NEA/CSNI/R(91)7

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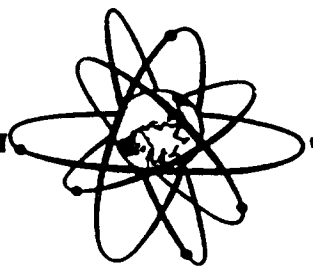
# REGULATORY PRACTICES

# ON

# PRESSURIZED THERMAL SHOCK

## RESULTS OF AN INTERNATIONAL SURVEY

OCTOBER 1991



**COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS**
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-- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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The primary objectives of NEA are to promote co-operation between its Member governments on the safety and regulatory aspects of nuclear development, and on assessing the future role of nuclear energy as a contributor to economic progress.

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The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers. It was set up in 1973 to develop and coordinate the activities of the OECD Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries.

## *C N R A*

The NEA Committee on Nuclear Regulatory Activities (CNRA) constitutes an international forum for the exchange of information and experience among regulatory organisations. Set up in 1989, it is responsible for the programme of the OECD Nuclear Energy Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety.

NEA/CSNI/R(91)7

# REGULATORY PRACTICES ON

# PRESSURIZED THERMAL SHOCK

## RESULTS OF AN INTERNATIONAL SURVEY

COMPILED BY: Mr. H. NJO*

1990

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## 1. Foreword

For many years Pressurized Thermal Shock (PTS) has been recognized as an important issue, that has to be taken into account in the integrity assessment of the Reactor Pressure Vessel (RPV). In several countries research programs concerning PTS have been performed in the past and different activities in this field are still continuing in an effort to resolve this issue.
In 1985 the USA codified the PTS issue in their 10 CFR 50 and subsequently in 1987 issued a Regulatory Guide dealing with PTS-Safety Analysis. This codification was instigated after extensive industry and NRC analyses using specific US experiences and data were performed. It reflects the USNRC position and aproach in dealing with the PTS issue.
For this reason, we in Switzerland are planning to write a status report concerning PTS, which should aid us in our attempt to carry out an in-depth evaluation of the issue for our Swiss PWR and BWR Nuclear Power Plants.
One important aspect that has to be considered is what other countries require and do, regarding the protection of the RPV against PTS-events. Therefore a questionnaire (Annex 1) was circulated to responsible persons in different countries in December 1987 and a first status report concerning this questionnaire was issued as a working document(WD) (88)9 by the CSNI-PWG3.
In September 1989 after receiving responses from 9 countries, a second progress report was issued as WD (89)25 and discussed in the PWG-3 meeting of 27/28 September 1989. As agreed in this meeting, additional response from France and corrections to the previously given response from Finland were received.

This final report includes the comments given during the PWG-3 meetings of September 1989 and April 1990 as well as additional information received since that meeting.

## 2. Introduction

In the United States on July 23, 1985 the so called PTS-Rule, which establishes a screening criterion based on RPV reference nil-ductility-transition temperature ($RT_{NDT}$) was issued as § 50.61 of 10 CFR Part 50 (50 FR 29937).
In January 1987 The USNRC issued Regulatory Guide 1.154 (Format and Content of Plant Specific Pressurized Thermal Shock Safety Analysis Reports for Pressurized Water Reactors).

If it is anticipated, that a PWR-RPV does not meet the screening criterion within their licensing permit, then a Plant-Specific PTS Safety Analysis has to be performed. Regulatory Guide 1.154 gives an outline of an acceptable format for this safety analysis.

It should be noted that in the USA only PWRs are considered. In § 50. 61 of 10 CFR 50 "Pressurized Thermal Shock Event" is defined as "an event or transient in pressurized water reactor causing severe overcooling (thermal shock) concurrent with or followed by significant pressure in the reactor vessel".

Some interesting technical points in the above-mentioned USNRC-Practice :

a) For the screening criterion, a so called "$RT_{PTS}$" is used and defined as the reference temperature that must be calculated by means of the equations given in paragraph (b)(2) of 10 CFR 50 §50.61 .

b) In the equations to be applied, only the fluence and the Cu- and Ni-content of the material are used as variables.

c) The screening criterion is 270 °F (≈ 132 °C) for plates forgings and axial welds, or 300 °F (≈ 149 °C) for circumferential weld materials.

d) The above-mentioned values were selected, based on generic studies of the expected frequency and character of a wide spectrum of transients and accidents, that could cause pressurized overcooling of the reactor vessel (PTS events), and using US operating experience data (about 350 PWR reactor years).

e) The risk due to PTS events was assessed in terms of probabilistic fracture mechanics calculations of the expected frequency of through-wall crack penetration of the RPV-wall due to the PTS events. The screening criterion thus selected corresponds to an accepted "failure" frequency of about $5 \times 10^{-6}$.

f) A combination of deterministic and probabilistic fracture mechanics analyses based on linear fracture mechanics (LEFM) was used in the generic analysis performed.

g) The deterministic FM-analysis is actually an RPV-Integrity analysis, which evaluate the response of the RPV to a PTS-event. Once the stress distribution is determined as a function of time and position, the FM-analysis examines the behaviour of preexisting cracks (postulated or real) in this stress field.

h) The probabilistic fracture mechanics analysis uses the Vessel Integrity Simulation Analysis (VISA) Code, which quantitatively analyzes the effect of a large number of uncertainties to estimate the failure probabilty of a RPV due to PTS. Monte Carlo techniques are used to assess failure probability based on a very large number of deterministic calculations in which the input parameters are varied.

i) The $K_{Ic}$ and $K_{Ia} = f\ (T - RT_{NDT})$ from the ASME-Code were used as the two sigma lower bound Initiation- and Arrest-Fracture Toughness of the RPV-Material. For $K_{Ic}$, sigma was 0,15 $K_{Ic}$-mean and for $K_{Ia}$, sigma was 0,10 $K_{Ia}$-mean.

This US-Practice serves as reference to the questionnaire, which was circulated, because as far as we know, the USA is the only country that has officially codified and published their rules and regulations concerning PTS.

As an example, to illustrate what is actually required from the questions, the answers to the questionnaire for the US-Practice are given in the following :

I. General Questions

I.1 Yes

I.2 a) Yes it is a formal requirement and stated in 10 CFR 50 § 50.61 "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Event".

b) It is a special requirement in addition to the general requirements (general design criteria).

c) PTS-Rule only for PWR's
Use of a new defined reference temperature "$RT_{PTS}$"
Screening criterion using "$RT_{PTS}$"

d) Yes

II. Technical Questions

II.1 c), Probabilistic and Deterministic FM-Analyses

II.2 Yes, this is stipulated in Regulatory Guide 1.154 "Format and Content of Plant-Specific Pressurized Thermal Shock Safety Analysis Reports for Pressurized Water Reactors"

II.3 a)Acceptable, if the PTS-related, through-wall crack penetration mean frequency will remain less than $5 \times 10^{-6}$ per reactor year

b) Yes

3. The Swiss Situation

The licensing activities for nuclear installations in Switzerland are based on the Atomic Law of 1959 and it's amendment of 1978.
In Article 10 of this Atomic Law it is stipulated, that to protect life and health, all measures should be taken, which according to experience and the state of science and technology are considered necessary.
This article 10 is actually the basis for all the requirements within the licensing process.

Codified rules and regulations like the 10 CFR 50 in the USA do not exist in Switzerland. However a limited number of so called "HSK-Richtlinie"(Guidelines) do exist, dealing with specific topics, issued by the Swiss Federal Nuclear Safety Inspectorate (HSK). The guidelines stipulate the HSK-requirements in the subjects and are comparable to the Regulatory Guides of the USNRC. Additional "HSK-Guidelines" are planned in the future. For new issues the approach is usually first to find out the following :

- The state of science and technology for the issue being reviewed
- Status of the worldwide experience on this issue
- Regulatory position in different countries

Then a decision on how to deal with the issue will be based on an evaluation of the above-mentioned steps and additional specific studies focussing on the Swiss-NPP.

As has already been mentioned in the foreword, we are still in our in-depth evaluation process concerning PTS. Notwithstanding this fact, we have already requested the Swiss-NPP-Owners to investigate the possible cosequences of PTS-events on their RPV's. This investigation should be done for both PWR and BWR, although we are aware, that PTS is considerably more relevant to PWR than BWR. Our main consideration is focussed on our "old" PWR-RPV.
We have requested specific deterministic fracture mechanics analyses for several PTS-events and different crack depths. We do not apply the USNRC-screening criterion, mainly because we are of the opinion, that such an important issue like PTS has to be a part of the RPV-Integrity assessments themselves.

We believe, that in most countries similar situations like that in Switzerland exist. However, some differences pertaining to efforts in the codification of the technical requirements for nuclear installations can be observed. For example you have the RSK-Leitlinien and KTA-Rules in the FRG and the RCC-P, RCC-M and RSEM-Codes in France.

## 4. Responses to the questionnaire

We have at present responses from the following ten countries:

1. Belgium ( Mr. H. Dopchie, Vincotte )
2. Federal Republic of Germany ( Mr. H. Schulz, GRS and Prof. K. Kussmaul, MPA )
3. Finland ( Mr. C. Ottosson, Finnish Centre for Radiation and Nuclear Safety )
4. France ( MMe. H. Horowitz, CEA/IPSN/DAS )
5. Italy ( Mr. P. P. Milella, ENEA )
6. Japan ( Dr. S. Miyazono, JAERI )
7. The Netherlands ( Mr. W. C. v. Brummelen, DGA/KFD )
8. Sweden ( Dr. K. Petterson, SKi )
9. Spain ( Mr. A. Esteban Naudin, CSN )
10. United Kingdom ( Dr. B. Hemsworth, NII )

Also the following documents have been received :

1. K. Kussmaul
"Der Integritätsnachweis für strahlenversprödete Reaktordruckbehälter" VGB Kraftwerkstechnik, 62 Jahrgang, Heft 12, Dez. 1982 Seite 1060-1076.
2. Pages 17, 18, 29, 30, 91, 92, 93 and 94 from KTA-Rules 3201.2 Edition 3/84, concerning FM-Method.
3. L. B. Dufour
"Analysis of the March 1981 Transient of the Reactor Pressure Vessel from the Dutch Borselle PWR" Aug. 1983
4. H. Okamura et al.
"PTS-Integrity Study in Japan"
SMIRT-Paper Aug. 1987.
5. Shiori Ishimo et al.
"The Effect of Chemical Composition on Irradiation Embrittlement" Oct. 1988 14th. MPA-Seminar.
6. S. Miyazono
"Research Programs of LWR Pressure Boundary Components in Japan (3. Research Programs on PTS Concern)" Oct. 1988.
7. Doc. DISP(87)10, ENEA/DISP, GUIDA TECNICA.
"Criteri Generali di Progetto per Centrali Elettronucleari di Tipo ad Acqua Leggera in Pressione". Settembre 1987
8. Finnish Centre for Radiation and Nuclear Safety.
YVL Guide 1.0 "Safety Criteria for Design of Nuclear Power Plants" 1. December 1982, Revised 15 August 1984.
(ISBN 951-46-8283-1/ISSN 0781-4321)

In the following a short summary of the responses to the questionnaire are given :

Question I.1 :

Is PTS a transient that has to be considered in the safety assessment of the reactor pressure vessel (RPV) in your country ?

Answers :

| | | |
|---|---|---|
| 1. | Belgium | Yes |
| 2. | FRG | Yes |
| 3. | Finland | Yes |
| 4. | France | Yes |
| 5. | Italy | Yes |
| 6. | Japan | No |
| 7. | NL | Yes |
| 8. | Sweden | No |
| 9. | Spain | Yes |
| 10. | UK | Yes |
| 11. | CH | Yes |

Question I.2 :

If the answer for I.1 is affirmative :

a) Is this an official (formal) regulatory requirement and if so, where is this documented ?
b) Is this requirement part of the general regulatory requirements or is this a special requirement in addition to them ?
c) What are the main points in this requirement concerning PTS ?
d) Is this requirement (e.g. as a document) available to the general public and if so, can you provide us with a copy of it ?

Answers :

1. Belgium
a) Formal in FSAR
b) General requirement
c) 10 CFR Part 50
d) Yes

2. FRG
a) Formal in RSK-Leitlinie 4.1.2 (2) and BMI-Kriterien Abschnitt 4.
b) General Requirement
c) No specific requirement
d) Yes

3. Finland
a) Formal in YVL-Guide 1.0
b) General requirement
c) YVL-Guide 1.0 Part 4.2
d) Yes

4. France
a) Formal, in Act of Febr. 1974
b) General requirements
c) No risk of brittle fracture in operation
d) Yes

5. Italy
a) Formal, in GDC § II,6
b) General requirement
c) GDC and ENEA/DISP Technical Guide
d) Yes

6. Japan
No formal requirement
But research is underway with as the main goal to get public acceptance for RPV-Integrity including PTS and in view of PLEX

7. NL
a) Formal, IAEA NUSS-Code of Practice are applied
b) General requirement
c) Integrity of RPV against brittle and ductile failure
d) Yes

8. Sweden
   No formal requirement, but it is probable that the utility has considered PTS.

9. Spain
   a) Formal, US-Practice
   b) General requirement
   c) 10 CFR Part 50 § 50.61
   d) Yes

10. UK
   a) Formal, in Safety Case
   b) General requirement
   c) Integrity of RPV :
      - Integrated Protection System
      - Stress and failure analyses
      - Low copper welds
      - No welds in core belt line region
      - Thicker cladding (7mm)
   d) No

11. CH
   a) Formal, based on Atomic Law
   b) General requirements
   c) Integrity of the RPV (also for PTS-events)
      Additional measures should be considered
   d) No

Question II.1 :

What is the basic approach in your assessment of PTS ?

a) Deterministic, or
b) Probabilistic, or
c) Acombination of both ?

Answers :

1. Belgium
   c, Combination of both (US Practice)

2. FRG
   a, deterministic
   PTS-Transient derived from frequency of events giving accident conditions with low probability.
   Evaluation of transient and consequences should consider system improvements and additional measures taken.

3. Finland
   c, however the first approach was deterministic.
   Because of many conservative assumptions, the results indicated limited lifetime for the RPV. Therefore the utility has made a probabilistic risk assessment of the Lo1 and Lo2 RPV's. The review of the analysis has been completed but the acceptability of the PSA based method is still under consideration.

4. France
   a, deterministic

5. Italy
   a, deterministic
   (supplemented by probabilistic considerations)

6. Japan
   a, deterministic

7. NL
   b, probabilistic

8. Sweden
   No information obtained

9. Spain
   c, combination of both (US-Practice)

10. UK
    c, combination of both

11. CH
    a, deterministic

Question II.2 :

Can you describe in sufficient detail the approach and the method (stress analyses, FM-analyses and/or others) used in your country to evaluate the consequences of PTS on the RPV ?

Answers :

1. Belgium
   U.S.-Approach (except for Doel 1 + 2 )

2. FRG
   KTA-3201.2 and Paper by Prof. Kussmaul " Der Integritäts -nachweis für Strahlenversprödete RDB "

3. Finland
   FM-Approach
   Two methods were used, the deterministic LEFM and the method developed by USNRC and ORNL (OCA-P Code) with minor modifications, such as influence coefficients for two dimensional axial and circumferential flaws on Lo pressure vessel geometry (thick cladding) and fracture toughness curves (Soviet made steel 15X2M0A)

4. France
   FM-Approach
   The methodology usually adopted is described in RCC-M Code Appendix ZG. The fracture mechanics analysis consists mainly in linear elastic calculations with a plastic zone correction factor. But, when necessary, elastoplastic calculations based on J-integral are done.

5. Italy
   FM-Approach.

6. Japan
   FM-Approach, Research Project PTS-Task.

7. NL
   FM-Approach, LEFM and RT-NDT-Concept.

8. Sweden
   No information obtained.

9. Spain
   U.S.-Approach, ASME III APP. G and ASME XI App. A.

10. UK
    Stress and Failure Avoidance.

11. CH
    FM-Approach
    LEFM and/or EPFM as applicable. Also plastic collapse has to be considered. The utility has to propose the method or methods to be used.

Question II.3 :

a) What are the criteria that have to be fulfilled, when evaluating the results of the safety assessment for PTS ?
b) As a criterion to decide on the necessity for a specific safety assessment for the RPV, do you also have "screening-criteria" such as are used in the USA, and which are based on the projected end of life (EOL) "$RT_{PTS}$" (see 10 CFR Part 50, § 50.61 "Fracture Toughness Requirements for Protection against PTS-events") ?

Answers :

1. Belgium
   a) 10 CFR Part 50
   b) Yes, U.S. Practice

2. FRG
   a) FM, including additional measures. Integrity of RPV with respect to crack-initiation and -growth.
   b) No, only old plants like KWO and KKS considered

3. Finland
   a) Fracture mechanics criteria including crack arrest were used in deterministic analyses.
      The criteria of the USNRC Regulatory Guide 1.154 was applied in the PSA based analyses. It gives the target value of $5 \times 10^{-6}$ for a through-wall crack penetration mean frequency per reactor year (under consideration).
   b) No

4. France
   a) FM-Analyses, absence of risk of fast fracture (RCC-M Code Appendix ZG).
   b) No

5. Italy
   a) Deterministic FM, supplemented by probabilistic considerations
   b) No

6. Japan
   a) FM-Analyses, SBLOCA and SLB, U.S.-Practice
   b) Yes, U.S.-Practice

7. NL
   a) FM-Criteria KI < KIa resp. JI < JIc
   b) No

8. Sweden
   No information obtained.

9. Spain
   a) ASME III, App. G and ASME XI, App. A
   b) Yes, U.S.-Practice

10. UK
   a) RPV not significantly stressed when not in upper shelf region
   b) No

11. CH
   a) FM-Analyses, RPV-Integrity shall be shown.
   b) No

These responses are collated in Table 1.

## 5. Some general observations on the responses from ten countries

1. Although not formally required to be analysed in all responding countries, PTS is a transient, that in one way or another is taken into account by all countries.

2. Different approaches and FM-Analyses methods are used worldwide to assess the consequences of PTS.

3. The only country that has codified the PTS issue in detail is the USA (since July 23 1985).
   This is stipulated in 10 CFR Part 50 § 50.61 and Regulatory Guide 1.154

4. It should also be noted that a very detailed code of regulations, rules and guides for PTS comparable to those of the USA does not exist on an official basis in other countries.

5. Since "Ageing" plays an important role in PTS, it is obvious that the main concern is related to "old" plants

6. It is also noted that for countries with a great number of plants the generic approach is certainly of advantage, whereas for countries with only a few plants a case by case approach seems to be appropriate.

7. If the plants as they are, cannot satisfy the requirements and criteria, it seems clear to me that system changes and other measures, where feasible, will be taken to satisfy the requirements.

8. Although probabilistic analysis is not yet generally accepted, it has been used by most countries to a varying degree, either as the main analysis, as a supplemental analysis or as an aid in PTS-Analysis e.g. in choosing the transient to be analysed.

9. The Screening Criterion as it is being applied in the USA is only accepted by 3 countries : Belgium, Japan and Spain. The reasons why this screening criterion is not accepted by several countries, could be the following :

   a) PTS is considered to be an important transient that has to be included in the specific integrity analyses of the RPV
   b) A Database specific to US-PWR has been used
   c) The use primarily of generic embrittlement data (calculated) instead of specific data from the surveillance program
   d) Only a temperature criterion is employed without also considering the specific "USE" at hand, although this is required in Appendix G of 10 CFR 50
   e) The uncertainty in NDT-Temperature determination (old ASTM E-208 practice, which has been revised in 1984, pertaining to the deposition of the crack starter weld)
   f) The surveillance programs of old plants (before ca. 1968) mostly contain only longitudinal Charpy-V specimens instead of transverse specimens. Transverse specimens are presently required for the $RT_{NDT}$ and the $RT_{NDT}$-shift determination.

## 6. Final remarks

As can be seen, different approaches and methods are being used worldwide to assess the consequences of PTS on LWR-RPV's. It is felt that it would be very useful and appropriate, if the CSNI-PWG3 takes the intiative to discuss and evaluate these approaches and methods as well as the underlying technical bases. A critical review of the approaches, FM-Analyses methods and the database used seems to be necessary.

As has already been discussed in the CSNI-PWG3 meeting of September 1989, this can best be done within the Fracture Assessment Group. I do hope that the CSNI-PWG3 will endorse this proposal.

Annex 1

# Questionnaire concerning Pressurized Thermal Shock (PTS)

## I General Questions

I.1 Is PTS a transient that has to be considered in the safety assessment of the reactor pressure vessel (RPV) in your country ?

I.2 If the answer for I.1 is affirmative :

a) Is this an official (formal) regulatory requirement and if so, where is this documented ?
b) Is this requirement part of the general regulatory requirements or is this a special requirement in addition to them ?
c) What are the main points in this requirement concerning PTS ?
d) Is this requirement (e.g. as a document) available to the general public and if so, can you provide us with a copy of it ?

## II. Technical Questions

II.1 What is the basic approach in your assessment of PTS ?

a) Deterministic, or
b) Probabilistic, or
c) A combination of both ?

II.2 Can you describe in sufficient detail the approach and the method (Stress analyses, FM-analyses and/or others) used in your country to evaluate the consequences of PTS on the RPV ?

II.3 a) What are the criteria that have to be fulfilled, when evaluating the results of the safety assessment for PTS ?
b) As a criterion to decide on the necessity for a specific safety assessment for the RPV, do you also have "screening-criteria" such as are used in the USA, and which are based on the projected end of life (EOL) "$RT_{PTS}$" (see 10 CFR Part 50, § 50.61 "Fracture Toughness Requirements for Protection against PTS-events") ?

| Country | | I.1 | I.2 | II.1 | II.2 | II.3 |
|---|---|---|---|---|---|---|
| 1 | Belgium | Yes | a) Formal, FSAR<br>b) General requirement<br>c) 10 CFR Part. 50<br>d) Yes | c<br>Combination of Probabilistic and Deterministic Approach (US Practice) | US-Approach, except for Doel 1 + 2 | a) 10 CFR Part. 50<br>b) Yes |
| 2 | FRG | Yes | a) Formal, RSK + BMI-Rules<br>b) General requirement<br>c) No specific requirement<br>d) Yes | a<br>Deterministic, supplemented by additional considerations + measures | KTA 3201.2 + Paper by Prof. Kussmaul (FM-Approach + additional considerations) | a) Integrity of PRV for Crack-initiation + Growth (FM)<br>b) No |
| 3 | Finland | Yes | a) Formal, YVL Guide 1.0<br>b) General requirement<br>c) YVL-Guide 1.0, Part. 4.2<br>d) Yes | a<br>Primarily deterministic but also Prob. Approach being performed | Deterministic FM and US-Approach using OCA-P-Code with Modification | a) Reg. Guide 1.154<br>b) No |
| 4 | France | Yes | a) Formal, in Act of Febr. 74<br>b) General requirements<br>c) No risk of brith fracture in Operation<br>d) Yes | a<br>Deterministic | FM-Approach<br>RCC-M Code App. ZG | a) Absence of Risk of fast fracture<br>b) No |
| 5 | Italy | Yes | a) Formal, GDC § II.6<br>b) General requirement<br>c) GDC + ENEA/DISP T.G.<br>d) Yes | a<br>Deterministic, suplemented by probabilistic considerations | FM-Approach | a) FM (deterministic suplemented by Probabilistic)<br>b) No |
| 6 | Japan | No | No formal requirements | a<br>Deterministic | FM-Approach in PTS-Research project | a) Consider SBLOCA + SLB (US Pract)<br>b) Yes |
| 7 | Netherlands | Yes | a) Formal, IAEA-NUSS-COP<br>b) General requirement<br>c) Integrity of RPV<br>d) Yes | b<br>Probabilistic | FM-Approach<br>LEFM + $RT_{NDT}$-Concept | a) FM-Criteria $K_I < K_{Ia}$ resp. $J_I < J_{Ic}$<br>b) No |
| 8 | Sweden | No | No formal requirements | No information | No information | No information |
| 9 | Spain | Yes | a) Formal<br>b) General requirement<br>c) 10 CFR Part. 50 § 50.61<br>d) Yes | c<br>(US Practice) | US-Approach<br>AMSE III App. G + ASME XI App. A | a) ASME II App. G + ASME XI App. A<br>b) Yes |
| 10 | UK | Yes | a) Formal, Safety Case<br>b) General requirement<br>c) Integrity of RPV (+ additional criteria)<br>d) No | c<br>Combination of both | Stress and Failure Avoidance | a) RPV not significantly stressed when not in upper shelf<br>b) No |
| 11 | CH | Yes | a) Formal, based on Atomic Law<br>b) General requirements<br>c) Integrity of RPV<br>d) No | a<br>Deterministic | FM-Approach<br>Plastic Collapse | a) Integrity of RPV<br>b) No |

Table 1