CHAPTER XII.

RESEARCH AND INSPECTION, AMERICAN EXPEDITIONARY FORCES.

When the first contingents of the American Expeditionary Forces arrived in France in the spring of 1917 they were brought face to face with the reality that modern warfare is above all an engineering operation in which every branch of scientific research must be utilized to bring about the defeat of the enemy. In no branch of the service is up-to-date technical knowledge more necessary than in the Signal Corps. American troops found themselves fighting an enemy whose organized and whose technical units had adapted to Army signaling the latest products of science. To combat the enemy's achievements our Signal Corps had only a limited equipment, which, though suited for operations such as might ordinarily be contemplated by the United States was not adapted to the conditions prevalent in the European War.

On the arrival in France of Gen. (then Col.) Edgar Russel, chief signal officer of the American Expeditionary Forces, he determined that these problems could best be handled by the creation of a new unit in the Signal Corps of the Expeditionary Forces. This unit was described as the division of research and inspection for Signal Corps supplies and material, and its organization and functions were based on that of similar units in the British Army, no organization of this kind ever having existed in the American Army.

The plans for this division were first outlined in Col. Russel's letter of June 20, 1917, to the commander in chief, American Expeditionary Forces, for transmission to the Chief Signal Officer of the Army, Washington.

The functions of the division as originally laid out were but slightly modified previous to the armistice. They were broadly as follows:

(*a*) The gathering of information on all signaling apparatus, allied as well as enemy.

(*b*) The dissemination of this information through channels among the Signal Corps units.

(*c*) The application to existing and proposed Signal Corps practice of devices which had already been tested out by the various armies and found satisfactory.

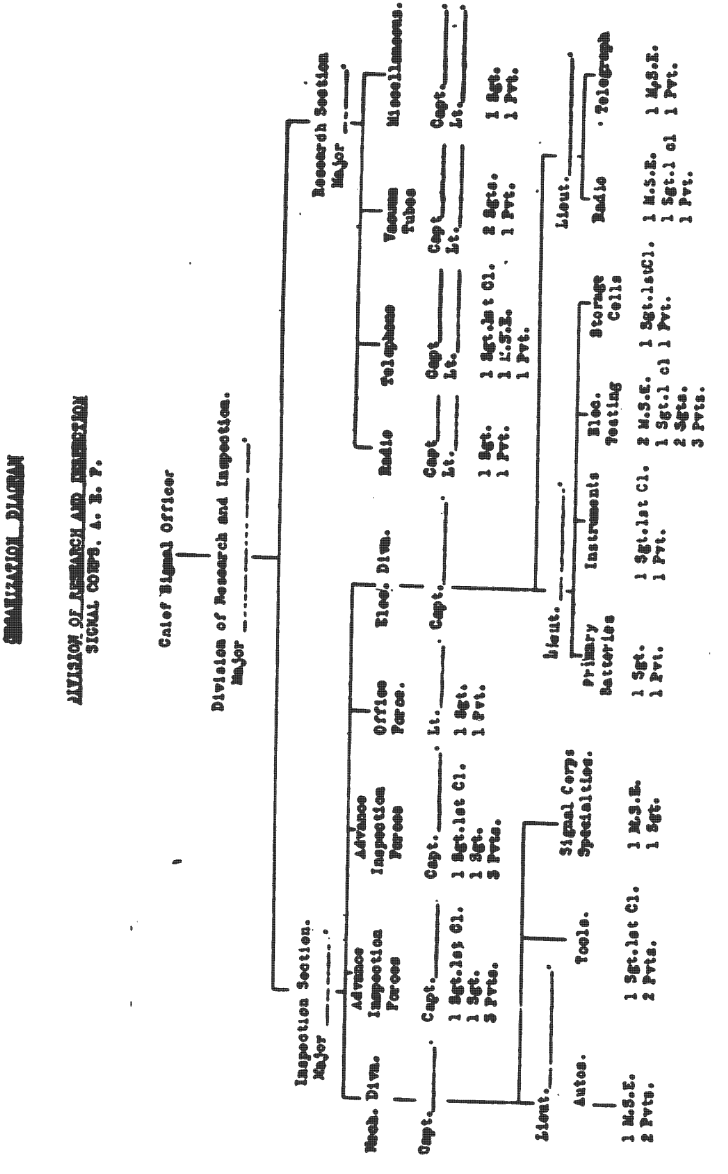
(*d*) Research along original lines and development of new apparatus.

(*e*) The inspection of all Signal Corps apparatus arriving from the United States or purchased in Europe to insure its reaching the combatant troops in serviceable condition.

(*f*) Constructive criticism of all apparatus used by the Signal Corps.

To carry out these functions, the division originally consisted of two sections, the research section and the inspection section.

Later, in order to relieve these sections from the routine duties connected with the smooth running of the large establishment, a third section—the service section—was established to handle all matters connected with property, buildings, transportation, clerical work.



The art of communication, around which the work of the new division centered, always has been one in which our country has been foremost. It was the aim of all concerned with the organization of this division to enroll in its ranks the best engineering

personnel possible. The selection of personnel and equipment for the division was, therefore, turned over by the Chief Signal Officer of the Army, Washington, to Col. (then Maj.) J. J. Carty, who as chief engineer of the American Telephone & Telegraph Co., had acquired an international reputation by his organization of the American Transcontinental Telephone System.

Col. Carty appealed to the leading scientific, educational, and commercial bodies of the United States, and from these he picked with painstaking attention as to individual qualifications a body of men such as had never before been gathered together. Inventors, professors, engineers, specialists in all forms of the art of signaling were enrolled in the new division.

Among the institutions which at this critical moment gladly gave up the services of their leading men were New York University, Columbia University, Johns Hopkins University, the General Electric Co., the Western Electric Co., and the Interborough Rapid Transit Co., New York. Other firms which contributed specialists in electrical and automobile work were the National Carbon Co., Cleveland; the Central Scientific Instrument Co., Chicago; the Electric Storage Battery Co., Philadelphia; and the American Express Co., New York. More than half of the original enlisted men of the division were university graduates.

The broad policy adopted in the selection of the personnel was amply justified later when the division was called upon to act in a consulting capacity on many technical problems not directly connected with Signal Corps work.

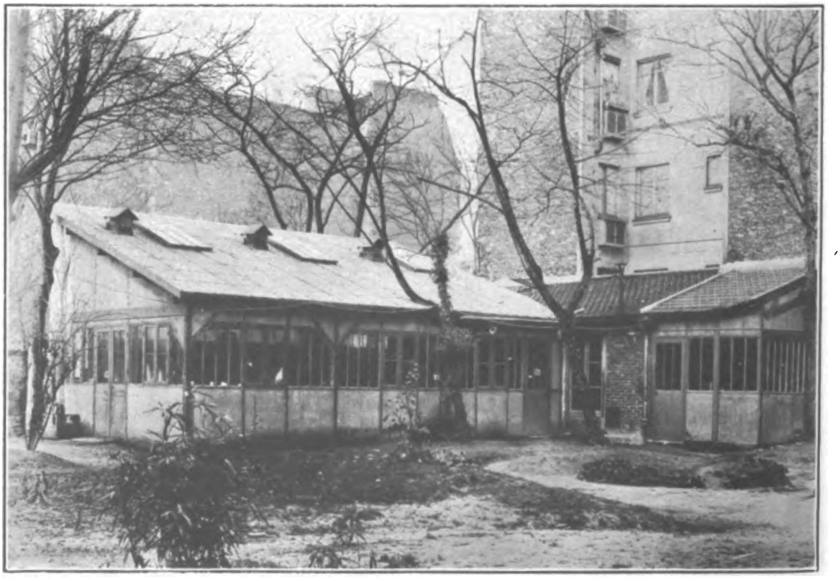
As officer in charge of the division was chosen Mr. H. E. Shreeve, an engineer, who, for 22 years, had been engaged in the development of telephone, telegraph, and radio equipment. During the two years immediately previous to his being commissioned as a major in the United States Reserve Mr. Shreeve had been executive officer of the research department of the Western Electric Co., and in this capacity had been in charge of several important missions for the American Telephone & Telegraph Co. The last of those placed him in charge of the experimental work in Paris in connection with the first demonstration of transatlantic wireless telephony.

The direction of the research section was intrusted to Maj. O. E. Buckley, a physicist, who, after studying and teaching at Cornell University, had taken up industrial research in the laboratories of the Western Electric Co., where he had been actively engaged in the development of radiotelephony.

The inspection section of the division was placed under Maj. (then Capt.) Maurice K. McGrath, whose long experience in the design and installation of telephone apparatus, both European and American, fitted him particularly well to take charge of this section. Maj. McGrath had, in addition, the advantage of a considerable amount of military training in connection with the organization of the Western Electric Radio Co.

The work of preliminary organization, commenced in the first days of August, was completed in three weeks. On Sunday, August 26, 1917, Col. Carty prepared a letter covering in detail the functions and qualifications of each man in the organization, and this, with charts and lists of the desired laboratory apparatus, was forwarded

EXTERIOR OF THE RESEARCH AND INSPECTION BUREAU, SIGNAL CORPS, PARIS, FRANCE.



REAR VIEW OF RESEARCH AND INSPECTION LABORATORY. PARIS, FRANCE.

to the Chief Signal Officer of the Army, Washington. The plan described therein went into effect immediately, and on September 8 the first of the division, a party consisting of Lieut. Col. H. E. Shreeve and seven officers, left New York City for France, arriving in Paris on September 29.

Before this advance party reached its destination the Chief Signal Officer had, in the month of August, commissioned in Paris Lieuts. D. V. Leland and P. H. Dike, who were assigned to the division, and immediately began the work of selecting laboratory space and of collecting samples of French radio apparatus. Temporary premises were obtained on the second floor of No. 64 Rue de la Boetie, Paris, and in this were assembled a number of pieces of radio apparatus borrowed from the "Etablissement Central du Matériel de la Radiotelegraphie Militaire." In addition, these officers set about finding more commodious premises to accommodate the laboratory equipment which was being forwarded from the United States. They selected the self-contained house and gardens at No. 140 Boulevard Montparnasse, and this house was later occupied by the division during the whole of its stay in Paris.

After the advance party left New York the enlisted men of the division were assembled and equipped at Fort Wood, N. Y., under the direction of Capt. J. H. Wetherholt, at that time the personnel officer of the division, and the officers and men given an opportunity to familiarize themselves with the latest developments in radio apparatus under the guidance of Mr. John Mills and Lieut. A. M. Curtis, of the Western Electric Co. Complete mechanical, physical, and electrical equipment costing approximately $100,000 was purchased and packed. The care with which this equipment was packed and conveyed is shown by the fact that of several hundred boxes containing the equipment only one was lost in transit and none was seriously damaged. The division brought over its own transportation, consisting of trucks, automobiles, and motorcycles with side cars, which transportation the division retained control of through its stay in France. All of the above equipment was sent to France in three shipments under convoy of the men of the division. Much of the material was packed in boxes specially designed, so that the boxes themselves could be used for the construction of laboratory benches and tables.

One of the first moves after the advance group arrived in Paris was a visit to the British and French fronts by Majs. Shreeve and Buckley. On this visit they were accompanied by Mr. Edwin H. Colpitts, research engineer of the Western Electric Co., who as a civilian inspector of the Signal Corps assisted the division in a consulting capacity up to December 2, 1917, when he returned to the United States.

Soon after their return from the western front these officers were joined by the first detachment of the enlisted men of the division who arrived in Paris on November 3, 1917. These men took up quarters at the Alexandria, No. 29 Boulevard Bourdon, near the Hotel Mediterranee, to which the officers of the division had been transferred from the Rue de la Beetie. Part of this detachment was put to work inspecting radio material purchased by the American Expeditionary Forces from the French Government. The re-

mainder set about preparing the future home of the division at No. 140 Boulevard Montparnesse, for the receipt of the laboratory equipment, the first shipment of which arrived in December.

Apart from the more concrete work of maintaining the standard of Signal Corps supplies, the division has acted as a clearing house for all technical questions connected with the Signal Corps in France. To carry out this phase of its work the first step was to establish connection with the various French Government departments who were either supplying the American Expeditionary Forces with signaling apparatus or who could assist in supplying technical information. The most friendly relations were entered into with the établissement central due matériel de la radiotelegraphie militaire, whose technical director, Col. Ferrie, never failed to assist our organization in every way. He immediately placed laboratories at our disposal at the Invalides, and during the whole of our stay in Paris our officers and men worked in close connection with his staff.

Liaison was likewise established with the établissement central du matériel de la telegraphie militaire and with the service des projecteurs, both under the control of Lieut. Col. Villeclere. At both of these establishments space was provided for our men to carry on the inspection of apparatus purchased from the French Government.

Our relations with the service geographique, the French post and telegraph administration, and the various large manufacturers of electrical supplies in Paris, also proved of great value in carrying out the function of the division.

Permission was obtained from the military governor of Paris to use Fort Chatillon, on the outskirts of the city, as an experimental field, and at this place much of the work on ground telegraphy and more especially on tank radio was carried out. The preliminary field work upon sound ranging was also done at Fort Chatillon. Later this work was carried out at the experimental field connected with the antiaircraft listening station at St. Cyr. At a later date further experiments in sound ranging were made at the antiaircraft experimental station at Arnonville. Final field tests were made on the Amiens front with Company C of the Fixty-sixth Searchlight Engineers.

One of the most tedious but nevertheless essential tasks assigned to the division was the preparation of descriptive bulletins of French radio apparatus. Altogether 40 of these bulletins were prepared and a total of approximately 75,000 copies printed and distributed throughout the American Expeditionary Forces.

This work was first handled by a group of officers and men under Capt. J. C. Hubbard. When the intelligence division of the office of the chief signal officer was attached to the division of research and inspection, Capt. Hubbard was made officer in charge, and, in addition to his duties of preparing and publishing the various pamphlets issued by the office of the chief signal officer, he retained the work of preparing the descriptive bulletins referring to French signaling equipment. When the division assumed the supervision of the intelligence division, the name of the latter was changed to the technical information section. The technical information section was located at headquarters, Services of Supplies, Tours, where it handled a large amount of work of a cataloguing and educational nature. After

the signing of the armistice the technical information section was detached from the division of research and inspection and intrusted with the work of preparing the history of the Signal Corps, American Expeditionary Forces.

A large amount of specification writing was also done by the division. The inspection section prepared routines covering each form of inspection carried out by it, and the research section prepared specifications on the manufacture of Signal Corps apparatus in France and requirements on apparatus to be built in the United States. To complete this later phase of our work, a complete machine shop was installed to permit the making of working models of all new apparatus.

The laboratories of the division in Paris soon became a recognized center of technical information, and they were visited by most of the principal Signal Corps officers. Gen. Russel visited the laboratories on an average of once a month, thus keeping in close personal touch with the activities and the staff. Visits were also made by many signal officers from the allied armies, French, British, and Italian. The laboratories also provided a very satisfactory means of training Signal Corps officers in the specialties of radio telephony and telegraphy.

The most important liaisons maintained by the division were those with the western front and with the Chief Signal Officer of the Army, Washington. In the first of these directions connection was maintained by frequent visits to the allied fronts and to the allied training grounds on the part of officers of the division.

Naturally, a large part of the work of the division was connected with aviation; both before and after the separation of the Aviation Section from the Signal Corps proper this division carried out all inspection and research on airplane wireless apparatus. To do this the division established laboratories at each of the experimental fields occupied in turn by the Air Service—Ville Coubley and Orly Field. Preparations were also made to establish laboratories at the flying field at Colombey les Belles, but owing to the armistice this was not carried out.

Liaison with headquarters, Services of Supply, at Tours was made effective by weekly visits on the part of Lieut. Col. Shreeve, who maintained an office at that point. Finally, liaison with the War Department, Washington, was kept up in both directions by means of officers who took with them working models of newly developed apparatus or up-to-date manufacturing information.

Among the work not strictly of a Signal Corps nature carried out by the Division of Research and Inspection, the outstanding items are the research on sound-ranging apparatus, the development of the Chilowski shell, and the design and assembly of the Shreeve gun-sight lighting device. It is safe to say that had it not been for the constant efforts of this division the possibilities of the Chilowski shell would never have been realized by the American Expeditionary Forces.

Another phase of activities was connected with the appointment of Lieut. Col. Shreeve as representative of the American Army on the Interallied Board of Inventions, whose bimonthly meetings were held in Paris. In this capacity Lieut. Col. Shreeve was of assistance in bringing to the attention of the various services of the American

Expeditionary Forces many of our Allies' latest war inventions. Among these were various types of message carrying shells, special aeroplane guns, incendiary bombs, and various aeroplane devices. Similar service was also given through the relation of the division with the technical attachés of the United States Embassy at Paris.

The division as a whole was stationed in Paris during the period of aerial attacks and long-distance shelling. The offices of the division were located within 200 yards of the axis of fire of the long-distance guns, and a number of shells fell within a radius of a few hundred yards of the building. No damage, however, was done, either to the building or to any of the personnel. Three of the enlisted men of the division were instrumental, however, in transporting to a French hospital some of the French civilians who were victims of a long-distance shell, for which action they were commended by Gen. Russel.

When the Germans were at Chateau Thierry and the artillery fire was plainly audible in Paris, plans were made to vacate the laboratories and some of the surplus material was shipped to Gievres. Col. Ferrie, of the "E. C. M. R.," in planning a similar evacuation of the French laboratories to Lyon, made a provision for our laboratories to be located with his own.

Early in the life of the division it was foreseen that Signal Corps apparatus, after the rough handling and exposure consequent to the long voyage across the ocean, would require very careful inspection to insure that it would be in good condition when issued to combatant troops. At the time the letter directing the organization of the division of research and inspection was written, June 20, 1917, it was believed that all or practically all Signal Corps apparatus would be shipped from America. The duty of the Inspection Section was specified in accordance with this belief and was to be the inspection and adjustment of all Signal Corps apparatus before issue from depots to troops. Up to the time of the arrival of the original research and inspection detachment in France, all plans concerning personnel and equipment were made with the above object in view.

The policy of purchasing large amounts of Signal Corps apparatus in France, which was adopted in the summer of 1917, resulted in a large increase in the proposed duties of the inspection section, as in addition to the originally planned depot inspection, the initial inspection of apparatus purchased in Europe was assigned to this section. Many obstacles were encountered in this readjustment, as the section had provided neither equipment nor personnel for this new and unforeseen work. Further additions to the duties of the inspection section were made from time to time, and at the time of the cessation of hostilities they were as follows:

Inspection of Signal Corps apparatus before issued from depots to troops.

Inspection of Signal Corps apparatus for acceptance of material purchased in Europe by disbursing officer.

Inspection of all salvage material before being turned over to repair shop at supply depots.

Inspection of all material from repair shops returned to depot stock.

Advice as to proper storage, packing, maintenance and repair of Signal Corps apparatus at supply depots.

Specifications for inspection of all Signal Corps apparatus purchased in Europe and for the reinspection of apparatus received from the United States.

Comparative studies of Signal Corps apparatus purchased in Europe.

Studies of manufacturing facilities when requested by the disbursing officer.

Studies of the suitability of apparatus for the purpose for which it is intended (by liaison established with the armies).

Recommendations as to disposition of defective material.

With the exception of poles and cross arms, and of line material obtained from the French Government depot at Angoulene, practically all Signal Corps apparatus purchased in France was secured in or delivered in Paris. Consequently, carrying out the general policy of inspecting material, in so far as possible at the source, inspection section detachments were located at various factories and warehouses in Paris, all reporting to the general laboratory at 140 Boulevard Montparnasse. These detachments inspected all Signal Corps material originating at the places where they were stationed except in cases where the apparatus was of such a nature that it required special tests for which they were not equipped, in which case it was sent to the main laboratory. In an effort to maintain inspection standards, certain standard measuring instruments were held at the laboratory to be used only for reference. A staff of men were also kept at the laboratories who could be sent to inspect material at points where there was insufficient work to justify a permanent inspector.

At first, due to the unfamiliarity with the apparatus and its technical nature, French methods of inspection were adopted practically without change. As knowledge of the apparatus and what it was required to do increased, modifications in methods were made from time to time with the idea of cutting out or simplifying some of the purely qualitative tests, which in most cases had already been made by the French, and devoting more attention to actual operating tests.

Inasmuch as up to the time hostilities ceased little American radio apparatus had arrived, practically all radio apparatus in use by the American Armies was obtained from the French. Until September, 1918, when the disbursing office took over the clerical work, this detachment, besides doing purely inspection work, obtained all the material from the French before inspection and supervised and kept records of the shipping of the material.

Inasmuch as the headquarters of the division was located at the laboratory, it was planned to make it the central point where special tests could be made upon samples of apparatus being inspected at the depots and factories and also carry on the inspection of apparatus requiring special tests or testing equipment.

All the material that could not conveniently be inspected at the Signal Corps warehouse in Paris was sent by truck to the laboratory for test. The following are the most important items inspected at the latter place: Field glasses, projectors, compasses, monocord switchboards, telephone sets, wire and cable, watches, dry cells. Numerous other miscellaneous items, such as charging sets, duplex telegraph sets, anemometers, barometers, etc., were also inspected at the laboratory.

As the work increased, in order to reduce the handling and packing of material, arrangements were made whereby inspectors were

placed at the French military warehouses and factories engaged in manufacture for the Signal Corps. The first one of these inspection points to be established was located at the factory of Le Matériel Téléphonique. A detachment was assigned to this factory in December and inspected all material purchased by the Signal Corps, which consisted for the most part of buzzerphones, line material, and telephone equipment. A detachment was also assigned to the warehouse of the Service de Projecteur and inspected all the projectors and the projector accessories, while another detachment was stationed at the warehouse of the établissement central de matériel de la télégraphie militaire to inspect all the monocord switchboards and miscellaneous telephone and telegraph material.

The establishment of these inspection points relieved the congestion at the laboratory and made it possible to use the space for special testing, such as life tests on dry cells, etc. When the new Signal Corps warehouse was opened at 76 Rue de Gaz in October, 1918, the remainder of the routine inspection work being done at the laboratory on field glasses, watches, flashlights, etc., was transferred to the warehouse.

Inspectors were stationed in August, 1918, at the storage battery factories which were supplying batteries to the American Expeditionary Forces. Inspections of batteries were made during the process of manufacture and after assembly. Before shipment from the French supply depots labels giving charging rates, specific gravity, and other information in English were attached to the batteries.

In order to keep the troops in the field supplied with tested equipment an inspection system at base, intermediate and advance supply depots was built up. Practically without exception all Signal Corps material destined for field troops, schools, and telephone construction projects, whether purchased in America or Europe, passed through the intermediate or advance supply depots. In order to insure that this material was in good condition when issued, detachments of the inspection section were located at these depots.

Actually these inspection detachments did much more than their specified duties. They supervised the charging and care of storage batteries, repaired apparatus, packed and unpacked material, assisted members of the depot force on questions of nomenclature, in many cases materially assisted in the control of shipments, made recommendations concerning the suitability and improvement of apparatus, and many other things of a similar nature.

Repair shops were located at all of the depots where inspectors of this section were stationed. The inspectors assisted in sorting this salvage and made recommendations as to the steps which should be taken for its repair. The same course was pursued with respect to apparatus damaged in transit. Repaired material was reinspected after delivery from the repair shop. Often when the repairs were of a complicated nature members of the inspection force assisted the men in the repair shop, and in some cases made the more delicate repairs themselves.

One very important duty of the depot inspectors was in connection with storage batteries. Changing stations were located at all depots at which this section had inspectors. The inspector was

eventually charged not only with the inspection of the batteries when received or issued, but also with the technical supervision of charging methods, actual charging and storage while in the depot.

The inspection routine and methods were so arranged at these depots that no material could be issued from them without having been checked at least once by a member of the inspection detachment. The depots furnished copies of manifests upon which all material was shipped. The inspector checked off and initialed each shipment on the manifest, thus attempting to catch incorrect shipments and at the same time making sure that uninspected apparatus was not issued. After shipment was made manifests were used as a basis of daily and weekly reports. Weekly reports covering this work were made to the officer in charge, inspection section.

The thoroughness of these depot-inspection detachments is attested to by the fact that practically no complaints of apparatus failing to operate or being in poor condition, except through damage in transit, were received from the troops at the front.

The first depot-inspection detachment was located at the Signal Corps general supply depot in Nevers late in December, 1917. The detachment was in charge of a master signal electrician until the latter part of January, when First Lieut. A. M. Curtis took charge. This detachment, in spite of the handicap of insufficient personnel (the maximum force at any one time being 10 men of the inspection section, 2 French adjutants, and 7 French women), carried on all inspection and auxiliary work in a very successful and efficient manner until the depot was closed and the personnel transferred to the new intermediate depot No. 2, at Gievres.

The inspectors at this depot and later on at Gievres made the first technical inspection of Signal Corps apparatus of American origin passing through the depot. It had all been inspected before leaving America, but due to rough handling, poor packing, and sometimes poor initial inspection much defective material was encountered. For this reason all American apparatus had to be very carefully inspected. The same was true in a less degree with French apparatus, which even though traveling a comparatively short distance was often damaged in transit. The inspectors also checked up our own initial inspection at Paris, bringing to the attention of the main office any defects found.

Lieut. Curtis, being released when the depot was closed, returned to inspection section headquarters at Paris, where he was given general supervision of radio-inspection work, with special reference to American radio apparatus.

Due to the lack of space for expansion at Nevers, a new depot, known first as general supply depot No. 2 and later as intermediate depot No. 2, was constructed at Gievres late in the spring of 1918 and depot work at Nevers gradually transferred to this place. The new Signal Corps depot began operations about the 20th of June, 1918. Lieut. George T. Droste, who had been assigned to this depot, besides directing the inspection work, was in charge of the Signal Corps warehouses and continued in both capacities until the 31st of August, 1918, when, on account of the great increase in work, he was released from duties in connection with the warehouse work in order that he might devote all of his time to the supervision of inspection.

From the time the depot was opened until the end of hostilities the work of the inspection detachment, keeping pace with the increasing flow of supplies, increased very rapidly. Lack of personnel and the necessity of dividing the inspection force between several different warehouses at some distance from each other handicapped the work.

In October, 1918, the inspection force at this depot took over the inspection of American radio apparatus which had been ordered by the Air Service. This required very careful inspection. Capt. Curtis spent a few weeks in October at this depot directing the equipment and testing methods of a new radio-testing laboratory.

At the time of the signing of the armistice the Signal Corps depot at this place was using four big warehouses, one building for the machine shop, power plant, storage-battery station, and salvage material, part of another building for a general office, six barracks for enlisted men, one officers' barracks, besides the pole and cable yard. The inspection force assigned to the depot had grown to 2 officers and 50 enlisted men. It was the largest separate detachment of the inspection section.

Up to the time of the cessation of hostilities only one advance supply depot had been established. It was known as Signal Corps advance depot No. 1 and was located at Is sur Tille, not far from Dijon. A branch of the inspection section was placed at this depot in April, 1918, being in command of Lieut. F. S. Dellenbaugh,

The work of this detachment differed somewhat from that of the detachment at the other depots in that practically all material received had been previously inspected at least once (and some of it twice) by members of the inspection section either at the general or intermediate supply depots, the Paris branch, or by detachments located at outlying points. A small amount of material, of which wire was the main item, was received direct from base ports. This class of material, although small in quantity, required a large amount of inspection work.

Material of a technical nature liable to damage or defects which could not be discovered by visual inspection was given operating tests regardless of the number of previous inspections. If defects were found, complete acceptance tests were made. Radio apparatus formed the greater part of this type of material.

Material more simple in nature was subjected to percentage check tests with further investigations based on the findings of the percentage check and the class of material being inspected. Salvaged and repaired apparatus was tested in the same manner as at the other depots.

The officer in charge of the depot at this place, Lieut. Col. Sadler, greatly facilitated the work of the inspection detachment by his spirit of cooperation. The liaison with the depot forces operated very smoothly. Various tabulations of apparatus were made up by the inspection detachment and promulgated throughout the depot by the supply officer in order to obviate errors that either occurred or seemed likely to occur.

The inspection force at this point, which at no time exceeded eight men and one officer, did very good work. Lieut. Dallenbough remained in charge of this detachment continuously from the time it was assigned to the depot until after hostilities ceased. He spent

considerable time in making original studies of testing methods, and furnished much information along this line to the officer in charge of the inspection section.

Following the general policy of the organization to inspect whereever possible at the source of supply inspectors were sent at various times to outlying points where no regular inspection detachments were stationed.

At different periods between March, 1918, and the close of hostilities an inspector was stationed at the depots of the établissement central de matériel de la telegraphie militaire at Angouleme, France. Most of the telegraph and telephone line material purchased from the French was delivered from this depot and inspection was made before shipment.

Early in the spring of 1918 it became necessary to detail an inspector to examine poles purchased in various parts of France. Later this inspection work was extended to cover crossarms. At the close of hostilities two officers, Lieuts. Olson and Batliff, and one enlisted man were assigned to this duty.

When the Inspection Section began operations there was very little information as to the requirements which apparatus was expected to fulfill. This was about equally true of French and of American apparatus. It was soon realized that it would be necessary to prepare inspection instructions, especially for French apparatus, which in most cases was radically different from any American apparatus with which the men were familiar. The work of preparing these inspection specifications, as they were called, which was commenced by Lieuts. Droste and Dike shortly after the arrival of the first detachment, was continued under the direction of Lieut. Christen until he was transferred to other duties in July, 1918. Up to this time no special section had been charged with this work, various men being called upon to furnish specifications covering apparatus with which they were familiar. In this manner specifications were written to cover the acceptance inspection of practically all material purchased in large quantities in France. With the large increase of work in the summer of 1918, and the consequent increase in unskilled personnel, the question of specifications became more important. In August a special section was created by Maj. Smith to take care of this work. Lieuts. Jeanne and Lack were assigned to this section. Plans were made to prepare inspection specifications for all apparatus inspected in France whether manufactured in France or the United States. These specifications were to be of two classes—initial-acceptance specifications and check-inspection specifications—only the latter class being necessary for American apparatus. These plans were in the process of fulfillment when hostilities ceased.

As large quantities of certain types of apparatus had to be inspected, and in many cases by inexperienced help, studies were made to determine if special testing sets of jigs could be used which would speed up the inspection work and at the same time reduce to a minimum the personal element. The following are the most prominent types of apparatus upon which such studies were made, and for the inspection of which special testing sets were built: Monocord switchboards, storage batteries, dry cells, vacuum tubes, amplifier sets, field glasses, flashlights.

At certain periods it was found necessary to use the personnel of the organization for some special repair or assembly work, which, owing to the urgent need of apparatus, could not be conveniently done elsewhere or on account of the testing facilities and specialized personnel could be most efficiently performed by the inspection section. Some instances of this work are outlined below.

A lot of about 5,000 Bausch & Lomb 6X prismatic binoculars were purchased from the Canadian Government, and upon inspection were found to be defective, owing to the formation of a film of dirt on the prisms. The formation of this film is believed to be due to atmospheric conditions, and apparently can not be avoided. The cleaning of these glasses was undertaken by the inspection section at the request of the Chief Signal Officer, and additional help in the form of French civilian labor was employed for the minor phases of this work. The inspection of these glasses, after cleaning, involved testing for parallelism, and a special machine for making this test was borrowed from the British Ministry of Munitions.

Approximately 1,000 special sets designed by Lieut. Col. Shreeve for lighting the range scale and sighting bar of the 75-mm. and 155-mm. guns were assembled by the inspection section for the Ordnance Department. The drawings and specifications necessary for the manufacture of the various parts of this equipment were also prepared in this section.

It was found that the wooden plug used with the French projectors absorbed moisture in service, and increased considerably in size, making it difficult to insert the plug in the socket. This was remedied by impregnating the plug in beeswax before shipment. As the French authorities would not do this work, the inspection section undertook to do it.

Among the items on which special studies were made at the request of the Chief Signal Officer or of the disbursing officer, Signal Corps, were:

(*a*) *Dry batteries.*—As a result of the large rejections on dry batteries purchased from the French Government a special study of this subject was made. As a result of our work on this, a decided improvement in quality was observed.

(*b*) *Wrist watches.*—An officer of this section—Capt. Christen—investigated sources of supply in France and Switzerland, placed orders for 47,000 wrist watches in the latter country, and inspected shipments. The result of this work was a big improvement in the quality of watches forwarded to the American Expeditionary Forces.

(*c*) *Pole climbers.*—At the request of the disbursing officer this section supervised the manufacture of pole climbers in Paris, with which manufacture the French were unfamiliar.

(*d*) *Pigeon wagons.*—At the request of the Chief Signal Officer various drawings of mobile pigeon wagons have been made.

(*e*) Valuable work was done by the inspectors placed at various storage battery factories. The manufacture and packing of these batteries were greatly improved.

(*f*) *Projectors.*—The first projectors furnished to the American Expeditionary Forces by the French Government proved to be more or less unserviceable. After conference with the persons concerned

a very much better projector was secured and an inspection point established at the French projector warehouse.

(*g*) *Radio tractors.*—Early in 1917 nine Ford tractors were turned over to this division with instructions to convert them into radio-tractors. Lieut. Leland was assigned temporarily from the general research and inspection offices to supervise this work. New bodies were built for the trucks by French firms; they were then equipped with E–3 radio sets and type D charging sets, all equipment work being done by members of the inspection section.

An idea of the enormous amount of material inspected by the inspection section may be obtained from a summary of the material rejected at the different inspection points during the time from January 1, 1918, up to the end of hostilities. The rejection of this material does not necessarily mean that it was lost. In the case of the rejections made at Paris, the Signal Corps simply refused to purchase the material rejected. The material rejected at the depots had already been accepted and paid for and was, in most cases, repaired in the depot repair shops and put in serviceable condition for shipment. In the case of some items, such as dry batteries and amplifier lamps, repairs were impossible, and it was necessary to junk the defective articles. The result has been to save a very appreciable amount of transportation. All of the material rejected would, in the absence of an inspection section, have been shipped to troops at the front. They would have found the material unserviceable, and would have been compelled to return it. A list of the principal items rejected is given below, together with an approximate estimate of their weight and the number of carloads of transportation which was saved by their rejection.

Item.	Number rejected.	Approximate weight.	Approximate carloads.	Item.	Number rejected.	Approximate weight.	Approximate carloads.
		Pounds.				*Pounds.*	
Accumulators	4,454	111,000	5.5	Switchboards:			
Amplifiers	24	480	.....	2-line	19	.....	.....
Amplifier lamps	844	200	1	4-line	891	5,400	2
Batteries, dry	56,514	103,000	7.	12-line	1,445	30,000	6
Buzzers	647	3,250	.5	20-line	35	7,000	2
Buzzerphones	526	5,620	.....	40-line	104	10,000	1
Cars, motor	70	.....	.....	Telephones:			
Cable, feet	4,030	4,000	.....	Camp	436	.....	.....
Crossarms	3,500	35,000	3	Camp (A)	696	.....	.....
Compasses	595	.....	.....	Camp (French)	107	.....	.....
Drills, diamond-point	200	2,000	.....	Buzzer	419	85,000	8
Flashlights	2,040	.....	.....	1375–B	3,693	.....	.....
Glasses, field	15,000	60,000	3	Miscellaneous	1,525	.....	.....
Gloves	1,160	500	.....	Trucks, radio	8	40,000	8
Poles, miscellaneous	8,777	2,200,000	400	Tubes, vacuum	135	.....	.....
Projectors	487	10,000	3	Watches, wrist	4,847	.....	1
Projector boxes	196	2,000	1	Wire, miscellaneous, reels	845	30,000	3
Projector lamps	782	.....	.....				
Receivers, radio, E–3	103	1,500	.....	Total	.....	2,795,450	462.5
Sets:							
Radio, E–3	52	25,000	2.5				
Radio, E–3–ter	53	25,000	2.5				
Radio, E–10	47	2,500	2				
SCR–74	405	4,000	.5				

Cost of inspection of Signal Corps material purchased in Paris during October.

Locality.	Value of material.	Cost of inspection.	Percentage.
	Francs.	*Francs.*	
Laboratories, 140 Boulevard Montparnasse	673,373	12,750	1.9
Storage-battery factory	1,354,700	2,420	.18
Etablissement Central du Matériel de la Télégraphie	445,855	2,900	.65
Le Matériel Téléphonique	133,290	1,040	.78
Etablissement Central du Matériel de la Radio Télégraphie Militaire	3,936,432	17,950	.46
Service de Projecteur	183,150	1,460	.8
Total of all Paris inspection	6,727,800	39,100	.58

The inspection section of the division of research and inspection was initially organized to inspect and adjust Signal Corps apparatus before issue from supply depots to troops. Equipment and personnel were assembled in the belief that American material only would be used by the Signal Corps. After arrival in France the plans of the inspection section were greatly modified due to a change in policy involving the purchase of much Signal Corps apparatus in Europe. The duties of the inspection section were enlarged to include the initial inspection of apparatus purchased in Europe and to act in an advisory capacity in respect to such purchases when requested by the disbursing office. At all times until shortly before the signing of the armistice the section was handicapped by inability to obtain sufficient personnel. Nevertheless, by hard conscientious work, inspection kept pace with the flow of supplies and all Signal Corps apparatus except that issued direct from base depots passed through the hands of inspectors of this section. The thoroughness of their work is attested to by the fact that very few complaints of poor apparatus reaching the front were received.

Besides regular inspection work, the inspection section carried on a large amount of investigation work regarding manufacturing facilities in France, furnished manufacturing information to the disbursing office when requested, and at times visited French factories in order to cooperate with them in reproducing, as well as facilities would permit, certain types of American apparatus which the French had never before manufactured.

The research work was very different from research in civilian institutions. It had to be carried on with limited personnel and equipment and with an ever-pressing need for practical results which is not generally conducive to the complete solution of research problems. In all of the work of the division it was necessary to bear in mind that a partial solution in, say, one month was of more value than a complete solution in six months. The work consisted not only of laboratory research, but also of field tests and the manufacture of models.

Among the original developments are: Lieut. Col. H. E. Shreeve, the gun-sight lighting device and the wire-marking device; Capt. E. H. Armstrong, the high-frequency amplifier (2 cases); Sergt. C. C. Graves, the shell-fire wire clip.

The section included the following main groups: Radio, telephone and telegraph, miscellaneous signaling, sound directing finding, and the model shop. Altogether the section worked on a total of about 80 research cases and in addition acted as a clearing house for information on approximately 150 other cases.

On the arrival in Paris of the division one of the first problems assigned to it was that of making a complete study of the possibilities of communicating by radio from a moving tank. Capt. Webb was put in charge of this work and, in line with the general policy of the division, he visited the British tank school to obtain information on the work of our Allies along this line. He also investigated the work of the French radio engineers.

The French authorities proposed to use a modified set of the E–10 series, called the E–10–ter. This set was designed to be used in connection with a trailing antenna supported about 6 feet above the tank and held taut by a heavy, dragging weight. This set transmits and receives on an undamped wave of 600 to 1,000 meters in length.

The British Army planned to use one of their standard field nets, which could be carried on board the tank but could only be used when set up outside the tank on the ground. Their intention was to use both damped and undamped waves and no definite wave length was specified. Later the British decided that undamped waves were best and decided to adopt one definite wave length for all tank-radio communication.

Neither the French nor the British schemes appealed to the division, the first because the constants of the trailing antenna were subject to large changes while the tank was moving, and the second because of the impossibility of communicating from the tank while in motion.

After considerable experimental work the general specifications of a set were worked out and Capt. Webb left for the United States to get the set in production. Work was continued by Lieut. A. D. Silva and Sergts. Pressley and Newell, and by careful design considerable improvements were made in the antenna current output. A tank transmitter, to operate on undamped waves of 600 to 1,000 meters in length, was built by the division according to this design. The antenna for use with this set was similar in construction to a Bristol fishing rod and extended 15 feet above the tank. The circuit employed was similar to that used in the E–10–bis set. Later it was found that an umbrella antenna 6 feet high with four arms 4 feet long was equally as satisfactory as the straight-rod antennæ and offered several advantages as, for instance, lower visibility and ability to pass under trees.

About the first week in June, 1918, following a conference with Capt. Bolitho, of the British tank wireless service, on the requirements of tank radio sets, Capt. Armstrong suggested the use of a circuit employing one tube as an oscillator and one or more tubes as high-power amplifiers. The particular advantage of this type of circuit is that the wave length is controlled by the constants of an internal circuit and in no way depends on the antenna constants. This is of supreme importance in tank radio, as there is always the possibility of a part of the antenna being shot away. In the ordinary type of transmitting circuit, in which the antenna is part of the oscillating circuit, any change in the antenna changes the wave length and hence the pitch of the note at the receiving station, whereas with the oscillating-amplifying system a change in the antenna can only affect the radiation. Following this idea, development of a set on these lines was carried out by Lieut. Silva and Sergt. Pressley during June and July, and a model constructed about the

1st of August. Numerous tests with the apparatus were made, using a Renault signal tank, and great success was obtained. Details were forwarded to the United States and the model was shipped under the first available convoy.

Lieut. Edwards, signal officer of the Tank Corps, advised the division of research and inspection in November, 1918, that the sets as designed at the laboratory could be tried out under actual fighting conditions. Three sets were built for this work. Unfortunately these sets could not be used in battle, as they were finished after the armistice was signed. On December 5, 1918, however, maneuvers were held at Bourg, the headquarters of the Three hundred and second Tank Center, and at these radio tanks equipped with this apparatus were used. Extremely gratifying results were obtained, and all the tank officers agreed that radio communication was the best and most reliable means available for tank work.

The two-way radio loop set was designed in France by the division of research and inspection, Signal Corps, primarily for communication between battalion and regimental headquarters, where previously the only electrical means of communication was the ground telegraph. This latter method of signaling had been much used by our Allies, but had the disadvantage of being heavy and of being difficult to maintain under shell fire. Moreover, its use was seriously limited by natural obstacles of low electrical resistances, such as marshes and streams. Attempts to replace the ground telegraph by radio sets in advanced positions had failed, chiefly because of the difficulty of maintaining antenna under fire.

To overcome this difficulty the British signaling authorities developed a trench radio set using instead of the ordinary antenna a small loop directly connected with the spark gap for transmitting and an antenna laid on the ground for receiving. This set had a range of 2,000 to 3,000 yards and required about 30 watts, power being obtained from storage batteries. The use of a loop for transmitting, designed small enough for use in a trench or dugout, allowed the practical use of radio communication in forward areas for the first time.

A loop set designed to cover a somewhat longer range but still adapted for trench use was suggested in April, 1918, by Capt. Armstrong and developed by Lieut. Priess, of this division. Preliminary experimental work was carried out in the laboratories of the division and two models constructed under his supervision. In this work Lieut. Priess was assisted by Sergt. (First Class) Harold M. Lewis and Sergt. H. W. Howk. The set as finally authorized for reproduction of models for test in the United States was designed to have a range of 5 to 6 miles, and to transmit on two wave lengths, 110 and 140 meters. The complete set consists of three parts—the box containing the set, a storage battery (10 volts and 20-ampere hours) and a bag containing loose parts, spare tubes, and spare plate batteries, each unit weighing under 30 pounds. This set has proved superior to the British set in that tuning is much sharper and the set has a much greater range.

The first two models were tried out by Lieut. Priess in the Toul sector in August, 1918, very satisfactory results being obtained. During these experiments the sets were located at various distances up to

12 kilometers apart, with one, and finally with both stations in dugouts. The radio officers present at these tests reported so favorably on the apparatus, that arrangements were immediately made to send Lieut. Priess to the United States with the models.

Lieut. Priess left Paris for the United States in September, 1918, to push the development of the loop set, and to use every possible means to put the set as originally designed on a production basis. He immediately took up with the Radio Division at Washington and with various manufacturers the details of the production of 10 of these sets for further trial. At the time the armistice was signed the first United States model of the apparatus had been completed by the E. J. Simon Co., of New York.

The fundamental piece of apparatus for use in listening station work, namely, the SCR 72 amplifier, was made in the United States, and the samples sent over to France proved to be better for this purpose than the French 3-ter amplifier. In order to establish a standard system for use in listening station work, Capt. E. O. Hulbert, of the division of research and inspection, made a complete study of the conditions to be met in this work.

In order to familiarize himself with the methods used by the French Army and with the difficulties which the Allies had encountered in their listening stations, he attended a conference held by French officers in charge of listening stations. Following this, experiments in the research laboratory in Paris were carried out to develop methods for reducing interference and for cutting out disturbing noises. The work included a study of the use of amplifiers, and as soon as the experimental apparatus had been assembled Capt. Hulburt took these to the American sectors north of Toul, at St. Mihiel and in Lorraine, where three weeks' practical work was done to determine the best combination of apparatus.

During this experimental work it was observed that a part of the noises met with at listening stations were due to low-frequency disturbances, such as power lines, motor, and generators. On his return to the research laboratory Capt. Hulburt developed a low-frequency filter to cut out the above types of disturbances. Field tests on this filter were carried out in the country near Paris under various conditions of disturbing noises. These experiments were followed by the manufacture in the model shop of the division of a number of these filters, and upon the invitation of the French authorities Capt. Hulburt proceeded to Flavigny, the general headquarters of the Eighth French Army, with his experimental apparatus. There experiments were made in collaboration with the French officers in charge of the listening stations in that region. Permission was obtained to install the new apparatus in the listening stations, which at that time were handled by French and American personnel.

The system evolved from these experiments consisted of a number of earthed antennas, the SCR–72 amplifiers and the low-frequency filter. This system was found to give better results than the French system. It was also easier to install and to maintain in working order, and it had the further advantage of being more readily adaptable to meet conditions at different stations. Owing to the satisfactory results obtained with this system, it was adopted as standard. The system was used successfully during the six weeks previous to the St. Mihiel attack.

The problem amplifying and receiving very weak high frequency oscillations was brought to the attention of the division by both the British and our own Intelligence Service. The particular need was an amplifier for radiogoniometric work in December, 1917. The requirements were that the apparatus should operate efficiently on wave lengths from 200 to 1,500 meters and be capable of extremely rapid adjustment.

At this time the French were using an amplifier of the 3-ter type and the British a round No. 16 circuit with a 3-stage L. G. amplifier on goniometric work. The radio engineers of both countries, however, had been working on the problem of high-frequency amplification for over a year, and shortly after the problem was brought to our attention both countries had completed experimental work and started manufacture. The French produced a 6-state 4-tube amplifier known as the type L 3. This amplifier was the work of Marius Latour. The British produced a 7-valve amplifier known as No. 55, which was the work of Capt. H. J. Round. The L-3 was adopted by the Americans, as it was the only amplifier available, but as still more amplification was very desirable the division was requested to continue work on the problem.

In receiving very weak radio signals it is desirable, in order to obtain the best results, to make use of both high and low frequency amplification. There are two reasons for this:

(*a*) For a given amount of amplification too much amplification of low frequency brings in local noises and singing.

(*b*) By using both high and low frequency amplification, the input and output sides of the apparatus can be well separated electrically so that a feed back action which causes singing can be prevented.

Up to the present it had been found very difficult to amplify frequencies of the order of 1,000,000 cycles, and practically impossible to amplify frequencies above 3,000,000, principally because at these high frequencies very small capacity effects in the valves and wiring constitute a very great handicap. Not only do these capacities permit energy to be dissipated uselessly and prevent application of the necessary input potential to the grid of the detector, but also extremely minute changes in the position of the operator's body in relation to the apparatus may cause a change in tuning which will seriously reduce the received signals.

A new method of receiving high-frequency oscillations, particularly application to very short wave lengths, was proposed to Maj. Buckley by Capt. Armstrong in June, 1918. The amplifier used in this method operates independently of frequency and will work on 5,000,000 cycles as efficiently as on 500 cycles. Briefly, Capt. Armstrong solves the problem by first reducing the high frequency, which can be more readily handled, and then accomplishes all amplification on this lower frequency. The reduction in frequency is brought about by the heterodyne method. In this case, however, the heterodyne does not reduce the incoming waves to audible frequency, but simply adapts them to the constants of the apparatus.

Preliminary experiments which showed the practicability of the method were made at this time, but on account of the large amount of more pressing work they were discontinued until about August 1. At this time Sergt. Pressley was assigned to work on the reception of undamped waves by this method. In the course of a few days

apparatus was set up, and exceedingly good results were obtained. More pressing work, however, in tank radio, for which Sergt. Pressley was required, prevented his continuation of this problem.

The development of the method for receiving damped and modulated continuous waves was the next step. On account of the fact that no men capable of handling the work were available this development was turned over to Sergt. MacDonald, who was regularly stationed at Orly Field, but who volunteered to work on the problem in his own time. The lack of help greatly delayed the development. Toward the middle of August Sergt. Lewis was available and was also assigned on the development. About the middle of September the experimental and development work was completed and the problem of putting the apparatus into practical form was taken up. It was decided to use six tubes. Two of these were used in transforming the incoming high frequency to the lower frequency, three for amplifying this frequency, and one for detecting it. This work was placed in charge of Sergt. Lewis, assisted by Sergt. Houck. On account of many unforeseen difficulties and the great amount of work required to complete the detail design of the various parts, the first model was not turned out until about the 1st of November. In preliminary tests the model gave several thousand times the amplification of the L-3, and the advantage could be increased by the addition of a two-stage audible frequency amplifier. Tests were completed, and it was ready for trial at the front at the time of the signing of the armistice.

Since high-frequency waves are much more easily directed than waves of lower frequency, the ability to detect and amplify these high-frequency waves in a practical manner brings within the range of possibility the employment at the transmitting station of a directed beam of energy. If this directed beam is found practicable a greater degree of selectivity and secrecy will be obtained as well as greater accuracy in direction finding. The new amplifier should be particularly useful in receiving on planes having built-in antennas, which, because of their small size, can only be worked efficiently near their natural periods. These natural periods are generally of the order of about 50 meters and outside the range of the present type of amplifiers. In conclusion, it may be repeated that Capt. Armstrong's method is believed to constitute a distinct contribution to the radio art and to present possibilities which should be extremely useful for both aerial and maritime navigation.

The SCR-76 is a two-way TPS set, including in one set box the TPS buzzer SCR-71, which is a copy of the French parleur and the two-stage low frequency amplifier SCR-72. Both the British and French have now a two-TPS set.

The design of the set was started in December, 1917, at the request of Col. Gibbs. Tests of the first sample of the SCR-72 showed it to be satisfactory. This work was referred to Capt. Webb, of the division of research and inspection, who started the construction of a model about December 15, 1917, in the laboratory at Boulevard du Montparnasse. Owing to the fact that the building had just been opened and practically no apparatus or tools were available the work started very slowly. Lieut. Clough was put in direct charge of constructing this model.

First tests of the completed model were made in the Forst de Neudon, early in January, 1918, and were successful. In the latter part of January, Capt. (then Lieut.) J. H. Clough and Sergt. C. C. Graves took this model set to the Army Signal School at Langres, where the set was given a service test and functioned satisfactorily.

The model set with the report thereon was sent back to the United States by Lieut. Howk early in February with the request that it be copied immediately and put into production as soon as approved. Owing to the difficulty in constructing models in the laboratory, the exact details of the set box were not worked out, but the improvements and changes desired were pointed out in the report. It was especially required that the set be waterproof and very rugged.

The two-way earth telegraphy set, known as the SCR–76, was designed in the United States by the engineers of the Western Electric Co., in accordance with this request, and several models of the set were sent to France in care of Capt. Cameron, arriving about June 1. These sets were given laboratory and field tests and found very satisfactory as regards operation. They were criticised, however, because of their weight, which was about 38 pounds. This excessive weight was due mainly to the fact that the specifications as understood in the United States were for a set so waterproof that it could be submerged for five minutes at a depth of 5 feet without having any water enter. This excessive requirement was due to a misinterpretation of the report of Mr. Colpitts and Maj. Buckley, sent back in January, which called attention to the need for a certain degree of waterproofing in trench sets.

Work on the production of these sets, with slight modifications suggested by Capt. Webb, who arrived in the United States about the 1st of June, was started early in June. Approval of the new design was given by the American Expeditionary Forces in July. The first 1,000 should have been ready for service early in the fall of 1918.

In order to cut down the weight and eliminate certain other objectionable features, Capt. Webb asked that a new design be started in the United States. The SCR–76A was therefore started at Little Silver about July 1. This SCR–76A set contained many improvements over the SCR–76, especially as regards the weight, which was reduced to about 28 pounds. Approval for adopting this design in place of the SCR–76 as soon as change could be made without delaying production was cabled to the United States late in September.

The section began the design and construction of a mobile telegraph office in April, 1918. This office was installed in a large automobile trailer and contained equipment for six operators and a message file clerk. Terminal facilities were provided for a total of 10 telegraph lines and the apparatus was arranged so that in case of necessity a total of 9 operators could be provided for. The apparatus included one Morse duplex set and one single-line repeater set.

A large force of officers and men was employed on this work and the office was ready for use by July 20. On August 2 it was placed in service at the headquarters of the First Army, and by the following day was handling the full telegraph business of the headquarters with 5 operators and 8 lines working. During the next six days an average of 40,000 words a day were handled without any trouble.

A very similar assignment to the above was the design and construction of a mobile telephone office equipped with terminal facil-

ities for 180 lines. This office was designed to handle the telephone business of an army headquarters. Work on it was begun in the latter part of August, 1918, and by putting the entire telephone and telegraph forces on it, including Sundays and overtime, it was possible to deliver this trailer on schedule at the First Army headquarters on September 19. The office provided for four operators' positions and contained complete ringing and testing equipment of the latest type.

This office proving satisfactory in service, it was decided to draw up complete specifications for both trailer and equipment and to proceed with the manufacture in France of two more offices of this type. These specifications can be found in the records of this division.

The development work of the section covered not only intricate apparatus of a highly specialized nature, but included also several pieces of simple but very practical equipment. One of these was the trench reel carrier developed by Capt. Cannon. This carrier was designed to carry the standard French and American field wire reels. It was intended to replace the French Brouette Derouleuse, which, though suitable for many purposes, was not entirely adapted to trench use.

After a preliminary model had been approved, a preliminary lot of 200 of these carriers was manufactured in France, and were distributed to front-line organizations as rapidly as they were constructed.

Another novel piece of apparatus developed by the Research Section was the shell-fire wire clip. This clip was designed to facilitate the rapid and effective splicing of all types of field wire without the necessity of removing the insulation. It consists of a metal plate studded with sharp points arranged so that when the two ends of the plate are squeezed together over the wire to be spliced, the points pierce the insulation and make permanent contact between the wires.

The first trials with this type of clip proved successful; the model shop of the division therefore prepared 2,500 of these clips for extended field tests. The clips have proved themselves highly satisfactory in principle and further development is only necessary in order to decide on the most practicable form in which to manufacture them. It is believed that this clip will form an addition of permanent value to the line installation equipment of the Army.

Among the many other pieces of telephone equipment developed by this section the following are the ones of principal interest. A model of the redesigned camp telephone switchboard was received from the United States and was thoroughly examined by Capt. Cannon, who approved it for immediate use. A model camp switchboard was, however, prepared by him showing how this board could be made very much lighter and more convenient to use without in any way making it less serviceable or less rugged. This model, with full reports thereon, was forwarded to the Chief Signal Officer of the Army, Washington, D. C.

Another piece of practical development work was the design of an improved model of the four-line monocord switchboard, so generally used throughout the western front. In the standard French design of this board the cords, both operator's and extension, were rather difficult to replace in the field. The units also were provided with fuses which were of very doubtful utility owing to their high blowing point

and the slight electrical risk to which these boards are exposed in practice. Both of these defects were remedied in the board designed by this section, and in addition the apparatus was made more compact by mounting the units directly in a carrying case instead of having a separate carrying case, as in the French board.

As a temporary measure, in order to simplify the existing boards of the French type, until the new model could be put in production, it was arranged to make the first two of these changes on all boards and units in stock. This section prepared details and specifications covering these changes. For use in conjunction with the above monocord switchboard this section developed a small but robust operator's set.

A direct reading combination test set for field use, enabling the operator to test the insulation and conductivity of field lines was designed by the telephone and telegraph section. Models of this set were made by the division and were taken for trial to the front, where they received favorable comment from the signal officers.

The Sagar Hi-wire device to facilitate the installation of field lines on trees, poles, or buildings was designed and made by this section. This device consists of a combination hammer and hook mounted on a light bamboo pole. The hammer is designed to hold a special wire hook, and this hook can be driven into the tree at a height of say 15 feet from the ground and the wire suspended on it in one operation without the necessity of climbing the tree. This device has given satisfactory results in field use as an aid to the rapid installation of lines. Its development should be continued so as to provide for the insulation of the special wire hook.

Maj. Buckley, officer in charge of the section, was a member of the American Expeditionary Forces board on signal and engineer equipment for antiaircraft service, and in this connection he assisted in the preparation of Signal Corps equipment tables for this service. Among the apparatus studied for this special work was a compact and rugged antiaircraft telephone set weighing only 9 pounds. Such a set was designed and constructed by the division, and the tests on it proving satisfactory, orders were placed with a local manufacturer for 500 sets based on this model.

At the request of the Corps of Engineers this division investigated the problems connected with the location of enemy airplanes by sound and the application of this method to the pointing of searchlights used in antiaircraft work. In this work the division obtained the services of First Lieut. Roy W. Chesnut, who had been working during the summer of 1917 as a civilian in Paris on this research problem with a number of French scientists under the French ministry of inventions. When Lieut. Chesnut was commissioned he was assigned to duty with the Division of Research and Inspection, Signal Corps, which was at that time the only fully equipped research unit in the American Expeditionary Forces. He continued his work at the Sorbonne with the French scientists under Commandant Perrin, who during the period between November, 1917, and April, 1918, developed the Perrin telesitemeter and did some experimental work on the Bougier Lissajous figure apparatus.

Airplane sound direction finding was definitely assigned as a function of the Signal Corps in February, 1918, and continued so until November, 1918, when it was officially transferred to the Corps of Engineers.

Lieut. Col. Shreeve and Lieut. Chesnut went to England in March, 1918, to establish liaison with the British scientists engaged on similar work and to obtain complete information on the most recent English developments in sound ranging apparatus. On their return to Paris it was determined to carry out extensive experimental work on all existing types of sound ranging apparatus, French, British, and American. In order to carry out this work samples of apparatus were obtained directly from the British Government, and further samples were constructed by the division in its model shop from British designs. Permission was granted by Col. Pierart and Commandant Perrin, of the French Commission d'Ecoute d'Avions, to use their apparatus and the telesitemeter at St. Cyr, near Paris. Permission was also obtained to use the Bailaud paraboloids at Gonese, near Armouville. In this manner the division was able to make comparative experiments on a more extensive scale than had ever previously been done.

Owing to the German drives in March and April, it was extremely difficult to obtain the necessary personnel. However, two additional officers and five men were gradually obtained and trained in the use of the various apparatus. In June work was begun at St. Cyr by collaborating with the French section d'experience d'ecoute d'avion, under the leadership of Lieut. Gosse. At this station comparative tests were made on the Perrin telesitemeter, the English horns and the Bailaud paraboloid. The sound direction finding section moved in July to Gonese, north of Paris, where the men obtained thorough training in the use of the British listening apparatus.

The group left for the Amiens front on August 9, 1918, with two sets of British 18-inch horns, to join Company C of the Fifty-Sixth United States Searchlight Engineers. Company C was attached to the First French Army and was operating 13 searchlights and our Bailaud paraboloids in the defenses about Amiens.

The comparison of the paraboloid and the British apparatus in actual application to antiaircraft searchlight work was continued under fighting conditions until October. Many difficulties arose because of the continued and rapid retreat of the enemy. Transportation was lacking, experimental apparatus was difficult to set up and adjust, and airplanes came at irregular and unexpected times. However, conclusive results were obtained on which the equipment necessary for antiaircraft work could be based.

While the work in the field was being carried on Lieut. P. H. Dike replaced Lieut. Chesnut in the experimental work at the Sorbonne. While there he assisted in the development of the Bougier apparatus in which, for the first time, optical methods are used for pointing the direction-finding apparatus toward enemy planes. During this time Lieut. Lee supervised the manufacture in Paris of 30 listening sets of the British type to be used as emergency apparatus by the United States Corps of Engineers.

From the time the group returned to Paris until the middle of December, 1918, the experimental and manufacturing work connected with this problem was completed, and the 30 sets of apparatus and complete specifications and reports were turned over to the Corps of Engineers in accordance with official orders from the War Department, Washington. This division, and Lieut. Chesnut in par-

ticular, have been highly commended for the thorough manner in which the problem was handled.

Among the general problems treated by the division of research and inspection is to be classed the ordnance work on the Chilowsky shell, carried on in the French laboratories. Lieut. Sewall, who represented the division in this work, was, at the time of his being commissioned, an assistant in the laboratory of Prof. Perrin at the Sorbonne in Paris, where numerous problems concerning the national defense were being investigated. After being commissioned in the Signal Corps, Lieut. Sewall was directed to report to the officer in charge division of research and inspection, for reassignment to his former duties.

It developed that Lieut. Sewall's work was mainly of a nature to interest the Ordnance Department and such information as from time to time was made available was turned over to that department for its consideration. The work consisted of experiments with a view to increasing the range of field guns by the application of what is known as the Chilowski process to the shells. The essence of the invention consisted in providing in front of the shell a flame of source of great heat, so that the air through which the shell traveled was reduced in density for its passage. The idea, which seemed at first entirely too imaginative for practical consideration was very early proved to have a foundation of truth, and experiments were carried on under the French Government, which led up to a demonstration on the proving grounds of the validity of the principle in January, 1918. The results of this demonstration gave an increase of 25 per cent in range for a number of experimental 75-mm. shells fired at a 25° angle.

These results of January, 1918, were of so much promise that an immediate effort was made to bring them to the attention of the proper American authorities, and copies of reports of these tests were transmitted through the chief signal officer, American Expeditionary Forces, to the chief ordnance officer, American Expeditionary Forces, and to the chief of staff, American Expeditionary Forces, who later carried them back to the United States. Pursuant to a request from the French workers, the Signal Corps then offered the services of another officer, Lieut. Carpenter, a chemist, who started work about the 1st of February. It was realized that the Signal Corps proper could receive no benefit from the services of these officers, but in view of the undoubted interest of the experiments and the importance of keeping the work under way it was thought best to keep these officers on this assignment until such time as the proper department could relieve them and take over the work for the American Army.

The work in itself consisted of experimental physical and chemical research with a view to obtaining the proper combustible to produce the flame and to determining its proper utilization. It involved considerable experimenting in a high velocity air current in which various new principles and hitherto little known phenomena were encountered. The Signal Corps was fortunate in being in touch with French scientists of great experimental ability, and although the fields investigated were for the most part entirely new to scientific research, results of great promise were obtained. Throughout the spring and summer of 1918 the work was continued, Lieut. Sewall working with the French on the problem, but owing to its complexity

and the decided shortage of personnel and material means available at this time, progress was not fast enough to enable a practical application of the idea in American ordnance.

The principle was demonstrated, and it was not only proved that the flame preceding the shell operated to reduce the air resistance to its flight but indication was obtained that the flame increased the stability of the shell, even to the point of rendering shells stable which would ordinarily have tumbled in flight. At the time of Lieut. Sewall's return to this division on October 1 the results actually obtained were not sufficient to justify an attempt at building a shell for field service. It was still thought, however, by both French and American experimenters, that further investigation was worth while.

After the Signal Corps' efforts to call the attention of the Ordnance Department to this work, the artillery ammunition section of that department became interested, and in July and August sent officers to investigate this new and unheard-of invention, and arrangement was finally concluded by which the Ordnance was to take over the active participation in this work, thereby relieving Lieut. Sewall. A captain was sent to Paris to familiarize himself with the details of the experimental study and to collect all useful information with a view to taking it back to the United States, where he was to assist in starting experimental work under American auspices. It was thus hoped by all concerned to put resources on the problem adequate to produce quick results. All information in the possession of the division of research and inspection was compiled in a report for transmittal to the Ordnance Department and turned over to them in October, 1918. But the Ordnance captain who was intended to take an active part in this work was taken ill and invalided home before the information could be compiled, and was thus cut off from further connection with this work.

One of the cases where the division was able to render assistance to other branches of the service along lines not directly connected with Signal Corps functions was the development of the gun-sight lighting device. This device intended for illuminating the cross lines on the colimeter of the 75 mm. field gun and the 150 mm. howitzer was designated by Lieut. Col. (then Maj.) Shreeve, for the Ordnance Department, in response to a request from the signal officer of the First Division, transmitted through the office of the Chief Signal Officer for a device which could immediately be produced to assist the Field Artillery officers in laying their guns for night shooting.

Since the speed of development of this device is rather unusual in regard to the short time which elapsed before the complete model was produced, the following steps in the development are given in chronological order:

Feb. 8. Telephone request from the office of the chief signal officer for Maj. Shreeve to procure some miniature lights and to visit the headquarters of the First Army to see if some device could be produced which would improve the sighting of the gun for night shooting.

9. Maj. Shreeve left for the headquarters of the First Division with a collection of miniature lights, switches, wire, etc.

10. Maj. Shreeve worked with the battery and studied the problem to find exactly what was wanted and under what conditions the lighting attachment would have to function.

10. Maj. Shreeve constructed a rough model in a cellar back of the lines, using a tin can, blow torch, and a pair of shears.

Feb. 11. Experiments made on a gun during a shoot and the operation of the device verified. Maj. Shreeve returned to Paris the same evening.

13. Factory-made sample of the lighting attachment finished and was sent by special courier to the battery for test.

15. The idea developed to include a self-contained unit comprising batteries, switches, special reflectors for the lights, rough sketches made and a source of supply for the various articles obtained.

Mar. 2. Complete model of the battery box, etc., completed and sent to the battery, through general headquarters, for verification.

Following the trial of this equipment, orders were placed by the Ordnance Corps with local manufacturers for sufficient of the completed outfits to equip 12 divisions. Owing to the success of the device orders were subsequently placed for 36 more divisions, making in all a total of 48 divisions.

During the subsequent fighting around Montdidier the device was found to be so effective that one of the Artillery officers was directed to visit Paris for the purpose of obtaining and taking back to Montdidier by motor transportation not only all of the completed devices which were available, but also any uncompleted parts which were available and could be pressed into service. In view of the urgency of this request a considerable amount of equipment, both complete and incomplete, was obtained from manufacturers, and on special permission from the chief signal officer was dispatched to the headquarters of the First Division by motor transportation belonging to the Division of Research and Inspection.

In order to facilitate the production and shipment of this equipment, the division of research and inspection undertook not only the supervision of the construction for the first order for 12 divisions but also the production of specifications and the inspection of the completed outfits.

The appointment of Maj. (later Lieut. Col.) Shreeve of the division of research and inspection to the Interallied Board of Inventions was only one of the points of contact with other technical bodies developed by the chief signal officer, American Expeditionary Forces, in an attempt to obtain for the American Expeditionary Forces the greatest benefit in the matter of technical assistance in the various problems which had to be solved. Membership on the board was particularly useful in giving members of the American Expeditionary Forces direct contact with other technical bodies, thus enabling them to obtain information and constituting a definite channel through which inventors of the various allied Governments could submit their ideas for proper action.

The comite interallie des inventions was formed under the French ministere de l'armament et de fabrication de guerre and administered under the direct control of the sous-secretarist des inventions. The function of the board was to keep the technical services of the various Governments informed of the new inventions found interesting and adopted by each allied country, with the idea that some of these might be found of use to the other allied Governments.

The chairman of the board was Monsieur Buisson (French), and the board included representatives of the French, Belgian, British, and American Governments. Two meetings of the board were held each month, generally on the Tuesdays of the second and third weeks

of the month. The meeting place was 23-bis Rue de l'Universite. At these meetings the French secretary of the committee communicated to the allied delegates notes on the inventions submitted during the previous month to the French comite supericure des inventions. The notes so transmitted referred to inventions which the committee had considered and recommended as worthy of further investigation. Each of the delegates was supposed to communicate to the board information in regard to inventions which had been adopted by their respective Governments, which it was believed the other Allies could profit by, such communication being with the permission of the respective Governments.

During the time the Signal Corps was represented on the Interallied Board of Inventions 42 devices and ideas were submitted for discussion. Although a very few of these were of practical interest to the Signal Corps, very many of them were of decided interest to other branches of the service, such as the Ordnance, Aviation, Engineers, and Medical Corps. In cases of this kind, copies of the literature, description of the tests, etc., were transmitted direct to the head of the service interested. During the membership of Lieut. Col. Shreeve on the board 25 inventions or information in regard to them were so transmitted. The devices reported upon included various inventions for use on airplanes, photographic apparatus, parachutes, airplane guns, training devices for pilots, new types of gun with antirecoil devices, message-carrying projectiles, special projectiles for cutting wire, balloon attachments for automatically dropping propaganda leaflets, bomb-throwing devices, delayed-action fuses, gas masks, brickmaking devices for use in the devastated regions, chemical mixtures for use in explosive engines, printing telegraphs, steroscopic devices for examining airplane photographs, sighting devices for rifle grenades, compasses, direction-indicating devices for use in trenches, pumps, etc.

In a great many cases inventors were interviewed, their devices examined, and if these appeared to have no particular interest to the American Expeditionary Forces the inventor was so informed.

The need for a machine shop in connection with the research section of the division was foreseen when the division was organized and orders were placed in the United States for the necessary equipment. However, at the time these orders were placed it was practically impossible to obtain deliveries of machine tools, gauges, etc., in less than six months, and as a result this equipment was the last property of the division to reach France.

As soon as the research work of the division was commenced it was found that personnel and equipment was urgently needed for the manufacture of experimental pieces of apparatus and of complete models. With such tools as were available a model shop of the division was started in a small way about the middle of December, 1917. It was with the greatest difficulty that special small parts were made for the various pieces of apparatus, as the only machinery we had up to the middle of March was one small hand-drill press and a small bench lathe which was turned by hand power. The only other equipment consisted of a few small tools of French make, and these were used until March, 1918, when the machine tools from the United States began to arrive. Model making was begun with two enlisted men and up until the middle of March a number of models were made under very difficult conditions because materials such as lumber,

brads, screws, and other small parts had to be obtained from French factories and shops. This was a difficult matter, due to the restrictions imposed by the French Government.

During the spring of 1918 the amount of work increased to such a degree that it became necessary to move to a separate building. About the middle of March tools and machinery were received from America which were installed in a small building adjoining the laboratory. For about two months a small bench lathe and a drill press, both motor driven, were the only machines available; however, with the aid of the American tools which had been received all the model work required by this laboratory was manufactured in a very satisfactory manner. Amongst others a number of amplifier nets were built and sent out to the Army for service.

The bulk of the machinery ordered in America for the model shop arrived during the month of May and was installed in the shop as rapidly as it was received. The amount of work at this time was such that at various times a force of 10 men was required to work nights and Sundays to get special apparatus out in time for field tests. An addition was made to the building and completed about August 10, making a total floor space of about 1,500 square feet. In addition to this space, the blacksmith work and woodcutting was done under a small tent, thereby keeping the sawdust and dirt out of the shop and saving considerable floor space. At the time this addition to the shop was finished the Germans were very close to Paris and a number of machines which had not been unpacked were shipped away, so that, in case evacuation was necessary, those particular machines would not be a hindrance in getting the other machinery out. After the danger had passed they were sent back and installed about the last of September, by which time the force had been increased to 15 men, all of whom were first-class mechanics or woodworkers.

Up to the time of the armistice more than 300 special pieces of apparatus and models were made. In several cases production of a number of pieces of a certain apparatus was made where this was necessary to successfully carry out experimental work. In a great many cases apparatus was made from rough pencil sketches furnished by the officers requiring apparatus.

Some of the large assignments carried out by this model shop included the special fitting and installation of apparatus in the telephone and telegraph trailers, the manufacture of all condensers and the variometers for spark and tanks sets, building of special transformers, finished models of amplifiers loops and telephone camp switchboard apparatus. A great many small parts which would ordinarily be bought ready-made by the shop had to be made due to the impossibility of obtaining standard electrical and hardware parts.

The following is a list of some of the more important developments in the American Expeditionary Forces of Signal Corps equipment. The first 12 of these improvements are described in detail in the chapter on the research section of the division of research and inspection, which section was responsible for the developments in question. The remaining 10 cases, which are largely the work of members of the engineering division, form the subject of this chapter:

1. Tank radio set.
2. Two-watt radio loop set.
3. Listening-station equipment.
4. High-frequency amplifier.
5. Two-way T. P. S. set.
6. Mobile telephone and telegraph offices.
7. Trench wire-reel carrier.
8. Shell-fire wire clip.
9. Camp switchboard.
10. Monocord switchboard.
11. Sagar Hi-wire attaching device.
12. Gun-sight lighting device.
13. Modification of Signal Corps artillery telephone sets.
14. Improvement of Signal Corps camp telephones.
15. Telephone sets for artillery fire control.
16. Telephone sets for balloon service.
17. New type field telephone set.
18. Buzzerphone set.
19. Field duplex telegraph set.
20. Adaptations of commercial telephone switchboard for American Expeditionary Force service.
21. Circuit design for long-distance service.
22. Design of circuits for long underground cables.

A commercial telephone known as the 1375–B telephone set was specified by tables of unit equipment for artillery service. This set, which was designed for railway service, was equipped with a hand telephone employing a push button to close the receiver as well as the transmitter circuit. This feature made it necessary to hold the button circuit closed while listening, thus draining the miniature battery and rendering service uncertain in case the button was not sufficiently depressed. The difficulty experienced in the field with this set was in April, 1918, called to the attention of Gen. Russel, who directed that immediate steps be taken to improve the set.

A modification which could be readily applied to the existing sets was devised by Capt. F. J. Clarke and instructions with sample sets were dispatched to both supply points and to the signal officers of the field within two days of the time the matter was brought up. This modification provided for listening without operating the push button, so that continued listening could be had and the transmitter battery was in use only when necessary to talk. Information and drawings were immediately sent to Washington in April and instructions were issued by the Chief Signal Officer of the Army at Washington in May, 1918, for the change to be applied to all sets in production in the United States.

The camp telephone, model 1917, was frequently used for long-continued periods of listening. When so used the battery was rapidly drained. For such use provision was made for attaching an auxiliary head receiver, connected so that the battery was not affected. This arrangement was developed by the equipment section of the engineering division and is of general application wherever the camp telephone is required for long-continued use. The head receiver may be carried within the standard carrying case.

Changes to include detail features in the camp telephone set were also worked out and submitted to Washington. These features included the improvement of the battery receptacle to enable the tungsten batteries to be readily inserted, and improvement in the mounting of the ringer magnets to prevent breakage. In February, 1918, the necessity of substituting a moisture-proof transmitter capsule in

the hand set was presented to Washington by cablegram which recommended a commercial type of capsule to supersede the type then furnished. This feature was of considerable importance, as the use of the hand set under the wet conditions experienced in France caused rapid failure of the transmitters.

Considerable development work was done by the engineering division on the design of sets for antiaircraft artillery fire control. This work was coordinated with the work on the design of a field telephone, with the view of producing a set suited for general field use. At the time of the signing of the armistice, definite decisions as to the future type of field telephone sets had not been reached. This work should be continued, as it is especially important that a suitable design be adopted to eliminate the use of numerous types for specialized purposes.

The balloon section of the Air Service was provided with a number of SCR–57 sets for balloon-to-ground service. These sets, being designed for interphone airplane service, could not be directly adapted for the service in view. As the sets were on hand and others were not available, Col. Chandler requested the assistance of the engineering division in solving the problem for immediate service. Capt. Clarke and Lieut. Cram, of the engineering division, made extensive tests, and after 24 hours' continuous work produced a modification which could be applied in the field for all of these sets.

The design of a head telephone set for such uses as balloon service, operators' sets at busy field boards in dugouts, and for artillery fire control was worked out by Capt. Clarke and Lieut. Cram, of the engineering division. This design provided for the use of standard American head receivers and breast transmitters by utilizing attachments to exclude noise from the head receivers, and a transmitter switch controlled by the mouthpiece of the standard breast transmitter. Sets of European design were purchased by the Signal Corps for these purposes, but these sets had many faulty features which could not be corrected without the complete redesign of the set. Further work along this line would be justified in order to develop a standard type of set suited for continued telephone service under conditions where the field set is not suited.

Considerable preliminary work on the design of a field telephone set was done by the engineering division. The field sets developed in the United States were experimented with, and recommendations were made for the production of these sets in the United States. At the time of the signing of the armistice this matter was not definitely lined up. It will be profitable to continue the work along the line of development of a standardized field set with a view to adopting a set suited for general purposes by the addition of auxiliary features, thus simplifying supply and maintenance conditions.

In 1917 Capt. Paddock, Signal Corps, in charge of field equipment engineering at general headquarters, adapted the Fuller phone of the British Army for construction along lines suited for our use. In conjunction with the Western Electric Co., Capt. Paddock developed the buzzerphone, model P–1917, which was produced in the factory of the Western Electric Co. at Paris.

Samples of the buzzerphone were furnished the United States and development and improvements were taken up by the Western Electric Co. there, resulting in the production of a buzzerphone which was

an improvement over the set manufactured in France. This set was not ready for service at the signing of the armistice. The "howler" receiving device was a distinct improvement over the buzzer device previously used by the British and American forces. Further improvement to make the internal insulation of the set more satisfactory is necessary, and work on this line could be taken up to advantage.

In September, 1918, Gen. Russel presented the necessity of developing an improved telegraph set for field service, particularly from the standpoint of battery supply. Capt. Clarke and Lieut. Hall, of the engineering division, took up the problem from the standpoint of increased sensibility of receiving instruments. Capt. Fay later continued the work, and a field duplex set was developed in October and was manufactured at Gievres and furnished the field by the time that the armistice was signed.

This set was found faulty in respect to types of apparatus furnished, but the principle was shown to be sound and worthy of further development of details.

Among the first engineering problems presented in the American Expeditionary Forces was the furnishing of high-grade telephone and long-distance communication for the headquarters and branches of the American Expeditionary Forces. As no switchboard equipment was received from the United States until late in February, it was necessary to utilize French commercial apparatus. This apparatus required many modifications, as the French equipment is not suited to the long-distance service or the speed of service which Americans require.

The first important work along this line was the rebuilding and enlarging of a four-position French switchboard provided at the line of communications headquarters, Hotel Mediterranee, Paris, to a seven-position full multiple switchboard with standard lamp signals, busy test and transmission features similar to those used in the United States. The French multiple switchboard provided at Chaumont was also modified to eliminate various objectionable features. Considerable work was required in this connection, as apparatus was difficult to secure, and many developments had to be worked out in order to secure the desired results with the apparatus which was obtainable. The design and installation of this work was carried out by Capt. Clarke and Lieuts. O'Shaughnessey and Royen, of the engineering division.

In December, 1917, an extensive network of long-distance circuits had been leased from the French Posts and Telegraph. In order to provide satisfactory service considerable work was necessary requiring an intimate knowledge of the French methods and apparatus. As a result of line and apparatus improvements carried out through our supervision a satisfactory grade of transmission was available in 1917 from general headquarters at Chaumont to Paris and the various base ports.

Telephone repeater equipment from the United States was received in April, 1918, and was immediately installed at Paris, Autun, and at British general headquarters at Montreuil in May, 1918. These repeaters provided a very high grade of transmission between general headquarters and Paris and thence to the several base ports, while the repeater at British general headquarters made possible satisfactory

transmission to London for both the British and our own services from our most distant points in France. Ten telephone repeater stations were established, the largest being at Briey, with seven repeaters.

The headquarters service at Chaumont, Tours, and Paris was enlarged greatly beyond the scope contemplated when orders for telephone equipment were placed. As a result it was necessary to devise many expedients such as switching trunks and long-distance cord circuits. The design and execution of this work was carried out by Capt. F. J. Clarke, assisted by Lieuts. Cram and Marsters and Sergt. Harper.

In connection with our Paris system, embracing at various times 10 different central offices, it was necessary to carry out circuits through underground cable for distances as high as 23 kilometers. As French facilities were inadequate to care for the numerous long lines brought into Paris for our use, arrangements were made with the French to place our own underground cables. These cables did not permit of the use of derived telephone circuits, so that it was necessary for us to balance these underground cables by means of a system developed in the United States in recent years for long-distance cable circuits. The French department of posts and telegraph was not familiar with these methods, and therefore it was necessary for the Engineering Division to design testing equipment and to carry out the work of balancing and reconnecting the circuits. This work was successfully accomplished, to the surprise of the French technical administration, by Sergt. L. V. Tennant, under the direction of Capt. Clarke. Sergt. Tennant's work was especially to be commended and was highly appreciated by the French authorities.