HOW CLINICAL THERMOMETERS ARE STANDARDIZED AND TESTED.

BY HERBERT T. WADE.

Few instruments play a more important part in illness than the clinical thermometer, and in the hands of physician and nurse it affords a most valuable indication of the condition of the patient. So useful is the observation of the bodily temperature, that changes that might seem minute and inconsequential often have a significance not to be underestimated. Consequently the accuracy of the clinical thermometer is most essential, and it is hardly an exaggeration to say that on its readings life and death may sometimes depend. For that reason physicians demand a correct instrument; and as few can test them by comparison with accurate standards, they usually are forced to depend upon the certificate accompanying the instrument. In many cases in order to have a certificate from a responsible laboratory or bureau, as that of Kew in England, or the Physikalisch-Technische Reichsanstalt in Germany, American physicians have purchased clinical thermometers of foreign make, as in the case of domestic instruments the only certificates issued in most instances were those of the maker, the correctness of whose standards there is often no means of determining.

This has been changed since the establishment of the National Bureau of Standards at Washington, now a branch of the Department of Commerce and Labor; for one of its most practical and important works is the testing of clinical thermometers. To such as meet its requirements a certificate bearing the seal of the Bureau and the signature of its director is issued, so that a purchaser or user may know what dependence to place on the accuracy of the instrument. Clinical thermometers either singly or in quantity are thus tested, and as the fees are merely nominal, the privilege is widely availed of, especially by manufacturers, who since the inauguration of this work by the bureau have seconded the efforts of its officials to raise the standard of American clinical thermometers. The Bureau of Standards has taken up this duty in a most systematic manner, and special and ingenious apparatus, the most important of which is here illustrated, has been devised to facilitate the work and is installed in a special laboratory in the recently completed building of the bureau.

Clinical thermometers are constructed in many forms, but the most usual type, designed to record the highest temperature to which they have been exposed, is self-registering, with a lens front, so that the image of the mercury thread and scale is magnified, enabling tenths of a degree to be read distinctly against the white enameled-glass background. The registration is effected by means of a contraction in the bore of the thermometer, through which the mercury when it expands in the bulb can only pass in fine globules. When the mercury has acquired the surrounding temperature and ceased to expand, it is held in the upper part of the tube by the contraction, and is not allowed to return to the bulb under ordinary conditions, until a reading has been made. However, the mercury can be forced back through this fine passage by using sufficient force, which in actual practice must be such as can be given with a quick and dexterous twist of the wrist and forearm. In this way the thread of mercury is brought below 95 deg. F. (98.4 deg. F. is the normal temperature of the body) and the instrument is in readiness to make a reading. In actual use the thermometer is placed under the tongue or elsewhere to secure the body temperature, and under ordinary conditions should assume the proper temperature in from half a minute to two minutes, the difference in time depending largely on the construction of the thermometer, such factors as the thickness of the bulb and the amount of mercury contained affecting the length of time that should elapse before a reading can be made.

Clinical thermometers, like other thermometers, should be thoroughly aged before being marked and tested, as the glass contracts and experiences other changes in the first few months. This question was one of the first to be agitated by the Bureau when the testing of thermometers was undertaken, as it was desirable to guarantee this aging. This matter has not yet been definitely determined, and consequently each certificate bears the proviso "Unless this thermometer has been suitably aged before testing, its indications are liable to change with time." In actual experiments, however, it was found that by using hard thermometer glass for the bulbs the changes in the indications after the first three or four months were practically negligible.

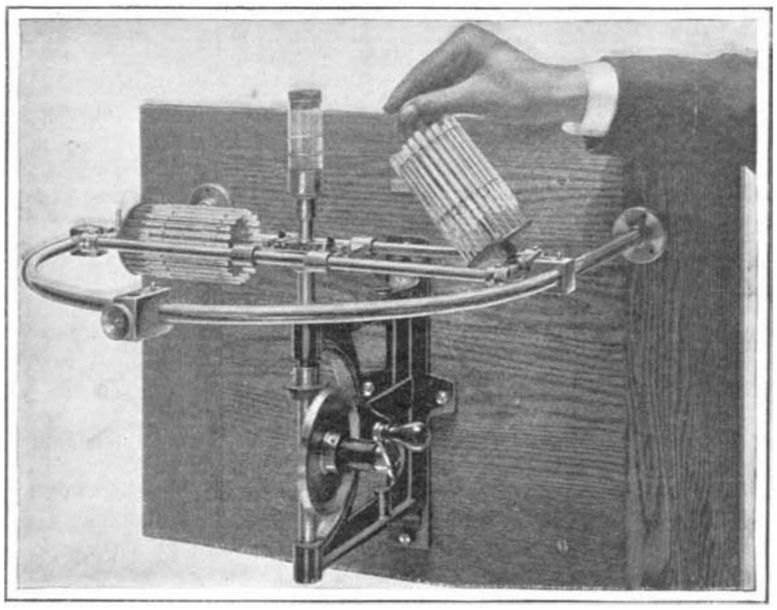

Fig. 2.—National Bureau of Standards Whirling Machine for Driving Back the Index into the Bulb.

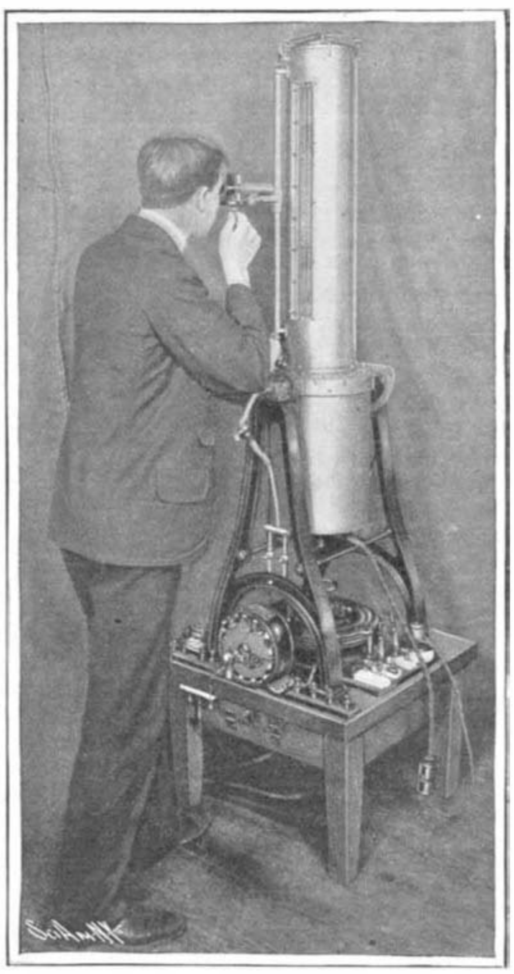

Fig. 1.—National Bureau of Standards Comparator for Testing Standard Thermometers.

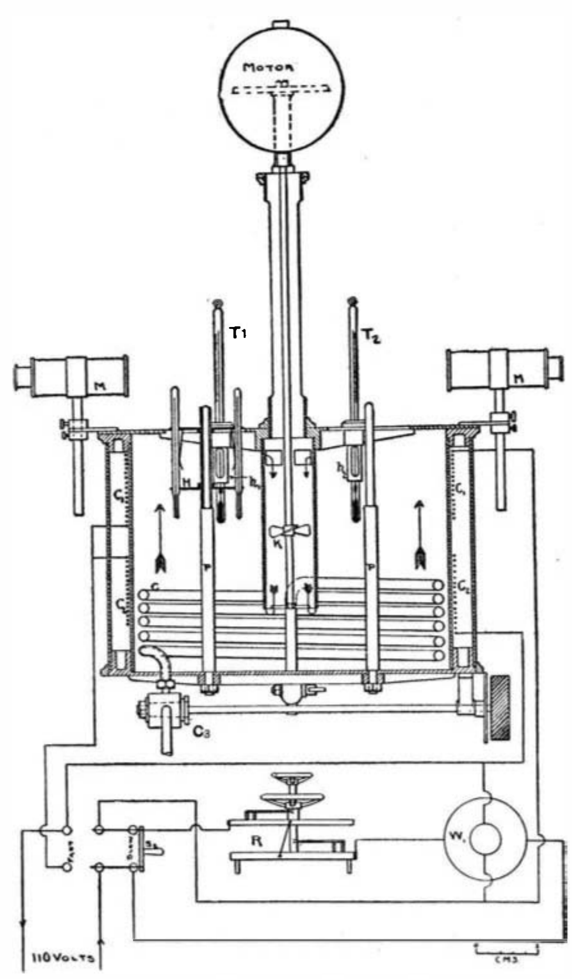

Fig. 4.—Section of Comparison Tank.

The bureau when it began first to test thermometers found most surprising variations in the readings of different instruments under the same conditions, and as in some instruments from certain manufacturers these discrepancies were constant it was suspected immediately that the standards on which they were based were inaccurate. Accordingly the leading manufacturers of the country were invited to submit their standards for study, and in many cases their inaccuracy was soon demonstrated, while in others it was found also that an unsuitable form of standard was being used. Accordingly certain standards of the bureau were loaned to manufacturers, others constructed according to its recommendations were submitted for test, while still others were graduated or pointed at the bureau. These standards were all compared directly with the primary standards of the bureau, which are graduated according to the international hydrogen scale adopted by the International Committee of Weights and Measures in 1887. This is the Centigrade scale of the hydrogen thermometer, where the fixed points of temperature are those of melting ice and of water vapor or steam at atmospheric pressure, the hydrogen gas being taken at an initial pressure of 1 meter of mercury or 1.3158 times the standard atmospheric pressure of 760 millimeters, or 30 inches, of mercury. For comparing the standard mercurial thermometers, use is made of an improved form of comparator which forms the subject of our illustration (Fig. 1). The thermometers are immersed in a tank of water whose temperature can be controlled by means of hot and cold water supply and a system of heating coils through which current can be passed at the will of the observer, who thus is enabled to secure with accuracy any desired temperature. The thermometers are read by means of the small microscope through the glass window in the cylinder, while an electrically driven agitator keeps the water in constant circulation. Such an instrument enables a direct comparison to be made between a standard and other thermometers for all points between the boiling and freezing points of water.

The first practical result of this activity on the part of the bureau was to bring to the same standard scale of temperature all the makers of clinical thermometers in the United States, and this was immediately shown in a highly improved grade of thermometers that were submitted when the testing work was established on a permanent and useful basis. This testing now has been reduced to a system which insures accuracy with facility of working, and a competent staff are able to pass upon all instruments submitted for test. Thermometers when first received for testing at the bureau are examined to detect any defects as regards actual construction. Thus air-bubbles in the mercury or in the capillary tube, cracks in the glass, defective graduation, and similar deficiencies eliminate the thermometers from further consideration. For the actual testing they are placed in lots of 24 in small holders in which they can be placed in the

(Continued on page 298.)

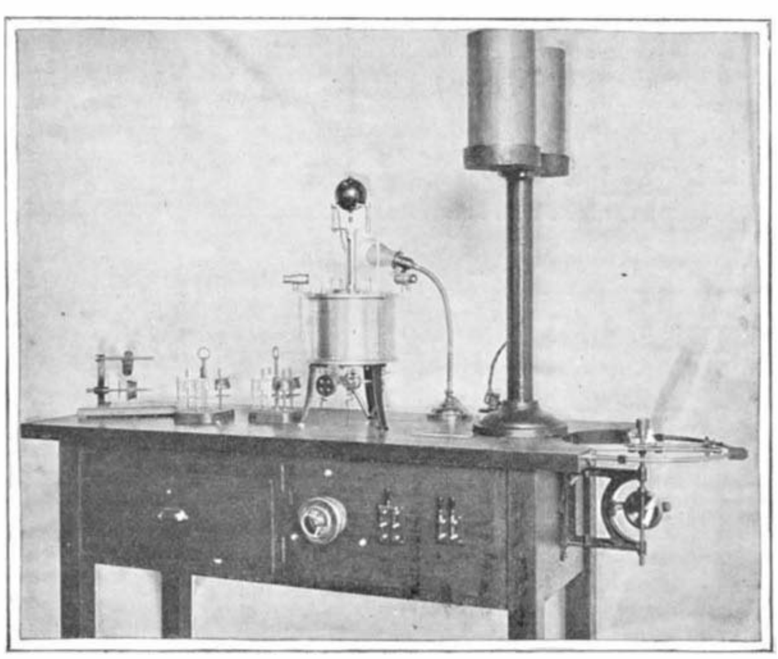

Fig. 3.—Clinical Thermometer Testing Table. National Bureau of Standards.

HOW CLINICAL THERMOMETERS ARE STANDARDIZED AND TESTED.

The first of the new steamers launched, the "Elbert H. Gary," in June last, broke all previous records for Great Lakes cargoes by carrying 12,003 tons, or 13,443 net tons of iron ore from Escanaba to South Chicago. The greatest records in unloading the new ships have been made at Conneaut harbor, where a cargo of 9,945 tons was unloaded from the "Gary" in four hours and fifty minutes. The sister ship, the "George W. Perkins," was unloaded at Conneaut on July 17 of 10,514 tons in four hours and fourteen minutes. This broke all previous unloading records.

It is said that an order will be placed with the shipyards for a vessel 578 feet long in the not far distant future. This would be still 9 feet longer than the four new ships of the United States Steel Corporation. The majority of ore vessels of the future will likely be of 10,000 tons capacity or thereabout.

HOW CLINICAL THERMOMETERS ARE STANDARDIZED AND TESTED.

(*Continued from page 296.*)

whirling machine, the comparison tank, and the reading stand without undergoing further separate handling. The thermometers when received are of course all numbered, and each lot is also given a number, so that it is easy to keep the record throughout the process. First to determine the ease with which the mercury can be thrown back the whirling machine shown in Fig. 2 is employed. This mechanical device takes the place of the individual throwing back of the index by hand, a performance that often proves so discouraging to the amateur nurse. Two holders whose thermometers have been heated above the normal point are placed in a frame so that the bulbs are at the opposite extremities of a horizontal axis. This is then revolved in a horizontal plane by a vertical shaft through the agency of a crank and bevel gearing as shown in the illustration. On top of this vertical shaft is a glass tube filled with oil or glycerin, and as it is revolved the surface of the liquid takes a parabolic form, the depression of the center of course depending on the speed of rotation. This can be so gaged as to correspond with the maximum muscular effort that should be expended in throwing back the index, and all the observer has to do is simply to turn the crank until the proper speed of rotation is attained. The thermometers that do not fall below 95 deg. F. are removed and rejected, and the holder is then placed in the comparison tank where the clinical thermometers are compared directly with the testing standards of the bureau. This comparison is made at four test temperatures, 96, 100, 104, and 108 deg. F. (or 35, 37, 39, and 42 deg. in the case of Centigrade thermometers) in a water bath, where there is a constant circulation of the liquid, and two standard thermometers are employed in each series of tests. This tank, which appears in the center of the clinical testing table shown in the illustration (Fig. 3), is shown in section in Fig. 4. It is a double-walled vessel of seamless brass tubing, within which is a propeller, *K*, driven by an electric motor and serving to keep the water continually in agitation, the direction of the currents being shown by the arrows. The tank also contains a coil of seamless copper tubing, *C*, through which hot or cold water from the regular laboratory supply can flow, the temperature being susceptible of regulation by the observer through the agency of the two-way mixing cock, C_3. There are four standards, indicated by *PP*, on each of which one of the thermometer holders, *H*, is placed, thus permitting ninety-six thermometers to be immersed in the tank at once. The standard thermometers, T, T_2, pass through the cover of the tank and can be read by the small microscopes, *M M*. In practice, however, one microscope proves sufficient, as it can be turned readily from one standard to the other. In the annular space surrounding the inner tank there are two heating coils of cotton-covered constantan wire, C_1 and C_2, shellacked in place around a fine layer of mica. These coils, the resistance of each of which is 80 ohms, are connected with a 110-volt circuit, a rheostat, *R*, to regulate the current, and a wattmeter, *W*, to measure the consumption of energy in the circuit as shown in the diagram. The switch, S_2, when in the position marked "Fast," allows the entire current to flow through the heating coils, but when turned to the "Slow" position it is possible to regulate the current with considerable nicety, as well as to measure with the wattmeter the amount of electrical energy consumed in maintaining a given temperature. The illustration shows the arrangement of rheostat and switches on the side of the table, the wattmeter being inside the top of the table and read through a glass plate. The electric light illuminates the scales of the standard thermometers, while at the right end of the table are shown the hot and cold water cylinders or tanks in which it is possible by electric coils to secure at will a considerable range of temperature.

The process of testing is first to bring the temperature of the water in the comparison tank up to nearly the lowest test point, first using the hot water supply, and then by employing the heating coils and fine regulation bring the temperature to exactly 96 deg. F., when the standard thermometers are read. All of the holders are then dipped at this temperature, readings of the standard thermometer being made and noted in each case. The holder on removal is placed in a reading microscope, shown on the extreme left of the table, where the exact position of the mercury in each thermometer is observed, the holder being rotated so that each thermometer successively comes into the field of view of the microscope. These readings are all tabulated and the performance is repeated at the three other test points, after which the whirling machine is again called into requisition, and then a second and independent series of tests of the holder is made. If the thermometers pass the tests they are coated with wax and the letters "B. S." and the proper serial number are engraved on the stem, which is permanently etched by immersion in hydrofluoric acid. The bureau demands, as a condition of certification, that the difference at any point in the two series of tests shall not be more than 0.15 deg. F., and that the correction at any point shall not be more than 0.3 deg. F., while the errors in the intervals between the test points must not exceed 0.3 deg. F. Quite naturally there is a demand that thermometers be supplied without any errors—or, speaking scientifically, with a zero correction—and this requires that the manufacturers use extraordinary care in their construction. From the practical point of view it is more important that the error should be known, as if a thermometer is correct to 0.1 deg. F. it is sufficiently accurate for all ordinary work and for most purposes should prove as satisfactory as one with a zero correction, while one with a correction of 0.2 deg. F. can be used, provided the correction is considered when necessary. In the year ending July 1, 1904, of the thermometers submitted for test 88.2 per cent were certified as meeting the requirements of the board, showing that while a fair standard of construction is maintained, yet there is a need of such an official examination. Large numbers of thermometers are being constantly offered for test, and it is the general belief of those interested that the standard of manufacture is being raised. It is possible that at some future time the bureau may provide for the aging of thermometers by placing them under seal for a certain length of time, and thus be in a position to insure that they have been thoroughly seasoned. Other changes in the requirements may be made from time to time as it is found necessary, but the work so far has proved satisfactory to all parties concerned, and is representative of one side of the activity of the Bureau of Standards. The section of thermometry of the Bureau of Standards is under the capable supervision of Dr. C. W. Waidner, whose interesting papers on thermometry and pyrometry published in the Bulletin of the Bureau of Standards, and elsewhere, can be read with profit by all interested in heat measurements.

The Current Supplement.

A. Frederick Collins opens the current SUPPLEMENT, No. 1554, with an article on industrial automobiles. Almost every engineer and electrician is familiar with the fact that the majority of steam-power plants are not operated under the most economical conditions. William McKay analyzes these conditions and makes some helpful suggestions. The completion of the twin tunnels under the Hudson River is described and illustrated. Sir William Crookes's paper on "Diamonds" is concluded. Dr. Alfred Gradenwitz writes on lignite producer-gas plants, describing some new installations. Although the information lately published concerning steam turbines is voluminous, it is difficult to find any unbiased general statements regarding all types of such machines. Prof. Storm Bull gives a classification of turbines and enumerates their peculiarities. Donald Murray presents a most thorough and excellent *résumé* of page-printing telegraphs. His article is of particular interest, inasmuch as he is himself one of the best known of printing telegraph inventors. Of minor articles in the SUPPLEMENT we may mention those entitled "Heat," "How to Read Wild Life," and "Aluminium Alloys."

Synthetic Alcohol.

The Compagnie Urbaine has recently conducted some experiments at its factory at Puteaux concerning synthetic alcohol. A mixture of coke, lime, and various metallic oxides was subjected to the heat of an electric furnace, and a carbide obtained denominated "ethylogene," which by the action of water engendered ethylene. The latter, absorbed by sulphuric acid, furnishes sulphoninic acid, from which alcohol is extracted by distillation with water. At the same time an ether is produced, a little acetic acid, and acetone.

Production of Cocaine in Peru.

This industry has been much developed of late years. The factories producing cocaine are scattered through different localities. The production has reached 11,000 kilogrammes per year, corresponding to the treatment of about 1,500 tons of coca leaves. The leaves are exported for use in the production of wine and various medicaments. The total production of leaves is estimated to exceed 2,000 tons, not including the quantity consumed by the inhabitants. The cocaine exported from Peru is not chemically pure; it contains from one and a half to two per cent of impurities. The most important market for the product is Hamburg, where the demand is constantly increasing. At that port the crude product is purified and resold.—Revue de Chimie Industrielle.

Correspondence.

Soaring of Birds.

To the Editor of the SCIENTIFIC AMERICAN:

In the summer of 1872 I was visiting on the Warm Springs Reservation in eastern Oregon. The residences of the government employes, etc., were in a deep valley between table-lands through which the water-courses had cut deep cañons. I climbed up on one of these tables, the edge of which was in most places perpendicular for ten, twenty, and more feet; and as I stood there in a strong breeze blowing against the face of the slope, a small hawk came gliding along eight or ten feet above the edge, and following the course of the edge; and he kept on until he was little more than a rod away from me. He seemed to be making no effort except a little balancing and turning in order to steer himself. The explanation seemed to me very simple; just there at the edge there was a strong, sharply-ascending current which enabled him to use wind and gravity against each other.

In the autumn of that year I went to Foochow, China, and there I found the city frequented by a species of large bird which we call a kite. It seems to be half hawk, half buzzard in its build and habits. Its flight is heavy and awkward, its wings being too big for its pectoral muscles; and their tips are not pointed like a hawk's, but broad and square across. But it is a master of the art of soaring. There are in Foochow two hills which lie square across the path of the afternoon sea breeze. Here, toward the close of a breezy autumn afternoon, a dozen or a score of these kites will resort and have a genuine coasting game. The sides of the hills are quite steep, and of course there results a strong, sharp upward current at the top. The kites come to the top, and, starting from the eddy in the lee of the top, glide out into the uprushing current, wings balancing up and down and head and tail turning and twisting, till they are in the heart of the upward current; and then they turn broadside to it and are borne upward and backward seventy-five or a hundred feet. Then they descend again into the eddy, and again steer themselves out into the uprushing current. Throughout it all there is very little flapping of the wings; and if the American boy could get his sled back to the top of the hill as easily as these kites get back into the uprushing current, no Chinaman could describe his coasting as: "Whish-sh-sh-sh—walkee backee mile!"

One autumn day here in the interior I came to a stretch of waste land by the river covered with tall, dry grass and dwarf bamboos. A Chinaman had just set fire to it, and a strong column of smoke and hot air was ascending, when I saw one of these kites steer straight into that ascending column, and begin to circle round and round in it; and as he did so, he was steadily lifted upward as much as 150 or 200 feet. Then he went soaring off again. One cool, sunny day last spring, when the air was cool, but the sun very hot, I saw a kite steering for a group of buildings just in front of me, from the dark tile roofs of which currents of heated air were ascending. I supposed that the kite was coming to see if he could nab a spring chick; but when he reached the place he at once began circling round and round, sometimes from right to left, sometimes from left to right, at the same time drifting away before a nice breeze from the north; but as he did so he was gradually carried upward till he was at least 500 feet above the ground. Then he drew in his pinions somewhat, just as a hawk does in swooping, and, turning square against the breeze, glided away to the north with the speed of a race horse.

Just west of where I now am is a long, steep slope of perhaps 2,000 feet. The lower half is in the lee of another mountain; but the upper half is fully exposed to the southwest winds of the season. Recently when the wind was almost a gale, I saw a small hawk having a merry coast. The wind was gusty, and sometimes it would bear him up finely; and he would even take a shoot both upward against gravity, and outward against the wind. Again, the wind would suddenly fail him, and then he would flutter his wings much as a kingfisher does when poising over the water, till a fresh gust came to his help.

I was much interested in the feats of Lilienthal. He had evidently mastered the kite's secret of the use of upward currents—the use of the upward current and gravity against each other—but alas! he did not have the kite's body, nor the kite's matchless skill in steering.

J. E. WALKER.

Shaowu, Fukien, China, August 7, 1905.