Translated April 18, 1983

In the event of any differences in interpretation of this guide, the Finnish version shall take precendence over this translation.

FUEL DESIGN LIMITS AND GENERAL DESIGN CRITERIA

1 GENERAL

The general requirements for the safety of fuel are presented in Guide YVL 1.0 "Safety Criteria for Design of Nuclear Power Plants". To provide for the prevention of fuel damage and for the maintenance of fuel coolability, fuel design limits with sufficient safety margins shall be determined in accoradance with the above-mentioned guide. The behaviour of control rods shall also be given consideration in these limits, and, where applicable, the limits shall be based on experimental results in regard to the fuel and type of control rods in question.

A fuel damage means a situation in which fission gases are released from the fuel rods into the coolant (fuel leakage) or the deformations determined as a design basis are exceeded. The loss of fuel coolability means such damage in the fuel that the fuel consequently loses its coolable form.

Postadress
P.O. BOX 268
SF-00101 HELSINKI 10
FINLAND
188201754A—22

Telephone
90-61 671
90-544722 (Research Department)

Telex
122691 STL-SF
124956 STLTO-SF

The fuel design limits constitute the design basis of both the fuel and the reactor, including its associated sytems. Some of these limits may be connected with the design of all these items, and some with the design of only one item. Guide YVL 1.0 shows how the limits are taken into account in the design of a nuclear power plant.

As applicable, the fuel design limits are presented in the safety analysis report of the plant unit, in the pre-inspection documents of the fuel, and in topical reports.

This guide includes, besides requirements for the fuel design limits, general design criteria of fuel. In Guide YVL 6.3 "Supervision of Fuel Design and Manufacture", it is described how these design limits and criteria are taken into account in the fuel design and in the analyses performed for the fuel.

2
DESIGN LIMITS CONCERNING PREVENTION OF DAMAGE

In determining limits concerning the prevention of damage, attention shall be paid at least to the following requirements in normal operation and in anticipated operational occurrences:

- Temperature of fuel pellets and cladding
  No melting shall occcur in the fuel pellets, and the cladding temperature shall not substantially exceed the coolant temperature. A sufficient cooling of the cladding is achieved if there is a 95 % probability, at the 95 % confidence level, that the hottest fuel rod does not experience a departure from nucleate boiling or transition boiling condition.

- <u>Cladding collapse</u>
  The fuel cladding shall not collapse into the axial gaps assumed in the fuel during the planned operating life.

- <u>Release of fission gases from fuel pellets</u>
  The internal pressure in the fuel rods caused by release of fission gases and pre-pressurization of the fuel rod shall not exceed the coolant pressure, unless it is separately demonstrated that the internal overpressure of the fuel rod does not cause harmful effects on fuel behaviour.

- <u>Pellet/Cladding interaction</u>
  To avoid damage caused by interactions, applicable operating limitations shall be determined for the fuel in question, taking into consideration the stress corrosion of the cladding.

- <u>Deformations</u>
  Upper limits shall be defined for the deformations of fuel and control rod parts, e.g. for bowing, distortion and growth of fuel rods, bundles and boxes and control rods.

- <u>Stresses, strains and fatigue of materials</u>
  Upper limits shall be defined for the stresses and strains of the various parts of fuel and control rods.

  To avoid fatigue damage of materials, limits shall be defined for cycling loads.

- <u>Corrosion and hydriding</u>
  The oxidation of the various parts of fuel and control rods, the hydriding of the cladding, and the thickness of the corrosion product layer

(crud) on the cladding surface shall remain below set limits. To ensure this, the chemical and physical properties of the coolant shall be provided with limits. Damages caused by the internal hydriding of fuel rods shall be prevented by limiting the internal moisture content of the fuel rods.

- <u>Densification and swelling of fuel pellets</u>
  Upper limits shall be defined for the densification and swelling of fuel pellets.

- <u>Spring inside the fuel rod</u>
  Lower limits shall be defined for the spring force of the spring inside the fuel rod to prevent fuel pellets from moving during the transport and handling of fresh fuel.

- <u>Handling of fuel and control rods</u>
  Limits shall be set for handling measures so that the stresses caused by handling and transport do not affect the behaviour of fuel and control rods during operation.

3 DESIGN LIMITS CONCERNING COOLABILITY

In determining limits concerning coolability, attention shall be paid at least to the following requirements in postulated accident conditions.

- <u>Embrittlement of fuel cladding</u>
  Excessive embrittlement of fuel cladding shall be prevented. To assure this, it shall be demonstrated with calculation methods approved by the IRP that

- the highest temperature of the cladding reached in accident conditions does not exceed 1200°, and

- the oxidation level of the cladding exceeds nowhere 17 % of the cladding thickness (after potential ballooning, but before significant oxidation).

The level of oxidation means the part of the total thickness of the cladding that would be converted to oxide if all the locally absorbed oxygen that has reacted with the cladding were converted to stoichiometric ZrO_2. The external and possible inernal oxidation of the cladding shall be given consideration when calculating the total oxidation.

- Structural deformations
  The fuel flow channels shall not become blocked so that the coolability of fuel is endangered due to ballooning and rupture of the fuel rod cladding and due to deformations in other parts of the fuel and in the reactor internals.

- Melting and movability of control rods
  No melting shall occur in the control rods. Structural deformations in fuel, in control rods and in reactor internals shall not prevent the moving of the control rods in the reactor.

- Interactions between various parts of fuel and coolant
  Interactions between various parts of fuel shall not lead to melting.

The amount of hydrogen generated from the chemical reaction of cladding with coolant shall not exceed 1 % of the amount that would be generated if the whole section of the cladding surrounding the fuel pellets reacted with the coolant.

- <u>Fuel rod fragmentation and melting</u>
  The fragmentation and melting of a fuel rod shall be prevented. The energy increase in postulated accident conditions shall not at any location in any fuel rod cause the exceeding of the radial average enthalpy value 963 J/g UO_2 (230 cal/g). In calculations concerning the release of radioactive substances, the fuel is assumed to be damaged when the radial average enthalpy value is 586 J/g UO_2 (140 cal/g).

4 GENERAL DESIGN CRITERIA

The fuel and the control rods shall be designed in such a way that the requirements presented above in sections 2 and 3 are taken into account.

To prevent damage and maintain coolability, attention shall further be paid to the following requirements in the design of fuel and control rods:

- <u>Hydraulic loads, compatibility with the reactor</u>
  The fuel and its location in the reactor shall be designed so that the fuel boxes and bundles as well as their parts remain stationary in all operational states and in postulated accident conditions, and that they are compatible with the other structures in the reactor.

- <u>Fuel structure</u>
  The fuel structure shall be designed in such a

way that it will not be damaged during operation and that the spacer grids prevent the excessive bowing and wearing of the fuel rods as well as damage caused by vibrations.

- <u>Movability of control rods</u>
  The free movability of control rods in the reactor shall be ensured.

- <u>Mechanical integrity and wearing and reactor physical properties of control rods</u>
  The control rods shall endure wearing and other stresses induced by operation and they shall retain their ability to absorb neutrons during operation.

- <u>Handling</u>
  Stresses caused by handling and transport shall be taken into account in the design of fuel and control rods.

5 LITERATURE

1) Guide YVL 1.0 "Safety Criteria for Design of Nuclear Power Plants"
2) Guide YVL 1.1 "The Institute of Radiation Protection as the Supervising Authority of Nuclear Power Plants"
3) Guide YVL 6.1 "Licensing of Nuclear Fuel and Other Nuclear Material"
4) Guide YVL 6.3 "Supervision of Fuel Design and Manufacture".