Fire technical and health physics improvements in fuel production facilities

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Abstract

IFE is producing standard and experimental fuel for its two research reactors a 25 MW HBWR (Halden) and 2 MW HWR (JEEPII, Kjeller). All fuel fabrication and examination, fresh fuel and refabricated experimental fuel, is done in one building at Kjeller. The facility is producing pellets from unirradiated, natural and up to 20wt% enriched UO_2 powders. To meet new demands the building and facilities had a fire technical and health physics upgrading. The presentation gives a background, illustrates the actions taken, and gives info on the tasks/capabilities of the facilities.

Keywords: **Fire and physical protection, fire hazard management, health physics, nuclear fuel production, fuel facilities**

1 Introduction

Due to new legislation, regulations, and recommendations the facilities had to meet enhanced requirements to facility safety over the years, i.e. fire/physical protection etc. IFE is preparing for a new licencing period (2009-2019) for the nuclear facilities in Norway. Licencing issues include risk assessment analyses and fire hazard management. To meet new demands the fuel/hot laboratory building and the facilities had to undergo a health physics, safety and a fire technical and upgrading.
At the same time the specifications for the experimental fuel got more stringent with respect to fuel diversity, quality, instrumentation, material data, etc., and there are new trends in the nuclear industry. De-regulation of the electricity market and increased requirements on the general performance of nuclear reactors have resulted in new operation schemes. Load-follow, longer operation cycles and power up-rates are keywords. A trend to increase fuel discharge burn-up continues. Operational problems have impact on fuel design and vendors are developing new and improved fuels. New reactors are being built and a significant increase over the next years is expected. Research related to development of generation IV type reactors is increasing.
The present and future fuel demands include the production of standard UO_2 fuel pellets acting as reference fuel for development and qualification of new types of fuel. Production of new types of fuel, namely fuel with additives (e.g. burnable poison like Gadolinium) for increased cycle lengths in commercial reactors, or doped fuel (with e.g. chromium-oxide) for grain size control providing improved fission gas retention properties and PCMI /**p**ellet-**c**lad **m**echanical **i**nteraction/ behaviour, or fuel for “innovative fuel-cycles” (e.g. thorium-oxide fuel), or innovative fuels for the qualification of the generation IV concepts (super-critical reactors - Liquid-metal cooled reactors - high-temperature gas-cooled reactors etc.). Concerning MOX /**m**ixed **o**xide/ -fuel an increased interest in the utilisation of MOX fuels is observed especially in Japan. This requires a production of instrumented MOX fuel rods following very strict quality control and within very strict specifications (e.g. on pressurization, free-volume measurements).

2 Fuel production facilities

2.1 UO_2 fuel production facility.

In 2005 the UO_2 pellet production at IFE moved into a new facility to separate clearly facilities for fresh fuel from the hot lab facilities. The UO_2 fuel production facility can produce pellets from fresh, natural and up to 20 wt% enriched UO_2 powders. The yearly production is on average about 200 kg UO_2, however the capacity is larger. The pellet geometry can be of the type: BWR, PWR, HWR, HBWR, booster pellets, etc. The facility performs

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assembly and production of instrumented UO_2 fuel rods for testing in the HBWR, i.e. cladding tests (creep, PCMI, etc.).

The size of the UO_2 fuel laboratory is about 180 m^2. It includes a complete line for UO_2-pellet production. The facility's infrastructure e.g. the systems for ventilation and gas-supply are separated from the rest of the building, where spent fuel activities are ongoing. The UO_2 fuel production facility is divided into a separate fire compartment with no windows, and into several criticality zones with physical separation. There are separate criticality zones, i.e for powder work in vent boxes and pressing, for sintering in reducing (H) atmosphere, and for pellet treatment & quality control. The fuel production facility is equipped with monitors/alarms, for radiation and airborne contamination, detectors for fire/smoke, gas, movement detectors, and technical alarms.

2.2 α-laboratory

The 30 m^2 large α-laboratory is equipped for the fabrication and instrumentation of MOX-containing fuel rods for fuel or cladding tests. The laboratory is not equipped for the production of MOX pellets from powder. The lab has glove-boxes for MOX–pellet modification operations, i.e. drilling for centre bore (TC), cutting of pellets, quality control of MOX pellets, and a glove-box for the fabrication and instrumentation of MOX-fuel rods, i.e. assembling of the rod, instrumentation, pressurisation, TIG welding of end-plugs and seal welding, He-leak testing.

2.3 Hot cells for hot refabrication and instrumentation of high burnup fuel[1].

The hot cells are equipped with a milling machine for hot machining of i.e. miniature specimens, tensile, compact tension and double cantilever beam specimens for mechanical testing and water chemistry[2]) studies.
Hot machining is also used in fuel production in processes such as refabrication and instrumentation of high burnup UO_2 or MOX fuel segments for further testing in HBWR fuel tests, cladding tests (LOCA / **l**oss **o**f **c**oolant **a**ccident), etc. Refabrication and instrumentation of experimental fuel involves quality control of the fuel segment by visual inspection, neutron radiography, measuring of the inner clad diameters, segment test by pressurisation and helium leak test, measuring of the Helium flow through the fuel stack. And further quality controls by neutron radiography after drilling of the centreline thermocouple hole, welding qualification of circumferential & seal welding, free volume measurement after assembly, dimension measurement -diameter profile of rod after refabrication, temperature control during pressurisation and seal welding, helium leak test of the finished rod, function testing of instrumentation before inserting into the reactor.
The hot cells are equipped with a modified lathe for machining, grinding, cutting, a modified lathe for drilling with CO_2 freezing (TC /**T**hermo-**C**ouple/ hole 2.5 mm, depth 65 mm), a working bench for TIG welding (max fuel rod length 1.5m), pressurization and seal welding, vacuum drying 200°C, and He leak inspection chamber. The fitting of an instrumented TF /**T**emperature **F**uel/ endplug for fuel temperature measurement involves the following main operations: machining, welding, drilling of the centreline thermocouple hole, drying, leak test, etc. Instrumented TF and EC /**E**longation **C**lad/ and gas line endplugs provide in HBWR tests insitu measurement data for fuel temperature, clad elongation and gas flow.
New machines – new capabilities are a TIG seal welding chamber designed for a pressure of 120 bar, and a spot welding machine for welding of thermocouples on the outer surface of the cladding. The equipment is used in the fabrication of experimental fuel for simulation of LOCA situations in the HBWR.

3 Fire technical improvements[3] [4]

3.1 Sectioning of the building into fire compartments

The building was sectioned into separate fire compartments. No windows in the outer containment of hot lab and fuel facilities towards the open air. The fire separation walls are in concrete or brick with no, or A60 fire resistant windows and A60 doors in outer shell of fire compartments. A60 means 60 minutes fire resistance. Pipes, cable trays, etc. penetrating the fire separation walls have a 60 minutes fire resistant insulation. The ventilation system has 500°C fire resistant HEPA filters in the cells and in the last filtration stage in the filtration room.

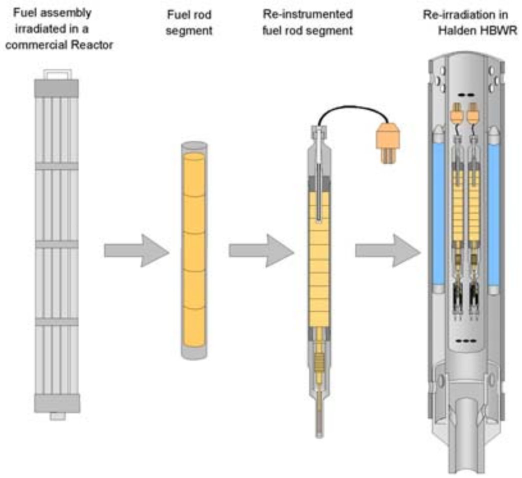

Fig. 1

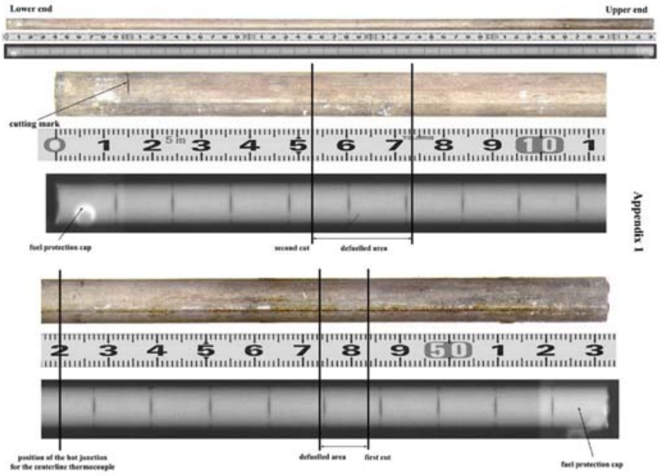

Fig. 2

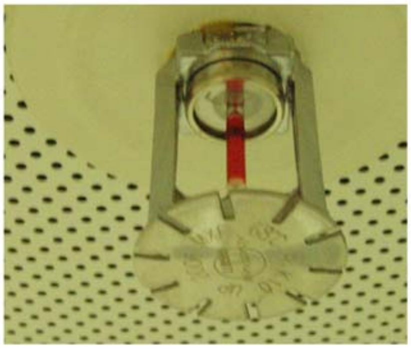

Fig. 3

Fig. 1: Experimental fuel – principle for refabrication & instrumentation and testing.
Fig. 2: Experimental fuel - Quality control of fuel segments prior, during, and after refabrication and instrumentation is crucial.
Fig. 3: Water mist sprinkler nozzle Type A with glass bulb.
Fig. 4a+b: Water mist sprinkler nozzle Type B2 (screw / magnetic valve)
Fig. 5: Water mist sprinkling in lead cell hot laboratory.

Fig. 4a

Fig. 4b

Fig. 5

Fig. 6

Fig. 7

Fig. 8

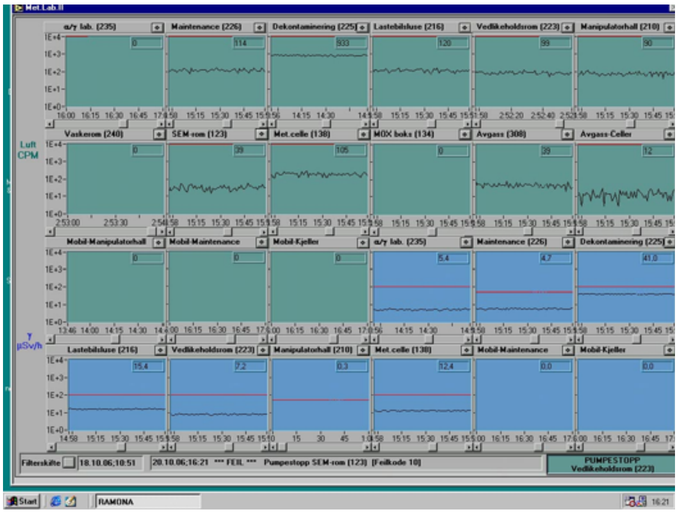

Fig. 9

Fig. 6: Water mist sprinkling in hot cells as a supplement to manual halotron gas fire extinguishing. Sprinkler nozzle type B1 without glass bulb / magnetic valve).
Fig. 7. Sectioning of the building in separate fire separation compartments. Walls of concrete or brick. No or A60 windows in outer shell of fire compartments (60 minutes fire resistant).
Fig. 8. Pipes, cable trays, etc. penetrating the fire separation walls have a 60 minutes fire resistant insulation.
Fig. 9. RaMona, computer assisted system for radiation monitoring and alarms

3.2 Water mist sprinkling for fire extinguishing and suppression

In the nordic countries there is experience from water mist sprinkling[5]. It is used in turbine rooms offshore, ships engine-rooms, historic buildings (Scandinavia), tunnels etc. Water mist sprinkling for fire extinguishing and suppression [6], [7], [8] was selected on the basis that the water mist supply should not run empty and the water damage is considerably reduced compared to conventional sprinkling. Compared to standard sprinkling mist sprinkling requires less water, smaller pipes. Nozzles produce droplet with a size of 50-200 microns water mist, where as high pressure gives fine mist and lower pressure gives coarser mist. Conventional sprinklers produce droplets in the range from 500 to 5000 microns. The principles for fire protection by water mist are based on primary cooling (due to heat extraction). In case of a fire the water mist contributes to make the atmosphere inert (oxygen displacement) and to provide heat blocking. Components in water mist sprinkling are: a tank, pump for water pressure, pipes, nozzles, and valves. In the case of a fire sprinklers in the fire area are released, only. This means a limited water damage.

It was decided on the installation of a low pressure water mist spinkler system installed in the controlled area and in hot lab facilities (hot cells, ventilation ducts etc). The supplier of the system is the Norwegian company Minifog LUX / Minimax GmbH (Germany). The water mist sprinkling covers about 800 m^2 of the 2000 m^2 controlled area. The water supply to the building required due to the sprinkler system is 100 l/min. It is assumed that a max. of 5 sprinklers are released at a time. The systems need a water booster tank of 1000 l. The mist sprinkler nozzle capacity is 20 l water / min, each. And the resulting flux density is 2.2 l /min m^2 (coverage per nozzle: 9 m^2). A 400 V pump increases the water pressure to 10 bars. The system has an electric control cabinet. The stainless steel water pipe system has screw-connections and is using pipe diameters of 20, 25, 32, 40 mm.

The system makes use of two types of sprinkler nozzles. Type A are sprinklers with glass bulbs similar to those of conventional sprinklers. The sprinklers are triggered by temperature. The glass bulb breaks at 68 °C and activates the water mist sprinkling (smaller rooms, <40m^2, height <3m). The sprinkler nozzle is installed vertically. The type A sprinklers must be stopped manually. Type A nozzles are applied in water mist sprinkling in lead cell hot labs, changing rooms, ventilation room, etc. The types B1 and B2 mist sprinkler nozzles are activated by a magnetic controlled water valve. Release of water mist from the sprinkler nozzle is triggered by an electrical signal of a temperature sensor or a smoke detector. The nozzles are installed vertically. Nozzles of the type B1 are basically the same as type A, but without glass bulb. Major locations where such nozzles were installed are in the ceiling of the hot cells, in the ventilation ducts, above motors for ventilation system, etc). The type B1 nozzles are designed for smaller rooms and are activated on the signal of a temperature sensor at 40 °C to give an alarm, at 67 °C to start sprinkling, and at 40 °C the temperature sensor signal stops sprinkling again. Water mist sprinkling of hot cells is planned as a supplement to manual halotron gas fire extinguishing. The sprinkler nozzle (1) is activated by a magnetic valve (2) on an electrical signal from a temperature sensor (40 °C: alarm, 67 °C: water mist release, 40 °C: stop sprinkling). The hot cells have one nozzle for smaller cells (3m x 3m x 4m) and two nozzles for larger cells (6m x 3m x 4m). Nozzles of the type B2 release water vapour from a screw head and are designed for larger rooms. The B2 sprinkler nozzles are installed horizontally. Such nozzles are used in the manipulation hall, maintainance hall, etc. Water vapour is triggered by a signal of a smoke detector and the sprinkling has to be stopped manually.
The vapour sprinkler system is electric supported by 24 V and backed up by a 24 V battery.

4 Health physics improvements

Health physics improvements are the installation of a new system for radiation monitoring, RaMona, and the separation of labs for work on fresh UO_2 fuel from hot lab facilities

4.1RaMona.

RaMona is a computer assisted system for airborne activity and radiation level monitoring and alarms to keep radiation and airborne activity levels as low as possible (ALARA principle). The RaMona system is developed, constructed and installed by IFE radiation protection department and it provides continuous monitoring and recording. RaMona has measuring monitors in the facilities and computer assisted graphical data presentation / documentation monitors in a control room. The system has both stationary measuring monitors in the facilities, such as γ-monitors DM-07and air monitors LM10, and portable monitors for m γ- and airborne activities. All alarms go locally and additionally the air alarms go to the IFE guard/control centre. The radiation protection/health physics department can survey continuously all monitor activities on-line.

5 Economic aspects

To follow up demands from licensing and national legislation, direct costs for upgrading of the building and infrastructure in the period 1996-2006 amounted in average to some 8 % - 10 % p.a. of the total NMAT department turn-over/budget - not included are IFE staff costs.
The upgrading activities in the period covered costs for improvements to the ventilation system, construction activities in the controlled zones, barriers, changing rooms, radiation monitoring including the installation of RaMona, fire technical improvements, fire hazard management, installation of a new α-lab and a new fuel production lab.

6 Summary

The presentation described the background, illustrated the actions taken for fire technical and health physics upgrading, and showed present and future tasks/capabilities of the fuel production and examination facilities.

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