GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. A-3998 GTRI/~~GIT~~ DATE 10 / 10 / 84

Project Director: T. L. Starr School/~~Lab~~ EMSL

Sponsor: U. S. Department of the Interior - National Park Service

Type Agreement: Delivery Order No. PX-0001-4-1220 (Under BOA No. CX-0001-2-0036)

Award Period: From 9/25/84 To ~~10/30/84~~ 11-15-84 (Performance) 10/30/84 (Reports)

Sponsor Amount:

	This Change	Total to Date
Estimated:	$ 6,228	$ 6,228
Funded:	$ 6,228	$ 6,228

Cost Sharing Amount: $ None Cost Sharing No: N/A

Title: Determination of Paint Deterioration Rates

ADMINISTRATIVE DATA

OCA Contact Brian J. Lindberg x4820

1) Sponsor Technical Contact:

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National Park Service
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Defense Priority Rating: N/A

Military Security Classification: N/A

(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

See Attached Gov't Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with sponsor if acquisition cost is $1,000 or more; However none is proposed

COMMENTS:

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FORM OCA 4:383

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 12/13/84

Project No. A-3998

~~School~~/Lab EMSL

Includes Subproject No.(s) N/A

Project Director(s) T.L. Starr

GTRC / ~~GIT~~

Sponsor U.S. Dept. of the Interior - National Park Service

Title Determination of paint Deterioration Rates

Effective Completion Date: 11/15/84 (Performance) 11/15/84 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [x] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [x] Final Report of Inventions
- [x] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. Continued by Project No.

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FINAL REPORT
PROJECT NO. A-3998

DETERMINATION OF PAINT DETERIORATION RATES

By

Thomas L. Starr
Leslie E. Henton

Under
NPS Contract No. CX-001-2-0036
Work Assignment #3

NOVEMBER 1984

Georgia Tech Research Institute

Energy and Materials Sciences Laboratory

GEORGIA INSTITUTE OF TECHNOLOGY

Atlanta, Georgia 30332

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INTRODUCTION

Determination of the damage to paint that can be attributed to air pollution, and in particular acid rain, is an important factor in any economic assessment of the effects of acid rain. Paint is a material that is routinely replaced in short time intervals compared to stone or bronze. The costs associated with more frequent repainting as a result of acid rain damage are potentially large. The economic consequences may be significant for both historic structures as well as for common construction. Preliminary estimates indicate that 40% of historic structures listed on the National Register of Historic Places are painted frame structures.

While retrospective estimates of acid rain exposure can be made for specific locations and times, suitable data on paint deterioration rates is not presently available.

The objective of this study is to identify existing data on paint deterioration that is suitable for calculation of damage functions. Such data would come from exposure studies that: (a) utilized similar or identical paints, substrates, and application techniques, (b) report a quantitative measure of deterioration (rather than a rank ordering), and (c) were located in sites with different levels of acid rain exposure but similar levels of other deterioration factors. Substrates of interest are wood, steel, and others (e.g. automobiles and masonry) in decreasing order of priority.

APPROACH

A two pronged assault on the above objective was made. The first approach was to retrieve published reports of exposure studies in hopes of identifying ones that meet the criteria above. The second approach was to locate paint exposure test sites which meet criterion (c), and attempt to obtain information on past and current tests at those sites which may yield appropriate data.

Published reports were sought utilizing the computerized search services of the Georgia Tech Library and the data bases World Surface Coating Abstracts and National Technical Information Service (NTIS). Paint and paint materials manufacturers, trade organizations and government agencies were queried in order to identify reports with limited distribution and which may not appear in the above abstracts.

Exposure sites were identified from the above literature search and by contacting manufacturers, trade associations, government agencies, and testing/research organizations known to be performing paint exposure tests. For sites that appear to meet the location criterion, additional information on past and present studies was sought.

RESULTS

Exposure tests

The literature search uncovered two published reports containing paint exposure data roughly meeting the above criteria. Both reports resulted from studies funded by the Federal government.

In the early 1970's, the Sherwin-Williams Research Center conducted a study for the Environmental Protection Agency which aimed at evaluating techniques for assessing air pollution damage to paints (Campbell, 1972). This study identified film erosion as a suitable measure of paint deterioration. Erosion rate data for five paints at four locations is reported after 24 months exposure (Campbell, 1974). The exposure sites and paint formulations are described in table 1A and the erosion data in table 1B. On-site monitoring for pollution levels was not performed but the average air quality was reported for each site.

In the early 1980's, the Department of Energy, Argonne National Laboratory, funded a study of atmospheric corrosion of batten and enclosure materials for flat-plate solar collectors. This study included exposure testing of a polyester paint on steel at nine separate sites (table 2A) in the National Solar Data Network. Deterioration after twelve months exposure was measured by ASTM rating of creepage from a scribe and by counting blisters (table 2B). On-site monitoring included relative humidity, ambient temperature, and electrochemical corrosivity.

A number of paint and paint materials manufacturers, trade organizations, and government agencies were contacted in order to locate pertinent unpublished data or reports with a limited distribution. The results of this effort are

PAINTS

House Paints

Lead/titanium/zinc extender in oil with 100% rutile TiO_2.
Titanium/extender in acrylic latex with 100% rutile TiO_2.

Industrial Maintenance Coating

Titanium in alkyd with 100% rutile TiO_2

Coil Coating Finish

Titanium/extender in urea-alkyd with 75% rutile and 25% anatase TiO_2.

Automotive Refinish

Titanium in nitrocellulose/acrylic with 100% rutile TiO_2.

LOCATIONS

Locations	Environment	Pollution Level 1970 Annual Average (SO_2 $\mu g/M^3$)	Oxidant $\mu g/M^3$
Leeds, North Dakota	clean, rural site	low	low
Los Angeles, California	high oxidant	low	34
Chicago, Illinois	high sulfur dioxide	97	low
Valparaiso, Indiana	moderate sulfur dioxide	22	low

Table 1A. Sherwin-Williams/EPA Study: Materials and Locations.

Coating		Leeds	Valparaiso	Chicago	Los Angeles
		Erosion rate (mils/month x 10^3)			
Automotive	N	1 (0.5)	2 (1)	1 (0.5)	1 (0.3)
	S	1 (0.7)	2 (0.8)	2 (0.2)	2 (0.2)
Latex	N	1 (0.3)	2 (0.6)	3 (0.5)	3 (0.9)
	S	1 (0.5)	2 (0.3)	3 (0.3)	3 (2.3)
Industrial Maintenance	N	3 (1.3)	5 (1.6)	5 (1.3)	6 (1.4)
	S	4 (2.4)	6 (1.2)	6 (2.2)	8 (2.1)
Coil Coating	N	2 (0.6)	8 (0.6)	10 (0.8)	10 (2.3)
	S	2 (0.8)	9 (1.7)	11 (1.4)	12 (2.5)
Oil House-paint	N	1 (0.9)	8 (2.4)	13 (2.2)	13 (6.2)
	S	2 (1.4)	10 (1.5)	16 (3.9)	16 (5.2)

N = north exposure (shaded)
S = south exposure (unshaded)
(2σ)

Table 1B. Sherwin-Williams/EPA Study: data

PAINT

Polyester paint with white pigment

LOCATIONS

Site	Environment
Alabama Power Company, Montevallo, Ala.	I
Oakhead Industrial Park, Santa Clara, Calif.	M
Irvine Unified School District, Irvine, Calif.	M
Reedy Creek Utility, Lake Buena Vista, Fla.	M
Florida I-95 Visitors' Center, Yulee, Fla.	M
Scattergood School, West Branch, Iowa	R
Argonne National Laboratory, Argonne,Ill.	I
Concord Municipal Light Plant, Concord, Mass.	I
Howard Grove School, Howard Grove, Wis.	R

I = industrial, M = marine, R = rural

Table 2A. Argonne National Laboratory/DOE Study: paint and location

Site	Creepage (ASTM D1654)	No. of blisters (max)
Yulee, FL	7	50
Irvine, CA	9	13
Santa Clara, CA	9	3
Lake Buena, FL	9	13
Argonne, IL	9	20
Concord, MA	9	15
Montevallo, AL	9	28
Howard Grove, WI	9	16
West Branch, IA	9	50

Table 2B. Argonne National Laboratory/DOE study: data summarized in table 3. Three data sets meeting the selection criteria are discussed below.

In 1968, the National Association of Corrosion Engineers began a study of five paints on steel exposured at seven sites (NACE, 1977 and Tator, 1983). These paints and the test sites are described in table 4A. Paint performance was measured using ASTM ratings of rusting and undercutting. Average performance after seven years for all paints was reported for each site and is shown in table 4B. No on-site monitoring for pollution or acid deposition levels was performed.

Rust-Oleum Corporation has performed in-house testing of paint systems for protection of steel using two exposure sites (Cunningham, 1984). Performance data for seven primers with and without topcoats are given in table 5. Performance measures include both visual (corrosion, chalking, mildew) and instrumental (gloss) ratings of deterioration. No environmental monitoring was performed.

Union Carbide Corporation has performed in-house testing of latex paints on wood at six separate locations. (Schaller, 1984). Visual and instrumental ratings of deterioration for up to 24 months exposure area given in table 6.

Exposure sites

Many exposure sites in all parts of the country are identified in the exposure tests results given above. Some of these sites may still have panels with accumulating

PAINT MANUFACTURERS	
Pittsburgh Plate Glass (PPG)	Has some data but did not send
Sherwin-Williams	Identified EPA funded study
Benjamin Moore	Qualitative observations on deterioration under eaves due to SO_2 and NO_2
Ameron	No test sites
Rust-Oleum	Sent data
Glidden	Has data but did not send
DuPont	Sold paint business
PAINT MATERIALS MANUFACTURERS	
Union Carbide	Sent data
Spencer-Kellogg	No test sites
Reichard-Coulson	No test sites
Thompson-Weinman	No test sites
ASARCO	Some old data. Did not send.
NL Industries	Only one site
Rohm and Haas	Four sites but different paints at each
New Jersey Zinc	Some data but did not send.
Pfizer	No response
TRADE ORGANIZATIONS	
National Flaxseed Processing Assn.	No test sites.
National Assoc. of Corrosion Engineers (NACE)	Sent report
Steel Structures Painting Council	Three sites. No data sent.

Table 3. Responses from personal communications

TESTING LABORATORIES	
South Florida Test Service	Three sites. Would not send data.
Ocean City Testing Lab.	Data not available
Applied Coatings Technology	One test site
U.S. Testing Lab.	One test site
Laque Corrosion Lab.	One test site
GOVERNMENT AND USERS	
Massachusetts Dept. of Public Works	One test site
Naval Civil Engineering Lab	Three sites. All marine.
Avondale Shipyards	One test site
Louisiana Dept. of Transportation	No test sites
West Virginia Dept. of Transportation	No data
National Bureau of Standards	No response

Table 3 (Con't). Responses from personal communications

PAINTS

3-Coat Vinyl
3-Coat Epoxy Polyamide
3-Coat Chlorinated Rubber
Post Cured Zinc/Epoxy
Self Cured Zinc/Epoxy

LOCATIONS

Kure Beach, North Carolina -- The panels are located at International Nickel's exposure facility at Kure Beach. The panels are located approximately 80 feet from mean high tide and are subject to salt air and humid winds which are typical of those found along an ocean coast line as well as the prevailing weather conditions of the North Carolina Atlantic coastline.

ARCO Refinery, Philadelphia -- The test panels are located on the roof of a building in the heart of Atlantic Richfield's Philadelphia refinery and storage yard complex. The predominating exposure atmosphere is typical of an industrial, urban environment.

Dow Chemical Company, Freeport, Texas -- The panels are exposed on a rack located on the outskirts of the Dow Chemical Company Freeport complex. The predominating environment is a typical industrial, semi-tropical Gulf Coast environment with salt air and high humidity.

Ameron Corrosion Control Division, Brea, California -- The panels are located in the vicinity of an orange grove on the Ameron Company site in southern California. The exposure is typical of the southern California weathering environment inland from the Pacific.

PPG Industries, Barberton, Ohio -- The panels are located on the roof of a building situated within a unit in which ammonia is synthesized. The environment is an urban/industrial environment with the addition of occasional ammonia fume concentration.

Monsanto Queeny Plant, St. Louis, MO -- The panels are located on the roof of a building in the vicinity of a

Table 4A. National Assoc. of Corrosion Engineers (NACE) study: paints and locations vanilla synthesis unit in the center of the Queeny complex. The predominate environment is typical of a light to medium industrial/urban environment in which there is no significant chemical fume concentration. This is the only location where the panels are exposed in a flat (horizontal) position on a roof.

Carboline Company, St. Louis, MO -- The test panels are located on the roof of the Carboline offices and laboratory. The atmosphere is typical of an urban/light industrial environment. However, the panels are located a short distance from an air conditioning/cooling tower and chloride containing spray may occasionally drift onto the panels.

Table 4A (Con't). National Assoc. of Corrosion Engineers (NACE) study: paints and locations

Seven Year Exposure - Avg. Ratings for All Paints

Location	Rust (Overall)	Rust (local)	Edge	Scribe
Kure Beach	90.2 (1.0)	78.7 (3.2)	75.5 (3.3)	42.4 (5.0)
Arco, Phila.	96.3 (1.1)	89.0 (2.5)	85.0 (2.9)	64.1 (4.0)
Dow, Freeport	97.9 (0.8)	82.2 (1.9)	73.6 (2.4)	85.4 (3.2)
Ameron, Brea	100.0 (0.0)	83.1 (3.9)	96.4 (2.6)	72.5 (3.0)
PPG, Barberton	77.4 (2.6)	70.9 (3.4)	79.5 (3.7)	65.7 (5.1)
Carboline, St. Louis	88.8 (2.8)	81.6 (2.6)	96.0 (2.4)	77.0 (4.6)
Monsanto, St. Louis	98.3 (0.8)	95.3 (1.2)	97.0 (1.3)	91.6 (2.4)

(1σ)

Table 4B - National Assoc. of Corrosion Engineers (NACE) study: Data

	Corrosion		Chalk		Retained Gloss (%)	
	M	L	M	L	M	L
Primer I	4	10	-	-	-	-
Primer I + topcoat	10	4	10	9	2	0
Primer II	9	4	-	-	-	-
Primer II + topcoat	10	10	2	6	27	0
Primer III	10	10	-	-	-	-
Primer III + topcoat	9	6	10	10	4	0
Primer IV	10	10	-	-	-	-
Primer IV + topcoat	10	10	6	8	2	0
Primer V	10	10	-	-	-	-
Primer V + topcoat	10	8	10	10	15	4
Primer VI	10	8	-	-	-	-
Primer VI + topcoat	10	10	10	10	21	4
Primer VII	10	6	-	-	-	-
Primer VII + topcoat	10	10	6	9	6	0

M = Miami, FL L = Louisville, KY

Table 5. Rust-Oleum Corporation Study

PAINTS - Fifty four formulations of latex paint on wood panels

LOCATIONS -	Alsip, IL	South Charleston, WV
	Garland, TX	Miami, FL
	Somerset, NJ	
	Torrance, CA	

DEGRADATION MEASURES - erosion, checking, cracking, chalking, flaking, blistering, fading, discoloring, gloss

EXPOSURE - 6, 12, 19, 20, 24 months

Table 6A. Union Carbide Corporation Study: Description

① • 19 [illegible]

TEST FENCE

RATING SHEET

Garland, TX.

DATA SHEET

Garland, TX.

RATE PERIOD CODE

A-Six Months	F-Five Years
B-One Year	G-Six Years
C-Two Years	H-Seven Year
D-Three Years	I-Eight Year
E-Four Years	J-Nine Years

SERIES # (1–5)	PANEL # (7–9)	DATE RATED YR. MO. DA (11–16)	RATE PERIOD (17)	GENERAL APPEARANCE (18)	DIRT (20)	MILDEW (22)	EROSION (24)	CHECKING (26)	CRACKING (28)	CHALKING (30)	FLAKING (32)	BLISTERING (34)	FADING (36)	DISCOLORING (38)	SHEEN (40)	20° GLOSS (42)	60° GLOSS (44)	INITIAL 20° GLOSS (46)	INITIAL 60° GLOSS (48)	COMMENTS (50–75)
79049	1A	810326	1	8	8	9	10	10	10	10	10	10	10	10						
	1B			8	8	10			10	9										
	2A			8	8	10			10	10										
	2B			8	8	10			10	9										
	3A			4	9	10			9	10										BOARD CRACK
	3B			6	9	10			9	10										BOARD CRACK
	3C			9	9	10			10	10										
	4A			9	8	10			10	9							35			KEY 77 PUNCH
	4B			9	9	10			10	9							40			
	4C			9	8	10			10	9							41			
	5A			9	8	10			10	10										
	5B			9	8	10			10	10										
	5C			9	8	10			10	10										
	6A			9	8	10			10	10										
	6B			9	8	10			10	10										

Table 6B. Union Carbide Corporation Study: sample data sheet (twelve sheets available) exposure and, thus, accumulating data on variable deterioration effects. More information is needed on the present status of these sites and other materials that may be on test.

One commercial testing operation, South Florida Test Service, Inc., maintains three separate test sites in Florida, Chicago, and Arizona. Each contains several thousand panels and a wide variety of paint materials. Information on specific tests is often held in confidence for the particular client and this commercial operation would require funding to provide data.

CONCLUSIONS

Substantial data is available on the performance of identical paints at different locations. Whether this data can be used to generate damage functions for acid rain effects has yet to be determined.

Several facts about paint deterioration and paint exposure testing make this task difficult.

1. Individual paints are very different. Even within a generic class of paints, slight differences in formulation can produce large changes in performance.
2. Paint deterioration takes many forms. Chalking, cracking, erosion, corrosion, blistering and many other phenomena are used to measure the performance of paints. The critical mode of failure for identical paints on identical substrates may change

with different exposure locations. Most reported measures of paint performance are semi-quantitative and have relatively large inherent errors.

3. Many exposure factors other than acid rain contribute strongly to the deterioration of paint films. Some of these are UV exposure, humidity, salt spray and non-acid pollutants. The effects of these factors must be separated in order to measure the effect of acid rain. Compounding this is the fact that most exposure test locations are chosen to have high levels of these other factors and, thus, provide accelerated exposure data. Also, the level of these other factors may vary considerably over a very short range. A site 100' from the ocean will be significantly more damaging to painted steel than a site 500' from the ocean.

These difficulties are not insurmountable. Identical paints can be exposed at multiple sites to eliminate the variability of formulations. Various deterioration data can be unified by converting to service life estimates. Exposure factors can be monitored or estimated retrospectively. The data identified in this report may provide the basis for reasonable estimates of acid rain damage functions.

Additional work will be required before such functions can be determined. This includes:

1. Reduce the data from each study to a uniform measure of deterioration. We recommend that

service life be used as a uniform measure of paint performance. Damage functions would then take the form of service life reduction factors. In addition to unifying the various paint deterioration data, this form for the damage function would be convenient for future economic assessments.

2. Identify in greater detail the various exposure sites. Descriptions for each site should identify the local environment of the exposure panels and their distance and orientation relative to nearby sources of deterioration. The descriptions given in the NACE report serve as a model. Similar descriptions are needed for the other sites.
3. Obtain additional data. For the NACE study, deterioration at the various sites was reported as averages of all paints. Deterioration data for individual paints would be more useful for damage function determination. In other cases, the reported data can not be used to accurately predict service life due to the short exposure time and small amount of observed deterioration. Efforts should be to identify panels that are still on test and to obtain additional rating data.
4. Convert all data to a uniform format. The data base thus created would then be usable for generation of damage functions.

REFERENCES

Campbell, G.G., Schurr, G.G., Slawikowski, D.E., "A Study to Evaluate Techniques of Assessing Air Pollution Damage to Paints", Final report to the Environmental Protection Agency on Contract No. 68-02-0030 (1972).

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ACKNOWLEDGMENTS

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