STUDY OF CORROSION OF ALUMINUM ALLOYS OF NUCLEAR PURITY IN ORDINARY WATER PART TWO

by

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Since 2002, the effects of corrosion on aluminum alloys of nuclear purity in ordinary water of the spent fuel storage pool of the RA research reactor at VINČA Institute of Nuclear Sciences have been examined in the framework of the International Atomic Energy Agency Coordinated Research Project "Corrosion of Research Reactor Aluminum-Clad Spent Fuel in Water". Coupons were exposed to the pool water for a period of six months to six years. The second part of this study comprises extensive results obtained by detailed visual and microscopic examinations of the surfaces of the coupons and represents an integral part of the first report on the topic, previously presented in this journal.

Key words: corrosion, aluminum alloy, SAV-1 alloy, fuel cladding, RA research reactor, ordinary water

INTRODUCTION

The International Atomic Energy Agency (IAEA) Coordinated Research Project (CRP), "Corrosion of Research Reactor Aluminum-Clad Spent Fuel in Water," was initiated in 1996 [1]. In the first part of this study [2], basic data about the RA reactor [3], spent nuclear fuel storage pool and chemical and radioactive parameters of the water were given together with information related to the composition of the IAEA test racks and their exposition to the influence of water at various positions in the spent fuel storage pool. Only the results of an initial visual examination of corrosion were presented.

This paper comprises research results obtained by detailed visual and microscopic examinations of the effects of corrosion on the surfaces of coupons made of aluminum alloys of nuclear purity in test racks exposed to pool water. It could be of great interest to the research community dealing with research reactors, due to the fact that the water of the RA research reactor spent fuel storage pool has unique chemical and radiological parameters. A relatively large bibliography published in the last 20 years, related to RA research reactor TVR-S fuel characteristics, spent nuclear fuel storage and corrosion studies of aluminum cladding in ordinary water, is also at the disposal of researchers [4-26].

Test racks with coupons made of different aluminum alloys and stainless steel were prepared and distributed to participants within phase I and phase II of the IAEA CRP on "Corrosion of Research Reactor Aluminum-Clad Spent Fuel in Water". During phase I, three racks were received and immersed in the RA reactor spent fuel storage pool. During phase II, two racks were received and immersed in the pool by March 2003.

The chemical compositions of aluminum alloys used for the test coupons of the racks are given in the first part of this study [2]. Corrosion effects due to the influence of water were examined, aside from single coupons, in galvanic coupon couples (stainless steel aluminum) and in crevice coupon couples (aluminum – aluminum). A sketch of positions of all racks immersed in the water basins of the spent fuel storage pool of the RA research reactor at the VINČA Institute, including rack exposition times, is shown in Ref. [2]. All racks were immersed in the water of the pool near storage containers with spent fuel elements in the "vertical position", *i. e.*, the rack axis was vertical and the surfaces of the coupons were horizontal.

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VISUAL AND MICROSCOPIC EXAMINATION RESULTS

The results of detailed visual and microscopic examination of the aluminum coupons of all racks, obtained after the coupons were, according to the IAEA Test Protocol, cleaned from sludge deposits and decontaminated using a solution of phosphoric acid, chloride free detergent and distilled water, are shown in this part of the study. All relevant information collected during the disassembly of the racks and cleaning of the coupons were given in the first part of the study [2]. Pitting, as a main localized form of corrosion of aluminum in water, was noted on surfaces (including edges) of all coupons. Spots of different shades of grey and black (assumed to be aluminum-oxide) were observed on them. After detailed visual examination of surfaces and edges of the cleaned coupons, areas damaged by corrosion were marked for further examination under a microscope with magnification 10 and 20 (fig. 1). The labels on the coupons given in following tables and photographs refer to the aluminum alloy or stainless steels type and the particular number of the coupon. Due to the enormity of data, only coupons with areas significantly damaged by the corrosion process were reported in the tables shown bellow. In the case of single coupons, both sides were exposed to water. In the case of couples, the front sides of the coupons referred in the tables were exposed to water, while the back sides of the coupons were the coupled ones. Stainless steel coupons were not examined, since steel corrosion was not the topic of the research. Also, the corroded areas of aluminum coupons under ceramic rings were not examined, since such coupling of aluminum cladding of spent fuel elements with ceramic material does not occur in spent fuel storage pools.

Figure 1. Microscope used for inspection of corrosion effects on coupon surfaces

Rack#1/CRP-I

Basic data on Rack#1/CRP-I are given in Ref. [2]. The rack was exposed to water in basin no. 4 of the RA spent fuel storage pool for six years. The results of visual and microscopic examination are shown in tabs. 1 and 2 and in figs. 2-6, respectively.

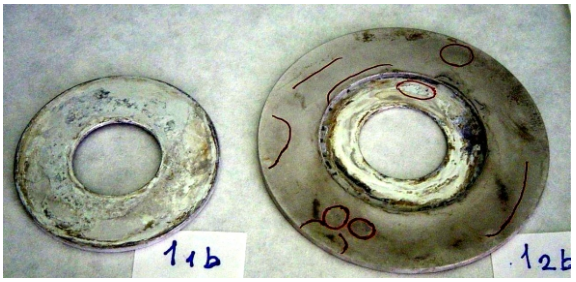


Figure 2. Visual inspection of SAV-1/04 and SAV-1/60 coupons

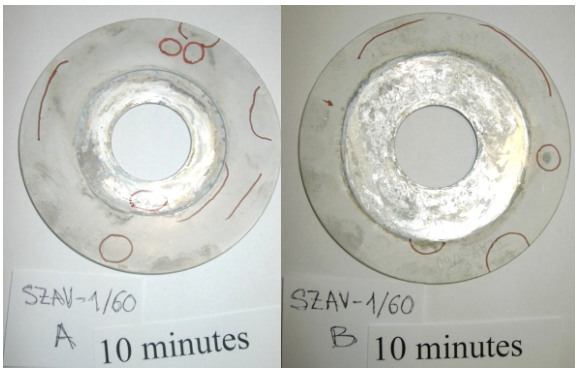


Figure 3. Front and back side surfaces of SAV-1/60 coupon

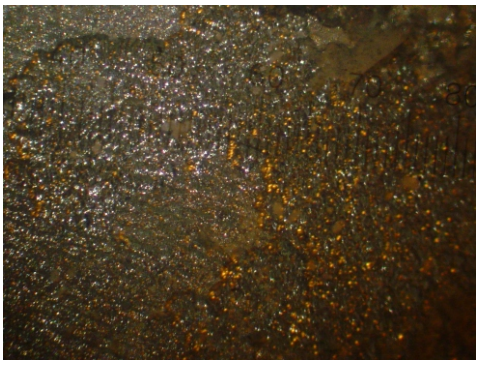


Figure 4. Pitted surface of coupon 6061/56 covered by spherical pits

Table 1. Visual inspection of Rack#1/CRP-I coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Crevice couple	SAV-1/04	Front	Dull surface. Uneven oxidation
		Back	Crevice corrosion on all coupons
	SAV-1/60	Front	Corrosion under ceramic ring. Uneven oxidation with pits in the rest area
		Back	Crevice corrosion under coupled coupon. General corrosion with spherical pits in the rest area
Galvanic couple	316/02	Front	Non-shining surface with yellow circular deposit
		Back	Almost entirely shiny. 40% under stains
	6063/68	Front	Corrosion under ceramic ring. Uneven oxidation with spherical pits
		Back	Galvanic corrosion under coupled coupon. Uneven oxidation with spherical pits
Galvanic couple	316/01	Front	Non-shining. With some stains and yellow deposit
		Back	Non-shining. White deposit
	6063/59	Front	Corrosion under ceramic ring with deep pits. Uneven oxidation with pits in rest area
		Back	Intensive galvanic corrosion under coupled coupon
Crevice couple	6063/05	Front	Uneven oxidation with some pits under ceramic ring
		Back	Crevice corrosion on all surfaces
	6061/60	Front	Uneven oxidation with pits. Corrosion under ceramic ring
		Back	Crevice corrosion under coupled coupon. Uneven oxidation on rest surface
Crevice couple	6063/04	Front	Uneven oxidation with spherical pits
		Back	Crevice corrosion on all coupons
	6061/56	Front	Uneven oxidation. Corrosion under ceramic ring
		Back	Intensive crevice corrosion under coupled coupon. Uneven oxidation in rest area
Crevice couple	6061/18	Front	Uneven oxidation. Two very large, irregularly shaped, deep pits
		Back	Crevice corrosion on all coupons
	1100/56	Front	Uneven oxidation. Corrosion under ceramic ring
		Back	Intensive corrosion under coupled coupon. Uneven oxidation in rest area
Crevice couple	6061/07	Front	Uneven oxidation. Corrosion under ceramic ring
		Back	Intensive crevice corrosion on all coupons
	1100/53	Front	Uneven oxidation. Corrosion under ceramic ring
		Back	Corrosion under coupled coupon. Uneven oxidation in rest area

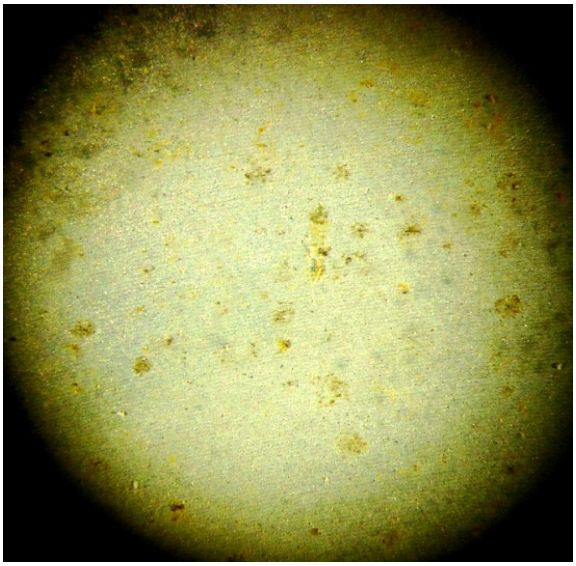


Figure 5. Large number of pits on front surface of coupon 6063/59

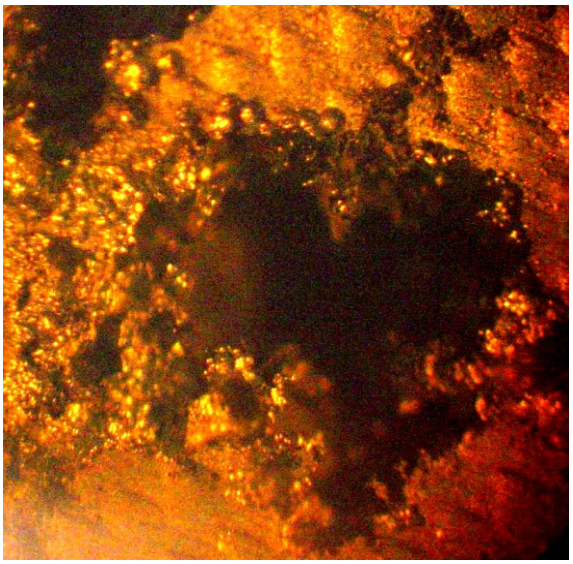


Figure 6. Very large pit on surface of coupon 6061/18

Table 2. Microscopic inspection of Rack#1/CRP-I coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Crevice couple	SAV-1/04	Front	
		Back	
	SAV-1/60	Front	Corrosion under ceramic ring
		Back	Pit covered with white blisters
Galvanic couple	316/02	Front	
		Back	
	6063/68	Front	Spherical pits
		Back	Galvanic corrosion. Deep pits of irregular shape. White blisters
Galvanic couple	316/01	Front	
		Back	
	6063/59	Front	Yellow deposit. White blisters
		Back	Intensive galvanic corrosion under coupled coupon. White blisters
Crevice couple	6063/05	Front	
		Back	
	6061/60	Front	
		Back	
Crevice couple	6063/04	Front	
		Back	
	6061/56	Front	
		Back	Intensive corrosion with deep pits under coupled coupon. Pitted surface with spherical pits
Crevice couple	6061/18	Front	Two very deep pits of irregular shape
		Back	
	1100/56	Front	
		Back	Uneven oxidation
Crevice couple	6061/07	Front	
		Back	
	1100/53	Front	Shallow pits under ceramic ring
		Back	Crevice corrosion under coupled coupon

Rack#2.1/CRP-I

Basic data on Rack#2.1/CRP-I are given in Ref. [2]. The rack was exposed to water in basin no. 1 of the RA spent fuel storage pool for 16 months. The results of visual and microscopic examination are shown in tabs. 3 and 4 and in figs. 7-10, respectively.

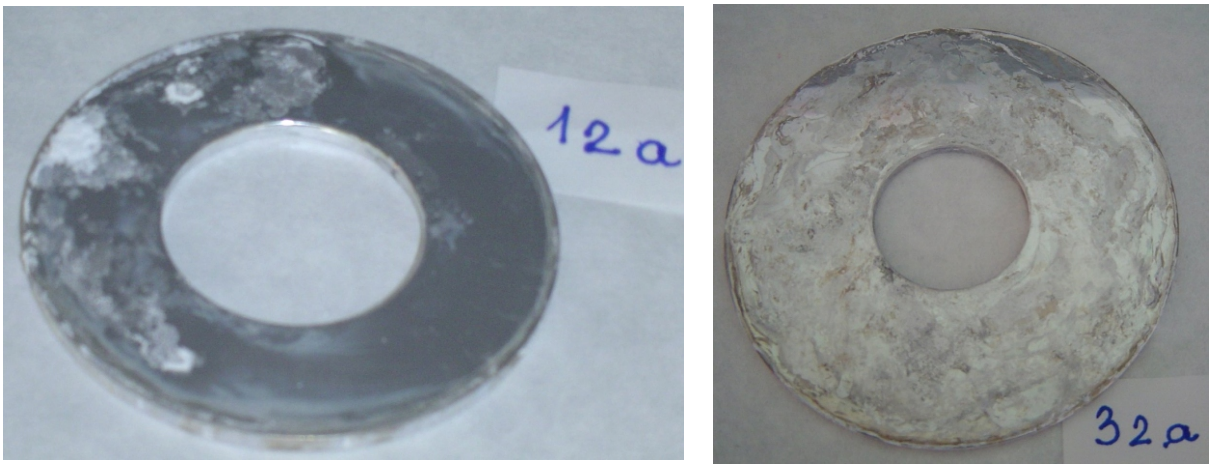


Figure 7. Back side surface of 6063/145 (left) and 6063/196 coupons (right)

Table 3. Visual inspection of Rack#2.1/CRP-I coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	316/133	Front	Shiny surface
		Back	Shiny surface with stains. White deposit on 40% of the surface
	6063/145	Front	White deposit on 50% of the surface. Deep pits
		Back	Uneven oxidation. Corrosion under ceramic ring with deep pits
Galvanic couple	316/121	Front	Shiny surface with white and yellow deposit
		Back	Shiny surface
	6061/123	Front	Corrosion under ceramic ring with deep pits
		Back	Dull surface near outer edge. Galvanic corrosion
Crevice couple	6063/159	Front	Dull discoloration. Corrosion under ceramic ring
		Back	No corrosion on scratched line. Crevice corrosion
	6063/196	Front	Dull discoloration. Corrosion under ceramic ring
		Back	Crevice corrosion on all surfaces
Crevice couple	6061/217	Front	Dull discoloration. Corrosion near outer edge
		Back	Crevice corrosion on 80% of the surface
	6063/227	Front	Crevice corrosion on 80% of the surface
		Back	Dull discoloration
Crevice couple	1100/229	Front	Dull discoloration. A lot of yellow deposits
		Back	Crevice corrosion on all surfaces
	1100/236	Front	Uneven oxidation. Pitted surface with shallow pits
		Back	Crevice corrosion on all surfaces

Table 4. Microscopic inspection of Rack#2.1/CRP-I coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	316/133	Front	Shiny surface. No corrosion
		Back	Shiny surface. White deposits
	6063/145	Front	Galvanic corrosion. Very deep pits of irregular shape
		Back	Very deep pits of irregular shape
Galvanic couple	316/121	Front	Shiny surface. White and yellow deposits
		Back	Shiny surface. White deposits
	6061/123	Front	Corrosion under ceramic ring
		Back	Galvanic corrosion with shallow pits
Crevice couple	6063/159	Front	General corrosion under ceramic ring. Pits od spherical shape
		Back	No corrosion on the scratched line
	6063/196	Front	Corrosion under ceramic ring
		Back	Crevice corrosion. Pits of irregular shape
Crevice couple	6061/217	Front	General corrosion
		Back	Crevice corrosion. Pits of irregular shape
	6061/227	Front	General corrosion
		Back	Crevice corrosion. Pits of irregular shape
Crevice couple	1100/229	Front	Yellow deposit
		Back	Crevice corrosion. Pits of irregular shape
	1100/236	Front	Shallow pits of irregular shape
		Back	Crevice corrosion

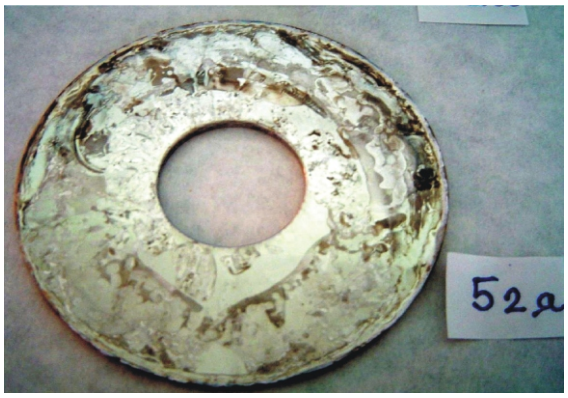


Figure 8. Back side surface of 1100/236 coupon

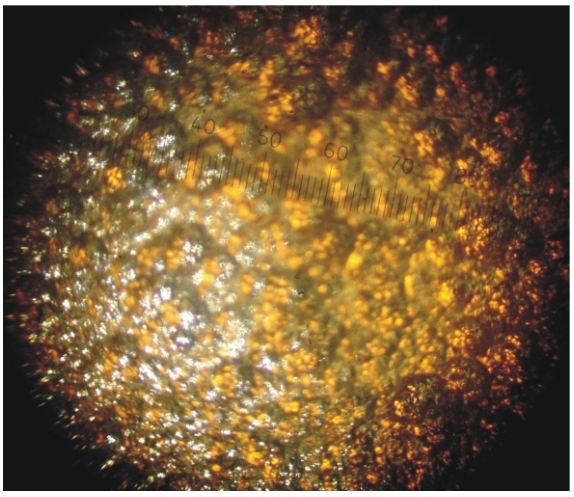


Figure 9. General corrosion under ceramic ring: spherically shaped pits at front side of 6063/159 coupon

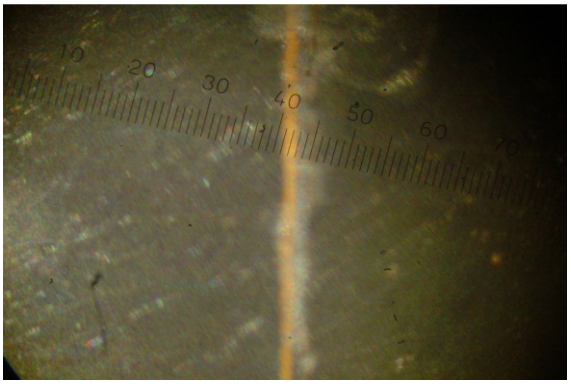


Figure 10. No evidence of corrosion on scratched line on back side of 6063/159 coupon

Rack#1/CRP-II

Basic data on Rack#1/CRP-II are given in Ref. [2]. The rack was exposed to water in basin no. 3 of the RA spent fuel storage pool for only six months. The results of visual and microscopic examination are shown in tabs. 5 and 6 and in figs. 11 16, respectively.

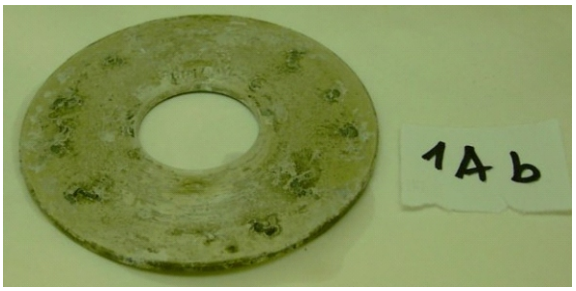


Figure 11. Back side surface of 6061/302 coupon

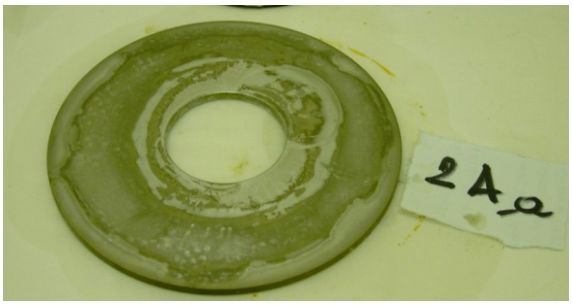


Figure 12. Front side surface of 6063/249 coupon

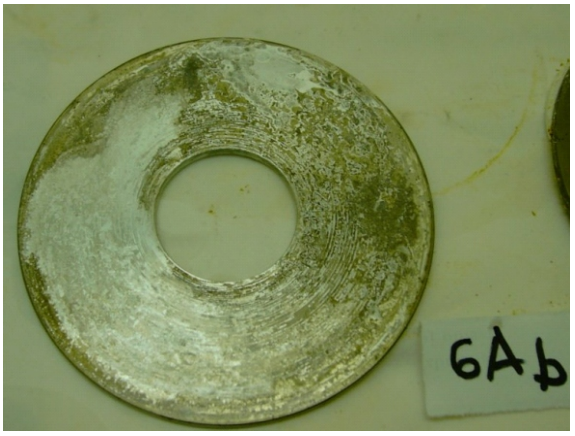


Figure 13. Back side surface of SAV-1/358 coupon

Rack#2.2/CRP-I

Basic data on Rack#2.2/CRP-I are given in Ref. [2]. The rack was exposed to water in basin no. 1

Table 5. Visual inspection of Rack#1/CRP-II coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	304/330	Front	Dull surface with red brown deposit. Corrosion under ceramic ring
		Back	Shiny surface with some stains
	6061/302	Front	Dull surface exposed to water. About 10 pits on the surface. General corrosion mainly under ceramic ring
		Back	Galvanic corrosion on all coupons. Very deep pits. White deposits. Corrosion at outer edge
Crevice couple	6063/249	Front	Dull surface. White and yellow deposits. Surface covered with jelly-mushroom sludge
		Back	Dull discoloration. Uneven oxidation. General corrosion
	6063/228	Front	Dull surface. General corrosion mainly under ceramic ring
		Back	Dull discoloration. Uneven oxidation. General corrosion
Single coupon	6063/204	Front	Coupon is without shine. Some yellow deposit. No corrosion on scratched line. Outer edge dull
		Back	Coupon is without shine
Single coupon	6061/312	Front	Dull surface. White deposits. General corrosion mainly under ceramic ring
		Back	Dull discoloration. General corrosion mainly under ceramic ring
Galvanic couple	304/350	Front	Shiny surface. White deposits
		Back	Shiny surface
	SAV-1/377	Front	Dull discoloration. General corrosion on about 10% of the surface under ceramic ring
		Back	Intensive corrosion of the entire surface
Crevice couple	SAV-1/358	Front	Completely dull surface with islands of pits. Corrosion in area under ceramic ring
		Back	Crevice corrosion on the entire surface. Bright and dark areas
	SAV-1/346	Front	Uniformly dull surface with white deposits
		Back	Crevice corrosion on the entire surface. Bright and dark areas
Single coupon	SAV-1/335	Front	Dull and pitted surface
		Back	Dull surface
Single coupon	SAV-1/312	Front	Dull discoloration on about 30% of the surface. Corrosion in area under ceramic ring. No corrosion on scratched line
		Back	Dull discoloration on about 30% of the surface

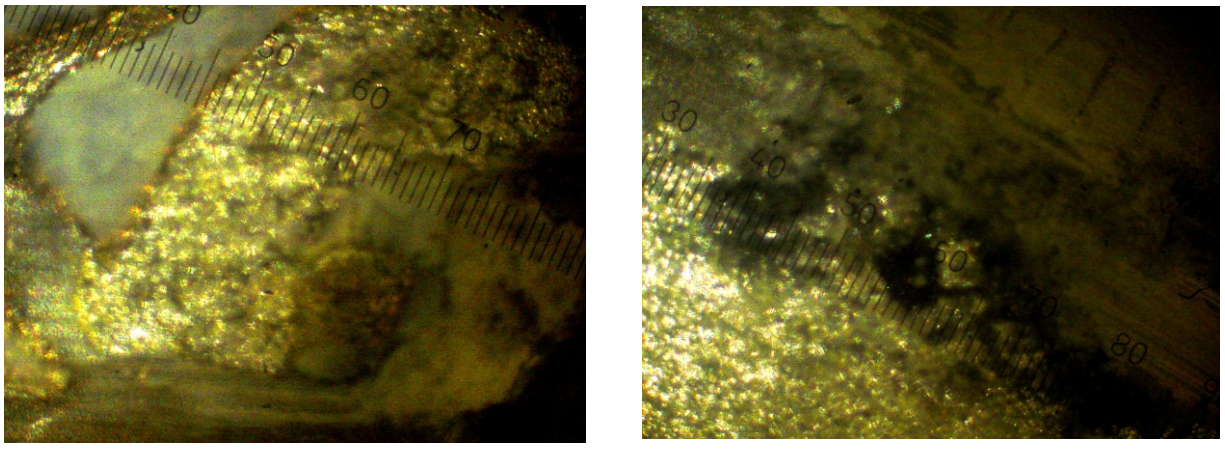


Figure 14. Pits on front (left) and back (right) side surfaces of SAV-1/377 coupon

Table 6. Microscopic inspection of Rack#1/CRP-II coupons

Coupons on the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	304/330	Front	
		Back	
	6061/302	Front	Dull surface with spherical pits (about 10 pits)
		Back	Galvanic corrosion with very deep pits
Crevice couple	6063/249	Front	
		Back	
	6063/228	Front	
		Back	
Single coupon	6063/204	Front	
		Back	
Single coupon	6061/312	Front	
		Back	
Galvanic couple	304/350	Front	
		Back	
	SAV-1/377	Front	Dull discoloration. Intensive general corrosion under ceramic ring with deep pits
		Back	Galvanic corrosion on 80% of the surface
Crevice couple	SAV-1/358	Front	
		Back	
	SAV-1/346	Front	
		Back	
Single coupon	SAV-1/335	Front	Pitted surface. Spherical, deep pits
		Back	
Single coupon	SAV-1/312	Front	Pits under ceramic ring. No corrosion on scratched line
		Back	

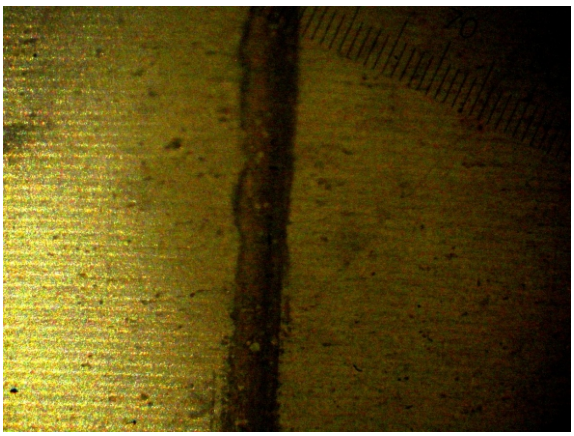


Figure 15. No corrosion under scratched line on 6063/204 coupon

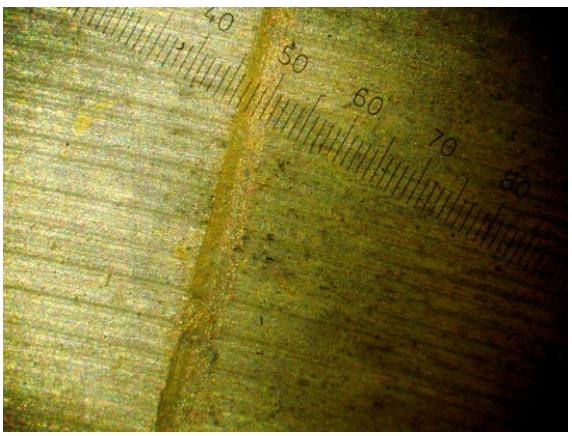


Figure 16. No corrosion under scratched line on front side surface of SAV-1/312 coupon

of the RA spent fuel storage pool for two years. The results of visual and microscopic examination are shown in tabs. 7 and 8 and in figs. 17 21, respectively.

Rack#2/CRP-II

Basic data on Rack#2.CRP-II are given in Ref. [2]. The rack was exposed to water in basin no.

Table 7. Visual inspection of Rack#2.2/CRP-I coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	316/114	Front	Dark-red sediments cover surface. After cleaning, shiny surface and white, thin, circular line
		Back	Shiny surface with some stains
	6063/135	Front	Surface exposed to water, dull. General corrosion mainly under ceramic rings
		Back	Shiny surface compared to top. White deposits with galvanic corrosion. Corrosion at outer edge
Galvanic couple	316/115	Front	Almost shiny surface. Broken, thin line under ceramic ring boundary
		Back	White deposit, irregular in shape, covering 80% of the surface. Corrosion at inner edge
	6061/142	Front	General corrosion in some areas under ceramic ring. Dull discoloration
		Back	White deposits on 80% of the surface. Galvanic corrosion
Crevice couple	6063/150	Front	Exposed surface is dull. Some bright spots under ceramic ring
		Back	White deposits and crevice corrosion on 20% of the surface
	6063/198	Front	Corrosion in area under ceramic ring. White deposits. 80% of the surface covered by mushroom
		Back	White deposits and crevice corrosion on 80% of the surface
Crevice couple	6061/212	Front	White deposits. 80% of the surface covered by mushroom. Corrosion in some areas under ceramic ring. Uneven oxidation. Shiny surface in area formerly with mushroom
		Back	Crevice corrosion on the entire surface
	6061/200	Front	Completely dull surface. Corrosion in some areas under ceramic ring
		Back	Crevice corrosion on the entire surface
Crevice couple	1100/240	Front	Completely dull surface. Corrosion in area under ceramic ring
		Back	Crevice corrosion on the entire surface. Bright and dark areas
	1100/244	Front	Uniformly dull surface with white deposits
		Back	Crevice corrosion on the entire surface. Bright and dark areas

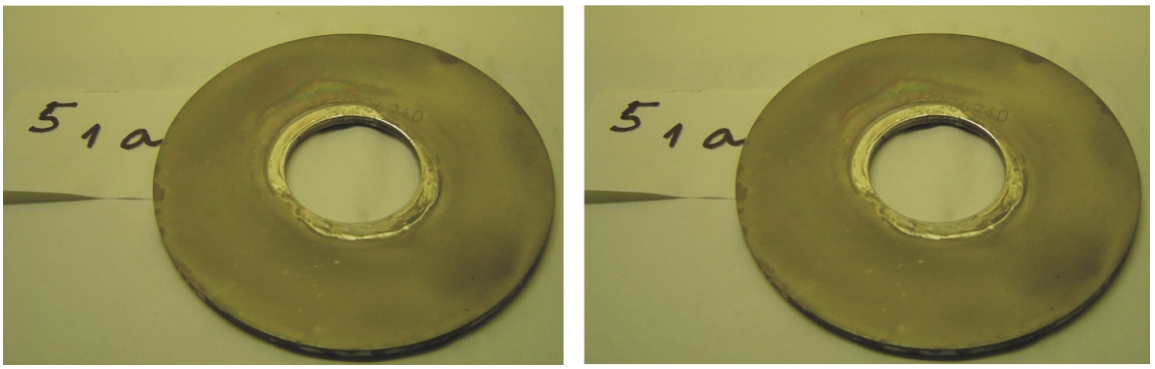


Figure 17. Front (left) and back (right) side surfaces of 1100/240 coupons

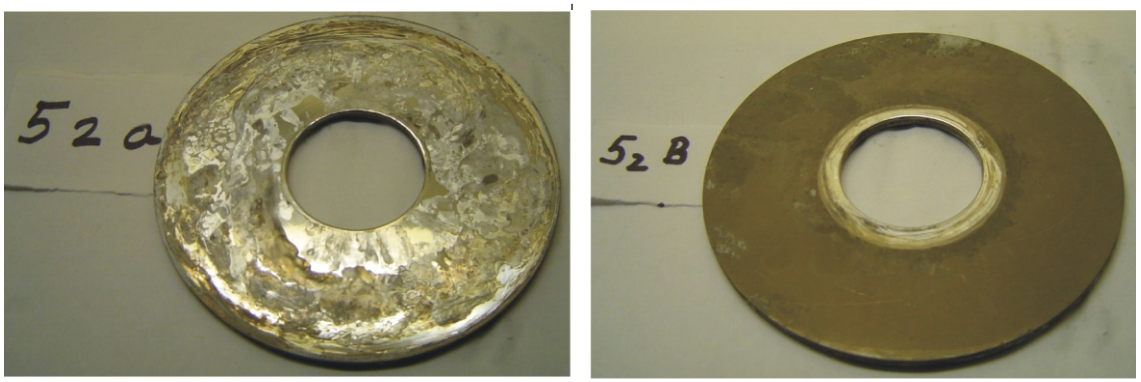


Figure 18. Front (left) and back (right) side surfaces of 1100/244 coupons

Table 8. Microscopic inspection of Rack#2.2/CRP-I coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	316/114	Front	
		Back	
	6063/135	Front	General corrosion under ceramic ring. Pit shapes: mostly round, shallow. Grain boundaries also etched in this region
		Back	Galvanic corrosion on 30% of the surface. Corrosion at outer edge
Galvanic couple	316/115	Front	Corrosion on inner edge. Ceramic ring produced a thin boundary line without any pits. Other areas bright and unattached. Some shallow pits on several points of the line
		Back	General corrosion on 80% of the surface
	6061/142	Front	Pits found in areas under ceramic ring
		Back	Galvanic corrosion on 80% of the surface. Shallow pits
Crevice couple	6063/150	Front	Pits under ceramic ring, various types, round and irregular
		Back	Some contact areas bright. Crevice corrosion on 10% of the surface
	6063/198	Front	Corrosion under ceramic ring with deep pits. Bright area under mushroom
		Back	Almost entire surface under corrosion with deep pits
Crevice couple	6061/212	Front	Bright area mushroom. Very deep pits under ceramic ring
		Back	Almost entire surface under corrosion with 4-5 areas with deep pits
	6061/200	Front	Pitting under ceramic ring (50% of the surface). Uniform scale formed on the entire exposed surface
		Back	Almost entire surface under corrosion with round and irregular pits
Crevice couple	1100/240	Front	Uniform and dense scale on exposed surface. Under ceramic ring, small shiny area left
		Back	Almost entire surface under corrosion
	1100/244	Front	Thick and uniform scale on exposed surface with 4-5 white areas. Some bright areas under ceramic ring
		Back	White deposits and almost entire surface under corrosion

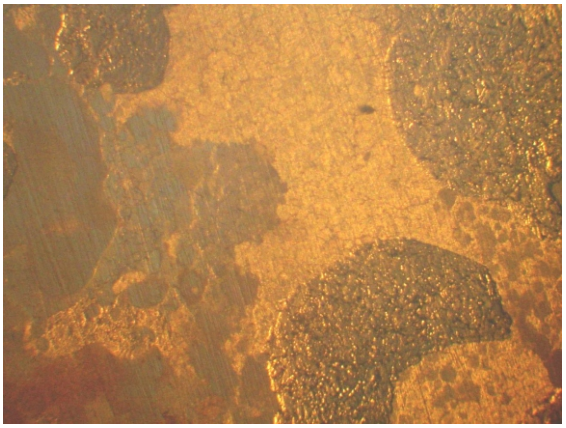
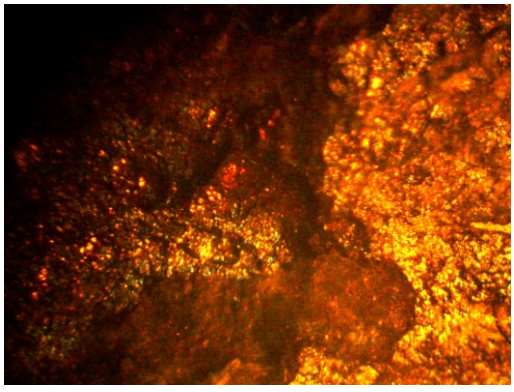


Figure 19. Galvanic corrosion on back side of coupon 6061/142 (magnification 10)



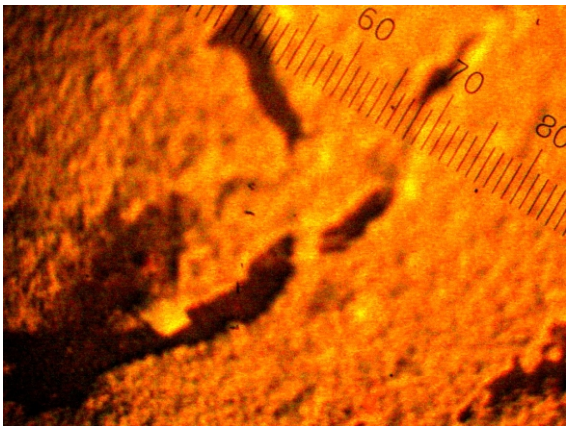


Figure 20. Corrosion on back side of 1100/244 coupon (magnification 10)

2 of the RA spent fuel storage pool for a year. The results of visual and microscopic examination are shown in tabs. 9 and 10 and in figs. 22-30, respectively.

Figure 21. Corrosion on back side of 6063/198 coupon (magnification 10)

Table 9. Results of visual inspection of Rack#2/CRP-II coupons

Coupons in the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	304/332	Front	Shiny surface. Broken thin line under ceramic ring boundary
		Back	White deposit off irregular shape covering 80% of the surface
	6061/305	Front	Dull discoloration with island of pits near outer edge. Corrosion in area under ceramic ring. Corrosion on outer edge
		Back	Intensive galvanic corrosion. Corrosion on outer edge
Crevice couple	6063/208	Front	Dull discoloration with uneven oxidation
		Back	Crevice corrosion on all surfaces
	6063/244	Front	Dull surface with islands of pits. General corrosion near outer and inner edge
		Back	Crevice corrosion on all surfaces
Single coupon	6063/221	Front	Uneven oxidation with island of pits
		Back	Uneven oxidation. No corrosion
Galvanic couple	304/360	Front	Almost shiny surface. Broken thin line under ceramic ring boundary
		Back	White deposit of irregular shape covering 80% of the surface
	SAV-1/366	Front	Dull surface with islands of pits. Intensive corrosion under ceramic ring
		Back	Intensive corrosion of the entire surface with white deposits
Single coupon	6061/321	Front	Dull discoloration with islands of pits. Corrosion under ceramic ring
		Back	Dull discoloration with islands of pits. Corrosion under ceramic ring
Crevice couple	SAV-1/376	Front	Completely dull surface with white blisters. Corrosion under ceramic ring
		Back	Intensive crevice corrosion on the entire surface. Bright and dark areas
	SAV-1/353	Front	Uniformly dull surface. Corrosion under ceramic ring
		Back	Intensive crevice corrosion on the entire surface. Bright and dark areas
Single coupon	SAV-1/317	Front	Uneven oxidation. No corrosion
		Back	Uneven oxidation. No corrosion
Single coupon	SAV-1/329	Front	Uniformly dull surface. Corrosion under ceramic ring
		Back	Uneven oxidation with red brown deposits. Corrosion under ceramic ring

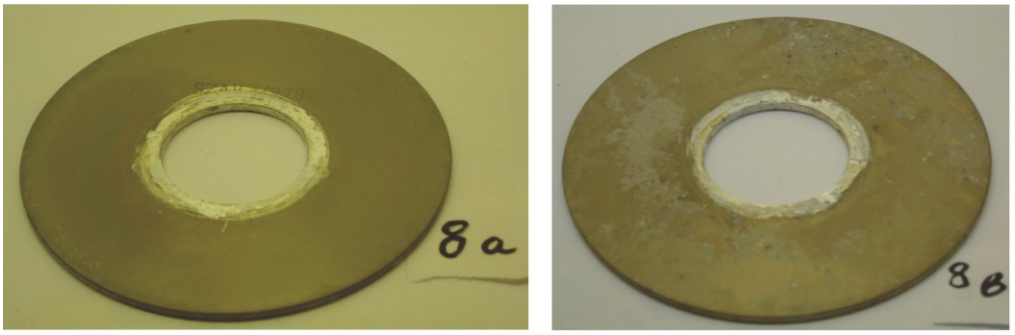


Figure 22. Front (left) and back (right) side surfaces of SAV-1/329 coupon

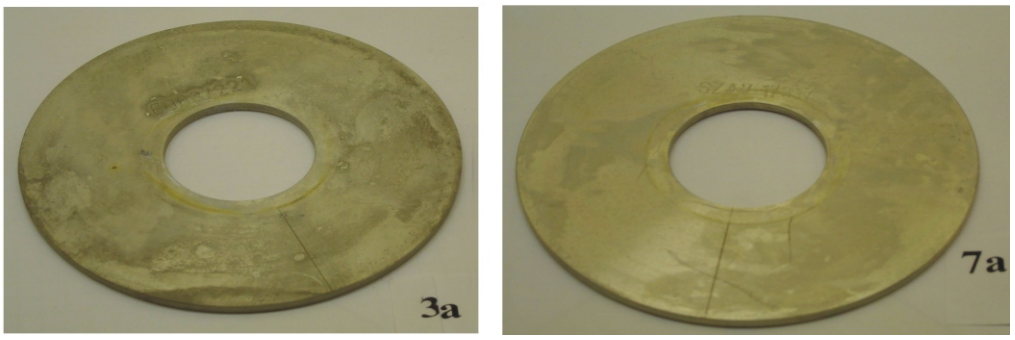


Figure 23. Front side surfaces of 6063/221 (left) and SAV-1/317 (right) coupons

Table 10. Results of microscopic inspection of Rack#2/CRP-II coupons

Coupon in the rack	Coupon label	Coupon side	Corrosion effects
Galvanic couple	304/332	Front	No corrosion. Sediment at edge to ceramic ring
		Back	Significant deposit at 80% of surface. No corrosion effects
	6061/305	Front	Large corrosion at outer edge. Damages at edge to ceramic ring
		Back	Galvanic corrosion on entire surface and outer edge
Crevice couple	6063/208	Front	Non-uniform colour of surface. No corrosion at surface and at scratch line
		Back	White sediment at whole surface. No corrosion
	6063/244	Front	Corrosion at outer edge. Uniform colour of the surface
		Back	Characteristic pitting corrosion of the entire surface
Single coupon	6063/221	Front	Intensive corrosion of the entire surface. Single pit at scratched line and single brown colour pit at surface
		Back	Small corrosion pits
Galvanic couple	304/360	Front	No corrosion at surface
		Back	Deposits on entire surface, no corrosion
	SAV-1/366	Front	Corrosion at outer edge. Pitting corrosion on the surface
		Back	Intensive corrosion on the entire surface and Al removed. Corrosion islands of approximately 1 cm^2
Single coupon	6061/321	Front	Corrosion on surface and at outer edge. Intensive corrosion near ceramic ring
		Back	Large pit near outer edge, about 1 cm^2 in diameter, depth of about 1 mm
Crevice couple	SAV-1/376	Front	Large corrosion at outer edge. Deep corrosion pits of brown colour
		Back	Corrosion of entire surface
	SAV-1/353	Front	Small corrosion at outer edge
		Back	Sediments and corrosion on entire surface
Single coupon	SAV-1/317	Front	No significant effects of corrosion
		Back	Initial corrosion process at scratched line and on surface
Single coupon	SAV-1/329	Front	Significant pitting corrosion on surface. Diameter of some pits up to 3 mm
		Back	Pitting corrosion on surface. Pit diameter up to 1 mm

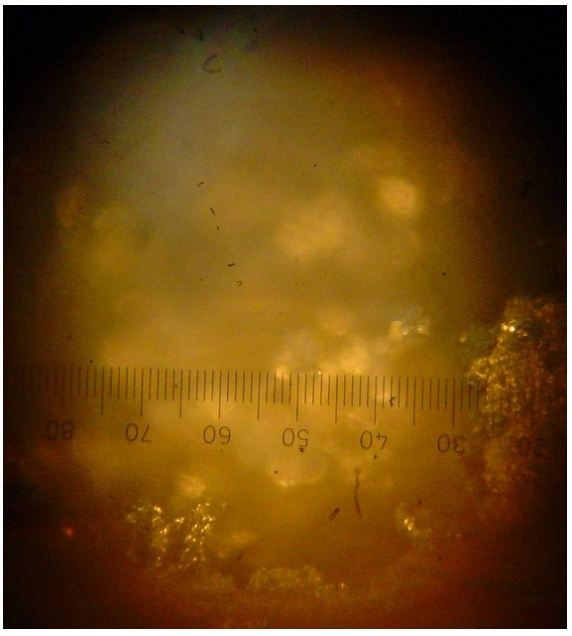


Figure 24. Corrosion at outer edge of the coupon 6061/305

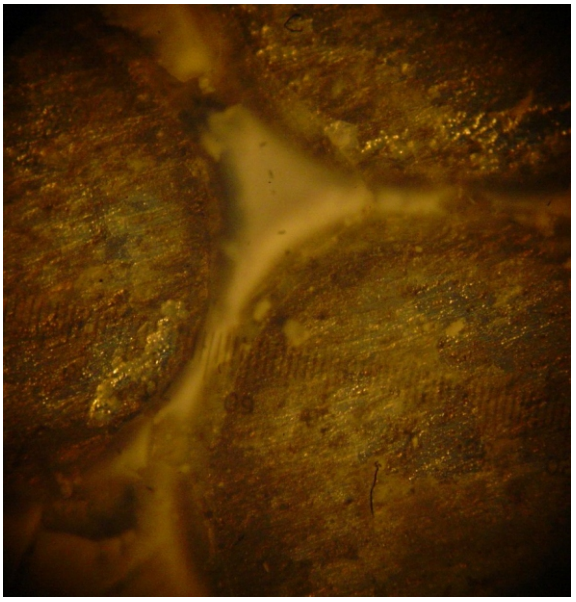


Figure 25. Galvanic corrosion on coupled side of coupon 6063/244

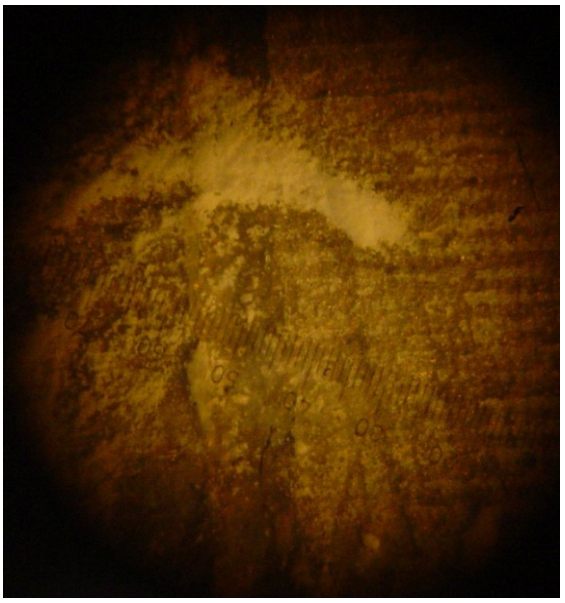
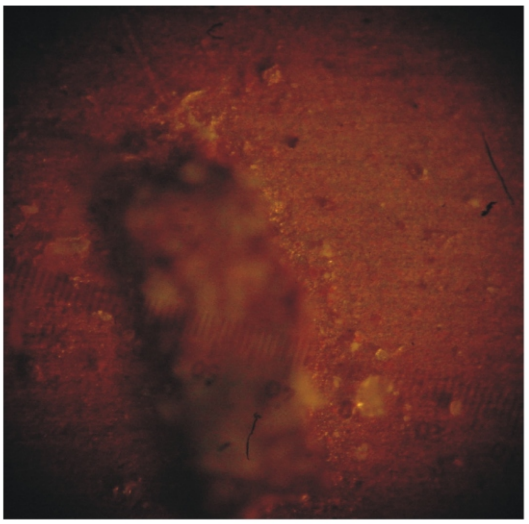


Figure 26. Corrosion on scratched line of front side of coupon 6063/221



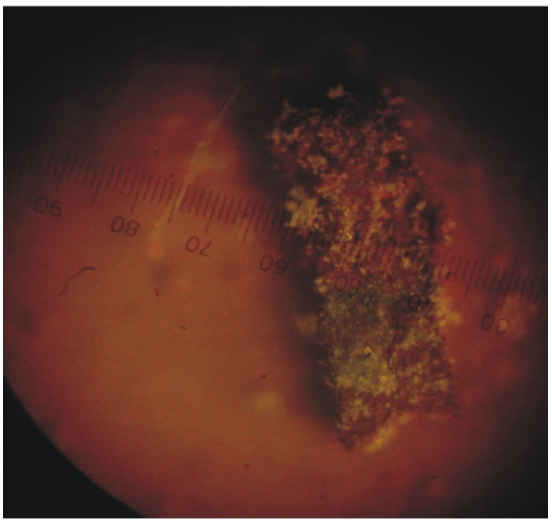


Figure 27. A large corrosion pit ("crater") on front side of coupon 6063/221

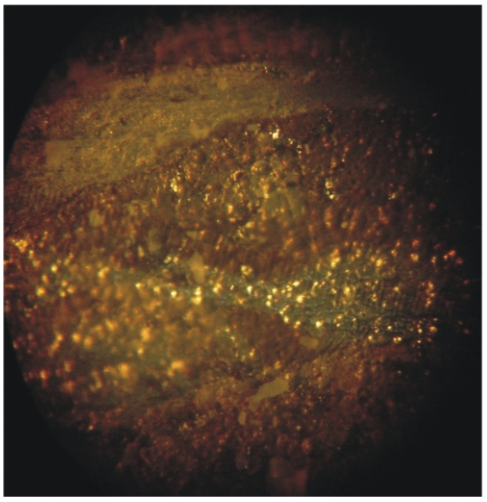


Figure 28. Crevice corrosion on back side of coupon SAV-1/366

Figure 29. Corrosion on scratched line on front side of coupon SAV-1/317

Figure 30. Initial pit corrosion on back side of coupon SAV-1/317

CONCLUSION

VINČA Institute of Nuclear Sciences, Belgrade, Serbia and Montenegro, participated in the IAEA CRP on "Corrosion of Research Reactor Aluminum-Clad Spent Fuel in Water – Phase II". Information related to the study of water and chemical and radioactive characteristics of the sludge in the spent nuclear fuel storage pool of the RA research reactor were given in the first part of this study. Racks with coupons, delivered by the IAEA to the Vinča site, were exposed to the influence of water in the spent fuel storage pool for a period of six months to six years. All aluminum coupons, either single or coupled to other aluminum (or stainless steel) coupons, were in a horizontal position in the water, so that the top surfaces of the coupons were covered by sludge. The effects of corrosion have been noted on all coupons and studied thoroughly, both visually and by use of a microscope, with the aim of determining the characteristics of the pits. The results obtained are shown systematically, respectively for each coupon, in tables and figures presented here.

Our study confirms that, regardless of exposition times, effects of intensive corrosion in tap water occur on all types of aluminum alloys of nuclear purity. Pitting, as a main localized form of aluminum corrosion in water, was visible on most coupon surfaces. Spots of different shades of grey and black (assumed to be aluminum-oxide) were often observed on coupons. Intensive corrosion regions on coupon surfaces can cover an area of about 1 cm^2. The largest pits may have a diameter of up to about 3 mm and the depth of up to 1 mm. Pre-oxidized aluminum coupons have shown considerable resistance to corrosion in pool water, in spite of the corrosion aggressive characteristics of the water or extensive exposition times. It has also been noted that, with one exception, corrosion has not occurred on the scratched line of the coupon surface.

Coupons made of SAV-1 alloy were examined with special attention, due to the fact that the spent nuclear fuel of the RA research reactor has cladding and fuel assembly construction components made of the same material. Unfortunately, it was not possible to confirm a higher resistance to corrosion of SAV-1 alloy compared to other aluminum alloys (1100, 6061, or 6063). Due to the various positions of the test racks with coupons in the pool, different ion electro-potentials were generated and, as a result, different corrosion rates occurred. As a result of such conditions, it was not possible to establish a correlation of corrosion effects to exposition times and water chemical parameters of the water.

ACKNOWLEDGEMENTS

This study has been carried out within the IAEA CRP "Corrosion of Research Reactor Aluminum-Clad Spent Fuel in Water, Phase II," under Project no. 11968/RBF. The authors are especially grateful to Mr. Lalgudi Ramanathan – "Ravi", from IPEN, Brazil, for his instructions and help offered in applying the IAEA Test Protocol procedures during the treatment of the test racks and the examination of corrosion effects on the surfaces of the coupons.

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ter (Phase II), to be presented at the IAEA 3rd RCM on Corrosion of Research Reactor Aluminum-Clad Spent Fuel in Water (Phase II), IAEA, Vienna, December 12-16, 2005

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СТУДИЈА КОРОЗИЈЕ НУКЛЕАРНО ЧИСТИХ АЛУМИНИЈУМСКИХ ЛЕГУРА У ОБИЧНОЈ ВОДИ ДЕО ДРУГИ

У оквиру координираног истраживачког пројекта Међународне агенције за атомску енергију "Корозија алуминијумске кошуљице озраченог нуклеарног горива истраживачких реактора у води", почевши од 2002. године, извршена су испитивања корозије легура нуклеарно чистог алуминијума у води базена за одлагање озрачених горивних елемената реактора РА. Узорци су били изложени утицају воде у периоду од шест месеци до шест година. Други део студије обухвата резултате испитивања ефеката корозије који су добијени детаљним визуелним и микроскопским испитивањима површине узорака и чини интегралну целину са првим делом извештаја о истраживању, приказаном у овом часопису.

Кључне речи: корозија, легуре алуминијума, SAV-1 легура, кошуљица горива, РА истраживачки реактор, обична вода