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# AN APPLICATION OF THE DUNMORE ELECTRIC HYGROMETER TO HUMIDITY MEASUREMENT AT LOW TEMPERATURES

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# APPLICATION DE L'HYGROMETRE ELECTRIQUE DE TYPE DUNMORE A LA MESURE DE L'HUMIDITE A BASSES TEMPERATURES

## SOMMAIRE

Le rayon d'action limité des détecteurs individuels d'humidité du type Dunmore et leur vitesse réduite de réaction aux basses températures tendent à restreindre leur emploi comme dispositifs de mesure directe de l'humidité dans certaines applications. Dans certaines conditions une augmentation considérable du rayon d'action et une amélioration de la sensibilité peuvent être possibles avec des détecteurs ayant un rayon d'action plus faible, en élevant la température de l'air que l'on échantillonne. On décrit dans cette étude une méthode faisant appel à ce principe laquelle a une application spécifique pour la mesure de l'humidité atmosphérique dans les conditions de basse température de l'hiver. Le dispositif particulier que l'on décrit utilise un détecteur à faible rayon d'action pour régler le réchauffage d'un filet d'air échantillonné de façon continue pour maintenir la resistance du dispositif à une valeur constante. La température qui en résulte dans le détecteur fournit un indice de l'humidité de l'échantillon, la relation entre la température du point de rosée et la température du détecteur étant presque linéaire. Au moyen d'un détecteur ayant un intervalle nominal d'humidité relative à 60°F de 3 à 8%, des températures du point de rosée allant de -25 à +25°F peuvent être mesurées avec des températures de détecteurs allant de 40 à 140°F. La substitution d'un deuxième détecteur à rayon d'action plus élevé augmente le point de rosée maximum que l'on peut mesurer à plus de 50°F avec une température limite de détecteur de 140°F. La précision de la méthode dépend de façon critique de la sensibilité et de la stabilité du détecteur Dunmore; cependant, avec un calibrage précis des mesures de température du point de rosée sont possibles sous zéro à ± 1.5°F près.

ANALYZED

# 28. An Application of the Dunmore Electric Hygrometer to Humidity Measurement at Low Temperatures*

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## ABSTRACT

*The limited range of individual humidity sensors of the Dunmore type and their decreased speed of response at low temperatures tend to restrict their use as direct humidity measuring devices in some applications. Under certain circumstances a considerable increase in range and improvement in sensitivity may be possible with sensors of a lower humidity range by raising the temperature of the air being sampled. This paper discusses a method employing this principle that has specific application to the measurement of atmospheric humidity under low temperature winter conditions.*

*The particular device described uses a low-range sensor to control the heating of a continuously sampled airstream to maintain the resistance of the sensor at a constant value. The resultant temperature of the sensor provides an index of the humidity of the sample, the relationship between dew-point temperature and sensor temperature being almost linear. With a sensor having a nominal relative humidity range at 60°F of 3 to 8 per cent, dew-point temperatures from −25 to +25°F may be measured with sensor temperatures between 40 and 140°F. Substitution of a second higher-range sensor increases the maximum measurable dew point to above 50°F with a limiting sensor temperature of 140°F.*

*The accuracy of the method is critically dependent on the sensitivity and stability of the Dunmore sensor; however, with precise calibration, measurements of subzero dew-point temperature to within ±1.5°F are possible.*

## INTRODUCTION

The limited range of individual sensors of the Dunmore type and their decreasing sensitivity with decreasing temperature tend to restrict their use as direct humidity measuring devices in some low temperature applications. In many such cases, however, the ambient relative humidity levels are high and the possibility of preheating a sampled airstream and employing a sensor of lower humidity range offers advantages. Increasing the ambient temperature at the sensor will improve its response in the first instance, because this characteristic is markedly influenced by sensor temperature.[1] Secondly, as the sensor resistance is primarily dependent on relative humidity, adjustment of the ambient temperature can be used as a means of extending its operating range.

The device described in this paper represents an application of these principles to the measurement of atmospheric humidity under the low-temperature conditions of the Canadian Prairies. Specifically, it involves the

* This paper is a contribution from the Division of Building Research, National Research Council, Canada and is published with the approval of the Director of the Division.

use of a Dunmore sensor to control the temperature of a sampled airstream so as to maintain a constant sensor resistance. Under these conditions the sensor temperature provides an index of the humidity of the airstream, the relationship depending on the characteristics of the sensor involved. This particular approach was followed primarily as a means of extending the operating range of a single sensor, but also to provide an output in terms of temperature, in keeping with the recording instrumentation available at the site.

The initial development of the apparatus was undertaken by the second author as his undergraduate thesis problem in Engineering Physics at the University of Saskatchewan in 1956. The subsequent availability of a precise humidity calibration facility at the National Research Council laboratory in Saskatoon made possible a more complete assessment of the accuracy of the device.

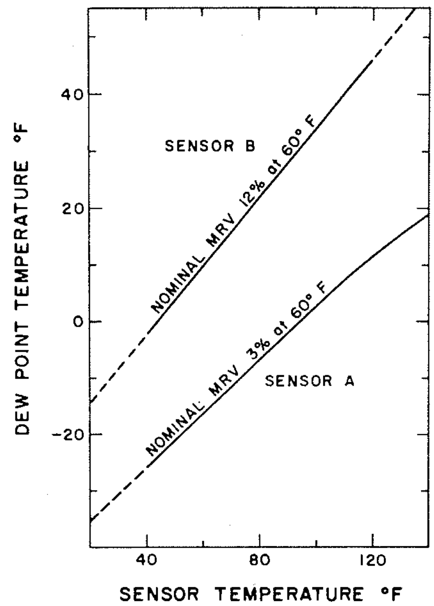


FIG. 1. Dew-point temperature–sensor temperature relationship for two commercial sensors at constant midrange resistance.

## DEW-POINT TEMPERATURE–SENSOR TEMPERATURE RELATIONSHIP

The calibration information supplied by manufacturers of this type of sensor is usually presented as a series of isotherms showing the relationship between relative humidity and sensor resistance or intrument reading. On the basis of these curves, relative humidities for different sensor temperatures can be obtained for any given sensor resistance or scale reading. Using these relative humidity values, it is possible to compute the relationship between dew-point temperature and sensor temperature for a constant sensor resistance. This relationship, based on midrange resistance, is shown graphically in Fig. 1 for two commercial sensors of different nominal humidity range.

If it is assumed that the operating temperature range of the sensors is from 40 to 140°F, sensor A, with a nominal midrange relative humidity of 3 per cent at 60°F, can be used to measure dew-point temperatures from —25 to +19°F; and sensor B, with a nominal midrange relative humidity of 12 per cent at 60°F, covers the dew-point range of —2 to + 57°F. These two sensors can therefore span a range of relative humidities from 4 to 100 per cent at 40°F if operated between the prescribed

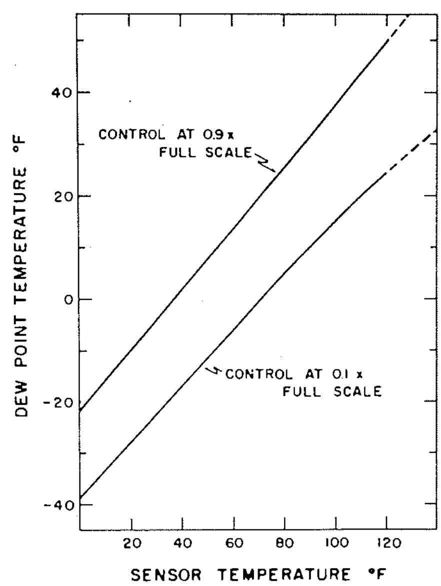


FIG. 2. Dew-point temperature–sensor temperature relationship for single commercial sensor at two levels of constant sensor resistance.

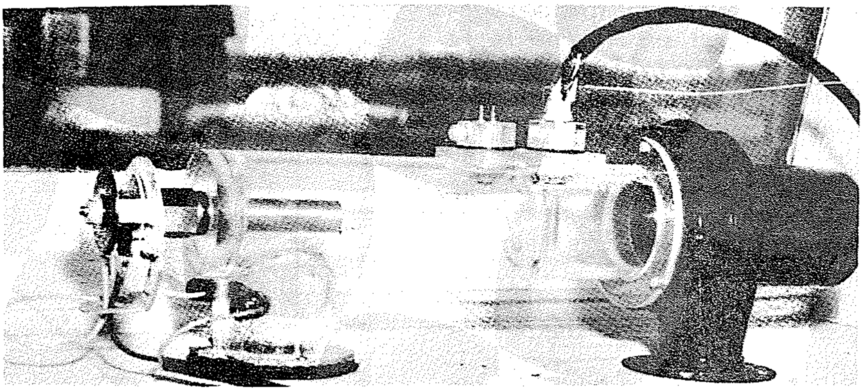

FIG. 3. Low-temperature hygrometer.

temperature limits. Although the upper limit of 140°F may not be exceeded for fear of permanent sensor damage, the measurable humidity range can be extended downward to much lower values, due consideration being given to the effect of lower sensor response.

An extension of range is also possible through adjustment of the control point to higher or lower values of sensor resistance. This is illustrated in Fig. 2 for sensor C which has a nominal humidity range between that of sensors A and B of Fig. 1. The upper curve represents the dew-point temperature–sensor temperature relationship for a control point equal to 0.9 of the instrument scale range, the lower curve that for a control equal to 0.1 of scale range. A single sensor with a suitable control point adjustment could therefore be used for the measurement of dew-point temperatures from 60 to −14°F, or lower.

Selection of a suitable sensor or sensors will depend on the requirements of the specific case. The application of primary interest to the authors involved the measurement of outdoor dew-point temperatures at Saskatoon during the winter period of December through March. The practical dew-point range involved was estimated to be between a minimum of −40°F and a maximum of +40°F.

## DESCRIPTION OF THE APPARATUS

The device used in Saskatoon is shown in the photograph of Fig. 3, and the various components are illustrated diagrammatically in Fig. 4. The air sampling system consists of a 3-in. diameter plastic tube fitted with an elbow at the intake end and a small centrifugal blower at the other. The intake elbow incorporates a glass-fiber filter, a 400-watt bare wire heating element, and a 140°F limiting thermostat. The entire assembly is mounted on a platform extending through a window opening in a heated building, the outside air sample being drawn from below this platform at the heater location and discharged to outside at the blower outlet.

The sensor is located in the horizontal section of the pipe, immediately downstream of a rectangular orifice designed to increase the air velocity over the sensor to approximately 2500 fpm. The sensor is connected to a conventional two-position indicator-controller, which operates a $\frac{1}{160}$ rpm reversible motor. This motor positions a variable voltage transformer, which supplies power to the bare wire heater through the limit thermostat. A thermocouple at the sensor location is used to measure temperature.

## GENERAL PERFORMANCE AND ACCURACY

The specific arrangement of components and the control system used resulted in a cyclical fluctuation in temperature at the sensor of less than ±1°F, corresponding to a dew-point temperature variation of approximately ±0.5°F. This fluctuation was considered to be due largely to the transient spatial variation in air temperature resulting from the bare wire heater and air turbulence

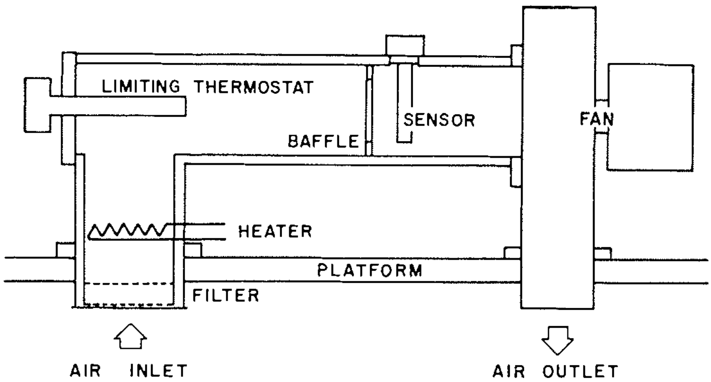


FIG. 4. Diagrammatic sketch of low-temperature hygrometer.

in the duct. Operation of the system during periods of constant outdoor temperature with a fixed voltage applied to the heater produced similar fluctuations that tended to confirm this possibility.

The response of the device to changes in atmospheric temperature and humidity during the winter proved to be satisfactory, but no rapid changes in sample inlet conditions were experienced. To provide a measure of its response under such conditions, the device was removed quickly from its normal outside air sampling position, exposed to room air conditions until equilibrium was established, and then returned to its original position. Outside air conditions were constant at 18°F with a dew-point temperature of 16°F, room air, at 72°F with a dew-point temperature of 22°F. The time required to reach equilibrium in each case was approximately 18 minutes.

The accuracy of the device is to a large extent dependent on the accuracy to which the sensor can be calibrated and on its stability under operating conditions. The sensor used for most of the measurements in Saskatoon was calibrated in a two-temperature recirculating atmosphere producer[2] capable of accuracies to better than 0.5 per cent RH. The resultant dew-point temperature–sensor temperature curve is illustrated in Fig. 5.

The potential accuracy of the device, based on a sensor calibration to within ±0.5 per cent RH, may be calculated as ±0.9°F at a dew-point temperature of −12.5°F. Assuming the potential error in temperature measurement to be equal to the fluctuation observed, the corresponding error in dew-point temperature measurement would be ±0.5°F. The total error in dew-point measurement, considering calibration tolerance and temperature deviation, may therefore be estimated at ±1.4°F.

The potential error at a dew point of 29.5°F, corresponding to a sensor temperature of 110.5°F, would be considerably greater because of the psychrometric relationships involved. Using the same basis for calculation,

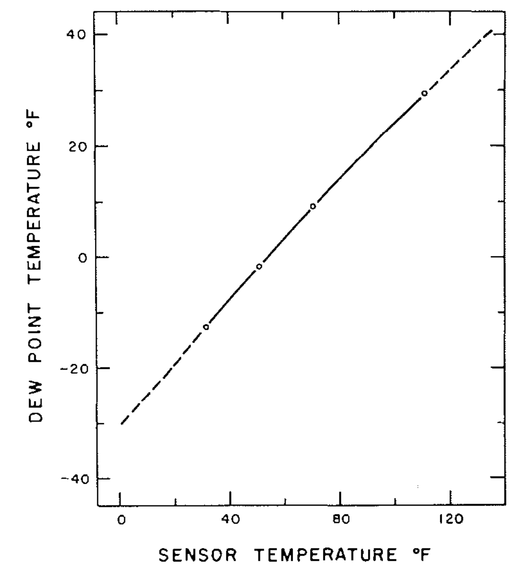


FIG. 5. Dew-point temperature–sensor temperature calibration of commercial sensor at constant midrange resistance.

it may be estimated at $\pm 2.3°F$. Some improvement in accuracy at this dew-point temperature could be realized by utilizing a sensor of higher humidity range.

The sensor used was recalibrated after exposure in the device for a period of one month, having operated within a range of temperature from 40 to 100°F. This recalibration revealed an upward shift in the curve of Fig. 5, corresponding to a change of approximately 1.5°F in dew point. A second sensor, of the same humidity range but exposed to slightly higher temperatures and for a longer period in the device, exhibited an upward shift in calibration of some 3°F in dew point.

## SUMMARY AND CONCLUSIONS

The technique described in this paper suggests a means of extending the range of a single Dunmore sensor by utilizing it to control the temperature of a sampled airstream. The accuracy of the device is critically dependent on the accuracy of calibration of the sensor used and on its stability under operating conditions. With precise initial calibration and periodic recalibration, accuracies of better than $\pm 1.5°F$ are possible at below zero temperatures. It is of interest to note that the almost linear relationship between dew-point temperature and sensor temperature permits some simplification in calibration procedure.

The improvement in speed of response of the sensor with operation at higher temperatures is not reflected directly in the output of the device, but is important in the operation of the control system. When it is desirable to measure more rapid fluctuations in humidity at low temperatures, control of air temperature directly and observation of sensor resistance change may be an alternative technique. When outside dry-bulb temperatures remain constant for suitable lengths of time, manual adjustment of heat input offers a basis for a simple indicating instrument. For such applications, a heating arrangement providing a more uniform airstream temperature would be desirable.

### References

1. Morris, V., and Sobel, F., "Some Experiments on Speed of Response of the Electrolytic Hygrometer," *Bull. Am. Meteorol. Soc.*, **35**, 226 (1954).
2. Till, C. E., and Handegord, G. O., "Proposed Humidity Standard," *Trans. ASHRAE*, **66**, 288–308 (1960).