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TRANSPORT OF TWO STEAM GENERATORS BETWEEN CHOOZ A NPP AND ANDRA'S VLLW DISPOSAL SITE

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ABSTRACT

Nuclear Power Plant of Chooz A was the first Pressurized Water Reactor in France, operated from 1967 to 1991. The NPP is now being decommissioned.
Two on the four Steam Generators of the reactor were transported in November 2012 to ANDRA's Very Low Level Waste disposal site.
These large objects (120 metric tons each) were decontaminated prior to being transported by road as unpackaged objects.
Steam Generator n° 2 was shipped under a special arrangement, as a "hot spot" was remaining within the object. Steam Generator n° 1 has undergone an additional process of decontamination and was fully in compliance with the SCO-1 criteria.

This paper presents EDF's experience with these two shipments, including:

- an overview of the strong and complex process of decontamination which was necessary to reach both the Very Low Level Waste French criteria and the SCO-I criteria, as several of the 1662 tubes of these Steam Generators were plugged during the operation of the NPP ;
- the determination of the nuclide vector by the means of samplings on the tubes bundle ;
- the description of the measurement phase, and how it was possible to determine the values of the contamination on the inner surfaces of the Steam Generators by gamma detection and numerical methods ;
- the design of the tie-down of these large objects onto the vehicles ;
- the overall transport safety analysis, and the technical and operational measures taken for the safe shipment of Steam Generator n° 2 under a special arrangement, as it was not possible to perform drop tests, nor to put the object into a package.

It was proved that such large objects can be transported as unpackaged SCO-I, providing that they undergo a long and complex process of decontamination and characterization.

INTRODUCTION

Located in the French Ardennes next to the Meuse River and the Belgium border, Chooz A nuclear power plant was the first Pressurised Water Reactor (PWR) built in France in 1963. This 305 MW 4-loop NPP produced electricity from 1967 until 1991 (fig.1). Chooz A NPP was permanently shut down in 1993 and the fuel was completely removed.

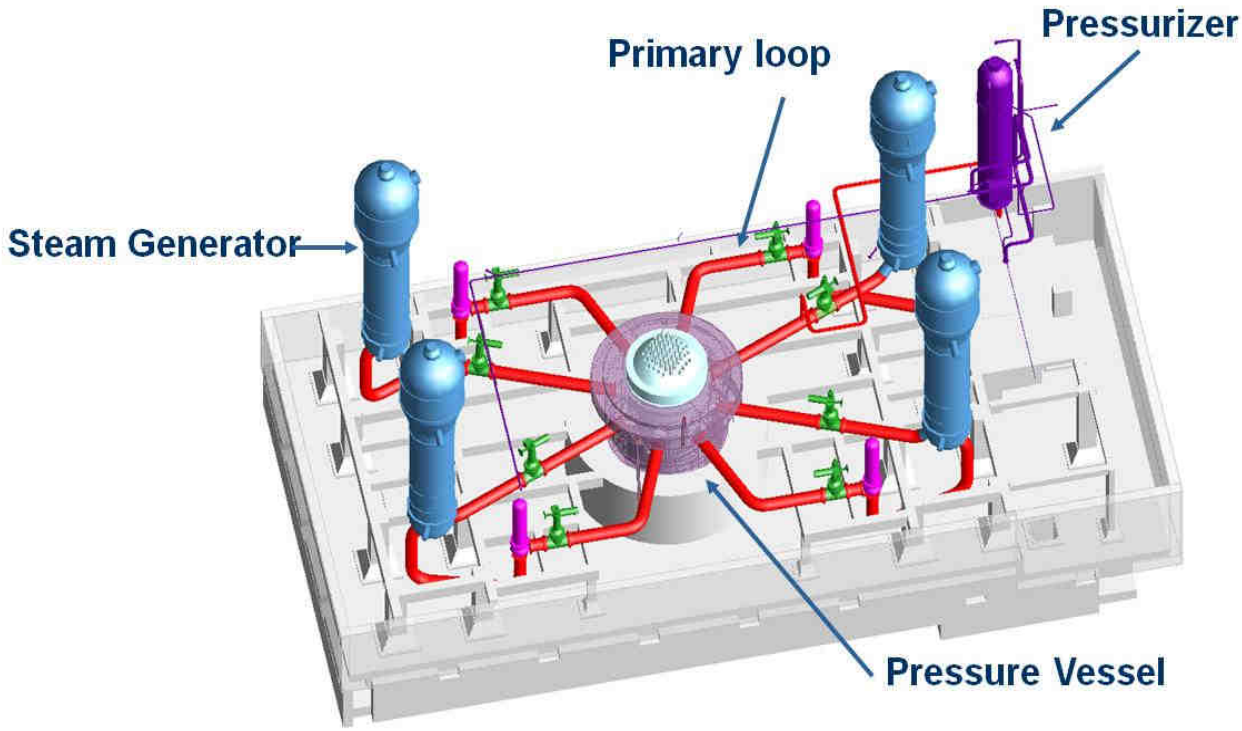

Figure 1. Four-loop PWR of Chooz A NPP

In 2010, the dismantling of the circuits connected to the vessel began. On April 2012, the fourth steam generator was extracted and prepared for decontamination.
The steam generators were decontaminated before being transported in one piece to the French nuclear waste storage facility of ANDRA (French National Radioactive Waste Management Agency).
The paper presents the transport by road of SG #1 and #2 from Chooz A nuclear power plant to the storage site.

DESCRIPTION OF CHOOZ A STEAM GENERATORS

On a PWR, the steam generators are heat exchangers designed to produce the steam for the turbine in the secondary circuit, from the heat of the primary circuit (fig 2).
The lower part of the steam generators is connected to the primary circuit by the primary coolant inlet and outlet. The upper part of the steam generators is connected to the steam secondary circuit by the feed water inlet and the steam outlet. The outer shell of the steam generators is pierced by several orifices: primary and secondary man ways, hand holes, connections, etc...
The carbon steel outer shell thickness is 50 to 95 mm.

The heat exchange is made through the tube bundle. 1,662 U-shaped tubes (internal diam. 16,5 mm) are connected to the tube sheet.

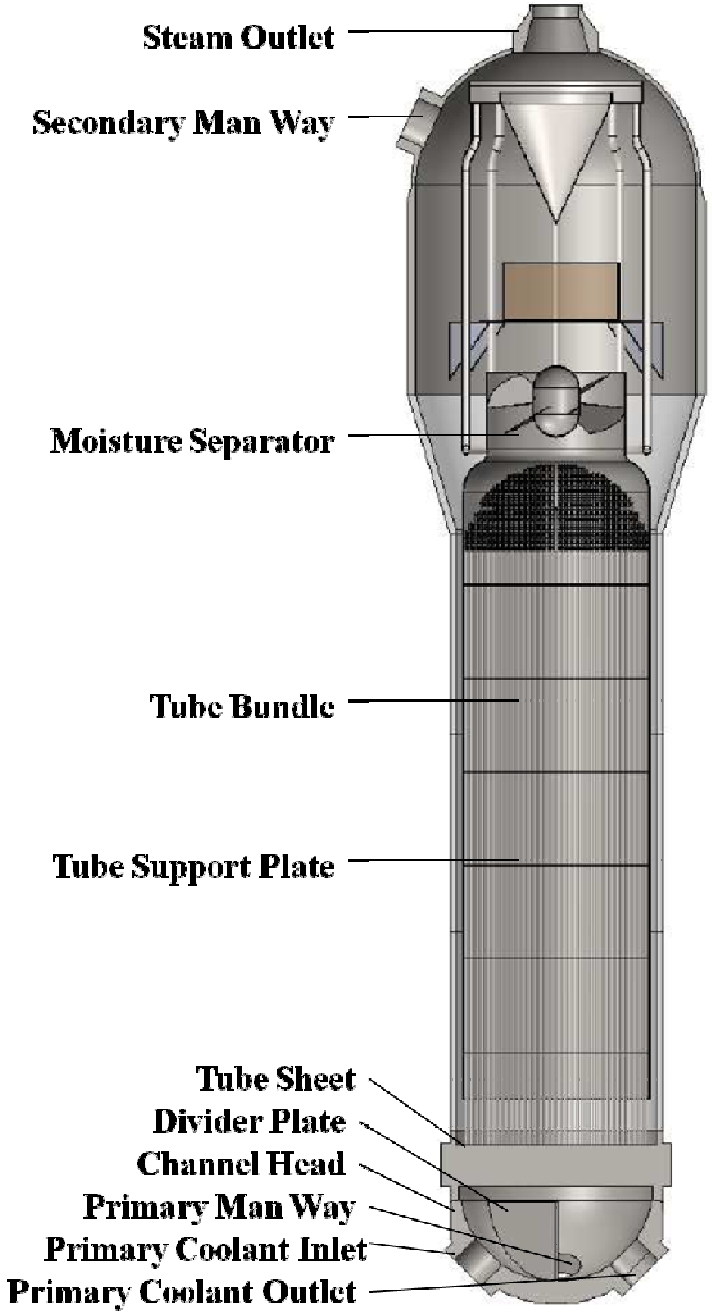

Figure 2. Chooz A NPP Steam Generator

The primary coolant circulates through the channel head, through the tube sheet, and within the tube bundle.

The overall diameter of Chooz A steam generators is 2.4m in the lower part, and 3.2m in the upper part.

The overall length of the steam generators in horizontal position (transport configuration) is 13,8m.

The overall weight of a steam generator, in transport configuration with its supports, is 120 metric tons.

DISMANTLING AND DECONTAMINATING THE STEAM GENERATORS

The first steam generator (SG #2) was extracted on February 1st 2011, and the fourth (SG #4) on April 26th 2012 (fig .3). The steam generators were placed in a horizontal position to undergo several decontamination operations.

Figure 3. Tilting and lifting of a SG

The goal of the decontamination operation is to remove enough contamination from these components in order to decrease the dose rate, and to meet both criteria for transport and storage.
Regarding their mass and geometry, the steam generators cannot be fitted into a packaging. The SG are meant to be transported as unpackaged contaminated objects SCO-I.

<u>The decontamination processes</u>
All the components of the primary circuit were contaminated by different elements from the operation of the plant. The purpose of the decontamination process is to remove the oxide layer, and several µm of base metal.
The 4 steam generators of Chooz A NPP were decontaminated. Two of them (SG #2 and SG #1) were transported in November 2012 to ANDRA VLLW site.

SG #2 was the first steam generator to be decontaminated, then transported to ANDRA. It underwent two different processes of decontamination. At the end of the process, it appeared that one of the tubes of this steam generator did not meet the SCO-I regulatory requirements for the contamination on the inaccessible surfaces. Consequently, SG #2 was transported under a special arrangement (UN2919). Then SG #1, 3 and 4 underwent three different processes of decontamination.

Step 1: Chemical process

An AREVA process (CORD©: Chemical Oydation Reducing Decontamination) was applied on site on the 4 steam generators by the mean of a mobile decontamination equipment. A chemical solution was circulated within the primary part of the steam generators (see fig.4).

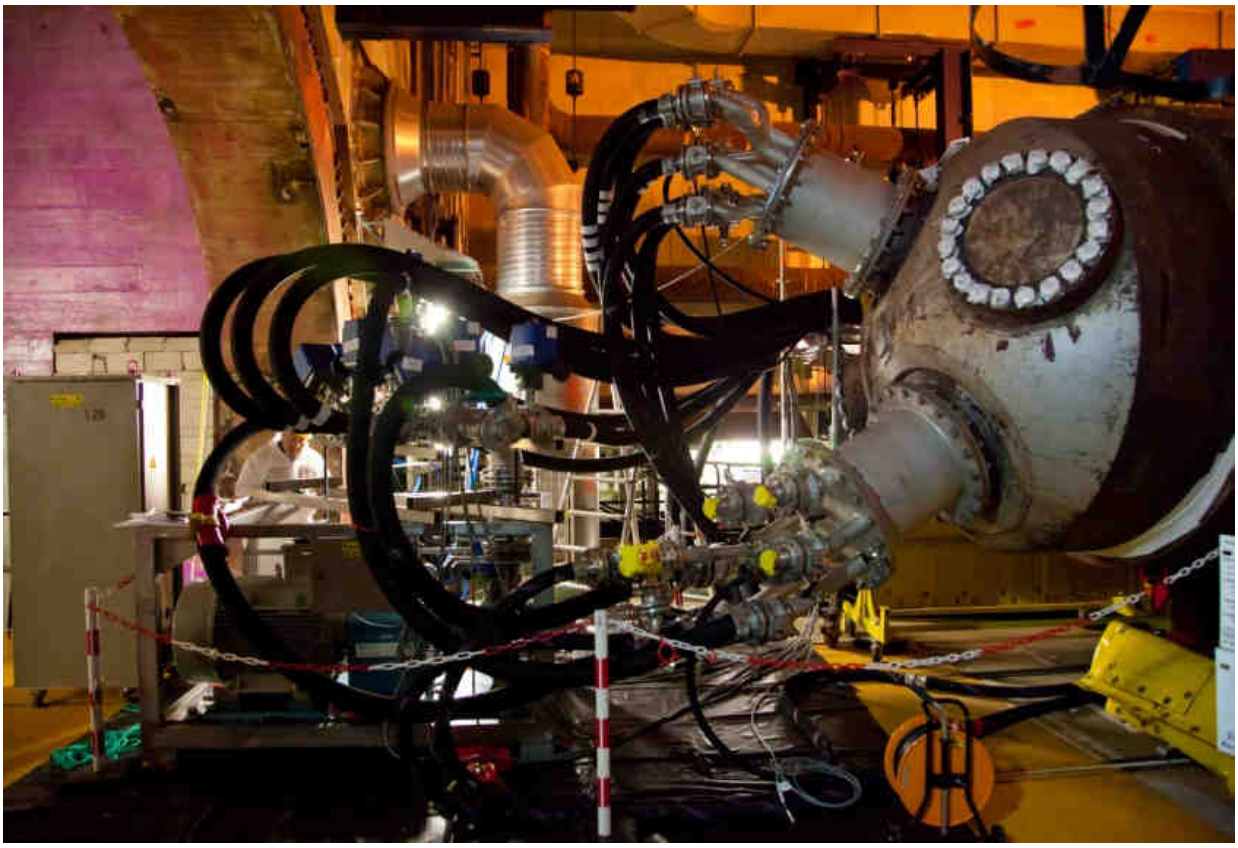

Figure 4. AREVA's chemical process CORD©

Step 2: Mechanical decontamination of sealed tubes

About a hundredth of tubes over the 6,500 tubes across the 4 steam generators were sealed during maintenance operations of the NPP.

The seals were extracted, before a specific decontamination process. The oxide layers were removed by spraying abrasive sand in the tubes with pressurized air (see fig.5).

Step 3: Chemical decontamination of sealed tubes

An additional chemical process was used for the oxidation and dissolution of the oxide layer of the sealed tubes. Only SG#1, SG#3 and SG#4 underwent this third process.

Figure 5. Specific treatment for sealed tubes

CHARACTERIZING THE STEAM GENERATORS

After being decontaminated, the steam generators were characterized by several types of measurements.

External measurements

After the decontamination process, the radiation levels remain in average lower than 1 µSv/h on the steam generators' shell, whereas some points reached 20µSv/h where the thickness of the outer shell is the smallest, near the orifice plugs and covers. Before the decontamination process, the average radiation level on the shell was about 700 µSv/h.

The accessible contamination (fixed and non-fixed) was controlled far below the SCO-I requirements, by direct measures, or by wiping.

The steam generators were then characterized by a gamma spectrometry chain (see fig. 6).

Figure 6. External gamma spectrometry chain

Internal measurements

Metal samples were taken from several tubes. The analysis of this samples confirmed the isotopic spectrum used to calculate the overall activity.

Gamma measurements inside the tubes using CZT probes were performed on 2% of the tubes minimum.

Numerical analysis

A numerical analysis on the steam generators was performed from the data collected. The result of this simulation gives the values of the contamination within the steam generators, and their overall activity.

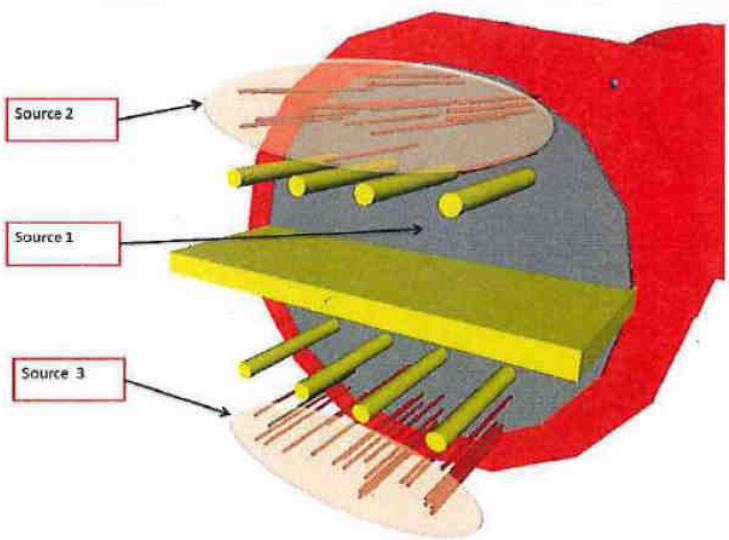

Figure 7. Numerical analysis of a SG

After this process it was shown that SG #2 met the contamination criteria for SCO-I, except within one tube, were the contamination remained close to 100 kBq/cm². SG #2 was transported under a Special Arrangement (UN2919).

SG #1 fully met the contamination criteria for SCO-I, and was transported as an unpackaged SCO-I (UN2913).
Both SG #1 and SG #2 had an overall activity lower than 0.1 A2.

THE CONTAINMENT

All the orifices of the steam generators were sealed by the means of welded covers or plugs (fig. 8). The welds were controlled by dye penetrant tests.

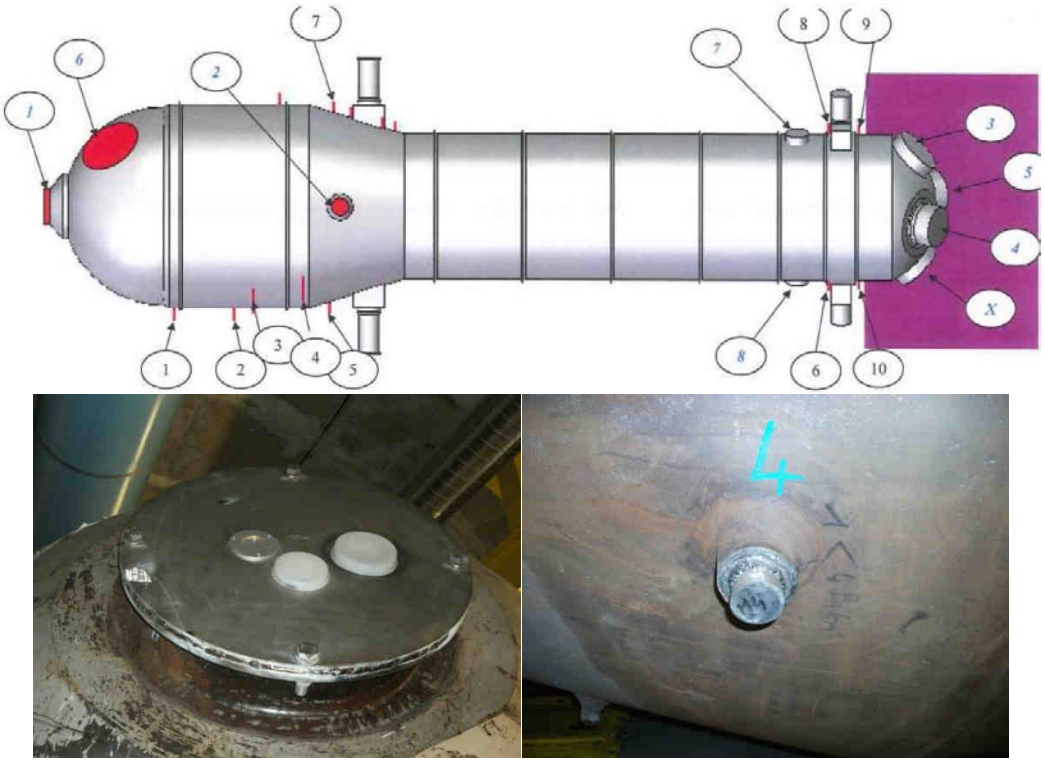

Figure 8. Welded cover and plug on SG orifices

THE TRANSPORT

SG #1 was transported as unpackaged SCO-I, SG #2 was transported under a special arrangement. Both steam generators were protected by a plastic tarpaulin.
During the loading and unloading phases onto the trailer, no crane was used. The steam generators were lifted by a jacking system (fig. 9) with saddle extensions.

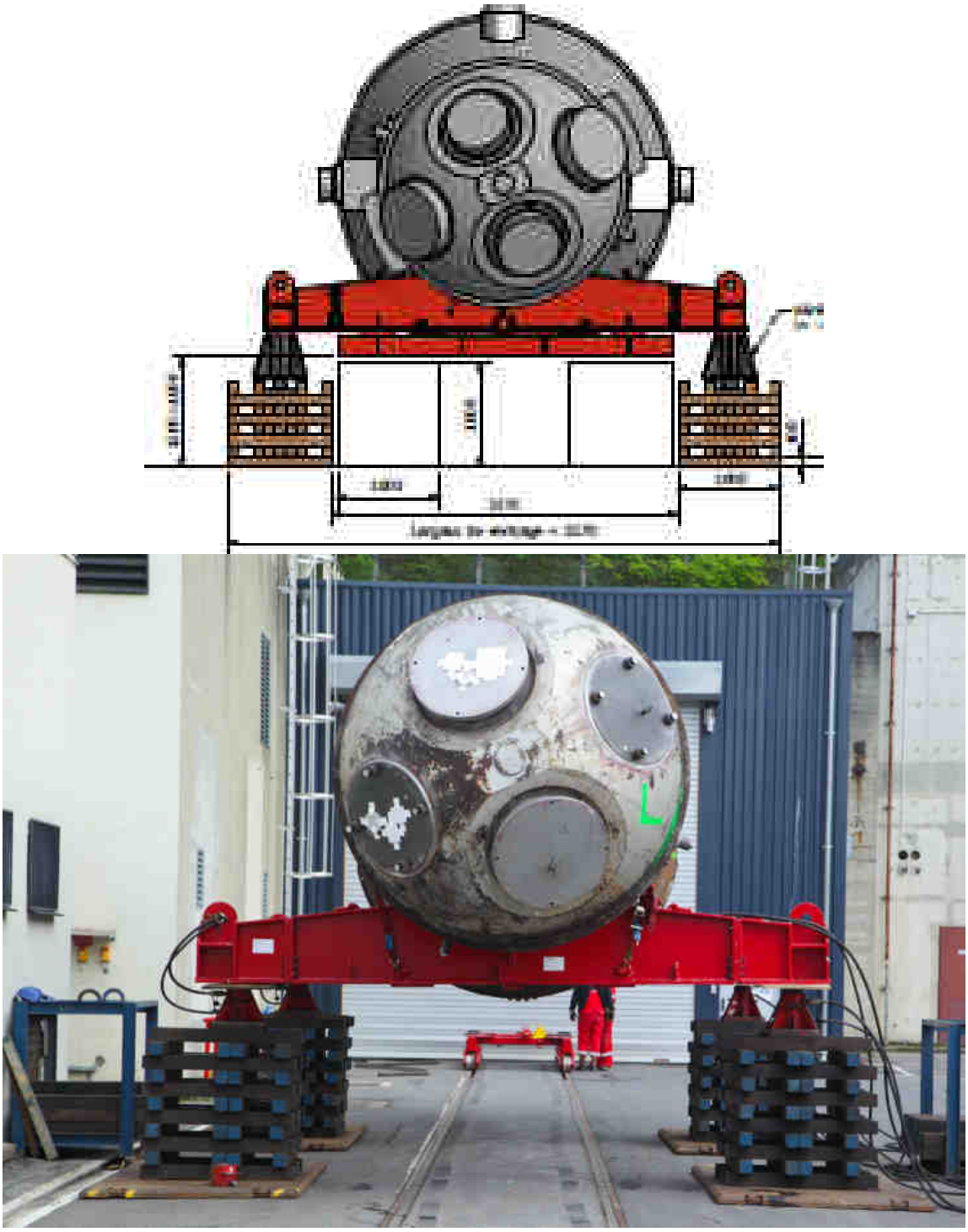

Figure 9. The SG was lifted by a jacking system

Once on the trailer, the steam generators were supported by two cradles and anti-slip mats. These mats prevented lateral movements of the steam generators and reduced the efforts in the retention system. During the dismantling operations, the 4 handling trunnions of the steam generators were removed, and replaced by 4 plates (fig. 10) for the attachment of the retention system.

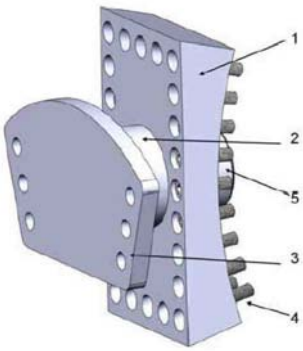

Figure 10. Plate for the attachment system

The steam generators were directly tied with twenty chains (20,000 daN each) attached to the plates (fig.11).
The retention system was designed according NF EN 12195-1 standard.

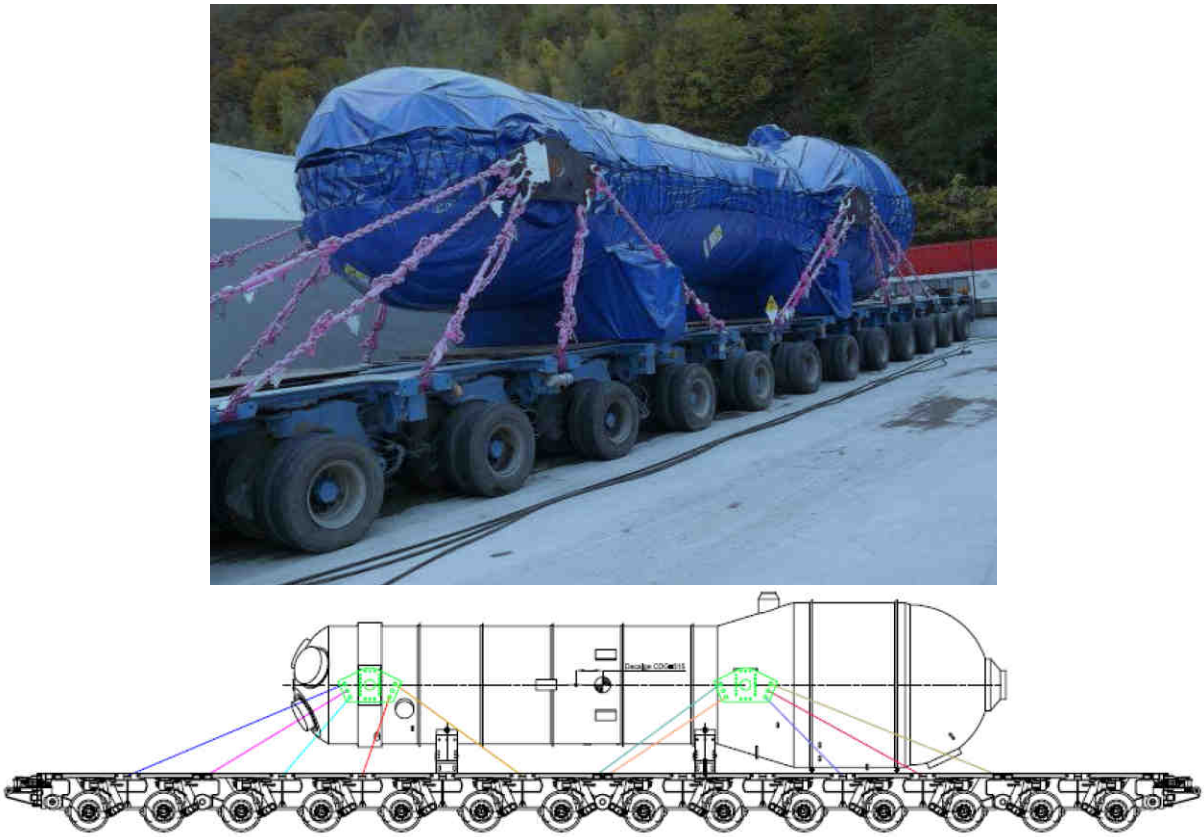

Figure 11. Retention system

The steam generators were shipped on a 14-line trailer (length: 20.4 meters), with one pull truck and one push truck (fig. 12). The overall length of the convoy was 45 m. Its overall weight was 230 metric tons.

Figure 12. 14-line trailer, with one pull truck and one push truck

SG #2 left Chooz NPP on Nov. 12th 2012 and reached ANDRA VLLW site on Nov. 14th 2012
The transport of SG #1 took place from Nov. 19th 2012 to Nov. 21th 2012.
Steam Generator #2 was transported under a special arrangement. Additional technical and operational measures were taken for the safe shipment, as it was not possible to perform drop tests, nor to put the object into a package.

- The route was recognized before the transport. All the obstacles were noted: the height of the bridges; the resistance of the bridges; the width of the roads; the park places were noted for night stationary.
- The weather report was consulted the days before the transport. The transport was not allowed in case of fog or snow.
- There was no loading / unloading during the shipment. The transport was exclusively done by road, with the same vehicle.
- The allowed speed was reduced from 50 km/h (transport of heavy objects) to 40 km/h.
- The road traffic was regulated by two motorcyclists.
- The vehicle was permanently guarded during all the shipment: including nights and days stops.
- The retention system was checked before the shipment, and after each stop.
- The vehicle was followed by a maintenance truck.
- Daily radiological controls were performed by the team during the shipment.

CONCLUSIONS

Steam generators #1 and #2 from Chooz A NPP were transported in November 2012 to ANDRA VLLW disposal site. Steam generator #2 was shipped under a special arrangement, whereas steam generator #1 was transported as “unpackaged” SCO-I.
These large objects underwent a long and complex process of decontamination and characterization. The characterization process includes:

- metal samples, before and after the decontamination process, in order to determine the isotopic spectrum,
- internal and external gamma measurements,
- numerical analysis.