

# CONTENTS

SUMMARY .....	1
CHAPTER 1. BACKGROUND OF THE IAEA CO-ORDINATED RESEARCH PROJECT .....	7
1.1. Introduction .....	7
1.2. Storage of research and test reactor spent fuel worldwide .....	8
1.3. IAEA Co-ordinated Research Project .....	10
1.3.1. Details of the corrosion monitoring programme .....	11
1.3.2. Initiation of the Co-ordinated Research Project .....	12
1.3.3. Monitoring corrosion racks at research reactor storage basins .....	12
1.3.4. Results .....	13
1.3.4.1. Comisión Nacional de Energía Atómica, Centro Atómico Constituyentes (CNEA-CAC), Buenos Aires, Argentina .....	13
1.3.4.2. Instituto de Pesquisas Energéticas e Nucleares (IPEN), São Paulo, Brazil .....	14
1.3.4.3. China Institute of Atomic Energy, Beijing, China ...	15
1.3.4.4. KFKI Atomic Energy Research Institute, Budapest, Hungary .....	15
1.3.4.5. Bhabha Atomic Research Centre, Trombay, India ...	16
1.3.4.6. Pakistan Institute of Nuclear Science and Technology, Islamabad, Pakistan .....	17
1.3.4.7. Research Institute of Atomic Reactors, Dimitrovgrad, Russian Federation .....	17
1.3.4.8. Russian Research Center, Kurchatov Institute, Moscow, Russian Federation .....	18
1.3.4.9. Office of Atomic Energy for Peace, Bangkok, Thailand .....	18
1.3.5. General comments on the CRP .....	19
1.4. SRS corrosion surveillance programme .....	19
1.4.1. Background .....	20
1.4.2. Component immersion tests .....	21
1.4.3. Research and test reactor spent fuel corrosion surveillance .....	23
1.4.3.1. Corrosion racks and test coupons .....	23
1.4.3.2. Schedule for withdrawal and analysis .....	26
1.4.3.3. Results .....	27

1.4.4. Myth of microbially influenced corrosion in the RBOF at SRS .....	29
1.5. Conclusions .....	31
Referencesto Chapter 1 .....	33

**CHAPTER 2. STATE OF THE ART REVIEW ON ALUMINIUM CORROSION .....** 35

2.1. Introduction .....	35
2.2. Fundamental factors affecting corrosion .....	36
2.2.1. Oxide films on aluminium .....	36
2.2.2. Kinetics .....	37
2.2.3. Types of corrosion .....	37
2.3. Environmental factors affecting aluminium corrosion .....	40
2.3.1. Influence of water composition .....	41
2.3.2. Conductivity of water .....	41
2.3.3. Effect of pH .....	43
2.3.4. Effect of impurities .....	43
2.3.5. Copper .....	44
2.3.6. Bicarbonate .....	45
2.3.7. Sulphates .....	45
2.3.8. Oxygen .....	46
2.3.9. Temperature .....	46
2.4. Pitting rate index .....	47
2.5. Conclusions .....	48
Referencesto Chapter2 .....	49

**CHAPTER 3. GUIDELINES FOR CORROSION PROTECTION OF RESEARCH REACTOR ALUMINIUM CLAD SPENT NUCLEAR FUEL IN INTERIM WET STORAGE .....** 51

3.1. Introduction .....	51
3.2. Scope .....	52
3.3. Corrosion experience with aluminium clad spent fuel in wet storage .....	52
3.4. Types of corrosion encountered in spent fuel storage basins .....	53

3.4.1. Uniform corrosion .....	53
3.4.2. Galvanic corrosion .....	53
3.4.3. Crevice corrosion .....	54
3.4.4. Pitting corrosion .....	54
3.4.5. Hydrogen blisters .....	55
3.5. Proposed guidelines for corrosion protection of aluminium clad spent fuel in wet storage .....	56
3.5.1. Water chemistry .....	56
3.5.2. Operational practices .....	58
References to Chapter 3 .....	61

#### CHAPTER 4. CRP TEST MATERIALS, RACKS AND EXPERIMENTAL PROTOCOLS .....

63

4.1. Introduction .....	63
4.2. Materials, coupons and racks .....	64
4.2.1. Batch I racks .....	65
4.2.2. Batch II racks .....	70
4.3. Test protocol .....	71
4.3.1. Preassembly .....	71
4.3.2. Assembly .....	72
4.3.3. Immersion in the storage basin .....	73
4.3.4. Exposure interval .....	73
4.3.5. Removal and examination of coupons .....	73
4.3.6. Post-storage detailed examination .....	74
4.3.7. Final report .....	74
4.3.7.1. Preparation .....	74
4.3.7.2. Evaluation .....	75
4.4. Concluding remarks .....	75

#### CHAPTER 5. CORROSION OF RESEARCH REACTOR ALUMINIUM CLAD SPENT FUEL IN WATER AT VARIOUS SITES IN ARGENTINA .....

77

5.1. General introduction .....	77
5.2. First stage: Rack I .....	78
5.2.1. Introduction .....	78
5.2.2. Experimental set-up .....	78

5.2.3.	Results of evaluation of rack 1 .....	80
5.2.3.1.	Disassembling and decontamination .....	80
5.2.3.2.	Metallographic examination .....	83
5.2.3.3.	Water chemistry .....	90
5.2.4.	Discussion .....	93
5.3.	Conclusions of the first stage .....	94
5.4.	Extended programme .....	94
5.4.1.	Introduction .....	94
5.4.2.	Experimental set-up .....	95
5.4.3.	Results .....	100
5.4.3.1.	Water chemistry .....	100
5.4.3.2.	Appearance of the samples .....	100
5.4.3.3.	Metallography .....	108
5.4.4.	Discussion .....	109
5.5.	Conclusions .....	113
References to Chapter 5 .....		116

CHAPTER 6. CORROSION BEHAVIOUR OF ALUMINIUM  
 ALLOYS IN THE SPENT FUEL STORAGE  
 SECTION OF THE IEA-R1 RESEARCH  
 REACTOR, IPEN, SAO PAULO, BRAZIL .....

6.1.	Introduction .....	117
6.1.1.	The IEA-R1 research reactor .....	117
6.1.2.	Spent fuel storage .....	118
6.1.3.	Fuel assessment — visual inspection of spent fuel assemblies .....	119
6.1.4.	Corrosion experience related to IEA-R1 reactor fuel and aluminium alloys .....	121
6.2.	The IAEA CRP .....	122
6.2.1.	IAEA rack 1 .....	122
6.2.2.	Results of the first inspection of rack 1 .....	123
6.2.3.	IAEA racks 2A, 2B, 3A and 3B .....	124
6.2.4.	The IPEN rack 1 .....	126
6.3.	Results .....	128
6.4.	Recommendations by the CRP participants from IPEN .....	128
References to Chapter 6 .....		129

CHAPTER 7. CORROSION BEHAVIOUR OF ALUMINIUM  
 ALLOY TEST COUPONS IN THE SPENT FUEL  
 BASIN OF THE CHINA INSTITUTE OF ATOMIC  
 ENERGY, BEIJING, CHINA . . . . . 131

7.1. Introduction . . . . . 131

7.2. Experiment . . . . . 131

    7.2.1. Test coupons and racks . . . . . 131

    7.2.2. Spent fuel basin . . . . . 132

    7.2.3. Reactor and spent fuel . . . . . 134

    7.2.4. Basin water monitoring . . . . . 134

7.3. Experimental details . . . . . 135

    7.3.1. Water chemistry parameters, radioactivity and radiation  
         level . . . . . 135

    7.3.2. Visual observation and inspection with a magnifying  
         glass . . . . . 136

    7.3.3. Photographic record . . . . . 137

    7.3.4. Metallographic analyses . . . . . 139

7.4. Conclusions . . . . . 140

References to Chapter 7 . . . . . | 141

CHAPTER 8. CORROSION OF ALUMINIUM ALLOY TEST  
 COUPONS IN THE SPENT FUEL BASIN OF THE  
 BUDAPEST RESEARCH REACTOR AT AEKI,  
 BUDAPEST, HUNGARY . . . . . 143

8.1. Introduction . . . . . 143

8.2. Reactor and spent fuel storage pool . . . . . 143

8.3. Investigations . . . . . 146

    8.3.1. Inspection and evaluation of rack 1 (after 6 and  
         12 months) . . . . . 146

    8.3.2. Inspection and evaluation of racks 2 and 3 (after 12 and  
         24 months) . . . . . 146

    8.3.3. Preparation of the second set of racks . . . . . 147

8.4. Results . . . . . 148

    8.4.1. Rack 2 . . . . . 148

    8.4.2. Rack 3 . . . . . 149

8.5. Conclusions . . . . . 151

CHAPTER 9. CORROSION OF ALUMINIUM ALLOY COUPONS  
 EXPOSED IN THE TROMBAY SPENT FUEL  
 STORAGE POOL AT BARC, MUMBAI, INDIA . . . . . 153

9.1. Introduction . . . . .	153
9.2. Experimental procedure . . . . .	154
9.2.1. Coupons received at the Budapest RCM . . . . .	154
9.2.2. Coupons received at the São Paulo RCM . . . . .	155
9.3. Observations . . . . .	156
9.3.1. Coupons received at the Budapest RCM . . . . .	156
9.3.2. Coupons received at the São Paulo RCM . . . . .	157
9.4. Discussion . . . . .	159
9.5. Conclusions . . . . .	160
Acknowledgements . . . . .	161
Referenceto Chapter9 . . . . .	161

CHAPTER 10. CORROSION OF ALUMINIUM COUPONS IN  
 THE FUEL STORAGE BAY OF PINSTECH,  
 ISLAMABAD, PAKISTAN . . . . . 163

10.1. Introduction . . . . .	163
10.2. Description of procedures . . . . .	163
10.3. Experimental procedure . . . . .	165
10.3.1. Preparation of rack assembly . . . . .	165
10.3.2. Immersion of rack 2 in the pool . . . . .	166
10.3.3. Basin water chemistry . . . . .	166
10.3.4. Radiation measurements . . . . .	166
10.4. Results and discussion . . . . .	166
10.4.1. Monthly inspections . . . . .	166
10.4.2. Basin water chemistry . . . . .	167
10.4.3. Radiation measurements . . . . .	168
10.4.4. Removal of rack 2 . . . . .	168
10.4.4.1. Observations at the site . . . . .	168
10.4.4.2. Detailed examination in the laboratory . . . . .	168
10.4.4.3. Post-exposure detailed examination . . . . .	169
10.4.5. Permanent withdrawal of rack 3 . . . . .	170
10.5. Conclusions . . . . .	170
References to Chapter 10 . . . . .	177

CHAPTER 11. CORROSION RESISTANCE OF DIFFERENT  
ALUMINIUM ALLOY COUPONS IN THE  
SPENT FUEL POOL OF THE MIR REACTOR,  
DIMITROVGRAD, RUSSIAN FEDERATION . . . . . 179

11.1. Introduction . . . . . 179  
11.2. Coupon preparation . . . . . 179  
11.3. Main features of spent fuel pool operation in the MIR reactor . . . . 180  
11.4. Results . . . . . 181  
    11.4.1. Investigation of coupon surfaces . . . . . 183  
11.5. Conclusions . . . . . 188

CHAPTER 12. CORROSION OF ALUMINIUM ALLOY  
COUPONS IN THE IR-8 REACTOR SPENT  
FUEL STORAGE BASIN AT KURCHATOV  
INSTITUTE, MOSCOW, RUSSIAN FEDERATION . . . 189

12.1. Introduction . . . . . 189  
12.2. Description of the aluminium alloy coupons of the three racks . . . . 190  
    12.2.1. Rack 1 . . . . . 190  
    12.2.2. Racks 2 and 3 . . . . . 190  
12.3. Reactor operating conditions . . . . . 190  
12.4. Results and discussion . . . . . 192  
12.5. Conclusions . . . . . 195

Acknowledgements . . . . . 196  
Reference to Chapter 12 . . . . . 196

CHAPTER 13. CORROSION OF ALUMINIUM ALLOY  
COUPONS IN THE SPENT FUEL BASIN AT THE  
OFFICE OF ATOMIC ENERGY FOR PEACE,  
BANGKOK, THAILAND . . . . . 197

13.1. Introduction . . . . . 197  
13.2. Experiment . . . . . 197  
13.3. Procedure . . . . . 198  
    13.3.1. Water basin chemistry . . . . . 198  
    13.3.2. Radiation field . . . . . 198  
    13.3.3. Coupon preparation . . . . . 198

13.3.4. Coupon monitoring .....	199
13.4. Results .....	199
13.4.1. Basin water chemistry .....	199
13.4.2. Coupon monitoring .....	199
13.4.3. Pit measurements .....	200
13.4.4. Glass ampoule coupons .....	207
13.5. Conclusions .....	207
Referenceto Chapter 13 .....	207
PARTICIPANTS IN THE CRP .....	209