Fire Preparedness Measures in Buildings with Hot Laboratories

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Important hot laboratory safety issues are the general design/construction of the building with respect to fire, fire prevention, fire protection, administrative controls, and risk assessment. Within the network of the European Working Group Hot Laboratories and Remote Handling items concerning "fire preparedness measures in hot laboratories" were screened and studied. Two questionnaires were sent to European hot laboratories; the first in November 2002 on "fire preparedness measures, fire detection and fire suppression/extinguishing in lead shielded cells, concrete shielded cells" and the second in June 2003 on "Fire preparedness measures in buildings with hot laboratories". The questionnaires were filled in by a total of ten hot laboratories in seven European countries. On request of participants the answers were evaluated and anonymised for presentation and discussion at the plenary meeting. The answers showed that many European hot laboratories are implementing improvements to their fire protection programmes to comply with more stringent requirements of the national authorities. The recommendations ("International guidelines for the fire protection of Nuclear Power Plants") given by the insurance pools are followed up with national variations. An ISO standard (ISO 17873) is in progress giving criteria for the design and the operation of ventilation systems as well as fire hazard management in nuclear installations others than reactors.

Introduction

The continued safe and economic exploitation of the existing conventional reactors asks for safe and appropriate hot laboratories for R&D. During the last decade conventional nuclear reactors reached a high degree of maturity and the negative perception created a further negative impetus on nuclear research. Fire in buildings with hot laboratories and hot cells especially such containing open fuel shall not represent a potential environmental hazard through spread of contamination to the environment. All measures have to be taken to prevent a fire to start and spread in a hot laboratory building. Many European hot laboratories were built in the sixties. The aged basic infrastructure of many hot laboratories needs upgrading in order to comply with the more stringent requirements of national regulatory authorities. At the same time the hot laboratories are facing more complex loads in a more stringent environment with reduced funding.

However, during the past 40 years and due to strict precautions fires in hot laboratories and hot cells did not represent any environmental hazard. In four cases a fire started in a hot cell. In all cases work was ongoing and the operators were present when the fire started. None of the fires got out of control. All fires could be controlled / extinguished by the operators. Causes of a fire to start were an electron spark and kerosene during erosion cutting, or fine metallic particles produced by maching, or Na /K fire, or self ignition of alcohol used in metallographic sample cleaning.

Due to the importance of achieving the highest reasonable level of fire protection and preventions the Steering Committee representing nuclear insurance pools from many countries (including from Europe countries as Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom) has developed in consultation with fire protection specialists and other technical experts "International Guidelines for the Fire Protection of Nuclear Powerplants"[1]. Hot laboratories, active workshops and radioactive waste facilities are included in the guidelines. The Fire Protection Guidelines focus on critical aspects of fire prevention and protection, including a fire protection

[1] American Nuclear Insurers, West Hardford, Conneticut, USA on behalf of the Nuclear Pool`s Forum, May 1997, "www.amnucins.com" **http://amnucins.com/FpgSelection/NPFIFPGa.pdf**

program, fire brigade, etc. The guidelines deal with measures to avoid a fire form starting and to delay a fire in spreading. The guidelines give reference to “Fire Protection in Nuclear Power Plants” IAEA Safety Series, No. 50-SG-D2” (Rev.1)[2]. The goal of the insurers guidelines is the improvement of fire protection. It is intended that engineers in the hot laboratory`s will evaluate their fire protection program against the "best practices”.described in the Guidelines on fire protection systems, fire brigade, and fire hazard analysis. The recommended main items are summarised in Table 1. National regulatory authorities are engaged in fire protection of hot laboratories and fire hazard analysis of the European hot laboratories.

Table 1a: Measures to be taken to avoid a fire from starting and to delay spreading[1)]

Fire protection programme

- fire compartments
    - Evaluation of physical construction and layout of buildings and equipment including ventilation system, electrical cables within the fire compartments including the fire resistance rating of the fire compartment boundaries
    - fire-compartments include ventilation system, electrical wiring
    - etc
- design and selection of non-combustible or limited combustible construction materials criteria
    - definition of maximum allowable inventory of all flammable and combustible material in the hot laboratory building and hot cells (fire load)
    - etc
- fire protection and fire suppression/extinguishing system and equipment
- administrative controls to minimize fire hazards
    - An inventory of combustibles
    - Routine inspections of the facility, testing and inspection of fire detection and fire suppression/extinguishing systems
    - Fire drills
    - Special precaution and procedures for operations involving electrical heaters, welding, cutting, grinding, or other potential ignition sources
    - Procedures for the storage and use of hydrogen
    - etc

Fire brigade

Fire hazard analysis

Experimental

Networking on the European level within the European Working Group Hot laboratories and Remote Handling was assumed appropriate in the evaluation of needs for infrastructure improvements. A survey was done on “fire preparedness measures, fire detection and fire suppression/extinguishing in lead shielded cells, concrete shielded cells” (November 2002) and “Fire preparedness measures in buildings with hot laboratories” (June 2003). Two questionnaires were sent to European hot laboratories in Belgium, France, Germany, Spain, Netherlands, Norway, Sweden, Switzerland, and the United Kingdom (UK). UK hot laboratories did not participate in the interview. The questions asked concentrated on “Fire preparedness measures in buildings with hot laboratories” and “.fire preparedness measures, fire detection, and fire suppression/ extinguishing in hot cells (lead shielded cells, concrete shielded cells)” as listed in Table 2.

[2] “Fire Protection in Nuclear Power Plants” IAEA Safety Series, No. 50-SG-D2” (Rev.1)

Table 2: Questions on fire preparedness measures in buildings with hot laboratories and fire suppression/extinguishing in hot cells (lead shielded & concrete cells)

- Year of construction of your hot laboratory / hot laboratory building?
- State the different areas (+ size) in the hot laboratory building (m^2)
    - hot cells, controlled area, office area
- Was your hot laboratory building constructed to contain fire separation walls between different areas?
- If your hot laboratory is divided into cells / compartments with fire separation walls, please state the fire resistance of the separation in terms of EI 60, REIM 120 etc.?

- Have you taken measures to upgrade your hot laboratory building with respect to fire? State the measures taken.

- In case of a fire in the hot laboratory building – hot cells - which measures have you taken to avoid spread of contamination to the environment? Please, explain.

- Which type/principle of fire detection system (Aspiration based system; standard fire/smoke detector system, others) do you have in the cells and where are the detectors located?
- Which fire suppression/extinguishing system do you have - a powder type (kg/cell volume), a gas type (kg gas / cell volume) or others?
- Do you have an automatic sprinkler protection in offices, labs, storage rooms etc. Please, explain.
- Installation year of your system.

- How is the fire suppression/extinguishing system triggered? Manually? Automatically?
- Is your ventilation system on or off when the fire suppression / extinguishing system is triggered?

- What are your fire preparedness measures
- What happens when the fire alarm in a cell is activated?
- How often do you test your fire detection fire suppression/extinguishing system

- Which regulations/recommendations are you applying?
- Are you following the “International Guidelines for the fire protection of nuclear power plants” given in **http://amnucins.com/FpgSelection/NPFIFPGa.pdf**

Results

On the questions concerning “Fire preparedness measures in buildings with hot laboratories” eight laboratories from five countries answered. On the questions concerning “ Fire preparedness measures, fire detection, and fire suppression/ extinguishing in hot cells (lead shielded cells, concrete shielded cells)” ten laboratories from seven countries answered. Normally, one laboratory per country was answering, except in one country answers were received from four laboratories.

Year of construction of your hot laboratory / hot laboratory building? Seven laboratories were constructed originally in the early sixties, whereof one was enlarged with a new facility in the 90s. One site has hot laboratorys constructed in the 80s and 90s.

State the different areas in the hot laboratory building. Give the size of the areas ($m^{2.}$) The elder hot laboratory buildings are housing offices, and a controlled area with hot cells and hot laboratories, some include offices in the controlled area. The newer site houses a controlled area with hot cells and hot laboratories, only, while offices are in another building. The variation in size of the facilities is given in Table 3.

Table 3: Size of the facilities

Concrete cells / lead cells (m^2)	***Hot lab (controlled area) (m^2)***	***Offices (m^2)***
36+10	1,800	800
200	2,450	400
200+40 60	13,000	2,000
7 hot cells	3,000	?
41	1,580	206
80	2,400	400
275+30	2,500	2,000
240	2,340	1,020

Was your hot laboratory building constructed to contain fire separation walls between different areas? Four hot laboratory sites answered with yes and five no, whereof there are 2 facilities in 1 site.

If your hot laboratory is divided into cells / compartments with fire separation walls, please state the fire resistance of the separation in terms of EI 60, REIM 120 or something else? Hot laboratories in two countries, namely France and Switzerland, answered to this question as specified in Table 4:

Table 4: Specifications on fire separation walls, doors, windows

Fire and containment sectors (containment wall) – walls of fire sectors associated to hot cells	***Fire sector (Fire wall)***	***Protected compartment (reinforced wall) min***	
120 min	120 min	30 min (some doors) 60 min (rooms)	France
60 min: all lab doors + Triple window systems			Switzerland

Have you taken measures to upgrade your hot laboratory building with respect to fire? State the measures taken. New national fire regulations force the upgrading of hot laboratory buildings. Most of the elder hot laboratories are in the process to upgrade or have already upgraded the buildings. In some countries upgrading and improvement of hot laboratory buildings is initiated and closely followed up and speeded up by continuous inspections of national nuclear authorities. Some improvements to European hot laboratory buildings are listed in Table 5.

Table 5: Measures taken to upgrade hot laboratories with respect to fire - summary of improvements to European hot laboratory buildings

Boundaries of inner and outer fire compartment Walls-Windows-Doors + Ventilation	***Fire detection / fire extinguishing system***	***Completed – work plan***
• Fire wall between controlled area and office area • Renovation of ventilation system	• Increase of safety (detection, prevention, etc)	Renovation completed in 2005.
	• Changing HALON into “FM200” automatic fire extinguishing	
	• Changed HALON into “Halotron” manual fire extinguishing systems • Fire detectors in all rooms not inside cells	Completed 2000 Completed 1996
• New installations with wire cables C1 • Replacement of the wires by C1 wires (except in hot cells). • Setting up of fire walls on wire tracks	• Addressable fire detector	
• Line of lead shielded cells is fire sector • Fire-blocking valves added to ventilation lines • Fire-resistant doors added in many places • A new lab inside the controlled area in progress. It will be a new fire sector	• Fire detector in the whole facility	
• Ventilation system was completely renewed • Fire resistant doors and fully separation • Each lab is completely separated from the others or corridors in ventilation system. • Fire safety valves to fully isolate the lab from the ventilation system. • Hot cell box / hood ventilation fully separated from the lab ventilation.		Work completed 2000-2002
	• Installation of a fire surveillance system in the hot cell area (fuel cells, chemistry cells), and offices	completed

In case of a fire in the hot laboratory building – hot cells - which measures have you taken to avoid spread of contamination to the environment? Table 6 shows that in most hot laboratories the main measures taken to avoid spread of contamination involves the ventilation system.

Table 6: Measures taken to avoid spread of contamination

Direct measures	***Procedure***
To avoid spread of contamination to the environment, Nuclear Safety Recommendations (RFS 1.4.a) which means: • Prevention: fire analysis, limitation of calorific density (calorific charge density (in French: DCC) en MJ/m²) • Detection and survey • Fire extinguishing system • Limitation of effects: compartments, rules for ventilation monitoring in case of fire, safety recommendation in case of fire (procedure, operating instruction, reflex sheet, etc)	Procedures exist, but are only available in French.
• Ventilation system:	• Protection of the last barrier filters (very high efficiency filter) • Controlling upstream temperature and filters filling up • Turning off exhaust fans if necessary.
Fire extinguishers (bottles) in the building and cells (old: HALON, new: CO_2 flooding)	
• Ventilation system	• Air injection will be stopped • Fire-blocking valves will be closed if temperature of ventilation tube is higher than 70°C.
• Ventilation system	• Isolation of the lab from the main ventilation system with isolation valves for each lab
Manual fire extinguishers in the building and cells (halotron flooding). Low fire load in the cells	• Shut down of ventilation
Separated filtration/ventilation system for chemical and fuel cells, the mechanical testing cells and the offices.	
All cells are operated in N_2 or CO_2 atmosphere	

Which fire suppression/extinguishing system do you have in your cells ? In cells operated in air the most common fire-fighting medium is gas (CO_2, N_2, HALON substitutes, Ar) in addition to mechanical fire fighting (metal covers etc). Table 7 summarised fire fighting systems in Hot cells.

Table 7: Fire suppression/extinguishing system in cells

Powder type (kg/cell volume)	***Gas type (kg gas / cell volume)***	***Others?***
	Inergen gas in all concrete cells 150 l in two cells (6+7) 50 l in 5 cells (1-5). CO_2 bottles can manually be mounted to prepared plugs in to the cells. Manual back-up.	Ventilation system off (automatic)
	In accordance with the type of fire (metal, chemical) present in the cell.	Ar for local fire extinguishing
	Halotron	Ventilation system off (manual)
Powder in the cells (about 1 - 2 Kg / m3) in container used manually, only (manipulator)	Some of our cells (specimen preparation / metallography) can be flooded with N_2 manually -it takes some time to fill up the cell. These cells can be operated under N_2 atmosphere if needed (but very expensive!).	The ventilation system can be shut down manually or automatically if smoke is detected in the ventilator area. Mechanical fire fighting: some special steel plate in hot cells to cover container that could burn (e.g. alcohol).
ABC type 6 kg/(powder) cell 55	B type 5 kg (gas)	
	Bi-ex Type 6 kg bottles can be recharged as needed. CO_2 injection (inert atmosphere in the cell) 2 bottles of 50 kg	
	CO_2 3 tanks, 50 kg each for all the cells. First tank is activated, then the second one if necessary, then the third one if necessary. Each cell could withstand the overpressure caused by the percussion of the 3 tanks.	Manuel activation and automatic percussion of the gas tank. One out of two ventilation engines is automatically turned off. Fresh air shutters are automatically closed. Utilisation of Marcalina powder if risk of metal fires (Sodium fire)
MG20 Powder – triggered manually (« 6 kg can be replaced as needed)	HCFC 141B(gas) for small hot cells (glove box) triggered manually or automatically (two detectors in alarm).	Triggering of HCFC 141B(gas) gas did not give an action to the ventilation system. After renovation goes the ventilation system off, automatically.
	Manual extinguishing by HALON gas injection, from bottles put at fixed places in the front area. A study in progress will be probably lead to use FM200 gas instead of HALON	
	áâã-cells PIE: N_2-atmosphere; âã-Zelle: CO_2-fire fighting Chem cell: N_2 –fire fighting, Lead cells – N_2 fire fighting	Decontamination cells - water sprinkling

Do you have an automatic sprinkler protection in offices, labs, storage rooms etc.? In old laboratories sprinkler systems seem not to be used. (Eight laboratories answered no). Reports were given on a sprinkler system installed in the controlled area of an old lead cell laboratory, an automatic 60 points extinction systems/sprinkler systems installed in a new hot laboratory building, and a sprinkler system in an office space area in a container system outside a main hot laboratory building.
One Hot Laboratory building has installed an automatic operated HALON-fire extinguisher system installed in a laboratory and an automatic N_2 fire extinguisher system for the electrical distribution system. Another hot laboratory building is equipped with an inert gas extinguishing system in the area of the chemical and fuel hot cells.

Which type/principle of fire detection system (Aspiration based system; standard fire/smoke **detector system, others) do you have in the cells and where are the detectors located?**
The offices and the controlled areas are often equipped with standard fire/smoke detectors in each room at some 3 m height. In some hot laboratory buildings one finds in addition temperature sensors and dynamic aspiration systems. Lead and concrete shielded cells are in many laboratories equipped with temperature sensors, or respiration systems, or fire+smoke detectors. The ventilation systems are controlled with smoke detectors, aspiration systems, or thermovelocimeter radiation resistant detectors above the extraction ducts. A more detailed summary on fire detection systems used in hot laboratory buildings is given in Table 8.

Table 8: Fire detection systems in hot laboratory buildings

Controlled area, offices	***Lead or concrete hot cells***	***Ventilation system***
Standard fire detection system (heat detectors)	Temperature sensors - increase of temperature in each room	Smoke detector in ventilation pipes after the first filter from the cells
Standard fire/smoke detectors (optical/ionic system) in each room	Directly inside hot cells: fire/smoke detectors (optical: flames/light + ionic: smoke. The smoke detector is damaged by high radiations).	Aspiration system with two large ventilators (electrical motors) located in main filter room. Central smoke detectors in the ventilators area.
Temperature sensors – increase of temperature in each room	Two types in each hot cell are existing (except when to high radiation): Flame/smoke detector + aspiration system in front of the cells (in yellow zone / before renovation – in orange zone behind the cells / after renovation)	Thermovelocimeter radiation-resistant detector, above extraction ducts
ionic detectors (smoke) in the working (or front) area, and in the transfer (or rear) area at a 3 meters elevation in front and behind the line of shielded cells	Thermovelocimetrical detectors in each cell	Thermal detectors & smoke detectors fumes in ventilation ducts at the level of high efficiency filters
Smoke sensors + temperature sensors + thermodifferential sensors	Dynamic aspiration	.
Dynamic aspiration	Thermovelocimeter radiation resistant detectors	

Installation year of your system. The majority of the hot laboratories has upgraded their fire detection systems in the last years.

What happens when the fire alarm in a cell is activated? Table 9 summaries procedures when an fire alarm is activated.

Table 9. The fire alarm in a cell is activated

Inergen gas system is released. In all concrete cells (1-7)
Security room alarm (switch on) and also on the fireman office of facility site
If smoke is detected in the ventilator area, all safety valves for all cells are automatically closed, and an alarm will blow in the lab and is sent to the facility site fire team. All labs have there own in- and out-air pipe with valves that are closed in case of alarm in order to isolate the laboratory. The hot cells themselves have also in- and out-air pipe (only one per lab) that can be closed by safety valves
Noise and visual alarm in the room. Report of alarm in the control room of the hot laboratory. => people should leave concerned areas. Report of alarm in the security control room of the centre => one team should intervene
If the fire detection in a cell IS CONFIRMED (simultaneous activation) by a temperature detection (T>180°C) in the aspiration sheath before the last barrier filter (very high efficiency filter), the aspiration stops. Otherwise, the fire extinguishing system is activated and one out of two ventilation engines is automatically turned off
Accustic alarm in the room and hot laboratory building + visual alarm on control bord on the laboratory building => one team should intervene. Report of alarm to the security control room of the site + alarm to the fire brigade => people should leave concerned areas.
Alarm network linked to a central control room with one permanent operator: 2 alarms from the front area and 1 from the rear area
Local alarm (noise + visual) and also reported inside the fire brigade control room.

How often do you test your fire detection fire suppression/extinguishing system? Many hot laboratories do test their fire detection system every 6 months and the fire suppression / extinguishing system on yearly basis (control of bottles). In some laboratories a complete test of CO_2 injection system is done when the cells are refurbished.

What are your fire preparedness measures? Which regulations/recommendations are you applying?
Most hot laboratories have an on-site industrial fire brigade. Special-trained firemen will be in the laboratory within few minutes.

Regulations are often given by national regulation authorities and the fire brigade. The regulations and basic rules are defined locally in “fire procedure for hot laboratories”. The fire procedure includes the list of the responsibilities in case of accident. Many hot laboratories have these procedures/rules checked and approved by the national regulation authorities.

Some hot laboratories have a thermal load density limitation per each cell (e.g. to 600 MJ/m^2). In France the French fundamental safety rule RFS 1.4.a (Insurance French regulations Nuclear Safety French recommendations) applies.

Conclusion
The paper summarises answers from European hot laboratories on questions concerning local fire protection programmes. To comply with more stringent requirements of national authorities many European hot laboratories are in the process of doing or having completed improvements to their fire protection programmes. The fire protection programmes are subject to national laws. The recommendations given in the “International guidelines for the fire protection of Nuclear Power Plants” of the insurance pools are followed up with national variations. An international standard “ISO 17873”

is about to be published.[3] The main objectives in ISO 17873 are ventilation and fire hazard management.

References

1) “International Guidelines for the Fire Protection of Nuclear Power Plants”, ed. American Nuclear Insurers, West Hardford, Conneticut, USA on behalf of the Nuclear Pool`s Forum, May 1997, “www.amnucins.com” http://amnucins.com/FpgSelection/NPFIFPGa.pdf

2) “Fire Protection in Nuclear Power Plants”, IAEA Safety Series, No. 50-SG-D2” (Rev.1)

3) ISO 17873 “Criteria for the design and the operation of ventilation systems for nuclear installations other than reactors”.

[3] ISO 17873 - Main objective: ventilation and fire hazard management. ISO 17873 will apply to all types of nuclear installations other than the containment envelope of nuclear power plants or certain categories of research reactors. The installations concerned are particle accelerators, radiation generators, fusion machines, research and examination laboratories, and more generally all types of nuclear fuel cycle installations (e.g. enrichment plants, nuclear fuel fabrication and examination laboratories, plutonium handling facilities, reprocessing plants, radioactive waste treatment stations, radioactive waste storage facilities, etc). It can also be applied to the containment envelope of research reactors, where only low pressure can occur during accident scenarios, as well as to auxiliary rooms of nuclear power plants.