Characterization of Contaminated Stacks at Nuclear Facilities - 9355

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ABSTRACT

The stack decommissioning processes have been explained at irregular intervals in procedural literature; there is almost no complete treatment of dismantling and decommissioning methods for contaminated chimneys. In addition, the International Atomic Energy Agency (IAEA) has published only one technical report that really focuses on this subject. The dismantling of contaminated stacks at nuclear facilities is one of the least topics approached in the decontamination and decommissioning (D&D) field. The demolition of several stacks located at Oak Ridge National Laboratory (ORNL) is on the priority list of D&D activities at this national laboratory. Decommissioning is the final stage of the life-cycle for a nuclear facility after its design, construction, commissioning and operation. The decommissioning process involves decontamination operations, dismantling and demolition. Also, decommissioning techniques are mainly driven by the results obtained in the process of characterization. The main purpose of the characterization process is to gather enough data to evaluate the radiological status of the nuclear plant or facility and to better understand the level of contamination. The whole approach of decommissioning is affected by the accuracy in the estimation of the amount and class of radioactivity in the nuclear facility. In addition, this estimation will establish and drive several factors such as the need for decontamination, waste management and disposal, shielding or remotely operated equipment, and estimating potential radiation exposures to the work force. One of the biggest challenges presented at ORNL is that the stacks are located between buildings that are currently being occupied and three of the five stacks are in deplorable conditions with high levels of contamination. Therefore, the use of remotely controlled equipment is needed.

To characterize a contaminated nuclear stack, a systematic procedure is used. First, the stack is divided into four sections by height, each section is zoned into four quadrants, and samples and measurements are taken in each quadrant by wall swiping, core sampling and scanning. These samples and measurements are collected and evaluated to estimate the levels of contamination inside of the stack. This presents an engineering challenge: to design a mechanism capable of swiping, drilling, collecting, and coordinating locations. There are several companies that offer alternative technologies for the characterization process; however, very few are applicable to high elevations and cylindrical structures. For this reason, a conceptual design is presented in this technical report that satisfies the needs for this project and it also opens a new alternative for non-conventional equipment in the process of radiological characterization.

INTRODUCTION

Elevated ventilation stacks are one of the most common structures present at nuclear sites. Their main purpose is to weaken and disperse the permitted airborne release from the active plant system. Environmental regulations stipulate the design of these elevated structures; this is for the safety of the personnel that work at the site as well as for the local area outside the site. The stack's height depends on several factors, such as the surface type and height of nearby buildings, weather conditions, and the potential nuclear capacity of the facility. These factors can result in a needed stack height of over 300 feet. Also, depending on the facility and its use, stacks are made of different materials, such as brick, concrete and reinforced steel.

Stacks become contaminated due to continuous use throughout the life-cycle of the nuclear facility. Depending on the levels of contamination and the physical conditions, the decommissioning of a nuclear facility can vary from a simple to a more complex level of difficulty. For these reasons, characterization is a key factor in the development of decontamination and decommissioning (D&D) plan at a nuclear site. The characterization process consists of collecting data to identify the physical and chemical characteristics of the structure being analyzed. This database will help the decommissioning planner to choose the best strategy for the specific site. Due to big challenges brought about by D&D activities in the past, several technologies have been developed in the last decades to ease decommissioning operations. However, because of several factors, such as specific shape, height and accessibility, contaminated stacks are a new challenge for this field. In addition, the location of the stacks within the nuclear complex adds another level of complexity into the D&D preparation; in many nuclear facilities, some of the stacks are built next to building offices. For these cases, available technologies are limited and the levels of risk for the workforce within the complex are extremely high. In this technical report, the general process for characterization of contaminated stacks will be summarized as well as all the previous work related to the decommissioning of nuclear stacks in the United States. This report will also summarize the technology available on the market for D&D projects, pointing out the advantages and disadvantages of each.
The dismantling of the contaminated stacks located at Oak Ridge National Laboratory (ORNL) represents a great concern for the safety and protection of the workforce involved in the D&D process as well for the personnel that work in nearby offices. As shown in Figure 1, the stacks at ORNL are located within an office complex, thus requiring more elaborate and specific technologies than the ones actually offered in market. A conceptual design is being developed with the collaboration of the Robotic Department at ORNL and Florida International University (FIU). This technical report will give a detailed explanation of all the requirements involved in the development of this conceptual design, including all the operations to be executed, activities such as contamination detection, core drilling and wall swiping. To make this process automated and remotely controlled, cameras and positioning sensors play a great part in the design. In addition, to make this mechanism economically efficient, one single prototype must fix into all the different size stacks. The use of a crane will be proposed for this first model, which helps in the execution of operations and deployment of this device in these cylindrical elevated structures.

CHARACTERIZATION PROCESS

Precise physical and chemical characterization is a key factor in the selection of stack dismantling tactics and technologies. Physical characterization gives the essential elements for calculating the residual mechanical properties of the stack and the time period in which the structure can safely remain in place. Nevertheless, accessing an elevated structure to acquire samples for physical or chemical characterization purposes needs cautious consideration of industrial safety for the protection of the workforce and surrounded areas. Characterization activities in contaminated areas will involve radiological protection provisions. Most of the stacks have a port access into the interior of the structure; the opening of this gate can precipitate and disperse the in situ contamination. This is one of the issues that a decommissioning planner has to face for the protection of the personnel. In many cases, remote controlled techniques such as video-graphic and/or robots are deployed to overcome the personnel safety issue. In the process of characterization, it should be noted that the technical reports related to the material discharged through a nuclear stack may be incomplete or outdated. The data obtained from the characterization process provides information that will help the decommissioning planner to establish whether the stack can be decontaminated in a cost-effective way. The depth of contamination through the inner wall is another important piece of information. The characterization process requires the use of a practical, effective, and efficient method. For example, instead of sampling the entire interior wall of the stack, which is also possible, the decommissioning planner may suggest the coring or swipe sampling of selected areas to obtain an accurate estimation of the level of contamination inside of the stack. As previously mentioned, the stack characterization affects the path of the whole D&D process, from the selection of technologies and techniques to the management of waste resulting from the D&D activities.

CHARACTERIZATION TECHNIQUES AND APPROACHES

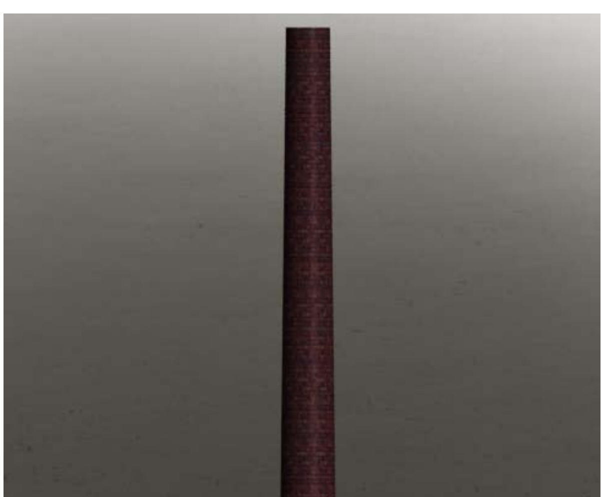
There is not a single technology that can attend to the full range of requirements for facility and material characterization. Frequently, characterization techniques are used in combination with one another to take advantage of the strengths and to compensate for the weaknesses of each method. Due to the different needs presented at each nuclear site, there is a large variety of techniques and devices built specifically for the deployment of the characterization process. The technologies on the market vary in their capabilities as well as their limitations.

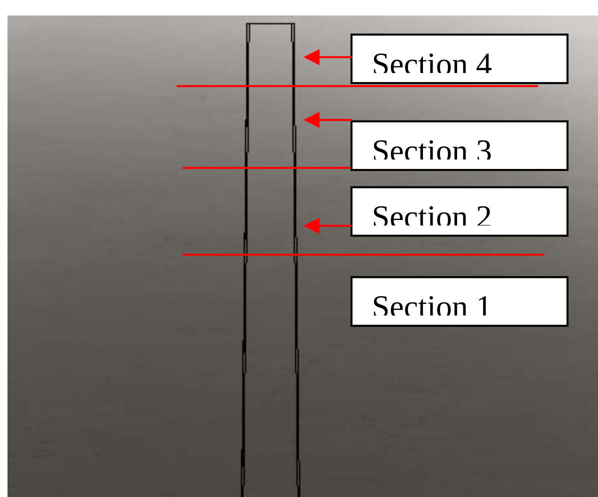
CONCEPTUAL DESIGN

The conceptual prototype presented in this technical report only includes the kinematical design of the mechanism. Also, an alternative deployment system is suggested since the use of a crane would reduce the general cost of operational execution. The main idea of this prototype is to create a mechanism that safely performs the general basic operations needed for stack characterization. These operations include core drilling, wall swiping and scanning for radioactive areas on the surface. To effectively achieve these electro-mechanical functions, several devises must be considered in the design, such as positioning sensors, linear actuators, gear boxes, cameras and stepper motors.

DEPLOYMENT

The stack will be characterized at four different heights, as shown in Figures 1 and 2.





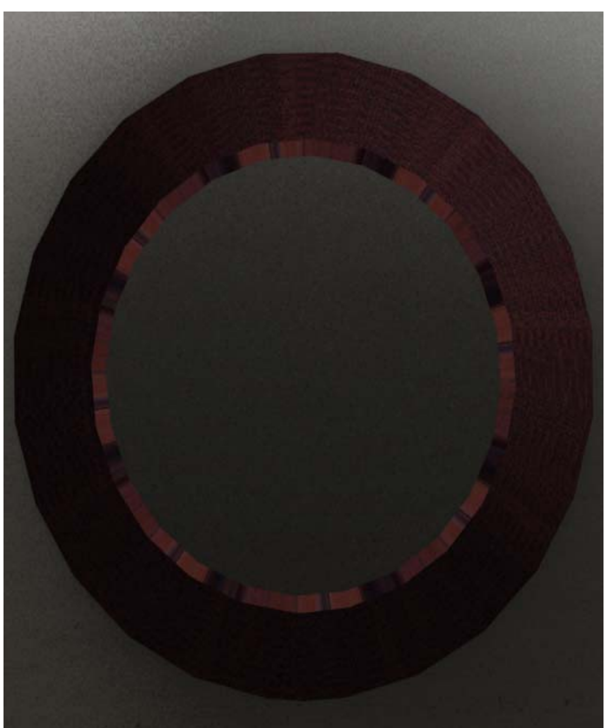


Figure 1. 3D representation of a brick stack.

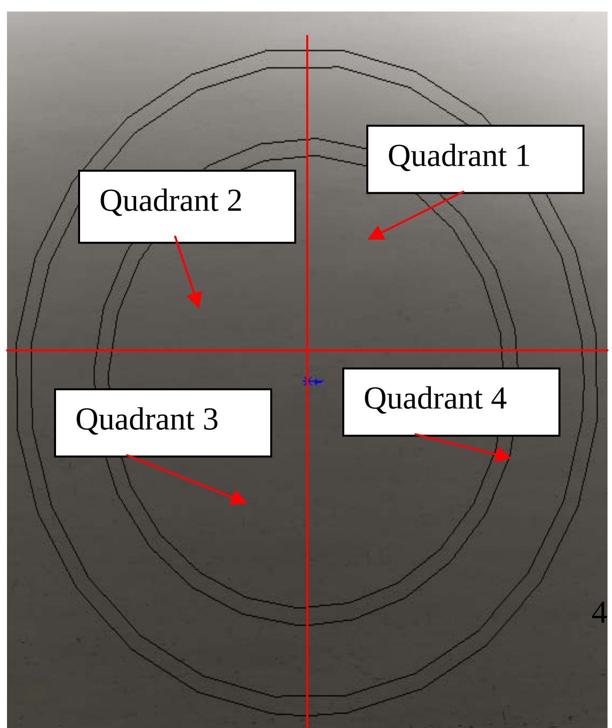


Figure 2. Sampling areas.

At each section, three main operations must be done. First, identify the most contaminated quadrant of the section with a scanning method. Second, wall swiping and core drill sampling are done for the most contaminated quadrant. Third, for the remaining quadrants, just wall swiping is performed. This cycle is repeated for every section. Each sample collected must be stored and protected from cross contamination. For this reason, the samples are taken from the bottom of the stack to the top. Figures 13-18 illustrate the conceptual design of the stack characterization mechanism.

Figure 3. Top view of a nuclear stack.

Figure 4. Quadrants of sampling areas.

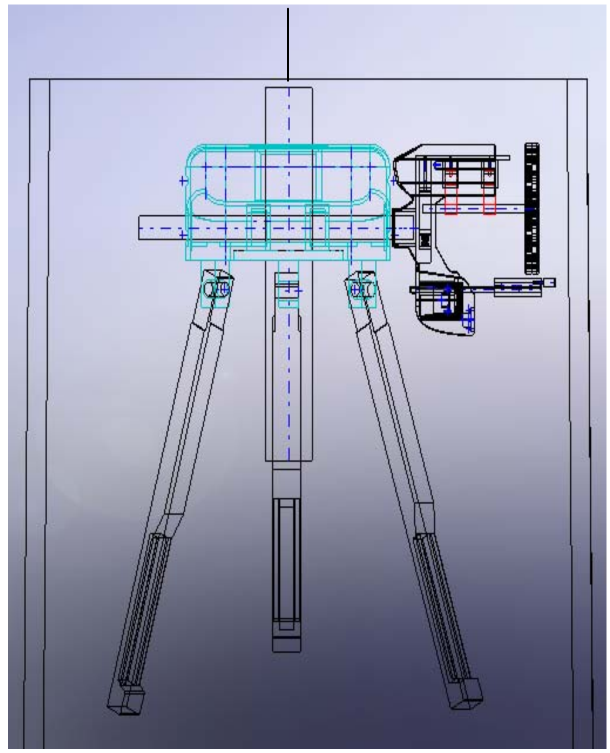
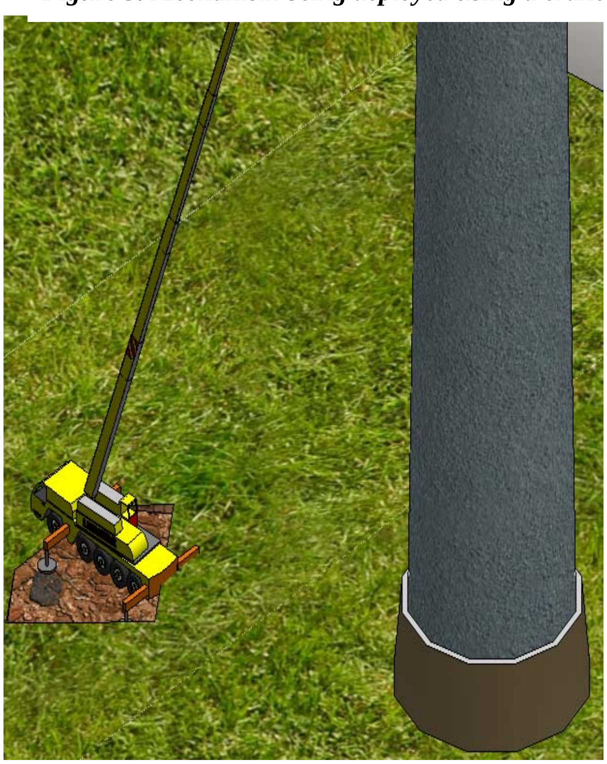


Figure 5. Mechanism being deployed using a crane.

Figure 6. Mechanism being held by a crane.



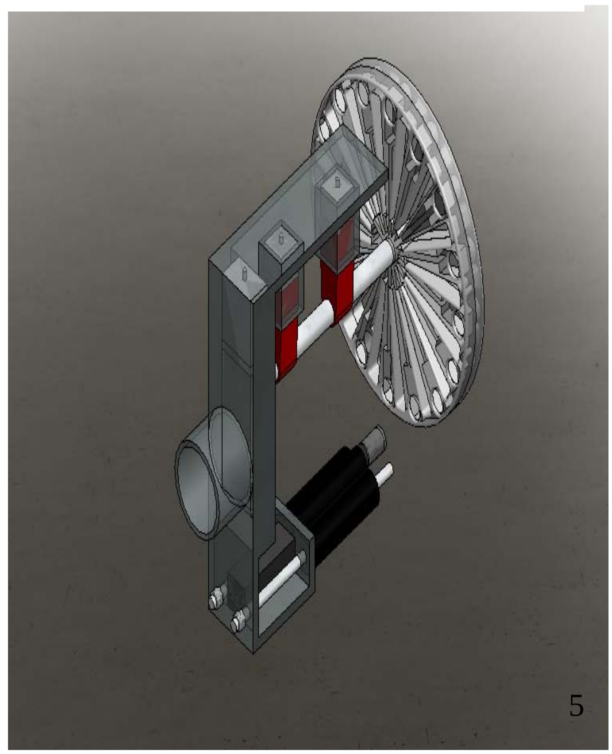
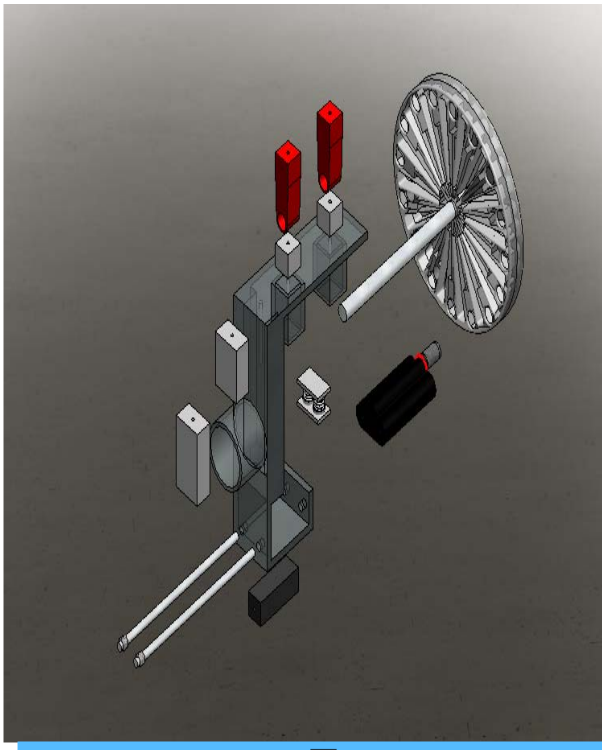


Figure7. Top view of the crane close to the nuclear stack.

Figure 1. Core drill device.



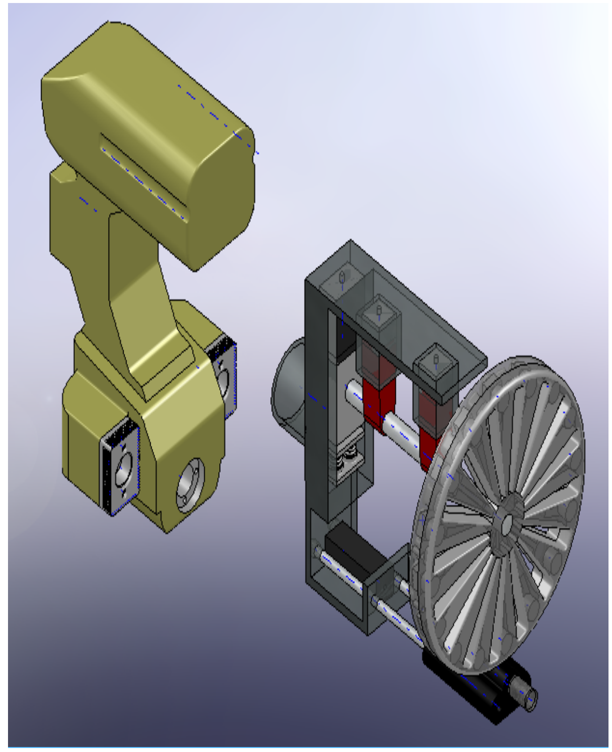
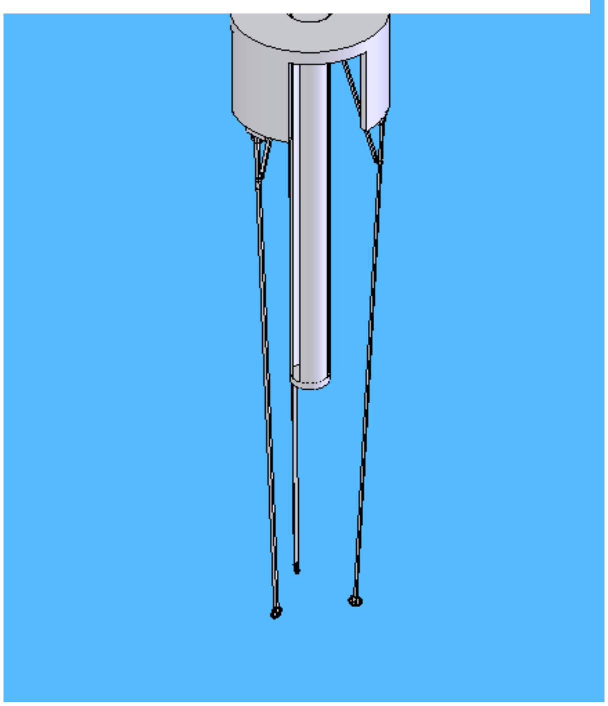


Figure 9. Main components of the core drill.

Figure10. Core drill ant its cover.



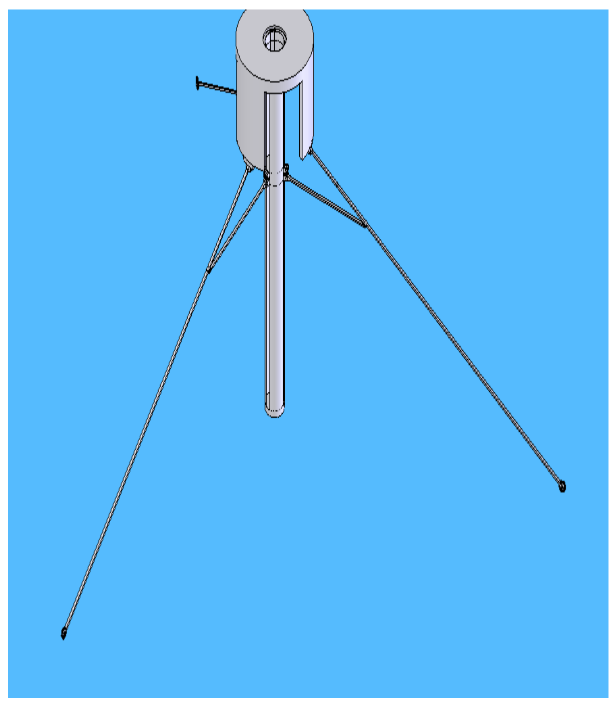


Figure 2. Kinematic representation of mechanism, initial phase.

Figure 12. Kinematic representation of mechanism, phase 2.

The mechanism is deployed by a crane to the top of the stack as shown in Figure 7. From there, using the data obtained from the physical characterization of the stacks, a positioning sensor is started at this fixed origin equalized to zero. Slowly, the device is set for the initial section at the base of the stack (Figure 5). The three leg mechanism expands until it reaches stability for the whole devise as shown in Figure 6. The whole system is able to rotate respective to its axis, enabling it to perform all the previously mentioned operations.

A special mechanism has been designed for the purpose of core drilling. This particular device is capable of taking core samples and storing them to prevent cross contamination between each sample collected (Figure8). The mechanism is composed of a drill wheel (13a), which holds the drill bits; a main frame (13b), utilized to support all the different components; linear actuators (13c, 13d); a commercial core drill (13e); a shaft (13f); and an external frame (Figure14) that provides protection from contamination for all the internal components and also serves as a holder for the camera and the scanner. The execution of the core sampling is the most difficult overall operation. Figures (15- 18) show the characteristics of the mechanism. Once the core drill is placed against the wall, the execution is divided in several steps. First, the axis of the core drill is presented to the axis of the drill bit held by the wheel (Figure15). The drill bit is taken by the core drill and mechanically locked by pressure (Figure16). Next, the wheel is held by a shaft that moves in a vertical direction to permit the operations done by the core drill. Also, the wheel possesses a pneumatic system that allows it to release and hold the drill bit. Once the drilling operation is done, the drill bit is placed back in its corresponding space in the wheel (Figure18). Then, the wheel is rotated with an angle value corresponding to the next drill bit and the whole operation is repeated (Figure19). Finally, the whole mechanism is pulled away from the wall.

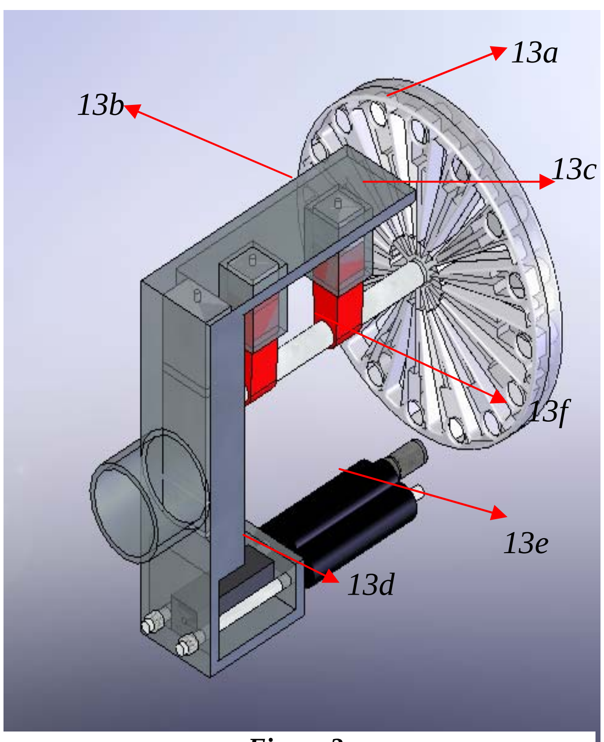


Figure 3

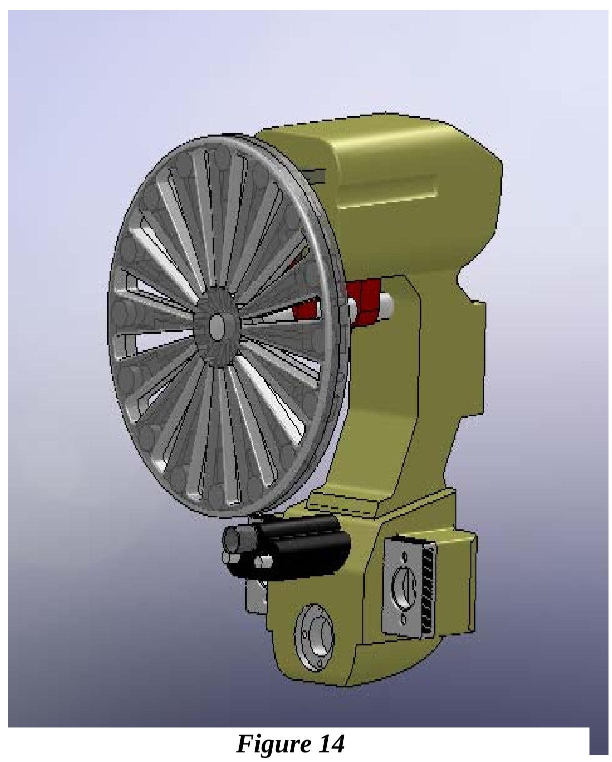


Figure 14

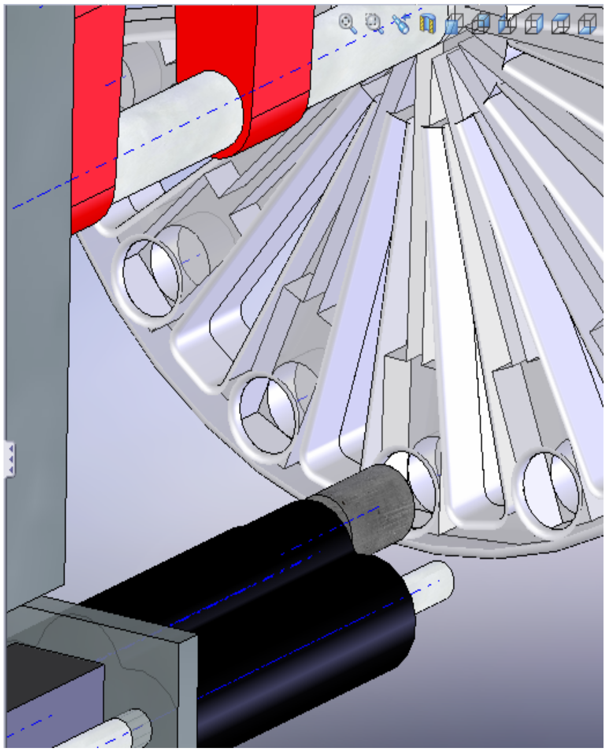


Figure 15

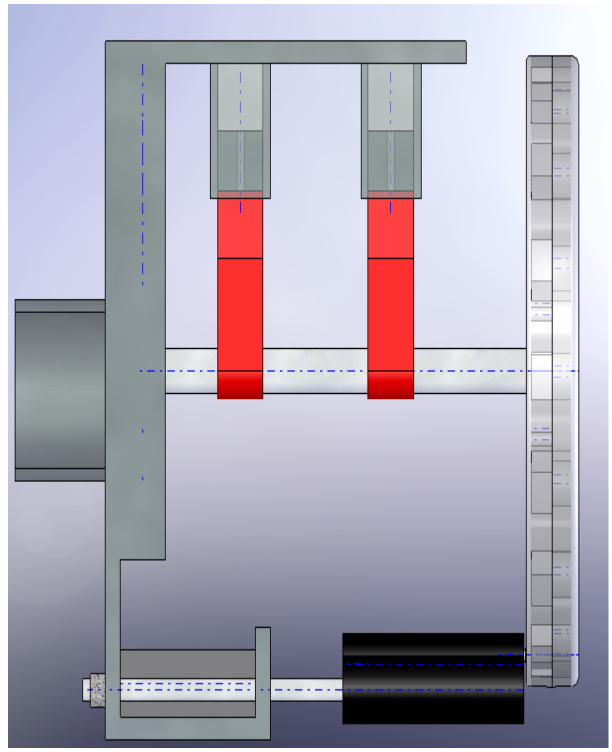


Figure 16

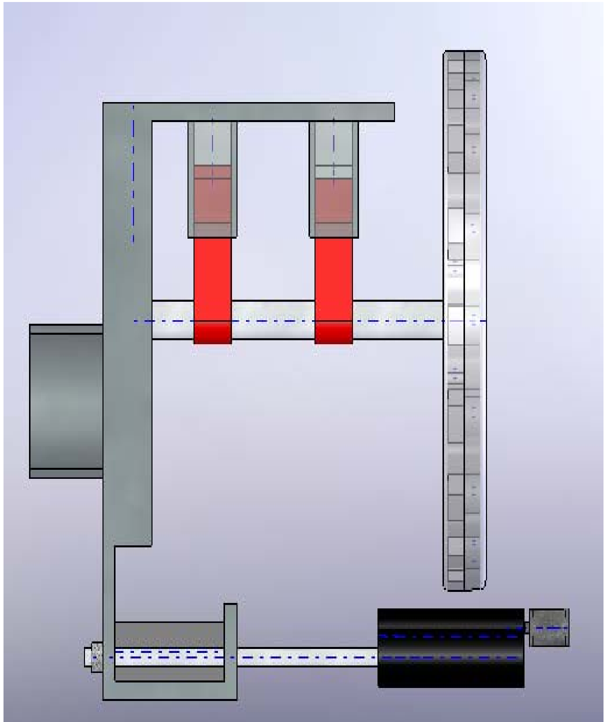


Figure 17

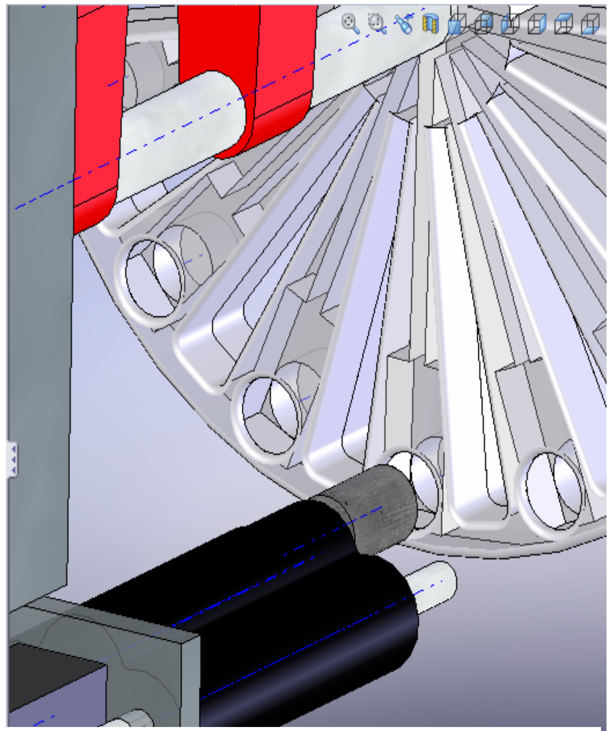


Figure 18

CONCLUSIONS

Physical and chemical characterizations are the key elements needed prior to the D&D activities. The dismantling process of nuclear facilities depends on the accuracy of this fundamental step. In the development of this technical report, the following conclusions have been made:

- A well organized characterization plan lays out the path for the whole dismantling process. It determines several factors, such as the selection of deployment technologies, the pre-decontamination process, demolition techniques and waste management.

- The more data and information available, the better the decommissioning planning will become.

- There is not a large amount of experience related to stack dismantling, but with the combination of lessons learned from a few previous projects, a review of the technical literature, and an analysis of the technology currently available in the market, new technology can be developed to meet the requirements of this D&D challenge.

- The dismantling process of nuclear stacks varies according to several factors, including the level of contamination, the physical conditions and the location within the nuclear facility. Other factors are involved but are not limited to technical execution.

- Every nuclear facility uses stacks and they will be eventually required dismantling. Therefore, the development of technologies to ease this process is required.

- An automated technology to handle the difficult task of characterizing nuclear stacks does not yet exist. Currently, direct manual methods by human workers are the preferred approach. This can be accomplished only at great risk for the stacks that are in much deteriorated physical condition or that contain high levels of contamination.

- Several technologies and methodologies are available for the performance of characterization. However, some situations will require special planning and need highly skilled engineering. These non-conventional techniques are expensive but more than justified for the protection and safety of all the personnel involved in the process as well as the areas near the nuclear facility.

REERENCE

1. International Atomic Energy Agency. Technical report series number 440, Dismantling of Contaminated Sacks at Nuclear facilities.

2. International Atomic Energy Agency. Technical report series number 389, Radiological Characterization of the Shut Down Nuclear Reactors for Decommissioning Purposes.

3. U.S. Department of Energy, Office of Environmental Restoration, Decommissioning Hand Book, 1994.