Aluminum-Oxide Humidity Sensors

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20358986
Technical Note (National Research Council of Canada. Division of Building Research), 1970-01-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

No. 542

TECHNICAL NOTE

LIMITED DISTRIBUTION

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DATE January 1970

PREPARED FOR Record Purposes

SUBJECT ALUMINUM-OXIDE HUMIDITY SENSORS

Some of the early development work on aluminum oxide humidity sensors was carried out by Jason(1) and, more recently, by Stover(2). The results of the latter work have been to develop the commercial device which is the subject of this report(3).

The sensor consists of a piece of aluminum, about 0.010 in. thick, with a thin layer of anodized material, approximately 1/8 in. by 1/2 in. A porous layer of gold is placed over the anodized material so that moisture can be transmitted to the active substance. The gold layer and the parent material serve as electrodes. When subjected to changes in humidity, both electrical resistance and capacitance exhibit a marked change (Fig. 1).

The device can be used for measuring humidity in gases, and also for measuring moisture content in liquid hydrocarbons. For the latter case, the manufacturer states that it exhibits the same response whether the sensor is located above the material or immersed in it. The present report applies only to operation in air. The sensors described by Jason are sensitive to relative humidity; the present device, however, is claimed to be sensitive to the dewpoint temperature with no correction for ambient temperature being required.

Two types of sensors are manufactured: one for operation at dewpoint temperatures ranging from -110°C to +20°C and at ambient temperatures from -110°C to 60°C, and the other for operation at dewpoint temperatures from +20°C to +60°C and at ambient temperatures up to 85°C. The sensor output is displayed on a panel having three ranges. Provision is made for the simultaneous use of five or six sensors, and for connection to recording equipment.

TEST RESULTS

Two sensors were used in the course of the investigation. These were of basically the same construction, except that in sensor No. 374 (an early model) the electrical lead was connected to the gold electrode by means of a fine wire. This wire was found to break frequently and was replaced in the newer design (Sensor No. 2119) by a spring loaded contact.

Calibrations were conducted in the Atmosphere Producer at dewpoint temperatures down to -30°F. To test at dewpoint temperatures down to -100°F, air was passed through a saturator immersed in an alcohol bath. It was then piped to a chamber containing the sensor at room temperature. At low dewpoint temperatures, sorption of moisture on the walls of the apparatus and leakage of small amounts of the moisture into the calibrating air stream will cause significant errors. Where it was possible in the second apparatus, stainless steel tubing and containers were used to minimize the sorption effect. In addition, the entire system was operated at a pressure above atmospheric so that flow would be outward if leaks existed. As a further precaution, the air leaving the calibration chamber was bubbled through a chamber of oil to avoid entry of ambient moisture through the exit tube.

Several calibration curves were found for sensor No. 2119 over a period of somewhat more than a year (Fig. 2). In finding a calibration point, the sensor was allowed to equilibrate for one half hour to one hour following a change in humidity level before a reading was taken. The calibration curves indicate either that some hysteresis exists or that the sensor does not reach equilibrium within the time allowed. Furthermore, substantial variations of calibration occurred over a period of a year. Whether these fluctuations are related to drift, occasioned by changes within the sensitive material, or by the problem of mechanical contact in the sensor, is not known. There is some evidence that movement in the spring loaded contact, causes variations in instrument response.

Two types of tests were made to assess the influence of sensor temperature on instrument output, and hence to test the validity of a single calibration curve involving instrument output and dewpoint temperature. In the first test, calibration curves were obtained at two sensor temperatures, -22°F and 68°F (Fig. 3a). The calibration curves did not coincide as they should have done. In a second series of tests, the sensor temperature was varied for four fixed dewpoint temperatures: 30°F, 0.6°F, -11°F and -43°F (Fig. 3b). The instrument response remained nearly constant for the 0.6°F case, but varied substantially for the 30°F, -11°F and -43°F cases. In these tests the indicated dewpoint temperature varied as much as 20F° with variations in sensor temperature; this demonstrates that serious errors will result from the use of an instrument output vs. dewpoint temperature curve if no corrections are made for sensor temperature.

The response rate of one of the sensors was tested by enclosing it in a small tubular capsule which could be opened suddenly. The assembly was mounted in the Atmosphere Producer and the enclosed capsule space was flushed with air of known humidity. When it was opened, the sensor was immediately exposed to the new humidity condition in the calibration chamber. With the sensor at 70°F and ambient dewpoint temperatures of 51 and 65°F, the time for the instrument to go 63 per cent of the way to a new equilibrium point following a step change in humidity was approximately 2 seconds for both increasing and decreasing humidity (Fig. 4a). At 70°F and an ambient dewpoint temperature of -29.5°F, the 63 per cent response time for humidity decreasing from 11.3°F dewpoint was approximately 20 seconds, and for humidity increasing from -60°F dewpoint it was about 50 seconds (Fig. 4b). Instrument indication rather than humidity ratio was used for the ordinate, since calibration accuracy would not have permitted a more accurate result to be obtained by employing the latter.

CONCLUSION

Tests were conducted on two commercial aluminum oxide humidity sensors. Calibration results showed some hysteresis and for one of the sensors, which was recalibrated several times, the results changed significantly with time. The sensors were sensitive to humidity down to the lowest level tested, approximately -100°F dewpoint.

The results showed that there is a substantial temperature coefficient and appropriate steps must be taken if errors are to be avoided. One possibility is to calibrate the sensor at the same temperature at which use is anticipated, and a second is to calibrate at more than one sensor temperature and apply a temperature correction.

REFERENCES

1. Jason, A. C. "Some Properties and Limitations of the Aluminum Oxide Hygrometer." Humidity and Moisture, Vol. 1, Reinhold 1965, p. 372-90.

2. Stover, C.M. "Aluminum Oxide Humidity Element for Radiosonde Weather Measuring Use." Rev. Sci. Inst., Vol. 34, No. 6, 1963, p. 632-35.

3. Chleck, D. and F.J. Brousaides. "A Partial Evaluation of the Performance of an Aluminum Oxide Humidity Element." Humidity and Moisture, Vol. 1, 1965, p. 405-14.

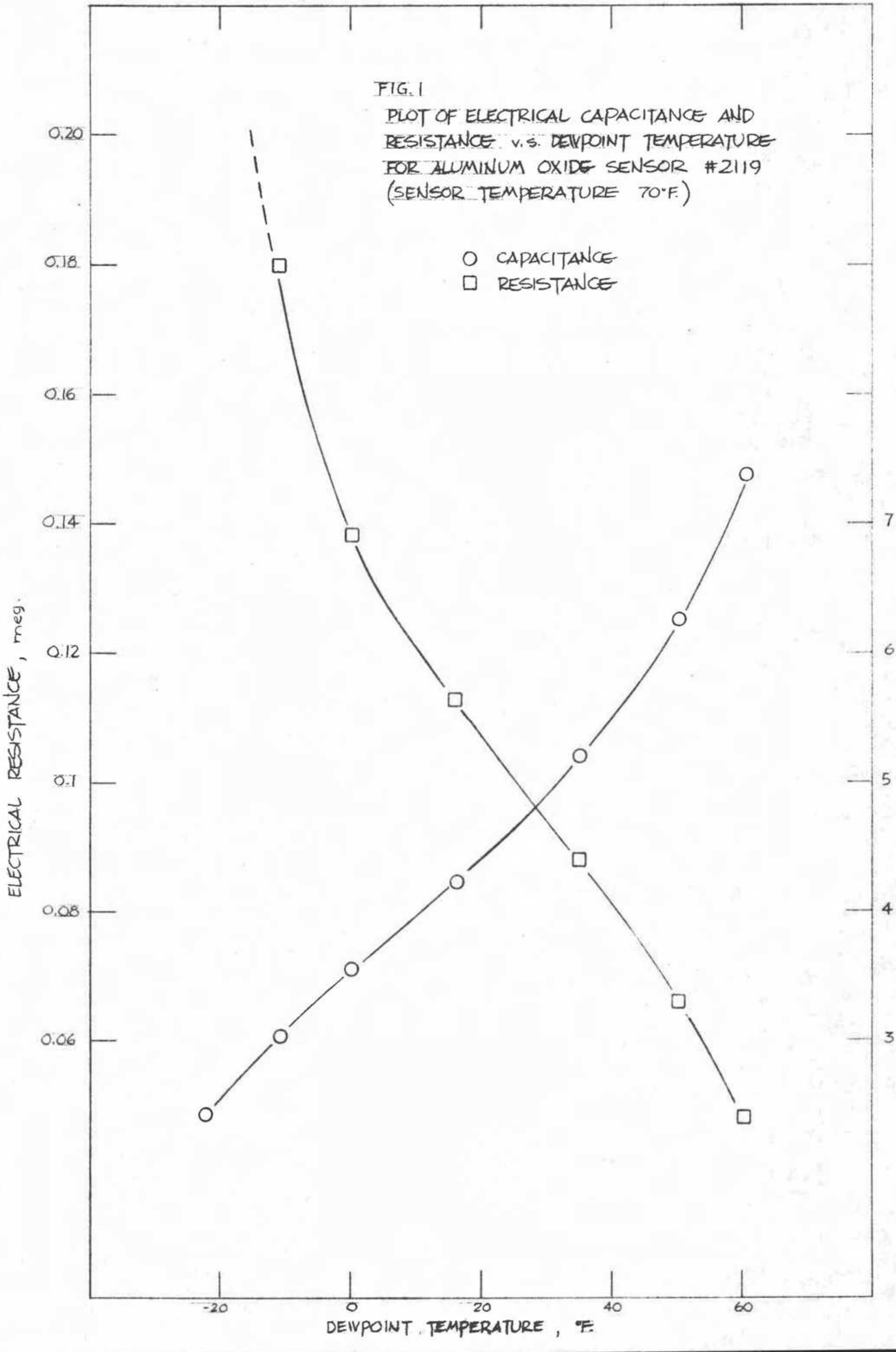
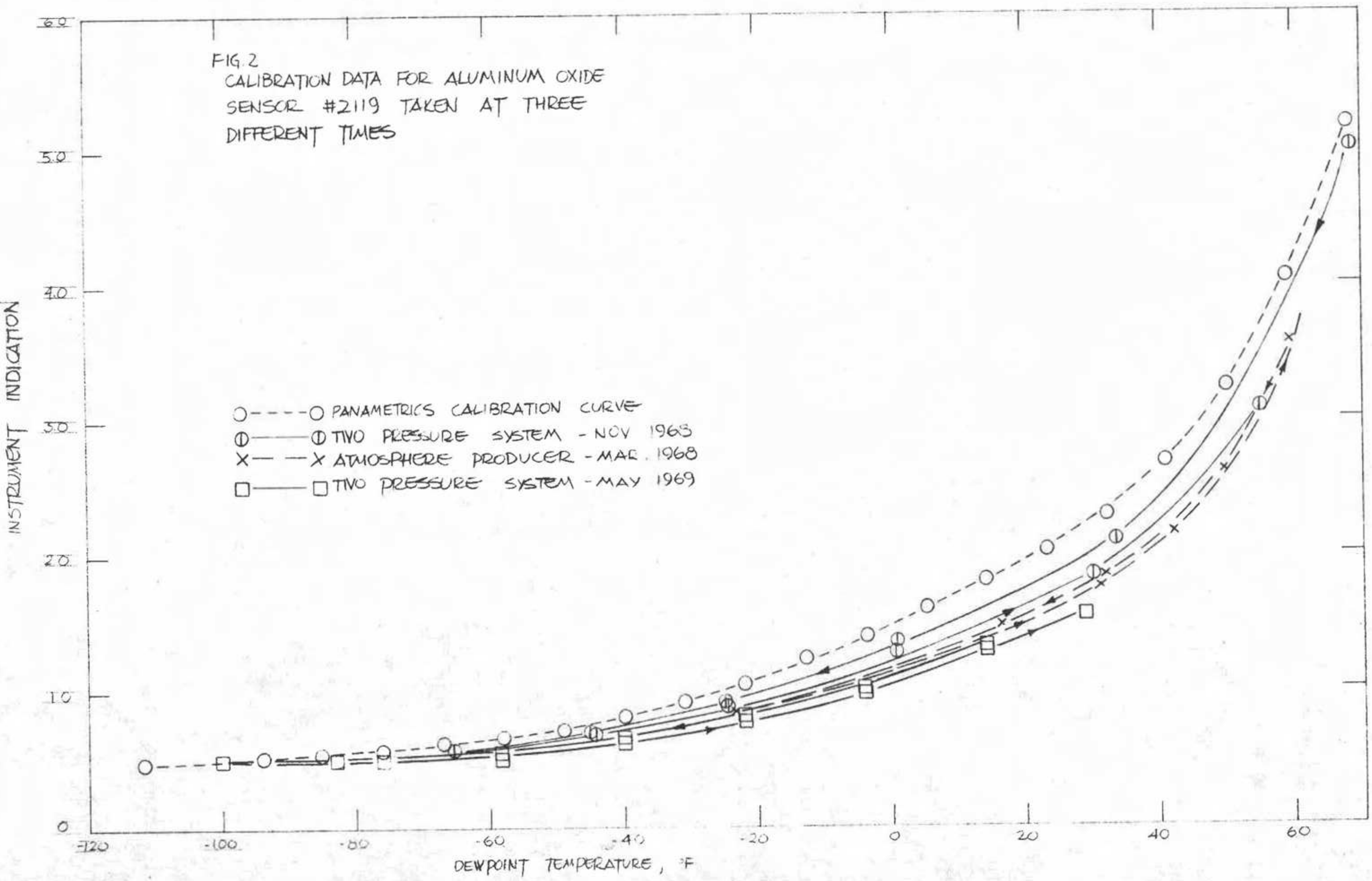


FIG. 1
PLOT OF ELECTRICAL CAPACITANCE AND RESISTANCE v.s. DEWPOINT TEMPERATURE FOR ALUMINUM OXIDE SENSOR #2119 (SENSOR TEMPERATURE 70°F.)
O CAPACITANCE
□ RESISTANCE
ELECTRICAL RESISTANCE, meg.
0.20
0.18
0.16
0.14
0.12
0.1
0.08
0.06
CAPACITANCE, nF
7
6
5
4
3
-20
0
20
40
60
DEWPOINT TEMPERATURE, °F.

FIG. 2
CALIBRATION DATA FOR ALUMINUM OXIDE SENSOR #2119 TAKEN AT THREE DIFFERENT TIMES



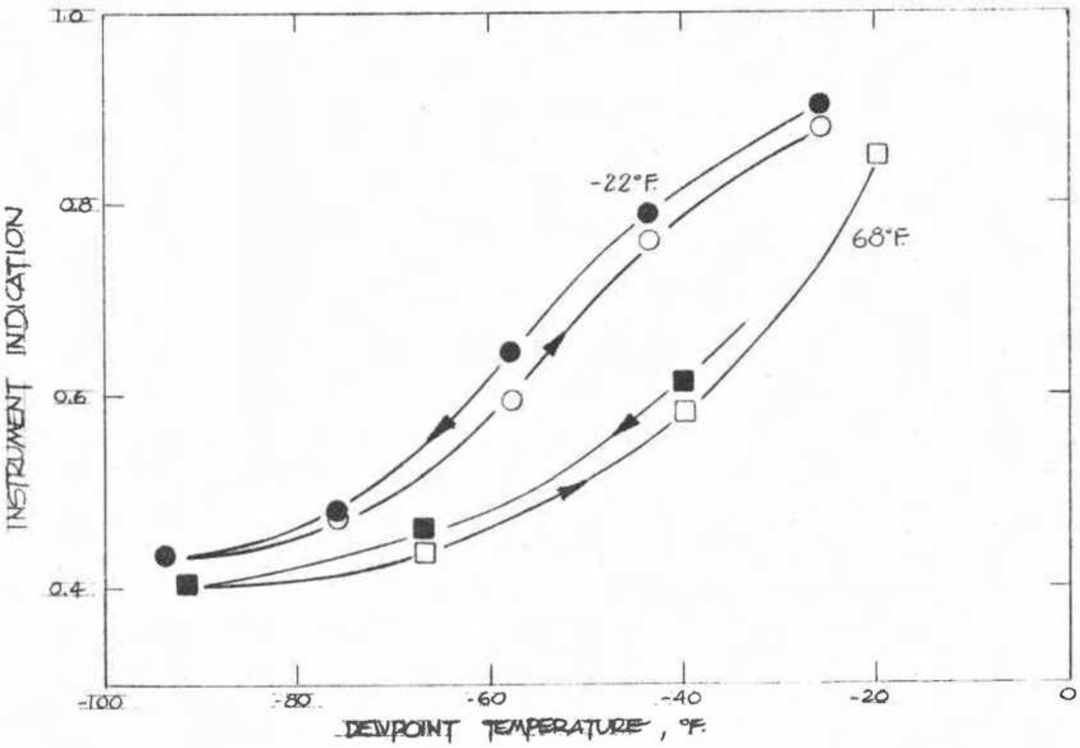


FIG. 3a.
CALIBRATION CURVES FOR SENSOR #307
FOR TWO SENSOR TEMPERATURES (-22°F. & 68°F.)

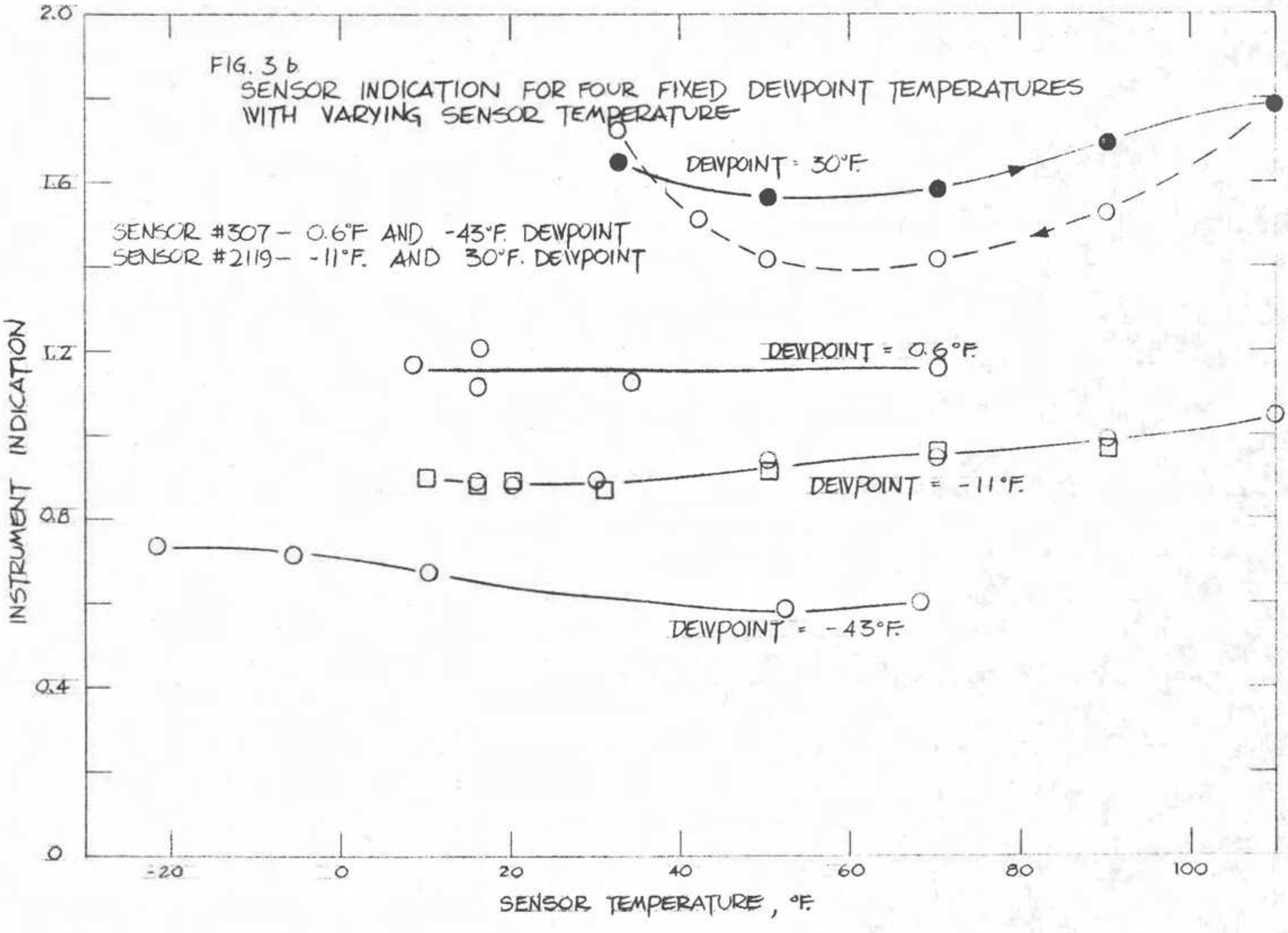
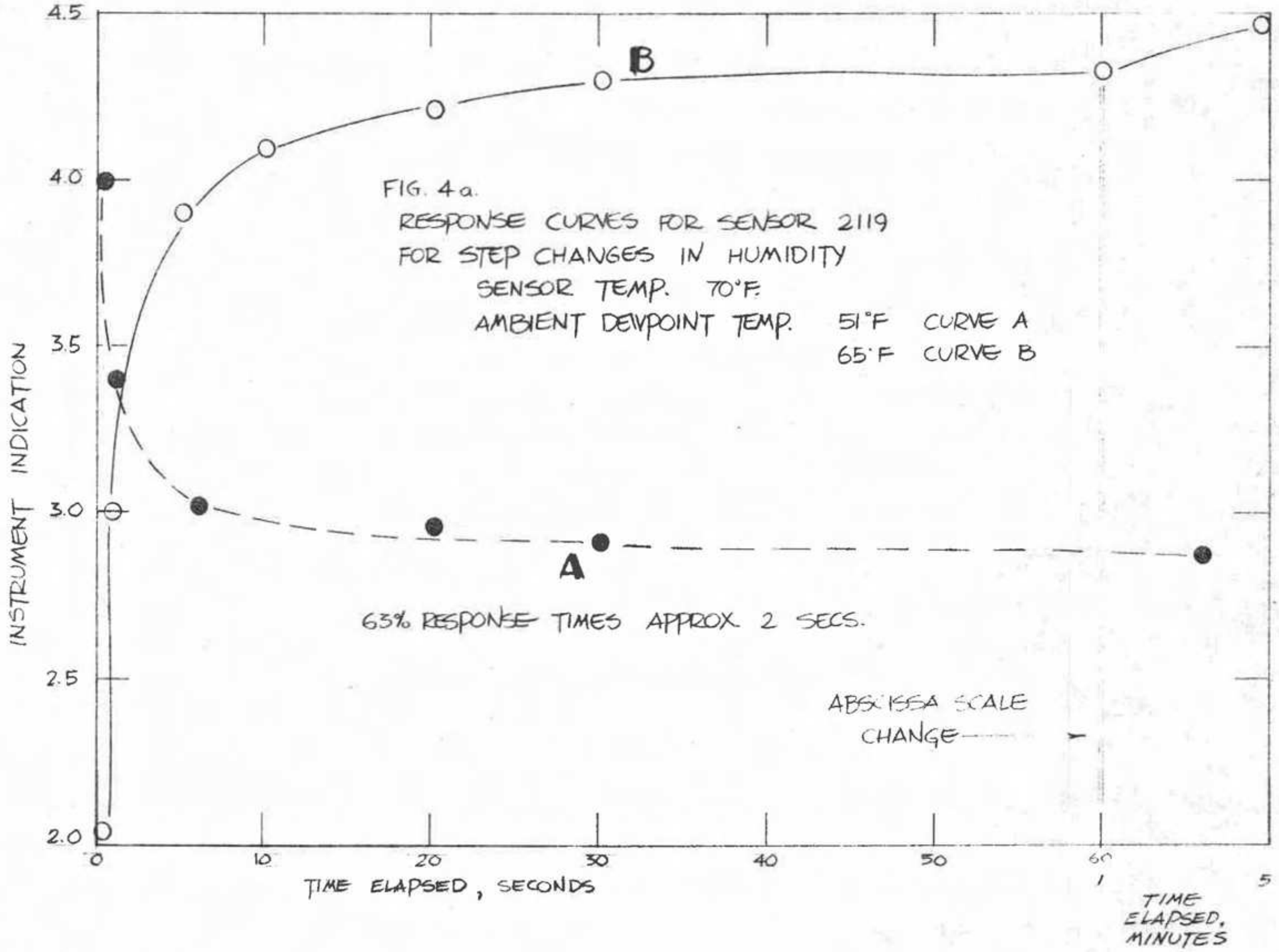
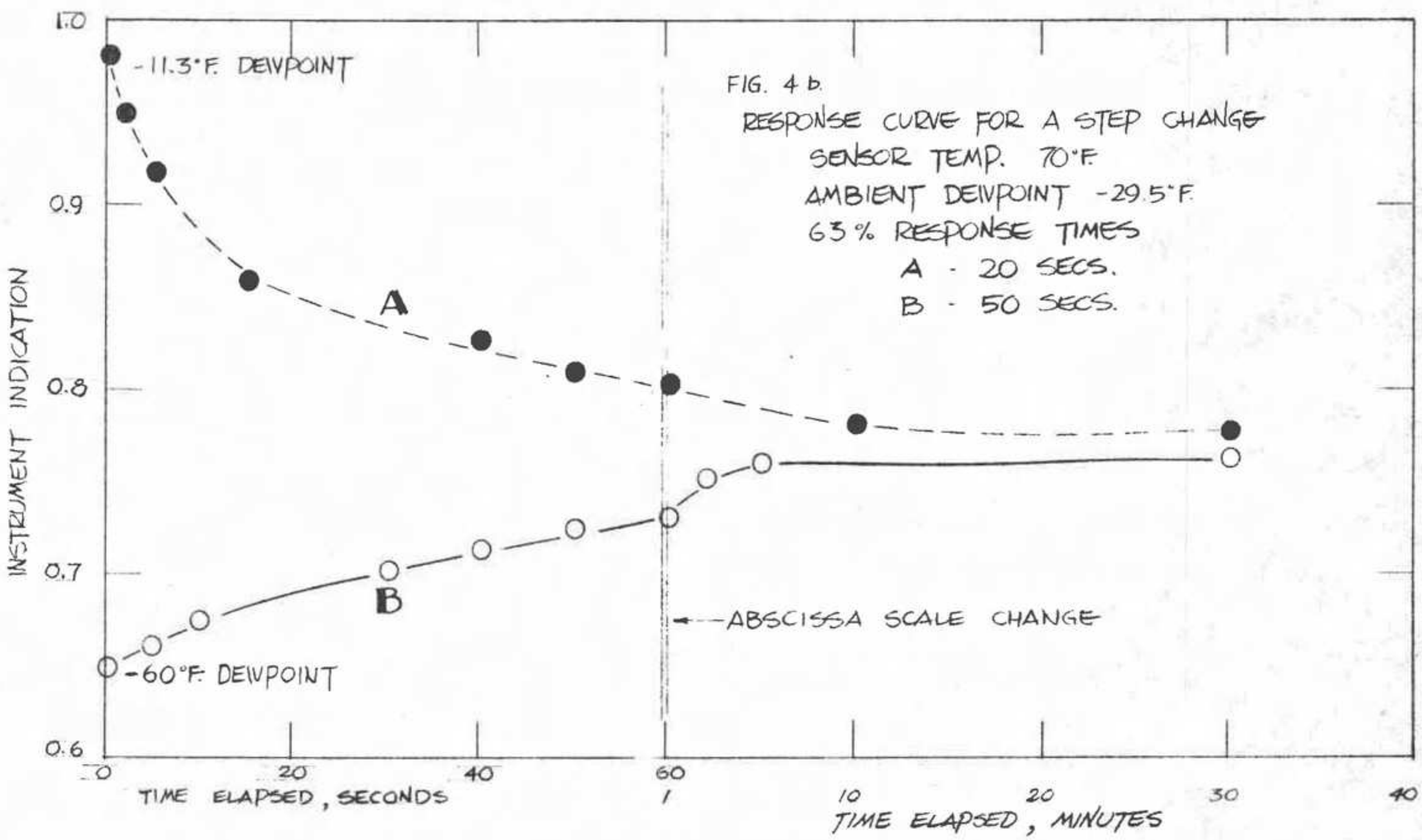


FIG. 3 b
SENSOR INDICATION FOR FOUR FIXED DEWPOINT TEMPERATURES
WITH VARYING SENSOR TEMPERATURE
DEWPOINT = 30°F
SENSOR #307 – 0.6°F AND -43°F DEWPOINT
SENSOR #2119 – -11°F AND 30°F DEWPOINT
DEWPOINT = 0.6°F
DEWPOINT = -11°F
DEWPOINT = -43°F
2.0
1.6
1.2
0.8
0.4
0
-20
0
20
40
60
80
100
INSTRUMENT INDICATION
SENSOR TEMPERATURE, °F


4.5
4.0
3.5
3.0
2.5
2.0
INSTRUMENT INDICATION
B
A
FIG. 4 a.
RESPONSE CURVES FOR SENSOR 2119
FOR STEP CHANGES IN HUMIDITY
SENSOR TEMP. 70°F.
AMBIENT DEWPOINT TEMP. 51°F CURVE A
65°F CURVE B
63% RESPONSE TIMES APPROX. 2 SECS.
ABSCISSA SCALE
CHANGE
0
10
20
30
40
50
60
1
5
TIME ELAPSED, SECONDS
TIME ELAPSED, MINUTES


1.0
0.9
0.8
0.7
0.6
INSTRUMENT INDICATION
-11.3°F. DEWPOINT
A
B
-60°F. DEWPOINT
FIG. 4 b.
RESPONSE CURVE FOR A STEP CHANGE
SENSOR TEMP. 70°F.
AMBIENT DEWPOINT -29.5°F.
63 % RESPONSE TIMES
A - 20 SECS.
B - 50 SECS.
ABSCISSA SCALE CHANGE
0
20
40
60
1
10
20
30
40
TIME ELAPSED, SECONDS
TIME ELAPSED, MINUTES