

**UNCLASSIFIED**

---

---

**AD 287 680**

*Reproduced  
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY  
ARLINGTON HALL STATION  
ARLINGTON 12, VIRGINIA**



---

---

**UNCLASSIFIED**

**NOTICE:** When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

62-1037

287 680

REGULARITIES OBSERVED IN MIXTURES OF LIQUID  
FUEL DURING IGNITION

By

V. I. Blinov

# UNEDITED ROUGH DRAFT TRANSLATION

## REGULARITIES OBSERVED IN MIXTURES OF LIQUID FUEL DURING IGNITION

By: V. I. Blinov

English Pages: 6

Source: Inzhenerno-Fizicheskiy Zhurnal, Vol. 4,  
No. 2, 1961, pp. 95-98

SC-1400  
SOV/170-61-4-2-10/18

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.

PREPARED BY:

TRANSLATION SERVICES BRANCH  
FOREIGN TECHNOLOGY DIVISION  
WP-APB, ONO.

REGULARITIES OBSERVED IN MIXTURES OF LIQUID  
FUEL DURING IGNITION

V. I. Blinov

1. The ignition temperature of a liquid is the lowest temperature for this liquid at which the emergent flame will not be extinguished.

We showed [1] that in the case of the ignition of individual liquids in a cylindrical tube

$$p = p_0(1 - e^{-bh}), \quad (1)$$

where  $p$  is the saturated-vapor pressure at ignition temperature;  $p_0$  is the atmospheric pressure;  $h$  is the distance of the surface of the liquid from the edge of the tube;

$b = 7.5 \cdot 10^4 M_0 R / p_0^3 D_0 T_1$ ;  $D_0$  is the diffusivity of vapor at  $0^\circ\text{C}$ ;  $T_1$  is the ignition temperature in  $^\circ\text{K}$ ;  $\beta$  is the number of moles of oxygen required for the combustion of one mole of vapor;  $M_0$  is the number of moles of oxygen entering the flame in 1 sec;  $R$  is the universal gas constant.

P. G. Ipatov showed [2] that relation (1) holds true for binary mixtures of liquids if we put

$$D_0 = D_{10} y_1 + D_{20} y_2; \quad \beta = \beta_1 y_1 + \beta_2 y_2, \quad (2)$$

where  $y_1$  and  $y_2$  are the mole fractions in the vapor phase of the mixture components.

P. G. Ipatov found the empirical dependences of the ignition temperature on the composition of ideal and nonideal binary mixtures of liquid, but did not explain

these dependences. In this paper, we attempt to explain the basic regularities in  
FIRST LINE OF TEXT  
the variation of the ignition temperature with variation in the composition of  
mixtures of liquid fuels.

2. It follows from (1) that the ignition temperature of a specific liquid and  
of mixtures of liquids is equal to the temperature at which the saturated vapor  
pressure  $p$  is equal to  $1 - \exp(-bh)$ .

Since the value of  $M_0$  may be considered the same for various materials, given an  
invariable radius of the tube and an invariable concentration of oxygen in the  
atmosphere, when  $p_0 = \text{const}$  for mixtures of liquids, the ignition temperatures of  
which do not greatly differ, we may assume that

$$b_0 = 7.5 \cdot 10^4 M_0 R / p_0 T_1 = \text{const.}$$

then

$$b = b_0 / D_0 \beta. \quad (3)$$

If  $D_0 \beta$  changes slightly with a change in the composition of the mixtures, then  
at the given value of  $h$  for a mixture of the given two components  $p \approx \text{const}$ . In this  
case the dependence of the ignition temperature  $\vartheta_1$  ( $^{\circ}\text{C}$ ) on the composition of the  
liquid and the vapor phase is graphically represented by curves which coincide with  
the curves which give the relation between the boiling temperature  $\vartheta_b$  and the com-  
position of the phases at constant pressure, determined by relation (1).

It is clear that the curves of  $\vartheta_1(x)$  and  $\vartheta_1(y)$ \* when  $h$  is variable will differ  
from  $\vartheta_b(x)$  and  $\vartheta_b(y)$  at constant pressure, but the character of the curves  $\vartheta_1$  and  
 $\vartheta_b$  will be the same. Thus, in the case of nonideal mixtures, with a maximum on  
the pressure curve there should be a minimum on curves  $\vartheta_1(x)$  and  $\vartheta_1(y)$ , while the  
ignition temperature of the mixtures is lower than the ignition temperature of the  
mixture components. These curves were obtained by P. G. Ipatov in a study of the

---

\*  $x$  and  $y$  are the mole fractions of a component in solution and in the vapor  
phase.

following mixtures: ethanol + benzene (see Fig. 1), ethanol + toluene, methanol + benzene.

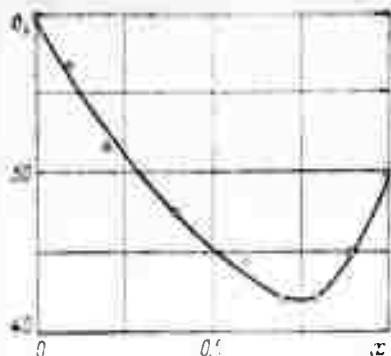


Fig. 1. The dependence of the ignition temperature on the composition of mixtures of ethanol and benzene.

For mixtures with a minimum on the pressure curves, the dependence of  $\theta_1$  on  $x$  and  $y$  should be represented by curves with maxima. The addition of one component to another in this case should lead to the formation of mixtures, the ignition temperatures of which are higher than  $\theta_1$  of the pure components. The minima and maxima on the ignition curves should correspond to the azeotropic measures.

In those cases where the mixtures are ideal or close to ideal, the dependences  $\theta_1(x)$  and  $\theta_1(y)$  should be represented by monotonic curves close to the corresponding boiling curves, which is also confirmed in the work of Ipatov [2].

In the work of Ipatov [2] it was found that for ideal mixtures of toluene and benzene,  $\theta_1(y)$  is represented by a straight line. This is easy to explain in the following way. For ideal mixtures

$$p = p_{10} + (p_{20} - p_{10})x_2, \quad x_2 = \frac{a' p_2}{1 + (a' - 1)y_2}, \quad a' = \frac{p_{10}}{p_{20}} \quad (4)$$

where  $p_{10}$  and  $p_{20}$  are the saturated vapor pressures of the pure components at the ignition temperature of the mixture;  $x_2$  and  $y_2$  are the mole fractions of the second component in the solution and in the vapor phase.

If the value of  $p$  for the given mixtures changes only slightly when  $x_2$  changes and if  $a'$  is constant, the pressure  $p$  will be constant for all practical purposes; let us designate this value of  $p$  as  $p'$ . Then from (4) we find that

$$a' p_{20} = p' [1 + (a' - 1)y_2]. \quad (5)$$

Let us now designate the ignition temperatures of the mixture and of the second component as  $T_m$  and  $T_2$  measured in  $^{\circ}\text{K}$ . Let  $T_m - T_2 = \theta$  and  $\theta/T_2 \ll 1$ . Now we may assume that

$$\frac{1}{T_m} = \frac{1}{T_2 \left(1 + \frac{\theta}{T_2}\right)} = \frac{1}{T_2} \left(1 - \frac{\theta}{T_2}\right).$$

Since the saturated vapor pressure is determined by the relation  $p = a e^{-\frac{Q}{RT}}$ , where  $Q$  is the molar heat of vaporization

$$\begin{aligned} p_{20} &= a \exp\left(-\frac{Q}{RT_m}\right) = a \exp\left[-\frac{Q}{RT_2} + \frac{Q}{RT_2^2} \theta\right] = \\ &= p_{20}' \exp\left(\frac{Q}{RT_2^2} \theta\right) = p_{20}' \left(1 + \frac{Q}{RT_2^2} \theta\right), \end{aligned} \quad (6)$$

where  $p_{20}'$  is the saturated vapor pressure of the second component of the mixture at ignition temperature  $T_2$ .

Since the value of  $\alpha'$  changes slightly with temperature, it follows from (5) and (6) that

$$\theta = T_m - T_2 = \vartheta_m - \vartheta_2 = a_1 + a_2 y_2.$$

where  $a_1$  and  $a_2$  are constant;  $\vartheta_m$  and  $\vartheta_2$  are the ignition temperatures of the mixture and the second component.

Taking into consideration the fact that  $\vartheta_m = \vartheta_2$  when  $y_2 = 1$  and  $\vartheta_m = \vartheta_1$  ( $\vartheta_1$  is the ignition temperature of the first component), when  $y_2 = 0$ , we will have

$$\vartheta_m = \vartheta_1 - (\vartheta_1 - \vartheta_2) y_2. \quad (7)$$

Relation (7) agrees with the empirical formula found by P. G. Ipatov.

3. The lowest temperature of a liquid at which its vapor forms with air a mixture which ignites in the presence of an ignition source is called the flash-point of a liquid.

The flash-point  $\vartheta_{f1}$  is closely related to the low concentration limit of the ignition of a mixture of vapor and air. This relation may be determined in the following way. The ignition limit

FIRST LINE OF TEXT

$$k = \frac{V_v}{V_v + V_a} \cdot 100 = \frac{p_v}{p_v + p_a} \cdot 100,$$

where  $V_v$  and  $V_a$  are the volumes and  $p_v$  and  $p_a$  are the partial pressures of vapor and air in a mixture. Since  $p_v + p_a = p_0$ , when  $p_0 = 760$  mm

$$p = 7.6 k. \quad (8)$$

Evidently, in formula (8)  $p$  equals the saturated vapor pressure at the flash point.

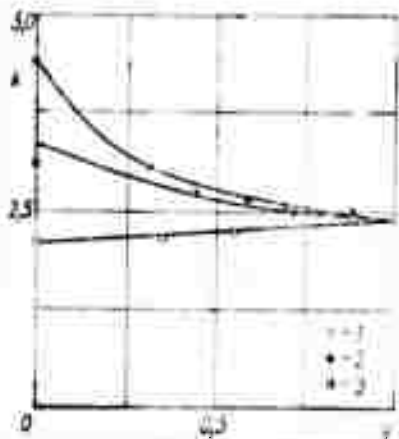


Fig. 2. Dependence of the ignition limit on the composition of the mixtures: 1, 2, and 3 are the results of tests [3] for mixtures, respectively, of benzene with toluene, ethanol with benzene, and acetone with benzene. The solid lines were calculated from formula (10). The value of  $\frac{1}{D}$  is taken as the same for all mixtures; the value  $D$  was calculated from formula (2).  $y$  are the mole fractions of benzene in the vapor phase.

Since the flash point is close to the ignition temperature, we may use the above relations for the determination of the limit of  $k$ . From (1) and (3) when  $\frac{1}{D}$  is constant and the value of  $\frac{1}{D}$  is small

$$p = p_0 \frac{1}{D} = A/D_0^3. \quad (9)$$

Bearing in mind the fact that the values of  $p$  in relations (8) and (9) are similar, we may write

$$k = B/D^3, \quad B = \text{const.} \quad (10)$$

It can be seen from Fig. 2 that formula (10) satisfactorily describes the given data.

In conclusion, it should be noted that the ignition limit of mixtures is frequently determined by the Le Châtelier principle. This principle, which is an application of the displacement principle to mixtures of liquid fuels, gives results close to those of the tests in a number of cases. If we use it, we would need six empirical constants for the given data in Fig. 2, while when we use relation (10) we need only one constant determined from experiment.

FIRST LINE OF ...  
1. V. I. Blinov. DAN SSSR, Vol. 52, 9, 1946.

2. P. G. Ipatov. Information Symposium of TANIPO,\* 1952.

3. P. G. Ipatov. Works of the Leningrad Institute of Aviation Instrument Design, No. 7, 1954.

4. Y. Iost. Explosions and Combustion in Gases. Inostrannaya Literatura, Moscow, 1952.

\* Central Fire Protection Scientific Research Institute

Institute of Aviation Instrument Design,  
Leningrad

Submitted July 1, 1960

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE	Nr. Copies	MAJOR AIR COMMANDS	Nr. Copies
		AFSC	
		SCFTR	1
		ARO	1
HEADQUARTERS USAF		ASTIA	10
		TD-B1a	3
AFCIN-3D2	1	TD-B1b	3
		SSD (SSF)	2
		BSD (BSF)	1
		AFFTC (FTY)	1
OTHER AGENCIES			
CIA	1		
NSA	2		
AID	2		
OTS	2		
ABC	2		
PWS	1		
NASA	1		
RAND	1		

**UNCLASSIFIED**

**UNCLASSIFIED**