COMMON SYSTEMS
"N1" CARRIER TELEPHONE
LOW-HIGH REPEATER CKT.

CHANGES

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 To cover the complete detailed circuit description which was not furnished with issue 1 of the drawing.

D.2 Note 103 revised to add 152V.

All other headings under "Changes," No change.

1. PURPOSE OF CIRCUIT

This circuit is used as a repeater in the high frequency line of a Type N1 Carrier System. It is one of two similar repeater circuits and is designated a Low-High (L-H) Repeater.

3. FUNCTIONS

3.1 This repeater receives signals at low group frequencies (44 KC - 140 KC) from the line, translates them to high group frequencies (164 KC - 260 KC), then suitably amplifies and regulates them for transmission at the desired output level. This repeater is used alternately along the cable with another repeater designated High-Low (H-L) Repeater.

3.2 The repeater provides a transmission slope across the band adjustable to about zero, two or four db.

3.3 Wiring adjustment is provided to obtain a fixed repeater gain in place of the regulated gain to be used when the repeater is used for testing or in the repeater switching set.

3.4 The repeater provides means, when required, to transmit power over the cable in either or both directions to another repeater or to receive power in a like manner from another repeater.

3.5 The repeater provides means for making filament activity tests and for measuring space currents, filament current and the regulated voltage for the tubes.

4. CONNECTING CIRCUITS

4.1 "N1" Carrier Telephone - Application Schematic for Repeater SD-95124-01.

DESCRIPTION OF OPERATION

5. GENERAL

5.1 Over-All Repeater

5.11 The signals are handled on a four-wire basis throughout and the circuits of the E-W and W-E subassemblies are identical. The input signals from the line pass through an input filter to remove unwanted frequencies. They are then modulated by a 304 kc carrier to change bands from the low group to high group. The same oscillator is used to supply the 304 kc carrier in the H-L Repeater. The action whereby the repeater transmits a different frequency band than it receives is termed "frequency frogging". It is also the basis for the repeater nomenclature Low-High (L-H). The modulator output is passed through the second filter to suppress carrier leak and the unwanted sideband. The output of this filter is applied to the input of the regulating feedback amplifier. This amplifier automatically adjusts the gain by a thermistor regulator to maintain an output power which is almost constant over the operating range of the input power.

5.12 Only a small amount of equalization is accomplished by the repeater. Most of the equalization depends upon having approximately equal cable lengths between repeaters and use of "frequency frogging" at each repeater. The residual slope equalization is adjusted by the (SLOPE ADJ) Control in the amplifier.

6. DETAILED DESCRIPTION

6.01 Repeater Input Coil

6.011 The repeater input coil (T1) serves to match the impedance of the incoming 135 ohm line to that of the 3000 ohm filters. Condensers (C1) and (C2) are shunted across the coil to improve the transmission characteristic. This input coil provides the simplex connection to the line for the purpose of obtaining or supplying power over the line. It also aids in maintaining an adequate longitudinal balance to the line to suppress longitudinal noise.

6.02 Modulator Filters

6.021 The modulator filters used at the input and output of the modulator select the desired frequency groups. These filters are designated (FL1, 2, 3 and 4).

6.022 The modulator input filter (FL1) passes signals of the incoming low group frequencies onto the modulator and rejects the unwanted low group signals that are present at the repeater input due to crosstalk between the cable pairs. This filter is a low pass filter with a configuration and characteristic, (measured between 3,000 ohm resistances) as shown in Fig. 1.

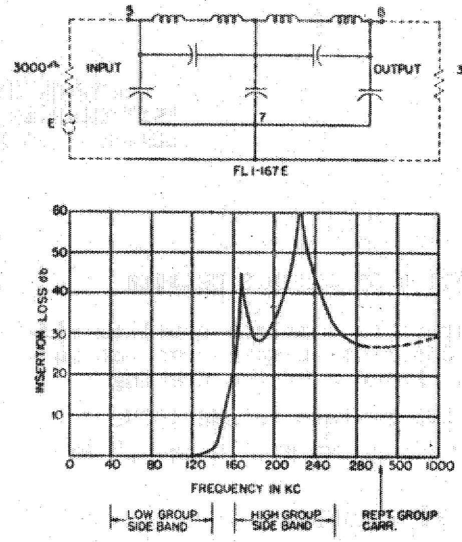

FIG. 1 - SCHEMATIC AND INSERTION LOSS CHARACTERISTIC OF (FL1) FILTER

6.023 The modulator output filter (FL2), (FL3) and (FL4) (Fig. 2) selects for transmission to the amplifier the lower sideband created by the modulator and rejects the upper sideband, all other modulation products and the signals of the frequency group applied at the input of the modulator. This output filter also includes a peak section to reject the 304 kc carrier that is present due to imperfect modulator balance.

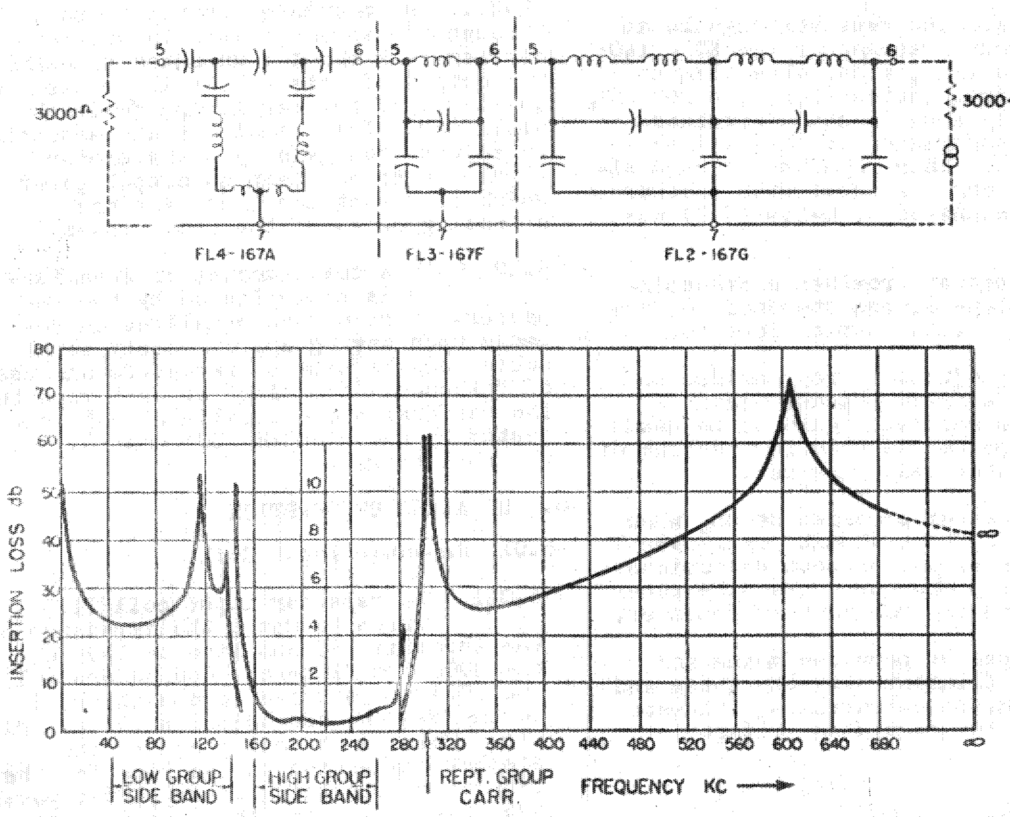

FIG. 2 - SCHEMATIC AND INSERTION LOSS CHARACTERISTIC OF (FL2, 3 & 4) FILTERS

6.03 Modulator Pad

6.031 A 4 db pad (R1, R2 and R3) is used between the modulator output coil and the modulator output filter. This pad improves the impedance match between the filter and modulator and materially improves the transmission characteristic and stabilizes the changes with temperature.

6.04 Modulator

6.041 The modulator receives the low frequency group and modulates it with the group carrier (304 kc) to produce the high frequency group. Of the modulation products produced by the modulator only, the lower sideband is desired. The modulator is of the double balanced type (input signal and carrier both balanced from the output). It consists of a copper-oxide varistor (CR1) connected between two repeating coils (T2) and (T5).

6.042 The modulator action may be considered as a double-pole double-throw switch inserted in the signal path between the input and output coils. This switch action is activated by the plus and minus voltages of the carrier applied longitudinally through the transformers (T2) and (T5). When the carrier voltage is positive at (JE9) and negative at (JE10), the carrier current flows through the two outer rectifying elements. Their impedance is then made low. A signal present in the input will then flow directly through the modulator to the output transformer. During the next half cycle of carrier, the carrier potential is reversed and the current flows through the inner rectifying units making their impedance low. This is equivalent to reversing the path for signal voltages from the input to the output transformer.

6.043 This double-pole double-throw switch action of the balanced modulator has the inherent function that many of the modulation products formed do not appear at the output terminals of the circuit. If the symbol (v) represents the incoming group of signals and (c) represents the 304 kc carrier, the modulation products formed within the modulator may be considered in four sets. These sets are:

$$n_oc \pm n_ov$$

$$n_oc \pm n_ev$$

$$n_ec \pm n_ov$$

$$n_ec \pm n_ev$$

where n_e represents even integers and n_o represents odd. Of these modulation products only the odd order set, $n_oc \pm n_ov$ appears at the output terminals of the modulator, all the other sets of modulation products are theoretically balanced out. Of the odd order set the simple difference (c-v) is the modulation product desired

$$304 - (40 \longleftrightarrow 140) = (154 \longleftrightarrow 256)$$

The other components of this order are rejected by the filters following the modulator. As perfect modulator balance is not achieved some energy from the other sets of modulation products does appear at the output terminals. This is composed principally of the input signals (v) which are suppressed about 20 db and the 304 kc carrier (c) which is suppressed about 40 db.

6.05 Modulator Repeating Coils

6.051 A low group sideband coil (T2) is used at the input to the modulator and a high group sideband coil (T5) at the output of the modulator. These coils have an impedance ratio of 3,000 ohms to 130 ohms and serve to match the impedance of the filters to that of the modulator and to change from an unbalanced filter circuit to a balanced modulator circuit. A condenser (C3) is shunted across the low impedance side of the (T2) coil to improve the transmission characteristic. To maintain the proper balance in this circuit, it is important that the only a-c ground connection to this modulator circuit be at (T5) as indicated. These same two coils are used for the H-L repeater but in reverse circuit positions.

6.06 304 KC Carrier Oscillator

6.061 The carrier frequency used at each repeater is supplied by the 304 kc crystal oscillator. This oscillator employs a 408A electron tube and a quartz crystal to form the oscillating circuit. The plate of the tube is not included within the oscillating circuit, but provides the coupling to obtain the carrier power for the modulators. This power passes through the output transformer (T40) which steps down the impedance of the oscillator to match that of the two modulator circuits in parallel. By use of an electron coupled oscillator better stability of frequency and output power are obtained than if the plate of the tube and output transformer were directly in the oscillating circuit. The output transformer is tuned by condenser (C47) to provide discrimination against harmonics of 304 kc. Between the output transformer and the varistors, there is a rejection filter composed of components (L40), (C49), (C50) to further suppress all frequencies in this circuit above 304 kc. This filter has a peak suppression at 608 kc.

6.062 The frequency of the oscillation is controlled by the crystal (Y40) and is 304,000 cycles ± about 10 cycles within the range of operating temperatures expected.

6.063 The screen voltage for the oscillator tube comes from the repeater regulated voltage supply, in order to provide as stable a source as possible. This stabilization is not necessary for the plate excitation which comes from the non-regulated voltage used for the amplifier tubes. The cathode of this oscillator is maintained 20 volts above -B voltage by resistances (R41) and (R42) to keep the cathode and heater potentials within about 40 volts of each other. Resistance (R42) provides a voltage drop for measuring the (V40) vacuum tube current. Resistances (R43) and (R44) with condenser (C44) provide filtering in the regulated power supply to the oscillator. Condenser (C43) provides the screen load impedance for the oscillator circuit. The oscillator feedback voltage from the screen to the grid is provided by condenser (C40) and crystal (Y40). The grid circuit load impedance is provided by condenser (C41) with resistance (R40) providing the grid bias resistance. Resistance (R46) is a high frequency anti-sing resistance.

6.07 Amplifier

6.071 A high group amplifier is used in the L-H repeater. The amplifier uses two 408A pentode tubes stabilized by feedback and is transformer coupled at both input and output. It has a thermistor flat gain adjustment and a slope control adjustment incorporated into the feedback circuit. The feedback circuit is connected as series feedback at the input and bridge type high-side hybrid feedback at the output.

6.072 The input to the amplifier is coupled from the modulator output filter by the amplifier input transformer (T3). It has a 3,000 ohm low side impedance to match the impedance of the modulator output filter and a 20,000 ohm high side impedance thereby giving as much gain as is practical for the band-width and frequencies used. The impedance values of the transformer are stabilized in the circuit by the 20,000 ohm resistance termination, (R6) on the high side. This transformer also serves to provide d-c separation of the grounded filter circuit from the amplifier circuit which is operated at 70 volts from d-c ground when power is received over the cable.

6.073 The interstage network is a simple impedance coupled circuit consisting of an inductance (L2) in the plate circuit, a 330,000 ohm grid leak (R19) and a coupling condenser (C8) between them. The inductance is anti-resonant with the tube and circuit capacitances in the high group frequency range.

6.074 The coupling from the amplifier output to the line is obtained by the amplifier output transformer (T4). This transformer is a hybrid coil and also provides coupling to the feedback circuit. The output transformer has impedance transformation ratios from 18,000 ohms at the plate to 1800 ohms at the feedback circuit and 130 ohms at the output. These impedance values are chosen to provide the desired level of the regulated output signal. The nominal value of 130 ohms closely matches the cable impedance over the frequency range of the high group. The vacuum tube does not terminate the output transformer by its correct resistance, but the feedback and the value of resistance (R21) do produce the desired output impedance of 130 ohms to match that of the cable pair.

6.08 Flat Gain Adjustments

6.081 The feedback voltage to the input tube (V1) from the thermistor is controlled by resistances (R7), (R9), (R10), (R12), (R13), (R25), and condenser (C5). Resistances (R12) and (R13) act as a voltage divier. Resistances (R9), (R10) and (R25) provide 1 db gain adjustment steps for use in manufacture to compensate for the accumulated variations due to all the circuit components. Condenser (C5) and resistance (R7) form a d-c block and bypass so that the grid bias on the tube will not be altered with gain adjustment changes. Condenser (C4) provides the a-c ground connection for the entire amplifier circuit.

6.082 When the repeater is used for switching purposes or during maintenance tests a fixed gain without regulation is desired. This condition is obtained by using the 20,000 ohm resistance (R24) in place of the thermistor regulator. This resistance provides 6 db more repeater gain than that provided by the thermistor at its mean operating value. The resistance is also used for manufacturing and repair testing. It will normally be replaced by the thermistor for field installation.

6.09 Repeater Gain & Regulation

6.091 The repeater gain is controlled by the loss of the feedback circuit. The fixed gain condition is provided by use of the fixed resistance (R24). The regulated gain condition is provided by use of the thermistor regulator (RT1) which functions to hold the repeater output nearly constant for a considerable range of inputs. This regulated gain is essentially flat with frequency. The thermistor is activated in proportion to the total power at the output of the repeater. This power is nominally +12 dbm and the thermistor holds this output power to within ± 1.5 db for a change in input level of ± 10 db. This regulation performance in terms of change of output from a mean condition vs. change in input is shown in Fig. 3. The thermistor pellet is protected from dc voltages between it and the thermistor heater by the condensers (C11) and (C12).

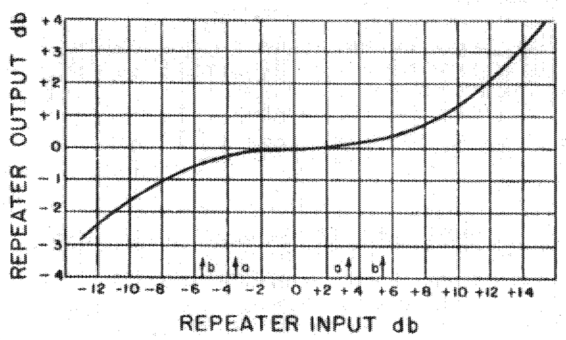

FIG. 3 - REGULATION CHARACTERISTIC OF LOW-HIGH REPEATER

6.092 The thermistor regulator reaction time is plotted in Fig. 4 in terms of the time required for the regulator to attain a given percentage of its ultimate change after a transmission alteration. This reaction

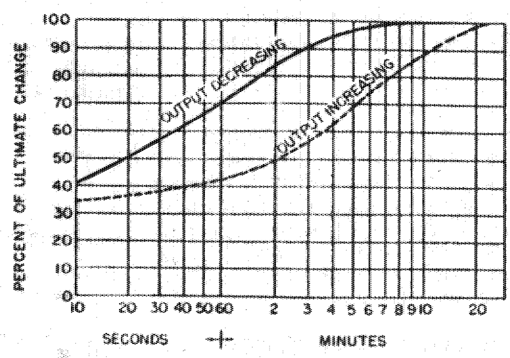

FIG. 4 - THERMISTOR REGULATING TIME

time is different in the two directions of regulator change. The regulator decreases output three to five times as fast as it increases it. This reaction time materially influences field use in that after any transmission change, a waiting period is required before the circuit will stabilize within any desired measuring accuracy. This waiting period is plotted in Fig. 5 in terms of stabilization within one quarter db and also one tenth db measuring accuracy. The "Output Increased" curves

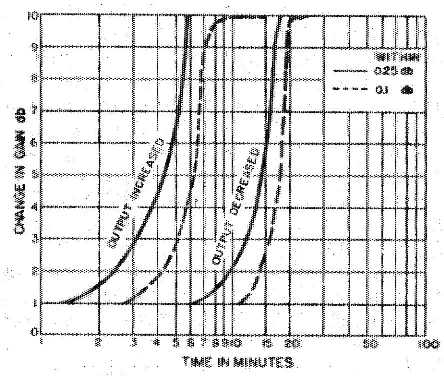

FIG. 5 - STABILIZATION TIME (WITHIN 0.25 DB AND 0.1 DB OF FINAL VALUE)

apply for changes which have increased the output above normal and which the regulator restores to normal by decreasing the repeater gain while the "Output Decreased" curves apply for decreased changes in output which the regulator restores to normal by increasing the repeater gain. Thus an increase in input of 2 db would require a wait of about four minutes for one tenth db measuring accuracy, whereas a decrease in input of 2 db would require a wait of about fourteen minutes. A cold repeater when inserted is at high gain and for a normal input will have a high output; so to obtain one quarter db accuracy of stabilization output requires about six minutes wait. Accuracy within one tenth db requires a wait of fifteen to twenty minutes.

6.093 The thermistor unit (RT1) consists of a thermistor pellet and the associated ambient temperature control for this pellet. The thermistor pellet is a negative temperature coefficient resistance unit that normally varies from about a thousand ohms to about twenty thousand ohms. Under abnormal transmission conditions, it may vary from a few hundred ohms to upwards of forty thousand ohms. For a repeater having the "nominal" gain the thermistor resistance will be about nine thousand ohms. This value is referred to as the "design" value.

6.094 Because the thermistor changes its resistance with temperature changes in the ambient temperature would affect the resistance value. Hence a heater is built around the pellet and the pellet is maintained at a temperature above normal ambients. The temperature at which it is held by the heat from this ambient compensation heater is adjusted in manufacture so that with +12 dbm output from the repeater the pellet resistance is 9000 ohms. This thermostated temperature in general is between 135° and 185° F. This temperature compensation is obtained by a disc thermistor in the heater network which varies the power dissipated in the pellet heater with the ambient temperature. The power for the heater network is obtained from the regulated supply for the electronic tube heaters. This ambient temperature control permits the regulating thermistor to be used at operating temperatures between -20°F and +130°F without appreciable change in its operating performance. Beyond these temperature extremes the regulating level will vary with increasing temperature producing decreasing repeater output level. However, this change is not cumulative from one repeater to the next and so in general is not vital to operating performance.

6.10 Slope Adjustment

6.101 The amplifier slope adjustment provides the manual control of the amplifier frequency characteristic to obtain the desired slope across the band. The slope changes are produced by varying the amplifier feedback as shown in Fig. 6. The adjustment is in three steps designated A, B and C, respectively providing slopes of about 0 db, -2 db and -4 db of gain for channel 12 with respect to channel 1. These adjustments are so arranged that for each setting the repeater has the same power output. Thus change in slope setting may be made on an operating system without effecting the thermistor regulating action. The slope adjustment network is a shunt across the feedback circuit. In position A the shunt is a resistance (R14) which does not provide shaping. In position A the shunt is a resistance (R14) which does not provide shaping. In positions B and C the shunt consists of an anti-resonant circuit composed of inductance (L6) and capacity (C14) with resistances (R26) and (R17) respectively to control the slope of the gain characteristic and resistances (R15) and (R16) respectively to keep the integrated power gain for the usual twelve channel carriers at the same value.

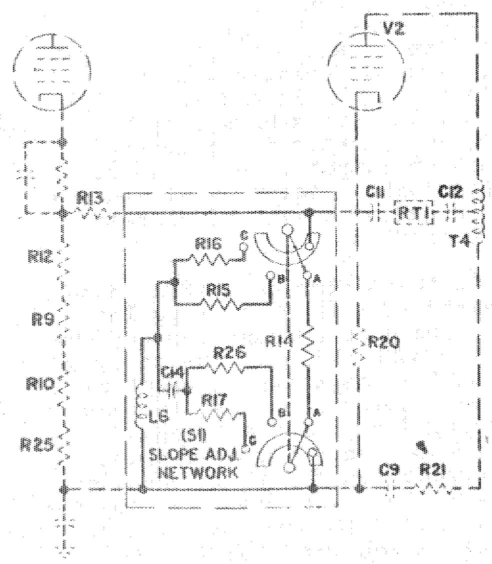

FIG. 6 - LOW-HIGH REPEATER SLOPE CIRCUIT

7. POWER ARRANGEMENTS

7.1 The power connections to the cable pairs are made at the center tap of the appropriate repeater input and output coils through the choke coils (L1) and (L5). Condensers (C42) and (C51) with choke coils (L1) provide power supply filtering.

7.2 The power used by a repeater is applied to the repeater at jacks (PA9) and (PA11), and is distributed to the several components as shown in Fig. 7. The power to the amplifier vacuum tube plates is supplied with only noise filtering, whereas the power to the heaters of the vacuum tubes, the screen of the 304 kc oscillator tube, and the thermistor ambient temperature control is regulated as well as filtered. The main power supply is filtered by condenser (C48) across the battery leads. This filter is supplemented for the amplifiers by resistances (R22) and (R23) with capacity (C13) and further by resistance (R18) and inductance (L4). Inductance (L4) also serves to prevent the power supply to the output transformer from being a low impedance connection across the output impedance control resistance (R21). The (C48) condenser filter is supplemented for the 304 kc oscillator by resistance (R45) with capacities (C45) and (C46). The regulated voltage is required by the heaters of the tubes to give good life, by the 304 kc oscillator to provide frequency stability and by the thermistors to control their thermostated temperature.

7.3 The heaters of the tubes are used two in parallel and these pairs in

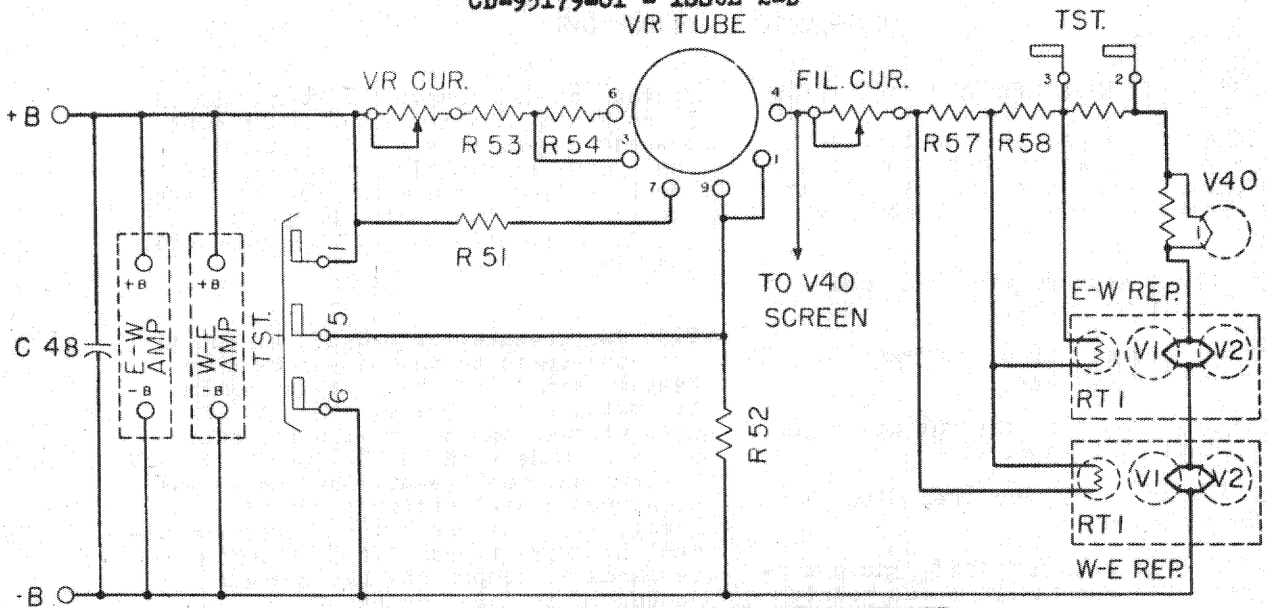

FIG. 7 - POWER REGULATOR-DISTRIBUTOR CIRCUIT

series. This arrangement gives an approximation of the desired condition of constant heater power which is preferred rather than either constant current or constant voltage heater operation. The heater string includes a potentiometer (Fil. Cur.) for adjusting the circuit current to the desired 98 milliamperes and has test jacks TST2 and 3 to measure it.

7.4 The regulated voltage of 100 volts is obtained by means of a 427A voltage regulator tube. This tube produces a large change in current through it (3 to 40 milliamperes) for a small change in applied voltage (100 to 101.5 volts). This large change in gas tube current varies the line current which flows through the line resistance and produces a voltage drop to compensate for a change in the applied voltage. The degree to which this balancing action is obtained is indicated by the regulation characteristics shown in Fig. 8. Changes in gas tube current are plotted against changes in applied battery voltage (B), line resistance (A) and electron tube space currents (C). Each curve expresses the change due to one variable only. The net effect on the gas tube current is the summation of the individual effects.

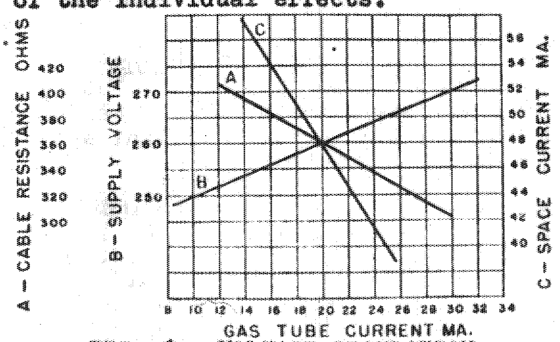

FIG. 8 - VOLTAGE REGULATION

7.5 The V.R. tube current is adjusted, by the variable resistance (VR CUR), for differences in tubes and applied line voltages to a nominal value of 20 milliamperes. With this adjustment there is sufficient regulation range available to accommodate for the changes in line resistance with temperature and for applied battery voltages of about ± 10 volts from the nominal 260 volt value.

7.6 The V.R. tube requires an applied voltage of 130 volts or more on the trigger electrode to make the tube conducting and to start regulation action. To obtain this the trigger electrode (#7) is connected by means of resistance (R51) to the power supply ahead of the adjusting resistances to obtain the full applied voltage. The tube has a small resistance (R52) connected in series with its cathode to provide test voltage for adjusting purposes. This tube is wired internally so that it serves as a switch to connect as well as to regulate the voltage applied to the thermistor and vacuum tube heaters.

7.7 At a locally powered repeater station where the applied repeater voltage is obtained directly from a regulated battery source, the voltage regulator is not required and a 337A shorting plug is used in place of the voltage regulator tube. This shorting plug serves as a switch to connect the heater and thermistor circuit to the power source as did the V.R. tube. It also has a connection to short out part of the regulator circuit control resistance to compensate for the nominal applied voltage of 130 volts instead of the 140 volts used at a non-battery repeater. Where a 136 or 152 volt battery is used a 16A resistance lamp is used in place of the 337A plug.

8. TESTING ARRANGEMENTS AND FACILITIES

8.1 The testing facilities for the type N1 repeater are arranged so that all routine tests may be made on an in-service basis. The tests include:

1) The customary electron tube activity tests.

2) Adjustment of the current for the heater string.

3) Adjustment of the voltage regulator tube current.

These tests can be performed with the 2P Tube Test Set.

8.2 The (FIL ACT) and (TST) jacks provide the necessary access points in the circuits for the tube tests and adjustments. The tube activity test is made at the (FIL ACT) jack with the 2P Tube Test Set in the usual manner by observing the change in tube space current for a ten percent reduction in the heater current. As all of the tubes in the repeater are in one string this test can be made for the whole repeater at once. The change in heater current is obtained by connecting an adjustable resistance to provide the desired change The tube space currents are measured by jack connections across the cathode resistors (R8) and (R20). Resistance (R8) is by-passed by condenser (C6) to prevent cathode feedback around the first stage. Resistance (R20) has no by-pass condenser and this cathode resistance introduces about five db local feedback around the second stage. The screen of the (V1) tube is by-passed to its cathode by condenser (C7) and (V2) by (C9).

8.3 The measurement and adjustment of the currents in the vacuum tube heater string and the voltage regulator tube, and the measurement of the line voltage applied to the repeater are also made with the 2P Tube Test Set. The current requirement for the electron tube heater string is 98 milliamperes. The current requires individual adjustment each time a tube is replaced to compensate for varying heater resistances or variations in voltage provided by the voltage regulator tubes. The current of 20 milliamperes required in the voltage regulator tube also necessitates individual adjustment to compensate for the variations among V.R. tubes with the same applied voltage and to compensate for variations that may existing in the applied line voltage. The applied line voltage measurement is made to check and to control the adjustment of the nominal value of 140 volts to the repeater. Although this measurement is primarily an installation adjustment procedure, it provides a good maintenance check.

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