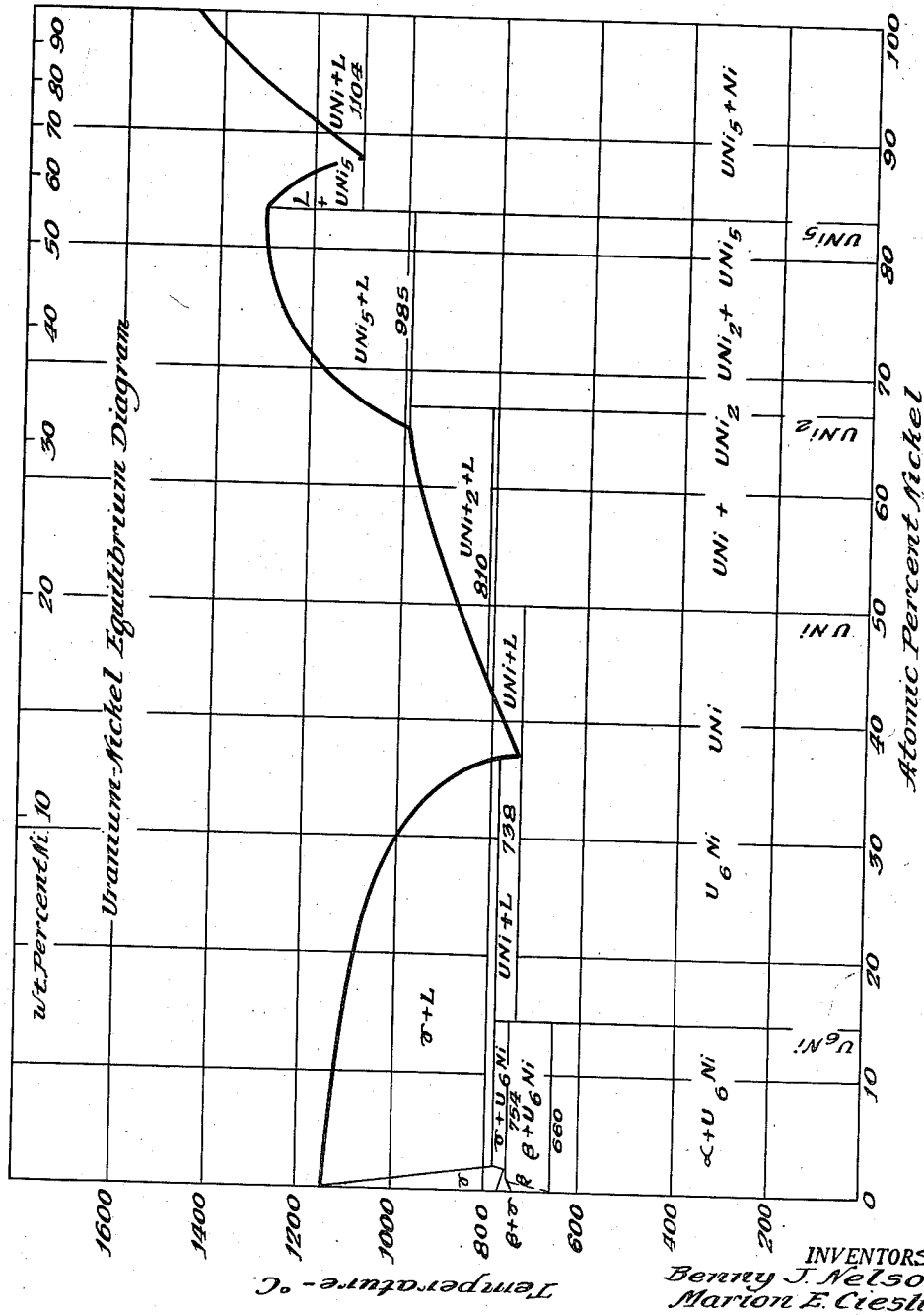
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URANIUM-NICKEL METAL ALLOY

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URANIUM-NICKEL METAL ALLOY

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1 Claim. (Cl. 75—134)

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The present invention is concerned with uranium-base alloys and more particularly binary uranium-base alloys containing nickel.

An object of the present invention is to improve the corrosion resistance of uranium and uranium-base alloys.

Another object of this invention is to produce binary uranium-nickel alloys which are useful in the design and construction of neutronic reactors.

Still another object of this invention is directed toward the formation of new and novel uranium-nickel alloy compositions which are useful as additives in the formation of other metal alloys containing uranium and nickel.

Other objects of the present invention will be apparent from the following description taken in connection with the accompanying drawing, in which the single figure is a phase equilibrium diagram defining the uranium-nickel system.

In accordance with the present invention it has been found that the corrosion resistance of uranium and uranium-rich alloys may be substantially improved by the incorporation of a quantity of nickel in such uranium or uranium-base alloys. The amount of nickel which may be added to uranium metal is capable of variation extending through the phase diagram wherein four distinct intermetallic compounds have been identified. The formulae, U_6Ni, UNi, UNi_2, and UNi_5 have been assigned to these compounds on the basis of thermal, X-ray and microscopic evidence.

In order to determine the possible compositions and usefulness of uranium-nickel alloys, the constitutional diagram of the system has been determined. In examining the microstructures of as-cast uranium-nickel alloys, the effects of heat treatment upon the microstructures of the varying compositions were also observed.

The initial structure of a 1.1 atomic per cent nickel alloy of uranium in the as-cast structure consists of a eutectoid matrix with precipitated or peritectic compounds at the grain boundaries. Upon heating the as-cast structure to 705° C., the microstructure appears to spherodize the eutectic and the grain boundary composition to give a fairly uniform dispersion of U_6Ni particles in the uranium matrix. This alloy appears to be close to the eutectoid composition. The microstructures of these as-cast 2.6, 5.4, and 10.0 atomic per cent alloys of uranium-nickel showed primary gamma uranium solid solution in a network of peritectic compound, U_6Ni. The 10 atomic per cent nickel alloy of uranium contained considerable eutectic as a result of the incomplete peritectic reaction. All these alloys responded to heat treatment. The eutectic structure in the primary phase was not evident in the alloys which were water-quenched from 715° C. It appears that the peritectic reaction had gone to completion. There appeared to be no evidence of retained beta phase in these alloys and the thermal analysis showed a break at 754° C.

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The microstructure of a 15.3 atomic per cent nickel alloy was cast and examined. It was found that slightly above the peritectic compound composition, the compound of simplest atomic ratio having a composition slightly less than 15.3 atomic per cent would be U_6Ni at 14.3 atomic per cent nickel. X-ray diffraction patterns of the 15.3 atomic per cent nickel alloys indicate that the compound U_6Ni has a face centered cubic lattice with $a_0=4.88$ Å.

Upon increasing the atomic percentage of nickel in a nickel-uranium composition, it was found that upon examining the microstructure between a 30.5 atomic per cent nickel cast alloy and 41.7 atomic per cent nickel cast alloy, there was exhibited a primary phase eutectic, but the primary phase of the 30.5 per cent nickel alloy appeared to be different than in the 41.7 atomic per cent nickel alloy. It was found that a eutectic alloy containing 37.4 per cent nickel contained no primary phase and appeared to be entirely eutectic. Thermal analysis fixed the eutectic temperature of the first eutectic of nickel-uranium alloy at 738° C.

As described above, the 41.7 atomic per cent nickel alloy showed a primary phase different from uranium, and thermal analysis of alloys in the composition range of 45–66 atomic per cent nickel showed a break at 810° C. The microstructure of the 53 atomic per cent nickel alloy was characterized by an incomplete peritectic reaction; and upon heat treatment, the peritectic reaction went to completion. It was found that these alloys in this composition range were extremely difficult to produce and were subject to considerable segregation. In examining the phase diagram, it shall be noted that a peritectic reaction occurs at 810° C. in this composition range and that the microstructure analysis indicated that the peritectic compound formed was UNi.

A third peritectic compound UNi_2 was formed in alloys containing from about 67 to 80 atomic per cent nickel. Thermal arrests were obtained at 985° C. indicating the peritectic compound to

be UNi_2. In examining the microstructure of the 67 atomic per cent nickel it was found that the composition exhibited nearly single phase composition; thus the third peritectic compound has the formula UNi_2 which is formed at 66.6 atomic per cent nickel composition by the peritectic reaction at 985° C. In extending the composition range of the nickel-uranium system from 67 to 90 atomic per cent nickel the liquidus rises to a maximum of about 1295° C. at 83 atomic per cent nickel and then drops rapidly to 1104° C. at 88 atomic per cent nickel. The microstructure of a 79.5 atomic per cent nickel alloy composition was nearly single phase; and the 90 atomic per cent nickel showed considerable eutectic and was well beyond the compound composition. Thus the simplest compound formula which was consistent with these data was UNi_5 at 83.3 atomic per cent nickel. It was found that UNi_5 melted at 1295° C. and was identified by a hexagonal lattice with a_0=4.70 Å. and c_0=7.24 Å.

Thermal arrests at 1104° C. were obtained in the thermal analysis of high nickel content uranium alloys. The microstructures of 95 atomic per cent nickel alloys revealed a eutectic structure plus primary nickel. The microstructure of the 90 atomic per cent nickel alloy showed the same atomic structure plus a primary phase which may be either nickel or UNi_5.

These new uranium-nickel alloys may be conveniently prepared by melting in vacuo the required amounts of uranium and nickel in a refractory crucible, such as a beryllium oxide lined Alundum thimble.

Microscopic examinations were made on these alloys in the as-cast conditions and some were re-examined after appropriate heat treatment. The specimens were polished mechanically with alumina and then electrolytically polished with a phosphoric acid-ethylene glycol-ethyl alcohol solution.

The alloys of the present invention are useful as protective coatings for uranium shapes which may be exposed to corrosive action of chemical reagents. These uranium-nickel alloys may be cast into various shapes and forms to be used in the construction of neutronic reactors, and the addition of nickel to the uranium metal decreases the rate of corrosion by chemical reagents, such as acid solutions and aqueous solutions containing hydrogen peroxide. It was found that the addition of as little as 4 atomic per cent of nickel to uranium metal decreased the hot water corrosion rate of uranium by a factor of approximately twenty.

It shall be noted that this invention is primarily concerned with binary alloy compositions consisting of uranium and nickel. Since uranium is an essential component in the construction of neutronic reactors, it is extremely important to substantially increase the corrosive resistance of uranium without introducing a large quantity of neutron absorbers other than the essential alloying agent, nickel, which has a relatively low neutron adsorption cross-section.

In addition it was found that the binary eutectic alloy of uranium and nickel at about 37 atomic per cent nickel having a melting point of 730° C. afforded a new and novel low melting point alloy having a high percentage of uranium. This eutectic alloy was found to exhibit extremely high resistance to oxidation; and the high density of this eutectic alloy afforded a very suitable material to be used as an alloying additive in the formation of more complex uranium-containing alloys, such as those having a base metal, as for example, steel, nickel, copper or the like. When the eutectic alloy is added to a ladle of molten steel, nickel or copper, it sinks rapidly and alloys with the bath without excessive oxidation and loss of the expensive uranium metal. Furthermore, the eutectic composition exhibits extremely high resistance toward the corrosive effect of acids as indicated by its high resistance to acids, including aqua regia. Furthermore the resistance of these binary uranium alloys to acids indicates that the uranium-nickel alloys with or without the addition of other elements, constitute a new and novel series of corrosion resistant materials which offer unique advantages over uranium.

All of the alloys above described, in addition to the physical-metallurgical advantages, exhibit resistance to corrosion far superior to that of uranium metal.

It will be understood that the particular alloy compositions described above should not be deemed to constitute the limits of the invention. The scope of the invention is defined in the appended claim.

What is claimed is:

A peritectic composition of matter consisting essentially of uranium and nickel represented by the formula U_6Ni having a face-centered lattice with a_0=4.88 Å.

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