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Hamilton Rice

THE HYDROPLANE (& THE RADIO-TELEGRAPHY) OF THE HAMILTON RICE EXPEDITION 1924-1925

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THE HYDROPLANE OF THE HAMILTON RICE EXPEDITION, 1924–25

From the Report prepared at the direction of Dr. Hamilton Rice for Major-General Mason M. Patrick, Chief of the Air Service, U.S. Army, by Capt. A. W. Stevens, U.S. Air Service.

DESCRIPTION of the Curtiss Sea-gull Hydroplane.—Biplane, pusher type; engine: Curtiss C-6, 160 h.p., 6 cylinder; ignition: Splitdorf magnetos; gasoline system: air pressure, 5 lbs. normal; capacity of tank: 42 gallons; gasoline consumption per hour, cruising, 11 to 12 gallons. Maximum time actually covered on one flight was 3¾ hours, with 5 gallons remaining in tank at end of flight. Speed of plane, about 70 land miles an hour. Capacity, three persons, including pilot. Only two persons were carried, however; the weight of one person was carried in camera, food and supplies.

Wings and control surfaces were covered with aluminium dope. This resisted the action of the sun's rays very successfully, and the fabric retained its life and did not become inert even with nine months of constant exposure to tropical rains and sunlight. It must be borne in mind that the plane had no protection whatever, being anchored in rivers all the time. It was pulled out at intervals for a few days whenever opportunity came, to dry out the hull, on a sand-bar or on a sloping bank. The plane was in the water at least 80 per cent. of the time. The bottom of the hull was covered for the most part with two layers of planking, with canvas and marine glue between. The tail section, however, was originally covered with veneer, and after four weeks of use this became so soft that some of it came off during a take-off of the plane. It was necessary to replace the tail veneer with planking; this was done at a place called Sirorocco, a collection of huts about 1½° north of the equator. The work had to be done under particularly unfavourable conditions, on a muddy bank, with frequent rains, and with swarms of piumes and mosquitoes present. In two days the plane was ready for use again, and the tail section has since proven to be as tight as the balance of the hull. Marine glue and canvas are invaluable for repair work of this nature.

Under constant exposure to the sun, the woodwork apparently shrank a trifle, and after two months of use it was necessary to take up half a turn to a turn on most of the turn buckles. Part of the slack may be accounted for by strains in flying, and by fittings pulling into place. It was not necessary to replace any flying wires or control wires.

The magnetos (Splitdorf) required practically no attention, beyond oiling and inspection of the contacts. The spark plugs were B-C, and it was not necessary to remove or clean a single plug on either of the two engines during the whole flying time of 174 hours.

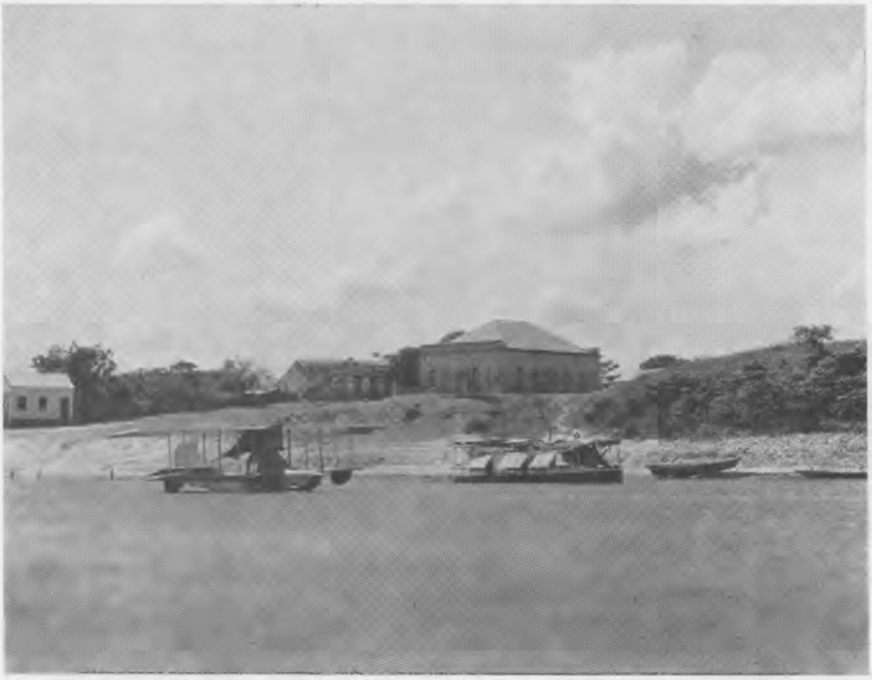
Two engines were provided. The first engine was replaced at a settlement called Vista Alegre, 2° north of the equator, after it had sixtyfive hours' use. While this motor was running perfectly, the spare engine was at hand, and it was considered advisable to change while there was a good opportunity. The magnetos were transferred to the second engine. Up to the time the plane reached the Parima River the second engine had been run 88 hours, and at the time the plane returned to Manaos it had a total of 109 hours' service. The total flying time of the plane was therefore 174 hours; at 60 nautical miles per hour this gave 10,400 miles, or at its equivalent of nearly 70 land miles per hour, a total mileage of 12,000 land miles.

The lubricating oil used was a mixture of 50 per cent. castor and 50 per cent. mineral oil, and was furnished by the Curtiss Company; it was transferred to 5-gallon tins for convenience in transportation. In ordinary weather there was no trouble in starting the motor from normal temperature condition. As the plane began to get up into the mountains, at elevations over 800 feet above sea-level, the nights became sufficiently cool to cause the oil to thicken. This thickening made it impossible to spin the motor fast enough to cause ignition. It was therefore necessary to heat water in the early mornings, with which to fill the radiator and engine.

Early morning take-offs were the rule, for the hydroplane climbed much better in the comparatively cool morning air, and did not overheat the engine, as in the middle of the day. Furthermore, the air was comparatively calm and free from bumps. For photographic purposes early morning work was necessary, for clouds were certain to form between 8.00 a.m. and 8.30 a.m. During the middle of the day clouds always were present. Often there was a clear period after 4.00 p.m., but as the air was then hot, it was seldom advisable to take off unless conditions were especially favourable, such as a pronounced breeze up or down river. Practically all the photographic work was done, therefore, in the early morning, and it was only possible to secure sufficient exposure in these early morning hours by making use of Hypersensitized Panchromatic Film, which is sensitive enough to other light than blue, to permit good exposure at the hour of 6.30 a.m.

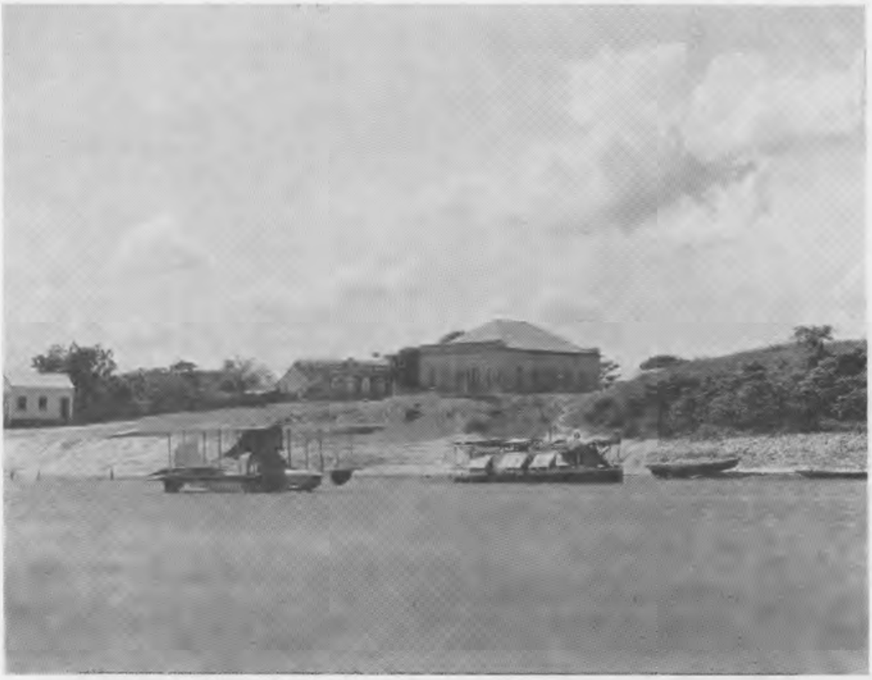
Gasoline.—The gasoline was supplied from Para in 5-gallon tins, two to the case, by the Anglo-Mexican Petroleum Co., Ltd. The cans were inspected to see that each was full before shipment, and the cans were given an outside coat of black asphaltum varnish to prevent rusting, and also to prevent confusion with cans of kerosene used for launch propulsion.

Gasoline Troubles.—No trouble was experienced with the gasoline. While reports have been made of trouble from moisture in gasoline in the tropics, it was found that no water was present in the plane tank in quantity large enough to detect (although the tank was drained several times in search of water). It is true that a tank like that of the Curtiss "Sea-Gull" is protected from extremes of heat by its location within



The hydroplane at Boa Vista

An island breached by the upper Rio Branco



The hydroplane at Boa Vista

An island breached by the upper Rio Branco the hull, and is not liable to acquire moisture through breathing action. A chamois strainer of the "sock" type was *always* used to strain all gasoline into the tank. Entering this was a metal funnel, with fine brass strainer and grounded to metal tank before pouring. It was found that a certain amount of chipped varnish from the cans, and some particles of sand, were always caught by the chamois. The metal screen of the funnel caught globules of solder from the cans. The gasoline furnished was not aviation gasoline, but was nevertheless superior in quality to ordinary bulk automobile gasoline. No water whatever was found in any can, even in those which had leaked part of their contents of gasoline out while partly in water in canoes. After much handling, about a third of the cans were found to leak; in one case, in a consignment of twenty-eight cans that had been transported by canoe several hundred miles, only about 50 per cent. on the original contents were recovered. It had been necessary to remove the cans from their wooden cases to get them readily into the bottom of the canoe, where the centre of gravity must be kept low, especially in rough water. Because of frequent collisions with rocks, the canoe leaked so badly that it was necessary to remove the entire load, including gasoline, each night to prevent the canoe from sinking while the crew were asleep; these frequent removals, over a period of forty days' travelling, caused the cans to leak. In another instance, three cans of lubricating oil were sent by pack-horses from one settlement on the Rio Branco to another, some 25 miles higher up. The constant movement of the sides of the tins, from the slopping of the oil within, cracked them in several places, and much of the oil was lost.

Where the tins stay in their wooden cases, they hold out much better, but it is difficult to convince native carriers that the extra weight and bulk of the cases are paid for in the greater certainty of the tins arriving with their original contents at the final destination.

Oil.—The consumption of oil was very small; less than a pint per hour. A practice was made of changing the oil in the engine completely every twelve or fifteen hours of flying, and sometimes as often as every ten hours. It required 5 gallons to fill the engine base; as stated, the mixture was 50 per cent. castor and 50 per cent. mineral oil. The old oil was saved for possible use again in the plane, or was used in launch engines.

Anchor.—A small patent folding anchor, weighing a little over 3 kilograms, was carried. Other anchors were available, but were considered too heavy to carry constantly in the hydroplane. In very swift water this light anchor was sometimes found to be too small to hold well unless the bottom happened to be rocky; if doubt was felt about the anchor holding, two courses were open: if the supply boat was near, a 75-point anchor was brought out to the plane; if no assistance was near, the plane was taxied in to a place where thick foliage overhung the bank, and the bow pulled in and made fast. In getting clear of such a place, the anchor was thrown out in mid-stream as far as possible, the bow line loosened, and the plane pulled clear of the bank. Usually this involved a systematic inspection of the wings for possible damage, and particularly to see that no twigs or vines were caught in the pulleys carrying the control cables, especially those on the top wings. One advantage of the light anchor was that the plane could be manœuvred by throwing the anchor some 30 feet, letting it strike bottom, and then pulling the plane to it; by repeating this procedure some forty times, the plane was once successfully taken, without power or outside assistance, a distance of nearly a mile down a section of river fairly bristling with rocks. To get out of the same place, the engine was throttled down to lowest speed and the plane taxied very slowly against the current; as the engine got quite warm during taxi-ing, it was necessary to anchor for half an hour when clear of the rocks, before it was safe to attempt a take-off on the clear stretch above. About 30 metres of 18-thread Manila line was carried for anchoring purposes, and this was changed three times in eight months because it went bad so quickly in the warm river water.

Instruments.—These consisted of air-speed meter, gasoline pressure gauge, oil pressure gauge, engine-water thermometer, clock, curved bubble tube, and compass (G.E. Compass). So much trouble was experienced with the long tachometer drive that the tachometer was finally removed from the plane to save bother and weight. The wind shield was removed, with a slight increase of speed and ease of take-off. The seat cushions, even, were discarded to save weight.

It was necessary to inspect the Venturi or vacuum tube on the wing strut daily, for it was almost certain to be made the temporary home of a spider. Unless the insect was poked out, the air-speed meter was sure to register zero. This happens in the States occasionally, but in the tropics it is a daily occurrence.

Air-pump Troubles.—An air-pressure system for gasoline feed is far from desirable; however, it was the system furnished with the plane, and it was necessary to make the best of it. It may be noted that the only mechanical trouble with either of the two engines used, was that due to the air pumps. First, while in flight, the pressure suddenly rose from 5 to 8 lbs., and the tank came within one of bursting before the pump was shut off; the top of the tank bulged so badly that the filler head came clear up through the veneer top of the hull. On landing, a safety valve was secured from extra parts, and tapped into the filler cap; set at 5 lbs., this made high pressure in the tank impossible. This safety valve should have been added by the plane manufacturers; the regulating valve on the pump itself is not enough.

This was the most serious trouble due to air pump; on three occasions afterward the pump failed to function at all. Each time it was found that the pin holding the drive gear to the pump shaft had sheared. The pin was renewed at the first opportunity, the hand pump being used while flying in the meantime, sometimes for an hour, until a landing could be made.

In this Curtiss pump, the closed end of the cylinder points downward, and there is a supplementary piston in the end of the cylinder working against a spring ; this supplementary piston comes into play when the pressure exceeds a certain amount. A small hole in the cylinder cover was supposed to permit breathing action, but this was sometimes prevented by the heavy oil which leaked by the supplementary piston. A hole considerably larger, or of $\frac{5}{32}$ inch diameter, was drilled in the cylinder cover or head, and the pump trouble ceased from that time on.

Propellers.—Two oak propellers were furnished by the Curtiss Company. Both proved satisfactory. A walnut propeller furnished by another company was tried, but was found to have too great pitch. A duralumin propeller made by Curtiss was furnished, but was found to be somewhat out of track. Efforts were unsuccessful to straighten it at Manaos, and shimming it at the hub was not satisfactory. The propeller was used for three flights, and was found to be very efficient, pulling the plane off the water much quicker than an oak propeller. However, the engine vibrated so badly with the metal propeller that the oak ones were used after leaving Manaos.

Radiator.—This was made especially for the tropics by the Curtiss Company, with the idea of providing 25 per cent. more radiating capacity than the one regularly provided with the "Sea-Gull." It was reported on test to keep the engine 20° cooler. The radiator was built by Curtiss from drawn copper tubes manufactured by the Winchester Arms Company. These tubes were of circular cross section with hexagonal ends. It is possible to draw a defective tube by heating both ends until the solder loosens, and replace it with a new tube. The regular size radiator case was used. It was unnecessary to do any repair word on the radiator ; a small leak developed at the top, but it practically closed itself, and the daily loss was so small as to be almost negligible. The leak occurred where the radiator is braced to the top wing, and some canvas washers served to close off practically all the loss.

Controls.—The pilot was provided with D. & P. control. Provision was made for stick control by the observer ; the latter feature was occasionally useful when the pilot required for a few minutes the use of both hands, or to relieve him for an hour on long flights. The ailerons were of the balanced type, and provided on the upper wings only. The same control wires were used throughout eight months. Regularly greased and inspected, they gave no trouble.

Pulling out Plane for Drying or Examination.—Whenever the chance occurred, the hydroplane was beached to permit the hull to dry. In the Rio Negro and lower Rio Branco the water was at high stage, but on the upper Rio Branco it had begun to drop, and a few spots were found where there was not too great a slope to the bank to haul the plane out. Later on the river dropped much more, and sand-bars appeared; it was much easier to beach the plane on these bars. Usually the plane was headed tail to the beach; enough Indians could usually be found to push and lift it ashore, though hardly ever did they get the hull completely clear of the water. With a falling river it was only a day or two before the plane would be entirely out of water. Care was taken to remove sharp rocks from the sand or clay bank before beaching the hull. On one occasion it was necessary for the two occupants to beach the plane alone, because they ran the hull on a submerged rock while taxi-ing after making a landing. The plane was taken off at once, before much water leaked in, and was headed back to camp, but darkness forced a landing short of camp. A landing was made near to a low sand-bar, and the plane pulled by power on the bar as far as it would go. Here it was necessary for the men to wait several days until fluctuations of the river-level allowed them to get at the bottom and make temporary repairs, which consisted of replacing two strips of planking on the outside and applying marine glue outside and inside the hull. On a previous occasion it was necessary to replace three triangular pieces of outside planking which proved to be soft. These pieces were of veneer, and were originally fitted by workmen for small areas, as being apparently stronger. Strips of mahogany were carried in the tail section for repairs, and marine glue, canvas, and screws were carried under the seat in the cockpit at all times. Once it was necessary to use a piece of gasoline tin to complete repairs to the tail. (This piece is still on the plane.) After repairing the plane it was necessary for the men to wait several days more until it rained and the river rose high enough to permit them to work the hull off by digging around it. Altogether, they were absent eleven days.

Elevation above Sea.—At Manaos, about 90 feet above the sea, there was no difference in take-off, nor was there any difference noted up to Boa Esperança, 250 feet elevation. At Kulekuleima Rocks, 800 feet above the sea, it seemed that a longer time was required for take-off; the plane took off from the latter location eight times. So many conditions are changing, however, that it is hard to judge; the plane may be taking off with or against a stiff current of the river, the atmosphere may be hot or cool, and there may or may not be wind. The highest point at which landing was made was above the 4-mile caxoeira on the Parima River, where the level is probably in excess of 1000 feet above the sea. The occupants of the plane were the first white men to gaze upon this region, as the formidable 4-mile cañyon had caused the only previous explorers to take the "Aracasa" branch to the north, rather than the Parima branch to the south, although the Parima is by far the larger stream. The expedition following were to cut a 5-mile path around this cañyon, and, carrying their lightest canoes overland, embark again above the cañyon.

It may be noted that the last flight of the plane in this region was made from the junction of the Aracasa and the main stream. To this point, with great labour, 70 gallons of gasoline had been taken by Chas. Bull and four Indians, with a lead of about two weeks over the main party. Forty gallons were used for a flight to the headwaters of the Parima, a distance of 120 miles as the river goes. The plane followed the bends going south at an elevation of 6400 feet, but to save gasoline, cut the bends coming back. In one place a flight was made directly across 30 miles of dense tropical forest, where a forced landing meant that the aviators, even if uninjured, would have a long job cutting their way to the river. To land in a short clear stretch of river looked often possible, but even there the situation was bad, for the river below had many high falls and rapids. Tools were carried with which to cut away the wings and remove the engine, with the idea of proceeding as far as possible in the hull. Whether the hull would have stood the rough journey through rapids is uncertain; fortunately, the engine gave no trouble whatever, and so it was not necessary to change from air to water transportation. On this trip, as on other trips, a complete sketch was made of the river and its tributaries, and aerial photographs were made of features of importance. These sketches were tied in to positions to be determined about every 30 or 40 miles from night observations with theodolite, by surveying party in canoes following.

This stretch of river proved to be the most deserted of all, for the entire distance of 120 miles separated the only visible signs of human life—Indian Maloccas and clearings—located at the headwaters and at the 4-mile cañyon. It was quite impossible to land at the upper Indian camp, for the river was too small, being very narrow and crooked; the channel was so small that, unless the plane were directly over it, the trees on its banks hid the stream completely from view. In such a region one has to fly at times by the general lie of the land and the slope of the cañyons, for the stream is lost for minutes at a time. Furthermore, it would have been inadvisable to land, for these Indians are at war with those below, and are almost certainly hostile to all intruders; it is likely that they would have retreated into the forest during the day, only to appear with the earnest intention of messing up the occupants of the plane in case the plane stayed over night. Just above this Indian clearing and Malocca (large hut), the stream, hardly bigger than a good-sized creek, tumbles down a cañyon a mile in length—a mass of rushing water that shows white from one end of the cañyon to the other. Evidently this is the end even of canoe travel; from this point it is likely that the famous "Guahariba" Indian trail leads across the divide to the Orinoco headwaters. To this point the main expedition is travelling; whether it will get there, considering the dense forest, the steep hills, the high falls and long stretches of rapids, is problematical. To make progress in such a region requires a fairly large band of whites and Indians, equipped with ropes to pull canoes through the rapids, and with axes and machetes to cut a way along the steep slopes, over which to carry the canoe in case the river is quite impossible. It is not known that even the native Indians attempt river travel. It is more likely that during past decades parties from down river have met Indians from up river, both exploring through the woods, and that fights have always ensued. At least, the down-river Indians, friendly toward whites, hold the others in great dread.

The plane proceeded for ten minutes beyond the upper Indian camp, but there was nothing more to see except the ridges of the dividing range, and as the gasoline was half used up it was necessary to head back for the "Aracasa Junction." On getting back, the remaining 30 gallons of gasoline were put aboard, and two days later the plane was headed down river to meet the main party and deliver copies of the sketches of the previously unknown Parima.

On this trip and on the remaining flights which eventually took the plane back to Manáos, heavy rains were passed through, and clouds and mist sometimes forced the plane down to within 100 feet of the tree-tops. In such circumstances it is vitally important not to lose sight of the river, for a short distance away its wooded banks hide it completely, and the country then becomes an unbroken sea of forest in whatever direction one looks.

Landing Sites in General.—The Amazon near Manáos is so wide that a plane may take off in any direction, and the same thing is true of the Rio Negro for at least 400 miles above Manáos. The Rio Branco is narrower, and landings and take-offs must be made largely up river against prevailing winds from the north-east. There is plenty of room, however, on the Branco, up to the small town of Boa Vista, for handling a hydroplane. Twenty-five miles above here the river forks and loses its identity as the Rio Branco. A landing was made in the smaller branch, the Tacutú, about 30 miles from the junction, and had it been necessary, it is likely that a landing could have been made at least 100 miles higher on this branch.

Vertical aerial photographs were made of the lower section of the Tacutú, and the series was continued down to Boa Vista. The other and larger branch, the Uraricoera, was used thereafter, as the expedition's progress was to the west up the headwaters of the largest and supposedly longest tributary, known to Indian tribes as the Parima.

In the next 120 miles of the Uraricoera many rocks appeared, but still there were frequent landing-places, and it was found possible to handle the plane with full load of gasoline from the river opposite the two-house settlement of Boa Esperança. At Boa Esperança the river divides around an island known as Maraca—about 50 miles long and 30 miles wide. Both channels were followed at different times, and on the south furo, as it is called, no landing-places at all could be seen. Rocks filled the channels between countless islands. The north furo, or Santa Rosa Furo, was better, and a landing was made near the western end. The take-off was with such a narrow margin of safety that it was never repeated at this point.

From the head of Maraca Island, some 40 miles west, the main river was found to be divided into many narrow channels by islands, and these channels were thickly spotted with rocks over which the water poured in white foaming masses. At one place a series of three falls (Purumame Falls) had a total drop of 90 feet. The canoes of the expedition, following later, were from eight to sixteen days passing this 40-mile stretch, depending on cargo carried and stage of water. A rise of 6 feet, which occurs after a few days of rain, makes progress doubly difficult. In the true rainy season, from May to August, the river rises from 15 to 20 feet, and progress against it is quite impossible; even though many of the caxoeiras are buried deep beneath the waters, the current is too strong to work against. Also, it is then practically impossible to find a camping-place anywhere along the banks, for the river penetrates the forest, and canoes cannot be worked through the dense foliage to higher spots that may be back at a distance from the stream. For these reasons, certain tribes living on tributaries of the Uraricoera, in making their yearly voyage down stream for the purpose of trading at Boa Esperança, choose the month of February, when the water is the lowest. Altogether, the Uraricoera bears the reputation in South America of being one of the most difficult rivers to travel on. Up to the time of the Rice Expedition, one Brazilian had gone about halfway up it, and two Germans had gone as far as the Parima Junction, finally taking the Aracasa Fork as being easier. It is perhaps interesting to give the impressions of the aeroplane observer, in his report to Dr. Rice on the first flight over this region:

"Having filled with gasoline and oil the night before (November 3, 1924), we left Boa Esperança at daybreak and flew up the southern channel (Maraca furo), getting an altitude of 5400 feet (nearly the maximum that is possible with the hydroplane with full load of gas). The river under us became very wide, some 4 miles, and was divided by islands into so many very small streams that landing-places were non-existent. The last outpost to the west of the open cattle-grazing country, over which roam thousands of half-wild cattle, was now behind us. The landscape changed from open campos to dense tropical forest, and from our elevation the palms below, scattered through the forest, looked like hundreds of star-fish at the bottom of an ocean, their lighter green bringing them out in strong contrast against the darker green of the jungle. Before us at this time (6.30 a.m.) the streams or waterways over a tremendous expanse of country were indicated by a thin white vapour that hung at perhaps 1000 feet or less. Three-quarters of an hour later this vapour was burned off by the hot sun, but for a time it enabled us to get the compass bearings of the general directions of streams and to note them on our sketch.

"A tail wind swept us along rapidly—how rapidly we had no way of judging until our return trip. Except for the spirals, blankets, and clouds of mist-like emanations ascending from numerous hidden streams of water, there was nothing in sight but the sombre, seemingly endless forest, premonitory in its silence and vastness.

"We passed in half an hour the end of a large island, formed by the south furo, over which we had just passed, and a northern furo; ahead of us was the full flow of the main river, and we flew in an almost westerly direction for half an hour more. The stream was still divided by jagged-edged islands and outcropping rock; in the narrow channels, caxoeira appeared under us, marked by boiling, foaming masses of white water.

"We had agreed to go only an hour, because of the high wind behind us, but ahead appeared a sharp elbow in the river, where its course was at right angles for a few miles. So we flew for five minutes more, and sketched to this point, which proved to offer a chance for landing, and apparently a good place to make a cache of gasoline. Turning, we made slow progress against the wind, and were forced immediately to drop down to 1000 feet in order to ensure that our gas supply would hold out for the return trip. Reaching the head of the island, we took the northern channel, and found landing conditions on this fork much better, although the river-bed was badly broken in half a dozen places. After a total of three hours and ten minutes' flying, we saw the first sign of human life—a hut on the bank about 5 miles above Boa Esperança. We landed and measured out gasoline, and found we had 6 gallons left. After making some Graflex pictures of the natives, we flew on to Boa Esperança, completing our sketching as we went. In this country no one lives, not even Indians, it is said; we saw no huts, no clearings, and no signs of man or canoes."

Just below the right-angle elbow in the river, above noted, is a rocky point, opposite which are several islands of granite, washed bare yearly of all vegetation by the flood waters that pour over them. The place is known as Kulekuleima by the Indians; above it the river becomes free from islands and from rocks to some extent, and in the next 125 miles there proved to be nine places large enough to take off from, from observation from above. The difficulty with some of these places is that a stretch of rock-free water ended at a bend in the river; at two places where take-offs were made this bend had an angle of 90°. The very high forest, growing right to the banks, makes it impossible to get off over the trees, and the plane must be banked, at low elevation, to follow the channel. In these narrow channels, between heavily and highly wooded banks, there is very little wind, and the air at mid-day is very hot, making climbing difficult. By following the channel for perhaps a mile the

Extreme S.W. point of air reconnaissance, 11 *March* 1925

Last place for take off, junction of Uraricoera and Aracasa

Upper Parima, near source: no landing possible elevation of the tree-tops is reached, and here the air proves to be very rough and "bumpy," except in early morning or late afternoon. In the entire basin of the Rio Branco the wind was almost always from the north-east. At a mile elevation the velocity varied from 15 to 45 miles an hour. There were days when the velocity must have been much higher, but no flying was then attempted.

Altitude gained by Plane.—With full load of gasoline and equipment it was possible to get to 6000 feet in a little over half an hour, and most of the photographic work was done from this altitude. On one occasion, with a half-tank of gas, photographs were made from 8400 feet, and the plane could have been pushed higher as the gasoline load lightened. When flights were made at the higher elevations with the wind, it was always necessary to drop to less than 1000 feet in order to make the return trip with the gasoline remaining. On several occasions the plane returned with 5 or 4 gallons only remaining, and once the engine stopped from lack of gasoline directly over the landing-place.

Distribution of Fuel.—Coming up from Manáos, the plane used a small river steamer as a base. Flights were made ahead 75 miles, and the plane was anchored beside the steamer at night. Sketch-maps and photographs were made on these flights. The steamer left gasoline and oil at several points to provide for the plane flying back. When the head of steamer navigation was reached, it was necessary to send gasoline and oil ahead to small settlements by light-draught launches. Later the launches were stopped by rocks and rapids; the supplies then went forward by canoe entirely to locations designated as landing-sites on the sketch-maps prepared by the man in the plane. Finally, the canoe progress became so slow that the plane made a last reconnaissance trip ahead, and was then forced to wait for nearly two weeks until the limited supply (70 gallons) on hand could be pushed ahead 125 miles, and until 35 gallons could be brought from Purumame Falls to Kulekuleima Rocks to fill the then empty tank.

Up to the time that canoes were used there was little trouble from loss of gasoline by leakage. The rough handling in the rapids, or caxoeiras, and frequent unloading, caused the cans to leak, and often the cans would be found to be less than half full when opened up river.

Water Conditions.—For the radiator there was no trouble in getting plenty of clean water, free from sand. In fact, the river water was always clean enough to drink, though often containing considerable vegetable matter in suspension. The Rio Negro water, in masses, is black in colour, and the Rio Branco light brown. In making landings on the mirror surface of the black Rio Negro water, it was sometimes necessary to land in the wake of the supply steamer, as otherwise it was very difficult to determine the level of the water.

While the densely wooded banks, with high trees, made take-offs difficult on narrow streams, this feature helped where the river channel was cross wind, for there was usually little breeze below the tree-tops where the width of the channel was small.

Sometimes, when the current exceeded 3 knots, it was difficult to hold the plane at anchor, and when the supply boat was near a much heavier anchor was dropped. The problem of approaching the plane in a swift current was considerable, and in one instance a heavy canoe was capsized while trying to get an anchor line aboard. The men clung to the plane, but the canoe was swept under the bow and disappeared entirely, never being recovered. Several men, by very energetic paddling, managed to work against the current up to the tail of the plane in another canoe and took the first crew and the crew of the plane ashore, two at a time.

There are many small stretches of water on these rivers where a hydroplane may be landed without injury, but where there would not be room to take off again. A new landing-place must be studied carefully from the air, particularly for ripples that indicate rocks just below the surface. In landing, the anchor must be kept ready to throw out quickly, if the plane is near the wooded bank or above rapids. In one case the plane after landing was worked down stream to an island, through scattered rocks, some of which were just below the surface, by alternately throwing the light anchor some 30 feet and pulling the plane to one side. The plane would then drift until it was necessary to avoid other rocks by the same process. It is particularly necessary to watch while drifting, that a wing does not get caught by some projecting branch ; in such case the nose of the plane turns in to the bank, the hull is broadside to the current, and there is a tremendous pull at the point where it is caught.

The presence of large buzzards at an elevation of 1000 feet or less made it desirable to keep a very close watch, particularly on take-offs, for these large birds are liable to fly in any direction. It was sometimes advisable to reduce throttle and dive the plane to avoid hitting them. Other birds, such as the brilliantly coloured macaws, would strike a bee-line course when alarmed by the noise of the plane, and would hold this course regardless. Birds were seen at elevations of 3000 feet, but in general they flew over the rivers and forests at less than 1000 feet.

Needless to say, in a pusher plane, the occupants must be very careful that there is nothing loose that may blow back into the propeller.

Ants and other Insects.—Where the plane is nosed in to a bank to avoid swift currents, ants pour aboard by the hundreds wherever contact is made with foliage. Although ants caused much trouble ashore by eating clothes and shoes, the fabric of the plane did not meet their taste ; there was no sign of damage from these insects. The termite, or wood borer, would be a bad insect to have aboard, but fortunately he does not travel along the twigs and leaves as do the ants ; furthermore, he likes to work in the dark, and is less likely to do damage to a hull that is outdoors than to one that is inside a building. The plane, even if moored in midstream, often was covered with spider-webs overnight, and there was almost sure to be a spider lodged in the venturi tube of the air-speed meter.

Photographic Work.—The vertical camera could not be arranged inside the cock-pit; there was no room without complete overhaul of the control system. Furthermore, the scheme of fitting a large circular aluminium casting into the hull did not seem good, as it would have weakened it greatly. A frame, therefore, was made up to fit on the starboard side of the hull forward of the wing. This frame held the standard Fairchild mount, which allows the camera to be turned or levelled during flight. Some trouble was expected from air currents disturbing the camera, but in this comparatively low-speed plane, with heavy hull, the suspension proved rigid enough to hold the camera steady. Exposures were made at $\frac{1}{100}$ and $\frac{1}{50}$ second.

The hydroplane was found to be very good to make oblique exposures from. With the Fairchild 20-inch (Model K-6) camera, exposures could be made directly ahead, over the bow, or from either side, without the aid of a suspension. The plane was very steady, and a comparatively low shutter speed could be used when desirable. One thing was poorly arranged in the cockpit: that was the magneto switch, located on the right-hand side of the compartment, away from the pilot. The observer accidentally hit this with the oblique camera one day, and the engine ceased firing, but fortunately he realized what he had done and kicked the switch back again within a few seconds.

Sketching from Hydroplane.—Traverses were carried out in practically the same manner as those made from the boats or canoes of the expedition. The hydroplane had the advantages of more nearly constant speed, of being able to cut corners, and of seeing both banks of the river and both sides of islands in the river. With boats, the river-flow is measured at intervals, and the rate of progress is the boat rate less the current rate. Where the river narrows, the current rate rises, but there is no time to stop to measure it. Consequently, with boat traverses, the details are drawn out where the current is swift and compressed where the water is still. In sketching with the hydroplane, flights were made as soon after daybreak as possible, before a wind sprang up. The traverse was checked on the return flight always, and if wind existed, it could be calculated and the sketch corrected.

The hydroplane had the further advantage that very long shots could be made. From 5000 feet it was possible to see 10 to 20 miles ahead and behind, and to get the bearings of distant bends of the river, large islands in the river, or other features that could be positively identified when the plane finally got over them and notation of time was made. The pilot swung the plane until the parallel strips of the top of the hull pointed to the required bend or island. The observer read the compass, after allowing it time to settle, and laid off the bearing on his board with a protractor. Then the plane was swung until a bearing could be obtained over the tail. As the plane then swung on straight-line course up river, the angles were laid off to correspond, and the time was noted as the lower and upper ends of islands were passed ; these were located at once on the sketch, allowing a nautical mile per minute per division of scale selected. The width of river and islands, and the shape, were filled in on the sketch by the observer, but he was in a much better position to judge the relative proportions than the personnel in the boats or canoes. The canoe party measured the width of the river from time to time by theodolite, and such information was available the same day to the hydroplane crew. With wide stretches it was possible to get a measure by flying the plane from bank to bank and noting the number of minutes and seconds taken to cross. There are long stretches of the Rio Negro, filled with large islands, that are 15 to 25 miles across, and on the upper Rio Uraricoera there is a stretch, island filled, that is 5 miles across. A canoe party can only guess the width and shape of the river as it passes up one of the many narrow channels, for there is no time to stop for an extended survey. The hydroplane gets a fairly correct idea in a few minutes of the same region.

The Aerial Camera records faithfully all details of the river and islands, but at 6000 feet such a small area is covered that it takes a tremendous amount of film to cover a large territory thoroughly. For this reason film was saved for the more important spots, and sketching was relied on for the remainder.

At intervals of about 30 miles the canoe party made night observations and calculated the latitude and longitude. The sketches were oriented and compressed or stretched as necessary to fit these calculated positions. The sketches from the hydroplane proved to fit the skeleton map of latitudes and longitudes remarkably well, and were especially close in direction, showing that the hydroplane compass was dependable. It was necessary to compress the sketches, usually from 5 to 10 per cent., in fitting them to the determined positions of latitude and longitude ; it was necessary to change the direction but very little—less than 5°.

There is no question that sketching strange rivers from an airplane is much faster, is more accurate, and gives more detail than the same work done from boats, especially where there is considerable island formation. Aerial photographs give a still greater degree of accuracy, and it is desirable that a plane be capable of climbing to a high altitude, in order that as great an area as possible may be covered in each photograph of a series. This economizes both in film and in flying time. A plane should do this work at 15,000 feet at least. Next it is desirable that a short-focus lens be used in the camera, that a large angle of view may be covered. On standard film, giving 115 negatives per roll, each 7 × 9 inches, a 12-inch lens is commonly used, but the Series IIb Tessar, F/6.3, of 10-inch focus, will cover the same size film perfectly. It is possible, at a small sacrifice in definition and covering power, to use lenses of 8-inch focal length, or even 7 inches. The illumination falls off appreciably at the edges of the negatives with lenses of less than 10-inch focus.

It is probable that a plane of the Douglas-Davis type, fitted with metal pontoons, will be as satisfactory as any. A plane for work in exploration should have a gasoline capacity of at least seven hours, and perhaps ten hours. It should be able to get off the water quickly with its load; a large wing area is desirable at a sacrifice of speed. There are few opportunities for landing except on the rivers, and pontoons only should be fitted. A Liberty motor, with Delco ignition, is desirable; with a 12-volt system, the same battery may be used for camera operation. The gasoline system should not be of the air-pressure type; the gas supply should be pumped from the tanks by either syphon or gear pump. There should be an auxiliary hand pump for the observer to operate in case of failure of the engine-operated pump. It is desirable that a small emergency gasoline supply tank be located in the upper wing. The seats should be designed to allow the crew to wear parachutes. It is likely that a compass of the earth inductor type will permit greater accuracy in making sketch-maps.

Provision should be made for mounting the camera inside the fuselage. A vertical view-finder, calibrated, should be provided for. The wings should be painted with aluminium dope to resist the sun's rays. Woodwork should have best protective varnish; wires should be well greased. Altimeter should be provided with a correction chart. A turn indicator should be part of the instrument equipment. A metal propeller should be furnished on the plane, and the design of it should permit quick climbing rather than high speed. The radiator should be extra large to ensure cooling when take-offs are necessary in the middle of the day or afternoon. Shutters should be provided for use at high altitude. Complete tool kit should be provided. Anchor and line should be part of equipment. Light-weight covers should be provided to completely cover the cockpits while the plane is moored. It is advisable to have four fittings for securing lines: one at bow, one at tail, and one at each end of lower wing, forward edge. Funnel and chamois strainer are necessary equipment. Oil-tank cap should be of ample diameter; oil tank capacity sufficient for ten hours' flying. Double stick control should be provided.

Future Work.—Some consideration has been given to making use of such a high-powered plane on a future expedition in this region, possibly two years from now. Tentative plans are to send a launch with aeroplane supplies up the Rio Negro, leaving gasoline and other materials at designated settlements, the latitude and longitude of which have been determined on previous Rice Expeditions. Another launch with supplies would be sent up the Rio Branco. Starting from a settlement on the Rio Negro, the plane would fly across to the Rio Branco, following and sketching in the courses of the nearest rivers that feed into these two larger streams; coming out on the Branco, the plane would be headed up or down river to the nearest settlement, where gas would be available. The plane would then move up river, fill tanks, and fly back to the Negro, again following the nearest watercourses, and making for the nearest settlement on the Negro. In this way, in a few weeks, assuming no motor trouble, the system of waterways of the huge area between these two great rivers would be mapped with reasonable accuracy. At the present time almost nothing is known of this waterway system; no two maps show these tributaries alike for direction or length, for the reason that geographers must guess, or work from meagre information furnished by Indians or by parties gathering balata, rubber, or nuts. With accurate information available, it may be possible for parties to work from one waterway to another. In fact, some of these are likely to be joined together by canals, as the Rio Negro and the Orinoco are joined by the Casiquaire Canal.

With a high-altitude plane and a wide-angle camera, the survey could be carried out photographically with greater accuracy than by sketching; with automatically driven camera, the sketching could be carried out at the same time by the observer, to ensure results in case of possible loss of photographic record (as might happen should large masses of clouds form between the plane and the ground). In case of motor trouble, there is a fair chance of making a landing in some waterway, when the crew of the plane would have to work their way to civilization as best they could. A large plane could carry sufficient firearms, provisions, etc., to give the flyers a reasonable chance for escape from the forest.

With wireless equipment on both launches, departure of plane would be given, and failure of plane to arrive on time would be communicated back. Knowing the tributary followed from one river, and the probable stream followed to the other, relief parties could start out immediately from both ends, which would increase the chances of the aviators. A few rockets, to be used nights at a certain designated hour, by both aviators and relief parties, would perhaps be worth using.

While motors are now very reliable, there is always a chance of trouble, and every precaution should be taken to ensure reliable operation, for a forced landing on any of the many flights that would have to be made, would be considered by those acquainted with the Amazonian forest a very serious situation for the flyers, even though the plane be landed on a waterway without damage. If not over a waterway, parachuting would be advisable before the plane crashed in the massive trees of the forest; the only hope of the flyers would then be to find the wreck of their craft, and secure food. With machete and compass, they could perhaps cut their way to the nearest river, build a raft, and escape. A broken arm or leg would mean certain death, of course. These are chances that people who venture over this region must take, and no expense would be spared to give them as reliable an aircraft as may be had at the present day.

THE CAPTAIN SCOTT POLAR RESEARCH INSTITUTE

THE inauguration of the Institute for Polar Research in memory of the late Capt. Scott took place in Cambridge on May 22 last, and now that it formally enters upon its career it seems proper that a full statement of its history and aims should be published for the information of those who may wish to use its facilities or who are ready to assist in its aims.

The germ of the idea may be said to have been born in 1913, when certain of the scientific members of Scott's last expedition sat down to prepare their reports and found considerable difficulty in obtaining the scientific reports of previous expeditions. It grew to large proportions when, in 1919, the member in charge of the report on the maps and surveys found that without access to the original records he could form no judgment of the value of earlier work. After diligent inquiry he obtained some of the field note-books of a former expedition, but found that the usual fate of such things in the past had been to be relegated to the lumber room of the original owner or dispersed as souvenirs to friends and relatives. In examining the few original journals which were obtained he and others engaged on the reports made the sobering discovery that observations which they had fondly considered were originated by them were often enough noted in detail many years before, but, not being published, had been unknown and inaccessible.

It was therefore with considerable enthusiasm that two or three of those engaged on the work at Cambridge approached various people with the suggestion that something should be done to preserve for the future whatever records were obtainable. They met with encouragement from all those who knew the real state of affairs, especially from the authorities of the Royal Geographical Society, who recognized that the Society, while remaining the inspiration and general guide of British polar exploration, could not undertake the specialized study of technical and literary records, and the direction of research, which was the central idea of the scheme proposed.

This encouragement and an introduction from Sir Arthur Shipley enabled the promoters to approach the Trustees of the "Scott Memorial Fund," which was established in 1913, and of which £10,000 had been allotted "in aid of polar research." At that time the trustees were

Sir J. J. Thomson, as President of the Royal Society, Sir Francis Younghusband, as President of the Royal Geographical Society, and the Lord Mayor of London. They very kindly received a deputation of one of the promoters, and not only indicated their general approval of the scheme but gave a grant of money to enable a beginning to be made in the collection of material. They also wrote to the University of Cambridge promising a sum of £6000 under certain conditions in the future.

With this help the Institute came into being, but as it had no money except a small capital sum its work was not advertised in any way, and consisted of collecting by gift and occasional purchase the nucleus of the material required. The grant was exhausted by 1925, and a further appeal was then made to the Trustees. Sir Charles Sherrington, Lord Ronaldshay, and the Lord Mayor heard the appeal with interest, and decided to hand over the balance of the whole fund (nearly £12,000) to the University of Cambridge for the foundation and maintenance of the Polar Research Institute. The only condition attached to the gift was that £6000 of the sum should be set aside to provide a suitable memorial building for the institute, to be erected within ten years. The generous offer of the Trustees was formally accepted by the Senate of the University, and in January of this year it proceeded to appoint a Committee of Management. The Committee, consisting of Dr. A. C. Seward (Chairman), Dr. H. R. Mill (representing the R.G.S.), Mr. R. E. Priestley, Mr. J. M. Wordie, and Mr. Frank Debenham, appointed the latter as first Director of the Institute.

Such is a brief outline of the history of the Institute, and we must now consider its aims. Polar research is a wide and indefinite title, and though it was chosen for that very reason it is important that its meaning as interpreted by the Committee of Management should be clearly understood.

It will be conceded at once that polar research is not confined to the men who actually visit the polar regions. For every one such there are in this country alone many whose interest in those regions is just as keen, whose knowledge is in many ways just as deep, and whose services to polar research may be just as notable and lasting though perhaps less public. It is, in fact, the duty of all those fortunate enough to have taken part in a polar expedition to realize that their opportunity is often but the outcome of the thoughts and plans of hundreds who have, however indirectly, sent them there, and whose assistance is the real basis of all polar research. The author of 'The Siege of the South Pole' is one such: his services to polar work are already beyond assessment, and the fact that he is on the Institute Committee is an earnest for its close touch with all recent polar work. There are many others of equal zeal if less talent. For instance, the most complete press record of all recent expeditions of which the writer knows has been the result of years of compilation by a lady in the north of England, whose knowledge of the facts

Mopepe again. I had the greatest difficulty in forcing my way through in my small dug-out canoes in this which was considered a record flood. There must have been a considerable flow not so very long ago, for the stream-bed below Mopepe is lined with the stumps of gigantic muchweri trees.

The arrangement of the water at Mopepe is a very perplexing one, and could not be even guessed at unless the channels were full. In recent years the area has been surveyed by Passarge in 1897; in 1909 Dr. Graetz came in a motor car from South-West Africa. In 1910 a party of twelve Germans came along with speedometer and a cartographer; Dr. Seiner was through in 1911; and in 1914 Messrs. Ziegler and Theron came here photographing. In 1924 the locust expedition passed through, under Col. Williams.

At Gomo, E. C. Ingleton's store, there is the Kode inlet into lake Kumadow. It runs more or less parallel to the Botletle, joining a similar inlet at the Doe Kode drift. The united stream flows south and disperses through the marsh in a number of small runnels. The main stream turns south at Karapa drift, where I had to abandon my boats, and turns round at Pororga drift, comes north and would flow into Domato pan, but this year the water came only as far as the Chukwe pan. Another branch comes off at Pororga drift, which makes a similar loop further south, and the channel comes north and joins the other one some 6 miles north of Mopepe. This loop was quite dry, but it carries an abundant and permanent supply of underground water, so the large towns of the Bahrutsis, Chapo, Pompi, and Racomo, are built along it, and the Makalaka town of Mopepe as well.

At Nkwa Kwena there is a bar of green quartzite holding up lake Kumadow, and only when the water rises above this sill can any flow towards the Soa. This latter pan is filled annually, but from the east; never more, nowadays, from the west.

The soil of the Kumadow is precisely similar to that in the Mababe and Ngami; it ignites spontaneously, forming burning pits, which are very dangerous, as when a native falls into one nobody will venture to help him out. Wind devils race over the surface, raising enormous columns of black dust, resembling smoke, and the upper air is charged with the fine vegetable particles. I have obtained similar material from the roofs in Kimberley after what has been called " black rain," and no doubt the origin of the dust was in one of these Ngamiland lakes.

This year the floods have not been reinforced by additional rain, and lake Ngami is drying up and smelling horribly. In lake Kumadow the same is probably happening. Immense numbers of fish, mostly bream, come down the river, and are caught in hundreds by the Batete Bushmen; when the lake dries they lie about on the surface and rot, but the natives collect them and eat them all the same. The odour of putrid fish comes through their skins, making them unpleasant companions.

THE RADIO-TELEGRAPHY OF THE HAMILTON RICE EXPEDITION, 1924–25

EARLY in 1925 we received two wireless messages from Dr. Hamilton Rice on the Rio Branco, the first through Mr. Gerald Marcuse's station at Caterham, the second by the courtesy of Mr. E. J. Eckert, of Philadelphia. The remarkable success of the short-wave transmission, used for the first time by an expedition in the field, makes it desirable to publish the technical details as soon as possible, for the instruction of other geographers. Dr. Hamilton Rice has very kindly placed at our disposal the reports of Mr. John W. Swanson and Mr. T. S. McCaleb, his two wireless operators, and also the report which Capt. A. W. Stevens, of the U.S. Air Service, made by his direction to Major-General Mason M. Patrick, Chief of the Service.

The three reports naturally overlap, but it seems better to print them nearly in full than to risk elimination by an inexpert editor. The importance and novelty of the material justify a treatment more technical than is usual in the *Journal*.

REPORT BY JOHN W. SWANSON

On two previous expeditions with Dr. Hamilton Rice, from October 1916 to June 1920, the use of radio equipment was confined solely to receiving time signals, and press despatches from the United States and Europe which kept the members of those expeditions fully informed of current events. A report on this work appears in the *Geographical Journal*, October 1918 and September 1922.

With the rapid development of the radio art since the 1919–20 expedition it was in logical sequence that Dr. Rice should incorporate as one of the objects of the 1924–25 expedition into the Brazilian Amazonas and Venezuelan Guayana the test of radio communication in the field.

Dr. Rice decided to embark on this project prepared for any emergency, and about $6000.00 worth of selected radio equipment was purchased. Not only were sufficient spare parts taken on this expedition but a large quantity of radio material for experimental work, anticipating the fact that we could improve our equipment from time to time or build new apparatus if circumstances warranted.

Offices were rented at 80, Beaver Street, New York City, from 1 January 1924, and here all our materials and apparatus were assembled or constructed. Mr. Thomas S. McCaleb, former radio laboratorian at the U.S. Navy Yard, Norfolk, Virginia, was the writer's capable assistant.

Provision was made for the following equipment :

1. A supersensitive radio time signal receiver, having a wave-length range of 1000–20,000 metres ; loop antenna, 1 stage of radio frequency amplification, detector, and one stage of audio frequency amplification. The radio frequency transformer consisted of honeycomb coils which were interchangeable for the various wave-lengths. A circuit diagram is attached hereto. The receiver was enclosed in a moisture-proof case constructed of brass, and could be submerged in water for hours without damage (see Fig. 1).

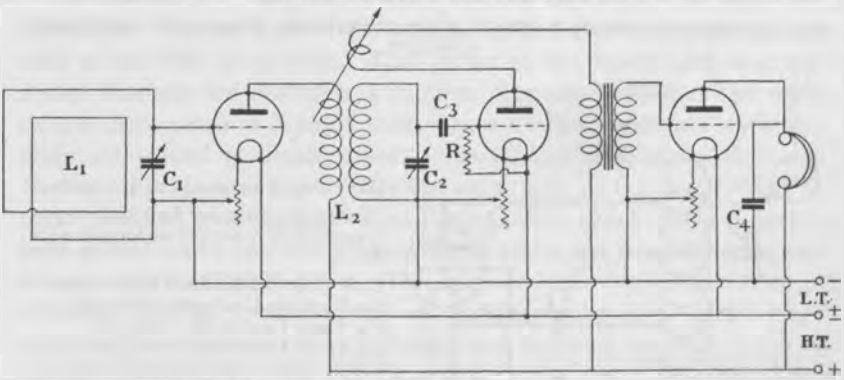
2. A portable base radio station consisting of a ½-K.W. vacuum tube transmitter to operate on the wave-lengths of 95, 1500, 1950, and 2250 metres. This

transmitter consisted of 8 UV 203 A R.C.A., V.T. tubes paralleled in a standard Hartley circuit. A circuit diagram is included herewith [not reproduced].

The primary power plant for this transmitter was a 1½ K.W. Delco electric 110-volt system. A generator driven by an efficient kerosene motor arranged in a very compact unit charges 60 cells Exide storage battery, 100 ampere type. A standard dynamotor of the Electric Specialty Company 110 volts D.C. primary, 1200 volts D.C. secondary at 1 ampere, was used for supplying current to the plates of this transmitter. The windings of this machine were especially treated to withstand moisture. A 12-volt 210-ampere-hour battery supplied current to the filaments of the tubes.

3. A portable 25-watt V.T. transmitter to operate on a maximum wave-length of 100 metres, for use by the advance party in communicating with the base. This transmitter utilized two 50-watt UV 203 A R.C.A. vacuum tubes, arranged in a standard Hartley circuit. Two 6-volt 40-ampere-hour Exide

FIG. 1.—TIME SIGNAL RECEIVER



Wave-length range, 1000 *to* 20,000 *metres.*

L_1, Loop Antenna.
L_2, Honeycomb Coils, covering range of wave-length.
C_1, Variable Condenser, 1000 $\mu\mu$F.*
C_2, Variable Condenser, 1000 $\mu\mu$F.
C_3, Grid Condenser, 250 $\mu\mu$F.
C_4, By-pass Condenser, 2000 $\mu\mu$F.
R, Grid Leak, 2 MΩ.
L.T., Low Tension Battery.
H.T., High Tension Battery.

storage batteries supplied current to the Electric Specialty dynamotor, 10 volts D.C. primary, 500 volts ·3 amperes secondary. The complete equipment, exclusive of the battery-charging unit, which consisted of an automobile generator bolted to a small gasoline engine, weighed but 50 lbs. (see Fig. 2).

4. A 10-watt V.T. transmitter and radio receiver for the air-plane. This equipment including necessary accessories weighed 50 lbs.

" B " batteries manufactured by the Burgess Battery Company, Madison, Wisconsin, were selected. The smallest size made were connected into 45-volt units and placed into small light wooden boxes made large enough to receive them and still allow the battery to be completely covered on all sides with pure paraffin. Packed thus, a battery will withstand considerable mishandling and

* To convert the condenser ratings from micro-micro-farads ($\mu\mu$F) to micro-farads, divide by one million. *E.g.* 1000 $\mu\mu$F = ·001 μF.

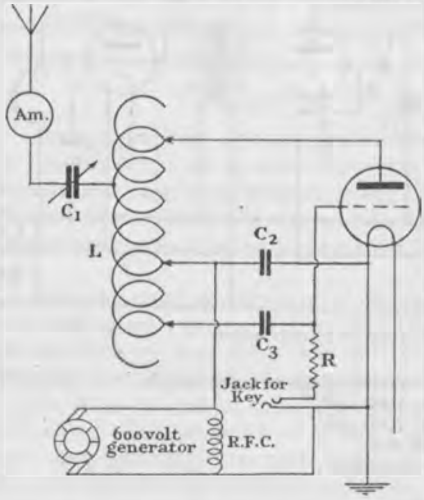
have absolute protection against moisture, which is the chief cause of rapid deterioration of dry-cell life in the tropics.

The electrical measuring instruments as manufactured by the Weston Electrical Instrument Company were used exclusively, and consisted of various milliammeters, ammeters, voltmeters, thermo-galvanometers, thermo-ammeters, resistances, etc.

Two wave meters were included in the equipment: one covering the short-wave band 40–150 metres, and one covering the band between 150–3000 metres.

All equipment was in order and ready for packing by 15 March 1924. Special attention was given to packing. Each individual piece was carefully protected and wrapped, and then packed away in extra strong boxes which had been lined with a heavy tar paper that affords a certain amount of protection against moisture and the attacks of insects. The cases were purposely made small so they could be easily handled—a very important factor in the successful shipping of heavy but delicate materials.

FIG. 2.—FIELD STATION PORTABLE TRANSMITTER, STANDARD HARTLEY CIRCUIT



Wave-length range, 40 to 100 metres.

The diagram has been rearranged to make it more easily comparable with No. 3.

L, R.C.A. Oscillation Transformer.
C_1, Variable Condenser, 500 $\mu\mu$F.
C_2, Fixed Condenser, 2000 $\mu\mu$F.
C_3, Fixed Condenser, 2000 $\mu\mu$F.
R.F.C., Radio-Frequency Choke.
R., Grid Leak, 5000 ohms.
Am., Ammeter.
Input, 50 Watts on 100 metres.

At this time the Brazilian Radio Laws strictly prohibited all but Government-operated radio stations; but, through the efforts of the American Ambassador to Brazil, a licence to operate our equipment was granted by the Brazilian Government, and permission was given to use the American call signal "WJS" allotted by the U.S. Department of Commerce subject to the approval of the Brazilian Government. In the course of negotiations I had occasion to visit the Ministro do Viacao, or Commissioner of Public Works, who is charged with the supervision of all radio matters in Brazil. The courteous manner in which this piece of important business was handled will always be a pleasant recollection. When the proposed radio work of the expedition was thoroughly understood, not only was permission granted to work with the radio station at Manaos, but telegraphic instructions were sent to the Federal Radio Inspector of the Amazon District to extend us all possible cooperation. Dr. Manoel De Barros, Chefe do Distrito Radio Amazonas, was untiring in his efforts to assist us in making the radio experiment a success. Permission was granted to erect our experimental station at the Manaos Radio Station (SQM) grounds. Dr. Barros was responsible in no small degree for the success of our work.

The collapsible hut for the base radio station WJS was built at Manaos and subsequently erected on the grounds of the Manaos radio station. It is a simple structure, a few posts accommodating screened panels, designed for practicability and the comfort of the operators. Under the canvas of our hut, safe from the onslaughts of mosquitoes and other pestiferous insects, we successfully communicated with Para, about 850 miles from Manaos as the crow flies, using our tube transmitter with a power of 400 watts input to the antenna on a wave-length of 1500 metres (200 kc.). With that accomplishment went some assurance of success. Tests of short-wave receiving equipment at Manaos did little to bolster the confidence of the radio detachment. Nights of dial twisting and ear straining brought in but three short-wave stations, two of them broadcasters. Hearing KDKA and WGY with regularity on high frequency was, it is true, a distinct contribution to the expedition's entertainment, but reception of a lone code station—it was 8XI—was discouraging.

The next test involved the radio equipment for the air-plane. Successful communication was established with the air-plane from the experimental base radio station. However, the plane used was not sufficiently large to accommodate the weight of a radio operator in addition to the pilot, aerial photographer, etc. This enforced the abandonment of that important radio communication link.

Radio work at Manaos was drawing to a close when a political tidal wave engulfed the town. On July 23 we found ourselves in the midst of a revolution. The upheaval hampered the expedition's work but little, though it brought an end to radio tests. Under rebel rule, with absolutely no communication with the outside world, the mails, cable, and radio services being interrupted, Dr. Rice was the only other man in Manaos conversant with current events, for with our loop long-wave receiver I heard the news from the world over.

When the time came to move up-river, an old stern-wheel steamer transported the party to Vista Alegre, on the Rio Branco. Arrangements had been made with Dr. Barros that, should the revolution cease and it was possible for him to do so, the Manaos station was to broadcast the expedition's messages. On 7 September 1924 the Manaos station broadcasted that the revolution was over, and a series of important messages for the expedition was received.

Ascertaining that Vista Alegre was a poor radio location, we placed our equipment aboard a batalao, towed by a steam launch, and proceeded farther upstream to Boa Vista, which was to be the expedition's base.

McCaleb went down with high fever the day of his arrival at Boa Vista. Two weeks he lay ill at the small mission, attended by the kindly padres. While he convalesced, the erection of a station at Boa Vista went forward, the main trouble encountered in putting it up being inability to secure timber for masts in a treeless territory. Four days' journey from the camp mast material was found, cut, and floated. With the help of natives, most of them Indians, three masts, 80, 75, and 40 feet high, went up. An antenna for long-wave work was suspended between the two highest: a short-wave antenna was hoisted between the shorter sticks. There was an elaborate ground system for long-wave work, and a litzendraht cable counterpoise for the high-frequency set. Our radio hut in place, a barbed wire fence was erected enclosing the station, to protect us from half-wild cattle that roamed the campos.

There followed six days of calling and listening while static alone caused the headphone diaphragms to vibrate. Two operators were deep in the dumps, half sick, and nearly played out, when a woman's voice floated in on the 60-metre wave. The song, ironically enough, was "Happy Days." KDKA's short-wave set did a physician's work at Boa Vista that night.

The next night an American amateur shattered the silence with a readable signal, but failed to respond when called repeatedly. This was a disheartening chapter, and the events of the next few days produced more gloom. McCaleb, sent down the river to join the expedition proper at Vista Alegre, took with him the 25-watt transmitter, hoping to effect communication with the base station WJS at Boa Vista. The attempt failed dismally. The only silver lining during these days of discouragement was that another American amateur was heard, and WSC, an American coastal station of the Radio Corporation of America, boomed in. They could not be made to hear us, however. Then things brightened, for Manaos, called in vain for days, one morning responded with a snappy "OK" reporting signals strong and clear.

The base party having established itself at Boa Vista, and McCaleb in charge of WJS, the advance party early in December started on its journey, the 25-watt transmitter, under the care of the writer, accompanying it. Communication between the two parties was established without difficulty after the advance party had made some progress, and radio stock soared. Equipment overlooked when the party set out, and needed urgently by the scientists, was ordered and despatched in pursuit from Boa Vista. The portable set was demonstrating its usefulness.

At this juncture, with things going swimmingly, partial failure loomed in the radio detachment's path. The rock on which the plans threatened to wreck was the heavy tube mortality at WJS. The 50-watters expired in such numbers that not enough remained to power the long-wave base transmitter. The Boa Vista–Manaos link broke, and the expedition's communication with the outside world was disrupted.

Short waves and the American amateur saved the day. During the months since the expedition's sailing, the great amateur migration to the 40–80-metre band had taken place. So, unable to work Manaos, which was, as radio distance is measured, but a step away, WJS began shooting Rice Expedition traffic almost daily to American amateurs. First two-way communication was effected with 2CVS, Ellison Thompson, New York City. This success was followed by the transmission of long and important messages to dozens of other amateurs in the United States. Stations 2 AG, C. R. Runyon, Yonkers, N.Y., and 2 BR, operated jointly by A. C. Lopes and J. W. Baldwin, handled the bulk of our messages in a praiseworthy manner. Messages were also exchanged with G2NM and G2OD in England; CB8 in the Argentine; and the United Fruit Company's efficient station at San Jose, Costa Rica.

Some of the traffic was destined to American points, but much of it was addressed to Manaos. Consider what this meant: Manaos was about 400 miles from WJS, but could not be reached direct during the tube shortage days. A message for Manaos went 3000 miles by ether to the United States, 3000 miles by cable from the United States to Para, Brazil, then another 1000 miles by cable to Manaos. Costly? No end! Subject to delays? Yes, frequently. But the messages, many of them of utmost importance to the party, reached those to whom they were addressed, and that was the object of the game.

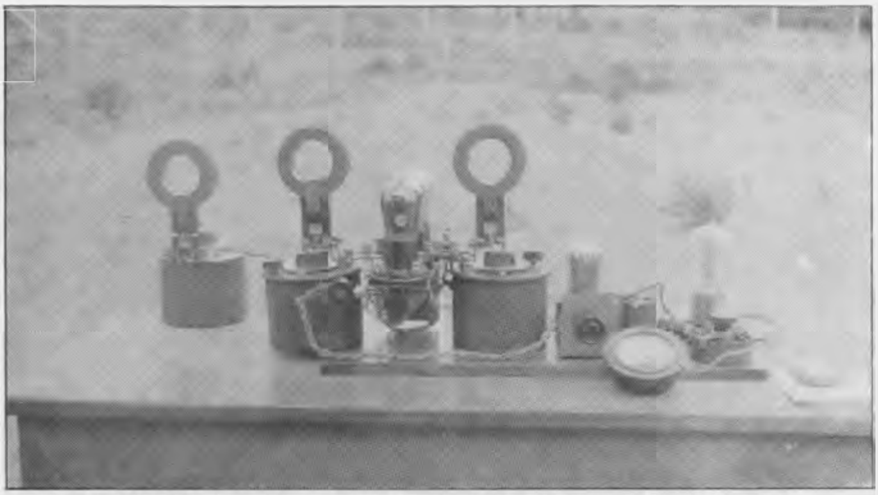
In a clumsy, heavy, spoon-billed craft, more scow than canoe, radio made its start up the angry river, its guardians being Weld Arnold, topographer; Indian boatman of the region, Antonio, in whose veins ran mixed negro and Indian blood; and the writer.

THE BOA VISTA STATION

MR. SWANSON RECEIVING AT BOA VISTA

SHORT-WAVE TRANSMITTING (Fig. 3) AND RECEIVING SET (Fig. 4)

LISTENING IN ON THE RIO BRANCO



SHORT-WAVE RECEIVER (Fig. 4) SET UP FOR STATIC STRENGTH

MR. McCALEB RECEIVING A SHORT WAVE IN THE FIELD: TIME SIGNAL RECEIVER AND FRAME AERIAL IN BACKGROUND

Erection of an antenna was the first step in the establishment of radio stations at the jungle camps. Trees were the masts, and the vegetation for some distance about the antenna trees was cleared away to give the wires breathing space. The receiving antenna was usually a 30-foot length of wire, suspended 1 foot off the ground. The low antenna reduced signal strength materially, but reduction in static more than compensated for this loss. In a tropical region, where every night is a static night, LR, the field station, thumbed its nose to atmospherics. Obtaining an efficient ground was no problem ; a length of antenna wire thrown into the river served well.

Having nothing but the long-wave time signal receiver with which to receive WJS signals, the operator had an interesting time away up there in the forest with this sudden and unexpected introduction to communication on these very short wave-lengths. A short-wave receiver, put together in the wilds out of odds and ends, including two empty sugar-tins procured from Kwong, the Chinese cook, was an instrument that would bring a blush of shame to the cheek of the radio constructor who likes to see things shipshape. That its appearance was not a measure of its sensitiveness was demonstrated when it picked up amateur signals from every radio district of the United States, and from many foreign countries. A simple Armstrong circuit was used.

The transmitter, designed for maximum efficiency on 100 metres wave-length, was reconstructed up-river after its operator became convinced that better results were obtainable lower down the scale. Alterations fitted this set for 80 and 40-metre work.

The lack of a wave meter at the portable station was met one night when the operator had the good fortune to pick up the standard frequency signals emitted by WWV, the Bureau of Standard's station at Washington. Utilizing the system of harmonics, a hastily assembled but accurate instrument was calibrated.

The portable station's power supply was a dynamotor operated by storage batteries, which were charged by an automobile generator bolted to an outboard motor, which in turn did canoe duty at other times. Both outboard motor and generator threatened frequently to give up the ghost, but were nursed along to a remarkable performance by the gas-engine experts of the party, who lent a hand to the radio operator when failure of the power supply loomed.

Anti-ant measures became a regular part of radio routine after the short-wave receiver, opened one day for inspection, was found to be full of very live radio bugs. Hornets, of a species which build a mud dwelling, took possession of LR one day up-river. The operator found that all crevices in the apparatus had become hornet home-sites. Their mud huts shorted the grid and plate terminals of one transmitter tube, and a veritable firework display resulted when the current was turned on.

There were few nights spent in camp when traffic was not exchanged between WJS and LR, and scarcely a night when signals from American amateur stations were not heard on the crude short-wave receiver. Owing to the necessity of conserving power, the portable station's messages destined to the outside world were habitually sent to the base station, which relayed them northward. This was, however, no insult to the 25-watt set at LR, for on one occasion, when the operator's curiosity to learn how the low-power equipment would reach out got the best of him, he passed with ease a message direct to station 4DO of M.M. Burns, at Atlanta, Ga. We were quite surprised to learn that the signals from this small transmitter were being received all over the United States.

There were times when, unsuccessful in raising WJS on 80 metres, a shift to the 40-metre wave brought immediate results. Even after nights when signals carried poorly, when static was terrific, there was a short period just following sunrise when the world could be heard. Sometimes this fruitful interval lasted two hours, often not longer than fifteen minutes.

The amount of power used in transmission appeared not to be a factor of much importance. Many of the amateurs heard in the forest were using sets with as little as 10 watts of power. McCaleb reported that he was often warned that LR was about to call by a clearly audible sound which could only have been occasioned by a minute amount of radio frequency energy leaking into the antenna when the tubes were lighted but when the key contact points were not actually meeting.

Elevation above sea-level was important, the ease with which traffic could be handled apparently varying consistently with the elevation. During early evening the short waves gave poor results. It was a rare night when much work could be done before nine o'clock.

On a whole, while transmission on high frequencies proved to a certain extent freaky, communication was established over such long distances, with so little power that the conclusion seems unescapable that short waves will come to be used extensively in long-range work. We have not yet solved many of the mysteries of their propagation, but we have opened the gate wide enough to enable us to see that there is much inside the field we hardly realized, until recently, was ours to explore and to use. Hereafter there is no reason why any properly equipped expedition, with a mere handful of apparatus, cannot be in daily and reliable communication with the outside world. Dr. Rice has demonstrated to the world that this work can be done, and he deserves the highest commendation for opening this new field for radio communication.

REPORT BY THOMAS S. McCALEB

The expedition carried wireless equipment to receive time signals from Balboa, Panama, and Annapolis, Maryland, for daily chronometer checks, and for reliable communication with its base and the United States.

The original scheme for establishing communication from advance party to base made use of short wave-lengths in the neighbourhood of 200 metres. From the base, where all traffic was relayed, a wave-length of approximately 3000 metres was employed to communicate with the Brazilian station at Manaos, 400 air miles south of the base at Boa Vista. At Manaos traffic was further relayed *viâ* cable to New York, and thence to its destination *viâ* Western Union Telegraph.

This crude method proved unreliable and required considerable time; moreover, there existed numerous dangerous opportunities for errors in the various relays. After this system of communication had been in effect for three months, extreme adverse atmospheric conditions practically limited the transmission and reception of messages to approximately 150 words per week. Later, with the use of short waves, it was possible to handle on an average 150 words daily.

The Rice Expedition was the first to attempt radio communication in the tropics on a short-wave system. The entire operation was no more than an experiment, for everything pointed to defeat. The miles of tropical forests to absorb energy of transmission, atmospheric conditions that seriously interfere with reception, and a peculiar kind of atmosphere that absorbs electro-static and electro-magnetic energy make communication unreliable between Brazilian stations using 40 k.w. of power to cover a distance of 800 miles. Probably the greatest obstacle was moisture, which may cause serious damage in the high-potential circuits of a transmitter and render receiving equipment inoperative.

In designing and constructing the radio equipment used on the expedition all these obstacles were taken into consideration and the conditions likely to be met with were taken care of in the best manner possible, principally by making the apparatus capable of withstanding overloads and preventing the entrance of moisture by constructing parts of moisture-proof material.

The Time Signal Receiver.—The original time signal receiver was made in three parts: the collector or loop, the receiver, and the power system which consisted of a 6-volt, 40-ampere-hour storage battery, and anode batteries. The receiver contained a standard three-valve circuit, one stage of high frequency amplification, detector, and one stage of audio-frequency amplification. This unit was encased in a brass box, and its cover hinged down on a rubber gasket surrounding the outer edges.

No further description need be given, as this receiver was entirely too cumbersome, considering that a time signal receiver could be constructed within a weight of 30 lbs., and the entire apparatus encased in a box whose dimensions should not exceed 12 inches long by 6 inches high, and 6 inches in depth. It is recommended that dry batteries supply power and the super-heterodyne principle for reception be employed.

Time signals were received twice daily from Balboa and Annapolis under the worst conditions. Regardless of atmospheric or geographic conditions a perfect time check was always obtained. For example, while returning downstream in a canoe going approximately 6 miles per hour with the current, shooting minor rapids and following the many twists and turns in the narrow river (Furo de Maraca), the operator stood up in the canoe and rotated the loop in order to keep the loop's plane always pointing towards the transmitting station for maximum signal strength. After receiving for three minutes a strong wind blew the loop, which was sewn in cloth, from its frame. This necessitated the operator temporarily converting himself into a loop frame by supporting the loop with outstretched arms. Only one half-minute was lost in the change, and no perceptible difference in signal was noted. Besides successful time signal reception, a newspaper was published.

During the final lap of the journey up the Uraricoera it was necessary to reduce weight, and an experiment was tried with dry batteries formerly used for gasoline engine ignition, and flashlight batteries, as power supply for the filaments in the receiver. This proved to be most satisfactory and considerably reduced weight. Also dry batteries are far more practical where natives are used as carriers, for there is no acid to be spilled. It seemed to be a practice among Indians and Brazilian natives to place a storage battery in an inverted position.

Flashlight batteries were used successfully to furnish power for illumination lamps on the theodolite. These batteries may be covered with paraffin and kept for more than a year until put into actual service.

NBA (Balboa) was to be the time-signal station for our chronometer checks, but by careful comparison between NBA and NSS (Annapolis), Balboa was found to have an error which increased gradually up to as much as three-tenths of a second, reaching a maximum at the end of two weeks. Thereafter (exact date unknown) the signals would check and the error at NBA would again occur.

At two points on our journey hills 1000 feet in height completely encompassed the camp located in thick jungle ; yet, with this combination of screens, excellent reception was obtained from both Balboa and Annapolis on long waves 7500 and 17,500 metres approximately. At these two points just described, successful short-wave communication was established between New York and Canada during severe electrical storms.

Short-Wave Equipment.—On 14 December 1924 a small transmitter and receiver designed to work with frequencies from 3000 to 7000 k.c. (100 to 40 m.) were designed, constructed, and put in operation. Station 2CVS in New York City was the first to communicate with the expedition. One week later stations 2MC, 2AG, and 2BR established nightly schedules, and most of our traffic was handled through them. Numerous others all over the United States also handled messages. Besides communication with regular scheduled stations, others in various parts of the world were "tied in" as possible links in our system. The greatest distance covered was 8500 miles, with Station 2AP at Wellington, New Zealand. At the base station the approximate power delivered to the antenna was 150 watts at 3750 k.c.

Station 2NM, at Caterham, Surrey, owned by Mr. Gerald Marcuse, was the first English station to communicate with the expedition. Several messages from Dr. Hamilton Rice and the Royal Geographical Society were handled and a precedent established for communication from expedition in the field to the R.G.S. Had not the operator at the base station been handicapped by fever a regular morning schedule could have been maintained with 2NM.

To the Radio Club of America, and members of the American Radio Relay League, great credit is due for efficient, rapid, and accurate transmission and reception of messages of the expedition.

A record was established by Station 2AG at Yonkers, New York, when a message of twenty-five words to New York City was delivered and a reply received by the sender at the portable station on the Uraricoera. The total time was 7·5 minutes. It was necessary to telephone the message from Yonkers to New York City.

An urgent message was also sent to the S.S. *Leviathan*. This time 2AG received and delivered the message to the Radio Corporation of America, who relayed it through their large land station.

Short-Wave Transmitter.—The transmitter design followed new principles. All parts in any magnetic field were made of wood impregnated with paraffine, which offers the lowest possible loss of power. No panel was used, but all apparatus mounted on a small wooden board. All connections were made short as possible and ran direct to the instrument next in circuit. The appended schematic diagram is self-explanatory (Fig. 3). The circuit L1, C1, determines the frequency of the transmitted wave, and by virtue of their ratio a high capacity and low inductance form an ideal low-resistance circuit.

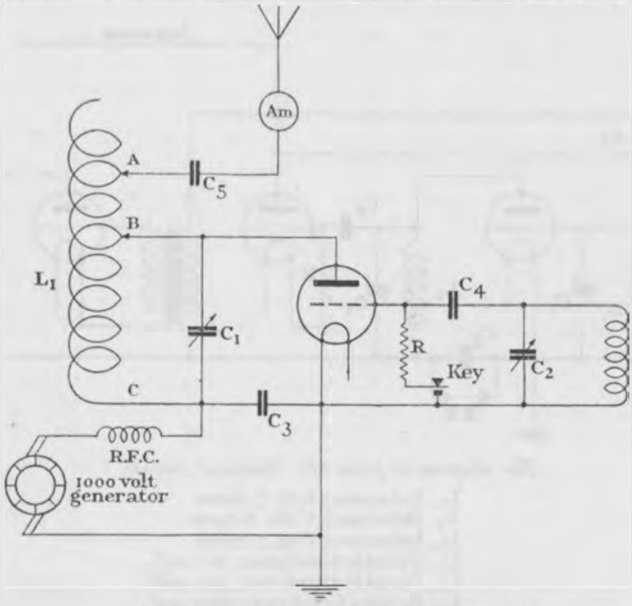
The antenna is coupled by a very low capacity of 0·000025 micro-farad. This reduces considerably the effect of swinging, or varying antenna constants on the outgoing frequency. With this arrangement of tuning grid and anode circuits, the transmitter becomes a potent oscillator, and no difficulties will be encountered when using harmonic radiation. As proof of this, the eighth harmonic of the long-wave antenna at the base station was used with great success. By connecting the anode tap across L1, C1 at point "B," the tube capacities are added to C1 and C2, which prevents circuit from "swinging over" to other electrical periods in circuit—an ideal arrangement for ultra-short waves. Primary source of power was $1\frac{1}{4}$ K.W. Delco, 110-volt system.

Receiver.—Like the transmitter, the receiver follows new design, mostly original, using only such parts as would be essential to efficient operation.

The inductances were made of number 18 D.C.C. waxed wire. This was the proper size for minimum high-frequency resistance ; any larger wire would only involve losses due to eddy currents. The inductance coils were self-supported and made rigid by sealing wood strips at four points around their periphery.

The three sockets were mounted on a strip of " bakelite " ; underneath were filament resistance and audio-frequency amplifying transformer. The central valve functioned as a high-frequency magnifier, and its four terminals of copper bus bar one-sixteenth inch thick, connecting to the two variable

FIG. 3.—SHORT-WAVE TRANSMITTER, ARMSTRONG TUNED PLATE CIRCUIT



The diagram is from Mr. Swanson's report.

L_1, Plate Inductance of 9 turns, $3\frac{3}{4}$ inch diam. (4 turns between B and C).
L_2, Grid Inductance of 5 turns, $3\frac{3}{4}$ inch diam.
C_1, Variable Condenser, 1000 $\mu\mu$F.
C_2, Variable Condenser, 500 $\mu\mu$F.
C_3, By-pass Condenser, 2000 $\mu\mu$F.
C_4, Grid Condenser, 25 $\mu\mu$F.
C_5, Antenna Condenser, 25 $\mu\mu$F.
R.F.C., Radio Frequency Choke.
Am., Ammeter.

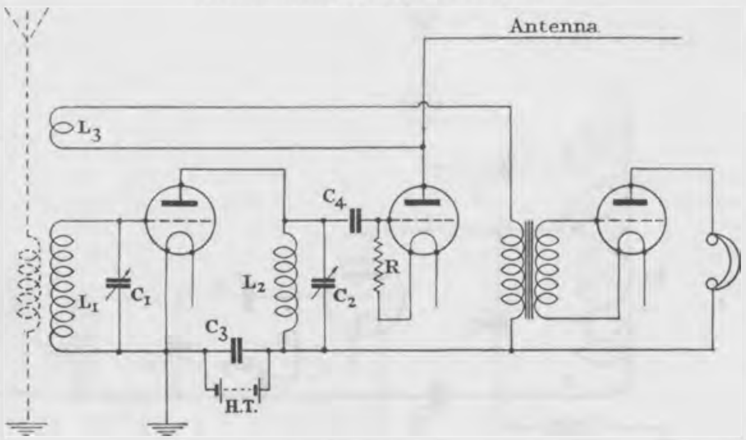
condensers, formed supports for the entire valve unit. This compact arrangement made possible extremely short connectors. By simply changing inductances this receiver would function efficiently over a range of 40 to 17,500 metres.

This circuit is very similar to the transmitter circuit involving the tuned plate and grid in the H.F. amplifier. The voltage to operate the detector is gotten across the coil, in circuit L2, C2. This is highly desirable, for by virtue of a parallel resonant circuit of low resistance, maximum voltage drop occurs across the coil when this circuit is resonant to the incoming signal frequency ; any other signal off resonance will produce a lesser voltage drop with a consequent reduction of interfering signal.

A unique method of coupling the antenna is shown in the diagram. The inductance L3 used as a reaction coil also inductively couples the received signal energy to input of H.F. amplifier. The antenna is connected directly to anode of detector. This arrangement reduced atmospherics to a larger degree with the accompanying result of an increased signal. No definite theory can be given at present as to the exact effects produced in this circuit by coupling antenna energy through the reaction coil.

An excellent instrument for use in the field would be a single unit combining short-wave transmitter and receiver, the receiver capable of functioning over

FIG. 4.—SHORT-WAVE RECEIVER



The diagram is from Mr. Swanson's report.

L_1, Inductance Coil, 7 turns.
L_2, Inductance Coils, 6 turns.
L_3, Inductance Coil, 7 turns.
C_1, Variable Condenser, 500 $\mu\mu$F.
C_2, Variable Condenser, 500 $\mu\mu$F.
C_3, By-pass Condenser, 2000 $\mu\mu$F.
C_4, Grid Condenser, 250 $\mu\mu$F.
R, Grid Leak, 2 MΩ.
H.T., High Tension Battery.

By changing the inductance coils, this receiver worked efficiently over a wave-length range of 40 to 17,500 metres.

The antenna was originally coupled as shown by the dotted line, but this arrangement was abandoned in favour of an antenna 30 feet long placed 6 feet above the ground.

The filament battery circuit is omitted for the sake of clearness.

a range of 40 to 17,500 metres. This unit may be encased in a metal box of duraluminum and made moisture proof. The lid or the top should contain transmitter inductance so that this inductance may have its field free of metal. The overall weight (primary source of power excluded) might be within 50 lbs.

The secondary source of power would be derived from a 12-volt 80-ampere-hours storage battery placed in a box with the anode battery. The primary source of power would be a two-cylinder gasoline engine of small dimensions : on one end of the crankshaft a high-tension generator directly connected, and on the other end a low-tension generator for filament power. With this arrangement for primary power, the low-tension generator may be used as a self-starter for the gas engine. Dry cells will supply the modern low-current receiving tube.

Portable Radio Station.—After the base radio station was closed down in March 1925, the receiver used at that station was sent to the portable station, and the original transmitter reconstructed to design of base transmitter.

The original primary source of power was a 2-H.P. single-cylinder gasoline engine weighing approximately 75 lbs. This unit contained a 12-volt generator belted to the flywheel, but owing to mechanical faults it was abandoned, and the generator removed and belted to an outboard canoe motor, which served efficiently throughout a period of three months. This generator was used to charge a 12-volt 80-ampere storage battery. This low potential power was converted by a dynamotor. The transmitter was connected to a one-wire antenna 40 feet long that was supported by trees. Here an extraordinarily small amount of energy, in the neighbourhood of 25 watts, found its way through the thick foliage of the jungle forest and skyward over hills 1000 feet in height to a destination some 3000 miles distant.

During winter months north of the equator one may expect reliable communication over a distance of 4000 miles with 150 watts of H.F. power at approximately 3750 K.C. During the summer months it will be necessary to increase power to 500 watts to cover this same distance. Greater distances may be covered with less power during daylight on ultra-short waves.

Observation on Atmospherics.—After close observation of meteorological conditions covering a period of six months, nothing could be associated with favourable and unfavourable conditions of radio reception. It was shown that the presence of high ground winds brought about increase of atmospherics. It is believed that dust particles stirred up into motion are the principal causes of this atmospheric increase. The static or atmospherics were of the regular "grinder" variety. The receiving circuit herein before described was particularly advantageous in reducing this species of static. Instead of a static train being heard in the telephones for a period of the duration of its pulses, it was reduced to simple sharp clicks.

"Wave jumping" is the term applied to a phenomenon noted on two occasions in Brazil. After thirty minutes of trying to "raise" an American station from a point on the Uraricoera called Cujuma, the operator was surprised to hear a Canadian station calling. After communication was established the Canadian operator explained that he had been unable to communicate with the U.S.A. for a week. Here was a perfect example of radio-energy on short wave-lengths completely jumping the U.S.A. from points north and south. Two hours later stations in the U.S.A. were worked in the usual manner.

After the expedition had returned to Boa Vista, Rio Branco, the base station attempted communication with the U.S.A. after an absence of one month during travel down-river. Three nights and mornings were devoted to intermittent calling and listening, but no stations could be heard except a faint signal from the "carrier frequency" of a broadcast station at Pittsburgh. One night at 8 p.m. 60th M.T. this carrier was a bit louder and gradually increased in strength up to 10 o'clock. This rather encouraged the operator, and at 12 p.m. a station in Philadelphia was worked and acknowledged receipt of 300 words of traffic. This phenomenon was only experienced during the summer months north of the equator. During the winter months consistent communication over a range of 4000 miles could be expected from a transmitter having an output of 150 watts at 7500 K.C.

Effect of Daylight on Short Waves of 80 *Metres*.—Absolutely no difference in night or daytime signal from portable station sending over a distance of 200 miles was noticed at the base station. Transmission took place at 10 a.m. and 8 p.m., 50th M.T.

An excellent opportunity for observing daylight effect on radio signals was afforded on 18 January 1925, when WJS (base station) held communication with 9ZT at Minneapolis, Minnesota. Communication was established at 4 a.m., 60th M.T., and continued until 6.40 a.m. During this time it was possible to observe the sun rise while receiving signals on approximately 80 metres from 9ZT. This was an excellent example of both stations working through partial daylight, and the only effect perceptible was a superb clarity of the received signal after the sun had risen. Results on long waves of 7000 metres from NBA Balboa, Panama, show a 60-per-cent. decrease in signal as daylight comes over the 60th Meridian.

Experimental work with ultra-short waves to-day shows that certain frequencies must be employed at certain times during daylight and darkness to obtain greatest efficiency in transmission. The 46-metre wave, 7500 K.C. has been found to work best during daylight. The range of transmission on other frequencies appears to depend entirely on the relative position of the sun.

EXTRACTS FROM REPORT OF CAPT. A. W. STEVENS, U.S. AIR SERVICE, TO CHIEF OF AIR SERVICE, WASHINGTON, D.C.

The recent expedition achieved greater success than usual, because improved apparatus was taken, capable of modification to the use of short waves. With this light field outfit 100 and 200 word messages were sent to and received directly from London, England, and communication was established regularly at night with practically all points in the United States, from New York to San Francisco. Although located in the heart of the world's greatest forest, the apparatus was so efficient that the signals it sent across thousands of miles of jungle and ocean were reported all over the United States as being "very strong." In another direction, a point as far distant as New Zealand was sent to and heard from, although the messages in this case were brief.

Before the expedition proceeded up-river a test was made of a ¾ K.W. tube transmitter to determine how far messages could be sent with this small outfit. This test was carried out at the City of Manaos, and messages were sent at night to the town of Santarem, approximately 400 miles east of Manaos, on the Amazon River. The station at Santarem was called, but did not reply. An operator on watch at Manaos reported that Para, 850 miles east of Manaos, was calling the expedition station at Manaos to report reception of signals from the ¾ K.W. tube set. Communication was then started with Para, and several messages were sent and received without difficulty over a distance of 850 miles. At this time an unsolicited report from the operator at Para stated that the signals from the expedition's ¾ K.W. tube set were more readable than the signals from the Manaos station using a 40-K.W. spark set.

At the station of Boa Vista the 360-metre wave from KDKA, Pittsburgh, could not be heard, using a receiver consisting of one stage radio detector and one stage audio amplification, while the 62-metre sent simultaneously was received in good strength to the extent of enjoying the music. It is to be understood here that conditions here create the worst possible output to the transmission and reception of electric magnetic waves. While broadcasting stations in the United States have been reported many miles more distant than the Boa Vista location, they could not be received with a standard arrangement of three tubes. It is interesting to note that ocean-going steamers travelling up and down the Amazon River do not use their wireless apparatus until they get to the Atlantic Ocean, partly on account of the difficulty of receiving and sending signals over the forest with the long waves customarily used.

Short Waves.—Realizing the possibility of short-wave communication, a receiver and transmitter were constructed and put in operation December 1924, and communication established with amateur station 2CVS New York. Since that time signals have been exchanged with the following distant stations :

Station.	*Date.*	*Time.*	*Location.*
2CVS	14–12–24	12 a.m.	New York City.
6OI	15–12–24	5 a.m.	Stanford Univ., Cal.
2AP	24–12–24	4 a.m.	Wellington, New Zealand.
1COT	26–12–24	12 a.m.	Braintree, Mass.
5SK	9–1–25	11.30 a.m.	Fort Worth, Texas.
1AB	14–1–25	4 a.m.	Rio de Janiero.
6CHL	15–1–25	2.40 a.m.	San Francisco, Cal.
9ZT	18–1–25	6.40 a.m.	Minneapolis, Minn.
2NM	19–1–25	3.40 a.m.	Caterham, Eng.

Time is 60th Meridian West.

All stations, with the exception of Rio de Janeiro and New Zealand, have reported signals from this station as being VY QSA (very loud). This was accomplished with 180 watts energy output at 356·2 K.C. One instance of working through partial daylight is the exchange of signals with station 9ZT in Minneapolis, 6.55 a.m., 60th Meridian. 9ZT called just as 2MC New York had finished sending to this station WJS, so that both stations were worked in daylight, and signals from this station were reported loud and strong at 9ZT and 2MC. It must be remembered that atmospheric disturbance is maximum at night and always very strong in this part of the country, but short-wave signals may be copied during all hours between 6 p.m. to 7.30 p.m. Those received after 7 a.m. are usually from west coast and middle west of United States.

After six months of observation, only high wind can be associated with the increase of atmospherics. Clouds do not affect conditions for reception ; although the entire sky visible may be formed into nimbus clouds, no perceptible effect has been observed. Therefore the tremendous advantage of short waves can be readily estimated for use in consistent communication, especially in tropical countries.

Most efficient reception of the short waves is obtained by using an insulated wire between 30 and 40 feet long, pointed in direction of station to be received, and either buried or placed on the ground. The receiver consists of only three tubes (Fig. 4).

For transmission, antenna constructional cost and time are exceedingly small, compared to that of long waves for a given distance of communication. It is particularly adapted to mobile stations, having a limited space to erect antenna, particularly aircraft.

Equipment : Receiving.—Utilizing a stage of radio-frequency amplification in which regeneration of the original signal is obtained by the " tuned plate " system, the elimination of the usual coupling coil to transfer energy from the amplifier to the detector for rectification by taking advantage of the high-voltage drop across a parallel resonant circuit of low resistance at a resonant frequency, a stage of audio frequency amplification to amplify the rectified signal—one stage only to be used where atmospherics are strong. [Printed as received.]

A slight increase of signal and perceptible decrease of static is obtained by connecting antenna on plate of detector. Closer coupling may be used, the "feed back" effect of the coil L3 compensating increase of resistance (Fig. 4).

Transmitter.—A persistent oscillator may be made by the use of a circuit developed at this station called a momentum circuit, consisting of a small inductance and large capacity, thereby obtaining a low resistance circuit and very large currents flowing therein. The action of this heavy current flowing is to offset any shifting phase in plate circuit due to D.C. current flowing therein to plates of tubes. Secondly, it has the effect of a flywheel in motion when the driving member meets with resistance.

This circuit very nearly determines the frequency of the emitted wave. It is disturbed slightly by adding antenna capacity (see Fig. 3).

By drawing this circuit differently, we have one that is ideal from the point of view of power transference [diagram not reproduced].

The tube is replaced by an alternator feeding a parallel circuit of low resistance L1 C1. The impedence of this is maximum at its resonant frequency. Across this is connected the circuit to be supplied, namely, the antenna, which is a series resonant circuit offering minimum impedance to the frequency to which it is attuned, and by adjusting L2, C2 so that its period is equal to that of L1 C1, we have the following ideal conditions.

A supply circuit having maximum impedance to a frequency determined by its L1 C1 values, consequently having a very high voltage drop across its terminals, to which is connected a series circuit L2 C2, offering minimum impedance to the frequency to which it is attuned, in this case the frequency of circuit L1 C1, which by virtue of working it about 20 per cent. below its fundamental contain high radiation resistance.

Primary Power Supply.—Delco 1½ K.W. generating plant, battery unit of 120 volts, 80 ampere-hour capacity. Due to desirability of a light weight unit, the batteries could only have a maximum of 80 amperes, but by floating the Delco generator across them the current drainage is equally divided so that batteries are not abused. This system had been in operation approximately eight months, running ten hours per day and unfailingly delivering 7·33 K.W. hours per gallon of kerosene and pint of lubricating oil. A 3 h.p. motor generator delivering 1000 volts at 1·2 amps. converts the low potential supply to power suitable for the input of the transmitter.

Field Station.—The field station, or portable canoe outfit, was operated as follows:

A "Caille" single-cylinder canoe motor was used to drive an automobile generator, which charged a storage battery. The motor was left attached to the end of the canoe, but the canoe was drawn out of water until only the stern remained immersed. The motor then ran uniformly, with the propellor acting as a brake, and received its cooling water from the river. A V-shaped rim had been bolted to the fly-wheel, and from this V pulley a belt ran to the auto generator. Thus it was only a moment's work to start charging the battery after landing for a camp. Later in the evening, or in the early morning hours, the battery and generator together delivered current to a small motor generator, which delivered current of higher voltage to tube set. For receiving, the motor was shut down because of noise, and battery only used; this involved keeping an extra man up to start and stop the motor on signal from operator.

The same motor was used for propelling the canoe, wherever clear stretches of water were available; at other times the canoe was paddled, poled, pulled, or carried.

From consideration of size and portability, the field station was limited to a power output of between 25 and 50 watts, this being sufficient power for reliable communication on short waves to distances up to 200 miles day or night.

The practice was to send messages from the field station to the operator at the base station at Boa Vista, where it was easily possible with a power output of one-fifth K.W. to reach either England or the United States, the operator at base copying and re-sending.

Comparison: Short and Long Waves.—After station WJS had been in operation for four months, weather conditions caused frequent interruptions in communication between Boa Vista and Manaos, a distance of 400 miles. Up to this time work had been confined to present long-wave transmission and improvements on antenna system.

On December 10 a short-wave set of about 100 watts output was put in operation and a New York station worked. This was the beginning of a very efficient link in communication.

With original arrangements, amateur stations in New Zealand, England, and United States were worked. Later, by increasing the output power to about 150 watts, uninterrupted communication was conducted with New York in spite of extremely adverse tropical weather conditions.

Another link in communication was added when messages were exchanged with England. This gave WJS at Boa Vista, Brazil, lat. 2° 49′ 17″ N., long. 60° 39′ 45″ W., direct communication with New York and London, and from both places signals from this station were reported as being very loud and consistent.

Had there been more than one operator at the base station, regular service direct between any of the cities in the United States and important cities of the world, such as Rio de Janeiro, Buenos Aires, and London, could have been maintained.

Obviously, with those numerous routes to handle traffic as compared to the one, viz. Manaos on long waves, the supremacy of short waves is proven.

Apparatus.—Primary source of power consists of a Delco 1¼ K.W. unit and battery of 80 ampere-hour capacity. When large long-wave transmitter is used, it is floated across line to take up excessive drain on battery.

Long-wave transmitter having an output of ½ K.W., and made in two separate units, inductance, and set including tubes, etc., both mounted on detachable legs for supports. With this circuit shown in print [not reproduced], advantage was taken of the property in a parallel resonant circuit at its natural frequency and the high voltage drop across its terminals due to heavy circulating current in L1 C1 having low inductance and high capacity resulting in a low-resistance circuit having a maximum impedance at its natural frequency. An antenna of suitable characteristics was directly connected across the terminals Antenna and Earth, and no increase in efficiency was noticed when antenna was tuned. The natural period of the antenna was within 40 per cent. of the working wave.

This circuit L1 C1 had determined the frequency of the transmitted wave and prevented any trouble with grid period affecting frequency. This was particularly advantageous for a semi-permanent antenna having average resistance of those constructed hurriedly in the field.

Short Waves.—A small power set having an output of approximately 150 watts is shown in Fig. 3. This is a "tuned plate" circuit, and takes advantage of coupling to a portion containing very large currents; in this case the antenna circuit is tuned. The long-wave antenna was excited at one of its harmonics, and proved to be an exceptionally good radiator on 93 metres.

Receiver.—This utilizes the tuned plate system of regeneration, and again advantage is taken of the high voltage drop across the terminals of a parallel resonant circuit at the frequency determined by its inductance and capacity. Selectivity is afforded by virtue of a decreased signal for other than the frequency to which circuit is attuned (see Fig. 4).

The antenna, which consists of about 30 feet of insulated wire, is laid on the ground in direction of transmitting station, and is connected to the plate of the detector, thus transferring energy through the tickler coil to the radio frequency amplifier.

A reduction of static is accomplished by connecting the antenna to plate terminal of the detector tube. Due to the reduction of static greater signal energy may be transferred to the radio frequency amplifier by closer coupling of L_3 to L_1. The added antenna resistance due to closer coupling is compensated by feed-back action of tickler coil. Thus it may be seen that this tickler coil L_3 has many uses, but principally that of changing the signal-static ratio.

In conclusion, it has previously been supposed that stations near the equator were exceptionally poorly located for regular communication, because of static and other troubles. The Boa Vista station was less than 3° from the equator; it was about 300 feet above sea-level; it was surrounded by many hundreds of miles of dense tropical jungle. In spite of these difficulties, and the fact that it was possible to erect an antenna only 80 feet above the ground, the station apparently got better results than many other stations more favourably located and that had far more power output. One feature to be noted is that stations in Great Britain said, "Your signals are very strong; we have been hearing you every night." New York reported, "Very strong signals."

Amateur stations were communicated with on short wave, as against professional stations on the long wave. Many of the amateur stations reached in the United States were located at colleges, and operated by students interested in radio. Other amateur stations were worked by enthusiasts connected with radio supply houses; still others were worked with privately owned outfits. In all cases the amateurs worked in connection with a radio league, and there was fine cooperation in getting messages forwarded to any point desired. Advantage was taken to send messages *via* New York to the Chief of Air Service at Washington. Messages were sent to the American Geographical Society in New York very regularly, and replies were received regularly; long messages were sent to the Royal Geographical Society through amateurs in England. Many messages were sent to families of members of the expedition, scattered all over the United States, assuring them at Christmas time that all was well with the expedition.

Supplies were ordered by wireless; in several cases the order was wirelessed to New York, then cabled back to Manaos, to be shipped from Manaos up-river to Boa Vista and other up-river points. This was necessary whenever long-wave communication could not be held direct from Boa Vista to Manaos. From the experience gained on this recent trip, it is certain that another expedition will depend wholly for communication on wave-lengths of 80 metres or less.