36th NACC, June 28-29, 2022, Salt Lake City, UT

Replacement of Inlet Vane Dampers

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ABSTRACT

In the development of the nuclear site of Petten in the Netherlands a hot cell laboratory was commissioned in 1964. The main purpose of this laboratory was to do post irradiation examination. Currently it is also used to develop and produce industrial isotopes and medical isotopes for diagnostic purposes and also the treatment of several types of cancer.

For safe operation of the laboratory, it relies on several systems with a safety function. The ventilation system is one of those systems and ensures safety functions like dynamic confinement/ monitoring/ purification, and cleaning of air. This protects workers, public and environment against the spread of radioactive contamination. This makes it an important system and challenging to work on in an operational laboratory.

While changes were made on the ventilation system and the laboratory itself since it was commissioned, the components that serve the safety functions and other key components of the ventilation system were never replaced. As operation of the laboratory will continue for at least 20 years, a project was initiated to extend the technical lifetime of the ventilation system accordingly.

The project started with a verification of the documentation against the as-built situation and also the inspection of components to identify their technical condition. Results of the inspection showed that the inlet vane dampers were in a poor operating condition and in need of replacement. Inlet vane dampers are used to control the amount of flow through the system and are therefore critical for controlling the dynamic confinement. Dynamic confinement is one of the main safety functions of the laboratory's design, making it a challenging replacement. It was decided to replace the IVD's "Like for like" which means the functionality of the original design should not change. Limited information on the original IVD's was available, so a specification for the new IVD's was based on the inspection and today's standards. During the replacement process, there were deviations from the original design and valuable lessons were learned, but the replacement was a success and has made the ventilation system more reliable again.

INTRODUCTION

In the development of the nuclear site of Petten, in the Netherlands, a hot cell laboratory (HCL) was commissioned in 1964. The original main purpose of this laboratory was to do Post Irradiation Examination (PIE) of materials, but applications for isotopes have changed throughout the years. At present, the laboratory is mainly used for production of industrial isotopes and the development and production of medical isotopes for diagnostic purposes and also for the treatment of several types of cancer.

The laboratory is originally set up with five high active (HA) cells. These cells are made from barite concrete, equipped with lead glass and tele-manipulators. Extension was taken into account with the original design, so through the years more cells, gloveboxes and rooms were added. Currently, the five HA-cells are in use together with 17 lead cells and 15 gloveboxes.

For safe laboratory operation, it relies on several systems with a safety function, according to IAEA Specific Safety Guide SSG-30 [1], of which the ventilation system is one. The ventilation system ensures safety functions like dynamic confinement/ monitoring/ purification, and cleaning of air as described in standard ISO 17873 [2]. This protects workers, public and environment against the spread of radioactive contamination. The ventilation system is equipped with several safety classified components to serve the safety functions and it also contains other key components to serve other functions like comfort. The safety functions make the ventilation system an important system and therefore difficult to work on in an operational laboratory.

Main components of the ventilation system are located in the technical area on the upper floor. A civil air handling unit (AHU) is located there, which supplies the building with fresh air and with heat if needed. On the outskirts of the laboratory, air is being brought into the building through a series of ducts. Air is either being transferred through the laboratory from the outer rooms to the central hall or to hot cells and gloveboxes due to the pressure cascade within the building. Several hot cells are ventilated with nitrogen and do not use air or use air as a back-up. Air is extracted from the central hall through the building exhaust system. The building exhaust system consists of ducting, a series of filters (including HEPA) and fans. Cells are extracted through the cell exhaust system which consists of ducting, a series of filters (including redundant HEPA filters) and fans. Gloveboxes are extracted through the offgas system, which consists of ducting, a HEPA filter and fans. Filters and fans of these three systems are located in the technical area on the upper floor. The three systems join downstream of the fans in a plenum from which the air is released to the environment through a stack.

While changes were made on the ventilation system and the laboratory itself since it was commissioned, the safety components and other key components of the ventilation system were never replaced. This led to doubts about the reliability of the system and since operation of the laboratory will continue for at least 20 years, a project was initiated to extend the technical lifetime of the ventilation system accordingly.

Several projects had been initiated in the past to make the ventilation system reliable again, but without success. Lessons have been learned from those initiatives and the approach was different this time. Instead of one large project covering the whole ventilation system, this time the system was split into smaller subsystems and also subprojects. To be able do this, the project first started with an as-built assessment of the ventilation system, after which the project was split up per subsystem. The key components of the ventilation system were selected to be inspected for state of operation, integrity and expected lifetime.

The ventilation exhaust systems serves the safety function of dynamic confinement, meaning preferential airflow is maintained to limit backflow and prevent the release of radioactive material. The preferential airflow is maintained by a cascade of negative pressure between areas and is created by the ventilation exhaust systems. Key components in the exhaust systems are the flow control dampers that control the pressure cascade. These dampers were therefore selected for the inspection. These dampers are of the Inlet Vane Dampers (IVD) type.

INLET VAN DAMPER

The dampers that control the flow and maintain dynamic confinement are fitted on the suction side of the exhaust fans and are called Inlet Vane Dampers (IVD). The other end of the IVD is connected to a plenum with a flexible connection.

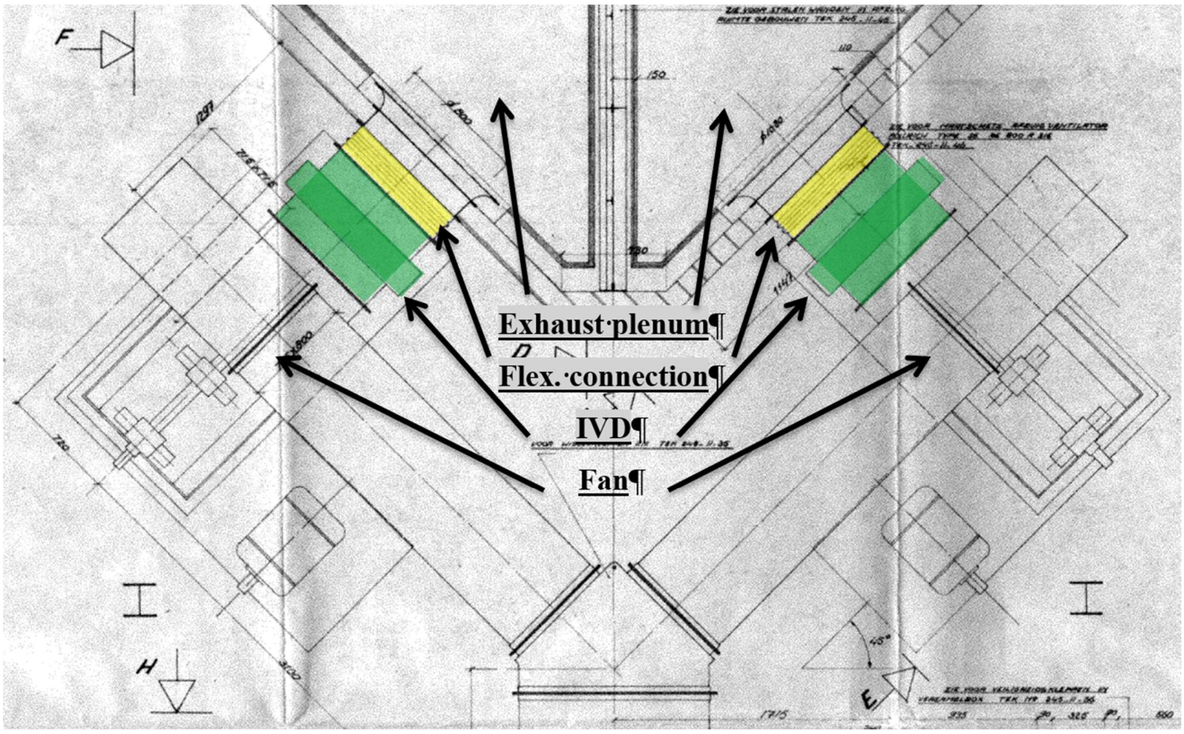

Figure 1 Lay-out building exhaust IVD's

Inlet Vane dampers are used to modulate the flow/pressure relationship. The IVD has a tubular housing and multiple blades arranged around the center of the damper. When the blades are partially closed, these will direct the air in a rotating movement due to the circular position of the blades. Air will enter the fan rotating in the same direction of the fan impeller. This reduces fan pressure, capacity and power without degrading the speed. This enables the system to control the exhaust flow and with that the pressure within the building and cells. Pressure setpoints to which the IVD's control, are:

- -80 [Pa] in the central transport hall for the building exhaust system
- -1300 [Pa] in the main cell exhaust duct for the cell exhaust system

For operation of the blades, the dampers are fitted with pneumatic actuators. These actuators use both a pneumatic signal as well as pneumatic drive which make a reliable compressed air supply mandatory. The actuators are also fail safe and use springs to fully open the IVD's in the event of a loss of compressed air. This produces the largest amount of exhaust flow which is best for dynamic confinement and therefore a safe condition.

In addition to the IVD's, a number of systems/components are present to realize the pressure control, namely:

- Pressure reference system. This transmits the outside pressure on the leeward side of the building;
- Pneumatic pressure booster and controller;

IVD ASSESSMENT

The system dates from the sixties and although drawings have been archived well, there are no details of the original IVD's. They have been delivered as part of the fans and therefore mechanical details were not provided. A maintenance program specifically for the IVD's was also not in place. As a result, knowledge about the mechanical functioning of the IVD's was lacking and a plan had to be made to do the assessment.

Assessment Method

The scope of the assessment was an external and internal visual inspection with regard to the operation and integrity of the IVD's. Disassembly of components was part of the inspection. The inspection of the IVD's was executed in order to identify

1. damages that already constitute a loss of integrity or functioning (e.g. cracks, holes, excessive wear etc.) and
2. abnormalities that could result in a loss of integrity or functioning (e.g. corrosion, scratches, bad alignment etc.).

The visual inspection was executed without following requirements of a specific standard but relied on the experience of the mechanic performing the inspection.

Assessment Results

The exhaust systems for both the building and the cells are redundant. This made it possible to shut down the redundant trains of both systems and still maintain the pressure cascade. From the operational license this is only possible when there is no production so this inspection was planned in the maintenance period. After shutting down the redundant trains, the protective covers on the outside of the IVD's were removed. The inside of the IVD's was inspected from the inlet by entering the plenum to which the IVD's are fixed to. Pictures and a sketch of the mechanical drive were made, see Figure 2.

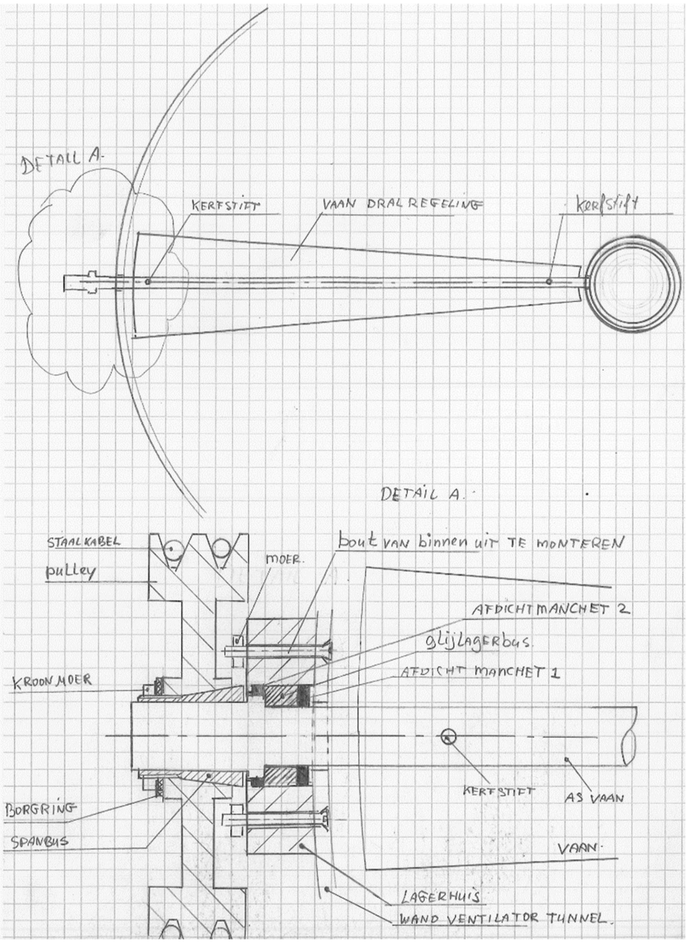

Figure 2 Sketch of the mechanical drive from the assessment in 2016

A hub was positioned in the center of the IVD to which shafts with vanes/ blades were attached to. On the outside of the IVD, pulleys were attached to the vane shafts which were driven by steel cables. A bearing housing with a shaft seal, sliding/ plain bearing and second shaft seal was mounted behind the pulley. The shafts/ pulleys were interconnected by the steel cable and driven from the main shaft. The main shaft contained a lever and positioner outside of the protective cover, making manual operation possible when pneumatic drive was shut down.

Investigation has shown that the IVD's have been severely affected by wear and corrosion, which has deteriorated the functioning of the valves. When removing the protective covers it was apparent that these had been collecting metal particles through the years. These metal particles came from wear on the pulleys. The metal cable had been cutting in het metal pulleys causing them to wear and since the cable was not tensioned by an automatic tensioner, this had a high amount of slack. Slack in the cable caused another problem. The shafts positioned further from the main shaft contained more and more play causing a different position of the vanes and the IVD to be less efficient.

Due to corrosion, a number of parts have come loose, causing rotating parts to move very heavily and show excessive wear. The heavy movement of parts was also found in the drive rod of the pneumatic actuator. The rod was bent due to the excessive power needed. Corrosion and loose parts are irreparable and damage continues to increase, reducing the operability/ efficiency of the IVD’s.

The flexible connections on the inlet of the IVD’s were aged and showed traces of released plasticizers. As a result, the connections had become brittle and had a reduced reliability.

The IVD’s were re-assembled after the assessment and did not suffer any further damage as a result of it.

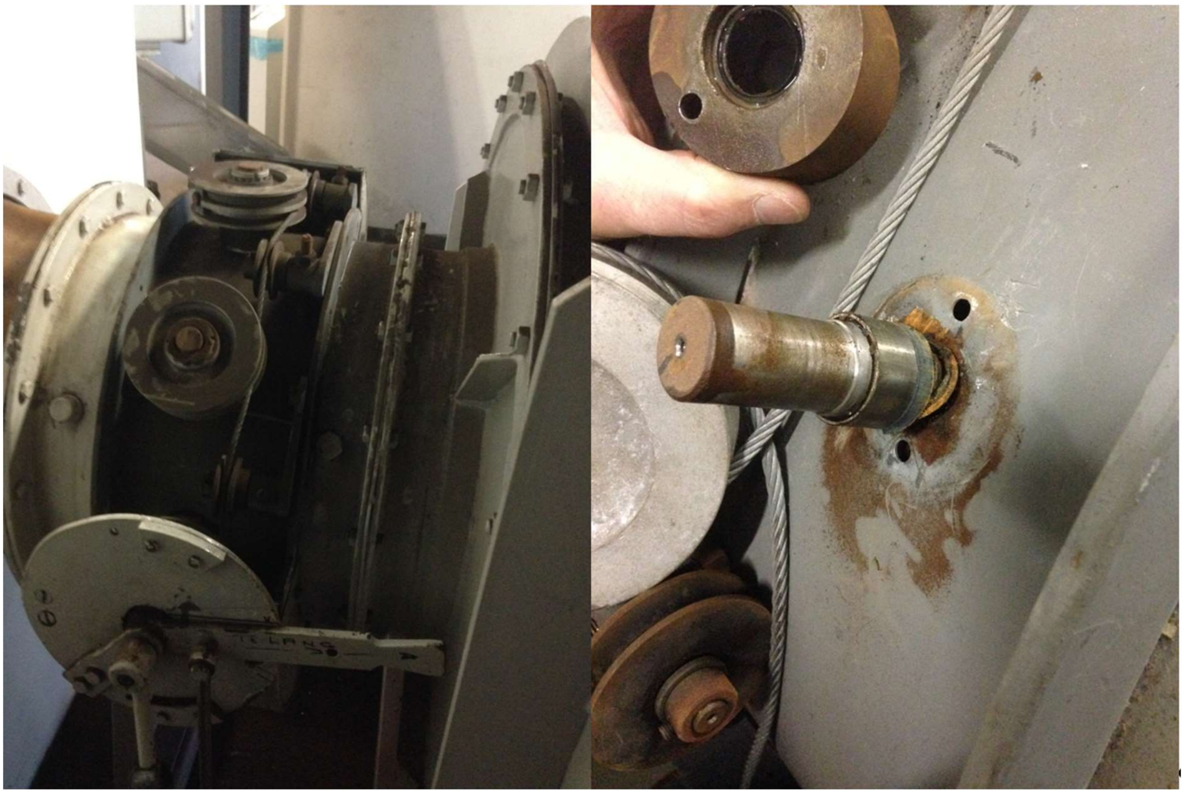

Figure 3 Assessment; covers removed on the left, corrosion and deteriorated seal on the right

Assessment Conclusion

All moving parts were worn and the integrity of the housing material was compromised by corrosion. Repairing corrosion is time consuming and meant that the ventilation system would be out of service for a relatively long period of time. The unavailability of spare parts would require them to be custom made which is relatively expensive. This made the replacement of the IVD’s the best option and since it’s functioning affects the pressure cascade and confinement function, replacement was required as soon as possible.

ENGINEERING

All key components within the ventilation system were assessed and showed signs of ageing. The state of operation of the IVD’s turned out to be the worst and required replacement as soon as possible. Replacement of the exhaust fans, including the IVD’s, was also considered since the fans showed signs of ageing, but modifications were foreseen within the ventilation project that would affect the design of the fans. These modifications had to be engineered first and it was estimated that this would take too long. The IVD replacement was therefore separated from the rest of the project and was given the highest priority.

Scope of the Replacement

Modifications within the ventilation system were foreseen and would affect the duty point of the fans, e.g. placement of extra filters. These modifications still had to be engineered but it had already been decided that flowrates would not change or at least remain within the current limits. This formed the basis of the IVD design and made it a "like for like" replacement. Within the scope was replacement of the following components of each of the four exhaust fans: flexible connection including mounting flange, IVD, pneumatic actuator and upgrade of the compressed air system. Due to lack of maintenance and reduced system reliability, more components in the compressed air system needed to be replaced. These changes will not be described in detail.

Within the engineering department of NRG there is a modification of change (MOC) procedure in which it is mandatory to notify and document any change to the installations. A change is categorized based on the type of system and modification as well as impact on the installation. In this case it was categorized as a low impact change with a “like for like” replacement. This meant that only the relevant and necessary documentation had to be in place (compared to a high impact change) and review would be done by internal reviewers.

A "like for like" replacement means that a component can be replaced by a different make/ type and may have minor differences but key parameters and functions should remain the same. In this case the replacement had an impact on the flow/ pressure characteristics of the exhaust systems and is connected to the pneumatic controllers and compressed air system. To maintain the same flow range for the IVD’s it was necessary not to change the pressure drop across the damper for the fully closed and the fully opened position. All flows in between the minimum and maximum capacity can be reached through the control system. To keep the same pneumatic controller it was necessary to replace the pilot positioner with a pneumatic type and keep the same pressure range for the pneumatic signal range of 0.3 to 1.0 bar(g).

Specifying the IVD’s

Detailed design information about the ventilation system and the IVD’s was not available (the used codes and standards for example). The new IVD’s would therefore be based on the assessment results and selected codes or standards. Since there are no set codes or standards from the regulatory body or the license, it was up to the engineering department to determine this. Multiple codes and standards have been considered and ASME AG-1 was selected. The final selection was between ASME AG-1 and DIN 25496 and the decision was based on the availability of suppliers.

A technical specification was written based on ASME AG-1. The level of detail of the ASME AG-1 code is high and made it straightforward to set up the baseline for the specification. Due to the unavailability of the original design, filling in the details took some more effort. Neither the IVD's nor other components within the ventilation system were classified according to SSG-30 [1] and therefore had no safety class. Setting up the classification of all ventilation components was already assigned from the beginning of the ventilation project but had its challenges. While the specification for the IVD's was being written, the classification was not finished and discussion arose about the required safety class. The discussion centered on whether the IVD's should be class 3 or 2. In order to maintain progress in replacing the IVD's, the decision was made for the higher safety class 2. Filling in other details could be done through research. For example the leak tightness requirement for the damper housing was based on the requirement for the ducting and since the IVD's do not have a shut off function, the leak tightness of the damper blades was unclassified.

Some changes were specified that did not affect the functioning of the IVD's but made them more durable compared to the original design. These changes were:

- Material. The original IVD's were made of carbon steel, but because these were affected by corrosion, the new IVD's were specified in stainless steel. Special attention was paid for galvanic corrosion as the connecting elements were still made from carbon steel;
- Seismic requirements. These requirements have been introduced over the years that the Petten site has been in is use. The original IVD's were not seismically classified or tested. For the new IVD's, the seismic profile was specified and incorporated in the design;
- Drive power. Pressure for the pneumatic drive of the actuators was raised from 1.4 bar(g) to 6.0 bar(g) resulting in more power for the drive. The ability to shut off the drive power was also introduced to enable manual operation. A shut-off valve and a blow-off/ drain valve were specified in the compressed air supply for each IVD;
- Manual operation. A manual control with clutch was specified to allow manual operation by disengaging the actuator and operating the IVD with a handwheel. In the original design, a handle was available for manual operation, but the actuator must first be detached using tools;
- Visibility. The actuators positioner was specified to be equipped with a valve position indicator for visual display and an electronic valve position indicator. This makes it easier and more accurate for the operator to see the blade position on the IVD. In the future it will also be possible to incorporate the display of the IVD's blade position when the control system of the HCL-RL ventilation system will be modified;

Design with the Supplier

Several suppliers had been found suitable to supply the IVD's. These were selected on the basis of experience with: the manufacture of IVD's, the codes ASME AG-1 / NQA-1 and the European machinery directive 2006/42/EC. Three suppliers were requested for a quotation, one of which has been selected.

The selected supplier had experience in delivering IVD's and had a design for this component. This design had several advantages over the original design. The drive of the shafts of the blades was with rods instead of the cables from the original design. This makes the drive more robust with less play and therefore more precise which is good for the efficiency of the system. It is also more easy to maintain because there is no need to tension cables, only the connecting elements have to be lubricated. Seals are double and almost directly mounted on the IVD's housing in a seal plate and together with the right type of grease it makes a robust seal in the right place. A different type of flex material was provided, a silicone-impregnated/coated glass fiber. This material has a number of advantages over the original PVC type material:

1. It is qualified radiation resistant;
2. It can withstand higher temperatures, 260 [°C] compared to the original 60° [°C];
3. It is UV resistant.

In addition to the design improvements mentioned above, there were some engineering steps that did not go as well as planned and required more effort for both parties, these included:

- Measurements which were required for the design were specified to be done by the supplier. This changed during the contract formation and it was agreed that NRG would take the necessary measurements (dimensions and pressure drop). Due to a lack of resources within NRG, measurements took longer than anticipated, causing a delay in delivery. It also led to a change in size with increase in costs. Pressure drop across the IVD's also had to be measured. As previously mentioned, pressure drop in a fully closed and fully opened position was needed for the "like for like" replacement. Measurement facilities were not available, so these had to be created. Since the air up and downstream of the fan is very turbulent, a suitable measurement setup had to be designed. The supplier proposed to make a measurement tap in each quadrant of the IVD housing both up- and downstream of the damper blades. The four points were connected both up- and downstream to get an average value on each side of the damper blades. The pressure drop could then be measured by using a differential measurement device. The IVD's were operated from the pilot positioners to fully open and fully close the dampers. Unfortunately, due to the system setup and the state of operation of the IVD's, data was only collected for the fully opened position. In this position, data was logged for 5 minutes. Data was also collected from the flow transmitters within the ventilation system. Flow and pressure drop for the closed position was unknown. The supplier's proposed design deviated from the specification because the proposed design had an opening in the center of the IVD instead of the center hub. The pressure drop in the closed position would therefore be less than that of the original IVD's, causing a change in range. Since the IVD's are mounted in the exhaust systems and these systems fulfill the confinement function, this was accepted. A larger flow would mean a more negative pressure;

Figure 4 dp measurement taps installed and dp measurement being performed

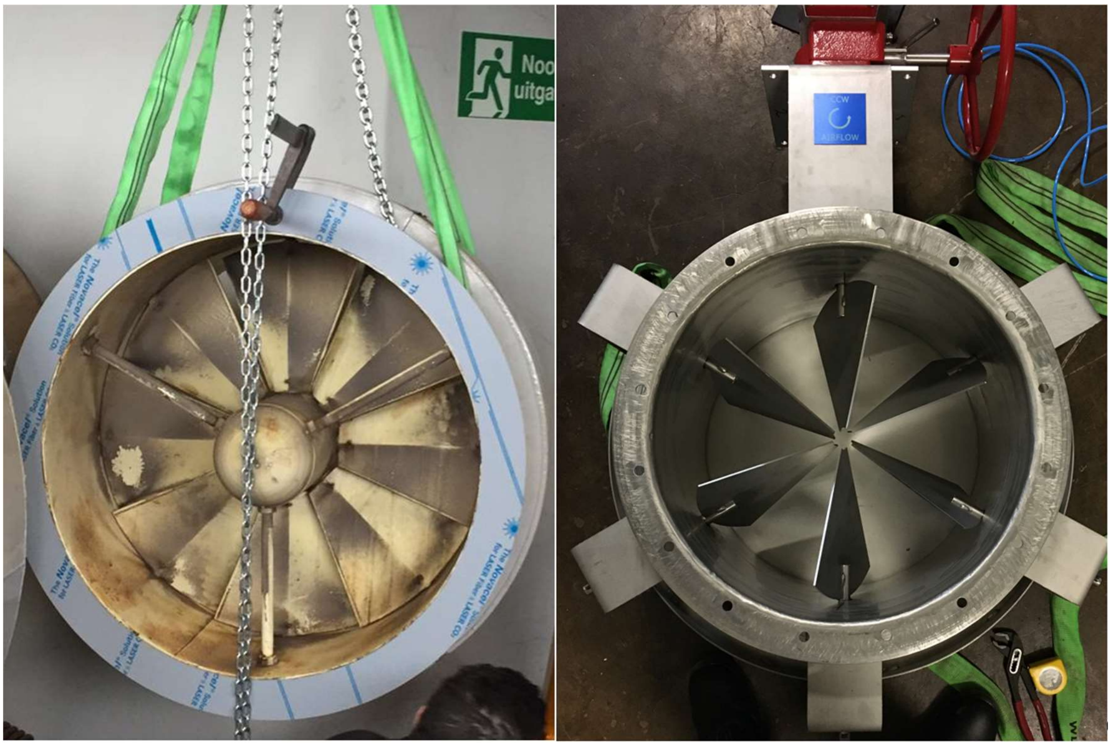

Figure 5 Original IVD on the left with center hub and new IVD on the right with center opening

- The use of metric sizes was not specified and since the suppliers design uses ANSI sizes, they are included in the design;
- Applying the machinery directive was specified and included in the supplier selection but turned out to be difficult. Materials in Europe must be supplied with a material certificate according to the machinery directive (materials according to EN 10204 type 3.1) but for the seismic calculation materials had to comply to the ASTM standard as this was necessary for the calculation software. This meant materials purchasing materials with dual certificates or setting up Particular Material Appraisals (PMA). With the PMA could be declared that the ASTM material would comply to EN 10204 for the specific function/ property allowing ASTM material to be purchased. Eventually, material was purchased with dual certificates so it complied to both codes.
  The CE required documentation was also difficult to be delivered and delayed the process. The supplier contracted a notified body to ensure that the equipment and documentation were in compliance with the machinery directive. This was not successful and in the end, the required documentation and CE marking were provided by the supplier in close cooperation with NRG

REPLACEMENT

This was a first time replacement of the IVD's, and since the mid 90's also the biggest refurbishment on the ventilation exhaust systems. The exhaust systems have a potential of being contaminated and also provide the safety function of confinement, so the replacement was considered a high-risk replacement. This meant that the execution of works had to be prepared and written down step by step in advance in a work plan together with the commissioning tests. Radiological risks and health and safety risks also had to be written in the work plan, together with the mitigating measures. The replacement had to be carried out by NRG maintenance technicians, so the work plan and preparation of the replacement was done in close collaboration between the engineering and maintenance departments. After approval of the work plan and commissioning plan, the work permit was granted. It was decided to start with the replacement of one building exhaust IVD because this system has a lower potential of being contaminated and a failure of the building exhaust system poses a low emission risk. As part of the commissioning process, the first new IVD had to run for a minimum of at least for two weeks with the removed original IVD next to it, so that in case problems would occur, the original IVD could be put back in place.
Special tools and equipment were ordered and set in place first. As a precautionary measure, a new controller and signal amplifier were also ordered just in case these would fail due to the works. The new IVD was inspected, tested and approved during pre-commissioning. After that, the replacement started by carrying out commissioning tests. Different settings for the exhaust system and also different situations within the building have been created and data for flow and pressure has been collected. This was done to establish the baseline for the new IVD. After this first step of commissioning, work on the system was started by switching off the specific fan and putting safeguards in place. Tests have been done to check for contamination and no contamination has been found for the building's exhaust. For the cell exhaust, one IVD had a low amount of contamination which could be secured easily because the work was well prepared for contamination. The plenum and pneumatic feed to the actuator were then blocked and the IVD

could be removed. The new IVD was installed and connected to the original pneumatic signal supply and the new pneumatic power supply of 6.0 bar(g) for the actuator drive. This allowed the technicians to test the IVD before connecting it to the plenum. For 2 IVD's, the pilot positioner zero-point had the be reset, but because the IVD's were pre-commissioned this was easily done and no further adjustments had to be done. After these tests the IVD was connected to the plenum with the new flexible connection. These turned out to be too long and needed to be shortened on site. After that, a controlled start was made with the new IVD and the first commissioning steps were repeated. Values for the baseline and final measurements were evaluated and although differences occurred, they remained within the limits. This meant that the new IVD's were put into service. By replacing only one of the two building exhaust IVD's, the system would work with one new and one original IVD. Operating them side by side went well. After this first successful replacement, the other building exhaust IVD was also replaced and for the cell exhaust it was decided to replace both IVD's within one maintenance stop.

The new IVD's were delivered with a manual for periodic preventive maintenance and maintenance was scheduled after one year of operation. Technicians had to learn the system and maintenance steps, but the maintenance was well designed and therefore easy to learn. Traces of oil were found from the declutchable gear for manual operation. The manual for the gear states that 5 [%] of oil can separate from the grease due to temperature rise. The gear is greased for life and cannot be refilled except during an overhaul. Since the oil traces seemed quite large, it was decided to order a complete spare actuator drive with declutchable gear, actuator and pilot positioner, in case problems should arise, this can be replaced relatively quickly.

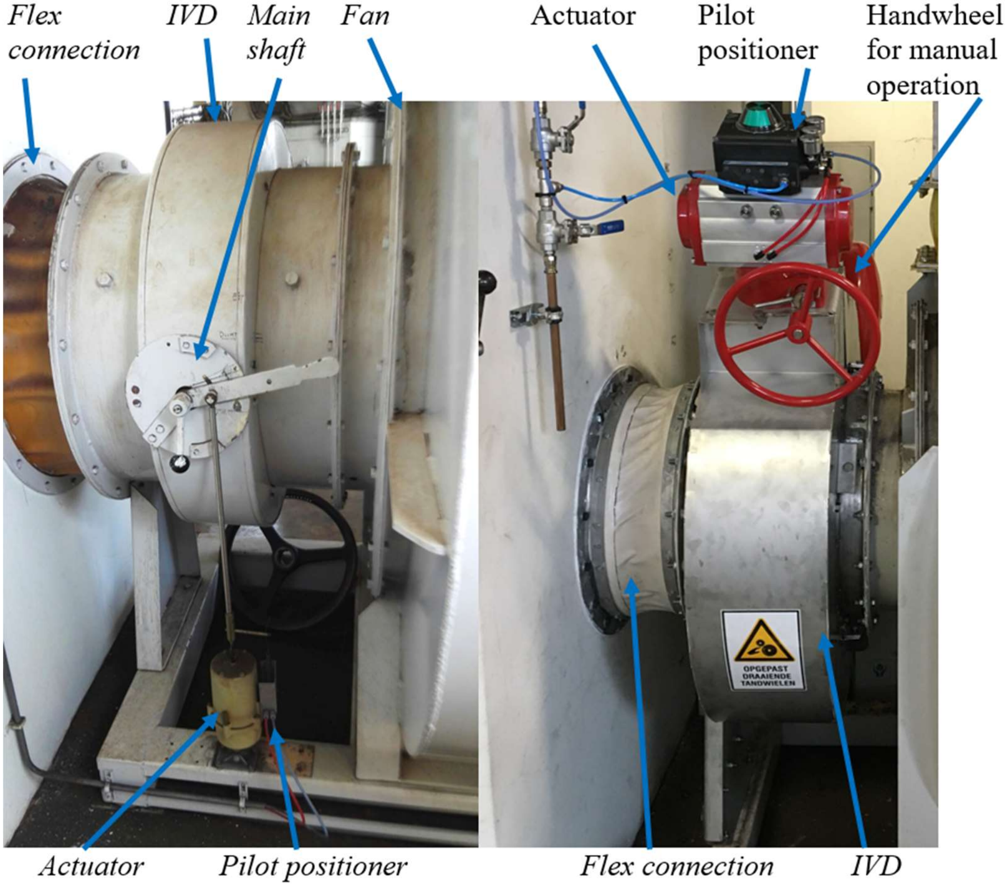

Figure 6 Pictures of the original IVD on the left and new on the right

LESSONS LEARNED

Neither the IVD’s, nor any other component within the ventilation system were safety classified. This made it difficult to agree to what safety class the components should be designed. In order to maintain progress, it was decided to design according to the higher safety class. As a result, the IVD’s may have become more expensive than necessary. Components that fulfil a safety function within a system should be safety classified so that there is a better understanding of these components, regardless of replacement. Safety classification should be part of the as-built information.

During the design phase with the supplier, it turned out that they were unable to deliver according to the specification/ contract. Specified was an IVD with a center hub, but as this was not the supplier’s typical design, they have proposed a design without a center hub. This meant that there was less pressure drop across the IVD’s, resulting in a higher flow. This change was accepted by the project team, but without further internal approval, which meant a risk for the project. The impact of this change should have been documented by the project team first and then reviewed and approved outside of the project team. The change in range was eventually accepted because it meant a better capacity for confinement.

The contract required measurements by the supplier. During the formation of the contract, the supplier proposed not to do the measurements and have them performed by NRG. This made NRG responsible and resulted in cost increase. For future projects, this should remain the responsibility of the supplier.

Machinery directive is European and was difficult for the supplier who was not European. Future selections should pay more attention to the supplier's experience.

The commissioning plan was delivered quite late in the project, which had an impact on the time for review and thus on the quality of the plan. As a result, tests did not fully complied to the requirements. The commissioning plan and tests should be written in parallel with the design. This gives more time for review and makes it possible to include test facilities in the design when required for commissioning, e.g. measurement taps.

Scope creep due to required changes and replacement of aged equipment in the compressed air system. Utility systems are also obsolete, so any change in these systems means a fairly large replacement. Changes in utilities should therefore be kept to a minimum.

CONCLUSION

Replacement of the IVD’s, in both the building and cell exhaust systems, was a success. The equipment was put into operation without any problems. Maintenance procedures are in place and are being carried out, meaning the IVD’s will continue to operate as designed, making the exhaust systems more reliable.

REFERENCES

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2. ISO/TC 85, “Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors”, 47 pages, published in 2004, by the International Organization for Standardization