Article 171

"LAZY" THERMOMETERS AND THEIR USE IN MEASURING GROUND-WATER TEMPERATURES

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Abstract.—The temperature of ground water at selected depths in unpumped, nonflowing wells can be measured in place with high-lag "lazy" thermometers. These thermometers are constructed by enclosing the bulb of liquid-in-glass thermometers with material of high specific heat, a layer of insulation, and a protective case.

Data on ground-water temperatures have been applied successfully in recent years to a variety of problems, and such data promise to become one of the most useful tools in ground-water hydrology. In most ground-water investigations, temperature measurements are obtained only for water being discharged from flowing or pumped wells. Such measurements are of limited usefulness because they represent a weighted average of the temperature of the producing zone open to the well, which in some places may be more than 100 feet thick.

Measurements of water temperature in wells have been made with thermometers inserted in bottles and lowered down the wells. There are drawbacks to this method and, unless special precautions are taken, the measurements may be in error by several degrees. The most precise way to measure the temperature of water in place in wells is with an electrical thermometer. Such thermometers, accurate to 0.1 °F, are available from several manufacturers. However, because electrical thermometers are fairly expensive, and somewhat delicate, they are not practical for many field investigations.

Where it is desirable to measure the temperature at the same depth in the same well periodically, satisfactory data can be obtained with so-called "lazy" thermometers. These thermometers are made by enclosing the bulb of an ordinary liquid-in-glass thermometer in such a manner that its response to change in temperature is delayed. Figure 171.1 shows the features of a lazy thermometer recently built by the author. It consists of four parts:

1. Standard liquid-in-glass thermometer in a metal case
2. Layer of material of high specific heat
3. Layer of insulation
4. Outer protective metal case.

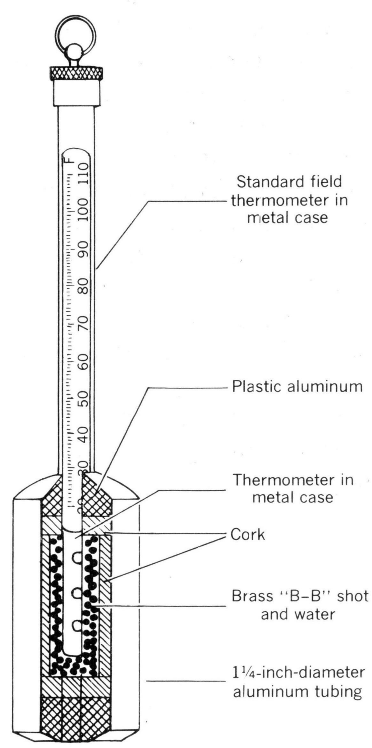

Figure 171. 1—Detail of a "lazy" thermometer.

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Many materials are probably suitable for use in constructing lazy thermometers. The author uses aluminum tubing for the outer case. A layer of cork about 0.15 inch thick is used for insulation, and a layer of brass "B–B" shot is inserted between the thermometer case and the insulation. The top and bottom are sealed with plastic aluminum. However, because the annular space between the thermometer and its metal case is difficult to seal at the top, water displaces the air in the pores between the brass shot when the thermometer is submerged. This is, in fact, desirable because of the high specific heat of water.

In order to determine whether a lazy thermometer is suitable for the use intended, its inertial characteristics must be determined. This is done by immersing the thermometer in water of a constant temperature, either above or below the air temperature. After the thermometer reaches the same temperature as the water, the thermometer is removed and a record is made of the change in temperature with time as the thermometer approaches the air temperature. The time is recorded to the nearest second and the temperature estimated to the nearest 0.1 degree. A graph is plotted of log of the time, in seconds, versus log of the change in temperature, in degrees Fahrenheit, divided by the difference between water and air temperatures. The time, in seconds, during which different percentage changes of temperature occur may be determined directly from the graph.

The next step depends on the accuracy desired in the temperature measurements for which the lazy thermometers are to be used. Many field investigators read thermometers only to the nearest degree or nearest half degree. With care, however, the thermometer in common field use in the Water Resources Division of the U.S. Geological Survey can be read to 0.1 degree with an error of ±0.1 degree. (It is recognized, of course, that many field thermometers are not accurate to 0.1 degree. A part of this difficulty can be resolved by calibrating the field thermometer to a laboratory-tested master). Therefore, if it is desired to read the lazy thermometer to the nearest 0.1 degree, the problem is to determine the length of time required for a change of 0.1 degree at the maximum expected difference between water and air temperature at the locality in which the thermometer is to be used. Figure 171.2 shows the time required for a change of 0.1°F in one of several lazy thermometers built by the author.

For comparison, the inset in the upper right-hand corner of figure 171.2 shows the time required for the standard field thermometer in its metal case to change 1.0°F. It may be seen that its lag is one-fortieth that of the lazy thermometer.

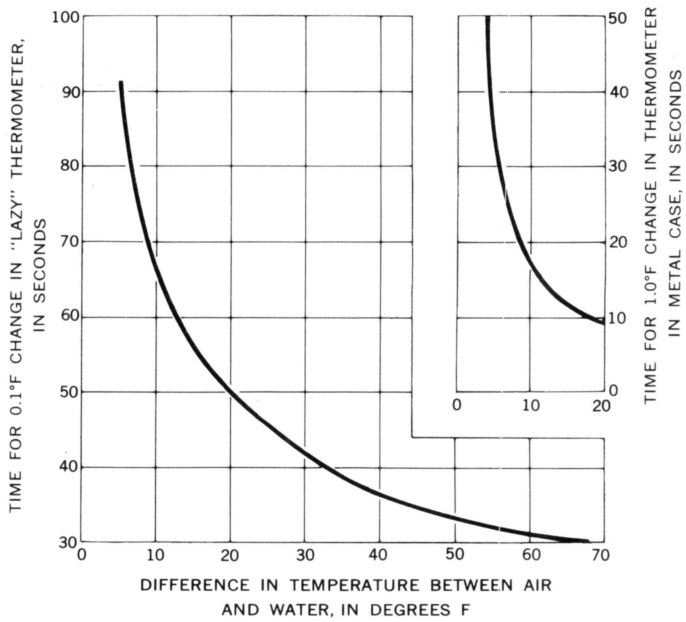

FIGURE 171.2.—Inertial characteristics of a "lazy" thermometer.

Whether a specific lazy thermometer can be used in a given well depends on (1) the inertial characteristics of the thermometer, (2) the depth at which temperatures are to be measured, and (3) the maximum expected difference in temperature between the water and the air. In normal practice the thermometer is left submerged at the desired depth between readings. (Parachute cord has been found to be highly satisfactory for holding the thermometers). Therefore, the time required to withdraw the thermometer from the well and read the temperature is the limiting factor in precision.

Thermometers can be withdrawn from wells at a rate of about 3 feet per second and can be read in 5 to 10 seconds, depending on the skill of the observer. To determine the maximum depth at which a particular lazy thermometer can be used, it is necessary to determine the lag, in seconds, at the expected maximum difference between water and air temperature, subtract 10 seconds, and multiply the remainder by 3. For example, the expected maximum difference between water and air temperature at Albany, N.Y., is about 60°. The "lazy" thermometer for which data are plotted in figure 171.2 has a lag of 31 seconds at this difference. Therefore, by subtracting 10 seconds and multiplying by 3, it is found that this thermometer can be used at any depth down to about 60 feet. If measurements accurate to 0.2 degree were acceptable or if the expected maximum difference between water and air temperature was only 30°, the thermometer could be used to a depth of about 90 feet. As seasonal fluctuations of ground-water temperature, regardless of whether they are caused by stream infiltration or changes in air temperature, occur at depths greater than about 60 feet only under unusual conditions, it is obvious that lazy thermometers are an economical and practical tool for monitoring fluctuations in ground-water temperatures.