Rock Island Arsenal Laboratory

TECHNICAL REPORT

PACKAGING IN TRANSPARENT BAGS

By

Linden W. Wagner

Department of the Army Project No. 1-H-0-24401-A-110

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Approved by:

A. C. HANSON
Laboratory Director

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Rock Island, Illinois

ABSTRACT

Eighteen transparent plastic films of various thicknesses were made into bags. Bare steel panels, panels overwrapped in vinylidene chloride copolymer, panels coated with an emulsifiable rust preventive and panels protected with VCI materials were sealed in the bags. These packs were then subjected to fresh water immersion, static and dynamic humidity, cyclic exposure and one year of indoor storage tests to determine the suitability of plastic bags for packaging applications. The extent, nature and intensity of the rusting of the test specimens were noted through the transparent bag materials.

The control packs, after one year of indoor exposure at ambient temperature, provided adequate protection without the use of VCI materials. It was also determined that the packs were unable to provide adequate protection to the control panels when immersed in fresh water and exposed to high humidity conditions. Cyclic exposure revealed that the emulsifiable rust preventive coating was unable to withstand exposure at high temperature. Incompatibility between polystyrene and the vinylidene chloride copolymer overwrap was noted at high temperature. A yellowish coloration was also noted on several plastic bags containing VCI materials.

CONCLUSIONS

It is concluded that:

1. Transparent plastic films, which can be made into interior packaging bags with the conventional heat sealing machines, will find suitable application for the packaging and preservation of Ordnance items. Films which tear easily, are difficult to seal, cannot be sealed on themselves, leave the seals in a porous condition on cooling, or contain pin-holes, may find a limited application.

2. The permeability of the film to water vapor or corrosive gases may also limit its use in providing protection to items sealed in a bag where corrosion protection is necessary.

3. A bag material which is not compatible with VCI may deteriorate or cause the item to corrode more rapidly.

4. Polyethylene (0.004") and vinylidene chloride copolymer (0.0015") bag materials provided the best protection for the bare steel panels sealed in the packs, in the fresh water immersion test.

5. Heat shrinkable polyethylene bags (0.004") provided the best protection for the bare steel panels sealed in the packs in the static humidity test at ambient temperature.

6. By sealing 0.05 to 0.06 grams of VCI in the packs with the bare steel panels, the period of protection was extended in the static humidity test.

7. Polyethylene (0.004") and polyvinyl chloride acetate copolymer (0.008") bag materials provided the best protection for the bare steel panels in the humidity cabinet test at 90 ± 2°F and 95 to 98% R.H.

8. After 164 days of continuous exposure in the humidity cabinet at 100 ± 2°F, and 95 to 100% R.H., (a) the rate of rusting of a bare steel panel sealed in a pack was quite uniform. Each bag material varied in its permeability to moisture vapor and this was reflected in the rust rating. (b) An overwrap of vinylidene chloride copolymer applied loosely around a bare steel panel followed the contour, decreased the void and provided a slight amount of additional protection from corrosion. (c) An emulsifiable rust preventive compound provided a thin film on a bare steel panel and afforded a period of protection until breakdown occurred. Then the rate of rusting on the polished panel face proceeded at a slightly greater rate than that on the sandblasted face. (d) The VCI inserts provided protection to the bare steel panels; however, when the VCI was decreased by loss through

small openings, or incompatibility with the bag materials, the rate of rusting was increased.

9. The control packs in the cyclic exposure test of MIL-P-116, Test A, were unable to provide protection when pinholes were present in the film. When 0.10 gram of VCI was sealed in the packs, they were protected from rust.

10. When the packs were submitted to high and low temperature changes no leakers developed on exposure to the Quick Leak Test; however, when the packs were subsequently exposed in the cyclic exposure test of MIL-P-116, Test A, differences in the rust ratings of the control packs were noted.

11. Alternation of the control packs at low temperature followed by exposure at ambient temperature was too mild a test to produce rust on the steel panels.

12. Bare steel panels sealed in plastic bags were free of rust after one year of indoor heated storage.

RECOMMENDATIONS

It is recommended that:

1. The test methods used in this report be adopted to evaluate transparent plastic bag materials for interior packaging applications.

2. The following films may be used in the preparation of bags because of their flexibility and ease of heat sealability.

a. Polyethylene/polyglycol-terephthalate, laminate.

b. Polyvinyl chloride-acetate copolymers.

c. Polyethylene.

d. Cellulose acetate butyrate.

e. Vinylidene chloride with controlled shrinkage of seal.

3. The following films, because of inherent physical characteristics, may not be adopted for bag packaging application:

a. Polystyrene - (tears easily).

b. Cellulose acetate - (seals with difficulty and tears easily).

c. Irradiated polyethylene - (difficult to control shrinkage of heat seal without the use of special equipment).

d. Polyglycol terephthalate - (cannot be sealed on itself without adhesive).

4. In an environment with prolonged high humidity, transparent plastic bag materials should not of themselves be relied upon to provide adequate protection to bare steel surfaces.

5. The emulsifiable rust preventive compound, MIL-C-40084 (ORD) applied as a preservative film in a sealed pack, should not be heated to 165°F, because it is unable to withstand the temperature.

6. Polystyrene bag material and vinylidene chloride copolymer film should not be placed in contact with each other and exposed to a temperature of 165°F, because the vinylidene chloride film becomes incompatible with the polystyrene and renders it opaque.

PACKAGING IN TRANSPARENT BAGS

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PACKAGING IN TRANSPARENT BAGS

OBJECT

To investigate and evaluate transparent plastic films for suitable use in the preparation of bags for Ordnance packaging applications.

INTRODUCTION

The packaging of Ordnance materiel for the prevention of corrosion has been practiced by the Department of the Army for a long period of time. The criterion of packaging has been embodied in Military Specification, Methods of Preservation, MIL-P-116[4]. In this specification the methods have been outlined in detail so that uniformity will be achieved throughout the system. In the specification, however, the use of opaque barriers, based on previous years of experience, have been prescribed.

At the present time, a new kind of barrier material has made its impact upon the packaging systems - transparent plastic films. These films of many kinds are being used in commercial packaging, and their use in Military Packaging System will be but a matter of time. These films have two advantages - transparency and flexibility. These films can be made into bags or pouches. An item sealed in a transparent bag can be easily inspected. The same item in an opaque bag would have to be removed, inspected and repackaged. The identity of items in transparent bags can easily be established by observation.

The Department of the Navy has investigated transparent plastic films[2] and items packaged in films are being used on board Naval vessels and submarines.[3]

Military Specifications for the procurement of these materials are: MIL-F-22019(Aer), Film, Transparent, Flexible, Heat Sealable, Volatile Corrosion Inhibitor Treated; MIL-B-22020 (Aer), Bags, Transparent, Flexible, Heat Sealable, Volatile Corrosion Inhibitor Treated; MIL-F-22191(Aer), Films, Transparent, Flexible, Heat Sealable, For Packaging Applications; MIL-B-22205(Aer), Bags, Transparent, Flexible, Heat Sealable for Packaging Applications.

This Arsenal has been designated to investigate transparent plastic films for their applicability in military packaging methods.

Sealed packs containing bare steel panels with and without the use of a corrosion preventive were used to evaluate the films for (a) waterproofness, (b) moisture-vaporproofness, and (c) high and low temperature changes.

EXPERIMENTAL WORK

Materials Employed:

The commercially available transparent plastic films used in the investigation are identified in Table I by film number, material and gauge. The conditions under which the seals were made with a heated jaw type sealer are also listed.

Two volatile corrosion inhibited materials were used: (1) a coated Kraft paper containing approximately 2 grams of VCI per square foot and (2) a VCI crystalline material.

Panel Preparation:

Open hearth, low carbon steel, Federal Specification QQ-S-636 was made into panels 2" x 4" x 1/8". They were surface ground on one face to a 20 to 30 microinch finish. The panels were then scrubbed with solvent soaked rags and rinsed in hot VM & P naphtha to remove any residual corrosion preventive. The unpolished face and the edges were then sandblasted with clean, white, silica sand, sprayed with naphtha and then placed in hot naphtha. Each panel was then hand polished with number 150 grit silicon carbide abrasive cloth and finished with number 280 grit silicon carbide abrasive paper to renew the surface. The tailings were removed with a soft brush. The refinished surface was rubbed with surgical gauze to remove the remaining superficial dust. The panels were then positioned in a rack at 25° from the vertical and sprayed on each face, flushing the test surface progressively downward. The panels were then placed in hot VM & P naphtha, withdrawn, allowed to flash dry, and then given a final rinse in hot anhydrous methanol. They were placed in a desiccator to cool.

Rust Rating System:

The panels were carefully inspected through the transparent films for any rust and rated on three factors[1] (a) extent of rusting, (b) nature of rusting, and (c) intensity of rusting. For example, 1-5/dSA/1,2,3. The first figure 1-5 denotes the extent or percent of the surface area rusted where 0 denotes "no rusting" to 100 for complete rusting. The letters d, S and A, denote the nature of the rusting, that is, d for dots, S for spots and A for an area. A dot is numerically considered to be 1 mm, a spot as 2 mm, and an area as 2 to 4 mm. The intensity of rusting is arbitrarily defined as (1) light, (2) medium, and (3) heavy rusting. It is noted by the buildup of corrosion products.

TABLE I

SEALING OPERATIONS

FILM NO.	MATERIAL	GUAGE (Inch)	TEMP. (°F)	DWELL (Sec)	AIR PRESS. (psi)	WITH OR WITHOUT AL-FOIL BUFFER
1	Polyethylene/polyglycol terephthalate laminate	0.001	240	2	35	With
2	"	0.0025	240	2	35	With
3	"	0.003	240	2	35	With
4	Polyethylene	0.004	220	2	15	With
5	Polyvinyl chloride-acetate copolymer	0.004	240	2	15	With
6	"	0.008	240	4	15	With
7	Polyglycol terephthalate w/GT-100 adhesive tape	0.005	240	2	30	Without
8	Vinylidene chloride copolymer	0.0015	230	3	30	With
9	"	0.002	240	3	30	With
10	Cellulose acetate butyrate	0.005	240	4	40	With
11	"	0.010	270	4	40	Without
12	Polyvinylchloride	0.010	200	2	40	Without
13	Polystyrene oriented	0.002	200	4	40	With
14	"	0.007	200	6	40	With
15	Cellulose acetate butyrate	0.007	280	2	40	Without
16	Cellulose acetate	0.001	360	5	40	With
17	"	0.0015	340	4	40	With
18	Irradiated polyethylene	0.002	240	2	60	With

Bag Preparation:

The transparent plastic materials shown in Table I were each assigned a film number for ease of identification. Bags made from these materials also bore the assigned number. A heated jaw type sealer was used to make the bags. The inside dimensions of the bags were 3 x 5 inches to accommodate a 2 x 4 x 1/8 inch panel. The bags were closed with a one-half inch exterior seal. The conditions under which each of the films were sealed on itself is shown in the Table. In order to make smooth seals, or to control the contraction of certain films, and to prevent the molten plastic from sticking to the heated jaws of the sealer, aluminum foil was folded in the form of a V and placed over the two edges of the film before it was sealed, thus, acting as a heat buffer. These bags were used in fabricating the experimental packs used throughout the many test phases. Some of the bags were not too flexible, some tore easily and some required the use of aluminum foil to control the shrinkage. Bags made from material numbers 1, 2, 3, 4, 5, 6, 8, 9 and 18 were very flexible. Those made from material numbers 7, 10, 11, 12, 14 and 15 were less flexible and were slightly stiff. Material numbers 7, 9 and 18 were heat shrinkable under the jaws of the heat sealer and required aluminum foil to control the shrinkage. Bags made from material numbers 16 and 17 were difficult to seal and on cooling, the seals were porous to moisture vapor.

PROCEDURE AND RESULTS

The films were fabricated into packs and tested under the following conditions.

Fresh Water Immersion Test:

One set of 18 packs, consisting of bare steel panels sealed in plastic bags, were subjected to the Quick Leak Test of MIL-P-116. They were then immersed in fresh water at a depth of about six inches at ambient temperature. The packs were inspected daily through the plastic films, except on weekends, for a period of 30 days. At this time the packs were again subjected to the Quick Leak Test to determine if any deterioration of the film could be noted. Final inspection was made of the polished and sandblasted faces of the panels after they had been removed from the test. The film numbers, days of inspection, rust ratings and ambient temperature of the water are shown in Table II. The rust ratings of the packs are listed at the bottom of the Table. Film numbers 5, 6, 10, 11, 13, 15, 16 and 17 failed at the seals within four days of immersion, whereas film numbers 1, 2, 3, 4, 7, 8, 9, 12, 14 and 18 failed to provide protection from 21 to 30 days after immersion. Film numbers 4, polyethylene, 0.004" and 8, vinylidene chloride copolymer 0.0015", provided the longest periods of protection to the bare steel panels.

TABLE II

RUST RATING DATA

FILE NO.	1	2	3	6	7	8	9	10	13	14	15	16	17	20	21	22	23	24	27	28	29	30	Final Rust Ratings Polished	Final Rust Ratings Sandblasted
	DAYS OF EXPOSURE																							
1	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	1-5/d/1	6-25/d/1	→	→	26-50/d/1	51-75/d/2	76-100/d/2	→	76-100/dS/2-3	76-100/d/1
2	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	6-25/d/1	26-50/d/2	51-75/3/2	76-100/A/2	76-100/d/1	76-100/d/1
3	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	6-25/d/1	→	26-50/d/1	→	26-50/d/1	51-75/d/1
4	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	1-5/d/1	6-25/d/1	1-5/d/1
5	OK	Fail																						
6	OK	→	Fail																					
7	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	6-55/d/1	26-50/d/2	→	51-75/d/2-3	51-75/dS/1	76-100/dS/1
8	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	1-5/d/1	6-25/d/1	6-25/d/1	26-50/d/1
9	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	6-25/d/1	26-50/d/1	→	26-50/d/1	51-75/d/1
10	OK	→	Fail																					
11	OK	→	→	Fail																				
12	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	1-5/d/1	6-25/d/1	26-50/dA/1	26-50/A/1	51-75/A/1
13	OK	Fail																						
14	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	1-5/d/1	6-25/d/1	→	→	→	26-50/d/1	→	51-75/dSA/2	51-75/A/1	51-75/A/1
15	OK	Fail																						
16	Fail																							
17	Fail																							
18	OK	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	6-25/d/2	26-50/A/2-3	→	26-50/A/2-3	51-75/A/1
Ambient Water Temp. (°F)	78	80	78	78	76	75	75	76	78	76	77	76	76	85	82	78	76	75	76	75	75	75		

NOTE: Completion of 30 Days of Fresh Water Immersion at Ambient Temperatures.

Rust Rating of Packs: 1-5%, 4; 6-25%, 8; 26-50%, 3, 9, 12, 18; 51-75%, 7, 14; 76-100%, 1, 2; Fail - 5, 6, 11, 15, 10, 13, 16, 17

Static Humidity Tests:

Three static humidity tests were conducted. In the first test a bare steel panel, with one face polished and the other face sandblasted, was inserted into each of the 18 numbered bags with a metal hook and sealed therein without a preservative. The plastic films were in contact with the panel faces. Each of the packs was then placed in a large desiccator over distilled water at ambient temperature so that the effect of moisture vapor on the packs might be observed. Inspection of the panel surfaces was then made through the transparent bag. Table III lists the plastic film by number, the periods of inspection and the rust ratings noted on both the polished and sandblasted faces. The average rust ratings on the faces of the panels after 31 days of exposure are listed at the bottom of the Table. They have been summarized as follows: One pack, film number 18, heat shrinkable polyethylene (0.002") was without rust. Nine packs, film numbers 1, 2, 3, 4, 8, 10, 11, 12 and 14 had from 1 to 5% of the panel surface area rusted. Eight packs, film numbers 5, 6, 7, 9, 13, 15, 16 and 17, had from 6 to 25% of the panel surface area rusted.

In the second test, conducted under similar conditions, small glass vials were placed in the packs so that the plastic films were distended and not in contact with the panel faces. Figure 1 shows the heat sealed pack containing a bare steel panel and the glass vial. The packs were subjected to the Quick Leak Test to insure that the seals were adequate and would prevent the ingress of moisture. The packs were placed in a large desiccator over distilled water at ambient temperature. The packs were inspected through the transparent bags after 6, 13, 20, 27 and 30 days of exposure. The rust ratings were noted on both the polished and sandblasted panel faces and an average value of these ratings is shown in TableIV. They have been summarized as follows: One pack, film number 18, heat shrinkable polyethylene (0.002") had 1 to 5 % of the panel surface area rusted and provided the best protection. Eight packs, film number 6, 7, 10, 11, 12, 13, 15 and 17 had 6 to 25% of the panel surface area rusted. Four packs, film number 1, 8, 9 and 14, had 26 to 50% of the panel surface area rusted. Five packs, film numbers 2, 3, 4, 5 and 16 had 51 to 75% of the panel surface area rusted.

Each of the packs failed to afford satisfactory protection to the bare steel panels indicating that some type of preservation was necessary to prevent corrosion.

On comparing the average values of the rust ratings of Table III with those of Table IV, it may be noted that the

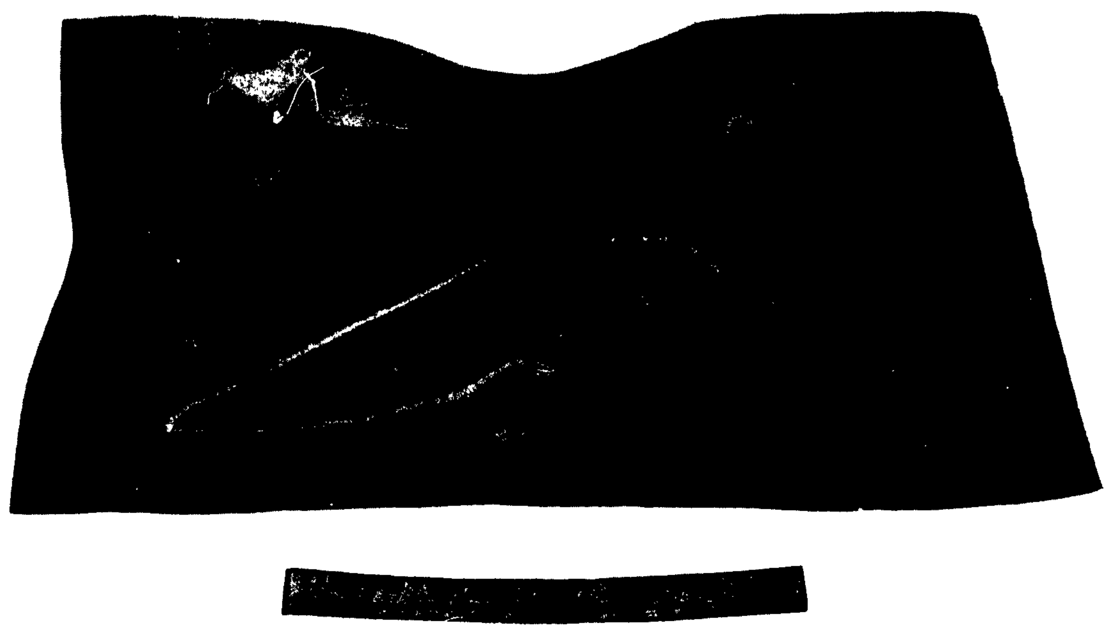
TABLE III

RUST RATING DATA

FILM NO.	Polished Panel Face, Days: 7	14	21	31	Sandblasted Panel Face, Days: 7	14	21	31	Average Values of Rust Ratings on Polished and Sandblasted Panel Faces (%)
1	OK →	1-5/d/1			1-5/d/1 →	→	6-25/d/1 →	→	1-5
2	OK →	→	1-5/d/1		1-5/d/1	6-25/d/1	6-25/d/1 →	→	1-5
3	OK →	→	→	1-5/d/1	1-5/d/1 →	→	→	→	1-5
4	OK →	→	→	1-5/d/1	1-5/d/1 →	→	→	→	1-5
5	OK →	1-5/d/1 –	6-25/d/1		1-5/d/1 →	→	6-25/d/1 →	→	6-25
6	6-25/d/1				6-25/d/1 →	→	→	→	6-25
7	6-25/d/1				6-25/d/1 →	→	→	6-25/d/1 →	6-25
8	1-5/d/1				1-5/d/1 →	→	→	→	1-5
9	1-5/d/1 →	→	6-25/d/1		1-5/d/1 →	→	6-25/d/1	6-25/d/1 →	6-25
10	1-5/d/1				1-5/d/1 →	→	→	→	1-5
11	1-5/d/1				1-5/d/1 →	→	→	→	1-5
12	1-5/d/1				1-5/d/1 –	6-25/d/1 →	→	→	1-5
13	6-25/d/1				6-25/d/1 →	→	→	→	6-25
14	1-5/d/1				6-25/d/1 →	→	→	→	1-5
15	OK →	→	→	6-25/d/1	OK →	→	→	6-25/d/1 →	6-25
16	1-5/d/1 →	→	→	6-25/d/1	1-5/d/1 –	6-25/d/1 →	→	6-25/d/1 →	6-25
17	1-5/d/1 →	→	→	6-25/dSA/2-3	1-5/d/1 –	6-25/d/1 →	→	26-50/d/1 →	6-25
18	OK				1-5/d/1 →	→	→	→	OK
Ambient Temp. (°F)	80	82	86	86					

NOTE: Completion of 31 days static humidity test at ambient temperatures, films in contact w/panels.

Rust Rating of Packs:
0 - None, 18
1-5% - 1, 2, 3, 4, 8, 11, 10, 12, 14
6-25% - 5, 6, 7, 9, 13, 15, 16, 17



HEAT SEALED PACK CONTAINING BARE STEEL PANEL WITH GLASS VIALS

FIGURE 1

Neg. No.1843
63-2583

TABLE IV

RUST RATING DATA

FILM NO.	Days in Test – Polished Panel Face: 6	13	20	27	30	Days in Test – Sandblasted Panel Face: 6	13	20	27	30	AV. VAL. OF RUST RATINGS ON POLISHED & SANDBLASTED FACES (%)
1	6-25/d/1 →			26-50/d/1	—	—	6-25/d/1 →		26-50/dSA/2 →		26-50/dSA/2
2	6-25/d/1	26-50/d/1 →		51-75/d/1	—	—	26-50/d/1 →		51-75/dS/1 →		51-75/dS/1
3	6-25/d/1	26-50/d/1 →		51-75/d/1	—	—	26-50/d/1 →			51-75/dS/1	51-75/dS/1
4	1-5/d/1 →		26-50/d/1	51-75/d/1	—	—	6-25/d/1 —	51-75/d/1-2	76-100/dS/2 →		51-75/dS/2
5	OK →	1-5/d/1 —	6-25/d/1 —	26-50/d/1	—	—	26-50/d/1 →		51-75/d/2	76-100/dS/2	51-75/dS/2
6	OK →			6-25/d/1	—	—	OK →	OK —	6-25/d/1 →		6-25/d/1
7	6-25/d/1 →			6-25/d/1	—	—	6-25/d/1 →		6-25/d/2 →		6-25/d/2
8	6-25/d/1 —	26-50/d/1			—	—	26-50/d/1-2 →				26-50/d/1-2
9	6-25/d/1 →		26-50/d/1		—	—	26-50/d/1-2 —		51-75/dS/2-3 →		26-50/dS/1-2
10	OK →	1-5/d/1 —	6-25/d/1		—	—	1-5/d/1 —	6-25/d/1 —	26-50/dS/1-2 →		6-25/dS/1-2
11	1-5/d/1 →			6-25/d/1	—	—	26-50/d/1 →			26-50/dS/1-2	6-25/dS/1-2
12	1-5/d/1 →			6-25/d/1	—	—	6-25/d/1 →			6-25/dS/1-2	6-25/dS/1-2
13	1-5/d/1 —	6-25/d/1			—	—	6-25/d/1 →		26-50/d/1	26-50/dS/1-2	6-25/dS/1-2
14	6-25/d/1	26-50/d/1			—	—	26-50/d/1 →			26-50dS/1-2	26-50/dS/1-2
15	OK —	1-5/d/1			—	—	1-5/d/1 →		6-25/d/1 →		6-25/d/1
16	1-5/d/1 →		26-50/d/1	51-75/d/1-2	—	—	6-25/d/1 —	26-50/d/1	51-75/dA/2-3 →		51-75/dA/1-2
17	1-5/d/1 →			6-25/d/1	—	—	6-25/d/1 →		26-50/d/2	26-50/dS/2-3	6-25/dS/2-3
18	OK →	1-5/d/1			—	—	1-5/d/1 →		6-25/d/1 →		1-5/d/1
Ambient Temp.	80°	82°	86°	86°			80°	82°	86°	86°	

NOTE: Completion of 30 days static humidity tests at ambient temperatures, films not in contact w/panels.

Rust Rating of Packs:
1-5% - 18
6-25% - 6, 7, 10, 11, 12, 13, 15, 17
26-50% - 1, 8, 9, 14
51-75% - 2, 3, 4, 5, 16
76-100% - None

rust ratings of the packs containing the glass vials were much greater in extent, in most cases, than those in which the plastic films were in contact with the panel faces. This can be explained by the fact that the glass vials provided a larger void about the surface of the panels and the moisture vapor was able to permeate the space more easily.

Where the film is in contact with the panel, the film follows the contour of the panel and the void is at a minimum. The amount of moisture vapor impinging on one face may vary with the number of openings or pinholes in the film and the amount of rust may be localized at these openings. The surface area of a sandblasted panel is greater because of the hills and valleys. Localized corrosion is more intense than that under similar conditions where the moisture impinges on a smooth polished surface.

In the third test conducted under similar conditions, 0.05 to 0.06 grams of VCI crystals were placed in the pack in contact with the steel panels and the plastic films. Table V lists the plastic films by number, the days of inspection and the rust ratings of the packs after 31 days of exposure. No rust was noted on the polished panel faces, however, on the sandblasted faces, pack numbers 4, 5, 9, 13 and 15 exhibited a light rust. The panels in pack numbers 16 and 17 were wet with moisture, however, no corrosion was noted. Film number 6, in contact with VCI crystals, developed a yellowish color. This made observation through the film more difficult.

No explanation can be given for the differences in the rust ratings between the polished and sandblasted faces other than immediate contact may set up a cell-like action in the presence of moisture to cause corrosion. The polished face offers a surface which is less active to corrosion.

<u>Dynamic Humidity Tests</u>:

In all the previous tests, the sample packs were subjected to static humidity conditions. In the following tests, the packs were suspended in a humidity cabinet in which the moisture-laden air was circulated around the packs suspended in a vertical position. Two tests were conducted.

In the first test, a bare steel panel was placed in each of 17 numbered bags with two small glass vials inserted so that the plastic films were not in contact with the panel faces (See Figure 1). The packs were sealed and suspended so that the weight of the panel was supported by the bottom seal. The packs were prepared in quadruplicate. One set of

TABLE V

RUST RATING DATA

FILM NO.	Polished Panel Face: Days in Test 7	14	21	31	Sandblasted Panel Face: Days in Test 7	14	21	31
1	OK				OK			
2	OK				OK			
3	OK				OK			
4	OK				OK			1-5/d/1
5	OK				OK	1-5/d/1		
6	OK				OK	yellow coloration on film		
7	OK				OK			
8	OK				OK			
9	OK				OK	1-5/d/1		
10	OK				OK			
11	OK				OK			
12	OK				OK			
13	OK				6-25/d/1			6-25/dS/1-2
14	OK				OK			
15	OK				OK		1-5/d/1	
16	OK	wet inside			OK	wet inside		
17	OK	wet inside			OK	wet inside		
18	OK				OK			
Ambient Temp. (°F)	80	82	86	86	80	82	86	86

NOTE: Completion of 31 days static humidity tests at ambient temperature with VCI pack preservation.

SUMMARY:
Polished Surface Area -
18 Packs - No visible rust.

Sandblasted Surface Area -
4 Packs - 1-5% rusted.
1 Pack - 6-25% rusted.
13 Packs - No visible rust.
2 Packs - Wet inside with no visible rust.

packs was used as a control. This set was exposed at ambient temperature. The three remaining sets were placed in a humidity cabinet at 90 ± 2°F, and 95 to 98% R.H. Inspections of the panels were made through the transparent films. After 8 days of exposure the packs were removed and the final rust ratings were recorded. The results are shown in Table VI. The ratings of the control packs at ambient temperature, the percentage of the panel surface area rusted, the intensity of the rust, the days to initial failure and the pack ratings have been tabulated in Table VII. Initial failure was noted when the surface area of the panel was from 1 to 5% rusted. The pack ratings are shown at the bottom of the Table by film numbers.

The bare control packs exposed at ambient temperature were without rust.

The pack ratings show that film numbers 4 and 6, polyethylene (0.004") and polyvinyl chloride-acetate copolymer (0.008") provided the best protection for the bare steel panels.

In the second test, transparent plastic film numbers 2, 3, 4, 5, 6, 7, 9, 12, 14 and 15 were used. Packs were then fabricated with steel panels as follows: (1) one panel was used as a control; (2) one panel was overwrapped with a film of vinylidene chloride copolymer; (3) one panel was coated with a film of Water-Emulsifiable, Oil-Type Corrosion Preventive Compounds, MIL-C-40084(ORD), 1 to 10 dilution, and dried overnight and (4) one panel was placed in contact with a VCI insert, size 2" x 4" of MIL-P-3420. These panels were then placed in plastic bags, heatsealed and placed in the humidity cabinet at 100 ± 2°F and 95 to 100% R.H. Periodic inspections of the packs were made through the transparent bags. The rust ratings of the panel faces have been plotted in Figures 2 through 7 by film number, bag material and exposure periods. Figures 2 and 3 show the plotted rust ratings of the control packs on the polished and sandblasted panel faces. The rust ratings agree quite closely, however, the rate of rusting varies with the kind of bag material used and the number of days of exposure.

Figure 4 shows the rust ratings of the packs with an overwrap of vinylidene chloride copolymer film with exposure of the polished panel face. The graph shows that a secondary overwrap applied loosely around the panel without sealing prevents the moisture vapor from reaching the panel surface and provides an additional amount of corrosion protection.

Figures 5 and 6 show the rust ratings of the packs with a film of emulsifiable rust preventive compound on both the

TABLE VI

RUST RATING DATA

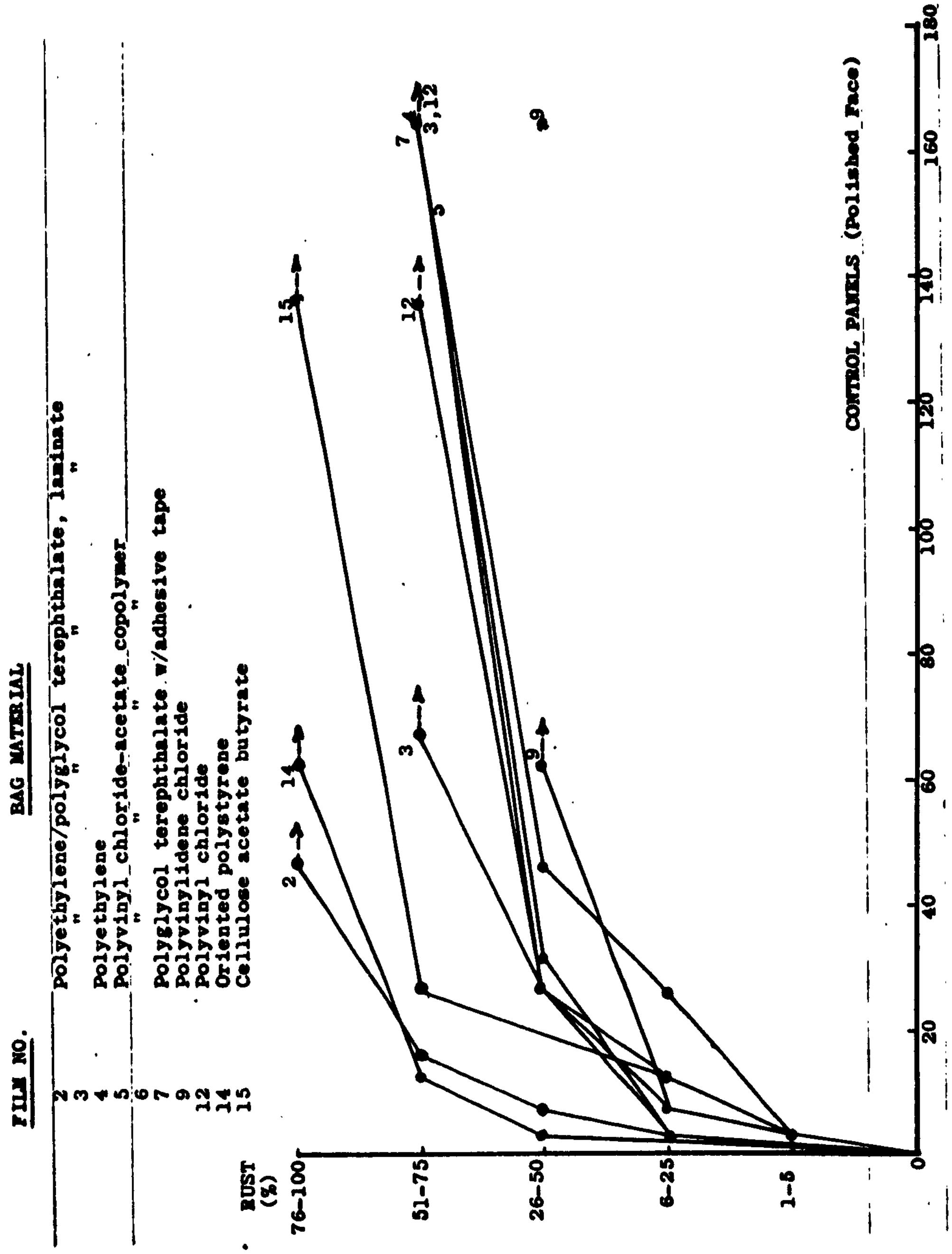
FILM NO.	DAYS OF EXPOSURE / BAG MATERIAL	1/3	1-1/3	1-2/3	2-2/3	3-2/3	4-2/3	5-2/5	6	7	8
1	Polyethylene/polyglycol terephthalate laminate 0.001"		OK		1-5/d/1		6-25/d/2	26-50/3/2			51-75/ds/2
2	Polyethylene/polyglycol terephthalate laminate 0.0025"		OK		1-5/d/1		6-25/d/2	26-50/d/2			51-75/ds/2
3	Polyethylene/polyglycol terephthalate laminate 0.003"		OK		1-5/d/1		6-25/d/2	26-50/d/2			
4	Polyethylene 0.004"		OK				1-5/d/1				
5	Polyvinyl chloride-acetate copolymer 0.004"		OK		1-5/d/1		6-25/d/1				6-25/d/1-2
6	Polyvinyl chloride-acetate copolymer 0.008"		OK				1-5/d/1				
7	Polyglycol terephthalate, w/GT-100 adhesive tape 0.005"		OK				1-5/d/1	6-25/d/1			
8	Vinylidene chloride, copolymer 0.0015"		OK		1-5/d/1		6-25/d/1			26-50/d/2	
9	Vinylidene chloride, copolymer 0.002"		OK		1-5/d/1						6-25/d/2
10	Cellulose acetate butyrate 0.005"	OK	1-5/d/1		6-25/d/2		26-50/d/2			51-75/d/2	
11	Cellulose acetate butyrate 0.010"		OK		1-5/d/1			6-25/d/2			
12	Polyvinyl chloride 0.010"			1-5/d/1				6-25/d/2	26-50/d/2		51-75/ds/2
13	Polystyrene, oriented, 0.002"		OK		1-5/d/1	6-25/d/2		26-50/d/2			
14	Polystyrene, [illegible]nted, 0.007"	OK	1-5/d/1	6-25/d/1	26-50/d/2		51-75/d/2				
15	Cellulose acetate butyrate 0.007"	OK	1-5/d/1	6-25/d/1			26-50/d/2		51-75/d/2		
16	Cellulose acetate 0.001"	1-5/d/1	6-25/d/1	26-50/A/1	51-75/A/1	76-100/d/2-3					
17	Cellulose acetate 0.0015"	1-5/d/1	6-25/d/1	26-50/d/1		51-76/A/2-3	76-100/A/2-3				

NOTE: Completion of 8 day humidity cabinet tests at 90° ±2° and 95 to 98% R.H., (Polished Panel Faces)

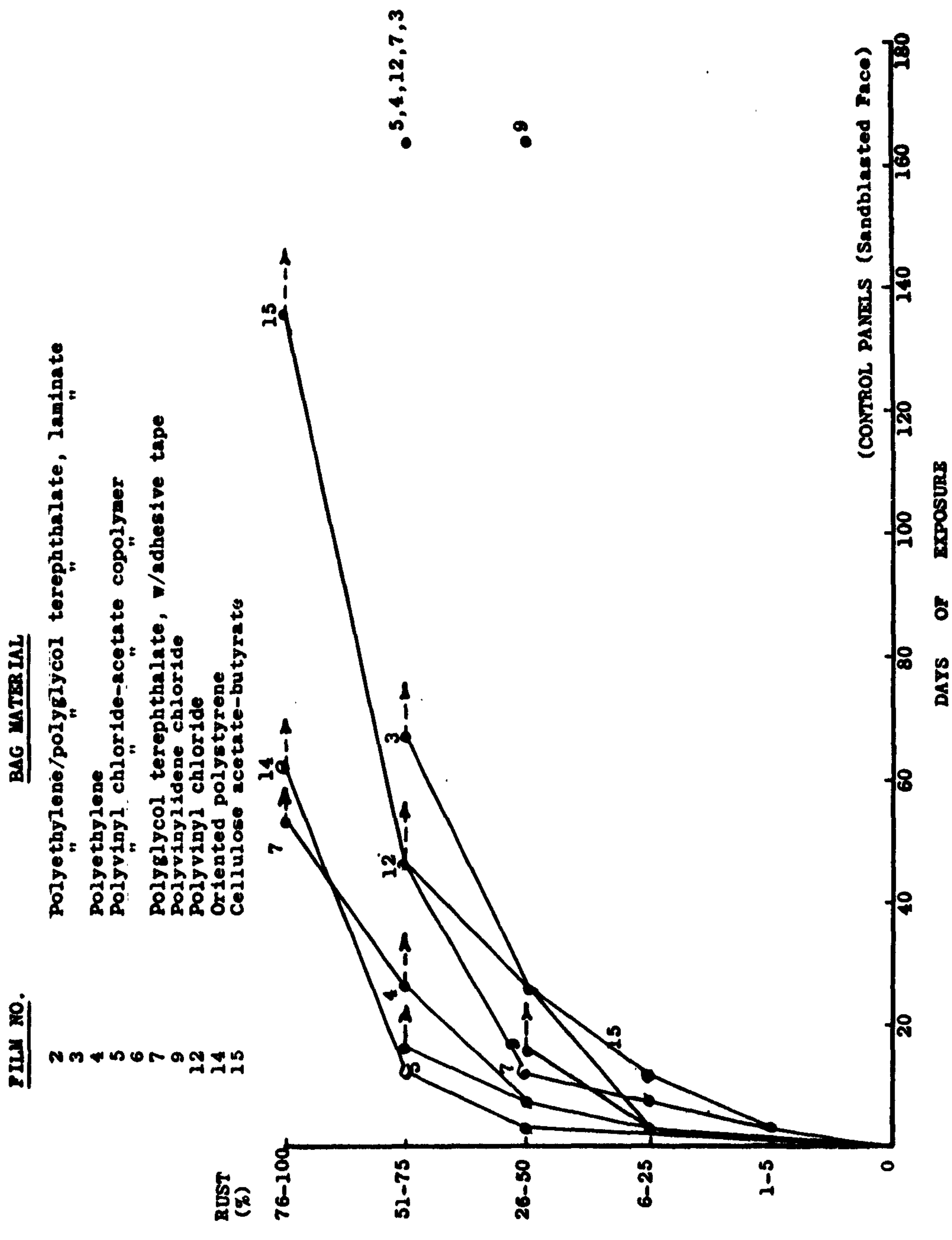
TABLE VII

SUMMARY OF HUMIDITY CABINET TEST AT 92° ±2°F and 95 to 98% R.H.

FILM NO.	CONTROL PACKS OF AMBIENT TEMPERATURE (82° - 85°F)	PERCENTAGE OF PANEL SURFACE AREA RUSTED 1-5	6-25	26-50	51-75	76-100	DAYS TO INITIAL FAILURE
1	No Rust ↓				Med.r.		2.6
2					Med.r.		2.6
3				Med.r			2.6
4		Lt. r					4.6
5			Lt to Med. r				2.6
6		Lt r					4.6
7			Lt r				4.6
8				Med r			2.6
9			Med r				2.6
10					Med r		1.3
11			Med r				2.6
12					Med r		1.6
13				Med r			2.6
14					Med r		1.3
15					Med r		1.3
16						Med to Hvy r	0.3
17						Med to Hvy r	0.3
	Pack Rating Film No.	4,6	5,7,9, 11	3,8,13	1,2,10, 12,14,15	16,17	

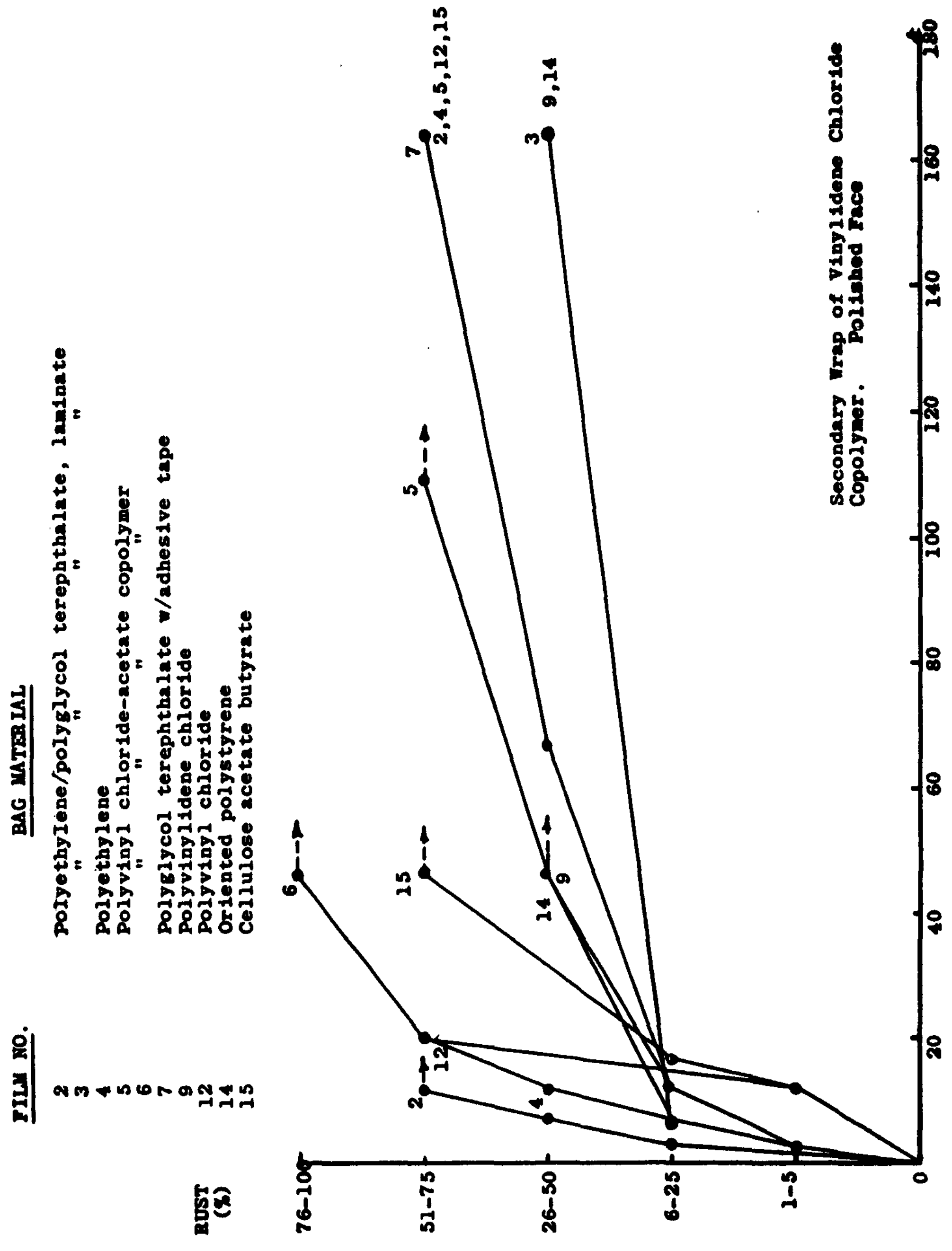


PERCENT OF PANEL SURFACE AREA RUSTED IN TRANSPARENT SEALED BAGS VS DAYS OF EXPOSURE IN HUMIDITY CABINET AT 100° ±2°F, & 95 to 100% R.H.

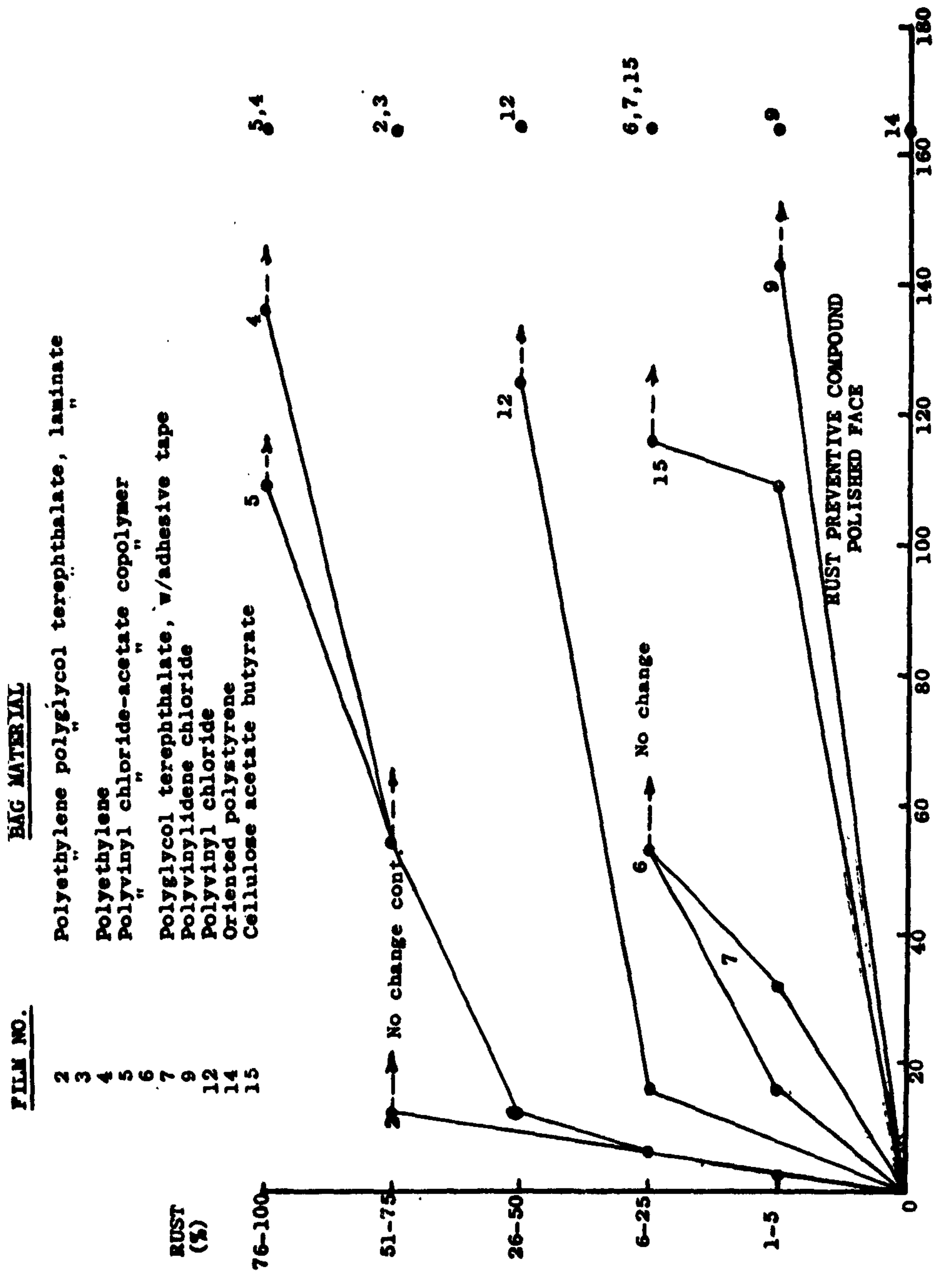


PERCENT OF PANEL SURFACE AREA RUSTED IN TRANSPARENT SEALED BAGS VS DAYS OF EXPOSURE IN HUMIDITY CABINET AT $100^{\circ} \pm 2^{\circ}F$, & 95 to 100% R.H.

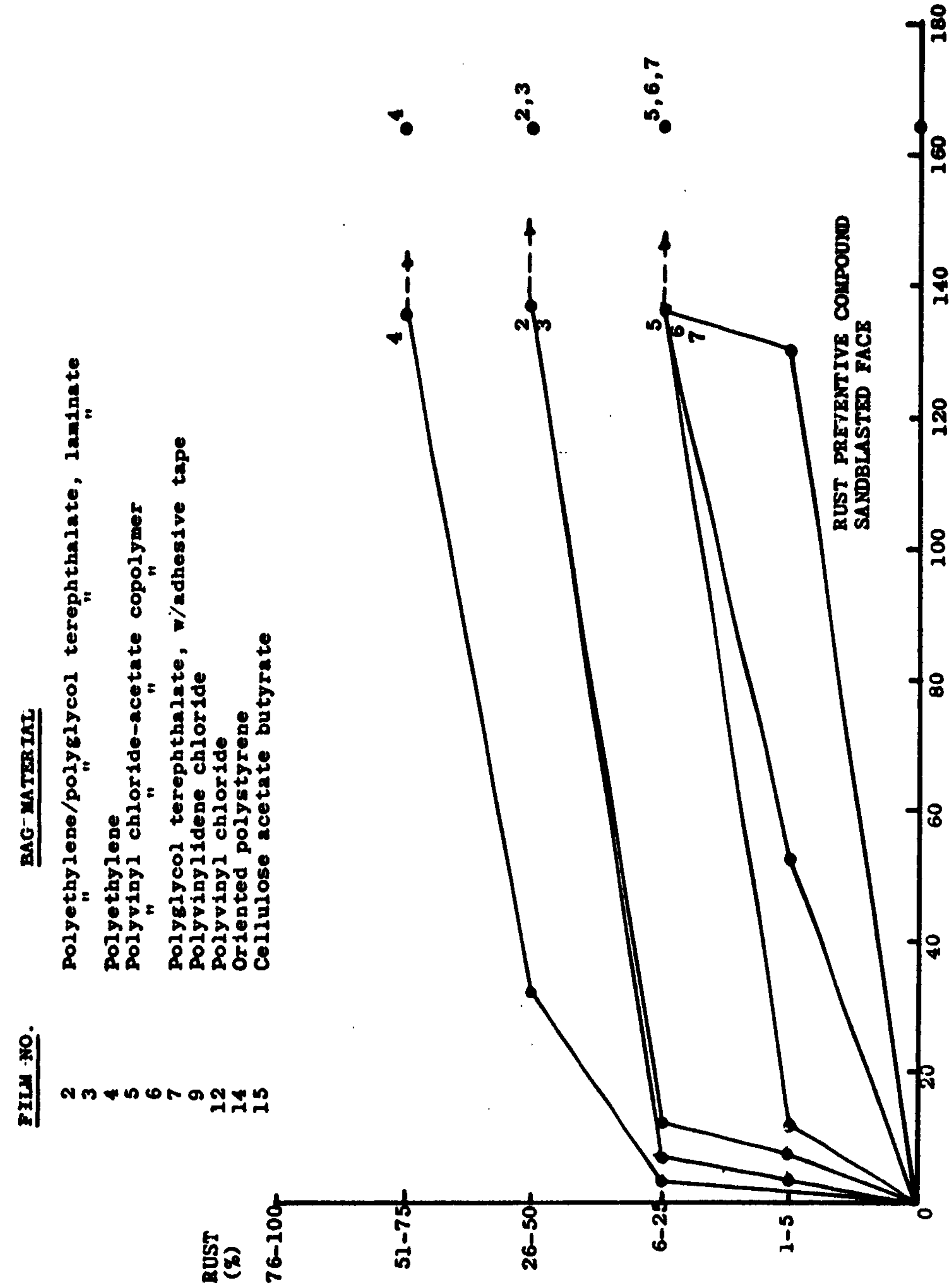
FIGURE 3



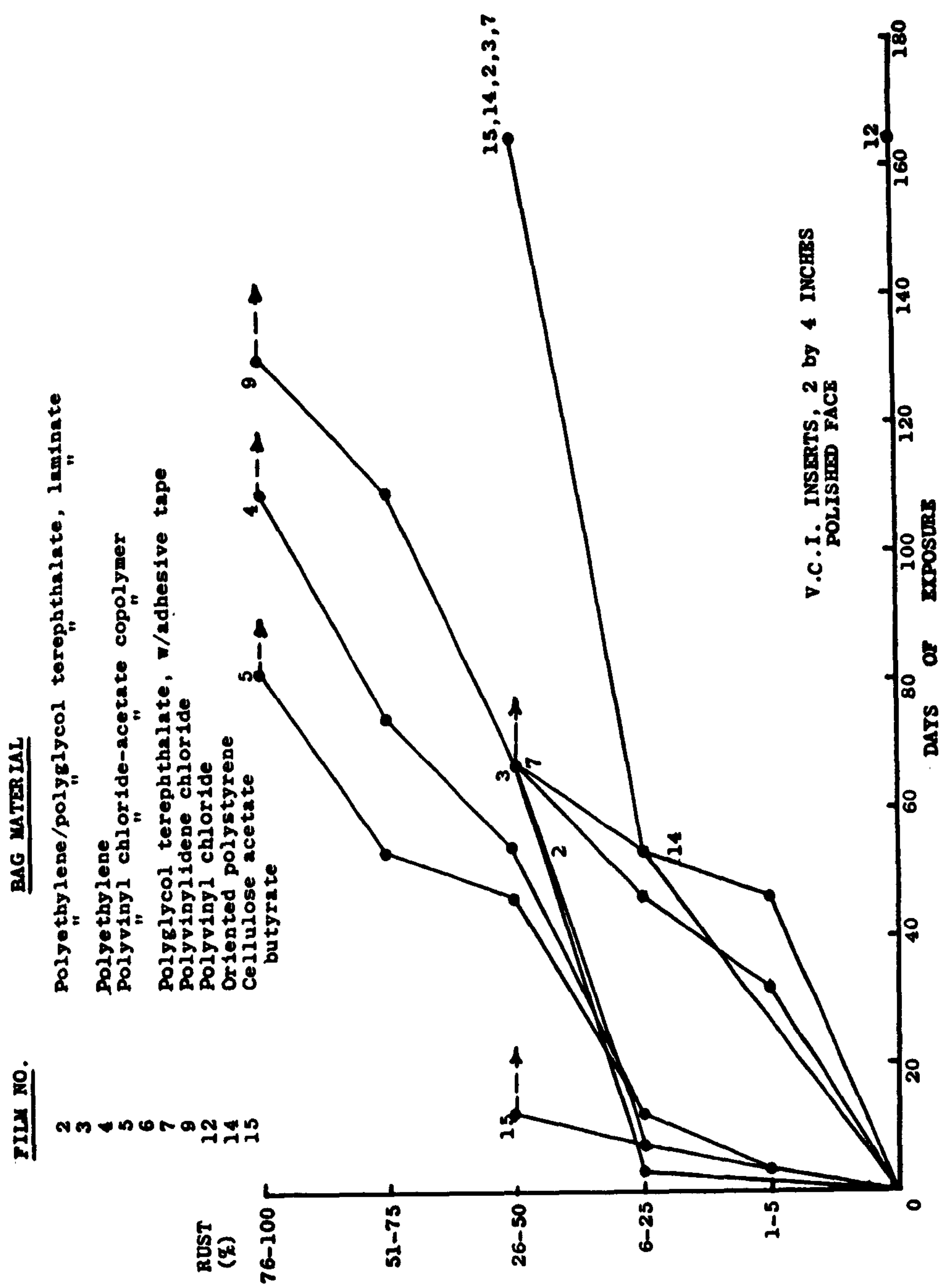
PERCENT OF PANEL SURFACE AREA RUSTED IN TRANSPARENT SEALED BAGS VS DAYS OF EXPOSURE IN HUMIDITY CABINET AT $100^{\circ} \pm 2^{\circ}F$, & 95 to 100% R.H.



PERCENT OF PANEL SURFACE AREA RUSTED IN TRANSPARENT SEALED BAGS VS DAYS OF EXPOSURE IN HUMIDITY CABINET AT 100° ±2°F, & 95 to 100% R.H.



PERCENT OF PANEL SURFACE AREA RUSTED IN TRANSPARENT SEALED BAGS VS DAYS OF EXPOSURE TO HUMIDITY CABINET AT $100^{\circ} \pm 2^{\circ}F$, & 95 to 100% R.H.



PERCENT OF PANEL SURFACE AREA RUSTED IN TRANSPARENT SEALED BAGS VS DAYS OF EXPOSURE IN HUMIDITY CABINET AT 100° ±2°F, & 95 to 100% R.H.

polished and sandblasted panel faces these graphs show that a rust preventive compound decreases the rate of corrosion and extends the period of protection, however, the rate of rusting of the polished surface is a little more rapid than that of the sandblasted surface. The packs containing the panels showing the lowest percentage of rust after the greatest number of days of exposure provided the best protection against corrosion.

Figure 7 shows the rust ratings of the packs containing an insert of VCI with exposure of the polished panel face. The graphs show that VCI extends the period of protection for the steel panels, however, when the amount of volatile corrosion inhibitor is decreased by loss in volatilization, the rate of rusting is greatly accelerated. On comparing the graphs of Figure 7 with those of Figures 5 and 6, the rate of rusting vs. time can be noted.

A summary of the rusted areas of the steel panels recorded in Figures 2 through 7 was made after 62 days of exposure. The results were as follows: Each of the control packs on both the polished and sandblasted faces was more than 25% rusted. Each of the panels wrapped loosely in the vinylidene chloride copolymer on the polished face was more than 25% rusted. The panels protected by the water-emulsifiable rust preventive compound were rated on both the polished and sandblasted faces. Five were without rust, two were from 1 to 5%, two from 6 to 25% and one from 26 to 50%. The panels protected by the VCI inserts were rated on the polished faces because the sandblasted faces could not be observed. One was without rust, five from 6 to 25%, two from 26 to 50% and one from 51 to 75%. One was not rated because the weight of the panel forced the seal to open.

The water-emulsifiable rust preventive compound afforded the best protection.

A summary of the rusted areas of the steel panels after 164 days of exposure was made as follows: The control packs on the polished faces showed that one face was from 26 to 50% rusted, five from 51 to 75% rusted and three from 76 to 100% rusted. One pack failed at the heat seal. On the sandblasted faces, one face was from 26 to 50% rusted, four faces were from 51 to 75% rusted, four faces were from 76 to 100% rusted and one pack failed at the heat seal. Each of the panels overwrapped loosely in vinylidene chloride copolymer, on the polished face, showed that three were from 26 to 50% rusted, five from 51 to 75% rusted and two from 76 to 100% rusted. The final ratings of the sandblasted faces showed that three were from 26 to 50% rusted, six from 51 to 75% and one from 76 to 100% rusted. The panels protected by the emulsifiable rust preventive compound on the polished faces showed that one was without rust, one from 1 to 5%, three from 6 to 25%, one from 26 to 50%, two from 51 to 75% and two from 76 to 100% rusted. On the sandblasted faces, the final ratings were as follows: Four were free of rust, three from 6 to 25%, two from 26 to 50% and 1 from 51 to 75% rusted. The panels protected by the VCI inserts on the polished faces showed that one was free of rust, five from 26 to 50%, three from 76 to 100% and one pack failed at the heat seal. The final ratings on the sandblasted faces in contact with the VCI inserts, when the panels were removed from the packs, showed that four were without rust, one from 1 to 5%, two from 6 to 25% and two from 26 to 50% rusted.

Cyclic Exposure Tests:

Four cyclic Exposure Tests were conducted.

Cyclic Test A

Eighteen plastic films shown in Table I were made into bags,as previously described,to accomodate steel panels. The bags were used in preparing four sets of experimental packs as follows: One set contained only bare steel panels and was used as a control. The three remaining sets were prepared with 0.10, 0.20 and 0.40 grams of VCI crystals, respectively. Each of the experimental packs was then checked for leaks in the Quick Leak Test. Subsequently the packs were placed in the cyclic exposure test of Military Specification MIL-P-116, Test A, as outlined in Appendix I.

Final inspection of the packs was made through the transparent films for entrance of moisture and corrosion of the steel panels in the presence of,as well as in the absene of. the VCI crystals. The results are shown in Table VIII. There is evidence to show that plastic film numbers 1, 2, 3, 4, 5, 6, 7, 12 and 18 did provide some protection to the control panels. In those cases where the rust ratings were from 1 to 5%, it was noted that pinholing in the film allowed moisture to reach the panel and produce rust under each pinhole. It was noted that the use of VCI in the amount of 0.10 gram protected the panels from rust even though a few were wet with water. When the seal is defective and the panel is retained in the pack with a large quantity of water, the VCI may be dissolved and drained away. A black corrosion soon developed on the panel surface. Since 0.10 gram of VCI provided adequate protection for the bare steel panels in the packs, the addition of 0.20 and 0.40 grams was only exploratory. A yellowish coloration was noted on the interior of the packs of film numbers 5, 6, 9, 11 and 15.

TABLE VIII

RUST RATING DATA

FILM NO.	CONTROL PANELS WITHOUT VCI: POLISHED FACE	CONTROL PANELS WITHOUT VCI: SANDBLASTED FACE	AVERAGE VALUES OF RUST RATINGS ON POLISHED & SANDBLASTED PANEL FACES (%)	PANELS WITH VCI (gms): 0.10	PANELS WITH VCI (gms): 0.20	PANELS WITH VCI (gms): 0.40
	RUST RATINGS OF STEEL PANELS					
1	No rust	No rust	No rust	OK	OK	OK
2	1-5/d/1	1-5/dS/1	1-5/dS/1			
3	1-5/dS/1	1-5/dS/1	1-5/dS/1			
4	No rust	No rust	No rust			
5	6-25/d/1	1-5/d/1	1-5/d/1			
6	No rust	No rust	No rust			
7	No rust	No rust	No rust	Wet, no rust		
8	26-50/A/1	26-50/A/2-3	26-50/A/2-3	OK		Wet 51-75/A/3
9	51-75/A/1-2	51-75/dA/2-3	51-75/A/1-2			OK
10	76-100/A/2-3	76-100/dSA/2-3	76-100/dSA/2-3			
11	76-100/A/2	76-100/dS/2-3	76-100/dSA/2-3			
12	1-5/d/1	No rust	No rust			
13	51-75/dS/2-3	26-50/A/1	26-50/dSA/1-2			
14	51-75/A/2-3	51-75/A/2-3	51-75/A/2-3			
15	76-100/A/2-3	76-100/A/2-3	76-100/A/2-3			
16	98-100/A/3	98-100/A/3	98-100/A/3	Wet, no rust	Wet, No rust	Wet, no rust
17	98-100/A/3	98-100/A/3	98-100/A/3	Wet, no rust	Wet, no rust	Wet, no rust
18	No rust	1-5/A/1	No rust	OK	OK	Wet, 51-75/A/3

NOTE: After completion of cyclic exposure Test A, MIL-P-116.

Table VIII was summarized as follows:

PERCENT OF PANEL SURFACE AREA RUSTED						
No VCI Controls	No Rust	1-5%	6-25%	26-50%	51-75%	76-100%
Film Nos.	1,4,6, 7,12,18	2,3,5		8,13	9,14	10,11,15, 16,17
Total No. Control Packs	6	3	0	2	2	5
Packs With VCI (gms):						
0.10	18 Packs	0	0	0	0	0
0.20	18 "	0	0	0	0	0
0.40	16 "	0	0	0	8.18	

Cyclic Test B:

In this test the experimental packs were prepared in triplicate as follows: A bare steel panel without a preservative was sealed in each of the transparent thermoplastic bags, film numbers 1 through 18, and used as a control. Two additional sets were prepared in a similar manner except that 0.05 to 0.06 grams of VCI crystals were added as a preservative. Each of the packs was given the Quick Leak Test to detect any defects in the seals. The packs were then placed in a gravity convection oven at 165 ± 2°F for 24 hours. They were then removed and again given the Quick Leak Test to note any changes caused by high temperature. The packs were then placed in a cold box at -65° ± 1°F for 24 hours. After this period the packs were allowed to remain in the cold box until the temperature was 40°F. They were then removed and allowed to reach ambient temperature. Again they were subjected to the Quick Leak Test to detect any leaks. They were then subjected to the cyclic exposure test, MIL-P-116, Test A. The results of the tests were as follows: After 24 hours at high temperature and 24 hours at low temperature, the Quick Leak Test showed that no leaks were present. Wide variations in temperature did not affect the plastic packs. The results of all the cyclic exposure tests are shown in Table IX.

Table IX is summarized as follows:

TABLE IX

RUST RATING DATA

RUST RATINGS OF STEEL PANELS

FILM NO.	CONTROL PANELS WITHOUT VCI POLISHED FACE	CONTROL PANELS WITHOUT VCI SANDBLASTED FACE	AVERAGE VALUES OF RUST RATINGS ON POL. & SANDBLASTED PANEL FACES (%)	WITH 0.05 - 0.06 GMS.OF VCI POLISHED & SANDBLASTED FACES
1	6-25/A/1-2	No rust	6-25/A/1-2	OK
2	1-5/d/1	No rust	1-5/d/1	OK
3	1-5/d/1	No rust	1-5/d/1	OK
4	No rust	No rust	No rust	OK
5 *	6-25/dSA/1-2	No rust	6-25/dSA/1-2	OK
6 *	6-25/A/1	No rust	6-25/A/1	OK
7	No rust	No rust	No rust	OK
8	51-75/A/1-2	51-75/A/1-2	51-75/A/1-2	Light yellowish coloring of plastic
9	No rust	No rust	No rust	OK
10	76-100/dSA/1-2	76-100/dSA/1-2	76-100/dSA/1-2	OK
11	76-100/dA/1-2	76-100/dS/1-2	76-100/dS/1-2	OK
12	No rust	No rust	No rust	OK
13	51-75/d/1	51-75/d/1	51-75/d/1	OK
14	51-75/A/1	51-75/A/1	51-75/A/1	OK
15	76-100/dSA/2-3	76-100/dSA/2-3	76-100/dSA/2-3	OK
16	98-100/A/3	98-100/A/3	98-100/A/3	OK
17	98-100/A/3	98-100/A/3	98-100/A/3	1-5/A/1 Panel is wet with moisture.
18	No rust	No rust	No rust	OK

* Films tend to block together

NOTE: Data recorded after 48 hour cycle of temperature changes and cyclic test A, MIL-P-116.

PERCENT OF PANEL SURFACE AREA RUSTED

Controls Without VCI	No Rust	1-5%	6-25%	26-50%	51-75%	76-100%
Film numbers	4,7,9, 12,18	2,3	1,5,6	-	8,13,14	10,11,15, 16,17
Total No. Control Packs	5	2	3	-	3	5
Packs With 0.05 - 0.06 gms. of VCI	17 Packs	1 Pack	0	0	0	0

On comparing Tables VIII and IX, the following differences can be noted in the rust ratings.

FILM NO.	RUST RATINGS OF CONTROL PACKS TABLE VIII	TABLE IX
1	No rust	6-25/A/1-2
6	No rust	6-25/A/1
8	26-50/A/2-3	51-75/A/1-2
9	51-75/A/1-2	No rust

The rust ratings for pack numbers 1, 6 and 8 were greater after the high and low temperature changes. Pack number 9, however, has a rust rating which does not agree. The seal in this case became defective during the cyclic exposure test.

In comparing the summary of Table VIII with that of Table IX, it can be noted that the control panels do show some differences in the percentage of the panel surface area rusted. The packs containing the VCI crystals also show some differences; however, where differences do occur, it can be attributed to pinholes in the films or inadequate seals.

Cyclic Tests C and D:

The ten transparent films previously used in preparing the bags were fabricated into packs with steel panels as follows: A bare steel panel was placed in each of the ten bags and used as a control. A bare steel panel was overwrapped with a film of vinylidene chloride copolymer and inserted into each plastic bag. A bare steel panel was coated with an emulsifiable rust preventive compound, MIL-C-40084(ORD), dried overnight and inserted into each plastic bag. A bare steel panel was placed in contact with a 2" x 4" piece of Kraft barrier material, coated with VCI of MIL-B-3420, and inserted in each bag. The sample packs were prepared in quadruplicate and divided into two sets.

Each set consisted of duplicate packs of the ten plastic materials. They were tested as follows: Cyclic Test C was conducted in a cold box at -65 ± 1°F for 6 hours, alternated by exposure at ambient temperature (82 to 85°F) for 18 hours for a period of 24 days. The packs were exposed at ambient temperature over the week-ends. On completing the test, the results did not disclose any failures to the bare steel panels protected only by the plastic bags. The packs in which the panels were protected by the plastic overwrap, the MIL-C-40084(ORD) compound and the VCI inserts, were also free of rust. Since none of the control packs failed, the test was considered too mild so it was discontinued.

Cyclic Test D was conducted in an oven at 165 ± 2°F for 6 hours alternated by immersion in fresh water overnight at ambient temperature for 18 hours for a period of 10 days. The packs were left immersed in fresh water over the week-ends. The results are shown in Table X.

Summary of Rust Ratings of Table X after 10 Days of Cyclic Exposure:

PERCENT OF PANEL SURFACE AREA RUSTED

Experimental Packs	No Rust	1-5	6-25	26-50	51-75	76-100	Remarks
Bare Control Panels	-	2	5	-	2	-	One pack Opened at seam.
Vinylidene Chloride Over-wrap	1	3	5	1	-	-	
Emulsifiable Rust Prev. Compound	1	-	2	5	1	1	
VCI Inserts	7	0	3	0	0	0	

Each of the ten plastic films failed to protect the bare control panels from rust. Each of the bare steel panels,

TABLE X

RUST RATING DATA

FILM NO.	BAG MATERIAL	FILM THICKNESS (in)	BARE CONTROL PANELS POL. FACE	BARE CONTROL PANELS S.B. FACE	VINYLIDENE CHLORIDE COPOLYMER OVERWRAP POL. FACE	VINYLIDENE CHLORIDE COPOLYMER OVERWRAP S.B. FACE	EMULSIFIABLE RUST PREVENTIVE COMPOUND POL. FACE	EMULSIFIABLE RUST PREVENTIVE COMPOUND S.B. FACE	VCI INSERTS POL. FACE	VCI INSERTS S.B. FACE
2	Polyethylene/polyglycol terepl thalate laminate	0.0025	6-25/dA/1	6-25/dA/1	1-5/dA/1	1-5/dA/1	26-50/dSA/1-2	26-50/dSA/1-2	OK	OK
3	"	0.003	1-5/dA/1	6-25/dA/1	1-5/dA/1	1-5/dA/1	26-50/dSA/1-2	26-50/dSA/1-2	OK	OK
4	Polyethylene	0.004	1-5/dA/1	6-25/dA/1	1-5/dA/1	1-5/dA/1	26-50/dA/1	26-50/dSA/1	OK	OK
5	Polyvinyl chloride-acetate copolymer	0.004	6-25/dA/1	6-25/dA/1	6-25/dA/1	6-25/dA/1	51-75/dSA/2	51-75/dSA/2	6-25/dA/2	OK
6	"	0.008	6-25/dA/1	6-25/dA/1	6-25/dA/1	6-25/dA/1	51-75/dSA/2	26-50/dSA/2	6-25/dA/1	OK
7	Polyglycol terephthalate w/adhesive tape	0.005	6-25/dA/1	6-25/dA/1	6-25/dA/1	6-25/dA/1	6-25/dA/1	6-25/dA/1	OK	OK
9	Polyvinylidene chloride	0.002	Packs leaked and were removed.		6-25/dA/1	6-25/dA/1	1-5/dA/1	OK	OK	OK
12	Polyvinylchloride	0.010	51-75/dA/2	51-75/dSA/2	26-50/dA/1	26-50/dA/1	76-100/dSA/2-3	76-100/dSA/2-3	OK	OK
14	Oriented polystyrene cellulose acetate	0.007	6-25/dA/1	6-25/dA/1	OK	OK	26-50/dSA/1-2	26-50/dSA/1-2	OK	OK
15	Cellulose acetate butyrate	0.007	51-75/dSA/2-3	51-75/dSA/2-3	6-25/dA/1	6-25/dA/1	6-25/dSA/1-2	6-25/dSA/1-2	6-25/dA/1-2	51-75/dSA/2

NOTE: Completion of 10 day cyclic test at $165^{\circ} \pm 2^{\circ}F$ alternated with fresh water immersion at ambient temperatures.

overwrapped loosely in the vinylidene chloride copolymer film and then inserted into the plastic bags, afforded slightly better protection than that of the controls. The emulsifiable rust preventive coating on the test panels was unable to withstand the exposure at high temperature. When the packs were subsequently immersed in fresh water, the coating contributed to the formation of stain and corrosion on the test panels. The bare steel panels with the VCI inserts were afforded the best protection.

Incompatibility between the polystyrene material and the secondary overwrap of vinylidene chloride film was noted because the polystyrene became opaque and the panel could not be rated visually.

Indoor Storage:

Eighteen transparent thermoplastic films, shown in Table I, were made into bags. Five sets of packs were prepared: One set consisted of bare steel panels sealed in each of the bags and used as a control. Each of the four remaining sets was prepared by inserting the following quantities 0.05 - 0.06, 0.10, 0.20 and 0.40 grams of VCI crystals, respectively, into the packs before they were sealed. The five sets were placed in separate racks and exposed indoors at ambient temperature from about 75°F in winter, to over 100°F in summer. After one year of indoor storage, the packs were removed and inspected. The results were as follows: No rust was noted on the control packs or on the packs with the VCI crystals. Since no rust was noted on the control packs, the films did provide protection for the panels for one year. A light yellowish coloration was observed on the exterior of the following pack numbers: 5, 6, 8, 9, 10, 11, 14, 15 and 16. Since no coloration was noted on the packs containing the bare steel panels, it was shown that some incompatibility did exist between the plastic films and VCI crystals.

DISCUSSION

The Department of the Army is interested in the application of transparent plastic films for packaging to determine the condition of the item prior to issue. Transparency will provide "see through," eliminate repackaging during surveillance inspections and permit visual identification by observation. This report discusses the behavior of the transparent plastic films in affording protection to steel panels sealed in a bag, with and without the aid of a preservative.

Fresh Water Immersion Tests:

Since the sample packs containing the bare steel panels were low in weight and small in size, no difficulty was experience in placing them in a large desiccator and subjecting them to the Quick Leak Test of MIL-P-116. This was done to detect any leaks which could result from inadequate seals or defects in the plastic film. In the fresh water immersion test the pack is subjected to two factors: First, the film may have pinholes through which moisture may enter the pack and second, on continuous exposure, the moisture has a tendency to enter the seal through minute capillaries which the Quick Leak Test is unable to detect. In time of an emergency it is possible that a box with its contents may become immersed in water. If the items were packaged in transparent thermoplastic bags, it is probable that they could be identified, salvaged, stored and issued after a period of submergence. At least the package would not have to be opened for inspection. The experimental work has shown that certain packs are capable of passing a 20 day waterproofness test.

Static Humidity Tests:

Three tests were conducted on bare steel panels sealed in plastic bags. In the first test, the bag film was in contact with the panel faces. The film prevented moisture from moving freely within the pack. Pinholes in the film allowed moisture vapor to penetrate into the pack and rusting of the panels usually occurred at these openings. The differences in the rust ratings between the polished and sandblasted panel faces can be attributed to differences in the contacting areas and the ingress of moisture through the plastic film and the seals.

In the second test, small glass vials were inserted to keep the bag film from contacting the panels. The bag film was distended by the glass vials and the larger void created about the panel allowed the moisture-laden air to permeate the space more easily. The rust ratings in most of these packs were slightly greater in extent than they were in the first test.

In the third test, a small amount of VCI crystals was placed between the bag film and the panel faces. It was thought that a small amount of VCI might provide the necessary protection. The results were very gratifying. None of the polished surfaces were rusted; however, on the sandblasted faces, 13 were without rust and 5 showed initial failure. Two of the packs were wet inside yet the panels were without rust. Incompatibility between one film and the VCI was noted by a light yellowish coloration. A bare sandblasted surface needs more protection from rust than a polished one. This may contribute to small differences in the rust ratings.

Dynamic Humidity Tests:

In the first test glass vials were used to separate the bag film from the panel faces. One set of sealed packs containing bare steel panels was exposed as controls at ambient temperature. Three sets of sealed packs, prepared in a similar manner, were exposed in the humidity cabinet. (Reference page 10, this report). The control packs exposed at ambient temperature were without rust. In the humidity cabinet, the air was practically saturated with moisture vapor and it was circulated about the packs. The permeability of the film to moisture vapor was at a maximum. Some films, on a comparative basis, were more permeable to moisture vapor and this was reflected by the amount of rust noted on the steel panels sealed in the plastic bags. The glass vials prevented any incompatibility between the bag film and the panel faced.

In the second test, the effect of high humidity on the sealed packs was investigated with and without the use of VCI. No glass vials were used in the packs. Four sets of experimental packs were prepared. One set consisted of bare steel panels sealed in the plastic bags. They were used as controls. One set was wrapped loosely in vinylidene-chloride copolymer film, as a secondary wrap, and sealed therein. One set was coated with an emulsifiable rust preventive compound and one set contained a VCI paper insert. After 164 days of continuous exposure the following information was obtained. By reference to Figures 2 and 3, each of the bags was unable to afford complete protection from rust to the bare control panels. The rate of rusting of a bare steel panel sealed in a pack is quite uniform, however, each bag material varies in its permeability to moisture vapor. It can be noted that pack numbers 2, 14 and 15 rusted the most rapidly. Pack number 3 rusted slowly. A comparison of Figure 3 and Figure 4 shows that the vinylidine chloride copolymer film, used as a secondary wrap, provided a slight amount of additional protection from corrosion. Figures 5 and 6 show that the emulsifiable rust preventive compound provided temporary protection for the steel panels. It extends the initial period of protection on the polished face until breakdown occurs, and then the rate of rusting proceeds at a uniform rate. Figure 7 shows the VCI rust ratings.

Cyclic Test A:

Eighteen plastic films were fabricated into four sets of experimental packs: One set of controls and three sets containing 0.10, 0.20 and 0.40 grams of VCI crystals, respectively. They were then subjected to MIL-P-116, Test A (see Appendix I) to determine how the packs would behave.

On completion of the test, the following information was obtained. Of the control set, 5 packs were without rust, the remaining 13 packs had varying degrees of rust. Since the sets containing VCI crystals were prepared with varying amounts of the protective medium, it was found that 0.10 gm. was sufficient to prevent corrosion in the packs.

Cyclic Test B:

These experimental packs were prepared in triplicate, one set of bare controls and two sets containing 0.05 to 0.06 gms of VCI crystals. The three sets were exposed in an oven at 165 ± 2°F to determine the effect of high temperature on the plastic bag materials. Any change was to be noted in the Quick Leak Test. The three sets were then placed in a cold box at -65 ± 1°F to determine the effect of low temperature change on the plastic bag materials. On reaching ambient temperature any change in the film was to be noted in the Quick Leak Test. The three sets were then placed in the cyclic exposure test of MIL-P-116, Test A. It was shown that 0.05 to 0.06 gms of VCI crystals were sufficient to afford complete protection for the packs. High and low temperature alternation, prior to the cyclic exposure of MIL-P-116, Test A, did not produce failures in the bags when subjected to the Quick Leak Test.

Cyclic Test C:

This test was conducted on ten sample packs containing bare steel panels as controls; bare steel panels with a secondary overwrap of vinylidene-chloride copolymer film bare steel panels with a coating of MIL-C-40084(ORD) rust preventive compound and bare steel panels with a VCI paper insert.

The packs were subjected to low temperature in a cold box and alternated by exposure at ambient temperature for a period of 24 days.

This cyclic test proved to be quite mild and no failures of the packs were noted. Test was discontinued.

Cyclic Test D:

This test was set up as previously described, except that the packs were subjected to high temperature in an oven, alternated by immersion in fresh water at ambient temperature for a period of 10 days of cyclic exposure. This test was considered satisfactory because each of the ten plastic films, by itself, was unable to protect the bare control panels from rust.

The vinylidene-chloride-copolymer film wrapped loosely about the bare steel panels served as a thin transparent secondary wrap. Its purpose was to provide additional corrosion protection to the steel panel.

The coating of MIL-C-40084(ORD) material was unable to withstand the oven temperature, and,on immersion in fresh water, the coating contributed to the formation of stain and corrosion on the test panels.

The VCI paper inserts afforded protection to the bare steel panels as long as the concentration of the inhibitor was sufficient, however, the high temperature drove off the volatile matter and, on repeated cycling, the packs reached a point where rusting of the panels appeared to be accelerated.

Incompatibility between the polystyrene bag material and the overwrap of vinylidene-chloride-copolymer film was noted on the packs heated in the oven and alternated by immersion in fresh water. The polystyrene bag became opaque and lost its transparency.

Indoor Storage:

A bare steel panel, polished on one face and sandblasted on the other, was sealed in a plastic bag. Eighteen kinds of plastic films were used to make the bags. The packs were stored indoors at ambient temperatures. The relative humidity varied with the seasons. Dust was ever present in the atmosphere. After one year in storage, the packs were removed and inspected. The panels were free of rust. Each of the packs provided protection for the bare steel panels under the storage conditions for a period of one year.

LITERATURE REFERENCES

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3. Stambler, S., Katz, C., Gordon, S., "Transparent Packaging," Bureau of Supplies and Accounts, Department of the Navy, Washington D. C., 22 July 1960

4. Methods of Preservation, Military Specification MIL-P-116D, 29 September 1960.

LIST OF PRIOR REPORTS

RIA No.	Date Issued	Title
60-1051	4-6-60	Characteristics of VCI Materials When Applied as Packaging Media
62-3600	10-31-62	Transparent Skin and Blister Packaging

APPENDIX NO. 1

CYCLIC EXPOSURE TEST
EXTRACT FROM MILITARY SPECIFICATION MIL-P-116

4.4.5.1, Test A:

Overnight at 120° to 130°F.
Two hours of water spray at 50° to 60°F.
Two hours at -10° to 0°F.
Two hours of water spray at 120° to 130°F.
Two hours of water spray at 50° to 60°F.
Overnight at 35° to 50°F.
Four hours of water spray at 50° to 60°F.
Two hours at 35° to 50°F.
Overnight at 120° to 130°F.
Two hours of water spray at 50° to 60°F.
Two hours at -10° to 0°F.
Three hours at 35° to 50°F.
Overnight at 120° to 130°F.

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PACKAGING IN TRANSPARENT BAGS by Linden H. Wagner

RIA Lab. Rep. 63-2583, 8 Aug 63, 44 p. incl. illus. tables, (DA Project No. 1-H-0-24401-A-110, AMC Code No.5025.11.842) Unclassified Report.

Eighteen transparent plastic films of various thicknesses were made into bags. Bare steel panels, panels overwrapped in vinylidene chloride copolymer, panels coated with an emulsifiable rust preventive and panels protected with VCI materials were sealed in the bags. These packs were then subjected to fresh water immersion, static and dynamic humidity, cyclic exposure and one year of indoor storage tests to determine the suitability of plastic bags for packaging applications. The extent, nature and intensity of the rusting of the test specimens were noted through the transparent bag materials.

The control packs, after one year of indoor exposure at ambient temperature, provided adequate protection without the use of VCI materials. It was also determined that the packs were unable (continued) over

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