MASTER

STRESS CORROSION CRACKING OF URANIUM-NIOBIUM ALLOYS

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Stress Corrosion Cracking of Uranium-Niobium Alloys[#]

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ABSTRACT

The stress corrosion cracking behavior of U-2¼, 4½, 6 and 8 wt. % Nb alloys
was evaluated in laboratory air and in aqueous Cl⁻ solutions. Thresholds for
crack propagation were obtained in these environments. The data showed that Cl⁻
solutions are more deleterious than air environments. Tests were also conducted
in pure gases to identify the species in the air responsible for cracking. These
data showed the primary stress corrodent is water vapor for the most reactive
alloy, U-2¼% Nb, while O_2 is primarily responsible for cracking in the more
corrosion resistant alloys, U-6 and 8% Nb. The 4½% alloy was found to be sus-
ceptible in both H_2O and O_2 environments.

Introduction

One of the major problems facing the users of uranium alloys is stress corrosion cracking. Of the uranium-rich alloys tested to date, all have been found to be susceptible to stress corrosion cracking.* Some alloys are susceptible in environments as innocuous as laboratory air while Cl^- solutions have been found to be very aggressive toward all uranium alloys. It is shown in this report that uranium-niobium alloys with 2 to 8 wt. % Nb are susceptible to stress corrosion cracking in both types of environments.

Uranium-niobium alloys are heat treated by quenching from a temperature where the γ (bcc) phase is stable followed by aging in a lower temperature two phase field. On rapid cooling from the γ field a series of metastable martensitic phases form. The U-2¾% Nb alloy forms a distorted orthorhombic varient of α uranium, labeled α'. The U-4½% Nb and U-6% Nb alloys form a monoclinic phase labeled α". The U-8% Nb alloy retains a γ type of structure upon quenching. Aging at 500-600 C results in transformation of the metastable phases to an equilibrium α uranium and γ_2 (~60 wt. % Nb) mixture. Lower temperature aging increases the strength of the alloys without the equilibrium transformation taking place.

The purpose of this report is to present stress corrosion cracking data obtained on U-2¾, U-4½, U-6 and U-8 wt. % Nb at this laboratory over the past several years. It is hoped these data will be of some use to designers interested in high density structural materials. These results will be followed by some comparisons of results and by correlations that have been observed in this alloy system.

\# Alloys with up to 12 wt. % alloy addition have been evaluated.

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<center>Experimental</center>

Materials

The alloys used in this investigation were homogenized at ~1100 C, hot rolled, heated to ~800 C and water quenched. Some of the material was subsequently heat treated in either laboratory air (low temperature ages) or in a vacuum (higher temperature ages). The chemical analyses of the alloys are shown in Table 1 and the mechanical properties shown in Table 2.

Fatigue precracked single-edge-notched specimens were used for the stress corrosion tests. The specimens were 5.50 cm x 1.00 cm x 0.51 cm. A Physmet* fatigue cracking machine was used to initiate and propagate the precrack which was $\leq$ 0.5 a/w or $\leq$ 0.5 cm including the 0.2 cm notch. The specimens were electrically isolated from the loading fixtures and deadweight loaded in tension.

Environments

The pure gas environments were obtained by filling a leak tested all metal chamber with the appropriate gas. The dry air environments were obtained by sealing a polyethylene bag containing a $CaSO_4$ desiccant around the specimen. The 100% RH air environments were obtained by replacing the desiccant with water. The air environment in the bags was allowed to equilibrate for a minimum of 16 hours before the specimens were loaded. The Cl$^-$ environments were obtained by bonding small glass cups to the specimens with a Cl$^-$ free adhesive (Dow Corning 3145). Tripled distilled water with the appropriate amount of NaCl was added and the load applied.

Physmet Corp., 156 6th Street, Cambridge, MA 02142.

Table 1
Alloy Composition

		ppm					
Alloy	Nb (%)	Fe	Si	C	N_2	O_2	H_2
U-2.3% Nb	2.22	65	24	27	46	28	3.7
Vacuum solution treated	"	"	"	"	"	"	1.8
U-4.5% Nb	4.48	80	60	110			
U-6% Nb							
quenched	6.12	43	27	59	24	37	1.9
200 C/2 hours	6.23	18	20	64	29	31	1.8
U-8% Nb	7.86	25	40	100			

Table 2
Mechanical Properties

Alloy	Yield Strength		Ultimate Strength		Elongation
	MN/m^2	(KSI)	MN/m^2	(KSI)	(%)
U-2¾% Nb					
Quenched	924	(134)	1235	(179)	2.5
500 C/5½ hrs	724	(105)	1180	(171)	16
U-4½% Nb					
Quenched	310	(45)	1035	(150)	23
260 C/80 hrs	1070	(155)	1270	(184)	7.8
U-6% Nb					
Quenched	170	(24)	790	(114)	31
200 C/2 hrs	360	(52)	800	(116)	27
U-8% Nb	780	(113)	860	(125)	10

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<center>Results</center>

U-2¾ wt. % Nb

Pure Gases

Tests were conducted in pure gases so the species responsible for cracking in laboratory air could be identified. In addition to O_2 and H_2O environments, a 10^{-6} vacuum was used as a control environment to separate material and stress corrosion properties and a H_2 environment was evaluated because it has been shown that all U-Nb alloys react with H_2O vapor liberating $H_2(g)$.[1] Failures of quenched U-2¾% Nb were observed in similar time frames in the vacuum, O_2 (150 torr) and H_2O (20 torr, 100% RH) environments at 28 $MN/m^{3/2}$ (~60% of K_Q").* Failure times were 40-200 hours for the vacuum, 20-150 hours for O_2 and 70-400 hours for the H_2O. Significantly shorter times were observed in H_2 (150 torr), 4 hours average.

Because failures were observed in a vacuum, specimens were solution treated at 800 C for 4 hours in a vacuum to reduce the internal $H(s)^\dagger$ in order to assess the role of $H(s)$ in the cracking process. Hydrogen levels were reduced from ~3.7 to ~1.8 ppm and the cracking behavior was dramatically affected. Failures were not observed at 28 MN/m^2 in the vacuum or O_2 environments after 1000 hours in test. Failures still occurred in the H_2O and H_2 environments. The average times were 400 and 12 hours respectively. It was concluded from these data that internal $H(s)$ was playing a major role in the failure of as received specimens. Solution treating the specimens in a vacuum and requenching them eliminates this problem. These data also illustrate the importance of environmental H_2 (from $H_2(g)$ or from U + H_2O → UO_2 + $H_2(g)$) in the stress corrosion cracking process.

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* K_Q is the overload stress intensity obtained for the stress corrosion specimens used in this investigation.

$\dagger$ Hydrogen in solution in the metal.

Aging the solution treated material at 500 C for $5\frac{1}{2}$ hours in a vacuum did not affect the behavior in vacuum, O_2 of H_2. At 17 $MN/m^{3/2}$ (~60% of K_Q for the aged material) failures were not observed in 1000 hours in the first two environments while a 10 hour average was observed in the H_2 environment. Aging did affect the behavior in water vapor. Specimens failed in ~8 hours in H_2O which is attributed to the enhanced reactivity of the equilibrium $\alpha + \gamma_2$ microstructure with H_2O producing H_2.

Laboratory Air

The results for tests conducted on as quenched U-2$\frac{3}{4}$% Nb in wet and dry air are shown in Figure 1. The data show that the threshold for crack propagation, K_{ISCC}, is slightly higher in wet air than in dry air, ~23 vs. ~18 $MN/m^{3/2}$. This corresponds respectively to ~50 and ~40% of K_Q. Material quenched and aged at 500 C for $5\frac{1}{2}$ hours was also evaluated in wet and dry air. Cracking was not observed in 1000 hrs. at stress intensities only slightly lower than overload which was ~28 $MN/m^{3/2}$. Since cracking was observed at much lower stress intensities (~17 $MN/m^{3/2}$) in pure H_2O it is concluded stress corrosion cracking of the reactive over-aged material is inhibited by O_2. A similar type of behavior was observed in another very reactive uranium alloy, U-3/4 wt. % Ti.[2]

Chloride Solutions

Both quenched, and quenched and aged U-2$\frac{3}{4}$% Nb were tested in 50 ppm Cl⁻ solutions. The data in Figure 2 show that both alloys are very susceptible to cracking in dilute Cl⁻ solutions. K_{ISCC} is ~13 $MN/m^{3/2}$ for the quenched alloy and only ~7 $MN/m^{3/2}$ for the quenched and aged alloy. These values both correspond to ~30% of their respective K_Q values showing the degree of degradation is similar.
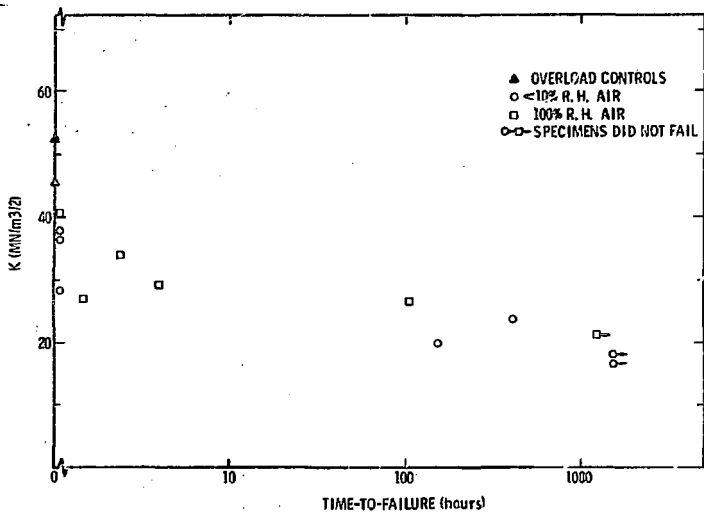
Figure 1. Failure times for quenched U-2¼ wt.% Nb tested in wet and dry laboratory air.

Figure 2. Failure times for quenched, and quenched and aged (500 C/ 5½ hr) U-2¼ wt.% Nb tested in 50 ppm Cl⁻ solutions.

Literature Data

.Machi and Kochen[3] observed stress corrosion cracking in smooth U-2¼% Nb specimens aged at 230 C for 24 hours and exposed to 50 ppm Cl⁻ solutions. In the same environment stress corrosion cracking did not initiate in overaged (430 C/24 hours) U-2¼% Nb and the specimens failed by general corrosion. Embrittlement of U-2¼% Nb in humid environments in several heat treated conditions has also been observed.[4]

Miller[5] evaluated material aged at 455 C for 35 hours and 600 C for 5 hours from the same heat used in this investigation. He observed crack propagation in both of the overaged conditions in 100% RH air. Thresholds for propagation were 20 $MN/m^{3/2}$ for the 455 C/35 hours material and 22 $MN/m^{3/2}$ for the 600 C/5 hour material.

U-4½ wt. % Nb

Pure Gases

Quenched U-4½% Nb was also tested in vacuum, O_2 (150 torr), H_2 (150 torr) and H_2O (20 torr, 100% RH). Tests conducted at 30 $MN/m^{3/2}$ (~50% of K_Q) showed stress corrosion cracking would not occur in a vacuum in 1300 hours but occurred in O_2 in 90 hours, in H_2O in 160 hours, and in H_2 (~27 $MN/m^{3/2}$) in 90 hours. Longer term tests (15,000 hours) were carried out on U-4½% Nb aged at 260 C/80 hours at ~25 $MN/m^{3/2}$ (~50% of K_Q) in dry N_2 without specimen failure. These data show that an external environment is required for crack propagation at stress intensities ~50% of K_Q, and therefore, internal H(s) is not playing an important role in the failure process.

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[b] Significant differences in cracking behavior between smooth and precracked uranium alloy specimens have been frequently observed. The data on U-2¼% Nb simply show that it is difficult to initiate a crack in overaged material, but once the crack initiates propagation can occur in dilute Cl⁻ solutions. This type of behavior has also been observed in other alloy systems, the most noteworthy being titanium alloys.

Tests were also carried out on aged U-4½% Nb at higher stress intensities, ~34 MN/m$^{3/2}$ (~70% of K_Q), in H_2 and H_2O. At these higher levels cracking was more rapid in H_2 than in H_2O; time-to-failure was 0.5 hours vs. 40 hours.

Laboratory Air

Quenched U-4½% Nb was evaluated in wet and dry laboratory air. The data (Figure 3) show that the thresholds for crack propagation are essentially the same for both environments, ~23 MN/m$^{3/2}$. Aging the U-4½% Nb alloy at 260 C for 90 hours did not significantly affect the cracking behavior despite the resulting dramatic increase in strength. The threshold for crack propagation for aged material in both environments is ~22 MN/m$^{3/2}$, Figure 4.

Chloride Environments

Tests were conducted on U-4½% Nb aged at 260 C/80 hours in aqueous solutions ranging from distilled water to solutions containing 500 ppm Cl$^-$. The data illustrated in Figure 5 show that K_{ISCC} is not dramatically affected by Cl$^-$ concentration in this range. The thresholds are ~20 MN/m$^{3/2}$ (~33% of K_Q). The data also show that propagation in distilled water was much slower than in the solutions with Cl$^-$.

The effect of specimen orientation on stress corrosion cracking was evaluated with extruded U-4½% Nb aged at 245 C/24 hours. The results of tests conducted with axial and transverse specimens in 50 ppm Cl$^-$ are shown in Figure 6. These data show that both the crack propagation rate and K_{ISCC} are independent of orientation. The observed threshold was ~19 MN/m$^{3/2}$ which is essentially the same as the 260 C/80 hour material in dilute Cl$^-$ environments. While orientation effects on cracking have not been extensively studied in uranium alloys, tests on U-3/4 wt. % Ti have also shown no effect of orientation on crack propagation.[6]
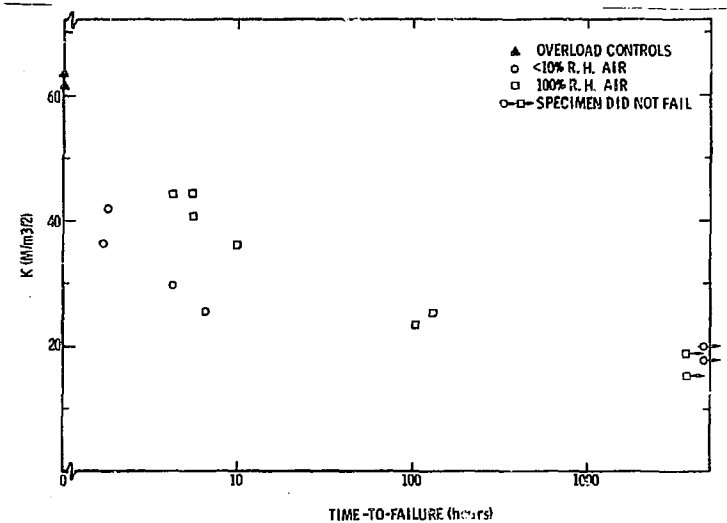
Figure 3. Failure times for quenched U-4½ wt.% Nb tested in wet and dry laboratory air.
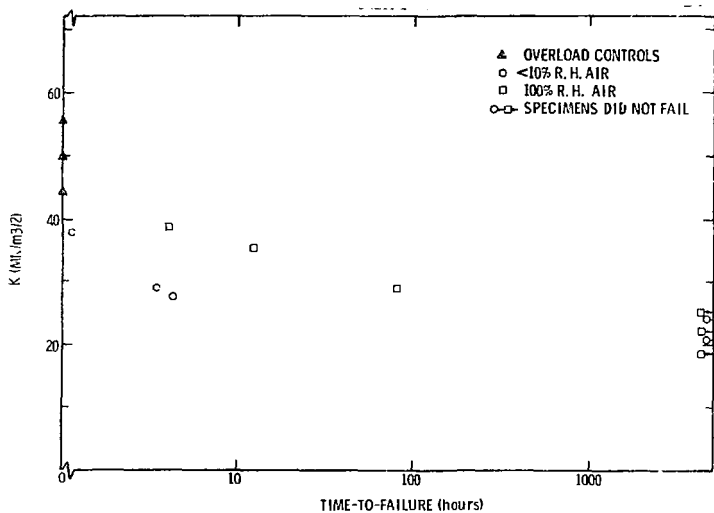
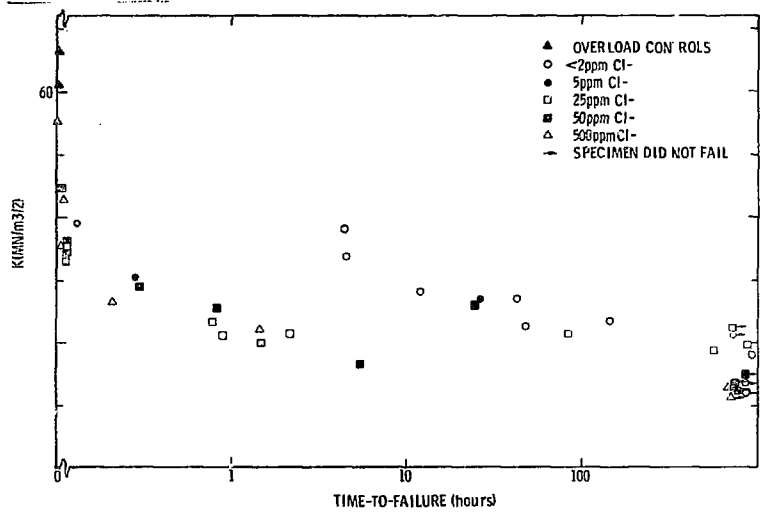Figure 4.   Failure times for U-4½ wt.% Nb aged at 260 C for 80 hours tested in wet and dry laboratory air.

Figure 5. Failure times for U-4½ wt.% Nb aged at 260 C for 80 hours tested in aqueous solutions.
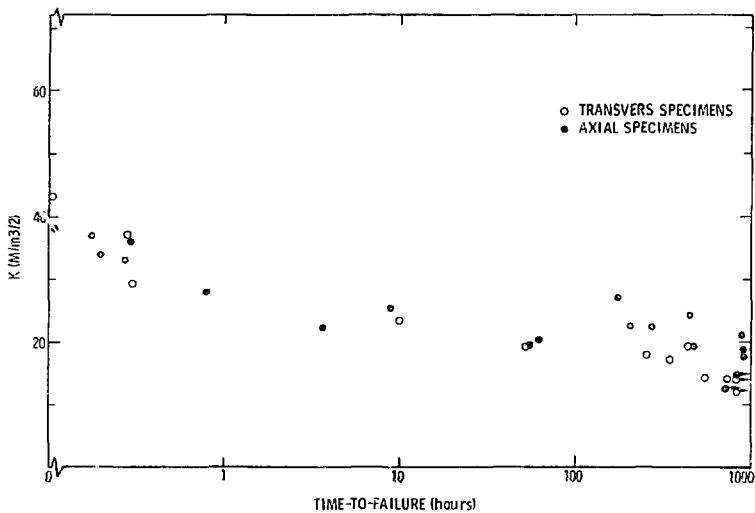
Figure 6. Failure times for axial and transverse U-4½ wt.% Nb specimens aged at 245 C for 24 hours and tested in a 50 ppm Cl⁻ solution.

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<u>Literature Data</u>

Macki and Kochen[7] observed that Cl^- (presumably other halides would be effective), O_2, and H_2O were required for crack initiation in U-4.2 wt. % Nb aged 260 C/80 hours. In the absence of either Cl^- or O_2 failure times in aqueous solutions ranged from 1000 to 11000 hours while with all species present, O_2, H_2O, Cl^-, failures occurred under identical loading conditions in less than 30 hours. They also observed cracks would not initiate in wet or dry air in 10,000 hours.

McLaughlin et. al.[8] studied the effect of aging on the stress corrosion of U-5 wt. % Nb wires. They showed that overaging at 550 to 600 C provided the maximum resistance to stress corrosion cracking in dilute Cl^- solutions. Aging at 450 C (2 to 80 hours) provided high strength alloys which were very susceptible to stress corrosion crack initiation.

U-6 wt. % Nb

<u>Pure Gases</u>

The cracking behavior of U-6 wt. % Nb in pure gases differed from that observed for U-2½ and U-4½% Nb. Quenched specimens failed in ~80 hours in H_2 (150 torr) and O_2 (150 torr) but did not fail in 1700 hours in N_2 or in H_2O (20 torr, 100% RH). These tests were conducted at 34 $MN/m^{3/2}$ (~40% of K_Q). U-6% Nb is a very corrosion resistant alloy and this resistance to reaction with water to form an oxide and liberate H_2[1] is felt to be responsible for its cracking resistance in water vapor.

<u>Laboratory Air</u>

Tests were conducted on quenched U-6 Nb in wet and dry air. The data, Figure 7, show that the alloy is not very susceptible to cracking in dry
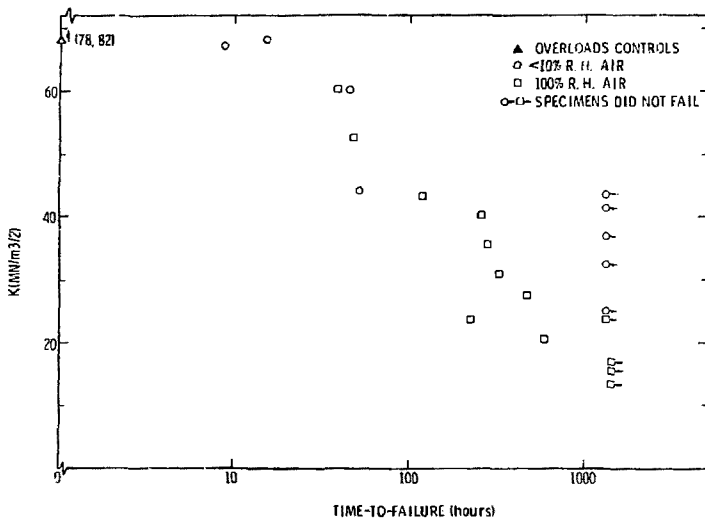
16

Figure 7. Failure times for quenched U-6 wt.% Nb tested in wet
and dry laboratory air.

laboratory air, $K_{SCC} \approx 44$ MN/m$^{3/2}$.* The addition of water to the air did not
affect the velocity above this stress intensity but did dramatically lower
the threshold to ~24 MN/m$^{3/2}$ (~30% of the overload). This behavior seems to
be inconsistent with the data showing cracking occurs in $H_2O(g)$ but not O_2.
Recent unpublished data have shown that the addition of $H_2O(g)$ to O_2 increases
the stress corrosion crack propagation rate of U-6% Nb. The cause of this
effect is not known at the present time. Aging the alloy at 200 C for 2 hours
increased the yield strength by a factor of two and lowered the threshold in
wet air to about 17 MN/m$^{3/2}$, which is ~30% of overload, see Figure 8.

Chloride Solutions

Both quenched, and quenched or aged (200 C/2 hours) U-6% Nb were tested
in 50 ppm Cl⁻ solutions. As was the case in wet air, aging lowered the thresh-
old for propagation. K_{ISCC} values of 18 MN/m$^{3/2}$ for the quenched alloy and
12 MN/m$^{3/2}$ for the aged material were obtained from the data shown in Figure 9.

Literature Data

The author estimates cracking thresholds of 22 MN/m$^{3/2}$ for the U-6% Nb
aged at 250 C/3 hours and at 250 C/6.4 hours, and 9 MN/m$^{3/2}$ for material aged
at 360 C/1.2 hours from the data of Miller.[5] Koger et. al.[9] showed that under-
aged U-6% Nb and overaged U-6% Nb are resistant to stress corrosion crack
initiation while peak aged material is very susceptible to initiation. Quenched,
and 150 C/2 hours, 200 C/2 hours, 250 C/2 hours aged materials had good resis-
tance to stress corrosion cracking as did material aged at 600 C for 10 hours.
Materials aged at 300 and 400 C were very susceptible to cracking. These
results show the U-6% Nb alloy follows the same pattern as U-4½% Nb but that the

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* Does not represent a plane strain threshold because of insufficient specimen
thickness.

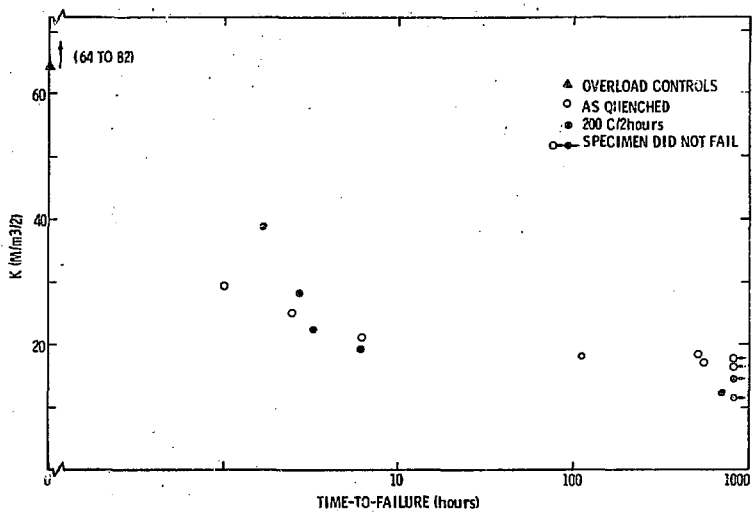Figure 8. Failure times for U-6 wt.% Nb aged at 200 C for 2 hours tested in wet laboratory air.

Figure 9. Failure times for quenched, and quenched and aged (200 C/ 2 hr) U-6% Nb tested in 50 ppm Cl⁻ solutions.

cracking resistance for the 6% alloy is degraded at lower aging temperatures than for the 4½% alloy.

U-8 wt. % Nb

Pure Gases

As was the case with the 4 and 5% Nb alloys cracking did not occur in a vacuum, i.e., internal H_2 was not a problem. Specimens tested at 28 $MN/m^{3/2}$ (~40% of K_Q) did not fail in 2000 hours. Cracking occurred in 120 hours in O_2 (150 torr) which is also similar to the behavior observed with the 4 and 6% Nb alloys. Cracking occurred in water vapor (20 torr) but it took ~1200 hours for failures to occur. The behavior in H_2 (150 torr) was completely unexpected. Specimens did not fail in H_2 at 29 $MN/m^{3/2}$ in 4000 hours. These tests were repeated and failures were not observed in over 1000 hours. The resistance to cracking cannot be solely attributed to the fact the alloy is in the γ phase since another γ alloy, U-7½ wt. % Nb-2½ wt. % Zr is very susceptible to cracking in H_2.[10]

Laboratory Air

The quenched 8% alloy was tested in dry air and a threshold of 18 $MN/m^{3/2}$ (~25% of K_Q) was obtained, Figure 10. Miller[5] evaluated the same heat of material in wet laboratory air and his data are also presented in Figure 10. The threshold is higher in wet air, ~39 $MN/m^{3/2}$.

Chloride Solutions

The U-8% alloy is very susceptible to cracking in chloride solutions. Quenched material has a threshold of ~10 $MN/m^{3/2}$ which is only about 14% of K_Q, see Figure 11. The data also show that the crack velocity in the Cl⁻ solutions is much faster than in the air environments.

OVERLOAD CONTROLS
○ **<10% R.H. AIR**
□ **100% R.H. AIR**
○ **SPECIMENS DID NOT FAIL**
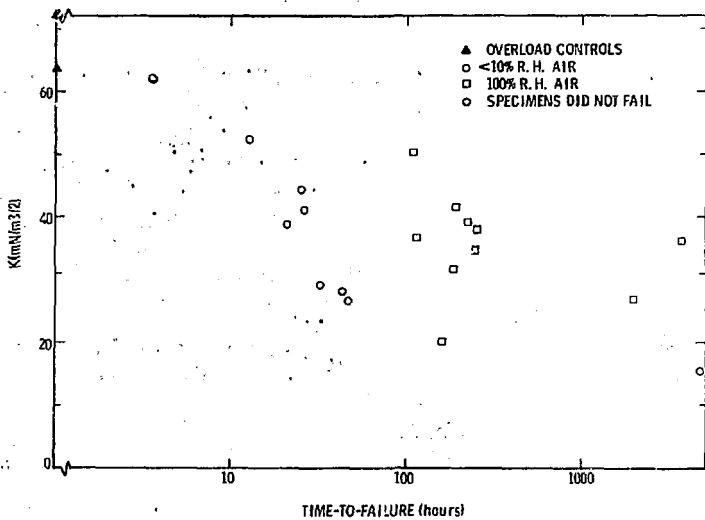
K(mN(m3/2)

TIME-TO-FAILURE (hours)

Figure 10.   Failure times for quenched U-8 wt.% Nb alloy tested
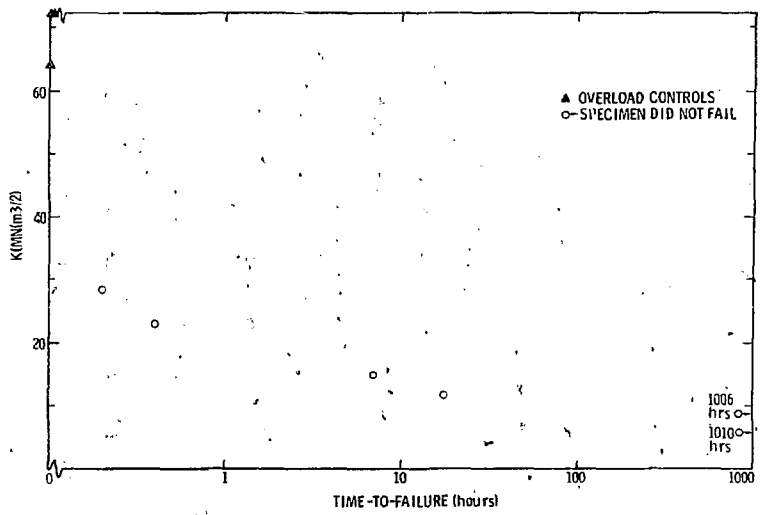in wet and dry air.   The 100% R.H. air data from
Miller.[5]

Figure 11. Failure times for quenched U-8 wt.% Nb tested in 50 ppm Cl⁻ solutions.

Literature Data

With the exception of the wet air data of Miller[5] presented in Figure 10, this alloy has not been studied elsewhere.

Discussion

As previously mentioned, all uranium alloys which have been evaluated are susceptible to stress corrosion cracking. Three mechanisms have been proposed for embrittlement and/or cracking in the uranium system.[10] A hydride mechanism[2] has been proposed for the intergranular cracking observed in the more corrosion resistant alloys such as U-6% Nb and U-8% Nb. The transgranular cracking observed in O_2 containing environments has been attributed to either an oxide stress generation mechanism or to a stress sorption mechanism.[12]

Since both the fracture mode and the environments which will cause cracking are important in elucidating cracking mechanisms, a discussion of these features in the U-Nb system follows. A tabulation of the fracture modes for the U-Nb alloys studied in this investigation as a function of the testing environment is shown in Table 3. Transgranular fractures were observed in all of the laboratory air tests. In the case of the 4½, 6 and 8% alloys intergranular stress corrosion cracking was only observed in Cl⁻ solutions and its occurrence increased with increasing Cl⁻ level and with increasing Nb content. The increasing susceptibility to intergranular fracture, and presumably anodic dissolution stress corrosion cracking, with increasing Nb content is probably due to the increased corrosion resistance as the Nb content is increased. The fact that the structures of the alloys differ, complicate the issue.

U-Nb alloy cracking behavior in H_2, H_2O and O_2 is complex. The failure times for the alloys in these pure gases are shown in Table 4. Several points

Table 3

Stress Corrosion Fracture Modes

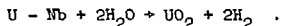| Alloy	Environment			
	Dry Air	Wet Air	Dilute Cl⁻	50 ppm Cl⁻
U-2⅓% Nb	Quasicleavage	Quasicleavage	Quasicleavage	Transgranular (cleavage)
U-4½% Nb	Quasicleavage	Quasicleavage	Quasicleavage	Intergranular + transgranular
U-6% Nb	Quasicleavage	Quasicleavage	Intergranular + transgranular	Intergranular
U-6% Nb	Quasicleavage	Quasicleavage	Intergranular	Intergranular

Table 4

Failure Times* For U-Nb Alloys Exposed to Pure Gases

Alloy	Environment			
	Vacuum	O_2 (150 torr)	H_2O (20 torr)	N_2 (150 torr)
U-2½% Nb				
Quenched (28 $MN/m^{3/2}$)	40 - 200 hrs	20 - 150 hrs	70 - 400 hrs	4 hrs
Vacuum solution treated (28 $MN/m^{3/2}$)	No failure 1000 hrs	No failure 1050 hrs	400 hrs	12 hrs
Aged 500 C/5½ (17 $MN/m^{3/2}$)	No failure 100 hrs	No failure 1200 hrs	8 hrs	10 hrs
U-4½% Nb				
Quenched (30 $MN/m^{3/2}$)	No failure 1300 hrs	90 hrs	160 hrs	90 hrs (27 $MN/m^{3/2}$)
U-6% Nb				
Quenched (34 $MN/m^{3/2}$)	No failure† 1700 hrs	80 hrs	No failure 1700 hrs	75 hrs
U-8% Nb (28 $MN/m^{3/2}$)	No failure 1200 hrs	120 hrs	1200 hrs	No failure 4000 hrs

*Data average of 2 or more points or range indicated if a large amount of scatter existed.

†Tests conducted in N_2 instead of a vacuum.

can be made from these data: (1) All of the alloys except U-8% Nb are sus-
ceptible to cracking in $H_2(g)$. The lack of cracking observed for the U-8% Nb
alloy may be due to small quantities of O_2 poisoning the process. (2) The
more reactive alloys, U-2¾ and U-4½% Nb, are susceptible to cracking in H_2O
vapor while the more corrosion resistant alloys are either only slightly
susceptible or are not susceptible. Cracking in this environment is attributed
to the reaction

$$U - Nb + 2H_2O \rightarrow UO_2 + 2H_2 \quad .$$

(3) The most reactive alloy, U-2¾% Nb, was not susceptible to cracking in O_2
while the three more Nb rich alloys were observed to crack in this environment.

A schematic representation of O_2 and H_2O cracking is shown in Figure 12.
The figure shows O_2 cracking susceptibility increases with increasing Nb con-
tent and H_2O cracking susceptibility decreases with increasing Nb. The 2¾%
alloy is in a region where only H_2O cracking is observed, the 4½% alloy is in
an intermediate region where both types of cracking are observed, and the 6
and 8% alloys are in a region where only O_2 cracking is readily observed.
The decrease in H_2O susceptibility is understood and thought to be related to
the decreasing reactivity of the alloy with H_2O and hence a decrease in
available H_2. A study of U-3/4 wt. % Ti,[2] a reactive alloy which should
behave chemically in a manner similar to the 2¾% Nb alloy, showed that the
kinetics for propagation in H_2O and H_2 were similar and it was proposed for
the U-3/4% Ti alloy that the cracking in both environments was caused by the
same mechanism. The reason for the increasing O_2 susceptibility with increasing
Nb is not well understood. In a more extensive study[12] of cracking of U-4½% Nb
in laboratory air, it was proposed that the formation of thin oxide layers
(absorbed O_2 or epitaxial oxides) played an important role in the cracking
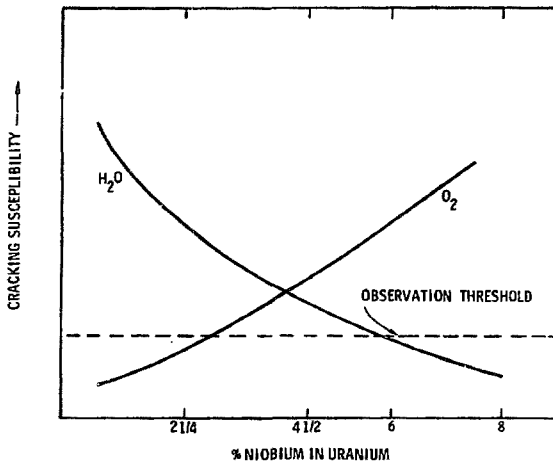
Figure 12. A schematic representation of the relationship between cracking susceptibility and alloy composition.

process. The significantly different structure of the $2\frac{1}{4}\%$ alloy would be expected to greatly effect this type of interaction (for example, do epitaxial oxide films even form on the $2\frac{1}{4}\%$ alloy?).

The fractography and pure gas data show that stress corrosion cracking caused by a hydride mechanism, an anodic dissolution mechanism and an oxide mechanism is observed in the U-Nb system. Hydride cracking appears to be responsible for $2\frac{1}{4}\%$ Nb alloy cracking in all environments evaluated* and to some extent with the $4\frac{1}{2}\%$ alloy (H_2O environment). The oxide mechanism appears to be responsible for $4\frac{1}{2}$, 6 and 8% alloys cracking in laboratory air and to some extent in very dilute Cl^- solutions while anodic dissolution cracking appears to be responsible for $4\frac{1}{2}$, 6 and 8% alloy cracking in Cl^- environments.

A tabulation of the thresholds for crack propagation are shown in Table 5. A correlation between strength level and cracking susceptibility has been observed by several investigators[3,8,9] for U-Nb alloys in smooth specimen tests. When the strength was increased by aging to close to peak levels, the susceptibility to stress corrosion cracking increased dramatically. However, the available crack propagation data for any one alloy are not extensive enough to allow for any type of correlation between strength and cracking threshold.

Acknowledgment

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*It should be noted that some H_2O is present in the dry air tests because of permeation through the polyethylene bags.

<div align="center">

Table 5

Thresholds* for Stress Corrosion Crack Propagation

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Alloy	Environments		
	Dry Air $(MN/m^{3/2})$	Wet Air $(MN/m^{3/2})$	50 ppm Cl $(MN/m^{3/2})$
U-2½% Nb			
Quenched	18	23	13
500/5½ hrs	24	23	7
U-4½% Nb			
Quenched	22	23	--
260/80 hrs	21	22	20
U-6% Nb			
Quenched	44	22	18
200/2 hrs	--	17	12
U-8% Nb			
Quenched	18	$30^{(4)}$	10

*K_{ISCC} values are tabulated except for quenched U-6 Nb specimens which were not thick enough to meet the plane strain criterion.

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