3 6.1

WINFRITH
UK ATOMIC ENERGY AUTHORITY

Materials Technology Division
Room 115/Building A59
Winfrith Atomic Energy Establishment
United Kingdom Atomic Energy Authority
Dorchester
Dorset DT2 8DH

Telex: 41231
Telephone: Dorchester (0305) 63111
Tel Extn 2846
Fax Extn 2305

Ref: DHC/BM/43

23 August 1988

HOT LABORATORIES AND REMOTE HANDLING
PLENARY MEETING
JULICH 28/29 SEPTEMBER 1988

Please find attached the paper "Decontamination in PIE and Related Facilities" by M J Sanders and R D Bond, AEE Winfrith.

This paper will be presented at the meeting by Mr D H Carter, Manager of the Active Handling and Decontamination Building, A59, AEE Winfrith.

D H CARTER
Building Manager, A59

Enc

B.6.1

HOT LABS AND REMOTE HANDLING - PLENARY MEETING OF EURATOM WORKING GROUP - JULICH - 28/29 SEPTEMBER 1988

DECONTAMINATION IN PIE AND RELATED FACILITIES

MALCOLM J SANDERS and ROGER D BOND

Winfrith Atomic Energy Establishment

Dorchester

Dorset, DT2 8DH, England

(0305) 63111 Extn 2135

1 Introduction

The Winfrith Atomic Energy Establishment is the UKAEA's lead site for the development of nuclear decontamination technology. In addition to the Site's day to day requirements, resulting mainly from the operation of the WSGHWR, (a 100 MW(e) boiling water pressure tube reactor) and the extensive fuel post-irradiation examination programme, methods are developed to meet the needs of the UKAEA, and Customers from other parts of the UK nuclear industry.

Our work at Winfrith has covered a wide range of tasks. Examples of large scale operations include regular chemical decontamination of the primary circuit of our power reactor, fuel transport flasks, and items of fuel pond furniture. Examples of work at a smaller scale include the decontamination of waste containers and items of reprocessing plant.

Decontamination is carried out for various reasons such as to reduce dose at maintenance time, to re-use expensive equipment and to minimise the volume of waste for disposal.

We are very conscious of the problems and costs associated with waste disposal and our choice of decontamination method is influenced by the waste disposal and treatment facilities available to us or our customer organisations.

This paper reviews the main areas of our development work in recent years which are relevant to decontamination in the PIE and associated fields.

Four main areas have been identified and details of the techniques appropriate to each of these are given. The areas are as follows:-

(1) Cleaning large equipment such as flasks, fuel skips etc.

(2) Cleaning equipment in a decontamination centre.

(3) Cleaning inside of caves, pressurised suit areas etc.

(4) Decommissioning and waste treatment.

Decontamination techniques can be divided into three categories - physical, electrochemical and chemical techniques; This paper deals with each of these and is illustrated by examples from the four main areas.

2 Physical Techniques

High Pressure Water Jetting

The principal advantage of high pressure water jetting (HPWJ) is that the waste stream, which consists of mainly insoluble particulate matter suspended in water, is straightforward to treat. Examples of the use of water jetting are as follows:

2.1 Decontamination of Fuel Pond Skips

Fuel pond skips are metal boxes 1.2 m cube used to hold irradiated fuel in fuel storage ponds. Skips used with Magnox fuel are simple open-topped mild steel boxes painted with epoxy paint. During prolonged storage in the fuel pond the skips become contaminated, and rusting of the substrate occurs at sites where the paint has been damaged. This contamination gives rise to surface radiation levels of > 10 mSv which complicate maintenance or disposal. In the development programme, samples were cut from a contaminated skip and the operating conditions required to achieve the required degree of decontamination were determined in a test rig. Using a 40^{o} fan jet at 12 mm stand off with a water flow of 54 lit/min at 540 Bar, DFs of > 300 were obtained on painted areas. A DF of 8 was achieved on corroded areas. Work rate was 108 mm^2/sec per nozzle. The resulting effluent was characterised to provide data to support the design of a full-scale treatment plant.

CAGR fuel skips are of welded stainless steel construction and each of the twenty fuel elements is contained in a separate compartment. Again, samples were cut from a contaminated skip and trials carried out in a test rig. Using a 20^{o} fan jet at 20 mm stand off and water pressures between 350-560 Bar, at a flow of 50 l/min, a DF of 8 was obtained. A full scale test rig has been constructed to demonstrate manipulation of the jet, and active trials will be carried out shortly.

2.2 Fuel Transport Flasks

In the UK, most fuel transport flasks are mild steel, painted externally with a high quality paint system. This is periodically stripped and replaced. High pressure water jetting with grit injection has been used to strip this paint but waste arisings are considerable. Tests have been carried out using proprietary ultra high pressure water jetting equipment at 2500 Bar = (35,000 psi) but the deep external cooling fins have caused problems which have not been satisfactorily overcome.

2.3 High Pressure Arklone Jetting

A comparative study of the decontamination effectiveness of high pressure water and Arklone (Freon 113) has been carried out at pressures up to 150 bar and at a flow rate up to 20 litres/minute. The same fan jet nozzles were used for each liquid throughout the test programme. The results showed that there was little difference between the two fluids in terms of decontamination effectiveness but Arklone was more tolerant to variations in stand-off distance.

High pressure Arklone is of particular interest where criticality safety is an issue; the absence of hydrogen simplifies criticality arguments. A further advantage is that it can be easily cleaned for re-use by filtration and distillation. The Berkeley Nuclear Laboratories of the CEGB have taken delivery of a low-pressure Arklone decontamination equipment which has been used for clean up of in-cave facilities. In this equipment, clean arklone is used to irrigate a manipulator-held decontamination brush. Contaminated Arklone is collected in trays and returned to the equipment for filtration and re-use.

2.4 Wet Abrasive Blasting

Wet abrasive blasting, using alumina grit or glass beads is a well established and effective decontamination technique. At Winfrith there is particular interest in machines of the re-circulatory type because of the limited arisings of secondary waste produced.

Wet grit blasting was selected as a candidate process for decontaminating the outer surface of stainless steel waste drums to remove splashes of cement grout, and an extensive test programme was carried out using proprietary equipment. Using 150 -300 micron glass beads at 20% V/V, main findings were:

(a) Contamination levels could quickly be reduced from approx $200Bq/cm^2$ to $< 4Bq/cm^2$.

(b) Working at 5 Bar air pressure, bead breakage rate was high; 95% of beads were < 150 microns after 60 hours operation.

(c) Operation at 3 Bar air pressure greatly extended bead life but did not significantly reduce decontamination effectiveness.

(d) The quantity of solids lost to the system overflow could be greatly reduced by allowing a settling period prior to discharge.

(e) Filtration of spent media was slow.

(f) Water droplet carryover into the ventilation system was $> 20\ mg/m^3$, consisting of droplets < 20 microns diameter.

(g) The process improved the condition of the substrate for future decontamination.

(h) Little nozzle wear was evident.

In the event, the process was not adopted because of the bulk of secondary waste arisings. Currently, the use of long life media to improve the secondary waste aspects of the process is being studied. Work so far has shown that metallic media decontaminates effectively (but more slowly) than conventional media and metallic media/water mixtures can be pumped satisfactorily provided the correct type of pump is used. Design and construction of an improved wet grit blasting machine, which sets out to overcome many of the shortcomings discovered in existing proprietary machines, is in hand.

This machine will be particularly suitable for processing miscellaneous items and waste semi-remotely. Waste will be brought to this equipment inside 200 litre drums and loaded, by hand, onto a turntable under full containment. The waste will be automatically treated by the cleaning heads followed by manual monitoring.

2.5 Vibratory Cleaning

Vibratory cleaning with metallic media is of particular interest because the basic process offers 'hands-off' capabilities; using metallic media, the secondary waste arisings are minimal and easy to treat. However the process tends to be slow and the equipment is noisy. A test programme has been carried out to study the following variables:-

- (i) The effect of process time
- (ii) The amplitude of vibration
- (iii) Decontamination effectiveness with different contaminants
  (eg: Cs 137/Co-60 solution; UO_2 doped with Eu-152)
- (iv) The effect of the process on different substrates
  (304 L stainless steel; epoxy painted steel)
- (v) The use of different lubricant solutions (water; 1% SDG3; 0.1 M NaOH; 1 M HNO_3)
- (vi) Media (stainless steel; ceramic)

The main conclusions were:-

(a) Vibratory cleaning is an effective decontamination method; it is least effective on soft substrates.

(b) Both amplitude and processing time directly effect decontamination; good DFs (> 100) were obtained at high amplitude and/or long process time.

(c) Weight loss from substrate was very low, especially with metallic media.

(d) Adding chemicals to the water lubricant improved decontamination; 1 molar nitric acid gave the best decontamination results but low foam detergent/surfactant not only improved decontamination but greatly improved the surface finish.

(e) Stainless steel media is preferred because it is self-cleaning, long lasting, generates minimal waste and has less effect on the substrate than ceramic media.

2.6 Strippable Coatings

Strippable (or peelable) coatings have been available for many years and new products come onto the market from time to time. Two categories are available; those based on organic solvents and those which are water based. The organic based materials rely on the evaporation of an organic solvent to form the paint film and as this is often flammable their use has been limited to special application eg where good resistance to water is required. Most of our work has been concerned with the water based material, where the problems associated with organic vapour are avoided. There are three roles which can be played by strippable coatings.

(a) As a decontamination method. Here, the liquid paint contacts particulate contamination on a surface and mechanically bonds to the particles during the drying process. After curing, the coating is removed, together with the contamination. Success is much dependant on the nature of the contaminant and the porosity of the substrate, the more loosely bound the particulates, the more successful the method is likely to be.

Some manufacturers have incorporated complexing agents in their products to promote the removal of soluble contaminents but we have not yet examined these materials.

(b) As a tie down coating. Here, the liquid paint is used to form a film over a contaminated surface which effectively ties down any loose contamination and provides a contamination-free surface when dry.

Tie down coatings have been used extensively to coat the interior surfaces of plutonium gloveboxes, prior to decommissioning. This reduces the levels of airborne contamination which arise during subsequent size reduction operations. Methods have been developed to apply coatings to the inside of pipes and ducts, again as a precursor to decommissioning.

The most valuable and widespread use of tie down coatings at Winfrith has been in conjunction with the Winfrith Modular Containment System, which will be dealt with later.

(c) As a protective coating. Here, the strippable coating is applied to the surface of an article or facility before it becomes contaminated. At the end of a period of operation, the coating is removed, leaving the article free from contamination. Service conditions will depend on particular applications but basic requirements are strength and durability, freedom from defects, and retention of good peelability properties after weeks or months in place. There may be a requirement for resistance to water or radiation.

2.6.1 Application Methods

Application by airless spray is fast and gives a good coverage. Usually, a second coat is desirable. The main equipment can be located outside of the active area leaving only the spray gun and small bore supply hose to be taken into the active area. The tendency to 'fog' the clear plastic windows of pressurised suit helmets is less than with conventional air spraying.

For coating the inside of pipes and ducts, the rate of application with airless spraying is too high but good results have been obtained with conventional air spray equipment. A special rigid lance arrangement has been developed for this application and paint and air are supplied to the spray head by internal pipes.

2.6.2 Winfrith Modular Containment System

In the nuclear industry, α-emitters are normally handled in gloveboxes or other fixed containments fitted with gloves. Installations in the latter category can pose problems at decommissioning time as sheer size and weight make transfer to a permanent pressurised suit area difficult or impossible. Traditionally, this problem would have been overcome by building a plastic "tent" to surround the installation to allow in situ decommissioning to take place. Safety considerations apart, tents of such size make a sizeable contribution to the waste stream. At Winfrith, a Modular Containment System (MCS) has been developed which sets out to overcome some of these problems.

A set of wall and ceiling panels has been fabricated from glass-reinforced plastic from which a containment of size appropriate to the job can quickly and easily be assembled to enclose the active plant. The panels are light weight and are joined together by bolting through external flanges. Additional rigidity can be provided by external tubular steel stiffeners. The unit is provided with its own ventilation plant consisting of electrically powered blowers and a standard HEPA filter unit. Pressurised suit operators enter and exit from the area by a shower tunnel. Air enters the pressurised suit area through the shower tunnel to replace that extracted by the ventilation plant. The velocity is sufficiently high to prevent back diffusion of airborne contamination (about 1.5 metres/sec). After assembly has been completed, all joints are covered with self adhesive plastic tape and the interior surfaces are sprayed with a water-based strippable coating. This is applied with conventional airless spray equipment and the coating is carefully inspected before active operations are started. Additional protection is given to the floor to prevent damage by heavy or sharp objects.

Once the MCS has been assembled, correct functioning of the ventilation plant has been confirmed and coating operations completed, active operation can commence. In the Winfrith facility operators dressed in pressurised suits have size reduced a series of fourteen mild steel gloveboxes, one of them containing a heavy press, and packed the pieces for disposal. We have carried out all sectioning operations using cold cutting methods. To minimise the spread of contamination the glovebox interiors were first coated with tie down coating whilst still on extract. After removal of demountable glovebox side panels, the remaining flat side panels of the shells were drilled at diagonally opposing corners and square holes cut with an electric jig saw to allow entry of an electric nibbler. The nibbler was then used to cut out the panels and size reduce them for packing into waste drums. The remaining frames, consisting of curved corner sections were size reduced with a portable hydraulic shear and an air driven reciprocating hack saw. The air driven hack saw was also used to cut up the press framework. After sectioning operations were completed and all waste packed into drums, the MCS was cleaned and given a further coating of strippable paint to sandwich the contaminated surface of the initial coating. After confirming that surface and airborne contamination levels were low, the complete lining was stripped out leaving the unit free of contamination and available for dismantling for re-use elsewhere.

Operational experience at Winfrith has confirmed that the MCS concept works well and possesses many advantages over conventional tenting techniques.

The design of the unit embodies the principal features found in a permanent pressurised suit area; that these can be provided in a modular re-usable structure has resulted in a safe and convenient solution to the containment problems associated with decommissioning large items of contaminated plant.

The reduction in arisings of PCM attributable to MCS operations is not easy to accurately quantify, but the total weight of strippable coating used in a typical MCS operation is significantly less than the weight of PVC that would be used to construct a tent of similar size.

3 Electrochemical Treatment

Decontamination of stainless steel using conventional electropolishing has long been recognised as an effective process, capable of reducing contamination levels to background. It suffers from the disadvantage that the high current density (150 mA/cm^2) requires very heavy current, a large power supply and electrical connections are difficult. Also, disposal of the spent phosphoric acid electrolyte is not straightforward because many contaminants form soluble anionic complexes. Finally, hydrogen gas is liberated by side-reactions.

The Work of Turner et al at Harwell [Ref 1-2] showed that good results can be obtained working at low current density (5 mA/cm^2) in 1 molar nitric acid electrolyte. The current requirements of this process are therefore much lower and the disposal of the spent electrolyte is easier. Throwing power is also improved.

At Winfrith, two large applications of the process have been developed. In the first, a full scale prototype electrochemical treatment plant for decontaminating items from a reprocessing plant has been designed, constructed and tested [Ref 3]. In the second, a plant for decontaminating CAGR fuel skips has been set up and tested.

3.1 Component Decontamination Plant

Items are processed in an open structure titanium basket in a process tank containing 1.4 m^3 electrolyte. The maximum surface area of the load was set at 10 m^2 for which a direct current of 500 amps was required (cf 15,000 amps for the same load using phosphoric acid electrolyte.)

The basket was loaded with a range of "typical" items, to which were fixed contaminated coupons; these were used to monitor the effectiveness of the process. The main conclusions were that:-

(a) The process is effective, giving DFs in the range 100-1000 after a 3 hour treatment time.

(b) No adverse change in surface finish occurs in a 3 hour treatment time.

(c) An anode efficiency of 60% was measured on a 6 m^2 load of type 304 stainless steel at 5 mA/cm^2.

(d) 1 Molar nitric acid is a satisfactory electrolyte and > 99% of the by - products remain in solution.

(e) Removal of metal in a controllable fashion only occurs with stainless steel; severe corrosion of brass, bronze and mild steel were noted.

(f) Gas production was minimal.

(g) Current density can easily be controlled, operating at a constant voltage of ~ 2 volts.

3.2 Electrochemical Decontamination of CAGR Skips

The second example of large scale electrochemical treatment is the decontamination of CAGR skips. As explained earlier, these are large stainless steel boxes containing twenty compartments to hold fuel elements and they become contaminated during immersion in fuel pond water. Decontamination is required to simplify handling and storage. Electrochemical treatment is a strong candidate because of the simplicity, speed and relatively low equipment costs. Because of their complicated structure, internal cathodes were used to ensure good decontamination of the compartments. Initial trials were carried out using a non-active skip fitted with an array of contaminated coupons to optimise operating conditions. The results of this work were then applied to the decontamination of an active skip. In this trial, the skip was decontaminated at 4.5 mA/cm^2 (total current 1675 amps) for 4 hours, and rinsed. Some loose contamination was still detectable and the skip was given a further 1 hour treatment and pressure rinsed. The initial radionuclide inventory of 620 MBq was reduced to 12.8 giving an overall DF of 48.

3.3 Electrochemical Decontamination of a Glove Box used for Plutonium Processing

Conventional electropolishing with phosphoric acid was used to decontaminate a glove box and its internal equipment used for plutonium processing. Here the mild steel glove box was size reduced, the epoxy paint removed with paint stripper and the pieces electropolished in a conventional phosphoric acid bath set up in a pressurised suit area. A stainless steel Z-blade mixer was also decontaminated. The work demonstrated that decontamination down to background levels was technically possible, but its widescale use was prevented by high cost of labour.

4 Chemical Decontamination

4.1 Decontamination of Fuel Transport Flasks

Fuel transport flasks (casks) become internally contaminated during use and there is a regular need to decontaminate these prior to maintenance, again for dose reduction[Ref 4]. A method has been developed and used to carry out this work using conventional decontamination reagents in conjunction with our TRANSDEC rig[Ref 5]. This consists of a heated 2½ te reagent tank together with circulating pump, filter etc, mounted in a steel frame. The rig is coupled up to a flask and hot decontaminant is circulated at approx 1 m^3/min at temperatures up to 90°C. The rig is constructed in stainless steel and is transportable.

4.2 Decontamination using Chemical Foams

Chemical foams have been developed to decontaminate equipment and facilities which are too large for treatment in centralised facilities. Examples include the inside surfaces of hot cells, where irradiated fuel is examined, pressurised suit areas[Ref 6], where plutonium contamination is present and the exterior surfaces of fuel transport flasks.

Decontamination reagents have been blended with an organic foaming agent to make foams which are sufficiently stable to give useful contact times. Using proprietary equipment, large surface areas can be quickly and easily coated with foam. After an appropriate period of contact, (normally, a few minutes) the foam is removed with a wet suction cleaner. Because expansion ratios of 15 or 20:1 are attainable, the technique uses only a small amount of reagent and the volume of secondary waste produced is low.

The decontamination effectiveness depends on the surface being treated and the nature of the contaminant. Foams containing EDTA and phosphoric acid are often effective. Other foams containing up to 10% nitric acid have been formulated and tested.

The method is quick and easy to use and operators obtain results comparable with conventional swabbing; faster and with less effort. When using the technique very large reductions in levels of airborne contamination have been noted.

5 Summary and Conclusions

This paper is intended to give an overview of recent developments in decontamination technology at the Winfrith Atomic Energy Establishment which are relevant to present and future needs in the field of PIE.

Work at Winfrith has concentrated on the development of existing physical, electrochemical and chemical processes to meet particular needs.

The high cost of disposal of solid wastes and the constraints on the disposal of liquid wastes have an increasing influence on the choice of decontamination processes; those which produce low volumes of easy-to-treat secondary waste will find favour and the physical processes, such as high pressure water jetting, vibratory cleaning and wet grit blasting are good examples.

6 Acknowledgements

Some of the work covered here has been carried out on behalf of British Nuclear Fuels plc and their permission to describe it is gratefully acknowledged.

7 References

1 TURNER A D, JUNKISON A R, POTTINGER J S, DAWSON R K. "Electrochemical Decontamination of Metallic Radioactive Waste." Proc ANS Conf on Decontamination - Spectrum 86 Niagara Falls, USA 1986 pp 1427-1438.

2 TURNER A D, POTTINGER J S, JUNKISON A R. "Electrochemical Decontamination of Plutonium Contaminated Stainless Steel". AERE Harwell Report AERE-R 10506.

3 BOND R D, SANDERS M J. "Decontamination in a Full Scale Prototype Electrochemical Treatment Plant". Proc ANS Conf on Decontamination - Spectrum 88, Pascoe, USA, Sept 1988.

4 BRIDLE D A, BIRD E J. "A Hands-Off Technique for the Internal Decontamination of Fuel Transport Flasks. Proc of PATRAM 1983.

5 HAWES P M. "Large Scale Chemical Decontamination using Transportable Decontamination Plant". Proc ANS Conf on Decontamination - Spectrum 88, Pascoe, USA Sept 11-15, 1988.

6 BOND R D, RANKIN J D, ROBINSON D H, M J SANDERS. "The Decontamination of a Pressurised Suit Area at AEE Winfrith Report AEEW-R1742.

DISTRIBUTION

MR DEMILDT	SCK/CEN-LHMA 200 BOERETANT 2400 MOL BELGIUM	4 Copies
MR BOHME	KERNFORSCHUNGSZENTRUM KARLSRUHE ABT RBT IT Postfach 3640 D-7500 KARLSRUHE	4 Copies
MR POTT	KERNFORSCHUNGSANLAGE HEIBE ZELLEN D-517 JULICH	23 Copies
MR CARLSEN	DANISH NATIONAL LABORATORY RISØ ROSKILDE DANMARK	4 Copies
MR VAN CRAEYNEST	D.TECH/SECS/SELECI CEN SACLAY 91191 GIF SUR YVETTE Cedex France	7 Copies
MR MARSICO	ENEA S.P. ANGUILLARESE km 1 + 300 PO BOX 2400 00100 ROMA A/D	5 Copies
MR STAHL	ECN PETTEN POSTRUS 1755 ZG PETTEN - NETHERLANDS	3 Copies
MR SAYERS	321/A32 AEEW DORCHESTER DORSET ENGLAND	3 Copies
MR SKINNER	UKAEA (WNPDL) SELLAFIELD CUMBRIA ENGLAND	3 Copies
MR CAUWE	CCR ISPRA 21020 ISPRA ITALIE 2B	4 Copies
MR SAMSEL	EUROPAISCHES INSTITUT FUR TRANSUREN - POSTFACH 2340 D-7500 KARLSRUHE	10 Copies