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An overview of research supported in the Commission's decommissioning programme and relevant to hot cell application

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Abstract

The Commission's cost-sharing research programme on decommissioning of nuclear installations has supported research and development of a number of techniques and processes which are applicable also in hot cell operation.

After a short outlay of the programme, a description of relevant decontamination and dismantling techniques is given; removable coatings tested may serve as a protection of steel and concrete surfaces in hot cell work.

Having discussed possible improvements in remote handling, the strategies and techniques for final dismantling of hot cells are addressed.

1. INTRODUCTION

At a first look there is no evident link between research done in a programme on decommissioning of nuclear installations and hot cell applications. But a closer examination reveals that a number of requirements, like remote operations, cutting operations and decontamination under conditions avoiding or minimizing secondary waste, and design for easy disassembly and cleaning of components are common features. After having given a short description of the Commission's cost-sharing programme on decommissioning, the most relevant techniques for use in hot cell operations, and, as there is an end to everything, the decommissioning of hot cells will be reported shortly.

2. THE COMMISSION'S DECOMMISSIONING PROGRAMME

The European Community's first cost-sharing programme on decommissioning (limited to nuclear power plants) covering the period 1979-1983, managed by the Commission and carried out under contract by national organisations and private companies, started effectively in 1980. With a total budget of 4.7 Mill. ECU of Community participation, about fifty research contracts on a variety of topics could be concluded.
The seven research projects are:

- maintaining disused plants in a safe condition
- decontamination for decommissioning purposes
- dismantling techniques
- treatment of specific waste materials: steel, concrete and graphite
- large waste containers
- estimation of waste arisings
- plant design features facilitating decommissioning.

The results of this research have been presented at a Conference devoted exclusively to communicating advances achieved in the course of the programme (ref/1/). In addition, virtually all final reports of the contractors have been published in the EUR-series.

The first programme has been followed by a second five-year programme (1984-1988), enlarging the scope from nuclear power plants to nuclear installations in general. This programme with 12.1 Mill. ECU of Community appropriations continues and extends the seven research projects of the previous programme and adds a section on the testing of new techniques within the framework of large-scale decommissioning operations undertaken in the Community Member States.

3. TECHNIQUES FOR HOT CELL APPLICATION

Applicable techniques refer mainly to decontamination and cutting procedures and are suitable either for treating contaminated (or activated) components in the cell, or the equipment and the structure of the hot cell itself.

3.1. Decontamination

Foams and gels are in quite general use in hot cell work, having the advantage of being nicely visible through the windows and producing little secondary waste; the big disadvantage of a lot of products is their low decontamination efficiency. In a programme by CEA Saclay gels containing decontaminants have been studied systematically (ref/2/). The four gel types examined were:

- glycerophtalic gels, with sulphamine acid, oxalic acid and sulphuric acid added respectively,
- glycerophosphoric gel, with phosphoric acid or a phosphoric detergent ("Pascodine 120" (TM)) added,
- silica gel as a carrier for sulphuric acid,
- diopside gel with sodium hydroxide and potassium permanganate added.

Two types of contaminants, fission products (Cs-137 and Sr-90/Y-90) and Plutonium 239, have been deposited on the samples; after drying, non-adhering contamination is washed off; after renewed drying the decontaminant is applied, and after rinsing, the decontamination factor as the relation of fixed activity to residual activity is determined.

On stainless steel (AISI 304L), compounds of glycerophosphoric gel gave decontamination factors between 20 and 200, values obtained likewise with silica gel as carrier of nitric or sulphuric acid. Decontamination for plutonium on stainless steel is effective with glycerophtalic gel as carrier of sulphuric acid (DF=165) or with diopside gel as carrier of sodium hydroxide and potassium permanganate (DF=740).
On mild steel, decontamination factors higher than 100 were obtained with glycerophtalic gel as carrier of sulphamic acid and a tensio-active commercial product (nonylphenol-polyglycol-ether), or with silica gel as carrier of sulphuric acid.
Aluminium is well decontaminated by diopside gel as carrier of sodium hydroxide and potassium permanganate for plutonium and by silica gel as carrier of sulphuric acid for fission products (DF=810).
On copper, sulphuric acid carried by glycerophtalic gel or silica gel gives good decontamination (DF>80).
Plexiglas is well decontaminated by glycerophosphoric gel as carrier of phosphoric detergent or by diopside gel as carrier of sodium hydroxide and potassium permanganate.

Costs for treatment of a $1m^2$ sheet have been in 1983 in the order of 150 FF for glycerophtalic gel with acid, 110 FF for glycerophosphoric gel, 8 FF for silica gel with sulphuric acid and 16 FF for diopside gel with sodium hydroxide or potassium permanganate. Liquid effluents produced are roughly 20 l/m^2 for glycerophtalic gel, and 10 l/m^2 for all the others.

The most promising gels are now tried out on a large scale on reactor contaminated material in the frame of a contract with CEN-Cadarache.

A further step in developing hot cell user friendly decontamination processes is a method which is to be tested under real conditions in the frame of a contract under negotiation in the second programme: first a tenside containing gel is sprayed on the surface; as a second step an acid containing gel is applied. After a waiting time a hardener is sprayed on the layer, and the now solid layer can be torn off like any strippable paint.

Electrolytical decontamination of metal surfaces is a well-known procedure, which removes not only oxides but also a thin surface layer (erosion rate 0.1 to more than 100µm/hour); due to the smoothing effect the tendency for recontamination in active service is lowered, and cleaning by rinsing will be more efficient after this treatment. Normal working procedure is to plunge the work-piece to be cleaned in an electrolyte-solution; in about 10 to 50 cm distance an electrode is emplaced, which will work normally as the cathode; the work-piece is in the anodic side; the electrolytes are mostly water-acid solutions. Large quantities (more than 100 tons) of contaminated steel from the steam-side of the BWR-KRB Gundremmingen A have been decontaminated to unrestricted release level (ref./3/).

The selected electrolyte was a 70% phosphoric acid solution. Current densities between 0.1 and 0.65 A/cm^2 are reached and 200 to 300µm of ferritic steel are removed per 10^5 Coulomb for each cm^2 of steel surface. As secondary waste after regeneration of the electrolyte less than 25 kg of iron phosphate are produced for a ton of steel treated. The application of this method in hot cells could probably be useful from the economic point of view, when rather large quantities of contaminated material of high value were to be cleaned and sold as scrap afterwards. Other electrolytical devices, for example tools with a swab through which the electrolyte is circulated, are to be tested by CEN-Cadarache.

Also in the frame of the ongoing programme, it is intended to develop a module for remote electrochemical decontamination for hot cell application; the techniques investigated are immersion in tanks and in-situ electropolishing. The in-situ high-rate electropolishing of alpha-, beta- and gamma-contaminated samples in nitrate media is examined as a remote decontamination technique.

Decontamination by chemical methods and by high pressure water lance are possible methods also for hot cells (see ref./4/), but secondary waste production certainly is a serious problem in such applications.

Decontamination of concrete surfaces is done routinely using scrubbers with liquids, foams and strippable paints; the most recent and probably most efficient non-destructive method is freon-cleaning, where the cleaning agent Freon-113 is continuously purified. As radionuclides penetrate to some extent into concrete walls, a more thorough decontamination calls for removal of a surface layer. All methods, from drilling and blasting, jet guns, hammering, grinding, high pressure water lance to flame-spraying, which has been tried out in the frame of the programme (see ref./5/) produce aerosols and dust in addition to the concrete waste chipped off from the surface.

To avoid problems of occupational exposure, the chipping operations may be done remotely: in the present programme, it is proposed to develop a remotely operated so-called rack-torch unit with piezo-electric ignition; main difficulties are to build a system for aspiration, sedimentation and filtration of aerosols and concrete particles, and the management of the umbilicals (for fuel gas, oxygen and liquid nitrogen coolant).

Another attempt to minimise aerosol and particle production is the development of concrete spalling by microwaves. This method has been demonstrated to work by Japanese companies; in a study under negotiation, spalling of up to 200 mm of concrete will be attempted, and a remotely operated prototype including removal of debris, is to be designed.

3.2. Cutting techniques

Most of the well-known cutting techniques, mechanical or thermal methods, have been studied and further developed for application in decommissioning. The drawback of these techniques is the production of aerosols, vapours and particles, making remote handling and careful filtration necessary, and the production of relatively large quantities of debris.

One particular technique appears to have a large potential application field in hot cells: metal cutting by intergranular fissuration. Through

ther gradient / 700°C / 100 mm /
molten metal - / loosening the bonds between the metal

local heating, a stress gradient through the steel sheet thickness is created; under the effect of stress, sliding occurs at the grain boundaries provided the temperature is higher than a specific value, which is about 700°C for face-centred cubic Gamma-iron. When a liquid metal is wetting the tip of the joint, the energy of attraction between the atoms is lowered; under the effect of stress the bonds break and fissuration progresses. As the temperatures to be reached (in the order of 800°C at the heated surface) are much lower than temperature of fusion, virtually no aerosols are produced. CEN-Grenoble (see ref./6/), using copper as the added metal has performed cuts on stainless steel sheets from a few mm to 50 mm thickness, and on mild steel plates till 60 mm. Cutting of mild steel of up to 100 mm thickness appears to be feasible with this method. This process has been adapted already to cutting hexagonal sleeves of fuel sub-assemblies in hot cells.

Another method which is quite suitable for remote operation, is laser-beam cutting. FIAT TTG performed tests (see ref./7/) with a 1 to 15 kW CO_2-laser in order to define cutting parameters on carbon steel, stainless steel and concrete. Maximum steel thicknesses cut are 110 mm for carbon steel and about 80 mm for stainless steel with a 10 kW beam at a rate of 0.01 m/min. At the same rate concrete of 160 mm has been separated. The particles produced during cutting operations have been characterised; measurements of aerosols and particle emission and development of filter systems are part of currently performed research.

Remote laser cutting is the subject of contractual work by CEN-Saclay in the running programme: a robot arm with five degrees of freedom will be developed and tested, which may be introduced through holes down to 250 mm diameter (available plug diameters in hot cells). The source, an industrial laser, is situated outside the cell, and mirrors are guiding the beam inside the robot arm to the work-piece.

3.3. Protection of surfaces against penetration of contamination

Protective coatings for steel and concrete surfaces are applied in industry as a temporary protection for a long time and removable coatings are well known to hot cell operators. Generally, in the nuclear field, such paints should protect the base-material against contamination, possibly fix contaminants and be easily decontaminable; additionally, resistance to corrosive action and mechanical resistance, and low modification of characteristical values by ageing is needed. A large number of tests of paints from the main suppliers in Europe have been performed by CEN-Saclay (see ref./8/) and Nucleco (see ref./9/).

The main result is, that one-layer systems, at least on porous surfaces like concrete show a poor performance. A normal epoxy paint, not strippable, should form the base layer. Ideally, a second layer with good stripping characteristics would follow, and a third layer, being readily decontaminable, would finalise the protective system. This multi-layer system is to be applied to form a rather thick layer, not less than 150µm in order to resist mechanical damage and corrosion. Chlorine-containing paints are to be avoided as well as any inflammable solvent; a choice of water-soluble paints exists from the main suppliers. Some of the paints tested exhibited an interesting feature: decontaminability was low, as contamination even soaked in and was trapped by the coating.

4. IMPROVEMENTS IN REMOTE OPERATION

The main development in the transition from remote mechanical handling to robotics in the nuclear environment has been centred on the master-slave manipulator. A second line of development is based on the industrial robot and has led to long reach and heavy-duty manipulators. The third development is mobile robots, which seem to suffer from a lack of maturity for the time being. Ref./10/ discusses the actual situation in the field and identifies the technologies to be promoted and possible means for supporting development.

In a study made by the Robot Laboratory of the University of Warwick under CEC-contract (see ref./11/) it has been proposed to abandon the traditional hot cell approach in favour of a laboratory similar to a section of warehouse racking servized by two automatics: one automatic simply loads and unloads pallets (modular units) containing experimental rigs, instrumentation, material or any equipment; the second automatic contains one or more vertical units which carry a manipulation and inspection module. The entire area is shielded, and access is provided only through the post from the preparation area for the pallets, which contains a number of handling devices.

As a preparation of contractual work in the 2nd decommissioning programme, two companies, GST Essen and ACEC Charleroi have established a review of systems for remotely controlled operations (see ref./12/). The sections on state-of-the-art of the equipment, specification of hard- and software, and advanced technologies expected are certainly of interest for hot-cell users and designers.

5. DECOMMISSIONING OF HOT CELLS

These exists a large number of hot cells having more than 20 years of operational history, and for some of these installations definitive shutdown and dismantling is near. The work done in the decommissioning programme provides a wealth of helpful information.

One of the main activities will be removal of concrete having experienced penetration of contaminants; mainly where cracks are present, and in drains. In addition to the well-known mechanical methods, removal of layers of controlled thickness by explosive demolition techniques, avoiding damage of the non-active part could be applied. The technique has been studied (ref./13/) and experimental work continues during the 2nd programme.

Another important aspect is the separation of active and "inactive" waste from dismantling, which involves consideration of values for unrestricted release ("exempt values") and the measurement techniques for measuring very low-level activities. Conditioning of decommissioning waste and design and availability of large transport containers is also to be considered.

6. CONCLUSIONS

The overview of research in the Commission's decommissioning programme, which is applicable in hot cell design, operation and dismantling, has shown that a number of techniques developed or adapted, might improve present hot cell operation procedures. For new hot cells and equipment to be designed, the evolution in techniques for remote handling has to be taken into account. It might be regretted that the 2nd decommissioning programme, which is open to all types of nuclear installations, does not include actually in its section on large-scale applications the decommissioning of a line of hot cells.

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