Source: Hamburg, Met.Amt Nordwestdeutschland,
Annals of meteorology, issue 10-12, 1951, pp.480-482.

4. The accuracy of measuring water temperature with the water scoop thermometer (Marinepütz - German Scoop Thermometer). By ROLL, H.U.

Summary: The change in water temperature in the Marinepütz caused by heat exchange and evaporation between the time when the water is drawn and when the temperature is read is examined in the wind tunnel and presented in summary form.

On German ships the water temperature is measured preferably with the so-called "Marinepütz". This is a scoop with a thick rubber wall which houses the thermometer in a tubular attachment and is more closely described in the previous article.

The errors in the measurement of water temperature at sea associated with this scoop method have been discussed by ASHFORD 1) for the various types. The above-mentioned "Marinepütz" was also briefly dealt with. The relatively large changes in temperature of the water sample after drawing it as a result of heat exchange and evaporation were characteristic of this method. As the errors in water temperature measurement caused in this way are of basic practical significance, they were thoroughly examined by us in the wind tunnel.

The method of measuring was simple. The Marinepütz was dipped in a large tank of water of a selected temperature, checked that it recorded the same temperature then pulled out and hung in the airstream of the wind tunnel. For 10 minutes in intervals of 30 seconds after it was pulled out, the water temperature on the Pütz thermometer was read and at the same time the temperature and humidity of the airstream determined with an electrically ventilated Assmann aspiration psychrometer. These measurements were carried out for various temperature differences Δ T air-water between +5 and -10°C and wind speeds U in the region 2 - 19 m/s. The desired Δ T-values can easily be achieved by appropriate tempering of the water in the tank.

As an example of the results achieved we show in fig. 1 the temporal change in the water temperature in the Marinepütz after it has been taken from the water at a Δ T-value of -10°C (water 10° warmer than the air) for eight different wind speeds. As appropriate for the lower air temperature, the water temperature constantly drops with time, this being most noticeable in strong winds. After 1 minute drops of 1-2° were ascertained. As the air temperature was approached, the drop in water temperature became less as indicated by the curves in the figure.

Fig.1: Temperature change δT_w of the water sample in the Marinepütz after drawing water for various wind speeds at an air-water temperature difference of -10°C.

For practical purposes it is useful to know what changes occur in the first minute after the scoop is pulled from the water as, at worst, a period of this order may pass between drawing the water and taking readings on board (this time is usually 1/2 minute). The table explains this change in water temperature in the Marinepütz in the first minute for various Δ T-values and wind speeds. We deduce from this table that noticeable errors in the readings will only occur if the wind speed affecting the Pütz is greater than 10 m/s or if the air is colder than the water by 5° or more. In large negative Δ T-values and strong winds, very considerable errors can occur. (Of course the apparent wind speeds are to be inserted on board a ship).

Table: Temperature change δT_W of the water sample in the Marinepütz during the first minute after drawing water.

Thus the practical requirements were met for the most part as the time between drawing water and taking readings should seldom be longer than 1 minute. For shorter periods of time, as a result of the initial linearity of the water temperature change, appropriate interim values can easily be taken from the table. In general it can be said that the error in water temperature measurements taken with the scoop thermometer (Marine-Pütz) caused by heat exchange and evaporation can be adequately off-set by quickly taking readings shielded from the wind unless the temperature difference water-air is very great.

Going beyond these purely practical questions, it seems expedient to present in a survey form all the measurement results gained in the wind tunnel. We will then, in part, follow the deliberations of F.RÖSSLER 2) concerning the heat transfer to damp surfaces.

We will indicate the equivalent air temperature with Θ_L and that of the water with Θ_W and thus describe the heat flow dQ/dt between the water mass of the surface F and the surrounding air by the following (Newton's) equation

$$dQ/dt = \alpha . F . (\Theta_L - \Theta_W) . \qquad (1)$$

Here α the so-called "coefficient of heat transfer is in $g.cm^{-2}.sec^{-1}$. It is not an absolute constant but depends on the flow conditions, the type of gas and the condition of the surface of the water. In our case the conditions are complicated by the fact that heat exchange and evaporation not only occur at the "open water surface" of the open upper side of the scoop but most probably also - to a lesser extent - through the rubber and cork isolated side and lower surfaces of the scoop. Here the evaporation can only play a role if the external wall of the scoop is damp. As these various processes cannot be separated we will describe them together by a "coefficient of effective heat transfer".

If we take dQ/dt as the temporal change of the heat content of the water, (1) becomes, if we call the mass M and the temperature of the quantity of water T_W. ($M \sim 610$ gr)

$$dT_W/dt = \frac{\alpha F}{M} (\Theta_L - \Theta_W) \qquad (2)$$

Here $\alpha F/M$ is the amount describing the heat transfer in the special case of the Marinepütz which we, taking into account the difficulties mentioned of exactly determining the surface F, wish to discuss together under the designation β .

So

$$\beta = \frac{dT_W/dt}{\Theta_L - \Theta_W} \quad [sec^{-1}] \qquad (3)$$

shows the dependency of this "coefficient of temperature change of the Marinepütz" on flow conditions ie on wind speed.

For the purpose of our measurement results we refer the temporal change of the water temperature in the scoop dT_W/dt to one minute, ie $dT_W/dt \sim \delta T_{Wmin}$.

As the reading of the water thermometer installed in the scoop is not very accurate (tenths of degrees can only be estimated) we must confine ourselves, when determining the coefficient of temperature change β , to the cases of large temporal temperature change ie to the series of measurements for Δ T-values between -2.5 and -10°C. Where there are smaller temporal temperature changes, δT_{Wmin} would become too inaccurate. The distribution of β values within the same wind speed is relatively small with the result that we are justified in deriving averages from the individual values of the coefficients of temperature change β for the same wind speeds. Fig. 2 shows as a result of this summary of 30 individual values, the dependency of the average "coefficient of temperature change of the Marinepütz" β on the wind speed U. The measurement points form a smooth line rising steeply as the wind speed increases. The line represents the overall result of our investigation of the sea scoop in the wind tunnel. Using this and the equation (2) it is easy, with the given difference in equivalent temperatures of air and water, to determine the value of the change of water temperature occurring every minute in the water scoop.

I would like to thank the instrument section of the meteorological office for north west Germany for the provision of the wind tunnel, my colleague Mr. O. Petri for his help in carrying out and evaluating the measurements.

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2) F.Rössler, Heat transfer at damp surfaces and evaporation. Journal "Mining and energy" vol. 1, 165 1948 and Natural Science 35, 219 (1948). [Naturwiss.]

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Wind speed	2	4	6	8	10	13	16	19 m/s
Temperature difference air-water in °C								
+5,0	+0,1	0	0	0	+0,15	+0,1	+0,2	+0,2
+2,5	0	0	0	0	-0,05	-0,1	-0,05	-0,05
0	0	-0,05	0	0	-0,05	-0,1	-0,25	-0,2
-2,5	0	0	0	-0,1	-0,25	-0,25	-0,4	-0,7
-5,0	-0,05	-0,15	-0,2	-0,2	-0,3	-0,6	-0,8	-1,1
-10,0	-0,1	-0,3	-0,3	-0,4	-0,85	-1,0	-1,3	-1,7

Table: Temperature change δT_W of the water sample in the Marinepütz during the first minute after drawing water.

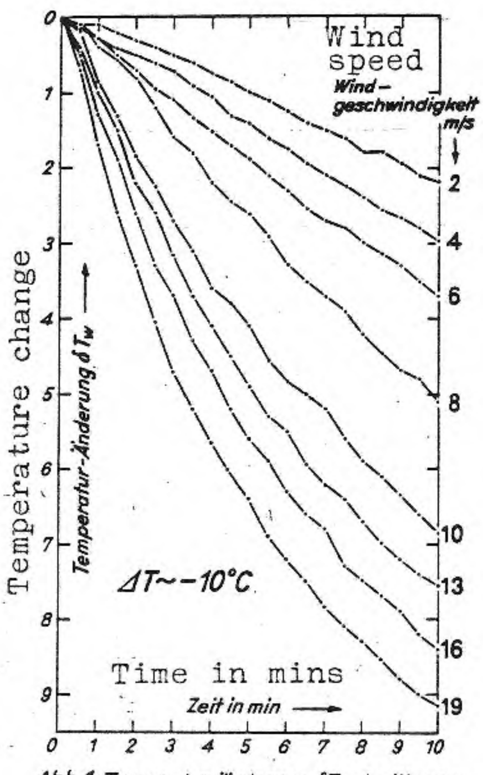

Abb. 1: Temperatur-Änderung δTw der Wasserprobe in der Marine-Pütz nach dem Schöpfen für verschiedene Windgeschwindigkeiten bei einer Temperaturdifferenz Luft–Wasser von −10°C

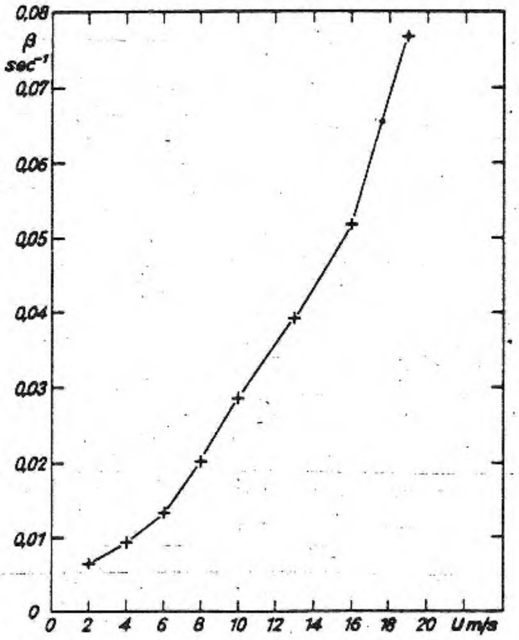

Abb. 2: Temperaturänderungszahl β des Wasserschöpfthermometers (Marine-Pütz) als Funktion der Windgeschwindigkeit U