DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150784

CERTIFICATION AND VERIFICATION FOR CALMAC FLAT PLATE SOLAR COLLECTOR

Prepared from documents furnished by

Calmac Manufacturing Company
150 S. Van Brunt Street
Englewood, New Jersey 07631

Under Contract NAS8-32253 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

(NASA-CR-150784) CERTIFICATION AND VERIFICATION FOR CALMAC FLAT PLATE SOLAR COLLECTOR (CALMAC Mfg. Co.) 159 p HC A08/MF A01 CSCL 10A N78-33532
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U.S. Department of Energy

Solar Energy

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This work was done under the technical management of Mr. John Caudle, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

This document contains information used in the certification and verification of the Calmac Flat Plate Collector. Contained are such items as test procedures and results, information on materials used, Installation, Operation, and Maintenance Manuals, and other information pertaining to the verification and certification.

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SECTION 1

CERTIFICATION REPORT

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MARSHALL SPACE FLIGHT CENTER

FOR

THE SUNMAT LIQUID FLAT PLATE COLLECTOR

CALMAC Mfg. Corp.
150 S. Van Brunt St.
Englewood, NJ 07631

The SUNMAT's compliance with the IPC was reviewed and confirmed by Engineering Testing Laboratories, and their analysis is included with this report. The report also includes test results from Desert Sunshine Exposure Tests confirming the SUNMAT's compliance with thermal performance and efficiency specifications.

John M. Armstrong, VP, Project Manager
CALMAC Manufacturing Corp.
4/20/78

DESERT SUNSHINE EXPOSURE TESTS, INC.

We Test Anything Under the Sun

BOX 185 • BLACK CANYON STAGE
PHOENIX, ARIZONA 85020
(602)465-7525

TAWA.
THE SUN KACHINA

April 14, 1978

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OF POOR QUALITY

Mr. John Armstrong
CALMAC MANUFACTURING CORPORATION
150 South Van Brunt Street
Englewood, New Jersey 07631

Subject: Test Sequence of Sunmat Collector to Conform to 1975 IPC and HUD/HWI

Dear Mr. Armstrong:

Desert Sunshine Exposure Tests, Inc. performed an ASHRAE 93-77 thermal performance, a 30-day stagnation and a thermal performance retest in accordance with the HUD requirements for the Hot Water Initiative. The data and results of these tests are presented in DSET Report No. 77S1111A. ASHRAE 93-77 is the test standard that is generally accepted, industry-wise, as the standard for thermal performance testing of solar collectors. On the basis of the DSET tests, the collector is judged to meet the HUD/HWI requirement that no more than a 10 percent change be observed for the values of $F_R\alpha\tau$ (the intercept) and F_RU_L (the heat loss coefficient) after 30 days of stagnation. Thus, paragraph b of Criterion 5.1.1 of the 1975 Interim Performance Criteria is also judged to be met.

Other criteria applicable to the 1975 IPC were evaluated by Engineers Testing Laboratories, Inc. Their letter report is attached to this summary.

Respectfully submitted,

DESERT SUNSHINE EXPOSURE TESTS, INC.

Gene A. Zerlaut
President & Technical Director

GAZ:lf

Enclosures

Report No. 77S1111

DSET No. 18471S

SOLAR COLLECTOR PERFORMANCE TEST

For:

Mr. Cal MacCracken
President
CALMAC MANUFACTURING CORP.
150 South Van Brunt Street
Englewood, New Jersey 07631

From:

Desert Sunshine Exposure Tests, Inc.
Box 185 Black Canyon Stage
Phoenix, Arizona 85020

By:

William J Putman
William J. Putman
Research Engineer

Approved by:

William T. Dokos
William T. Dokos
Manager, Solar Operations

January 27, 1978

This test report contains only findings and results arrived at after employing the specific test procedures and standards listed. It does not constitute a recommendation for, or endorsement of, or certification of the product or material tested. Desert Sunshine Exposure Tests, Inc. makes no warranty, expressed or implied, except that the analysis has been made, and a report prepared, based upon the sample or samples furnished by the client. Any extrapolation of data from the sample or samples relating to the batch or lot from which it was obtained may not correlate and should be interpreted accordingly with extreme caution. We assume no responsibility for variations in quality, composition, appearance, performance, or other feature of similar subject matter produced by persons or under conditions over which we have no control.

INTRODUCTION

A program has been instituted by the United States Department of Housing and Urban Development to encourage homeowners to install solar hot water systems. This program, commonly referred to as the HUD Solar Hot Water Initiative (SHWI), requires manufacturers of solar equipment, who wish to qualify their products for this program, to meet certification requirements set forth by the HUD Intermediate Standards for Solar Domestic Hot Water Systems/HUD Initiative.

Desert Sunshine Exposure Tests, Inc. (DSET) has been approved to perform the "Thermal Stability" test which is part of the certification requirements. DSET, Inc. conducts the thermal stability test in accordance with the procedure outlined by the HUD Intermediate Minimum Property Standards Supplement (MPS 4930.2, Sec. 5-515-2.1.2).

The thermal stability test consists of three parts:

A. Initial ASHRAE 93-77 thermal performance test.

B. 30-day stagnation exposure test.

C. Final modified ASHRAE 93-77.

A. INITIAL ASHRAE 93-77

The initial ASHRAE 93-77 thermal performance test consists of four separate parts: (1) Preconditioning, (2) Determination of the collector's time constant, (3) Instantaneous efficiency performance tests, and (4) Determination of the incident angle modifier for the collector.

Preconditioning

In preparation for the preconditioning test, the collector is filled with water and the inlet sealed. The panel is then placed in a non-operational stagnation mode in which the water is allowed to evaporate out during exposure. The collector is exposed for three days in a stagnation mode during which the cumulative incident solar radiation in the plane of the collector is at least 1500 BTU/ft^2/day.

Time Constant

The time constant is an indication of the transient response of the collector to a step change in insolation and is utilized to determine the proper data intervals for the instantaneous efficiency tests.

The test to determine the "Time Constant" is performed in accordance with ASHRAE 93-77 (Section 8.3.1, Method (1)). ASHRAE 93-77 defines the time constant as the time required for the outlet fluid temperature to attain 63.2 percent of its steady state value after the collector has been shaded with a cover to provide a step change in insolation.

Instantaneous Efficiency Test

The instantaneous efficiency tests are conducted to determine the efficiency of the collector as a function of the incident solar radiation, ambient temperature, and collector fluid inlet temperature.

ASHRAE 93-77 defines the solar collector efficiency as the amount of useful energy extracted from the collector divided by the amount of incident solar energy intercepted by the gross area of the collector.

At least sixteen (16) efficiency "data points" are obtained during the test in order that a governing "efficiency curve" can be generated.

All instantaneous efficiency testing is conducted in accordance with ASHRAE 93-77 and DSET Specification 75-SE2, appended herewith, utilizing a sun-tracking altazimuth mount which maintains the collector at normal incidence during the test periods.

Analysis of the effficiency data is performed by employing a 2nd order least squares polynomial resulting in an efficiency equation given as a function of the inlet parameter, (T_i-T_a/q_i).

Procedures and instrumentation employed for this test are described in DSET Specification 75-SE2 with the following exception: standard pressure gauges were used for pressure measurements. The pressure gauges used were not considered highly accurate; therefore, caution is advised in forming any conclusions based upon these measurements.

Incident Angle Modifier

In order to predict the collector efficiency at incident angles other than zero, the incident angle modifier, $K_{\alpha\tau}$, is determined for the collector. The incident angle modifier is a factor used to modify the performance curve (determined at normal incidence) to account for the changes in performance due to the sun's incident angle.

The test is conducted by adjusting the altazimuth mount such that incident angles to the collector are 30°, 45°, and 60°. Data are taken in each of the incident angle positions and the efficiency is calculated. For an incident angle of 0°, data from the instantaneous efficiency test are used.

The data from the incident angle modifier test are analyzed to determine the equation that describes $K_{\alpha\tau}$ as a function of $\frac{1}{\cos\theta} - 1$, where θ is the incident angle of the sun.

B. 30-DAY STAGNATION EXPOSURE TEST

The 30-day stagnation exposure test is designed to identify potential problems associated with the collector's materials and/or construction. The test is conducted by the method outlined in the HUD Intermediate Minimum Property Standards Supplement (MPS 4930.2, Sec. 5-515-2.1.2 A-D).

Pre-exposure preparation for the collector consists of filling the collector with tap water and sealing the inlet. A pressure relief valve is placed on the outlet for those collectors that operate under pressure. The relief valve is set to a value within 10 percent of the manufactorer's recommended maximum value.

The exposure test requires the collector to undergo 30 days of cumulative exposure to a minimum daily incident solar radiation ot at least 1500 BTU/ft^2/day as measured in the plane of the collector aperture. During this test the collector is exposed for at least one consecutive four-hour period with a minimum flux of 300 BTU/ft^2/hr after "boilout" of the water has occurred.

Appropriate data records, such as insolation, ambient temperature, wind velocity, and precipitation are obtained for each day of stagnation. During the 300 BTU/ft^2/hr period, these data are recorded every 30 minutes. Observations of the physical appearance of the collector are recorded during weekly visual inspections.

C. FINAL ASHRAE 93-77

The final modified ASHRAE 93-77 test differs from the initial ASHRAE 93-77 test in that the preconditioning, determination of the time constant, and the determination of the incident angle modifier are eliminated.

The final test requires a shortened instantaneous efficiency test. This shortened test requires 12 efficiency "data points" compared with a minimum of 16 from the first test.

An efficiency curve is generated from these data and the $F_R\alpha\tau$ and F_RU_L values are found for the collector.

A composite graph is provided in the following report which shows the instantaneous efficiency data and analysis results for both initial and final tests.

D. SPECIAL TEST

A special test is also reported along with the results of the final ASHRAE 93-77 test. Four instantaneous efficiency points were taken at approximately the same collector fluid inlet temperatures with the glazing of the collector removed. This test was performed to determine indirectly the losses through the cover at the collector under the imposed operating parameters.

EXPERIMENTAL

This section of the report presents the data and results of the thermal performance and stagnation test performed on the Calmac Manufacturing Corporation's "Sunmat" solar collector.

The collector's design incorporated the use of plastic absorber tubes connected to a copper header, with a single plastic cover.

A. INITIAL ASHRAE 93-77

The data and results for this test have been previously reported in Report No. 77S1111 of January 27, 1978.

B. 30-DAY STAGNATION EXPOSURE TEST

Fifty (50) days were required to achieve 30 days of exposure representing 1500 BTU/ft^2.day in the plane of the collector. This exposure period was unusually extended due to uncharacteristic winter weather experienced at the test site. All relevant data including visual inspection information, are presented in the following tables (Tables 1 and 2).

DESERT SUNSHINE EXPOSURE TESTS, INC.

Box 185, Black Canyon Stage
Phoenix, Arizona 85020

30 DAY STAGNATION

Company: CALMAC MANUFACTURING CORPORATION
Rack #: 160

DSET No: 18471S
Angle: 45° South

Collector: Sunmat
Start Date: January 18, 1978
3:50 p.m.

Pressure Rating: 25 psi

Days	Date	BTU/Ft^2	Cummulated BTU/Ft^2	Ambient Temperature High	Low	Wind Velocity	Precipitation
1	1/19/78	166	166	52	46	7	0.12
2	1/20/78	273	439	50	40	Calm	0.13
3	1/21/78	2155	2,594	58	38	5	
4	1/22/78	2063	4,657	61	40	8	
5	1/23/78	1834	6,491	57	39	13	
6	1/24/78	2033	8,524	57	35	10	
7	1/25/78	2125	10,649	56	33	7	
8	1/26/78	2232	12,881	61	35	6	
9	1/27/78	1557	14,438	68	41	8	
10	1/28/78	1841	16,279	76	50	10	
11	1/29/78	1974	18,253	74	50	7	
12	1/30/78	177	18,430	56	48	16	0.42
13	1/31/78	269	18,699	53	47	4	0.14
14	2/1/78	1719	20,418	64	46	7	
15	2/2/78	2184	22,602	71	47	9	
16	2/3/78	2277	24,879	71	48	12	
17	2/4/78	889	25,768	69	50	18	
18	2/5/78	616	26,384	71	51	6	
19	2/6/78	568	26,952	61	49	Calm	0.55
20	2/7/78	1738	28,690	64	44	5	0.12
21	2/8/78	1701	30,391	64	46	8	
22	2/9/78	1731	32,122	68	49	8	
23	2/10/78	295	32,417	58	46	14	0.80
24	2/11/78	1077	33,494	52	41	12	0.54
25	2/12/78	1255	34,749	54	40	5	
26	2/13/78	299	35,048	51	39	3	1.07
27	2/14/78	491	35,539	50	36	5	0.08

These do not meet 1500 BTU/Ft^2, minimum requirements

DESERT SUNSHINE EXPOSURE TESTS, INC.

Box 185, Black Canyon Stage
Phoenix, Arizona 85020

30 DAY STAGNATION

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Company: CALMAC MANUFACTURING CORPORATION (p. 2)
Rack #:
DSET No:
Angle:
Collector:
Start Date:
Pressure Rating:

Days	Date	BTU/Ft²	Cummulated BTU/Ft²	Ambient Temperature High	Ambient Temperature Low	Wind Velocity	Precipitation
* 28	2/15/78	1343	36,882	54	40	6	
29	2/16/78	2395	39,277	57	36	8	
30	2/17/78	2244	41,521	59	36	6	
31	2/18/78	2428	43,949	62	39	18	
32	2/19/78	2413	46,362	62	40	15	
33	2/20/78	2365	48,727	61	38	9	
34	2/21/78	2402	51,129	74	42	12	
35	2/22/78	2421	53,550	73	47	7	
36	2/23/78	2406	55,956	73	49	11	
37	2/24/78	2317	58,273	70	43	12	
38	2/25/78	2125	60,398	68	43	9	
* 39	2/26/78	1029	61,527	67	47	7	
* 40	2/27/78	480	62,007	56	49	5	0.98
* 41	2/28/78	786	62,793	59	51	7	0.79
* 42	3/1/78	801	63,594	63	51	14	1.00
* 43	3/2/78	542	64,136	56	51	12	1.35
44	3/3/78	2410	66,546	64	48	14	
* 45	3/4/78	686	67,232	65	47	10	
* 46	3/5/78	207	67,439	55	46	10	0.27
47	3/6/78	1845	69,284	62	46	15	0.07
48	3/7/78	2395	71,679	69	43	10	
49	3/8/78	2771	74,450	71	48	8	
50	3/9/78	2162	76,612	73	48	9	

* These do not meet 1500 BTU/Ft², minimum requirements

)ay's	Date	BTU/Ft^2	Cummulated BTU/Ft^2	Ambient Temperature High	Low	Wind Velocity	Precipitation
tal							
/ Total			76612				8.43

Weekly Inspection Report

k 1	1/26/78	Light outgassing spread uniformly throughout inner glazing. Absorber plate delaminating from backing. Some condensation noted in lower right corner of inner glazing.
2	2/6/78	No apparent change.
3	2/17/78	Outgassing was more intensive throughout the collector.
4	2/24/78	Delamination of absorber from backing is more developed. A white discoloration of glazing is forming in lower right corner of the collector.
	3/3/78	Lower 1/4 of the glazing has discolored.
	3/9/78	Top end of the collector has a white discoloration. Some of the insulation is wet from condensation in the collector.

TABLE 2.

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4-HOUR STAGNATION PERIOD*

Company: CALMAC MANUFACTURING Collector: SUNMAT

DSET No.: 18471S Date: MARCH 17, 1978

Solar Time	T_a (°F)	BTU/ft^2/hr
1000	72.5	349.50
1030	74.1	355.03
1100	76.9	347.28
1130	78.1	347.28
1200	81.0	349.50
1230	82.9	356.13
1300	82.8	356.13
1330	81.1	356.13
1400	82.2	352.81

*Test was conducted with the collector mounted on an EEK (follow-the-sun) mount.

C. FINAL ASHRAE 93-77

The data (Table 3a,b,c), and the efficiency graph (Figure 1) are attached at the end of this section. Also attached is a graph (Figure 2) which compares the initial and final instantaneous efficiency results (reference is again made to the fact that the initial data were furnished previously).

Analysis of the efficiency data resulted in the following second order equation:

$$\eta = 0.633 - 1.014 \left[\frac{T_i - T_a}{q_i}\right] - 0.165 \left[\frac{T_i - T_a}{q_i}\right]^2$$

The $F_R\alpha\tau$ product for this test is equal to 0.633 (63.3%).

The overall heat loss equation is presented below along with its evaluation at three parameters.

$$\frac{d}{d\left[\frac{T_i - T_a}{q_i}\right]} = F_R U_L = -1.014 - 0.330 \left[\frac{T_i - T_a}{q_i}\right]$$

Inlet Parameter:*	0.00	0.15	0.30
$F_R U_L$:**	-1.014	-1.064	-1.113

*°F/BTU/ft^2.hr
**BTU/ft^2.hr/°F, negative sign denotes loss

DESERT SUNSHINE EXPOSURE TESTS, INC.
BOX 185
BLACK CANYON STAGE
PHOENIX, ARIZONA 85020

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SOLAR COLLECTOR TEST DATA

COMPANY: CALMAC
REFERENCE NO.: 6506 (MCCRACKEN)
DSET NO.: 184718
REPORT NO.: 7731111A
TEST DATE: 03/19/78

COLLECTOR: SUNMAT
COVER: PLASTIC, SINGLE
APERTURE AREA: 29.26 SQ.FT.
GROSS AREA: 32.68 SQ.FT.
TRANSFER FLUID: WATER

TEST METHOD: DSET 75 - SE2.7 (ASHRAE 93 - 77)

SOLAR TIME	START	10:55	11: 0	11: 5	11:10	12:50	12:55
	END	11: 0	11: 5	11:10	11:15	12:55	13: 0
LOCAL TIME	START						
	END						
MASS FLOW		1491.29	1491.08	1491.44	1491.67	1472.04	1471.95
T IN (F)		191.88	191.73	191.47	191.26	139.38	139.33
INTEGRAL		15.99	15.98	15.96	15.94	11.62	11.61
T OUT (F)		193.96	193.84	193.56	193.27	142.77	142.71
INTEGRAL		16.16	16.15	16.13	16.11	11.90	11.89
T AMB (F)		78.92	80.01	81.22	80.48	80.63	80.20
INTEGRAL		6.58	6.67	6.77	6.71	6.72	6.68
SURFACE WIND		SE	SE	S	S	SE	S
AIR OVER COLL.		50	50	500	500	600	500
CP(BTU/LB(F))		1.[illegible]424	1.00423	1.00420	1.00417	0.99950	0.99950
QI *		336.25	336.25	336.42	336.75	337.64	337.42
INTEGRAL		28.02	28.02	28.04	28.07	28.13	28.12
QI, %DIFFUSE		12.45	12.48	17.60	17.63	12.64	12.76
TILT ANGLE		37.95	37.52	37.12	36.75	37.19	37.60
AZIMUTH ANGLE		25.73	23.83	21.88	19.90	-22.28	-24.22
INCIDENCE ANGLE		0.	0.	0.	0.	0.	0.
P IN (PSI)		20.0	20.0	20.0	20.0	20.0	20.0
DELTA P		17.0	17.0	17.0	17.0	17.0	17.0
DELTA T		2.08	2.09	2.09	2.00	3.39	3.39
INTEGRAL		0.17	0.17	0.17	0.17	0.28	0.28
T FLUID AVG		192.92	192.80	192.51	192.26	141.08	141.02
TF - TA		114.00	112.79	111.29	111.78	60.45	60.82
TI - TA		112.96	111.74	110.25	110.78	58.75	59.13
(TF - TA)/QI **		0.339	0.335	0.331	0.332	0.179	0.180
(TI - TA)/QI **		0.336	0.332	0.328	0.329	0.174	0.175
EFFICIENCY		0.282	0.282	0.282	0.271	0.449	0.449
OUTPUT *		94.74	94.95	94.97	91.29	151.65	151.64

* BTU/FT2/HR
** DEG(F)/BTU/FT2/HR

TABLE 3B.

DESERT SUNSHINE EXPOSURE TESTS, INC.
BOX 185
BLACK CANYON STAGE
PHOENIX, ARIZONA 85020

SOLAR COLLECTOR TEST DATA

COMPANY: CALMAC
REFERENCE NO.: 6306 (MCCRACKEN)
DSET NO.: 184713
REPORT NO.: 77S1111A
TEST DATE: 03/13/78

COLLECTOR: SUNMAT
COVER: PLASTIC, SINGLE
APERTURE AREA: 29.26 SQ.FT.
GROSS AREA: 32.86 SQ.FT.
TRANSFER FLUID: WATER

TEST METHOD: DSET 75 - SE2.7 (ASHRAE 93 - 77)

SOLAR TIME	START	13: 0	13: 5	14:45	14:50	14:55	15: 0
	END	13: 5	13:10	14:50	14:55	15: 0	15: 5
LOCAL TIME	START						
	END						
MASS FLOW		1472.07	1472.16	1463.82	1463.81	1463.77	1463.76
T IN (F)		139.28	139.21	88.34	88.38	88.42	88.49
INTEGRAL		11.61	11.60	7.36	7.37	7.37	7.37
T OUT (F)		142.71	142.66	92.76	92.78	92.81	92.83
INTEGRAL		11.89	11.89	7.73	7.73	7.73	7.74
T AMB (F)		81.41	81.24	79.57	80.14	80.05	79.70
INTEGRAL		6.78	6.77	6.63	6.68	6.67	6.64
SURFACE WIND		S	S	SW	S	S	S
AIR OVER COLL.		100	600	500	600	600	400
CP(BTU/LB(F))		0.99930	0.99949	0.99797	0.99797	0.99797	0.99797
QI *		337.03	337.12	326.16	323.43	319.73	320.18
INTEGRAL		28.09	28.09	27.18	26.95	26.65	26.68
QI, %DIFFUSE		12.68	12.70	14.96	15.18	15.34	15.41
TILT ANGLE		38.05	38.32	52.74	53.62	54.51	55.41
AZIMUTH ANGLE		-26.13	-27.39	-57.19	-58.30	-59.39	-60.45
INCIDENCE ANGLE		0.	0.	0.	0.	0.	0.
P IN (PSI)		20.5	20.0	20.5	20.5	20.5	20.5
DELTA P		17.0	17.0	18.0	18.0	18.0	18.0
DELTA T		3.43	3.45	4.42	4.40	4.39	4.34
INTEGRAL		0.29	0.29	0.37	0.37	0.37	0.36
T FLUID AVG		140.99	140.93	90.55	90.58	90.62	90.66
TF - TA		59.58	59.69	10.98	10.44	10.57	10.96
TI - TA		57.87	57.97	8.77	8.24	8.37	8.79
(TF - TA)/QI **		0.177	0.177	0.034	0.032	0.033	0.034
(TI - TA)/QI **		0.172	0.172	0.027	0.025	0.026	0.027
EFFICIENCY		0.396	0.399	0.602	0.604	0.611	0.602
OUTPUT *		133.33	134.57	196.42	195.36	195.22	192.86

* BTU/FT2/HR
** DEG(F)/BTU/FT2/HR

TABLE 3c.

DESERT SUNSHINE EXPOSURE TESTS, INC.
BOX 185
BLACK CANYON STAGE
PHOENIX, ARIZONA 85020

SOLAR COLLECTOR TEST DATA

COMPANY: CALMAC
REFERENCE NO.: 5006 (MCCRACKEN)
DSET NO.: 184713
REPORT NO.: 7781111A
TEST DATE: 08/19/78

COLLECTOR: SUNMAT
COVER: PLASTIC, SINGLE
APERTURE AREA: 29.26 SQ.FT.
GROSS AREA: 32.65 SQ.FT.
TRANSFER FLUID: WATER

TEST METHOD: DSET 75 - 8E2.7 (ASHRAE 93 - 77)

SOLAR TIME	START	13: 5	13:10	13:15
	END	13:10	13:15	13:20
LOCAL TIME	START			
	END			
MASS FLOW		1463.57	1463.61	1463.67
T IN (F)		88.55	88.61	88.72
INTEGRAL		7.38	7.38	7.39
T OUT (F)		92.85	92.97	93.03
INTEGRAL		7.74	7.75	7.75
T AMB (F)		79.79	79.53	79.27
INTEGRAL		[illegible]	6.63	6.61
SURFACE WIND		5	8	6
AIR OVER COLL.		300	400	600
CP(BTU/LB(F))		0.99737	0.99737	0.99737
QI *		317.24	317.26	315.41
INTEGRAL		26.44	26.44	26.26
QI, %DIFFUSE		15.46	15.91	17.33
TILT ANGLE		56.32	57.23	58.16
AZIMUTH ANGLE		-61.49	-62.50	-63.50
INCIDENCE ANGLE		0.	0.	0.
P IN (PSI)		20.5	20.5	20.5
DELTA P		16.0	16.0	16.0
DELTA T		4.31	4.36	4.31
INTEGRAL		0.36	0.36	0.36
T FLUID AVG		90.70	90.79	90.87
TF - TA		10.91	11.26	11.60
TI - TA		8.76	9.08	9.45
(TF - TA)/QI **		0.034	0.035	0.037
(TI - TA)/QI **		0.028	0.029	0.030
EFFICIENCY		0.603	0.610	0.606
OUTPUT *		191.33	193.46	191.25

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* BTU/FT2/HR
** DEG(F)/BTU/FT2/HR

DESERT SUNSHINE EXPOSURE TESTS, INC.
Box 185 Black Canyon Stage
Phoenix, Arizona 85020

COMPANY: CALMAC
REFERENCE: 6506 (MCCRACKEN)
DSET NO.: 18471S
REPORT NO.: 77S1111A
DATE: 03/19/78

COLLECTOR: SUNMAT
COVER: PLASTIC, SINGLE
AVG FLOW RATE: N / A.
AVG AMBIENT TEMP: N / A.
AVG INSOLATION: N / A.
COLLECTOR AREA: N / A.

TEST METHOD: DSET 75-SE2.7 (ASHRAE 93-77)

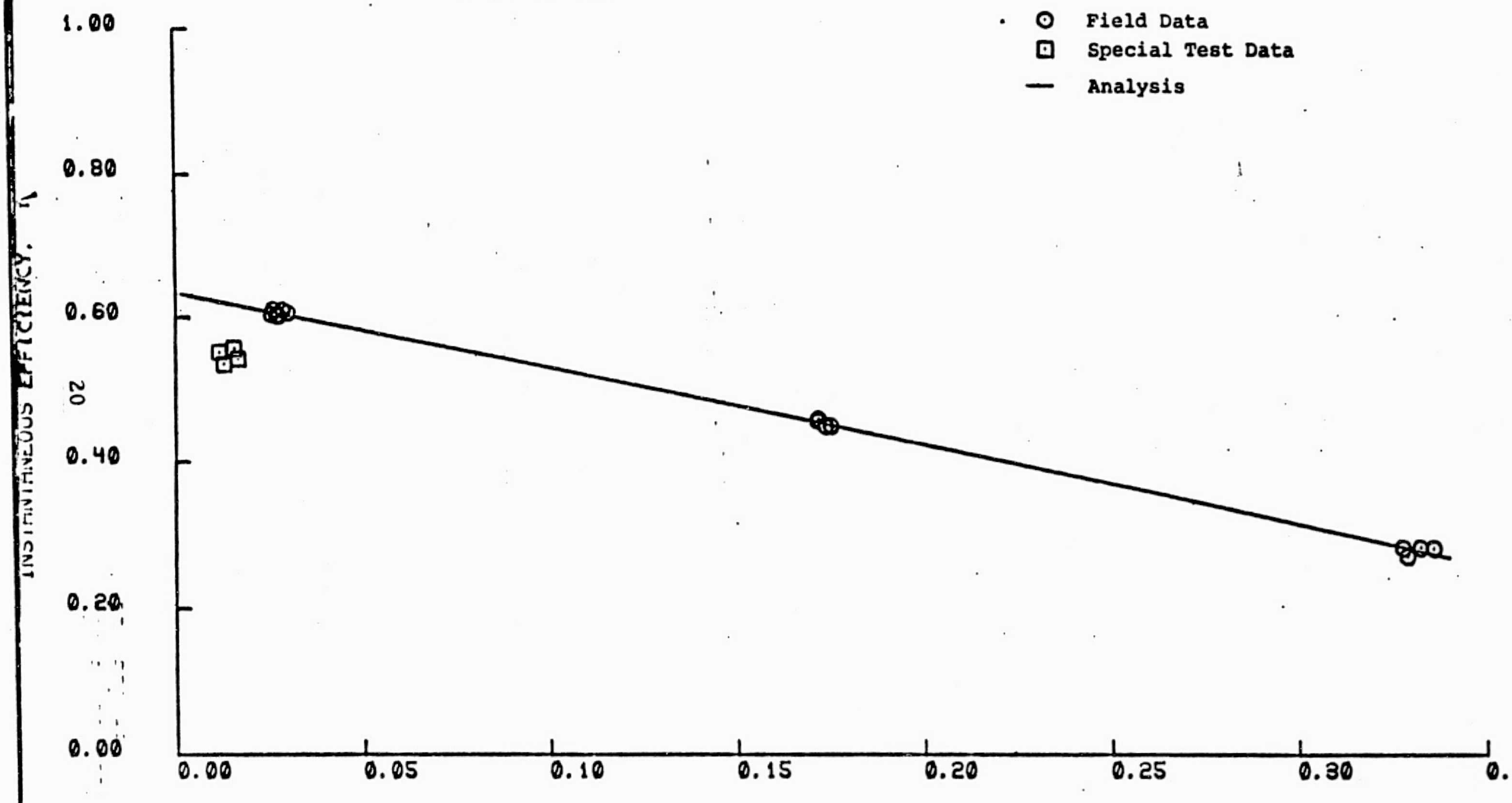

Figure 1.

DESERT SUNSHINE EXPOSURE TESTS, INC.
Box 185 Black Canyon Stage
Phoenix, Arizona 85020

COMPANY: CALMAC
REFERENCE: 6506 (MCCRACKEN)
DSET NO.: 18471S
REPORT NO.: 77S1111A
DATE: 03/19/78

COLLECTOR: SUNMAT
COVER: PLASTIC, SINGLE
AVG FLOW RATE: N / A.
AVG AMBIENT TEMP: N / A.
AVG INSOLATION: N / A.
COLLECTOR AREA: N / A.

TEST METHOD: DSET 75-SE2.7 (ASHRAE 93-77)

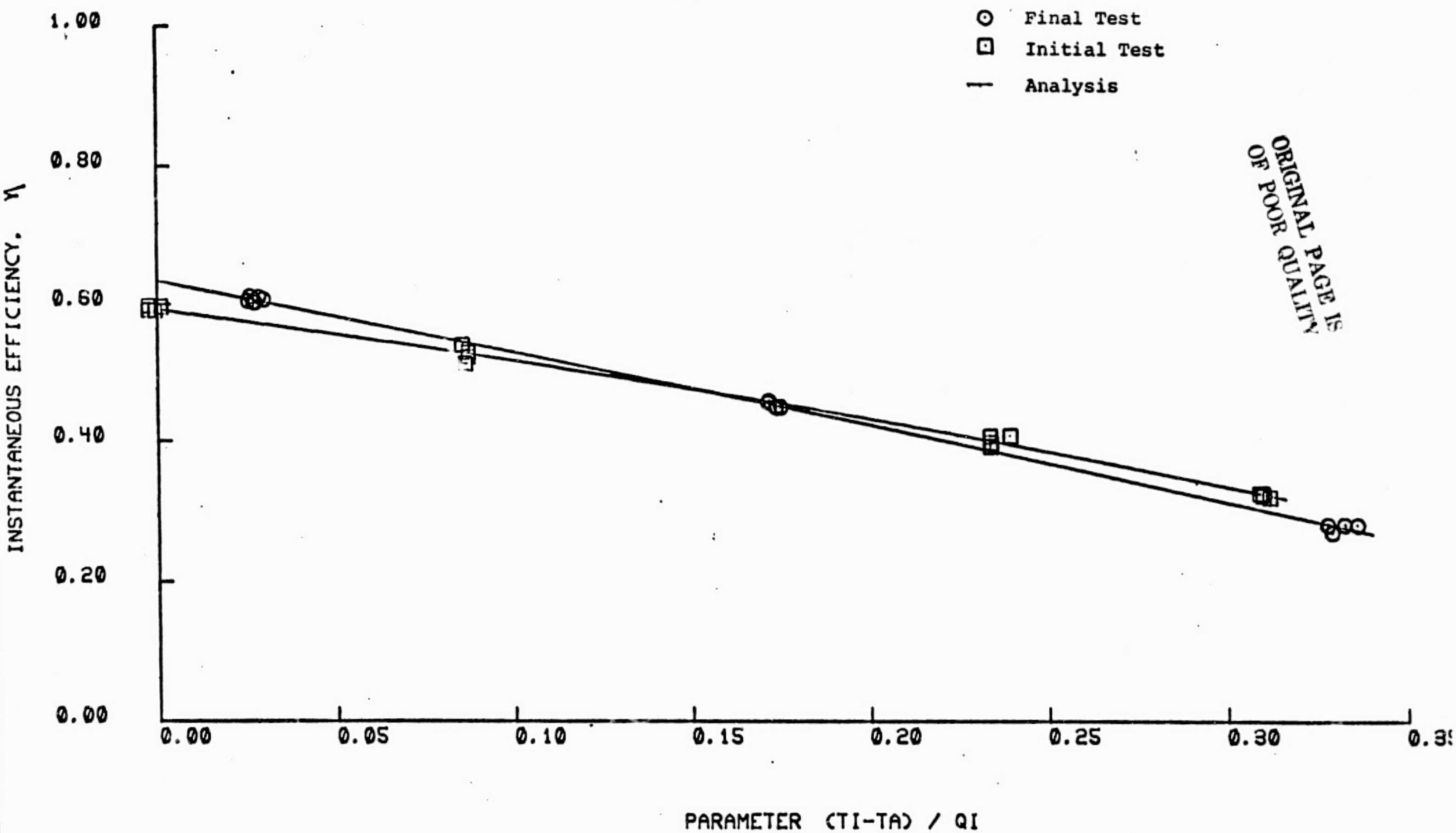

Figure 2.

D. SPECIAL TEST

The four instantaneous efficiency values obtained at an inlet fluid parameter of approximately 0.015 is presented in Table 4 and on Figure 1 (these data are designated by squares).

TABLE I

DESERT SUNSHINE EXPOSURE TESTS, INC.
BOX 185
BLACK CANYON STAGE
PHOENIX, ARIZONA 85020

SOLAR COLLECTOR TEST DATA

COMPANY: CALMAC
REFERENCE NO.: 6506 (MCCRACKEN)
DSET NO.: 18471S
REPORT NO.: 7781111
TEST DATE: 03/23/78

COLLECTOR: SUNMAT
COVER: NONE
APERTURE AREA: 29.26 SQ.FT.
GROSS AREA: 32.88 SQ.FT.
TRANSFER FLUID: WATER

TEST METHOD: DSET 75 - SE2.7 (ASHRAE 93 - 77)

SOLAR TIME	START	9:30	9:35	9:40	9:45
	END	9:35	9:40	9:45	9:50
LOCAL TIME	START				
	END				
MASS FLOW		1467.81	1467.77	1467.85	1467.74
T IN (F)		70.31	70.39	70.38	70.53
INTEGRAL		5.86	5.87	5.87	5.88
T OUT (F)		74.34	74.54	74.38	74.67
INTEGRAL		6.20	6.21	6.20	6.22
T AMB.(F)		64.87	65.28	66.18	66.71
INTEGRAL		5.41	5.44	5.52	5.56
SURFACE WIND		S	CALM	CALM	CALM
AIR OVER COLL.		200	0	0	0
CP(BTU/LB(F))		0.99853	0.99852	0.99853	0.99851
QI *		331.46	332.13	333.65	334.04
INTEGRAL		27.62	27.68	27.80	27.84
QI, %DIFFUSE		12.13	12.27	12.14	12.08
TILT ANGLE		47.97	47.14	46.33	45.53
AZIMUTH ANGLE		53.65	52.38	51.08	49.75
INCIDENCE ANGLE		0.	0.	0.	0.
P IN (PSI)		24.0	24.0	24.0	24.0
DELTA P		---	---	---	---
DELTA T		4.03	4.15	4.00	4.13
INTEGRAL		0.34	0.35	0.33	0.34
T FLUID AVG		72.33	72.47	72.38	72.60
TF - TA		7.46	7.19	6.20	5.89
TI - TA		5.44	5.11	4.20	3.82
(TF - TA)/QI **		0.023	0.022	0.019	0.018
(TI - TA)/QI **		0.016	0.015	0.013	0.011
EFFICIENCY		0.542	0.557	0.534	0.551
OUTPUT *		179.64	184.89	178.26	184.18

* BTU/FT2/HR
** DEG(F)/BTU/FT2/HR

DISCUSSION OF RESULTS

30-Day Stagnation and ASHRAE 93-77 Retest

The visual changes that occurred in the collector during stagnation were substantial. Moisture entered the collector during stagnation. Severe outgassing occurred and accumulated predominantly on the inner surface of the transparent cover. As shown in Figure 2, the thermal performance was not seriously affected as a result of these observed changes. This is attributed to the general nature of the collector -- since plastic/plastic thermal bond result in lower F_R values than would be experienced by metal/metal (thermally) bonded plates. Thus, this type of collector is judged to be less sensitive to these types of changes than might be expected. No predictions of durability can be made for stagnation periods of greater than that employed in this test.

Special Test

The lower efficiency values obtained when the glazing was removed (Table 4) -- compared to the efficiency of the glazed (covered) collector, is expected for collectors having characteristically low F_R values (heat removal efficiency factor). The greater energy incident on the plate resulting from removal of the glazing was overshadowed by increased thermal losses (otherwise contained by the glazing) due to higher plate temperatures that result from a low F_R value.

CONCLUSION

The Sunmat liquid collector was tested in accordance with ASHRAE 93-77 and the subsequent 30-day stagnation and ASHRAE Standard 93-77 retest were performed in conjunction with both the HUD requirements for the Hot Water Initiative and applicable sections of the January 1, 1975 Interim Performance Criteria. ASHRAE 93-77 is the generally accepted, industry-wise standard for testing the thermal performance of solar collectors.

ENGINEERS TESTING LABORATORIES, INC.
3737 East Broadway Road
P. O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

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Desert Sunshine Exposure Tests, Inc.
Box 185, Black Canyon Stage
Phoenix, Arizona 85020

18 April 1978
(*Revision date)

Attention: Mr. Bill Putman

Invoice/Lab No. 221-0051

Re: Evaluation of Field-Assembled
Sunmat Liquid Flat Plate Collector

In accordance with your request, we have evaluated the submitted Sunmat liquid flat plate collector. This evaluation was completed at E.T.L., Inc. by the undersigned on 2-21-78.

*The collector plate was disassembled and the individual components of the apparatus were examined and compared with the Interim Performance Criteria, the construction drawings and Installation, Operation and Service Manual. The enclosed list enumerates each of the construction drawings and the discrepancy found.

*Conclusion: There was no divergence from the Interim Performance Criteria, the construction drawings, or service manual that would appreciably effect the installation, operation, or efficiency of the device.

If any questions should arise concerning this evaluation, please contact us at your convenience.

Respectfully submitted,
ENGINEERS TESTING LABORATORIES, INC.

James E. Weaver, E.I.T. Reviewed by Jeffrey J. Danielski, P.E.

bd

copies to: Addressee (1)
Calmac Mfg. Corp./John Armstrong (1)

Enclosure

The following list enumerates each of the construction drawings and the deviation found. Some of the variations listed below are required by service manual for the field-assembled model and are noted as such.

Drawing No.	Discrepancy
A-S126	The collector panel was mounted on a 4' X 8' X 1" thick plywood base for stability. The glazing panel was glued around it's perimeter, and the top and bottom trim strips were eliminated as shown in the service manual for field assembled collectors.
A-S109-A	Constructed as shown.
A-S115	Constructed as shown.
A-S114	Constructed as shown.
A-S106	This item not included on field assembled collectors.
A-S119	Constructed as shown.
A-130P-B	Constructed as shown.
A-S111	Constructed as shown.
A-S117	Constructed as shown.
A-S113-A	Constructed as shown.
A-S118	Constructed as shown.
A-S108	The drawing indicates an 8", ¼" dia. copper tube with 1/8" dia. holes in the condenser dryer. The bill of materials specifies a 6" copper tube and the dryer sample had a 2" copper tube.
B-ST277-D	Both header pipes were 45" in length with 30 take offs spaced over 39 1/16". The drawing indicates the header pipes to be 44" in length with 30 take offs on 1 5/16" centers for 38 1/16".

Drawing No.	Discrepancy
B-S127	This item not included with submitted panel.
C-156P-C	Constructed as shown.
C-S125-B	Constructed as shown except as previously noted.

SECTION 2

VERIFICATION REPORT

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MARSHALL SPACE FLIGHT CENTER

FOR

THE SUNMAT LIQUID FLAT PLATE COLLECTOR

CALMAC Mfg. Corp.
150 S. Van Brunt St.
Englewood, NJ 07631

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VERIFICATION SUMMARY

The report includes an item-by-item breakdown of the applicable IPC, together with the appropriate verification based on analysis, similarity, inspection or testing. The IPC, prepared in 1975 by the National Bureau of Standards, is generally considered to be among the first set of nationally recognized standards and codes for solar heating and cooling.

John M. Armstrong, VP, Project Manager
CALMAC Manufacturing Corp.
4/20/78

1.2.4 Criterion Operational Impairment. The functional capability of the DHW system/subsystem shall not be impaired to a greater extent than conventional systems when system repairs or modifications are being made.

Evaluation Engineering review of specifications and drawings.

Commentary This criterion is intended to ensure that the shutdown for repair or modification of solar powered portions (e.g., the collector subsystem) of the DHW system/subsystem will not impair the function of the DHW system/subsystem for periods of time longer than those expected for conventional hot water equipment.

The duplication of components such as heat exchangers, controls and pumps is dependent upon the degree of integration of the auxiliary energy subsystem and the availability of replacement parts.

1. The collector is designed for use in systems having conventional systems for backup. In the event of shutdown for repair the backup system will take over. Nothing in the SUNMAT subsytem influences the operation of the backup system.

2. Several features of the SUNMAT design facilitate repair and minimize down time. The zipper lock on the plastic frame allows easy access to the absorber for repair. Leaks in the tubing can be repaired on site with the use of splicer tubes.

1.3 Requirement Collector performance. The solar collector shall absorb and convert incident solar energy into useful thermal energy. The collector shall be capable of dissipating thermal energy, where this function is included in the design.

1.3.1 Criterion Collector efficiency. The collector subsystem (including reflectors where applicable) shall be capable of absorbing and converting incident solar energy into useful thermal energy at its designed efficiency under operating conditions. For applications employing nocturnal radiation, the collector shall dissipate thermal energy at the design rate under design operating conditions.

Evaluation Engineering evaluation of drawings, analytical calculations and/or test data.

An analytical model, when used, shall include radiant, convective and conductive heat transfer, where appropriate.

The design collector thermal efficiency may be experimentally verified utilizing a full-scale test panel or a model test panel of sufficient size to have equivalent full-scale thermal characteristics.

It is intended that testing be performed only if performance data for the particular collector or one with similar materials and/or configuration is not available. Because of the influence of solar radiation characteristics, climatic conditions and system operating requirements on performance, experimental evaluations shall include heat transfer media flow rates and temperatures consistent with the geographic region and system conditions.

Commentary Some examples of analytical methods and data presentation are shown in the references [1] [12] [13] [14] [15] [16] [24] [25] [26] [27] [36] [37]. Descriptions of collector test techniques and representative test data are presented in references [13] [28] [29] [30] [31] to illustrate methodologies considered to be state-of-the-art. The use of material, fluid and insolation property data available in the open literature is encouraged.

See results of collector efficiency testing.

1.4 Requirement **Thermal storage performance.** When included in the design, the storage subsystem shall be capable of providing its rated output under design loads.

1.4.1 Criterion **Storage capacity and rate.** The storage subsystem shall provide sufficient heat transfer rates and thermal energy capacity to absorb and store energy at the maximum design collection rate and, when fully charged, supply energy for its design time period with no solar energy or auxiliary energy input.

Evaluation: Engineering review of drawings, calculations and/or test data.

A thermal analysis of the storage subsystem shall be performed to determine the thermal energy storage capacity, heat losses, energy addition rate and energy extraction rate under operating conditions. For designs where adequate calculations are not possible these parameters shall be experimentally determined utilizing a full-scale test specimen or a model test specimen of sufficient size to have equivalent full-scale thermal characteristics.

Commentary: Descriptions of storage techniques and representative test data are presented in references [12][13][14][16][32][33][34] to illustrate methodologies considered to be state-of-the-art. The thermal capacity is a function of system dynamic characteristics and may be sized to include factors such as insolation level, collector area, thermal loads, energy loss, temperature gradients, material thermophysical properties and auxiliary energy type and amount.

The collector is designed for use in systems both with and without storage systems. Collector efficiency data should be used to determine the optimum size of the thermal storage system.

2.1 Requirement **System design conditions.** The systems for heating (H) and combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem shall be capable of functioning at their designed flow rates, pressures and temperatures.

2.1.1 Criterion **Equipment capabilities.** Pumps, fans, or other components shall be sized to move the heat transfer fluid through the collector, piping and/or ducts at design flow rates.

Evaluation: Review of drawings, specifications, historical performance, previous test data, and design calculations. Systems or applications that do not lend themselves to engineering analysis may require prototype tests to demonstrate compliance.

Commentary: In order to transfer heat through the system/subsystem, a number of different transfer approaches such as gravity circulation, combined forced and gravity circulation, or forced circulation may be used.

1. The maximum operating temperature and pressure of the collector is 210°F and 20 PSI. Maximum allowable tube temperature is 350°F and the burst pressure is 80 PSI, so ample safety margins are allowed between design and maximum allowable.

2. The pressure drop through a 50-foot mat at 110°F is 9 PSI, which is well below the maximum design operating pressure of 20 PSI.

3. The minimum flow rate required to force fluid through the furthermost tubes of the mat is 2 GPM.

2.1.2 Criterion Noise or erosion-corrosion. The piping or ducts and associated fittings shall be sized to carry the heat transfer fluid at design flow rates without excessive noise, as defined by HUD[1], or erosion-corrosion.

Evaluation Review of drawings, specifications, historical performance, previous test data and design calculations.

Commentary In order to prevent whistling noise in piping and cavitation noise in fittings and valves, it is recognized practice to limit velocities of transfer fluids to 8fps[2]. Lower velocities may be required depending on the limit set by the pipe manufacturer to prevent deterioration of their piping materials due to erosion-corrosion. It is common practice to limit flow velocities in small diameter copper tubing to 4fps when water having a pH value lower than 6.9 or softened water is used. A velocity of 4fps is commonly used as the upper limit for hot water piping with working temperatures above 150°F for copper tubing[2]. Some equipment designs may require higher flow velocities in order to inhibit scale formation. In air ducts, the velocities normally should not exceed recognized values, e.g., the values listed on U.L. labels.

The velocity of fluid through the header is the limiting factor for this criterion as the cross-section area of the header is smaller than the total cross-section area of the 30 SUNMAT tubes (Header: $(3/8)^2 \times 3.14 =$ .442 in^2; tubing: $(3/32)^2 \times 3.14 \times 30 =$ .828 in^2). The velocity of 4fps sets a flowrate maximum of about 5 gpm: $(3/8)^2 \times 3.14 \times 4fps \times 12''/ft =$ 21.2 in^3/sec = .0123 ft^3/sec = .77 pounds/sec = .0924 gal/sec = 5.54 gpm. For a 50-foot mat this translates into a difference in temperature between the inlet and outlet of the collector of 19°F for fairly extreme conditions:

$$\frac{200\ ft^2 \times 300\ BTUH \times 80\%\ eff}{5\ GPM \times 60\ min/hour \times 8.33\ \#/gal} = 19.2^\circ$$

2.1.3 Criterion Operating conditions. Collectors, space heaters, water heaters, pumps, valves, regulating orifices, pressure regulators and similar components shall be capable of being operated over the pressure and temperature ranges anticipated in actual service without breakage, rupture, binding, galling, or significant loss in pressure that could impair their intended function.

Evaluation Review of drawings, specifications, historical performance, previous test data and design calculations. Systems or components that do not lend themselves to engineering analysis shall be tested at the maximum and minimum service temperatures with anticipated fluid pressures. To show compliance with this criterion it is desirable that the design consist of components that are covered by recognized standards, where available, and are specified by the manufacturer to be suitable for the pressure, temperature, and flow application.

See testing for Criterion 2.3.1 and 5.2.4 plus testing for this specific Criterion.

CALMAC

TEST RECORD

Contract #NAS8-32253

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Project: Collector

1. Item Being Tested: Ability of collector to operate over anticipated range of temperature and pressure. 2.1.3

2. Test Objectives: To verify that collector can be operated over the pressure and termperature ranges anticipated in actual service without breakage, rupture, binding, galling, or significant loss in pressure that could impair its functioning.

3. Location of test facilities and scheduled test dates:

   CALMAC Factory, simulatneously with efficiency testing, March 15 - April 15

4. Prerequisites for Passing or Failing:

   During and after operation at different temperatures and pressures within the normal operating range, the collector shall not show any signs of system failure.

5. Test Procedures: This test will be run simulatneously with the efficiency testing. The collector will be operated at a wide range of temperatures and pressures, up to 200oF at 40 psi, and observed for any indication of failure of any part of the system.

6. Test Results: The collector was operated at normal operating temperatures and pressures during the period of July and August. During this period the collector was allowed on occasion to stagnate, which brought the temperatures up to 200°F and above (see test results of test of fail-safe system). No damage was observed at absorber temperatures of 200°F.

2.1.4 Criterion		Fluid flow in collectors. When an array of collectors is connected by manifolds, provision shall be incorporated in the manifolds and/or collectors to maintain the design flow rate of the heat transfer fluid through each collector.
	Evaluation	Review of drawings, specifications, historical performance, previous test data, and design calculations or testing to determine that each collector will receive its design flow rate.
	Commentary	Because of friction in the manifold, flow rates may be inadequate through collectors remote from the pump or other fluid supply source. This can result in inefficient collector operation. The provision of flow regulating valves is one means of correcting for this problem. Another method is the use of reversed supply and return headers for parallel arrays of collectors with graduated header sizes as the flow rate in the header changes. Useful design information is given in reference [5].

One collector can be connected to the supply/return plumbing system through the header manifold system of one other collector. This limitation is outlined in the collector manual.

This configuration is subject to the 5 GPM maximum flow rate ceiling set to avoid noise and erosion-corrosion problems. See Criterion 2.1.2. This means that using this configuration the maximum flow rate through each collector is 2.5 GPM.

2.1.5 Criterion		Entrapped air. When liquid heat transfer fluids are used, the system shall provide suitable means for air removal.
	Evaluation	Review of drawings and specifications.
	Commentary	Trapped air in a piping system can impede the flow of liquids through piping, decrease pumping efficiency and otherwise reduce system efficiency. Possible icing up of exposed fittings is an important consideration.

An air vent should be installed in the at the inlet header of the collector. Because of the small inside diameter of the tubing in the collector trapped air is readily swept away by circulation of fluid through the system. As a result it is possible to install the collector with the inlet and outlet headers located at the lower end of the installation.

The ease of having air swept out of the tubing has been proven in applications using the ICEMAT, which has a similar size and configuration to the SUNMAT. We have been able to sweep air out of ICEMATs 200-feet long on slopes used for refrigerated toboggan slides.

2.1.6 Criterion Thermal expansion of fluids. Adequate provisions for the thermal expansion of heat transfer fluids that would occur over the service temperature range shall be incorporated into the system designs.

Evaluation Review of drawings, specifications and design calculations.

Commentary Water expands about 4% in volume when heated from 40°F to 200°F. Other heat transfer fluids may have different coefficients of volume expansion. Means should be provided in the system design to contain this additional fluid volume without exceeding the operating pressure of the system or resulting in spillage.

An expansion tank is required in the collector loop. See manual.

2.1.7 Criterion Pressure drops. Pressure drops shall not exceed the limits specified in the design.

Evaluation Review of calculations, and detailed plan and elevation drawing layouts.

Commentary Since the energy requirements of pumps and fans are a function of the system flow resistance, pressure drops should be kept as low as possible, commensurate with good design. The unnecessary use of fittings such as bends, tees, globe valves, reducers, or obstructions to flow should be avoided by careful arrangement of piping runs. Accepted practices for plumbing design are discussed in standard plumbing guides[6] [7].

See graph showing pressure drop vs. collector length vs. fluid type and temperature.

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CALMAC

TEST RECORD

Contract #NAS8-32253

Project: Collector

1. Item Being Tested: SUNMAT tubing and headers & U-bends.
   2.1.7

2. Test Objectives:
   To measure the pressure drop through the SUNMAT grid system.

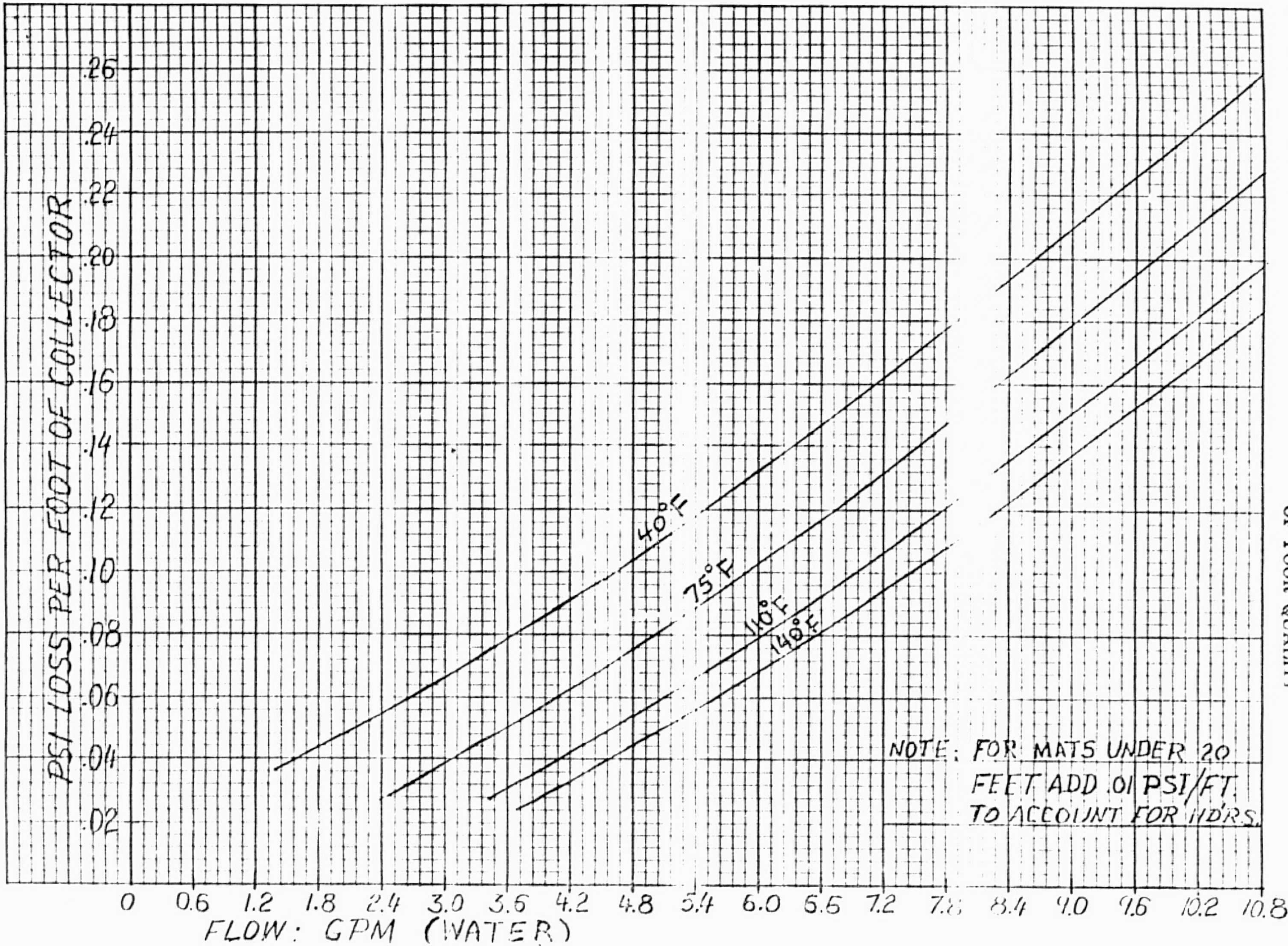
3. Location of test facilities and scheduled test dates:
   CALMAC factory, March 1-30

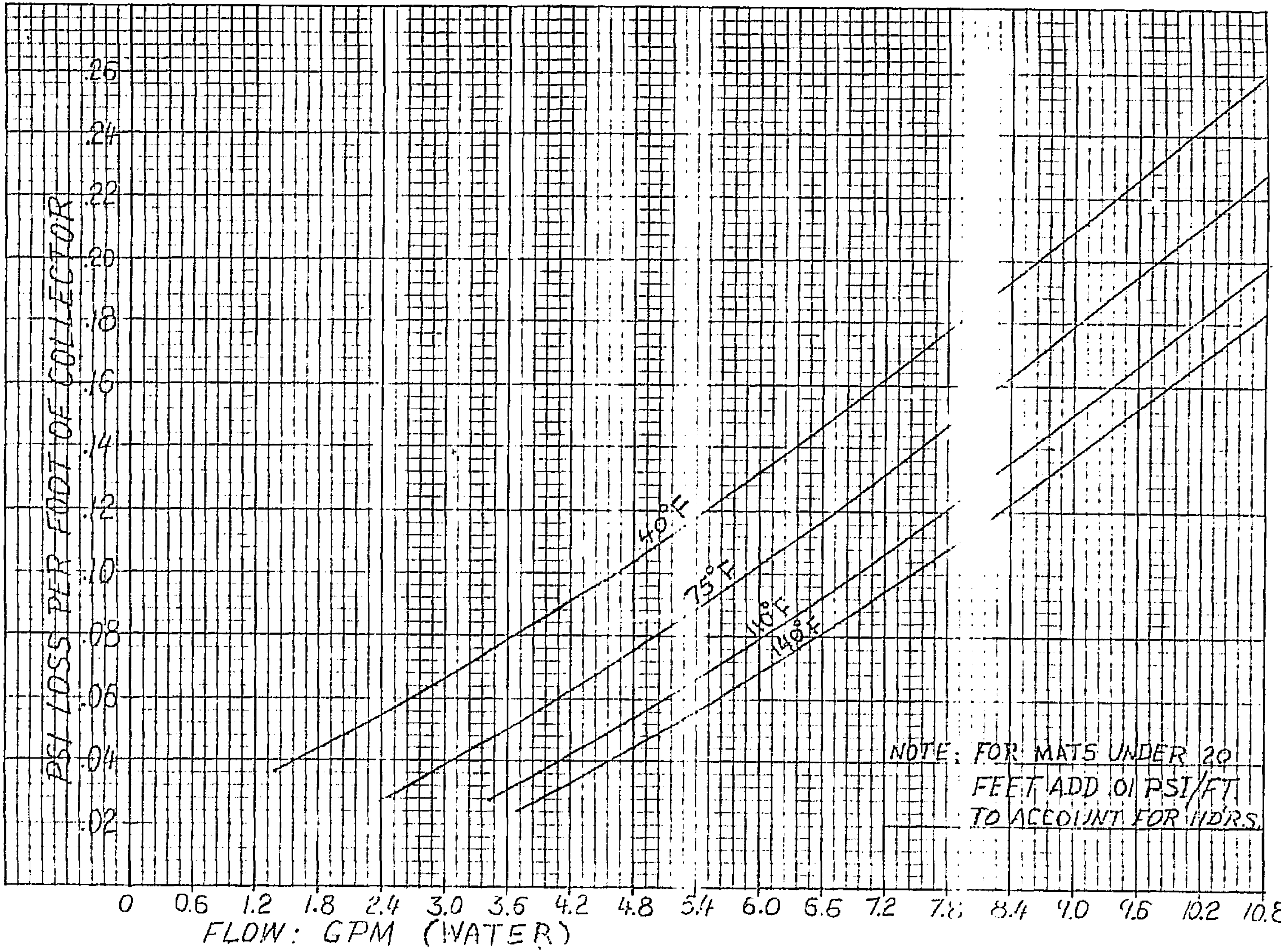
4. Prerequisites for Passing or Failing:
   The purpose of this test is to measure the pressure drop through the system so that it will be possible to specify the proper pump to be used with the collector. The test will gather engineering information - there are no standards to be met.

5. Test Procedures:
   Standard procedures for measuring pressure drop with manometer

6. Test Results:

   See attached Loss vs. Flow Chart


PSI LOSS PER FOOT OF COLLECTOR
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
.22
.24
.26
0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2
7.8
8.4
9.0
9.6
10.2
10.8
FLOW: GPM (WATER)
40°F
75°F
110°F
140°F
NOTE: FOR MATS UNDER 20
FEET ADD .01 PSI/FT
TO ACCOUNT FOR HD'RS.



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2.2 **Requirement** <u>Mechanical stresses</u>. Mechanical stresses that arise within the system shall not cause damage or malfunction of the system or its components.

2.2.1 **Criterion** <u>Vibration stress levels</u>. Vibrations in piping, ducts, instrumentation lines, and control devices shall be controlled to reduce stress levels below those that could cause fatigue and subsequent component damage.

Evaluation Review of drawings, specifications, historical performance, and previous test data for adequate piping and equipment supports.

Commentary Examples of possible vibration sources in piping are as follows:

a. Lengths of piping and connecting equipment that are resonant with pressure pulsation frequency.
b. Vibration resulting from motors, pumps, fans, and compressors which are not properly mounted.
c. Water hammer and quick closing valves.
d. Expansion and contraction of piping on hangers.
e. Wind pulsations on certain lengths and diameters of piping supported by loose hangers or supports.

Conventional safeguards in the design and installation of the system must be followed.

2.2.2 **Criterion** <u>Vibration from moving parts</u>. Pumps, fans and compressors or similar equipment shall be balanced and/or mounted in a manner that will avoid vibration that could cause damage or excessive noise as defined by HUD[1].

Evaluation Review of drawings and specifications. Prototype inspection and testing if deemed necessary. The equipment supporting structure shall not have natural frequencies within ± 20 percent of the operating speeds. The equipment when mounted and placed in operation should not exceed a self-excited vibration velocity of 0.10 inches per second when measured with a vibration meter on the bearing caps of the machine in the vertical, horizontal, and axial directions or measured at the equipment mounting feet if the bearing caps are concealed[8].

The collector contains no moving parts and is not susceptible to the type of vibration described.

2.2.4 Criterion Vacuum relief protection. Closed storage tanks and piping located at elevations above the system served shall be suitably protected against collapse by pressure if subjected to a vacuum. Such components shall be designed to withstand such pressures or have vacuum relief protection.

Evaluation Review of drawings and specifications.

Commentary Possible collapse of large diameter tanks and piping by atmospheric pressure is an important design consideration[11].

The SUNMAT EPDM tubing, the copper U-bends and the copper headers are all of small diameter and can easily withstand a vacuum. Collectors have been subjected to vacuums of 10 PSI with no visible change in the tubing or the copper components.

2.2.5 Criterion Thermal changes. The system components and assemblies shall be designed to allow for the thermal contraction and expansion that would occur over the service temperature range.

Evaluation Review of drawings, specifications and calculations.

Commentary Piping and other components may experience changes in dimensions as a result of temperature changes. Such changes can result in excessive stresses within the piping, piping supports, structure, pumps, compressors, and solar collectors if means are not incorporated in the piping system design to allow for the thermal movement.

Stresses within the collector resulting from thermal expansion and contraction are accomodated by the high degree of flexibility of the materials used in the collector. The EPDM absorber tubing stretches and flexes adequately to absorb stress in the absorber system. The polyshim glazing seal absorbs stress between the glazing and the frame. The use of elongated holes in the mounting frame allows for differential expansion between the collector and the supporting structure.

2.2.6 Criterion Flexible joints. All systems employing heat transfer fluids shall be designed to be capable of accommodating flexing of plumbing and fittings.

Evaluation Review of drawings and specifications.

Points where the inlet and outlet headers pass through the collector wall and join the supply and return plumbing are sealed with flexible materials to absorb flexing from expansion and contraction and from mechanical stress. Normal precautions in supporting the supply and return lines must be followed.

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2.3 Requirement — Leakage prevention. System assemblies containing heat transfer fluids shall not leak to an extent greater than that specified in the design when operated at the design conditions.

2.3.1 Criterion — Pressure test: nonpotable fluids. Those portions of the H, HC and DHW systems which contain heat transfer fluids (other than air) and are not directly connected to the potable water supply shall not leak when pressures of not less than 1-1/2 times their working pressure are imposed for a minimum of 15 minutes.

Evaluation — Review of specifications and testing. The test pressure shall be applied for a period of time necessary to inspect each joint for leakage. The pressure gage would be observed for this period to determine that a pressure drop has not occurred.

Commentary — Various building codes differ with regard to pressure tests. One plumbing code requires hydrostatic testing at the working pressure for water supply piping[12]. Another code requires hydrostatic testing at the working pressure or an air pressure test of not less than 50 psi for not less than 15 minutes[13]. A third code requires a hydrostatic test of not less than 25 psi above the working pressure [14]. However, plumbing codes do not give guidance concerning solar systems which can contain liquids other than water. In these cases, hydrostatic testing of the system at 1-1/2 times the maximum is considered to be appropriate[15]. "Dead-Weight" testers are frequently used to calibrate pressure gages[16].

The maximum recommended operating pressure is 20 PSI. See attached test results for operation at elevated temperature and pressure.

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CALMAC

TEST RECORD

Contract #NAS8-32253

Project: Collector

1. Item Being Tested: Entire system – tubing, headers, clamps and U-bends.

   2.3.1 + 5.2.4

2. Test Objectives:

   To verify that system can be operated at required pressures [illegible] psi without leaking.

3. Location of test facilities and scheduled test dates:

   CALMAC factory. March 2 – March 30.

4. Prerequisites for Passing or Failing:

   Tubing must withstand 40 psi at 225° and 60 psi at 160°.

5. Test Procedures:

   As described in Section C-1, Chapter Five of Interim Performance Criteria

6. Test Results: Small mats approximately one foot square were made up and tested at these pressures and temperatures. Each morning it was necessary to repressurize the mats somewhat as in the course of the preceding 24 hours air would escape. The source of these leaks could not be located by submerging the system in water – as the rate of leakage was very slow. No leaking at the header nipples or the U-bends was ever noted. Some thinning of the tubing wall was also noted because of stretching from the pressure, but the tubing did not [illegible].

2.4 Requirement Collector adjustments. The collector subsystem shall be capable of being located, oriented, and tilted as required by the design to capture sufficient solar energy to meet functional requirements.

2.4.1 Criterion Orientation and tilt. The collector mount shall be capable of maintaining the design tilt and orientation.

Evaluation Review of drawings and specifications.

Commentary Collectors can either be fixed, require seasonal adjustment or be continuously movable. Detailed information concerning orientation and tilt is given in ASHRAE[17]. It is not the intent of this criterion that the collector necessarily be reoriented or tilted after initial installation.

The collectors must be mounted on some underlying surface--a roof or plywood frame, for example. They are not self-supporting to the extent that a 2x4 or pipe frame alone could be used to support them.

2.6.4 Criterion Freezing protection. Heat transfer liquids shall be prevented from freezing at the lowest ambient temperatures that will be encountered in actual use where such freezing would impair the function of the system.

Evaluation Review of drawings and specifications.

Commentary The purpose of this criterion is to insure that rupture or other damage to solar collectors and associated piping and equipment will not occur from expansion of water if it freezes. The intent of this criterion is not to restrict the designer to the use of antifreeze solutions.

The use of glycol antifreezes will not damage the collector in any way. EPDM hose is commonly used in automtive radiator systems.

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2.8 Requirement <u>Excessive pressure and temperature protection</u>. The piping system and associated equipment shall be protected against rupture or leakage from excessive pressures and temperatures.

2.8.1 Criterion <u>Relief valves and vents</u>. As required for protection of a particular system design, combination temperature and pressure relief valves, separate pressure relief valves, pressure reducing valves, and/or atmospheric vents shall be provided.

Evaluation Review of drawings and specifications.

Commentary This criterion is intended to prevent safety hazards resulting from inadequate pressure and temperature protection.

A relief system opening at 210°F or 20 PSI is required in the system, and is called for in the Installation Manual.

3.1 Requirement <u>Structural design basis</u>. The structural design of the heating (H), combined heating and cooling (HC) and domestic hot water (DHW) systems including connections and supporting structural elements shall be in accordance with nationally recognized codes and standards and shall be based on loads anticipated during the service life of the systems.

3.1.1 Criterion <u>Applicable standards</u>. The structural design and construction of H, HC and DHW systems including connections and structural supports thereof shall comply with the following provisions:

Conventional elements* shall comply with the provisions of the HUD Minimum Property Standards (MPS)[1] for single family and multifamily housing or ANSI A119.1[4], in the case of mobile homes, and such additional criteria as specified in this chapter. Non-conventional elements** shall comply with all the criteria stipulated in this chapter.

Evaluation Review of drawings, specifications and structural calculations.

Commentary In addition to complying with the design and construction provisions of the MPS or ANSI A119.1 (for mobile homes), conventional elements and connections are required to comply with Criteria 3.1.2 (Service loads), 3.2.2 (Ice loads), 3.2.3 (Vehicular loads), 3.5.1 (Design provisions - cutting of structural elements), 3.7.1 (Hail size and loading), and 3.9.1 (Design provisions - ponding conditions).

See 3.1.2, 3.2.1, 3.2.2, 3.2.4, 3.3.1, 3.4.1, 3.7.1, and 3.9.1

3.1.2 Criterion **Service loads.** The following loads shall be used in the structural design of conventional and non-conventional elements and connections of H, HC and DHW systems:

1. Dead loads (D) shall be the "Design Dead Loads" stipulated in Section 601-3 of the MPS.

2. Live loads (L) shall be all applicable 'Design Live Loads" stipulated in Section 601-4 and "Snow Loads" stipulated in Section 601-5 of the MPS.

3. Wind loads (W) shall be "Wind Loads" stipulated in Section 601-6 of the MPS. In all cases consideration of local wind conditions shall be assured by compliance with Section 6.3.3 of ANSI A58.1[2].

4. Earthquake loads (E) shall be those stipulated in Section 601-9 of the MPS which references the provisions of the Uniform Building Code (UBC) [3]. For non-conventional system components and connections, the value of "Cp" used in the UBC shall be taken as 2.0.

1. Dead load equals the system's own weight, which is about 2.5 pounds/square foot. D = 2.5 PSF

2. L = 20 PSF per section 601-5 of the MPS.

3. W = 1.25 x 15 PSF = 19 PSF per Section 601-6 of the MPS.

4. $E = Z \times I \times C_p \times S \times W_p$
$= 1 \times 1 \times 2 \times 1 \times 2.5$
$= 5.0$

I = Importance factor = 1
$Z = 1$
$S = 1$, where $C_p = 2$
$W_p = 2.5$ (Weight per squre foot)

This criterion simply established service load standards. Analysis of the collector's ability to meet these loads is covered in the other criterion.

5. Constraint loads caused by the environment, normal functioning of the system and time-dependent changes within the materials of the system shall be taken as the most severe likely to be encountered during the service life.

6. Constraint loads induced by differential foundation settlement shall be taken as those corresponding to a differential foundation settlement of the magnitude stated under Criterion 3.8.1.

7. Ice loads (I) shall be taken as those produced by the accumulation of ice on surfaces exposed to the natural environment. The thickness of ice shall be determined in accordance with Criterion 3.2.2.

8. Hail loads (H) shall be taken as those produced by the impact of hail on surfaces exposed to the natural environment. Hail particle size and kinetic energy at impact shall be determined in accordance with Criterion 3.7.1.

9. Vehicular loads on below grade installations shall be determined in accordance with Criterion 3.2.3.

Evaluation For experimental or analytical evaluation of structural response, the selection of system components shall be done in a manner representing the least margin of safety to the system but consistent with its interaction with structural systems to which they are attached. Test loads applied to the system components shall result in the most critical conditions encountered in service. Additional eccentricities of loading caused by drift due to lateral loads and anticipated differential foundation settlements shall be provided for in tests of supporting structural elements of the system. The effects of service history caused by fatigue, sustained load, temperature, moisture, ultraviolet light or other environmental factors, shall be provided for in tests.

Commentary The intent of the criterion is to state the required reliability of performance and, therefore, the specified loads should have a defined probability of occurrence.

The assumption is made (with the exception of wind and snow loads, which are based on statistical analysis) that the MPS "design loads" are loads anticipated during the service life of the system.

The minimum uniformly distributed live load on relatively flat horizontal and inclined surfaces of the system is taken in accordance with roof loads prescribed by MPS. Snow load is based on ANSI A58.1 and is treated as live load in lieu of the MPS roof load if it produces a more severe loading condition. This is consistent with MPS which uses ANSI A58.1 by reference.

Earthquake loads are determined by the applicable provisions of the Uniform Building Code. It is recognized that for cases involving new material applications it may be difficult to select the appropriate C_p factor. The prescribed C_p value intended for use with nonconventional elements and connections is consistent with the values specified in UBC for connections of exterior panels.

5. Neither the environment, normal functioning of the system or time-dependent changes are expected to exert loads approaching the loads i mposed by such factors as ice or live loads.

6. See 3.8.1.

7. See 3.2.2.

8. See 3.7.1.

9. Vehicular loads do not apply as the collectors will not be installed below grade.

3.2 Requirement **Failure loads and load capacity.** The structural elements and connections of the H, HC and DHW systems shall not fail under ultimate loads expected during the service life of the system.

3.2.1 Criterion **Ultimate load combinations.** Non-conventional elements and connections shall comply with this criterion. (Conventional elements and connections are deemed to satisfy this criterion.)

Structural components, connections and supporting elements shall be designed for the following ultimate load combinations:

(1) 1.4 D + 1.7 L
(2) 0.9 D + 1.7 W
(3) 0.9 D + 1.45 E
(4) 1.1 D + 1.3 L + 1.7 W
(5) 1.1 D + 1.3 L + 1.45 E

where the multipliers are load factors and the letters are the service loads defined in Criterion 3.1.2.

Evaluation Review of structural calculations, specifications and drawings.

Commentary The intent of the criterion (along with Criterion 3.2.4) is to provide a minimum level of safety against loading situations which have a suitably low probability of occurrence during the service life. The load factors represent present-day design practice for building structures and are similar to the load factors used in ACI 318[5]. These factors will produce ultimate loads comparable to those presently used in the design of steel structures. Adoption of similar levels of performance requirements for the H, HC and DHW systems will also permit the designer to explore the potential use of system components as structural elements for purposes of providing enclosure or diaphragm rigidity to the supporting structure in addition to their primary heating and/or cooling function.

(1) 1.4 x 2.5 + 1.7 x 20 = 37.5
(2) .9 x 2.5 + 1.7 x 19 = 34.6
(3) .9 x 2.5 + 1.5 x 5.0= 9.5
(4) 1.1 x 2.5 + 1.3 x 20 + 1.7 x 19 = 61.9
(5) 1.1 x 2.5 + 1.3 x 20 + 1.5 x 5 = 36.0

3.2.2 Criterion **Ice Loads.**

(a) Above-ground installations of conventional elements for which ultimate design provisions apply, and of all non-conventional elements, including connections and structural supports thereof, shall comply with Criterion 3.2.1 for load combinations (1) and (4) in which live load (L) shall be taken as that produced by the accumulation of ice on all surfaces exposed to the natural environment.

(b) Above-ground installations of conventional elements for which working stress design provisions apply, including connections and structural supports thereof, shall comply with Criterion 3.2.2(a) with the following modification: load factors in load combinations (1) and (4) of Criterion 3.2.1 shall be taken as 1.0.

The radial thickness of ice around the circumference of exposed wires, pipes, and structural members shall be based on the annual frequency of occurrence of glaze shown in Figure 3.2.2 (see reference [6]) and shall be computed as follows:

Mean annual number of days with glaze	under 1	1-4	4-8	over 8
Thickness of ice (inches)	0	1/2	3/4	1.0

Evaluation Review of structural calculations.

Commentary The intent of this criterion is to account for the effect of ice loads primarily on wires, pipes and other similar components which are exposed to the natural environment, in recognition of the fact that ice storms have been particularly detrimental to such components in the past.

The map of Figure 3.2.2 with documented information of the accumulation of ice recorded for major ice storms [6] and ice loads considered in the design of steel transmission pole structures [7] have been utilized to relate thickness of ice to frequency of occurrence of such storms. This assumption is made in view of a lack of statistical data on accumulation of ice and should result in a generally conservative practice even though it is recognized that thickness of ice cannot be solely expressed in terms of rate of occurrence.

1" Thickness of ice equals 1/12 of a cubic foot, which weighs 62.4 pounds, so 1/12 equals 5.2 pounds. L = 5.2

(1) $1.4D + 1.7L = 1.4 \times 2.5 + 1.7 \times 5.2 = 12.3$
(2) $1.1D + 1.3L + 1.7W = 1.1 \times 2.5 + 1.3 \times 5.2 + 1.7 \times 19 = 42$

42 PSF is less than the 75 PSF load tested in Criterion 3.3.1.

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3.2.4 Criterion <u>Load Capacity</u>. Non-conventional elements and connections shall comply with this criterion. (Conventional elements are deemed to satisfy this criterion.)

The load capacity, R, of the system or a portion thereof shall exceed the required ultimate load, U, in Criterion 3.2.1 and shall be derived from the mean load capacity R_m:

$$U \leq R = R_m \phi c_u$$

where:

ϕ = variability factor which shall be such that approximately 95% of the system or portions thereof exceed $R_m\phi$ in resistance. For normal distribution of resistance, $\phi = 1 - 1.65v$.

v = coefficient of variation of resistance with respect to R_m.

c_u = coefficient for ductility = $(\mu + 7)/12$, but not more than 1.0 for loadings not including earthquake, and equal to 1.0 for loadings including earthquake.

μ = ductility factor for loading condition U, as defined under Evaluation below.

Evaluation Where adequate existing test data on the various material properties comprising the system are available, evaluation will be performed using engineering analysis. Where adequate test data is unavailable, system elements and subassemblies will be evaluated in the laboratory using simulated static load levels consistent with the specified load combinations.

The ductility factor will be evaluated as follows: For an ideal elasto-plastic (elastic-perfectly plastic) resistance function (plot of applied load as ordinate and deflection as abscissa), the ductility factor is defined as the ratio of ultimate deflection to yield deflection ($\mu = d_u / d_{ye}$). For an actual (nonlinear) function, the ductility factor shall be computed from an "effective" function (Fig. 3.2.4). The effective function consists of 2 straight lines. The first line is drawn through the origin and a point on the actual function at which the resistance is 60 percent of its maximum load value (P_u). The second line is a horizontal line ending at the ultimate deflection (d_u), which shall not exceed that where the resistance function falls below 95 percent of its maximum load value. The horizontal line is located so that the area under the 2 lines forming the effective function is equal to the area under the actual function up to the point of ultimate deflection. Effective yield deflection (d_{ye}) shall be taken as the deflection at the point of intersection of the 2 lines, which is at a resistance level termed "effective yield resistance." The ductility factor is based on the effective resistance function: $\mu = d_u/d_{ye}$.

Commentary The intent of this criterion (along with Criterion 3.2.1) is to provide a minimum level of safety against loading situations which have a suitably low probability of occurrence during service life.

See 3.2.1

3.3 Requirement		**Damage control**. The structural elements and connections of H, HC and DHW systems shall be designed to withstand service loads without damage of unacceptable magnitude.
3.3.1 Criterion		**Resistance to damage**. Non-conventional elements and connections shall comply with this criterion. (Conventional elements and connections are deemed to satisfy this criterion.)
		Under the effect of deflections caused by loading combinations of (1), (2) and (4) of Criterion 3.2.1, with load factors of 1.0, in addition to the anticipated creep deflections, the system as a whole or any component, connection or support thereof, shall not suffer permanent damage which would require replacement or repair, or which would impair its intended function during its service life.
	Evaluation	Evaluation of documented data for design, tests, and installation. Evaluation and/or testing of components and elements where deemed essential. Determination of compliance with generally accepted standards and engineering and trade practices, where applicable.
		The criterion is deemed satisfied if it can be demonstrated that deflections caused by the specified load combinations can be accommodated by suitable details or adequate flexibility.
	Commentary	The intent of this criterion is to provide for the proper functioning of the system under service loading conditions without breakdown or permanent impairment beyond levels comparable to conventional heating and cooling systems.

(1) D + L = 2.5 + 20 = 22.5
(2) D + W = 2.5 + 19 = 21.5
(4) D + L +W= 2.5 + 20 + 19 = 41.5

9" of sand weighing 100 pounds per cubic foot was loaded onto a horizontal collector supported off the ground on 2x4s. After removing the sand the collector was inspected for damage and none was noted. See test results. The effective load on the collector was 75 PSF.

CALMAC
TEST RECORD

Contract #NAS8-32253

Project: Collector

1. Item Being Tested: Entire collector

3.3.1

2. Test Objectives:

To verify ruggedness and durability of the collector structure.

3. Location of test facilities and scheduled test dates:

CALMAC factory, March 15 – April 15

4. Prerequisites for Passing or Failing:

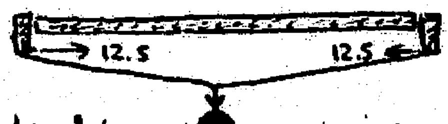
Part I: Collector should withstand 41.5 psf pressure.

Part II: Residual deflection shall not exceed 25% of the maximum deflection measured in the first cycle of load application.

5. Test Procedures:

Part I:
1) Place a piece of 3/4" plywood 4'×8' on top of a 4'×8' collector.
2) Keep adding weight to the plywood evenly across its surface until the collector begins to collapse.

Part II:
1) Mount a 2'×4' collector section upside down.
2) At the center of the glazing attach a weight which will exert a 12.5 psf pull against the perimeter wall:



3) Cycle the weight up and down once and measure the distance from one edge of the collector to the other.
4) Cycle the weight 1000 times and ~~again~~ measure the residual deflection after waiting 24 hours.

6. Test Results:

Part I: Instead of using plywood, we piled dirt and sand 9" deep on the collector. Density of the dirt and sand was 100 lb/ft³, so resultant weight on collector was 75 lb/ft². When sand was removed, collector was checked and no sign of damage to either the glazing or the side walls was noted.

Part II: We suspended the collector (2'×4') by hooks from 8 holes in the glazing — one per ft² — and put a 100-lb weight on the bottom of the collector. We then raised and lowered the collector 1000 times, putting a 12.5 psf force on the glazing. No damage, deterioration, or residual deflection was noticeable after this cycling.

CALMAC

TEST RECORD

Contract #NAS8-32253

Project: Collector

1. Item Being Tested:

Entire collector
3.3.1 (partial)

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2. Test Objectives:

To verify ruggedness and durability of the collector.

3. Location of test facilities and scheduled test dates:

CALMAC Mfg. Corp. May 1-15

4. Prerequisites for Passing or Failing:

Part I. Collector should withstand 41.5 psf pressure.

5. Test Procedures:

Part I

1.) Build frame around collector, extending 8" above collector
2.) Build a 5" layer of sand(density=100 lbs./ft^3) and let sit over night.
3.) Remove sand and check for any change in collector.

6. Test Results:

1.) Collector was loaded gradually up to 9" of sand(75lbs./ft^2)
2.) After removing sand only a slight wave was noticed in collector surface.
3.) All sides walls and adhered areas were checked, with no signs of damage.

3.4 Requirement — Cyclic loads. The structural elements and connections of H, HC and DHW systems shall not fail under the application of cyclic loads expected during the service life.

3.4.1 Criterion — Deflection limitations. Non-conventional elements and connections shall comply with this criterion. (Conventional elements and connections are deemed to satisfy this criterion.)

Structural components, connections and supporting elements shall be capable of resisting the following repeated loads without failure and without a residual deflection in excess of 25 percent of the maximum deflection measured in the first cycle of load application:

(1) 100 cycles from 1.0 D to 1.0 D + 0.5 L
(2) 1000 cycles from 1.0 D to 1.0 D + 0.5 W

Evaluation — Physical simulation and testing or analysis based on available test data.

The cyclic loading (1) and (2) shall be assumed to be applied after reducing system slack by the prior application of one preloading cycle of the following loads:

for (1) from (1D) to (1D + 1L)

for (2) from (1D) to (1D + 1W)

Cyclic loading shall commence only after deflection recovery from the preloading cycle is substantially complete. The residual deflection shall be taken as the difference between the deflection measured 24 hours after removal of the superimposed cyclic load and the residual deflection, if any, not recovered from the preloading cycle.

Commentary — Even though the service load history cannot be simulated the imposition of the stipulated cyclic loads is intended as a conservative representation of service conditions. The residual deflection limitation assures preservation of structural integrity under cyclic loading.

(1) D = 2.5 D + .5L = 2.5 + .5 x 20 = 12.5
(2) D = 2.5 D + .5W = 2.5 + .5 x 19 = 12.0

A force of 12.5 PSF was exerted pulling against the glazing of a test collector for a thousand cycles and no damage or measurable residual deflection was noted. See test results.

This test was performed twice, once using a collector without a trim strip with the glazing cemented to the insulation board wall, and the other time using a collector with a trim strip with the glazing held in place with Polyshim.

3.7.1 Criterion — **Hail size and loading.** System components and supporting structural elements that will be exposed to the natural environment in service shall be designed to resist, without excessive damage or major impairment of the functioning of the system, the perpendicular impact of falling hail having a particle diameter (in inches) equal to 0.3d where d is the mean annual number of days with hail determined on the basis of the hail map shown in Figure 3.7.1 [6].

Evaluation — Evaluation will be based on analysis using known structural information on the physical characteristics of the system components or on physical simulation and testing using the NBS hail resistance test described in the NBS Building Science Series 23[9]. In the absence of physical test data, the portion of the kinetic energy dissipated by system components shall be taken as 50 percent of the kinetic energy at impact corresponding to the resultant velocity specified in Table 3.7.1 (reproduced from Ref. [10]) for the predetermined hail size.

In cases where protective measures are provided to prevent impact of hail on system components, such as the use of screens or deflectors, these protective measures shall be included in the test specimens.

Commentary — It is not the intent of this criterion to prevent punching or local cracking of nonstructural elements such as glass cover plates of collector panels under hail impact, but rather to control damage by keeping it at a level which would not create a major curtailment in the functioning of the system, premature failure or hazards created by excessive shattering of glazed elements.

The correlation of hail size with mean annual number of days with hail is based on studies on the probability of exceedance of a given particle size as a function of frequency of occurrence of hail, a twenty year recurrence interval reflecting the life expectancy of the system and observations of statistical data [11] indicating that a representative hailstorm area is generally one order of magnitude smaller than the regions for which statistical information is compiled.

The worst condition in the U.S. is 6-8 days/year (mean = 7 days). 7 x .3 = 2.1" From Table 3.7.1 the kinetic energy at impact for a 2 1/4" ice sphere is 50.96 foot/pounds. 50% of that is 25.5. Data from Kalwall shows it takes 25 to 32 foot-pounds to shatter the glazing. Fiberglass reinforced polyester is extremely resistnat to this type of stress.

3.8 Requirement — Constraint loads. The structural elements and connections of H, HC and DHW systems shall comply with Criterion 3.2.1 while simultaneously subjected to constraint loads expected during the service life.

3.8.1 Criterion — Foundation settlement; contraction and expansion. Non-conventional elements and connections shall comply with this criterion. (Conventional elements and connections are deemed to satisfy this criterion.)

System components, connections and supporting elements shall comply with Criterion 3.2.1 while simultaneously subjected to the following constraint conditions:

1. A differential foundation settlement of 2 inches in any horizontal distance of 50 feet except that in cases where the foundation at a particular site is specifically designed to control differential settlements, the constraint conditions should be those consistent with the specified design. Uplift forces caused by a swelling of expansive soils shall be calculated assuming a level of 0.9D for gravity loads.

2. Constraint loads arising from thermal expansion and contraction of system components and structural elements or from time-dependent changes within the material.

Evaluation — Analysis and/or physical simulation.

Commentary — Soil-structure interaction is usually a design function since constraint loads are dependent on the characteristics of the soil as well as the effects of structural framing. Due to economic considerations in foundation design, the assumption is usually made that the superstructure is capable of accommodating a reasonable amount of differential settlement. The requirement in part (1) is consistent with observed performance of conventionally designed foundations and represents the threshold at which structural damage occurs. This criterion is relaxed when special precautions are used in foundation design to control differential settlements.

The requirements in part (2) of the criterion account for other types of constraint loads such as those introduced by thermal expansion and contraction of system components or creep and shrinkage in supporting structural elements.

Stress created by foundation settlement will be absorbed by the ability of the collector to flex to a small degree. The absorber tubing, insulation and frame pieces can all withstand slight bending and flexing.

Stress created by differential expansion between the collector and its supporting structural elements can be absorbed partly by the ability to flex as described above, and also by proper mounting procedures.

3.9 Requirement		Ponding condition. Horizontal surfaces of the H, HC and DHW systems shall be designed in a manner that will assure stability in service under ponding conditions.
3.9.1 Criterion		Design provisions. Horizontal surfaces exposed to the exterior environment shall be designed to have either sufficient stiffness to prevent failure as a result of ponding caused by the accumulation of water or shall be provided with sufficient slope to permit free drainage or adequate individual drains to prevent the accumulation of water.
	Evaluation	Analysis based on documented strength and stiffness properties or physical simulation and testing.
	Commentary	Ponding is defined as the retention of water due to the deflection of horizontal surfaces. The lack of sufficient vertical stiffness causes the surface to continuously deflect and accumulate additional water until collapse occurs.

The collector has a design minimum slope requirement of 2 in 12. This allows water to run off the glazing. A test was performed to insure that at a 2 in 12 slope water would run off. See test results.

CALMAC

TEST RECORD

Contract #NAS8-32253

Project: Collector

1. Item Being Tested: Glazing and perimeter wall, and bond between the two, and spacer blocks. 3.9.1

2. Test Objectives:

To verify that at a 2 in 12 slope water will run off the collector.

3. Location of test facilities and scheduled test dates:

CALMAC factory, March 15 - April 15 (Test date 5/15/77)

4. Prerequisites for Passing or Failing:

Water should not accumulate on the collector face during or after test.

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5. Test Procedures:

1) Set collector at slope of 2 in 12 (9.5°) a leveling protractor was used to set slope.

2) Spray vigorously with water to simulate heavy rainfall.

3) Turn off water.

4) ~~Observe~~ Examine for any ponding during and after spraying of water.

5) Repeat test with smaller slope to see if any water accumulates.

6. Test Results:

2-12 slope (9.5°): Water ran off collector immediately with no accumulations anywhere.

1-12 slope (4.8°) Water ran off collector immediately with almost no ponding. 1 pond occurred, 1/2" deep x 24" in diam. No measurable deflection in collector cover. The ponding was due to a small wave in Kalwall surface. It was located on the upper half of collector where our present slope of Kalwall (?:12) almost cancelled out 1:12 slope

4.1 Requirement — Plumbing and electrical installation. The design and installation of the systems for heating (H), combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem and their components shall be in accordance with nationally recognized plumbing and electrical codes and standards for health and safety, where applicable.

4.1.1 Criterion — Plumbing codes and standards. Plumbing materials and equipment and their installation shall be in accordance with Sections 515 and 615 of the MPS (4900.1 and 4910.1)[1] and Part C of ANSI A119.1[2], where applicable.

Evaluation — Review of drawings and specifications. Testing to show compliance, where necessary.

Commentary — Suitable standards are available for conventional equipment. Unique innovative installations may require special consideration.

All plumbing connections are standard. A review of the National Standard Plumbing Code did not indicate any areas where the collector would not be in compliance.

4.2 Requirement — Fail-safe controls. The H, HC and DHW systems shall be fail-safe in the event of damage to system components or a power failure.

4.2.1 Criterion — System failure prevention. The control subsystem shall be designed so that in the event of a power failure, or a failure of any of the components in the subsystem, the temperatures and/or pressures developed in the H, HC and DHW systems will not be damaging to any of the components of the systems, and the building, or present a danger to the occupants. The safety devices shall meet the requirements of Section 515-6.4 of the MPS (4900.1 and 4910.1)[1].

Evaluation — Review of drawings, specifications and design calculations.

Perform test of fail-safe control installation for all probable failure events.

Commentary — The excessive pressures and temperatures that can build up in collectors under "no flow" conditions are an important consideration. Consideration should be given to the thermal shock which could occur when cool heat transfer fluids are introduced into collectors which have been exposed to solar radiation under "no flow" conditions.

Fail-safe systems are called for and described in the Installation Manual but are not a part of the collector itself. Fail-safe tests were run using the recommended fail-safe devices. See test results.

CALMAC

TEST RECORD

Contract #NAS8-32253

Project: Collector

1. Item Being Tested: Fail - safe system features (4.2.1)

2. Test Objectives: To verify that in the event of a power failure, or failure of any other components of the system, no damagewill result to the other components of the system or to the building and its occupants.

3. Location of test facilities and scheduled test dates:

   CALMAC factory, March 15 - April 15

4. Prerequisites for Passing or Failing: If the temperature/pressure relief valve opens at the prescribed temperature/pressure, the fail safe system will have passed. The test will be repeated several times for various combinations of temperature or pressure.

5. Test Procedures: The temperature/pressure relief valve will be set at ~~225~~ 210°F and 40 psi. Water pressure will be allowed to increase up to 40 psi and beyond until the valve opens--the point at which it opens will be noted, and the test repeated several times to determine the variance. The same procedure will be repeated with by increasing the water temperature up to 225°F and beyond until the valve opens--the point at which it opens will be noted, and the test repeated several times to determine the variance.

6. Test Results:

   The collector was allowed to stagnate for 1 hour (pump off) on a sunny day (insolation 250-270 BTU/hr/ft^2). The pump was then turned on with valve closed at pump outlet and valve slowly opened. Collector outlet thermocouple temperatures adjoining releif valve were observed. Relief valve opened at 210°F. This was repeated for a total of three tests. Pressure relief valve was also tested by adjusting the pressure regulating valve up through 40 PSI from a lower pressure. Relief valve opened at 40 PSI on three separate tests.

4.2.2 Criterion — Automatic pressure relief valves. Adequately sized and responsive automatic pressure relief valves shall be provided in those parts of the energy transport subsystem containing pressurized fluids. Automatic pressure relief valves shall be set to open at not less than 25 percent in excess of working pressure and at not more than maximum pressure for which the subsystem is designed.

Evaluation — Review of plans and specifications, and/or determination that methods, devices, and materials to be used are approved by a recognized testing and evaluation agency as being suitable for the proposed use.

See 4.2.1 and accompanying test results.

4.3 Requirement — Fire safety. The design and installation of the H, HC and DHW systems and their components shall provide a minimum level of fire safety consistent with applicable codes and standards.

4.3.1 Criterion — Applicable fire standards. Assemblies and the materials used in the H, HC and DHW systems shall comply with nationally recognized codes and standards for fire safety, where applicable.

Evaluation — Review of drawings and specifications for conformance with the MPS, ANSI A119.1, and applicable sections of NFPA 89M[4], NFPA 90A and 90B[5], NFPA 211[6], NFPA 54[7], NFPA 31[8], ASTM E 108[9] and the National Electric Code [10]. Testing to show compliance, when necessary. Potential heat, rate of heat release, ease of ignition, and smoke generation will be considered in assessing potential fire hazards.

Commentary — It is the intent of this criterion to (1) prevent the use of materials, equipment and fluids which present a fire hazard significantly greater than that of conventional systems, (2) to provide proper clearances and venting of heat build-up for those system components that operate at elevated temperatures, and (3) to give consideration to the combustibility of materials adjacent to high temperature components in determining the clearances that are required.

A review of the specifications for the materials used in the collector indicates compliance with applicable fire standards.

4.3.2 Criterion **Penetrations through fire-rated assemblies.** Penetrations through fire rated walls, partitions, floors, roofs, etc. shall not reduce the fire resistance below the levels specified in Section 405 of the MPS (4900.1 and 4910.1)[1], where applicable.

Evaluation: Review of drawings and specifications. Testing to show compliance, where necessary.

Commentary: It is the intent of this criterion (1) to prevent the passage of system components through fire-rated assemblies from adversely affecting the fire endurance rating of the assembly, and (2) to ensure that proper techniques are employed in constructing these components so that adequate protection can be provided.

Nothing in the design of the system for mounting the collector affects the fire resistance of penetrations through the roof structure.

4.4 Requirement **Toxic and flammable fluids.** Heat transfer fluids which require special handling because of toxicity and/or flammability shall not be used unless the systems in which they are used are designed to avoid exposing the occupants of dwellings to unreasonable hazards.

4.4.1 Criterion **Provision of catch basins.** Adequately sized and protected catch basins shall be provided, when liquids requiring special handling are used, to collect and store the overflow from pressure relief valves, liquids drained from the system when it is being serviced, potential leakage, and accidental drainage.

Evaluation: Review of drawings and specifications.

Commentary: The leakage of toxic fluids into the ground could contaminate the ground water.

Use of a catch basin to hold heat transfer fluids that may vent from the temperature/pressure relief system is called for in the manual for the collector.

4.4.2 Criterion Detection of toxic and flammable fluids. If heat transfer fluids that require special handling are used, means shall be provided for the detection of leaks and the warning of occupants when leaks occur.

Evaluation Review of drawings and specifications. Testing of detection and warning system(s).

Commentary It is common practice to relate toxicity and flammability ratings to the level of hazard created at ambient temperatures. Heat transfer fluids which do not present a hazard at ambient temperatures may be hazardous at the temperatures developed in the system.

The use of a catch basin (4.4.1) provides evidence of overflow from the system. The use of a pressure gauge in the collector loop provides a means of identifying leaks in the system--if a leak develops pressure in the system will drop. The use of a pressure gauge is called for in the collector manual.

4.6 Requirement Protection of potable water and circulated air. No material, form of construction, fixture, appurtenance or item of equipment shall be employed that will support the growth of micro-organisms or introduce toxic substances, impurities, bacteria or chemicals into potable water and air circulation systems in quantities sufficient to cause disease or harmful physiological effects.

4.6.1 Criterion Contamination by materials. Materials which come in direct contact with potable water shall not affect the taste, odor or physical quality and appearance of the water in an undesirable manner.

Evaluation Review of plans and specifications for compliance with the 1962 Edition of the Public Health Service Drinking Water Standards [11].

See the attached certification from the tubing supplier. This particular formulation of tubing has been used in food-grade applications such as for the spout in a coffee vending machine.

Early production items, including those manufactured for NASA, were not made from tubing from this supplier and should not be used in potable water systems. A notice to this effect has been included in the manuals delivered with collectors made from non-certified tubing.

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December 6, 1977

CERTIFICATION

This is to certify that all of the ingredients used in EPDM compound E-809 are within the limitations prescribed by the Food and Drug Administration as listed in the Federal Register under paragraph 121.2562.

PAWLING RUBBER CORPORATION

Allan G. Kjellman

Allan G. Kjellman
Chief Chemist

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4.6.3 Criterion Backflow prevention. Backflow of nonpotable heat transfer fluids into the potable water systems shall be prevented.

Evaluation Review of drawings and specifications. Inspection of assembled systems.

Commentary Pollution of the potable water supply can occur by way of backflow caused by back pressure and/or backsiphonage within a cross connection between the potable supply and nonpotable fluid in the system. The former type of backflow can occur, for example, from elevated tanks, or pumps. The latter can occur when the potable water supply system is under vacuum such as might occur with a broken street water main.

Piping arrangements, backflow prevention devices, and/or air gaps may be used to prevent contamination of the potable water system.

The use of check valves and double-walled heat exchangers is actively being discussed by HUD and the solar industry, and this topic is not explicitly covered in the collector manual. Nothing in the collector design affects the use of these items.

4.6.4 Criterion Growth of fungi. Components and materials used in the H, HC and DHW systems shall not promote the growth of fungi, mold or mildew.

Evaluation When tested in accordance with Appendix D, Section E of the MPS (4900.1 and 4910.1)[1], there should be no evidence of the growth of fungi.

Commentary Special consideration should be given to the presence of fungi in air handling systems since such micro-organisms are frequently allergenic.

Fungi can feed on some organic materials and generally thrive in warm, moist environments. They can be killed by sufficiently low wavelength ultraviolet radiation but much of this radiation may be absorbed by the earth's atmosphere. It may be possible for fungi to grow on both the interior and exterior of collector components and possibly affect the collector performance.

Material specifications for the fiberglass insulation, where fungi would most likely grow, indicate resistance to this type of growth. Operation of collectors prior to and during the contract showed no evidence of growth of fungi either on the interior or exterior of the collector components.

4.7 Requirement **Excessive surface temperatures.** Temperatures of exterior surfaces of the H, HC and DHW systems shall not create a hazard.

4.7.1 Criterion **Protection from heated components.** Subassemblies of the H, HC and DHW systems that are accessible, located in areas normally subjected to public traffic and which are maintained at elevated temperatures shall either be insulated to maintain their surface temperatures at or below 140°F at all times during their operation or suitably isolated. Any other exposed areas that are maintained at hazardous temperatures shall be identified with appropriate warning signs.

Evaluation Review of drawings and specifications.

The collector is not likely to be located in areas subjected to public traffic, and the glazing would only approach 140° under unusual situations.

5.1 Requirement <u>Effects of external environment</u>. The systems for heating (H) and combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem and their various subassemblies shall not be affected by external environmental factors to an extent that will significantly impair their function during their design life.

5.1.1 Criterion <u>Solar degradation</u>. Components or materials that are exposed to sunlight shall not undergo changes in their properties during their design life that would significantly impair the function of the system.

a. When components or materials are exposed to UV radiation in combination with an intermittent water spray at their maximum "no-flow" temperature, there shall be no signs of excessive deterioration such as cracking, crazing, embrittlement, etching, loss of adhesion, changes in permeability, loss in flexural strength or any other changes that would significantly affect the performance of the components in the system.

b. The collector shall be capable of providing its rated output after exposure to levels and intensities of solar radiation and temperatures that are equivalent to those that would be expected in actual use over the life of the collector.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 03 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary The transmittance, emittance and absorptance data required to estimate the effects of degradation by solar radiation in reducing the collector efficiency are available for most materials currently being used in collectors.

The maximum "no flow" temperature and other in-use temperatures are discussed in detail in Section 01 of the Appendix at the end of this chapter.

Kalwall: See summary of testing done by Kalwall Corp.

EPDM Tubing: Samples were subjected to a four-month accelerated test on DSET's EMMAQUA (Equatorial Mount with Mirrors for Acceleration Plus Water) equipment and showed no signs of cracking, dimensional change, chalking or other deterioration. This test provided the equivalent of about 3 1/3 years of normal exposure. One sample was under a single glazing of KALWALL.

CAL-ZORB: This particular material is 35% carbon black by weight, and is made of a base of urethane which has very good resistance to ozone, ultraviolet and heat-aging.

Noryl: See manufacturer's data package.

Complete Collector: See DSET results of testing in accordance with ASHRAE 93-77.

5.1.3 Criterion Airborne pollutants. Components that are exposed to airborne pollutants such as ozone, salt spray, SO_2, NO_x, and/or HCl with or without the presence of moisture shall be resistant to attack by these factors to the extent that these factors shall not significantly impair the performance of the components during their design life.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 05 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

The maximum pollutant levels in the area(s) where the system will be installed shall be used to determine the pollutant levels required for testing. If components are to be used in areas where they are not exposed to any or all of these pollutants, tests that are not applicable need not be conducted.

Commentary Ozone concentrations in normal dry air have been reported to range from 1-5 pphm/volume. However, concentrations of 100 pphm/volume have been reported during very smoggy conditions. Ozone is known to degrade some organic materials but it has little effect on inorganic materials other than metals.

The effects of solar radiation in combination with airborne pollutant may also be an important consideration.

Kalwall glazing: See Manufacturer's data package.

EPDM Tubing: See data package on EPDM.

CAL-Zorb: See data package on Cal-Zorb and urethane.

Noryl: See manufacturer's data package.

Polyshim: See Manufacturer's data. This material is being used exactly as it was engineered to be used. The other materials are being used in non-conventional ways

5.1.4 Criterion Dirt retention on cover plate surface. The collector cover plate surface shall not collect and retain dirt to an extent that would significantly impair the function of the collector during its design life.

Evaluation Engineering analysis, documentation of satisfactory long-term performance under in-use conditions and review of plans and specifications.

Commentary The possible collection and retention of dirt by the cover plate and the effect of retained dirt on the collector performance may be significant. The retention of dirt may depend on the tilt angle of the collector. Rainfall and snow melt are generally sufficient to keep the collector cover plates clean.

The minimum recomended angle of installation is 2 in 12. This angle allows rainwater to run off and to keep the glazing clean. This requirement is spelled out in the collector manual.

5.1.5 Criterion **Abrasive wear**. The ability of the collector to function at its rated capacity shall not be significantly impaired by the abrasive wear to which its surface will be subjected over its design life.

Evaluation Engineering analysis, documentation of satisfactory long-term performance under in-use conditions and review of surface hardness specifications for cover plate materials.

Commentary Test methods which are currently available for measuring abrasion resistance are believed to be too stringent for testing organic collector cover plates. Abrasive wear is expected to present a possible problem in areas subject to wind driven sand.

Some surface erosion of the Kalwall polyester glazing is expected, and resurfacing of the glazing every five to seven years is called for in the manual. See Kalwall's data package.

5.1.6 Criterion Fluttering by wind. Components that are subject to fluttering by wind shall not degrade under in-use conditions to an extent that their function will be impaired during their design life.

Evaluation Documentation of satisfactory long-term performance under in-use conditions, engineering analysis, or testing using an experimental verification procedure which can be shown to meet the intent of the criterion.

Commentary Thin films that increase in brittleness at low temperatures may be particularly susceptible to degradation by fluttering by wind.

Kalwall's resilience over a wide range of temperatures and over long periods of time is documented in the Kalwall data package.

The effect of fluttering on the bond between the Kalwall and the collector has been effectively tested in the testing of the collector's structural strength. See test results for 3.3.1. A 75-mph wind across the face of the collector was also created using a wind tunnel in the factory with no evidence of breakdown. See test results.

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CALMAC

TEST RECORD

Contract #NAS8-32253

Project: Collector

1. Item Being Tested: Perimeter wall and glazing and bond between the two.

   5.1.6

2. Test Objectives: ~~To determine resistance of collector to fluttering by the wind.~~

   To measure force required to rip glazing away from the insulation board structure and determine resistance to fluttering by the wind.

3. Location of test facilities and scheduled test dates:

   CALMAC factory, March 20–April 15

4. Prerequisites for Passing or Failing:

   ~~glazing should be able to withstand 15 psf pull away from the collector.~~

   glazing should not rip away from collector when subjected to 80 mph wind — constant and in gusts

5. Test Procedures:

   ~~1) Build a 2' x 4' section of the collector and mount it upside down.~~

   ~~2) Divide the area up into 8 sections of 1 ft² each, and at the center of each 1 foot square attach some means for suspending weights.~~

   ~~3) Keep adding weights until some part of the glazing pulls away from the collector.~~

   Using a blower and chamber, expose collector to wind.

6. Test Results: Photographs attached show test setup. 75 mph wind was achieved. Glazing ballooned out from the collector but showed no sign of ripping away

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5.2 Requirement — Temperature and pressure resistance. Components shall be capable of performing their intended function for their design life when exposed to the temperatures and pressures that can be developed in the system.

.1 Criterion — Thermal degradation. Components shall not thermally degrade to the extent that their function will be reduced below acceptable levels during their design life when exposed to in-use temperatures.

Evaluation — Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 06 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary — Some organic components which may be used in the system may be particularly susceptible to thermal degradation under prolonged exposure.

Kalwall glazing: See Kalwall data package.

EPDM: See descriptive data package on EPDM.Also see test results for Criterion 5.2.4.

Cal-Zorb: See data on Cal-Zorb. In addition, collectors using the adhesive have been stagnated at absorber temperatures clese to 300°F without deterioration.

Noryl: See descriptive data.

1300 Cement: See product specifications.

Fiberglass insulation: See manufacturer's specifications.

5.2.2 Criterion — Deterioration of heat transfer fluids. Except when such changes are allowed by the design of the system, the heat transfer fluid shall not freeze, give rise to excessive precipitation, otherwise lose its homogeneity, boil, change pH or undergo large changes in viscosity when exposed to its intended service temperature and pressure range.

Evaluation — Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 07 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary — Thermal cycling may cause metastable precipitation to occur. Systems may be pressurized to prevent boiling.

Maintenance of the heat transfer fluid is called for in the collector manual.

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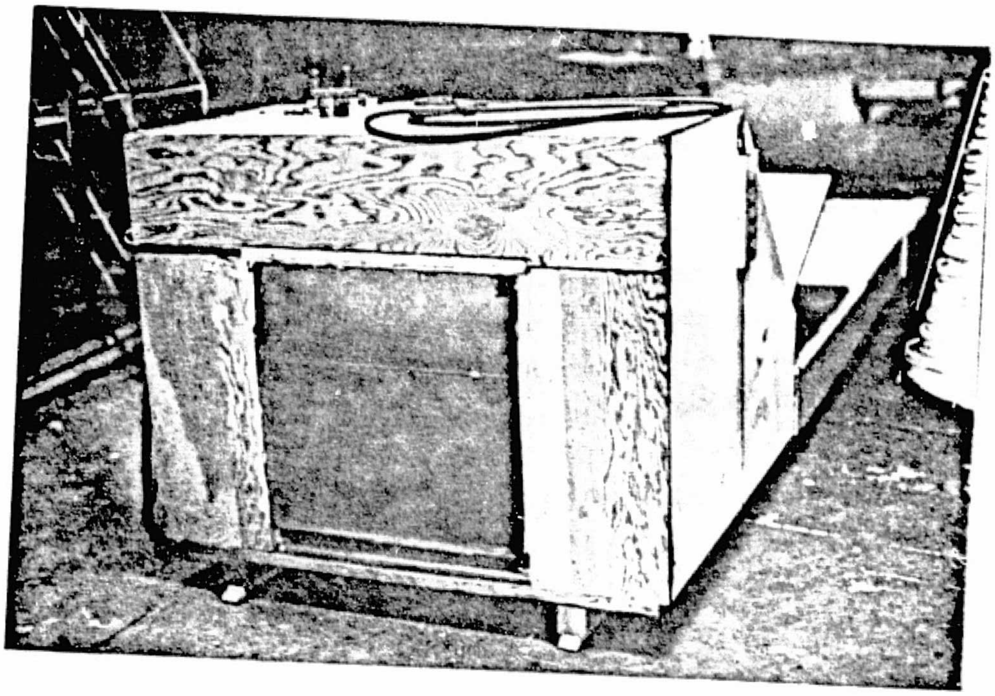

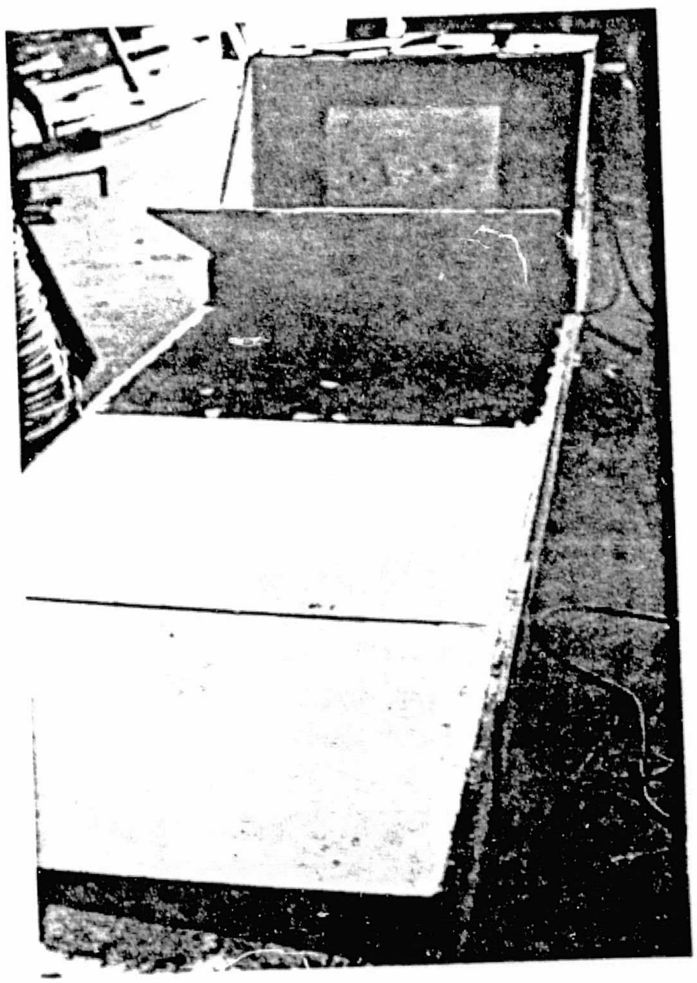

5.2.3 Criterion Thermal cycling stresses. The H, HC and DHW systems and their various subassemblies shall be capable of withstanding the stresses induced by thermal cycling for their respective design lives.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 08 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Physical restraints that will be imposed on the system in actual use shall be considered when testing is required.

Commentary This criterion is intended to identify potential problems that may occur as a result of differential thermal movement. Thermal compatibility is especially critical in the case of collectors which may contain large expanses of glazing. Edge flaws in glass may result in cracking of the glass when it is under stress.

See 2.2.5.

5.2.4 Criterion Leakage. All assemblies or subassemblies which contain heat transfer fluids (other than air) shall not leak when tested at a pressure equal to 150% of the working pressure of the system over the entire service temperature range.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 09 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary This criterion is intended for materials which may creep or become brittle at service temperatures.

See Test results for Criterion 2.3.1.

5.2.5 Criterion Deterioration of gaskets and sealants. Gaskets and sealants in direct contact with heat transfer liquids shall be capable of withstanding repeated cycles consisting of soaking and drying under in-use conditions without significantly impairing their ability to function during their design life.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 10 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary Gaskets, sealants, and similar organic materials frequently swell when exposed to liquids and shrink upon drying, thus losing their ability to function.

No gaskets or sealants other than [illegible] cement at the connection between the headers/U-bends and the tubing are used. This cement is an epoxy and does not absorb liquid or swell in use.

5.2.6 Criterion **Transmission losses due to outgassing.** Outgassing of volatiles that will reduce collector performance below specified design values shall not occur when the collector is exposed to the temperature and pressures that will occur in actual service.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 11 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary Outgassing from components inside the collector could lead to condensation on the underside of the collector cover plates which may reduce the transmissivity of the cover plates.

The organic binder in the rigid board fiberglass will vaporize to a certain extent at temperatures the collector might reach during stagnation (250°F+). This problem was experienced during testing. By outgasing the insulation in an oven at 350°F for an hour the organic material that outgases at these temperatures is driven off. Since initiating this practice no problem with outgassing has appeared.

5.3 Requirement Chemical compatibility of components. Materials used in the systems and their various subassemblies shall have sufficient chemical compatibility to prevent corrosive wear and deterioration that would significantly shorten the intended service life of components under in-use conditions.

5.3.1 Criterion Materials/transfer fluid compatibility. Materials designed to be used in contact with heat transfer fluids shall not be corroded by these fluids to the extent that their function will be significantly impaired under in-use conditions during their intended service lives.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 12 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary Corrosion by heat transfer fluids could be a serious problem in solar energy systems.

The only two components in contact with the heat transfer fluid are the copper headers/U-bends and the EPDM tubing. Copper is used extensively in the collector field and has been proven to be compatible with water and glycol mixtures. The EPDM tubing is used in the automotive industry as radiator hose where glycol antifreeze is commonly used, and no chemical incompatibility has been noticed.

5.3.2 Criterion Corrosion of dissimilar materials. Non-isolated dissimilar materials with or without corrosion resistant finishes, where used either in contact with a transfer fluid, or without such contact, shall not be corroded to the extent that their function will be significantly impaired under in-use conditions during their intended service lives.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 13 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary The use of corrosion inhibitors or dielectric fittings that electrically isolate dissimilar materials may be desirable. In the case of plastics, plasticizer migration may be a concern. The presence of pinholes in protective coatings may drastically accelerate corrosive action.

Copper is the only metal used in the collector, so there are no cases of dissimilar metals which might corrode through galvanic action.

All the other materials are plastics and elastomers which have shown no evidence of corrosion or chemical interaction during the months of testing and use.

The 60/40 solder used in the copper headers is designed specifically for use with copper to avoid corrosion.

5.3.3 Criterion Corrosion by leachable substances. Chemical substances that can be leached by moisture from any of the materials within the system shall not cause corrosive deterioration of any other components that would significantly impair the ability of these components to perform their intended function over their service lives.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 14 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary Salts such as those that can be leached by moisture from some types of glass fiber and mineral wool insulation or from organic components may cause corrosion of system components that are in close proximity.

The fiberglass insulation board meets military specification MI244 for leaching, which allows only an extremely low amoung of leaching. No leaching has been seen during testing or operation.

See Criterion 4.6.1 for leaching of the EPDM tubing.

5.3.4 Criterion [illegible] that are expelled from components under in-use conditions shall not cause the degradation of other components within the system to the extent that it would significantly impair their ability to perform their intended function over their service lives.

Evaluation Documentation of satisfactory long term performance under in-use conditions or engineering analysis. Where adequate existing information is unavailable, testing using either the methodology outlined in Section 15 of the Appendix given at the end of this chapter or other methods which can be shown to meet the intent of the criterion will be used.

Commentary Some components may yield degradation products during their service life without impairing their function or aesthetic properties. These degradation products could significantly impair the performance of other components in the system.

Outgassing from the insulation board did condense on the glazing but did not cause any degrading of any components. The outgassing has been handled by factory outgassing prior to assembly. See Criterion 5.2.6.

In early use the EPDM tubing may tend to give up small pieces of sediment. To remove this sediment, a filter in the line is recommedded in the collector manual.

6.1 Requirement Accessibility for maintenance and servicing. The systems for heating (H), combined heating and cooling (HC) and the domestic hot water (DHW) system/subsystem shall be designed, constructed, and installed to provide sufficient access for general maintenance, convenient servicing and monitoring of system performance.

6.1.1 Criterion Access for system maintenance. All individual items of equipment and components of the H, HC and DHW systems which may require periodic examination, adjusting, servicing and/or maintenance shall be accessible for inspection, service, repair, removal or replacement without dismantling of any adjoining major piece of equipment or subsystem.

Evaluation Review of drawings and specifications.

Commentary Accessibility as a function of component life is an important consideration.

Information on access provisions is provided in Reference [1].

Access to the collector absorber system, which is the only component that might require service, is facilitated through the zipper-lock construction of the panel collector. The glazing can be popped off and pulled back easily to allow repair of the tubing. In the field assembled design the glazing can be cut away from the insulation with a knife and then recemented after repairs are made.

6.1.2 Criterion <u>Access for system monitoring</u>. Appropriate access for sensors shall be provided for inspecting and checking essential system parameters such as temperature, pressure and critical voltages.

Evaluation Review of drawings and specifications for the location of test fittings.

Commentary Adequately located test fittings will permit system monitoring and expedite the maintenance and repair of equipment.

The collector sensor for the differential thermostat can either be inserted in the header or can be clamped onto the header.

6.1.3 Criterion <u>Draining and filling of liquids</u>. To facilitate system or subsystem maintenance and repair, subsystems employing liquids shall be capable of being conveniently filled and drained.

Evaluation Review of drawings and specifications.

Commentary The potential buildup of vapor which could create air pockets and thus block or restrict the flow of heat transfer fluids should be considered. (See Criterion 2.1.5)

Complete draining of the EPDM tubing is difficult because of capillary action. To empty out the tubing completely air must be pumped through the system. Complete draining, however, is rarely necessary as there is enough flexibility in the tubing to absorb expansion caused by freezing.

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6.1.4 Criterion <u>Flushing of liquid subsystems</u>. Suitable connections shall be provided for the flushing (cleaning) of liquid energy transport subsystems.

Evaluation Review of drawings and specifications.

Commentary The recommendations of the system manufacturer for cleaning agents compatible with the materials of the system should be followed.

Water is the recommended agent for flushing. See the collector manual.

6.1.5 Criterion <u>Filters</u>. Filters shall be designed and located so that they can be cleaned or replaced with minimum disruption to the system and adjacent equipment. Cleaning frequencies shall be specified by the system manufacturer in the maintenance manual.

Evaluation Review of drawings and specifications.

The use of a filter is recommended in the collector manual. See Criterion 5.3.4.

6.2 Requirement — Installation, operation and maintenance manual. A manual shall be provided for the installation, operation and maintenance of the H, HC and DHW systems.

6.2.1 Criterion — Installation instructions. The manual shall include physical, functional and procedural instructions describing how the subassemblies of the HC and DHW systems are to be installed.

These instructions shall include descriptions of both interconnections between the system subassemblies and their interfaces and connections with the dwelling and site.

Evaluation — Review of installation instructions.

See the collector manual.

6.2.2 Criterion — Maintenance and operation instructions. The manual shall completely describe the H, HC and DHW systems, their breakdown into subsystems, their relationship to external systems and elements, their performance characteristics, and their required parts and procedures for meeting specified capabilities.

The manual shall list all parts of the systems, by subsystem, describing as necessary for clear understanding of operation, maintenance, repair and replacement, such characteristics as shapes, dimensions, materials, weights, functions and performance characteristics. The manual shall include a tabulation of those specific performance requirements which are dependent upon specific maintenance procedures. The maintenance procedures, including ordinary, preventive and minor repairs, shall be cross-referenced for all subsystems and organized into a maintenance cycle. The manual shall fully describe operation procedures for all parts of the system including those required for implementation of specified planned changes in mode of operation.

Evaluation — Review of maintenance and operating instructions.

See the collector manual.

6.2.3 Criterion — Maintenance plan. The manual shall include a comprehensive plan for maintaining the specified performance of the H, HC and DHW systems for their design service lives.

The plan shall include all the necessary ordinary maintenance, preventive maintenance and minor repair work and projections for equipment replacement.

Evaluation — Review of maintenance plan.

See the collector manual.

6.2.4 Criterion Replacement parts. Parts, components, special tools and test equipment required for service, repair or replacement shall be commercially available or available from the system or subsystem manufacturer or supplier.

Evaluation Review of specifications for the availability of parts.

Commentary This criterion is intended to preclude long periods of system down-time due to the need for the repair or replacement of parts.

A repair kit providing all commonly needed parts for repair will be provided with each collector. Instructions for use of the kit are included in the manual.

6.3 Requirement Repair and service personnel. The H, HC and DHW systems shall be designed in such a manner that they can be conveniently repaired by qualified service personnel.

6.3.1 Criterion Maintenance of H and HC systems. The H and HC systems shall be capable of being serviced with a minimum amount of special equipment by a trained HVAC service technician using a maintenance manual.

Evaluation Review of drawings, specifications, and maintenance instructions.

Commentary The complexity and design of certain components may require their removal and replacement for repair of the system.

See the collector manual and Criterion 6.1.1.

6.3.2 Criterion Maintenance of DHW system. The DHW system shall be capable of being serviced with a minimum amount of special equipment by a qualified service technician using a maintenance manual.

Evaluation Review of drawings, specifications, and maintenance instructions.

See the collector manual and Criterion 6.1.1.

8.3 Requirement Mechanical and electrical functioning of connections. The connections between the H, HC, and DHW systems and the dwelling or site shall function mechanically or electrically as intended.

8.3.1 Criterion Plumbing connections. Plumbing connections between the solar subsystems and water service or waste disposal systems shall be in accordance with the MPS[3] or ANSI A119.1[4], as applicable.

Evaluation Review of mechanical drawings and any details or specifications related to plumbing connections.

Commentary Particular attention should be given to making sure that plumbing connections are dimensionally coordinated, that pipe sizes and threads are compatible, and that changes in direction do not unduly restrict the flow of fluid.

The pipe connections at the inlet and outlet headers are standard 3/4" NPT.

11.2.1 Criterion — Chemical corrosion. Solar subsystems shall not cause chemical corrosion of the building or site elements to an extent that would significantly impair their intended performance.

Evaluation — See Evaluation: Criteria 5.3.3 and 5.3.4 in Chapter Five, Systems and Components.

See Criterion 5.3.3 and 5.3.4.

11.2.2 Criterion — **Heat and moisture. Roof mounted solar subsystems shall not cause a buildup of heat or moisture that would cause excessive deterioration of the roofing system or other components of the dwelling.**

Evaluation — **Review of architectural plans, specifications and calculations for temperature buildup caused by solar subsystems.**

Commentary — **The presence of the collector can cause abnormal heat rises which could cause thermal degradation and the buildup of moisture which could cause rotting.**

The collector is designed to be mounted to the roof and flashed to prevent moisture from building up under the collector. The temperature of the roof structure is a function of the absorber temperature, the air temperature underneath the roof, the amount of insulation under the roof and the amount of insulation in the collector, which is fixed by the design of the collector at a K value of .115 BTUH/ft^2/°F. Assuming the collector insulation is twice as effective as insulation in the roof, which is quite conservative given losses through joists and the fact that most attic insulation is on the attic floor and not under the roof, the roof structure temperature would be two-thirds between the absorber temperature and the air temperature underneath the roof. Assuming an extreme case of stagnation at 300°F and inside air temperature of 90°F, the roof would be about 160°F. The SUNMAT Collector has no design features to distinguish it in this respect from other collectors designed for direct mounting on the roof.

11.3 Requirement — Durability and reliability of connections. The connections between the H, HC and DHW systems and the dwelling that are exposed to external environmental factors shall not undergo changes that will impair their functions.

11.3.1 Criterion — Material compatibility. Connector materials shall be chemically and physically compatible under in-use conditions.

Evaluation — **See Evaluation: Criterion 5.3.2 in Chapter Five, Systems and Components.**

See Criterion 5.3.2.

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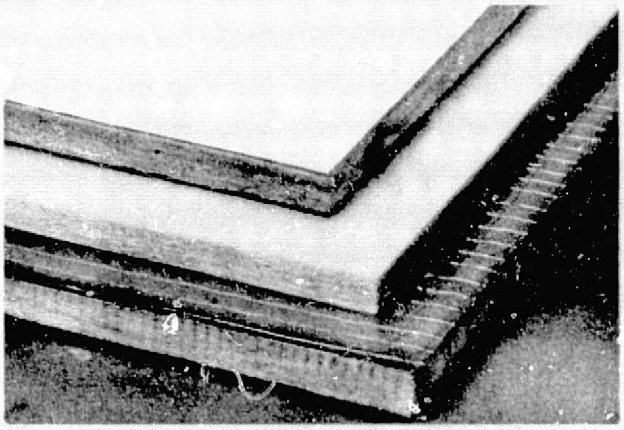
APPENDIX A

MATERIALS

OWENS/CORNING FIBERGLAS

Industrial Insulation, 700 series, Plain and Faced

A highly versatile group of Fiberglas insulating boards designed to insulate ductwork, equipment, vessels, and tanks, both thermally and acoustically. For operating temperatures to +450F



uses

The 700 series Boards have been designed primarily to insulate heating and air conditioning ducts, ovens, tanks, boilers, hot water generators and other hot equipment.

Type 701—A lightweight resilient insulation, in board form, used on vessels having irregular surfaces where the exterior finish is supported by welded studs, pins, or other mechanical attachments.

Type 703—A semi-rigid board recommended for use on equipment, vessels, and air conditioning ductwork.

Type 705—A rigid board with very high strength characteristics for use on chillers, hot and cold equipment, heating and air conditioning ductwork where greater abuse resistance and good appearance is required.

description

Fiberglas* 700 Series Industrial Insulations are made of inorganic glass fibers pre-formed into semi-rigid to rigid rectangular boards of varying densities. The series consists of Types 701, 703, and 705. Each type has specific thermal and physical characteristics which make it suitable for the uses described. Types 703 and 705 are available with factory-applied FRK-25. Type 705 is available with ASJ-25. Both facings are vapor barriers and provide a neat, finished appearance.

benefits

Lower operating costs—the exceptional thermal efficiency of Fiberglas 700 Series Insulations lowers operating costs.

End-use tailored—three densities offer a selection of products to meet specific performance and economic requirements.

Lower maintenance costs—700 Series Insulations resist damage, maintain structural integrity and efficiency. Thickness stays uniform.

Wide temperature-use range—applications range from -60F to +450F.

Neat finished appearance—the boardlike characteristics of the heavier density Type 703 and 705 products provide neat square corners. The factory-applied facing provides an attractive finished appearance.

Immediate building code approval—Fiberglas 700 Series Insulation (faced and unfaced) has a UL flame spread rating of less than 25.

Noise control—a versatile group of Fiberglas products that efficiently reduce sound transmission.

*Trademark registered Owens-Corning Fiberglas Corporation.

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performance characteristics

Sound absorption characteristics (2" thick, #6 mounting)

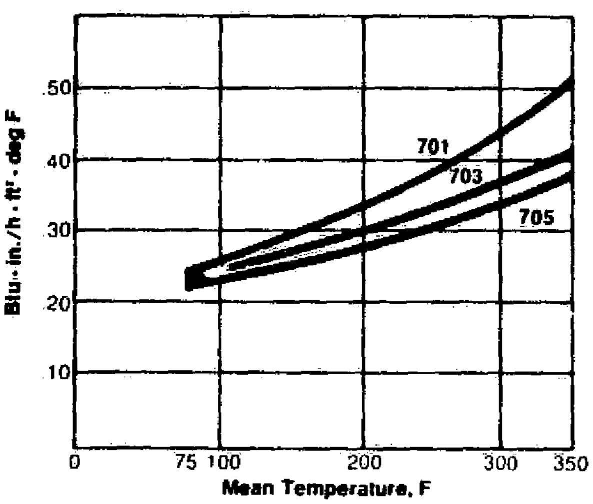
Frequency (Hz)	Insulation type (unfaced) 701	703	705
125	34	.32	.48
250	.70	74	82
500	.96	97	.97
1000	.97	98	.99
2000	.86	.87	.90
4000	83	85	.86
NRC	.87	89	.9[illegible]

Size and Density

	701	703	705
Density (pcf)	1.58	3.00	6.00
Thickness (½" (increments)	1½"-4"	1"-2"	1"-2"
Compressive strength (psf at 10% deform.)	4.5*	100	350
Standard size (inches)		24"x48"	
Thermal conductivity at 75F mean temp	0.242	0.230	0.220

*After compression packaged

Thermal Conductivity



Moisture absorption—less than 2% by volume
Bacteria and fungus resistance—does not breed or promote
Humidity and temperature effect—cycling conditions will not cause spalling or crumbling
Corrosion—does not accelerate corrosion of copper, steel, or aluminum
Fire safety—Fiberglas 700 Series, both faced and unfaced, can be specified and used without danger of contributing to the spread of fire or liberation of excessive smoke.

facings

Types 703 and 705 are available with the following factory-applied vapor barrier facings, with UL labels available if specified:
FRK—Foil reinforced kraft: 703, 705
ASJ—Embossed white kraft foil laminate: 705 only
Vapor transmission rates: ASJ-25-.02 perms
FRK-25-.02 perms
Beach puncture resistance ASJ-25-50 units
FRK-25-25 units

surface burning characteristics

(unfaced or faced*)

flame spread	25
fuel contributed	50
smoke developed	50

(compared to untreated Red Oak as 100)

application recommendations

Type 701—lightweight unfaced flexible insulation in board form for use on vessels having irregular surfaces, where the compressive strength is not a performance criterion.

Types 703 and 705—board insulations normally impaled on welded pins on flat surfaces. They are cut in segments and banded in place on irregular surfaces. Unfaced boards are normally finished with reinforced insulating cement or weatherproof mastic. For outdoor application Types 703 and 705, faced.

ASJ-25 or FRK-25 faced insulation boards shall be applied using mechanical fasteners such as weld pins or stick clips. Fasteners shall be located not less than 3" from each edge or corner of the board. Pin spacing along the duct should be no greater than 12" on centers. Additional pins or clips may be required to hold the insulation tightly against the surface where cross breaking is used for stiffening. Weld pin lengths must be selected to insure tight fit but avoid "oil canning" effect.

Apply only OCF vapor seal ASJ or FRK pressure-sensitive patches. Rub hard with the nylon sealing tool to insure a tight bond and a vapor seal.

All insulation edges and butt joints are to be sealed only with OCF pressure-sensitive joint sealing tape to match the jacket. Rub hard with nylon sealing tool. Use 3" wide tapes on flat surfaces, or where edges are shiplapped and stapled 5" wide tape can be used in lieu of shiplapping.

Precautions:

- Keep all contact adhesive surfaces clean.
- Use nylon sealing tool to prevent wrinkles and fish-mouths.
- Duct-work or radius may require pre-scoring to allow the board to conform to the surface.
- When painting the facings for indoor applications, use only water base/latex products.

Limitations:

- Pressure-sensitive sealing tapes or patches should only be applied when the ambient temperature is between +35F and +110F.
- Maximum insulation surface temperatures in use are limited to −10F to +150F.
- Outdoor applications require additional weather protection.

economic thickness

Caution: The recommended Economic Thicknesses shown are chosen with respect to cost, thermal performance, and energy conservation. It is possible that heat may be generated from the resinous binder of insulations if ignited by external sources such as welding slag, cutting torches, etc. Care should be taken to avoid direct contact with the insulation by fire or ignition sources.

Selection of an insulation for any specific application should take into consideration the following important criteria: **1.** Cost of insulation applied. **2.** Cost of heat energy at midlife. **3.** Cost of capital. **4.** Capital investment in heat production equipment. **5.** Temperature differential. **6.** Size of the pipe surface. **7.** Conductivity of insulation. **8.** Depreciation period—insulation and facility. The thicknesses shown in the tables below are based on the following typical conditions:

Commercial (full time):
Annual fuel price increase 4%
Initial heat cost $2.75 1000 lb steam
Heat cost at midlife $4.07 1000 lb steam
Cost of money 7½% year
Capital investment $20 lb steam hour
Flat insulation cost (1") $3.40 sq ft
Depreciation time 20 years
Hours of operation 8760 year

Economic thickness for heated equipment to 450F
(80F ambient, still air, commercial full time)

Surface Temp., F	Type 701			Type 703			Type 705		
	ET	HL	ST	ET	HL	ST	ET	HL	ST
150	2½	5	84	2½	5	84	2½	5	84
200	3½	6	86	3½	6	86		*	
300	5½	8	87		*			*	
400	7	9	88		*			*	
450	7½	10	89		*			*	

ET - economic thickness inches
HL - heat loss Btu hr sq ft
ST - surface temperature deg F

*For requirements in this area, contact your local OCF representative

Commercial (part time):
Annual fuel price increase 4%
Initial heat cost $3.00 1000 lb steam
Heat cost at midlife $4.44 1000 lb steam
Cost of money 7½% year
Capital investment $20 lb steam hour
Flat insulation cost (1") $3.40 sq ft
Depreciation time 20 years
Hours of operation 5400 year

Economic thickness for heated equipment to 450F
(80F ambient, still air, commercial part time)

Surface Temp.	Type 701			Type 703			Type 705		
	ET	HL	ST	ET	HL	ST	ET	HL	ST
150	2	6	86	2	6	85	2	6	85
200	3	7	87	3	7	86	3	7	86
300	4½	9	88	4	10	89		*	
400	5½	11	90		*			*	
450	6	12	91		*			*	

ET = economic thickness, inches
HL = heat loss, Btu hr sq ft
ST = surface temperature, deg F

*For requirements in this area, contact your local OCF representative.

Thickness to prevent condensation on cold ducts and equipment—faced board

The following chart indicates the recommended thickness for installation on cold air ducts at various temperature differences (duct to air). Also shown are values for heat gain and approximate maximum relative humidity allowable.

Temperature Differences deg. F	Recommended Thickness (inches)	Heat Gain Btu/sq ft/hr	Permissible Relative Humidity
20	1	4.3	90%
25	1	5.2	87%
30	1	6.1	89%
35	1	7.1	88%
40	1½	5.7	90%
45	1½	6.3	89%
50	2	5.4	90%

specification compliance

	701	703*	705
HH-I-558B, Form A, Class 1	•	•	•
HH-I-558B, Form A, Class 2		•	•
HH-I-558B, Form B, Type 1, Class 7	•		
Navy Bureau of Yards & Docks TS-15180		•	•
Corps of Engineers C E.—301.08, .11, .12		•	•
NFPA 90A		•	•

*Type 703 G is specially produced for contracts where certification of compliance to the above Federal Specification is required. Available plain or faced for use on hot or cold equipment and for air conditioning ductwork.

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Pub. No. 1-IN-6360-D Litho U.S.A. Nov., 1975

NORYL®
THERMOPLASTIC RESINS

extrusion

Contents

Introduction

Extrudable NORYL Resins

Performance and processability no other extrudable material can match.

With their combined properties and processability, extrudable NORYL resins offer advantages to both the designer and the fabricator.

On performance, NORYL resins feature heat resistance under load from 212° – 265°F. Combined with this are impact strength of 5.0 ft-lbs. notched Izod, dimensional stability, broad U.L. recognition, excellent electrical properties and extremely low moisture absorption.

From an extrusion standpoint, this family of materials delivers excellent processability, melt strength and stability and high thru-put rates.

Extrudable NORYL resins' combination of performance and processability makes them ideal for a wide range of applications. It also opens new opportunities for the economics of plastics extrusion where metal was once required.

Products Available

Extrudable NORYL resins are available in three high performance grades to meet a wide range of engineering requirements efficiently and reliably.

NORYL EN-212

Heat resistance of 212°F at 264 psi, a U.L 94 V-1 rating and excellent mechanical and electrical properties are all combined in NORYL EN-212. This all-around performance represents a significant step up over FR ABS and PVC, and allows thinner-walled designs for material savings.

NORYL EN-265

For applications requiring higher heat resistance plus broad U.L. recognition and impact strength, choose NORYL EN-265.

Its heat resistance of 265°F under load is coupled with high impact strength, excellent electrical properties and a U.L. 94 V-1 rating. Combined, these properties make it the ideal metal replacement material for extrusions requiring durability, stability and U.L. approval.

NORYL ENG-265

High performance NORYL ENG-265 offers a property profile quite similar to EN 265, without the U.L. 94 V-1 rating. This general purpose grade is an excellent material for applications requiring high mechanical strength and heat resistance under load

Performance Profile

Extrudable NORYL resins answer the need for materials that offer a significant step up in performance over FR ABS and PVC. And with their higher thermal and mechanical properties, extrudable NORYL resins allow the designer to replace more costly metal extrusions for economy without sacrificing performance.

The combined properties of extrudable NORYL resins also mean you can design for thinner walls than are possible with PVC or FR ABS, for a significant savings in material. In fact, one application formerly in commodity plastics has been redesigned in NORYL resins with a 30% thinner wall. And the parts actually outperformed their predecessors with higher mechanical and thermal properties.

Compare the performance of extrudable NORYL resins to traditional commodity materials. While others may offer one key property, NORYL resins combine all the properties you need for all-around performance and reliability.

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Properties

Thermal Stability

With extrudable NORYL resins, you can choose from a range of heat distortion temperatures from 212°F to 265°F at 264 psi. And this heat resistance shows little decrease with increasingly applied stress.

Low thermal conductivity and coefficients of linear thermal expansion add to the heat-related advantages of extrudable NORYL resins.

Agency Recognition

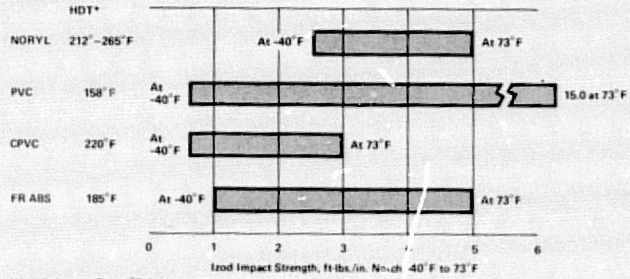
All three extrudable NORYL resins carry broad U.L. recognition. U.L. continuous-use ratings range from 80°C to 110°C, and two grades meet U.L. 94 V-1 requirements.

NORYL resins also carry a strong record of approval for sole-support of current carrying parts, a critical factor in many electrical applications.

Impact Strength

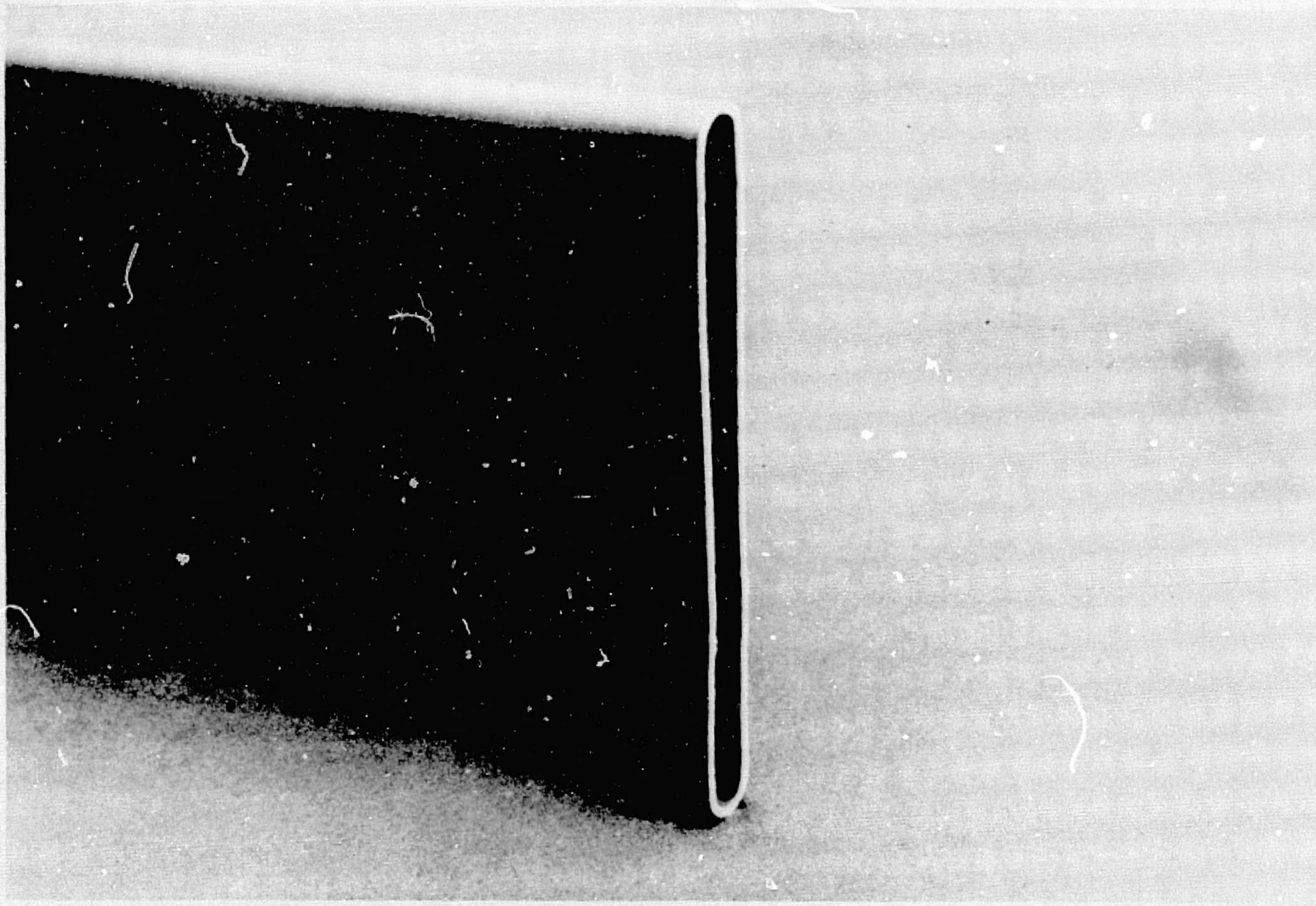
Unlike CPVC and FR ABS, extrudable NORYL resins combine heat resistance with high impact strength (Fig. 1). And they retain more of their toughness down to −40°F to insure durability at temperature extremes.

Figure 1: Impact Strength



*Heat Deflection Temp. °F @ 264 psi

NORYL resin's ability to withstand a 20 KV voltage test, its resistance to an industrial alkaline environment, low creep and U.L. recognition prompted the manufacturer of this bus bar sleeve to use NORYL EN-265. The material also cut the cost of the unit significantly over its fiberglass predecessor.



Structural Strength

Where structural strength counts, extrudable NORYL resins deliver better than FR ABS or PVC (Fig. 2).

Tensile strengths range from 7,800 to 9,600 psi. Flexural modulus ranges from 360,000 to 380,000 psi, and is only slightly affected by elevated temperatures.

With this mechanical strength, extrudable NORYL resins are the ideal choice for structural or load bearing applications. They're also ideally suited for functional designs such as snap-fits for mating two extruded parts.

Hydrolytic Stability

All NORYL resins feature an extremely low water absorption rate at 0.066% (Fig. 3).

What's more, even long term exposure to hot water or steam has minimal effect on their mechanical properties. This characteristic helps insure dimensional stability and long term performance for any application exposed to moisture.

Extrudable NORYL resins are also completely resistant to hydrolysis, and can withstand virtually all acids and bases.

Figure 2: Tensile Strength

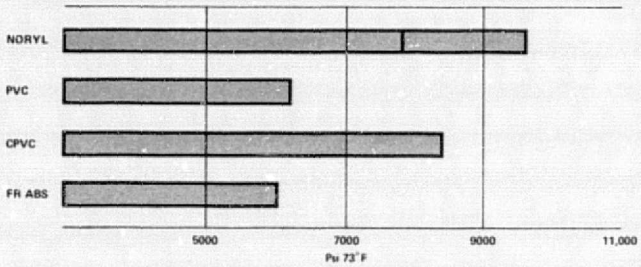
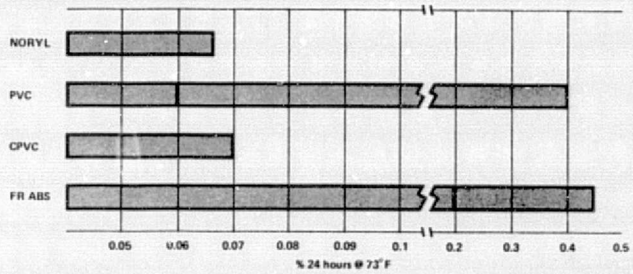


Figure 3: Water Absorption



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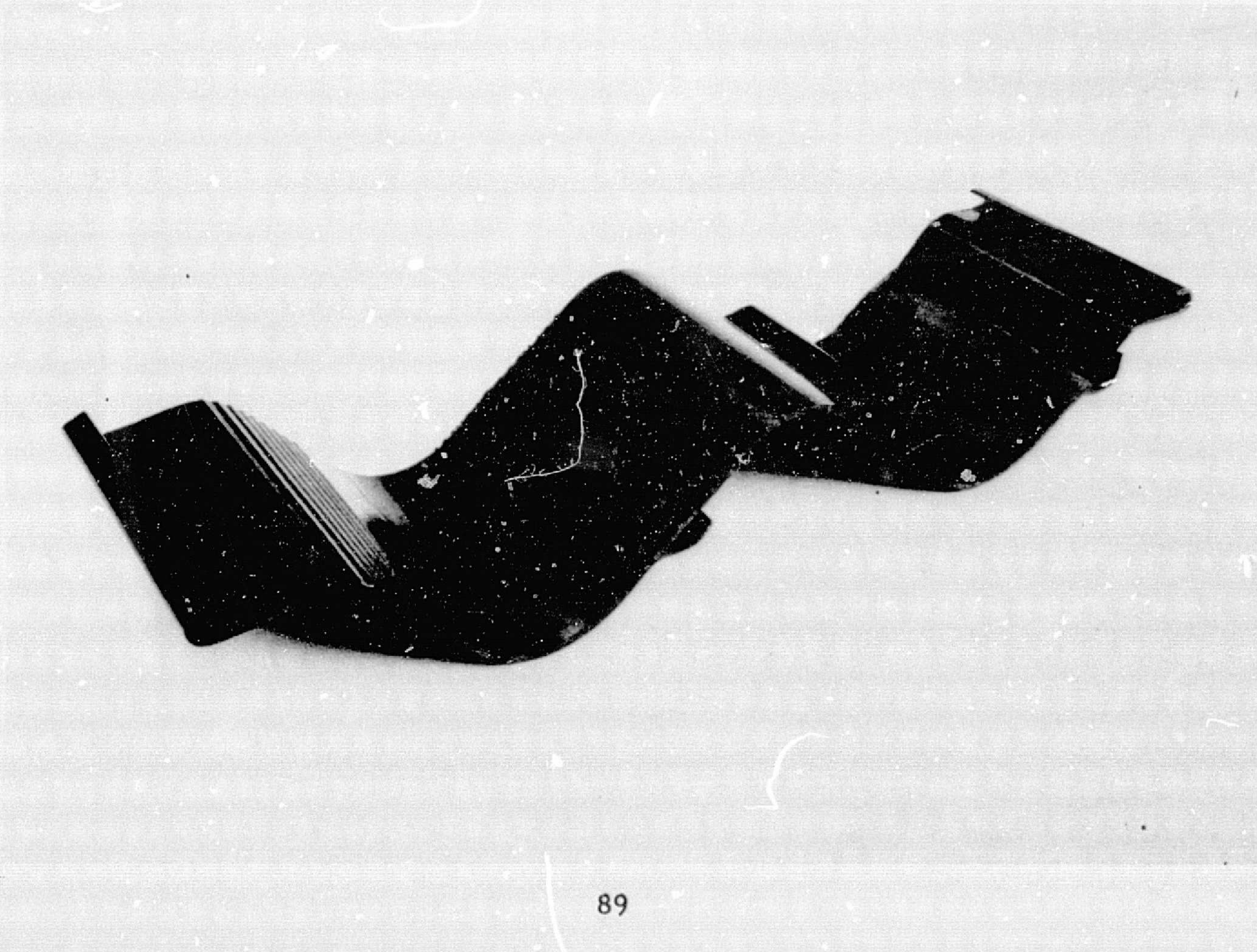
With its excellent hydrolytic stability, low creep, resistance to acid and alkaline solutions, and its processability, NORYL ENG-265 was the choice over PVC for this scrubber vane and mist eliminator used in processing plants and environmental equipment.



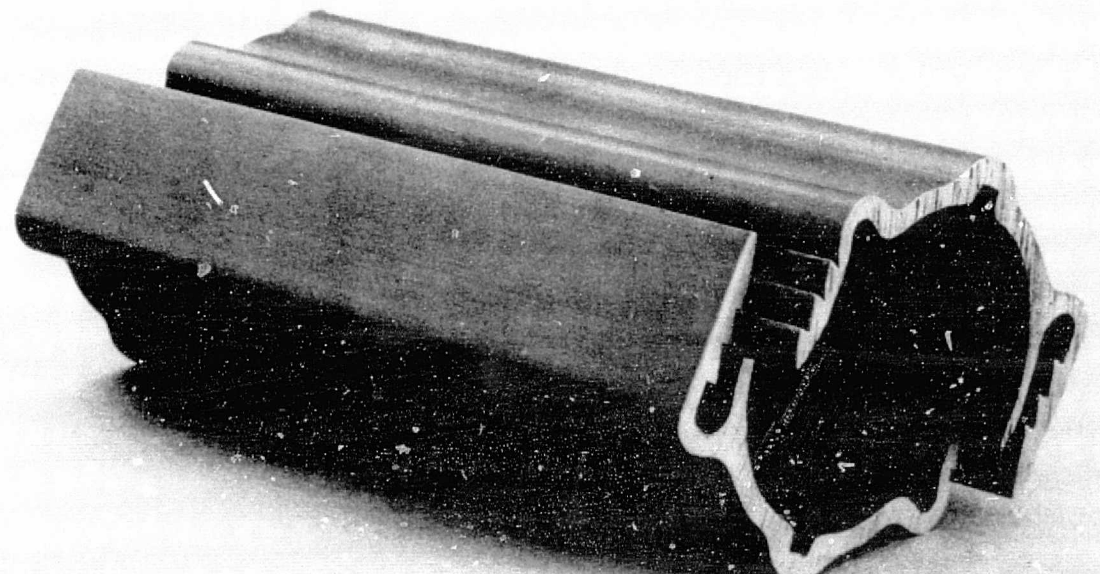
Electrical Properties

High volume resistivity and dielectric strength make extrudable NORYL resins ideal for a variety of electrical applications. Their low dielectric constants and dissipation factors are virtually unaffected by frequencies from 60 to 10^6 cps, changes in humidity and by high temperatures.

Creep Resistance

With excellent creep resistance at elevated temperatures, extrudable NORYL resins offer high stability and predictable long term performance under load. Their ability to resist deformation under prolonged stress also makes them ideal for metal replacement.

In this interlocking wiring splice cover, NORYL resin offered the high impact strength needed to withstand handling and installation abuse, even in sub-zero temperatures. NORYL resin also had the processability to allow fast, efficient production of this complex shape.



Typical Properties—Extrudable NORYL Resins

	ASTM	NORYL ENG–265	NORYL EN–265	NORYL EN–212
PHYSICAL				
Specific Gravity, 73°F	D792	1.06	1.06	1.10
Water Absorption	D570	0.066	0.066	0.07
Tensile Strength, psi at 73°F	D638	9,600	9,600	7,800
Elongation at Break, %	D638	60	60	50
Tensile modulus, psi at 73°F	D638	355,000	355,000	380,000
Flexural Strength, psi at 73°F	D790	13,500	13,500	12,800
Flexural Modulus, psi at 73°F	D790	360,000	360,000	360,000
Compressive Strength (10% deformation) psi	D695	16,400	16,400	16,000
Shear Strength, psi	D732	10,500	10,500	6,900
Deformation Under Load, % at 2,000 psi, 122°F	D621	0.30	0.30	0.50
Creep (300 hrs 73°F at 2,000 psi) % Strain (e)	D674	0.63	0.63	0.80
Izod Impact Strength, ft lbs. in. Notch @ 73°F	D256	5.0	5.0	5.0
@ 40°F		2.5	2.5	2.5
Rockwell Hardness	D785	R119	R119	R115
THERMAL				
Heat Deflection Temperature (264 psi), °F	D648	265	265	212
Thermal Conductivity, Btu/hr/ft²/°F/in	c177	1.5	1.5	1.1
Coefficient of Thermal Expansion, in/in/°F (20° to 150°F)	D696	3.3×10^{-5}	3.3×10^{-5}	3.8×10^{-5}
ELECTRICAL				
Dielectric Constant (50% RH, 73°F at 60 cps)	D150	2.64	2.69	2.65
Dissipation Factor (50% RH, 73°F at 60 cps)	D150	0.0004	0.0007	0.0007
Volume Resistivity, dry, ohm. cm., 73°F	D257	10^{17}	10^{17}	10^{16}
Surface Resistivity, ohm/sq	D257	10^{17}	10^{17}	10^{16}
Dielectric Strength (1/8" sample), volts/mil	D149	550	500	400
Arc Resistance (Tungsten), sec	D495	75	75	70
U. L.				
U. L. Subject 94	--	HB	94 V-1	94 V-1
U. L. Continuous Use, °C				
With Impact	--	90°C	105°C	80°C
Electrical Without Impact	--	105°C	110°C	95°C

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Processing Advantages

One of the key advantages of extrudable NORYL resins over FR ABS and PVC lies in processing.

NORYL resins have shown up to 30% faster production rates over PVC in actual applications. This is a product of NORYL resins' significantly higher thru-put rate. Draw-down ratios up to 50% have virtually no effect on properties, unlike materials which are more subject to orientation. Another asset is processing stability. Noryl resins offer a broader range of processing conditions to minimize the problem of degradation during the extrusion process. They also feature excellent melt strength for better sizing ability.

NORYL resins also exhibit excellent regrind stability with little loss of properties after several recycles (Fig. 4). The combination of this processability, plus the performance which often allows thinner wall designs over PVC and ABS makes NORYL resins an economical, higher performance extrusion material.

Extrudable NORYL resins can be processed over a wide range of conditions. Optimum settings should be developed at the extruder according to available equipment, sizing equipment and cooling system.

1. Drying

While moisture has virtually no effect on the properties of NORYL resins, drying is recommended to remove surface appearance defects which moisture may cause in processing.

Figure 4: Physical Properties of NORYL EN-265 after Repeated 100% Regrinding

Property	Virgin NORYL EN-265	100% Regrind 1st Cycle	100% Regrind 3rd Cycle
Tensile Strength, psi	9,500	9,600	9,750
Flexural Modulus, psi	360,000	360,000	365,000
Elongation, %	55	50	50
Notched Izod Impact	5.0	4.7	4.5

Although vented extruders are preferred, non-vented extruders have been used successfully with NORYL resins pre-dried in shallow trays, 1" to 1-1/2" deep in an air circulating oven, at the following temperatures:

Recommended Drying Times/Temperatures

	NORYL EN-265	NORYL ENG-265	NORYL EN-212
Drying Temp.	220-240°F	220-240°F	200-220°F
Drying Time	2-4 hours maximum	2-4 hours maximum	2-4 hours maximum

2. Screw Design

Both single and two-stage screw designs can be used successfully with extrudable NORYL resins (Fig. 5). *L/D ratio* of 24 to 1 or greater is recommended. *Compression ratio* of 2.85 to 3.65 has been used very successfully. A long and shallow metering section is recommended for good melt preparation.

A typical two-stage screw is described below on a 2-1/2", 24/1 L/D ratio extrusion machine:

Section	No. Diameters	Depth, Inches
Feed	5	0.370
Transition 1	3.5	— —
Meter 1	6	0.110
Vent	3.5	0.350
Transition 2	2	— —
Meter 2	4	0.190

Both CPVC and NORYL EN-265 were considered for this lighting track. NORYL resins came through with better heat resistance, U.L. approval and a faster production rate.

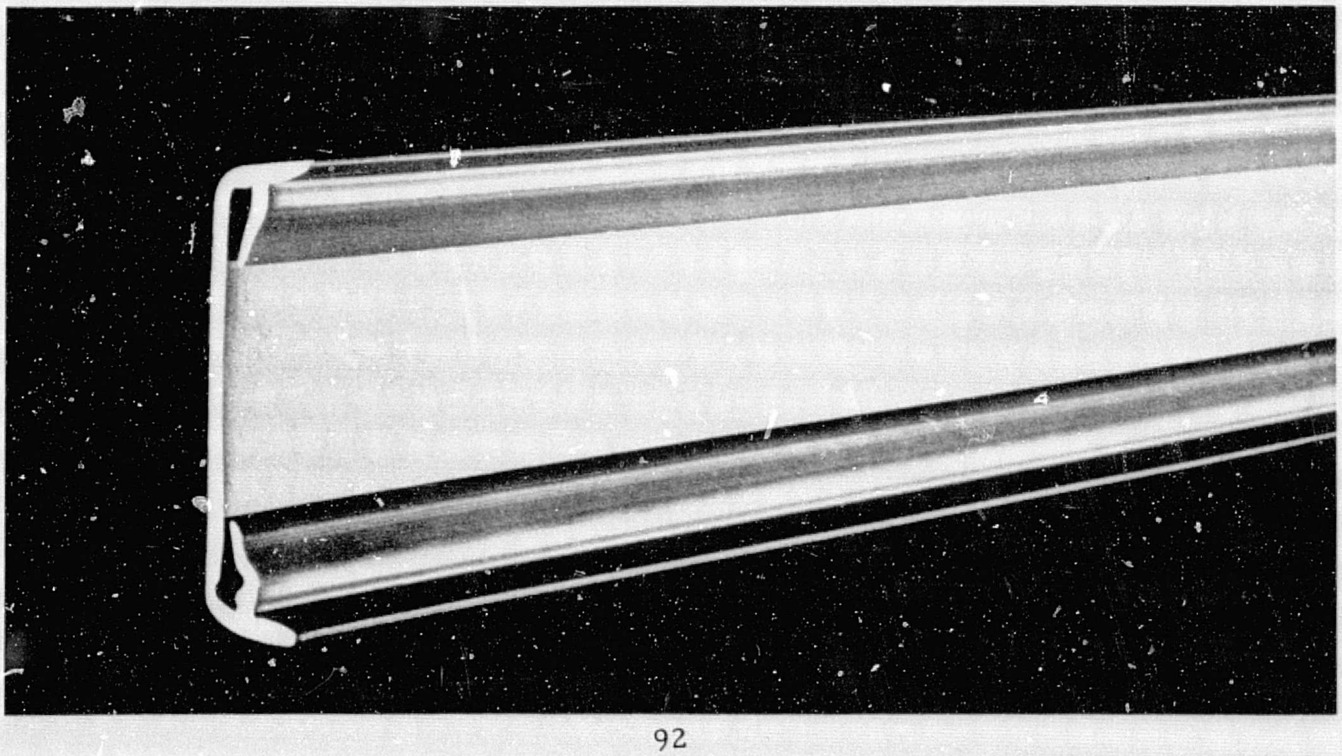
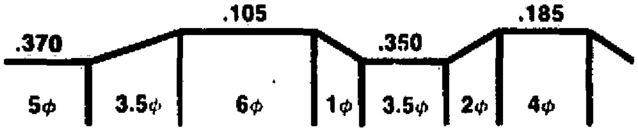
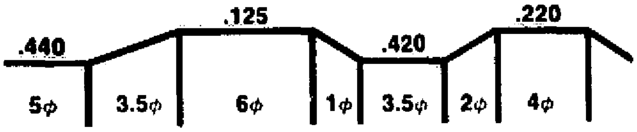


Figure 5: Recommended Screw Designs for Extrudable NORYL Resins (for reference only)

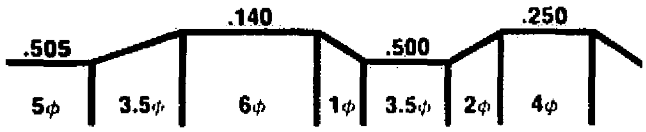
2½ INCH 24:1 TWO STAGE



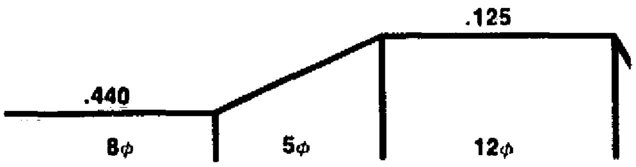
3½ INCH 24:1 TWO STAGE



4½ INCH 24:1 TWO STAGE



3½ INCH 24:1 SINGLE STAGE



3. Processing Guidelines

- The screw should not be left idle with melt in the extruder for more than a few minutes, to prevent carbonization and black spots
- Satisfactory operation has been achieved without screen packs and with sizes as fine as 100 mesh

Processing Temperatures:

NORYL EN 265 & NORYL ENG 265	420°-500°F
NORYL EN 212	390°-450°F

4. Die

- Draw down ratios of 20-50% have been used with no effect on physical properties in the end part
- While NORYL resins do not emit harmful fumes or corrosive by-products, chrome plating of inner die surfaces is recommended for optimum production rates and appearance
- Polished inner die surfaces are usually sufficient in most applications
- Streamlined dies are preferred, though shear dies are acceptable
- NORYL resins exhibit die swell characteristics of 30% under the processing temperatures recommended above

5. Cooling

Slow cooling of the NORYL resin extrudate is preferable to quick quenching to minimize residual stress

6. Purging and Cleaning

- Use conventional cleaning techniques with reground acrylics as the purge material
- The die may be cleaned in a hot salt bath such as potassium chloride for 15 minutes. Remove all components that might be affected by the cleaner, such as the electrical heater

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Applications

With their combination of properties, extrudable NORYL resins can improve the performance of many existing extruded plastic products. In addition, it can open new areas where metal can be replaced in extrusions for greater economy without sacrificing the required performance.

Typical applications include:

Electrical
- Wiring splice devices
- Protective shields
- Wire enclosures/Conduit
- Electrical appliance enclosures, mountings and escutcheons

Utility/Construction
- Cooling tower scrubber vanes & mist eliminators
- Bus bar sleeves
- Building products
- Protective cable covers
- Ground wire covers

Lighting
- Ceiling light housings
- Lighting tracks
- Enclosures

Technical Assistance

The NORYL Products Section has qualified technical personnel ready to assist you at every phase of product development, from design through production.

Design

Capitalize on the high performance of NORYL resins to develop designs using thinner wall sections than are possible with FR ABS or PVC. NORYL design engineers will work with you on the most efficient design that makes the most of the material.

Agency Approval

All NORYL resins carry broad recognition by Underwriters' Laboratories and the Canadian Standards Association. The agency specialists can help speed your product through the required approvals for fast market introduction.

Extrusion

Extrusion process specialists can assist you in insuring optimum processing conditons for NORYL resins, to help you maximize the material's productivity.

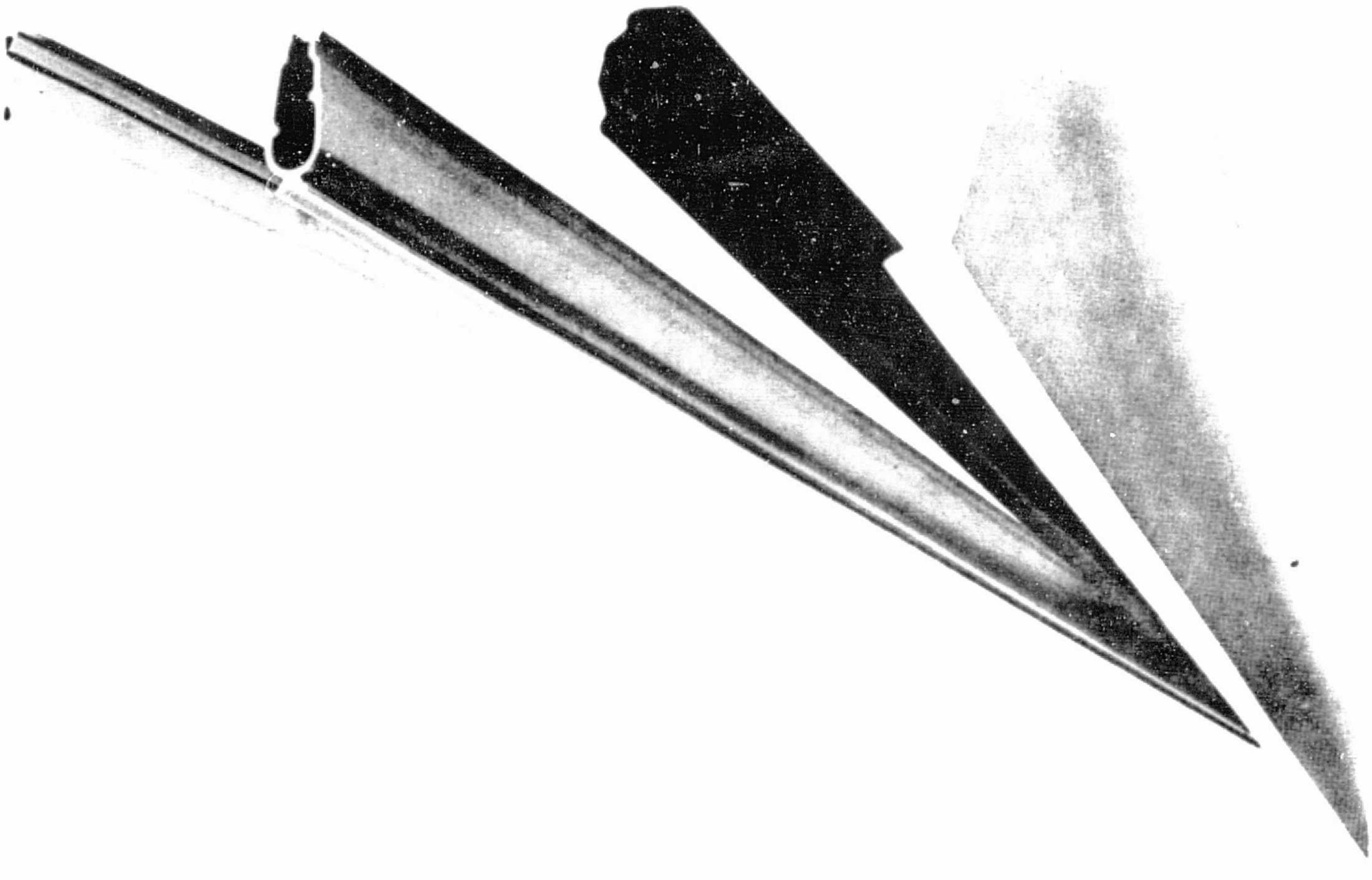
Finishing

If your product requires painting or other secondary finishing, you can turn to NORYL Products Section personnel for the latest systems, techniques and suppliers.

For further information, contact:

Extrusion Technical Team
NORYL Products Section
General Electric Plastics
Selkirk, New York 12158

Inasmuch as General Electric Company has no control over the use to which others may put the material, it does not guarantee that the same results as those described herein will be obtained. Each user of the material should make his own tests to determine the material's suitability for his own particular use. Statements concerning possible or suggested uses of the materials described herein are not to be construed as constituting a license under any General Electric patent covering such use or as recommendations for use of such materials in the infringement of any patent.



WORLD LEADER IN ENGINEERING PLASTICS

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GENERAL ELECTRIC

PLASTICS DEPARTMENT

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CDX-265

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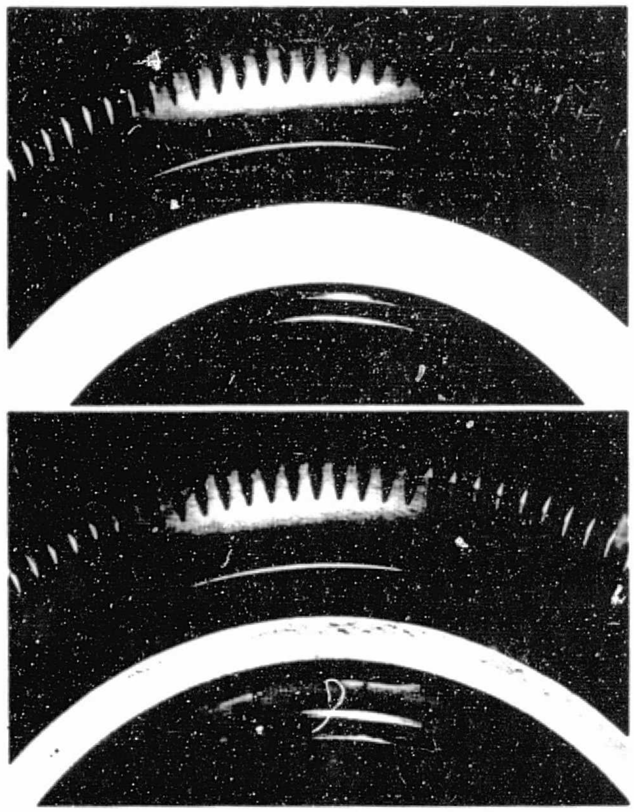
Royalene® EPDM "Crackless Rubber."

For extended service life of rubber products.

Royalene EPDM is a general-purpose rubber that has many uses.

Royalene can be used for a wide variety of products.



Both tires were aged 18 months. The one that didn't crack (top) contains Royalene, the "Crackless Rubber." Most whitewall and cover strips now contain Royalene.

Royalene EPDM (a terpolymer of ethylene, propylene and a controlled amount of non-conjugated diene) has proved to be a materials break-through of significant proportions because it can be easily made into a variety of objects that resist weather and ozone degradation far longer than was ever possible before.

Automotive applications.

Royalene has demonstrated its superiority in many automotive applications presently using SBR, natural, butyl and other rubbers. Therefore, Royalene has gained wide acceptance for many engineering uses in the automotive industry: sealing weather strips (windshield, back lights, body shims, bumper guards), cellular sealing strips (door weather strip, deck lid seals), windshield wiper blades, windshield wiper tubing, hose tubes and covers (both heater and radiator), brake cups, shocks, pedals, specialty coated fabric auto topping, motor mounts, ignition cable insulations, wiring grommets, miscellaneous gaskets, dust seals and boots.

EPDM is also keeping tire whitewalls white. Practically all the EPDM sold for this purpose is Uniroyal's "Crackless Rubber" (sold under the registered tradename Royalene).

Appliance applications.

In the appliance field, ability to resist cracking after repeated flexing, its wide temperature range and resistance to acids and alkalis, ideally lends itself to use for many washer, dryer, refrigerator and other appliance parts including hoses, seals, door gasketings and appliance wire.

Wire and cable applications.

Since Royalene can be specially formulated for excellent physicals together with flame, abrasion, weathering and moisture resistance, wire and cable jacketing represents a sound application for this material in many cases.

An added feature of Royalene is that its unique combination of properties makes a true rubber-like integral 600 V insulation and jacket possible for the first time.

Other applications.

Royalene resists many chemicals. It is finding wide applications in tank liners, hoses, and other uses requiring resistance to phosphate esters, ketones, glycols and alcohols. It is especially useful for long maintenance-free service in the storage of peroxides and caustic soda.

The excellent water resistance of Royalene has led to its widespread use for water conservation and for prevention of contamination and leakage. Such applications include the lining of reservoirs, irrigation ditches and brine storage pits and the waterproofing of underground structures.

Royalene EPDM has physical properties superior to other general-purpose rubbers.

Comparison of Royalene EPDM with other commonly used polymers.

Property		Royalene	Butyl	Neoprene	Polybutadiene	Polyisoprene; Natural rubber	SBR
Hardness range; shore A		40 to 90	40 to 75	30 to 95	40 to 90	30 to 90	40 to 90
Specific gravity		0.865	0.92	1.23	0.91	0.93	0.94
Tensile strength; black loaded (psi)		3500	3000	3500	2000	3500	2500
Tensile strength; pure gum (psi)		500	2000	3500	500	3000	400
Cold flow		E	F	E	P	P*; E†	E
Color stability		E	G to E	P	G to E	G to E	G to E
Compression set		G	F	G	G	E	E
Cord adhesion		G	P to F	G	G	G	G
Cure rate		G	S	M	E	E	E
Dynamic properties		G to E	P	G	E	E	G
Electrical properties		E	E	P	G	G	G
Loading; black		E	P	G	G	G to E	G
Loading; oil		E	P	F	F to G	G	F to G
Tack		G	F	G	F	E	F to G
Resistance to:	Abrasion	G	F	E	G	G to E	G
	Acids	G to E	E	G	G	G	G
	Bases	G to E	E	G	G	G	G
	Cold	E	E	F	G	E	F to G
	Flame	RSC	RSC	G	RSC	RSC	RSC
	Gas permeation	F	E	G	F	F	F
	Heat	E	G	G	G	F	F
	Oils; animal & vegetable	G	E	G	F	F	F
	Oils; mineral	NS	NS	G	NS	NS	NS
	Ozone	E	E	G	P	P	F
	Solvents; aliphatic	P	P	G	P	P	P
	Solvents; aromatic	P	P	F	P	P	P
	Solvents; chlorinated	P	P	P	P	P	P
	Solvents; lacquer	P	P	P	P	P	P
	Solvents; oxygenated (i.e., ketones)	G	G	P	P	G	P
	Steam	E	E	G	G	G	G
	Tearing	G	G	G	F	G to E	F
	Water	E	E	F	E	E	E
	Weather	E	E	E	P	F	F

Code: E = excellent; G = good; F = fair; P = poor; NS = not suitable
S = slow; M = medium; RSC = requires special compounding

*Polyisoprene
†Natural rubber

Royalene has many properties superior to other commonly used elastomers. The table at the left shows this comparison with SBR, natural rubber and other polymers.

Vulcanizates of Royalene exhibit many outstanding properties.

Lower specific gravity.

The specific gravity of Royalene is lower than all other rubbers. Consequently, Royalene offers a higher yield of fabricated parts per pound.

Final product cost also benefits by the ability of Royalene to be highly extended with inexpensive oils and blacks.

Petroleum oils suitable for the extension of Royalene are less expensive than the esters normally used to plasticize neoprene, butyl, or acrylic rubbers. In addition, Royalene can accept larger amounts of fillers than other rubbers with good retention of physical properties.

Retains properties at high temperatures.

Royalene is serviceable for extended periods of continuous use at temperatures in excess of 300 degrees F and has shown good results in intermittent uses as high as 400 degrees F.

Such vital properties as resilience, tensile strength, elongation and hardness are largely retained in aging tests at elevated temperatures. Royalene is far superior to any other general purpose synthetic rubber on high temperature resistance.

Retains properties at low temperatures.

Royalene retains its flexibility at extremes that shatter most rubber materials.

Royalene compounds remain serviceable at temperatures as low as minus 70 degrees F.

Other benefits.

Other benefits of Royalene are excellent processing, good to excellent physical properties, excellent weather and ozone resistance, excellent electrical properties, good abrasion resistance, good set properties and excellent resistance to polar liquids such as water, phosphate esters, ketones.

Royalene EPDM is commercially available from Uniroyal Chemical in numerous types to suit the varying demands of rubber compounders.

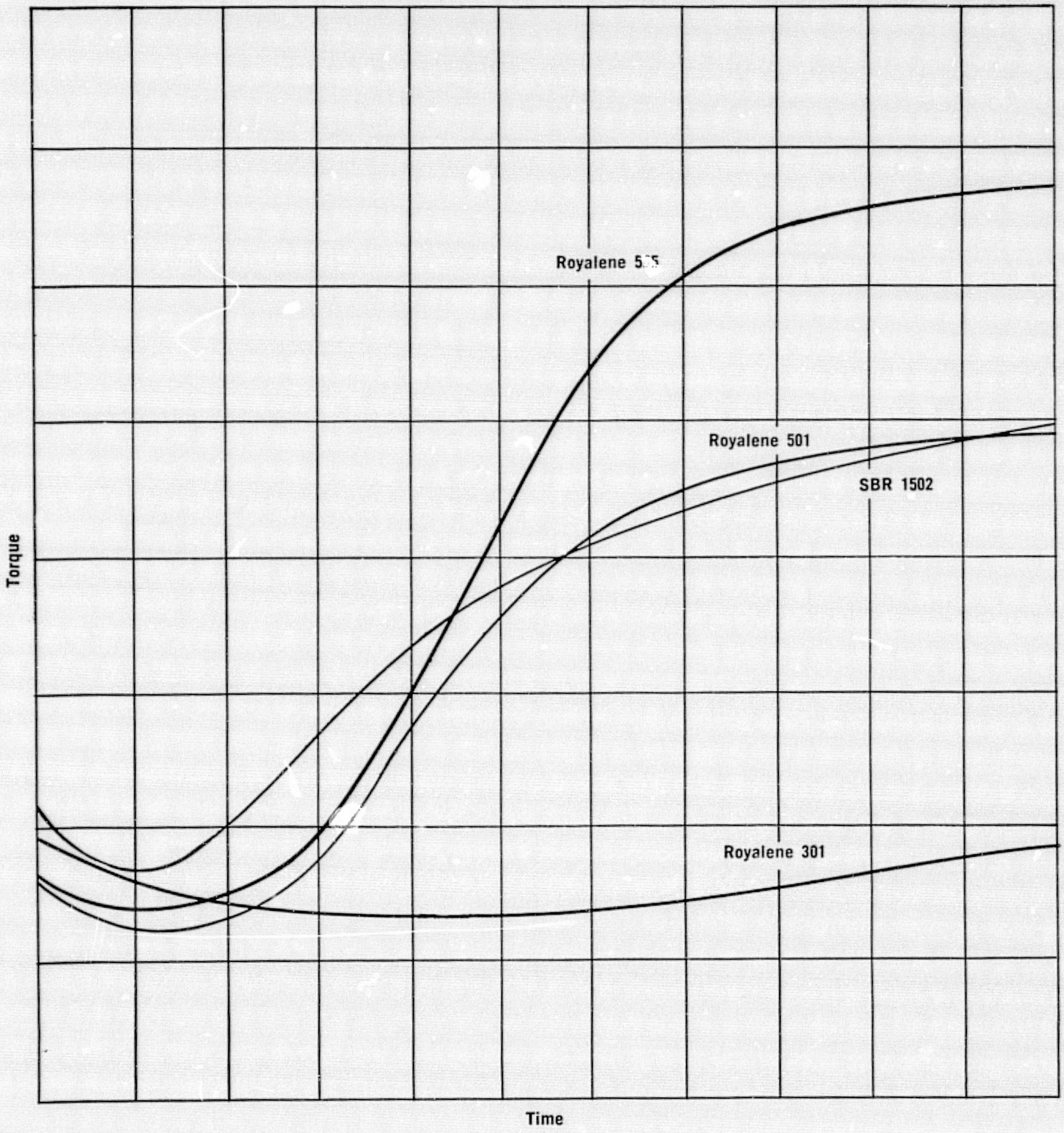
Ultraviolet aging effects

U.V. aging (hours)	Polymers			
	Royalene	Butyl	Neoprene	SBR
2	NC	NC	NC	EFC
24	NC	EFC	NC	EFC
48	NC	EFC	EFC	EFC
100	NC	VVS	VVS	EFC
200	NC	VS	VS	EFC
340	NC	S	VS	EFC
Sample curing	30 min. at 320°F	30 min. at 307°F	30 min. at 307°F	15 min. at 307°F
Code	NC = no crazing visible at 20× magnification.			
	EFC = extremely fine crazing visible at 20× magnification.			
	VVS = very, very slight cracking visible at 20× magnification.			
	VS = very slight cracking visible at 20× magnification.			
	S = slight cracking visible without magnification.			

Table above shows outstanding ultraviolet aging of Royalene compared to other polymers. Test made on Atlas Weather-ometer with 1-inch sample bent double on self.

Royalene EPDM has many processing advantages and premium properties.

Rheometer curves show outstanding cure rates of Royalene compared to SBR.



The various types of Royalene available from Uniroyal have replaced other polymers because of the superior performance and/or lower cost of Royalene in a wide variety of important applications.

The Royalene 500 series, developed by our polymer chemists, is a new chemical composition which retains all of the outstanding properties of existing Royalene compounds and yet gives you the fastest curing EPDM rubbers on the market today.

Easy to process.

Because of its inherent properties Royalene does not require compounding with expensive antioxidants in many applications.

It is also sulfur curable and free from objectionable odor, as well as peroxide curable.

Reduces per part cost.

Users have found that when the Royalene 500 series of fast cure EPDM rubbers are combined with Royalene 400 series of oil-extended polymers, per part costs are reduced because the combination can readily be vulcanized on conventional equipment with good control and a fast cure rate.

With increasing use of oil-extended rubbers, it is believed that Royalene 400/500 low cost compounds could be used for many rubber applications, including many types of open cell sponge and closed cell sponge applications.

Extends product life.

Due to its remarkable combination of properties, Royalene can extend product shelf life and service life. Those properties include resistance to abrasion, ozone, weather and extremes of temperatures (from minus 70 degrees F to as high as 400 degrees F).

And Royalene has excellent resistance to polar liquids such as water, phosphate esters and ketones.

In addition to superior performance, Royalene also offers great savings potential.

It offers a higher yield of fabricated parts per pound because of all rubbers, it has the lowest specific gravity: 0.865.

Can be highly extended.

Final product cost also benefits since Royalene can be highly extended with inexpensive oils and black and still have good retention of its physical properties.

If you use natural or synthetic rubbers of any kind, for any purpose, chances are Royalene EPDM can do the job better. Or cheaper. And probably both.

Properties	Features	Advantages in use
Ozone and weather resistance.	Ozone protective additives normally used for other rubbers are not required in black and non-black EPDM vulcanizates.	Elimination of strain limitations, allows less costly and restrictive design. Better appearance. Longer product, shelf and service life.
Heat degradation resistance.	Some Royalene EPDM serviceable for extended continuous use at 300°F, intermittent use at up to 400°F.	Suitable for engine compartment components.
Low-temperature utility.	Stays flexible below −70°F. Won't embrittle at −100°F.	Permits use in broad temperature range: −100°F to +400°F.
Electrical insulation.	Excellent insulating properties.	Suitable for many power and control applications.
Chemical resistance.	Particularly resists polar liquids like water, esters, glycols and ketones.	Suited for use in heating-cooling components and brake systems.
Dynamic properties.	Effective over a broad range of temperatures and frequencies.	Potential application as vibration isolators and body mounts.

Various types of Royalene EPDM have replaced other polymers because of their superior properties, lower cost, outstanding features and advantages in use.

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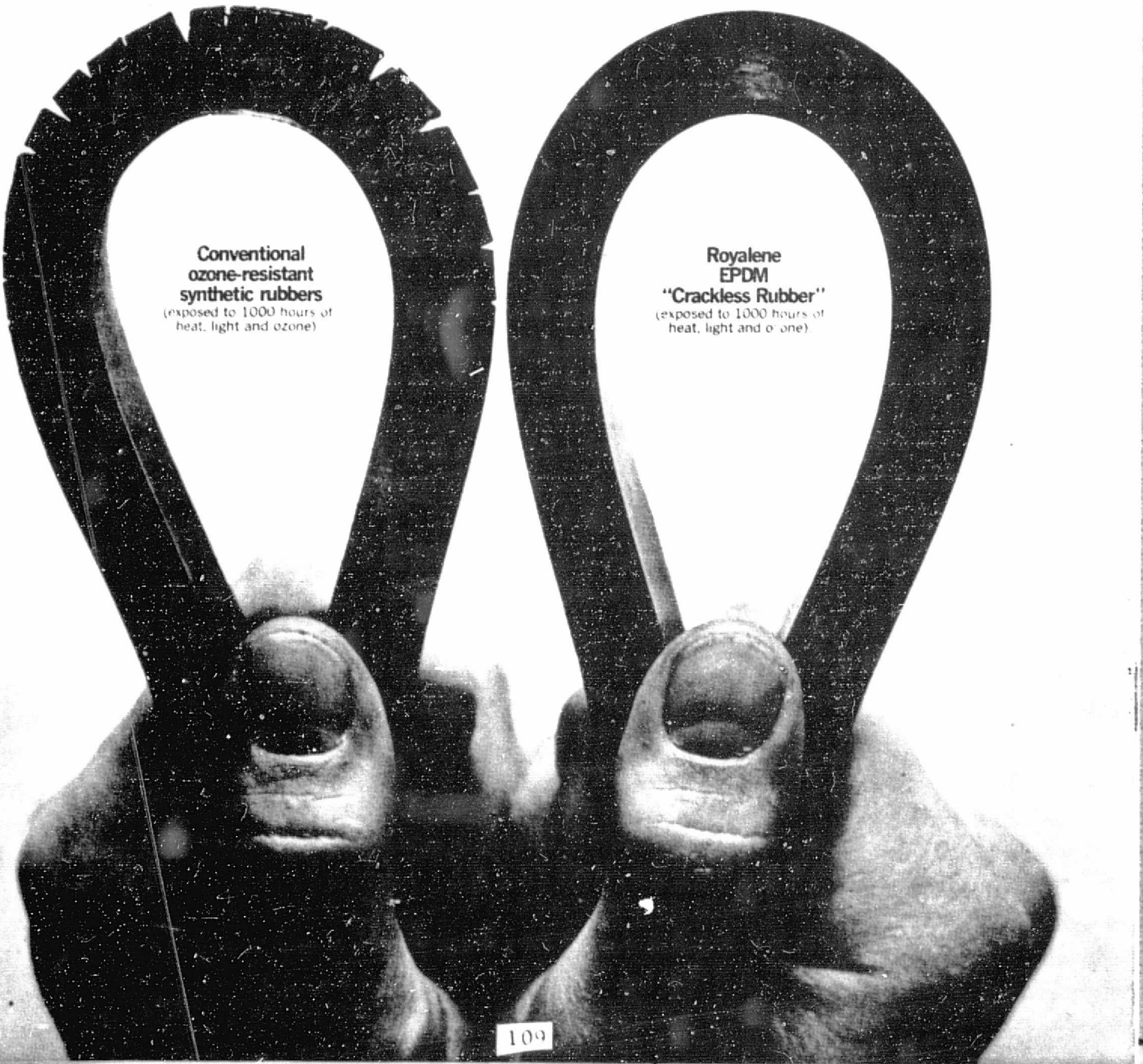
Uniroyal Chemical, Division of Uniroyal, Inc., Naugatuck, Connecticut 06770.



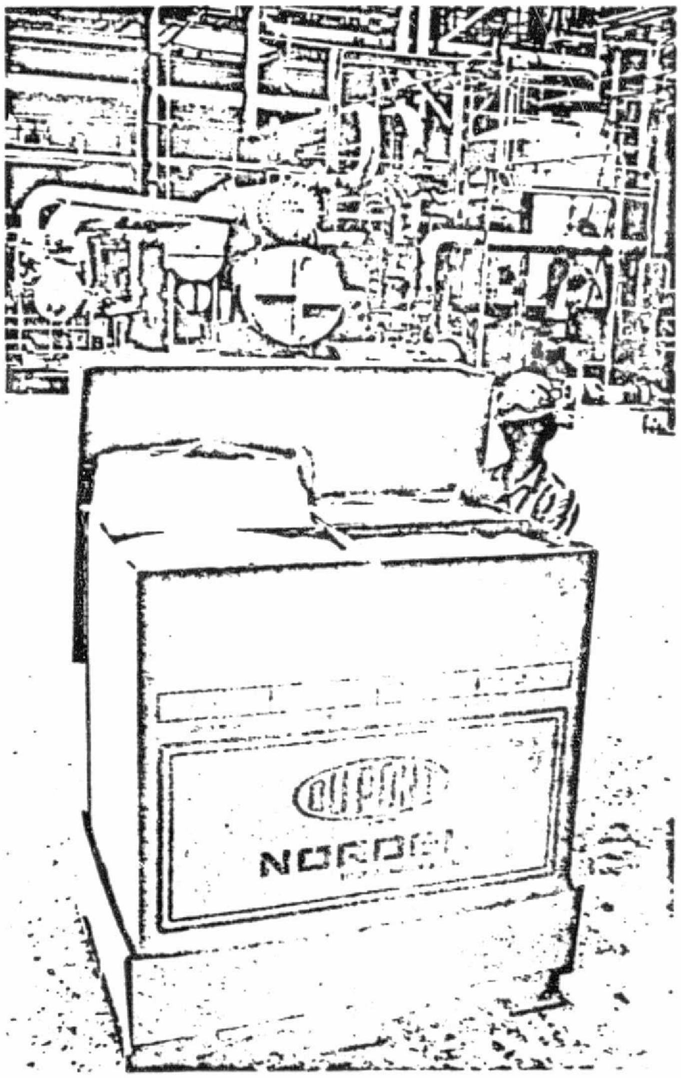
I THIS IS NORDEL

What is NORDEL? How does it differ from other synthetic rubbers? What new opportunities does it offer to the designer and user of rubber parts? Answers to these and other questions are explored in this profile of an important engineering material.

NORDEL is a synthetic rubber developed by Du Pont and supplied to rubber goods manufacturers throughout North America and many other parts of the world. In chemical terms, it is a terpolymer of ethylene, propylene and a nonconjugated diene—a hydrocarbon-based elastomer that can be processed and vulcanized by standard rubber-industry techniques. Rubber chemists usually refer to this class of elastomer by the initials EPDM.

To the specifying engineer, NORDEL might be better defined as a general-purpose synthetic rubber with premium-performance properties. It offers the broad utility and many of the good properties of such long-familiar materials as natural rubber and SBR (styrene-butadiene synthetic rubber); like them, it has found use in a wide range of industrial and consumer products.

The distinctive difference that sets NORDEL apart from other general-purpose rubbers is performance in categories of properties (particularly resistance to environmental conditions) usually found only in special-purpose elastomers.



This is NORDEL hydrocarbon rubber as Du Pont produces it—a basic raw material which other manufacturers compound and process into finished products for a range of industrial and consumer uses.

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HOW DU PONT *NORDEL* COMPARES WITH OTHER GENERAL-PURPOSE ELASTOMERS*

Property	*NORDEL*	Natural Rubber	SBR
Specific Gravity	0.85	0.93	0.94
Tensile Strength	good to excellent	excellent	good to excellent
Dynamic Properties	excellent	excellent	good
Color Stability	excellent	good to excellent	good to excellent
Electrical Properties	excellent	good	good
Resistance to:			
Weather	excellent	fair	fair
Ozone	excellent	poor	fair
Heat	excellent	fair	fair to good
Cold	good to excellent	good to excellent	fair to good
Chemicals			
Acids	good to excellent	good	good
Bases	good to excellent	good	good
Oils	poor	poor	poor
Abrasion	good to excellent	good to excellent	good
Tearing	good	good to excellent	good
Steam	excellent	good	good
Compression Set	good	excellent	excellent
Flame	poor	poor	poor

*Ratings in this chart are based on performance of conventional compounds of NORDEL, natural rubber and SBR. For each elastomer, any given property can usually be improved by selective compounding.

PERFORMANCE PROPERTIES

The performance abilities of vulcanized NORDEL are superior to those of any other type general-purpose rubber. In some characteristics (notably ozone, weather, heat and steam resistance), NORDEL actually performs on a level with many specialty elastomers.

Just how "premium" are the performance characteristics of NORDEL? The table at left partially answers this question by comparing selected properties of NORDEL with those of natural rubber and SBR. From this quick comparison, the *relative* superiority of the Du Pont elastomer over conventional general-purpose rubbers is quite evident. To better illustrate *degree* of performance, here are some brief quantitative observations:*

NORDEL is virtually immune to attack by ozone. In laboratory tests at concentrations as high as 10,000 parts ozone per hundred million parts of air, technicians have never been able to damage a sample of vulcanized NORDEL. This is an inherent characteristic of the ethylene-propylene-diene terpolymer; the ozone resistance of NORDEL is *not* dependent upon the use of chemical additives.

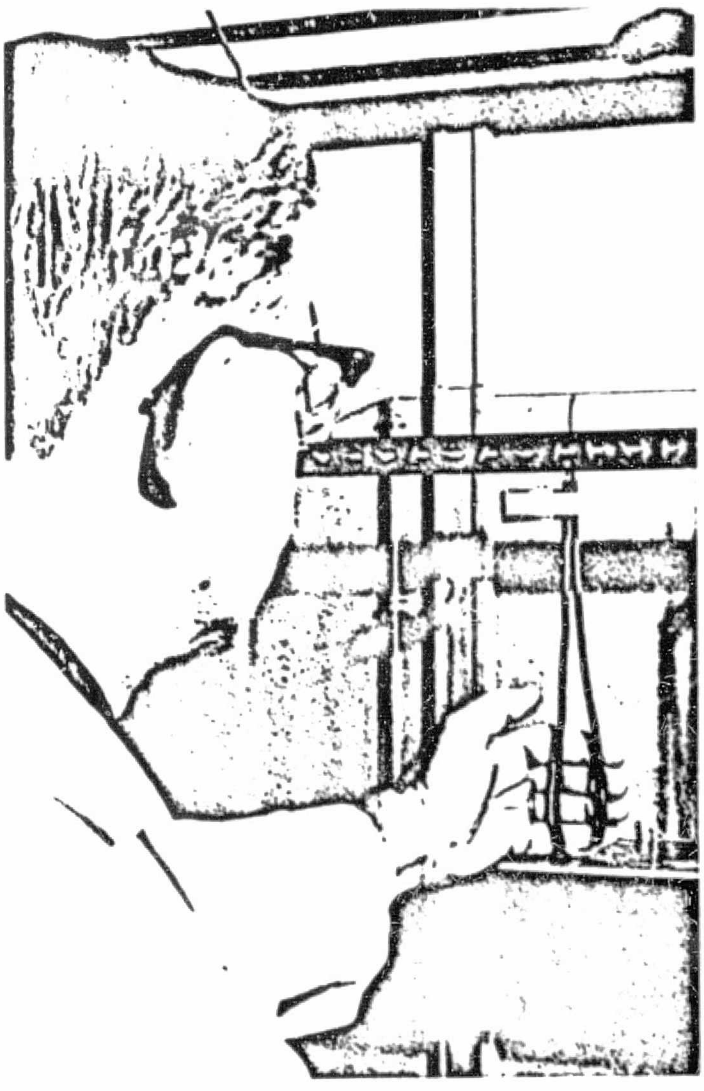
NORDEL has outstanding heat resistance. Products of NORDEL can be compounded for service at temperatures of 300-350°F., well above the capabilities of either SBR or natural rubber. Intermittent service from 350-400°F. can be obtained with these heat-resistant formulations, and even higher temperatures can be tolerated for brief exposure periods.

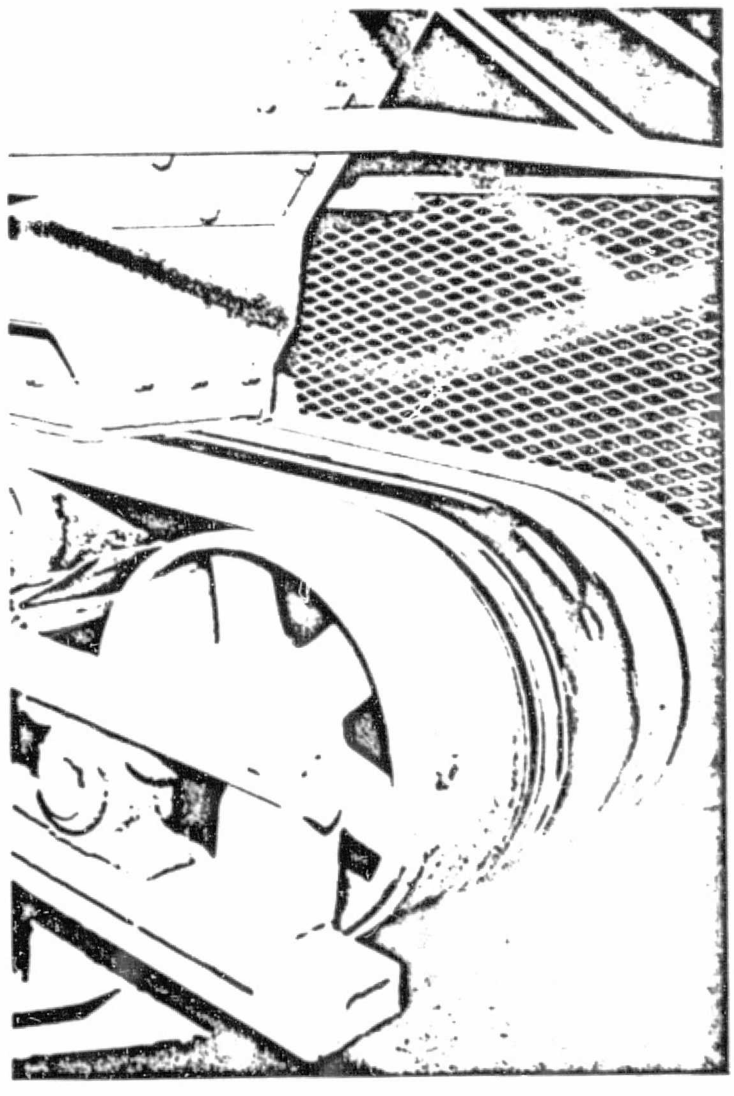
*Section 3 of this report (pages 15-19) discusses properties of NORDEL in more complete detail.

NORDEL stays flexible at low temperatures. Clash-Berg stiffness values of typical products usually fall between -60°F. and -70°F. Impact brittle points are usually -90°F. or below.

NORDEL has exceptional resistance to steam. Service testing has shown that commercially made steam hose of NORDEL in round-the-clock use has a life of one year (more than 8,000 hours) carrying 150 psig saturated steam (366°F.), and three months (more than 2,000 hours) carrying 250 psig saturated steam (407°F.). This is several times the life of hoses made from other elastomers.

Other important performance characteristics of NORDEL include dynamic properties that remain constant over a wide temperature range; resistance to weather and sunlight aging (in colored as well as black products); excellent electrical properties; chemical resistance and good mechanical properties. Since NORDEL is basically a hydrocarbon, it is not resistant to flame or petroleum-based oils.



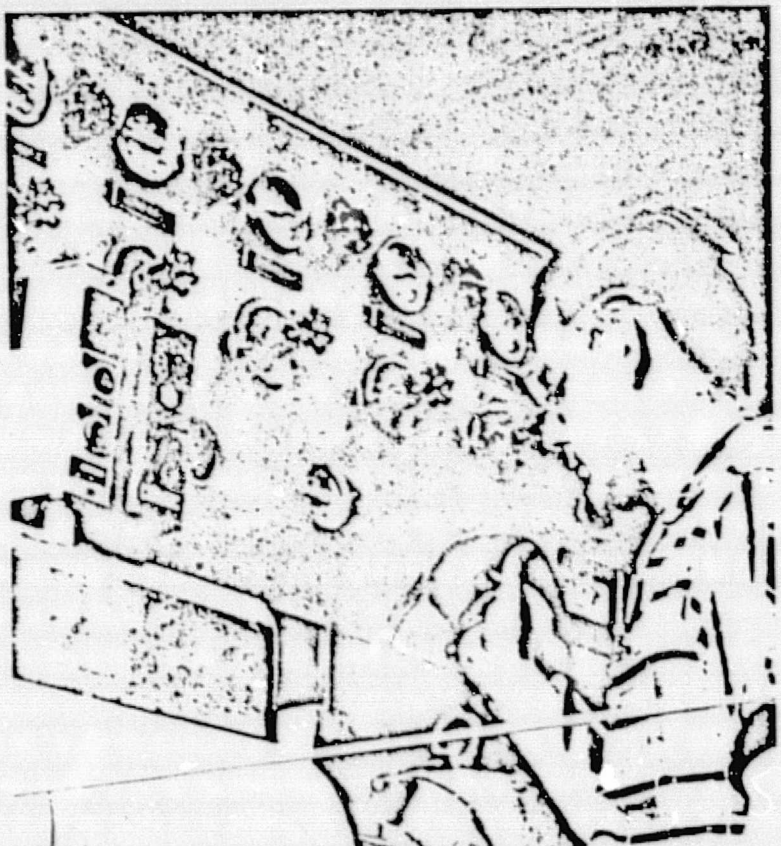


Both laboratory testing and actual use in commercial service have established the performance advantages of products made from NORDEL. Left: Electrical wire insulation is undamaged after 10,000-volt corona test. Right: Hot-chemicals belt is still excellent after 4 years' service.

MANUFACTURING CHARACTERISTICS

NORDEL* hydrocarbon rubber is processed and vulcanized into finished parts by the same techniques and with the same equipment used for other general-purpose rubbers. Compounded material is molded, extruded or calendered in routine fashion; final products are vulcanized by curing methods standard in the rubber industry. Products made of NORDEL move through the production line as easily as products made of any other type of elastomer, natural or synthetic. Cellular products also are made by conventional methods and may be of either the open- or closed-cell variety.

This, then, is NORDEL hydrocarbon rubber—a general-purpose ethylene-propylene-diene terpolymer with premium performance abilities. NORDEL is made by Du Pont, fabricated into finished goods or component parts by rubber companies, and used by manufacturers of automobiles, appliances, electrical equipment and other industrial and consumer products. Areas of application for NORDEL are discussed in the next section of this report.



Extrusion of wire insulation is typical of the conventional rubber-industry manufacturing processes in which NORDEL is used. No specialized fabrication or curing techniques are needed.

Scotch-Grip BRAND RUBBER ADHESIVE	PRODUCT SPECIFICATION **1300**
	DATED: APRIL 1, 1972 Revised Feb. 1, 1975

DESCRIPTION:

- A fast drying adhesive that develops high immediate strength. Has excellent heat resistance.
- Bonds Neoprene, reclaim, SB-R and Butyl rubber to metal, wood, most plastics and many other substrates.

PHYSICAL PROPERTIES

BASE Synthetic Elastomer	**NET WEIGHT** 7.3 ± .2 lbs./gal.	**CONSISTENCY** Medium Syrup
SOLVENT Petroleum Distillate, MEK	**FLASH POINT** —14°F.	**VISCOSITY (APPROX.)** 2400 cps
COLOR Yellow	**SOLIDS CONTENT** (APPROX.) 37%	**BROOKFIELD VISCOSIMETER** RVF #4 sp. @ 20 rpm

APPLICATION CHARACTERISTICS

METHOD Brush or Flow	**COVERAGE** (1 MIL DRY FILM) 396 sq. ft./gal.	**BONDING RANGE** (10 Mil Wet Film, 2 Surfaces) Up to 12 Minutes

EQUIPMENT SUGGESTIONS

5 Gallon Pail Dispensing System:

1. Pump—4:1 double acting ball type check pump, 4 cu. in./cycle 3" air motor.
2. Pail Cover required to reduce solvent loss.

55 Gallon Drum Dispensing System:

1. Pump—4:1 ratio double acting ball type check pump, 4 cu. in./cycle 3" air motor, bung style pump.

Accessories:

1. Hose—Samuel Moore Synflex hose or equivalent. 500 psi working pressure minimum.

Chemical Resistance Requirements:

1. Synthetic materials in contact with this adhesive must be resistant to ketones and aromatic solvents. Compar, nylon and Teflon are suggested.

Adhesives, Coatings and Sealers Division 3M COMPANY

3M CENTER, ST. PAUL, MINN. 55101 PHONE: 733-1110 AREA CODE 612

PERFORMANCE CHARACTERISTICS

180° PEEL STRENGTH Canvas/Steel			OVERLAP SHEAR STRENGTH ⅛" Birch/⅛" Birch	
Time @ 75°F.	Test Temp.	Value (lbs./in. width)	Test Temp.	Value (psi)
1 day	75°F.	18	– 30°F.	343
3 days •	75°F.	48	75°F.	549
5 days	75°F.	51	150°F.	195
7 days	75°F.	52	180°F.	136
2 wk.	75°F.	30	200°F.	65
3 wk.	75°F.	20	225°F.	85
after 3 wk.	– 30°F.	49		
after 3 wk.	150°F.	32.5		
after 3 wk.	180°F.	26		

All test data reported represent the typical average obtained using the testing procedures described. The typical range, where applicable, represents the range in average values that can be expected on multiple lots of material.

The data reported portray typical product performance and are not intended to be used for specification limits. Establishment of specification limits, certification requirements, and the test procedures involved must be reviewed and approved by 3M.

DIRECTIONS FOR USE

SURFACE PREPARATION: Surfaces must be clean, dry and dust free. Wiping with Scotch-Grip Brand Solvent No. 3* will aid in removing oil and dirt. For best results, temperature of adhesive and surfaces should be at least 65°F. If stored below 30°F., warm up, followed by thorough agitation may be required.
APPLICATION: Stir well before using. Brush or flow a thin, uniform coat of adhesive on each surface. Allow adhesive to dry until tacky but so that it does not transfer to your knuckle (maximum dry time about 4 minutes). Assemble materials with sufficient pressure to insure contact.
DRYING TIME: Bonded parts have high immediate strength to facilitate normal handling.
CLEAN-UP: Excess adhesive may be removed with Methyl Ethyl Ketone, Toluol, or Scotch-Grip Solvent No. 2 or 3.
REACTIVATION: Greater immediate strength may be obtained by solvent reactivation. To solvent reactivate, coat both surfaces with adhesive. Allow to dry tack-free. *Lightly* wipe one surface with Methyl Ethyl Ketone.* Complete bond within 30 seconds.
*When using solvents for reactivation or clean-up, it is essential that proper precautionary measures for handling such materials be observed.

STORAGE AND HANDLING

Store product at 60-80°F. for maximum storage life. Higher temperatures reduce normal storage life. Lower temperatures cause increased viscosity of a temporary nature. Rotate stock on a "first in-first out" basis. Upon request, your 3M Adhesives, Coatings and Sealers Sales Representative will be pleased to advise you of the anticipated shelf life of this product under the storage conditions in your plant.

Clean-up can be accomplished with Methyl Ethyl Ketone, Toluol or Scotch-Grip Brand Solvent No. 2 or 3. When using solvents for clean-up, it is essential that proper precautionary measures for handling such materials be observed.

ICC SHIPPING CLASSIFICATION: Adhesive Cements, NOI. Red label required.

DANGER: EXTREMELY FLAMMABLE

Keep product and its vapors away from heat, sparks and open flames. The vapors given off from this adhesive will burn. Contains petroleum distillate. Use only in well ventilated areas with enough air movement to remove vapors and prevent vapor buildup. Avoid breathing vapors. Avoid eye contact and prolonged or repeated contact with skin. Suggested first aid for eye contact; immediately flush with plenty of water and obtain medical attention. Keep out of reach of children. Keep container closed when not in use.

IMPORTANT NOTICE TO PURCHASER

All statements, technical information and recommendations contained herein are based on tests we believe to be reliable, but the accuracy or completeness thereof is not guaranteed, and the following is made in lieu of all warranties, express or implied:

Seller's and manufacturer's only obligation shall be to replace such quantity of the product proved to be defective. Neither seller nor manufacturer shall be liable for any injury, loss or damage, direct or consequential, arising out of the use of or the inability to use the product. Before using, user shall determine the suitability of the product for his intended use, and user assumes all risk and liability whatsoever in connection therewith.

No statement or recommendation not contained herein shall have any force or effect unless in an agreement signed by officers of seller and manufacturer.

Z-1300(25.4)R2

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KALWALL CORPORATION

1111 CANDIA ROAD
P. O. BOX 237
MANCHESTER, N. H. 03105
TELEPHONE: A/C 603 627-3861

SUN-LITE SOLAR COLLECTOR COVER MATERIAL PROPERTIES

FEATURES:

- **Solar Properties as Good as or Better Than Glass
- **Superior Impact and Shatter Resistance
- **Easy Maintenance and Repair
- **Economical (Low Initial and Life Cycle Costs)
- **Thermal Expansion Matches Aluminum
- **UV and Weather Resistant
- **Inert to Chemical Atmosphere
- **Large Sheet Size Eliminate Joints
- **Easily Cut with Hand Tools
- **Light Weight, Yet Rigid

AVERAGE PHYSICAL PROPERTIES	METHOD	UNITS	SUN-LITE REGULAR	SUN-LITE PREMIUM
Solar Energy Transmittance	E 424 Method B	%	85%-90%	85%-90%
Estimated Solar Lifetime (1)		Years	7	20
Thermal Senstitivity (2)	@	200°F	Excellent	Excellent
	@	300°F	Poor	Good
Heat Transmittance	5-20 Microns	%	10%	10%
Index of Refraction	D 542	Ratio	1.54	1.54
Tensile Strength	D 638	PSI	16,000	16,000
Flexural Strength	D 790	PSI	24,500	24,500
Flexural Modulus	D 790	PSI x 10^6	1.0	1.0
Shear Strength	D 732	PSI	14,000	14,000
Izod Impact	D 256	Ft.lb./In.	18	18
Water Absorption	D 570	%	0.20-0.33	0.20-0.33
Thermal Expansion	D 696	(In./In./°F) x 10^{-5}	1.4	1.4
Thermal Conductivity	C 177	BTU-In./Hr./Ft.^{2}/°F	.87	.87
Specific Heat	D 2766	BTU/lb./°F	.35	.35
Specific Gravity	D 792	Ratio	1.4	1.4
Weight	NBS PS53	Oz./Ft.^{2}	2.8-4.7	2.8-4.7
Thickness	NBS PS53	Inches	.025 or .040	.025 or .040
Sheet Size	NBS PS53	Feet	4' or 5' wide, up to 1,200 long	

NOTE:

1. Tests indicate that Regular Sun-lite will lose about 10% solar transmission in 7 years while Sun-lite Premium should have no appreciable loss for 20 years (estimate).
2. Sun-lite products are generally not affected by higher temperatures. The resins will not melt or cold flow since they are thermosetting and reinforced with glass fibers. The ignition temperature exceeds 900°F. However, continuous exposure at temperatures exceeding 200°F will cause a slight amber color to appear which will have only a modest effect (5%) on Sun-lite's properties. Continuous exposure at 300°F, causes about a 10% decline in solar transmittance in Sun-lite Premium and a more severe decline in Sun-lite Regular.
3. Special Sun-lites are now under development to meet additional fire code requirements and for moist heat applications. Sun-lite Regular and Premium are not recommended for moist heat applications.

The above information is presented in good faith, but no warranty is expressed or implied.

Form: SP-33
5/20/75

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PRODUCT NAME & CODE NUMBER	GENERAL DESCRIPTION	Service Temperature Limits °F	Type of Volatile	Color
[illegible]	Tough washable lagging adhesive-coating. Used with lagging cloth, canvas, and 20 x 20 glass cloth. Needs no additional finish.	0 to 180	WATER	CREAM
[illegible] ADHESIVE [illegible]1-10, [illegible]1-19	Quick-setting, rubber base adhesives for bonding fibrous glass and acoustical duct lining. For shop use only.	—20 to 200	SOLVENT	GREEN BLACK
[illegible]ROUS ADHESIVE [illegible]1-27, [illegible]1-93	Sodium silicate base adhesive for bonding calcium silicate insulation to itself and to substrates, and for laggng asbestos cloth.	50 to 800	WATER	GRAY
FIRE RESISTIVE ADHESIVE [illegible]1-33	A superior adhesive for bonding insulation to most structural surfaces. Also used for fitting fabrication, and joint sealing with polyurethane.	—50 to 300	SOLVENT	GRAY
LAGFAS® ADHESIVE 81-42W	Quick-setting, water base, thixotropic adhesive for sizing and adhering canvas, glass, and other fabrics to insulation. Washable and mildew resistant.	—50 to 180	WATER	WHITE
KOLD-FAS® ADHESIVE [illegible]2-08, [illegible]2-09	Water base, vapor barrier adhesive that bonds most low density insulations and vapor barrier facings to all surfaces. Practically odorless.	—50 to 170	WATER	BLACK
TA[illegible]AS CONTACT CEMENT [illegible]0 NON-FLAMMABLE	Fast drying contact cement for sandwich panel construction, bonding flexible cellular insulation, and whenever two impermeable surfaces are to be bonded.	0 to 180	SOLVENT	LIGHT AMBER
SPARK-FAS® ADHESIVE [illegible]5-11 (SPRAY)	Non-flammable, quick-setting rubber based adhesive for bonding fibrous glass and acoustical linings on air handling ducts. For shop use only.	—20 to 200	SOLVENT	BLACK
STIC-SAFE® ADHESIVE [illegible]5-15	Fast-setting rubber adhesive for adhering low density fibrous insulation to sheet metal and to most other construction materials.	—20 to 200	SOLVENT	AMBER
JAC-TAC® ADHESIVE [illegible]5-17, [illegible]5-62	High strength, water-base adhesive for attaching low density fibrous insulation and duct liner to painted and unpainted metal surfaces.	—10 to 180	WATER	WHITE BLACK
SPARK-FAS® ADHESIVE [illegible]5-20 (BRUSH)	Non-flammable, quick-setting adhesive for bonding fibrous insulation (up to 6 lb. density) to sheet metal and aluminum. Also for lap sealing.	—20 to 180	SOLVENT	OFF WHITE
DRION® CONTACT CEMENT 85-75 NON-FLAMMABLE	Contact cement with high initial strength. Used for lap sealing and bonding two impermeable surfaces. May be applied down to 12°F.	—20 to 200	SOLVENT	OFF WHITE

fostor JOINT SEALANTS

PRODUCT NAME & CODE NUMBER	GENERAL DESCRIPTION	Service Temperature Limits °F	Type of Volatile	Color
FOAMSEAL® SEALANT 30-45	Vapor barrier joint sealant that remains flexible and will not shrink or crack. Also used for flashing, and bedding cellular glass.	—100 to 300	SOLVENT	GRAY
INSULATION SEALANT [illegible]6	Moisture-vapor barrier joint sealant and bedding compound. Solvent free, suitable for use with polystyrene and other insulations.	—50 to 200	NONE	GRAY
[illegible]LASTOLAR SEALANT [illegible]5-44, 95-49	Elastomeric vapor barrier joint sealant and flashing compound. For insulation, masonry, metal jacketing and low velocity ducts. Fast drying.	—100 to 250	SOLVENT	ALUMINUM WHITE

®Sealfas, Lagfas, Spark-Fas, Stic-Safe, Kold-Fas, Jac-Tac, Drion, Foamseal, are registered Trademarks of H B Fuller Company

Rolled Flange Eyelets

ALL DIMENSIONS IN INCHES
PHOTOGRAPHS - ACTUAL SIZE
* LENGTH IS UNDER FLANGE

Part	O.D.	LONG•	FLANGE	METAL
A227	.330/.320	.175	.468	.020
A1635	.330	.316	.475	.016
A500	.332	.185	.593	.010
A2384	.335/.255	.119	.448	.013
A1950 *	.335	.100	.545	.009
A563	.335/.327	.233	.460	.014
A1984 *	.338/.255	.107	.445	.013
A1190 *	.340	.243	.600	.013
A1479	.341	.100	.468	.020
A1480	.341	.120	.468	.020
A1481	.341	.135	.468	.020
A1482	.341	.170	.468	.020
A1490	.341	.220	.468	.020
A60	.341	.275	.468	.014
A69	.341	.403	.470	.018
A213	.343	.230	.594	.013
A2368	.345	.150	.468	.009
A1650	.346	.325	.450	.013
A1057	.350	.080	.468	.016
A2744	.350	.187	.592	.016
A1379	.350	.335	.595	.013
A1339 *	.355	.075	.565	.010
A1146	.355	.250	.750	.050
A617	.356	.355	.562	.020
A1708	.356	.477	.675	.013
A2535	.357	.175	.780	.016
A2486	.357	.270	.780	.016
A2703	.357	.358	.780	.016
A2127	.364	.335	.593	.016
A1340 *	.375	.105	.705	.010
A1465	.375	.130	.525	.029
A1627	.375/.335	.245	.705	.013
A2098	.375/.350	.245	.705	.013
A1904	.382	.237	.687	.036
A1457	.385/.335	.305	.705	.013
A1673	.385/.355	.305	.705	.013
A1755	.385/.355	.308	.656	.013
A1224	.390	.260	.580	.012
A2634	.394	.347	.880	.036
A2891	.394	.347	.880	.036
A2353	.396	.325	.745	.010

Rolled Flange — .330 to .396

See page 66 to 69 for matching telescoping eyelet or neck washer.

BAYPORT, NEW YORK 11705
(516) 472-2000
Stimpson Co. Inc.
POMPANO BEACH, FLA. 33060
(305) 946-3500

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Product Data #305

FEED WATER & COOLING TOWER CHEMICALS
MAINTENANCE CHEMICALS • EPOXY COATINGS
POLYURETHANES • INDUSTRIAL FLOORS

K & K CHEMICALS, INC.

?0 ROXBORO ROAD • LAWRENCEVILLE, N. J. 08648
TELEPHONE: (609) 396-0061

TABLE I

Typical Properties

	(mixed 1:1 by weight)	Component 305-1	Component 305-2
Color	Blue	Clear Amber	Blue
Consistency	Medium - Heavy Syrup	Medium Syrup	Heavy Syrup
Viscosity (77°F) (25°C)	——	10,000 - 18,000 (10-18N S/M^2)	20,000 - 45,000 cps (20 - 45N.S/M^2)
Solids Content	97 to 99 Percent	99 to 100 percent	96 to 99 Percent
Specific Gravity	1.06	1.14 - 1.18	0.97
Weight (Lbs./Gal.) (Kg/M^3)	8.8 - 8.9 1054 - 1066	9.6 - 9.8 1150 - 1174	7.9 - 8.1 947 - 971
Flash Point	Non-flammable	Non-flammable	Non-flammable
Shelf Life	——	More than 1 year	More than 1 year
Working Life (1 lb. batch)	1½ to 2 hours	——	

TABLE II

Test Results

	Alternate A Ratio A	General Purpose Ratio	Alternate Ratio B
Mixing Ratio (By Weight)	**2 parts 305-1 1 part 305-2**	**1 part 305-1 1 part 305-2**	**1 part 305-1 2 parts 305-2**
Hardness (Shore D)	87	85	57
Rubber to Metal **Peel Strength** (Lbs./In. at 77°F.) (25°C)			
SBR Elastomer to Steel	176 (30.8N/mm)	188 (32.9N/mm)	60 (10.5N/mm)
Neoprene to Steel	107 (18.7N/mm)	99 (17.3N/mm)	93 (16.3N/mm)
Metal to Metal **Shear Strength** (psi at 77°F) (25°C)			
Aluminum to Aluminum	2610 (17995N/mm)	2720 (18753N/mm)	1932 (1332[illegible] N/mm)
Steel to Steel	1946 (13417N/mm)	2366 (16313N/mm)	1616 (1114[illegible] N/mm)
Gardner Labs **Impact Strength**			
160 inch pounds at 77°F. (25°C.)	Fail	Pass	Pass
160 inch pounds at -22°F. (-29°C.)	Fail	Fail	Pass

KALWALL CORPORATION

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MANCHESTER, N. H. 03105
TELEPHONE: A/C 603 627-3861

KAL - LAC

Kal-lac is a transparent air drying coating material for fiberglass reinforced polyester material. Kal-lac will restore the original luster and finish of such material which may have become dulled or roughened by prolonged exposure to the weather.

<u>Surface Preparation</u>: Using general grade, very fine type a Scotch Brite, rub the exposed surface moderately, until the free exposed fibers and embedded dirt are removed. Wet down the panel with clear water to rinse off loose surface fibers and dirt. Allow to dry thoroughly.

<u>Application</u>: Use Kal-lac as supplied without dilution. Application by roller coater is an inexpensive and efficient method. The core of the roller should be impregnated cardboard. Plastic cobes will soften in the Kal-lac. A minimum dried thickness of 1.0 mil is recommended. It will probably be necessary to apply two liberal coats, and possibly a third coat to the more severly weathered sheets but ~~in any case~~, enough Kal-lac must be applied to give a glossy finish to the entire surface when dry. Allow adequate drying time between coats.

<u>Drying Time</u>: Kal-lac will dry to tack-free condition within 5-10 minutes. Maximum hardness is attained at 10 to 15 hours at room temperature.

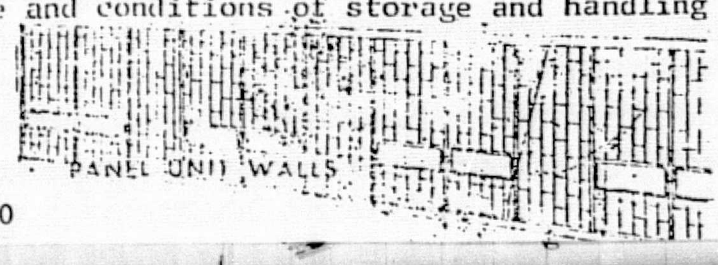
<u>Equipment Cleanup</u>: Methylethyl Ketone (MEK), Acetone, or lacquer thinner will satisfactorily clean up the application equipment.

<u>Precautions</u>: Kal-lac contains <u>flammable liquids</u> and should be <u>kept away from open flames</u>. Provide adequate ventilation. Prolonged breathing of vapors should be avoided.

<u>Cleaning Kal-lac Coated Panels</u>: Commercially available detergents are satisfactory. Do <u>not</u> use Ketone based solvents, gasoline, lacquer thinner, or other petroleum based materials.

The information contained herein is presented in good faith. No warranty or guarantee expressed or implied is made regarding the performance or stability of the product, since the manner of use and conditions of storage and handling are beyond our control.

2/7/75



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CENTER FOR INDUSTRIAL AND INSTITUTIONAL DEVELOPMENT

TOXICITY OF SMOKE FROM BURNING
KAL-LITE PANELS

for

Kalwall Corporation
88 Pine Street
Manchester, N. H.
03101

By

Laurance E. Webber, P. E.
Research Professor

June 19, 1973

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CENTER for INDUSTRIAL and INSTITUTIONAL DEVELOPMENT
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TOXICITY OF SMOKE FROM BURNING KAL-LITE PANELS

PURPOSE

To conduct a toxicity test of the products of combustion of Kal-lite as manufactured by Kalwall Corporation, Manchester, New Hampshire.

Since there is no standard test for measuring the toxicity of smoke from burning plastics, we followed a test which we believe is indicative of the hazard to be expected from burning fiberglass reinforced polyester (FRP) plastic. Obviously, the carbon monoxide usually generated by limited-oxygen burning can be lethal, and the smoke can displace the air (oxygen) from the area, but in this test we were concerned with the toxic effects of breathing the smoke generated by the burning FRP.

PROCEDURE

Six female albino rats of the CD strain (Sprague-Dolly descendants) aged 65 days and weighing between 150 and 200 grams were the subjects of the experiment. The rats were placed in a clear plastic cylinder 14" in diameter and 8" high. The cylinder was covered except for three 1/4" holes in the top. The bottom consisted of 1/4" mesh hardware cloth. Pieces of the plastic sheets were burned about 2 feet away from the test cylinder and the smoke was led into the chamber through a 3" galvanized pipe. (This was done to prevent and discomfort to the rats that might have resulted from hot wire in contact with their feet.) The density of smoke was quickly built up to a point at which the rats could only be hazily seen and the other side of the chamber could not be seen. The source of smoke was cut off at this point and no more was added. The

WHITTEMORE SCHOOL OF BUSINESS & ECONOMICS - COLLEGE OF TECHNOLOGY

atmosphere remained hazy for over one-half an hour.

Six other female albino rats of the same strain and ancestry, and of the same 65 days of age, were similarly subjected to smoke generated by burning a mixture of paper and wood.

CONCLUSION

The rats exposed to the FRP smoke showed no signs of distress and/or abnormality and were returned to their lab cages 1 hour after the start of the smoke exposure. When examined 120 hours later, none of the rats exhibited any signs of reaction to their exposure to the smoke from this burning FRP.

The rats exposed to the combination paper and wood smoke likewise showed no signs of distress and/or abnormality and were returned to their lab cages 1 hour after the start of the smoke exposure. When examined 72 hours later, none of the rats exhibited any signs of reaction to their exposure to the smoke from this burning wood and paper.

In these tests, the smoke from the FRP caused no different reaction in the rats than was caused by the smoke from wood and paper.

Respectfully submitted,

L. E. Webber

Laurance E. Webber, P.E.
Associate Director
Research Professor

University of New Hampshire

Lab Report No. K-101

June 19, 1973

LEW:l

the fire-resistant properties of
KALWALL® TRANSLUCENT WALLS

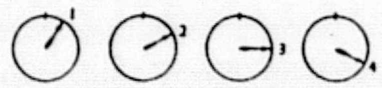
Translucent Kalwall's sandwich construction - two face sheets of fiberglass bonded to an aluminum grid core - presents an outstanding practical fire barrier. Under direct exposure to flame, Kalwall will usually prevent the spread of fire to other parts of a building. Kalwall cannot shatter or otherwise endanger persons or property, and Kalwall's faces contribute a minimum amount of fuel to a fire.

A summary of the results of extensive testing by independent laboratories and by Kalwall Corporation is presented below as a guide to the fire-resistant properties of Kalwall.

4-hour fire test ....

An independent laboratory tested samples of window glass and standard Kalwall which were individually mounted in the front opening of a chamber enclosing an oil burner. A fire was maintained at a temperature of approximately 1,200°F. While the glass samples cracked and burst out of the frame in less than five minutes, the fire had not burned through the outside of Kalwall after a period exceeding four hours.

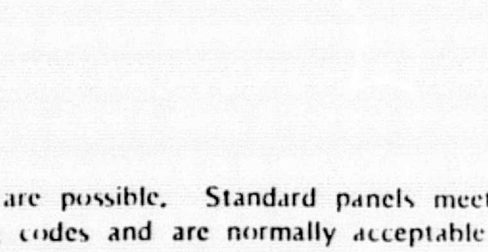
The table at right points out that the exterior face of the Kalwall sample never attained a sufficient temperature to ignite. This is a direct result of Kalwall's sandwich construction. The plastic resin in the face exposed to the flame was consumed; however, the fireproof fiberglass mat remained bonded to the grid, thus preventing the flame from reaching the exterior face.



	1 hour	2 hours	3 hours	4 hours
interior face temperature	1220° F	1208° F	1200° F	1230° F
exterior face temperature	413° F	397° F	405° F	405° F

high ignition temperatures ....

The temperature required to ignite the resin in Kalwall's face material is 650°F, when tested in accordance to ASTMD1929*. This significantly higher than that for many materials commonly found in a building. The graph shows that Kalwall's ignition temperature is about 100% greater than that of wood, common plastics, curtain material and paper.



* *Other tests show temps as high as 850°F.*

tunnel tests....

Several categories of interior flame resistance and smoke development by ASTM E 84 Tunnel Tests are available to meet the requirements of various local building codes. Flame spreads down to and including 25 are possible. Standard panels meet most building codes and are normally acceptable. Consult Technical Services Department if assistance is required.

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burn rate....

The face sheets of Kalwall panels have a burn rate of less than 1½ inches per minute by ASTM D 635. This is a test designed to measure the response of plastics to fire under laboratory conditions and correlation with flammability under actual use conditions is not necessarily implied. However, many national and model building codes use a burn rate of less than 2½ inches per minute by this test as minimum standard for approved plastics.

class "a" burning brand test....

ASTM E 108 is a test designed to measure the fire retardant characteristics of roof coverings against fire originating outside the building on which they are installed. Insulated Kalwall panels will pass the requirement of a class "A" Burning Brand.

A burning wooden brand 12" x 12" x 2 3/8" was placed on a Kalwall panel. The flames were fanned by a 12mph wind. The brand was allowed to burn until it completely burned out.

Although the under side of the Kalwall panels smoked, no flames or drippings were observed on the under side of the Kalwall panel.

97% non-combustible materials .. shatterproof

In the case of a fire, the plastic resin in Kalwall's faces will contribute very little fuel . . . in fact, hardly more than several coats of paint on a masonry wall, or the draperies commonly found behind windows. And unlike common glazing materials, Kalwall will not shatter or explode from its frame . . . does not present a possible hazard to nearby persons. We do favor the use of sprinklers for fire protection whenever practical.

a case history....

The enclosed mall of a shopping center under construction in London, Ontario, Canada featured translucent Kalwall in a clerestory application. During the final stages of construction, a welder's spark caused a fire in the build-up asphalt roof adjacent to the Kalwall. Spreading rapidly across the roof the flames threatened to create extensive damage within the building. But the Kalwall contained the fire, preventing it from entering the building.

Both the architect and contractor attribute the relatively low loss to Kalwall's fire-resistant properties. The architect states: *"It is estimated that damage could easily have amounted to $1,000,000 if Kalwall had not been used in the above mentioned areas."** Less than 7% of this amount was actually lost.

*(Name and address of building, architect and contractor available on request).

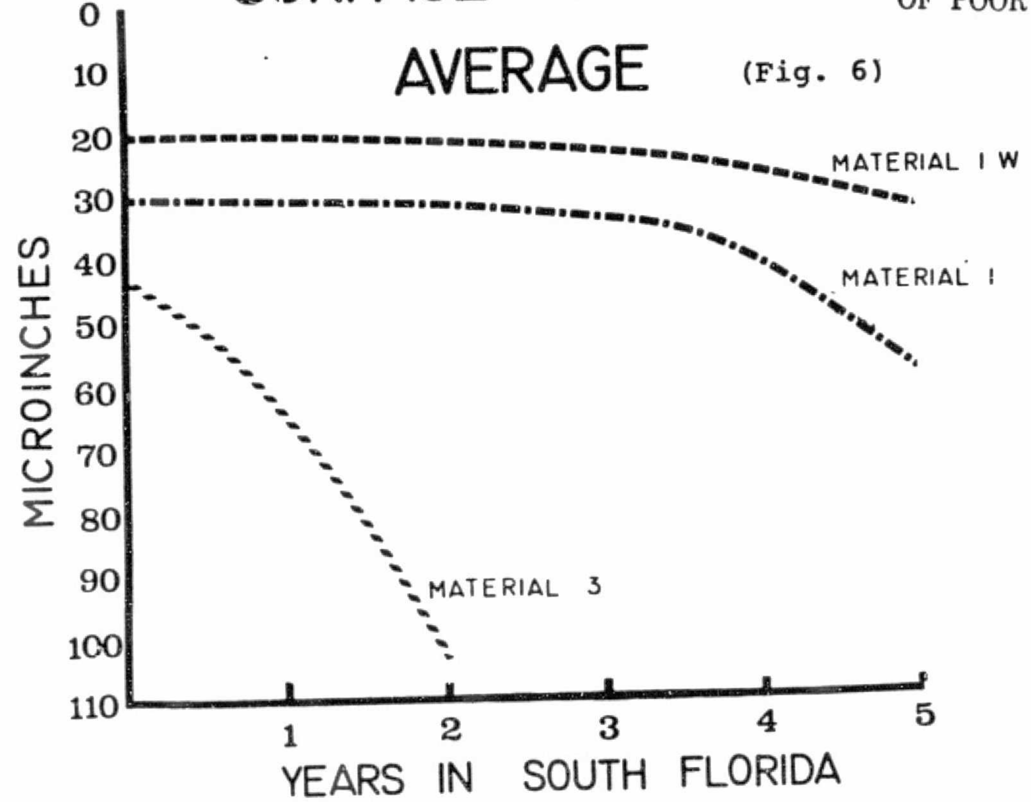
SURFACE EROSION

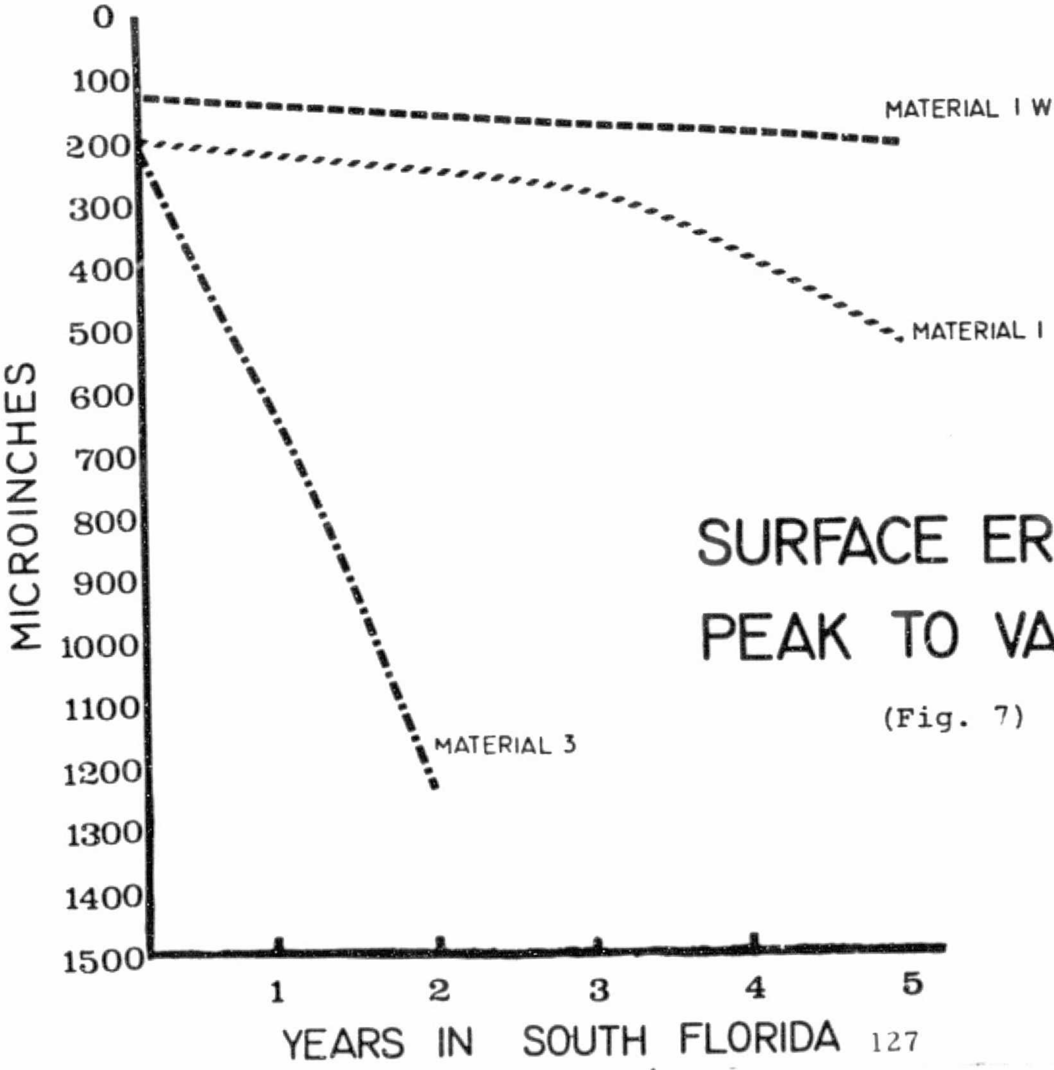
One of the weathering factors that should be considered for maintenance of long term performance is surface erosion. Surface erosion is the actual physical wearing away and oxidation of the surface. The result is exposed fibers on the surface sometimes called "fiber bloom". In order to measure the amount of surface erosion, measurements were taken with a Clevite 1200 Surfanalyzer. Both average roughness and peak-to-valley roughness were measured.

First consider average surface roughness (the average magnitude of all surface irregularities reported in microinches or 1/1,000,000 of an inch). The surface erosion for material #1 is not noticeable for the first three years of outdoor weathering in South Florida. However, at the end of four years, some surface roughness was noticeable, and after five years, there was about 55 microinches of average erosion. A standard grade of fiberglass can have more than 105 microinches of average erosion after only two years of South Florida exposure. (Fig. 6) In order to halt this kind of surface erosion, a proprietary high temperature coating manufactured by Kalwall Corporation called <u>Kalwall Weatherable Surface</u> can be applied. After five years of weathering exposure, only 14 microinches (hardly noticeable to the human eye) of average erosion was measured on material #1 with this coating. (Material #1W). A more dramatic measurement is of peak-to-valley roughness. (Fig. 7)

Using peak-to-valley measurements instead of average measurements, material #1 showed a maximum roughness of approximately 300 microinches change, while the coated sample showed only 100 microinches. Both samples had been weathered for five years in South Florida. A standard grade sheet can have more than 1,000 microinches of erosion after only two years to this same exposure.

SURFACE EROSION
AVERAGE (Fig. 6)





SURFACE EROSION
PEAK TO VALLEY

(Fig. 7)

THERMAL DEGRADATION

In most efficiently operating flat plate collectors the cover temperature will not be above 200°F; therefore, tests were conducted on samples continuously aged in a 200°F oven for 1 year. The drop in solar energy transmission for both material #1 and material #2 was approximately equal (about 10%). However, the standard grade sheet lost more than 50% solar energy transmission in one year of continuous exposure. (Fig. 4)

Cover plate temperatures higher than 200°F may occur during stagnation in collectors with improperly designed venting systems. Stagnation temperatures occur when no fluid (water or air) is flowing through the collector. For example, with 300 BTU/sq. ft./hr. insolation, the absorber plate could reach 380° and the inner cover of a double cover could reach 50 if the outside temperature is 60°. For this reason, short term tests were conducted at 300°F. (Fig. 5)

After 300 hours (equal to 10 hr./day for 30 days), material #1 lost only 2% solar energy transmission, while material #2 lost 4%. Extending the test to 5,000 hours, material #1 lost approximately 10% solar energy transmission at 300°F. Material #2 lost 22% and standard grade material lost 40% under the same conditions.

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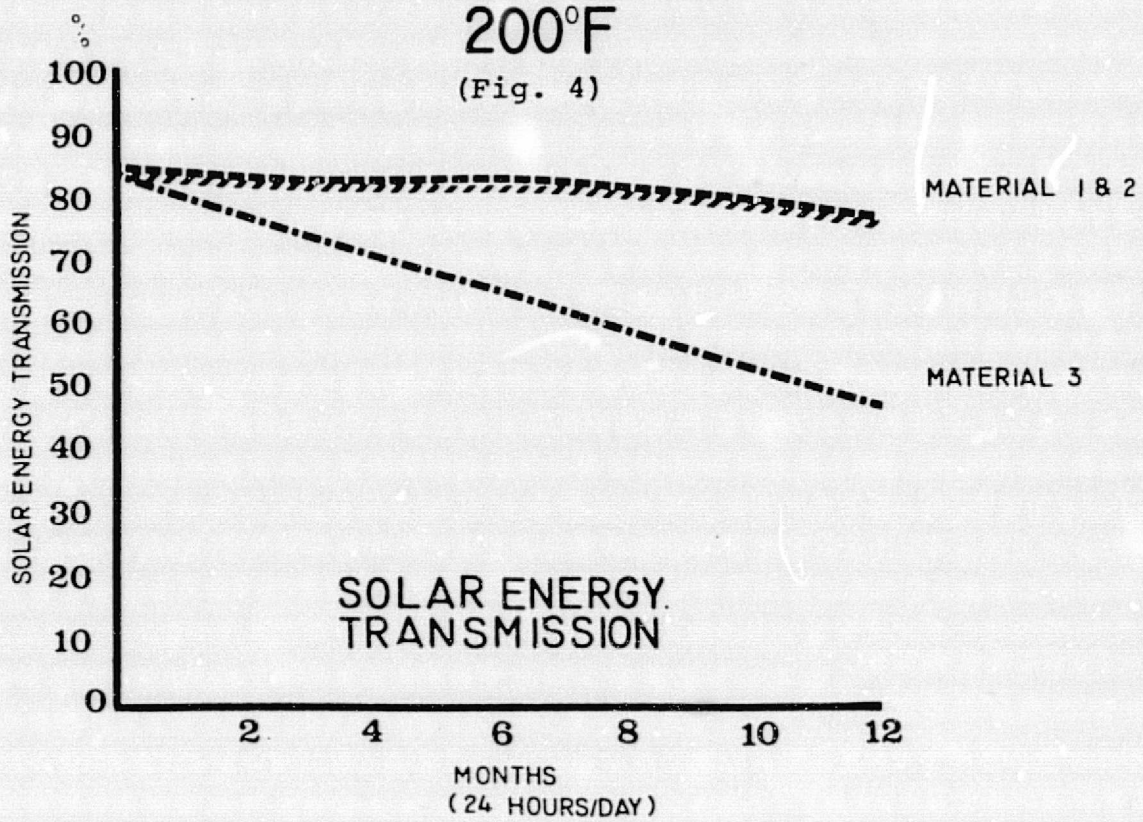
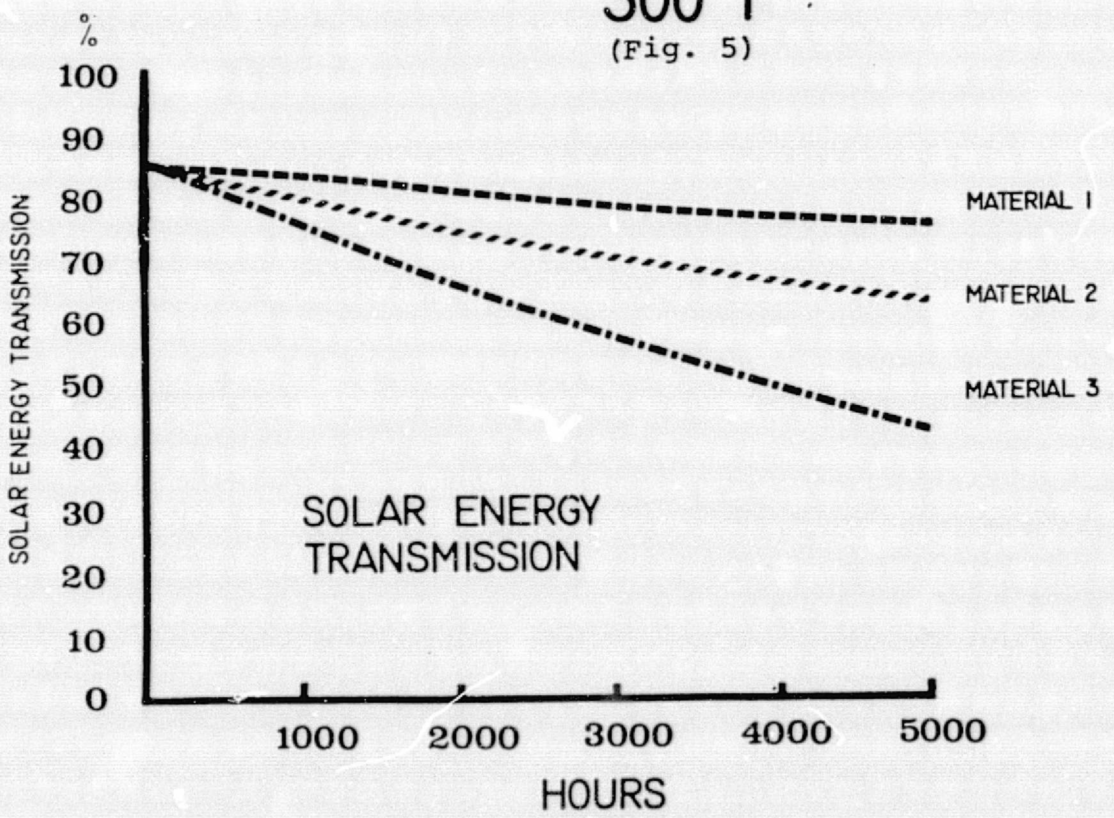
THERMAL DEGRADATION
200°F
(Fig. 4)



THERMAL DEGRADATION
300° F
(Fig. 5)



ULTRAVIOLET DEGRADATION

Degradation due to ultraviolet radiation has long been of great concern to those people designing or using products exposed to sunlight. Researchers in the FRP industry have come a long way in retarding ultraviolet degradation. A typical non-light stabilized general purpose polyester can lose more than 15% transmission in just 50 hours of exposure to a sun lamp. One of the earliest attempts to improve the UV resistance of polyester was to add ordinary aspirin as a light stabilizing additive. After 50 hours exposure to a sun lamp, a general purpose polyester will only lose 5% transmission if aspirin is added as a light stabilizer.

Obviously, today's researchers have gone much beyond aspirin in the field of light stabilization. Altering the polyester backbone (modifying the glycols and acids which make up polyester), adding acrylic, adding sophisticated light stabilizers, and applying special coatings or films are necessary to produce a quality solar collector cover.

In order to facilitate research into UV degradation, several different weatherometers were developed and are in general use today. The most common are the Fluorescent, Carbon Arc, and Xenon weatherometer. The Fluorescent weatherometer has a high concentration of UV and causes more severe changes than the Carbon Arc or Xenon weatherometer.

Although it is extremely difficult to correlate weatherometer hours to real time outdoors, many researchers use 250-400 weatherometer hours as approximately 1 year actual weathering. (2,000 hr.=approx. 5 yrs. real time.)

Samples were exposed in a fluorescent weatherometer for 2,000 hrs. Color change (ΔE) and light transmission readings were taken at 500 hr. intervals.

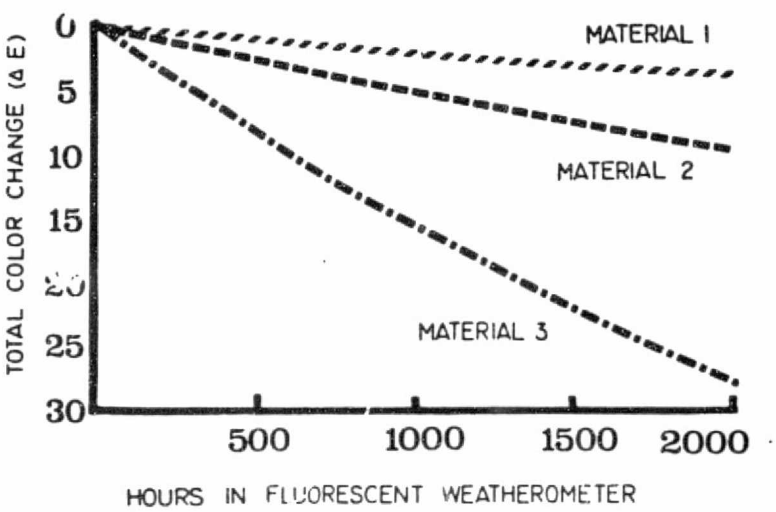
COLOR CHANGE - Measurements were taken in accordance with ASTM D 2244 Material #1 had a color change of 3.5 after 2,000 hours. Material #2 had a color change of 10. Depending on formulation, a standard grade FRP sheet could have a total color change of around 28. (Fig. 2)

In order to verify the weatherometer results, color change measurements were taken on a sample of material #1 weathered in South Florida for 5 years. The color change was found to be 4.4. (A specially coated piece of material #1 had a color change of only 1.1!)

South facing exposures in South Florida are considered the most severe natural environment in the United States because of large quantities of sunlight, heat, and moisture.

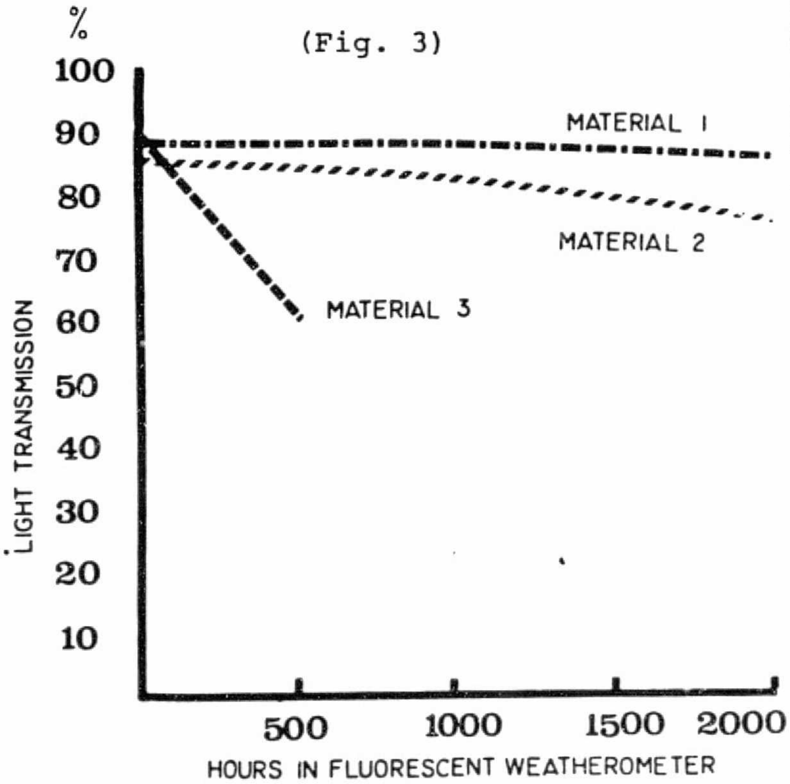
COLOR CHANGE
FLUORESCENT WEATHEROMETER

(Fig. 2)



LIGHT TRANSMISSION
FLUORESCENT WEATHEROMETER

(Fig. 3)



LIGHT TRANSMISSION - Light transmission measurements were taken on the same weatherometer specimens. Material #1 lost only 3% light transmission after 2,000 hours, while material #2 lost 11%. A standard grade fiberglass reinforced polyester can lose up to 20% light transmission in only 500 hours exposure time. (Fig. 3)

It is apparent from the above data that it is extremely important to consider the grade of fiberglass reinforced polyester when trying to decrease ultraviolet degradation. Another area of extreme importance for solar collector covers is thermal degradation.

Embrittlement is often of great concern to people using plastics. One of the major reasons fiberglass reinforced polyester is used as a solar collector cover is its remarkable impact strength and shatter resistance. Unlike glass, which can be easily broken into dangerously sharp pieces, fiberglass reinforced polyester is completely shatter resistant. The best way to measure impact resistance for solar collector covers is to use the falling ball method.

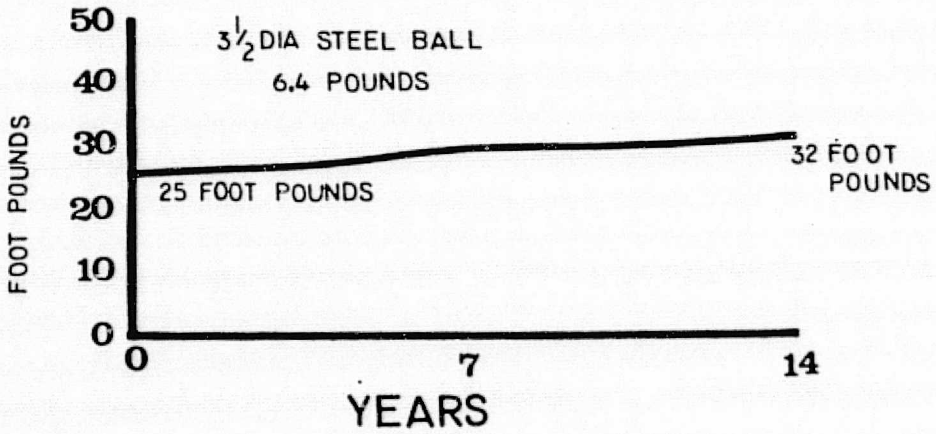
To prove fiberglass does not lose its remarkable impact strength after many years of outdoor exposure, a 14 year old sample was taken from a building and tested. The control (un-weathered) sample required 25 foot pounds, (6.4 pound steel ball dropped from 4 feet) to cause a rupture of the material while the 14 year old sample required 32 foot pounds (6.4 pounds from 5 feet) to cause rupture. (Fig. 8).

Low temperature impact does not cause a problem. Tests have been conducted on fiberglass reinforced polyester at -40 F, and the results showed almost a 50% increase in the dynamic load required to cause failure.

IMPACT STRENGTH

(SHATTER RESISTANCE)

(Fig. 8)



THERMAL SHOCK

The final property to be considered for a solar collector cover to be able to withstand the effects of weathering is thermal shock. Many times during the life of a solar collector, a rain storm or other rapid change in temperature may cause a severe thermal shock to a heated collector. To test fiberglass reinforced polyester's resistance to thermal shock, a sample was heated to 300 F and then quickly submerged in cold water. The thermal shock did not cause any harmful effects or noticeable degradation.

SUMMARY

It has been shown that high grades of fiberglass reinforced polyester exhibit excellent weatherability. Critical properties for solar collector covers such as solar energy transmission, ultraviolet and thermal degradation resistance, erosion resistance, impact resistance, low temperatures, and thermal shock have been examined and shown to be highly acceptable for safe and efficient use in the solar industry.

Special thanks are extended to the American Cyanamid Company and Owens-Corning Fiberglas Corporation for their generous technical assistance and testing.

BIOGRAPHY

James S. White, Product Development Manager for Kalwall Corporation, one of the leaders in research and development of fiberglass reinforced plastics for over 25 years, has been involved in the development of special FRP products for the past 8 years, including the development of the accepted industry testing procedures for load/deflection, shatter resistance, and the visual rating system for weathered FRP.

Mr. White is a registered professional engineer and an active member of the Society of the Plastics Industries, the Society of Plastics Engineers, American Society for Testing and Materials, Solar Energy Industries Association, and the American Society of Heating, Refrigeration and Air-Conditioning Engineers.

March 24, 1975

To Whow It May Concern:

The face sheets of Kalwall panels are made of Orthophthalic polyester reinforced with fiberglass. These are general purpose polyesters and completely crosslinked.

Polyester reinforced fiberglass sheets shrug off most harsh acids, alkalies and fumes. The enclosed test report shows the specific reaction of polyester reinforced fiberglass sheets to fifty different chemicals.

Jame S. White
Tech ical Services Manager

JSW/jr
Enclosures

RESISTANCE TO CHEMICAL REAGENTS

ASTM D 543-67

Significance

The limitations of the results obtained from this test should be recognized. The choice of t pes and concentrations of reagents, duration of emersion, temperature of the test, and properties to be reported is necessarily arbitrary. Correlation of test results with actual performance or serviceability of plastics is dependent upon the similarity between the testing and in-use conditions. It should be noted that both temperature and concentration have substantial effects on chemical resistance

Procedure

Specimens are emersed in the chemical reagents for seven days at room temperature. The reagents are stirred every 24 hours by moderate manual rotation of the containers. A visual examination is used to detect the effects of each of the chemical reagents.

Test Specimens

Three specimens 4" x 1" by varying thicknesses were used for each material tested and for each reagent involved.

Results

See chart

U.S. Testing Company
Report No. LA 57135

Chemical	Standard
Acetic Acid (Glacial)	F
Acetic Acid 5%	A
Acetone	C;F;K
Ammonium Hydroxide 28%	C;D;F
Ammonium Hydroxide 10%	F
Aniline	X
Benzene	C
Carbon Tetrachloride	A
Chromic Acid 40%	B;F
Citric Acid 10%	A
Cottonseed Oil	A
Detergent Solution 1/4%	A
Diethyl Ether	C
Formamide	C;F;G;K
Distilled Water	F;K
Ethyl Acetate	F
Ethyl Alcohol 95%	F
Ethyl Alcohol 50%	F;K
Ethylene Dichloride	X
Ethylhexyl Sebacate	A

Legend: A - No effect; B - Decreased opacity; C - Increased opacity; D - Yellowed; E - Stain; F - Internal Fiberbloom; G - Swelling; H - Brittle; J - Crazed; K - Blistered; X - Destroyed

Chemical	Standard
Heptane	A
Hydrochloric Acid 37%	F;K
Hydrochloric Acid 10%	A
Hydrofluoric Acid 40%	C;F;H;K
Hydrogen Peroxide 28%	A
Hydrogen Peroxide 3%	A
Isooctane	A
Kerosine	A
Methyl Alcohol	F;K
Mineral	A
Nitric Acid 70%	D;F;K
Nictric Acid 40%	A
Nitric Acid 10%	A
Oleic Acid	A
Olive Oil	A
Phenol 5%	F;K
Soap Solution 1%	A
Sodium Carbonate 20%	A
Sodium Carbonate 2%	A
Sodium Chloride 10%	A

Legend: A - No effect; B - Decreased opacity; C - Increased opacity; D - Yellowed; E - Stain; F - Internal Fiberbloom; G - Swelling; H - Brittle; J - Crazed; K - Blistered; X - Destroyed

Chemical	Standard
Sodium Hydroxide 60%	C
Sodium Hydroxide 10%	C;F
Sodium Hydroxide 1%	A
Sodium Hypochlorite 5%	A
Sulfuric Acid 97%	X
Sulfuric Acid 30%	B;F
Sulfuric Acid 3%	C;F
Toluene	C;F;K
Transformer Oil	F;J;K
Turpentine	A

Legend: A - No effect; B - Decreased opacity; C - Increased opacity; D - Yellowed; E - Stain; F - Internal Fiberbloom; G - Swelling; H - Brittle; J - Crazed; K - Blistered; X - Destroyed

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SPI

SHATTER RESISTANCE

BY THE FALLING BALL METHOD

This test was conducted to determine the shatter resistance of fiberglass reinforced polyester panels. The test panels were mounted in a manner simulating use and a 3 1/2-inch diameter steel ball was used.

9.1.1 Method B of the SPI Shatter Resistance was followed.

9.1.2 There were five test specimens 16" x 16" of each type material. Type I material was clear and Type II material was clear.

9.1.2.1 No commercial designation. Company -- Kalwall Corporation --(D)

9.1.2.2 Type I material had an average thickness of .044 inches and an average weight of 5.0 ounces per square foot. Type II material had an average thickness of .061 inches and an average weight of 6.9 ounces per square foot. (See data sheet.)

9.1.4 The average distance the ball was dropped to produce failure for Type I material was 12 feet. The average distance the ball was dropped to produce failure for Type II material was 16 1/2 feet.

9.1.5 The average diameter of the hole for Type I material was approximately 5 inches. The average diameter of the hole for Type II material was approximately 5 inches.

DATA SHEET

TEST: <u>FALLING BALL</u>

MATERIAL: <u>COMPANY D</u>

		Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Avg.
Type I	Weight, Oz.	8.8	8.8	9.0	9.0	8.8	8.9
	Thickness, In.	.044	.044	.043	.044	.043	.044
Type II	Weight, Oz..	12.1	12.4	12.1	12.1	12.5	12.2
	Thickness, In.	.058	.063	.059	.060	.064	.061

	Type I					Type II				
Distance Ft.	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5
2	OK					OK				
3	OK					OK				
4	OK					OK				
5	OK					OK				
6	OK					OK				
7	PULL OUT	PULL OUT	OK			OK				
8			OK			OK				
9			OK			RUP. 5" Long	OK			
10			OK				OK			
11			PULL OUT	PULL OUT			OK			
12					FAIL 4 1/2" Dia. Avg.		RUP. 5" Long	OK		
13								OK		
14								OK		
15								OK		
16								PULL OUT	FAIL 6" Dia. Avg.	OK
17										PULL OUT

CALMAC

CAL-ZORB 3968

CAL-ZORB 3968 is a black, flexible, heat absorbing coating designed for use in solar heating equipment. It makes excellent bond to vinyl or vinyl containing materials such as ABS plastics. When catalyzed with CAL-ZORB 4562 its bond strength improves to a wide variety of substrates and its heat resistance is in excess of 200^{0}F.

PHYSICAL CHARACTERISTICS

1. Dires to a dull, black, tack-free heat absorbing coating.
2. High film strength.
3. Flexible through wide temperature extremes.

TECHNICAL SPECIFICATION

	Base	Catalyst
BASE:	Polyurethane	Isocyanate
COLOR:	Black	Clear
SOLVENTS:	MEK, MIBK, Toluene	MEK Toluene
SOLIDS:	22.5%	55.75%
VISCOSITY:	1800-2000 Cps, RVF Brookfield #5 Spindle @10 RPM	-
WEIGHT/GALLON:	7.39 Pounds	8.76 Pounds
SPECIFIC GRAVITY	.886	1.05

PREPARATION OF SUBSTRATES:

Surfaces should be free of dust and oil to obtain maximum bond strength. Solvent washing or abrading is recommended where feasible.

METHOD OF APPLICATION

Before using, mix thoroughly 10 parts of CAL-ZORB 3968 with 1 part of CAL-ZORB 4562 by volume. The blend should be stirred sufficiently long to insure a homogenous dispersion. The ratio of 3968 to 4562 can be varied to reduce the extent of cure and extend pot life and exact ratio is not critical.

CALMAC MANUFACTURING CORPORATION
Box 710, 150 S. Van Brunt St., Englewood, N.J. 07631 • (201) 569-0420 • (212) 586-5178

Brush or coat the mixed system and allow to dry thoroughly. Drying is relatively slow to provide a bubble free film. Ultimate bond strength will be reached in approximately 24 hours, however, the bond or coating may be heated to affect a quick cure after solvent evaporation. Typical cycle is 30 minutes.@200^{0}F.

CLEANING AND THINNER:

Methyl Ethyl Ketone

PRECAUTIONARY DATA:

These two products are extremely flammable. Vapors may cause flash fires. Vapors may ignite explosively under certain conditions. Keep away from fire, sparks, and sources of heat. Open all doors and windows. Extinguish all flames and pilot lights. Turn off electric motors, stoves, or heaters, or any source of ignition during use and until all vapors have been dispersed. Do not smoke. Close containers after use.

FLASH POINT: CAL-ZORB 3968- 22^{0}F T.C.C.
CAL-ZORB 4562- 22^{0}F T.C.C.

TOLERANCE LIMIT VALUE: 100 Parts per million in air.

USE WITH ADEQUATE VENTILATION
AVOID PROLONGED BREATHING OF VAPORS
AVOID PROLONGED AND REPEATED CONTACT WITH SKIN
KEEP OUT OF REACH OF CHILDREN
STORE AT TEMPERATURES OF 90^{0}F OR BELOW FOR MAXIMUM SHELF LIFE

APPENDIX E

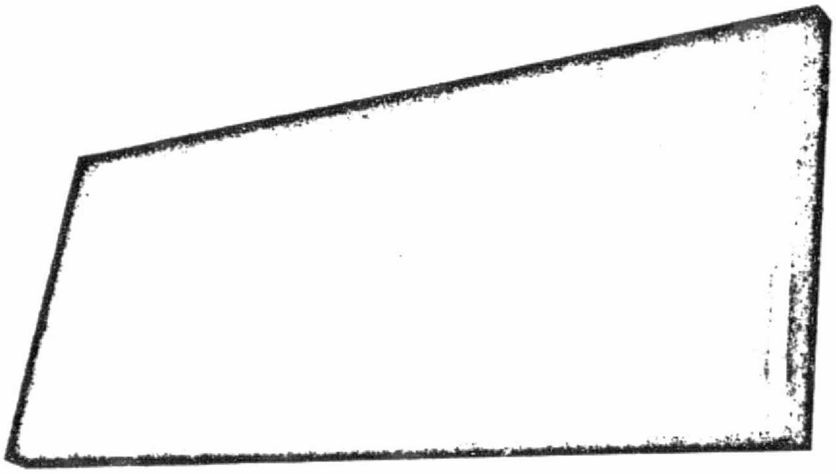
Collector Installation, Operation and Service Manual

TECHNICAL GUIDE
SE-3056
December, 1977

SOLAR ENERGY

SUNMAT Solar Collector

Installation, Operation and Service Manual



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This Technical Guide is written to provide a complete and comprehensive procedure for the installation of the SUNMAT Solar Collector. It is not the intent of this guide to exclude sound and proven methods of installation by contractors who have, through experience and past performance, developed an efficient method of installation expertise.

ALL work must be performed in accordance with LOCAL, STATE and NATIONAL codes.

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A. General

1. The SUNMAT Solar Collector has been specially designed for space heating and other solar applications requiring large collector areas. The panels are custom-built to fit the dimensions of the roof--a feature that speeds installation and improves esthetics. The panels can also be built in very large sizes--up to 4' by 25'. This means lower costs for plumbing and installation. The extensive use of synthetic materials makes them very lightweight and reduces corrosion problems. The special zipper lock feature allows easy access to the absorber in the event servicing is necessary.

B. Collector Sizing

1. The proper sizing of a collector system is a complex process and a number of acceptable methods are available. For a proven, workable procedure refer to CALMAC Technical Guide SE-1223. The efficiency of the collector--a key input in the sizing calculations--is shown in Figure 1-1.

C. Damage in Transit

1. Upon receipt of shipment of this material, inspect all cartons for external damage. If external damage is noted, open the carton and inspect for damage to equipment. Mark the number of cartons received in this condition on the delivering carrier's waybill, and request the services of the inspector.

2. If upon opening a carton concealed damage is discovered, open the entire shipment and note all equipment so damaged. Contact the delivering carrier and request inspection of the damaged equipment. Do not destroy the carton as the inspector from the freight company will need this to determine the reason for damages.

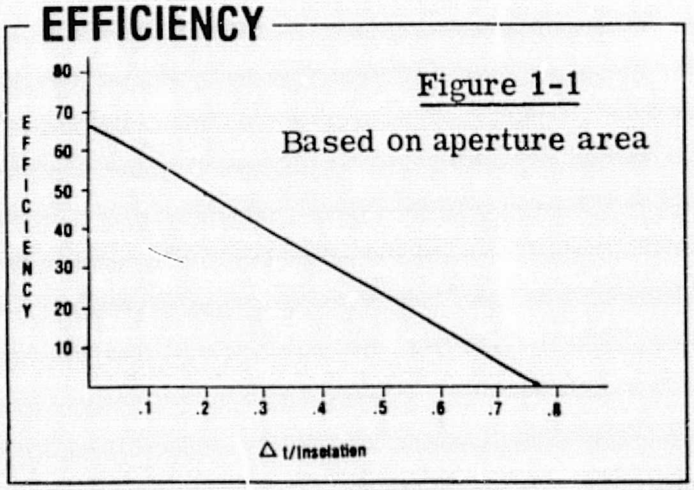


Figure 1-1

Based on aperture area

3. Normally, claims for any and all damages should be filed with the freight company within five working days after receipt of shipment.

4. Since all materials are sold FOB factory, it is the responsibility of the consignee to file claims with the delivering carrier for materials received in damaged condition.

D. System Design

1. Air Vent. An air vent should be installed at the highest point in the supply or return line in order to release air trapped in the piping.

2. Expansion Tank. An expansion tank is required in the supply or return line to allow for thermal expansion and contraction of the heat transfer fluid.

3. Pressure Drop. In sizing pumps for systems using water as the heat transfer fluid the pressure drop through the collector can be determined from Figure 1-3. For systems using anti-freeze heat transfer fluids, the pressure drops should be adjusted based on data provided by the supplier of the heat transfer fluid.

4. Relief Valves. A temperature relief valve set to open at 210°F and a pressure relief valve set to open at 20 PSI must be included in either the supply or return line. Ordinarily the pressure relief valve is located indoors and connected to a catch basin. The appearance of liquid in the catch basin provides evidence of a malfunction, and in closed loop systems the possible need to add more heat transfer fluid.

5. Strainers. A strainer should be installed in the supply line to the collector. This strainer should be checked one week after startup and annually thereafter.

6. Pressures and Flows. The maximum recommended operating pressure is 20 PSI. In practice this means that the collector should not be connected directly to a water main. Subjecting the system continuously to pressure above 20 PSI will cause the SUNMAT tubing to stretch over time and may lead to leaks in the system.

The minimum recommended flow rate throughaa collector is 2 GPM to insure optimum efficiency. The maximum recommended flow rate through a collector is 5 GPM. Higher flows will create velocities through the headers which may cause whistling and/or erosion.

7. Gauges. In closed loop systems a pressure gauge reading the system pressure (usually 20 PSI) is recommended. A drop in system pressure usually indicates a leak in the system.

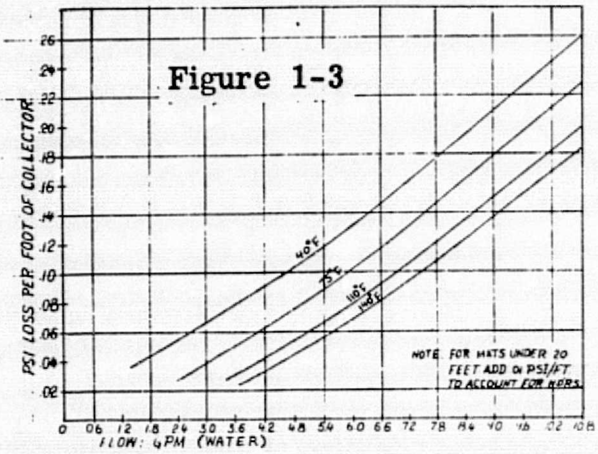


Figure 1-3

E. Installing the SUNMAT Solar Collector

1. The inlet and outlet plumbing connections to the SUNMAT collector are located at the same end of the collector. The 3/4" NPT connections are located either on the right or left side, both sides, or the back side of the collector. The configuration, which depends on where the pipes will best penetrate the roof, is specified at the time the order is placed with the factory.

2. The collector may be mounted vertically or horizontally with the plumbing connections at either the top or the bottom. Because the inside diameter of the collector tubing is small, trapped air is readily swept away when heat transfer fluid is circulated through the system, so the headers may be located at the bottom of a vertically mounted collector.

3. When two or more collectors are to be used side-by-side, it is permissible to make the inlet/outlet connections to one collector through one other collector. In this way four collectors can be hooked up to one supply and return line. See Figure 1-2.

4. For esthetic reasons care should be taken to insure that collector sides are parallel to adjacent roof lines. A chalk line is also helpful in getting the correct alignment. It is also helpful to have someone on the ground visually confirm the alignment.

5. If the roof structure underlayment is plywood and is in good condition, the collectors may be bolted to the plywood. The most secure connection is to bolt the collectors into the rafters. Holes in the collector mounting flange should be made to coincide with the location of the rafters. Holes in the flange should be 3/8" diameter. To allow for differential expansion they should also generally be elongated (up to 1" for 25-foot long collectors). To locate the rafters, use a stud finder or tap the roof with a hammer. The more solid sound indicates the rafter. Once the general location of the rafters has been determined, a nail can be driven through the roof to more precisely locate the rafters. These rafter location nails can be driven through a 2" x 4" that will also serve as a temporary horizontal support at the bottom of the collectors while they are being bolted to the roof.

6. The collectors can now be brought up onto the roof. One way to bring the collectors onto the roof is to slide them up a ladder. With one person at the top of the ladder pulling and a second person pushing from below, the collector can be moved into place relatively easily.

7. Drill holes through the roof into the rafters. If 1/4" diameter lag bolts are used (min. recommended diameter) then the holes drilled into the roof should be several drill sizes smaller. After the holes are drilled into the rafter they should be filled with silicone sealant before the bolts are inserted. The bolts should be of sufficient length that they penetrate the plywood underlayment, and engage a rafter by at least 2".

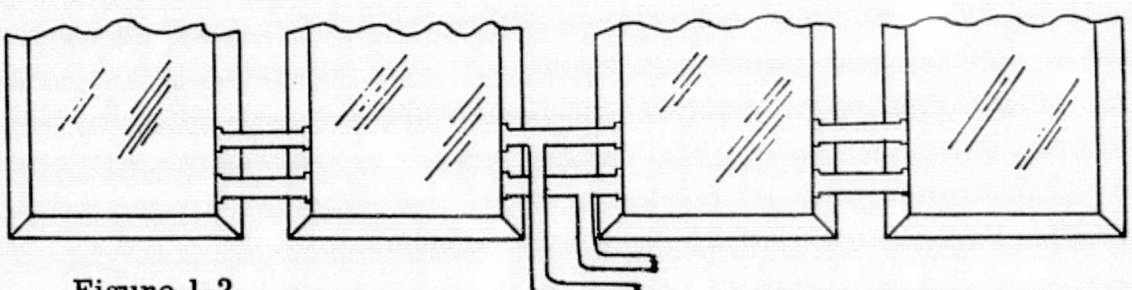


Figure 1-2

8. The collectors should be spaced a minimum of 1/4" apart so that thermal expansion and contraction of the frame does not disturb the mounting.

9. The manifold inlet and outlet connections are 3/4" NPT. Teflon tape is recommended as a sealant for all threaded connections. Do not insulate the piping or add flashing until the system is pressure-tested. Finding the leaks under flashing and insulation is quite difficult.

10. All roof penetrations should be sealed a second time to insure against leaks. Silicone sealant is a good choice.

11. Remove the nailer at the bottom of the collector that was used to hold the collectors on the roof and fill the nail holes with silicone sealant.

F. REPAIRS AND MAINTENANCE

1. No routine maintenance is required, but the system should be checked at least annually for breakdowns in the system.

2. Rain should keep the collector cover relatively dirt-free. However, if dirt or dust accumulates, it may be necessary to hose and wash the cover. Normal wind and water gradually abrade the cover panel, and to insure optimum performance every five to seven years the panel must be spray-coated with Kal-Lac, a fast-drying liquid applied by roller, spray or brush.

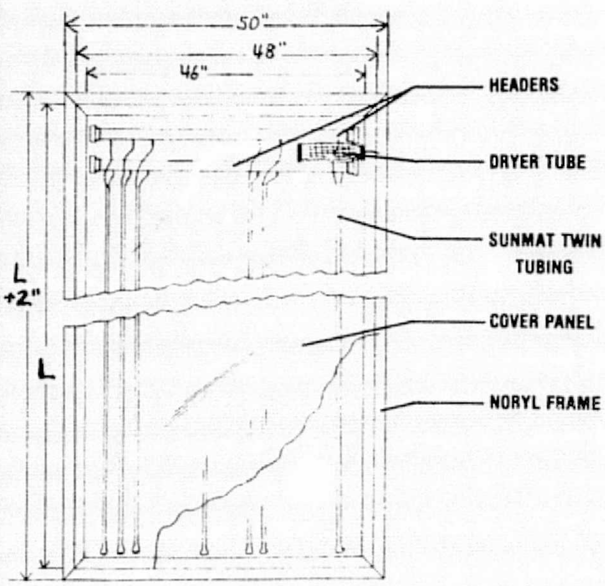
3. Any leaks that may develop in the tubing system can be repaired with copper splicer tubes and Stimpson clamps from the repair kit To make this type of repair a heavy, wide-bladed screwdriver should be used to pop the glazing frame piece off from the side wall. It is usually best to start at one corner. After the plastic zipper lock is undone, the cover can be rolled back to expose the tubing. To repair the tubing the damaged piece should be cut out and a splicer tube put in its place and fastened with Stimpson clamps at either end. Then the glazing should be repositioned in place and the side and top plastic frame pieces snapped back together with a rubber mallet starting at the corners and finishing midway between.

4. Because of the small diameter of the SUNMAT tubing, capillary action prevents complete draining of the tubing. In the event the collector must be completely drained, air pressure must be used to force fluid out of the tubing grid.

5. Every several years flushing the system may be advisable. Water run through the system at 40 PSI is generally adequate. Connections for flushing should be included at the time of installation.

6. Heat Transfer Fluids. Heat transfer fluids should be maintained in accordance with specifications provided by the manufacturer. The SUNMAT system is compatible with glycol anti-freezes. Contact CALMAC before using other anti-freezes.

SPECIFICATIONS



COVER PLATE:
Fiberglass-reinforced polyester, .040"
Transmissivity: 88% at 0°, 78% at 45°
Wind Load Design: 100 MPH

ABSORBER:
Surface: Black, high temperature urethane coating
Aluminum Sheet: .002" thick
Tubing: 5/16" OD EPDM dual tubing
—Tube spacing 1½" on center
—Manifold and outlet ¾" OD type L copper
—U-bends and manifold-to-tubing connections ¼" copper

INSULATION:
High temperature (350°F) rigid fiberglass
Density: 4.0 lbs/ft³
2" on bottom, R = 9 1" on sides, R = 4.5 @70°F

DESICCANT:
Silica gel in 3/4" x 10" wire mesh tube

COLLECTOR FRAME:
.125" thick Noryl extrusion

MOUNTING PROVISIONS:
1" flange around total perimeter
External plumbing connections ¾" standard pipe thread

FLUID:
Capacity .03 gallons/ft²

MAXIMUM OPERATING TEMPERATURE: 210°F

MAXIMUM ALLOWABLE TEMPERATURE: 300°F

DESIGN LIFE OF COLLECTOR: 20 years

FLUID PRESSURES:
Maximum operating pressure: 20 PSI
Tubing test pressure: 80 PSI

FLOW RATES:
.018 GPM / square foot of mat
Minimum flow rate: 2.0 GPM

NOMINAL PRESSURE DROP:
.16 PSI per foot of length of mat

APPENDIX C

Field-Assembled Solar Collector

Installation, Operation & Service Manual

CALMAC

TECHNICAL GUIDE

SE-1298

December, 1977

SOLAR ENERGY

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SUNMAT Field-Assembled Solar Collector Installation, Operation & Service Manual

INDEX

The SUNMAT Field-Assembled Solar Collector System is a non-metallic single-glazed collector designed to be constructed on site in much larger sizes than conventional factory-assembled panels. The system allows the collector to be tailored to fit the dimensions of any installation and provides economies of scale in construction and plumbing.

The SUNMAT consists of a flexible grid of 30 closely spaced elastomer twin tubes cemented to an insulation board base and covered with a flexible reinforced plastic cover. The grid substitutes for the metal absorber plate used in conventional panel-type collectors.

ALL aspects of this installation must comply with NATIONAL, STATE and LOCAL codes.

The information in this manual has been prepared to save time, obtain the best possible installation and insure continuous trouble-free operation of the collector system.

All materials obtained locally or from suppliers other than CALMAC Manufacturing Corporation must be in accordance with specifications set forth in the Section on Specifications.

CALMAC MANUFACTURING CORPORATION
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I. GENERAL

A. Collector Sizing

The proper sizing of a collector system is a complex process and a number of acceptable methods are available. For a proven, workable procedure refer to CALMAC Technical Guide SE-1223. The efficiency of the collector--a key input in the sizing calculations--is shown in Figure 1.

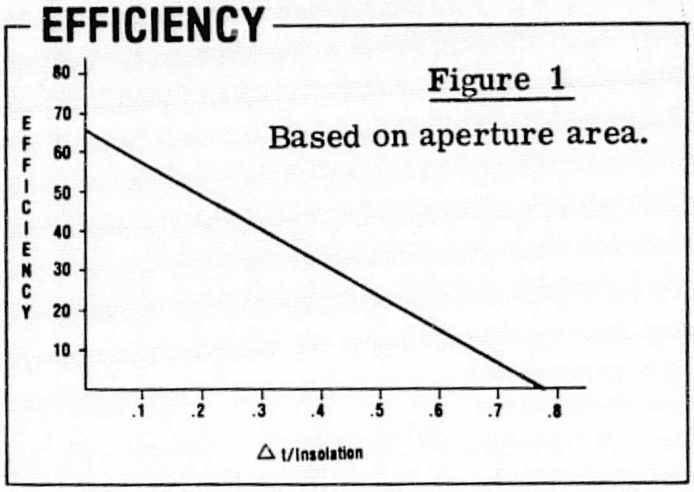


Figure 1

Based on aperture area.

B. Materials and Tools

1. The following materials are required to build the collector:

Item	Quantity
Absorber tubing system (EPDM tubing grid with copper U-bends and headers)	4' x desired length
Absorber cement	One gallon for every 40 square feet
Plastic Cover Panel	4' x desired length
Insulation Board	220% of collector area
Contact Cement	One gallon for every 130 square feet
Insulation Cement	One gallon for every 60 square feet
EPDM Hose	1/2" per square foot of collector
Roofing Mastic	One gallon for every square feet
Condensation Dryers	One for every 200 square feet of collector or fraction thereof
Foil-Faced Tape	Four feet for every four feet of collector length

For further specification on the materials refer to the Specifications Section.

2. The following tools are required to build the collector:

12" adjustable wrench
12" pipe wrench
knife
pair of hand gloves
bicycle pump or other source of compressed air
pair of pliers
measuring tape
straight edge
masking tape

C. Damage in Transit

1. Upon receipt of shipment of this material, inspect all cartons for external damage. If external damage is noted, open the carton and inspect for damage to equipment. Mark the number of cartons received in this condition on the delivering carrier's waybill, and request the services of the inspector.

2. If upon opening a carton concealed damage is discovered, open the entire shipment and note all equipment so damaged. Contact the delivering carrier and request inspection of the damaged equipment. Do not destroy the carton as the inspector from the freight company will need this to determine the reason for damages.

3. Normally, claims for any and all damages should be filed with the freight company within five working days after receipt of shipment.

4. Since all materials are sold FOB factory, it is the responsibility of the consignee to file claims with the delivering carrier for materials received in damaged condition.

D. System Design

1. Headering. When two or more collectors are to be used and assembled side by side, it is permissible to connect the header system of one collector to the in and out piping through one other header system. Using a T-connection it is possible to hook four header systems to the same in and out piping. See Figure 2.

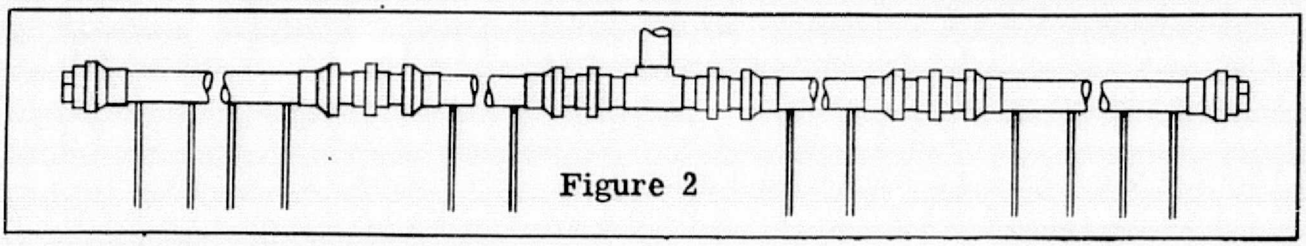


Figure 2

2. Air Vent. An air vent should be installed at the highest point in the supply or return line in order to release air trapped in the piping.

3. Expansion Tank. An expansion tank is required in the supply or return line to allow for thermal expansion and contraction of the heat transfer fluid.

3. Pressure Drop. In sizing pumps for systems using water as the heat transfer fluid the pressure drop through the collector can be determined from Figure 3. For systems using anti-freeze heat transfer fluids, the pressure drops should be adjusted based on data provided by the supplier of the heat transfer fluid.

4. Relief Valves. A temperature relief valve set to open at 210°F and a pressure relief valve set to open at 20 PSI must be included in either the supply or return line. Ordinarily the pressure relief valve is located indoors and connected to a catch basin. The appearance of liquid in the catch basin provides evidence of a malfunction, and in closed loop systems the possible need to add more heat transfer fluid.

5. Strainers. A strainer should be installed in the supply line to the collector. This strainer should be checked one week after startup and annually thereafter.

6. Pressures and Flows. The maximum recommended operating pressure is 20 PSI. In practice this means that the collector should not be connected directly to a water main. Subjecting the system continuously to pressure above 20 PSI will cause the SUNMAT tubing to stretch over time and may lead to leaks in the system.

The minimum recommended flow rate throughaa collector is 2 GPM to insure optimum efficiency. The maximum recommended flow rate through a collector is 5 GPM. Higher flows will create velocities through the headers which may cause whistling and/or erosion.

7. Gauges. In closed loop systems a pressure gauge reading the system pressure (usually 20 PSI) is recommended. A drop in system pressure usually indicates a leak in the system.

II. MOUNTING THE COLLECTOR

A. Mounting the Collector

1. When the system is built on a steeply slanting roof, a scaffolding should always be used. A scaffolding makes the installation much easier and is the safest method.

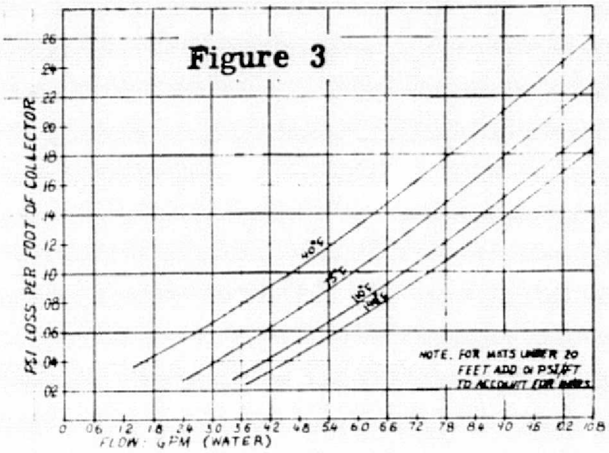


Figure 3

2. The surface on which the SUNMAT system is to be built must be sturdy and flat. As a rule, any normal roofing surface is acceptable as long as the fiberglass insulation which forms the collector bed can be bonded firmly to it with roofing mastic. Since the SUNMAT is quite lightweight, installation on an existing roof does not add appreciably to the load on the roof and is usually quite safe.

3. The layout of the collector installation must take into consideration the size and shape of the space available for the collectors. Each grid of the SUNMAT system is 4' wide. The length of the SUNMAT collector can be any size up to 50' and is therefore cut to fit the available space. In laying out the length, however, it is important to keep in mind that an additional 4" must be allowed beyond the desired length of the absorber system for connecting the headers and U-bends. It is also advisable to keep the length of the SUNMAT as long as practicable since this reduces the cost per square foot.

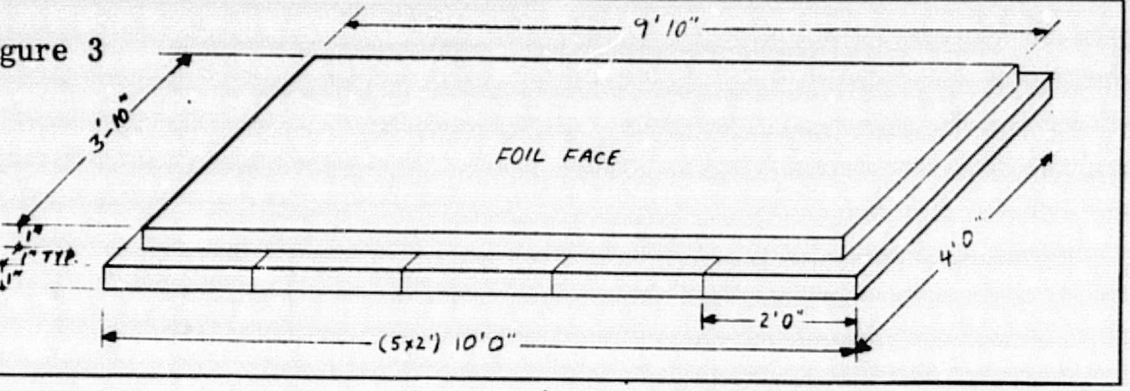
4. The collectors should not be mounted absolutely horizontal since in this position water will pond on the glazing and dirt will accumulate. The minimum recommended slope is 1 in 12.

III. INSTALLATION

A. Constructing the Insulation Bed

1. Cut and build the bed of insulation board. This bed is made of 1" thick foil-faced fiberglass insulation boards cemented face to face. The bottom boards are 2' x 4'. The top boards are 4' x 10' boards that have been factory-outgassed at 350°F for an hour. 1" must be trimmed off these boards to allow for the perimeter walls.

Figure 3



The boards must also be trimmed to the proper length, which is a function of the size of the collector. The top board must be 2" shorter than the bottom board--again, to allow for the perimeter walls. The unfaced sides of the boards are cemented together using the insulation cement to make a 2" board foil-faced on both sides. In order to make one unified section the top and bottom boards are overlapped. The top boards are centered on the bottom board to allow for the perimeter walls. See Figure 3.

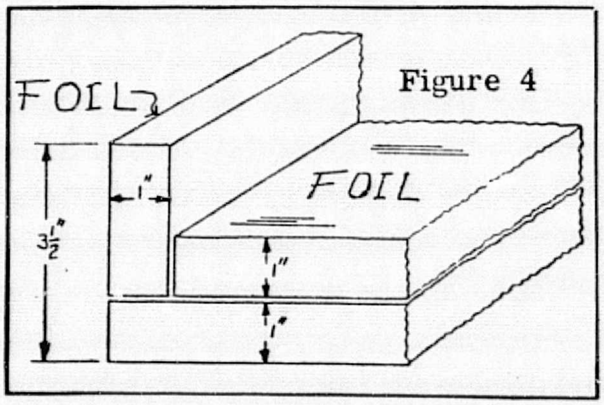
2. Cut and cement the fiberglass insulation perimeter strips to the bed. This wall provides the surface to which the cover panel is cemented. The strips are 2 1/2" wide. The length depends on the size of the collector. Contact cement is used to adhere the strips to the insulation bed. See Figure 4.

3. Mount the insulation board bed on its supporting surface. The bed can be affixed directly to smooth supporting surfaces with ordinary roofing mastic. On surfaces that are irregular, such as shingled roofs, laying down a plywood frame and adhering the bed to the frame with roofing mastic is recommended.

B. Pressure-Testing the SUNMAT for Leaks

1. Pressure-test the tubing system for leaks using a portable air compressor, bicycle pump or canister of compressed air to pressurize the tubing to 40 PSI. One of the headers is supplied with a tank valve to facilitate testing for leaks.

Figure 4



Any leaks should make a hissing sound. Leaks are rare and are usually caused by improper connections between the SUNMAT tubing and the U-bends or headers. Leaks can be detected by applying soapy water and looking for bubbles. Leaks can be repaired by adjusting or replacing the Stimpson clamps. The tubing itself does not generally leak unless it has been damaged in shipment or handling. Leaks in the tubing are repaired with splicers from the repair kit in accordance with instructions in the section on Repairs and Maintenance.

C. Cementing the SUNMAT Grid to the Insulation Bed

1. Position the SUNMAT grid in place. The header end of the mat should be butted against the end border of the bed. If the mat is fairly short, it can be placed directly on the insulation. If it is long, it may be easier to roll it off the shipping roll and onto the insulation bed. The header and U-bend ends of the mat should be secured in place with a piece of foil-faced tape pressed down between each tube onto the foil-faced insulation board. Similarly, foil-faced tape should be used to hold the mat itself in place every four feet. See Figure 5.

2. Put three spacer blocks in place 12" apart every two feet. These blocks are made of 1 1/2" lengths of 1" EPDM hose. They are set in place between slightly spread tubes and held in place by the absorber cement (next step). See Figure 6.

3. Spray or brush the two-part absorber cement over the entire surface until the aluminum foil is completely blacked out. To insure a good bond the joint where the tubes and foil meet must be filled with adhesive. In mixing the two-part cement, directions on the can should be followed carefully.

4. At the side of the collector where the external plumbing connections are to be made, passageways for the connections should be cut through the perimeter strips and pipe nipples for the connections should be cut through the perimeter strips and pipe nipples extending through the perimeter wall should be installed. At this point in the construction process it is usually advantageous to hook up the sensor that measures the outlet temperature for the differential thermostat and any other valves or vents indicated. See Figure 7.

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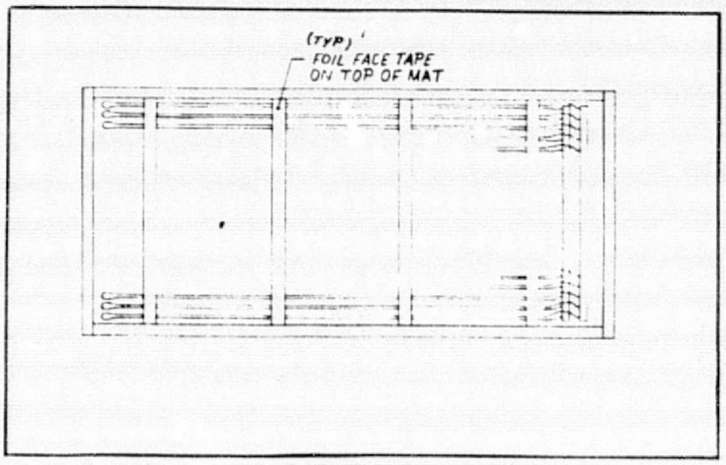


Figure 5

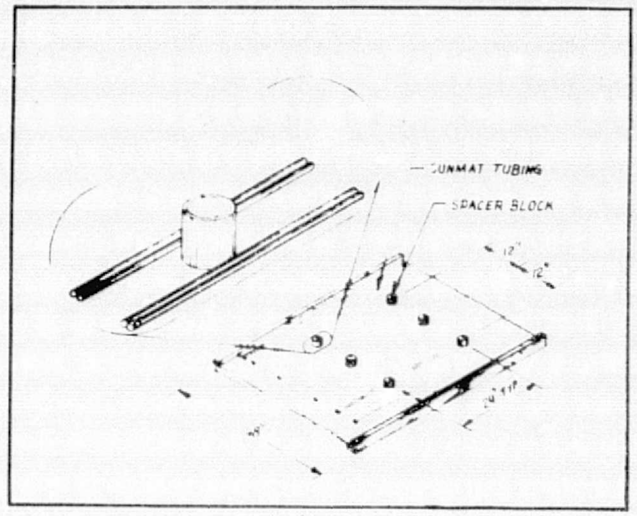


Figure 6

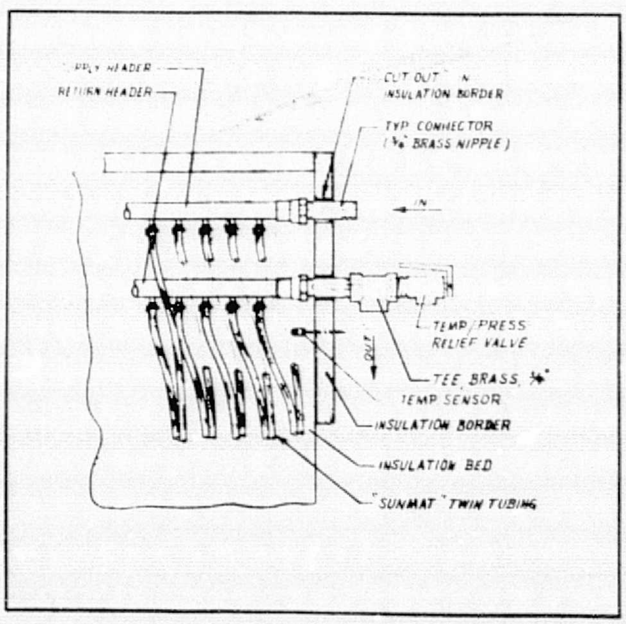


Figure 7

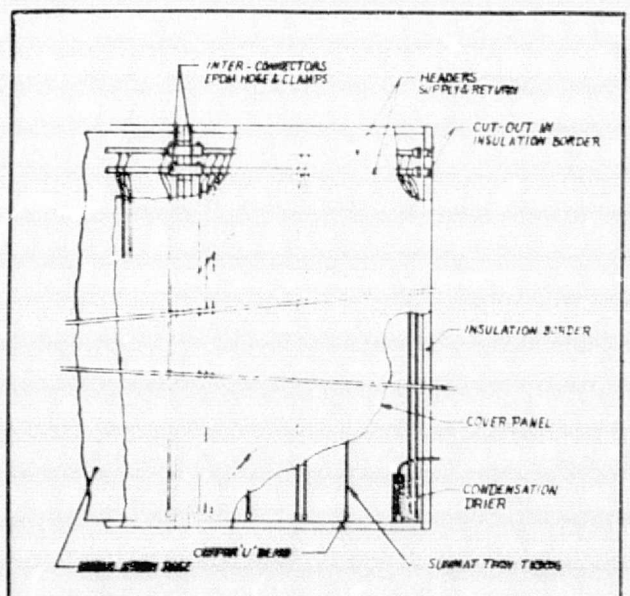


Figure 8

D. Dryer Tubes

1. Install one dryer tube for every 200 square feet of collector or fraction thereof. Dryer tubes are used to prevent the build-up of moisture condensation under the collector glazing. The dryer tube is installed along the outside perimeter by punching an outlet in the border strip with a screwdriver. See Figure 8.

E. Installing the Plastic Glazing

1. Apply a coat of contact cement to the top edge of the perimeter strip. Start from one end, then move to the sides and down the borders toward the opposite end, catching the spacer blocks as well. If the length of the collector is less than 12 feet, the contact cement can be applied in one step but if the length exceeds 12 feet, more than one step may be necessary since the cement dries quickly.

2. Place the end of the rolled up plastic glazing over the end of the collector coated first, and unroll the glazing. The glazing should be unrolled gradually, making sure that it is running square to the border. After it is completely unrolled, press it lightly against the border and spacer blocks to insure good bonding.

F. Waterproofing the Complete Collector

1. Waterproof the entire system by applying roofing mastic to all the exposed insulation, and to the 1" edge of the plastic glazing that overlaps the insulation board perimeter. Cement should be used liberally to make a seal around the header pipes and dryer tube where they come through the insulation board. Use masking tape on the glazing so as to make a straight edge between mastic and glazing.

IV. REPAIRS AND MAINTENANCE

A. General

1. No routine maintenance is required, but the collector should be checked at least annually for breakdowns in the system.

2. Rain should keep the collector cover relatively dirt-free. However, if dirt or dust accumulates, it may be necessary to hose and wash the cover. Normal wind and water gradually abrade the cover panel, and to insure optimum performance every five to seven years the panel must be spray-coated with Kal-Lac, a fast-drying liquid applied by roller, spray or brush.

3. Over time cracks may develop in the waterproofing, particularly in areas where the roofing mastic was put on too thin. These cracks can be easily repaired with fresh mastic.

4. Any leaks that may develop in the tubing system can be repaired with copper splicer tubes and Stimpson clamps from the repair kit. To make this type of repair a knife should be used to cut through the fiberglass border strips. After the cut is made, the cover can be lifted to expose the tubing. To repair the tubing the damaged piece should be cut out and a splicer tube put in its place and fastened with Stimpson clamps at either end. See Figure 11. Contact cement can then be used to cement the fiberglass back together. Finally a new coat of mastic should be applied to seal the collector.

5. Because of the small diameter of the SUNMAT tubing, capillary action prevents easy draining of the tubing. In the event the collector must be completely drained, air pressure must be used to force fluid out of the tubing grid.

6. Every several years flushing of the system may be advisable. Water run through the system at 40 PSI is generally adequate. Connections for flushing should be included at the time of installation.

7. Heat Transfer Fluids. Heat transfer fluids should be maintained in accordance with specifications provided by the manufacturer. The SUNMAT system is compatible with glycol anti-freezes. Contact CALMAC before using other anti-freezes.

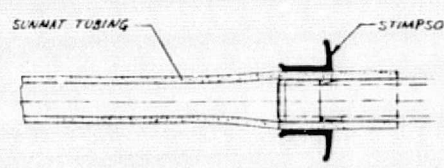
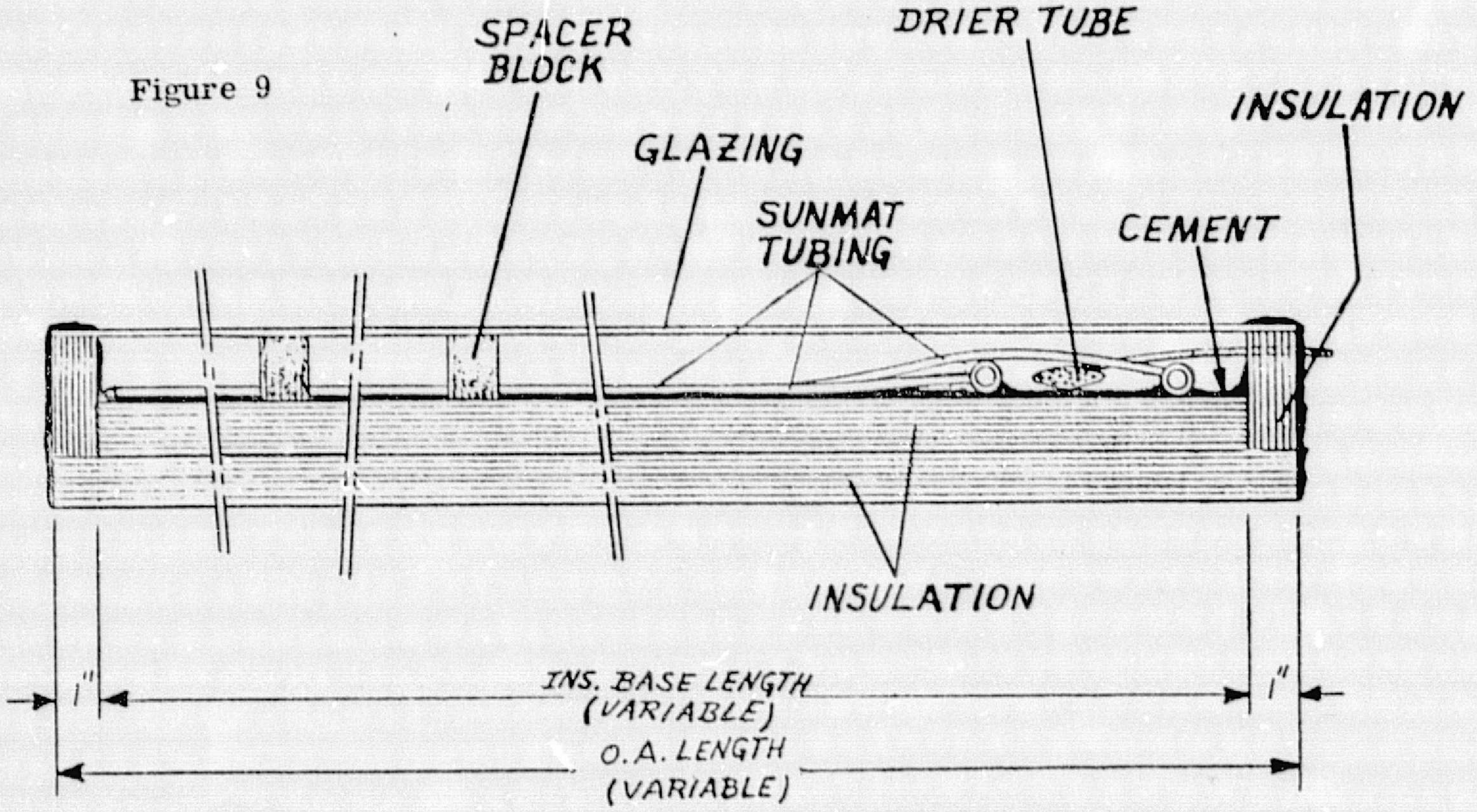


Figure 11

Figure 9



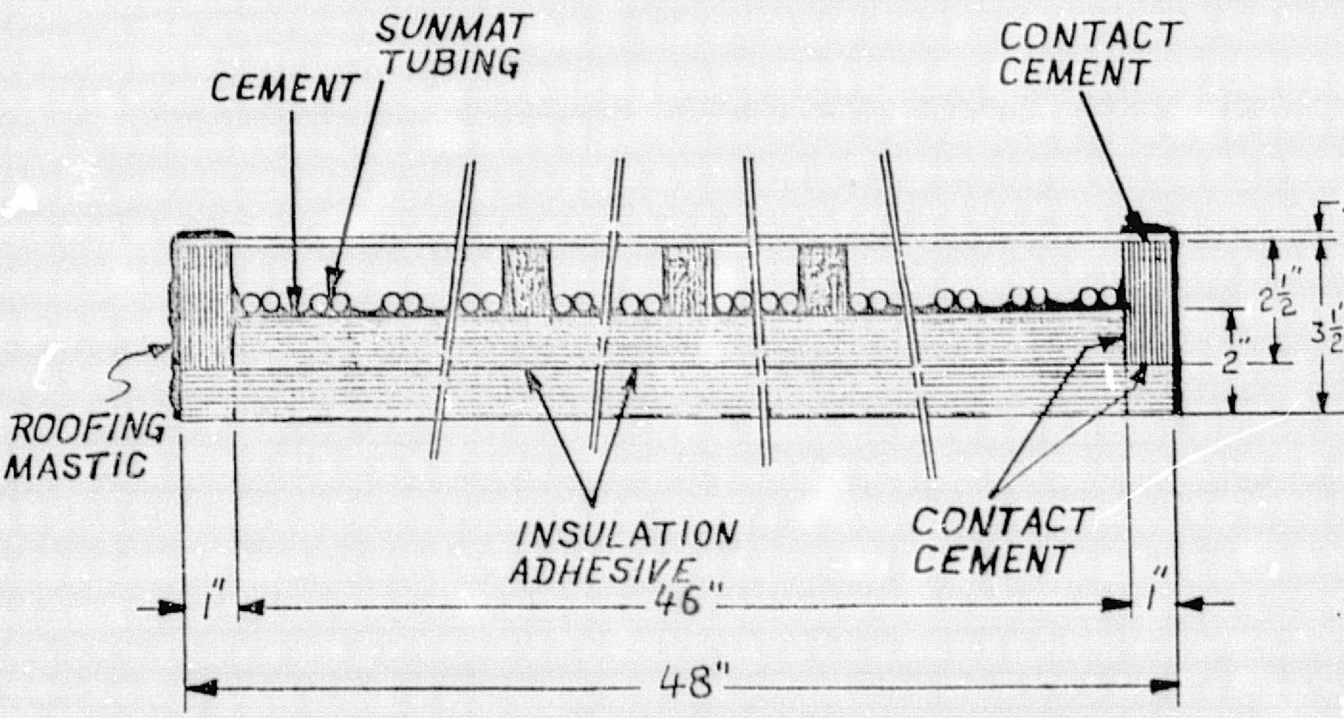


Figure 10

V. SPECIFICATIONS

PHYSICAL DATA:

Width: 4'
Length: Up to 50'
Depth: 3 1/2"
Weight (unfilled): 2.0 pounds/ft^2
Coolant Weight: .2 pounds/ft^2

MATERIALS:

Glazing: .025" guage fiberglass-reinforced polyester. 88% solar transmittance at 0^o, 78% at 45^o. Kalwall SUN-LITE Premium II or equivalent.

Absorber: 5/16" OD, 3/16" ID EPDM dual tubing spaced 1 1/2" on center bonded to insulation board with CAL-ZORB urethane cement. One gallon covers 40 square feet.

Headers: 3/4" x 42 1/2" type L copper pipe. External connections are 3/4" threaded pipe connections soldered to the pipe. Connections to the absorber tubing are 1/4" nipples soldered to the pipe every 1 3/8". Two headers per mat.

Desiccant: Silica gel in aluminum wire mesh tube. One dryer required for every 200 square feet of collector or fraction thereof.

Insulation: Fiberglass duct board, high temperature (350^{o}F), three pounds per cubic foot density, foil-faced, 1" thick. Owens-Corning Fiberglass 703 or equivalent.

Adhesives: Contact cement used to bond cover panel and perimeter walls to insulation bed, 3M 1300 Rubber Adhesive or equivalent. One gallon for every 130 square feet of collector. Adhesive used to waterproof the collector, roofing mastic. Adhesive used to bond insulation together, Foster 85-15 Stic-Safe Adhesive.

Coolant: Water or mixture of glycol and water. .03 gallons per square foot.

OPERATING DATA:

Flow Rates: .018 GPM per square foot of mat, minimum of 2.0 GPM.
Pressure Drop: .16 PSI per foot of length of mat, water.
.2 PSI per foot of length of mat, 40% ethylene glycol at 100^{o}F.
Temperature: Maximum operating temperature, 210^{o}F.
Maximum allowable tubing temperature, 350^{o}F.
Fluid Pressure: Maximum operating pressure, 20PSI. Tubing burst pressure, 80PSI.

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