L3 CARRIER SYSTEM

REGULATORS, EQUALIZERS, PILOT INDICATORS, AND ALARMS

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1. GENERAL

1.01 This section describes the loss equalization facilities provided to regulate the equalization, the indicators, and alarms of the L3 carrier system. Additional information is contained in Section 359-010-105, L3 Carrier System Repeaters; Section 359-010-100, T3 and R3 Television Terminals for the L3 Carrier System; and Section 359-010-110, L3 Amplifiers.

1.02 This section is reissued to provide a more comprehensive description of equalization, regulation, and pilot alarm features of the L3 carrier system. Due to the general revision, marginal arrows normally used to denote changes have been omitted.

1.03 Good transmission quality requires that compensation be made for the loss-versus-frequency characteristic of the line. With any transmission line, a certain flatness of frequency must be maintained to overcome the effects of system misalignment. Since the 4000-mile coaxial cable used in the L3 carrier system has a gain distortion of nearly 40,000 db between 0.3 and 8.5 mc, an elaborate system of equalization and amplification is necessary to prevent excessive misalignment and to provide a reasonable signal-to-noise ratio over the transmission path. The line amplifiers provide the bulk of equalization required in the L3 carrier system. The residue is equalized by the application of fixed and adjustable terms of loss equalization which provide losses of the correct proportion in each area of the frequency spectrum required to restore flatness. The equalized signal is then amplified by one or more flat-gain amplifiers to the required level for satisfactory transmission over the next leg of the path. If the transmission level is too low, the signal will be degraded. If the signal level is too high, the modulation noise and crosstalk performance may be penalized.

1.04 The loss equalization may be classified as two types, fixed and adjustable. Fixed equalizers provide compensation at each equalizing or main repeater for accumulated design deviations from the ideal characteristics. Fixed equalization is also employed at each repeater to compensate for the various types of coaxial cable employed. Adjustable equalization is provided to compensate for changes in system gain. These changes may be slow or rapid, depending upon their cause. Slow changes in system gain are corrected by manual adjustment, and rapid changes are corrected by automatic adjustment.

1.05 A pilot regulator provides the automatic adjustment by producing a direct current which automatically changes in accordance with the level of the particular pilot frequency. Several pilot frequencies are placed at points in the spectrum that are sensitive to variations in the respective types of equalization. At some auxiliary repeaters the line amplifier gain is controlled by temperature changes in the coaxial cable near the hut. Interaction between the broad equalization shapes might result from the tendency of one regulator to correct for a change in characteristic introduced by another regulator. A computer circuit is employed to translate pilot errors and drive the appropriate regulating networks in such proportion that no gain change will occur at any pilot frequency except the one originally disturbed.

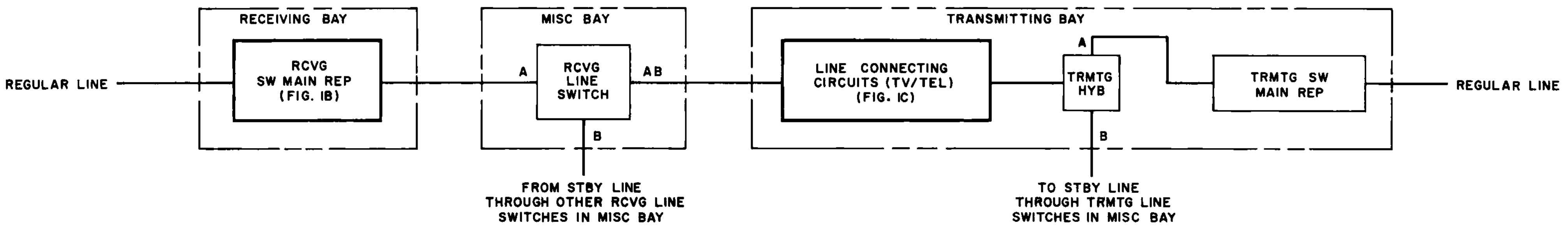
1.06 Delay equalization is provided for systems of combined message and television transmission to correct the difference in the transit time of the line frequencies in the TV portion of the band. Since the bandwidth of a television signal is more than 4 mc, the delay-versus-frequency distortion over the broad band creates a serious problem. Delay build-out equalizers are installed to accommodate each particular circuit length. At switching main and terminal repeater points, an adjustable phase build-out network is used to produce the same electrical length in the regular lines as that existing in the standby lines, a practice which enables hitless switching. Section 359-010-125 describes the switching systems.

1.07 Pilot indicators are provided to show the variation of dc output current produced by the respective pilot regulators. If abnormal departures from the normal levels are experienced, alarm signals are produced which may be used to operate office alarm equipment through direct or remote facilities.

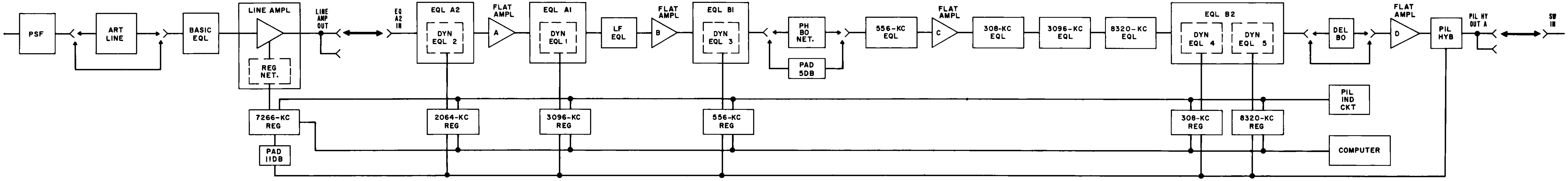
1.08 Table A lists application of units in the various types of repeaters. Fig. 1A shows a switching main repeater station (odd direction) which consists of the receiving bay, the miscellaneous bay, and the transmitting bay. The receiving switching main repeater and the line connecting circuits are represented by dark lines and are shown in detail in Fig. 1B and 1C, respectively.

2. EQUALIZATION

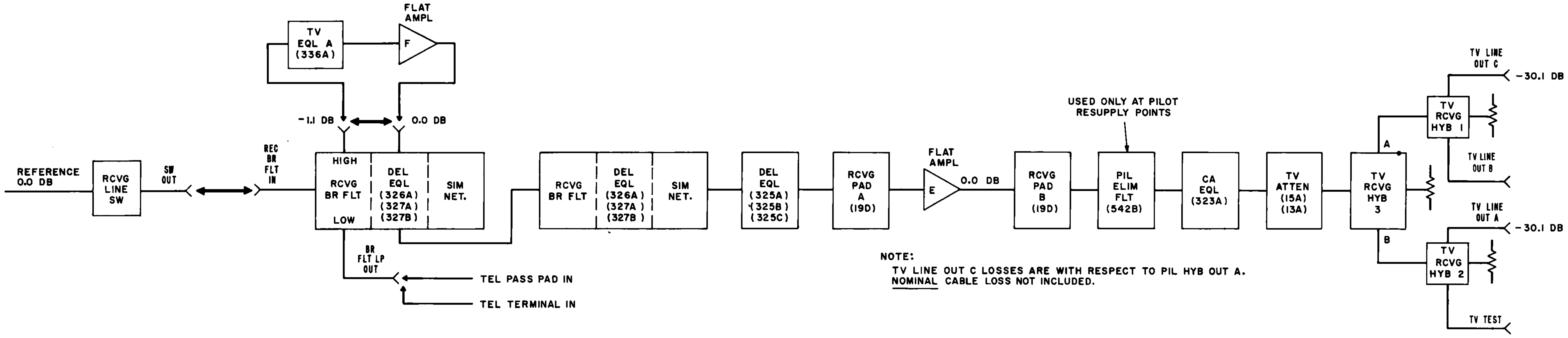
2.01 Equalization is the process of correcting system ***gain*** and ***delay*** deviations sufficiently to permit the satisfactory transmission of signals. The application of loss equalization to restore flatness compensates on all systems for gain deviations at the various frequencies. The equalizers are followed by flat-gain amplifiers to compensate for the losses incurred in the process of equalization. Also on all systems, phase deviations due to the difference in the electrical length of a regular line and the standby line are equalized by the phase build-out network employed at the receiving end of switching sections.



A-BLOCK DIAGRAM



B-EQUALIZATION AND REGULATION AT A RECEIVING TERMINAL REPEATER-BLOCK DIAGRAM



C-EQUALIZATION OF TELEVISION SIGNAL PATH IN A TYPICAL LINE CONNECTING CIRCUIT-BLOCK DIAGRAM

Fig. 1 — Switching Main Repeater Station (Odd Direction)

TABLE A

APPLICATION OF COMPONENTS AT A RECEIVING REPEATER

TYPE REPEATER	AMPLIFIERS							EQUALIZERS													REGULATORS							
	LINE AMPLIFIER	FLAT AMP A	FLAT AMP B	FLAT AMP C	FLAT AMP D	FLAT AMP E*	FLAT AMP F*	ARTIFICIAL LINE	BASIC EQ	LF EQ	EQ A1	EQ A2	EQ B1	EQ B2	308 KC	556 KC	3096 KC	8320 KC	PHASE BUILD-OUT	DELAY BUILD-OUT	TV EQUALIZERS*	THERMOMETER OR 7266 KC (AUX)	7266 KC	2064 KC	3096 KC	308 KC	556 KC	8320 KC
AUX	X	—	—	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
EQ AUX	X	X	X	—	—	—	—	X	X	—	X	X	—	—	—	—	—	—	—	—	—	—	X	X	X	—	—	—
EQ MAIN	X	X	X	—	—	—	—	X	X	—	X	X	—	—	—	—	—	—	—	—	—	—	X	X	X	—	—	—
SW MAIN	X	X	X	X	X	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X	*	—	X	X	X	X	X	X
TERM.	X	X	X	X	X	*	*	X	X	X	X	X	X	X	X	X	X	X	X	X	*	—	X	X	X	X	X	X

* Additional units for TV systems located in the line connecting circuit: 336A equalizer with flat-gain amplifier F. 325A, B, and C; 326A; and 327A and B equalizers with flat-gain amplifier E.
All other items in Table A are located in the receiving repeater.

On TV systems, delay deviations are corrected by the delay build-out network, which compensates for the differences of transit time across the bandwidth.

2.02 All repeater stations ranging from the simplest auxiliary repeater to the most complex terminal repeater use the artificial line, the basic equalizer, and the line amplifier. The artificial line is used only where necessary to build out the repeater spacing to an equivalent 4 ±0.2 miles at 55° F. The basic equalizer compensates for the differences between one type of cable and another. The line amplifier provides an equalization shape which varies with the square root of frequency. The average auxiliary repeater matches the preceding 4 miles of cable to within ±0.12 db, but this error accumulates to over 3 db in 30 repeaters. Since this gain deviation is approaching the design limit for the L3 system, further equalization is necessary. This is supplied by supplementary fixed, manual, or automatic equalizers at the equalizing auxiliary or main repeaters. The gain error is thus reduced to less than 0.5 db by fixed and manual equalization. The dynamic equalizers automatically prevent this residue from appreciably degrading the signal during the interval between the performance of manual adjustments. Equalizers B1 and B2 are added to this complement at the switching main and terminal repeater stations to satisfy the strict gain stability requirements at a switching point. Also added are the delay build-out and phase build-out equalizers to accommodate the delay requirements.

A. Fixed Equalization

2.03 The first step of fixed equalization is accomplished at auxiliary repeater stations where the nominal gain of the line amplifier compensates for the loss of 4 miles of coaxial cable. The line amplifier is discussed in Section 359-010-110. An artificial line is used to build out the loss of shorter lines to the 4-mile length. Basic equalizers are provided to compensate for the differences in the loss characteristics of the different types of cable employed.

2.04 The second step of fixed equalization occurs at equalizing auxiliary and equalizing main repeater stations to compensate for an accumulated gain deviation which is dependent upon the number of auxiliary repeaters. The insertion of this design deviation equalizing network in the A2 equalizer helps to preserve the range of the manual shape networks by building out the flat loss of the equalizer to 34 db to avoid overloading the succeeding flat-gain amplifier.

2.05 Equalizer B1 is factory-equipped with fixed delay network(s) between each cosine equalizer network and the associated rheostat used for adjustment.

B. Manual Equalization

2.06 Manual equalization networks provide compensation for minor system misalignment not equalized by the fixed networks and for the slow variations of gain due to temperature and aging. Manual equalization networks are contained in equalizer units A1 and A2 which are employed at equalizing auxiliary and equalizing main repeaters. For finer manual equalization at the switching main and terminal repeaters, adjustable networks are provided in the B1 equalizer unit. The manual networks of the three equalizer units provide a total of 1 flat and 14 cosine shapes which are very effective for the 8-mc band of the L3 system. The manner of accomplishing cosine equalization is described in the succeeding paragraphs.

2.07 An electrical wave of any shape may be synthesized by correctly adding a sufficient number of harmonic shapes. The exactness to which a particular waveshape may be formed is dependent upon the number of components that is added. In general, the higher the frequency of the harmonics the lesser the magnitude required. A loss curve may be synthesized in the same way. In the case of equalizing the L3 system, 1 fundamental and 13 harmonics have been found sufficient to give a tolerable degree of equalization. Designated controls give continuously variable control from one extreme through a flat loss to the other. Table B lists the equalizer containing each network, the loss when each is set flat, and the variation in loss with respect to flat loss.

2.08 The FLAT control in equalizer A1 is a variable attenuator which has a total range of ±2.7 db from a nominal flat loss of

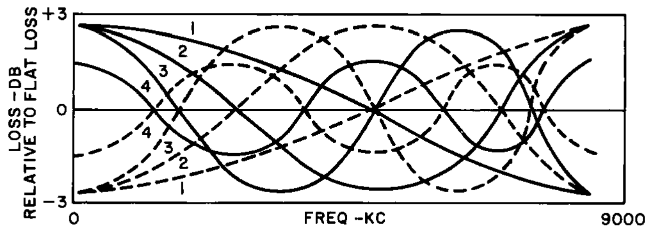
4.18 db across a 0.0- to 8.5-mc band. Table B lists the knob designations and number of cosine cycles across the band for each network.

TABLE B

MANUAL EQUALIZERS

EQUALIZER	KNOB DESIGNATION	NUMBER OF COSINE CYCLES IN 8.5-MC BAND	FLAT LOSS	RANGE
A1	FLAT	0	4.18	±2.7
	1	½	4.18	±2.7
	2	1	4.18	±2.7
	3	1½	4.18	±2.7
	4	2	4.0	±1.5
A2	5	2½	4.0	±1.5
	6	3	4.0	±1.5
	7	3½	3.75	±1.0
	8	4	3.75	±1.0
	9	4½	3.75	±1.0
B1	10	5	3.4	±0.5
	11	5½	3.4	±0.5
	12	6	3.4	±0.5
	13	6½	3.4	±0.5
	14	7	3.4	±0.5

2.09 Control number 1 controls the loss of a network whose loss shape with frequency follows 180 degrees of a cosine wave between 0 frequency and 8.5 mc, as shown by curve 1 in Fig. 2. With the control knob set to position 0, the loss at zero frequency is a minimum of −2.7 db with respect to the nominal flat loss of 4.18 db (zero on the curve). The loss shape follows a cosine curve crossing the 0-db (nominal flat loss) axis at its midpoint, and reaches a maximum of +2.7 db (with respect to the nominal flat loss of 4.18 db) at 8.5 mc. With the control set to position 10, the signs of the losses are interchanged. Thus, since the control is continuously variable, between positions 0 and 10 a cosine-shaped loss curve of any amplitude between ±2.7 db (with respect to 4.18 db) may be obtained. A nominal flat loss of 4.18 db results when the control is set to the approximate center of its range.



NOTE:
SOLID CURVES ARE FOR A CONTROL SETTING OF ZERO;
DASHED CURVES ARE FOR A CONTROL SETTING OF TEN.

Fig. 2 — Loss Range of Manual Networks of Equalizer A1

2.10 Control number 2 controls the loss of a network whose loss shape with frequency follows 360 degrees of a cosine wave between 0 frequency and 8.5 mc, as shown by curve 2 in Fig. 2. With the control knob set to 0, the loss at zero frequency is a minimum of −2.7 db with respect to the nominal flat loss of 4.18 db (zero on the curve). The curve follows a cosine wave crossing the flat-loss axis at 90 degrees, reaches a maximum of +2.7 db at 180 degrees, again crosses the flat loss axis at 270 degrees, and is −2.7 db at 8.5 mc. With the control knob set to position 10, the signs of the losses are interchanged. Thus, since the control is continuously variable, a cosine-shaped loss of any amplitude between ±2.7 db with respect to 4.18 db may be obtained. A flat loss of 4.18 db is obtained with the control at the approximate center of its range.

2.11 Controls 3 through 14 control the loss of networks similar to those controlled by knobs 1 and 2, except for the number of cosine cycles in the shape, the flat loss, and the range loss.

2.12 Fig. 3 shows a simplified circuit of manual network 1 in equalizer A1. If all the reactive components of the shaping sections were eliminated, this network would then be equivalent to the FLAT network. The rheostats indicated are on one shaft and have characteristics of change of resistance versus angular position which are similar in shape, but inverse. These controls govern the amplitude of the loss curves. The network designated 2 in Table B has the same configuration as that shown in Fig. 3, except for the addition of a second shaping section at each set of terminals marked A, B, and C.

Each higher numbered network is the same as Fig. 3 except that the number of shaping networks in each arm is the same as the number of the network.

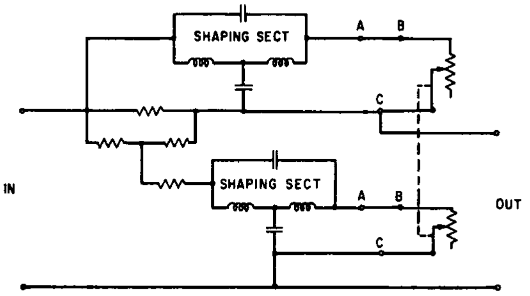


Fig. 3 — Manual Network — Simplified Schematic

2.13 With a total of 14 cosine-shaped networks to be adjusted manually, adjustment to fit a given loss curve would be very difficult with ordinary measuring equipment. Special cosine equalizer adjustment test sets, described in Sections 103-453-100 and 103-453-101, give a meter indication produced from a swept signal which indicates whether or not operation of a particular control improves the equalization of the line under test. With these sets, adjustment of the cosine equalizer consists merely of operating controls in turn to obtain a minimum deflection of the meter; when no further reduction in reading is obtained, optimum equalization is achieved.

2.14 At equalizing auxiliary and equalizing main repeaters where only equalizers A1 and A2 are used, the number of manually controlled networks is reduced to 10, including the FLAT adjustment. The 9 instead of 14 cosine-shaped loss curves are sufficient to reduce cumulative deviations to a tolerable degree. At switching points where it is essential that each regular and standby line have gain curves which are closely alike, equalizers A1, A2, and B1 are used. Equalizer B1 provides the additional five cosine-shaped loss curves. This permits adjusting the transmission characteristics of working lines to be alike within ±0.25 db and the line-up requirements of a switching section.

2.15 Switching main and terminal repeaters are further equipped with a low-frequency (LF) equalizer which may be adjusted to correct for gain deviations at the lower end of the spectrum. Also provided are four bump-type equalizers associated with the 556-, 308-, 3096-, and 8320-kc pilot frequencies. Each bump equalizer provides fine adjustment over a small range of frequencies and is used to reduce the residual variations at the pilot frequencies after all other gain equalization has been performed.

2.16 The switching main and terminal repeaters, when transmitting television groups, provide an adjustable delay build-out network to equalize the transit time across the television frequency band of more than 4 mc. The same repeaters employ a phase build-out network with all-message or the combined groups of message and television. The phase build-out network is adjusted to produce the same electrical length in each of the regular lines and the standby line of a switching section. Hitless maintenance switching of the phase-equalized lines may be accomplished by using the automatic protection switching equipment described in Section 359-010-125.

C. Dynamic Equalization

2.17 All repeaters use some form of automatic-gain equalization to compensate for the more rapid changes which may occur during the interval between the performance of manual adjustments. Since the cable loss varies with changes in temperature, the gain characteristic of the line amplifier is dynamically controlled. At auxiliary repeaters, the dynamic portion of the line amplifier is controlled by a 7266-kc pilot regulator or a thermistor buried with the cable. Two types of circuits, indirect and direct, are used to control the dynamic network control (thermistor). The indirect method compensates for changes in ambient temperature and is discussed in 2.21. The direct method is discussed in 2.18.

2.18 Equalizing auxiliary and equalizing main repeaters provide networks to match system gain variations by controlling the dynamic portion of the line amplifier and the A1 and A2 equalizers. The gain characteristic of the line amplifier is varied automatically under the control of a thermistor for changes in the detected amplitude of the 7266-kc pilot. Equalizer units A1 and A2 contain dynamic networks 1 and 2 which provide coarse compensation for short-term changes of temperature and aging, respectively. The thermistors controlling dynamic equalizers 1 and 2 are driven by changes in the detected amplitude of the 3096- and 2064-kc pilot frequencies, respectively.

2.19 Switching main and terminal repeaters use equalizers B1 and B2 in addition to all the units described in 2.18. Equalizer B1 is equipped with dynamic network 3, and equalizer B2 contains the dynamic networks 4 and 5. The thermistors in their networks are controlled by the detected amplitudes of the 556-, 308-, and 8320-kc pilot frequencies, respectively. The respective networks automatically compensate for the short-term effect of fine changes in temperature, aging, and line gain.

2.20 The methods of control applied to all the dynamic equalizers are described in this section under Pilot Regulator (Part 3) and Control of Dynamic Networks through Computer (Part 3). Each of the five dynamic equalizers employs the dual thermistor card which is used to compensate for changes in ambient temperature (see 2.21).

D. Compensation for Changes in Ambient Temperature

2.21 As outlined in 2.17 through 2.20, each dynamic equalizer automatically readjusts the loss of the transmission circuit by means of a thermistor and associated elements. The elements associated with the thermistor determine the loss shaping versus frequency. The change in thermistor resistance determines the amount of change in loss. In order to avoid the effect of ambient temperature changes upon the thermistor control element, another compensation must be made. As shown in Fig. 4, each dynamic equalizer network is equipped with a thermistor card on which are mounted two thermistors. The first is the ambient temperature-compensating thermistor which functions in conjunction with fixed series resistance as the variable element of an L pad. As the ambient temperature changes, the resistance of the shunt arm varies in such a way as to regulate the 60-cps current delivered to the heater of the network control thermistor. The heat generated therein is always just sufficient to hold the temperature of the network control thermistor above ambient temperature by a reasonable amount and to eliminate the effect of changes in ambient temperature upon the control network. The isolated heater supply of the control network is biased to operate at +190 volts to ground in order to avoid a large difference of potential between the heater and the bead of the network control thermistor, since the bead also operates at +190 volts to ground. The bead potential is supplied by the dc amplifier of the pilot regulator. The value of the network control thermistor, which controls the loss of the dynamic equalizer, is thus controlled from two sources: indirectly by the temperature compensation current applied to the heater, and directly by the application to the bead of the controlling plate current of the dc amplifier in the pilot regulator.

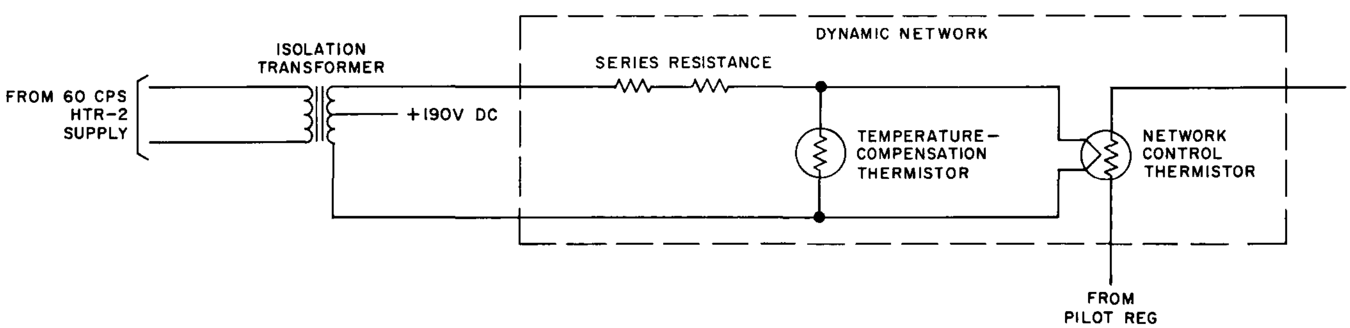


Fig. 4 — Ambient Temperature-Compensation Circuit

E. Equalizer A1

2.22 Equalizer A1, used at equalizing auxiliary repeaters, is sealed. A compartment is provided in the equalizer for desiccant to absorb entrapped water vapor. The desiccant is not furnished but is put in place during initial line-up and replaced as part of the normal maintenance routine.

2.23 Fig. 5 shows the face of equalizer A1 with the dust cover omitted. The control knobs are on shafts which drive the variable resistors for control of network losses through a worm gear to give fine control. A graduated dial with numbers from 0 to 10 is visible through each of the oblong windows. The cover has a hinged section, forming a secondary cover over the controls, which can be opened to obtain access to controls without removing the dust cover.

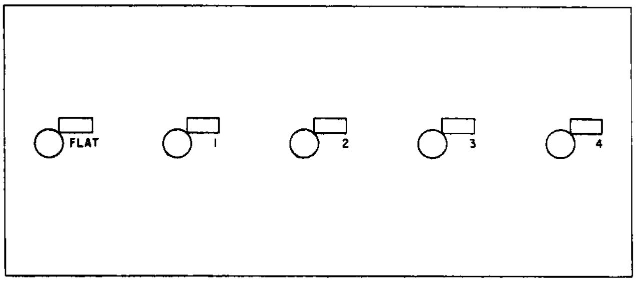


Fig. 5 — Face of Equalizer A1

2.24 Equalizer A1 contains four cosine-shaped manual equalizers, one flat manual equalizer, and one dynamic equalizer for equalization due to variations in hut temperature. The loss of the dynamic equalizer is automatically controlled by regulators varying the current in a thermistor contained in the network. The purpose of the network is to compensate for variations in line gain resulting from changes in the temperature of repeaters. The combined effect of temperature changes on all elements in the repeater is shown in Fig. 6 for plus or minus 40-degree F. variations in the ambient temperature of the repeater. When the thermistor current is in the center of its range, the network presents a flat loss of approximately 9 db, which is the zero axis of the curve.

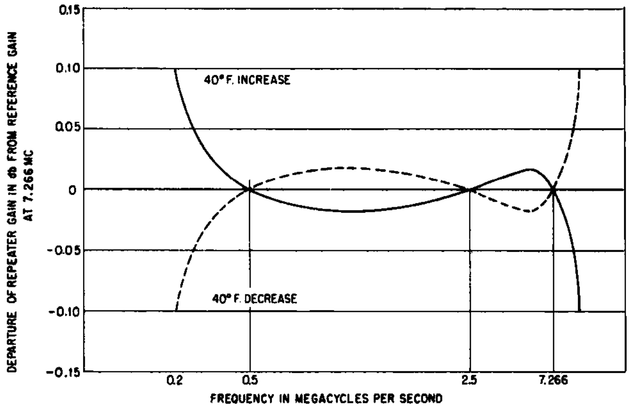


Fig. 6 — Combined Effect of Positive and Negative Variations of Ambient Temperature of Repeaters

F. Equalizer A2

2.25 Equalizer A2 is similar in appearance to equalizer A1, except that its controls are designated 5 through 9. In addition to the manually controlled networks, equalizer A2 contains a dynamic network shaped to compensate for gain changes resulting from aging of electron tubes in amplifiers and a fixed design deviation network shaped to compensate for fixed, known deviations from design characteristics of repeaters.

2.26 Since the magnitude of correction for deviations from design values increases with the number of auxiliary repeaters through which signals pass, three applications of design equalizations have been chosen. When there are 1 to 10 auxiliary repeaters in tandem, a flat pad of 8.5-db loss is used since the amount of design error that can accumulate is small. This pad builds out the flat loss of equalizer A2 to 34 db to avoid overloading the succeeding flat amplifier. When there are 11 to 22 repeaters, a fixed shape 218D design deviation equalizer that compensates for 19 repeaters is used to equalize the systematic error and helps to preserve the range of the manual shape networks. When there are 23 to 32 repeaters in tandem, a 218E design deviation equalizer is employed to compensate for 28 repeaters.

2.27 Fig. 7 shows the variation in loss equalizer A2 having the 19-repeater design deviation network. This variation is caused by the dynamic network when all other networks are set flat. Since the middle curve shows the case where the dynamic network is flat, this curve represents the design deviation network.

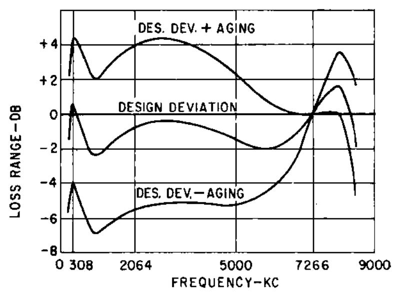


Fig. 7 — Dynamic Network Loss Variations of Equalizer A2

G. Equalizer B1

2.28 Equalizer B1 is used at switching points to produce the finer degree of equalization necessary for each regular line and each standby line to have virtually the same gain curves. It provides manual adjustment of the five cosine shapes designated 10 through 14 in Table B. The adjustable cosine networks are also equipped with factory-aligned delay networks. Equalizer B1 further provides dynamic equalizer No. 3, which is shaped to automatically compensate for gain changes resulting from temperature changes that may occur during the interval between the performance of manual adjustments. The dynamic network is controlled by the 556-kc regulator. Equalizer B1 is also equipped with fixed delay networks which are aligned during manufacture.

H. Equalizer B2

2.29 Equalizer B2 is used at switching main and terminal repeaters as is equalizer B1. Equalizer B2 has no manual equalizers but contains the two dynamic equalizing networks, No. 4 and No. 5, and a 5.8-db pad. Dynamic equalizer No. 4 is controlled by the 308-kc regulator and provides fine aging corrections. Dynamic equalizer No. 5 is controlled by the 8320-kc regulator and provides fine line level corrections.

I. The 308-KC Equalizer

2.30 The 308-kc equalizer, a 226S-type network, is manually adjustable, furnishing additional equalization at the low-frequency end of the line. Its function is to reduce the residual variation at the 308-kc pilot after the manual equalizers have been adjusted.

2.31 Fig. 8 shows graphically the variation of loss in db of the 226S-type network, plotted against frequency in megacycles. The actual loss may deviate from the value indicated by ±0.10 db at the lower end of the frequency band. Above 1 mc the permissible variation is ±0.05 db.

J. The 3096-KC Equalizer

2.32 The 3096-kc equalizer, a 226W-type network, is manually adjustable and is intended to correct for gain deviations after mop-up at the 3096-kc pilot frequency.

2.33 Fig. 9 shows graphically the insertion-loss characteristics in db of the 226W network plotted against frequency in megacycles. The network provides an approximate loss swing at 3096 kc of ±0.5 db. Flat loss is 1.27 db.

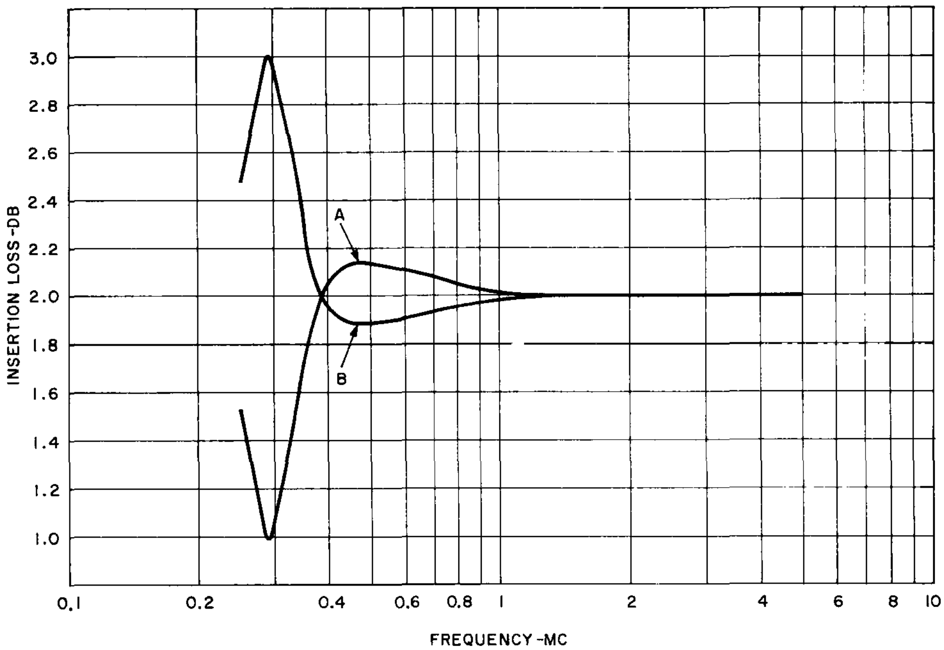
K. The 8320-KC Equalizer

2.34 The 8320-kc equalizer, a 226Y-type network, is manually adjustable and is intended to correct for gain deviations after mop-up at the 8320-kc pilot frequency.

2.35 Fig. 10 shows graphically the insertion loss characteristics in db of the 226Y network plotted against frequency in megacycles. The network provides an approximate loss swing at 8320 kc of ±1.5 db to ±2.0 db. Flat loss is 2.2 db.

L. The 556-KC Equalizer

2.36 The 556-kc equalizer, a 226AB-type network, is manually adjustable and is intended to correct for gain deviations after mop-up at the 556-kc frequency.



NOTE:
POSITION A IS EXTREME COUNTERCLOCKWISE POSITION; POSITION B IS EXTREME CLOCKWISE POSITION.

Fig. 8 — 308-KC Equalizer (226S Network) Measured Loss

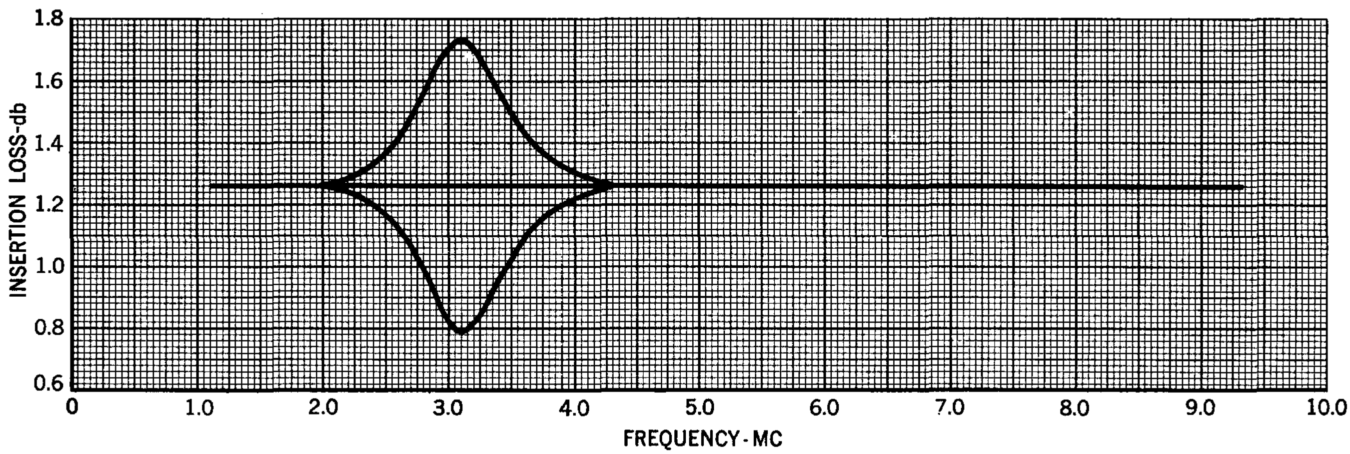


Fig. 9 — 3096-KC Equalizer (226W Network) Measured Loss

2.37 Fig. 11 shows the insertion loss characteristics in db of the 226AB network plotted against frequency in kc. The network provides a loss swing of ±2.5 db at 556 kc about a flat loss of 3.5 db. The loss swing tapers to the flat loss at 370 and 800 kc.

M. The LF Equalizer

2.38 The LF (low-frequency) equalizer, a 226AC network, is manually adjustable and is intended to correct for gain deviations after mop-up at the 308-kc frequency.

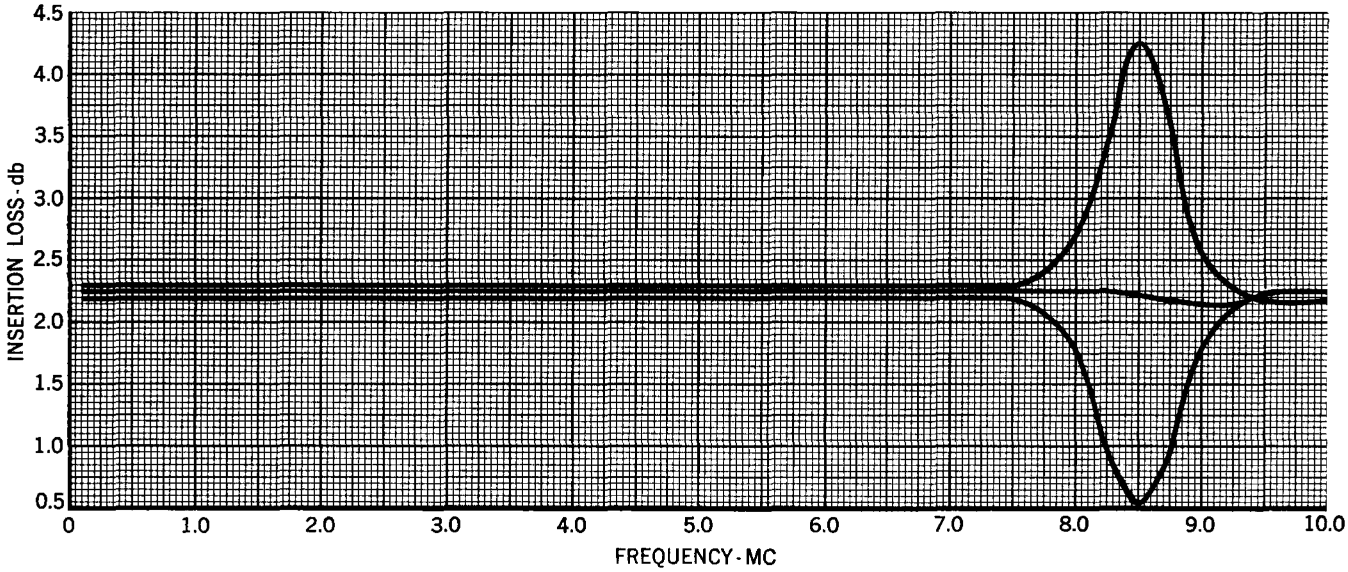


Fig. 10 — 8320-KC Equalizer (226Y Network) Measured Loss

2.39 Fig. 12 shows the insertion loss characteristics in db of the 226AC network plotted against frequency in kc. The network provides a loss swing of ±2.5 db at 308 kc about a flat loss of 3.5 db. The loss swing tapers to the flat loss at 800 kc.

N. The Delay Build-Out Equalizer

2.40 Transit time of line frequencies over a coaxial cable is not uniform, with higher frequencies being subject to more delay in transmission than the lower frequencies. This delay in transmission is not noticeable in the telephone systems, as each channel has its own small bandwidth. In a system used for television, where the frequency band is more than 4 mc, the delay distortion is considerable and requires additional equalization for transmission of a satisfactory television signal.

2.41 Delay distortion equalization is optionally provided in the receiving terminal repeater equipment at switching main and terminal repeaters, as shown in Fig. 1. A 475A adjustable delay distortion build-out network, whose function is to equalize the difference in transit time by building out the line delay by adding equal and opposite delay to that of the line equipment, is included in the receiving high-frequency equipment at switching main and terminal repeaters.

2.42 The 475A delay equalizer, in the receiving side of the high-frequency line, has four knob-type switches which adjust the relative delay in microseconds for various line sections from 1/4 auxiliary repeater section up to and including 3-3/4 sections. Fig. 13 shows the delay in microseconds relative to the delay at 3.5 mc. Therefore, all the curves approach zero ***relative*** delay at the 3.5-mc reference frequency. The ***absolute*** value of the 3.5-mc delay of the network and its connecting cables is given by the chart above the curves. The relative delay over the 3.5- to 9.0-mc range varies from 0.0 μsec to 0.02 μsec for the 1/4 section switch position to 0.0 μsec to 0.7 μsec for 3-3/4 sections. The measured insertion loss in db is a function of the same four switches and is approximated in Fig. 14. For the switch positions 1/4 to 3-3/4, the losses vary from as small as 0.02 db at 3.0 mc to as great as 1.82 db at 9.0 mc, depending upon the number of switch sections used. A dip in transmission level of about 3.0 db might result during the operation of the switches. The switches must therefore be operated quickly or an automatic switch to a standby line may result.

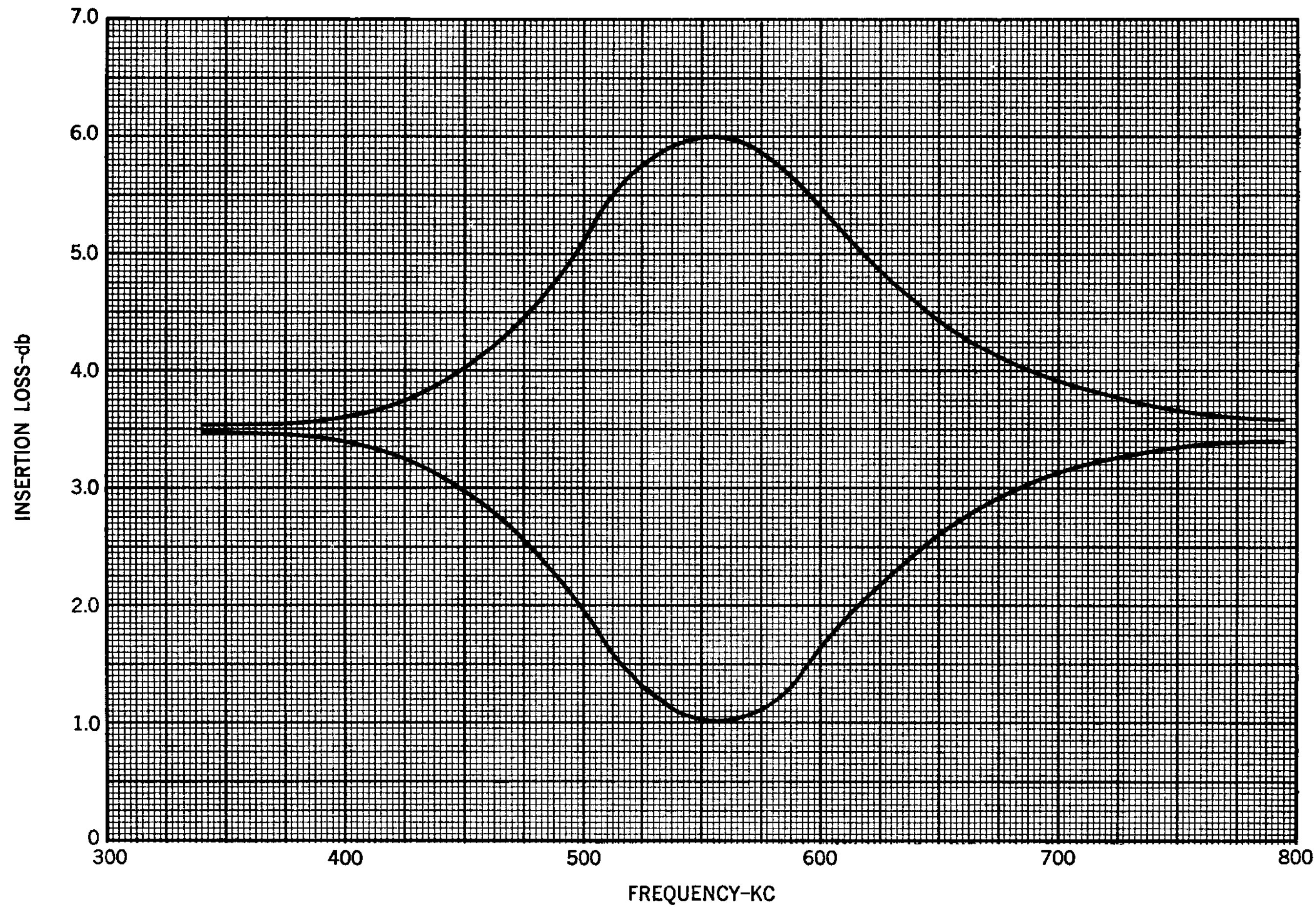


Fig. 11 — 556-KC Equalizer (226AB Network) Measured Loss

O. The Phase Build-Out Equalizer

2.43 All regular lines and the standby line in a switching section must be of the same electrical length to minimize errors in data transmission which otherwise would be introduced by switching from a regular line to a standby line. The J68836T adjustable phase build-out equalizer is provided at switching and terminal main repeater stations. Measurements to determine the amount of phase build-out required cannot be made until a line and its standby are both installed and operable.

2.44 In applications where hitless line switching is not supplied, the J68836T panel is not provided. A 19D or 19E pad is substituted to provide the 5.0-db insertion loss of the equalizer.

2.45 The adjustable phase build-out equalizer consists of networks used in combination which provide up to 625 degrees per mc slope. The networks are available in 14 options, and they employ a combination of two adjustable phase sections and up to four fixed phase sections or pads as required.

2.46 The two adjustable phase sections always provided with the panel are each equipped with a 16-position selector switch. The one, a 4054A network, provides a fine adjustment up to 20.75 degrees per mc in 1.25-degree per mc steps. The other, a 4054B network, provides a coarse adjustment up to 78.0 degrees per mc in 5.0-degree per mc steps.

2.47 In addition to the adjustable phase network, a combination of fixed phase networks or pads may be employed in 14 options.

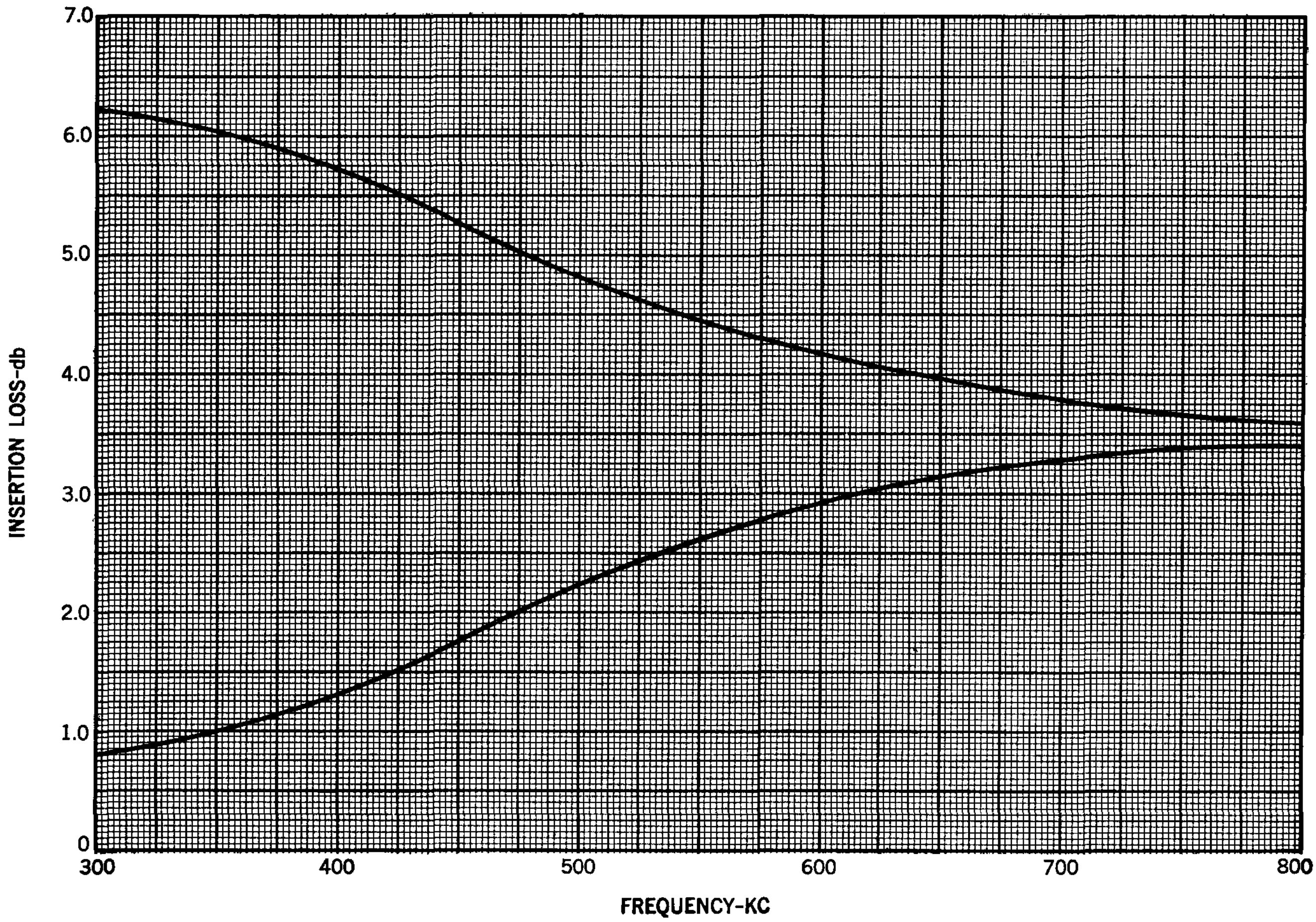


Fig. 12 — LF Equalizer (226AC Network) Measured Loss

A total of four fixed networks or pads are wired on the panel in tandem and are considered as building blocks of phase. There are three different fixed networks, each succeeding one having approximately double the amount of phase of the previous one. The phase shift provided by the networks is approximately 78.4 degrees per megacycle for the 4055A, 156.5 degrees per megacycle for the 4056A, and 39.1 degrees per megacycle for the 4057A.

2.48 An attenuation pad with insertion loss equivalent to a particular fixed network is used in the absence of any fixed phase adjustment network to maintain the same output level for all options. Two types of pads are used, the 41A and 42A. The 41A pad with 0.8-db attenuation is used in lieu of the 4055A network; the 42A pad with 1.4-db attenuation is substituted for the 4056A or 4057A network. The pads fit onto the J68836T panel in the same mounting as their respective fixed networks and are wired in the same manner.

P. Equalization of TV Signals in Line Connecting Circuit

2.49 Fig. 1C shows the television signal path in a typical line connecting circuit. When television facilities are part of the L3 carrier system, supplemental gain and delay equalizers are employed in the line connecting equipment. These equalizers provide equalization for all the high-frequency line equipment between the pilot hybrid and the transmitting hybrid. This description will be limited to the equalization provided for television signals. Section 359-010-130 contains a complete description of the line connecting circuits.

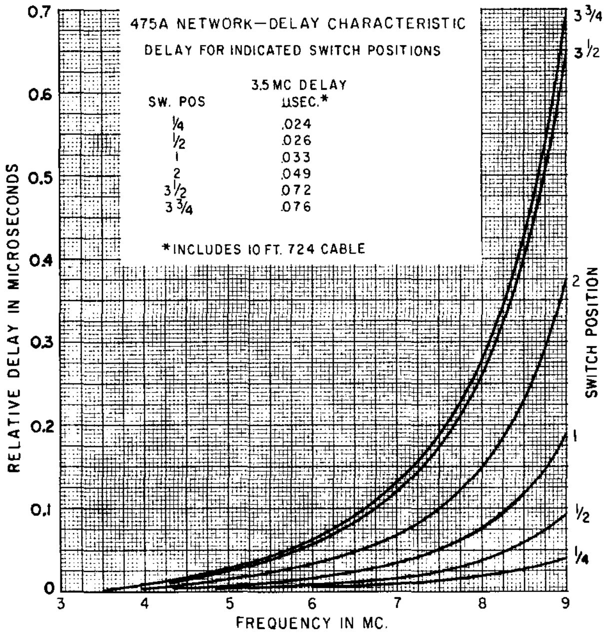


Fig. 13 — 475A Network Delay Characteristic Curves

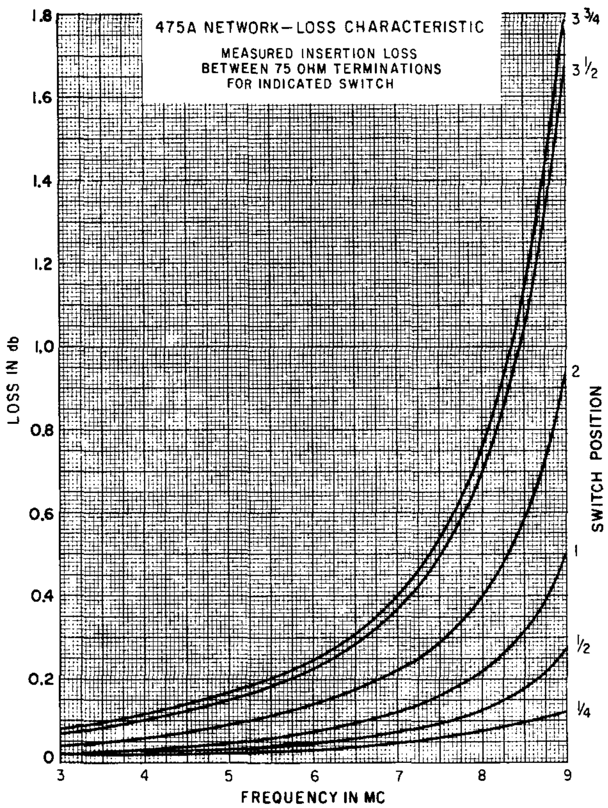


Fig. 14 — 475A Network Loss Characteristic Curves

2.50 The combined television and telephone signals are separated in a receiving branching filter. The filter is a part of the 326A, 327A, or 327B equalizer. One or more of these equalizers may be employed in cascade to coarsely equalize the delay distortion of the television band. The 326A network equalizes the distortion of approximately 15 line sections. The 327A and 327B networks match the distortion of approximately 20 and 25 line sections, respectively. In addition, the 325A, 325B, and 325C equalizers, which are employed to provide a finer degree of equalization, equalize the delay for approximately two, four, and eight line sections, respectively.

2.51 The six types of fixed delay equalizers listed in 2.50 are employed in combination as necessary to equalize the delay distortion of a switching section. Where the combined insertion loss of the equalizers exceeds the amount of gain normally available, further amplification is provided by the amplifier (FLAT AMP E). Television receiving pads are provided to maintain correct transmission levels. The values of each pad (TV REC PAD A) and (TV REC PAD B) are dependent upon the number of fixed delay equalizers employed.

2.52 Since the branching filter is used only in the first equalizer unit, a simulating network is used in each subsequent 326A, 327A, or 327B equalizer to supply the delay of missing branching filters. The simulating network is not used in the first unit.

2.53 The cable equalizer compensates for the transmission deviations introduced by the cable used in the connecting circuit, hybrid coils, and the receiving line switch. The cable equalization over the TV band is produced by the 323A equalizer. Strapping terminals are provided to equalize the loss characteristics of various lengths of No. 724 cable in steps from 50 to 300 feet.

2.54 TV hybrids 1, 2, and 3 produce the outputs TV LINE OUT A, TV LINE OUT B, TV LINE OUT C, and TV TEST. The A, B, and C outputs may be used for branching, connecting through and/or termination of the television signal.

2.55 From line to line, the deviations within the TV band are unpredictable and may sometimes be excessive. When required, the 336A equalizer (TV EQ A) and amplifier (FLAT AMP F) are inserted between the branching filter output and the first fixed delay equalizer section. The amplifier compensates for the adjustable equalizer loss. The 336A equalizer is a transversal equalizer and provides 23 harmonically related adjustable cosine shapes of loss versus frequency and 15 of delay versus frequency across the television band.

2.56 Unlike other equalizers in the L3 system, the 336A equalizer is a transversal equalizer, which is a special case of the general class of time domain equalizers. Because of the equivalence of echoes and transmission deviations in a system, the deviations which cause echoes may be corrected by using compensating echoes. The transversal equalizer employs a unique scheme of adding echoes, which cancels those echoes already existing in a system. By providing taps on delay lines and providing means for adjusting magnitudes of the paired echoes picked off and adding them to the original signal, any desired pattern of leading and lagging echoes around a signal can be provided. As shown in Fig. 15, the transversal equalizer is composed of a delay line, a hybrid coil, and a summing network. The equalizer uses an unbalanced delay line and a balanced summing network without active elements.

2.57 The delay line is composed of 38 identical sections, each of which is required to have a linear phase change of 180 degrees over the TV frequency band. In order that the terms be cosines, the phase shift at each band edge must be a multiple of 180 degrees. The hybrid coil serves several purposes. It splits the signal from the leading line into the component that energizes the lagging line. It inverts the phase of the signal of the lagging line, thus providing the odd symmetry required for the delay terms. The hybrid coil also provides isolation between the lagging line and the main signal. This is desirable because mismatches in the lagging line produce reflections that appear as lagging echoes if transmitted without attenuation to the output of the equalizer. Fig. 16 shows the individual potentiometer summing circuit. The summing circuit is used for combining each leading or lagging echo

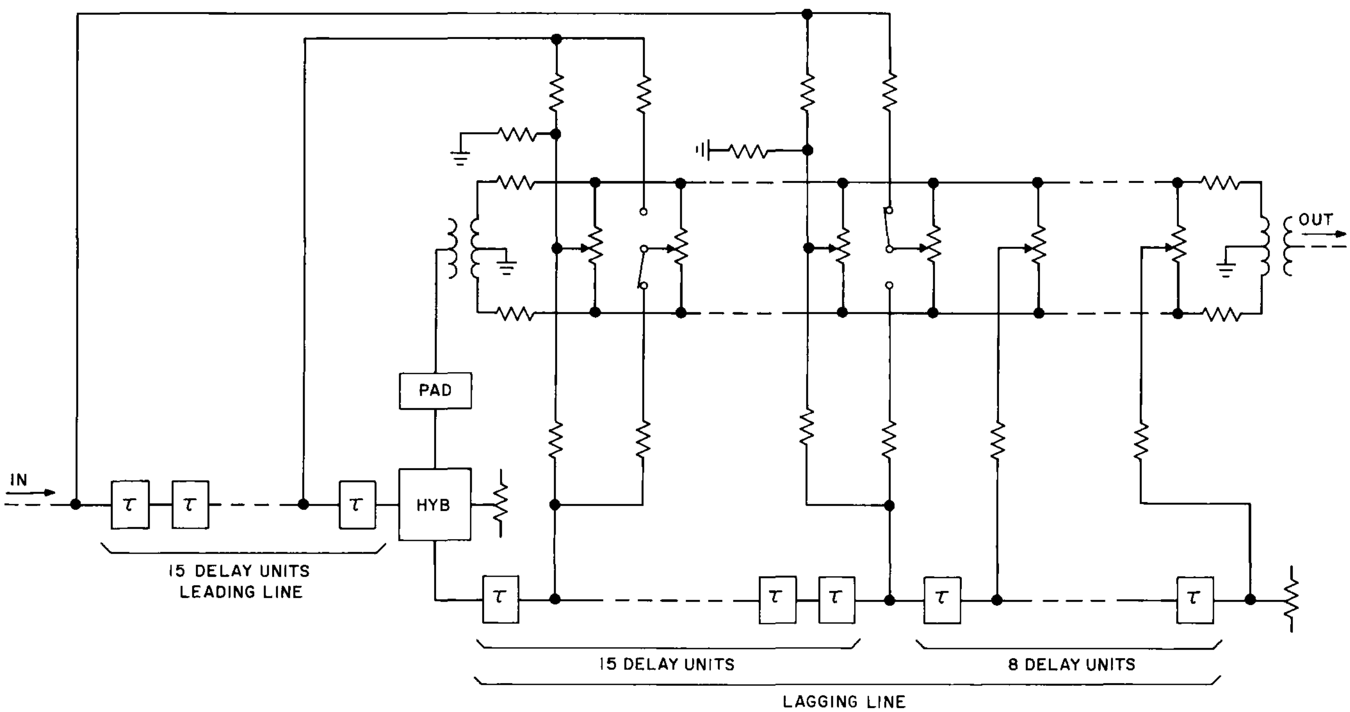


Fig. 15 — Transversal Equalizer — Block Schematic

pair on the balanced line between the transformers in Fig. 15. The position of the variable arm controls the magnitude as well as the sign of the echo with respect to the main signal. To reduce the loading of the delay line at the tapped points, high values of resistors in the summing networks are required. This inherently restricts the echo magnitudes, and thus the ranges, unless the magnitude of the main signal is reduced. The pad between the hybrid and summing transformers serves to reduce the magnitude of the main signal. The pad is in the main transmission path and is made large enough to achieve good range in loss and delay shapes, but small enough to avoid degrading the signal-to-noise ratio. The ranges are listed in Table C. Since the harmonic terms are not completely independent in the 336A equalizer, minor term interactions exist and consequently several iterations may be required to adjust the equalizer. It is equipped with a sliding mask to allow access to either the delay controls only or gain controls only. An additional knob is provided near each gain control to select leading or lagging echoes for loss equalization. The controls near the base are for simple all-pass networks that are switched in and out to supplement the first and second delay terms. Fig. 17 shows the mask positioned for access to the gain controls. Fig. 18 shows the mask positioned for access to the delay controls.

2.58 Fig. 19A shows gain and delay characteristics which might be expected on a 400-mile line without a 336A equalizer. Since the line-to-line deviations differ greatly and are unpredictable, a very flexible equalizer such as the 336A is required. The distortions of approximately ±0.7 db and ±0.15 microsecond are excessive. Fig. 19B shows the corresponding characteristic which might be expected after adding a 336A equalizer and adjusting the 23 gain and

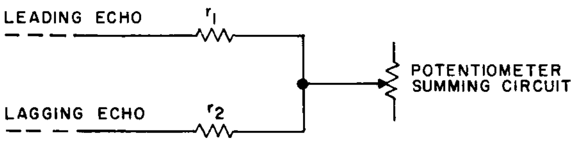


Fig. 16 — Method of Combining Leading or Lagging Echoes to Produce Pure Loss or Pure Delay

TABLE C

336A EQUALIZER — LOSS AND DELAY CHARACTERISTICS

HARMONIC TERM	LOSS RANGE (DB)	DELAY RANGE (μSEC)
1	1.1	0.03
2	1.1	0.06
3	1.1	0.09
4	1.1	0.12
5	1.1	0.14
6	0.8	0.09
7	0.7	0.10
8	0.7	0.11
9	0.7	0.12
10	0.7	0.13
11	0.5	0.11
12	0.5	0.12
13	0.5	0.12
14	0.5	0.13
15	0.5	0.13
16	0.4	—
17	0.4	—
18	0.4	—
19	0.4	—
20	0.4	—
21	0.4	—
22	0.4	—
23	0.4	—

15 delay terms. The residue now may be expected to be approximately 0.1 db and ±0.05 microsecond. Fig. 20 represents the gain and delay characteristic of an 800-mile loop which might be expected after equalization with two 336A equalizers to provide distortions of approximately ±0.15 db and ±0.07 microsecond. Section 359-077-502 describes the adjustment of the 336A equalizer.

Q. Adjustment of Equalizers

2.59 Manually adjusted networks permit compensation, within reasonable limits, for any shape of gain curve. In making an equalization line-up, the dynamic networks are set to a fixed loss by means of a thermistor control set (see Section 103-452-100). The adjustment results in

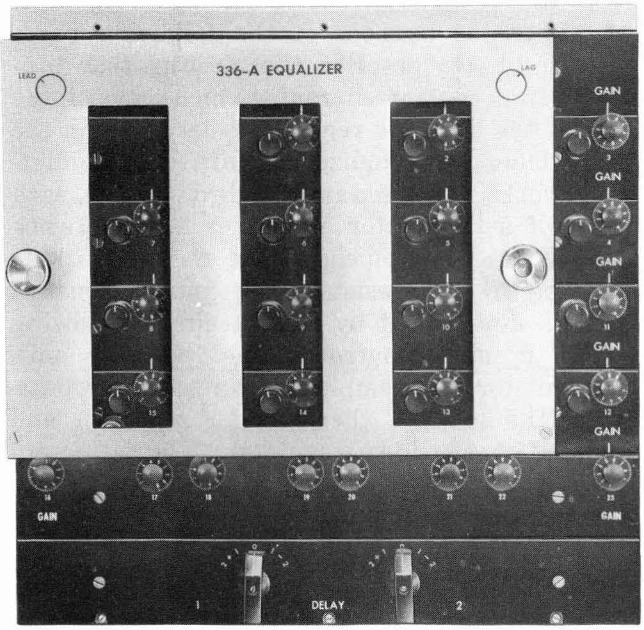


Fig. 17 — 336A Equalizer — Gain Controls

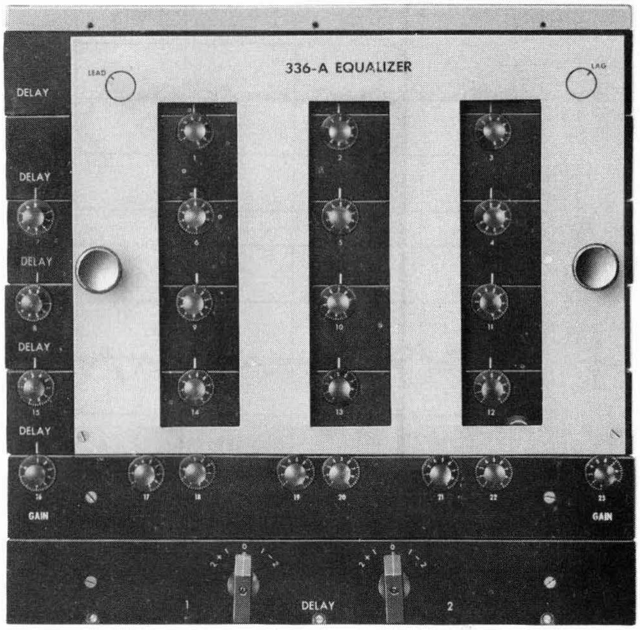
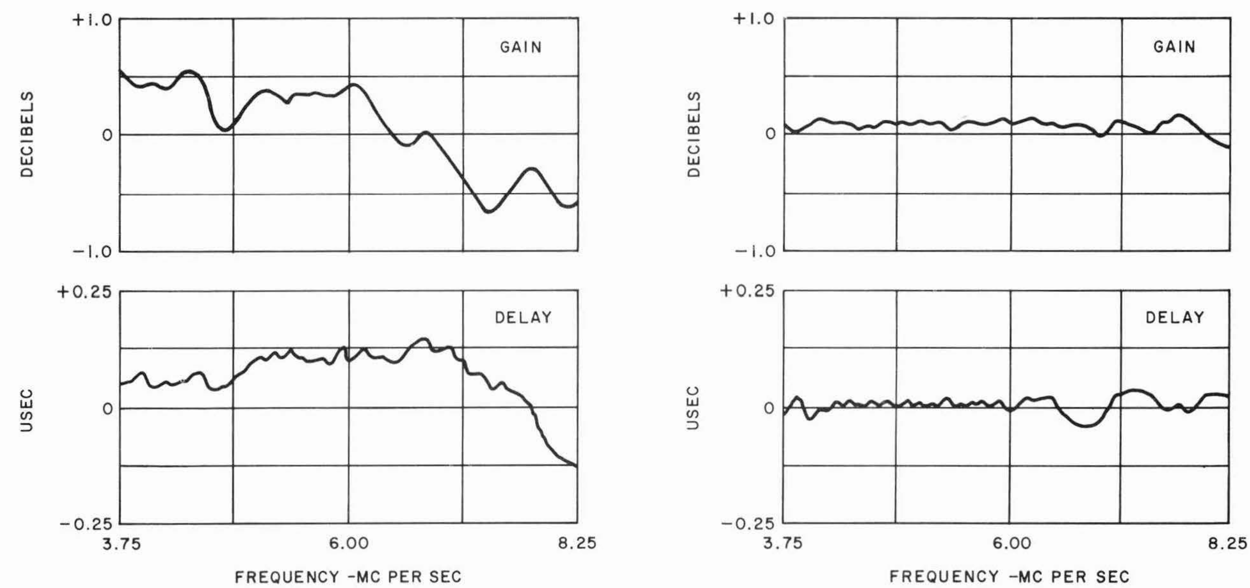


Fig. 18 — 336A Equalizer — Delay Controls



A–BEFORE EQUALIZATION WITH 336A EQUALIZER

B–AFTER EQUALIZATION WITH 336A EQUALIZER

Fig. 19 — Typical Delay and Gain Characteristics of a 400-Mile Circuit

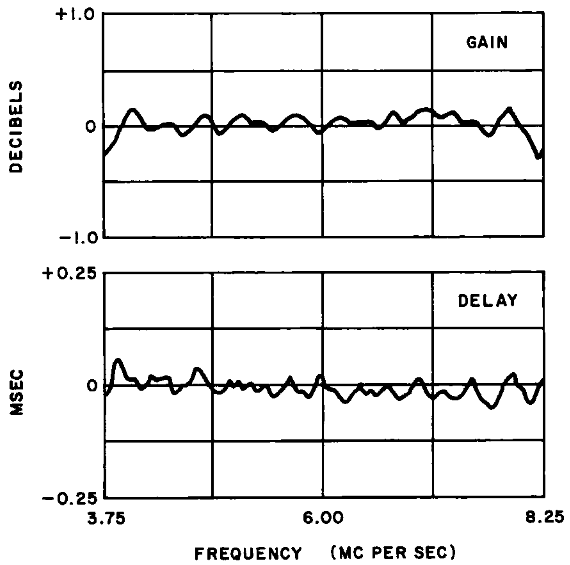


Fig. 20 — Delay and Gain Characteristics of 800-Mile Circuit After Equalization with Two 336A Equalizers

the equalizers generally not being at the middle of their ranges, but offset so that they will have more margin in the expected direction of change than in the other. For example, aging electron tubes will always require equalization in one direction; the direction of temperature changes is generally known so that the temperature network may be biased in one direction. Adjustment of the manual shapes will then reduce to a tolerable level any gain deviations between pilots that have accumulated during the period between equalization line-ups.

2.60 As a preliminary to equalizer adjustment, the 7266-kc pilot should be adjusted to reference value at the output of the line amplifier and should be held there by a test set which furnishes thermistor current. After adjustment of the line characteristic to a flat condition, the flat network in equalizer A1 and the gain controls on flat-gain amplifiers may be adjusted to give an overall loss of 0.0 db between receiving line amplifier out and pilot hybrid out at 7266 kc. Equalization will then be maintained satisfactorily until deviations between pilots have again reached magnitudes which require readjustment.

3. REGULATION

3.01 It is the purpose of the following paragraphs to describe the circuits that produce the dc control currents which govern the losses of the dynamic regulating networks in the line amplifier and equalizer circuits. The regulating networks, discussed in 2.17 through 2.20, each consist of a thermistor and other fixed network components. The impedance of the network is controlled by the resistance of the thermistor, which is determined by the dc current flowing through it under control of the regulator unit. The regulator units employed at auxiliary repeaters are the J68817T thermometer regulator and the J68817A auxiliary regulator. The latter operates at the 7266-kc pilot frequency. All other repeaters use some or all of the J68817G, D, C, B, AB, and H regulators which operate at the 7266-, 3096-, 2064-, 556-, 308-, and 8320-kc pilot frequencies, respectively. The uses are outlined in Table A. The thermometer regulator (see 3.03, 3.04, and 3.05), the auxiliary regulator, and the 7266-kc regulator individually contain an ambient temperature oscillator used to prevent ambient temperature changes from affecting the resistance of the regulating thermistor (see 3.06, 3.07, and 3.08). The other regulators, which control dynamic equalizer networks 1 through 5, contain the ambient temperature-compensation circuit discussed in 2.21.

3.02 One type of die-cast moistureproof container, shown in Fig. 21, is used for housing all J68817-type regulators. This container consists of a shallow base on which are mounted all components, including connecting plugs, and to which a deep cover is attached. This enables easier accessibility for maintenance purposes. Regulators mount by means of self-locking slides on brackets in transmission panels.

A. Thermometer Regulator

3.03 The J68817T thermometer regulator is used at some auxiliary repeater stations and contains two circuits. One is the dc control circuit, which adjusts the power that is fed to the regulating thermistor in the line amplifier. The other is an ambient temperature oscillator, which maintains a constant temperature at the control thermistor in the absence of dc regulating

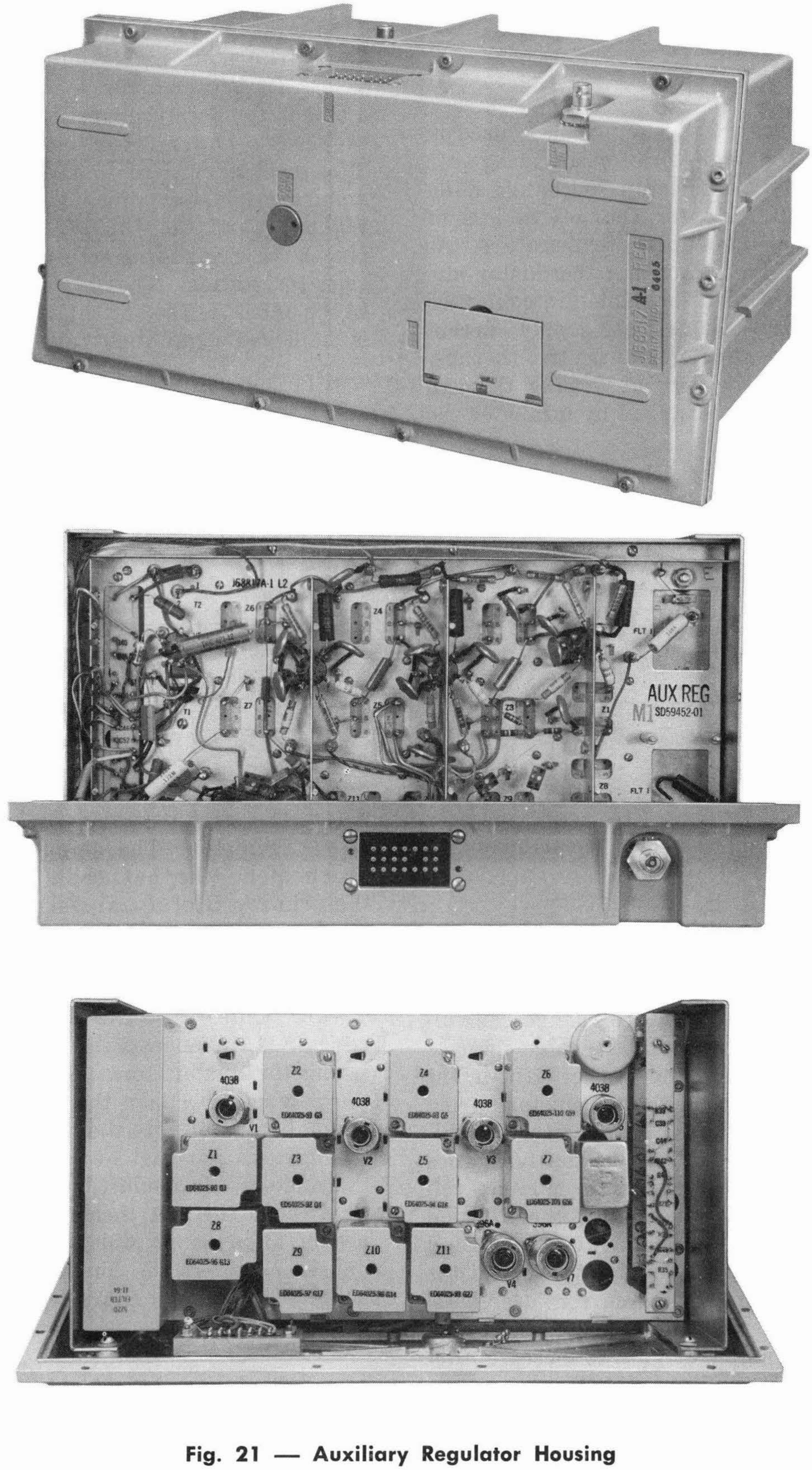


Fig. 21 — Auxiliary Regulator Housing

current and prevents the undesired effect of changes in ambient temperature upon the value of the regulating thermistor.

3.04 Fig. 22 shows the circuit which is used in thermometer regulators for adjusting gain manually and for causing gain to change automatically to compensate for changes in loss of the cable due to changes in its temperature. As shown in Fig. 22, the regulating thermistor and a thermistor buried with the cable are connected in parallel. The 190-volt dc plate supply current flows through a potentiometer to the two thermistors. The value of the current flowing through the combination can be changed by means of the GAIN control.

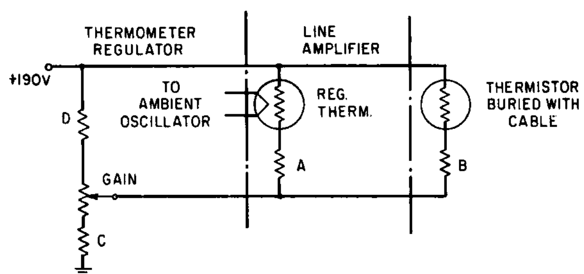


Fig. 22 — Manual Gain and Temperature-Correction Circuit

3.05 After an initial manual adjustment of gain to obtain normal pilot, the circuit operates to correct for cable temperature changes as follows. When the temperature of the cable changes from the value existing at the time of adjustment of pilot, the temperature of the thermistor buried with the cable also changes. An increase in temperature will cause a decrease in the resistance of the buried thermistor and more current will flow through it. This will change the division of the total current between the regulating and buried thermistors. The regulating thermistor will receive less current. As the current decreases, the resistance of the thermistor increases, which in turn causes the amplifier gain to increase. Resistors A, B, C, D, and the GAIN control are chosen to give the correct gain change for given changes in cable temperature.

B. Ambient Oscillator

3.06 The ambient oscillator shown in Fig. 23 compensates for the effect of changes in ambient temperature upon the resistance of the regulating thermistor bead contained on the 30A thermistor card in the line amplifier. The ambient oscillator is included in the thermometer regulator and the J68817A auxiliary regulator, one or the other being employed at each auxiliary repeater station. The oscillator is also included in the J68817G 7266-kc pilot regulator unit which is employed at all other repeater stations.

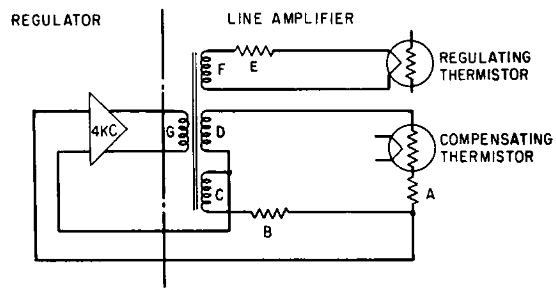


Fig. 23 — Circuit of Ambient Oscillator

3.07 The circuit consists of an amplifier in the regulator. The amplifier is tuned to approximately 4 kc, having its output connected to the primary G of a transformer which is a component of a 30A thermistor card mounted in the line amplifier. The two halves of the secondary winding, C and D, form two arms of a bridge circuit, while resistor B forms a third arm and resistor A, in series with the bead of a compensating thermistor, forms the fourth arm. A tertiary winding F on the transformer connects through resistor E to the heater of the regulating thermistor, also part of the 30A card. The two thermistors are mounted within one glass envelope, coded the 29A thermistor, and are made as nearly alike as possible, even to including the unused heater in the compensating thermistor to make their thermal characteristics as much alike as possible.

3.08 The input of the 4-kc amplifier is connected to one diagonal of the bridge in the correct phase to result in positive feedback in the circuit.

This causes the loop to oscillate at approximately 4 kc. When the oscillator is connected to power supply voltages, the output power from the amplifier is delivered to the compensating thermistor, causing it to heat. The resistance of the compensating thermistor will be reduced as it heats until the bridge balances at a loss which just equals the gain of the amplifier, at which point the amplitude of oscillation will stabilize. A portion of the oscillator output power is delivered from the tertiary winding to the heater of the regulating thermistor.

3.09 If the temperature of the amplifier in which the 30A card is located is reduced for some reason, the resistance of the compensating thermistor will increase, thus unbalancing the bridge and causing the output power to change. The circuit will again stabilize at the value of output power which will restore the resistance of the compensating thermistor to its former resistance. Since the ambient temperature in which the card operates is lower, a decreased amount of heat will hold the bead of the compensating resistor at the same resistance. Lowered oscillator output decreases the amount of power delivered to the regulating thermistor.

3.10 The temperature compensation is made so exact that less than a ±3 percent change in the regulating thermistor bead resistance results from an ambient temperature change from —20° to +160° F.

C. Pilot Regulator

3.11 Pilot regulators are designed to automatically control the losses of the networks contained in the line amplifier and any dynamic equalizers employed. The control is governed by variations in the level of a pilot frequency component in the transmission path. The transmission output at the auxiliary repeater (see Fig. 24) is sampled by a series resistor mounted in the transmission panel near the output coaxial connection and is applied to the auxiliary regulator input. The combination of the series resistance and the shunt input impedance of the pilot regulator form an L pad with an attenuation of approximately 16 db. The transmission output at all repeaters except the auxiliary repeater is sampled by a pilot hybrid inserted in the through circuit. The insertion loss to the through circuit is 1.4 db. The loss to the pilot frequency line is 6 db. As shown in Fig. 25, the pilot frequency line is terminated in 75 ohms at the end of the line near the 7266-kc regulator input. In addition, a pad installed in the unit with the terminating resistor provides 11-db decoupling between the regulator input and the pilot line. The remaining regulator inputs are each bridged directly across the pilot frequency line to select the applicable signal, 3096, 2064, 556, 308, or 8320 kc.

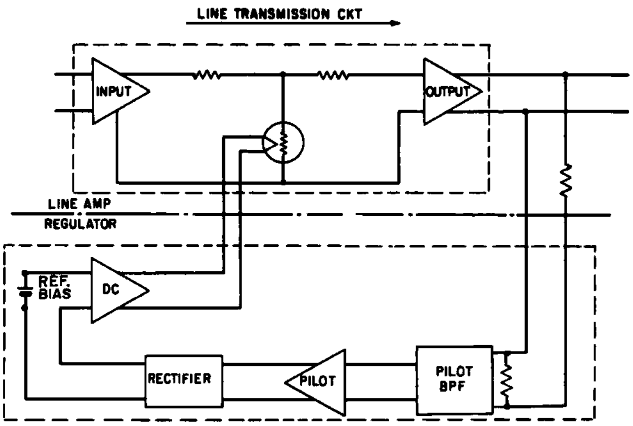


Fig. 24 — Pilot-Controlled Regulator at Auxiliary Repeater — Block Diagram

3.12 The several pilot regulators are similar in circuit detail, with each basically consisting of a pilot frequency input filter, a pilot frequency amplifier, a rectifier, and a dc amplifier. The regulators provide a dc signal to a meter for indicating pilot level and a dc signal to control a pilot alarm unit. The indicators and alarms are discussed in Part 4.

3.13 The 7266-kc pilot frequency at the transmission output is —16 dbm, and when the 16.3-db L pad is added at the auxiliary repeater, the auxiliary regulator input is −32.3 dbm. At other repeaters the 7266-kc pilot level in the transmission circuit is −14.6 dbm which, when attenuated 1.4 db, results in the same −16 dbm at the transmission output of the hybrid to the interconnecting circuits. The −14.6 dbm level is attenuated 6 db in the hybrid to the pilot frequency line to give −20.6 dbm and, when further attenuated 11 db, results in a 7266-kc regulator input of −31.6 dbm. The 8320-kc pilot

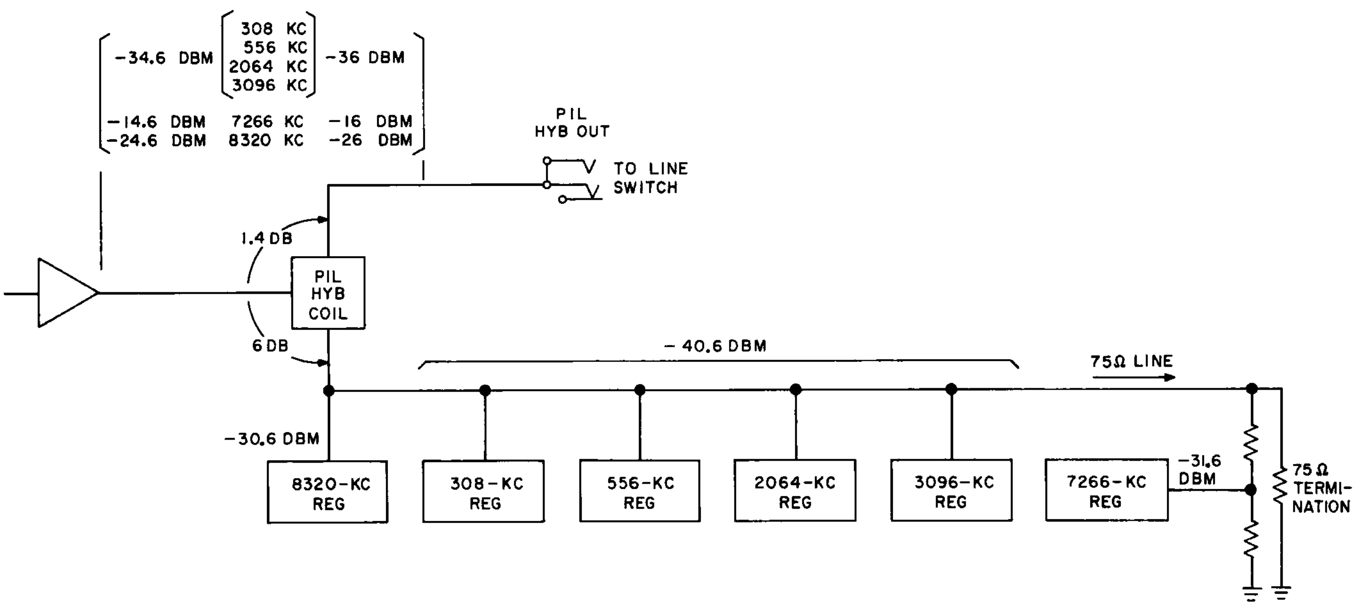


Fig. 25 — Connection of Regulators at Pilot Hybrid for Through Transmission

frequency at the transmission input to the hybrid is −24.6 dbm and when attenuated by the hybrid is −30.6 dbm at the 8320-kc regulator input. All other pilot frequencies are −34.6 dbm at the hybrid input and, when attenuated the 6 db, are each −40.6 dbm at the regulator inputs.

3.14 The transmission signal applied to each regulator is passed through a highly selective crystal filter, which rejects all signals except the particular pilot signal required so that only the selected pilot can control the operation of the regulator.

3.15 The auxiliary pilot frequency amplifier provides a voltage gain of approximately 90 db at the 7266-kc pilot frequency. The 7266-kc and 8320-kc pilot amplifiers each produce 85-db voltage gain, and all other pilot amplifiers each have 95-db gain. The pilot amplifier uses three tuned-rf stages with a gain of 110 to 120 db. A T network feedback circuit is employed with a loss of about 90 db which results in feedback of 20 to 30 db. The feedback circuit employs resonant and antiresonant circuits that are tuned to the pilot frequency. At other frequencies the loss and phase compensate for the performance of the tuned circuits in the interstages, so that adequate phase margins can be maintained around the feedback loop and the amplifier will be stable. To further prevent high-frequency oscillation, inductors are placed in the control grid of each amplifier tube. Tubes in the amplifier have large bypassed cathode resistors which place the cathode at +13 volts to ground with a normal plate current of 10 ma. Grids are returned to a regulated +11 volt bias source, so that the net grid-cathode voltage is −2 volts. This arrangement places local dc feedback on each tube which stabilizes plate current and therefore mutual conductance.

3.16 Fig. 26 shows the general configuration of pilot amplifiers used. The GAIN ADJ control is a variable capacitor in the feedback path. Test leads indicated are brought to a test plug on the amplifier case, thus permitting measurement of bias and bias activity of tubes on an in-service basis as a means of checking their condition. Measurements are made using a 1AL power test set described in Section 103-451-100.

3.17 The third interstage network between V3 of the amplifier and the V4 diode is essentially an impedance transformer designed to step up the plate signal voltage to be rectified while

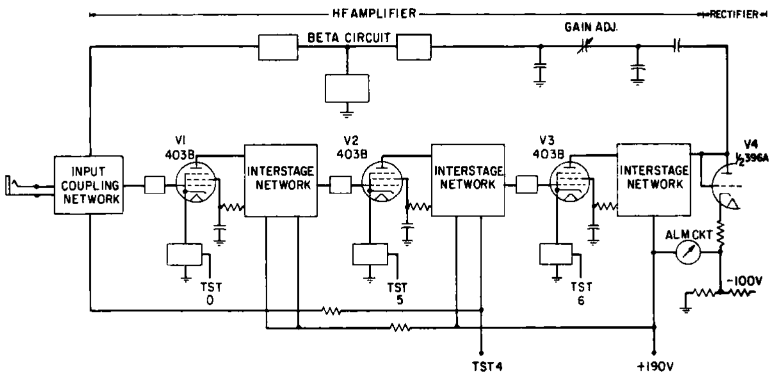


Fig. 26 — Pilot Amplifier — Simplified Schematic

presenting the correct load impedance to the plate. When the pilot is at its correct level, the rectified voltage in the auxiliary regulator will be +60 volts which, when added to the −62 volt fixed reference bias, will introduce the difference of −2 volts to the grid of the next stage. The dc amplifier of the auxiliary regulator (see Fig. 27) consists of two stages, V4B and V7. The second stage is normally biased to cutoff by the cathode circuit of V4A, and under these conditions the thermistor current is supplied entirely by V4 until the pilot level increases at the pilot amplifier output, causing the potential on the grids of V7 to decrease in magnitude below the cutoff value. When V7 begins to conduct, a sharp increase in thermistor current is produced to restore the pilot to normal. The thermistor current range of the auxiliary regulator is 1 to 20 ma. The meter in Fig. 27 is a microammeter relay equipped with high and low contacts and a moving coil which responds to changes in rectified pilot current. When the regulator reaches the limit of its range a further change in rectified current, which varies linearly with pilot, will cause the meter contacts to close and thus a pilot alarm to operate. If the pilot changes faster than the thermistor can react to control the gain of the pilot amplifier, the alarm relay will also operate.

3.18 Pilot regulators other than the auxiliary regulator produce a nominal rectified signal of +40 volts. The fixed reference bias is −44 volts and the differential applied to the dc amplifier is therefore −4 volts. These regulators provide a 1- to 40-ma current range for the thermistor. When the 7266-kc pilot is at the correct level, the thermistor current rests at 6 ma. When any other pilot signal is at its correct level, the thermistor current provided by its regulator will be 8.5 ma. As stated in 3.17, the auxiliary regulator has a 2-stage dc amplifier, V4B and V7. The 7266-kc regulator uses V6, V7, and V8. All other pilot regulators use V6, V7, V8, and V9.

3.19 The function of the dc amplifier in a regulator is to provide an output current for driving the thermistors in the equalizing networks. The magnitude of the variation in output current for a given incremental change at the amplifier input is consistent with the loss sensitivities of the individual equalizer networks and the amount of gain in the dc amplifier to achieve the desired loop feedback. Thus, to hold the pilot constant within a few tenths of a db over the regulation range of the device controlled by the

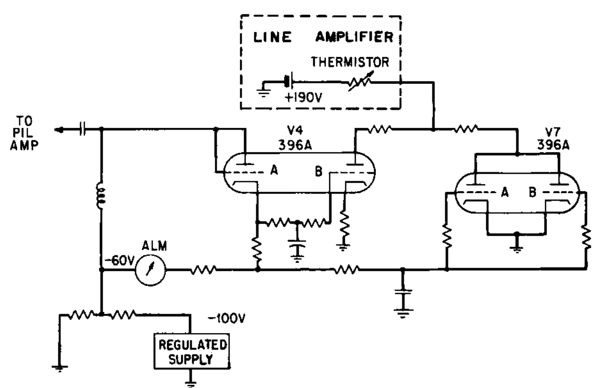


Fig. 27 — DC Circuit of Auxiliary Regulator

regulator, the dc amplifier output or thermistor current must change over its entire range for a few tenths of a db change in rectified voltage. The remaining regulators are used in lesser numbers than the auxiliary regulators and operate with more feedback in the regulating loop. The input-output characteristic in Fig. 28 for the "Other" regulators is somewhat steeper than that for the G regulator. The thermistors used in dynamic equalizers are less sensitive than those used in amplifiers, i.e., they require more current change than the others to cover their complete variable resistance range. The higher current range accounts for the difference between the curve for the "Other" regulators and the "A" regulator curve.

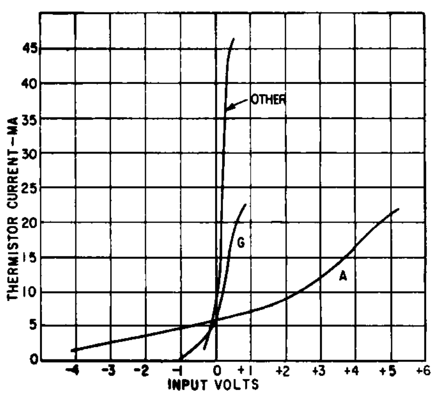


Fig. 28 — DC Amplifier Characteristics — Input Voltage and Output Current

3.20 The J68817G regulator operates to control gain of the line amplifiers used at main repeaters. Since better control of the 7266-kc pilot is required at main repeaters than at auxiliaries, the dc amplifier of the regulator at a main station has higher gain than that of a regulator at the auxiliary station. The regulator at a main station therefore provides greater feedback in the regulating loop than does the auxiliary regulator.

3.21 Fig. 29 shows the dc amplifier circuits of regulators used at equalizing auxiliary or main repeaters. Triode V4B in this circuit is a cathode follower used to obtain suitable impedance for connection of rectified output signal through a computer circuit to the following portion of the amplifier. The control of the thermistor current output of each of the regulators is not solely under control of the pilot input to that regulator; instead, each other regulator may control the output current of the first as required to secure correct operation of the first equalizers.

3.22 In Fig. 29 the plate of V4A triode, connected as a diode, and its cathode operate at 44 volts negative with respect to ground. This bias is from a regulated source. The value applied is adjusted by the GAIN control, mounted in the pilot indicator equipment to be near the meter which indicates the value of the pilot. Since the dc amplifier input is the difference between rectified pilot voltage and the nominal —44 volt reference, an adjustment of the GAIN potentiometer would produce a change in the difference signal for amplification just as though the pilot level had changed. The dc GAIN potentiometer permits a small adjustment of the bias voltage centered at approximately −44 volts from ground. Changing this voltage fed to the regulator is equivalent to adjusting the gain of the regulator, so that the GAIN control acts as an adjustment of the pilot.

3.23 The plate and cathode of the rectifier are at −44 volts with respect to ground with no pilot applied. With the normal value of pilot applied, a dc voltage of about 40 volts is generated across the cathode resistor of the rectifier which is in series with and opposite in polarity to the applied bias, thus setting the cathode of triode V4A and the grid of triode V4B at −4 volts with respect to ground. Triode V4B operates with its cathode connected to a —100 volt supply circuit through a large cathode resistor; its operating point is such as to make the grid-cathode voltage −4 volts. The cathode resistor drop is therefore 100 volts, and the cathode is at ground potential.

3.24 The COMP 1 lead connects the cathode of triode V4B to the computer. The computer is shown (see Fig. 29) as a simple voltage divider without connection of signals from other regulators merely to indicate that the output signal of triode V4B is transmitted to the computer, where it is reduced by a given ratio and then connected to the grid of triode V6A. Since the cathode of triode V4B is at zero volts to ground, no signal voltage is applied to the grid of triode V6A.

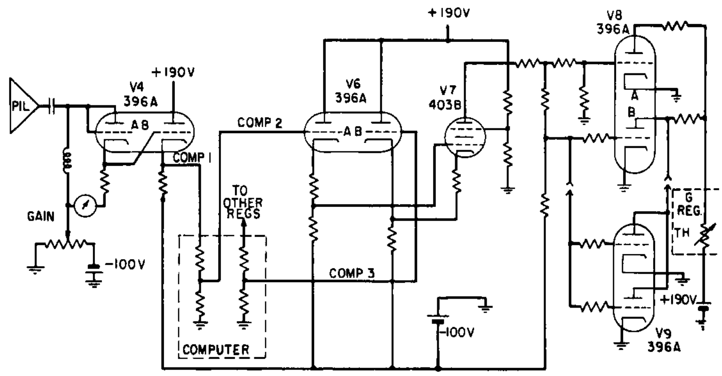


Fig. 29 — DC Circuits of Regulators Used at Equalizing Repeaters

Triode V6A, the cathode of which is returned to the −100 volt supply, therefore generates a cathode-voltage drop of about −104 volts with respect to ground, so that the tube operates with approximately −4 volts grid bias. Under normal conditions of pilot, signal voltage applied to the grid of triode V6B through the computer is also zero, so that triode V6B operates similarly to triode V6A. The cathodes of triodes V6A and V6B are connected respectively to the grid and cathode of tube V7.

3.25 Tube V7 amplifies any applied signal and under normal pilot conditions applies sufficient bias to the grid of triode V8A, which passes the major portion of the normal thermistor current of 6 ma (see Fig. 29) for the G regulator. Triode V8B passes a portion of this current. Tube V9, added in regulators other than the J68817G, passes enough plate current to raise the normal current to about 8.5 ma as indicated by the curve "Other" regulators in Fig. 28.

D. Control of Dynamic Networks through Computer

3.26 The computer translates pilot errors into shape errors and drives the appropriate regulating networks by a process equivalent to the solution of simultaneous equations. All pilot-regulating networks correct in a coordinated manner to produce no gain change at any pilot frequency except the one originally disturbed, thus preventing interaction between the broad equalization shapes. The computer, shown in Fig. 30, consists of a resistance network which divides the detector output voltage from one pilot regulator and applies the resultant voltages to several pilot-regulator dc amplifier inputs, but affects only one pilot. Each dc amplifier has two input terminals. The voltage applied to one input terminal increases the magnitude of equalization. If assigned to the other input, the voltage decreases the magnitude of equalization.

3.27 A 3-pilot computer is placed at equalizing auxiliary and equalizing main repeater points. It is used to combine three rectified pilots (3096, 2064, and 7266 kc) which provide coarse regulation for rapid temperature, aging, and line level changes by driving thermistors in equalizers A1 and A2 and the regulating network of the line amplifier, respectively. The 6-pilot computer is placed at switching main and terminal repeater points and combines, in conjunction with the above three, three additional rectified pilots (556, 308, and 8320 kc) which provide fine regulation for rapid temperature, aging, and line level changes respectively in a similar manner by controlling equalizers B1 and B2. Equalizer B2 contains two dynamic equalizing networks.

3.28 If the dc amplifiers were coupled directly to the detector outputs of the regulators associated with these pilot frequencies, each time the system changed gain, in accordance with one or more of the shapes, a gain transient would be set up in the system because the equalizers would interact with one another before reaching a point of equilibrium coincident with correct equalization. With the use of a computer, no gain transients are initiated because each of the networks is driven only once in the proper proportion to the system change and no interaction occurs between the shapes.

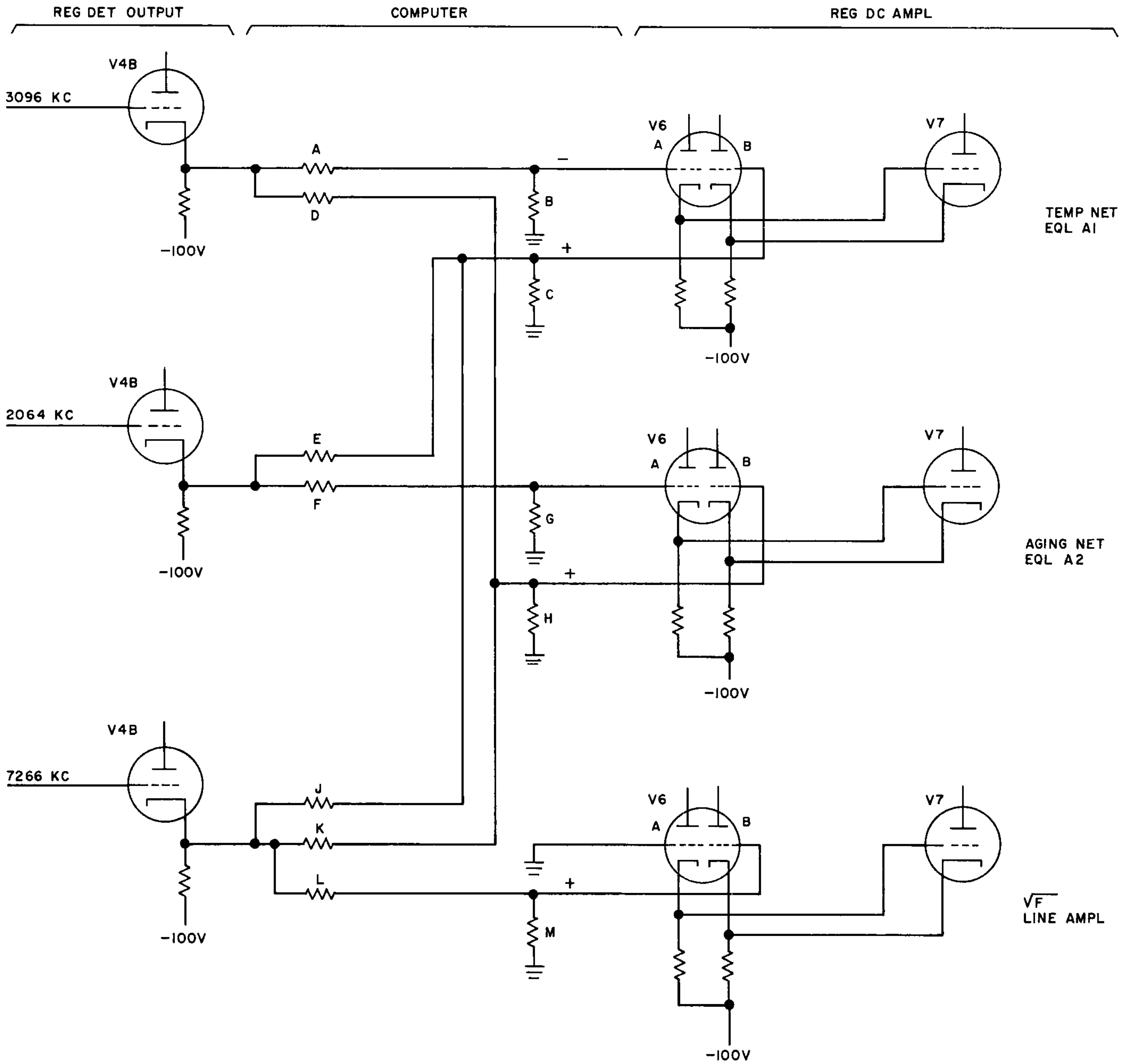


Fig. 30 — Three-Pilot Computer Circuit Connected to Regulators

3.29 The 3-pilot computer is shown in Fig. 30. Detector output of each pilot regulator (V4B) is applied through the computer network to the regulator dc amplifier inputs (V6A and V6B). The dc amplifiers drive their respective equalizer networks. Consideration of a specific example may assist in understanding the control system. Assume that the electron tubes in the amplifiers in a line section have aged, thus inserting in the line an equalization deviation of the shape of the aging curve shown in Fig. 7. To correct for this, a change is needed in the loss of the aging network. Such a change would affect both 3096- and 2064-kc pilots, however. Assuming further that the original change caused a decrease in the 3096- and 2064-kc pilots, the potentials across resistors B and H (see Fig. 30) delivered by the 3096-kc detector V4B would be negative. Similarly, the potentials across C and G, delivered by the 2064-kc detector V4B, would also be negative. Since the aging shape has no loss at 7266 kc, the potentials across the resistors C and H, delivered by the 7266-kc detector V4B, would be zero. The values of resistors A, B, E, and C are so selected that the potentials across resistors B and C will be equal both in sign and magnitude, so that the thermistor in the temperature equalizer will not be driven. The values of resistors D, F, G, and H are so selected that the combined negative potential from the 3096- and 2064-kc detectors is such that the aging equalizer is driven by the proper amount and direction to compensate for the presumed system change. The 3096-kc detector output voltage might initially appear to be coupled through resistors D, K, and L to the dc amplifier in the 7266-kc regulator. Although a resistance path does exist, the voltage presented to the 7266-kc dc amplifier is negligible due to the cascade of voltage dividers in the path. The first division occurs between resistors D and H, is further divided between resistor K and the 7266-kc detector impedance, and still further divided between resistors L and M. Therefore, it should be noted that the conductance to ground from the dc amplifier grids also determines the ratio of the detector output fed to the dc amplifier.

3.30 Table D outlines the change in thermistor current at the network for an ***increase*** in pilot level to the regulators listed. The plus (+) signs denote an increase in thermistor current, and a decreasing change is indicated by a minus (−) sign. It should be noted that an increase of the 7266-kc pilot level and the incidental increase of current through the thermistor in the line amplifier regulating network will produce a ***reduction*** in gain. As the 3096- or 2064-kc pilot levels increase and the thermistor currents increase at the equalizers for temperature or aging networks respectively, an ***increase*** of loss will be produced over most of the band. In each case, the effect upon the transmission signal level will be the same because the ***reduction*** in the gain of an amplifier is equivalent to ***increase*** in the loss of an equalizer network.

3.31 The 6-pilot computer functions in the same manner as the 3-pilot system. The principal difference is that in the employment of three additional regulators and equalizer networks to provide a finer degree of dynamic equalization, the number of computer inputs, outputs, and resistors is increased accordingly. Approximately n^2 resistors are used for n regulators. Fig. 31 shows the 6-pilot computer circuit. Table E outlines the change in thermistor current for an ***increase*** in pilot level.

TABLE D

CONTROL OF DYNAMIC NETWORKS THROUGH 3-PILOT COMPUTER

(See 3.30)

REGULATORS		CHANGE IN THERMISTOR CONTROL CIRCUIT						
PILOT	NET. CONTROL ASSIGNMENT	PILOT CHANGE	LINE AMPLIFICATION		TEMPERATURE NET.		AGING NET.	
			COARSE	FINE	COARSE	FINE	COARSE	FINE
3096 kc	Coarse Temp	+	0		−		+	
2064 kc	Coarse Aging	+	0		+		−	
7266 kc	Coarse Line	+	+		+		+	

TABLE E

CONTROL OF DYNAMIC NETWORKS THROUGH 6-PILOT COMPUTER

(See 3.30 and 3.31)

REGULATORS		CHANGE IN THERMISTOR CONTROL CURRENT						
PILOT	NET. CONTROL ASSIGNMENT	PILOT CHANGE	LINE AMPLIFICATION		TEMPERATURE NET.		AGING NET.	
			COARSE	FINE	COARSE	FINE	COARSE	FINE
3096 kc	Coarse Temp	+	0	—	—	—	+	—
2064 kc	Coarse Aging	+	0	—	+	+	—	+
7266 kc	Coarse Line	+	+	+	+	—	+	—
556 kc	Fine Temp	+	0	+	—	—	+	+
308 kc	Fine Aging	+	0	—	+	+	—	—
8320 kc	Fine Line	+	0	—	0	0	0	0

4. PILOT ALARM AND PILOT INDICATOR CIRCUITS

4.01 As mentioned in 3.19, the dc output current of pilot regulators follows the variation of pilot level at the point of bridging of regulators on the line. At auxiliary repeaters equipped with pilot regulators and equalizing auxiliary repeaters, alarm relays having high and low contacts are used to indicate departure of pilots from normal, with provision for transmitting an alarm indication to an associated main repeater. This alarm indication from auxiliary repeaters may be either over one alarm pair for both directions of transmission or over two alarm pairs, in which case one is used for each direction of transmission. At main repeaters, similar alarm relays are used where they operate office alarm circuits directly, initiate operation of a line switch, or give alarms indirectly through the switching circuit. Operation of the switching circuit and the resulting alarms is not covered herein but is discussed in Section 359-010-125. Indicating meters are connected in series with the alarm relays at main repeaters, and both are mounted on panels designated PIL IND (pilot indicator).

A. Auxiliary Repeaters

4.02 At auxiliary repeaters with pilot regulators, two types of repeaters and pilot alarm units are available. One alarm unit is intended for use with a single alarm pair, while the other type, having the same external appearance and other features, is arranged for two alarm pairs, one for each direction of transmission. The two types are not interchangeable. Fig. 32 is representative of the front panel of either pilot alarm unit.

4.03 Fig. 33 shows the circuit of the pilot alarm unit used with one alarm pair for both directions of transmission. A circuit of the alarm unit arranged for two alarm pairs is shown in Fig. 34. Both figures include the rectifier circuit of the ODD and EVEN pilot regulators with which a pilot alarm unit is associated. Rectified 7266-kc pilot flows through the moving coils of the ODD and EVEN microammeter relays, which deflect to midscale with a rectified current of about 300 microamperes which is reduced to 30 microamperes in the relay windings by the PIL ADJ potentiometers. Regulators are ad-

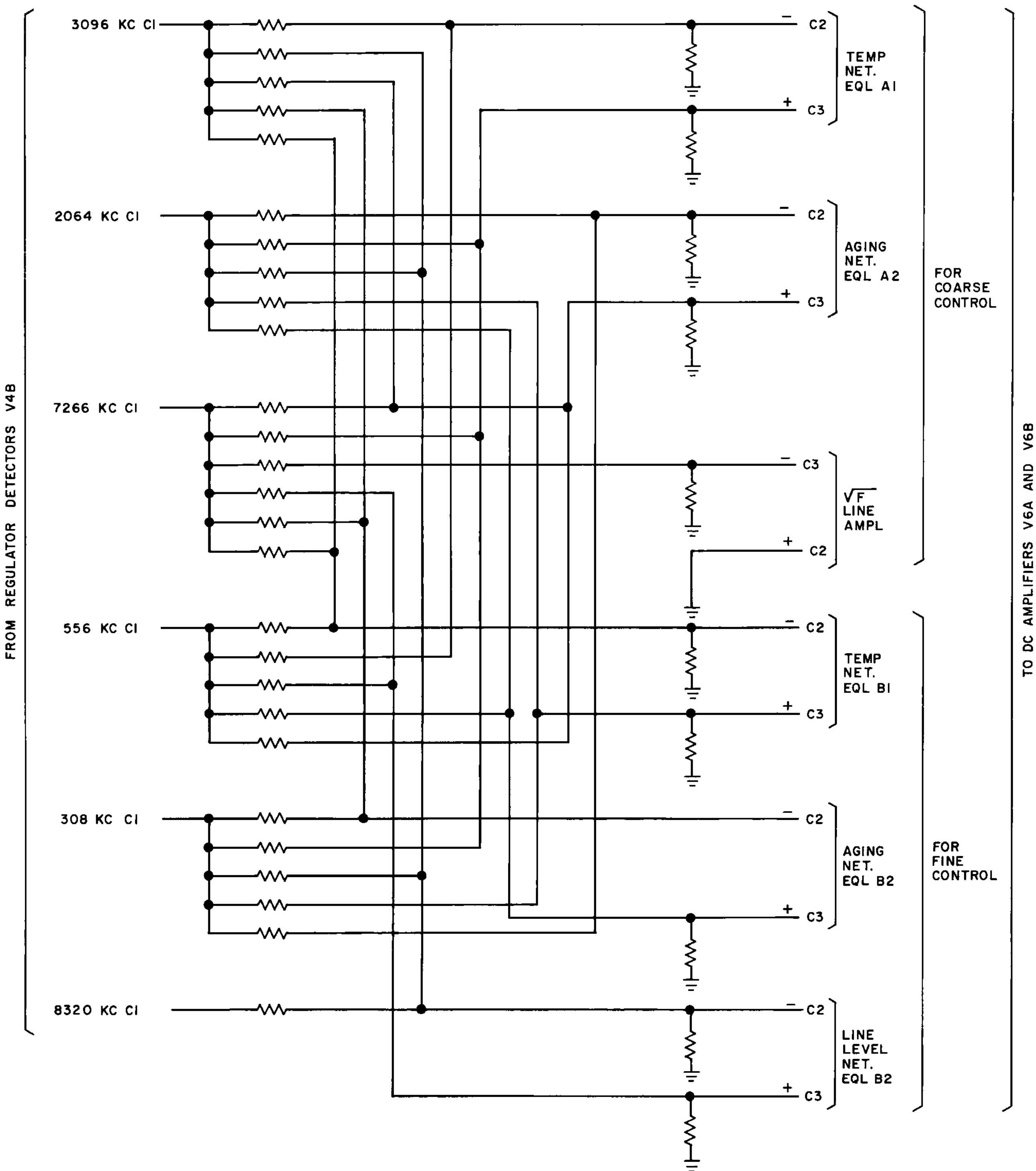


Fig. 31 — Six-Pilot Computer Circuit

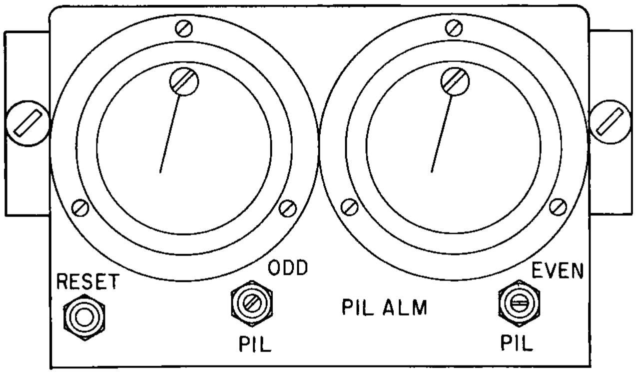


Fig. 32 — Pilot Alarm Unit — Auxiliary Repeater

justed at maintenance centers so that 300 microamperes is the rectified current obtained with normal pilot level at the input to the regulator. When the end of the regulation range of the line amplifier is exceeded by ±3 db, the pilot is no longer regulated and the alarm relay contacts will close. Also, when the pilot departs from normal by more than ±3 db at such a rate that the regulator cannot correct for it and the period is sufficient to allow operation of the alarm relays, the contacts close. This closure of contacts bridges a relay across an alarm pair, thereby operating alarm circuits at a main repeater.

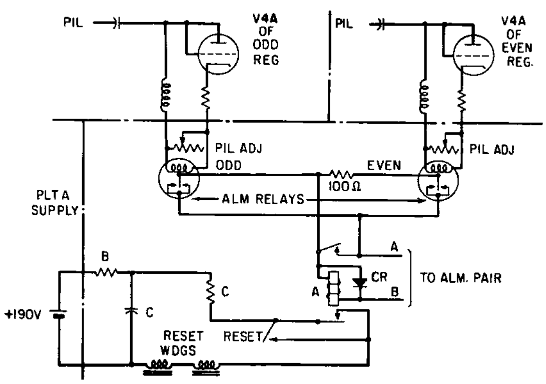


Fig. 33 — Circuit of Auxiliary Pilot Alarm Unit for Use with a Single Alarm Pair

4.04 With one alarm pair at an auxiliary repeater, the functioning of the pilot alarm unit is as follows. Referring to Fig. 33, if only the EVEN alarm relay operates, the A relay is bridged across the pair in series with a 100-ohm resistor. If only the ODD relay is operated, or both are operated, the A relay is bridged directly. Therefore, a bridge location measurement can be made using a current in the alarm pair that is less than the operate current of the A relay. A second measurement can then be made at a current which will operate the A relay. With the A relay operated, the alarm relay contacts are short-circuited, thus removing the 100-ohm resistor if in the circuit originally. The first measurement will locate the repeater causing the alarm, while the second measurement will indicate whether or not the 100-ohm resistor was in the circuit. This will indicate the direction of transmission which caused the alarm. The ambiguity which results when both the ODD and EVEN alarm relays are operated usually must be resolved by some other means. Auxiliary repeaters, using pilot alarm units arranged for ***two alarm pairs***, function as follows. As shown in Fig. 34, if the ODD alarm relay contacts close, the A relay is bridged across the alarm pair for the ODD direction of transmission. Similarly, operation of the EVEN alarm relay will bridge the B relay across the pair associated with the EVEN direction of transmission. In either case, this will cause an alarm indication at a main repeater. With two alarm pairs, the 100-ohm resistor which was used to indicate the direction of transmission causing an alarm is no longer required. If a low-current bridge measurement is made on the appropriate alarm pair, the location of the defective repeater can then be readily determined. The circuit used for locating auxiliary alarms is known as the pilot alarm location circuit.

4.05 When alarm pair protectors at auxiliary repeaters are leaky, the bridge balance may be affected by leakage to ground so that balance occurs at a different resistance when high and low currents are used, even though the resistance of the pair is constant. A deflection from balance at low current may also occur from an increase in bridge sensitivity as current is increased. This may obscure the fact that the 100-ohm difference between measurements existed for pilot alarm units on a single pilot alarm pair.

4.06 When several repeaters are alarmed, thus bridging several A (or B) relays across a pilot alarm pair, it is essential that the operate current quoted in maintenance sections not be

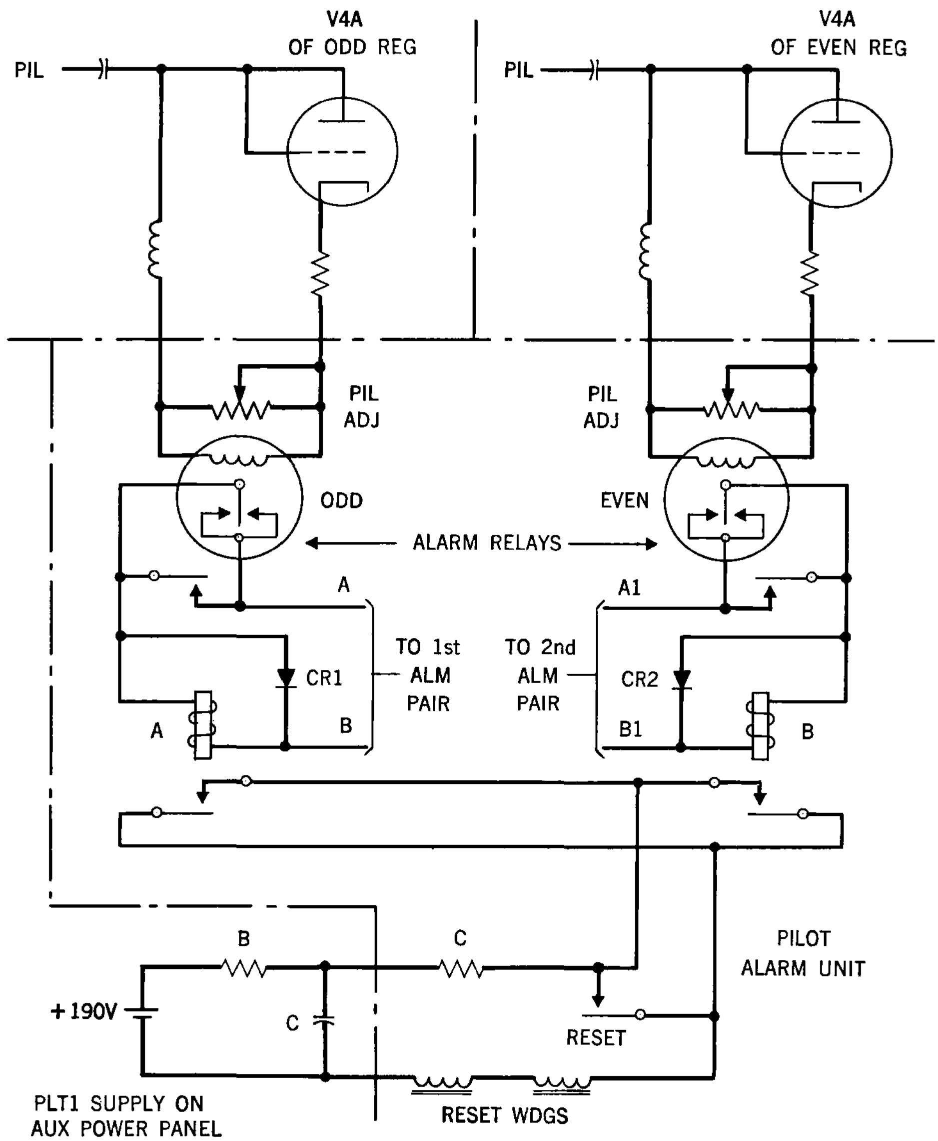


Fig. 34 — Circuit of Auxiliary Pilot Alarm Unit for Use with Two Alarm Pairs

exceeded in order to avoid operation of more than one A (or B) relay at a time. The second operated relay from a main repeater is bridged across the first one in series with a section of cable pair. The resistance of this combination must be high enough to reduce the current through the second operated relay to less than the operate current when the first relay is receiving operate current. When one or more thermometer regulators not equipped with alarm features are used between adjacent pilot regulators, the resistance of the added sections of an alarm pair, in series with the second bridged relay, reduces the probability of inadvertently resetting more than one alarm unit at a time.

4.07 When an A (or B) relay operates, it also closes the circuit through the resetting solenoids of the alarm relays. For simplicity, these solenoids are shown separated from the relays in Fig. 33 and 34. Since resetting opens the operated contacts of the alarm relays, the upper contact of an A (or B) relay closes the circuit to maintain a closed path for measurement. The source of energy for resetting is a large electrolytic capacitor that is charged slowly through resistor B, which is used to limit the current taken from the PLT 1 supply. Resistor C limits the surge current through the alarm relay contacts so as to provide sufficient time for resetting and to prevent too violent action of the mechanism.

4.08 At a main repeater, alarm battery is applied to a pilot alarm pair, with the positive side connected to lead A or A1. When an alarm relay contact closes, the capacity of the pilot alarm pair, which is charged to 130 volts, discharges through the diode connected across the winding of an A (or B) relay instead of through the relay winding. This prevents immediate operation of an A (or B) relay and clearing of the operated alarm relay, thereby providing a continued alarm on very short failures of pilot. Bridge battery for measurement is applied to the pair in opposite polarity to that of the alarm battery. The impedance of the diode is high in order to bridge battery voltage so that it does not interfere with measurement or operation of an A (or B) relay when desired.

4.09 The manual RESET key is used during maintenance routines when resetting of the alarm relays is required. It may also serve as a check that the electrolytic capacitor has sufficient capacity to operate the resetting solenoids. For pilot alarm units on a single alarm pair, the RESET key may also be used to discharge the capacitor after removal of the unit from service, thus avoiding shock which might result from a charged capacitor.

B. Equalizing Auxiliary Repeaters

4.10 The pilot alarm relays and associated items used at equalizing auxiliary repeaters are mounted in two panels. The front view of one panel is shown in Fig. 35. The second is similar, except for the omission of the RESET key. The RESET key on one panel resets all operated relays associated with the ODD and EVEN directions of transmission in one repeater.

4.11 Fig. 36 shows the alarm circuit associated with one pilot regulator at the switching or terminal main repeaters. This circuit is the same as that used at equalizing auxiliary repeaters except that no indicating meter is used at the latter. Five other similar circuits are used, operating in conjunction with the 3096-, 2064-, and 7266-kc regulators for each direction of transmission. Using two panels, the relays for each direction of transmission can be mounted in the bay for each direction.

4.12 The equalizing auxiliary alarm circuit differs from that used at the auxiliary repeater (see Fig. 33 and 34) only in that an additional control designated GAIN is used (see Fig. 36). This control is a potentiometer which permits variation of the nominal 44-volt reference potential applied to the rectifier in the associated regulator. As noted in 3.22, adjustment of this voltage is equivalent to making a change in the pilot-frequency gain of the regulator, since the dc amplifier of the regulator recognizes only the difference between the rectified pilot voltage and the dc biasing voltage. The GAIN control may therefore be mounted adjacent to the meter which is observed while making adjustments.

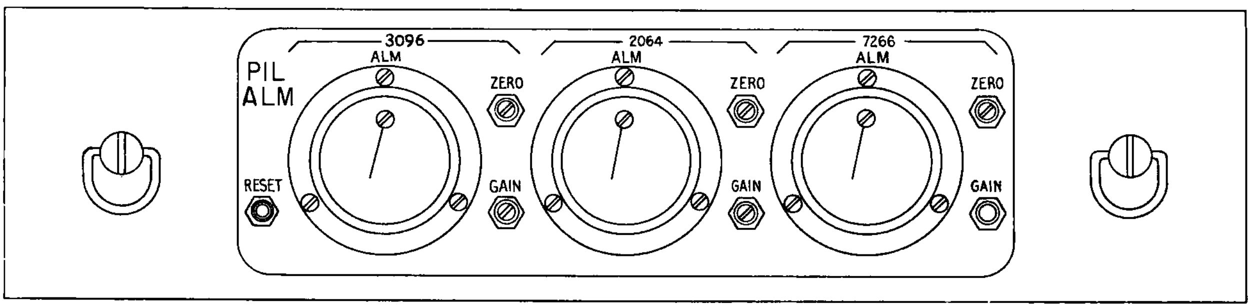


Fig. 35 — Pilot Alarm Unit — Equalizing Auxiliary Repeater

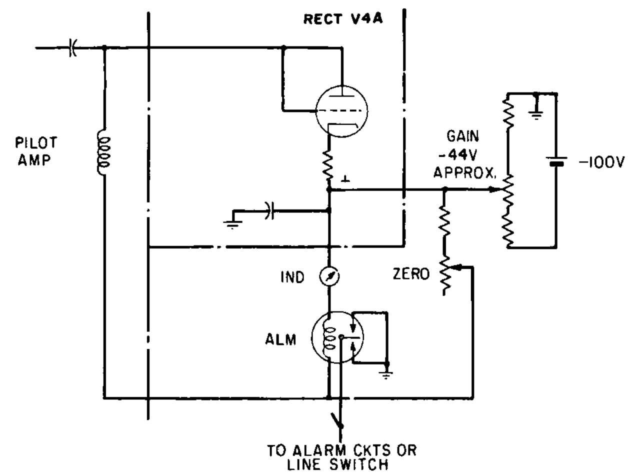


Fig. 36 — Alarm Circuit Used at a Switching or Terminal Main Repeater

4.13 The ZERO control adjusts the current flowing through the ALM relay and the IND meter. This is used to make both readings indicate 0 after the GAIN control has been adjusted to obtain the correct value of pilot as indicated by a standard reference of calibration.

4.14 The contacts of the six ALM relays used are connected in parallel. One A relay is used for clearing all six alarm relays. The circuit involving the alarm relay contacts is shown in Fig. 33 for the auxiliary pilot alarm unit.

C. Main Repeaters

4.15 The individual alarm circuit associated with each regulator at main repeaters (see Fig. 36) includes an indicating meter in series with each alarm relay. The same mounting panel, designated PIL IND, is used at each type of main repeater. When used at a switching or terminal main repeater where six regulators are used for each receiving circuit, the panel is equipped as shown in Fig. 37. The indicating meter for each frequency is mounted above its associated alarm relay, with the ZERO and GAIN controls mounted above the meter. Meters and relays are mounted in order of rising pilot frequency across the panel. The wiring side of the panel may be exposed by removing the two screws which appear between each end pair of meters and then pulling the top of the panel, which is hinged at the bottom, away from the relay rack.

4.16 At switching or terminal main repeaters, the contacts of all alarm relays in one panel are wired in parallel and are connected to the line switching circuit. The line switching circuit gives all alarms to indicate irregularities in pilot power. The ALM lamp on the panel lights on operation of any alarm relay contact. The RST (reset) key energizes the resetting circuits of the ALM relays from 24-volt office battery. The line switching circuit in normal operation resets the operated alarm relays periodically

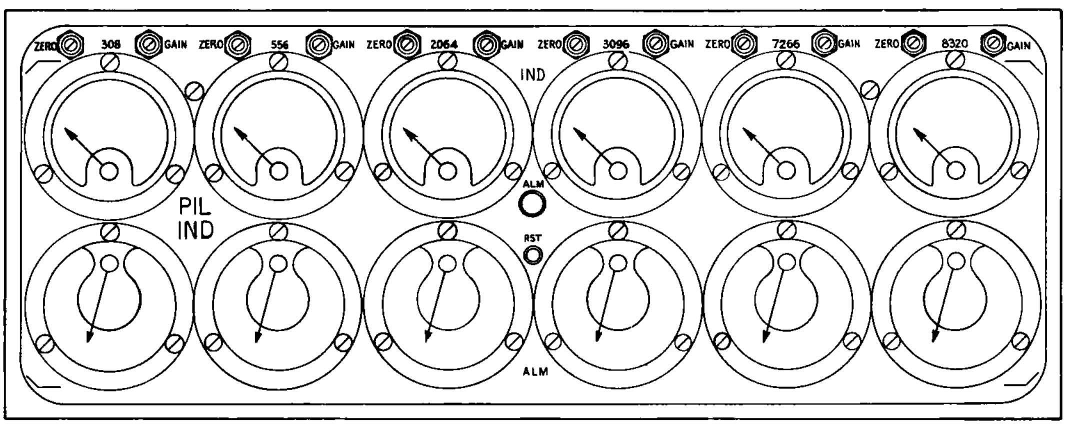


Fig. 37 — Pilot Indicator Unit — Switching or Terminal Main Repeaters

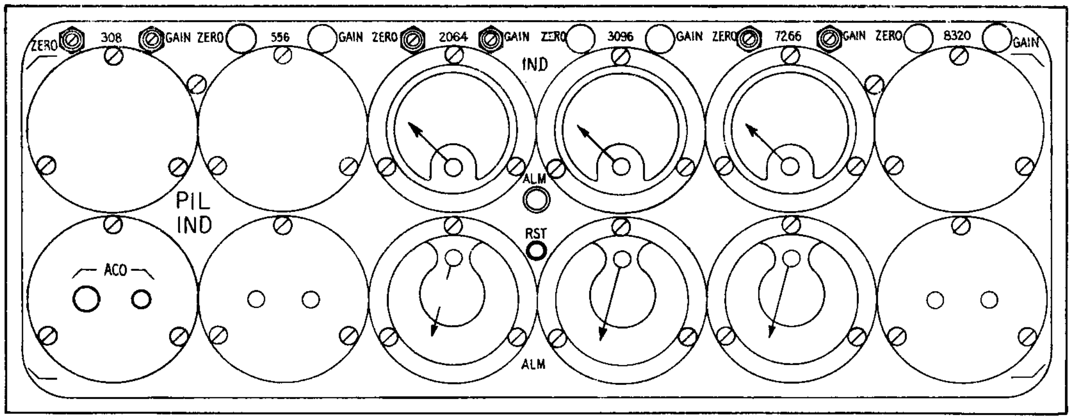


Fig. 38 — Pilot Indicator Unit — Equalizing Main Repeaters

after certain operations of the switch, as described in Section 359-010-125 covering line switching.

4.17 The PIL ALM panel, equipped for use at equalizing main repeaters where only three regulators (3096, 2064, and 7266 kc) are used, is shown in Fig. 38. The meters and relays for the regulators not used are simply omitted, and the holes are covered with flat plates. Contacts of the alarm relays used are connected in parallel so as to energize a U-type relay whose contacts close office alarm circuits. The relay is mounted in a bracket, which is in turn mounted on the cover plate over the opening provided for the 8320-kc ALM relay.

4.18 When the equalizing main repeater is equipped for control by means of the B1 alarm and control system, a second relay for operation by the control system is mounted in the cover over the opening for the 556-kc alarm relay. This relay operates to reset operated pilot alarm relays.

4.19 The ACO (alarm cutoff) key is provided at the equalizing main repeater to cut off the local alarms. The ACO lamp is a guard lamp which indicates when the ACO key is operated. The key and lamp are mounted on the cover plate over the opening provided for the 308-kc alarm relay.

5. DRAWINGS (NOT ATTACHED)

5.01 Section 359-010-116 lists applicable drawings.