# METHOD OF APPROXIMATION OF A CURVE "A HUMIDITY - OPTICAL PARAMETER" AND THE ALGORITHM OF DEFINITION OF CALIBRATING CHARACTERISTICS

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**Summary**

The questions of information - methodological support of the problem-oriented computer complex for the automated technology experimental research for infra-red measurement of humidity are considered. The offered method reduces an error called by an error of approximation by curve "humidity - optical parameter". An error of approximation is caused by complexity of preparation and test of a plenty of samples of a material. The method of definition constant “a, k, b” of logarithmic function of definition of humidity, by means of three samples appropriate to the minimal, maximal and average importance of the given range of measurement is offered.

**Keywords:** Method of approximation. Automated technology. Experimental research. Infra-red measurement.

## 1. Introduction

The analysis of metrological properties of infra-red analyzers shows, that the significant share of an error is due to a degree of accuracy of approximation of a curve of experimental data caused by complexity of preparation of a plenty of samples with given humidity in the given range. For elimination of the specified factor of an error the method of approximation of a curve by means of three samples with humidity close to the minimal, maximal and average value of a range of measurement is developed.

## 2. Methods

The offered method consists in the fact that many curves are being approximated with required accuracy by logarithmic function. Curve dependences "a humidity - optical parameter", which are applied by devices at measurement of humidity based on a spectrometer method look like those given in figure 1-4, where G is an optical parameter, W - humidity.

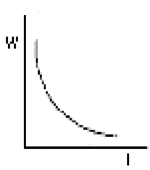

**Fig. 1**

**Fig. 2**

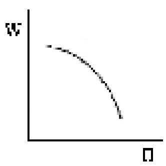

**Fig. 3**

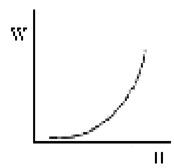

**Fig. 4**

Most general view of function of approximation,

$$w=a+k\ln(\Pi - b) \qquad (1)$$

where a, k, b are constants.

For definition of concrete values of constants it is necessary the values of the function in three points.

Let at: $\Pi=\Pi_1$ have $w=w_1$;

$\Pi=\Pi_2$ have $w=w_2$;

$\Pi=\Pi_3$ have $w=w_3$;

Then according to (1)

$$w_1=a+k\ln(\Pi_1-b) \qquad (2_1)$$

$$w_2=a+k\ln(\Pi_2-b) \qquad (2_2)$$

$$w_3=a+k\ln(\Pi_3-b) \qquad (2_3)$$

By elimination of "a" we get

$$w_2-w_1=k\ln\frac{\Pi_2-b}{\Pi_1-b} \qquad (3_1)$$

$$w_3-w_2=k\ln\frac{\Pi_3-b}{\Pi_2-b} \qquad (3_2)$$

$$w_3-w_1=k\ln\frac{\Pi_3-b}{\Pi_1-b} \qquad (3_3)$$

From $(3_1)$ and $(3_2)$ by elimination of "k" we have

$$\frac{w_2-w_1}{w_3-w_2}=\frac{\ln\dfrac{\Pi_2-b}{\Pi_1-b}}{\ln\dfrac{\Pi_3-b}{\Pi_2-b}} \qquad (4)$$

With respect to "b" we receive transcendental equation. It becomes considerably simpler if we assume that

$$\frac{w_2-w_1}{w_3-w_2}=1$$

$$w_2=\frac{w_1+w_3}{2} \qquad (5)$$

Then from (4) we shall determine

$$\ln\frac{\Pi_2-b}{\Pi_1-b}=\ln\frac{\Pi_3-b}{\Pi_2-b}$$

$$\frac{\Pi_2-b}{\Pi_1-b}=\frac{\Pi_3-b}{\Pi_2-b} \qquad (6)$$

$$b=\frac{\Pi_1\cdot\Pi_3-\Pi_2^2}{\Pi_1+\Pi_3-2\Pi_2^2} \qquad (7_1)$$

From $(3_2)$ is received

$$k=\frac{w_3-w_1}{\ln\dfrac{\Pi_3-b}{\Pi_1-b}} \qquad (7_2)$$

From $(2_1)$ is received $a=w_1-k\ln(\Pi_1-b)$ $(7_3)$

The formulas $(7_1)$, $(7_2)$, and $(7_3)$ give the values of constant coefficients of function of kind (1), provided that the ordinates of three points of approximating function satisfies condition (5).

The offered method can be applied to curves (2, 3, 4), similar given in figure 1.

All given four curves are described by one equation

$$w=a+k\ln|(\Pi-b)| \qquad (8)$$

For determination of b instead of (6) we receive equation

$$\left|\frac{\Pi_2-b}{\Pi_1-b}\right|=\left|\frac{\Pi_3-b}{\Pi_2-b}\right| \qquad (9)$$

Taking into account, that x=b is vertical asymptote to logarithmic function and is located more to the left in diagrams 1 and 2, that is, if to arrange on increase $Ï_1= Ï_2= Ï_3$ we shall have $b<\Pi_1<\Pi_2<\Pi_3$, and for diagrams in fig. 3 and 4 is located more to the right, i.e.

$$\Pi_1<\Pi_2<\Pi_3<b$$

We receive that, $\Pi_1$–b= $\Pi_2$–b= $\Pi_3$–b= have identical signs in both cases and equation (8) is reduced to (6), i.e. constant b in all four cases will be determined by formula ($7_1$). For definition of constant a instead of ($7_3$) we shall have formula

$$a=w_1-k\ln|(\Pi_1-b)| \qquad (10)$$

At application of computer there is no necessity to have built beforehand a curve of kind of fig. 1-4. With the purpose to find such points, that satisfy condition (5) it is enough to know coordinates of three arbitrary points.

Let curve looks like that given in fig.1 and points ($x_1$, $y_1$)= ($x_2$, $y_2$)= ($x_3$, $y_3$) are known. Let us find coefficients a, k, b, in equation (8) by determining of point ($x_c$= $y_c$), where $y_c=\dfrac{y_1+y_3}{2}$, while "$x_c$" is determined by consecutive approximation according to the following algorithm:

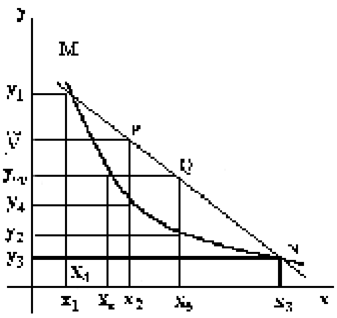


**Fig. 5-a**

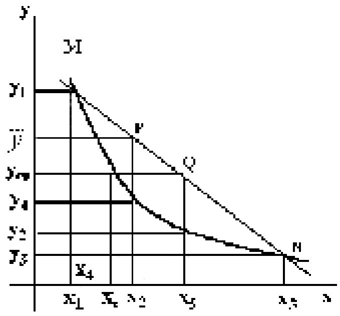


**Fig. 5-b**

The curve is below a straight line, passing through extreme points M($x_1$,$y_1$) and M($x_3$,$y_3$), i.e. if to define the ordinate of point "P" on a straight line MN,

$$\tilde{y}=\frac{(x_2-x_1)(y_3-y_1)}{x_3-x_1}=y_1$$

Then we have $\tilde{y}>y_2$. Simultaneously $y_1>y_3$, therefore $x_c$ is more to the left of $x_5$, where $x_5=\dfrac{x_1+x_3}{2}$ and is the abscissa of an average point Q of segment MN.

Let's give to the value of $x_1$ a symbol $x_4$. For the first approach of $x'_c$ for the values of $x_c$, we shall accept

$$x'_c = \frac{x_4 + x_5}{2}$$

By formulas ($7_1$), ($7_2$), (10) we shall determine constants a, k, b. Calculate ordinate $y_4$ of the point laying on received curve and having abscissa [$_2$, that is

$$y_4 = a + k\ln|\Pi_2 - b|$$

If $y_4>y_2$ (fig. 5a), we shall accept $x'_c$ for $x_5$ and we shall repeat the algorithm. If $y_4>y_2$ (fig. 5b), we shall accept $x'_c$ for $x_4$ and we shall repeat the algorithm.

The coefficients a,k,b of function (8), describing a curve passing through points ($x_1$= $y_1$)= ($x_2$= $y_2$) and ($x_3$= $y_3$)= are determined, then we shall receive $y_4$=$y_2$.

The similar algorithms are applied and in a case of curves, given in fig.2-4 only with that difference, that since in case of a curve given in fig.6 we have $\tilde{y} < y_2$ and $y_1$<$y_3$= then we shall accept

$$x_4 = \frac{x_1 + x_3}{2} \text{ and } \overline{x_5} = x_1.$$

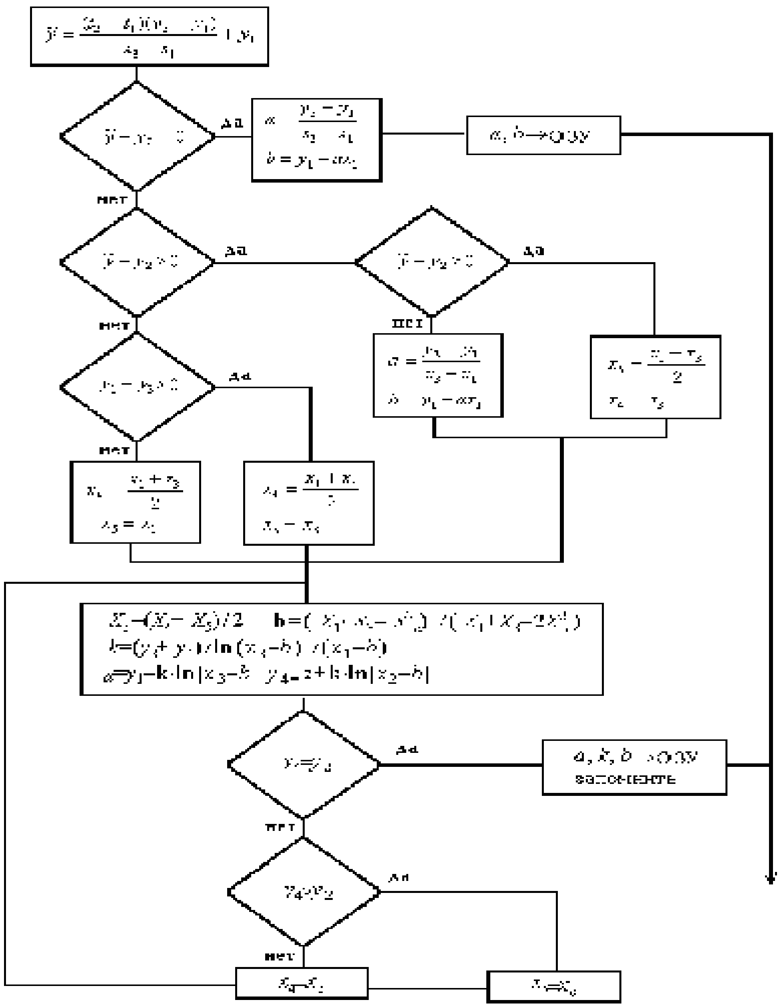

Fig. 6

Since in case of a curve given in fig. 7, we have $\tilde{y} > y_2$ and $y_1<y_3$, (fig. 6), then we shall accept $x_4$.

$$x_4 = \frac{x_1 + x_3}{2} \quad \text{and} \quad x_5 = x_3$$

Since in case of a curve given in fig. 2, 3, 4, we have $\tilde{y} > y_2$ and $y_1<y_3$ then we shall accept

$$x_5 = \frac{x_1 + x_3}{2} \quad \text{and} \quad x_4 = x_3$$

For general consideration it is necessary to provide a case, when $\tilde{y} = y_2$, in this case curve is described by linear function,

$$y=ax+b$$

where "a" and "b" are determined by formula:

$$a = \frac{y_3 - y_1}{x_3 - x_1} = \quad b=y_1-a \cdot x_1$$

In fig. 9 the algorithm of definition of coefficients and ordinate of a point laying on approximating curve, appropriate to given "x" is given.
It is necessary to note, that calibration curve can be described by the exponential function of a kind

$$y=b+p \cdot e^{q \cdot \chi} \qquad (1')$$

where b, p, q) - constant. If we shall take 3 points ($\chi_1$; $y_1$), ($\chi_2$;), ($\chi_3$; $y_3$), similarly we shall receive for " q ".

$$q=(1/(\chi_1-\chi_2)) \cdot \ln(y_2- y_1)/ (y_3; y_2)$$

for p; $$p= (y_2- y_1)/ (e^{q\chi}{}_1- e^{q\chi}{}_2)$$

for b; $$b= y_1 - p \cdot e^{q.\chi}{}_1$$

The accuracy of definition of humidity is checked up by both dependences experimentally and is received, that exacter estimation is given by dependence (1).On this the decision on use of logarithmic function in infra-red analyzers of humidity was accepted.

**Results of investigation.** The developed method is tested at definition of humidity of antibiotics, paper, vitamin powder mixes, synthetic fiber, plaster, alumina, dolomite, wood sawdust, wood shaving, plywood, lime, potassium fertilizers, kaolin, cardboard, starch, dairy powder, detergent powder, cooking salt, wheaten flour, cement, tea, and many others friable, firm and liquid materials.

## 3. Conclusions

As it is shown in results it is necessary to note, that calibrating characteristics "a", "k", "b" for different materials have different values. Proceeding from a variety of materials for their definition it is required numerous and labor-consuming experiments on samples with different humidity in a different range of measurement. The difficulty of experiment consists in preparation of numerous samples with different humidity and performance numerous measurement in the given range, registration and data processing. Use of the offered method at application of computer facilities considerably simplifies process of approximation and reduces a cycle of experimental research.

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**რეზიუმე**

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## МЕТОД АПРОКСИМАЦИИ КРИВОЙ „ВЛАЖНОСТЬ-ОПТИЧЕСКИЙ ПОКАЗАТЕЛЬ" И АЛГОРИТМ ОПРЕДЕЛЕНИЯ ГРАДУИРОВОЧНЫХ ХАРАКТЕРИСТИК


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**Резюме**

Анализ метрологических свойств инфракрасных влагомеров показывает, что существенная доля ошибки измерения приходится на степень точности аппроксимации кривой „влажность-оптический показатель", обусловленной сложностью подготовки большого количества образцов с заданной влажностью в заданном диапазоне. Для устранения указанного фактора погрешности предложен метод аппроксимации кривой „влажность-оптический показатель“ посредством трех образцов с влажностью, соответствующей минимальному, максимальному и среднему значению некоторого диапазона измерения. Данный метод реализован, как униффицированное методическое средство и используется в ПОК ИК влагометрии для проведения экспериментальных исследовании.