PLENARY MEETING: "HOT LABS" CONFERENCE
RISO, JUNE 1990
PAPER 2.3:

DECONTAMINATION TO SUPPORT OPERATIONS IN HOT CELLS

by W D CURREN

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by W D Curren, AEA Technology, Winfrith, UK

1. INTRODUCTION

The handling of radioactive materials leads to the contamination of in-cell equipment and of other items such as transport flasks which interface with the cells. This follows inevitably from the Laws of Thermodynamics, which predict that a concentrated source of radioactive material will disperse spontaneously throughout its surroundings.

Decontamination in Hot Laboratories is carried out for 2 reasons. Firstly, because all equipment needs periodic repair and maintenance, and preliminary decontamination reduces operator dose during manual maintenance. Secondly, because all equipment eventually is disposed of as waste. Whilst waste disposal routes and costs vary between Laboratories, it is usually possible to identify 3 categories of waste.

Upper level waste:	with high disposal costs per unit volume
Low level waste:	with low disposal costs per unit volume
Non-active waste:	with zero disposal costs.

A second requirement for decontamination therefore is the re-distribution of contamination between waste streams, and this is justified if there is an overall reduction in cost.

Decontamination is carried out therefore in Hot Laboratories either to support maintenance work or to contribute to waste management. This paper discusses the different decontamination strategies necessary to meet these 2 objectives, and reviews the range of available techniques.

2. DECONTAMINATION PRINCIPLES

Before reviewing available decontamination techniques, some fundamental points should be noted.

2.1 The progressive dispersion of radioactive contamination noted above can be reversed, in principle, by devising a decontamination flow sheet which separates the active contaminant in a pure, concentrated form, from the larger mass of non-active items. This approach requires large expenditure of energy. Most popular decontamination processes therefore avoid this energy cost by introducing a third component (for example water, or abrasive grit) into which the contamination is transferred. It follows that decontamination processes invariably generate secondary waste. Whether decontaminating for maintenance, or to improve management of existing waste streams, the management of secondary waste is an important factor.

2.2 When decontamination is used for maintenance (or refurbishment) reasons, a major requirement is to minimise damage to the substrate. When decontaminating waste (or when decommissioning) damage is unimportant, and more aggressive techniques can be used.

2.3 There are advantages in bringing items to be decontaminated to a central facility, where a variety of techniques can be made available. In addition, manual work on these items is facilitated since the dose-rate depends only on the object to be cleaned, and is not influenced by other contaminated items nearby. A more difficult problem is to clean items in-cell, where background dose-rates are high, and there is no space to introduce bulky cleaning equipment.

3. CONTAMINATION MECHANISMS

In a hot-cell, the bulk of contamination is found in crevices which are not accessible to routine cleaning procedures. Examples include joints between sheets of stainless steel on a bench, or an electric motor which cools itself by drawing contaminated air through its own windings. The need for regular decontamination must be recognised at the design stage to minimise these potential contamination traps.

Consideration of the mechanisms by which contamination is attached to smooth surfaces shows that both physical and chemical forces can be involved.

Most films of radioactive contamination comprise small particles with diameters in the micron range. Van der Waals forces (which originate in electrical interactions between adjacent atoms) are important at this scale, and their effect is that the particles adhere to each other and to surfaces. As an example, for a 1 um diameter particle adhering to the underside of a horizontal surface, the Van der Waals force acting upwards is about 10^6 times greater than the downwards gravitational force. Once the film of contamination is attached to the surface, abrasion can result in physical entrapment in valleys etc on the surface. It follows that smooth surfaces retain less contamination than rough ones. There are signs that Designers have adopted this principle, and equipment for active work is increasingly prepared in a polished state. Experimental work has shown that retained contamination is inversely proportional to hardness. This suggests that hard chromium, or heat-treated electroless nickel plating, which are both hard and smooth, offer special advantages.

Alternatively, contamination may be held by chemical forces. The contamination of paint films on pond-loaded fuel flasks, (originating in radio-caesium dissolved in the pond), depends on the movement of the caesium ion through the paint and its absorption either by pigment particles or by rust films which underlie the paint.

4. DECONTAMINATION TECHNIQUES

As discussed above, the adhesion of contamination to a substrate depends on interaction between the two components, and knowledge of the physical and chemical properties of each is necessary to select the most effective decontamination method.

A number of factors must be taken into account in formulating the decontamination strategy. The required degree of decontamination must be defined, either as a proportion of active material to be removed or as a limit on final contamination levels. The process of decontamination invariably increases the total volume and weight of the system, and plans must be made for the disposal of this secondary waste - with an additional treatment stage if necessary. The monetary cost of the equipment and its operation must be justified by its benefits. The cost in man-dose (both internal and external) also needs justification.

Where equipment is to be re-used, decontamination should involve the minimum of damage to the underlying surface. This is best achieved by matching the cleaning technique to the chemistry and physics of the contaminant rather than the substrate. Where items are being cleaned for disposal as waste, substrate damage is unimportant, and deliberate attack on the substrate is often the most effective technique.

4.1 *Physical Techniques*

Vacuum cleaning, brushing and swabbing are invariably carried out as a first stage, either manually or by using manipulators. Items are usually cleaned by these methods before removal from the cell.

Fluid jetting: Water jetting is effective, and produces an effluent which can be cleaned easily eg by filtration, with or without precipitation. Hand-held equipment capable of delivering water at 500 bar pressure and at 15 litres per minute is available. Higher pressures up to 2000 bar have been used to remove the surface eg from concrete. Effluent volumes are large unless the water is recycled. Addition of grit to the water stream increases effectiveness by at least one order of magnitude. Whilst the grit adds another component to the waste stream, ceramic or metallic grit can be cleaned and re-cycled. A prototype plant is illustrated in Figures 1 and 2.

Freon jetting uses a liquid which is chemically inert, and which can be recycled after filtration or distillation. The technique is not very aggressive, and the loss of freon to the environment is difficult to prevent.

Dry grit-blasting, using air as propellant, is effective but air-borne contamination levels are high.

All these methods are directional, requiring the methodical exposure of all contaminated surfaces to the jet. All these methods can be mechanised or robotised, and this is recommended for high pressure water jetting for safety reasons.

Scrubbing/Scouring: Examples include immersion of contaminated components in a liquid bath which is then vibrated at sonic or ultra-sonic frequencies. A variant is vibrocleaning, in which items are cleaned in a vibrating tank containing sharp-edged pieces of metal or ceramic. A small flow of water is maintained through the bed of cleaning media. This carries away the bulk of the contamination, and the media remains clean. These techniques are limited to relatively small items.

4.2 *Chemical Methods*

Chemical decontamination operates by dissolving some of the contaminant or the substrate so that the bond between the two components is broken. Advantages included the non-directional nature of the process, and the ease of remote application to reduce man-dose.

Cleaning of vessels and circuits with water-based reagents is carried out using equipment such as the Winfrith TRANSDEC rig, illustrated in Figure 3. Cleaning of smaller items - say up to 1 m^3 - is carried out by immersing them in a tank of reagent. Chemical decontamination is accelerated by heating the reagent and providing agitation.

Waste volumes are large and require more sophisticated treatment than those produced by physical methods, because a proportion of active material is dissolved rather than suspended in the liquid.

Foam cleaning is used effectively where waste volumes must be minimised. Application and collection of the foam is rapid, and can be carried out by simple machinery. The process is limited by low temperatures and lack of stirring, but studies are in hand to examine foam circulation systems.

4.3 *Electrochemical Techniques*

Reverse electroplating will progressively remove the surface of a metal substrate, therefore removing the contaminant. Reagents are available which enable crevices and even the bores of long tubes to be cleaned. The process is easily controlled, and it is the only process which can guarantee to clean a metal surface to background levels. Cleaning in immersion tanks or by mobile probe has been demonstrated. Often, a specific job will need special jigs or fixtures; for example, a special cathode array. Effluent treatment poses the same problems as effluent from chemical decontamination.

4.4 *Flow Sheet Selection*

For preliminary cleaning of equipment before it is removed from the cell, the simple techniques of vacuum cleaning and brushing should first be used. If the equipment is designed to be dismantled remotely into its component parts, some of them will be suitable for cleaning by immersion in chemical reagent tanks, and it should be possible to position tanks adjacent to the cells and within the shielding, so that a useful decontamination factor is achieved before the equipment is brought out into the Laboratory.

The items to be cleaned are then transferred to the decontamination centre, which will be provided with ventilated (but unshielded) enclosures in which various techniques can be used. The choice of these will be dictated by space, cost, and the Site's waste management system. A useful selection of techniques would include water/grit blasting, and a series of baths for immersion cleaning with facilities for heating, agitation and de-electroplating. The installation of a vibro-cleaning tank for small items would be an advantage. Foam-cleaning equipment should be available for decontaminating large surfaces ranging from laboratory floors to in-cell benches.

Large items such as transport flasks are cleaned internally by water jetting or by the circulation of water-based solutions or foams.

The treatment of waste by selective decontamination involves measurement of radioactivity and sorting of materials into categories eg metals, plastics, cellulose. Size reductions is useful to provide a standardised feed to the decontamination plants. The decontamination techniques listed above for metal items will then be applicable. For plastics, work has been carried out using vigorous washing techniques with satisfactory results.

5. CONCLUSIONS

In spite of the advances in decontamination technology which have occurred over the past 30 years, the typical hot laboratory still does most of its routine clearing by traditional "hands-on" methods.

Three important new factors are emerging:-

(a) The concern to limit exposure of staff still further, requiring the eventual introduction of robotics and the urgent short-term introduction of mechanisation.

(b) The growing need for decommissioning, with associated concern for decontamination.

(c) Changes in the acceptance criteria for waste disposal, which encourage positive interest in effluent treatment.

The better the understanding of the physics and chemistry of the contaminant and substrate, the more effective the choice. Where geometries are complex, chemical decontamination is a prime candidate. Simple shapes can be cleaned by line-of-sight fluid flow methods, which can be readily adapted to become automatic mechanised systems. Other criteria which influence the decision include the acceptable final contamination levels, capital and operational costs, man-dose cost, and the type and quantity of effluent which results. Multi-stage flowsheets can provide excellent results on occasion. Continuing evaluation and development work is needed on decontamination since the topic is of increasing concern and importance.

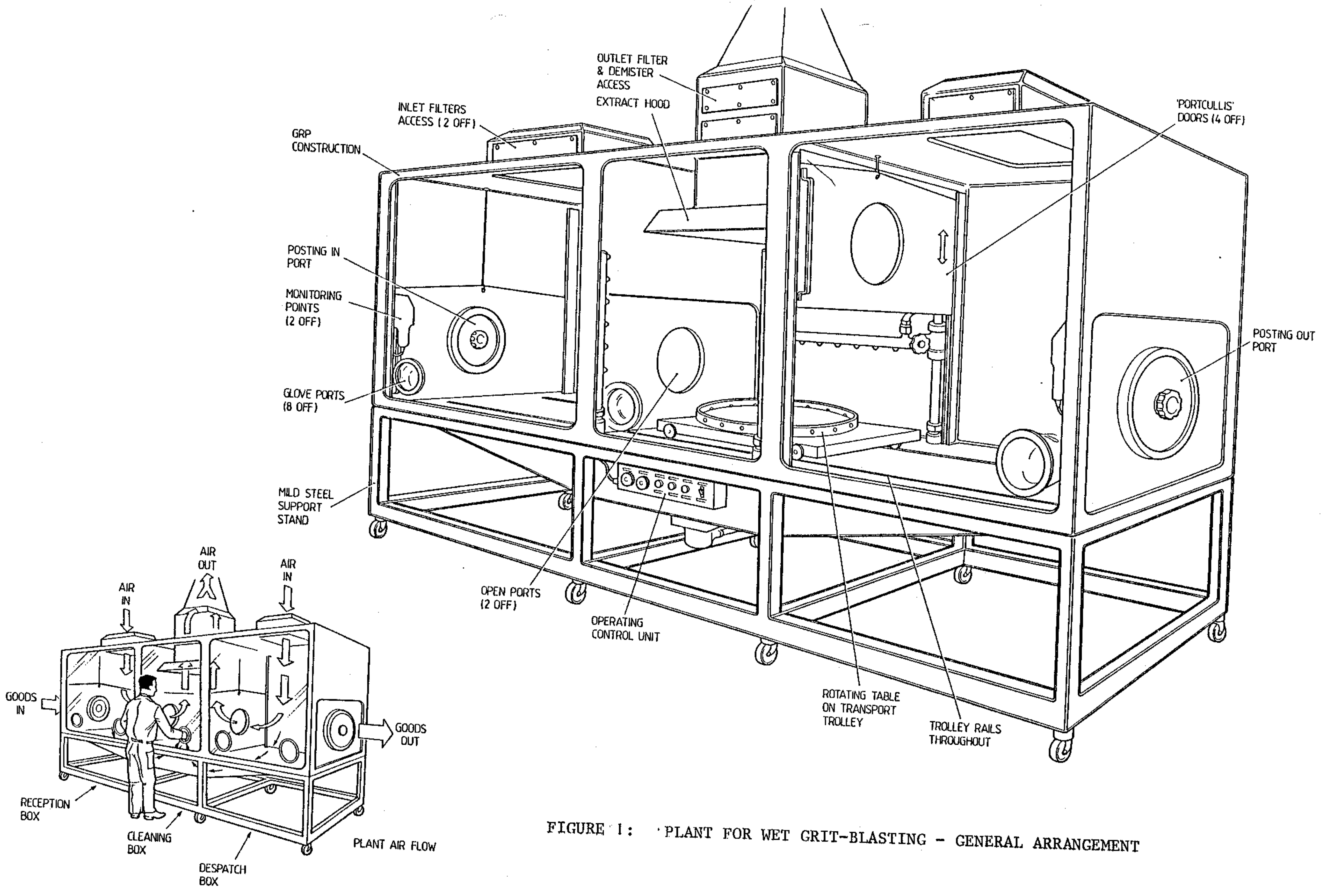

FIGURE 1: PLANT FOR WET GRIT-BLASTING - GENERAL ARRANGEMENT

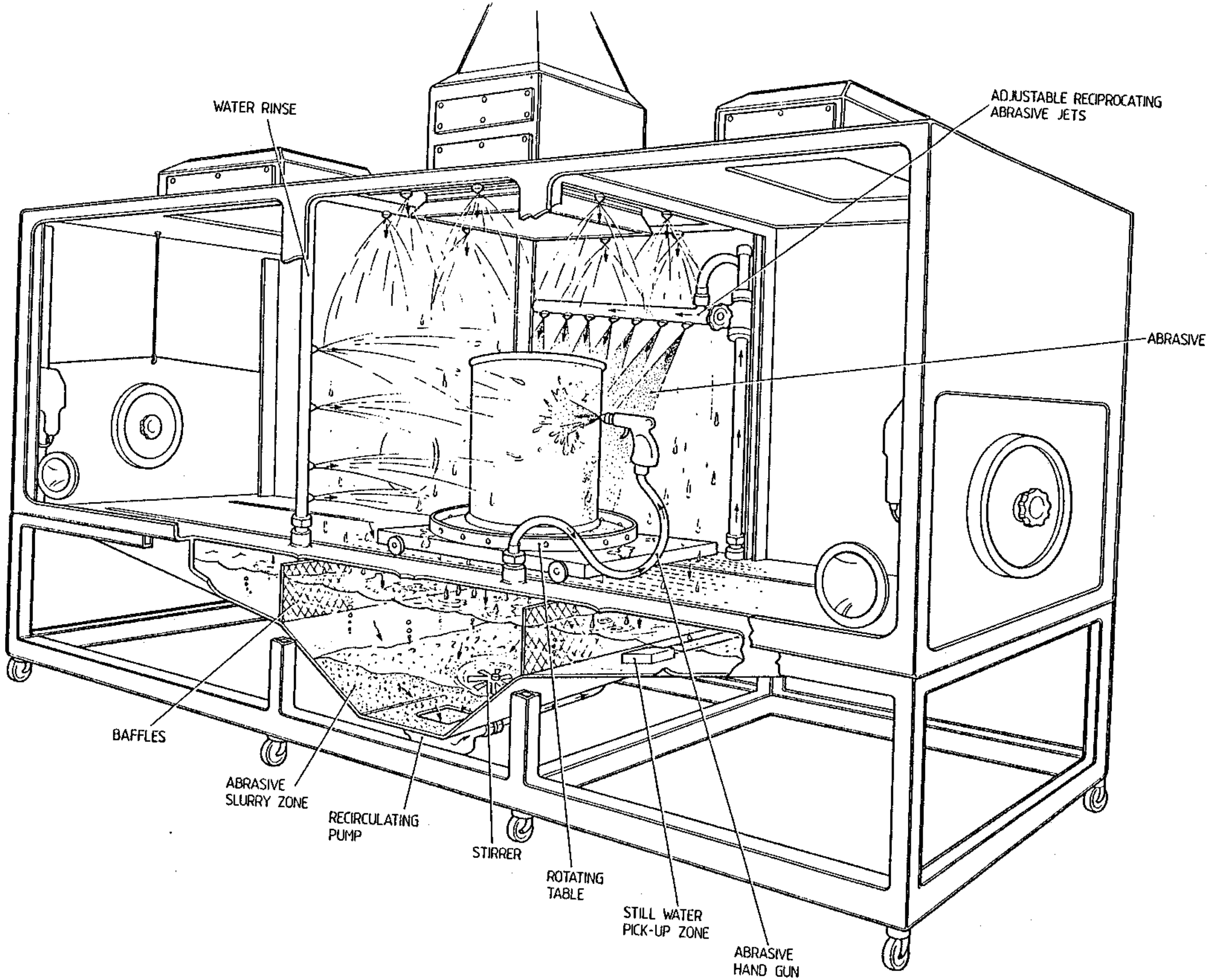

FIGURE 2: PLANT FOR WET GRIT-BLASTING - OPERATION

The TRANSDEC Rig

The TRANSDEC rig was designed and manufactured to provide a mobile facility for the decontamination of internal surfaces of plant, especially nuclear transport flasks. The equipment consists of a heated storage vessel with associated pumps and pipework to enable the preparation and circulation of chemical decontamination reagents.It is completely contained within a self supporting structure so that it may be lifted onto a vehicle for transportation. In order to achieve flexibility and mobility the power supply is provided via a single trailing cable, with all control and instrumentation contained onboard.

The Instrumentation Shows

- Liquid level in the storage tank
- Flowrate of liquid out of storage tank
- Pressure development by the main circulating pump
- Pressure developed by the drainage pump
- Pressure in the storage vessel
- Temperature of liquid in the storage tank

Overall size	3.96m x 2.44m x 2.59m high
Weight	5.73 tonnes empty
	8.28 tonnes full
Storage vessel capacity	800 galls
Heating	24 Kw
Material	321 stainless steel
Main circulating pump	Centrifugal pump, stainless steel, 275 galls / min
Drainage pump	Diaphragm pump, stainless steel, 22 galls / min

The decontamination process involves continuous circulation of the chemical reagents from the storage vessel, through the flask and back to the vessel. The rig can be operated at temperatures between ambient and 90°C. Upon completion of the decontamination, the spent reagent can be pumped to the active drainage system or to a bowser, using the on-board drainage pump.
The storage vessel and pipework is in stainless steel, Lloyds approved to 90 psi.
The self-supporting structure is mild steel. A drip tray is incorporated into this structure to retain any spillage.

Transportable Decontamination Plant Connected to Excellox Type Flask ▽

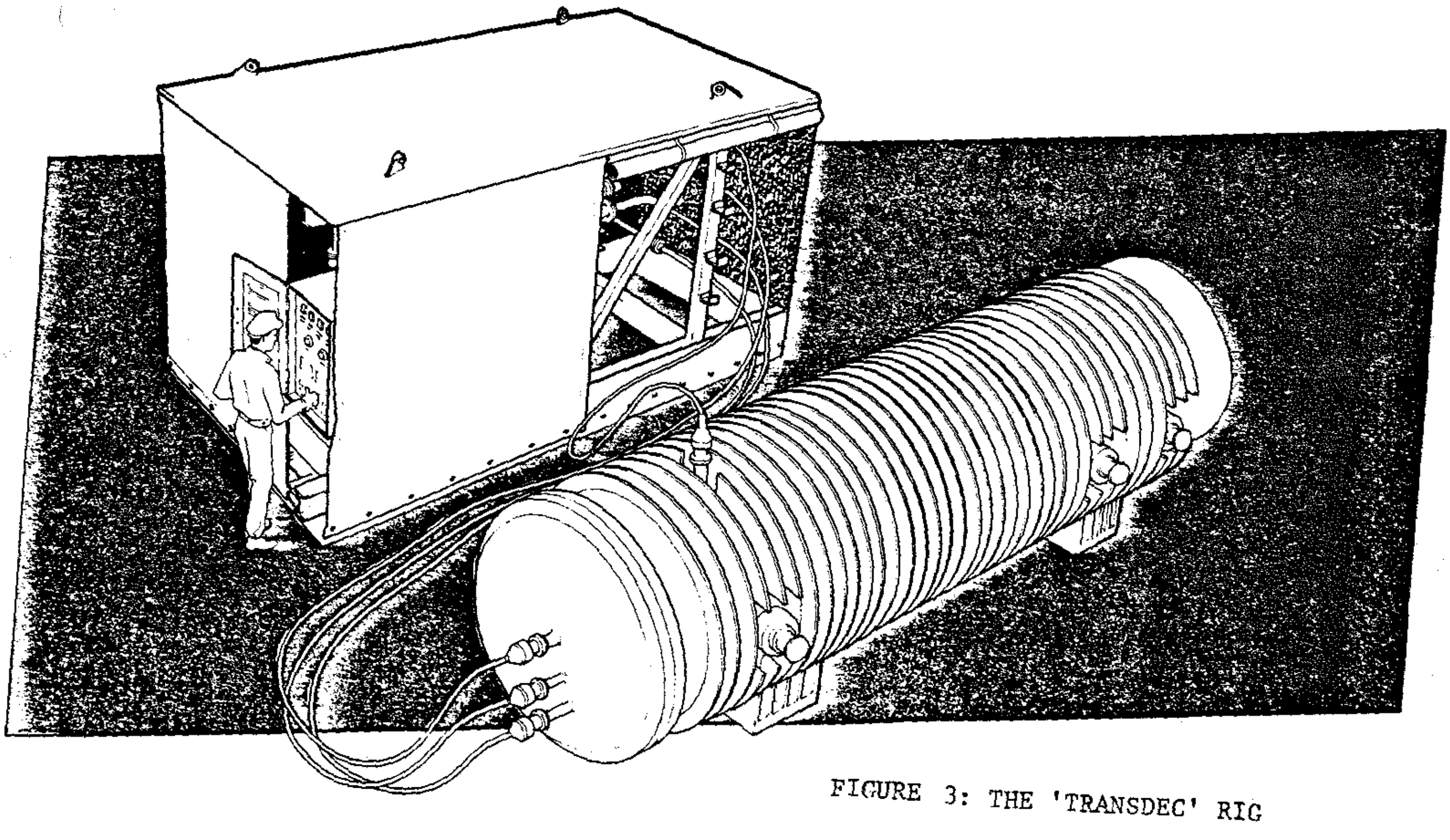

FIGURE 3: THE 'TRANSDEC' RIG