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QUALITIES OF PRODUCTS OF BTS TRANSFORMER OIL DECOMPOSITION BY ELECTRIC ARC WITHIN TEMPERATURES OF 4000—20000 K[1])

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This paper follows up a previous publication [2] and deals with data of chemical composition of the BTS transformer oil products decomposition by electric arc within the range of temperatures $(4—20) \times 10^3$ K and their thermodynamical qualities.

СВОЙСТВА ПРОДУКТОВ РАЗЛОЖЕНИЯ ТРАНСФОРМАТОРНОГО МАСЛА BTS ЭЛЕКТРИЧЕСКОЙ ДУГОЙ В ИНТЕРВАЛЕ ТЕМПЕРАТУР 4000—20000 K

Данная работа, которая непосредственно связана с ранее опубликованной статьей [2], содержит данные о химическом составе и термодинамических свойствах продуктов разложения трансформаторного масла BTS электрической дугой в интервале температур 4000—20000 K.

I. INTRODUCTION

Calculation of the chemical composition and the thermodynamical qualities of products of the BTS transformer oil decomposition by electric arc represents the principal data for the determination of the transport properties of the gas mixture producd. In their complex these data represent a basis for evaluating the extinction properties of mineral oil, which has been successfully used in the construction of hv and uhv circuit breakers.

II. CALCULATION OF THE SYSTEM CHEMICAL COMPOSITION

The principal data of the calculation of the C—H—S—O—N system are mentioned in [2]. The particularity of the solution of this problem consisted in selecting the system components and assembling the constitutional matrices for

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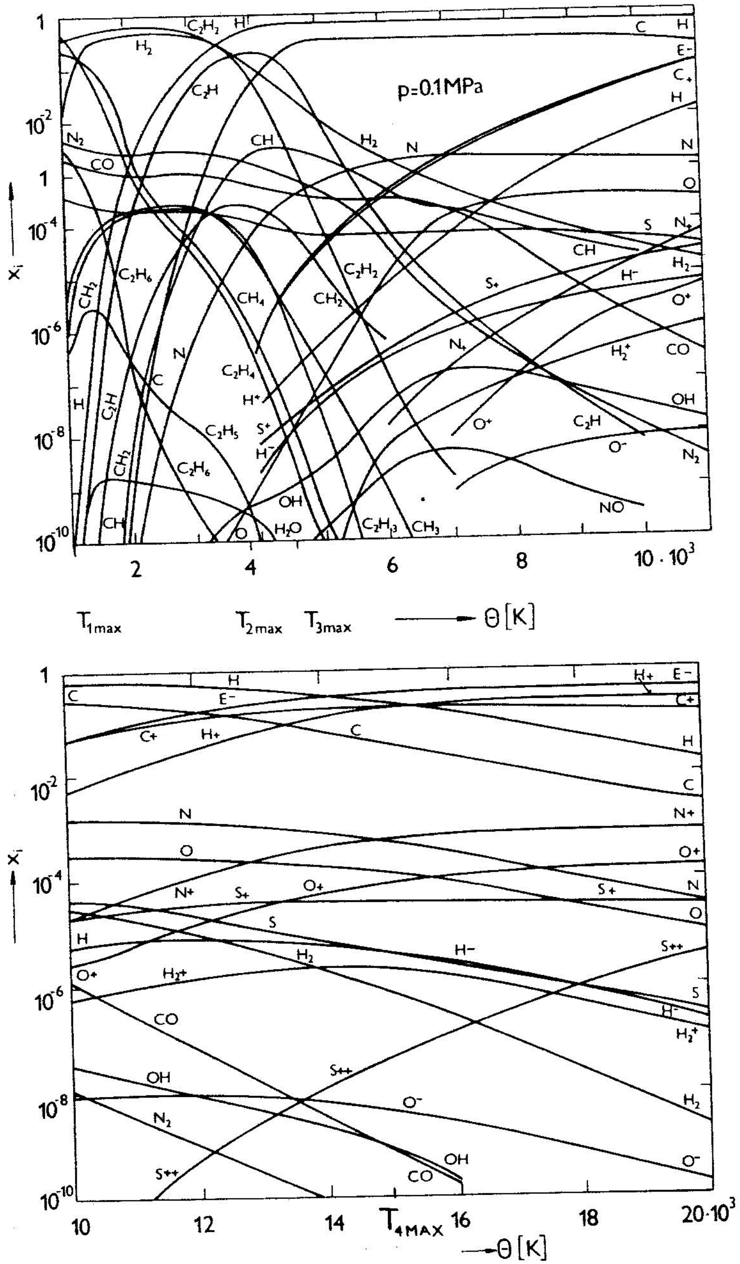

Fig. 1.

various temperature ranges. When starting to solve the system one could consider all constituents which are decisive for the chemical composition and other properties of the mixture. Neverheless, the total sum of all constituents (compounds) considered has, at the same time, an influence upon the size of the given task and upon the great demands upon its solution. The more intricate compounds of carbon and hydrogen have been of use to a greater extent at lower temperatures in the composition of products of the BTS transfomer oil decomposition by electric arc. For temperatures of 4000 and 5000 K the system has been described by $N = 37$ constituents, the constituents CH_4, CH_3, CH_2, C_2H_6, C_2H_5, C_2H_4, C_2H_3 and SO ($N = 29$) were left out of this system and further constituents CH, C_2H_2, C_2H, CO_2 and OH (−), i. e. $N = 24$ were omitted, too, for temperatures of 10 000 to 20 000 K. Fig 1 represents the calculation results for the pressure of 0.1 MPa, where, for better illustration, the temperature range of 1000—4000 K calculated with more precise input data, is represented, too. In the main, the calculations for the given temperature range were elaborated for the pressure of 0.1—3 MPa and it can be claimed that the decomposition rate drops with increasing pressure.

III. DETERMINATION OF MIXTURE THERMODYNAMICAL QUALITIES

For the determination of thermodynamical qualities of products of the BTS transformer oil decomposition the methods in [1] have been applied under the same assumptions as in [2].

The calculation results are represented in Figs.2 and 3. Fig. 2 represents the dependence of specific enthalpy h, specific weight and molar weight M_{sm} upon temperature. The course of molar weight of the system characterizes its stability. A steep linear drop within the range of 1000—2000 K indicated a quick decomposition of molecular compounds to simpler ones (e. g. C_2H_4, $C_2H_2 + H_2$). Slowing down the drop at temperatures of 2000—3000 K expresses the stability of the whole system given by a high content of C_2H_2 and H_2 (97 % approximately). A further increase of temperature up to 5000 K leads to the occurrence of atomary components of hydrogen and carbon shich make 98 % of the mixture at 5000 K. A further rising of temperature leads to ionization processes. Apart from main atomary constituents in the system electrons and ions C^+ appear, the representation of which through 10 000 K is 10 % only, which means that the system is stable up to this temperature. Only a further rise of temperature leads to the ionization of hydrogen atoms and from $T = 15\,000$ K the constituents E^-, H^+ and C^+ become the main constituents and the system is stabilizing again. On the dependence of the system stability even the character of the dependence of changes of specific enthalpy determined when specifying equilibrious specific heat C_{pe}, the temperature dependence of which together with dependences of sound speed a_f and specific heat C_{pf} are represented in Fig. 3.

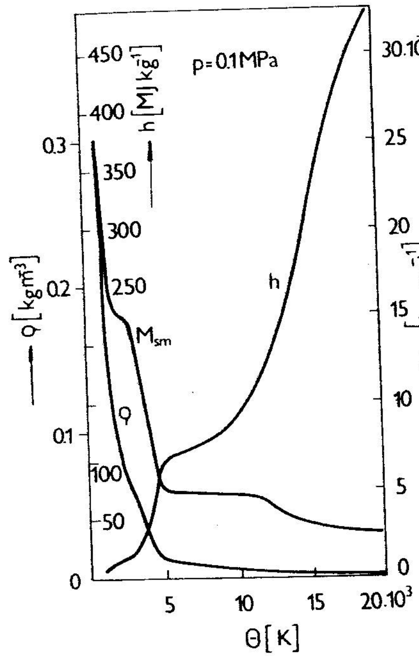

Fig. 2.

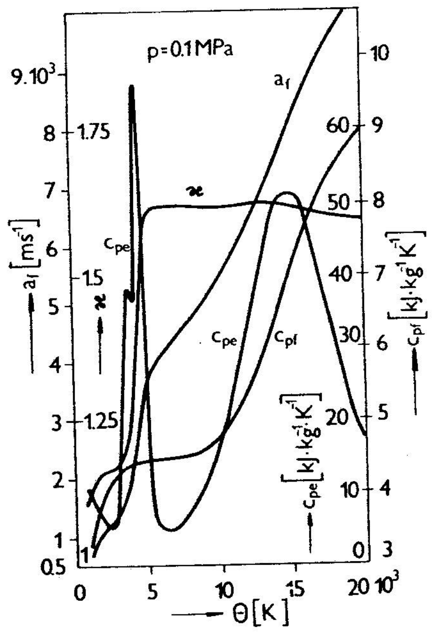

Fig. 3.

Specific equilibrium heat C_{pe} has been determined by graphical derivation of temperature dependence of the specific entalpy. With respect to the temperature step selected for calculation of the composition and thermodynamical qualities the accuracy of determination of C_{pe} is within the following values: ± 0.2 kJ^{-1} K^{-1} ($T = 1000$ to 1600 K), $\Delta T = 100$ K), ± 1 kJ kg^{-1} K^{-1} ($T = 1600 - 4000$ K, $\Delta T =$ 200 K) and ± 0.5 kJ kg^{-1} K^{-1} ($T = 4000$ to 20000 K, $\Delta T = 1000$ K). Characteristic maximum values of $C_{pe} = f(T)$ with p = 0.1 MPa can be found at following temperatures: $T_{1\,max} \approx 1000$ K (dissociation C_2H_4), $T_{2\,max} \approx 3800$ K (dissociation C_2H_2 and H_2), $T_{3\,max} \approx 4500$ K (dissociation C_2H, H_2 and C_2H_2), $T_{4\,max} \approx 15000$ K (ionization of atoms C and H).

Dissociation and ionization, if any, of further components do not influence the temperature difference C_{pe} because of their low representation in the system. With increasing pressure the values of T_{max} tend to shift towards higher values.

Relative stability of the system within the range of temperatures of 500 to 2000 K leads to a nearly linear dependence of sound speed a_f. The delay of frozen specific heat C_{pf} with temperatures of 5000 to 9000 K is caused by the constant atomary components H and C.

IV. CONCLUSION

The calculation carried out which is the input data for the following calculation of transport properties indicates that, within temperatures of 3800 to 4500 K even an extreme value of thermal conductivity will appear with negligible electrical conductivity. This fact unknown so far opens new vistas for the transformer oil as extinction medium for HV and UHV circuit breakers.

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