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MASTER

Corrosion Testing of Urea-Formaldehyde Foam Insulating Material

R. Weil
A. Graviano
K. Sheppard

PART OF
THE NATIONAL PROGRAM
FOR
BUILDING THERMAL ENVELOPE SYSTEMS
AND INSULATING MATERIALS

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CORROSION TESTING OF UREA-FORMALDEHYDE FOAM
INSULATING MATERIAL

R. Weil, A. Graviano, and K. Sheppard
Department of Materials and Metallurgical Engineering
Stevens Institute of Technology
Hoboken, NJ 07030

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OTHER REPORTS IN THIS SERIES

1. DOE/CS-0059: The National Program Plan for Building Thermal Envelope Systems and Insulating Materials (January 1979).
2. ORNL/SUB-7556/I: Assessment of the Corrosiveness of Cellulosic Insulating Materials (June 1979).
3. ORNL/SUB-7504/3: Recessed Light Fixture Test Facility (July 1979).
4. ORNL/SUB-7559/I: Problems Associated with the Use of Urea-Formaldehyde Foam for Residential Insulation (September 1979).
5. ORNL/Sub-7551/I: Interim Progress Report on an Investigation of Energy Transport in Porous Insulator Systems (October 1979).
6. ORNL/TM-6494: A Technique for Measuring the Apparent Conductivity of Flat Insulations (October 1979).
7. ORNL/Sub-79/13660/I: Minnesota Retrofit Insulation In Situ Test Program Extension and Review (February 1980).
8. ORNL/TM-7266: An Experimental Study of Thermal Resistance Values (R-Values) of Low-Density Mineral-Fiber Building Insulation Batts Commercially Available in 1977 (April 1980).
9. ORNL/Sub-78-97726/I: A Field Study of Moisture Damage in Walls Insulated Without a Vapor Barrier (May 1980).
10. ORNL/CON-46: An Appraisal of the M Factor and the Role of Building Thermal Mass in Energy Conservation (July 1980).
11. ORNL/Sub-7686/I: Smoldering Combustion Hazards of Thermal Insulation Materials (July 1980).
12. NBS/BS Series 123: The Effect of Moisture on the Thermal Conductance of Roofing Systems (April 1980).

FOREWORD

This is one of a series of reports to be published describing research, development, and demonstration activities in support of the National Program for Building Thermal Envelope Systems and Insulating Materials. The National Program involves several federal agencies and many other organizations in the public and private sectors who are addressing the national objective of decreasing energy wastes in the heating and cooling of buildings. Results described in this report are part of the National Program through delegation of management responsibilities for the DOE lead role to the Oak Ridge National Laboratory.

Ted S. Lundy
Program Manager
Building Thermal Envelope Systems
and Insulating Materials
Oak Ridge National Laboratory

E. C. Freeman
Program Manager, Buildings Division
Office of Buildings and Community
Systems
Department of Energy

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ABSTRACT

Two tests of the corrosiveness of urea-formaldehyde (UF) foam insulating materials were compared. One test in which test coupons are foamed in place has been named the Timm test. In the second test, blocks of foam, already set are placed in contact with test coupons. It is called the Canadian test. The Timm tests uses 10 gage thick coupons, while the Canadian test specifies 3 mil thick ones. In the comparisons described herein, both coupon thicknesses were employed in each test. The Timm and Canadian tests also differ in that in the former, the coupons are kept under essentially ambient conditions for 28 and 56 days respectively. In the Canadian test, the coupons are exposed at 40°C under humid conditions. The corrosion rate in both tests is calculated from weight losses. Steel probes, which measure corrosion rate from changes in the electrical resistance, were also foamed along with the coupons in the Timm test.

Two samples of UF foam were tested by the Timm and the Canadian tests. The electrical-resistance probes showed that the corrosion rate against steel was initially quite high, of the order of 12-20 mpy (mils per year). After about 20 days, the rate was almost zero. In the Timm test, the corrosion rates of steel coupons were of the order of 0.5-2 mpy when averaged over the 28 or 56 day test period. Corrosion rates calculated on the assumption that the weight loss occurred during the first 1-2 days only, were of the same magnitude as those from the electrical-resistance-probe data. In the Canadian test, the corrosion rates exhibited by the thick steel coupons were much greater than those of the thinner ones, exceeding for one foam the value of 6 mpy which constitutes failures. The thin steel coupons of the Canadian test showed pinhole corrosion.

The greater corrosion rate of the thick coupons in the Canadian test as well as poor reproducibility of the corrosion rates was attributed primarily to variations in the contact areas between the sample and the UF foam.

The corrosion rates of galvanized steel coupons in the Canadian test in several cases exceeded the failure value. In the Timm test, the corrosion rates averaged over the whole test period were quite low. The corrosion rates of copper and aluminum in both tests were quite low.

On the basis of the results of this study the following recommendations for a corrosion-test procedure for UF foam were made:

1. Two corrosion tests should be conducted, one for foam while curing and one for after it has stabilized.

2. The test for corrosiveness while curing should be of the type recommended by Timm, but last for 1 to 2 days only. Provisions should be made to insure a constant contact area.
3. The test for corrosiveness after stabilizing should be of the accelerated type such as the Canadian one. To insure a constant contact area, thicker coupons should be used.
4. The coupons for both tests should have a controlled part of the area not in contact with the foam to simulate field conditions.

INTRODUCTION

The formulation of procedures for testing the corrosiveness of urea-formaldehyde (UF) foamed-in-place thermal insulation presents several problems. When the UF is foamed in place in a wet state, it contains acidic catalysts which can render it corrosive to metals with which it comes in contact. This condition should be tested. Upon setting, the pH rises which would tend to make it less corrosive. However, there is shrinkage then which tends to separate the foam from metal with which it was in contact. Complete loss of contact is rare, however. Where the foam is in contact with metals, corrosion can continue and may, in fact, be accelerated due to the uncontacted area acting as a cathode. In a test, if the weight loss in the area still in contact and corroding is averaged over the whole area of the test coupon, a misleadingly low corrosion rate is calculated. There is also the problem which is general to most accelerated corrosion tests, namely, of determining how closely they relate to field conditions. To date there is no corrosion test for UF foam which addresses itself to all these problems.

At present there exists a corrosion test of UF foam which has gained some degree of acceptance. It is the Canadian Government Specifications Board Standard for Thermal Insulation, Urea Based, Foamed In Situ which will henceforth be referred to as the Canadian test. A copy of the test procedure is Appendix I. Some slight modifications to the Canadian test were proposed by the ASTM C16.23 Task Force in Oct. 1979. The pertinent aspects of the Canadian test are that relatively small and thin test coupons [50mmx50mmx76µm] of mild steel, copper and aluminum and slightly thicker (1mm) of galvanized steel are contacted with foam which has already cured. Thus the metals are not in contact with the foam when it is setting and in its most acidic condition. Some provisions are made to maintain contact between the metal and foam in the Canadian test. The coupon-foam samples are kept at 40°C under conditions of relatively high humidity to accelerate corrosion.

Another corrosion test for UF foam was proposed by the ASTM C16.32 task force under the chairmanship of Mr. William Timm which will henceforth be referred to as the Timm test. The text of this proposed test is Appendix II. The main aspects of this test as compared to the Canadian test are that the coupons are considerably larger and thicker and that they are foamed in place. The coupons for the Timm test are 88.1 mm (3½") diameter disks approximately 3.5 mm thick. The Timm test also uses a 6061 aluminum alloy, where the

Canadian test employs Type 3003. The Timm test is conducted at room temperature and 50% relative humidity.

It is seen that the two principal differences between the Canadian and the Timm tests are the condition of the insulation, i.e., foamed in place or cured, and the thickness of the test coupons. The test temperatures and humidities are also higher in the Canadian test. The purpose of the investigation reported here was to compare the two test methods as to these two aspects with the same UF foam materials. Therefore, two samples of UF foam were subjected each to the Canadian and Timm test. Also the thicker coupons specified in the Timm test were included in the Canadian test and disks of the thin materials of the Canadian test used in the Timm test.

EXPERIMENTAL PROCEDURE

Two batches of UF foam were prepared at Dr. Keith Long's laboratory at the University of Iowa on October 29, 1979. These two foams, named A and B, are the same ones so designed in Report ORNL/SUB-7559/I. Pertinent data about these two foams are presented in Table I. The two foams differ principally in the amounts of free and extractable formaldehyde.

Table I
Foams Data

	Foam A	Foam B
pH at foaming	3.25	3.10
Density after 3 days (mg/cm ³)	7.28	7.06
Setting time (sec) (determined outside chamber)	60	60
Free formaldehyde (ppm) after 3 days	100	40
Extractable formaldehyde	0.55	0.02

The arrangement of the test coupons for the Timm test is shown in Figure 1. Two such containers were prepared, one to be left for 28 days and one for 56 days in the test chamber. As can be seen in Figure 1, there were two each of the thick disks of copper, aluminum, galvanized steel and steel and one each of the thin disks. The arrangement thus differs from that specified for the Timm test in that one thin disk of the four metals was substituted for a thick one.

In order to monitor the corrosion rate during the setting of the foam, a steel electrical-resistance probe was included in each Timm-test container. This probe measures the corrosion rate from the change in electrical resistance due to the change in the cross-sectional area of the test coupon when it

corrodes. The probes were precleaned according to the procedure specified for the steel disks.

The samples for the Timm test were precleaned in acetone, dried and placed in the plastic trays. The coupons of the same metal were separated by one polyethylene spacer. There were two spacers between dissimilar metals. The trays were foamed to the top edges and then placed in a test chamber at 34-45% relative humidity at room temperature. They were kept in the chamber at the University of Iowa for 28 and 56 days, respectively and shipped to Stevens. The coupons were then removed from the trays and cleaned according to the ASTM G1 Specification.

For the Canadian test, samples of Foams A and B, made at the same time as the Timm-test coupons were foamed, were cured for 63 days. Coupons of area 50 mm x 50 mm and of the thicknesses and materials specified in the Canadian test procedure as well as the thicknesses and materials of the Timm test were sandwiched between blocks of foam. In the other aspects, the procedure specified for the Canadian test was followed.

The corrosion products from the steel coupons were analyzed by X-ray diffraction.

RESULTS AND DISCUSSION

Electrical-Resistance-Probe Results. A typical record of steel electrical resistance probe output vs time is shown in Figure 2. The corrosion rate is proportional to the slope of the curve. It can be seen that the data can be represented by two straight lines. There is an initial relatively large slope lasting for about 2 days, followed by an essentially horizontal line. Thus there are two corrosion rates, a relatively large one lasting for about 2 days and then a very low one when the slope is almost zero. The two slopes and the time of the changeover as calculated by a least-squares analysis of the data for the 4 probes used are listed in Table II. It may be recalled that there were 2 assemblies like those shown in Figure 1 for each of the two UF foams. In one assembly the coupons were exposed to the foam for 28 days and in one for 56 days. The data from the electrical resistance probes in the 28-day and 56-day assemblies for each foam were thus essentially duplicate runs. In two of the probe data, there was a question as to whether certain points near the changeover belonged to the initial or horizontal parts of the graph. The slopes were therefore calculated with and without these points, resulting in

Table II
Corrosion Rates
Electrical-Resistance Probe

	Initial Rate (mpy)	Time at Slope Change (days)	Rate After Slope Change
Foam A, 28-day Sample	20.7	2.84	0.96
Foam A, 56-day Sample	12.9-14.5	1.91-2.84	0.75-1.0
Foam B, 28-day Sample	15.7	1.91	0.35
Foam B, 56-day Sample	13.2-14.3	1.91-2.54	0.60-0.74

in a range of values as listed in Table II.

The higher initial corrosion rate is probably due to the low pH and the moisture content of the UF foam. No specific data are available for the conditions under which the two foams were prepared. However, in Report ORNL/SUB-7559-I, Long et al. show in their Fig. 12 that the density of Foam A initially decreases and then becomes essentially constant after 3 days at 33°C and low humidity. The decrease in density was primarily due to moisture loss. It is therefore quite likely that the changeover to the slower corrosion rate observed after about 2 days also corresponds to the drying of the foams. There are no data from which the effect on the corrosion rate of the rise in pH due to curing of the foam can be evaluated.

The slower corrosion rate is probably due to Foams A and B becoming less corrosive rather than loss of contact with the test coupons. As will be discussed later, the control coupons of the Canadian test which were in contact with cured foam under ambient conditions showed almost no corrosion. This result indicates that cured samples of Foam A and B are not very corrosive when the temperature and moisture content are low. It is less likely that the slower observed corrosion rates after about 2 days were due to foam shrinking away from the coupons as it cured.

The variation in the initial, higher corrosion rate between duplicate samples is probably due to differences in the actual area of contact between the probe and the UF foam from the beginning. Figure 3 shows two probes after corrosion exposure. The top probe which had an initial rate of 15.7 mpy shows relatively uniform corrosion. The probe on the bottom of Figure 3, which had an initial rate of 20.7 mpy, shows much heavier corrosion on the left side. There is a small stripe indicated by an arrow which was apparently never in contact with the foam, as it shows no corrosion. The heavier corrosion

resulted in a greater reduction in the cross-sectional area of the probe and therefore a greater decrease in the electrical conductivity. The decrease in the conductivity, in turn, resulted in a greater calculated corrosion rate.

The fraction of the area of a probe or a test coupon which is not in contact with the foam can affect the corrosion rate as calculated either from a change in the electrical conductivity or a weight loss as in the Timm and Canadian tests. If part of the area of a steel sample is not in contact with the corrosive medium, there is more oxygen available there, causing it to become cathodic. This phenomenon raises the potential difference between the parts in contact and not in contact. Therefore, the corrosion current density (current/unit area) on the anodic part, i.e., that in contact with the foam, increases. The weight loss which is proportional to the corrosion current can decrease or increase depending on the relative cathodic or anodic areas. If the anodic area is relatively large, the current which is the product of current density and anodic area also increases and there is an increased weight loss over that which would have been found if the total area had been in contact with the foam. However, if the anodic, i.e., contact area, is small, the current and weight loss can decrease in spite of the higher current density. As the weight loss is averaged over the total area as is done in the corrosion-rate calculations, an apparently low rate is obtained. It is thus seen that corrosion rates calculated from weight losses are not reliable indices if the contact area varies.

Timm-Test Results - Steel Coupons. The corrosion rates as calculated from weight losses are listed in Table III. The corrosion rates are less than those specified for failure. So both foams passed the Timm test. The weight losses after 28 and 56 days were the same within the error, resulting primarily from variations in the contact area. This result plus the data from the electrical-resistance probes, which were included in the Timm-test assemblies along with the coupons, strongly indicates that most of the corrosion occurred during the first few days. When calculating a corrosion rate on the basis of weight loss, a uniform rate over the whole exposure-time period is assumed. A corrosion rate was also calculated assuming that the weight loss occurred over the time period until the changeover to the lower rate exhibited by the electrical-resistance probes. These modified corrosion rates are also listed in Table III. It is seen that these modified rates are in the same range of values as those calculated from the initial slopes of electrical-resistance-probe data. The variations in the rates were due, at least partly, again to

Table III
Corrosion Rates
Weight Loss

Steel Coupons

Test	Foam A, 28-day Timm			Foam A, 56-day Timm			Foam A Canadian		
Sample	S-1	S-2	S-3*	S-1	S-2	S-3*	S-1	S-2	S-3**
Corrosion Rates (MPY)	1.72	1.84	1.39	0.5	+	0.6	0.51	0.73	6.32
Modified, Initial Corrosion Rates (MPY)	17.0	18.1	13.7	9.9	+	11.8			
	Pitting	Pitting	Pinholes	Pitting	Pitting	Pitting	Pinholes	Pinholes	Pitting

Test	Foam B, 28-day Timm			Foam B, 56-day Timm			Foam B Canadian		
Sample	S-1	S-2	S-3*	S-1	S-2	S-3*	S-1	S-2	S-3**
Corrosion Rates (MPY)	2.03	0.72	0.85	1.02	0.25	0.41	0.35	0.35	5.87
Modified, Initial Corrosion Rates (MPY)	21.8	10.6	12.5	30.5	7.3	12.0			
	Pitting	Pitting	Fitting	Fitting	Pitting	Pitting	Pitting	Pitting	Pitting

Galvanized Steel Coupons

Test	Foam A, 28-day Timm			Foam A, 56-day Timm			Foam A Canadian		
Sample	Z-1	Z-2	Z-3*	Z-1	Z-2	Z-3*	Z-1	Z-2	Z-3**
Corrosion Rates (MPY)	0	0.4	<0.01	0	0	0.14	2.05	5.3	2.08

Test	Foam B, 28-day Timm			Foam B, 56-day Timm			Foam B Canadian		
Sample	Z-1	Z-2	Z-3*	Z-1	Z-2	Z-3*	Z-1	Z-2	Z-3**
Corrosion Rates (MPY)	0.30	0.76	0	0	0	0.11	2.07	4.72	7.92

Table III (Continued)

Copper Coupons

Test	Foam A, 28-day Timm			Foam A, 56-day Timm			Foam A Canadian		
Sample	C-1	C-2	C-3*	C-1	C-2	C-3*	C-1	C-2	C-3**
Corrosion Rates (MPY)	0.75	0.65	0.10	0.13	0.80	0.01	0.1 Pitting	0.3 Pitting	0.31 Pitting
Test	Foam B, 28-day Timm			Foam B, 56-day Timm			Foam B Canadian		
Sample	C-1	C-2	C-3	C-1	C-2	C-3*	C-1	C-2	C-3**
Corrosion Rates (MPY)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.11 Pitting	0.28 Pitting	0.17 Pitting

Aluminum Coupons

Test	Foam A, 28-day Timm			Foam A, 56-day Timm			Foam A Canadian		
Sample	A-1	A-2	A-3*	A-1	A-2	A-3*	A-1	A-2	A-3**
Corrosion Rates (MPY)	0	0	0	0	0	0	0	0	0.30
Test	Foam B, 28-day Timms			Foam B, 56-day Timm			Foam B Canadian		
Sample	A-1	A-2	A-3*	A-1	A-2	A-3*	A-1	A-2	A-3**
Corrosion Rates (MPY)	0	0	0	0	0	0	0	0	0.22

* Sample had thickness specified in Canadian Test, i.e., 3 mils.

** Sample had thickness specified in Timm Test, i.e., 10 gage.

† No data due to probable error in weighing.

variations in the actual contact area between the foam and the steel coupon. A test coupon, which showed a high modified rate of 21.8 mpy; namely, S-1 of the 28-day test in Foam B, is shown in Figure 4. It is evident that some areas were again never in contact with the UF foam as they show no corrosion. As already discussed, such areas acting as cathodes to the ones in contact can result in a high corrosion rate. The actual rate in this case is even greater than that shown in Table III as the weight loss was assumed in the calculation to result over the total coupon area.

Canadian Test - Steel Coupons. Among the results of the Canadian test as listed in Table III, one which stands out is that the corrosion rate calculated from the weight losses are much greater for the thicker test coupons, i.e., S-3 in both foams. In Foam A, this rate exceeded the 6 mpy which constitutes failure according to Appendix I. However, as the Canadian test specifies a 3 mil test coupon, i.e., S-1 and S-2, both foams technically passed the test on the basis of corrosion rate.

A probable reason for the higher corrosion rates exhibited by the thicker test coupons is again the contact area. This fact was evident from examination of the corroded coupons. As the foam layer on the bottom does not uniformly support the coupon when a weight is placed on the top layer, the thin coupons probably bend. This bending probably resulted in a small contact area and a lesser total weight loss. As this weight was averaged over the whole area, a smaller corrosion rate was calculated. The actual corrosion rate at the points of contact was undoubtedly quite high as previously discussed, resulting in the observed pinholes.

A modified corrosion rate was not calculated because no electrical resistance probes were included in the Canadian test. As the Canadian test is conducted with UF foam which has already set, it is likely that the actual corrosion rate does not vary over the exposure-time period. Corrosion rates of 5-6 mpy as determined with the thick coupons are therefore probably indicative of the actual ones. Such rates are thus less than encountered during the first 2 days after foaming. The rates, however, are greater than those obtained after 2 days in the Timm test. This result is consistent with the nature of the Canadian method as an accelerated corrosion test. The elevated temperature

and higher humidity of the Canadian test would be expected to cause a higher corrosion rate than the Timm test which is conducted under ambient conditions. The control coupons for the Canadian test which were kept under ambient conditions essentially did not show any corrosion regardless of the type of metal exposed. This result, as already mentioned, indicates that the tested foams are not corrosive under ambient conditions after they have become stabilized and the pH has risen.

Galvanized Steel Coupons. From Table III, it is evident that the accelerated corrosion conditions of the Canadian test, resulted in higher rates for the galvanized-steel coupon. In Foam B, a higher rate was also obtained for the thicker coupon, Z-3. The thicker coupon in Foam A was apparently not in good contact with the UF foam. Both foams failed the Canadian test on the basis of coupons Z-2 as the corrosion rate for passing is 3.5 mpy. No galvanized steel electrical-resistance probes are available. Thus no data about the variation of the corrosion rate during the stabilization of the foam could be obtained. Both foams passed the Timm test for galvanized steel.

Copper Coupons. Both foams passed both tests for copper coupons. The pitting which occurred during the Canadian test was again indicative of the accelerated nature of this test. Only slight discoloration was observed on the Timm-test coupons showing that even during curing, the foams were not very corrosive to copper.

Aluminum Coupons. Both foams passed both tests for aluminum coupons. The only coupons which showed any corrosion were the thick ones exposed according to the Canadian method. This result again shows the effect of the accelerated test and the contact area as previously discussed.

General. Photographs of the test coupons after cleaning off the corrosion products are shown in Figure 5.

Analysis of the corrosion products on the steel coupons from both the Timm and Canadian test using X-ray diffraction showed them to be primarily Fe_2O_3 .

It should be pointed out that there are UF foams which are more corrosive than the two described in this report. Two lots of other foams, which were tested here by the Canadian method, resulted in virtual destruction of the steel coupons. Here even the control coupons showed evidence of corrosive attack. It appears that Foams A and B are relatively noncorrosive.

CONCLUSIONS

Neither the Timm nor the Canadian tests appear to be satisfactory by themselves for determining the corrosiveness of UF foam against steel. If there is an initial corrosion rate of about 20 mpy lasting for 2 days, and then a rate of 6 mpy for the 28 days of the Canadian test, the former is 20% of the latter. Therefore, the amount of corrosion which takes place right after foaming is not negligible. It appears that two tests are required. One test of the type proposed by Timm, but conducted for only 1 or 2 days so that the weight loss is not averaged over too long a time period, would measure the initial corrosion. The Canadian test is then probably adequate to test the corrosiveness of the foam that has stabilized provided that adequate provisions are made to control the contact area by using thicker coupons.

Under field conditions, there are likely to be some areas on metal components in contact with the foam and others which are not. As the areas not in contact acting as cathodes, raise the current density, this phenomenon should be included in both test procedures. Thus there has to be a constant area in contact and one not in contact with the foam.

Even though it could not be determined whether the foams are more corrosive against copper, aluminum and galvanized steel before they are stabilized, coupons of these metals should be included in the short-time Timm test.

There is a longer-range effort under way to develop a corrosion test for all insulating materials. However, until such a test has been formulated, some way to determine the corrosiveness of UF foam is needed. The ASTM C16.23 task force is in the process of writing such standards. The recommendations of this report are intended to assist this task force.

RECOMMENDATIONS

On the basis of the results of this study, the following recommendations are made:

1. Two corrosion tests should be conducted, one for foam while curing and one after stabilization.
2. The test for corrosiveness while curing should be of the type recommended by Timm, but last for 1 to 2 days only. Provisions should be made to insure a constant contact area.
3. The test for corrosiveness after stabilizing should be of the accelerated type such as the Canadian one. To insure a constant contact area, thicker coupons should be used.

4. The coupons for both tests should have a controlled part of the area not in contact with the foam to simulate field conditions.
5. Some provisions to account for pitting should be included in the tests.

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FIGURE 1. TIMM TEST SET-UP

FIGURE 2
STEEL CORROSION DATA
ELECTRICAL RESISTANCE vs. TIME
FOAM A
SAMPLE FOR 28 DAY EXPOSURE TEST

Figure 3. Electrical Resistance Probes After Corrosion. Top Probe Was in Contact With Foam B for 28 days. Bottom Probe Was in Contact With Foam A For 28 Days.

Figure 4. Steel Coupon S-1 of 28-Day Timm Test.

Figure 5a

Figure 5b

Figure 5c

Figure 5d

Figure 5e

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APPENDIX I

CANADIAN GOVERNMENT SPECIFICATIONS BOARD

Standard
for

THERMAL INSULATION, UREA BASED, FOAMED IN SITU

4. 6.2.8 Corrosiveness

6.2.8.1 Apparatus and Materials

- Oven capable of maintaining $40 \pm 2^{\circ}\text{C}$.

-*Small container, approximately 90 x 50 mm, made of inert material such as polypropylene and equipped with a lid so designed that water condensing on it will not drip but will run to the walls of the container.

Large container, capable of housing the small container but that will fit inside the oven.

Test specimens, approximately 50 x 50 mm by 76.2 μm thick metal, free of tears, punctures or crimps as follows:

3003 bare aluminum, soft temper.

ASTM B 152, type ETP, Cabra No. 110, soft copper

low carbon, commercial quality, cold rolled shim steel.

Test specimens, approximately 50 x 50x1.0 mm made from hot

*The container shall be designed such that it is not potentially hazardous after it has been sealed at room temperature and heated to 40°C .

_____ dipped galvanized sheet steel conforming to Grade A or B, ASTM B 446 with a total zinc coating of $275 -0, +31 \text{ g/m}^2$. At least 40% of the zinc shall be on any one side of the test specimens. Metal of this quality is used in the manufacture of truss plates.

_____ 1,1,1-trichloroethane* analytical reagent grade.

_____ Balance, capable of determining the mass of the galvanized specimen to an accuracy of 1 mg.

_____ Distilled water, nitric acid (relative density 1.42), ammonium hydroxide (relative density 0.90), chromium trioxide, silver nitrate, hydriodic acid, reagent grade chemicals.

_____ Several noncorrosive plastic supports and a 150 g mass.

6.2.8.2 Specimens of Foam Insulation

Prepare foam specimens from blocks obtained from the test in par. 6.2.5. Cut a specimen 60 x 60 mm square and 15 mm thick from the blocks such that the surface is that obtained from foaming and not slicing the foam. All other surfaces of the specimen shall be obtained by slicing the foam. Surfaces obtained from foaming shall be placed adjacent to the metal specimens in the test.

*It has been established that exposure to trichloroethane may present a health hazard and corresponding precautions should be taken.

6.2.8.3 Procedure - Make duplicate tests for each determination.

Wash the metal specimens with 1,1,1-trichloroethane to remove any oil or grease. Dry at room temperature. Weigh the specimens and record their masses. Place a noncorrosive plastic screen support in the small container and add 20 mL deionized water. Place a foam block on the support at least 5 mm above the surface of the water. Place the metal specimen on the foam block, put another foam block on the metal specimen and then place on top of the sandwich a noncorrosive plastic screen and a 150 g mass. The 150 g mass shall not block air flow to the top foam block. Seal the small container with a lid. Place the small container in the large container, add sufficient distilled water to the large container and seal it. Place the assembly in an oven at $40 \pm 2^\circ\text{C}$ for 28 d. Upon completion of the test remove the assembly from the oven and dismantle. The large container shall still have some water in it: if there is no water present at the end of the test, then results for those materials passing the test are suspect and the test should be repeated. Remove the corrosion products from the metal specimens by the procedures recommended in ASTM G1. Rinse all metal specimens in distilled water and dry. Examine and weigh the specimens and controls. The controls shall be metal specimens not exposed in the oven but which are cleaned identically to the specimens. Subtract the loss in mass of the controls from the loss in mass of the specimens. For each

set of duplicate specimens to meet the requirements of par. 4.3.3, the spread between results shall not exceed an absolute value equal to 15% of the maximum permissible corrosion rate specified for that material and the average of both results shall be below the maximum limit set for that material.

APPENDIX II

TIMM TEST

8.7 Corrosion Test The following test procedure utilizes the principle of ASTM G 4 testing method to simulate the actual environment in which pieces of carbon steel, galvanized iron, copper, and aluminum (alloy 6061) will be subjected to an actual field conditions. The cleaning and evaluation of the corrosion test specimen will utilize the recommended practice in ASTM G 1, and G 46; the resulting data will be evaluated by the recommended practice in ASTM G 16.

8.7.1 Preparation of Test Coupons Six (6) test coupons of each material, three (3) coupons each for each test tray, shall be cut or punched from a no. 10 U.S. gauge sheet (approximately 3.5 mm thick) with a diameter of 3 1/2" (88.9 mm) as shown in Figure 1. The test material shall be cut from sheets of carbon steel, galvanized iron, copper, and aluminum (alloy 6061) and have 11/32" diameter (11.9 mm) hole drilled in the center and all edges shall be machine finished. Each test coupon shall be stamped with an appropriate letter to identify the material of the coupon, and a number to identify the particular sample. The following letter identification shall be used for the test materials:

- a. aluminum
- c. copper
- s. carbon steel
- z. galvanized iron.

All coupons or test specimens shall be prepared in accordance with

ASTM G 1. The coupons are degreased in an organic solvent, such as acetone, hexane, methanol, or a combination of these. Hot alkalis and chlorinated solvents are not to be used since they may attack some metals. Abrasive cleaners are not used and brushing is kept to a minimum to prevent work hardening of the surface. Cleaning of the coupons is followed by a water rinsing, drying by an air jet, and storing in an oven maintained at 110°F (43°C) until ready to be used. Handling of the clean coupon must be kept to an absolute minimum, and no towel drying used to avoid the introduction of grease, lint, or other foreign materials on the coupon.

8.7.2 Apparatus

- 1 Analytic balance capable of weighing test coupons to 0.2 mg (0.0002 g).
- 1 Specimen corrosion box. A plastic tray with inside dimensions of no less than 12" x 7 3/4" x 5" (304.8 mm x 196.9 mm x 127.0 mm) shall have three (3) 5/32" holes drilled in the 12" long side, 2 1/2" above the bottom of the tray and at the center line of the 12" side, and 4" on each side of the center line as shown in Figure 3.
- 6 1/4" PVC or other suitable plastic threaded rod with plastic nuts.

Plastic spacers, fabricated from 5/8" (15.9 mm) diameter PVC or other plastic rod, with a 9/32" (7.14 mm) diameter hole drilled through the center, which should have one (1) edge machined to a 7/16" (11.1 mm) diameter for a depth of 1/8" (3.18 mm) on one end of the rod, as shown in Figure 2.

The test coupon is to be slid over the machine end, and the adjacent spacer secures the test coupon on the 1/4" diameter threaded plastic rod.

8.7.3 Test Procedure Remove test coupons from oven maintained at 110°F (43°C) and allow to cool to room temperature. Weigh test coupon on the analytic balance to the nearest 0.2 mg and position on plastic spacer on the 1/4" diameter plastic rod. Place all similar coupons adjacent to each other and place a plastic spacer between each coupon. Place two (2) plastic spacers between dissimilar materials and continue mounting test coupons on the 1/4" diameter plastic rod.

After all coupons are mounted on plastic rod, add special spacer measured to hold all the spacers tightly when fitted into the plastic tray. While holding the coupon firmly on the rod by the spacers, slide the 1/4" plastic rod through one (1) hole in the tray, and then slip the rod down moving it out in the hole just positioned into, and slide through the second hole in the tray. Place plastic nuts on both ends of the rod to hold the coupons rigidly in the plastic sample tray.

The tray is fitted with three (3) holes, so that two (2) additional plastic rods with three (3) sets of samples can be installed in the tray for additional testing to increase the reliability of the results. A minimum of two (2) test trays are prepared in this manner. Foam each test tray to the top edge and allow to cure at room temperature 73°F ±3°F (23°C ±2°C) and 50% ±5% relative humidity. One corrosion tray is to have the test coupon removed

after 28 days following initial foaming, and the second test tray shall have the test coupon removed after 56 days following initial foaming (an additional 28 days from the first control tray).

The samples are removed by cutting the foam parallel to the plastic rod and 2" from the rod for the full width and depth of the tray. The plastic nuts are removed from the threaded plastic rod, and the rod with the test coupon and block of foam are removed from the tray as a unit. The foam is cut away from around each test coupon and loose particles removed with an air jet. Remove each coupon from the threaded rod, and remove any excess loose foam by light brushing or an additional air jet treatment. Weigh each coupon on an analytic balance to the nearest 0.2 mg (0.0002 g) and compare weight with initial weight of sample. Any weight increase is reported as weight of corrosion products. Clean test coupons by method outlined in ASTM G1 for the respective materials and weigh each coupon after each cleaning. Determine the weight loss of sample from repeated weighings after each cleaning and determine weight loss from corrosion by method A2 in ASTM G1.

Any pitting attack will be evaluated by ASTM G46 and be reported as a ratio of deepest metal penetration to average metal penetration (pitting factor).

8.7.4 Calculations The corrosion rates, expressed as mils penetration per year (mpy) or mm per year (mmpy) can be calculated by the following equation:

$$\text{Corrosion rate} = \frac{K \times W}{A \times T \times D}$$

where:

K = a constant to correct for different units.

T = a time of exposure in hours to the nearest 0.01 hours.

A = the total surface area in in² to the nearest 0.01 in² or cm² to the nearest 0.01 cm².

W = the weight loss in mg to the nearest 0.2 mg.

D = the density in g/cm³ (See Appendix A1. ASTM G1).

Constant K

<u>Corrosion Rate Units</u> <u>Desired</u>	<u>Area in Square</u> <u>Inches</u>	<u>Area in Square</u> <u>Centimeters</u>
mils per year (mpy)	534.75	3450
mm per year (mmpy)	13.57	87.6

$$\text{The area} = \frac{2\pi}{4} (D^2 - D_h^2)$$

where:

D = diameter of the test coupon (3 1/2" or 88.9 mm).

D_h = diameter of the hole (15/32" or 11.9mm).

8.7.5 Reporting Corrosion Rates The pitting factor shall be reported for both the initial corrosion rate and the average corrosion rate as determined from both test coupons. The actual corrosion rate will be the corrosion rate of the 56 day sample minus the corrosion rate of the 28 day sample. These corrosion rates shall be compared with the limiting values given in 6.7.

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