POSSIBILITIES FOR ACCURATE CONTROL OF THE RELATIVE HUMIDITY OF AIR

K. Kostyrko and B. Klenovskaya

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Studies considering the control of relative humidity are analyzed.

The published studies on control of the relative humidity of air with which the authors are familiar do not analyze control accuracy, so that erroneous data are often given for humidity-variation errors, and unvalidated average values are frequently used.

A typical example is furnished by the error made in estimating the accuracy of psychrometers in meteorology [1, 2], where it is assumed that when the temperature is read from dry-bulb and wet-bulb thermometers (with an error of ±0.1°C), the relative-humidity measurement is made with an error of ±1%. This is only valid for a narrow range of temperatures and at low humidities, as may easily be shown (see Table 4).

Our purpose is to make a theoretical comparison of the possible errors in determining the relative humidity of air (the control processes) when relative-humidity sensors, psychrometer sensors, and dew-point sensors are used, and when standard data are processed to estimate the accuracy with which relative humidity is determined.

The relative humidity of the air is found or controlled directly or indirectly by means of pairs of thermodynamic quantities adequately characterizing the state of the air. These pairs are: a) the dew point and the temperature of the air; b) the wet-bulb and dry-bulb temperature.

Within the range of measurement or control error for each of the parameter pairs, all states of the air may be represented in the coordinates of these parameters on a graph (i, x) as a climatic region (Fig. 1). We analyzed these regions, determining the maximum control deviations expressed in percent of relative humidity.

The same region may be determined for control of relative humidity by the direct method and for simultaneous temperature control.* For constant moisture content, the relative humidity of air is uniquely associated with the temperature, so that very accurate relative-humidity control depends solely on the temperature deviations.

The calculations were carried out by digital computer and were based on standard data calculated at the State Hydrological Meteorological Institute (Warsaw) with allowance for the Goff–Gratsch equation [3-6]. These data take the form of a saturation curve in the –50 to +50°C temperature range.

For water we have

$$\log e_w = 10.79574\left(1-\frac{T'}{T}\right)-5.02800\log\left(\frac{T}{T'}\right)+1.50475\cdot 10^{-4}$$
$$\times\left[1-10^{-8.296}\left(\frac{T}{T'}-1\right)\right]+0.42873\cdot 10^{-3}\left[10^{4.76955}\left(1-\frac{T'}{T}\right)-1\right]+0.78614;$$

*The arrangement used to control relative humidity when there is no need for temperature control is uncharacteristic and shall not be considered here.

Warsaw, Poland. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 27, No. 6, pp. 991–1001, December, 1974. Original article submitted March 28, 1973.

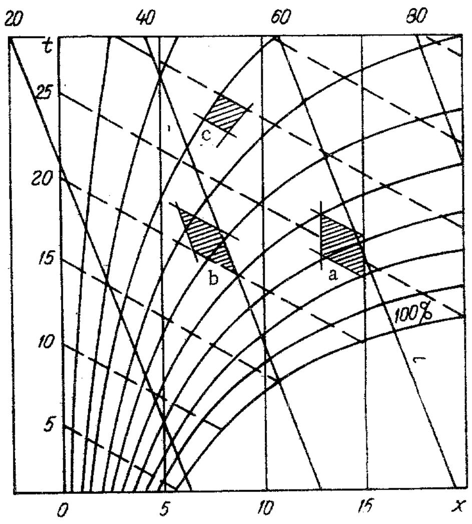

Fig. 1

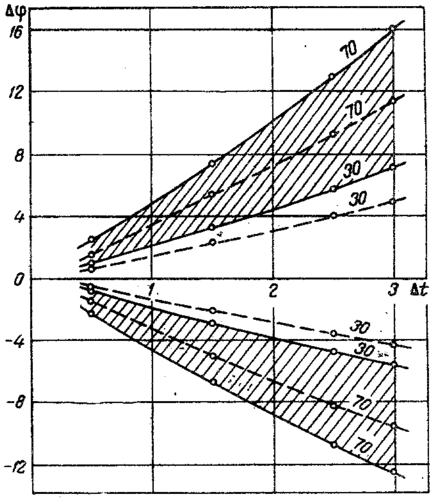

Fig. 2

Fig. 1. Graph for thermodynamic properties of moist air (i – x) with indicated climatic regions obtained by various types of control systems. Pairs of quantities: a) t", t; b) t', t; c) φ, t, t, °C; i, kJ/kg; x, g/kg.

Fig. 2. Graph of the function $\Delta\varphi = f(\Delta)$ for $t_0 = 10 \ldots 50$°C and $\varphi_0 = 30 \ldots 70$%. Solid curve) t = 10°C; dashed curve) t = 50°C; the numbers on the curves indicate φ in %. $\Delta\varphi$, %; Δt, °C.

and correspondingly, for ice

$$\log e_w = -9.09685\left(\frac{T'}{T} - 1\right) - 3.56654 \log\left(\frac{T'}{T}\right) + 0.87682\left(1 - \frac{T}{T'}\right) + 0.78614.$$

The following method was used to calculate the relative-humidity increments in the –50 to +50°C temperature range and the 10 to 90% relative humidity range as a function of the temperature increments.

For $\Delta\varphi > 0$ and when $(t + \Delta t) > t$, we have

$$\Delta\varphi = \varphi\left(1 - \frac{e_w(t)}{e_w(t + \Delta t)}\right);$$

for

$$\Delta\varphi < 0, \qquad (t - \Delta t) < t$$

$$\Delta\varphi = \varphi\left(1 - \frac{e_w(t)}{e_w(t - \Delta t)}\right).$$

Table 1 and Fig. 2 show the results of the calculations for three temperature increments (0.1, 0.5, and 3°C).

The following method was used to calculate the limiting values of the error in determining of relative humidity for systems measuring the dew point t" and the ambient temperature t.

We find $e(t) = \varphi e_w(t)$ for the given temperature t and the assumed relative humidity.

Taking $e(t) = e_w(t'')$, we determine t" for the value of $e_w(t'')$ obtained on the saturation curve.

We find the values of $e_w(t'' \pm \Delta t'')$ on the saturation curve.

We compute

$$\Delta\varphi > 0 \qquad \text{for} \qquad |\Delta t''| = |\Delta t|,$$

$$\Delta\varphi = \varphi - \frac{e_w(t'' - \Delta t'')}{e_w(t + \Delta t)} \cdot 100$$

TABLE 1. Deviation in Relative Humidity $\pm\Delta\varphi$ (in −50 to +50°C temperature range and 10 to 90% relative-humidity range) as a Function of Temperature Δt

t, °C	φ, % 10	20	30	40	50	60	70	80	90
					Δφ, % for $\Delta t = \pm 0{,}1$ °C				
−50	−0,13	−0,25	−0,38	−0,50	−0,63	−0,75	−0,88	−1,00	−1,13
−40	0,12 −0,11	0,23 −0,22	0,35 −0,33	0,46 −0,44	0,58 −0,55	0,69 −0,66	0,81 −0,77	0,92 −0,88	1,04 −0,99
−30	0,10 −0,10	0,21 −0,21	0,31 −0,31	0,42 −0,41	0,52 −0,52	0,62 −0,62	0,73 −0,73	0,83 −0,83	0,94 −0,93
−20	0,10 −0,10	0,19 −0,19	0,29 −0,29	0,38 −0,38	0,48 −0,48	0,58 −0,57	0,67 −0,67	0,77 −0,77	0,86 −0,86
−10	0,09 −0,09	0,18 −0,18	0,27 −0,27	0,36 −0,35	0,45 −0,44	0,54 −0,53	0,63 −0,62	0,71 −0,71	0,80 −0,80
0	0,08 −0,07	0,17 −0,14	0,25 −0,22	0,33 −0,29	0,41 −0,36	0,50 −0,43	0,58 −0,51	0,66 −0,58	0,74 −0,65
10	0,07 −0,07	0,13 −0,13	0,20 −0,20	0,27 −0,27	0,34 −0,33	0,40 −0,40	0,47 −0,47	0,54 −0,53	0,61 −0,60
20	0,06 −0,06	0,12 −0,12	0,19 −0,19	0,25 −0,25	0,31 −0,31	0,37 −0,37	0,43 −0,43	0,50 −0,49	0,56 −0,56
30	0,06 −0,06	0,12 −0,11	0,17 −0,17	0,23 −0,23	0,29 −0,29	0,35 −0,34	0,40 −0,40	0,46 −0,46	0,52 −0,51
40	0,05 −0,05	0,11 −0,11	0,16 −0,16	0,21 −0,21	0,27 −0,27	0,32 −0,32	0,37 −0,37	0,43 −0,43	0,48 −0,48
50	0,05 −0,05	0,10 −0,10	0,15 −0,15	0,20 −0,20	0,25 −0,25	0,30 −0,30	0,35 −0,35	0,40 −0,40	0,45 −0,45
−50	−0,60	−1,19	−1,79	−2,39	−2,98	−3,57	−4,18	−4,77	−5,37
−40	0,58 −0,55	1,15 −1,10	1,73 −1,66	2,31 −2,21	2,88 −2,76	3,46 −3,31	4,04 −3,86	4,61 −4,42	5,19 −4,97
−30	0,53 −0,51	1,07 −1,01	1,60 −1,52	2,14 −2,03	2,67 −2,53	3,21 −3,04	3,74 −3,55	4,28 −4,06	4,81 −4,56
−20	0,49 −0,46	0,98 −0,94	1,48 −1,40	1,97 −1,87	2,46 −2,34	2,95 −2,81	3,44 −3,28	3,93 −3,74	4,43 −4,21
−10	0,45 −0,43	0,91 −0,87	1,36 −1,30	1,82 −1,73	2,27 −2,17	2,73 −2,60	3,18 −3,04	3,64 −3,47	4,08 −3,90
0	0,42 −0,36	0,84 −0,72	1,26 1,07	1,68 −1,43	2,11 −1,79	2,53 −2,15	2,95 −2,50	3,37 −2,86	3,79 −3,22
10	0,34 −0,33	0,68 −0,66	1,02 −0,99	1,37 −1,32	1,71 −1,64	2,05 −1,97	2,39 −2,30	2,73 −2,63	3,07 −2,96
20	0,32 −0,30	0,63 −0,61	0,95 −0,91	1,26 −1,22	1,58 −1,52	1,89 −1,83	2,21 −2,13	2,52 −2,43	2,84 −2,74
30	0,29 −0,28	0,58 −0,56	0,88 −0,85	1,17 −1,13	1,46 −1,41	1,75 −1,69	2,04 −1,98	2,33 −2,26	2,63 −2,54
40	0,27 −0,26	0,54 −0,53	0,81 −0,79	1,08 −1,05	1,35 −1,31	1,62 −1,58	1,90 −1,84	2,17 −2,10	2,44 −2,36
50	0,25 −0,24	0,50 −0,49	0,75 −0,73	1,01 −0,98	1,26 −1,22	1,51 −1,47	1,76 −1,71	2,01 −1,96	2,26 −2,20
−50	−3,06	−6,13	−9,19	−12,25	−15,32	−18,38	−21,44	−24,51	−27,57
−40	4,09 −2,85	8,19 −5,70	12,28 −8,55	16,38 −11,40	20,47 −14,25	24,57 −17,10	28,66 −19,96	32,76 −22,81	36,85 −25,66
−30	3,72 −2,65	7,43 −5,31	11,15 −7,96	14,87 −10,61	18,59 −13,27	22,30 −15,92	26,02 −18,58	29,74 −21,23	33,45 −23,88
−20	3,38 −2,48	6,77 −4,95	10,15 −7,43	13,53 −9,91	16,92 −12,38	20,30 −14,86	23,68 −17,34	27,06 −19,81	30,45 −22,29
−10	3,09 −2,31	6,18 −4,63	9,28 −6,94	12,37 −9,26	15,46 −11,57	18,55 −13,88	21,64 −16,20	24,74 −18,51	27,83 −20,83
0	2,84 −1,94	5,68 −3,88	8,51 −5,81	11,35 −7,75	14,19 −9,69	17,03 −11,63	19,86 −13,56	22,70 −15,50	25,54 −17,44
10	2,26 −1,80	4,51 −3,60	6,77 −5,41	9,02 −7,21	11,28 −9,01	13,53 −10,81	15,79 −12,61	18,04 −14,41	20,30 −16,22
20	2,07 −1,68	4,14 −3,36	6,20 −5,03	8,27 −6,71	10,34 −8,39	12,41 −10,07	14,48 −11,75	16,54 −13,42	18,61 −15,10
30	1,90 −1,57	3,80 −3,13	5,71 −4,70	7,61 −6,26	9,51 −7,83	11,41 −9,39	13,31 −10,96	15,22 −12,53	17,12 −14,09
40	1,76 −1,46	3,51 −2,93	5,27 −4,39	7,02 −5,85	8,78 −7,32	10,53 −8,78	12,29 −10,24	14,04 −11,71	15,80 −13,17
50	1,62 −1,37	3,25 −2,74	4,87 −4,11	6,49 −5,48	8,12 −6,85	9,74 −8,22	11,37 −9,59	12,99 −10,96	14,61 −12,33

TABLE 2. Limiting Values for Error in Control of Relative Humidity for Systems Measuring Dew Point t" and Ambient Temperature t

t, °C	φ, % 10	20	30	40	50	60	70	80	90
	Δφ, % for $\mid\Delta t''\mid = \mid\Delta t\mid = 0{,}1$ °C								
—20	—0,21 0,23	—0,41 0,42	—0,60 0,60	—0,80 0,80	—0,97 0,99	—1,17 1,18	—1,35 1,37	—1,53 1,55	—1,72 1,75
—10	—0,19 0,20	—0,38 0,38	—0,56 0,56	—0,73 0,75	—0,91 0,92	—1,08 1,10	—1,25 1,27	—1,43 1,44	—1,59 1,62
0	—0,17 0,18	—0,33 0,36	—0,49 0,53	—0,64 0,69	—0,79 0,86	—0,95 1,02	—1,10 1,18	—1,24 1,34	—1,39 1,50
10	—0,16 0,16	—0,31 0,31	—0,46 0,46	—0,60 0,61	—0,71 0,70	—0,82 0,84	—0,95 0,96	—1,08 1,09	—1,21 1,22
20	—0,15 0,15	—0,29 0,29	—0,40 0,40	—0,52 0,53	—0,64 0,65	—0,78 0,77	—0,88 0,89	—1,00 1,01	—1,12 1,13
30	—0,14 0,14	—0,25 0,25	—0,37 0,37	—0,48 0,49	—0,60 0,60	—0,71 0,72	—0,82 0,83	—0,93 0,94	—1,03 1,05
40	—0,12 0,13	—0,24 0,24	—0,35 0,34	—0,45 0,46	—0,56 0,56	—0,66 0,67	—0,76 0,77	—0,86 0,87	—0,96 0,97
50	0,12	0,22	0,33	0,43	0,52	0,62	0,72	0,81	0,90
	Δφ, % for $\mid\Delta t''\mid = \mid\Delta t\mid = 0{,}5$ °C								
—20	—1,00 1,12	—1,95 2,16	—2,88 3,18	—3,80 4,18	—4,71 5,19	—5,61 6,18	—6,50 7,16	—7,39 8,13	—8,27 9,11
—10	—0,93 1,03	—1,82 2,00	—2,68 2,94	—3,53 3,87	—4,37 4,79	—5,21 5,70	—6,04 6,60	—6,86 7,50	—7,68 8,39
0	—0,83 0,96	—1,61 1,85	—2,36 2,72	—3,11 3,59	—3,85 4,43	—4,58 5,27	—5,31 6,11	—6,03 6,94	—6,75 7,76
10	—0,78 0,84	—1,50 1,62	—2,22 2,39	—2,91 3,14	—3,57 3,61	—4,00 4,29	—4,63 4,96	—5,25 5,62	—5,87 6,28
20	—0,73 0,79	—1,41 1,52	—1,94 2,07	—2,54 2,71	—3,13 3,34	—3,72 3,96	—4,30 4,58	—4,87 4,19	—5,44 5,79
30	—0,69 0,74	—1,23 1,31	—1,81 1,92	—2,36 2,51	—2,91 3,09	—3,49 3,67	—3,99 4,24	—4,53 4,80	—5,05 5,35
40	—0,60 0,64	—1,15 1,22	—1,69 1,79	—2,21 2,33	—2,72 2,87	—3,22 3,40	—3,72 3,93	—4,22 4,45	—4,71 4,96
50	0,60	1,14	1,66	2,17	2,67	3,17	3,65	4,14	4,61
	Δφ, % for $\mid\Delta t''\mid = \mid\Delta t\mid = 3$ °C								
—20	—4,70 8,82	—9,19 16,98	—13,63 24,92	—18,02 32,72	—22,37 40,41	—26,69 48,02	—30,97 55,57	—35,27 63,06	—39,53 70,49
—10	—4,45 7,99	—8,71 15,37	—12,89 22,55	—17,03 29,59	—21,13 36,54	—25,20 43,41	—29,25 50,23	—33,29 56,98	—37,30 63,69
0	—4,05 7,30	—7,90 13,99	—11,67 20,51	—15,62 26,91	—19,09 33,22	—22,75 39,46	—26,39 45,64	—30,01 51,37	—33,61 55,41
10	—3,48 6,23	—7,49 11,94	—11,06 17,47	—14,58 22.67	—18,05 25,99	—20,52 30,79	—23,58 35,53	—26,78 40,22	—29,95 44,87
20	—3,66 5,74	—7,11 10,54	—10,12 14,75	—13,02 19,26	—16,09 23,68	—19,13 28,04	—22,14 32,35	—25,12 36,61	—28,09 40,83
30	—3,48 5,32	—6,36 9,29	—9,34 13,51	—12,26 17,63	—15,14 21,67	—17,98 25,65	—20,80 29,57	—23,60 33,46	—26,38 37,80
40	—3,15 4,51	—6,01 8,55	—8,81 12,43	—11,55 16,20	—14,25 19,90	—16,92 23,54	—19,57 27,14	—22,19 30,69	—24,79 34,21
50	4,18	7,90	11,47	14,94	18,34	21,69	24,99	28,25	—

and

$$\Delta\varphi < 0 \quad \text{for} \quad \mid\Delta t''\mid = \mid\Delta t\mid,$$

$$\Delta\varphi = \varphi - \frac{e_w(t'' + \Delta t'')}{e_w(t - \Delta t)} \cdot 100.$$

Table 2 shows the calculated results for three temperature increments (0.1, 0.5, and 3°C).

The results shown in the table may be used to judge the reliability of data from measurements in a climate chamber (Table 3).

The following method is used to calculate the limiting values of relative-humidity deviations in psychrometer systems.

The values of e(t, t') and e(t + Δt, t' − Δt'), and e(t − Δt, t' + Δt') are taken from psychrometric tables [7].

TABLE 3. List of Claimed Data for Accuracy of Relative Humidity $+\Delta\varphi$ in Climate Chambers (with dew-point sensors used)

Chamber	Data			Should be		
	t, °C	10%	98%	t, °C	10%	98%
Karl Weiss Grünbach—Österreich Klimamess-und Klimaprüfschranke Type-300 AB/30 JM $\Delta t \pm 0{,}2$ °C $\Delta t' \pm 0{,}2$ °C	—30 —10 +10 +95	±1%		—30 —10 +10 +95	0,5 0,4 0,3 0,1	4,0 3,4 2,6 0,7

We calculate

$$\varphi = \frac{e(t,\ t')}{e_w(t)} \cdot 100.$$

We find $\Delta\varphi > 0$ for $|\Delta t| = |\Delta t'|$:

$$\varphi = \frac{e(t-\Delta t,\ t'+\Delta t')}{e_w(t-\Delta t)} \cdot 100 - \varphi$$

and $\Delta\varphi < 0$ for $|\Delta t| = |\Delta t'|$:

$$\varphi = \frac{e(t+\Delta t,\ t'-\Delta t')}{e_w(t+\Delta t)} \cdot 100 - \varphi.$$

Table 4 shows the calculated results for temperature increments of 0.1, 0.5, and 3°C.

As we have noted, the smallest error in humidity measurement occurs when the errors in the systems regulating both temperatures are of opposite sign.

TABLE 4. Limiting Values for Error in Relative-Humidity Control for Systems Measuring Dry- and Wet-Bulb Temperature t'

φ, %	Δt, °C: 0,1		0,5		3	
			Δφ for $t = -10$ °C			
18,7	—4,8	4,7	—24,7	—	—	—
45,1	—5,1	5,0	—26,2	23,9	—	—
72,2	—5,4	5,3	—27,8	25,4	—	—
86,0	—5,4	5,4	—	26,1	—	—
			Δφ, % for $t = 0$ °C			
11,2	—2,3	2,2	—11,8	10,7	—88,8	—
38,9	—2,6	2,5	—13,4	12,1	—	—
68,4	—2,9	2,8	—15,0	13,7	—	68,1
83,9	—3,1	3,0	—16,1	14,5	—	72.4
			Δφ, % for $t = 10$ °C			
16,9	—1,3	1,3	—6,8	6,3	—49,4	—
41,8	—1,6	1,6	—8,1	7,5	—58,2	38,0
59,9	—1,8	1,7	—9,0	8,4	—	42,7
89,4	—2,1	2,0	—10,6	9,9	—	50,4
			Δφ, % for $t = 20$ °C			
15,0	—0,8	0,8	—4,2	3,9	—30,3	—
36,9	—1,0	1,0	—5,3	5,0	—37,9	25,4
62,2	—1,3	1,3	—6,6	6,2	—	31,9
91,8	—1,6	1,6	—8,2	7,7	—	39,6
8,5	—0,5	0,5	—2,5	2,4	—8,1	—
30,3	—0,7	0,7	—3,6	3,4	—25,4	17,4
58,0	—1,0	1,0	—5,0	4,7	—34,9	24,4
93,2	—1,3	1,3	—6,8	6,4	—	33,4
			Δφ, % for $t = 50$ °C			
8,4	—0,3	—	—1,3	—	—8,9	—
24,0	—0,4	—	—2,0	—	—13,8	—
45,6	—0,6	—	—3,0	—	—20,6	—
75,7	—0,9	—	—4,4	—	—	—

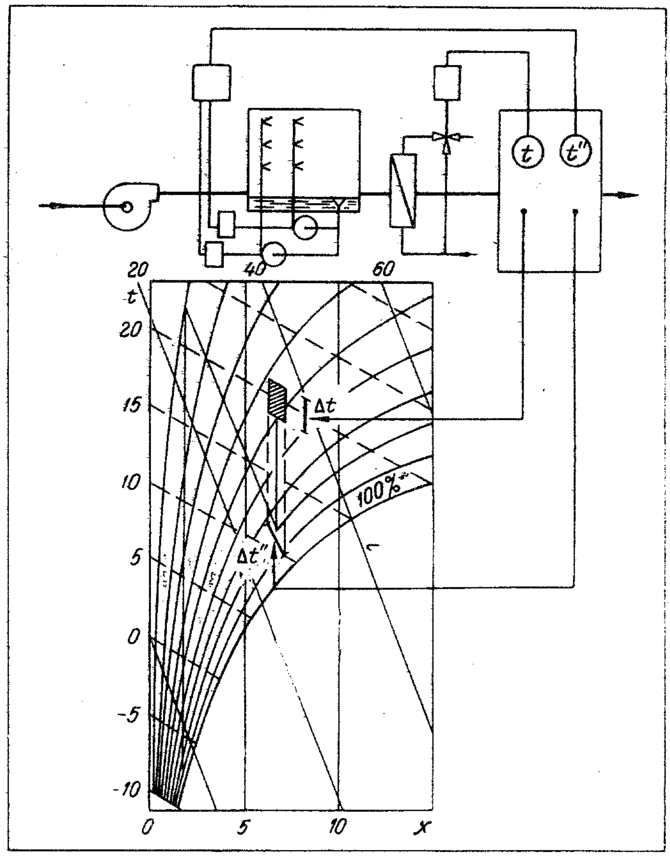

Fig. 3. Control system of climate unit with dew-point sensors within chamber; t, °C; i, kJ/kg; x, g/kg.

It follows from what we have said that for regulation in a system using measurements and using the error in the wet-bulb depression, relative-humidity control will be twice as accurate. As an example, if the wet-bulb depression is controlled to within ±1°C, the error in relative-humidity control will be the same as for control of wet- and dry-bulb temperatures to within ±0.5°C.

Examples of Determination of Error in Control of Air Relative Humidity in Controlled-Climate Systems. The climate regions shown in Fig. 1 may be realized by different types of control. Figure 3 shows a system for controlling the dew point and stream temperature in climate equipment and the pattern of changes in the state of the air during establishment of the climate. The graph of the air-state changes indicates the climate region maintained by the control system. It is bounded by the isotherms for the temperature of the t-chamber within the limits of the deviations and by the x-const lines, which correspond to the maximum deviations of the dew points t'' in the chamber.

Figure 4 shows the control system for a different type of climate equipment, for which it is difficult to determine the climate region by mathematical calculation. In this system, the controlled space contains only the thermometer belonging to the temperature-control system, while the thermometer used to measure the dew point is located beyond the spray chamber in which the process of adiabatic humidification is carried out. The climatic region is marked off by the isotherms for the limiting temperatures t maintained in the controlled space, and by the constant-humidity lines x corresponding to the limiting deviations in the temperature t_c beyond the spray chamber, at the so-called chamber point. As we know, these temperatures are equal to the dew points only when the air is moistened to a state of relative-humidity saturation ($\varphi = 100\%$). Then, when $x = f(t'')$ is known, the determination of the x-const line presents no problems. Actually, air saturation does not exceed 96% (depending on chamber efficiency), and the unknown pattern of the function $x = f(t_c)$ and the associated limiting deviations in x hinder both exact determination of the climate region and evaluation of the accuracy of humidity control for this system.

The accuracy with which the relative humidity is controlled by the system shown in Fig. 4 may be estimated approximately if we assume that the chamber point moves along a curve parallel to the saturation curve. Such an assumption is permissible for a specified chamber spray coefficient. Then the system shown in Fig. 4 may be treated like that shown in Fig. 3.

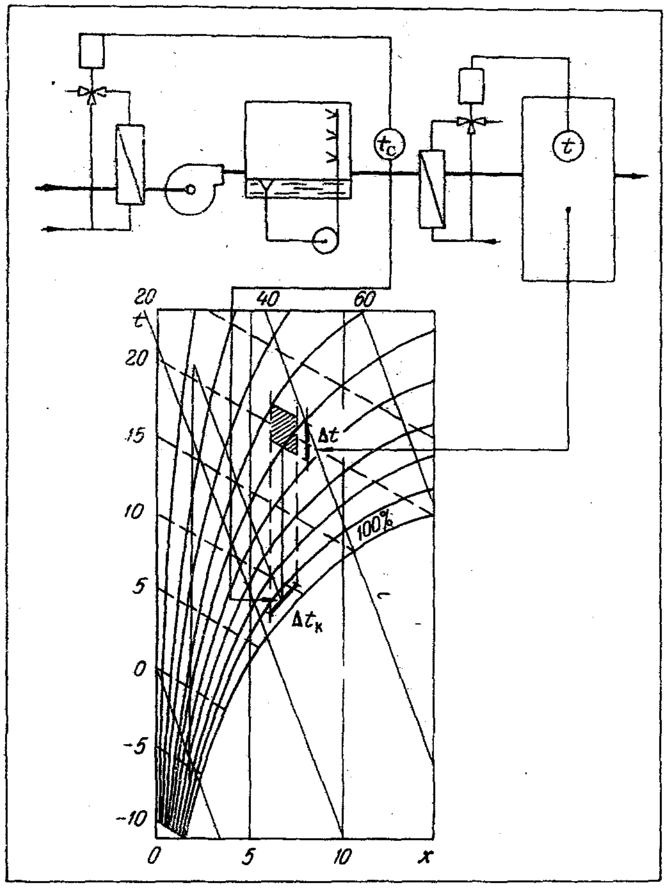

Fig. 4. Control system of climate unit with dew-point sensors beyond spray chamber; t, °C; i, kJ / kg; x, g / kg.

The calculations show that the theoretically possible accuracy of humidity-control using relative-humidity and temperature sensors is far better than the accuracy attained by using dew-point sensors or psychrometer sensors of the same accuracy as the temperature sensors. As an example, for a temperature-control accuracy of ±0.5°C (under conditions of 20°C and 50% relative humidity), we have the following maximum deviations in a relative-humidity control system using the following sensors: relative humidity $+\Delta\varphi = +1.58\%$ and $-\Delta\varphi = -1.52\%$; dew-point $+\Delta\varphi = +3.3\%$ and $-\Delta\varphi = -3.13\%$; wet-bulb temperature (psychrometer) $+\Delta\varphi = +5.8\%$, and $-\Delta\varphi = -6.0\%$. The discrepancies indicated above are still greater for negative temperatures (for example, at −10°C), all other conditions being equal. The maximum relative-humidity deviations for the various sensors are: relative-humidity $+\Delta\varphi = +2.27\%$ and $-\Delta\varphi = -2.17\%$; dew-point $+\Delta\varphi = +4.79\%$ and $+\Delta\varphi = -4.37\%$; wet-bulb temperature $+\Delta\varphi = +24\%$ and $-\Delta\varphi = -26.3\%$.

The practical result of the consideration of climate-establishment accuracy was a determination of the temperature deviations that may be allowed in full climate-control systems (by the "dew-point" method for example) for specified relative-humidity tolerances of 2-4% (used in 40% of the electronics industry, 30% of the textile industry, and 50% of the photochemical industry [8]); the error in dew-point and air-temperature regulation should not exceed 0.5°C (Table 2).

The permissible temperature errors for exact psychrometric measurements have been determined by analyzing the relationships between the errors in measurement of dry- and wet-bulb temperature and the resulting errors in relative humidity. As an example, for thermometers accurate to ±0.1°C, the relative-humidity error in measurements by psychrometer may reach 2% in the 10-30°C temperature range, and not ±1% as is often said in manufacturer's literature and published studies.

NOTATION

i is the enthalpy of air, kJ / kg;
x is the moisture content, g / kg;
e_w is the saturated vapor pressure, mbar;

e is the partial vapor pressure, mbar;
φ is the relative humidity, %;
$\Delta\varphi$ is the relative-humidity gradient, %;
t is the dry-air temperature, °C;
t° is the wet-bulb temperature, °C;
t" is the dew-point, °C;
Δt is the temperature gradient, °C;
T is the temperature;
T° is the triple-point temperature, T' = 273.16°K;
0 is the working parameters of moist air.

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