

trated atmospheric violence which often results in deaths and heavy property damage. When we combine the increased understanding of the dynamics of storms of this type (as provided by meteorological research) with the research efforts in electron physics which produced radar and television, and then use radar for storm detection and television to inform the populace about the progress of a storm, death and destruction are reduced to a minimum.

Meteorology should be much more widely offered, and students who are non-science majors should be encouraged to take this course as a satisfying means of completing their physical-science requirement.

JOHN A. DAY

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## Arctic Waters

Regarding the report entitled "Tritium tracer in Arctic problems," by Giletti and Kulp [*Science* **129**, 901 (1959)] and the subsequent exceptions taken by Barnes and Coachman

[*Science* **130**, 273 (1959)], I am not sure whether I am lessening or adding to the confusion with the following remarks, but there are some factors very pertinent to the matter which I feel should be brought out.

As Barnes and Coachman pointed out, the curves in Giletti and Kulp's Fig. 1 do not agree with the reference (6) cited in the figure's caption. The figure presents temperature-depth curves for "Icicle" stations, 2, 5, 10, and 11. The first two curves were derived not from reference 6 but rather from reference 5, cited in the text [namely, L. V. Worthington, *Woods Hole Oceanog. Inst. Tech. Rept.* 53-92 (1953)]. The other two curves were drawn from data gathered by Goldstein in 1955. I am not aware that the curves from the last two stations have appeared in previous literature, but the data received some small distribution.

Barnes and Coachman have used a bottom temperature read from the curve for station 11 to show that this water, if it were a mixture of Atlantic water and arctic surface water as proposed by Giletti and Kulp, was at best only 20 percent arctic and 80 percent Atlantic water. Giletti and Kulp replied

that this accorded with their theory.

I should like to point out two items. First, the bottom temperature shown in the station-11 curve is actually an extrapolated value, the deepest observation having been made 22 meters above the bottom. This extrapolated bottom temperature is about  $+0.1^{\circ}\text{C}$ ; the deepest observation shows a temperature of  $+0.21^{\circ}\text{C}$ . I am not sure that other extrapolators would have drawn the curve in quite the same manner as it appears in the Giletti and Kulp report.

The second item is, I believe, the crux of the matter. The tritium sample which led Giletti and Kulp to their conclusions was collected at a depth of 400 meters at a location very close to station 11. Therefore it would seem to be only proper to use the interpolated 400-meter temperature of  $+0.35^{\circ}\text{C}$  given by Giletti and Kulp for station 11 in carrying out the computations proposed by Barnes and Coachman for figuring the percentages of Atlantic and arctic surface waters.

If this is done, we find that if surface water having a temperature of  $-1.9^{\circ}\text{C}$  (which it would have if the salinity concentration were to be raised the requisite amount by freezing) is mixed, in

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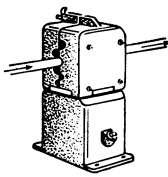
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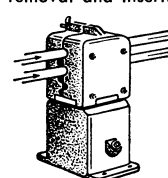
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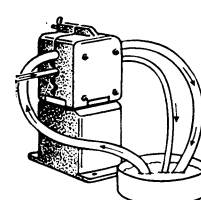
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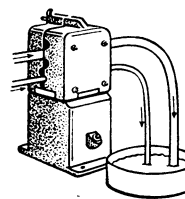
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sinking along the archipelago slope, with water of Atlantic origin having a temperature of  $+0.50^{\circ}\text{C}$ , a resulting mixture with a temperature of  $+0.35^{\circ}\text{C}$  at 400 meters would consist of nearly 94 percent Atlantic water and only about 6 percent locally formed water.

This would seem to make Giletti and Kulp's point (iv), that "a new source of the deeper water of the Arctic Ocean was found to be in the Canadian archipelago," sound a bit pretentious, especially as it is based on a single tritium measurement the results of which, as Barnes and Coachman point out, tend

to support the more generally accepted theory nearly as strongly as they suggest the Giletti and Kulp conclusion.

WILLIAM G. METCALF  
*Woods Hole Oceanographic Institution,  
Woods Hole, Massachusetts*

We wish to thank W. G. Metcalf for his comments on our report "Tritium tracer in Arctic problems" and our subsequent exchange of letters with Barnes and Coachman. The point under discussion is our interpretation of the high value of tritium concentration found in a sample of Arctic Ocean

water at a depth of 400 meters. In our explanation of this value we suggested that the supply of tritium occurred by the sinking of local surface water (normally richer in tritium) to this depth. We drew the analogy with other localities where sinking takes place as a result of freezing surface conditions. It would appear from Metcalf's calculation that only about 6 percent of the sea water in our 400-meter sample could have been derived from the surface as a result of such freezing.

In the generally accepted view of Arctic Ocean circulation the water at this depth is derived by the sinking under the arctic surface water of more highly saline water from the Atlantic. This water would then circulate cyclonically, traveling past Siberia before reaching our sample location north of Canada. If this were so, a very rapid rate of circulation would be required, and the net effect would be a generally high tritium content for all the deep water partaking of this pattern. As we pointed out in our reply to Barnes and Coachman, improbably high natural tritium production rates are required to maintain this concentration.

Metcalf suggests that the tritium data actually do "as Barnes and Coachman point out, tend to support the more generally accepted theory nearly as strongly as they suggest the Giletti and Kulp conclusion." On the contrary, there is a major contradiction between the tritium data and the expected tritium concentration. If the major cyclonic-flow pattern is excluded from this area, however, then all the data can be made to fit without the need for fresh supplies from the arctic surface. In this case, the Atlantic-derived water must flow in a fairly direct line to the sample location.

A possible solution to the problem may therefore be a more sharply defined version of the generally accepted theory. Should subsequent measurements support these original tritium observations, the theory may have to incorporate direct flow of Atlantic-derived water to the region north of Ellesmere Island. Further, if cyclonic flow exists over most of the Arctic Ocean, it must bypass the sample area.

Finally, we wish to stress the point that tritium can be used as a tracer to derive information on mixing rates in the Arctic Ocean. The present limited amount of data is as yet insufficient for drawing firm conclusions.

BRUNO J. GILETTI  
J. LAURENCE KULP

*Lamont Geological Observatory,  
Torrey Cliffs, Palisades, New York*

#### Note

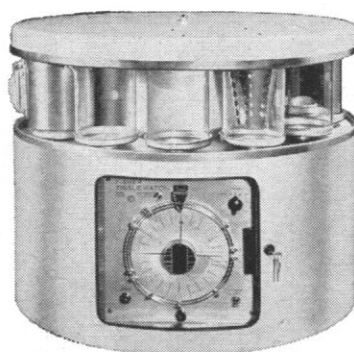
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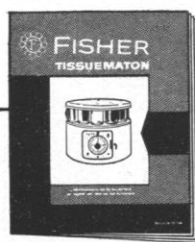
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