A NEW APPROACH TO DECONTAMINATION FOR THE NUCLEAR INDUSTRY

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Abstract

All industries try to avoid or minimise waste in all its forms and the nuclear industry is no exception. Delays for the availability of a Nirex(*) repository have probably focused the industry's attention on this subject more than ever before. A new decontamination technique has been evaluated by AEA Technology as a means of minimising radioactive waste volumes.

The technique uses dry sponge to wipe contaminated surfaces at high pressure. This has been successful in removing loose and fixed contamination from materials. As well as reducing volumes of ILW (Intermediate Level Waste) or LLW (Low Level Waste) it has been successful in reducing dose uptake from the maintenance of contaminated equipment. This paper describes the decontamination process and its performance in minimising waste.

* **Nirex** - United Kingdom Nirex Limited was set up by the UK nuclear industry with the agreement of the Government to carry out the national strategy for the disposal of solid low-level and intermediate-level wastes.

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1 Introduction

Waste in the nuclear industry is not simply confined to the radioactive materials generated, limited resource such as personnel dose uptake is often expended as a necessary part of many operations. While much effort is devoted to minimising either material waste or dose uptake, many existing processes do so at the expense of one or the other. For example in certain circumstances the remote cleaning of a cell may take longer and generate larger amounts of secondary waste material than controlled man access, but the latter will use a much larger dose budget.

AEA Technology has recently evaluated and developed a process for surface treatment of radioactively contaminated materials. Initial work has been directed at reducing personnel dose uptake during maintenance operations, but more recent work has successfully treated a number of waste materials. This has some important implications as to how some Low Level (LLW) and Intermediate Level Waste (ILW) might be processed in the future.

This paper describes some of the characteristics of this innovative process, highlights the main advantages, considers various practical uses to which the process has been used thus far, and discusses some of the challenges to its extended use within the Nuclear Industry in the future.

2 The Decontamination Process

At the centre of the process is a blasting system (see Figure 1) which fires particles of a polymer based sponge media at up to $150 m.s^{-1}$ on to the contaminated surface. This is effectively creates a high pressure wiping action. The polymer sponge can also be embedded with various types of grit during manufacture to provide flexibility of choice between abrasive or non-abrasive decontamination. This is an important feature should the contaminated material or equipment be required for reuse, such as tools or a cave bench. There are several different types of abrasive media available from very abrasive (Al oxide or steel grit) media that will remove highly tenacious scale coatings and substrata down to bare metal, to less abrasive media which will remove coatings (eg. paint) without damage to the underlying surface (see Figure 2).

The equipment required for the safe and successful operation of this process in the Nuclear Industry consists of;

(i) a high volume compressed air supply,

(ii) a media loading and blasting system,

(iii) a blast deployment and containment system,

(iv) a media management system.

The compressed air supply is not only required to provide the blast air, but also to run the media loading system. The loading system consists of a pressurised vessel where the media is contained in a fluidised state, such that it can be fed mechanically into the blast stream at a controlled rate.

The blast emanates from a venturi nozzle under choked throat conditions. The blast pressure can be adjusted to suit the application, and all radioactive applications require a method of blast deployment and containment. This will minimise or eliminate dose uptake from the contaminated object, and keep all media contained within the immediate vicinity of the blast zone.

All air and media needs to be carefully controlled, if contamination is not to be spread elsewhere. A system has therefore been developed to remove media automatically from the blast containment through a filtered classification system. This permits reusable media to be recycled and degraded media to be disposed of efficiently.

The media can be recycled up to 10 times depending on the blast pressures, with attendant losses due to break up of the media. This greatly improves the economics of the process for certain decontamination problems. Media life is currently being evaluated in order to enhance the process value.

The process requires a large compressed air supply. The greatest requirement is on system start-up, but during operation this reduces to a level determined by the blasting conditions required. The sponge loading and delivery system needs pressurisation to keep the the media fully fluidised ready for delivery to the blast stream. The blast stream can be controlled and run at a range of pressures, delivering media to the contaminated surface at a rate of up to several kilogrammes per minute, travelling at ~150m.s^{-1}. Controlling the blast at lower pressures will extend blast time and media life for any given charge size, but at a reduced surface removal rate. The successful application of the process depends on system integration and a thorough understanding of the process economics.

The non-abrasive open cell polymer media removes loose contamination by a form of adherance on impact, this is a characteristic that is still retained by the sponge of the abrasive media where additional substrate material is removed at the same time. This is particularly desirable where coatings such as oxide scales or paints are present. The abrasive media will produce consistent profiles up to ~30-40μm Ra, depending on the media selected. This provides a surface that is prepared to a standard suitable for repainting or fixing, enabling subsequent active operations to be carried out more safely. The surface removal rate at maximum operating pressures with the more aggresive media has shown the process capable of removing ~3mm of steel (locally) in ~2 minutes. This offers an advantage over less aggressive operations such as washing, when confronted with localised in ground high spots of radioactivity.

3 Process Benefits

A critical part of any decontamination process is containment or prevention of airborne contamination. Conventional blasting processes using grit or shot, generate large amounts of airborne particulate which apart from reducing visibility, would transfer nearly 100% of the contamination to the surrounding environment, leading to more waste and further decontamination. The sponge media used in this decontamination process exhibits a micro-adsorb/absorb containment characteristic. When the particles are fired at a contaminated surface they flatten out on impact. At the start of recoil the particles reshape in such a manner that the media grips surface material, fixing or adhering most of the contaminants onto the polymer surface (see Figure 3). Abrasives cut into the surface to enhance substrate removal. Secondly the effect of the open celled structure flattening at impact, then opening quickly on recoil helps to draw local airborne contamination in to the sponge body, creating an absorbant effect. This coupled with the relatively high voidage (and therefore available surface area) within each particle, enables the media to retain the majority of contaminants taken from the impact surface. This means very low levels of airborne dust and contamination are generated, making the process more managable for many nuclear operations.

The kinetic behaviour of the media particles on impact leads to a mainly plastic deformation (as opposed to the mainly elastic impact involved with grit or shot blasting), which results in low recoil from the impact surface. This makes the process safer for manual operation on lower radiation materials. It also places a lower demand on containment design.

Although high voidage allows the media to retain relatively large amounts of contaminant, it also makes the particles subject to break-up on impact. Trials have shown that losses are at a rate of just over ~20% for each blast cycle under maximum blasting conditions. This recycleability is key to the economics of the process for the nuclear industry, as it enables the cleaning or decontamination of waste without generation of excessively high volumes of secondary waste. The media is separated during recycle in to reusable and waste media in order to retain the surface cleaning characteristics of the process. If the media was not segregated the efficiency of the surface decontamination would fall due to interference from the waste particles. The waste particles consist of fine degraded media, grit, abraded material and the contamination which has fallen from the reusable media. This aspect of the process can be automated for remote operation within shielded facilites during higher active work. For lower active work a degree of automation is still desirable to increase throughput and reduce dose exposure if only by reducing cycle time.

The process is a one-stop decontamination technique which does not require secondary cleaning operations (such as wash water cleaning). Since the process is a dry operation it can clean materials and equipment that would otherwise give rise to solutes if washed with conventional water based processes (Eg. Caesium).

4 Case Studies

This process has been used in a number of areas to date and work is currently proceeding on a number of new applications. These areas can be summarised as applications involving the minimising of personnel dose uptake during various nuclear operations, minimisation of LLW, and minimisation of ILW. The following sections aim to describe some of these applications and the benefits that have already been gained as well as those that may aaccrue from future use of this sponge blasting process.

4.1 Dose Minimisation

Pipe End Decontamination For Steam Generator Replacement

A necessary part of PWR steam generator replacement involves time consuming alignment and welding of the new generator to the 'hot' and 'cold' legs of the primary circuit. Once cut the open pipe ends are a significant source personnel radiation exposure. AEA technology has developed a delivery and media management system that removes the scale from the inner surfaces of these pipe ends, greatly reducing the overall dose rates (see Figure 4). Actual dose rates have been reported as high as ~150mSv.hr^{-1} at the pipe openings which after decontamination of the pipe end, has been reduced to under 20mSv.hr^{-1} [(1)]. This does not really represent the true performance of the process, because most of the dose rate measured after decontamination is from uncleaned surfaces further down the pipe. Nevertheless these figures suggest that up to a seven fold saving in dose budget can be achieved for this particular aspect of reactor refurbishment.

Machine Tool Decontamination For Maintenance

A vertical milling machine was retrieved from a 'hot' cave at the Windscale Active Handling Facilities (WAHF), after several prolonged campaigns manufacturing active specimens for Post Irradiation Evaluation (PIE). The machine needed refurbishment in preparation for further programmes of work. The tool was given a limited remote clean down in-cave to remove as much loose swarf and dust as possible prior to transfer to a specifically designed blasting enclosure.

A survey of the machine tool indicated dose rates up to 18mSv.hr^{-1} $\beta\gamma$, in close working proximity to the equipment. Manual cleaning with tissues involved dose uptake of 0.12mSv within 10 to 15 minutes. The machine was then monitored at 3mSv.hr^{-1} $\beta\gamma$ (a DF of 6). A trial application of the non-abrasive media saw a more extensive clean down with the operator standing (in full PVC suit and respirator) at least 1 to 1.5 m from the tool. This involved a dose up take of 50µSv in ~15 minutes. The machine was subsequently monitored, indicating dose rates of 0.4mSv.hr^{-1} $\beta\gamma$ (a DF of 7.5), in close proximity to the tool surfaces. Subsequent maintenance work was easily effected within ~2 hrs, incurring a 0.2mSv dose penalty.

Clearly the manual decontamination dose budget (if allowed to continue) necessary to provide adequate maintenance time would have exceeded the maintenance dose budget. This does not include dose uptake involved in removal and transfer of the machine tool from cave. Had sponge blasting been applied prior to retrieval from cave additional dose uptake could have been saved.

Cave Decontamination Ready For Re-use

New project work often requires rigs and equipment to be installed to caves at WAHF. Traditionally this involves the remote dismantle and removal of equipment, followed by prolonged remote decontamination of the existing benchwork. Sometimes sources of high radiation prove difficult to remove and operators have to resort to local shielding or laborious cleaning in order to reduce dose rates to a level which permits practical man-access for further manual decontamination. Manual decontamination is carried out to achieve even longer access periods in order to effect refit or installation of new equipment. This can involve overall dose budgets of 6-8mSv and some 20 to 30 man entries (see Figure 5).

AEA Technology is currently adapting the sponge blasting process to assist in 'fast-tracking' the remote cave decontamination operations, to levels that will be suitable to go direct to the installation phase of operation. The cave bench area is ~30m^2, and it is expected to generate ~0.5 to 0.75m^3 of spent medis as ILW. This compares with about 0.3m^3 of tissues and mops etc. from the traditional approach. It is possible to obtain a 6:1 compaction ratio from the spent sponge media leading to a final ILW volume of between 0.1 and 0.13m^3. It is anticipated that the process will provide benefits of more than 50% reduction in dose uptake and lead time to installation.

4.2 Low Level Waste Minimisation

Redundant Flask Station Decontamination

The WAHF's carried out an extensive Magnox PIE programme over the last 30 to 40 years, which has now diminished to a level that has seen some items of plant decommissioned. Included in this are three old flask posting stations. The largest individual part of each station is a large ~1.8m long by 1.3m diameter cylinder, weighing ~7.6te (see Figure 6). All three stations were contaminated up to 5k cps. A decontamination trial has been carried out within a purpose built enclosure. The stations were decontaminated to levels that should permit 'free release' disposal. The stations have been monitored and indicate levels $<4Bq.cm^{-2}$ $\beta\gamma$.

The volume of LLW these stations would represent had they gone for direct disposal is estimated to be ~40m^3. The secondary waste arisings volume of spent media has been measured at <1m^3 (uncompacted).

4.3 Intermediate Level Waste Minimisation

The cleaning capabilities of this blasting process suggest that it may be capable of reducing ILW down to LLW. This coupled with the recyclability of the media may make the process economically viable. AEA Technology is currently developing an in-cave decontamination system that will initially be used for equipment clean-up prior to retrieval for maintenance. It will also be the subject of a series of limited more highly active trials on suitable ILW.

The LLW limit is $7.5mSv.hr^{-1}$ and $12GBq.te^{-1}\beta\gamma$. Decontamination factors approaching 10 appear to be possible from the more active decontamination work carried out so far. It is therefore reasonable to assume that material up to $75mSv.hr^{-1}$ could be targeted for decontamination. Only material that has not been activated will be decontaminated. The recycle of the media will be crucial to the success of this technique, along with suitable volume reduction of the spent media. Trials with a prototype in-cave system will shortly take place, the results of which will be reported at a later date.

5 Discussion

The sponge blasting process has clearly demonstrated that it can return substantial benefits in terms of dose minimisation for a variety of applications. The main challenge to the process' extended use in this area is its safe and satifactory deployment for each application problem. AEA Technology now has a wide experience of deploying this process and is well positioned to provide solutions (taking each case on its merits) for delivering radiation exposure reductions for the nuclear industry.

LLW minimisation using sponge blasting is technically feasible for lightly contaminated metals with corroded or painted surfaces. Apart from the radiation levels manual application is limited by the airborne contamination levels that might be generated. Trials have shown for a particular contamination situation that ~10% of the contamination present can become airborne. This will vary depending on the levels of loose contamination present. Up to about 70% of contamination can be retained by the sponge particulate. Remote decontamination within shielded 'hot' facilities such as caves, with adequate ventilation should therefore be favoured for materials and equipment with radiation levels above $\sim 0.5mSv.hr^{-1}\beta\gamma$, over surface areas no larger than $1.5m^2$.

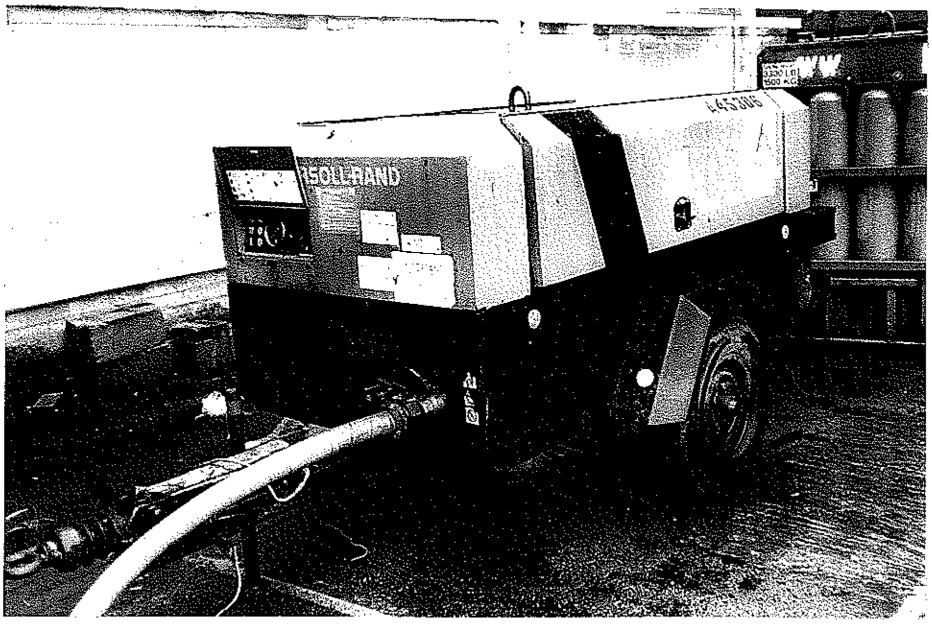
The ecomomic limitations of the process depend on the ratio of surface area per unit LLW/ILW volume to be cleaned, to the spent media volume generated in doing the decontamination (see Figure 7). This value less the actual operational costs will determine whether a certain type of waste is worth decontaminating. It has been shown that higher bulk to surface area items or materials are viable candidates for decontamination by this sponge blasting process.

6 Conclusions

1. The sponge blasting process is a proven technique that will reduce personnel dose uptake for a wide range of applications within the nuclear industry.
2. The minimisation of LLW volumes is technically feasible depending on the surface area per unit disposal waste volume of the waste under consideration.
3. This technique can be applied to the problem of ILW minimisation, and further active trials will determine its viability in the near future.
4. System integration of the process is key to its success.

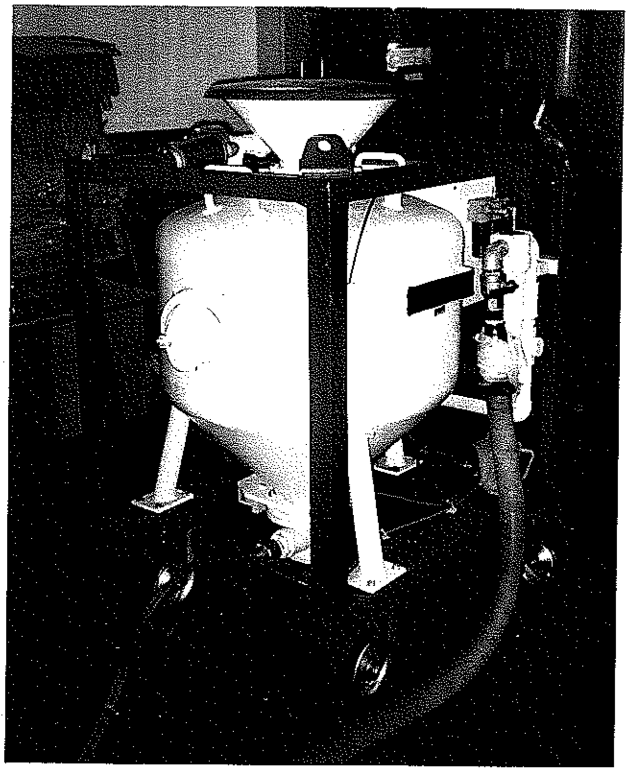
References

1. Experience in the Decontamination of Reactor Coolant Pipe Ends using the Abrasive Sponge Blasting Process during the Almaraz SG Replacement; E Damien, J Flaherty, AEA Technology, September 1997.



Mobile Compressed Air Supply

Mobile Blasting System



Control System

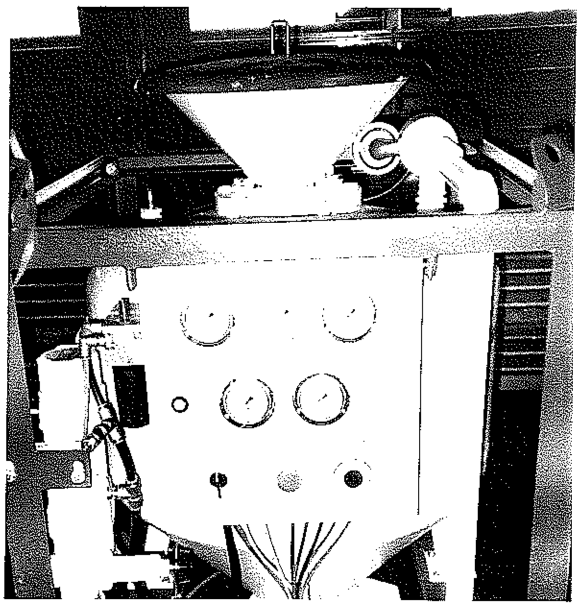
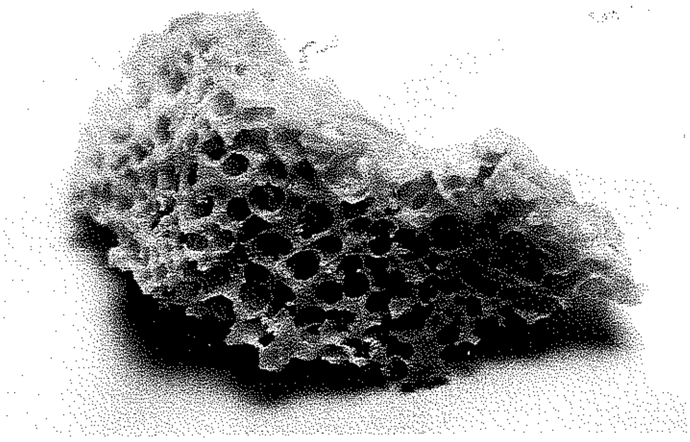
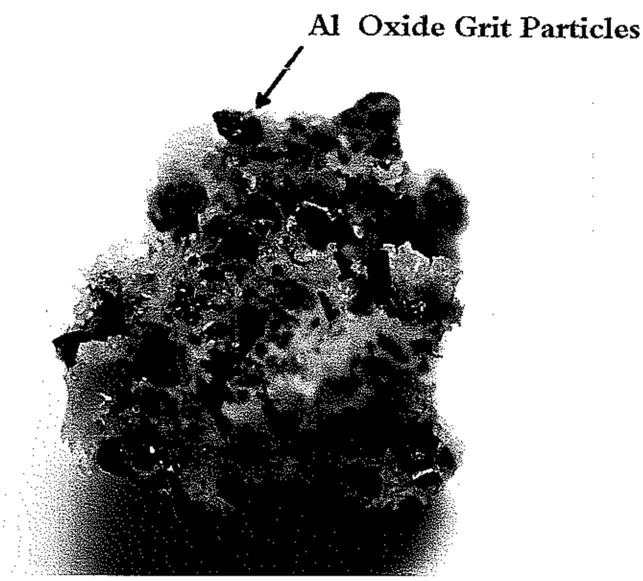


FIGURE 1 : The Sponge Blasting System

Photographs of Typical Media Particles



Non-abrasive media used for loose contamination removal, degreasing and is washable.



Abrasive media containing aluminium oxide grit, for removal of heavy coatings, scale and substrate removal.

FIGURE 2 : Sponge Media Description

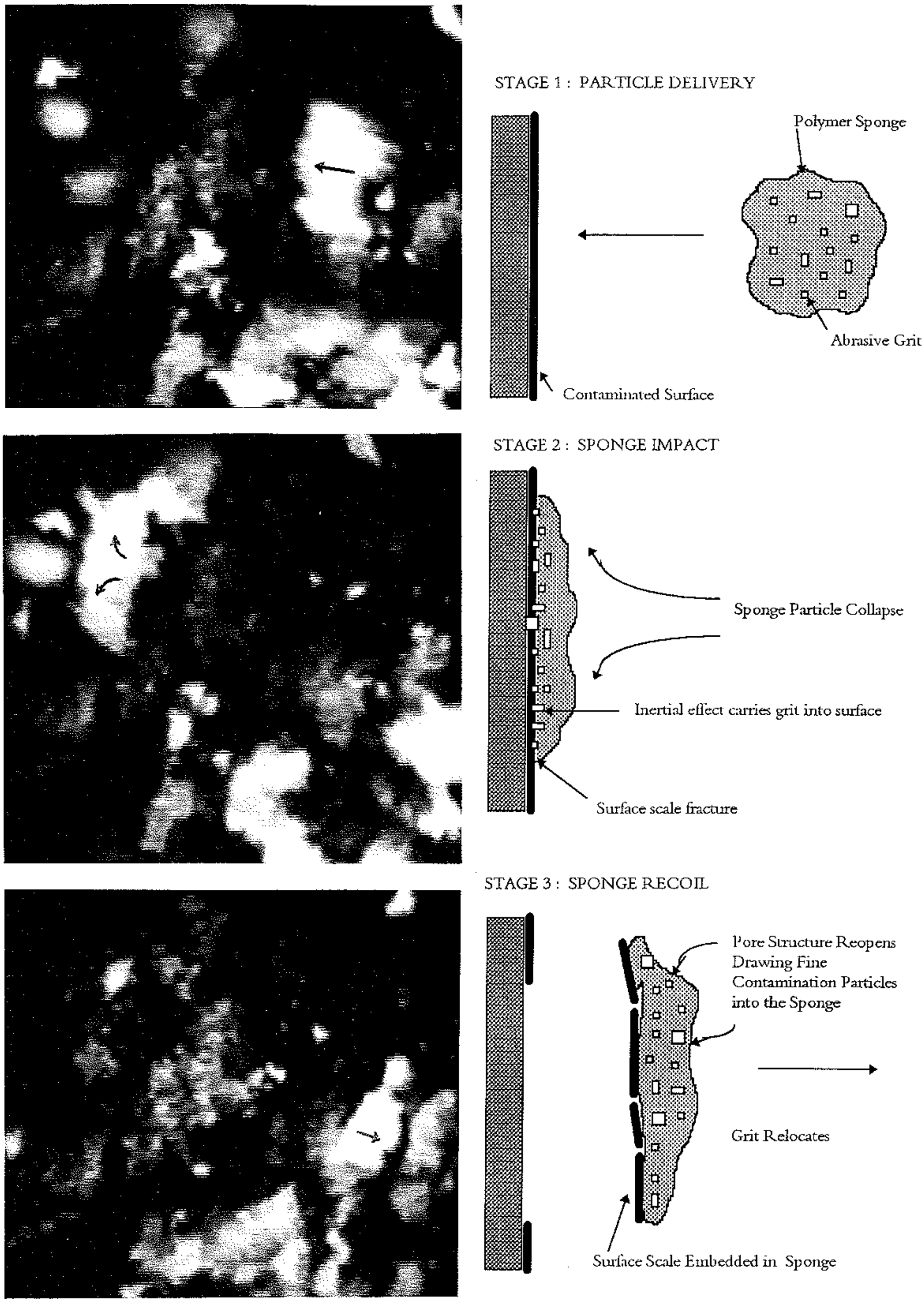


FIGURE 3 : Sponge Microcontainment Characteristics

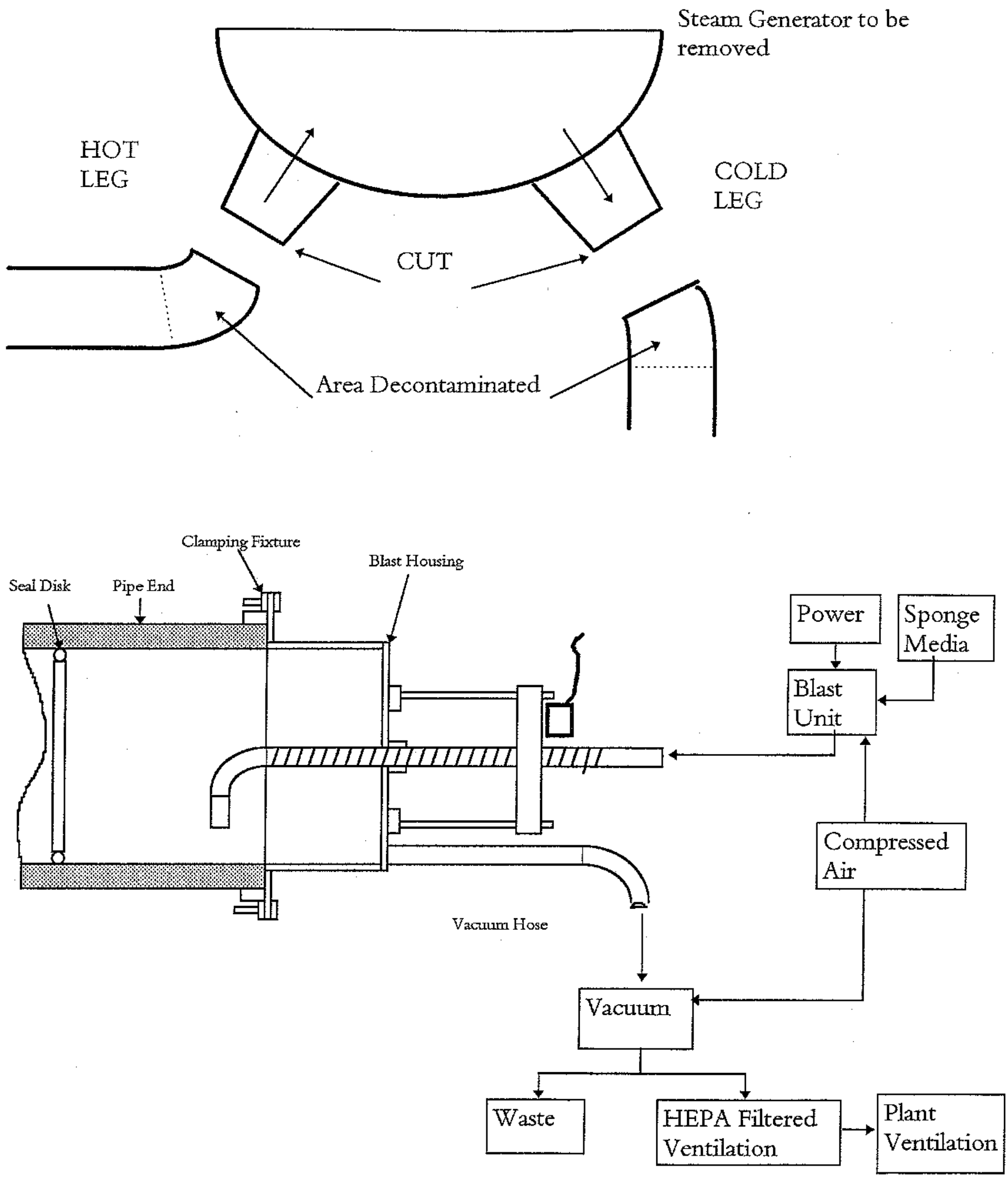


FIGURE 4 : Pipe End Decontamination

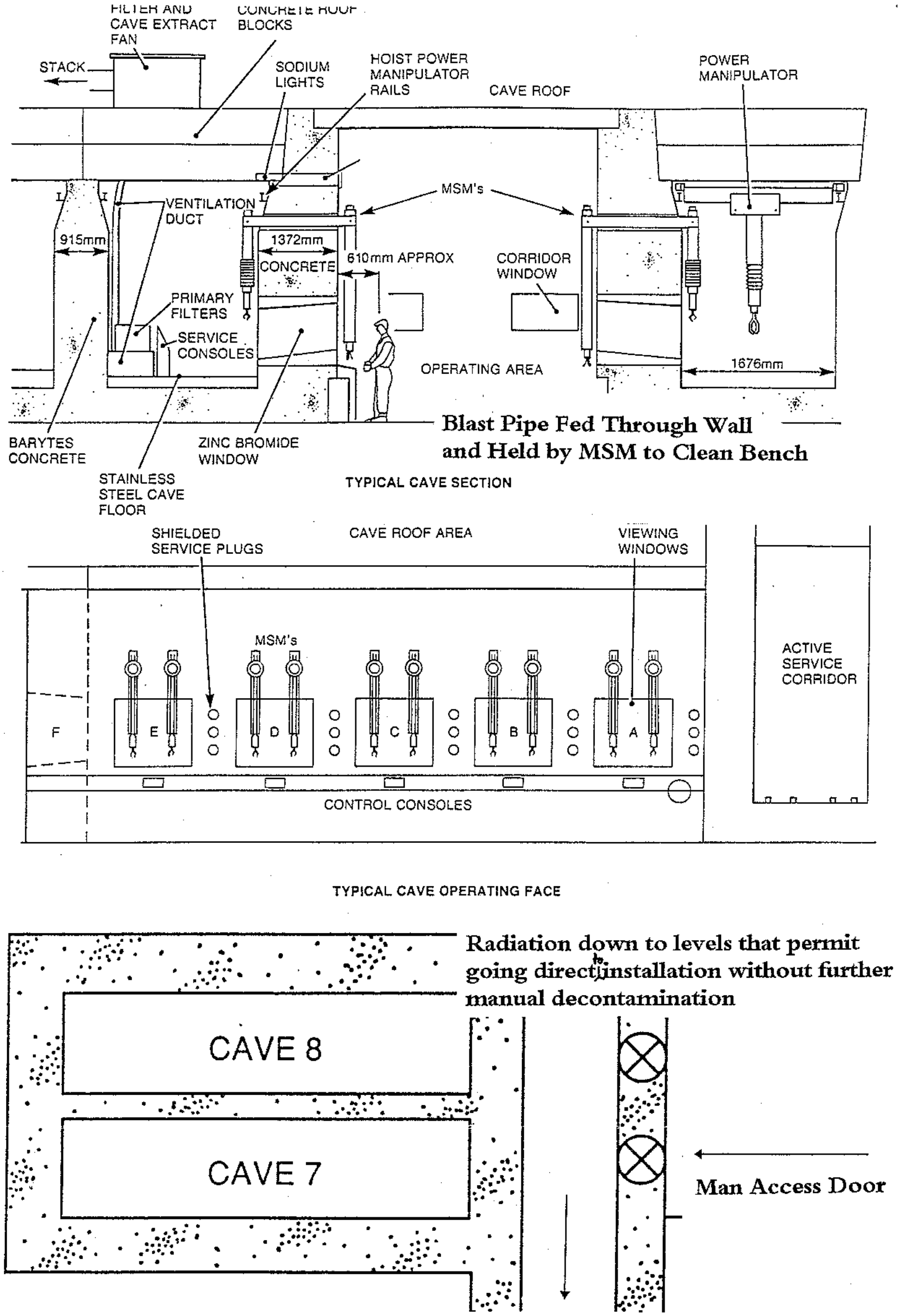


FIGURE 5 : Summary of Cave Decontamination Ops.

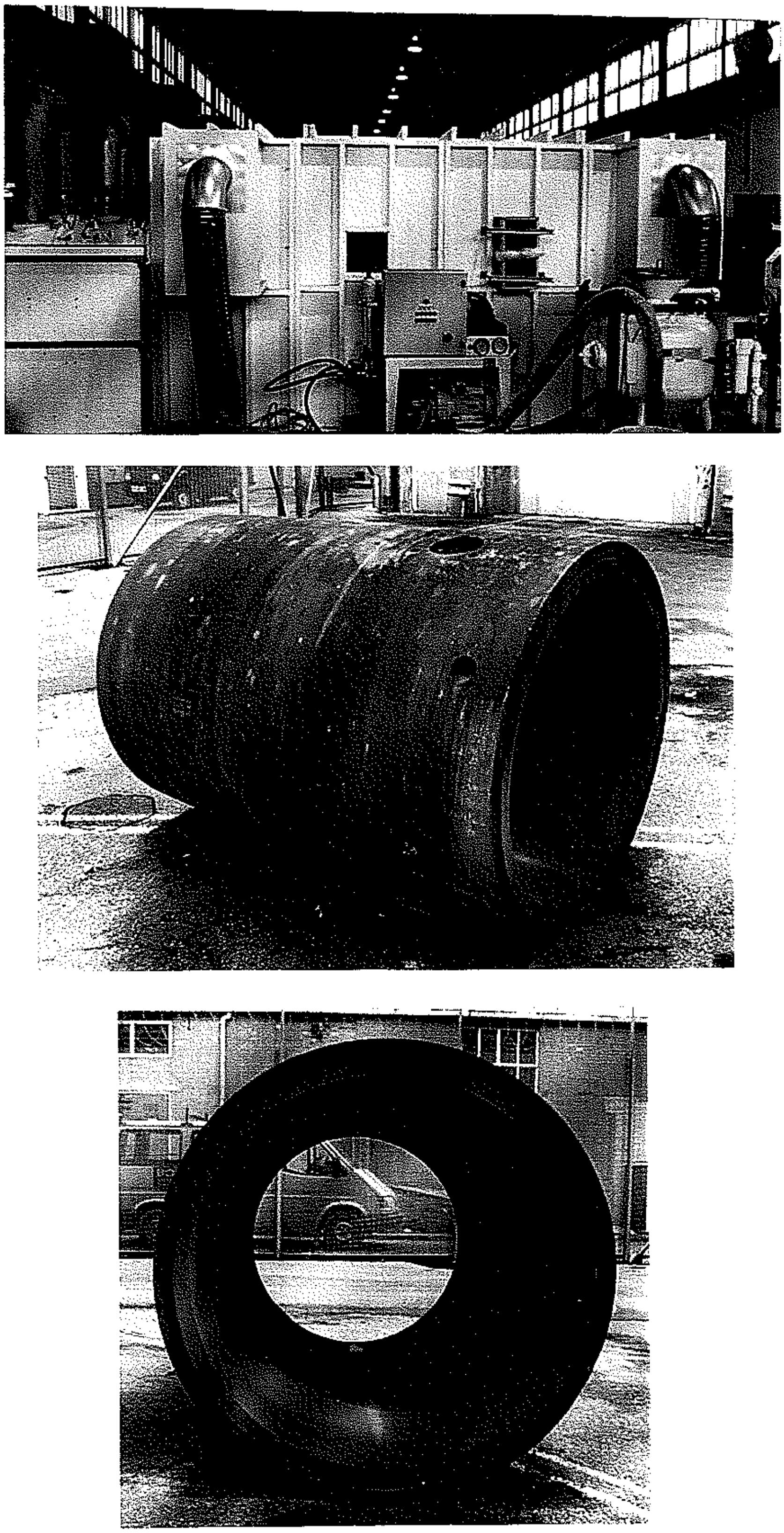
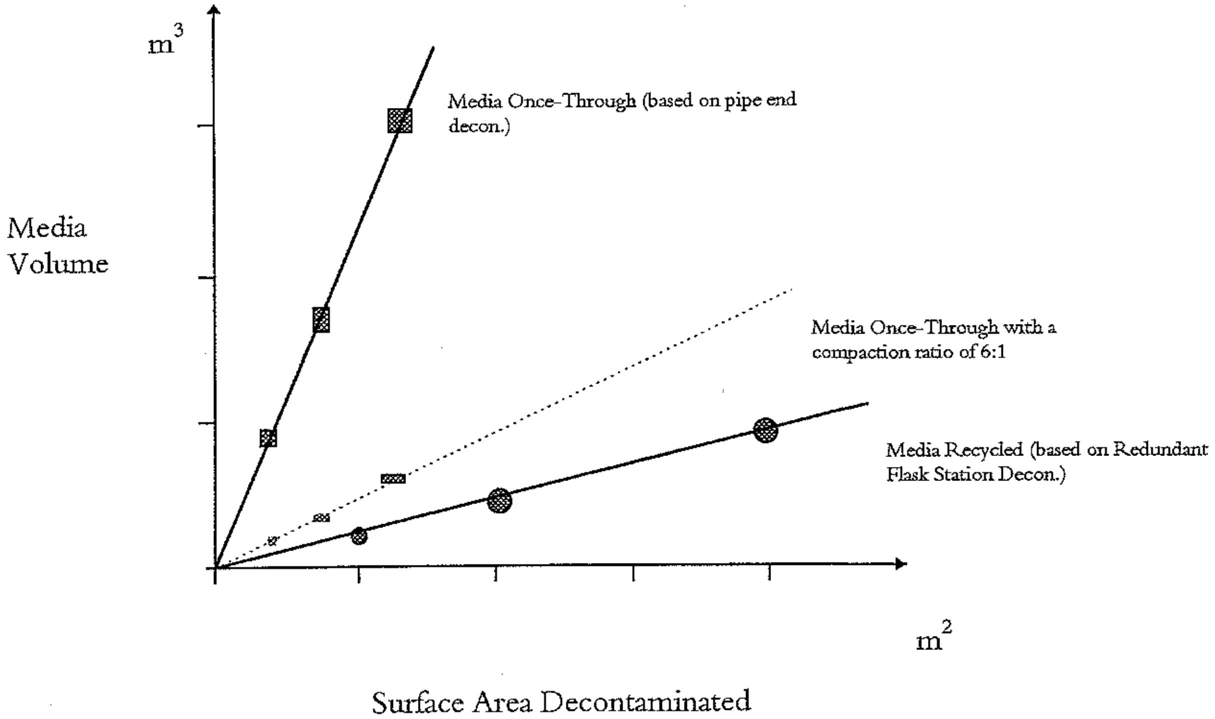
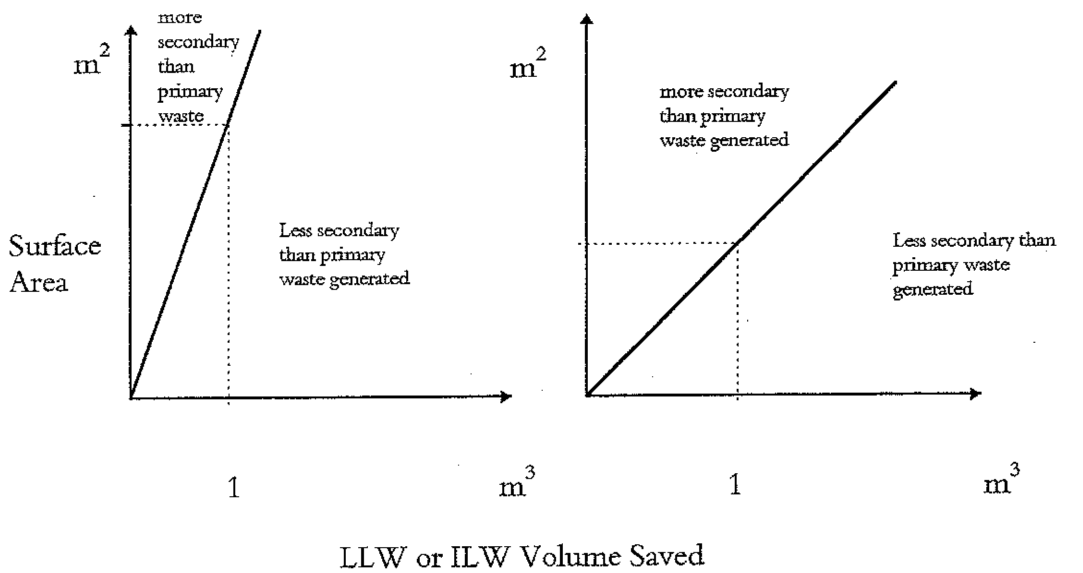


FIGURE 6 : Blast Enclosure and Redundant Flask Stations



Media Volume Generated for Surface Area Decontaminated



Once Through **Recycled**

FIGURE 7 : Process Recycle Economics