IMPLEMENTATION OF FUNCTION RESTORATION GUIDELINES AT THE HFR IN PETTEN

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ABSTRACT

The High Flux Reactor (HFR) in Petten (The Netherlands) is a tank in pool type research reactor, operated at a maximal core power of 50 MW. The reactor is operated by NRG and is among others used for the production of medical isotopes by irradiation facilities.

During the past years new Function Restoration Guidelines (FRGs) were developed and implemented for the HFR. The FRGs address emergency situations even if the operators have lost insight in the ongoing scenario (in opposite to the event based procedures). Early in the course of the accident the operators are monitoring a set of Critical Safety Functions (CSFs) by using a new developed diagnosis instruction for the HFR. The CSFs define a set of functions ensuring the integrity of the physical barriers against the releases of radioactive material: fuel matrix/cladding, primary system boundary and confinement building.
Monitoring of the CSFs is performed through a cyclic application of status trees. For each CSF a status tree with setpoints has been developed. Determination of present instrumentation capabilities was part of this work. The specific Functional Restoration Guidelines are entered when the CSF monitoring identifies a challenge of the functions. For each FRG all available strategies for restoration were implemented.

During the implementation phase operator training was performed. The operator training for the FRGs consists of different phases:

- courses into the HFR specific FRGs and the use of FRGs.
- table-top exercises focussed on training the operators in understanding and application of the FRGs and communication within the Emergency Response Organisation
- full-scale emergency exercises focussed on training the Emergency Response Organisation up to and including the use of the FRGs.

Main purposes of these courses and exercises are to give the operator insight in the structure of the FRGs, give insight in the strategies as proposed in the FRGs and give the operator experience in the usage. At the same time the exercises serve as a review of the FRGs and training of the Emergency Response Organisation (ERO).

For the table-top exercises specific accident scenarios are defined which guide the operator through specific parts of the FRGs. An EXCEL tool was created to represent the information that the operator normally retrieves from the HFR computer.

By implementation of the FRGs the HFR improves the reactor safety, operator knowledge and skills, and the ERO organisation efficiency. In addition the HFR is implementing currently Severe Accident Management Guidelines.

1. Introduction

In 1979 the accident at Three Mile Island Unit 2 (TMI-2) happened. The basic lesson from the TMI accident was that, although the provisions were in place, an accident could happen beyond the design basis, because the control room staff lost insight in the ongoing specific scenario. Before the accident happened only event based Emergency Operating Procedures had been written for design basis accidents.

After the accident at TMI the United States Nuclear Regulatory Commission (USNRC) established a set of requirements addressing the objective to improve the procedures dealing with emergency events in commercial electric generating nuclear power plants. As a result symptom based emergency operating procedures were developed in addition to event based procedures.

At most research reactors in the world event based emergency operating procedures are currently implemented, which are selection from a (limited) predefined list of design basis accidents. However no symptom based procedures are implemented yet. This paper presents the development and implementation of symptom based Function Restoration Guidelines (FRGs) at the High Flux Reactor (HFR) in Petten during the past years.

2. Development of Function Restoration Guidelines

At the HFR a multi-discipline team was formed for the FRG development with participation of experienced operators, procedure writers (by consultants), analysts, I&C experts and trainers. A project plan, including a detailed description of the methodology, the different tasks and work breakdown was prepared.

The FRGs use reactor symptoms/states, by monitoring Critical Safety Functions (CSFs), to diagnose the actual status of the reactor. The CSFs were defined as a set of functions ensuring the integrity of the physical barriers against the releases of radioactive material:

- Fuel matrix/cladding
- Primary coolant system boundary
- Confinement building.

Within the project for development and implementation of the FRGs also a new diagnosis instruction was developed for diagnosis and guide the operator to the specific procedure(s). The development of the diagnosis instruction and of specific FRGs for the HFR is presented in the next paragraphs. The FRGs are valid for the operating conditions: power operation and startup for power operation.

2.1 Development of diagnosis instruction

A new diagnosis instruction was developed. The instruction is entered after each reactor scram or if the reactor is shutdown unintendent.
In the diagnosis instruction the actions which have to be performed immediately are mentioned, the operator is guided (in a prioritized way) to the specific HFR event-based emergency operating procedure(s) and monitoring of the status trees of the Critical Safety Functions is started. If the status of one or more Critical Safety Function(s) is not satisfied the operator is guided to the specific FRG. Furthermore additional checks with respect to safety of the installation are made in de diagnosis instruction.

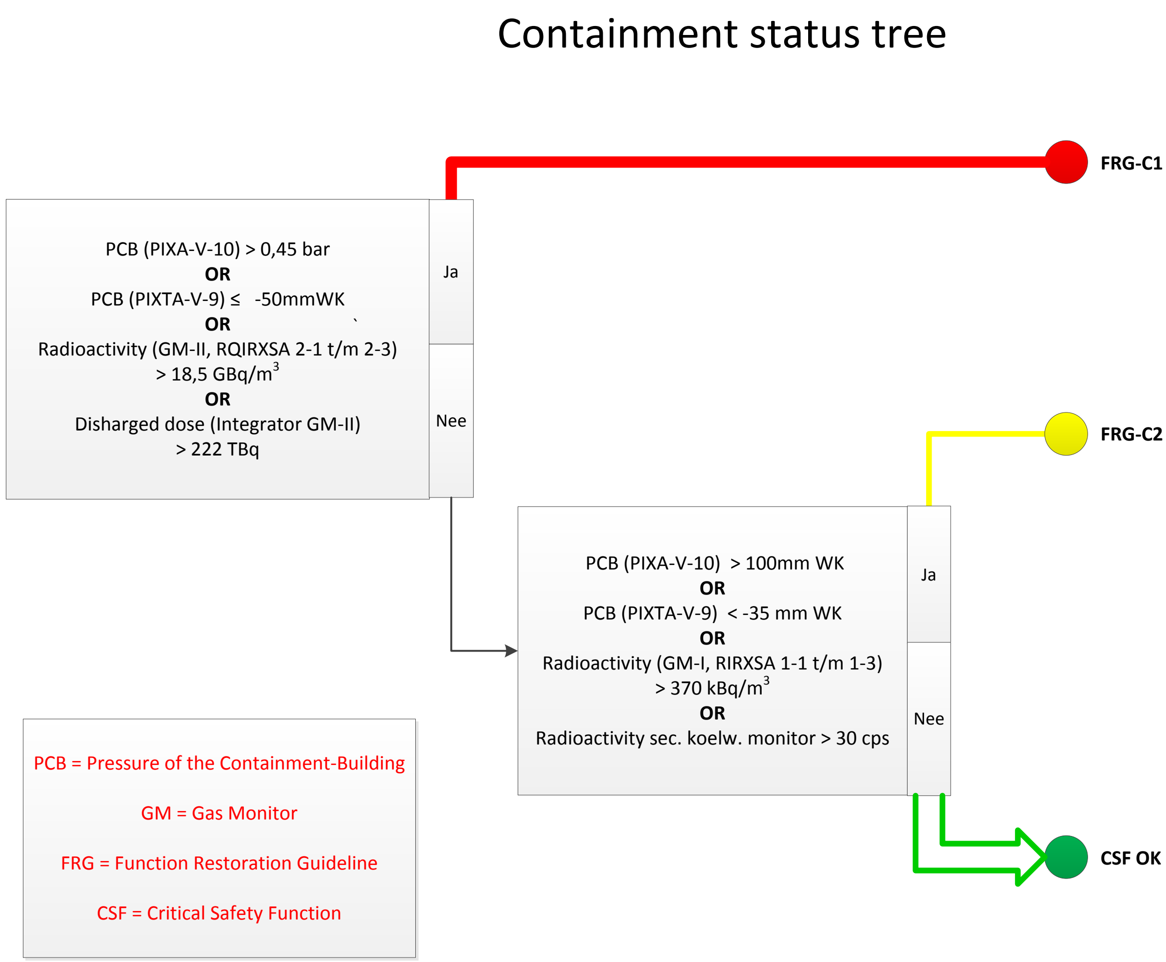
2.2 Development of HFR specific FRGs

As first step the CSFs were defined which ensure the integrity of the physical barriers against the releases of radioactive material. The following CSFs were identified:

- Subcriticality
- Cooling of the primary system
- Containment function
- Inventory of the primary coolant system and the pools
- Heat sink (performed by the secondary side cooling system).

Monitoring of these functions is performed continuously through a cyclic application of Status Trees. For each CSF a HFR specific status tree was developed. An example of a status tree for the containment function is depicted in figure 1. For each status tree the used instrumentation was selected and the setpoints were determined, justified and documented.

Fig 1. Example of a status tree for the containment function



The FRGs are entered when the Critical Safety Function Monitoring identifies a challenge to one or more of the functions. Based on the status of the Critical Safety Functions the operators are directed to use specific FRG(s) to restore a safety function or mitigate the events. Each FGR has a colour (red, yellow or green) which indicates the severity of the challenge:

- A red colour indicates a severe challenge
- A yellow colour indicates a (minor) challenge
- A green colour indicates no challege.

Depending on the severity of the challenge, the transfer to the specific FRG(s) can be immediate for a severe challenge (if the color of the CSF is red), or delayed for a (minor) challenge (if the color of the CSF is yellow).

The FRGs are independent of the scenario of the accident, but are based on plant parameters representing the actual status of the systems and components.

The repetitive diagnosis ensures that the operators respond to changing plant conditions that could be more threatening to the fuel integrity than the initiating event and it helps to correct any initial misdiagnosis.

Once in a FRG the operator takes the appropriate actions and checks the status of the actions to confirm that the appropriate actions are performed for maintaining the safety functions and mitigating the event.

The following FRGs were developed for the HFR:
- Restore Subcriticality: FRG S1 and S2
- Restore cooling of the Primary system: FRG P1 and P2
- Restore the Containment function: FRG C1 and C2
- Restore Inventory of the primary system and the pools: FRG I1 and I2
- Restore Secondary side cooling: FRG SEC1 and SEC2.

A detailed structure of the procedures was established by grouping the actions into logical and technically consistent series of actions for plant operation. For each FRG the possible restoration strategies were determined and prioritized. The performed strategies depend upon both the severity of the challenge and the possible available measures for restoration of the specific safety function(s) in danger. Extreme recovery measures are only implemented with increasing severity of the challenge.

Consistency in how the information is written and structured was established throughout the whole package. Each FRG contains a flow diagram and a list with relevant instrumentation. The whole package was among others reviewed by control room operators and other reactor staff.

3. Function Restoration Guidelines training

3.1 General

FRG training has been provided to the shift and persons within the plant staff who have been designated for a decision making and support role in case of accidents. This training had sufficient depth and provided the shift and staff with the ability to make independent judgements on accident conditions and appropriate response actions.
The operator training for the FRGs consists of three phases:
- Courses into the HFR specific FRGs and the use of FRGs
- Table-top exercises focussed on training the operators in understanding and application of the FRGs and communication within the Emergency Response Organisation (ERO). An overview of the ERO is presented in the next paragraph.
- Full-scale emergency exercises focussed on training the Emergency Response Organisation up to and including the use of the FRGs.

Main purposes of these courses and exercises are to give the operator insight in the structure of the FRGs, give insight in the strategies as proposed in the FRGs and give the operator experience in the usage. At the same time the exercises serve as a review of the FRGs and training of the ERO.

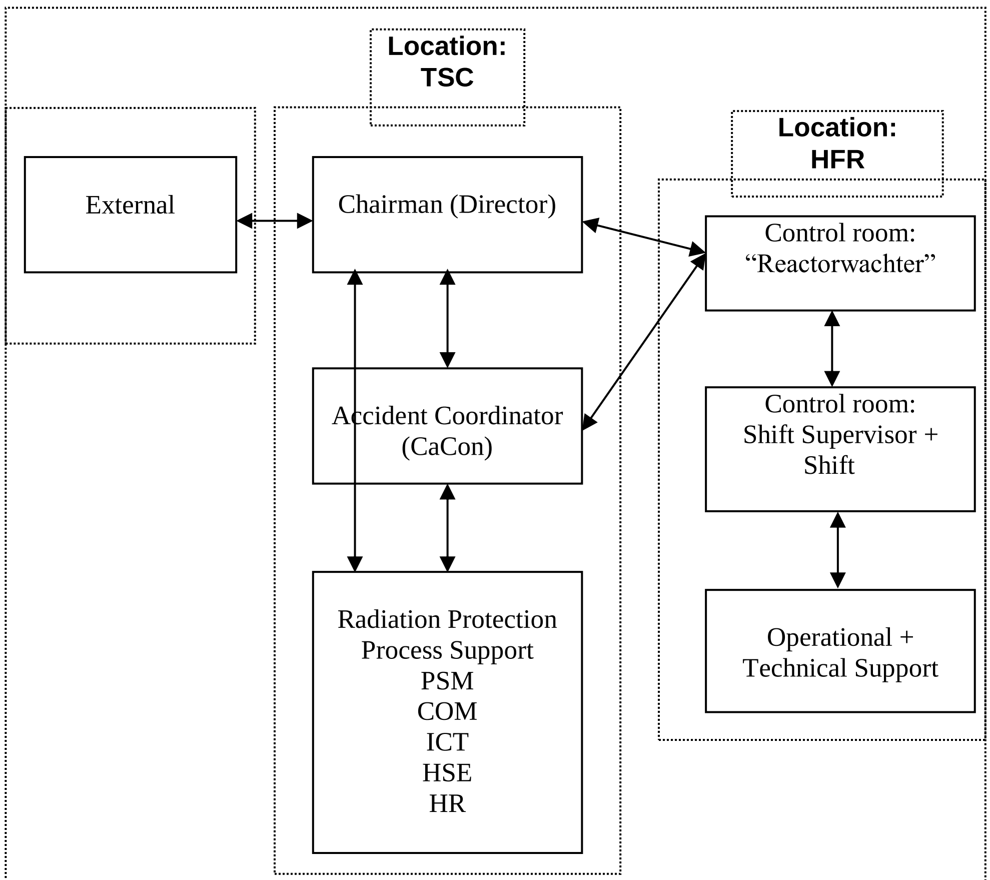
The main information for the operator training is based on the next HFR sources:
- Technical documentation of the HFR, such as system descriptions and process diagrams

- (Design basis) accident analyses and safety evaluations. From this the behaviour of the installation during accidents is determined
- Available event based procedures for accidents
- General operator instructions and operator experience
- Full-scope PSA level 1, 2 and 3.

3.2 Organisation of emergency response

A brief overview of the Emergency Response Organisation (ERO) in case of nuclear accidents (at the level crisis management) is depicted in figure 2.

Fig 2. A brief overview of the ERO during nuclear accidents



Used abbreviations:

- COM Communications
- HR Human Resources
- HSE Health, Safety and Environment
- ICT Information and Communication Technology
- TSC Technical Support Centre (location for members of the ERO)
- PSM Plant Security Manager

The operational aspects of the emergency response are specified in the Emergency Plan. In this plan among others the responsibilities for the ERO members are specified in detail.

3.3 Courses into the HFR specific FRGs and use of FRGs

As first step in the implementation of the FRGs, an initial training program was provided. The program included:

- An introduction and background to the FRGs
- The new diagnosis-instruction
- The Status Trees of the FRGs
- An overview of each of the FRGs
- Review of the FRGs
- The Rules of Usage
- Questions and recommendations for improvement of the FGRs

The applicable recommendations for improvement were incorporated in the FRGs.

3.4 Table-top exercises

For the table-top exercises specific accident scenarios were defined by NRG which guide the operator through specific parts of the FRGs. The exercises are focussed on training the operator in understanding and application of the FRGs, responsibilities and communication within the Emergency Response Organisation.

An EXCEL tool was created to represent the information that the operator normally retrieves from the HFR computer screens in the control room. The information is shown on several parameter screens. The information is based on accident analyses, system descriptions, safety evaluations and operator experience. An example of a parameter screen is shown in table 1.

The schedule of the table-top exercises is:

- Briefing of the operators and decision makers by the scenario leader(s). They are informed about the initial sequence of the accident and from which point the accident is started
- Exercise. The duration is approximately 2.5 hours. The information of the HFR parameters is updated every 15 minutes
- Concerning the remaining information during the exercise (e.g. the response on proposed actions) the operators communicate with the scenario leader(s)
- Debriefing and evaluation. The operators are informed about the scenario and the exercise, the performed actions, and way of communication are discussed and evaluated. Also recommendations for improvement are made and discussed. The applicable recommendations for improvement of the FRGs are taken into account for the next revision of the FRGs.

Table 1. An example of a parameter screen

PARAMETER	DIMENSION	VALUE at t = 2 h
TOTAL POWER	MW	1.95
NEUTRON FLUX	Ampere	1.8 E-6
CONTROL ROD POSITION		
• CR 1	cm	21.1
• CR 2	cm	21.2
• CR 3	cm	21.1
• CR 4	cm	21.1
• CR 5	cm	21.2
• CR 6	cm	21.1
COOLANT TEMP		
• Inlet reactor vessel	°C	47.8
• Outlet reactor vessel	°C	48.9
WATER LEVEL		
• Primary system	m	23.2
• Expansion tank	%	51
CONTAINMENT PRESSURE		
• Overpressure	mm WK	-6
GAS ACTIVITY		
• Gasmonitor 1	Bq/m^3	281 E3
• Gasmonitor 2	Bq/m^3	0.2 E6

3.5 Full-scale emergency exercises

Full-scale exercises focussed on training the Emergency Response Organisation including the FRGs are held as part of the normal Emergency exercises for the ERO. During these exercises (almost) all members of the ERO are participating.

4. Conclusions

At the HFR FRGs have been developed and implemented. Training has been provided to the shift and persons within the HFR staff who have been designated for a decision making and support role in case of accidents. This training had sufficient depth and provided the shift and staff with the ability to make independent judgements on accident conditions and appropriate response actions.

By implementation of the FRGs the HFR improves the reactor safety, operator knowledge and skills, and the ERO organisation efficiency. In addition to the FRGs the HFR is implementing currently Severe Accident Management Guidelines (SAMGs) to cope also with severe accidents.