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REPORT OF

SURVEY OF AERONAUTICAL RADIO TECHNICAL DEVELOPMENTS IN EUROPE AND ACTIVITIES IN CONNECTION WITH THE THIRD WORLD CONFERENCE OF RADIOTELEGRAPH EXPERTS.

by

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SUMMARY

This report is the chronological record of the writer's movements, activities, and observations in connection with an official trip as United States delegate to the Third World Conference of Radiotelegraph Experts for Aeronautics, which met at Paris, France, November 3 to 5, inclusive. Taking advantage of the opportunity thus presented to make a survey of European radio technical developments in the field of aeronautical communications, an itinerary was arranged and officially approved which included the principal centers of aeronautical radio research in France, Germany, Belgium, Switzerland, Holland, and England.

Through contacts previously made in the United States with visiting foreign representatives, the offices of our local American Foreign Service officials, and personal acquaintances made at the Paris conference, I was everywhere accorded the utmost courtesy and consideration.

The results of the conference with comments thereon are contained in a report to the Secretary of State submitted jointly with Mr. Denis Mulligan under date of November 9, 1938.

The detailed technical descriptions of European aeronautical radio developments as contained in this report will further emphasize the inherent dissimilarity in the aviation communications and navigational systems in use on the domestic airways of the United States as contrasted with equipment design and operating procedures abroad. Radio directional aids everywhere have from the beginning been largely confined to the medium long waves because of their relative freedom from errors introduced
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by multiple-path wave propagation or "night effect." The United States was first to recognize the advantages of high frequencies for aircraft communications. This resulted in our present system of radiotelephone communications on chain or route frequencies. Abroad the tendency has been to concentrate all types of communications on the long waves and to use radiotelegraph signaling instead of radiotelephone. The sole exception in the latter case is a limited use of radiotelephone for itinerant aircraft in England. Several reasons for this may be cited: relatively short distances were involved; military considerations dictated a navigational system based upon direction finding rather than directional transmitting stations; there was comparatively little night-time operation; the air traffic load was relatively light; there were no designated airways and therefore ground aids possessing omni-directional characteristics were preferred; and of course language difficulties dictated the use of the international telegraph code rather than voice. As the volume of air traffic grew, direction finder stations which can only serve one airplane at a time had to be supplemented by local radio facilities which like our own range stations were capable of simultaneously providing guidance to all aircraft in the vicinity. Another recognition of the American system was forced by the establishment of empire routes, over the entire length of which for various reasons communication had to be maintained with home bases. The great distances thus involved called for high frequencies with appropriate propagation characteristics. Other similar tendencies which indicate a growing convergence of European and American practice could be mentioned, all of which demonstrate the growing recognition of the necessity for adopting as nearly as possible a uniform aeronautical communication system throughout the world. The Third World Conference of Radiotelegraph Experts for Aeronautics gave further evidence of this recognition when it designated a subcommittee on intercontinental air route communications.

In general, European aeronautical aids to navigation and communications were considered to be reasonably efficient, considering the limited number of frequencies available and the limitations of the system in use. Air navigation by means of ground direction finder facilities which telegraphically transmit observed data to the aircraft — once the primary system — is now definitely giving way to the use of radiobeacons especially of the omnidirectional type, and ultra-high frequency radio range localizers. There is a decline in the number of pilot requests for bearings although ground direction finders will undoubtedly continue as a valuable supplementary aid to regular air carrier operations and as an essential to military operations.

Omnidirectional beacons are rapidly being installed throughout Europe. There being no prescribed airways, aircraft may approach a terminal from almost any direction over whatever route may be appropriate under the circumstances at the time. For this reason, the Europeans have probably directed relatively more attention to terminal radio facilities than to intermediate aids. As a result, instrument landing systems consisting of approach localizers and markers are installed at almost every important airport in Europe.

What would seem to be unlimited funds are apparently available in Germany for new aeronautical radio developments. Several all-metal trimotored airplanes with highly trained instrument pilots are available for conducting tests under the worst possible flying conditions. Well equipped laboratories are operated by the Air Ministry for developing and testing new equipment.

England is spending huge sums of money on instrument approach systems inasmuch as she feels that this is the most important link in getting planes down safely at airports under bad weather conditions. Unsettled conditions in Europe have given this work tremendous impetus. It is of interest to note that the English have adopted the Lorenz instrument landing system for use until something better is available, while on the other hand, the French have tested and discarded it and are developing an improved system more in line with American principles. The Dutch have also discarded the Lorenz system and have developed a greatly improved localizer unit.

REPORT

Leaving Washington, D. C., on October 18th, I embarked at New York the same day and arrived in Paris at 1:05 p.m., October 26. On that date, I visited the laboratories of Le Materiel Telephonique and was shown through the vacuum tube department. Some very interesting tubes have been developed there for ultra-high frequencies. Some were designed to operate with water cooling. These tubes were approximately 2 inches long and capable of between one and 2 kilowatts output. A television transmitter was also on display in this laboratory. It had a very unique system of neutralization, the grids being tied to ground, and the filaments were excited. As a result, the control grids acted as shield grids, inasmuch as they were grounded and it was therefore unnecessary to use neutralizing condensers which are normally required. This arrangement permitted the use of large water cooled tubes capable of delivering approximately 40 kilowatts into an antenna at a frequency of approximately 40 megacycles. In other words, it is possible to operate water cooled tubes, or any tubes for that matter, at a frequency much higher when omitting the usual neutralizing circuits.

I also saw a very interesting rectifier of approximately 500 kilowatts capacity which utilized 12 mercury vapor tubes. The filament lighting transformers, filter chokes, and filter condensers were all immersed in one large tank of oil. The only external elements were large insulators mounted on top of this tank. They supported the sockets that held the mercury vapor tubes in place.

On October 27th, I presented my respects at our embassy and was welcomed by Mr. Reagan, the Commercial Attache'. I again visited the

L.M.T. Laboratories and met Dr. Busignies and Dr. Lewis. A trip was then made to Trappe, which is a small radio research development station owned by this company on the outskirts of Paris approximately 20 miles from the center of the city. At this station was a large open field where research on many types of direction finder equipment is conducted. The most interesting device observed at this station was a rotating radio compass, operating at ultra high frequencies on a rotating Adcock antenna made up of a pair of vertical doublets. The rate of rotation was essentially constant at 5 revolutions per second. The horizontal leads from the doublets were shielded and balanced two-wire lines. In order that the physical dimensions of the antenna system should be as small as possible, loading coils were used in the center of each vertical doublet and the spacing between the doublets fixed at approximately 5 feet. Proper balance of the system was obtained by extending a vertical rod on top of the rotating shaft between the two vertical antennas. This arrangement was necessary in order to reduce polarization errors which in turn greatly improved the accuracy of aircraft bearings taken at high angles of elevation. A motor was used to rotate the antennas and an indicator similar to that used in the Busignies compass was used to indicate the direction of the received station. This equipment operated on frequencies between 30 and 60 megacycles. The cardioid pattern was obtained by connecting a condenser from the shield of the antenna transmission line to one side of the input coil which is connected to the receiver. This arrangement provided the necessary vertical pick-up through capacitive coupling between the shielding and the vertical antennas, thus giving sufficient in-phase current to create the necessary cardioid pattern. The antenna was on top of a wooden tower approximately 30 feet high. The radio compass building was almost immediately below this tower. With this equipment, bearings taken on transmissions from aircraft were accurate to 1 degree at 60 to 70 kilometers at an altitude of 2000 meters. I was permitted to manipulate this compass and was able to obtain bearings on the Eiffel tower television transmitter operating on 46 megacycles, which were accurate to within 1 degree. In order to demonstrate the errors which would be caused by close-by hangars or reflecting objects, a large chicken-wire screen, approximately 15 feet wide and 25 feet long was gradually raised between two poles which were approximately 70 feet away from the antenna. As the screen was raised, errors as great as plus or minus 3^{o} were observed.

An inspection was made of another L.M.T. ground direction finding Adcock system developed for frequencies between approximately 150 and 1500 kilocycles and used at many stations throughout France. Each antenna consisted of a mast approximately 40 feet high and supported by guy wires which were broken up with bakelite insulators. Symmetrical ground screens were located at the base of each of these antennas. The base of each antenna mast rested on heavy springs on top of porcelain insulators. The springs between the antenna and the insulator prevented breakage of the insulator under conditions of mechanical vibration. Five of these masts were disposed in similar arrangement to our standard 5-tower TL transmitting station antenna systems in the United States. However, the spacing between these antennas was considerably less, being only approximately 300 feet between diagonal antennas. In order to balance the pick-up from each pair of antennas, arrangements were incorporated to increase or decrease the height of each antenna. At the base of each antenna, a shielded transformer was installed to couple the energy from the antenna to a balanced 2-wire shielded radio frequency line. The radio frequency line employed a dielectric of high grade paper between the conductors which made its cost very low. However, this type of line demands a very careful installation procedure, inasmuch as any leakage at the ends of the cable permitting moisture to enter will render it useless. All joints and terminals of the cable have to be very carefully sealed. One of the outstanding features of this equipment was the possibility of utilizing remote control which permitted the location of the complete Adcock array on the airport at a distance of as much as 3000 feet from the goniometer and receiver location. Received energy was fed through the cables without excessive loss and bearings could be made under such conditions without any additional error. The electrical loss in these cables was 3 to 4 db per kilometer. The goniometer used with this system was very simple in operation and the nulls obtained with one of these remotely controlled direction finders were excellent. The method of determining sense was to note whether the goniometer dial had to be rotated to the right or to the left in order to obtain a minimum after the sense antenna was connected in the circuit. If the goniometer had to be rotated counterclockwise to obtain a minimum after connecting the sense antenna, the transmitting station would be on the bearing observed without the sense antenna. However, if the reverse were true, that is, if the goniometer had to be rotated clockwise to obtain a minimum after the sense antenna was connected, then the direction of the station would be 180° from the bearing observed before connecting the sense antenna.

A portable Army Adcock system was also observed. The equipment was installed in an enclosed truck with the antenna system mounted externally. It was designed to operate on the same frequencies as the system just described. It was impossible to obtain access to the inside of the truck due to the military status of this equipment, but it is understood that the apparatus was identical to that used with the Adcock system already described. It could be seen that the antennas actually were identical to those first described, except that they were designed for portability and were arranged for easy erection. The truck that housed the goniometer and receiving equipment also carried an engine-generator power supply which furnished the power necessary for the portable direction finder station. This entire equipment including antennas could be installed by three men in approximately five hours' time. This system is designed to supplement the standard aeronautical direction finder system used throughout France.

An inspection was also made of a direction finder loop and vertical antenna connected to a cathode ray tube. The pattern obtained was a very thin ellipse which pointed directly to the bearing of the station received. Bearings with this arrangement could be read within 1 degree. A very fine scale was placed directly over the end of the cathode ray tube. This scale was illuminated indirectly by projecting light through a window slightly in front of and to the side of the cathode ray tube on a glass set at 45 degrees to the axis of vision. The outstanding characteristic of this type of direction finder was the ease with which the bearings could be read on either telegraph or telephone stations.

On October 28, I met Mr. Mulligan and visited the Embassy. We conferred with Mr. Murphy, First Secretary of the Embassy, the Military Attache', the Naval Attache', and Mr. Hugh Fullerton, Chief of the Economic Division. Mr. Mulligan and I then visited the laboratories of L.M.T. again, and saw a model of the Lorenz blind landing system. By means of various push-buttons, this unit demonstrated the instrument indications which would be observed in the cockpit with the airplane in various positions above and below the glide path, to one side or the other of the path and directly on the glide path. This model has been carried out in considerable detail and has proved to be a very valuable aid in demonstrating instrument landing to both pilots and laymen. A discussion was had with Dr. George Lewis Director of European I.T.&T. Laboratories, Dr. Deloraine of the L.M.T. company, and Mr. Mulligan, in connection with the results obtained by the French Air Ministry on the curvature of the Lorenz glide path using vertical polarization and the new type of horizontally polarized glide path designed by Dr. Perroux of the L.M.T. Laboratories. These results indicated that horizontal polarization gave a flatter glide path than was obtained with vertical polarization. An average of all the flights taken by the Air Ministry indicated that Perroux's antenna gave a slightly straighter glide path than that used in the United States. However, the path was still definitely curved. Perroux's antenna differed from the conventional antenna in that one horizontal element was fed 180 degrees out of phase with another one directly over it so that a minimum of energy was transmitted along the localizer path. Mr. Mulligan and I were invited to inspect the L.M.T. instrument landing at Troyes the following day.

On October 29, we proceeded with Dr. Lewis to Troyes. Here we met Dr. Perroux, Dr. Lair, and other engineers, who described the system which they had developed for the Air Ministry in France. The localizer antenna consisted of two vertical antennas, one half wavelength apart, excited approximately 170 degrees out of phase by means of balanced two-wire open lines. In the center of each antenna was an inductance coil. One inductance coil consisted of four turns, whereas the other inductance coil consisted of five turns. Across the two inside turns of the latter inductance, the contacts of a relay were connected for shorting them. By opening and closing this relay, a course was produced perpendicular to the plane of these two antennas. It is apparent from the description given that one antenna is slightly inductive when the contacts are open and the same antenna becomes slightly capacitive with the contacts closed. The magnitude of this reactive component controls both the sharpness of the course and the field strength obtained along the course. The other antenna is normally tuned to zero reactance. Courses as sharp as one-tenth of one degree in width may be obtained. In Europe, it is standard practice to key all radio ranges with dot and dash signals in order to provide for both visual and aural indication of courses. The maximum amplitude ratio of dash to dot and dot to dash occurs approximately 12 degrees off course on either side of the course. A course width of one-tenth of one degree has been pronounced by French pilots to be too sharp and as a result the course width has been increased to approximately one degree. Measurements were made on the course width and observations were made on key clicks at a distance of approximately 400 feet from the antenna with a portable monitor receiver. Key clicks were negligible and the quality of keying was very good. The course was also much sharper than observed on the Lorenz instrument landing system when it was first tested in America. The major advantage of this localizer is that only one relay is required, thus minimizing key clicks and the difficulties involved in synchronizing two relays as used in the

Lorenz system. The major objection to this localizer was that at right angles to the main course, there were two very broad courses which were approximately 30 degrees wide. It was noted that there was a small displacement of the main courses from a true reciprocal relation due to the fact that the current in the resonated antenna was slightly greater than that in the antenna which remained reactive. This condition could have been eliminated by inserting a fixed resistance in series with the non-reactive antenna; however, this was considered unnecessary and was not used. Perroux pointed out that if it were necessary to have reciprocal courses, he would prefer to shunt the loading coil in the center of the antenna with a resistance rather than use a series resistance. This method was considered more desirable from the point of view of resistance failure, since an opening resistor would not cause a course failure, but would only shift the course one or two degrees. It was their experience when testing the Lorenz system at Le Bourget that key clicks were one of the major problems encountered and considerable time and patience were required to eliminate them. This system they claim gave no key click difficulties whatever even though the circulating current through the relay was approximately 10 amperes. One of the relays which had been in service for approximately a year carrying a circulating current of 10 amperes was inspected. It was found that this relay was in excellent condition and the contacts were still entirely satisfactory. This was contrary to what would naturally be expected, but apparently with proper design this is not a problem of any consequence.

The glide path was produced by another transmitter operating on a different radio frequency into a separate antenna. This antenna was located approximately 18 feet in front of the localizer antenna. It was their ultimate plan, however, to locate this glide path antenna to one side of the runway, with an arrangement such as was originally developed by the Civil Aeronautics Authority in order to completely divorce the two transmission systems, thus enabling each antenna to be designed to best advantage. The arrangement of the glide path antenna was as follows: Two horizontal doublets fed in the middle and located in a plane perpendicular to the localizer course were spaced a half wavelength and excited 180 degrees out of phase. In the same plane and one quarter wavelength below the lowest antenna was located a reflector. Another reflector was located one quarter wavelength behind the lowest excited antenna. The method of adjustment was to first tune the lower excited antenna to zero reactance as indicated by maximum current with the upper excited antenna disconnected. The upper excited antenna was then connected and its length adjusted for minimum current in a horizontal doublet located several wavelengths in front of the antenna at a height approximately 1/2 wavelength above the ground. In the particular installation observed, the upper antenna was approximately 5% shorter than the lower excited antenna. The two reflectors were approximately 5% longer than the antenna. The height of the lower reflector above ground was approximately 1/4 wavelength.

The two antennas were physically identical in all respects, but different modulation frequencies were used. The localizer was modulated at approximately 1150 cycles and the glide path transmitter at 2000 cycles. The localizer and the markers were all operated at a frequency of 33 megacycles; the glide path at 38 megacycles. This differs from the Lorenz system in which the localizer and glide path are both on 33 megacycles, inasmuch as the same transmitter is utilized to produce both the glide path and the localizer signals. The markers with the Lorenz system are operated on 38 megacycles. L.M.T. realizes the importance of having the markers on a frequency separate from the localizer and is considering steps to be taken to obtain a third frequency for the markers. In other words, they feel that the three fundamental transmissions required for instrument landing should be supplied on three different radio frequencies. In this respect, they concur entirely with American practice.

It was interesting to note that the transmission lines to both the glide path and to the localizer transmitter were made of 12-gauge open-wire transposition insulators at frequent intervals. The transmitters were located in a building approximately 30 feet behind the glide path antenna. The tube line-up used in the transmitters was rather unique in that the fifth harmonic was taken directly off from the first oscillator tube and sufficient power was obtained therefrom to drive a 304-B, which was the type of tube in the first doubler stage. A tube very similar to our 807 was utilized in the crystal stage. Two 304-B doubler stages were next in the sequence after which came a 304-B push-pull fundamental amplifier stage driving two large triode output tubes which delivered approximately 400 watts to the antenna. All tubes in this transmitter were said to give at least 3000 hours of life. The frequency of the crystal used was 3.8 megacycles. The crystal oscillator circuit was described as one which gave "partials". In other words, there was no circuit in the oscillator stage which was tuned to the fundamental of the crystal; the plate circuit was tuned to the fifth harmonic directly. A copy of this circuit was obtained for comparison with circuits which we are now utilizing. It should be mentioned in this connection that two watts output was obtained from the fifth harmonic of the first tube. The high voltage rectifiers used in both transmitters were selenium tubes and have been in operation for approximately two years without any difficulty whatsoever. It might be mentioned that the transmitter has been left unoperated for several months at a time under relatively damp conditions. When months later the transmitter was again placed in operation, no difficulty has been encountered due to moisture on the disks of the rectifier. Experience with these rectifiers indicates that they are very conservatively rated. The secret of their success is partially due to this fact. In other words, the only possibility of damaging such a rectifier is to subject it to excessive overload for a prolonged period or to apply excessive voltage across the rectifier elements.

The marker beacons we saw were very ingenious in their construction and the results obtained with them were excellent. The thickness-to-length ratio of the field pattern was approximately 6 to 1, which makes this design of antenna ideally suited for fan markers and inner or outer markers of instrument landing systems. Briefly, the antenna may be described as consisting of a fan marker similar to our own with another set of antennas one-half wavelength above the lower antennas and fed 180 degrees out of phase therewith. The arrangement devised to accomplish this consisted of four symmetrical loops in line in the same plane, each having a physical dimension of one-half wavelength on a side. The two central loops were excited through connections to the inner lower adjacent corners. The mutual impedance between the inner and outer loops resulted in voltages being fed to the outer loops by the vertical members between the inner and outer loops which were adjacent. The dimensions of the pattern at an altitude of 450 feet were 525 feet in width by 3000 feet in length. The output of the transmitter and the sensitivity of the receiver were adjusted in order to give a maximum service height of 2100 feet. The maximum thickness occurred at 1200 feet where it was 660 feet. In normal flight the marker could be heard for approximately 5 seconds. Only one marker beacon indicator light was used in the cockpit; it served both the inner and outer markers. The French felt that one light was sufficient and that the visual difference between short dots and long dashes was enough to enable the pilot to differentiate between them as he passed over the inner or outer markers. This naturally simplified the equipment in that only one output filter was required, since the same modulation frequency was utilized on both markers. This differs from our practice in that separate audio frequencies are used in America for the inner and outer marker. Each has its own indicator light of different color, which gives the pilot a still more positive check as to whether he is over the inner or the outer marker. In this country, the pilot has three complementary possibilities of determining whether he is over the inner or outer marker. First, he has the difference in tone between the inner and outer marker, which may be heard in the headphones; second, he has different colored lights which operate only on their corresponding marker; and, third, he has the very rapid dots which are transmitted aurally and visually on the inner marker only and dashes which are transmitted only on the outer marker.

The aircraft receiving apparatus designed for use with the L.M.T. system was interesting. It consisted of a single chassis on which were mounted two superheterodynes. The total weight, including the power supply and indicating instruments, totalled only 30 pounds. The localizer superheterodyne receiver consisted of the following general tube line-up: one radio frequency amplifier, one first detector and converter, two intermediate frequency amplifiers, second detector, two audio amplifiers, a crystal oscillator, and a crystal frequency doubler. The glide path receiver was identical in all respects, except that only one I.F. amplifier was used and the first radio frequency tube was biased well back in order to greatly reduce its sensitivity. The localizer receiver had a sensitivity of one microvolt with automatic volume control. The glide path receiver had a sensitivity of approximately 3000 microvolts. It was noted that the glide path and localizer instruments were extremely lightweight, that is, much lighter than those utilized in America.

A control was provided on the output of the glide path receiver in order that the pilot as he passed the outer marker might within definite limits select the proper glide path. This was accomplished by means of a bridge circuit in order that the sensitivity of the glide path pointer will not vary at different settings. It should be pointed out that a shunt across the glide path meter would not be a satisfactory means of accomplishment, inasmuch as the sensitivity of the instrument would vary widely, depending upon the value of the shunt resistor as it is adjusted. For this reason, a bridge circuit was devised so that the sensitivity of the needle would remain constant regardless of the actual glide path flown. The circuit diagram of this bridge arrangement was obtained. Actual experiments proved this to be essential. With this receiver, it was possible to come in over the outer marker at any altitude between definite limits, say from 600 to 1000 feet, and descend at any rate which the flight characteristics of the airplane would permit.

A large number of glide path curves obtained with both the Lorenz system and the L.M.T. system were analyzed. It was noted that there was considerable variation between the Lorenz glide path and the L.M.T. glide path. This difference is attributed to the fact that vertically polarized waves were used with the Lorenz glide path, whereas the L.M.T. system used horizontally polarized waves. Many tests were conducted on the L.M.T. system by changing the phase relations between the upper excited antenna and the lower excited antenna and it was found that this resulted in slight differences in these curves. This indicated that when the field in front of the transmitting antenna was at a minimum, the path was slightly straighter. The very best condition which was observed followed the law of approximately $X^{1.9} = py$. This differs very slightly from the curves we have flown in this country which indicate that the equation which the glide path follows is equal to $X^2 = py$. In order to provide a further reference of these points, averages were computed. The following values are given for horizontal polarization utilizing the phase difference between the upper and lower excited antennas which gave the straightest glide path with the vertically polarized Lorenz system.

Polarization	X	Y
Horizontal	4600	230
	2800	106
Vertical	4600	223
	2800	90

X = the distance from the antenna to a point immediately beneath the airplane.

Y = the height of the airplane.

Two methods of observing the glide path were used. One utilized a recording barograph. When directly over the inner and outer markers, the graphic recording was marked. The plane was then flown down the glide path and the curve obtained on the barograph indicated the curvature of the glide path directly. This method is not considered sufficiently accurate due to lag in response of the barometric recording instrument. Another method which is considered to be much more satisfactory is to fly at a constant altitude, intercept the path and observe the point on the ground over which the plane was at the instant the path was intercepted. A bomb sight is used in noting this point as indicated by the exactly horizontal position of the indicating instrument pointer. In addition to noting the points at which the horizontal needle is centered for given positions of the airplane, points are taken for other positions of the glide path pointer so that the glide path can be calibrated throughout its entire range for various positions of the indicator. In other words, curves of altitude against distance are plotted for various receiver outputs. This gives a complete graphical indication of the limits and tolerances which would have to be established in order to clear all obstructions along any particular glide path.

October 30 and 31 and November 1 were spent preparing for the sessions of the Third World Conference of Radiotelegraph Experts for Aeronautics. On October 31, a visit was made to Mr. Giusta of the Air Ministry of France, who has charge of all equipment for use in all government aircraft. It was learned that all fighting airplanes in the Army carry transmitters which weigh 28 kilograms and have an output of 260 watts. Apparently, Mr. Giusta's greatest concern at the moment was the combating of ice on aircraft. He was planning a trip to the United States in order to study the work done by the civil airlines in America in order to obtain information which would assist them in eliminating ice from military aircraft.

November 2, 3, 4, and 5 were spent in the sessions of the Third World Conference of Radiotelegraph Experts. The entire work of this conference is covered in a separate report to the Secretary of State by the Delegation of the United States, copies of which have been furnished the Authority.

November 6 was devoted to the preparation of that report and to the inspection of inventions which were in the process of development by Marcel Wallace. One was a 5-meter device using a cardioid pattern in conjunctions with a cathode ray tube. Another development was a receiver with cathode ray tube for obtaining simultaneously three bearings from three different radio stations operating continuously on three different radio frequencies. Neither of these developments was in operating order and so could not be demonstrated; therefore, it was impossible to obtain an idea of their practical value. I also saw an ultra-high frequency panoramic receiver which operated on 5 meters. A rotating condenser operated by a motor swept the R.F. amplifier, the first detector, and the oscillator simultaneously through a given frequency range while a cam on the same motor shaft operated a switch in synchronism on a cathode ray tube so that the output of the receiver ignited the cathode ray tube only half of the time. This was necessary in order to give a sweep in one direction without a confused picture on the cathode ray oscillograph. A model of a radio compass was observed which worked on the principle of connecting first one loop and then another to the input of the receiver. A synchronous motor accomplished the switching through a pair of contacts which alternately connected first one then the other of two cross loops to the input of a receiver. By mechanically linking this arrangement up with the output of the receiver, it was possible to operate a cathode ray tube which would indicate the direction of the station. This development was not yet complete, but showed considerable ingenuity in application of the idea.

On November 7, I visited Villacoublay which is a military airfield just outside of Paris. Permission for this visit was obtained by our

Military Attache' at the American Embassy. I observed a Morane-Saulnier pursuit ship with a complete ultra-high frequency transmitter and receiver. Both the transmitter and receiver had a continuous frequency range from 5 to 10 meters. Ordinarily they were adjusted to operate on two particular predetermined frequencies which could be remotely selected in flight. The transmitting antenna protruded from the top of the fuselage about 2½ feet. The receiving antenna was projected from the bottom to a length of approximately 2½ feet. The antenna underneath the ship had to be retracted when the wheels were let down for landing or takeoff. This was accomplished by mechanically arranging for the antenna to be tipped up against the bottom of the ship when the wheels were in landing position, and for extending the antenna when the wheels were retracted. This entire equipment weighed approximately 38 kilograms. In this aircraft which was equipped for instrument landing, it was observed that the marker beacon antenna was placed inside a piece of streamlined bakelite or wood which was affixed to the bottom of the ship approximately 1½ inches below the steel members. This gave an antenna post entirely protected from ice and one which presented very little drag on the aircraft. It was mentioned that their tests had proved this antenna to be entirely satisfactory.

I inspected also two complete two-way ultra-high frequency communication stations which were contained in trucks and trailers and entirely portable. They were used for communications from ground to plane on ultra high frequencies. One of these complete equipments was made by Thompson-Houston and the quality of the workmanship was found to be very good. The manufacturer of the other equipment is not known. The truck carried the transmitting equipment and power supply for the entire unit including the receiver. Power and control cables extended from the truck to a trailer which could be located approximately 300 feet away. This trailer carried the ultra-high frequency receivers and microphone control apparatus. Instructions from the ground were transmitted directly from the trailer to the aircraft in flight. In addition, equipment was incorporated in the trailer for communication by wire line with a command unit which could talk back to the aircraft over wire line and ultra high frequency radio. The transmitter of one unit was operated at approximately 50 watts output, the other 200 watts. The receivers were superregenerators, which the French like very much for telephone communication with aircraft, but do not recommend for beacon reception due to their tendency to overload, giving the effect of broad localizer courses. Both the transmitting and receiving antennas were halfwave vertically polarized doublets arranged so they were entirely portable. In each of the trailers were located three ultra-high frequency receivers, which could simultaneously guard three different radio frequencies. In one of the installations, I saw a rubber covered flexible ultra-high frequency concentric cable of very low loss construction. It was made of flexible wire, cup-shaped beads, copper braid, and rubber covering and very highly developed and entirely satisfactory for transmission lines to portable antennas.

I was next shown a complete portable radio station for two-way communications with equipment for reception of frequencies from 30 megacycles to 30 kilocycles. The station was also equipped with a rotatable loop antenna. Transmitting equipment covered both low frequencies and high frequencies. They were located in a truck together with engine generator equipment; the receivers were carried in a separate trailer after the manner of the ultra high frequency units previously described. There was demonstrated also a very ingenious portable mast which could be raised in about one minute to a height of approximately 60 feet. The antenna consisted of about six sections of concentric tube which extended itself by means of compressed air forced in at the bottom of the hollow mast. At three different points, sets of three guy wires were located. When it was desired to raise the mast, a portable electric air compressor, powered from a 110-volt portable line, was brought to the bottom of the mast. The compressor forced air into the bottom of the antenna and the mast automatically projected itself upward. Each of the sections was approximately 10 feet long. This mast was used to support the long wave antenna. To dismantle the mast, an air valve was opened and the sections slowly telescoped without any attention.

Probably one of the most interesting things I saw while in Europe was the demonstration of the S.A.D.I.R. ultra-high frequency direction finder which covered frequencies from 30 to 60 megacycles. This equipment was installed in a trailer. It consisted of an ultra-high frequency ganged superheterodyne receiver with tuning range from 30 to 60 megacycles. It incorporated a push-pull tuned radio frequency amplifier, a push-pull first detector, and a single ended oscillator, all of which employed the 954 type of tube. Its two intermediate frequency amplifiers, second detector, and two stages of audio amplification all used metal tubes. The power supply was external to the receiver and operated from a 50 cycle, 110 volt power supply. The antenna was very unique, consisting essentially of an Adcock in one plane, except that each of the dipoles was a U-shaped antenna. The entire Adcock system could be rotated in the same manner that a loop is rotated. The distance between the vertical U members of the Adcock was 4 to 5 feet. The separation between the two sides of each U was approximately

5 inches. Between the two ends of each U section were connected a transmission line and a resistance which was roughly equal to the surge impedance of the line. This in effect gave for each antenna circuit a complete loop which was terminated at its middle portion by a series resistance. The antenna system operated exactly as any null type direction finder. In order to obtain a sense indication, a bellows located on the main shaft actuated a pneumatically operated relay which closed a pair of contacts in one of the antenna junction boxes. This distorted the pattern and by rotating the loop either to the right or to the left it was possible to determine which null gave the true station bearing. The claim made for these special U-shaped antennas was that much greater accuracy could be obtained should it be necessary to locate them relatively close to reflecting objects such as hangars, trees, or houses. This equipment was set up in a field approximately 400 feet from a metal hangar, yet an accuracy of within approximately 1 degree was obtained when taking bearings on the Eiffel tower several miles away. Many flights with Army aircraft indicated that accuracies of plus or minus 1 degree could be obtained from bearings on their transmissions up to distances of 100 to 150 miles depending on altitude. The Air Ministry officials spoke very highly of the results obtained with this equipment. They of course realized that it is still important whenever possible to keep the equipment located relatively clear of surrounding objects.

Although conditions obtaining when I was present were not exceptionally favorable in that there were many hangars and buildings at distances of 400 to 500 feet away, the bearings obtained were very sharp and could be easily read on the scale of less than plus or minus 1/2 degree. It was mentioned that before I arrived they had picked up a station in Czechoslovakia and also one on Long Island. They had neglected, however, to obtain the bearings of these signals. The mechanical construction of this equipment which was manufactured by S.A.D.I.R. was considered to be excellent.

The next demonstration was of a rotating radiobeacon of the two-course type which in our terminology would be described as an omni-directional radiobeacon. This equipment was also manufactured by S.A.D.I.R. The results obtained with it were most interesting. The principle of the rotating range consisted of producing alternately two partial cardioids keyed with dots and dashes respectively. These patterns were rotated clockwise at a constant rate of one revolution per minute. Associated with the receivers employed with this system is a standard stop watch which has 15 seconds converted to 90 degrees, 30 seconds converted to 180 degrees, and 45 seconds converted to 270 degrees. When the course having the dots on the right is in the true north direction, the modulation frequency is changed from 1000 cycles to 2000 cycles for about one second. At this time, the stop is started. When the extremely sharp course formed by the interlocked keying changes from dashes to dots, the watch is stopped and the bearing is read from its dial directly in degrees. The course is very sharp and the bearing may be taken within approximately one-degree accuracy. With the superregenerative receiver which is normally used in aircraft, the detector if overloaded gives what appears to be two very broad courses at 90 degrees to each of the sharp courses. Each of these courses is approximately 40 degrees wide as compared to the two sharp courses which are approximately one degree wide. It is therefore a very simple matter to differentiate between the narrow and wide courses. Actually the ratio of field strength at these wide courses is approximately in the ratio of 1.06

to .94. This was obtained by reading a calibrated field strength meter which operated directly on the field strength received from the dash and dot. It should be mentioned that with an ordinary receiver the two wide courses would not be heard, but either the dash or the dot would easily predominate over the other signal, thus giving only the two sharp courses during one complete rotation of the transmitting antenna. It might be mentioned that the two major reasons why superregenerative receivers are so popular in France is that the signal to noise ratio is very good and that they are very light and inexpensive. The mechanical construction of the rotating radiobeacon was similar to the direction finder except for the dimensions of the rotating Adcock and the terminating resistors which were used in the vertical U-shaped loops. In addition to what might be designated as the major Adcock, there was another Adcock located perpendicular to the plane of the former, which consisted of two shorter and more closely spaced Adcocks. The major Adcock consisted of two antennas approximately 10 feet apart and U's which were approximately 6 inches between the vertical sections. The shorter Adcocks were approximately 6 feet long and roughly 5 feet apart. This equipment was all rotated on top of a small steel mast approximately 20 feet in height. The actuating motor and gear box were located at the bottom of the tower rotating the entire antenna structure at 1 r.p.m. Mounted on this vertical shaft was a cam which was used to transmit the reference signal consisting of the one-second change in audio frequency at the instant the proper course is lined up with magnetic north. The object of the major Adcock was to produce a figure-of-eight pattern whereas the two smaller antennas were used to produce an elliptical pattern 90 degrees out of phase with the major Adcock; the combination of the two produced a partial cardioid. The inner antennas were of course tuned 90 degrees out of phase with the major Adcock. A relay was mounted in a box at the top of the tower which reversed the patterns by reversing the phase of the current in the major Adcock antenna. The relay was d.c. operated. A single conventional 200-watt modulated transmitter was used. The transmitter with its power supply was installed in a trailer located approximately 35 feet from the base of the antenna. Tests conducted on this equipment showed that the presence of the trailer did not distort the pattern, thus indicating that the U-type antenna construction represented in this equipment was of definite advantage in obtaining accuracy. The r.f. output of the transmitter was fed to the antenna through a two-wire shielded transmission line. The construction was of 7/8-inch thick-wall copper tubing in the center of which were located two No. 18 conductors. These wires were held in place by a white substance which was said to be manganese. The transmission loss was rather high, but the length of the line was relatively short, so the efficiency was still entirely satisfactory. It was necessary in their work to use balanced shielded lines in order to achieve accuracy. This line could be bent on approximately a 5-inch radius. At the bottom of the rotating shaft were two vertical contacts which dipped into two concentric cups filled with mercury. These stationary cups were connected to each side of the balanced concentric line from the transmitter. Connection of the vertical contacts to the junctions of the antennas was also through a balanced line. Every effort was made in the design of this equipment to preserve symmetry. My tests of this equipment were very satisfactory. With about two minutes training, I was able to obtain bearings in space with an accuracy of approximately one degree.

In the afternoon, a visit was made to Le Bourget airport. The direction finder station was first inspected. It was found that there were three separate direction finder units. Two of these units used 30-inch diameter loop antennas and the other was a very crude Adcock. The latter unit was used for obtaining bearings at relatively great distances. The procedure was to take bearings on a plane when it was anywhere from 30 to 100 miles from the station. This was accomplished on one pair of low frequencies. When the plane came within the 30 mile area, the aircraft changed to another frequency and communicated with the loop direction finder units which kept him advised at all times of the order in which he would make a landing and also his position with respect to the airport. When the aircraft was ready to make a final approach to the field, it was then necessary for the aircraft to change its transmitter to still a third frequency and during the approach and landing, bearings were taken from another radio compass station located approximately 3000 feet from the edge of the field in line with the best approach to the field. The frequency used on the aircraft for distances between 30 and 100 miles was 333 kilocycles; in the air traffic control zone, or within a radius of approximately 30 miles, the frequency of 327 kilocycles was used. A third frequency was utilized for landing procedure. The precise frequency to be used depends upon the particular airport and country in which the landings are to be made. Communications from ground to plane were handled on transmitters and frequencies still different. At the time I visited the direction finder station, the ceiling was approximately 500 feet and there were five airplanes stacked up over Le Bourget waiting to get down. It took 25 minutes to land a Spanish airplane which was not very skilled in the so-called "ZZ" procedure. During this time the other pilots became very much concerned and requested that the Spanish pilot be sent out of the area so that they could come down without further delay. This request, however, was ignored because by that time it appeared that the Spanish pilot would get down successfully. This he eventually did after which the remaining pilots each took from 10 to 12 minutes to land under these conditions. The landing procedure, of course, depended entirely upon radio direction finding. The receiving station on the ground transmitted its observed bearings of the aircraft to the pilots by means of radiotelegraphy. The frequency of these reports was approximately every 30 seconds. In addition, it was the practice for an observer to stand outside the radio building and listen for motors of the aircraft in its final approach to the field. If his aural observations indicated the aircraft to be in proper position for landing, the pilot was informed by radio and advised to come on through and make a try for the field. If it appeared that the pilot was not lined up properly and could not make a landing, he was told to try another approach. The ZZ procedure on the whole was very very cumbersome from the point of view of the pilot, and also considering the large number of trained personnel required to furnish the aircraft such a continuous succession of bearings. It should also be mentioned that when fixes were required, bearings were coordinated over land wires with simultaneous observations from another station approximately 40 miles from Paris. The intersection of these two bearings gave the pilot a fix. All information was coordinated and transmitted to the aircraft by the Le Bourget receiving station. As fast as one plane would land, other aircraft would come into the control area and stack up over the airport. It was very confusing while the ships were in this area to differentiate between the sound of the motor of an airplane making a pass at the field and other aircraft at altitudes of 2000, 3000, and 4000 feet above the field. On one occasion, I saw an observer who listened for the Spanish airplane's motors mistake another airplane at a higher level for the one with which he was communicating by radio. The observer reported that the Spanish ship was over the airport and flying west, whereas he was actually some distance from the airport headed in approximately a southerly direction. This may have caused the pilot some concern, but probably not since he knew he was flying south and probably disregarded the report. However, it is possible that if the mistaken plane had been flying south also, considerable confusion would have resulted.

The accuracy of the Adcock system was claimed to be within one degree, but I very much doubt this, judging from the general appearance of the equipment. The antennas were made of 7/8" copper tubing, supported by power type insulators mounted on the side of wooden poles approximately 8 inches in diameter. R.F. transformers with the external appearance of standard outdoor type power transformers were located at the bottom of each antenna. Symmetrical screen grounds were used with each antenna. Parkway cable transmission lines connected the transformer and the goniometer. It was pointed out that they had difficulty during winter months due to moisture in the transformers which gave bad errors. However, they were replaced with new improved transformers which eliminated this trouble.

The low frequency Loth inner marker operating on 397 kilocycles was next inspected. Its antenna consisted of two loops in the vertical plane perpendicular to the axis of the low frequency radio range. The loops were approximately 150 feet in length, about eight feet high, and separated from each other by about 150 feet. It was later indicated by the Loth engineers that this arrangement gave better results than the ultra high frequency marker which they designed along similar principles. They said that it was very sharp and also very effective to the sides. It operated on the same frequency as the low frequency two-course range.

The low frequency range manufactured by Loth was situated at the other end of the field. It consisted of a single loop antenna perpendicular to the course and well supported in four directions to eliminate swaying. The central vertical antenna was located in a plane projecting through the center of the loop and perpendicular to it. This arrangement permitted zero coupling between the vertical antenna and the vertical component of the loop and made it possible to run the vertical lead directly into the transmitter without any horizontal component or coupling between antennas. The exact coefficient of coupling is not known although it is evident that two partial cardioids would be expected and that they would interlock to give on-course signals. Dot-dash keying is universally used in all range systems in Europe. This particular system is considered to be very good, although rather expensive. One advantage is that since the same antenna array is used for both the dot and dash signals, changes in antenna characteristics will not change the position of the course, but will merely change the sharpness or amplitude of the course.

The L.M.T. ultra high frequency instrument landing localizer was next inspected. It was identical in all details to the localizer already described as installed at Troyes. This equipment was situated in identically the same location as the Lorenz equipment which never had proved satisfactory due to an excessive number of multiple courses over a large area. It is quite apparent that these multiple courses were caused by a long row of metal hangars which extended along one side of the field. The nearest hangar was approximately 250 feet away from the antenna and at an angle of approximately 40 degrees to the range course. In order to eliminate the multiples, L.M.T. made the course very sharp and in addition had to erect a screen approximately 60 feet away from the antenna on a line to the closest hangar.

The plane of the screen was perpendicular to this line. The screen consisted of approximately 30 vertical wires spaced one foot apart. The wires stretched between a rope stringer at the top and bottom which in turn was supported by small wooden frames. The lower ends of the vertical wires were about eight feet above the ground. It was explained that the distance between the antenna and the screen was very critical. Using sharper courses decreased the multiples to only two. It took approximately nine months of experimentation to completely eliminate the multiple courses on this localizer. When the L.M.T. system was first installed, there were only two courses separated by about 2 degrees, whereas the Lorenz had several courses apread over a 13-degree angle. It was the elimination of this one additional course which proved so difficult.

The communications center was the next point of interest. In one room, teletypewriters handled all message traffic, consisting of passenger lists, load information, times of take-off and arrival, etc. In another room was a large number of teletype machines which handled only sequence weather information. Several radio receivers for reception of synoptic weather information were in operation in another large room. All synoptic weather transmissions were also made from this same room. Siemens tape printers were used for reception on the Berlin high frequency circuit. No diversity antenna arrays were used and it is believed that the radio printer is generally unsatisfactory.

On November 8, I paid another visit to the L.M.T. laboratories and went through the micro-ray laboratory where waves down to 1.5 cm. were under investigation. They were measuring all of the propagation characteristics. I also went through the crystal laboratory. It was interesting to learn that they were using "partials"; that is when the crystal circuit is tuned directly to the third, fifth, or seventh harmonic. Standard practice at these frequencies is to use the fifth harmonic. As much as 2 watts output is available on the fifth harmonic.

The design of the television antenna installed on the Eiffel tower was also investigated. It was said to have essentially uniform characteristics over a 3-megacycle band centered at 46 megacycles. Rods spaced about one foot apart were used to make low impedance antennas having broad resonance curves. A quarter wave transmission line connected the antenna to its reflectors. This reversed the reactance curve of the antenna with respect to frequency at the junction of the reflector and the quarter wave line to the antenna and also broadened the resistance curve. The array consisted of eight antennas and four reflectors arranged in a circle.

On November 9, I called on the Loth company. We discussed the long range beacons at Marseilles, where the service coverage is 600 to 800 miles at a frequency of approximately 140 meters. They were constructing two new units for operation at 75 meters for transoceanic service, one to be installed at St. Peirre and one on the coast of France.

We discussed range methods using a large circular carrier pattern and a small amount of modulated signal transmitted directively. Their apparent intent was to create patterns by shifting phase relationships. Their ideas for eliminating multiple courses were to make the course as sharp as practicable, to radiate as little energy to the side as possible, and to provide considerable signal in the on-course zones. We also visited the television transmitter at the Eiffel tower. The installation was obviously a difficult job, but very well done. Television pictures produced here were the best I had ever seen.

Leaving Paris at 11 p.m. on this date, I arrived in Lyon, France, at 6:30 a.m. the following morning, November 10. First an inspection was made of the airport facilities. They had point-to-point low and high frequency circuits for traffic and weather, and used the teletype for dispatching and ship notices. A Loth instrument landing system was located only 50 feet from the side of the steel hangar. The result was considerable scalloping of the field patterns, but only one course was present. Loth and Lufthansa pilots who flew the course claimed that key clicks were negligible.

A ground direction finder station had been installed here by L.M.T. It was of their U type previously described. The mechanical installation was good. The correction curve was irregular, as much as 15 degree variations being noted. A plane flying in each direction would encounter about a 4-degree difference. The general curves are the same. All transmitters were in one building and remotely controlled from the field.

Leaving Lyon at 11:50 a.m., I arrived at Geneva, Switzerland, at 3:20 p.m., and departed at 5:50 p.m., arriving in Berne, Switzerland at 8:20 p.m. the same evening.

The following day, November 11, I met Mr. E. Hofer, Director of Bell Telephone Manufacturing Co., and visited with Mr. Gsell, Director of Air Navigation. Later I visited the Berne Airport and had a talk with the manager. The airport was small, but had approaches from two sides, there being hills on the other two sides. A visit was made to the Berne Bureau, where I talked with the Assistant Director, who had also attended the Third World Conference of Radiotelegraph Experts for Aeronautics at Paris.

I left Berne at 11:20 a.m. on the same day and arrived at Zurich at about 1 p.m. There I also visited the airport. The manager was out of the city, but I talked with his secretary. I was shown through a DC-2 and a DC-3 airplane, and inspected the radio maintenance shops. I was permitted to inspect the radio equipment on all the aircraft then available.

Instrument landing radio equipment had been installed on all of them. The usual complement included marker receivers, together with two long wave transmitters (one spare), and two long wave receivers (cw - code). One receiver was a Telefunken visual compass, the other was capable of aural-null operation and non-directive reception. The instrument landing installation at Zurich was of the Lorenz type and was excellent. The course was broad with no key clicks. Landings were made with a 90-ft. ceiling, and occasionally under zero-zero conditions. With the ZZ system (loop), about a 300-foot ceiling is required. The loop station was located about one mile from the edge of the field. No Adcock antennas were used. I was informed that on one occasion, the loop antenna direction finder had given an erroneous bearing and a crash had resulted. The Telefunken impulse system is theoretically an excellent idea, but the power of the transmitter is insufficient for use beyond a few miles. The greatest improvement had been brought about by using a small fixed antenna on the plane and taking bearings with loops. Errors due to mountains were serious and averaged about 15 degrees. They varied with distance and height, even when taken in the middle of the day.

A spring shock absorber was always inserted in the antenna in order to eliminate breakage of weights. Long bakelite fairleads were used to prevent a weight from whipping and striking the ship.

Next I inspected the communication center which was located about one-half mile from the airport. Both low and high frequencies were used for communication. National type HRO receivers were preferred. Loop receiving antennas were used on long waves to avoid interference from stations in directions other than the one desired.

The following day, I left Zurich at 6:50 a.m., and arrived at Munich at 1 p.m. There discussions were had with Dr. Kramar and Dr. Hahneman of the Lorenz company, and I met Dr. Boetcher and Dr. Grunhart of the Air Ministry.

On November 14, a trip was made to the Munich airport where I saw the German "H" type Adcock antenna which is considered to be one of the best in Europe. This Adcock was built by the Navy, but improvements and modifications had been made by the Air Ministry. Null observations with it were very good. Telephone and power leads had been brought in to the center through chokes and filters. Symmetry is preserved in every detail. All transmitters were located in one large building. Four towers 300 feet high supported seven long-wave T antennas. Some used transmission lines and others did not. Vertical polarization was used on all low frequency antennas. A very ingenious type of variable antenna was noted, which permitted tuning by changing its physical length. It was used with a circular counterpoise mechanically operated by remote control.

All large towers were supported on insulators of a novel design not used in the United States. Our insulators are considered far superior both mechanically and electrically. These towers were not excited, but were insulated to prevent distortion of long wave antenna patterns. This transmitting station was about six miles from the present field which is about 15 miles from the new Munich airport.

A visit was paid to the new airport, which was on the east side of the city. This was indeed impressive. The field was approximately one mile in diameter. It had no runways, but had large taxi strips running around half the field. The control tower was 90 feet high. The administration building and hangars on the north side of the field were all inter-connected.

I left Munich at 3 p.m. for Leipzig, arriving at 9 p.m., November 14. On November 15, an inspection was made of a large 50 KW radio station at

Leipzig. I was interested in the 500-foot wooden tower and antenna design. The carrier was partially controlled by audio, that is, normal carrier without modulation was about 35 amperes and increased to 46 amperes with 70% modulation.

At the airport, an inspection was made of the straight line glide path antenna and transmitter. The weather was very poor with about a 300-foot ceiling and visibility of about one-half mile.

I left Leipzig at 8:10 in Air Ministry airplane and arrived in Berlin at 9 p.m. the same evening. Tests were made on the ultra-high frequency localizers at Leipzig and Berlin. Observations were made of the operation of the fan marker at Berlin at 15 kilometers from the airport and the outer and inner markers. The audio frequency absolute altimeter was used for landing. The maximum height at which it could be used was 240 feet. The accuracy, however, was very good. The method of taking readings was a large improvement over any acoustic altimeter in the United States. A non-directional radiobeacon station was located at the fan marker and was used to home on with the aircraft compass.

On November 16, I had a conference with Dr. Kramar on methods used to give simultaneous visual and aural range, and discussed their method of modulating the localizer. They used separate rotating condensers in the center of each reflector. It was pointed out that no cross coupling was obtained. Courses were produced by exciting the center antenna with unmodulated carrier, and effectively keying the reflectors with a rotary condenser which alternately throws the reflector circuits into resonance and anti-resonance at an audio frequency rate. Another possible method would be to modulate the transmitter alternately at 90 and 150 cycles and to mechanically open and close the reflector antennas. It was thought by Dr. Kramar that this modulation frequency was not high enough to keep the course indicator needle from wabbling. If the scheme were used, they would want to use 4000 and 5000 cycles. I pointed out the necessity of using only one motor with a shaft of bakelite and three slip rings in the center. This would preclude the possibility of any cross coupling and would permit the taking of independent patterns.

On November 17, I visited the Telefunken laboratories and saw the instrument landing receivers they were using. These were combined localizer and marker receivers. The circuits of each were designed to use three tubes with provision for plate and filament voltage regulation. The complete unit was very light in weight. One dynamotor supplied both receivers.

Several different loop compasses and the impulse type of receiver were also inspected. It was explained that the chief disadvantage of the latter receiver was that every airplane had to have an impulse keyer in order to obtain bearings. It was also pointed out that the idea was being abandoned because with such a system they could not take bearings on enemy stations or aircraft. For this reason, they planned to replace all impulse loop systems with Adcock antennas. Another disadvantage of the impulse system is that the power on the aircraft is insufficient to show the ground wave on the cathode ray oscillograph.

Several of the new designs of radio compass had a second loop at right angles to the loop on which the null was observed. This was for the purpose of taking bearings more rapidly. When sense was required after taking the null bearing, the loop was not rotated, but a sense switch automatically connected the second loop and the vertical sense antenna. By observing the weaker signal when the phase of the vertical antenna was reversed, the direction of the station could be ascertained.

At a nearby field experimental station, still another "U" type Adcock antenna installation was inspected. It consisted of four 90-foot insulated and guyed towers, two of which supported a vertical wire midway between them. The distance between the diagonally opposite towers was 240 feet. Bearings using this Adcock were very sharp. It was explained that "U" antennas were only successful in very moist ground of a uniform character. This station was located in marshy ground. The feeder cables had to be placed about 6 feet below the surface of the earth.

The goniometer design was investigated in detail. The rotor was wound on a core of powdered iron. The coefficient of coupling was about 70%. The stator coils were wound on a torroidal form of powdered iron. The permeability of the powdered iron was 45. The accuracy of the goniometers was said to be better than 1/2 degree, which takes into account all errors in the sinusoidal mutual impedance characteristics.

On November 18, I visited the Templehof Airport, and went through the new buildings which were then under construction, and also through the model shops. The most outstanding feature of the airport building was the tremendous cantilever construction of the shelter under which all loading and discharging of planes will take place. Twelve to fifteen 40- to 50-passenger planes may be loaded simultaneously under the same roof. Over three thousand separate rooms are available for various offices. Restaurants occupy most of the roof. Part of the Air Ministry will move to the airport as soon as it is completed.

I next visited Lufthansa and inspected a Fokker-Wolf four-engine 26-passenger plane. Engines were equipped with ignition shielding, and only two bladed propellers were used. Duplicate instruments were provided for the pilot and co-pilot. Standard aircraft radio apparatus was used and instrument landing equipment was included. A bakelite mast installed forward fulfilled many functions. It supported the airspeed pitot tube and another static tube together with the long wave "L" type antenna. The ultra high frequency antenna was inclosed inside the supporting mast.

An inspection was next made of the laboratories on the airport of the Air Ministry civil aeronautics engineering and testing department under Mr. Boetcher. The building was approximately 125 feet long, and 50 feet wide, and contained about thirty offices and laboratories. They had a larger and better supply of measuring and testing equipment than I have ever seen before. Everything was kept remarkably clean and neat.

A visit was next made to the "U" antenna located on the airport and purchased from Lorenz by the Air Ministry. It consisted of insulated self-supporting pipes about 40 feet high and spaced approximately 240 feet between diagonals. Around the bottom of each antenna was an insulated counterpoise. A very small box at the bottom of the antenna housed the shielded coupling transformer and the condenser which placed the transmission line at zero electric field. This was accomplished by inserting a condenser in series with the counterpoise and very carefully tuning. The transmission line was balanced and was contained in a pipe. The method used for balancing the antenna was to induce a modulated carrier voltage into the sheath of the transmission line and adjust the balancing condenser of the counterpoise to give zero audio output. This same procedure was carried out for each antenna. The Air Ministry reported that results were very satisfactory.

I next flew to Leipzig accompanied by Air Ministry and Lufthansa officials to check the straight-line glide path developed by Lorenz.

Several approaches to the field indicated the path was straight from any altitude down to about 90 feet, where it took a sharp curve to the point of landing. A rate of approximately 2 meters/second held the plane on the path down to about 90 feet. At this point, the rate of descent was changed to about 1 meter/second. Even though this rate of descent was maintained, the point of contact with the earth was short of the indicated point of contact.

I flew the Junkers three-engine test plane back to Templehof on instruments. I found the ship very stable and easy to fly. All instruments worked well, except the visual type of radio compass, which was sensitive in operation and generally erratic. This same difficulty was observed on all Telefunken visual compasses. The American visual compasses are far superior.

I had a very interesting discussion with Professor Von Handel of the D.V.L. with regard to ultra-high frequency propagation and rain static. He mentioned that they had tried to duplicate the experiments made in this country by United Air Lines, but said they could find no value of resistance in series with the bleeder wires that had any effect in reducing rain static interference. Their conclusions were that two tungsten points should be located in the bottom of the trailing antenna weight and permitted to trail behind the plane by at least 40 feet. After an optimum length was found, no appreciable improvement resulted from the use of longer bleeder wires. The antenna reel when used should of course be connected to the fuselage of the ship to drain of static charges.

Dr. Von Handel also pointed out that the two turn steel loops of very low impedance manufactured by Telefunken were very effective in reducing rain static when compared directly with an unshielded high impedance loop.

However, if the low impedance loop is shielded, a further slight improvement in the reduction of rain static will be noted, indicating the much greater necessity of shielding a high impedance loop.

I also visited Mr. Grobel of Lufthansa, and also the chief of trans-atlantic operations of that company. We discussed radio navigation as applied to the north Atlantic. They indicated that they were going to use direction finders on the ground at high frequencies up to 23 megacycles. They said that at the present time high powered broadcast transmitters are the most useful aids on the west side of the Atlantic. They indicated that they did not use our range stations chiefly because they couldn't be heard at great enough distances. They indicated that beginning next year, they are going to change their base from the Azores to Lisbon, Portugal. One trip each way a week is being made across the south Atlantic. Next year they will begin schedules calling for two flights a week each way. They have completed 28 Atlantic crossings from a base northeast of Hamburg in the Baltic sea to the Azores and to Port Washington.

On November 19, I visited the Lorenz company and discussed many problems relating to localizers, the straight line glide path, and the Fort Worth instrument landing installation. I also made tests of their simultaneous visual and aural range. The visual operation was excellent and the N-A operation very good except for ringing and rounding of dots and dashes which makes the signal less acute.

I visited the Air Ministry and had luncheon at the Flyers' Club with Dr. Koch, Dr. Zetzmann and Dr. Petzel's assistant. I also contacted our Naval Attache' and Captain Peel, his assistant.

On November 20, I left Berlin at 8 a.m. and arrived at Hamburg at 11:20 a.m. I met the Radio Operator in Charge and his assistant, Freddy

Dellith, and visited radio and communication facilities in the Hamburg area. The radio installations on the airport were identical to those at other airports. Teletype was used for messages pertaining to dispatching of planes. All weather information was handled by radio on low and high frequencies. Communication with planes in flight and direction finding was handled on low frequencies. An instrument landing system of the Lorenz type with inner and outer markers was installed along the best axis of the field. Along the same axis was also located a long wave loop type direction finder to assist aircraft in landing by use of the ZZ procedure. About two miles from the airport, a new long wave Adcock direction finder station was in the process of construction. This equipment was being installed by the Lorenz Company. The masts were approximately 50 feet high and 200 feet apart. Although the counterpoises were not yet installed, it was understood that the system would be a modified U with counterpoise similar to the system used at Berlin. The transmitter station was next inspected. It was located approximately 12 miles from the airport and was essentially identical to that at Munich, except that all transoceanic transmitters were also located at this point. The antennas were of several types including "V" antennas, vertical quarter-wave antennas, vertical multiple harmonic antennas, and horizontal half-wave antennas. The engineering principles represented in the antenna design for the high frequencies were not the best in that, with the exception of the V antenna, no directivity was used. It was obvious that they relied entirely on expensive high powered transmitters, 5 to 10 KW, to insure communication rather than the use of highly directive beams with lower powered transmitters. All of the approximately fifteen high and medium high frequency antennas were located on a plot approximately

800 feet square, which obviously is inadequate for such a number of directive arrays. The low frequency antennas on the other hand were very good in that they were strung from four 300-foot insulated towers located in a square approximately 500 feet on a side. The transmitters were excellent and their maintenance excellent. A 40 KW diesel engine generator plant was used for standby power in case of failure of the regular supply. Standby power was standard equipment in practically all stations visited in Europe. The radiophare, a non-directional carrier radiobeacon transmitter operating on low frequencies was synchronized by clock control installed as an integral part of the transmitter. This operated one minute on and two minutes off, sending in code the call letters of the station before and after each fifty-second transmission. This station was synchronized with two other similar stations operating on exactly the same radio frequency and arranged in triangular geographical relationship and separated by approximately 100 to 200 miles. This permitted aircraft to obtain their position from cross bearings without interference or retuning. This system was necessitated by the limited number of frequencies available for this service. It works fairly well when a plane is a considerable distance from each of the stations; however, when a plane is close to one of these stations, its pilot can easily pass over during the two minute off period without recognizing this fact which usually leads to loss of time and confusion. The system used in America where our simultaneous type range stations operate continuously and can be used for direction finding is considered far superior to the European part-time radiophare system.

The transatlantic receiving station which was located approximately 18 miles from the Hamburg field was next visited. I was very much impressed by this installation. Apparently expense was not a consideration in its design. It is estimated that this station cost approximately $500,000. Seven 300-foot steel towers of heavy construction were erected for the support of six highly directive horizontally polarized receiving antennas. The arrays consisted of either 24 or 32 half-wave doublets fed in phase and with a complete reflector system located one-quarter wave behind the antenna system, both of which were supported from the same tower by means of outriggers. Three antennas were used for the south Atlantic and three were used for the north Atlantic circuit. Four towers were used for the south Atlantic circuit with an antenna between each of them whereas three towers were used for the north Atlantic circuit. In order to support three beam antenna arrays between three towers, it was necessary to hang two arrays between one pair of towers. This was accomplished by placing an array operating on a higher frequency in between the antenna and reflector of the lower frequency. It was said that this system worked very well without inter-action. It is obviously a good economic arrangement in that it saves the cost of a tower and the cost of additional land. On three of the towers were located vertical receiving antennas with large circular grounded counterpoises which were used to check the gain of the arrays. The receiving station housed the operators, standby power plant and receivers. Weather reports were picked up from the various ships at sea and retransmitted by means of automatic equipment to the transatlantic planes and bases. All the transatlantic transmitters were controlled from this point. Constant watch is kept on each plane crossing the Atlantic.

The next point of interest was a new Lorenz high frequency U-type Adcock then nearly completed. It operated on frequencies from 3 to 20 megacycles. The four antennas were large tubular masts approximately 8 inches in diameter. They were mounted on very large corrugated porcelain insulators and self-supporting. Each was approximately 35 feet high and spaced approximately 30 feet between diagonally opposite masts. The receiving house consisted of a cement vault placed entirely underground. The apparatus therein consisted of a high frequency receiver and a goniometer. The null method was used to obtain bearings and an average of ten bearings taken in quick succession was considered the most accurate procedure. Several bearings were taken on 5-, 14-, and 16-megacycle bands and the accuracy appeared to be fairly good. Calibration curves had not yet been made; in fact, the transmission line cables had not yet been installed. The receiver was operated by storage batteries which were carried to the station expressly for this demonstration. The feeders from each antenna was buried 6 feet in the ground. The power and telephone cables which will be laid to the underground station will be buried 6 feet in the ground. The site selected was very flat and marshy. Wooden fences were used around this Adcock station as well as all other Adcock stations in Germany employing either low or high frequencies. This is the direction finder station which will be used to give bearings to aircraft flying across the north and south Atlantic and was scheduled to be completed in about three weeks' time.

On November 21, I arrived at Brussels, Belgium, at 11:12 a.m., and visited the Embassy there. I saw Mr. Lecomte, Director of Radio for the Belgian Air Ministry, and he personally conducted me to all the radio and communication facilities at the airport. They have a Philips two-course radiobeacon situated on the edge of the field and use it also for a localizer. A Lorenz instrument landing system complete with markers is also in the process of installation.

An inspection was made of the first receiving Adcock system installed in Europe. It was a Marconi U type. A wooden tower supported each antenna which was hung between the four legs of the structure. The feeder was a concentric line about one foot above the earth's surface and connected every few feet to a ground rod. The equipment was housed in a wooden building at the center of the plot and included a goniometer, sense antenna, receiver, storage batteries and chargers. Excellent results were claimed of the accuracy of this Adcock.

The transmitters were located together at a point away from the field and were operated by remote control from the administration building where all the operators and receivers were situated. The standard of equipment maintenance was considered generally poor in Belgium. Obviously, there was very little money available with which to buy new equipment and as a result, most of it was antiquated. Teletypes were located at the administration building for handling dispatch traffic. A loop direction finder was available on the airport to assist pilots in landing using the ZZ procedure. Mr. Lecomte also had charge of all the rotating beacon lights in Belgium, which only totaled twelve. Before leaving I paid a visit to the Director of Civil Aviation, Mr. Doumerie.

On November 22, I arrived in Antwerp, Belgium at 9:30 a.m. My first call was upon Mr. Thonus and Mr. Wielmans of the Bell Manufacturing Company. An inspection was made of their plant where some radio equipment was being manufactured for military purposes in the French Army. This was primarily portable equipment operating on ultra high frequencies between 30 and 60 megacycles. The power supply was obtained from a combination of batteries and hand generator. Low power transmission could be accomplished using the battery supply and for higher power transmission, the hand generator was employed. A number of radio telephone sets were also being constructed for fishing vessels. Typical broadcast receivers were also being manufactured along American lines of production. Many of the parts used in the equipment were of American manufacture. At this plant, large quantities of selenium rectifiers were assembled and sold for use in rectifiers for transmitters of all types, particularly broadcasting transmitters. Rectifiers of this type were employed with great success in all machine switching applications. After making a study of the reliability of selenium rectifiers in Europe which have been in use for about ten years with apparently indefinite life, I am of the opinion that we should adopt them for all future designs of ground radio transmitters. The only disadvantages of these rectifiers are their increased bulk, weight, and initial cost which are certainly overcome by the long uninterrupted and reliable service which they render. Like any other electrical device, however, they should not be overloaded.

The laboratory of the machine switching department was inspected. Here life and maintenance tests were conducted on the rotary switches which were manufactured by this company and used throughout Europe and other parts of the world. Their construction is more massive and rugged than that of Strowger switches. They claimed that their maintenance was much less than with Strowger switches. They had a Western Electric cross bar system in the laboratory which they considered excellent from a maintenance point of view, but claimed that the initial expense of the equipment was out of proportion to the added reliability. Also, it appears that many additional circuit complications are necessary in order to use the cross bar system.

I was shown a new piece of laboratory equipment which had just been received. It was a device manufactured in England and used for analyzing the amount of pulse distortion over any length of line of given characteristics.

An inspection was made of the Antwerp Airport, which had very little activity. A Marconi type loop direction finder was being installed in the control tower. This consisted of two fixed crossed coil loops with a goniometer and receiver.

On November 23, I visited the Philips plant at Eindhoven, Holland, and had a very profitable discussion with Mr. Volz, Mr. P. Zylstra, and Mr. K. Posthumus. The Philips company in cooperation with the Loth company in Paris has done the most progressive work in connection with instrument landing. Their views on localizers dealt primarily with considerations of flexibility and simplicity. In order to reduce the possibility of multiple courses, they strongly advocated a very sharp course. They also advocated transmitting as little energy to the side as possible, but at the same time to emit sufficient energy to the side to mask any spurious lobes. In order to obtain these patterns, they used two vertical antennas fed 180 degrees out of phase and spaced 3/4 of a wavelength. In line with these two antennas, two other were symmetrically spaced 3/8 wavelength apart and fed in phase with one another, but 90 degrees out of phase with the outside antennas. The phase of the outside antennas is reversed by dot-dash keying. The result is two overlapping kidney bean shaped patterns with very sharp courses. There are no key clicks for two fundamental reasons; first, when on-course the only energy received is from the in-phase antennas which are unkeyed, and second, electronic bias keying with a single polarized relay is used, thus eliminating contact arcing. Equipment of the type just described was installed at Schiphol Airport, which was visited the following day.

They stated that a single antenna at the center of the system was preferred instead of the two in-phase antennas, since this reduced the mutual impedance between the antenna systems and made them easier to handle. The Dutch Air Ministry insisted however on the two in-phase antennas in order to get a stronger on-course with less energy to the sides, so they had to construct it as specified.

The antenna installed at Lyon and already described was discussed in detail by the Philips engineers. They said they did not like this system as well due to the reversal of signals as one passed over the station. In one instance, however, they were able to eliminate multiple courses by using this scheme when the kidney bean patterns were unsuccessful. This test would definitely indicate that radiating less energy to the side was helpful in reducing multiple courses. Some of the interesting features of this system are that even though there are two channels, variation in amplitude of either channel does not affect the course position, but only affects the course width and possibly the amplitude of the on-course signal. Relatively large variations in phase of the two channels have a small effect on the course position and primarily affect the course width. Any change in phase between the antennas which are normally 180 degrees out of phase will affect the course position. In practice, however, this is the easiest phase relation to maintain. The various circuits which affect phase in the transmitter are deliberately loaded to have a Q less than 10 so as to make them as non-critical as possible.

With regard to audio phase, care must be taken to insure that the audio frequency energy applied to each channel is in phase. This requires special networks when the loads presented by each channel are different.

Another point of interest in the equipment which was made for Schiphol was the fact that all antennas were housed in glass tubing about 2½ inches in diameter to reduce the effects of weather and snow and ice. Spacers were used to keep the antennas in the center of the tube. The feeders from the transmitter were two-wire balanced transmission lines inside of 3-inch round copper pipe. All lines were exactly symmetrical in order to avoid as far as possible balance and phase difficulties.

The use of radio frequencies in Europe was discussed and it was indicated by the Philips engineers that they were of the opinion that higher frequencies than 33 and 38 megacycles should be employed in order to eliminate interference which sometimes occurred.

On November 24, I visited our Embassy at the Hague and also called on Mr. Selis, who was Mr. Hof's assistant. Mr. Hof is in charge of all radio communication and navigation for the Air Ministry of Holland. Mr. Selis took me to the Schiphol Airport at Amsterdam and showed me all of the radio equipment at the field. All the communication transmitters were located in one building about a mile from the field. As is the usual European practice, many antennas were strung up in a relatively small area. They had an old 10 kilowatt low frequency transmitter which they couldn't use any more because of the excessive interference it caused. It could only be used on very low power in case of an emergency. Most of the transmitters were rated between 400 watts and one kilowatt. The usual radiophare was in operation at this station. All transmitters were remotely controlled from the airport.

On the airport was located the usual long-wave Philips two-course radiobeacon of the same type used at Le Bourget and Brussels. The remarkable feature of this station was the fact that it operated on a strictly unmodulated carrier. For reception, an oscillating receiver was used. In order that I might listen to the course, they let me take a portable monitor receiver and explore the course on the opposite side of the field. The course width appeared to be very broad, approximately 5 degrees, but the key clicks were negligible. In conjunction with this beacon were two markers. One was at the edge of the field on the same frequency with the radiobeacon and was keying dots. The outer marker was operated continuously, but the frequency was wobbulated at the rate of once a second through a five kilocycle band on both sides of the carrier of the radio localizer beacon.

A Lorenz beacon had at one time been installed and operated at this airport, but had been taken out and replaced by the Philips' transmitter already described. In a six months' period, they had 15 failures of various parts of the Lorenz transmitter, most interesting of which was the fact that the antenna relays would stick, resulting in a large displacement of courses. This confirmed the difficulties observed at Zurich and later observed in several instances in England.. These experiences point definitely to the necessity for mechanical interlocking. The use of only one relay that can only be in one of two positions such as opened and closed or connected to the back or front contact would accomplish this.

The Philips ultra high frequency localizer operating on 33 megacycles was inspected and found to be an excellent installation. Each channel had a capacity of 500 watts. The distance range "on-course" was considerably greater than that obtained with the Lorenz beacon at Berlin when making comparisons on the same ship with the same antenna and receiver. Using a monitor, the course was checked at 150 feet from the antenna. It was only about a foot wide and no key clicks whatsoever could be observed. This was the smoothest keying I had ever observed at such close proximity to the transmitter. The marker beacons consisted of conventional low power transmitters and single half wave doublets a quarter wave above ground screens. Four of these markers were used, an inner and outer marker on each side of the field. This is typical European practice to use one localizer for two wind directions although the pilots prefer to fly toward the localizer rather than fly over it just before landing. This equipment was being made ready for flight tests and approval by the Air Ministry. I was invited to participate in these tests which would take place the following week, but had to decline due to lack of time. From what I observed, I believe that this will be the most satisfactory instrument landing localizer in Europe. By merely turning a knob on the transmitter, the course width could be changed from 0.2 degree to 4 degrees. The optimum course width in practice on other localizers has been found to be approximately 1.5 degrees. It has been found in Europe that inexperienced pilots prefer broader courses of 4 to 5 degrees, whereas experienced pilots prefer courses from 1 to 2 degrees in width.

The equipment at the administration building was inspected and found to be typical in all respects of that used at other airports.

An interview was had with the operations manager of K.L.M., who invited me to inspect the radio equipment on their DC-3 planes. The installation on the ship was the best observed in Europe. The apparatus was installed as if it actually belonged to the ship and was not a necessary gadget that had to be hung on as an afterthought. The transmitter had a power output of 300 watts c.w., which enabled them to maintain constant communication with their ships on the Dutch East Indies route. The radio equipment was all manufactured by the Philips Company. The antenna systems on the airplane were identical to those already described and used by Swiss Air.

On November 25, I visited the Philips transmitter works at Hilversum, which was about 15 miles from Amsterdam. I had a discussion with the chief engineer relative to equipment which they had built and were building for aircraft use. It was discovered that they had made a complete radio range transmitter operating on 50 cms. for the French Air Ministry several years ago. The power output was approximately 75 watts. Magnetons were used as oscillators for the transmitter. Standard 954 tubes were used in the receiver with triple detection. Distances up to about eighty miles were obtained at an altitude of 5000 feet. The results obtained were said to be excellent and it is not understood by Philips why the French did not pursue this development more diligently.

It was found that they were manufacturing several hundred aircraft receivers and transmitters for the French to operate in the band 195-200 megacycles. The construction was very good. Concentric lightweight copper tanks had been developed so that all machine thread and friction contacts were eliminated. This was accomplished through a corrugated flexible diaphragm permanently connected to the inner and outer tubes of the concentric tank. It allowed sufficient freedom of movement to permit the inner tube to be screwed in and out thus tuning through the frequency range required. The inner concentric tube had the conventional disc attached to the end and was designed to use metals which had differential coefficients of expansion thus maintaining constant electrical capacity with varying temperatures. The sockets which were designed to hold the 954 tubes were original in design and the best that I had yet seen. I ordered one of these to be sent to us for further inspection and test.

Considerable time was spent in the Philips laboratory inspecting a typical receiver which they brought out to compete with the one made by Telefunken which is used on most ships in Europe. The Philips receiver of the type used on all KLM aircraft is very flexible in design. It has a six-position switch which enables the receiver to be used as follows: as a null-type figure-of-eight direction finder, as a cardioid for sense indication, as an orthodox receiver with a non-directional receiving pattern, as an N-A type direction finder of the aural type, as a visual radio compass for homing, and as a dot-dash radio range visual course indicator. The first four of these applications worked very well while the last two worked only fairly well. The major difficulty with the last two applications was a considerable lag due to time constants which were necessary to give steady pointer indication. They had definitely taken the stand that a kicking pointer was the wrong type of indication for the pilot, so undertook to develop a steady type of indicator to work on the dot-dash keying of radio range localizers which is standard throughout Europe on both ultra-high and low frequencies. The indicator which they finally produced was inferior to the indicator which we at one time developed for the same purpose but finally abandoned because of inherent difficulties in the practical application of the principle. Tests with this equipment showed that a delay of from five to seven seconds occurred when crossing rapidly from one side of the course to the other. The action of the pointer was relatively smooth although it kicked approximately 3/16 of an inch when operating at full deflection on either side of center. The usual difficulties with zero centering were also noted. They claimed, however, that they had developed a new model in which this difficulty is greatly reduced.

In order to obtain a visual compass that would swing right or left, they reversed the phase of the loop antenna at a dot dash keying rate and combined this energy with that picked up by a vertical antenna. This was fed through the receiver and standard dot-dash visual indicator circuit and indicator which showed whether the airplane was headed to the right or the left of the station being received. The method is very ingenious in its application in that it is very simple and no phasing or synchronization is required between the input and output circuits. Each is entirely independent of the other. The dots and dashes are produced by a single cam and pair of contacts. The major difficulty here is still that 5 to 7 second delay in recording the true heading of the plane as a turn is being made. Also the needle kicks slightly on either side of center.

A switch is incorporated in the receiver so that the same indicator and visual indicator circuit may be connected to the output of the ultra high frequency receiver for use on the localizers.

A brief inspection was made of a 50 kilowatt broadcast transmitter operating adjacent to the factory. The two most unusual features observed were the guyed radiator, which was supported on two small pieces of barrel shaped porcelain about four inches long and three inches in diameter, and the counterpoise system which was only about 15 feet in radius and yet was claimed to be better than using the ground. Special wooden troughs about 25 feet long were used to catch all the water from the tower in order to keep it from running over the insulators. The transmitter was conventional in all respects.

An inspection was made of PCJ, PC1, and PC2, which were three high frequency stations for regular broadcasting to the Dutch colonies. I saw three beam antennas of conventional construction which were supported on towers about 300 feet high, each with its associated transmitter. Another beam antenna of the most unusual construction was also inspected. It consisted of two 300-foot wooden towers placed adjacent to each other and mounted on a circular rail track. An extensive beam antenna with fed reflectors was supported by these towers. With this antenna array, beam transmission could be effected in any direction in a very few minutes. The towers were rotated on the tracks by means of two motors operating on opposite sides of the circular track. In practice they directed it toward the Dutch East Indies for certain hours of the day and the rest of the time toward Dutch Guiana.

On November 26, I arrived at London and visited our Embassy where I met Mr. Homer Fox of the Commercial Attache's office, and Mr. C. E. Brookhart, American Trade Commissioner. I made arrangements through the Embassy to visit the British Air Ministry, Croydon and Heston Airports, and the Marconi company.

On November 27, I met Mr. Spanoletti of the Standard Electric Company and Mr. Bullock of the International Telephone & Telegraph Corporation, and had a long discussion concerning instrument landing systems, radio compasses for aircraft, and air navigation facilities.

On November 28, I visited Air Commodore Nutting, Colonel Lywood, Captain Chandler, and Senior Signals Officer Duncan of the Air Ministry. Instrument landing as applied both in England and in America was the major topic of discussion. Mr. Duncan then personally conducted me on a tour of both the Croydon and Heston Airports, which are located on opposite sides of the city of London. At the Croydon Airport, a Lorenz system was installed for instrument landing. The localizer was in what appeared to be a quite satisfactory location in that it was in the clear from hangars and other objects by several hundred feet. An iron fence close to the localizer had been removed and replaced with a wooden fence. The nearest hangar was approximately 600 feet to the right of the course and at an angle of approximately 50 degrees off course. This course was said to give entirely satisfactory results without multiple courses.

The control tower equipment was inspected and found to be quite similar to that used elsewhere in Europe. Three loop antennas were located in the immediate vicinity of the control tower and arrangements had been worked out whereby it was possible to operate two receivers simultaneously on a single loop and take bearings independently. The results obtained under conditions of existing high levels of local interference were quite surprising. It was explained that England was broken down into specified control areas within which all aircraft had to report to the central traffic control tower in order to proceed within that area. All traffic in the Croydon control area which encompassed the southeastern portion of England was controlled from the Croydon tower, whereas traffic bound for Heston which is on the north side of London was all controlled from the Heston control tower. It was very interesting to note that a narrow portion of designated airway led from the Heston Airport due south to the coast of England immediately west of the Croydon control area. This was done so that ships destined for the Heston Airport from France could fly directly into Heston without crossing the Croydon control area. This was necessary in order to reduce the communications burden on the Croydon control tower. All ships are requested to contact the control station immediately upon entering a given control zone. The size of each of these control zones depends somewhat on the congestion and flow of traffic. England is divided into approximately 25 control zones. Two Adcock ground direction finder stations are closely coordinated with the London control tower and furnish bearings upon request. These stations are located 40 or 50 miles from London. One is in a southerly direction whereas the other is to the northeast. It was very interesting to note that the number of requests for position fixes had been rapidly on the decline whereas the number of bearings had been on the increase. This would indicate that under ordinary conditions aircraft are entirely satisfied with information on their bearing with respect to the terminal station. Under conditions of low ceilings, aircraft are brought into the vicinity of the airport on such bearings and then generally utilize the Lorenz ultra-high frequency localizer and marker beacons for approaches to the field.

An inspection was next made of the Heston airport. Inasmuch as this was the place where the first Lorenz localizer was installed in England and in view of the fact that considerable difficulty with multiple courses had been experienced with this station, it proved to be of great interest. A localizer was situated well out in the field clear of all hangars by approximately 700 feet. There were a few trees approximately 400 feet behind the localizer and also some small houses were in that vicinity. The location appeared to be quite ideal. Upon checking further into the history of the installation, it was found that about three months ago it had been moved from its original location which was slightly to one side and nearer the edge of the airport. I also learned that the reason for the move was primarily to eliminate multiple courses. It was also determined that a portable installation had first been made in the exact location of the new antenna and that after numerous trials in different other locations, this final site had been selected. After completing the permanent installation, however, it was found that multiple courses were nevertheless present. During the period between the time when the original tests were made with the portable equipment and the installation and test of the final equipment, no new buildings or structures had been erected on the airport. However, a very large reinforced concrete apron had been erected in front of the administration building and the hangars. It was suggested that possibly this apron may be responsible for the divergent results obtained.

Approximately one week prior to my arrival, the Air Ministry had taken steps to eliminate multiple courses on the localizer. They had succeeded through the device of erecting a director immediately in front of the central fed antenna and a reflector immediately behind the central antenna. This gave more energy in a forward direction and decreased to some extent the energy to the sides and at the same time greatly reduced the energy in a backward direction. The reports on the localizer were said to show entirely satisfactory results. It was decided, however, that the localizer should be removed entirely from the airport, inasmuch as it was considered an obstruction. A survey was made in the vicinity of the airport and in line with the runway and a more satisfactory site was found approximately one mile back from the edge of the airport in a clear area in line with the best approach to the field. It is now planned to relocate the entire localizer in this new site. During the tests on the original localizer when multiples appeared on the back course, it was found that by cutting down two trees at the edge of the airport, it was possible to eliminate two of these spurious courses. This information is very significant in that it was the first reported case of its kind. It would definitely indicate that trees may act as reflecting objects. The control tower transmitters were inspected and were typical of other installations in Europe.

On December 29, a visit was made to the Hughes Company, where a sonic altimeter was in the first stages of development. Another device inspected was a magnetic compass operated by a specially designed cathode ray tube which gave currents in two indicating instruments which were proportional to position with respect to the earth's magnetic field. This also was in its initial stages of development. The possibilities of using this device to measure angle of dip were being investigated. It was quite apparent that the two currents developed by the cathode ray tube could be used to operate a differential type of meter which would show the true magnetic indication. The greatest difficulty appeared to be that it would be necessary to stabilize the cathode ray tube with a gyro controlled device in order that it would be unaffected in rough air. This would probably require a fairly heavy gyroscopic mechanism.

A visit was made to the radio research board at Slough, where I met Messrs. Smith Rose and Barfield. I was taken to their development field station where I inspected a modified Adcock U antenna using a cathode ray indicating tube for obtaining bearings. Demonstrations were made on this equipment and it was found that telegraph signals could be used for obtaining bearings and also that it was possible to rapidly take a bearing on a swinging null by visually integrating the readings. In order to measure polarization errors, they had erected a pole fairly close to the antenna and of considerable height. It was therewith possible to transmit either vertically polarized or horizontally polarized waves and determine definitely the polarization errors in each case. It was with this experimental equipment that they were able to learn much about the elimination of polarization errors and eventually succeeded in eliminating the undesirable effects of horizontal polarization. It was stated that they were beginning to do some very interesting work on ultra-high frequency direction finding, but time was not then available to demonstrate or show this equipment to me.

I met Messrs. F. S. Barton and Cox Walker of the Air Ministry at Slough and we discussed aeronautical radio problems in England. They explained to me that they were making test set-ups of the Lorenz localizers at various airports throughout England, Ireland, and Scotland. They had already inspected 40 different airports for their suitability as localizer sites and had checked each one of these with an airplane in order to predetermine if the equipments could be installed without multiple courses. The group that was assigned to this problem consisted of nine men including an airplane pilot and eight radio engineers. It took approximately one week to thoroughly investigate each airport and decide upon the proper location for the localizer. They mentioned that they were only part way through the program, which indicated that they were installing possibly 60 or 70 of these Lorenz localizer transmitters. The policy of the Air Ministry is to establish exact copies of the Lorenz equipment throughout England so that low approaches and instrument landings may be made under all conditions of poor visibility and low ceilings. Actually only six Lorenz beacons were purchased from Germany and installed in England; the remaining transmitters are copies of the Lorenz equipment being manufactured in England by the Standard Electric Company.

On December 30, I visited the Standard Electric plant at New Southgate. Here I met Mr. Strong, the chief engineer, and discussed with him methods of construction of radio equipment and also policies of the company with respect to production of various types of equipment. The general scheme they have adopted is to use the panel type of construction of many units. Although it costs more to produce the separate units, the engineering costs are less and they are assured of more reliable apparatus, since it is possible to use the same units in many different types of transmitters, each of which has been highly developed and proved by long experience to be reliable. In this connection, it is the general policy of the company to use the same design of component parts wherever possible and never change to different or newer types of parts unless there are some very good reasons. Furthermore, new parts are not accepted until they have undergone every conceivable test to insure satisfactory service.

We discussed instrument landing at considerable length, and I learned that they are working on the problem for military reasons. At the present time, they are manufacturing a large number of exact copies of the Lorenz ultra-high frequency instrument landing systems which are being installed at over forty different fields in Ireland, Scotland, and England. They seemed quite irked by the fact that they were forced to copy the Lorenz design which is inherently expensive. I saw some of the castings for this equipment and they were the typically massive German design. The entire frame, side, back, and top, is a single casting; the front shields are made of separate machined castings. The cost of such construction is obviously excessive.

Mr. Earp, development engineer, showed me a new 360-degree radio compass, which works on the Busignies rotating principle, but which has been converted to work with two fixed crossed loops and a vertical antenna with electrically rotated cardioids and synchronously rotated field in the compass indicator. The result is a pointer that automatically and continuously indicates the bearing of the station to which it is tuned. In result this is similar to the Sperry-RCA compass recently developed in the United States, but the principles used to obtain these results are entirely different. Each loop uses a separate modulator tube and these tubes must be balanced. A simple switch is provided for balancing each modulator. All other tubes in the receiver are common to both loop channels as contrasted to the Simon double-loop compass which uses separate balanced channels throughout. This compass should prove to be a very valuable aid to air navigation. It is recommended that we purchase one of these units for test and comparison.

Plans for the high-frequency Adcock system which the Standard Electric Company is developing were next discussed. Essentially, they plan use of the same general scheme as adopted by the Western Electric Company. The antennas will be H type Adcocks, each to be modulated at a different audio frequency. The modulation frequencies are 1500 and 2500 cycles respectively. After detection these frequencies are fed through an I.F. amplifier, redetected, amplified, and made to operate a cathode ray tube. The trace is a line which indicates the direction of the aircraft from the receiving station. The fixed sense antenna is of course necessary to eliminate ambiguity effects. It is arranged to operate automatically.

I made a general inspection of all radio equipment being manufactured in the plant. The execution of the mechanical ideas in all the apparatus I saw was considered to be excellent.

The entire plant of the British Broadcasting Company television station was next inspected. Among the features viewed were studios, camera equipment, sound equipment, transmitters both video and sound, monitor equipment, low level amplifying equipment, transmission lines, and antennas. The results obtained with this equipment are probably the best in the world. Programs are transmitted twice a day; one hour in the afternoon and two hours in the evening. The video carrier frequency is 45 megacycles. Sidebands cover from 42 to 48 megacycles; voice is transmitted on 41.5 megacycles. The total band width is 6.5 megacycles. Average coverage is a 50-mile radius, although there are many listeners up to 100 miles and a few as far as 200 miles. The total number of lines is actually 385, although the number available is 460. Synchronizing pulses use up some of the available lines. The size of the pictures in most cases was about 7 inches by 10 inches and the detail was amazing. One of the most interesting things I learned was the fact that television signals could be transmitted over two miles of telephone cable. This fact should give considerable impetus to television. Already a high grade cable has been installed around the city of London. At one point in this ring, a repeater is installed and any signals fed into the ring are carried over a high grade line direct to the studio. This arrangement enables them to tie at any point in the ring, which is broken up at manholes with junction boxes through which runs standard telephone cable. This means that programs may be picked up in any part of the city and transferred to the television transmitter by means of both standard telephone cable and special high frequency cable. It was very interesting to note that the amount of light now required on the subject being televised is only 8 to 10 foot candles which means that the subjects no longer object to being televised on that account. This is in contrast to some of the work in America where 1000 foot candles have been used on the subjects to their great discomfort due to overheating. The technical features in television have been highly developed in England and are considered to be suitable for public service.

The major question now confronting television is not the technical difficulties, but the economic considerations. The cost of operating one of these stations is tremendous as compared to a typical broadcast station. An indication of this cost may be obtained from the fact that there are 110 radio engineers on the payroll of this one television station. In view of the economic factors thus involved, it is believed that television will not come as rapidly as the industry and the Federal Communications Commission would lead one to believe. In short, I am of the firm opinion that entirely too many frequencies have been set aside for television, frequencies which could be used more properly for aeronautical, and other legitimate commercial services.

On December 1, I visited Dr. T. L. Eckersley at the Marconi Company in Chelmsford, England. Dr. Eckersley is in charge of all fundamental research dealing with the propagation of radio waves. He pointed out that with respect to transmission on ultra-high frequencies, horizontal polarization may or may not be as good, but never better than vertical polarization. However, if noise is present at the receiving location, then it is possible for the horizontal polarization to give a better signal to noise ratio. He also pointed out that an ultra-high frequency wave will not follow normal line-of-site laws of propagation unless the straight line drawn between the transmitting and receiving antennas misses the highest point of intervening earth by at least several wavelengths.

One of the major problems which they had encountered was the effects of variable refraction caused by variable content and distribution of water vapor in the lower atmosphere. These effects have been observed on all frequencies; however, they become more apparent as frequency is increased. This applies particularly to frequencies between 10 and 50 cms. for which circuits have been installed and found to give excellent service for several months and then for no apparent reason all signals disappear and the circuit becomes worthless for two or three months. Sometimes the circuit is good in the summertime and poor in the winter and at other times the reverse is true. With regard to the reliability of signals in the 60 to 65 megacycle band below line of sight, their experience indicates that if sufficient power is used to get a good initial average field strength, the circuit can be considered reliable for better than 99.9 per cent of the time. They experience a few extremely deep fades of only a fraction of a second in length throughout the year. This confirms our experience on the ultra-high frequency circuit between Baltimore and Washington.

Another general statement of considerable importance made by Dr. Eckersley was that the higher the frequency the more important it is to obtain a site clear of local objects such as trees, buildings, hills, and discontinuities in the ground. This applies to any problem where directional patterns are required for either transmission or reception such as radio ranges, omnidirectional radio ranges, and ground direction finders.

Before leaving Chelmsford we visited the development station which consisted of several hundred acres of flat ground. Here I saw three different types of direction finders all separated from one another to avoid interaction. One was an H-type long-wave direction finder which they were investigating. This work has been prompted by the fact that the U type antennas which they have been manufacturing for years are not successful when located where ground conditions are non-uniform or where ground conditions are poor.

The next direction finder we saw was a U type identical to the one installed in Ireland and Newfoundland by Marconi for transoceanic service. The system consisted of four steel masts each approximately 35 feet in height and spaced approximately 25 feet between diagonally opposite antennas. A vertical sense antenna was suspended from a point at the center of the arrangement. The equipment was located in a wooden building which was electrically screened inside. The feeders from the aerials were buried six feet and converged at the building in the center of the plot where they were brought up vertically through the center of the floor to the goniometer unit. The remaining equipment was of conventional nature. The frequency range of this equipment was approximately 5 to 20 megacycles.

The third direction finder consisted of two spaced loops mounted on a wooden turn-table framework. The plane of each loop was parallel to the other and separated by approximately 40 feet. Each antenna consisted of a single turn shielded loop connected to the receiver at the center of the turntable by means of shielded balanced two-wire lines. Opposite loops were connected in opposite phase so that when in the plane of propagation and each equidistant from the source of transmission, the phase and amplitude of the received signal would be such that absolute cancellation in the output would occur. The outstanding features of this equipment are that no night effect is obtained and accurate bearings may be obtained with two loop antennas using this principle. Another very interesting application of this equipment is to determine the angle of arrival of waves reflected from the Heaviside layer. This is done by rotating the turntable 90 degrees to the position where the null signal is observed and determining the phase difference required in one transmission line to give a null. Knowing the frequency, the physical distance between the plane of the loops, and the phase difference in one line to give a null, the angle of arrival may be calculated. On one occasion, simultaneously measurements were taken on the height of the Heaviside layer and knowing the angle of arrival and the bearing of the unknown station, it was possible to determine the position of the transmitting station which happened to be within 20 kilometers of Munich, Germany. This was later verified.

Although such results appear optimistic, it does indicate what can be accomplished under favorable conditions with adequate equipment. This equipment is said to be so accurate that bearings may be taken which are correct to within one-tenth of a degree. It has been used to confirm the belief that signals do not always follow the great circle path, but under some conditions may deviate therefrom by as much as plus or minus 2 degrees. Inasmuch as this has now been shown to be a fact, it indicates that there will always be errors of this order on all frequencies reflected from the Heaviside layer. In other words, these difficulties which are associated with the Heaviside layer are inherently propagation characteristics independent of equipment refinements. It is quite possible, however, that ultra-high frequencies will not exhibit these inherent difficulties provided sufficiently high frequencies are chosen to penetrate the Heaviside layer and never return to earth.

It is interesting to note that originally the ground surface under the antenna system was not level and, therefore, calibration of the compass was necessary. Thereafter the ground was very carefully levelled off, resulting in the elimination of calibration difficulties.

Probably the greatest disadvantage in the practical use of this system is the difficulty in taking null bearings since the entire structure including the antennas has to physically rotete in azimuth. This is obviously cumbersome and slower than rotating only a goniometer.

An application which would appear to have considerable merit would be for aircraft use where fixed loops could be mounted on each wing. The plane of each loop would be parallel to the direction of flight which would give a minimum aerodynamic drag. This arrangement would permit aircraft to take accurate bearings at night by swinging the heading of the airplane or to home on any station at night without experiencing the usual difficulty due to swinging bearings.

On December 2, I sailed from Southampton for New York City, arriving on December 9.