

THE RELATION OF THE U. S. NAVAL OBSERVATORY TO THE NAVY AND SHIPPING INTERESTS OF THE COUNTRY.*

BY

REAR ADMIRAL J. A. HOOGEWERFF,

U. S. Navy.

Superintendent, U. S. Naval Observatory, Washington, D. C.

WHEN a sailor comes into the open he casts an eye aloft and scans the heavens, not only to form an estimate of the seeing and probable weather conditions, but also to note the positions of the heavenly bodies. From this glance he gets an estimate of the course his ship is steering and the possibility of obtaining sights to locate her position on the ocean.

A good navigator, by constantly watching the heavens and consulting his almanac, carries in his head the best times to get his observations of the sun, and just what other heavenly bodies will be in position to be observed at twilight or when the moon is sufficiently bright to light up the horizon distinctly. When cloudy and observations are badly needed, the accomplished seaman knows at once, when a star shows up sufficiently to be observed, what star it is and what use can be made of a snap-shot taken of it with his sextant.

When the navigator gets his observations he notes the conditions under which they are taken and decides mentally on the amount of confidence he will place in them. But when he picks some figures out of his Nautical Almanac with which to work out these observations it never occurs to him to question the accuracy of the tables, nor to question the wireless time signals which he uses to determine his longitude, and which he receives from the Naval Observatory through Arlington by radio practically every day, if he is within three or four thousand miles of Washington.

It is astronomers who furnish the basis of these aids to navigation, and the sailor's confidence in them and their results is complete.

This confidence, while flattering to astronomers and computers, has its drawbacks in that the public is prone to believe that

* Presented at the Stated Meeting of the Institute held Wednesday, November 19, 1919.

the practical results of astronomy are free gifts from heaven, requiring little or no labor on the part of man to keep them up to date.

Astronomy is not only the oldest of sciences, but the father of all sciences, for it was from Astronomy that man first learned of the existence of law in nature which is the basis of scientific progress, and from that knowledge was led to turn his attention to other and nearer phenomena, believing that they, too, must be governed by law.

By watching the heavens through centuries man was gradually impressed with the harmony of motion of the heavenly bodies and the regular recurrence of celestial phenomena.

The risings and settings of the sun, the phases of the moon, the periodic positions of the planets, and the recurrence of the seasons gave food for thought and led to the discovery of rules for the prediction of these phenomena.

Then came Newton's discovery of the universal law of gravitation, which, applied to the observations of the positions of the bodies of the solar system obtained in the past, enabled predictions of their future positions to be made.

Although the laws of gravitation as announced by Newton have stood the test of time, we must not forget the multiplicity of conditions existing because of the number of bodies in space, and the difficulty of obtaining accurate observations.

It is marvellous that observations so accurate can be made from a rotating earth, revolving around the sun, which, with the whole solar system and the so-called fixed stars are themselves rushing through space with great velocities.

But these complications necessitate constant and improving observations, which, in turn, lead to more accurate equations and tables.

The principal practical applications of these tables are in the determination of time, of positions at sea, and in the determination of primary positions on the earth for use in making maps and charts.

These practical applications of astronomy are so essential to a seafaring people that countries having large shipping interests have sooner or later established government observatories to make the fundamental observations, and offices to compute and publish the tables in form for the use of sailors.

Congressional action for instituting a national observatory in this country originated in the earliest movement for establishing a first meridian in the United States, and a report was made by a select committee in the House of Representatives, March 28, 1810, which reported the following resolution: "That it is expedient to make provision by law, authorizing the President of the United States to cause the longitude of the city of Washington from the Observatory at Greenwich to be ascertained with the greatest degree of accuracy, and, for that purpose, to procure the necessary astronomical instruments."

This resolution was laid on the table, and a bill accompanying the report of another select committee was probably destroyed in the burning of the records of the Capitol in 1814. This committee had reported in January, 1813—"that, in their opinion, astronomical observations are highly useful to a navigating and commercial people."

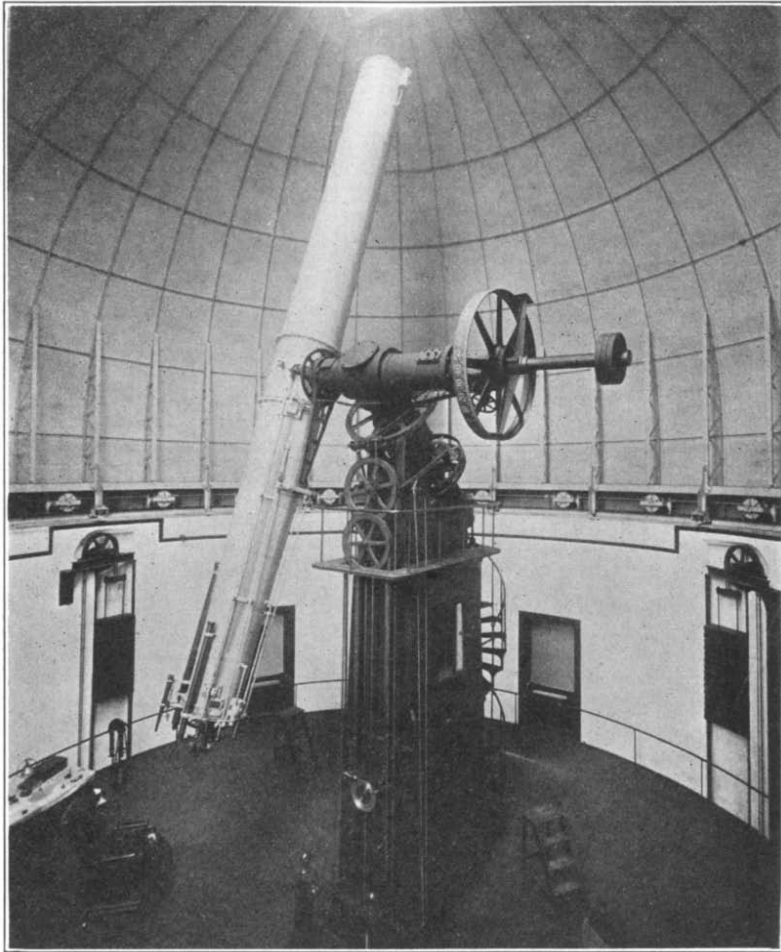
Though numerous scientific reasons were presented to Congress from time to time urging the establishment of a National Observatory, the practical uses of an Astronomical Observatory were not put on record until the Secretary of the Navy, in a letter to the Chairman of the Committee on Naval Affairs of the House of Representatives, dated March, 18, 1830, stated "an Astronomical Observatory"—"would furnish the means of making such observations as would enable astronomers to ascertain or calculate the positions of the heavenly bodies at any time, without being dependent on other nations for the same; and would be, moreover, a fixed point to whose meridian—terrestrial objects may, with certainty, be referred, as far as respects their longitudes," and Commodore John Rodgers, in a letter of the same date to the Secretary, stated as one of the principal objects of an observatory—"to furnish annually our naval and commercial interests with a correct ephemeris, upon the accuracy of which depends so much the safety of our commerce and the lives of our seamen."

In 1830, the Navy established a bureau in Washington for the care of the instruments, charts, etc., of the Navy, and Lieutenant Goldsborough, who had charge, collected the navigation outfits of the Navy there.

About the same time the Navy Commissioners in a letter to the Secretary wrote: "As a matter of national pride and independence, it would be desirable to have an American Nautical Al-

manac adapted to a first meridian of our own—an almanac of this kind would be one of the first fruits of an Observatory, should Congress deem it expedient to establish one.”

The necessity for careful rating of the chronometers for the



U. S. Naval Observatory. 26-inch equatorial.

Navy led to the acquisition of a transit instrument to determine the time, and Lieutenant Goldsborough then erected the first astronomical instrument for the Navy at Washington.

Lieutenant Wilkes, who succeeded in charge of the depot in 1833, removed the office to Capitol Hill, and here erected, at his

own expense, an Observatory, sixteen feet square, in which was mounted a five-foot transit loaned by the Coast Survey.

In the spring of 1837 Lieutenant Gilliss was placed in charge of the depot, and, under instructions from Secretary Paulding, commenced a series of astronomical observations of moon culminations, occultations and eclipses, which, with similar observations, to be made by Mr. William C. Bond at Boston, were to be used in determining differences of longitude in connection with the Exploring Expedition to the South Seas under Lieutenant Wilkes.

Gilliss not only succeeded in obtaining some necessary astronomical instruments, but persuaded the Secretary of the Navy to authorize the purchase of magnetic and meteorological instruments and to order additional assistants for the work at the depot.

Under these instructions of the Secretary of the Navy, Lieutenant Gilliss of the United States Navy, himself made most of the astronomical observations and was "the first in the United States who conducted a working observatory, and the first who gave his whole time to practical astronomical work; it was he who first published a volume of observations, first prepared a catalogue of stars, and planned and carried into effect the construction of a working observatory as contrasted with one intended chiefly for purposes of instruction——."

As the observations progressed and the usefulness of the depot to the navigational outfit of the Navy increased the necessity for suitable buildings became more and more apparent, and the practical work already accomplished by Gilliss being gradually brought to the attention of Congress, he succeeded, with the backing of the Navy Commissioners and the Secretary, in getting Congress to pass "an Act to authorize the construction of a depot for charts and instruments of the Navy of the United States," which was approved August 31, 1842.

The report of the Naval Committee which accompanied this bill said, in reference to the value of such a depot: "Since its organization, the Navy has not only been furnished with better instruments and more recent charts, at a greatly less original cost than before, but greater care has been observed in their use, consequent upon the regulations of the Depot, making the masters

of our public vessels directly responsible for each article delivered to them.

"Prior to that time, chronometers were purchased as the wants of a ship or the judgment of a commander dictated, without trial or examination, the only guarantee of its value being the word of the seller. Sextants which were rejected by experienced judges and left as shop-keepers, too frequently found their way into the Navy, through the inability of navy-agents and store-keepers to discriminate between good and bad. A ship rarely went to sea without having the master's store-room half filled with wood compasses, from the prejudice that a light compass could only be obtained by making the bowl of that material. As a necessary consequence, the same set of instruments rarely went to sea two cruises. When the ship returned, they were tumbled into the Navy store, chronometers and all, where they remained till the fitting of a new ship would find them unworthy of further use. This no longer exists; Navy store-keepers are required to render a monthly report of every instrument in their charge; and, as before stated, masters are held directly accountable, so that, with a little additional repair at the end of each cruise, the same set lasts many years. The saving, from this cause alone, is more than the annual cost of the whole establishment."

In reference to Astronomy, the committee say:

"In the summer of 1838, the honorable Secretary of the Navy directed the Superintendent to make a constant series of observations in astronomy, magnetism, and meteorology, ordering an additional number of assistants, and granting authority for the purchase of all necessary instruments."

"We are indebted to other nations for the data which enable our ships to cross the ocean. Not only has the Navy failed to contribute to the common stock from which all our navigators borrow, but our country has never yet published an observation of a celestial body which bore the impress 'by authority'; and it is believed that, until the observations before alluded to in this report, none have ever been directed by the Government which can be considered continuous.

"That great errors exist in the tabulated places of the heavenly bodies, the labors of astronomers of the present day sufficiently prove. Indeed, all who were at all curious in such matters could not have failed to remark how great a difference there was

between the observed and computed times of the last annular eclipse visible in the United States."

"Observatories, though not expensive, cannot prosper in our country until we can obtain rest from the pursuit of mercantile affairs, or their charge is undertaken by the Government. The duties are confining; if properly executed, arduous: and but few are qualified by experience or habits to undertake them. If officers can be found with taste for such duties, an Observatory will give more information to the world, under a military organization, in one year, than under any other direction in two."

"The subject of Magnetism is scarcely less important to the Navy than astronomy. Without a knowledge of the variation of the compass, none but coasting-craft dare venture beyond the precincts of a harbor; yet how few have more than a practical knowledge of the mode of determining its amount. The daily changes of the variation, its extraordinary fluctuations during auroras, the causes, amounts, and modes of correcting the local attraction of ships, and, indeed, the laws governing magnetized bodies generally, are mysteries with which a large portion of the officers have had neither means nor opportunities to become acquainted. Great complaints are made that chronometers perform badly; that ships have been influenced by currents when, if the true cause could be ascertained, it would be found to consist in having steered a wrong course, no allowance being made for local attraction."

"There can be no doubt a large number of the wrecks of shipping occur solely from this cause."

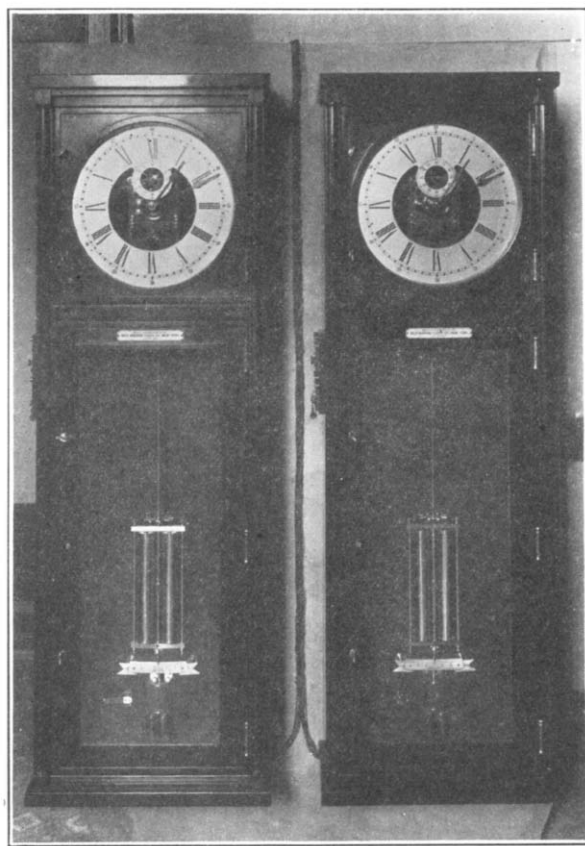
"The magnetic observatories which were established by the European governments two years since, and which have a location in almost every part of the world, were earnestly recommended to us by the learned men of England. Active and extensive co-operation, they say, will be the only mode of setting at rest the conflicting theories of this most important branch of science."

"In regard to Meteorology, if Professor Espy's theory is correct, the day is not distant when we shall be able to calculate the precise point where a storm is raging."

"Meteorological observations are more important at night than by day, because of their scarcity hitherto; and it is scarcely to be expected that amateurs can be found in sufficient numbers to

make all the required observations. Night-watching in stormy weather finds few followers, and we can only hope to obtain the desired information, when those engaged in its pursuit have duty to compel a flagging inclination."

"Deeming an establishment of this description essential to



U. S. Naval Observatory. Transmitting clocks which automatically send out the time signals.

the welfare of the Navy, the committee report the accompanying bill."

A separate report of a select committee on memorials presented by citizens of Philadelphia, New York and Baltimore stated: "—It is incumbent on Congress to provide for the safety of our mariners and of the immense treasures which the enterprise of our merchants throw daily upon the waters.

It is by celestial observations only that charts can be accurately projected——"

The passage of this act in 1842, marks Congressional approval of the Naval Observatory, though it was first called the Depot of Charts and Instruments, and later the Hydrographical Office. In the volume of astronomical observations for 1848, the institution first bears the name of United States Naval Observatory in place of National, by order of the Secretary of the Navy, because the Institution had always been under the control of the Navy Department, and was conducted by Navy Officers, "its reputation is the property of the Navy."

In the act of Congress of March 3, 1849, in appropriating the expenses of the Hydrographical Office it was "Provided that a competent officer of the Navy, not below the grade of lieutenant, be charged with the duty of preparing the Nautical Almanac for publication, and that the Secretary of the Navy may, when, in his opinion, the interests of navigation would be promoted thereby, cause any nautical works, that may, from time to time, be published by the Hydrographical Office, to be sold at cost——."

From and since the Act of Congress of August 5, 1854, specific appropriations have been made for the American Nautical Almanac, and the Revised Statutes, Sec. 436, provided that "The Secretary of the Navy may place the supervision of the Nautical Almanac in charge of any officer or professor of mathematics in the Navy who is competent for that service——."

Lieutenant Matthew Fontaine Maury, to whom Lieutenant Gilliss turned over the new building for the Observatory (which had been completed under his direction), became Superintendent on October 1, 1844, and held that position until he went South in April, 1861, when he was succeeded by Gilliss, who had meanwhile been promoted to a Captaincy in the Navy.

Maury devoted a great deal of his attention to hydrography and interested the Navy and Merchant Commanders in making and preserving "observations on all parts of the ocean upon winds, currents, the barometer, and air and water thermometer, and upon other phenomena calculated to improve navigation." From these reports and the logs of vessels Maury planned and published wind and current charts, and sailing directions on which are still based our present charts, and which have not only materially shortened the passage along the highways by which

our ocean borne commerce passes, but have enabled shipping to avoid locations where large percentages of bad and unfavorable weather conditions are found.

Gilliss, who was a practical astronomer and who had said in his report in 1845, that "he would have regarded his time as misspent to labor so earnestly only to establish a depot of charts and instruments; that his aim was to place an institution under the management of Naval officers, where, in the practical pursuit of the highest known branch of science, they would compel an acknowledgement of abilities hitherto withheld from the service," built up the astronomical staff of the Observatory and acquired new instruments during his Superintendency lasting until his sudden death February 9, 1865.

The Naval Observatory at this time included an Astronomical Observatory, a Hydrographical Office, a Depot of Charts and Instruments, a Meteorological and Magnetic Observatory, and the Superintendent was even required to make a report on inter-oceanic canals and railroads under the resolution of the United States Senate of March 19, 1866—"Resolved, that the Secretary of the Navy furnish, through a report of the Superintendent of the Naval Observatory, the summit-levels and distances by survey of the various proposed lines for interoceanic canals and railroads between the waters of the Atlantic and Pacific Oceans, as also their relative merits as practicable lines for the construction of a ship canal and especially as relates to Honduras, Tehautepec, Nicaragua, Panama, and Atrato lines."

These were too diverse activities for a single institution and Congress, by its Act of June 21, 1866, established the United States Hydrographic Office, which then took over the hydrographic work which the Observatory had started.

In 1880 Congress appropriated funds for the purchase of a new site and the preparation of plans for new buildings for the Naval Observatory, and in 1886 the funds for the buildings.

Under these appropriations the site for the present Observatory was carefully selected with a view to its fitness for mounting astronomical instruments and observing with them, and at the same time to be accessible from the city of Washington, and the buildings were carefully designed to suit its needs.

Upon the completion and acceptance of the new buildings on Georgetown Heights the Naval Observatory was moved

there in 1893, and at the same time the Nautical Almanac Office with its library was transferred to and made a department of the Observatory.

In order to give very briefly the reasons for the establishment of the Naval Observatory and the American Nautical Almanac and to afford time in which to tell of the practical assistance they now afford our Navy and Merchant shipping, I have been obliged to leave out practically any account of the work of the many distinguished men who have been connected with their activities.

I must, however, mention, in addition to Gilliss and Maury, the names of Goldsborough, Wilkes, Charles Henry Davis, father and son, John Rodgers, Asaph Hall and Simon Newcomb, of the Navy, and George William Hill, all of whose names are well known to science, but an account of whose work it would take up too much time to attempt to give now.

THE WORK OF THE NAVAL OBSERVATORY.

The first object in acquiring an astronomical instrument for the Depot of Charts and Instruments was for the correct determination of time in order to find the errors and rates of the Navy chronometers.

This service has been continued ever since, and has expanded until now the Naval Observatory not only furnishes accurate time by radio, twice each day, via the Navy radio station at Arlington (and other Navy radio stations when desirable), to vessels anywhere within three or four thousand miles of Washington, and to thousands of private parties who have set up receiving sets throughout the country; but also puts the time signal on any telegraph or telephone wires which are run to the Observatory for the purpose of receiving it.

This has resulted in the Western Union Telegraph Co. supplying Naval Observatory time wherever their wires are run. West of the Rocky Mountains the time signals originate at the Navy Chronometer and Time Station maintained at the Mare Island Navy Yard.

The benefit of standard time signals to the shipping and inland transportation interests of this country, and to watchmakers, jewelers and persons engaged in scientific and other pursuits requiring accurate time, not to mention the general public, is so tremendous that it is difficult to conceive of the confusion and

troubles that would arise were this service discontinued even for a few days. It is often amusing to note the surprise of persons who thought they possessed perfect time keepers, when, on making continuous comparisons with an accurate time signal, they find how much their supposedly accurate watches vary from day to day.

To maintain a time service the Naval Observatory keeps up continuous observations, when weather conditions do not prevent, of the passage of so-called clock stars over the meridian of the Observatory, by means of telescopes set permanently in the meridian and provided with suitable mechanism for accurately determining the time of passage of the stars. These times are compared by means of chronographs with standard clocks whose errors are thus determined whenever a set of stars is observed. The standard clocks are not only the most accurate clocks made, having pendulums of invar, which practically does not expand or contract, but they are secured to solid piers set so far in the earth as to avoid all tremors or vibrations short of those occasioned by earthquakes, and are in a vault where the temperature is maintained constant within one-tenth of a degree Fahrenheit. Each clock is sealed in a glass case and the air partially exhausted so that the resistance of the air and its moisture content is kept constant. They are wound by electricity.

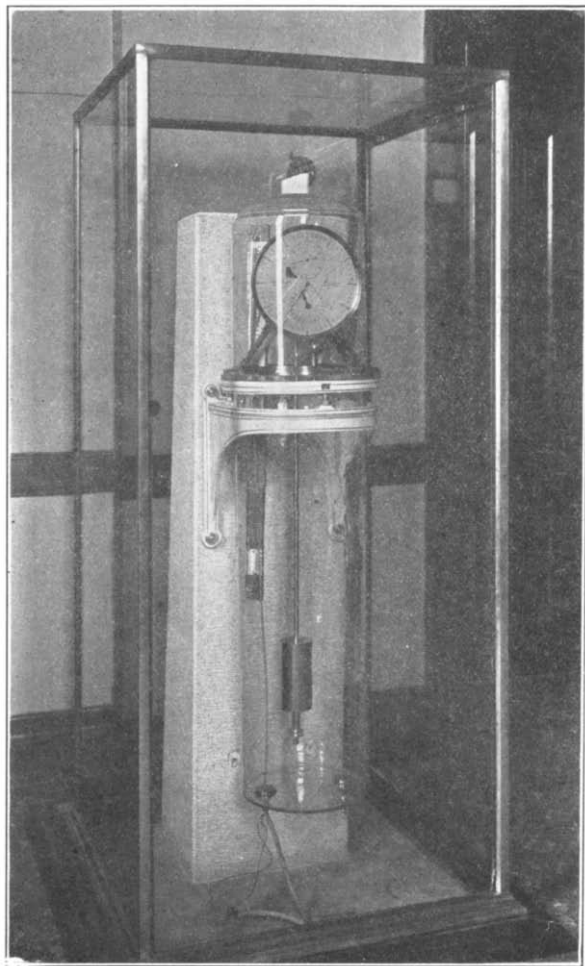
Through electric connections the reading of any one of the three standard clocks is communicated throughout the Observatory and can be compared on chronographs with any other time keeper, star or other observation.

In order to transmit the time signal at noon and 10 P.M., two auxiliary clocks made for the purpose are used, so that having set one of these clocks correctly by comparison with the standard clock shortly before the time for the signal, the clock automatically transmits the signals to as many electric relays as may be desired. The actual time of this signal at different places is checked back from time to time, and the lag, as it is called, at Arlington, is within .01 second of time, and, at Key West, due to the signal being several times relayed by land wire, averages .28 second.

The number of the private radios receiving time was hardly appreciated by the Observatory until they were shut down by the war, and the usefulness of them to the public was emphasized

by the number of immediate requests for permission for their reestablishment as soon as peace conditions prevailed.

Of course during the war the time signals went out by Navy



U. S. Naval Observatory. Standard clock, three of which are kept at a constant temperature and pressure in an underground vault. These clocks are wound by electricity, and their beats are transmitted by electricity throughout the Observatory so that the vault does not have to be entered unless in case of emergency.

radio and land lines without intermission, and were so necessary to shipping passing through the submarine zone that all other radio work was stopped while the time signal was being sent.

The determination of time by the transit instruments at the

Naval Observatory is only a small part of the work of the Observers on those instruments, and while these results are more immediately apparent, the real work of the instrument is in the determination of the absolute positions of the heavenly bodies.

These positions are ultimately used, not only for time determination, but for navigational and astronomical work.

The astronomical work of the Naval Observatory is planned and executed, "To furnish to the Nautical Almanac Office, as far as possible such observations and such data as may be needed for carrying out the purpose of the law under which the appropriations for that office are made from year to year, which is as follows:

"For—preparing for publication the American Ephemeris and Nautical Almanac and improving the tables of the planets, moon, and stars."

The principal astronomical work of the Observatory is in the field of the astronomy of position as distinguished from astrophysical work, and is the continued maintenance of observations for absolute positions of the fundamental stars and of stars which are to be made fundamental, and in addition the independent determination by observations of the sun, of the position of the ecliptic, and of the equator among the stars, and of the positions of the stars, moon, and planets with reference to the equator and equinoxes.

For carrying out this plan of work the principal instrumental equipment of the Observatory consists of a 9-inch and a 6-inch transit circle, a prime vertical transit instrument, an alt-azimuth, a photographic zenith tube (for the determination of the variation of latitude), a 26-inch and a 12-inch equatorial, a photographic telescope, and a photoheliograph, besides the necessary chronographs and clocks and a clock vault where the standard clocks are kept at a constant temperature. The handling, lighting, and recording of these instruments requires an electrical equipment of motor generators, storage batteries, switchboards, and thermostats and fans, and the mechanical equipment for opening and closing shutters, turning domes and raising the floor of the large equatorial is considerable and requires constant attention. All of these instruments are in actual use now, excepting the prime vertical transit with which a series of observations, continuous for 19 years, has lately been completed.

In order that the work of computing and publishing the observations, without which they are valueless, may keep pace with the observational work there is a small computing division which assists the observers on the instruments in reducing their work; and, incidentally, furnishes a try-out for the young men who first come to the Observatory, and a source from which to draw for observers. Fortunately for Astronomy, it is such an absorbing science that those really devoted to it are almost indifferent to their own material welfare, and work night and day in cold and heat, with sleep and meals at irregular intervals, on a mere pittance. If it were not for this devotion to Astronomy on the part of a few men it would be impossible to get any one to do the work of the Observatory on the salaries allowed by the Government.

These men, because of their knowledge of instruments, optics and glass, were tremendously valuable to the Navy at the outbreak of the war, because of our previous dependence on foreign countries, particularly Germany, for these things, and the necessity for having advisers for the firms undertaking to provide us with glass and instruments made in the United States.

THE NAUTICAL ALMANAC OFFICE

Fortunately Congress in 1912 in authorizing the Secretary of the Navy to arrange for the exchange of data with such foreign almanac offices as he might from time to time deem desirable, with a view to reducing the amount of duplication of work in preparing the different national nautical and astronomical almanacs, and increasing the total data which may be of use to navigators and astronomers available for publication in the American Ephemeris and Nautical Almanac, "Provided, further, that the work of the Nautical Almanac Office during the continuance of any such arrangement shall be conducted so that in case of emergency the entire portion of the work intended for the use of navigators may be computed by the force employed by that office, and without any foreign coöperation whatsoever."

This saving clause enabled the Nautical Almanac to be published as usual, notwithstanding the war, and from 1300 Ephemerides and 1165 Nautical Almanacs for the year 1916, the numbers of the 1918 volume required increased to 1597 copies of the American Ephemeris and 5153 copies of the Nautical Almanac.

These increases were principally due to the increase of our shipping, both naval and mercantile; but the War Department required 845 copies of the American Ephemeris and 535 copies of the Almanac, and of these the American Expeditionary Forces in Europe took 500 copies of the American Ephemeris for strictly military work.

The Departments of Agriculture, Commerce, Interior, and Treasury took 229 copies of the Ephemeris for 1918 and 323 copies of the Almanac.

These publications, besides giving the positions of the sun, moon, planets and stars, give the celestial phenomena for the year, such as eclipses, occultations, etc., tables for the use of navigators and astronomers for converting time and for finding the latitude by an observed altitude of Polaris; and the times of sunrise and sunset and moonrise and moonset, the value of which not only in war but to the average citizen and to light and power companies is obvious.

NAVIGATIONAL INSTRUMENTS

The Naval Observatory is charged with the development, supply, upkeep and inspection of gyro and magnetic compasses, compass equipment, chronometers, clocks, watches, sextants, sounding apparatus, spy glasses, binoculars, and in fact all navigational and meteorological instruments used by the Navy, not only for its surface craft, but for submarines and aircraft.

Prior to the war, the increasing speed and draft of surface vessels, increased gun ranges, and the development of underwater and air craft necessitated new and improved instruments and methods for accurate and rapid navigational and plotting work. The Naval Observatory had encouraged suggestions and the development of methods and instruments, sending out to the service for trial all that gave promise of usefulness.

Special efforts had been made to interest American firms in the manufacture of chronometers, torpedo boat watches and timekeepers in general, of sufficient accuracy to pass the Observatory tests.

Still the number of any one kind of navigational instrument required by the Navy was not great; our merchant marine required but few, and so the manufacture of nautical instruments in this country was confined to a few firms of limited capacity.

Although some chronometers were assembled in this country, the chronometer parts and all torpedo boat watches were manufactured abroad, and practically all optical glass was imported. However, the possibility of American firms undertaking to substitute their products for imported ones had been thoroughly gone into, and where it had not been undertaken it was due to the fact that the American firms did not believe it could be done at a profit, principally because of the limited demand for nautical instruments.

Fortunately the Naval Observatory had encouraged the development of a compass in this country which was not influenced by the magnetic materials of the ships, and a number of these gyro compasses were in use on the dreadnaughts and submarines of our Navy.

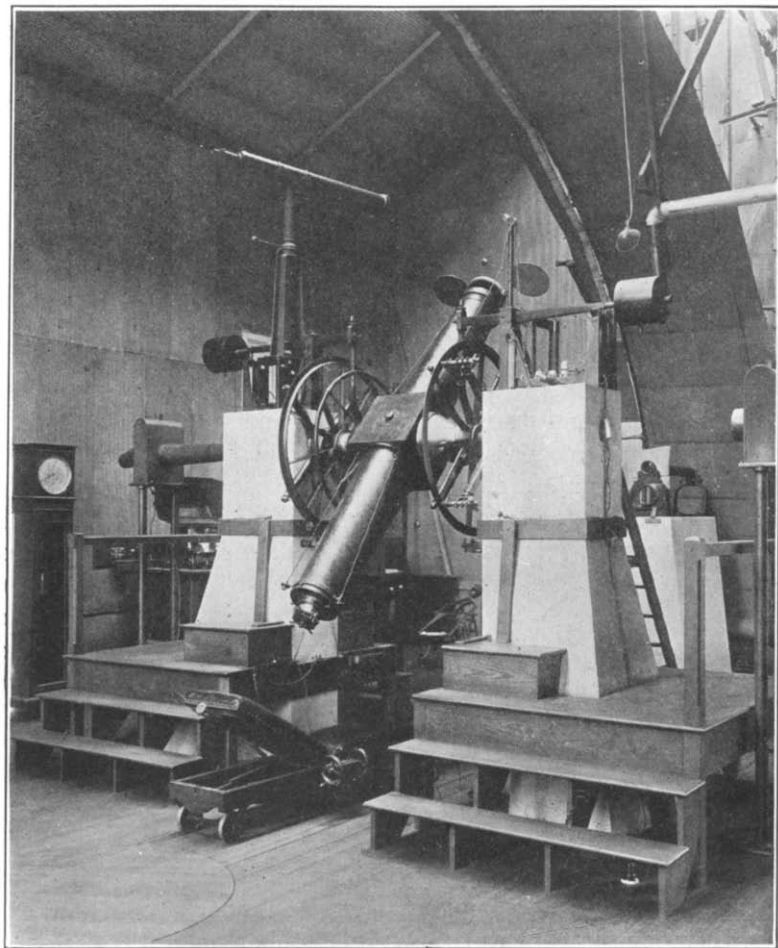
The want of sufficient directive force, the necessity of its installation in an exposed position, the inaccuracies due to movements of large masses of steel (such as turrets and guns), and the practical difficulties in the way of transmitting the readings of the magnetic compass to other points had made it extremely desirable to provide a compass much superior in these respects, at least, to the magnetic compass for battleships, while for the submarine a magnetic compass confined within a steel shell was practically useless. The development of the gyro compass had also been aided by the demand for it, before our entry into the war, by the countries allied against Germany; and as, outside of Germany, America had produced the only gyro compass, the demand for it became very great.

While the Navy had but few aircraft prior to our entry into the war, the necessity for navigational and meteorological instruments for aircraft had been recognized, and the Observatory was encouraging and taking part in their development.

Still all this preliminary work, because of the limited demand in this country, and the small amount of money available by the Navy for development work, furnished only a part of the foundation for the increase required when we entered the war. But attention had been directed to our possible requirements and there were a number of people who had spent considerable thought over them and who were prepared to assist commercial firms in developing into makers of navigational instruments.

A few years before the war the repairing of navigational in-

struments by outside contract was so unsatisfactory, not only in regard to cost but in the time taken and the impracticability of getting the contractors to distinguish between urgent jobs and those that could be delayed, that the Naval Observatory started a repair



U. S. Naval Observatory. 9-inch transit circle.

shop and got an appropriation for furnishing a suitable building in which to locate the shop.

During the war this shop was invaluable not only for the work it turned out, but because the foreman and mechanics were in a position to advise firms undertaking work that was new to them

as to the machinery necessary for their plants and the qualifications of their mechanics.

As the war progressed the Naval Observatory found that it not only had to supply a tremendously enlarged Navy, but vessels taken over from the merchant marine for transports and freight carriers, and finally the vessels built by the Shipping Board.

The latter has helped to prevent waste, loss to contractors and an undue accumulation of a surplus of instruments contracted for before the armistice was signed by taking them over for their shipping which is still being turned out in large numbers.

One of the most urgent needs of shipping plying in the submarine zone was for large numbers of binoculars and other glasses, in order that the lookouts, whose numbers were greatly increased over those required in times of peace, might pick up and distinguish suspicious objects promptly. To meet this demand a call was made on the citizens of the country by the Assistant Secretary of the Navy, Mr. Roosevelt, to loan their glasses, and any navigational instruments they might have, to the Navy for the duration of the war. The response from patriotic citizens was so enthusiastic that 32,000 serviceable pairs of glasses were received, and those that could be were issued and used. They have practically all been returned to the owners with suitable acknowledgment.

THE LIBRARY

One of the features of the Naval Observatory that deserves mention is the library, which is believed to be the most complete mathematical and astronomical library in the world.

The books are not only constantly used by the astronomers of the Observatory but by others engaged in mathematical and astronomical research.

ECLIPSES

In checking up the positions of the sun and moon, solar eclipses furnish a means of verifying their relative positions by marking the times of contact, and for this purpose the Naval Observatory has sent out a number of eclipse expeditions, and at the same time has taken advantage of them to make photographs of the sun's corona and to afford opportunities for spectroscopic observations of it.

DETERMINATIONS OF DIFFERENCES OF LONGITUDE

The Naval Observatory has taken part in or assisted with a number of determinations of differences of longitude; and, in the winter of 1913-14 made a determination of the difference of longitude between Washington and Paris, using radio signals between the Navy Radio Station at Arlington, Virginia, and the Eiffel Tower at Paris.

This work was done in duplicate by observers from the Naval Observatory and by the French, but owing to the war, the computation of the French results was delayed so that the Naval Observatory published the first transatlantic radio determination which was also the first trans-Atlantic determination without intermediate stations.

The distance between Washington and Paris is 3830 miles and radio had never previously been used for longitude determinations at a distance exceeding 960 miles.

When the French results were obtained they were found to agree very closely with those of the Observatory, differing only by two thousandths of a second of time, making the determination of great accuracy.

DISCOVERY

While the principal observational work of the Observatory is in the field of astronomy of position as distinguished from astrophysical work and discovery, the satellites of Mars were discovered by Prof. Asaph Hall of the Navy with the 26-inch Equatorial, and other minor discoveries have been made.

FACILITIES FOR THE PUBLIC

In order to afford the general public a view of the heavens the 12-inch equatorial is given over to their use one evening in each week, cards of admission being issued, and the Astronomer, in charge, besides showing celestial objects, gives a short talk on popular astronomy.

SUMMARY

To sum up, the Naval Observatory performs four principal functions, which are not only absolutely necessary to the Navy and Shipping interests of this country but to the country at large. These functions have been developed by the Navy as the needs for them have arisen, and the plant has been pro-

vided by Congress upon the representations of and work done by the Navy.

These functions are:

(a) The furnishing and transmission of daily time signals both by radio and telegraph.

(b) The computing and preparing for publication of the American Ephemeris and Nautical Almanac and the Nautical Almanac.

(c) The continuous maintenance of observations for absolute positions of the fundamental stars, and the independent determination by observations of the sun, of the position of the ecliptic, and of the equator among the stars, and of the positions of the stars, moon, and planets with reference to the equator and equinoxes in order to furnish data to assist in preparing the American Ephemeris and Nautical Almanac and improving the tables of the planets, moon, and stars. At the same time this department furnishes the observations for determining the time.

(d) The development, supply, upkeep and inspection of all navigational instruments for the Navy, which incidentally the Observatory has practically done for the Shipping Board, and has established standards for the growing merchant marine of the country.

The Naval Observatory started the development of the Hydrographic Office; made the first systematic meteorological and magnetic observations at the Capital; and has lately fostered the development, amongst many other instruments, of those necessary for the navigation of submarines and air craft.

Alcohol from Wood. (*Chemical Age*, vol. ii, 1920, 329.)—The production of ethyl alcohol from wood has long been a matter of investigation. The vast amount of wood-waste, for which but little use is made other than for fuel has made the question one of great practical importance. That cellulose, the most characteristic proximate principle of wood, is of the same type as starch and sugar and capable of conversion into a fermentable carbohydrate, dextrose, commonly called glucose, has long been known. In the article from which this abstract is being made, F. W. Kressman gives a great deal of interesting information and presents the practical side of the utilization of wood as a source of ethyl alcohol. As a preliminary he gives some data in regard to