# AUTOMATIC LINE INSULATION TEST EQUIPMENT
# GENERAL DESCRIPTIVE INFORMATION
# NO. 1 AND 350A STEP-BY-STEP OFFICES

CONTENTS PAGE



## 1. INTRODUCTION

1.01 This section describes automatic test equipment for making high-speed tests of the insulation resistance of subscriber lines in step-by-step offices. The equipment consists of the following:

(a) Line insulation test control circuit for selecting the lines in sequence, connecting each line in turn to the measuring circuit and transmitting to a teletypewriter connector circuit the data needed if a line fails to meet the test conditions imposed.

(b) A circuit for measuring the line insulation resistance which is called the line insulation test (LIT) circuit.

(c) A teletypewriter connector circuit which transmits the failure data to the local test center which may be located in a distant building.

(d) A teletypewriter located in the local test center and its associated control circuit (TTY selection circuit) which prints a record of the failure data transmitted by any of the line insulation test frames in the offices served by the local test center, whether step by step or crossbar.

(e) Remote control starting means to start the test equipment in operation from the local test desk.

## 2. OPERATING PRINCIPLES

### A. General

2.01 The line insulation test control circuit gains access to the subscriber lines through a test distributor and the associated test connectors. The test circuit is arranged to connect to a single test distributor or to as many as five, one for each of five offices. However, in most cases more than one test frame will be required for five offices depending upon the total number of lines served. Operation of the test equipment may be started in any one of the test distributor groups served by the test control circuit, but once the circuit is started it continues in operation until all lines have been tested, skipping busy lines and other lines which would produce false trouble indications.

2.02 A line insulation test frame will usually be associated with test distributors within the building. In such test distributor circuits, wiring modifications are installed in order to obtain maximum testing speed. The speed of testing for this arrangement is about 6000 terminals per hour. The test frame may also be associated with one or more test desk trunks for testing subscriber lines in distant buildings over the regular test trunk conductors. A minor modification is required in the test distributor used for this purpose and three additional cable conductors are required for extra circuit paths between the test distributor and the test control circuit. The testing speed of this arrangement is about 4500 terminals per hour. A test frame may be equipped to test only on-premise offices, only off-premise offices, or any combination of both not to exceed the total of five.

2.03 The line insulation test frame may be started in operation in any one of the following ways, namely, by the operation of keys located on the frame, by a time switch operating from 120-volt, 60-cycle commercial power, or by dialing a code over a test desk trunk.

2.04 The test frame is arranged to make any one of nine different tests. There are three types of tests with respect to the way in which the measuring circuit is connected to the line, and each type of test may be made in three different ranges of resistance. If a line has an insulation resistance within the

resistance range of the test, the control circuit momentarily stops the testing progression and summons the teletypewriter connector circuit. The teletypewriter connector circuit transmits the failure data to the teletypewriter in the local test center. The teletypewriter prints the record of the failure on page-width paper, one line for each trouble record.

2.05 A typical traffic diagram of an automatic line insulation test installation for testing lines within the building only is shown in Fig. 8. A similar diagram of an installation for testing, in addition, lines in an outlying office is shown in Fig. 9.

B. Resistance Ranges and Test Conditions

2.06 There are four resistance ranges: A, B, C, and D. Each range is divided into three bands: low, medium, and high. The limit of the high band is double that of the medium band, and the limit of the medium band is double that of the low band. The resistance limits of the various ranges and the bands within each range are shown in Table A. Three sets of values are shown for each range. The one marked Normal will usually be used, but the bands within a range may be halved or doubled by making cross-connection changes. This flexibility permits a choice in range values which is best suited for the particular outside plant conditions prevailing.

2.07 The three kinds of tests are:

(1) Short circuit and ring ground

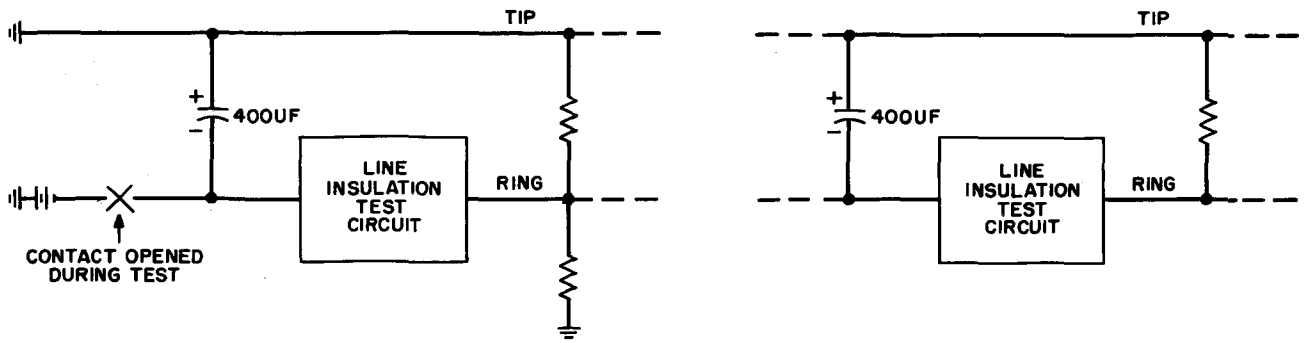
(2) Tip and ring ground

(3) Foreign EMF

The ways in which the line insulation test circuit is connected to the tip and ring leads of the line for each kind of test are shown in Figs. 1, 2, and 3. The ranges in which each type of test is made and the numbers 1 to 9 assigned to each are shown in Table A.

Table A - Test Numbers, Ranges, and Resistance Limits

| Range | Bands - 1000 Ohms | | | Cross Connection | Test Numbers | | |
|---|---|---|---|---|---|---|---|
| | 0(Low) | 1(Medium) | 2(High) | | Short and Ring Grd | Tip and Ring Grd | Foreign EMF |
| | 0-20 | 20-40 | 40-80 | Option | | | Not |
| A | 0-40 | 40-80 | 80-160 | Normal | 1 | 4 | Used |
| | 0-80 | 80-160 | 160-320 | Option | | | |
| | 0-80 | 80-160 | 160-320 | Option | | | |
| B | 0-160 | 160-320 | 320-640 | Normal | 2 | 5 | 7 |
| | 0-320 | 320-640 | 640-1250 | Option | | | |
| | 0-320 | 320-640 | 640-1250 | Option | | | |
| C | 0-640 | 640-1250 | 1250-2500 | Normal | 3 | 6 | 8 |
| | 0-1250 | 1250-2500 | 2500-5000 | Option | | | |
| | 0-640 | 640-1250 | 1250-2500 | Option | Not | Not | |
| D | 0-1250 | 1250-2500 | 2500-5000 | Normal | Used | Used | 9 |
| | 0-2500 | 2500-5000 | 5000-10,000 | Option | | | |




(A) FIRST TEST CONDITION MEASURES COMBINED SHORT & RING TO GROUND RESISTANCE

(B) RETEST AFTER FAILURE ON COMBINED TEST MEASURES SHORT ONLY

Fig. 1 - Short Circuit and Ring Ground Test

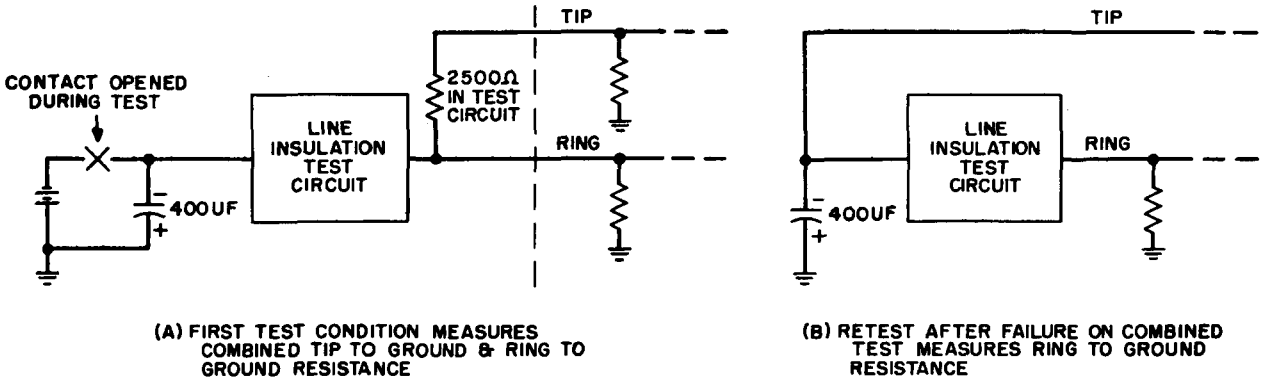



Fig. 2 - Tip and Ring Ground Test

2.08 When a failure occurs on a short circuit and ring ground test, it is followed immediately by a retest for a short condition only, to determine whether the failure is caused by a leak across the pair, which is the principal indicator of drop wire trouble. When a failure occurs on a tip and ring ground test, a retest is made to determine the magnitude of the leak on the ring side of the line. Foreign EMF tests are made chiefly to detect leaks in cable. When a failure occurs, a retest is made to determine the magnitude of the leak to the ring side of the line under test.

2.09 The bands in the teletype record are represented by the numbers 0 (low), 1 (medium), and 2 (high). The digit 3 is recorded for the retest if there is no leak within the resistance limit of the test.

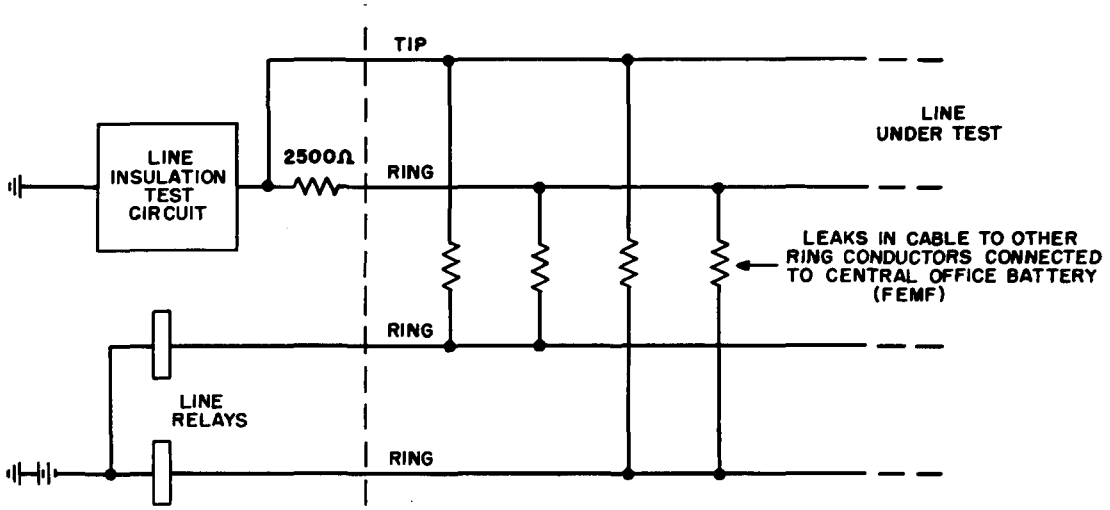
C. Control of Tests

2.10 The operation of the test frame may be controlled from a test desk position over a test desk trunk. Either of two arrangements may be used for this purpose as shown in Fig. 4.

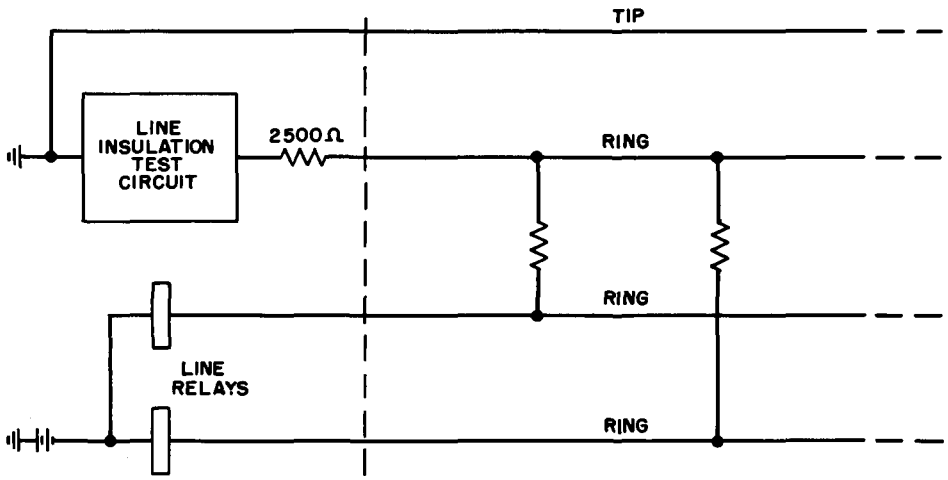
2.11 If there is a spare terminal available on the bank multiple of any one of the test distributor groups in the building where the line insulation test frame is located, a test connector may be wired to this spare terminal. Levels on this test connector are wired to the line insulation test frame or frames, one level for each test distributor group. The first nine terminals on each of these levels control the tests 1 to 9, and the tenth terminal 0, is a monitoring and stop terminal. Other levels on this test connector may be connected to plugging-up lines for test desk access if there is a plugging-up frame in the building. The operation of the line insulation test frame or frames in the building may be controlled over any one of the regular test desk trunks to the associated central office unit.

2.12 An alternate arrangement is to provide a test trunk in the test desk for use, exclusively, in controlling the line insulation test frame or frames in a building. This trunk terminates in a test trunk and selector circuit which contains a step-by-step switch of the connector type. The bank terminals of this switch are wired to the line insulation test frame in the same manner as described above for the test connector. This trunk circuit is the type used with the local test desk No. 14, and it will not function with a 12-type test desk unless the test desk primary and secondary test circuits have been modified for operation with No. 14 test trunks.

2.13 The line insulation test frame may be started to operate in any desired test distributor group by dialing the digit of the switch level which controls that particular group. If the start control switch is a test connector, two digits are dialed first to reach the test connector. The last digit dialed is the test number which steps the control switch to the corresponding test number terminal. The subsequent operation of a tip party ringing key starts the test frame in operation and low tone is connected to this selector terminal to indicate that the test frame is operating. When the test deskman hears the tone, he may disconnect the test trunk. If the frame stops because of trouble in the test control circuit, the tone on the selector terminal changes to ringing induction. If the test circuit is operating, tone is also present on the monitoring and stop terminal 0, and it may be called at any time to determine whether the frame is operating. If the test deskman wishes to restore the test frame to normal before the completion of a test cycle as might be the case if it were desired to change to a different test range, he may dial the 0 terminal of any associated level of the control switch. The subsequent operation of a tip party ringing key stops the frame. The disappearance of the tone indicates that the test circuit is restored to normal.

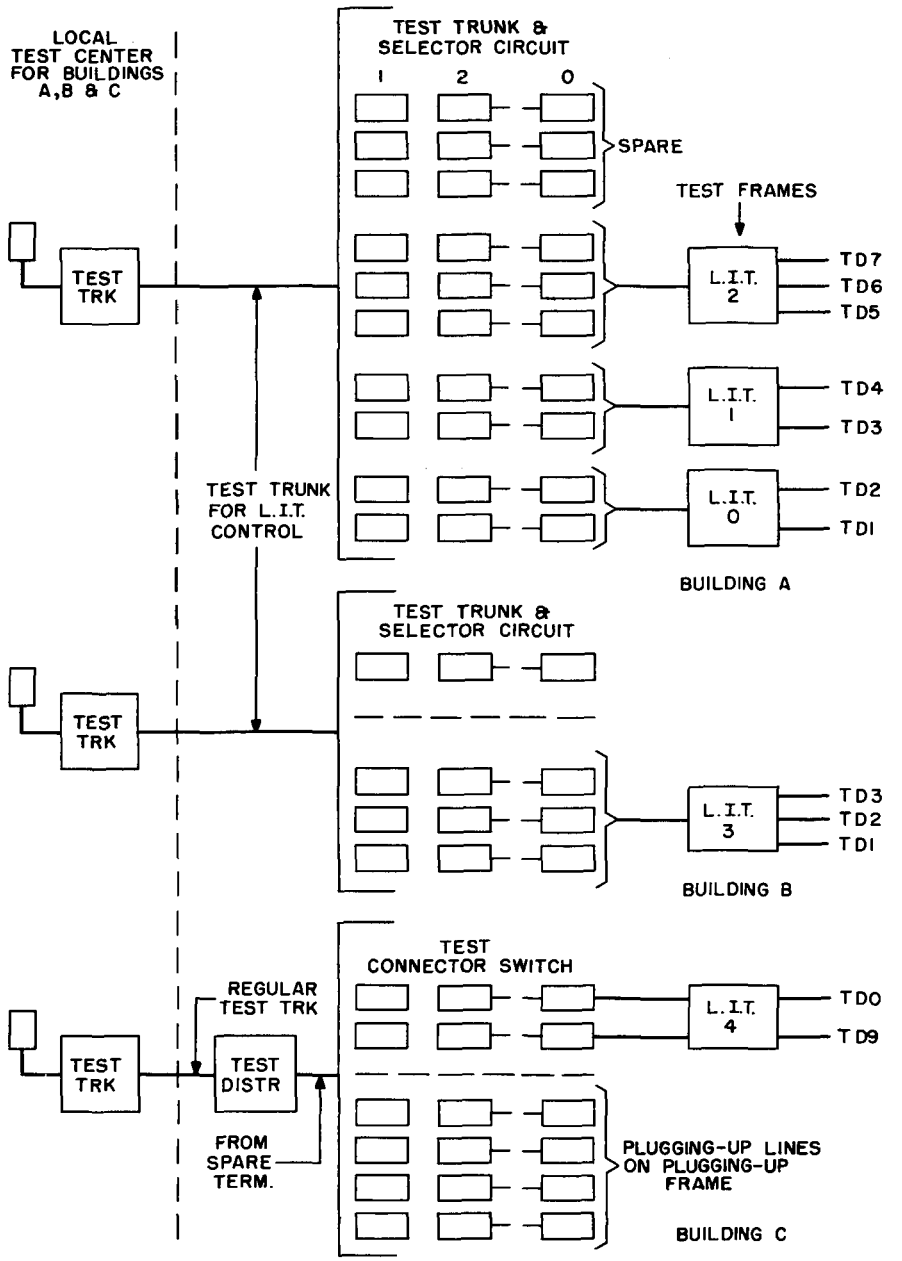



(A) FIRST TEST CONDITION MEASURES COMBINED TIP TO BATTERY & RING TO BATTERY (F.E.M.F.) RESISTANCE




(B) RETEST, AFTER FAILURE ON COMBINED TEST, MEASURES RING TO BATTERY (F.E.M.F.) RESISTANCE

Fig. 3 - Foreign EMF Test




NOTES:
1. "X" IS TEST NO.; FROM 1 TO 9
2. "T" AND "H" ARE "THOUSANDS" AND "HUNDREDS" OF TEST DISTRIBUTOR TERMINAL.

Fig. 4 - Test Desk Control Arrangements With Dialing and Teletypewriter Codes

2.14 The test frame may be started in operation by means of keys located on the test frame. There is a key for each test distributor group, a key for each of the nine tests, and a key for restoring the circuit to normal before completion of the test cycle. Operation may be started in any test distributor group by operating the associated start key. These keys are used mainly by the central office maintenance personnel for checking the operation of the frame, for calibrating the line insulation test circuit, and for trouble clearing.

2.15 A third way to start the test frame is under control of an electrical time switch. The time switch may be set to start the frame at any time of the day, usually about 4 to 5 a.m. It is equipped with a skipping device so that testing may be skipped regularly on certain days of the week, usually Saturday and Sunday. A jack is associated with each of the nine Test No. keys and a tenth jack with one of the test distributor start keys. The time switch starts the frame to make a certain test if there is a make-busy plug in the corresponding Test No. jack and a second make-busy plug in the tenth jack. Make-busy plugs in these jacks will not interfere with test desk starting at any other time of the day.

2.16 The test circuit may be temporarily stopped without restoring to normal by the operation of a key, TS, located on the test frame. The test distributor and test connector switches remain connected to the bank terminals. The operation of another key, RTS, causes the test circuit to resume testing. The temporary stop feature cannot be controlled from the test desk. It is provided at the test frame mainly for use in locating trouble.

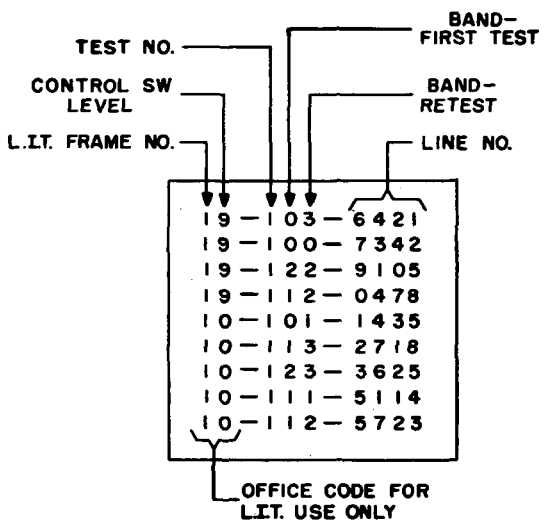



Fig. 5 - Teletype Record of Failures

D. Test Record

2.17 A test distributor group which may have a single office name and directory dialing code is assigned a 2-digit code for test record purposes which is in no way related to the directory name or code. As shown in Fig. 4, the line insulation test frames which are connected through teletypewriter connector circuits to a teletypewriter in one local test center are numbered from one up. This number is the first digit of the teletypewriter code for the test distributor group. The second digit of the code is the number dialed from the test desk to reach the control switch level for starting operation in that test distributor group. The other items of the test entry are explained in the sample teletype record shown in Fig. 5.

## 3. PRINCIPAL CIRCUIT ELEMENTS

### A. Line Insulation Test Circuit

3.01 The line insulation test circuit is connected to the line by the test control circuit to measure the insulation resistance according to the conditions of the test set up by the control circuit. The line insulation test circuit is a type which will stay in calibration without adjustment for relatively long periods of time. The circuit elements are shown in Fig. 6. The principal element is called a magnettor. A portion of the direct current flowing through the leak resistance passes through the magnettor. This produces an output of 2000 cycles, which is proportional to the direct current flowing in the magnettor.

3.02 The magnettor consists of two identical toroidal coils in the same case, each having two windings. The primary windings are connected in series to a 1000-cycle supply which saturates the coils on each half cycle. The secondary windings have a relatively large number of turns and are connected in series opposing. The output of the magnettor is connected in series with the line leak resistance to be measured. The test control circuit adjusts resistances in series and in shunt with the magnettor for the different ranges as indicated in Fig. 6. For 5- and 10-megohm ranges there is no shunt resistance, and all the leak current flows through the magnettor.

3.03 If there is no leakage current flowing through the magnettor, there is no dc voltage output because the flux changes in the two cores are in phase and the secondaries are connected in opposition. If leak current is flowing, this current produces a unidirectional flux, in one direction in one core, and in the opposite direction in the other. The result is that the zero flux state in one core does not occur at the same time as that in the other core, and this produces pulses which generate even harmonics in the secondary windings.

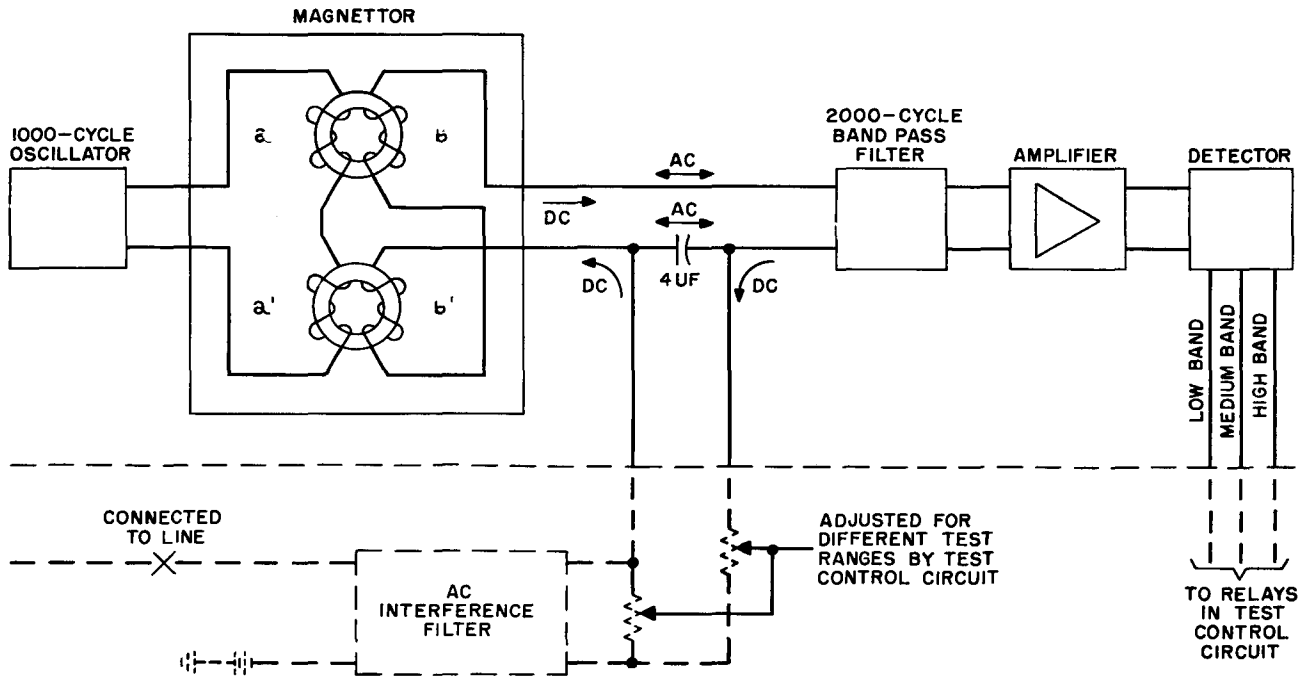



Fig. 6 - Block Diagram of Line Insulation Test Frame

3.04 A 2000-cycle filter separates the second harmonic output from the direct current and supplies it to an amplifier detector circuit. The 2000-cycle ac is amplified and the plate circuit of the last stage is connected to the control grid of each of three gas-filled vacuum tubes. These tubes have different steady state grid bias values. One tube will break down and conduct on the direct current flowing through the magnettor when the external resistance is equal to or slightly below the limit of the test. If the external resistance is in the middle band of the test, the output voltage of the amplifier is higher, causing two gas-filled tubes to break down to indicate a medium band failure. If all three gas-filled tubes break down, a low band failure is indicated.

3.05 The low band tube has a fixed bias through a voltage divider circuit containing two potentiometers, one wired to the grid of the medium band tube and the other to the grid of the high band tube. These two potentiometers and a third potentiometer, which controls the amplifier gain, are adjusted so that the low, medium, and high band tubes will operate at or near the top limit of the receptive bands. If the insulation resistance of the line is more than the limit of the range in which the test is made, none of the tubes will break down. This latter condition is an OK indication to the test control circuit and it proceeds to test the next line in the regular rotation.

3.06 The line insulation test circuit provides a filter in the test path to the line to block stray currents from induced 25- or 60-cycle potentials on the line. Without the filter, induced potentials on some lines might be high enough to produce false failure indications on the higher range tests. If any pairs in the longest runs of subscriber cable are used for 20-cycle PBX generator feeders, currents induced in the other pairs may be sufficient to cause false trouble indications. Trouble from this source may be prevented by providing the option for increasing the time interval allowed before indicating a failure. This option includes an additional filter condenser for by-passing induced 20-cycle currents.

B. Test Control Circuit

3.07 The test control circuit uses a test distributor of one of the test desk trunks, and while testing is in progress, the busy signal on the trunk is lighted at the test desk. If the test circuit finds the test trunk busy when it is ready to use a test distributor, operation of the frame will be interrupted until the distributor becomes available. Delays can be prevented if the test deskmen refrain from using the test trunks associated with the line insulation test frame while the frame is operating.

3.08 In connection with the installation of the LIT equipment, it is necessary to "mark" test distributor bank terminals which the test control circuit should skip. The marking condition for test distributors in

the same building with the test frame is battery through 2500 ohms connected to the line sleeve bank terminal. This marking condition may be used to skip a terminal wired to a test connector (for example, the test connector used for LIT control or plugging up line access) as well as a terminal not wired to a test connector. The marking condition for a test distributor in a distant building is ground connected to the test tip bank terminal. This "mark" can be used only on terminals not wired to test connectors.

3.09 The test control circuit generates pulses to step the test distributor and test connector to the lines in numerical sequence according to directory number. The pulse generator (condenser-resistance timed) also controls register relays to record the number of the connected line while it is being tested. The number identification is needed as a part of the failure record if the line fails to meet the test conditions.

3.10 When the test frame is started in operation, the control circuit steps the test distributor to the first terminal and seizes the test connector. The test connector steps from one line to another on the same level, then selects the next level and so on. If a line is busy at the time it is reached, the test control circuit recognizes the busy condition and immediately steps the connector to the next line terminal. If the line is idle the test control circuit momentarily releases the cutoff relay to make a check of the central office line circuit. The line circuit conditions determine which of the following steps the test circuit will then take.

(a) Connect the LIT circuit without reversal of the tip and ring connections.

(b) Connect the LIT circuit with tip and ring connections reversed.

(c) Recognize the line as invalid and proceed to the next terminal. Nonworking lines are so recognized on all tests, and dial PBX lines only on those tests where the PBX line condition would produce a false trouble indication.

3.11 The control circuit keeps the line insulation test circuit connected to the line long enough for the magnettor current to reach a stable condition before it records a failure. The time interval provided in the test circuit for this purpose is normally about 450 milliseconds. However, a circuit option makes provision for increasing the over-all waiting time to about 2-1/2 seconds to allow more time for stabilizing lines to wiring plans or cordless PBXs equipped with thermistors. During the additional time, beyond the first time interval measured, an additional condenser is connected across the filter to increase the attenuation to 20-cycle ringing current. If an appreciable number of lines to be tested are equipped with the thermistors or are subject to interference from PBX generator feeders, the option for the increased time interval should be equipped.

3.12 If sufficient leak current is flowing at the end of the measured time interval to keep one or more of the gas-filled tubes conducting, the control circuit recognizes this condition as a failure and makes connection to the teletypewriter connection circuit for transmitting the failure data to the teletypewriter.

3.13 If the control circuit stops because of trouble or because the test distributor or test connector does not become available at the end of a period of about six minutes, an audible alarm is sounded in the switch room. In addition, audible ringing tone is substituted for low tone on the terminal corresponding to the test in operation and on the zero terminal of the selector or connector level used for starting the test from the local test desk. This enables the local test center to check, at any time, to determine whether the test frame is operating.

C. Teletypewriter Connector Circuit

3.14 The teletypewriter connector circuit is used in common by all test frames in a building, including any crossbar LIT frames. The circuit is arranged to serve a maximum of five test frames. The transmitter-distributor which transmits the failure data operates at a speed equivalent to 75 words per minute.

3.15 Two pairs of leads are required from the teletypewriter connector circuit to the teletypewriter circuit in the local test center. One is a control pair and the other a sending pair. The sending circuit operates on a 20 milliampere basis and resistances are provided to adjust the current to this value. The sending loop may be connected through a wave-shaping set if the cable loop is such as to require one.

3.16 The teletypewriter connector circuit includes a test feature for sending a sequence of the digits 4 and 6 which correspond in pulse code to R and Y characters, respectively. This feature is for use in lining up the teletypewriter and for trouble analysis.

D. Teletypewriter Selection Circuit

3.17 The teletypewriter selection circuit which includes the teletypewriter and a relay circuit is arranged to connect to all teletypewriter connector circuits in the buildings served by the local test center. The associated line insulation test frames may be either step by step or No. 1 or No. 5 crossbar.

3.18 A preference chain in the relay circuit connects the teletypewriter to only one sending pair at a time so that all test frames in the local test center area can be operated simultaneously. Another function of the relay circuit is to delay the transmittal of the teletypewriter signals until the teletypewriter motor has reached normal speed.

## 4. MAINTENANCE FEATURES

### A. General

4.01 Located at a convenient maintenance height on the test frame is a jack, lamp, and key panel. This panel contains control keys for starting and stopping the test frame. Other keys, lamps, and switches are provided on the panel for making check tests to determine whether the test frame indicates failures properly and for calibration when it becomes necessary to recalibrate the line insulation test circuit.

### B. Resistance Range Check

4.02 Two switches are provided on the panel to which resistances are connected to simulate line-leak resistances when the maintenance test feature is used. These switches are used to check that the range cross connections are intact and that they are made to give the desired resistance values within each range in accordance with Table A. Resistances controlled by one switch LR simulate leaks on the ring and those controlled by the other switch LT simulate leaks on the tip for tip and ring ground and foreign EMF tests. The LT resistances simulate leaks across the pair for short and ring ground tests (tests 1, 2, and 3). The switches may be set to connect resistances within any band in any range. The proper failure indications may be checked by a test call using any Test No. key and appropriate LR and LT switch settings.

### C. Calibration

4.03 A third switch CAL on the jack, lamp, and key panel is used for checking the calibration of the line insulation test circuit and for calibrating it accurately if it fails to meet the calibration test. The CAL switch provides resistance approximately 15 per cent above and 15 per cent below the top limit of the normal bands of the B range, that is, 160,000, 320,000, and 640,000 ohms. In this test, it does not matter whether these values are being used for the B range in regular testing. The Test No. 5 key is used to make the calibrate test. When the switch is set on OP (operate - 15 per cent lower) in any one of the bands, the corresponding test lamp T0, T1, or T2 should light. If the switch is set on NO (nonoperate - 15 per cent higher), the next higher band lamp should light (T1, T2, or RT3).

4.04 If the calibrate test fails, the potentiometers with screwdriver controls located on the line insulation test panel require readjusting. These controls, accessible from the front of the panel, are labeled AGC (amplifier gain control), M (medium), and H (high). The AGC potentiometer adjusts the low band automatically but its adjustment also affects the medium and high bands. For use in adjusting these controls, three positions of the CAL switch are connected respectively to 160,000-, 320,000-, and 640,000-ohm resistances. With the switch set on these positions in turn, the AGC, M, or H potentiometer is adjusted with precision so that the next higher band lamp just fails to light.

4.05 Jacks in the lower portion of the left-hand panel are connected to the polarized relays in the pulse generator circuit for making current flow tests and for checking the per cent break and speed of the pulses.

## 5. EQUIPMENT ARRANGEMENTS

5.01 The line insulation test frame is a single-bay frame assembly equipped with 23-inch mounting plate units for the apparatus and wiring of the line insulation test control circuit and the line insulation test circuit. These units are surface-wired. The general purpose relays in the test control circuit are the wire-spring type.

5.02 The general arrangement of the equipment in the bay may be seen in Fig. 7. The jack, lamp, and key panel used chiefly for maintenance and testing purposes is located at a convenient maintenance height immediately below the line insulation test unit. The layout of the equipment on the panel is shown in Fig. 10.

5.03 The first test frame installed in the building mounts the teletypewriter connector equipment which is located on the lower part of the frame. A teletypewriter selection circuit is mounted above the teletype connector circuit if the local test center is within the building.

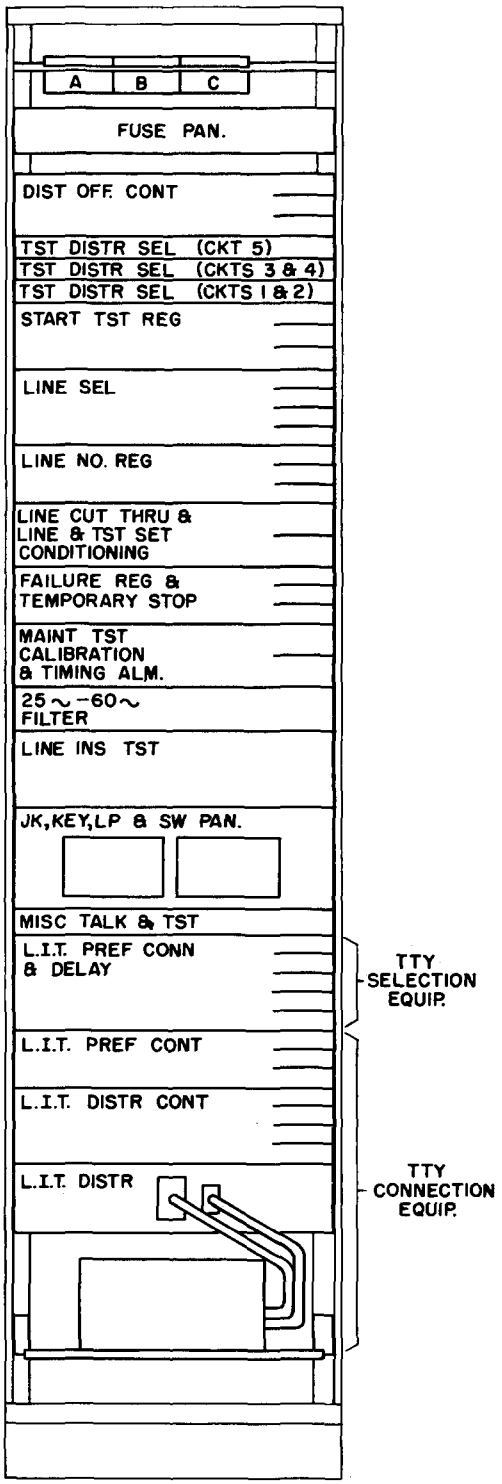



Fig. 7 - Line Insulation Test Frame Equipment

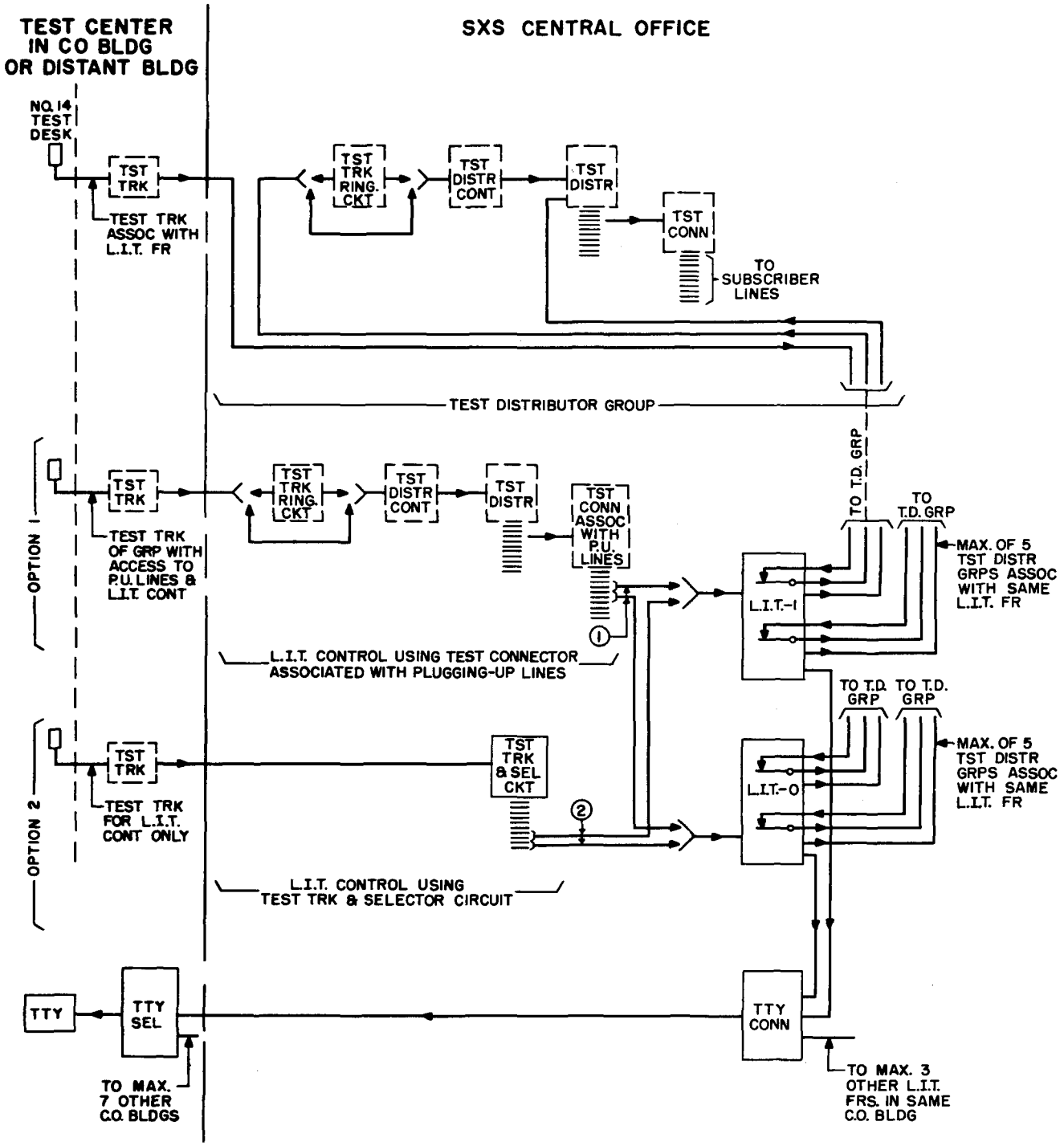



Fig. 8 - Typical Traffic Diagram for LIT Frames Arranged to Test Lines in One Building Only

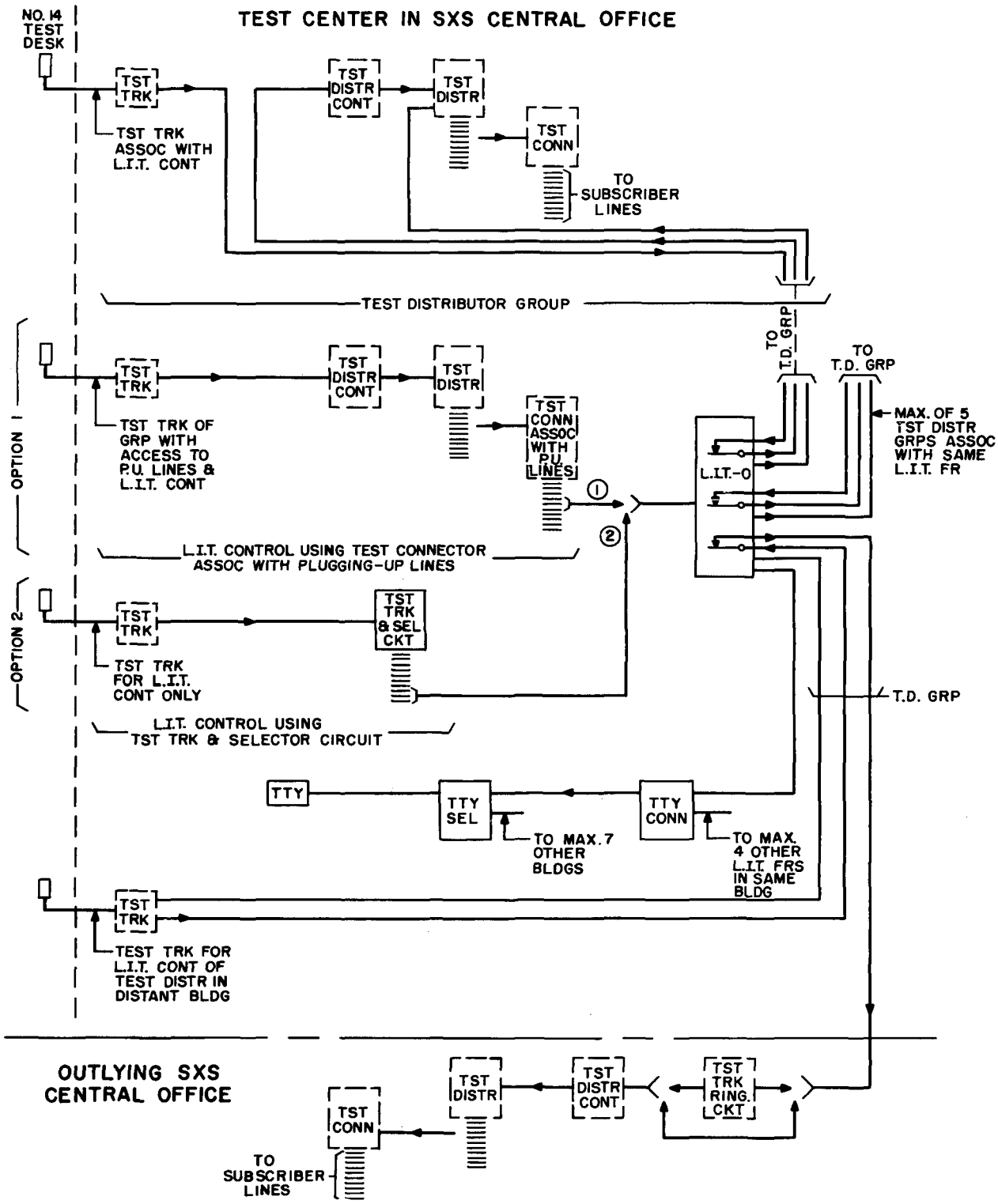
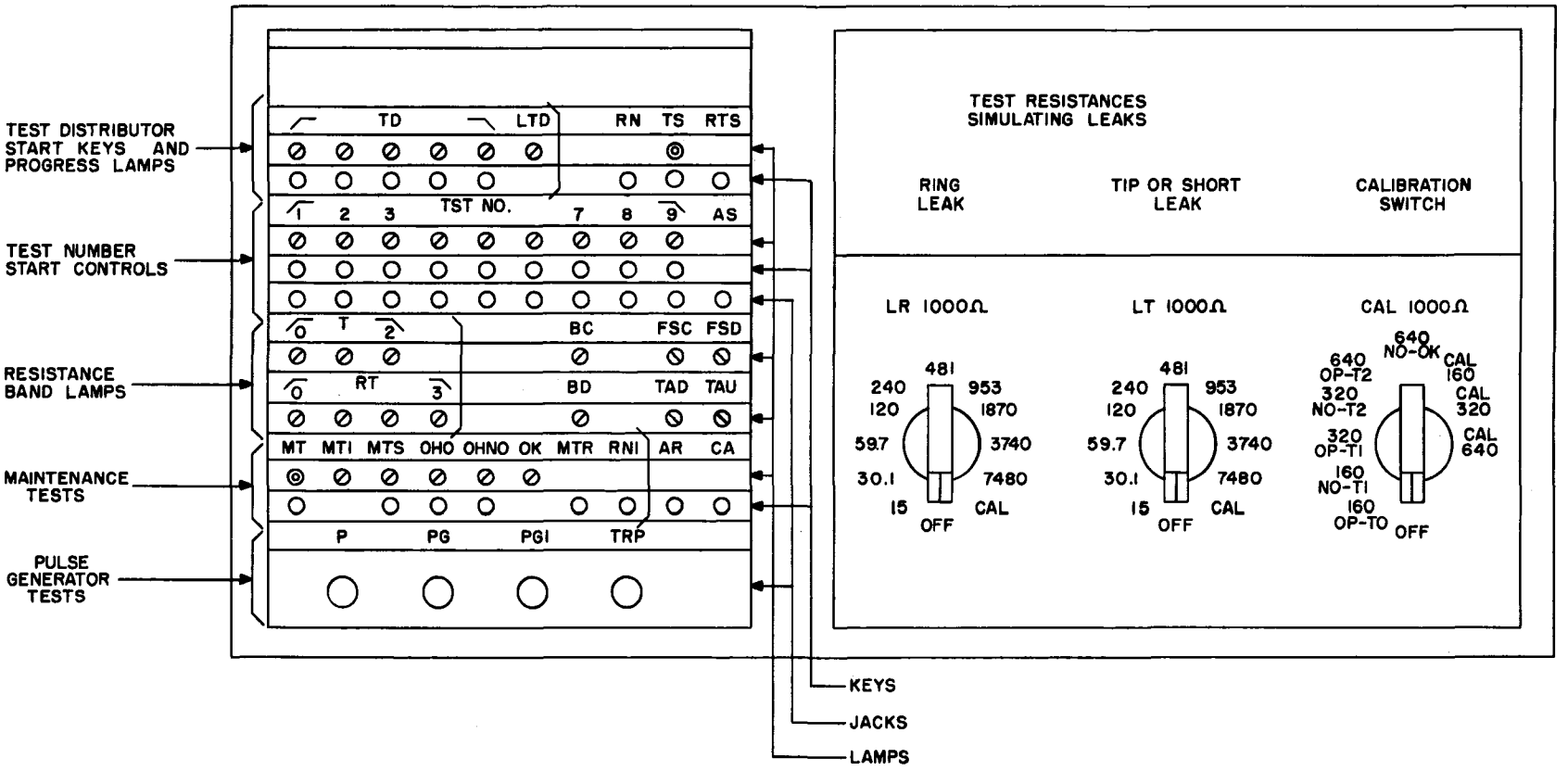



Fig. 9 - Typical Traffic Diagram for LIT Frame Arranged to Test Lines in More Than One Building




NOTE: LAMP DESIGNATIONS

◎-AMBER

⊘-WHITE

⊘-RED

Fig. 10 - Control and Test Panel Equipment