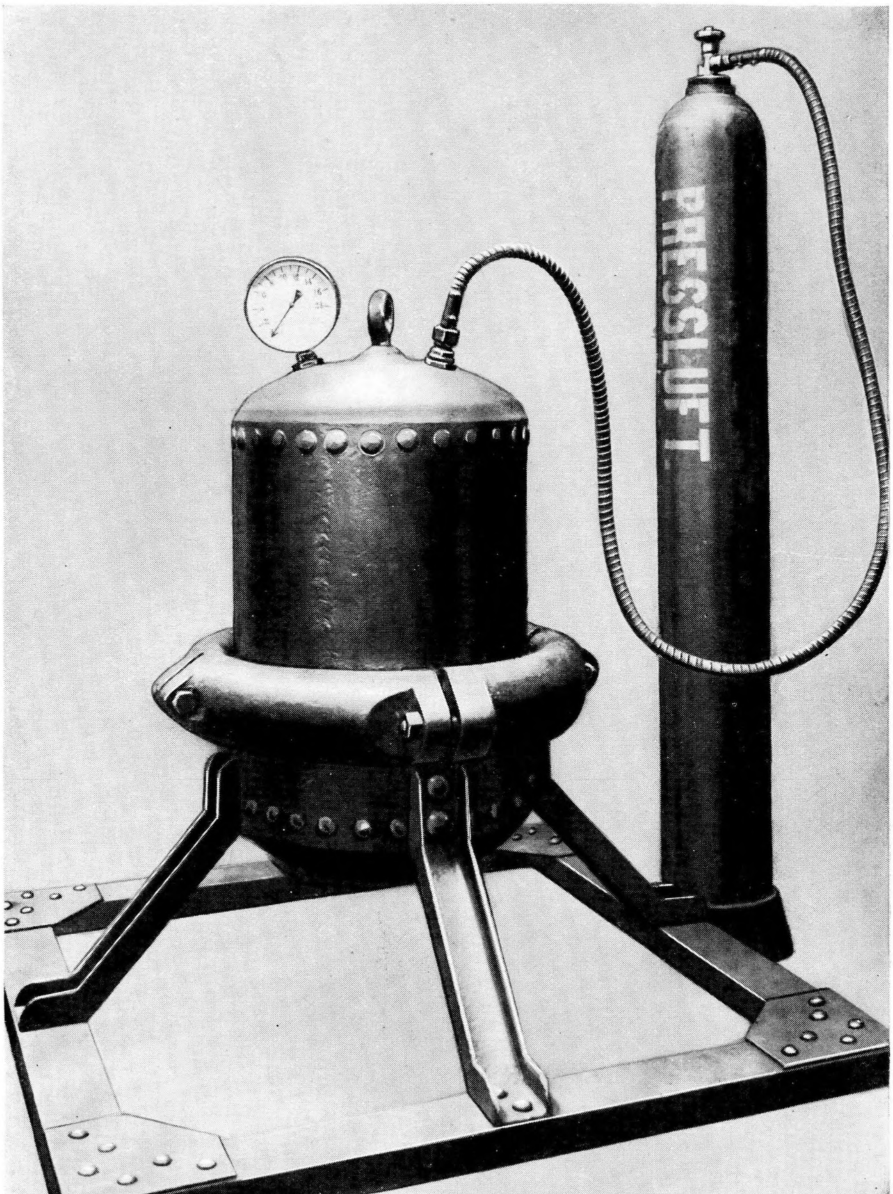

FIG. 1 — Kuhlmann Tide-Gauge — Putting under Pressure.

THE KUHLMANN SUBMARINE OR HIGH SEA TIDE GAUGE. (*)

DESCRIPTION AND WORKING DIRECTIONS

From Notes supplied by FRANZ KUHLMANN,
Werkstätten fur Präzisions-Mechanik,
Rüstringen — Wilhelmshaven (Germany).

The high sea tide gauge is used to ascertain tidal conditions and shows the variations of level at high and low tide, in respect of both time and altitude, by means of a curve, and independently of the actual depth of the water.

The gauge consists of a tank, which is air and watertight and supported by means of a frame. The plate marked (1) divides the tank into two separate compartments or chambers, both air and watertight, the said plate being firmly bolted to the base of the tank. Both compartments are kept securely together by a quadruple crampring (2), and the screws (3).

The recording apparatus with a Bourdon Tube (4) is located in the top portion of the tank. All parts are easy of access, after removing the cover (35).

The lower chamber is fitted with a device which automatically admits and shuts off the water.

The recording device consists of the above mentioned Bourdon Tube (4) with direct inner connection to the lower chamber. The closed extremity of the tube, which consists of six single tubes, is fitted with a pin (5), and this can be adjusted by means of the adjusting screw (6). Pin (5) rests on a plate (7), connected leverwise to axle (8). The lever becomes longer or shorter according to the displacement of the pin, so that the displacement degree of tube-end will bring about a larger or smaller turning angle of the axle (8). A clock spring (36) is fitted on the axle, the lever and plate being thus gently pressed against pin (5). A small mirror (9) is also mounted on the axle, both revolving simultaneously. Opposite the plate or instrument board, the two clockwork movements (10 and 11) have been mounted.

Clock (10) is an accurately timed movement, fitted with a barrel (drum) (12) and marking 24 hours. The circumference of the barrel covers 12 m/m per

(*) NOTE BY THE DIRECTING COMMITTEE.— An apparatus based on almost identical principles was invented by the Hydrographer FAVE and has been used in France for about twenty years. It is described in the *Annales Hydrographiques,* Vol. 30 (1908-10) and Vol. 4 (1921).

hour. The movement goes on uninterruptedly for 14 to 15 days. The purpose of clock (11) is to wind the paper issuing from barrel (12) on to drum (13) It has no pendulum or vibration-rod, its motion being regulated by the paper which comes from drum (12). The device (14) is to stop the working.

A third drum (15) is used as a storage-drum for the unused paper. The paper is of highly sensitive silver bromide nature and should be carefully shielded from light. There is a top and bottom layer of black paper 1 metre long, and it is wound on a paper cone. This enables the fixing of the roll and its subsequent removal to be carried out in daylight.

Figure 5 shows the direction followed by the paper (*see* dotted line).

The drum (13) is provided with a spring to grip the paper right from the start and this is worked either by pulling or releasing.

Stop-device (14) consists of a spring-pin, lodged — when at rest — in one of the holes of the spring-drum, and this effectively prevents the movement of the clockwork. A pull on knob (37) will release the clock. To obviate involuntary stoppages, the pin has a crossbar that rests in a groove of the pin-holder. The right position is arrived at by turning 90° to right or left.

To stop the clock, turn the pin 90°, then let go and it becomes lodged into the next hole of the spring barrel. Barrels or drums can be shifted if the side-nuts (32) and (33) above the barrel axle or spindle are loosened. The storage drum is held by two nuts, one being the lock-nut. A washer is inserted between nuts and barrel. Care must be taken, when placing the storage-drum (15) in position, that the nuts are not too tight, and the drum should revolve with just a light pull on the paper. To work the paper, first place the paper roll on the cylinder, arrange the paper around the clockwork barrel (12), convey it to the winding on roll (13), where it is clamped under the spring. Care should be taken that paper is laid uniformly in a flat position. At this stage, both the side-nuts of the clock-barrel (roller) and of the raising roller should be loosened somewhat, to ensure smooth running of the cylinders. Also see, when placing the paper, that the black paper is wound about one complete turn on the raising roller, as otherwise the highly sensitive silver bromide paper might come forward. Then tighten the side-bolt of the raising roller, place the casing (19) over the drums so that the slit is in the direction of the mirror. Finally fix the cover (31) and secure it with the side-screw (30) Then wind up both clock movements, by means of the key.

In addition to the movable mirror (9) already described, there is also a fixed mirror (16). Both mirrors catch a narrow ray of light, about 0.5 m/m wide and 16 m/m long, traversing lenses (17) and produced by a small electric lamp (18). The ray in the shape of a narrow horizontal stripe, is reflected from both mirrors on to the slit of the casing (19), in such a way that the two stripes practically coincide when there is no load on the tube. If loaded, the luminous ray from the fixed mirror remains in the same position, whereas that from the movable mirror deviates upward. The slit in the casing (19) allows just a mere fraction of the strip to pass, say about 0.5 m/m, both rays thus appearing as points which illuminate the silver bromide paper. The current is supplied by 3 dry batteries and led over a contact (Fig. 5). The latter is controlled by the clockwork (10), which has a contact-disc (25) on

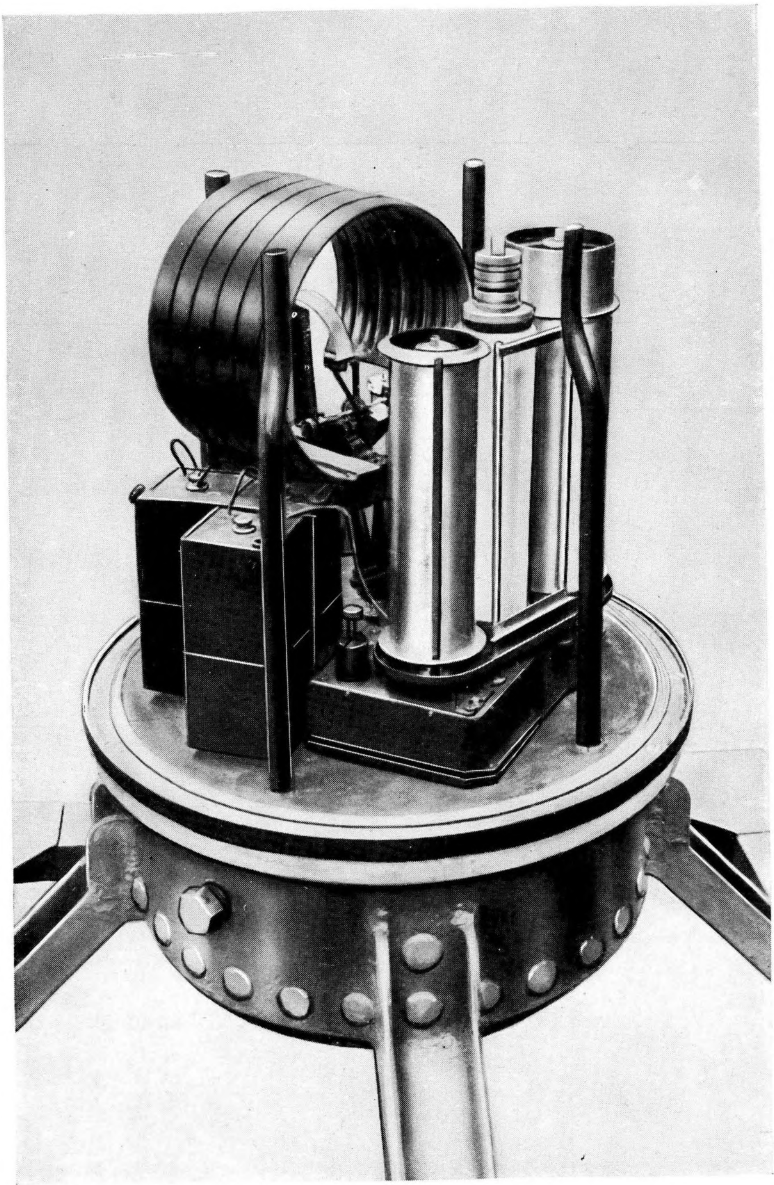

FIG. 2 — Kulmann Tide-Gauge — Bourdon Tube and Registering apparatus.

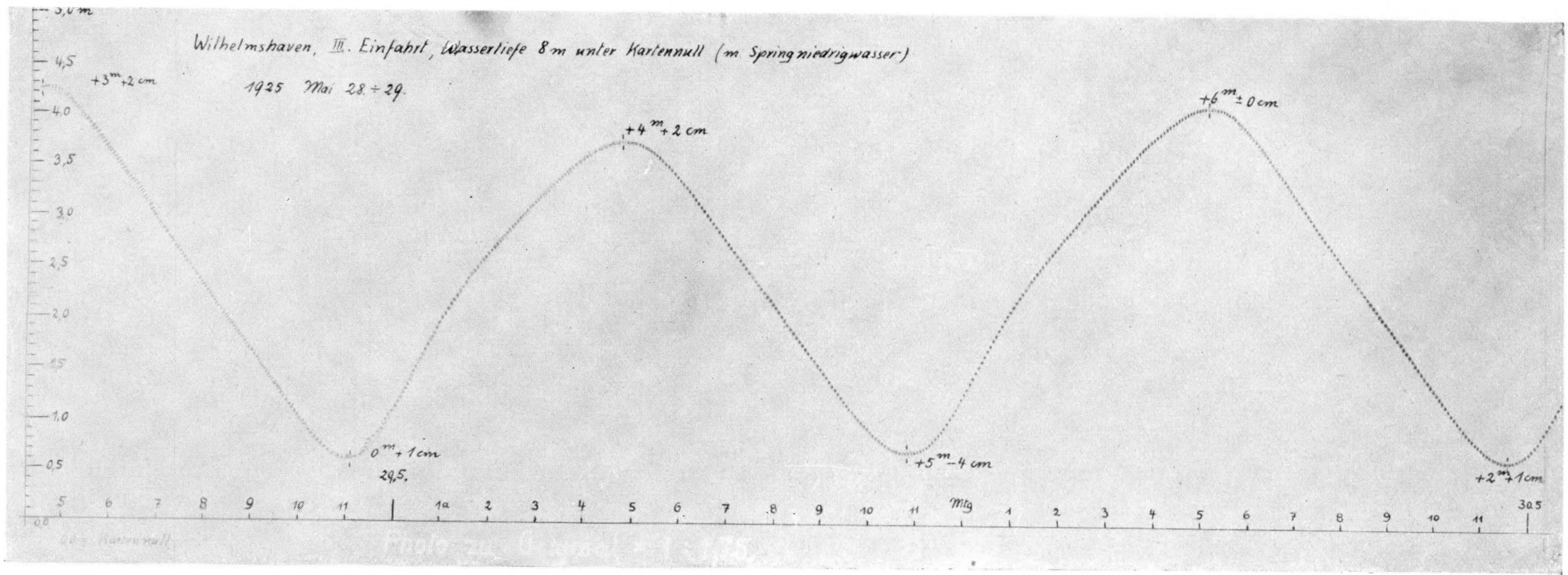

FIG. 3. — Kuhlmann Tide-Gauge — Graph

the wheel-axle (38). The device is so arranged that a contact of about 4 seconds' duration takes place every five minutes.

The curve of the movable mirror and the staight line of the fixed one appear in the shape of linear points in rows, from which the time can be ascertained. The carrier pins of drums (12) have a distance above of one hour and below of six hours, so that in conjunction with the curve-points the time can be easily determined. The straight line, projected from the fixed mirror, represents the base-line which will help to find the curve-heights. The scale taken for the heights will depend on local conditions. The paper, 24 c/m wide, will be used for drawing the curves. As already indicated, pin (5) is connected to the curves. As already indicated, pin (5) is connected to the Bourdon Tube in such a way as to enable the lever length, in connection with the axle, to be made larger or smaller.

With a short lever-length, the mirror projection will be bigger than with a longer one. A scale can thus be selected to suit the tide conditions. If there is but a small difference between high and low water level, a large scale can be adopted and vice versa. The curve-height in centimetres, which represents the difference in metres, should be read at the division point near the spindle.

The automatic water inlet and shut off consists of a tube (20) with piston-track and piston (21). The piston track has an independent mouth and its various openings (22) lead to the inner part of the bottom tank. The piston, as shown by the sketch, blocks these openings. Water comes in through the damper-plate (27), the latter having a rather small inlet-hole to stop possible excessive differences in the water-level. A sieve is fitted in front of the damper plate. The tube (20) communicates with the lower tank by means of the valve (23) operated from outside, which device effectively protects the Bourdon Tube from over-loading. Plate (1) is likewise fitted with a valve (24) for the same purpose, and the latter is also worked from outside by a screw arrangement (26). The method is as follows :

If the gauge were to be submerged without this device, *i.e.* with open water inlet, the pressure would gradually increase within the Bourdon Tube, becoming very high at great depths. A depth of 200 m. would engender a pressure of about 20 atm. To withstand such a pressure the tube would have to be made specially strong, and with small pressure variations, as is often the case with normal tides, only small curve-heights would be shown, even with the air previously pumped into the top chamber to bring the pressure therein to 20 atm. Thus, at a depth of 200 m., pressure inside the tube would be identical with the outer pressure, and the tube would therefore be subject to pressure on one side only.

The above mentioned device enables the Bourdon Tube to reach the sea-bottom in an unloaded condition. An example will show the procedure. At lowest tide, the depth is taken to be 200 m.

First, open valves (23) and (24) and pull up piston (21) if the latter happens to be low down. To this end, the piston is fitted with shank (28), to which it can be drawn, after removing plate (27) by loosening nut (39). Both the upper and lower tanks, as well as the inner section of tube (20)

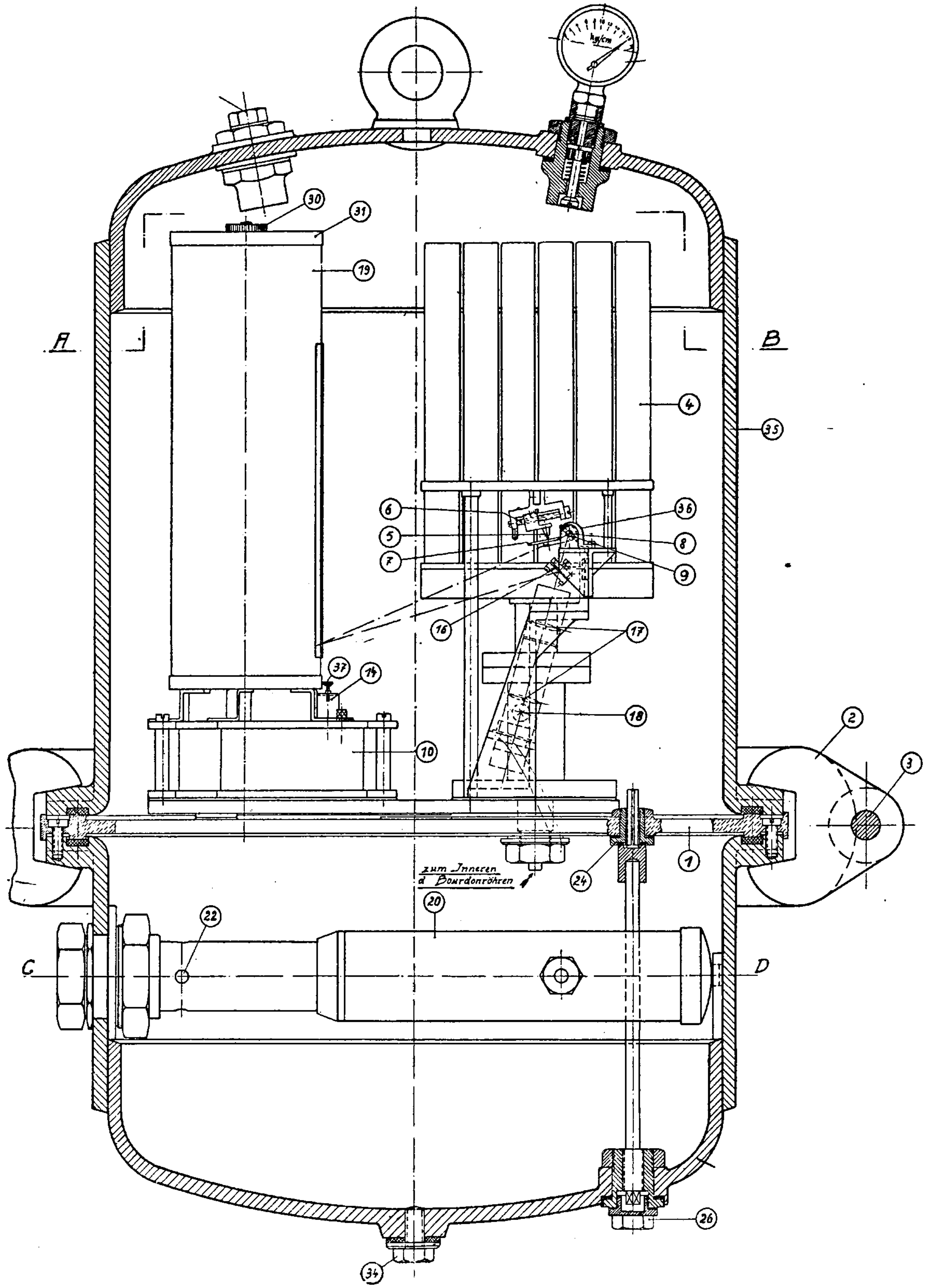

FIG. 4 — Kuhlmann Tide-Gauge — Vertical Section

are now connected. There are two connections on the upper tank, one for a pressure gauge and the other for a compressed air bottle. The water inlet device works at a depth of 10 m. less than that ascertained after soundings have been taken. Compressed air is now let into the gauge, until the pressure gauge shows a superpressure of 19 atm. All compartments are now subjected to that pressure, whilst piston (21), under pressure, rests against the side of the water-inlet aperture and blocks the latter. Close valve (23). More compressed air is let in, until the pressure gauge registers 19.8 atm. above atmospheric pressure. Close valve (24).

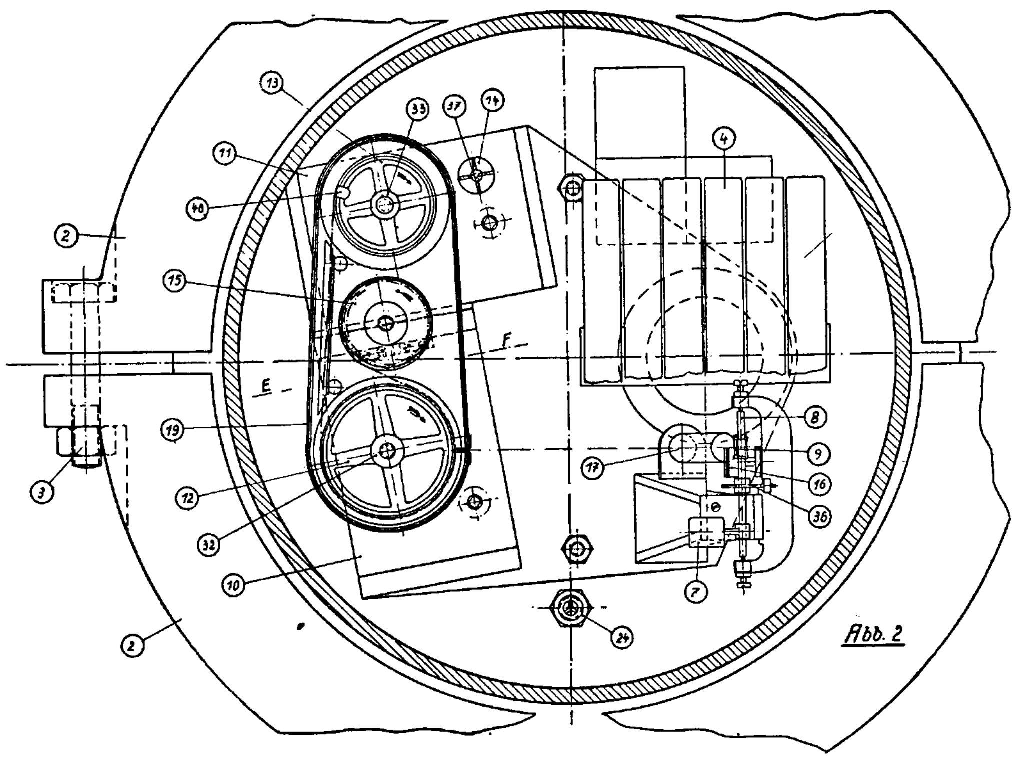

Fig. 5 — Kuhlman Tide-Gauge — Section A B

The air inlet at 19.8 atm. affords some guarantee that the gauge, at a depth of 200 m. will be subjected to but a small outside superpressure. Remove the pressure gauge and compressed air connections and tighten the bolts of the supports thereof. The water capacity of a compressed air flask is 40 litres. The air, in freshly filled condition, and under a pressure of 150 atm. will be sufficient for about 3 fillings at depths of 200 m., and even longer for lesser depths. Let the air come in slowly and with care, so that there be time for it to penetrate the inside of the dry elements.

Due regard should also be paid to temperature differences when admitting compressed air. Thus, with a substantial difference between the temperature at sea-bottom and that of the air, such as 10° at 50 m. depths, or over 5° up to depths of 100 m., the formula would be :

$$p' = p\frac{273 + t'}{273 + t}$$

t and p representing the temperature at sea-bottom and the pressure in *atm.* there required, whilst t' and p' stand for the temperature of the air and the admissible pressure.

If, *e.g.* the air temperature is + 15°, and the temperature at sea-bottom (as above stated) + 5°, and should the pressure at sea-bottom, as above stated, reach 19.8 *atm.*, the correct pressure (admissible) would be $p = 19.8 \frac{273 + 15}{273 + 5} = 20.6$ *atm.*

The air influx into the gauge will heat the latter in direct ratio to the speed of influx and to the degree of the pressure. Pressure increases under the influence of this higher temperature and it will be found that the moment the air inlet is stopped, both pressure and heat gradually decrease, a normal

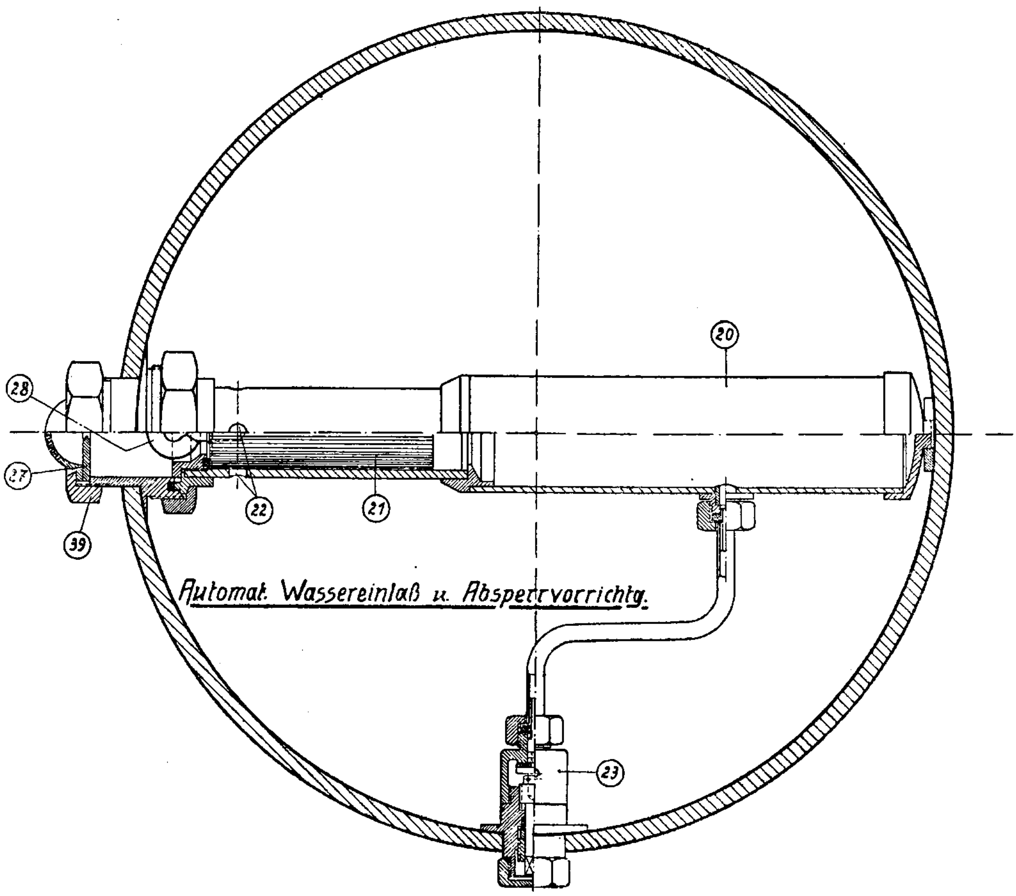

Fig. 6 — Kuhlmann Tide-Gauge Section C D

condition being attained within about 10 minutes. It is therefore advisable to provide a little extra pressure, say 0.5 *atm.* for the gauge when starting, to let it stand 10 minutes, and after unscrewing the tube, then to let additional air in, by pressing down the valve, as required. Valve (24) must be shut at this stage only.

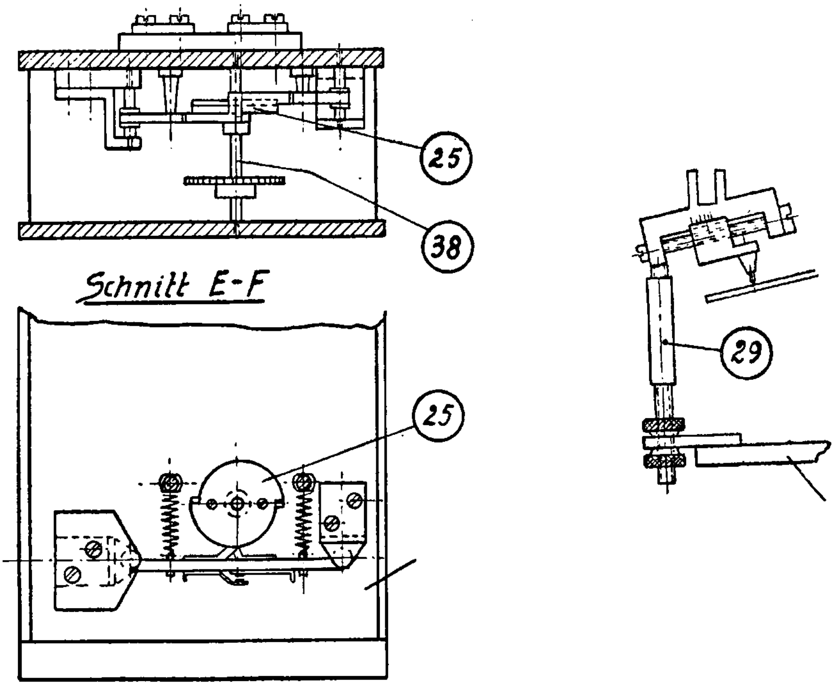

Fig. 7 — Kuhlmann Tide-Gauge — Contacts and Stylus

If there be any variation of water temperature during operations, which of course affects the record of pressure, this will be shown by the altered distance of gauge-curves from the zero point. A metallic thermometer built into the gauge, registers the temperature as a curve, on the same silver bromide paper. The small lamp (18) is responsible also for producing this curve. The latter can be read from the cellon tablet which holds the temperature scale on the left, the latter being set at zero point and on the curve. (*See Directions for Use*). With the aid of the variations in temperature, pressure changes can be found on the basis of the above formula, and examined in relation to the gauge curve.

With the gauge submerged at a depth of 190 m. the water pressure outside on the piston will equal the inner air pressure of tube (20) on the reverse side of the piston. If the gauge is lowered further, there is excess water pressure outside, which will force the piston inward, thus releasing apertures (22). At this moment, compensation pressure arises between the water and the lower tank, and the varying water pressure will react on the Bourdon Tube. The tides will then begin to affect the Bourdon Tube. After a period of 14 days, raise the gauge and then the sequence of events can be reversed.

With the gauge at the 190 m. limit. there is again a process of compensation between the outer pressure and the one within tube (20), and as the latter subsequently rises, the piston will be forced upward and thus close apertures (22). Further changes are out of the question. The gauge resumes its normal condition upward and paper may be renewed. The course is as follows:

First open valve (24) until air and water are expelled. Valve (23) may remain shut, if the gauge is to be submerged again later at the same depth, but if not, open this also and let the air in tube (20) flow out. Then loosen the screws (3), remove the one-piece ring and take off cap (35). Unwind the paper completely. The slit of the casing will show whether the yellowish silver bromide paper has been unrolled or not and if the black paper is lying under it. The black paper strip is 1 m. long. After winding off the black paper, the clock movement (11), will work more feebly and this should be remedied by winding it up a bit, until all the black paper is wound on to the drum (13). The side screw (30) may now be loosened and cover (31) with casing (19) removed. The black paper end is rolled firmly around drum (13), the latter being subsequently removed after loosening nut (33), and replaced by an empty drum. After shifting the empty paper cone, place a new roll and follow the same course with the fresh paper.

A new submersion can then be commenced.

To get rid of any sand and mud which may have penetrated, use screw (34) underneath. This can be done, after raising the gauge, when the connecting valve (24) is open to the extent that both upper and lower chambers or compartments communicate.

To preserve the Bourdon Tube during the transport of the gauge, the former can be fixed by means of screw (29). To loosen, use the milled nut and unbolt the casing. If the gauge is in constant use, the device had better be removed altogether.

DIRECTIONS FOR USE OF KUHLMANN HIGH SEA WATER GAUGE.

A steel hawser which is not too heavy should be used with a fairly small anchor buoy, but ample for the hawser, so that in rough weather the gauge be not subjected to heavy oscillations.

Weight of the gauge: 385 kilogs. The length of the steel hawser should be, say, thirty per cent more than the depth of the water. For the purpose of finding the whereabouts of the submerged gauge, a large buoy should be placed in proximity to the site. It is not advisable to connect the buoy to the gauge.

Should there be a risk of the gauge sinking too deep, owing to the soft nature of the bottom, nail a few boards 1.20 m. long underneath the base, and for this purpose holes have been provided wherein nails can be driven from above.

Before submerging the gauge, make sure of the following: the nearest possible determination of the depth of water at the submersion spot, bearing in mind the state of the tide. If for instance soundings are taken at high tide and the water level variation is about 3 m., deduct first 3 m. from the sounding and a further 2 m. for safety's sake in the event of specially low tides, altogether 5 m. Then get the temperature at the sea-bottom and also on board, near the gauge, and calculate, as per formula indicated, the total pressure to be admitted within the gauge, bearing in mind the two items mentioned which are to be deducted. The moment the gauge touches bottom, mark the time.

DEVELOPING.

Develop the paper inside a tin-plated drum in a dark room. The drum contains 5 litres of developing liquid. A good developer is Metol-Hydroquinone 1:6, or Rodinal 1:25. Unroll the paper from the drum, tear off the first black wrapper and then roll up again, so that the highly sensitive side, facing outside on the drum, again shows inwards. Also tear off the other or final black wrapper. Then dip the roll in the developing solution, where, using the hands and commencing at the side of the tank, slowly unroll or loosen the paper. After about 2 minutes wind the roll up again inside the receptacle, take it out, dip once in water, place it in the fixing bath, unroll, leave for about 10 minutes, roll up again and soak for one hour, in frequently changed water. To dry, unroll, spread and hang out on canvas.

CONCISE DIRECTIONS FOR USE.

a) First Submersion.

1. removal of ring (2).
2. *d* cap (35).
3. *d* cover (31) and casing (19).
4. insert highly sensitive paper.
5. fit the casing and the cover.
6. wind the clock movements.
7. remove the Bourdon tube fastenings (29).
8. place curve height at the division.
9. place the thermograph at points (42) and (43).
10. fix the elements and connections.
11. pull the highly sensitive paper behind the slit.
12. place the cap (35).
13. fit the ring (2) and tighten the screws uniformly.
14. admit requisite pressure inside the gauge.
15. submerge.

b) Raising and Subsequent Resubmersion.

1. After raising : ease the pressure after opening valve (24).
2. *do.* allow the water to flow out and open cap.
3. totally unwind the paper band.
4. remove light-tight casing.
5. remove the paper drum, work in dark room and fix empty drum.
6. fix a new store-drum and tighten the paper.
7. see items 5 to 15.