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SUBMERGED TELEGRAPH REPEATERS
CURRENT DEVELOPMENTS AND APPLICATIONS

by

C. H. CRAMER and P. H. WELLS

THE RADIO CLUB OF AMERICA

11 West 42nd Street ★ ★ ★ New York City

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SUBMERGED TELEGRAPH REPEATERS - CURRENT DEVELOPMENTS AND APPLICATIONS

By
C. H. CRAMER and P. H. WELLS*

Presented before the Radio Club on February 21, 1952

In September 1950 the first submerged d-c telegraph repeater was installed in a transatlantic cable, the 1PZ cable of The Western Union Telegraph Company, terminating at Penzance, England and Bay Roberts, Newfoundland.[1] That installation, 170 nautical miles from the coast of Newfoundland in a depth of 270 fathoms, was essentially experimental in nature, providing the initial field test in a development program begun about two years previously. The substantial improvement in signal transmission indicated by theoretical and laboratory studies was fully realized in practice. The previous maximum operating speed of the cable, 50 words per minute, was increased to more than 150 words per minute by use of the repeater. This successful demonstration led to plans for further development of the repeater and its extensive application in the North Atlantic cable system of Western Union.

After about four months on the bottom of the ocean, the 1PZ repeater was successfully recovered and returned to the laboratory. The gradual deterioration in performance which had taken place during that period was discovered upon inspection to have resulted from loss of resistance in several of the component resistors. A change in type of resistor and other modifications were found desirable following the experience accumulated up to that point. After incorporation of the more important of the indicated improvements, the repeater was reinstalled on July 5, 1951, and it has had a uniformly excellent performance record since that time.

A second repeater, involving further changes in electrical and mechanical design, was installed in October, 1951, about 100 nautical miles off Long Island, in a cable extending from Bay Roberts, Newfoundland to Rockaway Beach, New York. The operating speed was increased from the previous 83 words per minute to an interim speed of 155 words per minute. Tests point to a probable ultimate speed of 300 words per minute on this cable when suitable terminal operating equipment is available.

Seven additional repeaters, following the design of the second model, are scheduled for installation in 1952. Of these, six will be installed in transatlantic cable sections connecting Newfoundland and the British Isles. The seventh will be inserted in a Nova Scotia-Rockaway Beach cable. It is anticipated that the coming installations will provide speed increases of the same proportions as those already obtained, with ultimate speeds in several instances of 300 words per minute or more.

SUBMARINE CABLE TRANSMISSION

Within the past two decades electronic signal-shaping amplifiers have come into general use at the receiving terminals of the principal transatlantic cable systems. Previously the maximum satisfactory operating speeds of these cables were determined in considerable part by the limitations of the electro-mechanical types of receiving equipment then in use. These terminal limitations were effectively overcome by reason of the greater gain provided by modern vacuum tube amplifiers in combination with more efficient signal-shaping or equalization networks. The signal-noise ratio is the ultimate transmission limitation on any communication circuit. By and large, the cable system is now close to that limit. For stable operation the noise or disturbance at the receiving terminal of a cable should be at least 20 decibels below the received signal level. This requirement, together with the sending level and the cable attenuation, determines the maximum operating speed.

Extraneous disturbances on cable circuits are in part man-made and in part of natural origin.

* The Western Union Telegraph Co.

[1] Submerged Repeaters for Long Submarine Telegraph Cables - C.H. Cramer - AIEE TRANSACTIONS, Vol. 70,1951. Western Union TECHNICAL REVIEW, Vol. 5, No. 3, 1951.

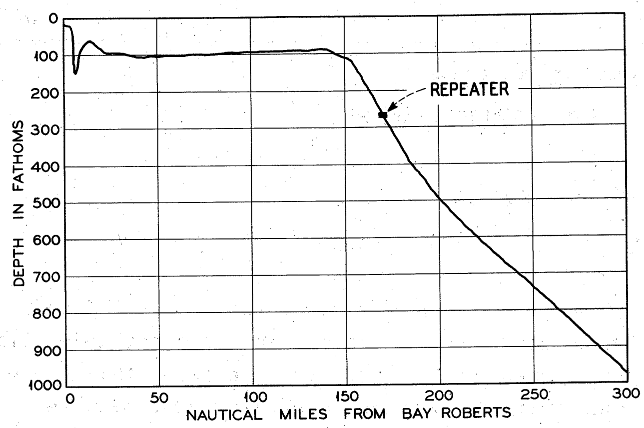


Fig. 1. Profile of Western End of 1PZ Cable

The man-made disturbances, arising from operation of other cables or other electrical systems, are usually susceptible to control and need not be considered further here, since corrective measures have been applied or are available. Natural or static disturbances, originating in the atmosphere, affect all cables in some degree. These disturbances are propagated downward through the seawater, undergoing attenuation which increases with frequency, as in the usual transmission medium. The total attenuation depends directly upon the depth of water. For all practical purposes, disturbances within the range of cable signaling frequencies may be regarded as completely attenuated in depths greater than about 300 fathoms. The transatlantic cable sections average about 2000 nautical miles in length. Of this, the center 1400 to 1700 miles are in depths greater than 300 fathoms and hence are completely shielded from natural disturbances. The two terminal end sections, in relatively shallow water, are 150 to 350 nautical miles long. Typical in that respect is 1PZ cable on which the original repeater installation was made. Figure 1 is a profile of the Newfoundland end of the route of 1PZ. All of the natural disturbance appearing at the receiving terminal is picked up in the adjacent shallow-water section of cable. The disturbance arising in the shallow water adjacent to the transmitting terminal is of no consequence because the signal level in that part of the circuit is 80 to 90 decibels above the disturbance level. Signals transmitted from the Penzance, England, end of the cable thus arrive at the edge of the shallow water, 170 nautical miles from Bay Roberts, attenuated to a very low level but free from disturbance. An amplifier inserted in the cable at that point increases the signal-noise ratio at Bay Roberts by the amount of the gain employed, and the operating speed of the cable can be raised until the minimum satisfactory signal-noise relation is again reached. In practice, a minor part of the available gain is utilized to provide greater signal-noise ratio at the increased speed, so that the complete result is a considerable improvement in circuit stability at a speed three times the previous speed.

ELECTRICAL CIRCUIT AND CHARACTERISTICS OF THE REPEATER

The repeater includes a 3-stage push-pull amplifier, signal-shaping elements and a switching device, the latest circuit being as shown in Figure 2. Western Electric 310-A Pentodes are used in all stages with two tubes in parallel and operated as triodes in each side of the output stage to provide adequate undistorted signal output level. The power requirements of the repeater, 0.32 ampere at 150 volts, are supplied from the receiving terminal station over the single cable conductor which serves also as the signal transmission medium. The impedance of the power supply circuit is thus relatively high, in some cases as much as 1200 ohms. This condition and the narrow frequency range available for discrimination between low-frequency signal components and power

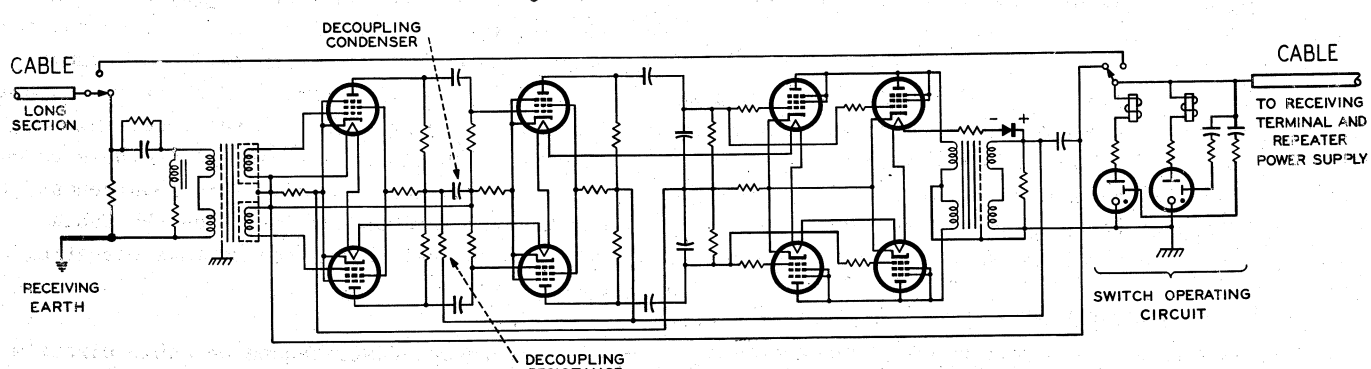


Fig. 2. Circuit of Repeater

supply are potential sources of amplifier instability. Measures taken to insure stability include decoupling as indicated in Figure 2 and a longitudinal feedback circuit obtained by coupling the cathode resistors of the first and third stages to correct for the effects of the outgoing signals upon the supply voltage. Uniformity of gain and other amplifier characteristics are obtained by careful selection and matching of tubes as discussed in a subsequent section of the paper.

The signal-shaping elements are a tuned circuit at the input of the repeater, an input transformer, and an output transformer circuit, which are the principal factors determining the frequency response characteristic of the repeater. The frequency response is related to the operating speed of the repeatered cable, and the network values must be carefully predetermined for each specific cable in accordance with the estimated optimum operating speed. Figure 3 shows a characteristic suitable for operation at a maximum speed of 167 words per minute corresponding to a signaling frequency of 21 cycles per second. It will be noted that the response peaks at approximately twice the signaling frequency. In the case of the 1PZ repeater, the gain at the peak frequency is about 70 decibels. The attenuation of 1PZ cable before and after installation of the repeater is given in Figure 4. Without repeater, the attenuation at 6.25 cycles (50 words per minute) is 71 decibels. At the signaling frequency of 21 cycles per second, the repeater reduces the overall attenuation from 117 decibels to 67 decibels.

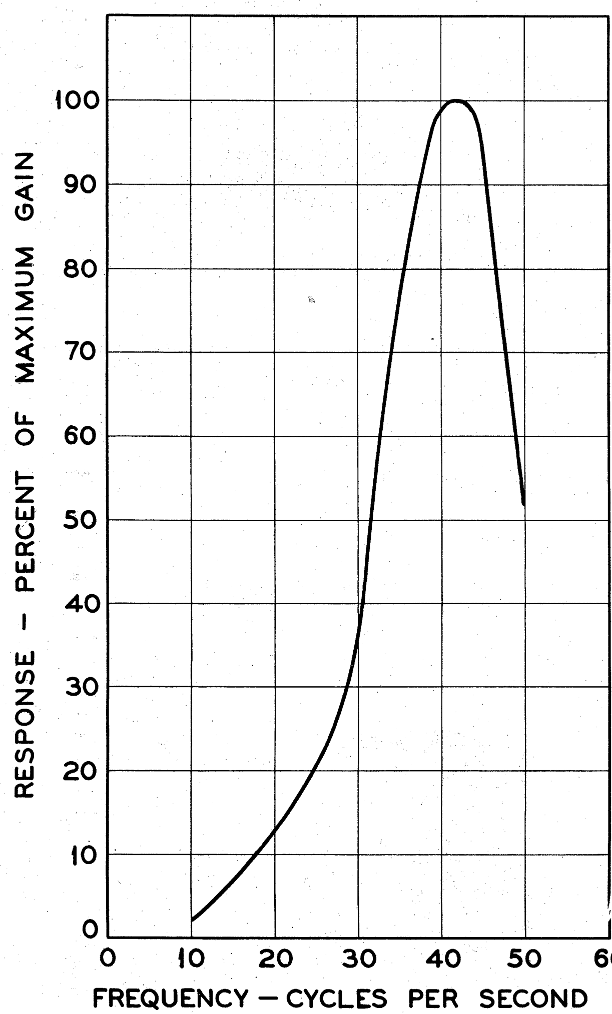


Fig. 3. Frequency-Response Characteristic of 1PZ Repeater

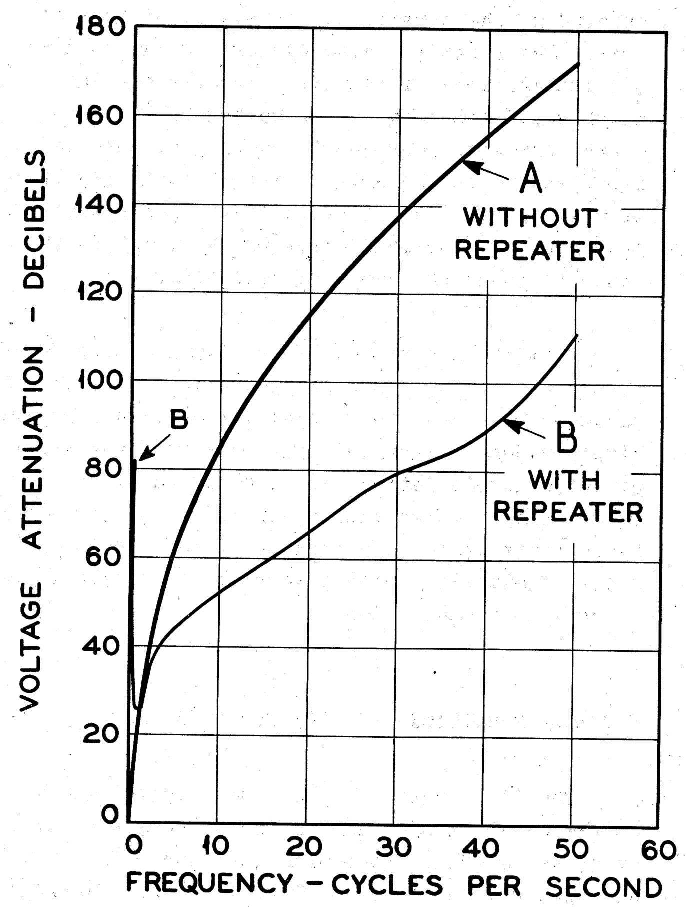


Fig. 4. Attenuation of 1PZ Cable

Each repeater is provided with a complete spare amplifier. The regular and spare amplifiers may be interchanged as required by the switch circuit indicated schematically in Figure 2. Other functions of the switch are to disconnect the repeater and join the cable through for operation without repeater or for cable testing and to connect into circuit test positions by which certain conditions at the repeater may be measured from the terminal. The rotary ratchet-stepped switch is operated by direct-current pulses transmitted from the receiving terminal. At the repeater the operating circuit of the switch, comprising a series arrangement of capacitors, cold cathode gas triodes and the switch windings, is permanently connected from cable to ground. The gas triodes are poled so that the switch is unaffected when the repeater is powered for normal operation. To operate the switch the repeater power is shut off and d-c pulses of about the same voltage and opposite polarity are applied to the cable at the terminal. A copper oxide rectifier provides high resistance in the heater supply circuit for the switching polarity so that the switch is not shunted by the normal low resistance of that circuit. The rectifier also avoids the numerous on-off applications of amplifier heater current which would otherwise occur during switching operations with consequent lowering of tube life. Experience with the switch circuit indicates that it will operate satisfactorily at any distance from the cable terminal over which it is practicable to power the repeater amplifiers.

From the standpoint of traffic handling, reversible operation is perhaps the most significant advantage derived from use of the switching system. With a repeater inserted near each end of a cable, direction of operation may be reversed at will in accordance with the flow of traffic. At times of cable interruptions particularly, the increased system flexibility with reversible operation is an important consideration.

PHYSICAL CONDITIONS AT REPEATER LOCATIONS

The first repeaters have been installed in depths of about 300 fathoms where the hydrostatic pressure is about 780 pounds per square inch. It now appears that factors other than shielding from natural disturbances will require installations in depths up to 2,000 fathoms or more, thus involving pressures greater than 5,000 psi. For example, a crossing or near parallel with another cable relatively close to the input side of the repeater may result in appreciable crossfire disturbance to the repeatered cable. In isolated instances such a situation may be avoided by relocation of cables. In the usual case, however, that solution is not practicable and it is desired that the repeater be so located that crossings and parallels are on the output side of the repeater, in some instances requiring installation in greater depths.

It is thus evident that hydrostatic pressure is a major factor in repeater design. Another factor of some importance is sea-bottom temperature. In deep water the sea-bottom temperature is fairly constant at about 36 degrees Fahrenheit. In lesser depths, particularly in areas affected by arctic currents, temperatures several degrees lower may be encountered.

THE REPEATER HOUSING

The oustanding requirement in the design of the housing is that it remain free of water leakage indefinitely under pressures up to 5,000 psi

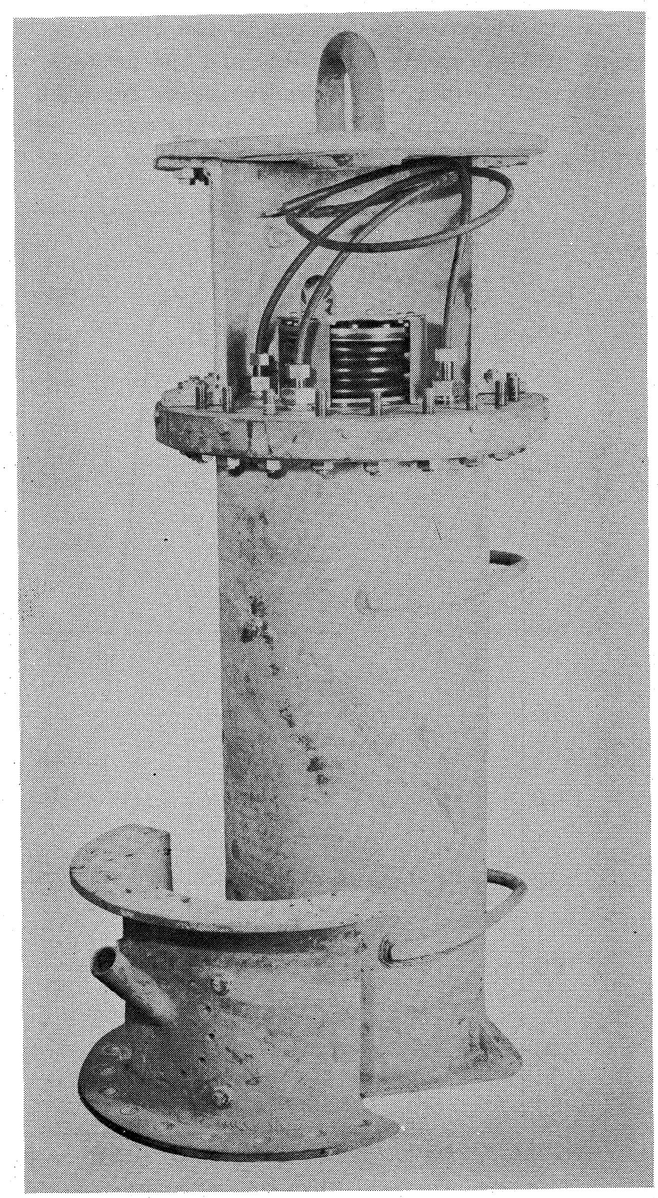


Fig. 5. Complete Repeater with Cable Entrance Chamber Open

or more. Early in the development it was decided to avoid the difficulties inherent in providing a structure of relatively large size with sufficient strength and adequate seals to withstand the external pressure while the interior remained at or near atmospheric pressure. In the method adopted, space within the housing not taken up by repeater elements is completely filled with oil and a pressure equalizer adjusts the internal pressure automatically to the external pressure. Elements of the repeater which cannot withstand the pressures encountered are sealed in subhousings which present considerably less difficulty in design because of the comparatively small sizes required.

A complete repeater, with one side of the top structure removed, is shown in Figure 5. The repeater proper is contained in the cylindrical bottom section of the housing which is constructed of cold rolled steel. The dimensions of the cylinder are: inside diameter, 13 inches; wall thickness, one-half inch; inside height, 34 inches. A cover plate is bolted to a flange welded to the top or open end of the cylinder and a gasket of synthetic rubber is used as a seal between cover plate and flange. The pressure equalizer consists of a bellows sealed to the outer side of the cover plate as shown in Figure 5, supplementing a second bellows sealed to the inner surface of the cover plate, Figure 6. A hole in the center of the

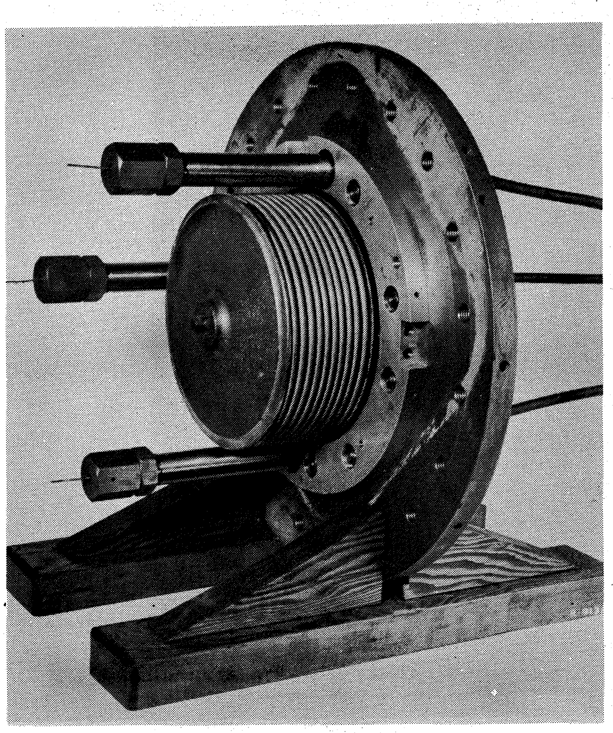


Fig. 6. Cover Plate with Cable Entrance Glands and Internal Pressure-Equalizing Bellows

cover plate connects the interiors of the two bellows which are also filled with oil. The internal bellows has thin walls to provide pressure sensitivity and is constructed of monel or stainless steel for protection against corrosion. The external bellows is of a molded synthetic rubber compatible with both oil and seawater. The rubber bellows is exposed to the medium surrounding the housing - air before installation, seawater after submersion - and transmits the pressure of that medium to the oil within the housing by way of the metal bellows. The sensitivity of the equalizer is such that the external-internal differential pressure is less than 10 pounds per square inch. The equalizer has sufficient capacity to allow for the compression under pressure of any small air or gas pockets resulting from the incomplete filling of the housing and to compensate for the relatively large volumetric temperature coefficient of the oil. A repeater may be subjected to a temperature change of as much as 50 degrees Fahrenheit between completion of construction and arrival at sea-bottom. To minimize the required capacity of the equalizer, use is made of solid filler material having volumetric temperature coefficient lower than oil. Residual pockets of air or vapor are reduced by evacuating the housing during the filling process and by use of oil having very low vapor pressure.

Two cable leads and an earth lead enter the housing through glands mounted in the cover plate, as shown in Figure 6. The monel metal parts of a gland and elements of a high pressure terminal used at the inner end of the gland are shown in Figure 7. In assemblying a gland a short piece of standard polyethylene cable core is used. A "pudding" of a polyethylene compound is formed near one end of the stub and this enlarged section is inserted in the outer portion of the gland body and sealed by means of a packing nut. A small gauge wire previously spliced to the cable conductor extends through a high pressure terminal at the inner end of the gland to the repeater chassis. Voids in the gland are filled with Vistac, a semi-liquid insulating compound.

CABLE ENTRANCE CHAMBER

The cable entrance chamber enclosed by two semicircular channels and a top plate, forms the top section of the repeater housing as shown in Figure 5. In preparing for installation of a repeater on board the cable ship, the two ends of

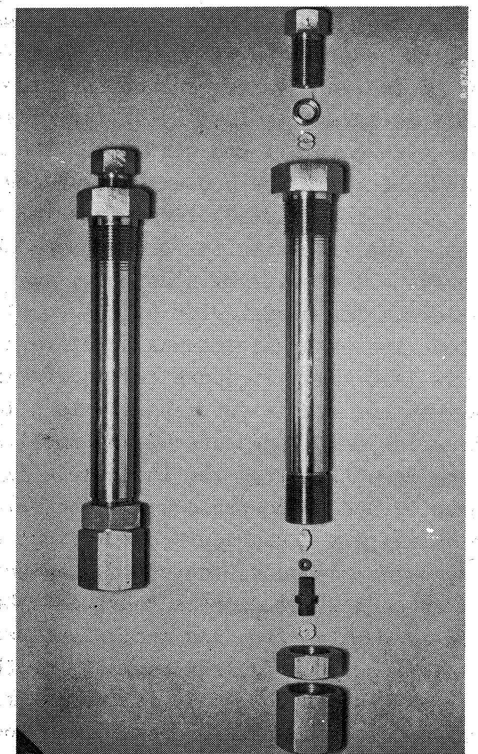


Fig. 7. Cable Entrance Gland

the armored cable are brought into the chamber, one through each channel. Bicore cable is used at the input side of the repeater, the second core providing connection to a receiving earth located about one-quarter mile from the repeater. The armor wires, looped back individually through small holes in the channel, are clamped to the inner side of the channel and secured to the cable outside of the chamber. Within the chamber the cable cores are spliced to the gland cores. Construction of the chamber is such as to admit sea-water while serving to prevent damage of the unarmored splices and of the rubber bellows described previously. A heavy lowering eye on the top plate provides a means of eliminating hazardous strains on the cables at the points of attachment to the channels. For each of the two cable sections, a chain extends out from the eye followed by a stranded steel rope which is spliced to the cable armor about 15 feet from the repeater, in a manner to allow some slack in the cable between that point and the repeater.

The overall height of the repeater, including the cable entrance chamber, is 53 inches. Its weight in air is 1,030 pounds. All external surfaces of the housing are spray-coated with zinc to

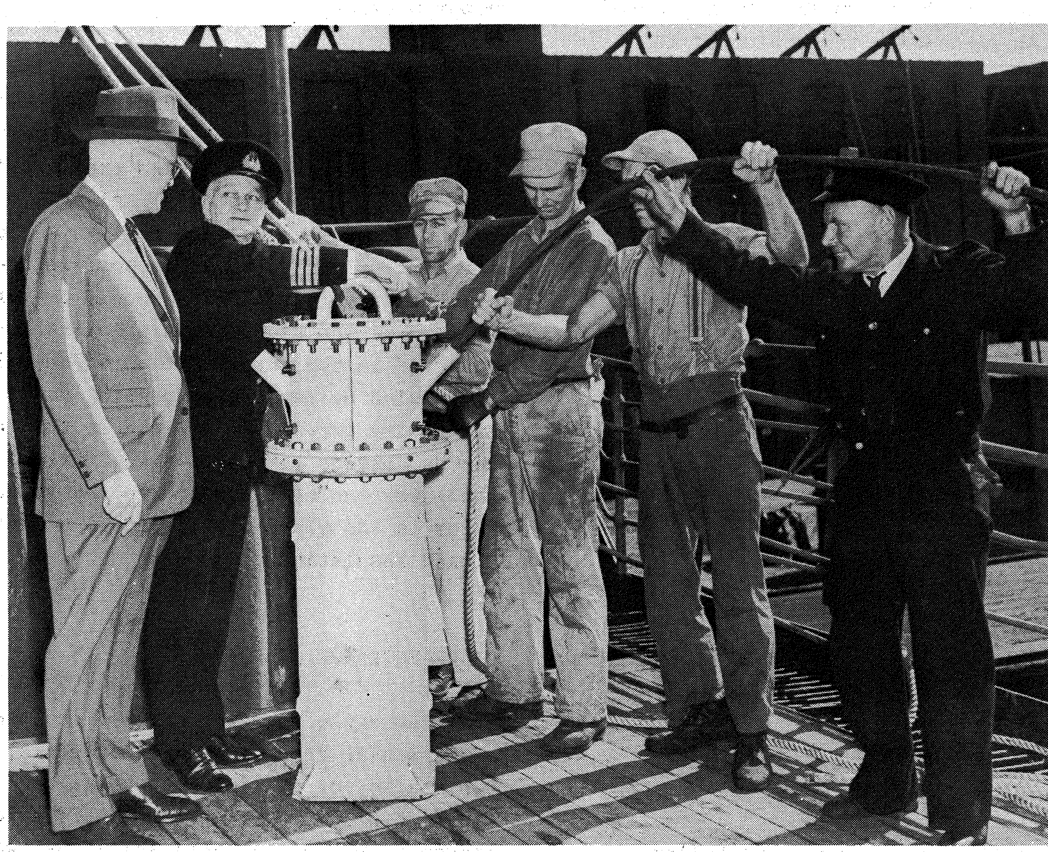


Fig. 8. Repeater on Board Cable Ship; One End of Cable in Place

inhibit corrosion. Monel bolts and nuts are used in the assembly of the housing. Figure 8 shows a repeater with one cable end in place on board the Cable Ship Lord Kelvin.

THE REPEATER CHASSIS

The structure provided for the repeater chassis is formed of circular shelves supported at the circumference by vertical members which are also utilized to fasten the chassis to the inner side of the cover plate. The structural parts of the chassis are aluminum, for the most part, to keep the weight of the repeater as low as practicable. A completely assembled chassis is shown in Figure 9.

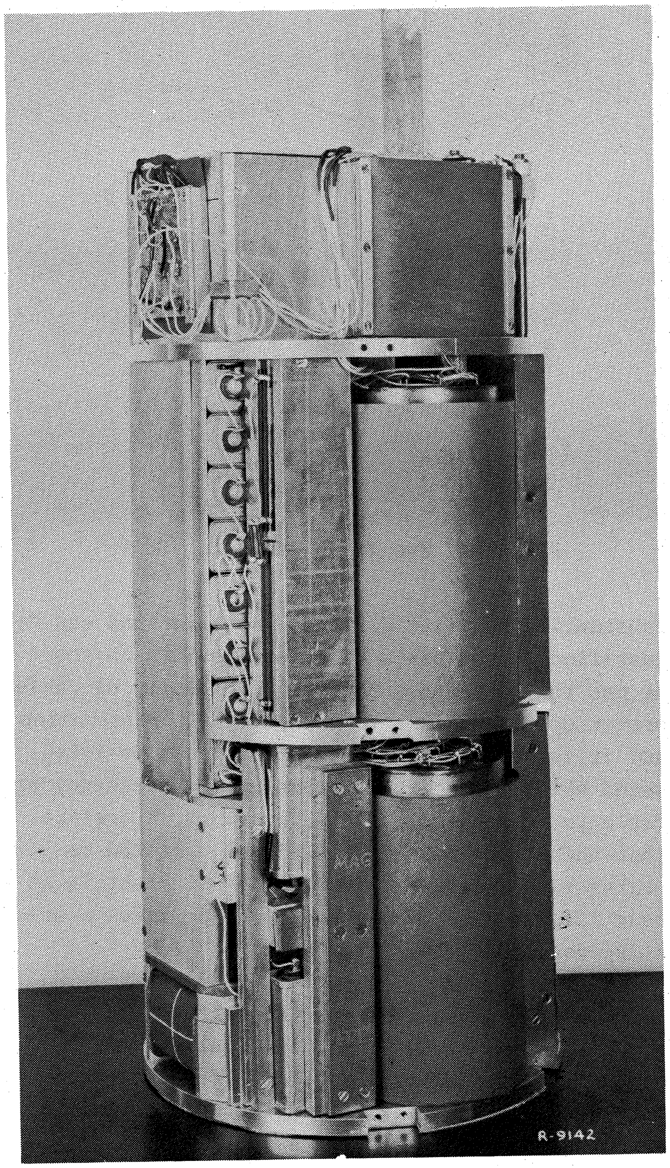


Fig. 9. Completely Assembled Repeater Chassis

Certain of the repeater elements are mounted directly in oil and subjected to full sea-bottom pressure. These include: the capacitors which are of the paper-foil type, in standard commercial metal containers, filled with mineral oil; the transformers and inductor which utilize Hypersil wound cores and layer-wound, paper-supported windings; the copper oxide rectifier; the low-value resistors, wire-wound on mica cards, which are used in the signal-shaping circuits and in the current-carrying circuits such as the heater circuit. The vacuum tubes and cold cathode gas tubes are not capable of withstanding the required hydrostatic pressures.

The vacuum tubes together with the associated functional resistors are sealed in four steel cylinders, four tubes to a cylinder. The first and second stages are housed in one cylinder, the output stage in a separate cylinder. The spare amplifier units are mounted in the remaining two cylinders. The resistors are a commercial type of pressed carbon core with molded plastic covering. Figure 10 shows a tube cylinder and a completed tube chassis ready for insertion. The steel plug, to which the tube chassis is mounted, is seated in the cylinder by hydraulic press. The mating surfaces of the plug and cylinder are finished to close tolerances with the plug slightly larger than the inside diameter of the cylinder. Before pressing, the cylinder is expanded by heating it to about 200 degrees Fahrenheit. The resulting very tight mechanical joint is further insured against leakage by soldering a fin on the plug to a corresponding fin on the cylinder. Connections are brought out through high pressure terminals in the plug. Before final sealing of the terminals, the cylinder is evacuated and dry nitrogen is circulated through it to remove any remaining traces of moisture. The completed unit is filled with nitrogen at about atmospheric pressure. All tube units are tested under pressure before acceptance for use in a repeater.

While the switch might be mounted directly in the oil so far as pressure effects are concerned, it was decided to avoid possible harmful long-term effects of oil on the performance of the switch contacts. It is essential that the initial low contact resistance and freedom from contact noise remain substantially unimpaired throughout the life of the repeater. The switch and the cold cathode gas tubes and related resistors are sealed in a steel cylinder similar to but somewhat larger than the vacuum tube cylinders. Figure 11 shows two views of the switch chassis.

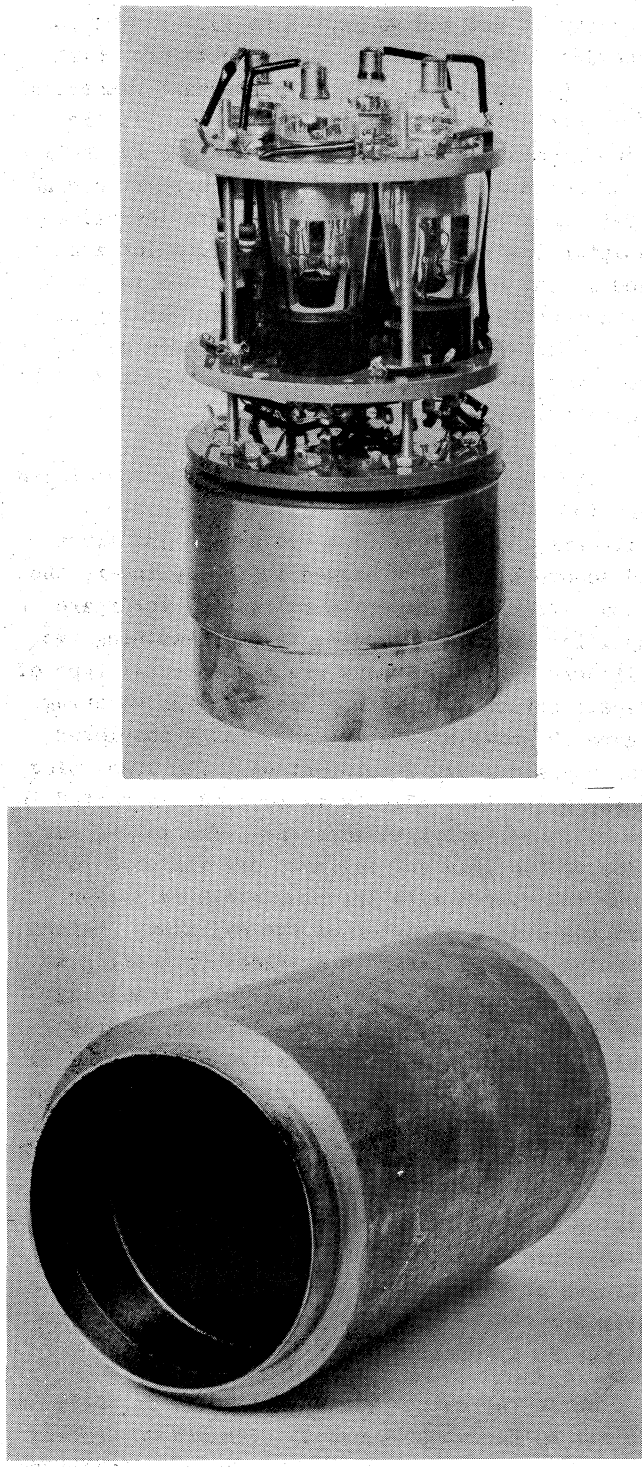


Fig. 10. Vacuum Tube Unit

CIRCUIT COMPONENTS

The costs of a repeater and its installation are small in relation to the investment in a long cable, being of the order of one percent. If viewed only from the standpoints of cost and the

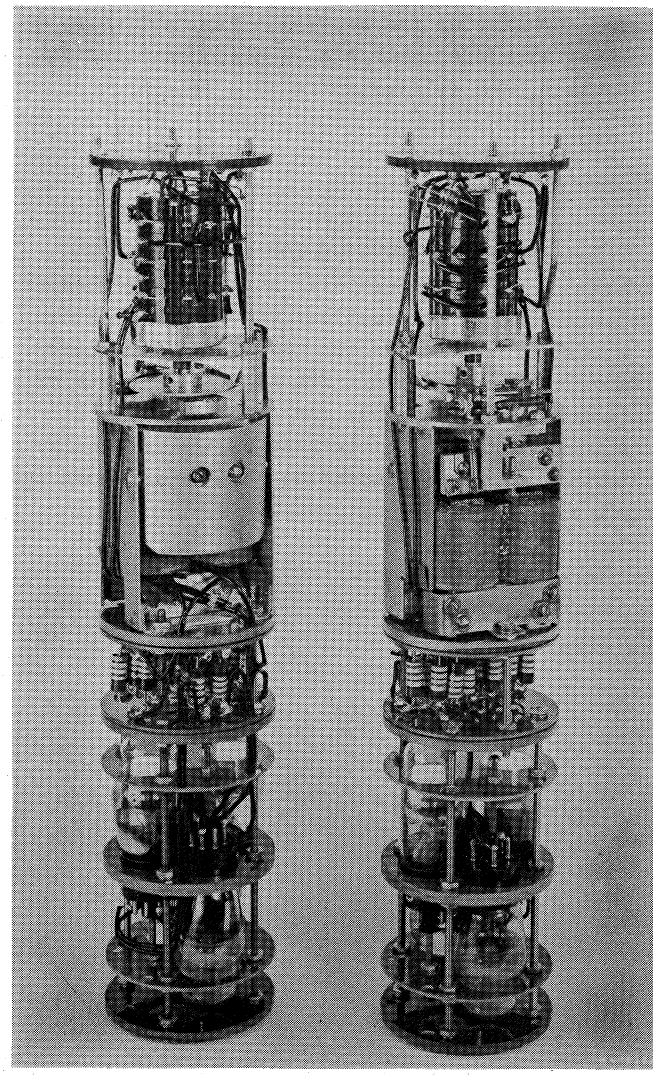


Fig. 11. Two Views of Switch Unit

substantial benefits derived, installations can be justified on the basis of a service life as short as one to two years. However, continuity of cable system operation is a very important consideration, and it is evident that no factor should be introduced which appreciably increases the frequency of cable interruptions. It is important, therefore, that the electrical circuit elements of the repeater be selected and applied so as to obtain as long life as practicable under the required operating conditions.

In designing electronic equipments for long life the vacuum tube itself is usually considered to be of first importance. The time devoted to this development was hardly sufficient to permit the parallel development of a special long life tube. It was decided to proceed with the best commercially available tubes. In the first model of the repeater type 5693 pentodes were used. The short service period of that installation gave no indication of the probable average life of the 5693. Because of somewhat better electrical characteristics for the purpose and the promise of substantially longer life, the 310-A was adopted for the modified original model and for the later units. Before selecting tubes for assignment to a repeater they are aged under simulated operating conditions - one group as pentodes for the first and second amplifier stages and one group as triodes for the output stages. It has been found that aging of 2,000 to 2,500 hours is required to stabilize the tube characteristics. Figures 12 and 13 are typical respectively of the change of

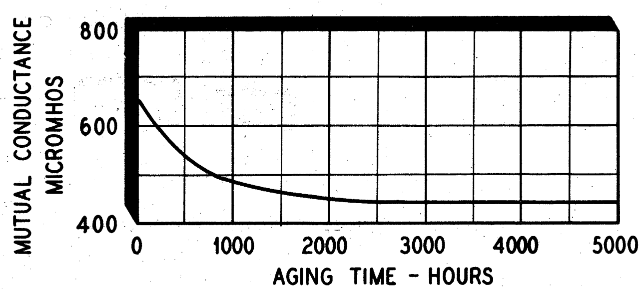


Fig. 12. Effect of Aging on Mutual Conductance of 310-A Tubes

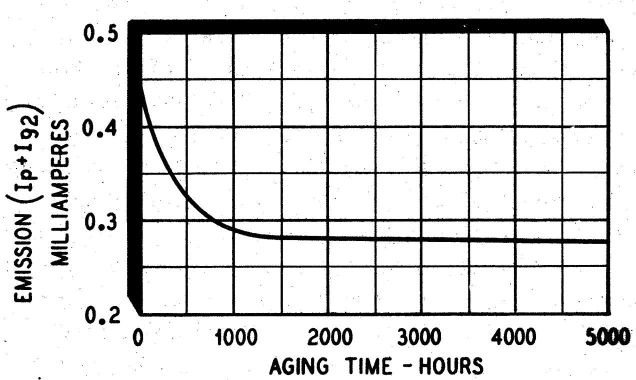


Fig. 13. Effect of Aging on Emission of 310-A Tubes

mutual conductance and emission of the 310-A with age when measured under operating conditions as pentodes. For this purpose emission is measured as the sum of the plate and screen grid currents. Thus far about 180 tubes have been aged for at least 2,000 hours and 50 others have been aged for various periods. Of this total only three tubes have been definitely rejected, one because of a short and two with excessive grid leakage. Any substantial variation from normal aging characteristics is cause for rejection. Following the aging process, tubes are selected on the basis of their individual static and dynamic characteristics to provide accurately matched pairs for push-pull operation. Figure 14 gives the static characteristics of a typical matched pair of 310-A's for pentode operation. Pairs with the lowest range of linearity are assigned for use in first stages, intermediate ranges for second stages and the greatest ranges for the output stages. This method of selection assures production of amplifiers with the highest practicable distortion-free signal output level and a good degree of uniformity.

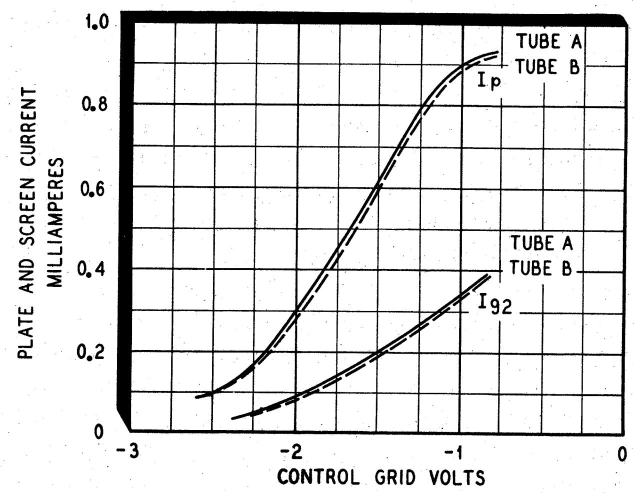


Fig. 14. Static Characteristics of Matched Pair of 310-A Tubes

Oil-filled paper-foil capacitors were chosen for use in the repeaters following tests which gave reasonable assurance of satisfactory performance when operated in oil under pressure. The observed effects of pressure are: (1) to increase capacitance, most of the change occurring in the first 500 pounds per square inch and reaching a total of about three percent at 8,000 psi; (2) to increase the voltage of breakdown. The capacitors are rated by the manufacturer in accordance with accepted standards at 600 volts d-c working voltage for a life of one year. Capacitor life varies inversely as about the fifth power of the working voltage. Since the repeater capacitors operate at voltages of 150 or less it appears that, in the absence of initial defects, long life can be expected of these components. Prior to selection for use in repeaters all capacitors are tested and aged under pressure. Capacitance, dielectric resistance, insulation resistance to case and variation of these characteristics with pressure, temperature and time are measured. Those having abnormal characteristics are rejected. Also rejected are the few units exhibiting leakage of oil after subjection to pressure. Rejections from all causes amounts to about three percent.

The high-value low-current resistors used in the original model of the repeater were of the form having a thin spiral film of resistive material on a ceramic core. Laboratory tests had indicated satisfactory performance under the proposed conditions of operation in oil under pressure. Although all resistors of that type suffered substantial loss of resistance during the field trial, subsequent efforts to duplicate those results in the laboratory were unsuccessful and thus far the cause of failure remains undetermined. Because of the unknown factors, the resistors were changed to a common commercial type having a core of compressed carbon with a molded covering of insulating material. They are mounted within the vacuum tube cylinders and the switch cylinder to avoid possible harmful effects, if any, of oil and pressure. Following an initial selection on the basis of stability and very low noise level, the resistors are aged and then subjected to further tests before final selection. About 40 percent of the resistors tested are rejected because of noise, most of the rejections occurring in the initial tests. While the repeater does not require close tolerances with respect to resistance values, accurately matched pairs are necessary for the push-pull positions. No trouble has been encountered thus far with this type of resistor.

Other components and materials are selected critically and processed carefully under constant engineering supervision. Electrical tests are made during various stages of assembly and wiring and in the final stages a repeater is given laboratory signal transmission tests under conditions accurately simulating the electrical characteristics of the specific cable in which the repeater is to be installed. A test tank is now available in which completed repeaters will be tested at pressures up to 3,000 psi or more.

TERMINAL EQUIPMENT

The power supply and terminal control equipment for the repeater involve conditions almost as unusual as for the repeater itself. The equipment is located at the receiving terminal and is thus up to 350 nautical miles from the repeater. On the single cable conductor between the terminal and the repeater, signals and power are transmitted simultaneously. The circuit is subject to earth potentials, normally of very low voltage but which at times may reach a maximum of several hundred volts accompanied by reversals of polarity. Under these conditions the power current transmitted through the cable to the repeater must be maintained at a near constant level. If adequate controls are lacking the repeater will, at best, be unstable in operation and, at worst, in danger of serious damage.

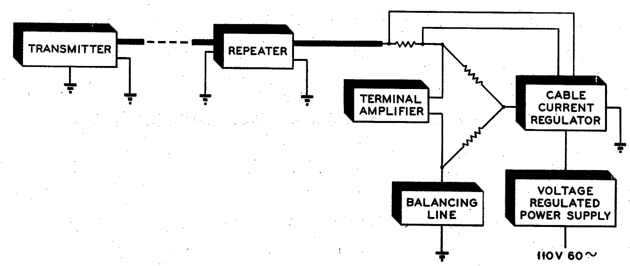


Fig. 15. System Diagram of Repeatered Cable

The terminal circuit and its relation to the repeater is shown in the block diagram of Figure 15. The arrangement is somewhat similar to a standard bridge duplex cable terminal. Power for the repeater is supplied by rectifiers, working from commercial or special sources of alternating current, and fed into the apex of the bridge. The impedance of the cable from the terminal to the repeater and of the repeater to ground are balanced by an artificial line so that the terminal amplifier is unaffected by residual noise components in the power circuit. Control amplifiers maintain the power current at 0.32 ampere within about one percent for wide fluctuations in the a-c supply and in the presence of earth potentials varying through a range as high as minus 300 to plus 300 volts. When the earth potentials exceed the range of the controls or the control circuit fails or if for any other reason the power current approaches a conservatively safe limit, a circuit-breaker arrangement functions to protect the repeater. To produce 150 volts at the repeater, the voltage applied to the cable at the terminal, determined by the specific conditions in each installation, is in the range 250 to 360 volts. Adding the drop in the terminal bridge arm, the normal voltage at the apex is 425 to 535 volts. When earth potentials are present, the voltages at the apex and the cable head follow the variations of that disturbance.

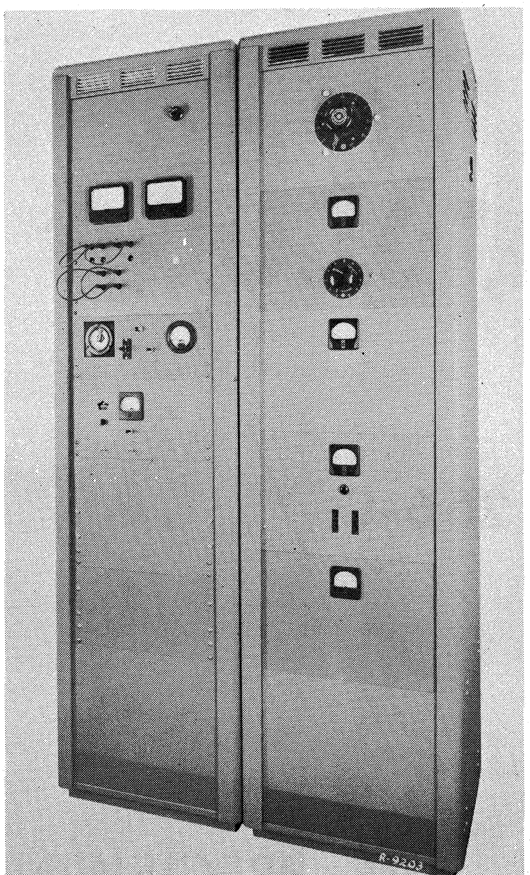


Fig. 16. Regulated Power supply (right) and Control Unit (left)

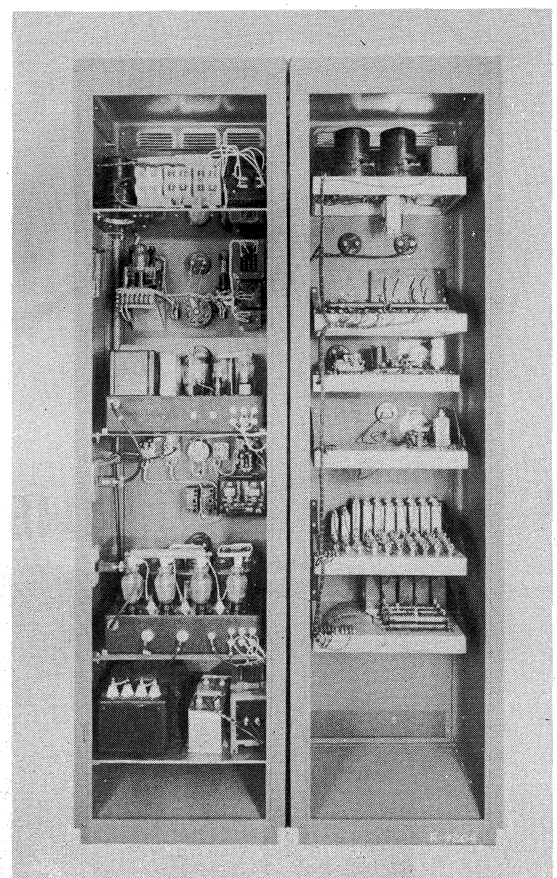
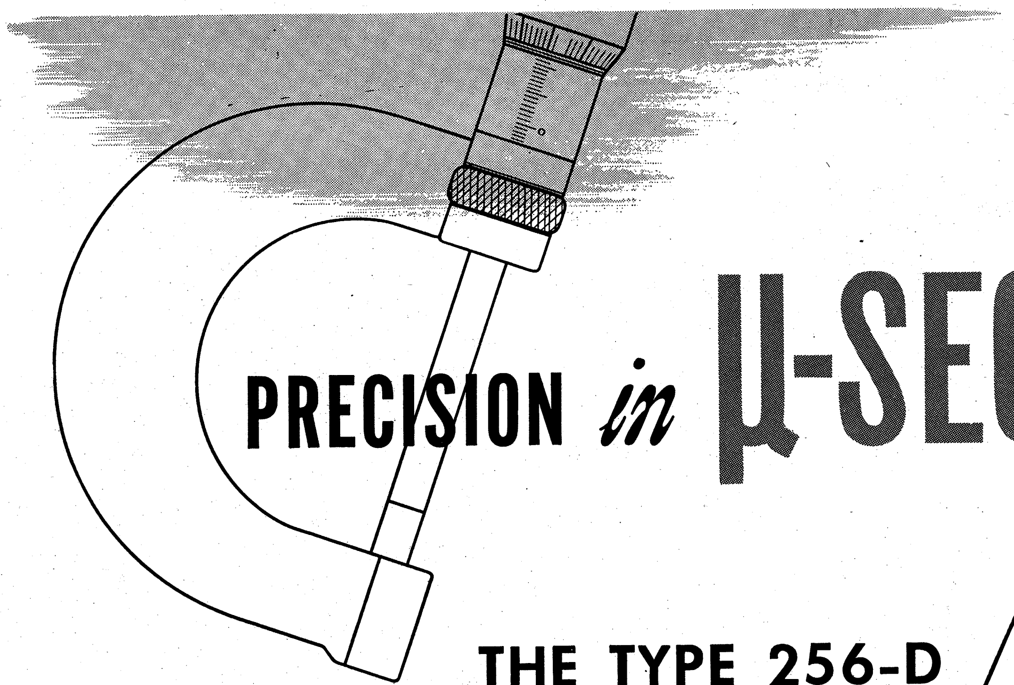


Fig. 17. Interior View - Power Supply (left) and Control Unit (right)

The terminal equipment is mounted in two rack cabinets, a rectifier unit and a control unit, as shown in Figures 16 and 17. The control cabinet includes means for transmitting switching pulses to the repeater and for indicating the position of the switch.

CONCLUSION

The centenary of the submarine cable was celebrated recently and transatlantic telegraphy nears its one hundredth anniversary. As the cable art enters its second century, submerged repeaters seem destined to play an important part in meeting the expanding needs of international communications. In the present early stages of its development the submerged telegraph repeater makes available a substantial increase in the message capacity of existing long cables. Further development of the repeater itself and of the method or system of utilization may well result in further increases of capacity. When new cables are required, either telegraph or telephone, they will undoubtedly be repeatered cables.



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THE TYPE 256-D

and for PRECISION IN YARDS

THE TYPE 256-E

A high-precision time-measuring device designed for general-purpose functions in laboratory work.

The calibrated sweep delay of the Type 256-D will measure time intervals up to 1000 microseconds with an accuracy of ±0.1% of the full scale ranges of 100 μ-secs. or 1000 μ-secs. A movable marker indicates the portion of the sweep which is expanded on shorter delayed sweeps. Delayed sweeps are of 4-, 10-, and 25-microsecond durations. Undelayed sweeps are available in six ranges from 4- to 4500-microseconds.

Response of the video amplifier is within ± 1 db at 20 cps; down less than 3 db at 8 mc, no more than 6 db at 11 mc. Sensitivity is 0.7 peak-to-peak volt per inch. Pulse response is such that a rise time of 0.01 microsecond will be reproduced as a rise time of 0.04 microsecond or less.

Crystal-controlled timing markers calibrate the delay circuits. Delayed and undelayed sweeps may be started by external trigger pulses of either polarity or by built-in trigger generator providing 1 microsecond pulses of either polarity, having a rise time of 0.3 microsecond and amplitude greater than 100 volts. Trigger repetition rates up to 2000 P.P.S. are available.

Electrically similar to the Type 256-D. Calibrations in yards instead of microseconds. Designed especially as test equipment for electronic ranging systems, or as an accessory unit for radar systems.

Provides undelayed sweeps of 800, 2000, 4000, 20,000 and 200,000 yards in addition to a 4500-microsecond sweep. Delayed sweeps of 800, 2000 and 4000 yards may also be selected.

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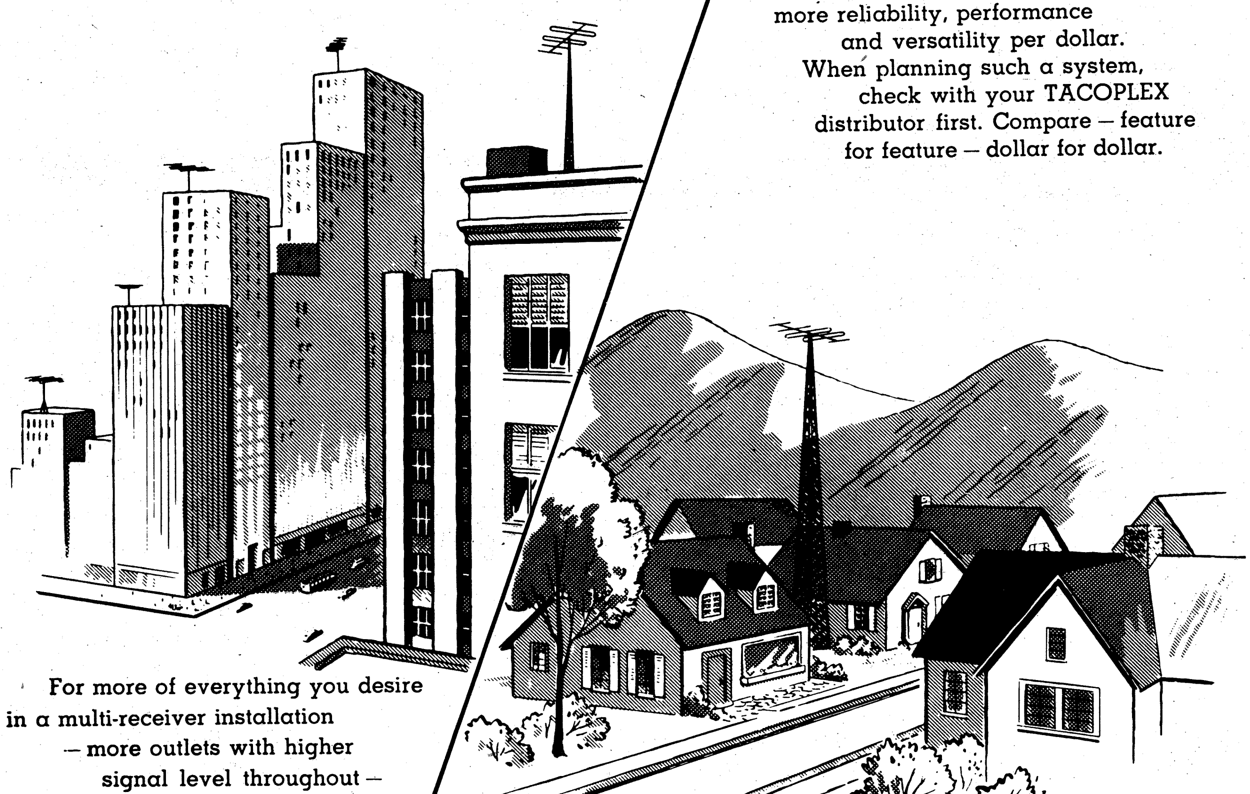

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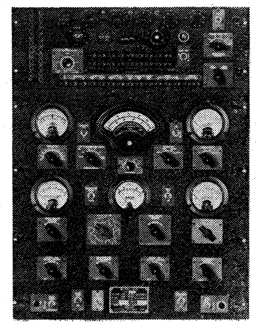
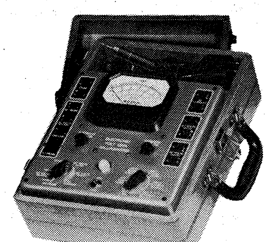
TEST EQUIPMENT by WESTON

Mutual Conductance ELECTRONIC TUBE ANALYZER



(Model 686) an "all purpose" tube analyzer that tests tubes under exact operating potentials. Accurately determines true mutual conductance of all tubes both in accordance with manufacturer's rated operating conditions, as well as at other values for non-standard applications.

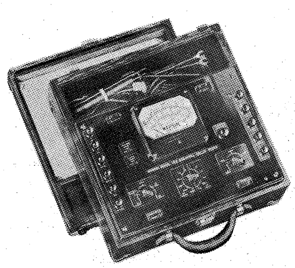
High Frequency ELECTRONIC ANALYZER (Model 769)



three instruments in one: a Volt-Ohm-Milliammeter with self-contained power source — a high impedence electronic Volt-Ohmmeter using 115 volt 60 cycle power—a stable, probe type Vacuum Tube Voltmeter for use to 300 megacycles.

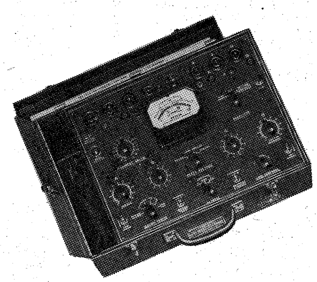
for ALL electronic and electrical maintenance needs!

Multi-Purpose CIRCUIT TESTER



(Model 785) a versatile, portable tester for laboratory or maintenance needs, where an ultra-sensitive instrument is required. Provides 28 A-C and D-C voltage, A-C and D-C current, and resistance ranges. (D-C sensitivity 20,000 Ohms per volt.)

Mutual Conductance PORTABLE TUBE CHECKER



(Model 798) for general testing of all receiving tubes, voltage regulator tubes and low power thyratron tubes. Provides proportional mutual conductance ranges 3000/6000/12000 micromhos. Compactness and light weight make it ideal for all servicing requirements.

All WESTON Test Equipment is specifically designed to provide time-saving facility and increased efficiency for all electronic or electrical maintenance jobs. For complete information on all equipment in this broad line, consult your nearest WESTON representative, or write for Test Equipment Bulletins . . . WESTON Electrical Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, New Jersey . . . manufacturers of Weston and TAG Instruments.

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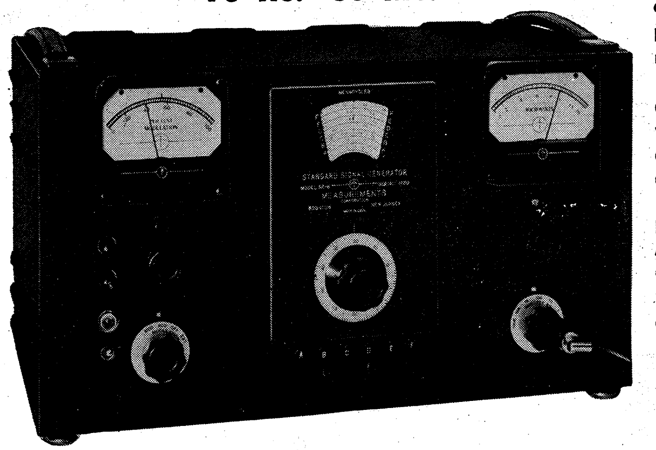
Laboratory Standards

STANDARD SIGNAL GENERATOR - Model 65-B

75 Kc. - 30 Mc.



FREQUENCY RANGE: 75 kilocycles to 30 megacycles in 6 push button ranges.

FREQUENCY CALIBRATION: The frequency dial is direct reading and individually hand calibrated for each range. It is accurate to ± 0.5%.

OUTPUT VOLTAGE: Continuously variable from 0.1 microvolt to 2.2 volts.

OUTPUT IMPEDANCE: 5 ohms to 0.2 volt, rising to 15 ohms at 2.2 volts.

MODULATION: Continuously variable from 0 to 100%. Modulation depth is indicated directly by a meter on the panel. Modulation may be obtained either from an internal source of 400 or 1000 cycles or from an external source.

ENVELOPE DISTORTION: Less than 4% at 100% modulation at 1 megacycle.

LEAKAGE: Less than 0.1 microvolt leakage with attenuator set for 0 output.

POWER SUPPLY: 117 volts, 50-60 cycles. 115 watts.

DIMENSIONS: 11" high x 20" long x 10¼" deep, overall.

WEIGHT: Approximately 55 pounds.

FM STANDARD SIGNAL GENERATOR - Model 78-FM

86 Mc. - 108 Mc.

FREQUENCY RANGE: 86 to 108 megacycles, individually calibrated dials. Accurate to ± 0.5%.

OUTPUT VOLTAGE: 1 to 100,000 microvolts.

LEAKAGE: Less than 1 microvolt.

MODULATION: Deviation continuously variable from 0 to 300 kc. Indicated on directly calibrated dial. 400 cycle internal audio oscillator. Can be modulated from an external source providing 6 volts across 5000 ohms.

FIDELITY: Flat within two db from DC to 15,000 cycles. Distortion is less than 1% at 75 kilocycles deviation. Transient response is excellent.

POWER SUPPLY: 117 volts, 50 to 60 cycles. 36 watts.

DIMENSIONS: 10" high x 13" wide x 7" deep, overall.

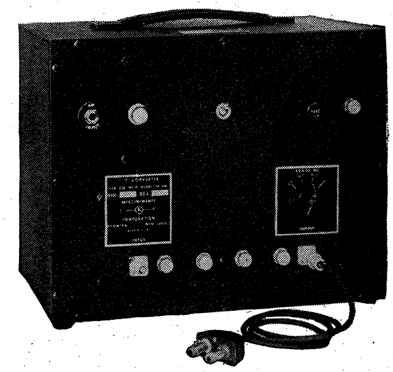
WEIGHT: Approximately 25 pounds.

Special one-band Model 78-FM Signal Generators, with a tuning ratio of approximately 1.2 to 1, are available for use within the limits of 30 to 165 megacycles.

I. F. CONVERTER - Model M-275

This instrument was designed for use with the Model 78-FM Standard Signal Generator to provide carrier output at the IF frequencies used in FM and Television receivers.

(Special Frequencies up to 23 Mc. available on order)



CARRIER FREQUENCIES: 4.5, 10.7, 21.7 Mc.

OUTPUT VOLTAGE: 10 microvolts to 1.0 v. when used with Model 78-FM.

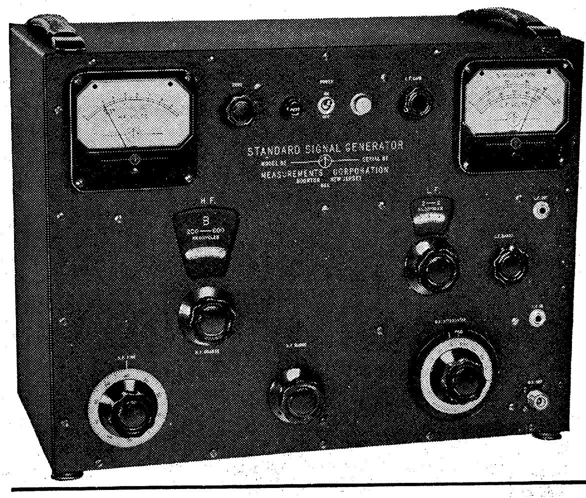
BAND WIDTHS: 5% down, ± 250 Kc. from center frequency.

AMPLITUDE MODULATION: Provision for external AM up to approximately 80%, combined with, or exclusive of, FM. There is negligible spurious FM due to AM. The envelope distortion is less than 10% at 80% modulation.

MEASUREMENTS CORPORATION
Laboratory Standards

STANDARD SIGNAL GENERATOR - Model 82

20 CYCLES - 50 Mc.



FREQUENCY RANGE: 20 cycles to 200 kilocycles in four ranges. 80 kilocycles to 50 megacycles in seven ranges. Position available for special range.

FREQUENCY ACCURACY: Each range is individually calibrated. 20 cycles to 200 kilocycles, accurate to ±5%. 80 kilocycles to 50 megacycles, accurate to ±1%.

OUTPUT VOLTAGE AND IMPEDANCE: 0-50 volts across 7500 ohms from 20 cycles to 200 kilocycles. (The output voltage and impedance in this range can be reduced by an external attenuator). 0.1 microvolt to 1 volt across 50 ohms over most of the range from 80 kilocycles to 50 megacycles.

MODULATION: Continuously variable 0-50% from 20 cycles to 20 kilocycles from low frequency variable oscillator or external source.

HARMONIC OUTPUT: Less than 1% from 20 cycles to 20 kilocycles; 3% or less from 20 kilocycles to 50 megacycles.

LEAKAGE AND STRAY FIELD: Less than 1 microvolt from 80 kilocycles to 50 megacycles.

POWER SUPPLY: 117 volts, 50-60 cycles. 75 watts.

DIMENSIONS: 15" high x 19" wide x 12" deep overall.

WEIGHT: 50 pounds.

STANDARD SIGNAL GENERATOR - Model 80

2 Mc. - 400 Mc.

FREQUENCY RANGE: 2 to 400 megacycles in 6 bands, individually calibrated direct reading dial.

FREQUENCY ACCURACY: ± 0.5%.

OUTPUT VOLTAGE: Continuously variable from 0.1 to 100,000 microvolts.

OUTPUT IMPEDANCE: 50 ohms.

MODULATION: Amplitude modulation is continuously variable from 0 to 30%. Modulation depth is indicated by a meter on the panel. Internal modulation, 400 and 1000 cycles. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector.

LEAKAGE AND STRAY FIELD: Attenuator leakage less than 0.1 microvolt. Power line leakage less than 0.5 microvolt. Stray fields less than two microvolts.

POWER SUPPLY: 117 volts, 50 to 60 cycles. 70 watts.

PULSE GENERATOR MODEL 79-B

This instrument is specially adapted for plate pulsing of the Model 80 Standard Signal Generator.

REPETITION RATE: 60 to 100,000 pulses per second.

PULSE WIDTH: Continuously variable from 0.5 to 40 microseconds.

OUTPUT VOLTAGE: Approximately 150 volts positive with respect to ground.

"SYNC" OUTPUT: 75 volts positive with respect to ground. Displaced by ½ period from pulse output.

"SYNC" INPUT: May be synchronized with as little as 2 volts peak from an external source.

POWER SUPPLY: 117 volts, 50-60 cycles. 115 watts.

DIMENSIONS: 10" high x 13⅝" wide x 10½" deep, overall.

WEIGHT: Approximately 31 pounds.

MEASUREMENTS CORPORATION BOONTON · NEW JERSEY

NEW GR T-V MONITOR

for the VHF and UHF bands

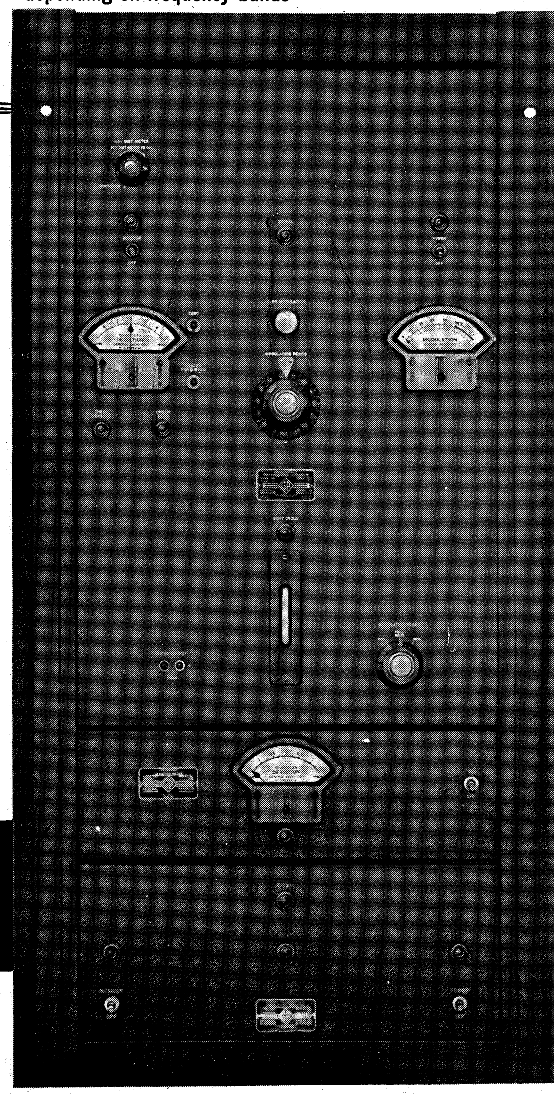
Channels 2 to 83

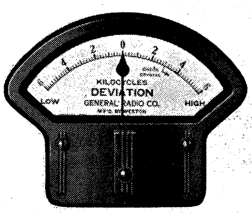
The new G-R Type 1183-T T-V Station Monitor meets all of the requirements of the FCC, including those recently established for offset operation. This instrument — the first UHF Monitor — is another example of the pioneering in engineering, design and workmanship which has characterized G-R monitoring equipment since the beginning of broadcasting. Stability, accuracy, ease of operation and maintenance, dependability and long life are optimum. The G-R trademark guarantees trouble-free operation with a minimum of maintenance.

F E A T U R E S

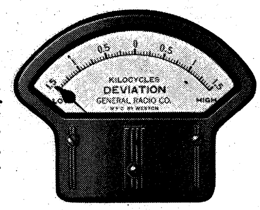
- ★ *Continuous indication of percentage modulation and frequency deviation of aural and visual transmitters — terminals for remote metering.*
- ★ *Overmodulation alarm for aural transmitter — lamp flashes when modulation exceeds predetermined level.*
- ★ *High-fidelity audio output for distortion and noise-level measurements, and for audio monitoring — residual noise level is down 65 db or better for 25 kc deviation.*
- ★ *Sensitivity 1 volt, or better, on high impedance input; 500 mw or less on low, for both aural and visual inputs.*
- ★ *Excellent signal-to-noise ratio through channel 83.*
- ★ *Separate heater inputs allow direct connection of crystal oven to station standby power.*
- ★ *Highly stable temperature-controlled master crystal oscillator — stability ±0.5 parts per million for 10 days, or better — output level read on panel meter.*
- ★ *Counter-type discriminator linear to better than 0.1% for ±100 kc range, permitting accurate distortion measurements and center-frequency indications reliable even with heavy modulation.*
- ★ *New Cabinet arranged for maximum heat dissipation and easy removal for servicing.*

Prices: Type 1183-T T-V Station Monitor—from $2435 to $2535 depending on frequency bands

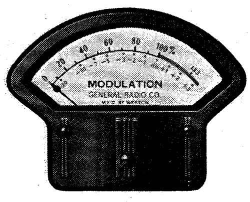




Large-scale illuminated meter continuously indicates frequency deviation of aural transmitter in terms of highly stable crystal oscillator. Zero correction for crystal oscillator easily accessible from panel, to compensate for long-time drift.



Continuous indication of frequency deviation of visual transmitter in terms of same master crystal is provided by this large-scale meter. Overall stability is ±(0.5 parts per million + 100 cycles) for 10 days.



Modulation in both percentage and db is indicated continuously on this meter. Panel switch selects either peak, or both peaks simultaneously. Meter ballistics meet FCC requirements.

Write for the 1183-T T-V MONITOR Bulletin

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