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Laser-Based Coatings Removal

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3.3 Laser-Based Coatings Removal

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Needs

Over the years as building and equipment surfaces became contaminated with low levels of uranium or plutonium dust, coats of paint were applied to stabilize the contaminants in place. Most of the earlier paint used was lead-based paint. More recently, various non-lead-based paints, such as two-part epoxy, are used. For D&D (decontamination and decommissioning), it is desirable to remove the paints or other coatings rather than having to tear down and dispose of the entire building.

Problems with Other Coatings Removal Technologies

Table 1 gives a summary matrix that compares the various technologies for coatings removal. There are seven important factors to consider in this comparison.

- Waste volume: Radioactive waste storage accounts for ~33% of the cost of D&D. The DOE uses an average number of $300 per cubic foot for storage, disposal, and monitoring. Thus any reduction in waste volume results in a big cost savings. Sand blasting uses about a hundred pounds of sand to remove one pound of coating, and the sand becomes contaminated waste. Since using liquids generally results in radioactive-contaminated liquid wastes, and using chemicals generally results in mixed hazardous waste, it is highly preferred to avoid both liquids and chemicals. Dry ice pellet blasting does not add to the volume. Far-infrared laser light reduces the volume of coatings that contain hydrocarbons, such as lead-based and epoxy paints. We project waste volume reductions of 75% of the original paint volume.
- Cleaning out the surface pores: Only laser light does this effectively.
- Thermal damage to the substrate: Devices like CW (continuous wave) lasers can cause thermal damage,. In fact, CW lasers are available commercially for cutting metals. However, a pulsed-repetition laser can be designed to remove coatings faster than a thermal wave can propagate into the substrate, resulting in no thermal damage. This can increase the resale value of cleaned metal by a factor of nine from ~3¢ per pound for smelter feedstock to ~27¢ per pound for resale and reuse.
- Mechanical damage to the substrate: The chart shows five technologies that cause no mechanical damage. Again, this can increase the resale value of cleaned metal.
- Hazardous chemicals: In closed areas, the operators must wear breathing apparatus when using dry ice pellets or liquefied nitrogen. Otherwise, these technologies do not result in health hazards since the carbon dioxide or nitrogen evaporate into the air. Chemical strippers and strippable coatings can generate mixed hazardous wastes.
- Liquids: Both water blasting and liquid chemical strippers involve liquids that generally require wet-chemistry processing of residuals, such as the sludge from sodium-bicarbonate / air blasting.

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Table 1
Comparison of Contaminated Coatings Removal Technologies

	Waste Volume			Cleans out surface pores	No thermal damage	No mechanical damage	No hazardous chemicals	No liquids	Level-D dress
	Increase	Same	Decrease						
Mechanical scabbling		√			√		√	√	
Solid abrasives or air blasting	√				√		√	√	
Dry ice pellet blasting		√			?	√	√	√	CO_2 atmos
Water blasting	√				√				
Liquid nitrogen cryofracture		√			?	√	√	√	N_2 atmos
Wet chemical strippers	√				√	√			?
Dry strippable coatings	√				√	√		√	?
CW lasers		√	√	√			√	√	√
Pulsed-repetition lasers			√	√	√	√	√	√	√

- Level of worker dress: Unless operations are performed robotically, only pulse-repetition laser systems, with the prompt capture of ablated material, enable dress at Level D (as shown in Figure 1). The lowest possible level of dress will keep operations costs down.

Solution: Pulse-Repetiton Laser Systems

As can be seen in Table 1, pulse-repetiton lasers satisfy all of the desirable criteria. Although this technology does not remove in-depth contamination, such as chemicals that have migrated into concrete, the concept is to first remove the paint and surface contamination, and then determine if any scabbling is even needed.

Technology

General

To avoid substrate thermal damage, the time that each pulse lasts must be very short. With the appropriate pulse length and with laser power densities on target approaching a megawatt per square centimeter, coating material can be ablated faster than heat can propagate into the substrate. For any coatings that have hydrocarbons in them, a carbon-dioxide (CO_2) laser works best, since the far infrared wavelength of the laser light couples very well into hydrocarbon bonds. This "tuned" chemical-bond breaking is more sophisticated than simply putting heat energy on target. Data indicates that binders such as the linseed oil in lead-based paints are reduced to water vapor and carbon

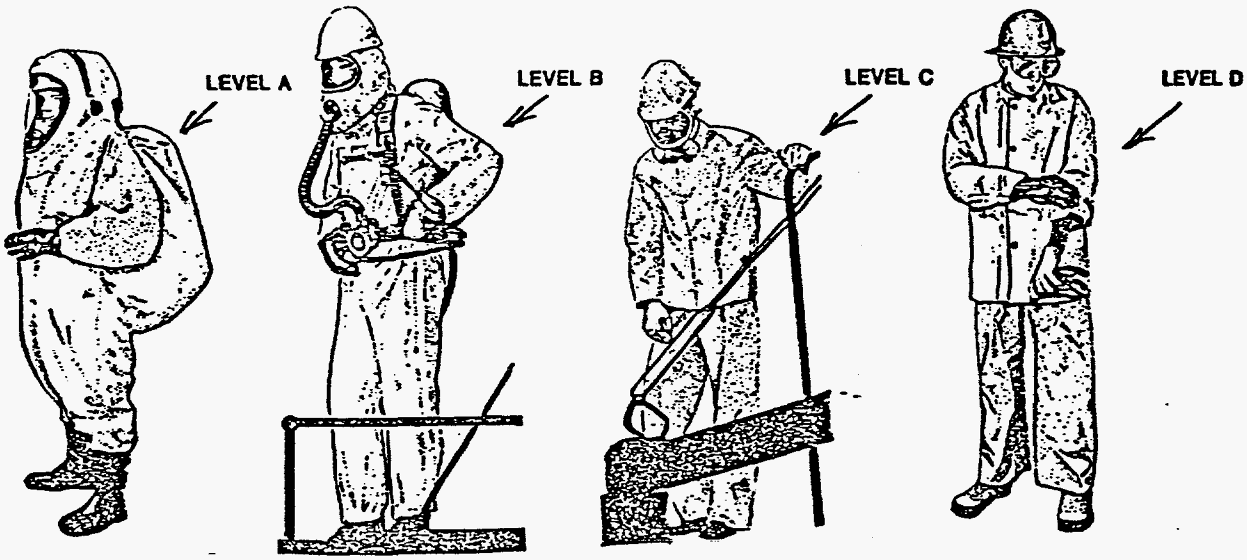
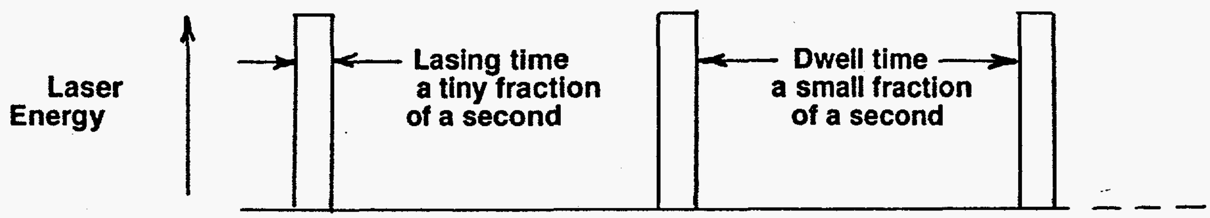
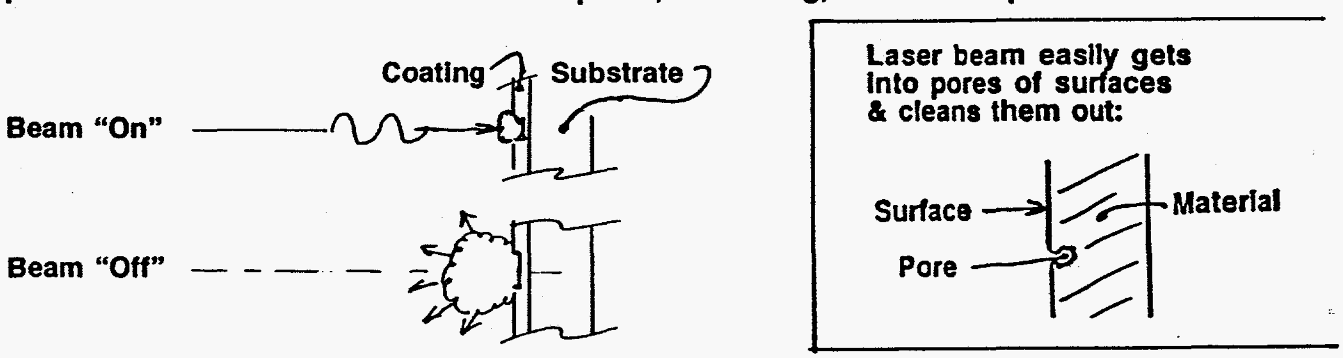


Figure 1
System Design Goals Targeted at Level D Protection During Operation
(Equipment Control Buttons, Switches, and Levers are Designed For Worst Case - Level A).



Lasing time pulse width must be 'just right'; if too short then little stripping, & if too long then excessive substrate heating.

Dwell time must be 'just right'; if too short then there is interference between the next pulse and the debris could from the last pulse; if too long, then a slow process.



USE SPECIAL VACUUM NOZZLE TO SUCK AWAY ABLATED MATERIAL / DEBRIS CLOUD

Figure 2
Coatings Removal With Pulsed Lasers

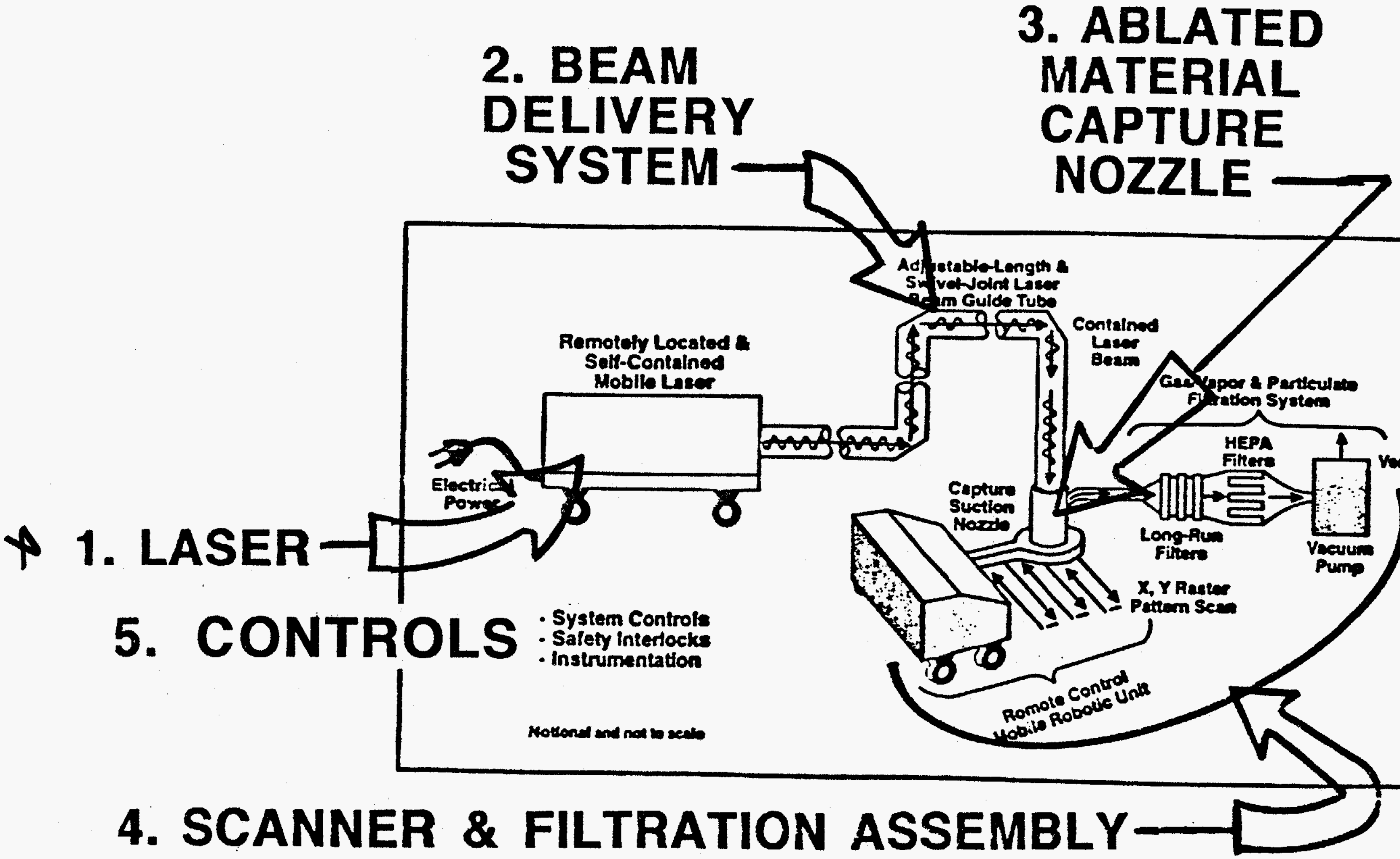


Figure 3
The Five Basic Elements of a Laser-Based Coatings Removal System

dioxide gas when the right power densities and pulse widths are used. For other coatings such as cadmium on steel, a shorter wavelength laser may work more efficiently in terms of the physics, but may not be as cost-effective as other lasers such as efficient CO2-gas lasers.

In a pulse-repetition system, the time between pulses must be long enough to clear (vacuum away) the cloud of ablated material (see Figure 2). Otherwise, the cloud may absorb and / or defocus the next pulse. However, the pulse-repetition rate must also be fast enough, and the spot-size on target must be big enough, to yield reasonable cleaning rates.

Floor and Wall Cleaning

As shown in Figure 3, there are five basic elements to a laser-based cleaning system.

1. Remote laser. This could be located in adjacent room or outside. Nd:YAG-crystal pulse-repetition lasers are commercially available, but not yet with the power for faster cleaning of large surfaces. Also, the near infrared wavelength does not couple into hydrocarbon binders quite as well as that of CO_2 lasers. For our system, we have chosen a high-power pulse-repetition CO_2 laser (see Figure 4). We have found only two suppliers of the such a laser in the world, both in Albuquerque, NM. Tetra Corporation is our supplier. Their laser is transportable, EMI shielded, and weather-proof. It needs only electrical power since it has its own chillers with air heat exchangers.

2. Laser-beam delivery system (BDS). This transports the beam from the laser to a cleaning head. Good fiber optics do not exist

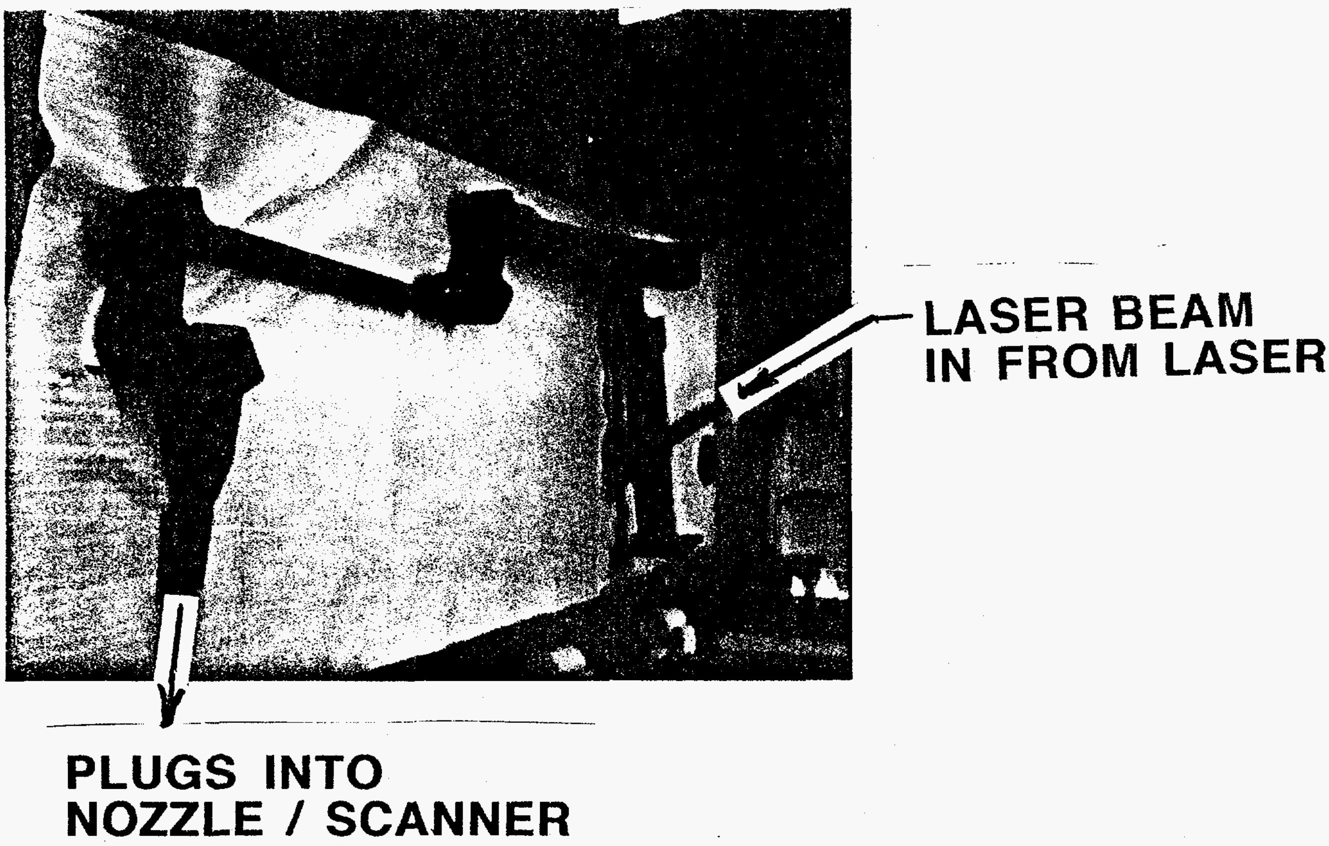


Figure 4
The Laser Beam Delivery System

for the far infrared where CO_2 lasers emit, so CO_2-laser beam delivery is done with rigid beam tubes fitted with corner mirrors in swivel joints, to deliver the beam through "articulating optics" to a cleaning head (see Figure 5). Work at Rutgers University on flexible hollow tubes coated on the inside with artificial-sapphire can also be used for flexible beam delivery from CO_2 lasers up to 2 kW CW, but not yet at the power levels of up to 6 kW average (higher peaks) that we require.

3. A cleaning head. This has optics to deliver the beam on target and promptly capture all ablated particulates, gases and vapors. The cleaning head will be located on a remotely operated scanner attached to the side of a Pentek VAC-PAC (see Figure 6). The scanner will also automatically maintain proper stand-off distance between the nozzle base and surface being cleaned. This will allow air in for dilution and cooling of ablated material, but keep any ablated material from escaping. For less delicate substrates, the 2

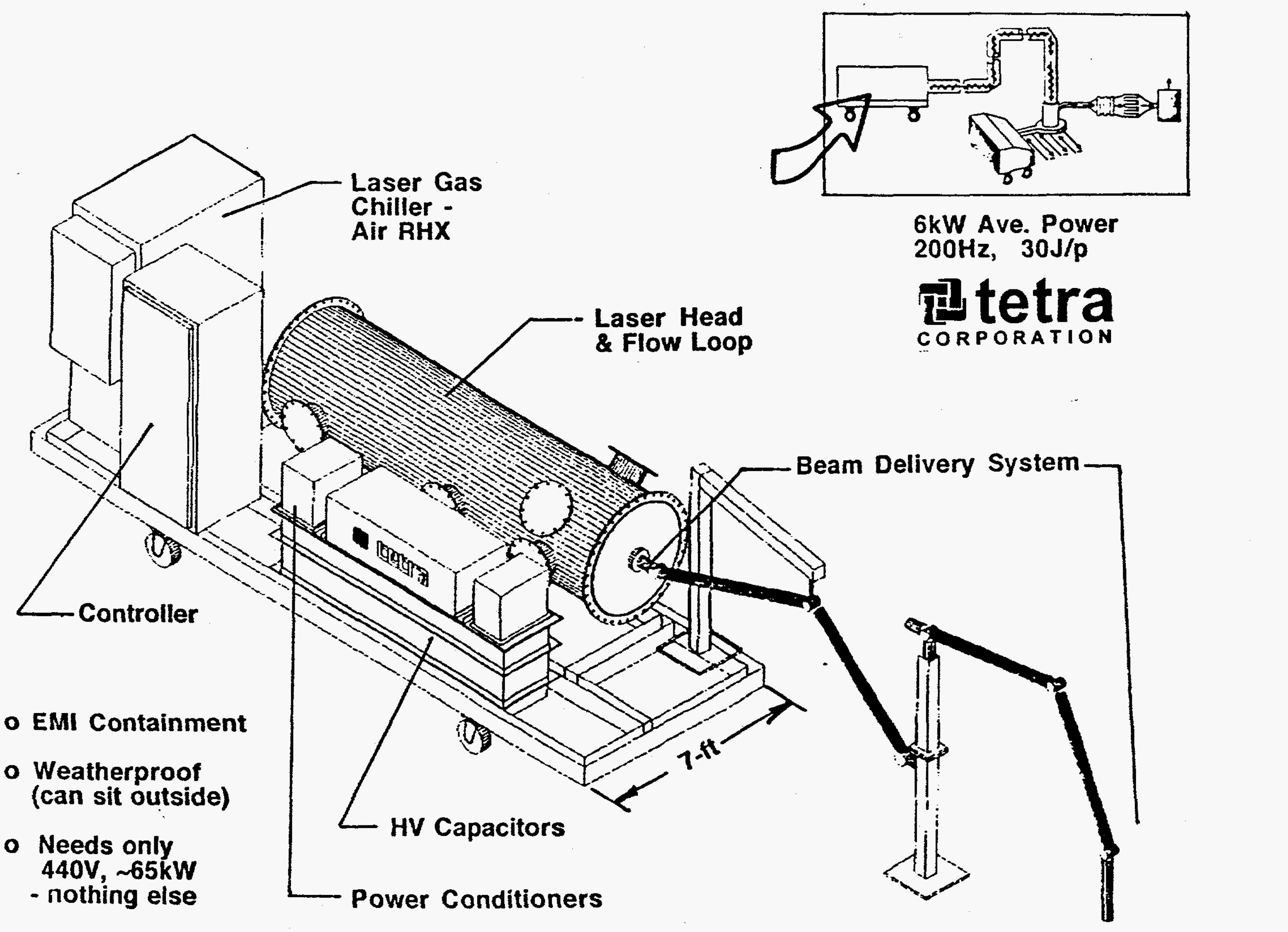


Figure 5
Transportable, Pulsed-Repetition CO_2 Laser

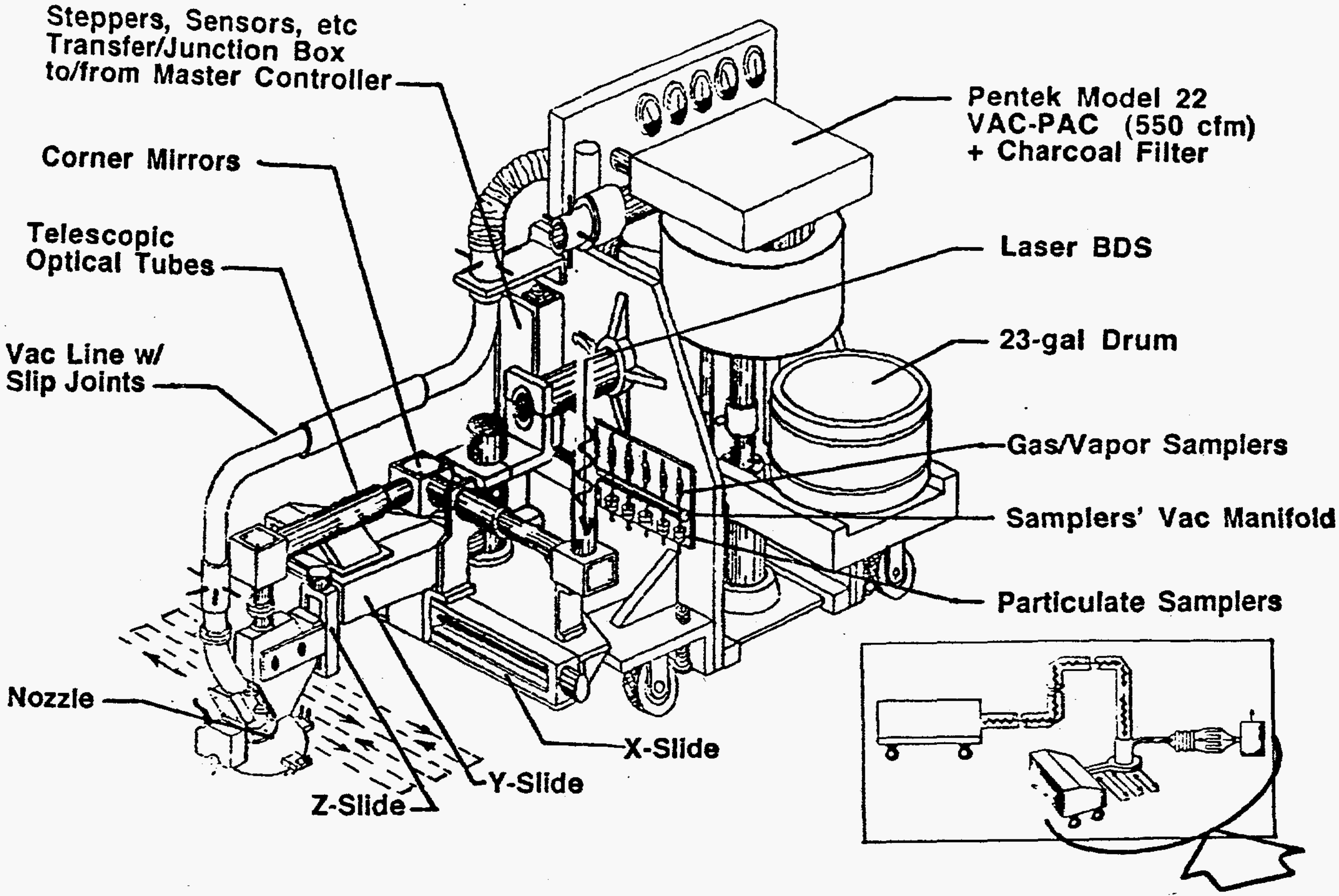


Figure 6
Nozzle, Scanner, and Filtration Assembly

centimeter by 2 centimeter square laser-pulse spots can have a high percentage of overlap during a lateral scan, ~95%. The scanner is designed to eventually be mounted on a MOOSE robot for floor cleaning, and a ROSIE robot for wall cleaning.

4. <u>A filtration system</u> with primary and HEPA particulate filters, and charcoal filters for gases and vapors. The on-line recleanable particulate filters are recleaned with periodic blow-back pulses of air. The system deposits the particulates directly into a 23 or 55 gallon drum for final disposal, thus requiring no further container transfers. These drums can be sealed in-line, with no worker exposure. We are using the Pentek VAC-PAC. With such a filtration system there are minimal residuals requiring any chemical processing.

5. <u>Sensors, safety interlocks, and controls</u>, all interconnected via a 486 computer (see Figure 7). The master controller records data from various places in the system on temperatures, pressures, and flow rates. The data is recorded and is also used in logic trees. For example, a growing pressure differential across a filter would indicate onset of clogging, or a drop to zero would

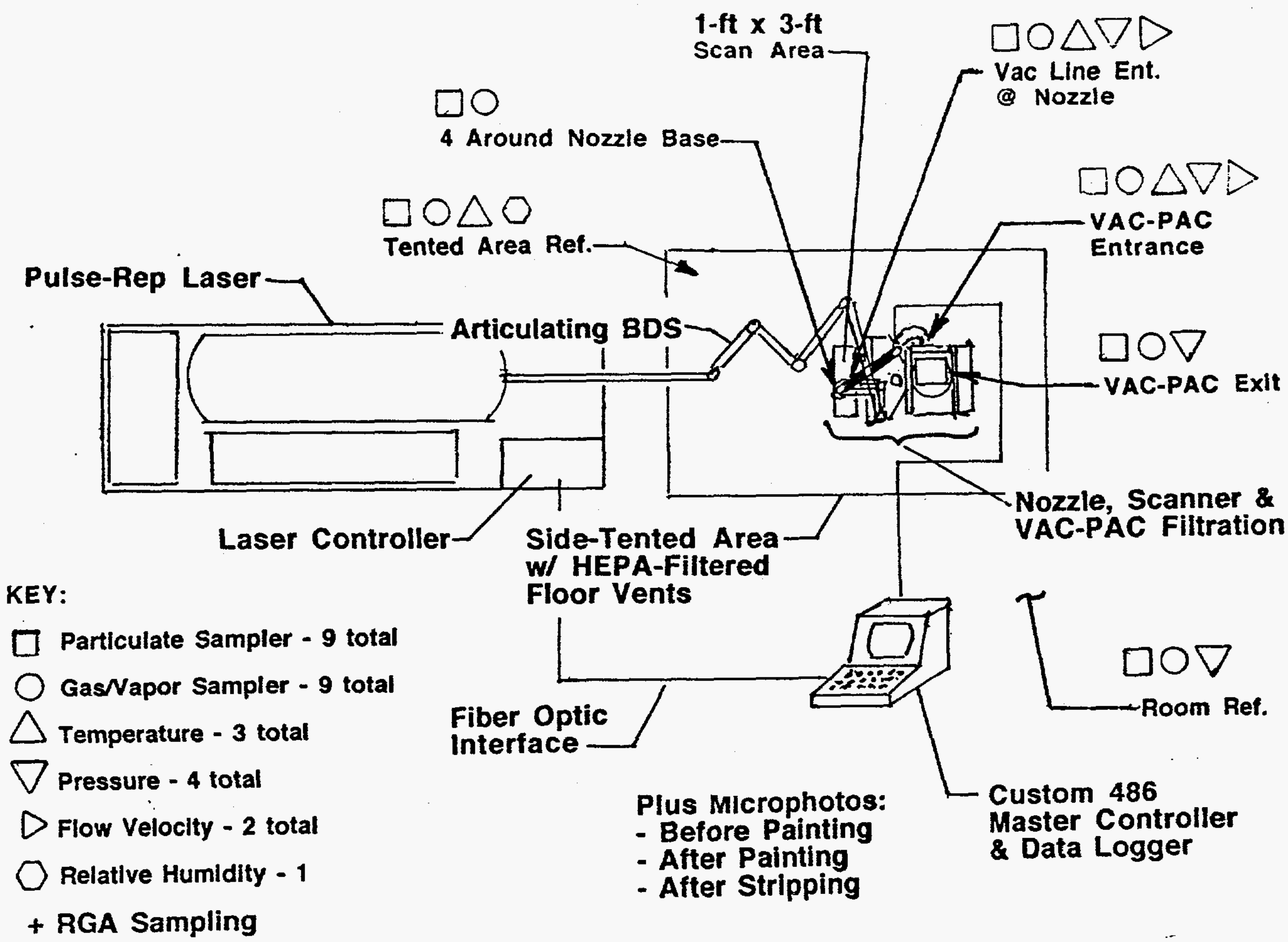


Figure 7
Phase II Test Layout, Instrumentation, and Controls

indicate a filter blow-out, triggering an orderly shut-down procedure. The controller also controls the firing of each pulse of the laser. For Phase II testing, we are also collecting data with gas / vapor and particulate sniffers at various places in the system, and gas / vapor samples using a resdual gas analyzer, plus test-cell relative humidity readings.

In addition, we are working towards adding on-line sensors such as a radioactive sensor, paint-thickness sensor, optical comparitor, and optical spectrometer to analyze the plasma plume (see Table 2). These can be used for feedback and control to the scanner speed and laser pulse rate. The spectrometer can provide an on-line assay of what is going into the drum. Then when a drum is full, the computer would print an integrated assay label to be attached to the drum, so it would never need to be opened again.

Thus, though the laser is an important subsystem, proper system integration is the key for operational performance, cost savings, and acceptability in teerms of the environmental, safety, and health aspects.

Parts Cutting and Cleaning

When a building undergoes D&D, the equipment, pipe, ductwork, etc. is stripped out. Then the floors, walls, ceilings, and girders

Table 2
On-Line Sensors

Phase II System

- Temperature, pressure, pressure differential, flow rate in the vacuum filtration system.
- Gas / vapor samplers, particulate sniffers in various places.
- On-line residual gas analyzer sampling in various places.

Potential Add-Ons

- On-line optical comparitor to tell when coating has been removed.
- On-line paint thickness measurement.
- On-line Spectrometer to look at plasma plume for spectral lines of uranium, plutonium, etc. and to provide an on-line assay of the material going into the VAC-PAC drum.
- On-line radiation monitor to indicate possible migration of contaminants into the substrate.
- Multi-sensor data fusion and correlation would reduce the uncertainty for the controller system logic, as well as controlling the scan rate and the laser pulse-repetition rate.
- On-line assay and label printout for the waste container to reduce the "downstream" assay costs.

would be cleaned. A conceptual design for a three step system to deal with the stripped-out material, using all commercially available subsystems and components, has been completed. As shown in Figure 8, it consists of three major components.

1. Robotic sorting of material in scrap piles, using a gantry robot with dual-arm end effector.
2. Robotic laser cutting of metals, such as longer pieces of pipe or ductwork, to reduce them to workable lengths for cleaning the insides. Laser cutting has the advantage that no physical cutting wheel or saw touches the contaminated material, and there is no need for use of acetylene torches. The laser is located outside of a filtered cutting cell, with a BDS delivering the beam to a pedestal robot.

- Small parts will be cleaned in a filtered glove box. Pre-designs are done.
- Larger parts will be cut before laser cleaning, such as when cleaning the inside of long pipes or duct work. For I-beams and other large parts, the resale value will be maximized if they are cleaned uncut.

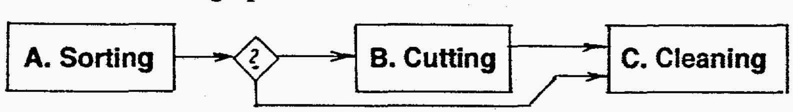


Figure 8
Lasers and Robotics For Contaminated Parts Sorting, Cutting, and Cleaning

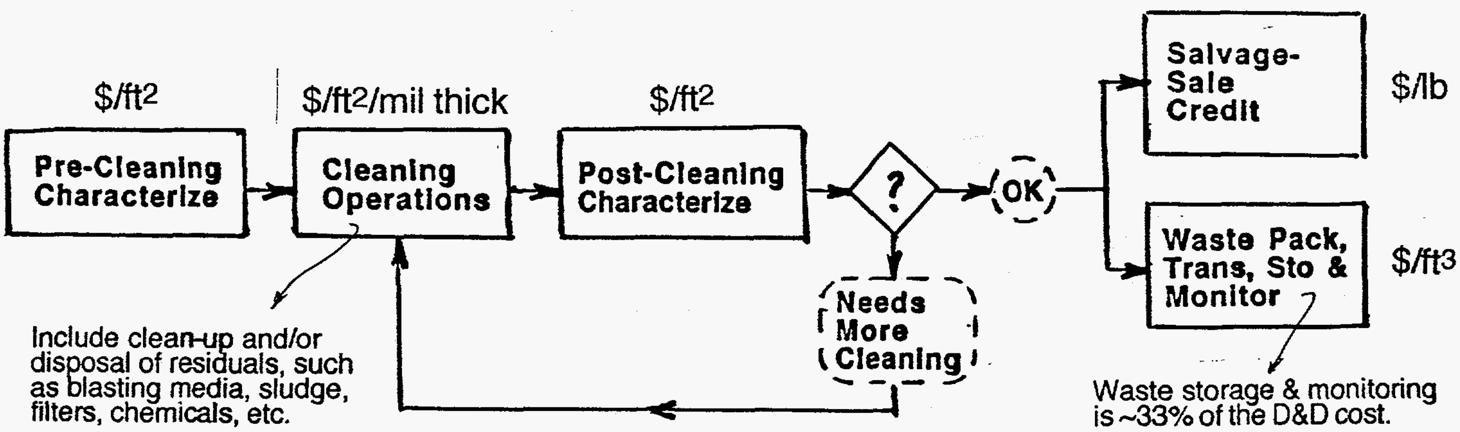
3. Robotic cleaning, using a modified version of the cleaning system described above, including saddle-gantry robot, and filtered cutting cell in addition to the nozzle.

Details were presented at the poster-session of the July 1995 DOE / METC Technology Developers and Users Interface Meeting. For laser cutting, the two worldwide commercially available and commonly used lasers are CW Nd:YAG and CW CO_2. They use electrical power and some cooling water (which can be closed-cycle using an air heat exchanger, eliminating need for water hook-up). Gas purge is used to clean out the kerf for thicker metals. This prevents the melt from clogging the kerf or absorbing and defocusing the beam. For surface-contaminated metals that are to be salvaged, it may also be necessary to first clean a path preceeding the cut so as to avoid having contaminants running into the melt zone.

There is also some interest in exploring the use of the chemical oxygen-iodine laser (COIL) for D&D, which emits in the near infrared close to Nd:YAG. COIL lasers "burn" chemicals (chlorine, hydrogen peroxide, potassium hydroxide, and molecular iodine) to create O2-singlet-delta that transfers energy to iodine that lases. Some scientific experiments funded by the USAF indicate that it may be possible to make large quantities of O2-singlet-delta electrically rather than chemically. The run time needs to be increased substantially; so this technology has awhile to go before being ready for industrial use.

Accomplishments

As reported at earlier METC conferences, in Phase I we demonstrated complete surface and surface-pore cleaning for lead-based paint and two-part epoxy on concrete and metal coupons. The full-scale industrial prototype system that has been under fabrication for several months is now being finished. Most subsystems have completed check-out testing. Half-power (3 kW) tests will be starting in early October 1995. Full-power testing is scheduled to start in early December 1995. PBased on small-scale tests, we predict that the system will be able to remove 100 square feet per hour of 20-mil thick aged lead-based paint. This rate should also apply to radioactive-contaminated lead-based paint since the contamination is usually much less than 1%, and uranium and plutonium are not far from lead in the periodic table.



- Reduced worker exposure, which can result in lower liability insurance costs ($/hr).
- Reduced needs for post-cleaning characterization ($/sq. ft).
- Reduced needs to assay waste-container contents ($/cu. ft).

Figure 9
Cost Comparison Algorithm

Costs and Benefits

A schematic cost algorithm is shown in Figure 9. A cost algorithm like this is needed to compare the different technologies shown in Table 1. For cleaning, most vendors quote dollars per square foot, regardless of thickness. It is not at all clear that credits are presently given for technologies that provide waste volume reduction, salvage value credit, saving insurance costs through reduced worker exposure, or on-line assay to reduce needs for post-cleaning characterization and post-operations drum assay. We will work up cost numbers for laser-based surface cleaning after full-scale testing late this year. FERMCO has done monitored testing to obtain comparative numbers for removing paint from steel using either dry-ice blasting, high-pressure water, plastic pellets, soda blasting, sponge, steel grit, ultra-high-pressure water, or wet ice blasting.

Benefits imbedded in the goals include pore cleaning, waste volume reduction, negligible substrate damage to maximize salvage or recycle value, reduced worker exposure, one-step final containerization, no wet chemistry for cleaning or for processing residuals, and possibly on-line assay. The market for nuclear D&D is quite large, involving both DOE and commercial nuclear facilities. In addition, the market for environmentally-safe non-radioactive lead-based paint removal is huge for ships, bridges, etc. The is also a large market for other applications such as aircraft cleaning. The technology is thus not only "dual use" but "multi-use."

Future Activities

A DOE-funded full-scale prototype system should be ready for laboratory testing by the end of this year. For these tests, we plan to remove lead-based paint from one foot by three feet concrete coupons. We hope to begin Phase III in the spring of 1995. This would involve field tests at a DOE facility to remove radioactive-contaminated paints. Pending funding, we will:

- Expand the test matrix to include two-part epoxy, and repeat all tests for metals.
- Add the other on-line instrumentation described above.
- Integrate the scanner into a MOOSE robot for floor cleaning and a ROSIE robot for wall cleaning.
- Continue development of parts cutting and cleaning systems.