Task 12 - Laser Cleaning of Contaminated Painted Surfaces

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TASK 12 - LASER CLEANING OF CONTAMINATED PAINTED SURFACES

1.0 INTRODUCTION

Paint contaminated with radionuclides and other hazardous materials is common in Department of Energy (DOE) facilities. Facility decommissioning and decontamination requires the removal of contaminated paint. Paint removal technologies include laser- and abrasive-based systems. F2 Associates are utilizing a pulsed-repetition CO₂ laser that produces a 2.5-cm × 2.5-cm beam which can be scanned across a 30- × 100-cm raster and, when placed on a robot, can be designed to clean any surface that the robot can be programmed to follow. Causing little or no damage to the substrate (concrete, steel, etc.), the laser ablates the material to be removed from a given surface. Ablated material is then pulled into a filtration and collection (VAC-PAC) system to prevent the hazardous substances from entering into the atmosphere. The VAC-PAC system deposits the ablated material into waste drums which may be removed from the system without compromising the integrity of the seal, allowing a new drum to be set up for collection without leakage of the ablated material into the atmosphere.

2.0 OBJECTIVES

The overall objectives of this project by the Energy & Environmental Research Center (EERC) are support of F2 Associates development activities for its laser-based coating removal system in the following three areas:

- On-line sensors for cleaning optimization and waste assay.
- Surface cleaning cost model for comparison of competing technologies.
- Engineering design handbook for easy decontamination of equipment.

The focus areas of work in the first year are to develop strategies for on-line sensors and to provide preliminary work on the cost analysis model. Work on the engineering design handbook will take place in the second year.

2.1 On-Line Sensors

Both of the major objectives of adding on-line sensors to the laser surface cleaning system will reduce the cost of applying this technology. On-line sensors will be used to optimize the cleaning process by allowing a smaller number of iterations on the survey-clean cycle typically employed in the removal of contaminated coatings from floors and walls in DOE facilities. On-line sensors also offer the possibility for performing chemical analysis in situ during removal of coatings, which results in reduced costs of assay for waste materials collected by the VAC-PAC system.

2.2 Surface Decontamination Operations Systems Analysis

The initial work to be performed on systems analysis will be limited to a survey of existing models available for application to surface decontamination and decommissioning (D&D)

operations and to the development of a plan for enhancing the existing models or for creating new algorithms. An effective model for assessing the economics of surface D&D operations can be a valuable tool for determining the optimal method of cleanup at least cost. Current models are designed for specific technologies and are not sufficiently general to be used for comparison of different technologies. The algorithm to be developed in the second year will be capable of comparing the cost and performance of many different surface D&D techniques.

3.0 ACCOMPLISHMENTS

Work during the last two quarters was focused on two areas: on-line sensors for real-time control of laser-based surface decontamination and surface D&D operations systems analysis. The on-line sensors work for this contract was almost entirely completed during the first two quarters; below is a summary of the activities over this period. The surface decontamination systems analysis work was done over the second two quarters and completes the proposed activities in this area for this contract.

3.1 On-Line Sensor Priority Items

We (F2 and the EERC) have identified two focus areas for the necessary sensors: spectroscopic analysis of the laser-induced plasma (LIP) and radiation detection. The spectroscopic analysis of the LIP will be used to optimize the surface cleaning and to provide information for waste assay. Radiation detection will be used to optimize surface cleaning, aid in detection of radionuclide migration from the coating to the underlying surface, and provide information for waste assay.

3.1.1 Spectroscopic Analysis of the Laser-Induced Plasma

Analysis of the LIP will be done using standard off-the-shelf hardware commonly applied in optical emission spectroscopy. The development of measurement techniques centered around the selected hardware is being done by Dr. Dave Cremers of Los Alamos National Laboratory (LANL). Preliminary work done by Dr. Cremers and his group was funded internally by LANL. Subsequent work to be done as a collaborative effort between F2 Associates and LANL is being proposed to outside funding sources. Additionally, Physical Sciences Incorporated (PSI) has obtained a Phase I SBIR grant to work on developing a less costly version of the hardware being used by F2 and LANL for their development work.

3.1.2 Radiation Detectors

Applicable radiation detectors have been researched, and some candidates for testing have been identified. Gas proportional counters (1) and phoswich detectors offer good possibilities for application to on-line radiation detection since they are sensitive to alpha, beta, and gamma radiation and, additionally, are small, rugged and possess adequate response times. Construction and testing of detectors with the F2 system as a test bed are being proposed to the DOE as a separate project.

For the separate proposal, the EERC will construct and test phoswich detectors. Phoswich detectors are a combination of two scintillation media (crystals) used to detect nuclear decay products. The two crystals are selected to have dissimilar decay characteristics for the light emission induced by a radiation quantum. The difference in light decay allows discrimination between an emission produced in either the primary crystal (scintillator) or the guard crystal. For application to on-line radiation detection for surface decontamination operations, we have selected $\text{CaF}_2(\text{Eu})$ as the primary crystal which detects alphas and betas and $\text{NaI}(\text{Ti})$ as the guard crystal which detects gammas. This produces a detector which is sensitive to alpha, beta, and gamma radiation. Since the application calls for differentiating between alpha, beta, or gamma radiation, detector signals may be processed using pulse-shape discrimination (PSD) (2-4). PSD will allow determination of which crystal (primary or guard) produced the emission, thereby classifying the radiation quantum as alpha, beta, or gamma.

The phoswich detector and support electronics to be tested in this project will be built by the EERC, and preliminary testing will take place at the EERC. An integrated phoswich detector and photomultiplier tube (PMT) assembly will be constructed from commercially available materials. The scintillation detector (phoswich and PMT) will be connected to a PMT high-voltage power supply and low-level preamplifier for the PMT signals. The complete scintillation detector assembly will be connected to a high-speed waveform digitizer for analysis of the signals produced by detection of radiation quanta. The waveform digitizer will be interfaced to a personal computer for collection, storage, and analysis of detector signals. Figure 1 illustrates the detector and test setup.

Figure 1. Phoswich scintillation detector and data acquisition system.

3.2 Surface Decontamination Systems Analysis

3.2.1 Literature Search

A survey of available literature on cost, waste disposal, and occupational safety and health issues associated with surface decontamination was done. A listing of the literature database is given in Appendix A.

3.2.2 Systems Analysis Development

Careful analysis of the issues relating to the surface decontamination process requires a view of the entire operation, not just the removal of contamination. In other words, one has to think of several process elements in addition to the surface cleaning: precleaning characterization, postcleaning characterization, and a repeated cycle of preclean survey, clean, postclean survey until the desired decontamination level is reached. After this is done, the operation calls for waste assay, packaging, storage, transportation, monitoring, and/or treatment. Figure 2 illustrates a macroscopic view of the process (5).

Figure 2. Simplified flowchart of the surface decontamination process.

A more detailed treatment of the issues, taking into consideration factors which vary over the range of techniques which may be applied to surface decontamination (such as mechanical scabbling, solid abrasive blasting, air blasting, dry ice pellet blasting, water blasting, liquid nitrogen cryofracture, wet chemical stripping, dry strippable coatings or laser ablation), leads to a

longer list of details to be considered before a technique is selected. Explicitly, the list should address the following aspects of surface decontamination:

- Project scale
- Concrete or metal surfaces
- Contamination by radiological and other hazardous materials
- Stage of surface decontamination technology development (commercial, R&D, etc.)
- Equipment operating costs
- Collection of waste generated by surface decontamination
- Occupational health and safety requirements
- Utilities required for operations
- Real-time control of surface decontamination
- Recycling or reuse of decontaminated substrates
- Waste
 - Characterization
 - Transport
 - Treatment
 - D&D equipment decontamination
 - Classification
 - Storage
 - Disposal

Putting the detailed systems analysis into an algorithmic framework results in a flow diagram which points out criteria to be considered during selection of a surface decontamination technique. Figure 3 (pages 7-8) depicts a flowchart which facilitates an analysis of a given technique.

4.0 FUTURE WORK

An outline amplifying details to consider for each box in the flowchart above is under development and will be completed. Work during the proposed second year of this contract will continue to refine the surface decontamination systems analysis and develop a software version of the analysis which may be applied when selection of a surface technique is desired for a given situation.

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Figure 3. Surface decontamination systems analysis.

Figure 3. Surface decontamination systems analysis (continued).

APPENDIX A
LITERATURE DATABASE

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U.S. DEPARTMENT OF ENERGY
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1. Program/Project Identification No. DE-FC21-94MC31388		2. Program/Project Title EM Task 12 - Laser Cleaning of Contaminated Painted Surfaces			3. Reporting Period 7/1/98 through 9/30/98																																																																																																												
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11. Major Milestone Status	Units Planned	
	Units Complete	
Subtask 12.1 In Situ Analytical Instrumentation for Characterization of Hazardous Materials	P	
	C	
Subtask 12.2 Economic Analysis of Laser Cleanup Operations	P	
	C	
	P	
	C	
	P	
	C	
	P	
	C	
	P	
	C	
	P	
	C	
	P	
	C	

12. Remarks

13. Signature of Recipient and Date

31 OCT 96

14. Signature of DOE Reviewing Representative and Date

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Milestone ID. No.	Description	Planned Completion Date	Actual Completion Date	Comments	
12.1	In Situ Analytical Instrumentation for Characterization of Hazardous Materials	9/96			
A	Develop Detailed Measurement Objectives	4/96	4/96	100%	
B	Compile Listing and Critical Review of Applicable Analytical Techniques	6/96	8/96	100%	
12.2	Economical Analysis of Laser Cleanup Operations	9/96			
A	Complete Review of Existing Cost Assessment Models	8/96		80%	