

NOISE IN TOLL OFFICE EQUIPMENT

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1. GENERAL

1.01 This section has been reissued to renumber it into the nine digit Plant Series, to remove references to obsolete apparatus and testing equipment, and to update information on clicks and impulse noise. Since this revision involves extensive deletions and additions, the marginal arrows usually used to indicate such changes have been omitted.

1.02 This section covers a discussion of the types of noise troubles which may be encountered in toll office equipment and explains principles which have been effectively employed in locating and clearing these troubles.

1.03 Since the possible causes of noise are numerous and the effects may be the result of a

combination of contributing conditions, it is impracticable in the general case to follow a definite preconceived procedure in running down noise trouble. The methods used and tests made must be adapted to meet the needs of a particular situation.

1.04 In any case it is advisable, before undertaking extensive tests, to ensure that the noise is not due (1) to some obvious defect of the disturbed equipment or circuit, or (2) to the use of the equipment or circuit in a manner, or for a purpose, for which it was not designed. In the first case a knowledge of whether the equipment or circuit meets all transmission or other performance requirements (other than noise requirements) will be helpful. In the second case, special engineering may be required in order to enable the disturbed equipment or circuit to meet noise requirements.

2. TYPES OF NOISE TROUBLES

A. Induced Noise

2.01 In a majority of noise problems the noise originates in a piece of equipment or circuit other than the one under investigation and is transferred from the source by inductive or conductive coupling. As described in the following paragraphs, there are three important factors to consider.

2.02 The capacity of a circuit or piece of equipment to produce noise in another circuit or piece of equipment is called its noise influence. Methods of measuring and comparing noise influence are described in other information. Examples of types of equipment producing noise influence are battery charging generators and rectifiers, ringing and tone generators and interrupters, signaling circuits (including dc telegraph, carrier telegraph, ringing circuits, dialing order wire circuits, etc.), relay operated control circuits, and dial office circuits. Features of disturbing equipment which contribute to excessive noise influence are:

- (a) Magnitude of noise voltages or currents generated

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- (b) Frequency composition of voltages and currents generated
- (c) Mechanical or electrical condition including adjustment and maintenance
- (d) Omission of filters for limiting the noise influence
- (e) Use under conditions not anticipated in design.

2.03 The amount of noise in a piece of equipment or circuit, caused by exposure to a disturbing source having a stated amount of noise influence, through a stated amount of coupling, is termed the susceptiveness of the disturbed circuit. Susceptive equipment and circuits usually include such items as carrier frequency apparatus, telephone repeaters, program amplifiers, equalizers, repeating coils, connecting trunks and circuits, switchboard cord circuits, etc. Characteristics of any piece of equipment which have an important bearing on its susceptiveness are:

- (a) Shielding and grounding arrangements
- (b) Balance
- (c) Transmission levels
- (d) Power supply arrangements within the equipment, including correctness of noise filters normally employed as an integral part of the disturbed equipment.
- (e) Frequency characteristic of transmission path between point of entry of the noise and observation point.

2.04 The degree of exposure between the disturbing equipment circuit and the disturbed equipment is called the coupling. Coupling may be inductive or capacitive. Features which contribute to coupling are:

- (a) Lack of physical and electrical separation between disturbed and disturbing equipment or circuits
- (b) Circuit elements which are common to both pieces of equipment or circuits.

Nearly all noise problems arise because of one or more of the above three factors, namely:

- (a) Excessive noise influence of disturbing equipment
- (b) Undue susceptiveness of disturbed equipment to noise
- (c) Excessive coupling between disturbed and disturbing equipment.

Methods of determining which of these three factors are contributing to a particular noise problem and methods of rectifying the difficulty are described in Part 3, below. In rare cases it may appear that none of the three factors are out of line, yet the noise in the disturbed equipment is excessive. Such cases will generally require special engineering investigations.

B. Self-Generated Noise

2.05 In some cases it may be found that all of the contributing causes of the noise are confined to the disturbed piece of equipment or circuit itself. In practically all of such cases, with the exception of microphonic noise which is discussed in the next paragraph, the noise may be due to a faulty transmission condition such as carrier system troubles, low return loss, poor jack contacts, or defective parts in the transmission circuit. Examples of this type of condition are: carrier systems may generate intermodulation noise, poor jack contacts may intermittently interrupt speech currents giving the appearance of noise on the circuit; singing repeaters may cause various noise effects, as in the case where an intermittent high-frequency noise on a circuit was traced to a singing repeater causing an echo suppressor to disable the circuit. This latter condition stopped the repeater singing, and when the circuit was again operative, the repeater resumed singing, etc.

2.06 Microphonic noise may occur in any vacuum tube type of amplifier. Noise at the output of an amplifier may be caused by mechanical or acoustical disturbances producing microphonic effects in the vacuum tubes. If such an amplifier is jarred the resulting noise in a receiver connected to the amplifier output will have a ringing or semi-sustained character or will sound like noise due to a poor contact. The microphonic susceptiveness of an

amplifier can be checked in accordance with the methods outlined in the Bell System Practices.

3. TESTING METHODS AND METHODS OF ELIMINATING TROUBLES

3.01 In the following outline of methods of locating noise troubles, a certain order of procedure has been given. In a specific case the order of procedure may differ materially; in fact, other tests will probably suggest themselves. Generally speaking, the results of each test indicate successively the next preferable course of action.

A. Location of Noise Source and Reduction of Excessive Noise Influence

3.02 The first step usually considered in locating the source of noise may be accomplished in two ways:

(a) By listening to the characteristic sound of the noise. Many noise sources produce identifiable sound which alone may be sufficient to identify the specific source. Examples are standard tones, such as 1-kHz test tone, 2.6-kHz inband signaling tone; nonstandard tones, such as repeater howl, carrier beats, 60-Hz harmonics; central office clatter and inductive interference. Some suspected pieces of equipment can be removed from service and momentarily shut down to verify by listening that they are the disturbers in question. However, this is only possible when traffic loading permits. Further, the noise influence of some noise sources, such as central offices, some carriers and some radio systems may vary with the traffic load.

(b) By sectionalizing the disturbed circuit. Sectionalizing frequently leads to the portion of the circuit exposed and sensitive to the disturber, or wherein the noise originates.

3.03 After a piece of equipment has been located as an important noise source it should be scrutinized carefully. The fact that it is producing the noise does not necessarily mean that it is in any way abnormal. In order to determine whether the disturbing equipment is excessively noisy, measurements of its noise influence may be made. A comparison of noise influence measurements on several pieces of equipment of the same type, where such are available for test, will aid in

determining whether the noise influence of the suspected piece of equipment is above the average or normal. Where the noise influence appears to be excessive there are a number of possibilities to consider.

3.04 All pieces of equipment which generate ac voltage have noise influence. The ac voltages may be purposely generated to serve some function in the telephone plant, as in the case of common carrier supplies, ringing machines, tone generators, telegraph equipment, etc.; or generated unintentionally but as a normal by-product of the normal operation of equipment, such as in a dc generator; or caused principally by lack of proper maintenance and adjustment or by mechanical failure.

3.05 Where equipment is designed and constructed to purposely generate ac voltages, care is taken in the design to limit the effects of noise-producing currents and voltages. Noise filters are frequently incorporated in apparatus to accomplish this; in other cases the use of noise filters depends on the specific application of the equipment. Inadvertent omission or temporary defects in noise filters may result in equipment producing a relatively high noise influence. In such cases it is suggested that consideration be given to installing specified noise filters if not already present, or that where provided, the noise filters be carefully checked for irregularities.

3.06 These noise filters generally consist of inductors and/or capacitors incorporated as part of the equipment or circuit in which the equipment is used. Equipment drawings generally do not indicate their purpose. Therefore, it may be worthwhile to insure that all inductors and capacitors, particularly those listed as optional, are either installed as indicated on the drawings or that their omission is intentional.

3.07 Noise filters are frequently employed on equipment which generates ac voltages incidentally. For example, common noise filters are incorporated in battery discharge circuits, and decentralized noise filters are incorporated in battery supply leads to individual pieces or groups of equipment. Errors in connection or omissions of these filters may result in excessive noise. The effectiveness of these filters may also be impaired by lead arrangements such as, for example, by running the charge and discharge leads close together or by using a common lead for both. A

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high battery resistance tends to reduce the effectiveness of the filtering of noise from the charging generator and, where full float operation is used, can escape detection for a long period.

3.08 Section 870-700-500 describes the use of a 3-type noise measuring set, or equivalent, to measure the noise on battery supply circuits. Where the noise on the common battery supply circuits exceeds requirements in 800-700-500, it is generally advisable to check the following points.

(a) **Noise attenuation caused by the batteries and the battery supply filter:** This may be done by measuring the noise (1) on the signal battery supply at the battery control panel, and (2) on the output of the decentralized filter. Generally the noise attenuation between points (1) and (2) will be over 20 dB. Where smaller values are measured the points under items (e) and (f) below may be checked. Where smaller values are measured for the latter, the points under items (c), (d), and (f) may be checked. In making noise measurements in battery and power rooms, extreme care is required to insure against incorrect readings caused by pick-up in measuring equipment and leads. If noise arises in the office and is transmitted back to the power room over the battery leads, an apparent reduction of attenuation by the batteries and filter may be observed. This may be verified by temporarily stopping the charging generators and finding the noise on the talk battery supply and the signal battery supply or both unchanged.

(b) **Noise levels at various points on 130-volt battery supply circuits:** In this case various results will obtain according to the type of office (viz., rectifier supply, generator supply, 130-volt telegraph) and type of filter. While these may be carefully scrutinized it should be pointed out that, for some types of noise, values materially greater than 50 dB on the 130-volt plate battery supply as given in Section 870-700-500 can be tolerated without encountering trouble.

(c) **Circuit of the common battery supply filters:** Ensure that no errors of connection have occurred either during installation or during operation. The latter can occur if the switches on the power control panels are improperly operated.

(d) **Condition of the battery supply filter equipment:** This applies particularly to electrolytic capacitors. In checking battery supply filters be sure to check for missing or open capacitor fuses.

(e) **Resistance of the batteries:** This can be checked by measuring their terminal voltage under various loads without the charging generator operating.

(f) **Effectiveness of the battery supply filters:** This may be impaired by lead arrangements such as charge and discharge leads running very close together, a common lead in part for both, or by excessively long leads from capacitors.

(g) **Condition of the rectifiers or the generators:** This applies particularly to the condition of the commutator and brushes.

3.09 A more direct method of determining whether the noise is entering from the battery supply is to replace the regular battery supply to the piece of equipment under test by one which is known to be quiet. This may be done by using dry cells or portable storage batteries. Care must be taken, of course, to supply the proper current and voltage to the equipment to insure its normal operation.

3.10 A complete set of noise measurements on battery supply circuits at various fuse panels in the office and in the power room, as well as at equipment bays, will often help to indicate the direction of propagation of the noise. If the noise at the battery distributing fuse panel is less than at the equipment bays, the source of the noise may be suspected to be in the equipment bay rather than in the power plant.

3.11 Noise from battery supply circuits may enter transmission equipment, even if these circuits are relatively quiet, if individual noise filters in battery supply circuits to particular pieces of equipment are not properly provided. In such cases connections to all noise filters shown on equipment drawings should be carefully checked. Where a noise filter is common to several equipment units, the fact that the other equipment units supplied through the filter are not noisy does not necessarily ensure that the filter is normal. In some cases where several units are grouped on one battery supply circuit, there may be a dissimilarity between

the connections to each unit which may cause them to have different degrees of susceptiveness to noise on the battery supply.

3.12 In some cases, the noise influence generated by a piece of equipment is in a large measure dependent upon its maintenance and adjustment; therefore, it is important that such a piece of equipment is maintained and adjusted as prescribed in current instructions. Battery charging generators and vibrating contacts are examples.

3.13 Any performance tests which are listed in current practices may assist in determining whether there is an accidental trouble condition such as the failure or grounding of parts or wiring.

B. Apparatus Susceptiveness and Methods of Reduction

3.14 The second step usually considered in a noise problem is to determine how the noise enters the disturbed equipment. Each section of the disturbed circuit can be sectionalized and its noise measured until the point of entry is established. It should be borne in mind that, when the noise passes through an amplifier or an attenuator, it will be increased by the gain of the amplifier or decreased by the loss of the attenuator; therefore, allowance must be made for such amplification or loss when comparing the noise in different sections of the equipment. Where variable gains or losses are included in the circuits, changes in these may be made in order to ascertain whether the noise varies correspondingly, thus indicating whether the noise enters the circuits before or after the variable gain or loss.

3.15 Transmission circuits with relatively poor balance should preferably have adequate physical separation, or adequate shielding with proper grounding, from disturbing circuits which produce heavy longitudinal-circuit induction. Accidental unbalances may arise through incorrect connection or through failure or grounding of coils, condensers, resistances, etc. Very often circuits have modifications to improve balance. These should be checked against the circuit drawings to make sure circuits have been modified.

3.16 Circuits and equipment are sometimes provided with electrostatic shields for the purpose of preventing spurious voltages and currents from being induced on them. Shields which are improperly grounded or improperly associated with

transmission circuits may result in greater induced noise voltages than if not used. For example, occasionally an unbalanced portion of a transmission circuit has been improperly used in parallel with the shield as a path to drain longitudinal-circuit currents to ground. Shields are generally less important in voice-frequency message circuits. However, in program circuits, carrier circuits, and special types of circuits (such as voice-frequency terminals of radio circuits) they may be of major importance, particularly in the reduction of crosstalk and clicks.

3.17 In toll office equipment several separate terminals for ground purposes are sometimes provided. It is important, where wiring arrangements specify a specific grounding point to be used, that this and no other be employed. This precaution is necessary in order to maintain parts of sensitive equipment at the same noise potential or to avoid mutual impedance (resistance or reactance) between ground leads to noise producing equipment and any equipment or circuit which is sensitive to noise disturbances. This is considered further under coupling. Common impedances may be eliminated by grounding the two circuits independently.

3.18 The size and length of a conductor employed for grounding purposes warrants consideration. Every conductor of appreciable length, which is used as a ground path, has appreciable impedance. As the cross-sectional area of a conductor is increased, its dc resistance decreases proportionally; however, its reactance decreases much more slowly and for large conductors the decrease is very slight. For noise frequencies of the order of 1000 Hz, the reactance of the ground conductor will often control its impedance and the use of heavier grounding conductors would, therefore, have little effect on voice-frequency or carrier-frequency noise.

3.19 In the design of a piece of equipment consideration is always given to the relative amounts of signal and noise power present under normal conditions. Where equipment is used in a transmission circuit in an unusual manner, such that the amount of signal power being transmitted through the zone of influence is abnormally low, special precautions may have to be taken to ensure that excessive noise will not manifest itself on the circuit. Such cases will usually need to be treated specifically.

3.20 Where a piece of equipment has relatively high susceptiveness to noise on battery-supply circuits, or where it is to be supplied from a battery circuit having relatively high noise, inductors or capacitors or both are often installed in the power supply wiring within the piece of equipment. These are in addition to any decentralized filters in battery-supply circuits discussed above. Omission of such filters, improper connection or failure in service will cause noise troubles.

3.21 Loose connections can often be located by tapping parts of the equipment and listening to the effect upon the noise (allowance being made for microphonic noise in vacuum tube equipment).

3.22 Where suspicion falls on a piece of equipment, such as a coil, condenser, resistance, etc., it may be given tests for continuity, short circuit, grounds, value of resistance, etc. (Care must be taken in testing coils that excessive direct current is not passed through them thus magnetizing them.)

C. Reduction of Coupling

3.23 The amount of noise which is transferred from disturbing to disturbed equipment is controlled by the coupling between them. Coupling may be either inductive or conductive.

3.24 A common example of inductive coupling is where two circuits are run in the same form or cable run. Inductive coupling may also take place directly (not via leads) between pieces of equipment. For example, a piece of high-gain equipment may be located in the magnetic field of a nearby oscillator or of a battery-charging loop.

3.25 Capacitive coupling frequently occurs in battery-supply circuits and on ground connections common to two pieces of equipment. Common impedances as low as 0.1 ohm in battery-supply circuits and ground leads may give difficulties.

3.26 In order to reduce "crosstalk" effects of pieces of equipment supplied from the same battery circuits, the mutual impedance in the battery circuits should preferably be kept at a minimum. To accomplish this, battery is generally supplied over a metallic circuit, which is closely paired with its ground from the power plant fuse panel to the equipment. It is important that this pairing be

retained even when filament and signal grounds are tied together at the equipment bays.

3.27 Excessive coupling often occurs as the result of running high noise influence leads (power supply, telegraph, ringing or tone circuits, control circuits, etc.) in the same cables, cable runs or forms with low-level transmission wiring or talk battery-supply leads. The presence or absence of such a condition can often be ascertained by temporarily rerouting a lead outside of the usual form, cable run or cable. In carrying out this procedure care should be taken that the temporary wiring used gives the same transmission conditions as the normal wiring. Where both disturbing and disturbed circuits are metallic transmission circuits, crosstalk coupling measurements may be made to determine whether the coupling is abnormal.

3.28 These conditions may be permanently remedied by rerouting either the disturbed or disturbing wires or by adequate shielding of either or both the disturbed or disturbing wires.

3.29 Magnetic coupling between battery-supply circuits and amplifier equipment may cause amplifier noise. Here the primary magnetic field set up by unwanted currents in the battery-supply circuits (usually in the charging leads) links apparatus in the low-level portions of the amplifier equipment. This case may be more difficult to discover because turning off a charging generator on a given battery-supply circuit and observing a noise decrease in repeater outputs does not necessarily mean that the noise is entering the repeater through its battery-supply leads. It is not expected that equipment will be affected if located at a distance of over about 6 feet from charging generators, charge buses or power plant batteries. The following checks are useful in determining whether the trouble is due to this cause:

If the disturbed equipment is housed in metal can covers, removing the covers should increase the noise. (This test is also useful as a check where direct induction between pieces of equipment mounted on the same or adjacent bays is suspected.) Changing the switching arrangements in the power room so as to change the location of the charge-lead loop will materially affect the noise. Furthermore, the intensity of the noise will depend upon the separation of the disturbed equipment from the charge buses, i.e., equipment at the top

of bays will show less noise than equipment at the bottom of bays (assuming that the power plant is on the floor below the repeaters) and equipment in bays farther from the charge buses will show less noise than in bays closer to the buses.

Where trouble of this sort arises, the case is usually one requiring special treatment.

4. CLICKS AND IMPULSE NOISE

4.01 Clicks and impulse noise are a form of noise having properties somewhat different from ordinary types of noise and require somewhat different technique both from the standpoints of measurement and methods of reduction.

4.02 Clicks and impulses are caused by sudden changes of current in a reactive circuit, such as, for example, when the circuit is opened or closed. The transient voltages resulting therefrom have a steep wave front and contain component frequencies from low audible frequencies to the highest radio frequencies. The disturbances are propagated over all circuits coupled (either inductively or directly) to the circuit containing the source. The frequencies and amplitudes of the disturbances which are impressed upon a transmission circuit depend upon the constants of the path over which they are propagated from the source to the disturbed circuit. Where coupling is close, audible frequencies are generally relatively important; where coupling is mainly through small capacitances, the disturbances impressed upon the transmission circuit are mainly of radio frequency. In the latter case vacuum tubes and transistors in amplifiers act as demodulators to give noise of audible frequencies.

4.03 Clicks and impulses of infrequent occurrence are seldom of importance on message circuits unless they are of relatively great intensity or last more than 100 to 200 milliseconds. However, when a four-wire telephone circuit is used for voice-frequency carrier telegraph or other type of data, clicks and impulses which occur even infrequently can cause errors in transmission. Clicks in program circuits are often relatively important.

4.04 Clicks and impulse noise on circuits may be caused by power line induction in the outside plant. The treatment of these is beyond the scope of this section, but benefits may be obtained by the use of varistors, acoustic shock reducers, etc.

A. Measurement of Clicks And Impulse Noise

4.05 Because clicks or impulses are of very short duration they may affect types of circuits not involving listeners, e.g., voice-frequency telegraph, telephoto circuits, and any type of data in a different way than they would affect the human ear. Therefore they cannot be measured satisfactorily with ordinary noise measuring equipment. The methods listed below may be employed in the field with reasonable success where precise results are not warranted.

4.06 Methods of determining the importance of clicks on program circuits are incorporated in sections of Bell System Practices dealing with program circuits.

4.07 The 6-type impulse counters have been developed for measuring clicks and impulse noise, particularly that affecting data channels. Procedures for evaluating the severity of impulse noise are covered in detail in the Bell System Practice divisions for teletypewriter, voiceband data, wideband data, and for the 6-type impulse counters. In addition, sections in the above series describe methods and apparatus for control of clicks and impulses. A brief review of some of the methods for controlling impulse noise follows.

B. Suppression of Clicks And Impulses

4.08 There are two general methods of suppressing clicks: (a) diverting and absorbing the energy which is released by the opening of the contacts in the disturbing circuit by means of a suitable "spark killer," thus effectively eliminating or reducing the transient and (b) reducing the coupling between the disturbing and disturbed circuits by physical separation or by shielding.

4.09 Various types of "spark killers" have been used in telegraph practice and in other applications to relay circuits. Most of these are capable of eliminating or materially reducing clicks in nearby transmission circuits. The most generally used type of spark killer consists of a capacitor in series with a resistance, although varistors have been successfully used to some extent. The spark killer is bridged directly across the contacts controlling the inductive circuit which is the source of the disturbance or directly across the inductive load. The use of a capacitor of larger than 1/4 microfarad gives relatively little additional click protection. In

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some cases serious troubles, such as delay introduced into relay chains, reduction of printer margin in telegraph circuits, etc., are caused by the use of a larger capacitor. The value of resistance used is not critical. A value of about 300 to 600 ohms has been found to be suitable. The use of a capacitor alone without a resistance is not recommended for this purpose. The other successfully used means of reducing click trouble is to segregate wires associated with relay contacts breaking appreciable currents (including telegraph equipment) from transmission wiring and equipment as much as possible.

4.10 Methods of reducing clicks in program circuits are included in sections of Bell System Practices dealing with program circuits.

4.11 Locating and clearing noise troubles requires judgment and experience. Few occasions will arise where situations are identical and tests which are useful in one case may be of little value in others.