TIME LAG AND HUMID FATIGUE OF HYGROMETERS

(MAHAJAN'S OPTICAL HYGROMETER AND OTHERS)

BY L. D. MAHAJAN *

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ABSTRACT.—By experiments it is found that the best substance for use in the pans of the optical hygrometer is a mixture of about 1% calcium chloride, 9% plaster of Paris and 90% small pieces of hair.

Some improvements have been made in the construction of the optical hygrometer, such as, hard glass agate grooves are fitted into thick heads of the screws, which are fitted into the slotted supports.

The methods adopted for determination of time lag and humid fatigue are described.

It is found that the optical hygrometer behaves like other kinds of hygrometers. Its time lag is about 16 minutes which is smaller than that of the other types of hygrometers. Time lag of all hygrometers depends on their construction, rate of circulation of air in them and their immediate past history.

The rate of change of humidity decreases rapidly with time in the logarithmic relation and the major change takes place in the first few minutes.

INTRODUCTION

In previous papers (Mahajan, 1941a) the author explained the construction, theory and working of the optical hygrometer in detail. Since then, further work has been conducted on its time lag. Time lag of a few other kinds of hygrometers have also been studied and compared with that of this hygrometer. The hygroscopic substance used in the instrument has also been improved. The method used for determination of its time lag and the results obtained therein are given below in detail.

SELECTION OF HYGROSCOPIC SUBSTANCES

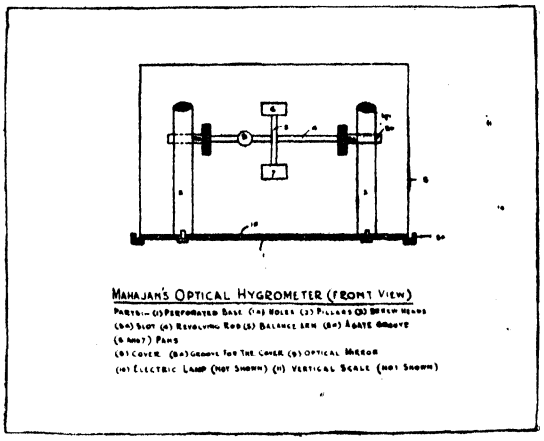
In the last paper (Mahajan, 1941b) a short account has already been given regarding the selection of suitable hygroscopic substances for the instrument. But further study of many other substances and mixtures reveals that the mixture of 1% calcium chloride, 9% plaster of Paris and 90% small pieces of animal hair forms the best substance for this instrument, as it has high power of absorption of moisture from the moist air and desorption of moisture to the dry air, and these rates of absorption and desorption are fairly equal.

IMPROVEMENT IN CONSTRUCTION

The construction of this instrument has also been improved. The perforated base of the instrument has been slightly enlarged in size and a groove has been made all round it. The rectangular glass cover just fits into this groove. The revolving rod of brass has been substituted by a fine rod of best steel, which is

* Fellow of the Indian Physical Society.

thicker in the middle and very thin at the ends. In place of ordinary screws the thick screws are fitted in the slotted supports (only the tops of the supports are slotted) with their thick heads inwards. Hard glass agate grooves are fitted into the thick heads of the screws and the thin ends of the revolving rod are fitted in them. The details of its construction are clearly shown in figure 1.



MAHAJAN'S OPTICAL HYGROMETER (FRONT VIEW)

FIG. 1

THE METHOD

The method used for the study of time lag and humid fatigue is the same as that devised by the author for the study of adsorption of moisture from the moist air by the soils and is described in the paper (Mahajan, 1940), on the subject. The instrument was placed inside a rectangular glass vessel which was connected by means of two rubber tubes, with two bottles, each of one litre capacity, one containing water and the other strong sulphuric acid. A current of air was passed through either vessel by means of pressure pump, according to the requirements. When the humidity was to be decreased inside the glass chamber, a current of air through the sulphuric acid vessel was sent to the glass chamber and when the humidity was to be increased a current of air through the water vessel was pushed into it. Thus by regulating rates of flow or quantity of dry and wet currents of air, any humidity could be arranged inside the chamber.

The optical hygrometer was placed inside a glass chamber and humidity of air inside it was varied. The time period was recorded for attaining a constant reading at various humidities.

In the same way, humidity of air inside a chamber was varied and readings on the vertical scale of the optical hygrometer were recorded after regular intervals of time.

The instrument was placed under a glass cover on a separate wooden support fixed in the wall in order to avoid even the slightest disturbances to it by any means. It was placed at some distance from the walls as they are good absorbent of moisture from the air. The distance between the instrument and the vertical scale was kep about two metres so as to make it very sensitive.

TABLE I(*a*)

Serial No.	Kind of hygrometer.	Initial reading on the vertical scale in cms	Reading on the vertical scale in cms.	Time taken in minutes from the start.	Time-lag in minutes.	REMARKS
1	Optical hygrometer.	87.3	87.3	0		1. Variable humidity chamber used. 2. Decrease of humidity.
			87.7	1		
			92.6	5		
			93.0	10	15	
			93.5	15		
			93.5	20		
			93.5	30		
2	,,	98.0	98.0	0		
			96.0	5		
			94.0	10		Decrease of humidity.
			91.3	15		
			90.5	20	20	
			90.5	25		
			90.5	30		
3	,,	90.0	90.0	0	20	
			91.3	2		
			93.3	8		Increase of humidity.
			94.2	15		
			94.5	20		
			94.5	25		
4	,,	80.0	80.0	0	15	
			81.0	1		
			86.6	5		
			87.1	10		,,
			87.2	15		
			87.2	20		
5	,,	90.0	90.0	0	20	
			86.0	5		
			83.0	10		
			82.0	15		Decrease of humidity.
			81.0	20		
			80.0	25		
			80.0	30		
			80.0	35		
6	,,	95.6	95.6	0	13	1. Increase of humidity. 2. Current of moist air passed in for the first three minuts
			97.5	3		
			98.0	5		
			98.7	8		
			99.0	13		
			99.0	21		
7	,,	85.3	85.3	0	15	,,
			86.2	3		
			89.8	8		
			90.8	15		
			90.8	19		
8	,,	86.5	86.5	0	11	,,
			88.8	4		
			89.5	5		
			90.5	8		
			90.6	11		
			90.6	13		

Mean time lag 16 minutes

Besides this apparatus, two dessicators, one containing strong sulphuric acid and the other water, were also used for arranging 0% and 100% humidity chambers. The optical hygrometer was placed in them and the effects of extreme limits of humidity on the instrument were also studied. Similarly time lag of a few other kinds of hygrometers were also studied by the above method.

THE OBSERVATIONS

The optical hygrometer was kept inside a chamber of any known humidity and the time lag was observed for the decrease as well as increase of humidity. Similarly, similar observations were recorded for some other kinds of hygrometers. A few sets of observations are given below in Table I (*b*, *c*, *d* and *e*).

TABLE I(*b*)

Number of sets. 1	Kind of hygrometer. 2	Initial humidity. 3	Final humidity. 4	Time taken in minutes. 5	Time lag in minutes. 6	REMARKS. 7
1	Hair-hygrometer.	61%	61%	0		Increase of humidity.
			76	5		
			89	12		
			80	17	22	
			81	22		
			81	34		
2	,,	79%	79%	0		Decrease of humidity.
			62	2		
			52	5		
			51	9	15	
			50	15		
			50	26		
3	,	50%	50%	0		Increase of humidity.
			70	4		
			74	10	15	
			75	15		
			75	20		
4	,	75%	75%	0		Decrease of humidity.
			68	3		
			65	6		
			63	10	20	
			61	15		
			60	20		
			60	25		
5	,	90%	90%	0		,,
			88	5		
			86	10		
			82	15	20	
			80	20		
			80	25		

Mean time-lag 19 minutes.

DISCUSSION OF RESULTS

Time lag.—The study of observations recorded in Table I (*a*, *b*, *c*, *d* and *e*) clearly shows that every hygrometer needs a period for which it should be exposed to a surrounding medium in order to reach a steady state and to indicate the correct reading. This period is the time lag of the hygrometer. It is different for different hygrometers. It is approximately 16 minutes for the optical hygrometer, 19 minutes for the hair hygrometer, 35 minutes for the paper hygrometer, 50 minutes for the humatograph and 18 minutes for the wet and dry bulb hygrometer. Thus the time lag for the optical, the hair, and the wet and dry bulb hygrometers are almost the same. The range of variations of time lag is 11 to 20 minutes for the optical hygrometer, 15 to 22 minutes for the hair hygrometer

TABLE I(*c*)

Number of sets. 1	Kind of hygrometer 2	Initial humidity 3	Final humidity. 4	Time taken in minutes. 5	Time lag in minutes. 6	REMARKS. 7
1	Paper hygrometer	60%	60%	0		Increase of humidity.
			72	5		
			74	14		
			75	20	35	
			75.6	30		
			76	35		
			76	45		
2	,,	50%	50%	0		
			50	5		
			71	13		
			76	20		,,
			78	25	30	
			79	30		
			79	35		
			79	40		
3	,,	79%	79%	0		Decrease of humidity.
			75	5		
			71	10		
			67	15		
			64	20		
			62	25		
			59	30	40	
			58	35		
			57	40		
			57	45		
			57	50		
4	,,	76%	76%	0		
			72	5		
			69	10		
			67	15		
			66	20	35	,,
			65	25		
			64.5	30		
			64	35		
			64	40		

Mean time lag 35 minutes.

TABLE I(*d*)

Number of sets. 1	Kind of hygrometer. 2	Initial humidity. 3	Final humidity. 4	Time taken in minutes. 5	Time lag in minutes. 6	REMARKS. 7
1	Humato-graph (containing hair)	54%	54%	0		
			61	5		
			74	12		
			78	15		
			83	20		Increase of humidity.
			88	26		
			92	31		
			94	35	50	
			95	40		
			97	45		
			98	50		
			98	55		
			98	60		
2	,,	80%	80%	0		
			75	5		
			73	10		Decrease of humidity.
			69	15		
			66	20	50	
			62	33		
			61	50		
			61	55		
			61	60		

Mean time lag 50 minutes.

TABLE I(*e*)

Number of sets 1	Kind of hygrometer. 2	Initial humidity. 3	Final humidity. 4	Time taken in minutes. 5	Time lag in minutes. 6	REMARKS. 7
1	Wet and dry bulb hygro-meter.	100%	100%	0		1. Wet cloth used to start with. 2. Decrease of humidity.
			84	3		
			83.5	5	15	
			83	10		
			82	15		
			82	20		
2	,,	40%	40%	0		1. Dry cloth used to start with. 2. Increase of humidity.
			54	5		
			59	10	20	
			64	15		
			67	20		
			67	25		
3	,,	64%	64%	0		1. Wet cloth used to start with. 2. Increase of humidity.
			69	5		
			72	10		
			75	16	20	
			77	20		
			77	25		

Mean time lag 18 minutes.

15 to 20 minutes for the wet and dry bulb hygrometer, 35 to 40 minutes for the paper hygrometer and 50 to 55 minutes for the humatograph. Therefore it seems better that these instruments are exposed to the surrounding medium for their respective maximum time lag periods and a steady reading be taken.

This period of time lag also depends upon the flow of current of air in the hygrometer. It is long when there is no current of air passing through it or when there is very slow current of air passing through it. But it decreases rapidly with the increase of speed of current of fresh air through it. The observations recorded in the case of the optical hygrometer in Table I*a* show that the mean time lag when the current of air is not passing inside the chamber is 17 minutes (mean of the first five observations), and the mean time lag when the current of moist air is passed for three minutes in this chamber is 13 minutes (mean of the last three observations). Thus the time lag decreases very effectively when the regular current of air is passed through the hygrometer. It is why the time lag of humatograph which is also a kind of hair hygrometer enclosed inside a big cover, has a very long time lag (say, 50 minutes in this case), while an open type of hair hygrometer has about 19 minutes time lag.

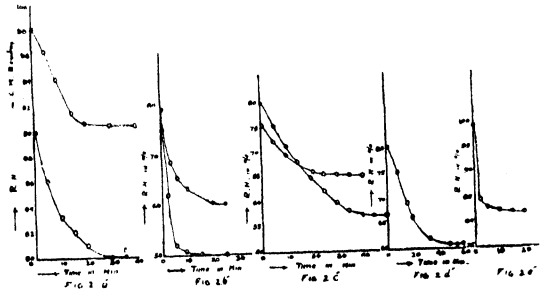


FIG. 2

In figure 2, some curves have been drawn showing the relation between time and humidity (when it is increasing) during the unsteady state, *i.e.*, before the reading becomes steady, as well as between time and humidity when it is decreasing. The curves *a*, *b*, *c*, *d*, and *e* in figure 2, represent the speed of increase of the humidity in the optical hygrometer, hair-hygrometer, paper hygrometer, humatograph, and the wet and dry bulb hygrometer respectively and the curves *a'*, *b'*. *c'*, *d'*, and *e'* in the same figure represent the speed of decrease of humidity in the same said hygrometers respectively. These curves indicate very high speed of variations in the beginning but much slow later on. The speed of variation goes on decreasing very rapidly with time. After the time lag, the curves give a horizontal line and the reading becomes steady. All these curves are similar in shape. The curves for the increase of humidity and the decrease of humidity are roughly complimentary.

HUMID FATIGUE

By the method given above, the observations of the time lags of the various types of hygrometers were recorded while treating them with currents of moist

and dry air alternately without any break in the cycle. Such cycles of observations were repeated again and again on each hygrometer. Time lags of some of the hygrometers for each cycle are given below in Table II.

TABLE II

Kind of hygrometer. 1	No. of set of observation. 2	I cycle		II cycle		REMARKS 7
		Increase of humidity. 3	Decrease of humidity. 4	Increase of humidity. 5	Decrease of humidity. 6	
Mahajan's Optical hygrometer.	1st set	22 min.	37 min.	21 min.	34 min.	All sets taken on different days and times.
	2nd ,,	20 ,,	38 ,,	15 ,,	30 ,,	
	3rd ,,	18 ,,	34 ,,	11 ,,	23 ,,	
	Mean	20 ,,	36 ,,	16 ,,	29 ,,	
Hair hygrometer	1st set	20 ,,	40 ,,	17 ,,	29 ,,	,,
	2nd ,,	17 ,,	39 ,,	16 ,,	27 ,,	
	3rd ,,	18 ,,	38 ,,	15 ,,	25 ,,	
	Mean	18 ,,	39 ,,	16 ,,	27 ,,	
Paper hygrometer	1st set	35 ,,	45 ,,	22 ,,	32 ,,	
	2nd ,,	29 ,,	43 ,,	25 ,,	29 ,,	
	3rd ,,	34 ,,	48 ,,	21 ,,	35 ,,	,,
	Mean	33 ,,	45 ,,	23 ,,	32 ,,	
Wet and dry bulb hygrometer.	1st set	20 ,,	42 ,,	18 ,,	39 ,,	
	2nd ,,	18 ,,	38 ,,	18 ,,	37 ,,	
	3rd ,,	16 ,,	36 ,,	15 ,,	35 ,,	,,
	Mean	18 ,,	39 ,,	17 ,,	37 ,,	

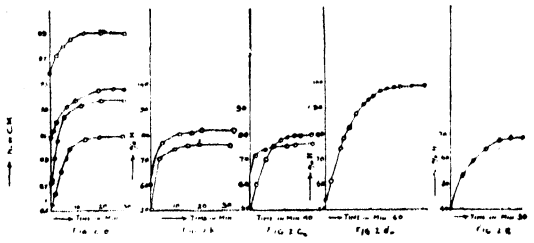


FIG. 3

In the above table, column 3 gives time lag when hygrometer is treated with a current of moist air, and column 4 represents time lag when it is merely exposed to dry air of the room. Time lag is longer in the latter case as the circulation of air was not as rapid as in the former case.

Then just after this first cycle, the second cycle of action is repeated in the same way, and its observations are recorded in columns 5 and 6. The data

clearly indicates that the time lags in the second cycle are less than the corresponding time lags in the first cycle. For example, the time lag to start with in the case of optical hygrometer is about 20 minutes but immediately after when exposed to dry air it takes 36 minutes to come to the steady state. Again when this cycle is repeated, the time lags are 16 and 29 minutes respectively.

This shows that the time lag of hygrometer which has been treated a number of times with rapid changes of humidity by currents of moist and dry air alternately comes to rest and gives a constant value in a shorter time than otherwise. Therefore time lag of hygrometer is not a constant factor depending merely on kind of hygrometer and speed of circulation of air in it but also *depends upon the immediate past history of hygrometer.*

The time lags of other types of hygrometers under similar conditions were also studied and are given in the same table. The results indicate that the effect of immediate past history is found in other types of hygrometers as well. This phenomenon may be called *the humid fatigue of hygrometers.*

The effect of humid fatigue is large in the paper hygrometer and almost negligible in wet and dry bulb hygrometer.

CONCLUSION

The results obtained from the above investigations are encouraging and interesting. Some of the important results are given below :—

1. The optical hygrometer behaves like the other kinds of hygrometers, such as, paper hygrometer and hair hygrometer.

2. Its sensitiveness increases when agate edges or grooves are used in thick heads of screws.

3. It is more sensitive than the other types of hygrometers and minor changes in humidity of the surrounding medium can easily be detected with it.

4. Its time lag is about 16 minutes and is much smaller than the time lag of other hygrometers.

5. The time lag of all types of hygrometers depends on (*i*) their type, (*ii*) rate of circulation of air in them and (*iii*) their immediate past history.

6. The rate of change of humidity in the optical hygrometer decreases rapidly with time in the logarithmic relation. The major change takes place in the first few minutes.

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PHYSICS RESEARCH LABORATORY,
MAHENDRA COLLEGE,
PATIALA.

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