adjustment to size, will remain of constant size over a considerable period of time. Provision is made for use of the natural horizon, when required, by swinging the bubble gear out of the way. As the instrument is designed for use both by night and day, electric lighting for both bubble and scales has been provided.

THE SEXTANT PROPER. (See Figures 1 and 2).

The sextant proper consists of a box *A* in which are housed the micrometer worm with its fittings, and an arc in engagement with the same, the latter constituting the limb of the sextant. The limb is divided to single degrees and is read through a window *B* against a fixed index mark, while the minutes are read through an adjacent window *C* on the micrometer drum.

The movements of the limb and the index mirror are controlled in either of two ways :-

(*a*) For slow movement or fine adjustment by rotating the outer rim *E* of the right handle.

(*b*) For quick setting or searching by rotating the outer rim *E* of the right handle after pushing home below the edge of the left handle the lever *D*. On releasing the lever *D* the motion reverts to slow.

The whole of the mechanism of both the quick and slow motions is contained within the sextant box *A* and is protected from dirt and also accidental damage.

The horizon mirror is secured to the casing of the sextant work while the index mirror is secured to the pivot of the limb which is carried through the limb casing for that purpose. The horizon mirror is fully silvered, the index mirror *F* being unsilvered so that the sextant can be used in two different ways as will be explained later. The mirrors are protected by a guard plate, mounted on three pillars, which also serves to carry three shade glasses *G* and the left handle *H*.

The theory of the mechanism forming the bubble was explained in the above mentioned *Hydrographic Review*, p. 153, so we shall not revert to it here. The bubble gear *K* consists of the actual bubble chamber *M* which is in communication with the operating chamber *L* and the reserve chamber *N*. It is also known that the bubble is formed by manipulation of the screw *O*.

Daylight illumination of the bubble is provided by the white reflector *P* which must be folded down over the bubble chamber *M* at a slope of about 45°. In the photograph the reflector *P* is folded away to enable the chambers to be seen clearly.

At night illumination is provided by the lamp *Q* shining on the reflector *P* folded down as before. The light given by the lamp *Q* is controlled by the rheostat *R*, the adjustment being made by moving the small knob *S* till the bubble illumination is sufficiently dim.

Night illumination of the scales is given by the lamp *T* controlled by the lamp switch *U*. A 2-volt battery is connected by means of flexible cord and plug to the socket *V* when electric lighting is required. Three shade glasses *G* may be interposed as required in the path of the sun rays reaching the index mirror.

GRADUATION OF PRECISION CIRCLES. (*)

(Extract from the *Journal of the Franklin Institute*, Lancaster, Pa., November 1934, p. 623).

The Bureau's circular dividing engine and the type of graduating work done on it have been briefly described in *Technical News Bulletin* Nos. 128 and 149 (December 1927 and September 1929). This instrument has been used during the past nine months in

(*) *Notes from the U. S. Bureau of Standards : United States of America.*

producing graduated circles of a high order of accuracy, for the U. S. Coast and Geodetic Survey.

The triangulation program of the Coast and Geodetic Survey has necessitated the acquiring of a considerable number of graduated circles for new theodolites. Two types of PARKHURST theodolites, for which circles have been supplied, are employed in this program, the first order theodolite using a 9-inch circle, and the second order theodolite using a 6 ½-inch circle. Both sizes of circles have been made and graduated at the National Bureau of Standards. In addition to the new circles, a number of old ones have been regraduated.

Nearly all of the new circles are of cast sterling silver. A few circles are of duralumin and a few, for regraduation, are of bronze with an inserted sterling silver ring. These special circles require no particular discussion at this time.

The circles go through the following processes: (1) casting of the sterling-silver disk; (2) heat-treatment to relieve the casting strains; (3) machining to approximate size; (4) heat-treatment to relieve machining strains and to further stabilize the material; (5) machining to a size suitable for plating; (6) electro-plating with silver, using cyanide bath; (7) machining to finished size; (8) inscribing the coarse series of numbers and graduations; (9) polishing to a plane on pitch-lap with chromium oxide; (10) inscribing the fine numbers; (1) polishing the burrs from the fine numbers; (12) graduating the circle; (13) polishing the burrs from the graduation lines; and (14) filling the lines with special black ink.

With the exception of a few of the first circles, the entire task from the casting of the silver to the completion of the graduated circle was carried out at this Bureau.

In the heat treatment to relieve casting strains, the disks are placed in an electric muffle furnace, and the temperature slowly raised to between 550 and 600° C. with the disks in a reducing atmosphere of illuminating gas. This temperature is held for two hours and the disks are then allowed to cool in the furnace. The second heat treatment, given after the disks are machined nearly to size, is similar to the first one, except that the temperature is only 400° C. and the time 1 ½ hours. In this second treatment each disk is mounted on a special mandrel so as to be supported as uniformly as possible. The distortion of circles by internal strains is believed to be one cause in the past for what have been regarded as incorrectly-graduated circles. These two heat treatments are for the purpose of obtaining as great dimensional stability as possible.

The silver-plating was found necessary because it was not possible to graduate the sterling-silver disks and obtain the kind of graduation-line required, for example, on rolled silver. The crystals of the sterling silver are large, and differ in physical characteristics even in a single circle so that the graduating tool will not cut uniform lines all around the circle. Many of the lines made on the sterling-silver crystals seem to be torn rather than cut.

The polishing of the circle is an essential part of the present procedure. This is not done to produce a reflecting surface but for the purpose of getting a true plane for two reasons, first because the accuracy required demands it and secondly because lines with smooth, sharp edges can be made only on such a surface.

In the actual graduation of the circles several changes and improvements have been made, perhaps the most important of which is that of using a specially constructed diamond-point, adjusted so that a very fine shaving is cut out of the material, leaving sharp edges to the line and a very small amount of burr which is quickly removed with a pitch-lap and chromium oxide. No charcoal is used in the process at any time.

Although several changes in the ruling mechanism of the dividing-engine were found necessary, the principal elements of the machine, the main central bearing, the worm, the gear-teeth around the periphery of the central table, and the contour of the correcting-device, were found to be satisfactory.

After the circles have been completed they are checked on the Bureau's circle-testing machine. Because of the limited time a complete test of the circle cannot be made, but with the microscopes set 90° apart it is possible to determine with fair accuracy whether or not the graduations are uniformly spaced.

The Coast and Geodetic Survey then makes a more extended test of the circles when actually mounted in a theodolite. A series of collimators set up around a room with the theodolite in the centre enables measurements to be made just as they would be in the field, sighting many miles away. The results obtained in these tests agree with those made by this Bureau within the range of experimental error.

There is considerable difficulty in stating precisely how accurate these circles are. When it is considered that there are 4320 lines on each of these circles and that on these 9-inch circles an angle of one second is about 0.00002 inch, one must have considerable numerical data to support any statement made. These circles certainly are accurate within the tolerance of two seconds of arc given in the specifications. It is believed that they may be within approximately $\pm$ 1 second.

The successful carrying out of this program of preparation, graduation, and calibration of precision-circles at the National Bureau of Standards has involved the fullest cooperation of several technical divisions of the Bureau, particularly the divisions of metallurgy, chemistry, optics, and weights and measures. L. V. JUDSON, chief of the length section, has had the immediate supervision of this program and B. L. PAGE has carried out the actual graduation of these circles.

A paper giving more detailed technical description of this work is in preparation.

IDRAC APPARATUS FOR MEASURING VERTICAL SUBMARINE CURRENTS.

by

PIERRE IDRAC.

(Extract from the *Bulletin de l'Institut Océanographique*, No. 636-637, Monaco, 25th November, 1933).

(See also : *International Hydrographic Bulletin* No. I, 1934, p. 15.
The Hydrographic Review, Vol. V. No. 2, Nov. 1928, p. 155.
" Vol. VII. No. 1, May 1930, p. 238.
" Vol. IX. No. 1, May 1932, p. 235).

This apparatus is intended for measuring the vertical component of a deep-sea current (submarine or sublacustral).

It consists essentially of a screw on a vertical axis, the blades of which are slightly inclined to the horizontal, the whole being mounted in a specially designed casing, the details of which it would be too long to go into here. The peculiarities of the mounting are such that, due to the perfect symmetry of form about the horizontal axis and a great dissymmetry of weight, the axis of the screw is truly vertical in any current, and this screw, wholly insensitive to horizontal currents, can begin to rotate only if the current includes an ascending or a descending component; the speed of rotation of the screw is very nearly proportional to this component.

The screw operates a revolving contact so designed as not be influenced by electrolytic phenomena, and provided with a make-and-break system arranged to give Morse signals.

The reading device, fitted on board the vessel, consists of a Wheatstone bridge with milliammeter, balanced by means of an adjustable resistance. The breaking of the current destroys the balance of the bridge and causes the pointer to move.

The dissymetry of the signals selected (*U* or *D*, according to the direction) enables a distinction to be made between the ascending and descending movements, and also obviates doubts arising from the rolling of the ship.

Owing to the clearness of the signals, the insulation need not be perfect, and experience has shown that a well insulated flexible two-core (9/10 gauge) cable, as used in commerce, is sufficient to ensure both the transmission of the electric current and the support of the apparatus, which is of very light weight (about 11 lbs).

This apparatus, which starts giving readings at a vertical current velocity of 3 cm/sec. can easily be used from a small craft and lowered down to several hundred metres depth.

Trials of the apparatus were made last summer in the *Eider*, of the Monaco Oceanographic Museum, with a view to exploring the submarine springs off Cap Martin. It was thus ascertained that the vertical current engendered by the spring furthest off-shore attained 25 cm/sec. in certain places, and that of the spring nearest the coast, 50 cm/sec. This shows the considerable output of these springs, which must be considered as veritable submarine discharges from a small underground river.

The same apparatus has been used in the bay of Villefranche with the assistance of the Zoological Laboratory and of M. TRÉGOUBOFF; the trials are being continued in order to ascertain whether the vertical movements might not, at times, account for the migration to the surface of animals from great depths.
