

Memorandum

To: Prof. Noel de Nevers
From: Mr. David Fikstad
Date: 6 February 2006
Subject: Calibration and Evaluation of an Omega Model HX93V Relative-Humidity and Temperature Transmitter
cc: Sarah Read

Summary

During the period from January 6 to January 27, 2006, the members of Group F calibrated and evaluated the performance of an Omega Model HX93V relative-humidity and temperature transmitter (Omega Engineering, Stamford Connecticut). The transmitter was calibrated with an Omega HX92-CAL relative-humidity calibration kit, and its accuracy was tested with various solutions of ethylene glycol and water ranging from 10% to 100% relative humidity (RH)¹. The transmitter was accurate to within 5% RH at higher relative humidities (>50%) but was not accurate to within 5% RH at humidities lower than 50%. The transmitter's performance in a moving airstream at temperatures greater than room temperature was also investigated. A cardboard tube and an air blower containing a heating element supplied a suitable stream of heated air. A brief summary of the calibration and the results of our performance evaluation follow.

Apparatus and Procedure

The relative-humidity sensor uses a capacitor containing a water-absorbing polymer as its detector. The water absorbed in the polymer alters the dielectric constant of the capacitor which causes a change in output current. In the HX93V model, this current output is converted to a voltage from 0 to 1 volt. The voltage output of the transmitter was monitored with a Hewlett-Packard (HP) on-line data-collection system and two digital multimeters. The on-line data-collection system operated at sampling intervals of 20 seconds. The HP system also served as the power source for the RH transmitter; the entire system was disconnected daily between experimental runs.

The transmitter was calibrated by attenuating the voltage output by adjusting the two potentiometers built into the transmitter. The procedure follows.

- a) Potentiometer A, the RH-zero value, was adjusted to give an output of 0.00 volts in a low-humidity environment (air above a saturated LiCl solution from the HX92-CAL RH Calibration Kit, 11.3% RH at 82°F).

¹ Seader, J. D., Jeffrey J. Siirola, and Scott D. Barnicki, "Distillation" in Perry's Chemical Engineers' Handbook, 7th Edition, D. W. Green and J. O. Maloney, eds., p 13-12, McGraw-Hill, New York (1997).

- b) Potentiometer B, the RH gain, was then adjusted in a high-humidity environment (air above saturated NaCl solution, also from the HX92-CAL, 75.3% RH at 82°F) to give a voltage reading equal to the RH difference between the two solutions.
- c) Potentiometer A was adjusted to give a voltage output of 0.753 V while the sensor was in the high-humidity environment.

An unfortunate problem with the transmitter was that, when it was disconnected from its power supply (currently, its power supply is the HP data-collection system) the calibration was not maintained. Repeated calibrations were required each time the system was shut down and restarted.

Results and Discussion

The accuracy of the transmitter was tested by measuring the RH in air above solutions of ethylene glycol (EG) and de-ionized water. Also, its repeatability was checked with a measurement of the LiCl solution used for calibration after several measurements of EG/water solutions. The upper range of the transmitter was determined by placing it above pure water. The results from these experiments are shown in Figure 1. The transmitter was noticeably less accurate over the lower humidity EG/water solutions and was reproducible only to within 5% RH for the measurement of the air above the LiCl solution. The maximum measurable relative humidity was found to be about 97%. This value is slightly higher than the maximum value reported in the transmitter literature.

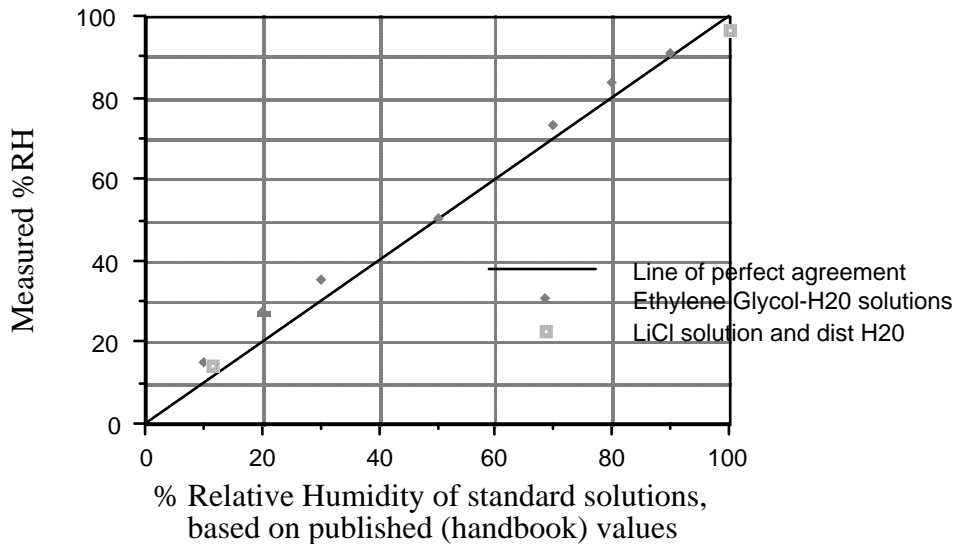


Figure 1. Measurements taken by the Omega transmitter in the air space over solutions of known relative humidities. The data points represent the mean over four sampling intervals. (Data collected on Jan. 18, 2006). The linear least-squares representation of the data is $y = 3.8708 + 0.93179x$; $R^2 = 1.000$

The time constant of the transmitter was determined by analyzing the response curve after the transmitter was removed from the air space above a solution of constant RH and placed in room air. A semi-log plot of a typical response is shown in Figure 2. Because the response is approximately linear, I assume that the transmitter can be modeled as a first-order system. The results of a curve fit to the equation

$$RH = A \exp\left(-\frac{t}{\tau}\right) \quad (1)$$

are shown in Table 1. Here A is the value of the RH at time zero, t is the time since the change in ambient humidity, and τ is the time constant of the instrument. The time required for 90% response based upon the mean time-constant given in Table 1 is approximately 50 seconds in still air, whereas the value given in the transmitter literature for 90% response in moving air is approximately 10 to 15 seconds or less. Because convective transport in moving air could speed the absorption or desorption of water from the transmitter's capacitor, I conclude that this time-constant value is reasonable.

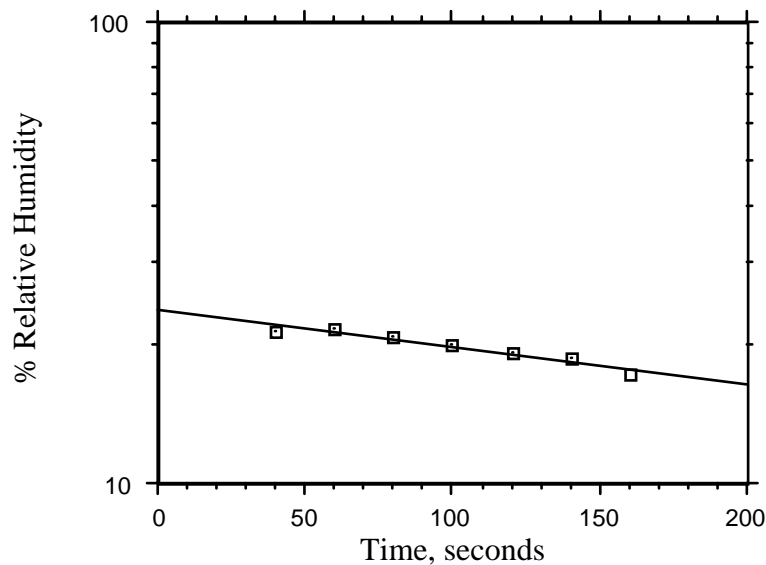


Figure 2. Typical response curve for the Omega transmitter upon exposure to a rapid change in humidity conditions. The data shown are from Case #3 in Table 1 which corresponded to a change from 30% RH to ambient air at 17% RH. (Data collected on Jan. 18, 2006). The least-squares line on the plot is represented by $RH = 33.9 \cdot 10^{(-1.59 \text{ E-}3 \cdot t)}$; $R^2 = 0.977$.

The response of the transmitter in a moving airstream, was investigated with the transmitter inserted in a 2.5-inch-diameter tube, 16.5 inches downstream of a heated blower. The transmitter behaved as expected--increases in temperature

produced decreases in the measured RH. However, the RH values measured were significantly different than theoretical expectations and the temperature measurements of the transmitter generally lagged behind the temperatures measured with a mercury thermometer. This lag may have been the result of heat retention in the aluminum screen surrounding the transmitter's sensors.

Table 1. Estimates of the RH Transmitter Time Constant in Still Air

Data Set	Correlation Coefficient (R ²)	-1/τ, sec ⁻¹	Time Constant, sec
1	0.922	-0.0042	240
2	0.816	-0.0016	626
3	0.949	-0.0025	402
4	0.977	-0.0037	273
5	0.861	-0.0015	649
Mean ± uncertainty (95 % confidence level)			438 ± 192

Conclusions

The Omega relative-humidity and temperature transmitter performed adequately in most of our tests, but the following problems should be corrected before the transmitter is used for further experiments.

- a) The transmitter should be connected to a constant power source which would eliminate the need for calibration each time the transmitter is used.
- b) The transmitter should be calibrated for more accurate and repeatable values at relative humidities less than 50 %. This improvement might be possible if the transmitter is calibrated with solutions in this range to give a full-scale voltage output at 50 % RH.

If these improvements can be made, the transmitter may be useful in humidification or drying experiments in the Chemical Engineering Senior Laboratory.