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Elementary models of thermal influence of different factors on the rate of layer-by-layer propagation of the front of combustion

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Introduction

New perspectives for development of the physics of combustion of different systems can be related with the ideas of the thermal model of layer-by-layer propagation of the front of exo- and endothermal transformations of reagents [1], beginning in a zone of heating (further named a heat absorption zone **HAZ**) and coming to the end in a reactionary zone (a heat emission zone **HEZ**) with formation of the heated up gaseous and condensed substances (end-products). As one can see in the work [1] the fractional-linear equation, which comes out from this model, has some important advantages over parametric equations obtained on the basis of theoretical ideas of the thermal model of propagation of the wave of an exthotermal reaction. These advantages include extrapolation properties of the equation as well as thr accuracy and completeness of description of the multifactorial experimental laws of propagation of the burning front of any systems. In particular: descriptions of experimental multifactorial laws of speed of flat front exo-and endothermal transformations of reagents into charges condensed substances **CS** with the help of the parametrical fractional-linear equation; revealings of mechanisms of thermal and material interaction on border of unit **HEZ** and **HAZ**; the decision of a task of forecasting of experimental values **RPFC** and its derivatives in the expanded ranges of change of diverse factors; establishments critical values of influencing factors, near to which exists or a limit of going out (the terminations of distribution of front) of combustion of charge **CS** or a limit of transition of burning of a charge in explosion (changes of a stationary mode of distribution of front of burning on accelerated); The analysis of stability stationary **RPFC** in charge **CS** as in the cases connected to joint small indignations of influencing factors, and in case of significant indignation (sharp change) separately taken factor (see Figure 1).

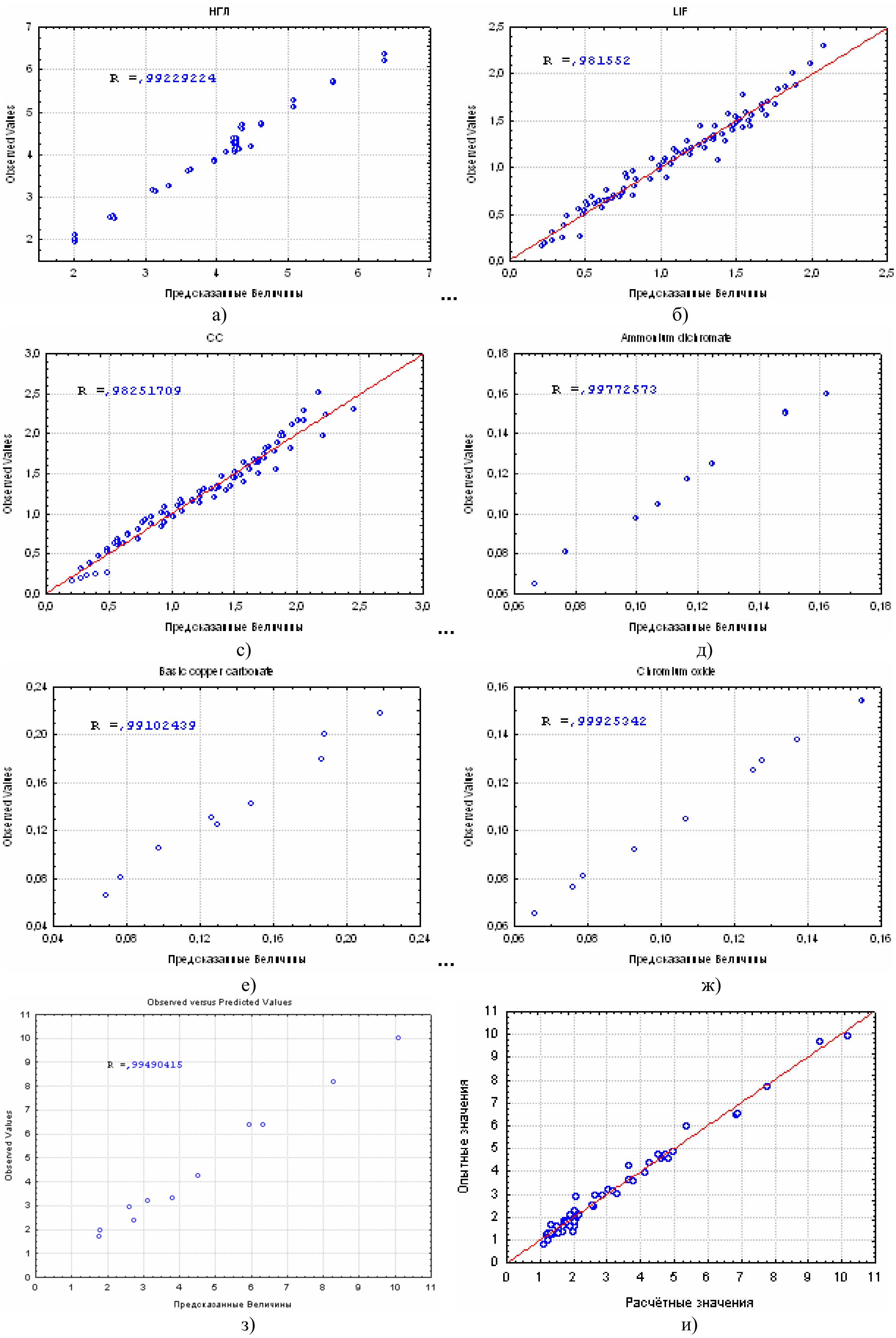
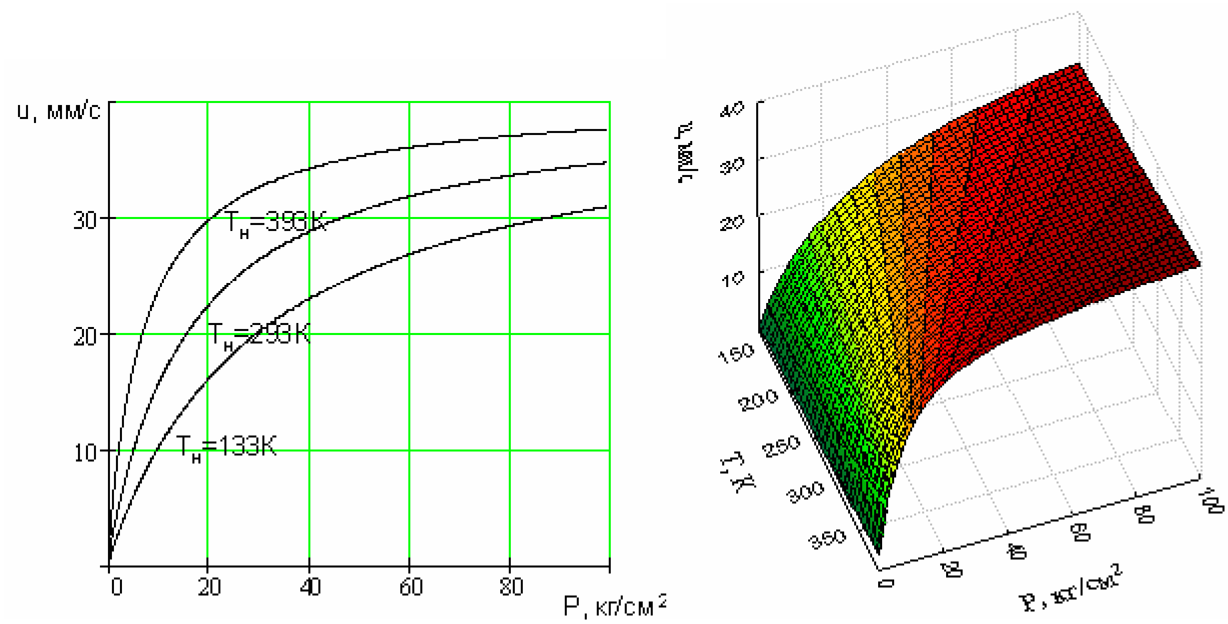


Fig. 1. Correlation of measured and settlement values RPFC for multifactorial dependences: a)-m [h ($\tau_н$), p, d] nitroglycol [3]; б) and c)-u [h ($\tau_н$), p, x, $\xi_к$] CTT [4]; д), e) and ж)-u [h ($\tau_н$), x, ξ] CTT [5]; з)-m (p, ρ_{rw}) mixes $_{0,9W+0,1KClO_4}$ [6]; и)-u ($\tau_н$, p, d, ρ, ρ_{Ta}, ξ) mixture 0,938Ta (2мкм) +0,062C (0,1) + ξTaC [7].

Let's consider opportunities of the description of multifactorial experimental laws of burning rate with the help of the parametrical fractional-linear equation. As an example we shall consider dependence u ($T_н$, p, ρ, x) for mix W+$KClO_4$ [8] which mechanism of burning in opinion of authors is determined by exotermal reaction in condensed phase (HAZ). However at values of parameters a_0=1; a_1=7,219; a_2=-21,952; a_3=169,635, b_0=8,107; b_1=0,179; b_2=-2,232; b_3=16,275 and h($T_н$)=0,016$T_н$, providing a deviation{rejection} of the measured burning rate of charges from calculated with factor of correlation R=0,9968 the mechanism of thermal influence, for example pressure, upon burning rate corresponds to a dominating role exotermal reaction in gas phase (HEZ). In this case experimental dependence u ($T_н$, p) the family of monotonously growing curves u (p), right branches being equal sides hyperboles with negative factor of return characterizes proportionality (fig. 2a).



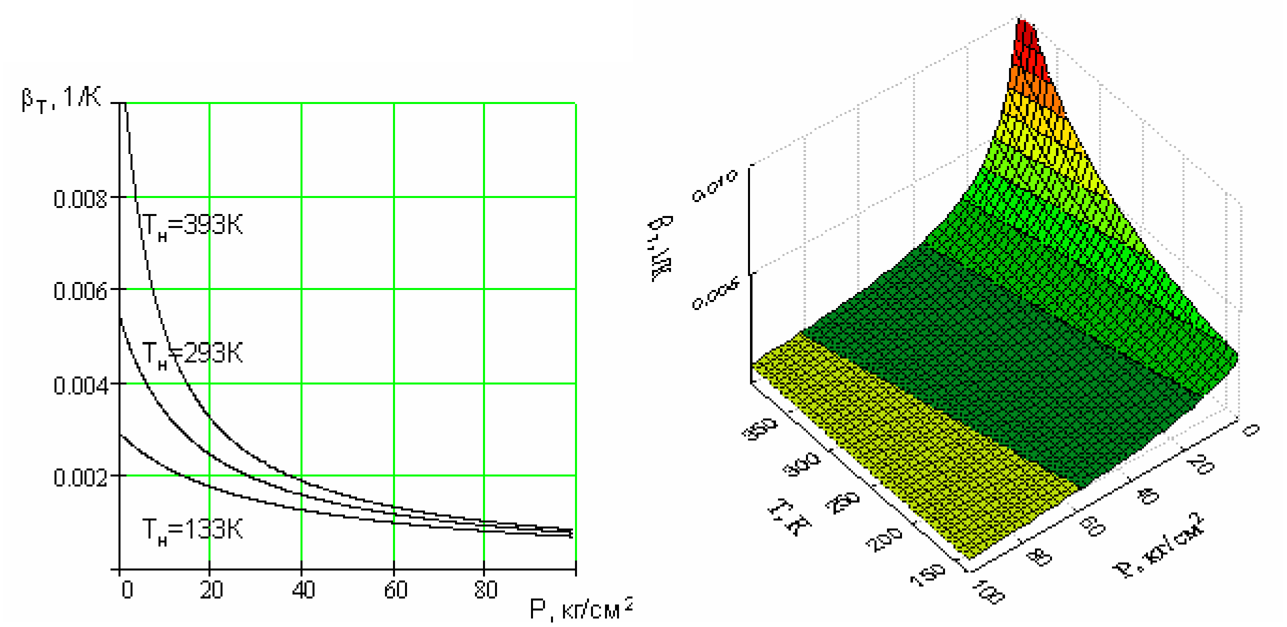
a) б)

Fig. 2. Forecasting of influence of initial temperature of a charge for dependence of burning rate of a mix 0,74W+0,26$KClO_4$ from pressure of nitrogen at d=5мм and ρ =5,59г/sm3 in coordinates: a) - p, u; б) - $T_н$, p, u.

Thus limiting value of burning rate which determines position of the common (not dependent on initial temperature and other influencing factors) асимптоты, is equal 40,305 mm. According to parametrical dependence u ($T_н$, p) with increase in initial temperature burning rate of a mix increases. The image of values of burning rate by set of points in spatial system of coordinates (fig. 2б) gives evident representation about joint influence on burning rate of continuously varying factors.

The dependences shown on fig.2 , as well as the data of the analysis of connection u ($T_н$, p, ρ, x) will well be coordinated to experimental data [8].

From fig.3a it is visible, that dependence β_p($T_н$,p) is characterized by family of monotonously decreasing curves, which are sites of family of the right branches hyperboles with equal sides (with the common horizontal асимптотой, conterminous with an axis of abscissas, and vertical асимптот which position on an axis of abscissas depends on value of initial temperature) with positive factor of return proportionality. At any pressure with increase of initial temperature of value $\beta_p(T_н,p)$ increase. From family of the curves shown on fig.3б, it is visible, that at high initial temperatures ($T_н \approx 393$ K) and low pressure (close to atmospheric) values $\beta_p(T_н,p)$ are accepted with the big values.



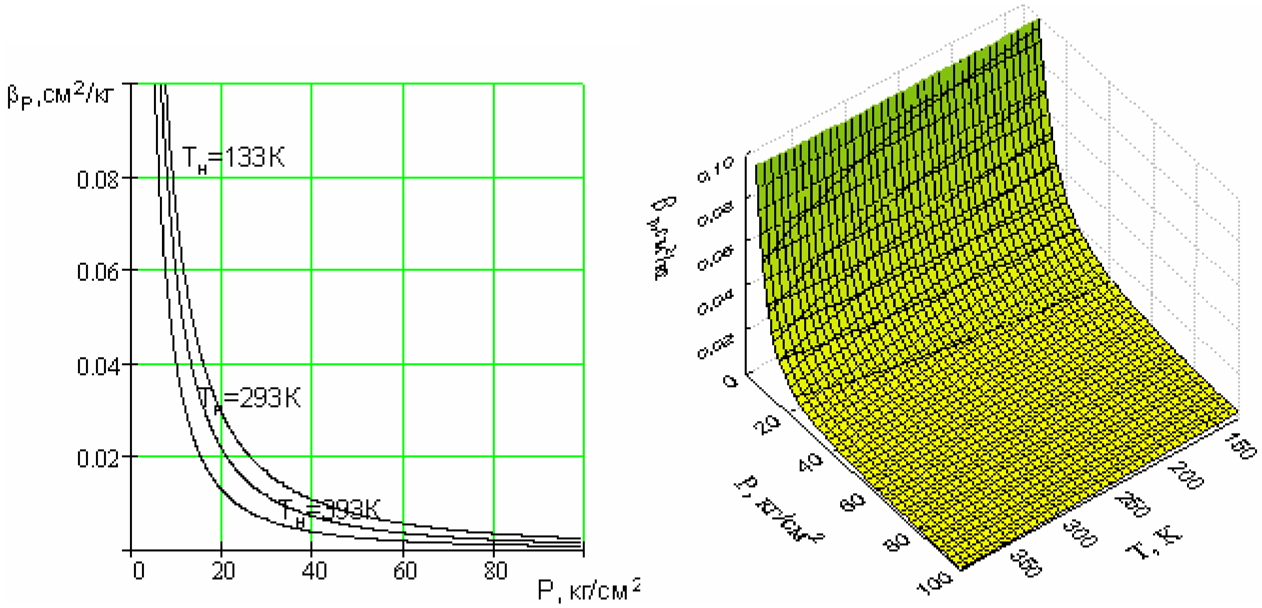
a) б)

Fig. 3. Forecasting of influence of initial temperature of a charge for dependence of temperature factor of burning rate of a mix 0,74W+0,26KClO$_4$ from pressure of nitrogen at d=5мм and ρ =5,59 г/sm3 in coordinates: a) - p, $\beta_T(T_н,p)$; б) - $T_н$, p, $\beta_T(T_н,p)$.

The set of values $\beta_T(T_н,p)$ represented on fig.3 for the investigated range of change of initial temperature $T_н$ and the expanded range of change of pressure ($1 \le p \le 100$ kg/sm^2) testifies, that smaller sensitivity of burning rate joint change of influencing factors corresponds to low initial temperature ($T_н$=133 K) and to high value of pressure (p=100 kg / sm^2), and high $T_н$=393K and p=100 kg / sm^2.

Thus it is possible to approve, that in the field of the raised{increased} initial temperatures and the lowered pressure infringement of stationary burning of a charge of the mix, connected with thermal influences, can result in his{its} transition in explosion, and in the field of low initial temperatures and high pressures-к to going out.

From fig.4a it is visible, that with increase of pressure and initial temperature of a charge sensitivity of burning rate to baric influences is reduced. Thus influence of initial temperature on size baric sensitivity of burning rate is connected to negative influence of increase of initial temperature of a charge on baric sensitivity of change enthalpy reagents in HAZ, determined by the equation $\beta_p^h(T_н,p) = -\frac{b_1}{b_0+b_1p-h(T_н)}$.



а) б)

Fig. 4. Forecasting of influence of initial temperature of a charge for dependence baric factor of burning rate of a mix $0,74W+0,26KClO_4$ from pressure of nitrogen at d=5мм and ρ =5,59 г/sm3 in coordinates: а) –p, $\beta_P(T_н,p)$; б) – ($T_н$, p), $\beta_P(T_н,p)$.

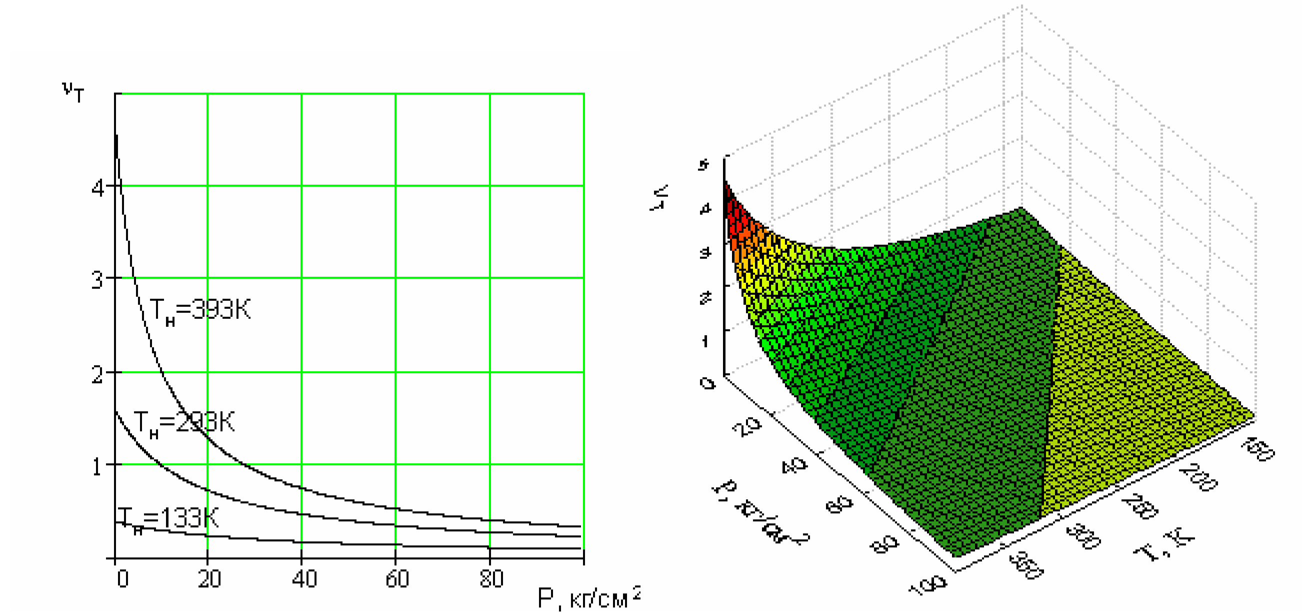
It is necessary to pay attention also, that $\beta_P(T_н,p)$ with increase of pressure the size accepts final values at p=0: at $T_н$=133 K β_P=1,86 sm^2 / kg; at $T_н$=393K β_P 1,76 sm^2 / kg. Insignificant weakening influence of increase of initial temperature on baric sensitivity of burning rate is visible also from fig.4б.

Thus, influence of baric influences on burning rate is limited.

As influence of initial temperature and pressure upon relative factors temperature and baric sensitivity of burning rate CS are determined by connections: $\nu_т(T_н,p)=T_н\beta_т(T_н,p)$ and $\nu_p(T_н,p)=p\beta_p(T_н,p)$ the description of these characteristics family of the curves shown on fig.5а and 6а, and also set of values of relative factorial factors of the speed represented in spatial systems of coordinates on fig.5б and 6б, is excessive.

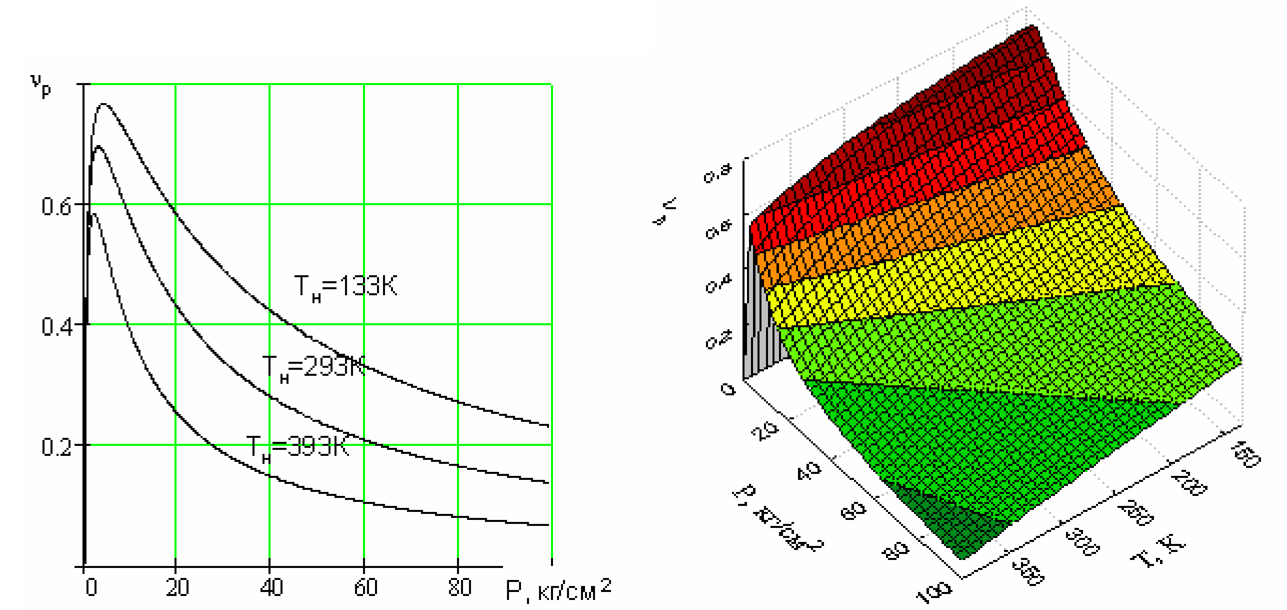
However it is necessary to pay attention to extreme character of dependence эр (T_H, p), having the maximal value ν_{max} dependent on initial temperature. Position ν_{max} corresponds{meets} to size of pressure $p_{\nu max}$, also a charge dependent on initial temperature and calculated under the formula:

$$p_{\nu_{max}} = \sqrt{0,5288(42,8526 - 0,0893T_н)}\,. \qquad (1)$$



а) б)

Fig. 5. Forecasting of influence of initial temperature of a charge for dependence of relative temperature factor of burning rate of a mix $0,74W+0,26KClO_4$ from pressure of nitrogen at d=5мм and ρ =5,59 г/sm3 in coordinates: а) – p, $\nu_т(T_н,p)$; б) – ($T_н$, p), $\nu_т(T_н,p)$.



а) б)

Fig. 6. Forecasting of influence of initial temperature of a charge for dependence relative baric factor of burning rate of a mix $0,74W+0,26KClO_4$ from pressure of nitrogen at d=5мм and ρ =5,59 г/sm3 in coordinates:
а) – p, $\nu_p(T_н,p)$; б) – ($T_н$, p), $\nu_p(T_н,p)$.

From it is visible, that with increase in initial temperature of a charge position ν_{max} is displaced aside the lowered values pressure (fig. 6a); value ν_{max} is simultaneously reduced also.

The analysis of above mentioned analytical dependence $u(T_н,p,\rho,x)$ allows to receive representations about influence on stability of burning rate and other factors. In particular from this dependence follows, that at reduction of density of a mix burning rate of a charge increases, and the temperature factor is reduced; an opportunity of going out of burning of a charge of a mix at atmospheric pressure and room temperature in case of decrease of the contents of tungsten up to x=0,5.

Bases of the common method of forecasting of Stability stationary **RPFC** in charges **CS**

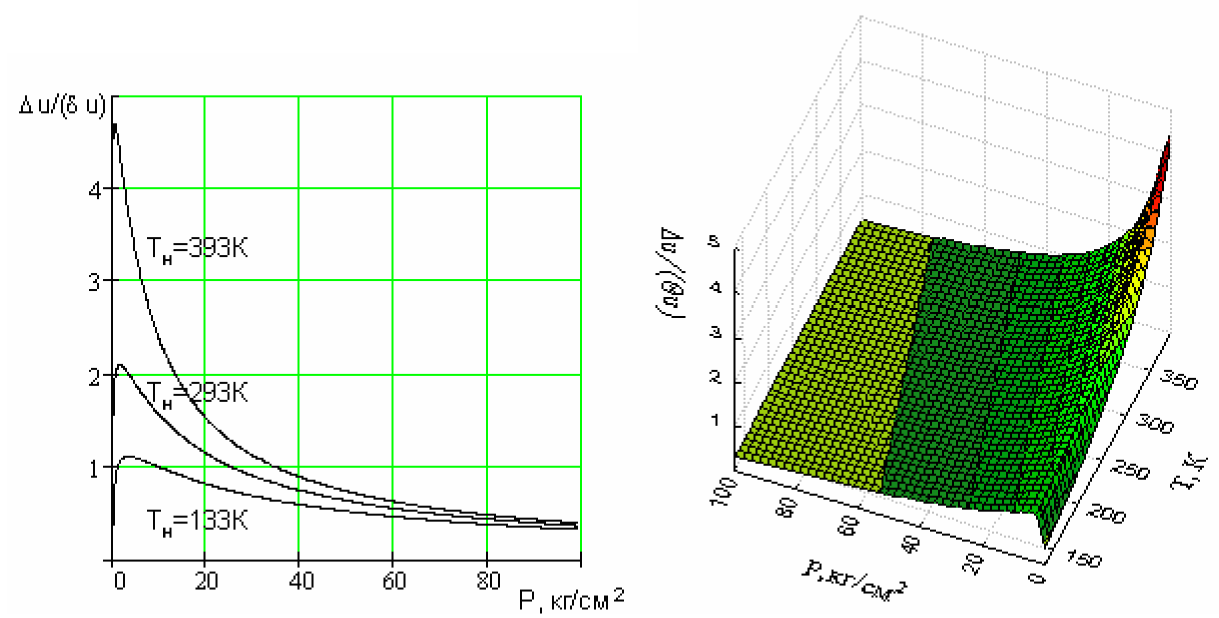
Use of the fractional-linear equation in the decision of fundamental problems{tasks} of stability stationary **RPFC** in charges **CS** opens new ways of increase of reliability of functioning of pyrotechnic means and safety of their application. As a quantitative criterion of stability **RPFC** in physics of burning the size of relative change **RPFC** frequently is accepted. For example, forecasting of going out of burning of charges of gunpowder's, explosives, solid propellants, etc. at reduction of diameter is carried out on size of the attitude{relation} of adiabatic **RPFC** to **RPFC** in a charge (with limiting value of diameter) which is accepted equal $\sqrt{e} \cong 1{,}67$.

The general{common} way of an estimation of stability offered{suggested} here stationary **RPFC** in charges **CS** also is based on values of relative size **RPFC** but which, being dependent on changes of all influencing factors, is determined by the equations (2) and (3). These equations allow to estimate values relative **RPFC** in charges **CS** at anyone (both at small, and at significant) indignations of influencing factors.

For an example we shall consider the elementary case of joint influence of small relative changes of working factors on size of relative change **RPFC**. If we shall take advantage of an assumption about equality of possible relative changes of influencing factors: $\frac{\delta h}{h(T_н)} = \frac{\delta p}{p} = \frac{\delta d}{d} = \frac{\delta \rho}{\rho} = \frac{\delta x}{x} = \frac{\delta \xi}{\xi} = \frac{\delta s_к}{s_к} = \Theta$, where Θ - the characteristic of a possible level of factorial indignations we shall find relative size:

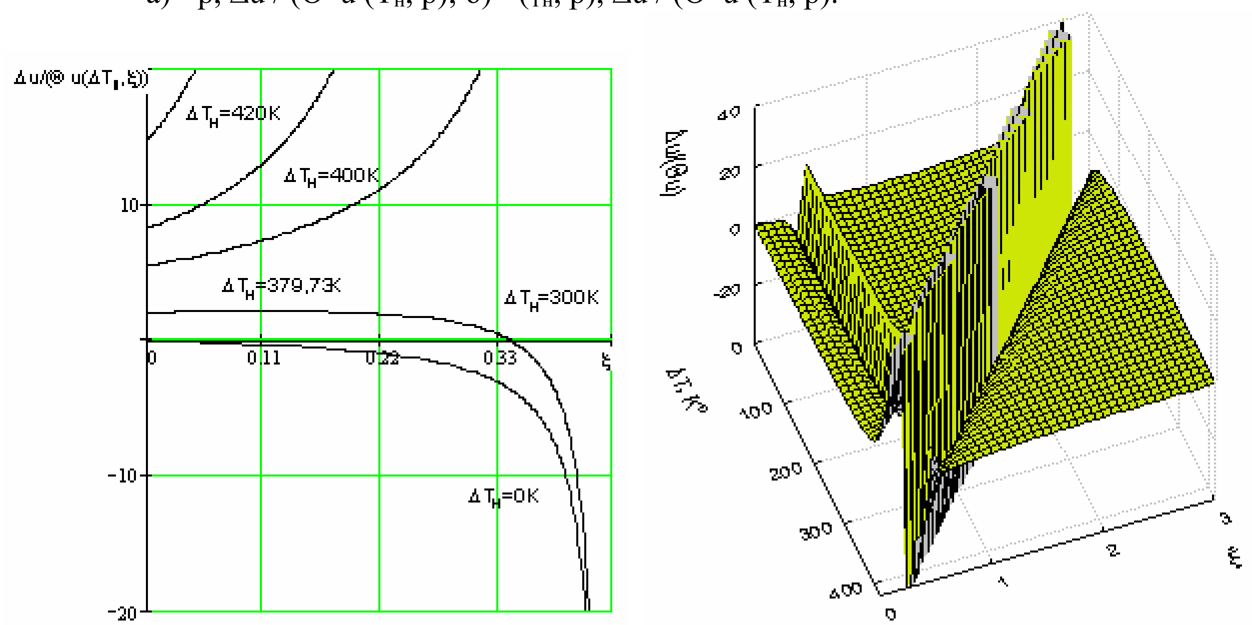
$$\frac{\delta m}{\Theta \cdot m[h(T_н), p, d, \rho, x, \xi, s_к]} = \nu_h + \nu_p + \nu_d + \nu_\rho + \nu_x + \nu_\xi + \nu_{s_к}, \qquad (2)$$

Which is the algebraic sum of dimensionless factorial factors of burning rate and can be accepted as a quantitative measure of stability stationary **RPFC** in a charge. Influence of all set of various factors on stability stationary **RPFC** in examined mixes can be investigated numerical methods. However evident representation about influence of pair combinations of any factors on stability **RPFC** can be received from graphic representations in flat and spatial systems of the coordinates shown for an example on fig. 7-12.



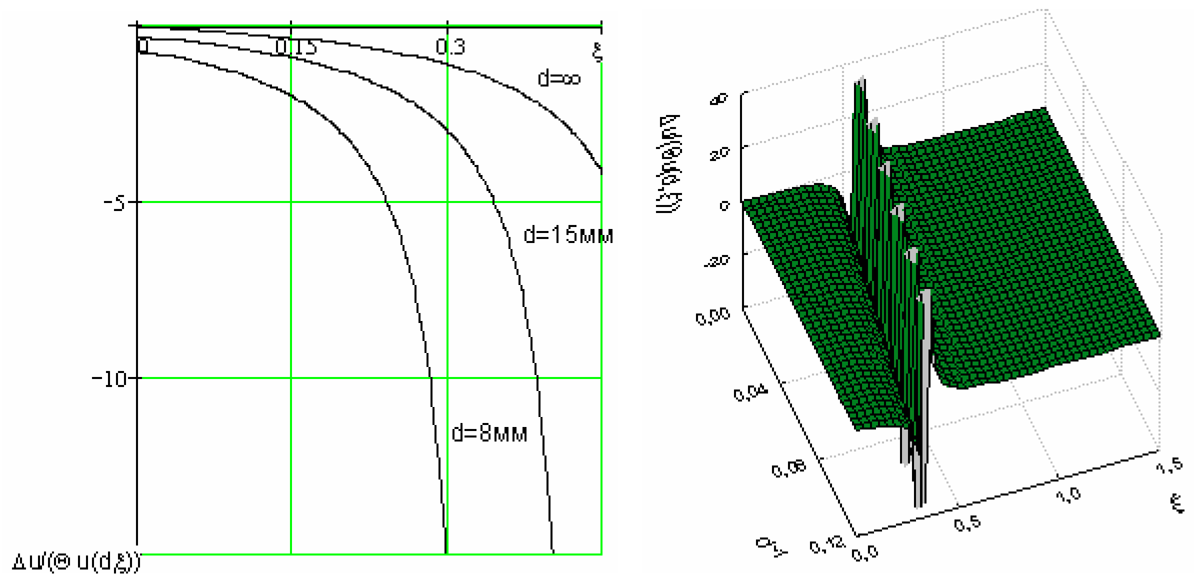
а) б)

Fig. 7. Forecasting of influence of initial temperature of a charge and pressure of nitrogen upon size of stability of burning rate of a mix 0,74 W + 0,26 $KClO_4$ to small indignations Θ at d=5мм and ρ =5,59 г/sm3 in coordinates:
а) - p, Δu / (Θ ·u ($T_н$, p); б) - ($T_н$, p), Δu / (Θ ·u ($T_н$, p).



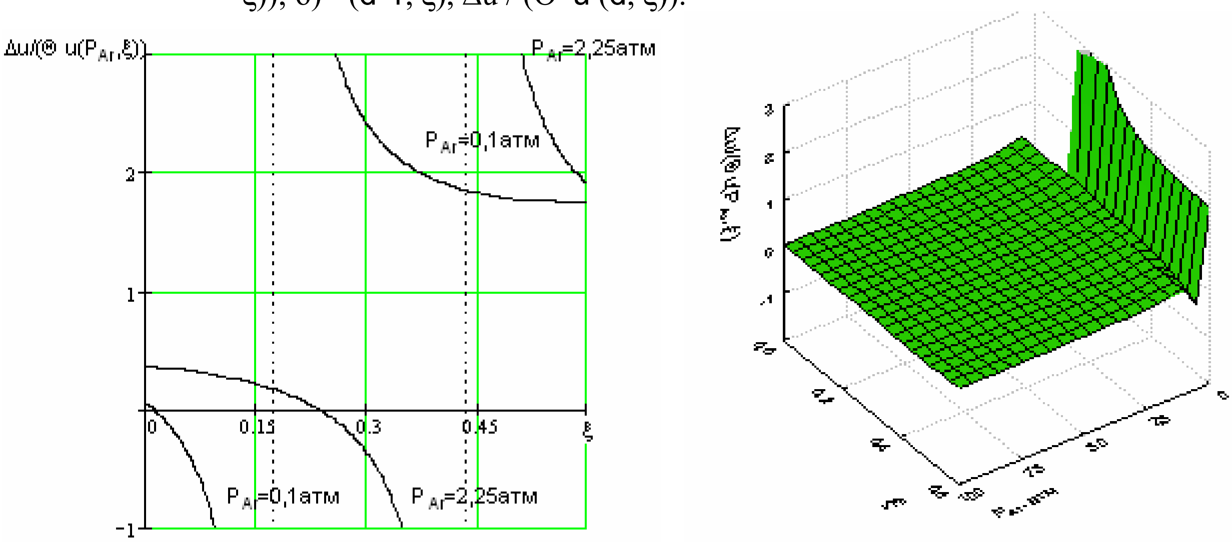
а) б)

Fig. 8. Forecasting of influence of change of initial temperature of a charge for size of stability of dependence of burning rate of a mix 0,938Ta (2мкм) +0,062C (0,1мкм) from the contents of additive to small KT indignations Θ at P_{Ar}=2,25атм, d=15мм, ρ =5,37 g/sm^3 and f=0 in coordinates: а) - ξ, Δu / (Θ· u ($ΔT_н$, ξ)); б) - ($ΔT_н$, ξ), Δu / (Θ u ($ΔT_н$, ξ)).



а) б)

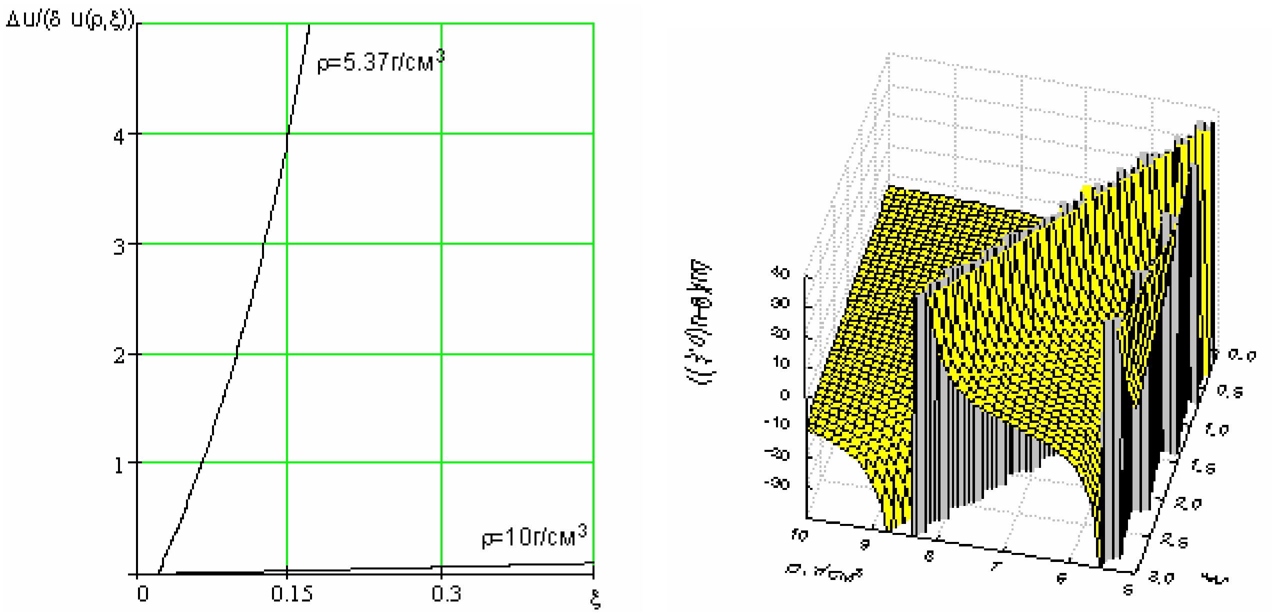
Fig. 9. Forecasting of influence of diameter of a charge on size of stability of dependence of burning rate of a mix 0,938Ta (2мкм) +0,062C (0,1мкм) from the contents of additive KT to small indignations Θ at $\Delta T_н$=0K, p_{Ar}=2,25атм, ρ =5,80 g/sm^3 and f=0 in coordinates: a) - ξ, Δu / (Θδ· u (d, ξ)); б) - (d-1, ξ), Δu / (Θ· u (d, ξ)).



а) б)

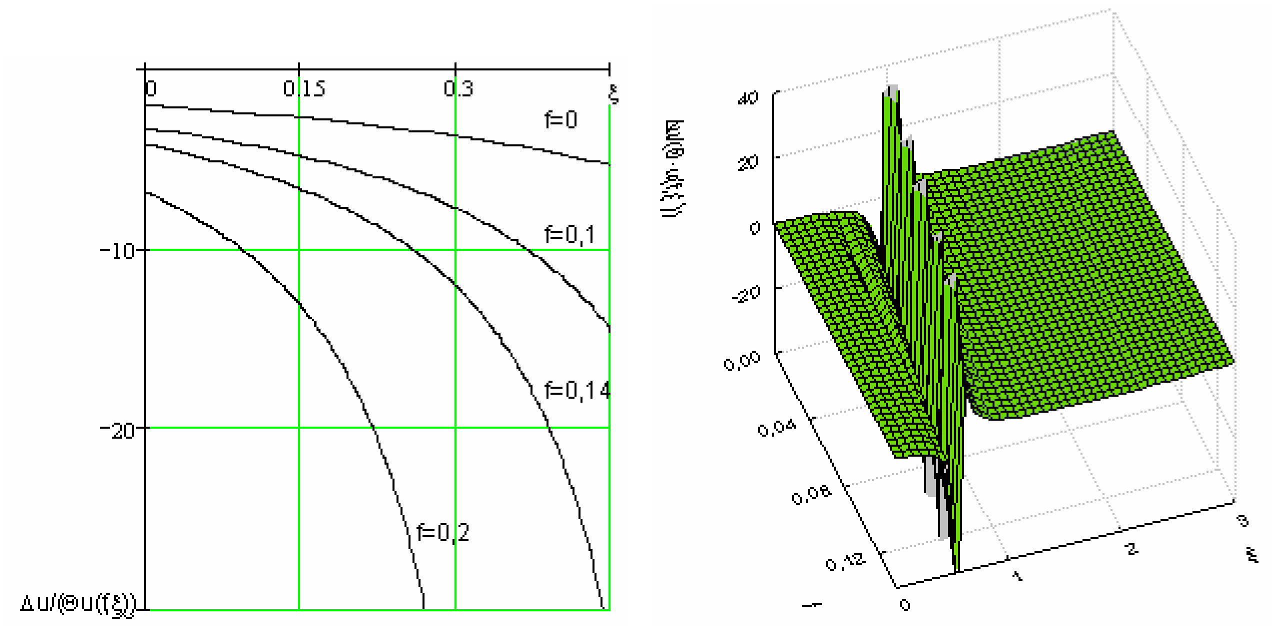
Fig. 10. Forecasting of influence of pressure of argon on size of stability of dependence of burning rate of a mix 0,938Ta (2мкм) +0,062C (0,1мкм) from the contents of additive KT to small indignations Θ at $\Delta T_н$=0K, d=15мм, ρ =5,37g/sm^3 and f=0 in coordinates:

a) - ξ, Δu / (Θ· u (p_{Ar}, ξ)); б) - (p_{Ar} , ξ), Δu / (Θ· u (p_{Ar} , ξ)).



а)   б)

Fig. 11. Forecasting of influence of density of a charge on size of stability of dependence of burning rate of a mix 0,938Ta (2мкм) +0,062C (0,1мкм) from the contents of additive KT to small indignations Θ at $\Delta T_{н}$=0K, p_{Ar}=2,25атм, d=15мм and f=0 in coordinates:
а) - ξ, $\Delta u / (\Theta \cdot u(\rho, \xi))$; б) - (ρ, ξ), $\Delta u / (\Theta \cdot u(\rho, \xi))$.



а)   б)

Fig. 12. Forecasting of influence of dispersiveness of a powder of tantalum on size of stability of burning rate of a charge of a mix 0,938Ta (2мкм) +0,062C (0,1мкм) from the contents of additive KT at $\Delta T_{н}$=0K, p_{Ar}=2,25атм, d=15мм and ρ =6g/sm^3 in coordinates:
а) - ξ, $\Delta u / (\Theta \cdot u(f, \xi))$; б) - (f, ξ), $\Delta u / (\Theta \cdot u(f, \xi))$.

Let's pay attention, that from (1) it is easy to receive the common expression describing influence of various factors on size of the relation mад/mпр, frequently used for an estimation of going out of charges of gunpowder's, explosives, solid propellants, etc.:

$$\frac{m_{ад}}{m_{пр}} = \frac{1}{1+\frac{a_8/d_{пр}}{a_0+a_1p+a_2\rho+a_3x+a_4\xi+a_5s_o+a_6s_г+a_7s_g}}. \quad (3)$$

For confirmation of individual dependence (3) values $u_{пр}$ and $u_{ад}$, burning rate determined from the experimental law u(d) are usually used, which is graphically represented monotonously growing (with increase in diameter) a curve with "saturation". At carefully spent experiments value $u_{пр}$ with comprehensible accuracy can be found on measured burning rate near to a limit of burning. However definition $u_{ад}$ is based on the qualitative reasons supposing, that value of adiabatic temperatures in a zone of burning is reached at final value of diameter, burning rate of a constant becomes higher which ("is sated), i.e. from the ratio $T_{ад}=\lim_{d\to d_{нас}} T_г(d)$, follows, that $u_{ад}=\lim_{d\to d_{нас}} u(d)$. Reliability of these assumptions can be proved only by the analysis of theoretical dependence $u_{ад}=\lim_{d\to\infty} u(d)$ which corresponds to strict concept $T_{ад}=\lim_{d\to\infty} T_г(d)$. According to expression (3) presence of size $u_{ад}$ (or $m_{ад}$) is unessential.

From the equation (3) follows, that the initial temperature of a charge does not render influence on size of the relation $m_{ад}/m_{пр}$ which essentially depends on character of heat exchange HEZ with an environment. In case of heat removal from HEZ (i.e. at presence heat loss a_8 <0) the relation $m_{ад}/m_{пр}$> 1, and in case of a supply of heat in HEZ (a_8> 0) this attitude{relation} becomes less than 1. Besides the equation (3) predicts influence of factorial components of the maximal density of a thermal stream on size $m_{ад}/m_{пр}$. Calculation on the equation (3) has shown, that value of the relation $u_{ад}/u_{пр}$ for charges of a mix 0,938Ta (2 microns) + 0,062C (0,1 microns) [7] at pressure p_{Ar}=2,25 атм is equal 1,37, and at p_{Ar}=0,1 атм appeared equal 1,681 (this value does not correspond to representations of the theory of burning of gasless systems.

Thus, the analytical method of the decision of practical problems{tasks} of stability of burning rate of charges concrete **CS** can be uniform.

In summary we shall note, that experiment was and remain a source of fundamental results of a basis of perfection existing and development new **CS**. In this connection, creation of methods of analytical forecasting of value of burning rate and its derivatives, and also the estimation of a role exo- and endothermal transformations into the mechanism of burning concrete CS at use limited (up to a minimum) volume of experimental researches (experimental basis), is an actual direction of applied development of physics of burning **CS**. In this connection development of the common theory of burning **CS** and in knowledge of the mechanism and laws of burning can promote methodology of its effective utilization both reduction of volumes of expensive experimental researches, and increase of reliability of functioning of pyrotechnic means.

The considered examples of forecasting of skilled values of burning rate with the help of the fractional-linear equation confirm a real opportunity of creation of the common quantitative theory of burning of **CS** which opens new opportunities of the analytical decision of the big spectrum of experimental problems: the description of experimental laws **RPFC** in charges **CS**; definitions of burning rate in the expanded ranges of change of influencing factors; estimations of joint change of influencing factors for burning rate and its derivatives; an establishment of conditions of stability stationary **RPFC**; substantiations of ways of purposeful regulation of burning rate, its dependence on all set of influencing factors, etc.

In this report the author has examined the elementary models of thermal influence of different factors on the rate of propagation of the burning front (RPBF) with exo- and endothermal transformations of the reagents (see the Table 1). **RPFC** in charges **CS** on the one hand it is determined by factorial exo-and endothermal components of the maximal density of a thermal stream q_m transferable{tolerable} of **HEZ** in **HAZ**, and with another factorial exo-and endothermal components of maximal enthalpy of reagents h_m in **HAZ**. Influence of these components on change RPFC essentially depends on a combination exo-and endothermal components q_m with exo-and endothermal components h_m (tab. 1).

Table 1.

EMTI factorial components q_m and h_m for speed of distribution of burning in charges **CS**

Types EMTI	Values of factorial components of enthalpy of reagents h_m.	Density of a thermal stream q_m
I	endo ($b_if_i > 0$) *	exo ($a_if_i > 0$) *
II	endo ($b_if_i > 0$)	endo ($a_if_i < 0$)
III	exo ($b_if_i < 0$)	exo ($a_if_i > 0$)
IV	exo ($b_if_i < 0$)	endo ($a_if_i < 0$)

*-a_if_i, b_if_i - the common designation of diverse factorial components q_m and h_m

From tab. 1 it is visible, that features of action of diverse factors on **RPFC** can be characterized four elementary models of thermal influence-EMTI. The combinations of factorial components resulted in tab. 1 q_m and h_m are a physical basis of possible{probable} thermal models of distribution exo-and endothermal transformations of the reagents proceeding in zones of absorption and allocation of heat, i.e. in **HAZ** and **HEZ**. These elementary thermal models allow to reveal a role factorial exo-and endothermal transformations into formation of characteristic laws **RPFC** in charges **CS**.

In particular, at a combination of components q_m and h_m which takes place in EMTI-I, exothermal transformations of reagents in **HEZ** render raising action on **RPFC**, and endothermal transformations in **HAZ-**lowering. Influence of the corresponding factor on **RPFC** in this case grows out opposite action of transformations of reagents dependent on it in **HAZ** and **HEZ**. Owing to opposite action of components q_m and h_m character of factorial dependence **RPFC** is determined by a role dominating (bringing the greatest contribution to change of speed) transformations of reagents. For example, with increase in value of the influencing factor at a dominating role of exothermal component q_m **RPFC** will grow, and at a dominating role of endothermal component h_m-to decrease.

At joint influence of components q_m and h_m, inherent EMTI-II, action endothermal transformations of reagents in **HEZ** and **HAZ** on **RPFC** is only lowering, i.e. influence of the factor on **RPFC** in the given thermal model is caused by synergism of endothermal components q_m and h_m. In this case lowering action of the factor on **RPFC** is the strongest.

As against EMTI-II the influence rendered on **RPFC** by exothermal by transformations of reagents in **HEZ** and **HAZ** EMTI-III is raising. Due to synergism of endothermal components q_m and h_m, raising action of the factor on **RPFC** and in this case is the strongest.

On character influence of components q_m and h_m on **RPFC** in charges **CS** concerning to EMTI _ IV, is opposite. With increase in influencing factor **RPFC** in charge **CS** increases in case of a dominating role of the exothermal component h_m and decreases in case of a dominating role of the endothermal component q_m.

Practical and theoretical interest represents use EMTI as a basis of classification **CS** on property of similarity of factorial laws **RPFC**.

<u>The common laws of speed RPFC in charges CS at Tн=293К.</u>

For forecasting common laws **RPFC** in charges **CS** at combinations of factorial components q_m and h_m, adequate established above EMTI, it is enough to consider properties of the simplified kind of the parametrical fractional-linear or hyperbolic equations containing only one generalized factor f_i (the index i which can concern to the physical nature of the investigated factor: to initial temperature, pressure, density, etc.). In this case at $T_н$=293К (i.e. value of initial temperature **CS** at which the enthalpy of components, and, hence and mixes, is accepted equal to zero) from the fractional-linear equation it is received parametrical one-factorial fractional-linear dependence:

$$m(f_i)=\frac{a_0+a_i f_i}{b_0+b_i f_i}, \quad (4)$$

which always can be resulted in a kind of the parametrical equation of hyperbolic type:

$$m(f_i)=a+\frac{b}{f_i+c}, \quad (5)$$

a,b.c, which are connected with parameters a_0, a_i, $в_0$, $в_i$ expressions (4) parities{ratio}:

$$a=\frac{a_i}{b_i};\ b=\frac{a_i}{b_i}\left(\frac{a_o}{a_i}-\frac{b_o}{b_i}\right);\ c=\frac{b_o}{b_i}, \quad (6)$$

Parameters a,b and c of dependence (5) determine not only geometrical properties of dependence m (fi), but also are physical characteristics of laws **RPFC** in charges **CS**. In particular, the parameter a, being the characteristic horizontal асимптоты hyperboles (5), on physical sense corresponds to limiting value RPFC in charge **CS** (i.e. $\lim_{f_i\to\infty} m(f_i)$=a); the parameter b (factor of return proportionality) determines an accessory of dependence $m(f_i)$, to growing or decreasing function: if $b > 0$ dependence (5) is decreasing, and at $b < 0$-growing; the parameter with, being the characteristic vertical асимптоты hyperboles (5), has the special physical sense connected to critical value of the factor $f_{iк}$=-c, with, at which dependence $m(f_i)$ has break of II sort (i.e. dependence $m(f_i)$ at f_{ik}=-c has no neither left and nor the right final limit). On physical sense the fact of absence of the left and right final limit means, that near to critical value of the factor f_{ik}=-c existence of two phenomena is inevitable: the phenomena of going out og the burning of a charge (when $\lim\limits_{fi \to -c+0} m(f_i) = -\infty$ in a case $b < 0$, and when $\lim\limits_{fi \to -c-0} m(f_i) = -\infty$ in a case $b > 0$); the phenomena of transition of normal burning in explosion (when $\lim\limits_{fi \to -c-0} m(f_i) = +\infty$ in a case $b < 0$ and when $\lim\limits_{fi \to -c+0} m(f_i) = +\infty$ in a case $b > 0$).

Full representations about critical values of diverse factors should be based on results of the analysis of the derivative equations (4) and (5). At critical values of factors these derivatives are equal to zero or do not exist. For an example we shall find critical values of factors of dependences (4) and (5). Their full derivative will consist of two composed, connected with **HEZ** and **HAZ**.

$$\nu_{fi}(f_i) = \frac{d \ln m(f_i)}{d \ln f_i} = \nu_{f_i ЗТВ}(f_i) + \nu_{f_i ЗТП}(f_i), \quad (7)$$

where $$\nu_{f_i ЗТВ}(f_i) = \frac{a_i f_i}{a_0 + a_i f_i} = \frac{f_i}{\frac{a_0}{a_i} + f_i} = 1 - \frac{\frac{a_0}{a_i}}{\frac{a_0}{a_i} + f_i} = 1 - \frac{1}{1 + \frac{a_i f_i}{a_0}} \quad (8)$$

$$\nu_{f_i ЗТП}(f_i) = -\frac{b_i f_i}{b_0 + b_i f_i} = -\frac{f_i}{\frac{b_0}{b_i} + f_i} = -1 + \frac{\frac{b_0}{b_i}}{\frac{b_0}{b_i} + f_i} = -1 + \frac{1}{1 + \frac{b_i f_i}{b_0}} \quad (9)$$

$$\nu_{f_i ЗТВ}(f_i) = \frac{f_i}{f_i + c + \frac{b}{a}} = 1 - \frac{1}{1 + \frac{f_i}{c + \frac{b}{a}}}, \quad (8')$$

$$\nu_{f_i ЗТП}(f_i) = -\frac{f_i}{f_i + c} = -1 + \frac{1}{1 + \frac{f_i}{c}}. \quad (9')$$

From the equations (8), (9) and (8 '), (9 ') follows, that the full (total) derivative does not exist at two critical values of the generalized factor:

$$f_{ikЗТВ} = -\frac{a_0}{a_i} = -(c + \frac{b}{a}) \quad \text{and} \quad f_{ikЗТП} = -\frac{b_0}{b_i} = -c. \quad (10)$$

The critical value of the factor corresponding to a root of the equation concerns to stationary value $f_{ic}=0$, at which $\nu_{f_i ЗТВ}(f_{ic}) = \nu_{f_i ЗТП}(f_{ic})$.

It is necessary to pay attention, that dependence $m(f_i)$ has break of II sort only at critical value of the factor $f_{ikHAZ}=-\frac{b_0}{b_i}$=-c At $f_{ikHEZ}=-\frac{a_0}{a_i}$=-(c+$\frac{b}{a}$) its value $m(fi_{kHEZ})$ =0, i.e. dependence $m(f_i)$ can have one point of crossing with an axis of abscissas.

Let's consider characteristic dependences $m(f_i)$, determined for charges **CS** concerning to typical EMTI.

The important characteristic of examined below generalizing dependences is the area of their definition at which finding of usual ways it is necessary to take into account in addition and ranges of change of the influencing factors, connected with their physical essence. For example, in baric dependences m (p), pressure concerns to the factor of external physical influence on RPFC in charges CS, and therefore can change in a semilimite range from 0 up to +∞. However, as shown below, this range of change of pressure can not fully comply with a real range of definition of dependence m(p).

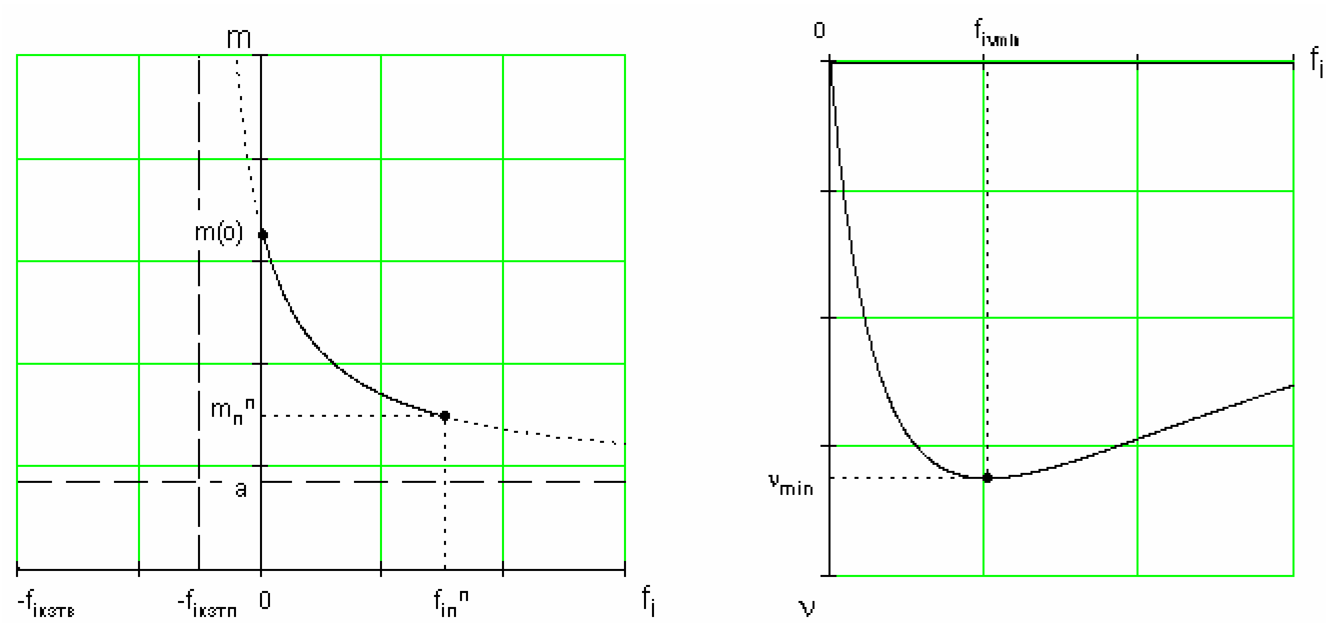
Generally the range of definition of dependences (4) and (5) should be from conditions corresponding to a range of definition of an inequality $m(f_i)> 0$ in view of a range of physically possible{probable} change of the influencing factor. In particular, the range of definition of dependence (4) should be established by conditions:

$$a_0+a_if_i>0,\ b_0+b_if_i>0; \quad a_0+a_if_i<0,\ b_0+b_if_i<0. \qquad (11)$$

Taking into account a range of possible change of physical size f_i.

For EMTI-I (i.e. at a combination exothermal component q_m with endothermal component h_m) values of parameters a_i, and b_i are positive, i.e. $a_i> 0$, and $b_i> 0$. In a case positive values of constants a_0 and $в_0$ the range of definition of dependence (4) according to (11) can be characterized by an inequality $f_i \geq 0$. However in the found range of definition parameters a and c of the hyperbolic equation (5) also will be positive, and value of parameter b, according to parities{ratio} (6), can be as positive (in case of a dominating role of endothermal component h_m, i.e. when $\frac{a_0}{a_i} > \frac{b_0}{b_i}$), and negative (in case of a dominating role of exothermal q_m, i.e. when $\frac{a_0}{a_i} < \frac{b_0}{b_i}$).

In case of positive values of parameters a, b and c of the hyperbolic law (5) dependence **RPFC** in charges **CS** from diverse factors should be characterized by a site of monotonously decreasing right branch равнобочной hyperboles with the camber directed downwards (fig. 13a).



а) б)

Fig. 13. Factorial dependences: а)-m(f_i) and б) - $\nu_{fi}(f_i)$ for charge CS, predicted EMTI-I at dominating endothermal component h_m (b> 0).

With increase in value of the factor f_i the size m(f_i) decreases, coming nearer to limiting value a which determines position of horizontal асимптоты. In an examined range of definition ($f_i \geq 0$) dependences (5) horizontal асимптота is the bottom border of values **RPFC** in charge **CS**. Values **RPFC** in charge **CS** have as well the top border which is determined by a point of crossing of the schedule of dependence (5) with an axis of ordinates, i.e. value of dependence m(f_i) at f_i=0 which is equal m(0). Thus, in an examined range of change f_i dependence (5) should be limited both from below, and from above. Approximately the range of change **RPFC** can be characterized an inequality: a<m(f_i)<m(0). The best way of a finding of the specified value of bottom limit **RPFC** is experimental, connected with measurements of values m(f_i) near to a limit of going out. However the decision of this problem can be practically interesting on the basis of analytical estimations of extreme value of a factorial derivative $\nu_{f_i}(f_i)$.

As $\left|\nu_{f_i ЗТВ}(f_i)\right| \leq \left|\nu_{f_i ЗТП}(f_i)\right|$ according to dependence (7) sensitivity **RPFC** change of the factor f_i is characterized by an inequality $\nu_{f_i}(f_i) \leq 0$. It is easy to show, that dependence $\nu_{f_i}(f_i)$ is extreme (fig. 13б). Position of a minimum of a derivative $f_{i\nu_{min}}$ is determined with formulas:

$$f_{i\nu_{min}} = \sqrt{\frac{a_0}{a_i} \cdot \frac{b_0}{b_i}} = \sqrt{c(c + \frac{b}{a})} \qquad (12)$$

For calculation of the minimal value of a derivative ratio can be used:

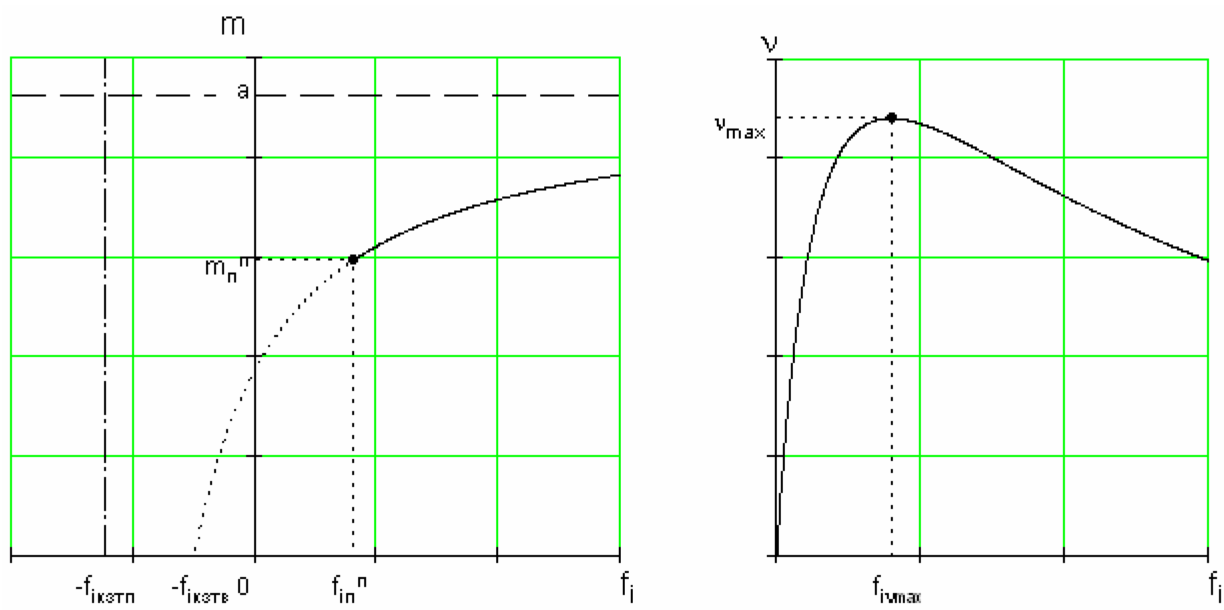
$$\nu_{min} = -\frac{\sqrt{\frac{a_0}{a_i}} - \sqrt{\frac{b_0}{b_i}}}{\sqrt{\frac{a_0}{a_i}} + \sqrt{\frac{b_0}{b_i}}} = -\frac{a}{b}\left(\sqrt{c} - \sqrt{c + \frac{b}{a}}\right)^2 \qquad (13)$$

Critical values f_{ikHEZ} and f_{ikHAZ} according to expressions (10) are sizes negative, i.e. not belonging to a range of definition of dependences (4) and (5). Thus the point f_{ikHEZ} belongs to the left branch of a hyperbole, and, hence, cannot be connected with the phenomenon of going out of burning of charges which on experimental data is realized at the limiting values $f_{i\text{п}}^{\text{п}}$ belonging to the right (working) branch of a hyperbole. The analysis of conditions of going out of burning of charges **CS** belonging EMTI-I at dominating endocomponent h_m, testifies to existence of natural conformity between $f_{i\text{п}}^{\text{п}}$ and $f_{iv_{min}}$, allowing to assert{approve}, that going out charges **CS** it can occur and near to position of a minimum of a factorial derivative. Thus the actual range of definition of dependence (5) represents the limited set $0 \le f_i \le f_{i\text{п}}^{\text{п}}$, in which change **RPFC** is more precisely characterized by an inequality $m(f_{i\text{п}}^{\text{п}}) \le m(f_i) \le m(0)$.

In tab. 2 and the subsequent tab. 3-7 for charges **CS** and other condensed systems are resulted received by a method of the least squares of value of parameters a,b and c of hyperbolic dependence (5) (values of these parameters for mass **RPFC** are resulted in parentheses). Characteristics of components of mixes are specified also: the numbers placed in parentheses after names or a chemical symbol of a component correspond to the size of its particles in a micron (and on occassion, to number of apertures on 1см in ситах, used at disperse of components); the numbers facing to the name or a chemical symbol of a component characterize its contents in mass fractions for fuel and an oxidizer, and for additives in mass fractions over unit (in a case stoichiometric ratio of components these numbers are absent before the name or a chemical symbol of fuel and an oxidizer); a mark "?" Means absence of the information under corresponding characteristic. Characteristics of charges (diameter d, density ρ, type of a heat-shielding covering-ТЗП a lateral surface) are resulted also; conditions of their burning (a kind of an environment; a range of change of influencing factor Δf_i); number N of analyzed experimental values RPFC and maximal relative deviation $|\delta|_{max}$ of experimental values of speed $m^э$ from settlement m.

Apparently from tab. 2, processes of distribution of a zone of burning in charges CS for the investigated ranges of changes of diverse factors are characterized by constant values of parameters a, b and c which can be physical characteristics of the established modes of thermal and material interaction on border of unit HEZ and HAZ.

In case of a dominating role of exocomponents q_m (i.e. at b <0) and values a> 0 and c> 0 hyperbolic dependence **RPFC** in charges **CS** from diverse factors f_i should be characterized by a site of monotonously growing right branch og the hyperboles with equal sides with the camber directed upwards (fig. 14a).



a) б)

Fig. 14. Factorial dependences: a)-m(f_i) and б) - $\nu_{fi}(f_i)$ for charge CS, predicted EMTI-I at dominating exocomponent q_m (b <0).

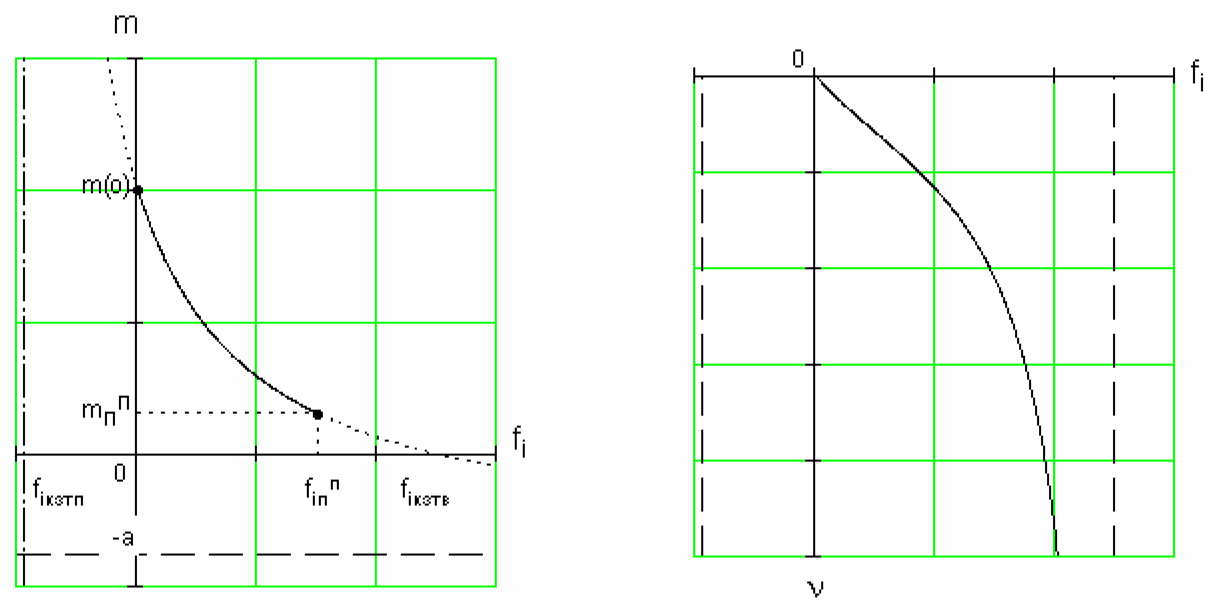
With increase of value f_i **RPFC** the size increases, coming nearer to limiting value a which is determined by position horizontal асимптоты the schedule of dependence (5). In a range of definition ($f_i \geq 0$) dependence $m(f_i)$ is also limited: the top border for values **RPFC** in charges **CS** is horizontal асимптота. The bottom border of values $m(f_i)$ approximately can be determined by value of dependence $m(f_i)$ at $f_i = f_{i\text{п}}^{\text{п}}$. In this case dependence (5) as is limited:

$$m(f_{i\text{п}}^{\text{п}}) \sim \leq m(f_i) < a$$

As $\frac{b}{a} < 0$ and $\left|\nu_{f_i\text{ЗТВ}}(f_i)\right| \geq \left|\nu_{f_i\text{ЗТП}}(f_i)\right|$ according to the dependence (7) sensitivity **RPFC** change f_i is defined{determined} by inequality $\nu_{fi}(f_i) \geq 0$. Dependence $\nu_{fi}(f_i)$ is also extreme (fig. 14б). Position of a maximum of derivative ν_{fimax} is determined by the formula (12) at b <0. For a finding of value ν_{fimax} the formula (13) should be used in view of negative value of factor b.

According to (10) size f_{ikHAZ} can have only the negative value which is not belonging to a range of definition of dependence (5). As $\frac{b}{a} < 0$ critical value f_{ikHEZ} can be both negative, and positive. At $\frac{b}{a} >$ c value f_{ikHEZ} is positive, i.e. belonging to a range of change of the factor f_i. In this case distribution of a front of burning in charge **CS** can be connected only with the phenomenon of going out of, taking place close f_{ikHEZ}. In tab. 3 parameters of hyperbolic dependence of experimental laws **RPFC** in charges CS and other condensed systems with a dominating role exocomponent q_m are resulted.

Values of parameters of factorial laws (4) and (5) EMTI-II (i.e. for a combination endocomponents q_m and h_m) it is defined{determined} by inequalities: a_i <0; b_i> 0; a <0; c> 0 and b> 0. In this case dependence $m(f_i)$ should be represented by a site of monotonously decreasing right branch og hte hyperboles with equal sides with the camber directed downwards (fig. 15a).



a) б)

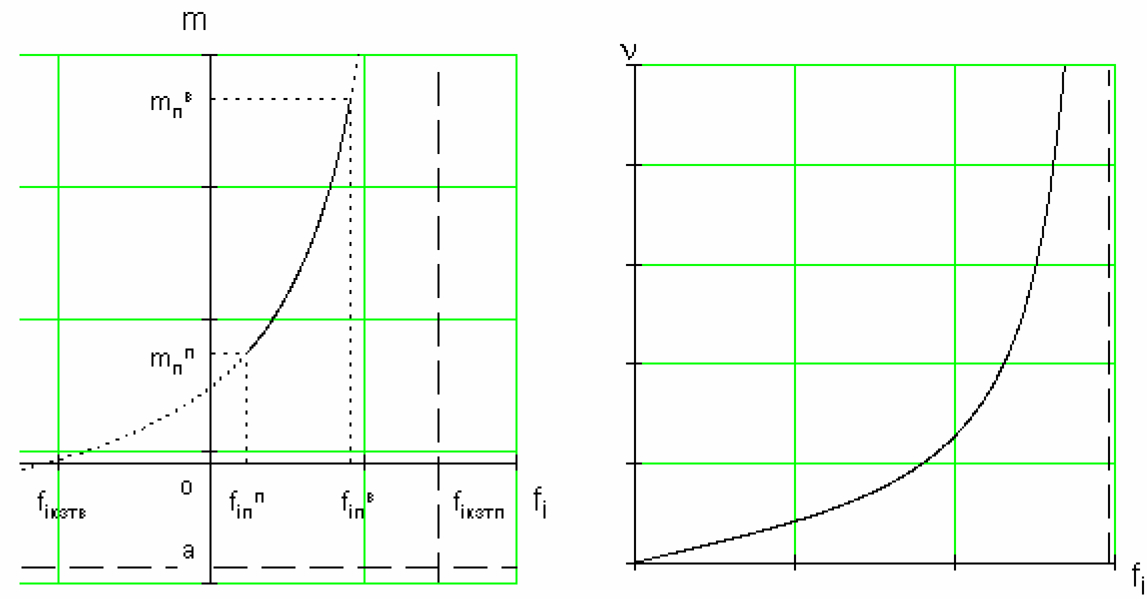
Fig. 15. Factorial dependences: a)-m(f_i) and б) - $\nu_{fi}(f_i)$ for charge CS, predicted EMTI-II at endocomponents h_m and q_m (b> 0).

To the important feature of dependence m(f_i) it is necessary to attribute{relate} the fact of existence of a point of crossing of a hyperbole with an axis of abscissas. Found from the decision of the equation m(f_i) =0 value of a root $f_i=f_{m=0}$ divides area of positive values f_i into two parts consisting of sets: $0 \le f_i < f_{m=0}$; $f_{m=0} < f_i < \infty$. At values of the factor f_i first set **RPFC** in charge **CS** is positive, and for values f_i the second set negative. Negative values m(f_i) mean, that process of selfmaintaining distributions of a zone of burning to charge **CS** at values f_i, belonging to the second set, is not possible. However selfmaintaining process of distribution of a fronte of burning is possible not at all values values f_i, belonging to the first set containing limiting value of the factor $f_{i\pi}^{\pi}$, at which comes погасание burning of charge **CS**. So as $m(f_{i\pi}^{\pi})>0$, limiting value $f_{i\pi}^{\pi}<f_{im=0}$ and the valid range of definition of dependence m (f_i) corresponds{meets} to the limited set $0 \le f_i \le f_{i\pi}^{\pi}$ Dependence m(f_i) is limited from below to value $m(f_{i\pi}^{\pi})$, and from above value **RPFC** in charge **CS** at f_i=0, i.e. m(0). Thus, dependence m(f_i) is limited and satisfies to an inequality: $m(f_{i\pi}^{\pi}) \le m(f_i) \le m(0)$.

According to (7), derivative $\nu(f_i) \le 0$ is monotonously decreasing function (fig. 15б). Critical value of the factor f_{ikHAZ} <0, i.e. does not belong to a range of definition of dependence m(fi), and therefore the phenomenon of transition of burning of a charge in explosion is not inherent EMTI-II. As critical value of the factor $f_{ikHEZ}=f_{m=0}$ the phenomenon of going out of burning of charge **CS** inevitably arises near to a point of crossing of a hyperbole with an axis of abscissas i.e. near to value of a root of the equation m(f_i) =0.

Parameters of experimental laws m(f_i) for charges **CS** and other condensed substances belonging EMTI-II are resulted in tab. 4.

Values of parameters of the equations (4) and (5) for a combination exocomponents q_m and h_m the basic zones of burning EMTI-III satisfy to parities{ratio}: $a_i > 0$; $b_i < 0$; $a < 0$; $c < 0$ and $b < 0$. In this case factorial dependence $m(f_i)$ should be represented by a site of monotonously growing left branch of the hyperboles with equal sides with the camber directed downwards (fig. 16a).



а) б)

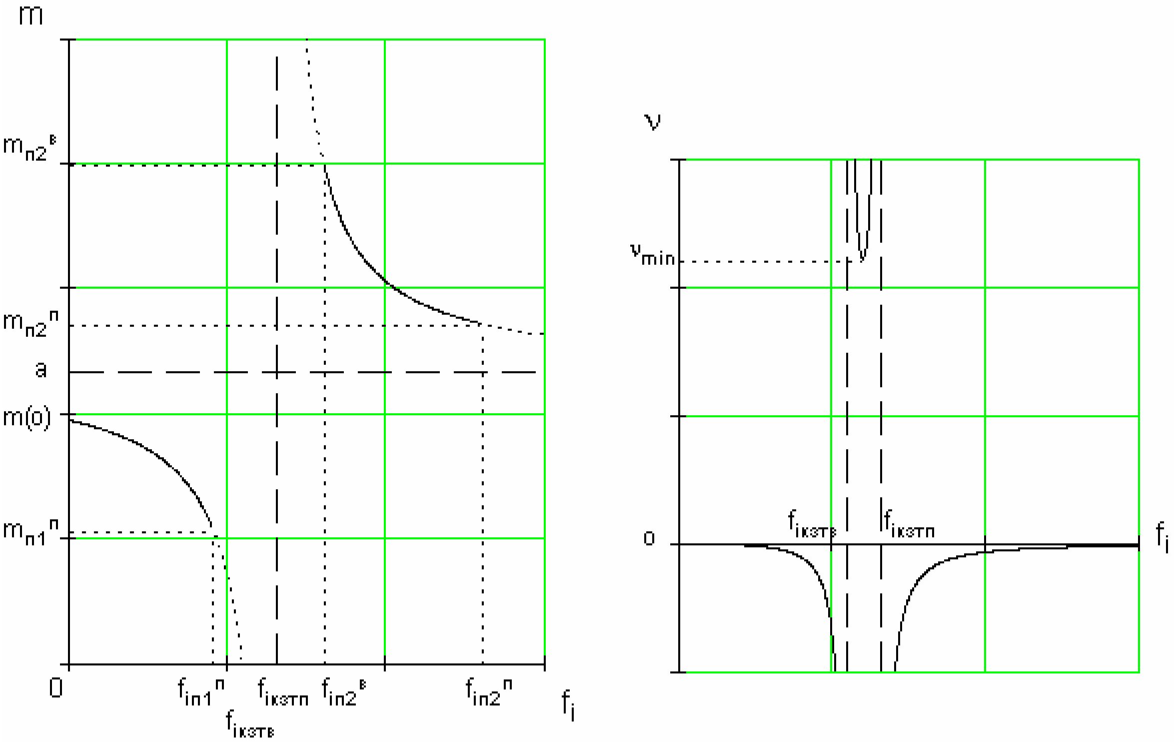
Fig. 16. Factorial dependences: а)-m (f_i) and б) - $\nu_{fi}(f_i)$ for charge CS, predicted EMTI-III at exocomponents h_m and q_m ($b < 0$).

The important feature of this dependence, as well as in case EMTI-II, existence of a point of crossing of the left branch of a hyperbole with an axis of abscissas is. This point, being a root of the equation $m(f_i) = 0$, divides an axis of abscissas into two sets: $0 \le f_i \le f_{m=0}$ and $f_{m=0} < f_i < c$. At values f_i the first set of selfmaintaining distribution of a front of burning is not feasible (value $m(f_i) < 0$). The opportunity of distribution of a front of burning in charges **CS** actually should correspond{meet} to a range of definition of the dependence which are taking place in limited set of values f_i: $f_{iп}^п \le f_i \le f_{iп}^в$, i.e. set which is limited to a limit of going out of burning of charge **CS** and a limit of transition of his{its} burning in explosion. Thus values **RPFC** change in limits $m(f_{iп}^п) \le m(f_i) \le m(f_{iп}^в)$.

Derivative $\nu(f_i) \ge 0$ determined by expression (7) also is monotonously growing function (fig. 5б). Critical value of the factor $f_{ikЗПТ} > 0$, i.e. belongs to a range of definition of dependence (5), and therefore at $f_{ikЗПТ} = c$ dependence $m(f_i)$ has break II-го of a sort. Close to the left of critical values f_{ikHAZ} there is a factorial limit $f_{iп}^в < f_{ikHAZ}$, at which burning of charge **CS** passes in explosion. Close to the right of critical value $f_{ikHEZ} = f_{im=0}$, there is the limiting value $f_{iп}^п$,corresponding погасанию of burning of charge **CS**.

Parameters of experimental laws $m(f_i)$ for charges **CS** and other condensed substances belonging EMTI-III, are resulted in tab. 5.

The special case briefly examined here, represents EMTI-IV, corresponding to a combination in zones of burning endocomponent q_m with exocomponent h_m. Parameters of laws (4) and (5) satisfy to inequalities: a_i<0; b_i<0; a>0; c<0; b>0 (for dominating endocomponent q_m) and b <0 (for dominating exocomponent h_m). As in a case b> 0 range of definition of the equations (4) and (5) belongs to two sets which correspond to inequalities: $0 \le f_i < f_{ikHEZ}$ and $f_{ikHAZ} < f_i < \infty$ dependence $m(f_i)$, having break II-го of a sort at critical value of the factor $f_{ik}=c=b_0/b_i$ should be characterized by two sites of monotonously decreasing hyperboles with equal sides: one site belonging to the left branch (shown on fig. 17a) with the camber directed upwards, and other site belonging to the right branch (on fig. 17a) with the camber directed downwards.



а) б)

Fig. 17. Factorial dependences: a)-m (f_i) and б) - $\nu_{fi}(f_i)$ for charge CS, predicted EMTI-IV at dominating endocomponent q_m (b> 0).

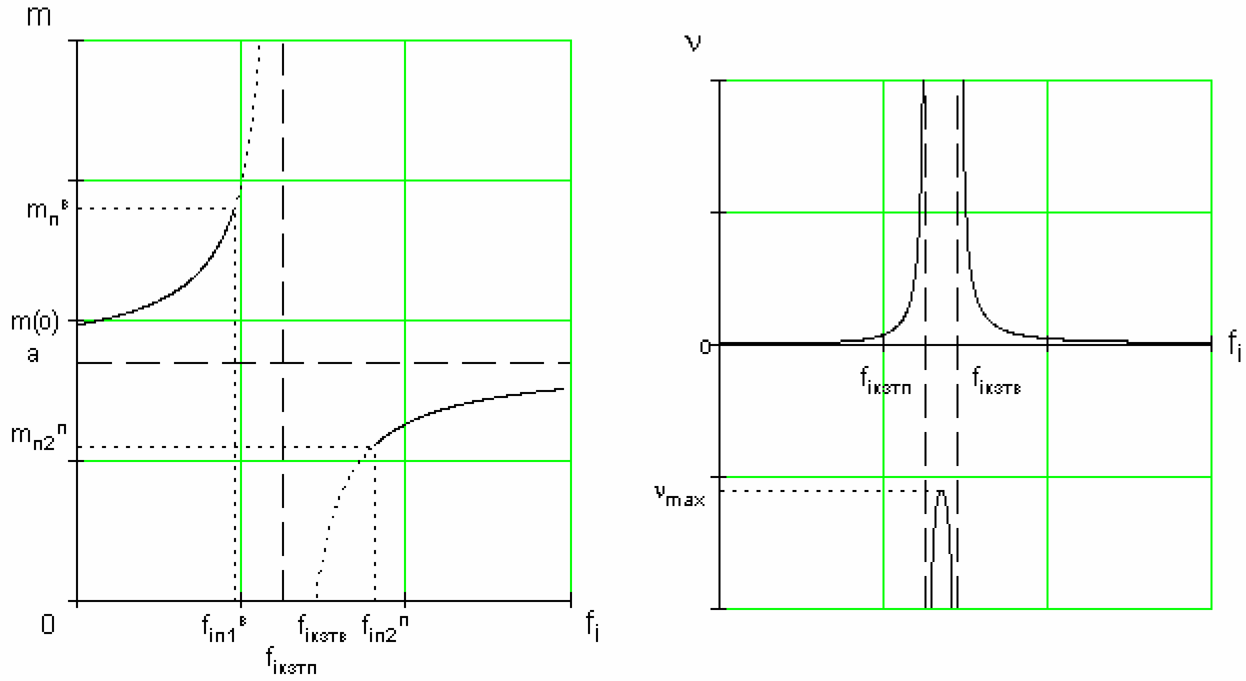
Change **RPFC** in charges **CS** in an examined range of definition corresponds to inequalities $m(f_{i\pi 1}^{\pi}) \le m(f_i) \le m(0)$ and $m(f_{i\pi 2}^{\pi}) \le m(f_i) \le m(f_{i\pi 2}^{в})$.

It is necessary to pay attention to factorial derivative $\nu(f_i)$ which on the left site of a range of definition of dependence $m(f_i)$ (shown on fig. 17б) is negative i.e. $\nu(f_i) \le 0$, and on the second can have both positive, and negative values. The factorial limit $f_{i\pi 1}^{\pi}$,corresponding погасанию of burning of a charge on the first site of a curve $m(f_i)$, belongs to the left branch of a hyperbole and is located near to critical value of the factor $f_{ikHEZ}=f_{im=0}$. The factorial limit $f_{i\pi 1}^{\pi}$,corresponding to transition of burning of charge **CS** in explosion, is located near to position of a positive minimum of a derivative $f_{i\nu min}$, and the limit is determined by negative value of derivative $\nu(f_{i\pi 2}^{\pi})$.

Parameters of experimental laws $m(f_i)$ for **CS** and other condensed substances belonging EMTI-IV, at a dominating role endocomponents q_m are resulted in tab. 6.

In case of a dominating role exocomponent h_m the range of definition of dependence $m(f_i)$

will consist also of two sites belonging to sets $0 \le f_i \le f_{ikHAZ}$ и $f_{ikHAZ} < f_i < \infty$ (fig. 18a).



a) б)

Fig. 18. Factorial dependences: a)-$m(f_i)$ and б) - $\nu_{fi}(f_i)$ for charge CS, predicted EMTI-IV at dominating exocomponent h_m ($b<0$).

For the first set dependence $m(f_i)$ the equations (5) should be characterized by a site of monotonously growing left branch of the hyperboles with equal sides with camber directed downwards (shown on fig. 18a), and for the second a site of monotonously growing right branch (on fig. 7б) of the hyperboles with equal sides with camber directed upwards. Change **RPFC** in charges **CS** on the first site is determined by an inequality $0 \le m(f_i) \le f^{в}_{iп1}$, and on the second $m(f^{п}_{iп2}) \le m(f_i) < a$.

Dependence of a derivative complex (fig. 18б): on the first site of a range of definition it is positive monotonously growing function, and on the second there are two dependences of a derivative, one of which is extreme (has a maximum with negative value), and the second is monotonously decreasing positive function. As well as in case of a dominating role endocomponents q_m near to critical values f_{ikHAZ} and f_{ikHEZ} there are phenomena of explosion and of going out of burning of a charge.

Parameters of experimental laws $m(f_i)$ for **CS** and other condensed substances belonging EMTI-IV, at a dominating role of exocomponents h_m are resulted in tab. 7.

Influence of an initial thermal condition of a mix on factorial laws **RPFC** in charges CS.

Generally features of influence of initial temperature $T_н$ on laws **RPFC** in charges **CS** are determined with dependence in which as the characteristic of a thermal condition of a mix it is used enthalpy (heatcontent), dependent on initial temperature $T_н$. In comparison with temperature which is frequently used as the characteristic of a thermal condition of substances, enthalpy is the exact characteristic of a thermal condition of mixed the systems containing components with phase transitions. Therefore, alongside with dependence $m(T_н, f_i)$ in which initial temperature $T_н$ can be in a complex connection with enthalpy of mixes, factorial laws $m[h(T_н),f_i]$ in which the direct characteristic of a thermal condition of investigated mixes is enthalpy will be considered also.

At the analysis of dependence $m[h(T_н),f_i]$ it is necessary to take into account special property of size $h(T_н)$ as characteristics of an initial thermal condition of charge **CS** which does not render influence on thermal parameters of critical section of a wave of burning. On the other hand the size $h(T_н)$, being one of thermal characteristics HAZ, defines{determines} a difference $[h_m(T_к)- h(T_н)]$, representing amount of heat absorbed at heating of a fresh mix from initial temperature up to its critical value $T_к$ at which enthalpy $h_m(T_к)$ mixes in HAZ becomes maximal [].

Influence of an initial thermal condition of a charge of mix $h(T_H)$ on factorial dependences **RPFC** $m(f_i)$ and its derivatives $\beta_{fi}(f_i)$ and $\nu_{fi}(f_i)$ is characterized by the equations: fractional-linear

$$m[h(T_н),f_i]=\frac{a_0+a_i f_i}{b_0+b_i f_i-h(T_н)}, \qquad (14)$$

or hyperbolic

$$m[h(T_н),f_i]=a+\frac{b'[h(T_н)]}{f_i+c'[h(T_н)]}, \qquad (15)$$

where the parameter $a=\frac{a_i}{b_i}$ does not depend on a thermal condition of a charge of a mix; with increase enthalpy mixes $h(T_H)$ the factor of return proportionality $b'[h(T_н)]=a\left[\frac{a_0}{a_i}-\frac{b_0}{b_i}\right]+\frac{a}{b_i}h(T_н)$ linearly grows, and the size $c'[h(T_н)]=\frac{b_0}{b_i}-\frac{h(T_н)}{b_i}$ linear decreases.

Approximately the range of definition of the equations (14) and (15) can be characterized a range of definition of an inequality:

$$m[h(T_{нп}^{п}), f_{iп}^{п}] \le m[h(T_н),f_i] \le m[h(T_{нп}^{в}), f_{iп}^{в}] \qquad (16)$$

in view of ranges of physically possible{probable} change of investigated factors.

The range of definition of the equations (14) and (15) on a range of allowable values initial enthalpy is defined{determined} by double inequality $h_п^п[T_{нп}^п, f_i] \le h(T_н) \le h_m(f_i)$. Ranges of change of the factor f_i can be found from the decision of two systems of inequalities:

$$\begin{matrix} a_0+a_i f_i>0 \\ b_0+b_i f_i-h(T_н)>0 \end{matrix}, \quad \begin{matrix} a_0+a_i f_i<0 \\ b_0+b_i f_i-h(T_н)<0 \end{matrix} \quad \text{for the equation (14)}$$

As negative values f_i have no physical sense values of investigated factors should satisfy to an inequality $f_i \ge 0$.

Thus, the analysis of influence of an initial thermal condition of charge **CS** on **RPFC** is reduced to an establishment of changes, which bring dependences $b'[h(T_н)]$ and $c'[h(T_н)]$ in factorial laws EMTI considered above.

According to (14) influence of a thermal condition (initial enthalpy) a charge on sensitivity **RPFC** charges **CS** to change f_i it is determined by dependence:

$$\nu_{fi}[h(T_н),f_i]=\nu_{iHEZ}(f_i)+\nu_{iHAZ}[h(T_н),f_i], \qquad (17)$$

Where value of first factorial component $\nu_{fiHEZ}(f_i)$ is under formulas (8) or (8'), and values of the second factorial component dependent on a thermal condition of a mix under the formula:

$$\nu_{fiHAZ}[h(T_н),f_i]=-\frac{f_i}{\frac{b_0-h(T_н)}{b_i}+f_i} \qquad (18)$$

Component $\nu_{fiHEZ}(f_i)$ characterizes sensitivity of density of a thermal stream q_m to change of the factor f_i and does not depend on an initial thermal condition of a mix. Component $\nu_{iHAZ}(f_i)$ determines sensitivity of amount of heat $b_0+b_1f_i-h(T_н)$, absorbed by a fresh mix in a zone of heating, to change of the factor f_i.

From (18) it is visible, that character of influence $h(T_H)$ on $\nu_{iHAZ}[h(T_н)]$ in essence depends on value of parameter b_i. With increase $h(T_н)$ component $\nu_{iHAZ}[h(T_н),f_i]$ decreases at values $b_i > 0$ and increases at values $b_i < 0$.Hence, with increase $h(T_н)$ mixes total size $\nu_i[h(T_н),f_i]$ is reduced at $b_i > 0$ and raises at $b_i < 0$.

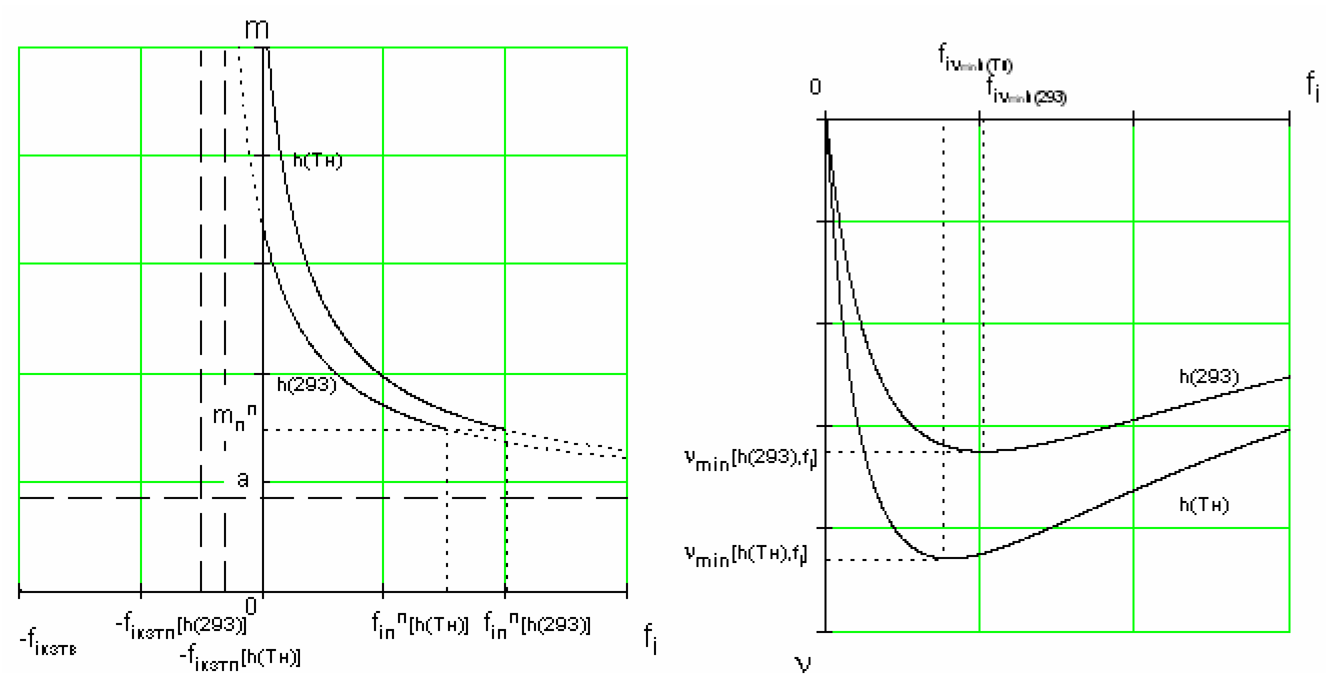
Let's consider features of influence of a thermal condition on the basic characteristics of factorial laws **RPFC** in charges of the mixes belonging typical ЭТМВ.

In case EMTI-I with dominating endocomponent h_m the family of factorial curves $m[h(T_н), f_i]$ with various values $h(T_н)$ has one horizontal асимптоту which corresponds to a limit $\lim\limits_{f_i\to+\infty}[h(T_н),f_i]=\lim\limits_{f_i\to+\infty}\left\{a+\frac{b'[h(T_н)]}{f_i+c'[h(T_н)]}\right\}=a=\frac{a_i}{b_i}$, not dependent on a thermal condition of charge **CS**.

As, $\lim\limits_{f_i\to-c'[h(T_н)]}m[h(T_н),f_i]=\lim\limits_{f_i\to-c'[h(T_н)]}\left\{a+\frac{b'[h(T_н)]}{f_i+c'[h(T_н)]}\right\}=+\infty$ is vertical асимптотой families of factorial curves $m[h(T_н), f_i]$.

On **RPFC** it is possible to judge influence of change of a thermal condition of a charge under the schedules describing factorial dependences $m(fi)$ at two values of initial temperatures, for example the initial temperature of a charge equal 293K (at which enthalpy $h(293K) = 0$) and initial temperature $T_н > 293K$ (at which $h(T_н) > 0$).

From fig. 19a it is visible, that with increase enthalpy mixes **RPFC** - increases, and its factorial limit is displaced aside the big values of this factor.



а) б)

Fig. 19. Influence of a thermal condition of a charge on dependences: a)-m(f_i) and б) - $\nu_{fi}(f_i)$ CS for factorial EMTI-I with dominating endocomponent h_m (b> 0).

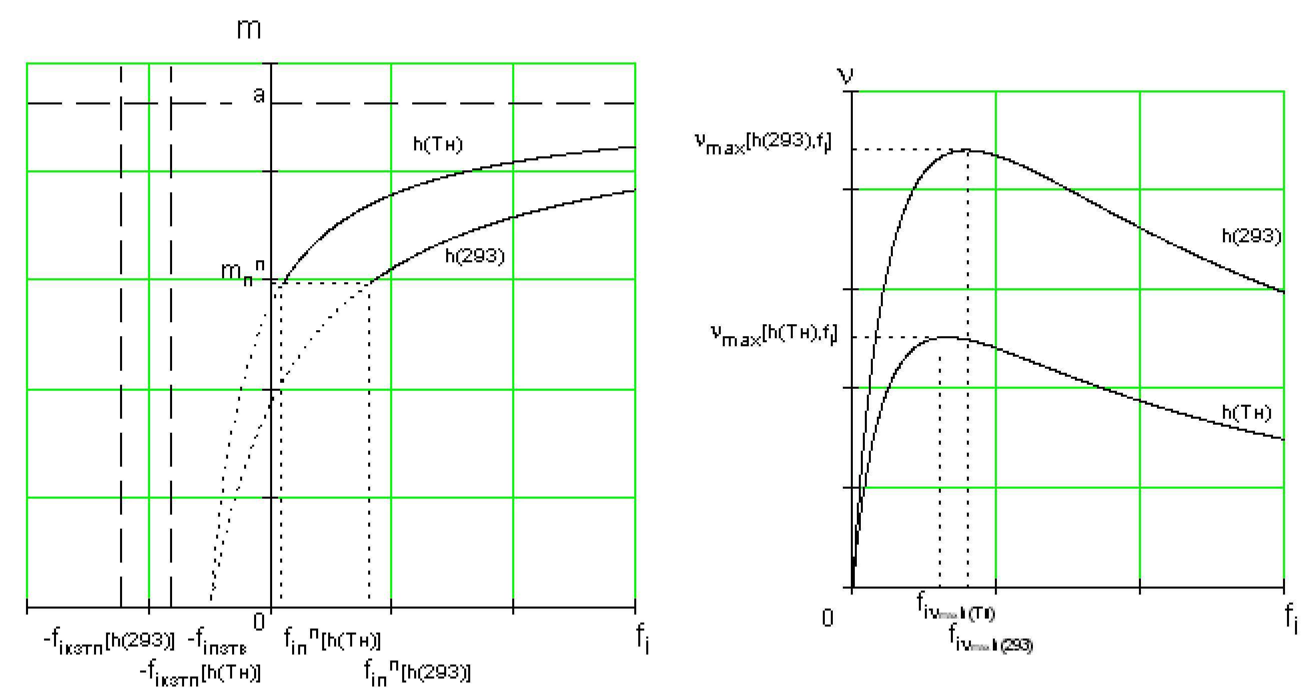
The thermal condition of a mix renders essential influence and on sensitivity **RPFC** to change of the factor f_i: with increase энтальпии $\nu_{fi}(f_i)$ decreases, and position of an extremum of dependence $\nu_{fi}(f_i)$ (a minimum of a derivative $\frac{\partial \nu_{fi}(f_i)}{\partial f_i}$) is displaced aside smaller values of the factor f_i (fig. 19б).

From the equation (14) follows, that sensitivity **RPFC** thermal influence quantitatively characterizes thermal factor of burning rate:

$$\beta_h[h(T_н),f_i]=\frac{1}{b_0+b_1f_i-h(T_н)}, \quad (19)$$

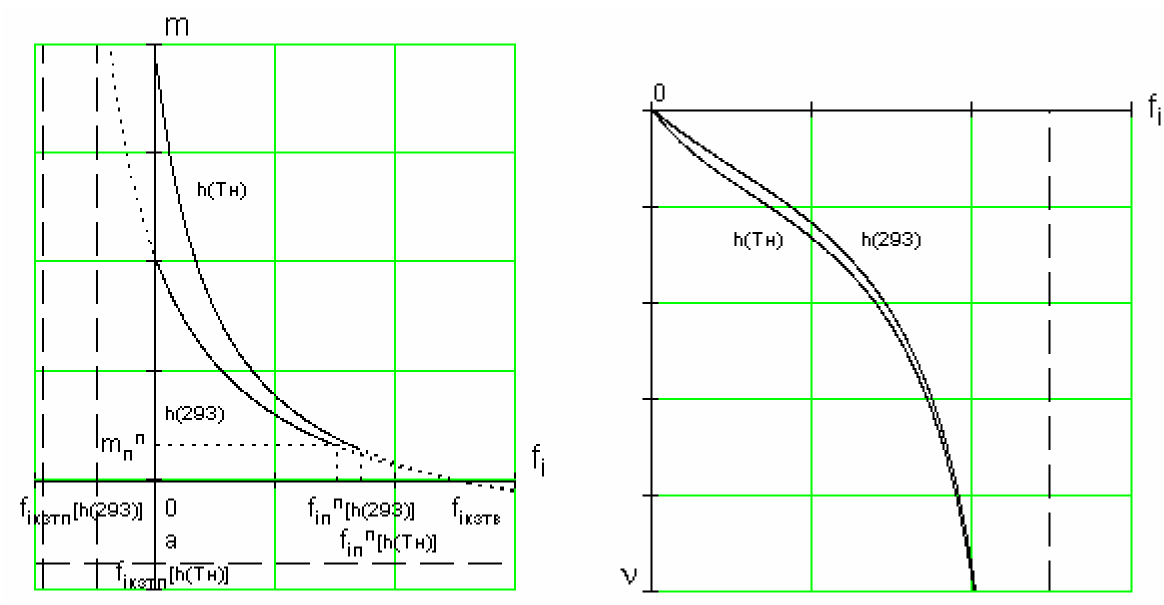
which increases with increase in initial enthalpy. With increase of pressure thermal dependence of factorial factor $\beta_h[h(T_н),f_i]$ is weakened at mixes at which $b_i > 0$ and amplifies at the mixes having $b_i<0$; at mixes at $b=0$ size $\beta_h[h(T_н),f_i]$ does not depend from f_i.

About influence of an initial thermal condition of a charge on factorial dependences $m(f_i)$ and $\nu_{fi}(f_i)$ **CS**, belonging EMTI-I with dominating exocomponent q_m and another EMTI full enough it is possible to judge under the schedules submitted on fig. 20-24.



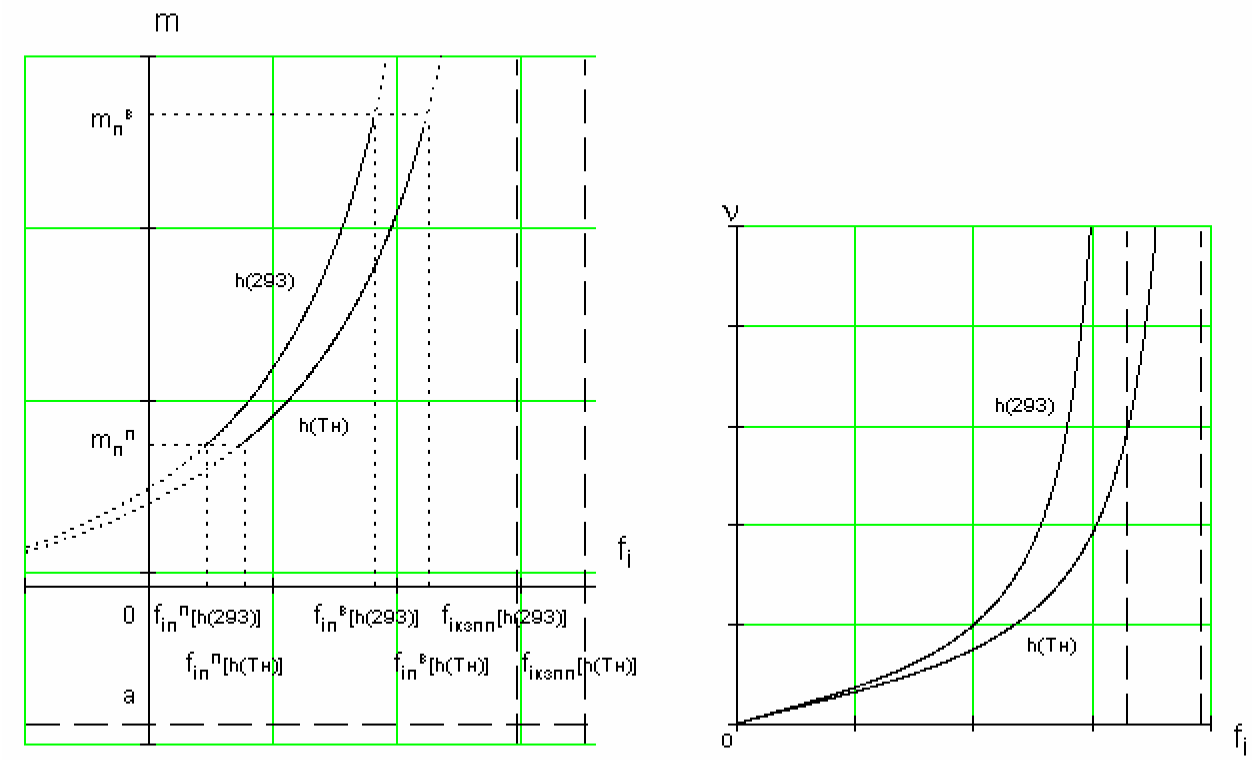
a) б)

Fig. 20. Influence of a thermal condition of a charge on dependences: a)-m(fi) and б) - $\nu_{fi}(f_i)$ CS for factorial EMTI-I with dominating exocomponent q_m (b <0).



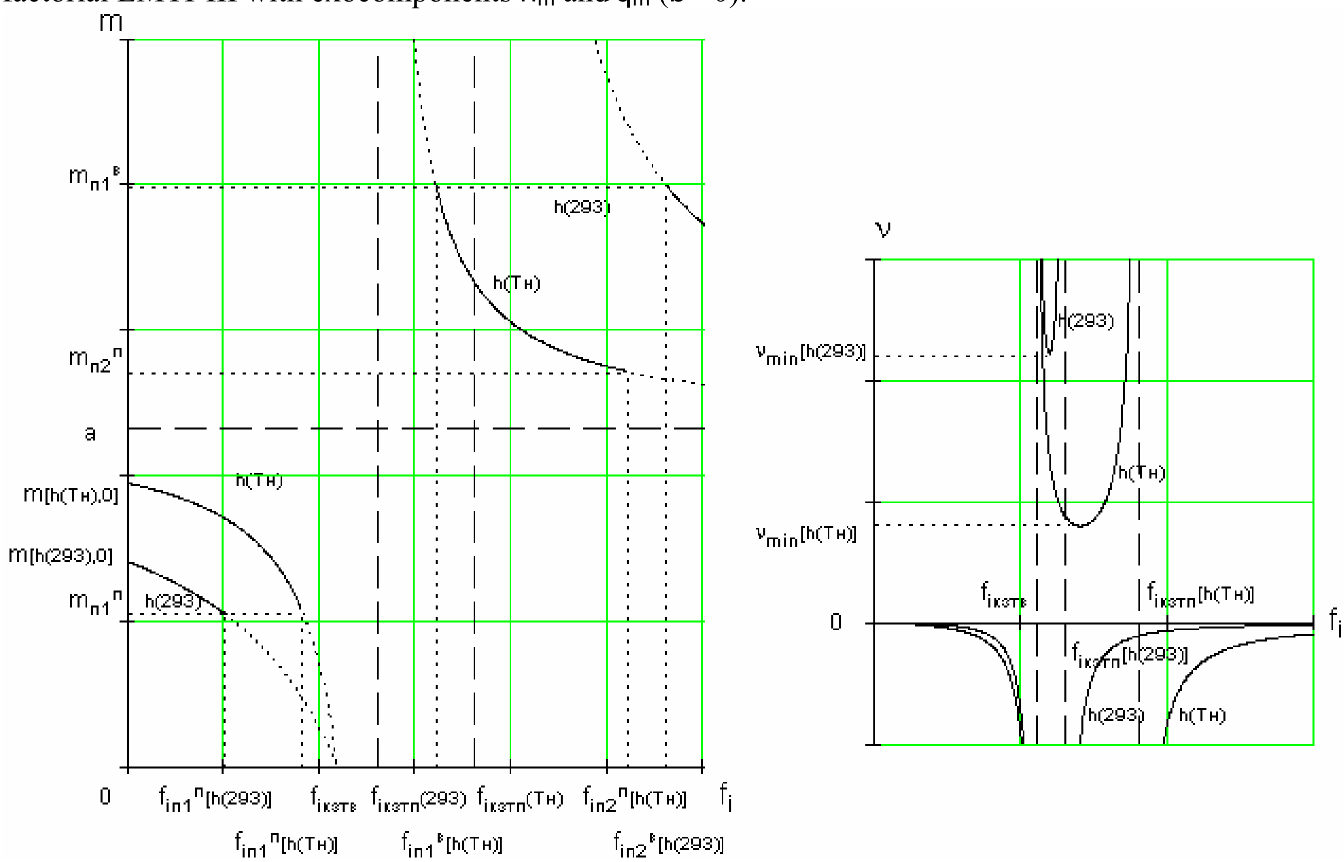
a) б)

Fig. 21. Influence of a thermal condition of a charge on dependences: a)-m(fi) and б) - $\nu_{fi}(f_i)$ CS for factorial EMTI-II with endocomponent h_m and q_m (b> 0).



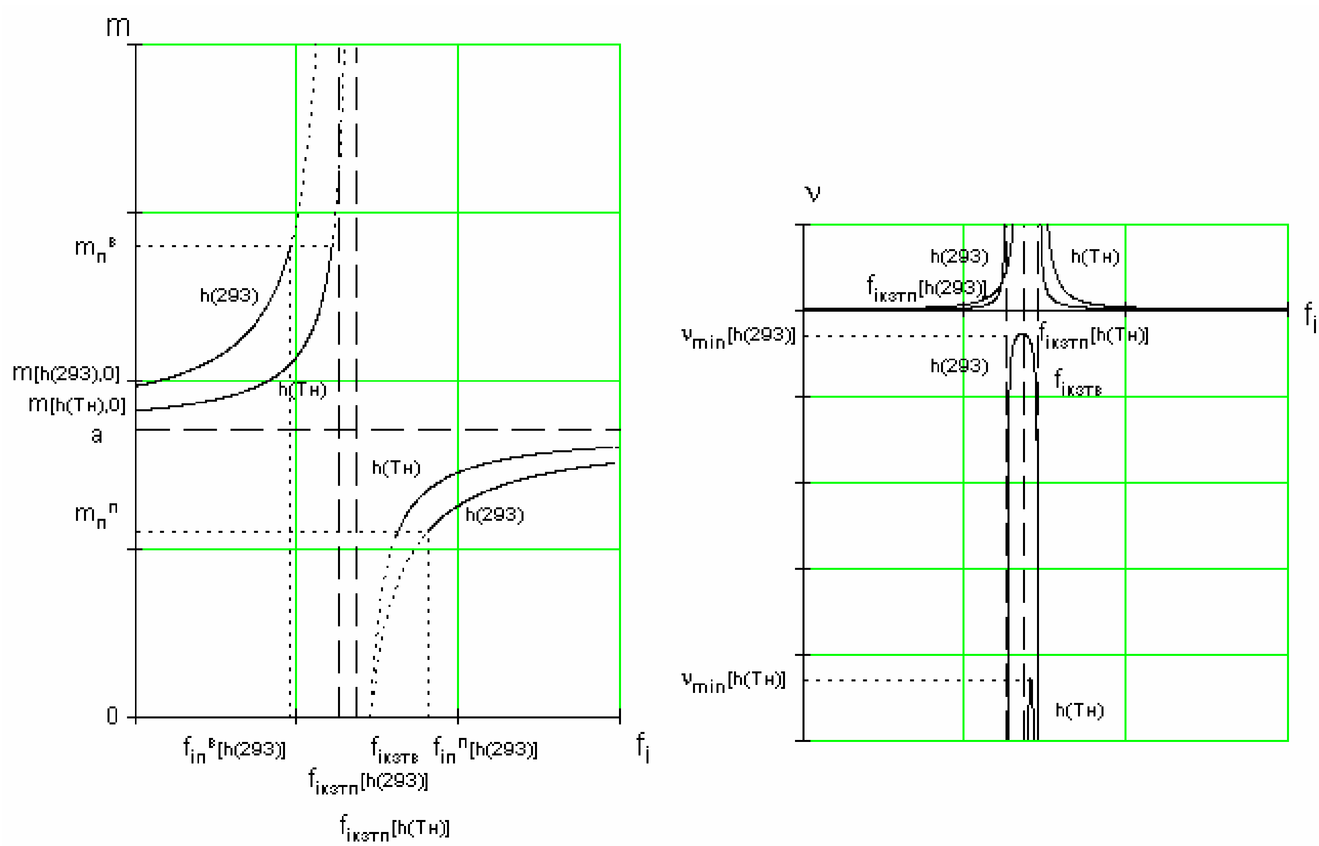
а) б)

Fig. 22. Influence of a thermal condition of a charge on dependences: a)-m(fi) and б) - $\nu_{fi}(f_i)$ CS factorial EMTI-III with exocomponents h_m and q_m (b <0).



а) б)

Fig. 23. Influence of a thermal condition of a charge on dependences: a)-m(fi) and б) - $\nu_{fi}(f_i)$ CS factorial EMTI-IV with dominating endocomponent q_m (b> 0).



а) б)

Fig. 24. Influence of a thermal condition of a charge on dependences: a)-m (fi) and б) - $\nu_{fi}(f_i)$ CS factorial EMTI-IV with dominating exocomponent h_m (b <0).

Influence of diameter of a charge on factorial dependences $m(f_i)$ and $\nu_{fi}(f_i)$

Other external factor influencing on **RPFC** in **CS** is scale diameter of a charge. As against the considered influence initial enthalpy of mixes h (Tн) with increase in diameter of charge **RPFC** can as to increase (in case of heat removal from **HEZ**), and to decrease (in case of a supply of heat in **HEZ**). At designing pyrotechnic mains in which the same mix is used in charges of different diameter, there is a necessity to take into account feature of influence of the scale factor on **RPFC** and its stability connected or with going out of burning of a charge, or with transition of its burning in explosion.

Influence of diameter of a charge on factorial dependence **RPFC** $m(f_i)$ and its derivatives $\beta(f_i)$ and $\nu_{fi}(f_i)$ at initial temperature $T_н$=293K (i.e. at h(293) =0) it is determined by the equations: fractional-linear

$$m(f_i) = \frac{a_0 + a_i f_i + a_2 d^{-1}}{b_0 + b_i f_i} \qquad (20)$$

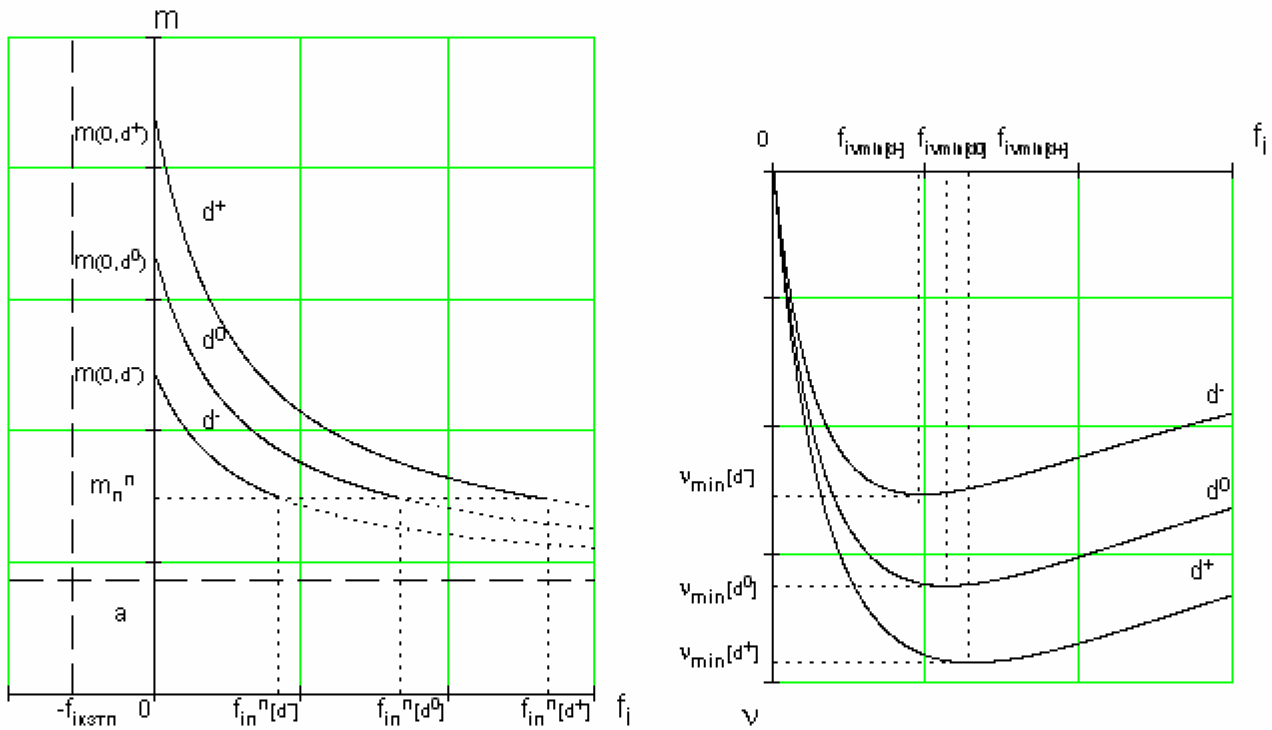
or hyperbolic

$$m(f_i) = a + \frac{b'(d)}{f_i + c}, \qquad (21)$$

in which parameters $a = \frac{a_i}{b_i}$ и $c = \frac{b_0}{b_i}$ also do not depend on the scale factor, and the factor of return proportionality $b'(d) = a\left(\frac{a_0}{a_i} - \frac{b_0}{b_i}\right) + \frac{aa_2}{a_i}d$ with increase in a linear range grows at $a_2 > 0$ (i.e. in case of a supply of heat in **HEZ)** and linearly decreases at $a_2 < 0$ (i.e. in case of heat removal from **HEZ**).

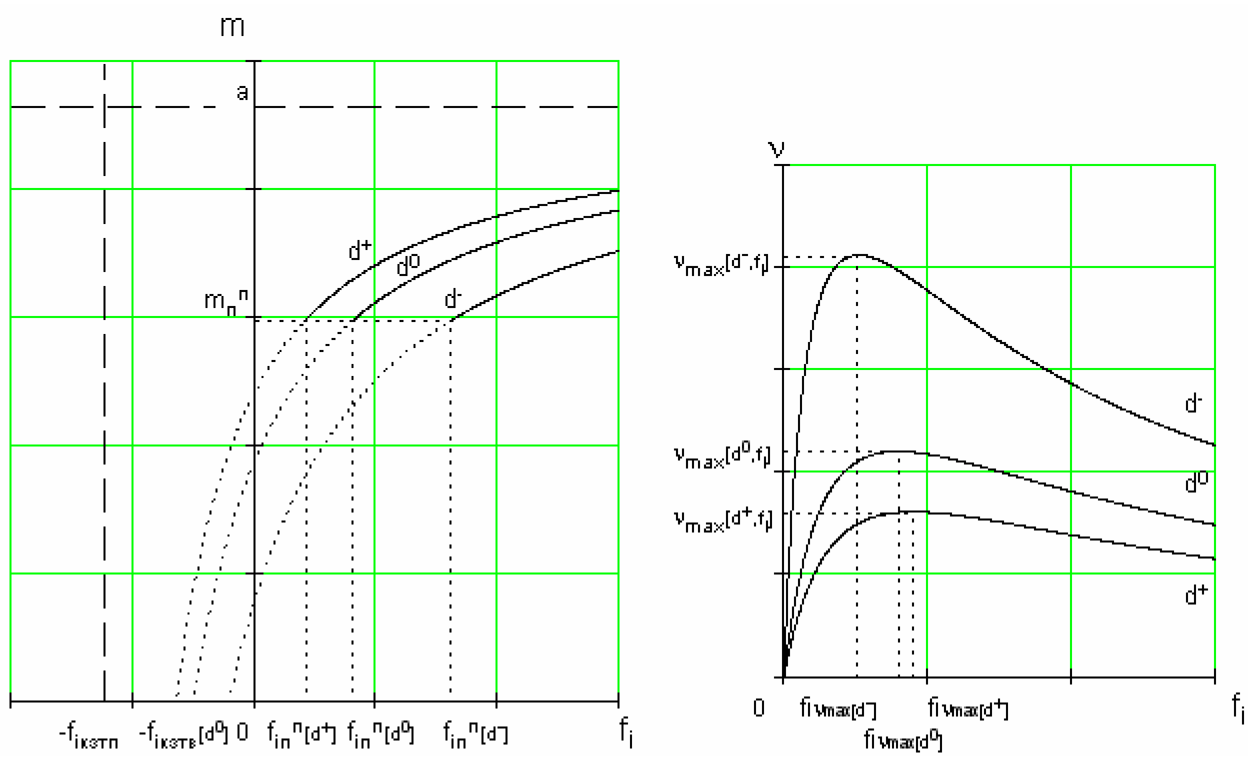
Investigating the equations (20), (21) with the help of the transformations tested on expressions (14) and (15) in range of definition of dependence $m(f_i, d)$, characterized by inequalities $f_i \geq 0$ и $d > 0$, it is possible to reveal features of influence of diameter of charge **CS** on factorial dependences

On schedules fig. 25-30 factorial dependences $m(f_i)$ $\nu_{fi}(f_i)$ for charges **CS** with various **ЭТМВ** are submitted.



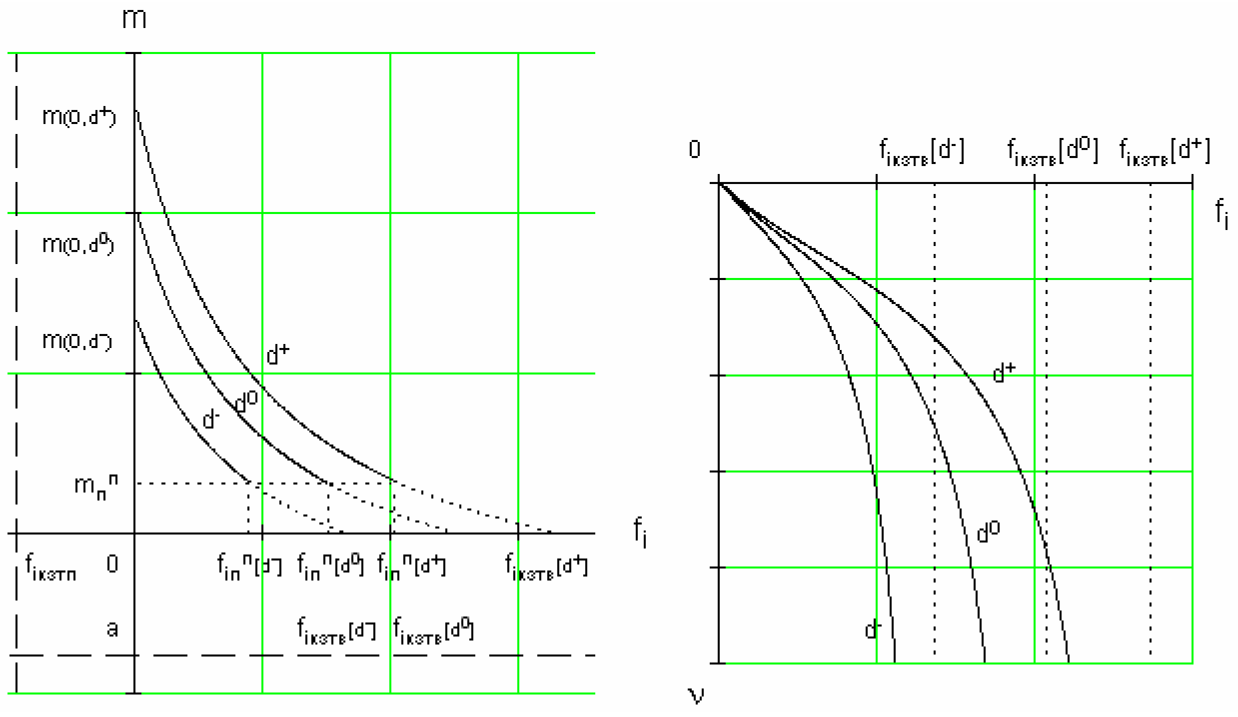
a) б)

Fig. 25. Influence of diameter of a charge on dependences: a)-m(f_i) and б) - $\nu_{fi}(f_i)$ CS factorial EMTI-I with dominating endocomponent h_m (b> 0).



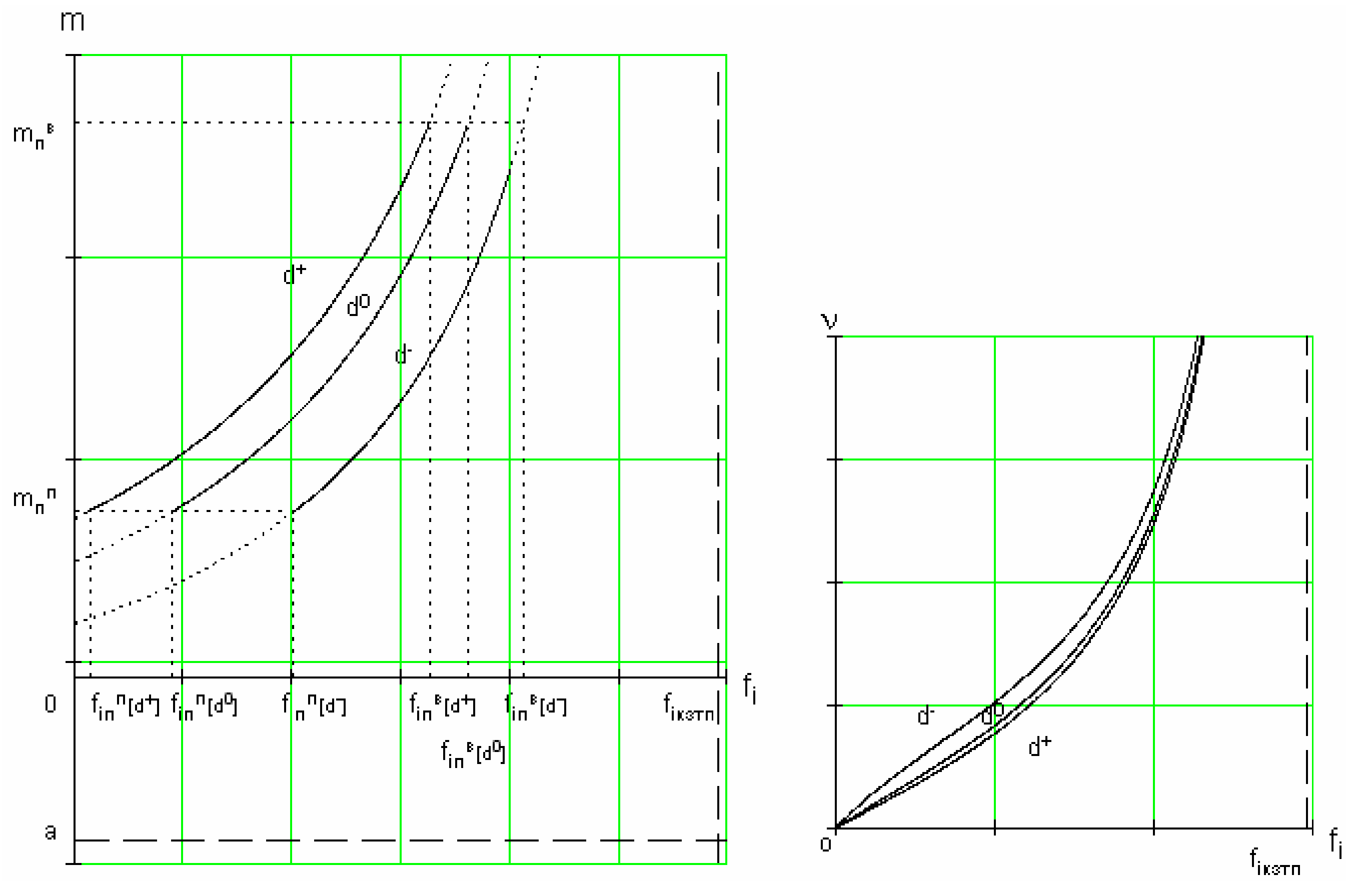
a) б)

Fig. 26. Influence of diameter of a charge on dependences: a)-m(f_i) and б) -ν_{fi}(f_i) CS factorial EMTI-I with dominating exocomponent q_m (b <0).



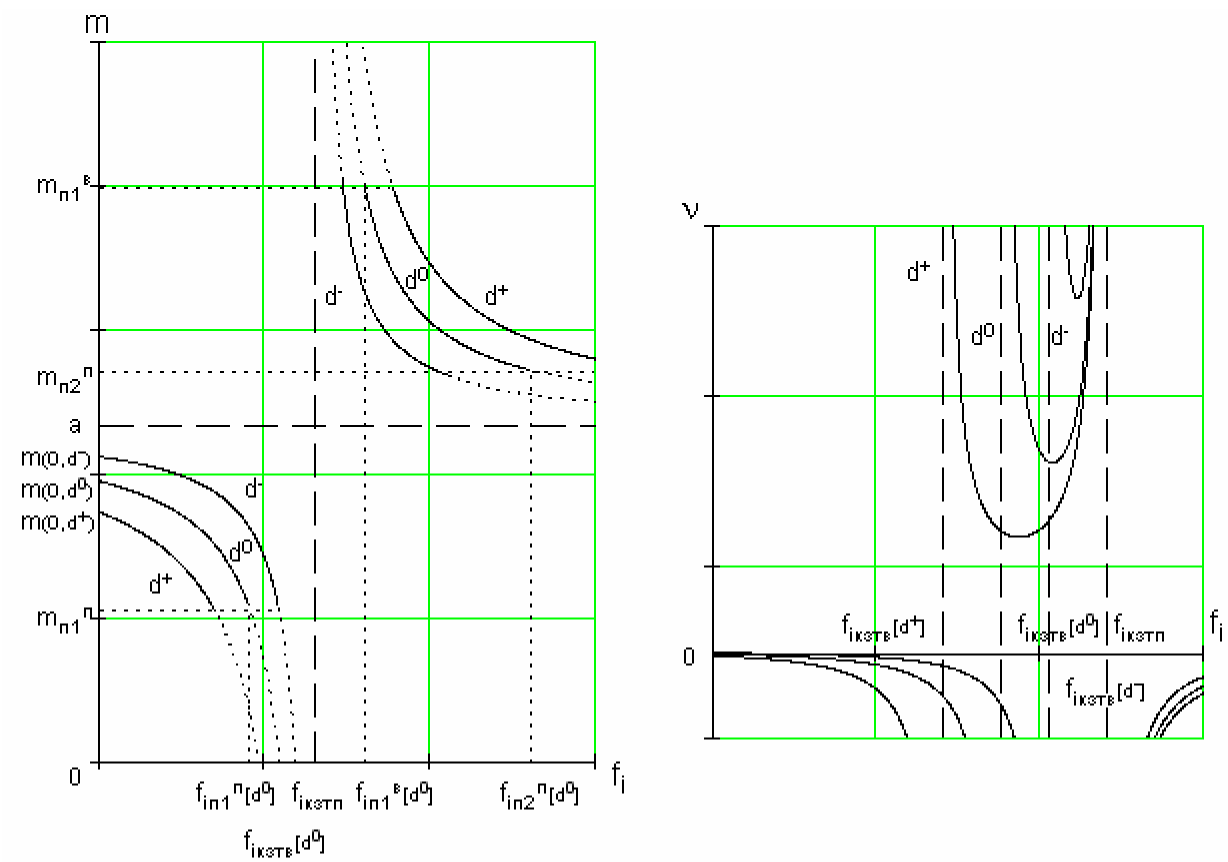
a) б)

Fig. 27. Influence of diameter of a charge on dependences: a)-m (f_i) and б) -ν_{fi}(f_i) CS factorial EMTI-II with endocomponents h_m and q_m (b> 0).



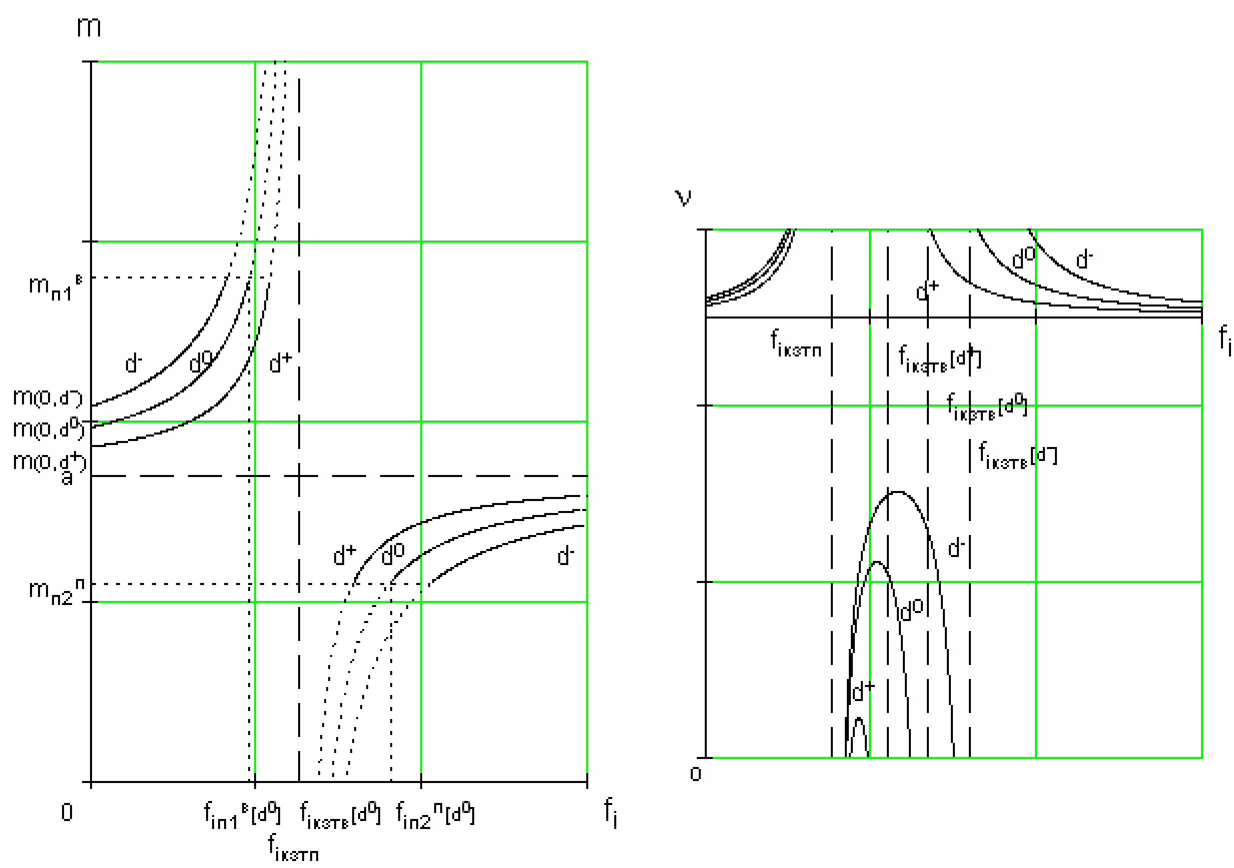
а) б)

Fig. 28. Influence of diameter of a charge on dependences: а)-m(f_i) and б) - ν_{fi}(f_i) CS factorial EMTI-III with exocomponents h_m and q_m (b <0).



а) б)

Fig. 29. Influence of diameter of a charge on dependences: а)-m(f_i) and б) - ν_{fi}(f_i) CS factorial EMTI-IV with dominating endocomponent q_m (b> 0).



a)   б)

Fig. 30. Influence of diameter of a charge on dependences: a)-m(f_i) and б) - $\nu_{fi}(f_i)$ CS factorial EMTI-IV with dominating exocomponent h_m (b <0).

<u>Disscution</u>

In the present report an attempt is made to describe experimental multifactorial laws of RPFC of CS. The main problem in the decision of this task involves consideration of a variety of physico-chemical processes which may occur in the combustion zones.

In theoretical description of EMTI we shall aim at mathematical and physical accuracy neither in the initial equation, nor in the final results, in order not to complicate the main point by unimportant details. All EMTI may be divided into four types. The analysis of EMTI gives a quantitative idea of possible types in substance conversion during combustion processes and permits to draw certain conclusions as regards the regularities in combustion. The above-mentioned simplest types of EMTI may be realized in the real CS.

Systematization of elementary combustion mechanisms and types of their interaction permits proposing a new classification of CS (Tabl.1). CS are classified by physico-chemical processes occurring in combustion. The division of CS to initiating, high explosives (secondary), powders and pyrotechnic systems, used in the theory of explosives reflects the practical use of the substances to a greater degree than their mechanisms of combustion.

The present report is not claimed to be a comprehensive analysis of all theoretical investigations within the field covered.

This report is not claimed either to create a complete theory of stationary combustion of CS. The report is combustion processes complicated by varieties in forms of substance conversion and at systematizing the results obtained.

It is apparently much to be done. In fact, the theory of combustion of CS is just arisen.

Experimental investigation of theoretical nature, especially experimental realization of elementary combustion processes on the simplest CS to correlate experimental and calculated models – all this is of great importance for developing the theory at the present time. Considerable body of the experimental results described in literature does not permit analyzing thoroughly the processes occurred due to complication of systems studied and deficiency in information obtained, and therefore, is of interest in fact for the combustion theory.

The following conclusions can be made:

- in typical models the dependences of RPDZ on different factors for any combustible systems are isomorphic;
- for ehdofactor components h_m, dominating in the model I, the dependence m(f) is decreasing and for exthofactor components q_m it is increasing;
- in the model IV there are critical values of factors; in the left and in the right parts of the neighbourhood of these critical values there are characteristic combinations of two phenomena: a) transition into explosion and extinction at dominating exthofactor components h_m, b) extinction and transition into explosion at dominating endofactor components q_m.

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Table 2

Parametres of the experimental laws $m(f_i)$ RPFC in charges CS, forecasting EMTI-I with dominate endocomponent $h_m(T_H \approx 293K)$.

Смесь, источник	$\frac{d, мм}{ТЗП}$	ρ, $\frac{г}{см^3}$ (ρ/ρ$_{max}$)	Δf$_i$, размерность, среда	a, $\frac{см}{с}$ ($\frac{г}{с \cdot см^2}$)	b,	c, [f]	N	$\lvert\delta\rvert_{max}=\frac{m-m^э}{m}\cdot 100$, %
1	2	3	4	5	6	7	8	9
Mg(94) + $Ba(NO_3)_2$(260) + ξидитол [8]	$\frac{15}{Б01}$	(0,78)	0≤ξ≤0,05	0,411	0,00131	0,00958	4	1,0
Mg(94) + $Ba(NO_3)_2$(54) + ξидитол [8]	$\frac{15}{Б01}$	(0,78)	0≤ξ≤0,05	0,450	0,00268	0,0116	4	1,3
Mg(94) +$Sr(NO_3)_2$(260) + ξидитол [8]	$\frac{15}{Б01}$	(0,78)	0≤ξ≤0,05	0,403	0,00141	0,0113	4	0,8
Mg(94) +$Sr(NO_3)_2$(54) + ξидитол [8]	$\frac{15}{Б01}$	(0,78)	0≤ξ≤0,05	0,471	0,00522	0,0196	4	1,1
Mg(94) +BaO_2(260) + ξидитол [8]	$\frac{15}{Б01}$	(0,78)	0≤ξ≤0,05	0,353	0,000204	0,0392	4	2,3
Mg(94) +BaO_2(54) + ξидитол [8]	$\frac{15}{Б01}$	(0,78)	0≤ξ≤0,05	0,?84	0,000425	0,0111	4	3,3
ПАМ-4 + $NaClO_4$(-018) + ξидитол(-0,18)	$\frac{21}{Б01}$	(0,70)	0≤ξ≤0,075	0,651	0,0202	0,0406	8	3,1
Аммонит №6 + ξ$(NH_4)_2CO_3$(?) [9]	$\frac{15}{Б01}$	(1,0)	0≤ξ≤0,20	(0,705)	(0,0608)	(0,0789)		1,9
Аммонит №6 + дифениламин(?) [9]	$\frac{15}{Б01}$	(1,0)	0≤ξ≤0,20	(0,0507)	(0,1038)	(0,0728)		7,4
МПФ-2 + $NaNO_3$(-018) + ξидитол (?)	$\frac{21}{Б01}$	(0,70)	0≤ξ≤0,20	2,667	39,425	2,274	8	2,1
NH_4ClO_4(100-140) [10]	$\frac{10}{Ñò±ÖÔÏ}$		0≤π≤0,35(π$_п{}^п$)	(0,0669)	(0,443)	(0,2353)	3	-

Продолжение таблицы

1	2	3	4	5	6	7	8	9
0,55МПФ-3 + 0,45KNO_3(-038)+ ξидитол (?)	$\frac{23}{Б01,5}$	(0,82)	0≤ξ≤0,15	0,3456	0,2275	0,162	5	6,4
0,55МПФ-3 + 0,45KNO_3(-038)+ ξидитол (?)	$\frac{23}{Б01,5}$	0,82	0≤ξ≤0,10	2,4550	36,102	5,174	4	1,8
Zr(?) + $Ba(NO_3)_2$(-018) + ξидитол (?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	1,8610	37,738	1,332	8	3,7
ПАМ-4 + $NaNO_3$(-018) + ξГК(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	1,6450	1,592	1,862	8	1,3
ПАМ-4 + $Ba(NO_3)_2$(-018) + ξпарафин(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,16	0,4660	3,422	1,172	8	4,7
Zr(?) + $Ba(NO_3)_2$(-018) + ξпарафин(?)	$\frac{21}{Б01}$	(0,92)	0≤ξ≤0,12	13,8450	90,309	2,982	8	9,5
МПФ-2 + $NaNO_3$(-018) + ξстеарин(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	0,2140	9,527	0,471	6	2,0
МПФ-2 + $Ba(NO_3)_2$(-018) + ξстеарин(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	0,8660	13,323	5,006	6	3,0
МПФ-2 + $NaClO_4$(-018) + ξстеарин(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	0,2550	16,431	4,498	6	1,5
ПАМ-4 + $NaNO_3$(-018) + ξстеарин(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	0,6480	3,780	10,695	6	1,0
Zr(?) + $Ba(NO_3)_2$(-018) + ξстеарин(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	0,1930	11,043	0,368	6	6,7
ПАМ-4 + $Ba(NO_3)_2$(-018) + ξстеарин(?)	$\frac{21}{Б01}$	(0,72)	0≤ξ≤0,12	0,4990	6,186	2,899	6	5,4
0,55МПФ-3 + 0,45KNO_3(-038) + ξГК(?)	$\frac{23}{Б01}$	(0,82)	0≤ξ≤0,15	1,1810	100,903	11,059	6	5,5

0,4Al(?) + 0,60$NaNO_3$(-038) + ξS(?)	23 / Б01	(0,82)	0≤ξ≤0,15	1,0980	0,337	0,840	6	4,0
0,55МПФ-3 + 0,45KNO_3(-038)+ξпарафин (?)	23 / Б01	(0,82)	0≤ξ≤0,15	1,033	0,0304	0,0169	6	R=0,9999

Table 3

Parametres of the experimental laws $m(f_i)$ RPFC in charges CS, forecasting EMTI-I with dominate exocomponent $q_m(T_H \approx 293K)$.

Смесь, источник	d, мм / ТЗП	ρ, $\frac{г}{см^3}$ (ρ/ρ_{max})	Δf_i, размерность, среда	a, $\frac{см}{с}$ ($\frac{г}{с \cdot см^2}$)	b,	c,[f]	N	$\lvert\delta\rvert_{max}=\frac{m-m^Э}{m}\cdot 100$, %
1	2	3	4	5	6	7	8	9
Бикфордов шнур белый (бомба стальная) [12]		? ?	1<P, атм<31,3	3,172 3,103	-20,17 -17,77	8,01 7,24	21 20	16 5,6
Бикфордов шнур белый (трубка стеклянная) [12]		?	0,279<P,атм<2,2	2,960	-10,0	3,69	14	6,1
0,417Mg(50C*) + 0,583$NaNO_3$ (?) [16]	4X4 / DUCO	?	0,99≤P,атм.≤85,1	(6,373)	(-34,088)	(6,521)	7	4,5
0,143Идитол(?) + 0,857KNO_3 (?)	13 / ÑO0,8	0,8	1≤P,атм.≤54	1,237	-23,79	24,98	9	3,6
Порох-Н [17]	? / ?	1,6	4,8≤P,атм.≤145,2	9,283 7,732	-4748 -3054	520,1 401	5 6	6,5 15
Пироксилиновый порох $T_н$≈363K [12]	3,5 ?	(1,0)	2≤P,мм.рт.ст.≤720азот 1≤P,мм.рт.ст.≤720азот	1,509 1,979	-6148,1 -11358,82	4286,17 5971,54	13 14	3,2 15,3
Этилнитрат (EN) [18]	4 / ПТ	(1,0)	13,6≤P,атм.≤61,2	0,86	-36,82	36,37	5	r=0.99
Пропиленгликольдинитрат (PGDN) [18]	4 / ПТ	(1.0)	20,4≤P,атм.≤51,0	10.591	-9481.69	798.28	6	r=0.9987

$[NiR^*_3](NO_3)_2$ (?) [19]	7 / Т0С	1.55-1.75	19,7≤P,атм.≤98,7 в азоте	0.467	-132.2	282	6	6,0
$[CrR^*_3](NO_3)_3$ (?) [19]	7 / Т0С	1,55-1,75	4,5≤P,атм.≤29,0 в азоте	0,402	-4,73	14,29	4	3,2
0,5W(2÷5) + 0,5BaO_2(<80) [20]	7 / ТПГ	0,8-0,97	4,5≤P,атм.≤40	33,89	-63,09	257,9	5	0,2
W(~)+$KClO_4$(~) [21]	8 / ЛГ	(0,7-0,9)	5,8≤P,атм.≤97,8 азот	13,56	-1817	143	5	3,3
Декстрин + $KClO_4$(~) [21]	8 / ЛГ	(0,96-0,98)	5,8≤P,атм.≤97,8 азот	2,64	-107,3	40,97	5	2,7
Плексиглас+$KClO_4$(~)желатинированная[21]	8 / ЛГ	(0,96-0,98)	5,8≤P,атм.≤97,8 азот	9,30	-2613	287,4	6	3,8
Плексиглас(<3) + NH_4ClO_4(5) [21]	8 / ЛГ	(0,96-0,98)	5,8≤P,атм.≤97,8 азот	1,73	-68,38	47,02	5	4,4
Плексиглас + NH_4ClO_4(5) [21] желатинированная	8 / ЛГ	(0,96-0,98)	5,8≤P,атм.≤97,8 азот	4,9	-340,9	89,29	6	4,2
Плексиглас(<3) + NH_4ClO_4(140-320) [21]	8 / ЛГ	(0,96-0,98)	5,8≤P,атм.≤97,8 азот	0,85 0,99	-21,19 -44,65	29,74 55,53	5 4	8,3 1,3
Плексиглас + NH_4ClO_4(140-320) [21] желатинированная	8 / ЛГ	(0,96-0,98)	5,8≤P,атм.≤97,8 азот	3,06	-936,9	325,7	5	2,4
0,25Каучук Р-13 + 0,75NH_4ClO_4(120) [22]	5x5 / –	?	1≤P,атм.≤100 азот	1,058	-51,598	53,63	12	r=0,98654
0,25Каучук Р-13 + 0,75NH_4ClO_4(16) [22]	5x5 / –	?	1≤P,атм.≤100 азот	1,913	-107,57	60,05	8	r=0,99079
Битум+$KClO_4$(10) [23]	?	(1,0)	1<P,атм<125	13,257	-3782,34	288,17	14	10
Битум+$KClO_4$(70) [23]	?	(1,0)	1<P,атм<125	6,441	-1320,67	210,8	13	9
Битум+$KClO_4$(200) [23]	?	(1,0)	1<P,атм<125	8,427	-3012,74	365,1	20	12
Битум+$KClO_4$(1700) [23]	?	(1,0)	1<P,атм<125	34,48	-72510,75	209,54	18	15

Нитрогликоль [24]	3,9 / ÑO0,8	(1.0)	305<P,мм рт.ст.<668	5.603	-9214,32	1639,72	16	4,55
Октоген [25]	7 / ÏÑ	1,72	0,3<P,атм<101	(37,525)	(-39876)	(1063,7)	10	8
Октоген + 0,15МНТ [25]	7 / ÏÑ	1,84	11<P,атм<101	(30,469)	(18314,9)	(602,9)	5	6
Порох Н + 0,05МНТ [25]	6 / ÏÑ	(1,0)	1<P,атм<100	40,62	-7850,92	199,1	15	5
Порох Н + 0,1МНТ [25]	6 / ÏÑ	(1,0)	1<P,атм<100	38,104	-4434	119,5	20	5
Порох Н + 0,15МНТ [25]	6 / ÏÑ	(1,0)	1<P,атм<100	50,555	-6671,68	135,81	24	5
0,70МПФ-3 + 0,30$NaNO_3$ (?)	13 / БО0,8	(0,8)	150≤P,мм.рт.ст.≤760	16,711	-253,120	120,14	5	3,4
0,70МПФ-3 + 0,30$NaNO_3$ (?)	13 / ЖО0,8	(0,8)	100≤P,мм.рт.ст.≤760	9,784	-3610,7634	1119,83	5	1,7
0,30МПФ-3 + 0,70$NaNO_3$ (?)	13 / БО0,8	(0,8)	10≤P,мм.рт.ст.≤760	0,933	-604,334	813,72	8	7,0
0,312МПФ-3 + 0,688Fe_2O_3 (?)	13 / БО0,8	(0,8)	100≤P,мм.рт.ст.≤760	0,977	-832,074	1060,17	6	7,6
0,130МПФ-3 + 0,870BaO_2 (?)	13 / БО0,8	(0,8)	10≤P,мм.рт.ст.≤760	0,925	-274,236	379,76	8	5,0
0,10$Al_{порошок}$ + 0,90BaO_2 (?)	13 / БО0,8	(0,8)	20≤P,мм.рт.ст.≤760	0,652	-93,781	169,50	7	5,2
0,10$Al_{пудра}$ + 0,90BaO_2 (?)	13 / БО0,8	(0,8)	20≤P,мм.рт.ст.≤760	1,274	-310,924	439,47	7	1,8
0,09S(?) + 0,91BaO_2 (?)	13 / БО0,8	(0,8)	10≤P,мм.рт.ст.≤760	0,470	-28,832	127,47	8	4,1

0,375МПФ-3 + 0,625KNO_3 (?)	$\frac{13}{ÑO0,8}$	(0,8)	10≤P,мм.рт.ст.≤760	0,845	-55,293	187,56	6	3,5
0,315МПФ-3 + 0,685$Ba(NO_3)_2$ (?)	$\frac{13}{ÑO0,8}$	(0,8)	300≤P,мм.рт.ст.≤760	0,564	-421,572	892,82	4	0,8
0,415МПФ-3(3) + 0,585$Na(NO_3)_2$ (?)	$\frac{13}{ÑO0,8}$	(0,8)	10≤P,мм.рт.ст.≤760 воздух	1,361	-143,181	139,20	7	5,6
0,143Идитол(?) + 0,857KNO_3 (?)	$\frac{13}{ÑO0,8}$	0,8	50≤P,мм.рт.ст.≤760 воздух	0,366	-75,391	187,81	6	4,8
0,143Идитол(?) + 0,857KNO_3 (?)	$\frac{13}{БO0,8}$	0,8	10≤P,мм.рт.ст.≤760 воздух	0,423	-139,016	399,47	6	2,3
0,55МПФ-3 + 0,45KNO_3(-038) + ξB(?)	$\frac{23}{БO1,5}$	(0,65-0,8)	0≤ξ≤0,15	1,35	-0,327	1,16	6	0,9
0,55МПФ-3 + 0,45KNO_3(-038) + ξSi(?)	$\frac{23}{БO1,5}$	(0,65-0,8)	0≤ξ≤0,15	1,38	-0,055	0,157	6	0,7
0,55МПФ-3 + 0,45KNO_3(-038) + ξSi(?)	$\frac{23}{БO1,5}$	(0,65-0,8)	0≤ξ≤0,15	2,310	-0,140	0,195	6	0,9975
0,55МПФ-3 + 0,45KNO_3(-038)+ξПАМ(?)	$\frac{23}{БO1,5}$	(0,65-0,8)	0≤ξ≤0,15	1,07	-0,0023	0,058	6	1,6
0,19$Al_{пудра}$(?) + 0,78BaO_2(?) + 0,03идитол(?)	?	(0,8)	10≤P,мм.рт.ст.≤760	1,446	-151,044	198,15	8	3,3
0,415МПФ-3 + 0,585$NaNO_3$(?) +0,05идитол (?)	?	(0,8)	10≤P,мм.рт.ст.≤760	0,9705 1,682	462,0 2805,0	580,3 1935	7 6	13 8,8
0,415МПФ-3 + 0,585$NaNO_3$(?) +0,05идитол (?)	?	(0,8)	10≤P,мм.рт.ст.≤760	0,980	-465,394	591,62	5	3,4
0,415МПФ-3 + 0,585$NaNO_3$(?) +0,05стеарин(?)	?	(0,8)	80≤P,мм.рт.ст.≤760	0,264	-60,691	261,84	6	3,0
0,315МПФ-3 + 0,685$Ba(NO_3)_2$	?	(0,8)	1≤P,атм.≤201 воздух	8,198	-2843,307	370,40	13	27,0
0,315МПФ-3 + 0,685$Ba(NO_3)_2$	?	(0,8)	1≤P,атм.≤50	3,618	-226,267	69,67	9	10,0

ПАМ-4 +$NaClO_4$(-0,1.) + ξидитол	$\frac{21}{ÁO1}$	(0,72)	0≤ξ≤0,12	0,664	-0,0059	0,0122	6	1,4

*-R -этилендиамин

Table 4

Parametres of the experimental laws $m(f_i)$ RPFC in charges CS, forecasting EMTI-II with endocomponents h_m and q_m (T_H ≈293K).

Смесь, источник	$\frac{d,\ мм}{ТЗП}$	ρ, $\frac{г}{см^3}$ (ρ/ρ_{max})	Δf_i,размерность ,среда.	a, $\frac{см}{с}$ ($\frac{г}{с \cdot см^2}$)	b,	c,[f]	N	$\lvert\delta\rvert_{max}=\frac{m-m^э}{m}\cdot 100$, %
1	2	3	4	5	6	7	8	9
Mg(<110) + 0,45$Ba(NO_3)_2$(-018) + ξидитол (?)	$\frac{21}{БО1}$	(0,7)	0≤ξ≤0,1	-3,57	2,237	0,424	-	1,7
0,55МПФ-3 + 0,45KNO_3(-038) + ξидитол (?)	$\frac{23}{–}$	(0,65-0,8)	0≤ξ≤0,15	-0,44	0,334	0,141	5	16
0,55МПФ-3 + 0,45$NaNO_3$(-0,38) + ξидитол (?)	$\frac{23}{БО1,5}$	(0,65-0,8)	0≤ξ≤0,15	-0,50	0,218	0,100	5	16
2CO + O_2 + 0,018H_2O + ξCCl_4 [26]	?	(1,35-1,41) 10^{-3}	0≤ξ≤0,055	(-37,53)	(3,216)	(0,0187)	4	14
0,55МПФ-3 + 0,45KNO_3(-038) + ξидитол (?)	$\frac{20}{–}$	(~0,82)	0≤ξ≤0,15	(-0,798)	(0,525)	(0,139)	5	(0,96505)
0,55МПФ-3 + 0,45KNO_3(-0,38) + ξидитол (?)	$\frac{23}{Б01,5}$	(~0,82)	0≤ξ≤0,15	(-0,410)	(0,280)	(0,138)	5	(0,99697)
0,55МПФ-3 + 0,45KNO_3(-0,38)+ ξканифоль (?)	$\frac{20}{–}$	(~0,82)	0≤ξ≤0,15	(-4,099)	(1,803)	(0,255)	5	(0,98576)

0,55МПФ-3 + 0,45KNO_3(-0,38)+ ξканифоль(?)	$\frac{23}{Б01,5}$	(~0,82)	0≤ξ≤0,15	(-0,121)	(0,0571)	(0,0333)	5	(0,99988)
0,55МПФ-3 + 0,45KNO_3(-0,38) + ξстеарин (?)	$\frac{20}{–}$	(~0,82)	0≤ξ≤0,15	(-1,131)	(0,199)	(0,0499)	5	(0,99624)
0,55МПФ-3 + 0,45KNO_3(-0,38) + ξстеарин (?)	$\frac{23}{Б01,5}$	(~0,82)	0≤ξ≤0,15	(-2,052)	(0,564)	(0,152)	5	(0,98088)
0,55МПФ-3 + 0,45KNO_3(-0,38)+ ξнафталин (?)	$\frac{21,8}{–}$	(~0,82)	0≤ξ≤0,15	(-5,752)	(6,340)	(0,730)	5	(0,97302)
0,55МПФ-3 + 0,45KNO_3(-0,38)+ ξнафталин (?)	$\frac{23}{Б01,5}$	(~0,82)	0≤ξ≤0,15	(-0,625)	(0,646)	(0,252)	5	(0,99934)

Table 5

Parametres of the experimental laws $m(f_i)$ RPFC in charges CS, forecasting EMTI-III with exocomponent h_m and q_m (T_H≈293K).

Смесь, источник	$\frac{d,\ мм}{ТЗП}$	ρ, $\frac{г}{см^3}$ (ρ/ρ_{max})	Δf_i, размерность, среда.	a, $\frac{см}{с}$ $\left(\frac{г}{с \cdot см^2}\right)$	b,	c,[f]	N	$\lvert\delta\rvert_{max}=\frac{m-m^э}{m}\cdot 100$, %
1	2	3	4	5	6	7	8	9
W(2÷5) + $Ba(NO_3)_2$(<80) [25]	$\frac{7}{ПГС}$	(0,8-0,97)	4,9≤P,атм≤80	-36,49	-41556,20	-11169,39	4	17
W(2÷5) + $Pb(NO_3)_2$(<80) [25]	$\frac{7}{ПГС}$	(0,8-0,97)	4,9≤P,атм≤80	-1489,49	-6081,49	-349,02	6	4,0
W(2÷5) + $KClO_4$(<80) [25]	$\frac{7}{ПГС}$	(0,8-0,97)	4,9≤P,атм≤80	-32,46	-20409,03	-437,26	8	3,2
NH_4 ClO_4( ) + 0,25ХМ(?) [27]			194≤P,атм≤348	-30,28	-36735,15	-1097,71	7	8,6
NH_4 ClO_4( ) + Cr_2O_3 [27]			237≤P,атм≤339	-11,33	-4368,08	-514,876	3	-

Уротропин(?) + NH_4 ClO_4(140-320) [28]			9,8≤P,атм≤97	-26,09	-81171,41	-2192,07	5	6,9
Уротропин(?) + NH_4 ClO_4(?) + 0,1Al(<2) [28]			9,8≤P,атм≤97	-910,99	-758343,61	-826,85	5	7,0
Порох пироксилиновый [24]	$\frac{5}{АШ2}$		6≤P,атм≤50 воздух	-512,83	-367484,61	-6072,59	7	4,2
Порох Н состава III [24]	$\frac{5}{АШ2}$		6≤P,атм≤50 воздух	-980,35	-1182528,13	-1204,36	10	2,5
Порох Н ($T_н$=383-388К) [17]	$\frac{3-5}{?}$		2≤P,мм.рт.ст.≤640 азот	-2,146	-13286,15	-6072,59	6	1,8
Порох Н ($T_н$=363К) [17]	$\frac{3-5}{?}$		2≤P,мм.рт.ст.≤640	-1,492	-6888,92	-4483,42	7	2,4
Пироксилин ($T_н$=363К) [17]	$\frac{3-5}{?}$		2≤P,мм.рт.ст.≤670 продукты сгорания	-0,182	-438,86	-1626,54	9	3,1
Пироксилин ($T_н$=363К) [17]	$\frac{3-5}{?}$		2≤P,мм.рт.ст.≤620	-0,616	-2135,09	-3051,63	10	
$[CuR_2](NO_3)_2$ (?) [19]	$\frac{7}{ТОС}$	1,55-1,75	19,7≤P,атм≤98,7	(-0,203)	(-65,07)	(-181,6)	10 8	14 6,0

Table 6

Parametres of the experimental laws $m(f_i)$ RPFC in charges CS, forecasting EMTI-IV with dominate endocomponent q_m ($T_H \approx 293K$).

Смесь, источник	$\frac{d,\ мм}{ТЗП}$	ρ, $\frac{г}{см^3}$ (ρ/ρ_{max})	Δf_i, размерность, среда	a, $\frac{см}{с}$ ($\frac{г}{с \cdot см^2}$)	b,	c,[f]	N	$\lvert\delta\rvert_{max} = \frac{m-m^э}{m} \cdot 100$, %
1	2	3	4	5	6	7	8	9
0,55МПФ-3 + 0,45KNO_3(-038) + ξAl(?)	$\frac{23}{Б01,5}$	(0,65-0,8)	0≤ξ≤0,15	2,28	2,805	-1,62	5	1,9
0,55МПФ-3 + 0,45KNO_3(-038) + ξC^*(?)	$\frac{23}{Б01,5}$	(0,65-0,8)	0≤ξ≤0,15	2,75	1,112	-0,67	5	10
ПАМ-4 + $Ba(NO_3)_2$(-018) + ξ идитол(?)	$\frac{21}{Б01}$	(0,7)	0,025≤ξ≤0,010	1,1635	0,116986	-0,28433	6	0,9
0,55МПФ-3 +0,45$Sr(NO_3)_2$(-038) + ξ идитол(?)	$\frac{23}{Б01,5}$	(0,65-0,8)	0≤ξ≤0,2	0,4214	0,0724	-0,437	5	0,8
Al(-90+110) + MnO_2(94) [8]	$\frac{15}{Б01}$		1,45≤ρ,г/$см^3$≤2,27	0,8875	0,00488	-2,305	4	6,8
МПФ-2 + $Ba(NO_3)_2$(-018) + ξидитол(?)	$\frac{21}{Б01}$	(0,7)	0б025≤ξ≤0,1	0,6657	0,01324	-0,1393	4	0,3
МПФ-2 + $Ba(NO_3)_2$(-018) + ξ идитол(?)	$\frac{15}{Б01}$	(0,7)	0≤ξ≤0,1	18,412	71,2019	-4,0548	4	0,9
Mg(54) + BaO_2(54) [8]	$\frac{15}{Б01}$		1,88≤ρ,г/$см^3$≤4,07	(1,273)	(0,1183)	(-2,482)	4	4,7
АМ(54) + MnO_2(54) [8]	$\frac{15}{Б01}$		2,22≤ρ,г/$см^3$≤2,5	(0,8858)	(0,00965)	(-2,615)	4	1,2
АМ(54) + $NaNO_3$(54) [8]	$\frac{15}{Б01}$		1,34≤ρ,г/$см^3$≤1,65	(0,1703)	(0,0875)	(-1,144)	3	-
АМ(54) + Sr $(NO_3)_2$(54) [8]	$\frac{15}{Б01}$		1,47≤ρ,г/$см^3$≤1,91	(0,0747)	(0,0459)	(-1,362)	3	-

ПХА(<53) [29]			156≤P,атм≤193	28,470	2605,048	-321,282	3	-
W(2÷5) + BaO_2(<80) [20]	$\frac{7}{ТПС}$	(0,87-0,97)	4,97≤P,атм≤80	22,326	316,163	-118,721	6	1,7
Mg(54) + $Ba(NO_3)_2$(54) [8]	$\frac{15}{Б01}$		1,27≤ρ,г/см^3≤2,43	(0,0866)	(0,4502)	(-1,1167)	4	9,5
Mg(54) + $Sr(NO_3)_2$(54) [8]	$\frac{15}{Б01}$		1,15≤ρ,г/см^3≤2,28	(0,215)	(0,368)	-0,9236	4	12
Zr(?) + $NaNO_3$(-0,18) + ξидитол(?)	$\frac{21}{Б01}$	(0,7)	0≤ξ≤0,10	48,299	338,783	-18,167	5	6,4
ПАМ-4 + BaO_2(-0,18) + ξ идитол(?)	$\frac{21}{Б01}$	(0,70)	0≤ξ≤0,10	8,648	8,573	-1,473	5	2,3
0,5W(2-5) + 0,5BaO_2(<80) [20]	$\frac{7}{ТПГ}$	(0,8÷0,97)	49,3≤P,атм≤80	15,56	198,1	-116,0	4	1,8

Table 7

Parametres of the experimental laws $m(f_i)$ RPFC in charges CS, forecasting EMTI-IV with dominate exocomponent $h_m(T_H \approx 293K)$.

Смесь, источник	$\frac{d, мм}{ТЗП}$	$\rho, \frac{г}{см^3}$ (ρ/ρ_{max})	Δf_i, размерность, среда	a, $\frac{см}{с}$ $(\frac{г}{с \cdot см^2})$	b,	c,[f]	N	$\lvert\delta\rvert_{max}=\frac{m-m^э}{m}\cdot 100$, %
1	2	3	4	5	6	7	8	9
$NH_4ClO_4 + MnO_2$ [29]			139≤P,атм≤343	17,18	-658,80	-84,94	9	5,5
$NH_4ClO_4 + NaMnO_3 \cdot 3H_2O$ [29]			100≤P,атм≤335	1,727	-394531	-406,53	4	25
NH_4ClO_4(<53) I $T_н$ [29]			111≤P,атм≤156	9,83	-44,44	-171,97	7	3,7
NH_4ClO_4(74-105) [29]			96≤P,атм≤158	16,27	-78,73	-16,51	5	1,2
Сахар (?) + $KClO_3$(-018)	$\frac{21}{БО1}$	0,7	50≤P,мм.рт.ст.	4,85	-551,18	-20,44	4	9,6
0,55МПФ-3 + 0,45KNO_3(-038) + ξFeSi	$\frac{23}{БО1,5}$	0,67-0,8	0≤ξ≤0,15 воздух	1,06	-0,00072	-0,20	5	2,8
Гексоген(?) [24]	$\frac{7}{ТПГ1}$	(0,9-0,95)	0≤h($T_н$), $\frac{Дж}{г}$ 0≤ h(453)	0	(-30,46)	(-561,9)	5	1,76
ПХА [30]	$\frac{12,7}{?}$		94,7≤P,атм≤195,2	(2,716)	(-36,780)	(-64,206)	7	0,23
ПХА [30]	$\frac{5x5}{}$	0,67-0,8	102,3≤P,атм≤198,8	(2,917)	(-64,716)	(-61,742)	6	0,47
$[CrR^*_3](NO_3)_3$ [19]	$\frac{7}{ТОС}$	1,55-1,75	29≤P,атм≤98,7	(0,205)	(-13,40)	(-141,5)	5	2,0
0,365МПФ-3 + 0,635$Sr(NO_3)_2$	$\frac{13}{ЖО0,8}$	(0,8)	200≤P,мм.рт.ст.≤760	0,486	-18,413	-73,953	4	0,3

0,55МПФ-3 + 0,45KNO_3(-038) + ξFeSi	$\frac{23}{БО1,5}$	0,67-0,8	0≤ξ≤0,15 воздух	1,06	-0,00072	-0,20	4	2,8
Н-пропиленнитрат NPN [18]	$\frac{4}{ПТ}$		51≤P,атм≤81,6	0,3024	-4,282	-22,468	4	(0,99687)
Na + воздух [31]	$\frac{100}{?}$	0,890 при T=533K	h(523)0≤h($T_н$), $\frac{Дж}{г}$ ≤h(1023)	0	(-5836)	(-1291,87)	18	15,6
0,419Mg(130) + 0,581KNO_3(120)		(0,8)	213-473	0	-6866	-663,8	6	1,1
0,365Mg(130) + 0,635$Sr(NO_3)_2$(120)		(0,8)	213-473	0	-5471	-732,4	8	1,3
0,317g(130) + 0,683$Ba(NO_3)_2$(120)		(0,8)	213-473	0	-4435	-696,7	5	1,8
0,314Mg(35) + 0,686Fe_2O_3(275)		(0,8)	213-473	0	-31970	-1284,6	7	1,5
0,262Al(40) + 0,738Cr_2O_3( )		(0,7)	213-473	0	-1989	-496,0	9	1,8