FINLAND

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Structural mechanics and safety of nuclear structures

The general aim of this programme is to develop and improve the methods and computer codes needed in safety related studies of nuclear power plant structures.

Research activities are based on the application of general purpose finite element codes ADINA, ADINAT and PAFEC and some special codes developed at VTT.

The total programme volume for 1985 is 4.4 man-years.

Programme manager is Kari Ikonen from the Nuclear Engineering Laboratory.

The programme is divided into projects, from which the most important are related to fracture mechanics, application of fracture mechanics or analysis of fracture behaviour of real structures and analysis if the leak-before-break concept in pressure boundary components. Attention is also paid on general development of calculational metods and computer codes.

Fracture mechanics

The objective of this project is to develop calculation methods for analysing cracks in real structures. Special features are programmed into ADINA code to calculate parameters, such as J- integral, for fracture mechanics analyses. Existing engineering solutions for different crack geometries are compared with detailed finite element calculations.

Special attention is paid on studying ductile fracture behaviour. For this purpose fracture mechanics tests willb e anlysed using 3D FE-models.

Participation in the European "round robin" programme for calculational elastic-plastic fracture mechanics is continued.

Fatique anlaysis based on crack growth calculation and probalistic methods for assessing structural safety and reliability are studied.

The developed methods are applied in assessing structural integrity of pressure vessels, pipings and other components of Finnish nuclear power plants as well as components of other fields of industry.

Duration:	January 1, 1985 - December 31, 1985
Project manager:	Heli Talja
Project volume for 1985:	2.1 man-years

Heissdampfreactor (HDR) programme

The Heissdampfreactor (HDR) programme of the Federal Republic of Germany offers test data from full-scale tests covering major areas of interest for nuclear power plant safety studies. Test data from some areas of interest will be used for verifying calculational methods according to the Finnish-German agreement. Theoretical calculations will be performed for thermal shock experiment for pressure vessel. Also dynamic pipe loading and pipe failure tests will be analysed.

Duration:	January 1, 1985 - December 31, 1985
Project manager:	Timo Mikkola
Project volume for 1985:	0.7 man-years

General development of calculational methods and computer programmes

In safety analyses of nuclear structures sophisticated calculational methods are needed and often fracture mechanics calculations are involved

in analyses. Versatile general capabilities to accomplish structural analyses are needed.

Capabilities are developed in many areas: nonlinear analyses, vibration problems, thermal stress analyses etc. Graphic interactive pre-and post-processing methods are also developed to ease and fasten the preparation and checking of input data, e.g. element meshes, and to evaluate the results.

Duration: January 1, 1985 - December 31, 1985
Project manager: Pertti Salminen
Project volume for 1985: 0.6 man-years

Analyses of fracture bvehaviour of pressure boundary components

The objective of this project is to develop procedures for anlaysing fracture bahaviour of pressurized components. The existing criteria for leak-before-break condition will be studied. Both best-estimate and conservative calculation methods will be verified using data from small-scale, semi-scale and full-scale tests.

Duration: January 1, 1985 - December 31, 1985
Project manager: Kari Ikonen
Project volume for 1985: 1 man-year

Reliability engineering

The methods and tools for relaibility analysis of complex systems will be studies and developed further in this programme. The main field of applicationc in PSA (Probalistic Safety Assessment) but also methods for more gereral applicaions are studied.

Programme volume in 1985 is 2.2 man-years
Programme manager is Urho Pulkkinen from Eelctrical Engineering Laboratory
The programme is divided into five projects.

Safety and reliability of nuclear components and materials

The general aim of this programme is to improve and increase the safety, reliability and availability to of the most important mechanical components and structures in nuclear power plants.

This three year research programme is divided into seven different projects in the areas of fracture mechanics, radiation damage, thermal shocks, environment sensitive cracking, corrosion, repair welding and materials related failures in nuclear power plants. These projects are carried out within extensive international co-operation.

Duration: January 1, 1984 - December 31, 1986
Programme volume in 1985 is 6 man-years
Programme manager is Kari Törrönen from the Metals Laboratory.

Fracture analysis of pressure boundary components

In the area of statistical fracture analyses the development work of the micromechanism based WST-model is continued. A model will be created for the fracturing of brittle particles in steel matrix. The effect of different crack depths (a/W-ratio) on reference fracture toughness curves will be evaluated. The mechanism of cleavage fracture will be studied by special model materials.

The mechanism of ductile fracture will be studied in co-operation with ENEL/CISE, Italy.

Theoretical correlations will be developed between fracture toughness parameters (K_{IC}, J_{IC}, and T) and simple quality control -type test parameters (Charpy V, tensile). These relationships will be verified experimentally and using statistical information from international co-operation (EPRI data banks, MPA/VTT data exchange) and literature.

An experimental study will be carried out to evaluate the effects of stainless steel overlay welded cladding on reactor pressure vessel fracture toughness. Based on this study the previously developed theoretical analysis will be verified or modified if needed.

Experimental techniques and necessary instrumentation will be developed for carrying out unloading compliance-based J-R curve testing in autoclaves. Testing of various reactor pressure vessel steels will be carried out.

Crack arrest testing will be developed to achieve reliable parameters for evaluation of thermal shock problems. VTT will participate in ASTM round robin testing as well as in a Nordic co-operative project.

Project volume in 1985: 1.3 man-years
Project manager: Klaus Rahka

Irradiation damage and thermal aging of RPV steels

VTT is participating in the IAEA co-ordinated irradiation damage programme. The objective of this programme is to develop internationally acceptable guidelines for conducting surveillance testing. As a part of this programme this project will focus on developing elastic-plastic J-R curve anlaysis using single specimen unloading compliance-based method with Charpy-size specimens. Additionally instrumented impact testing will be developed to obtain dynamic fracture toughness parameters with laser-based crack opening device. Irradiations in Loviisa NPS will begin in 1985.

Based on long-term thermal treatments since 1978 guidelines will be developed for taking into account thermal aging of RPV steels at reactor operating temperatures in fracture analysis.

The micromechanisms of irradiaton damage in reactor pressure vessel steels and damage recovery by thermal annealing will be evaluated in co-operation with the U.S. NRC programmes.

Project volume in 1985: 0.7 man-years
Project manager: Kari Törrönen

Heissdampfreactor (HDR) programme

The objective of trhe Heissdampfreactor programme, which is carried out in FRG, is e.g. to study the effect of different loading transients to cracking and safe use of reactor pressure vessel and pipings as well as to evaluate the reliability of different NDE-methods.

The objective of the work to be carried out at VTT is to evaluate the fracture behaviour of reactor pressure vessel steel under thermal shock conditions. Experimental work at VTT will consist of corrosion fatigue studies and fractographic evaluation of cracks obtained in the HDR-plant. A theoretical study of the stress and strain distribution in the crack tip area under thermal shock conditions will be carried out.

Project volume: 0.5 man-years
Project Manager: Rauno Rintamaa

Environmentally assisted cracking

Environmental acceleration of cyclic crack growth due to reactor water will be studied as a funciton of the chemical composition of the RPV steels, loading parameters and water chemistry. Special objectives are to evaluate

- the crack tip deformation mechanism
- electrochemical conditions
- crack growth in cladded specimens
- crack growth under variable amplitude variable frequency loading.

Stress corrosion cracking of RPV steels, stainless steels and Ni-based alloys will be studied using slow strain rate testing and

bolt-loaded WOL specimens in simulated reactor water. The mechanism of stress corrosion cracking will be studied using electrochemical methods and evaluating the chemical and electrochemical conditions inside artificial crevices.

This project will be carried out in co-operation with the ICCRG group and other international research institutes, as well as within the Nordic co-opertion and the COST-505 programme.

Project volume in 1985: 2.4 man-years
Project manager: Hannu Hänninen

Corrosion

The low temperature sensitization and stress corrosion cracking susceptibility of stainless steel weldments will be studied by performing long-term thermal treatments at elevated temperatures and by extrapolating the results to reactor operating temperature. Intergranular stress corrosion cracking tests, carbide evaluation and slow strain rate tests in autoclave will be carried out.

The galvanic corrosion effect of stainless steel cladding on reactor pressure vessel steels in case of through clad crack or otherwise defective cladding will be evaluated using long term autoclave treatments.

The development of decontamination techniques (e.g. LOMI and CANDECON) and the possible corrosion effects will be followed. Guidelines for decontamination will be prepared.

Electrochemical measuring techniques (e.g. corrosion potential, redox-potential and pH) will be developed for use in autoclaves and nuclear power plants.

Project volume in 1985: 0.8 man-years
Project manager: Hannu Hänninen

Repair Welding

The cold cracking susceptibility of reactor pressure vessel steels in connection of repair welding of the stainless steel cladding will be evaluated. The minimum preheated temperatures required in repair welding of various pressure vessel steels are studied.

The objective of this project is to prepare guidelines for repair welding of RPV steels.

Project volume in 1985: 0.3 man-years
Project manager: Reijo Pelli

Evaluation of materials related failures

The objective of this project is to gather information and prepare summaries of materials related failures in operating nuclear power plants on biannual basis.

Project volume in 1985: 0.2 man-years
Project manager: Reijo Pelli

Corrosion problems of the sea water cooling systems

This project is a continuation of an earlier Nordic project. The objective of the project is to study new highly alloyed stainless steels used in the sea water cooling systems. Especially the effects of cathodic protection on hydrogen embrittlement of ferritic stainless steels is studied.

Project volume at VTT: 0.1 man-years
Project manager at VTT: Hannu Hänninen

Intergranular stress corrosion cracking

Intergranular stess corrosion cracking of austenitic stainless steels in BWR conditions will be studied. Especially the role of sensitization is evaluated as well as the effects of corrosion potential and certain environmental species in the water (e.g. Cr^{6+}).

Project volume at VTT: 1.1 man-years
Project manager: Hannu Hänninen

Crack arrest

The objective of this project is to study and develop testing methods for crack arrest in reactor pressure vessel steels. The static and dynamic analysis will be compared. Materials data for evaluating constructions will be developed.

Project volume at VTT: 0.8 man-years
Project manager at VTT: Klaus Rahka

Elastic-plastic fracture mechanics

The main objective of this project is to study how to avoid catastrophic failure of pressure vessels and piping and to develop guidelines for preventing such failures. The project will contain the following tasks:

- elastic-plastic round robin testing of several pressure vessel steels
- semiscale testing of pressure vessel steels
- pressure testing into failure of several small pressure vessels and parts of piping as well as two nuclear reactor vessel size retired pressure vessels, all containing natural or artificial defects
- code development for leak-before-break calculations
- verification of leak-before-break concept
- evaluation of the use of acoustic emission testing during pressure testing
- preparation of guidelines for the use of leak-break-before concept in design.

Project volume at VTT: 7.6 man-years
Project manager VTT: Kari Törrönen

International PISC programme

VTT will participate in the international PISC II programme. Two interesting areas of plate number 9 from PISC II will be reexamined in Finland by VTT. In these parts there are undercladding defects found only by one group using some special techniques during round-robin examinations.

VTT's team will also inspect and report fourteen austenitic test parts, which are segments from a tube. The inspections will be carried out in Saarbrücken, FRG.

Duration: January 1, 1985 - April 30, 1985
Project volume: 0.1 man-years
Project manager: Pentti Kauppinen