

DEEP SEA DIVING

(SECOND BERMUDA OCEANOGRAPHIC EXPEDITION).

by

Dr. WILLIAM BEEBE.

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The International Hydrographic Bureau has received the report concerning the second Bermuda Oceanographic Expedition and the deep-sea diving operations carried out by Dr. William BEEBE with the aid of the Bathysphere. In this report, Dr. BEEBE gives a very interesting account of the preparation of this expedition, of the work undertaken at the Bermuda Islands, at the Nonsuch laboratory, and publishes the log of the fifteen dives he effected in the Bermuda waters by means of the Bathysphere. Numerous photographic reproductions show the arrangement of the gear and its operating conditions on board the barge on which it was installed.

During the various dives effected in the Atlantic Ocean in the vicinity of point 32°18' N.-64°42' W. Greenwich, a depth of 1426 feet (435 m.) was reached and, through the windows of the Bathysphere, crowds of fish representing most varied species could be observed *in situ*. A photograph was also taken of the spectrum of light, the various colours of which vanish with the depth.

The actual report is divided into several chapters: a few extracts thereof pertaining to the Bathysphere itself and to the depth records are given hereafter. Interesting reference will be made to the booklet itself for the study of the outfit and operation of the Bathysphere on board the barge *Ready*, which served for the diving purposes. The booklet, as already stated, also contains the published log of the fifteen dives effected from 27th May to 20th June, 1930, together with the detail of the telephonic communications between the Bathysphere and its barge during the various dives.

THE BATHYSHERE

by ORIS BARTON.

The Bathysphere is a spherical steel diving chamber, or tank, as we generally call it. It was designed by the writer, and Messrs. BUTLER and BARRET of Cox & Stevens. It consists of a single casting made by the Watson-Stillman Hydraulic Machinery Company. The first casting weighed five tons, which proved to be too heavy for any of the winches procurable in Bermuda. It was therefore junked. Our present tank weighs five thousand pounds, is four feet nine inches in diameter, and has walls at least an inch and a half thick.

It carries a four hundred pound door, fastened over the man-hole with ten large bolts. This door has a circular metal gasket which fits into a shallow groove. The joint, when packed with a little white lead, was entirely waterproof at twenty-four hundred feet. In the centre of the door is a wing bolt plug, which can be screwed in or out quickly.

The windows are cylinders of fused quartz eight inches in diameter and three inches thick. They are a special produce of the General Electric Company, the use of fused quartz being suggested by Dr. E. E. FREE. They are fitted into cannon-like projections in the front of the tank. The joint is secured with a paper gasket and white lead, and a light steel frame is bolted over each one in front. In all we have had five quartz windows. The first was chipped in an attempt to grind it into its seat. The second gave way under an internal pressure test of one thousand two hundred and fifty pounds

to the square inch. It seems probable that the frame in front was bent out, and that the resulting sheering strains broke the glass. The third was broken when the frame bolts were tightened unevenly. The remaining two, however, have never leaked a drop, and have withstood the pressure at twenty-four hundred feet, and will, no doubt, hold much more.

The electric cable was specially made by the Okonite Company. It is one and one-tenth inches in diameter, and has a heavy rubber insulation. Inside are two conductors for the lights and two for the telephone. The cable passes through a stuffing box in the top of the tank and is squeezed up by two glands, one on the outside of, and the other within, the sphere. It, too, proved entirely waterproof under all pressures we encountered.

The two big conductors passed to a two hundred and fifty watt spot-light (loaned by E. W. BEGGS of the Westinghouse Company) in the right forward projection. We were obliged to seal the left projection with a steel plug, since only two quartz windows were left. At depths of over seven hundred feet the beam of light could be seen passing through the water. When more illumination was desired, it was simply necessary for the divers to direct the deck crew to speed up the generator. The light was turned out by the divers when they wished to observe the effects of the natural submarine illumination. To facilitate these observations the entire interior of the sphere was painted black.

The small conductors passed to the telephone lent by C. R. MOORE of the Bell Telephone Laboratory. The two sets were run by a twenty-two and a half volt radio battery on deck. At times static occurred, especially when the free ends on the conductors were disturbed, but on the whole they were a success. All observations taken in the depths were recorded by the deck crew.

The breathing apparatus was designed by Dr. Alvin BARACH of New York. On either side clamped to the wall an oxygen tank was carried, either of which would take Dr. BARACH's special valve. We set this valve to allow two litres of oxygen per minute to escape for the two divers. One tank lasted about three hours at this rate. Above each tank was a wire mesh tray. One contained soda lime, which took up the CO_2 , and the other calcium chloride which absorbs the moisture. Palm leaf fans kept air in circulation. During our deepest dive of fourteen hundred feet we were comfortable and cool, although we had been inside more than an hour and a half.

For lowering the bell, we used Dr. William BEEBE's seven ton winch and special large reel. To operate these, we installed two boilers on the after part of the long deck of our lighter which had once been the H. M. S. *Ready*. The lighter was in turn towed by the tug *Gladisjen*, of the New York Zoological Society. This equipment was used on the Arcturus Expedition, as were also the three six-ton sheaves. One of these was bolted to the deck about 70 feet in front of the reel at midship. From this the cable returned to the second sheave close to the mainmast and then passed to the third at the end of the heavy boom.

The cable was a special seven-eighths inch, steel-centre, non-spinning one made by Roebling. It was thirty-five hundred feet long and would hold twenty-nine tons. It weighed about two tons under water. On our dive to fourteen hundred feet, therefore, the weight of the cable let out was nearly six-sevenths of a ton in the water. To this was added the weight of the bathysphere in water, about seven-eighths of a ton. The amount of cable out was tallied by the special meter wheel also from the *Arcturus*, as well as by a system of ribbons tied around the cable.

The comparatively light electric cable was let out by hand, and attached at intervals of not more than two hundred feet to the steel one. This we did at first with brass clamps, but later it was found better to tie them together with lengths of rope about a yard in length, since these took up much of the twisting. The winch could be stopped while the tie was made.

Several problems were naturally encountered in these operations. At first we found that the sphere swung badly when raised from the deck. To remedy this we lowered the boom, by means of a second winch, nearly down to the clevis, which connects the cable and sphere. The whole boom was then raised and pulled out over the side, with the top of the tank almost touching the third sheave. From this position the sphere could be lowered upon a single whip.

Perhaps the greatest trouble was caused by the twisting of the rubber hose about the steel cable. Most of this was apparently due to the failure to stretch the latter by

letting it all out without the rest of the apparatus and then to rewind it under tension on the reel. When twisting was bad we would tie up the loops every two hundred feet in a loose coil, through the centre of which the steel cable continued to operate. Eventually, however, we succeeded in getting out as much as two thousand feet without twisting.

Besides taking observations at great depths in the open ocean, we tried towing the tank along under the vessel, endeavouring to keep the bottom in sight and not to run into any of the ledges which rise up quite suddenly in these waters. In this work we nailed a wooden rudder on each skid behind, by which the windows were kept always to the front in the direction of motion.

It is with this outfit that we hope next season to study the contours of the bottom down to five hundred feet and also to make dives in the open ocean of two thousand feet.

A PERFECT DEPTH RECORDER

by WILLIAM BEEBE.

It has been the custom in recent years for oceanographic expeditions, instead of giving an estimated depth of their mid-water net hauls, to state the amount of wire out. Seldom are we told the size of the wire, the trawling angle at which it is drawn, the terminal weight, and the number and character of the collecting appliances.

In the Plymouth "*Journal of the Marine Biological Association*" (Vol. XIII, No 3, pp. 769-774) Dr. RUSSELL writes of a depth recorder loaned by the British Admiralty which registered exact depths down to fifty metres or twenty-five fathoms. How much deeper it could operate, or what the mechanism was we are not told, but an illustration of a diagrammatic record shows that this instrument is exceedingly accurate at least in shallow depths.

My own work at present deals with depths of five hundred to one thousand fathoms and with pressures from 1350 to 2700 pounds to the square inch.

Among a list of unsolved problems connected with the mechanics of oceanographic work which I discussed with Mr. L. R. SMITH of Milwaukee, was that of tracing the exact course of the deep sea nets. Mr. SMITH was eager to help us and had unlimited facilities both in trained engineers and in laboratories in his steel plants.

In 1929 he devised and sent me a circular depth gauge in which the outside pressure was transmitted to two needles on a disk. When brought to the surface the extreme depth was ascertained by the pounds of pressure indicated by the idle red needle. It was found exceedingly difficult to adjust this recording needle so that it would be flexible enough to shift easily, sufficiently stiff to maintain its ultimate position, and yet on the whole to resist displacement from the jerks and vibrations consequent upon being drawn through the water at the end of two miles of cable. Nevertheless, when first lowered vertically to a depth of six hundred fathoms it registered the correct pressure in pounds. There were two dials in the bomb, and on subsequent tests, both vertical and when drawn on regular hauls, the records did not coincide, and the gauge was always half full of water, the pressure forcing it through the pores in the three inches of brass.

In August 1930 a new pressure gauge was sent to me. This is a steel sphere, fourteen inches in diameter. It is divided transversely across the centre, the connection being made absolutely tight by a rubber ring fitting into a groove of less diameter, and the two halves fastened by sixteen long bolts and nuts. Great pains were taken to make the steel particularly dense. Steel castings were eliminated because of the possibility of their being porous. The steel used is a forging presented by Dr. WHITE of the Allis-Chalmers Company. Its weight is two hundred and ninety pounds.

Each half of the bomb is made to contain a separate recording apparatus. This mechanism has a needle which moves over a circular, soot-covered, clock-driven disk, divided concentrically into depth divisions, from surface to fifteen hundred fathoms, and radially into ten minute intervals, totalling twelve hours.

The connection of the recording instrument with the outside pressure is simple and direct. The pressure element is a flattened spiral tube which tends to straighten out when pressure is put in it. The water is admitted through a filtered and delicately guarded opening, actually into the tube, which in turn is so accurately devised and corrected that while it can withstand a maximum pressure of four thousand pounds to the square inch, yet moves the needle to the dial and thus records unerringly the change and duration of change from one to nearly three hundred atmospheres. This depth pressure gauge, devised for operating under such difficult combination of conditions of pressure, salt water, vibration and position was built by Mr. J. B. KELSEY of the British Gauge Company.

We have given it a number of severe trials before beginning to use it regularly, under all possible variants of usage, and the results are clear and accurate to the smallest perceptible degree visible on such a clock-driven, soot-recording device. The technical details of construction will be elaborated in a forthcoming number of "*Zoologica*".

The result is not only important as practical pioneering in this field, but especially gratifying to me as verifying in every respect our estimated depths from the beginning of our work throughout the nine hundred and seventy-odd nets hauled off Nonsuch.

