TRANSPORTATION RESEARCH BOARD
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IDEA *Innovations Deserving Exploratory Analysis Project*

**NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM**

*Report of Investigation*

NCHRP IDEA

**IDEA PROJECT FINAL REPORT**
CONTRACT NO. NCHRP–94–ID038

IDEA Program
Transportation Research Board
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# PAINT REMOVAL FROM STEEL STRUCTURES (PHASE II)

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**INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS**
**MANAGED BY THE TRANSPORTATION RESEARCH BOARD (TRB)**

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For information on the IDEA Program contact IDEA Program, Transportation Research Board, 500 5th Street, N.W., Washington, D.C. 20001 (phone: 202/334-1461, fax: 202/334-3471, http://www.nationalacademies.org/trb/idea)

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## FOREWORD

This report covers the activity on Contract NCHRP-38 for the period of 18 November 1996 to 20 May 1998. It is submitted in accordance with the contractual requirements of this contract.

The experimental work was conducted in the EMEC Consultants Laboratory in New Kensington, Pennsylvania. Daniel M. Hydock assumed responsibility for the experimentation until his departure in September 1997. He was supported by Brian J. Barca, who assumed a leading role for the demonstration. Dr. Rudolf Keller directed the effort as Principal Investigator.

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## ABSTRACT

This report covers the work performed during a contract to demonstrate the feasibility of a novel process to remove paint coatings from highway steel structures. The novel electrochemical method, the ElectroStrip™ Process, employs cathodic treatment of the steel to achieve debonding of the paint. It permits complete collection of lead-containing paint debris without any particles becoming airborne; the usual extensive precautionary environmental and occupational measures would not be necessary and lead components could be usefully recycled. The approach is patented by EMEC Consultants.

The ElectroStrip™ technology was demonstrated at an I-66 overpass in Arlington, Virginia.
In preparation for this demonstration, essential components of the process, such as ElectroPad™ design and scoring techniques, were refined. Equipment to treat up to 80 square feet in area simultaneously was acquired and assembled into an operational unit for field testing.

For the commercialization of the technology, the ElectroStrip Corporation was established. Development of the technology was publicized and encountered significant interest.

## EXECUTIVE SUMMARY

### DESCRIPTION OF THE INVENTION, THE ELECTROSTRIP™ TECHNOLOGY

EMEC Consultants invented a process to remove paint from steel structures without the need for abrasive blasting, using only benign chemicals, and collecting lead-containing debris to be used in a secondary smelter for lead production. The patented electrochemical method is called the ElectroStrip™ Process. By applying cathodic current to a substrate, electrochemically assisted debonding of the paint is achieved. The environmentally benign electrolyte is contained in a liquid-absorbent material to which a counter electrode is attached. This combination, called ElectroPad™ and shown in Figure 1, often includes a liner and is applied to the metal surface, in the case of steel with magnets. After electrochemical treatment for ½ to 2 hours, the ElectroPad™ is removed and paint fragments recovered. No particles become airborne, from environmental and occupational viewpoints a decisively advantageous feature for the removal of lead-based paint.

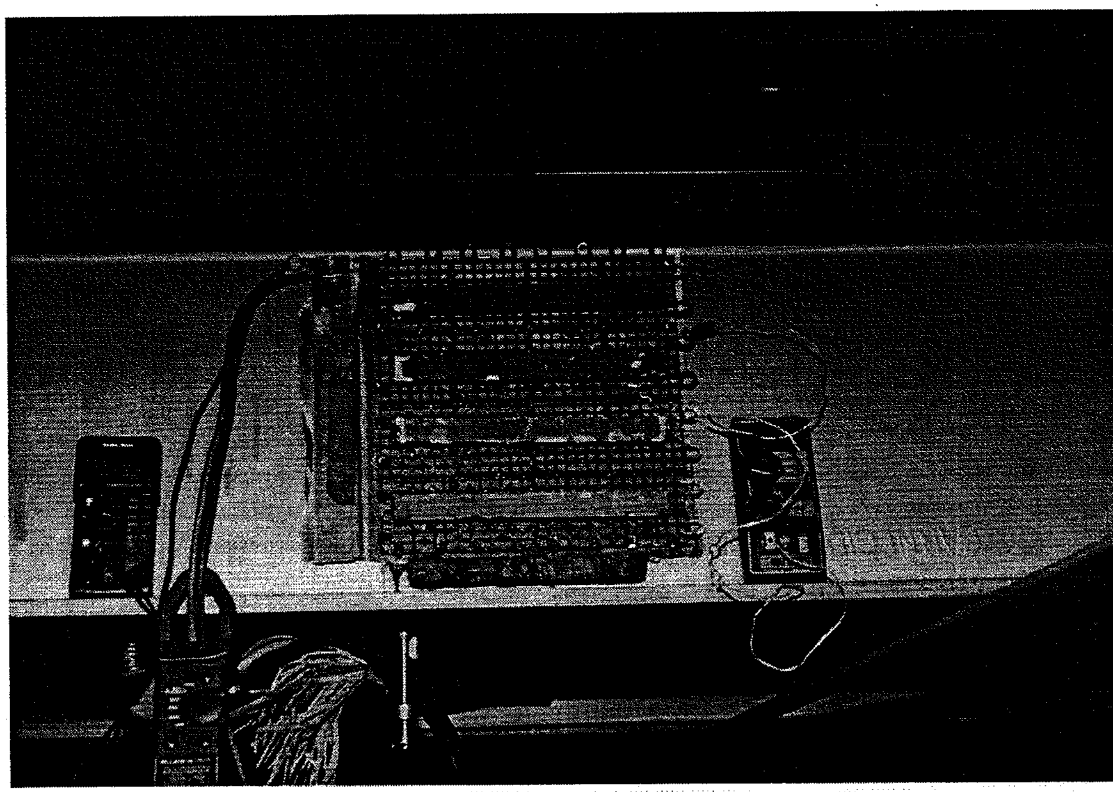


**FIGURE 1 ElectroPad™ attached to metal surface.**

## PROCESS DEVELOPMENT AND DEMONSTRATION

### Multipad Testing

After laboratory and field tests of Phase I were conducted on the one-square-foot scale with laboratory equipment, a 4,000-A rectifier and a bus bar system were acquired for testing of arrays of up to 80 one-square-foot pads. Multipad tests were then conducted on a bridge of the Pennsylvania Department of Transportation. They culminated in a day-long test with monitoring of personnel exposure to lead, with results confirming the occupational advantages of the ElectroStrip™ technology.

### Testing and Demonstration in Industrial Setting

The ElectroStrip™ technology was used to remove approximately 800 $ft^2$ of paint coating from a girder of a highway structure in Arlington, Virginia.

The equipment used permitted the treatment of an area of 60 to 80 $ft^2$ at one time. With a coverage of 60 $ft^2$ and a pad residence time of 1½ hours, a targeted rate of 40 $ft^2$ per hour could be achieved. While this rate was not actually demonstrated in a continuous mode over an extended period of time, elements of the process were performed at rates consistent with a removal rate of 40 $ft^2$ per hour by a crew of three people.

Complete, 100-% removal of the coating was demonstrated on the one-square-foot scale in preceding testing. In the large-scale demonstration, removal rates were between 70 and 90 % for various batches of ElectroPads™. Paint remnants were removed by RotoPeen equipment. Problems leading to incomplete debonding were: (1) incomplete scoring in early work, when the contractor's personnel first conducted this operation, and (2) premature aging of pad backings that did not hold the pads flat to the surface any longer. The first problem was resolved, and it appears that minor modifications can take care of the second problem. The appearance of these two problems showed clearly the importance of working in a practical setting at this larger scale.

The demonstration was organized by the Virginia Department of Transportation, with Mr. William Bushman of VDOT's Research Council being responsible for the technical coordination. It was financially supported by the Office of Technology Applications of the Federal Highway Administration (Mr. Donald R. Jackson). A "Show Case" was held on 15 May 1998 to introduce this new technology to owners and others; it was very well attended. An extensive article describing the demonstration in Arlington was published in the October issue of JPCL, the trade journal of the Society of Protective Coatings (SSPC).

## PLANS FOR IMPLEMENTATION OF THE TECHNOLOGY

The multipad testing and the large-scale test in Arlington have confirmed the promise of the ElectroStrip™ process. Several -- three to four -- additional large-scale tests on a pre-competitive basis, however, will be required to achieve the necessary perfection.

Research and development will be required to optimize details of the process. Such an effort exceeds resources presently available to EMEC Consultants. Government funding will be solicited, and other options will be considered.

Despite some present shortcomings, it is believed that the technology is ready for application at modest scale, e.g. at bridges of 1,000 to 5,000 $ft^2$ surface to be treated.

Research on fundamental issues is in progress and needs to be extended.

The mechanism for commercialization is in place, as the ElectroStrip Corporation has been formed for this purpose.

## IDEA PRODUCT: THE ELECTROSTRIP™ TECHNOLOGY

The ElectroStrip™ process is a novel, environmentally and occupationally attractive and cost-effective approach to remove paint coatings from highway steel structures. Using a benign electrolyte solution, it achieves debonding of the paint by electrochemical polarization. It permits a complete collection of lead-containing paint debris without any particles becoming airborne; the usual extensive precautionary measures are not necessary with this process, and the lead values can be recycled. It is amenable to be practiced efficiently at any scale, by small and large contractors. Equipment needs are modest. A U. S. patent has been granted to EMEC Consultants [1].

In the ElectroStrip™ process, the painted surface is covered by ElectroPads™, arrangements consisting of a pad of water-absorbent material, a counter electrode mesh, and an optional paper liner. The pads are held against the test object, preferably by means of magnets. Cathodic current is applied to the steel. After treatment, the ElectroPad™ are removed with debonded paint. The surface is cleaned from residual paint and repainted.

In a successful demonstration of the potential of the approach, a contractor treated approximately 800 square feet of a bridge girder in Arlington, Virginia, by the ElectroStrip™ process.

## PROCESS CONCEPT AND SIGNIFICANCE OF THE INNOVATION

The ElectroStrip™ Process is designed to commercially remove paint from steel structures. It is envisioned that it will be practiced by painting contractors, with on-site support by the supplier of the technology. ElectroPads™ will be provided by this specialized firm which also assumes quality control functions.

The ElectroStrip™ technology promises to become a versatile tool in the arsenal to remediate structures coated with lead-based paint. It is particularly suited where environmental and occupational considerations are of special concern and where total removal of lead is desirable or required. Environment and personnel are not exposed to airborne toxic debris or fumes. The method can be practiced at any scale, with pronounced advantages for smaller jobs over methods requiring large set-up cost for equipment.

Remediation of highway structures that are coated with lead-based paint is a nationwide problem [1]. There are approximately 200,000 steel structures, 80 to 90 % having lead based paint. The increased cost of maintaining such structures due to dealing with lead in the environment and in the workplace have reduced the number of structures painted each year. Alternative approaches to paint removal may provide welcome relief.

# GOAL AND SCOPE OF PROJECT

## PHASE I ACHIEVEMENTS

The technical feasibility of the depainting reaction was established in laboratory experiments and field tests. Areas of up to one square foot in size were treated on highway structures. Details of the approach were worked out, process parameters determined. Phase I work and achievements are summarized in a Final Report [1].

## PRESENT PHASE II EFFORT

The present Phase II effort focused on consistency of the process and multipad testing, with the appropriate special equipment. Preparations were made for a large-scale demonstration on a highway structure, which occurred in Arlington, Virginia, in the month of May 1998.

# TECHNICAL RESULTS

## PROCESS DEMONSTRATION IN ARLINGTON, VIRGINIA

### Introduction

The Virginia Department of Transportation contracted with the ElectroStrip Corporation and Superior Painting and Contracting Company, Inc., to remove about 800 square feet of paint from an I-66 overpass over Westmoreland Avenue in Arlington, Virginia. This demonstration of the technology was supported by the Office of Technology Application of the Federal Highway Administration. The interest and support of Mr. Donald Jackson is greatly appreciated.

EMEC Consultants prepared special equipment and supplies necessary to practice the ElectroStrip™ technology and cooperated with the painting contractor to conduct the work. Dr. Rudolf Keller, Sole Proprietor of EMEC Consultants, was the Principal Investigator, Brian J. Barca the lead operator, and Brian Lamb, a temporary employee, participated as assistant. John Korfiatis was the responsible representative of Superior Painting and Contracting, Co. The work was conducted during the period of 11 to 20 May 1998.

Mr. William Bushman of the Virginia Department of Transportation Research Council represented the Commonwealth of Virginia during the execution of the work. His interest and cooperation are gratefully acknowledged. Thanks go also to his colleague, Dr. Gerardo Clemeña, for his support and encouragement, and to the VDOT employees at the Fairfax office and at the site in Arlington for their outstanding cooperation.

Preparations for the demonstration were supported by the NCHRP-IDEA program of the Transportation Research Board. We thank Dr. K. Thirumalai, IDEA Program Manager, and Dr. Inam Jawed, Senior Program Officer, for their interest and support.

## Scope

All paint was to be removed from an area of approximately 800 $ft^2$ of a beam on a bridge carrying I-66 over Westmoreland Street, using the ElectroStrip™ method.

In this method, an electrochemical treatment causes the paint to unbond from the steel, and paint then can be recovered on pad material to facilitate recycling of the lead-containing paint residue.

The removal was accomplished by Superior Painting and Contracting Co. personnel, in cooperation with the EMEC Consultants team.

## The Object and Its Coating

I-66 has two overpasses over Westmoreland Street in Arlington, Virginia, one in each direction. The ElectroStrip™ technology was demonstrated on a beam in the easterly direction, as shown in Figure 2. The coating consisted 3 to 7 mils red primer and 5 mils buff topcoat, according to Tooke gage readings obtained on different beams by Corrpro Companies Inc. personnel. Adhesion of the primer was strong, 500 to 600 psi (ASTM D 4541 test). The coating was deficient, as the top coat flaked off on many spots. The situation was to be remediated by high-pressure washing and repainting, with power tool treatment of badly deteriorated spots. An area of 800 $ft^2$ of the second beam was to be cleaned by the ElectroStrip™ process.

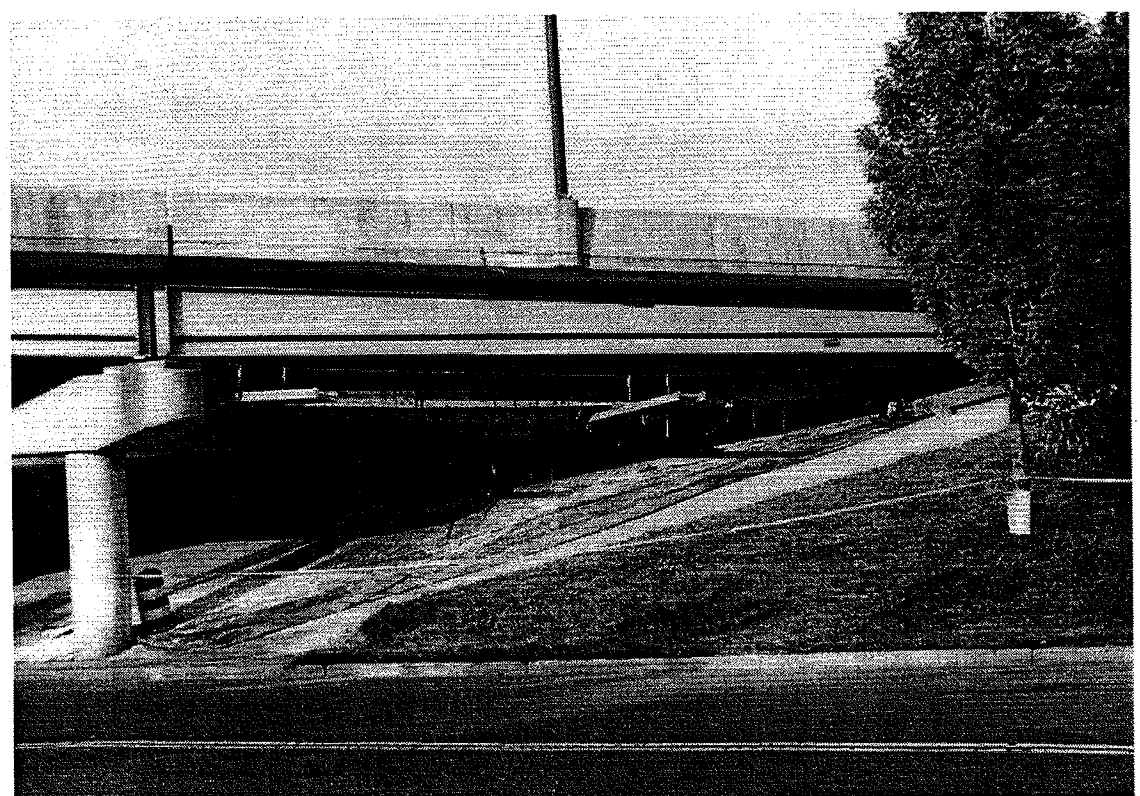


**FIGURE 2 I-66 overpass in Arlington, Virginia.**

**Tests at the Arlington Bridge Preceding the Demonstration**

<u>**One-square-foot Tests**</u>

The feasibility of using the ElectroStrip™ approach to remove the paint at the I-66 overpass was established in preliminary tests.

In a one-square-foot test, complete 100-% removal was demonstrated in the presence of Virginia Department of Transportation personnel. A current of 80 A was applied initially; it decreased to about 30 A towards the end of the 90-minutes treatment. Figure 3 shows the area, cleaned by wiping with moist paper towels. To the right of the treated area, scoring with a power tool is being demonstrated.

The surface created is shown in Figure 4. A clean surface with a preexisting profile was created. In this preliminary testing, the absence of flash rusting became obvious. Only traces of rust were noticed after one month.

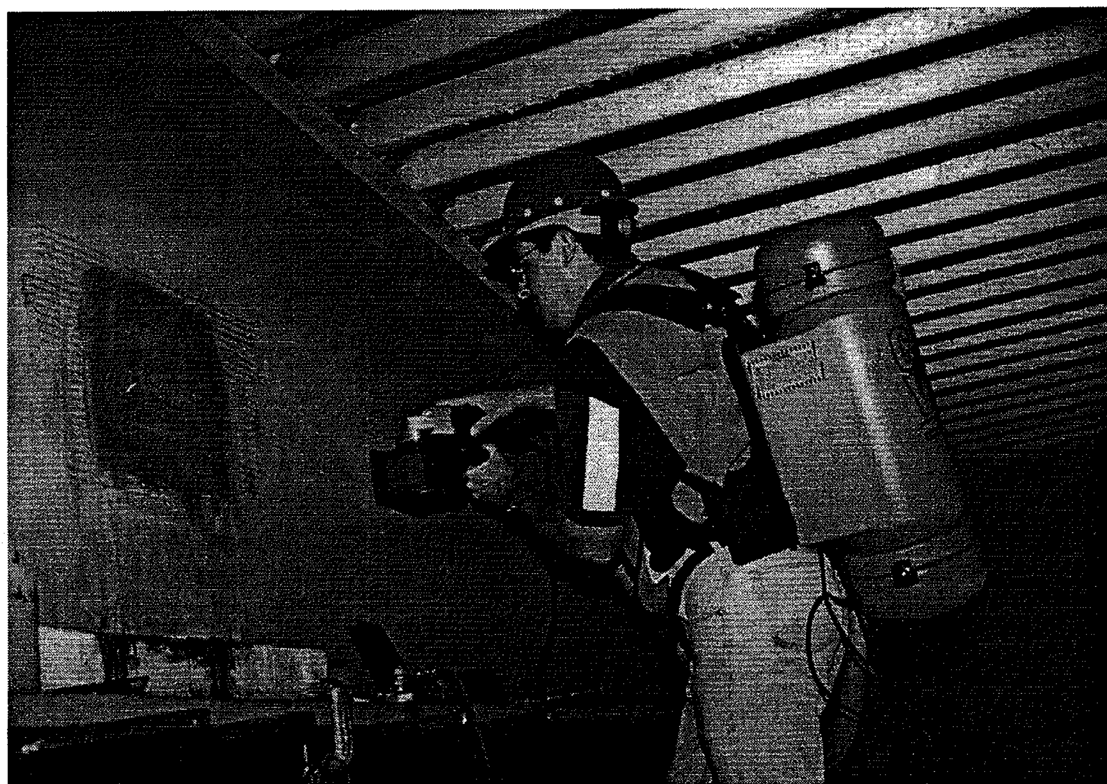


**FIGURE 3 Result of test at Arlington structure and demonstration of mechanized scoring.**

<u>**Core-drilled Samples**</u>

Three samples of 1¼-inch diameter were core-drilled at a structurally non-functional part. The paint was removed by the ElectroStrip™ treatment on one side and had the original paint on the other side of the samples.

It was established by X-ray that elemental lead was deposited (data also showed the absence of iron oxide, i.e. of mill scale). Wet chemical analysis indicated the presence of 0.3 mg Pb/cm$^2$, which is a level generally considered non-hazardous. For the original paint, 1.3 mg Pb/cm$^2$ was found in this analysis.

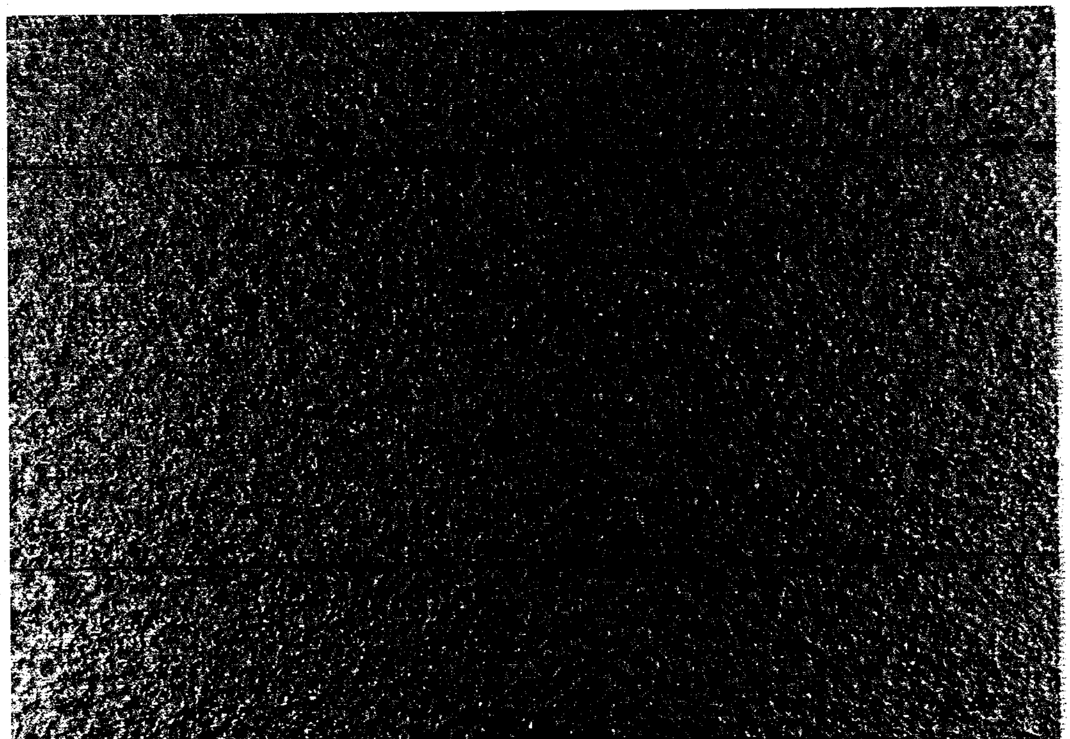


**FIGURE 4 Surface created by the ElectroStrip™ approach in pre-testing.**

**Process Steps**

In completing the demonstration, the following process steps were applied.

__Preparation of ElectroPads™.__ Pads were placed in a plastic container and electrolyte added. By agitating the container, the liquid was sloshed around and distributed to all areas of the pads. This operation was performed by EMEC Consultants' personnel.

__Scoring of Surface.__ Large flat areas of the surface were scored with a DESCO tool that was equipped with an especially arranged set of star wheel cutters which left score marks in lines 1 cm apart. One pass by the hand tool is sufficient if care is taken that the scoring is thorough enough to penetrate the entire paint coating

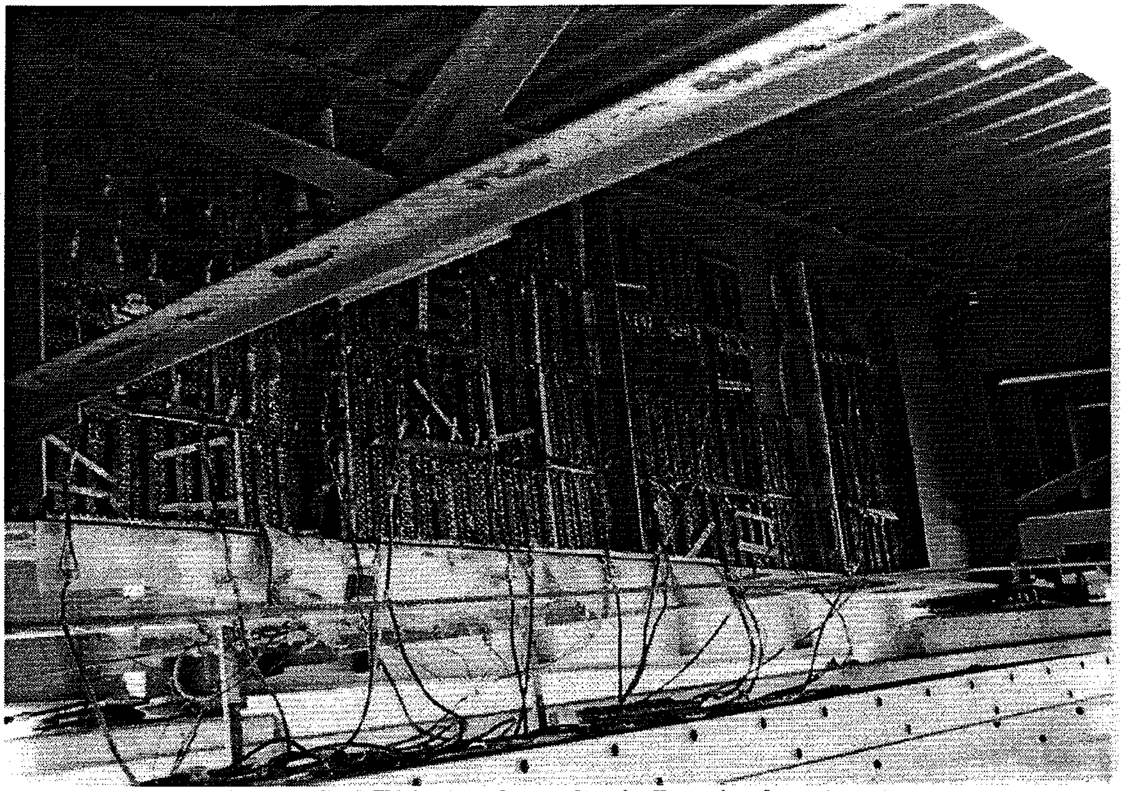


**FIGURE 5 Array of ElectroPads™ during electrochemically assisted treatment.**

down to the metal. Less accessible parts of the surface were scratched with carbide-tipped hand tools. A needle gun acquired for this purpose was not ready in time to be put in operation.

**Placement of ElectroPads™.** ElectroPads™ were hand-placed. Shorting with the structure, e.g., in corners should be avoided. Electrical connections were made to extensions of the Exmet screen of neighboring pad pairs. An array of placed pads is shown in Figure 5.

**Application of Electrical Current.** Current was initiated at the rectifier. It was interrupted automatically after a preset time. Voltage adjustments were made occasionally. While the current raises the temperature (as an example, a temperature of 88 °F was measured by Corrpro before start-up of the rectifier and 130 °F during treatment), excursions to excessive temperatures may occur, e.g., due to shorting. Temperatures were monitored and pads disconnected, if necessary.

**Moistening of Pads During Treatment.** Every 15 to 20 minutes, pads were sprayed with electrolyte to avoid any drying-out.

**Removal of ElectroPads™.** After automatic interruption of the current, pads were removed and collected in yellow marked bags. These bags were placed in 55-gallon drums and stored for disposal.

**Scraping, Cleaning and Washing of Surface.** It is estimated that about half of the debonded paint is collected with the spent pads. Loose paint adhering to the steel surface was hand-scraped and collected with a vacuum. The surface was then cleaned with wet paper towels which were collected with the spent pads. Figure 6 shows a surface after this cleaning. At the end, the entire area was washed at high pressure with a Recyclean unit; in this method water is collected by applying a vacuum and water consumption is minimal.

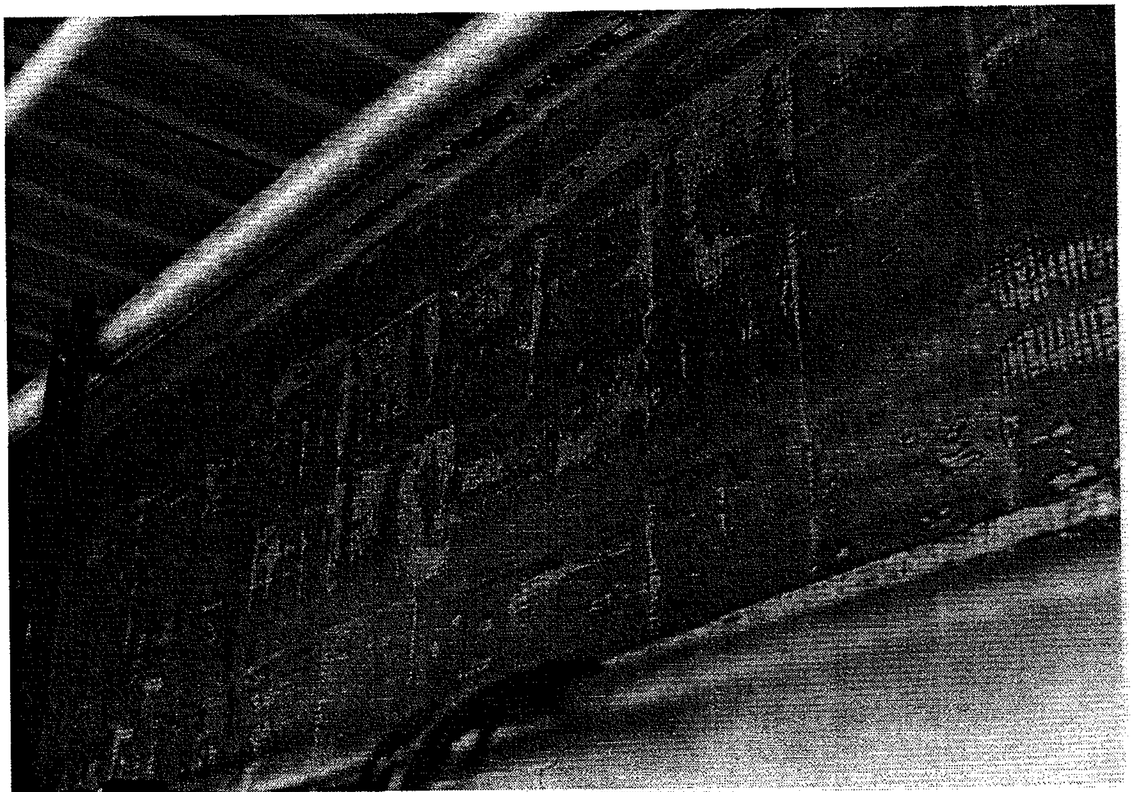


**FIGURE 6 Depainted surface after cleaning with paper towels.**

<u>Complete Paint Removal With Hand Tools.</u> Paint remnants that were not removed by the ElectroStrip™ treatment were removed using RotoPeen equipment. It appeared that the originally very strong bonding of the primer to the steel was weakened by the treatment. An operator removed these paint remnants at a rate of about 100 $ft^2$ per hour.

## Diary of Execution

A brief overview of events is given in the following diary-style account by EMEC Consultants.

**Monday, 11 May 1998**

The equipment and supplies having been readied the preceding week, we started early from Murrysville to Arlington, arriving there about 1 pm. We unloaded supplies that were then stored in a salt-storage facility made available by VDOT.

**Tuesday, 12 May 1998**

The contractor arrived with two crews and erected the scaffolding. The entire bus bar system was then installed within less than one hour. The trailer with the rectifier was positioned near the fence inside the VDOT facility.

The contractor scored one side of the beam. ElectroPads™ were mounted on part of the scored area and current applied, but the available (rented) generator could not support the full load required by 60 square feet of coverage. The load was reduced to 40 square feet. Two batches were processed, resulting in approximately 75 % of debonding on an area basis. It was concluded that scoring was not consistent enough and often did not penetrate the coating completely. Remaining areas were later rescored.

Shorting problems became evident because of the presence of the metallic scaffolding, for which no precautionary measures had been anticipated. Some anode screens were found to contact the steel substrate, a problem that was easily avoided after reviewing procedures with the contractor.

Overall, much more was accomplished on this first day than planned, despite the fact that continuous rain made working somewhat cumbersome.

**Wednesday, 13 May 1998**

A different generator became available, supporting batches at least as large as covering 70 square feet.

With the contractor's crew of three plus John Korfiatis, three arrays of 50 ElectroPads™ each were processed.

Results showed that debonding was 85 % and higher. Rescoring had the desired effect.

Difficulties were experienced with pads mounted on horizontal areas in the upside-down position, as the forces of the magnets would not always retain the pad reliably. Mounting pads without the plastic backing brought improvements.

**Thursday, 14 May 1998**

Three batches covering 60 $ft^2$ each were run. Extent of removal reached 90 percent. Pads were carefully placed.

Locations showing large amounts of residual paint were redone, but results were not rewarding. Additional debonding and softening of paint was noticed, but current evidently went primarily to debonded areas. Removing residual paint by hand tools was clearly more efficient.

**Friday, 15 May 1998**

Show Case presentation at the Ballston Holiday Inn. The attendance exceeded expectations. At about 11:30 am, people visited the bridge site.

An area of 60 square feet was run for the demonstration, after having run such a batch beforehand. Residual paint had been removed from previously treated areas by power tooling.

Working on this day was cut short; no additional batches were processed after visitors had left.

**Saturday, 16 May 1998**

Two batches of about 60 square feet each, on the back side, were processed by EMEC Consultants' personnel.

Extent of removal had declined to 75 % again, presumably because of premature aging of backing tile arrangements.

**Monday, 18 May 1998**

Plans to treat three sections and monitor time requirements were modified because only one man of the contractor's personnel was available.

A first batch covering 60 square feet was processed, then another batch of 70 square feet.

Preparation of pads, scoring of the surface, mounting and connecting of pads required less than an hour time with three operators.

**Tuesday, 19 May 1998**

Remaining area, about 20 $ft^2$, was treated.

The entire area was washed by one operator with the Recyclean unit. This process step went smoothly and expeditiously, with moderate water consumption.

The bus bar system was dismantled and components loaded on the trailer.

**Wednesday, 20 May 1998**

Contractor personnel removed residual paint by power tooling and repainted the debonded areas.

EMEC Consultants personnel departed at about 10 am. This departure was two days ahead of the original schedule.

## Rate of Progression

Complete debonding had been achieved in previous testing by electrochemical treatment during a period of 1½ hours. This treatment period was used in the present demonstration.

The available rectifier supplied a current of up to 4,000 A at a voltage of up to 18 V. At a current density of 50 $A/ft^2$, an area of up to 80 square feet could be treated at the same time. When setting the goals for the demonstration, coverage of 60 square feet was targeted. With a residence time of 1½ hours, this translates into a rate of 40 square feet per hour.

It was established that the preparation of pads, scoring of the surface and placement of the ElectroPads™ can be accomplished in less than an hour by a crew of three people. This leaves sufficient time for monitoring the pads during operation, for pad removal and washing of the surface. A removal rate of 40 square feet per hour with the present equipment and at the present state of familiarity with the technology is realistic.

It was planned to work at the targeted removal rate for an extended time period in a day in later phases of the demonstration. This could not be done because the required contractor's personnel was not available.

### Completeness of Debonding

After electrochemical exposure and removal of ElectroPads™, the surface was scraped and cleaned by wiping with wet paper towels. The extent of areas where coherent paint remained was visually estimated and the degree of completeness of debonding obtained. More accurate estimates were later derived from photographs.

Estimates for fraction of area with complete paint removal:

| | |
|---|---|
| Batch 1 | 75 % |
| Batch 2 | 75 % |
| Batch 3 | 85 % |
| Batch 4 | 85 % |
| Batch 5 | 85 % |
| Batch 6 | 90 % |
| Batch 7 | 80 % |
| Batch 8 | 80 % |

| | | |
|---|---|---|
| Batch 9 | 80 % | |
| Batch 10 | 75 % | |
| Batch 11 | 75 % | |
| Batch 12 | 70 % | |
| Batch 13 | 70 % | |
| Batch 14 | 70 % | |
| Batch 15 | 70 % | **Average 78 %** |

In early tests, scoring was deficient. Values reached 90 % for re-scored areas with carefully placed ElectroPads™. In later tests, debonding often was not complete because the backing material had become warped and magnets were partially broken.

It became very obvious that proper scoring is very important. Attempt for remedial action by applying a second pad over the area did not lead to satisfactory results. A second factor was the deterioration of the backing material -- an improved or different material with higher tolerance for the temperatures encountered may be necessary.

After having achieved complete, 100 % debonding in a one-square-foot test, we believe that paint removed to more than 95 % is achievable in industrial practice.

**Voltage Hazards and Shorting During Operation**

Typical voltages between the anode of a pad and the cathodic structure were between 10 and 12 V. The maximum voltage capability of the rectifier is 18 V. Typical ohmic loss in the busbar system at top currents was about 3 V.

Voltages encountered by the personnel are without electrical shock hazard. Shorting between positive and negative parts of the system, however, leads to sparking and excessive temperatures in and near the conductors. Ignition of small amounts of hydrogen-oxygen mixtures can occur and manifests itself by some noise generation.

Shorting between anode screen and leads and structural parts did occur, mainly in initial phases of the work. The metallic scaffolding presented new problems, and no measures were taken to provide protective insulation, e.g., by covering the floor with an insulating material such as plastic or wood, or wrapping the railing by an insulating sleeve.

For a while, sparks were produced in corner areas, when the anode screen was inadvertently pushed against the structural steel. This problem could have easily been avoided by mounting bent pads into corners.

**Explosive Hydrogen Mixtures**

A hydrogen sensor (Industrial Scientific Corporation Model LD322, rented from Premier Safety & Services, Inc.) was used to determine any potential hazard from emission of hydrogen into the atmosphere. Sampling immediately near the surface of pads under current showed typical values of 1 to 2 percent of a hazardous

explosive mixture, with a peak value of 6 percent. It was concluded that there could not be any significant accumulation of hydrogen. The area was not artificially ventilated.
Circumstances would be different if working in a confined space, where continuous monitoring is recommended.

Small amounts of hydrogen and oxygen evidently collected as explosive mixture under the pads, and sparks from unintentional shorting occasionally ignited such mixtures. Extent of such reactions, however, is inherently limited and no dislodging of material was noticed.

### Characteristics of Resulting Surface

Resulting surfaces were not particularly examined. A surface profile of 2.2 mils was determined by Corrpro, somewhat higher than the figure determined earlier by the Virginia Department of Transportation. Surfaces were cleaned and repainted.

Surface contamination samples were collected by Corrpro. Chloride contamination was absent, i.e. 0-2 $mg/cm^2$ was determined. The sulfate level at the untouched paint was 8 $mg/cm^2$, with a conductivity reading of 360 mS/cm. After ElectroStrip™ treatment, removal of the pads, scraping of residual paint and wiping with wet towels, sulfate values ranged from 24 to 160 $mg/cm^2$, conductivity values from 330 to 530 mS/cm. After pressure washing with the Recyclean unit, sulfate values dropped to 8 $mg/cm^2$ and conductivities to 18 to 52 mS/cm. These levels observed after pressure washing are suitable for repainting. It appears that acceptable values, below 25 $mg/cm^2$, could be achieved by washing with towels, if this is done carefully and with sufficient amount of water.

A remarkable feature observed was the lack of flash rusting. At this point, the reason is not clear. Perhaps some cathodically deposited lead rendered the surface inactive with regard to a reduction of oxygen from the air. Perhaps the reduction potential was shifted due to residual alkaline condition at the surface. Rust formation, however, was observed at locations where residual paint was removed by means of traditional RotoPeen hand tool equipment.

### Environmental Monitoring

Exposure of personnel to lead was monitored by Leighton Associates. During setting up of the first arrays of ElectroPads™, including scoring of an area of nearly 400 $ft^2$, the actual lead exposure of two workers of Superior Painting and Contracting Co. was measured. Reported values are 9.34 and 64.37 $mg/m^3$, respectively. The higher value is for the worker who did most of the scoring. It indicates that respiratory protection during the scoring with vacuum-shrouded hand tools is required. The exposure was relatively small, however, as a comparison with a data point of 224 $mg/m^3$ obtained when operating vacuum-assisted power tools at later stages of the project conducted by Superior Painting and Contracting Co. indicates. Even this result, however, is well within the Maximum Use Limit (MUL) of 500 $mg/cm^3$ for half-face negative pressure HEPA respirators as they were worn.

Area measurements inside the work area were taken on the first two days and indicated actual lead exposure levels of 5.24 and 13.67 $mg/m^3$, respectively. These values are well below the OSHA action level.

**Waste Disposal**

The waste was collected in drums. The paint was analyzed to contain 16.7 % lead, 1.17 % chromium and 0.06 % aluminum (analysis commissioned by VDOT). The chromium (and aluminum) content renders the waste unsuitable for recycling in a secondary lead smelter. The contractor had the solid waste disposed of with the other hazardous waste resulting from his activities.

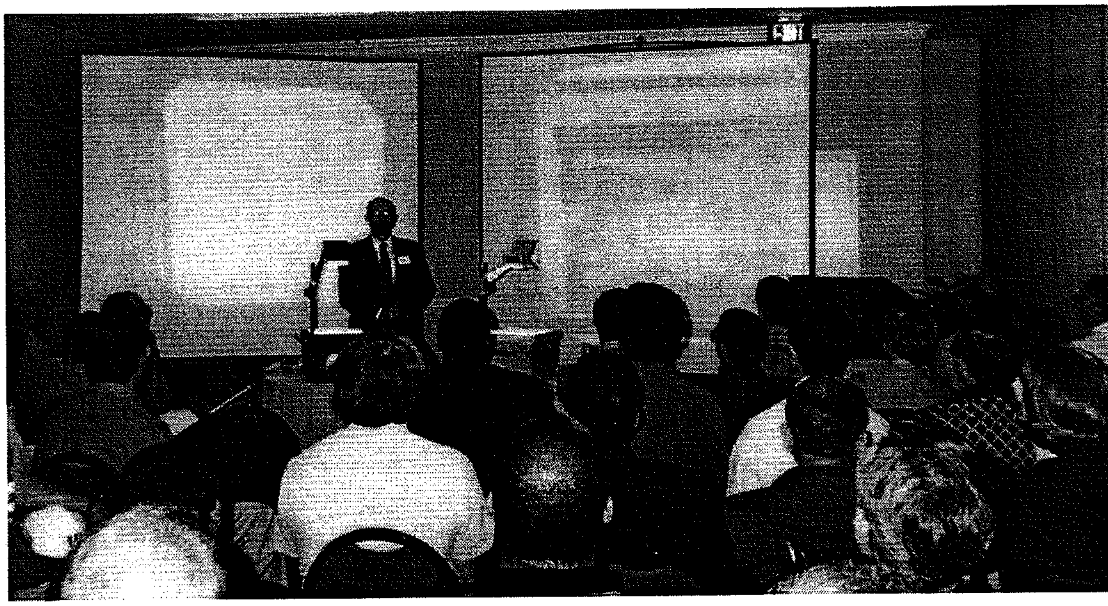
The debris generated was relatively small: three 55-gallon barrels of solid debris and two barrels of wash water (which was processed by the contractor together with other water).

**Show Case**

The Virginia Department of Transportation and the Federal Highway Administration, in cooperation with EMEC Consultants, hosted a Showcase event on 15 May 1998. Presentations were given at the Holiday Inn in Arlington, Virginia, starting at 10 a.m. An on-site demonstration followed at the I-66 overpass. Both contractor's and EMEC Consultants' personnel were on site.

The event was very well attended. Fifty-two guests signed the attendance list, ten of them from the Virginia Department of Transportation, the others from various FHWA entities, from DoTs of other states, local authorities, and industry.

Guests were welcomed by Mr. William H. Bushman of VDOT. Introductions were then given by Mr. Donald Jackson of the Office of Technology Application of the Federal Highway Administration, by Mr. Malcolm T. Kerley and Mr. Renaldo T. Nicholson, both of the Virginia Department of Transportation. A presentation by Dr. Rudolf Keller of EMEC Consultants gave an overview of the ElectroStrip™ technology and the demonstration; Figure 7 shows this briefing in progress.



**Showcase briefing (photo courtesy of Dr. R. Granata, Lehigh University).**

**Site visit.**

**FIGURE 7 Showcase 15 May 1998.**

**Summary of Results -- Arlington Demonstration**

This large-scale test at a structure in Arlington, Virginia, produced the desired results, although they were not perfect in every respect. Cooperation with an industrial contractor did not present major problems. Adaption of the technology by contractor personnel actually occurred faster and smoother than anticipated. Suggested corrective actions and improvements are essentially minor in character.

The targeted removal rates of 40 $ft^2$ per hour, in essence, were achieved. This is close to the limit of the present equipment and about half of the rate projected to be achievable by a mature technology. Such a rate makes the technology commercially competitive.

The extent of paint removal was 78 % in the average, while a 100-% removal had been demonstrated in a preceding one-square-foot test. Careful and sufficient scoring is essential; it was not practiced in early stages. It was found that attempts to remediate areas showing insufficient degree of debonding by re-running with a second pad did not lead to satisfactory results. In later stages, it was observed that backings holding the pads had warped, which led to incomplete contact of pads with the metal surface. This problem of premature aging of the backings should be addressed by employing a stiffer material. Also there was a problem of excessive breakage of magnets. Significant costs are involved in the replacement of backings and durability is essential.

Environmental and occupational advantages of the ElectroStrip™ technology were confirmed. The process can be practiced without containment of the air, eliminating the high cost for such containment and treatment of the air, as well as the occupational hazards associated with working in such a contained space. A tarp must be placed below the treated area. Respirators should be worn when scoring and scraping; with a respirator of an Assigned Protection Factor (APF) of 10 times, the Maximum Use Limit (MUL) is far from being reached.

If the exercise is being considered a first one in a series of several similar tests, it can be said that goals were fully met. Scoring techniques will be refined in future tests, minor modification applied to the ElectroPad™, and improved backing materials and designs evaluated. We believe that the technology is ready to be applied on a near-competitive basis in project of modest size, ranging up to 5,000 $ft^2$ in size, using our present equipment.

## PRECEDING FIELD TESTING, INCLUDING TEST WITH MONITORING OF ENVIRONMENTAL/OCCUPATIONAL FACTORS

The equipment for multipad operation was tested repeatedly at a Pennsylvania Route 28 overpass about a mile south of Exit 16, with permission granted by the PennDoT District 11 office (Mr. John Ekiert). ElectroPads™ covering a total area of up to 60 square feet were employed.

On 1 July 1997, a video was taken during a field test; a copy of this video is made available on request.

Some one-square-foot testing was repeated at the I-66 overpass in Arlington. This testing is discussed in the previous section.

A test extending over an entire day-long shift was conducted on 6 May 1998 at a Route 28 structure of the Pennsylvania Department of Transportation. Scaffolding was installed and three batches of 20, 40 and 20 $ft^2$, respectively, were processed in succession. All operational paint removal steps, from scoring to pressure washing, were conducted. Soil and air samples were taken and exposure of personnel to lead was monitored by KTA-Tator, Inc. (Stanford T. Liang, CIH, Senior Industrial Hygienist).

No environmental contamination was determined based on soil samples. Area air samples were between 4.4 and 5.8 $mg/m^3$, with a blank of 2.8 $mg/m^3$. Occupational exposure was also below the OSHA Action Level of 30 $mg/m^3$. Nevertheless it is recommended that personal protective equipment and clothing is worn during the scoring operation and scraping of paint remnants, while other process steps do not seem to lead to intolerable exposure. Overall, results were consistent with the projected environmental and occupational advantages of the ElectroStrip™ process.

## PREPARATIONS FOR MULTIPAD TESTING

To conduct multipad testing, a rectifier and a bus bar system was acquired. The custom-designed rectifier was supplied by Clinton Power and delivered a dc current of 4,000 A at a voltage of up to 18 V. To conduct the current from rectifier to the vicinity of the treated area, aluminum bus bars of 1 inch by 12 inch cross section were purchased as surplus item from Alcoa. They were cut into 10-feet long pieces that were equipped at each end with five holes to accommodate bolts assuring good electrical connection. The bus bars are actually overdesigned and could be used for currents of at least 6,000 A.

To mechanize the scoring of the surface, hand tools were acquired from DELTECH and PENTEK. RotoPeen inserts were replaced by special starwheel cutter assemblies, as discussed later in the report. With such a tool, operated electrically or by compressed air, indents in the paint arranged in lines 1 cm apart result. Attention has to be paid to operate the tool slowly enough such that the paint is penetrated to the metal surface. One pass over an element of the surface is sufficient with proper use of the equipment.

Depending on the paint coating, a larger or smaller fraction of debonded paint components are collected with the ElectroPad™, the rest remains on the treated surface. This remaining fragments can be removed by scraping, then wiping and washing of the surface. Initially, moistened Bounty towels served for the purpose. For cleaning larger surfaces, a Recyclean unit was acquired. This equipment is designed to wash surfaces with high pressure water and to contain the liquid by vacuum, using minimal amount of water. This equipment was used successfully at Arlington; the entire surface of approximately 800 $ft^2$ was washed with water filling two 55-gallon drums, which matches the consumption figure of 1 gallon per seven square feet given by the manufacturer.

## DEVELOPMENT OF PROCESS

To increase the effectiveness of developmental testing, particularly during the winter months, permission was obtained to do testing on the steel I-beam structure of Building 242 of the Schreiber Industrial District, right where our laboratory facility is located. The beams are coated with a lead based paint system similar to those used on highway structures.

### ElectroPad™ construction and support

An experimental effort was conducted to improve the consistency and degree of coating removal under the ElectroPad™. Up to this point typically 85 to 95 percent of coating was removed, leaving a few islands of adherent paint behind in the treated area covered by the pad. These islands were generally found at locations between the magnets used to attach the pads to the structure. We assumed that the effect was pressure related.

Magnets were now incorporated into a grid assembly to be used to support the ElectroPad™. A rigid grid material was selected to apply a more even pressure to flat surfaces. Candidate grid materials were fiberglass encapsulated with plastic and a polypropylene/rubber blended material. The fiberglass based material was more rigid but it was heavy and too hard to cut. The preferred polypropylene/rubber blended material, commercially available as Matéflex, was not quite as rigid but was lighter and easy to cut. Various magnet patterns, with varying magnet density and orientation, were used to try to increase the percent coating removal under the ElectroPad™. All attempts failed to obtain complete removal, except when the ElectroPad™ was completely covered with magnets.

This data led us to a modified, proprietary ElectroPad™ configuration which was used in conjunction with the 1 ft x 1 ft polypropylene/rubber blended grid fitted with four 1" x 0.75" x 10.5" ceramic magnets, as shown in Figure 8. The anode mesh was extended out on one side to facilitate the attachment of current leads. This pad design increased the percent removal to greater than 99 %. Patenting of this improved pad design is being considered.

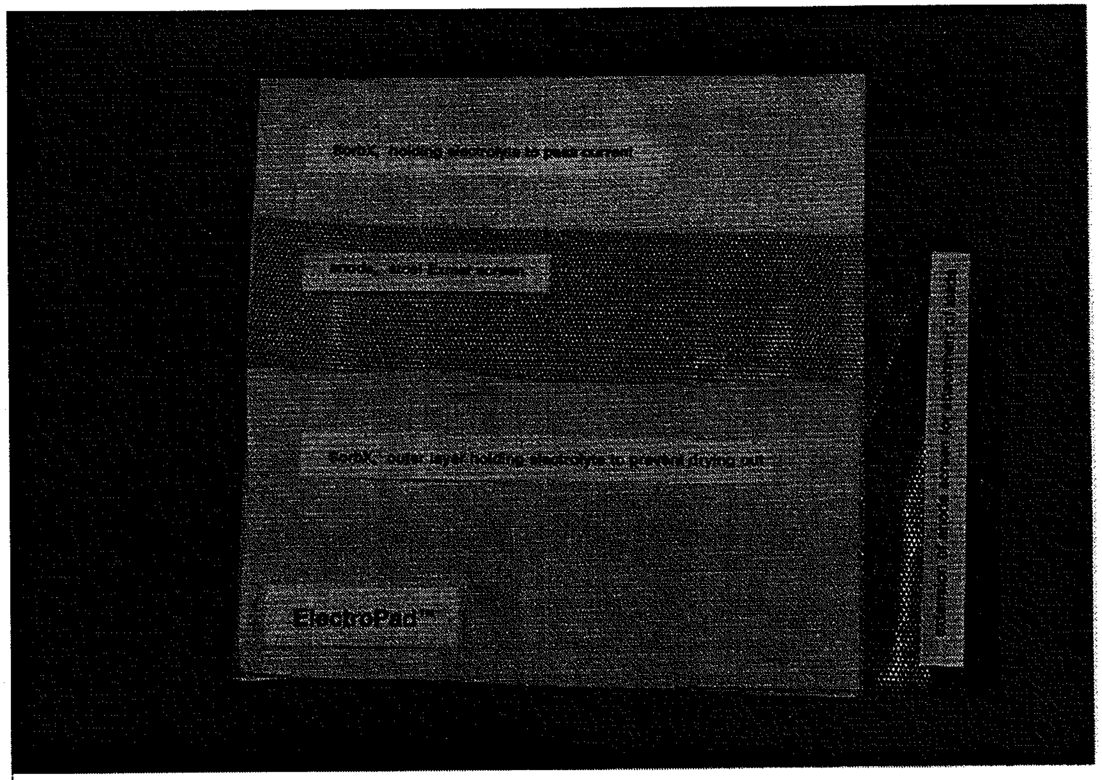



**FIGURE 8 ElectroPad™ configuration.**

## Expanded metal anode selection

Four expanded metal anode candidates were evaluated in view of their employment on the demonstration project in Arlington, Virginia: (1) low carbon steel, (2) stainless steel, (3) nickel, and (4) titanium with a precious metal oxide coating. Of these candidates, the titanium with precious metal oxide coating was the most stable. It was projected, based on electrolysis time, that each anode could be used up to 50 times. Fifteen tests have currently been run using one and the same of these anodes with no signs of degradation. The drawback of this material is its expense, which is predicted to be around $ 30 / sq.ft., and at least 30 recycles would be required for cost competitiveness. The other materials all seemed to have similar deterioration rates; costs were approximately $ 4 / sq.ft. for nickel, $ 1 / sq.ft. for stainless steel, and less than $ 0.50 / sq.ft. for low carbon steel. The nickel and stainless steel had the advantage that they kept better in the stored presoaked ElectroPad™ package, while the low carbon steel started to corrode. Keeping these factors in mind, nickel and stainless steel were eliminated from competition because of cost and because they would introduce other metal contaminants, such as nickel and chromium, into the system. Low carbon steel is economical and introduces no foreign contaminant. The slight corrosion experienced after presoaking the ElectroPad™ may not look attractive but should not affect the processing. The low carbon steel anode makes a single, or possibly two time, use of the ElectroPad™.

Low carbon steel Exmet screen will be the anode material of choice for the Arlington demonstration. One-time use of pads is planned. Entire spent ElectroPads™ can be fed into the lead recycling process.

## Scoring tools

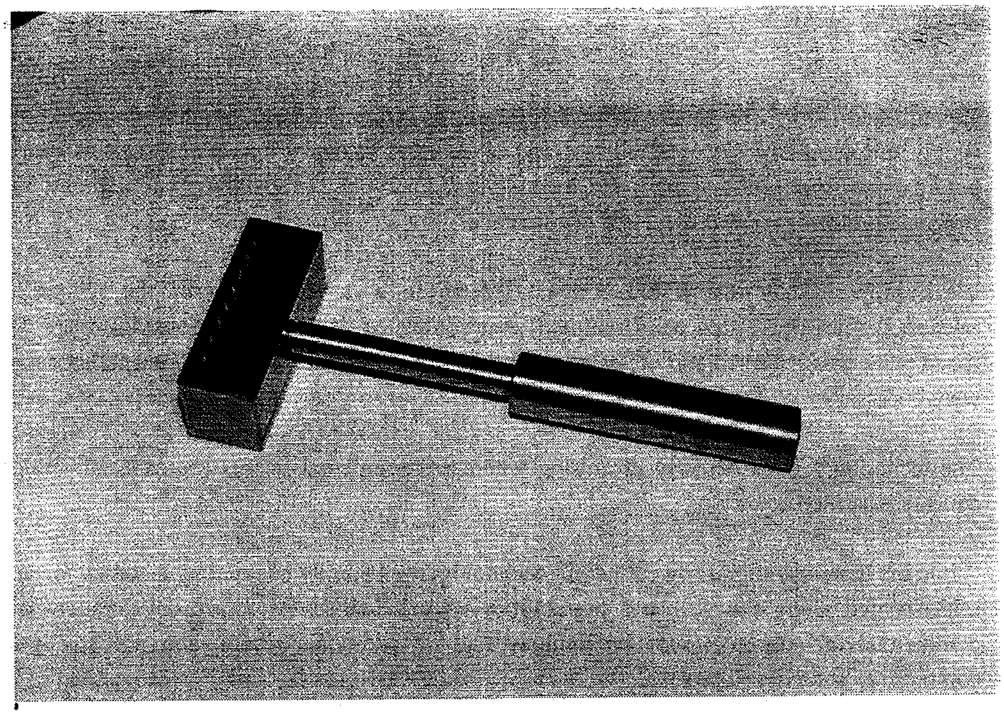
Two mechanical scoring tools have been tested for scaled-up use; they are shown in Figure 9. The first tool is a spring loaded carbide tipped tool that can be pulled across a surface to produce multiple scoring lines with 1 cm spacing. Hand scoring with this tool is more efficient than using a single-blade tool. The second tool consists of a commercial DESCO electric mini-flushplate tool, custom-fitted with a modified star cutter assembly. This rotating tool leaves score marks approximately every centimeter and allows its operator to quickly prepare the surface to be treated. The tool has a shrouded seal and loosened paint is collected by a HEPA vacuum; no dust is emitted into the environment during use of this equipment. This is particularly important when working on deteriorated coatings from which paint fragments detach. The DESCO tool is electrically driven. Tools driven by compressed air are significantly lighter and handier; such a tool has been acquired from PENTEK. A portable HEPA vacuum unit was also purchased.

Development of an additional, proprietary scoring tool was pursued outside this contract with funds from the Pennsylvania Ben Franklin program. It is designed as complementary tool, to be used on parts of the surface that are not flat and are hard to reach. This development, however, did not yet advance to a unit to be employed in field use.

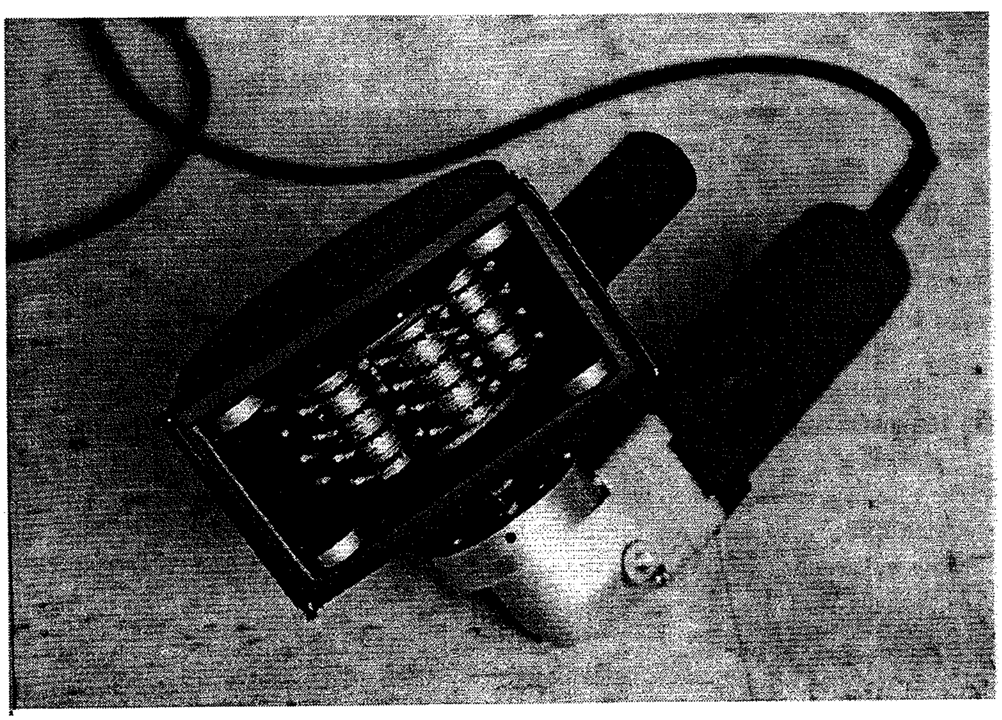
## Meeting of Corrosion Experts

Potential corrosion problems and fundamental aspects were discussed on 28 May 1997 in New Kensington with several corrosion experts. Mr. Samuel J. Manganello, Metallurgical Consultant and Dr. Don C. Kim, Senior Research Consultant, of U. S. Steel participated, also Dr. Richard D. Granata, Director of the Corrosion Laboratory at the Sinclair Laboratory of Lehigh University, and Dr. T. David Burleigh of the University of Pittsburgh.

In regard to hydrogen embrittlement, no problem exists at low strength steel, < 70 PSI strength. High-strength bolts may present a problem, although they have not been used in any structures typically in need of lead remediation. The conclusions reached by T. D. Burleigh during IDEA Phase I were confirmed. A method to identify high-strength bolts on site was recommended. Caution was voiced regarding scoring of welds; uninterrupted lines along welds may lead to problems. It may be advisable to use electrolytes other than sulfate, to eliminate any potential effect of bacterial reduction to sulfide.



**Tool to apply multiple scoring lines.**



**DESCO unit modified for ElectroStrip™ scoring.**

**FIGURE 9 Scoring tools.**

## CONCLUSIONS

The transition from one-square-foot tests to multipad testing was accomplished successfully. Equipment to supply the necessary electrical current and to conduct auxiliary operations such as scoring of the surface before electrochemical treatment and washing at the end before repainting was acquired and employed. The expected performance was achieved or surpassed.

Work supported by this IDEA contract led up to a demonstration of the ElectroStrip™ technology (electrochemically assisted paint removal) that confirmed the projected potential of the technology. Lead-based paint was removed and collected smoothly, and a minimum of environmental/occupational precautions were necessary.

The technology is particularly promising where environmental factors are especially important, such as in densely inhabited areas.

While the demonstration showed that the technology was readily adopted by a contractor, improvements were implemented along the way and possibilities were indicated for future development of the process. A commercial breakthrough may be unlikely without additional testing and process optimization, as it is common for such developments.

Focus of future efforts will be on incremental improvements of the process, additional demonstrations, and scale-up to commercial size equipment. Resources for these efforts are being solicited.

## INVESTIGATOR PROFILE

EMEC Consultants is a Sole Proprietorship founded in 1984. It is a Small Business presently employing three full-time employees, including Dr. Rudolf Keller, its proprietor and Principal Investigator of the project. EMEC Consultants is engaged in contractual research and development in electrometallurgy, electrochemistry and related areas. Several retirees of the ALCOA Laboratories participate as part-time advisors on a regular basis. In addition, Dr. T. David Burleigh, who played a key role in the invention, served as a consultant, also Mr. Daniel M. Hydock after his departure as an employee. EMEC Consultants maintains a laboratory of 3,200 square feet at the Schreiber Industrial District in New Kensington, Pennsylvania.

The ElectroStrip Corporation was formed to promote and commercialize the ElectroStrip™ technology. Dr. Rudolf Keller is its President, Mr. Brian J. Barca serves as Secretary/Treasurer. It is intended that this new entity will acquire exclusive rights from EMEC Consultants to practice and license the patented ElectroStrip™ technology.

## PUBLICITY

A four-page promotional brochure was prepared by the ElectroStrip Corporation and widely distributed around the end of 1997. A copy is added as Appendix III to this report. Periodic bulletins are issued and distributed. A web-site was created:

http:\\www.hyperionics.com\electrostrip.

Progress is up-dated.

A demonstration of the ElectroStrip™ technology was held at the Showcase in Arlington, on 15 May 1998.

Several publications, in conjunction with presentations at professional meetings, were prepared:

"Electrochemically Assisted Paint Removal -- an Emerging Technology to Remove Lead Based Paint from Metals, Proceedings of the SSPC 96 Seminars, SSPC 1996 International Conference and Exhibition.

"Electrochemically Induced Paint Removal -- An Environmentally Friendly Approach to Remove Lead-Containing Coatings From Steel", Extended Abstract, Joint Meeting of The Electrochemical Society and the International Society of Electrochemistry, Paris, France, September 1997.

"Paint Removal by the ElectroStrip™ Technology", Proceedings of the Paint - Depaint Technology Information Exchange, Concurrent Technologies Corporation, Contract No. DAAA21-93-C-0046, September 1997, pp. 439 - 445.

"Paint Removal by the ElectroStrip™ Process -- an Up-Date", Extended Abstracts, 1997 ACS Special Symposium on Emerging Technologies in Hazardous Waste Management, pp. 351 - 353.

Based on our publications, several write-ups summarizing or quoting our process appeared in various trade journals, often stressing occupational advantages of the process (as a consequence of this publicity, phone inquires and requests for additional information were obtained):

"Electrochemically assisted paint removal", CHEMTECH, April 1996, pp. 36-38.

"21st Century Painting", Chemical Engineering, July 1996, p. 37.

"New Lead Paint Removal System Said to be Safer for Workers", Lead Detection & Abatement Contractor, December 1996.

"Electrochemical Paint Removal Minimizes Environmental Contamination", Emerging Technology, a publication of the Civil Engineering Research Foundation (CERF).

An illustrated article was published in the Sunday edition of a local newspaper:

"ElectroStrip Process zaps away paint removal problems", FOCUS, Tribune-Review, 19 January 1997.

We participated with an exhibit at the 9th and 10th Annual Trade Show & Training Program of the Penn-Ohio Chapter of the Steel Structures Painting Council (SSPC) on 20 March 1997 and on 2 April 1998, respectively.

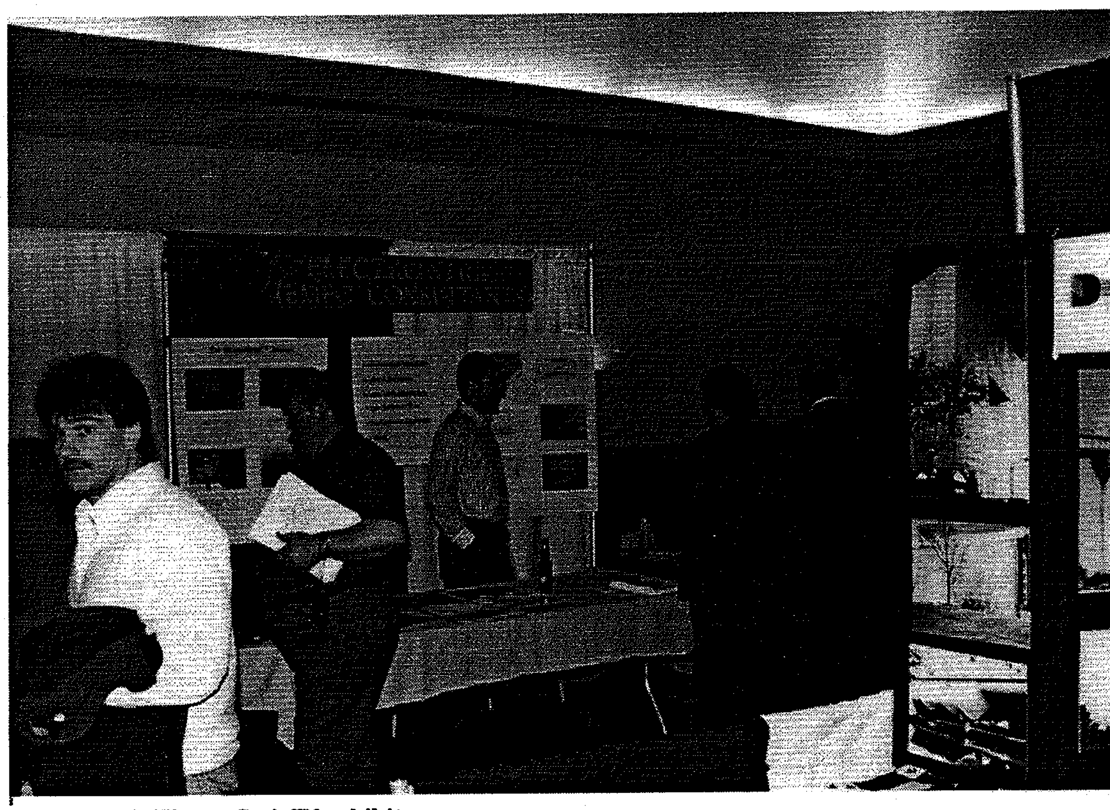


**FIGURE 10 ElectroStrip™ exhibit.**

# REFERENCES

[1]R. Keller, T. D. Burleigh, and D. M. Hydock, "Electrochemically Assisted Paint Removal From a Metal Substrate", U. S. Patent No. 5,507,926, issued on 16 April 1996.

[1]W. H. Bushman and D. R. Jackson, "Field Test of a New Procedure for Removing Lead-Based Paint from Bridges", Report VTRC 97-RP17, June 1998.

[1]Rudolf Keller, "Paint Removal from Steel Structures", IDEA Project Final Report, Contract NCHRP-94-ID023, May 1996.

# ElectroStrip™

## Demonstration in Arlington, Virginia

**Object:** I-66 overpass over Westmoreland Street in Arlington, Viriginia

**Owner:** Virginia Department of Transportation

**Contractor:** Superior Painting and Contracting Co., Inc., Baltimore, Maryland
John P. Korfiatis
(410) 282 7330

**Date:** 11 - 20 May 1998

**Description:** Paint was removed from an area of 800 $ft^2$ on a girder of the overpass, employing the ElectroStrip™ technology. Areas of up to 70 $ft^2$ were covered with ElectroPads™ and cathodic current applied to the steel for 1½ hours. Environmental emissions were small and did not require containment. Waste generation was limited to three 55-gallon drums of solid debris and about 100 gallons of wash water.

**Sponsor:** Virginia Department of Transportation
Mr. Bill Bushman, Virginia Department of Transportation Research Council
Mr. Donald Jackson, Office of Technology Application, Federal Highway Administration

**For information contact:**

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Dr. Rudolf Keller
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EMEC Consultants Laboratory
Brian J. Barca
New Kensington, PA 15068
(724) 335 2666 FAX (724) 335 8402

web-site: http://www.hyperionics.com/electrostrip

ElectroStrip™ Demonstration
I-66 Overpass in Arlington, VA
May 1998

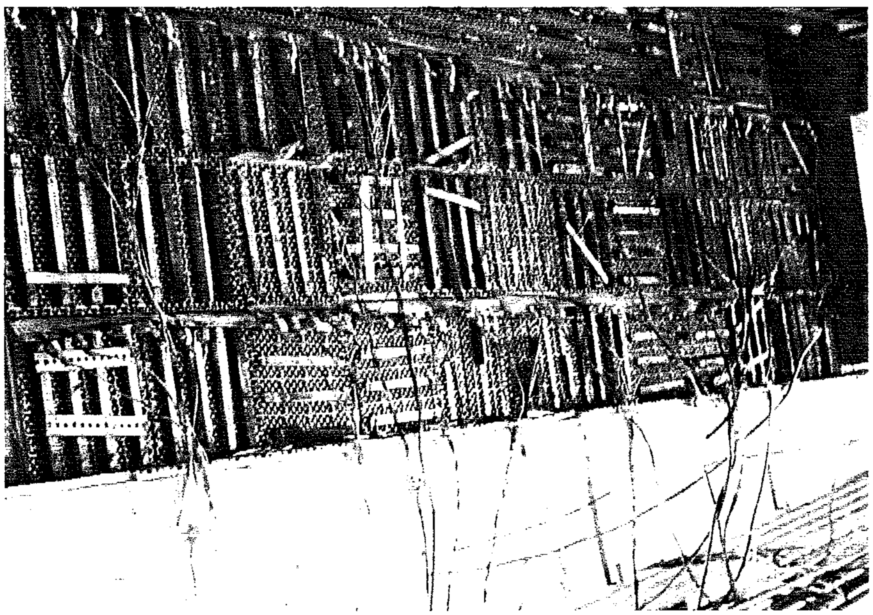
<1> VDOT Structure for Demonstration

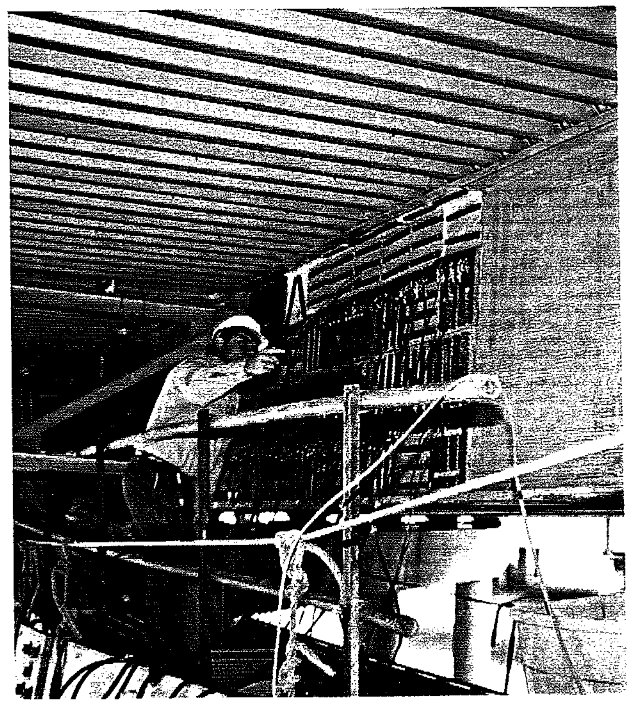
<2> Array of ElectroPads™

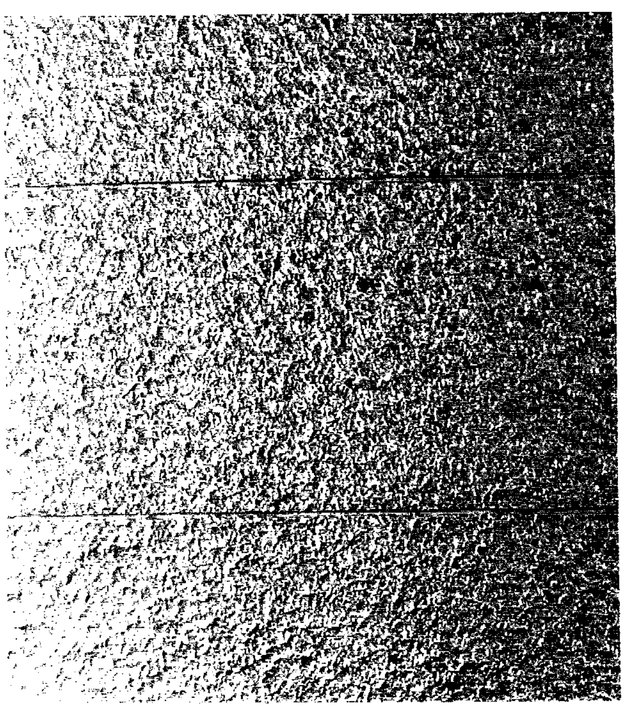
<3> John Korfiatis adding liquid

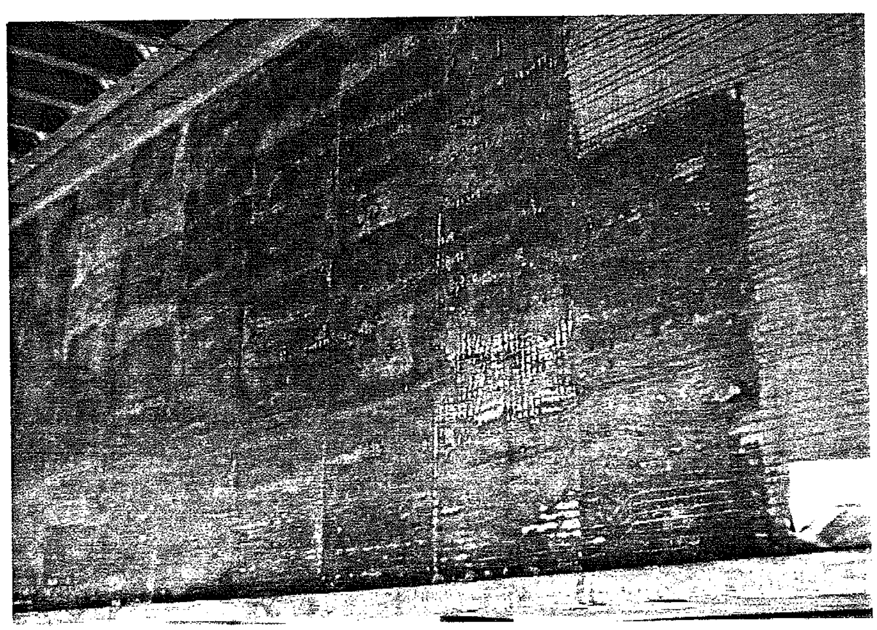
<4> Resulting surface, not showing flash rusting

<5> Surface after removal of pads and cleaning









# ElectroStrip™

## Remediation of Rails-to-Trails Bridge

**Object:** Rails-to-Trails (former railroad) bridge of Montour Trail, located in South Park, Pittsburgh area

**Owner:** Montour Trail Council

**Contractor:** Zenith Painting Company, Pittsburgh, PA 15215
Nick Chirigos, owner
Bob Lasagna, field engineer
(412) 784 8000

**Waste Disposal:** Two drums of solid waste shipped to Exide for recycling through American Waste Transport and Recycling, Inc.

**Date:** 19 - 30 October 1998

**Description:** The object was a former railroad bridge constructed in 1929. It was heavily corroded, covered with rust and to about a fourth with remaining paint. Paint was removed and rust was transformed by the ElectroStrip™ treatment and could be washed off. The area treated was about 500 $ft^2$. The contractor applied a three-coat paint system supplied by ICI Devoe Coatings: a penetrating sealer (Pre-Prime 167), an epoxy coating (Bar-Rust™ 235), and an aliphatic acrylic urethane (Devthane™ 369).

**Sponsorship:** EMEC Consultants
ICI Devoe Coatings

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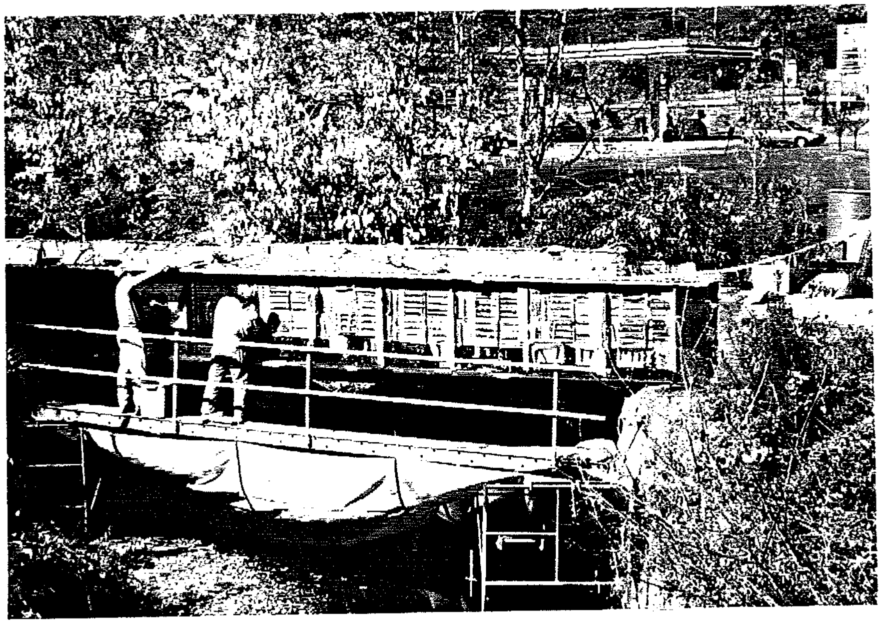

Bridge of Montour Trail near Brownsville Road, South Park, Pittsburgh, Pennsylvania

<1> Mounting of ElectroPads™

<2> Trail and equipment (rectifier and generator)

<3> Surface to be treated, showing paint remnants

<4> Washing of treated surface with Recyclean unit

<5> Repainted bridge