On Reaching 50: An Early History Of the Bathythermograph

This Remarkable Invention Led the Study of the Sea Out of the Expedition Stage and into Synoptic Oceanography

By Dr. Athelstan Spilhaus

The bathythermograph is 50 years old this year. It seems an appropriate time to recall its history. It started in June 1936 in Pretoria, South Africa, when a cablegram arrived from my great professor and mentor, Carl Gustav Arvid Rossby. His message was that he had made arrangements with Woods Hole Oceanographic Institution to pay my salary as research assistant and return to work with him at Massachusetts Institute of Technology in Cambridge.

On arrival in Boston, it was revealed that Rossby, who was then involved in his great work relating to jet streams and vorticity, wanted a rotating model ocean with a jet stream somewhat like the Gulf Stream in it. The counterclockwise rotation was to provide the model's Coriolis force.

To house the resulting 6-foot-diameter dishpan, the only space MIT had was a infrequently used men's room in the basement of the Mechanical Engineering Building. Here the laboratory was set up and the only interruptions were students with other pressing hydrodynamic problems.

Some of these smart MIT guys didn't know the difference between Coriolis and urinal—so it would sometimes be discovered upon arrival at work in the morning a two-layer "ocean" in the six-foot-diameter dishpan.

The features in which Rossby was interested were the eddies on both sides of the jet stream. Not only was he doing his theoretical studiesbut he was also trying to delineate the real eddies on the edge of the Gulf Stream, eddies that were well known to bring unusual warm water close in to Nantucket.

For an earlier *Atlantis* cruise during the summer of 1934, he had had built a great box-like contraption he called an "oceanograph" in an attempt to get continuous tracings of temperature versus depth in the surface layers of the ocean more conveniently than with the then-standard procedure of lowering a string of reversing thermometers attached to Nansen bottles.

But Rossby's oceanograph was not practical; it was cumbersome, full of multiplying linkages that got fouled with seaweed, and it vibrated, making the recordings unusable.

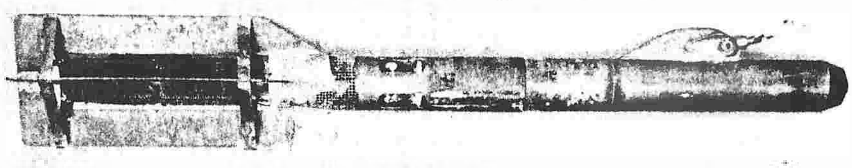
Nevertheless, the idea of an instrument that could be rapidly lowered and pulled up to give a record of temperature versus depth was entrancing. One design, conceived during a year in South Africa, became a project back at MIT, where it was built on a bootleg basis.

A Bootleg Beginning

All multiplying linkages and pivots were eliminated and the instrument was made small and rugged. It became simply a compressible metal bellows within a tubular casing to which it was attached at one end with a straight bimetal strip on the free end. The end of the bimetal strip was a stylus that scribed on a smoked-glass microscope slide held in the other end of the casing. Thus, the bellows compressed with pressure along the Y-axis, parallel to the length of the tubular casing, while the bimetal curved with temperature along the X-axis across the diameter of the tube—just two deformable parts.

Working at off-times in the machine shop of the Guggenheim Aeronautical Building—with great help from a machinist, Mr. Maddox, provided out of friendship without MIT's official sanction—the first bathythermograph was built.

Woods Hole, in the wonderful *personae* of Columbus Iselin and Dr. Henry Bigelow, the director, became intrigued enough with the first crude model that they provided the opportunity to sail on a number of cruises on late 1936 and early 1937 to test the gadget.



Allyn Vine's engineering genius transformed Spilhaus' Bourdon tube BT design into this streamlined, practical projectile that now could be deployed from high speed Navy destroyers.

On these cruises, more time was spent in the engine room redesigning the instrument than on deck testing it. By early 1937, a workable instrument was tested on the *Atlantis I* and the bathythermograph's small glass record slides showed remarkable discontinuities and inversions of the thermocline in the surface layers of the ocean hitherto unknown.

The instrument was ready to be christened and named. It recorded temperature against pressure, but the word barothermograph was already in widespread use for a meteorological station instrument which recorded atmospheric temperature and barometric pressure on a chart. So it was

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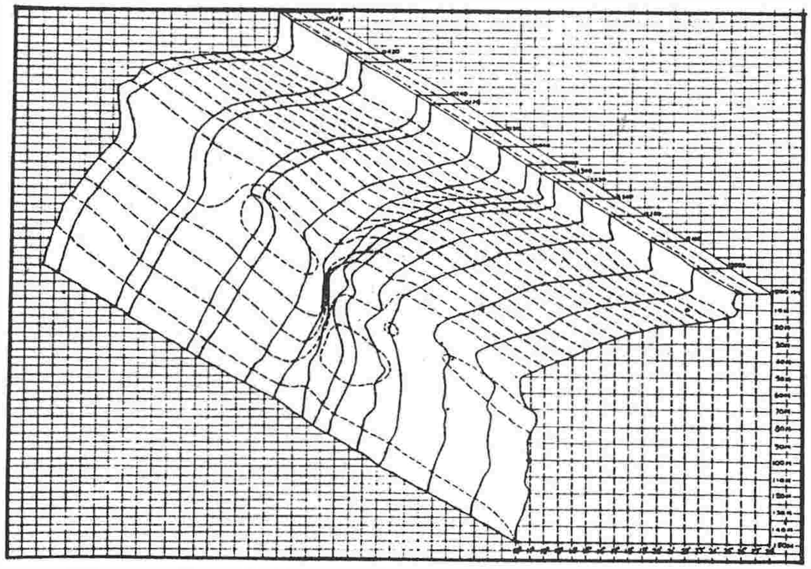

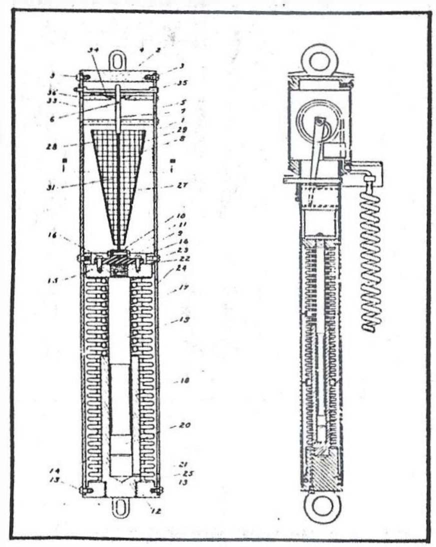

For the first time, the BT yielded data resulting in this temperature-depth versus time (far left) profile. Two patent application drawings at right show Spilhaus' original BT design (left drawing) and a later version—built and tested in 1937 at Woods Hole—that incorporated a Bourdon tube. In the original design, a compressible metal bellows (14) in a tube controls a stylus that scribes temperature changes on a smoked glass slide (5). The Bourdon tube version reduced temperature lags inherent in his first design and eliminated vibration as well.

settled that the device be named, "bathythermograph," from the Greek root for depth, *"bathos."* Later, the bathythermograph came to be universally called the BT.

The first paper entitled "A Bathythermograph" was written for the *Journal of Marine Research,* Vol. I, No. 2, 1937-38. This paper ended with the statement: "It is hoped that this instrument can. . .obtain widespread application, not only by biologists and oceanographers, but also in the fishing industry—the apparatus being such that it can be handled by entirely untrained personnel."

Columbus Iselin was not only a scientist but, it seemed, one who knew everything worth knowing about ships. Being conversant with the early developments of sonar in relation to the detection of submarines, he pointed out another sphere of application, He arranged for the two of us to take the *Atlantis* and conduct sonar-BT tests in conjunction with the *U.S.S. Semmes* and a Navy submarine out of New London (August 23-31, 1937)todemonstrate the importance of the bathythermograph in the detection of submarines by sonar.

The Navy scientist who accompanied us and who also saw the importance of the instrument was Dr. R. L. Steinberger of the Radio Laboratory, U.S. Navy Yard, Washington, D.C. At that early stage, detection of submarines was a hit-or-miss proposition. Sound engineers were attributing failures to deficiencies in the sonar equipment, whereas we were trying to convince them that it was the thermal layering of the oceans and the lens-like bending of the sound waves by the thermocline that were responsible for the misses.

In any case, the Navy Department's Bureau of Engineering started the paper work to order two bathythermographs to use on a southern cruise of the *Semmes,* which was to rendezvous with submarines out of the U.S. base in Guantanamo Bay, Cuba, in February 1938.

In October 1937, right after the *Semmes* tests, the Navy had asked to arrange for the manufacture of two bathythermographs. While at New York University at that time heading up the Department of Meteorology,

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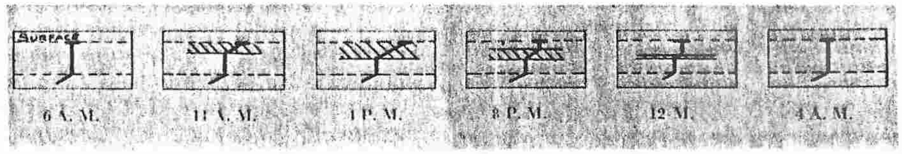
the immediate thought was of getting Sperry Gyroscope Company (which had given me my first job in the United States in the summer of 1933) to manufacture them. Sperry was willing to go ahead and received a requisition from the Navy with specifications by February 1938.



Series of traces shows diurnal heating and coolihg of seawater layers with passage of time. Temperature reads left to right; depth from top downward. (Submarine Signal Co.)

From Bimetal to Bourdon

The specifications were for the bimetal bathythermography; however further tests indicated a move to a Bourdon tube so that the moving temperature element was not exposed to the flow when used from a moving vessel.

Probably for this reason, the arrangement with Sperry never came to fruition. A Bourdon tube BT was built and tested at Woods Hole that summer.

With eventual uses by biologists, oceanographers, and fishermen in mind, the first vice president of a well-respected old Boston company called the Submarine Signal Company was contacted. Mr. H. J. W. Fay, the vice president, resisted all eloquent attempts to excite his interest. In response to the claim that "every oceanographer will be wanting one," his laconic reply was, "Yes, all six of them."

Submarine Signal Company was well-known and respected in seafaring circles because it produced a sonic depth finder and submarine signalling devices, which had been developed by Reginald Aubrey Fessenden.

Fay agreed to develop the bathythermograph because his company wished to maintain its long-standing reputation in the ocean instrument field. His company filed for a patent on the BT in my name but assigned to the company on August 10, 1938.

[An interesting sidelight is the expense account for a special trip to Boston to meet with them where they had offered to pay expenses. I found in my files the letter I wrote itemizing the expenses for the trip from New York to Boston and return. It was $10 up on the Merchants' Limited and $5.73 return on the day train. Total expenses $15.73—hardly padded.]

By September, Submarine Signal was already working and thinking about the Bourdon tube model. This device would show less lag with faster speeds through seawater and, as the moving part of the instrument was protected from the flow, would not be affected by vibration. In December, it was tested on the *Atlantis* with Mr. Hubbard of the Submarine Signal Company.

One amusing little problem involved the glass slides used to obtain the graph drawn by the stylus. From the very beginning, smoked-glass microscope slides were used, easily obtainable and easily smoked. However, the smoke would wash off with seawater. So, in the first models, one simply greased the slide a little bit before lightly smoking it. Very little grease was needed and it was discovered that it was only necessary to rub a forefinger along the side of the nose and then on the slide to give it adequate coating.

When Submarine Signal Company got into the act, this primitive but effective system had to go. We would have worn out a lot of noses in production.

Nosed Out by Skunk Oil

Columbus Iselin suggested another oil, that used to lubricate the valve mechanisms of the old Nansen bottles: skunk oil. Woods Hole had a plentiful supply and from then on skunk oil was used on the microscope slides until, much later when the BT was in quantity production, the slides were covered with a monomolecular coating of gold evaporated onto them. To this day, however, it has not been proved that "nose grease" and skunk oil aren't as good as gold.

The Bourdon tube BT was used on two cruises of the *Atlantis* in the summer of 1939, in July and August. In September, a paper was presented on rapid measuring hydrographic instruments at the International Association of Physical Oceanography meeting at George Washington University in Washington. It was a somber, sparsely attended meeting since the previous Sunday, September 3, Britain and France had declared war on Germany. Most notable at the meeting of course was the absence of any German scientists even though Germany was a leader in physical oceanography.

Within a short while there were reports in the U.S. newspapers of many sinkings of British tonnage by German U-boats in the approaches to the Straits of Gibraltar. The Germans were using their knowledge of physical oceanography in their submarine strategy to hide beneath the sharp thermocline that existed between the warm, less saline, light, low-density surface layers flowing into the Mediterranean and the saline water flowing out underneath through the Straits. The sharp discontinuity in density would refract the sonar beams of the primitive early sonar, the British ASDIC (Anti-Submarine Development Investigation Committee), and permit the German submarines to destroy surface shipping in relative safety.

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In discussions with Iselin, it became obvious that the attention of the British Admiralty should be directed to the fact that the use of the BT on surface escort ships could materially reduce the sinkings and make the submarines vulnerable to depth-charge attacks. He agreed, but it was tricky and risky. The U.S. was still officially neutral and it could be an awful mess if the infraction were discovered—not only a mess for the author but one that would perhaps shake the confidence of the Navy in Woods Hole for future work.

But, with Iselin's backing in early 1940, a meeting was arranged with the British Naval Attache in an apartment that he designated in New York City. He was handed a piece of paper entitled "Memorandum on Horizontal and Vertical Temperature Gradients in the Surface Layers of the Ocean with a View to the Possibility of their Influence on Problems Involving the Transmission of Sound through the Water."

It stated "The purpose of this memorandum is to draw to the attention of

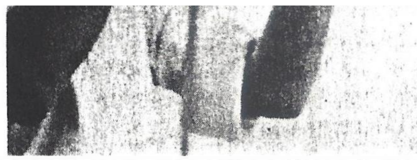
during operations." The "new instrumental technique" (bathythermograph) was mentioned and it was stated that it had been used from a vessel traveling at a speed of 11 knots. The memorandum was necessarily "weasel-worded," unsigned, undated, and unaddressed.

Also handed over were this memo, together with drawings of the latest BTs, data from cruises, and other supporting material to the British Naval captain in that anonymous New York apartment. He simply said, "Thank you, I think it is important. It will go into the lion's maw at the Admiralty in London to be digested. You may or may not hear more about it."

Much later, a "thank you" returned via circuitous paths from the First Lord of the Admiralty himself, signed simply "W.C."

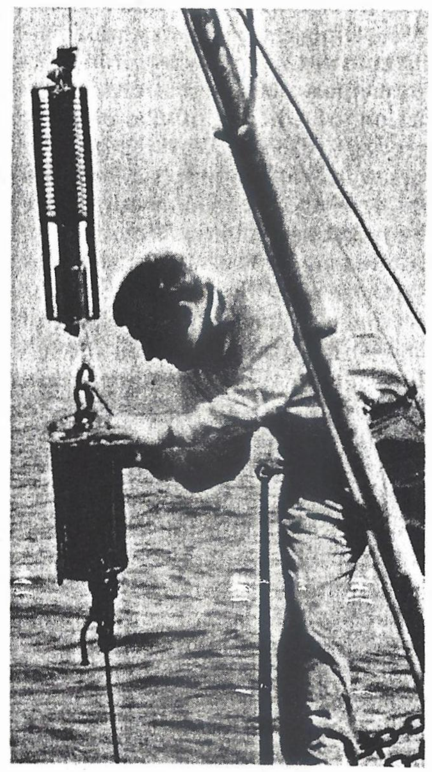
But this came only after the British had asked President Roosevelt to send them a quantity of about 200 bathythermographs.

This cloak and dagger stuff seemed pretty curious in the light of an inquiry in January of 1939 (before Germany and Britain were at war) from Professor-Doctor G. Dietrich, head of the Institut für Meereskunde an der Universitat Berlin. He had asked for details of the bathythermograph described in the *Journal of Marine Research,* who manufactured it, and how much it cost. That letter had, of course, been answered. However, to our knowledge, the Germans never used BTs, probably because their submarines were on the attack and could see the thermal layering of the water by simply watching the temperature of the water outside the submarine as it dove and surfaced. Also, in the early stages, Hitler regarded the war as a *blitzkrieg* that would soon be successful and he was not one to "waste time on novelties."



Submarine Signal's Hubbard (shown) assisted Spilhaus in testing the firm's Bourdon tube version aboard *Atlantis I* in late 1938. This model showed less lag with faster speeds.

By the end of 1939, interest in the bathythermograph came from many sides other than wartime Navy use. Inquiries were received from the U.S. Coast and Geodetic Survey as well as from Dr. Floyd M. Soule, senior



During the 1938 cruise, author Spilhaus here makes final adjustments on his "Sea Sampler," an invention for taking multiple samples of seawater for determining salinity and oxygen content. It was used in combination with the BT (above) but it never caught on.

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physical oceanographer for the U.S. Coast Guard, who was interested in the BT's use on the USCG cutter *General Greene* of the International Ice Patrol Force. Eddie Smith, called "Iceberg Smith" because of his work on the International Ice Patrol, was in on this request. He later became an admiral and director of Woods Hole Oceanographic Institution.

"[Allyn] Vine streamlined the whole apparatus into a projectile shape with a heavy weight at the nose, fins protecting the coiled temperature bulb at the tail, and made it so [the BT] could fall rapidly through seawater."

Requests for information also came from the University of Liverpool; from the Department of the Interior, Bureau of Reclamation, which was interested in the BT's possible use in Boulder Dam; from the Division of Fisheries in New South Wales, Australia; and from the government of India.

Despite all this interest and the primary urgency of the BT for anti-submarine work, Submarine Signal seemed to be just puttering along and making Iselin very frustrated. But, by the fall of 1940, the work was too hectic at NYU to allow sharing his frustration.

Iselin had brought Dr. Maurice Ewing onto the staff at Woods Hole in 1940. Ewing was a distinguished original scientist and had pioneered seismic work on the ocean floor. He was eminently qualified to assist in the sonic work in connection with sonar investigations that Woods Hole had gotten into through the BT. In October of 1940, Iselin wrote that they were simply going to proceed to build "a bathythermograph of your newest design" in their fully equipped shop where they would work days and nights.

I did not argue with this decision in the light of the slowness of Submarine Signal Company.

Enter Ewing, Vine, Worzel

Ewing and his associates, Allyn Vine and Lamar Worzel, had sailed on the *Atlantis* on one of the cruises in the summer of 1939 when the author was chief scientist aboard. Ewing brought aboard seismic detectors for the sea floor and a large quantity of detonators and dynamite. Between busy spells, his boys would trail a piece of meat or fish with a detonator inside, attached to two electrical wires that came on deck. They were fishing for sharks. The trick was to explode the detonator after the shark had taken the bait, but before he had broken the wires. When they hit it right, we had fragmented shark meat raining down all over the deck, in the rigging, and in the sails.

In the next months, Al Vine built the latest BT design with, as had been written two years before, "a bulb that should be a very thin tube of great length containing the liquid" (xylene) which, in response to temperature, operated the Bourdon tube and stylus.

Vine streamlined the whole apparatus into a projectile shape with a heavy weight at the nose, fins protecting the coiled temperature bulb at the tail, and made it so it could fall rapidly through seawater. He designed a special winch with a thin wire that ran freely on the descent. On reaching the desired depth, the BT was retrieved by engaging the clutch on the winch and pulling it up to the surface. This made the bathythermograph highly practical to the Navy's purposes as it could be used at high speeds from destroyers.

In addition to these modifications, Vine made a fundamental improvement by compensating for the difference in temperature between the water surrounding the Bourdon tube inside the body and the sea temperature around the outside capillary tube, which formed the bulb of the Bourdon tube thermometer. He compensated for this difference in temperature by putting a reverse-response bimetallic coil between the end of the Bourdon tube and the stylus, an Amthrop case compensation. They subsequently built 75 BTs in WHOI's shop.

About the same time (May 29, 1941), a secrecy order was applied on the original patent of the bathythermograph by the U.S. Patent Office. The reason was that the BT was extremely important to the Navy, but it seemed like locking the barn door after the horse had bolted.

In a letter dated September 22, 1941, to Dr. C. G. Darwin, head of the Central Scientific Office in Washington—the top civilian scientific board during the war years—Iselin pointed out the difficulties of this writer's "alien" status. Among other things he said, "Spilhaus invented the bathythermograph several years ago and it has naturally not been possible to keep him in the dark concerning its present usefulness. His lack of U.S. citizenship makes it impossible for him to be certified for the National Defense Research Committee. It seems ridiculous that one of the most able scientists in this country must be more or less excluded from developments for which his special abilities are badly needed."

Subsequently, nine copies of a very complicated form were produced and the author did, indeed, become a member—even though an alien—of Division 6 of the National Research Defense Council, headed by Dr. Jack Tate.

[Years later, when I became dean at the University of Minnesota's Institute of Technology, Professor Tate was on my faculty.]

Getting Serious about ASW

Now being a member of the NRDC, an important meeting was called on

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February 26, 1942, in Tate's office in New York. Harald Sverdrup and Dick Fleming from Scripps Institution of Oceanography were there, along with Iselin. This meeting was to discuss the relation of oceanographic work to the antisubmarine program and covered the whole spectrum of sonic echo ranging and the effect of oceanographic conditions on the propagation of sound in the sea. It really charted the course for the extensive work that was to be done later by Woods Hole and Scripps in this area.

Apart from participating in this meeting, training meteorological cadets became all-consuming. With the author more or less dropping out of the BT picture, Iselin took over and decided to just go ahead and build BTs at Woods Hole with Al Vine doing the engineering. The whole thing was in good hands; the mess of secrecy and patents could be straightened out after the important business of winning the war had been concluded.

The rest of the history of the BT is well documented. I only saw the BT in operation once on a naval ship. In the fall of 1943, I was in Bermuda on Air Corps business and begged a ride back to Boston on a newly commissioned destroyer-escort. This vessel had just completed her shakedown cruise with a newly trained crew. Naturally, I helped out working the BT. As "luck"would have it, the crew made contact with a U-boat and chased it quite a distance toward Ireland, eventually losing it, and finally arrived in Boston eight days after leaving Bermuda for a trip that should have taken a single day.

The bathythermograph then became routine in the Navy and widely used all over the world for the peaceful uses in oceanography for which it was originally intended. The BT had—as Columbus Iselin said—taken oceanography out of the expedition stage and into synoptic oceanography. The word bathythermograph, which I had coined, began to appear in dictionaries. Submarine Signal Company became a division of Raytheon and the bathythermograph eventually was manufactured by many different companies responding to Navy bids over subsequent years. Ultimately, it fathered the contemporary expendable BT (XBT) which carries on the BT's job.

Now, there is a new detritus building on the ocean floor, a litter of expended XBTs. /st/

Dr. Athelstan F. Spilhaus is affectionately known as "Spilly" to a great many in the oceanic community. Inventor of the bathythermograph, the 75-year-old scientist is equally well respected as a meteorologist, sculptor, educator, advisor to four NOAA administrators, and collector of antique mechanical toys (his collection now includes 3000 of them). His ideas have ranged from a jigsaw puzzle that demonstrates the concept of plate tectonics, to experimental cities, to arctic engineering projects, and to a network of National Sea Grant colleges across the country. Born in South Africa, Spilhaus emigrated to the U.S. in 1931 and has since collected a curriculum vitae *in which the "high points" cover nine pages, including a master of science degree from MIT and a doctorate from the University of Capetown (South Africa).*