SIMULATION OF FUNCTIONAL RELATIONSHIPS BETWEEN AIR PARAMETERS

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Inzhenerno-Fizicheskii Zhurnal, Vol. 14, No. 2, pp. 354–358, 1968

UDC 533.1

A method is presented for the simulation on an analog computer of the functional relationships existing between the parameters characterizing the heat-moisture state of the air when the latter is passed through air-conditioning systems.

The use of electronic analog computers to study the static and dynamic regimes of air-conditioning systems makes it possible to reduce the time and cost spent on the determination of reasonable parameters for such installations.

For the modeling of air-conditioning systems on analog computers, we have to use the known physical parameters of the air to determine other parameters. This involves certain difficulties, since the functional relationships between the parameters of the air are complex and not uniquely defined, i.e., some of the parameters of the air are functions of two variables.

Here we propose a method and a scheme for a set of functional generators to derive the values of the moisture content a (g/kg) and of the heat content i of the water vapors in the air (in kcal/kg), with these being functions of the vapor pressure e (mm Hg) and of the relative humidty of the air φ(%), which is a function of the known temperature θ (°C) and of the vapor pressure e (in mm Hg) of the air.

The vapor pressure e and the moisture content of the air are related by the expression [1]

$$e = \frac{1.0394ap}{622.14 + a} \text{ mm Hg.} \tag{1}$$

Solution of expression (1) for a yields

$$a = \frac{622.14e}{1.0394p - e} \text{ g/kg.} \tag{2}$$

The analytical relationship (2) can be achieved by means of the computational scheme presented in Fig. 1a. The scheme includes a scale converter with the transfer constant $K_1 = 3.11$, an adder with the coefficients $K_2 = 0.05$ and $K_3 = 0.502$, two inverters, and a division unit. A voltage proportional to 0.1 p is applied to the K_3 input.

Testing the accuracy of the computer circuit made up of elements from the MN-14 analog computer showed that the error in the determination of a does not exceed ±2% of the theoretical value.

When p is equal to 760 mm Hg, expression (2) can be replaced by the approximate expression

$$a \approx 0.806e \text{ g/kg.} \tag{3}$$

In this case, the error in the determination of a in the range of variation in e from 2.5 to 35.0 mm Hg does not exceed ±2.0%.

The block diagram for the set of functional relationships $i = f(e)$ can be set up in corresponding fashion. The difference in the circuits for the functional relationships $a = f(e)$ and $i = f(e)$ is found in the fact that the coefficient K_1 in the first case is equal to 3.11, while it is equal to 1.85 in the second case, which follows from the relationship $i = 0.596\,a$ [2].

The computer circuit used to derive the relative air humidity φ(%) must give the expression

$$\varphi = \frac{e}{e_{max}} \ \%. \tag{4}$$

The computer circuit for the derivation of φ (Fig. 1b) is made up of a NU-1 nonlinearity unit which gives the relationship $e_{max} = f(\theta)$ whose adjustment chart is shown in Table 1, in addition to a division unit, and three inverters designed to yield the variables e, θ, and e_{max} of various signs, since the multiplication units, the nonlinearity units, and the division units of the analog computers (according to factory instructions) require input voltages which are variables of differing signs. An investigation of the computer circuit yielding expression (4) on an MN-14 analog computer showed that the solution error does not exceed ±2.0% of the calculated quantity over a temperature range from 0 to 50° C.

Table 1

Chart for the Adjustment of the NU-1 Nonlinearity Unit Which Provides the relationship $e_{max} = f(\theta)$, $f(0) = 4.7$V

	X_{in}	Element no.								
		1	2	3	4	5	6	7	8	9
Quadrants		+	+	+	+	+	+	+	+	+
Constraint X		11.2	20.0	31.2	40.0	51.2	60.0	71.2	81.2	92.1
Output voltage Y for X_{in} = = 100V	25.6	31.3	39.1	48.8	56.3	66.2	75.3	85.3	92.2	96.0

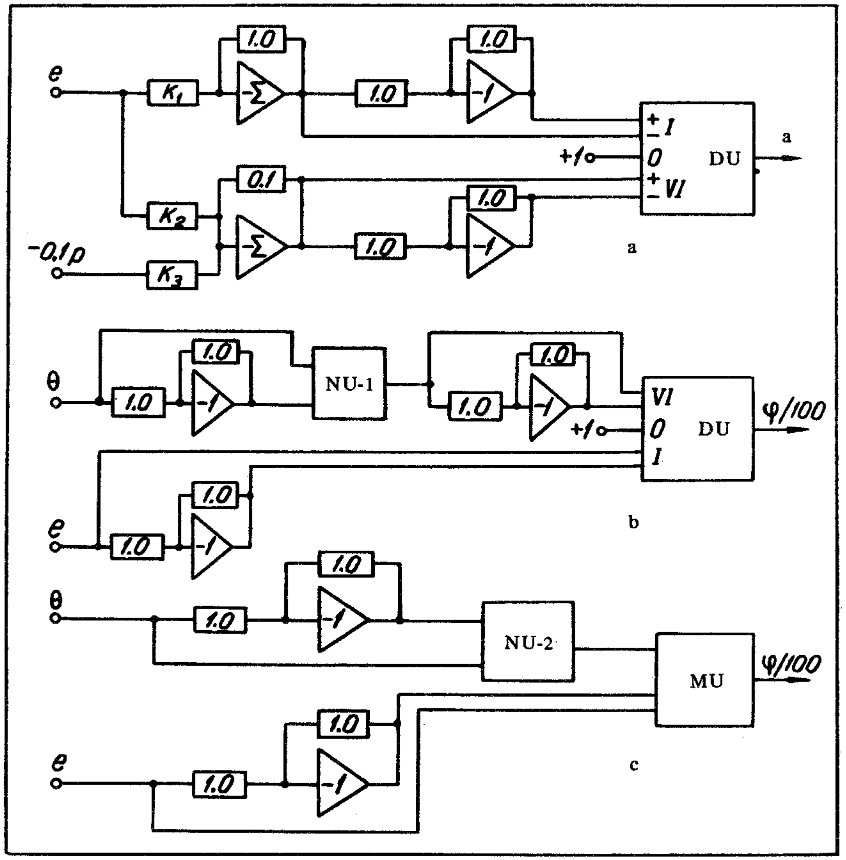

Fig. 1. Computer diagrams for calculating functional dependences: a) between moisture content a and the vapor pressure of the water vapor at various barometric pressures p; b, c) between relative humidity and the vapor pressure of the water vapor at various air temperatures θ.

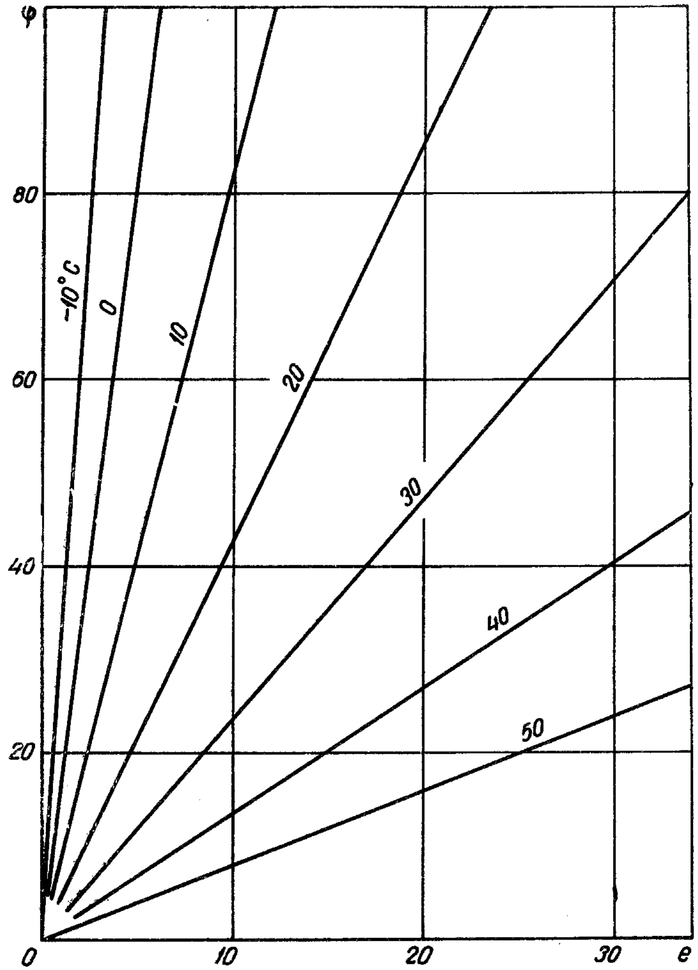

Fig. 2. Relative humidity φ(%) of air versus vapor pressure e of water vapor in air (mm Hg) and temperature θ (°C).

Table 2

Chart for the Adjustment of the NU-2 Nonlinearity Unit Giving the Relationship $\alpha_\varphi = f(\theta)$, $f(0) = 16.4$V

	X_{in}	Element no. 1	2	11	12	13	14	15	16	17	18
Quadrants		+	+	+	+	+	+	+	+	+	+
Constraint X		—2.5	—5.0	0	5.0	10.0	15.0	20.0	25.0	30.0	40.0
Output voltage Y for $X_{in} = -10$ V	—29.0	32.2	34.5	—	—	—	—	—	—	—	—
Output voltage Y for $X_{in} = 50$ V	—	—	—	—32.6	—18.8	—10.2	—5.1	—2.8	—0.9	0.3	0.8

To derive $\varphi(\%)$, we can use a circuit which operates on a different principle. In this case, the relationship $\varphi = f(e, \theta)$ (Fig. 2) is taken from psychrometric tables [3]. We see from Fig. 2 that φ is a linear function of e

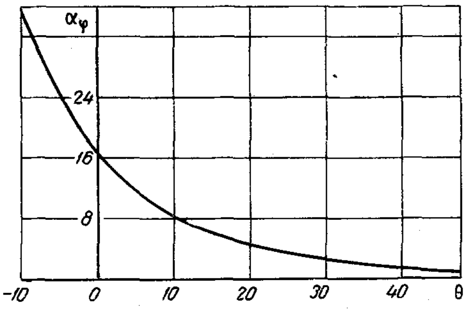

Fig. 3. Slope α_φ of lines representing $\varphi = f(e)$ at θ = const versus temperature θ (in the scale for α_φ = IV/unit and for θ = IV/°C).

when θ = const, and all of the lines representing $\varphi = f(e)$ emanate from a point with coordinates 0 and differ from each other at various temperatures only in the slope of α_φ. Consequently, the analytical expression for φ is given in the form

$$\varphi = \alpha_\varphi e \ \%. \qquad (5)$$

The scheme for the set of the given functional relationship (Fig. 1c) consists of a NU-2 nonlinearity unity (the adjustment chart is shown in Table 2) which gives the functional relationship $\alpha_\varphi = f(\theta)$ (Fig. 3), an MU multiplication unit in which e is multiplied by α_φ, and two inverters which are intended for precisely the same purposes as in the previous circuits. The accuracy of this circuit is the same as in that shown in Fig. 3.

This method may be used to construct the block diagrams of resolvers which reproduce similar functional relationships, characterizing the parameters of the air (for example: $e = f(a)$; $e = f(i)$; $e = f(\theta;\varphi)$ etc.).

NOTATION

a is the air humidity, g/kg; i is the heat content of the water vapor in air, kcal/kg; e is the vapor pressure, mm Hg; φ is the relative humdity, %; θ is the temperature of air, °C; p is the barometric pressure of air, mm Hg; e_{max} is the maximum vapor pressure in air at given temperature, mm Hg; α_φ is the slope of the straight lines representing $\varphi = f(e)$ at θ = const.

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17 May 1967

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