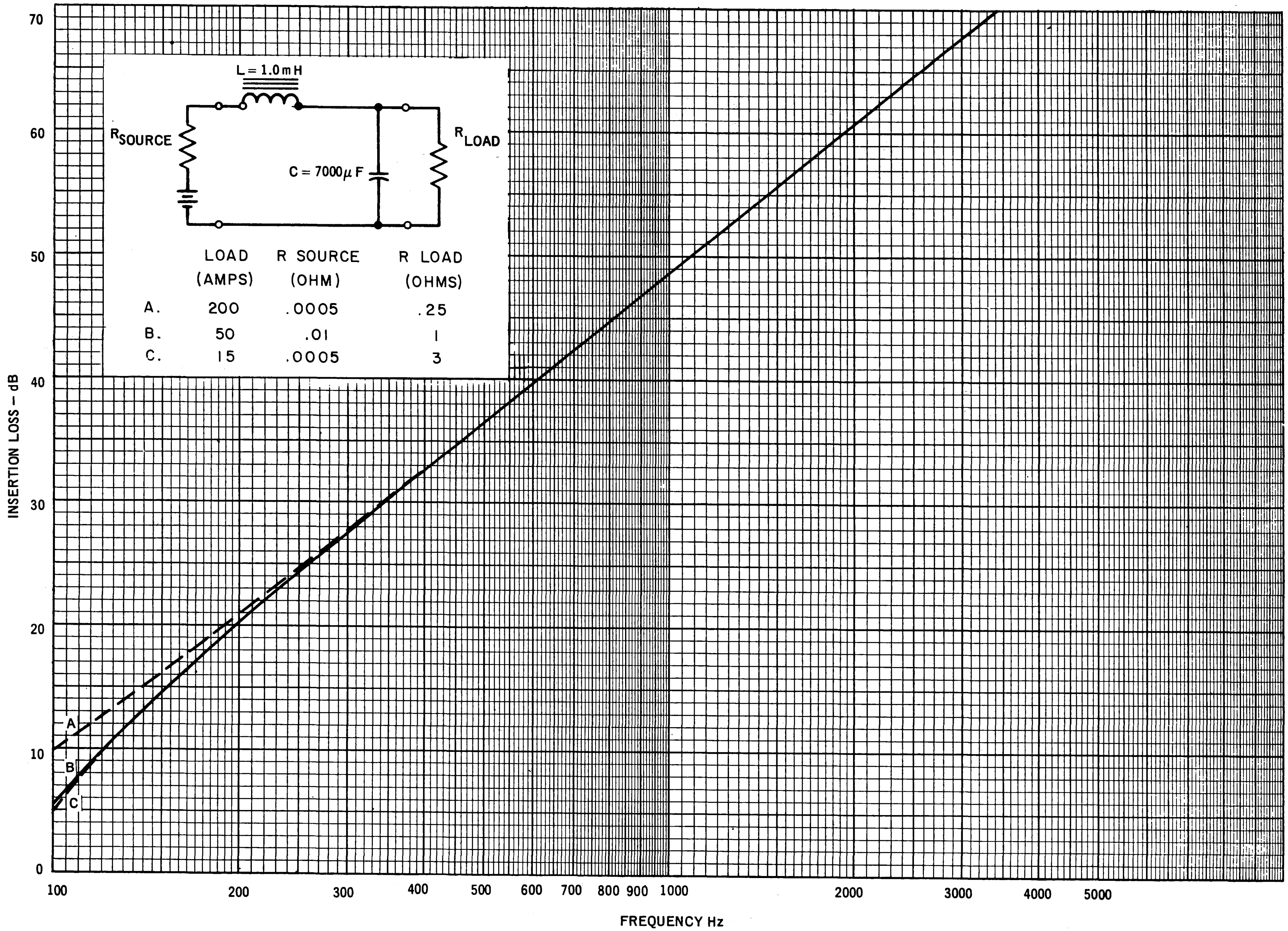

Fig. 2—Insertion Loss of Typical Decentralized Power Filter For 100 to 5000 Hz (SD-95571-01) See Appendix 2

describing noise measuring sets, their calibration, and their use.

3.03 An oscilloscope is occasionally useful to supplement the monitoring recevier. When connected across the monitoring receiver the oscilloscope will display the noise as affected by the weighting network used in the noise measuring set. Such an oscilloscope may serve as a quick check on the noise measurements. The input to most oscilloscopes is unbalanced. An oscilloscope connected directly across any balanced transmission circuit will unbalance it and increase noise if not isolated by a well-balanced shielded repeating coil. Further, when connected directly across a circuit, the oscilloscope will show unweighted wideband noise. Under these circumstances, its display is unrelated to message circuit noise.

> ***CAUTION: The grounded side of an oscilloscope if connected to the ungrounded "hot" side of the battery may cause serious damage, blow major fuses, and cause service interruption.***

C. Noise Measurements

3.04 As noted earlier, battery supplies present very low impedances. Therefore, the 3A, the 4A, and the 7A readings will not be true dBrn (power), but actually will be noise voltage indications. However, differences between two readings may still be expressed in dB. Since the battery impedance is so much lower than 600 or 900 ohms, the measuring sets should indicate about the same voltage, regardless of whether set for 600 ohms, 900 ohms, or bridging. The bridging or other high impedance setting is preferred.

3.05 Listening tests are very helpful when noise measurements indicate battery noise is a problem. The monitoring receivers furnished with the 3A, the 4A, and the 7A noise measuring sets are convenient for this purpose. A small loudspeaker with an amplifier, such as the AT7888 List 1A (Section 106-020-112), may be used in place of the monitoring receiver. A 10,000 ohm resistor should be in series with the amplifier input to avoid impairing the accuracy of the 3A NMS through loading effects. Appendix 3 lists a number of descriptive terms used to identify noise from various sources.

3.06 Test leads that parallel either charge or discharge leads may pick up noise by induction. This induced noise may cause large errors in noise measurements. Thus, the shortest possible twisted pair test leads running at right angles or well separated from power conductors, will assure reliable measurements.

3.07 In most central offices there are fuse panels or switchboards equipped with spare fuse holders located near the battery plant. These are reasonably safe and adequate for noise measurements. A small fuse, 1-1/3 amperes or less, placed in a vacant fuseholder which is then used as the "battery" terminal will protect test leads, the measuring instruments, and the power equipment.

> ***CAUTION: Central office batteries will supply large amounts of current under short circuit conditions. This current will generate heat in any conductor that happens to form a short circuit. Small conductors will fuse quickly and splatter molten metal as a result, exposing anyone in the vicinity to burns and flash. Larger metal objects, such as tools, if allowed to short circuit a battery, may seriously damage the conductors involved, the batteries themselves, or operate protective devices and cause a major service interruption.***

4. EVALUATION OF MEASUREMENTS

A. Objectives

4.01 Table C summarizes the noise objectives for central office battery supplies. The objectives refer to measurements at the battery supply fuse panel serving the equipment affected.

4.02 In general, noise measured at a talk battery fuse panel should not exceed 30 dBrnc. In no case should the noise exceed 40 dBrnc. These noise values include a reasonable allowance for the noise attenuation of the typical talking battery feed to subscriber loops of central offices. Although there are only two general types of talking battery feed circuits, repeating coil and bridged impedance, there is considerable variation in the apparatus used in different types of central office equipment. These differences, together with variations in loop current make the noise attenuation vary over a fairly wide range. Thus, measured noise in the range between 30 and 40 dBrnc may, or may not,

TABLE C

MEASUREMENTS AT BATTERY FUSE PANEL NEAREST EQUIPMENT SERVED

BATTERY SUPPLY	MEASURING SET	FURTHER ANALYSIS NOT NECESSARY	FURTHER INVESTIGATION	IMMEDIATE ACTION	NOTES
Talk		30 dBrnc or less	31-40 dBrnc	Over 40 dBrnc	1
24V or 48V	3A				
Signal					
24V, 48V	3A	55 dBrnc or less	Over 55 dBrnc	—	
130V	3A	70 dBrn 3kHz Flat	Over 70 dBrn	—	2
130V	7A	50 dBrn 3kHz Flat	Over 50 dBrn	—	3

Note 1: Typically, noise on the load side of decentralized discharge filters should be 20 dBrnc or less. Values above 20 dBrnc may indicate defective filter components. Values apply at fuse panel supplying talk battery whether supplied through a filter or direct from battery.

Note 2: Sections covering transmission requirements for various voice frequency amplifiers and carrier terminal equipment in general include C-message weighted noise objectives.

Note 3: Highest value in 3kHz band in 10 to 552kHz frequency range. ➧Includes any 130V battery supply, carrier terminal, or repeater equipment.➧

be satisfactory. Whether further investigation is required will depend on the noise levels in the transmission circuits served by the battery supply in question. Similar considerations apply to signal and plate battery supplies. If the noise in the affected circuits, cable or carrier, meets objectives as stated in the relevant practices, no further investigation is indicated.

B. Considerations for Reduction of Battery Supply Noise

4.03 Noise measurements on talk battery in the 30 to 40 dBrnc range do not necessarily indicate battery supply trouble. Such measurements do suggest further investigation of noise on the transmission path of circuits supplied by the battery supply in question. Where noise on trunks or subscriber lines is also excessive and correlates in harmonic content, or other characteristics, with the noise observed on the battery supply circuit, further investigation of the battery supply may then be indicated.

4.04 Noise in excess of 40 dBrnc on a talk battery supply requires immediate investigation and corrective action. The following paragraphs describe a number of likely trouble situations and what might be done to reduce the noise in each case.

4.05 Seasonal effects may increase noise considerably. An example is the effect of commercial ac power system loading. At certain times of the year these systems contain more harmonics that may enter communications circuits as inductive interference. Also the effect of high calling rates during busy periods on overall telephone system noise may obscure any noise effects contributed by battery supplies.

4.06 C-message weighted noise measurements should usually be considerably less on the load side of a filter than on the source side. Three-kHz flat weighted noise, however, is likely to be about the same on both sides of a filter. It may, in some cases, be higher on the load side, which might indicate either low frequencies coming in from the outside plant, or possibly resonance effects in the filter.

4.07 Excessive C-message weighted noise on the talk battery side of a filter may indicate an open or defective filter capacitor. However, such a measurement is not conclusive. A supplemental measurement of noise ahead of the filter will help clarify the first measurement. The second measurement should be at the signal battery fuse panel supplying the filter. Considerably higher noise readings at the signal battery bus suggest that the filter is working. Noise about the same on both sides of a filter or only moderately higher on the battery side tends to confirm the original inference that the filter capacitor is defective. This condition may also indicate trouble with the inductor or that the filter is reversed with the capacitor on the source side and the inductor in series with the load. An inductor in series with the load will unbalance the entire talk battery supply and further increase the noise.

4.08 Any inadvertent path connecting the talk battery side of a filter to signal battery will short the series inductor and essentially destroy the effect of the filter. Such paths will not be apparent because usually no fuses will blow. The only indication will be noise on the talk battery equal and similar to noise on the signal battery. As an example, ringing machines must be connected through a fuse to signal battery. An alarm fuse parallels the main fuse, although it does not need to be on the same fuse panel. This fuse could be inadvertently located on a talk battery fuse panel and thus provide a connection for noise between signal battery and the load side of the filter.

4.09 Common impedance crosstalk in the battery circuit is usually low except under trouble conditions. The crosstalk coupling loss from one subscriber line circuit to another via the common impedance of the battery supply path lies in the range of 120 to 150 dB without the discharge filter. Thus, crosstalk via the common impedance of the battery circuit is insignificant, and the presence or absence of discharge filters is inconsequential from a crosstalk standpoint. Defective discharge filters, where the series inductor is in the circuit but the shunt capacitor is out of the circuit, as could happen with a blown fuse, would be an exception. In this case, the increased source impedance will adversely affect the noise on the load side of the filter.

4.10 Investigation of high noise measured on signal battery will usually depend on the kind of noise involved. Listening tests often give the clue to the specific source of the interference. Repeated measurements on several or all of the fuse panels in a central office may, by comparative magnitudes, help establish the direction of flow of the noise and, at least, point to a general area where the source might be located.

4.11 Harmonic analysis, using the 4A frequency analyzer, or an equivalent instrument, will identify and give the magnitude of 60-Hz harmonics if any are present. The same procedure will help to identify tones of unrelated frequencies. Appendix 3 lists some of these.

4.12 In cases where C-message weighted noise is excessive and listening tests with the monitoring receiver do not clearly identify the trouble, additional listening tests with 3-kHz flat weighting may help. Such measurements, in general, will be higher than C-message weighted measurements because of the effect of 60 Hz and any of its harmonics below about 900 Hz. As Fig. 1 shows, discharge filters have very little insertion loss at the lower frequencies.

4.13 Occasionally, direct measurements such as those described above will not identify a particular piece of power apparatus that is in trouble. A technique of "on-off" testing is sometimes effective where load conditions permit. In this procedure one or more pieces of apparatus are shut down. A significant change in the noise should identify the source. The batteries will carry the full office load for a reasonable period while the charging apparatus is shut down. However, it is not possible to shut down both ringing machines at the same time. One must continue to run or the whole office will fail.

4.14 Where battery noise measurements indicate that all filters are working properly but excessive noise persists in the quiet battery leads, then either inductive interference in the outside plant or noise from within the office is likely. The presence of 60-Hz harmonics should identify inductive interference. These enter the battery circuit via both common impedance in the ground path and inductive couplings. The neutral of the 120/240 ac building supply, if grounded at any point beyond the service entrance, may introduce noise into the central office grounding system that can appear in the quiet battery and elsewhere.

4.15 Excessive coupling often occurs as the result of running high noise influence leads (power supply, telegraph, ringing, tone circuits, control circuits, etc.) in the same cables, cable runs, or bay wiring containing low-level transmission circuits or talk battery supply leads. The presence or absence of such a condition can often be ascertained by physical inspection of the cabling where the disturbed and disturbing pairs or wires are closely parallel and/or by temporarily rerouting either the disturbed or the suspected disturbing circuits.

4.16 Where measurements do suggest that battery noise may be a contributor to the overall noise originating in a central office, it may be helpful to check the physical condition of batteries, rectifiers, commutators, filter capacitors, etc. To be effective, the filter capacitors must be connected on the talk side of the filter inductor and polarized properly with the correct size capacitor fuse in place. Occasionally, a capacitor fuse may open or be removed without blowing the alarm fuse. The unblown alarm fuse provides a high impedance in series with the capacitor, greatly reducing its filtering action. Also, filter capacitors change their charactistics noticeably over longer periods of time due to aging effects. These, as they age, allow more noise to flow in the associated battery supply circuits. Division 032-1 contains a section describing tests on electrolytic capacitors.

4.17 Battery and ground supply conductors are paired only from the local fuse panel to the equipment. Between the power plant and the various battery distribution panels, the battery and ground leads are not twisted because of their heavy gauge. As a result, their balance tends to be somewhat poor. Noise voltages and currents on battery and ground conductors may therefore induce disturbing voltages or currents on paralleling conductors if they are close together.

4.18 Excessive talk battery noise, particularly in small dial central offices, may also arise because of the absence of any form of discharge filtering. In these situations decentralized filters and in some cases centralized filters should reduce the noise to satisfactory levels.

4.19 Where noise is excessive at talk battery fuse panels fed from existing centralized discharge filters, replacement by or supplementing with decentralized filters is indicated.

4.20 Because of various built-in noise control features, voice-frequency repeater or carrier-frequency noise may be at quite high levels when measured at a battery distributing fuse panel, and still be well within limits when measured on the voice-frequency transmission path. The objectives in Table C for measurements on the 130-volt battery take this into account. Most of the noise on battery supply wiring is induced by noise currents and voltages flowing on nearby wiring. The charge filters built into the various rectifiers substantially reduce any carrier frequency interference coming through or generated within the rectifier. Unless specified by design, external decentralized filters are not generally required for voice-frequency repeaters or carrier systems. Where the battery supply and associated wiring is clearly the source of noise, defective filtering apparatus furnished with the equipment may be a likely cause. To verify the operation of plate battery filter components, considerations similar to those described for talk battery filters apply.

4.21 Battery supply ground leads are frequently very noisy. This results from current transients, generated by switching functions and other relay operations, flowing through these leads. Even though these leads are usually very large, they begin to have appreciable impedance at mid-audio and higher frequencies. For this reason one should not rely on the battery supply ground leads for shield or other critical grounds, unless no other grounds are available.

APPENDIX 1

TERMS USED TO DESCRIBE THE DIRECT CURRENT ENERGY NEEDED TO POWER TELECOMMUNICATIONS APPARATUS

BATTERY: In addition to its technical meaning, it is used to describe any direct current supplied to telecommunications apparatus. When used to describe a direct current lead from a battery, the polarity is negative with respect to ground unless otherwise indicated.

BUS: When combined with "BATTERY" or "GROUND", describes the single large capacity conductor common to many branching, fused, battery supply leads.

CHARGE FILTER: A filter built into most rectifiers to reduce output ripple. This may be a large electrolytic capacitor, an inductor, or a combination of the two in "L" or "T" configurations.

DISCHARGE FILTER: These filters are on the load side of the power plant. Now most frequently decentralized, they supply quiet or talk battery to noise sensitive circuits.

FILAMENT BATTERY: Battery supplied to filaments or heaters of electron tubes, usually 48 volts.

GROUND: The grounded direct current lead. This is connected to the positive side of the direct current supply, unless otherwise indicated.

HARMONICS: These are the product of some fundamental frequency multiplied by any whole number. See Appendix 3 under "Harmonics of 60 Hz."

PLATE BATTERY: Usually 130-volt positive filtered direct current supply used for the plate supply of electron tubes in amplifiers, carrier systems, and similar apparatus.

SIGNAL BATTERY: Unfiltered 48-volt direct current supply from the telephone power plant.

TALK BATTERY: Used to describe filtered 48-volt dc, or sometimes 24-volt dc in older offices, applied to the subscriber's line to energize the transmitter. Sometimes the term quiet battery is also used to describe filtered battery.

TELEGRAPH BATTERY: Unfiltered positive or negative direct current supply used for neutral and polar telegraph lines. Usually ±130 volts.

APPENDIX 2

INSERTION LOSS OF FILTER AS SHOWN BY FIGURES 1 AND 2

Equation 1, below, permits computation of the insertion loss of a simple "L" configuration filter, provided the terminations are pure resistances.

$$(1)\quad dB_{\text{insertion loss}} = 10 \log_{10} \frac{(R_O + R_L - R_L LC\omega^2)^2 + (L + R_O R_L C)^2\omega^2}{(R_O + R_L)^2}$$

Where R_O = source resistance in ohms — Note 1

R_L = load resistance in ohms — Note 1

L = series inductance in henries

C = shunt capacitance in farads

$\omega = 2\pi f$

Note 1: The source and load reactive components are assumed to be very small in the aggregate as they are parts of many parallel paths. Also, the resistance of the filter inductor is assumed to be negligible. R_O, the source resistance, is quite indeterminate; however, an estimate is possible. The source resistance for a single filter will be the central office battery shunted by all charging machines and rectifiers in parallel with all signal battery loads, including any other centralized or decentralized filters. Table A gives estimates of the source resistance for a large and a small central office, based on 23 cells of the largest and smallest KS-5553 or KS-15544 storage batteries.

TABLE A

ESTIMATE OF SOURCE RESISTANCE

	AMP HOURS CAP OF BATTERY	8 HR DISCH RATE	RESISTANCE OF CHARGED CELL = R_c	K*	R_o = R_cx23xK
Large Office	1680	210 amps	0.0002	0.1	0.00046
Small Office	180	22.5 amps	0.0016	0.25	0.0092

****Note:*** The value "K" is dimensionless and represents what might be the total shunting effect of all other charging equipment and loads.

The load resistance, R_L, corresponds to the maximum current for three standard filter designs: 200, 50, and 15 amperes at 48 volts, or .25 ohm, 1 ohm, and 3 ohms.

Equation 1 generated the curves given in Fig. 1 and 2. Rather wide variations in the source resistance had very little effect on the shape of the curve. The load resistance, R_L, is the factor that controlled the depth of the resonant point near 50 Hz.

APPENDIX 3

DESCRIPTIONS OF NOISE FREQUENTLY ENCOUNTERED AT BATTERY FUSE PANELS AND ON OTHER CIRCUITS IN CENTRAL OFFICES

A number of sections list and describe the noise from various sources. For convenience, here is a summary of the more important types that may appear on a battery bus.

(a) ***Harmonics of 60 Hz or other fundamental frequency.*** The expression $v \cdot n \cdot f$ gives the frequencies of the harmonics that may appear in the dc output of a rectifier where:

v = 1, 2, 3...(any number)

n = The number of equal peaks in the dc ripple in one full cycle of the fundamental, called the "number of phases" of the rectifier.

f = 60 Hz or the fundamental frequency of the supply if not 60 Hz.

Rectifiers take harmonics from the ac system as well as the fundamental. The frequencies are $(v \cdot n \pm 1)f$; each frequency which appears on the dc side is accompanied by two harmonics on the ac side, one higher and one lower by the frequency of the fundamental. Occasionally, these harmonics may be observed in communications circuits as inductive interference. Thus, their source is most likely external to the telephone system.

(b) ***Other tones, not harmonics of 60 Hz***

In telephone central offices some tone generators receive their power from the battery plant and others from the ac line. In office wiring, tones on leads to and from these sources, if not segregated, may couple into battery leads and other circuits. Typical tones in offices are due to:

(1) Rotating dc generators used in Bell System power plants may contribute audio tones generated at their commutators. The frequencies of these tones will depend on the number of commutator bars and the speed of rotation.

(2) Singing repeaters can also be sources of tones that get back to the battery bus. Such tones might be almost any frequency from low audio to carrier.

(3) Ringing machines generate tones at high levels. Most common are dial tone, "high tone," and "low tone." The latter two, when interrupted, are the source of 60 IPM busy tone and 120 IPM reorder tone, etc.

(4) Central office tone generators produce 1000 Hz, 2600 Hz, howler tone, cable test tone, multifrequency signaling, and others.

(5) Carrier systems produce various carrier frequencies that can appear on the battery bus.

(c) ***"White" or "Gaussian" noise.*** This is present to some degree in all electrical equipment, but rarely at high levels capable of being sources of noise.

(d) ***Crosstalk:*** As the result of trouble conditions, crosstalk (including speech, tones, and noise) may travel via the common impedance of the battery supply lead and appear on the battery bus.

(e) ***Impulses:*** Some examples are:

(1) Dial train "clicks"

(2) Telegraph "thumps"

(3) Large single impulses of considerable magnitude, such as lightning, certain supervisory functions, and many other relay make and break contact combinations.

(4) Central office "clatter." Impulses coming quite frequently, but of higher level than the Gaussian background noise, usually easily identified as being generated by normal switching functions.