THE MANAGEMENT ROUTES FOR CONTAMINATED METALS FROM DISMANTLING OF NUCLEAR REACTORS

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ABSTRACT

The dismantling of the BR3 reactor produces quite large masses of contaminated materials, mainly metals or concrete. The main management routes are: conditioning of the radioactive wastes and disposal, recycling of radioactive materials in the nuclear sector and the recycling of cleared materials in the industrial sector or their evacuation as industrial waste.

The paper is focused on the management of the dismantled contaminated metals. It gives an overview of the main management routes followed with their associated dismantling and decontamination techniques. The administrative and the technical aspects starting from the dismantling up to the final evacuation are dealt with.

The radiochemical characterization is also important at all the steps of the dismantling process. Characterization is performed on site before dismantling to guarantee the workers safety and for the selection of the right evacuation route.

Melting in a nuclear foundry either for clearance or for reuse in the nuclear sector is used at SCK•CEN for low level metallic materials. As Belgium does not have any "nuclear" melting facility; contracts were signed with company's abroad.

For unconditional clearance, the issues related to the guiding values, the measurement procedures and the measurement techniques are dealt with and the experience obtained during the dismantling of our facility is presented.

We also give an overview of the various decontamination techniques that are used at SCK•CEN to reach the minimum amount of produced nuclear waste. For the metals, we use mainly simple washing, an abrasive sandblasting facility "ZOE" for pieces up to 3t and 3 m long and hard chemical decontamination with cerium in a facility called "MEDOC".

The specifications and the results obtained so far with these processes will also be detailed.

INTRODUCTION

BR3 is a small 10 MWe PWR shutdown in 1987 after 25 years of operation. It was selected as one of the four pilot projects of the EU for its R&D program on Decommissioning of nuclear installations. The decommissioning project started in 1989. In 1991, a Full System Decontamination of the primary loop reduced the dose rate in the vicinity of the primary loop by a factor 10. The same year, a first high active internal, the 5.4 t thermal shield was dismantled underwater by 3 different dismantling techniques, the EDM cutting, the milling cutter and the plasma arc torch. Mechanical cutting, essentially milling cutter and band saw, were selected for the further dismantling of the two sets of internals; the original Westinghouse internals ("33 years decay") and the Vulcain internals ("7 years decay"). This allowed to compare deferred dismantling with immediate dismantling. No significant radiological, technical or economical profit was gained by dismantling the old internals because due to the still high dose rate of 2 to 3 Sv/h at mid plane, remote underwater cutting is still required. The 28 t Reactor Pressure Vessel has been dismantled in 1999-2000 using mainly a circular saw for the horizontal cutting in rings and a vertical band saw for the cutting into segments. [1] This work is also extensively presented in another paper at this conference.[2] Dismantling of contaminated circuits is also performed using mostly hands on cutting techniques. The next important step is the dismantling of heavy massive pieces (reactor pressure vessel cover and bottom, neutron shield tank) and large components (steam generator, pressurizer). For these pieces, High Pressure Water Jet Cutting with abrasives using a remote operated arm will be used. [3]

Minimizing the amount of radioactive waste and recycling or clearance of the dismantled materials have always been our main objectives. The paper is focused on the main issues and results related to the management of the dismantled contaminated materials.

EVACUATION ROUTES

Dismantling of a nuclear reactor produces large quantities of materials and associated gaseous, liquid and solid effluents. Not only primary materials are produced i.e. the items dismantled but also secondary materials e.g. tools, equipments, new hardware for dismantling and decontamination and secondary effluents from the dismantling operations.[4] [5]

The major solid materials coming from the dismantling operations are:

- Burnable wastes such as protective clothing, wood from ventilated hoods, laboratory furniture...
- Low to High level massive metallic wastes such as reactor internals, reactor pressure vessel, primary pumps, reservoirs, valves, structural materials...
- Low to High level super-compressible metallic wastes from the same sources as above plus e.g. electric cables, light supports, contaminated instrumentation...
- Massive concrete wastes from slightly activated or contaminated slabs, floors, shielding walls, room walls...
- Concrete and bricks super-compressible rubble from demolition activities of activated or contaminated materials.
- Sludges from deposits in reservoirs and liquid sumps.
- Various light nonmetallic super-compressible materials such as thermal insulation.
- Special waste such as contaminated lead bricks and shielding.

Three main material categories can be distinguished:

- Material which can be considered as conventional and treated as such, e.g. evacuated as industrial waste or recycled in the industry: alternator, tertiary loop, equipments outside the controlled area.
- Material which has to be evacuated as radioactive waste, e.g. activated materials or strongly contaminated material which cannot be technically or economically decontaminated or cannot be recycled or re-used: reactor pressure vessel and its internals, highly activated concrete, contaminated insulation materials....

- Material which, a priori, has to be considered as radioactive material, but as alternative to its evacuation as radioactive waste can be cleared unconditionally after decontamination, cleared after melting or recycled in the nuclear industry: contaminated piping, reservoirs, pumps, structural equipments, contaminated concrete....

WORK ORGANIZATION

The dismantling of a nuclear facility is a complex task. Therefore the dismantling operations are divided in hundreds of different tasks. For each task, a working procedure is established. This procedure gives the details of the work to be done and makes an analysis of the safety aspects (conventional and radiological). The work is only started after approval from the Health Physics.

The main steps followed for a typical dismantling work such as the cutting of a contaminated loop are:

- On site ***dismantling*** in large pieces *e.g. cutting with a reciprocating saw of pipes.*
- ***Cutting*** in small pieces in a ventilated workshop *e.g. cutting with a plasma arch torch of a 3-m long pipe in 4 pieces.*
- ***Sorting*** *e.g. separation between pipes, pumps and electric motors etc.*
- ***Identification*** *e.g. this pipe is put in a batch for stainless steel and is contaminated at less than 1000 Bq/cm^2 in ^{60}Co.*
- ***Temporary storage***: *e.g. the cut pipes are stored in a 300-l container in a storage rack in the auxiliary building.*
- ***Treatment***: *e.g. a batch is treated by chemical decontamination.*
- ***Characterization***: *e.g. radiochemical characterization is performed using hand held b monitors.*
- ***Evacuation***: *e.g. the pieces are sent as scrap materials.*

In this process, the crucial point is the ***sorting***. It has to be carried out as soon as possible after dismantling (cutting) in order to guarantee the traceability i.e. where does it come from, what is its history? The sorting of the material must be well prepared in advance to accelerate the operation. The operator must know the destination of the material: is it foreseen to be evacuated as radwaste, sent to melting for recycling, sent to the chemical or to the physical decontamination unit....? Specifications are established to help the operator in its choice but it is not always an easy task because the pieces from the same origin can go to different routes. For example, a contaminated pump can be sent either to the chemical decontamination or to melting for clearance or recycling or be evacuated as radioactive waste. The decision depends on the contamination level, the geometry of the pump, the materials composition, the nature of the contamination...

The sorting of the materials leads to the creation of "batches".

A batch is a group of materials that will follow the same evacuation route. A batch can be a 300-l plastic container, a 200-l drum, a 400-l drum or an individual piece e.g. a reservoir or a heat exchanger.

Every batch carries a unique identification label. The content of a batch, its status and its location must be known at each moment.

All relevant information is collected:

- A unique identification number is written on a label fixed on the batch; this label gives the content of the batch, its weight and the evacuation route selected.
- The actual status is reported in the database
  - In buffer storage before treatment
  - In the characterization process
  - Evacuation route selected
  - Cleared, evacuated as radwaste or in storage
- Finally, a document is edited with all the necessary approvals. In function of the selected route it will be a clearance document, a request for treatment as radioactive waste or an authorization to send to a melting facility.

All this information is put into a "users friendly" database. This database can only be modified by one person and accessed "in read only" by a few persons.

Another important aspect is also the determination of the radioisotopes content. In dismantling, the contamination aspect for which not only the γ emitting nuclides such as ^{137}Cs and ^{60}Co are important but also the presence of α contamination can present a particular hazard and measurement issue. For waste management, it is also important to determine the so-called critical nuclides i.e. the nuclides which are difficult to measure and which are a long term issue due to their long lives and their specific radiotoxicity: the pure β nuclides such as ^{63}Ni and ^{59}Ni, ^{90}Sr, ^{94}Nb, ^{14}C, ^{3}H... and the α nuclides such as the ^{241}Am and the Pu and U isotopes.

The determination of these critical nuclides in waste packages is a difficult task. At BR3, this was done by a combination of calculations (neutronic activation) and measurements (sampling of activated and contaminated pieces and radiochemical analysis).

As an example, Table I gives an overview of the contamination vector we generally use for pieces which have been in contact with primary water. We determined also a mean $\alpha/^{60}$Co ratio of 0.01.

Table I: Overview of the radiochemical isotope vectors derived for the pieces contaminated with primary water (Reference date: 1998-07-01 i.e. 11 years after shutdown).

Correlation factors			
^{63}Ni/^{60}Co	1.1	^{241}Am/α_{tot}	0.456
^{59}Ni/^{63}Ni	2 E-3	^{238}Pu/α_{tot}	0.35
^{55}Fe/^{60}Co	1.83	$^{239+240}$Pu/α_{tot}	0.15
^{94}Nb/^{60}Co	4 E-3	^{240}Pu/^{239}Pu	1.8
^{14}C/^{60}Co	4.2 E-3	^{242}Pu/^{239}Pu	3.4 E-3
^{3}H/^{60}Co	3.2 E-4	^{244}Cm/α_{tot}	0.04
^{36}Cl/^{60}Co	3.7 E-6	^{241}Pu/^{241}Am	43.3
^{125}Sb/^{60}Co	1.9 E-3	U_{tot}/α_{tot}	0.004
^{99}Tc/^{60}Co	5.9 E-6		
^{90}Sr/^{137}Cs	4.3		

CONDITIONING PROCESSES FOR RADIOACTIVE WASTE STREAMS

The radioactive wastes from the D&D operations at BR3 are conditioned mainly by BELGOPROCESS, a subsidiary of ONDRAF/NIRAS [6].

This paper deals only with the Conditioning of Low Active solid Wastes (LAW)

The LAW wastes are defined by a maximum dose rate (<2 mSv/h on the waste package surface) and a maximum specific activity (<40 GBq/m^3 β γ and <40 MBq/m^3 α activity).

The solid wastes are conditioned essentially in a new facility, called the CILVA installation, which comprises:

- An incineration facility of a capacity of 10 t/week solids and 1 to 3 m^3/week burnable liquids based on a weekly operation time of 100 h. The ashes are supercompressible in 200 l drums.
- A pretreatment facility, in which the solid wastes are sorted, cut and eventually pre-compacted at 140 t.
- A super-compaction facility for 200 l drums with a 2000 t hydraulic press of 6000 drums/a capacity.
- A conditioning unit for immobilization and embedding: A cement matrix is used to fill 400 l drums in which supercompressible pellets or non compressible wastes are stacked. This installation also includes an active mixer for embedding of wet wastes like ion exchange resins and sludge.
- After solidification, inspection and measurements, the drums are transferred in an intermediate storage building.

TREATMENT OF RADIOACTIVE METALS BY MELTING

Nowadays, "nuclear" melting facilities are in operation in several countries for the treatment of low level metallic wastes. To be cost effective, these installations must have a sufficient throughput. Up to now, Belgium does not have any available facility so that conditioning contracts were signed with facilities abroad.

Melting for Recycling in the Nuclear World

Low level radioactive materials are recycled in the nuclear world. The melted materials are used for the fabrication of shield blocks or for the fabrication of radioactive waste containers. SCK•CEN has an agreement with GTS-Duratek in the USA; the recycled materials are used as shielding for the DOE facilities. The materials must respect composition and radiochemical criteria. The secondary wastes are conditioned and disposed off by Duratek. Up to now, we have sent, in agreement with all the competent authorities, 26 t of mild and stainless steel arising from the dismantling of very low contaminated or activated pieces. The specific mean activity of the pieces sent lied around 25 Bq/g for ^{60}Co and 6 Bq/g for ^{137}Cs.

Future transports are being considered for materials produced during the dismantling operations:

- Materials slightly activated: metal shielding, pool liners, fuel storage racks...
- Materials of complex geometry not possible to decontaminate economically: heat exchangers, pumps, complex structural materials, small pipes...

Melting for Clearance

Some dismantled materials are either very low contaminated, very difficult to measure or not homogeneously contaminated. For these materials, it can be advantageous to send them to a nuclear foundry. Melting offers several advantages:

- It decontaminates the metals by volatilization of some nuclides (e.g. ^{137}Cs) or by transfer to the slag (e.g. heavy nuclides such as alpha emitters).
- It allows an accurate determination of the radionuclides content thanks to the homogeneity of the metal melt.
- The amount of secondary waste (dust, slag) is rather low.

This practice has already been used in Belgium for dismantled waste. SCK•CEN has performed a first melting campaign in Studsvik Sweden. This first transport of very low activity materials comprised secondary reheaters with copper tubes, a carbon steel massive plinth and a variety of Carbon Steel and Stainless Steel small pieces stored in 200 and 400 l drums. About 18 t with an average activity of 0.26 Bq/g of ^{137}Cs and 0.15 Bq/g of ^{60}Co have been melted in September 2000.

The results are shown hereafter:

Fig 1. Ingots specific activity

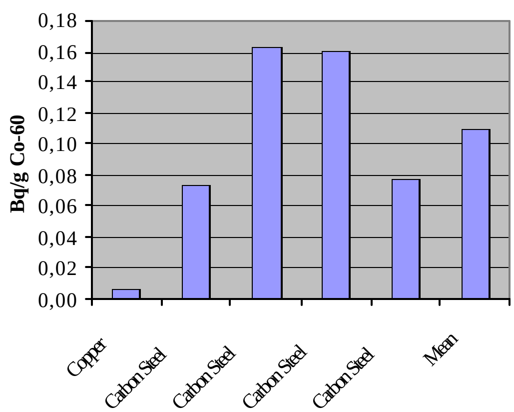
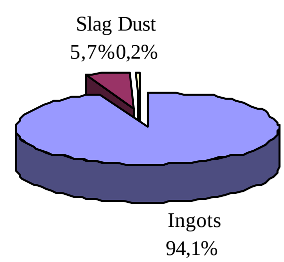


Fig 2. Melting: Mass balance of melting in weight



All the ingots (17.2 t) produced could be unconditionally cleared. The secondary waste (slag and dust) contains all the Cesium activity; it represents a mass of 1.1 t or a volume of 0.9 m^3 i.e. 5% of the initial waste volume. The secondary waste is sent back to Belgium for conditioning whereas the metal ingots are cleared in Sweden.

Future transports are being considered for materials produced during the dismantling operations:

- Materials refused for direct clearance after decontamination.
- Heterogeneous materials presenting some hot spots and/or difficult to measure.

The materials will be separated by type (carbon steel, stainless steel, copper, aluminum); lead and galvanized steel are not accepted in this foundry. The paint must be removed from the pieces either by sand blasting in our facility or by sand blasting in the Studsvik facility. The presence of organic matter and encapsulated water must also be avoided.

CLEARANCE OF METALLIC MATERIALS

The steadily increase of the conditioning and disposal costs as well as environmental concern and public perception are pushing the nuclear sector to decrease the amount of radioactive waste and hence is a strong incentive to the development of thorough decontamination processes and procedures for the clearance of obsolete radioactive suspected materials and their reuse in the industrial sector or their evacuation as industrial waste.

The clearance of radioactive materials requires a combination of factors to be successful:

- Procedures and well-defined clearance criteria: a consensus is not yet achieved on international level and generally a case by case management is still applied. IAEA, EU, OECD are progressively converging towards some harmonization. The council Directive 96/29 Euratom, that had to be implemented in national legislation by May 2000, does not prescribe the application of clearance levels by competent authorities It is the Competent authorities who may establish clearance levels below which the disposal, recycling or reuse of materials is released from the requirements of the Directive. In our case, the Health Physics department under supervision of the Competent Authority establishes procedures. This procedure is still a "case by case" practice and is applied currently for the clearance of materials from the BR3 dismantling.
- A strict follow-up of the dismantled materials comprising origin of the materials, treatment performed and characterization results.
- The traceability of the materials must be guaranteed at each step: this can only be achieved with a strong Quality Assurance program, presently being implemented.

The characterization of materials to be cleared is still a difficult topic. Materials candidate for clearance without melting can be subdivided into 3 categories:

- Materials of simple geometry for which a 100 % surface measurement is possible using hand held β monitors. For these materials, surface specific clearance values are established and the procedures are well known. The values used are 0.4 Bq/cm^2 for $\beta\gamma$ emitters and 0.04 Bq/cm^2 for α emitters.
- Homogeneous materials such as concrete rubble for which only volume or mass measurement is possible. For these materials, international mass specific guidelines are generally followed and measurement procedures are available (e.g. γ spectrometry of the whole amount in a 200 l drum or statistical sampling after homogenization). There are for the moment no fixed legal values for the clearance of such bulk materials; the health physics consider this still on a case by case basis. Their decision depends not only on the measured level but also on the origin of the material, its history and its final destination (e.g. recycling as scrap materials or disposal as industrial waste).
- Materials of complex geometry and/or heterogeneous (pipes internally contaminated, pumps, valves.): the question is how to prove that the activity level is lower than the current clearance guidelines? A procedure, based on a double measurement method has been worked out.

We use:

- Hand held ß monitors for direct surface measurements
- For volumetric measurements
  - Spectroscopy HPGe detectors: Q2-220 l waste barrels.
  - Versatile spectrometry with HPGe detectors: Isocs system.
  - Gross gamma counting with scintillation detectors: the ESM CCM monitor.

The procedures followed are:

- Hand held monitors for easy to measure materials; 100% of the surface measured twice at a max 3 months interval for materials submitted to a decontamination treatment (sweeping effect).
- For homogeneous materials, we actually use the Q2 spectrometer for measurements of 200-l drums.
- For heterogeneous materials, we have two possibilities:
  - The materials are sent to a nuclear foundry, which allows a further decontamination and a reliable measurement thanks to the homogenization.
  - We combine two measurements techniques:
    - A gross gamma counting with scintillation detectors for measurements of individual pieces or of small batches (1/10 of a 200-l drum).
    - A Q2 spectrometer for the determination of the specific activity per individual gamma nuclide.

The Q2 spectrometer is well known whereas the ESM gross gamma counter for the small batches as well as the Isocs system were recently used and the results obtained are further detailed.

The ESM CCM Gross Gamma Counter

The ESM is used to carry out 'selection' measurements, whereas the Q² spectrometer performs clearance measurements.

As the Q² spectrometer could not guarantee that the measured activity would not be concentrated on one item (or on a small volume), an extra measurement was requested to search for 'hot spot'. As the geometry of the items to be measured could be complex, and as the contamination could be located in an 'unreachable' area, a hand held measurement was considered as useless. The option of a tunnel device made of 2 detectors and a rolling band had been studied but was abandoned due to the difficulties to interpret a peak signal. This peak signal is strongly dependent on the position of the contamination. If a low-level contamination would be located close to one of the detector, the response of the detector would be high. While an important contamination in the middle of the 2 detectors, would give a low response. In those conditions, the decision process is very difficult to built (we needed a 'go' - 'no go' process, and not an interpretation, of each specific case). Therefore a 4 π geometry was considered to be a better solution, the response of the device being less dependent on the geometry. We selected the Cobalt Coincidence Monitor (CCM) developed by ESM: the FHT 3035.

This monitor has the following characteristics:

- 4 π plastic scintillation chambers with CCM technology,
- closed chamber (cube of 600mm side length) with 6 plastic detectors of 500 x 500 x 50 mm^3,
- 5 cm lead shielding on all the faces.

The purpose of the ESM is to:

1. Get closer to the assumption of an homogeneous drum, for the Q² measurement
2. Chase 'hot spot'
3. Assort between 'candidate for clearance' and 'not candidate', to increase the probability of clearance by the Q² measurement

Pictures 1 and 2: ESM-FHT 3035 installed in a low background area

The results are directly expressed in Bq or in Bq/g for:

- The **integral channel** measures all of the gamma's emitted between 60 keV and 1.8 MeV.
- The **CCM channel**: measurement of the ^{60}Co activity by the Cobalt Coincidence Measurement (detection of the simultaneous emission of the two gamma);
- The **Co-ROI channel**: measurement of the ^{60}Co activity by the selection of a ROI (Range of Interest) situated between 500 and 1250 mV
- The **Cs-channel**: calculation of the ^{137}Cs activity in function of the value measured in the integral channel and the ^{60}Co value obtained from the CCM channel.

The monitor has been calibrated in two configurations:

- Point sources of ^{60}Co and ^{137}Cs placed in the Center of the cube without any shielding;
- Linear sources of ^{60}Co and ^{137}Cs placed inside a mass of 17.5 kg of steel tubes.

The table summarizes the results of the calibration tests:

Table II. Results of the Calibration Tests

Efficiency in %	CCM	Co-60 ROI	Cs-137	Integral
Point sources	0.95	22.7	21.9	48.3
Linear sources shielded	0.39	15.0	15.6	40.3

The shielding effect decreases strongly the response in the CCM channel whereas in the integral channel, the response is decreased only by a factor 1.2.

The second calibration is selected to carry out the measurement.

Some problems occur for the detection of low Cs activity in presence of higher Co activity because the Cs value is calculated from the values obtained in the integral channel and in the CCM channel; as these values vary differently with the shielding mass, large errors can be done in the estimation of the Cs activity. Cs can be detected whereas no cesium is present. On the contrary, if there is no Co activity, the value measured in the CCM channel will always be around 0 even if a value is detected in the integral or ROI channel.

In conclusion:

- The Cs channel is only indicative and no alarm is set in this channel;
- The CCM channel clearly indicates if Co is present but due to the high variation in function of the shielding mass, its alarm is also not activated;
- The Co-60 ROI channel is quite reliable and its alarm is activated;
- The integral channel is very reliable, but suppose the knowledge of the ratio cobalt/cesium. As conservative assumption, the percentage of Cobalt is set to 60%. The alarm in the integral channel is activated.

A comparison between the results obtained by the CCM method and the results obtained by the Q2 spectrometer has been done.

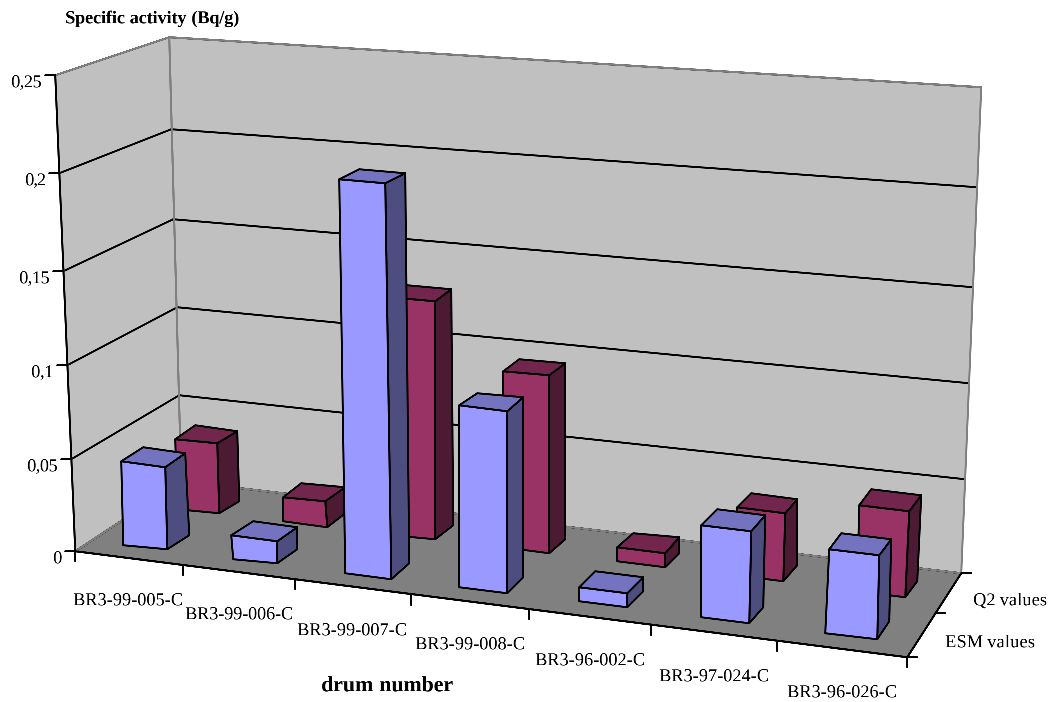


Fig. 3. Comparison between the results obtained by the ESM and the Q2

The results differ from less than 15 %. Moreover the ESM allowed to detect some pieces with "hot spots" (activity between 1 and 9 Bq/g). The removal of these pieces allowed to decrease the activity levels of these drums so that all the drums are now < 0.1 Bq/g ^{60}Co. For these drums, the ^{137}Cs activity was very low (<0.02 Bq/g) so that no conclusion could be drawn from the values in the Cs channel.

The guiding values used up to now for the unconditional clearance of the metallic pieces are:

0.1 Bq/g for ^{60}Co and 0.5 Bq/g for ^{137}Cs

The purpose of the measurement in the ESM is to avoid the presence of hot spots in a drum. Therefore, the alarms level in the integral channel and in the CO-ROI channel are set-up at 2 times the clearance levels. In general, the ^{60}Co fraction is higher than 60 % so that the alarm level is dominated by the Co guiding value. In the integral cannel, the alarms level are set at 0.22 Bq/g and at 4400 Bq corresponding to a mass of 20 kg. In the Co-ROI channel, the alarms level are 0.2 Bq/g and 4000 Bq. If one of these alarms is actuated, the small batch is refused and the operator can make a manual check to further detect the presence of a hot spot and eliminate it.

The batches measured by the ESM are collected in a 200-l drum, which is then measured by the Q2 spectrometer for the clearance measurement.

To be unconditionally cleared, the drums must have an activity lower than the guiding values.

Measurement of Large Pieces

During the dismantling of the secondary loop of the BR3, we detected some localized contamination on massive pieces:

- Detection of very low level ^{137}Cs contamination on the tubes of the secondary steam reheaters (Smears test, tube sampling). The heat exchangers (2 t each, 4.5 m long, 1 m diameter) were sent to a smelting facility for a successful clearance.
- Detection of ^{137}Cs contamination on the turbine shell localized on an accessible surface. After decontamination by wet abrasive, this 3.6 part could be measured directly and cleared.
- Detection of low level ^{137}Cs contamination on the rotor of the turbine. Qualitative measurements were done with a portable NaI(Tl) detector which allowed to detect the presence of contamination and to perform localized decontamination treatments (chemicals decontamination, wet abrasives, CO_2 decontamination). However, we missed a qualified measurement method, which could be accepted by the Health Physics for the clearance measurement. The ISOCS was then selected for this heavy piece of equipment weighing 6 t.

The pictures 3 and 4 show the turbine rotor during the final survey with the Isocs. It could be cleared unconditionally; all the measurements were below the 0.4 Bq/cm^2 criteria.

In a view of the future dismantling of "suspect" secondary parts, we needed also to characterize these equipments before dismantling so that the dismantling can be performed safely and in an optimal way to maximize the cleared quantities. This allows to determine which techniques can be used (mechanical cutting, thermal cutting...) and what kind of protection must be installed (local ventilation, confinement, and protective measures for workers).

The main parts considered for characterization before dismantling were;

the condenser 30 000 kg
the steam dryer
the main steam loop with the so-called Hopkinson valve (^{137}Cs contamination was previously detected).

The ISOCS allowed to detect some local contamination on these large objects and in conditions where conventional contamination measurements are difficult and sometimes non-representative. Another advantage for the ISOCS method is the relatively short calculation time (minute range) and the possibility to use different available mathematical models.

DECONTAMINATION TECHNIQUES

For metals, we use mainly

- Manual washing or cleaning in an ultrasonic rinsing bath: mainly for pieces only slightly contaminated on the surface by deposition of contamination on external surfaces (demineralized water piping, structural pieces, instrumentation boxes..).
- Wet abrasive decontamination: mainly used for rusted or painted pieces of simple geometry in which the contamination is fixed in the oxide layer or in the paint (structural equipment, beams..). An installation called ZOE is used for the treatment of pieces up to 3 t and 3 m long maximum.
- Hard chemical decontamination with the MEDOC Cerium process: mainly used for stainless steel pieces heavily contaminated up to 20,000 Bq/cm^2 ^{60}Co (primary loop, tanks,...). The Medoc installation has a capacity of about 0.5 to 1 t of metals per batch, which can be treated in one day. [7]

Up to now, about 50 tons of metals have been treated in these different decontamination workshops. About 10 to 20% were not directly cleared; they are then sent to a nuclear melting facility for further decontamination and clearance or for recycling in the nuclear industry; the choice between the melting facilities is a function of the residual contamination present.

CONCLUSIONS

The management of dismantling materials, with the objective of minimization of the amount of radioactive waste by applying decontamination and clearance or recycling, is a complex task due to the high variety of materials, the high variety of contamination levels and the low level measurement issues.

Up to now, we have been able to demonstrate that this is technically feasible and that it is cost effective since the overall cost of the decontamination-recycling-reuse route is still lower than the disposal and replacement route. Moreover, it saves natural resources and decreases the radioactive waste volumes.

This choice implies the setup of a strong Quality assurance program to guarantee the traceability and pushes the industry to develop cost-effective decontamination and measurements techniques.

A major effort must still be done to harmonize the different regulations and to fix "reasonable" clearance levels.

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