1 396 275

PATENT SPECIFICATION

(11) 1 396 275

(21) Application No. 477/74 (22) Filed 4 Jan. 1974

(44) Complete Specification published 4 June 1975

(51) INT CL^2 C22C 19/03, 30/00

(52) Index at acceptance

C7A A249 A279 A299 A329 A339 A349 A350 A35X A35Y A389 A409 A439 A459 A509 A529 A549 A579 A599 A609 A629 A671 A673 A675 A677 A678 A67X A681 A683 A685 A686 A689 A68Y A693 A695 A697 A699 A69X A70X

C7D 8H 8R 9A1E 9A5B

(19)

(54) NEUTRON-ABSORBING ALLOYS

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The present invention relates to neutron-absorbing alloys.

According to the invention, there is provided a neutron-absorbing alloy consisting of, by weight, from 1 to 20% indium, from 0.5 to 15% samarium, from 5 to 18% hafnium, the balance being nickel together with unavoidable impurities.

A preferred neutron-absorbing alloy has the following composition in % by weight: indium, 10; samarium, 8; hafnium, 13.5; and nickel, 68.5.

Alloys of the invention have good absorption capacity for thermal and intermediate neutrons, good neutron capture efficiency, and corrosion resistance. The alloys find application in automatic control and safety systems of nuclear reactors such as, for example, thermal and intermediate reactors used to generate power or for propulsion.

The hafnium which is present in the alloys of the invention in the range of from 5 to 18% by weight specified above provides for the maintenance of a reasonably high order of neutron capture efficiency throughout the lifetime of a reactor.

A preferred method of forming the neutron-absorbing alloys of the invention is as follows. The alloy is formed in a vacuum furnace operating in an inert gas atmosphere under a pressure of from 280 to 300 mm Hg. The sequence of events preferably is as follows: the nickel is placed in a crucible, and the indium, samarium and hafnium are placed in a metering hopper; the system is evacuated and filled with an inert gas under a pressure of from 280 to 300 mm Hg; the nickel is heated to a temperature of 900 to 1000° C.; indium, samarium and hafnium are introduced in succession; and the alloy obtained is poured into ceramic, metallic or other moulds at a temperature of from 1500 to 1510° C.

Preferred alloys of the invention have a corrosion resistance which is from 3 to 3.5 times that of the known silver-based alloy commonly employed to capture neutrons. When exposed, in a corrosion test, to the action of hot water at 350° C. and 168 atm for 3000 hours, a preferred alloy of the invention exhibited an increase in weight corresponding to a rate of 0.59 mg/md^2 per 24 hours. Under similar conditions, but at the lower temperature of 300° C., the known silver-based alloy corroded severely, the rate of weight increases being 0.83 mg/dm^2 per 24 hours, and the known alloy failed to withstand corrosion at a temperature of 350° C.

Preferred alloys of the invention exhibit a high residual neutron capture efficiency, which may be, for example, about twice that of the known alloy.

The castability of alloys of the invention allows automatic control and safety rods to be fabricated in a variety of sizes with minimum machining tolerances, and the structural strength of the alloys assures good reliability of the control system in thermal power reactors.

In order that the invention may be more fully understood, the following Examples are given by way of illustration only:

Example 1.

A neutron-absorbing alloy of the following composition in % by weight was prepared as described below:

indium, 10;
samarium, 8;
hafnium, 13.5;
nickel, 68.5.

The required amount of nickel was loaded into a crucible and the required amounts of indium, samarium (in the form of a nickel-samarium alloy) and hafnium were introduced into a metering hopper. The system was evacuated and then filled with an inert gas under a pressure of between 280 and 300 mm Hg. After heating the nickel to between 900 and 1000° C., half of the total amount of indium was added and heating was continued for another five to eight minutes until a melt was obtained. A nickel-samarium alloy and the rest of indium were then added to the melt (indium forms an eutectic with nickel with a melting point of 914° C.). After a further ten minutes heating to melt the mixture, the temperature of the melt was increased to between 1400 and 1450° C. and the hafnium was added. Finally, the melt was then heated to between 1500 and 1510° C., maintained at this temperature for a period of between five and seven minutes, and then the alloy was poured into moulds.

Relevant properties of the alloys so obtained are tabulated in Table 1 below.

Example 2.

A neutron-absorbing alloy, having the following composition in % by weight, was prepared following the procedure described in Example 1:

indium, 1;
samarium, 0.5;
hafnium, 5;
nickel, 93.5.

Relevant properties of the alloy are tabulated in Table 1.

Example 3.

A neutron-absorbing alloy having the following composition, in % by weight, was prepared as described in Example 1:

indium, 20;
samarium, 15;
hafnium, 18;
nickel, 47.

Relevant properties of the alloy are tabulated in Table 1.

TABLE 1

Properties	Known silver-based alloy	Alloy described in		
		Example 1	Example 2	Example 3
1. Neutron capture efficiency (that of B_4C taken as unity)	0.7	0.82 - 0.83	0.4	0.82 - 0.83
2. Residual neutron capture efficiency at end of reactor lifetime (that of B_4C taken as unity)	0.3	0.6	0.2	0.6
3. Density, g/cm^3	10.17	9.1-9.5	9.0	9.7
4. Corrosion resistance in water at 168 atm after 3000 hours (increase in weight, $mg/dm^2.24$ hours):				
at 300°C	0.83	0.21	0.2	0.7
at 350°C	fails to withstand corrosion	0.59	0.47	0.98
5. Ultimate tensile strength at 20°C, kg/mm^2	-	23-32	30-34	18-27

WHAT WE CLAIM IS:—

1. A neutron-absorbing alloy consisting of, by weight, from 1 to 20% indium, from 0.5 to 15% samarium, from 5 to 18% hafnium, the balance being nickel together with unavoidable impurities.

2. A neutron-absorbing alloy according to claim 1, having the following composition in % by weight:

indium, 10;
samarium, 8;
hafnium, 13.5;
nickel, 68.5.

3. A neutron-absorbing alloy substantially as herein described in Example 2 or 3.

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**Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1975.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.**