An Integrated Equipment for Massive Segmentation and Packaging of Control Rod Guide Tubes – 15161

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ABSTRACT

Over time, some utilities have decided to undergo safety upgrades that include replacement of some ageing components like control rod guide tubes (GT's). GT's are safety related components because they control the path of the control rods into and out of the core. These components are usually stored underwater in interim storage pools to decay their radioactivity. When the interim storage facility reaches saturation, treatment and final disposal of the retired Guide Tubes needs to be performed.

Based on more than 30 years of experience and lessons learned in the development of segmentation and packaging technologies for nuclear components, Westinghouse has designed, commissioned and will operate a dedicated system for cutting and packaging retired GT's from 900MW plants, currently stored in a EDF maintenance facility located in the south of France.

The first main technical challenge was the waste volume optimization. Two separate waste streams had to be considered for coping with the highly irradiated portion of the GT's (lower part) and the very low level waste sections (upper part). The segmentation plan has been designed to minimize the waste volume of the highly irradiated waste and therefore develop a process which could be adapted to the container size specified by EDF. Metallic baskets have been designed to optimize the packaging and storage density in the containers.

All cutting techniques previously used by Westinghouse in similar applications were assessed and underwater mechanical cutting with a band saw was selected as the preferred method. A turning stand positions the GT in front of the band saw. When the cut is completed, the remnant GT is inserted into the next turning stand for the next cut. Each cell of the turning stand positions the GT at the pre-defined cutting height. An integrated water filtration system is used to ensure good visibility during the cutting operations and to minimize water volume and limit the final liquid effluents.

The whole process of GT insertion, cutting, packaging and waste conditioning is carried out in a hot cell and controlled remotely. The operator can therefore follow the packaging plan accurately and safely by using a four axis pick and place unit, while keeping personal radiation exposure low.

This innovative process allows cutting and packaging large quantities of GT's in a safe and efficient manner. The pilot project covers the segmentation of 93 GT's but it can be further used for cutting larger quantities of retired GT's resulting from the upcoming GT replacement campaigns.

INTRODUCTION

EDF UTO (Central Technical Support Department) awarded Westinghouse Electrique France a contract to develop, commission and operate a dedicated system for cutting and conditioning retired 900 MW plant GT's stored at the EDF centralized hot operational facility (called BCOT). The BCOT facility is located at the Tricastin site, in the southeast of France. Operated by EDF, it is used for the maintenance and storage of contaminated components and equipment from all French nuclear power plants.

This paper is describes the main technical challenges for the design of this first of a kind equipment and highlights the solutions for ensuring successful and safe operations.

DESCRIPTION OF COMPONENTS TO BE CUT

Guide Tubes are safety related components in a Pressurized Water Reactor (PWR) and are part of the reactor's Upper Internals Assembly. The GT's are fastened to the upper support plate and are located by pins in the upper core plate for proper orientation and support. The design functions of the GTs and reactor internals include structural integrity and alignment to provide for movement of reactivity control into and out of the core. GT's perform the following functions:

- Provide a straight low-friction path for the control rods into or out of the fuel assemblies
- Provide sufficient protection for the control rods when they are withdrawn from the fuel elements to prevent damage due to parallel and lateral coolant flow
- Provide a convenient, safe storage place for the control rod drive lines during refueling

A GT is composed of an upper guide tube above the upper support plate, and a lower guide tube between the upper support plate and the upper core plate (see Fig.1). Both have a welded flange by which they are fixed to the upper support plate. The upper GT is a tubular casing and the lower GT is a casing with guide cards in the upper part. Its lower part has continuous guide sheaths and slotted tubes in the area of the flow holes.

The guide tubes at BCOT are stored with the lower guide tube bolted to the upper guide tube.

SCOPE OF WORK

The main purpose of this dismantling project is the segmentation of 93 Guide Tubes located in a BCOT hot cell in order to minimize final waste volume. A first contract covers the upfront engineering studies, the necessary equipment testing and qualification and the installation of the equipment in the BCOT hot cell. A second contract covers the segmentation of the GT's and loading of cut pieces into dedicated containers.

SEGMENTATION AND PACKAGING PLANS

Based on the waste disposal requirements and the radiological characterization of the Guide Tubes, the segmentation generates two types of waste (see Fig. 1):

- The lower part is neutron activated material and is considered as Low and Intermediate Level Waste (LILW). This part will produce two segments stored in baskets that will be placed in 5m³ steel containers with 100 mm of concrete which are sent to the Intermediate Level Waste repository at the French Radioactive Waste Management Agency site (ANDRA)

- The upper part, less exposed to the neutron flux of the core, has been mainly contaminated and is classified as a Very Low Level Waste (VLLW). This part will be divided in four segments and will be placed in baskets that will be loaded in 2m³ shipping boxes, which are sent to the CENTRACO facility which is the French nuclear center for processing and conditioning low-level radioactive waste.

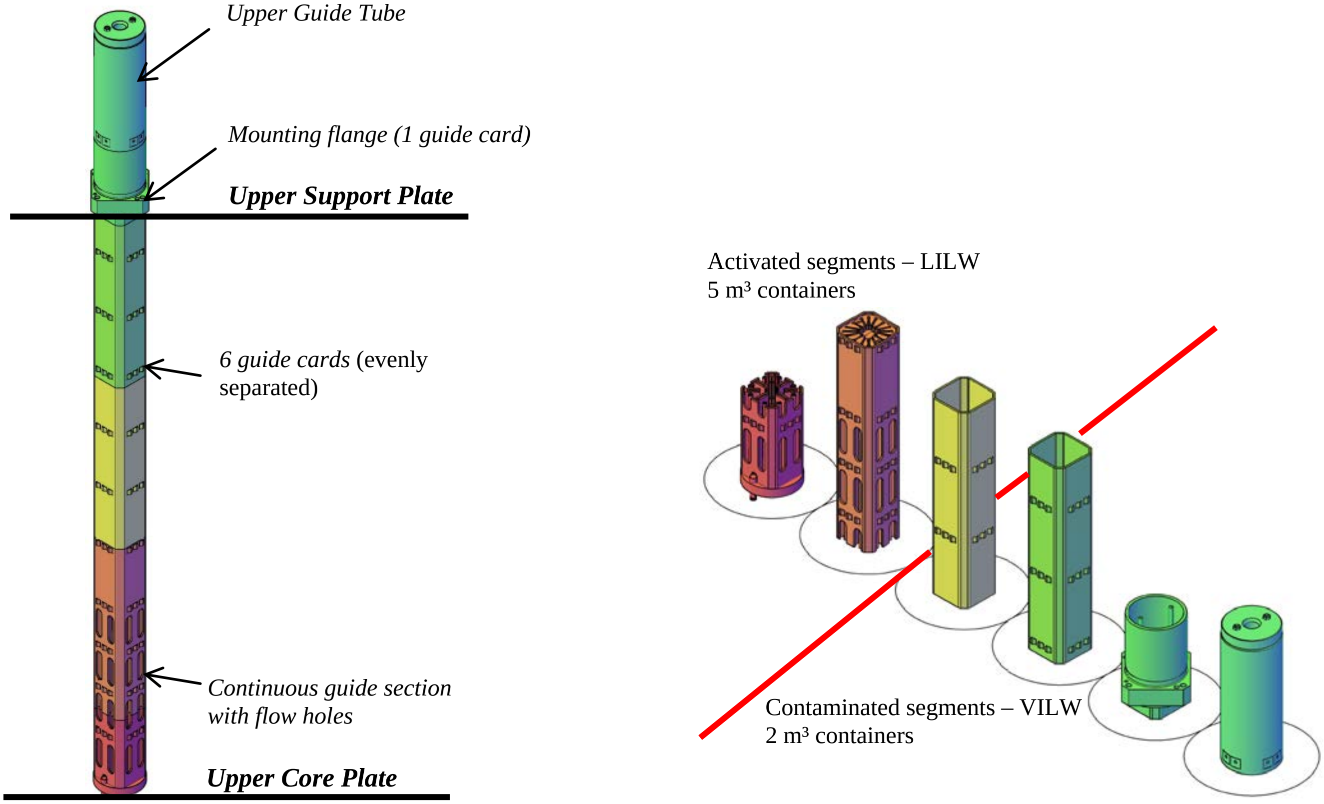

Fig.1: Segmentation plan

The separation into two streams substantially reduces the amount of LILW to be stored, and therefore its storage cost. The packaging of the segments is then optimized taking into account the conditioning and transportation regulations. Shielding and segments layout (see Fig. 2) in the containers have been determined by detailed calculations using radiological modeling and state-of-the art software.

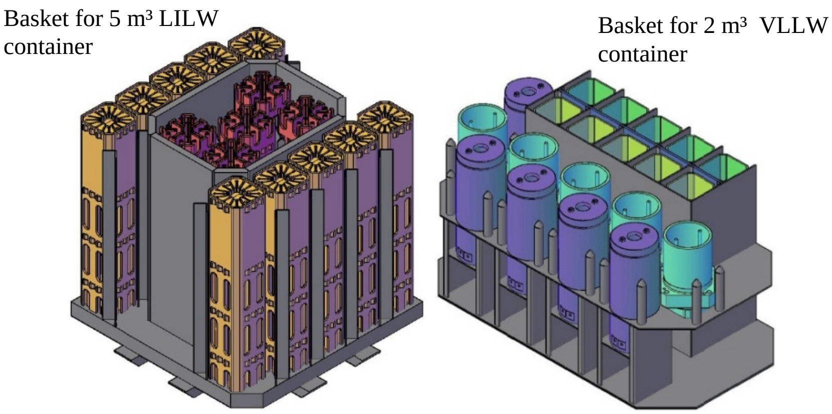

Fig.2: Packaging plan

The Westinghouse design of the GT’s segmentation equipment and process had to cope with various constraints such as:

- Site configuration,
- Separation of the segments in two types of containers,
- Management of effluents,
- Exposure of operators,
- Regulatory compliance.

SEGMENTATION EQUIPMENT

Choice of cutting Technique

Based on their extensive experience with reactor internals dismantling, Westinghouse has been able to assess the various cutting techniques possible for this GT segmentation project. Mechanical cutting has a number of advantages that make it the most suitable for the present application:

- The technique produces almost no secondary waste and ensures a good visibility while cutting.
- Chips from the cutting process fall down to the bottom of the cutting pool and are easy to collect.
- No gases are produced that can cause airborne contamination.
- The technique is safe and reliable.
- All sizes, materials and thicknesses can be cut.

Therefore, it was decided that the GT cutting equipment would be based on underwater cutting with a band saw.

Effluents

The selected cutting technique has a major advantage of avoiding any gas effluent issues, but the small size of the tank requires a water treatment for maintaining good visibility during all the cutting operations. Moreover, continuous chip removal is needed to enable access to the equipment for performing certain maintenance activities (e.g. saw blade replacement).
A filtration system is integrated into the cutting unit and collects the cutting chips directly from the bottom of the tank. The chips are then gathered in a cartridge for later packaging.

Remote Operations and Confinement

The GT's equipment at BCOT is installed in a vault next to the GT storage area. GT cutting and handling are performed remotely outside the vault. During all the cutting operations, additional shielding and alpha confinement are provided around the equipment inside the vault.

SEGMENTATION PROCESS

The GT's are initially stored in casks under deionized water. The process begins by the handling of one guide tube, by a shield bell provided on site.
The whole process is depicted on Fig. 3 and can be described as follows:

Step 1- Insertion

A heavy shielded bell transfers the guide tube from the storage cell into the GT segmentation equipment. Cutting heights are defined by the GT seating surface for each position in a rotating stand and by the fixed height of the band saw. This ensures an accurate cutting level that does not require any adjustment by the operators, i.e. only a visual check is needed. When positioned in the segmentation pool, the GT is clamped.

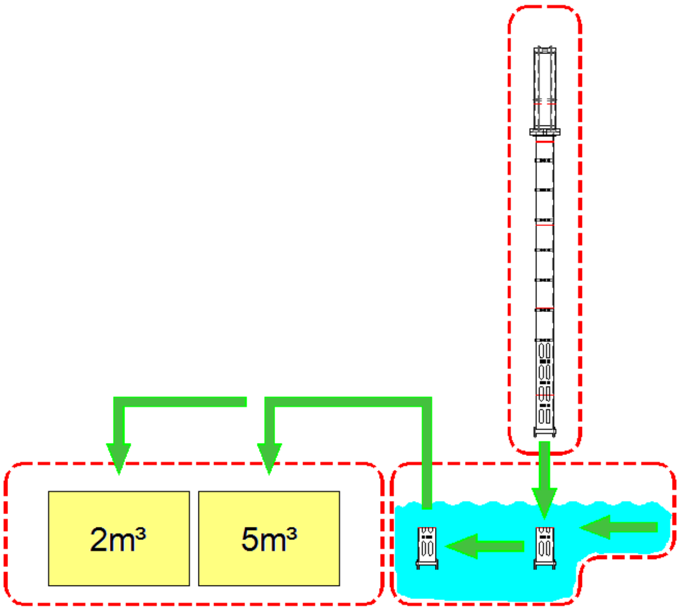

Fig.3: Simplified process

Step 2 – Cutting

The band saw cuts the GT underwater in order to produce a segment. A control system adapts the feed rate during the cut to the thickness and hardness being cut. This adjustment is necessary to optimize the lifetime of the saw blade.

A turning stand positions the GT in front of the band saw. When the cut is completed, the remnant GT is inserted in the next turning stand for the next cut. Each cell of the turning stand positions the GT at the pre-defined cutting height.

Step 3 – Packaging

The rotating stand brings the segment to the packaging unit. The extraction, transfer and insertion of the GT segments into their respective containers are performed by a four axis gripper (X, Y, Z and rotation). This freedom of motion allows for the perfect positioning of each segment in the baskets.

Steps 1 through 3 are repeated until the entire GT is packaged. Then the next GT is processed. Once the baskets are filled, a specific gripper handles the shielded covers in order to ensure safe radiological condition for the removal of the waste containers from the vault.

QUALIFICATION AND COMMISSIONING

The complexity of the work requires reliable tools. Before commissioning, a comprehensive qualification was performed on full scale mock-ups.
The validation of the cutting parameters (blade orientation, feed rate, cutting speed, blade type – see Fig.4) was part of the qualification phase. The biggest challenge was to have the fastest cut while generating small enough chips to avoid formation of metallic chip balls, which are difficult to remove by the water filtration system.

Fig.4: Various blade types and pitches

The band saw has been optimized to cut various shapes at the best achievable speed by using a dedicated control system. The cutting speed and feed adapts to the hardness and the thickness of the material. Fig. 5 illustrates the difference between each section from a dimensional point of view.

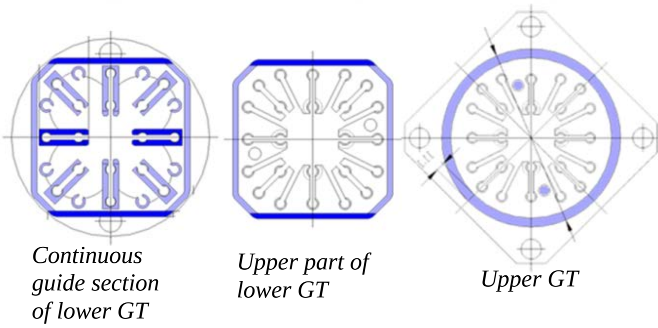

Fig.5: Different sections of a Guide Tube

Extreme conditions have been simulated using hardened materials (Super Duplex Stainless Steel) and conservative thicknesses. The qualification program included the segmentation and packaging of an actual "cold" GT so that dimensional interfaces could be checked. The equipment was installed on site and site acceptance tests were run successfully (see Fig.6).

The next site activities will include:

- Segmentation/packaging of 93 GT's
- Equipment tear down and decontamination

Fig.6: Equipment set-up in the BCOT vault

CONCLUSION

The segmentation and packaging of Guide Tubes depends a lot on the site conditions. The equipment designed, manufactured and commissioned by Westinghouse integrated the required functions and ensured safe and reliable operations.

The use of mechanical underwater cutting is the cornerstone of the design, and all the advantages of this technology combined with remotely controlled operations are significantly reducing the personnel exposure and safety risks.

This equipment together with the optimized packaging plan addresses the market need to minimize waste volume in a cost effective manner.

REFERENCES

1. P.Segerud, J. Boucau, S.Fallström, P.Kreitman, “Westinghouse PWR and BWR Reactor Vessel segmentation experience in using mechanical cutting process”, ICEM2010 - 40003