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WIRELESS LONGITUDE

BY

GEORGE D. COWIE
Hydrographic and Geodetic Engineer, U. S. Coast and Geodetic Survey

and

E. A. ECKHARDT
Physicist, U. S. Bureau of Standards

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WIRELESS LONGITUDE

By George D. Cowie, *Hydrographic and Geodetic Engineer, United States Coast and Geodetic Survey,* and E. A. Eckhardt, *Physicist, United States Bureau of Standards*

HISTORICAL NOTES ON WIRELESS LONGITUDE

Wireless longitude determinations have been practically confined to the past 20 years.

Probably the first determination was that between Potsdam and Brocken, in Germany, a distance of about 100 miles.[1] The signals were sent from a wireless station by means of an oscillating pendulum and received by the coincidence method at both longitude stations. A comparison between these results and those obtained by the wire-telegraph method agreed within 0.006 second.

In 1911 the French determined the difference of longitude between the Paris Observatory and Bizerte, a distance of 920 miles, and in 1912 between the Paris Observatory and Brussels. In each case the results agreed closely with check results by wire telegraph.

Following these came the trans-Atlantic wireless determinations made in 1913–14 between Paris and Washington. Time signals were transmitted from Radio, Va., and from the Eiffel Tower, Paris, and were compared at the American longitude station by the coincidence method and at the French station photographically. Provisions were made at the American station so that the sounds of the chronometer ticks would be similar to those of the incoming radio time signals and coincidences more precisely noted.

The results of observations from October 31, 1913, to March 5, 1914, gave the value of the longitude of the United States Naval Observatory clock room as $5^h\ 08^m\ 15.721^s$. This value is considered by the officials of the observatory to be the best so far determined, but for the sake of consistency all longitudes in this country are based upon the value of $5^h\ 08^m\ 15.784^s$ resulting from previous trans-Atlantic cable determinations, three of which were made by the United States Coast and Geodetic Survey and one by the British and Canadians.

In 1915 the British began longitude observations in Australia, using the time signals sent from Melbourne and Adelaide, and in 1920 determined longitudes by the use of time signals sent from Lyons and Bordeaux, France, and from Annapolis, Md., over distances of 11,000 miles. The time signals were received on the ear phones and compared by coincidences with the local chronometer.

Photographic recording of wireless time signals, recording on smoked glass or paper by means of a stylus attached to the diaphragm of a wireless-telephone receiver, and a coincidence method in which

[1] P. Baracchi Australasian Assoc. for Adv. of Sc., Vol. XIV, pp. 56–58.

the tick of the local chronometer causes an inductance in series with the coils of a wireless receiving set to be temporarily cut out of the circuit lowering the pitch of the sound in the receiver, have all been tried abroad. In the last method the incoming wireless signal raises the pitch, and the exact moment of coincidence is noted when the order of the high and low pitches is reversed.

In October, 1914, what was probably the first chronographic registration of wireless time signals in America was made by Dr. Frank D. Urie,[2] at the observatory of the Elgin Watch Co., Elgin, Ill. He recorded the signals from Arlington, Va., using a galena crystal detector and a four-stage amplifier. The ticks of the local Riefler clock were also recorded on the same chronograph sheet by means of the effect on the radio set caused by the sparking of a relay in the local time circuit.

Early in 1921 a portable radio outfit, in which the recording of both the chronometer ticks and the incoming wireless time signals was performed through the same chronographic-pen system, was made at the request of the United States Coast and Geodetic Survey by Drs. E. A. Eckhardt and J. C. Karcher, of the United States Bureau of Standards.

The performance of this set was demonstrated on March 26, 1921, before the Philosophical Society of Washington, at which time messages from Lyons, France, Annapolis, Md., and several powerful commercial stations on the east coast of the United States were recorded.

Owing to the desire to make some improvements in this set, it was not used by the Coast and Geodetic Survey field parties until the following year. Work was begun in Wisconsin in June, 1922.

Future work in wireless longitude, in addition to that necessary for the control of triangulation surveys, will be the determination of a belt of precise longitudes around the world, which, in addition to placing all continents on the same astronomical basis, will aid in the improvement of the accuracy of time observations at the principal world observatories.

PURPOSE OF PUBLICATION

This publication is intended to describe the instruments and equipment used by field parties of the United States Coast and Geodetic Survey in the wireless determination of longitude; the method of setting up this equipment; its operation; the methods of observing, recording, and computing; and some precautions for avoiding difficulties.

As wireless apparatus is continually undergoing change, no pretense is made of covering the field of equipment used in the reception of wireless time signals. Some general principles of wireless, which should be understood, will be referred to, and specific description given of receiving apparatus which has been used with success during the past two seasons.

The reader is referred to United States Coast and Geodetic Survey Special Publication No. 14, pages 7 to 102, for information regarding time and longitude work, and to Special Publication No. 35

Frank D. Urie. Popular Astronomy, Vol. XXIII, No. 9, Nov., 1915.

for much data pertaining to longitude determinations with the Bamberg broken-telescope transit which has been used on wireless longitude work. For the benefit of those who do not have the latter publication at hand, a description of the Bamberg transit is repeated here, together with the values of the hanging and latitude levels and of the micrometer screw.

INSTRUMENTS

The principal instruments used for wireless longitude determinations are Bamberg broken-telescope transit, with transit micrometer; sidereal break-circuit chronometers; chronograph, with differentially wound pen magnet; three-stage radio amplifier; radio recorder; wireless longitude switchboard.

BROKEN-TELESCOPE TRANSIT

In this instrument the light coming through the objective is reflected at right angles by a prism set in the axis of the telescope, to the eye end, which is in the prolongation of the axis about which the telescope revolves, and outside of the wyes (figs. 1 and 2). The objective has a clear aperture of 7 centimeters and a focal length of 67 centimeters. The instrument is fitted with an ocular micrometer which records electrically the times of the passage of a star through the field. The micrometer screw has an equatorial value of about 10.5 seconds for one turn, and the head of the micrometer has an agate rim in which are set 10 equidistant metallic strips, each strip being about one one-hundredth of a turn in width. In addition to these 10 strips, there are also 2 others, set one on each side of the zero strip and equidistant from it, to provide a means of idenifying the marks of the record. A platinum point is pressed by a spring against the surface of the micrometer rims, and as the head is revolved this point makes a contact and completes a circuit each time one of the metallic strips passes under it, and a record is made on the chronograph.

At the opposite end of the telescope axis from the micrometer there is arranged a very small electric light for the illumination of the cross hairs, and the light from it is transmitted through the large prism to the eyepiece by means of a small prism not over one-third of a centimeter in size which is cemented with Canada balsam on the diagonal face of the large prism. The faces of the two prisms must be accurately parallel to allow the passage of the light.

A small setting circle, about 15 centimeters in diameter, is attached to the telescope axis back of the micrometer box at the eye end. This circle carries a movable vernier and level, and reads to 1′. The graduations of the circle are numbered from 0 to 360, and the zero is so placed that the circle reads zenith distances for stars $\frac{\text{north}}{\text{south}}$ of the zenith when the eye end is $\frac{\text{east}}{\text{west}}$, and explements of zenith distances for stars $\frac{\text{south}}{\text{north}}$ of the zenith when the eye end is $\frac{\text{east}}{\text{west}}$.

A reversing apparatus is provided, and attached to it are four friction wheels which run in two grooves cut in the axis of the telescope. These wheels, two of which form a sort of cradle, one on each side of the telescope tube, rest in turn on springs which are sufficiently strong to support the greater part of the weight of the telescope. Thus, only a small part of the burden of the telescope is borne on the pivots and wyes. This reduces flexure to a minimum and permits the telescope to be made heavier and more solid than would be desirable if all the weight were carried on the pivots.

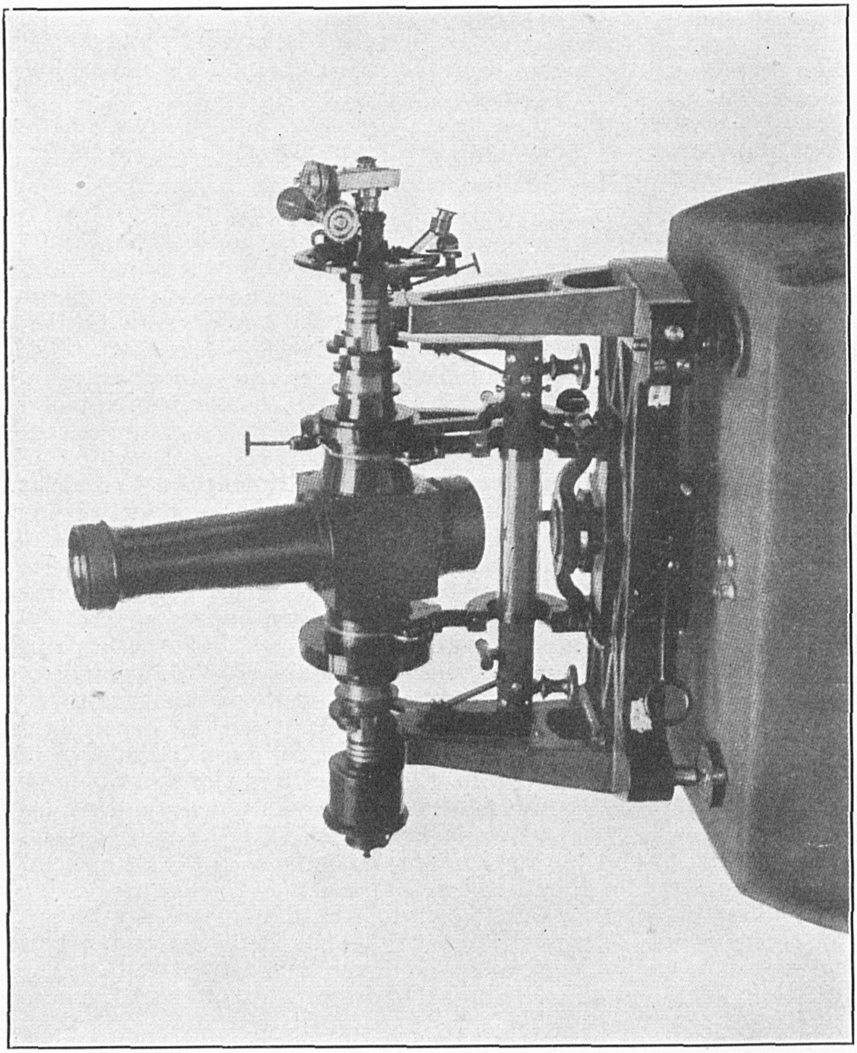

FIG. 1.—Bamberg broken-telescope transit arranged for longitude work

Instead of the usual striding level the instrument is furnished with a hanging level, and to permit its hanging directly below the axis of the telescope each standard of the reversing gear is cast with a semicircular arc at a point about halfway of its length. Two small cross levels are attached to the hanging level, one near each end, to indicate when it is in proper position for reading.

The frame of the instrument is skeletonized, but strength has not been sacrificed, nor has it been made too light in weight. In size it is 28 by 55 centimeters, with its top 8 centimeters above the top of the pier.

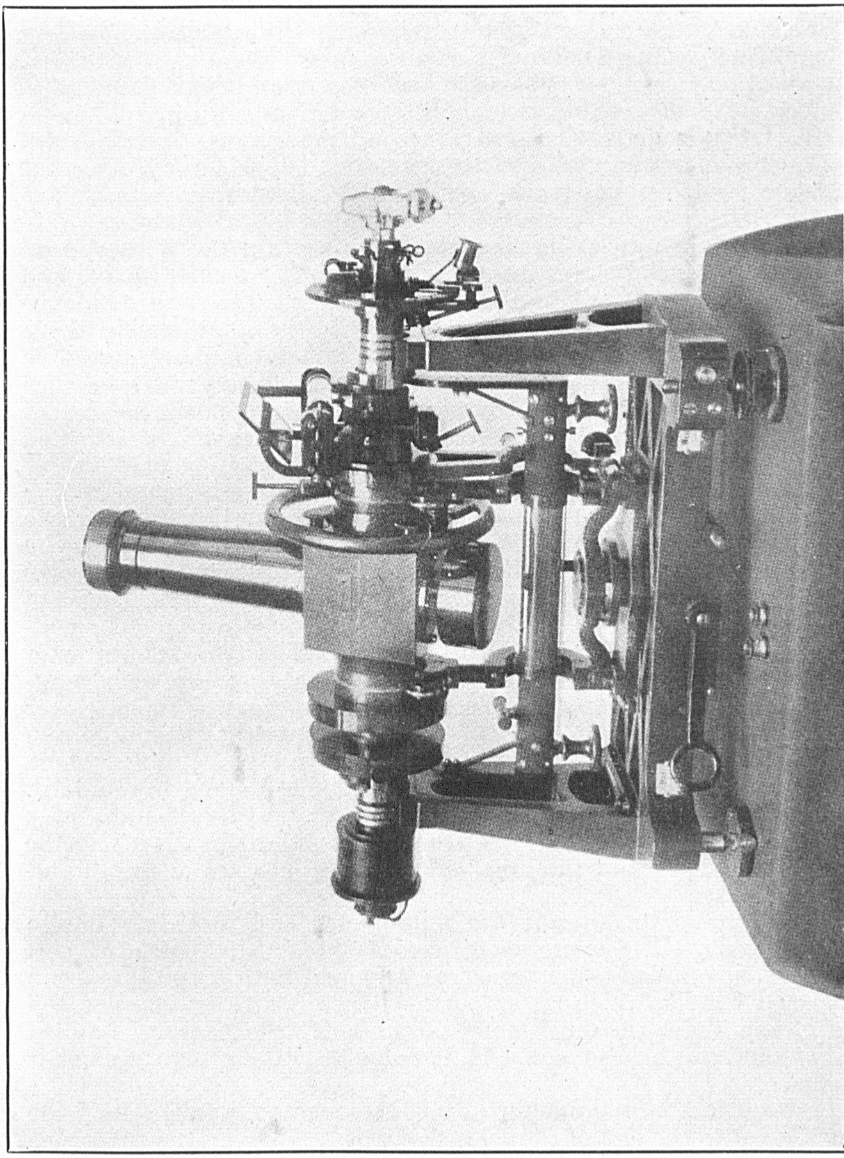

FIG. 2.—Bamberg broken-telescope transit arranged for latitude work

One peculiarity of the construction of the instrument is in the position of the foot screws. These are three in number, two being placed in line at the corners of the frame on the north side and the third being at the middle of the opposite side. The west foot screw rests in a hole in a footplate; the south one rests on a plane surface of hardened steel on a second footplate, while the east one rests in a V-shaped groove in a third footplate. This groove is cut in a steel block, which is movable in the footplate by means of two abutting screws. The object of this motion is to provide means of setting the instrument in the meridian. When the abutting screws are turned, the whole instrument, frame and all, revolves horizontally about the hole in the west footplate as a center.

In addition to what has already been described, the instrument is provided with detachable twin levels for latitude work. When in use for latitude determinations a second micrometer is employed. This micrometer has no electric connections. It is arranged so that it can be used for time-work, either by the key method or by eye and ear.

The care taken to avoid flexure by supporting the telescope on friction wheels has been mentioned. As another means to this end the telescope is very efficiently counterpoised. Thus, as a balance to the telescope tube, a weight is attached to the opposite side of the axis; as a counterpoise to the ocular micrometer and setting circle the mounting of the illuminating lamp is made heavy; as a balance to the clamp a counterweight is provided on the opposite side; and, finally, when the latitude levels are in use, a counterdisk is attached opposite them.

There are two independent electric circuits in the instrument, one for the illumination of the field and the other for transmitting the record of the transit micrometer, and they are so arranged as to be effective in both positions of the telescope. There are only three wires for the two circuits, one wire being common to both. Hence, in making the connections, the central, or common, wire must be connected with like poles of the two batteries. The two circuits enter the instrument at the southwest corner, where there are four binding posts. Two switches are placed here, by means of which either circuit can be opened or closed. The three wires are insulated and lead along the frame of the instrument to three metal springs, which are fastened to a strip of hard rubber at the top of each standard. These springs press upward against three insulated metal bands in the axis just outside the pivots. The outer and middle bands are in the micrometer circuit and the inner and middle ones are in the illuminating circuit.

It is desirable to describe the micrometer and recording device more in detail. The micrometer screw, with its divided head and metallic strips already mentioned, is provided with a suitable train of beveled wheels, which are in turn connected with an axis located back of and above the micrometer box. This axis has a large milled head at each end for use, one with each hand, in following a star as it transits.

The back of the micrometer box is attached to a tube which fits accurately into the end of the telescope axis. A lug on the tube runs in a slot in the axis, and the slot is made larger than the lug, so as to allow the tube to be rotated through a small angle by means of two abutting screws for adjustment of the verticality of the movable wires. The focusing of the wires is done by moving the tube in or out as required, and a clamp is provided to hold the tube in place after the adjustment for focus is made.

The movable threads of the diaphragm are parallel and three in number. Two of them are placed close together, so that observations may be made by keeping the image of the star midway between them, and the third is separated from the pair by the space of about half a turn of the screw. Observations may be made with this thread by bisecting the star image.

There are six fixed wires in the micrometer. Two of these are intended to indicate the path through which the star transits and are placed about 50 seconds of arc apart and parallel. These are of course at right angles to the movable wires. The other four fixed wires are parallel to the movable wires. Two of them are close together and serve to define the line of collimation; the other two are placed one at each side of the field at a distance of five turns of the micrometer screw from the line of collimation and indicate where the observations on a star begin and end. A small scale on the outside of the micrometer box numbered from 0 to 10 indicates the position of the movable threads. On the west end of the frame of the instrument there is a small plate bearing the inscription "0 R," and on the east end a similar plate is inscribed "10 R." These are intended to remind the observer that in position ocular west the micrometer should be set at 0 revolutions in preparation for the approach of the star, while in position ocular east it should be set at 10 revolutions.

The transit described above can be used also for the determination of latitude by the Talcott method.

CHRONOGRAPH AND SWITCHBOARD

The chronograph used is that described in Special Publication No. 14, except that the pen magnet has two opposing sets of windings, as shown in Figure 3.

The recording-pen armature, which is normally held over to the magnet on account of the current in winding *B*, is released by the neutralizing effect of the current in winding *A* whenever the break-circuit chronometer ticks.

The transit relay, which replaces the radio relay while star observations are in progress, causes the pen to be released every time a contact is made on the micrometer head as it opens the circuit through *B*. The radio relay does likewise under the influence of the incoming radio time signal.

Should the radio relay or the transit relay break the circuit through *B* at the same time that the chronometer tick makes a circuit through *A* the pen is jerked over to the magnet. This assures a record of chronometer seconds at all times.

An adjustment of the tension of the armature spring is necessary to make the recorded marks of the chronometer seconds of the same size when caused by the action of the two windings as when caused by one.

The switchboard is shown in Figure 4, and the wiring diagram in Figure 5. The switchboard consists of two relays with armature pivots set in jeweled bearings and a double-throw, double-pole switch. The chronometer relay has a resistance of 75 ohms and the transit relay of 20 ohms. By throwing the switch up the latter relay is cut out of circuit and the radio relay of the recorder put in.

RADIO APPARATUS

In the descriptions which follow detailed information is given which applies particularly to radio amplifier and recorder No. 1. A later section will describe the differences between set 1 and sets 2 and 3.

A three-stage radio amplifier (No. 1) is shown in Figure 6. It consists of a bakelite panel mounted in a box and carrying on its upper surface three vacuum tubes mounted in sockets, three filament rheostat control knobs, two dials for adjusting the variable air condensers, and several binding posts.

On the back of the panel (fig. 7) are two variable air condensers of 0.002 microfarad capacity each,[3] one fixed condenser of 0.001 microfarad capacity, three audio-frequency transformers, one 500-

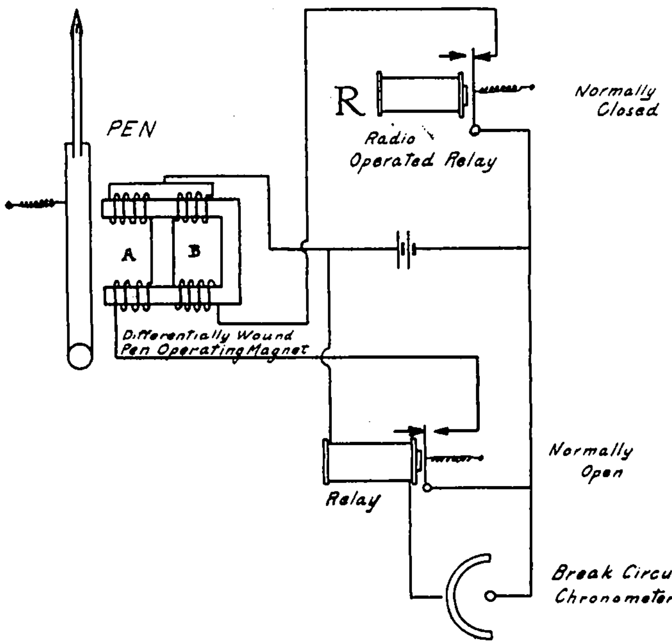

FIG. 3.—Circuit of the recording element

turn duolateral-wound inductance coil, three filament rheostats' three fixed resistances in series with the filaments, and the necessary wires for connections. The schematic wiring diagram of the amplifier is shown in Figure 8.

Radio recorder No. 1 is shown in Figure 9. It consists of a bakelite panel carrying on top a special high resistance relay (800 to 2,000 ohms), with inner and outer contacts insulated from each other, a vacuum tube and socket, a filament rheostat control knob, a variable condenser dial, a galvanometer, a grid or C battery switch, a potentiometer control knob, and various switches and binding posts.

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[3] Only one variable condenser is necessary, but as the removal of an inductance coil from a circuit through one of the two variables left this condenser mounted on the set as extra equipment, it was used in place of a fixed condenser.

On its under surface (fig. 10) is a variable air condenser of 0.002 microfarad capacity, a shelf carrying two 1,000-turn duolateral wound inductance coils, two fixed mica condensers of 0.001 and 0.002 microfarad capacities, one fixed mica condenser of 0.2 micro-

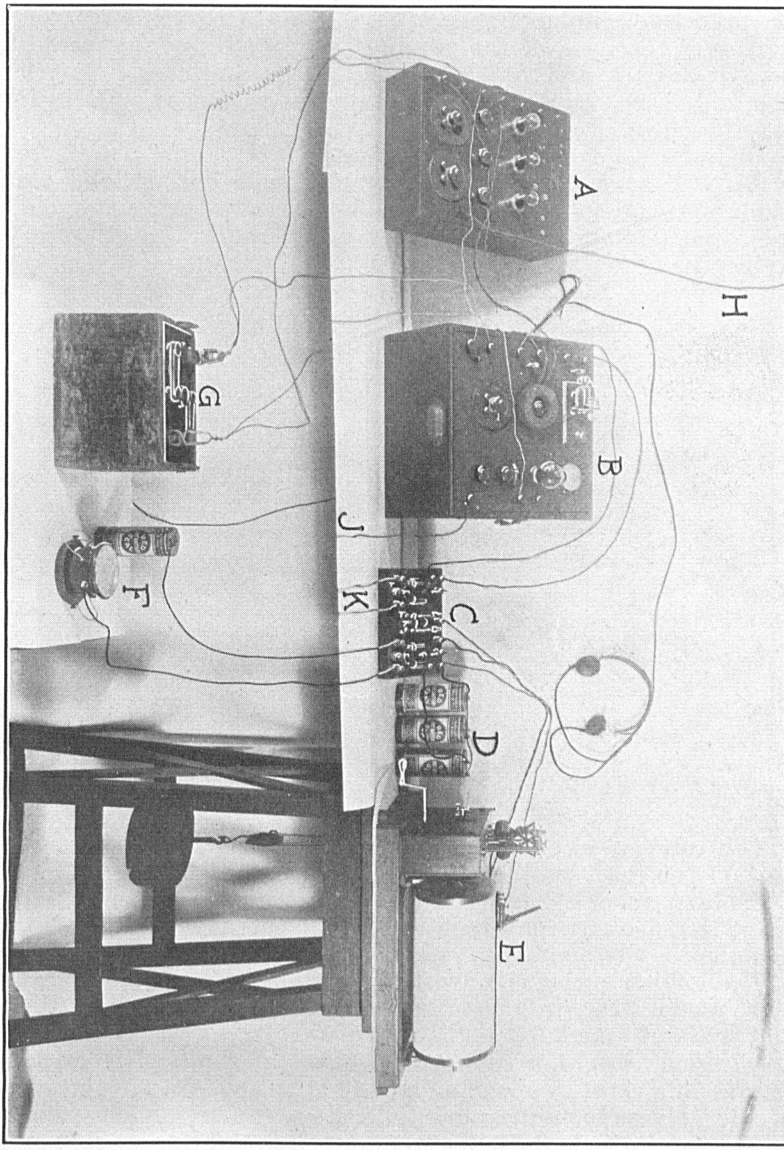


Fig. 4.—Radio apparatus arranged for recording

A, three-stage radio amplifier No. 1; *B*, radio recorder No. 1; *C*, wireless longitude switchboard; *D*, line battery for chronograph; *E*, chronograph; *F*, chronometer; *G*, "A," or storage battery; *H*, antenna "lead-in" wire; *J*, ground wire; *K*, wires leading to the transit micrometer of the observing telescope.

farad capacity, two 22½-volt B batteries, five 3-cell 4½-volt C batteries, one filament rheostat, potentiometer, shunt for galvanometer, switch points, and binding posts.

The schematic wiring diagram of the recorder is shown in Figure 11.

The physical wiring of the entire apparatus set up for work is shown in Figures 4 and 12.

The amplifier is connected to the recorder either by a direct wire from binding post 1, 2, or 3, depending on whether one, two, or three stages of amplification are desired, to post *A* on the recorder, or by an inductive coupling provided by a 1,000-turn duolateral wound coil laid over the coils of the recorder and with its ends connected to post 1, 2, or 3, and post *G* or −6 of the amplifier. (See fig. 12.) The inductive coupling has generally given good results in decreasing the effect of static or atmospheric electricity.

In radio set No. 1 Seibt condensers are used. They are especially well made, the plates being machined out of solid blocks of aluminum and so mounted that they preserve their shape and spacing. Satisfactory cheaper makes are used in the other sets, the former being no longer available.

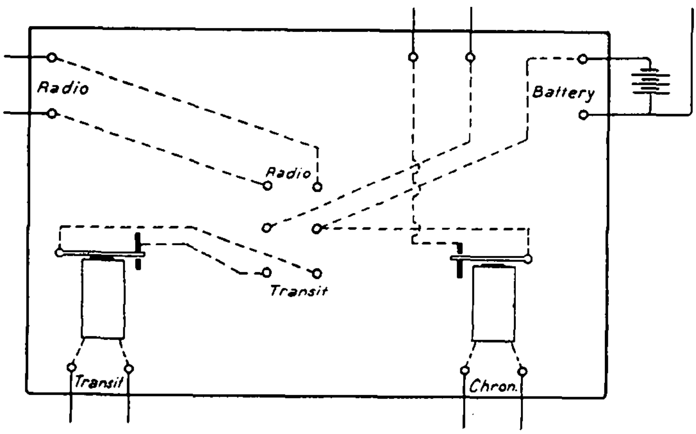


FIG. 5.—Wiring diagram of longitude switchboard

A double-pole, double-throw switch in the center of the board is used to switch in either the radio or the transit micrometer relay.

The tubes used on the amplifier are Western Electric No. 203–B, and on the recorder Western Electric No. 209–A (102 DW, and 102 D in later models); the filament rheostats are General Radio Co. No. 214A, 7-ohm; the potentiometers General Radio Co. No. 214A, 400-ohm.

The galvanometer is a Weston Instrument Co. student galvanometer, model 375. The pointer zero is at the center of the scale, and without shunt 0.6 milliampere will deflect the pointer the full 30 divisions to either side of the scale. A shunt of resistance wire wound on a sheet of mica and having about one-fifth of the resistance of the galvanometer is mounted across the terminals. Thirty divisions on the scale then correspond to approximately 3 milliamperes. A knowledge of the scale value of the galvanometer is not important, and if any occasion arises for replacing or repairing a shunt the replacement is satisfactory if the galvanometer pointer remains on the scale or gives sufficiently large deflections to judge the condition of operation of the set.

The transformers of the amplifier are Thordarson audio-frequency transformers. Radio-frequency transformers made by the Bureau of Standards, shown in Figure 13, and others made for the United States Navy have been successfully used.

Differences between sets 1, 2, and 3.—The schematic wiring diagram of amplifier No. 2 is practically the same as for No. 1, with the exception that two tuned circuits are used instead of one. The direct connection to the antenna in No. 1 permits louder signals to be heard in the telephones, while in the arrangement in No. 2 inductively coupled to the antenna circuit greater selectivity can be had, which also aids in reducing static.

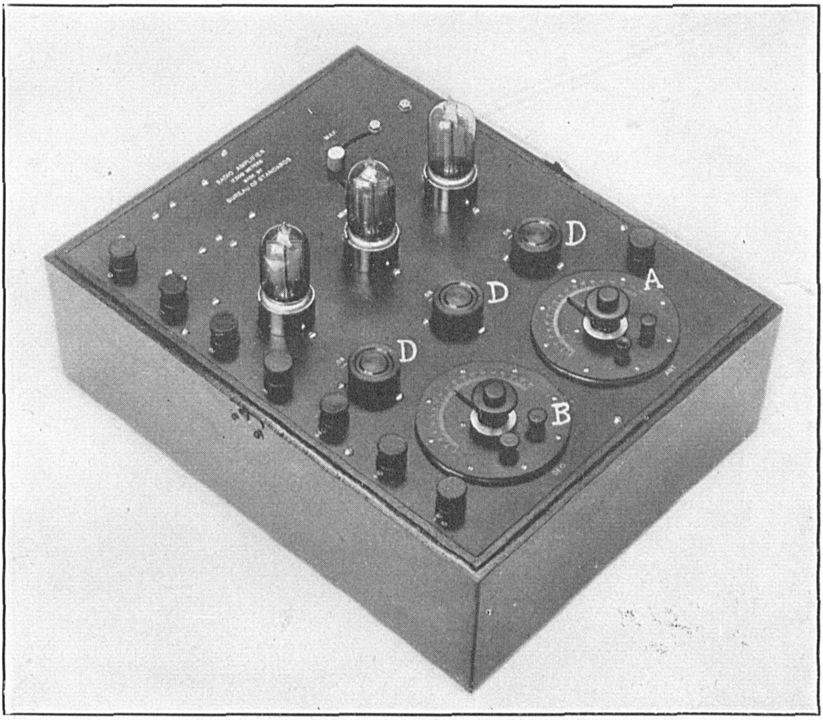


FIG. 6.—Radio amplifier No. 1, 17,000-meter wave length

A and *B* are variable air condensers; *D*, filament rheostat control knobs.

On No. 2 the coupling of the additional coil of 750 turns to the antenna circuit may be varied by moving one of the coils around an arc cut in the bakelite panel. Two thumb nuts are furnished for this purpose, one of which may be seen in the upper right-hand corner of Figure 6.

Different makes of variable air condensers are used in No. 2, but the capacities are the same as in No. 1.

The amplifier of set No. 3 is arranged for wave lengths from 6,000 to 24,000 meters. Figure 14 shows the arrangement of parts and Figure 15 the wiring diagram. The latter is practically the same as in amplifier No. 1, except that only one variable air condenser is used, and push switches are used to cut in or out fixed condensers in order to change the wave-length range of the set.

Radio recorder No. 2 (figs. 16 and 20) differs from No. 1 in that it has push switches instead of throw switches.

Radio recorder No. 3 (fig. 17) also has push switches for changing the wave-length range by cutting in or out of circuit fixed condensers as shown in Figure 18 and push switches for cutting out battery

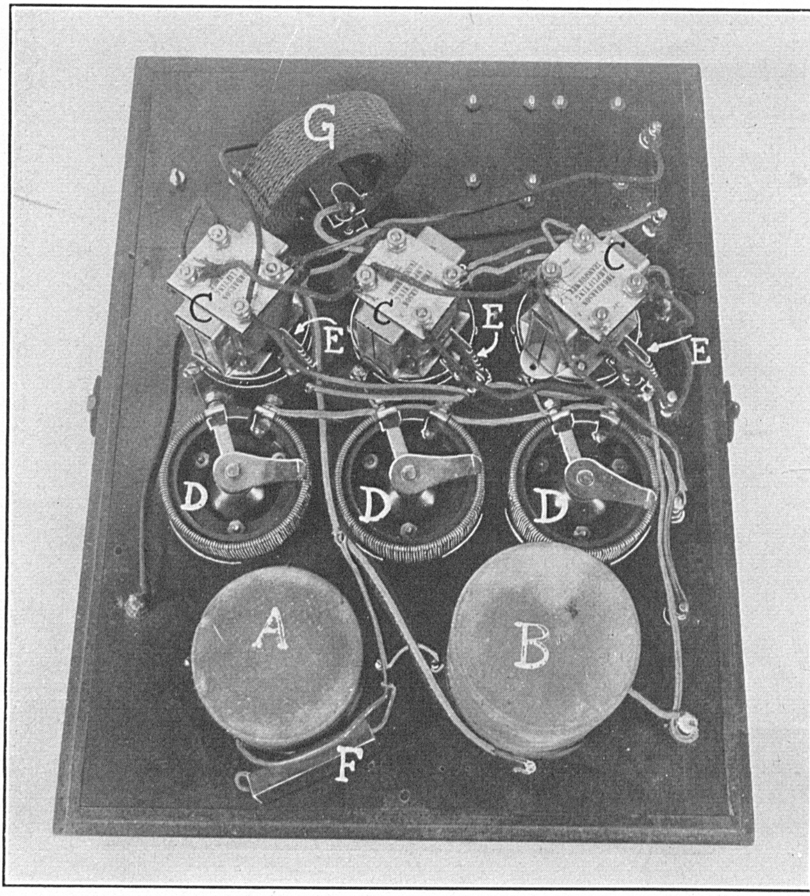


FIG. 7.—Back view of amplifier No. 1

A and *B*, variable air condensers; *C*, Thordarson audio frequency transformers; *D*, filament rheostats; *E*, resistances fixed in the filament circuits to prevent accidental burning-out; *F*, fixed condenser; *G*, inductance coil, 500 turns, duo-lateral winding.

circuits and the chronograph pen. The coupling coil which is laid over the recorders No. 1 and No. 2 is inclosed in this set. Three coils are shown in Figure 18 which may have their coupling varied by control knobs mounted on the top of the board. The C battery is carried in a section shown at the right in Figure 17, which may be removed as a unit in case new cells are to be inserted.

The telephones are connected by a plug instead of by binding posts for added convenience.

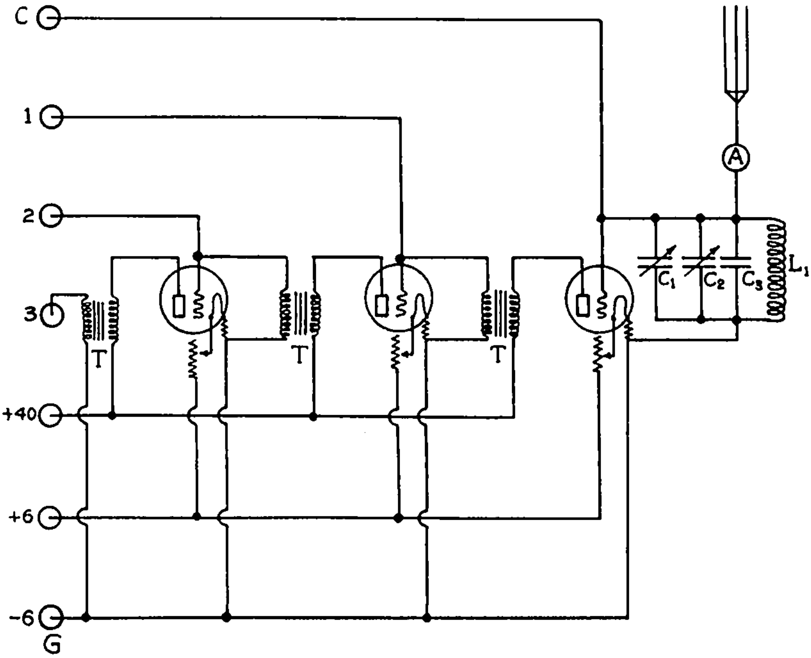


FIG. 8.—Schematic wiring diagram of amplifier No. 1

L_1, inductance, 500 turns, duo-lateral winding; C_1, variable capacity, 0.0006 mfd.; C_2, variable capacity, 0.002 mfd.; C_3, fixed capacity, 0.0025 mfd.; T, Thordarson audio-frequency transformers.

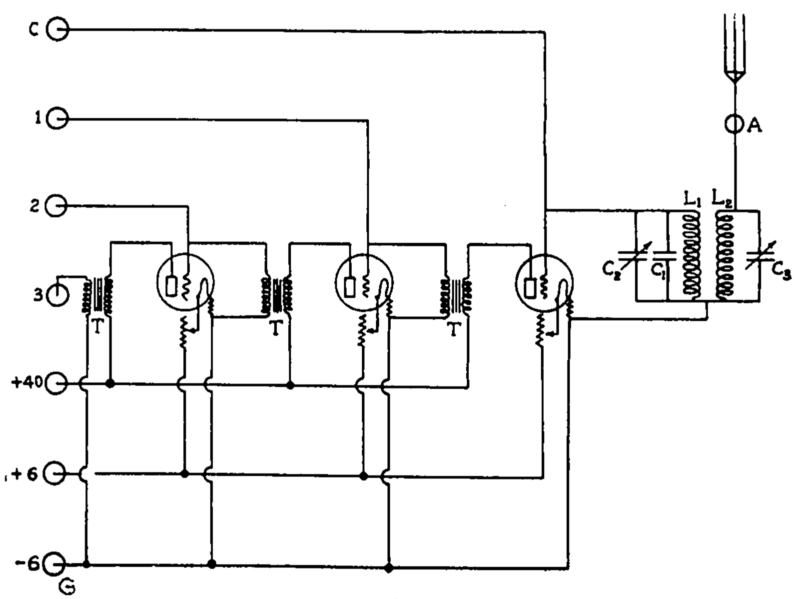


FIG. 8a.—Schematic wiring diagram of amplifier No. 2

L_1, inductance, 500 turns, duo-lateral winding; L_2, inductance, 750 turns, duo-lateral winding; C_1, fixed capacity, 0.003 mfd.; C_2 and C_3, variable capacities, each 0.002 mfd.; T, Thordarson audio-frequency transformers.

In recorders Nos. 2 and 3 a fixed condenser is shunted across the chronograph circuit, while in No. 1 this condenser (1-microfarad capacity) is connected across the chronograph terminals on the outside of the set. This condenser is not shown in the figures relating to set No. 1.

Antenna and poles.—Flat-top antennae are used, having four, five, or six wires 120 feet long and spaced from 18 to 24 inches apart by spreaders. The ends of the wires and spreaders are equipped with galvanized-iron snap hooks and eyes to facilitate mounting. The wires are stranded, phosphor-bronze No. 22 B. & S. insulated;

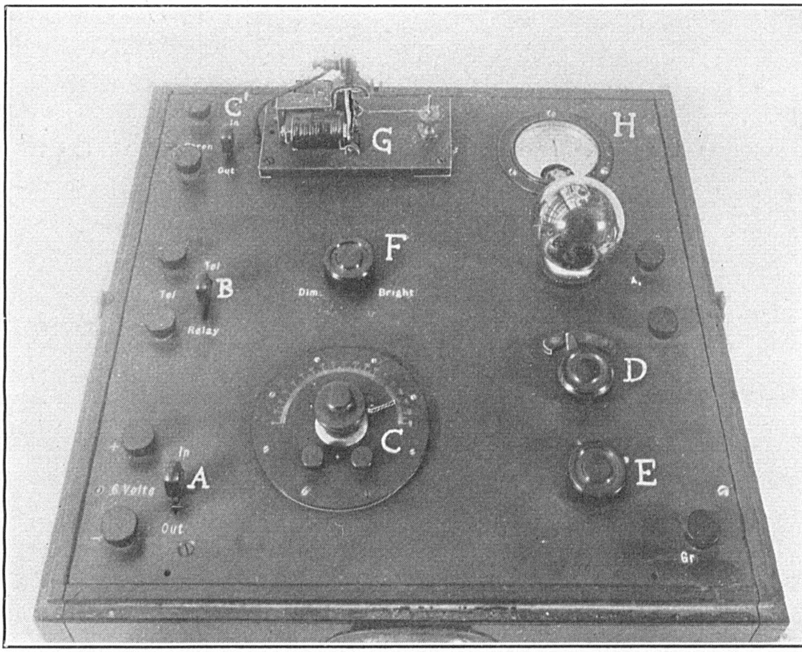


FIG. 9.—Radio recorder No. 1, 17,000-meter wave length

A, switch which cuts the storage battery in the filament circuits, and the grid, or "C," battery in the grid circuit of the tube; *B*, switch which cuts in the telephone or the relay as indicated; *C'* switch which cuts in the circuit to the chronograph through the longitude switchboard; *C*, variable condenser used to tune circuits; *D*, dial switch which varies the number of "C" batteries in the grid circuit; *E*, potentiometer control knob which is operated in connection with *D*; *F*, filament rheostat control; *G*, high resistance radio relay operating the circuit to the chronograph; *H*, student galvanometer used to assist in determining the desired brightness of the tube filament and to indicate satisfactory current through the radio relay. The extra binding posts on the variable condenser *C* permit the addition of condensers to change the wave length of the set within certain limits.

the "lead-in" is of the same wire with heavier insulation. Composition insulators 6 inches long and about one-half inch in cross section are used to insulate the antenna wires from the spreaders and the guy lines from the poles.

The lead-in wire is brought to the middle point of a lightning switch mounted on one of the antenna poles. The antenna is then connected to the amplifier by throwing the switch arm up and to the ground by throwing it down.

Hollow sectional poles, each section 8½ feet long, wrapped in several places with wire, and carrying iron tubing on one end and sockets on the other for joining together, have been used for antenna poles where travel was performed by truck.

For a 42-foot height three large and two small sections have been used, guyed by two sets of three guy wires and erected with the aid of a 25-foot gin pole. These poles, while light, are not durable

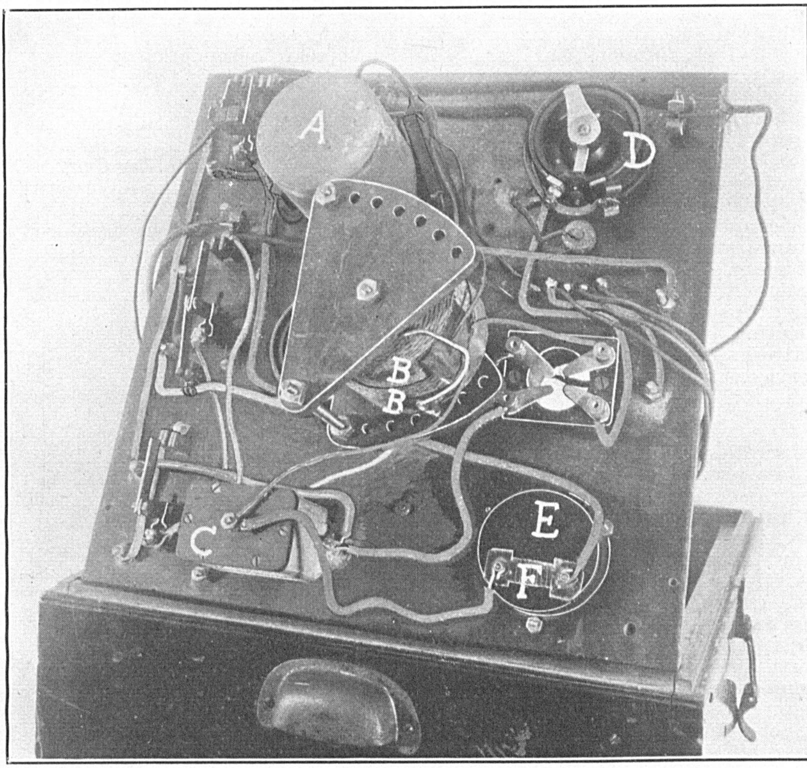


FIG. 10.—Back view of radio recorder No. 1

A, variable air condenser; *B*, inductance coils, 1,000 turns, duo-lateral winding; *C*, by-pass condenser; *D*, potentiometer; *E*, student galvanometer or indicator; *F*, shunt.

and cost about $10 a section. In Alaska or where parties may travel by boat single spruce poles are to be preferred, as they are strong, straight, and light, and may be cut locally. The gin poles used may be two sections of current pole joined together by a brass tubing 2 feet long.

OUTFIT FOR RADIO LONGITUDE WORK

LIST OF INSTRUMENTS

Ammeter, pocket	1
Amplifier, radio	1
Batteries, storage, 6-volt	2
Batteries, B, 22½-volt	4
Batteries, grid C—3-cell flashlight, 4½-volt	12
Cases, leather, chronometer	2
Chronograph, with differentially wound pen magnet	1
Chronometer, sidereal, 2-second break-circuit	1
Chronometer, sidereal, hack, break-circuit preferred	1
Coil, 1,000-turn, with 3-foot leads for coupling	1
Compass, azimuth, prismatic	1
Condenser, chronometer	1
Condenser, 0.001 mfd. capacity as shunt for phones	1
Generator, or motor-generator, if batteries can not be charged at service station	1
Headset, radio	1
Hydrometer	1
Lamps, hand electric	2
Micrometer for transit	1
Pens, fountain, for chronograph	2
Recorder, radio	1
Scale, glass, chronograph-reading	1
Switch, lightning	1
Switchboard, longitude	1
Tape, steel, 100-foot	1
Theodolite, 4-inch	1
Transit, astronomical, Bamberg	1
Tubes, vacuum, radio—Western Electric No. 203 B	9
Tubes, vacuum, radio—Western Electric No. 209 A	3
Typewriter, folding	1
Voltmeter, 0 to 150 volts, Weston Instrument Co	1

LIST OF EQUIPMENT

Bits, screwdriver	2
Box, battery, for illumination of instrument	1
Box, for chronometers—felt-lined	1
Brace, carpenter's	1
Chairs, folding camp	2
Cots, folding	2
Desk, Army field	1
Drum for antenna and guy lines	1
Flies, tent	2
Ground, iron pipe	1
Hammer, claw	1
Hammer, sledge	1
Hatchet	1
Heater, oil	1
Insulator, lead-in	1
Lantern, gasoline, Coleman Quick-lite	1
Lantern, common, oil	1
Mercury, small bottle	1
Plaster of Paris, pounds	5
Pliers, combination	2
Poles, gin, set	1
Poles, antenna, set	1
Poles, tent, sets	2
Reel, for gin pole	1
Screwdrivers	2
Stove, oil, cook	1
Table, folding camp	1
Tarps, bed	2
Tents, observing and living	2
Torch, gasoline, with soldering iron and solder	1
Tripod, aluminum, complete for mounting Bamberg transit	1
Wire, miscellaneous, for connections.	

MISCELLANEOUS

American Ephemeris and Nautical Almanac.
Baggage.
Bedding.
Chronograph sheets.
Logarithmic tables, Vega.
Mess gear.
Rations.
Record books.
Special Publication No. 14.
Stationery.

SELECTING SITE AND SETTING UP ANTENNA

In selecting a location for a station space must be secured that will permit a clear distance of 200 feet for the antenna and guy lines to be set up in the direction of the sending station, with a space large enough and flat enough for setting up the observatory and having a clear vista to the north and south for observing stars whose altitudes are from 45° to 90°.

The wooden observatory or observing tent is set up close to the foot of the antenna pole which is nearest the radio time-signal sending station in order to make the lead-in wire short.

The gin pole is set up easily by two men and guyed with three ropes, the stakes for the gin pole being later used for the middle guys of the antenna poles. The antenna pole sections are joined, laid out from the foot of the gin pole, with the guy lines and pulleys attached, and a bridle rope made fast to the hauling line led through a pulley at the top of the gin pole and down to a reel at the foot. With the foot tied to two stakes to prevent slipping the antenna

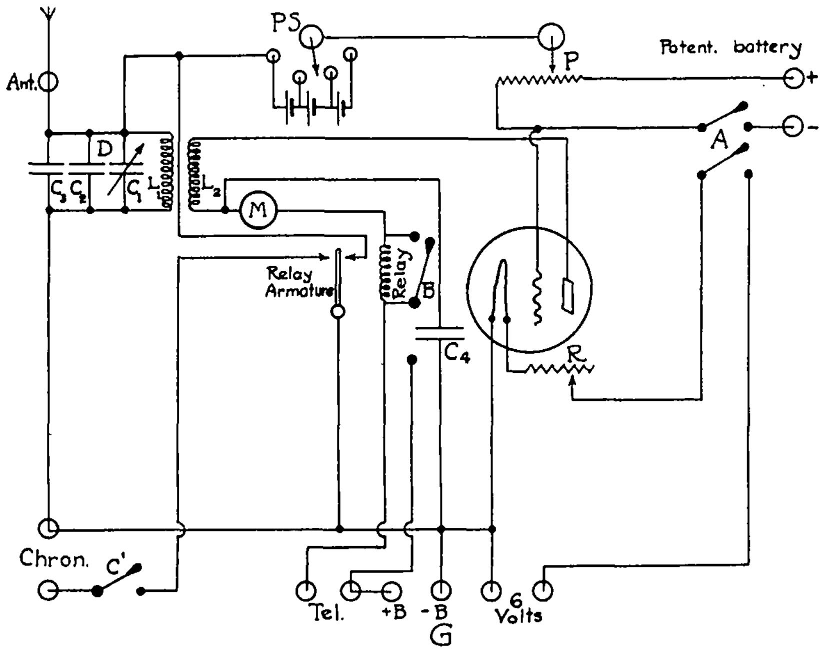


FIG. 11.—Schematic wiring diagram of radio recorder No. 1

A, double switch for storage and "C" batteries; *B*, telephone-relay switch; *C'*, chronograph switch; C_1, variable capacity; C_2 and C_3, fixed capacities in parallel with the variable; C_4, by-pass condenser around meter, relay, and "B" battery; *D*, tuning circuit of recorder; L_1, inductance, 1,000 turns; L_2, inductance, 1,000 turns, in the plate circuit; *P*, potentiometer; *PS*, potentiometer switch; *R*, filament rheostat.

In this set a fixed condenser is shunted across the chronograph terminals to prevent sparking at the relay points. It is not shown in the figure as it is not an integral part of the set.

pole is erected by one man winding the reel and another pushing with a pry pole.

The proper spacing of the poles is obtained by measurement or by stretching out the antenna on the ground. In order to take advantage of the full height of the poles the spreader bridles are made short and hauled up close to the tops of the poles. Lines are snapped on the ends of the spreaders to prevent the antenna from overturning.

If a counterpoise is used instead of a ground in dry country it is spread out beneath the antenna, on poles laid across stakes, and stretched. The ordinary ground is generally an iron pipe driven 2 or 3 feet into the ground or a metal surface, preferably copper

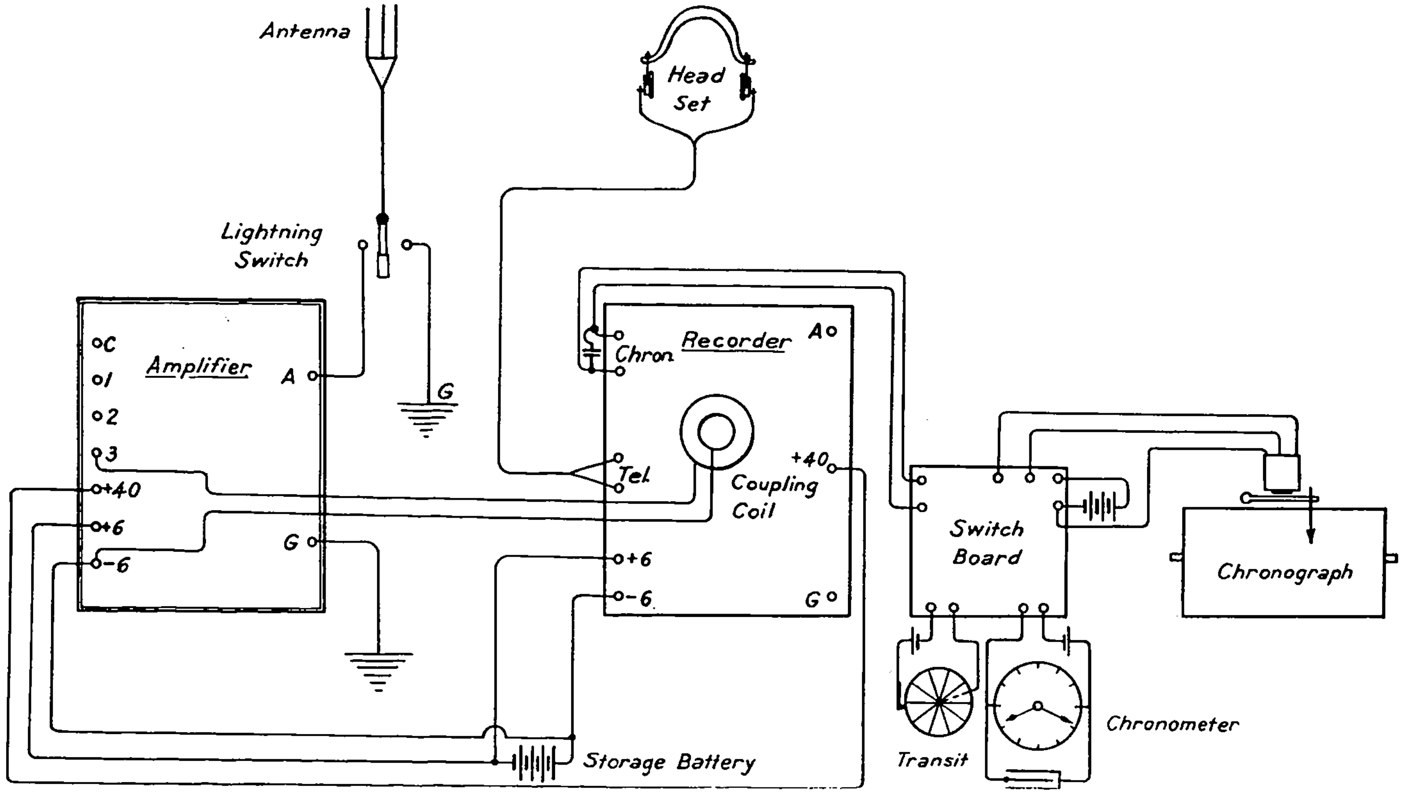


FIG. 12.—Wiring diagram of hook-up for longitude work

In set No. 1 a condenser is shunted across the chronograph terminals on the recorder and in the other sets the condenser is an integral part of the recorder.

buried in the ground or immersed in water and connected by a wire to the ground post of the radio recorder and by another wire to the lightning switch of the antenna pole.

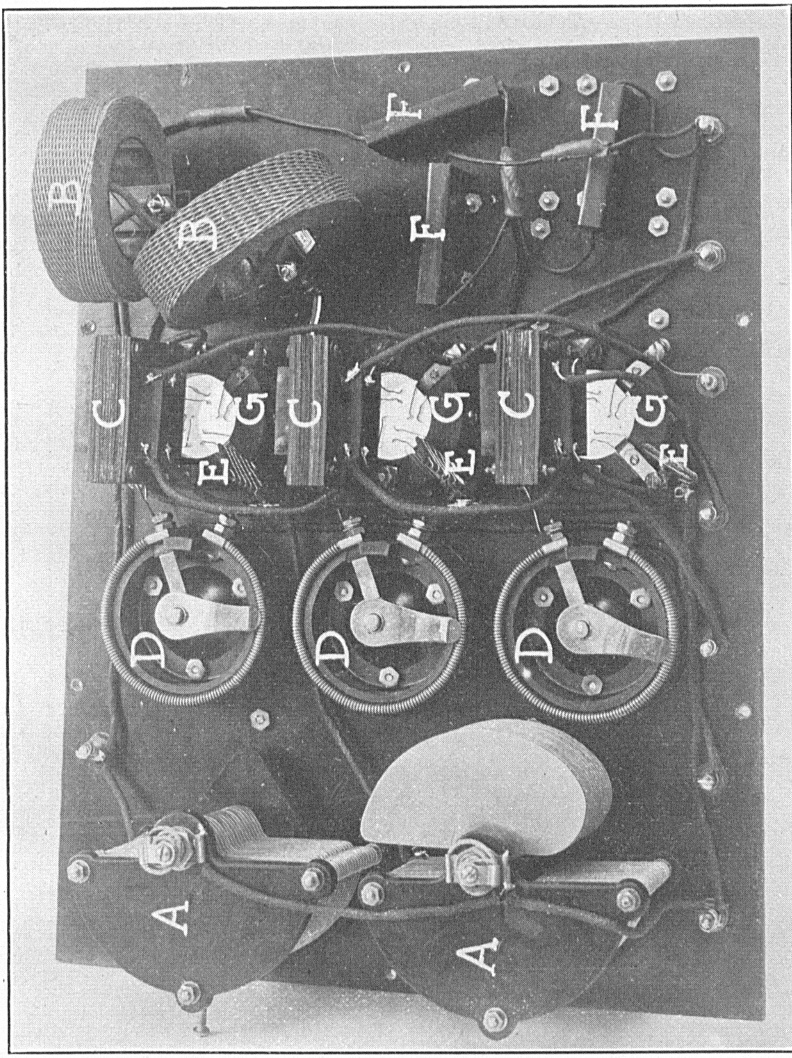


Fig. 13.—Back view of amplifier No. 2

A, variable air condensers in primary and secondary circuits; *B*, coupling coils, 750 and 500 turns, duo-lateral winding; *C*, Bureau of Standards radio-frequency transformers; D, filament rheostats; *E*, resistances fixed in filament circuits; *F*, fixed condensers in secondary tuned circuit; *G*, bases of tube sockets showing spring connections. Thordarson audio-frequency transformers have recently been subtituted for the radio-frequency transformers in this set.

OBSERVATORIES

An observing tent for astronomical work is convenient when traveling by truck and is quickly and easily set up. It has the disadvantage, however, that it might be blown over in a storm with probable damage to the delicate equipment. A wooden observatory is to be preferred in Alaska where stations have to be set up on exposed rocky points and where the average rainy conditions keep a party at a station for several weeks at a time.

Figure 20 shows the design of a suitable observing tent and the specifications for it are given below.

SPECIFICATIONS FOR LONGITUDE AND LATITUDE TENTS

General description.—Tent shall be ridgepole type, 11 feet 3 inches by 11 feet 3 inches, with side walls 3 feet 7 inches high and with ridge 9 feet above the bottom. Door opening in front end to extend to within 1 foot of the ridge, and special opening in the roof to reach to within 2 feet of the eaves on either side.

Material.—Tent of 12-ounce white duck, United States Army standard, mildew proof and free from flaws and imperfections. Bidders must submit with proposals samples of the material to be used, including samples of ropes and ties; different grades may be bid on with the price of each.

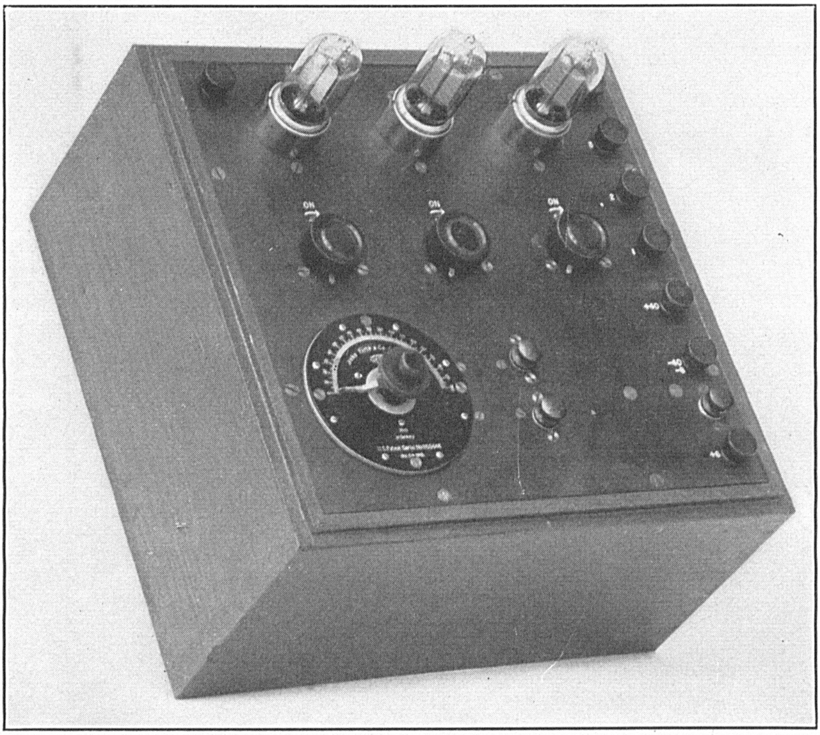


FIG. 14.—Radio amplifier No. 3, 6,000 to 24,000 meter wave length

This instrument is designed for a triple wave-length range. The low range is obtained by using the variable capacity alone and the high range by switching two fixed condensers in parallel with the variable. Intermediate values can be obtained by using either one of the fixed condensers with the variable.

Reinforcing.—Along the ridge, except at the roof opening of the tent, there shall be an inside reinforcing strip of the same material as the tent, extending 4 inches each side of the ridge; also at the four corners of the eaves, patches extending 6 inches each way from the corners; and in the rear wall 5 feet above the bottom and 3 feet from the center line another patch 1 foot square. (This last patch is to stiffen the tent and permit the attachment of an insulator for the "lead-in" wire of an antenna.)

Grommets.—The grommets shall be malleable-iron rings of suitable size, galvanized, and shall be worked in all holes and strongly sewed. There shall be two in the ridge at the ends for the spikes of tent poles, and the others as indicated in these specifications.

Door.—There shall be one door, in the end nearest the top opening of the tent; it shall have a double-guard flap, of same material as the tent, full length of the door, 8 inches wide in the clear, fastened both inside and out by four pairs of ties suitably placed. In between the guard flaps there shall be placed three ties of the best quality soft cotton cord, size three-sixteenths inch, to fasten to a like number of similar ties on the edge of the opposite side of the door.

Opening in roof.—There shall be an opening in the roof 16 inches wide, parallel to the inclined edges of the tent and extending to within 2 feet of the eaves on either side. The nearest edge of the opening shall be 3 feet from the front end (door end) of the tent. The edges of the opening shall be held together by seven ties of best quality soft cotton cord, size three-sixteenths inch, suitably spaced, strongly sewed to the tabling on one side of the opening, tied into an equal number of grommets, suitably spaced, on the opposite side of the opening. There shall be a double-guard flap on each side of the roof of 10-ounce duck, extending to the eaves (the upper end of one outside flap long enough to lap 1 foot over the ridgepole), and made the full width of the material (28½ inches) fastened

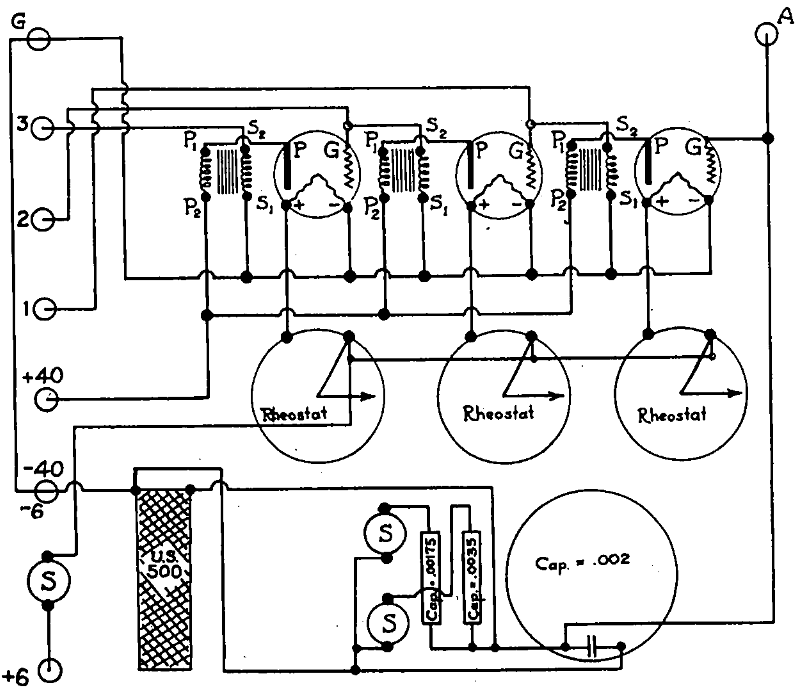


FIG. 15.—Wiring diagram of amplifier No. 3

on the inside by a suitable number of ties, and on the outside by five ties of three-sixteenths inch best quality soft cotton cord strongly sewed to the outer guard flap. The two lower ties, 12 inches long, shall tie to similar ties sewed and suitably spaced on the tent, the three upper ones, 10, 9, and 8 feet in length, shall be arranged to pass through rings strongly sewed to the tent and lead down to be tied to a larger ring strongly sewed to the forward inside corner of the tent. Two extra ties about 8 feet long shall be attached to the two corners of the overlapping piece of the guard flap. The guard flaps shall be sewed along one edge to the tent roof.

Sod cloth.—The sod cloth shall be 12 inches wide in the clear and extend from the door around on both sides and ends of the tent. It shall be cut at the corners. The material shall be 12-ounce Army duck.

Tabling.—When finished the tabling shall be 2½ inches in width at the foot, 1½ inches in width on the edge of the door, 1½ inches in width on the edge of the opening in the roof, and 1½ inches in width on the edge of the outer guard flap covering the opening in the roof.

Wall lines.—The wall lines are to be 18 inches long, of cotton tape, 1 inch broad, one pair placed on each seam for tying up the wall.

Guy or eave lines.—The eave lines are to be 10 in number, 5 on each side, of best quality manila line, five-sixteenths inch in size, each 10 feet long in the clear, with an eye 4 inches long spliced in one end and the other passed through a grommet in the eaves and fastened by a metallic slip of Army pattern.

Foot stops.—Foot stops shall be placed at each seam, and two at the foot of the door opening, and shall be loops 4 inches in the clear, of good manila line, five-sixteenths inch in size, both ends passing through a single grommet worked in the tabling at the seams, and held by a "Mathew Walker" knot.

Stitching.—All seams shall be double sewed with lock stitch, with an overlap of ½ inch.

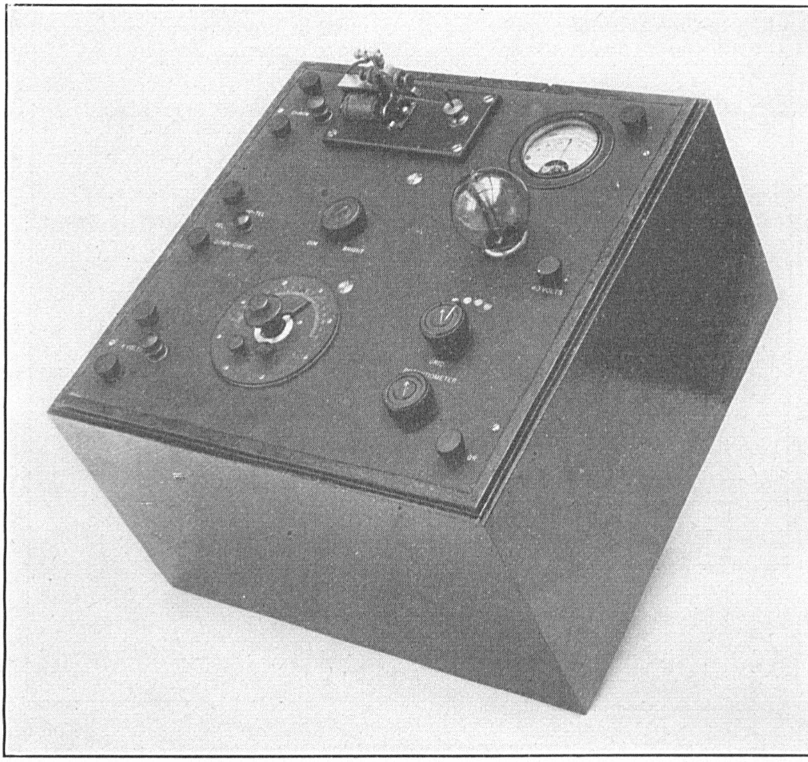


FIG. 16.—Radio recorder No. 2, 17,000-meter wave length

WOODEN OBSERVATORIES

A wooden observatory should be at least 9 feet square and if gravity work is to be done in connection with the astronomical work it should be 10 feet square. The wall on the north side should be 7½ feet high above the floor and the wall on the south side 6 feet high. There should be a door in the roof 12 inches wide directly over the observing transit and extending the full length of the roof in a north-and-south direction.

A tar-paper roof covering should be provided and an overlap left on the roof door to keep water from dripping through to the instrument. Cloth covers should be provided for the instruments when not in use, and in a wet country an oil or other heater should be used to dry out occasionally.

A portable aluminum pier, or a wooden pier made up of four 6 by 8 inch timbers well braced and capped, set firmly in the ground or on the rocks, is a suitable support for the observing transit. The floor should clear the pier by at least 1 inch on all sides and should allow no pressure to be transferred to the pier itself.

A shelf 2 feet wide should extend the full width of the building and be 3 or 4 feet above the floor. This shelf will carry the radio recorder, amplifier, switchboard, chronograph, and miscellaneous

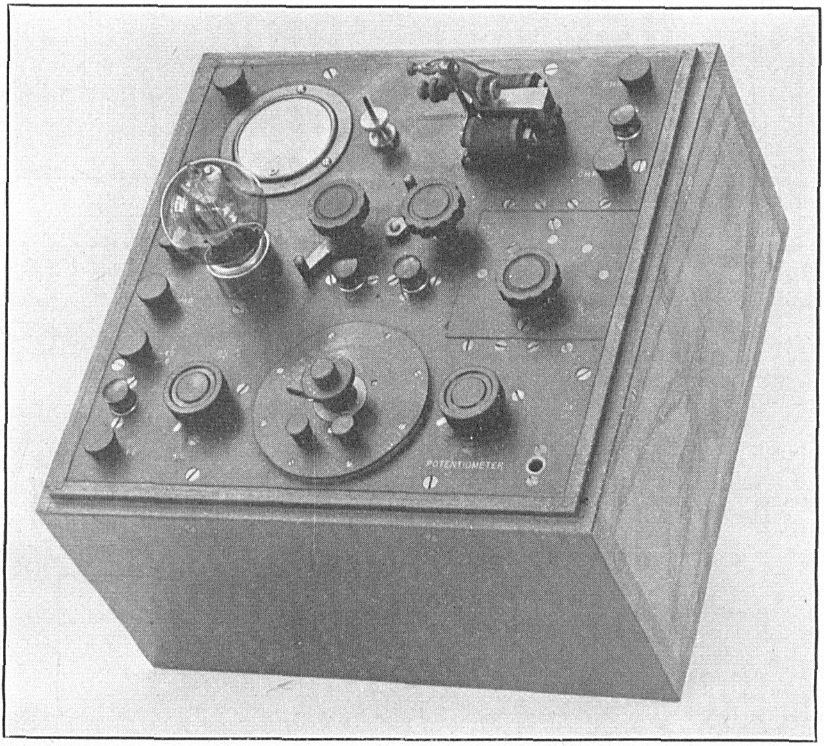


FIG. 17.—Radio recorder No. 3, 6,000 to 24,000 meter wave length

This has fixed capacity condenser cut-outs as in the amplifier, and control knobs for varying the coupling of the coils. The inductance coil for coupling to the amplifier is inclosed in the box and is operated by one of the control knobs shown to the right of the tube.

tools. Under it will be storage battery, chronometers in chronometer box, batteries for the relay circuits, chronograph weights, and extra equipment. An extra shelf or two in the other corners of the observatory will be convenient for chronograph paper, books, extra radio tubes, etc. Two seats for observing with the Bamberg transit should be made of convenient height for the observer.

SELECTION OF STARS

The present method of selecting stars differs somewhat from that described in Special Publication No. 35. All stars are taken from the American Ephemeris, and while it is slightly more accurate to use

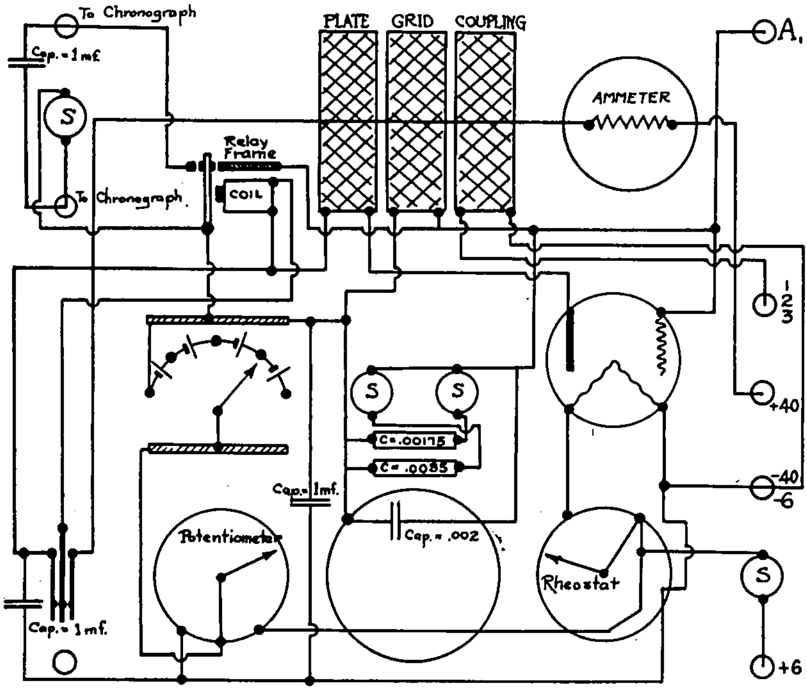


FIG. 18.—Wiring diagram of radio recorder No. 3

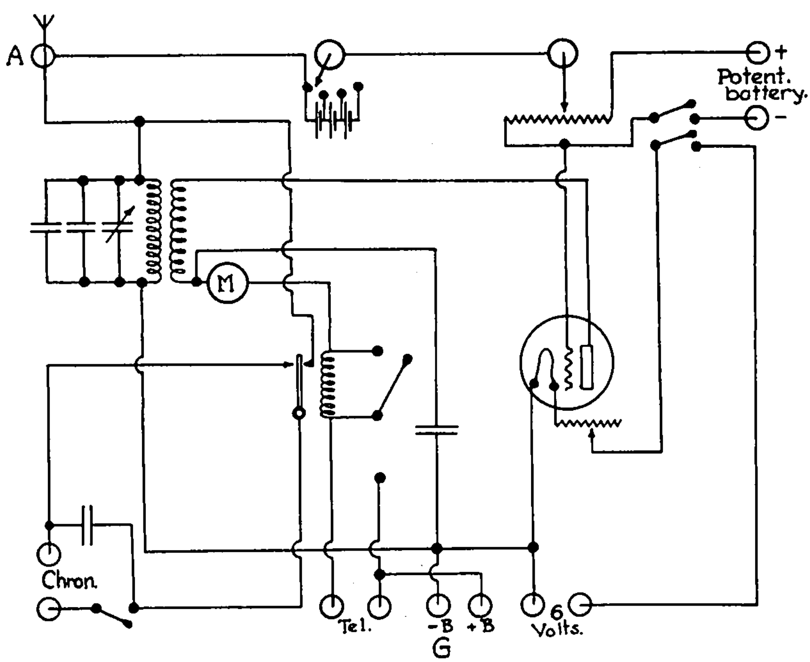


FIG. 19.—Wiring diagram of radio recorder No. 2

This is practically the same as Figure 11.

only close-zenith stars, no great delay should be made if stars are available whose azimuth factors are less than unity.

For the years 1923 and 1924 corrections to the American Ephemeris star places are applied by the Naval Observatory. Beginning with the 1925 volume these corrections are listed in the Ephemeris on pages 750–764.

In selecting stars determine the local sidereal time at the station when the radio time signals will begin to arrive, allow a few minutes for adjusting the radio set, then select from the list seven or eight stars which will transit across the meridian just prior to this time and an equal number which will transit later. It is well to allow at least four minutes between stars, so that the observer will not be rushed in setting the instrument, observing before and after reversal, and in reading the levels.

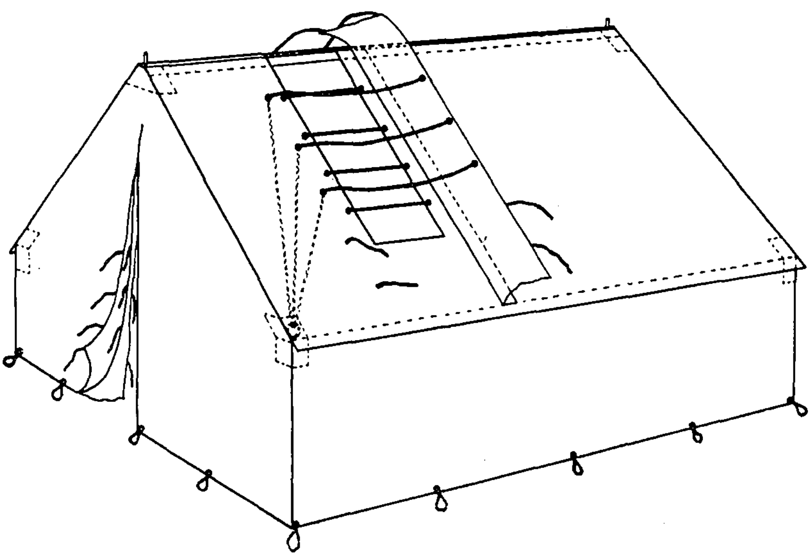


FIG. 20.—Observing tent opened for star observations

GENERAL INSTRUCTIONS FOR WIRELESS LONGITUDE DETERMINATIONS WITH TRANSIT MICROMETERS IN LOW LATITUDES

1. The observations upon each star should be given unit weight regardless of the declination of the star and of whether or not the observation of the transit is complete. Ten equally spaced record marks, corresponding to one complete revolution of the micrometer contact wheel before reversal of the instrument and 10 symmetrical marks after, constitute a complete observation. (For identification of the zero mark there are two extra marks one on each side of the zero mark.)

2. The limit of rejection for an observation upon one star (whether the observed transit is complete or not) is a residual of 0.20 second. No observation corresponding to a residual smaller than this should be rejected unless rejection is made at the time of observation.

3. Each set of time observations, of which there shall be two, should consist of observations on from five to seven stars (six preferred). In rare cases a set may consist of only four stars. All of these are to be time stars; no azimuth stars are to be observed. For the purpose of this paragraph an azimuth star is defined as one for which the azimuth factor, A, is greater than unity. The algebraic sum of the A factors in each set should be kept less than unity unless

it is found that to secure such a set considerable delay would be necessary. It is desirable to have the algebraic sum of the *A* factors as small for each set as it is possible to make it by the use of good judgment in selecting the stars, but it is not desirable to reduce the number of stars per hour to be observed in order to improve the balancing of the *A* factors if said balancing is already within the specified limit.

4. In selecting lists of stars to be observed, one should endeavor to secure the maximum number of stars per hour possible, subject to the conditions of paragraph 3 and to the necessity of securing level readings, reversing the instrument, receiving radio time signals, etc.

5. The position of the ocular of the transit (east or west) shall alternate for the beginning of observations on each successive star.

6. The observations on each night should consist, under normal conditions, of two such sets as are defined in paragraph 3. In case of interference with the normal progress of the observations by clouds or other causes, a determination on a given night may be allowed to depend upon two sets of four stars each provided the radio time signals are received some time after star observations have begun and before they end.

7. A determination of a difference of longitude will consist of either three or four such nights of observation as are specified in paragraph 6. If, before an opportunity occurs to take observations upon a fourth night, it becomes known that the result from each of the first three nights of observations will probably agree with the mean result within 0.07 second, no observations on a fourth night should be taken. If one or more of the first three nights give results which are suspected of being considerably in error, or if observations are secured on a fourth night before the results of the first three nights are all known, then observations on four nights are to constitute a complete determination of a difference of longitude. As the exact time of the signals sent from the U. S. Naval Observatory or other source can not be ascertained until their clock corrections are computed it is necessary to assume that these signals may be in error from 0.01 to 0.05 second.[4] After having determined the accuracy of his results at one station the observer will be able to estimate the accuracy at later ones. It is a rare occurrence to have a night's observations rejected on account of inaccurate observing.

8. When referring a longitude station to a triangulation station the angle and distance measurements should be made with check and with such accuracy that if necessary the longitude station may replace the triangulation station for future surveys.

9. The field computations are to be kept as closely up to date as practicable.

10. In making the computations of time in the field, the method shown on pages 34 to 37 of this publication should be followed.

11. If possible the radio time signals used should be those sent out from the United States Naval Observatory via the Annapolis, Md., or Arlington, Va., radio stations. If it is desired to use time signals from other observatories when the observer is remote from the above stations, investigation should be made to determine the reliability and accuracy of the signals and, if satisfactory, permission secured from the Director for their use.

12. In scaling the chronograph sheets about 40 second-marks of the radio time signals, preferably successive ones, should be measured to the nearest hundredth of a second, rejecting any whose residual is 0.05 second or more from the mean.

For instructions for work in high latitudes the reader is referred to Special Publication No. 14.

U. S. NAVAL OBSERVATORY TIME SERVICE

The radio time signals are sent daily from the time service room at the United States Naval Observatory in Washington at noon and 10 p. m., seventy-fifth meridian standard time.

Just prior to the transmission period the Riefler clock which sends out the signals is compared on a chronograph with one of the three master Riefler clocks in the vault of the observatory. The trans-

[4] On rare occasions the mechanical lag of the time signal from the U. S. Naval Observatory to Annapolis radio station has amounted to 0.16 sec. instead of the practically constant value of 0.08 sec.

mitting clock is then corrected by means of an electro-magnet which acts on the pendulum bob of the clock to speed it up or retard it as necessary. Comparison of the transmitting clock with a master clock is again made while the signals are being sent. Ten sets of marks are scaled on the chronograph sheet and the exact local sidereal time of the final signal deduced from the results. This value together with the correction to be applied to reduce the final signal to the exact time of noon or 10 p. m. is given in a monthly list furnished by the observatory. The correction seldom exceeds 0.05 second and the change from one day to another is small.

In determining the exact time of the signals the times from the three master Riefler clocks are corrected for rates and for the results of star observations on about six time stars made every other night, weather permitting.

The time signals are sent from the transmitting clock through a local circuit operating relays which control lines to the Western Union Telegraph Co., the Bureau of Standards, the Annapolis and Arlington radio stations, and several other places. At the Annapolis and Arlington radio stations the signals are received over land telegraph lines and transmitted automatically to the antennæ through gangs of 50 to 60 relays.

The mechanical action of the relay armatures in the circuits to the Annapolis and Arlington antennæ causes lags in the time signal. These lags are computed at the Naval Observatory from the data obtained by scaling the chronograph sheets on which are recorded the ticks of the transmitting clock and a hack chronometer, and the hack chronometer and the returning radio time signals.

This lag value has been found to be 0.08 second for Annapolis and 0.09 second for Arlington, and generally shows no fluctuation amounting to over 0.005 second. However, cases have happened where the lag value has amounted to 0.16 second. In these cases the Naval Observatory has listed the corrections for the particular dates to which they apply. Any error of the mean value of the time determined at the Naval Observatory or any fluctuation in the mechanical lag of the Annapolis and Arlington circuits will cause error in the determination of the field longitudes.

The wiring diagrams in Figures 21, 22, and 23 show the circuits concerned with the transmission of the time signals.

MEASUREMENT OF LAG OF TIME SIGNALS

In addition to the mechanical lag of the time signal in circuits from the United States Naval Observatory to the Annapolis antenna there is the lag in the local circuits of the Coast and Geodetic Survey field apparatus, which affects the time determinations. While it might be possible to measure with an oscillograph the lags of all parts of the circuits a simpler method has been used to determine the "over-all" lag of the entire time-signal circuit.

This method consists in setting up the field astronomical and radio equipment in one of the longitude houses on the United States Naval Observatory grounds and making the necessary observations for a determination of longitude by using the Annapolis radio time signals. The value thus determined is compared with the value obtained by direct linear measurement between the clock house and the observing pier. The difference obtained is the "over-all" lag.

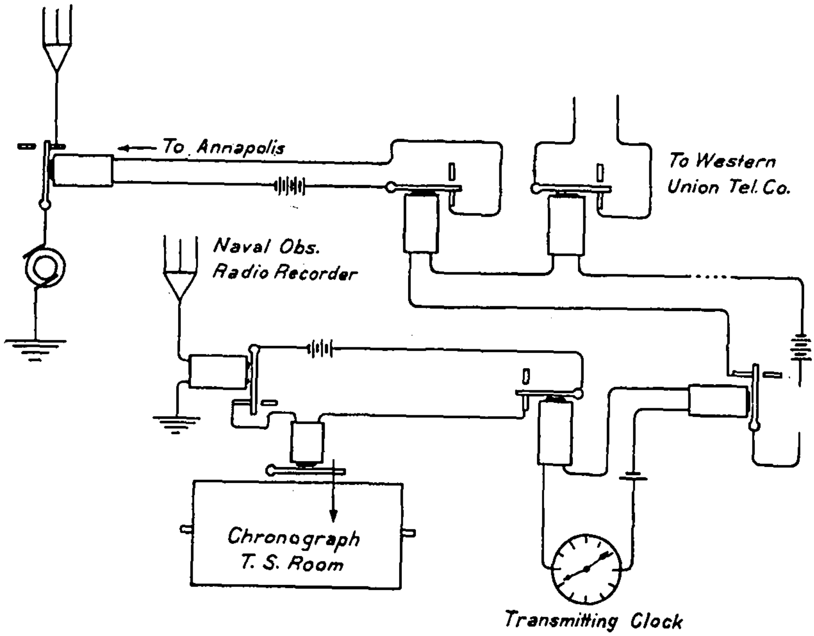


FIG. 21.—Wiring diagram of circuits when radio time signals are being sent from United States Naval Observatory to Annapolis, Md.

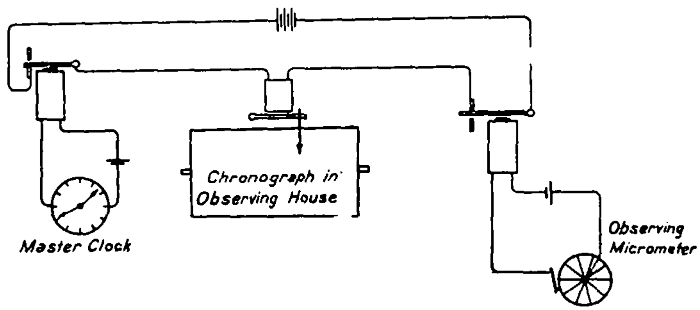


FIG. 22.—Wiring diagram showing circuits of master clock and observing micrometer at United States Naval Observatory

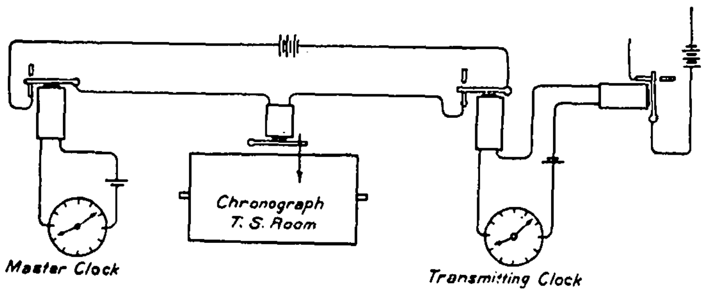


FIG. 23.—Wiring diagram showing circuits for comparing master and transmitting clocks at United States Naval Observatory

Ten nights' observations in 1922 gave a value of this lag as 0.025 ±0.006 second and five nights in 1923 gave 0.044±0.009 second, so that a mean for the two seasons was taken as 0.033±0.010 second.

The apparent inconsistency of the above value compared with the mechanical lag value of 0.08 second for a part of the circuit (Naval Observatory to Annapolis antenna) may be partly or wholly explained by the fact that the "over-all" lag is the difference between the mechanical lag of 0.08 second and the local lag on star observations at the field station. This latter consists of the personal equation of the observer or the interval from the time a star is actually on his meridian until his brain and hands have functioned to turn the

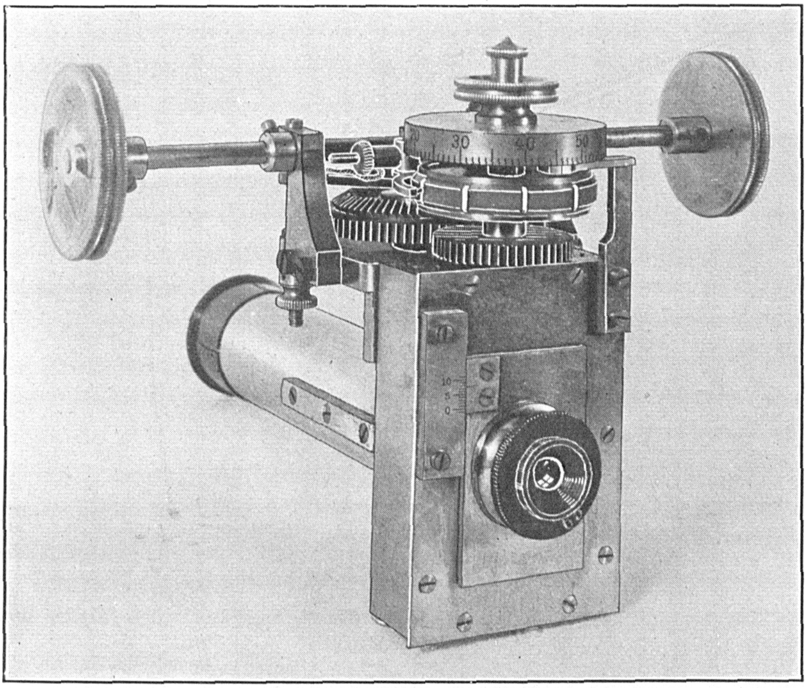


Fig. 24.—Transit micrometer of the Bamberg transit

micrometer wheels which give the record of this fact, and the mechanical lag in the circuit from the time the contacts are made on the micrometer head until the chronograph pen begins to move.

The personal equation with the transit micrometer may be any value from 0 to 0.02 second. No attempt is made to measure it in present Coast and Geodetic Survey practice. At the Naval Observatory it has been measured (but is not now applied) by using a personal equation machine in which the known rate of motion of a fictitious star across a field is compared with the value obtained by following it with a transit micrometer.

The "over-all" lag should be constant for the same observer provided the tension on the transit-relay armature spring, the pen-magnet armature spring, the radio-relay armature spring,

the mechanical lag of the Naval Observatory-Annapolis circuit, and the electrical current[5] values used remain constant.

Changes from time to time in the lag of the local circuit of the field chronometer and relay will have no effect, as the time to which both the star observations and radio time signals are referred is the instant that the recording pen begins to move on the chronograph sheet under the impulse of the chronometer second tick.

While the personal equations of different observers should differ by only a very small amount it is advisable that the "over-all" lag be measured by each new observer either before or after a season's work.

The Naval Observatory clock corrections are furnished monthly as follows:

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., April 13, 1923.

Time signals, March, 1923

	Signals ending at 5^h 0^m G. M. T.		Signals ending at 15^h 0^m G. M. T.	
	Washington sidereal time of last signal break (see note)	Mean time correction	Washington sidereal time of last signal break (see note)	Mean time correction
	h. m. s.	*s.*	*h. m. s.*	*s.*
Mar. 1....	22 25 37.538	−0.04	8 27 16.099	−0.05
2....	29 34.144	.00	31 12.723	+.01
3....	33 30.678	−.01	35 9.251	−.01
4....	37 27.231	−.01	39 5.813	.00
5....	41 23.818	+.03	43 2.382	+.02

+ = late. Lag of Arlington 0.09 sec.
− = early. Lag of Annapolis 0.08 sec.

Note.—The signal heard is caused by "break" in electrical circuit.

The time of the last signal break is not determined by measurement of the last break alone, but by 10 breaks throughout the signal, the results being reduced to the time of the last break.

The Washington sidereal time given above is the time of the middle of the clock house at the Naval Observatory. The longitude of this meridian is given in the American Ephemeris as 5^h 8^m $15^s.78$, while the value of the same derived from the Washington-Paris longitude determination in the years 1913–14 is 5^h 8^m $15^s.721$. The latter value is probably the more correct. However, in computing the mean time corrections given herewith, the value of the longitude given in the American Ephemeris was used, for the sake of uniformity.

PREPARATIONS FOR TIME OBSERVATIONS

After the astronomical transit is set up at a station it should be put into the meridian at the first opportunity. This consists in orienting the transit on its pier so that the telescope swings in a north and south plane. With the transit in this position the chronometer times of transits of north and south stars across the line of collimation of the instrument will differ by the same amount from their right ascensions.

[5] If these currents are several times the minimum operating current slight changes are less critical with respect to the lags.

First, get the approximate longitude from a map or chart and compute the approximate local sidereal time at the station in order to set the chronometer. The following is a sample computation:

		h.	*m.*	*s.*
Longitude from chart	132° 24′ =	8	49	36
Time by watch keeping 135th meridian standard time, p. m., Sept. 7, 1924		3	50	00
Sept. 7. Standard time 135th meridian		3	50	00
Reduction to station		--	10	24
Local astronomical time[6] at station		4	00	24
Sept. 7. Greenwich mean time		12	50	00
Sept. 7. Right ascension of mean sun at Greenwich mean noon		11	05	08. 3
Reduction for 12 *h.* 50 *m*		--	02	06. 5
Local astronomical mean time		4	00	24
Required sidereal time at station		15	07	38. 8

The hands of the chronometer may be set to this reading by turning them in a clockwise direction with a key which fits the end of the axis on which the hands rotate. A gentle rotary movement of the chronometer at the desired instant will set it going.

Next set the middle wire or wires of the fixed field of the transit in the line of collimation by the customary method of direct and reverse pointings on a distant object and correcting for half of the difference; or determine the readings of the micrometer head when the movable wire is set on an object near the center of the field with the instrument in both the direct and reverse position. Setting the micrometer head at the mean reading puts the movable wire in the line of collimation.

Then level the instrument and set the telescope for some bright star which is about to transit within 10° or less of the zenith. Observe the chronometer time of transit of the star across the line of collimation. This star being nearly in the zenith, its time of transit will be little affected by the azimuth error of the instrument and its right ascension minus its chronometer time of transit will be a close approximation to the chronometer correction.[7]

Now set the telescope for some star of large declination (slow-moving) which is about to transit well to the northward of the zenith. Compute its chronometer time of transit (star's right ascension minus chronometer correction), using the chronometer correction just found. As that time approaches bisect the star with the micrometer wire in the line of collimation and keep it bisected by turning the whole instrument on its footplates until the chronometer time indicates that the star is on the meridian. This will be approximate, as the instrument will be thrown somewhat out of level and will move by jerks. Relevel and repeat the process on another star, following the movement of the star in azimuth by turning the proper screw in the azimuth-adjustment footplate, taking care to hold this footplate to the top of the pier so that the instrument will be moved in azimuth rather than the footplate be moved under the instru-

[6] Attention is called to the fact that beginning with the American Ephemeris for 1925 civil time will be given instead of astronomical time to avoid the confusion caused by the present system.

[7] To avoid waiting for stars close to the zenith the chronometer correction may be estimated closely by comparing observations of two stars not very distant from the zenith, one north and one south, and these will also give some idea of the amount and direction of the azimuth error.

ment. After putting the instrument approximately in the meridian by the first star it is well to twist the north end of the instrument back to the eastward a little to make sure that the second star will reach the micrometer wire a few seconds before it transits and thus permit the observer to follow the star by means of the screw in the footplate until it reaches the meridian. When satisfactory position has been obtained cement the footplates to the pierhead with plaster of Paris or other quick-setting cement.

Later when computations of a night's work show the instrument to be slightly out of the meridian, correction may be made by turning the azimuth-adjustment foot screw a certain number of turns depending upon the value of the screw. This value may be found as follows: Wrap a piece of paper around the screw; from the impression of the threads determine the number of threads per centimeter, measure the distance from the point of the foot screw about which the instrument revolves to the point of the foot screw which rests on the azimuth footplate, and compute the angular change in direction caused by one turn of the screw. This value for one of the two abutting screws in the footplate of transit No. 20 is about 2.′5 per revolution.

INSTRUMENTAL CONSTANTS ADOPTED IN 1914 FOR BAMBERG TRANSITS

Hanging levels, value of one division:
- Transit No. 20, 1.″086±0.″004; 1/60=0.s0181.
- Transit No. 21, 1.″200±0.″002; 1/60=0.s0200.

Transit micrometer screws:
- Transit No. 20, equatorial value of one turn=10.s524±0.s0006.
- Transit No. 21, equatorial value of one turn=10.s541±0.s0006.

Latitude micrometer screws:
- Transit No. 20, one turn=78.″9.
- Transit No. 21, one turn=79.″0.

Latitude levels:
- Transit No. 20, levels numbered { 0 to 40, 1.″358±0.″006. 50 to 90, 1.″312±0.″007.
- Transit No. 21, levels numbered { 0 to 40, 1.″316±0.″006. 50 to 90, 1.″256±0.″005.

COMPUTATIONS

Star list

[Set 2. φ=38° 55′. West pier, Naval Observatory, Washington, D. C.]

Star	Magnitude	Right ascension α	Declination δ	Zenith distance ζ	Star factors A	Star factors B	Star factors C	Lost motion l	Diurnal aberration κ	Ephemeris correction Δα	First setting	Second setting
		h. m. s.	° ′	° ′				s.	s.	s.	° ′	° ′
i Cancri	4.7	8 42 03	+29 03	+9 52	+0.20	1.13	1.14	+0.06	−0.02	−0.12	W. 9 52	E. 350 08
σ^2 Cancri	5.5	49 33	+30 52	+8 03	+ .16	1.15	1.16	+.06	− .02	− .10	E. 351 57	W. 8 03
i Ursæ Maj.	3.1	53 57	+48 21	−9 26	− .25	1.49	1.50	+.07	− .03	− .09	W. 350 34	E. 9 26
κ Ursæ Maj.	3.7	58 23	+47 28	−8 33	− .22	1.46	1.48	+.07	− .03	− .11	E. 8 33	W. 351 27
κ Cancri	5.1	9 03 35	+10 59	+27 56	+ .48	0.90	1.02	+.05	− .02	− .08	W. 27 56	E. 332 04
40 Lyncis	3.3	16 22	+34 43	+4 12	+ .09	1.21	1.22	+.06	− .02	− .06	E. 355 48	W. 4 12

In the star list above the azimuth factor, *A*, the level factor, *B*, and the collimation factor, *C*, are given in the tables beginning on page 62, Special Publication No. 14; κ, the constant of diurnal aberration, is given in the tables on page 24 of the same publication; l is the correction for width of contact strips and lost motion; and $\Delta\alpha$ is the quantity for correcting the American Ephemeris star places (listed in the Ephemeris beginning with the 1925 volume).

The last two columns are the readings of the setting circle of the transit with the ocular east or west.

The value of l is determined from the following formula:

$$l = \frac{1}{2} R\ (s+m) \sec \delta = \frac{1}{2} R\ (s+m)\ C = nC,$$

where R is the equatorial value of one division of the micrometer screw, s and m, the values of the width of the contact strip and lost motion, respectively, in terms of one division of the screw. (See fig. 24 for view of transit micrometer of Bamberg transit.)

The value of s is determined once or twice a season from the difference of the readings of the micrometer head when clicks are heard in the transit relay caused by making forward and backward contacts on the contact strips, and m, in a similar manner, is determined by making forward and backward coincidences of the movable micrometer wire with the fixed wires of the field. This latter value is generally too small to be accurately measured if the train of bevel gears of the micrometer is properly set and the spring in the micrometer box is functioning normally. It is well, however, to test this lost motion, as a failure of the spring to operate properly might not be otherwise noticed.

Computation of time observations, set 2.

[Station, West Pier, Naval Observatory, Washington, D. C. Date, March 4, 1923. Chronometer No. 220. Observer, G. D. C.]

Star: *i* Cancri

Level:

W.	E.
18.7	44.2
45.2	19.6
+26.5	−24.6

+1.9
×0.0181 = +0.034

8 *h.* 41 *m.*	8 *h.* 42 *m.*	Sum.
s.	*s.*	*s.*
8.5	47.5	56.0
9.8	46.2	56.0
10.9	45.2	56.1
12.1	44.0	56.1
13.2	42.9	56.1
14.2	41.7	55.9
15.5	40.4	55.9
16.8	39.2	56.0
18.1	38.0	56.1
19.2	36.8	56.0
		56.02
½ sum		58.01

l			+0.06
κ			−.02
Bb 1.13			+.04
t	8	41	58.09
α	8	42	4.06
m−t			−.12
α−t			+5.85
Rate correction			+.04

σ² Cancri

W.	E.
45.3	19.5
17.6	43.6
+27.7	−24.1

+3.6
+0.065

8 *h.* 48 *m.*	8 *h.* 50 *m.*	Sum.
s.	*s.*	*s.*
34.8	22.1	56.9
36.0	20.8	56.8
37.2	19.4	56.6
38.5	18.3	56.8
39.9	17.1	57.0
41.1	16.0	57.1
42.3	14.8	57.1
43.5	13.5	57.0
44.7	12.5	57.2
45.8	11.2	57.0
		56.95
		28.48

l			+0.06
κ			−.02
Bb 1.15			+.07
t	8	49	28.59
α	8	49	34.62
m−t			−.10
α−t			+5.93
Rate correction			+.02

***i* Ursæ Majoris**

W.	E.
18.1	44.3
45.4	19.1
+27.3	−25.2

+2.1
+0.038

8 *h.* 52 *m.*	8 *h.* 54 *m.*	Sum.
s.	*s.*	*s.*
45.5	56.3	101.8
47.3	54.7	102.0
49.1	53.4	102.5
50.5	51.8	102.3
52.0	50.2	102.2
53.3	48.7	102.0
55.0	47.0	102.0
56.8	45.3	102.1
58.2	43.8	102.0
59.8	42.2	102.0
		102.09
		51.04

l			+0.07
κ			−.03
Bb 1.49			+.06
t	8	53	51.14
α	8	53	58.43
m−t			−.09
α−t			+7.20
Rate correction			+.01

***κ* Ursæ Majoris**

W.	E.
45.3	19.0
18.0	44.7
+27.3	−25.7

+1.6
+0.029

8 *h.* 57 *m.*	8 *h.* 59 *m.*	Sum.
s.	*s.*	*s.*
9.2	25.0	34.2
10.8	23.5	34.3
12.2	22.0	34.2
13.9	20.2	34.1
15.6	18.8	34.4
17.1	17.2	34.3
18.6	15.7	34.3
20.2	14.3	34.5
21.8	12.5	34.3
23.3	11.1	34.4
		34.30
		17.15

l			+0.07
κ			−.03
Bb 1.46			+.04
t	8	58	17.23
α	8	58	24.40
m−t			−.11
α−t			+7.06
Rate correction			.00

***κ* Cancri**

W.	E.
18.2	45.0
45.2	18.3
+27.0	−26.7

+0.3
+0.005

9 *h.* 02 *m.*	9 *h.* 04 *m.*	Sum.
s.	*s.*	*s.*
46.9	15.1	62.0
48.0	14.0	62.0
49.1	13.0	62.1
50.1	11.9	62.0
51.2	10.9	62.1
52.2	9.9	62.1
53.1	8.9	62.0
54.3	7.8	62.1
55.4	6.5	61.9
56.4	5.5	61.9
		62.02
		31.01

l			+0.05
κ			−.02
Bb 0.90			+.01
t	9	03	31.05
α	9	03	36.24
m−t			−.08
α−t			+5.11
Rate correction			−.02

40 Lyncis.

W.	E.
45.8	18.4
16.9	44.4
+28.9	−26.0

+2.9
+0.052

9 *h.* 15 *m.*	9 *h.* 17 *m.*	Sum.
s.	*s.*	*s.*
21.3	13.4	34.7
22.5	11.9	34.4
23.9	10.8	34.7
25.1	9.5	34.6
26.6	8.2	34.8
27.9	6.8	34.7
29.1	5.7	34.8
30.2	4.3	34.5
31.7	3.2	34.9
32.9	1.9	34.8
		34.69
		17.34

l			+0.06
κ			−.02
Bb 1.21			+.06
t	9	16	17.44
α	9	16	23.77
m−t			−.06
α−t			+6.27
Rate correction			−.06

Computation of clock corrections

[Station, West Pier, Naval Observatory, Washington, D. C. Date, March 4, 1923. Observer, G. D. Computer, G. D. C.]

Star	$(\alpha - t)$	δt	A	Aa	ΔT	v
SET 1						
	s.	*s.* (+6.30)	*s.*	*s.*	*s.*	*s.*
26 Lyncis	+7.05	+.75	−0.23	+0.67	+6.38	+0.07
ω Cancri	5.53	−.77	+.25	−.73	.26	−.05
27 Lyncis	7.31	+1.01	−.36	+1.05	.26	−.05
ζ Cancri	5.26	−1.04	+.38	−1.11	.37	+.06
31 Lyncis	6.63	+.33	−.11	+.32	.31	.00
o Ursæ Majoris	8.66	Reject	−.77			
Groombridge 1450	6.28	−.02	+.01	−.03	.31	.00
SET 2						
ι Cancri	+5.89	−0.41	+0.20	−0.58	+6.47	+0.01
σ^2 Cancri	5.95	−.35	+.16	−.47	.42	−.04
ι Ursæ Majoris	7.21	+.91	−.25	+.73	.48	+.02
κ Ursæ Majoris	7.06	+.76	−.22	+.64	.42	−.04
κ Cancri	5.09	−1.21	+.48	−1.40	.49	+.03
40 Lyncis	6.21	−.09	+.09	−.26	.47	+.01

SET 1

$$3\,\delta t - 0.70\,a - 2.09 = 0$$
$$3\,\delta t + 0.64\,a + 1.83 = 0$$
$$-1.34\,a - 3.92 = 0$$
$$a = -2.926$$

$$3\,\delta t + 2.048 - 2.09 = 0$$
$$\delta t = +0.014 \text{ sec.}$$
$$\Delta T = +6.314 \text{ sec.}$$

SET 2

$$3\,\delta t - 0.38\,a - 1.58 = 0$$
$$3\,\delta t + 0.84\,a + 1.97 = 0$$
$$-1.22\,a - 3.55 = 0$$
$$a = -2.910$$

$$3\,\delta t + 1.106 - 1.58 = 0$$
$$\delta t = +0.158 \text{ sec.}$$
$$\Delta T = +6.458 \text{ sec}$$

Radio time signals

[Station, West Pier, Naval Observatory, Washington, D. C. March 4, 1923]

Radio time signals, 75th meridian standard time	Observer's sidereal chronometer time of radio signals	Reduction to 10 p. m. signal[1]	Reduced value, chronometer reading of 10 p. m.
h. m. s.	*h. m. s.*	*s.*	*h. m. s.*
9 59 00.00	8 37 59.37	+60.164	8 38 59.534
1.00	38 00.39	59.162	.552
2.00	1.38	58.159	.539
3.00	2.39	57.156	.546
4.00	3.38	56.153	.533
5.00	4.38	55.151	.531
6.00	5.38	54.148	.528
7.00	6.39	53.145	.535
8.00	7.39	52.142	.532
9.00	8.40	51.140	.540
10.00	9.40	50.137	.537
11.00	10.40	49.134	.534
12.00	11.41	48.131	.541
13.00	12.41	47.129	.539
14.00	13.41	46.126	.536
15.00	14.41	45.123	.533
16.00	15.41	44.120	.530
17.00	16.41	43.118	.528
18.00	17.42	42.115	.535
19.00	18.42	41.112	.532
20.00	19.42	40.110	.530
21.00	20.43	39.107	.537
22.00	21.43	38.104	.534
23.00	22.44	37.101	.541
24.00	23.44	36.099	.539
25.00	24.45	35.096	.546
26.00	25.44	34.093	.533
27.00	26.46	33.090	.540
28.00	27.46	32.088	.548
30.00	29.46	30.082	.542
32.00	31.46	28.077	.537
33.00	32.46	27.074	.534
34.00	33.47	26.071	.541
35.00	34.46	25.068	.528
42.00	41.48	18.049	.529
43.00	42.47	17.047	.517
44.00	43.47	16.044	.514
45.00	44.48	15.041	.521
46.00	45.48	14.038	.518
47.00	46.49	13.036	.520
48.00	47.49	12.033	.523
49.00	48.50	11.030	.530
10 00 00.00	8 38 59.54	0.000	8 38 59.540
Means: 9 59 23			8 38 59.534
Rate correction for 37 secs. at +0.0028 per min.. =			−0.002
10 00 00 p. m., 75th meridian standard time =			8 38 59.532

[1] The values in this column are found in the American Ephemeris in the tables for conversion of mean solar into sidereal time.

Clock corrections and rates

Date	T_0	ΔT	Rate per minute
1923	h m.	s	
Mar. 4	8 06.81 8 57.23	+6.314 +6.458	+0.0028

At 8 *h*. 38.99 *m*., ΔT=+6.405 (correction at 10 p. m. by interpolation).

COMPUTATION OF LONGITUDE, MARCH 4, 1923

Field method

	h.	m.	s.
Sidereal time of mean noon, Washington sun tables, American Ephemeris	22	45	44. 38
Reduction for 8^m $15^s.78$ longitude to reduce to 75th meridian			−1. 357
Reduction to 10 p. m	+10	01	38. 565
Sidereal time of 10 p. m., 75th meridian	8	47	21. 588
Chronograph reading of the 10 p. m. radio time signal	8	38	59. 532
Chronometer correction at 10 p. m			+6. 405
Over-all radio lag			−0. 033
Transmission time			0. 000
Corrected reading of 10 p. m. signal	8	39	05. 904
Sidereal time, 10 p. m., 75th meridian	8	47	21. 588
Longitude difference from 75th meridian to west pier, Naval Observatory		+8	15. 684
Longitude of west pier, time	5	8	15. 684
	°	′	″
Longitude of west pier, arc	77	03	55. 260

Office Method

	h	m.	s
Corrected reading of 10 p. m. signal (see above)	8	39	05. 904
Sidereal time, last signal break (furnished by Naval Observatory)	8	39	05. 813
Longitude difference from clock room, Naval Observatory, to west pier			−0. 091
Longitude, clock room	5	08	15. 784
Longitude, west pier, time	5	08	15. 693
	°	′	″
Longitude, west pier, arc	77	03	55. 395

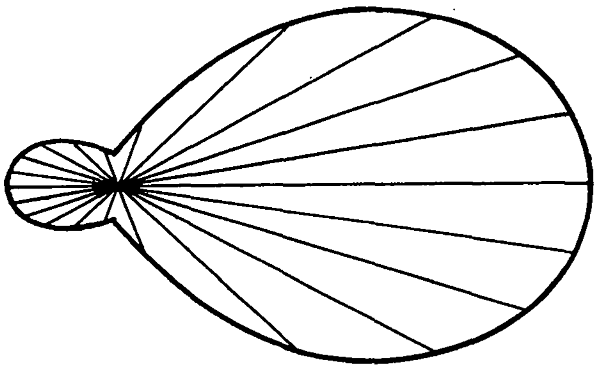
The first method is used in the field before the Naval Observatory clock corrections are known. This allows a comparison of the results of the different nights' observations.

The transmission time is computed on the basis that wireless waves have the speed of light waves, or 186,000 miles per second. The distance of the field station from Washington can be arrived at approximately by making a right triangle computation of the triangle whose legs are the differences of latitudes and longitudes converted into miles and solving for the hypotenuse.

The second or office method given above is precise and is somewhat more convenient to use.

DIRECTIONAL EFFECT OF WIRELESS

The nature of the directional effect of wireless may be seen graphically from the sketch:



The length of the line drawn from the point of intersection in any direction indicates the relative strength of the current received from a transmitting station located in that direction. An error of 20° from the best direction causes some reduction in signal strength, but the greatest reduction is when the antenna is broadside to the direction of the radio waves. With the elbow of an inverted *L* type antenna away from the direction of the transmitting station the strength is about one-fifth that of the reverse direction.

To determine the azimuth from the field station to the Annapolis radio station in order that the antenna may be put up with the elbow toward that station the following formula may be used:

$$\tan A = -\frac{\cot \phi \sec \phi' \sin \Delta\lambda}{1 - \cot \phi \tan \phi' \cos \Delta\lambda}$$

in which *A* is the azimuth of Annapolis counted in a clockwise direction from the north, $\Delta\lambda$ the difference in longitude of the two stations in degrees counted westward from the western station around to Annapolis, ϕ the latitude of Annapolis, and ϕ' the latitude of the field station.

While great exactness is not required in laying out the antenna, it is well to make one computation at the beginning of a season's work in a locality to determine the best direction. On account of the convergence of the meridians the direction is not apparent when the differences of latitudes and longitudes are considered alone.

The following example serves to show the effect of the convergence of the meridians. The field station is 20° north of Annapolis yet the azimuth is about 90° measured from the north clockwise:

Latitude of field station, southeast Alaska, $\phi' = 59° 20'$
Longitude of field station, southeast Alaska, $\lambda' = 136° 00'$
Latitude of Annapolis, Md., $\phi = 38° 58'$
Longitude of Annapolis, Md., $\lambda = 76° 30'$

Difference in longitudes, 300° 30′

Log cot ϕ	$=10.0921475$	Log cot ϕ	$=10.0921475$
Log sec ϕ'	$=10.2923936$	Log tan ϕ'	$=10.2269673$
Log sin $\Delta\lambda$	$=9.9353204n$	Log cos $\Delta\lambda$	$=9.7054689$
Log numerator	$0.3198615n$	Log sum	$=0.0245837$
		Number	$=1.05825$
Log denominator	$8.7652959n$	Denominator(1–1.05825)	$=-0.05825$
Log tan A	$=1.554565$		
A	$=88° 24' 09''$		

OPERATION OF RADIO SET

Connections are assumed to be made as shown in Figure 12. (See also figs. 4, 6, 7, and 9.)

Throw the lightning switch so that the antenna is connected to the amplifier.

Put on headset and throw switch to telephones.

Close storage battery circuit through the amplifier by making wire connection to plus terminal.

Throw switch *A*, putting storage and grid batteries in circuits of recorder.

Turn rheostats on amplifier until the tube filaments become somewhat brighter than a cherry red, and the rheostat of the recorder until its tube filament is a cherry red.

Next with condensers *A* and *B* set to readings of about 120 rotate condenser dial *C* until double-pitch sound of Annapolis (or the pitch note of the desired station) is heard, varying the settings of *A* and *B* until greatest intensity is obtained. If Annapolis is not sending code no double-pitch will be heard, but his generator may be running and a steady unbroken tone will be easily recognized by the listener after some slight experience.

Change the brightness of the tubes to improve the intensity of sound, striving to keep the filaments faint rather than bright in order to prolong their life.

Rotate *C* and find the two positions at which the sound is of equal pitch. Set the dial for the mid-position or at the point where the sound of the desired station can no longer be heard. This is the "dead point" and the point at which the maximum current is received by the phones.

Now throw switch *B* from phones to relay and turn dial switch *D* to the different contact points at the same time rotating the potentiometer knob *E* until the relay armature buzzes, then rotate the potentiometer knob *E* to the left until a point is reached where a slight movement to the right causes the armature to buzz and to the left causes it to stop. This combination of contact point and potentiometer setting should cause the relay armature to operate under the impulse of the incoming signals. A slight change in the dial setting of *C* may be required as the resistances of the phones and the relay not being identical will cause the "dead point" to be somewhat different.

The tension of the armature spring may be varied until satisfactory, too little tension causing the armature to stick over toward the magnet and too much preventing it from being drawn over. The gap at the contact points also should be made small and so arranged that when drawn over the armature will not come in contact with the cores of the magnet.

In tuning in on the Annapolis time signal, the observer should listen to the sound of the armature to ascertain if the buzz is due to the first part of the second of the time signal or the last part. The former is shorter, about two-fifths of a second duration, and is the desired part. If the latter part is being received turn the condenser dial *C* about 10° to the right and the proper signal should be received.

Now switch in the chronograph circuit (switch *C'*), making slight changes in the potentiometer, condenser C, and possibly *A* and *B* also until the best record of the signals is obtained.

Figure 25 shows a record made at Washington, 40 miles from Annapolis. Records nearly as good were made at Seattle, Wash., nearly 3,000 miles away.

When the proper brightness of the recorder tube filament has been reached the galvanometer should indicate a reading of from 15 to 25 divisions with each buzz of the armature caused by the incoming time signal.

To verify that the signals are those sent from Annapolis the observer should either listen on the telephones immediately after the conclusion of the final time signal for the code letters NSS or should record same on the chronograph sheet. One such record will be sufficient for a station provided the condenser settings remain the same at the station.

In the record shown in Figure 25, the following code was recorded immediately after the time signal:

CODE

—·—·—· —· ··· ··· — ·· —— · ——— —·—

(·) N–S–S T–I–M–E O – K

In disconnecting the batteries throw switch *A* out and also break the storage battery connection at the plus terminal.

Throw lightning switch to ground.

THEORY OF CONSTRUCTION AND OPERATION OF RADIO SET

The radio apparatus used in recording the radio time signals consists of two units which respectively are known as the amplifier and the recorder. The theory underlying the construction and operation of the latter will be discussed first.

The recorder must perform the functions of a relay. The power of the incoming signal is not large enough to operate a chronograph pen. Moreover it is in the form of high frequency currents and because of this fact also it is not directly available for recording purposes. The signal must, therefore, operate a type of relay which makes available local power which is sufficient in amount and in a form to operate the chronograph pen circuit.

A relay of this type is provided by a vacuum tube regenerative circuit. Such a circuit is shown schematically in Figure 26. It consists of a capacity C_1 and inductance L_1 in the grid circuit of the electron tube, the inductance L_1 being coupled to the inductance L_2 in the plate circuit of the tube. In order that the circuit may be regenerative the coupling must be of such sign that a rise in plate

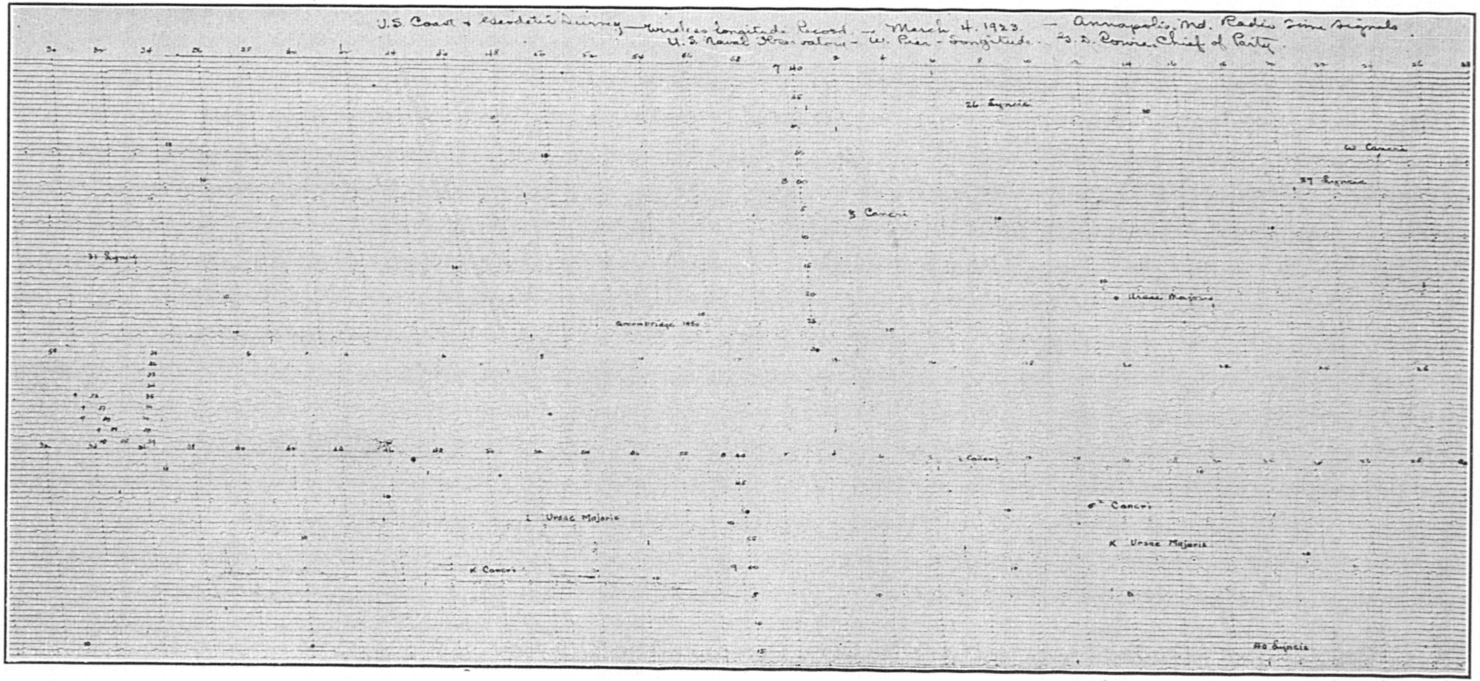


FIG. 25.—Chronograph sheet, wireless longitude record

. The chronometer, star transit, and radio time signal records are all on this sheet.

current results in a rise in the grid potential. Such a circuit is capable of acting as a generator of electrical oscillations. The frequency is determined in the main by the inductance-capacity combination L_1C_1.

The potentiometer P serves to adjust the mean grid potential over a suitable potential range. If, by adjusting the potentiometer P, the grid potential is gradually made more and more negative, the oscillations are stopped. Upon gradually raising the potential it will be found that there is a critical grid potential at which the oscillations set in. This grid potential is characteristic for the circuit used.

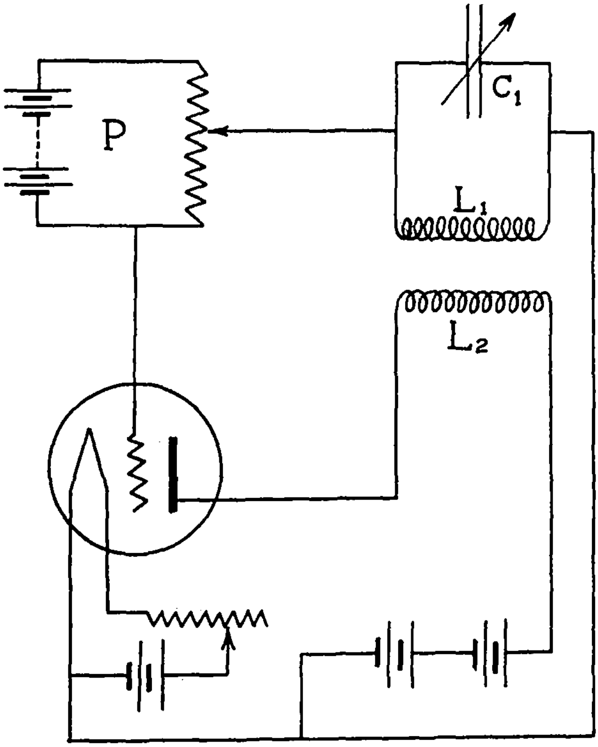


FIG. 26.—A regenerative circuit

Figure 27 shows the plate current-grid voltage characteristic of an electron tube and the manner in which the grid voltage and plate current grow in a regenerating circuit. If the grid be at a mean potential corresponding to the point C_r and an alternating E. M. F. be applied to it, the increase of plate current during the positive half of the cycle will be greater than the decrease during the negative half. This is due to the curvature of the characteristic. Thus the mean value of the plate current is increased by the periodic E. M. F. on the grid. If C_r is the critical point on the characteristic at which the circuit becomes self-oscillatory, for all grid potentials greater than this value the amplitude of the periodic component of the grid potential builds up; likewise the amplitude of the periodic plate current, and there results a rise in the mean plate current as shown by Figure 27. By proper design, conditions may be so chosen that the rise in plate current occasioned by the initiation of oscillations in the regenerative circuit is many times the plate current flowing just before the oscillations set in. With a 209A (102DW or 102D) tube and the actual circuits used in the radio recorder the rise is from less than one-fourth milliampere in the nonoscillatory to 2 milliamperes or more in the oscillatory state.

The rise in mean plate current which accompanies the starting of the oscillations is an important feature from the point of view of recording radio signals. An ordinary telegraph relay which will operate on 1 or 2 milliamperes when placed in the plate circuit will

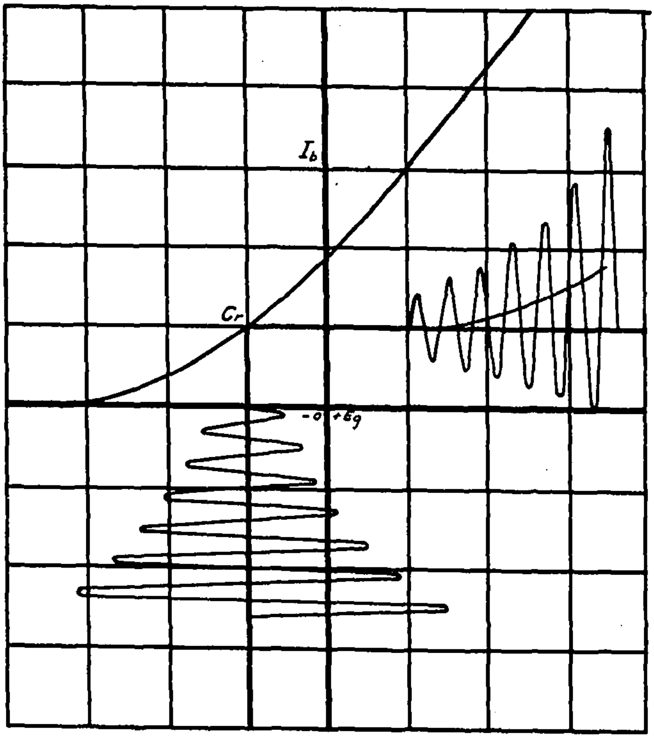


FIG. 27.—Growth of plate current I_b in a regenerative circuit

function with this current change and the relay contact may be used either to open or close a local circuit. Since the relay windings would serve as a choke to the radio-frequency currents and hence seriously limit the amplitude of the oscillatory current, in practice the relay must be shunted by a suitable by-pass condenser which offers much less impedance to these currents. With the by-pass much larger oscillating currents and consequently a greater rise of the mean plate current is obtained. If the local circuit is one operating the chronograph pen the starting of the oscillations may be chronographically recorded.

The change in grid potential necessary to pass from the nonoscillatory to the oscillatory state is very small, and hence the potentials provided by a radio signal received on an antenna suitably connected to the grid of the electron tube of the regenerative circuit may be sufficiently large to trip the relay. Figure 28 shows a suitable arrangement for this purpose. The antenna leads to the tuned circuit, which is connected to the grid of the tube through the potentio-

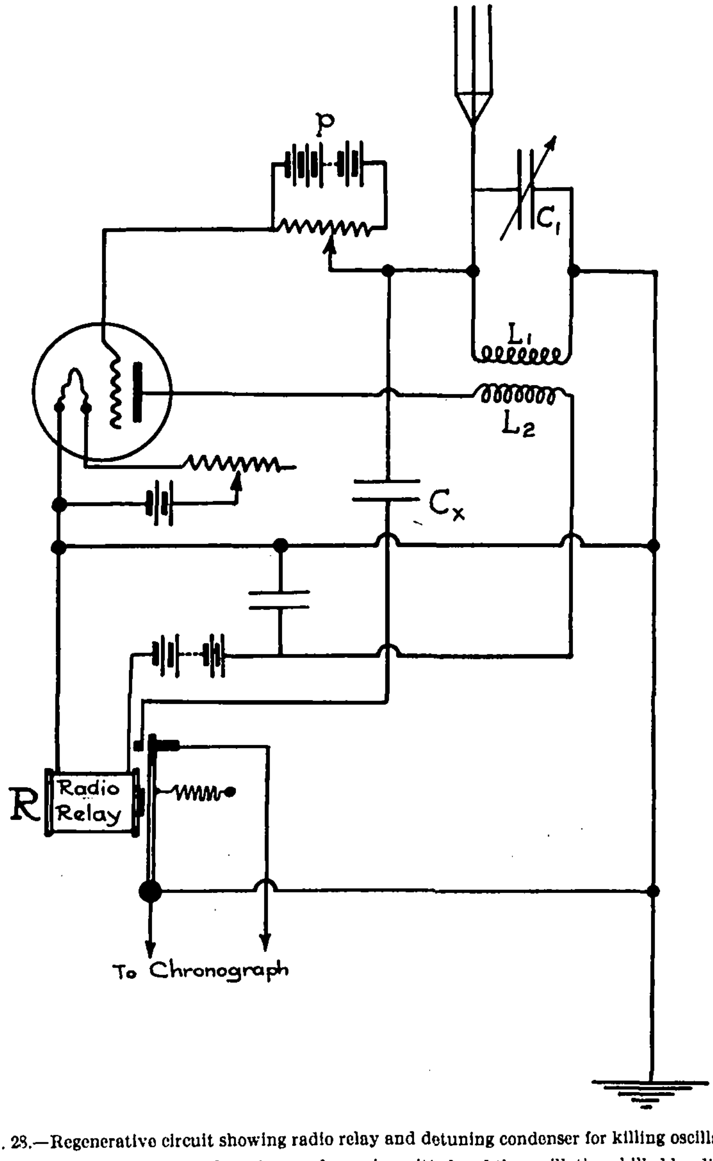


FIG. 28.—Regenerative circuit showing radio relay and detuning condenser for killing oscillations

In recorders Nos. 1, 2, and 3 the detuning condenser is omitted and the oscillations killed by direct short-circuit.

meter. The inductance of this tuned circuit is coupled regeneratively with an inductance in the plate circuit. The oscillations due to the incoming radio signal cause the grid potential to vary periodically about its mean value. If this mean value is just below the critical one peculiar to the regenerative circuit the incoming signal will cause the critical value to be reached or exceeded and local oscillations will be initiated. Unfortunately, however, the local oscillations persist even after the mean grid potential has been restored to its original value below the critical one. To stop these oscillations by changing the grid potential would require lowering it considerably below the critical value and hence the local oscillations persist after the initiating cause has ceased to operate. We are, therefore, thus far possessed of the means for setting up local oscillations by the incoming signal, but the instrument does not automatically reset itself.

Means must be provided for killing the local oscillations as soon as the periodic potential variation of the grid has ceased; that is, between signals. For this purpose the telegraph relay in the plate circuit is provided with a second contact, insulated from the first, which is closed when the relay armature is attracted by the relay magnet. This contact may be used to make changes in the circuit which will restore it to the nonoscillatory state. This may be accomplished in a great variety of ways. Figure 28 shows a condenser of relatively large capacity ($C_{\times}$) which the making of the auxiliary contact throws across the grid circuit inductance, detuning the circuit sufficiently to kill the local oscillations. This type of killing is used in several of the present recorders. In some of the recorders the killing is accomplished by simply short-circuiting the grid inductance by the operation of this contact.

In any case the local oscillations are stopped by the operation, of the second contact on the relay. This occasions a decrease in the plate current, the relay armature is released and the oscillation-stopping contact is opened. If the potential oscillations of the grid still persist as the armature is leaving the rear contact the local oscillations will immediately build up, the mean plate current will rise, and the relay armature will be attracted to the relay magnet before it gets far enough away to make the outer, pen-controlling, contact. Thus, during a long dash signal the relay armature simply chatters against the rear contact, without at any time moving far enough to make the outer one. It is clear, therefore, that during the arrival of the signal the relay armature is chattering against the rear contact and between signals it rests against the front one.

Figure 3 shows the front contact of the telegraph relay normally held closed by the tension spring. The starting of local oscillations causes the relay to operate in the manner previously described, and the front contact opens and the rear one closes. The opening of the front contact operates the chronograph pen, and closing of the rear one stops the locally generated oscillations. The making of the rear contact, therefore, causes the plate current to fall back to the nonoscillatory value, the relay to release and the front contact to close.

If a continuous dash signal is being received the local oscillations build up as soon as the relay armature leaves the rear contact and it is drawn back before the front contact is remade. Thus the chronograph pen continues in the released position until the signal stops long enough for the relay armature to remake the front contact. With no signal coming in, the front contact of the relay is closed and the chronograph magnet is energized. The pen-carrying armature is, therefore, held against the inner stop. When the incoming signal begins, the front contact is opened, the chronograph magnet is de-energized and the pen-carrying armature is released against the outer stop. It remains against the outer stop until the front contact of the plate circuit is again made. The pen then returns to its initial position against the inner stop.

In practice time signals from a local break-circuit chronometer are to be recorded over the time interval during which the radio time signals are being received. It is obviously desirable to have the same lag in the recording apparatus for both signals. If, therefore, both can be recorded by means of the same mechanical system—that is, with the same pen—a serious cause of difference in lag has been eliminated. How this has been accomplished, to a first approximation at least, is illustrated in Figure 3. The pen-operating magnet is differentially wound with two coils of approximately equal resistance and equal number of turns. The break-circuit chronometer operates a relay similar to that in the radio receiving-recording set. The clock-controlled relay energizes one of the pen-magnet coils during the brief period of the clock break. If the pen is in the released position during the clock break the pen magnet is momentarily magnetized and the pen is momentarily moved against the inner stop. If the pen is in the attracted position the clock break will serve to demagnetize the pen magnet momentarily and the pen will be released against the outer stop during the break. The pen will record the clock break, therefore, no matter what its status with reference to the radio signal. In general, the clock signals differ somewhat in character when made by attraction or release of the pen, but usually adjustments of spring tension and spacing of the armature in the "attracted" position can be made to provide adequate uniformity.

When star transits are to be recorded simultaneously with a local chronometer, the pen-magnet winding previously utilized for the recording of the radio signals may be included in a local signaling circuit. Making a contact on the micrometer head then operates in a manner similar to the starting of a radio signal.

It is seen clearly that the system has been designed to minimize the lag difference of the two kinds of signals. Since comparisons of two different kinds of signals are to be made, it is only the consistency of the lag or the magnitude of the lag difference which is of importance.

OPERATIONAL CHARACTERISTICS

The operator should familiarize himself with the characteristic curves of electron tubes (vacuum tubes) in general and with the nature of these curves for the tubes which he is using in particular. A relatively elementary knowledge of the facts involved will be of considerable assistance in operating the recorder.[8]

If the operator is listening on the telephones and the set sounds dead (no signals, tube noise, etc.) the set is below its critical potential. This potential is not a fixed value but depends upon the coupling between the grid and plate inductances (coupling readily adjustable in later recorders), the filament brightness, the grid potential, and the tuning. In general, adjustment of grid potential alone (rais-

[8] Operator should read Principles of Radio Communication, U. S. Signal Corps.

ing it) will make the set live and signals audible. Adjustment of filament brightness and coupling may occasionally be necessary.

For continuous wave signals the incoming radio signal has one frequency n_1 and the local circuit oscillates with another frequency n_2. The signal in the telephone is due to beats between these two frequencies. That is, if $n_2 - n_1 = 1{,}000$, the pitch of the note will correspond to 1,000 cycles. Rotating the tuning condenser of the recorder alters the frequency n_2. If the capacity is increased the frequency n_2 is decreased and consequently the beat note is lowered in pitch. If the air condenser is continuously turned in the direction of decreasing pitch a dead point will finally be reached beyond which the pitch will again rise. At the dead point the local oscillations and those of the incoming signal have the same frequency, and the tuned circuit of the recorder is in resonance with the incoming signal frequency. It is obvious, therefore, that the dead point is the point to which adjustment must be made to record the signal.

A switch on the recorder serves to throw either the telephone or the relay into the circuit. The two instruments are, however, not electrically equivalent and the dead point is moved slightly by throwing the relay into the circuit. A slight readjustment must therefore be made. In making it one observes the performance of the relay and also the meter in the plate circuit.

For any one station the scale range covered by falling pitch, dead point, and rising pitch may be large, and hence, in general, when several stations are sending the operator will observe a superposition with dead points corresponding to the several wave lengths. It may be quite possible therefore that at the dead point for the station which it is desired to record relatively loud signals from other stations are audible, but these rarely interfere with the recording of the desired signals.

Attention should be called to the advantage of keeping the coupling between grid and plate inductances as loose as possible. When so adjusted the signal may not sound as loud as for tighter coupling but it must be remembered that the listening is not done at resonance and the recording is. For loose coupling the resonance is sharper, there is less interference from other signals and from static. Loose coupling makes the set especially selective for the signal which it is desired to record. A weak signal at loose coupling is more likely to lead to satisfactory recording than a strong signal with tight coupling.

There is both a coarse and fine adjustment for the grid potential. The coarse adjustment simply switches 4.5-volt battery units into or out of the grid circuit. For the fine adjustment a similar battery unit is connected across a resistance of several hundred ohms. The magnitude of this resistance is of importance only in keeping the current to be provided by the battery to a suitable low value consistent with a reasonable life of the battery. By adjusting the potentiometer contacts fractional parts of the battery voltage may be thrown into the grid circuit, namely, the Ri drop of that portion of the resistance included in the grid circuit. In Recorders No. 1 and No. 2 the potentiometer is supplied by flash-light batteries, in later recorders it is supplied from the filament-heating battery.

In Recorders No. 1 and No. 2 the air condenser (0.002 microfarad full scale) in the tuned circuit has several fixed condensers (capacity 0.001 and 0.002 microfarad, respectively) connected in parallel with it. This restricts the instrument to a range of long wave lengths with a margin to either side of the setting for the Annapolis wave length. This arrangement makes the capacity change (or wave-length change) per division of shift smaller, and hence, makes the tuning easier. Two condensers were used, because a single one of proper capacity was not readily available. In the later recorders (Nos. 3 and 4) these additional condensers are of 0.00175 and 0.0035 microfarads capacity and switches are provided for switching them in or out. In this manner the wave-length range of the later recorders is considerably extended, the one instrument covering the range from roughly 6,000 meters to 24,000 meters.

AMPLIFIER

When the recorder is to be used at great distances from the station to be recorded it is necessary to amplify the signal before feeding it into the recorder. A three-stage radio frequency amplifier is used for this purpose. The three stages are transformer coupled and the unit is so designed that one, two, or three stages of amplification may be used. The schematic wiring diagrams of the amplifiers for sets No. 1 and No. 2 are shown in Figures 8 and 8*a*, respectively. In general it will be found desirable to use the direct connection of the antenna to the amplifier as indicated by Figure 8. If the signal is loud the inductive coupling as indicated by Figure 8*a* may be used. This mode of connection provides greater selectivity and hence less trouble from interference and static.

The coupling of the amplifier to the recorder is effected by means of a 500-turn coil which in sets Nos. 1 and 2 is connected into the output circuit of the amplifier with long leads so that the position of the coil with respect to the recorder can be changed at will. The amplifier and recorder are set up several feet apart. The coupling coil is disposed near the recorder, where the field set up by it is sufficiently strong to operate the recorder. The coupling used is extremely loose, which results in selectivity and advantage with respect to static. In sets Nos. 3 and 4 the coupling coil is built into the recorder and the coupling may be adjusted by rotating the coil axis with respect to that of the fixed grid coil. The building in of the coupling coil is simply a matter of practical convenience.

PRECAUTIONS IN THE USE OF RADIO LONGITUDE OUTFIT

Erect the poles and antenna so that the elbow will be pointed toward the sending station and use as short a "lead-in" wire as possible. This should pass into the tent or building through an insulator, leaving a short bight outside so that water coming down the wire will drip off the bight and not on the radio set.

The guy lines for the poles should be of flexible wire cable instead of rope, as rope shrinks considerably when wet, with the possibility of breaking the poles, and should be so led from the tops of the poles that they will be clear of the antenna wires by 2 feet or more. Guy lines should be insulated by one or two insulators at the tops of the poles. The antenna should also be hauled taut to take out much of the sag and give the greatest effective height.

Set up the radio outfit on a table or shelf which will not be jarred by the tent on a windy day, keeping the amplifier and recorder separated a foot or two to prevent any inductive effect except by the coupling coil laid on the recorder for that purpose. Make the necessary wire connections, insert tubes in sockets with filament resistances turned well to the left, and then verify the wire connections before hooking on the batteries. When working around the set always be careful to keep the plus terminal of the 45-volt B battery from a chance contact with parts in the filament circuit, as a single instantaneous contact would ruin all the vacuum tubes in circuit.

Be sure also to throw out the switch *A* on the recorder which cuts out the storage battery even though the wire is disconnected at the plus terminal of the battery, as this switch also cuts out the grid or C battery across the potentiometer.

Keep contact points of relay armatures, switches, tubes and socket contacts, core ends of relay magnet, transit and clock relays, and micrometer contacts clean, using a fine knife file if necessary. Remove mercury from the contact cup when it becomes dirty, and fill it again, using a fountain-pen filler.

Never allow the storage batteries to test below 1150 specific gravity nor to be charged higher than 1285.

When replacing the small C batteries be sure that the new batteries are inserted with their positive and negative contacts in their proper locations.

Test the strength of the current through the phones by laying the coupling coil from the amplifier over the coils of the recorder, first with one side down and then the other, and note which gives the loudest signals, or keep the coil in position and reverse the terminal connections on the amplifier. If troubled with "static" try reducing the coupling by moving the coupling coil further from coils of the recorder, and by reducing the amplification; that is, by connecting one side of the coil terminal leads to posts 2 or 1 on the amplifier instead of to 3.

Try various tubes on the set, selecting for steady use those which give clearest and loudest signals on the telephones; mark these and the sockets in which they operate best.

Dry out the tent or other observatory at each opportunity during the day, using an oil or other heater during rainy weather, as dampness in the set is very liable to cause trouble.

If the set fails to operate raise the lids of the boxes and examine wire connections, test batteries, test the direct-current circuits using a single battery in circuit with a voltmeter having leads of convenient length for reaching the different parts of the set. Test the relay especially, passing a current through the coil windings. If the armature is not attracted toward the cores there may be a short circuit or broken wire in the windings. Such a break will necessitate either repairing it or rewinding the coils.

If the galvanometer fails to deflect and the signal can be heard there is either a short circuit across the meter or the shunt is normal, but the galvanometer circuit is open inside the case of the instrument. Should the shunt wire be broken rewind with any wire which will serve to keep the galvanometer pointer on the scale but gives sufficiently large deflections to judge the conditions of operation of the set. A convenient temporary shunt is made by connecting a spare 7-ohm filament rheostat across the meter terminals and adjusting the resistance until the deflections correspond to normal performance.

When outfit is not in use be sure to have the lightning switch thrown to ground.

For shipping, have tubes well packed in cotton and in boxes where there are no heavy packages. All movable batteries and parts of set should be prevented from shifting in transit to avoid danger of breaking wire connections.

The other apparatus of the longitude outfit should have all bearings, axles, and gears frequently cleaned and oiled with good grade of clock oil, especially the journals of the Bamberg transit which are of polished steel and liable to become rusted. In shipping on long trips by water these journals should be coated with vaseline, cosmoline, or other similar grease.

ADVANTAGES OF WIRELESS METHOD OVER OTHER METHODS

The use of wireless outfits to record time signals has made it possible to reduce the cost of longitude determinations and at the same time to keep the accuracy as good as, or better than, that by the best previous method; that is, the differential method by wire telegraph.

The wireless method requires but one field observer and outfit instead of the two required for the wire method; observations can be completed in a shorter time at a station since the delay of waiting for fair weather to occur simultaneously at two stations is avoided; the possibility of longitude errors accumulating is avoided as each determination is referred directly to the longitude of the U. S. Naval Observatory at Washington instead of through a network of differences; and flexibility of operation is permitted so that stations may be located at any points along triangulation schemes that are accessible by boat, train, or truck.

This last advantage avoids the necessity of extending triangulation figures into towns off the main scheme in order to permit longitude stations to be established within reach of telegraph lines, and avoids the delay and expense incident to having wire connections made between telegraph stations and longitude observatories.

COST OF LONGITUDE STATIONS

The cost per station of longitude by the wire method in 1921 along the triangulation arc from Little Rock, Ark., to Needles, Calif., averaged $700. The cost per station for wireless longitude in 1922 in Wisconsin, Colorado, and New Mexico, using trucks for moving the outfit and personnel, was about $600.

In southeastern Alaska in 1923 the cost per station was $1,120, the party traveling by launch. This is not excessive, however, when it is considered that the overhead for any work in Alaska is large, and in this case no reduction is made for the cost of gravity and azimuth observations which were carried on by the party in addition to the wireless longitude and latitude work.

LATITUDE OBSERVATIONS WITH BAMBERG BROKEN-TELESCOPE TRANSIT

The Bamberg transit is arranged for latitude observations by substituting a latitude micrometer for the longitude micrometer eyepiece, and adding a level attachment and counterweight to the horizontal axis of the telescope. These additional parts are shown mounted in Figure 2.

The Horrebow-Talcott method should be used and the instructions given on pages 103–104 of Special Publication No. 14 followed. The cross hairs are put in the line of collimation of the telescope in the customary manner by sighting on a distant object or collimator in the direct and reverse positions and correcting half the difference; and the horizontal cross hair is made truly horizontal by means of the small screws which butt against the lug on the side of the draw-tube. This latter adjustment is very important and should be so accurately made that the star will follow exactly along the wire across the middle part of the field of view.

Observing lists are made as shown on page 108 of the above publication with the exceptions that in the column headed, star north or south, the position of the ocular is also given so that the column appears $\frac{\text{NE.}}{\text{SW.}}$, etc., and in the next column the settings are either the angle direct or its complement depending upon whether the ocular is east or west and the star north or south. The observing list should be made out to keep the continuous algebraic sum of the differences of the micrometer turns within the limit set in paragraph 6 of the general instructions.

A departure from the method given in Special Publication No. 14 is the manner of making the preliminary computation of the setting for the micrometer wire. For ocular east regardless of whether the star is north or south the setting is $20-\frac{N-S}{2}$, and for ocular west $20+\frac{N-S}{2}$. The center of the comb in the micrometer eyepiece is called 20 and larger readings on the graduated head correspond with larger zenith distances when the ocular is east and the star south or when the ocular is west and the star north, and larger readings correspond with smaller zenith distances when the ocular is east and the star north or when the ocular is west and the star south.

When setting for the first star of a pair the level bubbles are brought to the approximate center by rotating the level attachment on the horizontal axis, the clamp being temporarily loosened, and then perfecting the centering by use of the tangent screw which acts directly on the level holder. After reversal of the telescope the bubble should be brought back to center by using the tangent screw which changes the inclination of the axis of the telescope, but the tangent screw which acts directly on the level holder must not be touched.

The formula given on page 116 of Special Publication No. 14 when applied to the Bamberg instrument is as follows:

$$\phi = \tfrac{1}{2}(\delta+\delta') + \tfrac{1}{2}R(M_E - M_W) + \tfrac{1}{4}\left(\frac{d+d_1}{2}\right)\tfrac{1}{2}[(n+n_1+s+s_1)_E - (n_1+n+s_1+s)_W] + \tfrac{1}{2}(r-r') + \tfrac{1}{2}(m+m')$$

where δ and δ' are the apparent declinations of stars of a pair, $r-r'$, their difference of refraction, m and m', the corrections to measured zenith distances when stars are observed off the meridian, R, the value of one turn of the micrometer screw, d and d', the values per division of the latitude levels, n and n_1, and s and s_1, the readings of the north and south ends of the bubbles of the levels, and M, the micrometer reading. The subscripts E and W refer to the positions of the ocular.

Applying the constants given on page 32, the equations become as follows:

For transit No. 20,

$$\phi = \tfrac{1}{2}(\delta+\delta') + 39''.45(M_E - M_W) + 0''.167[(n+n_1+s+s_1)_E - (n_1+n+s_1+s)_W] + \tfrac{1}{2}(r-r') + \tfrac{1}{2}(m+m').$$

For transit No. 21,

$$\phi = \tfrac{1}{2}(\delta+\delta') + 39''.50(M_E - M_W) + 0''.161[(n+n_1+s+s_1)_E - (n_1+n+s_1+s)_W] + \tfrac{1}{2}(r-r') + \tfrac{1}{2}(m+m').$$

ADVANTAGES IN USE OF BAMBERG INSTRUMENT FOR LATITUDE

There are several advantages in the use of the Bamberg instrument for latitude over the zenith telescope although the accuracy of results is about equal. The Bamberg remains closely in azimuth, less care is necessary in the use of the micrometer eyepiece in preventing pressure which might cause flexure of the telescope, the continuous sum of the micrometer turns is easily kept small, the observer may make observations while comfortably seated as his eye is always at the same elevation, and when latitude is done in connection with longitude work a great saving in time is obtained by using the same instrument for both. The instrument when set up in the meridian for longitude work requires about 15 to 30 minutes to change over for latitude work, so that both longitude observations, requiring 2 hours' time, and latitude observations, requiring 4 hours' time, may be made by a single observer in one night without undue effort.