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National Ignition Facility Environmental Protection Systems

J. Mark Mintz
Thomas C. Reitz
Michael T. Tobin

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NATIONAL IGNITION FACILITY ENVIRONMENTAL PROTECTION SYSTEMS

J. Mark Mintz
Lawrence Livermore National Lab
P.O. Box 808
Livermore, Calif. 94550
(510) 422-8394

Thomas C. Reitz
Lawrence Livermore National Lab
P.O. Box 808
Livermore, Calif. 94550
(510) 422-9123

Michael T. Tobin
Lawrence Livermore National Lab
P.O. Box 808
Livermore, Calif. 94550
(510) 423-1168

ABSTRACT

The conceptual design of Environmental Protection Systems (EPS) for the National Ignition Facility (NIF) is described. These systems encompass tritium and activated debris handling, chamber, debris shield and general decontamination, neutron and gamma monitoring, and radioactive, hazardous and mixed waste handling. Key performance specifications met by EPS designs include limiting the tritium inventory to 300 Ci and total tritium release from NIF facilities to less than 10 Ci/yr. Total radiation doses attributable to NIF shall remain below 10 mrem/yr for any member of the general public and 500 mrem/yr for NIF staff. ALARA-based design features and operational procedures will, in most cases, result in much lower measured exposures. Waste minimization, improved cycle time and reduced exposures all result from the proposed CO2 robotic arm cleaning and decontamination system, while effective tritium control is achieved through a modern system design based on double containment and the proven detritiation technology.

I. INTRODUCTION

The National Ignition Facility is designed to achieve significant D-T fusion yield, up to 20 MJ/shot. In addition to unburned tritium, this process will generate neutrons, energetic particles and debris and x-rays. The neutrons will, in turn, mildly activate surrounding materials, including equipment, shielding, support structures and air gases. NIF Environmental Protection Systems have been designed to effectively minimize personnel exposures and adverse environmental effects. EPS elements are identified in Figure 1. Intrinsic NIF operational characteristics, coupled with conservative design principles, assure EPS designs that meet, or, guided by ALARA, frequently exceed all statutory and regulatory requirements. The selected designs depend on a variety of tritium processing systems, decontamination techniques and contamination control procedures.

Gas phase tritium from the target chamber or other sealed enclosures, such as glove boxes, will be processed through a central tritium scrubber system. The scrubber system design will be based on the well established technique of catalytic oxidation with the resultant HTO collected on molecular sieve dryers. The scrubber system will be sized to accommodate multiple sources of tritiated effluent simultaneously. Given the projected design of the target chamber vacuum system and operating parameters of the target chamber itself, the tritium scrubber system need not be sized to process gas at a rate equal to the pumping speed of the vacuum system. A moderately sized tritium processing system of approximately 2000 liters per minute should therefore meet NIF requirements. A larger capacity might prove necessary if chamber structures trap tritium more effectively than anticipated.

A relatively new process, CO_2 pellet cleaning, is being evaluated as the primary decontamination process for all tritiated NIF components. While some development work will be required to quantify the effectiveness on the various surfaces involved, a study completed by Martin Marietta indicates the process is applicable to this task. The technique could be applied to cleaning operations on both the interior and exterior of the target chamber and the associated debris shields. Assuming the initial optimism for CO_2 pellet cleaning of tritiated NIF components is validated by testing, a significant saving in labor, reduced cleaning cycle times and waste generation will be realized. To uniformly clean and access the interior of the target chamber, the nozzle of the CO2 cleaning equipment could be controlled by a robotic arm that would be inserted into the chamber during cleaning operations. A close capture collection shroud attached to the nozzle would collect and route the contaminates out of the chamber and away from the cleaned surfaces, thus minimizing recontamination during the cleaning process.

Off line work areas will be developed for secondary cleaning, decontamination, and waste processing operations. CO_2 pellet cleaning could also be applied to these off line operations with similar expectations for reduced labor costs and waste generation.

To provide information on the effectiveness of the tritium processing equipment, contamination control procedures, and to monitor tritium process releases, a comprehensive system of tritium monitors will be installed. In line tritium process monitors will evaluate scrubber performance, while work areas in glove boxes, ventilated hoods, and labs will be continually monitored for tritium levels. Stack monitors will evaluate both real time and accumulative stack releases. Liquid scintillation counters will be used to evaluate surface contamination levels.

Exposure to neutron gamma and x-radiation is minimized in NIF primarily by fixed shielding, access, and ventilation control. Target chamber debris will also be mildly activated, a factor which influences waste handling glove box design and procedures. All non-mixed radioactive waste is expected to qualify as low level waste and will be packaged and certified per criteria established by DOE/NV for disposal at the Nevada Test Site. Mixed waste generation is expected to be minimal due to extensive use of the CO_2 pellet cleaning process.

II. EPS ELEMENTS

A. Tritium Processing System (TPS)

Tritium will be present in the NIF target chamber, diagnostic lines of sight, vacuum systems and glove boxes. It's removal by the TPS will be accomplished by the catalytic conversion of tritium to tritiated water to be stored on dryer beds for disposal at a later date. Based on Tritium Inventory Removal Project experience for the LLNL tritium facility, the decontamination factor for the TPS should be approximately 10,000 or better. A flow schematic for the TPS os govem as Figure 2.

The TPS is composed of hardware which is mounted on a 10' by 10' by 7' high skid and monitoring and control systems located elsewhere.

The monitoring and control systems will be composed of the following:

- The flow monitoring system provides verification of gas flow.
- The pressure monitoring system provides for system pressure monitoring.
- The temperature monitoring system provides for process temperature monitoring.
- The preheater/reactor control system provides for reactor temperature control and over temperature protection.
- The hygrometer system provides for the monitoring of moisture breakthrough in the dryer beds.
- The tritium monitor system provides the means for monitoring tritium contamination levels of the gas entering and leaving the TPS.
- The process control system provides the control for the gas flow with the pneumatic valves.

The Tritium Processing System will have to interface with any system or work station which could or will be exposed to tritium. The main interfaces are the vacuum pumping systems for the target chamber and diagnostic lines of sight, the decontamination work stations and the target receiving and storage station. These systems, to the extent practical, will be co-located near the target chamber. Co-location will help assure contamination control (physical and HVAC pressure zone maintenance) and minimize the total EPS "footprint" and associated costs.

B. Debris Shield Decontamination

Debris shields protect sensitive NIF optics from blast damage. The cleaning/decontamination of the debris shields may be performed in one of two different ways—in situ, as part of the Target Chamber-Interior Decontamination or off-line within the confines of a dedicated Debris Shield Decontamination Station. At this time, the determining factor in choosing the appropriate cleaning method is whether or not the debris shield optical surfaces are coated and if so, are they coated with a material that would be damaged/removed by the CO_2 cleaning process? Assuming that the surface coating would be damaged by the cleaning process, the following procedure would be implemented.

The NIF Debris Shields (DS), configured in "cassettes," will be transferred directly from the NIF chamber into secondary containers, jointly removed and transferred to an off-line cleaning station. This process will be conducted using the philosophy of "total hermetic sealing" throughout the entire transfer sequence, i.e. from NIF chamber to transfer container to cleaning station. This methodology is designeded to protect personnel and the environment from exposure to tritium-contaminated surfaces and external radiation produced by activation. Upon insertion into the cleaning station, the DS/cassette assemblies are staged within an on-board sequencer and then individually cleaned to specification.

The proposed automated cleaning process concept involves techniques utilizing commercially-available, "pelletized CO_2 blasting" equipment for surface-contaminant removal. This concept (pending tritium removal-effectiveness experimentation/verification) will be utilized for DS cleaning. The process will involve simultaneous face-surface cleaning achieved by robotically-controlled single-axis (fore and aft) translation and indexing (up and down) of the DS/cassette assembly through the pelletized CO_2 media delivered by two opposed "nozzles"—each biased to achieve an impingement angle of 30-45 degrees to the respective DS surface. The subsequent air-born contaminants liberated from this process will be collected locally (approximately 90%) by two cone-shaped close-capture accumulator housings (surrounding each nozzle) and connected, via flexible ducting, to a HEPA-filtered-sub-atmospheric Debris Recovery System capable of an evacuation flow rate of approximately 6000 SCFM.

C. Target Chamber-Interior Decontamination

Assuming acceptable tritium removal/first-wall material compatibility, the interior of the NIF chamber will be cleaned and decontaminated remotely utilizing similar conceptual techniques, media and equipment outlined in Debris Shield Decontamination, i.e. "pelletized CO_2 blasting". The vehicle for delivering the cleaning media to the desired surfaces/locations will be an insertable (into NIF chamber) robotic arm with 6 degrees of freedom of movement and a minimum payload capacity of 150 pounds at the articulated "wrist". The robotic arm will be controlled by a computer-based controller with the ability to "learn" from the use of a model or 3-D CADD drawing to follow the required geometric paths for cleaning the complex internal surfaces. The use of the robotic system for cleaning minimizes the need for personnel entry into the NIF chamber and therefore reduces "risk" due to potential radioactive or questionable breathing-air environments. The robot is also capable of handling the massive cleaning nozzle/close-capture recovery system shroud assembly and the thrust generated by the CO_2 delivery nozzle while positioning it at desirable impingement angles thus providing consistent translational paths to achieve optimum cleaning characteristics.

The CO_2 cleaning media will be delivered, at the rate of about 200 pounds/hour, by dry compressed-air propulsion. The subsequent air-borne contaminants liberated from this cleaning process will be collected at the point of generation (approximately 90%) by a cone-shaped accumulator housing (surrounding the nozzle) and connected, via flexible ducting, to a HEPA-filtered-sub-atmospheric Vacuum Debris Recovery System capable of an evacuation flow rate of approximately 6000 SCFM. A Make-Up Air System, pressure controlled by the Make-Up air Pressure Control System, will provide moisture/oil free air to replace that which is being swept through the Debris Recovery system and exhausted [after being monitored by an in-line tritium monitor] to the atmosphere through the facility "stack".

D. General Decontamination Work Station

The purpose of the General Decontamination Work Station (GDWS) is to provide an off-line cleaning/decontamination capability for NIF-related components. The GDWS is comprised of a twelve-foot long (540 ft^3) glove box enclosure located within the confines of the Environmental Protection Systems (EPS) Processing Facility. This enclosure will be equipped with CO_2 cleaning capabilities (both pelletized and liquid-generated "snow"), a close-capture vacuum recovery system, and a pressure-controlled-make-up-air conditioning system. Due to the large mass of the CO_2 nozzle/recovery system shroud and the thrust produced by delivery of the cleaning media, the CO_2 cleaning head assembly will be remotely positioned by a joy stick-controlled robotic arm mounted within the glove box. Assorted positioning equipment such as a lift platform, rotating/tilting mechanism, etc. will also be installed to facilitate cleaning operations of a variety of shapes/configurations. Like the Debris Shield Decontamination Station, the aggregate of gases yielded from the GDWS will be exhausted to the atmosphere through the facility "stack" after being filtered by the HEPA-filtered-sub-atmospheric Debris Recovery System (shared with the Debris Shield Decontamination Station) and monitored by a dedicated tritium monitor.

E. Gamma and Neutron Monitoring

The gamma and neutron monitoring systems for NIF are designed to continuously measure radiation at their respective locations. These monitors will provide local readout and alarm, as necessary. These readings will be provided to the NIF control system and other locations as required. The central NIF computer system will be able to interrogate the system from the control room and at the entrances to the target area to determine function status and readout. The gamma measurement system provides an interlock signal to the target area and experimental doors to control entry, as required. The detectors will monitor radiation on a shot per shot basis. The neutron detectors are designed to not become activated from neutrons produced during each shot. All electronics associated with the monitoring system and which are located within the target area are designed to continue operation in all cases of neutron exposure and not be adversely affected by extra cameral effects. The monitors are designed to fail to the top of their measurement range. In no case will these monitors fail to the low end of their measurement range. The detectors are responsive to radiation over their entire range and their response is linear (within ± 20 percent). The monitor channels (i.e. the detector, cabling, electronics) are designed to be calibrated as a unit.

The gamma and neutron monitoring system will be located within the target room and other appropriate areas. In addition to the fixed locations shown in the figure, there will be four portable units for each type of radiation which can be placed in specific experimental areas to provide for comprehensive evaluations of local conditions. The monitoring systems are state of the art and are available from several vendors. Neutron detectors will be ^{3}He based, while gamma and beta detectors will be ion chambers. The gamma and neutron monitoring systems are interfaced with the NIF computer control system and to the target room and experiment room door locks. Interlocks are designed to fail closed.

F. Radioactive, Hazardous and Mixed Waste Streams

Routine NIF operations will generate a variety of waste streams, including low level radioactive waste (LLRW), hazardous waste and small amounts of mixed waste. This section briefly describes these waste streams and how they are to be managed.

Table 1 summarizes principal constituents and their estimated generation rates. Much of this data is extrapolated directly from NOVA experience. Mixed waste quantities for NIF are, however, much reduced by substituting the CO_2 pellet cleaning process described in II.B for the solvents used in NOVA for the chamber and debris shield cleaning. Waste stream reductions of up to 100 percent for liquid mixed waste and 50 percent for solid mixed waste are anticipated and are reflected in Table 1.

LLRW will be generated principally by tritium systems operations and by periodic cleaning of first wall debris shield and diagnostics accessing the target chamber. Protective clothing (gloves, lab coats, etc.) will make up the bulk of this waste stream with molecular sieves from the tritium processing system accounting for virtually all waste tritium inventory (~300 Ci/yr). LLRW will be characterized, packaged and shipped in accordance with existing LLNL procedures accepted for the disposal of tritiated waste at the Nevada Test Site.

Small amounts of particulate, which might include some mixed waste, will be dislodged during the cleaning operations described in Section II.C. These will be collected on HEPA filters and stored on site until determined not to be mixed or until a suitable processing site is available.

Liquid hazardous waste (in the forms and approximate amounts listed in Table 1) will be generated by various NIF operations, including optics cleaning (organic solvents) and photographic processing. These activities are routine at many large research facilities and the resulting incremental waste streams should be readily absorbed by the host site's existing waste management process.

Solid hazardous waste will consist primarily of sealed oil-filled capacitors with a smaller component of solvent exposed wipes and protective clothing. As for liquid hazardous waste, these items present no unusual disposal difficulties and can be readily absorbed by a host site's existing waste management infrastructure.

The assumed efficacy of the CO_2 pellet cleaning process is the key to minimizing mixed waste generation in NIF.

G. Tritium Monitoring & Contamination Control

1. Tritium Monitoring - A comprehensive system of process and work space tritium monitors will be utilized for all tritium operations associated with NIF. This monitoring scheme provides for continual monitoring of tritium operations from the location of the operation to the elevated release point. The approach selected is consistent with modern tritium facility design philosophy and will provide complete local and remote information on tritium concentrations within NIF systems and work spaces.

Gas phase tritium will be primarily monitored through the use of ion chamber based detectors. Tritium monitoring will be provided at the following locations:

- Central tritium processing system.
- Target chamber interior.
- Glove box enclosures.
- Ventilated hoods.

Figure 1: NIF EPS Elements

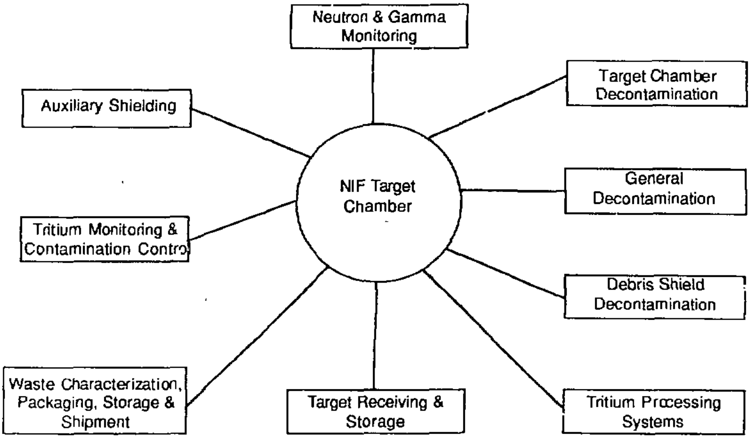
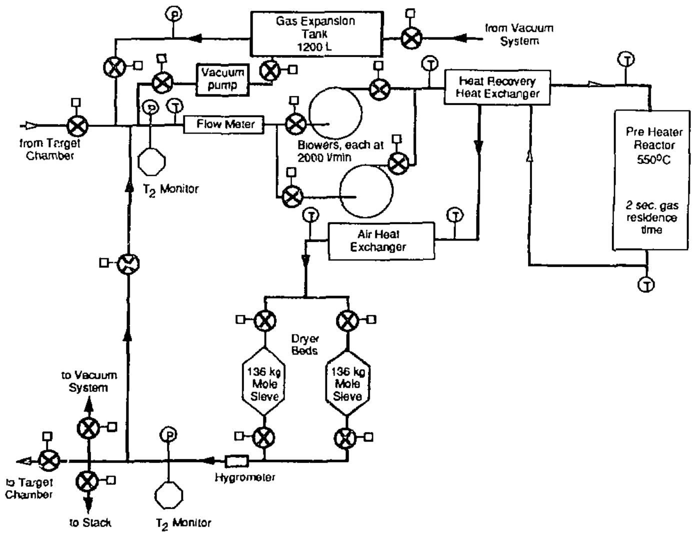


Figure 2: NIF Tritium Processing System



- Rooms involving tritium operations.
- Central exhaust stack.
- Diagnostic lines.

Local output of all tritium monitors will be provided.

A central control console will be provided in which the output of all monitors can be displayed and recorded. Provisions for alarms and interlocks will also be provided. In addition to the above permanent monitors, portable monitors will be utilized during localized maintenance type tritium operations.

To provide an accurate record of total tritium releases from NIF to the environment, an accumulative stack monitor will be provided. The instrument will be based on the Ostlund HTO/HT sampling technique and will monitor and record all stack effluent.

2. Contamination Control - As part of the overall facility radiological protection program, a detailed tritium contamination control plan will be developed that will address operational procedures, personnel training, and contamination control evaluation. Written operating procedures aimed at minimizing contamination at the source will be provided. These procedures, which will be specific to NIF operations, will be used to train individuals working in tritiated areas and will be a portion of an overall Health Physics program. To evaluate the effectiveness of the contamination control program, a liquid scintillation counting facility will be provided. The scintillation counter will be used to evaluate surface contamination levels through a routine surface wipe program. A bioassay program will be implemented to evaluate the effectiveness of the contamination control plan in relation to personnel exposures.

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Table I

Waste Generation Rates Projected for NIF

Waste Type	Quantity without CO_2 sys	Quantity with CO_2 sys	Source
Solid hazardous	7,000 lb/y	7,000 lb/y	capacitors, solvents on wipes and gloves
Liquid hazardous	500 gal/y	500 gal/y	paints, acids, bases, alcohols, organic solvents, and photodeveloper
Solid mixed	600 lb/y		solvents on wipes, gloves, and clothing exposed to low level H3
		300 lb/y	CO_2 cleaning system filters *
Liquid mixed	1,000 gal/y		rinse water with solvents and low level H_3; and contaminated organics
		500 gal/y *	rinse water with solvents and low level H_3 from components not efficiently cleanable by CO_2; and contaminated organics
Solid low level radioactive	2,000 lb/y	2,000 lb/y	gloves, suits, wipes, small hardware, molecular sieves e .posed to low level H_3, solidified liquids
Liquid low level radioactive	2,000 gal/y	2,000 gal/y	water based cleaners exposed to low levels of H_3

* bounding level for CO_2 system, levels during actual operation could be reduced.