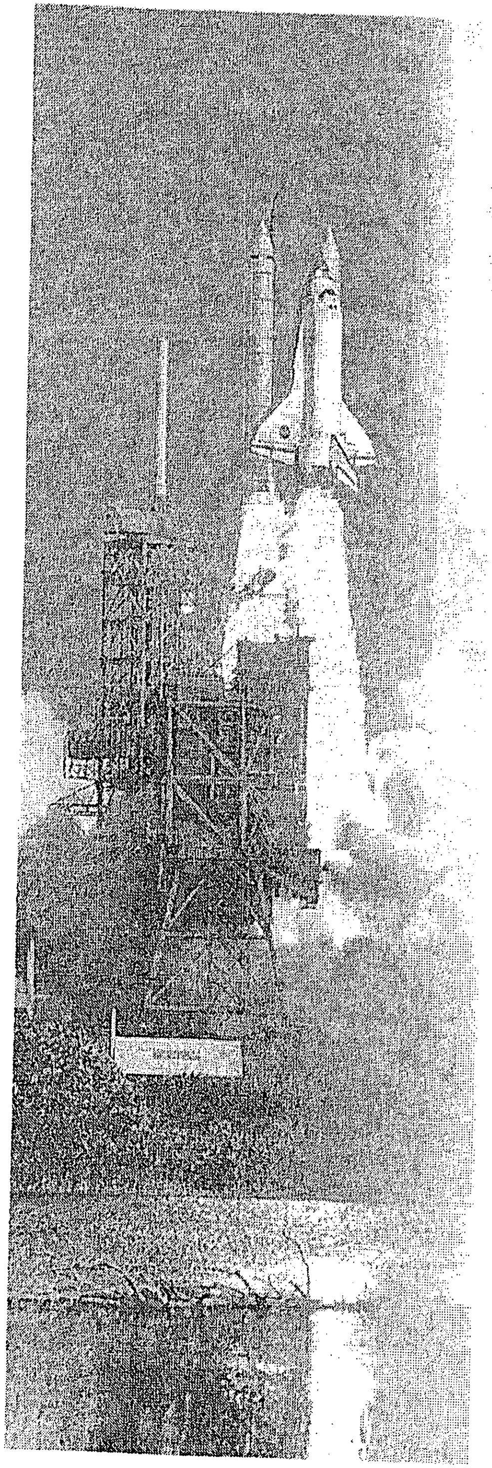
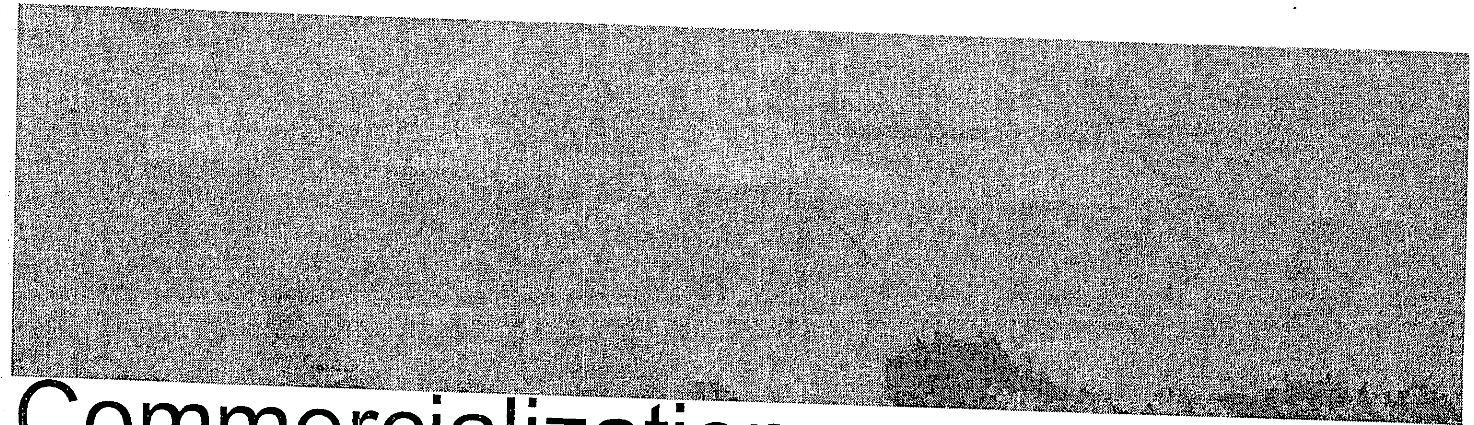
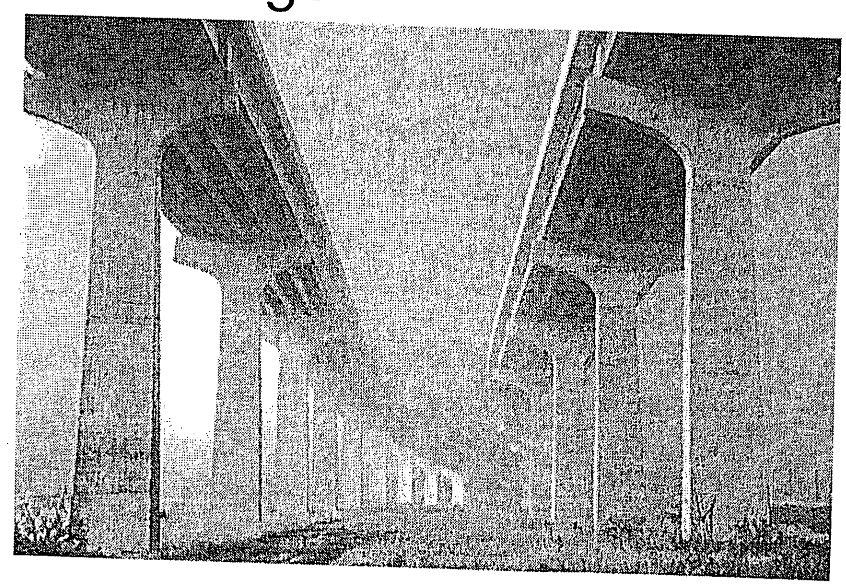
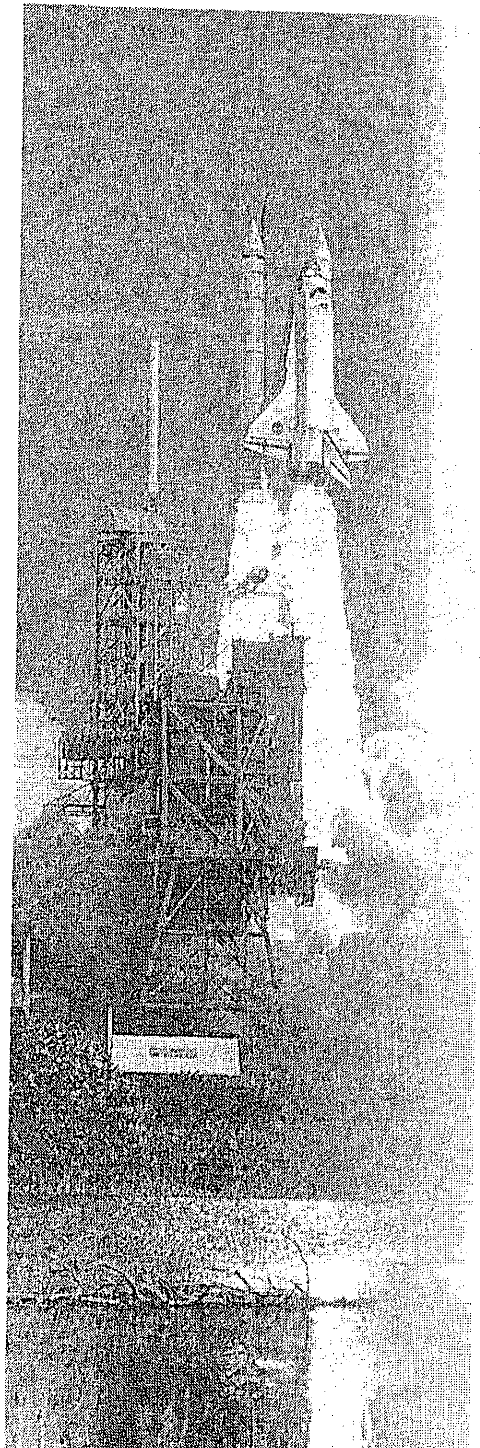


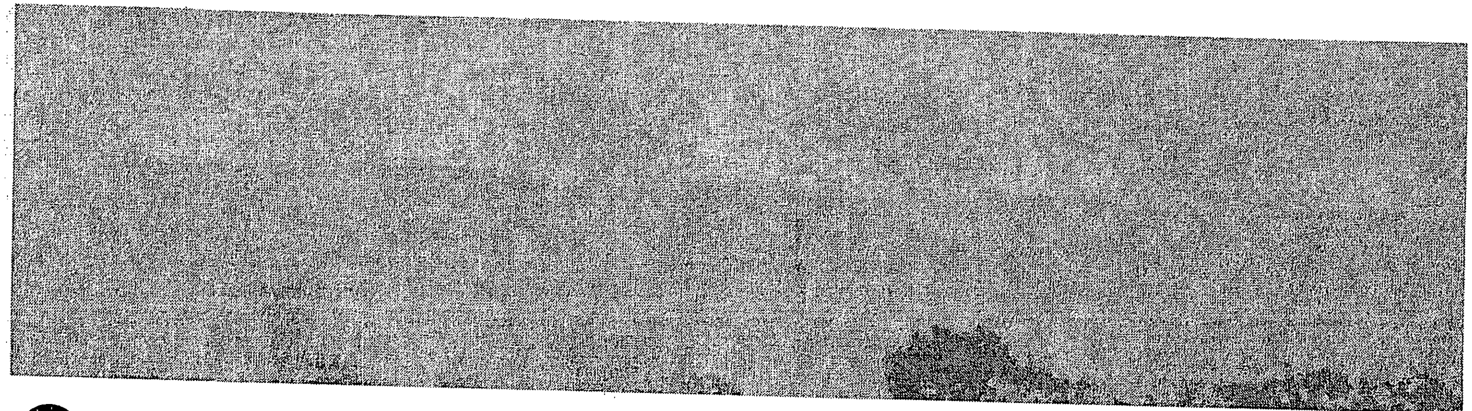


Commercialization--Applications:

- Highway and bridge infrastructures
- Piers and docks
- Concrete balconies and ceilings
- Parking garages
- Cooling towers



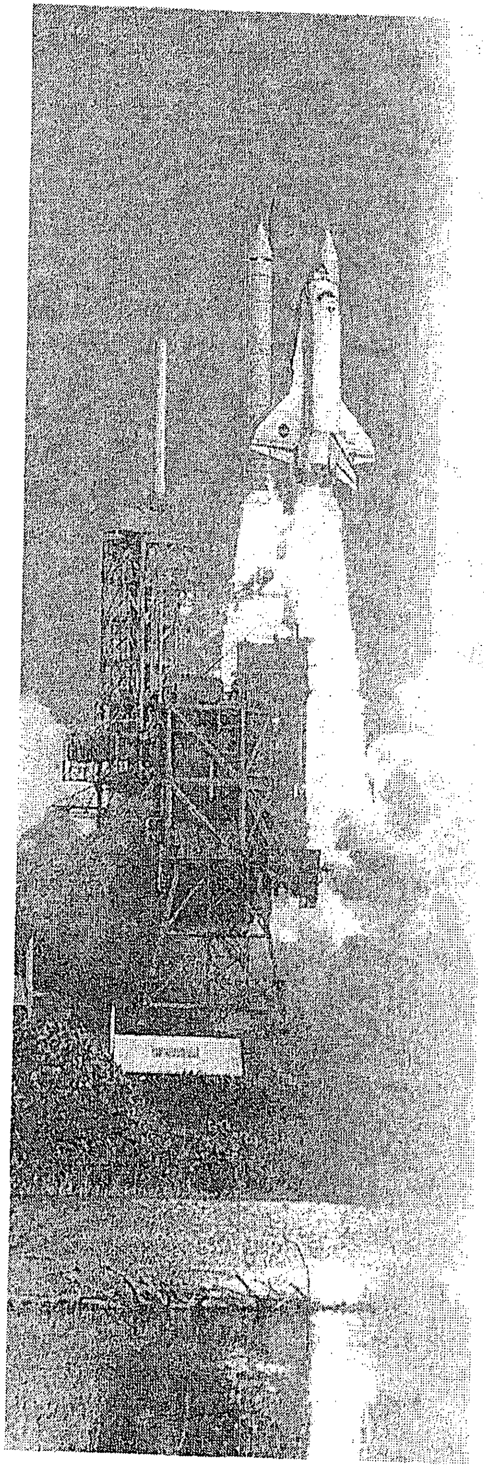


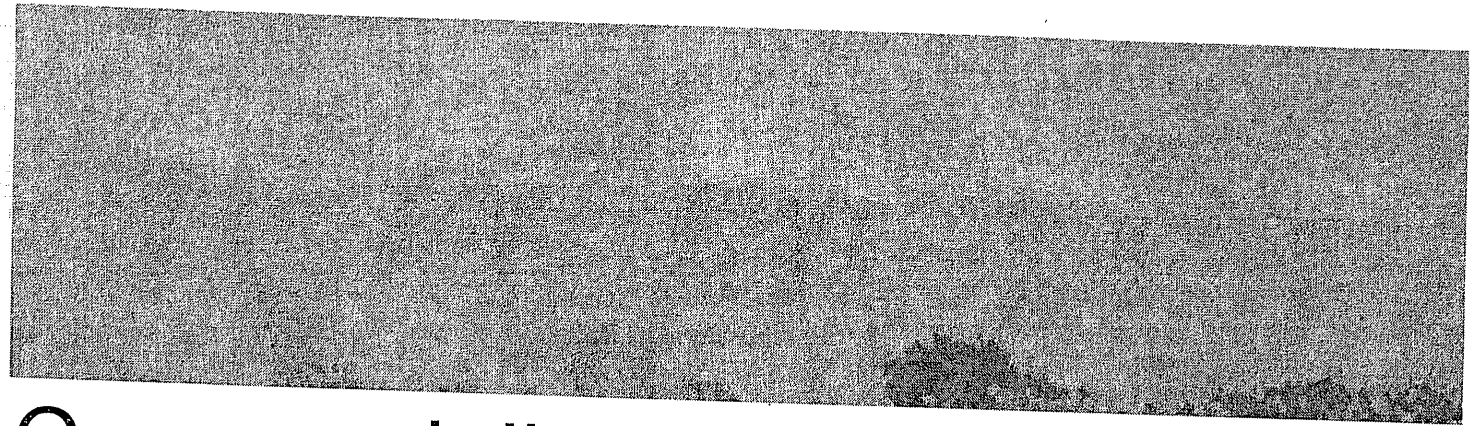


Commercialization Process:

- Technology Briefing
- Company expresses interest in technology—sign NDA and obtain detailed information about technology
- Company prepares a commercialization plan and a license/development application. Submit 5 copies to:

Vickie C. Johnston
Dynacs Incorporated
MS: DNX-4
Kennedy Space Center, Fl 32899
Vicki.Johnston-1@ksc.nasa.gov
1 (321) 867-8184



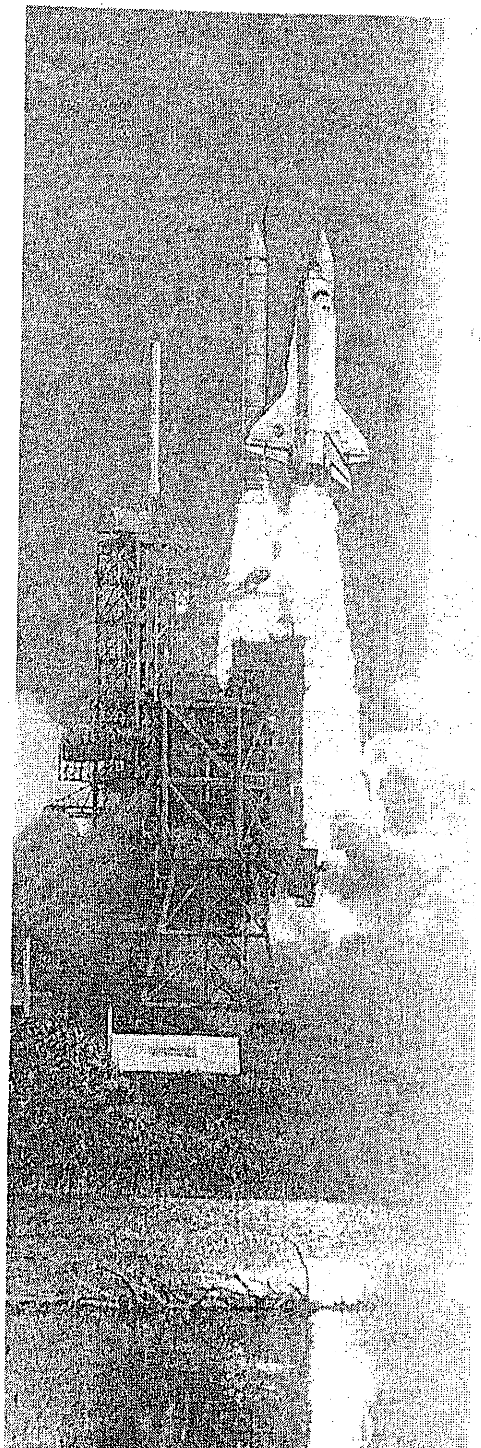


Commercialization Process:

- Information on how to submit a request for a license as well as evaluation criteria, can be found at:

  http://technology.ksc.nasa.gov/WWWaccess/Patents/license.htm

NASA Kennedy may grant licenses that are exclusive, exclusive for a specific field of use, partially exclusive, or non exclusive



Contact Information:

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Center for Technology Applications
RTI International
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Research Triangle Park, NC 27709-2194
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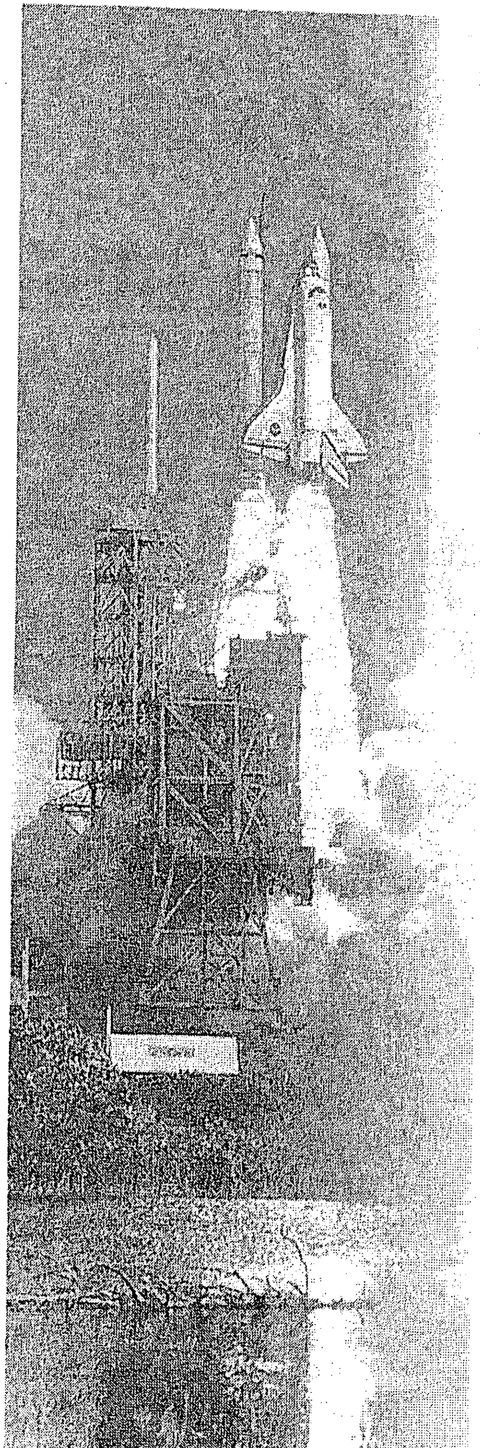

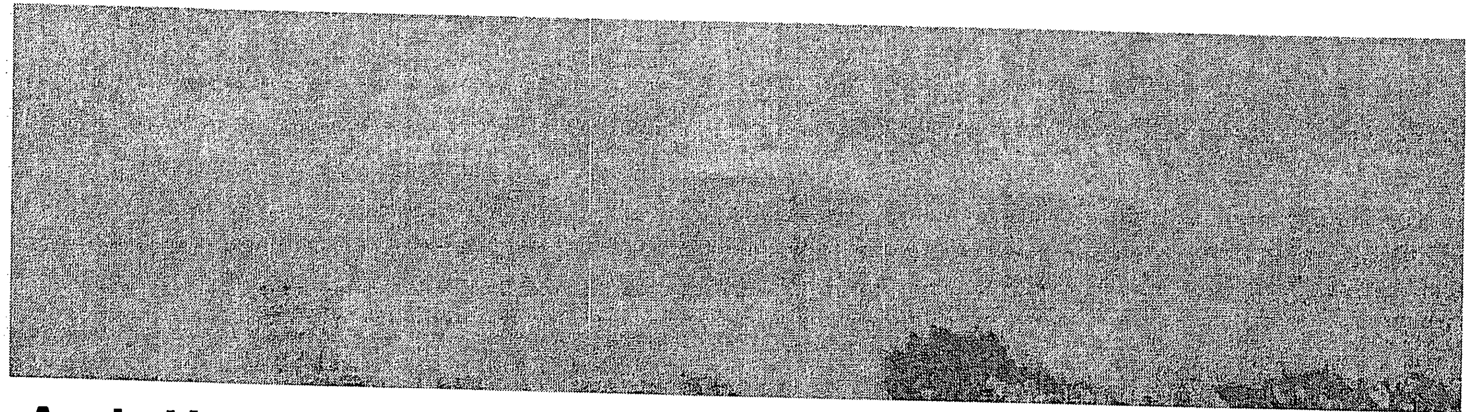

Additional Contact

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MS: YA-F2-T
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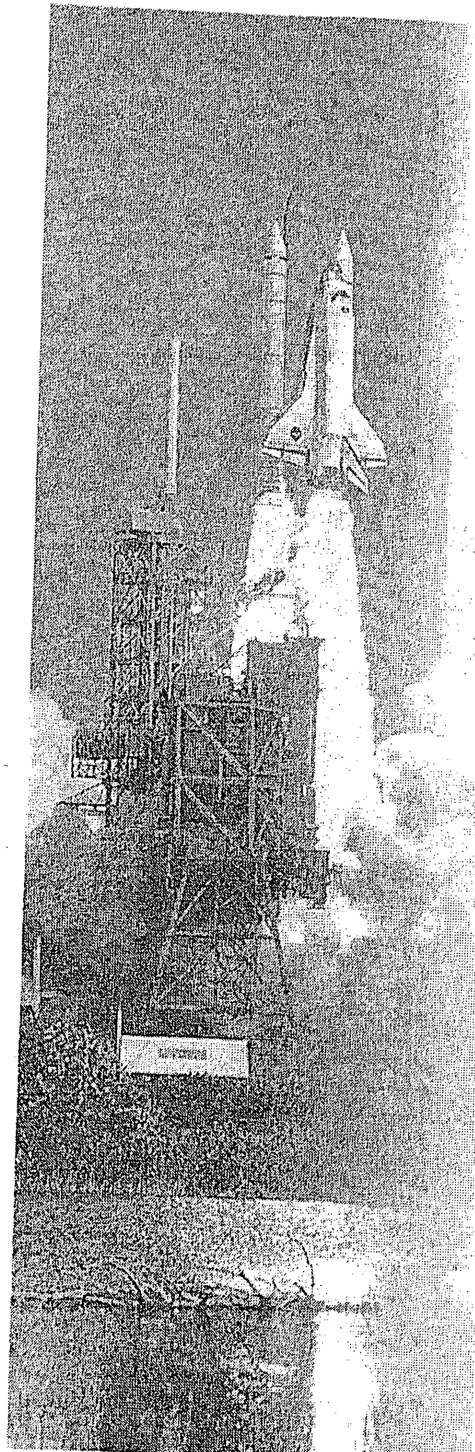
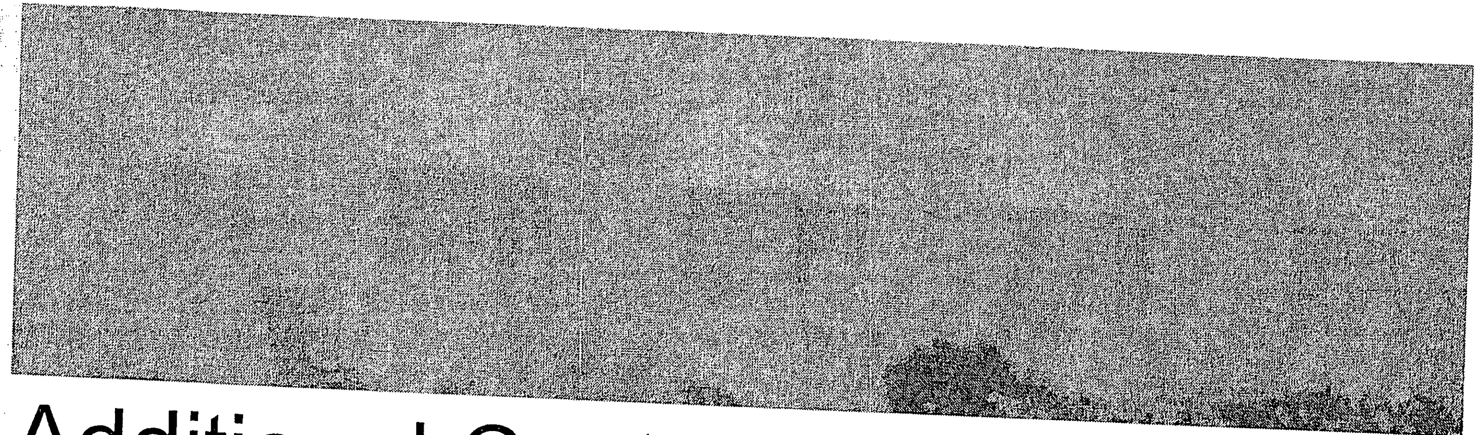
Louis.MacDowell-1@ksc.nasa.gov
1 (321) 867-4550





Additional Contact

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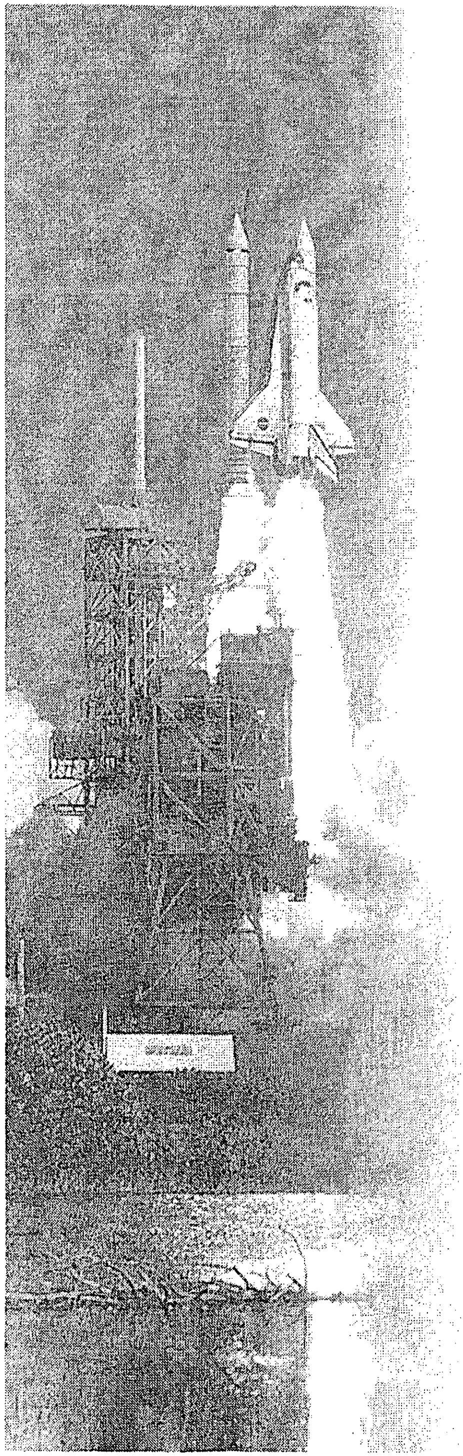
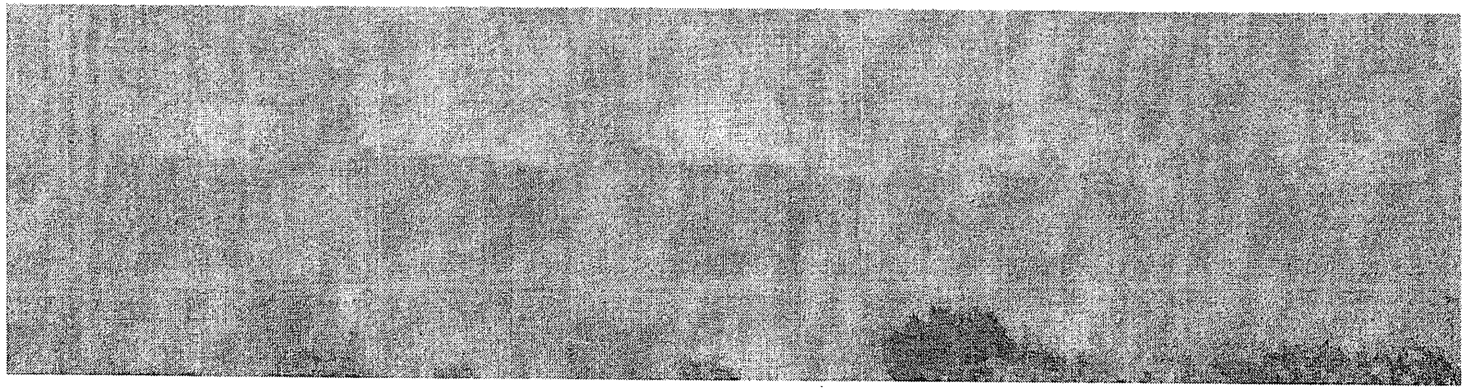
Kennedy Space Center, FL 32899
Joseph.Curran-1@ksc.nasa.gov
1 (321) 867-7558
1 (321) 867-4010





Galvanic Liquid Applied Coating System

for Protection of Embedded Steel Surfaces from Corrosion

Joseph Curran (Dynacs)

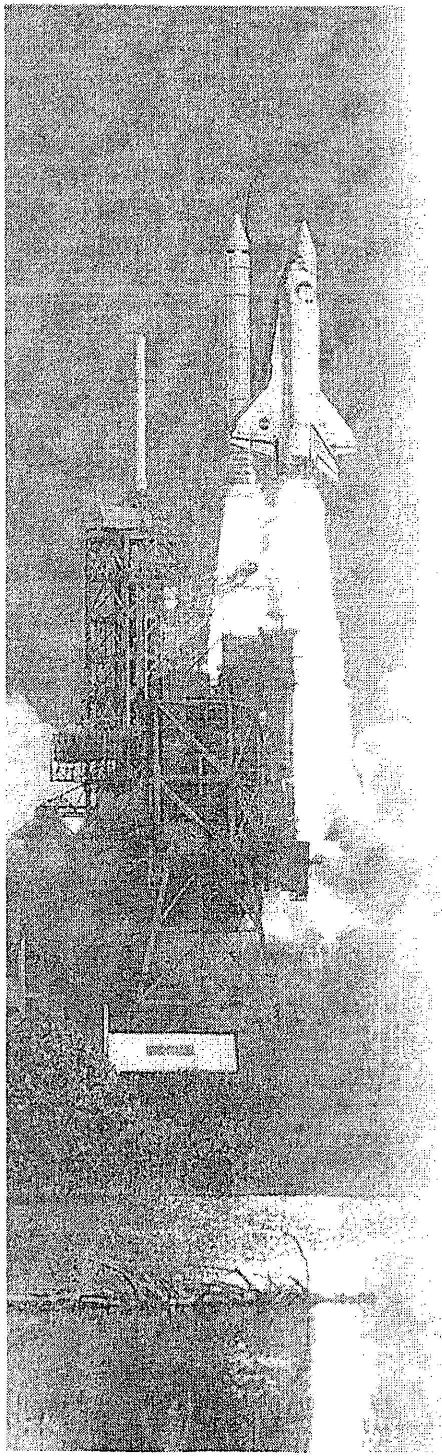
Chemical Instrumentation and Processing Laboratory

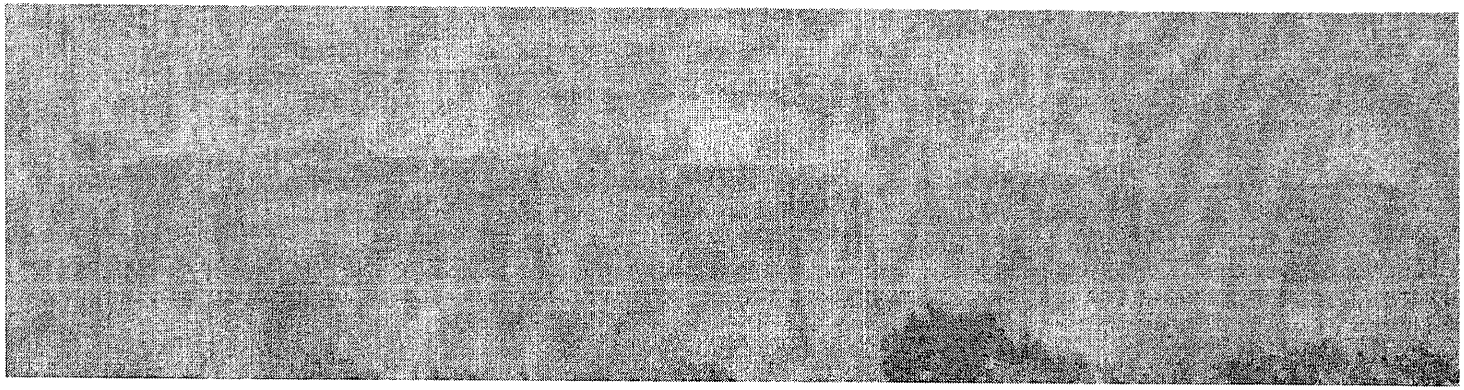
Louis MacDowell (NASA)

Labs and Testbeds Division

Kennedy Space Center

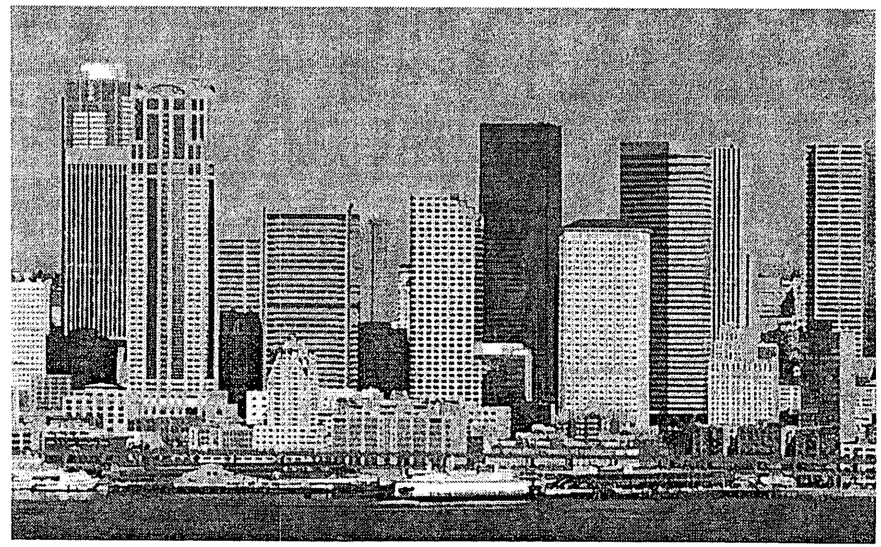
May 31, 2002

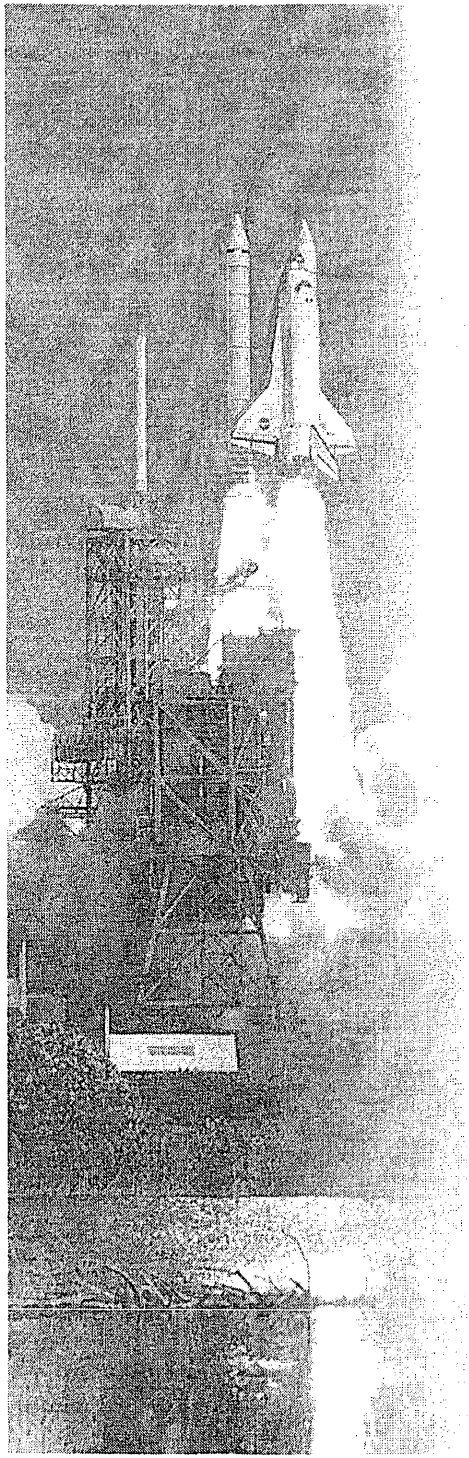




Overview:

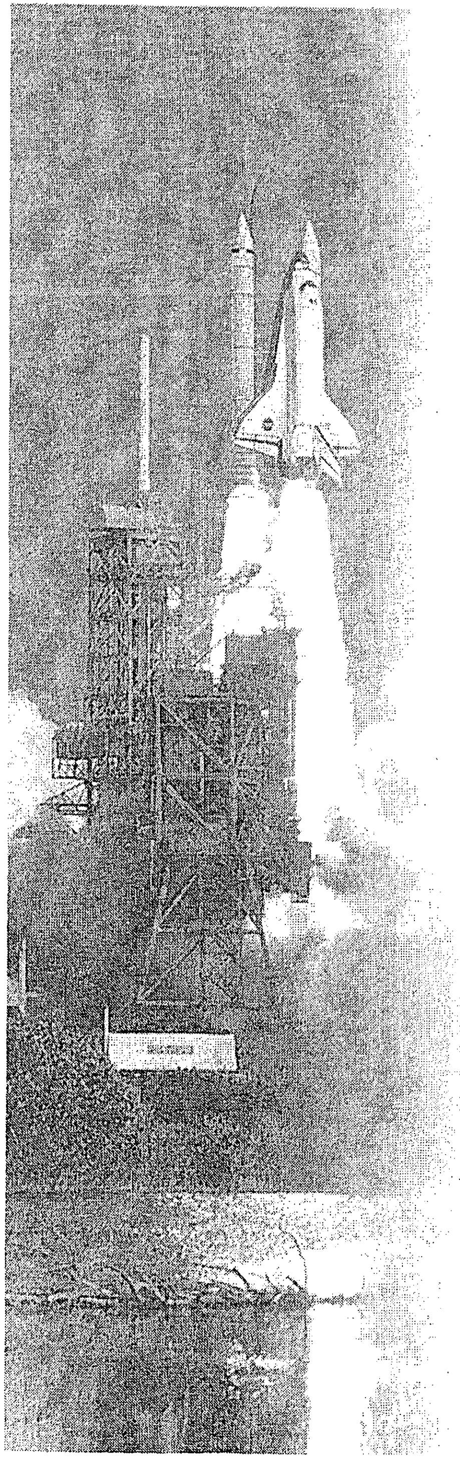
- History
- Technology
- Testing
- Commercialization
- Questions

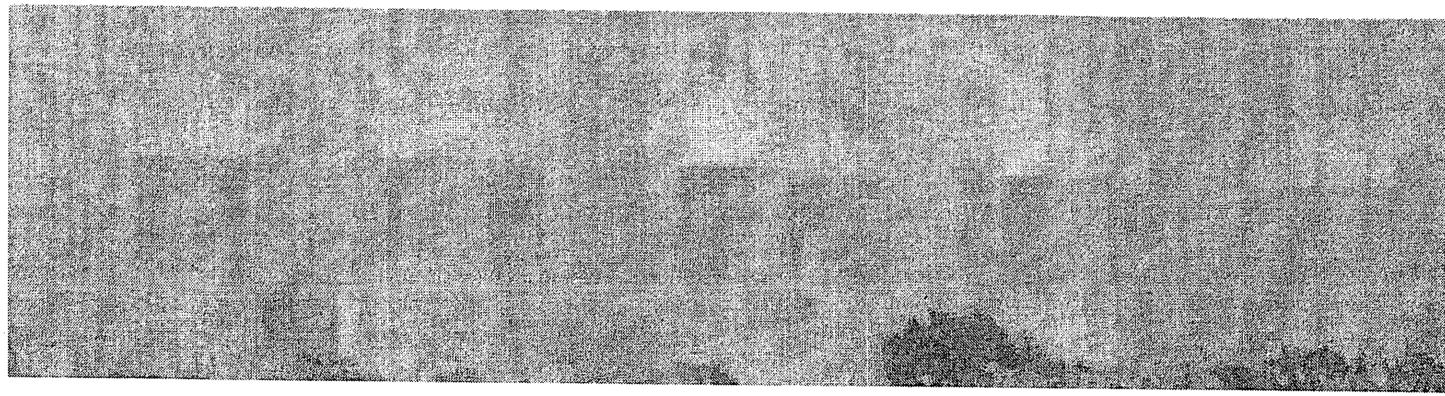




Historical Background:

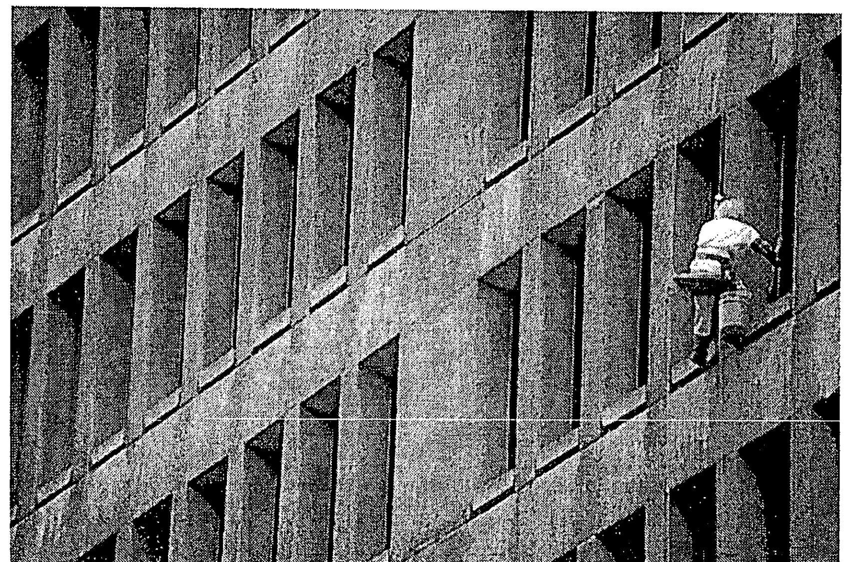
- Corrosion of reinforcing steel in concrete is an insidious problem for Kennedy Space Center, government agencies, and the general public
- Existing corrosion protection systems on the market:
  - Costly, complex, and time-consuming to install
  - Require continuous maintenance and monitoring
  - Require specialized skills for installation

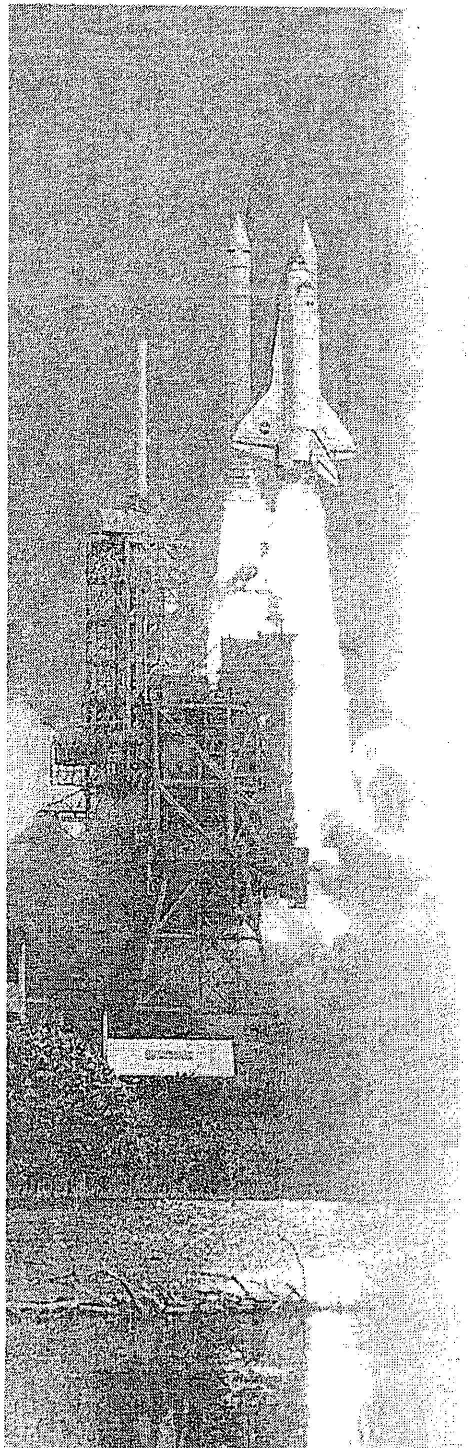




Technology:

NASA's galvanic liquid applied coating offers companies the ability to conveniently protect embedded steel rebar surfaces from corrosion

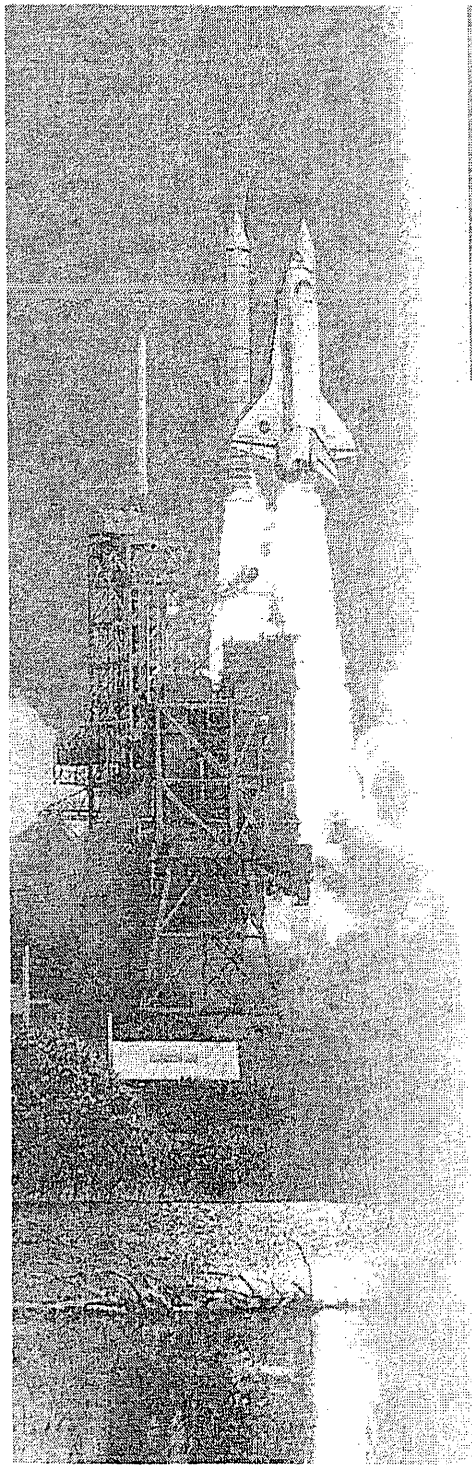


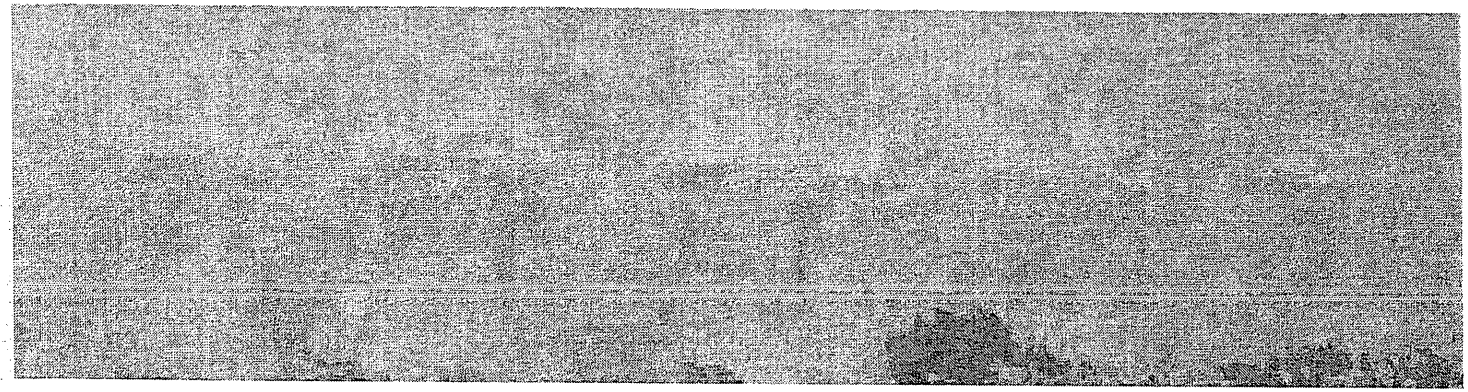


Technology:

- Liquid-applied inorganic, galvanic coating contains one or more of the following metallic particles:
  - Magnesium
  - Zinc
  - Indium

May contain moisture attracting compounds that facilitate the protection process



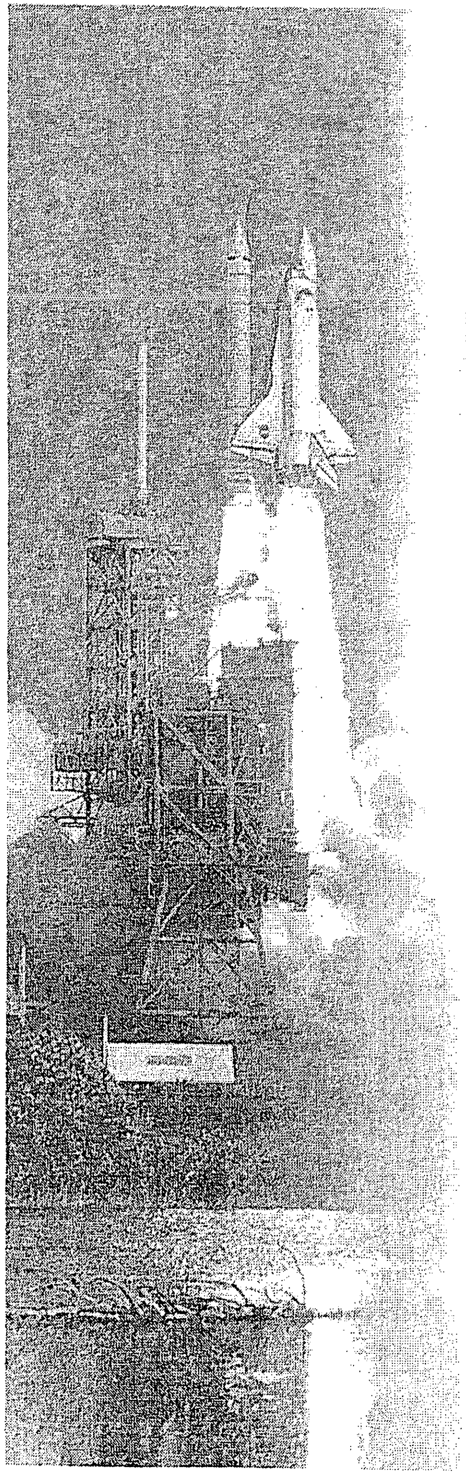


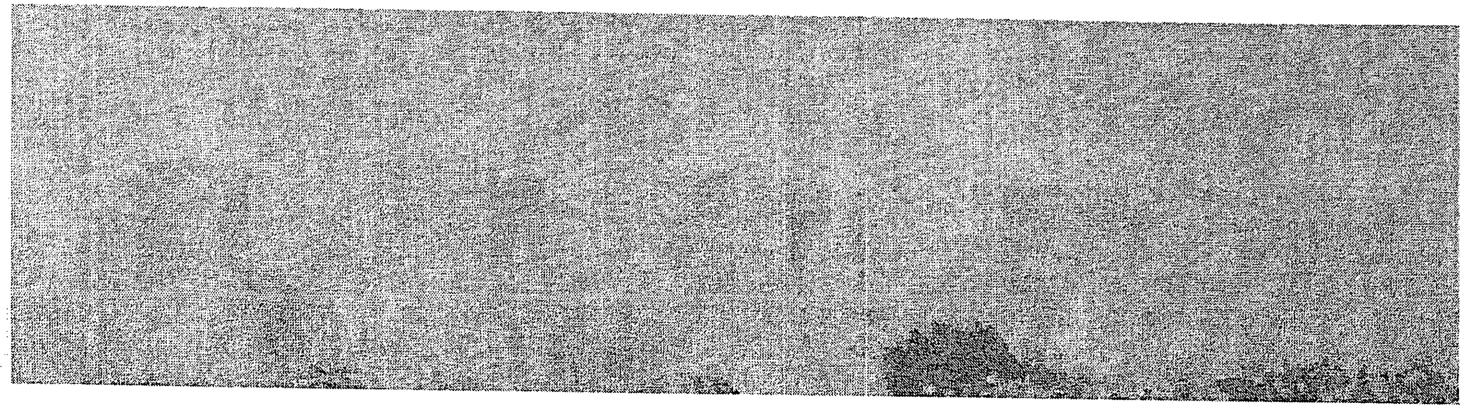
Technology:

The coating is applied to the outer surface of reinforced concrete:

Electrical current is established between metallic particles and surfaces of embedded steel rebar

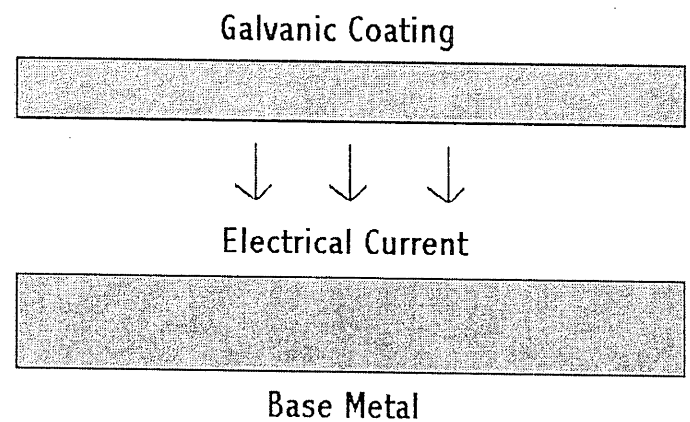
Electrical (ionic) current is responsible for providing the necessary cathodic protection for embedded rebar surfaces





Technology:

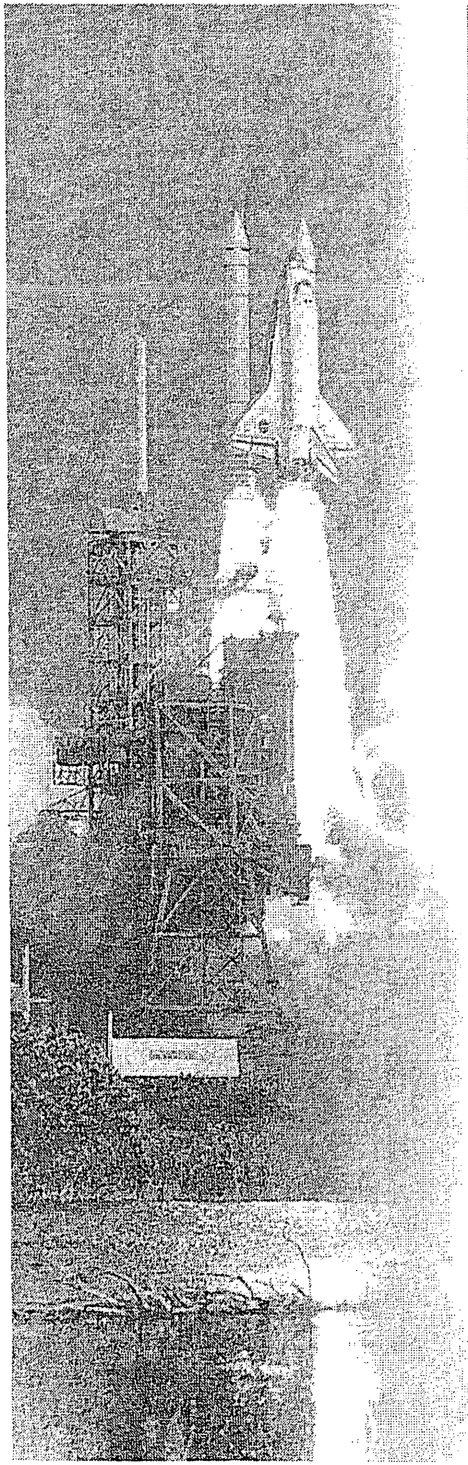
Cathodic protection using galvanic coatings:

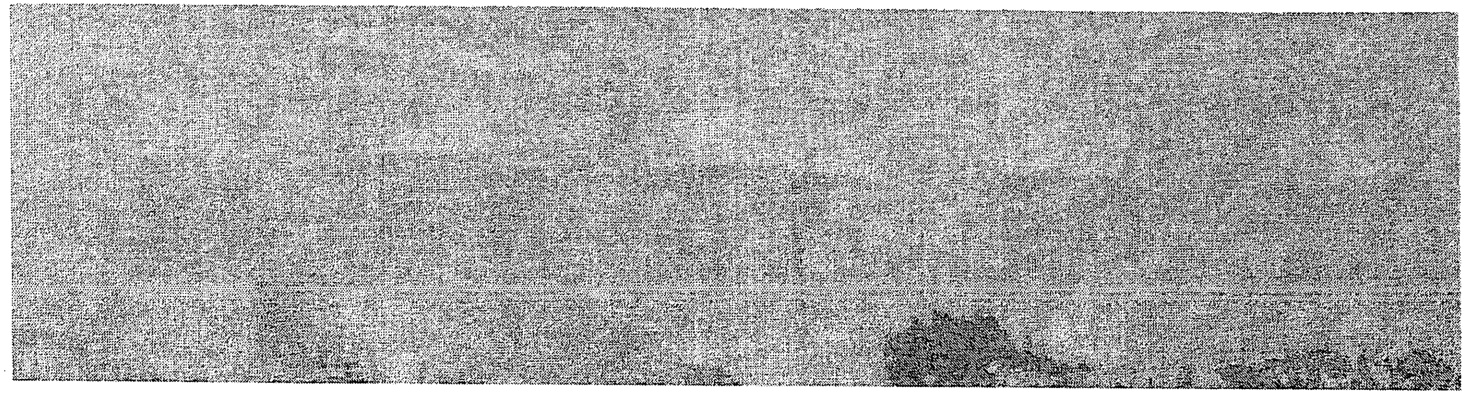


–Electrical current flows to surface of base metal

–Electron supply prevents metal ion loss from natural corrosion process

Galvanic coatings are currently used to

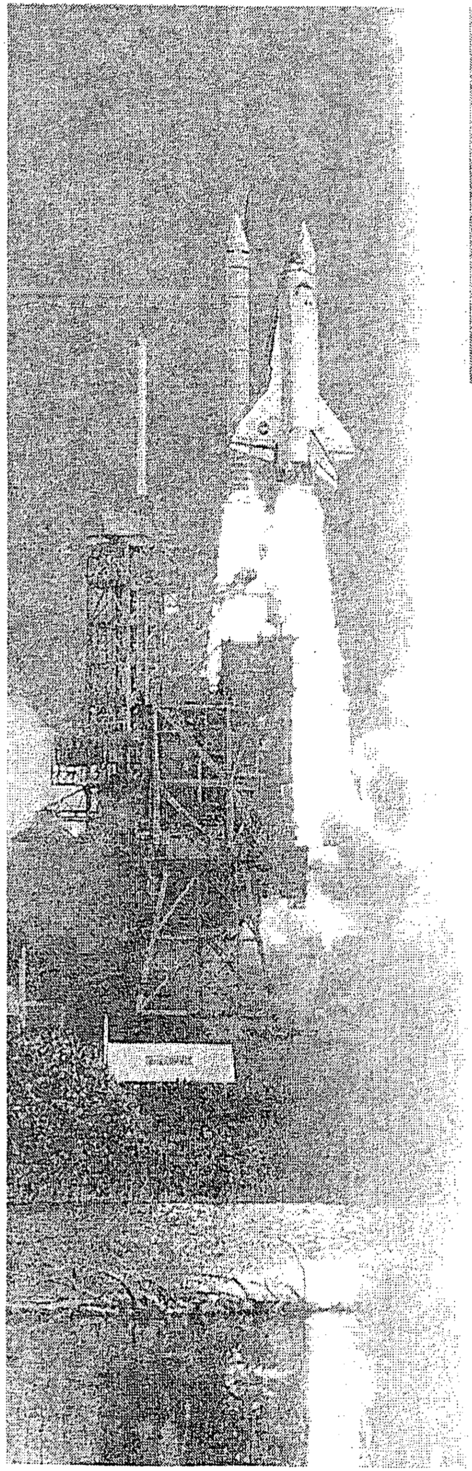


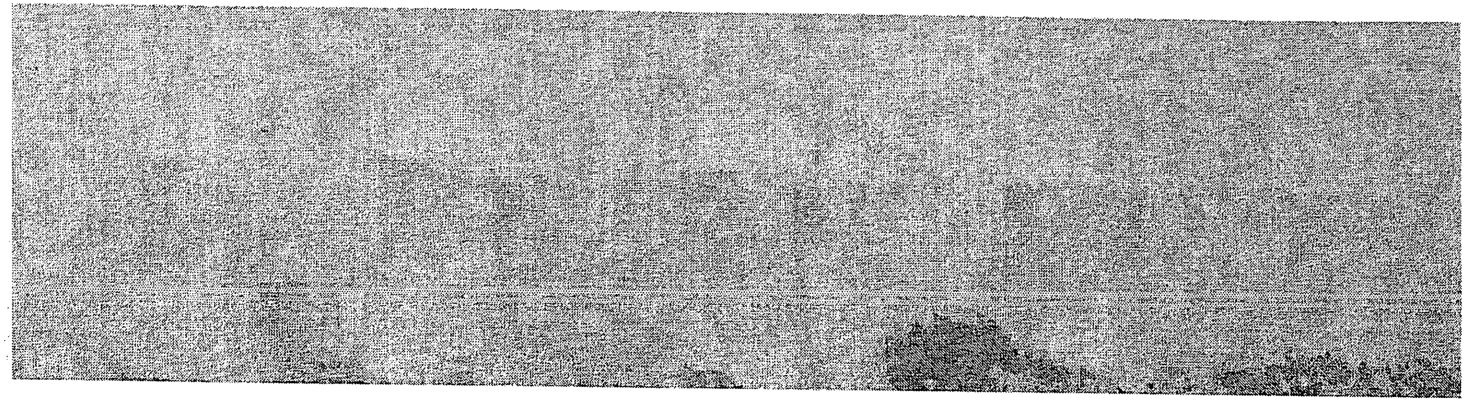


Technology:

Benefits:

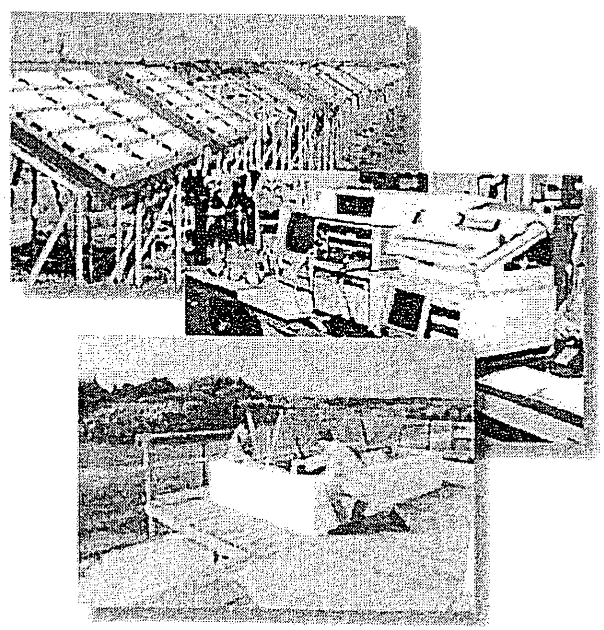
- –Coating applied to outer surface of reinforced concrete—not directly to rebar
- –Application performed quickly by spraying or brushing
- –Low cost achieved with relatively inexpensive labor and materials
- –Coating lasts 10 years or more, resulting in reduced maintenance cost
- –Coating easily re-applied to provide extended protection (>10 years)
- –Corrosion prevention achieved after construction is complete



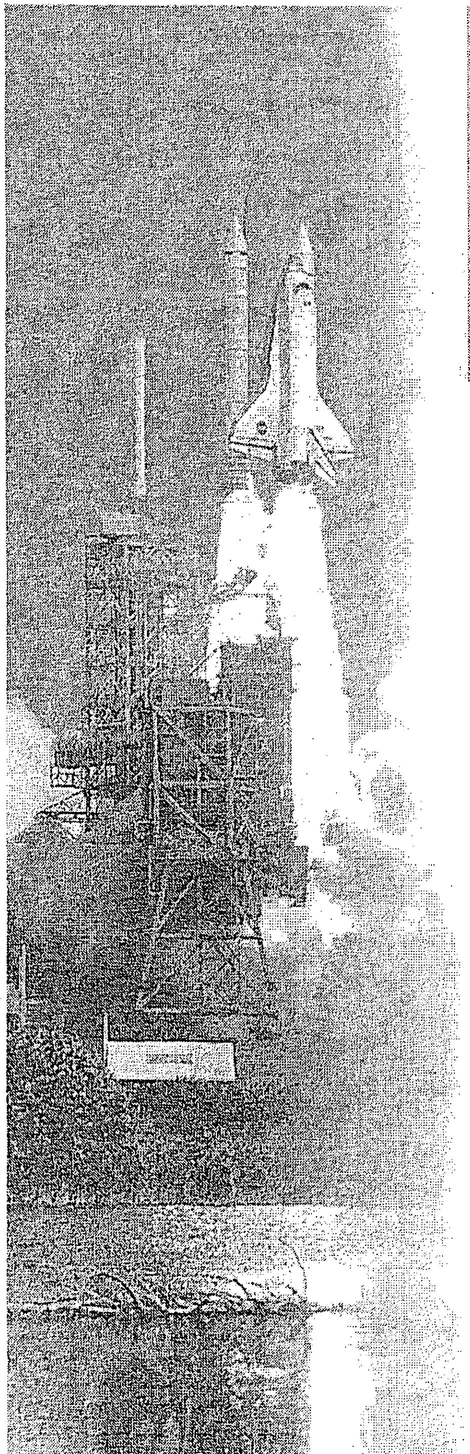


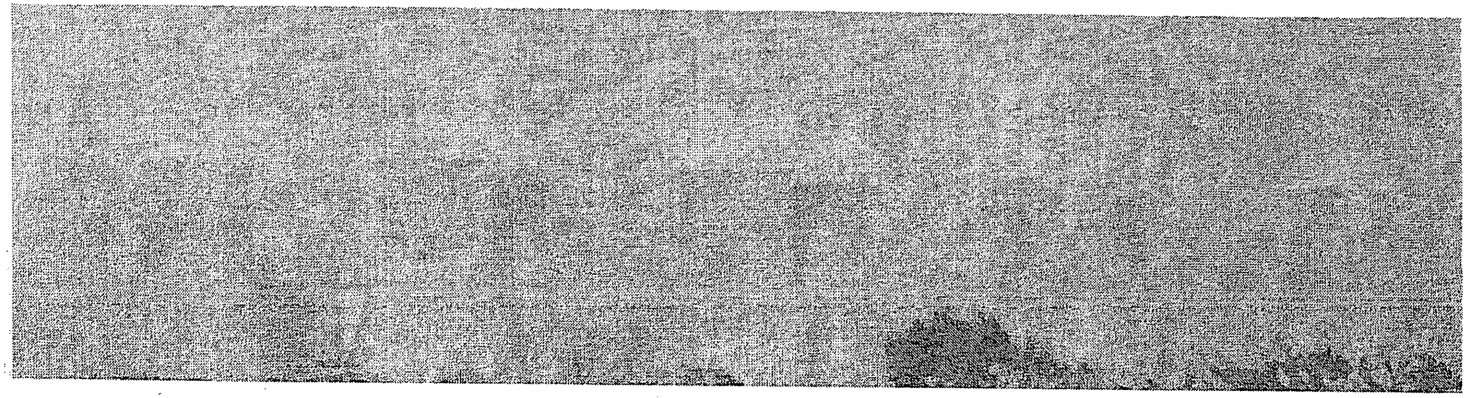
Testing:

Coating performance has been characterized by Kennedy Space Center's Materials Science Laboratory and Beach Corrosion Test Site



This site was established in 1960s to evaluate coatings used to protect steel in the structures of the early space program

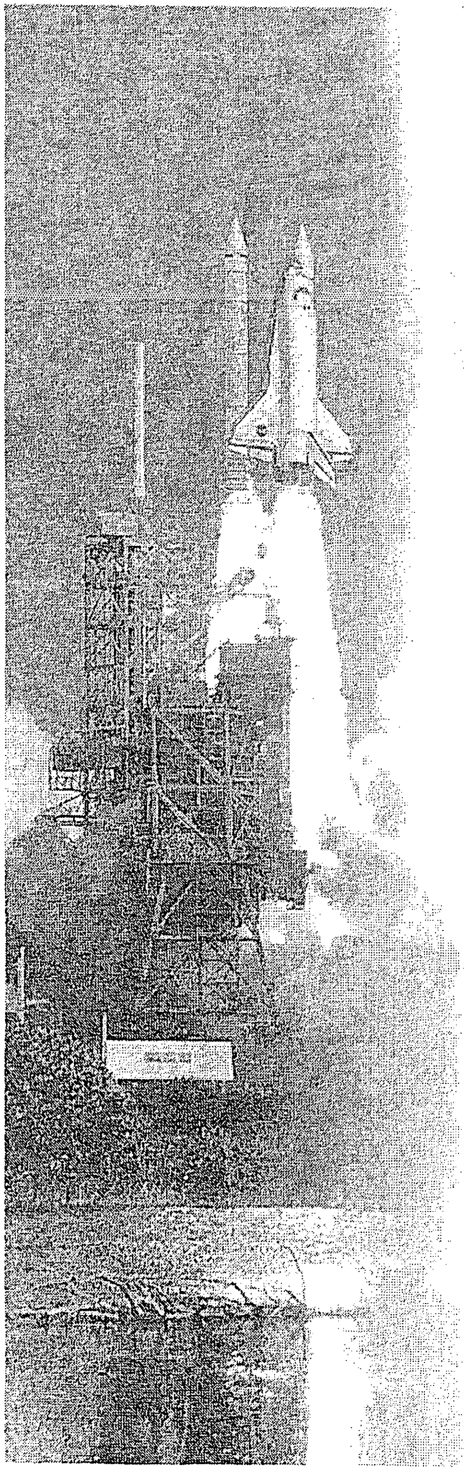




Testing:

- Phase 1 tests concentrate on formulation of coatings having the following characteristics:
  - –Easy application
  - –Predictable galvanic activity
  - –Long-term protection
  - –Minimum environmental impact

These new coating traits, along with the electrical connection system, will successfully protect the embedded reinforcing steel through the sacrificial cathodic protection action of the coating

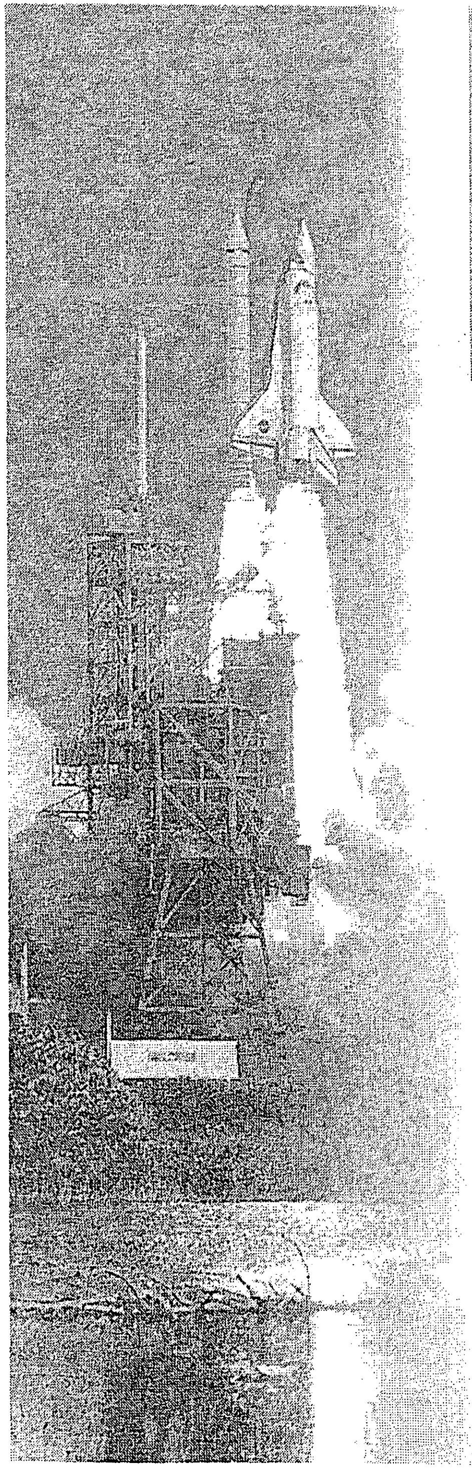


Testing:

- Phase 2 tests concentrate on improving the formulation of the coating through:
  - –Optimization of metallic loading
  - –Incorporation of humectants for continuous activation of the coating system

- Phase 3 incorporates improvements to the test blocks

- Phase 4 tests will incorporate the final upgrades into large reinforced concrete structures that are heavily instrumented

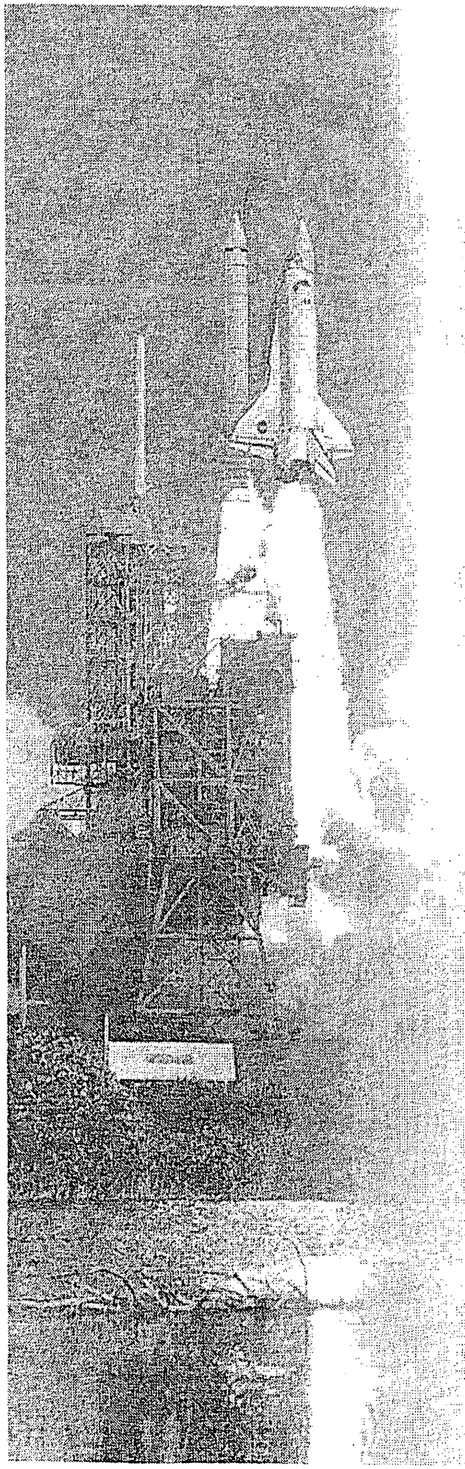


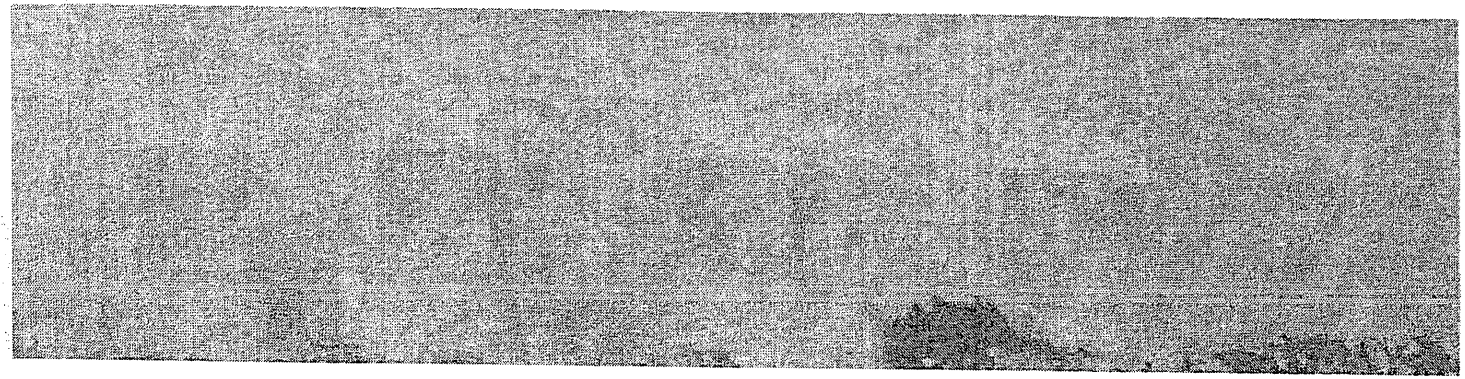
Testing—Phase 1 Results:

Phase 1 Results were obtained at the Beach Corrosion Facility from Jan 10-16, 2000

–Blocks were exposed to outdoor environments for six days, during which there were two rain events, one minor and one major. The data for the major event is shown on the next slide.

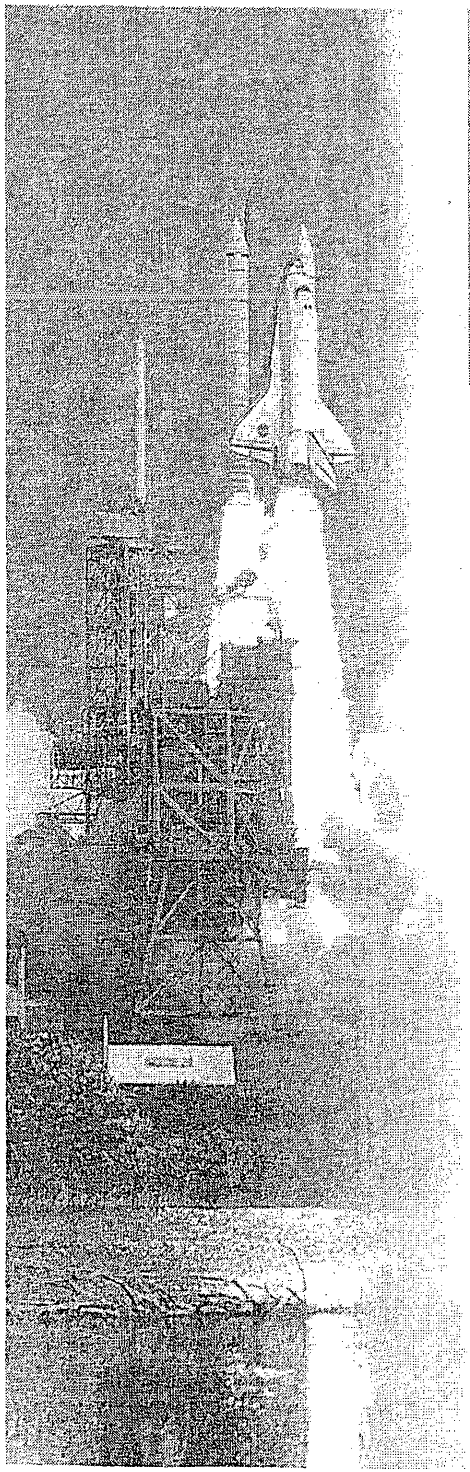
–When the current and potential data are graphed and correlated with weather data, coatings with magnesium included have a longer protection period, starting sooner and ending later than the coatings without magnesium

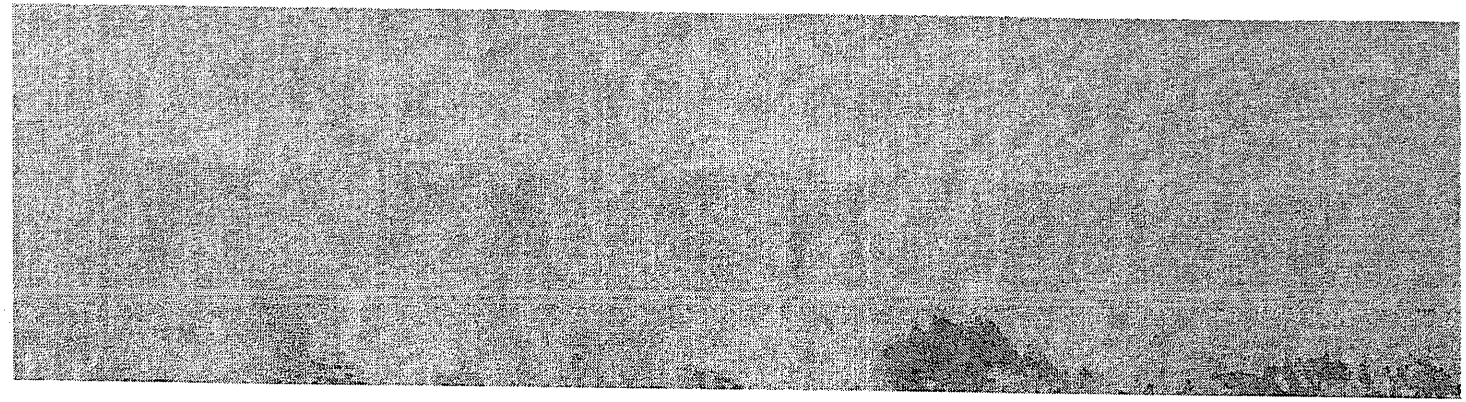




Testing—Phase 1 Results:

TEST PARAMETERS Phase I Designations				BEFORE RAIN		AFTER RAIN		CHANGES		PROTECTION SUMMARY	
Block #	Mg %	Zn %		I (uA)	V (mV) Ag/AgCl	I (uA)	(mV) Ag/AgCl	ΔuA	ΔmV	Corrosion	Protection
1	25	75		0	-30	270	-260	270[5]	-230	?	Good
3	0	100		na	-300	na	-330	na	-30	Yes	na
4	0	100		400	-300	700	-350	300	-50	?	Good
6	100	0		0	-30	5	-40	5	-10	No	Fair
7	0	100		0	-50	5	-130	5	-80	?	Fair
8	50	50		5	-60	20	-100	15	-40	No	Fair
9	50	50		0	-170	350	-350	350[5]	-180	No	Good

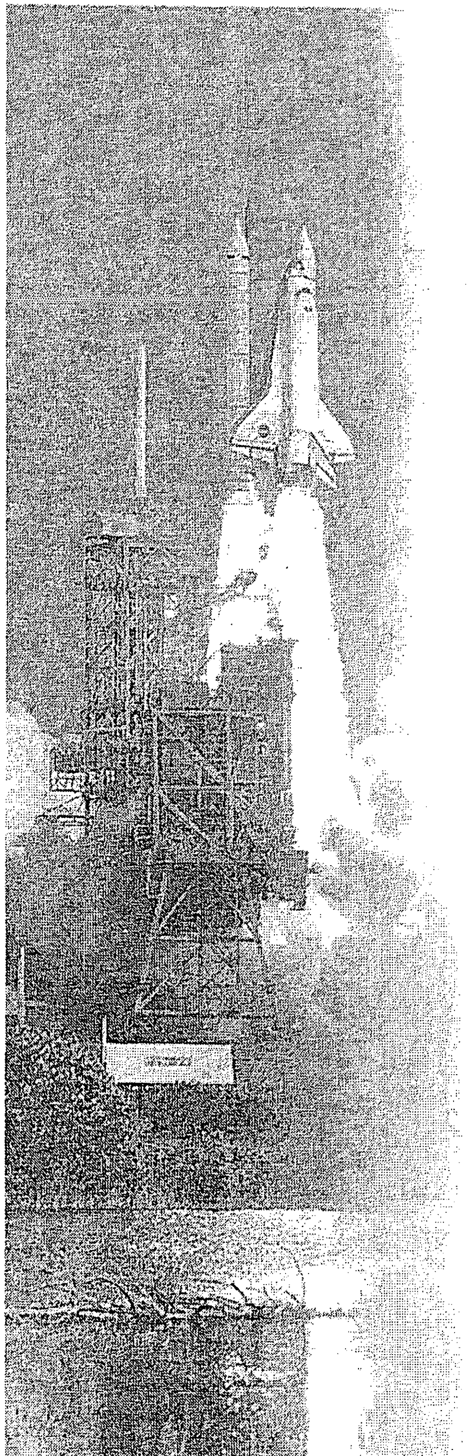




Testing—Phase 1 Results:

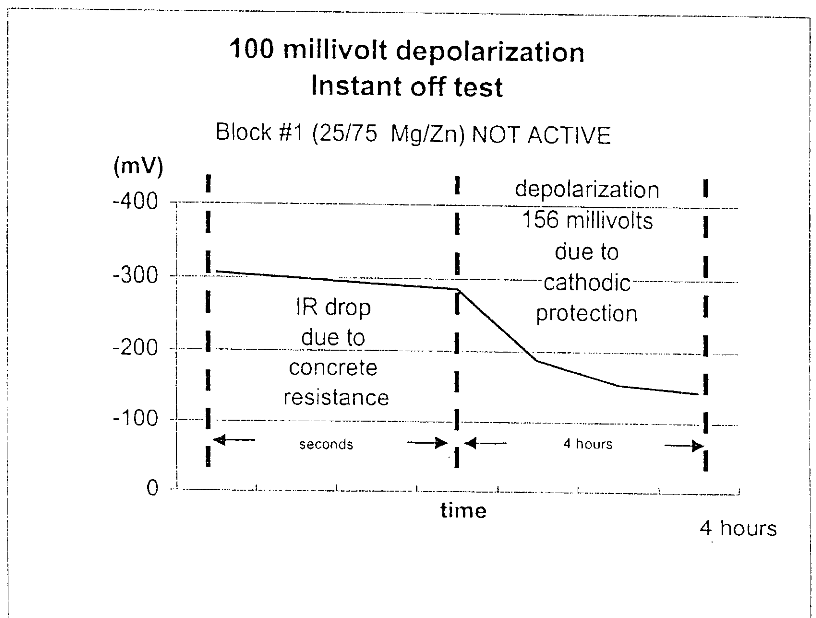
Final selection of a coating composed of 25% Mg and 75% Zn was made on the basis of depolarization method.

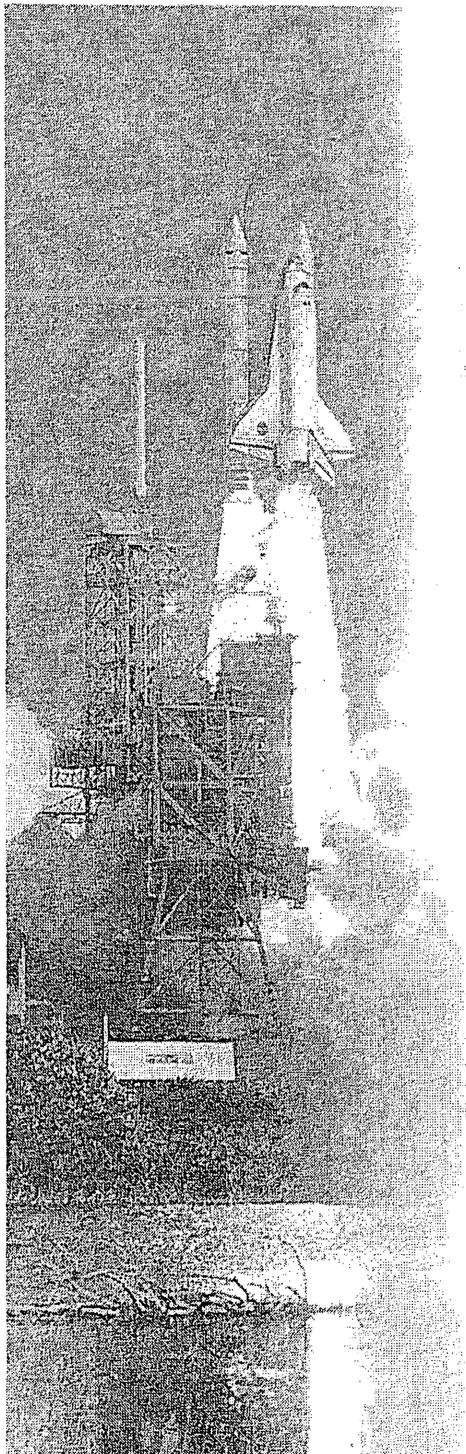
Mg/Zn	Active	Block #	Depolarization, mV
25/75	NO	1	156
0/100	YES	4	78
100/0	NO	6	35
0/100	NO	7	47
50/50	YES	9	28
25/75	YES	10	145

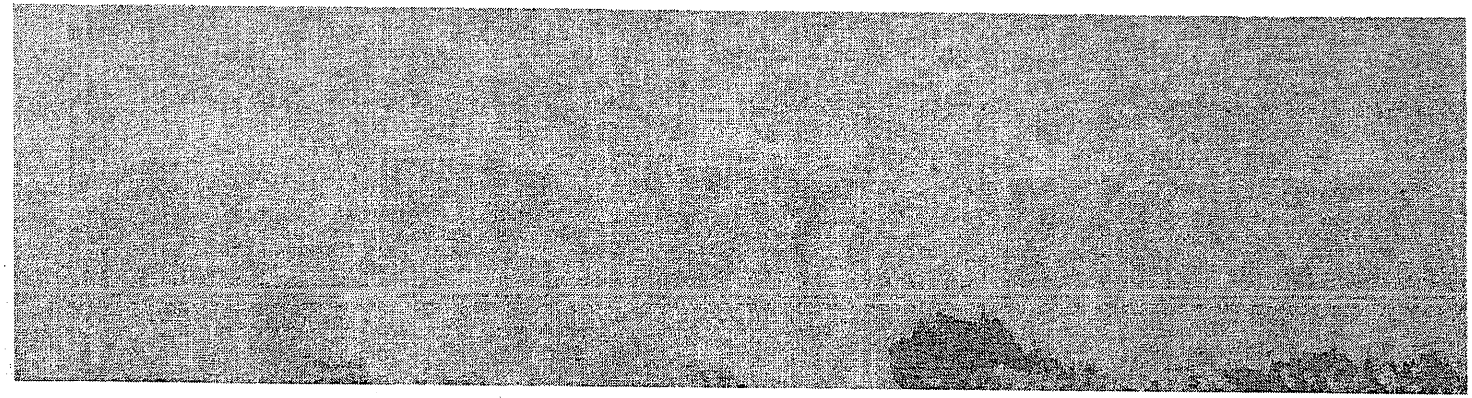


Testing—Phase 1 Results:

The best performer was considered to be the largest positive change in the rebar potential after disconnection:

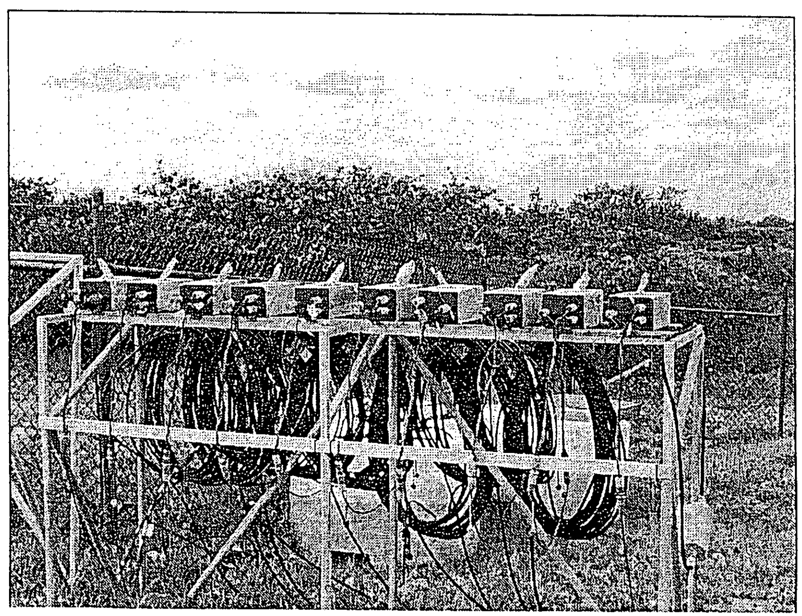


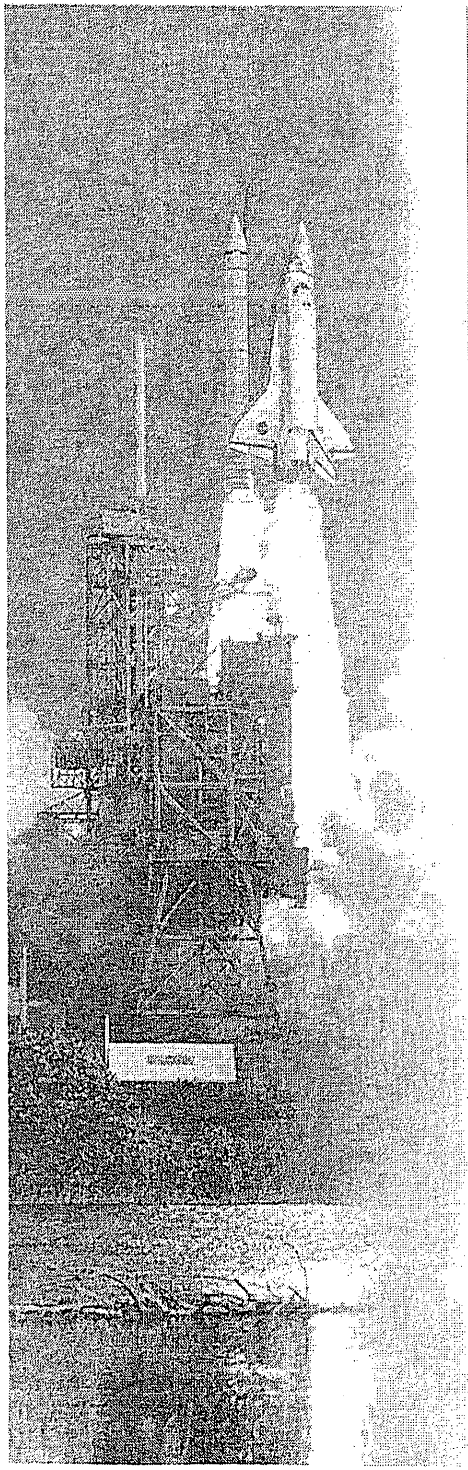


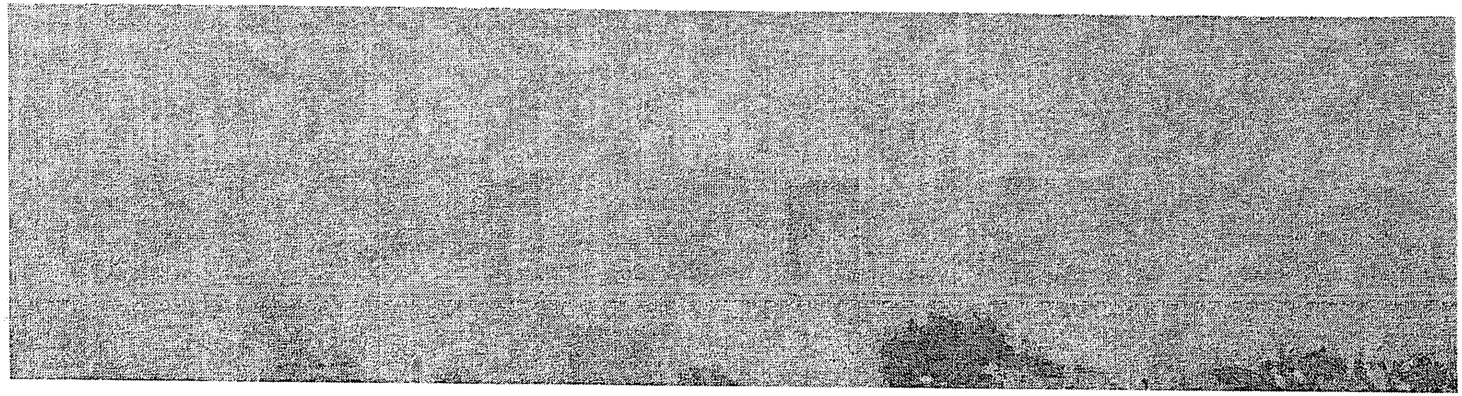


Testing—Phase 2 Results:

Monitoring of new coating formulation for effectiveness. Blocks were exposed to outdoor environment and potential, current, and weather data was recorded. Results were positive.



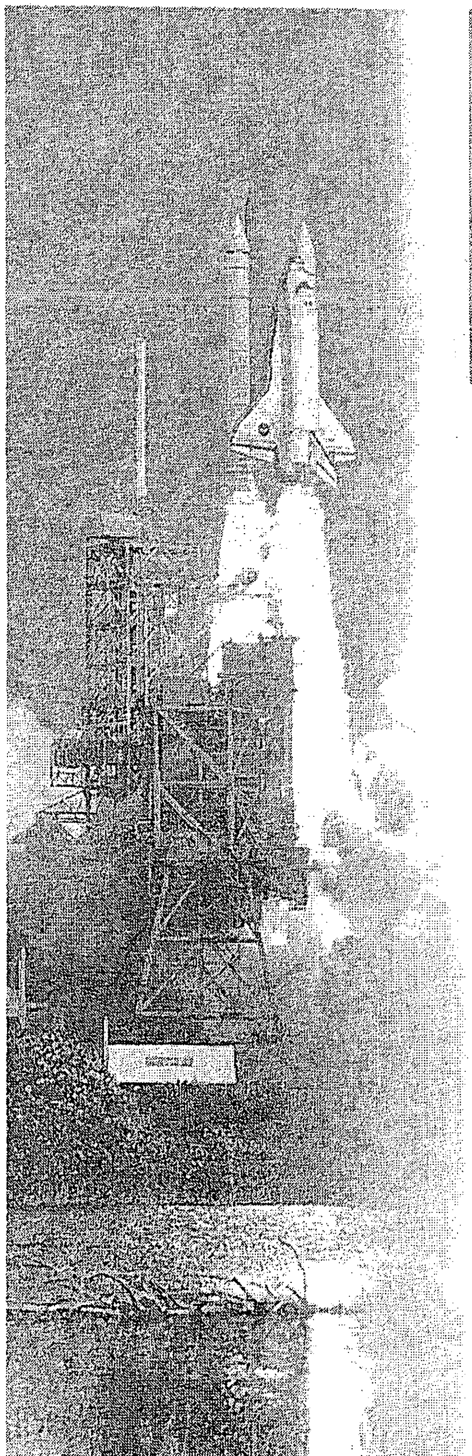


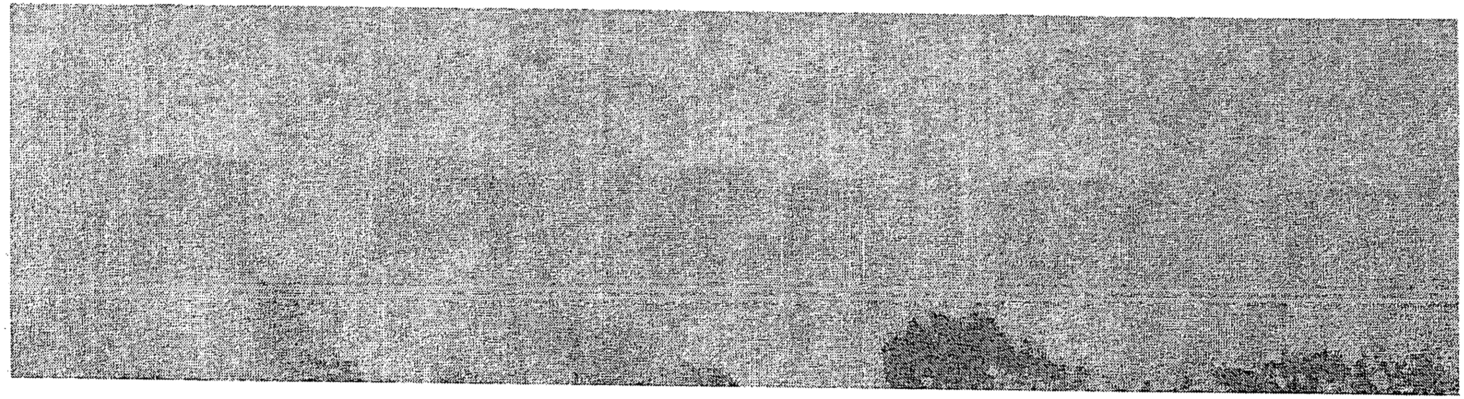


Testing—Phase 2 Results:

Test slabs simulating balconies were designed to evaluate new coating formulations.

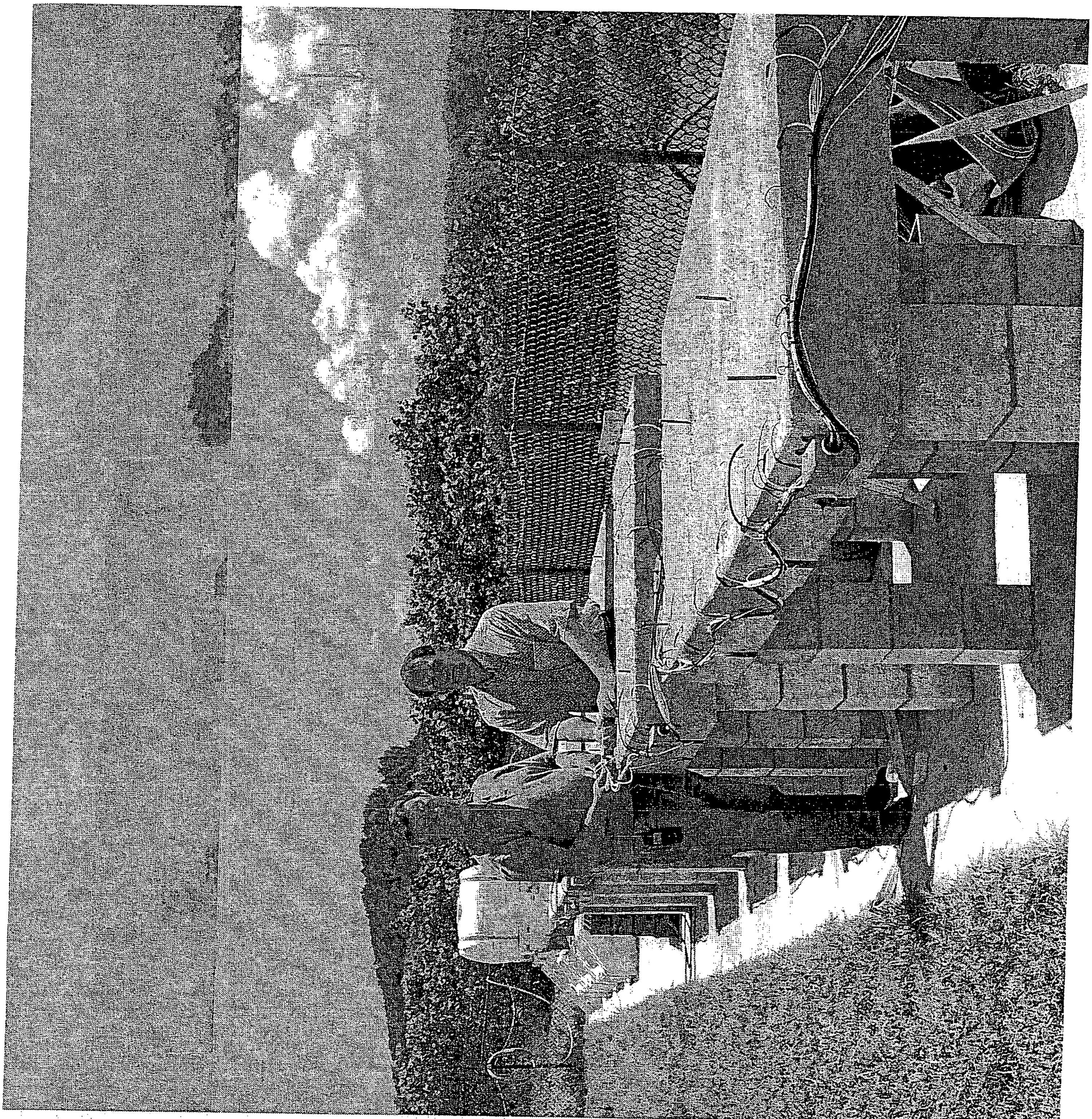
- Each slab contained two mats of reinforcing steel, two to four embedded reference half-cell electrodes and a current density probe.
- Five slabs were designed with a 2” cover and the remaining two with 3” cover

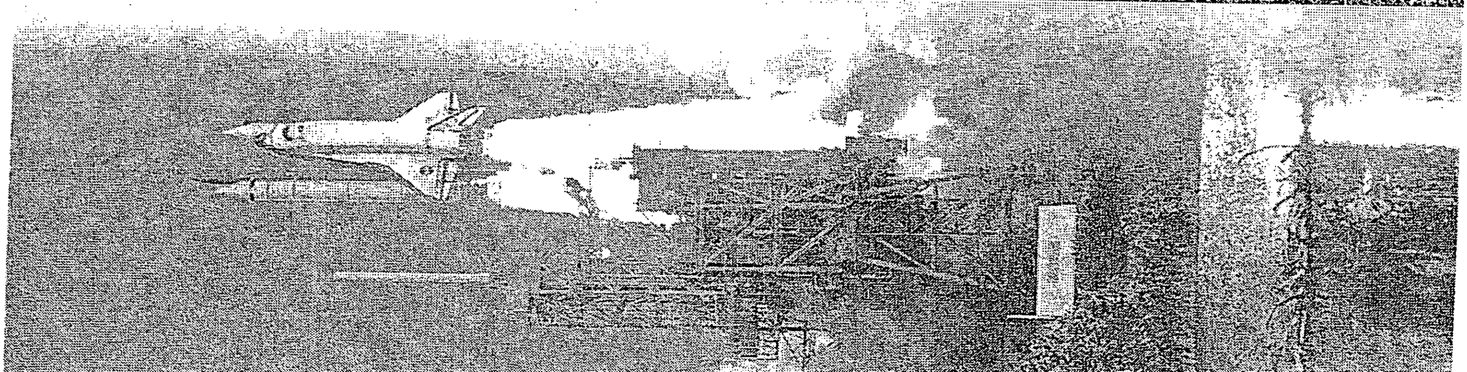


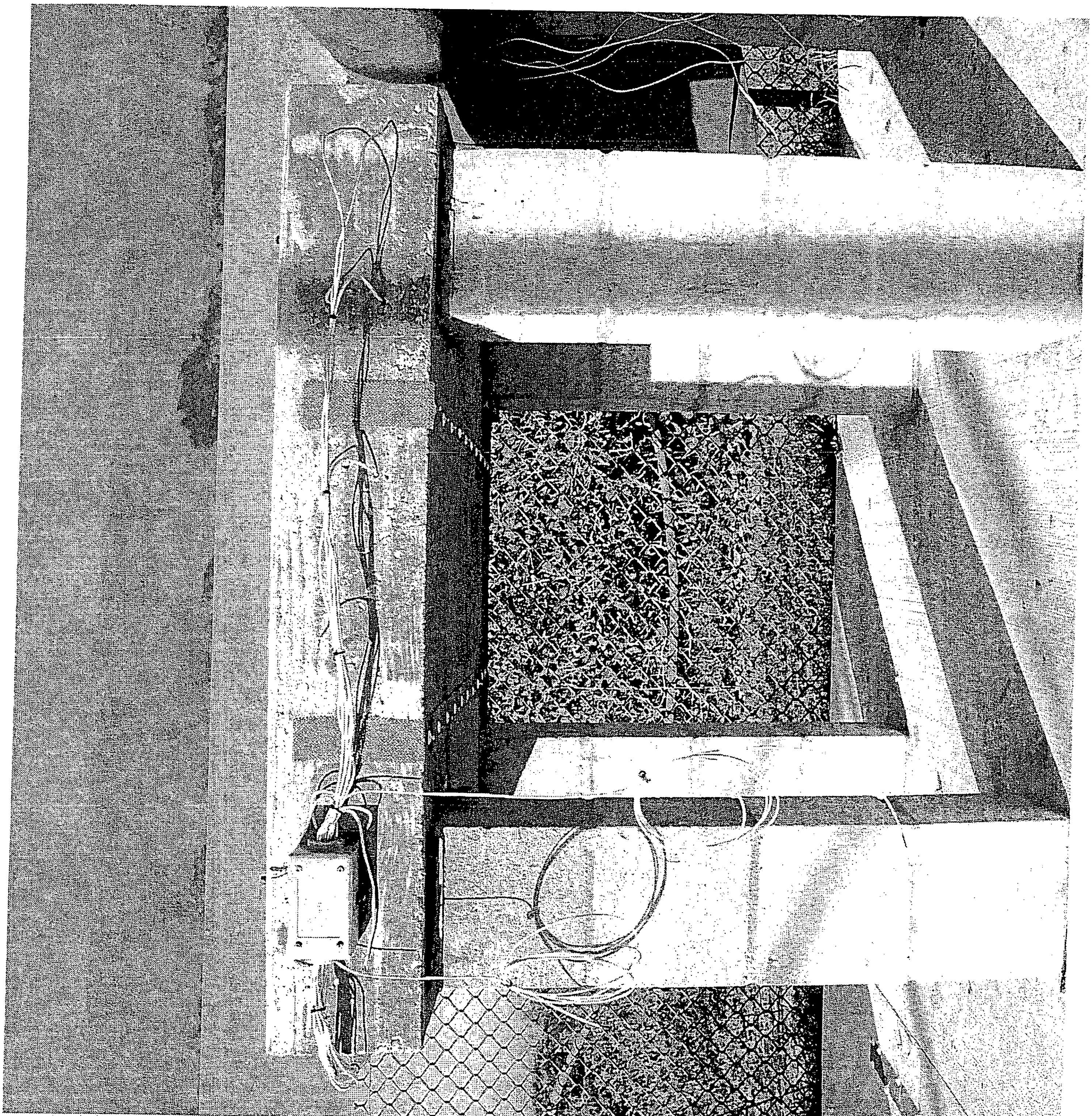


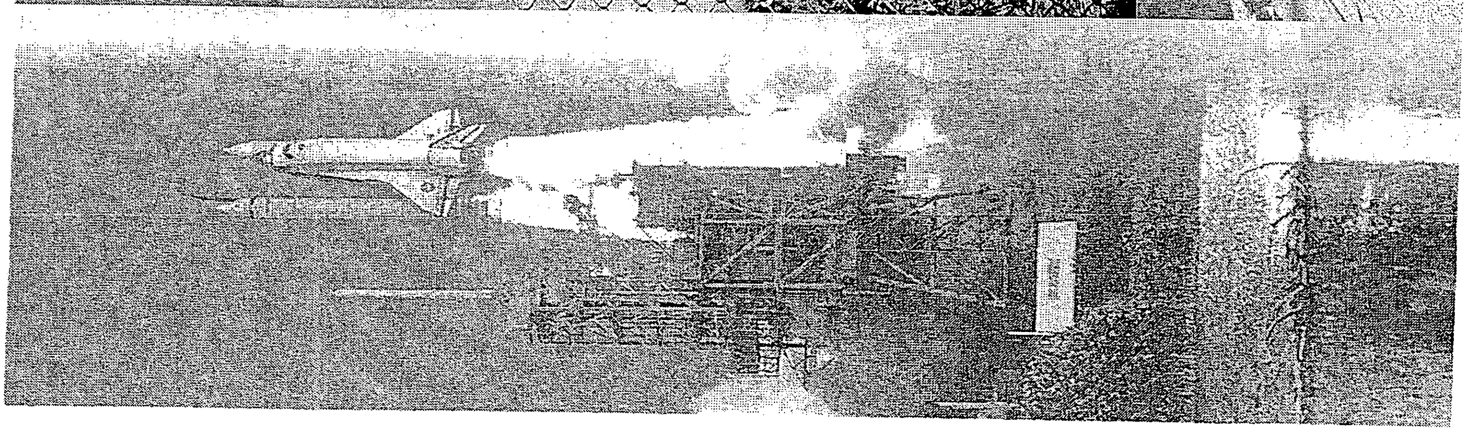
Testing—Phase 2 Results:

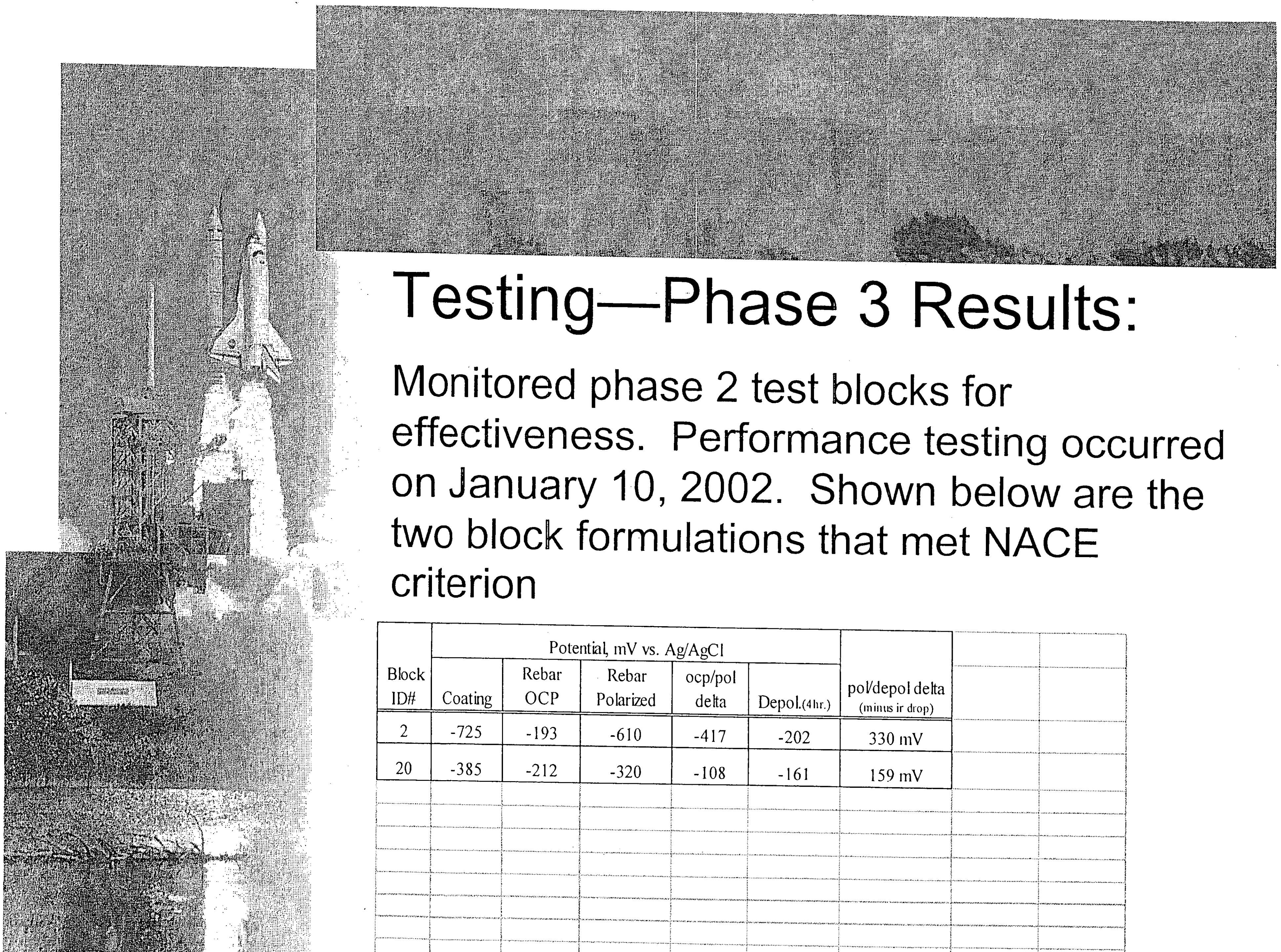
Slabs (5) were installed at the NASA Beach Corrosion Test Facility in December 2000. Two additional slabs were installed in March 2001.







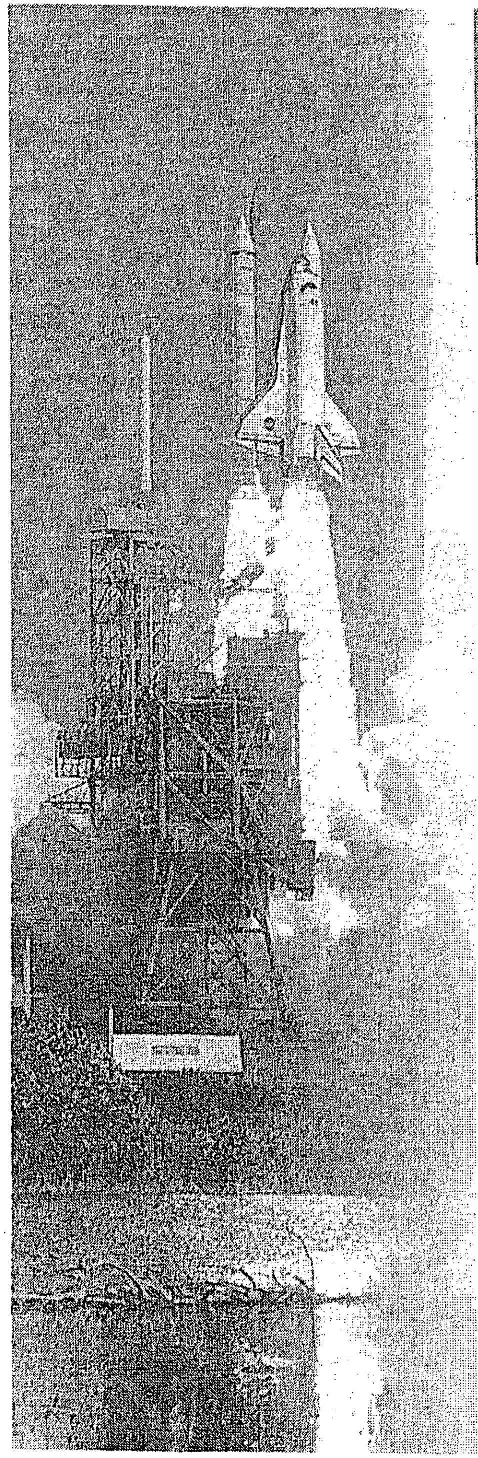


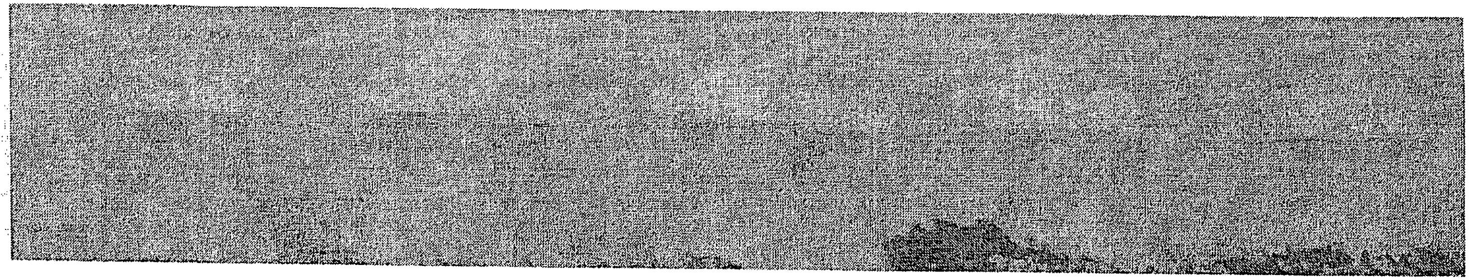


Testing—Phase 3 Results:

Monitored phase 2 test blocks for effectiveness. Performance testing occurred on January 10, 2002. Shown below are the two block formulations that met NACE criterion

Block ID#	Potential, mV vs. Ag/AgCl Coating	Rebar OCP	Rebar Polarized	ocp/pol delta	Depol.(4hr.)	pol/depol delta (minus ir drop)
2	-725	-193	-610	-417	-202	330 mV
20	-385	-212	-320	-108	-161	159 mV

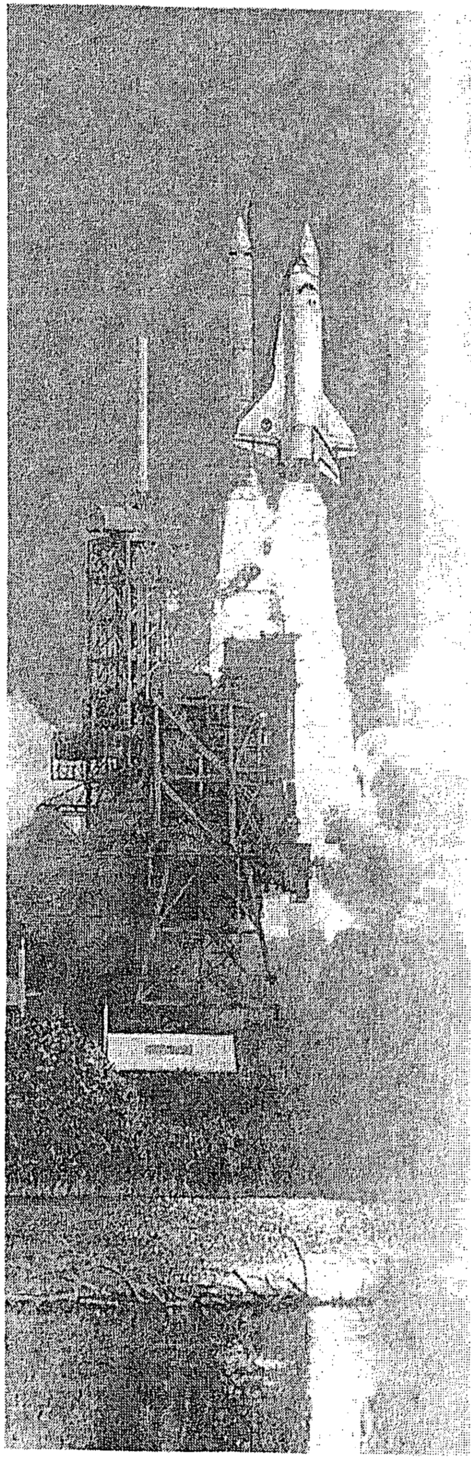




Testing—Phase 3 Results:

Refurbished test blocks on March 4, 2002.
Refurbished block status is shown below:

	Block #	Coating % Zn/Mg/In	Coating Dry Thickness	Coating Potential (Ag/AgCl)	OCP- Rebar (Ag/AgCl)	Rebar Polarized Potential (Ag/AgCl)
	2	75/25/0	old	-.725 mV	-193 mV	-610 mV
	10	75/25/0	38 mil	-1.25 mV	-213 mV	-642 mV
	14	75/25/0	38 mil	-1.23 mV	-267 mV	-590 mV
	15*	75/25/.2	39.5 mil	-1.28 mV	-254 mV	-870 mV
	16	75/25/0	35 mil	-1.23 mV	-150 mV	-615 mV
	17	75/25/0	38 mil	-1.25 mV	-282 mV	-587 mV
	18*	75/25/.2	37 mil	-1.29 mV	-299 mV	-900 mV
	19	Uncoated	0	n/a	-245 mV	-255 mV
	20	75/25/CuS	old	-.385 mV	-212 mV	-320 mV
	24*	75/25/.2	34.5 mil	-1.27 mV v	-343 mV	-740 mV

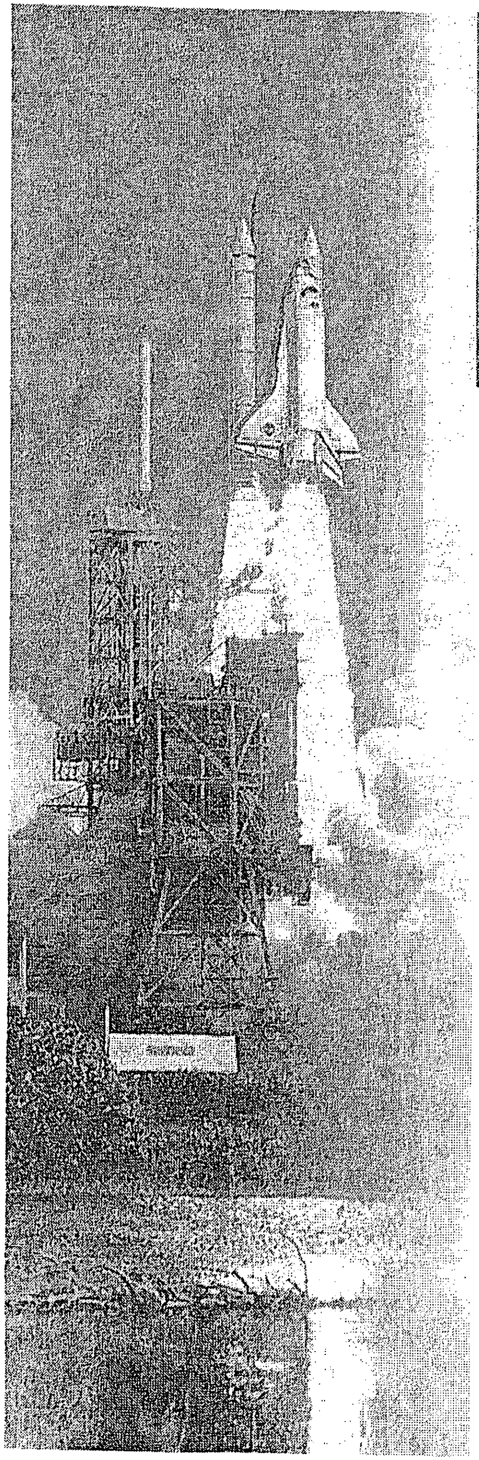


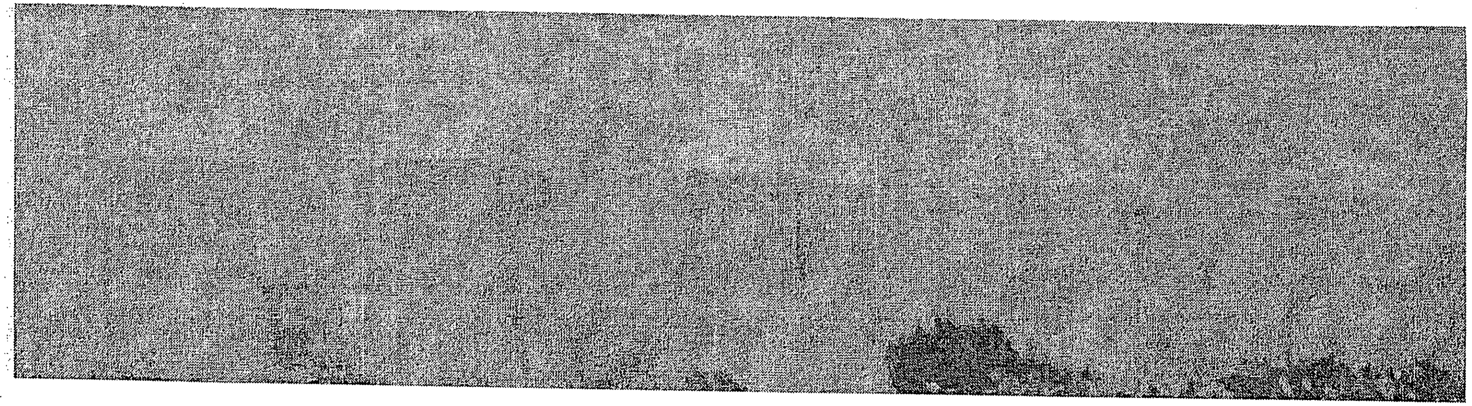
Testing—Phase 3 Results:

Compared and analyzed initial and current data. Potentials of Phase 2 blocks were compared with potentials of Phase 3 blocks. Results are below:

Block #	Potential, mV vs. Ag/AgCl		Delta	Protection*
	OCP 7/2000	OCP 1/2002		
2	-315	-193	122	Great
14	-490	-383	107	Fair
15	-345	-390	-45	Corroding
16	-480	-274	206	Good
17	-500	-324	176	Fair
18	-270	-200	70	Good
19	-350	-245	105	Fair
20	-343	-212	131	Great
24	-470	-309	161	Fair

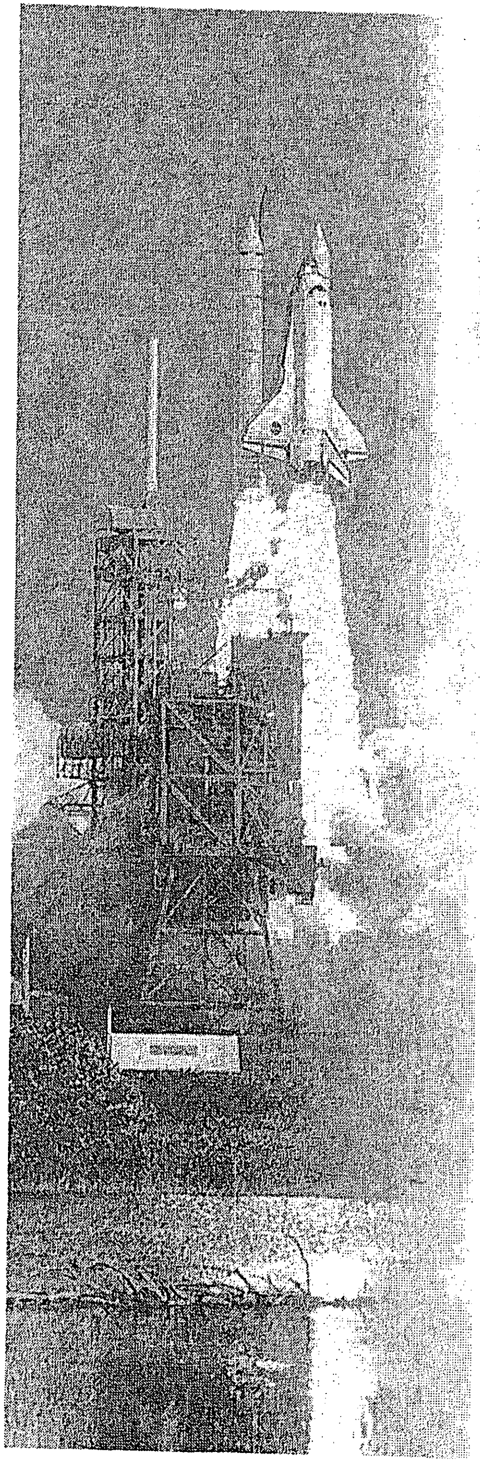
* Effects of phase II

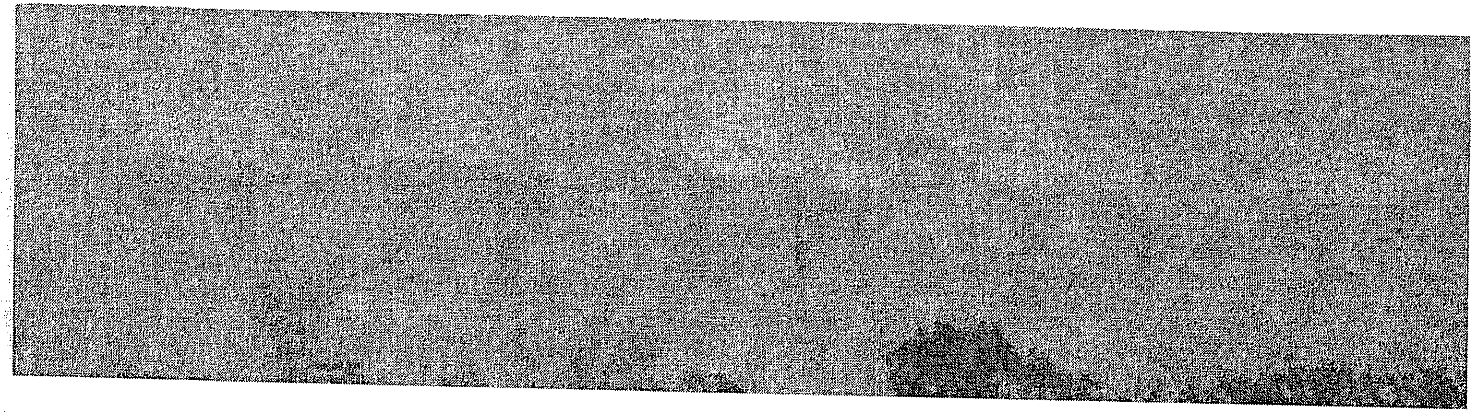




Testing—Phase 4 Results:

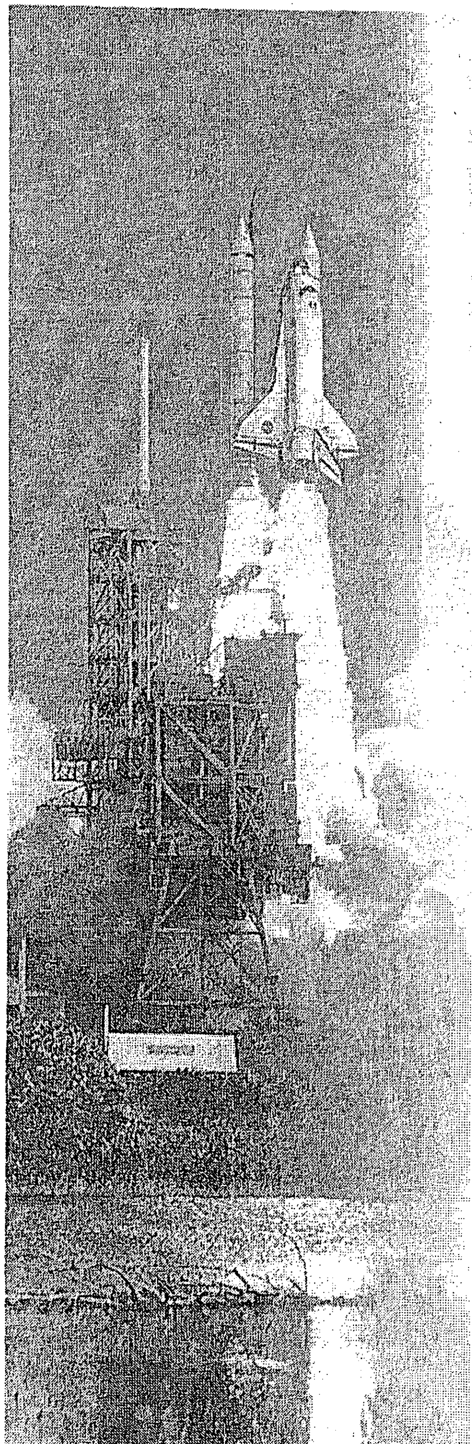
- Test slabs were prepared for the coating system
- Optimum electrical connections were designed and installed for the coating system and rebar
- Initial tests were performed on slabs to collect reference data. Chloride profiles and pH analysis were performed at depths of 0.5”, 1.0”, 1.5”, and 2.0” from the top surface. The slabs were designed with the following ranges.





Testing—Phase 4:

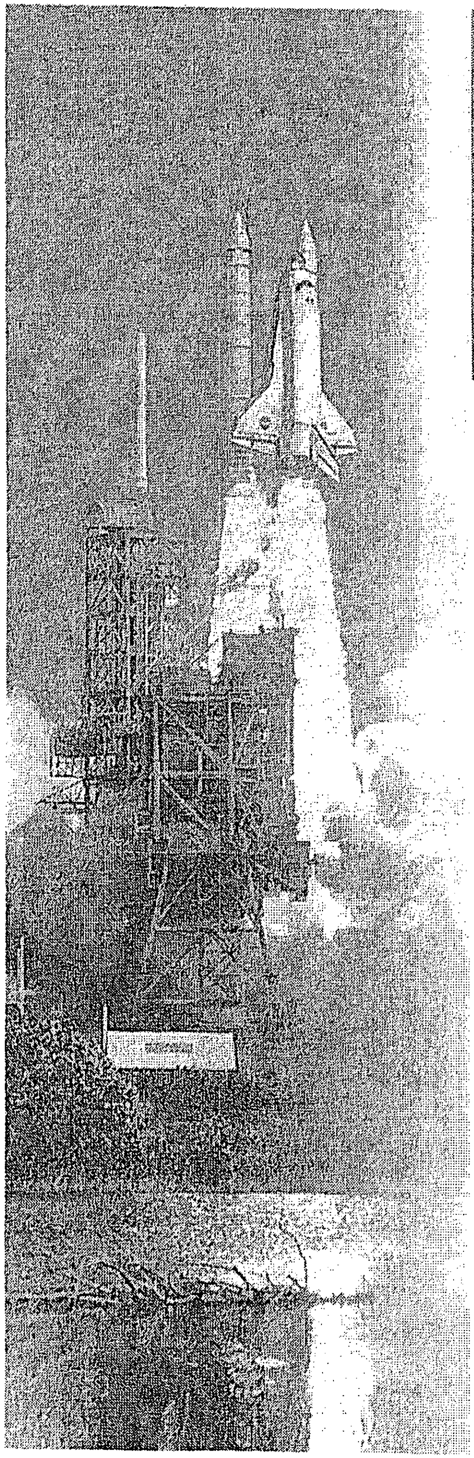
Depth:	Cl^- (ppm)	PH
0.5"	188---5632	11.2---11.6
1.0"	<360---3846	11.4---11.6
1.5"	<360---2492	11.6---11.7
2.0"	<360---3480	11.5---11.9

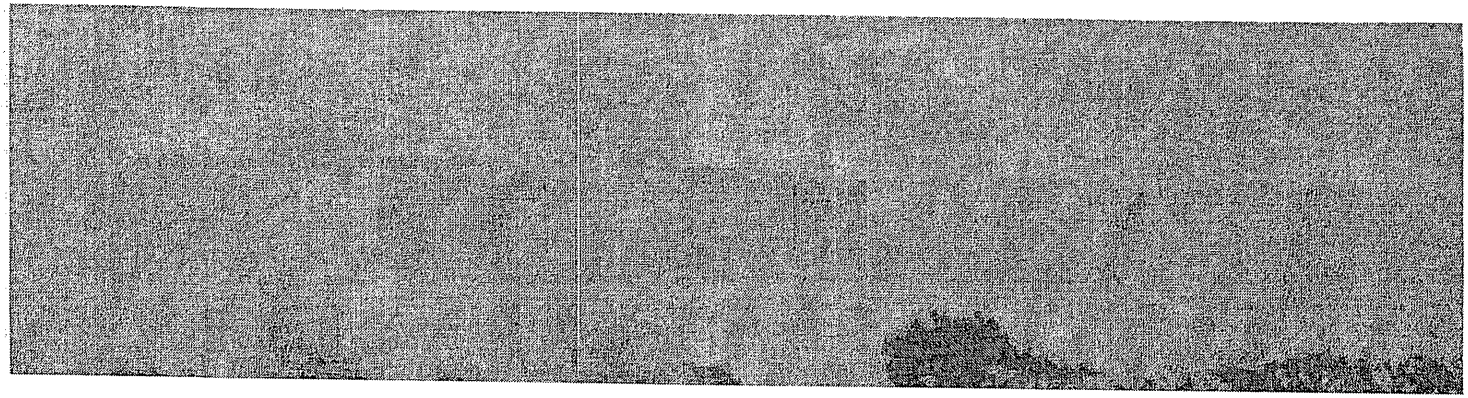


Testing—Phase 4 Results:

Rebar potentials were measured using the last test (ASTM C-876 procedures) and showed evidence of corrosion of the embedded rebar.

Rebar Potentials Ag/AgCl (mV)	Test Slabs						
	A	B	1	2	3	4	5
Top Mat	-381	-350	-150	45	-375	182	-175
Bottom Mat	-345	-350	-220	135	-320	110	-220

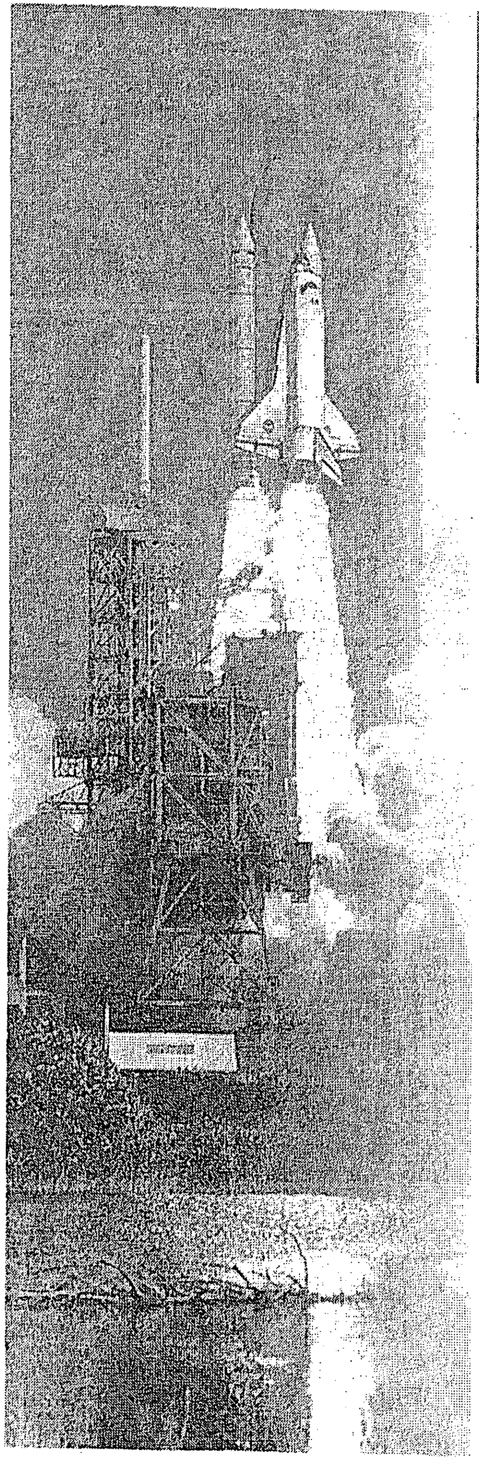




Testing—Accomplishments:

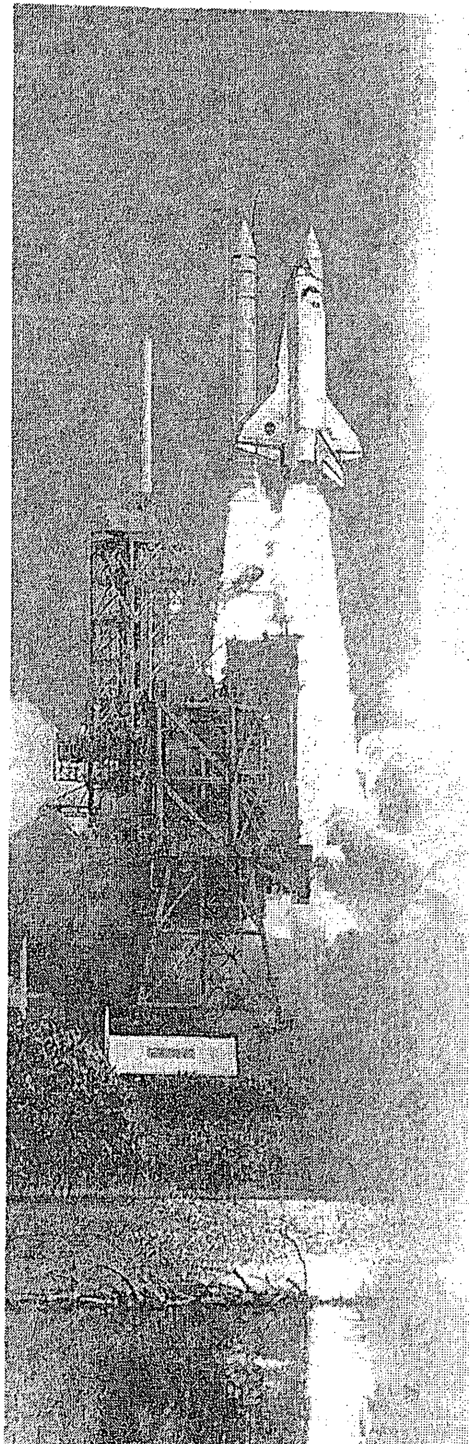
- Determined the optimum mix ratio for specific liquid applied coatings
- Proved the feasibility of using liquid applied coatings for protection of embedded reinforced steel in concrete

Note: The coating has met NACE (National Association of Corrosion Engineers) RP0290-90 100mV Polarization Development/Decay depolarization criteria for complete protection of steel rebar embedded in concrete



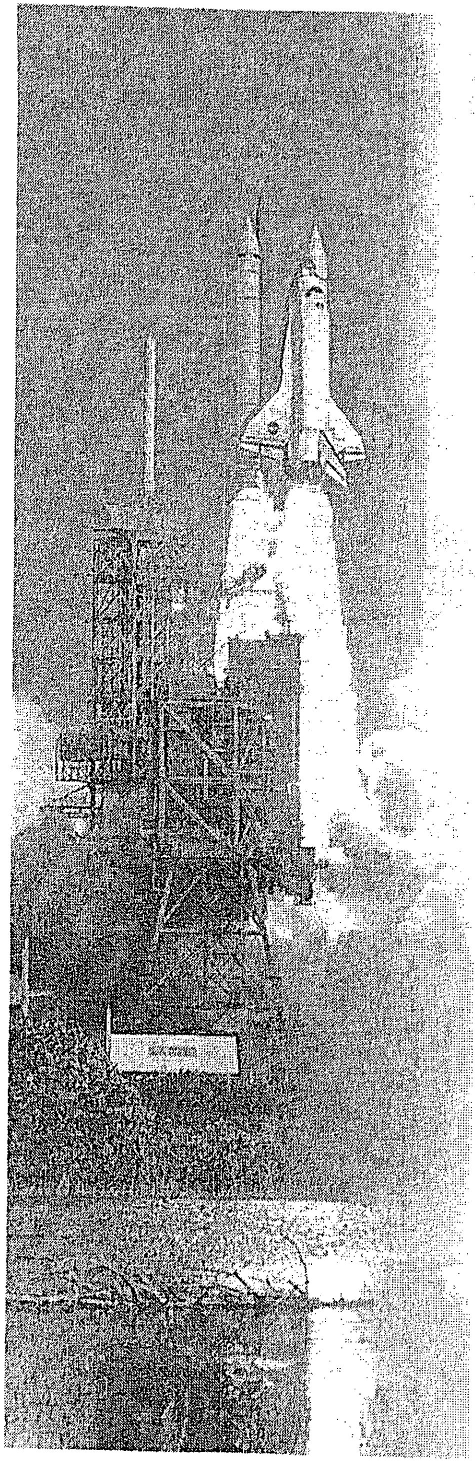
Testing—Accomplishments:

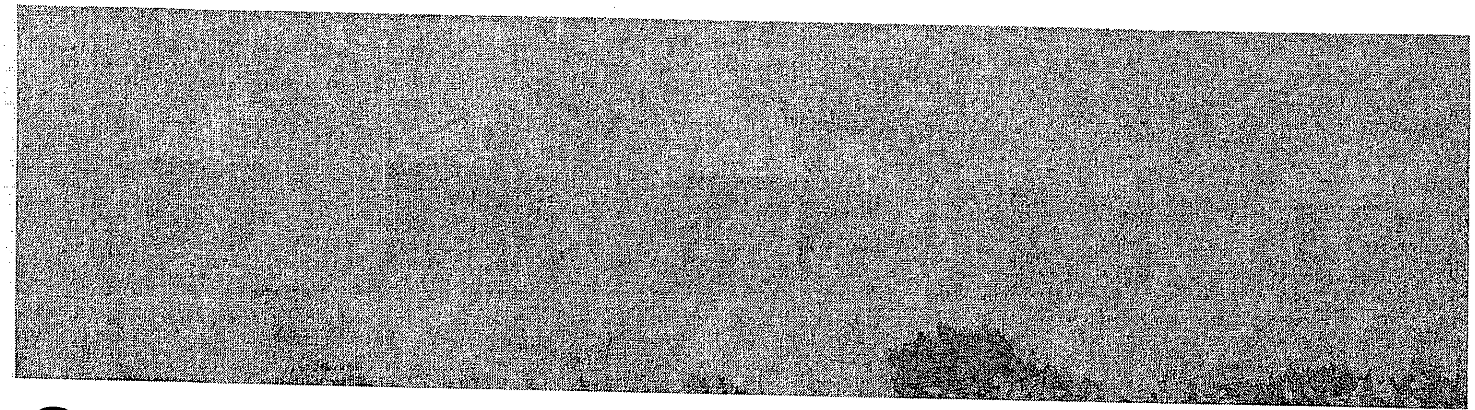
- Demonstrated that embedded rebar becomes negatively polarized
  - –Indicated the presence of a positive current flow with a shift in potential of over 400 mV.



Testing—Current & Future Tests:

- Accelerated life tests
- Tests with chloride to simulate contamination
- Coating optimization tests
- Potential, Linear Polarization, & Electro-chemical Impedance Spectroscopy

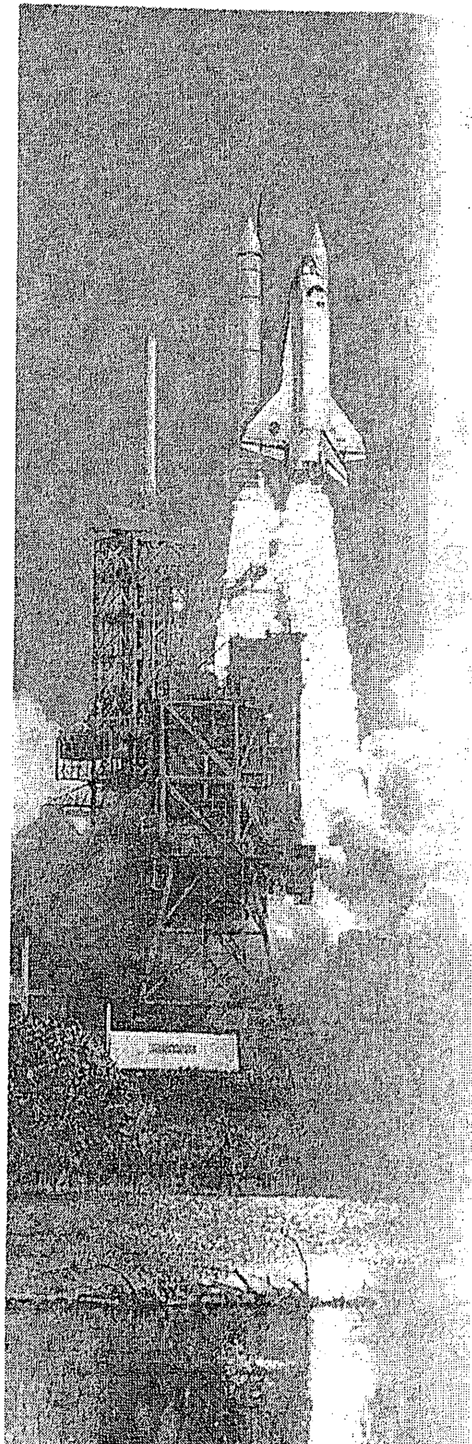


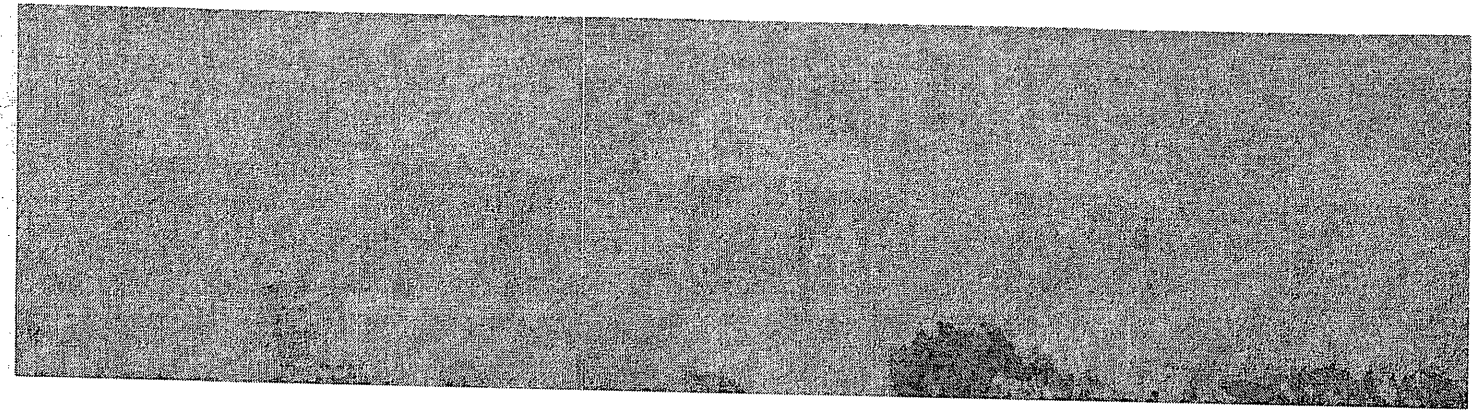


Commercialization:

By transferring the corrosion prevention process from the inside of the formed concrete slab to the outside of the concrete surface, companies will be able to conveniently slow or stop the internal corrosion process.

Without such technology, embedded steel structures will continue to corrode and deteriorate until failure occurs, costing companies billions of dollars to repair these infrastructures





Commercialization:

Primary goal of technology commercialization process:

Encourage broader utilization of technologies in American industrial community through internal developments, partnerships, and patents / licenses