DATE: 2006 January 30

TO: Noel de Nevers (Director, Research and Development)

FROM: David Fikstad (Research Engineer)

RE: Calibration and Evaluation of an Omega Model HX93V Relative-Humidity and Temperature Transmitter

Overview

I have calibrated and evaluated the performance of an Omega Model HX93V relative-humidity (RH) and temperature transmitter (Omega Engineering, Stamford Connecticut). In tests performed at 82°F and relative humidities greater than 50%, the measured humidities were accurate to within 5%. At lower humidities the accuracy decreased. A brief summary of the calibration procedure and the results of my evaluation follow.

Apparatus and Procedure

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

The transmitter was calibrated at 82°F by adjusting two potentiometers. The proceedure used salt solutions from a HX92-CAL RH Calibration Kit as described below.

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, 11.3% RH at 82°F).

b) Potentiometer B. The RH gain was then adjusted in a high-humidity environment (air above a saturated NaCl solution, 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 transmitter was in the high-humidity environment.

When the transmitter was disconnected from its power supply in the HP data-collection system, the calibration was lost. Calibration was required each time the system was 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. 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% for the measurement of the air above the LiCl solution. The maximum measurable relative humidity was 97%. This value is slightly higher than the maximum value reported in the transmitter reference manual.

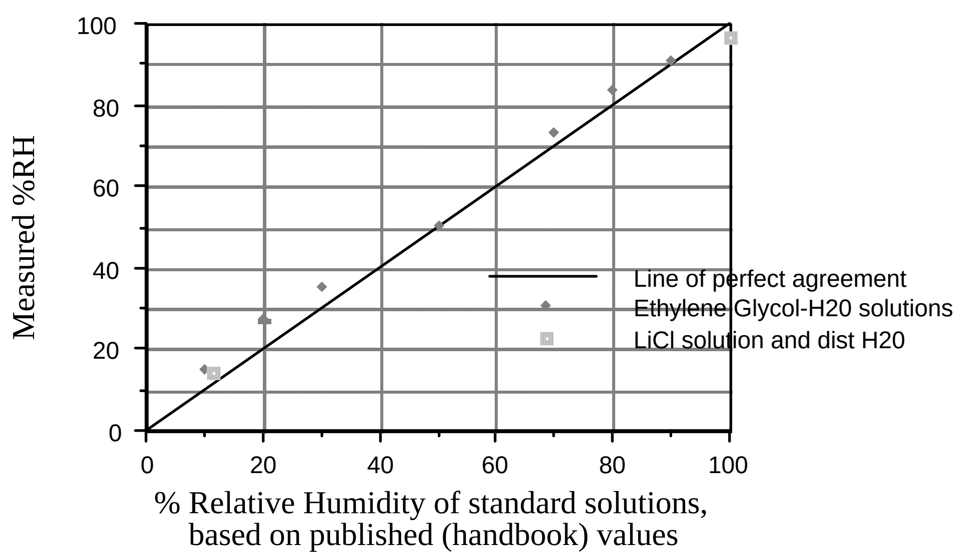

Figure 1. Measurements taken by the Omega transmitter in the air space over solutions of known relative humidities. The data points represent the mean over four sampling intervals. The linear least-squares representation of the data is $y = 3.8708 + 0.93179\ x$; $R^2 = 1.000$.

The time constant of the transmitter was determined by analyzing the response curve after the transmitter was suddenly placed in room air. A semi-log plot of a typical response is shown in Figure 2. Because the response is approximately linear, I assumed that the drying of the polymer could be modeled as a first-order process. The results of a curve fit to the equation

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

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 63% response based upon the mean time-constant given in Table 1 is approximately 400 seconds in still air, whereas the value given in the transmitter manual for 90% response in moving air is 10 to 15 seconds. Because convective transport in moving air would speed the desorption of water from the capacitor, I concluded that a time-constant of 400 s in still air is plausable.

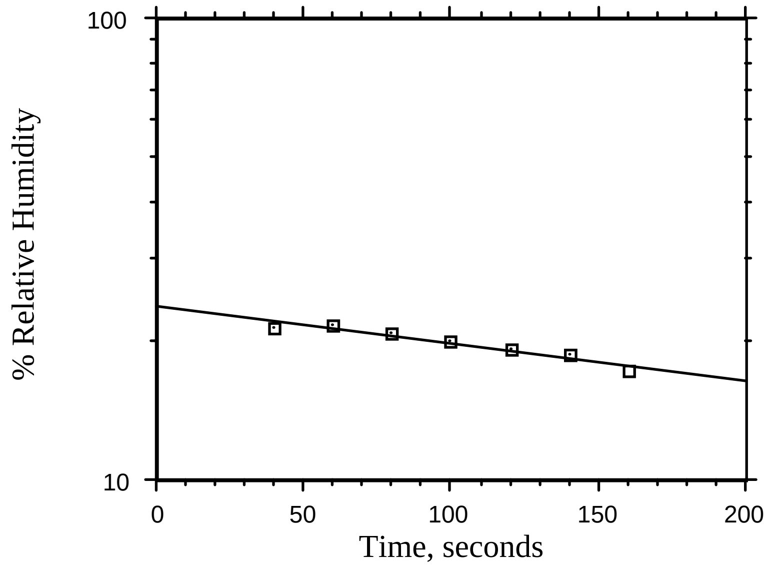

Figure 2. Typical response curve for the Omega transmitter upon exposure to a rapid change in humidity conditions. The data shown are from Case #3 in Table 1 and correspond to a change from 30% RH to ambient air at 17% RH. The least-squares line on the plot is represented by RH = 33.9 $\cdot 10^{(-1.59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

The response of the transmitter in a moving airstream heated to 120°F was investigated with the transmitter inserted in a 2.5-inch-diameter tube, 16.5 inches downstream of a hair dryer. 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 temperature sensor.

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

Data Set	Correlation Coefficient (R^2)	$-1/\tau$, 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)			400 ± 200

Conclusions

The Omega relative-humidity and temperature transmitter performed adequately. In tests performed at 82°F and relative humidities greater than 50%, the measured humidities were accurate to within 5%. At lower humidities the accuracy decreased. The following problems should be corrected before the transmitter is used for further measurements.

a) The transmitter should be connected to a constant power source which would eliminate the need for calibration each time the transmitter is disconnected from the data collection unit.

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 calibration is performed with solutions giving low relative humidities and with a full-scale voltage output at 50% RH.