

THE OXIDATION AND COMBUSTION ALLOYS OF MAGNESIUM AND URANIUM

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In article are brought given about study of the processes to corrosions and inflammation under raised temperature some construction and fuel material under development earlier for high-water gas-cooled (CO_2) reactor by types KS-150 and TR-1000. In work is described methods, equipment and results of the study magnesium alloy with beryllium and uranium alloys, raised corrosion stability, which were used in designs such reactors. They are determined temperatures and condition of the transition from corrosion stability to the condition in stage of the intensive oxidation and combustions. Work has on interest in connection with study of the different sort of the possible emergencies in atomic reactors.

INTRODUCTION

The Magnesium and uranium, their alloys are beautiful material for atomic reactor. With using such material in active zone were built and successfully worked the atomic reactors in England and France. In Soviet union with participation NNC HFTI was designed, built and successfully worked in Czechoslovakia hightwater cooled by carbon dioxides atomic reactor, in which nucleus fuels was a metallic uranium, but defensive shell of fuels was shown magnesium alloy with beryllium [1, 2]. Also, the project more powerful hightwater reactor TR-1000 was designed, building mounted-swarm was not realized.

The main dignity of such types reactor this possibility to work at natural unrich uranium.

At its time the big volume of research and design works on construction of fuel element and their assemblies for such type of the reactor, in which as coolant was used carbon dioxide or helium. Such reactor had high safety under possible damage.

These work were also executed in NNC HFTI with ITEF (Moscow) [2, 3].

At present, in connection with actual of researchs of the behaviour material in emergencies at overheat of the active zones above of the work temperature in reactor, we introduce interesting to give executed earlier, but unpublished, studies magnesium and yahoo-new alloy.

1. THE DESCRIPTION OF THE EXPERIMENT

Equipment. The study of the process of the inflammation magnesium alloy PMB (powdered magnesium-beryllium alloys) and uranium alloys was produced on autoclave installation (Fig. 1), equipped with by system adding the moisture to the gas or system, dosing mixes components different gases, when test are in mixture CO_2 and inert gas.

For study of the processes of the oxidation and combustion was used the method of weighting samples, thermal analysis, attraction microscopic analysis and visual examination.

Equipment (see Fig. 1) has an internal stove of the heating sample, and in bottom part is found an container (the glass) with water and separate stove of the heating

(for task of necessary moisture of the gas in autoclave way of the regulation of the temperature of the water insaid of capacity). Equipment allowed to realize the heating a sample before the temperature $900 \dots 1000^\circ\text{C}$. Moisture CO_2 in 0.1% was in source balloon, moisture 0.2% were created by putting into ampule accounting amount water in autoclave and following evaporations. Checking amount moisture was realized on dew point on special device.

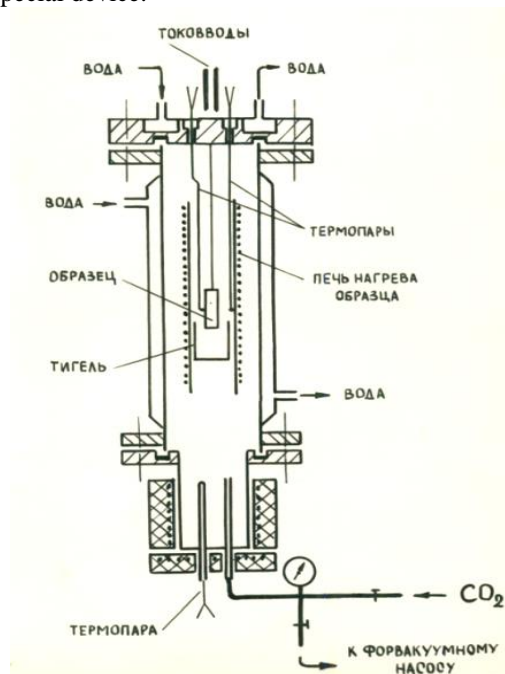


Fig. 1. An autoclave for corrosion tests of material under pressure of the gas (CO_2 and other) under different composition on admixture of H_2O

The alloys and sample. They were investigated double alloy PMB-2, containing 2% Be, and PMB-2AZ containing except beryllium of the additive Al and Zr, weakalloying uranium (the alloy KS), used in reactor KS-150, and uranium of the composition TR for reactor TR-1000. The composition alloys is brought below. There were explored also uranium alloys raised alloyed for the reason improvements corrosion stability:

Magnesium alloys:

Mg+2%Be – ПМБ-2,

Mg+2%Be+0,5%Al+0,5%Zr – ПМБ-2 АЦ.

Weakalloying uranium alloys:

U+0,025% Fe + 0,025%Si – the alloy KS,

U+0,12% Al + 0,05% Cr + ,025% Fe + 0,025%Si – the alloy TR.

The uranium alloys raised alloying: (RA)

U+10% Zr;

U + 4,5 %Zr +1,7%Nb + 1,0 %Mo;

U + 5%Zr +5%Nb + 5%Mo + 0,5 Mo +0 12%Al + 0,05Cr – the alloys RA.

The samples of alloy PMB and uranium were made from rods by diameter 7...9 mm. Finishing flesh processing to surfaces - turning lean processing on class 7. Some pickling did not use.

In the centre of samples on axis of the cylinder have drill hole by diameter 2.6 mm and depth 3...4 mm for accommodation of the thermocouples.

Besides, was designed equipment and methods of the test material in flow of the carbon dioxide (Fig. 2).

Work with flow of the gas was conducted under normal pressure gas.

For study of the behaviour alloy PMB scheme of gas supply was formed in mixture CO₂ + inert gas, consisting of two lines, equiped with manometer and reducers. The carbon dioxide attacked on one lines, on the other argon. The percent correlation in mixture possible was assign on correlation of the pressures of the gas.

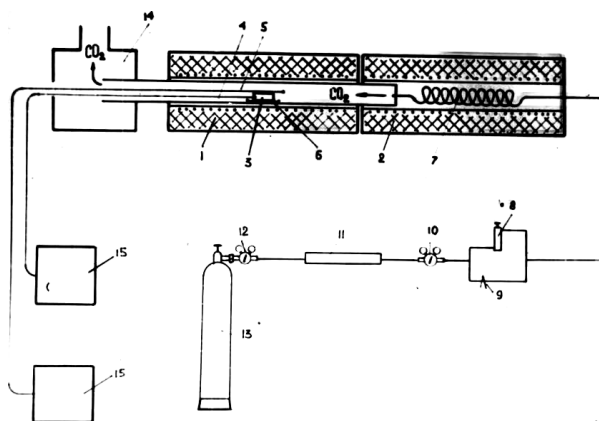


Fig. 2. The equipment for tests on inflammation material in flow of the carbon dioxide: 1 – stove of the heating sample; 2 – stoves of the heating of the gas; 3 – samples; 4 and 5 – measuring and writing thermocouples; 6 – a ceramic pump; 7 – a tube of the heating of the gas; 8 – помпа; 9 – a valve; 10, 12 – редукторы; 11 – a defogger of the gas; 13 – a balloon; 14 – gas collector; 15 – registering and measuring instruments

2. RESULTS EXPERIMENT

2.1. OXIDATION AND INFLAMMATION MAGNESIUM ALLOY PMB-2 AND PMB-2AZ

2.1.1. Inflammation on air. Typical picture change the temperature of the samples magnesium at premises its in area, where possible ignition, is shown on Fig. 3. The pure magnesium fired at the temperature, below melting point (at under 632 °C).

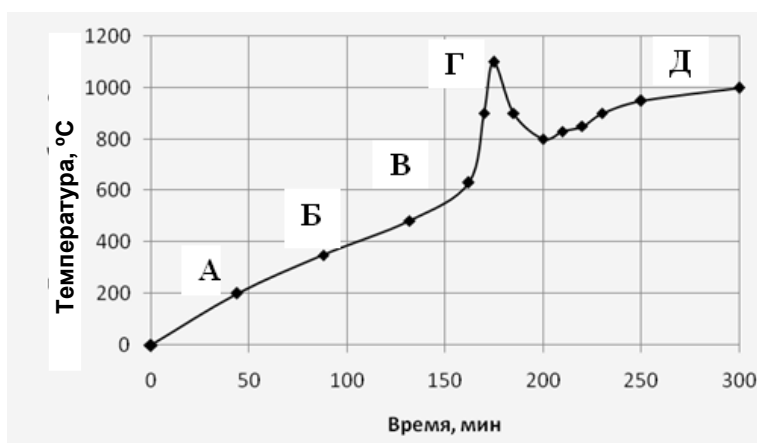


Fig. 3. The scheme of temperature move and begin combustions a magnesium in atmosphere of the air: А-Б-В – a heating of sample in stove; В – begin of autoheating; В-Г – an area of the inflammation; Г – a maximum temperature at combustion, combustion of sample; Д – a point of the completion of the experiment

Magnesium-beryllium alloys due to additive beryllium possess vastly more high corrosion stability, than unalloying magnesium, do not flare up before the temperature of the melting so we observe the warm-up platform of the melting (Fig. 4). Under the most further increasing of the temperature sample are reached such condition that defensive characteristic oxide film weaken and begins the autoheating of samples, bring about inflammation. Duration of lead time before the start of

autoheating on air depends on velocities of the heating and can form several groups of ten of the minutes (see Fig. 4).

Protection from oxidation and inflammation provides the oxide film. As soon as begin “aging” film (the growing their grain, accumulation of defects), they begin cracking, occurs increasing of penetrations oxidant to metal, and it is beginning the ignition.

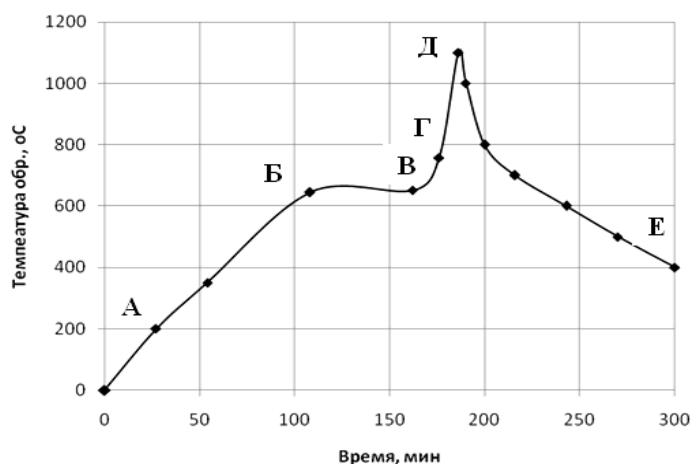


Fig. 4. The scheme ascent temperature and inflammation magnesium-beryllium alloy PMB-2 in atmosphere of the air: А-Б – a heating sample in stove; the interval; Б-В – a platform of the melting; В-Г – begin autoheating; Д – a maximum temperature of the combustion, combustion sample; Е – a completion of the experiment

2.2. INFLAMMATION MAGNESIUM ALLOY IN CARBON DIOXIDE

The carbon dioxide is comparatively defensive atmosphere, due to that is sometimes used when metal is melting. In some reactor carbon dioxide is used as coolant, so there is of interest study about the process of the inflammation metal in CO₂.

The experiments of the determination of the temperature inflammation alloy PMB in CO₂ were conducted similarly described above method of the measurement of the temperature of the inflammation mid air. Since corrosion stability magnesium alloy depends on admixture H₂O in CO₂, that in the beginning carried out a test in gas with moisture 0.1 mas.%O. The pressure of CO₂ was 6,0 Мпа.

The measured temperatures beginning combustions Mg-2%Be alloys were found in interval 745...755 °С (Fig. 5).

The Experiments on inflammation these alloys at moisture CO₂ of 0.2%O mas. have shown similar given on the temperature begin inflammation, t. e. these temperature lies in interval 750...760 °С.

In carbonic acid at pressure 10.0 МПа (in the event of experiment with unceasing heating) ignition approached under 770...790 °С, that is to say, either as at pressures 0.1 and 0,6 МПа.

At experiment with slow heating or long endurance in CO₂ with admixture H₂O in the field of given temperature inflammation occurs under more low temperature, than under unceasing heating. So at pressures CO₂ 0.1; 1.0 and 10.0 МПа autoheating and ignition existed already under 660 °С.

The endurance in CO₂ under 0.1 and 10.0 МПа at temperature 640 °С, so below the temperature of the melting the magnesium base during 50 h does not bring about carrying combustion or corrosion destruction sample PMB-2 and PMB-2AZ.

Got given alloy on ignition PMB in CO₂ different moisture were provided in Table 1.

From brought data follows that temperature of beginning inflammation magnesium alloy at pressures CO₂ 0.1...10.0 МПа without flow and moisture 0.1...0.2% are found in the field of 750...770 °С. The lower temperature of the ignition alloy magnesium with beryllium shall be for clearness to define as 750 °С. At moisture CO₂ 2.0% inflammation occurs under more low temperature, as follows, under 660 °С.

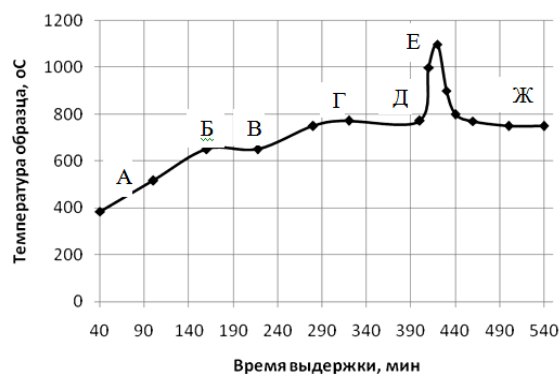


Fig. 5. The warm-up move at heating before 770 °С with endurance before begin inflammation in CO₂ sample of the alloy PMB-2: А-Б – a heating sample in stove; Б-В – a platform of the melting sample; В-Г – increasing of the temperature stove; Г-Д – endurance under given to temperature; Д – begin combustions; Е – a maximum temperature of the combustion; Ж – a decline of the temperature and completion of the experiment

2.3. INFLAMMATION MAGNESIUM ALLOY IN FLOW OF THE CARBON DIOXIDE

One of the factor, influencing upon combustion metals, is a flow oxidizing gas.

It was used installation, shown on Fig. 2. Used the balloon gas, velocity of the flow was regulated by reductor and formed from 0.01 м/с (a little flow) before 1.5 м/с (the big flow).

Table 1

A condition and temperature of the inflammation sample magnesium alloy PMB in carbon dioxide gas without flow

Name of alloys	Moisture CO ₂ , mas. %	Duration of the endurance before ignition	The temperature begin ignition, °C. Time of the endurance before inflammation			Notes
			0.1 MPa	1.0 MPa	10 MPa	
PMB-2, PMB-2AZ	0.1	Unceasing heating	750	760	770...790	Velocity of the heating 6.6 °C/мин
PMB-2, PMB-2AZ	0.2	so	–	–	750...760	so
PMB-2, PMB-2AZ	2.0	so	770	780	780	so
PMB-2, PMB-2AZ	0.1...0.2	Endurance under 660 °C	28 h	10 h	4 h	Full oxidation
PMB-2, PMB-2AZ	0.1...0.2	Endurance under 700 °C	7 h	–	2 h	Full oxidation
PMB-2, PMB-2AZ	0.1...0.2	Endurance under 750 °C	4 h	–	1.5 h	Inflammation
PMB-2, PMB-2AZ	2	Endurance under 660 °C	2.5 h	2 h	0.5 h	Inflammation

The temperatures at period of the endurance in zone stove of the accommodation sample to high temperature at: 660, 700, 750, and 820 °C. The flow of the gas in the beginning installed 0.01...0.05 m/s, pressure of the gas 0.1 MPa.

The visualizations for heated specimens through window in stove have allowed to notice change the form sample after melt metal. Under periodic extraction sample from zone of the heating examination exterior has shown that at the temperature 660...700 °C inflammation sample did not occur. The sample gradually acidified and moved over to powdery condition.

At the temperature 750 °C and above existed autoheating and inflammation sample alloy (Fig. 6). Typical picture of the move to warm-up dependency of the heating sample from time and flow of the gas is shown on Fig. 4.

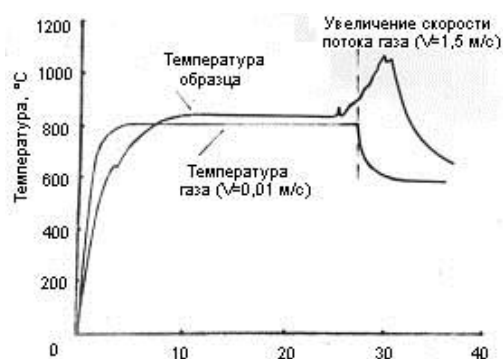


Fig. 6. Move warm-up crooked when inflaming sample alloy PMB-2 in variable flow CO₂

The temperature inflammation depends on velocities on-current of the gas and its heating. If at period of the such reinforcement of the flow not toppled the process of the inflammation. The similar position existed and at the temperature flow of 550 and 500 °C. But if the temperature of the gas in flow to reduce before 250 °C or before room temperature, that exists in similar

situation stewing fired sample. Sometimes managed, including and switching off flow of the gas, obtain the ascent of the temperature sample as a result autoheating and cessations of the process of the combustion one and same sample several times (Fig. 7). combustion flow gas enlarged before 1.5 m/c then if and when the temperature of the carbon dioxide in flow formed 600 °C and above.

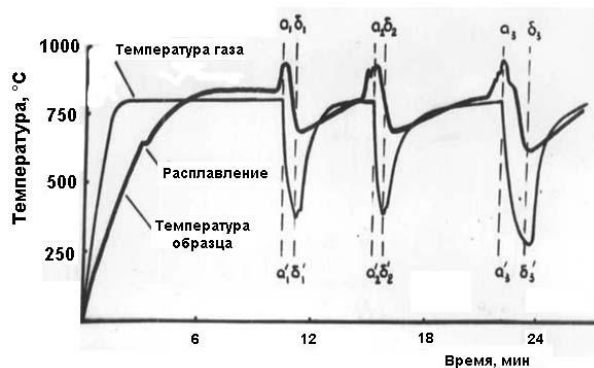


Fig. 7. The move crooked change the temperature when inflaming sample PMB-2 in variable flow CO₂. Before time $a_1 a_1^1$ velocity of the flow $v = 0.01$ m/s, the temperature for count autoheating increases; in maximum $a_1 a_1^1$ flow increased before 1.5 m/s – temperature sample falls. At moment $\delta_1 \delta_1^1$ flow once again is fixed $V = 0.01$ m/s before autoheating, hereinafter follows increase the flow before 1.5 m/s and the temperature decreased. At moment $\delta_2 \delta_2^1$ once again is fixed the small flow and goes increasing of the temperature sample before begin inflammation. The scheme is repeated before combustion image

The cessation of the inflammation under the action of flow speaks of that that gas cools the sample, flow carries away the surplus heat саморазогрева, and process of the inflammation pauses. Possible предполагать deep influence of the flow of the gas and at events overheat in reactor emergency condition.

2.4. THE OXIDATION OF THE URANIUM AND ITS ALLOY, METHODS AND DEVICE

The study of the kinetics of the oxidation uranium alloy composition KS and TR has shown that in all variant of moisture of the gas all compositions uranium alloy oxidize on linear law that speaks, in general, about unprotected nature oxidations such alloy (Fig. 8). On drawing there have show graphs of the oxidation of the uranium under 500 °C. The Similar dependencies are received and under 520 and 550 °C.

The velocity of the oxidation alloy in CO₂ with increasing of the temperature, in accordance with regularity of the oxidation metal, increases. The differences in regularity of the oxidation composition KS and TR is small. Importances of the velocities of the linear oxidation in the numerical expression under 500 °C are following:

for alloy KS 1,5 2,3 mg/(cm²·h);

for alloy TR 1,8 2,2mg/(cm² h).

For the temperature 550 °C velocities of the oxidation above (see Fig. 8).

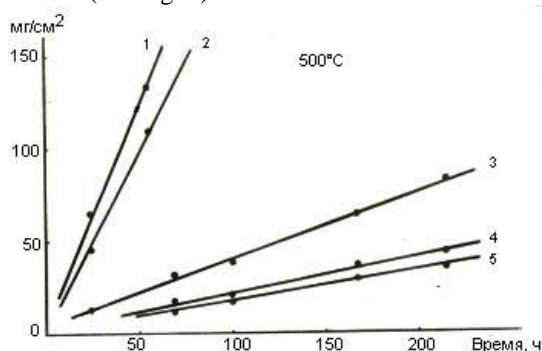


Fig. 8. The typical graphs of the oxidation alloy uranium in CO₂ at pressure 10 MPa and the temperature 500 °C. Moisture CO₂ – 0.1 mas. %.

The composition alloy: 1 – an alloy KS;

2 – an alloy TR; 3 – U+10%Zr;

4 – U+4.5%Zr+1.5%Nb+1.5%Mo+0.1%Al;

5 – U+5%Zr+5%Nb+1.5%Mo+0.1%Al

Increase to moisture CO₂ before 0.2% raises the velocity to corrosions both composition small, and linear regularities of the oxidation are saved.

If increase to moisture of the gas reaches 2.0 mas.%, velocity to corrosions increases in 10 once approximately. On sample material are formed friable products to corrosions.

The velocity to corrosions uranium alloy with additives zirconium, niobium and molybdenum in CO₂ with moisture of 0.1 mas.% noticeably lower, beside weakalloying alloys KS and TR. Data on velocities corrosion under 500 °C three alloys: U+10% Zr; U+4.5% Zr+1.5% Nb+ 0.1% Cr; U+5% Zr+5% Nb+0,1%Al form the values accordingly 0.4; 0.22 and 0.19 mg/(sm²·h).

As can be seen from data, velocity to corrosions alloy raised alloying noticeably less, than beside weakalloying composition of KS or TR.

2.5. INFLAMING THE URANIUM AND ITS ALLOY IN CO₂

Explored inflammability uranium of the composition KS and TR, as well as alloy with Zr, Nb and Mo in carbon dioxide with moisture 0.1 mas.%. It is shown that the most low temperature of the ignition of the uranium alloy KS and TR forms 730...750 °C. For alloy raised alloying temperature begin inflammation and ignition is found in inter-gross 750...800 °C.

When moistening the gas before 0.2% temperature begin inflammation, either as nature of the development process, corresponded to the test data in CO₂ with moisture 0.1%, i. e. for alloy KS and TR rate-parypa inflammation formed 730...750 °C, for alloy raised alloying – in interval 750...850 °C.

This speaks of cognate condition of the processes of the oxidation and autoheating on sample data alloy at moisture 0.1 and 0.2% H₂O.

Table2

Conditions of the inflammation alloy uranium in carbon dioxide

Name of alloys	Pressure CO ₂ , MPa	Moisture CO ₂ , mas. %	Temperature of begin combustions, °C	Moisture CO ₂ , mas. %	Temperature of begin combustions, °C
KS	6...10	0.1; 0.2	730...750	2.0	700
TR	6...10	0.1; 0.2	730...755	2.0	700
U-10	10	0.1; 0.2	750...780	2.0	720
U-4.5/1.7/1	10	0.1; 0.2	750...785	2.0	735
U-5/5/0.5	10	0.1; 0.2	750...780	2.0	740
KS, TR	0.1 (flow)	0.1	750...770	–	–
U-4,5/1.7/1	0.1 (flow)	0.1	750...770	–	–
U-5/5/0.5	0.1 (flow))	0.1	800	–	–

In CO₂, moistened before 2 mas.% (Table 2), at pressure 10,0 MPa temperature begin inflammation for alloy of the uranium KS and TP forms 750 °C, but for alloy with 10% Zr – 700 °C and alloys with Zr, Nb and Mo – 845...880 °C. At endurance below these tempera-

ture occurs the corrosion a sample without combustions. Does not exist the significant difference in importances of the temperature of the inflammation these material in gas with miscellaneous by moisture.

2.6. INFLAMING THE URANIUM US AND SOME ITS ALLOY IN FLOW CO₂

Test sample composition TR (U+0.12%Al+0.05%Cr) and U+4.5%Zr+1.7%Nb+1.2%Mo in flow 0,01 m/c after 5 h endurance under 720 °C while-common-rooms absence spontaneous ascent the temperature.

Does not occur autoheating these sample under such velocities of the flow of the gas and at endurance in the field of the temperature 750 °C during 2 h. Test sample in mode of the unceasing heating under 770 °C in such flow CO₂ (0.01 m/c) already caused the signs autoheating and ascent of the temperature sample (see Table 2).

As can be seen from table, time of the endurance before carry-combustions of the alloy U+0.12%Al+0.05%Cr noticeably greater, than beside the other alloy, provided in Table 2, though the temperature begin autoheating, beside alloys with Zr, Nb and Mo was above (before 800 °C). The last is explained more high corrosion stability of the alloy in consequence of addition zirconium, niobium and molybdenum. Follows to note that intensity autoheating in carbon dioxide under 0.1 MPa particularly, vastly lower, on air, so under inflammation here is implying the ascent of the temperature in the manner of low peak on termal crooked. The value such peak has about 50...100 °C.

By change the flow within specified values (0.01 before 1...1.5 m/s) possible was cause the condition autoheating and "stewings" the combustion of sample similarly under experiments with Mg-Be-alloy (Fig. 9).

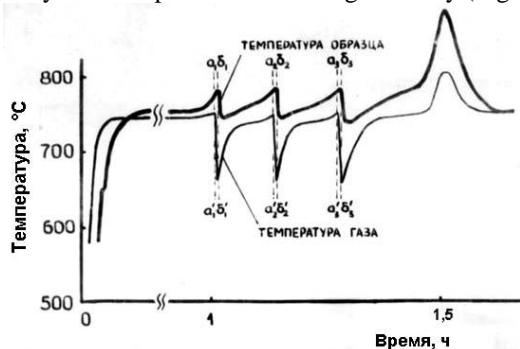


Fig. 9. Change the temperature sample and gas when inflaming the uranium in variable flow CO₂ (the pressure 0,1 MPa)

The move crooked on Fig. 9 is described thereby. Before time $a_1\delta_1^1$ at flow $v = 0.01$ m/s – a temperature for count autoheating increases; at moment $a_1\delta_1^1$ flow we enlarge before 1.5 m/c, the temperature sample falls before $\delta_2\delta_2^1$; the flow is fixed after reduction of the temperature $v = 0.01$ m/s before ascent of the temperature in vicinities $a_2\delta_2^1$, on peak autoheating on $a_2\delta_2^1$ flow of the gas increases to 1.5 m/c and temperature sample drops to $\delta_2\delta_2^1$ – hereinafter scheme is repeated several cycles before combustion sample.

2.7. TEST MODEL FUEL ELEMENT

At development fuel elements for reactor, cooled by carbon dioxides, were organized autoclave tests of

the test under design worker to temperature fuel element (500 °C) and raised before 520 °C during 20000 h. Magnesium-beryllium covering protected the uranium from oxidation specified time. Also successfully worked fuels in reactor condition. It was of interest research the behaviour an fuels at overheat before the temperature melt and above temperature of the melting the magnesium alloy.

Test model are organized at the temperature, below the temperature of the melting on 10 °C, as follows: under 640 °C, above temperature of the melting on 10 °C (660 °C), and under 750 °C. The pressure CO₂ 10.0 MPa, moisture 0.1 %.

In the beginning test three models under 640 °C during 500 h have not revealed the centre of the destruction or raised corrosions shell fuels from alloy PMB-2.

The heating model before 660 °C and endurance during 24 h in the field of the temperature of the melting have brought about melt material of the shell and flow down it in lower part of fuels. Remained dainty covering saved certain time a hermeticity, centre of the destruction on covering did not exist. Under 750 °C on surfaces of covering after 2.5 h endurance appeared the centres unhermeticals that brought about formation corrosion cankers. In some cases occurred local inflaming the alloy of the covering that caused the corrosion of the uranium (Fig. 10).

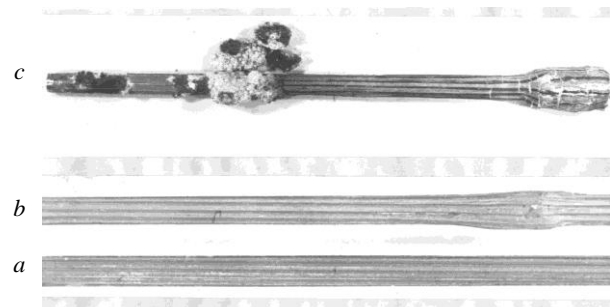


Fig. 10. The type model fuels after heating in CO₂, at pressure 10.0 MPa:
a – 640 °C, 500 h; b – 660 °C, 72 h; c – 750 °C, 2.5 h

2.2.4. Oxidation and inflaming the alloy PMB-2 in mixture argon+CO₂

That can suspend разогревы, stop them or do the impossible? Since main by reason of the combustion is an oxygen midair or in composition of the carbon dioxide, or pair, that, in final count, cessation of delivery oxidant will bring about stop of the chemical reaction of the separation of the heat as a result of corrosions. Was of interest study the behaviour an alloy in inert gas, in ge-pour for instance. Argon is chose as simulator. However in clean argon on magnesium alloy observed formation of the cankers because of evaporation. It happened to add the oxidant. At accompaniment 10...20% CO₂ to argon oxidation alloy was slowed, formed defensive film on samples, but inflammation did not occur (Fig. 11).

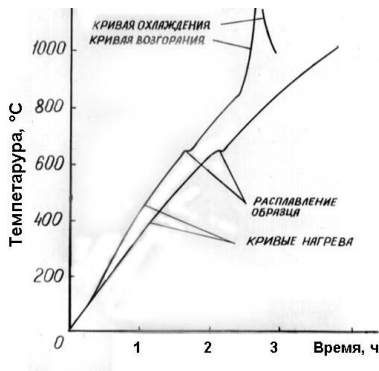


Fig. 11. The curves of the heating and inflammation sample alloy PMB-2 in mixture argon and carbon dioxide at pressure 10,0 MPa: 1 – a heating in mixture Ar + 50% CO₂ (the upper curve); 2 – a heating in mixture Ar + 80...90% CO₂ (lower curve)

3. DISCUSSION

Fuels of reactor KS-150 and TR-1000 differ from fuels of water-water reactor not only using new material, but also in principal. This fuels coupled by shell with uranium rods. This means that at breach of the hermeticities leaving the gas radioactive products of the fission from under shells and penetration oxidant before rod is defined only by area of the defect or open surface.

So one of the ways of increasing to vitality fuels of reactor TR-1000 is increasing corrosion stability material of uranium rod and magnesium shell. The experience to usages of the reactor KS-150 have shown that, in spite of experimental period of the usages of this reactor at 5 years, were received essential results on vitality assembly [3, 4].

Search work are organized on choice of composition uranium alloys and coolant, in which material fuels did not be subjected to inflammation. Such composition on gas in preliminary order is chose and explored. This – a helium with CO₂ as possible coolant, but argon was used as prototyping gas. They are received positive given on low velocity of the oxidation material fuels and increasing of the temperature or absence of the inflammation.

In this case many requirements to limiting safety to reactor TR-1000, cooled helium in mixture with carbon dioxides, could be satisfied.

The reasons and mechanisms of the inflammation magnesium and uranium be of interest as with stand point thathnic experivtyns, so and because of desire to understand the regularities of the processes. The alloy magnesium with 2% Be has high corrosion stability in CO₂, in consequence of additive beryllium while on uranium and uranium alloys defensive oxide film are not formed, and process of their oxidation is described by linear regularity.

Under raised temperature metallic sample are subjected to the quick oxidation and combustion if amount of the heat, standing out under chemical reaction of the oxidation, will exceed the amount of the heat, leaving through covering sample oxide layer in surrounding its space. In this case the temperature on to border "metal oxides" increases that enlarges the velocity to reactions, but this, in turn, raises the temperature a sample. Finally, approaches the strong oxidation, which have a name the combustion.

Mathematically balance to energy of the combustion begin under possible to express the formula:

$$\Delta H > \Delta Q,$$

where ΔH – amount of the heat, standing out under chemical reaction of the oxidation; ΔQ – amount of the heat, leaving through covering sample oxide layer in surrounding its space.

In work [5] is noted that spontaneous combustion materials are that metals, which possess the low energy to activations of the oxidation (Table 3). So for uranium at the temperature 350 °C it is 14.5 kkal/(g.at.); for magnesium 17.0...20.0 kkal/(g.at.), for zirconium under 700...1050 °C 45 kkal/(g.at.), for titanium under 700...900 °C 53.0 kkal/(g.at.), for nickel 41.0 kkal/(g.at.). Follows at questions autoheating metal to take into account and nature oxide film, the level of the vapour of the metal, as well as characteristic of the gas ambience; the concentration oxidant in zone of the oxidation, geometry sample; the correlation between it volume and area to surfaces; heatconducting metal and oxides and row other factor.

So the temperatures begin inflammation metal are not physical feature given metal, but function many external parameter, and they correspond to exactly that combinations of the conditions, in which occurs the process of the heating material.

Table 3

Maximum temperatures of the flame at combustion metal [5]

Metalls	Al	Mg	Be	Zr	Fe	Ca	K
Temperature, K	3800	3350	4300	4800	3000	3800	1700

If the temperature sample exceeds the temperature a stove (approximately on 100 With), that here possible already speaks of quick oxidation though if in this case external source of the heating to take away, that temperature sample will fall, will occur fading. The quick oxidation can move over to combustion in that event if difference of the temperature sample and stove will form more than 100...150 °C. Then the temperature of sample can increase before 1000...1200 °C and above. If beside metal high level vapour, that combustion moves over to ignition, exists forming the flame (for

instance, beside magnesium or aluminum). Beside metal with low balance by pressure of the vapour forming the flame under temperature before 1000...1200 °C does not occur.

In view of qualitative nature of the processes of the combustion and ignition, dependencies them from external factors, differences between them agreed, clear determinations on this subject does not exist, however indications in terminology inflammation, ignition and combustion metal (the alloy) allow to describe the experimental results.

CONCLUSIONS

1. The explored processes of the oxidation and inflammation magnesium alloy PMB-2 and PMB-2AZ in carbon dioxide at pressures 0.1; 1.0 and 10.0 MPa and moisture 0.1; 0.2 and 2% H₂O. Inflammation is studied at heating at the speed of 300...400 °C/h and under long endurance on given temperature.

The lower limit begin inflammation alloy magnesium under quick heating forms 750...790 °C at moisture 0.1...2.0 mas.% H₂O and pressure of the carbon dioxide 0.1...10.0 MPa.

In experiment with endurance under constant temperature 660 and 700 °C in CO₂ with moisture 0.1...0.2 mas.% H₂O under p = 10.0 MPa inflammation alloy does not occur while under moisture carbon dioxide 2% sample begin to flare up under 660 °C after 0.5...1.0 h exposures.

At the temperature, below the temperature of the melting magnesium, inflammation under investigation Mg-Be-alloy does not occur under all parameter of the experiment.

2. The certain velocities of the oxidation of alloy of uranium the composition by KS and TR and alloy raised content of additive Zr (before 5%), Nb (before 2%), Mo (before 1.5...2%) in carbon dioxide gas with moisture 0.1 and 2 mas.% H₂O. is shown that velocities of the oxidation uranium material in CO₂ at moisture 0.1 and 0.2 mas.% H₂O close, but at moisture 2% mass. increase in 2-3 times. The regularities of the oxidation uranium alloy are described linear dependency from time.

3. It is shown that inflammation alloy Mg-Be and uranium in small flow CO₂ (at the speed of 0.01...0.05 m/s) occurs under close temperature, either as without flow in stationary gas, but when presenting the flow at the speed of 1...2 m/s heat stops and ignition material does not occur.

4. The studied overheats sample uranium fuels with Mg-Be-shell. It is shown that overheats model above temperature of the melting the shell cause melting and flowdown material of the covering in lower parts model. At endurance during 2.5 h under 730...750 °C observed autoheating and local combustion sample of fuels.

Before the temperature of the melting the alloy magnesium (651 °C) on model at endurance before 2 h and more inflammation did not exist.

5. The limiting temperature, above which uranium fuels can come out of building way of the destruction of the shell, is 651 °C, when occurs the melt of shells. The

further overheat before the temperature 660...700 °C can cause inflaming the material of fuels and interaction with contacting materials.

6. In mixture of the selected composition (CO₂ + 80%Ar) do not flare up the magnesium alloys and uranium alloys before explored temperature of the interval 900...1000 °C, saving in ditto time corrosion stability at worker temperature of fuels.

FINDINGS

1. The designed methods of the determination of the temperature begin combustions and ignition alloy magnesium and alloy of the uranium at heating on air, in carbon dioxide, argon and mixture of the argon and CO₂.

2. The certain temperatures of the turning the processes of the oxidation in begin combustions and ignition depending on composition and moisture gas.

3. The mixture He + 10...20% CO₂, in which material save high corrosion stability and do not flare up, possible recommend for and using in gas reactor of the type KS-150 and TR-1000.

4. The results of the work can be used at analysis of the emergencies in atomic reactor.

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ОКИСЛЕНИЕ И ГОРЕНИЕ СПЛАВОВ МАГНИЯ И УРАНА

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Приведены данные об исследовании процессов коррозии и возгорания при повышенных температурах некоторых конструкционных и топливных материалов, разрабатываемых ранее для газоохлаждаемых (CO₂) с тяжеловодным замедлителем реакторов типов КС-150 и ТР-1000. В работе описываются методика, оборудование и результаты исследования коррозионно-стойкого магниевое сплава с бериллием и сплавов урана повышенной коррозионной стойкости, которые использовались в конструкции таких реакторов. Приведены температуры и условия перехода сплавов из коррозионно-стойкого состояния в стадии интенсивного окисления и горения. Работа представляет интерес в связи с изучением различного рода возможных аварийных ситуаций в атомных реакторах.

ОКИСЛЕННЯ ТА ГОРІННЯ СПЛАВІВ МАГНІЮ ТА УРАНУ

І.А. Петельгузов

Приведені дані про дослідження процесів корозії та загорання при підвищених температурах деяких конструкційних та паливних матеріалів, раніше розроблених для газоохолоджуваних (CO_2) з важководним сповільнювачем нейтронів реакторів типу КС-150 та ТР-1000. У роботі описуються методика, обладнання, результати дослідження корозійно-стійкого магнієвого сплаву з берилієм, уранових сплавів підвищеної корозійної стійкості, які використовувались у конструкції таких реакторів. Наведені температури та умови переходів сплавів із корозійно-стійкого стану в стадії інтенсивного окислення та горіння. Робота представляє інтерес у зв'язку з вивченням можливих аварійних ситуацій в атомних реакторах.