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Indigenous carbon humidity sensor for radiosondes

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सार – इस शोध पत्र में भारतीय बाजार में उपलब्ध सामग्री से भारत मौसम विज्ञान विभाग (आई. एम. डी.) में निर्मित कार्बन आर्द्रता सवेदकों के बारे में बताया गया है। इनका उपयोग संजाल में नेमी उपरितन वायु प्रेक्षण लेने के लिए भारत मौसम विज्ञान विभाग के एम. के.-IV रेडियो सौंदे में किया जाता है।

ABSTRACT. This paper describes the carbon humidity sensors manufactured in IMD using the material available in the Indian market. These are used in the IMD MK-IV radiosondes for taking routine upper air observation in the network.

Key words – Hygrister, Finally divided Carbon particle, Resistance, Electrode, Carbon film, Radiosonde, Cellulose, Deionization, Distilled water.

1. Introduction

The India Meteorological Department (*i.e.*, IMD) has a network of 39 radiosonde and radiowind observation stations. A radiosonde is a small box-like instrument that is carried into the upper atmosphere using hydrogen filled ascending balloon. As it travels upward, it transmits meteorological measurements to ground stations. Radiosondes measure temperature using the thermistor as a temperature sensor, humidity is measured using hygristor and air pressure using an aneroid capsule.

The 39 IMD stations take two radiosonde ascents daily at 0000 UTC and 1200 UTC as a result about 80 humidity sensors are required daily for routine use in IMD. From 1962 - 2000 Lithium Chloride (LiCl) type sensor was being used in IMD. Reliability of Lithium Chloride sensor is up to 0°C. The carbon sensor is better than Gold Beater's skin sensor & Lithium chloride and is reliable up to -40 °C temperature. In 1998 it was felt that to improve the data quality of humidity measurement beyond the heights of 0°C it is advisable to change the humidity sensor, so IMD imported some carbon sensors. However these sensors were very costly, so it was decided to manufacture these sensors in India.

A developmental project was given to Shri Ram Institute to develop and manufacture the humidity sensors but they were unable to succeed in this. Then it was decided to manufacture these sensors in-house in the hygristor lab at IMD New Delhi. After a lot of hard work the first prototype was made in 1998 and then these in-house developed sensors were tested at Radio Meteorological observatory at New Delhi. After the successful trial ascents its use was started at 8 stations and slowly but gradually all RS/RW stations started using these sensors. Thus the production work started at hygristor laboratory, O/o DDGM(UI) at New Delhi for manufacturing and calibrating the carbon hygristors for radiosondes. By 2004 all the RS/RW stations in the upper air observational network of IMD stopped use of Lithium Chloride sensors and were switched over to the in-house developed and manufactured carbon humidity sensors.

2. Theory

For the preparation of carbon humidity sensors the sensing element used is Hydroxy Ethyle Cellulose (HEC). It swells on absorbing the water molecule from air (moisture) and contracts after releasing the water molecule to dry air. Thus the space between the carbon particles gets increased or decreased in proportion to the humidity,

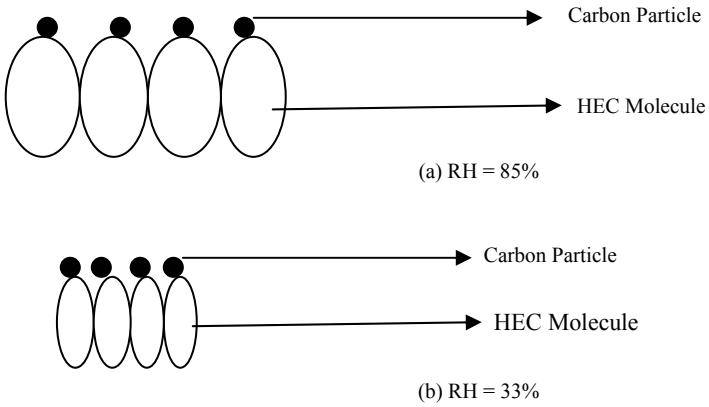

Fig. 1. Swelling and contraction of the HEC film with humidity

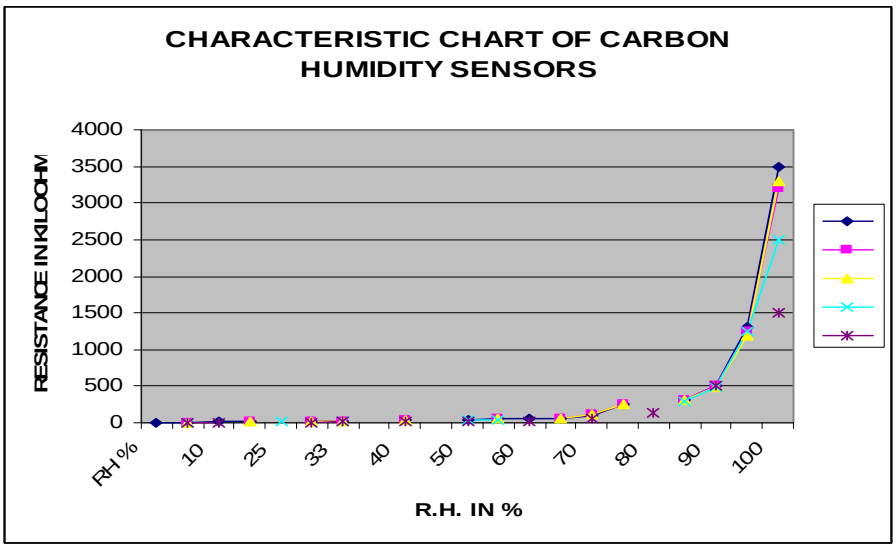

Fig. 2. Characteristic graph of carbon humidity sensors

(a) Resistance of the unscratched sensor 2-3 Kohms

(b) Resistance set to 10 Kohms

Figs. 3 (a&b). Scratched and unscratched sensors

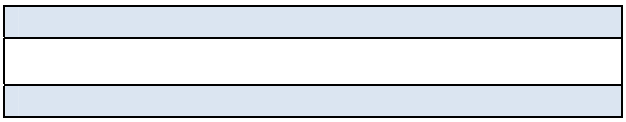

Fig. 4. Electrode after preparation

which is reflected in terms of resistance change. This property of HEC was studied by Stine S.L. in 1965 and published in Humidity and Moisture Volume I edited by Wexter.

Carbon dust is put on the cellulose (HEC) through a solution to make a film on this HEC molecule. As the RH increases it absorbs the water molecules from air and thus swells resulting in increase of the distance between carbon particles thereby increasing the resistance of the film and as it goes in to lower RH medium, it releases the water molecules to air and then contracts itself resulting in decrease of the resistance as shown in Fig. 1.

Another advantage of HEC is that it makes the equilibrium faster as compared to other sensors. So in high RH (at below freezing temperature) it absorbs water molecule quickly and in dry air releases water molecules fast so time lag *T* of carbon sensor is good in comparison to other sensors as shown in the Table 3. The resolution of humidity measurement with the indigenous carbon sensor is 1%.

Various sensors (developed by using carbon films of different composition) were subjected to different humidity levels and graph of humidity versus resistance were plotted. Then final pattern for the carbon film deposition to be followed was decided as depicted in the Fig. 2.

After various trials it was decided to keep the resistance at 25° C as 10 KΩ at 33% R/H and corresponding values of resistance was calculated at different humidity level. To set a fixed value of resistance as 10 KΩ was difficult therefore, a range of 9-14 K ohms at 33% RH was taken as acceptable and a multiplicative factor was also calculated as shown in the Table 1.

If at 33% RH the resistance of the sensor is exactly 10 KΩ (Fig. 3) then the resistance values shown in Table 1 are obtained. If the resistance is between 9-14 KΩ then we have to calculate resistance by using the multiplicative factor. (*e.g.*, If resistance at 33% RH is 12 KΩ then at 90 % humidity it should be 600 KΩ instead of 500 KΩ).

TABLE 1

Resistance at various humidity levels

R.H. (%)	Resistance at 25 degree celsius (KΩ)	Multiplicative factor
10%	5 K	0.5
30%	9K	0.9
33%	10K	1.0
40%	12K	1.2
50%	16K	1.6
60%	25K	2.5
70%	50K	5.0
80%	140K	14.0
90%	500K	50.0
100%	1500K	150.0

3. Manufacturing

The fabrication of Carbon sensor can be divided in to 3 parts.

(*i*) Preparation of electrode on polystyrene strip.
(*ii*) Deposition of carbon film
(*iii*) Testing of the sample.

Following materials are required

(a) Polystyrene strip of size (72*17.5*1) mm, colorless, transparent smooth with sharp edge.
(b) Conductive paint
(c) Thinner
(d) Printing screen
(e) Distilled water
(f) Tergitol
(g) Hydroxy Ethyl Cellulose (HEC)
(h) Resin anion and cation
(i) HCl
(j) NaOH
(k) Nylobold Cloth 325 mesh/inch
(l) Sorbitol
(m) Carbon black
(n) Triton × 100
(o) Potassium acetate
(p) Silica gel
(q) Zinc Sulphate
(r) Fused calcium chloride

TABLE 2

Comparison of carbon and lithium chloride sensors

Type of sensor	Date & time of ascent	Relative humidity range	Lowest temp. at which R.H. is reported	Lowest pressure at R.H. reported
Carbon	14 Jan 1998 1645 IST	88-18 %	-47.7 °C	192 mb
Lithium chloride	14 Jan 1998 1830 IST	85-23%	-30.3°C	315 mb
Carbon	21 Jan 1998 1645 IST	48-16%	-60 °C	175 mb
Carbon	28 Jan 1998 1655 IST	89-28%	-59.2°C	221 mb
Lithium chloride	28 Jan 1998 1825 IST	97-25%	-20.6°C	465 mb
Carbon	4 Feb 1998 1730 IST	54-13%	-57.7°C	159 mb
Carbon	11 Feb 1998 1645 IST	37-15%	-54.8°C	190 mb
Carbon	24 Feb 1998 1755 IST	100-25%	-58.7°C	167 mb

TABLE 3

Comparative time lag of different types of sensors

Sensor	Time lag (in seconds) at different temperatures					
	20°C	10°C	0°C	-10°C	-20°C	-30°C
Gold Beater's Skin	6	10	20	50	100	200
Carbon Sensor	0.3	0.7	1.5	4	9	20
Humicap	0.3	0.7	1.5	4	9	20

(*i*) *Preparation of electrode*

To make the electrodes we take the polystyrene strip and apply paint mixed with thinner on the screen. First it is painted on one side along its full length (3 mm broad) and dried at 50 degree centigrade. Then on the next day it is painted on the other side in same way. On the third day it is painted along the thickness and is dried and then packed on fourth day. The thickness of electrode remains 8-12 microns and resistance 1-2 ohms. The Fig. 4 shows how the electrode looks.

(*ii*) *Preparation of carbon solution for carbon film*

To put HEC and Carbon dust on the polystyrene strip, a carbon solution is made with utmost care by the following process:

(a) The Distilled water is mixed with tergitol and HEC and stirred carefully till jelly formation.

(b) The conductivity of the cation is adjusted to 1-2 mhos by method of repeated washing with dilute HCL.

(c) The conductivity of the anion is adjusted to 1-2 mhos same as that of the cation, by the same method using NaOH in place of HCL.

(d) The jelly of HEC is deionised by adding cation and anion.

(e) Sorbitol is then mixed to the filtered jelly. The conductivity of H.E.C. solution remains between 12 micro mhos to 25 micro mhos.

(f) For making the Carbon solution we add carbon black to the H.E.C. solution Cabot elfetex 8 and Tinter B 665 are added in the ratio 56% & 44% respectively. The conductivity is of the order of 30-40 micro mhos.

(*iii*) *Dipping of the sensor in carbon solution*

For dipping the substrate conditions of 33% humidity and 27° C temperature are maintained. The sensor is dipped in the solution and drawn out so that it comes out of the solution slowly creating a uniform thickness over the polystyrene strip.

After dipping the sensors are dried for one hour in the lab and then shifted to a desiccators maintaining RH of 30-40% with the help of silica gel. After 24 hours they undergo re-cycling at 85% RH and then at 30% RH followed by 90 % and then 33% RH so that sensors can repeat properly through out the range. This is done for removing the hysteresis.

4. Testing

For testing a sensor, first we set the resistance of film at 10 KΩ by scratching the film at 33% RH which is maintained in a desiccator with the help of potassium acetate.

The sensors can be tested in two ways:

(*i*) Manually

(*ii*) Automatic computerised mode

Manual Testing - For manual testing each sensor is subjected to three different levels of humidity in three chambers.

(*i*) 33% RH is maintained with the help of potassium acetate.

(*ii*) 55%RH is maintained with the help of sodium dichromate.

(*iii*) 85% RH is maintained with the help of zinc sulphate.

The air circulation in the chamber is maintained at about 6 m/s.

Firstly the resistance at 33% RH is measured then at 55% RH and then at 85% RH. The repeatability test is done at 33% RH. The sensor resistance should be within +4 KΩ in repeatability test.

Automatic Testing – The automatic testing is done in the humidity-temperature chamber. A Votsch 4018 model environmental chamber made by M/s Vostch Industrietechnik G.M.B.H Germany, has been installed by IMD in 2005. It provides the RH in the range of 10% to 98% and temperature in the range of 180 to -60 degree centigrade. The chamber operation is computer controlled and 100 sensors can be tested at a time. The resistance measurement is done at 33% RH followed by 85% and then again at 33% for the repeatability test. Then the software converts the resistance to corresponding RH.

The RH values measured by the carbon sensors are compared with the standard sensor fitted in the chamber. The sensors in the range of ± 3% from the standard are accepted and rest are rejected. The accepted sensors are sealed in a metal container in a paper folder and sent to stores.

This procedure is followed at surface pressure but remains valid at all pressure level because the resistivity of carbon film varies with the variation in humidity only. So there is no need of calibration at different pressure levels.

Comparison of carbon sensor and lithium chloride sensor

Many ascents were taken at RS/RW Station at New Delhi to compare the two types of sensors and it was noticed that the carbon sensor provides the humidity profile up to higher heights and at more negative temperature in comparison to Lithium chloride sensors. The results are shown in Table 2.

5. Calculations

Time in which a sensor shows the 63% of the total change is known as time constant of the sensor and the time lag in which sensor shows the change is given by

$$1/T = K(\rho v)0.46$$

Where

T = time lag in second

K = constant

ρ = density of air

v = velocity of air over sensor (for better result it should be 6 m/s)

Table 3 indicates the comparative time lag of different types of sensors. The time lag of carbon sensor is similar to that of the humicap up to -30 °C but beyond that, this time lag increases and is almost more than double that of the humicap.

6. Results & conclusion

By creating the in-house manufacturing facility for the carbon hygristor there is no need of importing the sensor for the routine use in the upper air observational network. This is also a matter of national pride that we are one among a few countries across the globe that are making there own sensors for radiosondes.

Acknowledgement

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