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OVERVIEW ON PRE-HARMONIZATION STUDIES CONDUCTED BY THE WORKING GROUP ON CODES AND STANDARDS

Introduction

For more than twenty years, the Working Group on Codes and Standards (WGCS) has been an Advisory Expert Group of the European Commission and three sub-groups AG1, AG2 and AG3, were formed to consider manufacture and inspection, structural mechanics and materials topics respectively. Representation of the WGCS and its sub-groups comes from designers, manufacturers, utilities and laboratories from European countries with active nuclear power programmes. In addition, there has also been a very valuable input from universities and research organisations in the countries concerned.

The WGCS seeks, inter alia, to promote studies at the pre-harmonisation level, for the clarification and building of consensus in the European Community concerning technical issues of relevance for the integrity of safety-related components. While the WGCS and its sub-groups are not directly involved in the production of standards, there is a very important input to the pre-standardization process regarding industrial codes whose rules are applicable to design, construction and operation of NPP components in the European Community.

Despite the different pace and intensity of topics developed by the WGCS along those twenty years in existence, which were adopted in response to evolving needs coming from the nuclear community, the methodology for work has been constant among several programmes and orientations implemented by the Group.

This methodology can be synthesized into three interrelated levels of activities :

- Collection and updating of codes, standards and related national regulations which are relevant to design, construction and operation of NPP components whose integrity is considered by regulators
- Identification of similarities and analysis of problems induced by discrepancies
- Definition of fields for which additional analyses are required to contribute to such gaps by encouraging the appropriate studies and development of work.

Objectives

The present paper intends to give an overview of those studies both completed and ongoing with interest for design rules and code developments. Neither descriptions nor number of selected studies encompassed by the paper, are a full picture of the whole production of the WGCS, therefore, the studies selected for this paper are a representative sample of recent work in the domain of design rules and connected areas.

Furthermore, a second objective which is folded by this paper is to provide the workshop session of Division F with a basic package of topics for further discussions in the corresponding round table session.

The paper includes two parts : on overview of studies conducted by the WGCS in the framework of pre-harmonization of nuclear industrial codes and standards whilst the second part is devoted to the establishment of several topics for future developments of European Codes and Standards.

1. OVERVIEW OF STUDIES PRODUCED BY THE ACTIVITY GROUP AG2-DESIGN RULES AND STRUCTURAL ANALYSIS OF THE WGCS

A sample of recent reports is provided under appendices 1, 2 and 3 of this paper.

The reports have been classified in accordance with studies exhibiting a marked content on comparisons of codes, and studies identified as providing methodologies for analysis supporting design rules.

1.1. Comparisons of codes

Since 1993 the WGCS has been promoting LWR activities with emphasis on preharmonization of main codes applied in the EU countries. In general, studies directed to comparisons of parts of codes have been divided into five groups :

1.1.1. Materials properties for design

The WGCS has been active in compilation of materials data, comparisons of materials specifications and testing procedures. Three recent studies addressed relevant topics about RPV materials of PWRs and FBR materials.

- Reevaluation of the K_{IR} reference curve for FM analysis of RPV materials. Ref ETNU-0057-F FRA/CEA/SIEMENS

The study reviews the references curves as recommended by design codes of nuclear components ASME, RCC-M and KTA. The study encompasses three main tasks :

a) Collection of 665 significant and recent data concerning KIC, NDT, RTNDT and Charpy transition temperature values for base and weldment materials of LWR pressure vessels such as 16MND5 ; SH 508 cl.3; 8A533 gr B cl. 1; 20 Mn-Ni-Mo55.

b) Critical analysis of fracture toughness parameters used for deriving KIC reference curve and indexing methodology.

c) Analysis of data and recommendations for review of fracture toughness reference curve.

In general, the report identifies a lack of validated KIC (for base and weldment materials) data in the transition region of the reference fracture toughness curve, and corrections are recommended for lower temperatures than RTNDT + 15°C. Finally the report established grounds for a future database of RPV materials for the WGCS.

- Two studies address variability of material properties for LWR-RPV analyses and FBR components respectively.

1.1.2 <u>Defect assessment procedures</u>

- Defect tolerance under level D loading

The purpose of the study to examine the sensitivity of representative reactor structures to the presence of defects, in particular, to assess whether the existing Level D criteria of ASME and RCC codes are infringed by realistic defects that may occur in practice. Defect sensitivity calculations are carried out on representative austenitic and ferritic structures, typical of LWR and FR technology, under Level D loading conditions and comparisons made with defect free calculations.

The document comprises two sections.

a) The first section reviews those parts of nuclear power plant design codes dealing with Level D loading and the prevention of unstable crack growth. The design codes considered are ASME III and Appendices, ASME XI, RCC-M and Appendices, and RCC-MR and Appendices.

b) The second section describes the methodology used in Appendix A16 of RCC-MR, and details the application of the methods to a circumferentially cracked ferritic pipe under a Level D loading. The simplified methods of Appendix A16 are compared with finite element calculations, and acceptable defects sizes under Level D loading are defined.

It is concluded, from the analysis of the model test, that allowable loadings, with margins for small defects, are best estimated using collapse load analysis, based on inelastic finite element analysis or experimental values of displacement.

This form of analysis, based on the initial non-linear portion of the load displacement curve, avoids problems associated with instability analysis, which arise from material 'necking' effects and the presence of small defects. It also avoids problems in the interpretation of code methods based on stress limits, which may lead to non-conservative assessments. This conclusion is at variance with code rules, which allow component acceptability under Level D loading to be demonstrated using any one of the methods listed in the codes.

The assessment of axial defects in the austenitic scale model vessel and circumferential defects in ferritic piping have indicted that tolerable defect sizes under level D loadings are up to 20 % of the vessel thickness (for a/c=0.1) and 7.5% of the pipe thickness for axisymmetric defects. However, these assessments show that the combination of material properties and defect geometrics, even for these simple cases, do not allow for the formulation of general rules defining acceptable defect sizes under level D loadings. The effect of defects should therefore be considered on an individual basis, using the R6 procedure or Appendix A16 of RCC-MR.

1.1.3. Benchmark study on the treatment of residual stresses in fracture assessment of pressure vessels

The study focuses on assessments for the necessary of procedures for the treatment of residual stresses in the fracture evaluation of pressure vessels with particular regard to highlighting new developments in the methods employed.

Each participating organisation has submitted a benchmark problem concerning the treatment of residual stresses in the fracture assessment of pressure vessels along with solutions for the benchmarks. The following conclusions can be made,

- For the AEA Technology benchmark problem concerning a part-circumferential through-wall defect in an RPV good agreement was obtained between the simplified methods which considered material toughness and the finite element validation. The simplified methods which did not take account of material toughness, i.e. flow stress and limit load approaches, were non-conservative compared with the finite element validation.

- For the Framatome benchmark problem, concerning a defect at a Bi-metallic-welded joint, good agreement was obtained between the Framatome simplified analysis and the finite element validation results. Results of the recommended simplified analysis by AEA Technology were conservative when compared with the finite element validation but with margins of up to 50 %.

The recommended simplified solution by Siemens was conservative for cases 1 and 2 by 22 % and 29 % respectively but non-conservative for case 3 by - 16 %.

- For the Siemens benchmark problem of an under-clad defect in an RPV reasonable agreement was obtained between the AEA Technology, Framatome, and Siemens simplified analysis results.

  However these results are quite conservative with respect to the finite-element validation results.

Residual stresses are present in almost all engineering components. The reported here shows how important the residual stresses can be and that they cannot be *ignored in engineering analyses. It has been demonstrated that the treatment of* residual stresses can be made using complex analyses (like the Finite-elements method) or through the use of simplified analyses. The different methods used in different countries show a range of simplified methods available. However, the use of one or the other the simplified methods leads to varying degrees of conservatism depending on the complexity of the problem and of the simplified method employed. From the Codes and Standards point of view, it is recommended that the results of this work are used as a starting basis for selecting simplified methods as potential candidates for inclusion in design and in-service assessment procedures.

1.1.4. Comparison of fast fracture analysis methods. Application on test cases

The study is an extension of the EdF REP 2000 programme which examined French and German practices for RPV components. Intentionally the work was restricted to design stages thus place assessment encompassed by ISI of components and related to ASME section XI and RSEM code were not considered by the study.

The present study covers the following aspects :

- concepts of fast fracture damage risk and existing general approaches for its assessment

- French, German and UK practises including : regulators, codes, standards and safety margins, have been addressed, in a great extent, for comparison purposes. In particular, the basic provisions exhibited by ASME Section III appendix G are larger by emphasized and discussed as a baseline for KTA and RCC-M comparisons. In addition the background of regulations, as applied in France, Germany and the UK, are reviewed from postulated reference defect, margins adopted, lowing assumed and areas of the component where requirements are being enforced.

- a benchmark was provided on the beltline of RPVs in order to evaluate applications from the three countries

The report states conclusions and recommendations which could be summarized as follows

a) GENERAL

- Mechanical evaluations compatible
- Differences on hypotheses may have an impact on governing transients
- General consistency of Benchmark results

b) REFERENCE VALIDATION DEFECT SIZES

- 1/4 thickness defects used in all countries for pressure-temperature curves
- Accident conditions :
  - Defect tolerance concept in UK
  - More realistic reference defects in France and Germany

c) MARGINS

- Margins on defect size in Germany and UK
- Margins on loadings or K in France

d) SPECIFICITIES

- "Plume Cooling considered in Germany"
- Warm press-stressing effect

e) RECOMMENDATIONS

- Extension to other countries
- Further
- Exchanges on Safety Margins

Use of experience gained to derive "screening criteria"

1.1.5. Analytical methodologies supporting design rules

Shakedown methodologies have been applied through benchmark exercises on tubeplates, piping for testing numerical techniques, seismic criteria and tubeplates geometrics for FBR components. Criteria on strain-based seismic assessment of pipework resulted the most appropriate when they were compared with stress-based criteria. A survey on simplified inelastic methods covering static and dynamic analyses contributed to emphasize the usefulness of advanced numerical methods whereas their complexity for taking up industrial problems was evaluated.

Two recent surveys on bi-metallic weldments and seismic analyses conducted by NNC gave an account of the current state-of-the-art in those two areas :

- The survey on bi-metallic weldments encompassed the following items :

  a) literature review of current design practice and existing design code procedures used in Europe and elsewhere for the assessment of bi-metallic welds

  b) to review the available experimental and service performance of bi-metallic weldments

  c) to draw conclusions on the potential for a common procedure approach and make recommendations on the suitability of such a procedure for design assessment

  The study outlined the lackness of methodologies in codes for establishment of limits and gives indications on how to focus the future works.

  The second study covers a review and comparison of seismic analysis methods and rules used in the different countries. The scope includes a review of design by analysis methods, methods for qualification by testing, design criteria and input data associated with components and equipment (including piping).

  The treatment of and implication on design criteria (Primary and Secondary stress damage) for aspects such as load levels (SSE, OBE, ...), load combinations, numbers of cycles (treatment of aftershocks) is examined. The purpose of the work is to draw conclusions on the alternative approaches used and identify areas where there is scope for improvement and for further studies within AG2 (benchmarks, comparisons, detailed reviews). The work focuses on LWR but could be extended to cover other reactor types where appropriate.

1.2. <u>FBR HT Codes</u>

In the area of LMFBR design codes, the latest studies have been devoted to comparisons between European and Russian design, assessments of design code margins, and developments of design rules for shell structures subjected to severe thermal loading.

In particular, the ongoing study on Russian design rules will make a detailed comparison of rules for Class I components based on the RCC-MR and equivalent sections of Russian codes for their vessels including the review of manufacturing and material specifications. In addition, the study will encompass rules for damage prevention and set up of benchmarks for assessments on differences and making common statements approaches.

Extensive studies have been implemented in the past for analyses of seismic criteria of FBR reactors, structural analysis of weldments as listed in the appendix 3 of the present paper. Regarding material properties such as 304 316 L and 316 NL materials, the WGCS has collected and updated a large number of data and assessed fatigue and creep behaviours in HT.

In addition to those three typical structural materials, about a dozen of studies have been devoted to the Mod 9 Cr 1 Mo (and 10-12 series) for collection of tensile and FM properties, however , studies in the Ks factor for these softening materials have not yet been assessed, and an ongoing study is being finalized for the Ks factor for codification purposes.

2. RECOMMENDATIONS FOR CODES AND STANDARDS AND FUTURE DEVELOPMENTS

The following areas are being seen as the future direction of design rules :

2.1. LWR Topics Related to the ETC-M Design Code

The WGCS now proposes to place most of its future efforts into the area of PWRs. Although the PWR situation in Europe is much more fragmented than was the case with the EFR (European Fast Reactor), the most active and advanced PWR work is currently being carried out by French and German organisations through NPI (Nuclear Power International) relating to the joint development of the EPR (European Pressurized Water Reactor).

Concurrent with this an advanced design code, ETC-M is being developed for mechanical components. The ETC-M code has five sections namely Nuclear Island Components (with 9 sub-sections), materials, Examination Methods, Welding and finally Fabrication. These sections clearly contain technical areas which are within the expertise of the WGCS. It is therefore proposed to develop close links between the WGCS and ETC-M. In particular ETC-M should be asked to identify those detailed technical areas for which further work is needed of the type normally employed with the WGCS before the ETC-M Working Groups can formulate the most appropriate rules. Some preliminary suggestions have already been made ; two of these namely re-enforcement of opening related to vessel design and fast fracture screening criteria are understood to be of high priority in terms of time scale. In order to develop a balanced and long term programme which would be mutually beneficial it is suggested that planning meetings are set up at an early stage between appropriate WGCS and ETC-M members.

2.2. Comparison of Structural Integrity Aspects of LWR Codes within Europe

In early 1995 a Seminar was held in London on “French, German, UK and US Advanced Water Reactor Structural Integrity related Design Codes and Licensing Requirements”. The reviews were confined to a comparison of structural integrity related design codes and licensing requirements that would currently be applicable to an advanced PWR. A special meeting was later held in London at the request of the RSWG (Reactor Safety Working Group)to assess how an extended examination national requirements could be achieved. ~~It was noted however that some of the aspects involved may be outside the scope of the WGCS.~~

The meeting concluded that the earlier comparative study should be extended to embrace the nuclear structural integrity related design and licensing requirements of other European countries such as Spain, Sweden and Belgium. It is now proposed to follow up this recommendation. In the first phase a survey of National Design Codes and Licensing Requirements should be carried out (already agreed and completed). This should be followed by a second phase to identify equivalencies and differences whilst a third phase would assess the potential for harmonisation. It is proposed now to extend these examinations, in the ongoing 1997 programme to include European Eastern countries and the Russian Federation.

2.3. Exchanges of views on Russian and Western codes (cooperation)

An exploratory meeting was held with MINATOM-RDIPE in November 1994 and this was followed in November 1995 by a first full exchange meeting between the Russian Federation led by RDIPE and representative of the WGCS. Although the meeting concentrated on FBR codes and standards some information was exchanged in the LWR area. In late 1995, Framatome were awarded a contract on "Comparison between European and Russian design codes for fast reactors". Specific materials topics were identified for future cooperation, namely properties of austenitic materials (welds and bolting materials) and identification of failure mechanisms in austenitic steels in FBR's; specific design topics were also agreed on progressive deformation, creep-fatigue methods, elastic follow up and, in general, inelastic analysis.

It is proposed to formulate a more comprehensive longer-term programme with the Russian side.

A second meeting held in March, 1997 identified several areas for future collaboration in the domain of assessment procedures such as LBB and fast fracture concept of RPVs.

2.4. Perspectives for the period 1997-1998

In the short-term, two contracts were awarded, in the beginning of 1997, and directed to RPV cladding and bi-metallic weldments ; both studies should provide actual status of structural analyses methodologies for safety related components, and further data on materials and fabrication specifications for cladding of vessels should be obtained. In the same period considered, a project on a review on basic concepts for fatigue analyses in codes will be finalized ; the project will deal with margins adopted for fatigue and make a review on some difficult components like partial penetration weldments, and S/M curves from current codes will be reviewed. Two significant topics about defect tolerance concept and qualification of inspection for manufacturing processes have been started, as well, in the current year. Moreover, several small projects have been implemented in order to assess the thermal striping damage for secondary LMFBR piping ; these studies were devoted to assess fatigue and FM procedures in addition to thermal-hydraulic codes for comparisons on a benchmark exercise based on a real safety case ; these studies are intended to support on Int'l benchmark on the same exercise conducted in the framework of the IWG-LMFBR of the IAEA.

Three studies whose completion is envisaged in the beginning of 1998 will bring in some light on the traditional problems deeding with the FM local approach for crack growth evaluation, assessments for determination of triaxial effects (Q factor) transferability of small specimens to large structures ; the study will intend to validate methodologies using the spinning cylinder experiment results (NESC project).

Finally, a review on outstanding reports produced by the WGCS will be finalized in the current year.

2.5. 1997 WGCS Programme for the near future

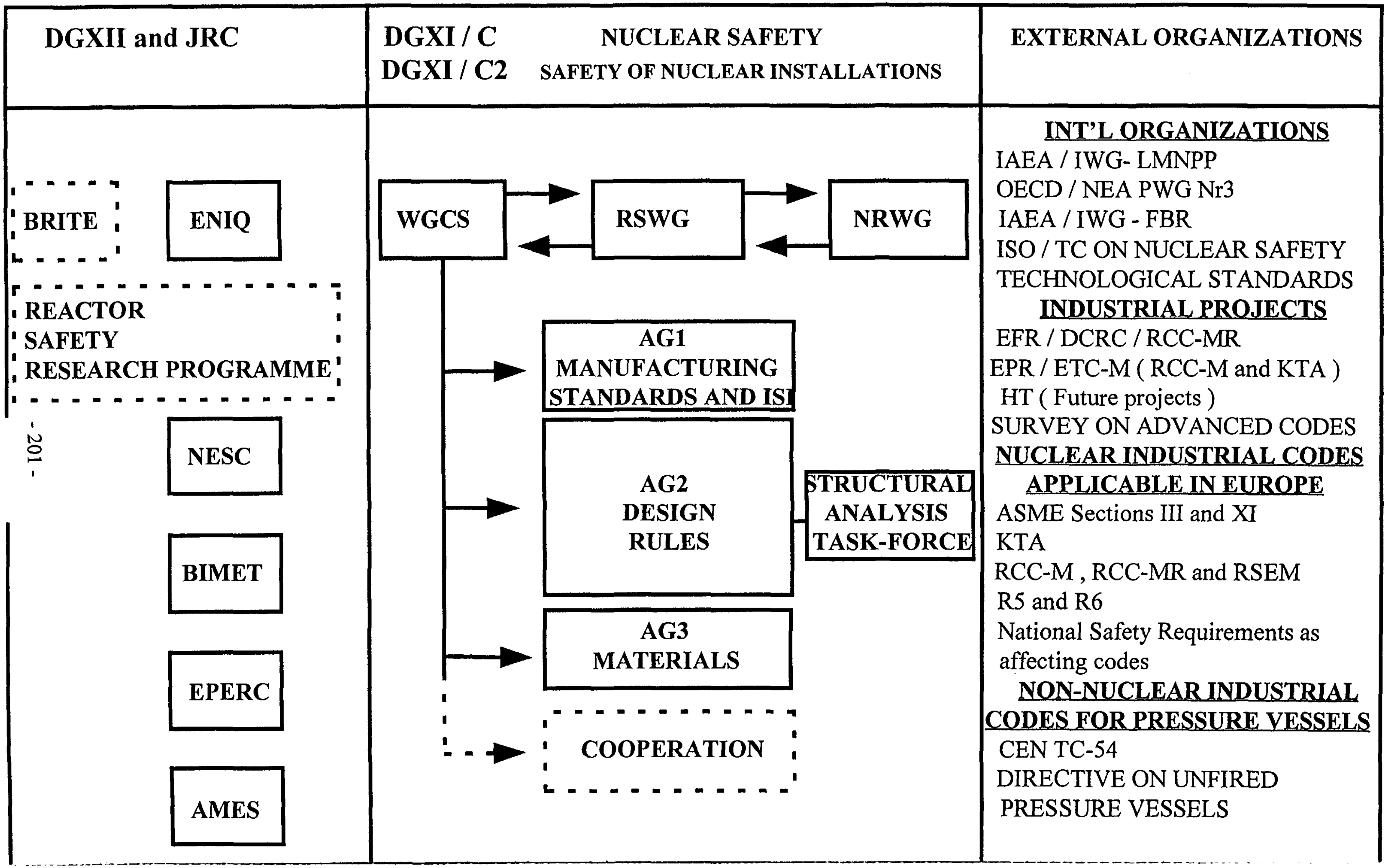
As mentioned above, the ongoing EPR project and specially its ETC-M code entail motivation for extending the harmonization effort, conducted by French and German partners in their developments, towards a set of recommendations for a European code on basic design rules ; in fact a proposed study is being fitted up for these purposes with the following objectives :

- To set up a methodology for work in the WGCS taking into account the harmonization carried out in the framework of the ETC-M
- To revisit the principles of design rules of actual codes with an updated views on :
  - a) stress classification. Design-by-Analysis philosophy. Limits and margins
  - b) provisions for safety margins
  - c) feedback from HT codes and convential codes

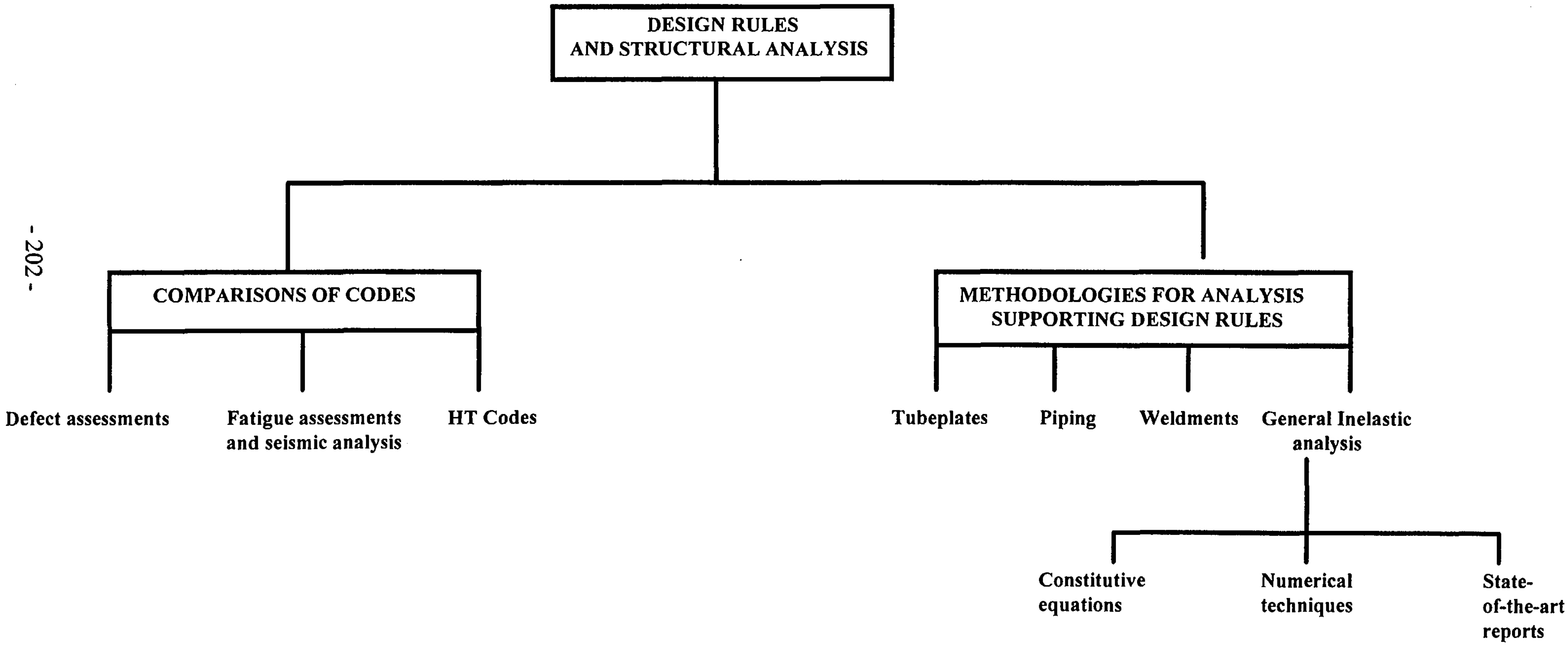
On the other hand, two studies on Fast Fracture assessments and LBB procedures will encompass a complete view on the current European status on those two domains of defect assessment ; on the materials side one project will be directed to attest and dynamise fracture toughness for finalization of a WGCS databank on RPV mate.

APPENDIX I.0

WGCS (Working Group on Codes and Standards)



APPENDIX 1


DESIGN RULES AND STRUCTURAL ANALYSIS
COMPARISONS OF CODES
METHODOLOGIES FOR ANALYSIS SUPPORTING DESIGN RULES
Defect assessments
Fatigue assessments and seismic analysis
HT Codes
Tubeplates
Piping
Weldments
General Inelastic analysis
Constitutive equations
Numerical techniques
State-of-the-art reports

APPENDIX 2

COMPARISONS OF CODES DESIGN RULES (1995-1997)

(SAMPLE OF REPORTS FINALIZED IN THE PERIOD 1995 1997 OR EXPECTED IN 1997)

(LWR) Materials properties for design	(LWR) Defect assessment procedures	(LWR) Fatigue damage assessments and seismic analysis	General surveys	(FBR) HT Codes
Reevalution of KiR reference curves for FM analyses of RPV materials ETNU-0057-F FRA/CEA 1/97	The treatment of residual stressses in FM assessments of Pvs ETNU-0099-UK AEA/FRA/Siemens 4/97	Re-evaluation of fatigue analysis criteria 95-D11-000876 FRA/Siemens/AEA/VTT/Ansaldo/ Tecnatom/Lausitz Univ. (1997)	Survey of European design codes and regulatory requirements relating to the structural integrity of NPPs 96-D11-000134 AEA Technology (1996)	Comparison between European and Russian Design Codes for fast reactors
Compendium of PV steels and weldments properties FRA/VTT, SIEMENS, CEA, EdF, 1997 95-D11-000877	Defect tolerance under level D loading ETNU-0074-UK AEA/CEA 7/95	Review of seismic analysis methods and criteria to be used for seismic events NNC/FRA/Siemens/EdF/Ansaldo/ Tecnatom (1996)	Review of structural analysis studies and defect assessment procedures produced in the WGCS for future harmonization 96-D11-000426 VITAL TECHN 1997	The assessment of design code margins in HT Siemens/NNC RA1-0207-D 5/95
Material variability in elastic assessments FRA/NNC/Siemens/GEC-Alsthom	Comparisons of fast fracture analysis methods. Application on test cases ETNU-0098-F FRA/AEA/Siemens/NE 1997		Improved design-by-analysis procedures for LWR design codesCOSU-064-UK AEA Tech 3-97	Design code rules for shell structures subjected to severe thermal loading Univ. of Leicester FRA RA1-0224-UK 6/96
	LBB assessments of pressurized components ETNU-0134-UK AEA/Siemens/NNC/FRA/BEL 1997			
	State-of-the-art report on transferability of data from small specimens to large structures for defect assessments in LWR 95-D11-001027 FRA/EdF/IWM/MPA/Siemens/ VTT/NE 1997			

APPENDIX 3

ANALYTICAL METHODOLOGIES SUPPORTING DESIGN RULES

TUBEPLATES	PIPING	WELDMENTS	SIMPLIFIED INELASTIC GENERAL ANALYSIS/Surveys
Design methods for tubeplates RA1-210-F FRA/NNC/ENEL 5/95	Simplified criteria for seismic stresses in pipework CEA/FRA/NNC 2/97	Structural analysis of weldments in 316 LN RA1-234-UK AEA/CEA/ENEA 2/97	Surveys on simplified inelastic analysis methods in static and dynamics ETNU-00551 Politecnico di Milano GEC-ALSTHOM 8/96
Application of shakedown methods to tubeplates RA1-208-UK NNC-FRA 10/95	Application of shakedown methods to piping RA1-0234-UK NNC/CEC/Siemens/FRA/Liège Univ. 2/97	Bi-metallic weldments ETNU-0133-UK 1997 NNC/FRA/Siemens/TNO, ENEA	Comparison and testing of numerical tecnhniques for shakedown analysis of NPP components. Application to LWRs and general ETNU-0110-B 12/96 Univ. of Liège/NNC
	Benchmark on strain-based seismic assessment of pipework RA1-0221-D Siemens/NNC/FRA 7/95	Bi-metallic weldments . material properties . methods for assessments for C and S 98	Guidance document for geometrical and loading discretisation in non-linear cyclic problems GEC-Alsthom (FRA-ENEA-CEA) 4/91
		RPV cladding Role of claddding in safety analysis 98	

APPENDIX IV

EUR publications 1997

In the current year, the WGCS expects the publication of the following reports:

AG1: MANUFACTURING AND ISI STANDARDS

RA1-CT93-0218-UK
Review of progress in the harmonization of European In-Service-Inspection codes.

COSU-CT94-0062-UK
The role of theoretical modelling applied to the ultrasonic inspection of nozzle to shell welds in PWR reactor pressure vessels.

RA1-CT90-0175-I
Evaluation of NDE acceptance criteria by fracture mechanics in the pre-service inspection.

AG2: DESIGN RULES

ETNU-CT94-0134-UK
Leak-Before-Break assessment of pressurized components.

COSU-CT94-0064-UK
Improved design by analysis procedures for LWR Design codes.

ETNU-CT93-0098-F
Comparisons of fast fracture analysis methods. Application on a test case.

AG3: MATERIALS

COSU-CT94-0066-B
Comparison of material properties specifications of austenitic steels. (Russian and Western materials specifications).

ETNU-CT92-0057-F
Reevaluation of KI reference curve of reactor pressure vessel materials for fracture mechanics analysis.

RA1-CT91-0198-UK / RA1-CT93-0226-UK
Properties of carbon steels:.
Part I - Collection of data. Tensile and impact properties.
Part II - Crack behaviour.

For information purposes, a catalogue of studies produced by the WGCS is available, and the titles headed by 'EUR' may be obtained from: OFFICE FOR OFFICAL PUBLICATIONS
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