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The earliest seawater sampling bottles such as used by the first Challenger expedition consisted of a simple tube, through which the water flowed more or less freely (flushed) while it was lowered to any desired depth on a sounding line. When in position, it was closed by striking a trigger mechanism with a small weight (messenger) slid down the line. The bottle and the sample were recovered by hauling the line aboard ship. With the advent of reversing thermometers in 1902, a reversing mechanism was added.

The most successful bottles are the Nansen (figure 1), Knudsen (figure 2) and Ekman (figure 3) in which the thermometers are attached to the tube which reverses (turns over) and closes when the trigger is actuated. In the first two, both ends of the bottles are attached to the sounding line while being lowered into position, but when the messenger strikes the release mechanism the top end falls away from the line by its own weight, and so reverses. The main difference between the two is in the tube closing mechanism. The Nansen bottle has a stopcock at each end closed by the weight of the bottle actuating a lever as it falls over. The Knudsen bottle has rubber gasketed lids which are spring loaded and are tripped individually by the messenger, as a separate action after the top of the bottle is released from the wire. Both of these bottles are light in weight and easy to handle. They have a common objection in that the end of the sampling tube is not perfectly sealed when the

1. Now with the Pacific Naval Laboratory, Defense Research Board.

bottle is reversed. As a result, contamination of the sample while in the sea and loss by leakage when it is brought on deck can occur. Their flushing characteristics are poor and they must be allowed to remain at sampling depth for some time to enable them to obtain a true sample. Once the bottles are tripped, they are fastened only at one end, and tend to gyrate around the line, and there is a possibility of damage against the side of the ship, particularly in bad weather.

In the Ekman bottle the thermometer and sample tube assembly is mounted on pivots in a frame that can be attached to the sounding wire at both ends. The lids are held to the ends of the tube by an internal spring and are pushed open by external cams, as the tube with thermometers attached is cocked before lowering. This bottle is rugged, but very heavy and tiring to handle. It has relatively good flushing characteristics, and with proper care the lids can be maintained leakproof. The method of locking the tube after reversal is poor, and usually does not function. In this case the bottle is free to rotate through 110 degrees and there is a real possibility that the thermometer readings could be altered, and the lids could be opened.

The ideal water sampler must obtain and preserve a true sample of the water at sampling depth, and bring it on shipboard intact. This requires good flushing characteristics when open, and a positive seal when closed. Furthermore, once the thermometers have reversed they should be locked in this position to safeguard the temperature readings. The unit should be fastened to the line at both ends to prevent damage against the side of the ship in rough weather. The thermometer cases should be readily removable so that the instruments may be stored properly(3)(5) between observations at sea. In addition, it should be light in weight, corrosion resistant, easy to manipulate, and must be dependable.

With the requirements of an ideal water sampler in view, a new bottle has been designed (figure 4) to incorporate as many of these features as possible. The design was commenced in 1949 and the prototype of the present bottle was first used in January 1950. Since then the design has been modified six times. It is presented here as a unit which has been proven under trying circumstances at sea and has been found dependable, easy to handle, and capable of obtaining true samples and temperatures.

This sea sampling bottle consists of a light weight metal tube with hinged lids on each end that are co-ordinated with a rotating frame holding three reversing thermometers. The tube is clamped to the sounding line at the top, and hooked at the bottom end similar to the Ekman bottle. A device for releasing a messenger below the bottle when it closes allows any number of units to be used in series on the line. The major features which have been designed into the bottle allow unrestricted flow of water through it when open, a positive seal when the lids are closed, and complete mechanical reliability.

The free flow of water through the bottle has been facilitated by placing the operating springs on the outside and providing large openings at the ends of the tube, in which the only restriction to flow is a 1/4 inch diameter axle passing transversely across it. This supports the thermometer reversing frame. The springs which hold the lids closed have been coiled around the hinge on which they are mounted, in a manner similar to screen door hinge construction.

The lid is carried on the hinge bolt (figure 5) which is bent in such a way that the lid comes normal to the axis of the tube in closing. The hinge bolt passes through the center of a pressed metal lid fitted with a rubber gasket, which is tight enough to prevent leakage, but flexible enough to allow the lid to move slightly. Consequently, if the hinge bolt is accidently bent, the lid can adapt itself to the end of the bottle and prevent possible leaks. The metal rim which forms the seal with the gasket has been recessed slightly inside the ends of the bottle to protect it from accidental burrs that would destroy the seal.

The linkage between the lids and the reversing frame is a flexible steel cable passing through a small hole in the axle of the frame, and attached at each end to a pulley on the hinge. When the frame is rotated to reverse the thermometers, the cable is wound around the axle and pulls the lids open against the action of the springs. With this arrangement, the thermometer frame is urged throughout the entire 180 degrees of reversal and when the lids are closed, a spring loaded plunger locks the frame to prevent oscillation and so safeguards the sample and the thermometer readings.

The removable thermometer case fits in a rack in the rotating frame where it is locked with two spring catches. The thermometers are held within their cases by a screwed-on lid, which covers all the tubes.

A hole is provided at one end of each tube to facilitate pushing the thermometers out of the cases.

The seawater sample in the bottle is in contact only with monel metal, which is used for the tube, lids, reversing thermometer frame, and axle. This minimizes the possibility of contamination of the sample with corrosion products. The castings on both ends of the bottle are manganese bronze, chosen for durability in service.

The weight of the new bottle (7.3 lbs.) compares favorably with that of the Nansen bottle, 7.7 lbs., and is the same as the Knudsen bottle. It is much lighter than the 17 pound Ekman bottle.

In use, the bottle is first attached to the sounding line by a spiral hook at the lower end (figure 6A) and then clamped at the top (figure 6B). The plunger locking the thermometer frame is released and the lids are opened by rotating the frame 180 degrees until it engages the trigger (figure 6C). The messenger is then attached to a spring loaded plunger bearing against the lower hinge bar (figure 6D) and the messenger is then fitted to the line (figure 7).

Every attempt has been made to reduce the number of motions required. The hook at the lower end is positioned so that the movements used in attaching and detaching from the line are those which would naturally be used in moving the bottle towards or away from the wire. The bottle is arranged for holding in the left hand, while the right hand performs the more complicated motion of screwing up the clamp, which has an extra large wing nut to ensure that it can be securely attached to the line, with reasonable effort. Both lids are opened and the thermometers reversed in a single motion. The messenger is attached after this action is completed, so that it is not necessary for the operator to try and co-ordinate two moving parts.

When the messenger hits the trigger, it releases the thermometer frame which is now free to rotate under the tension of the springs on the hinge bar, towards the reversed position, where it is locked. At the same time, both lids close and the messenger for the next bottle on the line is released.

The bottle is provided with an eye welded to the tube at each end, so it can be hung upright on a hook before the thermometers are read, and hung upside down after the sample is drawn and temperatures recorded. In this way, the reversing thermometers can be kept in the approved storage position (3) (5) when they are still on the bottles, if it is not convenient to transfer them to a separate rack. In practice, a wooden case is provided with hooks, which serves as a bottle rack on deck, as well as a case for shipping.

The messenger shown in figure 7 is a "split" type, cast on two pieces of manganese bronze, which are held together under tension by a heavy piece of rubber. The messenger is pushed onto the line, and pulled off, but has no tendency to fall off or to become jammed.

Flushing Efficiency

A Comparison with Other Seawater Sampling Devices

The speed at which the various water sampling bottles take up the water typical at their positions in the sea is of considerable interest and importance.

The relative efficiency of four types of bottles currently in use has been investigated in one experiment in water having a moderate salinity gradient. Strings of Nansen, Knudsen, Ekman and these bottles were hung side by side from a bar suspended from the main cargo boom of H.M.C.S. Cedarwood. There were four of each type of bottle on a string at intervals of two meters, and the end of the cargo boom was high enough above the sea to allow all of the bottles to be in the air at once. With the bottles open, and messengers attached, they were lowered into the water, and at a measured time from immersion of the uppermost bottle, messengers were dropped on each line simultaneously. The bottles were then hauled up, and the samples were drawn. This procedure was repeated to obtain samples after 0, 1/2, 1, 1 1/2, 2, 3, 4, 5, 6, 9, 11 and 15 minutes submersion time, the different intervals being observed in random order (Table I).

With this method of sampling it is believed possible to estimate the time required for a bottle to flush completely, by comparing the salinity of the samples taken. Ideally, the time required for complete flushing of all bottles is the time which must elapse after submersion, before all bottles at the same depth have identical samples. In this experiment an arbitrary reference salinity for each cast was assumed by choosing the maximum salinity at each depth, regardless of the type of bottle from which it was drawn. It was assumed that if the salinity as shown by one bottle was less than the reference at the same depth, it was because some water of a lower salinity had been trapped in the bottle, and carried down with it to the sampling position.

To evaluate the relative efficiency of the different bottles, the area between the reference salinity curve, and the curve shown by each type of bottle was measured for the various submersion times. It was assumed that as this area approached zero with longer "soaking", flushing became more complete. Thus, the area between the curves and the time required for it to approach zero, is the measure of efficiency. For discussion purposes, the units of area have been called "Salinity Meters" (S.M.).

The data are shown in Table I. The salinity profiles for a submersion time of 0 minutes are shown in figure 8., together with the reference profile.

The relative efficiency of the four types of bottles is shown in figure 9. The variation in the data is about 0.25 S.M. and becomes approximately constant after 9 minutes submersion time. The data for the 6 and 15 minute intervals are not consistent with the remainder of the series and cannot be explained from the records of the experiment. Despite these anomalies the relative efficiencies are clearly indicated. In these waters where the salinity (and consequently the density) gradient was large, the sample in the new bottle apparently was in equilibrium with its surroundings immediately, the Ekman bottle samples were in equilibrium after one half minute, the Knudsen samples after two minutes, but the Nansen bottle required five minutes "soaking" to obtain a true sample.

When a bottle is being lowered flushing occurs due to the velocity head in the fluid at the end opening, and after it is in position the lighter water entrapped and carried down in the lowering will float out and be replaced by the denser surrounding water. Small end openings and internal obstructions cause a flow resistance which is most effective in retarding the flushing while lowering when the velocity is greatest, but is also effective in retarding the hydrostatic flushing when the bottle is in position.

The data in figure 9 show that the efficiency is proportional to the effective size of end openings and freedom of flow through the bottles. The end caps on the Ekman bottles must retard free flow, but equilibrium is quickly attained (1/2 minute) because the openings are large, and the tube is unobstructed. The end opening of the Knudsen bottle is of a fair size, but is partially obstructed by the internal spring, which also occupies a large proportion of the cross section area of this narrow bottle. The stopcocks on the Nansen bottle constrict the end openings so much that they require more than twice the time of any other bottle for flushing.

The bottle described here approached the postulated requirements more closely than any of these standard designs, and it is believed to be an acceptable improvement.

N.B. Copies of the plans and specifications may be obtained at cost from the Oceanographer in Charge, Pacific Oceanographic Group, Nanaimo, B.C.

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TABLE I

The salinity of samples taken simultaneously in four types of sea sampling bottles after various intervals of immersion.

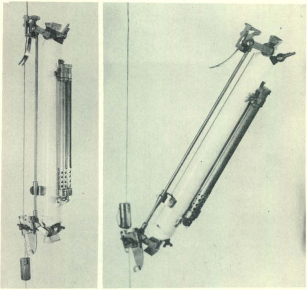
Types of Bottles

Depth Meters	New	Nansen	Knudsen	Ekman
		Salinity (S °/..)		
		0 Minutes "Immersion"		
0	23.35	23.39	23.33	23.31
2	23.42	23.33	23.35	23.37
4	24.43	23.57	23.64	24.30
6		24.69	24.78	25.48
		1/2 Minutes "Immersion"		
0	23.93	23.90	23.93	23.90
2	24.16	24.00	23.90	23.95
4		24.36	24.42	24.78
6	25.62	24.90	25.55	25.64
		1 Minute "Immersion"		
0	24.40	24.27	24.29	24.29
2	24.29	24.30	24.30	24.29
4	25.30	24.74	25.01	25.28
6	25.68	24.69	25.52	25.68
		1 1/2 Minutes "Immersion"		
0	23.98	24.50	23.98	24.02
2	24.20	24.14	24.16	24.16
4	24.81	24.61	24.69	24.81
6	25.81	25.52	25.73	25.80
		2 Minutes "Immersion"		
0	24.36	24.38	24.40	24.40
2	24.51	24.45	23.87	24.47
4	25.35	25.16	25.39	25.41
6	25.59	25.50	25.59	25.57
		3 Minutes "Immersion"		
0	24.02	24.00	24.02	24.00
2	24.00	24.04	24.00	24.04
4	24.92	24.61	24.92	24.94
6	25.75	25.53	25.73	25.72

TABLE I Continued.

Types of Bottles

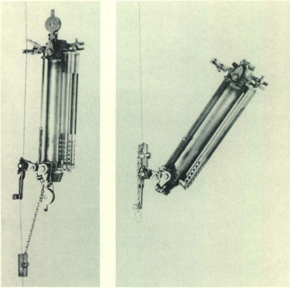
Depth Meters	New	Nansen	Knudsen	Ekman
		Salinity (S °/..)		
		4 Minutes "Immersion"		
0	23.60	23.69	23.71	23.69
2	23.73	23.71	23.73	23.74
4	24.34	24.05	24.18	24.34
6	25.59	25.48	25.57	25.57
		5 Minutes "Immersion"		
0	24.14	24.13	24.11	24.05
2	24.11	24.13	24.11	24.14
4	24.47	24.38	24.31	24.47
6	25.73	25.64	25.72	25.72
		6 Minutes "Immersion"		
0	24.11	24.18	24.11	24.11
2	24.22		24.27	24.27
4	24.76	25.16	24.69	25.10
6	25.82	25.84	25.82	25.84
		9 Minutes "Immersion"		
0	23.59	23.66	23.62	23.57
2	23.69	23.62	23.71	23.68
4	24.45	24.54	24.61	24.50
6	25.55	25.61	25.62	25.62
		11 Minutes "Immersion"		
0	24.18	24.07	24.11	24.11
2	24.22	24.25	24.27	24.27
4	24.58	24.54	24.52	24.60
6	25.81		25.81	25.80
		15 Minutes "Immersion"		
0	23.48	23.44	23.38	23.44
2	23.48	23.51	23.50	23.55
4	24.09	25.10	25.37	25.39
6		25.64	25.72	25.62



In position Reversing

<u>Figure 1.</u>

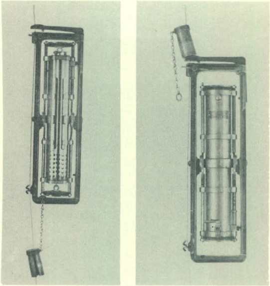
The Nansen deep sea reversing water sampling bottle.



In position Reversing

Figure 2.

The Knudsen deep sea reversing water sampling bottle.



In position Reversed

Figure 3.

The Ekman deep sea reversing water sampling bottle.

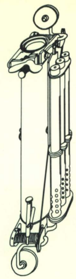


Figure 4.

The seawater sampling bottle.

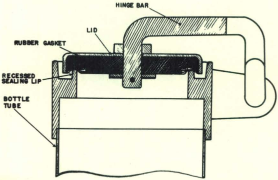
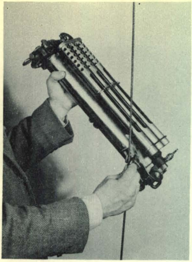
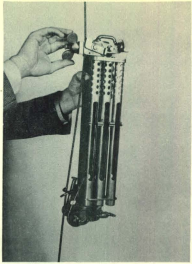


Figure 5.

Detail of lid construction on the seawater sampling bottle.



A



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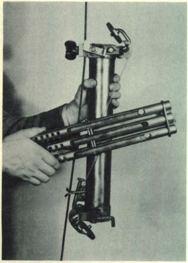

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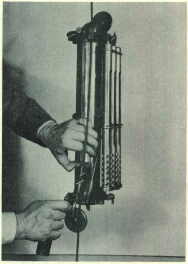

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Figure 6.

Attaching the new bottle
to the sounding line.

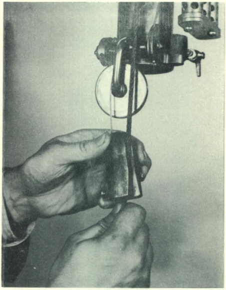

Figure 7.

Pushing the split messenger
onto the sounding line.

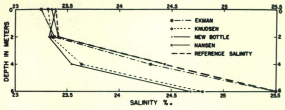

Figure 8.

The salinity of samples taken simultaneously in the four types of bottles after zero minutes submersion.

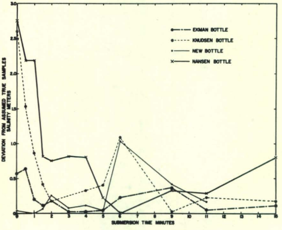

Figure 9.

Deviation of the salinity in each type of sample bottle from the reference value. Efficiency varies inversely with the deviation.