Analysis of Alternatives for Dismantling of the Equipment in Building 117/1 at Ignalina NPP – 13278

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ABSTRACT

Ignalina NPP was operating two RBMK-1500 reactors which are under decommissioning now. In this paper dismantling alternatives of the equipment in Building 117/1 are analyzed. After situation analysis and collection of the primary information related to components' physical and radiological characteristics, location and other data, two different alternatives for dismantling of the equipment are formulated – the first (A1), when major components (vessels and pipes of Emergency Core Cooling System – ECCS) are segmented/halved in situ using flame cutting (oxy-acetylene) and the second one (A2), when these components are segmented/halved at the workshop using CAMC (Contact Arc Metal Cutting) technique. To select the preferable alternative MCDA method – AHP (Analytic Hierarchy Process) is applied. Hierarchical list of decision criteria, necessary for assessment of alternatives performance, are formulated. Quantitative decision criteria values for these alternatives are calculated using software DECRAD, which was developed by Lithuanian Energy Institute Nuclear engineering laboratory. While qualitative decision criteria are evaluated using expert judgment. Analysis results show that alternative A1 is better than alternative A2.

INTRODUCTION

Ignalina nuclear power plant (NPP) was the only one NPP in Baltic States, build in north east Lithuania near the border of Belarus. Ignalina NPP was operating two world's largest and most advanced RBMK-1500 design reactors (electrical capacity – 1500 MW, thermal capacity 4800 MW) and supplied 70-80 % of Lithuania national electricity demand. In line with accession to the European Union treaty commitments Ignalina NPP was closed at around its exploitation mid-life: Unit 1 was shut down at the end of 2004, and Unit 2 - at the end of 2009. Since 1 January 2010 decommissioning has become the major Ignalina NPP activity. The auxiliary plant systems can now be progressively dismantled. The first area to undergo dismantling is the Emergency Core Cooling System (ECCS) equipment of Unit 1 which is in Building 117/1.

EQUIPMENT IN BUILDING 117/1

Building 117/1 is located close to Ignalina NPP reactor building of Unit 1. It is quite a big building (the volume based on overall dimensions is 13748 m^3) with more than 30 rooms located at -3.6-7.2 m levels. Part of the Ignalina NPP Unit 1 Emergency Core Cooling System (ECCS) is located in this building.

Main components to be dismantled are: helium facility equipment, ECCS 16 carbon steel water pressure vessels (at around 14 m high x 1.5 m diameter, 80 mm wall thickness with internal contamination), up to 400 mm diameter carbon steel pipes and fast acting valves on the main ECCS pipelines to Unit 1, small diameter carbon steel pipes, various carbon steel fabrications including floor structures with deck plates, steel platforms and staircases, miscellaneous plant items such as electric motors, control panels, gauges, etc.

Not all systems in the building can be dismantled at the same time. Some of them are still necessary for safety purposes in Unit 1 and will be also needed for safety assurance during the dismantling. During phase 1 the majority (94 % or ~957000 kg) of Building 117/1 equipment and systems will be dismantled. For phase 2 (6 % or ~61000 kg) transit communication lines of general power plant systems, as well as systems which maintain normal operating conditions inside the building (systems of heating and ventilation, lighting, firefighting, drainage system, etc.) will be left. In this paper only activities during phase 1 will be analyzed.

The biggest part (99 %) of the dismantled components consists of steel and only 1 % of the components consists of concrete, stainless steel and other materials. This is mainly because there are sixteen ECCS steel vessels in this building, with one vessel weighting ~48.000 kg.

In building 117/1 ECCS vessels, pipes and steel structures are the most common component types (79 %, 10 % and 8 % respectively). Other component types: concrete structures to be demolished, valves, tee fittings, electric equipment, instrumentation and control equipment (Figure 1).

Based on radiological characterization data about 91 % components are of very low level waste (VLLW), about 9 % of exempt waste (EW) and only <0.02 % of low level waste (LLW) (Figure 2).

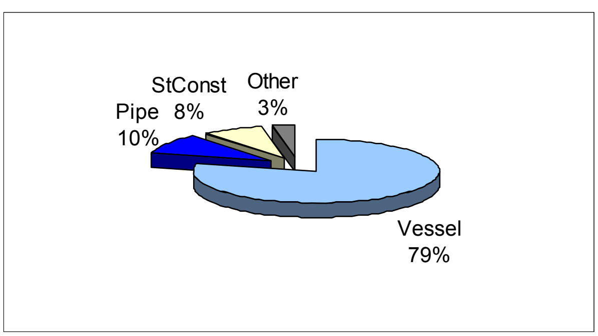

Figure 1: primary mass by component type

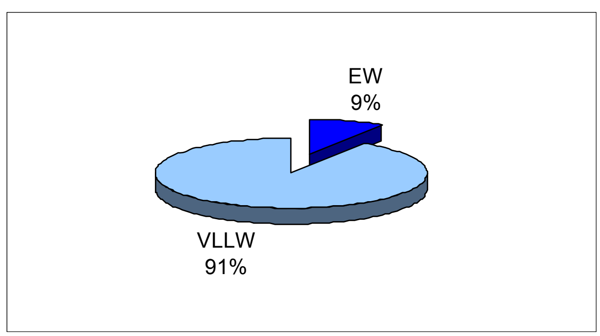

Figure 2: radiological characterization of components

METHODOLOGY

Quantitative data calculation tool – DECRAD

For the analysis of nuclear plants decommissioning activities computer programs such as Cora-Calcom [1], Omega [2], Dexus [3], etc. are used. They are mostly orientated to calculation of the data for preparation of the Decommissioning Plans.

For preparation of the equipment dismantling project more detailed information is necessary, so for analysis of different equipment dismantling alternatives in Building 117/1 DECRAD tool [4] was used. DECRAD was developed at LEI by Nuclear Engineering Laboratory.

The structure of the computer code is presented in Figure 3. DECRAD has been developed as a tool that provides the transition of planning results into project management measures. So the tasks of planning and calculation as well as documentation and the project controlling are simplified considerably.

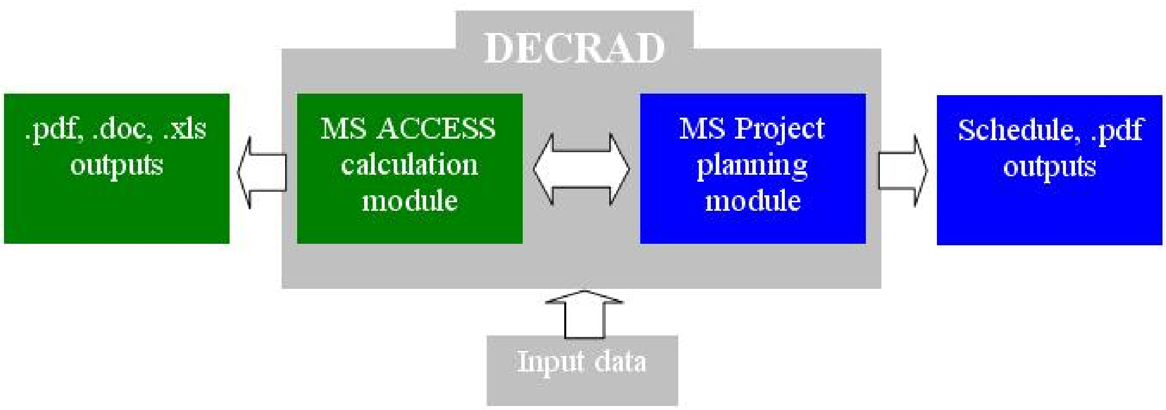

Figure 3: simplified structure of DECRAD

DECRAD allows calculation of the data:

1. For calculation of necessary data for assessment of different strategies/alternatives;
2. To support detailed dismantling projects of separate buildings;
3. Integrated waste disposal planning for the whole nuclear facilities.

Output data are presented in Table I.

In order not to operate with each single component, all components in Equipment technical data list were grouped into waste streams. Such approach allowed to group/generalize the types of equipment/components with the same features.

TABLE I: DECRAD outputs

1.Worker Safety (Radiological)	**6.Cost**
Collective dose [man Sv]	Labour cash flow (with OH) [Euro]
Individual dose [mSv]	Consumables cash flow [Euro]
2.Resource Usage	Procurement cash flow [Euro]
Needed manpower by qualification [man-day]	Waste management cash flow [Euro]
Total needed manpower [man-day]	Preparatory activities cash flow [Euro]
Consumables [kg or units]	**7.Waste Activity Data**
3.Non-Radiological Discharges	Liquid rad. Waste [Bq]
Chemical into the lake [m3]	Solid to Landfill (primary and secondary waste) [Bq]
4.Radiological Discharges	
Liquid into the lake [m3 or Bq]	Solid waste to NSR (primary and secondary waste) [Bq]
Aerosols to atmosphere [m3 or Bq]	
5.Hazard Potential	Bituminised waste [Bq] and etc.
Hazardous/toxic inventories	
8.Other	
Inventory data (primary waste by rooms, systems, types, material, phases, etc.)	
Radiological data (decontamination factor, waste class, nuclide vector, etc.)	
Waste management data (primary and secondary waste by: disposal ways, stages, tools; primary and secondary waste packaging data; etc.)	
Scheduling data (project duration, work breakdown structure (WBS), etc.)	
Data flows (masses, packages and doses by month)	

MCDA technique

Analytic Hierarchy Process (AHP) method was chosen for the analysis of equipment dismantling alternatives in Building 117/1 [5].

AHP is applied by breaking down an unstructured problem into hierarchical structures. Criteria weights and qualitative data are evaluated by the experts using pair-wise comparisons and eigenvectors to determine which variables have the highest priority.

Calculations were performed using universal software, i. e., MATLAB and MS EXCEL.

Alternatives

In market there are not much cutting techniques for 24 mm (ECCS pipes) and even less for 80 mm (ECCS vessels) thickness steel. Today we can count on one hand techniques for such tasks. Most popular thermal cutting techniques are: flame cutting (oxy-acetylene/propane/liquid fuel), thermic/oxygen lance, contact arc metal cutting (CAMC); and most popular mechanical techniques are: big sawing tools and water jet with abrasives [6].

Often components being dismantled are of quite complex structure, have difficult geometry and are hard to access, ability to easily move cutting equipment during dismantling is essential. CAMC, big sawing tools and water jet with abrasives are withdrawn because they are not movable and can only be placed in workshop. Flame cutting and thermal/oxygen lance cutting techniques are fast, reliable and easy movable, but thermal/oxygen lance generates much higher emission of small particles and there fore is rarely used in nuclear dismantling (for contaminated components) processes. So oxy-acetylene is often a most appropriate and barely changeable technology for dismantling tasks.

Different situation is when cutting equipment mobility is not necessary and cutting activities (segmentation) is done in workshop. Thermal/oxygen lance cutting is withdrawn because of previously said arguments. Big sawing tools are withdrawn because of lack of space for in situ workshop and water jet with abrasives is withdrawn too because of slow cutting speed and relatively high amount of accumulated used abrasives. Finally we have two suitable cutting techniques for segmentation: flame cutting and CAMC. CAMC speed is usually several times faster then flame cutting [7, 8].

For Building 117/1 equipment dismantling concrete bursters (for wall openings, etc.); tool boxes (scissors, hydraulic scissors, pendulum saw, angular grinder, etc.) for mechanical cutting (dismantling of small equipment, pipes with diameter less than 100 mm, etc.) and oxy-acetylene for thermal cutting (pipes with diameter more than 100 mm, vessels and supports of ECCS) are selected.

Two different equipment dismantling alternatives (named A1 and A2) there were formulated for Building 117/1. Alternatives aim to apply different cutting techniques only for segmentation/halving of vessels and pipes of ECCS (~80% and 8% of total mass respectively).

For alternative A1 vessels of ECCS are dismantled by cutting vessels horizontally and forming rings, which are segmented with flame cutting (oxy-acetylene) in situ. As for alternative A2 dismantled rings of ECCS vessels are transported to segmentation workshop and segmented using CAMC. Also there are differences halving pipes of ECCS: for A1 alternative pipes are halved using oxy-acetylene in situ where they are dismantled, as for A2 alternative they are transported to segmentation workshop and halved using CAMC technique.

Decontamination works for both strategies are the same: mechanical decontamination is performed (vacuum blaster) for contaminated dismantled components. They are decontaminated to EW level, if it is reasonable. The secondary waste and components that cannot be decontaminated to EW level, whether will be disposed at the VLLW repository or transported to the treatment facility for further treatment and disposal in the near surface disposal facility for

L/ILW.

Summary of alternatives definitions are explained in Table II.

TABLE II: summary of dismantling alternatives

D&D stage	Alternative A1	Alternative A2
Dismantling	Concrete burster for wall openings, etc. Tool box for small equipment, pipes ø < 100 mm, etc. Oxy-acetylene for vessels and supports of ECCS, pipes ø > 100 mm, etc.	
Segmentation/ halving	Oxy-acetylene for vessels of ECCS, pipes ø > 100 mm, etc. (in situ)	CAMC for vessels of ECCS, pipes ø > 100 mm, etc. (in workshop)
Decontamination	Vacuum blaster for contaminated components (if it is possible)	

During the analysis it was assumed that for both alternatives there will be one group of workers for dismantling and segmentation/halving (in situ – only for alternative A1) works, one group for segmentation/halving and decontamination works in workshop (segmentation/halving workshop is only for alternative A2) and one group for transporting the dismantled equipment for segmentation/halving, decontamination and radiological monitoring.

Criteria

Qualitative and quantitative criteria tree consisting of 5 criteria groups (waste streams, economic, duration, safety, technology, environmental and social) and 21 unique sub-criteria were formulated to suit Building 117/1 needs. Fragment of criteria tree is presented in Table III.

TABLE III: Fragment of criteria tree compare dismantling alternatives in Building 117/1

Criteria	Sub-criteria	Description	Type	Units
W1. Waste streams	W1.1. Primary waste ratio	The criterion compares the relation between the overall primary waste mass and primary exempted waste mass.	Quan.	%
	W1.2. Secondary waste ratio	The criterion compares the relation between the overall secondary waste mass and secondary exempted waste mass.	Quan.	%
…				
…				
S1. Safety	S1.1. Radiological worker safety	Radiological (collective dose) impact is considered.	Qual.	Expert judg.
	S1.2. Conventional worker safety	Non-radiological (e.g. falls, asphyxiation, etc.) impacts are considered.	Qual.	Expert judg.

RESULTS AND THEIR ANALYSIS

Quantitative data

Waste streams analysis for both alternatives shows that after D&D activities 99.86 % of the primary waste meets EW criteria and will be released from regulatory control. Approximately 0.14 % of primary waste must be disposed of into the VLLW repository. Minor part (0.002 %) of the primary waste can neither be decontaminated to the EW level nor meets waste disposal criteria for VLLW repository, so the waste must be transported to B3 (i. e., New Solid Waste Management and Storage Facilities) complex for treatment and storage till the final disposal in near surface repository for I/LLW.

Apart from the primary waste, there will certainly be the secondary waste such as cutting slag and swarf, spent decontamination and cutting media, liquids, filters and etc. Figure 4 demonstrates the distribution of the secondary waste by waste classes for both alternatives. VLLW amount is similar for both alternatives (~13.74 % higher for alternative A2) while LLW amount is much higher for alternative A2 compared to A1. This is mainly because CAMC technology generates contaminated water which has to be evaporated and bituminized in liquid waste treatment facility.

Analysis of workers collective doses has shown that for alternative A1 doses are ~6 % higher comparing to A2 (Figure 5). This is mainly because cutting activities take longer time and more workers are involved for alternative A1.

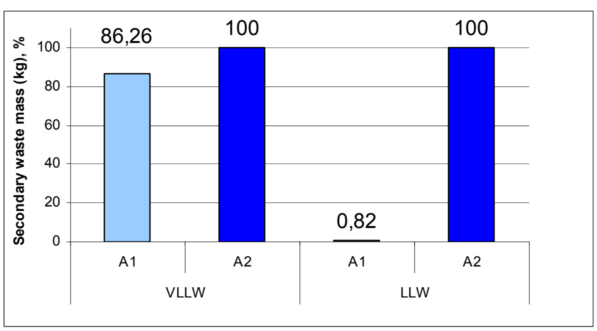

Figure 4: secondary waste amount

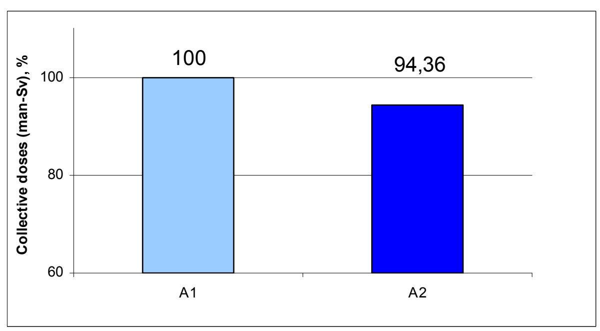

Figure 5: collective dose

Total project duration is the same for both alternatives, although dismantling is done quicker using CAMC, but segmentation in workshop and decontamination is performed simultaneously with cutting tasks therefore effecting overall duration. There is minor difference (~3 % less man-months for alternative A2) when comparing number of man-month, because segmentation/halving in workshop requires fewer workers (Figure 6).

Before the beginning of Building 117/1 dismantling activities, certain equipment (lifts, cutting, decontamination, radiological measurements and electrical equipment, containers for waste disposal and transportation, etc.) must be purchased to assure effective performance of the work. The analysis of the investment necessary to purchase the equipment for D&D activities has shown that investments are higher for alternative A2 because additional CAMC equipment is necessary (Figure 7: investment). But comparing D&D cost we have different situation. Alternative A1 D&D cost is higher (Figure 7: D&D). This is mainly because more man-months are needed for alternative A1.

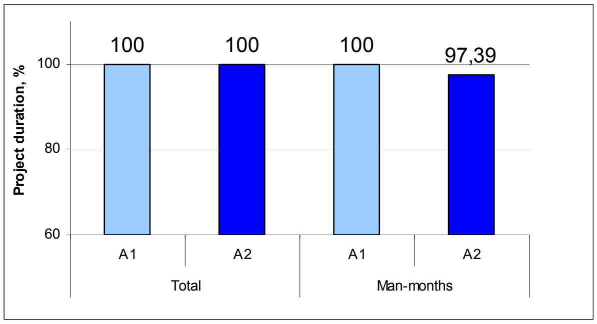

Figure 6: project duration

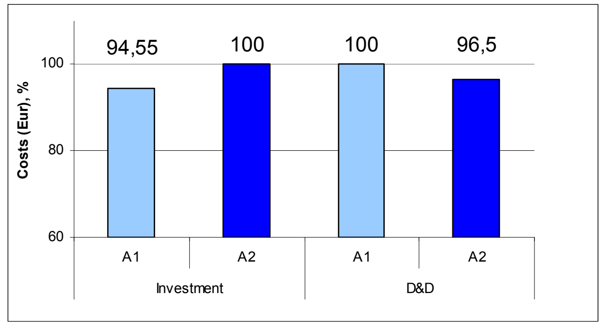

Figure 7: project costs

MCDA results

As it was indicated above AHP method was applied in this report for MCDA analysis. Five experts participated in the pairwise comparisons of criteria, sub-criteria and alternatives performance against qualitative sub-criteria. Experts are not used to evaluate alternatives performance against quantitative sub-criteria, therefore normalized weights of quantitative sub-criteria values are calculated by DECRAD. Final dismantling alternatives ranking is calculated based on expert evaluations and results of DECRAD calculations (Figure 8).

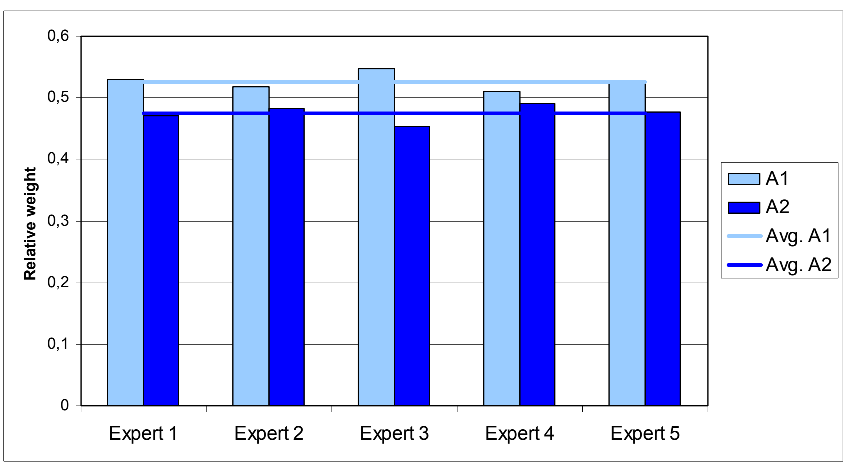

Figure 8: Final ranking of equipment dismantling alternatives

The assessment performed using the AHP method of Multi-Criteria Decision Analysis has shown that alternative A1 with 0.526 (relative weight) final ranking is better than A2 alternative with 0.474 final ranking. Thus the A1 alternative is recommended as the better option for the dismantling of Ignalina NPP Building 117/1 equipment where mostly very low level waste is generated.

CONCLUSIONS

After analysis of two alternatives for dismantling of the equipment in Building 117/1 such conclusions are made:

1. The biggest part (99 %) of the dismantled components consists of steel and only 1 % of the components consists of concrete, stainless steel and other materials. Also emergency core cooling system (ECCS) vessels, pipes and steel structures are the most common component types (79 %, 10 % and 8 % respectively).
2. Based on radiological characterization data about 91 % components are of very low level waste (VLLW), about 9 % of exempt waste (EW) and only <0.02 % of low level waste (LLW).
3. After D&D activities 99.86 % of the primary waste meets EW criteria for both alternatives (alternative A1 – segmentation/halving of ECCS vessels and pipes is performed oxy-acetylene; alternative A2 – segmentation/halving of ECCS vessels and pipes is performed in workshop by CAMC). However more secondary waste is generated for alternative A2 then for alternative A1.
4. Alternative A2 has some advantages against alternative A1 when comparing collective dose, man-months and D&D costs, but alternative A1 has some advantage when comparing investment costs.
5. The comparison of alternatives performed using the AHP method of Multi-Criteria Decision Analysis has shown that alternative A1 is better than alternative A2.

REFERENCES

1. Siempelkamp. NiS Ingenieure mbH CORA-CALCOM. Brochure. http://www.siempelkamp-nis.com/fileadmin/pdf/en/Cora_Calcom_GB_0408.pdf.
2. V. DANISKA and V. NECAS. Modeling of the decommissioning process of nuclear installations (2000). Journal of Electrical Engineering 51 (5–6), pp. 156–167.
3. Y. IGUCHI, Y. KANEHIRA et al. Development of decommissioning engineering support system (DEXUS) of Fugen nuclear power station (2004). Journal of nuclear science and technology, Vol. 41, No. 3, p. 367-375.
4. The software DECRAD validation report (2010). TA-14-13.10. LEI, Nuclear engineering laboratory, 2010

5. T. L. SAATY. Fundamentals of Decision-Making and Priority Theory with the AHP (1994). RWS Publications, Pittsburg, PA, USA.
6. Edited by M. LARAIA. Nuclear decommissioning: Planning, execution and international experience (2012). Woodhead Publishing Series in Energy No. 36, pp. 824.
7. EC – CND coordination network on decommissioning final report. Dismantling Techniques, Decontamination Techniques, Dissemination of Best Practice, Experience and Know-how (2009). CORDIS: FP6-Euratom: Nuclear Fission and Radiation Protection. World wide web: ftp://ftp.cordis.europa.eu/pub/fp6-euratom/docs/cnd-wp7-decontamination-dismantling-techniques-finalreport.pdf
8. R. BORCHARDT and J. RAASCH. Results of the Full Scale Testing of the Remote Dismantling in Greifswald NPP (2003). Presentation at 9th ASME International Conference on Radioactive Waste Management and Environmental Remediation. World wide web: http://asmedl.org/getabs/servlet/GetabsServlet?prog=normal&id=ASMECP00200303732700178900001&idtype=cvips&gifs=yes&ref=no