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REPORT ON A STUDY TO UTILIZE THE ICAL APPARATUS FOR THE DETERMINATION OF THE EFFECTIVENESS OF FIRE RESISTANT DURABLE AGENTS

A.F. Grand

United States Department of Commerce
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Prepared for
U.S. Department of Commerce
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899

By
A.F. Grand
16015 Shady Falls Rd.
Elmendorf, TX

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William M. Daley, *Secretary*
Technology Administration
Gary R. Bachula, *Acting Under Secretary for Technology*
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Raymond G. Kammer, Director

Notice

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Report On
A Study to Utilize the ICAL Apparatus for the Determination of the Effectiveness of Fire Resistant Durable Agents

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Prepared for:

Mr. Dan Madrzykowski
Building 224, Room A-345
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899
301-975-6677

Abstract

A test protocol based on the Intermediate Scale Heat Release Calorimeter (ICAL) was developed to evaluate the potential fire retardant effects of water-based durable agents applied to wood siding. The protocol includes exposure of one meter square specimens of wood siding to one or more constant heat fluxes consistent with those from wildland fires. Specimens both untreated and treated with a fire-retarding gel were evaluated. Time delay to ignition of the treated specimen was the primary measured property, while mass changes prior to and during the fire exposure were also recorded.

The description of the test specimen and the results presented herein are true and correct to the best of our knowledge and within the bounds of normal engineering methods and techniques.

Tests Conducted By:

James R. Bundick
Test Engineer

Report Prepared By:

Arthur F. Grand, Ph. D.
Director of Research and
Principal Investigator

Approved By:

William E. Fitch, P.E. No. 55296

April 29, 1999
Date

INTRODUCTION

Wildland/urban interface fires are a unique problem in fire research and testing. Generally, fires in buildings start with fires from inside, rather than outside, the structure. One exception to this is NFPA 268 which deals with the issue of flammability of siding, usually in commercial buildings. In that test method, specimens are exposed to a 12.5 kW/m^2 radiant flux as though it were near a building on fire. The wildland fire environment is not normally considered in problems related to building, especially housing. While "permanent" fire retardant treatments and coatings exist, it would be impractical to treat the exteriors of all houses to be resistant to wildland fires. However, temporary treatments, such as water-based fire retarding agents, have been used to protect structures during wildland fires.

There are two primary means of attack on a structure by a wildland fire, radiant heat and burning brands. In the case of radiant heat, a heat flux above about 25 kW/m^2 will ignite wood structures, even without a distinct ignition source. Heat fluxes down to about 15 kW/m^2, in the presence of an ignition source, will also ignite wood structures. In the case of burning brands, these tend to collect in protected areas, such as under eaves and in corners. Allowed to burn, these brands could be sufficient to start a fire along the exterior of the house. Without any protection or treatment, the wood structure will continue to burn.

Recently, durable agents and water-based gels have been used to protect homes against the threat of wildland fires. Without any standards, or even very much research, it is difficult to demonstrate the efficacy of these agents. Internal research studies at BFRL/NIST included treatment of wood siding and exposure to moderately high intensity fire sources. The study described in this report is a preliminary program to determine the feasibility of using an existing standard test method to characterize the usefulness of temporary, spray-on fire retardant treatments for wood siding.

OBJECTIVE

The objective of this study was to assess the suitability of the apparatus known as the Intermediate Scale Heat Release Calorimeter (ICAL) for the evaluation of water-based fire retardant gels or other durable agents used to protect wood siding from ignition by a wildland fire. The creation of a standard test protocol, including a simulated drying exposure to hot sun and subsequently to the fire, would greatly facilitate the evaluation of competitive treatments, application methods and various substrates. This was a preliminary screening study to lay the basis for future test development and product evaluation.

TEST APPARATUS AND MEASUREMENTS

Certain modifications to the standard ICAL apparatus and test method (ASTM E1623) were performed. These included the following:

1) The specimen support frame was modified to permit presentation of the complete surface area of the specimen, both for treatment and for exposure to the radiant heat (see Figure 1).
2) An open-flame burner, adapted from another test method, was employed (Figure 2).
3) The ICAL radiant panel was calibrated to achieve the range of heat fluxes required, from a maximum of 25 kW/m^2 to as low as "Texas summer sun" heat fluxes (ca. 1 kW/m^2).
4) The actual fire exposure was conducted for as long as necessary to evaluate the efficacy of the coating.
5) The temperature and relative humidity in the area during the application, drying and fire exposure periods were recorded.

The primary measurements sought during these tests are listed below:

1. Initial weight of specimen
2. Weight pick-up after treatment
3. Mass loss rate during drying or during preliminary heat exposure (i.e., prior to ignition)
4. Time to smoke, ignition, full flaming over the surface of the specimen, and burn-through, under the selected fire exposure conditions
5. Observations of sustained flaming over the exposed surface, burning on the back side, and/or failure of the coating
6. Video tape and still photographs.

Heat release rate, the primary measurement obtained from the standard ICAL test procedure, was not determined in these experiments.

An apparatus in conformance with the principles of ASTM E1623 (but not in strict agreement with that standard – e.g., propane used instead of methane) had previously been constructed at our laboratories. This included an approximately 1.5 m x 1.5 m radiant panel, the means to calibrate heat flux as a function of distance, a load cell on a moveable cart that rides on a track, and an exhaust hood (although primarily for measurement of heat release rate, the hood in these experiments was simply for exhaust).

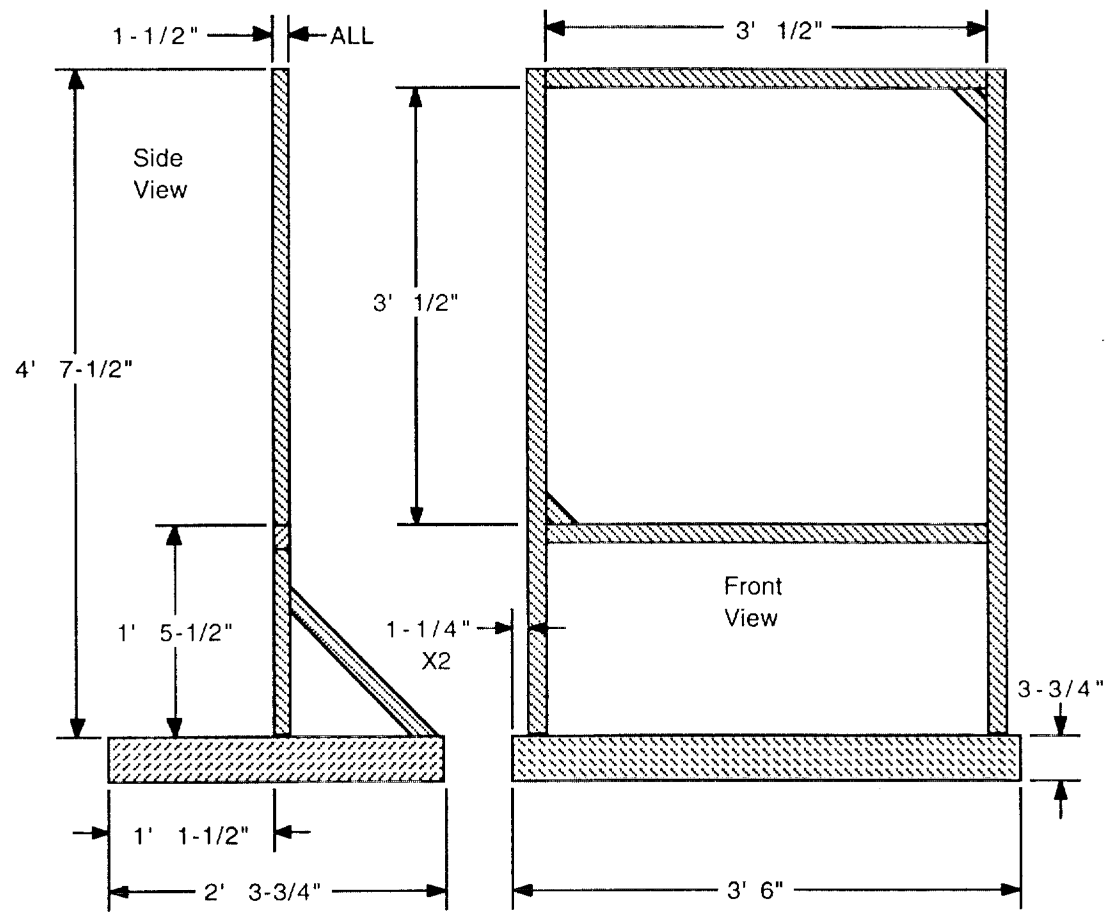


Figure 1. Specimen support frame for plywood siding

TEST PROCEDURE

The ICAL was calibrated at three heat fluxes and the distances of the specimens from the ICAL radiant panel were calculated for the heat fluxes of interest. An attempt was made to measure the radiant heat flux in the direct sun; however, we obtained little or no reading from our heat flux transducers. A heat flux of about 1 kW/m^2 was estimated from calculations of a black body at a temperature of 150-200 °F for a suitable "drying" exposure.

A propane "T" burner, from the standard mattress test method California Technical Bulletin 129, was used to ignite the specimens. The burner was positioned near the bottom of the specimen, and adjusted so that the flames were near, but not in direct contact with, the surface of the specimen (Fig. 2).

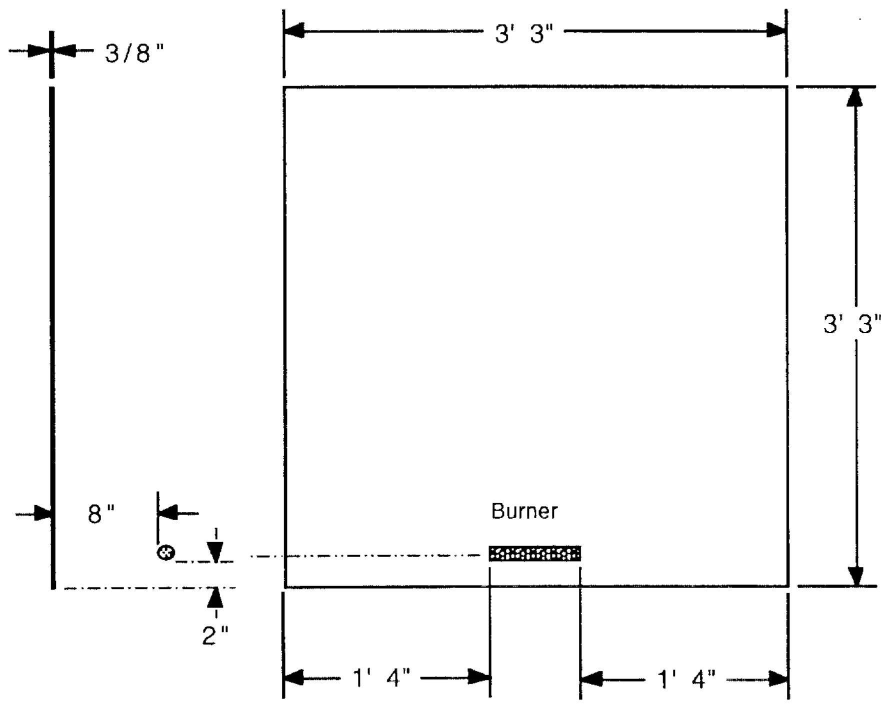


Figure 2. Location of ignition burner with respect to specimen, side view (left) and front view (right)

All but one of the specimens were sprayed outdoors. This was done in a protected area, with pavement and surrounding areas protected with plastic covers. The final treated specimen was sprayed while on the specimen support frame. The initial spray treatments were done in an area that was securely rigged to protect against excess spray. However, spraying the specimen in place on the support frame will be the preferred method for future tests. There were no means available to monitor the application rate of the treatment nor to judge the ratio of water to gel, factors that turned out to be critical to the performance of the system.

In case temperature and relative humidity affected the application and performance of the treatment, these measurements were taken at the drying and fire exposure locations.

Specimens were weighed before and after spray treatment and frequently enough during drying and heat flux exposure to be able to plot a smooth curve. The specimens were initially weighed on a calibrated load cell in a conditioned area, then on the load cell used for the ICAL experiments. Differences in the weights were "corrected" back to the initial weight. The specimens were treated with spray, reweighed, then exposed to the radiant heat protocol.

Drawings of the specimen support frame and the positioning of the igniter with respect to the specimen are shown in Figures 1 and 2. The frame was constructed of angle iron in such a way that the entire front face of the specimen was available for spray treatment and for exposure to the radiant heat flux (the standard ICAL specimen support frame masks the edges of the specimen). Photographs of specimens mounted in place are included in Appendix C.

MATERIALS

The following materials were used in this study:

- Plywood siding: T1-11, 10 mm (3/8 in.) thick, obtained locally (Home Depot)
- Red latex exterior flat paint: obtained locally (Home Depot); a single, heavy coat of stain was applied
- "Barricade®" Fire-Blocking Gel concentrate: supplied by Fire Protection, Inc., Jupiter FL (contact: John Bartlett, 561/575-6055)
- Delivery system for the gel was a "Home Protection AtakPak": supplied by Fire Protection, Inc.; this included a nozzle, hose, eductor and quick disconnect. The system aspirated the gel into a water stream and delivery of the diluted gel was through an adjustable water spray nozzle.

Certain equipment or materials are identified in this report. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment or materials identified are necessarily the best available for the purpose.

RESULTS

The results are presented in the following formats:

- Table 1. Summary of results on plywood siding (including treatment, drying time, exposure flux, time to ignition)
- Table 2. Mass pickup and loss for plywood specimens (including initial mass of specimens, pickup due to spray treatment, loss due to drying, and mass loss rate during heat flux exposure)
- Notes and observations on the wood siding experiments are located in Appendix A
- Plots of mass v. time for all experiments are in Appendix B
- Still photographs are in Appendix C, with an index to the photos
- A video tape of two experiments (Experiments No. 9 and 10) is enclosed

The additional heat flux due to the ignition burner was estimated by measuring the heat flux at two locations in the calibration board with and without the burner present. The results are shown below:

Location of measurement	heat flux without igniter, kW/m^2	heat flux with igniter, kW/m^2	Apparent increase in flux
Bottom row, center	22.1	31.8	44 %
2^{nd} row, center	19.5	25.3	30 %

Of course, the "total heat flux" transducers may not accurately reflect the combination of radiant and convective fluxes at those locations, but these readings provide some information on the increase in flux due to the igniter. The igniter did not impinge on the surface of the specimen. The position of the igniter is shown in Figure 2, and in photographs in Appendix C.

Table 1. Summary of Results on Plywood Siding

Expt. No.	Date (1999)	Wood[1]	Treat-ment[2]	Drying Flux[3] (kW/m^2)	Drying Time[4] (min.)	Exposure Flux[5] (kW/m^2)	Time to Ign.[6] (s)	Notes[7]
1	3/16	U	none	1	short	25	614	a
2	3/16	U	none	1	short	25	74	
3	3/16	U	water	1	short	25	125	
4	3/16	U	gel	1	60	25	211	
5	3/17	S	none	1	short	25	525	a
6	3/17	S	none	1	short	25	82	
7	3/17	S	water	1	short	25	91	
8	3/17	U	gel	1	short	25	1092	b, c
9	3/17	S	gel	1	short	25	923	c
10	3/17	S	gel	1	short	25	941	c
11	3/18	U	none	1	short	15	221	
12	3/18	S	none	1	short	15	134	
13	3/18	U	water	1	short	15	200	
14	3/18	S	water	1	short	15	171	
15	3/18	U	water	1	60	15	85	

Notes for Table 1:

1) Only two types of specimens were included in this study, unstained (U) and stained (S) T1-11 textured plywood siding. The stain was a single, heavy coat of a red, exterior latex stain.
2) The treatment protocols were as follows: "none" – no treatment of wood specimen; "water" – water spray from hose/nozzle; "gel" – water-based gel mixture using same nozzle and pressure as water treatment.
3) The drying flux was estimated from a plot of calibration heat flux vs. distance.
4) "Short" exposure to drying flux means less than 5 min. (time to mount specimen and obtain load cell reading).
5) The exposure flux was interpolated from a plot of calibration heat flux vs. distance.
6) Time to ignition after specimen was in place at the exposure flux.
7) Notes on specimen performance:
   a) No ignition burner used
   b) Same panel used previous day for unsuccessful application of gel.
   c) Ignition did not cover surface of panel and was not sustained for more than about 10 s. Flames died down and came back again repeatedly (see results of individual tests).

DISCUSSION

During the course of this brief study, a suitable protocol was established for evaluating temporary, water-based, spray-on fire retarding products for wood or plastic siding, and some successful tests were performed. However, difficulties in spraying this particular gel evenly and at the proper rate limited the number of experiments conducted with the gel. The spray problems were due in part to low water pressure (approximately 30 psi), but also due to a lack of any kind of indicator of quantity of product delivered. Indicators of quantity of product delivered may not be essential in the "field," especially in an emergency situation, but for research and development purposes it should be a requirement for any further studies. Tests on the product were stopped because of lack of control over delivery. Subsequent tests in this program were aimed at establishing and verifying the method.

Due to the experimental difficulties applying the gel, only 4 of the 15 tests were conducted with the product applied to wood specimens. The application was very irregular – sometimes very thin, other times extremely thick. Also, the gel sometimes would fall off in the corners when the panels were moved (three of the four specimens were sprayed outdoors, the fourth was sprayed in place on the specimen support platform). Any spots that were not covered adequately were the first to burn through and caused termination of the test before the gel coating failed to protect the substrate (except in test #4, the first coated specimen, where the coating was very thin and the wood did ignite through the coating).

In Table 2, the mass data are presented. Shown are the initial masses of the plywood specimens, the mass pickup due to treatment and the average mass loss rate for the period of exposure prior to ignition. The pickup from water alone on untreated wood was about 1 lb. (0.5 kg), except for test #15 which was sprayed for longer and picked up 2 lb. (0.9 kg). The pickup for stained wood was only about 0.5 lb. (0.2 kg). The mass of gel plus water ranged from 4.6 lb. (2.1 kg) to 55.1 lbs. (25.0 kg). These translate to a range of 0.4 lbs./ft^2 to 5.1 lbs/ft^2. No guidance was given for the application rate of the gel. However, the lower treatment rate obviously did not perform very well, and the higher treatment rate was almost certainly too much. More information on the water/gel ratios and the desired application rates will have to be determined through future studies.

Table 2. Mass Pickup and Loss for Plywood Specimens with Various Treatments

Exp. No.	Wood[1]	Treat-ment[2]	Mi[3], lb	(kg)	Mt[4], lb	(kg)	ΔM[5], lb	(kg)	Avg. MLR[6] (g/s)
1	U	N	12.7	(5.75)	12.7	(5.75)	----	----	7.1
2	U	N	11.4	(5.18)	11.4	(5.18)	----	----	2.3
3	U	W	12.7	(5.74)	13.7	(6.22)	1.0	0.5	2.9
4	U	G	11.2	(5.10)	15.8	(7.19)	4.6	2.1	6.2[7]
5	S	N	12.5	(5.66)	12.5	(5.66)	----	----	8.6
6	S	N	12.1	(5.47)	12.1	(5.47)	----	----	2.7
7	S	W	11.3	(5.15)	11.8	(5.36)	0.5	0.2	3.0
8	U	G	11.3	(5.13)	41.8	(18.98)	30.5	13.9	7.2
9	S	G	12.3	(5.60)	67.5	(30.62)	55.1	25.0	8.4
10	S	G	11.4	(5.17)	42.7	(19.37)	31.3	14.2	7.7
11	U	N	11.5	(5.22)	11.5	(5.22)	----	----	1.1
12	S	N	11.0	(4.98)	11.0	(4.98)	----	----	1.4
13	U	W	11.1	(5.04)	12.2	(5.52)	1.0	0.5	2.8
14	S	W	11.4	(5.19)	11.9	(5.42)	0.5	0.2	4.3
15	U	W	12.3	(5.56)	14.2	(6.46)	2.0	0.9	1.5[7]

NOTES:
1) U = unstained plywood; S = stained plywood
2) N = no treatment; W = water only; G = water plus gel
3) Mi = initial mass of plywood
4) Mt = mass of specimen after treatment, before exposure
5) ΔM = mass pickup due to treatment
6) MLR = average mass loss rate during heat flux/ignition exposure
7) MLR for Specimens #4 and #15 during the 60-min. "drying" periods were 0.18 g/s and 0.09 g/s, respectively.

Despite the experimental difficulties encountered and the limited number of tests conducted, the gel seems to have significant potential for protecting wood structures from igniting under moderate radiant heating conditions. However, with so little control over the application of the gel, some of the test runs were conducted with much more product than would normally be used. Thus, the true nature of the protective action was not adequately evaluated in this series of tests.

Table 3. Summary of Times to Ignition Results for Various Treatments and Substrates

Heat Flux (kW/m^2)	Condition or Treatment	t_{ig} (s) Unstained	t_{ig} (s) Stained
25	no treatment, no pilot	614	525
25	no treatment, pilot	74	82
25	water	125	91
25	gel (light), dry 60 min.	211	
25	gel (heavy to mod. heavy)	1092*	923*, 941*
15	no treatment, pilot	221	134
15	water	200	171
15	water treatment, dry 60 min.	85	

T_{ig} = time to ignition (sustained for at least 10 s, unless otherwise noted)
* "sustained" ignition was achieved, but flaming went out quickly and never progessed to full flaming across the surface.

CONCLUSIONS AND RECOMMENDATIONS

1. The ICAL apparatus is suitable for evaluating the response to heat and flame of wood siding (and potentially other substrates) with various applied surface treatments.

2. The repeatability of ignition on untreated wood with or without a pilot ignition burner was satisfactory.

3. Water spray treatment produced a measurable, but relatively small, effect which may permit it to serve as an internal laboratory standard for the protocol.

4. Drying at a low heat flux for up to an hour (or at room temperature conditions for as long as desired), prior to higher heat flux exposure, is achievable. Drying has a measurable effect on water treatment and presumably would have an influence on certain spray treatments.

5. Tests at both 25 kW/m^2 and 15 kW/m^2 heat flux were conducted with satisfactory results. At the lower flux, compared to the higher one, times to ignition were longer and the effect of simple water treatment became negligible (due to the extended time prior to ignition). Possibly, the lower flux will be useful for screening the lower performance agents, while the higher flux will be preferred for the "better" performers.

5. Unstained wood had a higher water pick-up than stained (painted) wood (approximately 0.5 kg/1.0 lb. vs. 0.2 kg/0.5 lb. for this study). As a result, the wet, unstained wood had a somewhat longer time to ignition than the comparable stained wood at a heat flux of 25 kW/m^2. It is unclear whether this effect will be important for any water-based fire retardant treatments.

6. Use of the "Barricade" gel treatment in this preliminary program produced some promising results. Further tests must have better control over the application rate (i. e., both water and gel).

7. While most of the specimens were sprayed in a remote area and then moved to the specimen support frame, a few specimens were treated while mounted on the frame. The latter setup is recommended as the preferred procedure for future tests.

8. Placement of thermocouples between the gel coating and the wood surface should be considered for future tests in order to provide input for modeling and for prediction of the efficacy of the coating as a function of coating thickness.

9. Measurement of heat release rate was not done for these tests, nor does it seem to be necessary for future experiments of this type. In order to measure any substantial HRR over that of the radiant panel and igniter, the specimen would have to be burning vigorously, which means the coating has failed. This is easy to detect visually and to quantify.

APPENDIX A

Observations on Tests

NOTES ON WOOD SIDING/ICAL EXPERIMENTS FOR NIST
OPL Project No. 15933-103926

Experiment No. 1: Unstained plywood, no treatment (ignition burner off)
116 °F, 28% R.H. (before radiant panel was on, 68 °F, 47 % R.H.)

Time (min:s)	Corr. Time	Observations
0:00	0:00	specimen in position: Start Test
0:09	0:09	Smoke
0:27	0:27	Darkening
0:45	0:45	More darkening
2:00	2:00	Sample completely dark
5:00	5:00	Small embers
6:21	6:21	Darkening back
6:48	6:48	Smoke back
8:22	8:22	Warping
9:30	9:30	Lower right hand fire
10:14	10:14	Ignition

Experiment No. 2: Unstained plywood, no treatment (ignition burner on)
99 °F, 33% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:19		Move
0:40	0:00	In place: Start Test
0:52	0:12	Smoke
1:21	0:41	Darkening
1:54	1:14	ignition
2:24	1:44	Terminate test

Experiment No. 3: unstained plywood, treated with water
99 °F, 33% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
1:24		move specimen
1:45	0:00	in position: Start Test
1:50	0:05	smoke or steam?
1:65	0:20	Photo 1-17
2:20	0:35	Photo 1-18
2:45	1:00	Blackening of surface
3:08	1:23	Photo 1-19
3:15	1:30	more blackening, smoke
3:50	2:05	Ignition, photo 1-20
4:00	2:15	end test

Experiment No. 4: unstained plywood, treated with gel
99 °F, 33% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Start watches (after 60 min. drying period)
0:17	0:00	in position: Start Test
:25	0:08	Photo 2-1
:29	0:12	Photo 2-2
1:10	0:53	Photo 2-3
1:15	0:58	small charred spot near bottom
1:30	1:13	slight smoke
1:40	1:23	charring near top
2:00	1:43	Photo 2-4
2:30	2:13	more significant discoloration
3:13	2:56	transient ignition
3:35	3:18	transient ignition
3:48	3:31	ignition (sustained even with igniter off)
3:55	3:38	Photo 2-5
4:30	4:13	end test (still burning)

Experiment No. 5: Stained plywood, no treatment (ignition burner off)
99 °F, 33% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:07		Move
0:23	0:00	In position: Start Test
0:40	0:17	Smoke
1:10	0:47	More smoke
2:11	1:48	Sig. Darkening
3:58	3:35	Very dark
5:12	4:49	Warping
8:00	7:37	Embers falling
8:40	6:17	Craking
9:08	8:45	Ignition

Experiment No. 6: Stained plywood, no treatment (ignition burner on)
99 °F, 33% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
1:18		Move
1:35	0:00	In place: Start Test
2:45	1:10	Significant darkening
2:57	1:22	Ignition

Experiment No. 7: stained plywood, water treatment
99 °F, 33% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:53		Move specimen
1:07	0:00	In position: Start Test
1:27	0:20	Smoke
2:38	1:31	Ignition

Experiment No. 8: unstained plywood, same board as unsuccessfully tried yesterday, gel treatment (modified eductor to increase hole size) to 1/2-3/4 in. thickness
99 °F, 33% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:13		Move specimen
0:28	0:00	In position: Start Test
0:55	0:27	Some steam or smoke
7:00	6:32	Small charred area (bottom) where coating had fallen off during move
10:00	9:32	Some darkening of foam
12:00	11:32	More smoke
16:00	15:32	Smoke increasing
18:00	17:32	Parts of surface bubbling and blackening
18:40	18:12	Ignition of about 1/2 of surface (in the center)
19:00	18:32	Flames dying down (a few remaining at bottom)
19:55	19:27	Re-ignition
20:08	19:40	Flames on back (spot at bottom)
21:30	21:02	Still only transient burning, mostly near igniter
22:50	22:22	Another spot on back flaming, bottom center
23:20	21:52	Further ignition on face
24:00	23:32	A lot more smoke, flaming
24:40	24:12	More burning on back side (burn through, bottom center)
24:50	24:22	Terminate test

Experiment No. 9: stained plywood, gel applied to about 1 to 2 in.thick (video tape of test)
91 °F, 43% R.H.

Time (min:s)	Corr. Time	Observations
0:00		start watches (specimen in place for several minutes)
		photo of specimen mounted, 2-9
1:07		move specimen
1:21	0:00	in position: Start Test
2:00	0:39	Photo 2-10
2:18	0:57	Photo 2-11
3:10	1:49	Photo 2-12
4:18	2:57	photo (from rear) 2-13w
6:40	5:19	some surface blackening. No smoke
7:30	6:09	Photo 3-1
9:30	8:09	photo 3-2
10:40	9:19	smoke
11:20	9:59	blackening on surface of foam
14:00	12:39	some incr in smoke, further blackening in center, bottom pieces charred (gel fell off of spots)
16:00	14:39	Photo 3-3
16:44	15:23	ign, died down very fast
17:00	15:39	most flaming gone, except along bottom
17:30	16:09	smoke from back of specimen
19:00	17:39	Photo 3-4, very little flaming except near bottom of specimen
21:00	19:39	further ign., out within about 20 s, still burning at bottom
23:30	22:09	blackening on back side (bottom)
23:45	22:24	some flame extension beyond igniter
24:55	23:34	some flame extension
25:20	23:59	more flaming, up to top in spots
25:40	24:19	flames on back
26:30	25:09	photo 3-5 backside (no flash)
26:40	25:19	photo backside 3-6
27:15	25:54	flaming to top in center, sig. flaming back side
27:30	26:09	end test
		estimate of specimen HRR – less than igniter (18 kW)

Experiment No. 10: stained plywood, treated with gel to about 1/2 in. thick (spray performed with specimen mounted on load cell), video tape of test
91 °F, 43% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
1:06		move specimen
1:19	0:00	in position: Start Test
1:40	0:21	Video start
2:30	1:11	Photo 3-10
3:20	2:01	Photo 3-11
4:05	2:46	photo backside 3-12
4:45	3:26	photo (vertical) 3-13 – last on roll
7:40	6:21	some blackening on the surface of the foam
9:50	8:31	gaps in foam in spots – center of specimen
11:10	9:51	smoke
12:00	10:41	spots in center have turned black
16:00	14:41	transient ignition (out in about 10 s)
17:00	15:41	further flaming
17:40	16:21	substantially more smoke
18:45	17:26	spotty flaming in "bare" spots, but not sustained
20:05	18:46	more flaming, out in about 10 s)
22:05	20:46	blackening on back side in spots near center
22:10	20:51	flaming over the top, transient
23:00	21:41	flaming comes and goes
23:45	22:26	smoke on back side
25:00	22:41	flaming still mostly in center
25:50	24:31	more smoke
26:18	24:59	shut off igniter, flames almost immediately out
26:50	25:51	small glowing hole through back side
27:10		end of test

Experiment No. 11: unstained, plywood, no treatment
78 °F, 67% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:15		Move specimen
0:35	0:00	In position: Start Test
0:57	0:22	Smoke
2:00	1:25	Dark
3:11	2:36	Very dark
4:16	3:41	Ignition

Experiment No. 12: stained plywood, no treatment
78 °F, 67% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:07		Move specimen
0:19	0:00	In position: Start Test
0:35	0:16	Smoke
2:33	2:14	Ignition (ignition at center)

Experiment No. 13: unstained plywood, treated with water (1 min. spray)
98 °F, 40% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:06		Move specimen
0:18	0:00	In position: Start Test
0:37	0:19	Steam (smoke?)
1:57	1:39	Darkening
3:05	2:47	Very dark
3:38	3:20	Ignition

Experiment No. 14: stained plywood, treated with water (1 min. spray)
98 °F, 40% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Mount specimen
0:05		Move specimen
0:15	0:00	In position: Start Test
0:29	0:14	Steam & smoke
1:33	1:18	Darkening
3:06	2:51	Ignition (starts at center)

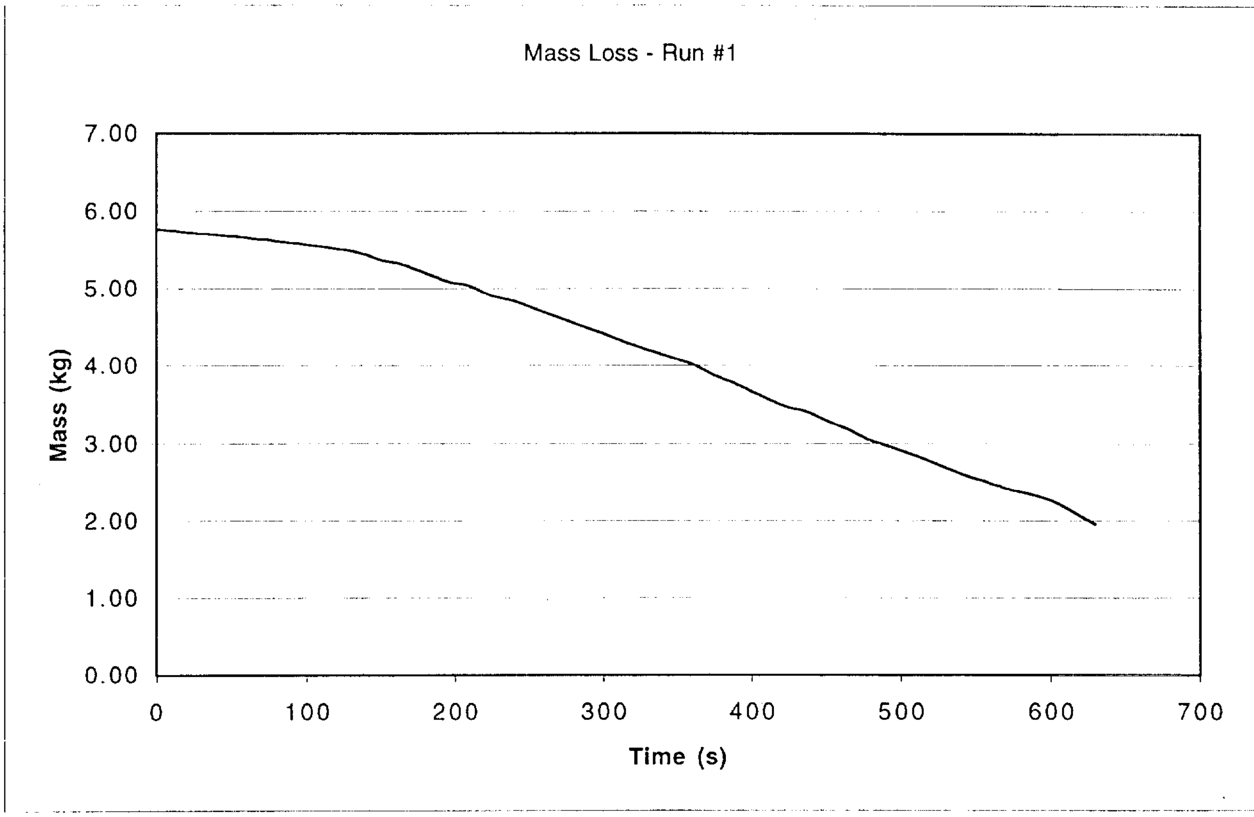
Experiment No. 15: unstained plywood, treated with water, dry for 1 hr.
98 °F, 40% R.H.

Time (min:s)	Corr. Time	Observations
0:00		Start watches
1:05:54		Move specimen
1:06:10	0:00	In position: Start Test
1:06:51	0:40	Darkening
1:06:59	0:49	Smoke
1:07:35	1:25	Ignition

APPENDIX B

Mass Loss Plots

OPL Project No. 15933-103926



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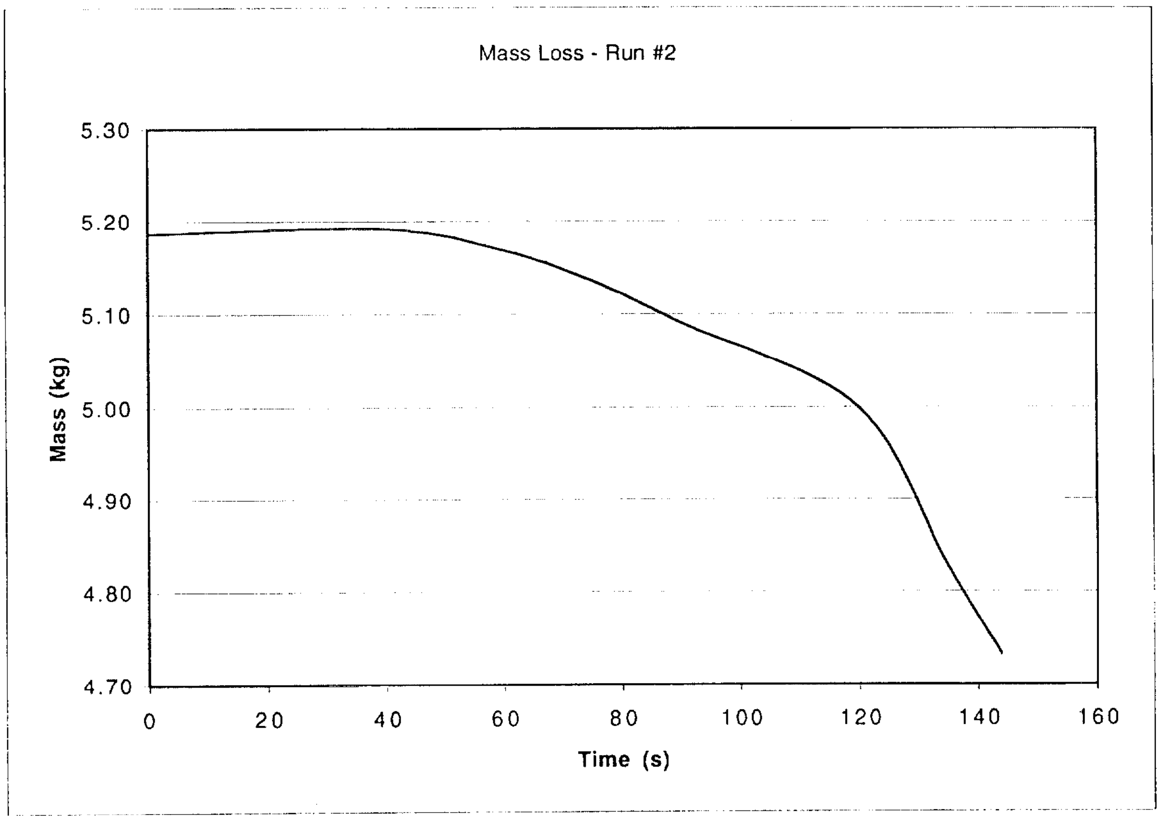

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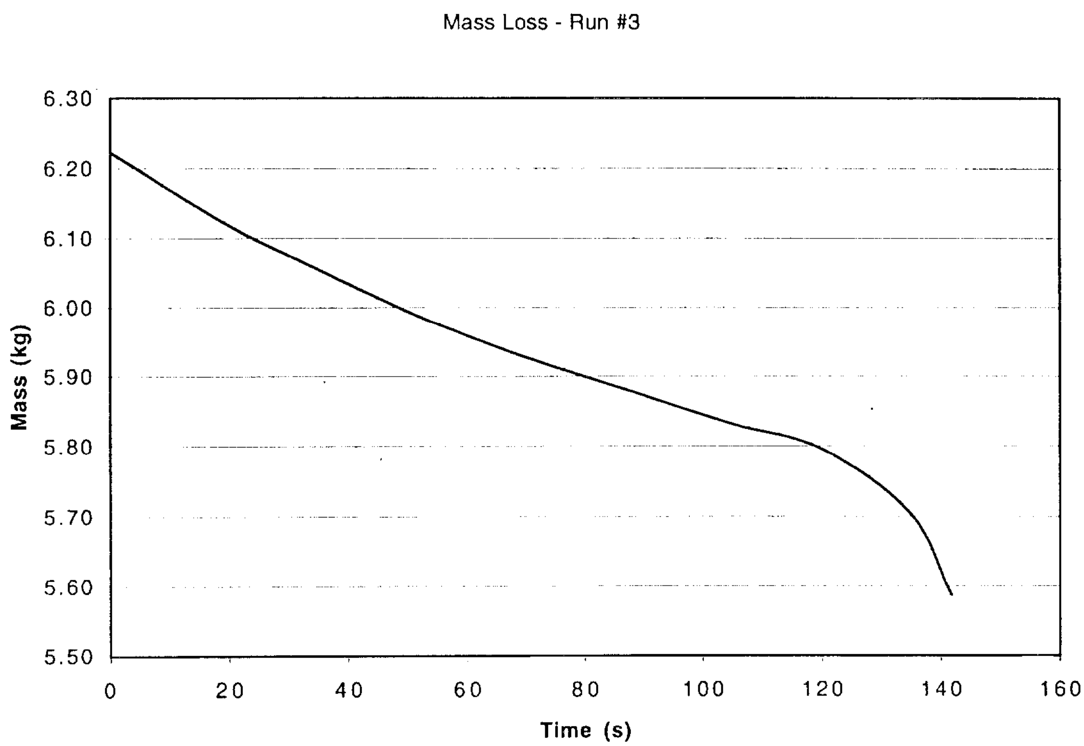

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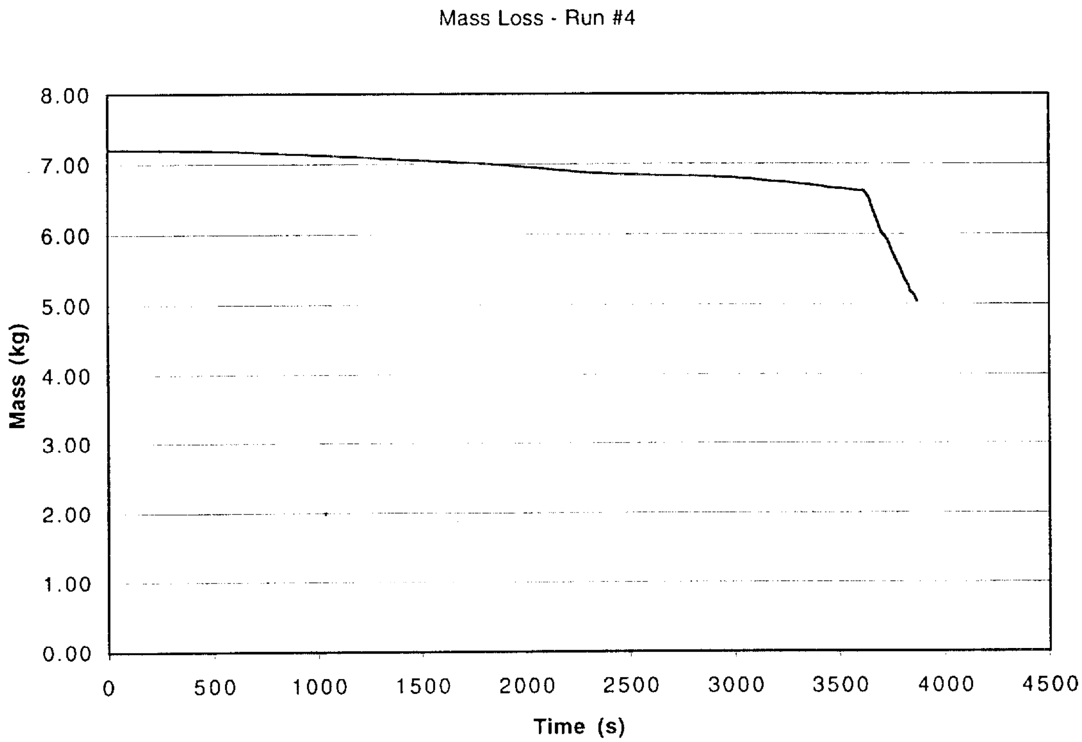

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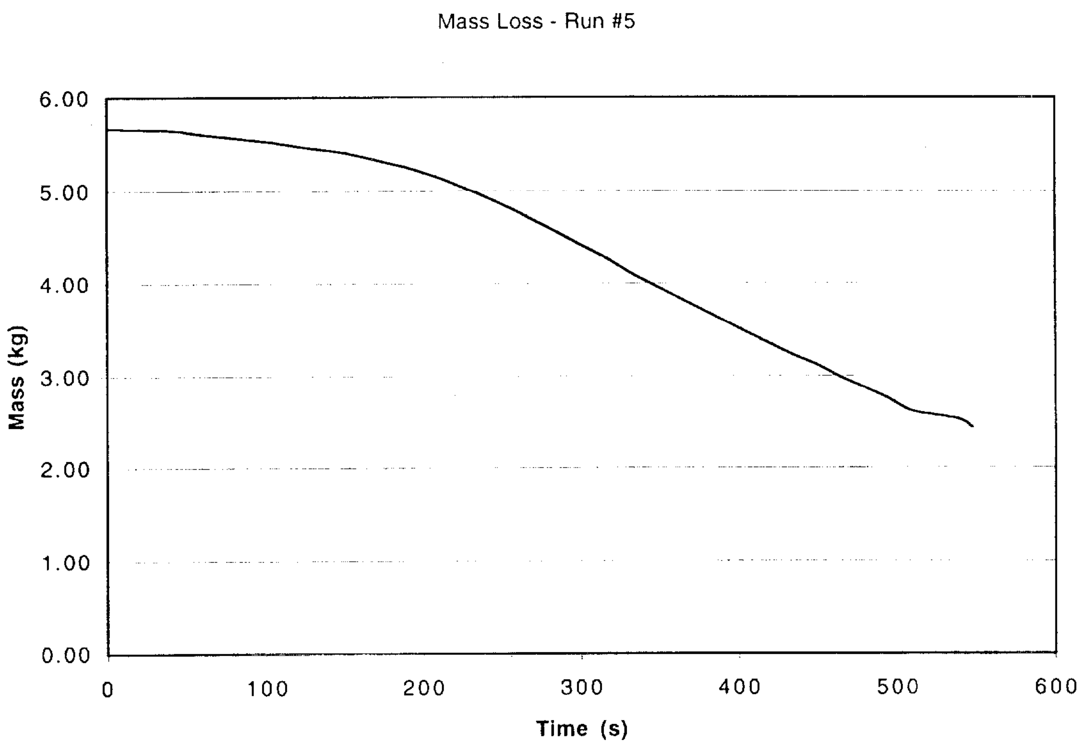

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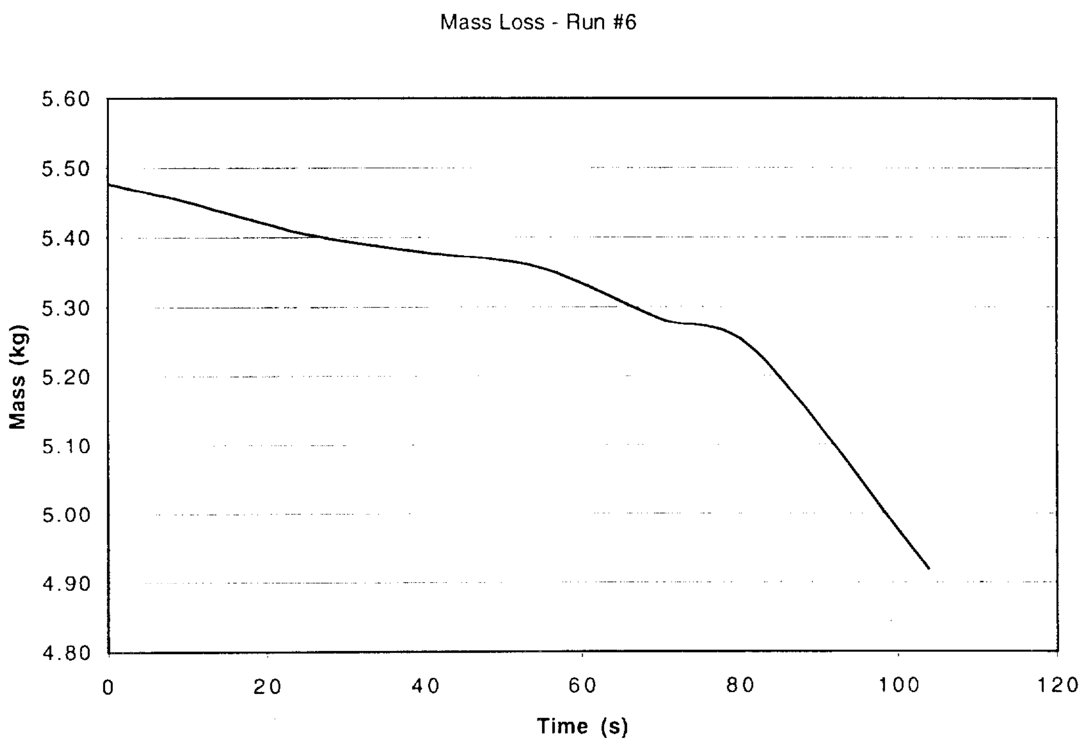

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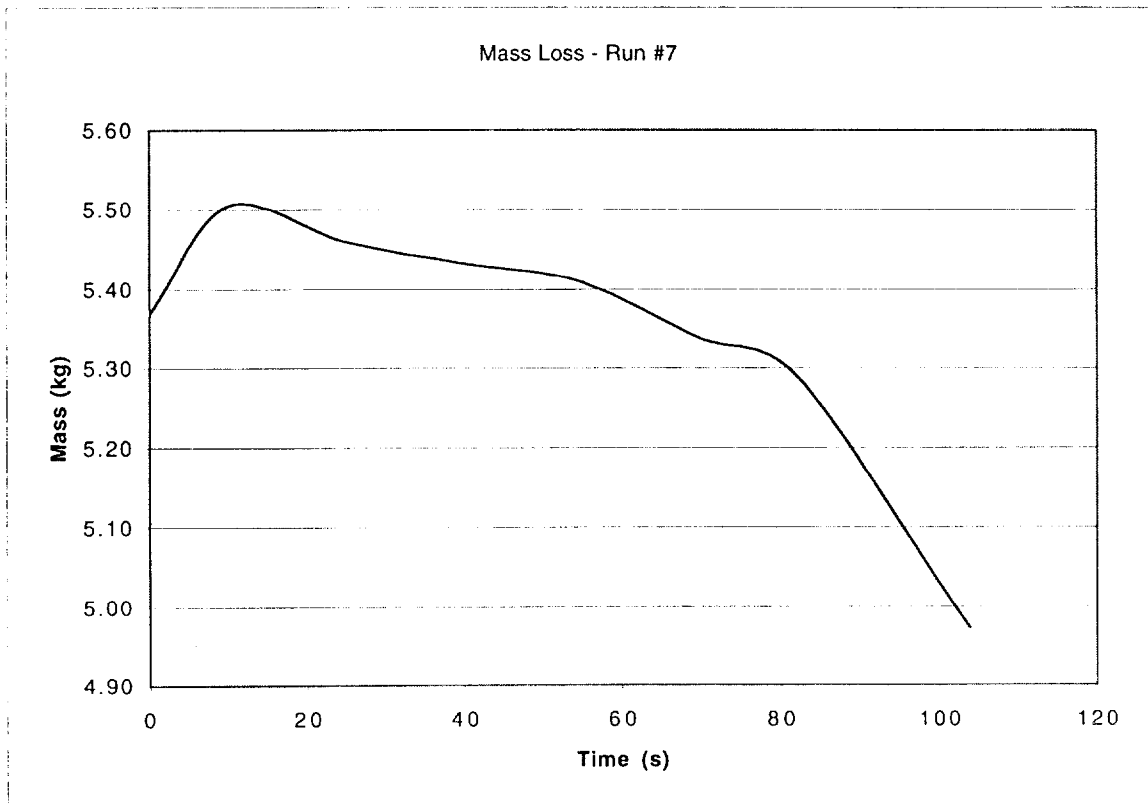

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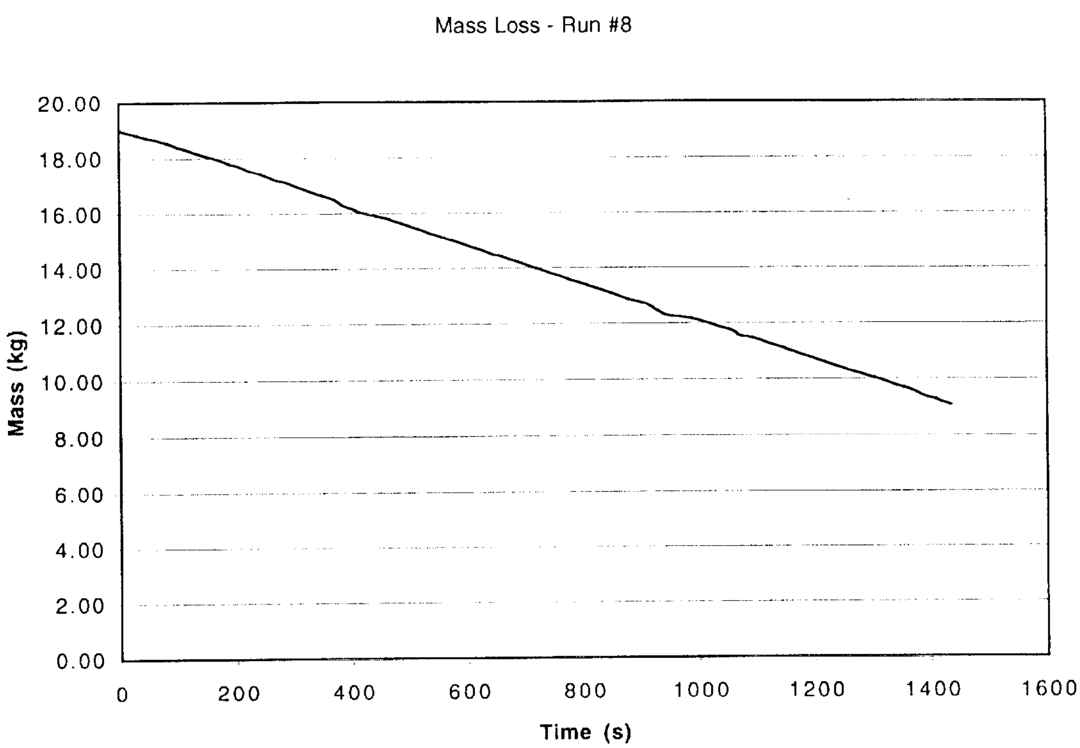

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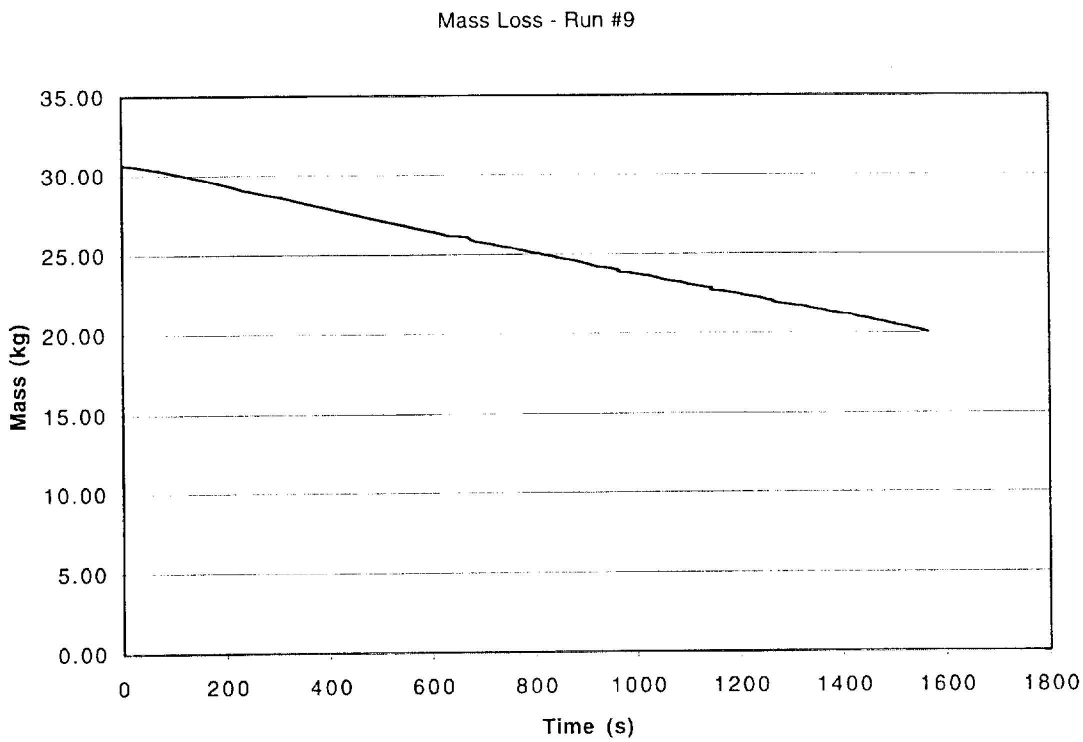

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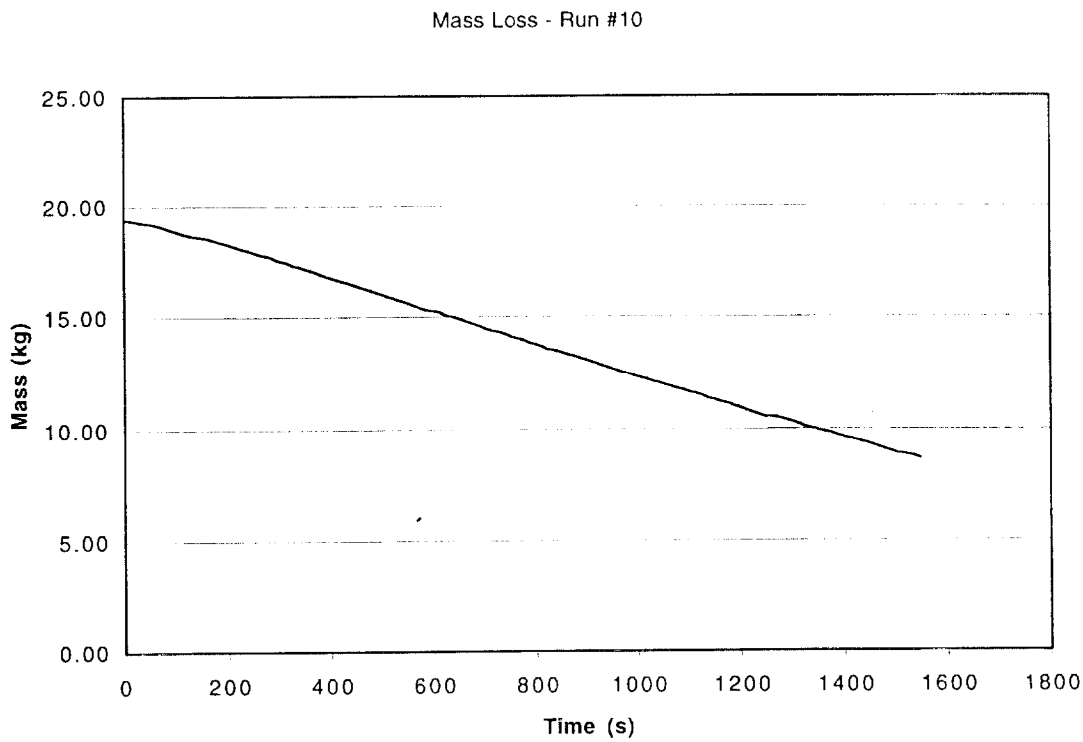

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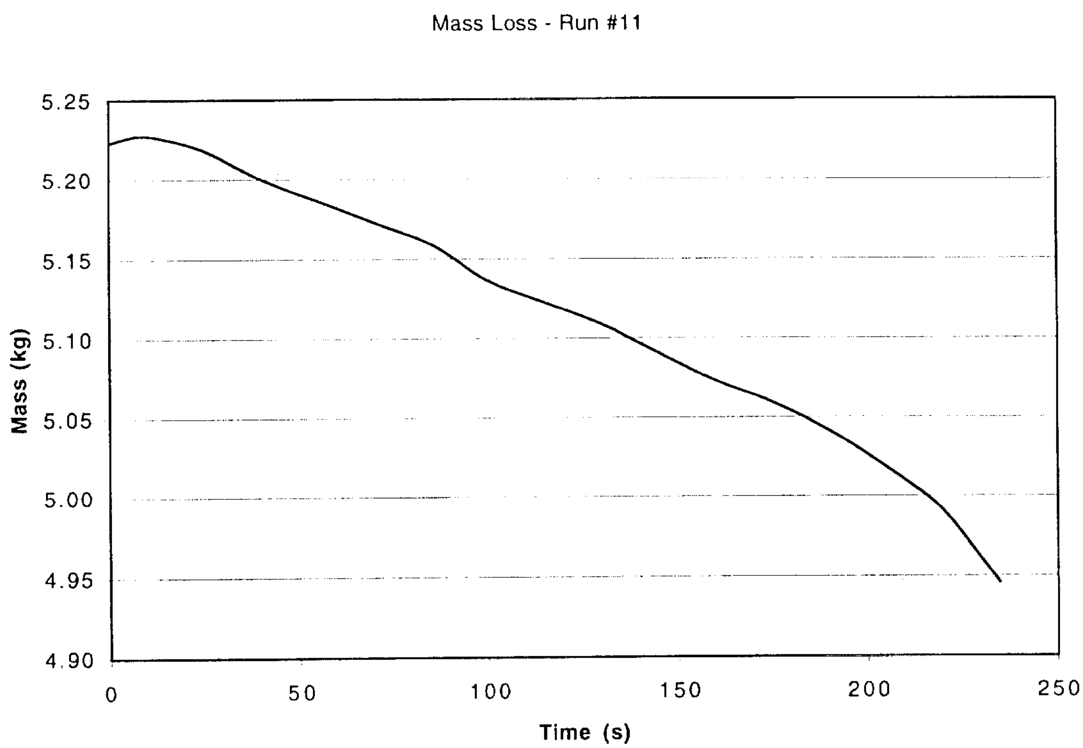

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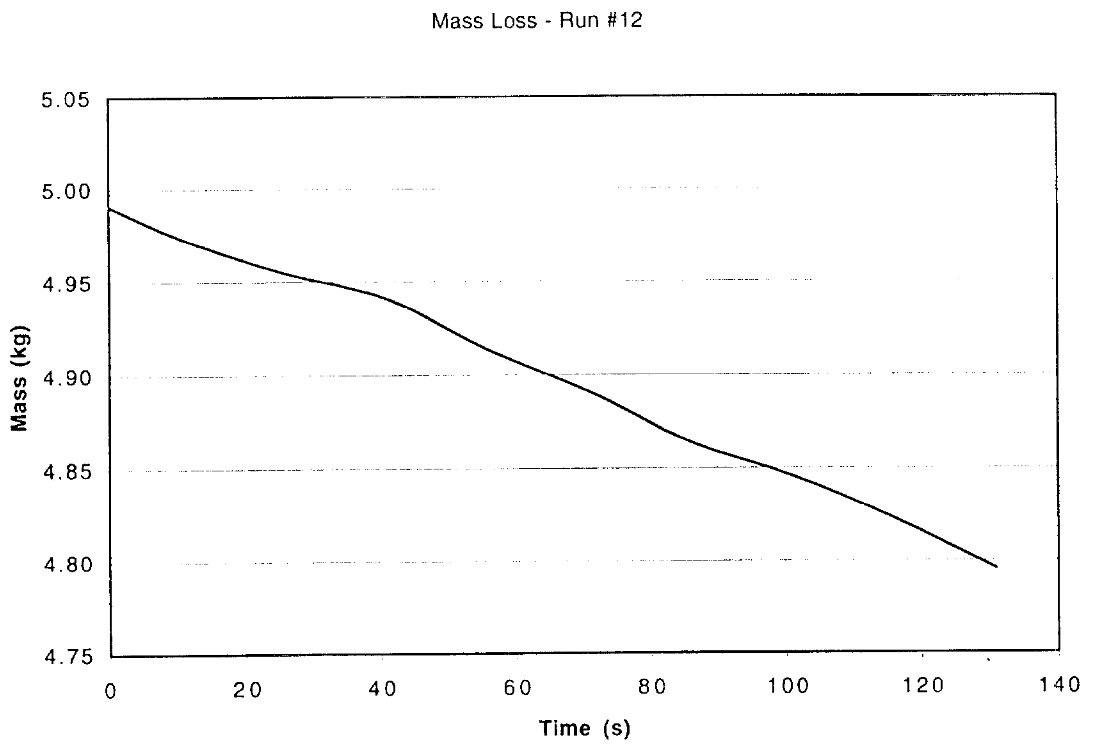

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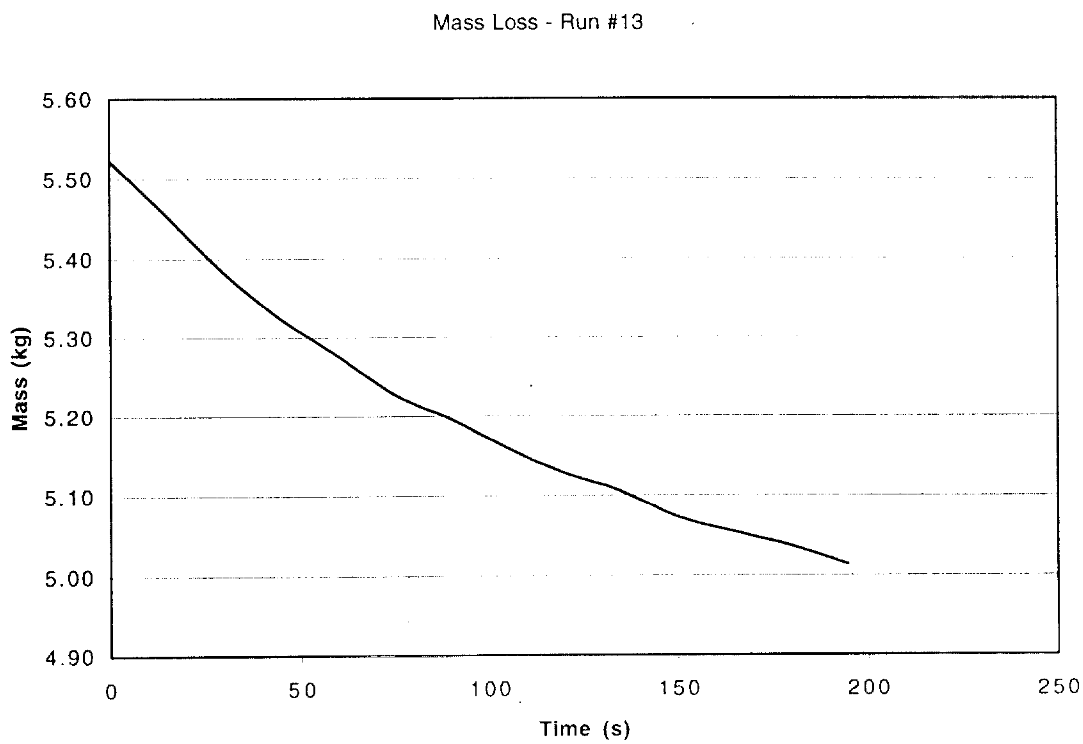

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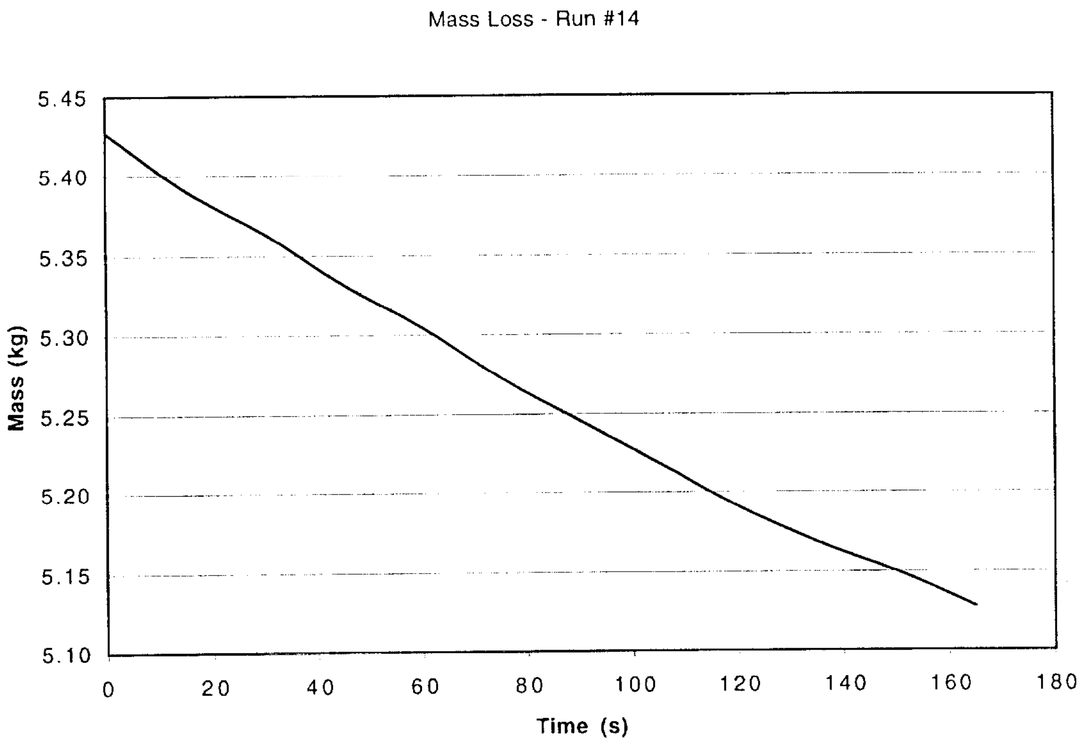

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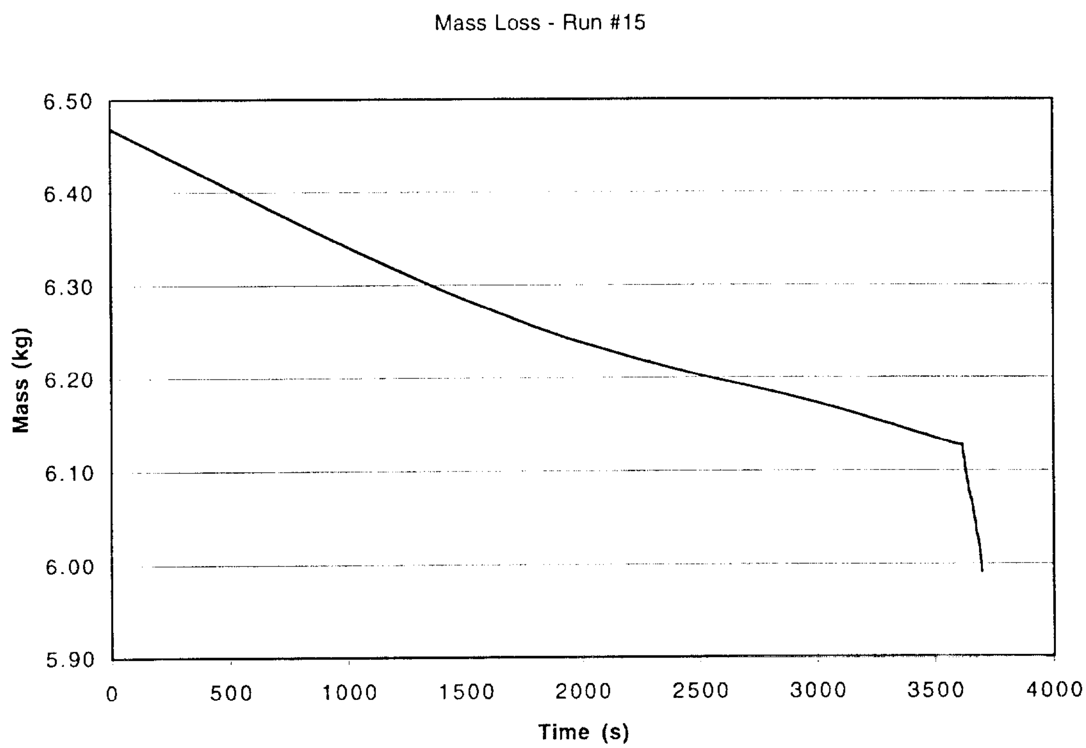


APPENDIX C

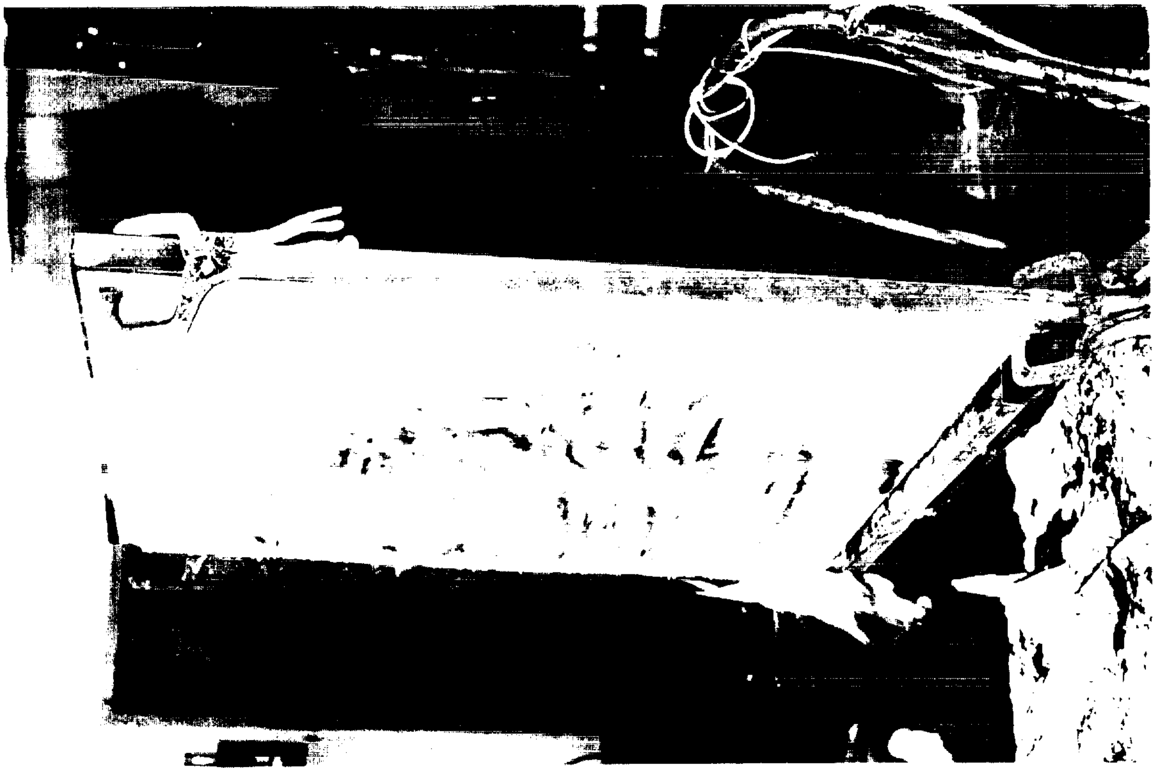
Photographs

INDEX TO PHOTOGRAPHS

Photo No.	Description – times are in minutes:seconds from the beginning of the test (i. e., exposure to the radiant heat flux, or exposure to the higher flux where drying was performed)
1-17	(first photo) Expt. No. 3 (unstained + water); approx. 0:20; note specimen support frame and position of igniter
1-18	Expt. No. 3; approx. 0:35
1-19	(vertical) Expt. No. 3; approx. 1:23; smoke, but prior to ignition
1-20	(vertical) Expt. No. 3; approx. 2:08; ignition
1-21	Expt. No. 4 (unstained + gel treatment); specimen mounted, during "drying" period
1-22	ICAL radiant panel, with igniter in position, but not lit
1-23	(similar to 1-22)
2-1	Expt. No. 4; approx. 0:08; specimen in place with igniter
2-2	Expt. No. 4; approx. 0:12
2-3	Expt. No. 4; approx. 0:53
2-4	(vertical) Expt. No. 4; approx. 1:43; some charring
2-5	(vertical) Expt. No. 4; approx. 3:38; ignition
2-6	Expt. No. 9 (stained + gel); prior to application
2-7	Expt. No. 9; applying gel coating (too thick)
2-8	Expt. No. 9; continuing to apply gel coating
2-9	(vertical) Expt. No. 9; specimen on support frame prior to test
2-10	Expt. No. 9; approx. 0:39
2-11	(vertical) Expt. No. 9; approx. 0:57
2-12	Expt. No. 9; approx. 1:49
2-13	Expt. No. 9; approx. 2:57 (photo from rear of specimen)
3-1	(vertical) Expt. No. 9; approx. 6:09
3-2	(vertical) Expt. No. 9; approx. 8:09
3-3	(vertical) Expt. No. 9; approx. 14:39; immediately prior to ignition
3-4	(vertical) Expt. No. 9; approx. 17:39; flaming has died down
3-5	(no photo)
3-6	Expt. No. 9; approx. 25:19; from backside
3-7	Expt. No. 10 (stained + gel); specimen mounted on support frame prior to treatment
3-8	Expt. No. 10; specimen being sprayed
3-9	(vertical) Expt. No. 10; immediately prior to start of test
3-10	Expt. No. 10; approx. 1:11; specimen in place
3-11	(vertical) Expt. No. 10; approx. 2:01
3-12	(vertical) Expt. No. 10; approx. 2:46; from the rear of the specimen
3-13	(vertical) Expt. No. 10; approx. 3:26

I-17

I-18



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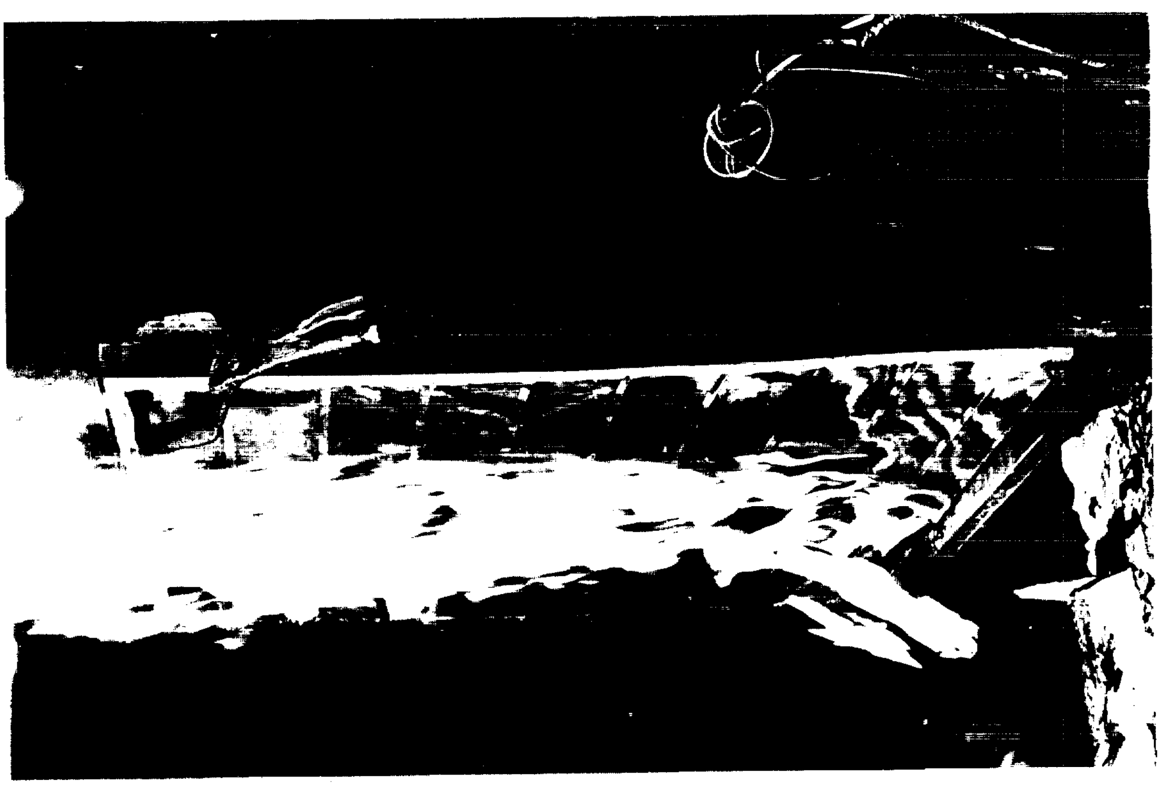

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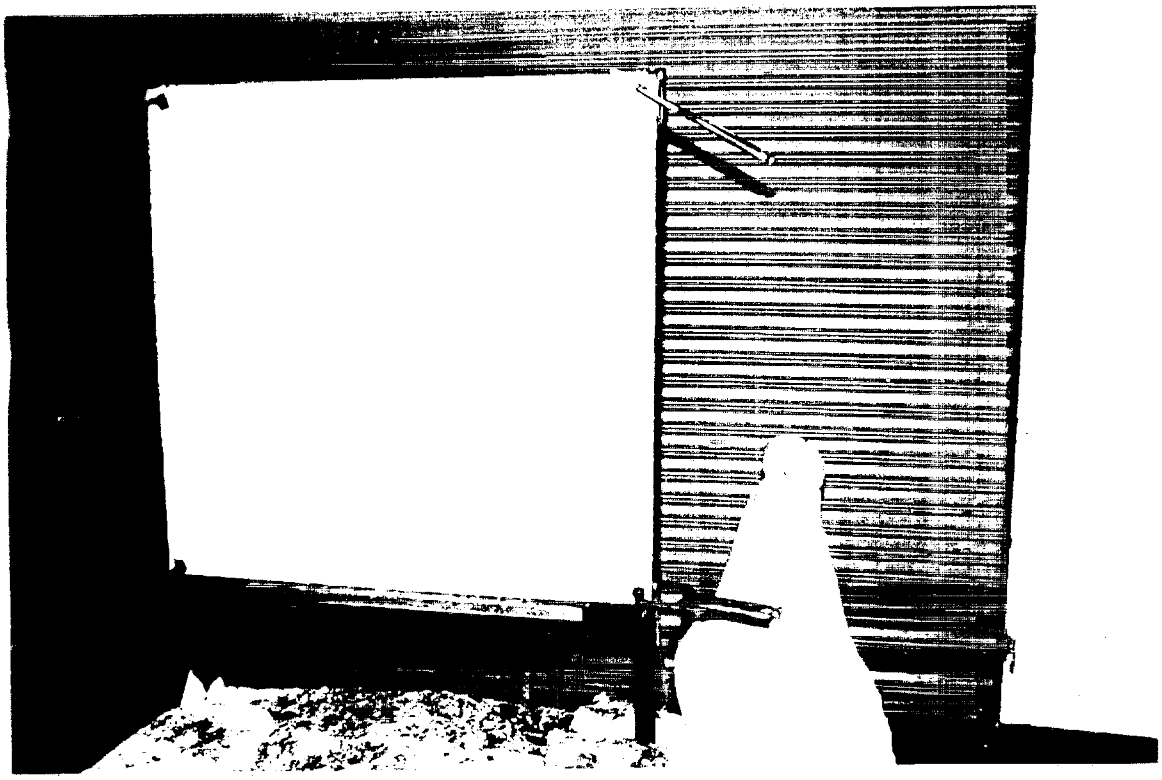

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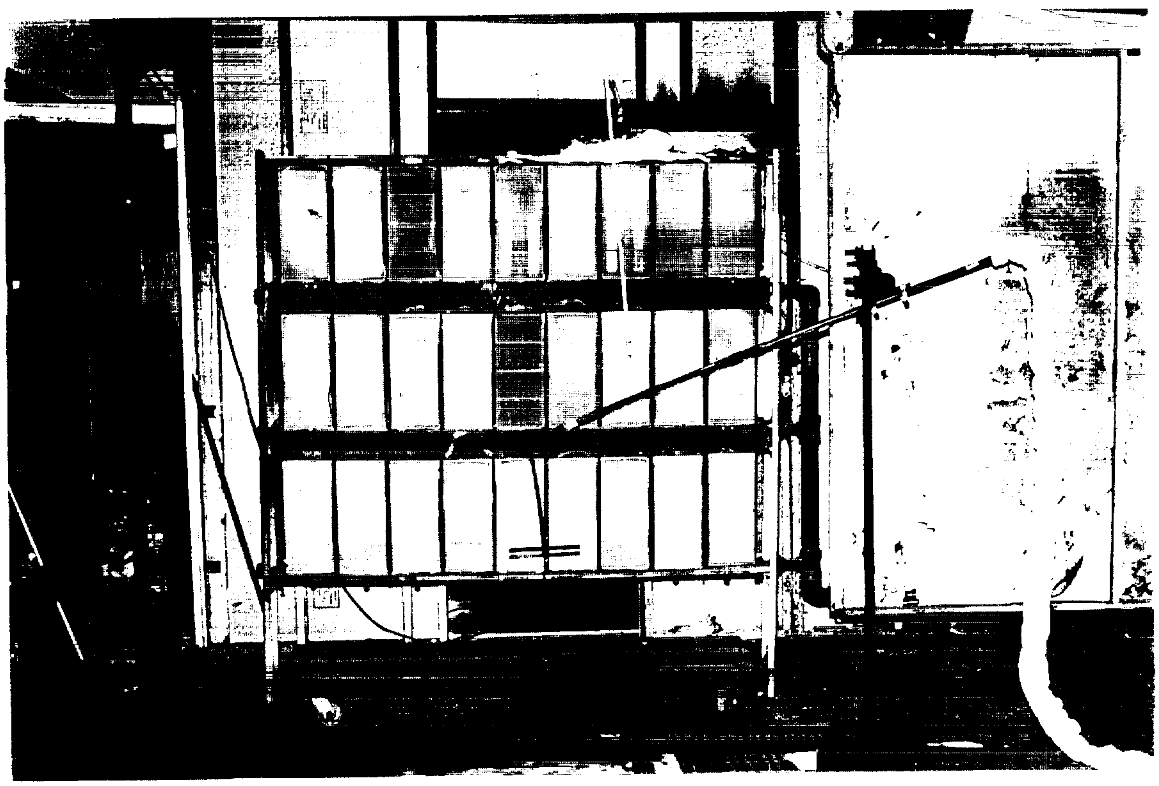

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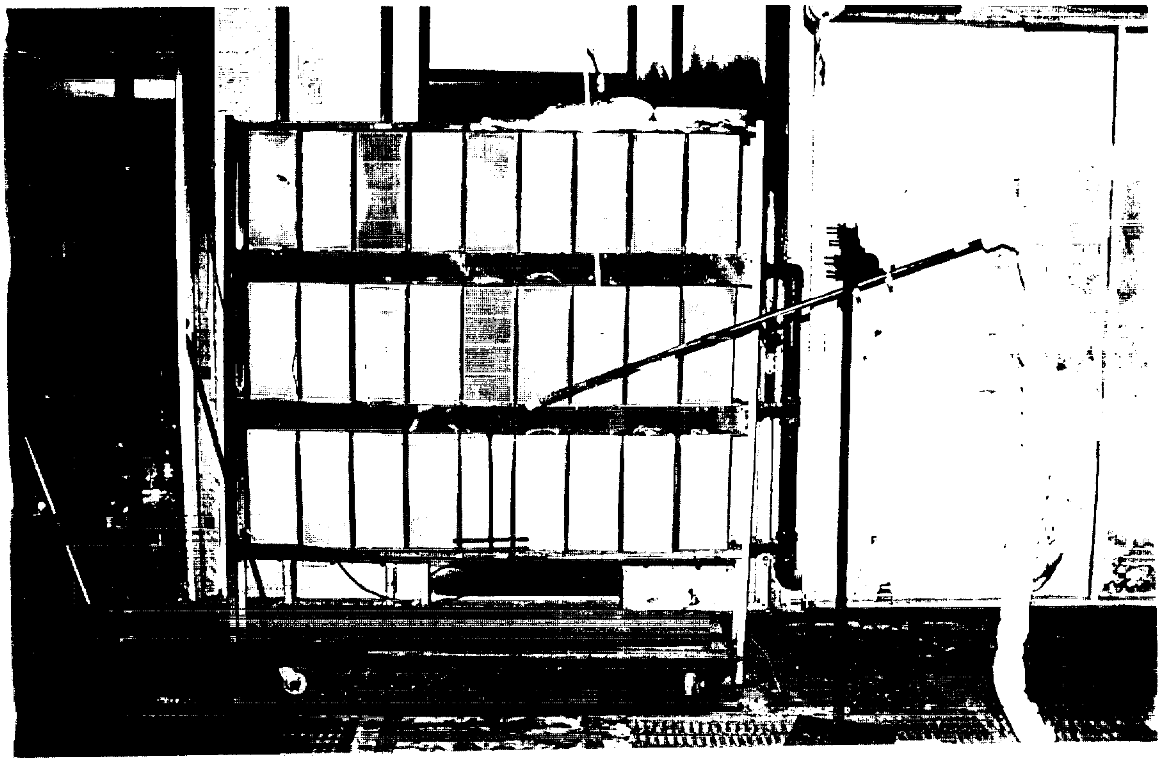

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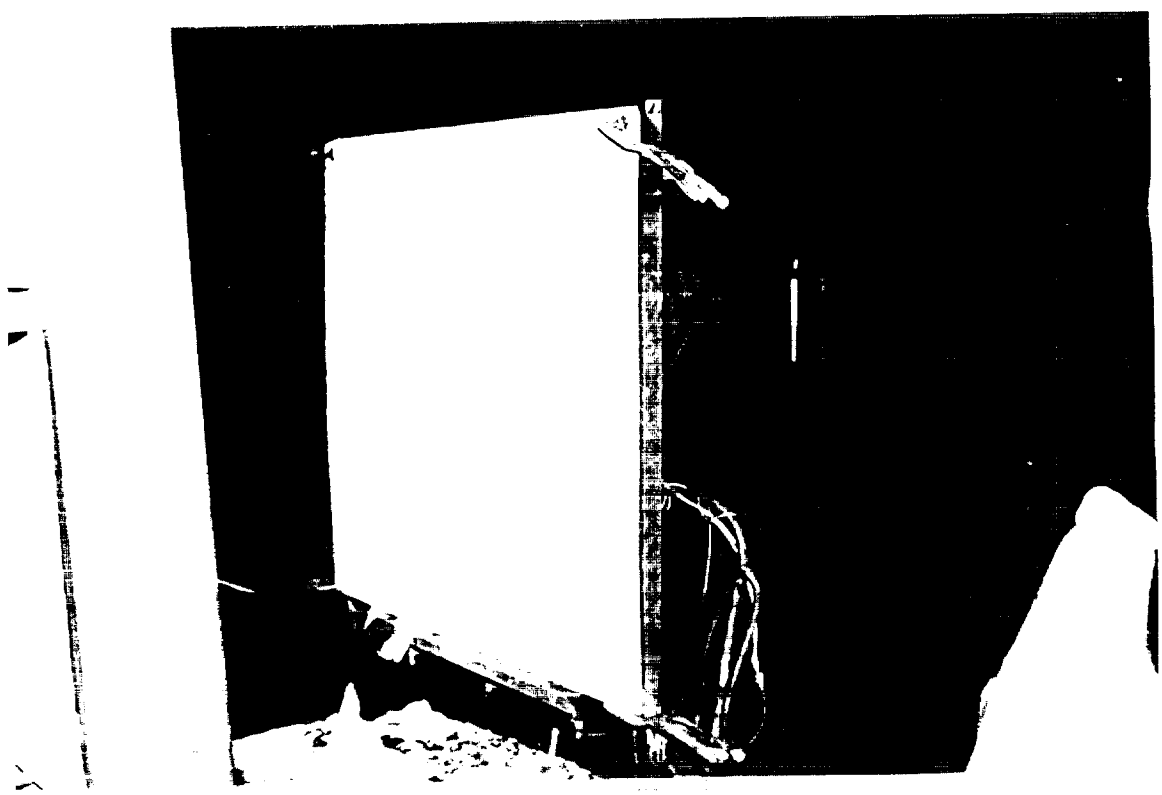

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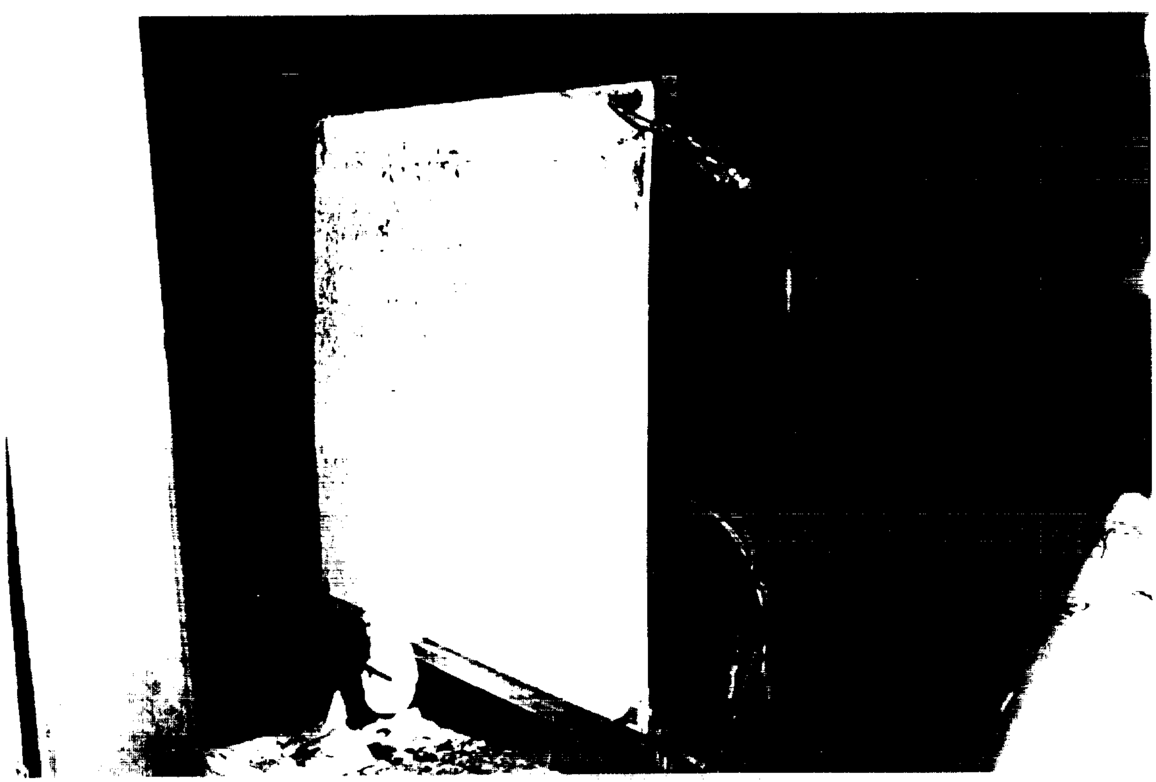

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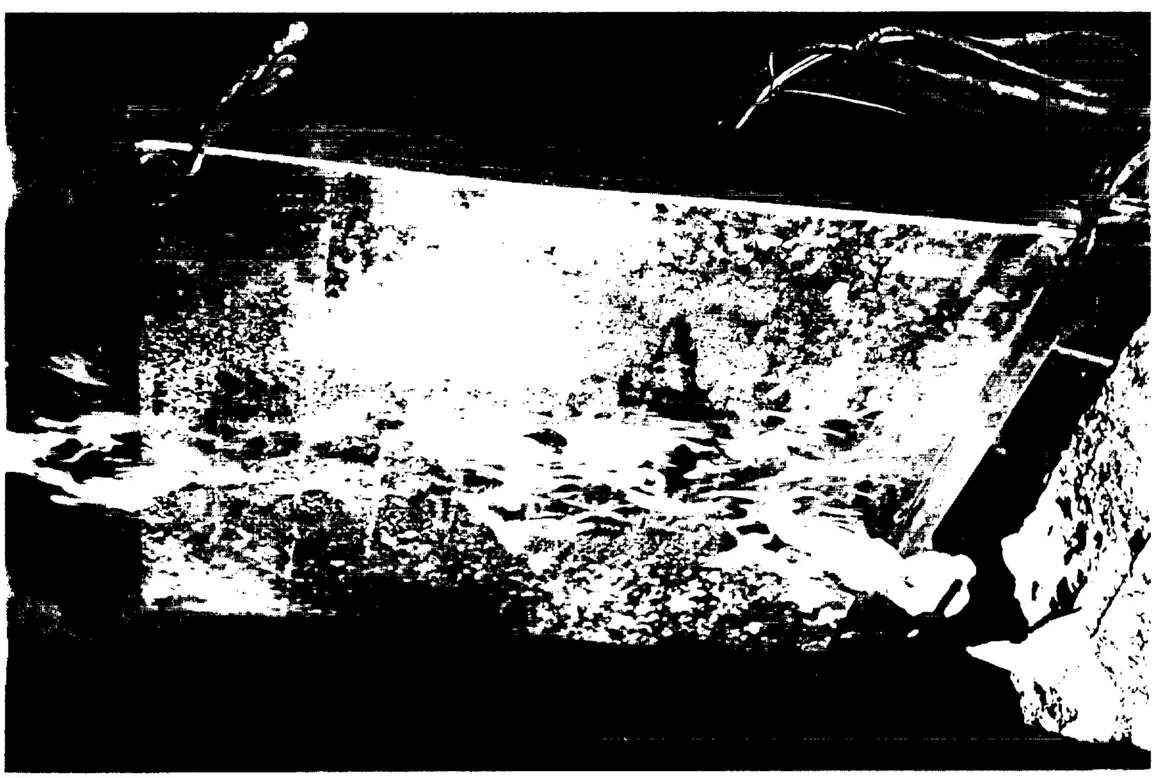

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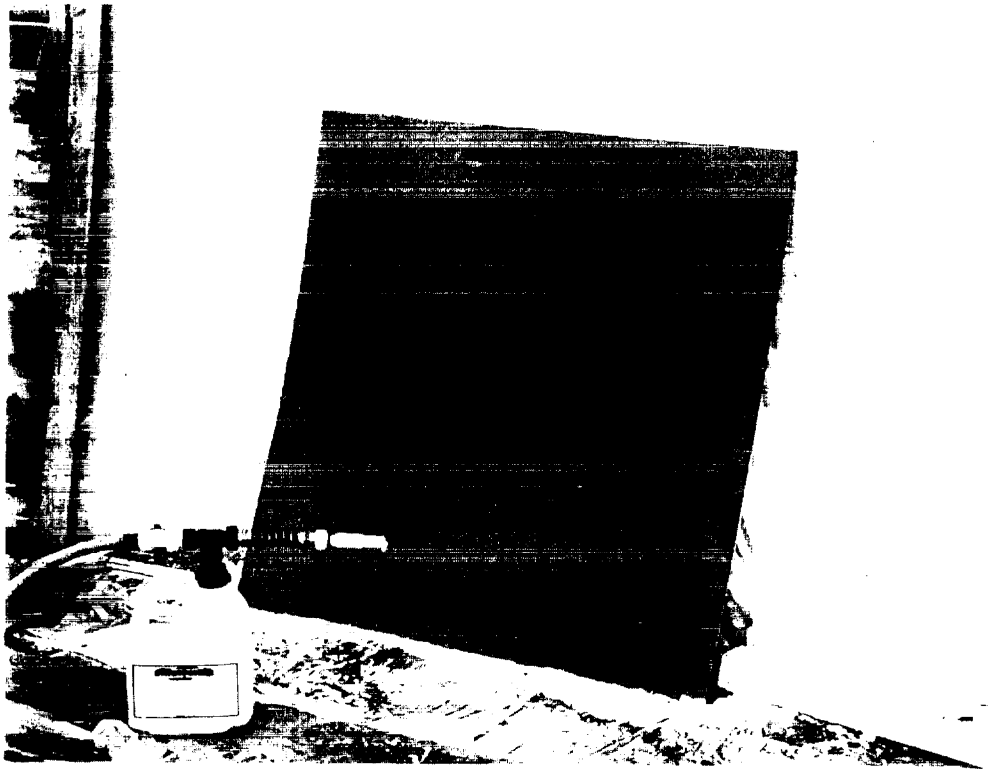

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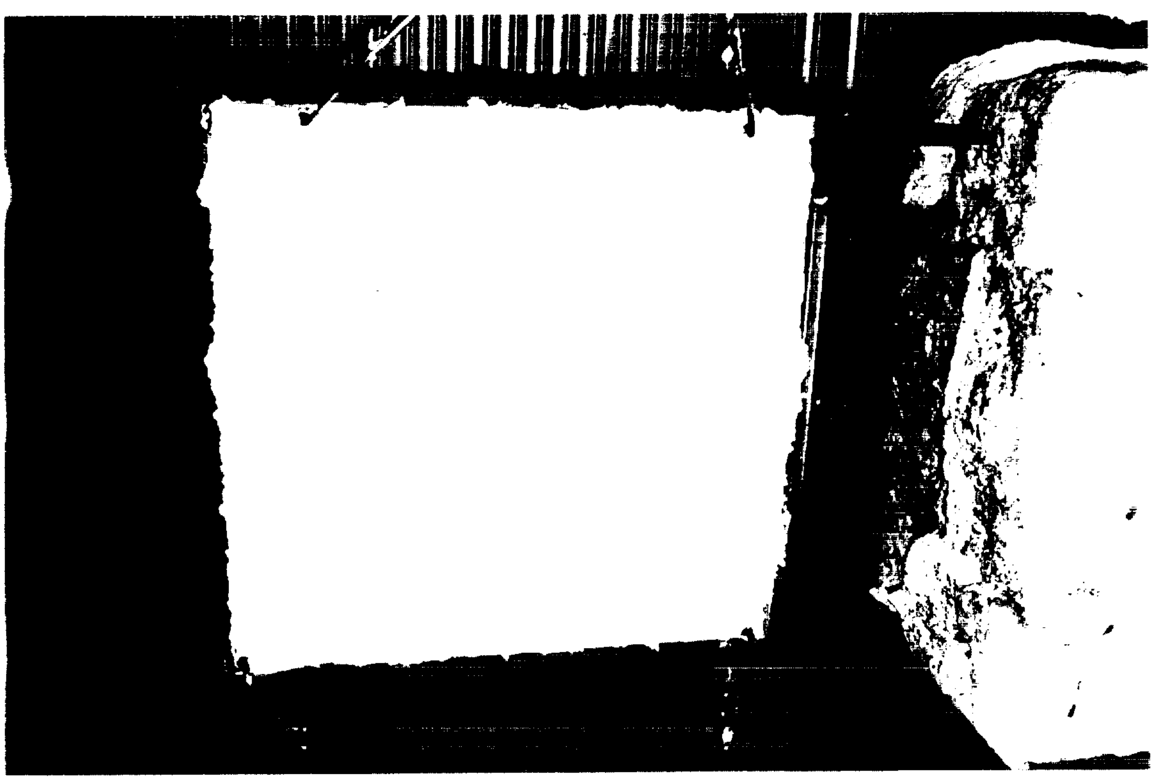

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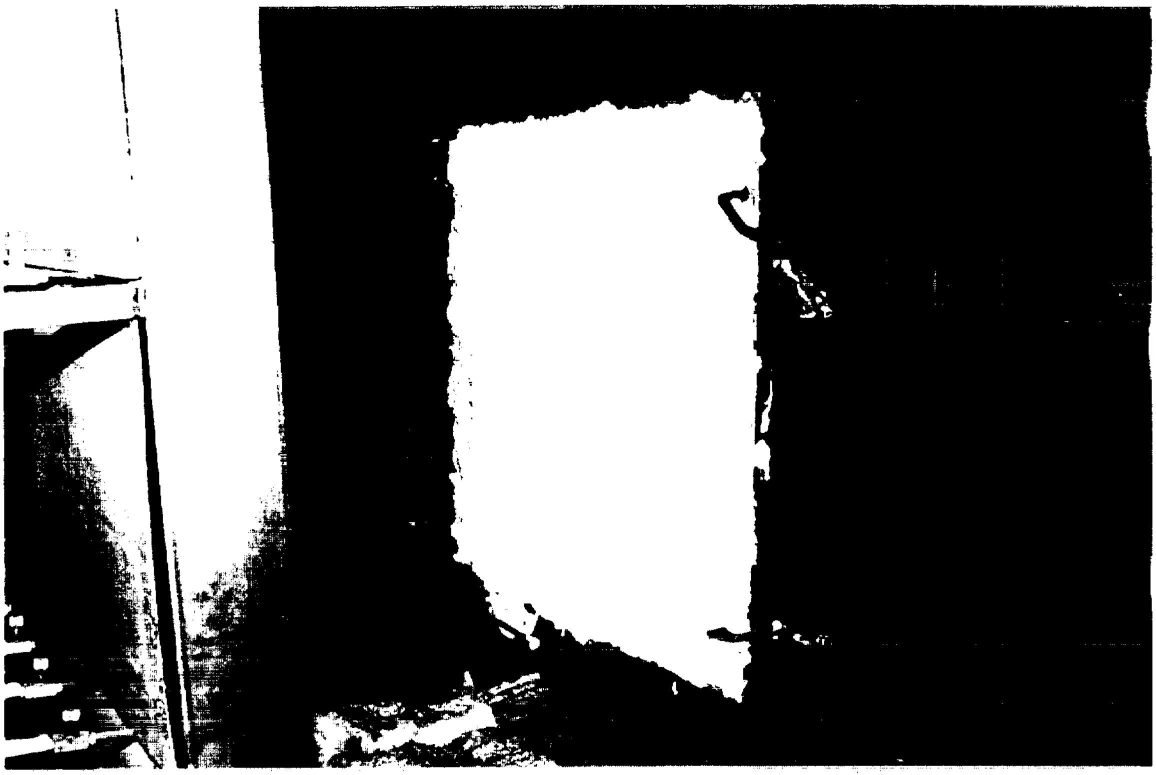

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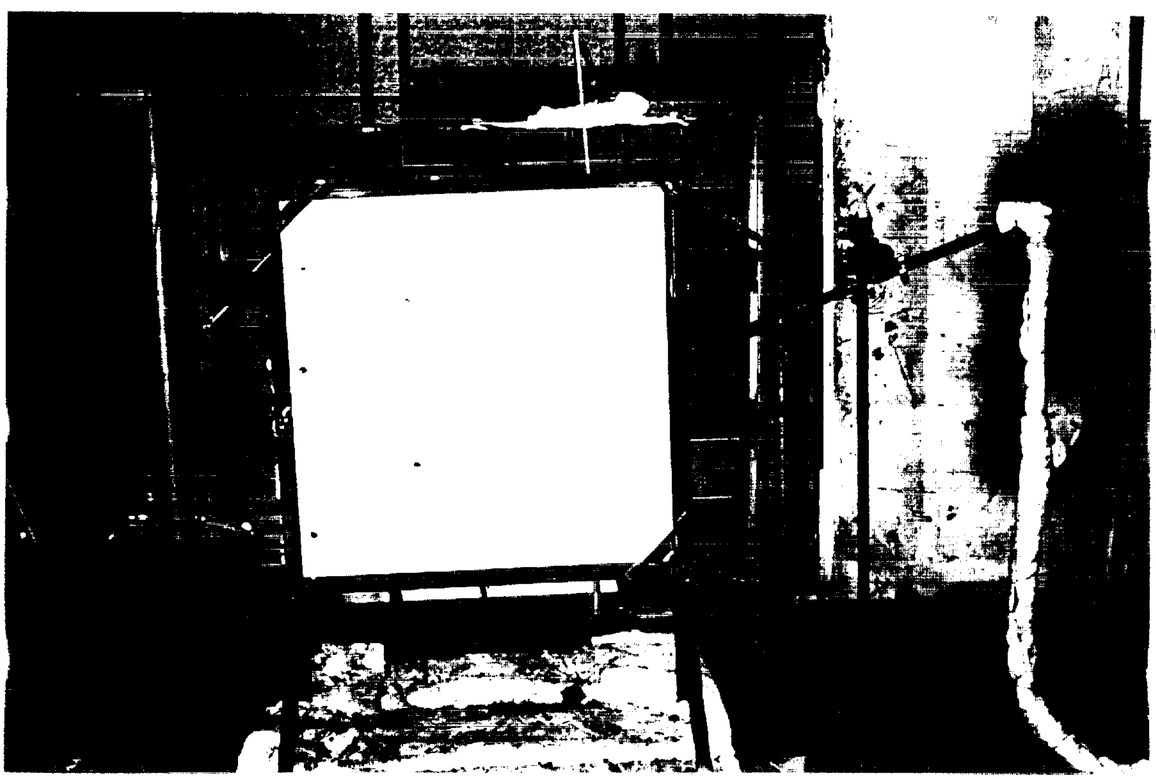

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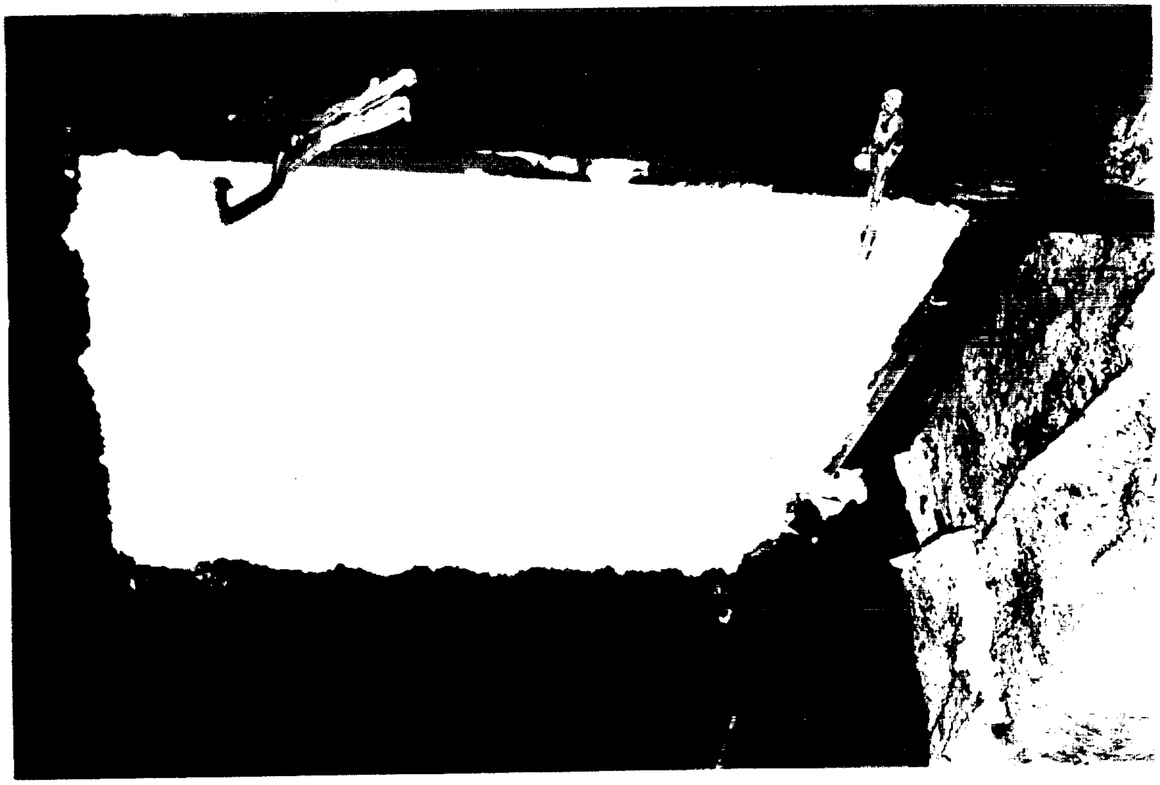

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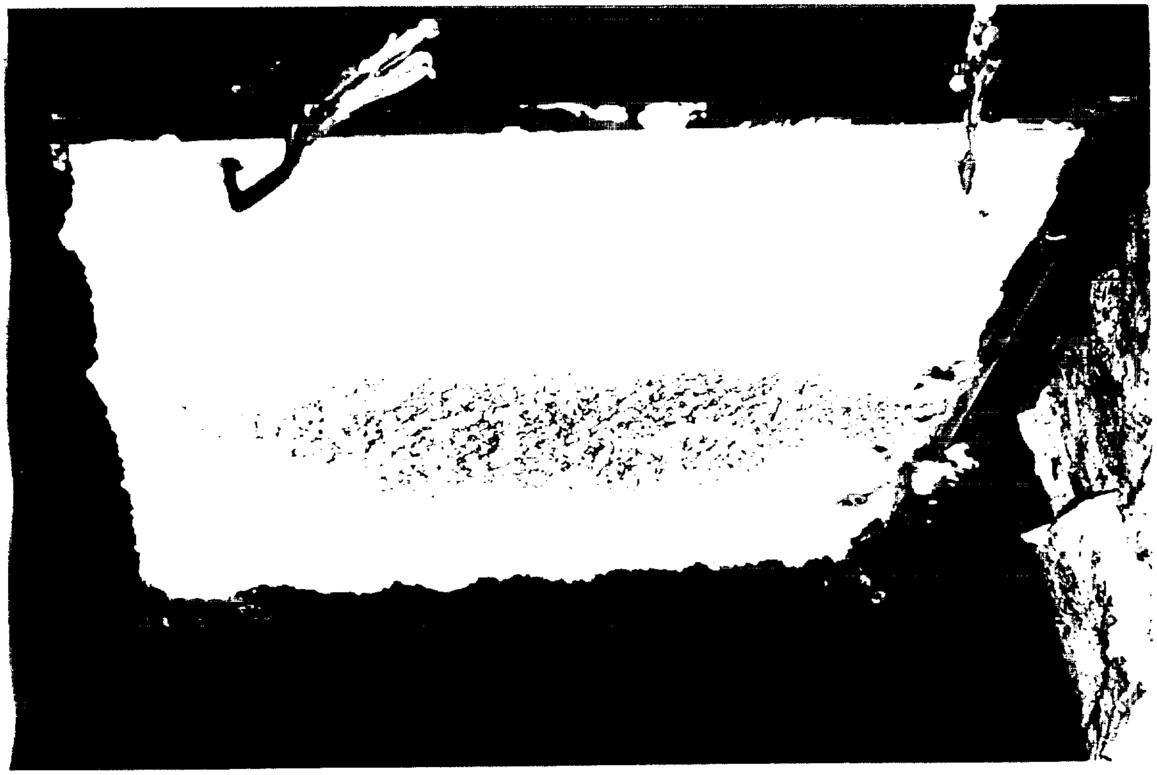

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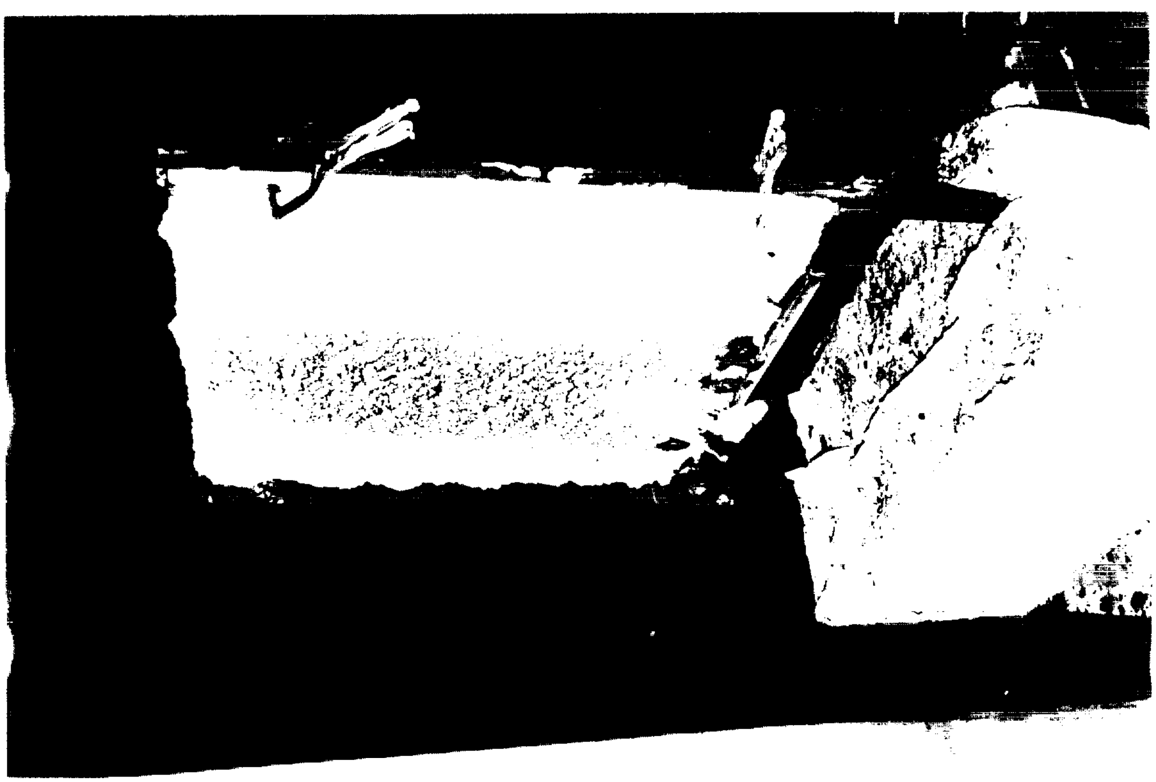

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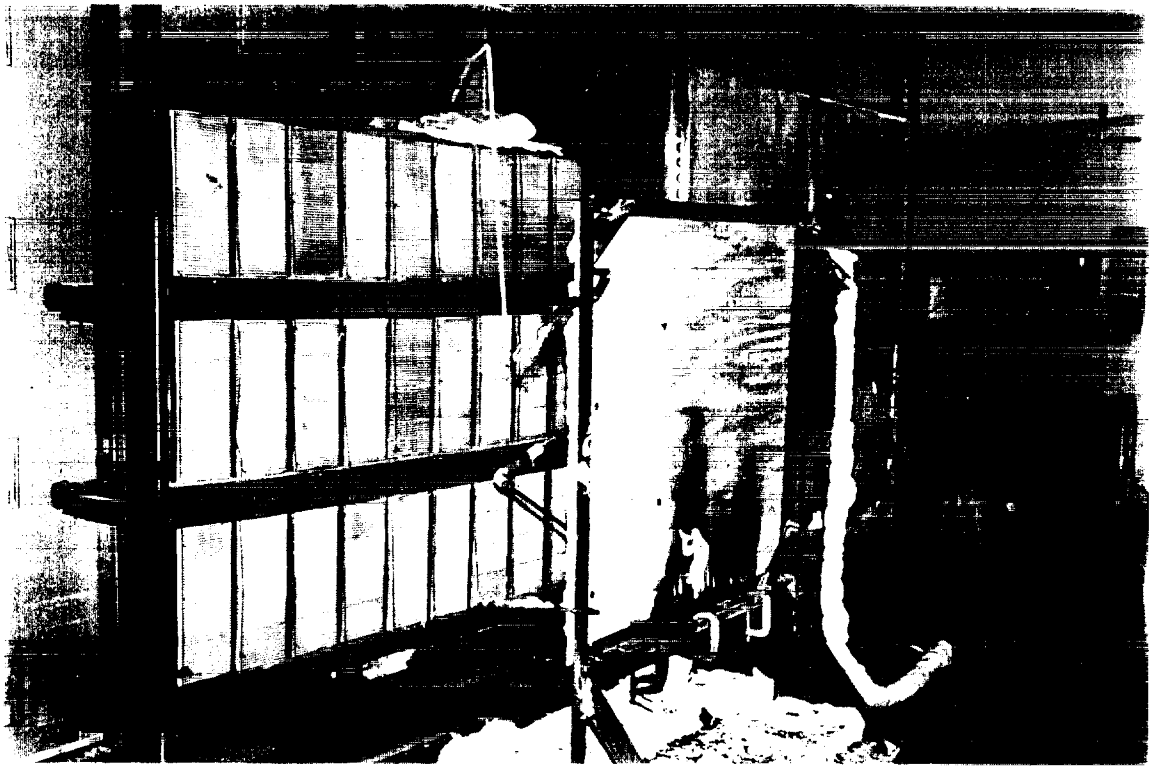

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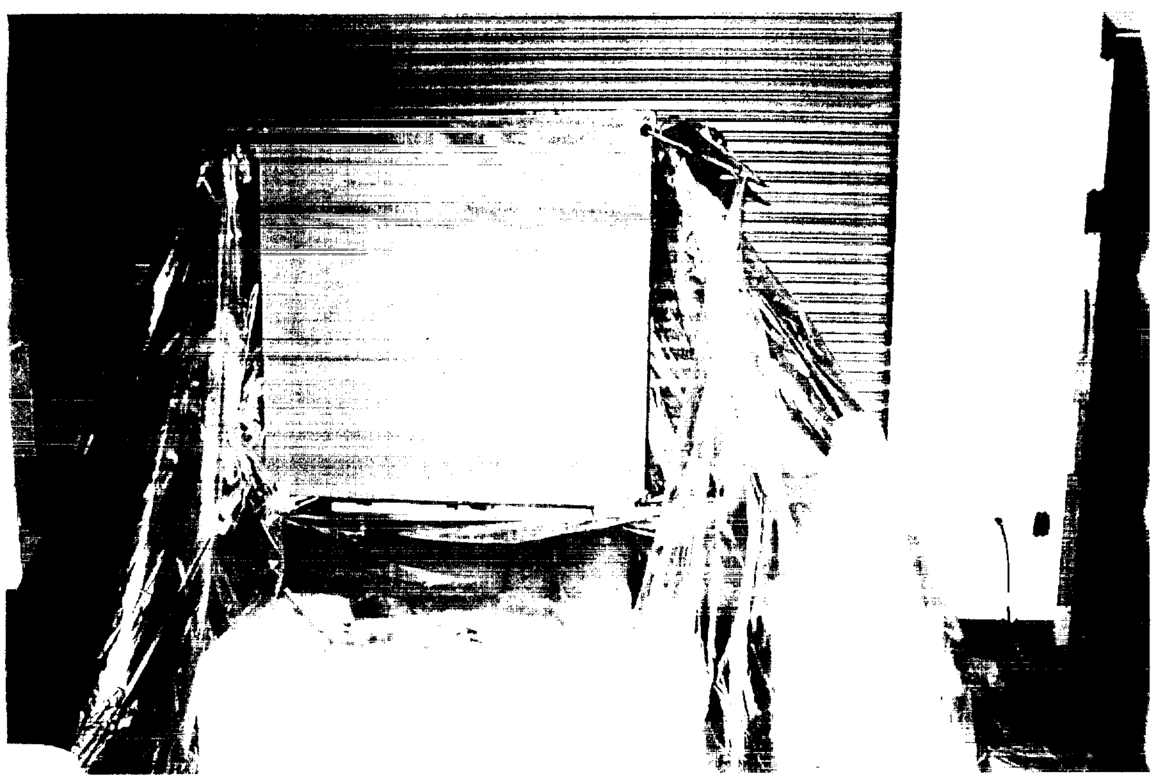

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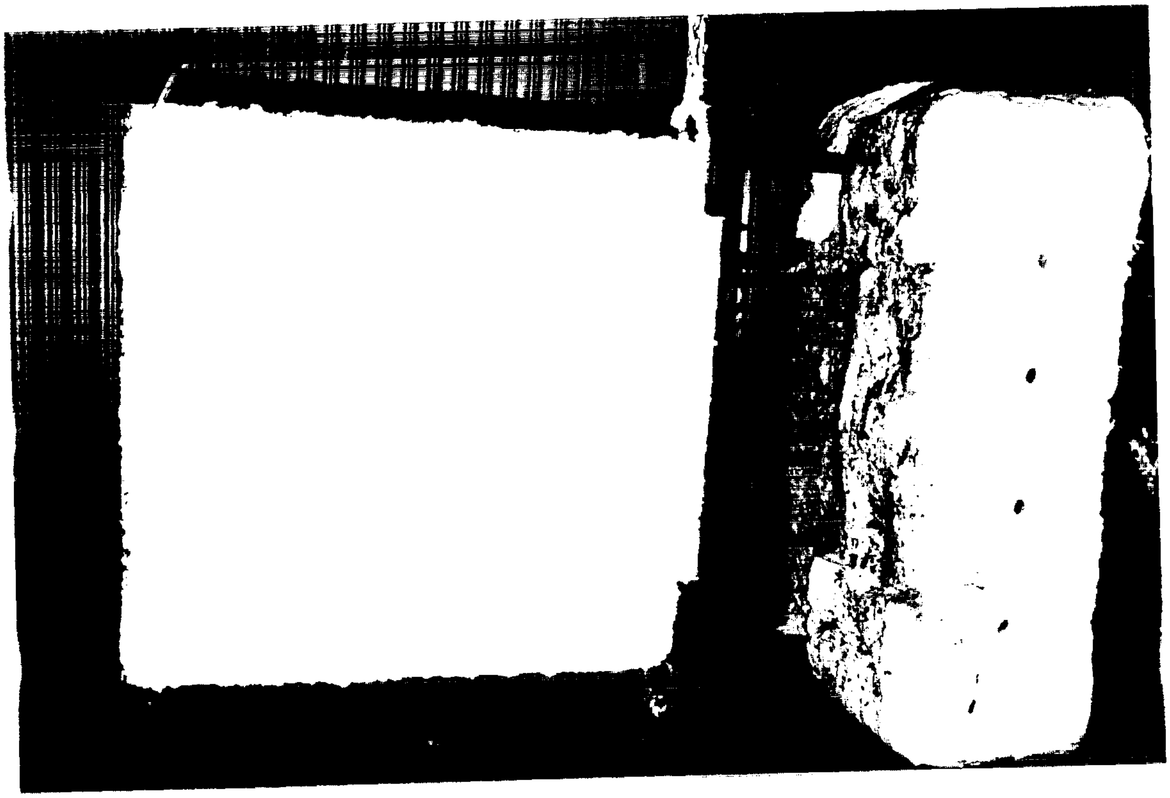

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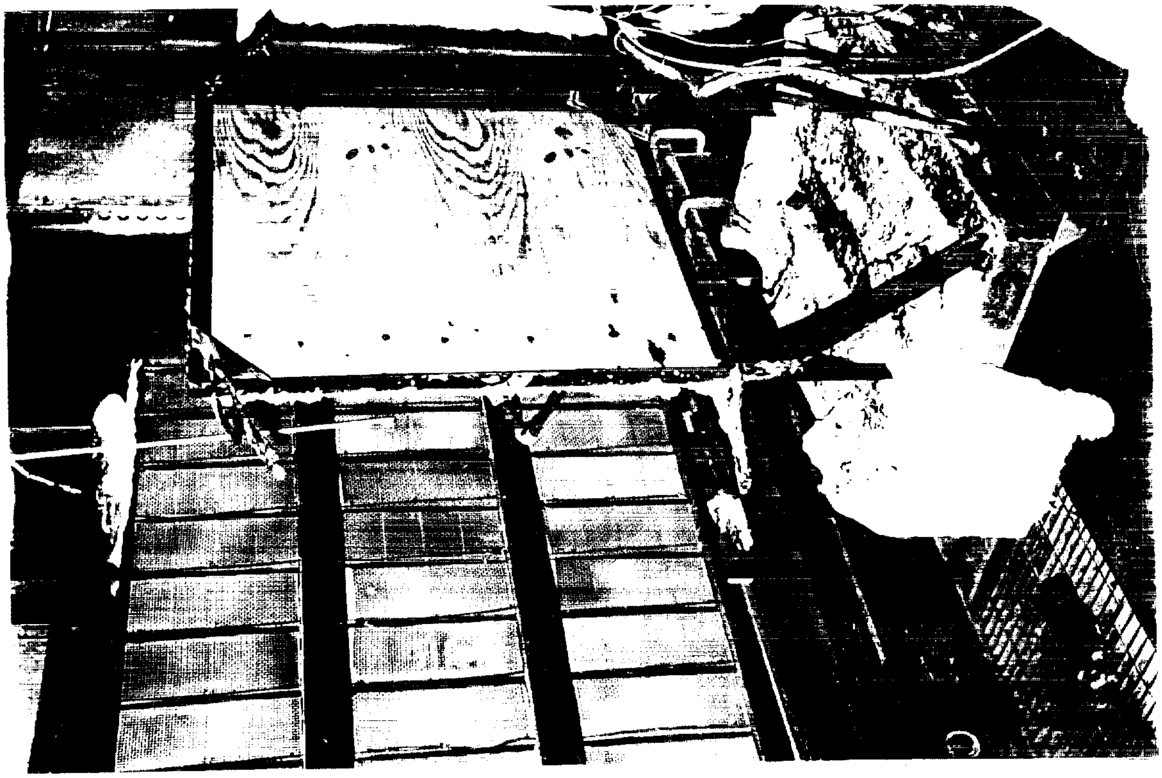

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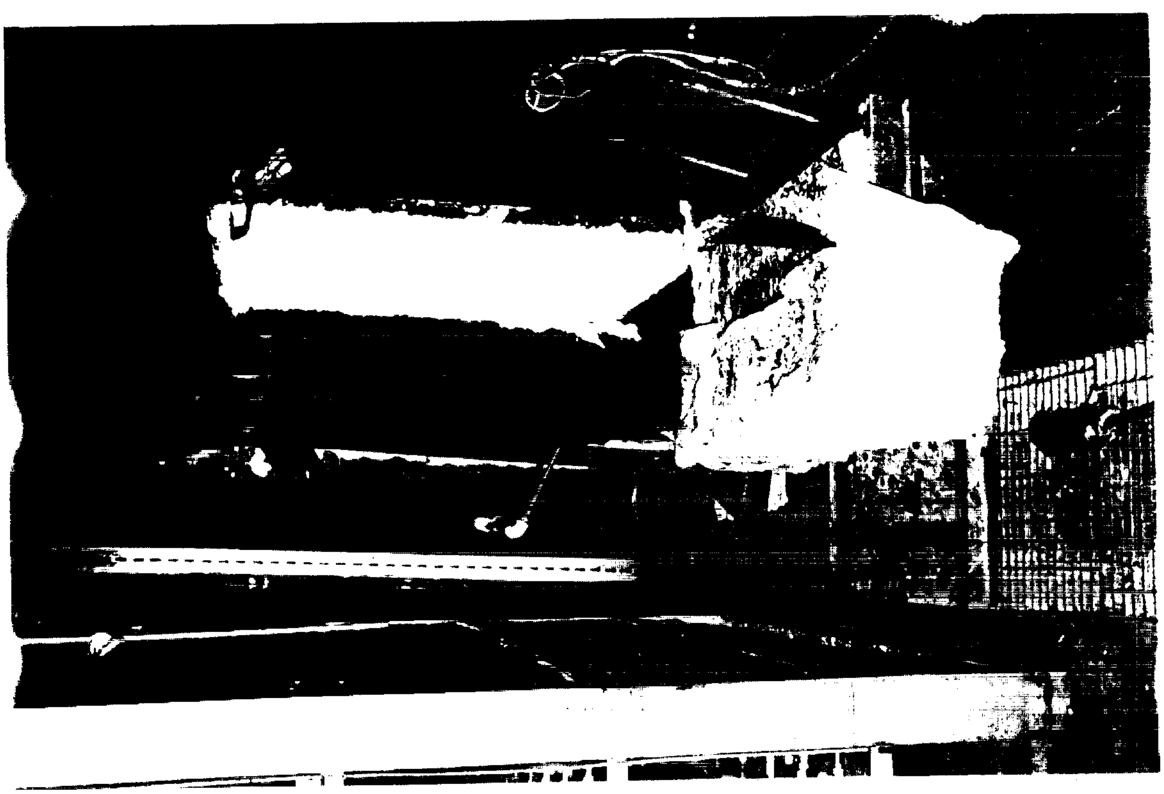

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Grand, A.F., Omega Point Laboratories, 16015 Shady Falls Rd., Elmendorf, TX

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A test protocol based on the Intermediate Scale Heat Release Calorimeter (ICAL) was developed to evaluate the potential fire retardant effects of water-based durable agents applied to wood siding. The protocol includes exposure of one meter square specimens of wood siding to one or more constant heat fluxes consistent with those from wildland fires. Specimens both untreated and treated with a fire-ending gel were evaluated. Time delay to ignition of the treated specimen was the primary measured property, while mass changes prior to and during the fire exposure were also recorded.

KEY WORDS (MAXIMUM OF 9; 28 CHARACTERS AND SPACES EACH; SEPARATE WITH SEMICOLONS; ALPHABETIC ORDER; CAPITALIZE ONLY PROPER NAMES)

calorimeters; exposure; fire extinguish agents; fire suppression; fire tests; flame retardants; heat flux; siding; water solubility; wood

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