Transactions of the 17th International Conference on Structural Mechanics in Reactor Technology (SMiRT 17)
Prague, Czech Republic, August 17 –22, 2003

Paper # D01-2

The AMES network in the 6th Framework Programme

F. Sevini[1)], L.Debarberis[1)], N.Taylor[1)], R. Gerard[2)], C. English[3)], M. Brumovsky[4)]

1) European Commission, Joint Research Centre, Institute for Energy, The Netherlands
2) Tractebel, Belgium
3) AEA Technology, UK
4) NRI Rez, Czech republic

Abstract

The AMES *(Ageing Materials European Strategy*) European network started its activity in 1993 with the aim of studying ageing mechanisms and remedial procedures for structural materials used for nuclear reactor components. Operated by JRC-IE, it has been supporting the co-ordination of the project cluster throughout the 4th and 5th EURATOM Framework Programs, carrying out projects on with plant life management implications. Among them we can list the development of non-destructive techniques applied to thermal ageing and neutron embrittlement monitoring (AMES-NDT and GRETE), improved surveillance for VVER 440 reactors (COBRA), dosimetry (AMES-DOSIMETRY, MADAM and REDOS), chemical composition effects on neutron embrittlement (PISA) and advanced fracture mechanics for integrity assessment (FRAME).

Main frame of the network in the 5th Framework Programme is the ATHENA project, which is aimed at summarizing the obtained achievements and edit guidelines on important issues like the Master Curve, Effect of chemical composition on embritllement rate in RPV steels, Re-embrittlement models validation after VVER-440 annealing and open issues in embrittlement of VVER type reactors.

In the 6th EURATOM Framework Programme started in 2003 the network will be part of a broader initiative on PLIM including in a more integrated way NESC, ENIQ, NET and AMALIA networks. This paper shows an overview of the concluded projects, achievements of the running ones and open issues tackled in the 6th EURATOM FWP and a summary of the plans for a new broader network on NPP Plant Life management (SAFELIFE).

KEY WORDS: Ageing, RPV, embrittlement, surveillance, plant life management, structural integrity

Introduction

During the 4th EURATOM Framework Program some projects proposed by the Steering Committee of the AMES *(Ageing Materials European Strategy*) network were carried out on non-destructive monitoring techniques for thermal ageing, reference dosimetry, reconstitution techniques and comparison of fracture toughness measurements. An overview of the outcome of REFEREE, RESQUE, MADAM and AMES-NDT projects is given.

Several other projects were successfully proposed for the *Nuclear Fission Safety Key Action* Within the 5th EURATOM Framework Programme.

Their focus is on the influence of chemical composition, namely phosphorus and nickel content, on the irradiation embrittlement of reactor pressure vessel materials, on the improvement of surveillance temperature measurement, on the validation of the master curve approach, and on non-destructive techniques to monitor ageing of irradiated steels.

Funding for the ATHENA (AMES thematic network) proposal was also obtained, allowing some resources to the newly defined AMES Task Groups.

In the 5th FWP several activities related to NPP Plant Life Management have been carried out also in the context of the NESC, ENIQ and NET networks, which were recently joined by AMALIA network dedicated to IASCC issues in core internals. In the 6th FP all these Fora will be coordinated by an integrated SAFELIFE network whose launch will be announced in September 2003, during the 10th Anniversary of the European networks.

1. Background of the AMES Network

The AMES (*Ageing Materials Evaluation and Studies*) network was set up to bring together the organizations in Europe having the greatest expertise on nuclear reactor materials assessment and research on ageing management [1].

To fulfill the strategy developed by the AMES network, in line with the priorities of the European industry, several key projects on the field of RPV irradiation embrittlement were executed during the 4th and are currently running in the 5th EURATOM Framework Programme. Their general purpose is to understand the influence of various embrittlement mechanisms; develop new techniques; improve the dosimetry aspects; improve the prediction of irradiated material fracture toughness.

The Steering Committee includes four organizations belonging to countries candidate to join the EU. AMES task groups, and the creation of the ATHENA thematic network, will make it possible to continue addressing key ageing issues in an effective way. The information coming from the running projects will be integrated with the results from different programs (EU-funded, national, Tacis-PHARE), enabling the defintion of a common European position on these issues. An overview of AMES projects throughout FP4 is given in [2] and [3].

The 5th EURATOM FWP projects

Hereby follows a short description of the status of presently running projects carried out by institutes members of the AMES network.

ATHENA (coordinator R. Gerard, Tractebel)

In order to optimise the fulfillment of its strategy, the AMES Steering Committee will start in November 2001 ATHENA, a thematic network organised in task groups on specific strategic and technical issues:

- Linking AMES strategy with Central and Eastern Europe; Russia and Ukraine
- Master Curve implementation for fracture toughness assessment
- Annealing and re-embrittlement issues
- Radiation embrittlement understanding
- Thermal ageing, stress/strain ageing and other ageing mechanisms: influence and synergism.

These task groups have the aim of improving the co-ordination and synergism on well-identified R&D topics concerning material degradation.

The objectives of ATHENA (AMES Thematic Network) are:

- To entrust the evaluation of specialised problems to a critical mass of experts; a mass that cannot be present in the Steering Committee;
- To create links with nationally-funded projects on the same or on complementary topics and valorises as such these in-kind contributions;
- To connect with projects on similar issues that are carried out in the framework of the Tacis and PHARE programs. The task groups provide an opportunity to share this information. In this way, some of the tasks carried out in the R&D projects can be re-oriented in order to obtain additional and/or complementary information on the same materials. It enhances the scientific and industrial co-operation with the partners of Eastern and Central Europe, Russia and Ukraine;
- To introduce links with American and/or Asian institutions that work on similar issues and can participate on an in-kind basis. This raises the stake of European contributions on a global level

This cross-fertilisation between projects represents the greatest added value of ATHENA. The thematic network will greatly enhance the return of the different programs (European R&D projects, national projects, Tacis-PHARE, bilateral co-operation projects). Besides the key participants identified in the ATHENA contract, the “work packages” are open to a wide participation on an in-kind basis, which should ensure an improved feedback on the real needs of the European industry.

REDOS (coordinator A. Ballesteros, Tecnatom)

Follow-up of FP4 MADAM, the scope of this project is the accurate determination and benchmarking of radiation field parameters, relevant for reactor pressure vessel monitoring. The neutron exposure of the reactor pressure vessel (RPV) and reactor internals is one of the key factors that should be quantified reliably when assessing their lifetime. Irradiation embrittlement is the most important damaging in the RPV lifetime evaluation.

Despite improvements in the calculation of neutron field parameters with the corrected cross section values, remarkable discrepancies exist between calculated and measured values, especially in ex-vessel position. To resolve these difficulties and discrepancies the experimental and computational techniques should be combined.

PISA (coordinator C. English, AEA Technology)

This project (Phosphorus Influence on Steel Ageing) has the objective of improving the understanding of irradiation embrittlement by segregation of phosphorus to internal grain boundaries and reducing the impact of brittle intergranular failure mechanism on the properties of the Reactor Pressure Vessel.

The range of the RPV steels considered includes the MnMoNi steels employed in European PWRs; the mild steels used in UK Magnox (steel) RPVs; and the steels employed in VVER 440s.

The approach employed to achieve this objective is to improve predictability through developing improved physical understanding of both the segregation process and any resultant change in mechanical properties. The necessary understanding will be developed through focussed experimental investigations of irradiated steels and *model alloys*, with associated modelling studies.

The project foresees three irradiations, respectfully at 200 dgC $5x10^{18}$, 290 dgC $5x10^{18}$ and 290 dgC $18x10^{18}$. Two of them have already been carried out. Post-irradiation examination will determine the microstructural and mechanical property changes in materials (both steels and model alloys) either irradiated as part of this project or pre-irradiated materials supplied by the partners. Finally the development of improved mechanistic understanding will be primarily achieved through modelling of the segregation process and the effect of such segregation on the mechanical properties.

COBRA (coordinator A. Ballesteros, Tecnatom)

This project tackles the open issue of the uncertainty in measurement of the correct irradiation temperature to which VVER 440 reactor surveillance capsules are subjected [4]. Non-homogeneous neutron and gamma flux distribution determines a temperature gradient along the capsule, and possible overheating as compared to the real conditions of the reactor pressure vessel. The latter phenomenon would produce non-conservative surveillance data.

Temperature melting monitors have shown uncertainties in assessing the temperature in the interval 272-292 dgC.

Hence a special direct temperature measurement system by thermocouple has been implemented in Kola NPP in order to prove the feasibility of the solution to the problem. The consortium includes Russian, Armenian and, European institutions.

Results show that the irradiation temperature of the surveillance specimens is about 272 dgC hence meaningful for RPV.

FRAME (coordinator M. Valo, VTT)

This project is concerned with fracture mechanics based trend curves for PWR and VVER RPV materials. The scope is to validate the use of the Master Curve approach, as compared to the usual increase of ductile-to-brittle transition temperature assessed by Charpy impact testing.

Cleavage initiation fracture toughness is the property needed in structural safety analyses of the reactor pressure vessel. However, this property is not measured directly for the irradiated (neither for the annealed or re-irradiated) material condition, instead a correlative embrittlement estimation based on the Charpy-V test is used. It is difficult to quantify the uncertainties inherent in the current estimation and hence the assumed uncertainties are addressed by the use of a conservative fracture toughness reference curve and by added margins. Charpy-V impact toughness is in many respects a clearly different material property than fracture toughness. Hence the current understanding of embrittlement may be a biased one.

In the FRAME project fracture toughness based embrittlement models will be created and they will be critically compared with the published Charpy-V based models.

Fracture toughness based trend curves do not exist nowadays, because the required databases are non-existing or are insufficient in size. Trend curve development is in essence mathematical fitting of candidate functions to measured irradiation shift data. Approximately twelve different materials are included in the test matrix. The irradiation in HFR LYRA rig is successfully carried out and the post-irradiation testing campaign is about to start.

GRETE (coordinator EdF)

The project is the follow-up of AMES-NDT, which was dedicated to ageing monitoring of non-irradiated materials. Object of GRETE is a round robin exercise on non-destructive techniques to assess and monitor degradation of reactor pressure vessel steels due to neutron irradiation and thermal fatigue of piping. The techniques studied are besides others based on thermo-electric and magnetic effects. The results will be of interest for RPV surveillance programs, because a validated non-destructive measurement of surveillance specimens could provide an alternative to destructive testing and therefore allow sparing of surveillance samples.

Non-Destructive Techniques for the characterisation of neutron irradiation damage are: Automated ball indenter; Magnetic Barkhausen Noise; Micromagnetic measurements; Non Linear Harmonic Analysis of Eddy Current signals; Thermo-electric power measurements.

For the characterisation of fatigue damage: Magnetic Barkhausen Noise; Micromagnetic measurements; Non Linear Harmonic Analysis of Eddy Current signals; Fluxgate, Giant Magnetic Resistor, Superconducting Quantum Interference Device; Ultrasonic Scattering or Backscattering. Analyses of the results and elaboration of conclusions are in progress.

AMES in the 6th FWP

In the context of the European Research Area there is a need for integrating the activities on NPP Plant Life Management into a common structure dedicated to the evaluation of open issues, elaboration of new activities and efficient utilization of available resources.

JRC-IE, starting from the experience accumulated since 1993 with the operation of NESC, ENIQ and AMES networks is presently elaborating a strategy to optimize common plans for FP 6 in the different areas, and launch in September 2003 the SAFELIFE network, which will have the aim of covering issues of NPP PLIM so far tackled in a scattered way by the single European networks.

The invaluable expertise and the differentiated background of the present networks will be kept by reconsidering their role as Expert Groups. This will ensure that all the different issues will be considered that when planning new activities, especially in the context of a Network of Excellence dedicated to PLIM or new proposals for Integrated Projects.

The Expert Groups will act as review bodies advising on the contents of new project proposals.

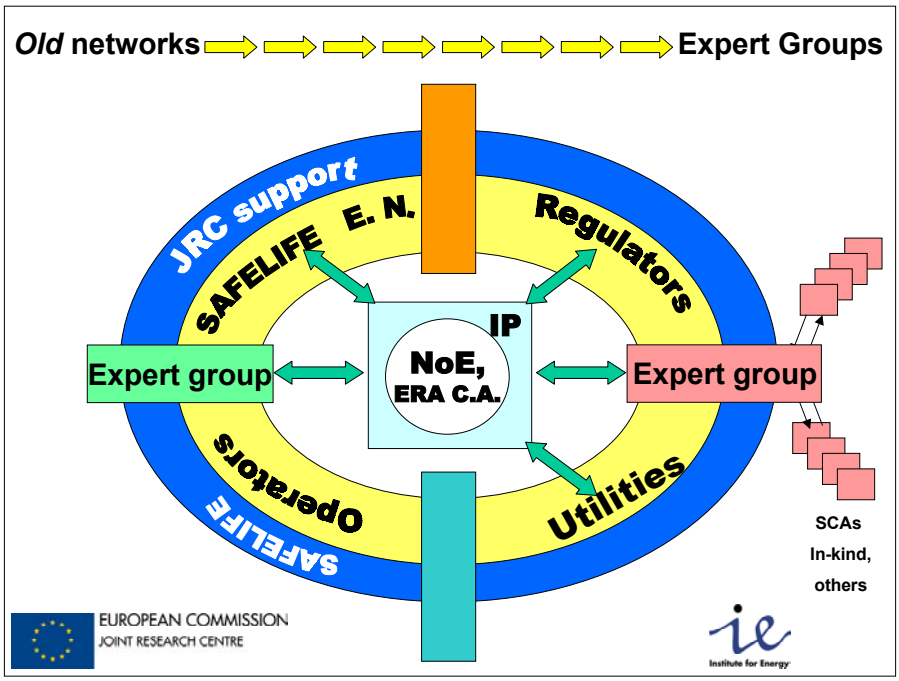

Fig. 1: Evolution towards an integrated approach to NPP PLIM in the EU

Plans for FP6: SAFELIFE and Plant Life Management of Ageing Nuclear Power Installations in Europe

An integrated approach to R&D activities on generic issues for plant life management of ageing nuclear power plants is required to support European needs for sustainability and for Safe & Secure Supply (3S) of electrical power. To meet this challenge the European Commission's Joint Research Centre proposes to form a Network focussed on structural integrity for plant life management of key components, covering the main R&D disciplines involved and considering all nuclear power plants designs both western and eastern. This is intended to provide a long-term structure capable of addressing generic issues relating to accident prevention, plant performance & risk informed methods, and to harness the efforts of the leading European R&D. In addition it can provide support for a rationalised EU approach basis for the plant decommissioning and related waste management issues.

The initiative will be based on the successful, established European Networks AMES, NESC (network for the evaluation of structural components), ENIQ (European network for inspection qualification) and on new ones such as NET (neutron evaluation techniques) and AMALIA (Assessment of Materials Ageing under the effect of Load and IASCC), operated by the JRC Institute for Energy.

SAFELIFE composition

- members of the European Networks AMES, NESC, ENIQ, NET and AMALIA
- members of running DG-RTD Thematic Networks and Shared Cost Actions in this area
- Representatives as appropriate from other European and international organisations

SAFELIFE network objectives

The main objectives are as follows:

- Establish a long-term structure to improve focus and effectiveness of European R&D for plant life management for key reactor components in ageing nuclear plants.
- Development and funding possibilities of major "integrated" project proposals at trans-national and EU level, consistent with European Research Area principles.
- Strategic planning and management of R&D actions in this area
- Promote harmonisation of best practice for improved European codes and standards.
- Organise training and professional development in advanced procedures and to maintain engineering competence for safe and economic operation of nuclear plants.
- Link and co-operate with all key international and national organizations.
- Optimise access to existing data, facilitate data exchange and support effective dissemination and technology transfer.

Plant Life Management Issues dealt by SAFELIFE

A complete list of NPP life management issues is not easy to draw but general agreement is anyhow achieved on several major items:

- RPV embrittlement
- Reactor Internals shroud cracking, bolts cracking
- Thermal fatigue in piping
- Dissimilar metal welds integrity
- Steam generator degradation cracking
- Electric cable and concrete structure ageing

Many issues have flagged so far in operating NPPs and more details are given in annex together with specific items for VVER design reactors in the enlarged EU. Many of the issues listed in the annex have direct consequences on safe operation of the plants. In general there is a need for improving the effectiveness of the European R&D effort to arrive at practical, consensus guidelines for a range of generic issues, many of which are multidisciplinary in nature.

Intended Activities of SAFELIFE network

SAFELIFE will consider activities in three main lines, to serve as a basis for a Network of Excellence proposal:

Multi-disciplinary actions: typically drawn on the Expert groups identified below. Co-ordinated themes can be component or technology related. The end-result should address an issue in an integrated manner. This activity can work at two levels: by defining new integrated projects or by identifying synergies between existing actions.

Examples of areas for integrated actions include:

- RPV lifetime assessment (ISI, embrittlement, mitigation measures, annealing/re-embrittlement, fracture assessment, degraded cladding, etc.).

- Lifetime assessment of key components other than RPV; including primary coolant piping, internals and the pressuriser, concrete structures, cables.

- Development and harmonisation of innovative methods of evaluation and monitoring of material degradation and residual stresses in welded NPP components; including optimisation of current practice in weld repair of ageing NNP components.
- Improved structural integrity assessment of nuclear components based on NDT and numerical modelling techniques.

- Development of large-scale European benchmark tests capable of validating critical aspects of structural integrity assessment methods.

- Focal point for development of structural reliability models and promotion of their use in risk-based approaches.

Expert groups development. The existing networks will continue to provide a basis of expertise in the following areas: inspection, ageing material characterisation (RPV, internals, etc), instrumentation & monitoring, structural analysis and fracture mechanics, risk-based approaches and reliability, residual stress measurement.

SAFELIFE will support the continued excellence of these groupings and advice on identifying actions to reinforce specific fields. Also there may be a need to address new areas not covered by the present networks or to establish suitable links to other centres of competence (examples could include thermodynamics, seismic analysis or characterisation of non-metallic materials).

CONCLUSIONS

Evolving from the 4th and 5th EURATOM Framework Programmes approach based on in-kind and co-financed initiatives promoted by its Steering Committee, AMES has reached important results and built a wide consensus on important issues related to neutron embrittlement of the reactor pressure vessel [5].

With the start of the 6th Framework programme and the introduction of new instruments like the Integrated Projects and the Network of Excellence there is a need for a broader and more efficient integration of activities and resources, in the spirit of the European research Area.

AMES, and the other European nuclear networks operated by JRC-IE, will therefore evolve into a Expert Groups of a more expanded new initiative on NPP Plant Life Management, called SAFELIFE, which will be promoted by JRC building on the experience acquired with the operation of the present networks.

SAFELIFE could this way constitute the basis for a future Network of Excellence on PLIM of nuclear power plants in the EU.

ACKNOWLEDGEMENTS

The project co-ordinators have provided most of the material here presented, but together with them all the FP5 project partners and European Networks members gave their contribution and are therefore acknowledged.

REFERENCES

1. F. Sevini, L. Debarberis, K. Törrönen, L. M. Davies, The AMES Network strategy developments in the 5th EURATOM Framework Program, Proceedings of ICONE 9 Conf., 9-12 Apr. 2001, Nice
2. F. Sevini, L.Debarberis, B.Acosta, S.Pirfo, A.Kryukov, A.Ballesteros, C.English, E. Grynik, M.Valo, R.Gerard, J.F.Coste, E.van Walle, C.Bolton, “Partnership projects on embrittlement Studies within the frame of the AMES European Network: Results and prospects ”, PLIM-PLEX ’01 Conference, London, Nov. 28-30, 2001;
3. L. Debarberis, F.Sevini, B.Acosta and A.Kryukov and M.Valo, “Results of Embrittlement Studies on Model Alloys, Reference Steels and RPV materials at JRC-IE”, PLIM-PLEX ’01 Conference, London, Nov. 28-30, 2001;
4. Ballesteros, L. Andersen, L. Debarberis, F. Sevini, D. Erak, S. Gezashchenko, A. Kryukov, Y. Shtrombakh, S. Goloschapov, A. Ionov, Y. Pytkin,Y. Anikeev, G. Banyuk, A. Plusch, F. Gillemot, A. Hovsepyan, “ASSESSMENT OF IRRADIATION CONDITIONS IN WWER-440(213) RPV SURVEILLANCE LOCATION”, 11th International Symposium on Reactor Dosimetry at Brussels on 18-23 August 2002
5. F.Sevini, L.Debarberis, R.Gerard, C.English, "The AMES network towards the 6th Framework Programme", 7th International Conference on Material Science Problems in NPP Equipment Production and Operation, St Petersburg, Russia, June 17-21, 2002