than the effective pore radius R_e, the penetrant is not fully absorbed by the developer, and than there exists a minimal residual depth of filling of the flaw with penetrant characterized by the value of n at which detection of the flaw is possible.

NOTATION

h, thickness of the powder layer; σ and μ, surface tension and coefficient of viscosity of the indicator liquid, respectively; θ and θ_1, contact wetting angle of the inspected surface and of the powder particles, respectively, by the penetrant; H, width of opening of the crack; R, radius of the cylindrical flaw; l_0, depth of the flaw; p_a, atmospheric pressure; R_{po}, mean pore radius of the powder; $R_e = R_{po}/\cos\theta_1$, effective pore radius; D_p, mean particle size of the powder; W, minimal with of the "trace" of a crack made visible; D, minimal diameter of the "trace" of a cylindrical flaw made visible.

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THE ACCURACY CHARACTERISTICS OF A THERMOREFRACTOMETRIC GAS ANALYZER

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Models have been constructed reflecting the dependence of the measurement error on gas analyzer parameters. The effects of each of the factors on the error measurements have been examined.

Recent researches in gas analysis have led to some novel methods based on fundamental results obtained for example in solid-state physics, optics, hydrodynamics, and heat transfer. These include the gradient-refractometric method of analyzing gas mixtures [1].

A thermorefractometric gas analyzer is one form of implementation for this method [2], but an examination of this instrument would be incomplete without an analysis of the accuracy characteristics. Separate analysis of the effects from each of the working parameters on the error of measurement has been based on experiment planning [3]. The instrument is considered as a multiparameter system, whose output (here the error of measurement) is dependent in a random fashion on the input parameters: cell wall temperature, gas mixture flow, temperature gradient in cell walls, cell length, and test component concentration. Most of the input parameters are working ones, i.e., they determine the mode of operation.

Models were constructed from experiment plans of Hartley type for five factors and Box type for four. The gas mixtures were nitrogen + nitrous oxide and nitrogen + carbon dioxide. For the first of these mixtures, experiment gave the following model relating the measurement error to each of the five factors:

$$S_1 = 3{,}6 - 0{,}5x_1 + 0{,}9x_3 + 0{,}5x_4 + 0{,}6x_5 + 0{,}9x_3^2 - 0{,}5x_1x_3 - x_2x_3 - 0{,}5x_1x_4 + x_2x_4 - 0{,}8x_1x_5 + 0{,}5x_4x_5. \quad (1)$$

This shows that the most marked dependence, which is also nonlinear, occurs between the temperature gradient along the cell and the error. More detailed analysis is best based on a graphical representation. We reduce the dimensions by fixing one of the factors such as the cell length at the zero level. We then substitute into the initial model for the values of the third factor at the upper and lower levels and at the central point of the plan, which

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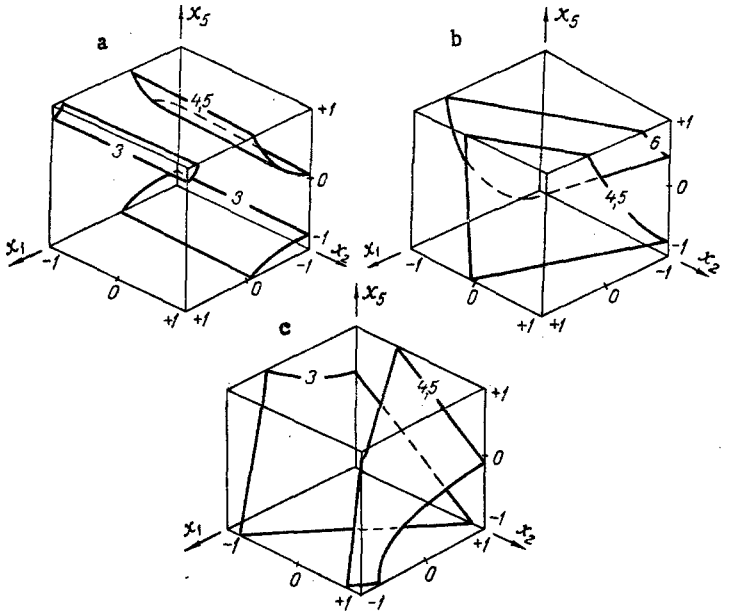

Fig. 1. Projections of the error isosurfaces on the factor space x_1, x_2, and x_5 (for $x_4 = 0$): a) $x_3 = 0$; b) $x_3 = +1$; c) $x_3 = -1$.

gives us three three-dimensional models, which are shown in Fig. 1 in projection for three values of the error. It is clear that the measurement error is dependent mainly on the test concentration in the absence of a temperature gradient along the cell, being only slightly dependent on the flow rate. When there is a gradient, the measurement error is reduced if the direction of it in the cell walls coincides with the flow direction for the gas mixture.

The error is dependent not only on the component proportions but also on the characteristics of the individual components; the latter was illustrated from models describing the error as a function of the four working factors for the two gas mixtures above:

$$S_1 = 6{,}3 - 0{,}8x_1 - 0{,}8x_2 - 0{,}2x_3 - 2{,}2x_2^2 + 0{,}4x_1x_2 + 0{,}6x_2x_3 - 0{,}5x_2x_4, \quad (2)$$

$$S_2 = 4{,}7 - 0{,}8x_2 - 1{,}6x_2^2 + 2{,}1x_3^2 + 0{,}8x_1x_3 + 0{,}8x_3x_4. \quad (3)$$

The models imply that the maximum possible error for the second mixture is less by almost a factor 1.5 than that for first, so there are optimal gas pairs for this type of analyzer as regards minimizing the error.

In testing the method, we incorporated as far as possible all the factors that may influence the accuracy and error; to exclude effects from unmonitored factors, the sequence was randomized. The error level was dependent on the factor levels and varied over the range 2.5-14%.

NOTATION

x_i, normalized dimensionless factor values; x_1, heating temperature of vessel walls; x_2, gas flow rate; x_3, temperature gradient in vessel walls; x_4, vessel length; x_5, concentration of gas component; S_1, mean square error for nitrogen-nitrous oxide; S_2, mean-square error for nitrogen–carbon dioxide.

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