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METHOD FOR COMBUSTION OF METALS

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Fig. 1.

Fig. 2.

Fig. 3.

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Fig. 5.

Fig. 4.

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Fig. 6.

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Fig. 7.

Fig. 8.

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METHOD FOR COMBUSTION OF METALS

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Application November 30, 1953, Serial No. 395,160

6 Claims. (Cl. 110—1)

This application is a continuation-in-part of my copending application Serial No. 260,424, filed December 7, 1951, and now abandoned.

This invention relates to the production and application of heat from the combustion of aluminum, magnesium, zirconium and related metals. More particularly this invention relates to combustion of a highly exothermic metal in a manner to concentrate and accumulate the heat.

It is an object of this invention to provide a temperature of a high degree by the combustion of highly exothermic metals.

It is a further object of this invention to provide a means for combustion of highly exothermic metals which concentrates and accumulates the heat produced.

A still further object of this invention is the provision of a furnace for the combustion of aluminum, magnesium, zirconium and similar metals which applies the heat produced to create unusually high temperatures.

Another object of this invention is to provide a torch burning aluminum, magnesium, or zirconium or similar metals which produces extremely high temperatures.

It is still another object of this invention to provide a process for melting or penetrating a ceramic, concrete or stone object.

It is a further object of this invention to provide a process of combustion which will penetrate a ceramic, concrete or stone object.

These and other objects of this invention will become apparent upon consideration of the following description taken together with the accompanying drawings in which:

Fig. 1 is a section of a furnace according to this invention;

Fig. 2 is a section of a furnace according to this invention which is movable;

Fig. 3 is a section of the furnace of Fig. 2 moved to a new position;

Fig. 4 is a chart showing the heat content in kilocalories per gram atom or mole of magnesium, aluminum, and oxygen;

Fig. 5 is a graph showing the heat content in kilocalories mole of magnesium oxide and aluminum oxide;

Fig. 6 is a section of an oxy-magnesium torch;

Fig. 7 is a section of a blowpipe according to the invention; and

Fig. 8 is a chart of the flame characteristics of a blowpipe of this invention.

It is disclosed in the above-mentioned copending application that a high temperature can be attained in and throughout an area by burning aluminum, magnesium or zirconium in the area. The metal is introduced into the combustion area, such as the center of a furnace, where it is mixed with oxygen and combines to form an oxide in an exothermic reaction which releases a substantial quantity of heat. When the combustion area is enclosed and the enclosing material is the proper substance the continuous feeding of the metal brings about a combustion reaction which will continually increase in temperature. One of the causes of this continual increase in temperature is the production of the metal oxide by the combustion reaction.

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The importance of the nature of the substance composing the material which encloses the combustion area can be understood in connection with a furnace according to this invention. By providing a furnace embodying this invention with a refractory or otherwise non-combustible material the combustion reaction of this invention can be brought about. An example of such a furnace material is the oxide of the burning metal, such as alumina in the case of aluminum. When a refractory or non-combustible material delineates the combustion area and a combustile metal of this invention is burned in the combustion area a reaction takes place which accumulates and concentrates the heat of the reaction. A factor in this reaction is the oxide product of the reaction. This oxide has a high temperature during the reaction. It is also a refractory and thus provides the reaction with its own refractory. The dissociation temperature of this refractory oxide product is the limiting factor on the increase of temperature. The dissociation point of the product of combustion depends upon the concentration of the products of combustion and the total pressure. For example, in burning aluminum the dissociation temperature of 3500° C. at atmospheric pressure can be increased to 4000° C. at ten atmospheres and 4500° C. at one hundred atmospheres.

Another factor in this invention is the thermochemical equation of the burned metal. The thermochemical equations representing the combustion of magnesium and aluminum are as follows:

(1) $Mg + \frac{1}{2}O_2 \rightarrow MgO$ 143,940 cal./mole at 25° C.

(2) $2Al + 1\frac{1}{2}O_2 \rightarrow Al_2O_3$ 399,050 cal./mole at 25° C.

Equation 1 indicates that 1 gram-atom of magnesium and ½ gram-mole of molecular oxygen under standard conditions will release 143,940 calories upon the magnesium and oxygen being reacted to form 1 mole of magnesium oxide. Similarly, Equation 2 indicates that 2 gram-atoms of aluminum and 1½ moles of molecular oxygen form 1 mole of aluminum oxide with the release of 399,050 calories. The calories released by the reactions represent the excess calories in the reactants magnesium, aluminum and molecular oxygen over the products magnesium oxide and aluminum oxide. This difference in calories may be expressed in terms of the heat content of the reactants and the combustion products. The heat content of a substance, as referred to here, relates to calories per gram-atom or gram-mole of the substance. In the operation of this invention the oxide produced in the combustion has a lower heat content than the reactants which form the oxide. Therefore, the formation of the oxide as shown in Equations 1 and 2 leaves a difference in heat content which is the release of energy and provides the exothermic heat of the reaction.

In Fig. 1 a simple furnace is shown in which this invention may be operated. An alumina pot-shaped sphere **10** is provided with an oxygen supply line **11** and a port **12**. The port **12** provides an opening in the upper surface of the sphere **10**. A rod **13** of aluminum is inserted into the sphere **10** through the port **12**. The rod **13** melting at its inner end **14** feeds the combustion of aluminum within the sphere **10**. A mass **15** is shown in the bottom of the sphere **10**. The mass **15** is liquid during the combustion reaction. On the surface of the mass **15** the combustion reaction is taking place at a temperature in excess of the melting point of the reaction product. The refractory and low conductivity nature of the aluminum oxide serve to retain this heat in the area of combustion. This action of the oxide both protects the sphere **10** and causes a concentration of the heat of the combustion. As the combustion continues the added heat from the exothermic reaction is retained to cause a further

concentration of heat. This increased concentration of heat is continued as long as additional aluminum **13** is fed into the sphere **10** to continue the combustion reaction. The maximum temperature to which this process can be raised is the dissociation of the combustion product. At the dissociation temperature the combustion product breaks down into its separate constituents.

In the sphere **10** the surface of the mass **15** becomes raised to a temperature where the burning aluminum **13** on the surface is formed into incandescent pieces **16**. The rate of reaction can be partially controlled by the rate of feed of oxygen into the sphere **10** through the oxygen line **11**. The introduction of pure oxygen is not necessary to the reaction. However, the closed nature of the sphere **10** requires a continuous supply of an oxidizing gas. A port suggested by dotted lines may be formed in the sphere **10** to expose the combustion reaction and the reactants. The reaction radiates a high degree of energy, the advantages of which are set forth in greater detail below. This radiation may be utilized from within the sphere **10** through the suggested port.

Another furnace embodying this invention is shown in Figs. 2 and 3. In Fig. 2 a reactor **17** of alumina has a port **18** closed by a removal plug **19**. The lower edge of port **18** is formed as a spout lip **20**. The aluminum feed is represented at **21** and the oxygen inlet at **22**. Burning metal **23** is shown resting on molten oxides **24** inside the reactor **17**. In Fig. 3 the reactor **17** is shown with the plug **19** removed from port **18** and the molten oxides **24** pouring over lip **20** into a mold **25** carried on a movable support **26**. A radiation shield **27** is shown. The reactor rotates on an axis perpendicular to the plane of Fig. 3.

The port **18** is closed during the run by the plug **19** of the same material as the furnace's reaction sphere **17**. When sufficient liquid oxide has accumulated, the plug **19** is withdrawn and the whole reactor **17** tilted (as shown in Fig. 3) to any desirable degree. After sufficient amounts of liquid oxide **24** have been poured out, the reactor **17** is returned to its original position.

A number of port holes **18** may be built into the reactor and liquid oxide poured out into various directions if desired.

It is not essential that the reactor sphere be formed with a pre-formed hole as any suitable means for breaching the reactor wall can be used to release the liquid product.

As a further method, the melting of the reaction sphere by means of a high temperature torch may be used. The highest temperatures are produced by the hydrogen-fluorine torch with temperatures about 4,000° C. At the same time, the fluxing and melting point depressing action of magnesium or aluminum (or other metal) fluorides, produced by the interaction of hydrogen fluoride and the metal oxide of the sphere, permits ready piercing of the shell. Instead of the expensive fluorine, chlorine trifluoride (ClF_3) may be used.

In the operation of this invention high temperatures are obtained also by heating the reactants before combustion. This preheating increases the heat content of the reactants as demonstrated by the charts of Figs. 4 and 5. The heat contents for magnesium, aluminum, oxygen, magnesium oxide and aluminum oxide are set forth in a temperature range from 0° C. including the specific heats, heats of fusion, heats of vaporization, atomic and molecular weights as shown in Figs. 4 and 5. Figure 4 is a graph showing heat content of magnesium, aluminum, and molecular oxygen in Kilocalories per gram-atom or gram-mole plotted against degrees centigrade of temperature. Figure 5 is a graph showing heat content of magnesium oxide and aluminum oxide in Kilocalories per gram-mole plotted against degrees centigrade of temperature.

Figures 4 and 5 show that at a higher temperature the heat content of magnesium and aluminum is greater in

proportion to the heat content of magnesium and aluminum at a lower temperature. Likewise, the differential between the heat content of the reactants and the heat content of the product is proportionally increased. As the amount of heat released by the combustion reaction increases with an increase in the heat content differential, preheating the reactants will increase the heat produced from the reaction.

The following example illustrates the release of heat according to this invention:

EXAMPLE I

One gram-atom of magnesium vapor heated to 2800° C. having a heat content of 48,910 calories per gram-atom is reacted with one gram-atom of molecular oxygen heated to 2800° C. having a heat content of 9,800 calories per gram-atom to form magnesium oxide having 40,000 calories per gram-mole and provide an exothermic heat of 18,700 calories per gram-mole of magnesium oxide in addition to and above the 143,940 calories per gram-mole generated at room temperature. Thus we have, at a temperature level of 2800° C. to start with, a release of 162,600 calories per 40.32 grams of magnesium oxide formed.

The Example I and Figs. 4 and 5 are based on heat content data at atmospheric pressure. The temperature at which the combustion reaction may take place with practicality can be further increased by placing the reaction space of the furnace under pressure. The following table shows approximately the expected increase of the vaporization temperature or boiling point of magnesium, aluminum and aluminum oxide with increase of pressure:

Table I

Pressure in atmospheres	Vaporization temperatures, 0° C.		
	Mg	Al	Al_2O_3
1	1,107	2,056	2,977
10	1,420	2,520	3,350
25	1,600	2,760	3,500
50	1,740	3,000	3,750
100	1,950	3,200	4,200

By placing a furnace operating according to this invention under pressure the temperature of vaporization is raised. Raising the temperatures of vaporization in turn raises the temperature at which the combustion reaction may be carried on and consequently the heat content differential between the reactants and the products providing in turn greater heat in the reaction space.

As stated above the limit on the operation of this invention is the dissociation temperature of the product of the burned metal. As present temperature measurement apparatus has a recording limit in the region of 2,000° Kelvin the actual temperature limit to this invention can only be estimated. At normal pressure of one atmosphere it is estimated a temperature of the magnitude of 3500° Kelvin can be obtained by the combustion of aluminum in this invention. Zirconium will produce an even high temperature.

A furnace similar to the type shown and described in Figs. 1–3 has been used to produce the temperatures of this invention. The following example demonstrates one such use and is set forth to merely illustrate the relation between the rate of feed of combustion materials and the volumes of a suitable reactor:

EXAMPLE II

500 grams of aluminum were fed into a reactor composed of two semi-spheres of alumina having an inside diameter of six inches and a volume of 1.855 liters. The aluminum was burned in pure oxygen, the oxygen was supplied and consumed at the rate of eight liters N. T. P. per minute and the combustion was continued for nineteen minutes, N. T. P. being the abbreviation for normal tem-

perature and pressure. At the end of this period 90 grams of unreacted aluminum was recovered in the form of a single lump in the sphere.

1 gram of aluminum generates 7410 calories in burning. In the reaction aluminum was burned at the rate of 21.6 grams per minute, or 160,000 calories per minute. The reaction produced 86,300 calories per minute per liter.

This example demonstrates the factors of the method of this invention. These factors include a rapid rate of feed of the combustion materials and a combustion of these materials in a confined area surrounded by a refractory material which both provides insulation against the escape of the heat produced and resistance to the temperature of the heat produced. The refractory material must therefore resist dissociation at temperatures over 1500° C. and preferably up to 3000° C. The refractory material also must provide good insulation against the escape of the heat. It has been found that in burning metals such as aluminum, magnesium and zirconium in the method of this invention that a refractory material is produced which has the desired qualities for the refractory material which surrounds the combustion reaction. Consequently, the refractory produced by the combustion itself may be employed to line the confined chamber and surround the combustion reaction.

Another factor in the production of the method of this invention is the relation of the volume of the reaction or combustion area to the rate of feed. The volume of the reaction area and the quantity of rate of feed of the combustion materials must provide an adequate concentration of reactants per unit volume of the reaction or combustion area.

The essential elements for attaining the method and results of this invention are as follows:

1. A relationship between the volume of the reaction area and the rate of feed which produces temperatures in the range of 1500° C. to 3000° C. throughout the reaction area for a substantial period of time. The volume of the reaction area must be related to the quantity of feed so as to provide an adequate concentration of reactants per unit volume of reaction area. The rate of feed of the combustion materials must be sufficient so as to provide adequate quantities of the reactants per unit of time per unit of volume of the reaction area to produce the temperature conditions of this invention.

2. A wall structure which surrounds and confines the combustion area of a thermal insulation which will retain the heat produced against rapid escape and resist dissociation at temperatures in the range of 1500° C. to 3000° C. The wall material must have a melting point in the range of 1500° C. so that it does not melt before it can be replaced by the combustion product of the combustion reaction. The following table sets forth representative wall structure materials and their melting points:

Table II

MELTING POINTS °C.

Al_2O_3	2034 ± 16
La_2O_3	2210 ± 20
ZrO_2	2710 ± 15
ThO_2	3220 ± 50
SiO_2	1710
CaO	2570
MgO	2800

The thermal conductivity of refractory materials vary according to physical state, generally, the more tightly packed and dense the material the higher the thermal conductivity. Conversely a lower thermal conductivity is obtained from looser material. The thermal conductivity of the wall surrounding the area of combustion of this invention will be of the order of the thermal conductivities of stone, brick, concrete, cement, and recognized refractories such as firebrick and alumina. The thermal conductivities of various other non-combustibles are satisfactory for the operation of this invention. For example, cinder, concrete and granite will be effective as well as more refractory materials.

It has been found that a material having a particularly low thermal conductivity can be formed by directing an oxy-aluminum torch flame on pure alumina. A sudden condensation of the alumina in the flame causes it to condense into a solid containing small spherical bubbles ranging in size from a few mm. in diameter down to less than 0.01 mm. This provides a material having extremely low thermal conductivity for a structural material, and can be incorporated in the furnace wall sandwiched in-between higher thermal conductivity but structurally stronger layers.

As shown by Example II above, a rate of caloric production of high order for volume of reaction area may be achieved by this invention. Heretofore rates of caloric production per volume of reaction area have been substantially less than 20,000 calories per minute per liter.

An increase of the pressure under which the combustion reaction takes place increases the dissociation temperature of the combustion product. The ultimate temperature obtainable is accordingly raised. In each combustion operation the dissociation temperature of the combustion product can be approached.

The heat of combustion of this invention may not only be applied in a confined space within a fixed furnace. This invention may be employed in burning obtained by an oxy-aluminum, oxy-magnesium or oxy-zirconium torch. One form of an oxy-magnesium torch is shown in Fig. 6. The torch **28** is made up of two coaxial tubes **29** and **30** together with a magnesium chamber **31**. The inner tube **29** supplies oxygen and is heated internally by suitable heating elements **32** to a temperature above the boiling point of magnesium. The admission of oxygen is suitably controlled by a valve **33**.

The outer tube **30** carries magnesium vapors from the chamber **31** to a combustion nozzle **34**. The tube **30** is also heated by a set of elements **35**. Magnesium vapors are generated in the chamber **31** from a magnesium rod **36**, suitably introduced into the chamber **31**. The torch **28** is insulated in a jacket **37**. The magnesium vapors are ignited at the nozzle **34** and the oxygen is fed to the burning magnesium vapors at a controlled rate to provide a variable flame having a high temperature.

Another form of the metal-burning torch is shown in Fig. 7. In this form a blowpipe **38** has a feed pipe **39** and an oxygen tube **40**. Oxygen is blown into the pipe **38** through the tube **40** while the metal to be burned is fed from feed **39** into the pipe **38** and into the oxygen jet from the tube **40**. The metal is introduced in powdered form and is carried in the oxygen stream to a nozzle **41** where the metal upon combustion burns with a flame.

The size of the particles of metal fed into the blowpipe **38** is critical as is the rate of flow of oxygen. The particles must be small and enough oxygen must be introduced at a high enough velocity to carry the particles to the nozzle **41** and burn them briskly. In Fig. 8 a chart shows the flow of oxygen and the particle size for burning aluminum in the blowpipe such as shown in Fig. 7. The mesh number of the aluminum is shown along the abscissa of the chart while the linear velocity of the oxygen in feet per second is shown along the ordinate of the chart. At the aluminum particle size of a mesh number of between 225 and 250 and linear velocity of the oxygen of from 15 to 35 feet per second a stable flame can be produced. In the low oxygen velocity range as the particle size is decreased the oxygen velocity must be slightly increased to prevent the flame from flashing back from the nozzle **41** into the blowpipe **38**. As the oxygen velocity is increased it is necessary to decrease the particle size to prevent the flame from blowing out.

A pilot light of ordinary city gas, or other suitable

igniting device, is necessary to start the flame of the torch if it is operated in an open space. Such an igniting device is not necessary if the torch starts operating in a confined space heated above the ignition temperature.

The torch that is provided by the combustion of aluminum, magnesium or zirconium as described above may be employed to produce a furnace according to this invention. A furnace produced by the use of the metal burning torch embodies the features of the furnaces described above.

The metal burning torch may produce such a furnace for example in a concrete or brick wall. A furnace may be produced in any body which has a refractory reaction to the metal burning flame, where the metal is aluminum, magnesium, zirconium or a metal with similar burning characteristics. In using the torch to produce a furnace according to this invention in a brick, cement or stone wall, the torch flame is used to cut out an opening in the wall. The opening in the wall becomes a confined area of combustion which encloses the torch flame and the combustion. The combustion of the metal in the confined area brings about a concentration and acclumulation of heat similar to that described above in connection with the furnaces in Figs. 1 and 2. The combustion product from the torch flame in such an area has the same action and function as in the above described furnaces.

In the combustion reaction of this invention the combustion products and the material enclosing the confined area of the combustion act to retain the heat of combustion to the point where the temperature exceeds the melting point of any known substance. The torch flame may thus be employed to melt and penetrate materials at a greater rate and with greater ease than any implement has heretofore. For example, highly refractory bricks composed of pure alumina are melted down and penetrated in less than a minute by an aluminum torch burning 100 grams of aluminum powder per minute.

The production of high temperature which is a feature of this invention is controlled and assisted by the rate of combustion of the burning metal. The rate of addition of the metal to the flame determines the temperature attained in the combustion area. This rate of addition has a critical point for attainment of the high temperatures which are provided by this invention. A rate of feed of combustible metal of 100 grams of aluminum per minute, for example, develops a temperature at which aluminum oxide is rapidly melted.

The advantage of this invention has been expressed in the description of the characteristics of the invention. The high temperatures produced according to this invention have a melting capacity which is adaptable to many uses. Also the radiation from the materials present in the combustion chamber has a hitherto unknown intensity. This radiation has several uses.

In describing this invention aluminum, magnesium and zirconium have been selected as the metals for the preferred embodiment. It will be understood that other metals producing high temperature are also adaptable to this invention. Iron can be used as an addition to the above described metals and also as a fluxing agent. It will be understood that these and other modifications of the above described embodiment can be made without departure from the spirit of this invention. Therefore it is intended that the scope of the invention be limited only by the scope of the appended claims.

I claim:

1. The method of producing heat above 1500° C. and up to 4500° C. by the combustion of aluminum in a confined chamber made up of and surrounded by a refractory material having a melting point above 1500° C. and a low thermal conductivity which comprises introducing metallic aluminum into the confined chamber at a rate of at least five grams per minute per liter of said confined chamber introducing oxygen into said confined chamber at the rate of at least 1.8 liters N. T. P. per minute per liter of said confined chamber, contacting and mixing 5 grams of said aluminum per minute per liter of said chamber with 1.8 liters of said oxygen in said confined chamber, igniting said mixture of oxygen and aluminum, burning said aluminum in said oxygen by oxidation to produce heat by the exothermic reaction of said burning at the rate of at least 20,000 calories per minute per liter for at least five minutes producing heat by said burning of a temperature in excess of 1500° C., continuously supplying aluminum at a rate of 5 grams per minute per liter of said confined chamber retaining said heat of burning in said refractory chamber surrounding material, producing a molten oxide product of said burning having a melting point of over 2000° C. and a low thermal conductivity, continuing to introduce said metallic aluminum and oxygen into the combustion in said confined chamber at said respective rates, burning additional quantities of said metallic aluminum in said oxygen in contact with said produced oxide product and at said rate to produce additional heat at the rate of at least 20,000 calories per minute per liter.

2. The method of producing heat in a confined chamber of refractory material having a melting point of at least 1500° C. by producing molten aluminum oxide in said chamber at a temperature in excess of the melting point of the refractory material which comprises introducing metallic aluminum into the confined chamber at a rate of at least 3 grams per minute per liter of said chamber, introducing oxygen into the confined chamber at a rate of at least 3 grams of oxygen per minute per liter of said chamber, contacting and mixing in said chamber at least 3 grams of said aluminum per minute per liter with at least 3 grams per minute per liter of said oxygen, igniting said mixture, burning said aluminum in said oxygen at a rate of at least 20,000 calories per minute per liter of said chamber, continuously supplying said oxygen at a rate of at least 3 grams per minute per liter of said chamber to maintain burning of said aluminum in said oxygen at a rate of at least 20,000 calories per minute per liter to produce heat at a temperature in excess of 1500° C., continuously supplying and burning aluminum at a rate of at least 3 grams per minute per liter of said chamber and producing molten aluminum oxide in said chamber at a temperature in excess of the melting point of the refractory material of said chamber.

3. The method of producing heat in a confined chamber of refractory material having a melting point of at least 1500° C. by producing molten aluminum oxide in said chamber at a temperature in excess of the melting point of the refractory material which comprises introducing metallic aluminum into the confined chamber at a rate of at least 3 grams per minute per liter of said chamber, introducing oxygen into the confined chamber at a rate of at least 3 grams of oxygen per minute per liter of said chamber, contacting and mixing in said chamber at least 3 grams of said aluminum per minute per liter with at least 3 grams per minute per liter of said oxygen, igniting said mixture, burning said aluminum in said oxygen at a rate of at least 20,000 calories per minute per liter of said chamber, continuously supplying said oxygen at a rate of at least 3 grams per minute per liter of said chamber to maintain burning of said aluminum in said oxygen at a rate of at least 20,000 calories per minute per liter to produce heat at a temperature in excess of 1500° C., continuously supplying and burning aluminum at a rate of at least 3 grams per minute per liter, producing molten aluminum oxide by said burning, contacting said chamber refractory material with said molten oxide and continuously supplying aluminum and said gas to said combustion at said rate to produce sufficient aluminum oxide to melt said chamber refractory material.

4. The method of producing heat in a confined chamber of refractory material having a melting point of at

least 1500° C. for producing molten aluminum oxide in said chamber at a temperature in excess of the melting point of the refractory material which comprises introducing metallic aluminum into the confined chamber at a rate of at least 3 grams per minute per liter of said chamber, introducing oxygen into the confined chamber at a rate of at least 3 grams of oxygen per minute per liter of said chamber, contacting and mixing in said chamber at least 3 grams of said aluminum per minute per liter with at least 3 grams per minute per liter of said oxygen, igniting said mixture, burning said aluminum in said oxygen at a rate of at least 20,000 calories per minute per liter of said chamber, continuously supplying said oxygen at a rate of at least 3 grams per minute per liter of said chamber to maintain burning of said aluminum in said oxygen at a rate of at least 20,000 calories per minute per liter to produce heat at a temperature in excess of 1500° C., continuously supplying aluminum at a rate of at least 3 grams per minute per liter, producing molten aluminum oxide by said burning, contacting said chamber refractory material with said molten oxide and continuously supplying aluminum and oxygen to said combustion at said rate to produce sufficient aluminum oxide to melt said chamber refractory material.

5. The method of producing heat in a confined chamber of refractory material having a melting point of at least 1500° C. by producing molten oxide in said chamber at a temperature in excess of the melting point of the refractory material which comprises introducing a highly exothermic metal selected from the group consisting of aluminum, magnesium and zirconium into the confined chamber at a selected rate of at least 3 grams per minute per liter of said chamber for aluminum, at least 3.5 grams per minute per liter of said chamber for magnesium, and at least 7 grams per minute per liter of said chamber for zirconium, introducing oxygen into the confined chamber at a selected rate of 3 grams of oxygen per minute per liter of said chamber for aluminum and magnesium and 4.5 grams of oxygen per minute per liter of said chamber for zirconium, contacting and mixing in said chamber said selected amounts of said highly exothermic metal and said oxygen, igniting said mixture, burning said highly exothermic metal in said oxygen at a rate of at least 20,000 calories per minute per liter of said chamber, continuously supplying said gas at said rate for said respective highly exothermic metal to maintain burning of said selected highly exothermic metal in said oxygen at a rate of at least

20,000 calories per minute per liter to produce heat at a temperature in excess of 1500° C., continuously supplying and burning said selected highly exothermic metal at said respective rate per liter of said chamber and producing molten highly exothermic metal oxide in said chamber at a temperature in excess of the melting point of the refractory material of said chamber.

6. The method of producing heat in a chamber of refractory material having a melting point of at least 1500° C. by producing in said chamber molten oxide of a metal of the group consisting of aluminum, magnesium and zirconium at a temperature in excess of the melting point of the refractory material which comprises introducing a supply of a metal of said group into the confined chamber at a rate of at least 12 grams of said metal per minute per liter of said chamber, introducing oxygen into the confined chamber of a rate of at least 3 grams of oxygen per minute per liter of said chamber, contacting and mixing in said chamber at least 12 grams of metal per minute per liter with at least 3 grams per minute per liter of said oxygen, igniting said mixture of oxygen and metal, burning said metal in said oxygen at a rate of at least 20,000 calories per minute per liter of said chamber, continuously supplying said oxygen at a rate of at least 3 grams per minute per liter of said chamber to maintain burning of said metal in said oxygen at a rate of at least 20,000 calories per minute per liter to produce heat at a temperature in excess of 1500° C., and continuously supplying and burning said material at a rate of at least 12 grams per minute per liter of said chamber and producing corresponding molten metal oxide in said chamber at a temperature in excess of the melting point of the refractory material of said chamber.

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