SibTest 2015 IOP Publishing
Journal of Physics: Conference Series **671** (2016) 012030 doi:10.1088/1742-6596/671/1/012030

Definition of Time Induction of Self-Ignition of the Substance on the Prognostic Extrapolation Depending on the Basis of Indicators Fire and Explosion Hazard

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Abstract. In this article the research directed on development of a technique of definition of time of induction of the self-ignition of substances and materials which is an indicator of the beginning of development of an emergency is conducted. The experiment consisting in supervision over process of self-ignition of coal and oil deposits was the basis for research. On the basis of experimental data the curve expressing analytic - expected dependence of size of temperature of ignition on induction time was constructed. Proceeding from graphical representation of process, functional dependence of time of induction on a temperature indicator was received: $y = 16920 \cdot x^{0.537}$. By means of known indicators of such substances as bitumen oil oxidized (the combustible solid substance received by oxidation of residual product of oil refining) and tar oil (the combustible solid substance which is residual product of oil refining) and the received algorithm, verification of reliability of the received dependence and a technique of definition of time of induction of spontaneous ignition of deposits of oil in general was carried out. The practical importance of the conducted research is that having data on time of induction of process of self-ignition, by means of preventive measures becomes possible to avoid and prevent accidents in oil and oil processing branches, at the same time loss of property and loss of human life.

1. Introduction

The phenomenon of spontaneous ignition of substances and materials can be defined as direct emergence of burning of substance in lack of a source of ignition. It causes interest of scientists since the end of the 19th eyelid, and to this day. The greatest attention is paid now to questions of calculation of time of induction of process of spontaneous ignition which has a practical interest: prevention of emergence of industrial accidents. Coal mining and processing of coal, and also oil and oil processing - the most presented influence of this process. They are united by one property of the recycled materials: spontaneous ignition under certain conditions. As shows the analysis of self-ignition of coal volumes and deposits, process this repeated factor and one of major factors – time of induction of process of spontaneous ignition. The analysis of the reasons of accidents which occurred in parks of a reservoir for storage of oil products and oil products [1, 2], allowed to show that about 40% of accidents happen during cleaning and repair of tanks, one of which reasons - direct ignition of oil pools as relevance of the reasons of a case in point and requirement of more attentive studying. Supervision of some materials, from the growing old provisions of time, I showed that their chemical activity doesn't decrease, and they remain in the same degree of potential danger as were [3, 4].

It is known that indicators of fire-and-explosion hazard of substances and materials decide on the purpose of receiving basic data for development of systems on ensuring fire safety and explosion safety [5]. But developers quite often come up against a situation when the lack of physical and chemical data

on substance doesn't allow to carry out by calculation methods of the complex analysis of fire-and-explosion hazard of this or that substance turned in technological process.

The known approaches to definition of conditions of thermal self-ignition of substances and materials offered by a number of the leading scientific centers of Russia are also not very successful.

Based on thermodynamic processes which happen in substance at its heating, the assumption was made that time of induction of these processes can be described by some one dependence – the speed of accumulation of heat in system. Temporary characteristics by which researchers the indicators of fire-and-explosion hazard of indicators of substances and materials are guided, were analysed from thermodynamics positions. The result of the analysis showed that it is possible to be guided by such indicators as group of combustibility, spontaneous ignition temperature, decay temperature, temperature of flash and temperature of the beginning of thermal destruction or sublimation of substance.

The problem which was solved in this work, consisted in definition on known temperature indicators of fire-and-explosion hazard of methodical approach in definition of time of induction of process of the self-ignition of substances and materials characterizing the beginning of development of some emergency process.

2. Calculated part

Process of self-ignition of coal [6,7] and oil deposits [8] was the basis for algorithm of research. These substances have a different set of indicators of fire-and-explosion hazard (Table 1 [5]).

Table 1. The list of the indicators of fire-and-explosion hazard presented to the analysis

Name of substance	Indicator of fire-and-explosion hazard of substance				
	Group of combustibility	Self-ignition temperature	Decay temperature	Flash point	Onset temperature of thermal decomposition or subliming
Coal of brand CC of the Kuzbass pool	+	+	+	–	+
Oil deposits	+	+	+	+	+

From table 1 it is visible that for coal of brand CC there is no possibility of use of an indicator – flash Temperature. Circuitry of the instrument on which experiments with samples of coal of brand CC of the Kuzbass pool were made, by determination of temperature of self-ignition is presented in figure 1.

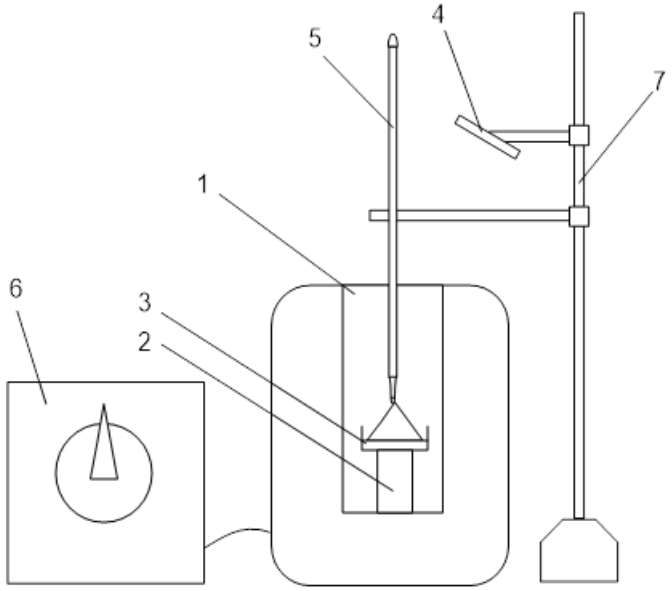


Figure 1. Circuitry of the instrument for determination of parameters of self-ignition of substances and materials: 1 – the electric furnace (V=1000ml); 2 – quartz support; 3 – a porcelain support for substance; 4 – viewing mirror; 5 – mercury thermometer; 6 – laboratory autotransformer; 7 – support.

Researches were conducted according to "A method of experimental determination of temperature of self-ignition of strong substances and materials", presented to industry standard 12.1.044-89.

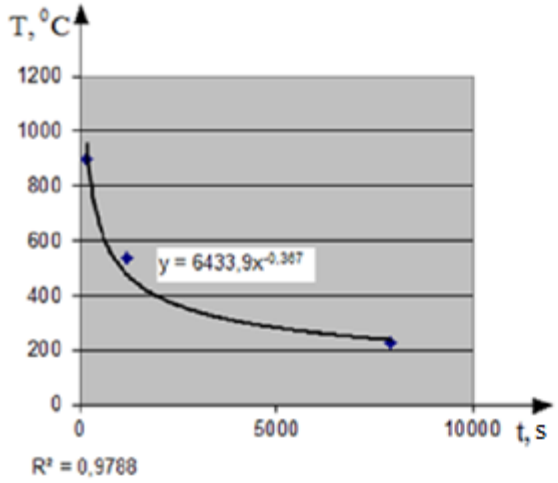
The received results of the conducted researches are presented in Table 2.

Having carried out the analysis of definition the fire-and-explosion hazard characteristics for the considered combustible strong substance – coal of the Kuzbass pool of brand CC, according to characteristics, known in literature, and also by results of the conducted researches (Table 2), the curve expressing analytic-expected dependence of size of temperature of ignition on time of induction (figure 2) was constructed.

Table 2. Sample temperature growth rate when carrying out experiment

Indicator temperature, ºC		Induction time, *s*	Temperature growth rate, ºC/s
Flammability class	900	35	26
Self ignition	535	60	9
Decay temperature	350	1200	0.3
Decay temperature	224	7920	0.03

The method of expected extrapolation – operation of extrapolation of a trend with use of the Microsoft Excel program was applied to processing of the received results.



Indicator temperature, ºC		Induction time, s
Flammability class	900	35
Self ignition	535	1200
Decay temperature	224	7920

Figure 2. Expected and extrapolation dependence of size of temperature of ignition on temperature growth rate at present time T/s, according to characteristics of fire-and-explosion hazard of coal of brand CC.

The size of reliability of approximation (*R2*) on the available initial temperature indicators makes 0.9788 that is considered admissible.

The function describing the received expected and extrapolation curve has an appearance of exponential function:

$$y = k \cdot x^n \tag{1}$$

where *k*, *n* – the constants determined by expected and extrapolation dependence on the basis of experimental data.

For coal of the Kuzbass pool of brand CC the following constants were defined: *k*=6433.9, *n*=-0.3674.

Thus, expression 1 is the expected and extrapolation dependence constructed on experimental data and allowing to define induction time before emergence of burning at a certain temperature. We will write down expression 1 in a form, convenient for production workers

$$T = 6433.9 \cdot \tau^{0.3674} \tag{2}$$

where *T* – substance temperature at the available speed of heating, °C; τ – a high-speed indicator of time of induction, *s*.

This expression 2 can represent great practical value for branches of coal mining, consumption and processing.

3. Results

The received algorithm of research was applied to studying of process of self-ignition of the oil deposit taken from an oil separator. Possibility of this step locates that the passing mechanism on a spontaneous ignition curve for coal and a deposit of oil is identical, that these substances in the course of the transformation pass physical and chemical phases similar each other.

Thus, for the studied oil deposit which part are, including oxides of metals, the complex of researches on the scheme presented earlier and construction Expected and extrapolation dependence according to characteristics of fire-and-explosion hazard (Table 3, figure 3) was carried out [5].

Table 3. Characteristics of fire-and-explosion hazard of deposits of oil

Indicator temperature, ºC		Induction time, s	Temperature growth rate, ºC/s
Flammability class	900	52	31.7
Self ignition	550	63	9
Flashover	150	4500	0.03
Decay temperature	100	10800	0.01

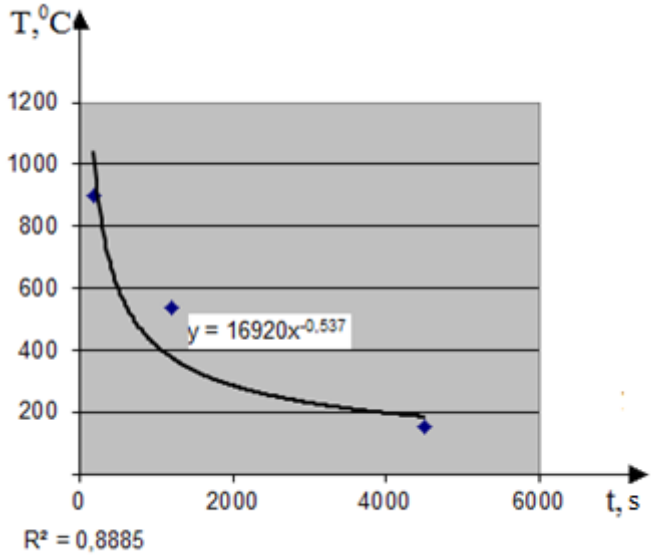


Figure 3. An expected and extrapolation curve according to characteristics of fire-and-explosion hazard of deposits of oil.

The received expected and extrapolation curve has sedate dependence:

$$y = 16920 \cdot x^{-0.537}$$

Having algorithm of calculation of time of induction for such substances as bitumen oil oxidized (the combustible strong substance received by oxidation of residual product of oil refining) and tar oil (the combustible strong substance which is residual product of oil refining), carried out an inspection of reliability of the received dependence and a technique of definition of time of induction of spontaneous ignition of deposits of oil in general [1, 3].

For the bitumen oxidized a formula for calculation of conditions of oil self-ignition:

$$lgt=2.2912-0.122 \cdot lg\tau \text{ [4]},$$

where t – temperature equal 204^{0}C; τ – time of induction of substance.

Value of the second parameter is calculated:

$$lg\tau = (lgt-2.2912)/(-0.122) = -0.151$$

$$\tau = 10^{-0.151} = 2542 \text{ s.}$$

For tar oil:

$$lg\ t = 2.3106 - 0.122 \cdot lg\ \tau \text{ [4]},$$

where t – temperature equal 204^{0}C; τ – time of induction of substance.

Value of time of induction is calculated:

$$lg\tau = (lgt-2.3106)/(-0.122) = -0.0079$$

$$\tau = 10^{0.0079} = 3665 \text{ s.}$$

Then put the used temperature indicator into the sedate dependence of an expected and extrapolation curve of characteristics of fire-and-explosion hazard of oil received by us.

$$y = 16920 \cdot x^{-0.537},$$

where y – a temperature indicator, x – induction time.

Respectively, time of induction made 3742 pages. Being guided by R^2=0.8885 – the size of reliability of approximation, it was received that

$$x = \tau \cdot R^2 = 3325s.$$

Comparison of the received results with settlement data for bitumen and tar, showed that temporary indicators of induction form range 2542<τ(s)<3665.

It is obvious that the size received by the developed technique τ = 3325s, taking into account the amendment, is admissible.

4. Summary

Thus, are received reliable and applicable in practice of oil and oil processing branches sedate dependence of time of induction on a temperature indicator: y=16920$x^{-0.537}$ and technique of its receiving.

The practical importance of the received results is in possibility of understanding, representation and the forecast of probable emergencies and acceptances of the appropriate measures directed on prevention of their emergence that eliminates or significantly reduces the damage caused by an emergency situation, which is expressed as in violation of technological process at the enterprise, financial expenses, and in death of people and in an adverse effect on territory ecology.

Thus, as a result of the conducted research:

It is offered, on known temperature indicators of fire-and-explosion hazard, the methodical approach in definition of time of induction of process of self-ignition of substances and materials characterizing the beginning of development of some emergency process.

The algorithm of definition of time of induction of emergence of explosive concentration in processing equipment is received, the result is presented in the form of a power function y=16920x-0,537, and allowing to predict development of certain events, the processes happening when conducting works in oil and oil processing branches that gives the grounds for acceptance of any precautionary actions.

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