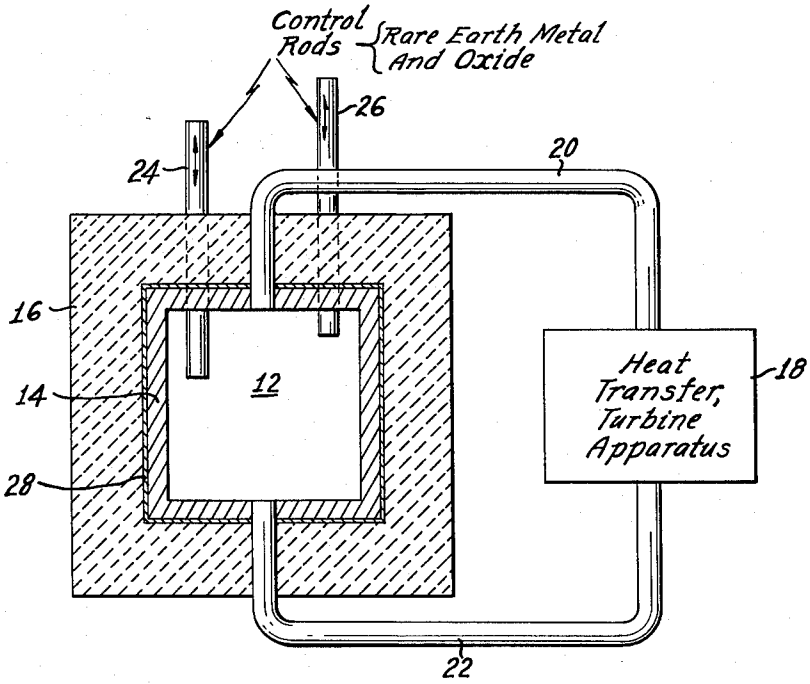
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REFRACTORY RARE EARTH MATERIAL

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REFRACTORY RARE EARTH MATERIAL

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This invention relates to rare earth materials, and has for its principal object the production of a rare earth composition of matter which is both ductile and refractory.

The rare earth metals with which we are concerned in the present case include the elements of atomic numbers 21, 39 and 57 through 71. Specifically, they include the elements lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. One of the group, promethium, atomic number 61, does not occur naturally but is a fission product. Scandium and yttrium, atomic numbers 21 and 39, occur together with the rare earths in nature and are also Group III–A elements. These last two elements are therefore generally included in the term "rare earth metals" and are so included in the present specification and claims. In addition to the designation "rare earth metals," the term "lanthanons" is often used in referring to this group of elements. By "lanthanon" is meant any element having an atomic number within the group having numbers 21, 39 and 57 through 71.

The rare earth metals in purified form are relatively ductile, have melting points which range from 800° C. to 1700° C., and are chemically active. The rare earth oxides are refractory in nature and have relatively high melting points. Because of the strong tendency toward rapid oxidation of many of the rare earth metals, it has been considered impractical to form alloys containing high percentages of these elements.

In accordance with the present invention, however, it has been determined that homogeneous mixtures of rare earth metals and rare earth oxides have high strength and high melting points, and also have a significant degree of ductility. Thus, for example, where pure fused quartz has a melting point of between 1700° C. and 1800° C., the rare earth oxides have melting points in the range of 2300° C. to 2500° C. By the use of homogeneous compositions including the rare earth oxides and the pure rare earth elements, materials may be produced which have good physical properties, and high melting points, in certain cases even higher than the melting points of the oxides in question.

In accordance with a feature of the invention, therefore, a ductile refractory material is composed of a homogeneous melt of one or more of the rare earth metals and one or more of the rare earth oxides.

In accordance with additional features of the invention, new compositions of matter are principally composed of these rare earth metals and rare earth oxides and includes at least 3 percent and preferably 10 percent of each of these materials. Furthermore, these compositions of matter may be employed in structural or control elements in combination with a source of intense heat or nuclear radiations, or both; in the case of nuclear radiations, it is desirable to use some samarium, europium, gadolinium, dysprosium or erbium in the composition.

Other objects, features and various advantages of the present invention may be readily apprehended from a consideration of the following detailed description and from the drawing, in which the single figure is a schematic showing of an atomic reactor system employing materials in accordance with the present invention.

In considering the present materials, it is useful to note the melting and boiling points of the rare earth elements and the melting points of the oxides. They are set forth in the following table:

Table I

Element	Melting point, ° C.	Boiling point, ° C.	Oxide melting point, ° C.
Scandium	1,570	2,450	2,500
Yttrium	1,550	3,000	2,400
Lanthanum	920	4,200	2,300
Cerium	804	2,900	2,350
Praseodymium	920	3,000	2,300
Neodymium	1,020	3,150	2,270
Samarium	1,050	1,600	2,350
Europium	900	1,400	2,400
Gadolinium	1,250	2,700	2,350
Terbium	1,365	2,500	2,300
Dysprosium	1,400	2,300	2,340
Holmium	1,500	2,300	2,300
Erbium	1,520	2,600	2,300
Thulium	1,600	2,100	2,300
Ytterbium	824	1,500	2,400
Lutetium	1,700	1,900	2,500

With reference to the drawing, the single figure shows schematically a nuclear reactor of the fission type designed for generating mechanical power, and ultimately electricity. The central core **12** of the reactor includes fuel and a moderator. Surrounding the core **12** is a layer of reflecting material **14**. Suitable heavy shielding **16** encloses the entire assembly. Heat from the reactor core **12** is transferred to the output apparatus **18** by a suitable coolant, such as liquid sodium which flows through pipes **20** and **22**.

The intensity of the nuclear reaction is controlled by the vertical positioning of the control rods **24** and **26** which extend into the core of the reactor. The general structural organization of the reactor is conventional and is discussed in many references on atomic energy, one of these being "Sourcebook on Atomic Energy" by Samuel Glasstone, second edition, D. Van Nostrand Company, Inc., Princeton, New Jersey.

In accordance with the present invention, however, the control rods **24** and **26**, the inner lining **28** of the shielding layer **16**, and other structural components of the reactor may be formed of rare earth oxides and rare earth metals in homogeneous compositions, as discussed above. From a broad standpoint, the ductile refractory materials in accordance with the present invention may be employed for their good mechanical properties at high temperatures. For certain specific purposes, however, there is a particular group of the rare earth elements which have excellent shielding and absorbing properties for neutron radiation. These materials are samarium, europium, gadolinium, dysprosium and erbium. In the following table, the thermal neutron cross sections of these five elements are tabulated.

Table II

Element:	Thermal neutron cross section (barns)
Samarium	5,500
Europium	4,600
Gadolinium	46,000
Dysprosium	1,100
Erbium	166

In regard to the thermal neutron cross section of dysprosium and erbium, it is interesting to note that the epithermal neutron cross section of these two elements is considerably higher than that indicated in the table. In other words, these two elements have relatively high absorption characteristics for higher energy or "faster" neutrons.

The materials in accordance with the present invention include rare earth oxides and rare earth elements in homogeneous compositions, or melts. Sample specimens were prepared by arc melting in an inert atmosphere of argon. In different cases, granular or solid rare earth metals were arc melted with powdered oxides of the rare earths without significant prior admixture. Details of one arc melting process which may be employed are set forth in Bernard Love patent application Serial No. 823,812, filed June 30, 1959, now Patent Number 3,083,094, and assigned to the assignee of the present invention.

In addition to the use of the materials of the present invention in connection with nuclear reactors as discussed above, the materials may also be employed in rocket nose cones, in furnace linings, and in rocket launching pads or flame deflectors. Other possible uses include gas turbine blades, rocket nozzles, and missile bodies. Similar applications involving high temperatures and the need for good mechanical properties are contemplated.

In one specific set of experiments, yttrium and yttrium oxide were arc welded in an inert atmosphere of argon, as noted above. With varying proportions of yttrium and yttrium oxide, the melting points of the melts increased from the 1550° C. melting point of yttrium to temperatures even above the 2400° C. melting point of yttrium oxide. Thus, one sample having approximately equal weight percentages of yttrium and yttrium oxide has a melting point of approximately 2600° C. All of the mixtures of yttrium metal and yttrium oxide appeared to be homogeneous.

Other melts having approximately equal weight percentages of rare earth metal and rare earth oxide have also been prepared. These include gadolinium-gadolinium oxide, having a melting point of about 2600° C.; yttrium and samarium oxide, having a melting point of about 2000° C.; and dysprosium and yttrium oxide, having a melting point of about 1740° C.

With regard to the proportions of rare earth oxide and rare earth metals, homogeneous samples have been made with proportions ranging from a few percent of rare earth oxide, with the balance being the pure rare earth metal, all the way to a few percent of the rare earth metal, with the balance being rare earth oxide. In order to obtain significant advantages of the present invention however, it is desirable that at least 3% to 5% and preferably 10% or more of each of the two components be included in the homogeneous composition of matter. The matter of homogeneity of the melts is particularly important, as it is well known that pure rare earth metals tend to become oxidized on their surfaces. Furthermore, in the case of impure rare earth materials, or rare earth metals of commercial purity, oxygen or oxides may be present at discrete points in the metal. However, such prior art compositions are clearly distinct from the homogeneous melts contemplated in accordance with the present invention.

Various properties may be obtained by using selected rare earth metals and the same or different rare earth oxides. Thus, shielding from both thermal and epithermal neutrons may be obtained by using both gadolinium and dysprosium and/or erbium, for example, as either the metallic or the oxide component of the proposed new compositions of matter. In addition, the total thermal neutron cross section of the resultant mixture may be controlled by using gadolinium or gadolinium oxide combined with varying proportions of another rare earth oxide or rare earth metal, respectively, having a low thermal neutron cross section.

In the case of control rods, it is interesting to note that only relatively small percentages of gadolinium are required in order to provide a neutron cross section equal to that of the hafnium control rods which are commonly used. Thus, approximately 0.25 percent of gadolinium

in melts composed principally of other rare earth metals and oxides of low neutron cross sections, produces a control rod having the same neutron cross section as one made entirely of hafnium. Thus, when gadolinium is used, significant shielding or control effects are provided with percentages as low as 0.1 percent. With the other materials as listed in Table II, somewhat greater percentages are required as indicated by the lower neutron cross sections.

It is to be understood that the above described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A nuclear reactor control element consisting essentially of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of an element within said group.

2. A nuclear reactor control element consisting essentially of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of an element selected from the group consisting of samarium, europium, gadolinium, dysprosium and erbium.

3. A nuclear reactor control element consisting essentially of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of another element within said group.

4. A nuclear reactor control element consisting essentially of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of the same element within said group.

5. A ductile refractory composition of matter consisting essentially of a homogeneous melt of at least three percent by weight of an element having an atomic number within the group having numbers 21, 39 and 57 to 71 and an oxide of an element within said group.

6. A ductile refractory composition of matter consisting essentially of a homogeneous melt of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of an element selected from the group consisting of samarium, europium, gadolinium, dysprosium and erbium.

7. A nuclear reactor shield consisting essentially of at least three percent by weight of an element having an atomic number within the group of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of an element within said group.

8. A nuclear reactor shield consisting essentially of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of an element selected from the group consisting of samarium, europium, gadolinium, dysprosium and erbium.

9. A nuclear reactor shield consisting essentially of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three percent by weight of an oxide of another element within said group.

10. A nuclear reactor shield consisting essentially of at least three percent by weight of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71 and at least three

percent by weight of an oxide of the same element within said group.

11. A nuclear reactor control element consisting essentially of at least 3% by weight of an element selected from the group consisting of samarium, europium, gadolinium, dysprosium and erbium and at least 3% by weight of an oxide of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71.

12. A ductile refractory composition of matter consisting essentially of a homogeneous melt of at least 3% by weight of an element selected from the group consisting of samarium, europium, gadolinium, dysprosium and erbium and at least 3% by weight of an oxide of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71.

13. A nuclear reactor shield consisting essentially of at least 3% by weight of an element selected from the group consisting of samarium, europium, gadolinium, dysprosium and erbium and at least 3% by weight of an oxide of an element having an atomic number within the group consisting of elements having numbers 21, 39 and 57 to 71.

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