**Compatibility of Pt-3008 with
Selected Components of the
Selenide Isotope Generator System**

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MASTER

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SELENIDE ISOTOPE GENERATOR SYSTEM

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ABSTRACT

The first in a new generation of radioisotopic thermoelectric generators being built by Teledyne Energy Systems and designated the Selenide Isotope Generator has thermoelectric materials that can be degraded by reaction with O_2 , H_2O , CO , and other gases. Consequently, for at least the first ground demonstration system a protective xenon atmosphere will be maintained over the thermoelectrics. The high-temperature portion of the atmosphere-retaining structure will be fabricated from the alloy Pt-3008 (Pt-30 wt % Rh-8 wt % W), which was developed at Oak Ridge National Laboratory. For this application Pt-3008 must be compatible with the various insulations and thermoelectric materials. We have studied the compatibility of Pt-3008 with these materials and found that Pt-3008 was embrittled after exposure to some of the insulations that were not adequately outgassed and by one of the thermoelectric materials (Cu_2Se) in some of the isothermal tests. We believe Pt-3008 will be compatible with the Selenide Isotope Generator materials we tested when they are well outgassed and under the temperature gradient conditions of the operating system.

INTRODUCTION

The Selenide Isotope Generator (SIG) being built by Teledyne Energy Systems uses thermoelectric elements composed of Gd_2Se_3 and Ag-doped Cu_2Se and furnished by the 3M Company. A $^{238}PuO_2$ radioisotopic heat source furnishes heat to the thermoelectric elements, and the system is expected to yield a higher net efficiency than presently used generators.¹ The

¹A. R. Lieberman et al., "The Low Cost High Performance Generator (LCHPG)," in *Proc. 11th Intersociety Energy Conversion Conf.* (held Sept. 12-17, 1976, State Line, Nevada), American Institute of Chemical Engineers, New York, 1976.

SIG is scheduled for its first space mission in 1981, but this will be preceded by one or two ground demonstration tests, the first in 1978. For at least the first ground demonstration system, the design includes an isolation hot frame (IHF), shown in Fig. 1, which will maintain a protective xenon atmosphere for the selenide thermoelectric elements.

ORNL-DWG 77-9413

Fig. 1 Schematic Drawing of Selenide Isotope Generator.

The IHF was originally expected to be constructed of Pt-30 wt % Rh-8 wt % W (Pt-3008) and to operate at a maximum temperature of 1050°C. The more fabricable Pt-30% Rh alloy may be substituted in lower temperature portions of the isolation hot frame, and because of design changes, some portions of the isolation hot frame are expected to reach 1100°C.

As shown in Fig. 1, the isolation hot frame is surrounded by various thermal insulations, which direct heat flow through the thermoelectrics. Consequently, it is essential that the insulations and the thermoelectric materials be compatible with the isolation hot frame. Therefore, this investigation was conducted to study the compatibility of Pt-3008 with insulation materials and with Cu₂Se.

We exposed Pt-3008 tensile specimens to thermal insulations and Cu_2Se for extended periods at high temperatures in evacuated, sealed quartz capsules. Following exposure, the Pt-3008 specimens were tensile-tested at room and/or elevated temperatures and then examined by optical and scanning electron microscopy and Auger electron spectroscopy. Because of the limited availability of Pt-3008, we used miniature tensile specimens having the dimensions shown in Fig. 2. The temperature of the exposures and the tensile testing temperature were varied in accordance with the anticipated operating conditions of the SIG. Exposure temperatures ranged from 800 to 1100°C for times of 1000 h and, in one case, 4000 h.

ORNL-DWG 78-21330

Fig. 2 Noble Metal Tensile Specimen Dimensions.

Our program was conducted in four sequential test series. The first series was intended to determine the magnitude of the compatibility problem, the second and third series were run to test

additional insulations, and the last series provided a more detailed study of the Cu_2Se -Pt-3008 compatibility problem. The first series consisted of 1000-h tests at 800, 950, and 1100°C. The test matrix is given in Table 1. Materials examined were Cu_2Se , Fiberfrax HiFi 660, and the couple Min K 1400 with Poco graphite. The Min K-graphite couple was tested because the reaction $\text{SiO}_2 + \text{C} \rightarrow \text{Si} + \text{CO}_2$ is thermodynamically possible at 800 to 1100°C and it has been found² that silicon can detrimentally affect Pt-3008.

Table 1. Series 1 Compatibility Test Matrix^a

Material	Position with Respect to Pt-3008
Fiberfrax 660 ^b	In Contact
Cu_2Se	In Proximity
Min K 1400 ^c - Poco Graphite ^d	In Proximity

^aFour specimens exposed at each temperature and condition:

Exposure Time: 1000 h

Exposure Temperatures: 800, 950, and 1100°C

Tensile Test Temperatures: 25, 760, and 1093°C

^bProduct of Carborundum Company, Niagara Falls, N.Y.

^cProduct of Johns-Manville Company, Denver, Colo.

^dProduct of Poco Graphite, Inc., Decatur, Texas.

For the second series of tests, additional insulation materials were included, all starting materials were well outgassed, and exposures were conducted for 1000 and 4000 h at 950°C. The test matrix is shown in Table 2. As shown in Fig. 3, the tensile specimens and the SIG

²W. H. Christie, D. H. Smith, and H. Inouye, "An Ion Microprobe Study of the Tensile Failure of a Pt-Rh-W Alloy," *J. Radioanal. Chem.* 32: 85-97 (1976).

Table 2. Second Test Series Compatibility Test Matrix^a

Material	Position With Respect to Pt-3008		
	In Contact	In Proximity	Separated By Poco Graphite
Cu ₂ Se		X	X
Fiberfrax 660	X	X	X
Min K 1800 ^b	X	X	X
Cotronics 360 ^c	X	X	X

^aTwo specimens exposed at each condition. Test duration 1000 and 4000 h. Exposure and tensile test temperature 950°C.

^bProduct of Johns-Manville Company, Denver, Colo.

^cProduct of Cotronics Co., New York.

Fig. 3. Capsule Used for Multicomponent Compatibility Tests.

insulations being evaluated were positioned so that tensile specimens were exposed in three conditions: bare, in contact with the SIG insulation, and separated from the SIG insulation by graphite. Tensile specimens were exposed in these conditions to simulate the possible conditions of the SIG where vapor transport or transport through the graphite are the most likely paths for impurities to reach the isolation hot frame (IHF). Because loose flakes of insulation might fall against the IHF during assembly, we included tests with the SIG insulation in contact with Pt-3008. For the Cu_2Se tests the tensile specimens were exposed in the conditions shown in Fig. 3; bare and enclosed in a graphite container.

After the second series of tests had been started, it became clear that additional insulations and conditions needed to be considered. Consequently, a third test series evolved. The third series of compatibility tests enabled us to evaluate the compatibility of Pt-3008 with two additional insulations and the compatibility of graphite with selected insulations. The test matrix for the third series of tests is given in Table 3.

Table 3. Third Test Series Compatibility Test Matrix^a

Test Material	Relation to Pt-3008 Specimen
Zircar ZYFB-3 ^b	On Gage Length
Carbon Bonded Carbon Fiber (CBCF)	On Gage Length
1/2 Zircar, 1/2 CBCF	Half of Gage Length Covered by Each Material
1/2 Min K 1800, 1/2 CBCF	Half of Gage Length Covered by Each Material
Zircar Dust on Graphite	On Gage Length
Min K 1800 Dust on Graphite	On Gage Length

^aTwo specimens exposed at each condition. Test duration 1000 h, temperature 1050°C. Specimen material was from the third scale-up heat.

^bProduct of Zircar Products, Inc., Florida, N.Y.

Tests were conducted at 1050°C for 1000 h, and in all capsules the Pt-3008 was in direct contact with the material being tested. The outgassing procedures used for materials of the second and third series are given in Table 4.

Table 4. Outgassing Procedure

Material	Temperature (°C)	Time (h)	Atmosphere
Cu ₂ Se	800	1	Vacuum
Cotronics 360	800	16	Air, then
	1000	20	Vacuum
CBCF	1100	21	Vacuum
Zircar ZYFB-3	1100	21	Vacuum
Fiberfrax	1000	20	Vacuum
Min K 1800	1000	20	Vacuum
Graphite	1500	28	Vacuum

The fourth series of compatibility tests was designed to study the thermoelectric material's compatibility with Pt-3008. Of the two thermoelectric materials, Ag-doped Cu₂Se and Gd₂Se₃, the Cu₂Se has the lower melting point and the higher selenium vapor pressure at the temperatures of interest. Because of the cost and difficulty of acquiring these materials, we felt it would be adequate to establish that Pt-3008 was compatible with the lower melting material. The first two test series included tests of this sort; the first with incompletely outgassed powdered Cu₂Se and the second with well outgassed larger granules of Cu₂Se. Because of the unsatisfactory results obtained with Cu₂Se in these first two test series, we performed two additional tests. The first involved exposure of Pt-3008 to TPM-217,³ Ag-doped-Cu₂Se thermoelectric, and was carried out at 3M's laboratories under the conditions shown in Table 5. The second involved a nonisothermal test

³Product of 3M Company, St. Paul, Minn.

Table 5. Conditions of Selenide Compatibility Tests

	Exposure of Specimens by 3M, Test by ORNL	Exposure and Test by ORNL
Outgassing of Pt-3008	28 h, 950°C, 10^{-3} torr) 0.1 Pa (10 ⁻³ torr)	None
Outgassing of Se Source	1 h, 800°C, Vacuum	1 h, 800°C, Vacuum
Nature of Se Source	TPM-217, High-Purity Ag-Doped Cu _{2-x} Se	99.999% Cu ₂ Se
Exposure Temperature	850°C	950°C
Exposure Time	1000 h	1000 h
Exposure Atmosphere	27 kPa (200 torr) Xe	0.1 mPa (10 ⁻⁶ torr)
Tensile Test Temperature	850°C	950°C
Elongation, % of Control Value	~84%	~38%

done at ORNL with chunk Cu₂Se. The experimental arrangement and temperature conditions of the ORNL test are shown in Fig. 4. Additional tests to relate the extent of grain boundary embrittlement of Pt-3008 to the selenium vapor pressure are reported elsewhere.⁴

⁴C. L. White, J. R. Keisr, L. Heatherly, and J. F. Newsome, "Intergranular Embrittlement of Pt-30% Rh-8%W by Se Vapor," submitted for publication.

Fig. 4. Capsule Arrangement Used for Non-Isothermal Compatibility Test.

RESULTS

In order to expedite the first test series, specimens were made from two Pt-3008 heats that were on hand, heats 5D and 5E. These heats had unusually high room-temperature ductility (40%) in the annealed condition. After aging for 1000 h at 1100°C in vacuum, the ductility was reduced to 9% at room temperature and 26% at 1093°C. The results of tensile tests of exposed specimens are given in Table 6. The Pt-3008

Table 6. Effect of Exposure on 0.2% Yield Strength of Pt-3008 (Test Series 1)

Material	Exposure Temperature	Yield Strength Ratio ^a at		
		25°C	760°C	1093°C
Fiberfrax 660	800	0.93	0.78	0.41
	950	0.87	0.87	<i>b</i>
	1100	<i>c</i>	<i>c</i>	<i>c</i>
Cu ₂ Se	800	<i>b</i>	<i>b</i>	<i>b</i>
	950	<i>b</i>	<i>b</i>	<i>b</i>
	1100	<i>c</i>	<i>c</i>	<i>c</i>
Min K 1400 — Graphite	800	0.78	0.63	0.93
	950	0.93	0.99	1.39
	1100	1.31	1.33	1.79

^aRatio of 0.2% yield strength of capsule-exposed specimen to that of vacuum-exposed specimen.

^bFractured before test could be run.

^cCapsule broke during exposure.

specimens exposed to the Min K 1400-graphite couple increased in yield strength at 950 and 1100°C and lost strength at 800°C. However, the specimens exposed to Cu₂Se were seriously embrittled, and those exposed to Fiberfrax 660 showed a propensity to fail intergranularly (Fig. 5).

Fig. 5. Fractures of Specimens Tested at 760°C Following Aging for 1000 h at 800°C with SIG Materials. (a) Control. (b) Aged with Fiberfrax. (c) Aged with couple of Min K 1800 with graphite. (d) Aged with Cu₂Se.

Auger electron spectrographic (AES) examination of the fracture surfaces detected phosphorus and sulfur on the Fiberfrax-exposed specimen and selenium on the Cu_2Se -exposed specimen. After removal of a few atom layers by sputtering, the concentration of sulfur and selenium dropped significantly, indicating that these impurities were most likely present as a thin film on the grain boundaries. Subsequent chemical analysis did show Fiberfrax to have a relatively high (~ 300 wt ppm) sulfur content. We also learned⁵ subsequently that oxygen at elevated temperatures will react with Cu_2Se to give an abnormally high selenium vapor pressure. In assembling this first series of tests, the test capsules were evacuated overnight and then heated slightly before sealing. We concluded that this outgassing was insufficient to remove some of the impurities, and, consequently, the more extensive outgassing treatment given in Table 4 was used for all subsequent experiments.

In the second test series the Pt-3008 specimen material came from a heat produced specifically for SIG use. This heat exhibited typically minor changes in ductility during aging in vacuum.

The results of tensile tests of specimens from the second test series are given in Table 7 and Fig. 6. The figure was made from an

⁵Personal communication, R. B. Ericson, 3M Company, St. Paul, Minn.

Table 7. Tensile Test Results From Second Test Series - Pt-3008 Exposed To SIG Materials for 1000 h at 950°C and Tested at 950°C

SIG Material	Exposure Conditions	Strength, MPa (ksi)		
		Ultimate Tensile	Yield	Total Elongation (%)
None		380 (55.1)	152 (22.1)	28.7
Fiberfrax	Contact	390 (56.5)	159 (23.1)	24.8
	Proximity	381 (55.3)	145 (21.0)	24.1
	Separated by Graphite	385 (55.9)	154 (22.4)	24.7
Min K 1800	Contact	399 (57.9)	157 (22.8)	26.6
	Proximity	407 (59.1)	162 (23.5)	28.1
	Separated by Graphite	398 (57.8)	132 (19.1)	27.2
Cotronics	Contact	396 (57.5)	138 (20.0)	31.1
	Proximity	399 (57.9)	161 (23.4)	28.3
	Separated by Graphite	387 (56.2)	147 (21.3)	28.9
Cu_2Se	Proximity	292 (42.4)	159 (23.0)	9.5
	Separated by Graphite	314 (45.6)	160 (23.2)	12.9

Fig. 6. Effect of Aging with Selenide Isotope Generator Materials for 1000 h at 950°C on Tensile Properties of Pt-3008 at 950°C.
(a) Yield strength (b) Ductility.

average of the results from the three configurations for each compatibility couple. These data indicate that no loss of yield strength occurred for any test condition, and a significant loss of ductility occurred only for the specimens exposed to the Cu_2Se . The fracture surfaces of some of these specimens are shown in Fig. 7. These pictures indicate some ductility in all the specimens, although the specimens exposed to Cu_2Se show less ductility than the others.

To determine just what effect the outgassing treatment in Table 4 had on the insulation's impurities, we analyzed the as-received and outgassed Fiberfrax for sulfur and phosphorus. Results of chemical analysis of insulations used in these experiments are given in Table 8. These

Table 8. Effect of Outgassing on Sulfur and Phosphorus Contents of Insulations

Insulation	Content, ppm			
	Before Outgassing		After Outgassing and 1000-h Exposure	
	S	P	S	P
Min K 1800	2	87	22	47
Cotronics 360	7	1893	31	393
Fiberfrax 660	287	651	36	73

results show that the outgassing removed sulfur from Fiberfrax and phosphorus from all three insulations. Min K 1800 and Cotronics both showed an increase in sulfur, but the higher level was still very low. The increased sulfur was most likely due to either random compositional fluctuations in the insulations or to some contamination picked up during outgassing. To support our belief that removal of the sulfur and phosphorus from the Fiberfrax was associated with the improvement in Pt-3008 ductility, we performed AES and SEM examinations of specimens exposed to as-received and to outgassed Fiberfrax. The AES work was

Fig. 7. Fractures of Specimens Tested at 950°C Following Aging for 1000 h at 950°C in Contact with SIG Materials.

- (a) Control.
- (b) Fiberfrax.
- (c) Min K.
- (d) Cotronics.
- (e) Cu₂Se (aging done in proximity to Cu₂Se).

done on specimens fractured at room temperature. These specimens failed intergranularly because at low temperatures Pt-3008 is brittle.⁶ The resulting spectra show a layer of sulfur on the grain boundaries of the specimen exposed to as-received Fiberfrax, as discussed previously, while the specimen exposed to outgassed Fiberfrax showed no evidence of sulfur. Scanning electron micrographs of high-temperature fractures show that specimens with high sulfur content fail on the grain boundaries, while specimens with lower sulfur content have a more ductile failure (Fig. 8). We consequently feel that if Fiberfrax insulation is to be used around Pt-3008, an effective outgassing treatment, such as that in Table 4, is essential.

The tensile test results for Series 2 specimens exposed 4000 h are given in Table 9 and Fig. 9. Table 9 shows clearly that yield strength

⁶A. C. Schaffhauser, *Isotopic Power Materials Development Quarterly Progress Report for Period Ending Dec. 31, 1976*, ORNL/TM-5882.

Table 9. Tensile Test Results from Second Test Series — Pt-3008 Exposed to SIG Materials for 4000 h at 950°C and Tested at 950°C

SIG Material	Exposure Condition	Strength, MPa (ksi)		
		Ultimate Tensile	Yield Strength	Total Elongation (%)
None		354 (51.4)	144 (20.9)	28.9
Fiberfrax	Contact	314 (45.5)	140 (20.3)	15.8
	Proximity	334 (48.4)	140 (20.3)	18.6
	Separated by Graphite	338 (49.0)	145 (21.0)	18.3
Min K	Contact	353 (51.2)	139 (20.1)	26.3
	Proximity	330 (47.9)	127 (18.4)	19.2
	Separated by Graphite	317 (46.0)	130 (18.9)	18.2
Cotronics	Contact	283 (41.0)	150 (21.8)	12.0
	Proximity	346 (50.2)	141 (20.4)	24.4
	Separated by Graphite	332 (48.2)	145 (21.0)	18.7
Cu ₂ Se	Proximity	^a	^a	^a
	Separated by Graphite	230 (33.4)	139 (20.1)	7.1

^aSpecimens damaged before tensile testing.

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Fig. 8. Scanning Electron Micrographs of Fracture Surface of Specimens Tested at 950°C After Aging 1000 h at 950°C in Contact with Fiberfrax . (a) As received. (b) Outgassed.

Fig. 9. Effect of Aging with Selenide Isotope Generator Materials for 4000 h at 950°C on Tensile Properties of Pt-3008 at 950°C.
(a) Yield strength (b) Ductility.

was essentially unaffected by exposure for all configurations used. The ductility varied significantly but somewhat randomly for the various exposures. An average of the measured properties for all specimens exposed to a particular insulation was used to make the charts in Fig. 9. The fracture surfaces of five specimens exposed in these 4000-h tests are shown in Fig 10. Of the specimens pictured, the control specimen shows the most necking and grain deformation. The specimens that had been exposed to Cotronics and Min K also show considerable necking. The specimen exposed to Fiberfrax shows less necking and has considerable grain boundary separation. The Cu_2Se -exposed specimen, as might be expected from the measured ductility, shows little evidence of plastic deformation.

The insulations tested in the third test series were Min K, Zircar ZYFB-3, and an insulation developed at ORNL, Carbon-Bonded Carbon Fiber (CBCF). The results of tensile tests of specimens from this series are given in Table 10 and Fig. 11. The bar charts of Fig. 11 show that the

Table 10. Tensile Test Results of Third Test Series — Pt-3008
Exposed in Contact with SIG Materials for 1000 h at
1050°C and Tested at 950°C

SIG Material	Strength, MPa (ksi)		
	Ultimate Tensile	Yield	Total Elongation (%)
None	324 (54.3)	112 (16.2)	29.9
Zircar	200 (29.0)	141 (20.5)	5.6
CBCF	361 (52.4)	122 (17.7)	32.0
Zircar and CBCF	335 (48.6)	128 (18.5)	21.8
Min K and CBCF	356 (51.7)	121 (17.5)	26.7
Zircar Dust On Graphite	292 (42.4)	119 (17.2)	18.7
Min K Dust On Graphite	364 (52.8)	118 (17.1)	27.2
Zircar ^a	338 (49.0)	121 (17.6)	20.8

^aAluminum-free material.

(a)

(b)

(c)

(d)

(e)

Fig. 10. Fractures of Specimens Tested at 950°C Following Aging for 4000 h at 950°C in Contact with SIG Materials. (a) Control. (b) Fiberfrax. (c) Min K. (d) Cotronics. (e) Cu₂Se (aging done in proximity to Cu₂Se).

Fig. 11. Effect of aging for 1000 h with Selenium isotope generator materials at 1050°C on Tensile Properties of Pt-3008 at 950°C. (a) Yield strength. (b) Ductility.

yield strength of all aged specimens was at least as good as that of the control, but specimens exposed directly to Zircar or to Zircar-containing combinations were less ductile than the other specimens. Photomicrographs of the fractured specimens are shown in Fig. 12. The specimen that had been exposed to Zircar exhibited a surface reaction layer. A duplicate was tested and also had low ductility and a reaction layer. To determine the cause of the reaction, a new set of specimens was encapsulated with Zircar and aged under the same conditions as the others in this series. Tensile tests on the second set showed improved ductility, and metallography showed no evidence of a reaction layer [Fig. 12(h), and Table 10]. Microprobe analysis of one of the first Zircar specimens indicated aluminum in the Pt-3008 specimen. A piece of Zircar insulation that had been used in the first exposure was examined by SEM and was found to contain aluminum-bearing fibers and whiskers. Nominally Zircar contains less than 50 ppm Al, so either a mistake was made in our handling of the Zircar or it was manufactured out of specifications. Representatives of Zircar Products, Inc. confirmed that their firm markets both zirconia-base and alumina-base insulations, and they reported it is unlikely, but not impossible, for some cross-contamination to have occurred.⁷ They also noted that the insulation we tested was fairly old and not representative of their current product. Other ORNL researchers have not observed aluminum in Zircar during their studies of SIG insulations,⁸ so the aluminum contamination appears to have been an isolated occurrence. In any event, since the IHF will be protected by a graphite coating, Zircar should not present a compatibility problem in the ground demonstration system.

Other experiments on the compatibility of Pt-3008 with Zircar were conducted by Inouye at ORNL, who found that when the exposure was done in a vacuum, very limited interaction was observed.⁹ However, exposures

⁷Personal communication, Brian Hill, Zircar Products, Inc., Florida, N.Y.

⁸Personal communication, George Wei, ORNL.

⁹R. G. Donnelly, *Isotopic Power Materials Development Progress Report*, April 1975, ORNL/TM-4953, p. 13.

Fig. 12. Fractures of Specimens Tested at 950°C Following Aging for 1000 h at 1050°C in Contact with SIG Materials. (a) Control. (b) Zircar. (c) CBCF. (d) Zircar and CBCF. (e) Min K and CBCF. (f) Zircar dust on graphite. (g) Min K dust on graphite. (h) Zircar (repeat).

done in helium resulted in excessive grain growth and a loss of strength and ductility, which is probably due to impurities in the helium.

The fourth and last series of tests in this report involved studies of Pt-3008 compatibility with selenium. As noted previously, the lower melting thermoelectric material, TPM-217 (Ag-doped Cu_2Se), was not made available for tests at ORNL; consequently, high-purity Cu_2Se was used at ORNL, and specimens were sent to 3M for exposure to TPM-217. Table 5 shows the exposure conditions for these latter tests as well as for the former tests, which were part of our second test series. The significant differences between the tests are the exposure atmosphere (Xe vs vacuum) and the exposure and tensile test temperature (850 vs 950°C). The results given in Table 11 indicate that the specimen exposed to TPM-217 had slightly lower strength and ductility than the control.

Table 11. Tensile Test Results of Pt-3008
Exposed by 3M for 1000 h at 850°C in Xe^a

Specimen	Strength, MPa (ksi)		Elongation (%)
	Yield	Ultimate	
Control	188 (27.2)	357 (51.8)	18.4
Proximity to TPM- 217	171 (24.8)	319 (46.2)	15.4

^aOf four specimens exposed at 3M, two were not returned to ORNL for evaluation. Only one specimen that had been exposed to TPM-217 was returned to ORNL.

Photomicrographs of the fracture surfaces (Fig. 13) show no significant differences between the exposed specimen and control. Auger examination of fresh fractures in the two specimens did not detect any selenium. These results are very different from the findings in test series 2, where exposures of Pt-3008 to Cu_2Se caused serious grain boundary embrittlement. The most probable explanation for the degradation in mechanical properties in the ORNL tests relates to our test temperature, 950°C, and the higher selenium pressure associated with this temperature.

Fig. 13. Fractures of Pt-3008 Tested at 850°C Following Aging for 1000 h at 850°C at 3M. (a) Control. (b) Aged with TPM-217.

Additional tests with selenium compounds were conducted at ORNL using the arrangement shown in Fig. 4, which was intended to reproduce the temperature conditions of the SIG. In the SIG, the isolation hot frame in the vicinity of the thermoelectrics will be at a temperature of about 1025°C, the thermoelectric elements will have a maximum temperature of 850°C, and the SIG outer wall will be below 200°C.¹⁰ The results of a tensile test on a specimen exposed in this study are shown in Table 12 along with results for a specimen tested after aging under similar conditions without the Cu₂Se. The Cu₂Se-exposed specimen shows slightly higher yield strength than the control, but the total

Table 12. Results of Pt-3008 — Cu₂Se
Temperature Gradient Studies

Pt-3008 Condition	Strength, MPa (ksi)		Elongation (%)
	Ultimate	Yield	
Aged 336 h at 1050°C Tensile test at 950°C	391 (56.8)	125 (18.2)	34.2
Aged 336 h at 1025°C with Cu ₂ Se Tensile test at 950°C	365 (52.9)	146 (21.2)	26.3

elongation and ultimate tensile strength are lower. The differences in yield and ultimate strengths are probably within experimental error, but the difference in elongation is not. Photomicrographs of the test and control specimens are shown in Fig. 14. We see that both specimens underwent considerable necking but also had some surface cracking. The improvement in ductility of this specimen over those exposed to Cu₂Se in previously discussed isothermal tests indicates that under the SIG conditions, where the Pt-3008 temperature does not exceed 850°C, the selenium effect on Pt-3008 appears to be much less than occurred in series 1 and 2 tests at 950°C.

¹⁰Personal communication, W. J. Barhett, Teledyne Energy Systems, Timonium, Maryland.

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Fig. 14. Fractures of Specimens from the Nonisothermal Cu_2Se Test.
(a) Control. (b) Aged with Cu_2Se .

SUMMARY

Our studies of Pt-3008 compatibility with components of the Selenide Isotope Generator have resulted in the following conclusions.

1. Sulfur from inadequately outgassed Fiberfrax can embrittle Pt-3008.
2. Outgassing of insulations, especially Fiberfrax and Cotronics, reduced their sulfur and phosphorus contents and markedly improved their compatibility with Pt-3008.
3. For our isothermal test conditions, selenium from both outgassed and nonoutgassed Cu_2Se embrittled Pt-3008.
4. In a nonisothermal test simulating the SIG conditions, the detrimental effects of selenium are significantly reduced.
5. Aluminum-bearing contaminants in Zircar severely reduced the ductility of bare Pt-3008 in one experiment. In a repeat of the test, no degradation was found.
6. The Min K insulations and CBCF had the least effect on the mechanical properties of Pt-3008.
7. If adequate outgassing procedures are followed, Pt-3008 should have adequate compatibility for use in the SIG.

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