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NOVA TARGET CHAMBER
DECONTAMINATION STUDY
For
Lawrence Livermore Laboratory
May 1979

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29

TABLE OF CONTENTS

	<u>Page</u>
List of Figures	iii
List of Tables	iv
1.0 Introduction	1
1.1 Program Requirements	1
1.2 Summary	2
2.0 Decontamination Methods	4
2.1 Cleanup Systems	4
2.1.1 Manual Decontamination	4
2.1.2 Automatic Washdown (Remote Decontamination)	4
2.1.3 Electropolishing	5
2.1.4 Ultrasonic Decontamination	6
2.1.5 Air Jet and Vacuum	7
2.1.6 Sandblasting	7
2.2 Removable Liners	7
2.2.1 Soluble Films	8
2.2.2 Removable Debris Shields	8
3.0 Feasibility	12
3.1 Personnel Exposure	12
3.2 Vacuum Compatibility	16
3.3 Debris Penetration	22
3.4 Chamber Configuration	23
4.0 Remote Operations	24
5.0 Concepts for Further Consideration	25
5.1 Automatic Washdown	25
5.1.1 System Description	25
5.1.2 Equipment Costs	27
5.2 Air Blast and Vacuum	29
5.3 Removable Debris Shields	29
5.3.1 System Description	29
5.3.2 Equipment Costs	30
6.0 System Effluents	31
7.0 Recommendations	32
8.0 References	33

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>	<u>Page</u>
1	Inventory of the Sum of the Fission Products	13
2	Gamma Flux to Give 1 Rem/Hr	15
3	Nova Target Chamber - Spherical Configuration	20
4	Nova Target Chamber - Cylindrical Configuration	21
5	High Velocity Jet-Vacuum Transfer Concept	26

LIST OF TABLES

<u>Table No</u>	<u>Title</u>	<u>Page</u>
I	Evaluation of Potential Nova Target Chamber Decontamination Methods	3
II	Summary of Potential Decontamination Methods	9
III	Outgassing Rates of Selected Materials After One-Hour in Vacuo	18
IV	Estimated Total Outgassing and Related Pumping Speeds for the Spherical Nova Target Chamber	19
V	Cleaning Time and Flow for Automatic Washdown Cleaning System	28

1.0 INTRODUCTION

1.1 PROGRAM REQUIREMENTS

The Nova Laser Fusion experiment is designed to prove the scientific feasibility of laser fusion by demonstrating high-energy-gain fusion microexplosions. The high neutron-yield targets used in these demonstrations will generate small quantities of radioactive debris, the bulk of which is expected to be embedded in the target chamber first wall. Contact maintenance of target chamber internal components following a laser-fusion shot, or series of shots, will require that residual radioactivity be reduced to an acceptable level.

The purpose of this engineering study is to provide an overview of current radiation decontamination techniques and to serve as the basis for selection of one or more methods for decontamination of the Nova target chamber. Documentation furnished the Los Alamos Technical Associates, Inc. (LATA) by Lawrence Livermore Laboratory (LLL) was reviewed in detail and pertinent information contained therein was used to establish the criteria for selecting the recommended decontamination technique. The following criteria were considered in evaluating the techniques surveyed:

- a. The decontamination operation should be completed in a reasonable time to minimize any delay to the programmatic schedule.
- b. The operation should have a minimum effect on the target chamber components.
- c. Personnel exposure should be within the permissible limits established by the Department of Energy (DOE) and LLL.
- d. The number of qualified technicians required to perform the decontamination task should be minimized.

- e. The degree of decontamination effected should be sufficient to permit personnel to enter the target chamber to perform their assigned duties in a low-radiation environment.
- f. Waste products generated during decontamination should be minimized and be susceptible to the proposed site waste handling system.
- g. Material introduced into the target chamber to serve as part of a decontamination scheme should have no deleterious effects on or interfere with the operation of the Nova equipment; e.g., materials must be compatible with the vacuum system. Also, the materials should have an induced activity contribution no greater than the combined Nova target chamber and internal support equipment.
- h. The cost for preparing the decontamination equipment and for carrying out the operation should be reasonable and within the imposed budgetary limitations.

1.2 SUMMARY

An engineering study was performed to determine the most effective method for decontamination of the Nova target chamber. Manual and remote decontamination methods currently being used were surveyed. In addition, a concept that may not require in-situ decontamination was investigated. Based on the presently available information concerning material and system compatibility and particle penetration, it is recommended that a system of removable aluminum shields be considered. It is also recommended that a series of tests be performed to more precisely determine the vacuum compatibility and penetrability of other materials discussed in this report.

Table I is an evaluation of the methods surveyed based on the established criteria and available documents.

TABLE I
EVALUATION OF POTENTIAL NOVA TARGET CHAMBER
DECONTAMINATION METHODS

<u>Decontamination Method</u>	<u>Personnel Exposure</u>	<u>Decon Time</u>	<u>System Compatibility</u>	<u>Decon Effects</u>	<u>Waste Gen.</u>	<u>Effect On Oper.</u>	<u>In-Situ Oper.</u>	<u>Cost</u>
I. Cleanup Systems								
1. Manual Decontamination	High	High	Good	Good ^(a)	Low	Good	Yes	Low
2. Automatic Washdown	Low	Mod.	Fair	Good ^(a)	High	Fair	Yes	Mod.
3. Electropolishing	Low	Low	Good	Exc.	Mod.	Good	No	High
4. Ultrasonic Decontamination	Low	Low	Good	Exc. ^(a)	Mod.	Good	No	Mod.
5. Air Jet and Vacuum	Low	Mod.	Fair	Poor ^(a)	High	Fair	Yes	Mod.
6. Sandblasting	Low	Low	Poor	Good	High	Poor	Yes	Mod.
II. Removable Liners								
1. Soluble Film	High	High	Poor	Good	Low	Good	Yes	Low
2. Debris Shields	Low	Low	Good	(b)	(b)	Good	(b)	Mod.

(a) Dependent on debris penetration depth.

(b) Dependent on cleanup system used.

2.0 DECONTAMINATION METHODS

The processes described in this section have been placed in two general categories: "Cleanup Systems" and "Removable Liners." This section is only intended to acquaint the reader with a number of established decontamination techniques and to introduce a new concept. The applicability of the established processes to the Nova target chamber decontamination problem is not discussed here but is addressed in Section 3.0.

2.1 CLEANUP SYSTEMS

The processes described in the following subsections have proven histories of effectiveness for radioactive decontamination. Each process is described in some detail with an indication of the quantities and types of radioactive waste generated. Available data relating the degrees of decontamination to different processes are limited to specific conditions and are too numerous to be included in this report. No documented general data covering a wide range of conditions are available.

2.1.1 Manual Decontamination

This is the simplest method of surface decontamination, but, because direct contact is necessary, it is restricted to low-level contaminants. The process requires manual scrubbing of the contaminated surface with cloths, brushes, and mild detergents. Manual decontamination is most effective on surfaces that are polished and free of cracks or irregularities. Solid and liquid low-level radioactive wastes in the form of cloth and detergent solution are generated by this method. Quantities of these wastes are low compared to those generated by other techniques.

2.1.2 Automatic Washdown (Remote Decontamination)

This method of surface decontamination utilizes a high-velocity spray of water or detergent solution to remove radioactive particles.

Systems designed for decontaminating large areas generally have several multinozzle manifolds. The process requires a hydraulic pumping system capable of producing a flow rate of several gallons per minute (gpm) per spray nozzle at a pressure of 3,000 to 6,000 psi. Carbide nozzle inserts are usually necessary to prevent excessive erosion of the nozzle by the liquid.

A typical four-nozzle system, providing a flow rate of 3 gpm per nozzle at a pressure of 6,000 psi for 30 min, will require a pump of approximately 50 hp and will generate 360 gal of low-level radioactive liquid waste. If a detergent is used, a subsequent rinse is necessary. Experience has shown that mechanical brushing used in conjunction with a high-velocity spray does little to improve the effectiveness of this method.

2.1.3 Electropolishing

Electropolishing is an electrochemical process that is known to be a rapid and effective technique for radioactive decontamination of metal surfaces. Metals for which this technique is applicable include aluminum, mild steel, stainless steel, copper, and highly alloyed heat- and corrosion-resistant metals. Electropolishing has been used for the removal of a number of radioactive nuclides including uranium, plutonium, strontium, cesium, radium, cobalt, and americium, and is especially well suited for the removal of contaminants that are embedded, baked-on, or difficult to remove by other means.

The object to be decontaminated is submersed in an acid bath (electrolyte) and serves as the anode for an electrolytic "cell." Surface material, along with the contaminants, is removed by anodic dissolution when an electric current is applied. This also results in a progressive smoothing of the surface, which enhances cleanup rinsing and subsequent decontamination operations. Typical decontamination times range from 5 to 30 min depending on the amount of surface material to be removed (usually several mils) and the applied electric current density.⁽¹⁾ The degree of decontamination is also dependent on the

amount of surface material removed. Though there is little information available that describes a broad range of decontamination ratios, it has been shown that the radiation level of stainless steel vacuum system components that were heavily contaminated with plutonium oxide could be reduced from 10^6 dis/min-100 cm² to background in less than 10 min.

The electropolishing process is simple and readily adaptable to remote operations. Process vessels can range in size up to several thousand gallons and are usually made of stainless steel to permit system self-decontamination. This can be accomplished by simply making the vessel anodic.

The electrolyte life can be extended and secondary waste volume minimized by removing dissolved metals and contaminants from the electrolyte and rinse solutions. Electrolyte purification methods include ion exchange, solvent extraction, precipitation, distillation electrolysis, and membrane separation.

In-situ electropolishing techniques are currently being developed; however, it appears that this method is very time consuming and would not be applicable where large areas are to be decontaminated. Surface decontamination rates are generally on the order of in.²/min.⁽¹⁾

2.1.4 Ultrasonic Decontamination

Radioactive materials can be effectively removed from surface and irregularities by the erosive action of an ultrasonically agitated bath. Sonic energy, produced by a high-power electronic generator, is transmitted to the bath by a transducer. Frequencies in the range of 10 to 90 kHz are common, with the lower frequencies generally more effective. The cleaning solution, which is generally maintained at a temperature of 120 to 160°F, must support cavitation in order to clean rapidly and effectively. Water solutions of alkalines or acids, or solvents like trichloroethylene, are typical cleaning agents. Power levels of 5 watts/cm² or 50 watts/gal of cleaning solution are commonly used.⁽²⁾

Like the electropolishing processes, this method is adaptable to remote operations. Liquid waste could be treated in the same manner as that from washdown methods.

2.1.5 Air Jet and Vacuum

This method consists of directing a jet of high-pressure air at a contaminated surface and then picking up dislodged contaminated particles with a vacuum cleaner. Because of the low mass of air, it would be necessary to keep the tip of the nozzle very close to the contaminated surface. In order to cover a large surface area in an acceptable period of time, it would be necessary to utilize multiple nozzles. Mechanical brushing could be incorporated into this procedure. A large volume of contaminated air would result from this operation. No reports have been found in the literature of applications of this method to decontamination on any large-scale project. It is judged relatively ineffective in removing any but loosely attached contaminated particles.

2.1.6 Sandblasting

For this application, the term sandblasting is used to cover the entire range of abrasive particles (grits, glass beads, etc.) that could be used in a decontamination operation. Also, liquid or gas carriers could be used. This is a very effective decontamination method that would be suitable for irregular surfaces. The process results in the removal of surface material from the item being cleaned. It would therefore result in damage to precision surfaces. A considerable volume of solid and liquid waste would result, which would be difficult to retrieve and dispose of.

2.2 REMOVABLE LINERS

The following subsections describe two approaches to the decontamination problem utilizing soluble films and rigid metal liners.

2.2.1 Soluble Films

For many years soluble films have been used successfully as surface protectives against radioactive particle contamination. The film materials can be applied by brushing or spraying and, depending on the material used, may be easily removed with an organic solvent, water, or steam. The film is applied prior to radiation exposure and is stripped, along with the radioactive particles, with one of the aforementioned solvents. This method is amenable to remote operations in applications where the covered components may be placed in a solvent bath and is especially well suited for irregular configurations. It is necessary, however, that the surface to which the film material is applied be finished to a high degree. Moderate quantities of solid and liquid radioactive wastes in the form of film material, cloth, and liquid solvent are generated by this method.

2.2.2 Removable Debris Shields

A system of removable, lightweight shields would comprise the target chamber first wall. Additional shields in the form of cylindrical sleeves would be provided as necessary for the numerous laser beam and diagnostics instrumentation ports. The shields would be retained by brackets or clamps, which would permit removal and replacement by established remote handling techniques. When personnel access to the target chamber is required, the shields would be removed, bagged, and transported elsewhere for decontamination by any one of the methods described in Subsection 2.1. Machine downtime could be made independent of decontamination time by employing an alternate set of clean shields with which to replace the contaminated ones. A further reduction in machine downtime could be realized if it were determined that only portions of the shield system need periodic replacement.

The decontamination methods discussed in this section are summarized in Table II.

TABLE II
SUMMARY OF POTENTIAL DECONTAMINATION METHODS

<u>Decontamination Method</u>	<u>Equipment Required</u>	<u>Advantages</u>	<u>Disadvantages</u>
1. Manual Scrubbing	Scaffolding or lifts for personnel, protective clothing and masks, liquid wash solutions, cloth wipes, liquid radwaste storage.	Simple, manual process requires no sophisticated equipment. Minimal radwaste products. Radwaste form primarily solid, some liquid.	Possible personnel over-exposure to radiation. Time consuming.
2. Automatic Washdown	High-pressure hydraulic system p > 3,000 psi), decontamination solution drain system and catch basins, drying system, liquid radwaste storage.	Remote process time conserving.	Large volume of radwaste liquid, high-pressure liquid system may be incompatible with vacuum system. Residuals on optics.
3. Electropolishing	Electrolyte systems-pump, tanks, piping. Electrolyte inventory, radwaste liquid storage, electrolyte recycle system (if desired), liquid radwaste storage.	High degree of decontamination attainable. Surface quality improved by process. System is self-decontaminating.	In-situ decontamination very slow (in. ² /min). Limited to metals. Removal and external decontamination of large areas required.

TABLE II
SUMMARY OF POTENTIAL DECONTAMINATION METHODS
(Continued)

<u>Decontamination Method</u>	<u>Equipment Required</u>	<u>Advantages</u>	<u>Disadvantages</u>
3. Electropolishing (Continued)		Contaminated electrolyte can be recycled. Adaptable to remote operations. Rapid decontamination. Material removed by process.	Possible damage to non-metallic components.
4. Ultrasonic Cleaning	Solvent bath, solvent inventory, tanks and generator, liquid rad-waste storage.	High degree of decontamination attainable. Rapid decontamination. Adaptable to remote operations. Possible solvent recycle.	Not applicable to in-situ decontamination.
5. Air Jet and Vacuum	High-pressure compressor vacuum pick up contaminated gas holding tanks, filter system.	Will not harm other components. Gases may be filtered and released.	Weak decontamination process. Large volume of gaseous waste.

TABLE 11

**SUMMARY OF POTENTIAL DECONTAMINATION METHODS
(Concluded)**

<u>Decontamination Method</u>	<u>Equipment Required</u>	<u>Advantages</u>	<u>Disadvantages</u>
6. Sandblasting	Pump, collection tank piping, solid waste disposal system.	Effective decontamination method.	Damage to components may result. Large volume of secondary waste.
7. Soluble Films	Solvent-soluble film material, solvents, H ₂ O, or steam, same equipment as for manual scrubbing, liquid radwaste storage.	Rapid decontamination. Radwaste inventory minimized.	Manual operation. Possible personnel over-exposure to radiation. System compatibility, i.e., vacuum and materials.
8. Removable Debris Shields	Thin plate shields, Decontamination equipment (options 1-5).	In-situ decontamination not required. Adaptable to remote operations. Decontamination options 1-5 applicable. System downtime minimized. Vacuum compatibility. Partial replacement possible. Personnel exposure limited.	Additional system components required.

3.0 FEASIBILITY

Although the decontamination methods described in Subsections 2.1.1 through 2.2.1 have proven histories of effectiveness, most have limited applicability to this particular decontamination problem. These limitations are due primarily to vacuum compatibility and low activity requirements for materials and target chamber size and configuration. The following subsections discuss in detail the problem areas that have been identified and the feasibility of the decontamination methods surveyed.

3.1 PERSONNEL EXPOSURE

To assess the requirements for decontamination, it is necessary to assess the level of contamination resulting from operations in the Nova target chamber. Figure 1, reproduced from the report Nova 78-24, "Inventory of Actinides and Fission Products for Shiva Nova II Operations," shows the fission product inventory resulting from 24 hr apart shots that result in 10^{17} fissions per shot. Actinide production was found to be only a minor contributor to the curie inventory.

Referring to Figure 1, it is seen that with a decay time of 24 hr, the fission product inventory would be approximately 30 curies. A curie is defined as 3.7×10^{10} disintegrations per second. Fission products decay with a wide spectrum of energies. To determine this in detail, it would be necessary to consider the list of fission products as given in Table 2 of the Nova report, and sum the decays (type and energy) of all. However, this was not considered necessary for the present study. If each disintegration is assumed to be, on an average, a gamma photon of 1 meV energy, the resultant dose calculated will represent a conservative estimate and permit an evaluation of the degree of decontamination that must be achieved before workers can safely enter the target vessel. The allowed exposure is determined by radiation protection standards specified in ERDA Manual Appendix 0524. The controlling dose is 3 rem per quarter year with the yearly dose

Figure-1.

Inventory of the sum of the fission products normalized to 10^{17} fissions per shot, as a function of decay time following 1, 5, 10, 25, 100 and 500 24-hour apart shots.

permitted of 5 rem for whole body exposure. Despite these limits, the responsibility exists to maintain personnel exposure as low as practicable.

Figure 2 gives the flux to dose conversion for gamma photons of various energies. It is seen that 3 rem/hr permits a flux of $3 \times 5.3 \times 10^5 = 1.6 \times 10^6$ 1 meV photons per cm^2 -sec whole body dose.

The inside surface area of the target vessel is approximately:

$$\pi d^2 = 3.1416 \times (400)^2 \text{ cm}^2 \approx 500,000 \text{ cm}^2 \text{ (spherical section only)}$$

$$30 \text{ curies} \Rightarrow 30 \times 3.7 \times 10^{10} \text{ dis/sec}$$

$$= 1.1 \times 10^{12} \text{ dis/sec}$$

The fission products are assumed to be uniformly distributed over the inside surface of the sphere. This then results in a surface activity level of

$$\frac{1.1 \times 10^{12}}{5 \times 10^5} \approx 2 \times 10^6 \text{ dis/cm}^2 \text{-sec}$$

Since approximately one-half of these photons would be directed outward, a worker standing next to the surface would receive a dose of approximately

$$\frac{0.5 \times 2 \times 10^6}{1.6 \times 10^6} = 0.6 \text{ r/hr}$$

To this would be added the dose received from the neutron-activated components in the chamber system. All tests planned for this equipment will not be at the maximum level resulting in 10^{19} fusion

Figure 2. Gamma Flux to Give 1 rem/hr

neutrons and 10^{17} fissions per shot. It has been estimated* that an average series of tests will be equivalent to five shots of 5×10^{16} fissions each.

Referring again to Figure 1, after a decay time of 24 hr, the fission product inventory would be approximately 10 curies.

$$10 \text{ curies} = 3.7 \times 10^{11} \text{ disc/sec}$$

$$\frac{3.7 \times 10^{11}}{5 \times 10^5} = 7.4 \times 10^5$$

$$\frac{0.5 \times 7.4 \times 10^5}{1.6 \times 10^6} = \frac{0.2r}{hr} = \frac{200mr}{hr}$$

This value is still too high to permit contact operations. The conclusions that can be drawn from this very crude approximation are as follows:

- Decontamination of the Nova target chamber will be required to allow personnel entry.
- Direct, manual decontamination would result in undesirably high radiation exposure to workers.
- Decontamination factors of 10^1 to 10^2 would permit limited operations or additional manual decontamination.

3.2 VACUUM COMPATIBILITY

Particular attention has been focused on this subject because of the low pressures (10^{-5} to 10^{-7} torr) to which materials will be exposed. With regard to the problem of time delay to allow for radioactive decay, the low-Z (atomic number) materials appear to be the most applicable. However, some of these materials are not compatible

* F. Rienecker, private communication.

with low-pressure environments. This is especially true of the epoxy resins and to some extent aluminum, both of which are being considered for the target chamber first wall construction, the former as an impregnating material for Kevlar* fiber. Outgassing from these materials, especially the polymers, will most likely present a major vacuum problem for such a large system.

The evolution of gas from materials occurs in several ways: the release from the surface of bonded gas and vapor films, the release of gas or vapor occluded in pores or in solution in the body of the material, and the release of a gas or vapor composed of molecules of the material itself. Table III gives representative outgassing rates for a number of materials, including those being considered for Nova target chamber application. The polyamides (e.g., Kevlar and nylon) are hygroscopic and will yield quantities of water vapor during the pumping process. Also, the water content of these materials can be expected to increase with time if exposed to normal atmospheric conditions following a period in vacuo. In general, the outgassing rates for polymers are approximately two orders of magnitude higher than for stainless steel.

The values given in Table IV for total outgassing rates and pumping speeds were based on a chamber having a configuration as shown in Figure 3, with an estimated internal surface area of 100 m^2 . The pumping speeds given are those that would be required of a system to maintain a pressure of 10^{-5} torr after 1 hr in vacuo and after neglecting any permeation. These values were compared with those given in Reference 6 to achieve a pressure of 10^{-7} torr. In that report, it was stated that a surface outgassing rate of approximately 10^{-8} torr- ℓ /s- cm^2 and a vacuum pumping speed of approximately 10^4 ℓ /s will be required to reach this pressure. Note the order-of-magnitude differences in these values and those given in Tables III and IV for pressures differing by two orders of magnitude.

Total outgassing rates and pumping speeds for the alternate chamber configuration shown in Figure 4 were not calculated, but will be approximately double those given in Table IV. It should be noted that

* An aromatic polyamide manufactured by Du Pont.

TABLE III

Outgassing Rates of Selected Materials After One-Hour in Vacuo

MATERIAL	PRETREATMENT	OUTGASSING RATE (TORR-L/SEC-CM ²)
EPOXY RESIN (4)	NONE	1.0×10^{-5}
NYLAR (4)	NONE	3.0×10^{-6}
KEL-F (5)	NONE	4.0×10^{-8}
NYLON (5)	NONE	1.2×10^{-5}
ALUMINUM (5)	NONE	6.2×10^{-9}
ALUMINUM (5)	ANODIZED-2 μ M PORES	2.8×10^{-7}
STAINLESS STEEL (5)	NONE	1.8×10^{-7}
STAINLESS STEEL (5)	ELECTROPOLISHED	4.3×10^{-9}

TABLE IV

Estimated Total Outgassing and Related Pumping Speeds
for the Spherical Nova Target Chamber

MATERIAL	PRETREATMENT	TOTAL OUTGASSING (TORR-L/SEC)	PUMPING SPEED (L/SEC)
EPOXY RESIN	NONE	10.5	1.05×10^6
MYLAR	NONE	3.0	3.0×10^5
ALUMINUM	ANODIZED-2 μ M PORES	0.28	2.8×10^4
STAINLESS STEEL	ELECTROPOLISHED	0.004	430

Figure 3. Nova Target Chamber - Spherical Configuration

Figure 4. Nova Target Chamber - Cylindrical Configuration

these values are for a bare chamber and that the inclusion of other systems of like materials, e.g., debris shields, could triple the total outgassing rate.

In general, coated and plated surfaces are not compatible with high-vacuum systems. Extended outgassing periods due to the diffusion of gases through surface coatings and the evolution of gases composed of molecules of the coating material itself (low vapor pressure) can be expected. For these reasons, soluble films, which generally contain oils, gums, and resins, and adhesive-backed foils or papers would not be suitable for this application.

Surface quality is important in that it affects both the radioactive decontamination and vacuum pumping processes. Void-free materials with smooth, fissure-free surfaces will reduce the possibility of virtual leaks and outgassing from entrapped decontamination materials. In this regard, the effect of epoxy resin surface spallation should be considered.

3.3 DEBRIS PENETRATION

It is expected that the bulk of the radioactive debris generated by the targets will be embedded in the first wall material. A material having sufficient hardness and thickness to prevent excessive or total penetration will be required. Foils of low-Z material (e.g., aluminum, aluminized mylar) and soluble films would have thickness ranging from 0.05 to 0.40 mm and probably would not suffice. Aluminum alloy 00-H18* (commercially pure) and epoxy resins are of similar hardness (Rockwell H80-H100)^(7,8) but, because of the necessity to remove surface layers of material in order to decontaminate, aluminum would offer several advantages.

* Chem. Composition 99.0% Al, 1.0 max Fe and Si, 0.20 max Cu, 0.10 max Zn, 0.05 max Mn.

First, aluminum surface material can be removed uniformly by electropolishing, a process that will also progressively smooth the surface. Second, the removal of surface material from the Kevlar/epoxy resin composite may expose voids or cracks as well as the hygroscopic Kevlar fiber. And finally, the methods required to produce a smooth surface while removing epoxy resin material are time consuming. The major disadvantage of electropolishing as applied to this problem is that in-situ decontamination is not feasible. The process would be most applicable to a system of removable debris shields as described in Subsection 2.2.2.

3.4 CHAMBER CONFIGURATION

Decontamination processes were investigated for the target chamber configurations shown in Figures 3 and 4. It was assumed that access to the chamber interior for decontamination and maintenance activities would be via the two removable domes on the conical frusta. The exposed internal surface area of the cylindrical chamber (Figure 4) is approximately twice that of the spherical chamber (Figure 3); however, the former could be more readily adapted to a remote decontamination process or debris shield concept. Also, fabrication of cylindrical rather than spherical shields or foils would be simpler.

Both chamber configurations may preclude in-situ decontamination processes that require quantities of liquid. Diagnostic penetrations, seams, and mechanical interfaces within the chamber would require special attention to ensure the complete removal of contaminated waste liquid. In fact, if flushing with quantities of liquid is not totally effective, it will only serve to accumulate radioactive particles in those areas that are most difficult to decontaminate.

4.0 REMOTE OPERATIONS

The level of induced radioactivity in the target chamber first wall following a series of shots may necessitate remote decontamination or disassembly procedures. A portable system comprised of heavy duty, extended reach, master/slave manipulators, and shadow shielding may be required. Programmable robot systems are also available but are generally used for pick-and-place operations. Also, the cost of a complete system with software package may be prohibitive.

If remote operations are warranted, the decontamination process and remote handling procedures should be developed concurrently.

5.0 CONCEPTS FOR FURTHER CONSIDERATION

The major unknown at this time is the properties of the debris generated by the targets. The particle size and the degree to which it is imbedded in the first wall material are the really important parameters that determine the decontamination procedures that will be required. It may be possible to obtain this information experimentally, but within the time scale that some decisions must be made, this will remain an unknown factor. Accordingly, three separate systems will be considered based on three different assumptions.

1. The debris will be attached to the first wall surface very lightly and can be removed by a compressed air blast and picked up by a vacuum. In other words, the degree of debris penetration is assumed to be such that 90% decontamination can be achieved by air jet and vacuum.
2. The debris is attached more firmly. An air blast would not be effective, but a high-pressure water system would be effective in removing 90% of the contamination.
3. The debris is attached very tightly and can only be removed in conjunction with a portion of the material surface.

5.1 Automatic Washdown

5.1.1 System Description

For remotely decontamination using high-pressure automatic wash-down, a typical system is shown in Figure 5. Required pressure is in the range of 3,000 to 6,000 psi. The equipment required to perform this operation is as follows:

- High-pressure pump.
- Water supply tank.

FIGURE 5
HIGH VELOCITY JET/VAC. TRANSFER CONCEPT

Los Alamos Technical Associates, Inc.

- Distribution piping and manifold system.
- High-capacity vacuum system.
- Liquid waste tank.
- HEPA filter system.
- Nozzle control mechanism.

The time required to clean the vessel interior depends on a number of factors including number of nozzles used, coverage and overlap per nozzle, and nozzle traverse speed.

The choice of these parameters will depend on the debris itself; particle sizes, degree of adhesion, and the character of the surface. The present state of the art reflects experience with equipment in the nuclear power industry where it has been found that high pressures, slow traverse rates, and high flow rates were required for effective decontamination. It was assumed that it would be highly desirable to accomplish the washdown operation with an 8-hr shift.

For a 10-nozzle manifold, nozzles spaced 30 cm from the surface with a 10% overlap, Table V gives the cleaning time (T) and liquid flow (Q) for various traverse rates (S) and flow rates (q) to cover 10^6 cm^2 of surface.

The nozzle, manifold, and high-pressure piping system inside the chamber would be a potential source of interference with the experimental program, would be difficult to pump down to the required vacuum, and would add to the neutron activation of the assembly.

5.1.2 Equipment Costs

The cost of these components could vary widely depending on a number of design details. For planning purposes, an order of magnitude estimate is as follows:

TABLE V
CLEANING TIME AND FLOW
FOR
AUTOMATIC WASHDOWN CLEANING SYSTEM

<u>S</u> (<u>cm/min</u>)	<u>q</u> (<u>gpm</u>)	<u>T</u> (<u>hr</u>)	<u>Q</u> (<u>gal</u>)
5	40	24.4	58,600
10	80	12.2	58,600
15	120	8.2	58,600
20	160	6.2	58,600
25	160	4.8	46,900
30	160	4.0	39,000
30	40	4.0	9,800
15	40	8.2	19,500

For 10^6 cm^2 Surface Area

Los Alamos Technical Associates, Inc.

Pump	\$ 2,500
Water Supply Tank	30,000
Distribution Piping and Manifold System	50,000
High-Capacity Vacuum System	100,000
Liquid Waste Tank (60,000 gal)	55,000
Filtration Systems	75,000
Nozzle Control Mechanism	<u>100,000</u>
Total	\$412,500

The vacuum system could not be 100% effective in removing the spray and loosened debris. Some would undoubtedly fall to the bottom of the chamber to be picked up later. Any liquid left in the tank would cause difficulties for the vacuum system. Care must be taken to keep water and debris out of the instrumentation ports. A large volume of both liquid and gaseous wastes would be generated with this process.

For this technique to be effective, a design should be developed that would permit the unit to be inserted and removed through an opening in the chamber rather than remaining in place during operations.

5.2 Air Blast and Vacuum

To remotely decontaminate using high-pressure air jet-vacuum methods, approximately the same equipment as the automatic washdown would be required with, of course, the substitution of an air compressor for a high-pressure pump. The cost of the equipment would also be approximately the same.

5.3 Removable Debris Shields

5.3.1 System Description

The equipment required for decontamination by removable debris shields would consist of extended reach manipulator systems with shielding to reduce operator exposure. These manipulators could be

withdrawn during the experiments and inserted when decontamination was required. This would require one or more additional openings in the chamber.

The removable shields could then be taken to another facility for decontamination. The length of time required to remove the shields and insert a clean set would be a design parameter. One day downtime should be a possible goal.

5.3.2 Equipment Costs

One set of manipulators and the required shielding is estimated to cost approximately \$100,000.

6.0 SYSTEM EFFLUENTS

Gaseous fission products are produced with each shot. These products are removed by the vacuum system between shots. The more important radioactive substances are isotopes of krypton, iodine, and xenon. While approximately 30 curies of these elements result from each shot, their relatively short half-lives quickly reduce the potential hazard. Appendix B of 10 CFR 20 lists the allowable concentrations in unrestricted areas. A holdup time of 24 hr and dilution by release through a stack would easily meet this standard. The present design concept has adequate provisions to accomplish this. Liquid effluents may result from cleaning and decontamination activities or from cooling water systems. Referring to Figure 1, the fission product inventory is 10 to 30 curies after 24 hr (depending on the number and timing of prior shots). The half-lives of some of these fission products are longer and the activity may be as much as 1 curie after a year. It is seen from Appendix B, 10 CFR 20, that permitted concentrations in water are quite variable, depending on the element involved, and are so low that unrestricted release of contaminated solutions will not be possible even after years of holdup time. Treatment of liquid wastes, such as by evaporation, will be required. The residue must then be disposed of as solid waste.

Solid waste will consist of contaminated pieces of equipment, residue from waste treatment activities (filters, etc.), contaminated clothing, cleaning materials, and supplies used in the decontamination process; it will require packaging and offsite shipment for disposal. Regulatory Guide 1.86 gives acceptable surface contamination levels for material to be released for unrestricted use. These values are on the order of 10^{-8} curies per 100-cm^2 surface area. It will obviously be very difficult to completely decontaminate an item.

It is very important that the generation of contaminated waste be kept to a minimum in this facility. A thorough review of all potential waste sources and a study of means of minimizing waste volume should be undertaken. Following this, a waste management plan for all types of waste should be developed.

7.0 RECOMMENDATIONS

As a result of this study, two problem areas, which have a significant impact on the selection of a method of decontamination, have been identified. More information regarding the vacuum compatibility of specific materials and the degree of radioactive particle penetration into these materials is required. It is therefore recommended that a series of tests be performed to establish a more precise data base for determining the best combination of material and decontamination method. The tests should be performed on material samples (aluminum, Kevlar/epoxy, etc.) of sufficient size to produce representative data. The existing Shiva experimental hardware could possibly be used to simulate the expected Nova conditions.

8.0 REFERENCES

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