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Renovation of the ventilation system at NRG's Research Laboratory

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ABSTRACT

The 'Research Laboratory' is an integral part of the Nuclear Research and consultancy Group's (NRG) facilities at Petten. This hot cell facility was completed in 1964. It plays an important role in NRG's research into reliable, sustainable energy production by conducting post irradiation examination (PIE) of nuclear fuels, fuel cladding and other power reactor materials. Today, this facility is among PIE also utilized in the development and production of various isotopes for nuclear medicine and industrial applications.

The ventilation system of the building ensures the safety of the workers and the general public. It provides external dynamic confinement and a pressure cascade between the rooms and enclosures to ensure airflow from clean or potentially contaminated towards high radioactive contamination hazard areas. Two separate systems ensure the controlled discharge of the potentially contaminated air, one for the building and one for the hot cells.

Although some changes were made on the ventilation system over the last decades, the majority of the subsystems and components are in use since the commissioning of the facility. The obsolescence of the components and unavailability of spare parts poses an operational risk. Therefore, a project was initiated with a goal to extend the technical lifetime of the ventilation system with at least 20 years. The project scope is twofold: renovation of the system by replacing components and subsystems based on obsolescence and implementation of improvements limited to the advices from operational license reviews.

This paper will firstly focus on what has been achieved since the project initiation in 2018, the specific inspections, improvements in the process monitoring necessary for the commissioning of the modifications, and the performed modifications. Furthermore, the specific project limitations and arising challenges due to the age of the facility, the building design and the operational planning of the facility will also be discussed. Finally, the work planned for the upcoming period will be highlighted.

INTRODUCTION

The brief history of the Research Laboratory

At the Energy and Health Center in Petten NRG carries out activities in the field of nuclear technology, especially for medical and technical/industrial purposes, safe generation nuclear energy, radioactive waste processing and radiation hygiene. Obtaining and maintaining knowledge in the nuclear field and the continuous innovation of nuclear technology is an important task for NRG.

The ‘Research Laboratory’ (RL) is an integral part of the Nuclear Research and consultancy Group’s (NRG) facilities at Petten [1]. The RL, completed in 1964 is intended for research into radioactive materials. The laboratory was set up at the time as an extension of the High Flux Reactor (HFR). Material irradiated in the HFR could be examined in the RL.

During the last 60 years extensive research programs have been carried out in the field of nuclear fuel and construction materials from light water reactors, fast breeder reactors and fusion reactor technology. In recent years, the focus has been on research into new innovative production methods for nuclear-medical and industrial applications.

Today, the RL plays an important role in NRG’s research into reliable, sustainable energy production and the facility is also utilized in the development and production of various isotopes for nuclear medicine.

Description of the Research Laboratory

The hot cells and laboratories are built around a central hall which consists of the transport hall and lead cells hall. A material air lock, decontamination room, cell loading locks and shielded storage pits are also located within this hall. Around this hall is a U-shaped corridor, which on the south side is the front of the High Active (HA) cells. These cells are labelled from A through E. The lead cell hall houses the F and G hot cell lines with 14 hot cells in total. Three mechanical testing cells are located on the west end of the corridor. The area on the outside of the corridor includes an access lock and changing rooms, mechanical and electrical workshops, maintenance workshop for master-slave manipulators, offices, storage rooms and the actinide laboratory.

The HA-cells are built of barite concrete as a shielded tunnel. Movable partition walls separate it into four compartments (cells): AB, C, D and E, and connect it through the cell loading locks to the transport hall. Each letter denotes a 30 m^3 partition of the tunnel. Virtually all processes begin in the these cells with the dismantling of irradiated capsules as these are designed for processing highly active components. Furthermore, conditioning and repacking radioactive waste, non-destructive testing and destructive testing of non-fissile materials, preparation and packaging of medical and industrial radioisotopes takes place also in the HA-cells.

The metallographic hot cell line (F cells) is designed for destructive testing of fissile materials as well as non-fissile materials in solid or in dispersible form including light and electron microscopic examination and characterization of materials. The G-cell line houses a chemical processing cell and multiple mechanical testing cells. Tensile tests, fatigue tests, creep tests and crack growth measurements can be performed on irradiated non-fissile materials in these mechanical testing cells.

The interim dry storage, called ‘tube nest’, consists of two cellars filled with a bundle of vertical tubes. By means of a shielded transport container with vertical loading and unloading possibility, canisters are transferred from the HA cells to and from this storage facility. The tubes are ventilated and is connected to the cell extraction duct via an iodine filter and an absolute filter.

In the actinide laboratory, chemical operations and measurements are performed on, among others, the elements technetium, americium, cerium, curium, neptunium, plutonium, uranium, thorium and radium. All these operations are performed in gas-tight glove boxes, with the exception of thorium compounds that can also be processed in a fume hood.

The fans, motors and filters of the ventilation system are located in a technical room, the so called ventilation loft located on the second floor. The exhaust filters are accessible via the transport hall, the supply filter via the ventilation loft.

VENTILATION SYSTEM

The primary purpose of the ventilation system is the controlled removal of potentially radioactive contaminated air to ensure the safety of the workers and the general public. The system provides dynamic confinement for the building and a pressure cascade between the rooms and enclosures to ensure airflow from low towards high radioactive contamination hazard areas. There is no recirculation of air within the building. Air from the areas accessible to personnel and from the enclosures are extracted through separate filter installations for the controlled discharge of the potentially contaminated air. In addition, the ventilation system is used for climate control of the building.

The ventilation system of the RL building consists of four major subsystems [1]:

1. the air supply system
2. the building extraction system
3. the cell extraction system
4. process ventilation system (‘off-gas’ system)

The main function of the building air supply system is to heat and filter the incoming ambient air, and to distribute the conditioned air to the low radioactive contamination hazard areas through the three main branch ducts serving the building on the Northern, Eastern and Southern sides. This system is sized for a total supply capacity of 33000 m^3/h and is fitted with a single supply fan.

The hot cells and gloveboxes which are ventilated with room air are equipped with air supply filters and draw their air supply from the transport hall or the lead cell hall. The metallurgical cell line (F-cells) and two G-cells are flushed with nitrogen while the gloveboxes can be ventilated with air, nitrogen or noble gases depending on the activities in the specific enclosure.

The building exhaust system draws air via a network of ducts and grilles from various rooms and the cell loading locks of the building. The building exhaust system is fitted with two 100% duty fans. Both fans are running continuously with a duty point of 35800 m^3/h. The system is controlled by a single pressure difference set point of -80 Pa between the transport hall and the reference ambient pressure. The system is regulated around this set point via the inlet vane dampers of the fans which receive their signal from the pneumatic control system.

Within the enclosures a negative pressure is maintained with respect to the surrounding room. This serves to prevent the spread of radioactive material to the building, both during regular work as well as in the event of an accident. The hot cells are connected to the main extraction ducts with branches per cell line. Each hot cell and glovebox is equipped with a HEPA filter within the enclosure. Some enclosures have two filters in series, depending on the processes within the specific enclosure. The flow rate of each HA-cel is 1100 m^3/h, totalling 5500 m^3/h for the HA cell line. Other cells are ventilated at a flow rate up to 50 m^3/h. The tube nest and the Actinide Laboratory room are also ventilated by the cell ventilation system, both connections equipped with filters.

The cell extraction system is fitted with two 100% duty fans. The fans are operating simultaneously with a duty point of 12760 m^3/h. Air extracted by this system is, in addition to filters provided on the enclosure outlets, filtered by a final HEPA filtration stage. An iodine filter is available in a bypass loop to remove volatile iodine from the extracted air when needed. A booster fan is utilized to overcome the high flow resistance of this filter battery. The switch between the two operating regimes is manual. The cell extraction system is controlled by keeping the main duct under a negative pressure in relation to the reference pressure around a set point of -1300Pa. The system is regulated around this set point via the inlet vane dampers of the fans which receive their signal from the pneumatic control system.

Dampers are installed downstream of the extraction fans for the building and the cells, which, in the event of fan failure, fan trip or fan shut-down, close to prevent backflow or short-circuit of air. The 'off-gas' ducting consists of two lines, respectively along the HA cells and the G-cell line, extending to the Actinide laboratory. All gloveboxes are connected to this system. The off-gas system is fitted with three fans, connected with a pipe manifold in a configuration that allows for various manually selectable fan configurations. The extracted air is filtered by a HEPA filtration stage.

The discharge of the building extraction fans, the cell fans and the off-gas system are united and discharge via an isolation valve on the plenum/collector box. This is the beginning of the channel to the 45 m tall stack.

The control of the ventilation system is split between an electrical motor control cabinet and a pneumatic control cabinet which controls the pressure differentials and temperature in the building. The electrical and pneumatic cabinets are independent of each other. Various small electric cabinets are utilized for other functions, such as motor control for the off-gas system or for the booster fan of the bypass loop.

This cabinet includes start and stop functionality for the motors of the building supply, building extraction and cell extraction fans. A start-up and shutdown sequence is also hard-wired in the control cabinet. The control cabinet is fed from the main electric supply of the building and from the emergency power generators of the site.

In the event of a mains power failure, the five main fans are supplied via the emergency power system. The switchover for the cell extraction system is done automatically and within a few seconds. Both fans remain in operation. A minimum of one of the building ventilation extraction fans is powered by means of an emergency power generator in the event of a mains power failure. A choice can be manually made prior to the event. The selected fan is then supplied via the emergency power system. The switchover is automatic.

The building supply system is interlocked with the building and the cell extraction systems to ensure the air pressure cascade in the building remains in place. The failure of either the hot cell extraction system or the building extraction systems shall signal a trip of the building supply system. In the event of cell extraction system failure, the building extraction system shall also trip to ensure that air is not drawn from the hot cells into the facility.

A pneumatic control cabinet houses the closed-loop control systems which are responsible for the two main pressure differentials (see above) and the temperature of air in the three main ducts of the building supply. Each of these five functions are fulfilled by a dedicated differential pressure controller.

THE VENTILATION RENOVATION PROJECT

The renovation of the existing ventilation system and modification of certain components have been recommended by various sources. These recommendations have been collected in a single project to implement all recommendations in an integrated and cost-effective way.

There were various projects initiated in the past with similar goals. These projects have failed to deliver to their goals for various technical or organisational reasons.
The current project was started in 2018 with the aim to provide a reliable ventilation system for the RL which complies with the safety and reliability requirements for a period of at least 20 years, including the Dutch Nuclear Energy Act (Kernenergiewet) [23] and recognized standards. The total project scope includes the air supply and extraction systems of the cells, glove boxes and of the building itself.

The project follows the regular internal procedure for nuclear safety and engineering of NRG, which is based on IAEA SSG-24 [2]. Furthermore, the internal procedures for asset management and project management are also applied. These procedures require the projects to be sorted into distinct phases, with regular stage-gates at the end of the phases. The regular project phases defined in the internal policies are: initiation, basic design, detailed design, work preparation, execution and commissioning. The stage-gates require a review of peers, safety committees or the regulator (depending on the project phase) and approval of the operating organisation's management. Approvals of these stage-gates are a prerequisite for the approval of requested changes of the facility.

The two major project limitations are the following:

- The principal process flow, as presented on the flow diagram of the ventilation system, shall not be modified, unless it is deemed necessary based on new analyses. The project shall be executed through targeted improvements and preferably one-on-one replacements of the existing components. In this way the reliability of the existing system can be improved quickly and effectively.
- The project shall be executed within the planned maintenance stops of the RL. No additional production stop shall be requested by the project. The RL year planning allow for about 5-6 weeks maintenance, spread out over 4-5 stop periods, depending on the planning of the HFR. As the ventilation system is necessary for the safe operation of the RL, work on the ventilation system during regular operation (handling of radioactive

material) is not permitted. This is a serious limitation of the project execution and results in a long-running project with a relatively small project team.

Project plan

The scope of the project is based on the recommendations from various inspections [3,4,5,6], failure mode, effects and criticality analysis (FMECA) [9], asset integrity and obsolescence management considerations [10] and 10-yearly license evaluations [7,8].

Due to the wide range of sources for the recommendations and actions, the complexity of the actions and modifications also varies. Therefore, during the initiation phase of the project, the recommended modifications were split into two categories: 'maintenance' or 'improvement' modifications. Maintenance modifications follow from the aging of the facility, these are functional 1-on-1 (functional) replacements of components. The criteria for the selection came from the change management categorisation process of NRG: if the modification has no impact on nuclear safety, or has limited impact on nuclear safety without changing the functionality of the system, it has been considered as a maintenance modification. The rest of the modifications were considered as 'improvement'. These modifications have an continuous improvement origin (regular license evaluations). With the end of the initiation phase, the project was formally split into a 'Maintenance' and an 'Improvement' subproject based on these lists.

The actions from the Maintenance subproject were combined into 6 work packages which were executed in parallel, with separate change requests, separate project phases and separate stage gates. The scope of the Improvement subproject was bundled into one large change request and into one integrated basic design phase. From the detailed design phase the Improvement subproject may be split up into separate work packages as it has been done for the Maintenance subproject.

Proposed modifications with limited impact on nuclear safety are subjected to less stage-gates than modifications with a higher impact. As all modifications of the Maintenance subproject fall into this category, these modifications were expected to be implemented quickly. This has enabled the project to replace obsolete components relatively fast, making the facility more reliable.

The maintenance modifications are executed with the assumption that the safety analyses of the facility shall not be modified at a later stage of the project. However, there are analyses commissioned for the improvement part of the project to further substantiate claims of the license.

This separation has been instrumental in prioritizing work arising from asset integrity considerations. This was necessary as many components and subsystems have reached the end of their technical life. These actions ranged from the smallest maintenance actions such as replacing gaskets or re-torqueing fasteners to work complex enough to classify as a separate project, such as the replacement of cell extraction ductwork or the replacement of the ventilation control systems.

The list of recommended modifications and their category is listed in Table 1.

Table 1: List of recommended modifications

Description	Category
Replacement of the ductwork of extraction systems where needed	Maintenance
Replacement of the ladder type filter housing of the building ventilation	Maintenance
Renovation of the Air Handling Unit and building supply system	Maintenance
Renovation of the bypass loop of the iodine filter	Maintenance
Replacement of the Inlet Vane Dampers of the building and cell extraction fans	Maintenance
Replacement of existing control system and cabling	Maintenance
Replacement of the primary filter housing of the HA cells	Improvement
Replacement of the last stage filter bank of the cell ventilation system with possibility to introduce online iodine filtering	Improvement
Upgrading HEPA-filters to H14	Improvement
Replacement of fans of extraction systems	Improvement
Filter test bench for acceptance testing of new incoming filters	Improvement
Replacement of cell supply of the HA cells and F/G cells	Improvement
Replacement of the pressure alarm system	Improvement
Decommissioning off-gas system, modifying the ventilation of the Actinidelab	Improvement
Decommissioning of iodine filter system, iodine filtering to last stage filter	Improvement
Replacement of reference pressure system	Improvement
Replacement of negative pressure measurements	Maintenance
Extension of control system with redundancies	Improvement
New process monitoring system	Improvement

CURRENT STATUS OF THE PROJECT

The project has started in the second half of 2018, with a long initiation phase which included a validation and update of the available as-built information. Documentation was inherited from the previous renovation project, which had to be validated as well. This has rendered the initiation phase long, with the advantage that the project team had gained sufficient knowledge of the facility. Inspections and analyses were executed in the period of 2019 and the list of modifications for the two subprojects were finalized in the end of 2019. The stage gate closing the initiation phase was approved in 2020. Since then the two subproject progress in parallel.

Maintenance subproject

The Maintenance subproject has been prioritized in order to be able to quickly replace the most deprecated components and subsystems. From the 6 work packages two, the replacement of the inlet vane dampers and the replacement of the control system are finished, and another two, the replacement of the extraction ducts and the renovation of the building supply system, are in the execution phases. A short summary is given in the next chapter about some of these work packages.

Replacement of inlet vane dampers

The original Inlet Vane Dampers (IVD) of the building and cell extraction fans had to be replaced with high priority because of aging. These dampers were supplied by Pollrich and were in operation since 1964.

The dampers were replaced with units similar to the existing ones because they were part of an existing system. Thus the new IVDs have been specified to the same functionalities and performance as the IVDs which were replaced. However, the technical specification of the new design was based on newer codes and regulations such as ASME AG-1 and the European Machinery Directive 2006/42/EC. The specification made by the project engineers covers the minimum requirements for the measurement of the actual situation, design, engineering, manufacturing, assembly, inspection, factory testing (FAT), preparation for shipment, delivery and transportation to site.

The new radial IVDs and their flexible connections were engineered, assembled and tested by PMT Nuclear. The dampers are driven by Spring Return Pneumatic Actuators. The damper operation is controlled by a pneumatic positioner. The actuator fails to the damper open position just like the actuators of the old IVDs.

Extensive pressure drop and flow measurements were performed on the old IVDs and on the new ones after they have been installed. This was needed because of a difference in the design, in the center of the damper blades is now an opening instead of a center hub, which results in a lower pressure drop for the new IVDs. This made the recalibration of the closed-loop control system of the ventilation systems necessary.

Replacement of the electric control system

The relay-based electric control system of the RL dated back to 1964. The reason for the replacement of this system is that it’s technical and economic life has been exceeded. The system was difficult to maintain as spare parts were scarce and the system was not touch-safe, components were controlled by 230 V AC. The availability of the system was also declining. Therefore, a high priority action was defined as the functional one-to-one replacement of the ventilation control system with the associated power distribution and cabling. Reliability and service life requirements were defined in accordance with the goals of the whole project. The relay control of the ventilation system was replaced with a PLC technology based system while retaining the original functionality by means of application of a “like for like” control.

The in-house team of engineers have thoroughly described the functionality of the existing system [11]. This, together with the technical specifications based on the relevant IEC standards for the electrical, instrumentation and control components have formed the base of the engineering process. This group of engineers stayed in the role of owner’s engineers until the modification was finished.

Various analyses, such as structured what-if and FMECA were used to demonstrate the compliance with the operating license of the RL and the required availability [12].

The new electric control system was engineered, assembled, tested, installed and commissioned by an external supplier. The design was detailed in three consecutive steps with a hold-point for client approval after each step. The whole engineering trajectory lasted for over a year but the regular reviews were important in de-risking the project.

The installation and commissioning work was estimated at 8-10 weeks. Given the longest production stop periods are two weeks, the installation of the new cabling and control cabinets had to be done during the regular operational period of the RL while the old system was fully functioning. The maintenance period was reserved for the commissioning of the new control system and to switching the operation of the ventilation system to the new control system. All functionalities of the completed control system were tested on the shop floor of the supplier and witnessed by the owner's engineers prior to delivering it to the RL. The full test protocol was repeated after integrating the control system with the ventilation system, including the switches from the mains to emergency power and back during the on-site commissioning of the new system. After a waiting period of 2 months the original electric control system was decommissioned.

Replacement of ductwork

A recommendation from safety evaluations and fire analyses was to replace the ductwork connecting the G-cells with the main extraction ducts. These, including the pressure control dampers and filter housing of the second HEPA-filter stages of the cells, were made of combustible and brittle PVC.

The extraction ducts of the F-cells were made of threaded steel pipes, copper, stainless steel, mastiek duct tape and partly made of PVC. The work carried out in these cells makes a high integrity ductwork necessary.

The work was conducted by the engineering and maintenance teams of the NRG organisation. The ductwork connecting to all F-cells, including all dampers and filter houses have been replaced with AISI 316L components. Engineering was done in-house, with as much as possible pre-fab in the workshops to limit the downtime of the cells. All cell connections have been designed for a maximum flow of 50 m^3/h. The ductwork has been realized with dampers and filter housings designed for this high integrity application using welded connections were possible. Welding is performed using a qualified orbital welding process by qualified welders.

Improvement subproject

The Improvement subproject is currently in the basic design phase. The majority of the design work has been outsourced to an nuclear engineering company. The planned deliverables for this phase are safety classification of the systems, subsystems and components (SSCs) of the ventilation system according to IAEA SSG-30 [13] and associated Safety Integrity Level (SIL) classification for the safety systems [20], an update of the deterministic and probabilistic fire analyses of the RL, the basic design of the new ventilation system and the safety evaluation of the new design.

This document package together will be the base for the approval of the stage-gate closing the current project phase. The planned finish of this phase is the end of 2022.

The safety classified functions of the control system are planned to be built as a Safety Integrity Level-classified (SIL) [14] system. In order to achieve this, a relation needs to be established between the safety classification and the SIL-classification. The IAEA guidance does not give the specific tools and restrictions to practically design a system. Moreover, quantitative design criteria are not given; the necessary redundancy, the need of safety certified components and the necessary risk reduction, are not immediately clear. To use the framework of standards that accompanies SIL, a relation between IAEA safety class and SIL has to be established. The concept of Functional Safety and SIL is well established in the group of standards to design and maintain safety related functions. From this basic standard a nuclear industry-specific series [15] are derived. A way to establish the required SIL that directly links to the classification of systems is to use of IEC 61226 [16]. This document follows the general principles given in IAEA SSG-30 among others, and it defines a structured method of applying the guidance contained in those codes and standards to the I&C and electrical power systems that perform functions important to safety in a Nuclear Power Plant (NPP). It links the IAEA safety classes 1, 2 and 3 directly to the IEC safety classes A, B, and C. In other publications [17] the link between IEC classes and SIL levels is defined.

In order to achieve safety classification based on the IAEA SSG-30, the classification has been linked with the permitted incident frequencies and corresponding consequences as defined in the Dutch 'Nuclear Installations, Fissionable Materials and Ores' Decree (Bkse) [18]. This was a complex process as the frequency for each Postulated Initiating Event (PIE) had to be determined. With the calculated consequences of each PIE the classification of functions and systems has been established. Then, the IAEA classification was linked with the SIL using the link between the IAEA and IEC classification as it has been established above.

A graded approach was applied in the latest version of the report which is currently under review by the site's safety committees [19]. The interlock between the ventilation systems (see in Chapter 'Ventilation system') and the control system of the pressure differentials have been classified with an safety class and a corresponding SIL 2 class. The other subsystems of the building and cell extraction systems must also reach a minimum availability to comply with the license requirements.

LESSONS LEARNED

In this chapter a few experiences distilled from past project activities are summarized.

Consider project limitations early

The most important limitation is the time available for execution. The RL operates with more than 300 planned production days per year (every week Monday to Friday and most Sundays). This planning is necessary for the continuous and reliable supply of medical isotopes. As the ventilation system is necessary for the safe operation of the RL, work on the ventilation system during regular operation is not permitted. This is the most important limitation for the project as it means that a few weeks are available for work execution. Furthermore, this time has to be shared with the preventive maintenance activities and the execution of other projects. Therefore, execution planning is already considered in the basic design phase within the project and the planning matures together with the design. This is a lesson learned over years of this project which by now is communicated with all the suppliers early on.

Check the available space and include this limitation early on

The last-stage HEPA filter house is due for replacement because of its obsolescence. The filter house is made of carbon steel for 8 HEPA filters of 610x610x610 mm. Currently H13 filters [21] are used. This filter bank was installed in the early 60' and doesn't allow for a safe bag-in-bag-out filter change procedure. According to the original design, the cell extraction needs to be shut down before filter change. This is no longer acceptable as safe filter change and ventilation of the enclosures during filter change are required. Finally, the possibility of in-situ filter efficiency measurement is also seen as a must in an up to date facility. The filter house is located in a separate room on the ventilation loft which is accessible through the transport hall via two small doors.

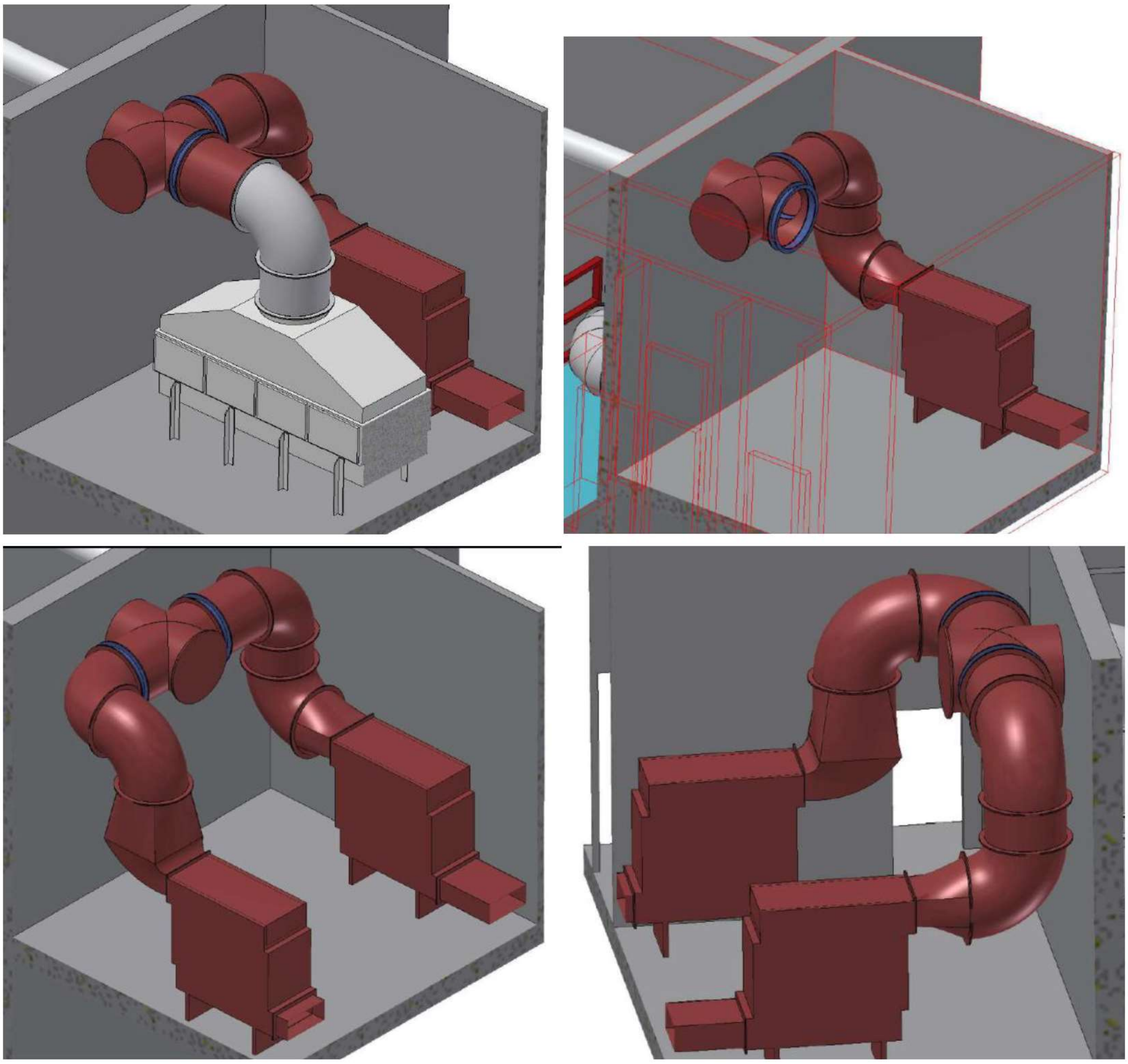

Figure 1: stepwise replacement of HEPA filter housing

As part of the Improvement subproject the replacement of this filter housing, the upgrade of the HEPA filters to H14, and the inclusion of iodine filtering in the new filter housing is planned.

Feasibility studies have been made on the possible replacement of this filter housing as early as 2014 [22]. The proposed solution is to install two complete redundant front-access bag-in/bag-out filter houses. This layout has the advantage that when the filters in one housing need to be changed, that housing can be temporarily blocked out of the system.

The project has to take the space and time constraints into account. The first requirement is that the filter houses shall be delivered fully compliant and pre-tested, either to be assembled in the room to avoid having to break down the walls, or to be delivered fully assembled to be able to lift them into position through a temporary roof opening. The second requirement is to minimize the down time of the RL due to the execution of this modification. Therefore, a stepwise plan of the modification is worked on already during the basic design phase of the Improvement subproject to aid component selection, to ensure limited downtime and that the filter change procedure will be viable within the available space.

The feasibility study proposes the introduction of a cross duct with dampers on all ends. The only needed interruption of the enclosure ventilation is for the installation of this duct. After the installation of the houses and the removal of the current one can be done with the ventilation in normal operation. The steps are presented on Figure 1. The first step is to install a cross duct. This is done with the ventilation fully off. Afterwards the ventilation is turned on, and the installation of the first filter housing can be done (top left). The ventilation can afterwards be turned to the new HEPA housing. This can be done without interruption of the ventilation of the laboratories. The old filter housing can be then taken out (top right) and the second housing build in (bottom left and right).

Define project scope and boundaries clearly, also include explicitly what won't be done.

The scope changes are almost unavoidable on such complex renovation projects, especially if inspections/technical state still have to be done. However, scope creep can be avoided with good definition of the project and its exceptions, and with finishing project activities before starting new ones. The choice was made for this project to exclude the static confinement of the building and the enclosures and the utilities (electricity and pressurized air) of the ventilation system. This allows for a focused effort on the project scope, and mostly avoids possible uncertainties associated with the excluded items.

Validate that the exiting utilities will be fit for the new components.

A hard-learned experience on the project is that although certain systems have been excluded from the project scope, those can still lead at least to incorrect budget estimates, or delays of the project. With the replacement of the IVDs the pressurized air supply of the system had to be inspected as the operational pressure of the new actuators is considerably higher than of the old ones. In contrast with the early evaluations suggesting that the replacement of pressure reducers will be sufficient, the whole piping of the pressurized air of the ventilation loft had to be replaced, including emergency supply system of a compressor, buffer tanks and fittings to meet the new requirements and new directives [24]. This resulted in two man-months of unplanned effort and considerable costs for the engineering and maintenance teams of the RL.

Make a detailed product breakdown and organize work according to it. Manage items independently of each other as much as possible, while keeping the overview.

One of the most important lesson from the past projects aiming to renovate the ventilation system is that when the whole project scope is bundled into one package for the review and approval of the stage gates, then delay with the work or approval of one scope item delays the stage gate of the all scope items. This can halt the whole project and has happened in the past. For this reason the separation of the scope items according to their origin, and the subsequent separation into Maintenance and Improvement subprojects was implemented. These subprojects were then broken down further into packages based on subsystems, with each package having one or more item assigned from the total project scope. The engineering and project management processes have progressed separately for these packages where the interfaces between the subsystems have allowed for it. This approach have made it possible that not the pace of the slowest scope item is setting the pace of the whole project.

Define early which process parameters are needed for the engineering of the new systems and components. Plan ahead how the missing parameters will be measured and what tolerances are acceptable.

During the initiation phase of the project, it was found that the ventilation process parameters needed for the safe operation of the facility is a subset of all parameters needed for the design. Only the pressure differentials between confinement boxes and the building, and between the building and the environment were continuously logged. It was quickly decided that a continuous measurement of flows in the main supply and extraction ducts were needed to be able to specify and commission new components. This additional activity has delayed the project early on and has led to unplanned costs.

Extensive measurements in well-defined conditions were also needed to gain enough information about the system for the basic design phase of the Improvement subproject. This could not have been achieved during regular operation of the facility and it has resulted in further delays of the design process. Furthermore, the existing ventilation ducts were not equipped with tapping points for measurements and the actual layout of the system did not allow measure according to codes to achieve small uncertainties of the measured values (straight ducts were not long enough).

Define all system interfaces early and don't make assumptions about the other system.

The new control system had to be interfaced with the building management system (BMS) of the RL. The project team has assumed that connecting to the BMS will be quick and easy based on a recent experience from another project of connecting to the BMS. However, the ventilation control system had to connect to another cabinet of the BMS than the other project. This cabinet was a different series and much more time and effort was needed to establish the connection than what was planned. Contacting the owner of the BMS earlier would have allowed for a realistic planning. Ultimately, a great effort of everyone involved has made it possible to establish the connection on time.

Commission a detailed asbestos survey for the room or system which will be worked on.

The existing asbestos survey of the building was not detailed enough for the renovation work on the ventilation system. Mainly gaskets of the building supply system and wall pass-through of the hot water piping were expected to contain asbestos. A detailed survey of the supply system was commissioned as part of the work preparation and plans were made to remove the asbestos in accordance with the legislations. Finding an undocumented asbestos source would have been dangerous for people working without protective equipment and would have brought the work execution to a complete stop.

The use of codes and guidelines for nuclear reactors, even with a graded approach, is difficult and time consuming.

The RL does not classify as a radiological laboratory in the Dutch system [25] due to its high inventory of radioactive materials. This, together with the fact that IAEA documents for research reactors are widely used by NRG, leads to the application of standards and codes for nuclear reactors. Often a graded approach is applied when using these documents with the intention to ensure that the necessary levels of analysis, documentation and actions are commensurate with the magnitudes of the hazards of the facility. Within the project this route was followed for the safety classification according to IAEA SSG-30, which is also safety guide for NPPs. The whole process was slowed down with many discussions, with the main perceived risk of following the NPP requirements too closely and over-engineering the system. It was unclear in the beginning whether the grading will be applied to the safety classification or to the technical codes. The choice was made for grading in the classification in order to be able to differentiate between safety relevant systems (to keep the number of classes). The disadvantage of this choice is that the translation of these graded classes to technical requirements is less straightforward than without grading.

CONCLUSIONS

In this paper the renovation project of the ventilation system of NRG's Research Laboratory was presented, with focus on the current status, the project plan and the lessons learned. The project is delivering it's results with a pace permitted by the planning of the RL facility and ultimately it contributes to the safe operation of this hot cell facility in the coming decades.

REFERENCES

1. Veiligheidsrapport Kernenergiewetvergunning NRG-Petten Deel 4a Hot Cell Laboratories – Research Laboratory, NRG report 16.139700, rev. 5, 14-9-2021
2. Safety in the Utilization and Modification of Research Reactors, IAEA Safety Standards Series No. SSG-24
3. NRG Ventilation and Air Cleaning Systems, Dr. Ronald R. Bellamy, June 2019
4. External Visual Inspection on Air Ducts, Inspection Report, J. Smollich, 23.07.2020
5. HCL-RL Compliance to ISO-17873, J.C.A.C. Engineering and Construction
6. Inspection of the HCL RL ventilators, NRG report 14.128019, 30 July 2014
7. HCL 10-EVA2017 Samenvattende Beoordeling, NRG report 19.157022/1.0
8. Verzamelde verbeterpunten en maatregelen 10-EVA voor HCL, NRG report 07.85762/C
9. Faalkansanalyse ventilatiesysteem HCL-RL 2019, NRG report 19.157029/C
10. Asset Integrity Programma NRG nuclear facilities, Asset Integrity Results Workstream 1, NRG report 13.120219
11. Functional description HCL Ventilation, NRG report 19.157070/B1
12. Integraal Wijzigingsvoorstel 'HCL RL vervanging besturing', NRG report IWV-2019-108, rev. 1.5
13. Safety Classification of Structures, Systems and Components in Nuclear Power Plants, IAEA Safety Standards Series No. SSG-30
14. Functional safety of electrical/electronic/programmable electronic safety-related systems, IEC 61508

15. Instrumentation, control and electrical power systems of nuclear facilities, IEC SC45A
16. Nuclear power plants - Instrumentation, control and electrical power systems important to safety - Categorization of functions and classification of systems, IEC 61226:2020
17. David J. Smith & Kenneth G.L. Simson, Functional Safety: A Straightforward Guide to Applying IEC 61508 and Related Standards, Second Edition, EAN 9781592783274, Elsevier
18. Besluit kerninstallaties, splijtstoffen en ertsen, BWBR0002667
19. Categorisering/klassering veiligheidsfuncties/systemen: Ventilatiesystemen van RL, NRG report 19.158492, rev. I, in draft
20. Safety Classification to Safety Integrity Level (SIL), NRG report 19.152107
21. EN 1822-1, High efficiency air filters (EPA, HEPA and ULPA) - Part 1: Classification, performance testing, marking
22. Feasibility study, HEPA filter housing change, NRG report 14.128018
23. Kernenergiewet, BWBR0002402
24. DIRECTIVE 2014/29/EU on the harmonisation of the laws of the Member States relating to the making available on the market of simple pressure vessels
25. Richtlijn 'Bijlage radionucliden-laboratorium', februari 2018, ANVS