GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 10-30-79

Project Title: Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings

Project No: A-2490

Project Director: Dr. Charles J. Ray

Sponsor: Department of Transportation; Federal Highway Administration; Washington, D.C. 20590

Agreement Period: From 9/28/79 Until 7/27/82 (Contract Period)

Type Agreement: Contract No. DOT-FH-11-9698

Amount: $127,200 (Phase I and II)

Reports Required: Monthly Progress Reports; Data Collection Report and Plan; Final Report

Sponsor Contact Person (s):

Technical Matters

Dr. B. Appleman, Contract Manager
U.S. Department of Transportation
Federal Highway Administration
Office of Research
Materials Division
Washington, D.C. 20590
(703) 557-5204

Contractual Matters
(thru OCA)

Mrs. Janet Ford, Contract Administrator
U.S. Department of Transportation
Federal Highway Administration
Office of Contracts and Procurement
Washington, D.C. 20590
(202) 755-9370

Defense Priority Rating: None

Assigned to: CMSL/MSD (~~School~~/Laboratory)

COPIES TO:

- Project Director
- Division Chief (EES)
- School/Laboratory Director
- Dean/Director—EES
- Accounting Office
- Procurement Office
- Security Coordinator (OCA) /
- Reports Coordinator (OCA) /
- Library, Technical Reports Section
- EES Information Office
- EES Reports & Procedures
- Project File (OCA)
- Project Code (GTRI)
- Other ____________

CA-3 (3/76)

ORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 7/25/84

ect No. A-2490 XXXXXLab EMSL

udes Subproject No.(s) ________

ect Director(s) Dr. Charles J. Ray GTRI / XXX

nsor U.S. Department of Transportation

: Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings

ctive Completion Date: 3/1/82 (Performance) 3/1/82 (Reports)

nt/Contract Closeout Actions Remaining:

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

inues Project No. ________ Continued by Project No. ________

IES TO:

ect Director
arch Administrative Network
arch Property Management
unting
urement/EES Supply Services
arch Security Services
rts Coordinator (OCA)
l Services

Library
GTRI
Research Communications (2)
Project File
Other I. Newton

OCA 60:1028

A 2490

MONTHLY PROGRESS REPORT

Number 1
October 1, 1979 through October 31, 1979
EES Project A-2490

CATALOGUE, EVALUATE AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract Number DOT-FH-11-9698
U. S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Material Sciences Branch
Chemical and Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

1.0 Introduction

The objective of the project is a determination of the feasibiltiy, merits, and workability of a data bank for the performance of coatings on steel bridges. This is the first reporting period under the contract. The work expended was directed at organizing the research team, reviewing the tasks, and identifying responsibilities and duties.

2.0 Research Results, Conclusions, Trends, and Progress

An initial review meeting was held with all the professional staff in attendance (N. Hilsen, C. Ray, F. Rideout, and F. Vogler). The tasks were reviewed to identify each member's role and responsibilities. A second review meeting was held following the visit of C. Ray, Project Director, with Dr. Appleman, the Contract Manager at FHWA. The information and data supplied by Dr. Appleman was reviewed and distributed to the appropriate team members. The subcontractor, SSPC, was also contacted.

3.0 Estimated Cost to Complete Work

Budget (Phase I)		$ 74,861
Cumulative Cost	$ 0.00	
Estimated Cost for Reporting Period (10/1/79 - 10/31/79)	$1,597.92	
		($1,597.52)
Estimated Cost to Complete Work		$73,263.08

4.0 Identification of Problems

Frank Vogler will not be able to participate on the research team due to his position now as a branch head in the Systems Engineering Laboratory.

A request to substitute Joseph F. Celko of the Software Applications Division of the Computer Science and Technology Laboratory has been written to the contract officer. This letter has been submitted to the Office of Contract Administration for handling and submission to FHWA.

A copy of Mr. Celko's biosketch is attached. His monthly charge rate is comparable to Frank Vogler's rate so that the level of effort desired for the computer specialist is not reduced. The man-hours expected for Mr. Celko are 491 in Phase I and 787 in Phase II, the level of effort for Mr. Vogler was 461 and 737. (Note: Article XI of DOT-FH-11-9698 incorrectly reports 615 man-hours due to an arithmetic error.)

5.0 Future Plans

During the next reporting period it is planned to:

1. institute of computerized literature search help to identify previous and current efforts at computer assisted record keeping and evaluation of coating performance;

2. start contacting raw material manufacturers, coatings manufacturers, research institutes, etc. to inquire about efforts at computerized record and data keeping;

3. identify major non-highway data sources for coatings performance data (here SSPC will play a major role);

4. start designing plans (Tasks A-2 and B-2) to obtain detailed information of programs and to characterize data sources;

5. Analyze the information processing system developed at Georgia Tech (W. R. Tooke, Jr., "Paint Evaluation Manual", Technical Report No. 1, Research Contract No. HPS-1(63), November 15, 1970).

6.0 Work Performed versus Scheduled Work

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
A. Review of Previous Computerized Evaluations	///	///	///	///	///							
1. Identify current & previous efforts	///	///										
2. Plan to obtain methodology information		///	///									
3. Execute Plan				///	///							
B. Classify & Characterize Sources of Coatings Performance Data	///	///	///	///	///	///	///					
1. Identify major non-highway sources	///	///										
2. Plan to characterize the data		///	///			///	///					
3. Select highway related sources of data			///	///	///							
C. Evaluation of Merits of Centralized Data Bank				///	///	///	///					
1. Significant variables affecting coating performance				///	///							
2. Data available versus significant variables						///						
3. Factors in establishing data bank					///	///						
4. Product Uniformity						///						
5. Types of Coating Data Banks Possible						///	///					

Months After Start of Contract

6.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
	Months After Start of Contract											
D. Format and Procedure for Data Bank							//////	//////	///			
1. Specific Recommendations							///					
2. Incomplete data, etc.							//////	/				
3. Specific Phase II Plan								//////	///			
Reports, Plans												
1. Monthly		Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ
2. Task A-2, B-2, D-3 Plan			Λ						Λ			
3. Draft Final									Λ			
4. Final												Λ

1 ///// Scheduled; ▒▒▒ Actual

Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
.eview Previous/Current Computerized ;valuation			$13,746	
.. Identify current/previous efforts	$3443	1597	5,165	1597
:. Plan to obtain methodology information			2,138	
;. Execute plan			6,443	
:lassify & Characterize Sources of Coatings Performance Data			$24,120	
.. Identify major non-highway sources			9,202	
!. Prepare detailed plan to characterize the data			2,759	
}. Select highway related sources of data			12,159	
:valuation of Merits of Centralized Data Bank			$19,956	
.. Identify and discuss significant variables			2,149	
!. Relationship of data to significant variables			2,150	
}. Factors in establishing data bank			5,979	
ł. Discuss product uniformity			4,299	
;. Describe type of coating data banks that could be established			5,379	
'ormat and Procedure for Data Bank			$13,632	
L. Prepare specific recommendations			4,544	
!. Discuss incomplete data problems, etc.			4,544	
}. Prepare specific Phase II plan			4,544	
:ts, plans			$ 3,406	

Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	20	20
Frank A. Rideout	20	20
Neil B. Hilsen	9	9

ADP Services

None.

A-2490

MONTHLY PROGRESS REPORT

Number 2

November 1, 1979 through November 30, 1979

EES Project A-2490

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract Number DOT-FH-11-9690
U. S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager

Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by:

Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director

Dr. Charles J. Ray

1.0 Introduction

The objective of the project is a determination of the feasibility, merits, and workability of a data bank for the performance of coatings on steel bridges. The work expended during this reporting period was directed at identifying previous and current efforts at computerized systems for handling coating performance data and formulating plans for obtaining information about them.

2.0 Research Results, Conclusions, Trends, and Progress

A computerized literature search was made on the subject of data banks of coating performance data. This was supplemented by a brief manual search. The literature data bases searched were Chemical Abstracts (1967 to current) and Compendex or Engineering Index (1970 - September 1979). It was planned to search World Surface Coatings Abstracts also, but the system will not be ready for computerized searching until February, 1980. The output from a literature search used in proposal preparation was again reviewed. Here, the data bases were NTIS (1964-1978).

Few pertinent references were obtained from the literature search. The work of Ray Tooke on a program for record keeping of performance and product development data was retrieved from NTIS. The manual search found two papers by Z. Hippe on the general subject of the utilization of computers in the organic coatings industry ("Chemical Informatics in the Organic Coating Industry Part I. Research", Progress in Organic Coatings 5, 219-227 (1977) and "Chemical Informatics in the Organic Industry Part II. Industry", Progress in Organic Coatings 5, 229-236 (1977)). Only a small part of the Hippe's discussion deals with processing of laboratory and outdoor data. It is a highly generalized presentation dealing mainly with standard statistical routines, regression analysis, curve fitting, etc. Most of the references are to European (i.e. foreign language) work.

The paucity of literature references on the project subject is not surprising. As expected, it appears that most of the relevant work is on-going in the coatings industry where the copious amount of data generated in developing new products requires automated processing.

Major raw material suppliers and coatings manufacturers have been contacted to learn of their efforts at data banks on coating performance data. To date the ones known to have programs of interest are Union Carbide Corporation, Rohm and Haas Company, and the Rust-Oleum Corporation. The data is from test fence evaluations where the substrate predominately used is wood. The interest, of course, in these programs is their structure and organization.

The SSPC has been contacted further about their role in the project. As outlined in the proposal, they will be taking the lead in accomplishing the objectives of Task B of Phase I "Classify and Characterize Sources of Coating Performance Data".

3.0 Estimated Cost to Complete Work

Budget (Phase I)		$ 74,861
Cumulative Cost Prior to Reporting Period	$1,597.92	
Estimated Cost for Reporting Period	$3,937.00	
	$5,534.92	(5,534.92)
Estimated Cost to Complete Work		$ 69,326.08

4.0 Identification of Problems

None

5.0 Future Plans

During the next reporting period it is planned to:

1. Continue to contact raw material manufacturers, coatings manufacturers, research institutes etc. to inquire about efforts at computerized record keeping.

2. Submit an announcement on the program to several trade journals as an aid to learning about current efforts at computerized record keeping and data sources
3. Continue with plans for Tasks A-2 and B-2 to obtain detailed information on programs and to characterize data sources
4. Analyze the information processing system developed at Georgia Tech by W. R. Tooke, Jr., "Paint Evaluation Manual", Technical Report No. 1, Research Contract No. HPS-1 (63), November 15, 1970.

6.0 Work Performed versus Scheduled Work[1]

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
	Months After Start of Contract											
A. Review of Previous Computerized Evaluations	//////	//////	//////	//////	//////							
	[redacted]											
1. Identify current & previous efforts	//////	//										
2. Plan to obtain methodology information		///	//////									
3. Execute Plan				//////	//////							
B. Classify & Characterize Sources of Coatings Performance Data	//////	//////	//////	//////	//////	//////	//////					
1. Identify major non-highway sources	//////	//										
2. Plan to characterize the data		///	//////			//////	//////					
3. Select highway related sources of data			/////	//////	//////							
C. Evaluation of Merits of Centralized Data Bank				//////	//////	//////	//////					
1. Significant variables affecting coating performance				//////	//////							
2. Data available versus significant variables						//////						
3. Factors in establishing data bank					//////	//////						
4. Product Uniformity						//////						
5. Types of Coating Data Banks Possible						//////	//////					

6.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
D. Format and Procedure for Data Bank							///	///	///			
1. Specific Recommendations							///					
2. Incomplete data, etc.							///	///				
3. Specific Phase II Plan								///	///			
.. Reports, Plans												
1. Monthly		Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ
2. Task A-2, B-2, D-3 Plan			Λ						Λ			
3. Draft Final									Λ			
4. Final												Λ

1 ///// Scheduled; [redacted] Actual

7.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts	$ 1722	1969	5,165	3566
2. Plan to obtain methodology information	713	984	2,138	984
3. Execute plan			6,443	
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	$ 6135	492	9,202	492
2. Prepare detailed plan to characterize the data			2,759	
3. Select highway related sources of data			12,159	
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank	$	492	5,979	492
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established			5,379	
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations			4,544	
2. Discuss incomplete data problems, etc.			4,544	
3. Prepare specific Phase II plan			4,544	
Reports, plans			$ 3,406	

8.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	48	68
Frank A. Rideout	40	60
Neil B. Hilsen	8	17
Joseph F. Celko	10	10

9.0 ADP Services

None

A-2490

MONTHLY PROGRESS REPORT

Number 3

December 1, 1978 through December 31, 1979

EES Project A-2490

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract Number DOT-FH-11-9698
U. S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by:

Material Sciences Branch
Chemical and Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles J. Ray

1.0 Introduction and Summary

Efforts have continued in seeking information about existing computerized efforts of storing and retrieving coatings performance data and sources of such data. Announcements of the program have been sent to several paint trade journals as an aid in gathering information.

2.0 Research Results, Conclusions, Trends, and Progress

Information has been received from Rust-Oleum Corporation about their computerized system for storing and retrieving weathering data. This information was obtained through Steve Ozenich, Manager, Technical Service Laboratory. The material sent was a sample report sheet from a testing service which contains the raw weathering data, a sample printout of the data, an explanation of the coding and data stored, and, finally, a printout of the data in a report format with labels to identify the coating being evaluated, the substrate, system make-up (primers, topcoat, thickness values), exposure conditions, and monthly performance data for properties such as chalking, color change, cracking, blistering, gloss, rusting, and adhesion. Overall, the data collected is qualitative in nature, based on visual assessment aided by pictorial standards. This data has been adapted to a computerized system by the use of a numerical scale with a one-to-one correspondence with the descriptive scale. For example, the degree of rusting is rated by:

description	value
none	0
trace	1
very slight	2
slight	3
definite	4
medium	5
bad	6
very bad	7

This scale does not appear to be related to the ASTM scale commonly used.

The computer storage/retrieval program for the exterior exposure of trade sales paints at Union Carbide Corporation has also been briefly reviewed. The type of data being stored is formulation, application, substrate, exposure condition, and yearly ratings for the properties of general appearance, dirt pick-up, mildew, erosion, checking, cracking, chalking, flaking, blistering, fading, discoloration, gloss (20^{o} and 60^{o}). The properties are rated by ASTM methods and assigned values on a scale of 1 to 10 except for the gloss readings where the actual values are recorded. The exposure tests are designed with the aid of a statistician.

The Rohm & Haas Company has a computerized system for handling the test fence data generated in their development efforts. This system may be 10 years old. To date, however, Rohm & Haas has been reluctant to discuss the program in any detail.

Harold Small, Marblehead Testing Laboratory, was contacted by Frank Rideout regarding computerized data bases for performance data. Mr. Small was interested in the subject but this interest is in developing such a program (software) and the hardware to sell.

Several other potential sources of information about existing computerized efforts were unsuccessfully contacted due to absences during the holiday season.

The Paint Data Base developed by Ray Tooke has been reviewed in the proposal document. Attempts to get a listing from the tapes on which the program is stored have been so far unsuccessful. A dump of the file containing KTA panel field exposure data is on-hand. It was obtained through Georgia DOT.

Announcements about the program, which included a solicitation for information, were sent to the following trade journals and publications:

Modern Coatings
Coatings (NPCA)
Journal of Coatings Technology
Materials Performance (NACE)
Chemical and Engineering News
American Paint and Coatings Journal

The plans to obtain methodology information and characterize data sources have several common features. The outline of the plans as now envisioned is:

1. contact the organization and/or people in advance to notify them of the type of information sought;
2. prepare a checklist of the information sought to insure all important points are covered in a visit;
3. request the documentation issued to the users of the program; request a listing of the program .

3.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861
Cumulative Cost Prior to Reporting Period	$5098	
Estimated Cost for Reporting Period	$3657	
	$8755	(8,755)
Estimated Cost to Complete Work		$66,106

4.0 Identification of Problems

None

5.0 Future Plans

During the next reporting period, it is planned to:

1. Continue to contact raw material manufacturers, coatings manufacturers, research institutes, etc. to inquire about efforts at computerized record keeping
2. Submit plans for Tasks A-2 and B-2 to obtain detailed information on programs and to characterize data sources

6.0 Work Performed versus Scheduled Work[1]

Task Description (Phase I)

A. Review of Previous Computerized Evaluations

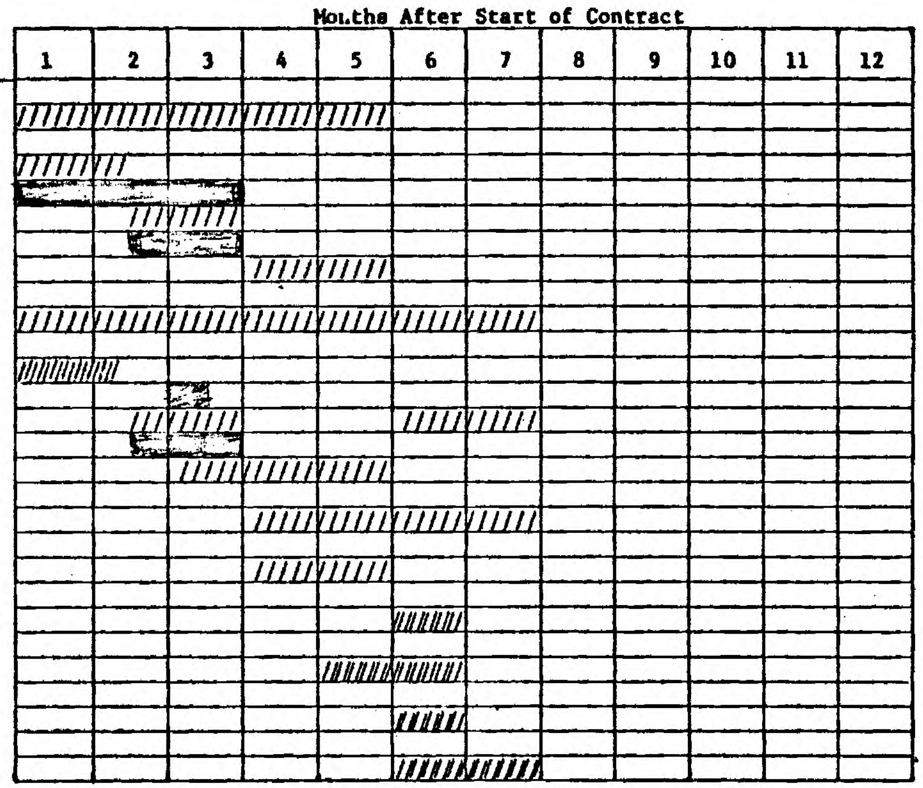
1. Identify current & previous efforts
2. Plan to obtain methodology information
3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

1. Identify major non-highway sources
2. Plan to characterize the data
3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Possible



6.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
	Months After Start of Contract											
D. Format and Procedure for Data Bank							//////	//////	///			
1. Specific Recommendations							///					
2. Incomplete data, etc.							////	//				
3. Specific Phase II Plan								//////	///			
Reports, Plans												
1. Monthly		▲	▲	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ
2. Task A-2, B-2, D-3 Plan				Λ					Λ			
3. Draft Final									Λ			
4. Final												Λ

1 ///// Scheduled; ▬ Actual

7.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts	0	1128	5,165	4694
2. Plan to obtain methodology information	1426	1128	2,138	2112
3. Execute plan			6,443	
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	450	9,202	942
2. Prepare detailed plan to characterize the data	1840	901	2,759	901
3. Select highway related sources of data	4053	0	12,159	
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank			5,979	492
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established			5,379	
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations			4,544	
2. Discuss incomplete data problems, etc.			4,544	
3. Prepare specific Phase II plan			4,544	
Reports, plans			$ 3,406	

8.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	36	104
Frank A. Rideout	30	90
Neil B. Hilsen	8	25
Joseph F. Celko	10	20

.0 ADP Services

None

A-2490

Monthly Progress Report

Number 4

January 1, 1980 through January 31, 1980

EES Project A-2490

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U. S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager

Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by:

Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director

Dr. Charles Ray

1.0 Introduction and Summary

Plans to obtain information about previous and/or current computerized storage and retrieval of coatings performance data, to characterize non-highway sources of data, and to identify and to characterize highway related sources of data have been formulated and written. Some direct contacts have been made to learn about the computer application efforts at Louisiana DOT and NACE Technical Committee T-6H-15. The program developed at Georgia Tech still is not operational.

2.0 Research Results, Conclusions, Trends, and Progress

The plans for Task A-2, "Review of Previous Computerized Evaluations of Coating Performance Data", Task B-2 "Classify and Characterize Sources of Coating Performance Data", and Task B-3 "Select Highway Related Sources of Data" were formulated and written. The plans are now to be reviewed and modified in consultation with the Contract Manager. A copy of the plans as submitted is attached.

A couple of computerized data storage and retrieval systems for polymers have been discovered in the course of manual literature searching to supplement the computerized search. These systems are:

1. "An On-Line System for Storage and Retrieval of Polymer Data", P. F. Roush, J. T. Seitz, and L. F. Young (Dow Chemical Company), Organic Coatings & Plastics Chemistry 39, 656(1978). The data base includes tradenames, structure and polymer class fragment codes, Wiswesser Line Notation, physical properties, plus other data. At the report time, 1100 polymers were in the system with a projection of 3000. Data can be recalled by searching by specific properties, structure and/or class of polymer, and tradenames.

2. "Computerized Numeric Data for Polymers", John Nardone (Plastics Technical Evaluation Center, U. S. Army ARRADCOM), Organic Coatings & Plastics Chemistry 39, 655 (1978). Data is stored for mechanical, thermal, electrical, optical, physical, and permeability properties. The program has been developed but, apparently, it lacks good input.

Due to the close relationship between paints and coatings and polymers, the structure of these programs, cost of establishing, updating, etc., will likely be useful in assessing the feasibility of the data bank for coatings performance. Current information about these data bases will be sought.

Al Dunn of the Louisiana DOT was contacted about his efforts in establishing a computerized system to monitor bridge maintenance and paint performance. He is sending a packet of information which includes 1) Structural Painting Manual, 2) Recording and Coding Guide for Computer Master Structure File, 3) information as listed in computer files on bridge paints, 4) computer generated reports of bridge paint ratings from inspections, and 5) Master Structure File computer sheets of data that can be included in the present system.

John Trim was contacted in regards to the computerized data storage/retrieval system developed through NACE Technical Committee T-6H-15 as part of their study of the effects of surface preparation on the performance of coatings for steel. The basic position on sharing detailed information about the program is that it cost NACE a considerable amount of money to develop the program, prepare coatings, and collect data; some of the cost has to be recovered. A letter is to be written outlining the information wanted about the program separate from the data. This will be presented to the committee at the Corrosion/80 who will then decide what information will be made available and associated cost.

The announcement on the project soliciting information on computerized coating data banks and data sources has appeared in (as far as we know):

1. American Paint & Coatings Journal, January 21, 1980, p. 36.
2. American Painting Contractor, January, 1980, p. 7.

So far, only a few inquires have resulted.

3.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861
Cumulative Cost Prior to Reporting Period	$8,424	
Estimated Cost for Reporting Period	5,024	
	$13,448	(13,448)
Estimated Cost to Complete Work		$61,413

4.0 Identification of Problems

None

5.0 Future Plans

During the next reporting period, it is planned to:

1. Do some manual literature searching for reports containing performance data of coatings on steel.
2. Revise plans for Tasks A-2, B-2, and B-3 as needed.
3. Continue to search for potential sources of data as a personal contact basis.
4. Determine if the Paint Evaluation Program developed by Ray Tooke is useable as it exists on the magnetic tapes.

6.0 Work Performed versus Scheduled Work[1]

Task Description (Phase I)

A. Review of Previous Computerized Evaluations

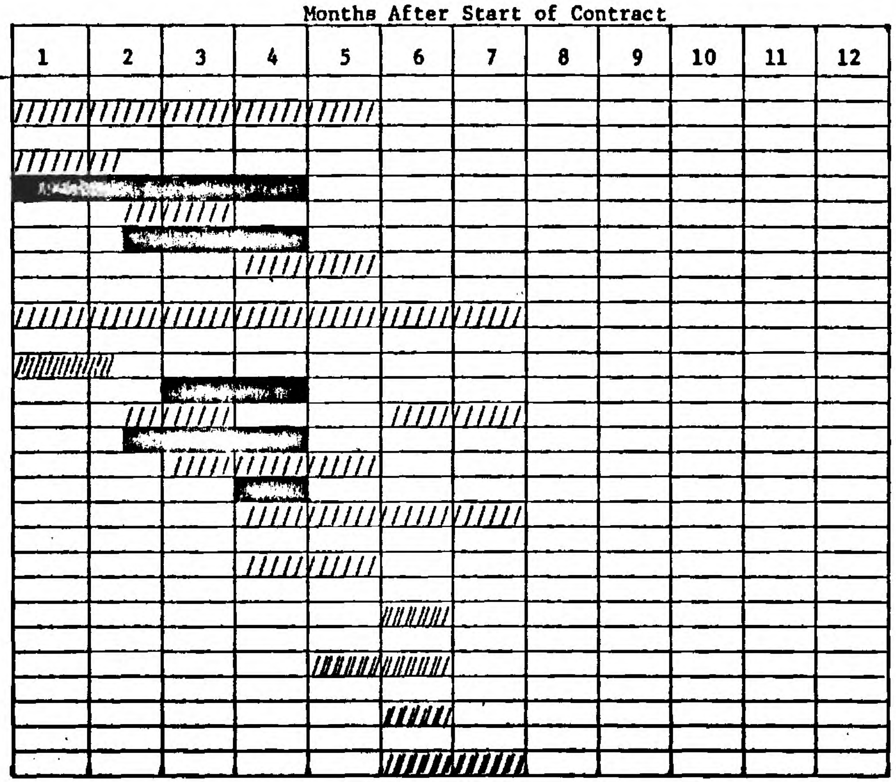
1. Identify current & previous efforts
2. Plan to obtain methodology information
3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

1. Identify major non-highway sources
2. Plan to characterize the data
3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Possible



6.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
							Months After Start of Contract					
D. Format and Procedure for Data Bank							////	////	////			
1. Specific Recommendations				████			////					
2. Incomplete data, etc.							////	////				
3. Specific Phase II Plan								////	////			
Reports, Plans												
1. Monthly		▲	▲	▲	▲	△	△	△	△	△	△	△
2. Task A-2, B-2, D-3 Plan				△	▲				△			
3. Draft Final										△		
4. Final												△

[1] //// Scheduled; ████ Actual

7.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts	0	500	5,165	5194
2. Plan to obtain methodology information	0	691	2,138	2803
3. Execute plan	3,221	0	6,443	
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	1797	9,202	2247
2. Prepare detailed plan to characterize the data	0	691	2,759	1592
3. Select highway related sources of data	4,053	691	12,159	691
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank			5,979	492
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established			5,379	
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations	0	654	4,544	654
2. Discuss incomplete data problems, etc.			4,544	
3. Prepare specific Phase II plan			4,544	
Reports, plans			$ 3,406	

8.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	106	210
Frank A. Rideout	26	116
Neil B. Hilsen	5	30
Joseph F. Celko	15	35

9.0 ADP Services

None

"Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings"

Contract No. DOT-FH-11-9698

Plan for Task A-2, Phase I

Review of Previous Computerized Evaluations of Coating Performance Data

The following is the plan to obtain detailed information on the methodology of data processing for selected efforts at computer assisted storage and retrieval of coating performance data.

Five computerized systems of storing and retrieving coatings performance data have been selected based on the results of a computerized literature search and contacts with industry. These five are the programs at Rohm and Haas Company, Union Carbide Corporation, Rust-Oleum Corporation, NACE Technical Committee T-6H-15 ("Effects of Surface Preparation in Service Life of Protective Coatings"), and Georgia Department of Transportation. This last effort was the one done under the direction of W. R. Tooke, Jr. while he was at Georgia Institute of Technology.

Several coatings manufacturers and raw material suppliers were contacted to generate a list of computerized efforts at performance data. PPG Industries does not have a computerized system for their development work in heavy duty maintenance paints. They do have a system in their industrial coating area but it is small scale now. The performance data collected is typical for the coatings industry: fading, chalking, gloss, blistering, rusting, etc., in addition to detailed information on formulation, substrate, and coating thickness. The ratings are on a scale of 0 to 9 but they are not ASTM designations. The data is collected at 6 month intervals at several test fence sites.

Glidden (SCM Corp.) has plans to computerize their test fence data record keeping in the near future. They are going to use a commercial data base package adapted to their specific needs.

The detailed analysis of the Paint Evaluation Program developed by W. R. Tooke, Jr. will be done at Georgia Tech. Tapes containing the program and data have been obtained from Georgia DOT. At this time, it is not certain if the program and data are recoverable from the tapes. Joe Celko of the Computer Science and Technology Lab at Georgia Tech will handle the task of getting the program up and running. Ray Tooke will be brought in to help if needed.

The data processing system developed and used by NACE Technical Committee T-6H-15 is also of interest. A request is to be made in writing to the committee through John Trim for the type of information sought from the program apart from the data. This request will be presented to the committee at Corrosion/80 in Chicago in early March. What information will be made available for this project and its associated cost will be determined by NACE but an exact timetable cannot be established since any action will require NACE board of directors approval.

The programs at Rohm & Haas, Union Carbide, and Rust-Oleum will be analyzed by personal visits. Prior to the visit, a letter will be sent to each organization which will list the information sought. A draft of this letter is given in Appendix A.

Rust-Oleum will be visited during Corrosion/80 since Frank Rideout is scheduled to go to the conference. The contact person at Rust-Oleum is Steve Ozenich, Manager of Technical Service Laboratory. Frank Rideout is going since several contacts and potential contacts for data and other information will be there. Some of these contacts are NACE Technical Committee T-6H-15 members, Richard Drisko (NCEL), Alfred Beitelman (CERL), and Daniel Gelfer (Ameron, Inc.).

"Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings"

Contract No. DOT-FH-11-9698

Plan for Task B-2, Phase I

Classify and Characterize Sources of Coating Performance Data

Based on the personal knowledge of the research team, including the staff at Steel Structures Painting Council, study of the technical literature, and contacts made during the early stages of the project, the following is a listing of likely non-highway data sources for coatings performance on structural steel.

1. Government Agency

   * U. S. Army Construction Engineering Research Laboratory (CERL)- Alfred Beitelman
   * U. S. Navy Naval Construction Battalion Command Naval Civil Engineering Laboratory - Richard Drisko
   * Bureau of Reclamation - Stan Henshaw
   * NBS (Paul Campbell)
   * NASA

2. Steel or Coatings Manufacturer or Raw Material Supplier

   * Armco Steel Corporation
   * Ameron, Inc. (coatings manufacturer) - Daniel Gelfer
   * Carboline Company
   * Mobil Chemical Company
   * NL Industries
   * DuPont, Maintenance Finishes
   * Union Carbide Corporation
   * PPG Industries, Inc.

3. Industrial User

   * Monsanto Company
   * Union Carbide Corporation
   * Florida Power and Light
   * Georgia Power

4. University, Research Agency, Trade Associations

   * Steel Structures Painting Council
   * International Lead & Zinc Research Organization (ILZRO)
   * Zinc Institute
   * International Bridge, Tunnel and Turnpike Association
   * North Dakota State University
   * Paint Research Association (England)

For the government agency sources and the university, research institute sources, it is planned to characterize their data from published reports where possible. Much of the data from NCEL and CERL will lend itself to this method. A list of published reports, papers, etc., in the area of coatings on structural steel will be requested from the various agencies. Initial contact will be made by phone in those cases where it has not already been made.

The data collected by SSPC through their coatings evaluation stations is to be included for analysis and characterization. This collection of data represents the accumulation of performance data over a 25 year period. It will be a good independent source of information on the durability of coatings on steel. Specific examples of the data expected from SSPC are results from project PACE, bridge paint tests on the Golden Gate Bridge, George Washington Bridge, Bayonne Bridge, Robert Moses Bridge, Chesapeake Bay Bridge, Delaware Memorial Bridge and the Passaic Bridge, and the results of SSPC work for the Corrosion Committee of the Federation of Societies for Coatings Technology on projects such as the minimum film thickness for protection of hot rolled steel and painting wet and cold steel. The performance of paint systems on railroad bridges from the Penn Central, Southern, Missouri-Pacific, and Sante Fe railroads amongst others is part of the inventory of data at SSPC.

The data from organizations such as the International Lead and Zinc Research Organization is expected to be available largely in published reports in sufficient detail to be of direct use. The Zinc Institute and the Paint Research Association are included here. Contact will first be made by phone and followed up by letter detailing the request for information on the type of data available. A draft of this letter is included with the plan as Appendix B-1.

The data from users and manufacturers are expected to be case history type or a series of maintenance records in addition to test fence results. Case history data can still be characterized as outlined in the statement of work (page 2-3) recognizing the difference between experimental installations and normal maintenance operations.

The characterization of the data from users and manufacturers will not be as easy to do as with the data from government agencies since the data are not readily available to the general public. Here, on-site visits are expected to be the best route to obtaining the desired information. As in other cases, the visits will be preceeded by phone and letter contact. The phone contact will be used to identify the correct people to see for the information. The letter in Appendix B-1 with minor modification will be used.

"Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings"

Contract No. DOT-FH-11-9698

Plan for Task B-3, Phase I

Select Highway Related Sources of Data

The selection of highway related sources is to be done in consultation with the FHWA contract manager. These sources are to be derived from various strata of the highway bridge maintenance community. The consensus experience of the research team has been with state departments of transportation and bridge authorities so we have not been able to identify city or county highway agencies as potential sources of bridge coating data. We are dependent on the contract manager for such sources.

The state DOTs felt to have information from controlled bridge coating tests are:

California

Florida

Louisiana

Massachusetts

Michigan

Washington

West Virgina

Port and Authorities which will likely have information of value are two, New York and New Jersey Port Authority and Massport. Other such agencies will be identified through the International Bridge, Tunnel and Turnpike Association.

For the state DOTs, the request for information on controlled, bridge coating performance evaluations will be accompanied by a letter from FHWA requesting cooperation. The letter requesting the information is in Appendix B-2.

This letter with minor modifications will be used to request the same type of information from other highway related sources. The initial characterization of the data will be attempted by phone with follow-up visits when possible.

APPENDIX A

Draft of Letter Requesting Information on Data Processing of Coatings Performance Data

Date

Inside Address

Dear Person:

As you know from our initial discussions, we are performing a research study for the Federal Highway Administration with the objective to determine the feasibility, merits, and workability of a data bank of coatings for steel bridges. After our initial review of existing computerized storage and retrieval systems for paint performance data, we feel that your experience in this area will be beneficial to the overall success of the project. We would like, then, to obtain some detailed information on your program.

A coarse classification of the type of information we would like to get is:

1. Extent and complexity of the computer program
2. Computer memory and other hardware requirements
3. Costs of establishing, operating, and updating.

We have chosen as indicators or parameters of the extent and complexity of the computer programs the division of the program into data base management program (DBM), utility programs, and analysis programs. For each type of program further characterization would entail the number of lines of code, match between programming language and functions performed, variability of data format, sophistication of the software, sophistication of coding, organization techniques, documentation, and overall organization complexity.

The computer resource requirement includes memory size, hardware, input/output methods, etc. Here, program source code can be examined to determine data area size and program length.

The cost of establishing, operating, and updating the data base can be measured in terms of the person-hours required to do these tasks.

There are other, more general questions of interest whose answers have an impact on the feasibility of FHWA establishing a data base. Some of these questions are:

1. What motivated the effort?
2. How was data generated (i.e., used existing data and/or new data generated which was standardized to fit the data base)?
3. What type of questions are asked of the data bank?
4. What type of answers are/were expected?
5. What is the frequency of updating? Method of updating?
6. How are requests (searches) of the data bank made?

For your general information, a computerized data base was developed at the Engineering Experiment Station under the direction of W. R. Tooke, Jr. during the 1960's and early 1970's. A microfiche copy of the final report describing this system plus ten years of R&D effort in protective paint systems for highway structural steel is enclosed. A listing of the program is also included with a breakdown into DBM, utility, and analysis routines. These documents are proffered since we feel that people involved in the development of a data base have a personal interest in the subject in addition to a job oriented interest and we want to have some measure of a two-way exchange of information and experience.

If a listing of your program could be made available to us, we can do most of the analysis and information extraction. This will help minimize your cost and effort. We will, of course, respect any restrictions on the use of the listing you deem necessary.

We thank you in advance for your consideration shown to our request and we look forward to visiting you and exchanging information in regards to FHWA's interest in a coatings performance data bank.

Sincerely,

Charles J. Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Division

Enclosure: Microfiche Copy of "Paint Systems for Highway Structural Steel"
Listing of Paint Evaluation Program

APPENDIX B-1

Draft of Letter Requesting Data on the Peformance of Coatings on Structural Steel

Date

Inside Address

Dear Person:

We are performing a research study for the Federal Highway Administration with the objective to determine the feasibility, merits, and workability of a data bank of coatings for structural steel and their performance thereon. The project is entitled "Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings".

Part of the study involves the classification and characterization of sources of coatings performance data. Since your organization is active in the field of protecting steel from atmospheric corrosion we feel that your findings will be of value in establishing of good base of data. Although the end interest is the performance of coatings on bridges, performance data of coatings on strucutral steel in general is sought. These data predominately are to be those derived from test fence studies and in-service testing. Data from accelerated testing coupled with outdoor exposures are also desirable.

The information we seek is such that we can characterize the data as to:

1. Extent of the data, including amount of replication, number of different coatings studied (at least by generic type).
2. Type, consistency, and objectivity of the rating system.

3. Number and significance of variables included in the experimental design, such as exposure environment, coating thickness or weight, surface preparation, etc.

If the results of your research and development efforts in the protection of steel from atmospheric corrosion are available in published reports, please provide us with a listing of the reports and, if possible, a copy of each. This will allow us to analyze the data at a minimum expense of your time.

If your data is not accessible through reports, manuals, booklets, case histories, etc., please advise us as to the method by which we may examine the data, any restrictions in its use, and any associated costs.

We thank you in advance to the consideration shown to our request and look forward to intracting with you in regards to FHWA's interest in a coatings performance data base.

Sincerely,

Charles Ray, Project Director
Material Science Branch
Chemical & Material Sciences Lab.

APPENDIX B-2

Draft of Letter Requesting Information from Controlled, Bridge Coating Performance Tests

Date

Inside Address

Dear Person:

We are performing a research study for the Federal Highway Administration with the objective to determine the feasibility, merits, and workability of a data bank of coatings for highway structural steel and their performance thereon. The project is entitled "Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings". It is part of FCP Project 4J "Coating Systems for Controlling Corrosion of Highway Structural Steel".

We are contacting you as a potential source of data on the performance of coatings on bridges gathered from controlled, bridge painting tests and case history records, past and current. We plan to characterize such data by parameters such as:

1. Extent of data including number of different coatings (generic type) and exposure time.
2. Documentation as to surface preparation, thickness of coating layers, application schedule, and exposure environment.
3. Rating system used to monitor the performance of the paint and frequency of inspection.
4. Availability of the data, restrictions in use, and cost of acquiring the data for the data base.

Please advise us so to what method would be most convenient to you that will allow us to learn of and benefit from your experiences in protecting highway structural steel. We would also like to learn about any future service tests of coatings you might have planned.

As part of the highway maintenance community, you will hopefully be a user of any data base that evolves from this study. Hence, we are vitally interested in your thoughts and comments about a computerized storage and retrieval system of bridge coatings. For example, we would like to know what kinds of questions you would ask of such a system, what type of answers you expect, and what mechanism should be used to request information from the system.

We thank you in advance to the consideration shown to our request and look forward to working with you in regards to this program that has the potential to help apply better corrosion control technology nationwide.

Sincerely,

Charles Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Lab.

A-2490

A-2490

"Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings"

Contract No. DOT-FH-11-9698

Plan for Task A-2, Phase I

Review of Previous Computerized Evaluations of Coating Performance Data

The following is the plan to obtain detailed information on the methodology of data processing for selected efforts at computer assisted storage and retrieval of coating performance data.

Five computerized systems of storing and retrieving coatings performance data have been selected based on the results of a computerized literature search and contacts with industry. These five are the programs at Rohm and Haas Company, Union Carbide Corporation, Rust-Oleum Corporation, NACE Technical Committee T-6H-15 ("Effects of Surface Preparation in Service Life of Protective Coatings"), and Georgia Department of Transportation. This last effort was the one done under the direction of W. R. Tooke, Jr. while he was at Georgia Institute of Technology.

Several coatings manufacturers and raw material suppliers were contacted to generate a list of computerized efforts at performance data. PPG Industries does not have a computerized system for their development work in heavy duty maintenance paints. They do have a system in their industrial coating area but it is small scale now. The performance data collected is typical for the coatings industry: fading, chalking, gloss, blistering, rusting, etc., in addition to detailed information on formulation, substrate, and coating thickness. The ratings are on a scale of 0 to 9 but they are not ASTM designations. The data is collected at 6 month intervals at several test fence sites.

Glidden (SCM Corp.) has plans to computerize their test fence data record keeping in the near future. They are going to use a commercial data base package adapted to their specific needs.

The detailed analysis of the Paint Evaluation Program developed by W. R. Tooke, Jr. will be done at Georgia Tech. Tapes containing the program and data have been obtained from Georgia DOT. At this time, it is not certain if the program and data are recoverable from the tapes. Joe Celko of the Computer Science and Technology Lab at Georgia Tech will handle the task of getting the program up and running. Ray Tooke will be brought in to help if needed.

The data processing system developed and used by NACE Technical Committee T-6H-15 is also of interest. A request is to be made in writing to the committee through John Trim for the type of information sought from the program apart from the data. This request will be presented to the committee at Corrosion/80 in Chicago in early March. What information will be made available for this project and its associated cost will be determined by NACE but an exact timetable cannot be established since any action will require NACE board of directors approval.

The programs at Rohm & Haas, Union Carbide, and Rust-Oleum will be analyzed by personal visits. Prior to the visit, a letter will be sent to each organization which will list the information sought. A draft of this letter is given in Appendix A.

Rust-Oleum will be visited during Corrosion/80 since Frank Rideout is scheduled to go to the conference. The contact person at Rust-Oleum is Steve Ozenich, Manager of Technical Service Laboratory. Frank Rideout is going since several contacts and potential contacts for data and other information will be there. Some of these contacts are NACE Technical Committee T-6H-15 members, Richard Drisko (NCEL), Alfred Beitelman (CERL), and Daniel Gelfer (Ameron, Inc.).

"Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings"

Contract No. DOT-FH-11-9698

Plan for Task B-2, Phase I

Classify and Characterize Sources of Coating Performance Data

Based on the personal knowledge of the research team, including the staff at Steel Structures Painting Council, study of the technical literature, and contacts made during the early stages of the project, the following is a listing of likely non-highway data sources for coatings performance on structural steel.

1. Government Agency

   * U. S. Army Construction Engineering Research Laboratory (CERL)- Alfred Beitelman
   * U. S. Navy Naval Construction Battalion Command Naval Civil Engineering Laboratory - Richard Drisko
   * Bureau of Reclamation - Stan Henshaw
   * NBS (Paul Campbell)
   * NASA

2. Steel or Coatings Manufacturer or Raw Material Supplier

   * Armco Steel Corporation
   * Ameron, Inc. (coatings manufacturer) - Daniel Gelfer
   * Carboline Company
   * Mobil Chemical Company
   * NL Industries
   * DuPont, Maintenance Finishes
   * Union Carbide Corporation
   * PPG Industries, Inc.

3. Industrial User

* Monsanto Company
* Union Carbide Corporation
* Florida Power and Light
* Georgia Power

4. University, Research Agency, Trade Associations

* Steel Structures Painting Council
* International Lead & Zinc Research Organization (ILZRO)
* Zinc Institute
* International Bridge, Tunnel and Turnpike Association
* North Dakota State University
* Paint Research Association (England)

For the government agency sources and the university, research institute sources, it is planned to characterize their data from published reports where possible. Much of the data from NCEL and CERL will lend itself to this method. A list of published reports, papers, etc., in the area of coatings on structural steel will be requested from the various agencies. Initial contact will be made by phone in those cases where it has not already been made.

The data collected by SSPC through their coatings evaluation stations is to be included for analysis and characterization. This collection of data represents the accumulation of performance data over a 25 year period. It will be a good independent source of information on the durability of coatings on steel. Specific examples of the data expected from SSPC are results from project PACE, bridge paint tests on the Golden Gate Bridge, George Washington Bridge, Bayonne Bridge, Robert Moses Bridge, Chesapeake Bay Bridge, Delaware Memorial Bridge and the Passaic Bridge, and the results of SSPC work for the Corrosion Committee of the Federation of Societies for Coatings Technology on rojects such as the minimum film thickness for protection of hot rolled steel nd painting wet and cold steel. The performance of paint systems on railroad ridges from the Penn Central, Southern, Missouri-Pacific, and Sante Fe railroads mongst others is part of the inventory of data at SSPC.

The data from organizations such as the International Lead and Zinc Research rganization is expected to be available largely in published reports in suffi- ient detail to be of direct use. The Zinc Institute and the Paint Research ssociation are included here. Contact will first be made by phone and followed p by letter detailing the request for information on the type of data available. draft of this letter is included with the plan as Appendix B-1.

The data from users and manufacturers are expected to be case history ype or a series of maintenance records in addition to test fence results. ase history data can still be characterized as outlined in the statement of ork (page 2-3) recognizing the difference between experimental installations nd normal maintenance operations.

The characterization of the data from users and manufacturers will not be s easy to do as with the data from government agencies since the data are not eadily available to the general public. Here, on-site visits are expected to e the best route to obtaining the desired information. As in other cases, he visits will be preceeded by phone and letter contact. The phone contact ill be used to identify the correct people to see for the information. The etter in Appendix B-1 with minor modification will be used.

"Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings"

Contract No. DOT-FH-11-9698

Plan for Task B-3, Phase I

<u>Select Highway Related Sources of Data</u>

The selection of highway related sources is to be done in consultation ith the FHWA contract manager. These sources are to be derived from various trata of the highway bridge maintenance community. The consensus experience f the research team has been with state departments of transportation and ridge authorities so we have not been able to identify city or county highway gencies as potential sources of bridge coating data. We are dependent on he contract manager for such sources.

The state DOTs felt to have information from controlled bridge coating ests are:

California

Florida

Louisiana

Massachusetts

Michigan

Washington

West Virgina

Port and Authorities which will likely have information of value are two, ew York and New Jersey Port Authority and Massport. Other such agencies will e identified through the International Bridge, Tunnel and Turnpike Association.

For the state DOTs, the request for information on controlled, bridge oating performance evaluations will be accompanied by a letter from FHWA reesting cooperation. The letter requesting the information is in Appendix B-2.

This letter with minor modifications will be used to request the same type of information from other highway related sources. The initial characterization of the data will be attempted by phone with follow-up visits when possible.

APPENDIX A

Draft of Letter Requesting Information on Data Processing of Coatings Performance Data

Date

:nside Address

'ear Person:

As you know from our initial discussions, we are performing a research tudy for the Federal Highway Administration with the objective to determine he feasibility, merits, and workability of a data bank of coatings for steel ridges. After our initial review of existing computerized storage and etrieval systems for paint performance data, we feel that your experience in his area will be beneficial to the overall success of the project. We would ike, then, to obtain some detailed information on your program.

A coarse classification of the type of information we would like to get s:

1. Extent and complexity of the computer program
2. Computer memory and other hardware requirements
3. Costs of establishing, operating, and updating.

We have chosen as indicators or parameters of the extent and complexity : the computer programs the division of the program into data base management :ogram (DBM), utility programs, and analysis programs. For each type of :ogram further characterization would entail the number of lines of code, ıtch between programming language and functions performed, variability of ıta format, sophistication of the software, sophistication of coding, rganization techniques, documentation, and overall organization complexity.

The computer resource requirement includes memory size, hardware, input/ ıtput methods, etc. Here, program source code can be examined to determine ıta area size and program length.

The cost of establishing, operating, and updating the data base can be easured in terms of the person-hours required to do these tasks.

There are other, more general questions of interest whose answers have ı impact on the feasibility of FHWA establishing a data base. Some of these ıestions are:

1. What motivated the effort?
2. How was data generated (i.e., used existing data and/or new data generated which was standardized to fit the data base)?
3. What type of questions are asked of the data bank?
4. What type of answers are/were expected?
5. What is the frequency of updating? Method of updating?
6. How are requests (searches) of the data bank made?

For your general information, a computerized data base was developed at ıe Engineering Experiment Station under the direction of W. R. Tooke, Jr. ıring the 1960's and early 1970's. A microfiche copy of the final report scribing this system plus ten years of R&D effort in protective paint stems for highway structural steel is enclosed. A listing of the program also included with a breakdown into DBM, utility, and analysis routines. ıese documents are proffered since we feel that people involved in the velopment of a data base have a personal interest in the subject in addition a job oriented interest and we want to have some measure of a two-way exange of information and experience.

If a listing of your program could be made available to us, we can do st of the analysis and information extraction. This will help minimize ur cost and effort. We will, of course, respect any restrictions on the e of the listing you deem necessary.

We thank you in advance for your consideration shown to our request and look forward to visiting you and exchanging information in regards to VA's interest in a coatings performance data bank.

Sincerely,

Charles J. Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Division

closure: Microfiche Copy of "Paint Systems for Highway Structural Steel"
Listing of Paint Evaluation Program

APPENDIX B-1

Draft of Letter Requesting Data on the Peformance of

Coatings on Structural Steel

Date

nside Address

ear Person:

We are performing a research study for the Federal Highway Administration ith the objective to determine the feasibility, merits, and workability of a ata bank of coatings for structural steel and their performance thereon. The roject is entitled "Catalogue, Evaluate, and Process Performance Data for ighway Bridge Coatings".

Part of the study involves the classification and characterization of sources f coatings performance data. Since your organization is active in the field f protecting steel from atmospheric corrosion we feel that your findings will e of value in establishing of good base of data. Although the end interest s the performance of coatings on bridges, performance data of coatings on rucutral steel in general is sought. These data predominately are to be iose derived from test fence studies and in-service testing. Data from celerated testing coupled with outdoor exposures are also desirable.

The information we seek is such that we can characterize the data as to:

1. Extent of the data, including amount of replication, number of different coatings studied (at least by generic type).
2. Type, consistency, and objectivity of the rating system.

3. Number and significance of variables included in the experimental design, such as exposure environment, coating thickness or weight, surface preparation, etc.

If the results of your research and development efforts in the protection steel from atmospheric corrosion are available in published reports, please rovide us with a listing of the reports and, if possible, a copy of each. is will allow us to analyze the data at a minimum expense of your time.

If your data is not accessible through reports, manuals, booklets, case stories, etc., please advise us as to the method by which we may examine the ta, any restrictions in its use, and any associated costs.

We thank you in advance to the consideration shown to our request and ok forward to intracting with you in regards to FHWA's interest in a coatings rformance data base.

Sincerely,

Charles Ray, Project Director
Material Science Branch
Chemical & Material Sciences Lab.

APPENDIX B-2

Draft of Letter Requesting Information from Controlled, Bridge Coating Performance Tests

Date

ıside Address

ɜar Person:

We are performing a research study for the Federal Highway Administration ıth the objective to determine the feasibility, merits, and workability of a ıta bank of coatings for highway structural steel and their performance thereon. ıe project is entitled "Catalogue, Evaluate, and Process Performance Data for ıghway Bridge Coatings". It is part of FCP Project 4J "Coating Systems for ›ntrolling Corrosion of Highway Structural Steel".

We are contacting you as a potential source of data on the performance : coatings on bridges gathered from controlled, bridge painting tests and ıse history records, past and current. We plan to characterize such data by ırameters such as:

1. Extent of data including number of different coatings (generic type) and exposure time.
2. Documentation as to surface preparation, thickness of coating layers, application schedule, and exposure environment.
3. Rating system used to monitor the performance of the paint and frequency of inspection.
4. Availability of the data, restrictions in use, and cost of acquiring the data for the data base.

Please advise us so to what method would be most convenient to you that ill allow us to learn of and benefit from your experiences in protecting ighway structural steel. We would also like to learn about any future service ests of coatings you might have planned.

As part of the highway maintenance community, you will hopefully be a ser of any data base that evolves from this study. Hence, we are vitally nterested in your thoughts and comments about a computerized storage and re-rieval system of bridge coatings. For example, we would like to know what inds of questions you would ask of such a system, what type of answers you xpect, and what mechanism should be used to request information from the ystem.

We thank you in advance to the consideration shown to our request and ook forward to working with you in regards to this program that has the otential to help apply better corrosion control technology nationwide.

Sincerely,

Charles Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Lab.

A-2490

Monthly Progress Report

Number 5

February 1, 1980 through February 29, 1980

EES Project A-2490

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U. S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by:

Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director

Dr. Charles Ray

1.0 Introduction and Summary

The activities for this reporting period centered upon answering responses to the magazine announcement on the project, modifying the task plans, performing a manual literature search for data sources, and trying to decipher the information on tapes expected to hold the PEP program and data developed by Tooke and co-workers.

2.0 Research Results, Conclusions, Trends, and Progress

The announcement on the project soliciting information on computerized coatings performance storage/retrieval systems and sources of data has appeared additionally in:

1. Coatings (NPCA), January 28, 1980, p. 5
2. Materials Performance, February 1980, p. 66.

The response has been light. Copies of letters sent to organizations that did respond are attached (Glidden Coatings and Resins-Powder Coatings Division, Ameron, Inc., Louisiana DOT, Hydrozo Coatings Company, and Tooke Engineering Associates). Other responses have been received but have not been answered yet or the information sent not yet reviewed. A coarse description of these are:

Company	Response
Davis Paint Manufacturers, Inc. Lynchburg, Virginia	No information offered but would like a copy of report.
Advanced Coatings and Chemicals Temple City, California	Product bulletin for waterborne coating.
Delkote, Inc. Penns Grove, New Jersey	Product brochure; offer of more information if wanted. May have field data of less than 4 years exposure.
Tnemec Company, Inc. Kansas City, Missouri	Product brochure on power plant coatings; offer to supply more information

Company	Response
Kenitex Coatings, Inc. Torrance, California	Catalog and specifications on bridge coatings; offer of further assistance.
American Hot Dip Galvanizers Assoc. Washington, D. C.	In process of transferring technical information on the performance of hot dip galvanized steel to a computerized system keyed on author, topic, application, and technical key terms. Copy of "Behavior of Zinc Coatings in Highway Environments" (7 yrs. exposure results on zinc coated steel coupons). Would like to supply data.

Each of the above will be written to for more information or to provide them with a better definition of our requirements and needs.

The plans for Task A-2, Task B-2, and Task B-3 have been reviewed with the Contract Manager and modified accordingly. In summary, the following is to be done:

1. Since the letter to be sent to Steel or Coatings Manufacturers or Raw Material Suppliers, Industrial Users, and University, Research Agency, and Trade Associations is essentially the same, a total of nine from these categories can be queried. These nine are Armco Steel Corporation, PPG Industries, Inc., Monsanto Company, Florida Power and Light, Georgia Power, International Lead & Zinc Research Organization, Zinc Institute, International Bridge, Tunnel, and Turnpike Association, and the Paint Research Association (England).
2. For the highway related sources of data, North Carolina, Iowa, and Ohio are to be added to the list of states while Massachusetts, Washington, and Florida can be removed since personal contacts can be used, avoiding a formal request.
3. Additional sources of highway related data are Golden Gate Bridge Authority, Allegheny County Highway Department, New York City, and the Chicago Department of Public Works.

A manual literature search has been made to identify and locate reports containing exposure data on structural steel coatings. This was done by scanning the entries in World Surface Coatings Abstracts listed under Occurence and Prevention of Deterioration By Weathering, Corrosion, etc. The period covered was 1974-1979. Reports selected will be characterized as to the suitability of their data for incorporation into a data bank.

The viability of Ray Tooke's program, denoted as PEP for Paint Evaluation Program, is still not known. Attempts to get a listing or print out from the tapes have been largely unsuccessful. Some readable statements from the program have been obtained but sequences of garbage also appear. An example of the "good stuff" is attached along with some of garbage which Joe Celko has tentatively identified as control characters.

A classification of the routines expected to be in PEP as to data base management, utility, and analysis is given in the following table. The classification was made based on the functional description of the routine and the following operational definitions:

DBM Program - routines for entering data, checking correctness of data, and deleting data

Utility Program - routines used to select spécified portions of the data, to prepare the data for analysis, to sort, etc.

Analysis Program - routines used to derive new information from the existing raw data.

The functional information on the routines was obtained from Tooke's final report (1974).

3.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861
Cumulative Cost prior to Reporting Period	$13,448	
Estimated Cost for Reporting Period	3,634	
	$17,082	($17,082)
Estimated Cost to Complete Work		$57,779

4.0 Identification of Problems

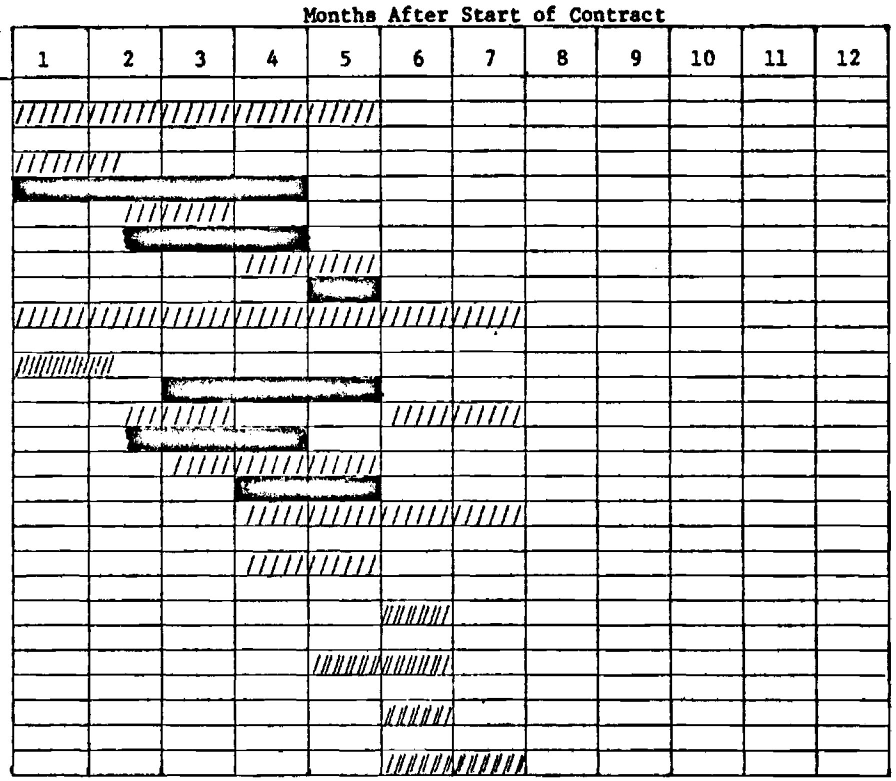
None

5.0 Future Plans

During the next reporting period, it is planned to:

1. Contact Rohm & Haas and Union Carbide Corporation for detailed information on their computerized coatings performance data storage/retrieval systems.
2. Develop detailed plans for work with SSPC regarding sources of data and characterization.
3. Characterize data from literature search.
4. Continue to search for sources of data through personal contacts.
5. Continue efforts to decipher PEP tapes.
6. Implement Task plans when approved.

6.0 Work Performed versus Scheduled Work[1]



Task Description (Phase I)

A. Review of Previous Computerized Evaluations

1. Identify current & previous efforts
2. Plan to obtain methodology information
3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

1. Identify major non-highway sources
2. Plan to characterize the data
3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Possible

6.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
	Months After Start of Contract											
D. Format and Procedure for Data Bank							/////	/////	/////			
1. Specific Recommendations				■■■■			/////					
2. Incomplete data, etc.							/////	/////				
3. Specific Phase II Plan								/////	/////			
Reports, Plans												
1. Monthly		▲	▲	▲	▲	▲	△	△	△	△	△	△
2. Task A-2, B-2, D-3 Plan			△	▲					△			
3. Draft Final									△			
4. Final												△

1 ///// Scheduled; ■■■■ Actual

7.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	$6372
2. Plan to obtain methodology information			2,138	2803
3. Execute plan	$3222	$1178	6,443	1178
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	$ 833	9,202	$3080
2. Prepare detailed plan to characterize the data			2,759	$1592
3. Select highway related sources of data	$4053	$1623	12,159	$2314
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank			5,979	$ 492
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established			5,379	
. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations			4,544	$ 654
2. Discuss incomplete data problems, etc.			4,544	
3. Prepare specific Phase II plan			4,544	
eports, plans			$ 3,406	

.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	32	242
Frank A. Rideout	21	137
Neil B. Hilsen	8	38
Joseph F. Celko	14	49

.0 ADP Services

None

Chuck

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 22, 1980

W. R. Tooke
Tooke Engineering Associates
P. O. Box 13804
Atlanta, Georgia 30324

Dear Ray:

I have delayed in responding to your letter of January 22, 1980 waiting for a determination by the computer specialists on the research team for the data bank project (Project No. A-2490) as to whether or not your program and/or data is still or can be made functional from the tapes we have. As scheduled now, analysis of the tapes transcribed from tapes at Georgia DOT is to start Monday, February 25. I'll contact you by phone as soon as the status of the tapes is established.

The work now (Phase I) is directed at establishing the feasibility and desirability of a coatings performance data bank for the highway bridge maintenance community. This is to be done by evaluating what others have done in terms of structure and size of the program and data base, costs, envisioned and realized advantages and disadvantages and by assessing the quality and quantity of data available for inclusion into the proposed data bank. On the basis of the reports covering your efforts in this field, your work obviously will have a large impact here.

include you in our proposal as a consultant.
pon your expert advice since we want your input
for activity. These topics, included under a
on of the Merits of a Centralized Data Bank",

ing a data bank;

coating data banks that could be established;

ure for Data Bank",

ommendations

ata problems.

detail in the near future.

Atth. 1

I have enclosed a copy of the Statement of Work for your information. It is essentially the same as it appeared in the RFP.

I am looking forward to meeting with you and discussing your work on computer applications in the coatings industry and your input for this FHWA project.

Sincerely,

Charles Ray
Material Sciences Branch
Chemical & Material Sciences Laboratory

CR:gp

Attachment

cc: B. R. Appleman, FHWA
F. A. Rideout
File, A-2490

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

uary 14, 1980

R. Farrell, General Manager
er Coatings Division
den Coatings and Resins
Glenwood Drive
lotte, North Carolina 28208

Mr. Farrell:

Thank you for your response to our announcement and solicitation for t for a data bank on coatings performance. As you know, the request is ehalf of the Federal Highway Administration.

The performance of powder coated highway guardrails is definitely of rest and of value to the overall goal of improving the corrosion control ighway structural steel. The use of shop coated steel in new construction in structural refurbishing of bridges may be the route through which er coating will see service on bridges. FHWA also has a specific interest he corrosion protection of guardrails.

The information sought now is such that will allow us to characterize data as to:

1. Extent of the data including amount of replication and number of different coatings evaluated (at least by generic type).

2. Type, consistency, and objectivity of the rating system used to assess performance (e.g., ASTM methods).

3. Number and significance of variables included in the experimental design such as exposure environment, coating thickness, and surface preparation.

If the data you have available is in published form such as brochures, histories, or reports, please provide us with a listing of such documents if possible, a copy of each. This will allow us to analyze the data at nimum expense to your time.

If the data is not available through reports, booklets, manuals, etc., se advise us as to the method by which we may examine the data, any rictions in its use, and any associated costs in procuring it for inclusion ne data bank.

Attch. 3

We thank you in advance for the consideration shown to our request and
: forward to examining your information in light of FHWA's interest in a
ings performance data bank and promoting better corrosion control tech-
gy. If you have any questions, please do not hesitate to call me; my
phone number is 404/424-9651.

Sincerely,

Charles J. Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Laboratory

gp

B. R. Appleman, FHWA
File, A-2490

Attch. 4

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 13, 1980

iel Gelfer
ron, Inc.
N. Berry Street
a, California 92621

r Mr. Gelfer:

Thank you for your offer to participate in the FHWA project on a coatings formance data bank of highway bridge coatings. The type of information ired now is intended to classify and characterize sources of data. Al-ugh the end interest is the performance of coatings on bridges, performance a of coatings on structural steel in general is sought, including test ce studies. Data from accelerated testing (laboratory) coupled with door exposures are also acceptable.

The information we seek is such that we can characterize the data as

1. Extent of the data including amount of replication and number of different coatings studied (at least by generic type).

2. Type, consistency, and objectivity of the rating system (e.g. ASTM methods).

3. Number and significance of variables included in the experimental design such as exposure environment, coating thickness, and surface preparation.

If the data you have available is in published reports, brochures, case tories, etc., please provide us with a listing of such documents and, if sible, a copy of each. This will allow us to analyze the data at a minimum ense of your time.

If your data is not available through reports, manuals, booklets, case tories, etc., please advise us as to the method by which we may examine data, any restrictions in its use, and any associated costs in procuring for inclusion in the data bank.

Attch. 6

Again, we thank you for your offer of help and for the consideration wn to our request in regards to FHWA's interest in a coatings performance a base. Frank Rideout, a member of the research team on this project, l be at Corrosion/80 so he and you may be able to meet there to discuss s request further. If you have any questions, please do not hesitate call; both Frank and I can be reached at 404-424-9651.

Sincerely,

Charles Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Laboratory

;P

B. R. Appleman, FHWA
File, A-2490

Attch. 7

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 13, 1980

\. J. Dunn, Structures Maintenance Engineer
e of Louisiana
rtment of Transportation and Development
ce of Highways
. Box 44245, Capitol Station
n Rouge, Louisiana 70804

Mr. Dunn:

Thank you for your quick and generous response to my request for rmation on your efforts at computerizing paint case history data for ges. I have not yet had a chance to study the material you sent but an to do so soon. I fully expect that your work will have a direct ct on our feasibility study of a coatings performance data bank for .

Sincerely,

Charles Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Laboratory

)

B. R. Appleman, FHWA
File, A-2490

Attch. 8

An Equal Employment/Education Opportunity Institution

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 13, 1980

ald Varina
rozo Coatings Company
"W" Street
coln, Nebraska 68508

r Mr. Varina:

Thank you for your offer of help in regards to FHWA's interest in a tings performance data base. As we discussed, the interest is in the formance of coatings on structural steel, especially highway bridges. a from test fence studies and service or field testing is the preferred ncipal source. Data from accelerated laboratory tests coupled with door exposures is also desired.

At this time, we want to classify and characterize the data sources. information we seek is such that we can analyze the data as to:

1. Extent of the data including amount of replication and number of different coatings (at least by generic type).

2. Type, consistency, and objectivity of the rating system (e.g., ASTM methods).

3. Number and significance of variables included in the experimental design or test installation such as exposure environment, coating thickness or weight, surface preparation, etc.

If the results of your R&D efforts are available in published form se histories, brochures, reports, etc.), please provide us with a listing he documents and, where possible, a copy of each. This will allow us to he analysis or characterization at a minimum expense of your time. Please se us as to any restrictions in the use of the information you might ly.

Again, we thank you for your consideration to our request and the interest m in helping to develop better corrosion control technology. If you have questions, please do not hesitate to call me. My telephone number is 424-9651.

Sincerely,

Charles Ray, Project Director
Material Sciences Branch
Chemical & Material Sciences Laboratory

p

B. R. Appleman, FHWA
File, A-2490

Attch. 9

An Equal Employment/Education Opportunity Institution

& associated curve fitting.

```
 1120 FORMAT(//1X,15HLN(Y/(10-Y)) = ,2E8.3,2H*T,52X,I7,I6,6X,E8.3,
     12X,E8.3)
 1130 FORMAT(//3X,8HLN(Y) = ,2E8.3,2H*Y,11X,I7,I6,6X,E8.3,2X,E8.3)
 1140 FORMAT(//3X,8HLN(Y) = ,2E8.3,2H*T,57X,I7,I6,6X,E8.3,2X,E8.3)
 1150 FORMAT(1H+,T20,1H+)
1160  FORMAT(4A6)
1170  FORMAT(F10.0)
1180  FORMAT(/5X,'ELAPSED TIME FOR DATA INPUT, LEAST-SQUARES FIT AND ',
     1A6,' IS ',F8.4,' SECONDS.')
1190  FORMAT(1H1,5X,'ERROR IN READING RECORD FROM MASS STORAGE.  LAST
     1FILE NUMBER WAS',I3,1H,/5X,'LAST ITEM NUMBER WAS',I5,
     1' LAST FORM NUMBER WAS',I2,1H.)
1200  FORMAT(1H1,5X,'RUN COMPLETE.' I6,' SETS OF DATA REDUCED.')
1210  FORMAT(1H1,5X,'FORM NUMBER IS BAD, FILE',I3,', ITEM',I5,
     1', FORM',I2,1H.)
 1230 FORMAT(1X,I4,2X,I4,4X,I1,3(F10.1,5(1X,I1)))
 1240 FORMAT(1H1,4HFILE,6H PANEL,5H FORM,3(20H EXP.  TIME   GRADES ))
 1250 FORMAT(1H1,5X,'INTEGRITY AND APPEARANCE PARAMETERS AFTER THE CALL
     TTO THE SORT ROUTINE'/5X,13HEXPOSURE TIME,5X,9HINTEGRITY,5X,10HAPPE
     AARANCE//)
      COMMON/BUFCOM/IBUF(1000)
      COMMON/JCTCOM/JCT
      COMMON/MCOM/M
      DIMENSION TPLOT(103),GPLOT(103),DPLOT(103),PT(103,4)
      DIMENSION AX(4),HLABEL(4),XLABEL(4),YLABEL(4)
      DIMENSION IGTY(30),JAPP(30),T1(3),I1(3,5),J1(3,2),IEXP(30)
      DIMENSION AX1(2,4),HL1(2,4),XL1(2,4),YL1(2,4),TL1(2)
1000  FORMAT(I2,I4,I1,3(F4.0,5I1,A6,A5),29X)
1010  FORMAT(I2,I4,I1,19E9.3,E9.3)
1020  FORMAT(I2,I4,I1,73X,6I1)
1030  FORMAT(I2,I4,I1,12A6,AI,6I1)
      DEFINE C1(SW,ST2,ST,SWT,N)=(SW*ST2/ST-SWT)/(N*ST2/ST-ST)
      DEFINE C2(SW,ST2,ST,SWT,N)=(SW-N*C1(SW,ST2,ST,SWT,N))/ST
      DEFINE W(Y)= ALOG(Y/(10.-Y))
      DEFINE YINT(A,B,T)=(10.*EXP(A+B*T))/(1.+EXP(A+B*T))
      DEFINE W1(Y)= ALOG(Y)
      DEFINE YINT1(A,B,T)= EXP(A+B*T)
      IFORM2=2
      NPL=0
      N7=7
      N5=5
      IPLOT=0
      READ(5,1160)INDPLT
      IF(INDPLT.NE.6HPLOT   )GO TO 5
      IPLOT=1
      CALL PLOTS(IBUF,1000,10)
      DO 3 I=1,2
      READ(12,1160)(AX1(I,J),J=1,4),(HL1(I,J),J=1,4),(XL1(I,J),J=1,4),
     1(YL1(I,J),J=1,4)
      READ(12,1170)TL1(I)
    3 CONTINUE
    5 CONTINUE
      NRED=0
   10 CONTINUE
      CALL TIME(K3,K4)
      READ(8,1000,END=100,ERR=200)IFILE,ITEM,IFORM
      IF(IFILE.LT.5)GO TO 10
```

Attch. 10

EOF1CALDARALE*PDPTAPE00000600010001000100 79130 79130 000052U1100-1] print out that is not decipherable to [illegible]

IJW3TZ"L#$E77DE__<#7W1;1&7M

_C.1)C)
1"B

↑ control characters

EOF2F0048000080

Attch. 11

Characterization of Paint Evaluation Program, PEP, Routines

Routine Name	Computer	Language	Purpose	Type
FILE/ADDITION (IPB-008)	B5500[1]	COBOL	Addition of card images to Master Data File	DBM[2]
DELETE-2 (IPB-009)	B5500	COBOL	Deletion of card images to Master Data File	DBM
UPDATE (IPB-002)	B5500	COBOL	Addition and/or deletion of card images to or from Master Data File	DBM
CLEANUP (IBP-003)	B5500	COBOL	Redundancy check and exposure time computation	DBM
SHAPEUP/SHIPOUT (IPB-004)	B5500	COBOL	Record check for experimental data portion of the Master Data Tape	DBM & UP[3]
FILE-SETUP (NOT FORMALLY DOCUMENTED)	B5500	COBOL	Rearrangement of experimental data for rapid processing	UP
LISTING (IPB-005)	B5500	COBOL	Production of complete and readable listing of paint and constituents information	UP
INTEGI (also referred to as CURRENT AWARENESS) (IPB-006)	B5500	COBOL	Generation of performance distribution from the output of the FILE/SETUP routine	AP[4]
SYSTEM (IPB-012)	B5500	COBOL	Generation of listing of paint names table and paint systems table from Master Data File	UP
FORMULA (IPB-013)	B5500	COBOL	Generation of listing of paint formulation from information stored on Master Data File	UP

Characterization of Paint Evaluation Program, PEP, Routines (continued)

Routine Name	Computer	Language	Purpose	Type
CORRECT/IT (not formally documented)	B5500	COBOL	Correction of erroneous data entries in a random access file such as that produced by FILE/SETUP	DBM
ALPH/SORT	B5500	COBOL	Preparation of an auxiliary file used in the Formula routine	UP
COPYIT (IPB-011)	B5500	COBOL	Copy of Master Data File for use by UNIVAC 1108	UP
SERIAL (IPB-010)	B5500	COBOL	Listing of paint system-panel number-set number relationship	UP
WATER (not formally documented)	U 1108[5]	FORTRAN	Water Immersion test data analysis	AP
ACCEL (IPB-015)	U 1108	FORTRAN	Accelerated Weathering test data analysis	AP
POLAR (IPB-015)	U 1108	FORTRAN	Polarization data analysis	AP
DIELTEMP (not formally documented)	U 1108	FORTRAN	Dielectric properties test data analysis	AP
MULTIPAN TIME/ GRADE (IPB-016)	U 1108	FORTRAN	Integrity-Time output for each panel on a 6-panel plot and a performance curve of a panel	AP
REDUCE-FILE 9 (not formally documented)	U 1108	FORTRAN	Environmental chamber test data reduction, plot option	AP
LEGEND (not formally documented)	U 1108	FORTRAN	Environmental chamber and field test panel data reduction, plot option	AP
COPY-DATA	U 1108	FORTRAN	Construction of random access file and directory from B 5500 magnetic type created by the COPYIT routine	UP

Characterization of Paint Evaluation Program, PEP, Routines (continued)

Routine Name	Computer	Language	Purpose	Type
CHEKREC (not formally documented)	U 1108	FORTRAN	Utility program for display of records as requested by the user from a random access file	UP
EDIT (not formally documented)	U 1108	FORTRAN	Utility program for correction of record in a random access file	DBM

1 B5500 = Burroughs B 5500

2 DBM = Data Base Management Program or routine

3 UP = Utility Program

4 AP = Analysis Program

5 U 1108 = Univac 1108

A-2490

Monthly Progress Report

Number 6

March 1, 1980 through March 31, 1980

EES Project A-2490

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U. S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by:

Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director

Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

Letters requesting information to characterize data sources have been sent to the Paint Research Association (England), Armco Steel Corp., International Lead & Zinc Research Organization, Inc. (ILZRO), and the International Bridge, Tunnel, and Turnpike Association as part of the Task B-2 (Phase I). In addition, letters have been sent to the following to further define the type of data sought for the project after their inquiries: Dennis Parrott (Bureau of Testing, Ohio DOT), William Renz (Premium Finishes), Ben Smith (Delkote, Inc.), T. A. Corboy (Advanced Coatings and Chemicals), Roy Jacobson (Davis Paint Manufacturers, Inc.), David Doucet (Kevitex Chemicals, Inc.), Gary Zinn (Tnemec Company, Inc.), Gary Satterfield (American Hot Dip Galvanizers Association, Inc.).

Frank Rideout attended Corrosion/80 to get more information on the computerized data storage and retrieval system at Rust-Oleum, discuss our request for information about NACE Technical Committee T-6H-15's computer program, and, where possible, to make contacts for sources of data. The commitments to supply data were obtained from:

Company	Contact Person
Koppers	John Williams, Bill Maxwell
Hercules	M. Lichtenstadter
Commonwealth Paint Corp	Allen Robinson
Carboline	John Montle
Union Carbide Corp.	Tom Ginsberg
Mobil Chemical	Mike Mascalli
Amerou	Daniel Gelfer
Naval Civil Engineering Laboratory	Robert Alumbaugh
Tator Associates	Ken Tator

It was also learned that NCEL tried a computerized system for handling test data about 10 years ago.

Frank Rideout also visited Florida DOT in late February and talked with Dick Ramsey (Coatings Engineer & Paint Chemist), John Karras (paint contractor), J. E.

Rogers, Jr. (Assistant Bridge & Facilities Engineer), and Jack Roberts (Bridge & Structures Engineer). Important points of information gathered are:

1. Records of painting by DOT crews are available from 1969 on as daily work logs with information on weather and work completed such as area cleaned, cleanliness specification, area painted, and paint used.
2. It is very time consuming to extract data from the work records.
3. Starting February 1, 1980, a record of the painting and annual inspection of each bridge in a district will be maintained by the district Bridge Engineer (previously, records kept at headquarters).
4. Touch-up painting is not routinely documented and done often to keep crews busy.
5. Florida DOT headquarters is planning to institute a computerized system to help in scheduling painting and budgeting. Data will include costs, environment, preparation, and materials. Information may be available in June.

Sixteen reports and papers from SSPC were reviewed to characterize the data in them. These reports were:

1. Painting of Welds
2. What Do You Know About Painting Welds
3. Painting Our Welds
4. Painting of Hard-Cleaned Steel
5. Surface Preparation Versus Durability, Phase I-Immersion and Humidity Exposures
6. Bridge Paints With Resistance to Salt Brine
7. Protecting Load-Bearing Surfaces of Steel Bridges
8. Painting Steel Bridges for Mild Exposures
9. Minimum Paint Film Thickness for Economical Protection of Hot-Rolled Steel Against Corrosion
10. Studies in Painting Structural Steel
11. New Bridge Paint Systems Show Promise in Tests
12. Protective Coatings for Steel Structures: An Evaluation

13. Surface Profile for Anti-Corrosion Paints
14. Golden Gate Bridge Evaluations
15. Topcoats for Zinc Coatings
16. Performance of Alternate Coatings in the Environment (PACE)

Several studies have additional data collected after the report period. Where needed, more information about data from the programs described in the above reports plus other programs not yet publically reported has been requested of SSPC.

A few case study reports from Hercules, Inc. concerning the performance of chlorinated rubber systems was also reviewed and the data characterized. In addition, the report "Behavior of Zinc Coatings in Highway Environments" supplied by the American Hot Dip Galvanizers Association, Inc. was reviewed for data content characterization.

Copies of reports containing exposure data on structural steel coatings identified through a manual search of WSCA for 1974-1979 have been obtained where possible. These will be reviewed to characterize the data.

2.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861.00
Cummulative Cost Prior To Report Period	$17,082.00	
Estimated Cost for Report Period	4,619.00	
	$21,701.00	
		$21,701.00
Estimated Cost to Complete Work		$53,160.00

3.0 Identification of Problems

The characterization of data sources may be delayed depending upon the time of receipt of the information. In order to minimize this potential problem, more reliance on phone contacts than letters will be used in getting information offered from paint manufacturers, etc.

4.0 Future Plans

During the next reporting period, it is planned to:

1. Finish sending the formal letters of request under Tasks A and B.
2. Visit Rohm & Haas and Union Carbide Corporation to get information on their programs.
3. Develop a work plan for coordination of efforts with SSPC.
4. Procure and characterize data sources.
5. Start work on Tasks C and D.

5.0 Work Performed versus Scheduled Work[1]

Task Description (Phase I)

A. Review of Previous Computerized Evaluations

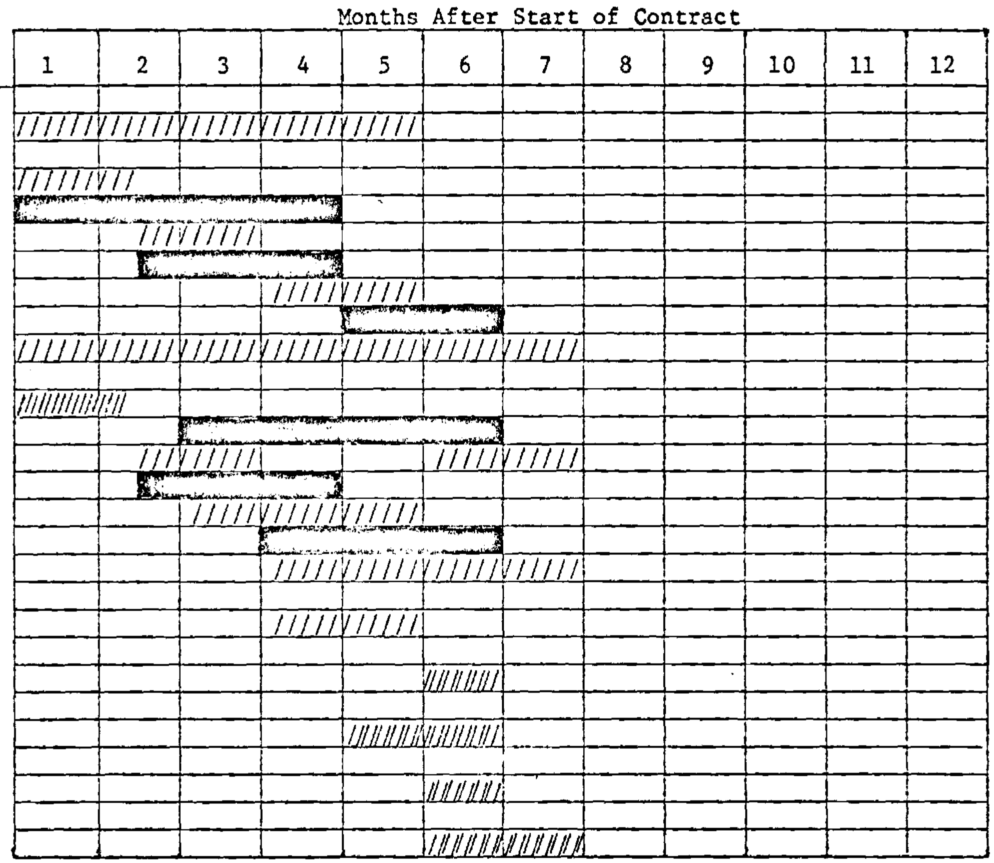
1. Identify current & previous efforts
2. Plan to obtain methodology information
3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

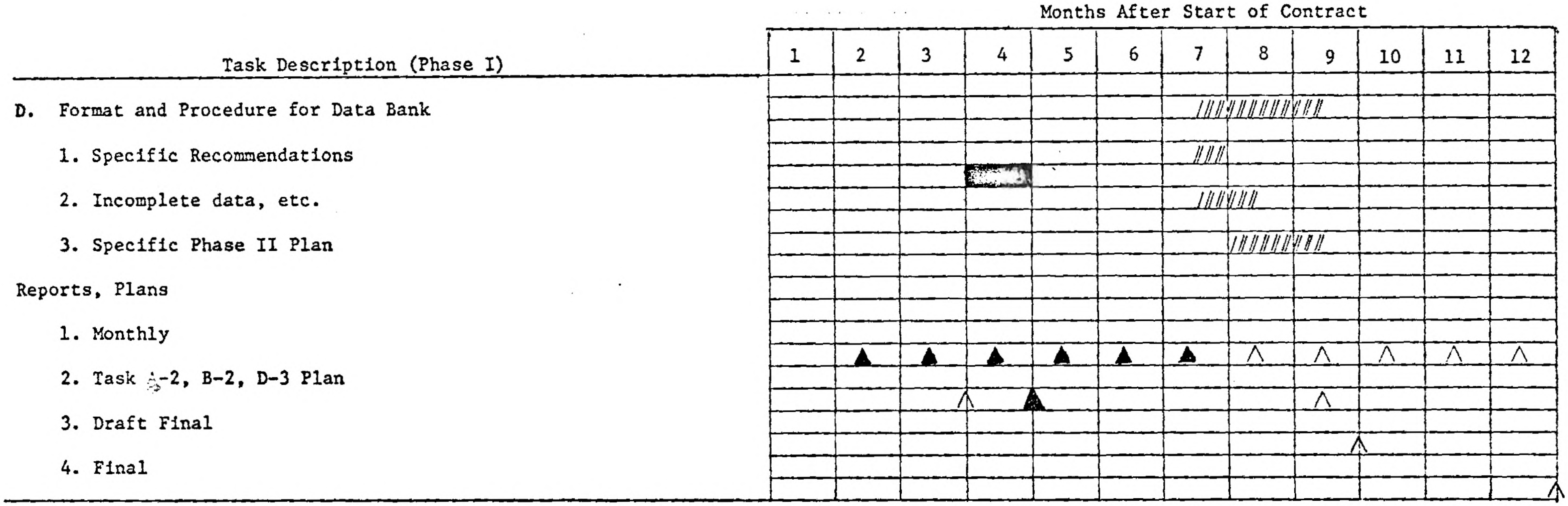
1. Identify major non-highway sources
2. Plan to characterize the data
3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Possible



5.0 Work Performed versus Scheduled Work[1] (Continued)



1 ///// Scheduled; [shaded box] Actual

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6,372
2. Plan to obtain methodology information			2,138	2,803
3. Execute plan	0	648	6,443	1,826
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	3,577	9,202	6,657
2. Prepare detailed plan to characterize the data			2,759	1,592
3. Select highway related sources of data	0	394	12,159	2,708
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank			5,979	492
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established			5,379	
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations			4,544	654
2. Discuss incomplete data problems, etc.			4,544	
3. Prepare specific Phase II plan			4,544	
Reports, plans			$ 3,406	

7.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	64	306
Frank A. Rideout	50	187
Neil B. Hilsen	4	42
Joseph F. Celko	15	64

8.0 ADP Services

None

A-2490

Monthly Progress Report

Number 7

April 1, 1980 through April 30, 1980

EES Project A-2490

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by;

Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director

Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

Computerized Efforts

The bridge paint information from Louisiana Department of Transportation and Development, Office of Highways was reviewed. The information was supplied by Al Dunn, Structures Maintenance Engineer. Louisiana's Master Structure File is a computerized system for storing descriptive and inspection data on bridges. The information recorded for the paint systems is minimal, however. The paint data initially recorded is project number for the paint job, paint system (two digit code uniquely identifying the primer, topcoat, and any intermediate layers selected from a qualified products list), completion date of painting, who did the painting, surface preparation or cleaning method (5 types), quantity of total paint used, color of paint (topcoat assumed), number of coats (total), cost of the painting, and the nature of the environment (14 categories). Inspection data is recorded using a scale of 0 to 9 where 9 represents a condition where no degradation has occured and 0 represents a critical condition demanding immediate attention. A rating can be given to the paint on the superstructure and the substructure for some bridges while for other bridges a single, overall rating is used.

Dr. Graham Milne was contacted to determine if information about Rohn & Haas's storage and retreival system could be made available for this project. The response was negative since it was Rohn & Haas's interpretation that we want their program. An attempt to change this view over the phone was not successful. In response to the general properties of the program, it was indicated that the typical performance properties monitored in developing trade sales paints were recorded. These are chalking, peeling, cracking, blistering, etc. Output included graphical and tabular presentation of the data, e.g. % gloss vs. exposure time.

The status of the request to NACE for information about the program developed by Technical Committee T-6H-15 was requested of Herc Tarlas, Chairman T-6H-15. Apparently, the request is in the hands of people at NACE headquarters. A letter may be needed to clarify the nature of the request. As with Rohm & Haas, NACE may have the impression that their program in toto is desired.

Union Carbide Corporation, through Dr. John Brezinski, was recontacted to learn more about their experiences in developing a computerized storage retrieval system. A visit to UCC at South Charleston, W. Va. is scheduled for early May.

Data Sources

A review of exposure studies of coated steel and other metals has begun. These studies are those published in the various journals dealing with coatings and corrosion protection. The reports are reviewed to extract information as to surface preparation (type, specification, substrate), coating systems (type, number, film thickness), application method and schedule, exposure (lab, field, environment), properties monitored and rating system, duration of exposure, and frequency of rating. Articles screened so far are:

1. P. Walker, "The Adhesion of Multicoat Systems after Nine Years' Exposure", JOCCA 57, 241-244 (1974).
2. M. H. Sandler, "Six Years' Tropical Exposure of Finishing Systems for Al and Mg", Materials Prot. and Perf., 12(7), 40-44 (1973).
3. A. J. Eickhoff, "Metal Protective Wet Ground Mica Finds New Role in Zinc Rich Primers", Am. Paint. J., July 16, 1973, 54-55, 58, 60, 62-63.
4. H. E. Townsend and J. C. Zoccola, "Atmospheric Corrosion Resistance of 55% Al-Zn Coated Sheet Steel: 13 Year Test Results", Mat. Perf., Oct. 1979, 13-20.
5. R. Tapasin, A. Papo, & G. Torriano, "New Shop Primers for Steel Based on Inhibitive Pigments of Low Toxicity", Br. Corros. J., 12(2), 92-102 (1977).
6. S. Haagenrud, "Atmospheric Corrosion Testing of Metallized, Metallized and Painted, and Painted Steel", JOCCA 60, 469-473 (1977).

7. J. H. Deatherage, "Evaluation of Protective Coatings for Prevention of Corrosion of High Strength Steels When Subjected to Extreme Environments" SAMPE Q, 4(2), 5-9 (1973).

8. E. S. Matsui, "Performance of Fencing Materials in a Marine Atmospheric Environment", Mat. Perf., Jan. 1974, 17-19.

9. "Dry Ground Limestone In Anti-Corrosive Primers", Am. Paint & Ctgs. J., Oct. 16, 1978, 58, 60, 62, 64.

Parker Helms, UCC, Central Engineering (Texas City) was contacted to determine what data was available from the testing done by UCC in selecting coatings to maintain their own facilities. Fortuitously, the data collected from test panels, drum tests, and structure evaluations had been computerized, at least to the extent that regression analysis was performed. The work was done in ~1973 for data collected from 1954-1973. Clearance to use the data has not been obtained. One condition of use will be that the specific product cannot be identified.

During the review meeting at FHWA (4/30/80), other sources of data were suggested. These were ASTM Committee A-05 Coated Steel Products, automotive companies, and Maine DOT (laboratory evaluation). These will be pursued.

2.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861.00
Cumulative Cost Prior to Report Period	$21,188.00	
Estimated Cost for Report Period	4,619.00	
	$25,807.00	($25,807.00)
Estimated Cost to Complete Work		$49,054.00

3.0 Identification of Problems

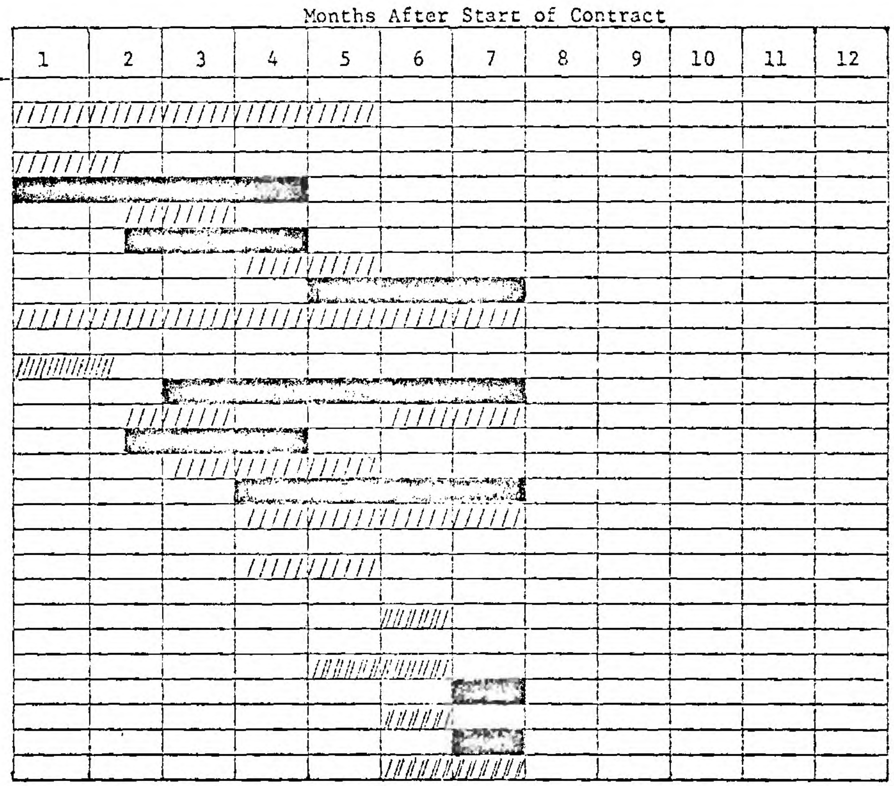
Due to delays in getting enough information to characterize data, the program schedule has not been followed. This will require an extension of Phase I by three months. Initial estimates at this time suggest that this can be done at no additional cost.

4.0 Future Plans

During the next period, it is planned to:

1. Contact people who volunteered data during Corrosion/80 to get data or information necessary to characterize the data.
2. Follow-up on letters sent as part of Tasks A and B.
3. Finish at least initial contacts with highway related sources of data.
4. Send follow-up letter to NACE T-6H-15 in regards to type of information wanted on their computer program.
5. Continue characterization of data from literature.
6. Work on ADP aspects of Tasks C and D.

5.0 Work Performed versus Scheduled Work[1]



Task Description (Phase I)

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3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Possible

5.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)	1	2	3	4	5	6	7	8	9	10	11	12
							Months After Start of Contract					
D. Format and Procedure for Data Bank							Actual; /////	/////	/////			
1. Specific Recommendations							Actual; /////					
2. Incomplete data, etc.							/////	/////				
3. Specific Phase II Plan								/////	/////			
Reports, Plans												
1. Monthly		▲	▲	▲	▲	▲	▲	▲	△	△	△	△
2. Task A-2, B-2, D-3 Plan				▲					△			
3. Draft Final										△		
4. Final												△

1 ///// Scheduled; [shaded box] Actual

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6,372
2. Plan to obtain methodology information			2,138	2,803
3. Execute plan	0	886	6,443	2,712
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	1,209	9,202	8,066
2. Prepare detailed plan to characterize the data	788	0	2,759	1,592
3. Select highway related sources of data	0	559	12,159	3,267
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank	0	710	5,979	1,202
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established	0	710	5,379	710
. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations	4,544	345	4,544	1,709
2. Discuss incomplete data problems, etc.	2,272	200	4,544	200
3. Prepare specific Phase II plan			4,544	
eports, plans			$ 3,406	

.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	81	387
Frank A. Rideout	21	208
Neil B. Hilsen	9	51
Joseph F. Celko	24	88

0 ADP Services

None

A-2490

Monthly Progress Report

Number 8
May 1, 1980 through May 31, 1980

EES Project A-2490
CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D.C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by
Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Computer Programs for Paint Performance Data Handling

A visit was made to UCC at South Charleston, W. Va. to discuss their data storage and retrieval program. Dr. John Brezinski was the contact person but other people directly involved in the design and implementation were also in the meeting. The major findings from the meeting were:

1. It was estimated that it was taking 3 man-months to generate reports using test fence data where the data assembly and analysis was done manually. With the program, data presented in formats suitable for incorporation into reports could be obtained with a half-day turnaround time.

2. The objectives of the program were the storage of large amounts of data, use of output in reports, and computer assisted analysis of data.

3. The design and debugging of the program took about one and a half years to complete.

4. Magnetic tape was chosen as the main storage media since a large amount of data was to be kept including five years of data collected before the program was operable. The costs for the tape storage are the tape itself and a mounting fee for each use. Disc storage costs, based on amount of storage space used and time occupied, would have been more expensive.

5. Laboratory data (e.g. accelerated weathering) was not included in the data since there was no demand for it. Customers want to see actual exposure data.

6. Performance parameters are rated by ASTM methods by the same person to maximize consistency. This same person is training others to do the ratings.

7. The sequence of data input is transcription from laboratory notebook to a coding sheet to a key punch. The correctness of the transcription is verified manually.

8. Factorial designs are used.

9. A packaged report generator is used to do sorting and to prepare tables and graphs (HP Plotter, four color).

10. The program and data are going to be run on a DED PDP 11/20 in the near future. Currently, the centralized computer facility is used through remote terminals. The language is PL-1 with some FØRTRAN routines.

11. A copy of the user's manual was given to us.

During the discussion it was learned that there is a small, portable device (hand held) that allows one to record data directly in machine readable form. This type of device might be of interest and use in the collection of data from bridges and test fence sites for incorporation into the data bank. No details on the device were available at the time of the meeting.

A report, "Marine Coatings Performance for Different Ship Areas", from the National Shipbuilding Research Program (U.S. Department of Commerce, Maritime Administration) was reviewed. The purpose of the project was the establishment of methods to reduce ship construction costs by increasing the reliability of the paint system selection method. A computer program was developed as part of the program. Its purpose is to store data from paint service histories so that, upon analysis, the best generic type of coating can be selected for a particular area of a ship. The data collected or extracted from case histories are:

1. Type of ship (8 categories)
2. Trade route (7 choices)
3. Area of the ship (8 area types)
4. Coating system for each area (54 types)
5. Surface preparation (SSPC standards or description)
6. Coating system age in years (to nearest tenth)
7. Film thickness of each layer in the coating system (coating system and thickness are coupled for up to 6 layers)
8. Ship's age
9. Performance rating: % area rusted, % failure, % area fouled, and type of fouling. These ratings are done for each area of a ship.

Analysis of the data collected is intended to determine if a real difference exists in performance for a given service area between generic paint systems. The report also emphasizes that a wide variance in performance can exist among generically similar paints from different sources. Hence, tests and case histories on specific products of a generic class still need to be evaluated.

A total of 1,072 case histories were incorporated into the data bank. Based on standard statistical analyses (not specified), it is estimated that a mimimum of 30 case histories and preferably 100 case histories are needed to make valid comparisons. However, the level of significance was not cited.

Copies of the questionnaire used in the course of the program are included here as Figure 1 and Figure 2. The "Ship/Paints Coatings Performance-Service Histories Questionnaire" was put together because of the recognized need to have standarized data.

The analogy between ships and bridges is obvious so that the work done in the National Shipbuilding Program can be very beneficial to the FHWA project. A correspondence of data is:

Type of ship ⟷ Type of bridge
Age of ship ⟷ Age of bridge
Age of paint system ——— Age of paint system (years since last painting)
Trade route ⟷ Bridge environment
Area of ship ⟷ Areas or major structural members of a bridge
% are rusted ⟷ % area rusted
% fouling ⟷ pilings, footings immersed in water?
% failure ⟷ covers things like blistering, peeling, fading, etc.

No information has been obtained on the program used by NACE Technical Committee T-6H-15 subsequent to the request made during Corrosion/80. Discussions with Hercules Tarlas, T-6H-15 Chairman, have indicated that there is no time available to respond to the request since the Committee's effort is on the writing of a report presenting the 10 year exposure history data from the project. Since there is some confusion on exactly what was requested at Corrosion/80, a letter redefining the request was sent to Hercules Tarlas, Ken Tator, and Ken Buffington.

1.2 Data Characterization

The collection of data or at least information sufficient to characterize the data has been slow at best.

The extraction of data from published reports has continued. For the overall objectives of the program however, this data will not be sufficient. The most beneficial data will come from maintenance records on bridges.

For the non-highway related data sources, the following contacts were made during the report period:

1. John Williams, Koppers - travel schedule has hampered the delivery of case history and test panel data.

2. Tom Ginsberg, UCC - a letter was sent defining what was wanted in terms of performance data.

3. Michael Masciale, Mobil Chemical Company - phone contact and letter; Mr. Masciale referred us to Bill Richter for information.

4. M. Lichtenstadter, Hercules - referred us to Rufus Wint who had already sent us performance data. Briefly, the exposure data supplied was: (a) 58 months marine exposure on inorganic zinc-rich topcoated with chlorinated rubber paints, (b) 4000 hours of salt spray testing on zinc-rich primers plus chlorinated rubber topcoats, (c) case history of 7 years duration of inorganic zinc-rich primer with chlorinated rubber and epoxy type paint topcoats on a tank and alkyd primer plus chlorinated rubber topcoat on pipes in a synthetic rubber plant in southeastern Mississippi, (d) 22 coatings (12 prototype + 10 commercial) evaluated on KTA panels and channel iron in marine, tidal, and industrial environment for 3-4 year period (rating system not specified), (e) 10 coating systems evaluated in environments of atmospheric/salt spray, tidal zone, and over cathodically protected steel with 0-10 rating system (not specifically identified with any standard rating system) for at least a 30 month period, and (f) brief, verbal descriptions of performance of chlorinated rubber paints on the interior surfaces of water tanks. In addition, the meeting notes from SSPC Advisory Committee on Chlorinated Rubber Paints (Nov. 27, 1979) indicate that C.M. Winchester also of Hercules presented color photographs describing the results of 7 years exposure testing at the Hercules Research Center. The data from this study is also wanted. Mr. Wint has offered to help further, if possible, so he will be contacted for information on the SSPC study and for some detail information on the reports already sent.

5. Florida Power & Light - The initial contact person was Dr. Ed Pilton. However, we have not be successful in reaching him after several attempts. Review of the SSPC Advisory Committee on New Surface Preparation Methods (Nov. 29, 1979) has identified Mr. Richard Ackerman of Florida Power & Light as another contact person.

6. Gary Satterfield, American Hot Dip Galvanizer Association - Mr. Satterfield has not been successfully contacted since a protracted illness has reduced his work schedule.

7. Randy Sharp, Tnemec - Mr. Sharp followed-up on initial response of Tnemec to solicitation for performance data. He will try to get case history data from company headquarters on coatings used on bridges.

8. Armco Steel Corp., Mr. Herbert Lawson - Armco Steel was selected as a data source based on listing in NBS Special Publication 396-3 "Critical Survey of Data Sources: Corrosion of Metals". However, it was learned that they do little work on structural steel, mostly sheet steel and coil stock. The request for performance data of coatings on structural steel has been forwarded to their Western Steel Division. Mr. Heney, who is in charge of organic coatings research, indicated that they had little data from their own facilities maintenance program since they rely on paint manufacturers and general experience with coatings.

9. Dr. Dodd Carr, and Albert R. Cook, ILZRO - Dr. Carr indicated that ILZRO work with paints and zinc has been directed at the level of zinc in primers and the topcoating of zinc-rich and galvanized steel. This work, however, is all done at SSPC. Mr. Cook suggested that a letter describing the information sought be sent and that, perhaps, a visit to their office would be the most beneficial in finding what useful information they have. He also suggested that Ernest Horvich of the Zinc Institute be contacted. This has been done.

10. The Paint Research Association - Their response referred us to two UK Government departments for the information requested. These are the Bridges Engineering Standards Division, Department of Transport and the Transport and Road Research Laboratory. The PRA estimated that it would be too costly to them and to us, consequently, to supply detailed information.

11. ASTM - ASTM headquarters was called for information on Committee A-5 (suggested during briefing at FHWA). Mr. Jim De Martini indicated that A-5 was involved in coated sheet steel, organic and metallic types, and that it has several atmospheric test sites. Much of their data has been published in the Proceedings. There is also a G1 Committee interested in the corrosion of metals with G1.04 specifically involved with atmospheric corrosion. He suggested contacting Seymour Coburn, U.S. Steel, or Darryl Tonini, American Hot Dip Galvanizers Association for specific information on G1.04 activities. Mr. De Martini also was to check with the paint committee people for other leads.

For the highway related sources, the following activities occured:

1. Ohio DOT, Martin Borke, Jr. - Due to man-power restrictions it would be impossible to retrieve information from maintenance files. Data available would be ten years old at the best since storage size restrictions require discarding older files. Paint inspection about once per year but the information recorded is generalized comments. Zinc-rich systems in use now for 5-6 years.

For zinc-rich primers, field application and surface preparation were the biggest problems. These difficulties are compounded since conflicting recommendations are obtained from suppliers. Mr. Borke suggested that California DOT be contacted as a source most likely to have useful data.

2. Massachusetts Department of Public Works, Richard McGinn, Structure Maintenance Engineer and Leo Stevens, Research & Materials - Massachusetts is participating in efforts to improve the Bridge Corrosion Cost model. More data is to be used, garnered from existing records, and additional independent variables are to be incorporated such as a location cost or distance (distance to the work site), a greater selection of bridge types, and special rigging costs (essentially a rating on the degree of difficulty). The type of input data includes surface preparation, type of paint and thickness, type of structure, and performance rating based on percent area rusted on a scale of 0-9.

3. North Carolina Department of Transportation, Bill Medford - NCDOT has run an experimental evaluation of coatings on a coastal bridge in which an exterior and interior girder were coated and the system performance monitored. The report on this work is in progress; more information is to be sent. The protective systems now used are zinc-rich primers for marine environment and Cor-Ten steel on inland bridges. Mr. Medford suggested that Jimmy D. Lee, Head, Bridge Maintenance Unit be contacted.

2.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861
Cumulative Cost Prior to Report Period	$27,492	
Estimated Cost for Report Period	4,370	
	$31,862	
Estimated Cost to Complete Work		($31,862)
		$42,999

3.0 Identification of Problems

As indicated above, the receipt of data or information sufficient to characterize the data has been slow. Hence, a no cost extension of three months was requested during the report period.

4.0 Future Plans

During the next report period, it is planned to:

1. Continue follow-up on people who volunteered data during Corrosion/80.

2. Complete and/or follow-up on sources of data: Florida Power &

Light, Georgia Power, NCEL, West Virginia DOT, California DOT, Michigan DOT (Gary Tinklenberg), AHDGA (Gary Satterfield), North Carolina DOT (Jimmy Lee), Massachusetts Dept. of Public Works (Richard McGinn and Leo Stevens).

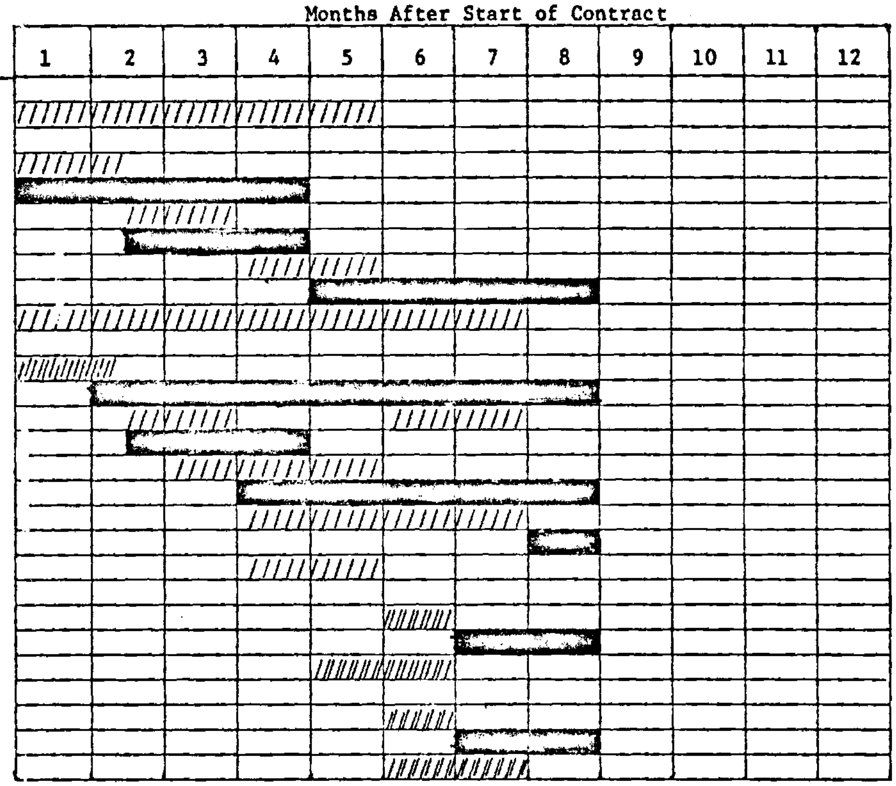
3. Contact Ben Fultz regarding the program for case history data of paint performance on ships (cost, size, effort, plans, etc.).

4. Continue characterization of data from the literature.

5. Work on AOP aspects and options of Task C and D.

5.0 Work Performed versus Scheduled Work

Task Description (Phase I)



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1. Identify current & previous efforts

2. Plan to obtain methodology information

3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

1. Identify major non-highway sources

2. Plan to characterize the data

3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance

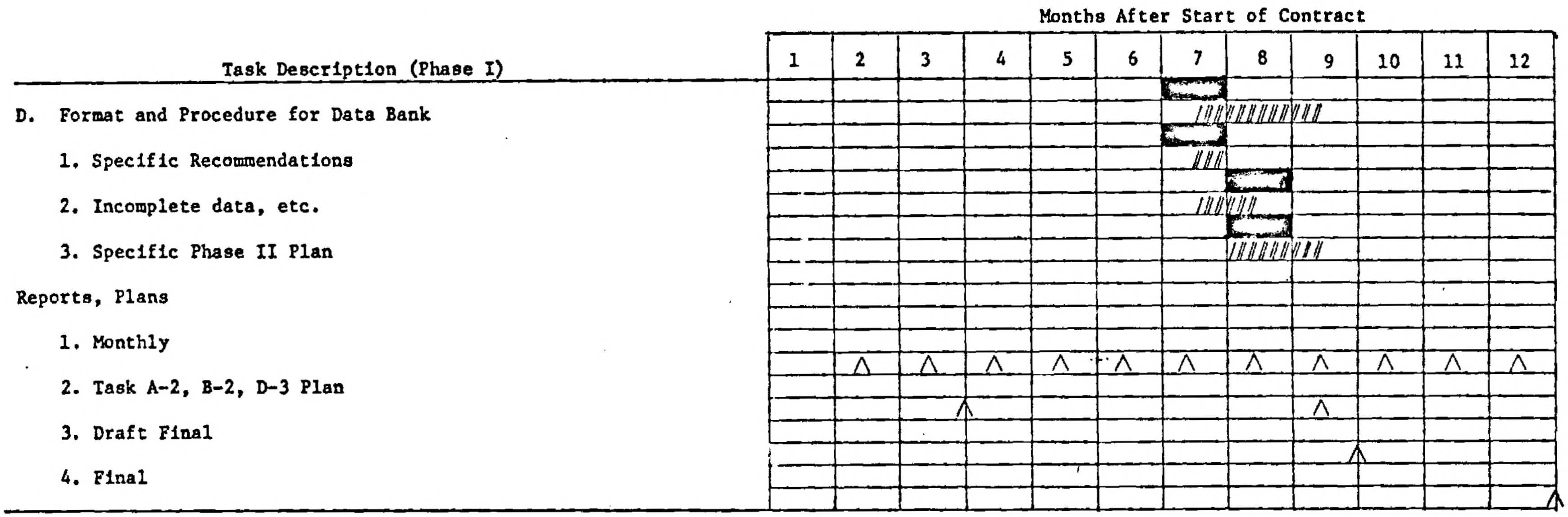
2. Data available versus significant variables

3. Factors in establishing data bank

4. Product Uniformity

5. Types of Coating Data Banks Possible

5.0 Work Performed versus Scheduled Work[1] (Continued)



[1] ////// Scheduled; ▬ Actual

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6,372
2. Plan to obtain methodology information			2,138	2,803
3. Execute plan	0	787	6,443	3,499
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	1,104	9,202	9,170
2. Prepare detailed plan to characterize the data			2,759	1,592
3. Select highway related sources of data	0	752	12,159	4,019
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables	0	431	2,149	431
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank	0	431	5,979	1,633
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established	0	431	5,379	1,141
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations			4,544	1,709
2. Discuss incomplete data problems, etc.	2,272	217	4,544	417
3. Prepare specific Phase II plan	3,029	217	4,544	217
Reports, plans			$ 3,406	

'.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	81	468
Frank A. Rideout	14	222
Neil B. Hilsen	9	60
Joseph F. Celko	24	112

.0 ADP Services

None

Figure 1. Marine Coatings Supplies Questionnaire

June 20, 1977

Dear Sir:

The National Shipbuilding Research Program, chartered by the Merchant Marine Act of 1970, has a major objective, the reduction of shipbuilding cost, thus reducing the percentage subsidy required for American Yards to be competitive with the foreign shipbuilding industry. This objective can be accomplished by greater productivity created by new and improved technology.

The Ship Production Committee of the Society of Naval Architects and Marine Engineers was selected as the evaluation and selection organization for proposed Maritime Research and Development Projects to accomplish the objectives of the 1970 Act. In accordance with this functional responsibility, the Ship Production Committee of SNAME recommended that the following two (2) projects for study during 1977 and early 1978:

A. Practical Shipbuilding Standards for Surface Preparation and Coatings

B. Marine Coatings Performance for Different Ship Areas.

Offshore Power Systems was selected to perform these two (2) studies.

The first step toward accomplishment of the objectives of these R&D projects is to poll the various facets of the Marine Industry. Your company, as a recognized leader in the Marine Coatings field, was selected to participate on a voluntary basis. Two (2) questionnaires are attached for this purpose. Please have someone in your organization fill out these questionnaires and return them to the undersigned at your earliest convenience.

The first questionnaire attempts to determine coatings suppliers interpretation of coatings criteria and generic recommendations for different geographical locations of application and ship area coated, and to determine formulation constraints imposed by raw material properties, availability and cost. The second questionnaire requests information on service histories.

Completed questionnaires will be compiled and incorporated into a computer evaluation program. A copy of this evaluation will be sent to each participant. Furnished data will be used on a cumulative basis with specific information used only as agreed upon.

The success, failure or usefulness of these projects is dependent upon the amount of participation by each respondent. This is a MarAd Project for the Marine Industry, OUR Industry. Please help.

Respectfully yours,

Benjamin S. Fultz
Project Manager
Paints and Coatings

BSF/nw

Enclosures

MARINE COATINGS SUPPLIERS - QUESTIONNAIRE

CONSOLIDATED LIST

NAME and ADDRESS of participating activity:

A. Ameron	E. Exxon	I. Mobil	M. Sigma
B. Briner	F. Imperial	J. M & T	N. Tnemec
C. Carboline	G. International	K. Napko	
D. Devoe	H. Keeler and Long	L. Porter	

What factors should be considered in selecting an optimum paint/coatings system? List as many as you like in order of priority.

See Attached List

What, if any, formulation contraints are imposed by raw material properties?

See Attached List

What formulation contraints are imposed by raw material availability and/or cost?

- Availablity of solvents meeting air pollution requirements.
- Toxicological restrictions
- Long delivery times
- Unavailability of some antifouling toxins such as arsenic and mercury
- Cost is a major factor depending on market, % solids in formula and raw material price rises.
- Temporary ingredient scarcity; e.g., recent zn dust shortage.
- Availability of resins to formulate 100% solid materials and aqueous coatings with corrosion resistance comparable to best solvent type.

your option, what is the optimum number of coats of paint which should be used a given paint system ?

Three

t the environmental factors which should be considered when applying a paint tem. Also include a method or standard for measuring a particular factor or dition.

See Attached List

: method or standard should be used to measure substrate cleaniness prior to ıting/coating? Visual by owners representative, Japanese SPSS - SSPC Surface paration Standards, NACE Visual Standards, SNAME Standards, Swedish Pictorial ndards; white hankerchief.

ld a materials qualification testing program be instituted to qualify coating ems for the following ships areas? If so, what standard should be used?

nderwater Bottom	7 - yes; 2- No; 5 - No comment
reeboard	4 - yes; 4 - No; 6 - No comment
anks, Ballast	6 - yes; 3 - No; 5 - No comment
anks, Potable Water	4 - yes; 3 - No; 7 - No comment
anks, Clean Cargo	5 - yes; 3 - No; 6 - No comment
anks, Crude	6 - yes; 3 - No; 5 - No comment
argo Holds/Spaces	2 - yes; 5 - No; 7 - No comment
ngine/Machinery Spaces	2 - yes; 5 - No; 7 - No comment
iving Spaces	1 - yes; 6 - No; 5 - No comment

ld paint inspectors be qualified/certified to a standard? If yes, what standard/ od? 14 - yes; 0 - no; 0 - No comment - No standard presently available. Some ors provide service; ASTM, NACE presently working on standards.

ast profile an important factor in paint/coating system performance? If yes, is the optimum, how can it be measured and to what standard?

- Varies with vendor. Depends on dry film thickness; "optimum is 1/3 of DFT";

standard presently exists. Keane-Tator Profile comparator; Clemco comparator;

: Microscopic method; Profilometer; pull off thickness gauge; select abrasive ticle size.

hould dry film measurement be accomplished? SSPC-PA-2-Magnetic pull-off gauge; ıfacturer" method not taking into account profile, "Tooke" gauge.

hould film thickness measuring devices be calibrated and to what standard?

: using NBS Standards; ASTM E-376-69

ould volume solids be measured and verified? What standard should be used? ganic zinc - volatile measurement or wet/dry film (GSA Method) Organic Coatings - D-2697

What attributes should be measured and verified during application of paints/coatings?

A. Surface Cleanliness	F. Film Thickness (Wet & Dry)	K. Equipment Set-up
B. Profile	G. Dry Times between Coats	L. Quality of Air
C. Temperature and Humidity	H. Ventilation	M. Film Appearance
D. Humidity	I. Holidays (Spark Test)	N. Time before immersio
E. Correct Mixing and Thinning	J. Area Coated	O. Hardness
P. Weight per Gallon	Q. Viscosity	R. Solvent Concentratio

Should painters be qualified/certified in accordance with a program similar to the welder qualification standards?

12 - Yes; 2 - No; no program available

If you could write a specification exactly the way you wanted to, what would be the format? Include generic types and a rational for using each type.

Would your company be interested in attending a seminar at Offshore Power Systems sometime in the month of November 1977?
The purpose of the seminar will be to discuss input and goals of the program.

Would your company be interested in participating in a materials test program where generic products from different sources are evaluated on an equal basis?

Figure 2. Sample Ships Paints/Coatings Service Histories Questionnaire.

S FOR COMPLETING SHIPS PAINTS/COATINGS - SERVICE HISTORIES QUESTIONNAIRE

(Also see completed example)

Paragraph 01 - As stated this is optional information

Paragraphs 02 and 03 - Self explanatory

Lines 041 through 049 -

a) Surface Preparation - See Surface Preparation Code Number

b) Primer and Topcoats - Select appropriate type code from Paint Types at the bottom of page, i.e. code 15 for alkyd, 32 for chlorinated rubber, etc.

c) Mils - List mils to the nearest tenth, i.e. 1.5, 10.0, 9.6 etc.

Add new column at the left of boxes 041-049. Insert life of system to the nearest tenth of a year, i.e. 0.5 for six months, 1.0 for one year, etc. This entry is one of the most important. (see example). Life of system is time since last overhaul or major maintenance period.

Paragraphs 0511 - 0594 - Place an X or check in the appropriate block.

Special Instructions - Any input will be appreciated. For example, if a survey is accomplished only on a specific area of a ship instead of the complete ship, please submit just this information. The more the information, the more valid the study becomes.

Mail completed questionnaires to:

Benjamin S. Fultz
Offshore Power Systems
P. O. Box 8000
Jacksonville, Florida 32211

SHIPS PAINTS/COATINGS PERFORMANCE–SERVICE HISTORIES QUESTIONNAIRE

CONTROL NUMBER [| | | |]

] OPTIONAL INFORMATION:

______________________ – ______________________ – ______________________

OWNER SHIPS NAME BUILDER

] TYPE OF SHIP *(Please circle most appropriate type)*

TANKER [1 0] / DRY CARGO [1 1] / FISHING [1 2] / OBO [1 3] / CONTAINER [1 4] / FERRY [1 5] /

RO-RO [1 6] / REEFER [1 7] /

] TRADE ROUTE *(Please circle most appropriate route)*

SOUTH PACIFIC [2 0] / WEST INDIES [2 1] / NORTH ATLANTIC [2 2] / SOUTH ATLANTIC [2 3] /

NORTH PACIFIC [2 4] / CARIBBEAN [2 5] / MEDITERRANEAN [2 6] /

IT SYSTEMS UTILIZED *(See table below for Code Numbers)*

AREA	Surface Prep.	PRIMER		COAT #2		COAT #3		COAT #4		COAT #5		COAT #6	
		TYPE	MILS	TYPE	MILS	TYPE	MILS	TYPE	MILS	TYPE	MILS	TYPE	MILS
UNDERWATER BOTTOM	1	2		3		4		5		6		7	
BOOTTOP	1	2		3		4		5		6		7	
FREEBOARD	1	2		3		4		5		6		7	
EXTERIOR DECKS	1	2		3		4		5		6		7	
EXTERIOR SUPER-STRUCTURE	1	2		3		4		5		6		7	
CARGO HOLDS & SPACES	1	2		3		4		5		6		7	
PRODUCT TANKS	1	2		3		4		5		6		7	
BALLAST TANKS	1	2		3		4		5		6		7	
MACHINERY SPACES	1	2		3		4		5		6		7	

FACE PREPARATION CODE NUMBERS:

;SPC–SP–1 12. SSPC–SP–5

;SPC–SP–3 13. SSPC–SP–6 14. SSPC–SP–10

T TYPES

kyd
kyd, Silicone
kyd, Modified Acrylic
kyd, Vinyl
ıtifouling, Coal Tar Epoxy, ganometalic
ıtifouling, Chlorinated Rubber, ›pper
ıtifouling, Chlorinated Rubber, ganometalic
ıtifouling, Epoxy, Copper
ıtifouling, Epoxy, Organometalic
ıtifouling, Hot Plastic, Copper
ıtifouling, Rubber Sheet, Organo-ıtalic
ıtifouling, Vinyl, Copper
ıtifouling, Vinyl Organometalic
ıtifouling, Other

31. Bitumenous
32. Chlorinated Rubber
33. Emulsion Latex
34. Epanol, Phenoxy
35. Epoxy, Adduct
36. Epoxy, Coal Tar
37. Epoxy, Ester
38. Epoxy, Ketamine
39. Epoxy, One Component
40. Epoxy, Phenolic
41. Epoxy, Polyamide
42. Epoxy, Polyamine
43. Epoxy, Polyester
44. Epoxy, Other
45. Lacquer
46. Metal Spray, Aluminum
47. Metal Spray, Zinc
48. Polyester

49. Polystyrene
50. Polyurethane
51. Polyvinyl Chloride Copolymer
52. Powder
53. Varnish
54. Vinyl
55. Vinyl Alkyd
56. Wash Primer
57. Water Borne, Epoxy
58. Water Borne, Enamel
59. Zinc, Galvanized
60. Zinc, Inorganic, Post Cure
61. Zinc, Inorganic, Self Cure Solvent Based
62. Zinc, Inorganic, Self Cure Water Based
63. Zinc, Inorganic, with conductive Extenders
64. Zinc, Inorganic, Other
65. Zinc, Organic
66. Others

(Over)

'ERFORMANCE EVALUATION

Please Mark Appropriate Box(s) [X]

NDERWATER BOTTOM:

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
511 (a) % Fouling	0	1	2	3	4	5	6	7	8	9
512 (b) % Corrosion	0	1	2	3	4	5	6	7	8	9
513 (c) % Coatings Failure	0	1	2	3	4	5	6	7	8	9

14 (d) General Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5
15 (e) Type Fouling	Grass 1	Shell 2	Slime 3	Comb. 4	

OTTOP:

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
1 (a) % Fouling	0	1	2	3	4	5	6	7	8	9
2 (b) % Corrosion	0	1	2	3	4	5	6	7	8	9
3 (c) % Coatings Failure	0	1	2	3	4	5	6	7	8	9

(d) General Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5
(e) Type Fouling	Grass 1	Shell 2	Slime 3	Comb. 4	

EBOARD:

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
(a) % Corrosion	0	1	2	3	4	5	6	7	8	9
(b) % Coating Failure	0	1	2	3	4	5	6	7	8	9

(c) General Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5

RIOR DECKS:

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
a) % Corrosion	0	1	2	3	4	5	6	7	8	9
b) % Coatings Failure	0	1	2	3	4	5	6	7	8	9

c) General Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5

OR SUPERSTRUCTURE

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
) % Corrosion	0	1	2	3	4	5	6	7	8	9
) % Coatings Failure	0	1	2	3	4	5	6	7	8	9

General Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5

HOLDS & SPACES

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
% Corrosion	0	1	2	3	4	5	6	7	8	9
% Coatings Failure	0	1	2	3	4	5	6	7	8	9

General Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5

T TANKS

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
% Corrosion	0	1	2	3	4	5	6	7	8	9
% Coatings Failure	0	1	2	3	4	5	6	7	8	9

ieneral Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5

TANKS

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
Corrosion	0	1	2	3	4	5	6	7	8	9
Coatings Failure	0	1	2	3	4	5	6	7	8	9

neral Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5

Y SPACES

	0%	1%	5%	10%	15%	25%	50%	75%	90%	100%
Corrosion	0	1	2	3	4	5	6	7	8	9
Coatings Failure	0	1	2	3	4	5	6	7	8	9

eral Appearance	Unsat. 1	Poor 2	Fair 3	Good 4	Excellent 5

A2490

Monthly Progress Report

Number 9
June 1, 1980 through June 30, 1980

EES Project A-2490
CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D.C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Material Division

Submitted by
Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Computer Programs for Paint Performance Data Handling

Prior to the SSPC meeting in June, the computerized storage and retrieval system at Rust-Oleum was discussed again with Steve Ozenich. He estimated that one and a half man-years was expended in getting the program designed, written, and operational. This effort was spread over a three year period. One analysis aspect of the program is the interpolation of performance properties so that different coatings can be compared at equal points in exposure time. A plotter is sought to do the graphics now done with a line printer.

Ben Fulty of Offshore Power Systems who was the Project Manager for the "Marine Coatings Performance for Different Ship Areas" has not yet been contacted about the case history storage and retrieval system developed as part of the program. However, some information has been extracted based on the program listing and general knowledge in the area of statistical analysis. First, the program is written in COBOL. The management and security system is a commercial one (PAN VALET from Pansophic Systems, Inc.) which handles the job control language (JCL) and secures the data. Sorting of records can be done by ship name, ship type, trade route, or ship area. The estimate of 30 case histories per population sample to derive useful information is consistent with general guidelines for sampling from an assumed normal population distribution at the 95% confidence level.

The information sent from UCC-Texas City has been reviewed again. The program was not directed at storage and retrieval of performance data but at establishing correlations between individual performance tests, correlation between a small set of performance tests and "net score" from the full battery of tests, and correlation between laboratory tests and/or individual tests and a net performance rating or index from the exterior exposure testing of the paints on steel drums. Linear regression analysis was used to examine possible correlations. No drum data however was included in the package of material sent. A short discussion of the type of data collected from laboratory tests and coated drum exposures is given in section 1.2.

1.2 Data Characterization

For the non-highway related data sources, the following contacts were made during the report period:

1. Bill Richter, Mobil Chemical Company - expressed interest and willingness to help but a large expenditure of man-power and time would be required since the performance data is not centrally stored. It is contained in laboratory notebooks and various report files. Data from test panels (Q-Panels) would be on performance in salt fog cabinet, humidity cabinet, and on test fences. The surface would in all cases be white metal. Ratings use ASTM methods. For service histories, initial data is available (surface prep., materials, film thicknesses, application method) but performance ratings would by-in-large be periodic assessments of general appearance. It was estimated that 30-40 man-days would be required to collect all the data on a particular type of coating of interest. Mr. Richter expressed reservations about the ability to adequately define exposure environment in such a way that meaningful comparisons could be made.

2. William Paton, NASA, Kennedy Space Center - Mr. Paton was contacted about continued evaluation of zinc-rich coatings at Kennedy Space Center subsequent to NASA TN D-7336 (July, 1973). Mr. Paton referred the request to Mr. Joe Morrison who sent (a) Status Report on Corrosion Performance of Zinc Rich Coatings (MTB 154-70, March, 1978), (b) Application Characteristics of Zinc-Rich Coatings Applied to Carbon Steel (MAB 154-70, March, 1971) and (c) Report on Relative Corrosivity of Atmospheres at Various Distances From the Seacoast (MTB 099-74, January, 1980). The status report (item a) presents ASTM D-610 corrosion ratings for commercial zinc-rich coatings after five years of exposure in a severe marine environment. Topcoated zinc-rich primers are also included in the study. NASA-KSC is also working on a report dealing with the effect of surface preparation on the performance of zinc-rich paints. The grades of surface preparation examined are near white, commercial blast, brush blast, and wire brushing. Surface profile is included. The data is for a 5 year exposure period. The intent of the study is to establish the minimum surface preparation for the zinc-rich coatings to give acceptable protection to steel structures at KSC. Mr. Morrison also suggested that performance data may be available from a program being done at SRI, International on corrosion control methods for the rapid transit industry. Information in general about corrosion control in the U.S. Army may be available through Lloyd Gilbert at Rock

Island Arsenal, Rock Island, Illinois.

3. Gary Satterfield, American Hot Dip Galvanizers Association - AHDGA is in the midst of establishing a computerized index for the reports they have on file. It is estimated that AHDGA has 5,000 - 8,000 reports on galvanized steel dealing with guard-rails, structural steel, sheet steel, atmospheric exposure, and some information on galvanized metal performance in immersion service and buried in soil. The system will use key terms and technical phrases to identify reports but no abstracts are stored. It is a computerized catalogue. The index system will have to be operational before the data available at AHDGA can be identified and characterized. This will take about 3 months.

4. Rufus Wint, Hercules - A letter requesting more information about the exposure history data supplied by Hercules was sent to Mr. Wint. The information requested was identification of commercial paints, identification of corrosion inhibitive pigments in systems characterized by the binder, description of the various rating systems used, and film thickness data where it was lacking. Information was also requested about exposure studies being done (assumed) by SSPC Advisory Committee on Chlorinated Rubber Paints.

5. Dr. Ed Pilton and Mr. Richard Ackerman, Florida Power and Light - Both men expressed willingness to provide information about performance data available from Florida Power and Light records. Each was sent a revised questionnaire to get a characterization of the data.

6. Dr. Robert Alumbaugh, NCEL - Dr. Alumbaugh was identified by Dick Drisko as the person at NCEL to contact regarding coatings performance data. A letter was sent to him describing the general nature of project and the interest in performance data. As with Florida Power and Light, a questionnaire to characterize the data available was sent.

7. Herbert Lawson, Armco Steel Corp. - The Western Steel Division of Armco has no performance data for coatings or structural steel.

8. Parker Helms, UCC - Texas City - The laboratory tests include salt spray, condensing humidity, impact resistance, adhesion, heat resistance, immersion in various fluids and chemical solutions, and weatherometer exposure. Various correlations have been examined using the test scores from these tests and field exposure results for the paints on 55-gallon steel drums. Correlations were examined amongst the individual tests, amongst selected subsets of the full test program and the total test score, and amongst selected subsets of the laboratory tests with the rating of the performance in the drum test. Computer output sheets were provided in which these various pairings and combinations were explored via linear multi-variable regression analysis. The drum test consists of applying the paint system to a standard steel drum which has been blast cleaned to a near white condition. The drum is tilted

slightly to allow dirt and moisture to collect on a portion of the top surface. The test areas include horizontal and vertical surfaces, crevices, welds (seam), scribe, and a triangular window of unpainted surface. This latter feature is used when evaluating untopcoated zinc-rich systems as a measure of the glavanic protection. The test runs two years. The paint system is evaluated for its ability to retard rust in or on the major aspects of the drum listed above using ASTM methods. The drum test had been used for ∿15-20 years but it is not currently used based on the strength of the correlation found between 3000 hour salt spray exposure and drum test results.

For the highway related data sources, the following contacts were made during the report period:

1. Jimmy Lee, Head, Bridge Maintenance Unit, North Carolina DOT - There is no fixed set of items used to evaluate the state of paint on bridges; only general observations are made and recorded. Whatever performance data avilable would be through Bill Medford (see previous progress report). The coating systems in use are two AASHTO specification coatings using red lead and aluminum flake, inorganic zinc-rich with vinyl topcoat, and some coal tar epoxy with aluminum flake. NCDOT is also using weathering steel (e.g. A588) on inland bridges.

2. West Virginia Department of Highways - Three reports from West Virginia DOH on the performance of paints on steel under atmospheric conditions have been reviewed. Three grades of surface preparation (white, commercial, and hand cleaned) were used on KTA type panels. The number of coating materials is 53 with several identified by specification. Film thickness data are also given. The properties rated are general appearance, rusting, rusting at welds, rust in the trough, checking, cracking, adhesion (substrate and intercoat), and chalking. The ASTM methods were used for ratings. There is also laboratory data for a cyclic test composed of exposure to condensation and exposure in a weatherometer. This data, however, is not reported.

1.3 Data Bank Considerations

A revised questionnaire was designed to more clearly define the type of information wanted and thought to be needed to characterize performance data from multiple sources. A copy is attached. It was designed under the hypothesis that there is a functional relationship between the performance of a coating and the generalized variables of coating composition (material), coating amount (dry film thickness), the nature of the substrate including the surface preparation, the exposure environment, application properties, time, plus other things such as adhesion:

Performance = f(composition, amount, substrate, environment, application, time,...)

This represents a fairly sophisticated level of use of the data bank in contrast to straight forward storage and retrieval coupled with simple descriptive statistics.

The performance quality of interest is the ability to retard or delay the rusting of steel. The operational measures of this quality are itemized in question 3 of the questionnaire. A breakdown description of the types of things for independent variables is given below.

1. Composition: vehicle(s) or binder(s), pigment(s), product name, product number (cf. question no. 1)
2. Amount: dry film thickness, wet film thickness, holidays (cf. question no. 2)
3. Substrate: type-test panels, structure sections, whole structures, alloy; surface state - degree of cleanliness, profile, generic identification of old paint if present (cf. question no. 2)
4. Environment: rural, urban, industrial, and marine; specific characteristics (e.g. (SO_2), pH of rain, corrosion rate of base metal, etc.), annual does of UV, others(?); laboratory tests (cf. question no. 2)
5. Application: lab, shop, field; brush, spray, roller, or other; climatic conditions at time of application; viscosity of material; cleaning and painting schedule; substrate condition (e.g. surface temperature, condensation, sunlight or shade)(cf. question no. 2)
6. Time: date of application, duration, inspection periods.

The generic classification of systems is somewhat a problem since traditionally paints are described by the binder with or without reference to the pigment. The interest in generic typing is based on the expected differences in resistance to weathering (UV resistance, hydrolysis, photochemical reactivity) for different organic materials based on their composition and bonding characteristics. Pigments, however, can interact with weathering forces and the polymers in addition to providing corrosion inhibitive attributes. Hence both general types of materials need to be catalogued. A starting point system is the Raw Materials Index from NPCA. At a minimum, the identification of the major vehicle and major functional pigment in a generic system is needed.

2.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861.
Cumulative Cost Prior to Report Period	30,190	
Estimated Cost for Report Period	3,789	
		(33,979)
Estimated Cost to Complete Work		$40,882

3.0 Identification of Problems

At the end of the report period, no notification about the requested three month extension had been received.

4.0 Future Plans

During the next report period, it is planned to:

1. Contact people by phone or letter who had volunteered data during Corrosion/80.

2. Complete and/or follow-up on sources of data: Georgia Power, California DOT, Michigan DOT (Gary Tinklenberg), Arkansas State Highway and Transportation Dept. (James Marshall), Iowa DOT (Max Sheeler), Monsanto, PPG, and Ken Tator.

3. Contact Ben Fultz, Offshore Power Systems, regarding the program for case history data for marine coatings.

4. Start detailed outline on Task C.

5.0 Work Performed versus Scheduled Work[1]

Task Description (Phase I)

A. Review of Previous Computerized Evaluations

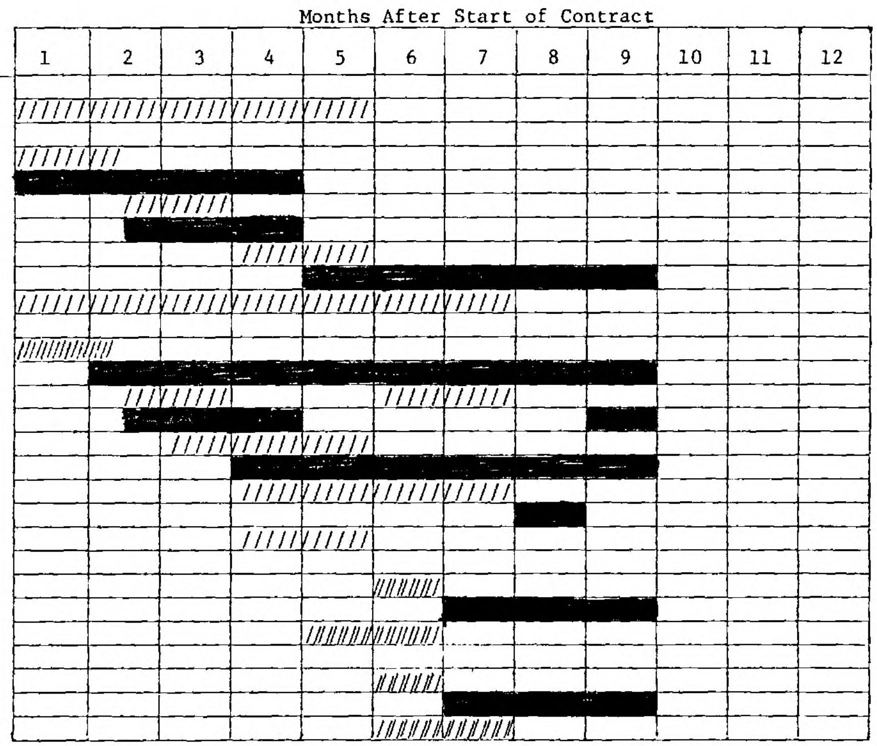
1. Identify current & previous efforts
2. Plan to obtain methodology information
3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

1. Identify major non-highway sources
2. Plan to characterize the data
3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Pôssible



... Versus Scheduled Work (Continued)

Task Description (Phase I)

D. Format and Procedure for Data Bank

1. Specific Recommendations

2. Incomplete data, etc.

3. Specific Phase II Plan

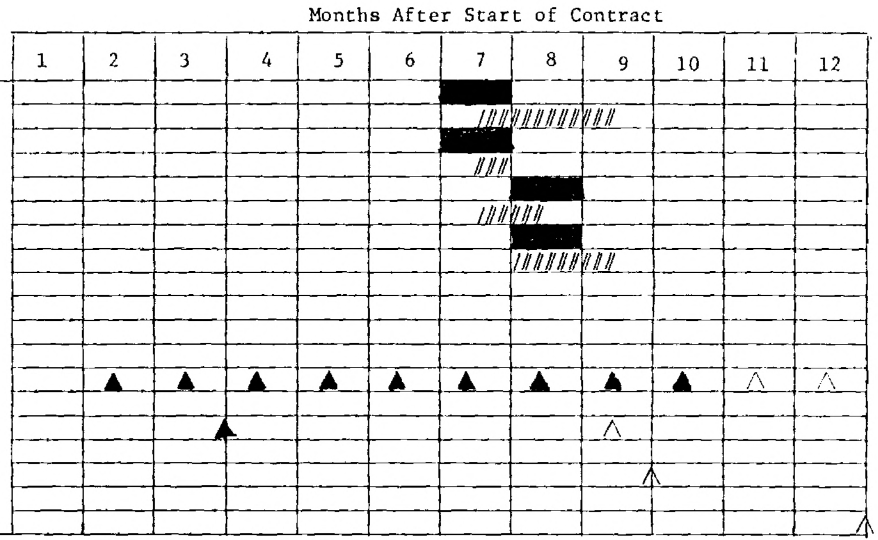
Reports, Plans

1. Monthly

2. Task A-2, B-2, D-3 Plan

3. Draft Final

4. Final



1 ///// Scheduled; ▇▇ Actual

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6372
2. Plan to obtain methodology information			2,138	2803
3. Execute plan	0	486	6,443	3985
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	944	9,202	10,114
2. Prepare detailed plan to characterize the data	0	715	2,759	2307
3. Select highway related sources of data	0	649	12,159	4668
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables	0	0	2,149	431
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank	0	486	5,979	2119
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established	0	486	5,379	1627
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations	0	0	4,544	1709
2. Discuss incomplete data problems, etc.	2272	0	4,544	417
3. Prepare specific Phase II plan	1515	0	4,544	217
Reports, plans			$ 3,406	

7.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	84	552
Frank A. Rideout	10	232
Neil B. Hilsen	12	72
Joseph F. Celko	32	144

8.0 ADP Services

None.

Questionnaire For
Characterization of Performance Data of Coatings on Structural Steel

1. To what level of detail can the coatings for which you have performance data be described?

	YES	NO
Product Name, Number, etc.		
Federal, Military, State Specification		
Generic Classification		
Generic Classification plus proportions		
Composition Formula		

2. Please indicate below the <u>variables</u> included in your laboratory and field studies on coatings performance.

	YES	NO	If yes, please give methods, specifications, or systems used.
Surface Preparation			
Surface Profile			
Substrate Composition (alloy, type of test panel)			
Film Thickness			
Presence, Density of Holidays			
Laboratory Test Environments			
Salt Spray			
95-100% Relative Humidity			
Accelerated Weathering			
Fluid Immersion			
Other (please specify)			
Exterior Test Environment			
Test Fence			
Section of Steel Structure			
Whole Steel Structures			
Classification of Environment (rural, marine, etc.)			
Application Process Parameters			
viscosity, temperature of material			
climatic condition during application			
substrate conditions during application			
cleaning, painting schedule			

3. Please indicate below the measures of performance used and recorded in assessing the durability, suitability of a coating for protecting structural steel.

	YES	NO	If yes, method, specification or rating system used.
Corrosion Protection			
Percent area rusted			
Mass loss			
Film undercutting			
Other			
General Film Integrity			
Blistering			
Checking			
Cracking			
Alligatoring			
Peeling			
Flaking			
Chalking			
Color Change			
Adhesion			
Other (please specify)			
Spatial distribution of degradation characteristics on a steel structure			

4. Please estimate the number of data records that you can or would be willing to supply for the proposed FHWA data bank. A data record is defined here to be a set of values for a given coating or coating system describing composition, film thickness, nature of the substrate, tests, and test results. If possible, please provide a coarse breakdown of these records as indicated.

Approximate total number of data records = ____________

Approximate number of different coatings classified by

a. product name, no., specification no. = ____________

b. use type: primer = ____________

tie, intermediate = ____________

topcoat, finish = ____________

c. generic type (major vehicle & pigment) = ____________

d. generic type with indication that the same specific material is used without having to identify the material by product name, member, etc. = ____________

Approximate number of different exterior test sites.

a. specific sites		=	______
b. grouped as:	rural	=	______
	urban	=	______
	industrial	=	______
	marine	=	______

Approximate number of different types of surface preparation classified by:

a. SSPC, ASTM, or NACE standards	=	______
b. other (please specify)	=	______

Approximate number of data records in which the substrate is:

a. test panels, laboratory tests	=	______
b. test panels, exterior exposure	=	______
c. sections of a bridge	=	______
d. sections of other steel structures	=	______
e. whole bridges	=	______
f. whole structures other than bridges	=	______

5. Under what circumstances and/or restrictions would the data be made available?

	YES	NO
FHWA personnel or contractor personnel to extract data from files?		
Supply information to FHWA or contractor on data forms?		
Supply information in computer readable, standardized format?		
Other (please specify)?		

A-2490

Monthly Progress Report

Number 10
July 1, 1980 through July 31, 1980

EES Project A-2490
CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D.C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Material Division

Submitted by
Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Computer Programs for Paint Performance Data Handling

The Paints and Coatings Performance program (PCP) developed under Maritime Administration funding was discussed briefly with the project manager at Avondale Shipyards, John Peart. The major points made by him were 1) one needs standardized data and reporting, 2) most of the case histories came from one supplier, and 3) the owners of the ships are not convinced of the utility of the program. A funding request is being evaluated to expand the PCP system to add analysis capability. The program now stores case history data and outputs this data sorted by either ship name, ship type, trade route, and ship area and coating system.

1.2 Data Characterization

Discussions have been held with Florida DOT about their work with the Bridge Corrosion Cost (BCC) model. The source of data will be old inspection records which are narrative in character. The ratings and observations rely on the judgement of the inspectors but they are given guidelines in training as to what to look for and where. The information in the inspection records will be transformed so that it can be used in the BCC. This data will likely be available for the coatings performance data bank but subsequent to the completion of Phase II.

Georgia DOT (Hugh Tyner, Chip Neill, and Vernon Smith, Jr.) feels that the best performance data available from it is contained in the work of Ray Tooke. The data, however, is stored on magnetic tapes which are a part of the computerized paint evaluation system developed by Tooke. Attempts to date to activate the program and to get the data outputted have not been successful.

1.3 Data Bank Considerations

Both Georgia DOT and Florida DOT have been helpful in giving insight to the type of performance information one can expect from maintenance inspection records. First, the information will be qualitative and dependent on the experience and judgement of the individual inspector. Second, inspections concentrate on the structurally critical parts of a bridge such as joints, welds, rivets, load bearing areas, and stress areas. Hence one can expect to get information about the state of the paint in these areas but some transformation or editing may be necessary if analyses are to be performed.

Georgia DOT also emphasized the application characteristics of a paint in assessing the overall merit of a paint. Although given a great amount of weight in the rating, the determination of the application characteristics is highly subjective, described as..." getting a feel for how the paint handles." Application properties are planned as potential input for the data bank.

2.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861
Cumulative Cost Prior to Report Period	$34,616	
Estimated Cost for Report Period	5,620	
	40,326	(40,236)
Estimated Cost to Complete Work		$34,625

3.0 Identification of Problems

At the end of the report period, no notification about the requested three month extension had been received.

4.0 Future Plans

During the next report period, it is planned to:

1. Make one last follow-up on potential data sources who have received the data characterization questionnaire.

2. Complete contacts with data sources not yet done: California DOT, Michigan DOT, Arkansas State Highway and Transportation

Dept., Iowa DOT, Monsanto, PPG, Ken Tator, and Georgia Power.

3. Contact Ben Fultz, Offshore Power Systems, regarding the program for case history data on marine coatings.

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6372
2. Plan to obtain methodology information			2,138	2803
3. Execute plan	0	706	6,443	4691
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	1375	9,202	11,489
2. Prepare detailed plan to characterize the data			2,759	2307
3. Select highway related sources of data	0	317	12,159	4985
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables	0	317	2,149	748
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank	0	1387	5,979	3506
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established	0	317	5,379	1944
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations	0	817	4,544	2526
2. Discuss incomplete data problems, etc.	0	386	4,544	803
3. Prepare specific Phase II plan			4,544	
Reports, plans			$ 3,406	

7.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	60	612
Frank A. Rideout	62	294
Neil B. Hilsen	4	76
Joseph F. Celko	32	176

8.0 ADP Services

None

5.0 Work Performed versus Scheduled Work[1]

Task Description (Phase I)

A. Review of Previous Computerized Evaluations

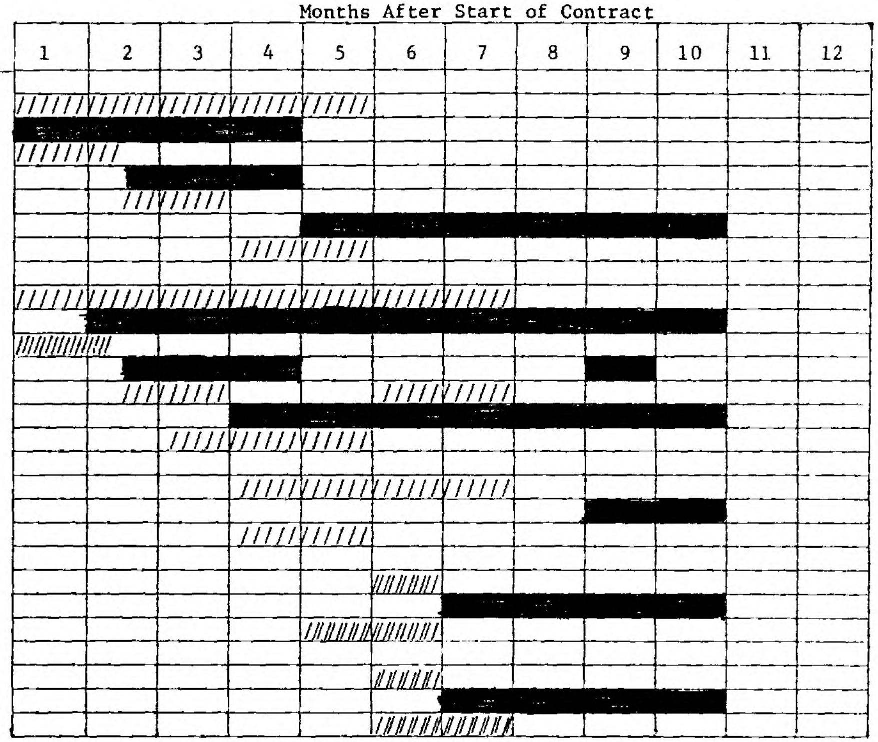
1. Identify current & previous efforts
2. Plan to obtain methodology information
3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

1. Identify major non-highway sources
2. Plan to characterize the data
3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Possible



5.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)		Months After Start of Contract 1	2	3	4	5	6	7	8	9	10	11	12
D. Format and Procedure for Data Bank	Scheduled							Scheduled	Scheduled	Scheduled			
	Actual							Actual			Actual		
1. Specific Recommendations	Scheduled							Scheduled					
	Actual								Actual		Actual		
2. Incomplete data, etc.	Scheduled							Scheduled	Scheduled				
3. Specific Phase II Plan	Scheduled								Scheduled	Scheduled			
Reports, Plans													
1. Monthly			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	△
2. Task A-2, B-2, D-3 Plan				▲						△			
3. Draft Final										△			
4. Final													△

[1] //// Scheduled; ■■ Actual

A-2490

Monthly Progress Report

Number 11
August 1, 1980 through August 31, 1980

EES Project A-2490
CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Material Division

Submitted by
Material Sciences Branch
Chemical & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Computer Programs for Paint Performance Data Handling

Ben Fultz of Offshore Power Systems was contacted about the Paints and Coatings Performance Program (PCP) developed under Maritime Administration funding. The following key items were noted:

1. The project developed to satisfy a need, defined by the Ship Production Committee of the Society of Naval Architects and Marine Engineers (SNAME), to provide historical data on coatings performance to ship building people. It was felt that performance data offered by coatings suppliers was picked to suit their needs, i.e., to present their materials in the best light.

2. The Ships Paints/Coatings Performance-Service History questionnaire was developed with the review and editing of SNAME. The information requested in it was felt to be available based on the knowledge of the types of things documented in docking reports and ship surveys.

3. International Paint Company, Inc. has a program similar to PCP. It predates PCP, is more elaborate, and concentrates on their own products. International Paint uses it as an aid in making recommendations and as a research tool in marketing. Data from International Paint was incorporated in PCP.

4. The writing and debugging of the program took about 1 man-month of a programmer's time, 40 hours of keypunching, 4 hours of CPU for compilation and testing. Outputting the program and data cost $400. The total in-house billing was $3,200.

5. The sorting routines were written for the program; no canned routines were used.

6. Future work will include addition of more service histories, a life cycle cost routine (LCC), correlation routines, regression analysis, etc.

7. The end users are design engineers, naval architects, owners, and operators. However, no plans have yet been made as to how they will access the data bank and analysis routines.

The computerized analysis of UCC drum test data and laboratory test data has been pursued further with F. Parker Helms (Central Engineering, Texas City, Texas). Unfortunately, the drum test data used in the original analysis cannot be identified. Mr. Helms has provided a set of drum test scores and corresponding salt spray and sea water immersion performance data. Hence, the analysis could be done again.

1.2 Data Characterization

West Virginia DOT was contacted to determine the status of the extensive exposure test panel study entitled "Paint Performance In Relation to Air Quality " and last reported in November, 1977. No additional ratings were made since the last report; the panels were removed. The data that has been reported will be wanted for the data bank. Additionally, a new program is underway concentrating on durability as a function of thickness for zinc-rich primers plus vinyl topcoats. Several different products of each type of material are to be included. The surface condition of the metal (test-panels) will be near white clean. Performance evaluation will use ASTM methods and scales. In addition, data is to be collected on several climatic and atmospheric variables throughout the course of the project such as ozone concentration, SO_2 concentration, solar insolation and rain fall. This work will be valuable and desirable for incorporation in a coatings performance data bank. The work is sponsored by FHWA so it should be easy to get once the data is collected.

The type of data or assessment of paint on bridges (service histories) available from West Virginia DOT is expected to be a rating such as good, fair, poor, or critical. The rating reflects the fact that inspections are done to provide recommendations as to which bridges need painting. It was felt that, as such, the information would be of little benefit to a performance data bank. Additional requirements to more fully describe and document the state of the paint in inspection was felt to be impractical since current inspection requirments and deadlines were already difficult to meet.

Michigan DOT was contacted through Gary Tinklenberg. Data collected from test panels exposed to salt spray, accelerated weathering, aerated brine, aerated water, and natural weathering in a semi-rural area can be made available. Inspection data from about 30 bridges can also be made available but the reliability of the results is questioned since the application of the paint (inorganic zinc-rich) may not have been done correctly even though the painting was done as a research effort. The inspection reports done routinely are expected to have little performance data with assessment falling into "good," "no good," "no need to paint," and "painting needed."

Georgia DOT has provided sample outputs from their Bridge Inventory Data Listing. All the bridges in the State are included. Information on paint is the last year painted, last inspection date, and a rating of the condition of the paint on main support memebers, pilings, and overlay. The rating is coded as 1 = good, 2 = fair, 3 = poor, and 4 = critical. The guidelines used to arrive at the ratings apparently stem from a FHWA bridge maintenance course for bridge inspections. Georgia DOT will try to identify those sections of the course dealing with the paint and provide it to us.

James Marshall, Research Project Coordinator, Division of Planning & Research, Arkansas State Highway and Transportation Department, was contacted about service history data. Although there is interest, it is felt that the State cannot get directly involved with providing input data due to full commitment of available man-power already. However, information will be sent about evaluation of paints through test fence exposure, guidelines used in bridge inspection, and sample inspection records. Again, it was felt that the inspection records would only contain information about the need to paint or not.

Parker Helms, UCC, has also sent us copies of drum test data. Mr. Helms estimates 3-6 months to computerize all the drum test data collected since 1954. All of it may not be needed so some judgement will be needed in selection.

Data potentially available from Ken Tator, KTA Associates Inc., has also been examined. Ken Tator would like the data used but needs to know what actually will be done with it if released. The data recorded includes product name, generic type, test panel type, surface preparation, film thickness, application method, classification of exposure, and sets of exposure time-performance rating pairs for rusting, blistering, peeling, etc.

.3 Data Bank Considerations

A meeting was held with Ray Tooke in which the incorporation of field data was the main subject (subsequent reflections of Ray Tooke are attached). Although the importance of providing corrosion protection to critical structural members or units is recognized, the evaluation of paints from an appearance standpoint will, most likely, always be a part of an inspection and the conclusions or recommendations stemming therefrom.

The case of performance data from field structures had been included in the Paint Evaluation Program. The evaluation procedures follows closely the ones used in evaluating a coating system on KTA panels, i.e., performance on topographic features is rated. These features include plane (flat) surfaces, rounded edges, sharp edges, crevices, welds, and pockets. The things rated are rusting, peeling, cracking, blistering, etc. This type of evaluating of paints on bridges has been considered in the overall design of the data bank.

2.0 Estimated Cost to Complete Work

Budget (Phase I)		$74,861
Cumulative Cost Prior to Report Period (estimated)	$40,236	
Estimated Cost for Report Period	4,418	
	44,654	(44,654)
Estimated Cost to Complete work		$30,207

3.0 Identification of Problems

At the end of the report period, no notification about the requested three month, no cost extension had been received.

4.0 Future Plans

1. Write draft final report.

2. Write specific Phase II plan.

5.0 Work Performed versus Scheduled Work[1]

Task Description (Phase I)

A. Review of Previous Computerized Evaluations

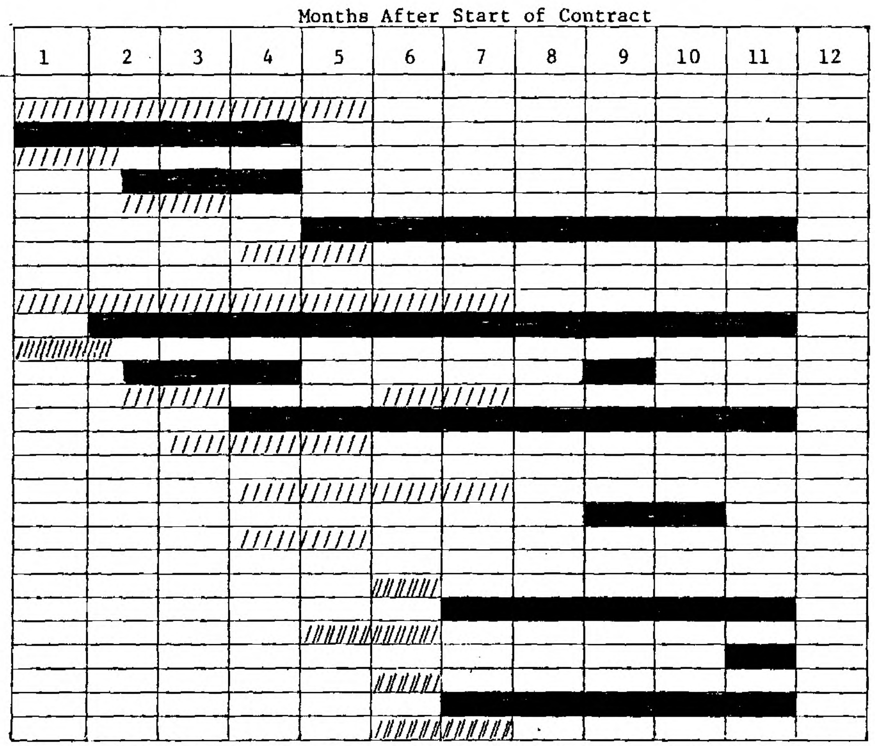
1. Identify current & previous efforts
2. Plan to obtain methodology information
3. Execute Plan

B. Classify & Characterize Sources of Coatings Performance Data

1. Identify major non-highway sources
2. Plan to characterize the data
3. Select highway related sources of data

C. Evaluation of Merits of Centralized Data Bank

1. Significant variables affecting coating performance
2. Data available versus significant variables
3. Factors in establishing data bank
4. Product Uniformity
5. Types of Coating Data Banks Possible



5.0 Work Performed versus Scheduled Work[1] (Continued)

Task Description (Phase I)

D. Format and Procedure for Data Bank

1. Specific Recommendations

2. Incomplete data, etc.

3. Specific Phase II Plan

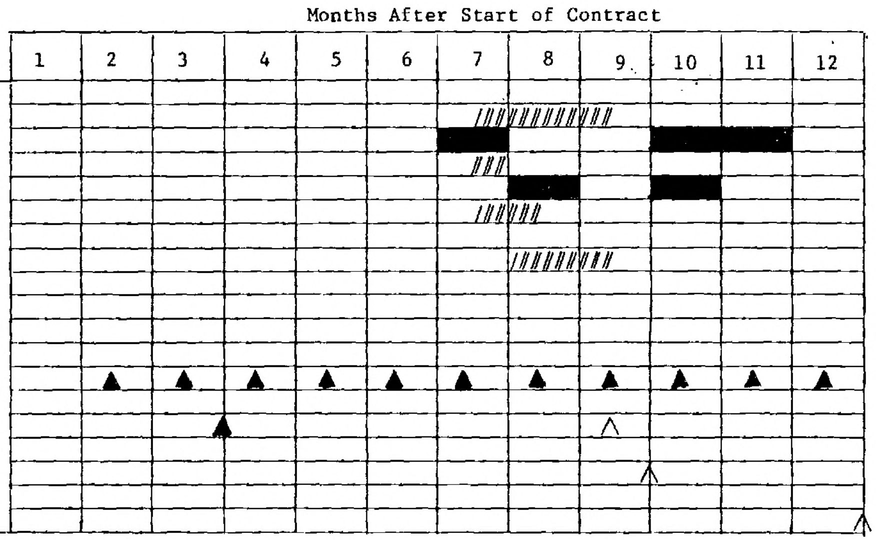
Reports, Plans

1. Monthly

2. Task A-2, B-2, D-3 Plan

3. Draft Final

4. Final



[1] ///// Scheduled; ■ Actual

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6372
2. Plan to obtain methodology information			2,138	2803
3. Execute plan	0	394	6,443	5085
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	992	9,202	12,481
2. Prepare detailed plan to characterize the data			2,759	2307
3. Select highway related sources of data	0	742	12,159	5727
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	748
2. Relationship of data to significant variables			2,150	
3. Factors in establishing data bank	0	589	5,979	4095
4. Discuss product uniformity	0	394	4,299	
5. Describe type of coating data banks that could be established	0	590	5,379	2534
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations	0	717	4,544	3243
2. Discuss incomplete data problems, etc.			4,544	
3. Prepare specific Phase II plan			4,544	
Reports, plans			$ 3,406	

7.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	60	672
Frank A. Rideout	42	336
Neil B. Hilsen	4	50
Joseph F. Celko	24	200

8.0 ADP Services

TOOKE
ENGINEERING
ASSOCIATES

Post Office Box 13804/Atlanta, Georgia 30324/Tel. (404) 325-3243

September 5, 1980

MEMORANDUM TO: Dr. Charles Ray

FROM: W. R. Tooke

SUBJECT: Conference On 9/4/80 - Paint Data Base

Several thoughts to summarize and follow-on our conversation:

1. As you know, the PAINT EVALUATION PROGRAM MANUAL does address the subject of Field Structures Testing (see pp VI-62 to VI 72).

2. The above-described procedure is exhaustive in detailed requirements and is probably only useful for a SERIOUS formulator.

3. One should not expect maintenance engineers to inspect and input bridge paint performance data of a quality directly usable by formulators.

4. The new data base could and should utilize data on bridges from maintenance engineers or other individuals within any governmental subdivision.

5. The desired data would be "Bridge Painting Histories".

6. The DATA BASE RECORD might include the following FIELDS: A) State/County, B) Bridge Name/Number, C) Type, D) Size (Tons steel), E) Erection Date, F) Orig. Paint Specs., G) Painting subcontract amount, H) Date, Specs. & Contract amount (or estimate) for each subsequent painting.

7. In my judgement the foregoing data would be of sufficient value to justify a special project, if necessary,to extract a reasonable volume of this information from existing archives.

8. The BRIDGE CORROSION COST MODEL (BCC) certainly contains some data of this sort (perhaps it is in fact an important available source) but it is not in the form of the "open" data base that we are here concerned with.

9. This part of the data base can serve a variety of research purposes, but the senior purpose would undoubtedly be to provide continuing "bench marks" to survey ongoing technical progress on "the firing line".

A-2490

Monthly Progress Report

Number 12
September 1, 1980 through September 30, 1980

EES Project A-2490
CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Material Division

Submitted by
Materials Research & Development Branch
Energy & Material Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Computer Programs for Paint Performance Data Handling

Information was obtained on two computerized storage/retrieval systems for plastics property data. One system, developed by Dow, is proprietary and was designed to serve both research personnel and marketing personnel. It has been described in the literature (P.F. Roush, et. al., "An On-Line System for Storage and Retrieval of Polymer Data," J. Chem. Info. Comput. Sci. 1979, 19, 74-76). The other system is being developed at the Plastics Technical Evaluation Center, U.S. Army Armament Research and Development Command. It is designed to store and retrieve property data needed in engineering design and materials selection. It is planned to expand the material property data base to cover metals, ceramics, composites, and rubbers. The latest report on the system has been obtained: J. Nardone, "Plastic Data Formats for a Computerized Material Property Data System," Plastec Note N33, August 1977 (NTIS Accession No. AD A047972).

A paper describing the paint performance data base of International Paint Company, International Dataplan, has been found through a literature search done for another project. A copy of the article has been ordered, the reference being: J. F. Davidson, "Measuring Marine Coatings," Shipping World and Shipbuilder, V. 172, March 1979, pp. 261-262. International Dataplan is the program after which the Paints and Coatings Performance Program of Offshore Power was modelled.

1.2 Data Characterization

Several reports were reviewed and analyzed for paint performance data. These were:

1. "Topcoats for Zinc Coatings," ILZRO Project ZC-184 Final Report April 10, 1979.

2. "Full-Scale Trials of Paint Systems for Steel Highway Bridges" TRRL Report LR 583, 1973 (British)

3. "Protective Coatings for Highway Metals" Research Report No. R-916, 1974 (Michigan DOT)

4. "Field Testing of Water Emulsion Epoxies," CEL-TN-1374, 1975.

5. "Coatings and Pavement Marking Materials 1969-1972," CA-HY-MR-5135-1-72-28, 1972.

6. "The Prevention of Corrosion in Steel Bridgework."

7. "The Prediction of Coating Performance on Steel," BISRA Open Report C/46/68, 1969.

8. "Tropical Exposure of Paint," NCEL Technical Note N-1242.

9. "Selection and Monitoring of Atmospheric Exposure Sites for Corrosion Tests," BISRA Report CEL CH 1370, 1973.

10. "Long-Term Wear and Immersion Tests of Polymer Coatings," NAEC-ENG-7934, 1977.

11. "Study of the Performance of Selected Premium Marine Coatings," in NBS Proc. of International Congress on Marine Corrosion, 1974.

12. "Protection of Steel Piles in a Natural Seawater Environment-Part I," 1974.

13. "Marine Corrosion Prevention of Steel with Thermal Sprayed Zinc and Aluminum Coatings-Results of 18 Years Exposure," Offshore Technology Conf. 1959.

14. "Painting of Metal-Sprayed Structural Steelwork - Report on the Condition of Specimens after 10 Years Exposure" - 1974

15. "Effort of Metallic Coatings and Zinc Rich Primers on Performance of Finishing Systems for Steel," 1972.

Several DOT's were contacted to inquire about test panel data both laboratory and field, bridge paint trials, and inspection records. These are listed below with brief comments.

1. Gary Tinklenberg, Michigan DOT - Sample inspection reports for bridges were sent. The form used is for laboratory personnel, not field inspectors. Performance descriptions are narrative. The bridges monitored apparently are those covered in a report cited above, (item 3).

2. Ray Warness, California DOT - A copy of FHWA/CA/TL-79/24 was sent. Bud Deason was identified as the person to talk to about inspection of bridges and the rating guidelines used. Ratings, on a scale of 1 to 5, correspond to: 1 = newly painted; 2 = initial evidence of fading, chalking, dirt accumulation; 3 = heavy chalking, severe fading, dirt but no rust; 4 = rust at some location; and 5 = painting needed within 5 years. In addition, the extent of rust is rated on a scale of 0 (complete failure) to 10 (no rust).

3. James Marshall, Arkansas State Highway and Transportation Department - Mr. Marshall provided the names of two people, one involved with paint selection, Wendell Williams, and the other involved with bridge inspection, John Hall. Mr. Williams sent a copy of a report on bridge inspections done jointly with the maintenance people. Mr. Hall sent a copy of Structure Inventory and Appraisal Sheet. One item in this form calls for a rating for paint condition in terms of per cent deterioration.

4. Jack Roberts, Florida DOT - Mr. Roberts was recontacted to follow-up on our request for samples of bridge inspection records and a copy of the training and inspection guidelines used to judge paint condition.

5. Bill Shuler, West Virginia DOT - Mr. Shuler was recontacted to get a copy of Research Project No. 3 Inspection Manual.

6. Fred Boyce, Maine DOT - Mr. Boyce was originally contacted to get information about laboratory performance data, panel exposure data, bridge painting trials, and inspection records. He sent two reports: "Experimental Paint Station at Rogue Bluffs" and "Review of Structural Steel Paint in Maine." The former describes the test plan and 4 month exposure evaluations on 22 coatings on angle iron test pieces mounted on a bridge; the latter summarizes the paint systems used in Maine and their expected service life on coastal and inland bridges. David Leyland, Maine's paint specialist, was also contacted at Mr. Boyce's suggestion. Mr. Leyland sent three interim reports on bridge painting projects in which the coating system is inorganic zinc-rich primer and vinyl topcoat. Mr. Abel Sirois, Director, Bridge Maintenance Operations, was also contacted to get information about inspection procedures and guidelines. A copy of their guidelines was to be sent.

7. Richard Ackerman, Florida Power and Light - A new request for information about paint performance data available from maintenance operations was made since the original request was never received.

From discussions with the various DOT's contacted, it is concluded that inspection records on paints will be one overall rating essentially reflecting a judgement on the need to paint or not. Several States have indicated that there are some FHWA guidelines on paint inspection but specifics have not been obtained. Such a request has been made to Georgia DOT but it needs to be renewed.

2.0 Estimated Cost to Complete Work

Budget (PhaseI)	$74,861
Cumulative Cost Prior to Report Period	44,069
Estimated Cost for Report Period	6,561
Estimated Cost to Complete Work	24,231

3.0 Identification of Problems

The draft of the final report for Phase I, due September 27, 1980, will not be ready on time. Report writing was delayed due to time spent on the activities above in section 1.0. The target date now as of this writing (10/15/80) is the end of October, 1980. A detailed outline of the report as well as the data base design has been prepared and discussed with the research team.

The late delivery had been discussed with the Contract Manager, Dr. Appleman, on 9/24/80 but the target date of 10/15/80 could not be met.

4.0 Future Plans

1. Complete draft final report and specific Phase II plan.

... Schedule for Contract No. DOT-FH-11-9090 Catalogue, Evaluate and Process Performance Data for Highway Bridge Coatings (Phase I).

TASK DESCRIPTION (PHASE I)

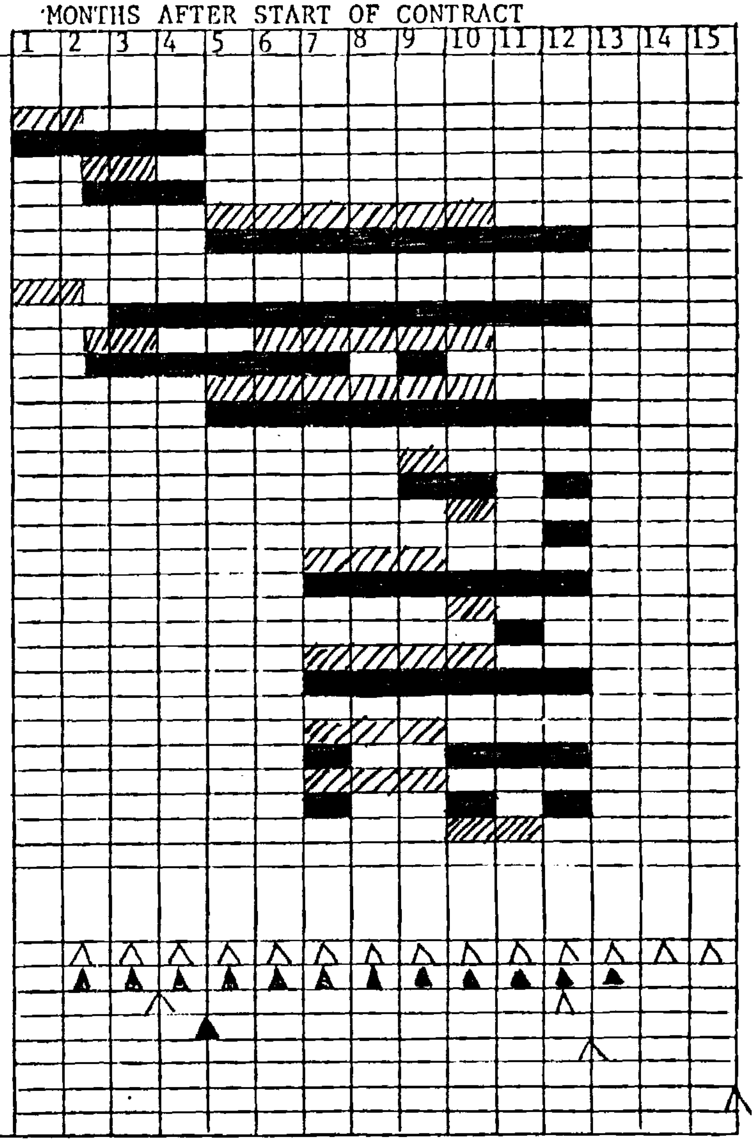
A. Review of previous computerized evaluations
   1. Identify current & previous efforts
   2. Plan to obtain methodology information
   3. Execute plan

B. Classify & characterize sources of coatings performance data
   1. Identify major non-highway sources
   2. Plan to characterize the data; execute plan
   3. Select highway related

C. Evaluation of merits of centralized data bank
   1. Significant variables affecting coating performance
   2. Data available versus significant variables
   3. Factors in establishing a data bank
   4. Product uniformity
   5. Types of coating data banks possible

D. Format and procedure for data banks possible
   1. Specific recommendations
   2. Incomplete data, etc.
   3. Specific phase II plans

Reports, plans
   1. Monthly
   2. Task A-2, B-7, D-3 plan
   3. Draft Final
   4. Final



scheduled; actual

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6,372
2. Plan to obtain methodology information			2,138	2,803
3. Execute plan	0	761	6,443	5,846
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources	0	1,700	9,202	14,181
2. Prepare detailed plan to characterize the data			2,759	2,307
3. Select highway related sources of data	0	691	12,159	6,418
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables	0	554	2,149	1,302
2. Relationship of data to significant variables	0	194	2,150	194
3. Factors in establishing data bank	0	823	5,979	4,918
4. Discuss product uniformity			4,299	394
5. Describe type of coating data banks that could be established	0	807	5,379	3,341
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations	0	672	4,544	3,915
2. Discuss incomplete data problems, etc.	0	165	4,544	968
3. Prepare specific Phase II plan			4,544	
Reports, plans	0	194	$ 3,406	194

7.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	96	768
Frank A. Rideout	14	350
Neil B. Hilsen	5	55
Joseph F. Celko	40	240

8.0 ADP Services

A-2490

Monthly Progress Report

Number 13
October 1, 1980 through October 31, 1980

EES Project A-2490
CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Material Division

Submitted by
Materials Research & Development Branch
Energy & Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles Ray

1.0 Research Results, Conclusions, Trends, and Progress

Work has concentrated on the preparation of the draft final report. A portion of an extremely rough draft of a description of the proposed data bank is given here.

Programming and data recording techniques available to handle non-homogeneous data and data from multiple sources are simply not found in the market place. Therefore a list structured approach is proposed which will solve these problems in such a way that statistical analysis routines and other conventional packages can be used to handle reports and other requests.

A list structure is a data processing concept applicable to building a data bank. A list is made up of nodes which contain data items and/or other nodes. The particular type of list structure here is a tree. A tree is a list that has either a data item or a sub-tree at each node. An organizational chart or a geneology are tree structures, for example.

In the data base, there will be nodes which are a list of items of the form "<variable> = <value>" separated by commas. The <value> will be either a constant or a sub-tree. If it is a sub-tree, then it is enclosed in parentheses. As an example, consider a family tree represented in this format:

```
(FAMILY="Jones", FATHER = "Tom", MOTHER = "Mary",
 CHILDREN= (SONS = (FIRST = "Melvin", SECOND = "Sam"),
            DAUGHTERS = "Jane")).
```

There are many trade-offs with this approach. It will provide a way of getting almost any data into the system. It will force that data to be viewed as part of a hierarchy which might not agree with the way that every human being views the data. This is a convenience for the system, however.

Another disadvantage is that it uses a great deal of space since data will be stored as character strings and will have the name of the variables (field labels) next to the values. But this feature achieves flexibility in the range of variables. Further, the entire file can be viewed as one long string of characters; it will have to be passed through a selection program to extract sub-files. This will take a longer time in comparison to searches in conventional data base structures, but it can be done on even the smallest and simplest of computer systems.

The techniques for programming list structures are well known and dependent on recursive techniques. They are mostly used by compiler writers and system programmers but not generally used by commercial programmers.

The major features of the data bank are a data dictionary, input programs, selector programs (search and retrieve), analysis, and management or utility routines.

Before a user can make an inquiry to the data base, he will have to know what type of data is on record. The source of this information is the data dictionary, a collection of data about the data. It will be also allow the user to search for variable names. The data dictionary can also carry information about the variables in the system, such as their ranges, the sources for them, and so forth.

Input to the system will be handled by a library of subroutines whenever a new set of data is added to the data base. The data dictionary will be used in conjunction with the input routines for on-line processing.

To build a sub-file (i.e., a set of records of particular interest), the user will submit a request to the system using simple logical and relational operations. The classic logical operations are AND, OR and NOT. The classic relational operations are <, >, and =. By making combinations of these primitives, it is possible to request any sub-file.

A variable in the tree structure will have to be referenced by the path from the top of the tree to it. If the variable has a unique name, the path can be found by the selector program, but if it is not unique, the user must provide enough details to identify the variable desired. Path names are traditionally shown by a dot between the owner node name and subordinate node name. Using the example record given in the last section, "FAMILY.CHILDREN.SONS.FIRST" is the path that uniquely identifies "Melvin Jones".

The selector program will have three phases to it. The first phase will take the text of the user's request and parse it just as a compiler would. All of the variables in the request must be in the data base and the syntax of the request must be correct. The request will then be converted into a reverse Polish internal code in this phase of the selector program. The selection request will have two parts to it. The first part will be a list of the desired variables in the subfile and the second part will be the selection criteria. It can be viewed as having the format " SELECT <List of Variables> WHERE <Criteria> ".

The second phase will examine the reverse Polish code to see if it can be re-ordered or optimized. A very common error in logical expressions is that the user has asked for everything or nothing without realizing it. For example, consider the request " NOT(A = 1) OR NOT(A = 2)"; the user probably meant to say "AND", but he has included all values of A for consideration. The user can also include redundant requests in his inquiry without realizing it. For example, consider the request "(A >= 1) AND (A = 2)"; the user probably forgot that he has included all values of A from one up, so that the value two is also included.

The final phase of the selector program is that part which reads in a record at a time from the data base and decides if it matches the request or not. This section has to inspect every record in the data base and therefore it will run slowly.

The system will require in some instances a statistical package which will provide the user with his final report. SPSS is the recommended statistical package because it is both cheap and the most widely known package on the market. It has the widest range of statistical routines of any of the statistical packages, including a good set of nonparameteric routines.

Utility programs would include those programs with which the data base is kept in proper form. Utility programs would check to see that all parentheses balanced in all records, close up unneeded blanks, check for minimum identification fields in records, and make back-up copies of the data base.

2.0 Estimated Cost to Complete Work

Budget (Phase I)	$74,861
Cumulative Cost Prior to Report Period	(50,235)
Estimated Cost for Report Period	(6,722)
Estimated Cost to Complete Work	$18,004

3.0 Identification of Problems

The report is behind schedule. A request for a no-cost extension was sent to FHWA on November 7, 1980. The requested due date for the draft final report is December 15, 1980.

4.0 Future Plans

1. Complete draft final report.

2. Prepare and submit working paper for 1980 FCP Conference.

[illegible] Catalogue, Evaluate
and Process Performance Data for Highway Bridge Coatings (Phase I).

TASK DESCRIPTION (PHASE I)

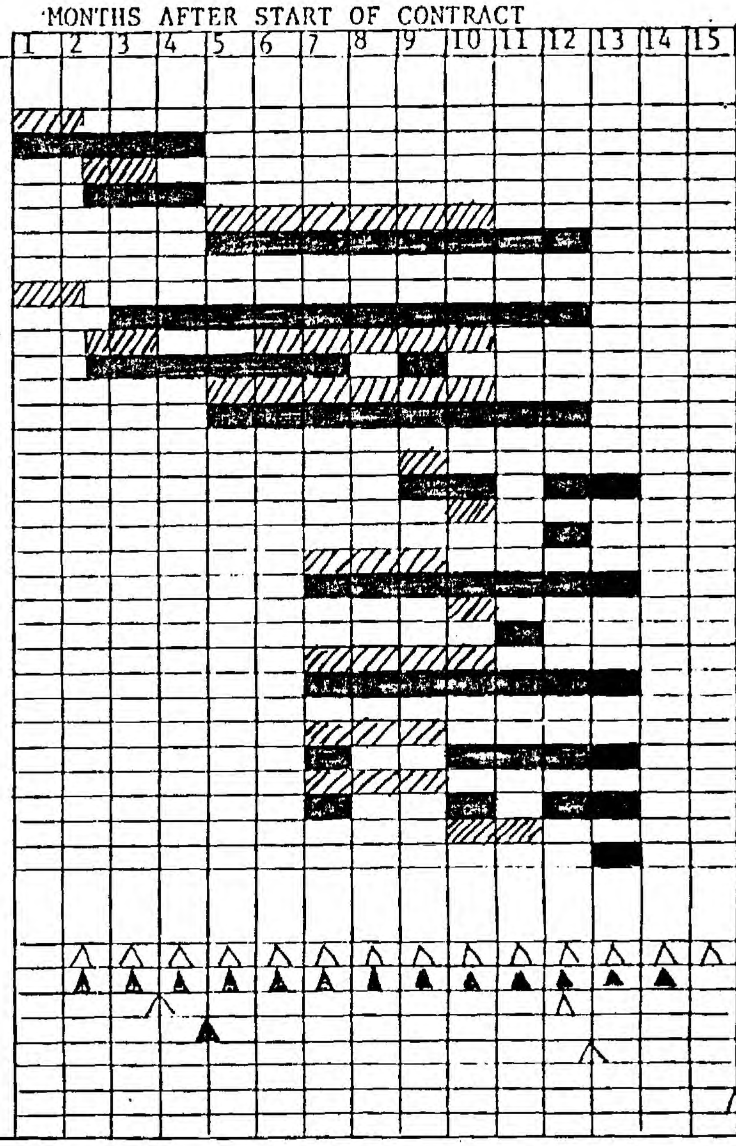
A. Review of previous computerized evaluations
   1. Identify current & previous efforts
   2. Plan to obtain methodology information
   3. Execute plan

B. Classify & characterize sources of coatings performance data
   1. Identify major non-highway sources
   2. Plan to characterize the data; execute plan
   3. Select highway related

C. Evaluation of merits of centralized data bank
   1. Significant variables affecting coating performance
   2. Data available versus significant variables
   3. Factors in establishing a data bank
   4. Product uniformity
   5. Types of coating data banks possible

D. Format and procedure for data banks possible
   1. Specific recommendations
   2. Incomplete data, etc.
   3. Specific phase II plans

Reports, plans
   1. Monthly
   2. Task A-2, B-7, D-3 plan
   3. Draft Final
   4. Final



scheduled; actual

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6,372
2. Plan to obtain methodology information			2,138	2,803
3. Execute plan			6,443	5,846
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources			9,202	14,181
2. Prepare detailed plan to characterize the data			2,759	2,307
3. Select highway related sources of data			12,159	6,418
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables		735	2,149	2,037
2. Relationship of data to significant variables			2,150	194
3. Factors in establishing data bank		805	5,979	394
4. Discuss product uniformity			4,299	394
5. Describe type of coating data banks that could be established		700	5,379	4,041
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations		1,014	4,544	4,929
2. Discuss incomplete data problems, etc.		1,014	4,544	1,982
3. Prepare specific Phase II plan		1,305	4,544	1,305
Reports, plans		1,150	$ 3,406	1,344

7.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	150	918
Frank A. Rideout	16	366
Neil B. Hilsen	8	63
Joseph F. Celko	66	306

8.0 ADP Services

None

A-2490

Monthly Progress Reports

Numbers 14 & 15
November 1, 1980 through December 31, 1980

EES Project A-2490
CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9693
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Material Division

Submitted by
Materials Research & Development Branch
Energy & Materials sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

Project Director
Dr. Charles Ray

1.0 Research Results, Conclusion, Trends, and Progress

The draft final report has been essentially completed. A typed version of the report was mailed to the contract manager on January 9, 1981. The Phase II work plan was submitted also. The work plan included a revised level of effort estimate for each task. This work plan is to be reviewed in January by the Georgia Tech personnel and a revised cost estimate made to coincide with it.

The 1980 FCP Conference was attended (December 10-11, 1980) and a status report on Phase I was given.

2.0 Estimated Cost to Complete Work

Budget (Phase I)	$74,861
Cumulative Cost Prior to Report Period	56,957
Estimated Cost for Report Period	11,210
Estimated Cost to Complete Work	6,694

3.0 Identification of Problems

None.

4.0 Future Plans

1. Review, edit, and revise final report in consultation with contract manager.
2. Provide FHWA with cost estimate for Phase II.
3. Present a paper at ASTM Symposium "Regimens for Predicting Performance of Decorative and Protective Surfaces," Orlando, Florida, January 21, 1981; submit same paper for ASTM publication and FHWA approval.

6.0 Current and Cumulative Costs

Task Description (Phase I)	Current Costs Planned	Current Costs Actual	Cumulative Costs Planned	Cumulative Costs Actual
A. Review Previous/Current Computerized Evaluation			$13,746	
1. Identify current/previous efforts			5,165	6,372
2. Plan to obtain methodology information			2,138	2,803
3. Execute plan			6,443	5,846
B. Classify & Characterize Sources of Coatings Performance Data			$24,120	
1. Identify major non-highway sources			9,202	14,181
2. Prepare detailed plan to characterize the data			2,759	3,307
3. Select highway related sources of data			12,159	6,418
C. Evaluation of Merits of Centralized Data Bank			$19,956	
1. Identify and discuss significant variables			2,149	2,037
2. Relationship of data to significant variables			2,150	194
3. Factors in establishing data bank	1,487		5,979	1,881
4. Discuss product uniformity			4,299	
5. Describe type of coating data banks that could be established	1,487		5,379	5,520
D. Format and Procedure for Data Bank			$13,632	
1. Prepare specific recommendations	1,487		4,544	6,416
2. Discuss incomplete data problems, etc.	620		4,544	2,602
3. Prepare specific Phase II plan	1,487		4,544	2,792
Reports, plans	4,642		$ 3,406	5,986

7.0 Level of Effort

Personnel	Level of Effort-Phase I (man-hours) Current	Cumulative
Charles J. Ray	105	1,023
Frank A. Rideout	18	384
Neil B. Hilsen	16	79
Joseph F. Celko	170	476

8.0 ADP Services

Monthly Progress Report No. 16

May 1, 1981 - May 31, 1981

Phase II

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Task A - Specifications for Computer Programming

Phase II was initiated May 1, 1981

Adrienne Harrington has replaced Jc Celko as the research team member who will have the task of writing the specifications for the data bank on performance data. She has reviewed the work plan for Phase II, reviewed the draft final report and proposed data bank organization (data record structure, data items, functions, SAS systems package) during the month. In addition, rough flow charts have been drafted for the data input routine. This cannot be finalized until the data dictionary is completed.

A meeting was held on May 13 at FHWA in Washington. The work plan was discussed in detail. From this, it was decided that a breakdown of the schedule for Task A - Specifications was needed as well as a separation of the man-power planned for Task D - Revision and final report writing. A revised schedule and man-power/task distribution chart are attached.

The order in which specifications are needed by FHWA/DSD is the data dictionary, input, proofreading, correction, updating, output, and processing.

1.2 Task B - Collect Performance Data

The data collections to be used in the demonstration of the data bank were discussed at the meeting also. The data to be used are:

1. PACE data on waterborne systems (SSPC)
2. Performance data on waterborne and solvent-borne coatings evaluated in NCHRP 4-14 "Coatings for Painting Old and New Structural Steel" (Georgia Tech).
3. Drum test data (Union Carbide Corp., Texas City, Texas)
4. West Virginia DOH-1 - data from studies on paint performance in relationship to air quality.
5. Michigan DOT "Protective Coatings for Highway Metals" - data from bridge painting trials.

It may also be possible to get the field exposure data from the Georgia DOT/Georgia Tech study on protective coatings for highway structural steel. However, no commitment is made to do so.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$63,929
Expenditures & encumbrances prior to report period	0
Expenditures & encumbrances for report period (est.)	5,063
Estimated Free Balance	$58,866

3.0 Identification of Problems

None.

4.0 Future Plans

4.1 Task A - Specification for Computer Programs

4.1.1 Prepare data dictionary

4.1.2 Prepare input specifications

4.2 Task B - Data Collection

4.2.1 Get data on PACE from SSPC

4.2.2 Prepare data (handwritten) from NCHRP 4-14

4.2.3 Obtain permission to obtain and use drum test data from UCC.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

Task	Current Costs Planned	Current Costs Actual	Cumulative Cost Whole Task	Cumulative Cost To Date	Per Cent Comp'n Cost	Per Cent Comp'n Time
A - Specifications	$7,306	5,063	$29,223	$5,063	17	25
B - Data Collection	2,821	0	11,285	0	0	25
C - Demonstration	0		6,572	0	-	-
D - Revisions	0		6,846	0	-	-
Final Report	0		10,003	0	-	-
Totals	$10,127	$5,063	$63,929	$5,063	8	10

7.0 Level of Effort

Personnel	Man-Hours Expended Current	Man-Hours Expended Cumulative
Charles Ray	42	42
Adrienne Harrington	134	134
Neil Hilsen	0	0

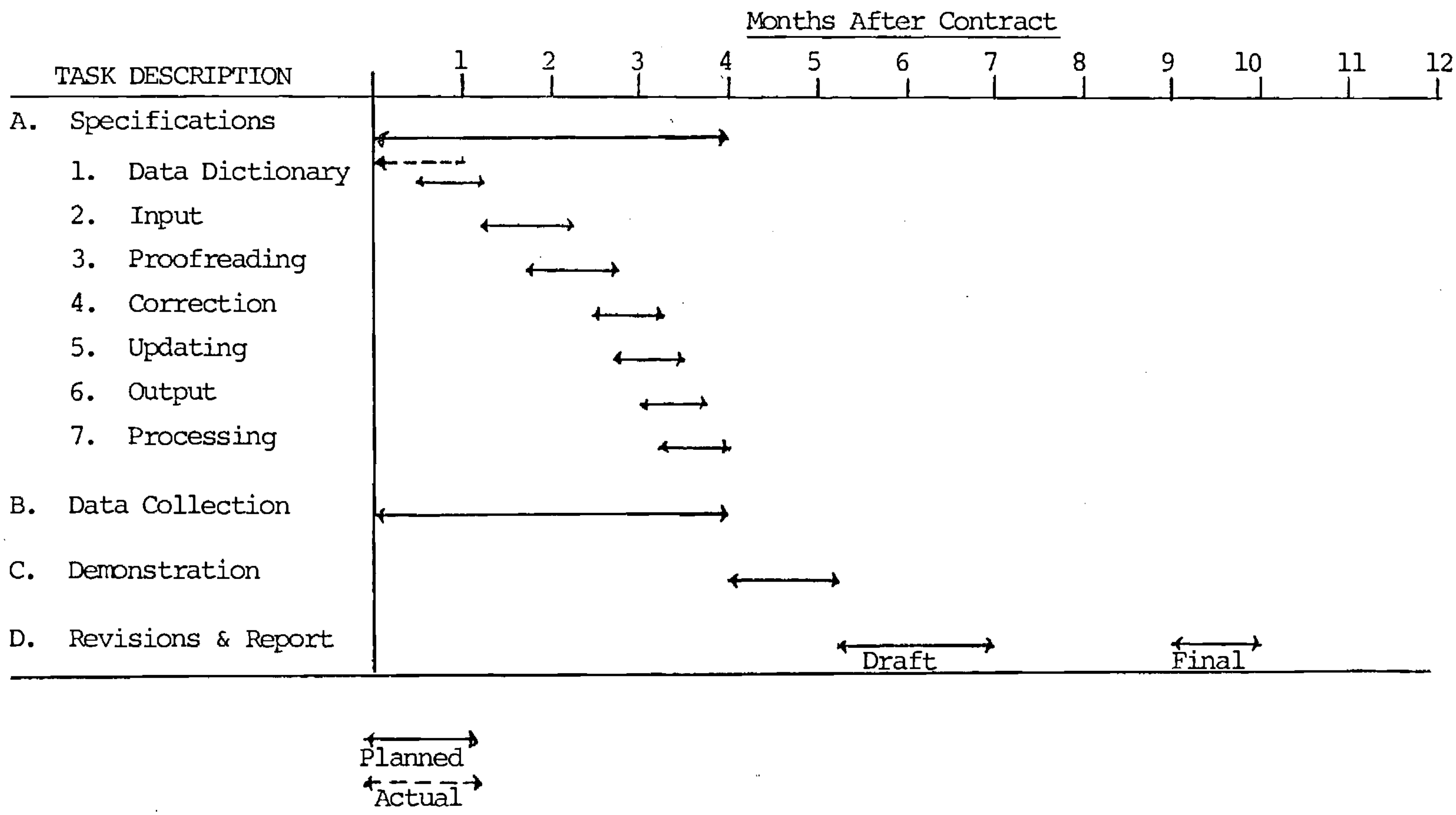
8.0 ADP Services

None.

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



Monthly Progress Report No. 17

June 1, 1981 - June 30, 1981

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Task A - Specifications for Computer Programming

Draft versions of the objectives, requirements, and structures of an interactive mode input routine and an interactive data processing routine have been developed and submitted to the data Systems Division for review and comments (mailed June 23, 1981). Copies of the descriptions for each routine (minus flow charts) are attached.

The data element dictionary has been worked on also during this reporting period. First draft copies of it are expected in early to mid July. The data element dictionary is a listing of each variable in the proposed data record in which each variable is described by a name, coded name, its function, its source, its field width and character type, and remarks. The remarks are used to provide things like the type of data, expected values, partial listing of standardized values, and definition of terms.

Review of the paint performance record or observation (SAS nomenclature) indicates that some consideration will have to be given to documenting panel conditioning prior to testing. The description should include time, temperature, relative humidity, and other information about the conditioning atmosphere. An example might be a simple designation of "weathering" plus an identification of any specific atmospheric contaminants expected to somehow affect the coating and its performance.

1.2 Task B - Data Collection

Permission to use some of data collected by Union Carbide Corporation through their drum test evaluation program has been requested. This was done by letter to Mr. Ray Azrak (Market Manager, Coatings Materials Division).

Dr. Joseph Bruno of Steel Structures Painting Council was contacted about the availability of data from the PACE project. Data available will be provided on disk and documentation will be sent that will help transcribe the information from SSPC format to the one developed for this project.

2.0 Estimated cost to Complete Work

Budget (Phase II)	$63,929
Expenditures & encumbrances prior to report period	6,574
Expenditures & encumbrances for report period (estimated)	6,338
Estimated Free Balance	$51,017
Per Cent Expended	20

3.0 Identification of Problems

None.

4.0 Future Plans

4.1 Task A - Specifications for Computer Programs

4.1.1 Complete data dictionary.

4.1.2 Complete input and proofreading routine specifications.

4.1.3 Start record correction routine specification.

4.2 Task B - Data Collection

4.2.1 Get data from PACE

4.2.2 Prepare data sheets with NCHRP 4-14 data.

4.2.3 Follow up request to Union Carbide Corporation for portions of their drum test data.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

Task	Current Cost		Cumulative Cost		Completion (%)	
	Planned	Actual	Task	To Date	Cost	Time
A - Specifications	$7306	$5849	$29,223	$12,423	43	50
B - Data Collection	2821	489	11,285	489	4	50
C - Demonstration	0	0	6,572	0	-	-
D - Revision	0	0	6,846	0	-	-
Final Report	0	0	10,003	0	-	-
Total	$10,127	$6338	$63,929	$12,912	20	20

7.0 Level of Effort

Personnel	Man-Hours Expended	
	Current	Cumulative
Charles Ray	34	76
Adrienne Harrington	169	303
Neil Hilsen	26	26

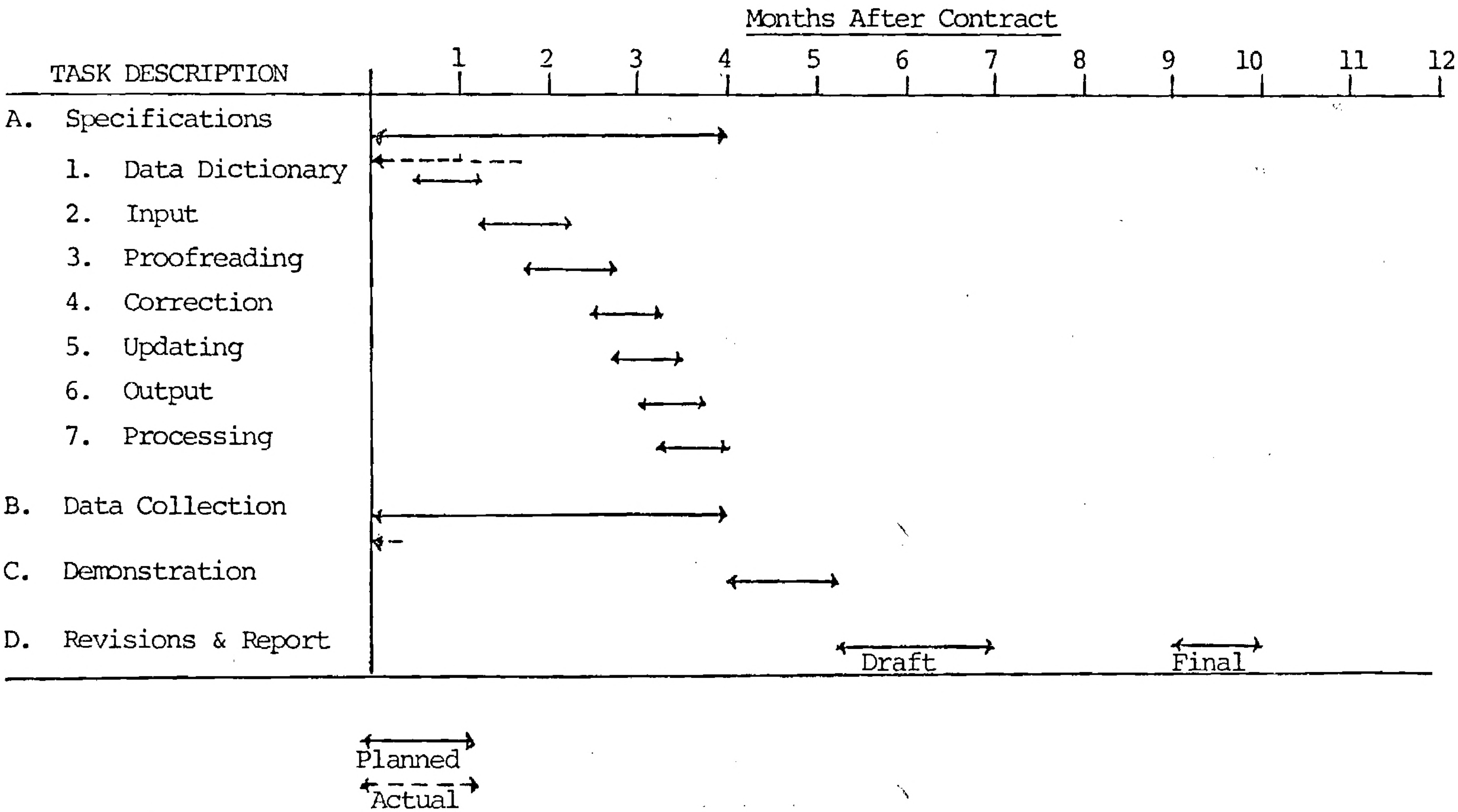
8.0 ADP Services

Accounts have been set up at the Georgia Tech and the University of Georgia facilities. The latter has SAS available.

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



A-2490

Monthly Progress Report No. 18

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Task A - Specifications for Computer Programming

A draft of the data dictionary has been completed and sent ot FHWA for review. The data dictionary has been reviewed in-house resulting in the addition of data elements to describe panel conditioning prior to testing and a set of variables intended to document service performance. These have been or will be sent under separate cover.

The scheme for documenting service performance replaces descriptors such as "good" or "poor" with essentially a "time to failure" judgement. Two types of time to failure are used based on the estimate of the degree of renovation required to establish adequate corrosion protection. The differentiation is based on touch up repair and complete repainting. Variables are also included to define the adequacy of corrosion protection for such structure features as welds, crevices, edges, and plane areas.

Data variables that may be eliminated or modified are listed here with a brief note of explanation.

Variable	Comment
II.B.8.d. Batch No. of Matrix Resin	Probability of users knowing this is essentially zero.
II.B.9.d. Batch No. of Pigment	Probability of users knowing this is essentially zero.
III.A.5.a.,b.,and c. Paint Viscosity	Not typically used as a variable affecting performance especially since it is adjusted to a correct value; more likely a variable for documenting quality control and assurance.
IV. B. 1. Steel Alloy	May be too detailed; alternative scheme might use. generic classes as PLAIN CARBON, LOW ALLOY, WEATHERING, HIGH STRENGTH LOW ALLOY (HSLA),...
V. b.2 General Environment	Possible addition of "DEICING" to indicate bridges subject to deicing salts although V. B. 3 may serve this purpose.
V. B. 3. b.2). Degradation Agent Concentration	May be too detailed or data not available; qualitative description of pollutants may be sufficient.

A list of generic classifications for resins and pigments has been assembled. Abbreviations rather than codes may help reduce the amount of space required to store this information while maintaining the "people" orientation originally intended. A copy of the classifications is attached to tihs report.

The following items were prepared and sent to the Data Systems Division on or about July 16:

1. System level description and block diagram for data entry.
2. Proposed record layout for the paint performance record (did not include variables for panel conditioning description and

service evaluation).

3. Proposed SAS data step cards and listing.

1.2 Task B - Data Collection

Permission to use some of the drum test data generated by Union Carbide Corporation has been received. F. Parker Helms who has custody of the "Drum Test" files has been contacted to arrange a visit in order to select data.

Dr. Joseph Bruno of SSPC is to send some data from PACE. It will be on a disk which will include documentation about the record layout also. Written documentation is to be sent as well:

2.0 Estimated tost to Complete Work

Budget (Phase II)	$63,929
Expenditures & encumbrances prior to report period	11,569
Expenditures & encumbrances for report period (estimated)	8,443
Estimated Free Balance	$43,917
Per Cent Funds Expended	31

3.0 Identification of Problems

The data collection is behind schedule. Sets of data from West Virginia and NCHRP 4-14 will be assembled into the record format during August using co-op student help.

4.0 Future Plans

4.1 Task A - Specifications for Computer Programs

4.1.1. Develop specifications for correction, updating, output, and processing routines maximizing SAS capabilities.

4.1.2. Make minor revisions to the Data Dictionary as needed.

4.2 Task B - Data Collection

4.2.1. Visit Union Carbide Corporation plant in Texas City to select drum test records.

4.2.2. Performance data from West Virginia reports and NCHRP 4-14 transcribed onto coding sheets following the record layout; transfer to cards and/or tape.

4.2.3. Follow up on offer from SSPC to provide a protion of PACE data.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

Task						
A - Specifications	$7306	8148	$29,223	20,571	70	75
B - Data Collections	2821	295	11,285	784	7	75
C- Demonstration	0		6,572	0	-	-
D - Revisions	0		6,846	0	-	-
Final Report	0		10,003	0	-	-
Total	10,127		$63,929	21,355	33	30

* Note: Adjustment ot expenditures shown in section 2.0 yields $20,012 expended or 31% funds expended.

7.0 Level of Effort

Person	Man-Hours Expended Current	Cumulative
Charles Ray	86	162
Adrienne Harringotn	164	467
Neil Hilsen (estimate)	26	52

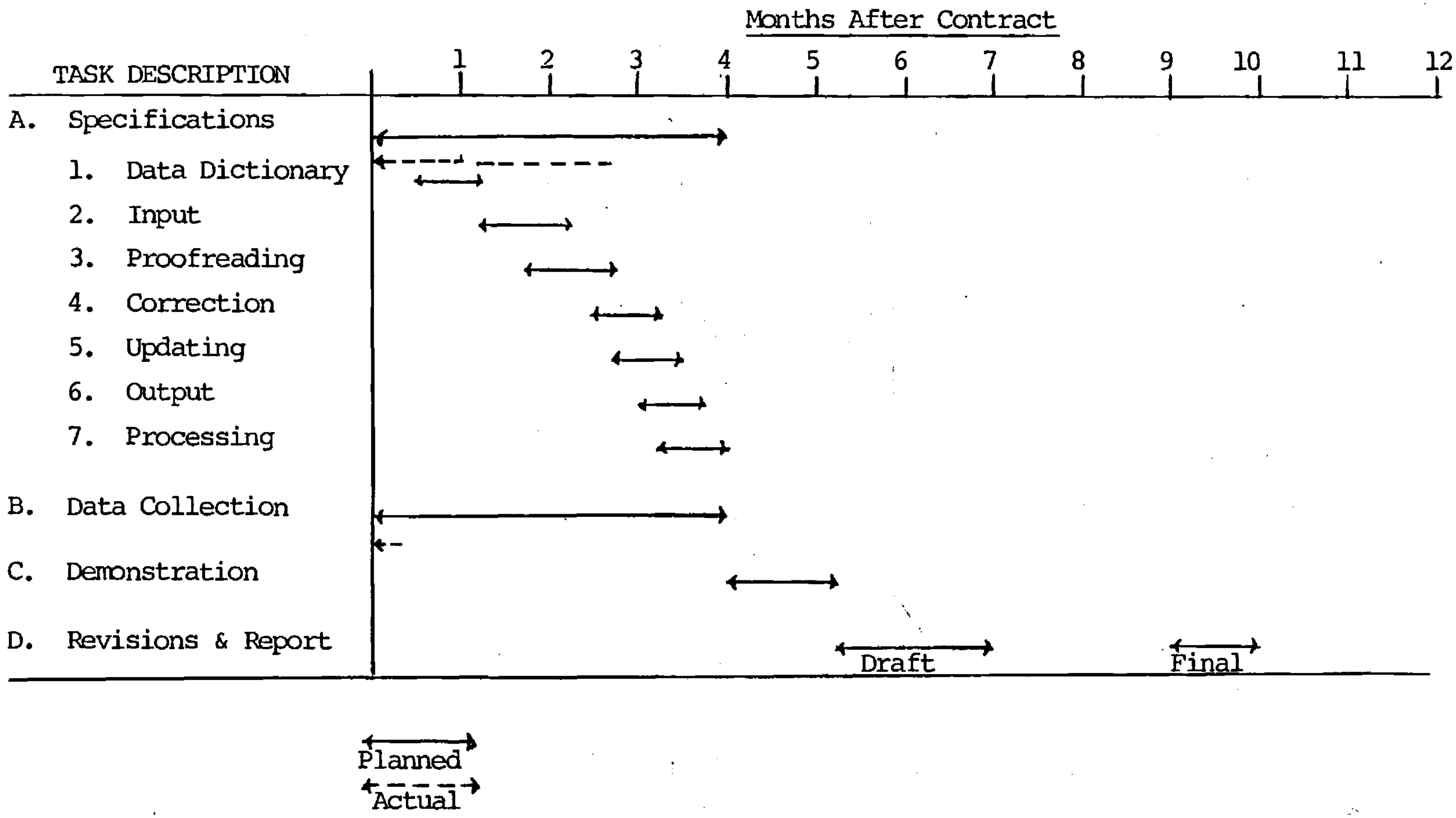
8.0 ADP Services

Georgia Tech Office of Computing Services:

Systems Resources	$0.88
Card Punching	0.58
Interactive	2.41
Outline Storage	.05
	$3.92

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



Major Generic Types for Coating Matrix Material

1. Alkyd
2. Acrylic
3. Bitumen
4. Cellulosic
5. Epoxy
6. Metallic
7. Oil
8. Phenolic
9. Rubber
10. Silicate
11. Silicone
12. Urethane
13. Vinyl

Alkyds

1. Short oil
2. Short oil + raw linseed oil
3. Short oil + bodied linseed oil
4. Medium oil
5. Medium oil + raw linseed oil
6. Medium oil + bodied linseed oil
7. Long oil
8. Long oil + raw linseed oil
9. Long oil + bodied linseed oil
10. Alkyd + raw linseed oil.
11. Alkyd + bodied linseed oil

Note: For alkyd + oil blends, the alkyd is the major component

<u>Acrylics</u>

1. Straight acrylic
2. Acrylic copolymers

Note:

1. Straight acrylic = all acrylic or methacrylic acid esters.
2. Acrylic copolymers = copolymers from acrylic and non-acrylic type monomers.

Bitumens

1. Asphalt.
2. Coal tar.
3. Coal tar-epoxy.

Cellulosics

1. cellulose acetate.
2. cellulose acetate butyrate

Epoxies

1. amine cure
2. polyamide cure.
3. epoxy ester.
4. amine/epoxy adduct cure.
5. ketimine cure.
6. phenoxy.

Metallic

1. Zinc, sprayed.

2. aluminum, sprayed.

3. zinc-aluminum alloy, spray.

4. zinc; hot dip galvanized.

Phenolics

1. phenolic.
2. modified phenolic.

Note:
1. Phenolic = condensation product of phenol and an aldehyde, usually formaldehyde
2. Modified phenolic = phenolic resin modified with rosin or other natural resins

Oils

1. raw linseed oil
2. bodied linseed oil
3. raw linseed oil + alkyd
4. bodied linseed oil + alkyd

Note: For oil plus alkyd blend, the oil is the major component.

Rubbers

1. Styrene-butadiene

2. Chlorinated rubber.

Silicates

1. alkali metal silicate, post cure.
2. alkali metal silicate, self cure.
3. alkyl silicate.

Silicones

1. silicone

2. silicone-alkyd

Urethanes

1. aromatic isocyanate, moisture cure
2. aliphatic isocyanate, moisture cure
3. aromatic isocyanate, polyester polyol cure
4. aliphatic isocyatate, polyester polyol cure
5. aromatic isocyanate, acrylic polyol cure
6. aliphatic isocyanate, acrylic polyol cure
7. aromatic isocyanate, polyether polyol cure
8. aliphatic isocyanate, polyether polyol cure

Vinyl

1. vinyl chloride-vinyl acetate
2. vinyl butyral
3. vinyl acetate
4. vinylidene chloride
5. vinyl chloride-vinyl acetate, hydroxy functional
6. vinyl chloride-vinyl acetate, acid functional

Major Generic Types for Pigments

1. Corrosion inhibiting

2. Barrier

3. Color/Hiding

Corrosion Inhibiting

Lead Containing

1. red lead
2. basic lead carbonate
3. basic lead silicate
4. dibasic lead phosphite
5. dibasic lead phosphosilicate
6. tribasic lead phosphosilicate
7. basic lead silicochromate
8. calcium plumbate

Chromate Containing

1. zinc yellow
2. zinc tetroxy chromate (basic zinc chromate)
3. strontium chromate

Other

1. zinc molybdate
2. calcium zinc molybdate
3. calcium boro silicate
4. barium boro silicate
5. barium meta borate
6. zinc phosphate
7. zinc phosphooxide
8. zinc dust

Barrier

1. aluminum flake, leafing
2. aluminum flake, nonleafing
3. mica
4. micaceous iron oxide
5. glass flake
6. stainless steel flake

Color/Hiding

Whites

1. basic carbonate white lead
2. basic sulfate white lead
3. zinc oxide - American
4. zinc oxide - French
5. titanium dioxide - rutile
6. titanium dioxide - anatase

Reds

1. red iron oxide
2. Rubine red or BON
3. Lithol rubine red
4. Quinacridone
5. molybdate red
6. Cadmium

Blues

1. phthalocyanine
2. iron blue

Greens

1. phthalocyanine
2. chrome

Yellows

1. benzidine
2. lead chromate
3. cadmium

Oranges

1. dinitroaniline
2. brominated anthanthrone (vat orange)
3. tetrachloroisoindolinone
4. perinone (vat orange)
5. chrome oranges
6. molybdate orange
7. cadmium

Violet

1. carbazole dioxazine
2. isoviolanthrone

Blacks

1. carbon black
2. iron oxide

Monthly Progress Report No. 19

August, 1981

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress.

1.1 Task A - Specifications for Computer Programming

The specification for the interactive mode input routine has been completed and sent to FHWA Data Systems Division for implementation. Five card decks were also sent constituting SAS data steps for the bridge evaluation record (list input), test panel evaluation record (list input), test panel record (named input), and two input files.

The specification for batch mode input is near completion. It is expected to be ready for FHWA in early September.

1.2 Task B - Data Collection

Some performance data from the PACE project has been received from the Steel Structures Painting Council. The data is from the alternate (alternative) primer pigment portion of PACE and is composed of the exterior exposure resistance ratings. The data is for 112 coating systems (56 primers and 56 primers plus a topcoat) applied over five different surfaces and exposed at three different sites. This will give 1680 performance records.

The initial approach to the transformation of the SSPC data into the record layout developed in this project involves first reordering the SSPC data to match the sequence of variables in the record and then writing each record using PACE data values or the missing value symbol as appropriate. It is expected that this data transcription will be finished by mid September.

The salt fog exposure data corresponding to these exterior exposures is not included in the data sent. If time and money allow, this data may be added to the set of records to be used in the demonstration program but it must be extracted from the published report on PACE.

A trip was made to the Union Carbide plant at Texas City, Texas to get some drum test data for use in the demonstration program. F. Parker Helms supplied a set of test results for a study that included exterior exposure data and salt fog exposure data for thirty commercial products. These products will not be identified except by generic type. The duration of the salt fog exposure was approximately 3000 hours while the exterior exposure ran 23 to 28 months.

A guide will have to be prepared to extract information from the package of data and enter it in the proposed record format.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$63,929
Expenditures and encumbrances prior to report period	19,798
Expenditures and encumbrances for report period (estimated)	6,740
Estimated Free Balance	$37,391
Per Cent Funds Expended	42

3.0 Identification of Problems

A review meeting was held at the Georgia Tech campus with the Contract Manager. The slippage in the schedule was discussed with the following target dates and goals established to maintain the overall schedule:

September 15, 1981	SSPC data
September, 1981	Collect other data and get into machine readable format
October, 1981	Revision of specifications and start draft of final report
November, 1981	Complete draft final report and program documentation
December, 1981 January, 1982	FHWA review of report
February, 1982	Final report revisions and submission

4.0 Future Plans

4.1 Task A - Specifications for Computer Programs

4.1.1 Work on specifications to interface with SAS routines for correction, updating, output, and processing of records.

4.2 Task B - Data Collection

4.2.1 Submit SSPC data in machine readable format

4.2.2 Get data from West Virginia exposure tests into machine readable format

4.2.3 Get UCC drum test data into machine readable format.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

	Current Cost		Cumulative Cost		Completion (%)	
Task	Schedule	Actual	Task	To Date	Cost	Time
A. Specifications	$7306	$4068	$29,223	$24,639	84	100
B. Data Collection	2821	2672	11,285	3,456	31	100
C. Demonstration	0	0	6,572	0		
D. Revisions	0	0	6,846	0		
Final Report	0	0	10,003	0		
Totals	$10,127	$6740	$63,929	$28,095*	44*	40

Note: Adjustment to expenditures shown in section 2.0 yields $26,538 or 42% funds expended.

7.0 Level of Effort

	Man-Hours Expended	
Person	Current	Cumulative
Charles Ray	16	178
Adrienne Harrington	161	628
Neil Hilsen	17	60

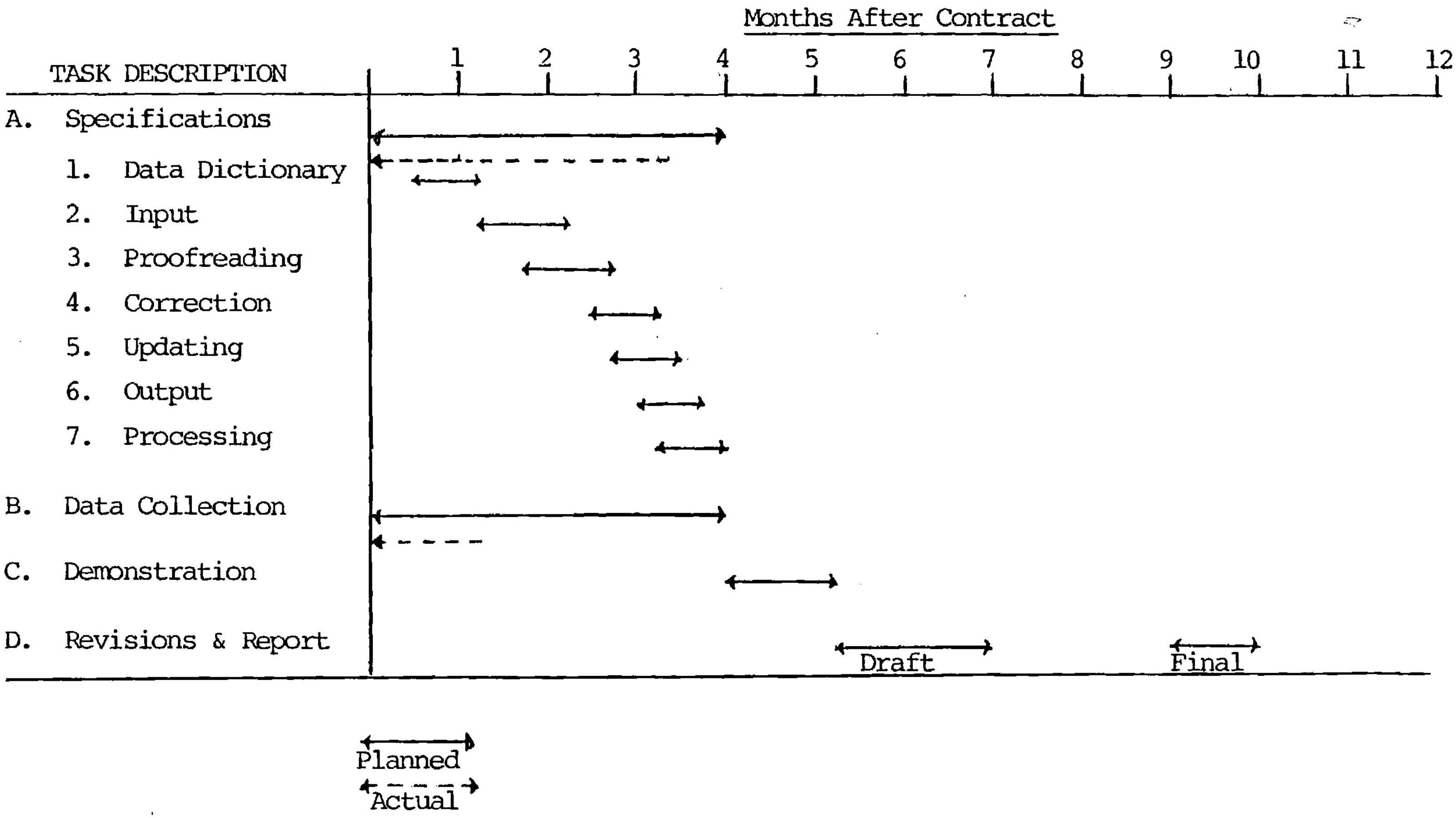
8.0 ADP Services

	Current	Cumulative
Programming	$2,762	$9,898
Systems Analysis	636	2,110
Computer Time		4
Data Preparation	431	431
Documentation	1,360	4,875
Total	$5,189	$17,318

HIGHWAY BRIDGE COATINGS

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



A-2490

Monthly Progress Report No. 20.

September, 1981

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Task A - Specifications for Computer Programming

The specifications for the non-interactive mode data input routine, HELP routines (on-line data dictionary for variables and groups of variables), and label statements for a formatted record output were supplied to the FHWA by the end of this report period (September 30, 1981).

1.2 Task B - Data Collection

The test fence exposure data from the alternative pigments section of the PACE project has been supplied to FHWA. This set of records will comprise the bulk of the paint performance records available for use during the demonstration period.

Two other sets of paint performance records were delivered to FHWA on September 30, 1981. One set was fifty records chosen from the approximately 600 test panels placed on exposure by the West Virginia Department of Highways. The data in this set was extracted from published reports "Evaluation of Structural Steel Coatings In Relation to Industrial Atmospheric Conditions" (Research Project 23) and "Paint Performance In Relation to Air Quality" (Research Project 49).

The other set of paint performance data was taken from records of the Union Carbide Corporation for its drum test series CUPE 73S. Thirty paint systems were evaluated in the test which ran for twenty-three months. A companion set of test results using salt spray as the test environment have not yet been obtained. Both sets are wanted to provide a case to try correlation type analyses.

1.3 Demonstration of the Data Bank

An initial demonstration of the data bank was held on September 30, 1981 at FHWA facilities in Washington, D. C. Various options to repeat information from record to record were demonstrated using system editor capabilities. These capabilities are expected to vary from facility to facility, however. It was recommended by FHWA that the SAS EDITOR not be used since it would change the master file.

A routine generated by Georgia Tech was discussed as a route to aid input of data from a variety of sources. The program was originally written to get the data sets from SSPC, Union Carbide, and West Virginia into the proposed data bank format. The main steps in the rountine are:

1. Establish which variables in the general record will have values from the data source.

2. Prepare a series of "READ" and "WRITE" statements for these variables.

3. Prepare a series of statements to set the values for the remaining variables to the missing value symbol.

This procedure can be generalized so that initially all variables have corresponding "READ" and "WRITE" statements. One could then list which variables will have data values and then give these values on a record-by-record basis; the remaining variables would be assigned a missing value symbol or no data entry by default. This can be used on batch or interactive modes.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$63,929
Expenditures and Encumbrances prior to report period	25,862
Expenditures and Encumbrances for report period (estimate)	10,379
Estimated Free Balance	$ 27,688
Per cent funds expended	57

3.0 Identification of Problems

None.

4.0 Future Plans

4.1 Task A - Specifications for Computer Programs

4.1.1 Programs to interface with SAS analysis routines

4.2 Task B - Data Collection

4.2.1 Get NCHRP 4-14 data into machine readable format

4.2.2 Get Union Carbide Corp. data for salt spray results to complement drum test data.

4.2.3 Get some records for painted bridges.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

Task	Current Cost		Cumulative Cost		Completeion (%)	
	Schedule	Actual	Task	To Date	Cost	Time
A. Specifications	$ 0	$2,923	$29,223	$27,562	94	125
B. Data Collection	0	5,566	11,285	9,022	80	125
C. Demonstration	4,381	1,890	6,572	1,890	29	80
D. Revisions	0	0	6,846	0	-	-
Final Report	0	0	10,007	0	-	-
	4,381	$10,379	$63,929	$38,474	60	50

Note: Adjusment to expenditures shown in section 2.0 yields $36,241 or 57% funds expended.

7.0 Level of Effort

Person	Man-Hours Expended	
	Current	Cumulative
Charles Ray	53	231
Adrienne Harrington	168	796
Neil Hilsen	17	67

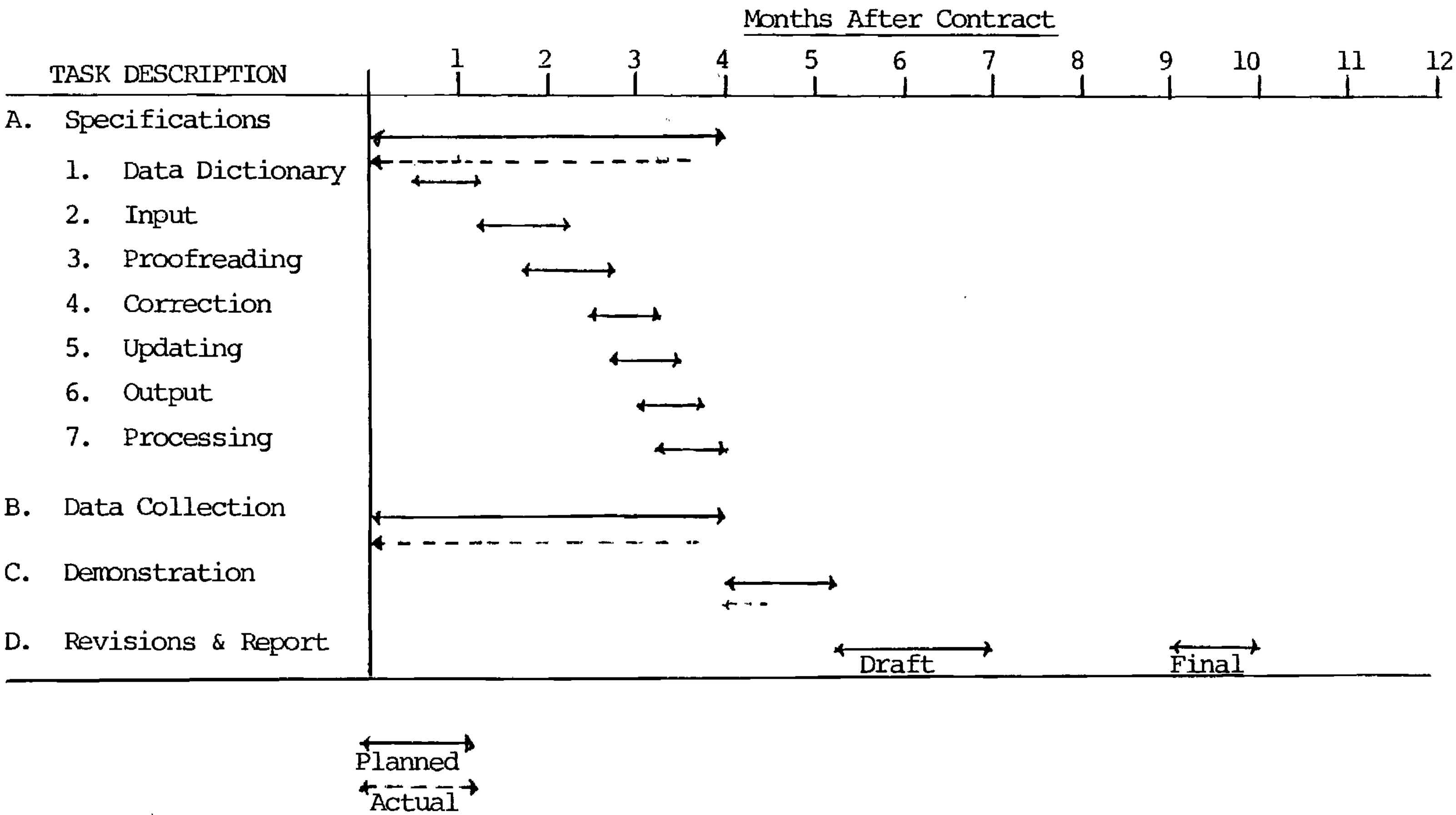
8.0 ADP Services

	Current	Cumulative
Programming	$2,877	$12,775
Systems Analysis	636	2,746
Computer Charges	1,114	1,118
Data Preparation	1,725	2,156
Documentation	1,417	6,292
Total	$7,769	$25,087

... DATA FOR HIGHWAY BRIDGE COATINGS

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



A-2490

Monthly Progress Report No. 21

October, 1981

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Task A - Specifications for Computer Programming

Specifications for routines to interface with the SAS data processing and analysis routines are in progress. Some will be written to handle typical requests expected to be made by users.

Modifications to the record structure in terms of variables to be deleted, added, and modified have been instituted. The data to be recorded for monitoring the performance of a protective coating system on a bridge has been changed. Three measures of a "time to failure" are used: (1) time to touch up repair without a refresher top coat, (2) time to touch up repair with a refresher topcoat, and (3) time to a complete repaint. Entries are simply the time in months if the state of the paint warrants one of these failure classifications. In addition, the per cent area showing rust on various features of the bridge can be recorded: overall area, plane, vertical areas, plane, horizontal areas, weld areas, edge areas, and crevice type areas. Decay of the paint film itself is also monitored through data on the per cent of the paint area affected by peeling or flaking, cracking, checking, blistering, fading, chalking, and color change.

The format for recording the performance data for both panel and bridge records has been changed. For each inspection, all the performance ratings are recorded on one line, not on several lines as originally designed.

1.2 Task B - Data Collection

Salt fog and synthetic sea water immersion exposure results have been obtained from Union Carbide Corporation through the help and efforts of Parker Helms. The paint systems covered in this set of data correspond to the systems evaluated in UCC's drum test program.

Salt fog exposure results from SSPC's PACE branch study on alternative primer pigments have been incorporated into the data bank. These records will complement the records for the same paints exposed at various weathering sites. The salt fog data was taken from coding sheets filled out by NBS personnel in the course of their study on "Short-Term Evaluation Procedures for Coatings on Structural Steel" which was (and is) funded by FHWA.

Inclusion of the performance data collected on project NCHRP 4-14 "Coating Systems for Painting Old and New Structural Steel" has not been done yet. The data can be entered but it may have to be done during the report review period.

1.3 Task C - Demonstration

A second demonstration of the data bank was held on October 14, 1981. The manipulation of the data was dependent on familiarity with SAS routines and procedures (selection of records, renaming or equating variable values, formats to present data, plotting, analysis such as averages and comparison of subsets of records). The need and desirability of providing an interface to SAS was emphasized as a result of the demonstration.

SAS does not provide an interpolation routine, so a short program was written to provide such capability. The routine will calculate performance ratings at arbitrary inspection or observation times based on a linear interpolation or straight line curve between two successive data points.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$63,929
Expenditures and Encumbrances prior to Report Period	34,916
Expenditures and Encumbrances for Report Prior (estimate)	8,581
Estimated Free Balance	$20,432
Per Cent Funds Expended	68

3.0 Identification of Problems

Revisions may have to be done during the report review period.

4.0 Future Plans

4.1 Task A - Specifications for Computer Programs

4.1.1 Specifications for interfaces to SAS routines.

4.2 Task B - Data Collection

4.2.1 Incorporate performance data from bridges used in BCC model

4.2.2 NCHRP 4-14 data

4.3 Task C - Demonstration

4.3.1 Plan on one more demonstration to identify needed revisions

4.4 Task D - Revisions

4.4.1 Start on revisions depending on timing of demonstration.

4.5 Final Report

4.5.1 Submit draft of final report.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

Task	Current Cost Schedule	Current Cost Actual	Cumulative Cost Task	Cumulative Cost To Date	Completion (%) Cost	Completion (%) Time
A. Specifications	$ 0	$3,641	$29,223	$31,203	107	150
B. Data Collection	0	2,643	11,285	11,665	103	150
C. Demonstration	2,191	2,297	6,572	4,187	64	133
D. Revisions	2,934	0	6,846	0	--	--
Final Report	4,289	0	10,007	0	--	--
	$9,414	$8,581	$63,929	47,055	74	60

7.0 Level of Effort

	Man-Hours Expended Current	Man-Hours Expended Cumulative
Charles Ray	79	310
Adrienne Harrington	176	972
Neil Hilsen	18	85

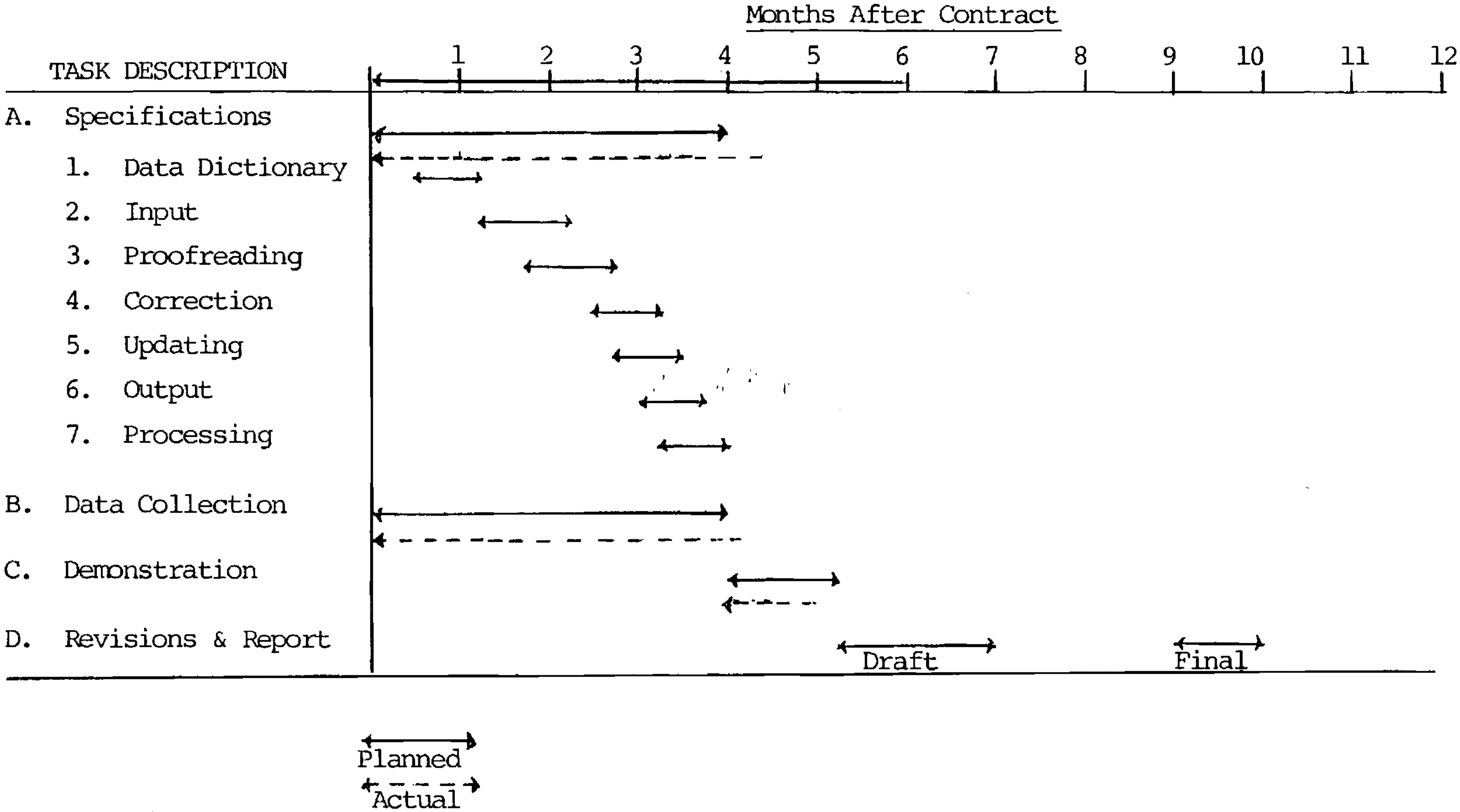
8.0 ADP Services

	Current	Cumulative
Programming	$2,000	$14,775
Systems Analysis	638	3,384
Computer Charges	10	1,128
Data Preparation	1,087	3,243
Documentation	1,421	7,713
	$5,156	$30,243

PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



Monthly Progress Report No. 22

November 1981

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

1.1 Task A - Specifications for Computer Programming

Specifications and sample SAS programs have been prepared to handle what is felt to be typical user requests. These routines are designed to:

1. Compare performance of two paints on test panels with the paints identified generically and the degree of surface cleanliness specified.

2. Identify coating systems potentially useful on a bridge given the bridge type, environment, and minimum desired design life.

3. Compare the performance of two generic types of coatings on the basis of exposure data from bridge cases.

4. Graphically and numerically present data to probe the effect of environment on the performance (service life) of generically different coating systems.

5. Graphically and numerically present data of the degree of rusting overall on a bridge against exposure time.

Specifications for outputting the data in a record in an outline format were also prepared.

1.2 Task B - Data Collection

The performance data (time between painting) used in the BCC model has been prepared for entry into the record format for the paint performance data bank. The actual transcription has not been done.

1.3 Task C - Demonstration

No specific activities were carried out during this report period.

1.4 Task D - Revisions and Report

Revisions to the record structure have been made although not all the data currently in the master file has been charged to the new format.

The draft of the final report has been started but not completed. Delivery of a rough draft copy is expected in mid December.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$64,524
Expenditures & Encumbrances prior to Report Period	46,059
Expenditures & Encumbrances for Report Period	9,237
Estimated Free Balance	9,228
Per Cent Funds Expended	86

3.0 Problem

The report draft will not be ready on time. A copy of the rough draft will be sent for review. The report is being entered also in a word processor which will be used to make revisions, corrections, and prepare the report in two column format.

4.0 Future Plans

4.1 Finish draft final report and submit.

4.2 Establish date for demonstration.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

	Current Cost		Cumulative Cost		Completion (%)	
Tasks	Schedule	Actual	Tasks	To Date	Cost	Time
A. Specifications	0	2793	29,223	33,996	116	175
B. Data collection	0	0	11,285	11,665	103	-
C. Demonstration	0	0	6,572	4,187	64	-
D. Revisions	3,912	1902	6,846	1,902	28	
Report	4,003	4542	10,007	4,542	45	
	$7,915	$9,237	$63,929	$56,272	88	

Note: Adjustment to the amounts shown is section 2.0 yield 86% funds expended.

7.0 Level of Effort

	Man-Hours Expended	
	Current	Cumulative
Charles Ray	102	412
Adrienne Harrington	135	1107
Neil Hilsen	15	100

8.0 ADP Services

	Current	Cumulative
Programming	1724	16,499
Systems Analysis	638	4,022
Computer Charges	18	1,111
Data Preparation	0	3,243
Documentation	1149	8,862
	3529	$33,737

A-2490

Monthly Progress Report No. ~~16~~ 23

December 1981

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

Task D - Revision and Reports

A copy of the draft report was completed except for recommendations and conclusions. This was sent December 11, 1981.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$64,524
Expenditures & Encumbrances prior to Report Period	55,297
Expenditures & Encumbrances for Report Period	5,971
Estimated Free Balance	3,256
Per Cent Fund Expended	95

3.0 Problems

None.

4.0 Further Plans

1. Revision of report
2. Finalize documentation

5.0 Program Schedule

See attached schedule

6.0 Current and Cumulative Costs

Tasks	Schedule	Actual	Task	To Date	Cost	Time
A. Specifications	$ 0	$1,030	$29,223	$35,026	120	200
B. Data Collection	0	0	11,285	11,665	103	-
C. Demonstration	0	0	6,572	4,187	64	-
D. Revisions	0	1,851	6,846	3,753	55	-
Report	0	3,090	10,007	7,632	76	100
	$ 0	$5,971	$63,933	$62,263	95	80

Note: Adjustment to values in section 2.0 gives 61,268 expended.

7.0 Level of Effort

	Man-Hours Expended	
	Current	Cumulative
Charles Ray	32	444
Adrienne Harrington	64	1171
Neil Hilsen	15	115

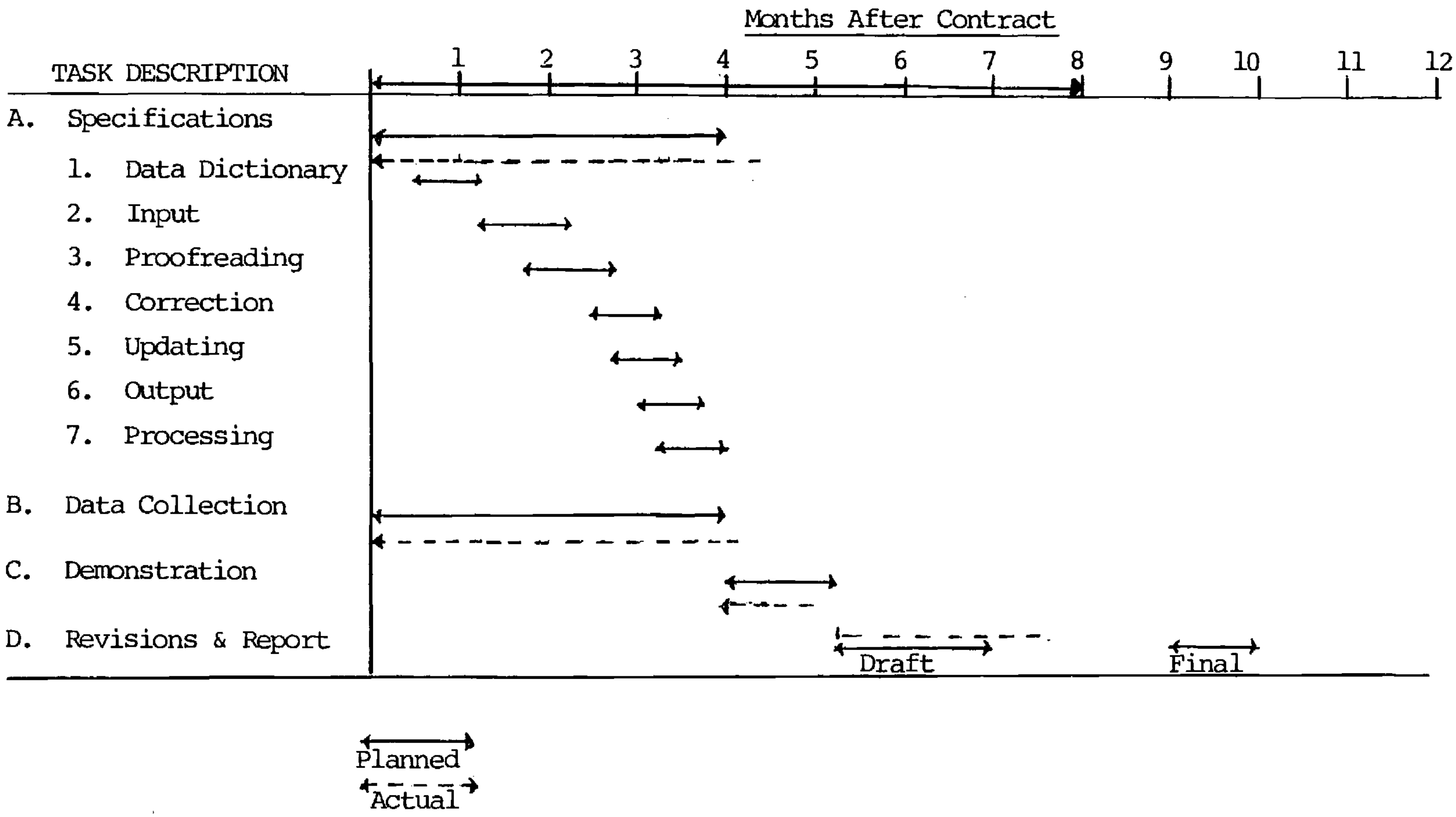
8.0 ADP Services

	Current	Cumulative
Programming	$ 0	$16,449
Systems Analysis	638	4,675
Computer Changes	16	1,127
Data Preparation	0	3,243
Documentation	0	8,862
	$654	$34,391

DATA FOR HIGHWAY BRIDGE COATINGS

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



Monthly Progress Report No. 24

January 1982

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

Activities this report period were limited to typing the report into a word processor and some editing.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$64,524
Expenditures & Encumbrances Prior to Report Period	61,268
Expenditures & Encumbrances for Report Period	1,026
Estimated free Balance	$ 2,230
Per Cent Expended	97

3.0 Problems

The software to format the report into two-column style is not working correctly. The vendor has been notified and corrections are in progress.

4.0 Future Plans

1. Make report revisions and submit final version.

2. Check routines written to debug and get example output.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

	Current Cost		Cumulative Cost		Completion (%)	
Task	Schedule	Actual	Task	To Date	Cost	Time
A. Specifications	0	0	$29,223	$35,026	120	-
B. Data Collections	0	0	11,285	11,665	103	-
C. Demonstration	0		6,572	4,187	64	-
D. Revisions	0	1,026	6,846	3,753	55	-
Report	0	1,026	63,929	63,289*	98*	

Note: Adjustment to figures in section 2.0 gives $62,294 expended or 97%.

7.0 Level of Effort

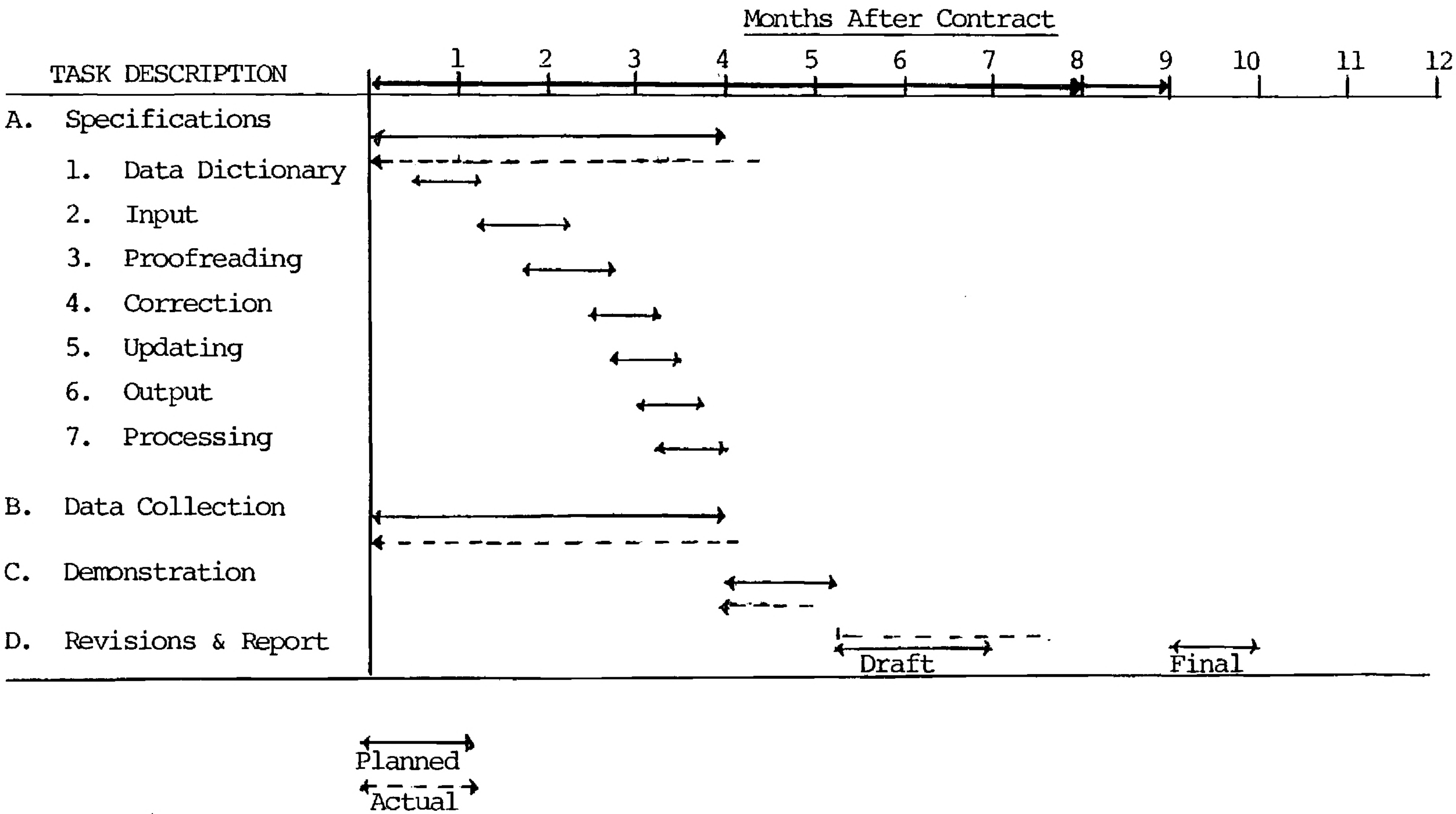
	Man-Hours Expended	
	Current	Cumulative
Charles Ray	0	444
Adrienne Harrington	0	1171
Neil Hilsen	15	130

8.0 ADP Services

	Current	Cumulative
Programming	$ 0	$16,449
Systems Analysis	0	4,675
Computer Charges	12	1,139
Data Preparation	0	3,243
Documentation	0	8,862
	$12	$34,403

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



Monthly Progress Report No. 25

February 1982

CATALOGUE, EVALUATE, AND PROCESS PERFORMANCE DATA FOR HIGHWAY BRIDGE COATINGS

Contract No. DOT-FH-11-9698
U.S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

Contract Manager
Dr. B. R. Appleman
HRS-23, Materials Division

Submitted by

Materials R & D Branch
Energy and Materials Sciences Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332

EES Project No. A-2490

Dr. Charles Ray, Project Director

1.0 Research Results, Conclusions, Trends, and Progress

The process routines were debugged and sample runs of each made. User's and operation manuals were prepared in draft form. Corrections and editing of the report were also done.

2.0 Estimated Cost to Complete Work

Budget (Phase II)	$64,524
Expenditures & Encumbrances Prior to Report Period	62,293
Expenditures & Encumbrances for Report Period	1,676
Estimated Free Balance	$ 555
Per Cent Expended	99

3.0 Problems

The Report and manuals are behind schedule. Submission of the report is targeted at mid March. Draft copies of the manuals may also be available then.

4.0 Future Plans

1. Finish report.
2. Submit manuals.

5.0 Program Schedule

See attached schedule.

6.0 Current and Cumulative Costs

Task	Current Cost		Cumulative Cost		Completion (%)	
	Schedule	Actual	Task	To Date	Cost	Time
A. Specifications	0	0	29,223	35,026	120	
B. Data Collection	0	0	11,285	11,665	103	
C. Demonstration	0	0	6,572	4,187	64	
D. Revisions	2,280	1,079	6,846	4,832	71	
Report	3,336	597	10,007	9,255	92	
	$5,616	$1,676	$63,933	$64,965	102	

* Note: adjustment to figures in section 2.0 gives 63,969 expended or 99%

7.0 Level of Effort

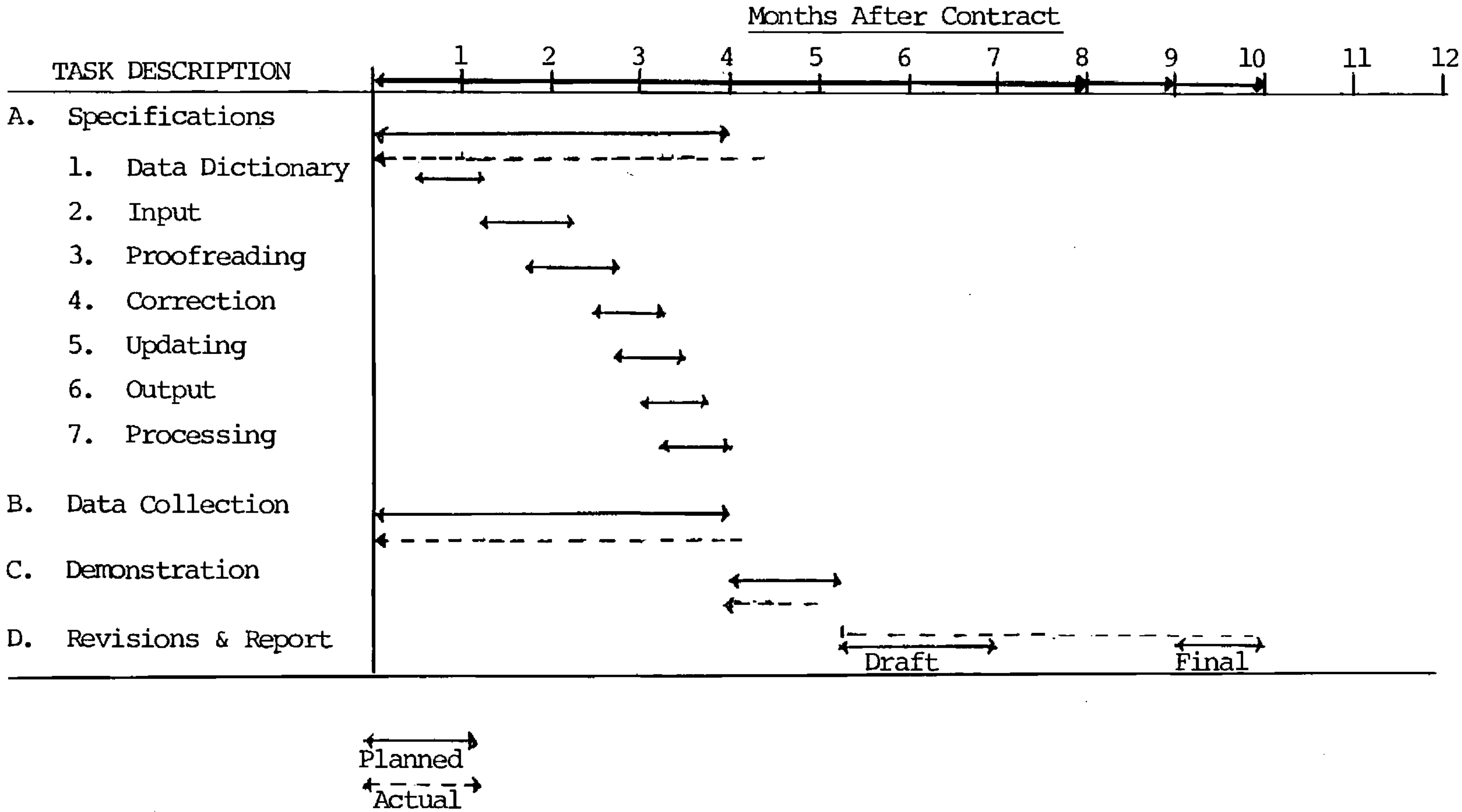
	Man-Hours Expended	
	Current	Cumulative
Charles Ray	0	16,449
Adrienne Harrington	40	1,211
Neil Hilsen	0	130

8.0 ADP Service

	Current	Cumulative
Programming	$ 0	$16,449
Systems Analysis	0	4,675
Computer Charges	29	1,168
Data Preparation	0	3,243
Documentation	540	9,402
	$569	$34,937

Phase II - Demonstrate Capabilities of Data Bank

Contract No. DOT-FH-11-9698



Contract No. DOT-FH-11-9698

DATA BANK FOR EVALUATING PERFORMANCE OF COATINGS FOR BRIDGES

Phase I - Feasibility Analysis

C. J. Ray, J. F. Celko, F. A. Rideout, and N. B. Hilsen
GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia 30332

June, 1981

Interim Report

Prepared For
U. S. Department of Transportation
Federal Highway Administration
Washington, D. C. 20590

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Georgia Institute of Technology
Atlanta, Georgia 30332

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15. Supplementary Notes

FHWA Contract Manager: B. R. Appleman. HRS-23

16. Abstract The application of computer techniques used to store, retrieve, and analyze paint performance data in the paint and coatings field is reviewed. Additionally, an assessment is made on the quality and quantity of data available for incorporation into a data bank. Finally, the outline of a data bank structure is proposed. Several computerized storage and retrieval systems used in the coatings industry were identified. Most are used to record the performance data generated from laboratory tests and test fence exposures in the course of product development. Two programs, however, were found that operate on data collected from in-service evaluations and inspections. In addition to logging performance data, data items are recorded that classify the type of exposure, surface preparation, and the paint materials. Several sources of data were examined, drawing from the raw materials supplier, published reports, and paint users, especially the transportation departments. Overall, the quality and homogeneity of data from laboratory tests and test fence exposures is good since the use of standardized ratings from ASTM is common. Data derived from in-service inspections is not homogeneous, however, since the evaluations are highly subjective and rating values such as "good", "fair", and "poor" are common. The data bank proposed uses a format free record structure and a commercial data processing system. The data elements comprising the performance record describe the coating materials, application process parameters, surface preparation, exposure environment, and performance ratings. Data from laboratory tests, test fence sites, field trials, and service use can be recorded. Major uses of the data bank envisioned include an inventory of coatings used on bridges, assessment and comparison of the performance attributes of new and/or competitive systems, product reliability estimates, and a decision aid to coating selection and maintenance strategy.

17. Key Words	18. Distribution Statement
Paints, Coatings, Corrosion Protection, Bridges, Structural Steel, Electronic Data Processing, Automated Data Processing, Computers, Performance Data.	

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14. Mr. Wendel Williams, Arkansas State Highway and Transportation Department.

Summary

The project "Catalogue, Evaluate, and Process Performance Data for Highway Bridge Coatings" had the objective to determine the feasibility, merits, and workability of a computerized storage and retrieval system of performance data of corrosion protection systems on highway structural steel. The scope of work included a review of computerized systems in the coatings field, identification and review of existing performance data, and assistance to the Federal Highway Administration in developing a data bank structure, formats and programs.

The project is one element of the Federal Highway Administration's Federally Coordinated Project 4J "Coating Systems for Controlling Corrosion of Highway Structural Steel." The objective of Project 4J is the identification of methods and materials that will concurrently improve corrosion control of highway structural steel and comply with environmental, health, and safety requirements.

The coatings industry has been active in developing and promoting new and improved paint systems for protecting structural steel exposed to the atmosphere. This has been done in response to and in anticipation of governmental regulations as well as the normal competitive pressures and need for improved performance. The highway community must, however, evaluate and compare the performance attributes of these coatings among themselves and in relation to established coatings. This is a difficult task.

The evaluation of new and improved coatings is a continuous process throughout the coatings industry, the highway community, research institutes, and private industry in general. The evaluations encompass laboratory tests, exposure at test fence sites, small scale field trials, and actual service use. The data generated in these evaluations represents an enormous information base from which to draw in making comparisons and/or selecting the "best" corrosion control strategy.

This project, then, is intended to develop the framework of an automated system to store the performance data, serving as an information source on paint performance in protecting bridge structural steel from corrosion.

Review of Computerized Storage and Retrieval Systems.

Several computerized storage and retrieval systems were identified during the course of the work. Only two systems were designed to handle case history data solely. These are International Dataplan, a proprietary system of International Paint, and Paints and Coatings Performance System (PCP) which was developed under the National Shipbuilding Research Program and modelled after International Dataplan. The Georgia DOT/Georgia Tech system, Paint Evaluation Program (PEP), is capable of recording data from field structures but it concentrates on documenting data from laboratory and test fence exposure of panels. The remaining systems were developed to handle performance data from coated test panels.

The information recorded in the computerized systems can be grouped into categories of identification of the paint system, the substrate, testing environment, and the performance data. The degree of detail in the data for each category varies, of course, from system to system. For example, the programs of Rohm and Haas, Union Carbide Corporation, and Rust-Oleum include the formulation for a coating either directly or through reference to a specific product code and batch number. For the vehicle portion of the paint, the monomer composition for a polymer product can also be recorded. In contrast to this, the PCP system uses a generic classification as the identifier of the coating system.

The paint system category can include specification of the film thickness for the total coating and/or the thickness of each layer, characteristic physical properties or

attributes of the wet and dry paint such as viscosity, solids, and/or gloss.

The substrate category often just indicates which of several standard test panels are used although provision has been incorporated in some cases to identify surface preparation.

The information used under testing environment at a minimum is the location of a test site for most of the systems reviewed although some additional data can be used to better describe the environment such as total solar irradiance, humidity range, characteristic temperature, and a description of the chief atmospheric pollutant.

The performance attributes monitored and rated in these systems are the ones commonly used in product development appropriate to the end use market. Collectively, they are resistance to gloss loss, color change, fading, chalking, rust development, blistering, undercutting, peeling, flaking, cracking, checking, alligatoring, and fouling. Most often these attributes are rated by ASTM methods. The grading usually is on a scale of 0 to 10, 10 being no change from initial conditions and 0 being complete failure. Grades like "excellent, good, fair, poor, failure" are also used.

The data record structure for the systems reviewed follows the 80 column "IBM" card format. That is, a fixed field format is used where the column location of a data entry is the key to the attribute or information category.

The nonnumerical data entries in the systems are coded using assigned alphanumeric equivalents or, as possible, abbreviations. This is done to conserve storage space and to maximize use of a computer's basic digital character.

Data input to the systems is on punched cards prepared from coding sheets although on-line entry via remote terminals is possible. The coding is done manually. Data output is presented in tabular or other style report formats including graphical presentation.

Data processing entails retrieving particular records that match an interest profile, updating records, and correcting records. In the systems reviewed, the parameters (keywords) on which one can search are limited by design, reflecting the prior knowledge of how data are usually requested. In addition to finding records that match a request, the records selected are usually sorted as a step in report preparation.

Analysis capability amongst the systems is varied. Some analyze the data in terms of the "effects" of formulation changes as part of factorial design experiments in addition to descriptive statistics and tests of statistical significance. It should be noted that analysis of the data can be done by any of several commercially available routines. One's retrieval scheme prepares the data for the analysis.

Data Sources

The sources of performance data of coatings on highway structural steel are the State DOTs and other governmental units with bridge maintenance responsibility such as bridge and turnpike authorities and county and city highway departments. Closely allied to these are the various industries that need to protect structural steel, research organizations, and coatings and raw materials suppliers. The performance data sought was from actual service (case history) and test fence exposure of panels although data from accelerated, laboratory tests were wanted if corresponding outdoor test results were available.

The data characterization involved a survey in terms of the quality of data, the quantity of data, and the homogeneity of data from multiple sources. The quality of data involved the objectivity of the rating or measurement system and its precision. Quantity of data considered features like the extent of replication, number of different coatings, number of different surface preparations, and number of different test environments. Homogeneity of data, i.e., the use of the same performance rating standards or ones that can be uniquely transformed to a common standard, was considered because of its direct bearing on the ability to collate data from several sources and draw meaningful conclusions therefrom.

The most important performance property in this study is retardation of the corrosion of steel. Here, the surface area rusted scale of ASTM D 610 is predominant in the laboratory (salt fog) and test fence data of the sources examined. Other attributes connected with resistance to corrosive environments are blister resistance and undercutting of the protective coating from a scribe line. Again, the ASTM methods are frequently used. For laboratory and test fence studies of performance then, the frequency of homogeneity in the rating systems is expected to be high. The quality of the data overall from such sources is good, reflecting the control over material and test parameters in dealing with small samples.

The data obtained from service performance or even experimental or trial painting of bridges is not homogeneous. This is due, basically, to the lack of a standard method of evaluating the coating on a bridge. The ASTM D-610 scale based on the per cent area rusted loses meaning on a bridge since bridges do not rust uniformly and their surface area is difficult to estimate. Evaluations are highly narrative and subjective although tempered by various levels of experience and training. Each state has its own system and evaluation criteria which support a decision to repaint a bridge or not. This generates a single performance rating value per inspection. Hence, ratings correspond to descriptions like "good," "fair," "poor," and "critical."

Based on a combination of selecting the better performance data available and a desire to show the versatility of the data bank structure to accept data of variable format and levels of description, the following data sources have been selected for demonstration of the operation of the data bank.

1. PACE (Phase I) - Steel Structures Painting Council (SSPC)
2. Drum Test Data (partial) - Union Carbide Corporation, Texas City.
3. Data used in the Bridge Corrosion Cost model, FHWA - RD-79-121.
4. Data extracted from "Protective Coatings for Highway Metals" Michigan DOT, Research Report R-916.
5. "Paint Performance in Relation to Air Quality," Research Project 49, and "Evaluation of Structural Steel Coatings in Relation to Industrial Atmospheric Condition," Research Project 23, West Virginia DOH.

Data Bank Structure

A major requirement imposed on the data bank for coatings performance was the ability to accept data from various sources in various forms. The intent was to provide at a minimum the data; analysis capability was secondary.

A fixed format record was not selected since the level of description for the significant independent variables affecting performance is variable as well as the level of description and duration of performance. Instead, a format free data record was chosen so that the data "as is" could be accepted, especially case history records.

In the format free record, the number of characters or digits used to supply the value of a data element is not restricted. The sequence of data elements that make up the data record is fixed and specified, however.

For the paint performance data bank, the records will be centered on the performance of a coating system or a particular substrate in a particular exposure environment. For laboratory based work, the record will document the initial state of the coated panel and test results. This includes panels exposed on test fences. For coating systems on structures, the record will consider the structure as one unit although provision can be made to describe performance on various subunits of the structure, classifying these subunits as part of the environment.

A record will contain information that will:

1. Provide unique identification and the source of the data.
2. Identify the protective coating system.
3. Describe the surface preparation used.
4. Identify application process parameters.
5. Describe the exposure or test environment.
6. Give the values of various performance attributes as a function of time (if appropriate).

Hence, all the major factors affecting performance are included.

Data Bank Operation

The major functional capabilities of the data bank are organized into input functions, output functions, and analysis.

The input functions are:

1. Accept input either in a batch or interactive mode. For the batch mode, the data values will be entered following a format given on data recording sheets. In the interactive mode, a program would lead the user through the record format, requesting field values.
2. Listing of the standard field values and definitions as requested by a user, i.e., on-line documentation. This will aid in homogenizing the data. The option does exist to enter "non-standard" data values.
3. A check on the "correctness" of data entered in terms of values being within the allowed range or the right "type." This is a proofreading function.

The output functions are:

1. Retrieve and sort records on any combination of parameters; documentation and interactive mode routines to help a user generate an interest profile on which to search.
2. Output data records.
3. Arrange interest file in proper format for analysis routines.

A commercial software package has been chosen that will provide the capability to do much of the data processing (sorting, correcting, updating, selecting records, creating subsets, etc.); report writing (output presentation), and analysis. The system is SAS (Statistical Analysis System) from SAS, Inc., (P. O. Box 80-0, Cary, NC 27511). A commercial package was chosen since it economically provides basic data processing and analysis capability that is adaptable to specific user's needs.

The analysis capability provided through SAS includes standard descriptive statistics (average, standard deviation, frequency distributions) and statistical routines to examine correlations, to test for statistically significant differences, and to run regression analyses, for example. The selection of the proper analysis of the data does require some knowledge about the nature of the statistical test (assumptions, type of data required, interpretation or meaning of key parameters and results), but the SAS documentation is sufficient for the background information needed.

Data Bank Uses

The collection of paint performance records from the various sources generating data (raw materials suppliers, coatings manufacturers, DOTs, government laboratories, research institutes, trade associations, industrial users, etc) provides a mechanism to pool information so that it can be stored, retrieved, and (potentially) analyzed conveniently. The relative ease of access and manipulation of the large amount of data that could be available makes tasks such as performance comparison of competitive products or the study of the dependence of a product's performance on surface preparation and environment manageable.

The data bank can be operated on a national scale, by individual states, or other government units. As such, it can be used to inventory the coatings used on bridges and provide information on their durability. Similarly, it could be used as the storage and retrieval system for the data generated in evaluating new, improved, or alternate coatings by laboratory tests and outdoor exposures, replacing or supplementing paper copy files and laboratory notebooks.

The use of the analysis routines provided through SAS or other commercial software package provides the opportunity to explore the applicability of these to paint performance type data without the need to dwell on the computations themselves. Hence, the data bank can provide sophisticated tools to help researchers and engineers study relationships, define service life and its dependence on certain factors quantitatively, and develop insights.

Feasibility and Advisability of a Data Bank

In summary, it is recommended that the development of a data bank be undertaken since it is feasible and advisable. It is feasible since (1) data record structure and recording techniques are available to handle inhomogenous data, data from multiple sources, and incomplete data, (2) data of interest exists, and (3) basic statistical analysis packages are available to help extract information from the collected data. It is advisable since (1) the need and pressures to convert to new coating systems requires the highway community and coatings industry to pool and disseminate data, (2) the pooled experience will aid in identifying better corrosion control technology, (3) quantitative characterization of the service life of a coating, coatings, or other protective systems can enhance the reliability of economic comparisons of different maintenance strategies, (4) quantitative characterization of the service life of a coating, coatings, or other protective systems can aid maintenance scheduling and anticipating maintenance needs, and (5) a data bank can be a resource against which manufacturers' product performance claims can be checked.

1.0 Introduction

The annual cost of metallic corrosion in the United States is estimated to be $70 billion based on 1975 data. This estimate resulted from a study undertaken by the National Bureau of Standards at the direction of the United States Congress. The economic model, assumptions, and data forming this estimate have been reported (1). It was also estimated that approximately $10 billion of the total cost was avoidable, i.e., the application and utilization of existing technology could have significantly reduced the cost.

The cost of corrosion of highway bridges has been explored by Frondistou-Yannas and co-workers (2). This study placed the annual corrosion cost of protecting steel highway bridges at $130-$160 million. This figure, however, is expected to be only fifty per cent of the minimum amount needed to adequately maintain the structures. This inadequacy of bridge maintanance is supported by other estimates of $19 billion to replace or rehabilitate bridges on the interstate highway system due to accelerated deterioration and a high percentage of bridges (approximately forty per cent) as structurally deficient (3). These latter points, however, include corrosion induced deterioration of bridge decks.

The highway community then is faced with corrosion control decisions that affect the safety of highway users and the long term (life cycle) costs of providing a viable transportation system. These decisions must be made in light of several factors. Requirements and options often change reflecting the impact of regulations that restrict materials and processes and the recognized need to implement cost effective corrosion control, i.e., the long term economic merits of competing maintenance strategies. Budget restraints are omnipresent. The selection of the protective system is also done in a competitive arena: raw material suppliers and coatings manufacturers are continually developing and promoting their products. It is difficult to judge the relative merits of the various products, both supported and claimed, since so many factors can affect the service performance of the protective system.

One aid to the selection of a corrosion protection system is a repository of performance data of coatings on highway bridges. Such a resource can help since it could provide a background against which to judge new and existing products, accumulating the experience of highway bridge personnel nationwide, and since it could provide a mechanism for standardizing testing and performance ratings to increase the objectivity of merit assessment. Because the protective coatings field is highly empirical, the large amount of data expected and its storage and retireval would require electronic data processing methods.

1.1 Objective and Scope

"Catalogue, Process, and Evaluate Performance Data for Highway Bridge Coatings" has as its objective a determination of the feasibility, merits, and workability of a computerized storage and retrieval system of performance data of coatings on highway structural steel. The scope of the work included a review of computerized systems in use in the coatings field, identification and review of existing performance data, assistance to the Federal Highway Administration in developing a data bank structure, formats, and programs and a demonstration of the operation of the data bank as proposed.

1.2 Research Approach

The project was divided into two phases. In Phase I, the feasibility of a data bank was to be established while in Phase II the operation of the data bank was to be demonstrated.

This report covers the work performed in Phase I.

Computerized storage and retrieval systems in the coatings field were identified by literature searching and through personal contacts and knowledge of the research team. These were reviewed for their structure, data items, language, input/output formats, analysis capability and hardware requirements amongst other attributes.

Performance data characterization involved a survey of potential data sources, drawing from the highway community, coatings manufacturers, raw material suppliers, users, research institutes,and academia. Data were assessed in terms of the objectivity of the rating systems used, number of different coatings, extent of replication, and the number of the significant factors affecting performance included. Preference was given to controlled tests on bridges and field exposure of coated test panels. Data from coordinated experiments and trials involving laboratory performance testing and outdoor exposures were also desirable.

The merits of a data bank were considered in light of the quality of the data available, in terms of the scope of significant variables included, reliability of the data, ability and/or need to handle inhomogeneous data, and benefits.

Based on the overall assessment (computerized data handling options, data quality, and merits), a specific data base structure was developed and outlined. It emphasizes the recording and retireval of performance data in a "people" oriented format, a format that easily and naturally can handle data from multiple sources and inhomogeneous rating systems.

2.0 Computerized Storage and Retrieval Systems for Coatings Performance Data

Computerized storage and retrieval systems for paint performance data identified during the course of the project are listed in Table 1. Each system is individually reviewed in section 2.1. Other systems of interest and value to this project in general are reviewed in section 2.2. The motivation and advantages in developing and using an automated data storage and retrieval system are discussed in section 2.3, while in section 2.4, an assessment of the effort involved in creating a data base for paint development work is given.

2.1 Storage/Retrieval Systems

2.1.1 Paint Evaluation Program - Georgia DOT/ Georgia Tech

The Paint Evaluation Program (PEP) was developed under the technical direction of W. R. Tooke, Jr. as part of a project for the Georgia Department of Transportation ("Paint Systems for Highway Structural Steel," Research Project No. 6301). The details of the program and corresponding documentation have been reported (4), supplemented by an overview and updating in the project's final report (5). Most of the data base system and processing were developed over a five year period starting in 1965 and required approximately a two man-year effort.

The data base of PEP is organized into thirteen files with provision for cross-referencing between them. A brief description of the information stored in each file is given in Table 2.

The file "Experimental Sets" is an organizational tool. It allows one to identify a number of data records as forming a coherent set from a designed study or some other basis of association. For example, a set of coatings formulated and tested for a particular project can be so identified as belonging together. Hence, the assignment of a set number to a collection of test results enables one to conven-

TABLE 1. LIST OF COMPUTERIZED DATA STORAGE/RETRIEVAL SYSTEMS

Organization	Type Performance Data or End Product
Gerogia Department of Transportation/ Georgia Institute of Technology	Structural steel coatings including composition, laboratory test data and field exposure data.
U. S. Navy, Naval Ship R & D Center	Anti-fouling paint evaluation data for commercial and developmental products.
Union Carbide Corporation	Trade sales paint development data; composition information and data from test fence exposure.
Rust-Oleum Corporation	Test fence data on products; expanding to include laboratory data from accelerated weathering, salt spray, etc.
Maritime Administration/Avondale Shipyards, Inc./Offshore Power Systems	In-service performance ratings for paints used on ships (case histories).
NACE Technical Committee T-6H-15	Performance ratings on various paints exposed at several sites for study entitled "Effects of Surface Preparation on Service Life of Protective Coatings"; statistical analysis on data collected.
International Paint Company	In-service performance ratings for company's paints used on ships (case histories).
PPG Industries	Performance ratings from test fence exposures on industrial coatings.
Glidden	Performance ratings on products under exterior exposure.
Rohm and Haas Company	Trade sales paints emphasized; performance ratings from exterior exposure of test panels; composition data also.

TABLE 2. DATA FILES OF THE PAINT EVALUATION PROGRAM

File Name	Description of Data Stored
Experimental Sets	Individual, planned units of work or experiments
Constituents	Raw material file; physical data characterizing the individual paint components (e.g., density, generic identity, non-volatile concentration, batch number, etc.)
Paint Data	Data on liquid paints and dry films (constituents and respective concentration, viscosity, pigment volume concentration, total solids by weight, total solids by volume, density, dry time, opacity, tristimulus color values, gloss, application ratings, generic classifications, etc.)
Water Immersion	Data from a water immersion test including the paint system number (unique), substrate, surface preparation, film thickness, initiation/termination dates, panel/film conditioning, and performance ratings (blisters, adhesion, scribe rusting, under film rusting.
Accelerated Weathering	Ratings on chalking, fading, checking, cracking, color change, and rusting as a function of exposure time plus initiation/termination information identifying the coating, film thickness, conditioning, etc. Ratings as to blisters, adhesion, rust creepage, underfilm corrosion using ASTM standards. Test run according to ASTM.
Mechanical Tests	Data for conical mandrel flexibility, reverse impact test, adhesion (angular scribe stripping), falling sand abrasion resistance, and pencil hardness. Initiation/termination data as to coating system, substrate, surface preparation, film thickness, panel conditioning, etc.
Environmental Chamber	Performance data from a specially designed accelerated weathering apparatus using wet/dry cycling in combination with light/dark cycling. Data recorded on blistering, checking, discoloration, erosion, fading, chalking, cracking, filiform corrosion, mildew, peeling, flaking, and rusting periodically as a function of exposure time. Normal initiation/termination data also included.
Flat Field Panel	Performance data from a typical test fence installation (45°, South) at three different locations: marine, fresh water humid, and mild industrial. Periodic ratings as to blistering, checking, discoloration, erosion, fading, chalking, cracking, filiform corrosion, mildew, peeling, flaking, and rusting on the plane and scribe areas of the panels. Normal initiation/termination data are also included covering substrate, surface preparation, coating system, film thickness, etc.
KTA Field Panel	Performance data for painted KTA panels exposed at test fence installations as above; periodic ratings covering paint performance on twelve distictive surface features of the KTA panels as to blistering, checking, discoloration, erosion, fading, chalking, cracking, filiform corrosion, mildew, peeling, flaking, and rusting. The routine initiation/termination data are also included.

TABLE 2. DATA FILES OF THE PAINT EVALUATION PROGRAM (Continued)

File Name	Description of Data Stored
Field Structure	Performance data of coatings on steel structures such as bridges, tanks, culverts, and guardrails. The structure or sections of it are treated as large KTA panels in terms of features and gradings of performance. Provision is made to detail the the location and environment (humidity, temperature range, etc.) as well as a detailed description of the coating system, surface preparation, film thickness values, etc.
Dielectric Properties	Data on the dielectric constant (capacitance) of a coating as a function of immersion time in water. Initiation/termination data also included.
Electrical Polarization	Data from electrochemical measurements of anodic current, cathodic current, and corrosion current as a function of time for painted panels with bare metal exposed through a scribe line.

iently and simply recall all the data for a project.

The "Constituent" file is a raw material file. The data therein is the density, weight, per cent concentration of solids, the density of the solid material, batch or lot number, cost, coding to classify the material, manufacturer, and trade name. The data is used in conjunction with the "Paint Data" file in calculating formulas and properties such as pigment volume concentration (PVC). The code system is based on a combination of two letters to identify generically the materials commonly used in paints. The major divisions of the materials are pigments, vehicles, additives, and solvents. However, only pigments are identified specifically as such in addition to their generic type. This was done as an aid to the calculation of PVC. For example, rutile titanium dioxide is coded TR (generic type) with the additional designation P for pigment; a vehicle, such as an epoxy-polyamide is coded EP without a special designation as belonging to the vehicles class.

The "Paint Data" file has five types of data sets. In two, the paint formula is listed in terms of the weight per cent of each component or constituent or, in cases where the formula is not known, a generic description of the major components is given using the same codes used in the "Constituent" file. The generic description is to include the major pigment and major vehicle. Classification of a paint is extended to include function (i.e., primer, intermediate or tie coat, finish coat, etc.) and type of solvent or carrier used.

Two record formats in this file are used to document several characteristics of the paint: fineness of grind, viscosity, density, dry times, pigment volume concentration, weight solids, volume solids, wet and dry opacity, a wetting index, application ratings, pencil hardness, storage stability, gloss values at different angles over different substrates, tristimulus values over white and black backgrounds, and Munsell color. Each paint is also given a name composed of the manufacturer, trade name, function, and major pigment(s) and vehicle(s).

The remaining ten files contain the performance data or ratings from a set of laboratory and field exposures representative of tests used to develop protective coatings. In addition, each file contains information (initiation data) describing the material, film thicknesses, substrate, surface preparation, sample conditioning, test start dates, and any special test conditions. Provision is also made to allow reference to laboratory notebook entries (i.e., original source of the data). The initiation data format is common to all the performance files (see Table 3) while the termination data format is common to the field test files ("Flat Panel," "KTA Panel," and "Field Structure") and unique to the rest. The termination data for the field exposure tests are the termination date, disposition action (repaint and re-expose, store, or discard), and a new panel number if reused.

The performance data recorded for each test has been briefly indicated in Table 2. For each of the files listed there, the format for acquired data is centered upon the standard 80 column IBM card. Detailed description of each file's format and content is given in the Paint Evaluation Program Manual (6).

For all the files, alphanumeric codes are used for input to the system. The original data entry mode was transcription form notebooks onto standard 80 column data sheets from which cards were keypunched. Hence, the PEP system is operated in a batch mode although future plans recognized and anticipated the use of remote terminals for on-line operation or interactive

TABLE 3. INITIATION DATA FORMAT FOR PERFORMANCE DATA FILES OF PEP

Field or Column Position*	Information Entered
01-02	File number
03-06	Panel number (serially assigned)
07	Identifier for initiation or termination data record
08-11	Previous panel number if applicable
12-13	Test condition (standardized condition for each test: coded)
14-15	Substrate (material and surface condition before surface preparation)
16-19	Surface preparation (22 standard methods; coded)
20-23	Paint number of first coat of paint (same number as in "Paint Data" file)
24	Application method
25-54	Same format as for field positions 20-24 for each successive coat up to seven coats.
55-57	Film thickness (specified)
58-60	Film thickness (actual)
61-66	Test or exposure start date: day, month, year
67-70	Exposure rack number and rack position number (field tests only)
71-73	KTA panel number (last three digits only; number supplied by KTA, Associates) or square feet painted if a field structure
74-76	Notebook reference = page number with original data.

* Designed for standard 80 column IBM card.

mode. The storage medium for the data was magnetic tape.

The data processing aspects of the initial PEP system have also been described by Tooke (7). The programs or routines involved are listed in Table 4. From the brief, functional description given, it can be seen that the routines fall into a few general categories. First, the permanent recording or creation of the data base (CREATE, UPDATE, FILE-ADDITION, and DELETE-2), proofreading the data base (CLEAN-UP and SHAPEUP), retrieval of data (LISTING, COMPARE, SERIALIZE, and DUMPTAPE), and data reduction and analysis (CURRENT AWARENESS). These functions are fundamental to the design of a data base.

The routine CURRENT AWARENESS is labelled as an analysis routine since it takes the recorded "raw" data and transforms it ("operates on it") into "new" data before outputting it. Based on various performance ratings of exposed panels, a paint is given an integrity value and an appearance value. Integrity is operationally defined as the lowest rating observed at a given inspection time for either rusting, blistering, cracking, flaking, or erosion. Appearance is defined as the lowest rating from among the attributes integrity, discoloration, fading, chalking, and mildew. CURRENT AWARENESS calculates integrity and appearance values and outputs the results.

Other programs were added to the PEP system subsequent to the initial reporting (8). These programs are listed in Table 5. The analysis routines there applied the integrity and appearance gradings to the sets of performance data gathered in laboratory testing. These reduced data then were used to examine and test a generalized paint weathering theory by curve fitting integrity-time data to an exponential or "S" shaped curve (8).

2.1.2. PANELS - Naval Ship R & D Center (U. S. Navy)

A computer program to aid in the evaluation of antifouling paints and other materials was developed by Appleman (9,10). It was written to store and retrieve fouling ratings for commercial and developmental products exposed at two sites used by the Navy.

The information recorded for each panel exposed is separated into two categories. In the first, constituting the panel parameter descriptors, the information is a unique identification number (four digit), exposure date, test series number, exposure location (usually either Miami or Pearl Harbor), substrate (e.g. steel, aluminum, fiberglass, rubber, etc.), generic characterization of the antifouling paint system by generic type and trade name or specification number, manufacturer, color, toxic or antifouling agent (e.g. cuprous oxide), and comments. Numerical coding is used on the parameter card (standard 80 column) using integers from 1 to N where N is the number of choices for a given descriptor. The decoding information is contained in Data Statements in the source program. For example, the integer 3 in the manufacturer field stands for DTNSRDC (David W. Taylor Naval Ship Research and Development Center), indicating that the paint was formulated there. The literal equivalent of the coded information appears in the printed output.

The second category is the fouling data. The fouling data or rating itself is composed of two types: barnacle fouling and total fouling. Total fouling includes non-barnacle fouling and film defects such as blisters, peeling, and/or checking. Ratings for each type of fouling observed on the front and back of a panel can be entered for an exposure time increment of a month or multiples thereof. The ratings are based on judgment of the percent area fouled. Four data cards are used per

TABLE 4. DATA PROCESSING ROUTINES OF PEP

Routine Name	Function
CREATE	Takes card file input, sorts based on file number, panel number, and form number, and writes sorted file on magnetic tape.
UPDATE	Adds or deletes records from master data tape from card input.
CLEANUP	Checks for and eliminates redundant records, checks for initiation record for each observation record, and calculates and records exposure time in months.
SHAPEUP	A program to check internal consistency of recorded information, e.g. panel number assigned to no more than one set and dates in format of day, month, year are not out of the range of acceptable values. Problem records are listed but not changed by the routine.
LISTING	Tabulation of the constituents and paint data files with labels.
CURRENT AWARENESS	Periodic summaries of the performance of selected panels in exposure tests with data reduction to integrity rating and appearance rating.
COMPARE	Retrieves data records from the master tape that match entries on an input card(s); card images outputted.
FILE-ADDITION	Addition of data to data tape.
DELETE-2	Deletes records matching input card images.
SERIALIZE	Orders test initiation records selected from the master data tape according to either paint system numbers, test fence locations, or panel numbers.
DUMPTAPE	Writes card images from master data tape onto line printer; maximum of 80 characters per line, one record per line.

TABLE 5. ADDITIONAL ROUTINES IN THE PEP SYSTEM

Program Name	Program Type	Function
FILE-SETUP	Data retrieval	Selected data from master tape and prepares file for analysis by other routines
SYSTEM	Data retrieval	Tabulation of paint names or paint system used on a panel or set of panels, identified.
FORMULA	Data retieval	Tabulation of constituents in a paint or paints specified.
CORRECT-IT	Data check or proofreading	Correction of erroneous entries in files set-up by other routines.
ALPH/SORT	Data retrieval	Preparation of sub-file used by FORMULA.
WATER	Data analysis	Operates on water immersion test data.
ACCEL	Data analysis	Operates on accelerated weathering data.
POLAR	Data analysis	Calculates and records corrosion current from anodic and cathodic current data from File 14 Electrical Polarization.
DIELTEMP	Data analysis	Calculates and records three capacitance index values based on the interpolation of capacitance-time data in File 13; plot capability included.
MULTIPAN TIME/GRADE	Data analysis	Prepares integrity-time output plot and curve fitting parameters.
REDUCE-FILE 9	Data analysis	Reduces data from environmental chamber testing with plotting option.
LEGEND	Data analysis	Reduces data from environmental chamber testing and field test of panels with plotting options.
CHECKREC	Data retrieval	Display records per user request.
COPY-DATA	Data retrieval	Generates random access file.
EDIT	Data proofreading	Correction of records in random access file.

panel on which up to six years of exposure data can be recorded. Seventy-two columns of the standard 80 column card are set aside for the performance ratings, with the remaining columns used to identify the side of the panel rated, fouling type, and the panel identification number. Hence, there are five cards per panel. Once entered, the record for each panel (parameters and exposure results) are stored on magnetic tape.

The program is written to enable new fouling data to be added to an existing panel record and to add new panels to the system. New cards and/or update cards simply follow an appropriate control card for the desired task.

The basic output from PANELS is a set of four graphs (line printer generated) showing a time profile of the per cent area failing: one graph for each side of a panel for each type of fouling failure. The information stored on the parameter card (identification card) is also printed in decoded representation to serve as a legend for the graphs.

Records of interest can also be selectively retrieved from the data bank based on items listed on the parameter card of a panel. Up to five parameters can be specified as a search profile of interest. Hence, one could retrieve all panel records for a given antifouling paint or toxic agent or both. In operation, the search parameters are listed on a control card. The output retrieved can be displayed and any of the following summary descriptions of the set of panels selected: (1) a plot of the percentage of panels maintaining a certain rating versus time, (2) an average fouling performance, and (3) a summary table giving (per panel) the exposure time, last fouling rating recorded, and the exposure time at which fouling was first noted.

2.1.3 Storage/Retrieval Program for Exterior Exposure of Coatings - Union Carbide Corporation.

The Union Carbide Corporation (Chemicals and Plastics, Research and Development Department, South Charleston, West Virginia) has developed a program to store and retrieve performance data for trade sales type paints on exterior exposure. The program can be described in terms of three major data categories: paint formulation data, initial test fence data, and exposure test fence data. These files can be updated and searched. Currently, the system operates in batch mode with the data stored on magnetic tape. The language is PL/1 with some FORTRAN in subroutines.

The paint formulation data describes the material under investigation and follows the usual practice of separating a formula into pigment dispersion and let down steps. The items recorded are given in Table 6. The data is transcribed from laboratory notebooks onto a standard form in which entries are made in boxes corresponding to a 80 column data card. Up to nine cards are used to describe the paint from which four cards are used for the pigment dispersion formula (up to twenty-four ingredients), three cards are used to document the let down formula (up to 18 ingredients), one card records physical properties and remarks, and one card is used to give a general or condensed description of the paint. A copy of the paint formulation form appears in Figure 1 (11). The data entered on the sheet is subsequently keypunched onto cards. Numerical codes are used to identify or specify ingredients (internal system).

The data recorded when a coated test panel is placed on exposure is a series number, panel number, test start date, substrate identification code, prime coat code, paint code for two subsequent coats (if applicable), coverage or spread rate in square feet per gallon, type test code, test site code, elevation code for

TABLE 6. FORMULATION ITEMS RECORDED IN UCC STORAGE/RETRIEVAL PROGRAM FOR TRADE SALES PAINT

Paint Formulation Data	Card Number	Column Number
Paint Code Number	1	1-5
Notebook Number	1	7-16
Formulation Number	1	18-23
Paint Type	1	24-25
Commercial Paint Identification	1	27-46
Latex Code Number	1	48-51
Number of Pigment Dispersion Ingredients	1	53-54
Number of Let Down Ingredients	1	56-57
PVC (%)	1	59-61
Level of Alkyd Modification (%)	1	63-65
Total Solids (%, weight)	1	67-69
Total Solids (%, volume)	1	71-73
Pigment Dispersion Ingredients (material and amount)	2-5	12 per ingredient: 4 for material, 5 for
Let Down Ingredients (Material and amount)	6-8	weight, and 3 for vol.
Stormer Viscosity	9	1-4
pH		5-7
Brushometer Viscosity		8-12
Brookfield Viscosity	9	13-18
Remarks	9	21-79

NOTE: ↓ = IMPLIED DECIMAL POINT

DATA SHEETS

PAINT FORMULATION FORM

NOTE SEPARATION

PAINT FORMULATION CODE # (1–5)	NOTEBOOK # (7–16)	FORMULATION # (18–22)	PAINT TYPE (24)	COMMERCIAL PAINT INFORMATION (27–46)	LATEX CODE # (48–51)	# OF PIGMENT DISPERSION INGREDIENTS ENTERED (53)	# OF LET DOWN INGREDIENTS ENTERED (56)	%PVC (59)	% ALKYD (63)	% WT. (67)	% VOL. (71)	80
02191	23CWG107		01		3308	10	09	408		571	409	A

PIGMENT DISPERSION

INGREDIENT	CODE #	POUNDS	GALLONS	80
# 1	5502	14100	169	B
# 2	5528	300	03	B
# 3	1004	1400	15	B
# 4	1601	300	03	B
# 5	2002	200	03	B
# 6	3651	2500	27	B
# 7	4401	1200	13	C
# 8	2522	900	09	C
# 9	8	17000	51	C
# 10	553	25400	112	C
# 11				C
# 12				C
# 13				D
# 14				D
# 15				D
# 16				D
# 17				D
# 18				D
# 19				E
# 20				E
# 21				E
# 22				E
# 23				E
# 24				E

LET DOWN

INGREDIENT	CODE #	POUNDS	GALLONS	80
# 1	1601	300	03	F
# 2	6244	45000	238	F
# 3	5502	0000	00	F
# 4	2002	400	06	F
# 5	5652	3500	42	F
# 6	1555	160	02	F
# 7	5531	1740	21	G
# 8	5676	320	03	G
# 9	4510	1840	15	G
# 10				G
# 11				G
# 12				G
# 13				H
# 14				H
# 15				H
# 16				H
# 17				H
# 18				H

(KU) (1)	pH (5)	BRUSHOMETER (POISE) (8)	BROOKFIELD VISCOSITY (CPS) (13–18)	COMMENTS (21–79)	80
1100	88			23 CWG 107-11A	I

FIGURE 1. PAINT FORMULATION DATA SHEETS FOR UCC STORAGE/RETRIEVAL SYSTEM (9).

panel (e.g. 45^{o}), azimuth code (e.g. south), code for air pollution character of environment, total film thickness, previous series and panel number (applies if recycled panels), latex code, paint type code, and comments. This information is entered on a 80 column data sheet which is used to direct keypunching.

The performance attributes monitored during the exposure duration are keyed to trade sales or consumer paints. They are listed in Table 7. ASTM methods and scales are used in assigning values of 0-10 as appropriate. Again, the data is entered on forms corresponding to an 80 column card, one card per panel section. Other information entered on the form is series number, panel number and section, observation date, rating period (six months, one year, two years,..., nine years), and initial gloss for 20 and 60 degrees with provision for comments (30 columns). As with the other data forms, items are transcribed from notebooks onto the data sheets in preparation for keypunching.

Updates and corrections to either the initial test fence data file or the performance data file are handled in batch mode with update or correction cards loaded with job control cards. This same general procedure is used to operate on the paint formulation file.

Information is retrieved from the files by specifying by code or number the item or items of interest on a card(s) (keypunched) submitted with appropriate job control or procedure cards. The paint formulation file can be searched by latex type, latex type and paint type, one to five ingredients alone or in combination with latex type or latex type and paint type, and by paint formulation codes. Special retrieval forms (80 column format with appropriate headings) are used. The procedure for searching the test fence data file is similar, i.e., it uses a customized form for keypunching instructions and operates in a batch mode. The test series number is specified as the search key with the option of also getting information on exposure angle, azimuth, type paint, primer, latex type, and formulation number and/or ratings for each panel section. A commercial routine is used to obtain printout in tabular or graphic form, especially for reports. In addition, analysis is done to check for statistically significant difference in performance complementing the use of factorial design experiments. The program, then, is used as a product development tool.

The system has been in operation since 1974 but data from 1969 is stored. A centralized, large computer facility is used for running the program but the system may be used on a smaller machine (e.g. DEC PDP 11/20).

2.1.4 Rust-Oleum Corporation

The Rust-Oleum Corporation has also developed a computer program to store and retrieve exposure data from test panels as part of the technical service function. The language used is PL/1. The data recorded follow the 80 column data card format. Fourteen cards are used to describe the exposure history of a panel. It is anticipated that the scope of the program will be increased to include laboratory testing such as accelerated weathering and salt fog resistance in addition to analysis routines. An effort is also being made to get old performance records onto the system.

The data recorded per panel can be grouped into materials identification, test location or environment, and performance property ratings. The specific items for these three broad categories are shown in Table 8 (12). Several of the properties listed there, such as color change and rusting, are given more than one descriptive rating based on standards adopted by the testing company. For example, color change is described qualitatively as none, fading, darkening, graying, yellowing, whitening,

TABLE 7. ATTRIBUTES MONITORED DURING TEST FENCE EXPOSURE - UCC

Appearance Attributes	Physical Atrributes
General Appearance	Erosion
Dirt Pick-up and Retention	Checking
Mildew	Cracking
Fading	Flaking
Discoloration	Blistering
Sheen	20° Gloss
Chalking	60° Gloss

TABLE 8. CATALOGUE OF DATA RECORDED IN RUST-OLEUM STORAGE/RETRIEVAL SYSTEM

Materials Identification	Test Equipment	Performance Properties
Product Number - n*	Testing Company (e.g. Sub-Tropical Testing Service) - L	Chalking - c
Run (Batch) Number - n	Exposure Type - L	Gloss - n & L
Laboratory Reference Number - n	Exposure Type - L	Color change - c
Topcoat Layers - n	Exposure Location - L	Dirt Pickup - c
Thickness (each coat) - n	Exposure Dates - n	Checking - c
Color - L	Exposure Duration - n	Blisters - c
Finish Type (gloss grade) - L	Total Sunlight Dose - n	Adhesion - c
Resin Type (generic) - L & c		Rusting - c
Project Number - n		Remarks - L
Application Method - L		
Substrate - c		

* Letter following entry indicates how data is recorded on coding sheets; n ≡ numerical, L ≡ literal or alphabetical, and c ≡ coded (usually numerical).

or bleaching and semi-quantitatively in terms of the ordered sequence none, trace, very slight, slight,..., very bad, i.e. an assessment of the degree of a noted color change. A numerical code is used for several of these with 10 indicating no change and 0 indicating "very bad." An illustration of code sheet entries is given in Figure 2 while Figures 3 and 4 represent the corresponding printed output. Data, such as the gloss versus exposure time presented in tabular form (Figure 4), can also be graphically displayed using the line printer (see Figure 5).

The performance ratings collected during the exposure period can be recorded on a monthly basis for a maximum of thirty-six months. The computer generated report then provides a tabulation of the ratings for gloss (60°), gloss retention (per cent retained), degree of chalking, color change, mildew resistance, dirt pick-up, checking, blistering, rusting, adhesion, and remarks. Gloss and gloss retention are also plotted as a function of exposure time as a routine part of the report.

2.1.5 NACE Technical Committee T-6H-15

The National Association of Corrosion Engineers (NACE) Technical Committee T-6H-15, whose interests are in coating materials for atmospheric service, has had a project since 1968 to study the effects of surface preparation on the service life of coatings. The major independent variables in this study are given in Table 9. Film thickness data is documented for each panel but film thickness was not included as an independent variable in the experimental design. The coated panels, 445 total distributed over the exposure sites, are periodically rated for depth of rust penetration from panel edges, amount of rusting along the perimeter, extent of undercutting at a scribe, overall rusting, and localized rusting. Since 1973, a computerized storage, retrieval, and analysis system has been used to process the collected data and as an aid to report generation (13). The rating systems or standards for these performance attributes are described in Table 10.

The analysis of the performance data is done to determine if differences observed between samples are statistically significant or not using the "Student's t" test (14,15). In addition, several descriptive statistical parameters are also calculated and reported by the processing system: number of panels, range in ratings observed, average rating, sample standard deviation, standard error of the mean, and lower and upper limits of the 90 per cent confidence band for the property average.

The output is tabular in form, one table for each performance attribute rated. Within each table the items reported are the descriptive statistics cited above, a matrix of significant difference codes (0 denotes no statistically significant difference and + or - denotes a significant difference) for the samples compared, a ranking based on the average performance of each sample for the attribute of interest and the number of failures observed in each sample. The samples compared are grouped or collected according to the three independent factors surface preparation, coating material, and exposure location. The statistical tests are performed between all possible sample pairs within one of these categories. For example, the significance of differences observed in overall rusting is determined for surface preparation types (sample for a particular surface preparation includes all coating systems and all test environments), for coating systems (sample for a system includes all surface preparations and exposure sites), and for test location (samples for each location include all surface preparations and all coating materials). The output format is shown in Figure 6.

Card 1

659A0 762202-662741082FLØRIDA TEST FENCE 45 DEG SØUTHSUB TRØPICAL

Card 2

1207/01/76 TØ 07101/77INLAND 125623 4 0 0 010000001500YELLØW

Card 3

GLØSS ALKYD 00000000000 SPRAY

Card 4

4544404239413835313121521

Card 5

NØNE NØNE NØNERUST-ØLEUMTS-01-76073

FIGURE 2. CODE SHEET ENTRIES IN RUST-OLEUM SYSTEM

RUST-OLEUM CORPORATION
TECHNICAL SERVICE DEPARTMENT

YONEFLA

TESTING COMPANY = SUB TROPICAL	EXPOSURE TYPE = FLORIDA TEST FENCE	POSITION = 45 DEG SOUTH
LOCATION = INLAND	APPLICATION METHOD = SPRAY	LANGLEYS OF RADIATION = 125623
BATCH NUMBER = 762202-66	LAB REFERENCE NUMBER = L741082	SUBSTRATE = ALUMINUM
FIRST PRIMER = NONE	SECOND PRIMER = NONE	THRID PRIMER = NONE
PRIMER #1 BATCH NO. = NONE	PRIMER #2 BATCH NO. = NONE	PRIMER #3 BATCH NO. = NONE
TOPCOAT #1= 659A (MILS= 1.5)		TOPCOAT #2= NONE
RESIN TYPE= ALKYD	COLOR= YELLOW	FINISH= GLOSS

****

********* REPORT PREPARED BY STEVE D. OZENICH *****************

659A 659A 659A

****

THIS REPORT CONTAINS DATA ON GLOSS, GLOSS RETENTION, CHALKING, LOSS OF ADHESION, MILDEW, COLOR CHANGE, BLISTERING, CHECKING OR CRACKING, AND RUSTING (IF TOPCOAT WAS EXPOSED ON A FERROUS SUBSTRATE) FOR 659A 762202-66 WHICH WAS EXPOSED BY SUB TROPICAL AT 45 DEG SOUTH EXPOSURE AT THE LOCATION STATED ABOVE.

KEY TO ALL INFORMATION:

TERM=	NONE	TRACE	VERY SLIGHT	SLIGHT	DEFINITE	MEDIUM	BAD	VERY BAD
NUMERICAL DESIGNATION=	10	9	8	7	6	4	2	0

FIGURE 3. SAMPLE OUTPUT FROM RUST-OLEUM SYSTEM

RUST-OLEUM CORPORATION
TECHNICAL SERVICE DEPARTMENT
GLOSS AND CHALKING DATA

YONEFLA
TEST FENCE EXPOSURE

PRODUCT NUMBER= 659A   BATCH NUMBER= 762202-66

MONTHS EXPOSED	60 DEG GLOSS	% GLOSS RETENTION	DEGREE OF CHALKING
0	73	100.0	NONE
1	45	61.6	NONE
2	44	60.3	NONE
3	40	54.8	NONE
4	42	57.5	NONE
5	39	53.4	NONE
6	41	56.2	NONE
7	38	52.1	NONE
8	35	47.9	NONE
9	31	42.5	NONE
10	31	42.5	NONE
11	25	34.2	NONE
12	21	28.8	NONE

THE AVERAGE GLOSS FOR 12 MONTHS EXPOSURE= 38.8

FIGURE 4. TABULAR PRESENTATION OF DATA IN RUST-OLEUM SYSTEM.

RUST-OLEUM CORPORATION
TECHNICAL SERVICE DEPARTMENT
60 DEGREE GLOSS VS. TIME-- 659A BATCH #= 762202-66
σ= CHALKING

YONEFLA
TEST FENCE EXPOSURE

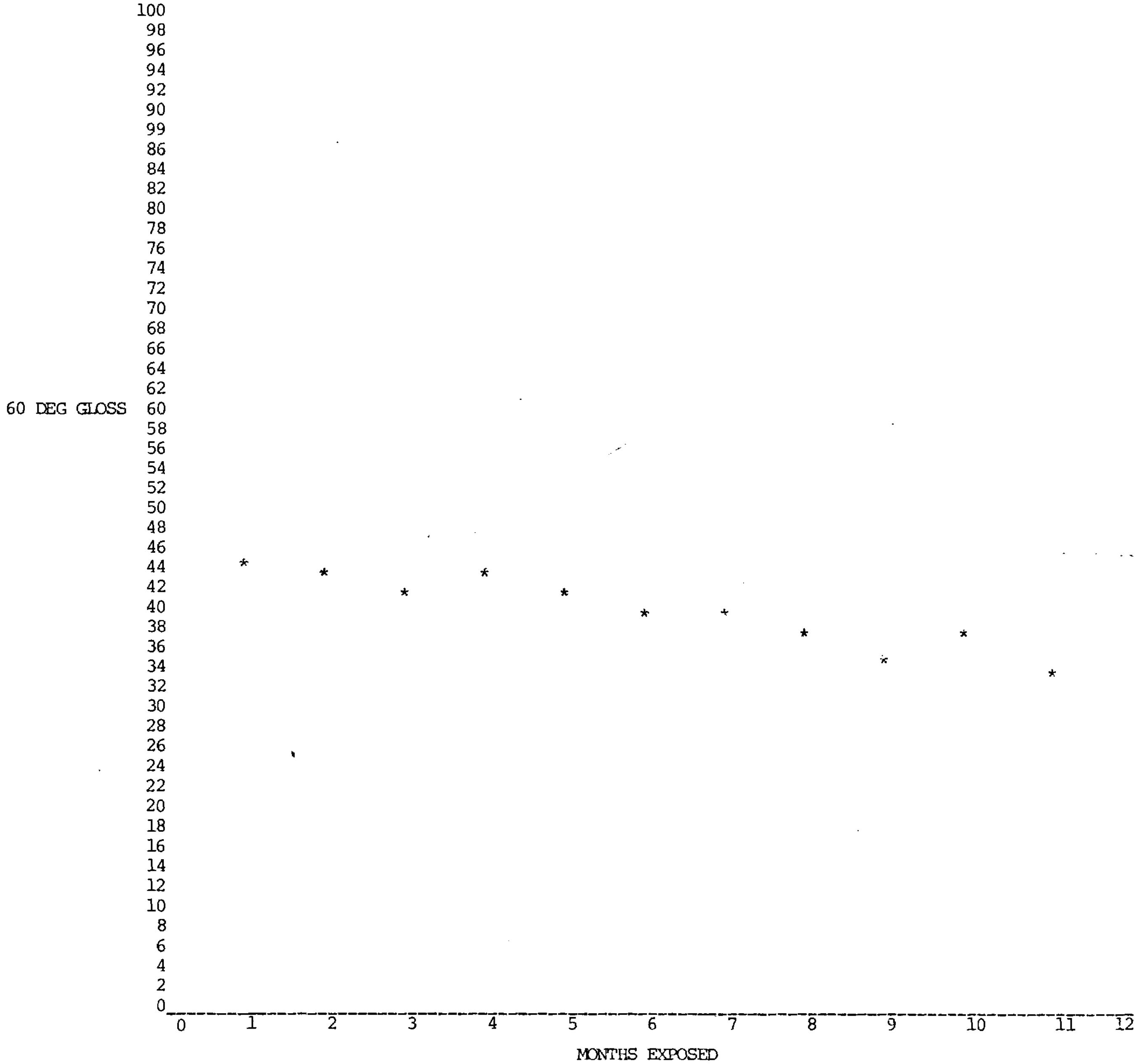

FIGURE 5. GRAPHICAL PRESENTATION OF DATA IN RUST-OLEUM SYSTEM.

TABLE 9. VARIABLES INCLUDED IN NACE TECHNICAL COMMITTEE T-6H-15 STUDY ON SURFACE PREPARATION EFFECTS ON COATINGS PERFORMANCE

Exposure Environment	Surface Preparation	Coating Material
1. Kure Beach, NC (coastal)	1. Solvent clean/intact mill scale	1. Vinyl (3 coats)
2. ARCO Refinery (Philadelphia, PA; industrial - urban	2. Pickling plus phosphitizing	2. Epoxy-polyamide (3 coats)
3. DOW Chemical (Freeport, TX; coastal-industrial)	3. NACE #4 Brush-off Blast	3. Chlorinated Rubber (3 coats)
4. Ameron (Brea, CA; inland-urban)	4. NACE #3 Commercial Blast	4. Inorganic Zinc-Rich Primer (post-cured) + Epoxy - polyamide finish coat
5. PPG, Industries (Barberton, OH; urban-industrial)	5. NACE #2 Near -White Blast	5. Inorganic Zinc-rich Primer (self-cure) + Epoxy - polyamide finish coat
6. Monsanto (St. Louis, MO; urban-industrial)	6. NACE #1 White Metal Blast	
7. Carboline (St. Louis, MO; urban-industrial)	7. NACE #1 Rotary Wheel Blast with Steel Grit	
	8. NACE #1 Rotary Wheel Blast with Steel Shot	

TABLE 10. RATING SYSTEMS ADOPTED BY NACE TECHNICAL COMMITTEE T-6H-15

Attribute	Measurement Standards
Overall Rusting	ASTM D-610* ratings of 6 to 10 transformed to scale of 0 to 100.
Local Rusting	ASTM D-610 ratings of 6 to 10 transformed to scale of 0 to 100.
Perimeter Rusting	Length of perimeter rusted in inches; 100 = no rust; 0 = 36 inches rusted.
Edge Rusting	Depth of rust penetration into panel face from edge in inches; maximum penetration and penetration averaged over the perimeter reported.
Undercutting	Average of maximum undercutting at the scribe and the average extent of scribe undercutting in units of 1/32 inch; scaled to 100 = no undercutting and 0 = 32 (i.e., one inch overall average).

* ASTM D-610 Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces is defined in terms of per cent area rusted such that a grade of 6 corresponds to 2 per cent and a grade of 10 corresponds to .01 per cent or less.

TABLE NO.

Composite Statistical Summary

Performance Attribute

Failures	Rank	Code	Treatment	Range Min	Range Max	N	X	S	x	90% Band Low	90% Band High	Sig Diff Frm Codes 1	2	3	4	5	6	7	8
			Total Sample																
			Ex Loc 2																
			Surf Preps																
		1	None																
		2	Pkl/Phos																
		3	NACE 4 Sbl																
		4	NACE 3 Sbl																
		5	NACE 2 Sbl																
		6	NACE 1 Sbl																
		7	NACE 1 Whgb																
		8	NACE 1 Whsb																

FIGURE 6. SAMPLE OUTPUT TABULAR FORMAT OF NACE T-6H-15.

2.1.6 Paints and Coatings Performance System (PCP) - Maritime Administration/Avondale Shipyards, Inc./Offshore Power Systems

The Paints and Coatings Performance System (PCP) is a storage and retrieval program for case history data of coating materials used on commercial ships (16). It was developed under the National Shipbuilding Research Program of the Maritime Administration as one facet of the program's overall goals of enhancement of ship manufacturing technology and reduction of ship production costs. The computer program was developed as a tool to generate and utilize a large data base so that materials selection, at least by generic identification, could be made on a statistically sound basis, increasing the reliability of the specification process. As such, it can be useful to design engineers, naval architects, ship owners, and ship operators. The need for such capability had been defined by the Ship Production Committee of the Society of Naval Architects and Marine Engineers (SNAME).

The data collected through a questionnaire for inclusion in the data base is based on the type of information normally documented in ship surveys and docking reports. The items recorded or requested in the Ships Paints/ Coatings Performance Service History Questionnaire are given in Table 11. The sum of these items then identify the material, the amount of the material, the environment both general (trade route and type of ship) and specific (ship area), nature of the substrate (surface preparation), and a description of performance.

At this time the PCP system is designed to provide basic manipulation of service history data. The input to the system is on punched cards carrying information transcribed from the service history questionnaire. The initial data base is composed of 1,072 case histories. The output is a listing of the input data decoded, formatted, and labelled. Four types of output reports are possible with sorting by ship name, by ship type, by trade route, or by area/coating system.

Analysis of the data is to provide a statistically sound judgement if performance differences exists among various generic paints. It is felt, however, that an insufficient number of case histories have been collected to draw statistically valid conclusions (17). Future plans then include expansion of the data base and addition of analysis routines such as correlation and regression analysis, tests of significance, and life cycle cost calculations.

2.1.7 Dataplan - International Paint Company, Inc.

International Dataplan is the name of the computerized data base of on-ship performance records of International Paint Company's products (18). It served as a model for the system developed by Offshore Power Systems in conjunction with Avondale Shipyards, Inc. discussed above. International Dataplan was put into full operation in 1977. After two years of operation, it contained over 4000 performance reports.

The data stored in the system is collected in the course of dry dock inspections of a ship. International Paint uses its own people to inspect their coatings so that, worldwide and over a long time period, uniform standards in performance ratings are used, strengthening the statistical validity of subsequent analyses.

In general, the data collected from an inspection are (1) ship identification (name, owner, weight, etc.), (2) dry dock location, inspectors, and use history since the previous drydocking, (3) identification and description of the condition of the coatings, and (4) a description of maintenance or remedial actions including surface preparation, coatings materials, thickness of each coating layer, and

TABLE 11. DATA ITEMS REQUESTED ON THE SHIPS PAINTS/COATINGS PERFORMANCE-SERVICE HISTORY QUESTIONNAIRE.

1. Optional Information: Ship Owner, Ship's Name, Ship Builder
2. Type of Ship: (8 types, coded) Tanker, Dry Cargo, Fishing, Obo, Container, Ferry, RO-RO, and Reefer.
3. Trade Route: (7 types, coded) S. Pacific, W. Indies, N. Atlantic, S. Atlantic, N. Pacific, Caribbean, and Mediterranean.
4. Ship Area: (9 types, coded) underwater bottom, boottop, freeboard, exterior decks, exterior super structure, cargo holds and spaces, product tanks, ballast tanks, and machinery spaces.
5. Surface Preparation: (SSPC standards, coded) SSPC - SP-1, -3, -5, -6, and -10.
6. Coating System: Primer (generic type and thickness) and up to 5 subsequent coats (generic type and thickness); 54 generic types coded; listed for each ship area.
7. Age: Years in service to nearest tenth of a year.
8. Performance: Rating for per cent area failed by corrosion, per cent area failed through other film defects (e.g. blisters or peeling), and an assessment of general appearance (unsatisfactory, poor, fair, good, excellent). The per cent area values are discretized to 0, 1, 5, 10, 15, 25, 50, 75, 90, and 100 per cent. For areas subject to fouling (underwater bottom and boottop), a rating for per cent area fouled is also used with an identification of the type of fouling (grass, shell, slime, or combination).

application conditions.

Retrieval of data has the usual capabilities in selecting cases that conform to a user's interest. The searches are directed at two basic performance categories aboard a ship; namely, antifouling performance and resistance to corrosion and film defects such as blisters, cracking, and loss of adhesion. Analysis is done in terms of the fraction of cases meeting a search profile that have a satisfactory performance rating. The criteria defining satisfactory are flexible and adaptable to a user's standards. Hence, in principle and with a large data base, products can be assigned a probability of giving acceptable performance in specific end-use areas. This type of information can be used in making cost-performance assessments.

2.1.8 Other Systems

Information less detailed than above was obtained for computerized storage and retrieval systems used by Rohm and Haas Company, PPG Industries, Inc., and Glidden Coatings and Resins.

The system at Rohm and Haas is expected to be similar to the one developed by Union Carbide since the product market is the same. Hence, the exposure data collected will be the same, i.e., gloss, blisters, cracking, peeling, fading, etc. Although the use of the system is primarily directed at the trade sales area, evaluation of developmental products on metal substrates is within the scope of the program. Reports generated from the data base include presentations in tables and graphs. These reports are useful mainly to Rohm and Haas customers in addition to, of course, in-house use.

The system at PPG Industries is used to store and retrieve exposure panel data from three testing sites used in industrial coatings product development. The items documented include paint composition with polymers described at a monomer composition level, film thickness, substrate, and performance resistance to fading, chalking, rusting, blistering, and gloss degradation. The rating systems are not ASTM but they are on a scale of 0 to 9. The computerized system was instituted to replace manual searching of laboratory notebooks for exposure history data. Implementation of the systems was started in, approximately, January, 1980.

The system at Glidden has been selected to store exposure data from their product line in general, for example, wood coatings and coil coatings. The system is a commercially available one designed to handle files but some modification was required to fit exact needs. Implementation of this system was not expected until March, 1980.

2.2 Storage/Retrieval Systems in Other Fields

A few computerized systems were located through literature searching that were felt to be of interest to this project since they dealt with allied materials (plastic) or dealt with documenting corrosion data from field operations. The systems found are listed in Table 12.

2.2.1 Rigid Foam Evaluation

The program developed for rigid foam evaluation was primarily directed at the computational capabilities of a computer (19). It was designed to take experimental data, calculate property parameters such as density, cell size, compressive strength and modulus, and thermal conductivity, and output the results for inclusion in reports. Sample or material identification, data, and procedure selection are inputted on standard 80 column keypunched cards. Data sheets mimicing the data card, were used as the primary records with columns blocked off and labelled for specific data entry. Besides reporting data and calculated properties in labelled, tabular form, output was also placed on punched cards which served as the storage medium. These cards were later reread if information retrieval and additional analysis were

TABLE 12. STORAGE/RETRIEVAL SYSTEMS IN OTHER FIELDS

System	Data
Plastics	
1. Foam Evaluation	Physical data collected and calculated properties used in developing and evaluating rigid plastic foams (Union Carbide Corporation).
2. Plastic Material Property Data	Various mechanical, electrical, thermal, optical and physical material property values and indices for plastics (Plastics Technical Evaluation Center, U. S. Army Armament Research and Development Command).
3. Polymer Data	Descriptive data and physical property data on commercial polymers (Dow Chemical).
Corrosion	
1. Corrosion Control Record	Location, identification, and status of cathodic protection for gas pipelines from field surveys.
2. Equipment Failures	Identification of equipment failing, type service, type of failure, location of failure, cause, and method of repair for oil well operation.
3. Maintenance History File	Maintenance records on oil well equipment and rigs.
4. Equipment Record	Description of equipment location, type of failure, method of repair, and cost of repair for oil well operations.

required. A similar program was also developed for elastomeric materials evaluation subsequent to the rigid foam program based on benefits gained in man-hours available for development work normally lost to routine, tedious calculations.

2.2.2 Material Property Data System for Plastics.

A computerized data base of properties of plastics used in material selection and engineering design is being developed at the Plastics Technical Evaluation Center, U. S. Army Armament Research and Development Command (20). An existing data management system (commercial) forms the basis of the system (21).

The properties to be included in the data base are grouped as mechanical, thermal, optical, electrical, and permanence. This last group includes properties such as permeability, water absorption, and chemical resistance. Property values are determined by ASTM methods whenever possible. The source of data is to be materials suppliers, the open literature, funded research, and, when necessary, testing specifically to complete the data record for important materials. To this end, data test procedure, environmental condition of the test (e.g. temperature and humidity), identification of the material by generic name, trade name, and supplier, fabrication method, sample conditioning as well as the property value with statistical information. Standardization is emphasized, reinforced, and required through this method.

The output format for data is graphical when possible. A material property will be presented as a function of some appropriate variable in addition to printed information that identifies the material, test method, testing conditions, a schematic of the test set-up, and special remarks. For example, the dielectric constant versus frequency at several different temperatures can be plotted and displayed or tensile stress-strain curves can be shown at different strain rates. Tabular presentation of data is also possible.

The plastic materials data base is to be accessed through remote terminals. The data base management system, written in FORTRAN, has been designed to lead users through a material selection logic sequence if they are unfamiliar with plastics or the system itself. This "question and answer" dialogue between the system and user generates a complete design criteria. This mode can be by-passed by users if desired.

The plastics material data base is to be expanded to include information on films, structural foams, composites, and rubber. A data base or bases for metallic and ceramic materials is also planned. This will result in a comprehensive materials property data base.

2.2.3 Polymer Data

The Dow Chemical Company has developed a proprietary data base for storage and retrieval of polymer data (22). It was designed for use by personnel in technical service, research and development, and marketing.

Data are stored on approximately 1,100 commercial polymers. Two broad types of data are stored for each polymer: descriptive data and property data. The descriptive data is a trade name or chemical name, source reference, chemical fragment codes, composition codes, and a modified Wiswesser line notation. The coding of composition is based on classes of polymers or their monomers and is similar to the plastics nomenclature system of ASTM (23). The property data has three parts: a property code (e.g. US = ultimate tensile strength per ASTM D 638), the property value, and a reference to the original source of the data. Property values determined by ASTM methods are preferred; non-standard values are given special coding.

The retrieval of data is accomplished through on-line, interactive searching. Step-by-step instructions for searching are included in the system design as well as decoding of the abbreviations and reference codes.

There are two basic search options. In the first, one can retrieve all or part of the data for a given polymer or generic class. In the second, polymers matching a set of criteria for chemical structure, composition, and/or property values can be identified. The results of a search are displayed at the user's terminal and can be printed if desired.

2.2.4 Corrosion Control Record - Gas Pipeline

A computerized system of record keeping on the location and status of cathodically protected gas pipeline was developed in response to government regulations requiring such accounting (24).

The input to the system is data obtained during periodic inspections. The data is recorded on a formated record sheet corresponding to one line of a 80 column keypunch card. The information entered is a unique identification for the section of pipe tested, its location, size, installation date, and coating system amongst other descriptors peculiar to this industry. Test results of the electrical survey (voltage, current) as well as the test date are also recorded. If the tests indicate that the level of cathodic protection is below standards, an additional form is completed which indicates what corrective actions are needed. This form also corresponds to a standard keypunch card.

The processing of the inspection records after keypunching takes place in two steps. First, the data is proofread in an edit program which determines if recorded entries conform to prescribed standards such as an entry for each item on the data sheet, proper location of numeric and alphabetic characters, values entered within allowed range, etc. If errors are found, the system rejects the record and reports the errors found. Second, accepted and/or corrected records are entered into the data base through the "Master File Update Program." The data base then constitutes a file of the location of all the structures (pipe sections) in the distribution system and their historical and current status of cathodic protection. The program also establishes the next inspection date for a structure and outputs this information to the appropriate department. A preprinted inspection record is outputted for the next inspection on which only the test data needs to be recorded.

The data base is also used to develop statistics on the size of the distribution system, frequency of repairs, and the frequency of the various types of failures.

2.2.5 Equipment Failures - Getty Oil Company

A computerized data processing system was designed by Getty Oil Company as an aid to corrosion control efforts for oil well operations (25). The system stores and handles information recorded in the field as to what equipment failed, how it failed, the cause of the failure, and the associated cost. A major part in the development of the program was the design of an equipment failure report form. It was designed to provide essential information about an equipment failure in such a form that it could be completed by field personnel. The completed form is used to keypunch cards for computer input.

The equipment failure report corresponds to one line of an 80 column data card. The allowed codes and their corresponding literal equivalents are listed on the form. For each major category of information, such as type of failure, the numerically coded response is circled. The form also carries a notation for the column numbers to be used for each response so that data can be keypunched directly from the field record. Provision is made to record qualifying remarks.

The data is processed in a centralized computer facility. The processing generates summary reports on equipment failures and can analyze the data to describe the distribution of failures as to equipment, location, service, failure type, and service life, for example. This information can then be used to evaluate corrosion control programs, characterize the reliability of equipment, and to anticipate maintenance needs.

2.2.6 Maintenance History File - Standard Oil of California

The Maintenance History File (MHF) was developed by Standard Oil to provide performance and cost information on the equipment used in its oil field operations (26). Most of the effort, at least initially, was placed in the definition of the data needed and design of data reporting forms.

The input to the system is broken down into eight categories corresponding to different machinery types or oil field operations such as pumping units, downhole pumps, and electrical. Again, the forms correspond to the standard keypunch card with data entered into specified fields.

The output capabilities of the processing system were limited to two types of reports. In one, a monthly summary of repair work done and its cost is printed with formatting keyed to the eight work categories used in input. The second report was designed to describe or identify equipment or parts subject to frequent failure and/or high cost repair jobs.

2.2.7 Standard Oil Company of Texas

The computerized system developed at Standard Oil Company of Texas was also done to provide assistance to corrosion engineers (27). The application of electronic methods to store and retrieve failure and maintenance records allows the corrosion engineer to use a large amount of data and experience in planning maintenance and remedial strategy.

The input form to this system is equivalent to one line of an 80 column card. Besides the usual provision for identifying and locating a piece of equipment, the input specifies the type of equipment, protective treatment, service environment, type of failure, location of failure (e.g. gasket or bearing), cause of failure (e.g. abrasion, corrosion, misalignment), repair method, cost (materials, labor, equipment), and comments. The data recording sheet contains a listing of the acceptable responses plus their codes (coding here is alphabetic, usually a three letter abreviation for the word response). The major data categories also are listed with their column positions so that transcription to punch cards can be made directly from the data sheets.

The processing capabilities of this system were not discussed but, at a minimum, the input data can be printed into a summary report so that maintenance information can be concisely and compactly presented for review.

2.3 Motivation and Advantages

The preceeding discussion has concentrated on the mechanical aspects of electronic storage and retrieval of data in the paints and coatings field. In essence, all the systems record the same type of data gathered and used in manual filing systems or laboratory notebooks.

The reasons for converting record keeping to an electronic system are summarized as follows. Each will be discussed and expanded upon separately:

1. Handle large volumes of data.
2. Reduction in man-hours and time to prepare reports.
3. Research and development tool.
4. Marketing and sales resource for technical service and planning.

5. Maintenance Planning and Procurement Aid.

The most fundamental advantage in the application of computer resources to data storage and retrieval is the ability to handle large volumes of data rapidly. The other reasons listed follow from this capability. More important than the shear ability to store large amounts of data is the ability to selectively extract information from a large data base. That is, a given data base can serve many different users by providing them with information peculiar to their interest (if the information is in the data base). The user does not have to search for data since "all" the data is centrally located nor does he have to sort through a mass of data since automated programs will sort through "all" the data and extract that which meets a set of key terms or descriptors that define the user's interest. This ability is, of course, the foundation of computerized literature or bibliographic searching.

Because paints and coatings are an empirical discipline, product development and advancement is accompanied by the generation of a lot of test data. Periodic reports required to monitor progress and provide direction for future work must first assemble the data and organize it into experimental units or other meaningful groupings before analysis can be done. Since the traditional method of data storage has been laboratory notebook entries, the recovery process is tedious and time consuming. For example, one estimate has been made that manual searching and data collection for exposure history reports was taking three man-months. With the computerized storage and retrieval system (Union Carbide Corporation), the equivalent tabulated data can be obtained with a half-day turnaround time. This comparison is also supported by an estimate of four to five man-hours to recover four to five years exposure data for a coating (PPG Industries, Inc.). Hence, the search capabilities of a computerized system provide a great reduction in man-power and time just to locate pertinent data.

Increased time available for analysis of data and experimental planning is a direct result of the efficiency of data retrieval with computerized systems. Of course, analysis of the data extracted can also be aided by application of the computational capabilities of computers to do, for example correlation analysis or even simple descriptive statistics. The researcher is relieved from tedious, repetitious, error prone calculations. The speed and versatility, in this regard, of the computer makes the use of sophisticated analysis more likely. Hence, the researcher can spend more time studying data and interpreting analysis results to derive and nurture insights into material performance relationships and provide direction to futrue work.

The ability to recall specific information about a product's performance on a batch-to-batch basis and <u>in toto</u> represents an opportunity for strengthening marketing and sales functions. Performance information can be expanded beyond the experience and recall of a relatively few people. With a data base such as International Dataplan, one can obtain a truer picture of a product's performance capabilities since all the case histories appropriate to a situation can be used, recalled easily on an as needed basis, and conveniently analyzed. International Paint illustrates this point for the performance of one of their antifouling paints over either of two sealer coats eliminating cases where the vessel had been used in ice, delayed in transit more than twenty-eight days, had the paints applied under non-typical conditions, or had the ship bottom cleaned while in the water (the selection process described was automated (18)). Of the cases meeting the criteria, (number not specified), 84 per cent were rated satisfactory in performance after twelve months of service with 41 per cent showing no fouling. Since the coating system is sold as providing acceptable protection for twelve months, the observed failure rate of approximately 16 per cent may be a concern. However, if sufficient cases exist so that conclusions are statistically valid, the case histories can be broken down further with finer differentiation as to geographical use area (e.g. trade route), application location (shipyard), paint batch, etc. in order to refine product recommendations. Strengths and deficiencies in a product line can be established in this manner. The strengths can be promoted and research and development resources can be directed at resolution of deficiencies. The case history data can be used directly as a marketing and sales tool since substantiated, reliable estimates of performance can be made and tailored recommendations can be made to each customer's individual needs, avoiding "stock" answers which, of necessity, gloss over potentially important details.

Technical service to a product line can also be aided potentially by a well designed data base. The data, in principle at least, can be analyzed to determine which factors are critical in determining and assuring acceptable performance and their relative importance. Hence, given a situation in which performance is not acceptable, a hierarchy of "things most likely to have gone wrong" can be generated and used as a guide to supplement individual experience and intuition.

The capability to define the service life of a product in a particular end use is also of great value to the user. That is, the design engineer or specification writer needs to have or would like to have some rational basis for the item chosen. In addition, with service life values for competitive products, realistic life cycle costs comparisions can be made. A user generated performance data bank would serve such a purpose as emphasized by the Maritime Administration sponsored system (16). A data bank generated by the product users has the additional feature of avoiding or minimizing decisions based on biased data or hand-picked case histories.

Maintenance operations in general also can benefit from a automated storage and retrieval system. This is best demonstrated by the systems designed to monitor equipment failures (24, 25, 26, 27). The collection of equipment failure data and corrective actions will allow one to assign a characteristic maintenance or replacement period to the various units included in the survey. With this information, equipment breakdowns can be anticipated and replacements planned to coincide with scheduled shut downs or slow production, for example, to avoid costly, unexpected downtime. The maintenance records can also be used to establish spare equipment and parts inventories. The information on frequency of replacement or useful life can be used as a reliability index on products and their manufacturers to guide procurement.

2.4 Level of Effort

The amount of man-power and computer time and charges to develop an operating data base is difficult to quantify since the effort involved will depend upon the scope of the data base, the accessibility of the raw data (ease of input), the amount of data per record, the expertise and experience of the programmer, and the computer equipment available. Estimates of the man-power involved in establishing several of the systems discussed in section 2.1 and 2.2 are given in Table 13.

The estimates of the level of effort are not very precise, in general and may reflect more faithfully the duration of the development period. The report on the Maintenance History File (MHF) does however, give a detailed description of the man-power and costs involved (26). Although the level of effort required to develop a system is fairly substantial, perhaps one to one-and a half man-years, it is essentially a one-time investment with a potentially short break even time depending on the manpower required to generate performance history reports or summaries, the number of such reports, and the frequency of reporting.

The MHF system used a general purpose retrieval system that had been developed for other company data processing needs. The pilot study, which covered a three year period and included the definition of the data needed, design of the data sheets, design of output reports, and training personnel, cost $198,000 (1965 dollars) (26). A breakdown of the costs is given in Table 14 including a projection of operating costs. The pilot study collected data from approximately 2,000 wells plus associated equipment on a monthly basis while the full system would monitor about 13,000 to 20,000 wells.

The yearly operating espense is, of course, large and, at first, seemingly prohibitive. However, only a two per cent reduction in annual maintenance costs through the application of MHF was necessary to economically justify its adoption. It was estimated that actual cost reductions could be five to ten per cent.

TABLE 13. MAN-POWER ESTIMATES FOR ESTABLISHING OPERATING STORAGE/RETRIEVAL SYSTEMS

System	
Paint Evaluation Program (Georgia Tech)	Two man-years (paint engineer and programmer) over five years.
Panels (U.S. Navy - Appleman)	Four to five man-months (non-professional programmer).
Exposure Data Storage/Retrieval (UCC)	One and a half man-years (non-professional programmer).
Rust-Oleum Corporation	One to one and a half man-years (non-professional programmer) over three years.
Paints and Coatings Performance (Maritime Administration)	One man-month (professional programmer); excludes data form development.
Maintenance History File (Stnadard Oil Company of California)	Five man-years over three years (pilot study); estimate 2 man-years per year for full scale operation.
Rohm and Haas Company	One and a half man-years.
Plastics Material Property Data (U.S. Army)	One-half man-year (adapted existing data management system).

TABLE 14. MAINTENANCE HISTORY FILE SET-UP AND OPERATING COSTS (26).

Set-up Costs:	Man-Power (5 man-years)	$91,000*
	Keypunching	25,400
	Computer Runs	49,600
	Programming	32,000
		$198,000
Yearly Operating Costs (Pilot Program):	Man-Power (2.25 Man-Years)	$34,800
	Input Costs (21,000 cards)	18,000
	Output Costs	12,000
		$64,800
Yearly Operating Costs (Full Scale)	Man-Power (2 Man-years)	$ 36,000
	Input Costs (900,000 cards)	91,200
	Output Costs	14,400
		$141,600

* 1965 dollars

3.0 Performance Data Characterization

The characterization of performance data was done to judge their quality and suitability for incorporation into a computerized data base. This is an essential part in determining the feasibility and desirability of undertaking the establishment of a data bank. The quality and correctness of conclusions stemming from the use and analysis of the data are fundamentally limited by the quality and correctness of the data itself. Performance data needs to be examined for homogeneity, i.e., the use of the same testing methods and evaluation schemes. The degree and extent of the homogeneity directly affects the structure of the data base and the ability to combine performance reports from different sources and draw conclusions therefrom. One also needs to know how much good data there is and its availability. This point affects the immediate incentive for developing the software to manage a data base but not the long term incentive since performance data is continually being generated.

Data was sought from two major sources. One source was considered "non-highway" related which included paint manufacturers, paint raw material suppliers, maintenance paint users, government agencies, and research organizations. The "highway" related sources were governmental departments directly involved with maintenance of highway structural steel. The characterization of data from various sources was done in terms of the number of coating systems, identification of coating systems, amount of replication, duration of tests, performance attributes used and corresponding measurement systems, number of independent variables (e.g. film thickness, surface preparation, etc.), ease of accessibility, and availability.

3.1 Non-Highway Related Data Sources

The non-highway related data sources sampled included the general technical literature in the paints and coatings field, research institutes or organizations such as the Paint Research Association and the Steel Structures Painting Council, maintenance paint users, and coatings manufacturers.

The technical and scientific literature is a traditional source of data so it was included. For this project, the entries in World Surface Coatings Abstracts (WSCA) listed under "Occurrence and Prevention of Deterioration by Weathering, Corrosion, Fouling, etc.," for the period 1974-1979 were scanned for exposure study reports. The citations selected from WSCA were supplemented by exposure studies found in the literature review done for NCHRP 4-14 "Coating Systems for Painting Old and New Structural Steel."

Reports were initially selected based on their title's content with keywords of exposure, performance, durability, bridges, structural steel, etc. Subsequently, they were reviewed to abstract their information on surface preparation (type, specification, substrate), coating systems (number, type, level of description, film thickness) application (method, schedule), exposure type(s), properties rated and corresponding methods or scales, frequency of ratings, and the duration of the exposure.

The reports selected for initial review are listed in the bibliography, but each report is not discussed separately here. A general assessment is given with a few reports highlighted.

3.1.1 Technical Literature

Based on the number of articles selected relative to the number of articles scanned, the open literature is not a concentrated source of performance data. Data can be found which provides some level of information on the major factors influencing performance. However, due to the nature of publishing work in journals, the full specimen-by-specimen detail is not given. This is the level though that one would prefer in a data bank. Data in published articles is often condensed, generalized, summarized, or selected to demonstrate and support a hypothesis.

Shop Primers with Low Toxicity Pigments

Lapasin and coworkers report on the performance of several corrosion inhibiting pigments (28). Nineteen unique coating systems were tested based on various combinations of ten pigments (not all inhibitive) and eight binders. The inhibitive pigments were identified as aluminum powder, zinc molybdate, zinc phosphate, chromic phosphate, and an organic pigment denoted only as an organic nitroderivative. The binders generically were a two package epoxy, a vinyl/phenolic blend, a single package epoxy at four different plasticizer loadings, a blend of phenoxy and phenolic resins, and a phenoxy resin alone. All the materials were identified by source and, where possible, product name. Two of the nineteen coatings were reference or control materials; they used zinc chromate as the inhibitive pigment. Dry film thickness data were not reported for each test specimen but the thickness range was given. Surface preparation was limited to blast cleaning with steel shot to a white metal condition; an upper limit to the profile height was reported but not the measurement system. The test environments were salt fog (ASTM B-117), synthetic seawater immersion, distilled water immersion, and exterior exposure in an industrial/marine atmosphere. The exterior exposure is further defined by specifying climatic data (mean temperature, mean winter temperature, mean summer temperature, mean relative humidity, yearly rainfall, and yearly hours of sunlight) and pollution index data (monthly areal concentration of insolubles, solubles, chloride ion, and sulfate). Mechanical tests for elasticity and adhesion (tape method) were also run on the paints. Overall, no replication was used.

The performance properties evaluated were rust and blister resistance. Rust was graded by ASTM D-610. Blistering was initially graded by ASTM D-714 but the blister sizes were used to calculate a blister density index which algebraically combines the fractional area blistered, blister density, and blister size. The blister grade according to ASTM D-714 cannot be determined from this blister density index alone.

The duration of the salt fog exposure was 300 hours. For the distilled water immersion, the exposure period was 120 days while the sea water exposure was up to 50 days. Exterior exposure results for six and eight months are reported but, here, the rust ratings and blister ratings were combined to give one performance parameter; the separate ratings cannot be extracted from the data reported.

Primers for the Underside of Bridges

The performance of primers commonly used on steel in England in the "microenvironment" of the underside of bridges is discussed by McKelvie (29). Fifteen systems were investigated. These fifteen coatings systems were made from twelve primers, nine intermediate coats, and one topcoat. The systems were evaluated as primer alone (single coat), two coats of primer, and primer plus topcoat. The individual paints are identified generically by vehicle and pigment. The materials included are poly vinyl butyral, phenolic varnish (pure and modified), an epoxy-polyamide, an alkyd, an ethyl silicate, iron oxide, metallic lead, zinc chromate, zinc phosphate, and zinc dust. Only a nominal thickness for each coat in a paint system is reported. The substrate used for exterior exposure was angle iron of mild steel; flat panels were used in laboratory tests. Two grades of blast cleaning were used (British Standards 4232, second quality and third quality) as well as two grades of grit.

Testing of the paints included exterior

exposure at three different sites and laboratory testing in salt fog and SO_2 atmospheres. The exposure sites were classified as marine, industrial (and highly polluted) and urban. The salt fog test was run according to British Standard BS 3900, Part F4. The SO_2 atmosphere was of unique design.

The performance properties rated were rust resistance and blister resistance with the European scale used for the former (0 = no rust, 5 = severe rust, complete failure) and a modified ASTM D-714 scale used for the latter. No details on this modification were given, however.

Only the ratings for one year exposure are given although ratings were made quarterly during the first year. The salt fog exposure was run for 1000 hours with data reported for 500 and 1000 hours. The SO_2 exposure covered 30 days with results reported for 15 and 30 days.

Metallic Coatings and Paints

Results of exposure tests on protective systems composed of sprayed metallic coatings and paints are given by Watkins (30). The metallic coatings were zinc and aluminum each sprayed by two separate processes; some specimens used a zinc/aluminum alloy. The paints included ten primers and nine topcoats combined to give twenty-nine paint systems. Some, but not all, of the paints were identified by reference to specifications; generic classification of pigment and binder was also used. Film thickness values were collected for the individual coatings but only nominal ranges were reported. The substrates were mild steel panels and channels. Substrates were blast cleaned but the degree of cleaning was not specified; iron grit was used as the abrasive. Some metal coated pieces were weathered six months before paint system application while others were metallized, primed, and then weathered for six months. Painting was then completed after this exposure. Paint systems alone, i.e., without a metal coating on the steel, were included in the study.

The exposure conditions for the systems were four field sites. They were classified as industrial, industrial/marine, marine/half-immersion, and fresh water/total immersion. The flat panels were used in the immersion tests.

The duration of the exposures reported was ten years although some channels were repainted in the interim. The properties rated were corrosion resistance, corrosion undercutting of films, chalking, flaking, and cracking. The rating scale is highly subjective though: A = good condition, B = beginning to fail and repainting needed, C = repainting overdue, and D = failure (loss of base metal).

Metallic Coatings

The long term performance of metallic coatings used to protect steel is outlined by Schrieber et. al. (31). Six protective systems were used in this study: four different "seal" coats were used with either zinc or aluminum. The seal coats are identified generically. Film thickness values for the coatings are given. The substrate was low carbon steel. Subsequent to mill scale removal by pickling, panels were blast cleaned with one of three different abrasive media: coarse silica sand, fine silica sand, or iron grit. The metallic coatings were applied by an automated machine.

Seven atmospheric exposure sites and four seawater immersion sites constituted the exposure conditions. The atmospheric sites were classified as marine (4), industrial (2), and urban (1). All the sites were ASTM exposure locations, e.g. the 80-foot lot at Kure Beach, North Carolina.

The performance results for corrosion resistance, blister resistance, and change in appearance are presented in a narrative fashion, generalizing observations on the two coatings at the various test sites.

Coatings on Steel Pilings

Twenty-two coating systems were evaluated on steel pilings in work reported by Kumar and Wittmer (32). The coatings, identified by manufacturer and product name, included coal tar epoxy, zinc rich primers, flame sprayed zinc and aluminum, and aluminum filled vinyl. Thickness values for each coating were given. The steel, either ASTM A36 or 690, was blast cleaned to near white.

The exposure conditions varied over the length of a steel piling. They included atmospheric, splash zone, seawater immersion, sand wash area in the vicinity of the bottom, and complete embedment in sand.

Rating of corrosion was done by ASTM D 610. Other measures of corrosion were pit depth and reduction in metal thickness.

Aluminum and Zinc Alloy Coatings

A very concise presentation of atmospheric corrosion resistance data was used by Townsend and Zoccola in reporting results of a thirteen year exposure study (33). The coatings were metallic ones: an aluminum-zinc alloy (Galvalume, Bethlehem Steel Corporation), aluminum, and zinc (G90 hot dipped galvanized). Coating thickness for each type was reported. The substrate was sheet steel but the surface preparation was not specified. Four exposure sites were used, classified as severe marine, moderate marine, rural, and industrial.

The primary data was weight loss which was fit to the equation $C = At^B$ where C is the reduction in coating film thickness, t is time, and A and B are constants characteristic of the coating and exposure site.

3.1.2 Research Agencies, Trade Associations, Universities

In the category covering sources such as trade associations, research intitutes, and universities, the contacts were the Steel Structures Painting Council (SSPC), North Dakota State University, the University of Southern Mississippi, the International Lead and Zinc Research Organization (ILZRO), Zinc Institute, and the Paint Research Association (England). Of these, only SSPC had pertinent data. ILZRO indicated that their work in protective coatings was done at SSPC.

Two of the reports or projects from SSPC are highlighted here because they provide information about the new and high performance systems of interest due to environmental restraints in addition to an exploration of the dependence of different operational parameters on performance.

PACE

"Perfomance of Alternate Coatings in the Environment (PACE)" is the title of a SSPC project designed to examine how well newer coatings protect steel from corrosion (34). Newer here denotes those coatings developed in response to concerns about air pollution, toxicity, and safety.

The investigation of materials in PACE covers pigments purported to be replacements for lead based and chromate based inhibitive pigments, waterborne coatings, and formulation variations of SSPC's vinyl paint (SSPC Paint No. 9). The effect of surface preparation or surface condition of the steel panels on performance was included in the experimental design as well as testing in several different environments. Primers alone or with intermediate coats with and without a finish coat are evaluated throughout the study.

The alternate pigment branch of PACE emphasized the replacement of lead pigments and chromate pigments in alkyd and linseed oil type vehicles by pigments such as zinc phosphate, barium metaborate, zinc molybdate, calcium borosilicate, calcium phosphosilicate, zinc sulfo-oxide, and calcium/zinc molybdate. Forty test formulations were evaluated along with sixteen specification paints. The test formulations were selected as the best available at the onset of the program for a particular pigment. Identification of the materials is incomplete for the test formulations; several coatings do not specify even generically the alternate pigment used or product source.* However, where formulation details are given, they include a composition breakdown of the pigment blend and vehicle blend.

Surface preparation was included as a factor in the experimental design. The steel panels were hot rolled A 36 steel. Levels of surface preparation included blast removal of mill scale with shot to SSPC-SP10 and wire brush cleaning (SSPC-SP2) of intact mill scale and mixtures of mill scale and rust obtained by weathering uncoated panels (10, 20, and 100 per cent rust).

The test environments used in evaluating the alternate pigments were salt fog (ASTM B 117) and exterior exposure at three sites: Marine-Kure Beach (800 foot lot), severe industrial-downwind from a coke plant, and industrial.

The performance measures used to evaluate the coatings were corrosion resistance graded by ASTM D 610, film undercutting from a scribe, and blister resistance. The size and density of blisters from ASTM D 714 are converted to an eleven point scale (0-10; 10 = no blisters) based on the per cent area blistered.

* Products and formulations were included that were still developmental, so certain disclosure restrictions were placed upon SSPC.

Other degradation attributes such as chalking were noted as warranted. Data for sixteen month exposures at the field sites was reported. For the salt fog exposure, the data were reported as the hours required to reach grade 9, 8, and 7 for both rust and blisters.

Red lead replacement pigments were also evaluated in a vinyl paint (MIL-P-15929). These pigments were barrier types aluminum flake and micaceous iron oxide and inhibitive types calcium borosilicate, zinc molybdate, zinc phosphate, zinc phospho-oxide, and tribasic lead phosphosilicate. However, only two of the eleven test formulations specify which pigment was used. The surface preparation scheme included blast cleaned steel (up to three levels) as well as hand cleaned steel which had intact mill scale or rust and mill scale as its surface condition prior to preparation. Test environments were salt fog, salt water immersion, fresh water immersion, and atmospheric exposure at a coke works (severe industrial). The performance attributes again were surface rust, blisters, and scribe undercutting. The salt fog data were reported for 11,506 hours (undercutting for only 3,535 hours); salt water and fresh water immersion data covered 5,700 hours; the field exposure history covered two years.

The waterborne coatings portion of PACE investigated twenty-six coatings along with seven control or reference coatings. The waterborne coatings included samplings from acrylic emulsions (latex), acrylic/styrene copolymer emulsion (latex), water soluble alkyds in addition to a waterborne epoxy, a waterborne acrylic/epoxy, and a coating using cement. The control coatings were alkyds and linseed oil based formulas using zinc chromate, red lead, or basic lead silico chromate. Several, but not all, of the coating systems are identified by their resin component (product name and generic type) and manufacturer's formulation number.

The surface preparations used in the evaluation of the waterborne coatings included hand cleaned (wire brush) panels with intact mill scale and mill scale and rust at 10, 20, and 100 per cent rust and panels blast cleaned to a near-white condition (SSPC-SP 10) or to a white metal condition (SSPC-SP 5). Different abrasives were used for each type of blast cleaning.

The exposure conditions for the waterborne systems were exterior exposure at the marine, industrial, and severe industrial sites and salt fog exposure. The exterior exposure periods reported were only four months at the most (evaluations are ongoing, though). Rust ratings and extent of scribe undercutting were also reported. For salt fog data, the time to reach rust grades of 9, 8, and 7 (ASTM D 610), are reported. The same scheme given above is used for the modified blister scale.

Vinyl coatings were explored to gather information on potential performance effects due to formulation changes in solvent blends to meet emission standards and vinyl resin substitutions to increase volume solids at the point of application. Four specification vinyl resins in the eleven experimental coatings are identified. Four distinct degrees of abrasive blast cleaning were used. Near-white surface conditions were obtained using steel shot while three white metal conditions were achieved separately with two grades of steel grit and one grade of steel shot. Exposures were severe industrial (coke works), water immersion, and salt fog. Data on rust, blisters, and scribe undercutting were presented for ten months exposure at the coke works, 6190 hours water immersion, and 7564 hours in salt fog.

The final segment of the PACE study looked at different methods of surface preparation, ones more compatible with pollution and safety factors than sandblasting. These methods are non-metallic abrasives, metallic abrasives, wet sandblasting with and without corrosion inhibitors in the water, rust conversion on hand cleaned steel, and power tool removal of mill scale. In all, twenty-four unique surface preparations were used. Six coatings used over these surfaces were identified as zinc rich, vinyl, alkyd, oil modified alkyd, latex and SSPC Paint 13. The exposure sites were marine (Kure Beach), industrial (Neville Island), and severe industrial (coke works). Salt fog cabinet testing was included. Exposure duration at the field sites covered in the report was at least fifteen months while salt fog duration was several thousand hours. Performance again was measured in terms of extent of rusting, blistering, and scribe undercutting.

Topcoats for Zinc Rich Primers

A second set of performance data on coatings generated by SSPC deals with topcoats for various zinc coatings, work sponsored in part by ILZRO as project No. ZC-184 (35,36).

In this work, thirteen zinc coatings, including a hot dipped galvanized film and a sprayed zinc film, were evaluated as primers under six topcoats. The use of two tie coats was included in the materials design.

The zinc rich coatings were proprietary materials and were not identified by product name. A generic classification system based on specification SSPC-Paint X20X was used, however, in which four major classes are identified: inorganic water reducible; inorganic, solvent reducible; inorganic, post cure; and organic. Sub-classes to these further define the type of zinc rich. For the inorganic, water reducibles, the sub-class identifies the alkali metal cation (Na-Li, Na-K-Li, or K); for the organic, solvent reducible, the organic radical of the silicate differentiates members; the generic resin type in the organic zinc rich class is the modifier.

The topcoats were SSPC specification paints.

The tie coat was either MIL-P-15328B wash primer or a thin coating of the topcoat. Additionally, the recommended proprietary tie coat/topcoat combination was used for each zinc coating. Film thickness values were not reported.

Most coating systems were evaluated over steel that had been blast cleaned to white metal defined by SSPC-SP5. However, topcoating of weathered primer was included in the study for a limited number of systems: two zinc coatings plus the five SSPC paints. Other surface preparations were also investigated as a segment of the main test. In this case, the additional procedures were dry sandblasting to a commercial surface (SSPC-SP6), dry sandblast to white metal, and wet sandblast to white metal with and without inhibitor. No topcoats were used in evaluating the effect of surface preparation on performance; only six zinc coatings were used.

The exposure environments for the zinc coating topcoat study included most of those used in PACE: the severe industrial atmosphere near a coke works, the industrial site (Neville Island, Pennsylvania), and salt fog. The 80 foot lot for marine exposure at Kure Beach was also used. Corrosion rates measured by weight loss for bare steel and zinc for the exposure environments are reported.

The properties monitored on these systems are rust development, blisters, and scribe undercutting in addition to phenomena like peeling and delamination. Since the zinc coatings galvanically protect the steel, appearance of rust in the scribe is also noted. The rating systems are ASTM D 610 for surface area rusted, ASTM D 714 for surface area blistered, and average distance of undercutting from the scribe. Exposure periods reported are three years for field sites and 6000 hours for salt fog. In addition to these data, data from electrochemical tests are also given. The data are potential-time and current density-time for panels immersed in aqueous NaCl.

Performance data from several other SSPC projects are also desirable for a data bank. For example, the exposure studies designed to identify a threshold film thickness value for long term protection of steel cover now a twenty year period. A report of the ten year results has been made (37). Eight unique coating systems were involved in this study (six primers, one intermediate, and eight topcoats) which included six surface preparations in the design and exposure at three different field sites. The rust grading was done using ASTM D 610.

The study "Surface Profile for Anti-Corrosion Paints" has extensive data (38). The emphasis is on the effects of surface preparation variables such as degree of surface cleaning and abrasive media type and size. The study does include evaluation of film thickness effects, coating material effects, and different field exposures coupled with salt spray testing. It supplements other SSPC projects.

The data from coatings exposed on sections of the Golden Gate Bridge and test panels thereon are also of interest (39). Some of the coatings in the zinc rich paint topcoat study are also on exposure at the Golden Gate Bridge (35). The Golden Gate Bridge program involves 94 coating systems, two surface preparations (near white metal and intact paint), and substrates with rivets. SSPC data from coating tests on bridges are also potentially useful (40).

3.1.3 Government Agencies

Several government agencies were initially identified as sources for coatings performance data. These were the U. S. Army Construction Engineering Research Laboratory (CERL), U.S. Navy Civil Engineering Laboratory (NCEL), Bureau of Reclamation, and NASA. Efforts were concentrated on reviewing reports from these agencies although key individuals were also contacted. The data from NASA on zinc rich coatings is discussed here.

Several reports describe the work done at NASA Kennedy Space Center in developing and confirming specifications for zinc rich paints (41,42,43). All the coatings evaluated were commercially available. Fifty-nine zinc rich coatings were used in the study along with forty-seven topcoats. Only three zinc rich primers were used in evaluation of the topcoats. All materials were identified by product name as well as by a generic description. For the zinc rich primers, four generic types were used to group the materials: (1) inorganic zinc rich, solvent reducible, (2) inorganic zinc rich, water reducible, (3) organic zinc rich, single package, and (4) organic zinc rich, multi-package. The topcoats included epoxies, coal tar epoxies, vinyls, acrylic latexes, chlorinated rubber, and urethanes. Film thickness was included as a factor in the experimental design at two levels for testing of the primers alone. One level was the manufacturer's recommended film thickness while the second level was four to six mils (102-152 microns).

The field exposure tests used KTA panels. The surface preparation was sandblast cleaning to near white metal (SSPC-SP10). Flat panels were used to test for film build characteristics, adhesion (balance-beam scrape method), and abrasion (Taber).

The testing program included field exposure (racks oriented 30^{o} from horizontal approximately 100 feet from mean high tide line; panels face the ocean) in which a small number of the panels were sheltered from rain and direct sunlight and a set of laboratory tests: abrasion resistance (Taber, Federal Test Method Standard 141a, Method 6192), adhesion (ASTM D 2197) and high temperature resistance. Corrosion rates of uncoated steel at the site are available (44).

The field exposure panels were periodically evaluated for rust development graded by ASTM D 610. The KTA panels were rated as a unit; no separate ratings were given for the several features characteristic of these panels. Blisters were described by ASTM D 714. For topcoated systems, general appearance attributes such as chalking and fading were included. The reports give performance data for one and a half, three, and five years of exposure.

3.1.4 Coatings Manufacturers, Raw Material Suppliers, Users

For the most part, data from coatings manufacturers and raw material suppliers are based on performance of test panels in laboratory tests and test fence racks. Case histories, although done, tend to be sporadic and dispersed, not easily assemblied. The use of salt fog testing by ASTM methods for operation and evaluation is common but not universal. Other accelerated tests include exposure to high humidity conditions and simulated weathering.

A large data pool developed by Union Carbide Corporation as a maintenance coating user is discussed here. The data represent screening and performance evaluations of commercial products over a twenty-five year period for the protection of a chemical plant in Texas City, Texas.* A summary of the testing procedure is given here; background information is available elsewhere (45).

The test procedure used to evaluate protective paints is called the drum test; it supplements other evaluation procedures used by Union Carbide Corporation that use test panels and laboratory tests. These latter tests, which

* Information about the data and test procedures was supplied by F. Parker Helms, Central Engineering, Union Carbide Corporation, Texas City, Texas.

form the Carbide Uniform Paint Evaluation (CUPE) Program, encompass salt spray, water immersion, seawater immersion, condensing humidity, and accelerated weathering evaluations.

In the drum test procedure, paints are identified and described by product name, generic type, and use. Other characteristics such as induction time, pot life, drying time(s), and viscosity are used to describe the material. Provision is made to record wet and dry film thickness for each coat as part of the application record.

The paints are applied by skilled painters under field conditions. The coatings are rated by the painter for several preparation, application, and drying characteristics. These ratings are on a scale of 0 to 10, 10 being the best. Properties included in the ratings are presence of sediment, amount of grit retained in straining, flow-out of applied film, and edge coverage.

The drum in the drum test is a common 55-gallon drum. Surface preparation in all cases is blast cleaning to near white metal defined by SSPC-SP10 with a profile of 1.5 to 2.5 mils. The drum, being a compound structure, has several features that allow one to generate a multicomponent performance rating for a paint or paint system. The drum is exposed "bottom up" and slightly inclined to trap water and soils. Horizontal and vertical exposures are present as well as a crevice line and weld seam. These are "natural" features. Other features are added to the painted drum to increase the performance characteristics data: a "X" shaped scribe is cut into the paint to expose bare steel, impact stress is imposed by striking the film with a ball peen hammer, and, in the case of zinc rich coatings, a triangular window of bare steel is left exposed to assess the galvanic protection.

The duration of a drum test is two years with inspections made every six months. The performance attributes are rust resistance, undercutting resistance, adhesion, blister resistance, and resistance to chalking, cracking, wrinkling, mildew growth, etc. Film thickness is also measured and documented during the inspections. The degree of rust development is measured by ASTM D 610 and blisters by ASTM D 714. The galvanic protection is measured by the height of the triangular window that remains rust free. Adhesion is measured by the knife adhesion test outlined in Federal Test Method Standard No. 141a, No. 6304.1; ratings are excellent, good, fair, and poor.

3.2 Highway Related Sources

Eleven state departments of transportation were contacted to identify the type and amount of performance data they might have. These were Arkansas, California, Florida, Georgia, Louisiana, Maine, Massachusetts, Michigan, North Carolina, Ohio, and West Virginia. Performance data for paint systems on bridges was the main request but data from test fence site exposures and laboratory testing was also solicited.

3.2.1 West Virginia Department of Highways

Three reports from the West Virginia Department of Highways describe laboratory and field testing of maintenance paints (46,47, 48). Fifty-three paints were included in these studies. These paints, used in various combinations, were identified at least by a generic description; several were specification paints. Metallic coatings (zinc and aluminum) and weathering steel were included in the materials. For paints, the method of application, either brush or spray, is reported as well as the thickness of each coating layer.

Four types of surface preparation or conditions were used: white metal, commercial blast, hand cleaned, and old paint. The surface preparations conformed to SSPC specifications, The panels for field exposure were KTA panels but flat panels were used for laboratory tests. Two test fence sites were used, each monitored for pollutant concentrations. The laboratory test was an accelerated weathering one in which panels were cycled through 300 hours in an environmental chamber in which common atmospheric pollutants were present (e.g. SO_2) followed by 300 hours in a weatherometer.

The properties monitored, graded by ASTM methods where applicable, were surface rust development, rust development in the weld area, chalking, checking, cracking, flaking, fading, yellowing, adhesive failures, peeling, and general appearance. In all, 600 panels were included in the field exposures. Of these, approximately 450 remained in good enough condition (ASTM D 610 rust grade 4 or greater) to stay on exposure for 99 months. The testing was terminated at that point.

3.2.2 California Department of Transportation

The Transportation Laboratory of the California Department of Transportation has recently reported on evaluations of waterborne coatings (49). Seventy-three coating systems were tested in this work.

Sixteen waterborne topcoat formulations, all using acrylic latex type resins, were tested over a California specification organic zinc rich primer (8010-61J-36). In some cases, a vinyl wash primer was used as an intermediate or tie coat. This was also a specification formulation (8010-61J-27). The primer thickness was nominally constant; the dry film thickness was in the 3-4 mil range (76-102 microns). The topcoats were applied to a dry film thickness of approximately 3 mils (76 microns). The substrate was steel test panels blast cleaned to give a profile of 1 to 1.5 mils (25-38 microns). Performance tests were salt fog exposure, 100 percent relative humidity, and exterior exposure in which the panels faced south at a 45 degree angle. The laboratory tests were done by ASTM procedures. Performance attributes monitored were resistance to corrosion and blistering and gloss changes. Rust was rated by ASTM D 610 and blisters were described by ASTM D 714. Gloss was measured at 60 degrees. The duration of the exterior exposure was two years.

The development of a waterborne primer and a topcoat was also part of the California work. The waterborne system was to be a performance equivalent replacement for an alkyd system. Primers and topcoats were evaluated separately then selectively combined.

Fourteen primer formulations were tested in which nine different resins and eleven pigments or pigment blends were used. The materials were identified by product name and generic description. The dry film thickness values are also documented. Steel test panels were the substrate. In all cases, clean metal was the surface condition but three different surface textures were used. One, obtained by abrasive blasting, had a profile in the range of 1 to 1.5 mils (25-38microns). Machine cleaning of the steel for the other two textures gave surface roughness of 1.2-2.6 mils (30-65 microns) and 0.6-1 mil (15-25 microns). Salt fog atmosphere exposure, 100 per cent relative humidity, and extensive exposure of panels mounted on the Golden Gate Bridge formed the testing scheme for the primer evaluations. The duration of the salt fog test was up to 3,000 hours; the report covers one year of the exterior exposure.

Nineteen topcoat formulations, two of which were used as topcoats over the organic zinc rich, were investigated. The resins are identified by manufacturer and product name; pigments are not identified but the color is given. Performance properties were assessed by salt fog and 100 percent relative humidity eposure of coated steel panels and weatherometer exposure (light and and water cycling) of coated aluminum panels. For these tests, the performance data (corrosion and blistering) are not reported but presented in terms of general behavior.

Ten waterborne primer and topcoat combinations formed the set of complete waterborne systems. The resin and pigments of the primer are specified but only the resin of the topcoat is given. The tests used were salt fog, 100 per cent relative humidity, and exposure at the Golden Gate Bridge site. Performance in salt spray is given for 1000 hours of exposure while exterior exposure gradings are given for one year for a couple of systems and three months for the others.

3.2.3 Georgia Department of Transportation

Data from laboratory tests and test fence exposures for Georgia DOT are described by Tooke and Hurst (2). The data represent evaluation of over 100 coating systems made from forty-five primers and twenty-eight topcoats. All the materials are identified by at least the major vehicle and pigment. Variables covered include thickness (total), surface preparation (hand cleaned steel through blast cleaned to white metal), application method, and environment. Salt spray testing and accelerated weathering are part of the testing regime. Tests of coatings on actual structures such as sections of a bridge and a water tank are included.

3.2.4 Coatings on Bridges

The performance of coatings on bridges, of course, is also a data source. The data are contained in case history reports, inspection reports, and similar documents. In general, they are not quantitative or as quantitative as performance assessments found in laboratory or field tests of painted steel panels. This simply reflects the complex nature of a bridge in terms of its many varied geometric features and its size which combine to create more than one "environment" that imposes degradation stresses on the corrosion protection system and the underlying steel.

The characterization of some data for paints on actual bridges was done based on conversations with state DOT personnel and review of inspection reports from Maine DOT (50) and Arkansas Highway and Transportation Department (51). Published reports on bridge paintings were also used (52, 53). A summary is given in TABLE 15.

The inspection reports do contain information that identifies the paints, surface preparation, and film thickness. The surface preparation listed usually is that which was specified; indications of areas where the surface preparation was different may be made in failure reports. Film thickness values are reported as single values for each layer or the total system as an average for the whole structure. However, due to the size and complexity of the bridge structure, one value for the film thickness is not a good representation. Other descriptors of film thickness are used such as the number of coats of paint and the specified thickness or thicknesses.

The major difference between the case histories and laboratory based panel tests lies in the performance data descriptions. It is much more difficult to quantify the extent of degradation and failure of the coating system on a bridge than on a small steel panel. The inspection report identifies the type of failures observed such as rust breakthrough, peeling, or fading, their location, and an estimate of the extent of each. Measures of the extent of damage include per cent area affected as well as narrative qualifiers such as minor, extensive, or spotty. In some cases, an analysis of the cause(s) or likely cause(s) of the failure is also given. For example, a measurement of film thickness in an area showing rust might show a thinner film than specified or peeling of paint might reveal an underlying old paint layer when the job specification called for a white or near-white metal blast.

An overall assessment of the state of the paint on a bridge forms a part of the inspection record. Here, the assessment is a statement such as "good," "fair," or "poor." It reflects an integration of the items observed during the inspection weighted by the experience and training of the inspector and the guidelines used by his particular state. This assessment is basically a decision on the need to repaint the structure or not.

3.3 Factors Affecting Performance

The factors affecting the performance or durability of a protective coating system are well known. They are the coating system itself, its thickness (individual layers and total), surface preparation, surface condition, exposure environment, and application. These factors have been recently reviewed in light of their effects on the cost of maintaining bridges (54).

The data sources reviewed above, for the most part, provide some level of description or factor value for each of the major factors. Hence, information is available.

TABLE 15. SUMMARY OF BRIDGE PAINT INSPECTION RATING SCALES.

State	Method
Arkansas	Overall per cent area of paint deteriorated; notes on location of severe corrosion; general guidelines to inspectors.
California	Rating scale of 1-5: 1 = newly painted, 2 = fading, chalking, dirt pick-up (first stages), 3 = heavy chalking, severe fading, dirt pick-up, 4 = rust on some part of structure, and 5 = needs repainting within 5 years.
Florida	Per cent area failed estimated, narrative description of state of the paint and location of the failures.
Georgia	Ratings of good, fair, poor, and critical
Louisiana	Rating scale 0-9, 9 = new condition and 0 = critical condition.
Maine	Narrative on condition and location of problems; judgement on touch-up or repaint; general guidelines to inspectors.
Massachusetts	Rating scale of 0 to 9 corresponding roughly to per cent area rusted.
Michigan	Assessment as good, fair, or poor.
North Carolina	General observations, narrative
Ohio	General observations, narrative
West Virginia	Condition of paint (good, fair, poor, critical) and recommendation on need to repaint; guidelines corresponding to per cent area rusted.

4.0 Coatings Performance Data Bank

A review of data sources above indicates that information about how well coatings protect steel from corrosion is available. This information is, in general though, dispersed and not easily identified and retrieved. Hence, a centralized repository of performance data of coatings on bridge steel would be beneficial. The use of computers and their associated storage media can provide such a repository compactly and provide the data quickly. The data provided and its analysis, if any, can be tempered by invidual experience. Such a data bank then can aid people who must specify or otherwise select a protective coating system.

The assembly of performance data of coatings on bridges allows one to share the experience of others involved with the same type of problems. The use of a computerized system to store and recall the information allows one to select those parts of the total data bank that are appropriate and allows one to concentrate on assimilating and analyzing the information. The data for products can be recalled to make an independent check on manufacturers' claims or to estimate their service life better. One could possibly use the data to study correlations between laboratory test results and field results, information that would be beneficial in product development quality control, and field reliability. Depending on the data and the interest of the user, study of functional relationships between performance and factors of the coating system such as its thickness, surface preparation, application, and exposure environment can be made.

There are limitations to the use of a computerized data base but these reflect more of a concern about having enough data cases to make conclusions statistically significant. This, however, does not affect the basic purpose of the data bank in providing potentially useful information.

The level of computer expertise or familiarity needed to work with a data bank is a genuine concern. However, those parts of the data bank program where the user interfaces with the system can be written so that plain English is used. The user basically directs the system by simple, short responses to programmed questions designed to identify and define his search or selection criteria.

A limitation that is difficult to resolve completely is the ability to screen input data as to its "correctness." Because of this concern, provision is made in the proposed data record to identify the source of data. The data bank itself can aid in the resolution of the problem. Assuming that data in the system has come from multiple and independent sources, a statistical description of the performance of a material or type of material for a given set of conditions can be generated. It is expected then that a few cases in which the data is suspect will not significantly change the character of the distribution. In fact, those suspect cases may well stand out in such an analysis in which case they will naturally draw closer scrutiny.

In addition to the above, initial screening of data can help eliminate "bad" data. Here the assessment must concentrate on the technical soundness of the experimental design in laboratory studies and test panel studies (i.e., control of independent variables). For case history data, good documentation is needed; in addition, where failure is observed and the cause(s) evident or evidence of nonconformance to specifications can be made, such information should also be recorded.

4.1 Data Bank Structure - General

Most data processing is based on the assumption that all records will be uniform. They are expected to have the same variables, in the same positions, with values drawn from the same set of scales.

The two most common types of record structures are fixed format and free (or stream) format. Each fixed format record has the same variables, in the same positions, in a field of a fixed length. The typical punch card is an example of this type of record. The free format record has its fields in a fixed order, but they are separated by commas (or other punctuation marks) and can vary in size. Terminal input in BASIC and other programming languages are examples of this type of format.

In either of these formats, missing data has to be shown explicitly. The fixed format record can simply leave blanks in the missing fields. The free format record can use either an explicit symbol for missing data (such as a "?") or omit the item completely (which would be shown by two punctuation marks together).

The PL/I programming language introduced yet another format for a record which uses the keywords GET DATA (55). This construction expects to find a stream of fields separated by commas in much the same way that a free format read statement would. The difference is that the items that make up the stream are simple PL/I assignment statements: " variable identifier = value ". By having the explicit variable identifier given with its value, there is no required or implied ordering to the fields.

The most general statement about the purpose of a data base is that it is to collect together information concerning one topic, in such a way as to make that data easy to manipulate. This implies that a data base will not be a mixture of "apples and oranges," of data on many topics. When all entries in the data base are made up of a uniform set of fields, all recorded with the same scales, the data is quite easy to manipulate.

There are problems when it is not possible to obtain uniform reports on all of the data items in the data base, or when the data items are not reported on the same scales. If the situation is such that there are only a few items that do not have reported values for the attributes that the data base is to record, then the use of a "missing value" token can be a solution. If a data base is very irregular in content then the 'missing value" solution is not desirable because every record would be filled with "missing value" tokens for a majority of its fields.

There are several sources for irregularity in a data base. The first source is simply that one subset of data does not report the same attributes as another subset. This need not be an oversight or error on the part of the data collectors. For example, there is no reason for every laboratory to test paint in exactly the same way. A test or set of tests that uniquely and correctly describe or predict the performance of a coating has yet to be established.

The second source of irregularity is in the use of different scales or measures for reporting the same attribute. This can be due to the use of different tests for the same attribute. Sometimes it is possible to convert one scale into another scale by a simple mathematical calculation. Converting English measure to metric is a common example of this. Not all scales can be converted so easily though. Prime examples of this are the gradings given to paint performance under service conditions, i.e., "good", "fair," "poor."

A third source of irregularity is in the reporting of data items. In the case of paint performance, some of the standard test scales are a matter of skilled judgement. Each reporter will assign different values for the same data item, even though they claim to be using the same scale of measurement.

A fourth source of irregularity comes from incomplete reporting of data items that are composed of several components.

4.1.1 Data Base Structure

For the paint performance data bank, the records will be centered on the performance of a coating system on a particular substrate in a particular exposure environment. For laboratory based work, the record will document the initial state of the coated panel and test results. This includes panels exposed on test fences. For coating systems on structures, the record will consider the structure as one unit although provisions can be made to describe performance on various subunits of the structure, classifying these subunits as part of the environment.

A record will contain information that will:

1. Provide unique identification and the source of the data.
2. Identify the protective coating system.
3. Identify the surface preparation and surface state of the substrate
4. Identify application process parameters.
5. Describe the exposure or test environment.
6. Give the values of various performance attributes as a function of time (if appropriate).

Hence, all the major factors affecting performance are included.

One way to organize the information (data elements) that make up the paint performance record is a data structure known as a tree. A tree structure alignment can be used to represent family trees, organizational charts and many other common hierarchies. It is characterized by having nodes which are either complete in themselves ("leaf nodes") or which divide into further tree structures ("subtrees"). Nodes which are of the form " variable = value " are leaf nodes in this record format. The nodes which have a list of values in parentheses are sub-trees. As an example, consider a family tree represented in this record format:

(RECORD alpha) = (FAMILY="Jones", FATHER = "Tom", MOTHER = "MARY",
CHILDREN= (SONS = (FIRST = "Melvin",
SECOND = "Sam"),
DAUGHTERS = "Jane"))

A more germane example is:

(RECORD alpha) = (COATING SYSTEM = (PRIMER = "alkyl silicate zinc-rich",
TIE COAT = "vinyl wash primer", TOPCOAT = "White vinyl, hi-build))

The tree structure of a general record, presented in an outline format, is given in FIGURE 7. The application information is presented as a sub-tree to each coating layer since, in general, each layer can have its own application characteristics. The performance ratings (results) are a sub-tree of the environment. The description of the environment can be a standard test method (e.g. ASTM B 117 standard Method of Salt Spray (Fog) Testing) or a classification of its corrosive character (e.g. marine, industrial, rural). The structure shown would consider a bridge as a single unit. More than one sub-tree is shown in FIGURE 7 for the results since coatings can fail in several different ways. For example, although a single panel painted with one coating system is tested in a salt fog cabinet, it can receive ratings for corrosion resistance, blister resistance, and undercutting resistance.

The sub-tree for identification is presented in FIGURE 8. The information about the source is important here since it can be used to help confirm that data has been entered correctly (transcription errors). Status is an indication if the record is complete, i.e., no more performance results are expected. This is an aid to updating records. The source's unique identifier is a key to his data records. It could be a project number and panel number or a dated inspection record for a bridge.

The coating system materials description is given in FIGURE 9 without the application detail. The example in FIGURE 9 is the infor-

PAINT PERFORMANCE RECORD

I. Identification

II. Coating System (Materials)

    A. First Coat

        1. Materials
        2. Application

    C. Third Coat

    N. Nth Coat

III. Substrate Surface Condition

    A. History or Previous Use

    B. Surface Preparation

IV. Exposure Environment

    A. Description

    B. Performance Results

        1. First Attribute
            a. Data Value
            b. Data Value
            c. Etc.

        2. Second Attribute
            a. Data Value
            b. Data Value

FIGURE 7. GENERAL STRUCTURE FOR PAINT PERFORMANCE RECORD.

PAINT PERFORMANCE RECORD

I. Identification

   A. Unique Record Number

   B. Date Data Entered

   C. Source of Data

      1. Literature Reference or Organization
      2. Person Providing Data
      3. Source's Unique Identifier of the Data

   D. Status

FIGURE 8. RECORD IDENTIFICATION DATA ELEMENTS.

mation wanted for each layer. In a multicoat system, the sub-tree for each coating would call for the same type (field labels) of data items. If a coating were a multipackage system, field labels for the number of components and their mixing ratio (volume or weight) can be part of the coating description. Each component would be described as if it were a single coat.

The function of the coating refers to the traditional roles for paints such as wash primer, primer, tie coat, intermediate coat, and finish coat or top coat. Since the intent is to provide data on coatings protecting the steel,metallic coatings are included.

The designation"carrier type" is a label provided to give a selection option on materials that comply with environmental and/or health restrictions. Likely field value options are solvent borne, waterborne, waterborne-latex, waterborne-dispersion, waterborne-soluble, high solids, etc. Modifiers to these descriptions can be used to specify with which regulations a coating complies.

Batch numbers have been included so that classical "batch-to-batch" variances can potentially be studied. It is expected that this data item will be most useful to maintenance engineers, providing basic data with product uniformity and reliability can be assessed.

The dry film thickness (DFT) is also part of the coating system description. In this record structure, the same materials used at different thicknesses constitute a different coating system.

The function classification under the pigment section is there to differentiate corrosive inhibitive pigments from pigments used to provide aesthetic qualities. Inhibitive pigments here include the barrier type. The generic typing on the pigments is fairly straight forward since the chemical names predominate.

The generic typing for the vehicle is not as well defined as for the pigments. Standardization is needed so that search criteria incorporating generic description of the resin will retrieve the correct records.

The application record is divided into two types, field application and non-field application which includes shop application and laboratory application. Both types include a description of the ambient conditions during the painting (temperature, humidity, climatic conditions), schedule information such as time elapsed between surface preparation and painting or elapsed time between paint applications, and information about the viscosity of the paint. The organization for the application record is given in FIGURES 10 and 11.

The detail given for application parameters is more than typically reported. It is expected that a minimum data set for lab, shop, and field applied coatings will be location (lab, shop, or field) and method (brush, spray-air, spray-airless, etc.).

As shown in FIGURE 12, the substrate condition gives information on surface preparation and the state of the substrate before surface preparation.

The field label "type" in the substrate sub-tree is used to classify the substrate as a test panel, bridge section, whole bridge, or other structure. Modifiers can be used to better define each such as KTA panel, channel iron, truss bridge, or girder bridge.

The initial surface state description is

II. Coating System (Materials)

A. Number of Coats or Layers

B. First Coat

1. Function
2. Product Name
3. Batch Number
4. Manufacturer
5. Carrier Type
6. Dry Film Thickness
7. Major Vehicle
   a. Product Name
   b. Batch Number
   c. Manufacturer
   d. Generic Classification or Type
   e. Weight Fraction
8. Major Pigment
   a. Function
   b. Product Name
   c. Batch Number
   d. Manufacturer
   e. Generic Classification of Type
   f. Pigment Volume Concentration
   g. Total Pigment Volume Concentration
9. Application Data

C. Second Coat.....

FIGURE 9. COATING SYSTEM MATERIALS DATA ELEMENTS.

II. A. 2. Application Data

- a. Location
- b. Temperature (Ambient)
- c. Humidity
- d. Substrate Temperature
- e. Paint Viscosity
  - 1. Method
  - 2. Temperature
  - 3. Value
- f. Induction Time
- g. Schedule
  - 1. Time after Surface Preparation
  - 2. Time After Previous Coating Application
- h. Application Method
- i. Wet Film Thickness

FIGURE 10. APPLICATION RECORD ELEMENTS FOR LABORATORY OR SHOP.

II. A. 2. Application Data

a. Location
b. Structure Identification
c. Date
d. Climatic Conditions
    1. Temperature
    2. Humidity
    3. Wind
e. Substrate Temperature
f. Painting Log
    1. Surface Preparation
        a. Degree of Cleanliness
        b. Method
        c. Area Cleaned
        d. Schedule
            (1) Start Time
            (2) Stop Time

    2. Painting
        a. Paint Viscosity
            (1) Method
            (2) Temperature
            (3) Value
        b. Induction Period
        c. Unit or Section of Structure
        d. Schedule
            (1) Time After Surface Preparation
            (2) Time After Previous Coat Application
            (3) Start Time
            (4) Stop Time
        e. Area Painted
        f. Wet Film Thickness

FIGURE 11. APPLICATION RECORD ELEMENTS FOR FIELD PAINTING.

III. Substrate Surface Condition

A. Type

B. Alloy

C. Initial Surface Condition

1. Per Cent Area Mill Scale
2. Per Cent Area Rust
3. Per Cent Area Paint
    a. Paint Identification
    b. Age
    c. Rating
4. Exposure Environment

D. Surface Preparation

1. Method
2. Material
3. Degree of Cleanliness
    a. Specification or Standard
    b. Per Cent Area Clean Metal
    c. Per Cent Area Rust
    d. Per Cent Area Mill Scale
    e. Per Cent Area Paint
4. Profile
    a. Method
    b. Value

FIGURE 12. SUBSTRATE SURFACE CONDITION DATA ELEMENTS.

potentially useful since surface preparation at times does not completely remove old paint systems, surface contaminants, or rust pits by design or by limits inherent in the method. The description of the surface preparation is the usual. Specifications that incorporate a limit on the per cent area of clean metal can be invoked to condense the surface state description. The most commonly used specifications are expected to be those of SSPC, NACE, and the Swedish ones. The material field is included to identify the abrasive used in blast cleaning. The method of determining the profile is needed since different values are obtained by different measuring techniques or instruments.

The environment portion of the record broadly describes the test conditions to include exterior exposure and laboratory tests. Although the emphasis is on performance or durability, the sub-tree can incorporate physical property data on the system such as adhesion or hardness. The outline of the environment branch is given in FIGURE 13 along with the results sub-tree. Since the record is centered on one test specimen, only one branch of the environment sub-tree will appear in a given record, either the laboratory branch or the field branch.

For standardized tests, their identification would be sufficient to define the test conditions. The data items listed under laboratory test will define most other cases that might be encountered.

The conditions under the field branch include the general environment. Here, the coarse classification into marine, industrial, urban, and rural will be used. The local environment descriptors are an attempt to better define the nature of the exposure. These are not unique; other measures of the corrosive nature of a particular locale may offer better differentiation but research is needed to establish them.

The results sub-tree, also pictured in FIGURE 13, emphasizes a coating system can change or respond to its environment is more than one way. Each attribute rated can be handled. The rating or grading system needs to be specified. Reference to standardized methods is sufficient but a description of the method can also be entered. The value items shown are the performance ratings. In general, they will be an ordered pair (time, value) in which time is the duration of the exposure and value is the number or name for the property rating. For example, an attribute sub-tree might be

CORROSION RESISTANCE = (GRADING SYSTEM = "ASTM D 610", DATA = ((6, 9.5), (12, 9.1), (18, 8.2), (24, 7.3))).

The unit of time, of course, would have to be standardized; in this example, the time unit intended is a month.

The grouping of the paint performance data record in the outline presented reflects an arbitrary although useful way of organizing the data. The hierarchy represented in the outline is also used in programming languages COBOL and PL/I. In COBOL, the hierarchy is represented through the use of "levels" of data which are shown explicitly in the data division of a program (55,56). In PL/I, a "structure" to the data record can be declared which also uses "levels" of data (57). For example, the level structure of COBOL is represented in Figure 14 for some of the data elements for the paint performance record. (The representation is not a complete COBOL record description; it is sufficient for the purposes of this discussion).

In COBOL the name of the record is and must be level 01; grouping of data elements of the record is at the discretion of the

PAINT PERFORMANCE RECORD

IV. Exposure Environment

A. Laboratory

1. Test Name
2. Conditions
    a. Specification or Standard Method
    b. Aggressive Agent
        1) Identification
        2) Concentration
    c. Temperature
    d. Humidity
    e. pH

B. Field

1. Location
2. General Environment
3. Local Environment
    a. Bare Steel Corrosion Rate
    b. Substrate Orientation
    c. Aggressive Agent
        1) Identification
        2) Concentration
    d. Prevailing Wind

C. Results

1. Attribute One
    a. Grading System
    b. Data
        1) Value
        2) Value
        3) Value
2. Attribute Two
    a. Grading System
    b. Data
        1) Value
        2) Value

FIGURE 13. ENVIRONMENT AND RESULTS (PERFORMANCE) DATA ELEMENTS.

```
01  PAINT PERFORMANCE

    02  ID...

    02  MATERIALS

      03  FIRST-COAT

          04  FUNCTION
          04  PRODUCT-NAME
          04  BATCH-NO
          04  MANUFACTURER, etc.

      03  SECOND-COAT

          04  FUNCTION...etc.
```

FIGURE 14. SCHEMATIC LAYOUT OF COBOL DATA DIVISION REPRESENTATION OF HIERARCHIAL RECORD.

programmer or record designer. The maximum number of levels is forty-nine. The advantage of this structured record is that record or information manipulation can be handled as if the record were an array. For example, the entire record can be moved by calling the record name. Alternatively, a group of data elements or individual elements can be moved or selected by calling the name of the group or individual elements. To illustrate, a reference to FIRST COAT would include all the data groups or elements which have level numbers greater than the level number of FIRST COAT and lie between FIRST COAT and the next level equal to FIRST COAT in the data division. Similar rules apply to PL/I.

4.1.2 Initial Data Base Structure

The initial recommendations for the paint performance data bank centered on a record composed of a series of assignment statements equivalent to PL/I assignment statements. That is, each record would explicitly contain not only the data items but also their labels as "<variable> = <value>." The hierarchy or structure of the record was to be shown by a series of nested parentheses.

The field lables or data items of the record would be fixed and standardized. No restrictions, however, would be placed on the values although there was to be a set of preferred values for each category to homogenize the data as much as possible. If no data were available for a particular field label, the field label would be eliminated from the record as an option. This circumvents the missing value problem cited earlier for fixed field and free format records.

The data recording technique was suggested since it can handle information from multiple sources even in cases of incomplete and inhomogeneous data. Although the need, value, and convenience of a standardized and homogeneous data base was recognized, it was felt that there was value in having a repository of performance data per se that would allow one to easily and rapidly collect data of interest.

Data processing and management routines would be written specifically for the proposed record structure. These were grouped coarsely as input, output, and analysis functions. The input functions were:

1. Accept input either in a batch or interactive mode. For the batch mode, the whole record would be entered including field labels and values. In the interactive mode only field values would be entered; a program would lead the user through the tree structured record format, requesting field values.

2. Listing of the standard field values and definitions as requested by a user, i.e., on-line documentation. This will aid in homogenizing the data. The option does exist to enter "non-standard" data values.

3. A check on the "correctness" of data entered in terms of values being within the allowed range or the right "type." This is a proofreading function.

The output functions were:

1. Retrieve and sort records on any combination of parameters; documentation and interactive mode routines to help a user generate an interest profile on which to search.
2. Check the logic in a set of search parameters for occurrences of mutually exclusive pairs or all encompassing pairs, etc.
3. Output data records in case history form.
4. Arrange interest file in proper format for analysis routines.

Analysis routines were not to be specifically written for the data bank since there are several commercial packages that can be used. The one chosen was SPSS (Norman H. Nie et. al., SPSS: Statistical Package for the Social Sciences, 2nd ed., McGraw-Hill Book Company, New York, 1975).

SPSS capability includes standard descriptive statistics such as averages, standard deviations, and frequency distributions and statistical analysis routines to examine correlations, to test for statistically significant differences, and to run regression analyses, for example. The selection of proper analysis of the data would require some knowledge about the nature of the statistical test (its assumptions, type of data required, interpretation or meaning of key parameters and results) but the documentation of SPSS is highly tutorial and sufficient for the background information needed.

4.1.3 Revised Data Base Structure

Review of the proposed data base and record structure by personnel in the Data Systems Division (DSD) of the Federal Highway Administration revealed some practical short comings. First, the use of nested parentheses to show the relationship of the data elements for records the size and complexity proposed would be unwieldy. The maintenance of such a system was also expected to be difficult. The operation of the system (input routines, retrieval routines, sorting, report presentation, preparation of data for analysis) would require a major specification and programming effort.

In light of commercial data management packages available, it was suggested that to design a set of data management routines was not necessary and impractical. Some of this philosophy, of course, was already recognized and put into practice with the use of the SPSS package to handle the data analysis.

No comparison of data management packages was made. At the suggestion of the DSD, the Statistical Analysis System (SAS) of SAS Institute, Inc. was investigated for its applicability to the project goals (58). The suggestion of DSD was based on their experience with SAS on other projects.

The SAS software package provides one with capability in data management, statistical analysis, and report writing. One can also write routines using SAS programming statements.

The data management capabilities of SAS include retrieval of data from files given a set of slection criteria, file updating and correction, sorting, and subsetting. These all are basic operations on data files which would have had to have been written if the initial proposal was followed.

The statistical analysis routines in SAS provide the same flexibility and variety of the SPSS package (see Appendix A). Hence, one can analyze a select set of data records or data elements by simple descriptive statistics or explore possible correlations and relations (regression). The routines are called by simple procedure commands in which the data is also identified. For example, if one had selected records giving the service life of inorganic, self-cure zinc rich primers with polyurethane topcoats in environments classified as coastal, the SAS statements

```
PROC MEANS
VAR SERVLIFE
```

would give an output of the number of records or data items (service life), the mean service life, the standard deviation, and the minimum and maximum service life.

The SAS software also includes report writing capabilities that range from tabular printouts of the data in a file or set of records and graphical presentation of data (bar charts, graphs) to customized report formats (titles, labels, print positions). The reports are generated through SAS procedure commands.

With the SAS package, the basic record structure is also changed. The record will be format free, i.e., the sequence of data items or categories is fixed but the length of each value is not restricted. The data items are those listed in Figures 7 to 13. The use of the format free record retains flexibility in handling nonhomogeneous data. An explicit "missing value" symbol will be used (SAS uses a period "." to denote a missing value).

Some aspects of flexibility in data recording are lost in using the format free approach. For example, the maximum number of coats or layers in a coating system will have to be specified and fixed. In practice, this is not expected to be a serious or frequently occurring shortcoming since most protective systems will have three to five coatings. Other areas where limits will have to be defined into the record are the number of physical or performance properties reported. Again, reasonable and practical limits can be used.

4.2 Data Bank Uses

The paint performance record is composed of a string of data elements that identify the coatings used, tell how they were applied, describe the substrate and its surface preparation, characterize the service environment, and provide a description of the durability and protective quality of the coating system as a function of time. These are the data elements necessary to describe coatings and their performance if comparisons and selections are to be made.

There are several uses or functions for the data bank. First, and at a minimum, it can serve as a repository of paint performance data and associated variables. This repository can be national in scope or it can be used by states on an individual basis to store and retrieve their own data. Merger of data from individual states, of course, would be possible so that information and experience can be pooled. The larger the data base, the better (potentially) the conclusions drawn therefrom. Potential sources of data are DOT's research institutes, published work, coatings manufacturers, and raw material suppliers.

As a repository, there are straight forward applications that can be useful. For example, a state could use it to inventory the coatings used on its bridges and also provide information on the condition of the paint on each. Simple listing of the inventory can be made although the use of descriptive, summary statistics would likely be useful and desirable also.

Since each state has perhaps, several thousand bridges, the ability to retrieve information on all bridges or on a select few can be beneficial.

Considering only, for the moment, in service data (case histories), different applications of the data bank can be envisioned.

One could examine the service life of a coating system as it is affected by such variables as environment and surface preparation. If the analysis were applied to several different coatings, one could generate a quantitative basis for selecting one system in preference to others for a particular bridge. Hence, the data and operations on it can be used as a decision aid.

The data bank can also be used to evaluate the reliability of a particular product. Its performance level could be tracked taking into account such factors as surface preparation, environment, bridge type, etc. on a batch to batch or job basis. The variability in performance could be used as one measure of reliability. Again, if this were done for several different products, the degree of reliability of each could be applied to the coating selection or specification process.

The reliability assessment would furnish one with an estimate of the service life (average) of a product in a specified type of environment as well as the spread in service life values (variability or dispersion). Both values could be used in life cycle cost comparisons when alternate or competitive systems are considered. The life cycle cost calculations with data derived from real experience can be expected to be realistic and practical.

If data from several states could be combined or compared or both the statistical reliability of conclusions, of course, would be increased.

The data that can be housed in the data bank are also of interest to materials engineers, designers, and specifiers. Designers and specifiers might approach the data bank in a manner similar to that illustrated above for maintenance engineers. This is the case since they too are also tasked with the protection of real structures.

Materials engineers and others such as coatings manufacturers and coatings formulators can also use the data bank. Again, at a minimum, it can function as a storage and retrieval medium for coated, test panel performance data derived from laboratory evaluations or field evaluations or both. This will save manual search time and allow more time to be spent on analysis.

There are several things that can be done with the data base and its associated data management, processing, and analysis capabilities that might be of interest to those more interested in the technology of coatings. It could be used to identify what coatings or types of coatings are being (or have been) evaluated for use on steel bridges. From there, one could make comparisons of the performance attributes of the coatings selected through the data iteslf or descriptive statistics. These comparisons could be made with data sets grouped according to generic type of coating, film thickness, and surface preparation, for example. These groupings or subsets would be done by the program based on user commands. The ability to arrange the data in such subsets would aid materials engineers and coatings formulators in studying the dependence of performance on such factors.

Since the data base will contain data from laboratory tests, field tests, and service histories, the potential to examine the correlations between the performance data from these three sources exists. Hence, one could study and attempt to define quantitatively the degree of correlation between performance defined by accelerated, laboratory tests and performance defined by test fence exposure or service use or the correlation of results from test fence exposure and service. Here, the statistical analysis routines for correlation analysis and regression analysis will be used.

The study of the correlation between service performance and test performance, be it laboratory or natural weathering of test panels is a very important aspect of the usefulness of the data bank. The degree of correlation is critical to the whole process of providing the best corrosion control technology since laboratory and exposure site testing of protective coatings are used to guide raw material selection, product formulation, product qualification, and product acceptance. Although, obviously, actual service performance and durability ultimately decide what coatings are or should be used, the time involved to generate a service performance profile sustains the reliance on short term tests and screening procedures.

In summary, a coatings performance data bank will provide a ready source of information about protective coatings for bridges. The information, gathered, potentially, from raw material supplies, coating manufacturers, research institutes, and, most importantly, users (i.e. DOTs, bridge authorities, turnpike authorities, etc.) is the same used now in discussing the merits and disadvantages of competing, protective systems, although it will not be dispersed and diffused as it is now in the open technical literature, research reports, numerous evaluation studies run by users, and in bridge maintenance files. Since computer capabilities will be used to store, retrieve, and process the data, more time and effort can be applied to the analysis of the data. The computational drudgeries of such analyses will also be handled by a computer so that the "people-time" for analysis is or can be applied to thinking about the data, its meaning, interrelationships, developing insights and testing the same.

5.0 Conclusions and Recommendations

From the analysis of the type and quantity of performance data generally available for coatings on structural steel and the computer programming techniques extant, it is concluded that it is feasible and advisable to undertake the establishment of a computerized coatings performance data bank.

5.1 Feasibility

A data recording technique that will handle inhomogeneous data and data from multiple sources has been chosen. The data recording technique selected is format free. The sequence of data items that compose the record is (or will be) fixed and specified but the field width (number of characters, number of digits) for each of the data items is variable. This gives the basic data recording flexibility in the acceptance of data values. The field labels or data items are centered around the concepts and general principles of the things affecting performance that have evolved in the coatings industry through research, development, and cumulative experience.

Although there is inhomogeneity in the performance data found in the protective coatings field, the format free record structure can handle such data since it basically accepts the data values as is. This reflects the primary emphasis placed on data recording and retrieval in the course of this study; analysis, which needs standardization, was secondary.

A commercial data management and analysis system has also been identified that will be used to process the data (correct records, update, subset, sort, etc.), generate reports or output, and do the statistical analysis as needed. This system is SAS (SAS Institute, Inc., Cary, North Carolina). The utilization of this system enhances the feasibility since established techniques of data management can be readily applied.

A data bank is feasible also because good data on systems of immediate and near future interest to the highway community exists. One source stands out here: the PACE project of the Steel Structures Painting Council. The PACE project is highlighted since it concentrates on those coatings, materials, and processes being developed to meet impending environment and health directed restraints, represents a state-of-the-art input from materials manufacturers and coatings suppliers, and uses state-of-the-art evaluation techniques. The systems evaluated, to be evaluated, and their developmental progeny will also likely be tested on bridges in different locales. Hence, there is an anticipated continuity from the PACE project that will aid in assessing the merits of laboratory oriented performance potential with actual service performance.

Performance evaluations of coatings on bridges can be incorporated in the data bank. These service evaluations ultimately are the critical test of a protective coating system. This feature will help people in the highway community share experiences in protecting steel bridges. It is not intended that the data bank be merely an inventory mechanism for the paint condition on bridges.

It is intended to help engineers make informed judgements on protective coating systems and their selection. Hence, bridge painting trials designed to yield the maximum information about performance of coating systems likely to be available for use need to be emphasized.

5.2 Advisability

It is judged advisable to develop a coating performance data bank because of several benefits that can be realized through it. First is the ability to pool and disseminate information about coatings performance. Currently, this type of information is diffuse and difficult to locate. Even if collected, manipulation and analysis manually is tedious and cumbersome. Hence, there is always the pressure to reduce the amount of data evaluated since the task otherwise is humanly overwhelming. This aspect of pooling and disseminating information is also timely since there is (or soon will be) pressure to convert to new coating systems about which the performance data base on an individual source basis is small.

Another aspect to the pooled experience in a data bank is the identification of the best corrosion control technology. Searching the data records for performance histories matching independent factors the same or similar to a project need has the potential to quantitatively compare options. This emphasizes the engineering aspects of protective system selection and de-emphasizes the "art" aspects. The data bank can then act as a decision aid.

The proposed data bank can also aid in the economics of the protective coating system selection process. Here, data from service histories (i.e. service life or time between painting) is needed. The average service life for competitive systems is one factor in the calculation of life cycle costs. This factor can, in principle, be calculated from the data. With the raw data in-hand, the variability in service can also be factored into the life cycle cost so that at least some of the elements of the risk involved in selecting one system over another can be explored. Because of the speed at which the computer can make life cycle cost calculations, coupling the performance data with cost data and economic evaluation routines will allow a specifier to explore many protection options conveniently.

Maintenance planning and scheduling can be helped with a performance data bank resource. The accumulation of performance histories meeting a set of criteria allows one to statistically describe the service life at least in terms of an average and variance. With this knowledge one can plan inspections and maintenance in advance, applying limited man-power and dollars where they are most needed. Early maintenance is also a possible strategy with a knowledge of the expected service life of a coating system in a particular environment. For example, one may choose to repaint before the coating has degraded to such an extent that costly surface preparation must be incurred.

The ability to potentially check a manufacturer's claims about product performance is another benefit that can be derived from a repository of performance data. The specific claim of an expected service life can be confirmed or supported by itself as well as balanced against the performance level for similar products. Included in this ability is a tracking of product performance uniformity with time. Performance comparisons can be done through laboratory and/or field oriented results.

5.3 Guidelines and Procedures

It is recommended that the data referenced in the following reports or projects be incorporated in the coatings performance data bank:

1. PACE, Phase I and Phase II - Steel Structures Painting Council (SSPC).
2. "Surface Profile for Anti-Corrosive Paints" - SSPC Report.
3. "Topcoats for Zinc Coatings" - SSPC project for ILZRO.
4. "Minimum Paint Film Thickness for Economical Protection of Hot-Rolled Steel Against Corrosion" - SSPC and Federation of Societies for Coating Technology (FSCT).
5. "Golden Gate Bridge Paint Test Evaluations" - Golden Gate Bridge, Highway and Transportation District and SSPC.
6. "Paint Performance in Relation to Air Quality" - Research Project 49, West Virginia Department of Highways.
7. "Evaluation of Structural Steel Coatings In Relation to Industrial Atmospheric Condition" - Research Project 23, West Virginia Department of Highways.
8. "Performance Characteristics of Zinc-Rich Coatings Applied to Carbon Steel" - NASA, TN D-7336.
9. "Status Report on Corrosion Performance of Zinc Rich Coatings" - NASA, MTB 154-70.
10. "Water-Based Coatings for Protection of Steel Structures" - California DOT,

Report NO. FHWA/CA/TL-79/24.

11. Drum Test Data - Union Carbide Corporation, Texas City, Texas.
12. "Marine Corrosion Prevention of Steel with Thermal Sprayed Zinc and Aluminum Coatings - Results of 18 Years Exposure" - Offshore Technology Conference 1974, paper OTC 1959.
13. "Paint Systems for Highway Structural Steel" - Georgia DOT and Georgia Tech.
14. Data from the Bridge Corrosion Cost Model (Report No. FHWA-RD-79-121).
15. NCHRP 4-14 "Coating Systems for Painting Old and New Structural Steel" - Transportation Research Board and Georgia Tech.
16. "Protective Coatings for Highway Metals" - Research Report R-916, Michigan DOT.

These reports represent performance assessments for a variety of protective coating systems and present a data base from which one can explore the relationship between performance and the coating materials, thickness, environment, etc.

Several sources of new data were identified also. Those listed below are felt to be beneficial to the data bank as their data is generated.

1. "Paint Performance in Relation to Dry Film Thickness" - West Virginia DOH, HPR 63.
2. "Evaluation of Alternate Coating Systems for Structural Steel Protection" Georgia DOT, HPR 8005.
3. Field evaluations of materials stemming from FHWA/CA/TL-79/24" Waterbased Coatings for Protection of Steel Structures" California DOT.
4. "Effect of Weathering of Proprietary Zinc-Rich Systems"-ASTM Committee D01.46.09.
5. Study to determine the minimum surface preparation and profile requirements for zinc-rich coatings-NASA, Kennedy Space Center.

The procedure for obtaining data in general will be a request for cooperation. For HPR studies, FHWA can add data reporting or submission in conformance with or by the recording formats to the project. For projects not funded totally or in part by FHWA, the cost for transcribing data into machine readable format or onto data forms most likely would have to be borne. Since the record structure is "people" oriented, the transcription should be easy, fast, and something technicians can handle.

Based on conversations with highway department personnel, the prospect of getting old data from maintenance files is nil. There is not the man-power nor funds available for such a task. There is little interest also since the coating systems represented therein are not the ones that will be available for future use. Data from bridges should initially be from those selected for painting or other protective scheme trials. More documentation and precaution is exercised on such projects so that good quality data is available.

The incorporation of data from normal, routine bridge inspections eventually can be accomplished by filling out data collection forms at the time of inspection. This will increment the time and effort on an inspection minimally while, with time and accumulation of records, directly contributing to the usefulness of the data bank.

The data bank will require updating and revision since all the problems involved with developing a workable system cannot be anticipated. The development is an interactive process. Apart from not being able to predict all the interests, needs, and questions and required data to answer them, the correct data (especially laboratory test data) needed to properly assess the performance and performance potential of a protective coating system has not yet been firmly established. Because of this, new screening tests and refinements of old screening tests are and will be developed.

The facility requirements anticipated for the data bank are a main frame computer of

256K main memory plus fast disk storage. Magnetic tape is used to provide back-up storage. The software needs are mainly the SAS package. The cost of SAS is $4,000 for the first year and $2,000 per year for the subsequent years. The yearly fee includes the maintenance on the package and updates.

In summary, it is recommended that the development of a data bank be undertaken since it is feasible and advisable. It is feasible since (1) data record structure and recording techniques are available to handle inhomogenous data, data from multiple sources, and incomplete data, (2) data of interest exists, and (3) basic statistical analysis packages are available to help extract information from the collected data. It is advisable since (1) the need and pressures to convert to new coating systems requires the highway community and coatings industry to pool and disseminate data, (2) the pooled experience will aid in identifying better corrosion control technology, (3) quantitative characterization of the service life of a coating, coatings, or other protective systems can enhance the reliability of economic comparisons of different maintenance strategies, (4) quantitative characterization of the service life of a coating, coatings, or other protective systems can aid maintenance scheduling and anticipating maintenance needs, and (5) a data bank can be a resource against which manufacturers' product performance claims can be checked.

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Appendix

Notes on Statistical Analysis Routines

The initial proposal on the coatings performance data bank used a package of statistical analysis routines known as SPSS. This acronym stands for Statistical Package for the Social Sciences (Nie., N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K., and Bent, D. H., SPSS: Statistical Package For the Social Sciences, 2nd ed., McGraw-Hill Book Company, New York 1975, 675 pp.). It was chosen since it is widely used and contains basic statistical analysis routines.

The routines most likely to be useful are described briefly. The same analysis capability is available through the SAS system cited in the body of the report.

CONDESCRIPTIVE - This routine computes the mean or average, standard error, standard deviation, variance, range, and minimum and maximum values. It operates on numerical, continuous data. For example, if one had selected an interest profile for the service life of alkyd-red lead primers with alkyd-aluminum filled topcoats applied to brush-off blast cleaned steel in an urban environment, CONDESCRIPTIVE could calculate the average service life, its variance, standard deviation and give the minimum and maximum service life values if requested. Any and all of the descriptive statistical parameters can be calculated as the user chooses.

FREQUENCIES - This routine calculates one-way frequency distributions, operating on discrete or category type data. For example, one can generate distributions showing how often a particular coating system is used in each general environmental zone or the frequency of the coating system being rated "good," "fair," or "poor" after a given exposure period. This routine can also be used to generate histograms, a graphic representation of the distributions.

CROSSTABS - This program computes two-way to n-way crosstabulation tables for discrete or category type data. These crosstabulations are also called joint frequency distributions. This type of distribution can be useful if, for example, one wanted to determine if one generic type of coating was better for a particular end use than other coatings or, more generally, if there was a correlation between generic type and performance. To illustrate, consider the case of comparing vinyl topcoats with chlorinated rubber topcoats both over inorganic zinc-rich primers. From the sub-file or interest file selected from the data bank, the crosstabulation table might look like that given in Table A-1. Given the sub-file, CROSSTABS examines each record and places it in its appropriate "box" or matrix element. The percentage value is then calculated (shown in the example in parentheses), allowing one to "normalize" the data which aids analysis when the total number of records in the categories are different. Here, the number of vinyl records is is forty-five (45) and the number of chlorinated rubber records is seventy-five (75). Based on the percentage breakdown shown, one intuitively feels comfortable with the conclusion that no difference exists between the vinyl topcoats and chlorinated rubber topcoats; the absolute differences observed are most likely due to a larger number of chlorinated rubber cases. This conclusion can be made objectively with other features of CROSSTABS. It can, at the user's option, test for the statistical significance of the differences seen in joint frequencies based on the chi-square statistic.

T-TEST. This is a routine used to compute Student's t statistic and to test if the difference between the means (averages) of two samples is statistically significant. Returning to the example above, one could compare the service lives of the vinyl and chlorinated rubber topcoats with T-TEST to determine if the difference observed, if any, was due to sampling error (variability) or not. This test can be used when the records can be classified into two groups.

PEARSON CORR - This subprogram is used to measure the strength of the association between two variables. The measure of this association is the Pearson product-moment correlation. It measures how well a linear relationship describes the correlation. It could be used, for example, to study the correlation between service life and film thickness.

NONPAR CORR - This routine can calculate two different correlation coefficients based on the rank or ordering of the variables. The program takes the data as inputted to it, orders it, computes the coefficient(s) (Spearman's rho and Kendall's tau), and tests the statistical significance of the result(s). Applications of this type of testing include studying the correlation between a laboratory test of performance and field results.

SCATTERGRAM - This subprogram enables one to visually assess the correlation of two variables. This complements the PEARSON CORR. It does a simple linear regression or least squares analysis on the paired data. Hence, one can determine how well a straight line describes the relationship between the variables and what the slope and intercept of the best straight line through the data are.

REGRESSION - This routine is used to describe or examine the relationship between a dependent variable (e.g., service life or time between painting) and two or more independent variables (e.g., coating system, film thickness, surface preparation, and environment). Multivariable regression analysis assumes some functional form between the dependent and independent variables and calculates the independent variable coefficients and an overall correlation coefficient from the data supplied. So, the method not only describes the relationship, it also provides one with information on how well it describes it. The regression analysis assumes that the effects of independent variables are additive and linear. An example of this regression technique applied to highway bridge coatings is presented by Frandistou-Yannas (1). The dependent variable was the number of years between painting; the independent variables were bridge type (either truss or girder), type of paint system (three choices), application (shop versus field), and environment (industrial, desert, rural, or marine). The linear regression equation derived from 641 data points was found to be

$$y = 12.99 - 1.02x_2 - 2.45x_3 - 0.76x_4 - 2.08x_5 - 2.16x_6 + 0.62x_7 + 2.16x_8 \quad (1)$$

where y is the predicted years between painting, x_2 represents the type of bridge, x_3 and x_4 denote which of the three paint systems are considered, x_5 is the application variable, and the combination of x_6, x_7, and x_8 serve to describe the environment.

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TABLE A-1. SAMPLE CROSSTABULATION TABLE.

	Performance		
	Satisfactory	Marginal	Unsatisfactory
Vinyl	28 (62*)	7 (16)	10 (22)
Chlorinated Rubber	45 (60)	12 (16)	18 (24)

* Per cent figure.