THE DECOMMISSIONING OF THE TRINO NUCLEAR POWER PLANT

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ABSTRACT

Following a referendum in Italy in 1987, the four Nuclear Power Plants (NPPs) owned and operated by the state utility ENEL were closed. After closing the NPPs, ENEL selected a "safestore" decommissioning strategy; anticipating a safestore period of some 40-50 years. This approach was consistent with the funds collected during plant operation, and was reinforced by the lack of both a waste repository and a set of national free release limits for contaminated materials in Italy. During 1999, twin decisions were made to privatise ENEL and to transform the nuclear division into a separate subsidiary of the ENEL group. This group was renamed Sogin and during the following year, ownership of the company was transferred to the Italian Treasury.

On formation, Sogin was asked by the Italian government to review the national decommissioning strategy. The objective of the review was to move from a safestore strategy to a prompt decommissioning strategy, with the target of releasing all of the nuclear sites by 2020. It was recognised that this target was conditional upon the availability of a national LLW repository together with interim stores for both spent fuel and HLW by 2009. The government also agreed that additional costs caused by the acceleration of the decommissioning programme would be considered as stranded costs. These costs will be recovered by a levy on the kWh price of electricity, a process established and controlled by the Regulator of the Italian energy sector.

Building on the successful collaboration to develop a prompt decommissioning strategy for the Latina Magnox reactor (1), BNFL and Sogin agreed to collaborate on an in depth study for the prompt decommissioning of the Sogin PWR at Trino. BNFL is currently decommissioning six NPPs and is at an advanced stage of planning for two further units, having completed a full and rigorous exercise to develop Baseline Decommissioning Plans (BDP's) for these stations. The BDP exercise utilises the full range of BNFL decommissioning experience and knowledge to develop a strategy, methodology and cost for the decommissioning of NPPs.

Over the past year, a prompt decommissioning strategy for Trino has been developed. The strategy has been based on the principles of minimising waste products that require long term storage, maximising 'free release' materials and utilising existing and regulatory approved technologies. The strategy incorporates methodologies for dismantling the reactor vessel and internals, for the removal of all plant, equipment and services from the containment building, for size reduction, for decontamination to current free release limits and for the handling and packaging of wastes for disposal. Practical experiences from both Sogin's site operations and BNFL's operations in North America and Europe have been used to quantify liabilities and progress the planning process to the point where Sogin have been able to define their funding requirements for Trino with their stakeholders.

HISTORICAL PERSPECTIVE

The history of commercial nuclear power in Italy dates back nearly 40 years to the opening of the Latina Magnox reactor in 1963. In 1964, Trino Vercellese, a Westinghouse four loop Pressurised Water Reactor (PWR) with an output of 270Mwe, commenced operation. In the same year, the nationalised electricity utility ENEL was formed by the combination of the existing private utilities, including Selni, the operator of Trino. By 1978, the BWR reactor at Caorso was on line and the earlier BWR at Garigliano had been retired. Plans for a further reactor at Alto Lazio were also well advanced. However, the Chernobyl accident in 1986 triggered anti-nuclear sentiment in Italy, and in 1987, a referendum resulted in a decision to close the remaining NPPs. In 1992, after a five-year moratorium, the Italian Government took the final decision to permanently shut down the Italian NPPs (Figure 1).

	Type	Designer	MWe	Commercial Operation	Plant Shutdown
Latina	Gas Graphite	TNPG	200	1963	1986
Garigliano	BWR Dual Cycle	General Electric	150	1964	1978
Trino	PWR	Westinghouse	270	1965	1987
Caorso	BWR	AMN - GETSCO	860	1978	1986

Fig. 1. The Italian NPPs

The closed NPPs continued to be owned and managed by the state owned utility ENEL. However, during 1999, decisions were taken to privatise ENEL and, at the same time, to transform the nuclear division into a separate subsidiary of the ENEL group. This subsidiary was renamed Sogin. Finally, in 2000, ownership of Sogin was transferred to the Italian Treasury.

DECOMMISSIONING STRATEGIES

Prior to the closure of the Italian NPPs, ENEL had developed a safestore decommissioning strategy. The strategy anticipated a safestore period of some 40-50 years. Both the strategy and the safestore period were designed to be consistent with the funds that had been collected during plant operation. Furthermore, the overall approach being adopted was reinforced by the lack of both an Italian LLW repository and an unambiguous set of Italian clearance limits for the free release of contaminated materials. However, when Sogin was formed, the new management was instructed to review the Italian NPP decommissioning strategy. The objective of the review was to assess the feasibility and impact (both technical and commercial) of changing from the existing safestore strategy to a more aggressive decommissioning strategy, with the target of releasing all of the nuclear sites by 2020. It was recognised that this target was conditional upon the availability, by 2009, of a national LLW repository together with interim stores for both spent fuel and HLW.

From the outset, the government recognised that any additional costs due to the acceleration of the decommissioning programme would have to be considered as "stranded costs" and that these extra costs would be recovered by a levy on the (kWh) price of electricity. The financing of the new decommissioning programme has been established and controlled by the Regulator of the Italian energy sector and a revised strategy, programme and review of associated decommissioning costs was required quickly so that the appropriate funding measures could be put in place.

Although the reactor decommissioning market cannot be regarded as mature, the key elements of strategy development, waste treatment, dismantling and delicencing have been separately demonstrated as achievable (2). As Sogin considered the development of prompt decommissioning strategies for their NPPs, BNFL was an obvious source of support and assistance. BNFL has enjoyed a long relationship with the Italian nuclear industry, both as a supplier of fuel and reprocessing services, but also as a fellow utility. Furthermore, BNFL is currently decommissioning six NPPs in the EU and USA and is at an advanced stage of planning for the decommissioning of two further NPPs, having completed a rigorous exercise to develop Baseline Decommissioning Plans (BDP's) for these stations

The BDP exercise incorporates the full range of BNFL decommissioning experience gained from decommissioning a range of reactor types and nuclear clean up sites. The company also has experience of applying the BDP to a range of reactor types operating under various national decommissioning regulations. For this exercise BNFL drew upon its significant experience of prompt decommissioning programmes through their work at WAGR in the UK and at Big Rock Point in the USA. The experience of Westinghouse PCI, who have significant experience of the remote segmentation, handling and packaging of reactor vessels was also incorporated. The combination of Sogin's site and plant operations experience with BNFL's remote operations, planning and regulatory experience was attractive to both parties.

THE DEVELOPMENT OF A PROMPT DECOMMISSIONING STRATEGY

The target set was that the reactor was to be decommissioned to green field within 20 years, recognising that the higher radiation levels would require the deployment of remote dismantling techniques for the reactor vessel and internals. A major factor in the planning assumptions was the availability of a repository in 2009. Without such a repository, prompt decommissioning is not a practical option.

Further critical issues identified are:

(a) The lack of free-release clearance levels. At this time there are no "free release" clearance levels set by law for the whole of Italy. During 2000, preliminary free release levels were set for Caorso by ANPA (3). Future permits for the other NPPs and other nuclear installations are expected on a case-by-case basis. The Caorso clearance levels have been assumed for Trino. The free release criteria used in this study are shown in table I and are satisfied if:

$$\sum_i \frac{A_i}{L_i} < 1$$

Ai being the activity of **ith** radionuclide present in moderate amount in the material to be released.

(b) Waste acceptance criteria. Technical Guide #26(4) is the Italian regulation that specifies acceptable final waste forms and the properties of the conditioned wastes. Three categories of waste are considered as a function of activity concentrations. It is assumed in the decommissioning plans that TG 26 will form the basis of the acceptance criteria for the national repository. Still to be defined however, are issues such as: the maximum dimensions and weights that can be handled in the repository, waste characterisation requirements and the cost of disposal. In order to reach conclusions in terms of waste packages, the overall size and weight of containers have been agreed with Sogin for use in developing the strategy.

(c) The speed at which licensing applications can be processed by ANPA. The Italian licensing process is complex and requires improvement. Sogin and ANPA are now working together to improve the situation. To assist this process, only proven techniques that have received regulatory approval in the country of use have been employed in the Trino decommissioning strategy.

Table I. Standard Release Criteria

Radionuclide (i)	**Li Metallic Materials**		**Li Concrete**		**Li Other Materials**
	Mass (Bq/g)	**Superficial (Bq/cm²)**	**Mass (Bq/g)**	**Superficial (Bq/cm²)**	**Mass (Bq/g)**
^{3}H	1	10.000	1	10.000	0,1
^{14}C	1	1.000	1	1.000	0,1
^{54}Mn	1	10	0,1	1	0,1
^{55}Fe	1	1.000	1	10.000	0,1
^{60}Co	1	1	0,1	1	0,1
^{59}Ni	1	1000	1	10.000	0,1
^{63}Ni	1	1000	1	10.000	0,1
^{90}Sr	1	1	1	100	0,1
^{125}Sb	1	10	1	1	0,1
^{134}Cs	0,1	1	0,1	1	0,1
^{137}Cs	1	10	1	1	0,1
^{152}Eu	1	1	0,1	1	0,1
^{154}Eu	1	1	0,1	1	0,1
Gross Alpha emitters	0,1	0,1	0,1	0,1	0,01
^{241}Pu	1	1	1	10	0,1

THE SCOPE OF THE TRINO STUDY

The boundary conditions for the project were defined as being, "the removal of the reactor, reactor systems and structures within the containment building". As such the strategy considers the reactor vessel and contents, the steam generators, reactor coolant pumps and all other related plant, equipment and services contained within the containment building as well as internal containment structures. The physical scope of the study is shown pictorially in Figure 2.

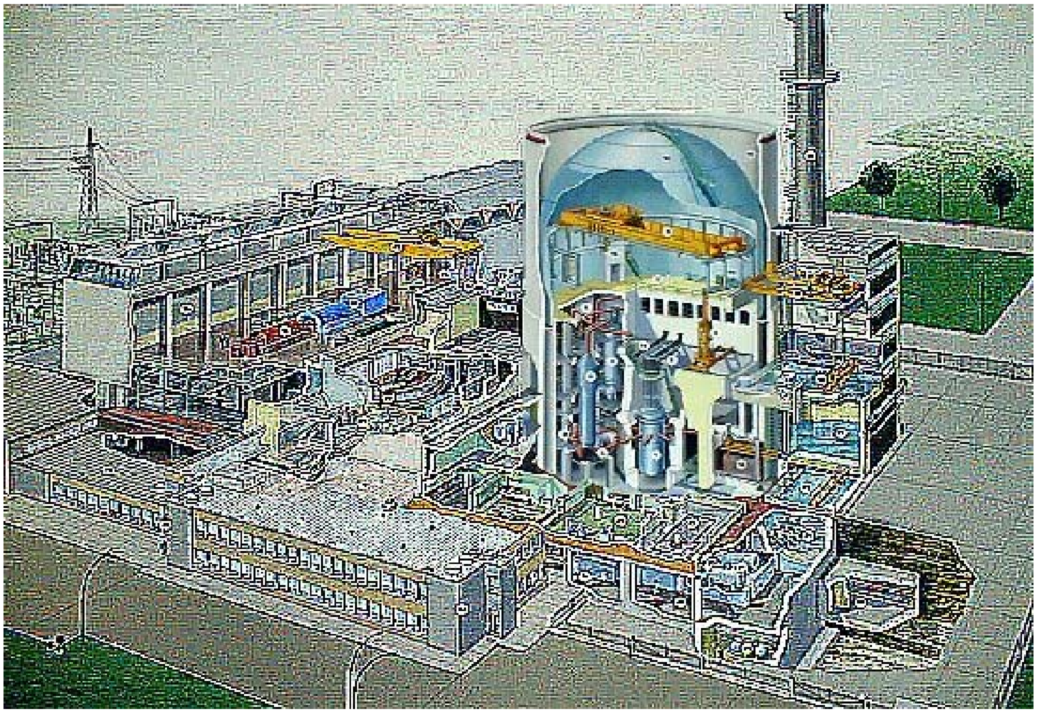

Fig. 2. Scope of the Study – Trino Containment Building and Contents

SETTING THE STRATEGY

In determining the optimum solution for the prompt decommissioning of Trino NPP in a safe and cost-effective manner, as well as the critical issues referred to above, the following aspects were considered:

- the station's operating history and current condition
- its condition at the commencement of the physical decommissioning phase
- the regulatory requirements for decommissioning and waste disposal
- the nuclear fuel programme
- operational waste remaining in the fuel and purifier pools

It was clear from the outset that the most advantageous strategy for decommissioning Trino, with regard to nuclear and radiological safety, was to remove all nuclear related materials from the containment buildings prior to decommissioning operations commencing. This eliminates all nuclear safety concerns and significantly reduces radiological safety concerns. It was therefore agreed that Sogin would undertake to remove all of the nuclear fuel (spent and fresh) and operational waste that remained in the containment building.

The next task was to review the operational history of the plant, its current state and determine any enhancements with regard to dose reduction that could be made prior to the start of dismantling. From the plant records, it was clear that if decommissioning started in 2006 (to take advantage of the national repository becoming available), all of the plant and equipment with the exception of the reactor vessel and internals could be removed by human intervention using ALARA techniques. To aid this, it was decided that the primary circuit would be decontaminated prior to removal. This would be achieved using a chemical cleaning process with a limited dose budget (about 50 mSv-man) and secondary waste target (5 m^3 of resins and 5 m^3 of DAW). It was calculated that this would result in a meaningful dose saving (3.3Sv-man) during the dismantling phase. It was also decided that the primary circuit decontamination process would bypass the reactor vessel due to the activation levels in the reactor. It was not thought possible to reduce the contamination levels to a level where alternatives to remote segmentation and long term packaging and storage could be considered. Therefore, there would be no benefit to offset the additional waste and transfer of contamination caused by passing the decontamination chemicals through the vessel.

Having reviewed the overall situation, taking due regard of all aspects of the plant from its physical and radiological condition through to its the logistics of removing plant and equipment, the following strategy was adopted for development:

- The existing containment ventilation, which is a positive pressure system, will be modified to be a negative system to help to ensure no contamination is released from the containment area during the course of operations.

- To maximise the amount of material to be recycled for re-use and hence reduce packaging and long term storage costs, a Waste Management Facility (WMF) will be constructed adjacent to the containment and fuel pool buildings. To facilitate the movement of waste materials through the containment into the WMF, a waste path will be formed in the containment area. This will be achieved by removing items of plant ahead of segmentation and decontamination and installing an electric lift adjacent to the entrance to the WMF, accessing all floors in the containment. The WMF will be accessed from the containment building by forming an opening in the containment wall at the 132.m (ground) level. The WMF layout is illustrated in Fig 3.

- From extensive studies and especially from experience gained in the field, the most timely and cost effective method of dismantling and decontaminating (D&D) plant is to use, where viable, human intervention techniques (5). Using this principle, the strategy for decommissioning the Trino reactor building is to eliminate as early as possible the highly activated and contaminated plant and equipment, thus allowing the D&D team access to the remainder of the plant, equipment and services. The study has established that the only item of plant to require remote removal, segmentation and packaging is the reactor vessel and internals. Consequently, these items will be the first to be removed. These will be followed by the four steam generators and reactor head, which will be decommissioned by work teams using 'hands on' D&D techniques but will still require filtered enclosures to ensure no spread of contamination in the containment area. From this point on, most items will be removed and segmented using local contamination suppression techniques, which will allow several activities to take place simultaneously within the containment building. Overall, using the premise of removing the more highly contaminated plant items first, dismantling will start with the vessel in the centre of the containment building and work progressively out to the edges of the containment. This will leave a clean structure that can be demolished in a conventional manner.

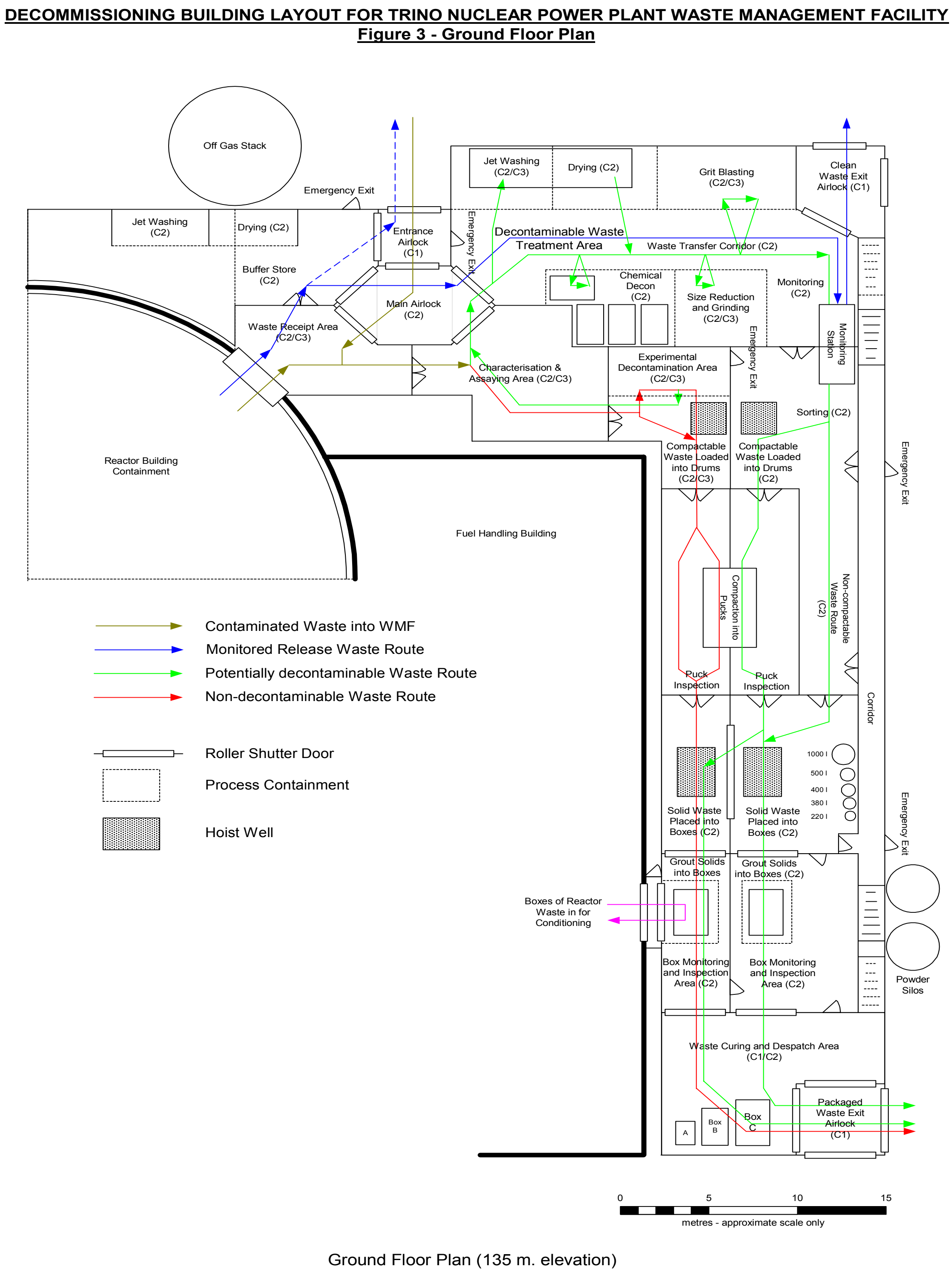

Fig. 3. Ground Floor Plan

An in depth review of cutting and segmentation techniques was undertaken. Taking into account Sogin's and BNFL's experience, a decision to flame cut the larger pieces of equipment was taken. This choice was based on efficiency, safety and practical experience (6) and has been underpinned by a safety analysis that shows that the worst-case accidental burning of a fully loaded HEPA filter will not breach the release limits set by the Italian regulators.

The strategy was then developed using the BNFL BDP process The BDP for Trino NPP was developed as a joint effort by BNFL and Sogin. This process requires that each item of plant, equipment, service or structure that is to be modified or removed is subject to a detailed analysis. This analysis identifies the tools and techniques to be used to carry out the work, the equipment and material lists, the waste produced (including all secondary wastes), the dose up-take and the personnel required, in addition to the time taken and hence overall cost. Each element has a unique Work Breakdown Structure number (WBS) allocated and all information is entered into the programme. Finally, a network analysis is carried out to ensure consistency of approach and to identify any inconsistencies or irregularities in the removal programme.

This approach allowed the complete set of activities to be compiled in a spreadsheet, with each component recorded as a line item identified against its WBS number. Against each item, all pertinent information was then recorded, such as scheduled start and finish dates, type of personnel required to complete the task (labourer, craftsman etc), man hours to complete the task dose uptake and the, type and amount of waste produced in completing the task. By producing this definitive record any future changes to say man hours or waste production can be simply and easily changed and the amended totals quickly found.

IMPLEMENTING THE STRATEGY

Waste Management Facility (WMF)

The WMF will be steel framed, profiled sheet cladding building constructed on the sides of the containment and fuel pool buildings before any physical decommissioning commences. Access to the existing buildings will be by new openings formed in the containment and fuel pool walls. These openings will receive closure doors. (See Fig 3). The WMF is designed to accept waste materials from the remainder of the NPP site as well as from the containment building.

The WMF is designed to handle solid Category I and II wastes as well as wastes destined for free release. The aim of the WMF is to decontaminate as much of the waste as possible to a free release condition. Wastes that cannot be successfully decontaminated will be packaged in the WMF to a standard suitable for final disposal at the waste repository. The WMF is not intended to process the reactor pressure vessel and internals. These items will have a separate waste route that bypasses the majority of the WMF but utilises the WMF box grouting systems. The WMF is intended to operate on the basis that completed boxes of waste and free released items will be removed from the WMF as soon as possible. The WMF has no facility for the storage of processed wastes. No liquids or sludges are to be processed via the WMF. These will go to a Liquid Radwaste Facility (LRF) elsewhere on the site. A skid facility will be used after 2010, when existing the liquid radwaste facility dismantling will start.

The ground floor process areas have an assumed height of 5m. The upper floor is expected to be a minimum of 3m high and will contain the heating and ventilation plant and box storage areas. The floor heights facilitate the inclusion of yet to be designed station plant and provide sufficient height for overhead craneage as required. The decontamination equipment provided will include chemical, high pressure water, grit blasting and mechanical cleaning equipment. The areas provided for this equipment have been designed to be flexible to cater for campaigns of material that require high use of designated techniques. The provision of jet washing and chemical cleaning facilities requires a dedicated vent system capable of extracting wet, corrosive air.

The concept design has been completed with the following aims and objectives:

- Ensuring compliance with AECP 1054 (1998) is achieved.
- Ensuring that for seismic considerations the foundations and walls are in accordance with US Nuclear Regulatory Guide Commission (NRC) Regulatory Guide 1.143 Rev.1, 'Design guidance for radioactive waste management systems, structures and components installed in light-water cooled nuclear power plants'.
- Designing the facility to fit within the space envelope allocated at the site.
- Ensuring the building is self-contained with respect to local change facilities, process activities, storage space (waste and maintenance spares), electrical controls and distribution, control rooms and support activities (grout mixing, box receipt etc.).
- Minimising the length of process streams to reduce the requirement for transportation between areas.
- Ensuring areas are (nominally) sized sufficiently for process and maintenance operations to occur.

Containment Waste Path

Once the WMF has been constructed, a waste path from the 152.68m reactor deck level to the 128.14m level will be constructed within the containment building. The waste path will facilitate the movement of material from all levels in the containment into the WMF at ground level. This will require the modification of several components and the removal of the main coolant pump, neutron shield tank, surge tank and attendant services. Once these components have been removed, an electric hoist of will be installed, sized to accept the majority of segmented components for transfer to the WMF. The existing polar crane within containment will handle larger components.

PLANT, EQUIPMENT AND SERVICES REMOVAL

Once all the modifications to existing plant and equipment have been completed and the reception facilities have been constructed and commissioned the removal of plant and equipment will commence. An overview of the main operations is given below.

The Trino NPP report and consequently this paper has fully considered reactor segmentation by removing the vessel from the cavity and remotely segmenting it in air. However other scenarios may be considered as applicable such as flooding the reactor cavity and segmenting the vessel underwater. In this context Sogin have completed investigations with regard to the preparation of a waterproof "tank" for RPV underwater cutting.

Set Up Large Equipment Segmentation Area

Prior to the removal of the reactor vessel, the reactor deck will be cleared of large items such as the reactor head and coolant pump, removed earlier to facilitate the construction of the waste path. The reactor head storage area on the 152.68m reactor deck level is designated as the segmentation area and a large enclosure with extract filters will be constructed on the deck. The ventilation system will discharge from the enclosure into the containment area where the filtered exhaust will be taken into the existing ventilation system for eventual discharge through the offgas stack. This area will be utilised for the segmentation of all reactor coolant pumps and similar sized contaminated plant and equipment, prior to dispatch to the WMF.

Reactor Internals Removal

The reactor internals will be segmented underwater in the re-fuelling pool due to the high radiation levels. The reactor cavity will be equipped with additional underwater filtration units to maintain water clarity. The Trino radiation monitoring system will be used to alert personnel should any materials get too close to the water surface. Operators will monitor the pool water level to ensure pool level and integrity is maintained. The internals removal and segmentation work will be undertaken in 2 shifts to efficiently complete the work. The internals removal and segmentation will be performed using Abrasive Water Jet Cutting using Abrasive Water Jet Cutting, Metal Disintegration Machining, and Plasma Arc Cutting where applicable.

Prior to the removal and segmentation operations commencing, a full inventory of all components will be made. This inventory will be monitored during the segmentation process to ensure that all items are accounted for and packaged in predetermined locations in the waste boxes prior to being grouted in the WMF. These operations including package lidding will take place underwater.

Reactor Vessel Removal

This work will be performed in the reactor cavity and movable covers will be installed to contain the cavity area. Local, filtered ventilation units will be used to maintain a slight negative pressure or inward airflow into the cavity. A lift system will be installed over the pool to lift the vessel and allow segmentation to be performed in the reactor re-fuelling area. The existing polar crane does not have sufficient capacity to lift the vessel from the cavity, but will be used to support the segmentation work. The reactor vessel will be segmented using an Oxy-acetylene system fitted with ventilation units to control airborne radioactivity. First the vessel nozzles will be cut to enable the vessel to be lifted. Once lifted, the bottom of the vessel will be cut and the pieces transferred to the cutting area for size reduction. The pieces will be surveyed and packaged ready for processing in the WMF. In addition to the dry cutting method, RPV removal using underwater mechanical cutting is deemed a practicable alternative, providing all access holes in the bioshield are sealed. To facilitate this method the upper portion of the vessel, including flange and nozzle region will initially be cut and removed. This process will continue until the remaining vessel is within existing polar crane lifting capacity. At this point the RPV can be lifted from the cavity and the bottom can be placed on a provisional support structure, allowing the supporting ring to be cut.

Neutron Shield Tank

The tank will be removed after the reactor vessel has been removed from the reactor cavity. Prior to beginning this work, the cavity will have been subjected to housekeeping and decontamination activities. The neutron shield will be removed using the reactor vessel segmentation lifting and cutting equipment.

The majority of the neutron shield contains neutron-activated materials and therefore will be segmented and packaged as radioactive waste and transferred to the WMF. The inner shell of the neutron shield tank as well as a portion of the outer shield adjacent to the reactor vessel is expected to be neutron activated and will not require conditioning. The majority of the outer shell will be decontaminated.

Activated Concrete Removal from Mid Level Reactor Core Region

The removal of activated concrete from mid-level reactor region of the primary biological shield will need to be removed. The concrete will be reduced using a Remote Operated Vehicle (ROV) fitted with remote tooling. Rebar will be remotely cut using a ROV mounted torch. While the constituents of the concrete have become radioactive through neutron activation, the radiation and contamination levels are low and will result in minor occupational hazards to the workers. Controlling silica dust from the concrete by misting the work area with water may be more important than the radiological hazard.

The concrete rubble will be packaged as radioactive waste and transferred to the WMF Facility. Based on sample data, and radionuclide decay to the year 2011, it is estimated that approximately 42,000 Kg. of concrete will require removal to meet release standards.

Steam Generator Removal

The re-fuelling pool will then be cleaned and used as an enclosed, ventilated area for the segmentation of the four steam generators. In order to enlarge the waste buffer area, unit C will be the first to be removed. The remaining generators will be removed in a sequence designed to improve access to the WMF. Each steam generator will be removed in two stages. In the first step, the steam dome will be cut in-situ and transferred to the reactor head containment area for segmentation. The sections will then be transported to the Monitor Release Facility (MRF) for radiological survey and free release. The second step will be to remove the remaining portion of the generator (lower mounting surface to top of tube bundle) using the polar crane and place it in the reactor cavity for segmentation. Clean components will then be separated from the radioactive components and transferred to the WMF or MRF. If these facilities become over-burdened, the reactor cavity will be used as a waste buffer store. Once any backlog has been reduced, the materials will be passed to the respective facility (WMF or MRF) as before.

Reactor Coolant Pumps

The Trino pumps and motor are one unit and will be removed as one piece. The first pump will be removed to facilitate the construction of the waste route. When the second pump is removed, it will be transferred to the 152.68m elevation and, based on knowledge gained from the first pump, may be partially disassembled in order to reduce dose rates. It is planned that the motor will be transferred to the WMF for additional disassembly and decontamination. The pump casing will be transferred to the 152.68 elevation and placed in the reactor cavity, where the pump casing and piping will be cut into segments for either decontamination or packaged as for disposal.

Pressuriser (PZR)

The 55300 Kg. pressuriser will be lifted as one unit by the polar crane and transferred to the reactor cavity for segmentation. The segmentation work will be conducted on the 137.06m elevation in an area prepared for large component segmentation. The pressuriser will be segmented using hot cutting techniques and, where applicable, clamshell cutters will be deployed. Waste produced as a result of the pressuriser sectioning will be processed for decontamination or as radwaste in the WMF. The PZR and the 108 PZR electric heaters are contaminated. The contaminated materials will be sent to the WMF for decontamination. In the event these facilities are over-burdened, the materials will be sent to the waste buffer store.

Removal of Containment Dismantling Enclosures

Once the major plant items and re-fuelling pool contents have been removed, the removal of containment dismantling facilities in the reactor building on the 152.68m elevation can commence. Two separate dismantling areas are involved, one at the head area for highly radioactive components and one in the reactor cavity for components that are radioactively clean or have a moderate radioactive contamination. Both dismantling areas will have HEPA ventilation and Continuous Air Monitors with alarms to detect airborne radioactivity inside and outside the areas.

The dismantling area in the reactor cavity on the 137.06m elevation will be the first of the areas to be removed. The reactor cavity segmentation area will be removed in order to start the refuel pool liner removal and decontamination of the pool concrete walls. The dismantling of this area will occur after all large components have been segmented. The removable cover on the 144.68m elevation will be the last item to be removed. Local HEPA ventilation units will be used to control airborne activity during the removal activities. The second dismantling area at the reactor head storage area on the 152.68m elevation will be removed later in the process. This area is not critical to the overall dismantling schedule and may be used for the segmentation of materials until the reactor building decontamination activities begin.

Fuel Pool Liner and Contaminated Concrete Removal

At this stage, the re-fuelling pool can be decommissioned. The removal of the fuel pool liner as well as the removal of contaminated concrete from behind the pool liner will be carried out. The pool liner will be segmented using thermal cutting. Liner sections will be packaged for processing in the WMF. The pool liner removal protocol and sequence were selected based on good contamination control practices and efficient use of personnel. The liner removal will start at the top of each wall and rows of liner segments will be removed. Health physics technicians will perform surveys to identify and assess the contamination level in each row. Once the liners from the tops of the walls are removed, the floors and walls are segmented, working from each deep cavity end to the 137m elevation. For safety and contamination control reasons, the 137m floor liner is the last to be removed and surveyed.

Decontamination of the pool walls and floors will be performed primarily with concrete shavers. In the case of concrete cracks or fissures, the concrete around the fissure will be cut out to remove the contamination. Fissures will be decontaminated in conjunction with the shaving activities. The concrete removal sequence will follow the same regime as the liner, with decontamination starting at the top of the pool walls and progressing to the floor level. However, the deep end floors will be decontaminated later in the sequence. Contaminated concrete will be packaged and transferred to the WMF for processing.

The remainder of the plant and equipment will be removed using tried and tested methods. Examples include the polar crane, which will be removed from inside the containment structure using hydraulic jacks placed on the 152.68m reactor deck level. The crane will be lowered and segmented prior to despatch to the WMF for cleaning and disposal.

WASTE OPTIMISATION, PROGRAMME AND COST

Waste Optimisation

A prime consideration was to develop a strategy that minimised waste while delivering a cost effective decommissioning programme that could meet the time restraints imposed by outside agencies. The Trino strategy has demonstrated that for an investment of €6M, a waste management facility can be constructed that will be able to treat most of the waste generated on-site and allow a significant amount to be released off site for re-use. The reactor study has concluded that for wastes that would otherwise have to be packaged, transported and disposed of, waste costs saved by the WMF will be as shown in table II.

Table II. Waste costs saved by the WMF

Waste releasable after decontamination (kg)	508760
Volume if all steel (m3)	65
Packing factor	50%
No. of 3.7m3 boxes at packing factor	35
Package purchase cost (Euros)	2099000
Package disposal costs (Euros)	1299000
Package Transport Costs (Euros)	361000
TOTAL WASTE COST SAVING (EUROS)	**3759000**

Table III. Totals of waste produced.

Waste Category	Total (kg)
Releasable	17,915,405
Cat II Type 1 waste	113,466
Cat II Type 2 waste	766,439
Cat III waste	14,845
DAW	160 m^3

The base estimate for implementing the strategy is €34.3M (2001 money values). This does not include any Sogin or station costs associated with the development and deployment of the strategy. Estimated waste disposal costs are shown in table IV.

Table IV. Estimated waste disposal costs.

	Cat II Type1 (waste) 1000 litre drums	Cat. II Type2 (Metal waste) 3.7 m3 Boxes	Cat II Type2 (Non Metal waste) 8.2m3 Boxes	Cat III 3.1m3 Gusscontainer	DAW Drums (33% in-drum compression)	Cost Subtotals (€)
Cost/container (€)	670	60,000	105,000	115,000	150	
Volume (m3)	1.68	5.20	10.80	5.40	0.25	
Disposal cost (€/m3)	7140					
Package cost (€)	28,140	3,000,000	525,000	345,000	110,400	4,008,540
Package disposal cost (€)	503,798	1,856,400	385,560	115,668	1,313,760	4,175,186
Transport cost (€/10te load)	5,165					
Transport cost (€)	216,930	516,500	51,650	30,990	76,029	892,099
Total waste costs (€)	748,868	5,372,900	962,210	491,658	1,500,189	**9,075,825**

SUMMARY AND CONCLUSIONS

The combination of Sogin's plant knowledge with BNFL's decommissioning experience and methodology has resulted in the generation of a costed decommissioning methodology for the prompt decommissioning of the Trino reactor. This methodology draws, where possible, on past experience and proven methodology and is considered to be a robust basis for the provisioning of Italian decommissioning funds.

This methodology will now form the basis for further planning and project development. After the strategy has been reviewed formally by the Italian regulators, Sogin will initiate further work such as safety case and technique development.

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