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Overall Summary and Conclusions

IAEA/LMNPP Specialists Meeting
Irradiation Embrittlement and Mitigation
Gloucester, England, UK

Attachment 2

Overall Reaction

- No new major issues
- No major problems solved
- Progress on a number of issues/themes applicable to operating plants

Major Themes

- Key emphasis on VVER reactor materials relative to mechanisms and microstructures leading to embrittlement (before and after annealing)
- Issues for high Ni materials covering Western, VVER-1000, and model alloys
- Increased emphasis on measuring actual fracture toughness and applying/understanding the Master Curve approach
- For all materials, need to know when dose rate effects are important

VVER-440 Mechanisms

- Role of P, both in hardening and non-hardening embrittlement
- Integration of mechanistic understanding with parametric dependence
- Need for high quality data to resolve questions
- Knowledge and relationship to Western steels for key element interactions
- Re-embrittlement path after thermal annealing

VVER-1000/High Ni Steels

- Role of Ni (coupled with Mn and P)
- Role of P, both in hardening and non-hardening embrittlement
- Integration of model alloy property data and microstructural link
- Need for high quality data to resolve questions
- Knowledge and relationship of VVER-1000 sttels to Western steels for Cu/Ni/P/Mn… interactions

Fracture Toughness/Master Curve

- Direct measurement of fracture toughness is best, but still need CVN and mini-CVN (or other parameter) correlations
- Master Curve approach gaining more use
- Fundamental curve shape model is key to defining when 'Master Curve' may not work; need tensile results when applying data sets
- Data scatter complicates proof and validity

Dose Rate Effects

- Dose-dose rate and temperature regimes of data and application (i.e., surveillance vs. vessel operation) determine magnitude of effects
- Value from model-type alloys
- Most important for precipitation damage; thus, Cu in matrix from PWHT, Ni/Mn/P/Si precipitates, re-irradiation after annealing
- Other novel damage measurement techniques and 'virtual reactor' modeling

Application to Meeting Operating Life for Vessels

- Master Curve methodology is continuing to evolve, but still needs physical pinning
- Research on VVER steels has developed current parametric understanding, but more microstructural work is needed to clearly define mechanistic basis
- Consequences of dose rate effects are secondary in nature since they primarily impact economics rather than safety of RPVs

Day	Start time	Item/Paper	Paper/ Section no
Monday am	0940	IAEA activities on NPP life management programmes *L M Davies, B Gueorguiev and V Lyssakov*	1
	1000	Effects of irradiation and post-annealing re-irradiation on RPV steel heat JRQ *R K Nanstad, Ph Tipping, W Waeber and R D Kalkhof*	2
	1020	Status of Activities by the US Nuclear Regulatory Commission and the US Nuclear Power Industry to Assure the Structural Integrity of Reactor Pressure Vessels in US Nuclear Power Plants *J Medoff, A.D Lee, A Hiser, M A Mitchell, B J Elliot, K R Wichman W H Bateman, J R Strosnider*	3
	1040	The development of the IAEA RPVMDB *F Gillemot, L M Davies and V Lyssakov*	4
	1130	European contribution to the REVE Project. Simulation of radiation effects in RPV steels *S Jumel, C Domain, J Ruste, J Van Duysen, A Barbu, E Van Walle, R Chouadi, L Malerba, M Perlado, D Gomes, M Mayoral, C Becquart, A Legris, M Pareige and M Hou.*	5
	1150	Surveillance specimen programmes realisation results in Slovak Republic *L Kupca*	6
	1210	Surveillance Programmes for Reactor Pressure Vessels of VVER-440/V-213C Type Reactors in NPP Dukovany *M Brumovsky, P Novosad and M Kytka*	7
	1230	Re-evaluation and Analysis of the VVER-440 RPV standard surveillance programme Results *M Brumovsky, P Novosad, M Kytka and M Falcnik*	8
Monday pm	1400	Comparison of the irradiation effects on the microstructure and mechanical properties of VVER-type RPV steels *H W Viehrig, J Boehmert and A Ulbricht*	9
	1420	Radiation embrittlement of low alloyed steel *Y Nikolaev, A Nikolaeva and Y Shtrombakh*	10
	1440	Irradiation embrittlement of model alloys and commercial steels: Analysis of similitude behaviours *L Debarberis, F Sevini, B Acosta, A Kryukov, Y Nikolaev, A D Amaev and M Valo*	11
	1550	Application of the SINTAP methodology for estimating the fracture toughness of reactor pressure vessel steels based on Charpy data *E Lucon, M Scibetta and E van Walle*	12
	1610	The AMES network strategy towards the 6th EURATOM FWP *F Sevini, L Debarberis, R Gerard and C English*	13
	1630	Radiation embrittlement kinetics of the first generation of VVER-440 RPVs after post irradiation annealing *P Platonov, Y Nikolaev and Y Shtrombakh*	14
Tuesday am	0920	Fluence rate effects on irradiation embrittlement of model alloys *L Debarberis, F Sevini, B Acosta and A Kryukov*	15
	0940	Spectrum effect on radiation embrittlement of WWER-440 RPV Materials *V A Nikolaev and L N Rjadkov*	16
	1000	Effect of dose rate on irradiation damage in high copper welds *R G Carter, N Soneda, K Dohi, T Onchi, S Ishino, J M Hyde, C A English and W L Server*	17
	1020	An assessment of the role of high nickel content in the irradiation degradation of PWR weldments *T Mager, G Embring and C Jansson*	18
	1040	A model of irradiation damage in high nickel submerged arc welds *T J Williams, D Ellis, C A English and J Hyde*	19
	1130	Neutron ageing of WWER-1000 steel weld metal *S Vodenicharov and T Kamenova*	20
	1150	Results from surveillance programmes and their analysis *E Grynik, V Gulakova, L Chyrko, V Revka, A Ballasteros, L Debarberis and A Kryukov*	21
	1210	Extended analysis of VVER-1000 surveillance data *A Kryukov, D Erak, L Debarberis, F Sevini and B Acosta*	22
	1230	Annealing and re-irradiation of VVER-440 weld *G Uri, E Czoboly, F Gillemot and M Horvath*	23
Weds am	0900	Advanced model for the VVER RPV material re- embrittlement assessment *A Kryukov, D Erak, Y Shtrombakh, R Ahlstrand, L Debarberis, M Valo, J Kohopaa and S Vodenicharov*	24
	0920	Tentative re-irradiation behaviour of WWER-440 welds after annealing *M Valo, Y Strombakh, A Kryukov, S Vodenicharov and J Kohopaa*	25

Attachment 3

Weds am (cont'd)	0940	SCK.CEN contribution to the IAEA round-robin exercise on WWER-440 RPV weld material: irradiation, annealing and re-embrittlement *E Lucon, E van Walle, M Scibetta, R Chaouadi and M Weber*	26
	1000	Grain boundary Phosphorus Segregation Under Irradiation and Thermal Aging and Its Effect on the Ductile-to-Brittle Transition S Song, *R G Faulkner and P E J Flewitt*	27
	1020	Evaluation of Transition Temperature Shift by neutron irradiation in RPV steels using small punch test *Yong-Jun Oh, Bong Sang Lee, Se Hwan Chi and Jun Hwa Hong*	28
	1040	Preliminary results of resistivity and thermo-electric measurements on irradiated model alloys *F Sevini, B Acosta and L Debarberis*	29
	1130	The influence of warm pre-stressing on brittle fracture resistance of heat resistant steels with cracks *V V Pokrovsky and A G Ivanchenko*	30
	1150	Determination of matrix copper levels in RPV steels *S Dumbill, C English, J Hyde and S Ortner*	31
	1210	Effect of postweld heat treatment temperature and cooling rate on matrix copper level and Charpy toughness of pressure vessel steel welds *M K Miller, M A Sokolov, R K Nanstad and S S Babu*	32
	1230	Review of the post irradiation response of an electroslag weld *K F Chivers, C M Mendes and R B Jones*	33
Wednesday pm	1400	Fracture toughness of weld metal samples removed from a de-commissioned Magnox RPV *C J Bolton, P J E Bischler, M R Wootton, R Moskovic, J R Morri, H C Pegg, A B Haines, R F Smith and R Woodman*	34
	1420	Methodological aspects of determination of the transition temperature for the radiation RPV lifetime rate *A A Popov, G F Banyuk, E V Parshutin and O B Sidorin*	35
	1440	Factors affecting the shape of the ductile to brittle transition *S Ortner*	36
	1530	Application of Master Curve fracture toughness for RPV integrity assessment in the USA *W Server, S Rosinski, R Lott, C Kim and D Weakland*	37
	1550	Master Curve application to determine fracture toughness of RPV steels *M Serrano, F J Perosanz and J Lapena*	38
	1610	Check of Master Curve application to embrittled RPVs of VVER type reactors *M Brumovsky*	39
	1630	Master Curve analysis of highly embrittled PV steel *T Planman, H Keinänen, K Wallin and R Rintamaa*	40
Th am	0900	Hunting down the RPV Life *A Ballasteros, L.Bustos, E U Grynik, L I Chyrko and L Debarberis*	41
	0920	On the prognosis of radiation service life of steel 15Kh2NMFAA *V K Shamardin and V N Golovanov*	42
	0940	Development of the Plant life Management Technology for RPV/RV materials *K Sakamoto, E Otsuka, K Koyama, K Taguchi and M Yamamoto*	43
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		List of participants	50