GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 11/1/79

Project Title: Evaluation of Water Borne Coatings for Marine Use

Project No: A-2412

Project Director: Mr. F.A. Rideout

Sponsor: Avondale Shipyards, Inc.; New Orleans, LA 70150

Agreement Period: From 7/1/79 Until 6/30/80

Type Agreement: Purchase Order No. N-445 (under DOC Prime No. 5-38071)

Amount: Not to exceed $33,704

Reports Required: Monthly Letter Reports; Quarterly Progress Reports; Final Technical Report

Sponsor Contact Person (s):

Technical Matters
Mr. John W. Peart
Project Manager
Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, LA 70150
(504) 436-2121, Ext. 494

Contractual Matters
(thru OCA)
Mr. S.L. Meredith
P.O. Box 50280
Avondale Shipyards, Inc.
New Orleans, LA 70150

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
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- Project Code (GTRI)
- Other ______

CA-

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 4/1/81

Project Title: Evaluation of Water Borne Coatings for Marine Use

Project No: A-2412

Project Director: Mr. F. A. Rideout

Sponsor: Avondale Shipyards, Inc.; New Orleans, LA 70150

Effective Termination Date: 2/27/81

Clearance of Accounting Charges: 2/27/81

Grant/Contract Closeout Actions Remaining:

X Final Invoice ~~and Closing Documents~~

_ Final Fiscal Report

_ Final Report of Inventions

_ Govt. Property Inventory & Related Certificate

_ Classified Material Certificate

_ Other ______

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

COPIES TO:

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Other: ______

A-2412

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

August August 13, 1979

John W. Peart, Program Manager
Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, Louisiana 70150

Re: Subcontract on Waterborne Shipboard Coatings
July Report - Georgia Tech Project A-2412

Dear John:

Attached is a copy of my report of my visit to your yard and lab July 9 and 10, which was written in summary form prior to a more detailed outline that Arvind is preparing.

We would also appreciate the specification numbers for the solvent-borne controls you now use and confirmation of the thicknesses shown in Table 1.

Note the specimen letter I proposed following our meeting. I read this to Arvind today and we will go ahead writing to the 20 odd coating suppliers we selected.

Tomorrow, August 14, I have an appointment to visit key people at Carboline Company in St. Louis to get their first hand recommendations. We will keep you informed.

Sincerely,

Frank A. Rideout
Principal Investigator
Chemical & Material Sciences Laboratory

FAR:dm
Attachment(s)
cc:Arvind Vira, Asst. Project Manager, Avondale Shipyards, Inc., P.O. Box 50280
New Orleans, La. 70150
bcc:C.J. Ray
OCA✓
J. Spurlock
L.E. Henton

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

July 16, 1979

TO: C. J. Ray

FROM: F. A. Rideout

SUBJECT: Avondale Contract on Waterborne Coatings for Ships visit at New Orleans, July 9 & 10, 1979, Project No. A-2412

John Peart, Arvind N. Vira, and Ms. Irena Wiewioroska made it clear that this first project is to review commercially available waterborne coatings for use in new ship construction. Based on claims by vendors of marine waterborne coatings we are to screen a reasonable number of candidates in selected tests like those listed in Table 1, report on their feasibility for shipboard use (most important), note opportunities to develop (by ourselves or through suppliers) specific systems for specific service in future follow-on projects, and, if time permits, plan and execute a trial aboard ship.

Our proposal idea of selecting one or two ship areas we feel can be coated adequately, will be a possible follow-on project.

Practical Application Parameter

The gist of our work is to evaluate vendor claims for practicality of application in shipyard shops and in the dock during and after assembly. Will special methodology be required? What application and drying equipment will be required? What thinning will be needed?

What time, temperature range, humidity range, and air ventilation volume will be required? Compare with solvent systems.

Details and Notes

The kitchen is mostly stainless steel and food service areas are covered with plastic panels. These will not concern our study except for an anticorrosive primer on the steel behind the decorative panels.

Attached is a list of suggested suppliers of marine coatings to contact. Let's get a few letters out to present Avondale suppliers while I am on vacation. A draft of the letter is also attached.

John and Arvind will send specification numbers and more description of the solvent-borne controls we may use and samples, if the suppliers do not furnish them.

Fire retardant properties are not required but a note as we go along may lead to a follow-on project that we could refer to in our final report.

As far EPA, OSHA, DOT and TOSCA anticipated requirements, John suggested we only concern ourselves with present requirements which I interpret at present to be only Rule 66, no lead, mercury, benzene, asbestos and certain other agents we do not expect to encounter from paint suppliers. Note in this waterborne study candidate systems include combinations such as Union Carbide's UCAR 4358 based system of two latex topcoats over ethyl silicate zinc tried on exterior superstructure and in the duct-keel area (pipe and wire tunnel) on two El Paso natural gas ships nearing completion. In these cases the zinc was coated from a solvent system but today a fair amount of waterborne zinc from Sigma Coating is now used in this yard.

When I mentioned the superior performance expected of latex panels that were washed and dried fully before the salt spray test, John suggested we include this variable in some of the tests. The feasibility and merits of washing latex paint before service is another possible future proposal that could result starting with preliminary results in the current project.

We need to search further for literature on waterborne coating case history performance. This information will help both Avondale and A-2092 projects with an eye for fire retardant ideas.

FAR:gp

cc: L. E. Henton
P. M. Hawley
J. Spurlock
D. J. O'Neil

E 1. Lab Tests for Project A-2412, Evaluation of Waterborne Coatings for Marine Use

of Ship	A	B			C	D	E
	Immersion	Salt Spray	100% RH	WOM	Tabor	Gloss Wash Scrub	$200^{o}H_2O$ 150^{o}Oil
om, Deep Load o Keel	X	X					
om, Deep Load o Deck		X	X	X			
		X	X	X	X		
rior uperstructure		X	X	X			
rior uperstructure						X	
ne Room & ork Spaces							
es		X					X
iner Holds							
Cargo Holds		X	X			X	
er Space		X	X				
& Wire nnel		X	X			X	
ast Tanks	X	X	X			X	
rols:	2x4.5 mils EPOXY 2x7 mils Coal Tar/Ep	3 mils IZ 2x3.5 mils CR or 3 mils IZ 2x3.5 mils Ep or 3 mils IZ 1x3.4 mils Ep 1 1/2 mils PU				1 Ct IZ or 1 Ct Ep plus 2x3 mils Acrylic also Alkyd	Coal tar/Ep Epoxy
	12 x 12 or 2-6x12			Alkyd	same plus another topcoat		
	32 psi water 30 days/0-10						

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

July 23, 1979

Some Paint Company
000 Some Street
Some City, Some State

Gentlemen:

As a reliable marine paint manufacturer recommended by our sponsor, Avondale Shipyards (John Peart, Project Manager), would you help us plan shipboard trials of waterborne marine coatings you have commercially available?

The objective of our study is to assess the feasibility of waterborne systems in the shipyard for specific areas of the ship and in various application and drying processes in comparison with present solvent-borne coatings such as epoxy, zinc, vinyls, urethane and alkyds. We want to study your coating recommendations especially with regard to application and drying and your data comparing performance for the service intended. Selected lab tests (including water immersion, salt spray, weatherometer, scrub, abrasion, and hot oil resistance) will compare promising waterborne coatings here at Georgia Tech. This phase of our study will conclude with detailed plans for shipyard trials.

May we have your suggestions for realistic waterborne trials for exterior hull coatings above and below water, deck coatings, superstructure in and out, cargo holds, pipe and wire ways, engine rooms, bilges, and living spaces? What equipment and procedure changes do you find will be required for present day waterborne coating technology?

Data comparing your product applied from solvent will be helpful in considering any tradeoffs necessary to make water work.

Sincerely,

Frank A. Rideout
Principal Investigator
Chemical Material and Sciences Laboratory

FAR:gp

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

September 19, 1979

John W. Peart, Program Manager
Avondale Shipyards, Inc.
P. O. Box 50280
New Orleans, La. 70150

Re: Purchase Order N445 - Research Contract on "Waterborne Shipboard Coatings" - Ga. Tech Project A-2412: August Progress Report

Dear John:

TASK A. RAW MATERIAL SUPPLIERS

In April we wrote these raw material suppliers for recommendations and case histories on shipboard coatings based on waterborne vehicles or pigments they offered to the marine coatings manufacturers.

Firm	Location	Contact	Possible Product
Cargill, Inc.	Minneapolis	none	"Cargill" 7407
Celanese	Louisville	Cliff Dukes	"Epicure" RDX-1647
Dexter-Midland	Waukegon	none	"Strudex" MD-100
Henkel/Gen. Mills	Hoboken	none	"Genepoxy" M-220
NL Industries	Highstown	none	"Titanox" 2020
Rohm & Haas	Philadelphia	Dave Watson	"Phoplex" MV-23
Spencer Kellogg	Buffalo	Dave Norby	"Aralon" 820-W49
Union Carbide	Garland	Ray Pierrehumbert	"UCAR" 4358
R. T. Vanderbilt	Norwalk	William County	"Vansil" W

The five respondents have been advised that the present project will concentrate on coatings now commercially available and with proven good performance as a marine coating or equivalent. So far, references from these material suppliers for paints using their recommended products is to be passed on through Sigma Coatings, Reliance Universal (Prufcoat), and Carboline.

TASK B. PAINT MANUFACTURERS

In the last month we have written the sample letter attached to our July Progress Report to the following paint manufacturers:

Firm	Location	Contact
Ameron	Brea, Ca.	Dan Gelfer
Carboline	St. Louis	Ernie Skiles Dennis Bryant Bill Rosenbaum John Mantle Paul Lodenwyck

Firm	Location	Contact
Reliance Universal	Houston, Tex.	Wally MacMahan
Bywaters Sales & Ser. Co.	Belle Chasse, La.	Nils Wirstrom
E. I. duPont de Neumours Co.	Wilmington, Dela.	Dr. Nicholas Pappas
Farboil Co.	Baltimore, Md.	Jerry Semerad
Glidden-Durkee Div.	Cleveland, Ohio	Don Nemunaitus
Hempel's Marine Paints, Inc.	New York, N.Y.	F. Olander
Hempel's Offshore Coatings	South Houston, Tex.	Peter Treleaven
Hughson Chemical Co.	Houston, Tex.	R. Keith Redford
International Paint Co.	New York, N. Y.	Wm. Norman Duncan
Koppers Company	Pittsburgh, Pa.	Charles Dorsey
Mobil Chemical Co.	Edison, N. J.	Michael J. Masciale
Mobil Chemical Co.	New York, N. Y.	Theodore W. Nelson
Napko Corp.	Houston, Tex.	Joseph E. Rench
Patterson-Sargent	New Brunswick, N. J.	P. J. Milazzo
Porter Paint Co.	Louisville, Ky.	Bob Goggins
PPG Industries, Inc.	Pittsburgh, Pa.	(Manager)
Sherwin-Williams Co.	Cleveland, Ohio	Ronald F. Curley
Sigma Coatings, Inc.	Harvey, La.	Dr. Max Winkler
Southern Imperial Ctgs. Corp.	New Orleans, La.	Tom Bauer
Sigma Coatings, Inc.	Harvey, La.	Richard T. Pope

As of this writing we have replies from Carboline, Mobil Chemical and Hughson Chemicals. The first two have many suggestions which we will review for our next report and consult with you on the selection. You indicated we will also hear from International Paint.

CARBOLINE VISIT

Our August 14 visit to Carboline Co. in St. Louis was helpful in identifying solvent-borne controls and we got a good perspective on the status of waterborne candidates. Specifically, Carboline management feels strongly that waterborne zinc rich primers must be thoroughly dried in every corner before any overcoating or exposure to a corrosive environment. Their experience is that no waterborne zinc rich has reached the level of corrosion protection of zinc rich deposited from an alcohol-borne system. However, they do have three formulations of waterborne zinc with the third one planned to be introduced in early 1980 that may be a viable candidate for practical shipboard and shipyard use. As you indicated, there is no problem with good waterborne zinc rich inside your controlled-air finishing rooms. The problem, which is the essence of our research project, is obtaining full dry of waterborne paint applied aboard ship.

TASK C. ANALYSIS FOR MARINE USE

Data is coming in.

TASK D. LABORATORY TESTING

As reported last month you have suggested we use present marine solvent-borne coating standards in the 9 tests shown, probably plus a cathodic dis-bondment test, instead of the performance specifications in Mil-P-28577A and 28578A. We are working at defining these tests and estimating what effect the change may have on the amount of laboratory time required.

The standard materials you suggested we use, a product number as suggested by Carboline, thickness and MILITARY spec reference for the test method is shown in the following table for your review and comment: This does not imply we have settled on Carboline controls. These are for initial commercial identification.

Standard Coating	Carboline No.	Dry Thickness	Test Methods
Inorganic Zinc	C2-11	3 mils	Mil-P-23236
Epoxy Polyamide	190HB	8 mils	Mil-P-24441
Coal Tar Epoxy	Carbomastic 14*	16 mils	Mil-P-23236
Cl Rubber	3630	7 mils	not identified
Acrylic	1294	6 mils	not identified
Alkyd	GP-62	6 mils	Mil-P-15146B
Urethane	1341	1.5 mils	not identified

* Carbomastic 16 is sold as passing spec. Carbomastic 14 is 75% total solids.

BUDGET

Funds Expended:	July	August
Personal Services	$ 503.00	$ 1,340.15
Total each month	$1,037.25	$ 2,705.31
Total to date	$1,037.25	$ 3,742.56

FUTURE PLANS

Besides writing to some other coating suppliers we plan to follow our written request with phone calls.

We will appreciate your comments about the suppliers cooperation and the test methods for our laboratory testing.

Sincerely,

Frank A. Rideout
Principal Investigator
Chemical Material & Sciences Laboratory

FAR:gp

cc: A. Vita

A-2412

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

October 18, 1979

John W. Peart, Program Manager
Avondale Shipyards, Inc.
P. O. Box 50280
New Orleans, La. 70150

Re: Purchase Order N445 - Research Contract on "Waterborne Shipboard Coatings" - Ga. Tech Project A-2412; September Progress Report

Dear John:

The paint manufacturer replies to our August 13th letter requesting waterborne marine coatings information are summarized.

Carboline recommends no waterborne system at this time for water immersion service. Their recommendation is Carbomastic 15, aluminum/epoxy, which is 90% volume solids. We have requested a gallon sample to use as a control to test other offerings against and also a gallon each of Carbozinc 33 waterborne, inorganic zinc rich and Carboline 288 WB, waterborne epoxy finish coat for service above the waterline. A description of their lab setup to run cathodic disbondment tests (ASTM-G8 and G42) is expected.

DuPont has several waterborne formulations under development but none commercially avaiable. They ask how far into the future our project will accept offerings including high solids coatings.

Farboil reported only zinc, epoxy and acrylic waterborne coatings on test but nothing ready for the marine market.

International Paint will respond shortly after Jack Hickey returns from the Paint Show in St. Louis.

Hughson Chemicals advises they have no waterborne system but concentrate on urethanes from solvent.

Mobil Chemical recommends no waterborne coatings for immersion service but do offer zinc rich, high-build epoxy, acrylic and a styrene copolymer all from water:

Hull above water.....System 1: 13-F-18* Epoxy Zinc 98, HB Epoxy 91, Epoxy Enamel

System 2: 46-F-1* Inorganic Zinc 98, HB Epoxy

Exterior
Superstructure.......System 3: 46-F-1* Inorganic Zinc 42 or 44, Acrylic

System 4: 13-F-18* Epoxy Zinc, 42 or 44 Acrylic

Interior
Superstructure &
Living Space.........System 5: 13-W-11 Styrene Cop./Lead, 44 Acrylic

* If zinc is not required, substitute: 13-R-165 Epoxy which also "could be used for wire ways, engine rooms, etc."

Porter Paints recommends waterborne systems...

Non immersion service: Aqualock 6600 primer, 6610 finish
Non abrasive immersion service: Primer, Aquator 7105 emulsion (not epoxy).
Ext./Int. non immersion to replace alkyds:
Acrylic emulsion 1660 over inorganic zinc or alkyd.

Sigma Coatings - Dr. Max Winkler will phone after the Paint Show.

Materials are being gathered to set up for cathodic disbondment tests.

Funds expended in September included $755. for Personal Services and totaled $1450.00, bringing the total to date expended $5,192.57.

Sincerely,

Frank A. Rideout
Principal Investigator

FAR:gp

cc: Armand Vira, Avondale

bcc: C. J. Ray
L. E. Henton
P. Hawley
Duane Hutchison, OCA xc: OHR
Jay Wilson, OCA

A-2412

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

November 17, 1979

John W. Peart, Program Manager
Avondale Shipyards, Inc.
P. O. Box 50280
New Orleans, La. 70150

Re: Purchase Order N445 - Research Contract on "Waterborne Shipboard Coatings"
Georgia Tech/EES Project A-2412, October Progress Report

Dear John:

Since our October 18th report we have the following additional recommendations from paint manufacturers on waterborne coatings suitable for marine applications from your efforts and our requests:

Corrosion Protection Systems is uncertain about their waterborne coatings for immersion service but do offer waterborne epoxies ("Deco-Rez" made by General Polymers Corp.), and acrylics ("Acryltex" 2500 made by General Polymers Corp.), for non-immersion use as well as 100% solventless epoxies, coal tar epoxies and "vinyl ester" coatings. Samples are coming.

Celanese is gaining confidence in their waterborne epoxy/acrylics and show no change after 48 hours water soak. They will now run water immersion tests.

Devoe & Reynolds Division Grow Chemical (Bert Kloos) offers to make us a plant run of the new Celanese waterborne epoxy/acrylics if our tests with the laboratory samples look promising. They also offer waterborne epoxy but not for immersion service.

International Paint offers samples of two waterborne systems they are now evaluating. Intertuf X8921/XV1531 epoxy will be sampled to us now, and later Intertuf WCA820/WCA821 WS Cement composition. The former compared favorably with its solvent counterpart after one year sea water immersion.

Napko recommends the following "water reducible" systems:

Exterior and Cargo Holds above water and Pipe Ways	137100	2.5 mils	IZ
	8-34740	5.0 mils	Epoxy/PA
	535000	3.0 mils	Epoxy/Acrylic
Exterior Hull below water	561700	2.0 mils	Epoxy/PA
	8-34740	5.0 mils	
	7-2471	2.0 mils	
Bilges (5 to 7 mils per J. Peart)	7-2371	2.0 mils	Epoxy
Living Spaces	Various-to be discussed later.		

Funds expended in October included $912.62 for Personal Services and totaled $2,280.94.

We hope you will see us when you fly by around December 12. We want to get your reactions to the test setup we are now building for the water immersion test and the cathodic disbondment test.

Sincerely,

Frank A. Rideout
Principal Investigator

FAR:gp

A-24 2

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

January 2, 1980

John Peart, Program Manager
Avondale Shipyards, Inc.
P. O. Box 50280
New Orleans, La. 70150

Re: Purchase Order N445, Research Contract on "Waterborne Shipboard Coatings", Georgia Tech/EES Project A-2412, November-December 1979 Progress Report

Dear John:

As suggested during your visit to our laboratory December 12 and 13, we have completed the list of candidate coatings we selected together from the responses to our letter. Others may come in that we wish to consider and some may have needed to be eliminated. May we have your further suggestions and approval before we begin coating coupons of pipe for cathodic disbondment testing and 6"x12" panels for pressurized water tests? We also need data and recommendations from Sigma Coatings.

Attached are the lists of candidates we selected for performance testing as outlined in our July Progress Report for Immersion Service, Above the Waterline, Exterior Super Structure and for Interior Use. Unless you prefer other standards, we plan to use the solvent-borne Carboline coatings listed on page 3 of our August Progress Report for controls in these lab tests.

In November Personal Services were $597.74 and total expenses $1,302.35. Estimating December Personal Services at $1517. and materials at $51.50, total December expended is $2880. to bring the total to date $11,656.

Sincerely,

Frank A. Rideout

FAR:gp

Attachments 4

cc: S. L. Meredith

Project A-2412
December 14, 1979

WATERBORNE COATINGS SELECTED FOR IMMERSION SERVICE

No.	Supplier	Product	Type	Dry Thickness
1	International Paint	Intertuf X8912/XV1531	Epoxy	14.0 mils (2 coats
2	International Paint	Interlite WCA820/ WCA821	Acrylic/Cement	30.0 mils (1 coat)
3	Sigma	Colturiet WSTEN Black	CoalTar/Epoxy	To be suggested
4	Corr. Prot. System	Acratex 2550	Acrylic/Cement	25.0 mils
5	Napko	7-2371	Epoxy/Acrylic	6.0 mils*(3 coats)
6	Devoe	Bar-Rust	Silicate	25.0 mils
7	Devoe	Catha Coat 305	2 Pack Inorg. Zn	6.0 mils*(2 coats)

* These thicknesses will be increased for comparison testing.

Project A-2412
December 14, 1979

WATERBORNE COATINGS SELECTED FOR ABOVE WATERLINE

No.	Supplier		Product	Type	Dry Thickness
1	Devoe		Deuran 259	Acrylic/Epoxy	9.0 Mils (2 coats)
2	Porter		Aqualock 6600	Acrylic/Epoxy	2.5 mils (2 coats)
		plus	Aqualock 6610	Acrylic/Epoxy	5.0 mils (2 coats)
					7.5 mils (3 coats)
3	Mobil		Val-Chem 98 Series	Hi B Epoxy/PA	10.0 mils (3 coats)
4	Napko		137100	Inorganic Zn	2.5 mils
		plus	8-34740	Hi B Epoxy/PA	5.0 mils
		plus	535000	Epoxy/Acrylic	3.0 mils
					10.5 mils (3 coats)
5	Corr. Prot. Systems		Acratex 2550	Acrylic/Cement	(This may not be suitable)
6	Bywater		Zinc-Gard 108	Inorganic Zn	3.5 mils
		plus	Flex-Gard 500	Acrylic Latex	2.5 mils
					6.0 mils (2 coats)
7	Carboline		CZ-33	Inorganic Zn	3.0 mils
		plus	288 WB	Epoxy/Acrylic	4.0 mils (2 coats)
					7.0 mils (3 coats)

Project A-2412
December 14, 1979

WATERBORNE COATINGS SELECTED FOR EXTERIOR SUPERSTRUCTURE

No.	Supplier		Product	Type	Dry Thickness
1	Bywater		Zinc-Gard 108	Inorganic Zn	3.5 mils
		plus	Aqua-Poxy 370	Epoxy Acrylic	2.5 mils
					6.0 mils (2 coats)
2	Mobil		46-F-1	Inorg. Zn	2.5 mils
			44 Series Acrylic	Pure Acrylic	3.0 mils (2 coats)
					5.5 mils (3 coats)
3	Carboline		C2-33	Inorganic Zn	3.0 mils
		plus	288 WB	Epoxy/Acrylic	4.0 mils (2 coats)
					7.0 mils (3 coats)
4	Union Carbide		5JG-66	Mod. Acrylic	5.0 mils (2 coats)
		plus	LP-3679A	Mod. Acrylic	2.6 mils
					7.5 mils (3 coats)
5	Sigma		LP-3702	Latex	3.0 mils (2 coats)
		plus	LP-3679A	Latex	4.0 mils (2 coats)
					7.0 mils (4 coats)
6.	Napko		561700	Epoxy/PA	2.0 mils
		plus	535000	Epoxy/Acrylic	3.0 mils (1 or 2 coats)
					5.0 mils (2 or 3 coats)

Project A-2412
December 14, 1979

WATERBORNE COATINGS SELECTED FOR INTERIORS

No.	Supplier		Project	Type	Dry Thickness
1	Sigma		LP-3702	Latex	3.0 mils (2 coats)
		plus	LP-3679A	Latex	4.0 mils (2 coats)
					7.0 mils (4 coats)
2	Devoe		Devflex Primer	Alkyd	6.0 mils (2 coats)
		plus	Devflex I	Acrylic(?)	2.0 mils (1 coat)
					8.0 mils (3 coats)
3	Mobil		13-W-11	Styrene Copolymer	3.0 mils (1 coat)
		plus	44 Series Acrylic	Pure Acrylic	3.0 mils (2 coats)
					6.0 mils (3 coats)
4	Bywater		Byco 500-1	(To be identified)	4.0 mils (2 coats)
		plus	Byco 500 Finish		4.0 mils (2 coats)
					8.0 mils (4 coats)
5	Napko		PN 4489		2.0 mils (1 coat)
		plus	PN 4499		3.0 mils (to be detn.)
					5.0 mils

((

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

March 17, 1980

John Peart, Program Manager
Avondale Shipyards, Inc.
P. O. Box 50280
New Orleans, LA 70150

Re: Purchase Order N445 Research Contract on "Waterborne Shipboard Coatings", Georgia Tech/EES Project A-2412, January-February 1980 Progress Report

Dear John:

We have started to apply the coatings we have on hand that we selected after our phone agreement of modification to the four lists attached to our January 2, 1980 report. These are summarized in two pages to avoid duplication of paint systems and to show the tests we are now beginning.

All the selected paints have been requested from the suppliers. We will be checking on the delivery of the samples not yet received within the next four days. We would especially appreciate your interceding with Sigma. Glenn Sugart of their lab agreed to get some latex samples and information off to us after talking with Max Winkeler. I also asked, by phone, for an appointment during the March 26-28 Marine Coating Conference.

Expenses are as follows:

	January	February	Total through February 29,
Personal Services	703.78	848.42	6,834.12
Total Expenses	1414.50	1584.21	13,962.53
Balance in Budget			19,741.47

I look forward to seeing you during the meeting to go over any questions or suggestions you may have. Especially important will be the paper from Cargocaire Marine Systems on dehumidification equipment.

Sincerely,

F. Rideout, Project Director
Chemical and Material Sciences Lab

FR/pr

cc: S. L. Meredith, Avondale

PROJECT A-2412

WATERBORNE COATINGS FOR SHIPBOARD USE

COATING SYSTEMS SELECTED FOR TEST

March 12, 1980

SHEET 1

IN WATER IW	ABOVE AW	SS	IN	Supplier	Product	Coating Type	Mil Thickness	Coats	32 psi. Immersion	B117 D1654 D714 Salt Spray	OCT 120°F 100% Humidity	G26 D523 WOM	141a 6192 Taber	D523 Gloss	D2486 Scrub	180°F Water	150°F Oil	MOD. G-8 Cathodic Disbond	Sample on Hand	
X				Int'l Pt	X8912	EpCoal	14.	2	(X)	X						X	X	X	1 gal.	1
X				Sigma	WS Ten	EpCoal	10.	2	X	X						X	X	X	1 qt.	2
X				Con Prot	2550	AcrCement	25.	1	X	X	X	X	X			X	X	X	1 qt.	3
X				Napko	7-2371	Ep Acr	6.	2	X	X	X	X	X			X	X	X	1 qt.	
X				Devo	BarRust	Silicard	25.	2	X	X						X	X	X		
	X			Devoe	Devran259	EpAcr	9.	2		X	X	X	X	X						
	X			Porter	6600	Ep Acr	2.5	1											1 gal.	5
					6610	Ep Acr	5.0	2		X	X	X	X	X					1 gal.	
	X			Mobil	98	HB Ep PA	10.	3		X	X	X	X	X						
	X			Napko	137100	IZ														
					B-34740	HB Ep PA													1 qt.	
				[illegible]	655000	Ep Acr	10.5	3		X	X	X	X	X					8 qt.	
	X			ByWater	108	I Z	3.5	1												
					500	Acrylic	2.5	1		X	X	X	X	X						
	X	X		Carbo	33	I Z	3.	1											1 gal.	
					288 WB	Ep Acr	4.	2		X	X	X	X	X	X				1 gal.	6
	X			Sigma	7445	Ep	3.	1		X	X	X	X	X					1 qt.	7
	X			Ameron	2120	Mod. Ep	4.	2												
					2133	Ep Acr	2.5	1		X	X	X	X	X						
									30	10	10	30	.5	.1	.3	21	.5	30		
									14	54	50	50	28	46	30	14	14	16		
									12	3	26	26	14	20	16	12	12	12		
									.06	.10	.02	.02	.12	.02	.13	.02	.10	.20		
									10	3.02	5.2	15.6	1.68	.4	2.08	5.04	1.2	1.2		
Controls																				
X				Carbo	CM14	EpCoal	14.	2	X	X						X	X	X		
X	X	X	X	Carbo	190HB	Ep PA	9.	2	X	X	X	X	X	X	X	X	X	X		

PROJECT A-2412

WATERBORNE COATINGS FOR SHIPBOARD USE

COATING SYSTEMS SELECTED FOR TEST

March 12, 1980

SHEET 2

IN / ABOVE WATER IW AW	SS	IN	Supplier	Product	Coating Type	Mil Thickness	Coats	32 psi. Immersion	B117 D1654 D714 Salt Spray	QCT 120°F 100% Humidity	G26 D523 WOM	141a 6192 Taber	D523 Gloss	D2486 Scrub	180°F Water	150°F Oil	MOD. G-8 Cathodic Disbond	Sample on Hand	
	X		By Water	108	I Z	3.5	1												
				Ap 370	Ep Acr	2.5	1		X	X	X	X	X	X					
	X		Mobil	46F1	I Z	2.5	1												
				44	Acrylic	3.0	2		X	X	X	X	X	X					
	X	X	Ameron		Mod. Acr	5.	2												
					" "	2.5	1		X	X	X		X	X					
—	X	X	Sigma		" "	5.	2												
					" "	2.5	1		X	X	X		X	X					
	X	X	Mobile	3743	" "	5.	2												
				3744	" "	2.5	1		X	X	X		X	X					
	X	X	Napko	561700	Ep PA	2.	1												
				535000	Ep Acr	3.	2		X	X	X		X	X				1 gal.	10
	X	X	Celanese	85379	Ep Acr	2.	1											4 qt.	
				3537E	Ep Acr	3	2		X	X	X		X	X				4 qt.	11
		X	Devoe	Devflex	Alkyd	6	2												
				DevflexI	Acr	2.	1		X	X	X		X	X					12
		X	Mobil	13 W11	Styrenecop	3.	1												
				44	Acrylic	3.	2		X	X	X		X	X					
		X	ByWater	500-1	Mod Acr	4.	2												
				500	Acrylic	4.	2		X	X	X		X	X					
		X	Napko	PN4489		2.	1												
				PN4499		3.	1		X	X	X		X	X					
	X	X	Rel. Univ.	130	PCIZ	3.	1												
				7633	Acrylic	4.	2		X	X	X		X	X					13
	X	X	Celanese	8535P	Ep Acr	2.	1											4 qt.	
				8535E	Ep Acr	3.	2		X	X	X		X	X				4 qt.	14
Controls																			
	X	X	Carbo	GP-10	Alkyd	2.	1											1 gal	

OHR
A2412

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

April 16, 1980

Mr. John Peart, Program Manager
Mr. S. L. Meredith
Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, LA 70150

Re: P.O. 445 Research Contract Modification

Gentlemen:

Attached is the Progress Report for March, 1980 that explains the delay in the Work Schedule due to slow receipt of candiate samples.

As agreed when Mr. Rideout met with you in New Orleans, March 26 & 27, 1980 at the Marine Coatings Conference, we request a time extension of three months* to complete the work planned with no change anticipated in the monetary consideration.

Please also acknowledge that the Work Plan, as shown in our Progress Report for July, November-December, 1979 and for January-February, 1980, has been altered in many details by direction from John Peart and is satisfactory for completion of the contract. The objectives and general plan of evaluation remain the same but a broader review of waterborne coatings for all areas of the ship for example with more severe tests has been replaced for the narrower performance tests given in MIL-P-28578A discussed under TASK D on page 28 of our Technical Proposal dated October 17, 1978.

Besides the broader approach to the use of waterborne shipboard coatings evaluation the change from the original proposal is also dictated by the disappointing response from the paint suppliers. Communications from the raw material suppliers indicated good progress had been made in the commercial development of durable waterborne industrial coatings suitable for marine service. Most coatings manufacturers are not ready to make that claim and say they are still doing their own testing and comparing alternative components. Most important, their customers and government regulations have not been pushing them to go to waterborne so the development work has not been top priority for their lab people.

We started this project by requesting waterborne coatings that were already being sold for marine or comparable heavy duty maintenance painting and we found a few, but now we are getting coating samples to evaluate that have shown promise in laboratory and limited field testing. In a few cases we are getting coating samples made by paint suppliers that depend on data given them by a raw material supplier. Simultaneously, they will run their own field and lab testing.

If you would like further information on our mutual advantage to extend the contract term, we will be pleased to respond to your questions. We appreciate this

*(through September 30, 1980) DSR

A-2412

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

April 16, 1980

Mr. John Peart, Program Manager
Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, LA 70150

Re: P.O. 445, Research on "Waterborne Shipboard Coatings"
Georgia Tech/EES Project A-2412, March 1980 Progress Report

Dear John:

As discussed in New Orleans March 27th, we are proposing by separate letter the term of the contract be extended through September, 1980 because of the delay in obtaining candidate coating samples from the paint manufacturers.

Our Jan.-Feb. Progress Report listed 26 waterborne candidate coatings which we selected together plus three control systems in organic solvents. We have since received coating samples for three more systems bringing the total on hand to 15 out of 26 which were offered.

Follow-up phone calls usually reveal that the coating supplier is still modifying and checking his product; sometimes to check out another raw materal supplier claims. In order to finish reasonably within the time frame of our agreement as modified by our current proposal we must make this month the deadline for candidates to be received. A meeting with many of the suppliers March 26 & 27 at the New Orleans NPCA conference brought new promises of cooperation.

The pipe specimen and panels for the tests planned for "In Water" and "Above the Waterline" for the first four candidates listed last month and the controls are all applied and some are on test for immersion, salt spray, and humidity. So far all samples look good after 20 days in 32 psi water immersion. Within a few days the first test for cathodic disbondment will be operating.

March expenses are as follows:

	March	Total to March 31
Personal Services	$1745.31	$8579.43
Total Expenses	3292.39	$17254.92
Balance in Budget		$16449.08

Your comments are always welcome.

Sincerely,

Frank A. Rideout
Project Director
Chemical & Material Sciences Laboratory

FAR/pr

cc: S. L. Meredith

P.S. We plan to use #2 Diesel Oil for the 150°F dip test for two minutes if you approve.

bcc: Paul M. Hawley
Charles J. Ray
Les E. Henton
✓Bob Cassanova
Dwane Hutchison
File

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

June 2, 1980

Mr. John Peart, Program Manager
Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, LA 70150

Re: P.O. N445 Research Contract on "Waterborne Shipboard Coatings", Georgia Tech/EES No. A-2412, Progress Report for May, 1980

Dear John:

As discussed during your visit May 20 we have begun the testing of waterborne systems received to date. The list is revised as of May 19 to eliminate those samples we have not been able to get and to eliminate the scrub test as not suitable as you suggested.

New information from Celanese increases our confidence that the two new Epoxy/Acrylic systems will be practical for our use in shipyards. Devoe and Raynolds have agreed to supply pilot quantities of these formulations from their plant.

We were impressed with the dehumidification story given at the New Orleans SPCA Marine Coating Conference and have received further recommendations from Leo Crotty.

We are sorry to report a fire in our lab oven that blew off one of the heavy doors from igniting the #2 diesel fuel in our oil immersion test after less than two weeks. The coatings are all charred beyond salvage. Fortunately no one was hurt.

April expenses are as follows:

	April	Total to April 31
Peronsal Services	$1161.36	$9740.79
Total Expenses	$2835.82	$20090.74

May charges will be available about June 16, 1980.

I believe you mentioned another waterborne sample you wanted tested. Please tell us about it so we can hold up those tests where you want it included.

Sincerely,

Frank A. Rideout
Project Director
Chemical & Material Sciences Laboratory

FAR/pr

cc: S. L. Meredith, Avondale

bcc: Chuck Ray
✓OCA
File, A-2490
Hans Spauschus

A-2412

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

404/424-9651

June 9, 1980

Mr. John Peart, Program Manager
Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, LA 70150

Dear John:

The revised list of coating systems and tests should be added to our June 2 report.

Sincerely,

Frank A. Rideout
Project Director
Chemical & Material Sciences Laboratory

FAR:pr

cc: S. L. Meredith, Avondale

Attachment

PROJECT A-2412

WATERBORNE COATINGS FOR SHIPBOARD USE

COATING SYSTEMS SELECTED FOR TEST

May 19, 1980

SHEET 1

IN WATER IW	ABOVE WATER AW	SS	IN	Supplier	Product	Coating Type	Mil Thickness	Coats	30 days 32 psi. Immersion	B117 D1654 D714 Salt* Spray	D2247 QCT 100°F 100%* Humidity	G26 D523 WOM	1000N 141a 6192 Taber	3000 rubs D523 Gloss	D2486 Scrub	180°F Water	30 days #2Diesel 150°F Oil	MOD. G-8 Cathodic Disbond	Sample on Hand
X				Int'l Pt	X8912	EpCoal	14.	2	X	X						X	X	X	1 gal.
X				Sigma	WS Ten	EpCoal	10.	2	X	X						X	X	X	1 qt.
X				CorrProt	2550	AcrCement	25.	1	X	X	X	X	X			X	X	X	1 qt.
X				Napko	7-2371	Ep Acr	6.	2	X	X	X	X	X			X	X	X	1 qt.
	X			Porter	6600	Ep Acr	2.5	1											1 gal.
					6610	Ep Acr	5.0	2		X	X	X	X	X					1 gal.
	X			Napko	137101	IZ													1 gal. + 137103 qt.
					B-34740	WB Ep PA													1 qt.
					535002	Ep Acr	10.5	3		X	X	X	X	X					8 qts.
	X	X		Carbo	CZ 33	I Z	3.	1											1 gal.
					288 WB	Ep Acr	4.	2		X	X	X	X	X					1 gal.
	X			Sigma	7445	Ep	3.	1		X	X	X	X	X					1 qt.
Controls																			
X				Carbo	CM14	EpCoal	14.	2	X	X						X	X	X	1 gal.
X	X	X	X	Carbo	190HB	Ep PA	9.	2	X	X	X	X	X	X	X	X	X	X	1 gal.

*Scribe per D1654 (ASTM)

EES 408 (8-53)

FINAL REPORT
PROJECT A–2412

WATERBORNE COATINGS FOR MARINE APPLICATIONS

By

Frank A. Rideout

Prepared for

NATIONAL SHIPBUILDING RESEARCH PROGRAM
U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION

In Cooperation with

AVONDALE SHIPYARDS, INC.
NEW ORLEANS, LOUISIANA

John W. Peart, Program Manager

Purchase Order No. N–445

June 15, 1979 – February 27, 1981

Under

DOC Prime No. 5–38071

March 1981

GEORGIA INSTITUTE OF TECHNOLOGY

Engineering Experiment Station
Atlanta, Georgia 30332

FINAL REPORT

PROJECT A-2412

WATERBORNE COATINGS FOR MARINE APPLICATIONS

BY

Frank A. Rideout

Prepared For

National Shipbuilding Research Program

U. S. Department of Commerce

Maritime Administration

in Cooperation with

Avondale Shipyards, Inc.

New Orleans, Louisiana

John W. Peart, Program Manager

Purchase Order Number N-445

June 15, 1979 - February 27, 1981

Under DOC Prime No. 5-38071

March 1981

Georgia Institute of Technology

Engineering Experiment Station

ATLANTA, GEORGIA 30332

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WATERBORNE COATINGS FOR MARINE APPLICATIONS

FOREWORD

This research project was performed under the National Shipbuilding Research Program by Georgia Institute of Technology, Engineering Experiment Station, Energy and Material Sciences Laboratory, Material Sciences Branch as subcontractor to Avondale Shipyards, Inc.

Acting under the direction of John W. Peart, Program Manager at Avondale Shipyards, Inc., this research was performed by the Georgia Tech team of Frank A. Rideout, Project Director and Senior Research Scientist, Dr. C. J. Ray, Senior Research Scientist and Head of the Materials Sciences Branch, Leslie E. Henton, Research Scientist, and Paul M. Hawley, Technician.

Special appreciation is given to the many chemical companies and paint manufacturers who supplied paint samples, product information, and field data where available.

Particular appreciation is due Mr. Peart for his patience, help, and advice in locating suitable materials and planning the actual test program.

EXECUTIVE SUMMARY

This project reviewed waterborne paint binders and manufactured paints made from them, their effectiveness in demanding environments, their limitations and their application requirements and tested eighteen systems in nine laboratory, accelerated tests for suitability in marine service.

Laboratory tests of eighteen waterborne coating systems in comparison with three standard solvent borne systems support the recommendation that pilot shipboard painting trials be scheduled for various ship areas.

Specific waterborne systems, including latex over zinc-rich primers, are suggested for trial on interiors, superstructure, above-water hull, and in immersion service. The fire rating of DEVRAN 258 may be particularly valuable.

Precautions to increase likelihood of success are discussed including adequate film drying and coalescence. Dehumidification equipment to dry the ambient air is available and a design factor for removing water of 0.031 pounds per square foot of substrate painted per hour with 10 dry mils of waterborne coating is suggested.

LIST OF FIGURES

LIST OF TABLES

WATERBORNE COATINGS FOR MARINE APPLICATIONS

1.0 CONCLUSIONS AND RECOMMENDATIONS

Waterborne coatings are now being developed which appear promising for use aboard ship and in drydock based on limited laboratory testing and reports of trials under severe exposure conditions provided the suggestions for surface preparation and drying are followed. This laboratory evaluation indicates candidates which may be selected for trials under actual shipboard and shipyard conditions. Longer drying times than those recommended by the coating manufacturer in some cases gave coatings with better resistance to water immersion and salt spray. For trials in an actual marine atmosphere careful attention to substrate temperature, air temperature, humidity and circulation during the drying cycle is recommenced. Properly applied, waterborne coating systems appear to perform in laboratory tests comparably with solvent borne marine coatings now in use.

Evaluation has been made for laboratory test performance when applied as suggested by the coating manufacturer. The thickness varies widely as a result and must be considered in a total economic evaluation.

The cost of the paint and its coverage in square-foot-mils per gallon, or the volume solids, have not yet been considered in this preliminary evaluation. The labor cost related to the mils thickness per coat needs to be a part of the final choice. These factors will vary with the general business climate and as these new products are improved while field experience is developed and competition works its pressures.

The present program compares the waterborne coatings for each ship service using appropriate standard laboratory tests in comparison with established solvent systems for control. Trials of these coatings on a ship are suggested so that comparisons may be made under similar exposure conditions, one against another and against a control from solvents when all are applied under the same conditions of temperature, humidity, and surface preparation. Ideally all of the water and most of the slow evaporating chemical additives in the paint must evaporate before encountering the service conditions that tend to attack the paint.

1.1 IMMERSION SERVICE

The best laboratory performance was with DEVRAN 258, a new proprietary waterborne coating from Devoe Marine Coatings Co., a division of Grow Group, Inc. DEVRAN 258, originally called BAR RUST II, is identified only as an epoxy silicate and contains the least volatile organic content (VOC) of all their coatings offered for our evaluation (66 g.VOC/liter).

It is the heaviest coating (20 mils) of those tested for immersion service and outperformed both solvent controls in resistance to rust spreading at the scribe in the 500 hour salt fog(spray) test, resistance to softening in #2 diesel fuel, and blistering in the cathodic disbondment test.

For immersion service all original manufacturers' recommendations were for a single coating although at different thicknesses. For maximum service the Carboline solvent control 190HB is improved by a primer of CM 193 and for superior resistance to softening resistance to diesel fuel a sealer coat of DEVRAN 259 is recommended for DEVRAN 258. (See Table 1.)

International Paint's new epoxy/coal tar carried in water, called INTERTUF X8912, gave good results under 32 psi water pressure, diesel fuel immersion, cathodic disbondment, and blister resistance in the salt fog but the panels failed the rust and scribe test in salt fog and also blistered in the 150^{O}F diesel fuel test. The rating of 6 was given for each of the two panels for rusting in the scribe as well as rust spots on the flat surface.

Sigma's epoxy coal tar waterborne coating performed better in the salt fog than in immersion tests but also blistered in the disbondment test.

1.2 ABOVE-WATER HULL

Of those coatings tested for above-water hull shown in Table 2 the best performance in these laboratory tests was the Carboline waterborne inorganic zinc, CZ 33, with its topcoat of their epoxy acrylic 288WB. The relatively poor abrasion resistance observed was unexpected and needs to be confirmed. The loss of gloss after 1000 hours in the weatherometer is substantially less than that of the straight bis A epoxy coatings.

The excellent performance of DEVRAN 258 in water immersion tests makes it also a candidate for the above-water hull and the other areas of the ship as well. It now needs to be tested in the weatherometer especially in view of the excellent fire-retardant properties claimed by the manufacturer.

The test performance of only 2 mils of Sentry's waterborne epoxy ester X5822 is remarkable and is deserving of further laboratory evaluation. The salt fog blisters did not appear until after 480 hours in the 100^{o}F cabinet. Under these test conditions the SENTRY X5822 outperformed the solvent borne alkyd control coating system.

The epoxy acrylic systems shown in Table 2 offered by Napko and Porter are also candidates recommended for ship trials. Note the superior gloss retention of the Porter system and the complete freedom from blistering in salt fog, humidity, and the weatherometer. The blistering of both panels of the Napko system in the weatherometer test when none appeared in the salt fog or humidity tests may be due to the rapid drying cycling in the weatherometer which is not present in the other cabinets.

1.3 SUPERSTRUCTURE

Table 3 shows the apparent prime candidates are the epoxy acrylic waterborne systems with either a waterborne zinc-rich primer, an epoxy polyamide primer, or a primer based on epoxy acrylic. Carboline's CZ 33 and 288WB discussed above for above-water hull coating compares well here except for the abrasion resistance and gloss retention ratings.

Bywater's 108 with AP370 topcoat started with a lower gloss but measured highest gloss after 1000 hours in the weatherometer and showed excellent Taber abrasion rating. No blisters appeared in the salt fog cabinet or the humidity cabinet but a few large blisters appeared in the weatherometer after 500 hours.

1.4 INTERIOR

Table 4 lists the eight waterborne paint systems and their results for the twelve laboratory tests. If salt spray and weatherometer results are not significant for interior ship coatings, the humidity test may be the most critical factor in selecting candidates for the next phase of evaluation. These results do not indicate the need for a zinc-rich primer but longer term testing is expected to justify their use.

The DEVFLEX system might be eliminated because of blistering in 100% humidity but it is recommended that it be held as a candidate because of the bonus property of fire resistance, which may soon become a requirement, and noting that the medium density of small blisters did not occur until after 456 hours of humidity at $100^{o}F$.

The single coat of SENTRY X5822 shows a remarkable performance, only a few large blisters after 480 hours in the salt fog chamber. Because of its oleoresinous chemical nature, longer testing is suggested to estimate its value. It is low cost and only available at present in brown iron oxide color.

Systems listed in Table 4 are recommended for further review with specific ship locations and a study of the projected applied costs to help make selections for ship trials.

TABLE 1

WATERBORNE COATINGS FOR WATER IMMERSION SERVICE

LAB TEST PERFORMANCE

SUPPLIER	GENERIC PRODUCT	COATING THICKNESS (MILS)	Water Immersion 32 psi 30 days		SALT FOG 500 Hours ASTM B117			HUMIDITY 100°F ASTM D 2247 500 Hours			180°F WATER RESISTANCE 30 Days		DIESEL #2 150°F RESISTANCE 30 Days		CATHODIC DISBONDMENT ASTM G8 30 days		TABER ABRASION WEAR INDEX[c]
			RUST	BLISTERS	RUST	CREEP*	BLISTERS	RUST	CREEP*	BLISTERS	RUST	BLISTERS	SOFTENS	BLISTERS	CREEP[a]	BLISTER[b]	
Gen. Polymers	Acrylic/cement AT 2500	10	10	10	7	5	10	9	10	10	10	10	8	10	10	10	1632
Devoe	Epoxy/Silicate Devran 258**	20	10	10	9.5	9.5	10	10	10	10	10	10	8**	10	10	10	
Int'l Paint	Epoxy/Coat tar Intertuf X8912	14	10	10	6	6	10	10	10	10	10	6M	10	10	10	10	
Napko	Epoxy/Acrylic 7-2371	6	10	6MD	10	6	2F,6M	10	9	6D	10	2M	5	10	10	8M	22
Sigma	Epoxy/Coal tar WS TCN	10	10	6M	10	7	10	10	10	10	10	2M	10	10	10	6F	
Solvent Controls:																	
Carboline	Epoxy/Coal tar CM14	14	10	10	9	6	10	10	10	10	10	10	10	10	10	6M	
Carboline	Epoxy/PAmide 190HB***	9	10	6M	7	5	10	10	10	10	10	2M	6	10	10	2F	34

* No loss of adhesion at scribe, ASTM D3359; rating is rust, ASTM D 1654. (10 = no change, 0 = complete failure.)

** Devran 258 needs 2 mils of sealer topcoat Devran 259.

*** Carboline 190HB needs 2 mils of Carboline primer CM193.

a Undercutting at holiday.

b Blisters rated by ASTM D 714.

c Wear Index is the average of two measurements in milligrams/1000 cycles. Federal Standard 141a 6192.

TABLE 2

WATERBORNE COATINGS FOR ABOVE WATER HULL

LABORATORY TEST RESULTS

SUPPLIER	TYPE	PRODUCT	COATING THICKNESS (MILS)	SALT FOG 500 Hours ASTM B 117 RUST	SALT FOG CREEP*	SALT FOG BLISTERS	HUMIDITY 500 Hours ASTM D 2247 RUST	HUMIDITY CREEP*	HUMIDITY BLISTERS	WEATHEROMETER 1000 Hours ASTM G 26 RUST	WEATHEROMETER BLISTERS	WEATHEROMETER INITIAL GLOSS	WEATHEROMETER FINAL GLOSS**	TABER ABRASION WEAR INDEX	ADHESION AT SCRIBE SALT FOG 500 Hours
Carboline	Inorg. Zn	CZ 33	3												
	Epoxy/ Acrylic	288WB	4												
			7	10	10	10	10	10	10	10	10	58	16	945	5
Devoe	Epoxy/ Acrylic	259	9	10	10	2F	10	10	4D	10	4F	91	4	28	5
Napko	Inorg. Zn	1371	2.5												
	Epoxy PA	8-3474	5.0												
	Epoxy Acrylic	5357	3.0												
			10.5	10	10	10	10	10	10	10	4F	28	8	33	5
Porter	Epoxy	6600	2.5												
	Acrylics	6610	5.0												
			7.5	9	8	10	10	10	10	10	10	63	45	27	10
Sentry	Epoxy Ester	X5822	2	9	9	2F	10	10	10	10	10	39	9		5
Sigma	Epoxy	7445	3	5	4	8M	10	10	6D	8	8D	84	4	11	3
Solvent Controls:															
Carboline	Ep Coal tar	190 HB	9	7	6	10	10	9	10	10	2F	4	1	34	10
Carboline	Alkyd	GP-10	2												
	Alkyd	GP-62	2	10	9	2F	10	10	10	10	4F	59	11	42	5
			4												

* No loss of adhesion at scribe. Rating is rust at scribe by ASTM D 1654

** Gloss measured by ASTM D 523 initially and after 1000 hours.

*** Wear Index is the average of two measurements in milligrams per thousand cycles, Federal Standard 141a 6192.

TABLE 3

WATERBORNE COATINGS FOR SUPERSTRUCTURE
LABORATORY TEST RESULTS

SUPPLIER	TYPE	PRODUCT	COATING THICKNESS (MILS)	SALT FOG 500 HRS. ASTM D 117 RUST	SALT FOG CREEP*	SALT FOG BLISTERS	SALT FOG ADHES'N	HUMIDITY 500 HRS. ASTM D 2247 RUST	HUMIDITY CREEP*	HUMIDITY BLISTERS	HUMIDITY ADHES'N	WEATHEROMETER 1000 Hours ASTM G 26 RUST	WEATHEROMETER BLISTERS	WEATHEROMETER INITIAL GLOSS	WEATHEROMETER FINAL GLOSS	TABER ABRASION WEAR INDEX
By Water	Inorg. Zn	108	4													
	EpAcrylic	AP 370	3	10	10	10	5	10	10	10	5	10	2F	41	23	35
Carboline	Inorg. Zn	CZ233	3													
	EpAcrylic	288WB	4	10	10	10	5	10	10	10		10	10	58	16	946
Celanese	EpAcrylic	24-192	2													
	EpAcrylic	24-146	2	10	10	8D	5	10	10	10		10	4MD	69	4	
Celanese	EpAcrylic	24-194	2													
	EpAcrylic	24-178	3	10	9	10	5	10	10	10		8	2M	93	9	
Devoe	EpAcrylic	259	9	10	10	2F	5	10	10	4MD		10	4F	91	4	28
Mobile Pt	Mod Acrylic	3743	5													
	Mod Acrylic	3744	3	6	8	6D	5	10	10	10	5	10	6F	1	0	
Napko	Epoxy PA	5617	2													
	EpAcrylic	5357	3	10	9	6M	5	10	9	4F	5	10	4D	69	11	
Reliance	Inorg. Zn	130	3													
Universal	Mod Acrylic	7633	4	8	8	2MD	5	10	10	4D		10	10	44	9	
SOLVENT CONTROLS																
Carboline	Epoxy PA	190HB**	9	7	6	10	5	10	9	10		10	2F	4	1	34
Carboline	Alkyd	GP-10	2													
	Alkyd	GP-62	2	10	9	2F	5	10	10	10		10	4F	59	11	42

* No loss of adhesion at scribe by ASTM D 3359. Rating is rust at scribe by ASTM D 1654.

** Carboline 190HB needs two mils Carboline primer CM193

TABLE 4

WATERBORNE COATINGS FOR INTERIOR SURFACES

LABORATORY TEST RESULTS

SUPPLIER	TYPE	PRODUCT	COATING THICKNESS (MILS)	SALT FOG 500 HRS. ASTM B 117 RUST	CREEP	BLISTERS	ADHES'N	HUMIDITY 100°F 500 HOURS ASTM D 2247 RUST	CREEP	BLISTERS	ADHES'N	WEATHEROMETER 1000 Hours ASTM G 26 RUST	BLISTERS	INITIAL GLOSS	FINAL GLOSS
Celanese	Ep Acrylic	24-192	2												
	Ep Acrylic	24-146	3	10	10	8D	5	10	10	10	5	10	4MD	69	4
Celanese	Ep Acrylic	24-194	2												
	Ep Acrylic	24-178	3	10	9	10	5	10	10	10	5	8	2M	93	9
Devoe	Latex	Devflex	6												
(F/R)*	Mod Acrylic	Devflex I	2	8	9	6F	5	10	10	8M	5	10	10	29	14
Mobile Pt	Mod Acrylic	3743	5												
	Mod Acrylic	3744	3	6	8	6D	5	10	10	10	5	10	6F	1	0
Napko	Acrylic	PN 4499	2												
	Acrylic	PN 3801	3	7	8	20	5	10	10	10		10	6F	26	4
Napko	Epoxy PA	5617	2												
	Ep Acrylic	5357	3	10	9	6M	5	10	10	10	5	10	40	69	11
Reliance	Inorg. Zn	130	3												
Universal	Mod Acrylic	7633	4	8	8	2MD	5	10	10	40		10	10	44	9
Sentry	Epoxy Ester	X 5822	2	9	9	2F	5	10	10	10		10	10	40	9
SOLVENT CONTROLS															
Carboline	Epoxy PA	190HB	9	7	6	10	5	10	9	10	5	10	2F	4	1
Carboline	Alkyd	GP10	2												
	Alkyd	GP62	2	10	9	2F	5	10	10	10		10	4F	59	11

* F/R - also has low flame spread rating.

2.0 PROJECT PLAN OF ACTION AND RESULTS

To become competitive with foreign shipbuilding, the U. S. shipyards' research in materials has been supported by the Merchant Marine Act of 1970. This National Shipbuilding Research Program must accomplish greater productivity created by new and improved technology.

The science of painting ships both interior and exterior has a part in this program and the applied technology has lagged behind known industrial coating technology progressing elsewhere in the U. S. economy. This is partly due to the difficult application conditions in shipyards and a reluctance to try new, unproven procedures and materials. Canada has found so few working days per year due to weather that are suitable for painting that they have built enclosed and conditioned dry dock facilities. Present module or subassembly construction permitting shop painting is one area where the newly developed waterborne coatings can be tried on a pilot scale to prove out their performance compared to established marine coatings.

Corrosion engineers agree that the performance of every type of commercial coating is substantially enhanced by cleaning the steel to white metal. They also agree that all primers perform best when applied immediately before any rust or contamination can interfere with the binder in the primer making intimate contact with the steel surface.

Experience shows that the thicker a given paint is applied, the more protection, but the choice of generic type, the quality of the formulation and proper application technique are known to be more significant in producing economic coatings with trouble-free, long service life. It is in the search for better materials and better application methods (including surface preparation) that coatings research will be most productive.

Solventless and waterborne coatings are two promising directions for the shipbuilding industry to look for reducing the overall costs of coating. However, other challenges face the painting task in the U. S. New environmental regulations and health and safety rules make solventless and waterborne coatings most attractive.

The organic coatings industry is in the midst of a severe challenge to provide durable coatings amenable to current and imminent restrictions on the amount of solvents and other volatile organic materials traditionally used to conveniently apply paints. This challenge started with Rule 66 instituted by the Los Angeles County Air Pollution Control District in July of 1967. Today, the emphasis has switched from the nature of the volatile organic emissions to the quantity of the organic emissions, i.e., the photochemical reactivity of the solvents is no longer the prime concern. CARB (California Air Resources Board) is leading the way in establishing limits of volatile emissions; the Environmental Protection Agency is in the process of establishing such guidelines for the nation which most likely will be modeled after the CARB emissions rules.[1] These regulations are being formed by the interplay of many legal, political, environmental, and safety oriented forces.

The marine coatings industry is directly affected by these emission restrictions. The proposed CARB standard to be fully implemented in 1985 calls for a limit of 295 grams of solvent per liter of paint.[2,3] The exemptions granted for epoxy based coatings, polyurethanes, and vinyls are only temporary. The lead time required to confirm the performance of new coating systems and formulations by field trial makes it absolutely necessary for the marine coatings industry to start evaluating coating systems designed to meet the probable regulations of the near future.

There are several avenues to compliance to meet the limits on the amount of solvent emissions in applying coatings. Add-on devices or techniques such as incineration of solvent fumes or absorption onto activated carbon have the advantage of allowing the coating applicator to continue to use the materials with which he is familiar and whose performance he knows. These techniques, however, are applicable only to factory or shop applied coating operations using ovens or other enclosures in which the majority of the emissions can be contained or recovered. This is not useful for the marine maintenance coating industry since most of the painting is done outdoors.

Nationwide, there is a major effort to develop waterborne coating systems to meet and surpass the volatile organic emissions restrictions. The waterborne classification covers several types of materials.

Latex systems are best known in the field of exterior house paints. Latex systems are also used in thermosetting systems in industrial coatings using, for example, water soluble or dispersible melamine type curing agents. Room temperature curing latex systems are also under development. Latex polymers are, perhaps, the most prevalent waterborne systems today because of the wide latitude in monomer selection which aids in the development of specific, desired performance properties. Hence, one can find all acrylic latexes (acrylic and methacrylic acid esters), vinyl-acrylic latexes, styrene-acrylic latexes, to mention a few.

Alkyd resins, polyester resins and epoxy ester resins are also found in the waterborne arena. Here, the polymers are usually designed to have excess or free carboxylic acid groups. Such resins are neutralized with a base to generate an ionized polymer. In this state, the resin is water soluble or dispersible depending on its acid number, degree of neutralization, and level of water miscible cosolvents. These materials are predominantly used in industrial finishes where they are crosslinked to tie-up the acid groups and reduce the water sensitivity of the films. The cure frequently requires heat so the use of these materials in a typical shipyard is unlikely or limited. Highly interesting crosslinking materials based on aziridine chemistry are available that react with the carboxylic acid group at room temperature. These materials can also be used in latex systems. The future of these crosslinking agents is doubtful at the present, however, due to their probability of being carcinogenic based on the Ames test.

Epoxy resin technology is now proving successful in the waterborne approach.[4,5,6] Epoxy esters with free acid groups can be neutralized with volatile organic bases to render them water soluble or dispersible as briefly outlined above. These materials are, subsequently, thermally cured. More germane to the marine industry which relies on coating systems that can dry and/or cure under ambient conditions is the water emulsifiable epoxy and copolymer resins.[5,6] These materials are, largely, liquid epoxy resins blended with surfactants and cosolvents that, with sufficient shearing and agitation, can generate acceptably stable oil-in-water emulsions. Water soluble curing agents are used. The epoxy resin and hardener will mix, as first the water, and then the cosolvents evaporate from the film and the emulsion droplets coalesce and react.

The application of the new, emerging coatings technologies to the marine industry is a demanding task. The coatings used on a ship must provide protection to the steel in the midst of one of the most severely corrosive environments. In addition to this pervading corrosiveness of the seawater locale, coatings are exposed to a variety of physical and chemical stresses from the handling and carrying of cargo (solvents, hydrocarbon fuels, corrosive crude oils, ore, etc.), fouling attack, and docking procedures. Because of the general severity of the marine environment to steel and the additional, localized environmental stresses on or in the various coated sections of a ship, the marine industry needs high performance, cost-effective coating systems. The application requirements for marine coatings are also difficult since most of the painting is done after construction of the ship or of major, discrete sections. The surface of the steel, hull and tank interiors for example, must be blast cleaned to at least a near-white condition to obtain the maximum performance of the coatings systems. This operation itself creates special demands in protecting the environment and workers from exposure to the blast debris and dust.

The painting of the interior of tanks and holds is especially difficult. These areas have restricted ventilation, lighting, and, often, limited access. The ventilation in these areas is important to protect the workers and provide the proper conditions for the coatings to dry and cure. The use of waterborne coating systems has the potential of significantly reducing worker exposure to potentially hazardous vapors although protection must still be provided to eliminate the inhalation of the atomized paint. Waterborne systems will still require ventilation to provide humidity control while the film is drying.

There can also be economic benefits associated with the use of high solids waterborne coatings. First, the cost of solvents would be largely eliminated: solvents are lost upon application and do not form part of the film. Secondly, the spraying of high solids film forming materials will give faster film build and require fewer applications, providing savings on the labor cost which is the major portion of the coating cost. The risk of fire and exposure to toxic materials will also be reduced with a resultant decrease in insurance costs.

The coatings application and performance standards for the marine industry are stringent. This results from the need for coatings that can provide corrosion protection to steel in the corrosive marine environment including continuous immersion, periodic seawater immersion, and exposure to seawater spray. Tank linings must not be affected by or affect the cargo they hold. This is especially true of tankers carrying aviation fuel. The application of the coatings is difficult since confined work areas are often encountered.

The above has served as a brief review of the marine coatings industry and the coating technologies available to help the marine industry meet the imminent environmental restrictions. There appear to be economic benefits in pursuing the development of waterborne coating systems which is in accord with the intent of the 1970 amendments to the 1936 Merchant Marine Act to strengthen the United States shipbuilding industry.

In addition, the use of water is in tune with the growing pressure from government regulations, environmentalists, and the public to improve worker safety and reduce pollution as represented by EPA, OSHA, TOSCA, etc. Ease of application and cleanup are further important advantages of waterborne coatings that directly affect costs.

2.2 OBJECTIVE

Determine the state-of-the art of waterborne coatings and their applicability for marine use.

2.3 PLAN OF ACTION

1. Determine the generic types of commercially available waterborne coatings.

2. Determine their usage in selected commercial applications and evaluate their effectiveness.

3. Determine their limitations and application requirements as applicable to marine use.

4. Proceed with limited laboratory testing as required to establish item (3), and to determine the generic types.

The laboratory tests appropriate to the coatings needs of the shipbuilding industry have been recently reviewed and assembled.[7] The purpose of that work, supported by the National Shipbuilding Research Program, was to provide quality control tests to maximize the probability of achieving the optimum performance from a given coating system. These tests dealt mainly with checking the wet paint properties, both in the can and freshly applied. For the development of new materials or the screening of alternate materials, several tests were recommended based on the experience of several shipyards and a review of the coatings literature.

The tests used for established coatings for U.S. military fuel and seawater ballast tanks[8] and tests for new latex primers[9] and topcoats[10] for metal surfaces used by the Naval Facilities Engineering Command were reviewed for selecting the test methods and standards most suitable for the present purpose. ASTM methods[11] were used in most cases as will be discussed individually in section 2.5.

2.4. WATERBORNE COATINGS AVAILABLE FOR TEST

2.4.1 Generic Types

From previous research done here, the following generic types of waterborne vehicles for air-dry coatings in marine use were identified.

Generic Type	Example	Source
Epoxy-Polyamide Emulsion	Genepoxy M-200	General Mills Div. Henkel
	Empirez WD510	Celanese
Styrene-Acrylic Latex	Arolon X820	Ashland Chemical
	Ucar 4341	Union Carbide
All Acrylic Copolymer Latex	Rhoplex MV-23	Rohm and Haas
Acrylic Terpolymer Latex	Ucar 4358	Union Carbide
	Rhoplex MV-9	Rohm and Haas
Acrylic-Vinyl Chloride Latex	Ucar 503	Union Carbide
Self-crosslinking Acrylic Latex	Ucar 4550	Union Carbide
Water-reducible Alkyd	Arolon 580	Ashland Chemical
Ethylene-Vinyl Acetate Latex	Airflex 500	Air Products & Chemicals
	Elvace 1962	DuPont
Ethylene-VA-VC Latex	Ucar 560	Union Carbide
	Airflex 728	Air Products & Chemicals
Vinylidene Chloride Latex	Saran Latex 143	Dow Chemical
Epoxy Ester Emulsion	CEE-5	Pacific Vegetable Oil Co.
Vinyl Chloride Copolymer Latex	Geon Latex	B. F. Goodrich
	Polyco 2607	Borden Chemical

2.4.2 WATERBORNE COATINGS RECOMMENDED BY SUPPLIERS FOR MARINE USE

To determine the usage of waterborne coatings in marine or other related commercial applications, various paint manufacturers were contacted for their recommendations of suitable waterborne coatings. The names were selected from a list composed of suppliers now working with Avondale Shipyards, suggestions made by the sources of the vehicles listed above, and other major marine coating suppliers.

The number of waterborne marine coatings already in commercial use was less than expected. In fact, no really established commercial uses were found except waterborne inorganic zinc-rich primers. Three of these were included in this study. Disappointingly few coatings were offered from successful applications in other industrial uses with severe exposure.

At this point in the study the basis for selecting coatings for testing was broadened to include developmental waterborne products that appeared promising for eventual use in marine applications. All the waterborne coatings selected (see Table 5) were recommended by their manufacturers for marine exposure conditions at the thicknesses shown and all were from coating suppliers except the two Celanese systems. These are newly developed epoxy/acrylic latexes with extensive industrial laboratory testing which Devoe Marine Coatings Co. has agreed to manufacture if larger quantities are required for field trials.

Several paint manufacturers replied that they were developing waterborne maintenance or marine coatings but none were ready for sampling. These firms included du Pont, Hughson, Farboil, Imperial and Rust-Oleum. The industry contacts for waterborne candidate coatings included nine raw material suppliers and twenty-three paint manufacturers.

2.5 Results of Laboratory Testing

The candidate coating systems were spray applied to solvent washed and aluminum oxide grit blasted test panels to the manufacturers' recommended thickness as shown in Table 5 for the specific areas of the ship reported in Tables 1 through 4. Table 6 illustrates the film thickness measurements made during laboratory preparation at nine points on each panel after each coat

TABLE 5

WATERBORNE COATING SYSTEMS TESTED

SUPPLIER	PRIMER		THICKNESS	TOPCOAT		THICKNESS
Bywater Sales & Service Co. 709 Engineers Road Belle Chase, LA 70037	ZINC-GUARD 108	Inorg. Zinc	3.5 mils	AQUA-POXY 370	Epoxy/acrylic	2.5 mils
Carboline Co. 350 Hanley Industrial court St. Louis, MO 36144	CARBO ZINC 33	Inorg. Zinc	3 mils	Carboline 288WB	Epoxy/acrylic	4 mils
Celanese Plastics & Specialties Co. 9800 Bluegrass Parkway Louisville, KY 40299	24-192	Epoxy/acrylic	2 mils	24-146	Epoxy/acrylic	3 mils
Celanese Plastics & Specialties Co. 9800 Bluegrass Parkway Louisville, KY 40299	24-194	Epoxy/acrylic	2 mils	24-178	Epoxy/acrylic	3 mils
Devoe Marine Coatings Co. P. O. Box 7600 Louisville, KY 40207	DEVFLEX Primer	Latex	6 mils	DEVFLEX I	Mod. acrylic	2 mils
Devoe Marine Coatings Co. P. O. Box 7600 Louisville, KY 40207	DEVRAN 258	Epoxy/silicate	20 mils	Same		Included
Devoe Marine Coatings Co. P. O. Box 7600 Louisville, KY 40207	DEVRAN 259	Epoxy/acrylic	9 mils	Same		Included
General Polymers Corp 3925 Huston Ave. Cincinnati, Ohio 45212	ACRYLTEX 2500	Acrylic/cement	25 mils	Same		Included
International Paint Co. Morris & Elmwood Ave. Union, NJ 07083	INTERTUF X8921	Epoxy/Coal Tar	14 mils	Same		Included

TABLE 5 (CONTINUED)

WATERBORNE COATING SYSTEMS TESTED

	PRIMER		THICKNESS	TOPCOAT		THICKNESS
Mobile Paint Co. P.O. Box 717 Theodore, AL 36582	LP 3743	Mod. Acrylic	5 mils	LP3783		2.5 mils
Napko Corp. P. O. Box 14509 Houston, TX 77021	Pipeliner 7-2371	Epoxy/Polyamide	6 mils	Same		Included
Napko Corp. P. O. Box 14509 Houston, TX 77021	Waterborne Zinc 1371*	Inorganic Zinc	2.5*mils	EPOXACRYL 5350	Epoxy/acrylic	3 mils
Napko Corp. P. O. Box 14509 Houston, TX 77021	VERSAFLEX PN 4499	Acrylic Latex	2 mils	TUX Enamel 3800	Acrylic Latex	3 mils
Napko Corp P. O. Box 14509 Houston, TX 77021	NAPKO 5617	Epoxy Polyamide	2 mils	EPOXACRYL 5357	Epoxy/acrylic	3 mils
Porter Coatings 400 S B. Street Louisville, KY 40201	AQUALOCK 6600	Acrylic/Epoxy	2.5 mils	AQUALOCK 6610	Acrylic/Epoxy	5 mils
Reliance Universal, Inc. P. O. Box 1113 Houston, TX 77001	REL-ZINC 130	Zinc-Rich	3 mils	RELTEX 7633	Mod. acrylic	4 mils
Sentry Paint & Chem. Co. Mill and Lawrence Sts. Darby, PA 19023	SENTRY X5822	Epoxy Ester	2 mils	Same		Included
Sigma Coatings, Inc. P. O. Box 826 Harvey, LA 70051	SIGMA 7445	Epoxy	3 mils	Same		Included
Sigma Coatings, Inc. P. O. Box 826 Harvey, LA 70051	SIGMA WS-TCN	Epoxy Coal Tar	10 mils	Same		Included

* Plus Intermediate 8-3470 HB Epoxy Polyamide 5 mils.

TABLE 6

THICKNESS MEASUREMENTS

Napko 7-2371

Measured Thickness (Mil)

Test										Average
Immer-sion	3.6	4.0	3.8	3.4	4.0	3.8	3.6	3.6	3.4	3.7
32 psi	6.2	6.8	6.0	6.2	6.8	7.0	7.2	6.8	6.6	6.6
Salt	3.0	3.2	3.6	3.4	3.0	3.8	4.0	4.2	4.0	3.6
Spray	6.4	6.2	6.8	4.0	6.4	7.0	6.8	6.4	6.6	6.6
100%	3.2	3.8	3.4	3.0	3.4	3.8	3.8	4.0	3.6	3.6
Humid-ity	6.4	6.6	6.0	6.4	6.8	6.4	6.2	6.8	6.4	6.4
WOM	4.0	3.8	3.8	3.6	4.0	3.2	3.0	3.2	3.4	3.6
	6.8	7.0	6.4	6.8	7.0	6.8	6.4	7.2	6.8	6.8
Oil	3.4	3.6	3.4	4.0	3.8	4.0	3.4	3.6	3.4	3.6
Immer-sion	6.2	6.0	6.8	7.2	6.4	6.6	7.0	6.4	6.2	6.5
Pipe	3.0	2.8	2.6	3.0	3.2	3.4	3.0	3.0	3.2	3.0
	6.2	6.0	6.0	6.2	6.0	5.8	6.0	6.2	6.0	6.0
180^{o}F Water	3.4	3.6	3.4	4.0	3.8	4.0	3.4	3.6	3.4	3.6
Immer-sion	6.2	6.0	6.8	7.2	6.4	6.6	7.0	6.4	6.2	6.5

TABLE 6 (CONTINUED)

THICKNESS MEASUREMENTS

Carboline 190 HB (Control)

Test	Measured Thickness (Mil)									Average
32 psi Immersion	4.6	5.0	5.2	4.8	4.6	4.4	5.0	5.2	4.8	4.8
	10.0	9.6	9.8	10.0	9.4	9.2	9.8	9.6	10.0	9.7
Salt spray	4.2	4.8	4.6	4.8	4.2	4.0	4.0	4.6	4.6	4.4
	9.4	9.2	9.8	10.0	9.6	9.4	9.2	9.8	10.0	9.6
100% Humidity	4.0	4.2	3.8	3.8	4.2	4.4	4.6	5.0	4.6	4.3
	9.6	9.8	10.0	11.0	9.8	9.6	10.0	9.8	10.0	10.0
WOM	4.2	4.6	5.0	4.8	4.4	4.6	4.8	4.2	4.6	4.6
	9.2	9.0	10.2	11.0	9.8	9.6	9.8	9.7	9.4	9.8
Oil Immersion	4.6	4.4	5.0	4.8	4.6	4.2	4.0	4.2	4.6	4.5
	9.0	9.2	11.0	10.0	9.4	9.6	9.8	10.0	9.6	9.7
Pipe	3.6	3.8	4.2	4.0	4.8	4.6	4.4	4.0	4.2	4.2
	9.2	9.0	9.4	9.2	9.4	9.4	9.6	9.2	9.4	9.3
180°F Water Immersion	4.6	4.4	5.0	4.8	4.6	4.2	4.0	4.2	4.6	4.5
	9.0	9.2	11.0	10.0	9.4	9.0	9.8	10.0	9.6	9.7

was dried. The final topcoat was air dried in the laboratory atmosphere for 14 days before exposure to the following tests.

2.5.1. Water Immersion at 32 psi

To simulate the condition for coatings for lining shipboard tanks that hold water, 6" X 12" panels were coated both sides as described above and suspended inside a five gallon pressure tank so that about 60% of the panel length was immersed in deionized water which was then pressurized by air and maintained at 32 ± 1 pounds per square inch for 30 days at room temperature. The tank was opened for a few minutes at about 4 day intervals to check for any obvious change. The results appear in Table 7.

The two solvent borne coatings and two of the four waterborne coating suggested for ballast tanks showed no effect. The Napko Pipeliner epoxy/polyamide 7-2371 which is used at only 6 mils showed no effect until the 30 day inspection. Sigma coal tar epoxy emulsion WS TCN was 10 mils thick and showed blistering at 13 days. This coating also showed whitening when removed from the water after 30 days. No rusting appeared on any panels.

2.5.2 Salt Fog Tests

The salt spray (or fog) test (ASTM Method B-117[11]) is one of the most popular laboratory tests for marine and heavy duty maintenance coating evaluations. A thorough review of the merits of the test written by Appleman and Campbell will soon be published in the Journal of Coatings Technology.[12] Duplicate 4" X 8" panels were run for 504 hours in a new cabinet conforming to ASTM B-117. The temperature was easily maintained at 35 ± 1C and 5% C.P. sodium chloride was used. A vertical scribe was cut through the coating

TABLE 7

WATER IMMERSION AT 32 PSI*

		Days of Exposure							
		4	6	11	13	17	21	25	30
Supplier	Product	Blister Rating (ASTM D 714)							
Devoe	DEVRAN 258								none
General Polymer	AT 2500								none
Napko	7-2371							none	6MD
Sigma	WS TCN				none	8D	8D	8D	6M Whitened
Controls:									
Carboline	CM 14								none
Carboline	190HB								none

* Blister ratings (ASTM D 714) after immersion in deionized water at 70°F.

exposing about 1/32" of bare metal after the 14 day drying period and exposed. The panels were rated each day for the first week and then about every 4 days until removal after 21 days (504 hours) or 22 days (528 hours).

Ratings for rust on the flat panel area through intact paint and also for rust as undercutting from the scribe down the center of the panel are given in Table 8 using the rating system described in ASTM Method D 1654. The results for the duplicate panels were virtually the same so only panel A values are shown. Tape adhesion test, ASTM Method D 3359, showed no loss of bond between the coating and the steel at the scribe after 504 or 528 hours on most panels which means a rating of 5. Sigma WS TCN was rated 4 and Sigma 7445 was rated 3.

Ratings for blisters are shown in Table 9 for the duplicate panels A and B using the rating scheme of ASTM D 714 with the code defined in a footnote.

The salt fog results are discussed in section 1.0 under each classifications of the ship areas.

2.5.3. Humidity Tests

The 100% humidity tests were run in a new Q-C-T Cyclic Environmental Tester using ASTM method D 2247 at 38 ± 1C (100 ± 2F) which provides continuously condensing humidity on the test surface of the panel. Panels were in duplicate and scribed in the same manner as for the salt fog tests. The duration was 504 hours (21 days), checked each day for one week, and then about every 4 days for signs of rust and blisters until 504 hours when the test was terminated and the ASTM tape adhesion test (D 3359) was made.

No loss of adhesion (D3359) was found on any panel except over the rust spots themselves. The rust (ASTM Method D 1654) observed is shown in

TABLE 8

SALT FOG RUST RESULTS

ASTM B 117

Supplier	Product	Rating:	Hours to Reach Rust Rating (ASTM D 1654)* 10	9	8	7	6	5	4	3	2	1
Int'l Pt.	INTERTUF X8912	Panel	96	216	336	408	504					
		Scribe	96	216	240	336	408					
Napko	7-2371	Panel	504									
		Scribe	96	216		336	408					
Carboline	CM 14	Panel	432	504								
		Scribe	96	216	240	336	408					
Carboline	190HB	Panel	48	72	336	408						
		Scribe	96	216	240	336	408					
Gen. Pol'r.	AT2500	Panel	24	48	96	504						
		Scribe	72	96	216	240	336	504				
Sigma	WS TCN	Panel	504									
		Scribe	72	96	240	336						
Sigma	7445	Panel		24	96			504				
		Scribe		24	96	216		240	504			
Devoe	DEVRAN 258	Panel	528									
		Scribe	528									
Devoe	DEVRAN 259	Panel	528									
		Scribe	528									
Porter	6600 6610	Panel	360	432								
		Scribe	192	264	432							
Napko	1371 8-3474 5357	Panel	528									
		Scribe	528									
Carboline	CZ33 288WB	Panel	528									
		Scribe	528									
By-Water	108 370	Panel	528									
		Scribe	528									
Mobile Pt.	3743 3744	Panel	24	96	264							
		Scribe	96	144	264		528					
Napko	5617 5357	Panel	528									
		Scribe	480	528								

* 10 = no rust; 1 = 75% area rusted.

TABLE 8 (CONTINUED)

SALT FOG RUST RESULTS

ASTM B-117

			Hours to Reach Rust Rating (ASTM D 1654)*									
Supplier	Product	Rating:	10	9	8	7	6	5	4	3	2	1
Celanese	24-194 } 24-178	Panel	528									
		Scribe	480	528								
Devoe	DEVFLEX	Panel	96	144	528							
	DEVFLEX I	Scribe	96	144								
Napko	4499 } 3801	Panel	96	144	264	432						
		Scribe	96	144	432							
Rel. Univ.	130 } 7633	Panel	96	144	432							
		Scribe	24	96	432							
Celanese	24-192 } 24-146	Panel	528									
		Scribe	528									
Carboline	GP-10 } GP-62	Panel	528									
		Scribe	480	528								
Sentry	X5822	Panel	480	528								
		Scribe	480	528								

Note: These data are for panel A. The duplicate panel, B, had practically the same performance. The final rating varied no more than one rating number and then only in three cases.

* 10 = no rust; 1 = 75% area rusted.

TABLE 9

BLISTER RATINGS (ASTM D 714) AFTER EXPOSURE
TO SALT FOG (ASTM B 117)

Hours of Exposure

Supplier	Product	24 Panel A	24 Panel B	48 Panel A	48 Panel B	72 Panel A	72 Panel B	96 Panel A	96 Panel B	144 Panel A	144 Panel B	192 Panel A	192 Panel B	216 Panel A	216 Panel B	240 Panel A	240 Panel B	264 Panel A	264 Panel B	312 Panel A	312 Panel B	336 Panel A	336 Panel B	360 Panel A	360 Panel B	384 Panel A	384 Panel B	408 Panel A	408 Panel B	432 Panel A	432 Panel B	480 Panel A	480 Panel B	504 Panel A	504 Panel B	528 Panel A	528 Panel B
Carboline	CP-10																																				2F
	GP-62																																				
Celanese	24-192																																			8D	8D
	24-146																																				
Napko	4499							6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	6M	2D	2D	2D	2D	2D	2D
	3801																																				
Napko	7-2371																					2F	6M	2F	6M	2F	6M	2F	6M	2F	6M	2F	6M	2F	6M	2F	6M
Rel. Univ.	130																																				
	7633							6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	2MD	2MD
Sentry	X5822																																			2F	2F
Sigma	7445													8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M	8M
Devoe	259																	4F	4F	4F	4F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F			2F	2F

* Blister Size Ratings: 8<6<4<2
* Blister Density: F<M<MD<D

All other coating systems including the solvent borne controls had no blistering through the test period: International Paint X8912, Carboline 190HB, CM14 controls, General Polymer AT2500, Sigma WS TEN, Devoe 258, Porter 6600/6610, Napko 5617/5357, Carboline CZ 33/288WB, and By-Water 108/370.

TABLE 10

RUST RATINGS AFTER HUMIDITY CHAMBER EXPOSURE

ASTM D 2247

Supplier	Product	Rating:	Hours to Reach Rust Rating (ASTM D 1654)* 10	9	8	7	6	5	4	3	2	1
By-Water	108 } 370	Panel	504									
		Scribe	504									
Carboline	CZ 33 } 288WB	Panel	504									
		Scribe	504									
Carboline	190HB	Panel	504									
		Scribe	96	216								
Carboline	GP-10 } GP-62	Panel	504									
		Scribe	504									
Celanese	24-192 } 24-146	Panel	504									
		Scribe	504									
Celanese	24-194 } 24-178	Panel	504									
		Scribe	504									
Devoe	DEVFLEX } DEVFLEX I	Panel	504									
		Scribe	504									
Devoe	DEVRAN } 259	Panel	504									
		Scribe	504									
Gen. Pol.	AT2500	Panel	456	504								
		Scribe	504									
Mobile	3743 } 3744	Panel	504									
		Scribe	504									
Napko	7-2371	Panel	504									
		Scribe	96	216								
Napko	1371 } 8-3474 } 5357	Panel	504									
		Scribe	504									
Napko	PN 4499 } PN 3801	Panel	504									
		Scribe	504									
Napko	5617 } 5357	Panel	504									
		Scribe	504									
Porter	6600 } 6610	Panel	504									
		Scribe	504									

* 10 = no rust; 1 - 75% area rusted.

TABLE 10 (CONTINUED)

RUST RATINGS AFTER HUMIDITY CHAMBER EXPOSURE

ASTM D 2247

Supplier	Product	Ratings:	Hours to Reach Rust Rating (ASTM D 1654)* 10	9	8	7	6	5	4	3	2	1
Rel. Univ.	130 } 7633	Panel	504									
		Scribe	504									
Sentry	5822	Panel	504									
		Scribe	504									
Sigma	7445	Panel	504									
		Scribe	504									

Note: Ratings for panel A and panel B for each evaluation is the same. The final rating shown is also the rating at 504 hours when test terminated.

Adhesion tested by scotch tape at 504 hours showed no lifting for all coatings; that is classified 5 by ASTM Method D 3359.

* 10 = no rust; 1 - 75% area rusted.

Table 10 with identical ratings for both panel A and B. Of the 18 systems tested, two systems showed some rust growing at points along the scribe to a maximum of 0.4 mm from the original scribe edge in one or two spots. These are shown in Table 10 as a "9" rating by the hours elapsed. One small rust spot was visible on the face of each panel for AT 2500 when they were removed at 504 hours.

Blistering on these panels, both A and B, are shown in Table 11. Five of the 18 systems tested showed some blisters. Ratings are by ASTM Method D 714 which is the same as for the salt fog tests. The code appears as a footnote in Table 9.

2.5.4 Weatherometer Tests

The Atlas 65 WR Weatherometer with a 6500 watt Xenon arc and a borosilicate glass filter was operated 102 minutes of light followed by 18 minutes of deionized water spray for 1000 hours (ASTM Method G-26).

Rust ratings at 500 and 1000 hours are given in Table 12 for panels A and B using ASTM Method D 1654. Table 13 shows the blister ratings at the same times using ASTM Method D 714. Fading or other paint problems were negligible or not evident. Discussion of the merits of various candidates appears in Section 1 under the four classifications of ship exposure conditions. The results of blistering from water penetration would be less for some coatings if longer drying was permitted before exposure to water. Another condition that will improve some waterborne coatings is a rinsing of the film with potable water after complete drying of the film and thoroughly drying again. The glycols, other slow evaporating water-coupling solvents and components of the surfactant usually present in small amounts in the paint, slowly come to the surface.

TABLE 11

BLISTER RATING AFTER HUMIDITY CHAMBER EXPOSURE

CLEVELAND CONDENSING HUMIDITY CHAMBER (ASTM D 2247)

		Hours of Exposure																			
		48		96		168		216		360		384		408		432		456		504	
Supplier	Product	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Devoe	DEVFLEX DEVFLEX I																			8M	8M
Devoe	DEVRAN 259					4M	4MD	4M	4MD									4MD	4MD	4D	4MD
Napko	7-2371									8D	8D	8D	8D	8D	8D	8D	8D	8D	8D	8D	8D
Reliance Univ.	130 7633					4M	4M	4M	4M									4D	4D	4D	4D
Sigma	7445					6D	6D	6D	6D									6D	6D	6D	6D

All other test panels showed no blisters after 504 hours:

Carboline GP-10/62, Carboline 190HB (controls), Porter 6600/6610, Napko 1371/3474/5357, Carboline CZ 33/288WB, By-Water 108/370, Mobile Pt. 3743/3744, Napko 5617/5357, Celanese 24-194/24-178, Napko PN 4499/3801, Celanese 24-192/24-146, Sentry X5822, and General Polymer AT2500

* A and B denote duplicate panels.

TABLE 12

WEATHEROMETER RUST RATINGS

ASTM D 1654

Supplier	Product	Initial Panel		500 Hours Panel		1,000 Hours Panel	
		A	B	A	B	A	B
Napko	7-2371	10	10	10	10	10	10
Carboline	190HB	10	10	10	10	10	10
Gen'l Polymer	AT2500	10	10	3	4	Taken out at 500 hrs	
Sigma	7445	10	10	8	8	8	8
Devoe	DEVRAN 259	10	10	10	10	10	10
Porter	6600/6610	10	10	10	10	10	10
Napko	1371/8-3474/5357	10	10	10	10	10	10
Carboline	CZ33/288WB	10	10	10	10	10	10
By-Water	108/370	10	10	10	10	10	10
Mobile Paint	3734/3744	10	10	10	10	10	10
Napko	5617/5357	10	10	10	10	10	10
Celanese	24-294/24-178	10	10	9	7	9	7
Devoe	DEVFLEX/DEVFLEX I	10	10	10	10	10	10
Napko	4499/3801	10	10	10	10	10	10
Rel. Univ.	130/7633	10	10	10	10	10	10
Celanese	24-192/24-146	10	10	10	10	10	10
Carboline	GP10/GP62	10	10	10	10	10	10
Sentry	5822	10	10	10	10	10	10

TABLE 13

WEATHEROMETER BLISTER RATINGS

ASTM D-714

Supplier	Product	500 Hours Panel A	500 Hours Panel B	1,000 Hours Panel A	1,000 Hours Panel B
Napko	7-2371	8D	8D	8D	8D
Carboline	190HB	2F*	None	2F*	None
Gen'l Polymer	AT2500			Porous Film	
Sigma	7445	4F	4F	8D	8D
Devoe	DEVRAN 259			4F	4F
Porter	6600/6610				None
Napko	1371/8-3474/5357	4F*	4F*	4F*	4F*
Carboline	CZ33/288WB				None
By-Water	108/370	8MD	8MD	2F*	2F*
Mobile	3734/3744	6F	6F	6F	6F
Napko	5617/5357	4MD	4MD	4D	4D
Celanese	24-294/24-178	2M	2M	2M	2M
Devoe	DEVFLEX/DEVFLEX I				None
Napko	4499/3801	6F*	6F*	6F*	6F*
Rel. Univ.	130/7633				None
Celanese	24-192/24-146	4MD	4MD	4MD	4MD
Carboline	GP10/GP62	6F*	4F*	4F*	4F*
Sentry	5822				None

* Fewer than 10 blisters on 3" X 9" panels

The water resistance of the residual film is improved when these are removed.[13]

2.5.5 Gloss Readings

The Weatherometer panels were measured in duplicate, A and B, for gloss readings before exposure, at 500 hours, and when terminated at 1000 hours. Measurements were made at 60° from the flat panel surface using a Gardner Glossgard and ASTM Method D 523. Table 14 reports each panel and their average readings. No requirement was requested of the supplier for gloss but some significance may be placed on the change of gloss over 1000 hours. The improvement of the epoxy/acrylic compared to the epoxy/polyamide is apparent.

2.5.6 Taber Abrasion Tests

The Teledyne Taber Abraser Model 505 using CS-10 wheels and a 250 gram loading was used for 1000 cycles according to Federal Test Method 141a, 6192. The wear index is defined as the weight loss of the film in milligrams per thousand cycles.

The results are given in Table 15 for panels A and B and their average. The high value for the portland cement/acrylic is not surprising in view of the roughness due to projecting sand particles. The reason for the high wear index of Carboline CZ33/288 is not known and repeat testing is recommended. Otherwise the abrasion resistance appeared to be in the same range for waterborne coatings as for conventional marine coatings.

2.5.7 Hot Deionized Water Immersion Tests

Table 16 reports the blistering by ASTM Method D 714 at various intervals up to 528 hours of 4" X 8" coated panels immersed about half way in

TABLE 14

GLOSS READINGS (ASTM D 523)

ON WEATHEROMETER PANELS

Supplier	Product	Initial Panel A	Initial Panel B	Initial Avg.	500 Hours Panel A	500 Hours Panel B	500 Hours Avg.	1,000 Hours Panel A	1,000 Hours Panel B	1,000 Hours Avg.
By-Water	108 370	45.5	36.4	41	31.7	33.2	32	22.8	23.9	23
Carboline	GP10 GP62	60.3	58.2	59	15.7	16.9	16	9.2	11.9	11
Carboline	CZ-33 288	64.4	51.3	58	44.9	43.6	44	13.2	19.3	16
Carboline	190HB	5.0	3.0	4	2.8	2.3	3	0.9	1.5	1
Celanese	24-192 24-146	68.4	70.4	69	11.1	10.6	11	4.4	3.0	4
Celanese	24-194 24-178	93.7	92.1	93	20.1	20.4	20	9.8	7.3	9
Devoe	Devran 259	92.7	90.0	91	9.0	9.8	9	3.4	5.2	4
Devoe	Devflex Devflex I	28.1	29.5	29	15.9	16.0	16	13.3	14.4	14
Mobile	3743 3744	1.5	1.4	1	0	0	0	0	0	0
Napko	5617 5357	71.2	66.9	69	19.8	20.0	20	11.0	10.6	11
Napko	4499 3801	25.9	25.4	26	4.8	5.2	5	3.7	3.9	4
Napko	1371/8-3474/5357	28.4	28.6	29	15.4	15.6	15	8.5	8.6	9
Porter	6600 6610	66.7	61.7	64	55.3	53.5	54	46.2	43.4	45
Rel. Univ.	130 7633	46.6	41.2	44	8.4	9.3	9	8.0	9.0	9
Sentry	5822	30.5	49.1	40	13.1	11.8	12	8.4	9.5	9
Sigma	7445	37.1	81.9	84	17.7	17.5	18	4.2	4.2	4

TABLE 15

TABER ABRADER WEAR INDEX*

Federal Test Method 141a 6192

Supplier	Product	Panel A	Panel B	Average
By-Water	108/370	42	27	35
Carboline	190 HB	33	34	34
Carboline	CZ33/288	934	957	946
Carboline	GP10/62	44	39	42
Devoe	259	27	28	28
Gen. Polymer	AT2500	1670	1595	1632
Napko	7-2371	23	21	22
Napko	1371/8-3474/5357	37	30	34
Porter	6600/6610	27	27	27
Sigma	7445	6	15	11

* Wear Index is loss in mg per thousand cycles using CS-10 wheels and a 250 gram loading.

180°F deionized water. The code for blister rating is the same as defined on Table 9. No panel showed any rust. These results are encouraging for the eventual use of waterborne marine coatings when compared to the controls. Note must be made of the manufacturer's present recommendation that Carboline 193 primer be used under Carboline 190 HB when exposed for water immersion.

2.5.8 Hot Oil Immersion Tests

A similar test immersed the coated panels individually half way in 150°F #2 diesel fuel for 30 days. The diesel fuel in which the 190 HB was immersed became dark after two days and the coated panels with AT 2500 and DEVRAN 258 were darkened by the oil after the 30 day test. The softening effect on the coatings, shown in Table 17, was measured both by probing with a knife and by pencil hardness (ASTM Method D 3363), before and after the test. The waterborne coatings appear to compare well with the conventional.

2.5.9 Cathodic Disbondment Tests

The test method is a modification of ASTM Method G8. Pipe specimens were prepared at the same time as the flat panels as described in section 2.5. Eighteen inch sections of 3/4" standard thickness iron pipe were sprayed while being slowly rotated to aid film thickness uniformity. The same recommended film thicknesses as shown in Table 5 were achieved.

Copper wire was silver-soldered to the top end of the pipe above the water level. The bottom end was sealed with a polyethylene cap. Three holidays were drilled 120 degrees apart with one in the center of the immersed length and the other two at locations one-fourth the distance from top and bottom of the immersed test length. As suggested in ASTM G8, a 1/4" diameter, circular holiday was drilled through the coating to expose bare steel without puncturing the pipe wall.

TABLE 16

BLISTER RATINGS (ASTM D 714) AFTER

EXPOSURE TO 180°F DEIONIZED WATER IMMERSION

Supplier	Product	Hours of Exposure 48	72	96	216	264	360	408	432	504	528
Devoe	DEVRAN 258										none
Gen. Polymer	AT2500										Porous Film
Int'l Paint	X8912		6M	6M	6M	6M	6M	6M	6M	6M	6M
Napko	7-2371		2M	2M	2M	2M	2M	2M	2M	2M	2M
Sentry	X5822										2,4,6,F
Sigma	WS TCN		6M	6M	6M	6M	6M	2M	2M	2M	2M
Controls:											
Carboline	CM14								8M	8M	8M
Carboline	190HB*		2M	2M	2M	2M	2M	2M	2M	2M	2M

* Primer coat of Carboline 193 not used but now recommended by manufacturer.

TABLE 17

RESISTANCE TO

30 DAYS IMMERSION IN #2 DIESEL FUEL AT 150^{O}F

				Pencil Hardness	
Supplier	Product	Softening	Stained	Before	After
Devoe	DEVRAN 258	none	film	5H	5H
General Polymer	AT 2500	none	film	3B	3B
Int'l Paint	Intertuf 8912	none		3B	3B
Napko	7-2371	slight		HB	2B
Sigma	WS TCN	none		3B	3B
Controls:					
Carboline	190HB	slight	oil	H	F
Carboline	CM14	none		2H	2H

The electrolyte was deionized water with the addition of one percent by weight of each of the following technical grade salts, calculated on an anhydrous basis: sodium chloride, sodium sulfate and sodium carbonate. This composition as specified in ASTM G8 is intended to represent a typical soil solution around a buried pipeline. Future runs might more appropriately use seawater.

The test vessel used was a five gallon polyethylene pail with the pipe specimens suspended through holes cut in the plastic cover reinforced with plywood. The center anode was zinc rather than magnesium because of the wider use of zinc metal and zinc-rich coating about the ship. Seven test pipes (cathodes) were equally spaced in a circle midway between the center anode, each other and the edge of the pail. This distance was about 2 1/2 inches. The reference electrode was a silver/silver chloride half cell immersed about 2 inches in the salt solution near the edge of the pail and the pail and at least 2 1/2 inches from any other electrode.

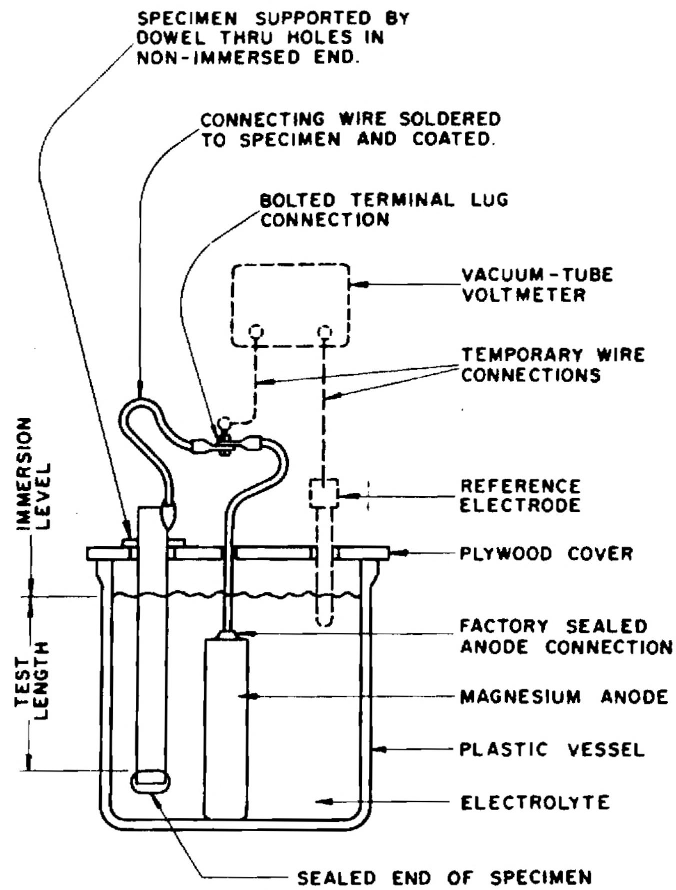
The electrical connections are shown in Figure 1 in ASTM G8 except that zinc was used for the anode and seven pipe specimens were connected where one is shown in the figure. A Simpson 360 digital volt-ohm-milliamp-meter with a power pack was used for all electrical measurements. A potential of 850 millivolts was measured between the zinc anode and the specimen pipe at each interval of the 30 day test and then the potential between the reference electrode and the specimen was recorded. The results are given in Table 18.

No rust was observed on the surface of any coated pipe; only in the 1/4 inch of bare steel. When they were removed after 30 days, blisters were noted on both of the controls and on two of the waterborne coatings. The three waterborne coatings that did not blister during the test were DEVRAN 258, General Polymer AT2500, and International Paint X8912.

The prinicipal mode of failure in the cathodic disbondment test is delamination between the steel and the coating spreading from the holiday or bare spot. No failure of this nature was observed in any specimen during the 30 day period.

FIGURE 1

ASTM G 8



TEMPORARY CONNECTIONS AND INSTRUMENTATION FOR CATHODIC DISBONDMENT TESTS (A ZINC ANODE WAS SUBSTITUTED FOR THE MAGNESIUM ANODE).

TABLE 18

CATHODIC DISBONDMENT TEST DATA

Supplier	Product	Before Holiday	After Holiday	Voltage Readings Between Coated Pipe and Reference Electrode (Millivolts) Test Duration (Hours) 2	4	8	24	48	72	144	192	240	312	360	408	648	720	ASTM D 714 Blisters 30 days
Devoe	DEVRAN 258	151	141	143	143	143	143	143	143	118	114	114	112	110	109	109	109	none
Fen'lPolymer	AT 2500	151	143	143	143	143	143	143	143	118	114	114	112	110	109	109	109	none
Int'l Paint	X 8912	151	146	143	143	143	143	143	143	118	114	114	112	110	109	109	109	none
Napko	7-2371	151	144	143	143	143	143	143	143	118	114	114	112	110	109	109	109	8M
Sigma	WS TCN	151	142	143	143	143	143	143	143	118	114	114	112	110	109	109	109	6F
Controls:																		
Carboline	CM 14	151	144	143	143	143	143	143	143	118	114	114	112	110	109	109	109	6M
Carboline	190 HB	151	146	143	143	143	143	143	143	118	114	114	112	110	109	109	109	none

3.0 DRYING WATERBORNE COATINGS

All organic coatings pickup water from a humid atmosphere, from splashing water, or immersion in water to some extent. The type of organic binder has an important influence on the water resistance, and hence durability and corrosion resistance, of any coating. A number of studies point to the superior performance of such binders as polyvinylidene chloride, hydrocarbon resins, vinyls, chlorinated rubber, acrylics, epoxy, etc. which have less chemically bound oxygen than alkyds, the old standard for most marine coatings. Each component of the dried paint will have an influence on the final water resistance and current coatings research compares these materials in an effort to formulate durable and economic paints. The organic binders have been selected from the low oxygen bearing resins for application as water-borne coatings but problems remain in the choice and amount of surfactants, antifreezing additives and other chemicals necessary to furnish stable paint.

The results of this project are testimony that good progress has been made. Some of the chemicals will slowly volatilize; others come to the surface where they can be washed or rubbed off leaving the dried coating with improved water resistance and durability. Generally, the longer the drying and the higher temperature reached during the drying phase the better.

In addition to the problem of long term, corrosion resistance, water-borne coatings may display two other corrosion phenomenon: "flash rusting" and "early rusting." Flash rusting occurs when improperly formulated water-borne coatings rust the steel during the initial drying. Heavily applied pigmented coatings may hide this rust so that the corrosion is not detected until months later. No flash rusting was observed to occur initially or in other testing with any of the waterborne coatings evaluated.

Early rusting, which physically appears like flash rusting, can occur after the film is dry to touch--hours to days after application.[14] Keeping the substrate steel cool (50^{o}F) and high atmospheric humidity after the initial drying holds water and water-coupling chemicals in the film and promotes early corrosion. Once these materials get out and the film fully coalesces, good water resistance is built up. The article by Grourke[14] suggests tests to compare paints for this early rust resistance. This phenomenon is further discussed in a later article by Dillon[15] giving a basis for selecting the type and amount of effective cosolvents.

Removing the water from the ambient air as the coating dries is essential. Circulation and elevated temperature are obvious aids but reducing the relative humidity of the air by heating without actual removal of the water may become a disappointment if the substrate temperature merely allows the moisture to recondense from the air as it cools on contact with the paint.

Leo Crotty of Cargocaire Engineering Corp. offered some solutions recently at the NPCA Marine Coating Conference.[16] Waiting for the weather or heating the steel surfaces are not practical answers. To prevent condensation in tanks being blasted and coated dehumidification of the air before entering the tank is recommended so that, regardless of weather and in spite of low surface temperatures (i.e., down to 50^{o}F for most waterborne coatings), no condensation can occur. Raising the air temperature reduces the relative humidity (RH) but does not change the (absolute) humidity or actual moisture content. Table 19 is a familiar table of RH or percent of saturation. Fortunately the relationships are well defined and the thermodynamic properties of air and moisture are well documented, so efficient machines have been designed to dehumidify recirculated air to maintain the dewpoint 5°F below the surface temperature. Whenever the ambient air dewpoint is 5°F below surface temperature. dehumidification is not needed, the dehumidifier can be shut off automatically and its operating energy saved. The thermodynamics are shown in Figure 2, which is called a psychrometric chart. Three methods of dehumidification are illustrated in Figure 3.

Cargocaire offers Model HC-9000 SEA designed for the marine coating industry to provide 9000 SCFM of dry air at 5 inches external static pressure with a normal drying capacity of 40 to 300 lb./hr. of moisture from the air. The volume solids for waterborne coatings is of the order 35 to 75 percent. Carboline 288 WB, a representative waterborne epoxy/acrylic, is 36% ± 1% solids by volume or 64% volatiles by volume. If one assumes all of the volatiles are water, 5.3 pounds will be released per gallon or for a 10 dry mil coating a square foot of surface should evaporate 0.0923 pounds of water. Allowing for an average overspray loss of 35% the water to evaporate would be up to 0.125 pounds per square foot for a 10 mil coating. Under ideal conditions, the major part of the drying would take place in 4 hours, but since the last stages of drying are so important, these drying conditions would be preferred at least overnight and up to 14 days if the ambient air would otherwise be high in humidity.

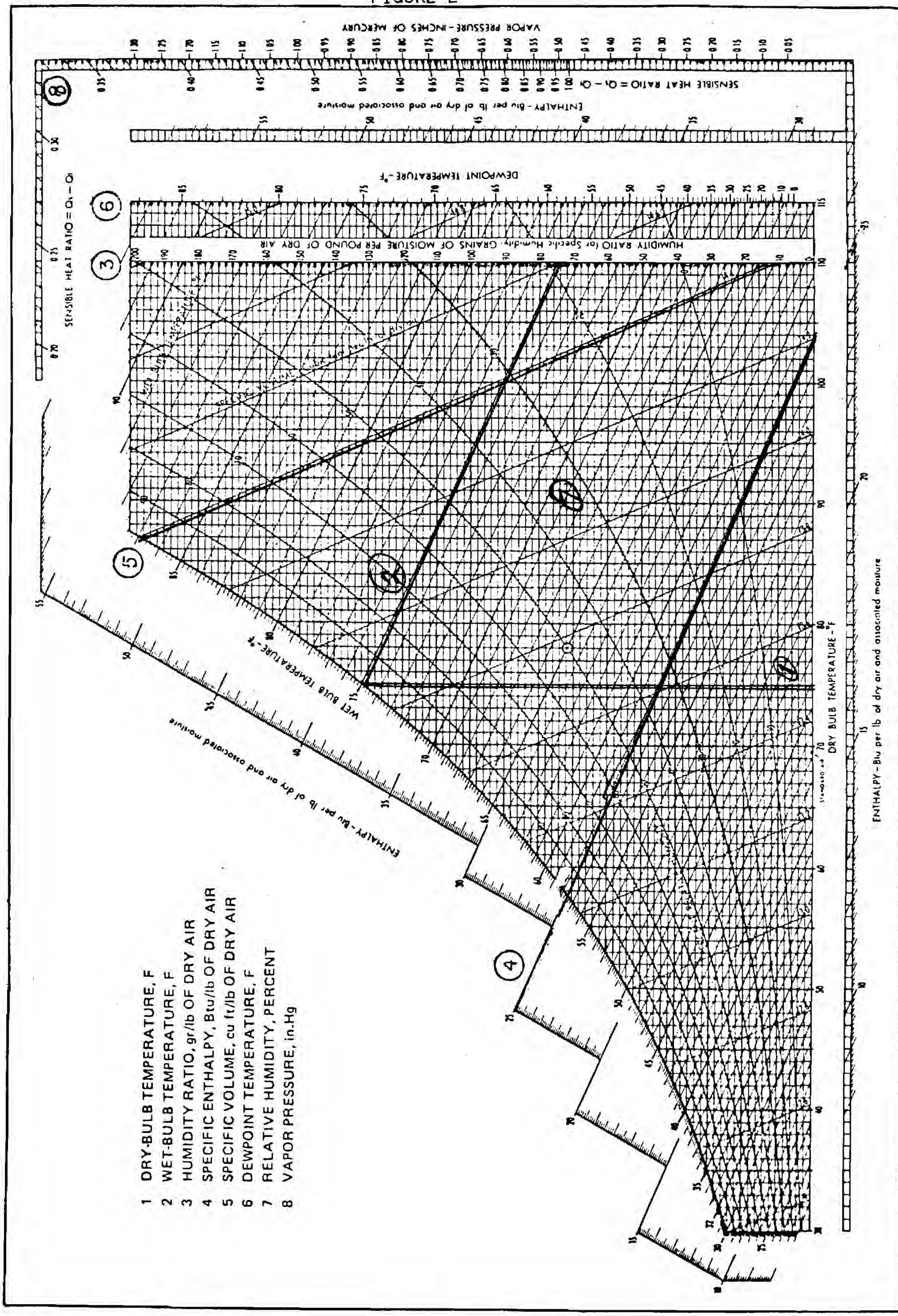
Humidity can be controlled adequately. Equipment specified to assure good waterborne performance will depend upon the area being coated at one time and how efficiently the dry air can be used with minimum loss to the atmosphere.

TABLE 19

FAHRENHEIT TABLE OF RELATIVE HUMIDITY OR PER CENT OF SATURATION

Dry Bulb Deg. F.	Difference Between Readings of Wet and Dry Bulbs in Degrees Fahrenheit																																			Dry Bulb Deg. F.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40	45	50	55	60	70	
30	89	78	67	56	46	36	26	16	6	0	0																									30
35	91	81	72	63	54	45	35	27	19	10	2	0																								35
40	92	83	75	65	60	52	45	37	29	22	15	7	0	0																						40
45	92	86	78	71	64	57	51	44	38	31	25	18	12	6	0	0																				45
50	93	87	80	74	67	61	65	49	43	38	32	27	21	16	10	5	0	0																		50
55	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	14	9	5	0	0																55
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	0															60
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	8	0														65
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	12	6	0	0												70
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	18	12	7	1	0											75
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	23	18	12	7	3	0										80
85	96	92	88	84	80	76	73	70	66	63	59	56	53	50	47	44	41	38	35	32	27	22	17	13	8	4	0	0								85
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	31	26	22	17	13	9	5	1	0							90
95	96	93	89	85	82	79	75	72	69	66	63	60	57	54	52	49	46	43	42	38	34	30	25	21	17	13	9	6	2	0						95
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	37	33	28	24	21	17	13	10	7	4						100
102	96	93	89	86	83	80	77	74	71	69	65	62	59	57	54	52	49	47	45	43	38	34	30	26												102
104	96	93	90	86	83	80	77	74	71	69	65	63	60	58	55	52	50	48	46	43	39	35	31	27	23											104
106	96	93	90	87	83	80	77	74	72	69	66	63	60	58	56	53	51	48	46	44	40	36	32	28	24	21										106
108	96	93	90	87	84	81	78	75	72	70	68	64	61	59	56	54	51	49	47	45	41	37	33	29	26	22	19									108
110	96	93	90	87	84	81	78	75	72	70	67	64	62	60	57	55	52	50	48	46	41	37	34	30	27	23	20	17								110
112	96	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	53	51	49	47	42	38	35	31	28	24	21	18	15							112
114	97	93	90	87	84	81	78	75	73	71	68	65	63	61	58	56	53	51	49	47	43	39	35	32	28	25	22	19	16	13						114
116	97	93	90	88	81	82	79	76	74	71	68	66	63	61	59	56	54	52	50	48	44	40	36	33	29	26	24	20	17	14						116
118	97	93	91	88	85	82	79	76	74	71	68	66	64	62	59	57	54	53	51	49	44	41	37	34	30	27	24	21	19	15						118
120	97	94	91	88	85	82	79	77	74	72	69	66	64	62	60	57	55	53	51	49	45	41	38	34	31	28	25	22	19	16	10					120
122	97	94	91	88	85	82	79	77	75	72	69	67	65	63	60	58	56	54	52	50	46	42	38	35	32	29	26	23	20	17	12					122
124	97	94	91	88	86	83	80	77	75	72	70	67	65	63	61	58	56	54	52	51	46	43	39	36	33	29	27	24	21	18	13					124
126	97	94	91	88	86	83	80	78	75	73	70	68	65	64	61	59	57	55	53	51	47	43	40	37	33	30	28	25	22	19	14					126
128	97	94	91	89	86	83	80	78	76	73	71	68	66	64	61	59	57	55	53	52	47	44	40	37	34	31	28	25	23	20	15					128
130	97	94	91	89	86	83	80	78	76	73	71	68	66	64	62	60	58	56	54	52	48	44	41	38	35	32	29	26	24	21	15	10				130
132	97	94	92	89	86	83	81	78	76	74	71	69	67	65	62	60	58	56	54	53	49	45	42	39	35	32	30	27	24	22	16	11				132
134	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63	61	59	57	55	53	49	46	42	39	36	33	31	28	25	23	17	12				134
136	97	94	92	89	86	84	81	79	77	74	72	69	67	65	63	61	59	57	55	53	50	46	43	40	37	34	31	28	26	24	18	13				136
138	97	94	92	89	86	84	81	79	77	74	72	70	68	66	63	62	60	58	55	54	50	47	43	40	37	35	32	29	27	24	19	14				138
140	97	94	92	89	87	84	81	79	77	75	72	70	68	66	64	62	60	58	56	54	51	47	44	41	38	35	33	30	27	25	19	14	10			140
142	97	94	92	89	87	84	82	80	77	75	73	70	68	66	64	62	60	58	57	55	51	48	44	42	39	36	33	30	28	26	20	15	11			142
144	97	95	92	89	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	52	48	45	42	39	36	34	31	29	26	21	16	11			144
146	97	95	92	90	87	85	82	80	78	75	73	71	69	67	65	63	61	59	57	56	52	49	45	43	40	37	35	32	29	27	21	17	12			146
148	97	95	92	90	87	85	82	80	78	76	73	71	69	67	65	63	61	60	58	56	52	49	46	43	40	38	35	32	30	28	22	17	13			148
150	98	95	92	90	87	85	82	80	78	76	74	72	70	68	66	64	62	60	58	57	53	49	46	43	41	38	36	33	30	28	23	18	13			150
152	98	95	93	90	88	85	83	81	79	76	74	72	70	68	65	64	62	60	59	57	53	50	47	44	41	39	36	33	31	29	23	19	14	10		152
154	98	95	93	90	88	85	83	81	79	77	74	72	70	68	66	65	63	61	59	57	54	50	47	44	42	39	37	34	32	29	24	19	15	11		154
156	98	95	93	90	88	85	83	81	79	77	74	72	71	69	67	65	63	61	59	58	54	51	48	45	42	40	37	34	32	30	24	20	15	11		156
158	98	95	93	90	88	86	83	81	79	77	75	73	71	69	67	65	63	61	60	58	55	51	48	45	43	40	38	35	33	30	25	20	16	12		158
160	98	95	93	90	88	86	83	81	79	77	75	73	71	69	67	65	64	62	60	58	55	52	49	46	43	41	38	35	33	31	25	21	17	13		160
162	98	95	93	90	88	86	84	82	80	77	75	73	71	69	68	66	64	62	60	59	55	52	49	46	44	41	39	36	34	31	26	22	17	13		162
164	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	56	52	49	47	44	41	39	36	34	32	26	22	18	14		164
166	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	66	65	63	61	59	56	53	50	47	44	42	39	37	35	32	27	23	18	14		166
168	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	67	65	63	61	60	56	53	50	47	45	42	40	37	35	33	28	23	19	15		168
170	98	95	93	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63	62	60	57	53	51	48	45	43	40	38	35	33	28	24	19	15		170
172	98	95	93	91	89	86	84	82	81	78	76	74	73	71	69	67	65	64	62	60	57	54	51	48	46	43	41	38	36	34	28	24	20	16		172
174	98	95	93	91	89	87	84	83	81	78	76	75	73	71	69	67	66	64	62	61	57	54	51	49	46	43	41	39	36	34	29	24	20	16		174
176	98	96	94	91	89	87	85	83	81	79	77	75	73	71	70	68	66	64	63	61	58	55	52	49	46	44	42	39	37	35	29	25	21	17	10	176
178	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	58	55	52	49	47	44	42	39	37	35	30	25	21	17	11	178
180	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	67	65	63	62	58	55	52	50	47	45	42	40	38	35	30	26	22	18	11	180
182	98	96	94	91	89	87	85	83	81	79	77	75	74	72	70	68	67	65	63	62	59	56	53	50	48	45	43	40	38	36	31	26	22	18	12	182
184	98	96	94	92	89	87	85	83	82	79	77	76	74	72	70	69	67	65	64	62	59	56	53	50	48	45	43	41	38	36	31	27	22	19	12	184
186	98	96	94	92	90	87	85	83	82	80	78	76	74	72	71	69	67	66	64	62	59	56	53	51	48	46	43	41	39	37	32	27	23	19	13	186
188	98	96	94	92	90	87	85	84	82	80	78	76	74	73	71	69	68	66	64	63	59	57	54	51	49	46	44	41	39	37	32	27	23	20	12	188
190	98	96	94	92	90	88	85	84	82	80	78	76	75	73	71	69	68	66	65	63	60	57	54	51	49	46	44	42	39	37	32	28	24	20	14	190
200	98	96	94	92	90	88	86	84	82	80	79	77	75	74	72	70	69	67	66	64	61	58	55	53	51	48	46	43	41	39	34	30	26	22	16	200
205	98	96	94	92	90	88	86	84	83	81	79	77	76	74	72	71	69	68	66	65	62	59	56	54	51	49	46	44	42	40	35	31	27	23	17	205
210	98	96	94	93	90	88	87	85	83	81	80	78	76	75	73	71	70	68	67	65	62	60	57	54	52	49	47	45	43	41	36	32	28	24	18	210

FIGURE 2

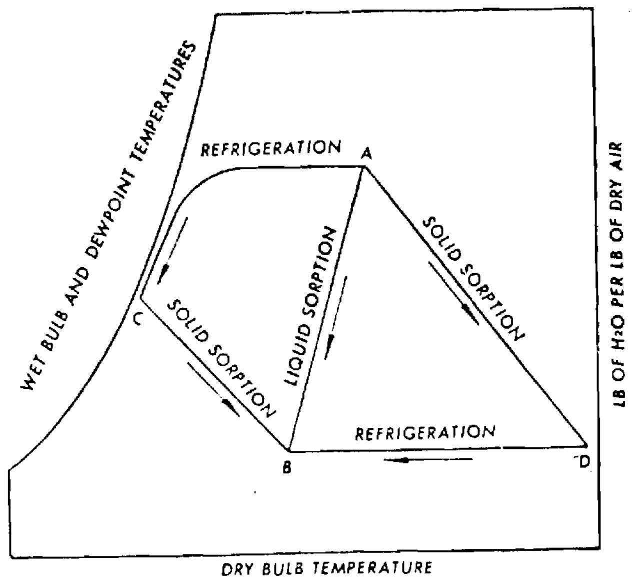


VAPOR PRESSURE - INCHES OF MERCURY
SENSIBLE HEAT RATIO = Qs - Qt
ENTHALPY - Btu per lb of dry air and associated moisture
DEWPOINT TEMPERATURE - °F
HUMIDITY RATIO (for Specific Humidity) GRAINS OF MOISTURE PER POUND OF DRY AIR
WET BULB TEMPERATURE - °F
DRY BULB TEMPERATURE - °F
1 DRY-BULB TEMPERATURE, F
2 WET-BULB TEMPERATURE, F
3 HUMIDITY RATIO, gr/lb OF DRY AIR
4 SPECIFIC ENTHALPY, Btu/lb OF DRY AIR
5 SPECIFIC VOLUME, cu ft/lb OF DRY AIR
6 DEWPOINT TEMPERATURE, F
7 RELATIVE HUMIDITY, PERCENT
8 VAPOR PRESSURE, in.Hg

FIGURE 3

THREE METHODS OF DEHUMIDIFICATION [16]

Dehumidification can be accomplished by liquid sorption, refrigeration and reheat, and solid sorption or combinations of these systems.



This represents a psychrometric chart illustrating three methods by which dehumidification with sorbent materials or sorbent equipment may be accomplished. Air at point "A" is to be dehumidified and cooled to point "B". This can be done in a liquid sorption system with inter-cooling directly, or it may be done with a solid sorption unit by pre-cooling and dehumidifying with refrigeration from point "A" to point "C" and then with solid sorption from point "C" to point "B". It could also be accomplished with solid sorption equipment by desiccating from point "A" to point "D" and then by refrigeration from point "D" to point "B".

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