

**LASER SURFACE CLEANING**

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### Laser Surface Cleaning

#### CONTRACT INFORMATION

Contract Number DE-AR21-94MC-30359

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Period of Performance: June 13, 1994 - March 13, 1996

#### Schedule and Milestones:

##### FY 94 Program Schedule

	O	N	D	J	F	M	A	M	J	J	A	S
<u>Phase I</u>												
Site Visits												
Test Plan												
Testing												
Design												
Topical Report												

##### FY 95 Program Schedule

	O	N	D	J	F	M	A	M	J	J	A	S
<u>Phase I</u>												
Site Visits												
Test Plan												
Testing												
Design												
Topical Report												

Phase II  
 Test Plan  
 Fabrication  
 Testing

##### FY 96 Program Schedule

	O	N	D	J	F	M	A	M	J	J	A	S
<u>Phase II</u>												
Test Plan												
Fabrication												
Testing												

## OBJECTIVES

The objective of this work is a laboratory demonstration that red-lead primer and two-part epoxy paints can be stripped from concrete and metal surfaces using surface cleaning systems based on pulsed-repetition CO<sub>2</sub> lasers. The three goals are:

- (1) Demonstrate coatings removal, including surface pore cleaning.
- (2) Demonstrate that there is negligible release of ablated contaminants to the environment.
- (3) Demonstrate that the process will generate negligible amounts of additional waste compared to competing technologies.

## BACKGROUND INFORMATION

There are various methods for cleaning coatings such as paint, oil, and grease from surfaces. These include:

- Surface blasting with 'pellets,' such as sand, shot, plastic pellets, walnut-shell shards, etc. In these processes, the blasting material becomes contaminated, adding to the waste mass. These processes do not clean out surface pores.
- Scabbling with surface beaters. This process takes off the surface, and can create significant airborne products that must be captured unless a very high performance vacuum / filtration system is used.
- Cryogenic techniques such as use of CO<sub>2</sub> (solid) ice pellets or LN<sub>2</sub> freeze cracking. These processes are expensive and require operators to wear 'space' suits, but do not add to the waste volume. These processes do not clean out surface pores.
- Chemical strippers, which are messy, result in mixed hazardous waste, and add to the volume of waste. These processes do not clean out surface pores.

- Water blasting, which results in contaminated liquid and more waste volume. These processes do not clean out surface pores.
- Incineration, which is not applicable for in-situ cleaning of structures nor large parts. These processes may not clean out surface pores.
- Radiation, such as the microwave technique developed at ORNL (but not useful for metal substrates) that takes off a surface layer, and lasers.

According to RMI and Fernald, processes such as scabbling, pellet blasting, etc, can damage or 'work-harden' surfaces, greatly reducing salvage value. This paper is focused on lasers:

The quantum theory of radiation was developed in 1917 by Einstein. Working lasers have been around since 1960. There are CW (continuous wave or "on") lasers and pulsed-repetition lasers. Both have been used for coatings removal. However, pulsed-repetition lasers are preferred for removing contaminated coatings. This is because, with proper laser parameters, material can be ablated faster than a thermal wave can propagate into the substrate (no substrate thermal damage), there is little chance of beam defocusing from the cloud of ablated material, and the time between pulses is used to assure clearing of the area and capture of contaminated ablated material before the next pulse.

Although several powerful pulsed lasers were developed for the SDI and other programs, it is only recently that powerful pulsed high-repetition-rate lasers have been developed with the right parameters for efficient coatings removal: >100 Hz, several Joules of energy per pulse, short pulse widths measured in microseconds, power densities of megawatts per square centimeter on target, etc. Such systems have demonstrated to clean coatings from concrete, metals, laminates, plastics, etc., with no damage to the substrate and no added contaminate mass. Data indicates that the laser ablation process actually results in coatings-to-ablated-material volume reduction.

Because of these laser advancements, F2 proposed to the DOE that a system based on such lasers be investigated for contaminated coatings removal. The proposal resulted in this contract.

The laser process will not address contaminants that have migrated into the substrate. Nevertheless, laser surface (and surface pore) cleaning may render many materials releasable or recyclable after post-cleaning characterization, especially most metals. If post-cleaning characterization of surfaces such as concrete indicate that radionuclides have migrated in the substrate, then some follow-on cleaning like scabbling may be needed.

### PROJECT DESCRIPTION

The basic system shown in Figure 1 consists of four (4) elements: 1) Remotely located high-energy pulsed-repetition laser, 2) articulating high-power optics between the laser and ablated-material gas / vapor / particulate capture-suction nozzle, 3a) nozzle, 3b) nozzle integrated into a surface scanner with other instrumentation and

controls (and the possible addition of robotics), and 4) long-run filtration system to capture the contaminated products from laser ablation. All four are needed for contaminated or other hazardous coatings removal.

Tetra Corporation and its subcontractors are supplying the laser, optics, and nozzle. F2 is the systems integrator and is responsible for the scanners, filtration system, robotics, operations, and ES&H issues.

In Phase I, preliminary instrumented tests were done with an existing lower-power, pulsed-repetition CO<sub>2</sub> laser to address Goal (1) above, to obtain data for Goals (2) and (3), and to obtain data on the products of laser ablation for DOE-specified paints (red-lead primer and two-part epoxy). The filtration-system design depends on the ablation products. The ablation products depend on the coating (at most DOE sites there were layers of different coatings applied over the years), on local humidity, and on certain laser parameters such as pulse length, power density on target, etc.

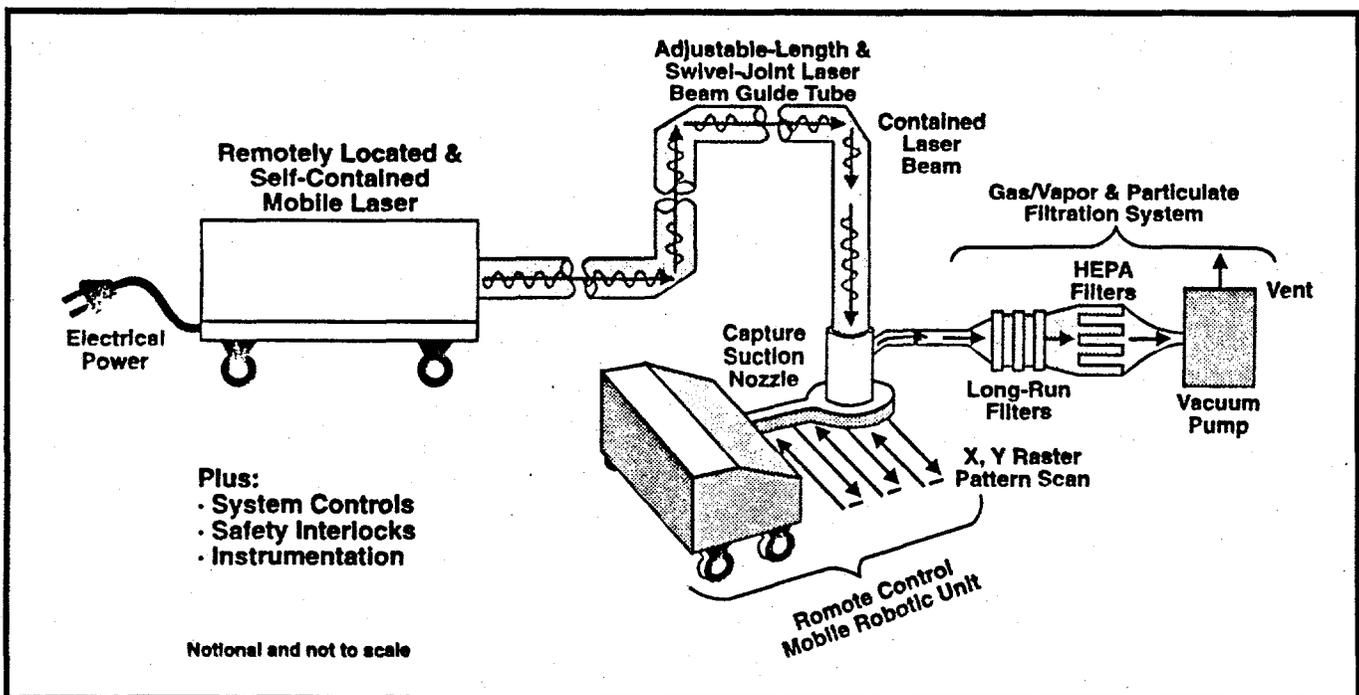


Figure 1. Laser Coating Removal System for Floors

Phase I also involved site visits to RMI and Fernald to assess the cleaning issues for buildings and parts. In addition, Phase I included detailed designs of a more powerful system for industrial cleaning rates, including laser, articulating optics, ablated-material capture suction nozzle attached to a horizontal raster scanner for floor cleaning, and filtration system. Some concept development is also being done for using robots, and for parts cleaning.

In Phase II a transportable 6 kW system will be built and tested, with a horizontal surface scanner for cleaning paint from floors. The laboratory tests will again be instrumented. Some concept development will continue for using robots, and for parts cleaning.

## PHASE I RESULTS

Please note that this paper was submitted October 31, 1994, near the end of Phase I when data from that phase was still being taken and analyzed.

### Laboratory Tests

The Phase I test set-up is shown in Figure 2. Tests were done by Tetra Corporation. Phase I laboratory tests are just being completed and are not yet fully analyzed. Two types of tests were done: single pulse and strip repetition-rate. The following data is preliminary, and only from the first tests.

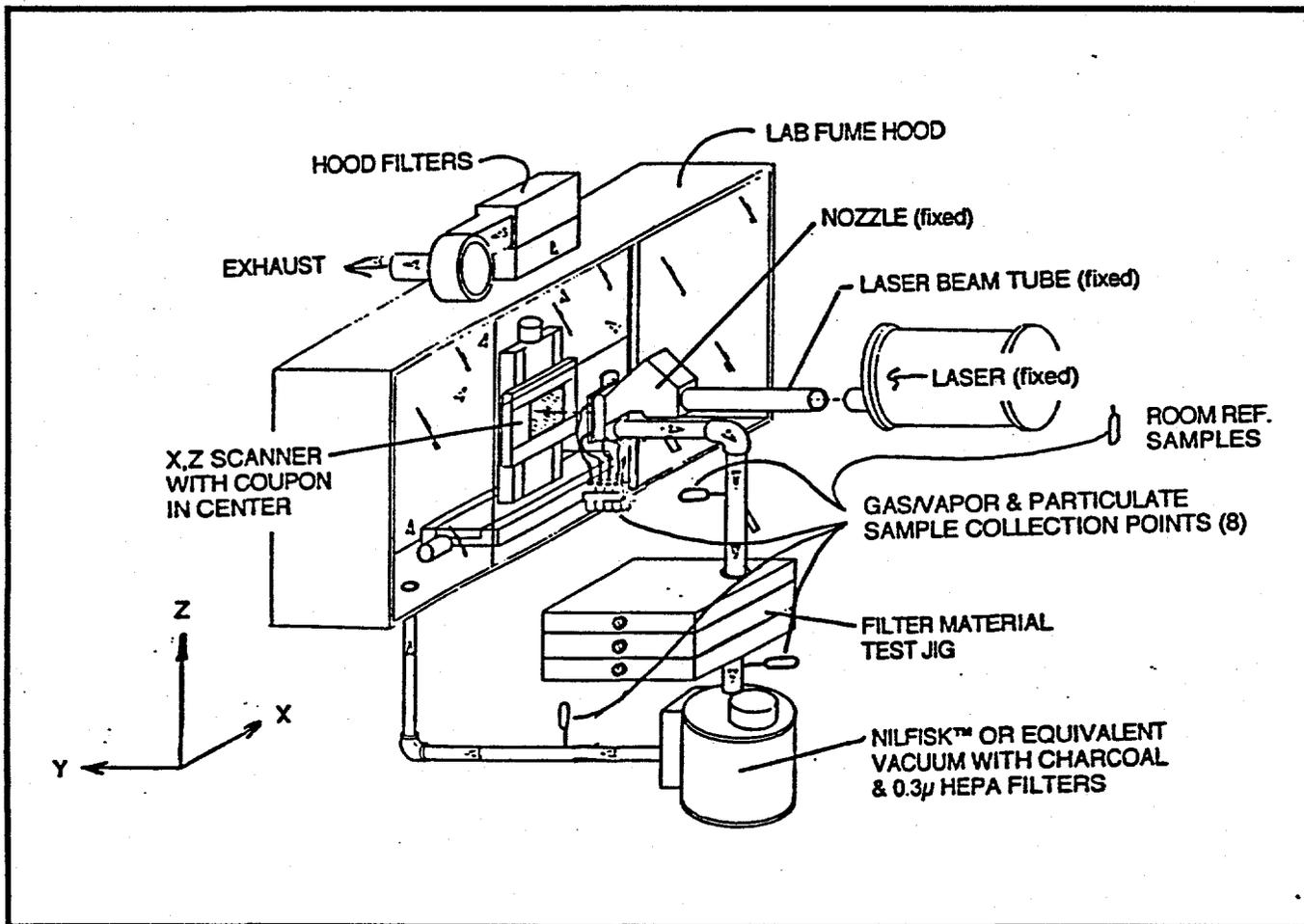


Figure 2. Phase I Laboratory Test Set-Up

**Single-Pulse Tests.** Single-pulse data was taken for four-mil red-lead primer and ten-mil two-part epoxy on metal. Data for removal energies ( $\text{cm}^3 / \text{J}$ ) for red-lead primer and two-part epoxy was found to be  $\sim 6.5\text{E-}5 \text{ cm}^3 / \text{J}$ , about the same for 'fresh' red-lead primer and two-part epoxy. Correlation with earlier Tetra Corporation data for removing red-lead primer with two overcoats of aluminized paint, and adjusting for age of paint, type of coating, and laser pulse width, still yields projections that the Phase II 6 kW system will be able to remove nearly 100 square feet per hour of  $\sim 20$ -mil thick coatings.

**Strip Repetition-Rate Tests: Cleaning Surfaces and Surface Pores.** Square metal and concrete coupons were fabricated, 7.5 cm x 7.5 cm. Some of each were coated with red-lead primer, and some were painted with two-part epoxy. Microphotographs were taken before painting, after painting, and after stripping, for comparative analysis. They indicate no paint is left on the surface or in the surface pores. The scan rate was such that the photos show what appear to be the onset of a few widely spaced silica-glass micro-spheres on the concrete, indicating the scan rate used resulted in threshold surface heating, but nowhere near enough for glassification to mask alpha emitters in radioactive contaminated coatings.

In addition, other concrete and aluminum coupons were made. The aluminum coupons were coated with four thick coats (each coat was a different color) of urethane paint. The paint was removed one layer at a time to demonstrate the control of the system.

One surface of the concrete coupons was painted with two thin coats (different colors) of Krylon spray paint. The coats were then removed one layer at a time. A different surface of the concrete coupons was painted with two-part epoxy, which was also laser-stripped to bare concrete. Inspection shows negligible material even left in the pores, with no damage to the substrates, and no fused silica in the concrete that would mask alpha emitters. Earlier tests with latex paint, and earlier Tetra tests with red-lead primer plus two coats of aluminized paint, have also been done. A  $\text{CO}_2$  laser with the right parameters doesn't seem to care what the coating

material is (even highly reflective aluminum paint) as long as the scan speed is optimized along with the other laser-beam parameters.

**Strip Repetition-Rate Tests: Gas / Vapor Data.** As shown in Figure 3, eight gas / vapor samplers were used: Four around the base of the nozzle (each edge), one before the pre-filters, one after the pre-filters, one after the final HEPA filter, and a room reference. Gas / vapor samples were collected in evacuated 150 cc bottles during strip tests. Analysis of the contents by Hauser Labs shows no detectable  $\text{CO}$ ,  $\text{CO}_2$ , other HCs, or  $\text{H}_2\text{O}$  vapor. Calculations indicate that the laser repetition rate (and thus material generation rate) was too low such that the high dilution factors (ambient air mixed with gas products from ablation) resulted in traces below the level of detection by the GC/TCD analysis. This will not be a problem in Phase II with the 6 kW laser.

**Strip Repetition-Rate Tests: Particulate Data.** Particulate samplers were co-located with the eight gas / vapor samplers. Data from analyzing the filter paper in the industrial samplers for the first tests showed traces of particulates escaping out from under the edge of the nozzle. Some deposits were also left on the surface. This indicated that the vacuum flow rates must be increased and the stand-off distance decreased. They will be in next tests. Data from the sniffer in the filtration system (#5 in Figure 3) before the prefilter showed over 700 times more particulates in the flowstream before the pre-filters than were detected under the edge of the nozzle (Numbers 1 through 4 in Figure 3).

**Strip Repetition-Rate Tests: Filtering System Design Data.** One purpose of these tests is to obtain data for filtration system designs for Phase-II. A filter test jig was fabricated and located in the flow stream between the nozzle and Nilfisk™ vacuum (see Figures 2 and 3). For the first tests, this jig was fitted with 170  $\mu$  and 14  $\mu$  filters and a charcoal filter. The Nilfisk™ has a final 0.3  $\mu$  HEPA filter. Preliminary data from the filter papers showed particulates mostly in the 1 to 5  $\mu$  range, and substantial clumping on the coarse filters. Other tests are underway with other filter arrangements. It is clear that the filter surface area also needs to be increased to reduce flow impedance and thus enable higher flow rates.

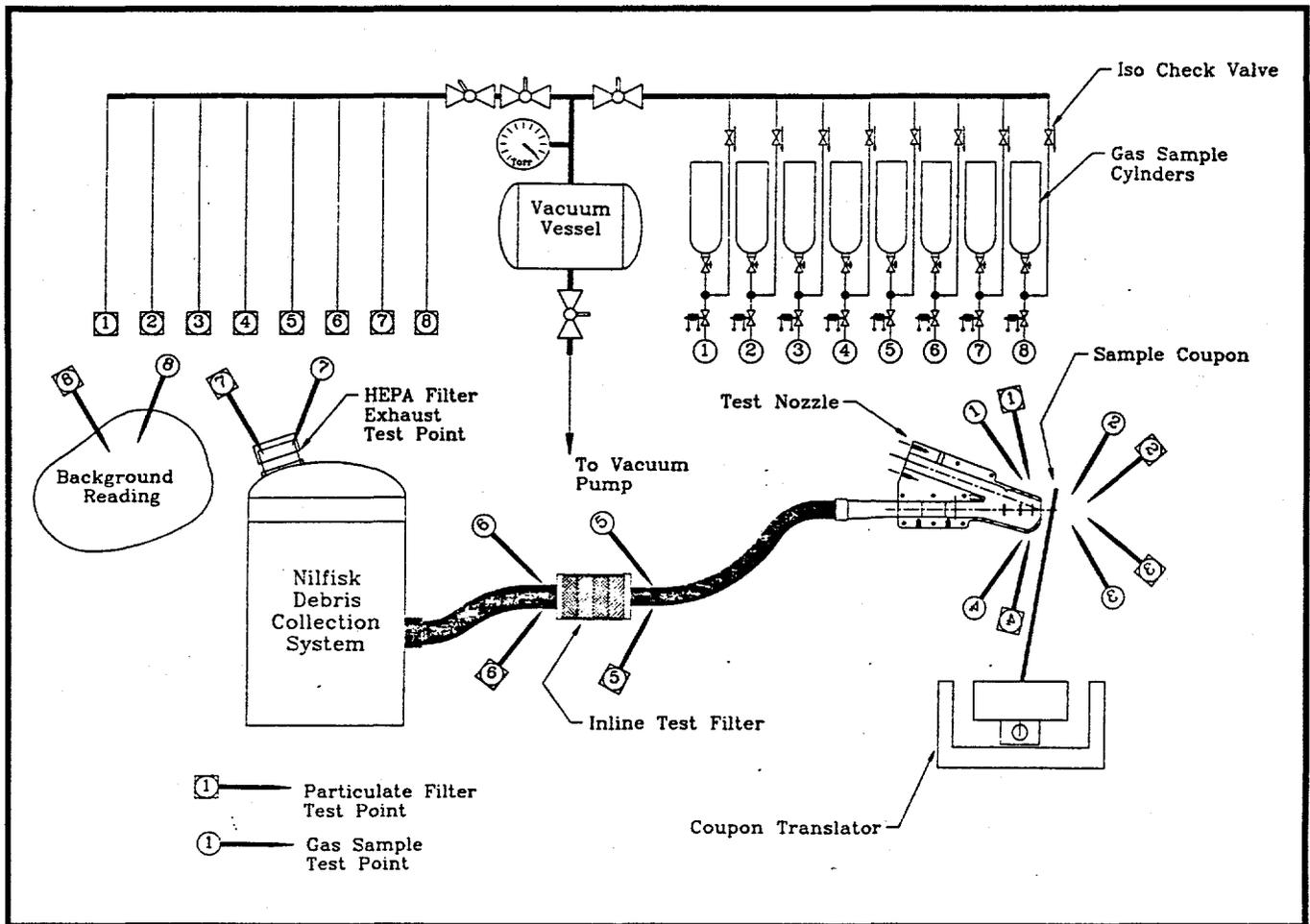


Figure 3. Phase I Gas / Vapor and Particulate Sample Points

### Site Visits

Information from site visits to RMI and Fernald, and to Carnegie Mellon University, RedZone, and Pentek on robotics, are summarized in the F2 trip report sent to METC. The people at RMI and Fernald were extremely helpful and cooperative, as were the robotics people.

### Design Work

Tetra Corporation has slightly modified their nozzle design based on Phase I test results.

F2 has designed the raster scanner, including options for stand-off control such as the diode-laser system from KAMAN, and an on-line scan-

speed control using an optical comparator subsystem such as that from BDM. Without bias, Mr. Vijay Kothari of METC put F2 in contact with several robotics companies. F2 winnowed down the list. The scanner system was designed such that the MOOSE and ROSIE robots can easily be integrated into it later. This approach is consistent with the DOE's expressed interest in faster-track 'buy-and-tie' demonstrations. The concept is to do concurrent engineering now to minimize re-design later.

Phase I test results are also being analyzed to determine the optimum stand-off distance of the nozzle for Phase II. This also feeds into filtration-system design calculations (e.g., dilution ratios and pump rates). Without bias, Mr. Bob Bedick of METC and Mr. Jerry Hyde of DOE HQ

put F2 in contact with several filtration firms. F2 winnowed down the list. F2 is further analyzing the data from the gas / vapor and particulate samplers, and is collaborating with filtration firms such as Pall, Pentek, and 3M to optimize the filtration-system designs for on-line re-cleanable filters. Pentek has also developed a process for changing out full containers of particulates from an on-line filtration system with no release. Los Alamos National Laboratory also provided F2 some theoretical data on laser ablation, under a small-business technical assistance grant.

F2 is also working with Pentek regarding modifying their MOOSE robot for floor cleaning, and with Carnegie Mellon University and Red-Zone Robotics on designs for using their ROSIE robot for wall cleaning.

Design work is also focused on minimum contact with surfaces in contaminated areas. System parts that might become contaminated are designed to be easy-to-clean or designed to be inexpensive and disposable.

Operations and ES&H issues are included in the design work. The goal is to maximize engineered ES&H controls rather than relying on complex operator procedures. The target is for Level D worker dress, plus laser protection.

## **FUTURE WORK**

### **Phase II**

As discussed above, an instrumented 6 kW system will be built and laboratory tested. This will be transportable, but not mobile. It will not incorporate much robotics, although some robotics might be considered as a later add-on to Phase II.

### **Beyond Phase II**

Pending successful results from Phase II, demonstrations at RMI and Fernald are being considered. Slightly upgraded Phase II equipment would be used for these demonstrations. Such upgrades are being considered in the Phase II

designs to avoid much re-design later. Other possible additions include using the Pentek MOOSE robot and the ROSIE robot (which is being developed by Carnegie Mellon University and RedZone Robotics with DOE funding).

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Freiwald, J. G., and Freiwald, D. A. August 1994. Laser Ablation of Contaminants from Concrete and Metal Surfaces, Phase I DOE METC Kick-Off Meeting. Unpublished presentation charts.