Design review of Belgian hot cells – Identification of design weaknesses

N. Noterman, F. Schmitz*, C. Mommaert*, E. Minne*, C. Peters*, C. Kennes*, H. Drymael*, G.Degreef*, G. Cortenbosch*, O. Smidts*, M. Van haesendonck**

*Bel V 148 Walcourt street, 1070 Brussels, *FANC 36 Ravenstein street, 1000 Brussels

Abstract: Somefacilities handling nuclear materialsare licensed by the FANC (Federal Agency for Nuclear Control) as Class 1 installations. In most of them, if not in all of them, shielded cells are used to protect workers against external irradiation but also to prevent contaminations being spread on the site or in the environment. A lot of licensees own quite old installations, designed and set up in the 70's. The identification of weaknesses by the licensee and the TSO (Technical Safety Organisation) during abnormalities or incident analysis, as well as the refurbishment or dismantling of old shielded cells have allowed both the licensee and the TSO to increase the technical experience with regard to shielded cells. Technical options and solutions that seemed appropriate 30-40 years ago are not so anymore in accordance with the current, by operational feedback experience, improved operational handling of the licensee and with a strengthened regulatory environment. In this paper we will describe recently encountered problems dealing with hot cell interfaces, hot cellautomation, design of filters inside the hot cell,… and give an overview of some of the lessons learned.

1 INTRODUCTION

Somenuclear facilities in Belgium are using hot cells to handle radioactive materials (in liquid or solid form). Hot cells are mainly used in the radioisotopes industry but also in waste management facilities or for research purposes. Most of those hot cells have been designed and set up in the 70's. In the past few years, some refurbishment operations have been performedin Belgium in order to improve the safety and the operability of hot cells. Nevertheless only a limited number of hot cells are concerned by those refurbishment operations. Itshould also be underlined that the effectiveness of arefurbishmenton the nuclear safety is sometimes limited due to the original design of the building or of the auxiliary systems.

Nuclear safety is an important aspect during the exploitation of hot cells. Indeed, the radioisotopes which are handled in hot cells usually generate a risk of internal and external exposurefor the workers but also a risk of contamination being spread on the site or in the environment that implies a risk for the population around the concerned facility.

In Belgium, the regulatory framework specificallydeveloped for facilities using hot cells is limited. At the present time few specific international guidances exist for the nuclear safety of hot cells facilities [1]. This observation can probably be explained by the large diversity in the original design and in the operation of hot cells (radioisotopes production, waste management, research…). This lack of specific regulationleads to a significant challenge for a TSO (Technical Safety Organization) or for a Regulatory Body whichhas to perform inspections and carry out the safety analysis assessment for this type of nuclear installations. With a limited regulation, an engineering judgement is mainly used by inspectors and safety analysts to assess the nuclear safety in those installations. Nevertheless an engineering judgement may be expert-dependant.It would be then necessary to tend to develop specific guidances for hot cells with regard to nuclear safety.
It has to be underlined that this paper only focuses on the nuclear safety and radiation protection aspects and not on the pharmaceutical aspect of those types of installations. Nevertheless, we would like to mention that even if the two aspects can sometimes be

contradictory, nuclear safety is always considered as a priority for a TSO or a regulatory body.
This paper begins with a brief description of the design of most of the Belgian hot cells. Weaknesses in design identified by the licensee and the TSO during abnormalities or incident analysis, as well as during refurbishment or dismantling activities of old hot cells are then presented. Finally an overview of some lessons learned and technical solutions adopted by the licensee to improve the nuclear safety of hot cells is given.

2DESCRIPTION OF HOT CELLS DESIGN

Most of the Belgian hot cells have been designed and installed 30 to 40 years ago. At this time, few rules or technical guidancesexisted on this topic. Consequently, the original design of hot cells was mainly relying on the experience of the company which was in charge of the design and the installation of the hot cells. With the passing years of operation, the licensees tried to improve the nuclear safety and thus performed some modifications on their installations. For some topics specifictechnical guidances have therefore been applied. A brief description of the Belgian design of hot cells is given hereafter for some specific topics which are assessed as important to the nuclear safety.

2.1 Shielding

Radioisotopesemitting ionizing radiations are handled in hot cells. To protect the workers against the irradiation risk, the hot cells are shielded. Various materials such as concrete, lead or depleted uranium can be used for the shielding. Among those materials, lead is generally used for hot cells with smaller dimensions whereas concrete is used for the hot cells with bigger dimensions.Lead glass is now mostly used forthe window allowing the operators to see inside the hot cell. The shielding thickness is definedsuch thatthe radiation dose at the workstations remains below the international recommendations and as low as reasonably achievable.Hot cells designers generally ensure a dose rate lower than 2,5 µSv/h at the workstation.

2.2 Ventilation systems and filtration

Ventilation systems are used to prevent the risks of contamination spread. The basic principle with regard to the prevention of the radioactive material spread is to limit the radioactive releases outside the facility and to maintain a level of contamination as low as reasonably achievable inside the facility during both normal and accidental conditions. The application of this principle leads to compel several different containment systems between the environment and the radioactive materials. In nuclear hot cell facilities three containment systems are generally distinguished. The primary containment includes the process equipment and the hot cell itself. Hot cells are normally made up of a stainless steel box called ”alpha box” which presents a high level of leak tightness. The secondary containment consists in the laboratory in which the operators are working. Finally a tertiary containment can be formed by the adjacent rooms of the building. These three confinement levels assure the static confinement.

To complement this static confinement, the principle of dynamic confinement is applied. Dynamic confinement is based on a series of negative pressure differentials between static containment levels or ventilation areas. The ventilation systems are designed to ensure that the pressure is lowest in the areas where the radioactive substances are contained (hot cells) in order to flush theair flow from the low contamination to the high contamination area, should a leak occur.
The ventilationareas present a different risk of potential contamination. Therefore, separate ventilation extraction networks are provided to fit with the associated potential risk.The reliability of each ventilation system varies in function of its safety significance for example

for the qualification of the equipment or the electrical supply. Redundancy is foreseen in the design by providing two or three extraction ventilators (2 or 3 x 100 %) to ensure the reliability of the extraction.
In addition to the static and dynamic confinement, filtration devices are placed on each ventilation extraction network in order to reduce the radioactive releases to the environment during normal and accidental conditions. Charcoal filters allow the filtration of iodine gases while High Efficiency Particulate Air filters (HEPA filters)are used for aerosols. The type and number of filtration levels depend in particular on the process carried out within the hot cells and on the ventilation extraction networks. For example four levelsof charcoal filters can be foreseen in the case of a hot cell extraction system where a process involving important concentrations of iodine gasesthat could be released, is foreseen. On the other hand only HEPA filters and no charcoal filters are present on the extraction systems of a facility releasing aerosols.

Concerning the technical framework, an international standard concerning the design and the operation of ventilation systems for nuclear installations other than nuclear reactors has been published [2]. It contains for example recommendations and criteria concerning the classification of ventilation areas and the design of filtration systems. Although all the criteria (for example the underpressure values) proposed in this relatively new standard cannot be strictly respected in old existing installations, the licensees are trying to meet those recommendations as close as possible for their ventilation systems.

2.3 Leaktightness and interfaces

A high level of leaktightness is an important parameter for hot cell design because it prevents the risks of contamination spread and helps maintaining the underpressures.As previouslymentioned, hot cells are normally made up of a stainless steel box called ”alpha box” which presents a high level of leaktightness. Several hot cells located in one laboratory are generally used in a row dedicated to a specific production process. Between two hot cells a space called ”interface” allows the transfer of products or materials between the cells. Guillotine doors sealed by compressed air ensure the leaktightness between the hot cell and the interface. A separate ventilationsystem extracts the air present in all the interfaces.
When the production process requires the introduction (or removal) of products or materials in (or from) the cells, the interface is opened. It is important in this case that the cell guillotine door remains tightly closed to avoid a loss of the negative pressure between the different ventilation areas.

2.4 Monitoring

The airflows extracted from the hot cells containment are contaminated with radioisotopes (either in gaseous phase or in aerosols). Therefore, measurement of the gaseous radioactive releases is an importantissue in hot cell facilities. The air monitoring is necessary in normal conditions to quantify the amount of radioactive releases but also during accidental conditions to rapidly identify the accident origin and toevaluate the needed protection measures for the environment and the population.

Two types of measurements are generally performed:off-line monitoring and on-line monitoring. Off-line monitoring consists in the accumulation of radioisotopes on filters during a defined period. A well-known fraction of the extracted airflow is deviated to the filters of the monitoring systems. Typically iodine is accumulated on charcoal filters and aerosols on paper filters. These filters are removed from the installations on a periodic basis (usually once a week) and are then measured in laboratory by gamma-spectrometry to determine the accumulated activity. Hence, this kind of monitoring provides a measurement of the radioactive release after a potential event. Off-line monitoring stations can be installed on subsystemssuch as the ventilation system of a specific process to measure the contribution of a subsystemor directly in the stack to measure the global radioactive releases.

In addition to off-line monitoring, it is also important to use an"On-line" measure of the gaseous radioactive releases, especially in case of accidents. This function is performed by the on-line monitoring system.As for the off-line monitoring, a well-known fraction of the airflow extracted is deviated from the ventilation systems and goes through three detectors. First, aerosols are collected on a paper filter which is permanently measured by aα/β-detector. Then iodine is accumulated on a charcoal filter which stands in front of a NaI scintillation detector to measure the γ-contribution. Finally the airflow continues through a chamber measured by a plastic scintillation detector to define the noble gases β-contribution. This on-line monitoring system virtually provides an instantaneous measurement of the radioactive releases. Generally, it is installed directly in the stack in order to measure the global releases of the installation. Alarm systems are linked to theon-line monitoring system.

A general surveillance system allowing the supervision of all monitoring measurements can be useful to get a global overview of the installation. If apredetermined threshold is exceeded on the on-line monitoring system, alarms can be generated by the surveillance system.

2.5 Fire protection

A fire in a nuclear hot cell facility can lead to the loss of integrity of the radioactive materials'confinement and consequently to significant radioactive releases to the environment.Therefore, fire protection systems are of paramount importance in these kinds of installations.

The first level of defence in depth related toa fire protection program is fire prevention. Particular precautions are taken by the licensees to minimize the amount of fire load within the hot cells. Specific procedures called "hot work permit" are also applied when operations presenting a risk of fire have to be performed.

When a fire occurs, it has to be detected and extinguished as soon as possible. This constitutes the second level of defence in depth. Automatic fire detection and protection systems are foreseen to comply with this objective. A general fire detection system is installed in all the rooms of the facility. Within the hot cells a fire detector is located in the ventilation extraction duct. The fire detection system allows the quick localization of a startingfire and the rapid warning of the security guards. To extinguish a fire, automatic suppression systems are foreseen. Gaseous fire suppression is, for the time being, installed in some hot cell facilities. For example,in the laboratories and adjacent rooms located in the controlled area, the extinguishing gas is sometimes carbon dioxide while in the hot cells itself, a suppression systems using nitrogen is used.
In addition to the automatic extinction systems, manual fire suppression capabilities are foreseen. A fire water supply with hydrants is installed outside the buildings and portable fire extinguishers are located inside the buildings. It should be mentioned that the use of water to extinguish a fire can be forbidden in some laboratories due to criticality or chemical risks.

The third level of defence in depth is defined as the measures to prevent the fire spreading inside a building. To achieve this objective a compartmentalization is used to subdivide the plant into separate areas or zones. This is achieved by using passive fire barriers (fire walls, fire doors, fire dampers...). Nevertheless an accurate compartmentalization is rarely observed in this kind of nuclear facilities because of the age and subsequent old-fashioned design of the buildings.

3IDENTIFICATION OF WEAKNESSESAND LEASSONS LEARNED

Operating experience feedback and incident analyses have permitted to identify some weaknesses in the design of hot cells. New guidances and standards have also recently been published to define a better technical framework for the nuclear safety of some topics related to hot cell facilities.

Lately, a lot of work has been performed by the licensees and the TSO to improve the nuclear safety in facilities using hot cells. Furthermore, efforts have been made to find technical solutions to the weaknesses identified during operation or incidents. The proposed solutions are also trying to comply as far as possible with the recommendations of the existing technical framework knowing that limitations and difficulties exist due to the age of the facility.
In this section some identified weaknesses are presented for each topic and, when possible, a technical solution is proposed.

3.1 Shielding

The design of the shielding in hot cell facilities is generally adequate and ensures a low level of dose rate for the operators. Very few weaknesses have been identified during the operating experience.
The only safety related weakness observed concerned the shielding of the ventilation ducts rather than the hot cells shielding. Indeed, it has been observed that ventilation ducts extracting airflow from hot cells were sometimes not located inoptimal places regarding the minimization of the radiation exposure of personnel in the facility.Indeed, in those cases, the contaminated air extracted from the hot cells could increase the dose rate to the operators especially if the ventilation ducts are located in close proximitytothe working spaces. In such cases, an additional shielding should be added around the ventilation ducts.

3.2 Ventilation systems and filtration

The identified weaknesses related to the ventilation systems of hot cells facilities consisted principally in the difficulties to comply with the recommendations concerning the underpressure values. In installations constructed in the 70's, criteria fixed in the international standard [2] could not always be strictly respected. The licensees launched projects to improve the installation in orderto get closer to the recommendations for their ventilation systems. The first step of these projects involved an in-depth study ofthe underpressure's dynamic system in the buildings. This study allowed the definition of, for instance, the influence of a door opening during operations.Following this analysis, the necessary modificationshave been implemented in order to improve the compliance with the underpressurecriteria. Those modifications mainly consisted in the installation of airlocks at some specific places in the building. Work to improve the leaktightness of some walls and penetrationshasalso been performed. Today, almost all observed underpressure values are in agreement with the international standard recommendations. To ensure the continued dynamic confinement, underpressure measurements have been installed in all areas and daily walkdowns have been set upby the licensee to verify the adequacy of the values.

Another weakness related to ventilation systems which has been identified in almost all of the hot cells facilities is the lack of physical separation between ventilators. To ensure the reliability of the extraction, a redundancy is foreseen in the design by providing two or three extraction ventilators (2 or 3 x 100 %). However, those ventilators are typically located in the same room. If a fire occurs in this ventilation room, it can be assumed that all the redundant ventilators are lost despite of the redundancy. Ameliorations of the installation can be carried out to solve this issue for example by constructing a fire barrier between the extraction ventilators. Nevertheless, this solution is not optimal as the ventilators are still located in the same room.This aspect has to be taken into account in the design of new facilities.

Concerning the filtration systems, various weaknesses have also been observed in hot cell facilities. It should be underlined that most of theencountered problems are in relation with iodine filtration. Indeed, few deficiencies were met with HEPA filters which present a high level of efficiency for radioactive particles filtering. The below-exposed weaknesses are thus mostly relevant for hot cells facilities handling iodine in their installations.

In Belgium, an accidental iodine release occurred in 2008 from a hot cells facility. More details about this incident are given in [3]. As lesson learned from this incident, it has been concluded that iodine filtration systems have to be reinforced. Indeed the number of charcoal filter levels was not sufficient to reduce the iodine releases in the case of this specific incident. The source of the release was not correctly considered during the design.Urgent modifications have been implemented during the days following the incident. For example, the extraction duct hasbeen deviated in order to get more charcoal filters but also the last level of HEPA filters has been replaced by an additional level of charcoal filters. These modifications have permitted a better management of the radioactive releases. Nevertheless, after this incident, other modifications of the filtration systems have been decided. Two additional levels of conditional charcoal filters have been added on the extraction systems of the hot cells. Unlike the normal filters, the conditional charcoal filters are normally in by-pass configuration. Nevertheless, in case of incidental release, those two filters can be inserted from a distance by means of the supervision system to allow a rapid reduction of the iodine releases.
The type and the number of filtration levels depends on the considered ventilation extraction networks. Several charcoal filters in series are present on the extraction system of hot cells handling iodine. On the other hand, the airflow extracted from laboratories goes through a fewer number of filters and this extraction system is sometimes only equipped with HEPA filters. In a normal situation, this is not problematicas no iodine is supposed to be released by this extraction path. However, in accidental situations, the dynamic confinement (underpressure differential between the ventilation areas) can be lost. In this case, a part of the air from the hot cells can diffuse into the laboratories and therefore be extracted by the laboratories'ventilation systems instead of the extraction system of the hot cells as foreseen in the design. This means that airflow potentially highly contaminated with iodine can be released to the environment without being filtered by charcoal filters. To avoid this scenario, modifications have to be foreseen to install a minimum of charcoal filters on all extraction network systems. In general, this issue shows that accidental situations, and not only normal situations, have to be taken into account during the conception of the filtration systems.

To ensure a good efficiency of the iodine filtration, some parameters of the airflow are very important. For example, the efficiency of charcoal filters decreases significantly when the relative humidity is higher than 70% or when the extracted airflow is contaminated with chemical poisons such as acids. Consequently, measurements of the relative humidity should be foreseen in the extraction systems. The installation of heaters prior to the charcoal filters should also be considered by the licensee. Concerning the potential presence of chemical poisons, an analysis of the airflow could give indications about this topic and the licensees could take measures to compensate the impact on the filter's efficiency.

Anotherinteresting phenomenonconcerning iodine filtration is currently being investigated by alicensee. It has been observed that iodine trapped on the charcoal is not necessarily definitively fixed. Indeed, if a significant airflow goes through a charcoal filter loaded with iodine, a non-negligible amount of iodine could be released from the filter. This phenomenon could be emphasized as the airflow through the filter increases. First tests with small specimens have been performed to demonstrate this hypothesis. Complementary large-scale tests should be foreseen to confirm the observed phenomenon. In any case, this point could be an important aspect to take into account in the design of filtration systems.

The last topic about filtration concerns the testing methods. It is important to ensure at any time that filters provide a sufficient efficiency. For this purpose, periodic testing of the filters'efficiency has to be foreseen. Several testing methods can be chosen but not all of them are equivalent. When choosing a testing method, it is important to take into account the representativeness of the test. Indeed, the element used for the test shouldpresent similar characteristics and behaviourto the radioisotope of interest that will be filtered.

3.3 Leaktightness and interfaces

In addition to the dynamic confinement, the static confinement prevents the risks of contamination spread. An adequate static confinement relies on a high level of leaktightness for the cells and their interfaces. For existing hot cells, it could be difficult to verify the adequacy of their leaktightness during the operation phase of the facility. Nevertheless, refurbishment activities are sometimes necessary to upgrade the hot cells. Onthis occasion, the inside of the hot cells is often cleaned and it is important to benefit from this opportunity to examine the leaktightness of the hot cells and the interfaces. This issue is described and cared for in an international standard [4]. In this standard, enclosures are classified according to the potential contamination level. In function of this classification, a leaktightness value is recommended. Hot cells are typically classified in the most stringent category whereas lower leaktightness is required for the interfaces. The objective of the licensee is to comply with the recommended values after the improvements implemented during the refurbishment of the hot cells. Methods to determine the leaktightness are also described in the standard [4]. The most commonly used method consistsin measuring the time of pressure rising.
To introduce to or remove products from the cells, the interfaces have to be opened. In this case the interface atmosphere is directly in contact with the atmosphere of the laboratory. Although an underpressuredifference exists between the two ventilation areas, the separated extraction system of the interfaces is capable to maintain the underpressure in the interface by increasing the extracted airflow. However, all the interfaces of the hot cells are connected to the same extraction systems. Consequently, if in another laboratory, another interface is simultaneously opened, the extraction systems of the interfaces may not be able to ensure the underpressure in the two opened interfaces. To improve this weakness, an interlock system has been installed on the interfaces doors. This interlock system has been designed to block the opening of allinterface doors when oneinterface is already opened in the facility. This modification ensures the dynamic confinement during the introduction of products in the hot cells.

The leaktightness between the interfaces and the hot cells is ensured by guillotine doors sealed by compressed air. It has been observed that the safety significance of the compressed air system was not always correctly considered by the licensee as illustrated by the following incident involving the compressed air system in a hot cell facility. Due to a lack of door seals' maintenance, a leak occurredat one seal. Consequently, when the compressed air systems injected the compressed air in the seal, the pressure in the interface raised significantly. While the pressure increased in the interface, the dynamic confinement between the ventilation areas was not respected anymore and a contamination spread occurred in the laboratory. This example shows that the impact of a malfunction of the compressed air system on the nuclear safety has to be correctly considered by the licensee.

3.4 Monitoring

Adequate monitoring systems are important to ensure the measurements of the gaseous radioactive releases. The specificity of the radioisotopes'mixture to be measured has to be considered.The following example gives an insight on considerations which have to be taken into account in the design of on-linemonitoring systems. In a hot cells facility, the radioactive releases are mainly composed of iodine,noble gas and potentiallyaerosols. The amount of noble gas released is largely higher than the amount of iodine. Theinstalled on-linemonitoring system includes a NaI scintillation detector for the γ-contribution of the releases. When the mixture noble gas/iodine flows in front of the NaI detector, the detection channel for iodine is saturated by the large amount of noble gas. Thedistinctive ^{131}I γ-peak cannot be distinguished on the monitoring because of the Compton effect due to noble gasand the alarm thresholds for iodine are exceeded, even if there is no iodine release. This phenomenon leads to a situation where the licensee is ”blind“ towards a realiodinerelease due to the saturation of the signal by noble gas. After the noble gas release, only iodine remains on charcoal filters and the NaI detector is then able to measure the iodine γ-peak. Consequently, when an alarm occurson the iodine channel, the licensee is not able to know if it is a real iodine release and has to wait to distinguish noble gas and iodine. To resolve this issue, an original solution has been proposed by a licensee who has decided to install a pure germaniumdetector at the chimney. Thanks to the very good detection efficiency, this detector is able to distinguish the iodine γ-peak, even when a large amount of noble gas is released simultaneously.

Concerning the off-line monitoring, a potential weakness could be that the entire radioactivity the licensee wants to measure is not accumulated on the charcoal filters. Indeed, in this case, the measurement would underestimate the real releases. To avoid this situation, modifications have been implemented tothe off-line monitoring systems byaddingseveral charcoal filters in series. During the weekly measurements, all the filters are measured and it is verified that no iodine has accumulated on the last filter, proving that no desorption occurred.

Another important issue related to the monitoring is the possible link with the efficiency of the filters of the ventilation systems. Indeed, when the filters' efficiency decreases, the radioactive releases will increase. Therefore, the measurements with the monitoring systems could be used as additional indication to evaluate the filters' efficiency. Hence, it is recommended to the licensee totry and determine a criterion based on the results of the monitoring systems to warn them to replace the filters of the ventilation systems.

Monitoring of the gaseous radioactive releases has previously been described. In addition, improvements related to the monitoring of the air in the laboratories have also been implemented. To ensure an adequate atmosphere for the workers, mobile monitoring stations have been installed in all the laboratories. Those systems measure the air contamination and provide an alarm if the atmosphere in the laboratory is not safe enough for the workers.

Finally, the surveillance system supervising the monitoring measurements is of paramount importance because of itsrole in generating alarms in accidental situations.Consequently, the safety significance of the surveillance system should be considered by the licensee and actions should be taken to ensure itsreliability and effectiveness.

3.5 Fire protection

Regarding fire prevention, a lot of remarks concerning housekeeping inthe installations had to be made during the inspections of the regulatory body and TSO. It was not unusual to find abandoned materials which werecreating an unnecessary fire load. Recently a particular effort has been made by some licensees to improve this issue. Some projects have been launched to sort the materials and equipments located in the controlled areain order todrastically reduce the amount of storedmaterials. Dedicated storage places have been defined for each type of materials and the allowed quantity in each place has been limited. A standard state has been established after the sorting ofeach room with the objective that the rooms remain in this standard state. Periodic controls are foreseen to verify the adequacy of the housekeeping. Concerning fire prevention it should also be underlined that fire retardant cabinets have been acquired by some licensees to improve the storage of flammable liquids.

Weaknesses related to fire detection inside the hot cells have also been identified. It has been pointed out that fire detectors located in the ventilation extraction ducts of the cells do not constitutethe best technical solution. Indeed, the fire is then only detected when the extracted smoke reaches the temperature threshold. At the beginning of the fire or if problems occur with the ventilation extraction system (filters plugging, failing of ventilators,...),the temperature threshold may not be reached and the detection time can be delayed. To improve this situation, Pt100 temperature sensors have been installed within the hot cells. Tests were performed and showed that the fire detection time can be significantly reduced due to this modification.

An evaluation of the existing automatic fire extinction systems in hot cells facility has been performed by some licensees. It was concluded that the gaseous fire suppression system with carbon dioxide was not efficient enough to protect the laboratories and the adjacent rooms. Nevertheless, alternatives have to take into account that water as extinguishing agent has to be minimized in that kind of installation because of the production of radioactive liquid wastes or the criticality risk. Therefore, alicensee has proposed to replace the gaseous suppression system by a water mist system. The quantity of water used by a water mist system is indeed significantly lower than the quantity delivered by a common sprinkler system. Nevertheless a decision has still to be taken about the installation of the water mist system in laboratories with hot cells containing the storage of fissile materials. Recent standards about this topic ([5], [6]) will be used for the design and the installation of the water mist system.

The evaluation of the automatic fire protection systems also lead to the conclusion that the nitrogen fire suppression system used in the hot cell itself may not be the best solution. Fire tests performed within a hot cell pointed out that this system is efficient to extinguish a liquid fire. However, the most significant fire risk in a hot cell is probably a solid fire for which a nitrogen suppression system is not appropriate. Consequently, it has been decided to look for an alternative fire suppression system to extinguish a fire in a hot cell.

Another issue to take in consideration in the evaluation is the risk of contamination spreading due to overpressure in the cell. Indeed, it was observed in some installations that an unexpected nitrogen injection generates a significant pressure peak in the hot cell leading to the contamination of the laboratory in which the cell is located. Interactions of the fire suppression system and the ventilation system have also a significant impact on the pressure in the cell and shall obviously be taken into account. Atthis moment, no technical solutions havebeen chosen yet but an evaluation is in progress. It should be noted that no recent standards or technical guidances have been found on this subject and that the few available documents date from the 70’s([7], [8]).

The third level of defence in depth for the fire protection relies on the compartmentalization to prevent the fire spread. It was already mentioned that hot cells facilities have been constructed around the 70’s and that fire compartmentalization is very limited in those installations. Despite the age of the buildings, some modifications have been implemented to improve the fire barriers. For example, fire doors have been added in the installations and some work has been performed on the penetration seals. Even if those modifications do not lead to a perfect fire compartmentalization because of the limitations of the buildings, the licensees are encouraged to perform that kind of modificationsand to identify the weaknesses of their installations.

A last point related to the fire protection of hot cells facilities is thelack of a global fire hazard analysis. A fire hazard analysis should be performed to demonstrate that the safety functions could still be guaranteed and that the radioactive releases will be minimized in the event of a fire. This study should demonstrate that the implemented measures for fire prevention, fire detection and fire protection are sufficient and should possibly identify weaknesses in the design for which improvements are necessary.

4 CONCLUSIONS

In Belgium, several nuclear facilities are using hot cells for different activities. Most of the hot cells facilities have been designed and set up in the 70’s.This paper has, in its first part, briefly described the original design of hot cells related to some important safety topics.

The second part of this paper presented some weaknesses in the design identified by the licensee and the TSO during operating of hot cells. It has been highlighted that the original design of the building and of the auxiliary systems could sometimes limit the nuclear safety improvements. Nevertheless, improvements have been made or could be found for some weaknesses. In those cases, the technical solutions adopted by the licensees or the recommendations provided by the TSO are presented in the paper.

Concerning the regulatory framework it was stated that few specific international guidances exist aboutthe nuclear safety of hot cells facilities. This issue is a significant challenge for a TSO or a Regulatory Body whichhas to perform inspections and to assess safety analyses for this kind of nuclear installations. Consequently, the elaboration of a specific guidance concerning the nuclear safety of hot cells facilities would be particularly useful. Ideally, this guidance should take into account the potential limitations of existing facilities due to their original design.

5 REFERENCES

[1] IAEA-TECDOC-1430 „Radioisotope handling facilities and automation of radioisotope production“ (December 2004)
[2] International standard ISO 17873:2004 „Nuclear facilities – Criteria for the design and operations of ventilation systems for nuclear installations other than nuclear reactors“
[3] Eurosafe 2009 „Incidental release in IRE“, Frédéric Schmitz
[4] International standard ISO 10648-2:1994 „Containment enclosures -- Part 2: Classification according to leak tightness and associated checking methods“
[5] NFPA 750 „Standard on Water Mist Fire Protection Systems“(2010)
[6] Draft European Standard prEN 14972 “Fixed firefighting systems - Watermist systems - Design and installation”(2004)
[7] ARH-3020 „Guide to Fire Protection in Caves, Canyons, and Hot Cells“, H.A. Lee, July 1974
[8]DP-1242 „Fire Prevention and Protection in Hot Cells and Canyons“, A. J. Hill