THE AMES NETWORK AND THE TASK GROUP ON WWER's

L. M. Davies*, J. C. van Duysen**, U. von Estorff***, D. Sycamore****

* LMD Consultancy, 176 Cumnor Hill, UK-Oxford OX29PJ, United Kingdom

** EdF, B.P. 1 Ecuelles, F-77250 Moret-sur-Loing, France

*** JRC-IAM of the EC, P.B. 2, NL-1755 ZG Petten, The Netherlands

**** DGXVII/C3 of the EC, Rue de la Loi 200, B-1049 Brussels

Abstract

The European Network on 'Ageing Materials Evaluation and Studies' (AMES) was created in 1993. Its main objectives are (a) to provide information and understanding on neutron irradiation effects in reactor materials in support of designers, operators, regulators and researchers and (b) to establish and discharge projects in the above areas. The Steering Committee is composed of at least one participant from each nuclear European Union country. The JRC's Institute for Advanced Materials of the European Commission plays the role of Operating Agent and Manager of the AMES Network.

This paper describes the structure, objectives, and major projects of the AMES network. Particular emphasis is placed upon the work it is intended to perform within the Task Group on 'WWER's" of the first AMES project (AMES1) on 'Validation of surveillance practice and mitigation methods'. EC DGXVII is addressing the question of how to facilitate contacts betweeen EU and Russian industries in the framework of nuclear Industrial co-operation,and this project may provide a suitable starting point upon which to develop a basis for further work of mutual interest.

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1. Introduction

The Institute for Advanced Materials plays the role of Operating Agent and Manager of the three European Networks ENIQ (European Network for Inspection Qualification), NESC (Network for Evaluating Steel Components) and AMES, each of them dealing with specific aspects of materials behaviour in structural components. The Networks are organised and managed in a similar manner to the PISC (Programme for the Inspection of Steel Components) programme. Participation includes utilities, engineering companies, R&D laboratories and regulatory bodies.

Although great progress has been made in understanding irradiation and thermal degradation of Reactor Pressure Vessel (RPV) steels, many aspects are still not fully understood (L. M. Davies, 1993). In particular the question of the qualification of remedial measures such as annealing and repairs remain where further study is essential.

The international effort of the IAEA Working Group on Nuclear Plant Life Management provides national contacts between institutions working in the field. Also the IGRDM (International Working Group on Radiation Damage Mechanisms for Pressure Vessel Steel) enables the exchange of information and collaboration for fundamental studies in this area. There remains, however, the problem of developing and maintaining a set of complementary capabilities inside Europe for the mutual benefit of its Member States.

There is also a need in Europe to create a focus for interaction with organisations in the Russian Federation and other countries of Central and Eastern Europe with respect to RPV material condition assessment and annealing.

2. Objectives and major activities

The AMES network was set up to bring together the organisations in Europe that have the main capabilities on RPV materials assessment and research, with the following objectives:

1. Provide information and understanding on neutron irradiation effects in reactor materials in support of designers, operators, regulators and researchers
2. Establish and discharge AMES projects in this subject areas.
3. Act as an European Review Group.
4. Provide technical support to regulatory bodies, General Directorates of the EC and provide a base for development of common European standards.

5. Participation in collaborative programmes with the New Independent States (NIS) and the Central and East European Countries (CEEC)
6. Promotion of: Coordination of common national programmes

   Validation of techniques

   Definition of European Standards

   Validation and establishment of safe limits for mitigation measures.

3. Organisation

The AMES Steering Committee decided to adopt the model of the successful PISC organisation, with well targeted terms of reference and project management. As shown in figure 1 the Steering Committee with an elected chairman gives guidance to the Operating Agent who appoints a Network Manager and other staff to manage the Network. Specific projects each have a task group to define the technical requirements, liaise with the Manager(s), co-ordinate joint activities, and monitor progress. The activities themselves are undertaken by the participating organisations.

The contractual aspects are governed by club-type arrangements between the members (multi-partner collaboration agreement). Participation in the activities of the Network is generally at the member's own expense.

Technical and administrative management of the Network and management of collaborative activities of projects are undertaken by the Operating Agent and Reference Laboratory (JRC-IAM of the EC) as performed in the past for PISC with the effective support or participation of national experts or laboratories as required (Debarberis and Tjoa, 1995)(von Estorff et al., 1996).

Particular projects, such as the setting up and undertaking of structural tests are sponsored either by individual members or by a common budget or partially through existing EC programmes.

The officers and members involved in AMES at the present time are listed in figure 2.

The network started in 1993 and is continually evolving to serve their primary purposes. At some stage consideration, by review, will probably look at the scope in terms of relevance to other branches of industry.

4. Projects

The Steering Committee has agreed upon the need to develop the following three projects in their order of priority:

AMES 1: Validation of surveillance practice and mitigation methods

AMES 2: Effects of irradiation on reactor internals

AMES 3: Significance of Phosphorus causing low toughness in steels during irradiation

The European Commission, Directorate General XI/C/2 (Safety of Nuclear Installations), has supported the detailing of these projects together with the project chairmen and all AMES members. The projects will be split into individual tasks that are then taken over by members for their completion. Some of the work for the tasks is financed as a contribution in kind; some is carried out by the JRC, the Operating Agent of the Network, and some could be supported by the European Commission, Directorate General XI, XII, XVII and IA (TACIS) and others as appropriate in order to reinforce common strategies in the field of pre-harmonisation studies which are relevant to safety related components.

4.1 AMES 1: Validation of Surveillance Practice and Mitigation Methods

In the first stage the project AMES 1 had been drawn up in the way it is reflected in the scheme in figure 3. After matching this scheme with the interests of the individual institutes the following Task Groups were established:

Task Group 1A: Chairman:	Reference Laboratory Group L. Debarberis, JRC, NL - L. Tjoa, ECN, NL
Task Group 1B: Chairman:	Small specimen M. Valo, VTT, FIN - E. van Walle, SCK/CEN, B
Task Group 1C: Chairman:	Correlation C. Bolton, Nuclear Electric, UK
Task Group 1D: Chairman:	Cladding K. Gott, SKI, S
Task Group 1E: Chairman:	Trend Curve C. English, AEA, UK
Task Group 1F: Chairman:	Irradiation conditions A. Ballesteros, Tecnatom, E
Task Group 1G: Chairman:	WWER J. C. van Duysen, EdF, F
Task Group 1H: Chairman:	WPS K. Wallin, VTT, Fin

The responsible officer for the project planning and co-ordination is Ralf Ahlstrand from IVO (FIN) supported by the Reference Laboratory and Operating Agent (JRC Petten).

The task groups were established at the 8th AMES S.C. meeting in Petten in January 1995. First task group meetings with key persons took place soon afterwards. The aim was to draft out the 'Terms of Reference' and to define a draft working schedule. These have been distributed to possible interested partners in a 'Call for Participation' by the Reference Laboratory and Operating Agent of AMES.

4.2 AMES 2: Effects of Irradiation on Reactor Internals

The second priority from AMES has been given to the project AMES 2 'Effects of Irradiation on Reactor Internals' which is still in an earlier stage.

The objective of the project is to evaluate the issues related to the degradation due to neutron irradiation of the properties of the materials of internal structures of PWR, BWR and WWER. For achieving that three groups of actions have to be considered:

- Collect and analyse information on problems actually observed in operation on internal structures of PWR, BWR and WWER
- Collect available irradiated materials and data on their properties from actual internal structures or from experiments in test reactors
- Generate relevant data for an accurate evaluation of the degree of the degradation of the material properties

A study contract was placed by the European Commission (DGXI/C2) to analyse the present situation. It is a SOA document describing internals, materials, conditions of operation, problems encountered, review of programmes, available materials, irradiation facilities, conclusions and recommendations for BWRs, PWRs and WWERs.

4.3 AMES 3: Significance of Phosphorus in Causing the Low Toughness in Steels

The initiating meeting revealed that there was a need for a project aimed at developing the methodology for both the re-distribution of Phosphorus and the impact of this on mechanical properties. At present there is insufficient insight to predict when non-hardening embrittlement might be important, and this made it difficult to provide Utilities or Regulators with advice on this phenomenon. Since there are also many different nation specific problems in the area it was agreed to firstly find a common approach with the integration of the national activities.

The potential interest of the different national representatives in a 'Phosphorus' project could be:

- Thermal and Irradiation Ageing (Magnox steels)
- Potential Phosphorus effect in RPV steels after long term irradiation
- Re-irradiation after embrittlement after annealing

A meeting is planned to assemble the necessary information from the national presentations expected, to detail the project and to produce a document like the one of Task Group 1G (WWER's) under item 5.

5. Task Group 1G: WWER's

5.1 Background

A major effort has already been undertaken to evaluate the risks of brittle rupture of WWER 440 and WWER 1000 reactor pressure vessel steels. There is indeed a lack of generic knowledge regarding the irradiation and annealing effects on the steels used to make these vessels. The existing international programmes concerning WWER pressure vessels are mainly focused on specific problems of some reactors. They will not be able to provide the required generic information.

Some institutes have planned, undertaken or completed studies to obtain such information. However, these studies taken separately can only provide partial answers. The volume of the task has probably prevented the organisations in question to grapple with it fully. The work is indeed difficult to carry out on an a local scale.

In the framework of AMES it is intended to complement and to co-ordinate all these efforts through this Task Group 1G.

5.2 Aims and project description

Task Group 1G addresses the open questions for the 'Validation of annealing conditions of WWER pressure vessels'. This Task Group includes representatives from 22 institutes in Eastern and Western countries involved in the study of the WWER pressure vessels. Its aim is to obtain all the data required to have an overall view of the state of the WWER pressure vessels before and after one or several annealings.

The Task Group had a meeting in Lille (F) in May 1995 with the objective to find a consensus on the following points:

- the main material issues which have still to be solved to ensure the safety of WWER 440 and 1000 pressure vessels
- the programme to be carried out in order to solve these issues
- a hierarchical organisation of the tasks of the programme according to their importance
- an identification of the tasks already undertaken
- identify the most appropriate laboratories to carry out the tasks

During and after the meeting a project proposal had been elaborated dealing with aspects of WWER 440 and WWER 1000 pressure vessels. One general or two reactor type specific proposals will be forwarded to the European Commission for partial support. The whole proposal was circulated amongst Task Group 1G and the Steering Committee members and it received full support.

5.2.1 Initial Properties of WWER-440/230 Pressure Vessel Steels

The assessment of the reactor pressure vessel integrity (before and after annealing) requires knowledge of the initial toughness properties of the steels used. For WWER-440/230 type reactors, these properties were not measured. They are now determined with materials sampled from the vessels and heat treated to suppress the irradiation-induced damage. However, several recent results seem to show that the applied heat treatment does not reproduce correctly the unirradiated state. New heat treatments are now proposed by experts.

The aim of the project is to determine the correct heat treatment to be used for this application.

The main activities of the project will be to:

- select irradiated steels for which the initial mechanical properties are known. So as to avoid any misleading effects due to accelerated irradiations, at least one of the steels will have undergone a long-term irradiation at a low neutron flux.
- compare the effects of several heat treatments on the selected steels which are supposed to reproduce the non-irradiated state. The choice of the heat treatments will be based on expert recommendations.

5.2.2 Embrittlement Kinetics of WWER-440/230 Pressure Vessels

The kinetics of irradiation-induced embrittlement are not well known for the welded joints and heat affected zones of WWER-440/230 pressure vessels.

This is particularly true for materials with high concentration of embrittling elements (Cu, P, ...).

The aim of the project is to determine the kinetics of embrittlement of 5 welded joints and to 2 heat affected zones with chemical compositions covering those of materials in service in WWER-440/230 type reactors.

The main activities of the project will be to:

- prepare representative welded joints and heat affected zones according to the manufacturing procedures of WWER 440/230 type reactors.
- irradiate the materials in surveillance positions of a WWER 440/213 type reactor to at least 2 fluences.
- carry out mechanical tests on the irradiated materials.

5.2.3 Annealing and Re-embrittlement Kinetics of WWER 440/230 Pressure Vessels

Most of the WWER 440/230 pressure vessels were, or will be, annealed to comply with the safety requirements. After this operation, one of the main problems is to correctly forecast the re-embrittlement kinetic of the annealed steels. Several methods are proposed.

The aim of the project is to determine the correct method to forecast the re-embrittlement kinetic of annealed WWER 440-230 pressure vessel steels. The work will be carried out on 5 welded joints, 2 base metals and 2 heat affected zones with chemical compositions covering those of steels in service.

The main activities of the project will be to:

- prepare representative welded joints, base metals and heat affected zones according to the manufacturing procedures of WWER 440/230 type reactors.
- irradiate the materials in surveillance positions of a WWER 440/213 reactor to at least 2 fluences.
- anneal the irradiated materials.
- re-irradiate the annealed materials to at least two fluences.
- determine the Charpy transition curves and tensile properties at each stage.

5.2.4 Prediction Formulae for WWER 440 Pressure Vessels

The assessment of the integrity of reactor pressure vessels is partially based on the use of embrittlement prediction formulae. For WWER 440 type reactors, many results show that these formulae are not precise enough to predict accurately the embrittlement of the vessels, mainly for the high fluence region. This problem is probably due to the fact that the formulas were mainly developed from results obtained in test reactors (it means with conditions very different of those of the RPV's).

The aim of the project is to determine a new formula from results obtained on materials irradiated in the surveillance positions of a WWER 440/213 type reactor (it means in conditions which are the closest of those of the RPV's).

The main activities of the project will be to:

- collect data obtained after irradiation in surveillance positions of WWER 440/213 type reactors.
- confirm the dosimetry measurements for the selected data.
- confirm the representativity of the irradiation conditions in the WWER 440/213 surveillance positions (tasks 7 and 10 of AMES 1G program).
- establish a forecasting formula by a statistical analysis of the selected data.

5.2.5 Flux Effect of WWER 440 Pressure Vessels

The surveillance specimens of WWER 440/213 type reactors are exposed to a neutron flux which can be 16 times higher than that incident on the pressure vessel. Due to this difference of flux, it is possible that the embrittlement of the vessel is different from what is expected from the surveillance program.

The surveillance positions of WWER 440/213 type reactors are also used to irradiate materials for the assessment of the embrittlement kinetic of WWER 440/230 pressure vessels. Thus, the embrittlement of these vessels could be also higher than expected.

The aim of the project is to determine the influence of the neutron flux on the irradiation-induced embrittlement of WWER 440 pressure vessel steels.

The main activities of the project will be to:

- select materials irradiated with a flux similar to that of the WWER 440 pressure vessels and for which archive material is available.
- irradiate the archive material in a test reactor with a flux similar to that of the surveillance specimens.
- compare the results of both irradiations.

5.2.6 Thermal Embrittlement of WWER 440 Pressure Vessels

Most of the available data concerning the embrittlement of WWER 440 pressure vessel steels have been obtained after short-term irradiations (at most 3 years). Thus, the consequences of long-term dwelltime at the in-service temperature are not known for these steels. Thermal embrittlement is possible, mainly for steels rich in phosphorus. With time, this element could diffuse to the grain boundaries and lead to brittle intergranular rupture.

The aim of the project is to determine the risk of thermal embrittlement on WWER 440 pressure vessel steels. The work will be carried out on 5 welded joints, 2 base metals and to 2 heat affected zones with chemical compositions covering those of steels in service.

The main activities of the project will be to:

- prepare representative welded joints, base metals and heat affected zones according to the manufacturing procedures of WWER 440.
- maintain over long period these materials in furnaces at 350 and 400°C. These temperatures are chosen a little higher than that of the WWER 440 pressure vessels so as to accelerate the phenomena.
- follow the evolution of the Charpy transition curves and tensile properties as a function of the dwelltime at temperature.

5.2.7 Mechanisms of Embrittlement and Recovery of WWER 440 Pressure Vessel Steels

The mechanisms which control the embrittlement and the recovery of WWER 440 pressure vessel steels are not known. Therefore it is not possible to anticipate precisely any irradiation or annealing effects on these steels.

The aim of the project is to microstructurally characterise the steels to obtain a good understanding of the underlying embrittlement mechanisms.

The main activities of the project will be to:

- select steels representative of those in service and available in different states (non-irradiated, irradiated, annealed, re-irradiated, ...).
- perform microstructural characterisations with various techniques (TEM, SANS, AP, ...).

5.2.8 Temperature of the WWER 440 Surveillance Specimens

For WWER 440/213 type reactors, the temperature may be higher on the surveillance specimens than on the pressure vessel. Thus, the embrittlement of the vessel could be higher than what is expected from the surveillance program.

The surveillance positions of WWER 440/213 type reactors are also used to irradiate materials for the assessment of the embrittlement kinetic of WWER 440/230 pressure vessel. Thus, the embrittlement of these vessels could be also higher of what is expected.

The aim of the project is to measure the real irradiation temperature of the specimens in a surveillance position of a WWER 440/213 type reactor.

The main activities of the project will be to:

- place thermocouples in a surveillance capsule of a WWER 440/213 type reactor.
- measure the temperature of the surveillance specimens under irradiation.

5.2.9 Monitoring of the Recovery of WWER 440 Pressure Vessels

The recovery of unclad WWER pressure vessels after annealing is assessed from samples machined from the inner surface of the vessels. This procedure is not fully satisfactory because it requires repair of the vessel surface. For clad vessels the assessment of annealing is not possible.

For both kinds of vessels, it is necessary to develop a non-destructive method to monitor the annealing recovery.

The aim of the project is to identify and develop the best method for this application.

The main activities of the project will be to:

- gather experts working, or having the competencies for working, on this issue.
- select the 3 methods which are the most promising according to expert opinion.
- perform experimental studies to assess the feasibility of the 3 selected methods.
- identify the best method for a programme of development.

5.2.10 Other Tasks of the WWER 440 Pressure Vessel Part of the Project

The tasks still to be detailed further under this Task Group are the 'Irradiation from Material from NVV2' and the 'Study of the cladding behaviour'.

Another large project in the frame of this Task Group is the use of some of the expertise from the Greifswald reactors, which is the subject of a separate paper (Valo et al. 1995).

5.2.11 WWER 1000

A programme directed towards the WWER 1000 type reactors is presently being set up where just the titles of the sub-tasks are given hereunder:

- characterisation of surveillance positions (flux, temperature)
- analysis of surveillance data
- Irradiation of high nickel (ca 1.9%)
- study of materials already irradiated (at temperatures lower than in service)
- expertise of a pressure vessel WWER 1000
- study of annealing behaviour of irradiated steels WWER 1000

6. Conclusion

AMES is a well established European network on the subject of irradiation embrittlement and its mitigation. After an initial phase of producing 'State-of-the-Art' reports, the main objective of carrying out common projects in the above mentioned field was started by detailing three projects. The first of these is the validation of surveillance practice and mitigation methods, which had been further sub-divided into eight Task Groups.

The first phase of detailing the AMES Task Group 1G into two major projects on WWER 440 and WWER 1000 type reactors with several sub-tasks has been completed. The second phase is now progressing.

The final proposal will be used to seek partial funding from the European Commission under its programmes within DGI (TACIS, PHARE), DG XII (Nuclear Fission Safety) and others.

7. References

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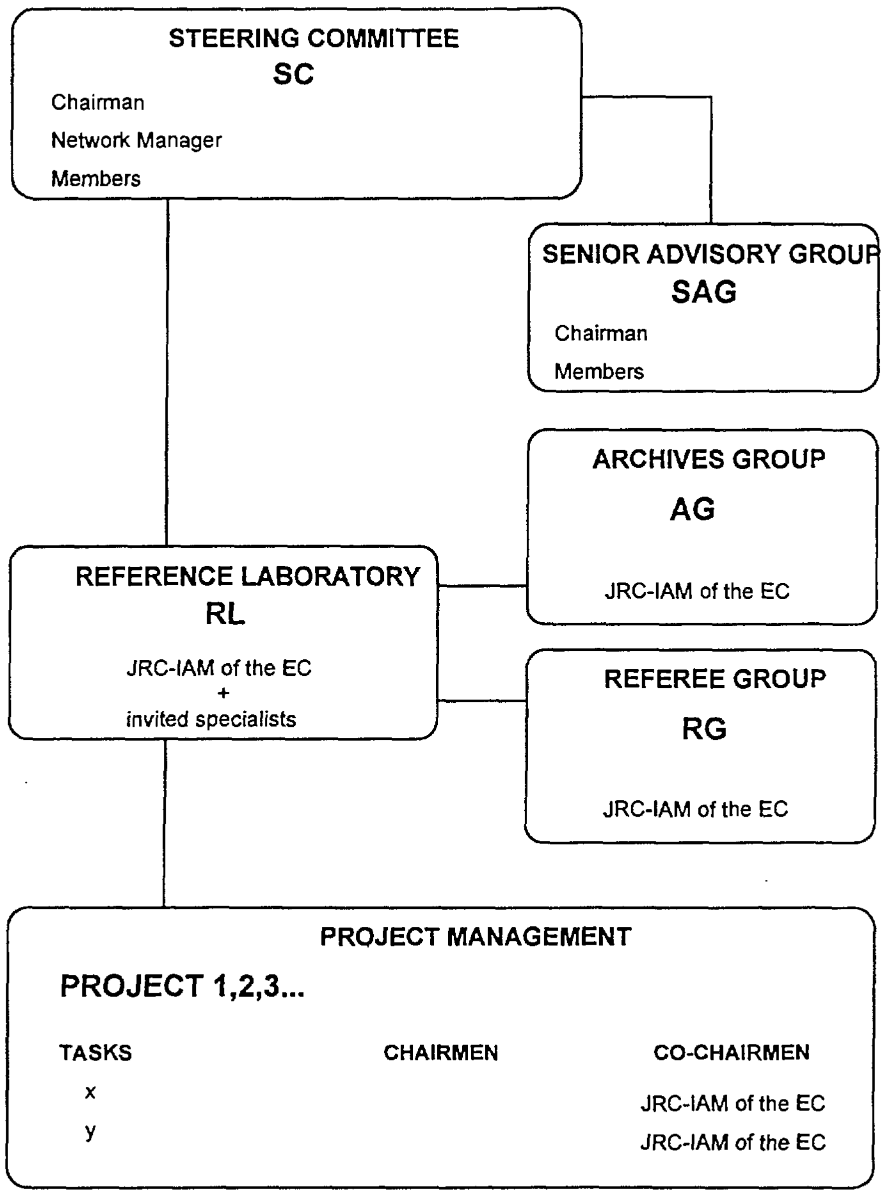

Figure 1: Network Organisation Scheme

Officers		
Chairman	L. M. Davies	Consultant
Scientific Advisor	C. A. English	AEA
Network Manager	S. Crutzen	JRC-IAM
Network Secretary	U. von Estorff	JRC-IAM
Project Co-ordinators		
AMES1: Validation of Surveillance Practice and Mitigation Methods		
	R. Ahlstrand	IVO
AMES2: Effects of Irradiation on Reactor Internals		
	P. Petrequin	CEA
AMES3: Significance of Phosphorus Causing Low Toughness in Steels		
	C. A. English	AEA
	R. Langer	Siemens
Steering Committee		
BELGIUM	Tractebel	
	SCK/CEN	
FINLAND	VTT	
	IVO	
FRANCE	CEA	
	EdF	
GERMANY	MPA	
	Siemens	
ITALY	ANPA	
NETHERLANDS	ECN	
SPAIN	Tecnatom	
	Ciemat	
SWEDEN	SKI	
UNITED KINGDOM	AEA Technology	
	Magnox Electric	
EUROPEAN COMMISSION	DGXI and DGXII/JRC and DGXVII	

Figure 2: AMES officers and Steering Committee

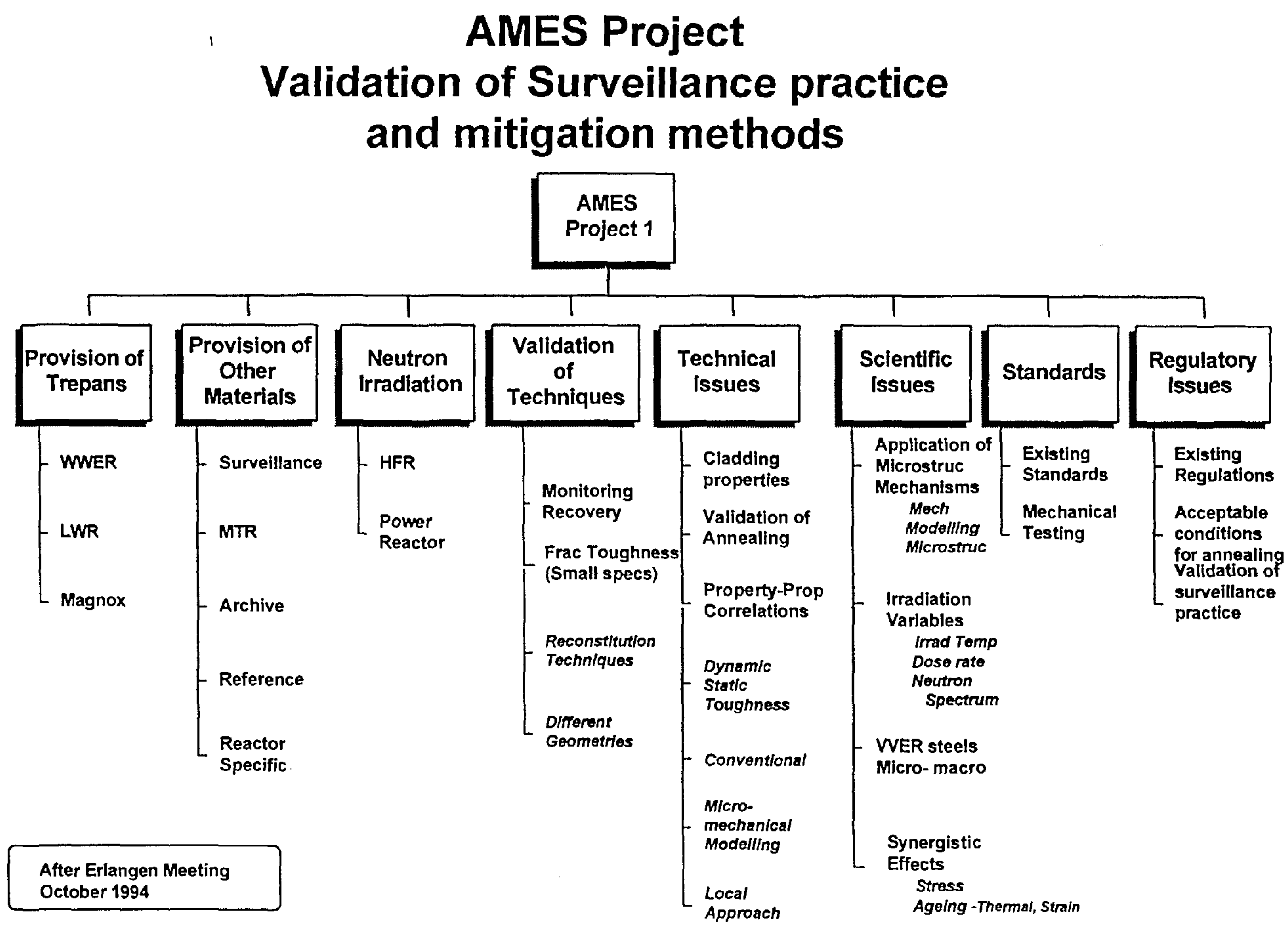

Figure 3: Scheme of the AMES 1 project