NEW RAYDIST RANGE SYSTEMS

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The value of Raydist as a precise tool for accurate position determination has been greatly increased by the introduction of the new Raydist Range Systems. Altough these systems employ the same general principles of heterodyne phase comparison as earlier Raydist systems, they are quite different in that they use less stations and have eliminated data reduction.

The newest of the Raydist Range Systems, developed during the latter part of 1955, uses only two shore stations and a master station on the vessel or aircraft. The position of the craft is displayed directly in terms of two ranges on a newly developed counter and dial indicator. No hyperbolic overlays or computations are necessary. In addition to the data presentation in terms of two ranges and the need for only two shore stations, the system offers higher accuracy at greater ranges than possible with any other electronic system. Furthermore, the Raydist Range System is capable of multiparty operation, thus permitting more than one user to share the same shore stations simultaneously. One set of ground stations can serve at least three mobile stations simultaneously, and with some minor modifications, this number can be increased almost indefinitely. This fact represents an important economy, since it avoids the complete duplication of ground equipment and sites when more than one vessel is operating in the same area. Figure 1 is an illustration of a Raydist Range System showing the two shore-based stations from which ships and aircraft can automatically and simultaneously determine their positions.

The accuracy of the Raydist Range System is limited only by the ability to predict the effective electrical center of the antennas and by the velocity of propagation of radio waves. Accuracies of one part in 50,000 are practical at near maximum ranges, with a sensitivity of a fraction of a meter.

One other important advantage of the Range System over previous Raydist systems is based on the geometry involved. A study of the overlays of all hyperbolic systems will show that the accuracy can degenerate very rapidly with range, due to the divergence of the hyperbolic lines and the poor angle of their intersections.

Raydist has been used in the hyperbolic form for many years, and has become widely recognized as a highly accurate and reliable tool in hydrographic surveying and other applications where precise position determinations are required. (References 1 through 5.) Raydist Range Systems, however, are relatively new. The first practical use of a Raydist Range System was in 1952, when a single-dimensional system was used for ship-speed measurements in the standardization tests of the *S.S. United States*. (Reference 6.) In these tests the Relay Stations were located in floating buoys, and the Master Station aboard the liner. Under these conditions, ranges up to 15 nautical miles were obtained with a low-power system. Since that time, with improvements in equipment and techniques, ever increasing range has been obtained.

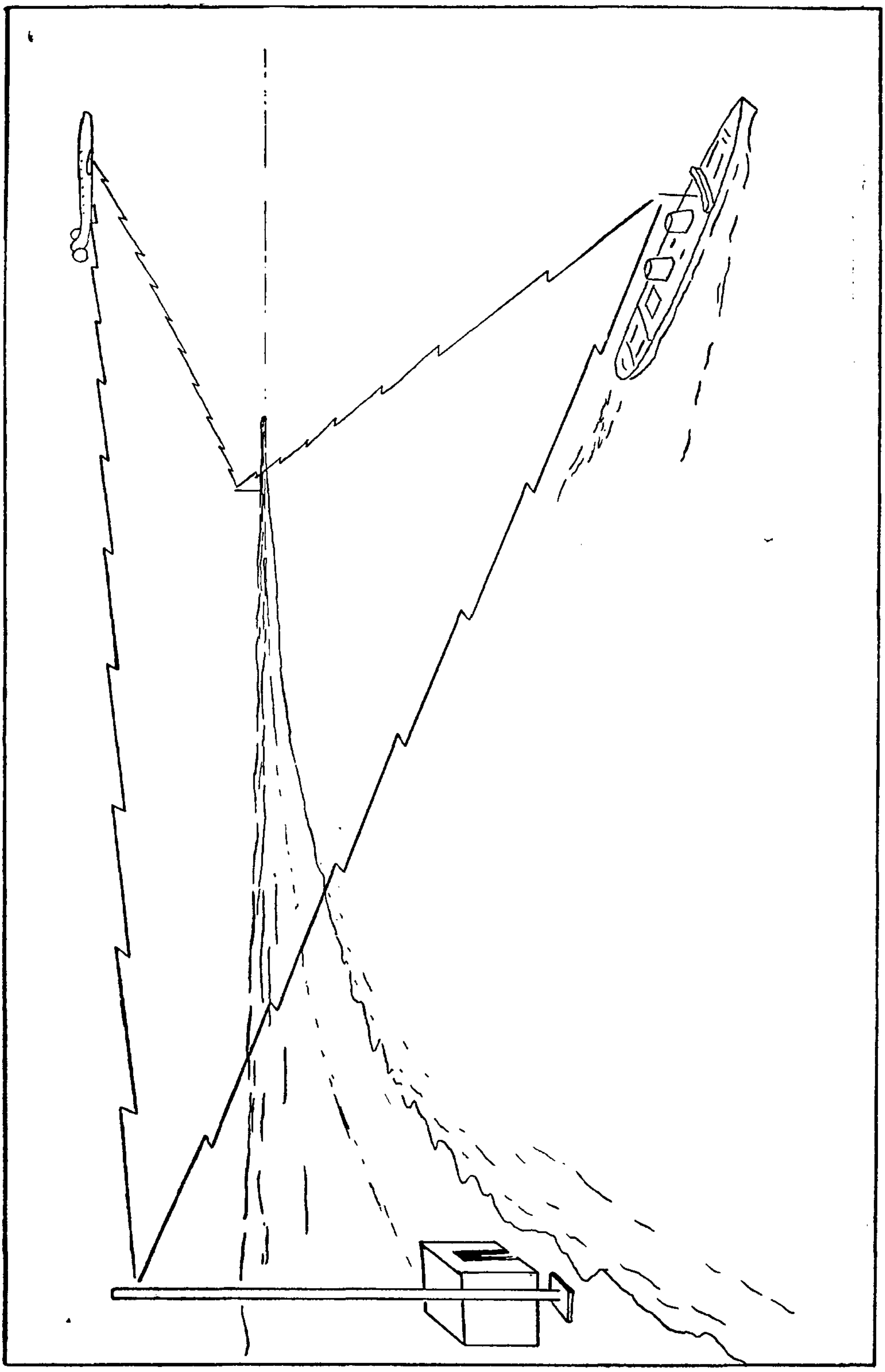

Fig. 1.
The new Raydist range system, using only two base stations, allows ships and aircraft to obtain exact position data directly and simultaneously.

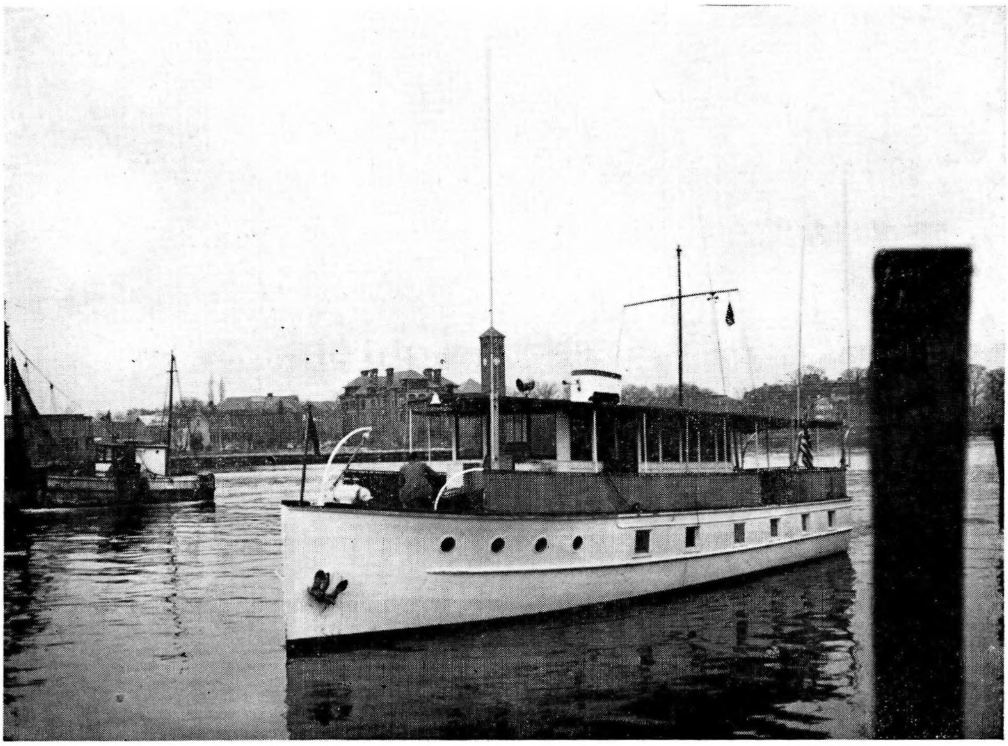

Fig. 2.

Motorship Romar, used in Raydist range tests in Chesapeake Bay, during which ranges beyond 50 nautical miles were obtained in spite of transmission paths being almost entirely over land. (See Figure 4.) Greater ranges can be expected in over water operation.

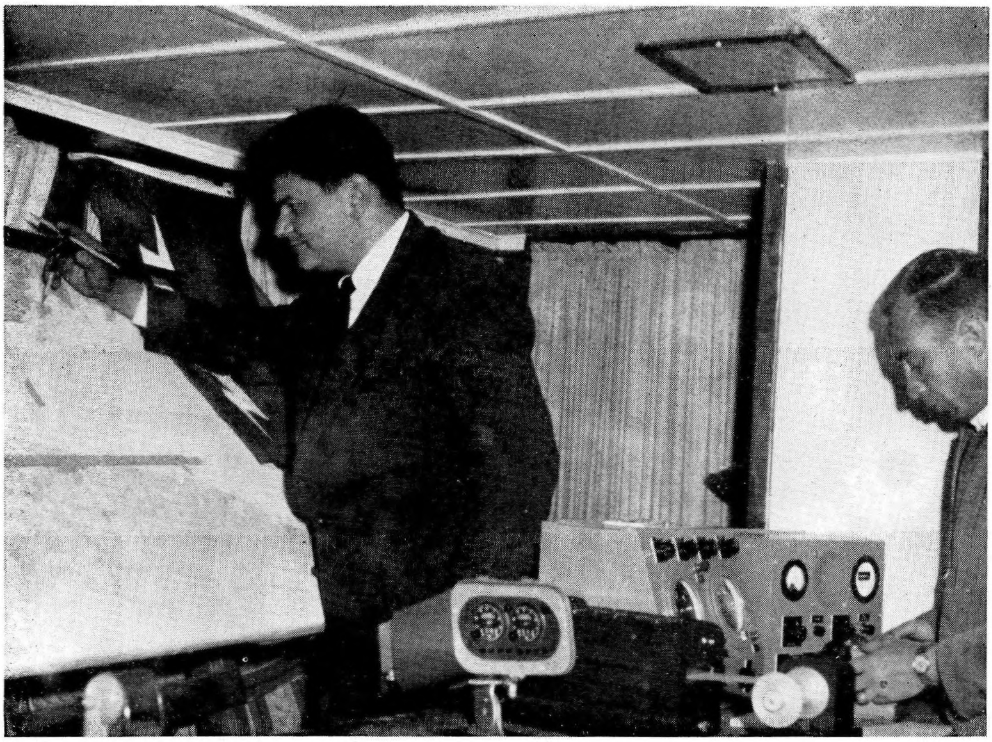

Fig. 3.

Raydist equipment in operation aboard the motorship Romar. At left, plotting positions, is Lt. Comdr. Isidoro Antonio Paradelo of the Argentine Navy; to the right, calling out Raydist ranges is Comdr. Julio Fernandez Gonzalez of the Brazilian Navy. In the immediate forefront is the new Raydist dynamic phasemeter which was simultaneously undergoing prototype testing. Immediately behind the dynamic phasemeter is a recorder which was continuously recording Raydist ranges along with time. Behind the recorder is the older type Er master station. Also undergoing prototype tests but not shown in the photograph was a Raydist automatic plotting board.

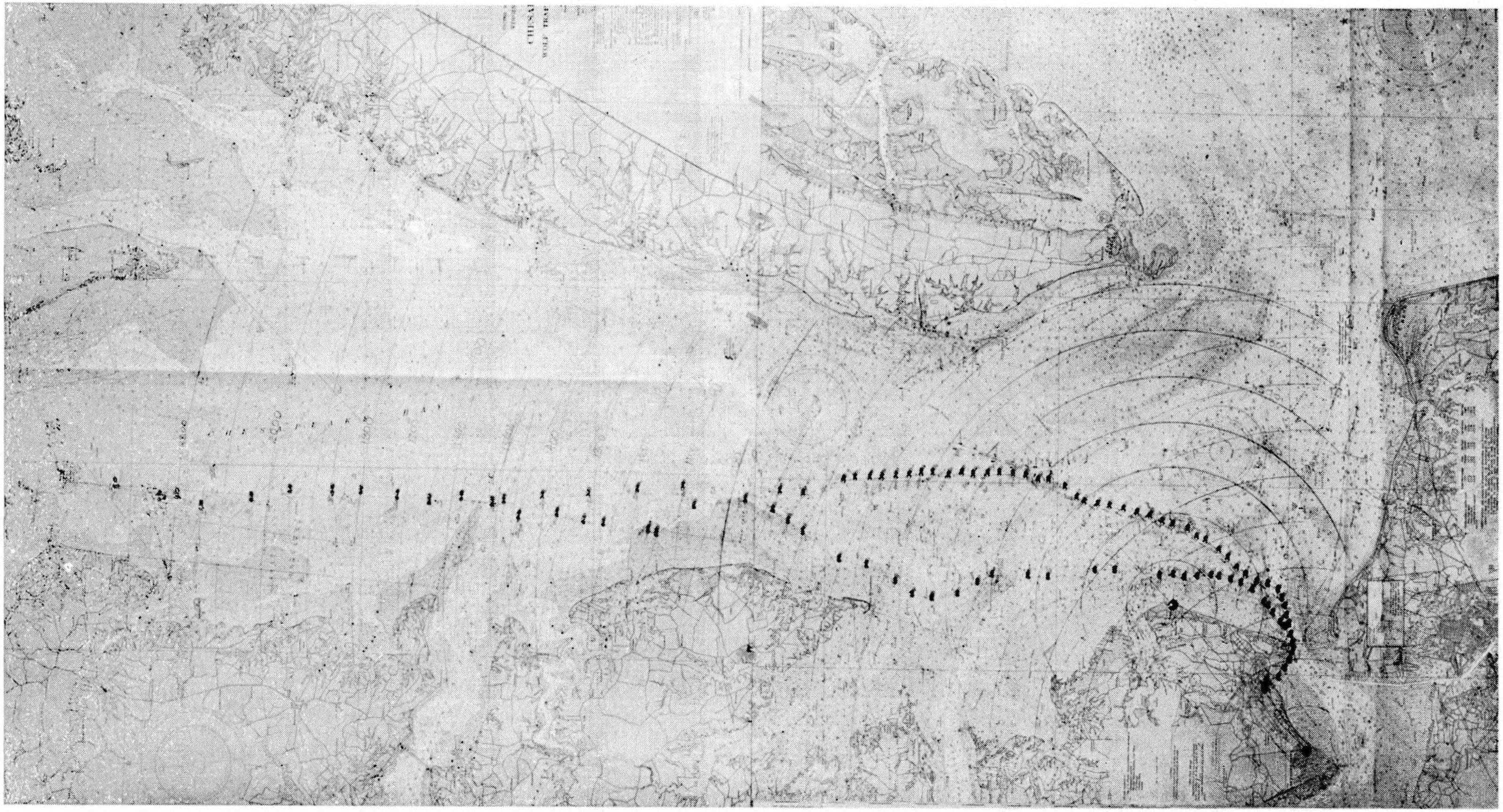

Fig. 4.

Photograph of actual plot of position of the motorship « Romar » during trip up Chesapeake Bay. Raydist positions were plotted in terms of ranges from Newport News, Virginia, and Grand View, Virginia.

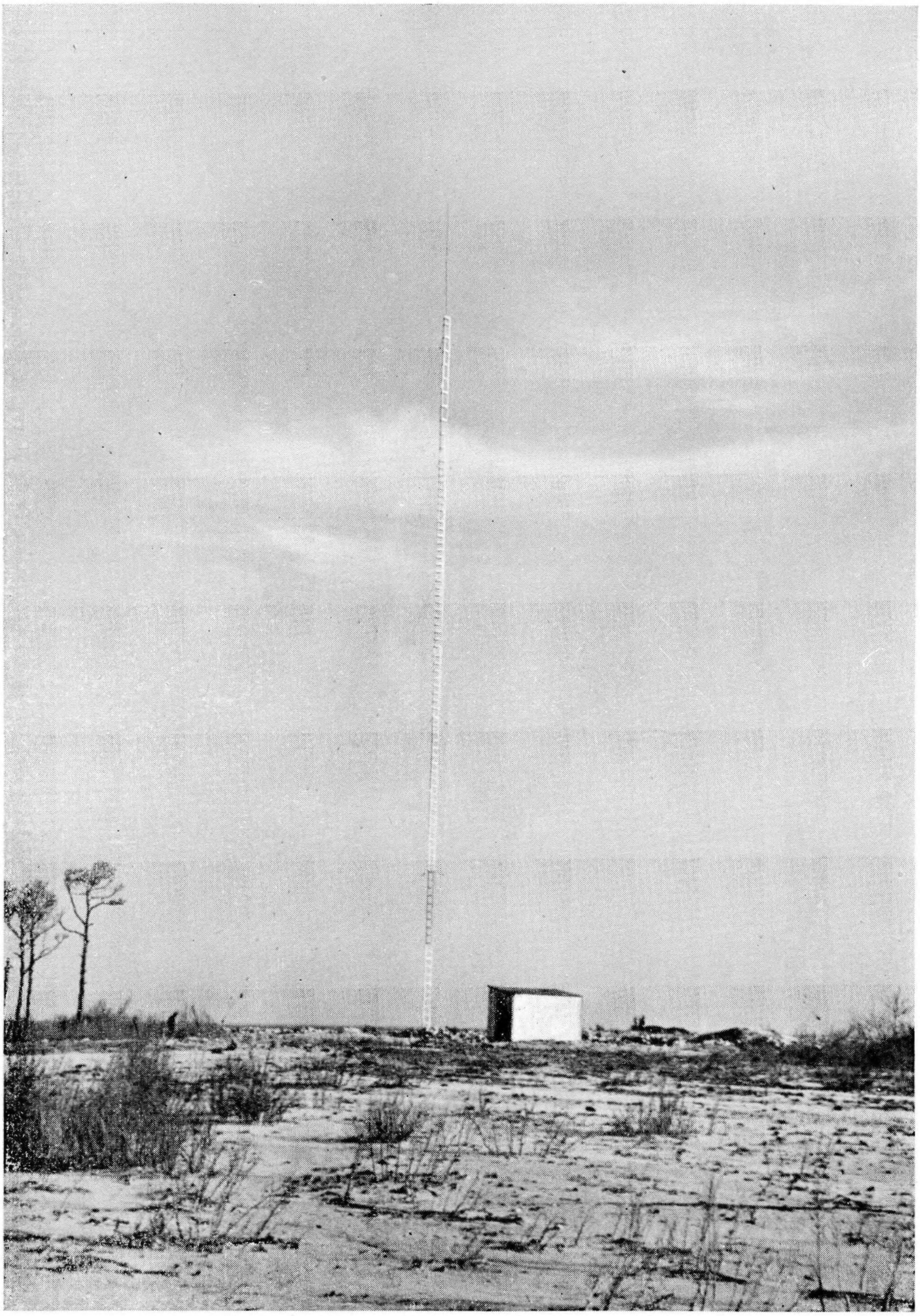

Fig. 5.

Typical Raydist base station installation at Grand View, Virginia, used during tests on the « Romar » and of DC-3 aircraft discussed herein. This installation, with a triangular portable aluminium mast, is suitable for use where maximum ranges of Raydist are required. 35 foot whip antennas are generally recommended up to 25 miles. 35 foot whip antennas were used at the second base station, however, when 50 nautical miles and 75 nautical miles were obtained in the tests of the « Romar » and the airplane.

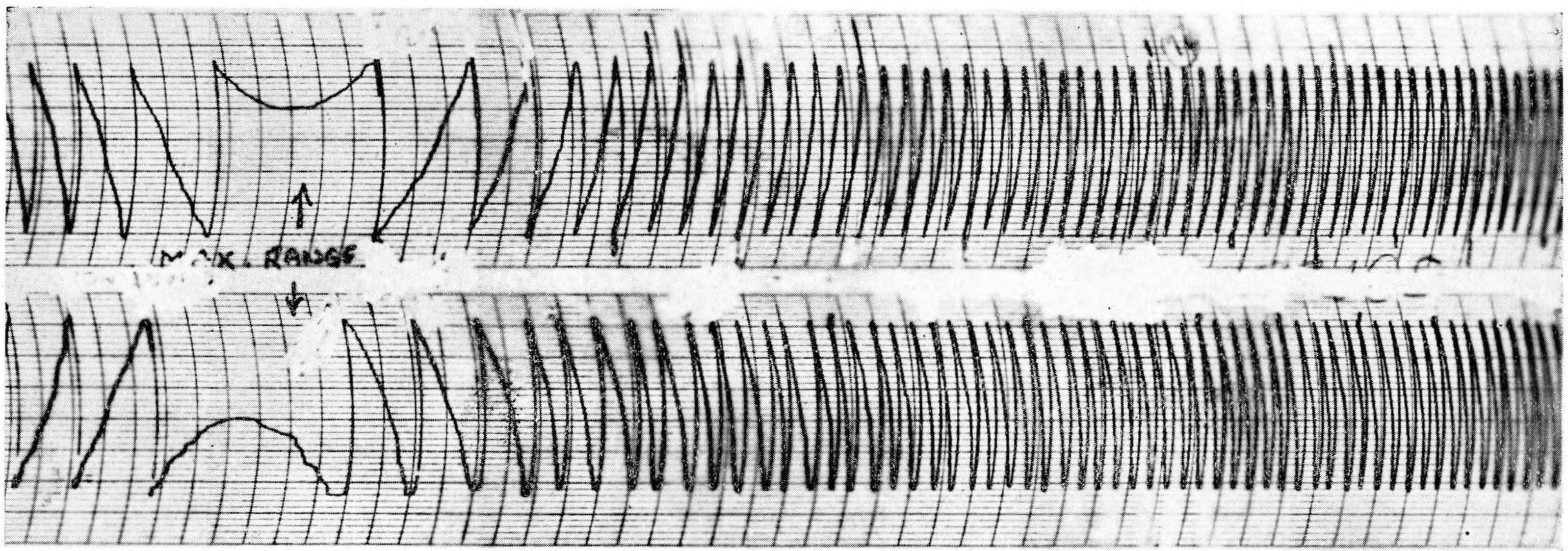

Fig. 6.

Section of Raydist range record at ranges of 75 and 80 nautical miles to the respective base stations, showing section where aircraft made a low pass to test signal strength at low altitude (approximately 100 feet) and then headed back to shore. Each sawtooth represents 360° of rotation of the phasemeter or a distance of 119 feet to the respective base station. The indicator shown in Figure 8 can easily be read to within 1 foot. The over-all accuracy at this range should be approximately that of first order if meteorological data are available for atmospheric corrections.

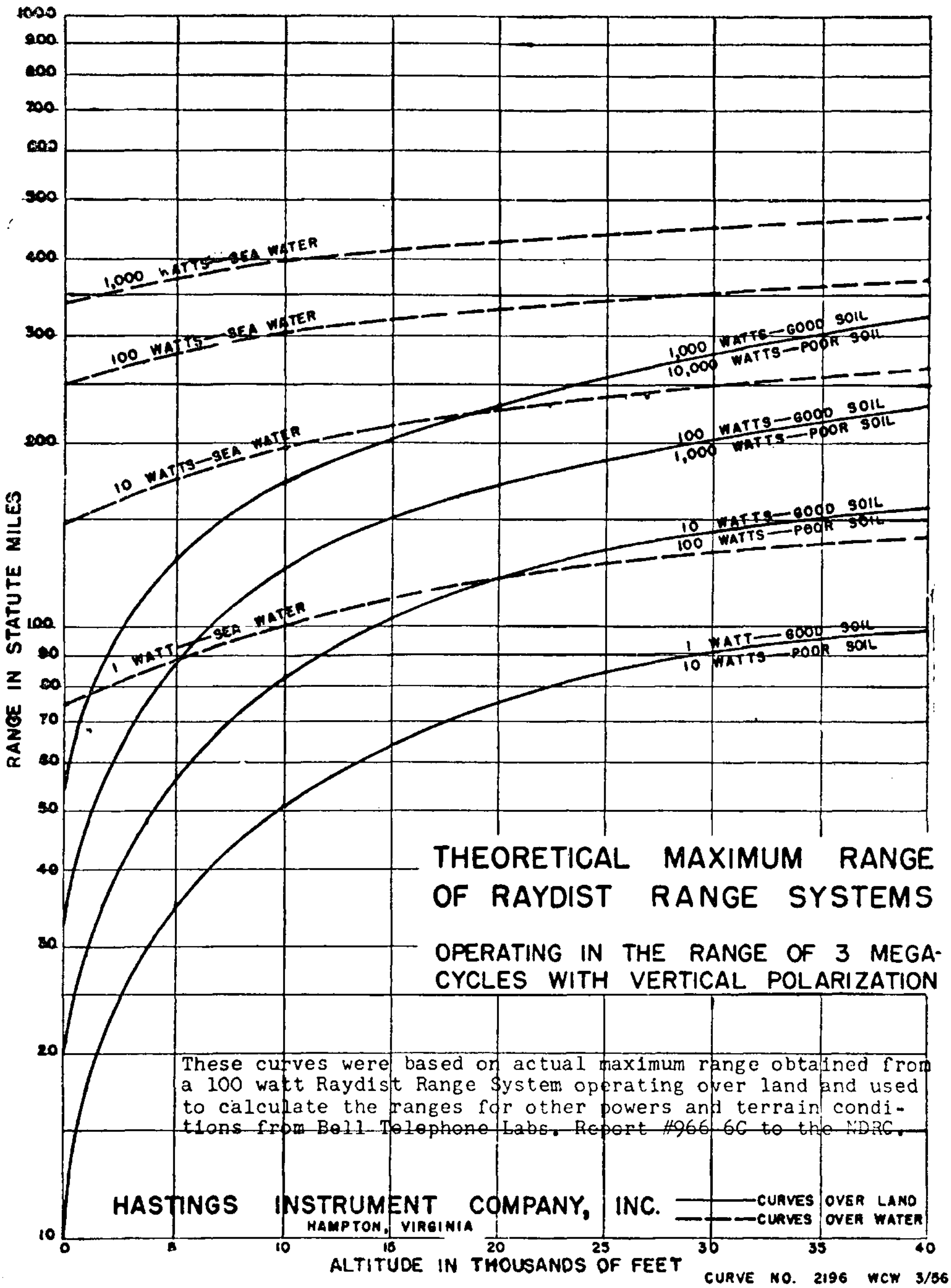

Fig. 7.
Theoretical maximum range of Raydist range systems.

The Hydrographic Office of the Brazilian Navy, using Raydist last summer for hydrographic work at the mouth of the Amazon River, achieved ranges beyond 54 nautical miles. This range could not be generally repeated, however, with the operating frequencies which were being used, one of which was above 30 megacycles. The newest Raydist Range Systems have overcome earlier shortcomings and have been operated at much greater ranges.

During tests of a recently delivered 100-watt Raydist Range System, the equipment was placed aboard a small motor launch and the position of the vessel continuously plotted as it left Hampton Roads and proceeded up Chesapeake Bay and then returned. Figure 2 shows the Motor Launch ROMAR in which the Raydist Range equipment was installed, and Figure 3 shows the interior of the cabin containing the Raydist indicators, recorder and the chart on which position was continuously plotted. Position determinations were, in general, made at five-minute intervals and plotted on a standard nautical chart of the area. Figure 4 is a photograph of this chart showing the plots of the position data.

The arrangement of the shore based stations was such that the greatest portion of the transmission path was over land. Figure 5 shows one of these stations. It was found that during both day and night the range of satisfactory operation was in excess of 50 nautical miles, even with these overland paths. It is believed that a typical 100-watt relay station such as the one shown here would give reliable over-water ranges seaward from the coastline considerably in excess of 100 miles, although the small craft used during these tests was not sufficiently adequate for sea travel to verify this fact during these tests.

Other range tests of the newest Raydist Range equipment have been conducted with a DC-3 aircraft flying at low altitudes. During these tests an airborne magnetometer for measuring magnetic data and an airborne scintillometer were installed in the aircraft, together with the Raydist equipment. Thus the aircraft had continuous recordings of magnetic data, radiolocation data and position of the aircraft, so that complete automatic data were obtained which would allow plotting of contour maps of this information of the area being covered. Flying 75 nautical miles from one shore station and 80 nautical miles from the other, the aircraft made a very low pass and found the Raydist signals still strong at low altitude and the equipment operating perfectly. No attempt was made to determine maximum range, but it is certainly safe to assume from the quality of the received signals that the maximum range would have been well in excess of 100 nautical miles at very low altitudes, and greater with increased altitude. This aircraft also followed a predetermined path from a special Raydist indicator installed in the pilot's compartment. Somewhat similar tests were performed the previous summer with a 10-watt Raydist Range System in co-operation with the United States Geological Survey and are described in Reference 7.

A strip chart record of the Raydist phasemeter indications of the distances to two points on shore with the aircraft operating at ranges of 75 and 80 nautical miles from the two points, respectively, is reproduced in Figure 6. Each sawtooth represents a change in distance to each respective shore station of approximately 119 feet at the particular frequency being used. Each dial division on the indicator represented 1.19 feet.

It was not possible, due to insufficient time and to safety limitations, to obtain maximum range data in the North Atlantic during the period when these tests were being run. However, from the overland maximum range data obtained during the tests and considering the propagation curves from the Bell Telephone Laboratories

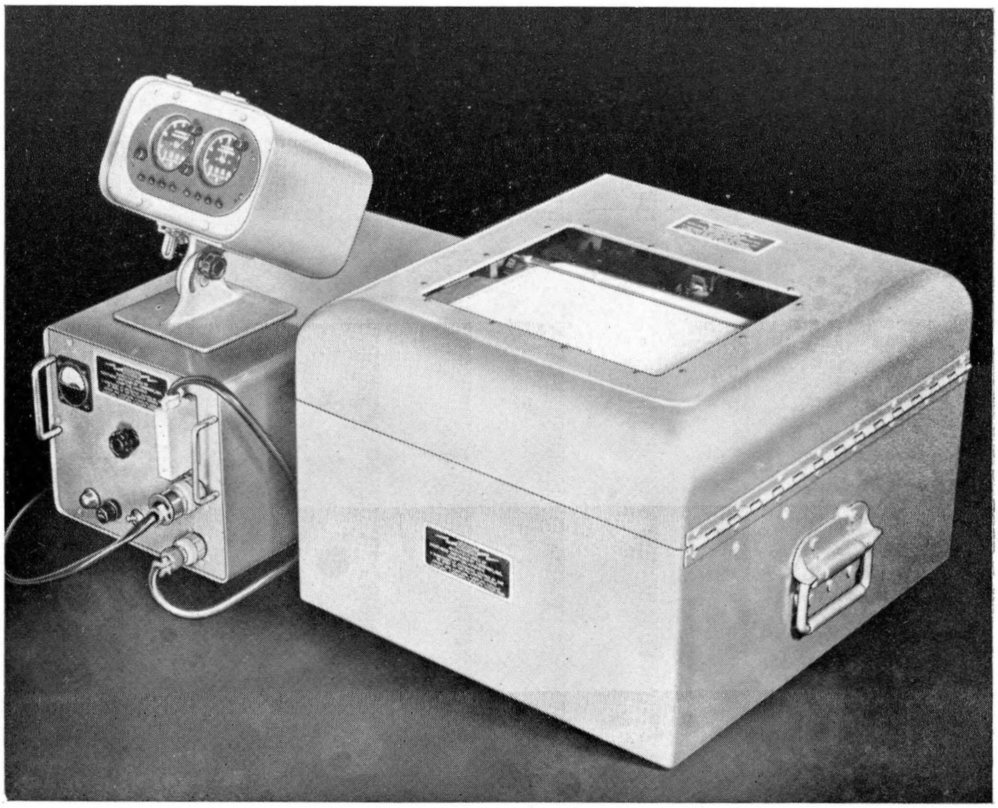

Fig. 8.

New miniaturized dynamic phasemeter which materially increases the accuracy of Raydist, particularly under conditions of high noise level. Each dial indicates directly the range to its respective base station. The plotter automatically furnishes a continuous direct indication and record of the motion of the craft. These units were both successfully used in aircraft as well as on the « Romar » tests.

Report 966-60 to the National Defense Research Committee, Division 15, it was possible to make a good approximation as to what the maximum ranges should be at different powers and with different types of terrain. The effects of the power output of the antennas, the altitude of the airplane, and the type of terrain of the transmission path, upon the maximum theoretical operating range to be expected from a system with the two base stations located at approximately sea level and the mobile station in an aircraft, are shown in Figure 7.

In general, the Raydist Range Systems are furnished in either 10 or 100-watt models. The 10-watt System is designed for close-in, short-range work and can be operated reliably up to 20 miles from the shore stations. This system is designed for portability and ease of installation. The components are small, light and easily transported from place to place. The antennas are short telescoping masts or dipoles and are easily erected.

The 100-watt System is designed for a more permanent installation and employs higher powered components and larger antennas to obtain greater operating ranges. The towers used for maximum range with this system are prefabricated, sectionalized, guyed aluminium masts from 60 to 100 feet high. The individual components are designed similar to the lower powered system to retain the feature of mobility.

Each system uses a pair of CW frequencies approximately harmonically related between 1.5 and 5 MC. In addition, two other link frequencies are used to return the signals from the shore stations of the vessel or aircraft. In the 10-watt System, these return links are frequency modulated signals in the 30-42 MC band. FM is chosen because these frequencies are easily obtained, the antennas are small and range of operation with the 10-watt System is not critical. With the 100-watt System, these links are low frequency amplitude modulated signals between 1.5 and 5 MC. The lower frequencies permit operation well beyond the optical horizon and permit the greater ranges. In both systems, the position display and recording is identical. Position, in terms of two ranges, is displayed directly on the two dial counters and the same data is recorded continuously on a strip chart recorder. Position plotting is simplified, since it only involves the intersection of two compass arcs corresponding to the known ranges.

Not only have the Raydist Systems been greatly improved, but many of the individual equipment units have been improved and miniaturized, as shown in Figure 8.

The new phasemeter, the very heart of the precise Raydist positioning system, has many advantages over the previous unit. Tests show that with good signals it has three times the accuracy of the previous unit, and even greater accuracy improvement with poor signals because in the new model the accuracy is less affected by signal strength. It should be vastly superior under thunderstorm conditions. The new phasemeter unit reduces the number of tubes by eight for a complete two-dimensional unit. In the new Raydist Dynamic Phasemeter only 80 watts of electrical energy are required for its operation in comparison with 165 watts for a two-dimensional old type unit. The new phasemeter is capable of following much more rapid changes in phase, and has much less lag than the previous unit. The phasemeter unit weighs only eight pounds, less than one half the weight of the previous unit, the space requirements are approximately 25 % of the former unit, and in addition to having greater accuracy, less space, less weight and less power requirements as mentioned above, this unit has approximately ten times the torque on the shaft and therefore is capable of driving counters, potentiometers, digitalizers and devices for which the previous units were not practical, except in the microtorque range.

The new Raydist Plotter, which is used as an accessory, is a small automatic plotter designed primarily for aircraft applications, and allows the pilot of a ship or aircraft to continuously see his position plotted directly on a chart, a feature which is of great assistance to the pilot in evaluating the data obtained with Raydist. This is a big advancement over the previously delivered automatic plotting boards used with Raydist, which by their size and weight were necessarily confined to use aboard ships or at fixed ground locations.

These new Raydist Range Systems, together with improved miniaturized equipment, will unquestionably greatly increase the suitability of Raydist for aircraft and helicopter navigation and will offer many advantages over previous Raydist systems in the fields of navigation, tracking, hydrographic surveying and positioning of ships and aircraft, where Raydist has already achieved wide recognition.

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