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COMPATIBILITY DATA SHEETS FOR CERIUM-144, CESIUM-137, CURIUM, AND STRONTIUM-90

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ISOTOPES DEVELOPMENT CENTER

COMPATIBILITY DATA SHEETS FOR CERIUM-144, CESIUM-137, CURIUM, AND STRONTIUM-90

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Isotopes Division

JANUARY 1969

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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COMPATIBILITY DATA SHEETS FOR CERIUM-144, CESIUM-137, CURIUM, AND STRONTIUM-90

REFERENCE COLUMN

CERIUM-144

The compatibilities of cerium compounds with various container materials have been summarized in the following table. 1

Source material and exposure	Container material									
	Superalloys					Refractory metals				
	Hastelloy X	Haynes 25	Ni-o-nel	N-155	Inconel X	Mo	Nb	Ta	W	TZM
Cerium metal										
1000°C, 168 hr	DR	DR	DR	DR						
1000°C, 1000 hr	DR	DR	DR	DR		MR		SR	NR	SR
Ceric oxide (CeO_2)										
1000°C, 1000 hr	SR	SR	SR	SR		SR	SR	SR	SR	
CeO_2-5% Nd										
1000°C, 1000 hr	SR	SR	MR	SR		NR	SR	SR	SR	
Cerium oxysulfide (Ce_2O_2S)										
1000°C, 1000 hr	SR	SR	SR	MR		SR		SR	NR	SR
1850°C, 1000 hr						SR		MR	SR	
Cerous oxide (Ce_2O_3)										
1000°C, 1000 hr	SR				SR					
1850°C, 168 hr						SR	MR	MR	MR	
Cerium hexaboride (CeB_6)										
1000°C, 1000 hr	SR	NR	SR	NR		SR	SR	SR	SR	
1850°C, 168 hr						DR	MR	MR	DR	
Cerous fluoride (CeF_3)										
1000°C, 1000 hr	SR	NR	NR	NR		NR	NR	NR	SR	
Cerous sulfide (Ce_2S_3)										
1000°C, 1000 hr	SR	SR	SR	MR		SR			NR	SR

Legend: NR – negligible or no reaction (compatible) SR – slight reaction
DR – destructive reaction (incompatible) MR – major reaction

Cerium metal was incompatible with all the superalloys. In the studies with the refractory metals, it was found that cerium metal apparently diffused into molybdenum, while it showed only a very thin diffusion zone along the surface of the tantalum capsule.

Ceric oxide (CeO_2) and ceric oxide with 5% neodymium showed only slight reaction with the container materials. Cerous oxide (Ce_2O_3) showed major reactions with niobium, tantalum, and tungsten; it showed slight reaction with molybdenum after 168 hr at 1850°C.

Only slight reactions took place between cerium hexaboride and container materials at 1000°C. At 1850°C, however, CeB_6 was judged incompatible with molybdenum and tungsten due to extreme penetration of the capsule, and niobium and tantalum showed major reactions. The compound apparently dissociated, and boron reacted to form very brittle borides with the container materials.

Slight reaction of Ce_2O_2S was demonstrated with most of the container materials except N-155 at 1000°C for 1000 hr and tantalum at 1850°C for 1000 hr.

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REFERENCE COLUMN

Cerium fluoride (CeF_3) and cerous sulfide (Ce_2S_3) were compatible with all capsule materials tested. These compounds showed only slight reactions in some cases.

CESIUM-137

A CsCl source which was encapsulated in stainless steel and contained 1540 Ci of ^{137}Cs showed no signs of reaction after being opened 9 years later. The source operated at slightly above ambient room temperature. 2

CURIUM

Curium-244 Sesquioxide (Cm_2O_3)

A molybdenum alloy containing 0.5% titanium and 0.1% zirconium (TZM) was contacted with an oxide mixture containing 29 wt % $^{244}Cm_2O_3$, 57 wt % $^{241}AmO_2$, and 14 wt % $^{239}PuO_2$. Static capsule tests at 1100°C for periods of 250 and 1000 hr and at 2000°C for 25 hr showed no reaction with molybdenum, even though the oxide fuel was molten at 2000°C. 3

The results of 1000-hr tests at 1650 and 1850°C on Ta, Ta-10% W, T-111, Mo, TZM, W, and W-26% Re with $^{244}Cm_2O_3$ have indicated that none of these refractory metals and alloys need be eliminated from consideration as potential container materials. Some interaction was noted in all of the systems. A very shallow reaction zone (<1 mil) occurred in W, Mo, and TZM at 1650°C, but in tantalum and tantalum alloys more serious interactions were noted. A platelet type of precipitate was found throughout the cross section of unalloyed tantalum, and a gray reaction product was found to a depth of 7 mils in T-111. Results at 1850°C were similar to those at 1650°C for Mo, TZM, W, and W-26% Re. However, in the tests with tantalum and tantalum alloys a small amount of tantalum apparently dissolved in $^{244}Cm_2O_3$ with resulting melting of the fuel form which spread into capsule crevices, but the reaction products observed at 1650°C were not seen. 4

Curium-242 Oxide Cermet

Tests at 1100°C for 1000 hr and at 2000°C for 24 hr with an oxide mixture containing 29 wt % Cm_2O_3, 57 wt % AmO_2, and 14 wt % PuO_2 showed that this oxide mixture was compatible with TZM. 3

With the use of iridium in a metal-metal oxide cermet, alloying of iridium with molybdenum was observed at 2000°C. Also the molten oxide mix appeared to react with iridium to form a lower melting alloy. At 1000°C the reaction between iridium and molybdenum was too slow to be observed, at least over a period of time of 1000 hr.

[redacted]

REFERENCE COLUMN

STRONTIUM-90

The compatibilities of various inactive strontium compounds with a number of container materials were determined and have been summarized in the following table. 1

Source material and exposure	Container materials								
	Superalloys				Refractory metals				
	Hastelloy X	Haynes 25	Ni-o-nel	N-155	Mo	Nb	Ta	W	TZM
Strontium metal									
1000°C, 1000 hr	SR	NR	SR	MR	NR		SR	NR	NR
1000°C, 5000 hr		MR		MR			SR	NR	
1000°C, 10,000 hr		MR	MR	MR	NR		SR	SR	
Strontium oxide (SrO)									
1000°C, 1000 hr	SR		SR	SR	NR	NR	SR	SR	
1850°C, 168 hr					SR	MR	SR	SR	
Strontium-9% beryllium oxide (SrO-9% BeO)									
1000°C, 1000 hr		MR	MR	SR	NR			NR	NR
Strontium fluoride (SrF_2)									
1000°C, 1000 hr	SR	SR	SR	SR	NR		SR	SR	
Strontium disilicide ($SrSi_2$)									
1000°C, 168 hr	DR	DR	DR	DR	DR		DR	DR	DR
Strontium titanate ($SrTiO_3$)									
1000°C, 1000 hr	SR	SR	SR	SR	NR		NR	NR	NR
1850°C, 1000 hr					NR	SR	SR	NR	MR

Legend: NR – *negligible or no reaction (compatible)*; SR – *slight reaction*; DR – destructive reaction (incompatible); MR – major reaction

A number of reactions were dependent on time and temperature, for example, Haynes 25 with strontium metal showed no attack at 1000°C up to 1000 hr, but fell into the major reaction classification after 5000 hr at 1000°C and also after 10,000 hr at 1000°C. This indicates that Haynes 25 should probably not be considered for use with strontium metal at temperatures >1000°C and times >5000 hr.

For periods up to 1000 hr at 1000°C, strontium metal showed little or no reaction with any metal except N-155, in which areas of severe subsurface void formation were found up to 22 mils.

At 1000°C SrO showed only slight surface oxidation reaction with most of the metals.

Strontium fluoride (SrF_2) showed very little attack with the metals tested.

At 1000°C $SrSi_2$ showed extensive reaction with Hastelloy X, Haynes 25, Ni-o-nel, and N-155. Molybdenum, tantalum, and TZM were resistant to penetration by silicon metal which formed from the dissociation of $SrSi_2$ at 1000°C.

Strontium titanate was compatible with all the container materials to which it was exposed except TZM at 1850°C for 1000 hr. Slight reactions occurred with all of the superalloys at 1000°C and niobium and tantalum at 1850°C, but in no case was attack severe enough to disqualify these couples for future tests.

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REFERENCE COLUMN

More extensive compatibility tests of Haynes 25, Hastelloy C, and type 316 stainless steel with inactive $SrTiO_3$ and Sr_2TiO_4 have not indicated any serious interactions after 1000 and 5000 hr at 1100°C. However, these materials were attacked to a maximum depth of 0.007 in. when exposed to SrO under the same conditions. It is believed that these latter results are due to reaction of the container materials with water vapor or excess oxygen dissolved in the SrO. Mechanical properties tests of specimens exposed to all three strontium compounds did not reveal any deterioration when compared with control specimens heat treated in argon under similar conditions of time and temperature. 3

After exposure for 2036 hr at 925°C to inactive liquid strontium metal, it was found that molybdenum and stainless steel 321 showed good compatibility with liquid strontium metal; that wrought iron and Haynes 25 were worthy of further study; and that Hastelloy C, Hastelloy N, Hastelloy X, and titanium had dissolved and were incompatible with strontium metal. 5

No attack on molybdenum was observed after 5000-hr contact with inactive liquid strontium metal at 1000°C. 6

Metallographic examination of inactive SrF_2 test specimens exposed for 19 months at 925°C gave the following results. 7

Encapsulating material	Penetration, in. Maximum	Penetration, in. Average
	Simulated SrF_2 fuel[a]	
Haynes 25	0.0006	nil
Ta liner in Haynes 25	Complete penetration of Ta liner	
Hastelloy C	0.001	0.0004
Hastelloy N	0.002	0.001
Hastelloy X	0.0075	0.0014
	Simulated aged feed material[b]	
Haynes 25	0.0015	0.0008
Ta liner in Haynes 25	Complete penetration of Ta liner	
Hastelloy C	0.0007	0.0003
Hastelloy N	0.0028	0.0011
Hastelloy X	0.0055	0.0011

[a]1 wt % Ca, 0.5 wt % Fe.
[b]SrF_2 plus 2-1/2 wt % Zr as ZrO_2.

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