A Cautionary Note on the Use of Dew Point-Frost Point Hygrometers for Frost Point Measurements

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Humidity, one of the important meteorological parameters which varies over a wide range in the atmosphere, has been and continues to be a difficult quantity to measure accurately. One of the instruments that is being used quite extensively for humidity measurements is the dew point-frost point hygrometer. Its operation is based upon the condensation or deposition of water vapor which occurs when an object is cooled to the dew point or frost point temperature. A thermoelectric module is commonly used to cool a mirror until an optical system coupled to a servo-mechanism detects and maintains a coating of dew or frost on the mirror. When the coating is stable, the mirror, in theory, is at the dew point (frost point) temperature which can be measured.

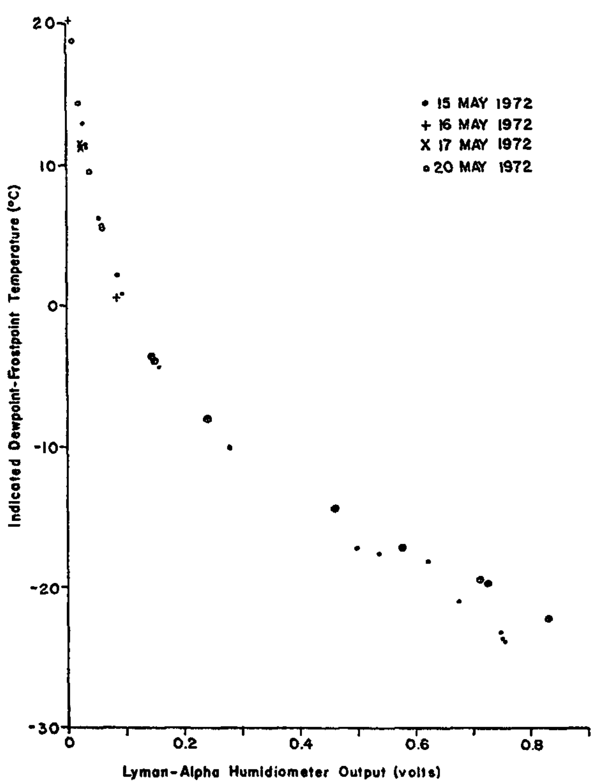

FIG. 1. Indicated dew point-frost point temperature determined by a dew point hygrometer versus the output voltage of the Lyman-α humidiometer. The points which are encircled indicate readings taken when the ice deposit on the mirror was observed to be reasonably uniform.

This method of humidity measurement has proven to be quite effective. However, during recent attempts to calibrate a Lyman-α humidiometer in controlled humidity in the NCAR particle control chamber by using a Cambridge Systems[2] Model 992 dew point hygrometer as a reference, we became aware of a potential source of error for frost point measurements.

The error is associated with the nature of the ice deposit on the mirror. By examining the deposit on the mirror while the dew point meter was operating, we sometimes observed a number of individual, isolated crystals forming on the surface, presumably at preferred nucleation sites, rather than a uniform ice layer. When this happened the mirror temperature dropped below the frost point until the ice crystals grew sufficiently large to be detected by the optical system.

Fig. 1 illustrates this error. Dew point (frost point) temperatures measured by the Cambridge Systems dew point meter are plotted versus the output voltage of the Lyman-α humidiometer. One can see from the figure that at dew point temperatures above 0C there is little scatter in the data. But gradually, as the frost point decreases, the scatter becomes much larger. Points on the figure which are encircled indicate readings which were taken when the ice deposit on the mirror had been observed to be reasonably uniform. The other points below 0C were taken at times when there was reason to believe that there were individual ice crystals

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[2] Cambridge Systems Inc. of EG&G, Waltham, Mass.

rather than a uniform coat of ice. Most of these latter readings were taken shortly after the meter had been thoroughly cleaned with alcohol, presumably leaving only a few nucleation sites. Later observations have confirmed this. The magnitude of the error originating from this source was dependent upon the number of crystals on the surface and their location relative to the optical detection system. Errors as large as 3–4C occurred at frost point temperatures near −25C. In contrast, it was possible to obtain consistent calibration curve measurements within about ±0.5C by being certain that the ice deposit on the mirror was uniform.

After realizing that a thoroughly cleaned mirror could impair the operation of the instrument, we tried cleaning the mirror with cleaner and conditioner supplied by Cambridge Systems Inc. instead of alcohol, but the results were much the same. The bridge settings were also changed to increase the thickness of the layer. This reduced the error to 1–2C but did not solve the problem entirely. We also tried to find an efficient ice nucleator that would nucleate a uniform coat of ice on the surface. Of the nucleating agents tried (various solutions of AgI and hygroscopic materials in acetone, and phloroglucinol in alcohol) nucleation still tended to occur at preferred sites. We did find that a temporarily uniform ice deposit could be obtained for frost points between 0 and −40C by force-cooling the mirror (which is possible on some models) from a temperature greater than 0C to a temperature below −40C. In this way a thick ice deposit was built up, much of which had to evaporate before the instrument was stable, but the remaining deposit was reasonably uniform.

Undoubtedly many users of dew point hygrometers are aware of this problem and correct for it. But there are perhaps many more who have not made the detailed comparisons necessary to uncover the problem, or whose instruments do not allow one to examine the mirror during operation. If critical measurements are desired below 0C, the following precautions are recommended: 1) examine the mirror directly to insure that the deposit is uniform; 2) do not clean the mirror too thoroughly, or alternately, try to wipe it with a conditioning agent; 3) buff the mirror with very fine jeweler's rouge; 4) use a thicker coat of ice; and 5) force-cool the mirror to a temperature well below the frost point.

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