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MINNESOTA RETROFIT INSULATION IN-SITU TEST PROGRAM: EXTENSION AND REVIEW

JOHN WEIDT ASSOCIATES, INC.

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

OPERATED BY
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John Weidt Associates, Inc.
Chaska, Minnesota 55318

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Part of
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Building Thermal Envelope Systems and Insulating Materials

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  Rick Hinkie, Northern States Power Co.
  Jim Adams, Insulation Contractors Association Northwest
  Bob Anderson, Diversified Insulation Corporation
  Ray Wallentine, Carney Insulation
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FOREWORD

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

The effort described in this report was stimulated in part by objections to various information contained in HCP/W2843-01: Minnesota Retrofit Insulation In Situ Test Program (June 1978). Included as Appendix 2 is an "Errata Sheet" which refers to the original document.

Other reports in this series include the following which are available from NTIS.

1. DOE/CS-0059: The National Program Plan for Building Thermal Envelope Systems and Insulating Materials (January 1979).

2. ORNL/SUB-7556/I: Assessment of the Corrosiveness of Cellulosic Insulating Materials (June 1979).

3. ORNL/SUB-7504/3: Recessed Light Fixture Test Facility (July 1979).

4. ORNL/SUB-7559/I: Problems Associated with the Use of Urea-Formaldehyde Foam for Residential Insulation (September 1979).

5. ORNL/Sub-7551/I: Interim Progress Report on an Investigation of Energy Transport in Porous Insulator Systems (October 1979).

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

E. C. Freeman
Program Manager, Buildings Division
Architectural & Engineering Systems
Branch/BCS
Department of Energy

1.0 INTRODUCTION

An insulation's performance is of primary concern to the consumer who is considering re-insulating his home. Few studies of re-insulation have been conducted outside the confines of a testing laboratory. A report entitled "Minnesota Retrofit Insulation In Situ Test Program", published by the Department of Energy in June 1978, detailed the findings of an in situ study of various thermal insulations installed in 55 residences in the Minneapolis/St. Paul area. The study, conducted in Summer, 1977, consisted of field observations and laboratory measurements of properties critical to the insulations' performance. Properties studied included density, thermal resistance, moisture content, shrinkage, flammability, friability and compression strength.

This study, hereinafter referred to as Phase I, was extended with a second phase to include further in situ study of retrofit insulations. Included in this extension work, hereinafter referred to as Phase II, was a further study of the moisture content of insulations, the corrosiveness of retrofit loose-fill cellulose insulation, thermography and field observations of sidewalls for signs of settling of retrofit loose-fill insulations, analysis of fuel consumption data for a number of the retrofitted homes, and density and thermal resistance retests of loose-fill insulations. This report details the field and laboratory findings of Phase II.

2.0 MOISTURE CONTENT

The moisture content of an insulation can indicate problems with vapor transfer. High moisture content within an insulation can adversely affect its thermal performance (Ref. 1) and can cause corrosion, paint peeling, degradation of building components and growth of fungus and mold.

The Phase I data indicated very low moisture contents for all loose-fill insulation. Since the Phase I samples were taken during the summer months when moisture content may be expected to be low, moisture content samples were retaken during the spring when increased moisture may be driven into the insulating materials (Ref. 1).

Forty ceiling and 6 wall samples of cellulose and mineral fiber insulations were taken between 15 March and 1 May 1978. The samples were taken from a cross-section of the entire thickness of the retrofit insulation, sealed in thick-walled polyethylene jars and sent to the laboratory for testing. Wet bulb and dry bulb readings were taken from the interior and exterior (or attic) environments immediately adjacent to the sample location. The moisture content was measured in the laboratory in the same manner as Phase I, using the procedure outlined in Appendix 1. During Phase I, all moisture content measurements were rounded to the nearest whole percentage, while Phase II moisture content measurements are reported to the tenth of one percent accuracy.

Samples were removed from 6 sidewall cavities in 4 homes in April of 1978. Two samples were rock/slag wool, and 4 samples were cellulose. The moisture content of these retested samples is shown in Table 1. As can be seen, the moisture content of the observed insulations in Phase II was still quite low and is generally comparable to or slightly lower than the measurements obtained during Phase I.

Samples were removed from 40 attics between 15 March and 1 May 1978. Twenty-three of these samples were loose-fill glass fiber, 14 were loose-fill cellulosic fiber and 3 were loose-fill rock/slag wool. The moisture content of these retested samples is shown in Tables 2 through 4. As can be seen from the data, the moisture contents of all the glass and rock/slag fibers measured during Phase II is generally comparable to or lower than the moisture contents found during the Phase I work. The moisture content of the cellulosic loose-fill materials measured during Phase II was higher than that measured during Phase I for 13 of the 14 samples, and ranged from 2.9 to 11.1%. The Phase II cellulose samples had a moisture content on the order of 4% greater than the Phase I samples.

The measured moisture contents of both the Phase I and II samples indicated relatively low moisture content in the thermal insulations. No moisture problems were observed that could be related to the insulation.

3.0 CORROSION

Cellulose insulation is comprised of products such as newsprint or wood fiber with chemicals added for flame retardation. It has been suggested that certain of these flame-retardant chemicals may be deleterious to metals such as copper, aluminum and steel and can result in corrosion (Ref. 3). Such corrosion could cause damage to electrical boxes, wiring and other metals commonly found in walls and attics.

Calibrated metal coupons nominally 2" x 2" were placed in 12 attics containing loose-fill cellulose insulation. One coupon each of steel, copper and aluminum was placed well below the surface of the insulation and left undisturbed for 12 to 13 months. The coupons were retrieved with the insulation that surrounded them, placed in polyethylene jars and shipped to the laboratory. Relative humidity readings were taken both during placement and retrieval of the coupons. The coupons were cleaned and weighed before placement in the attic and weighed again after removal. The condition of the coupons after removal was noted. These results can be found in Table 5.

Twenty-five percent of the aluminum coupons and 17% of the steel coupons exhibited minor pitting corrosion. No perforations were observed on any of the test metals. Discoloration was noted in both steel and copper coupons, the latter exhibiting the greatest amount of discoloration. The before and after weights of the coupons did not vary more than +- 2%. The relative humidity of the attics ranged from 28 - 92% at the time of placement and 40 - 71% at the time of retrieval.

The coupons exhibited only minor changes in color and weight. The results of this project did not indicate problems with the sampled cellulose insulation relative to the corrosion of the copper, steel or aluminum coupons exposed to the insulation in situ for a period of approximately 1 year.

4.0 SETTLING

Concern has been expressed over the possibility of settling of loose-fill insulating materials (Ref. 3). If excessive settling occurs, it can affect density, thermal resistance and overall performance of the insulation (Ref. 3). Work was done during Phase II to evaluate the methods by which settling might be observed and the extent to which settling takes place.

The project employed infrared thermography to observe potential areas of settling. Thermograms were made from the interior of the homes during periods when outdoor temperatures ranged from 27 - 33 Deg. F. Areas of potential insulation voids were identified by the technician and noted on photographs of the interior.

The sidewalls of 7 homes were scanned in March, 1978. After careful analysis of the thermograms, 4 homes (1 rock/slag wool and 3 cellulose) were opened where the technician indicated voids in the insulation. A total of 6 openings were made. The opening was made in such a way to confirm the existence and extent of the void and to allow removal of a sample of the insulation for testing. In 1 case, 2 openings were made in the same cavity, 1 at the top (23WX1) and 1 at the bottom (23WX2); in another case, 2 openings were made, 1 at the cavity showing an insulation void (6WX2) and 1 at the top of an adjacent cavity (6WX1). The density of the 6 samples was measured. The results of the density tests can be found in Table 6. A detailed description of laboratory procedures can be found in Appendix 1.

The thermograms of the homes scanned showed voids in 1 or more cavities in each home. No consistent pattern of settling was evident; that is, signs of voids appeared randomly at the top of a few wall cavities while wall cavities adjacent to the void area appeared completely filled.

The physical openings made in 4 homes confirmed that the thermogram had accurately portrayed the voids. Figures 1 through 17 are photographs, thermograms and field worksheets illustrating the areas opened. In 1 case (15WX), the void was caused by an obstruction in the cavity. The existing foil vapor barrier was torn and crumpled near the top of the cavity and prevented the insulation from completely filling the cavity. In the other 3 homes, no physical barrier was evident.

The fact that insulation voids occurred in certain cavities while adjacent cavities were completely filled raises speculation that the cavity may not have contained sufficient material to completely fill or to maintain complete fill of the cavity after settled density (Ref. 2) had occurred. Observations of the densities measured in the loose-fill cellulose sidewalls are of interest in this regard. House 23 had a grand total of 3 openings made in its sidewalls: 1 during Phase I, near the bottom of a cavity, and 1 near the top and bottom of a different cavity containing a void during Phase II. The densities of the 2 bottom openings were 3.7 and 3.8 lbs/cf, while the density of the material removed just below the void near the top was 2.7 lbs/cf. In House 27, 2 openings were made; 1 near the bottom of a cavity during Phase I and 1 near the top of a different cavity containing a void during Phase II. The density of the lower opening was 3.8 lbs/cf, while the density of the sample taken from the top of the cavity with the void was 3.0 lbs/cf. Two openings were also made in House 15; 1 near the bottom of a cavity during Phase I and 1 near the top of a different cavity containing a void during Phase II. The density of the lower cavity was 3.9 lbs/cf, while the density at the top of the cavity containing the void was 2.7 lbs/cf. It must be remembered that this cavity had some physical blockage near the top of the cavity.

The densities of the materials at the top of the rock/slag wool cavities (6WX1, 6WX2) during Phase II exhibited an unusual pattern. The density of the material at the top of the cavity containing the void was 7.6 lbs/cf, while the density at the top of the adjacent full cavity was 4.3 lbs/cf.

The density range of the cellulose material at the top of the void cavities compared with the density of the material found lower in the cavity raises the speculation that installation, coupled with a tendency of the insulating material to naturally reach a settled density, could be responsible for the voids at the top of the observed cavities. If insufficient material was installed in the cavity to assure a density range of +- 2.7 - 3.0 lbs/cf at the top of the cavity and +- 3.8 lbs/cf at the bottom of the cavity, the material might naturally settle to such a state over time. On the other hand, installation of sufficient material in the cavity to compensate for this effect may alleviate any tendency for voids to occur at the top of the cavity.

5.0 FUEL CONSUMPTION

The actual effectiveness of retrofit insulation on fuel consumption has recently been questioned (Ref. 4). Phase II of this project collected actual fuel consumption data on a number of residences whose retrofit insulations had been tested.

The fuel consumption records of 19 homes were analyzed. Where possible, monthly fuel consumption data for each residence was collected for 1-2 years before and after the retrofit date. The data was corrected for degree day and fuel Btu content for the major heating months of the year (November, December, January, February,March) and the average consumption per season was compared before and after the retrofit. Table 7 indicates the percent change in consumption before retrofitting to after retrofitting for the 19 homes divided between the various insulation retrofits. Change in fuel consumption ranged from a reduction of 49.9% to an increase of 30.4%, with an average reduction in fuel consumption of 15% after reinsulating.

The analysis does not account for a wide variety of factors that may influence fuel consumption in an individual residence, especially the lifestyle of the occupants and other measures they may have taken (weatherstripping, caulking, etc.) to reduce their energy use. It nonetheless indicates a positive correlation between reinsulation and a reduction in fuel use.

6.0 DENSITY AND THERMAL RESISTANCE RETESTS

The density values of glass fiber attic samples reported in the Phase I report were questioned by members of the insulation industry as being incorrect. Eight samples of loose-fill glass fiber were remeasured for density and thermal resistance in Spring, 1979. The samples were randomly selected from the data base established in Phase I. The results can be found in Table 8. Field and laboratory procedures were the same as Phase I except that density was calculated in the field as well as in the laboratory. Laboratory procedures can be found in Appendix 1. In all cases, an attempt was made to take the Phase II sample as close as possible to the location of the Phase I sample.

In every case, the Phase II results, as indicated in Table 8, differ considerably from the Phase I results. Whereas the in situ density reported during Phase I were considerably higher than would have normally been expected for loose-fill glass fiber materials, the Phase II measured densities were considerably lower and generally, in line with expected values. Phase I field and laboratory procedures were carefully scrutinized for possible error in measurement and identification. No explanation could be found for the great difference between Phase I and II. Because of the errors discovered, all references to in situ density, and thus, thermal resistance, of loose-fill glass fiber attic insulations should be deleted from the Phase I report. The Phase II results contained in Table 8 should be used in lieu of all reported density and thermal resistance figures for loose-fill glass fiber ceiling samples in the Phase I report.

SAMPLE NUMBER	INSUL TYPE	SAMPLE DATE		% MOISTURE CONTENT	
		PHASE I	PHASE II	PHASE I	PHASE II
6WX1	Rock/Slag Wool	6/23/77	4/15/78	*	<0.1
6WX2	Rock/Slag Wool	6/23/77	4/15/78	*	<0.1
15WX	Cellulose	7/27/77	4/15/78	4	1.2
23WX1	Cellulose	8/17/77	4/8/78	2	1.4
23WX2	Cellulose	8/17/77	4/8/78	2	1.2
27WX	Cellulose	8/22/77	4/8/78	2	1.3

* Phase I sample was cellulose; comparison not applicable

TABLE 1 PHASE I AND II SIDEWALL MOISTURE CONTENT RESULTS AND OBSERVATIONS

SAMPLE NUMBER	SAMPLE DATE		PHASE II % RELATIVE HUMIDITY		% MOISTURE CONTENT	
	PHASE I	PHASE II	HOUSE	ATTIC	PHASE I	PHASE II
9CX	7/13/77	3/15/78	*	*	<1	0.3
16CX	7/27/77	4/11/78	48.5	100	<1	0.3
18CX	7/28/77	4/13/78	33.5	50.0	<1	0.4
19CX	8/5/77	4/13/78	31.0	35.5	2	0.2
20CX	8/5/77	5/2/78	28.0	22.0	<1	0.6
22CX	8/5/77	5/2/78	41.0	22.0	<1	0.7
29CX	8/24/77	5/2/78	33.0	42.0	<1	0.3
30CX	8/24/77	4/4/78	42.0	65.5	<1	0.3
31CX	8/24/77	4/18/78	42.0	73.0	<1	0.1
36CX	8/25/77	4/18/78	41.0	72.0	<1	0.8
37CX	8/25/77	4/18/78	37.0	72.0	<1	0.4
38CX	8/26/77	4/29/78	46.0	50.0	<1	0.1
39CX	8/26/77	4/29/78	48.0	49.0	<1	0.2
43CX	8/29/77	5/1/78	40.0	46.0	<1	0.1
45CX	8/29/77	4/13/78	39.0	67.5	2	0.1
46CX	8/31/77	5/1/78	48.0	26.0	2	0.1
47CX	8/31/77	4/29/78	40.0	48.0	<1	0.4
48CX	8/31/77	4/18/78	29.0	76.0	1	0.3
50CX	9/1/77	4/4/78	31.0	93.0	<1	0.5
51CX	9/1/77	4/4/78	42.0	40.0	2	0.5
52CX	9/2/77	5/3/78	32.0	31.0	<1	0.1
53CX	9/2/77	5/1/78	53.0	46.0	2	0.4
54CX	9/2/77	4/13/78	29.0	38.5	2	0.2

* Unable to take reading due to equipment failure

TABLE 2 PHASE I AND II LOOSE-FILL GLASS FIBER MOISTURE CONTENT RESULTS AND OBSERVATIONS

SAMPLE NUMBER	SAMPLE DATE		PHASE II % RELATIVE HUMIDITY		% MOISTURE CONTENT	
	PHASE I	PHASE II	HOUSE	ATTIC	PHASE I	PHASE II
1CX	6/9/77	5/1/78	48.0	31.0	<1	5.3
11CX	7/14/77	5/1/78	39.0	30.0	<1	2.9
12CX	7/26/77	4/29/78	47.0	48.0	<1	4.6
13CX	7/26/77	4/11/78	39.0	52.0	<1	3.7
17CX	7/28/77	4/13/78	41.0	47.0	6	5.4
21CX	8/5/77	4/18/78	38.0	59.0	5	11.1
23CX	8/17/77	4/8/78	*	46.0	2	8.9
26CX	8/22/77	4/8/78	27.5	44.0	2	5.5
27CX	8/22/77	4/8/78	48.0	58.0	2	8.6
33CX	8/25/77	4/4/78	49.0	79.0	2	7.1
34CX	8/25/77	4/18/78	39.0	92.0	2	6.2
44CX	8/29/77	4/13/78	44.5	69.0	<1	6.9
49CX	8/31/77	4/11/78	39.0	49.0	5	7.6
55CX	9/2/77	5/2/78	25.0	28.0	<1	6.2

* Unable to take reading due to equipment failure

TABLE 3 PHASE I AND II LOOSE-FILL CELLULOSE MOISTURE CONTENT RESULTS AND OBSERVATIONS

SAMPLE NUMBER	SAMPLE DATE		PHASE II % RELATIVE HUMIDITY		% MOISTURE CONTENT	
	PHASE I	PHASE II	HOUSE	ATTIC	PHASE I	PHASE II
8CX	7/13/77	5/2/78	28.0	37.0	<1	0.2
14CX	7/27/77	4/13/78	32.0	57.0	2	0.3
42CX	8/26/77	4/13/78	39.0	51.0	<1	0.3

TABLE 4 PHASE I AND II LOOSE-FILL ROCK/SLAG WOOL MOISTURE CONTENT RESULTS AND OBSERVATIONS

Sample #	Steel Coupon			Copper Coupon			Aluminum Coupon		
	Before	After	Observation	Before	After	Observation	Before	After	Observation
1	1.4950g	1.4789g	undamaged	1.6615g	1.6615g	discolored	.6125g	.6125g	undamaged
2	1.4944g	1.4900g	undamaged	1.6865g	1.6869g	discolored	.6359g	.6362g	undamaged
3	1.5105g	1.5114g	slight pitting	1.6538g	1.6551g	"	.6302g	.6319g	some pitting
4	1.5186g	1.5190g	slight discol-oration	1.6677g	1.6681g	"	.6150g	.6154g	undamaged
5	1.5215g	1.5224g	some edge attack	1.6758g	1.6768g	"	.6098g	.6107g	"
7	1.5202g	1.5184g	some discolor-ations	1.6844g	1.6904g	"	.6235g	.6255g	slight pitting
8	1.4455g	1.4451g	some pitting	1.7107g	1.7119g	"	.6163g	.6179g	" "
9	1.4962g	1.4815g	undamaged	1.6852g	1.6535g	discolored and slightly etched	.6214g	.6223g	undamaged
10	1.4556g	1.4530g	"	1.6627g	1.6640g	discolored	.6322g	.6327g	"
11	1.4921g	1.4919g	"	1.6969g	1.6940g	"	.6234g	.6225g	"
13	1.5074g	1.5085g	"	1.6637g	1.6650g	"	.6123g	.6130g	"
14	1.5106g	1.5113g	"	1.6697g	1.6709g	"	.6741g	.6755g	some pitting

TABLE 5 SUMMARY OF LABORATORY WEIGHTS AND OBSERVATIONS OF CORROSION COUPONS

SAMPLE NUMBER	INSULATION TYPE	AGE YEARS PHASE II	DENSITY PHASE I	PHASE II
6WX1	Rock/Slag Wool	12 +	*	4.3
6WX2	Rock/Slag Wool	12 +	*	7.6
15WX	Cellulose	2.75	3.9	2.7
23WX1	Cellulose	2.10	3.8	2.9
23WX2	Cellulose	2.10	3.8	3.7
27WX	Cellulose	1.75	3.8	3.0

* Phase I sample was cellulose; not applicable for comparison

TABLE 6 PHASE I AND II SIDEWALL DENSITY RESULTS

DESCRIPTION OF RETROFIT INSULATION	SAMPLE NUMBER	% CHANGE IN FUEL CONSUMPTION
Added to Attic	21	-5.6
	28	+5.2
	30	+30.4
	32	-16.5
	33	-22.1
	35	-3.5
	36	-13.6
	51	-5.9
	42	-10.0
AVERAGE		-4.6
RANGE		-22.1 - +30.4
New Attic and Wall	23	-21.3
	25	-10.7
	26	-24.6
	6	+3.6
AVERAGE		-13.3
RANGE		-24.6 - +3.6
Added to Attic and Wall	5	-34.1
	9	-39.9
	13	-21.1
AVERAGE		-31.7
RANGE		-39.1 - -21.1
New Attic, Added to Wall	1	-10.3
Added to Attic, New Wall	27	-49.9
New Wall	41	-34.7
TOTAL AVERAGE		-15.0

TABLE 7 CHANGE IN FUEL CONSUMPTION AFTER APPLICATION OF RETROFIT INSULATION

PHASE I				PHASE II		
SAMPLE NUMBER	AGE YEARS	DENSITY LBS/CF	R PER INCH H SF F/BTU	AGE YEARS	DENSITY LBS/CF	R PER INCH H SF F/BTU
20C	3.0	2.10	3.05	5.03	.76	2.25
35C	2.0	2.35	3.00	3.83	.78	2.20
36C	1.0	4.20	3.70	2.82	.63	2.15**
43C*	3.5	1.70	3.25	4.93	.73	1.7(as rec'd)
43C						2.4 (fluffed)
45C	3.17	2.40	3.70	5.02	.98	2.30
46C	2.00	1.40	3.25	3.83	1.11	2.55
47C	3.00	2.30	3.45	4.82	1.85	3.15
50C	3.00	2.95	3.70	4.74	1.16	2.65

* Tested as received and machine-fluffed because of the unusually low value measured without fluffing

** Sample was machine-fluffed for thermal resistance test in order to achieve the removal density

TABLE 8 LABORATORY PROPERTIES OF LOOSE-FILL GLASS FIBER SAMPLES PHASE I AND PHASE II

MINNESOTA ENERGY AGENCY
INSULATION TEST WORKS T

SAMPLE NO. 6 Wall X-1
DATE 15 April 1978
SOURCE OF LEAD

GENERAL
AGE: retrofit over 12 house ORIENTATION north
HEAT SYSTEM INSTALLER & DATE unknown

FIELD OBSERVATIONS
plan location(s) bedroom-north venting n/a
framing type 2 X 4 stud condition of structure good
condition of wiring n/a
ORIGINAL: insulation type 0 vapor barrier type 0
RETROFIT: insulation type mineral fiber vapor barrier type
retrofit installation procedures/problems made second opening east of first
difficulty of opening/closing sample multiple layers/odd framing-second opening
PRESENCE OF: moisture, corrosion, odor, vermin, fungus
none
packing excellent/good friability n/a
REPLACEMENT: insulation fiberglass vapor barrier none

FIELD TESTS I 2.67"
insulation thickness see below flame n/a

SKETCHES (elevation/plan/section)
(siding, sheathing, building paper, existing insulation, new insulation, insulation thickness(es), vapor barrier(s), ceiling materials, flooring, gables, stops & firebreaks, ventilation, wiring, paint, installation procedures, general notes)

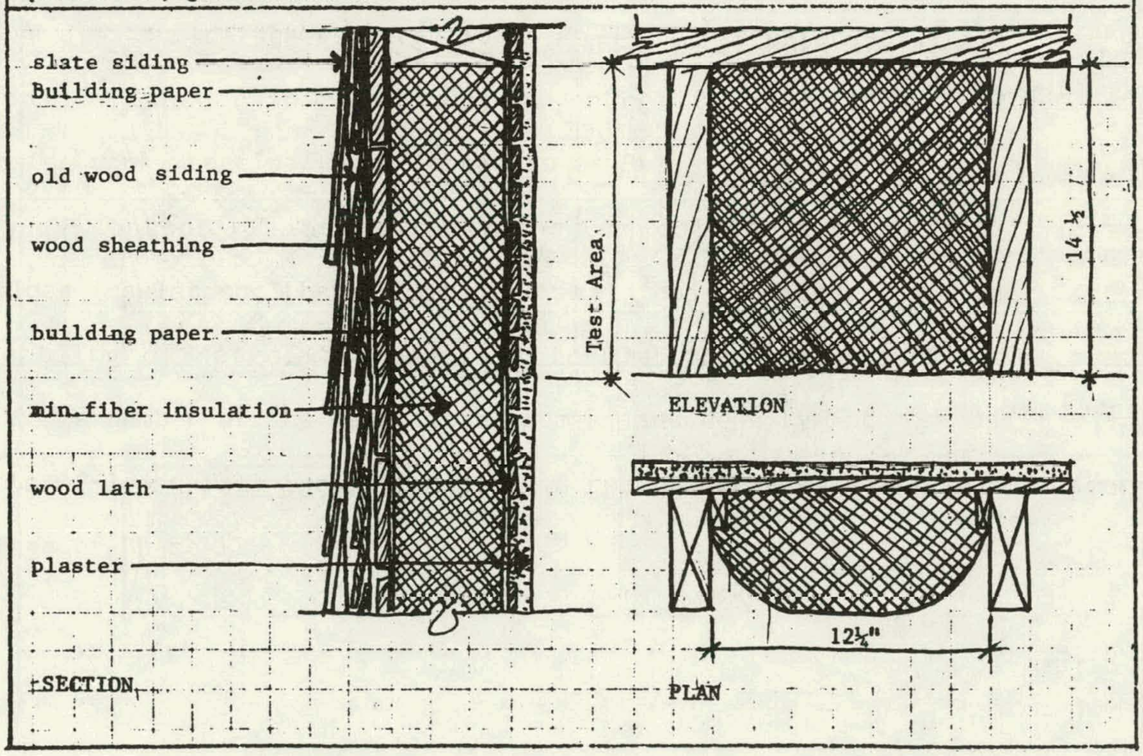

Fig. 1. Field worksheet, sample 6WX1, full cavity.

MINNESOTA ENERGY AGENCY
INSULATION TEST WORKS   T

SAMPLE NO. 6 Wall X-2
DATE 15 April 1978
SOURCE OF LEAD

GENERAL

AGE: retrofit over 12 house ORIENTATION north
HEAT SYSTEM INSTALLER & DATE unknown

FIELD OBSERVATIONS

plan location(s) bedroom north venting n/a
framing type 2 X 4 condition of structure good
condition of wiring n/a
ORIGINAL: insulation type 0 vapor barrier type 0
RETROFIT: insulation type mineral fiber vapor barrier type
retrofit installation procedures/problems made second opening east of first

difficulty of opening/closing sample multiple layers/odd framing-second opening

PRESENCE OF: moisture, corrosion, odor, vermin, fungus
none
packing excellent/good friability n/a
REPLACEMENT: insulation fiber glass vapor barrier none

FIELD TESTS

insulation thickness 2.84" flame n/a

SKETCHES (elevation/plan/section)
(siding, sheathing, building paper, existing insulation, new insulation, insulation thickness(es), vapor barrier(s), ceiling materials, flooring, gables, stops & firebreaks, ventilation, wiring, paint, installation procedures, general notes)

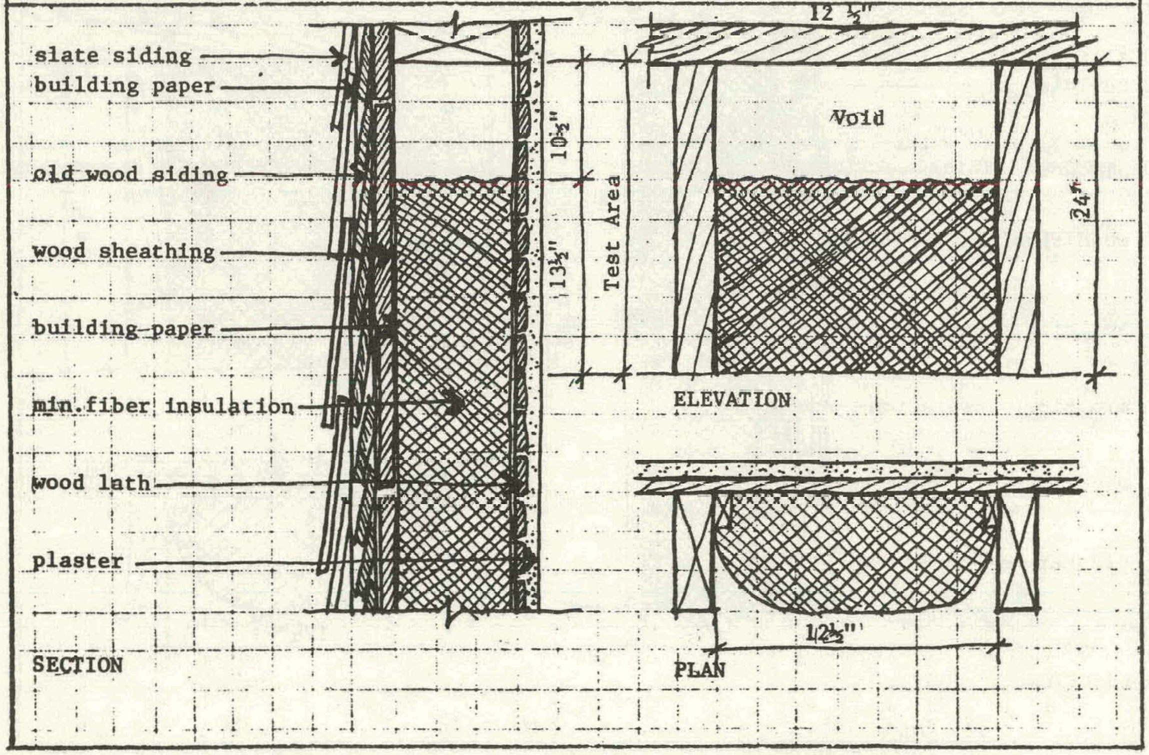

Fig. 2. Field worksheet, sample 6WX2, partial void cavity.

MINNESOTA ENERGY AGENCY
INSULATION TEST WORKSHEET

SAMPLE NO. 15 Wall X
DATE 15 April 1978
SOURCE OF LEAD

GENERAL
AGE: retrofit house ORIENTATION south
HEAT SYSTEM INSTALLER & DATE

FIELD OBSERVATIONS
plan location(s) kitchen venting none
framing type 2 X 4 stud condition of structure excellent
condition of wiring
ORIGINAL: insulation type vapor barrier type foil
RETROFIT: insulation type cellulose vapor barrier type above
retrofit installation procedures/problems foil torn- blocked complete cavity fill

difficulty of opening/closing sample shakes tight

PRESENCE OF: moisture, corrosion, odor, vermin, fungus of the three observers, one thought sample to be somewhat moist, two thought it to be dry.
packing good friability n/a
REPLACEMENT: insulation fiberglass vapor barrier none

FIELD TESTS
insulation thickness 3.5" flame not taken

SKETCHES (elevation/plan/section)
(siding, sheathing, building paper, existing insulation, new insulation, insulation thickness(es), vapor barrier(s), ceiling materials, flooring, gables, stops & firebreaks, ventilation, wiring, paint, installation procedures, general notes)

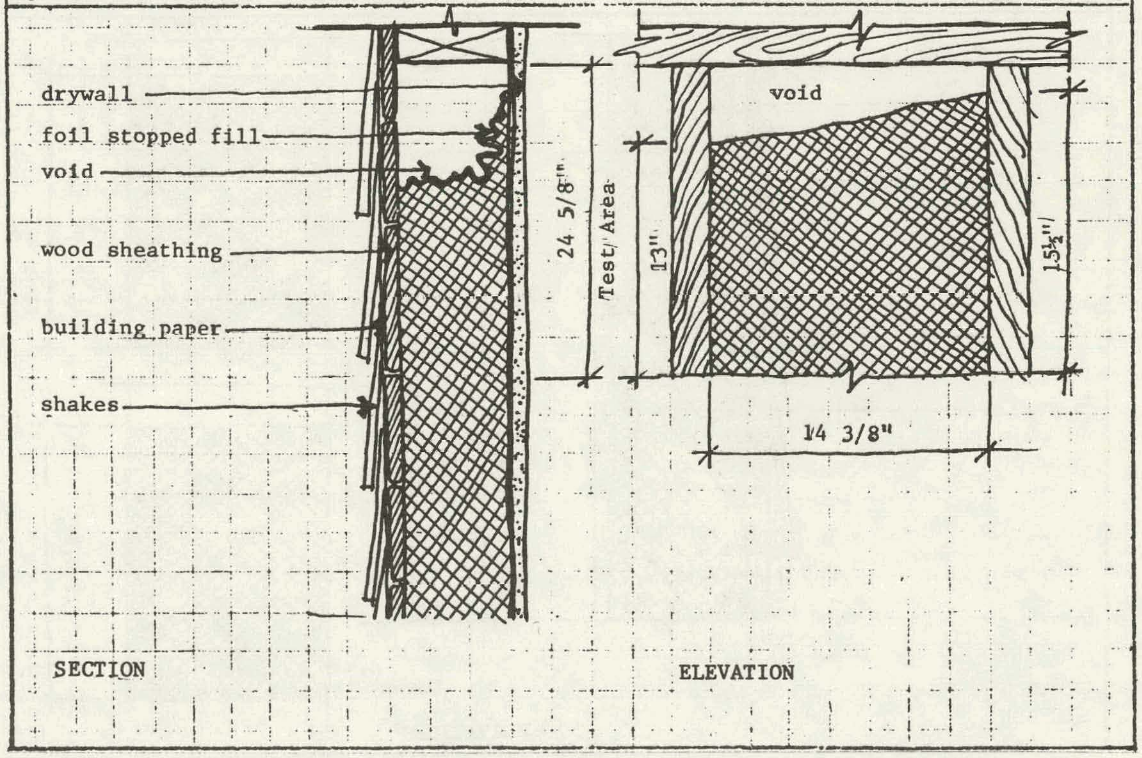

Fig. 3. Field worksheet, sample 15WX, partial void cavity.

MINNESOTA ENERGY AGENCY
INSULATION TEST WORKSHEET

SAMPLE NO. 23 Wall X
DATE 8 April 1978
SOURCE OF LEAD

GENERAL
AGE: retrofit house ORIENTATION
HEAT SYSTEM INSTALLER & DATE

FIELD OBSERVATIONS
plan location(s) rear stair venting n/a
framing type 2 X 4 stud condition of structure good
condition of wiring n/a
ORIGINAL: insulation type none vapor barrier type none
RETROFIT: insulation type cellulose vapor barrier type none
retrofit installation procedures/problems none

difficulty of opening/closing sample could not open from outside, selective cuts from inside
PRESENCE OF: moisture, corrosion, odor, vermin, fungus
none
packing OK friability n/a
REPLACEMENT: insulation fiber glass batt vapor barrier none

FIELD TESTS
insulation thickness 3.5" flame none taken

SKETCHES (elevation/plan/section)
(siding, sheathing, building paper, existing insulation, new insulation, insulation thickness(es), vapor barrier(s), ceiling materials, flooring, gables, stops & firebreaks, ventilation, wiring, paint, installation procedures, general notes)

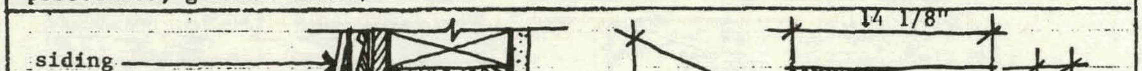

Fig. 4. Field worksheet, sample 23WX, partial void cavity.

MINNESOTA ENERGY AGENC^
INSULATION TEST WORKS T

SAMPLE NO. 27 Wall X
DATE 8 April 1978
SOURCE OF LEAD

GENERAL
AGE: retrofit house ORIENTATION
HEAT SYSTEM INSTALLER & DATE

FIELD OBSERVATIONS
plan location(s) dining room venting n/a
framing type stud/balloon/stopped condition of structure good
condition of wiring n/a
ORIGINAL: insulation type none vapor barrier type none
RETROFIT: insulation type cellulose vapor barrier type none
retrofit installation procedures/problems inside access

difficulty of opening/closing sample inside access

PRESENCE OF: moisture, corrosion, odor, vermin, fungus
none
packing OK friability n/a
REPLACEMENT: insulation fiber glass vapor barrier none

FIELD TESTS
insulation thickness 2.25" flame none taken

SKETCHES (elevation/plan/section)
(siding, sheathing, building paper, existing insulation, new insulation, insulation thickness(es), vapor barrier(s), ceiling materials, flooring, gables, stops & firebreaks, ventilation, wiring, paint, installation procedures, general notes)

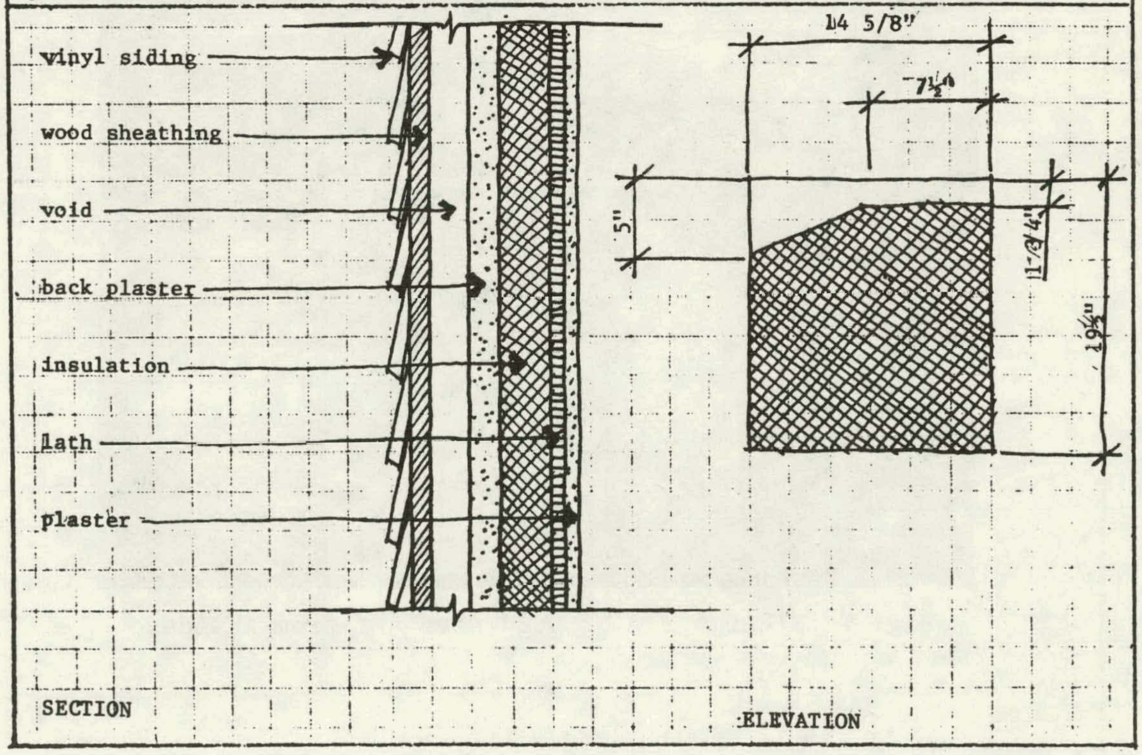

Fig. 5. Field worksheet, sample 27WX, partial void cavity.

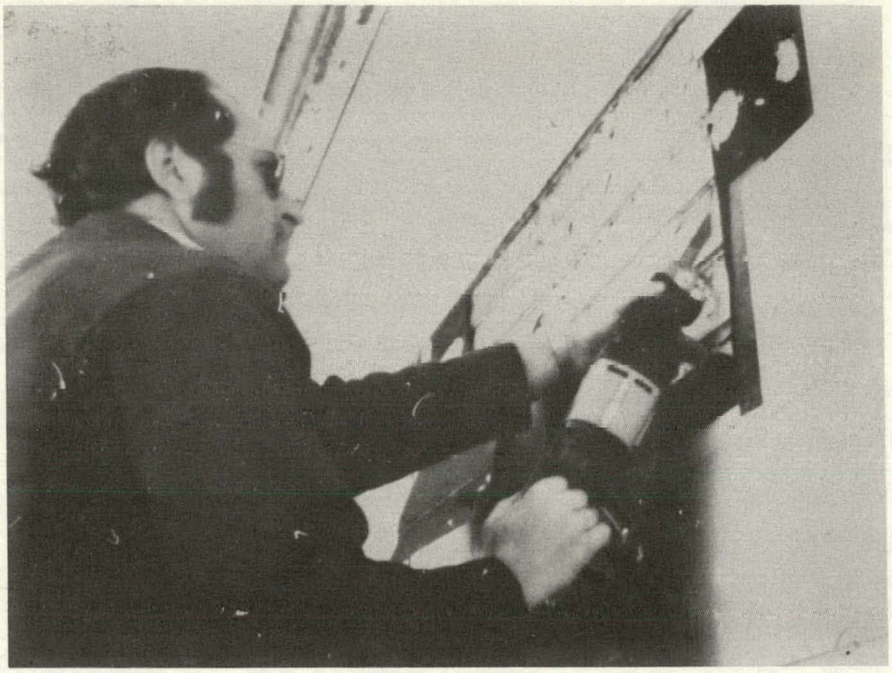

Fig. 6. Opening 6WX from outside.

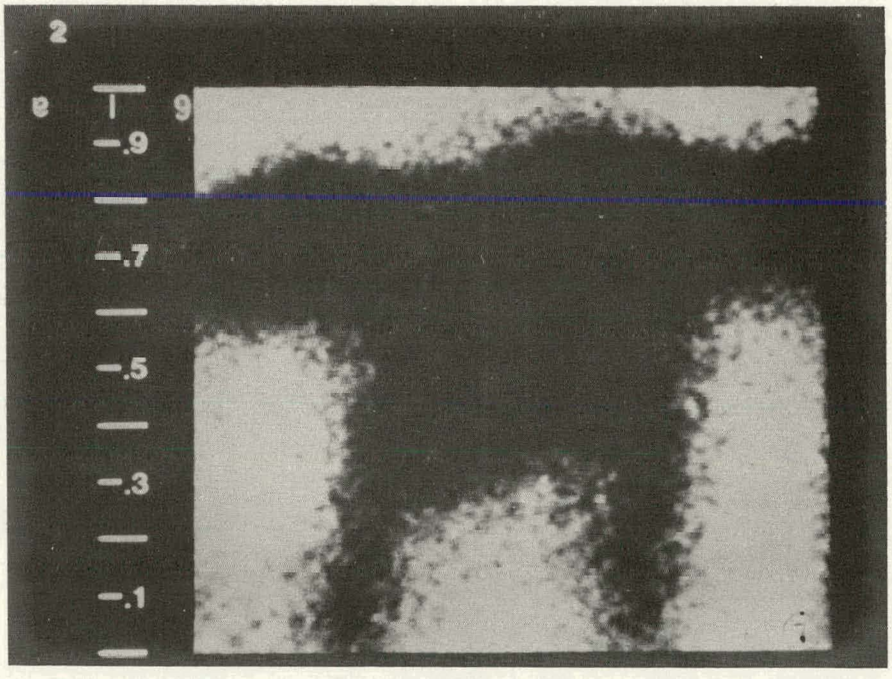

Fig. 7. Thermogram of void area 6WX from inside.

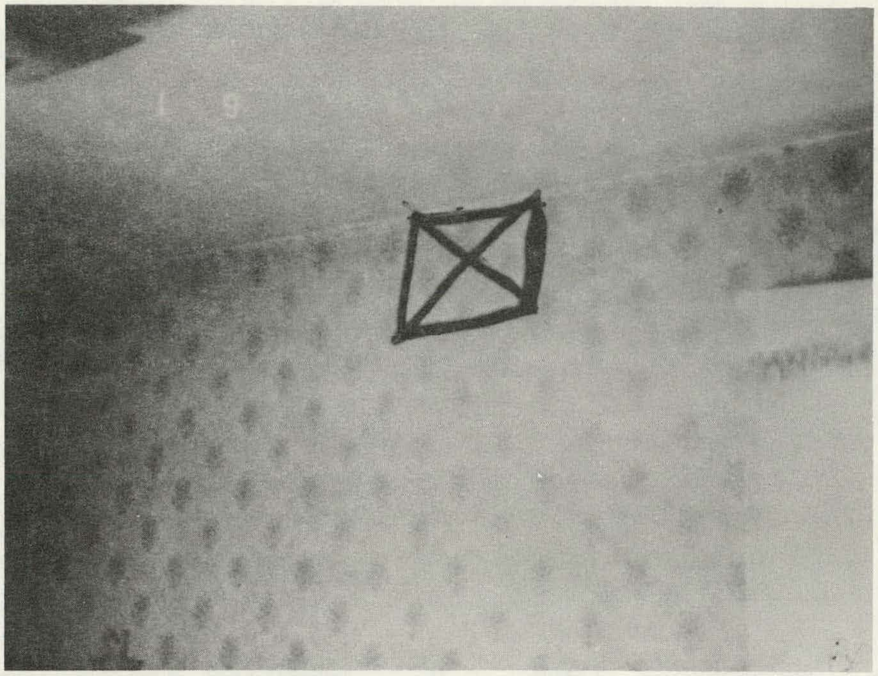

Fig. 8. Photograph of inside 6WX, marking area of void.

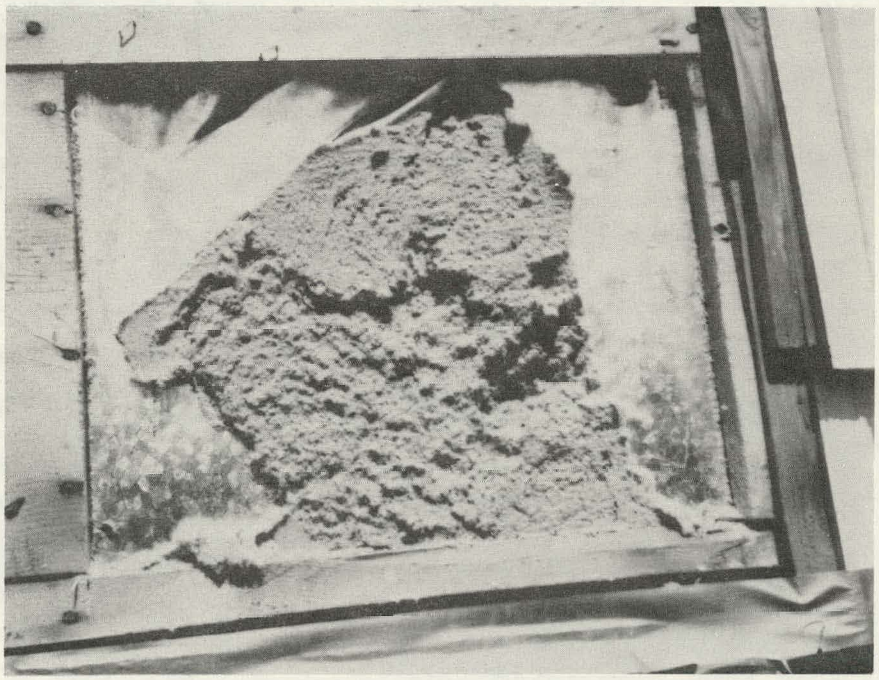

Fig. 9. 15WX opened from outside.

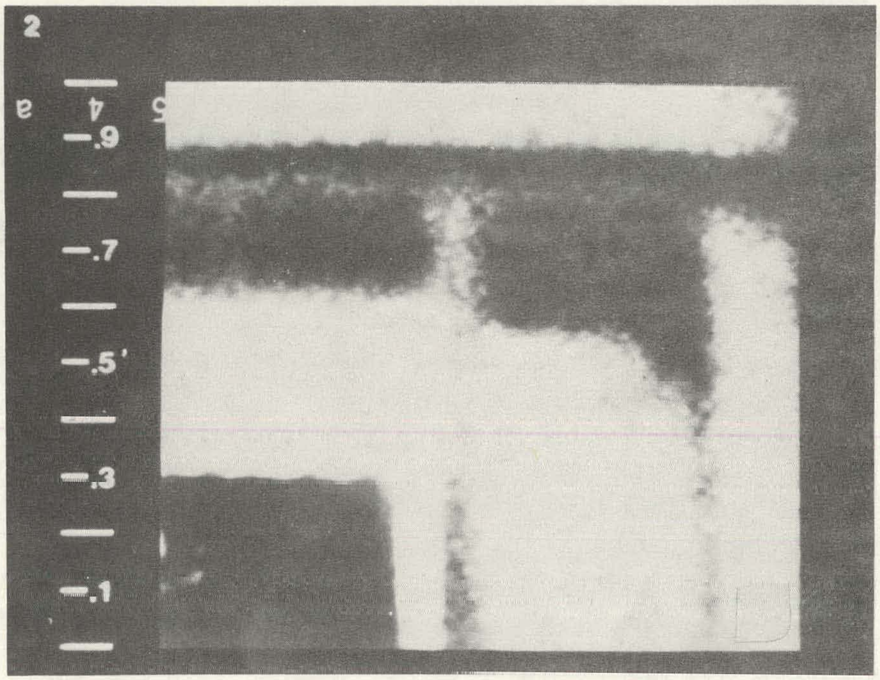

Fig. 10. Thermogram of 15WX area from inside.

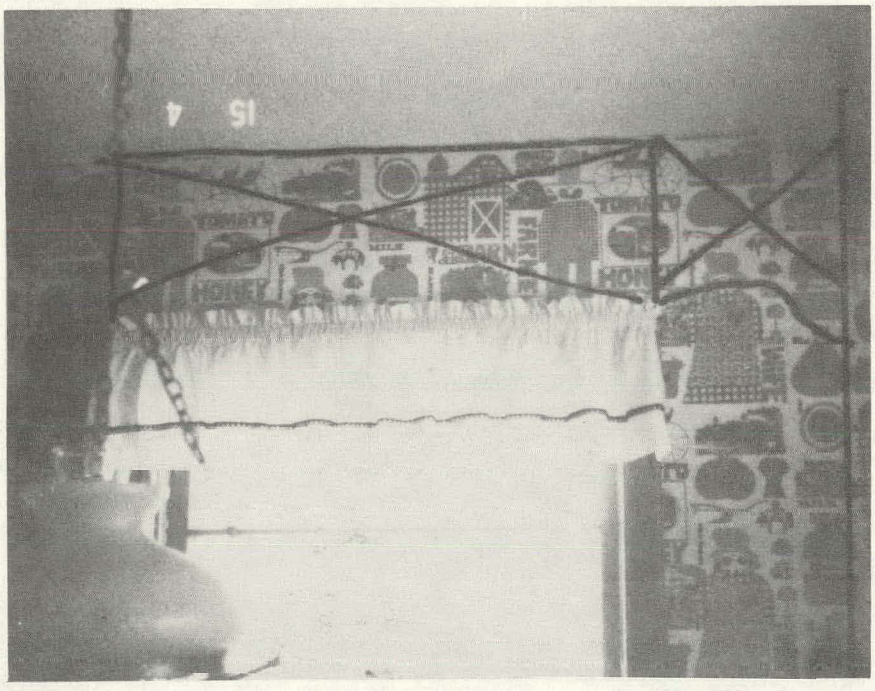

Fig. 11. Photograph of inside 15WX, marking void areas. Area opened was void to upper right of window.

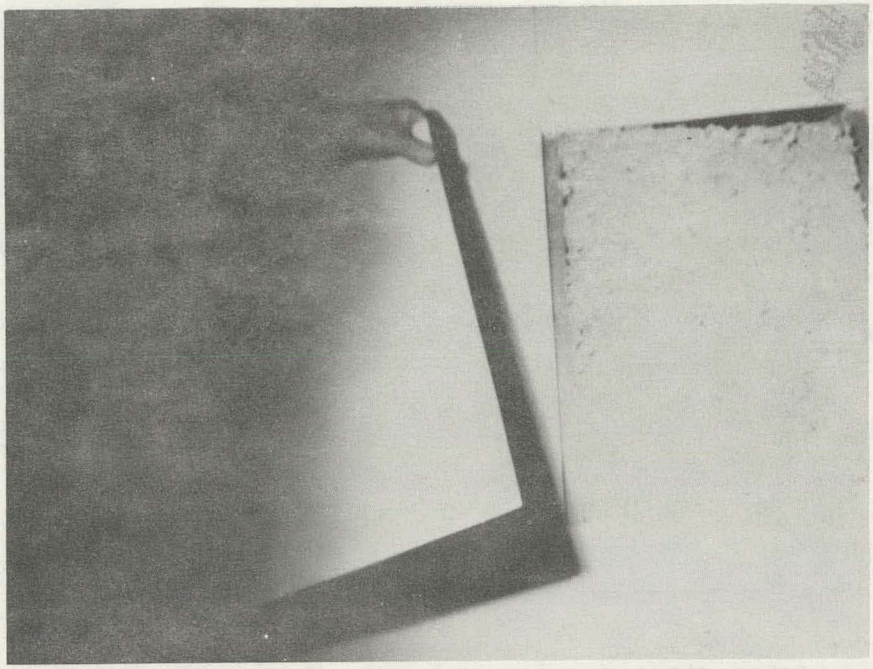

Fig. 12. Top opening from inside 23WX1 showing void.

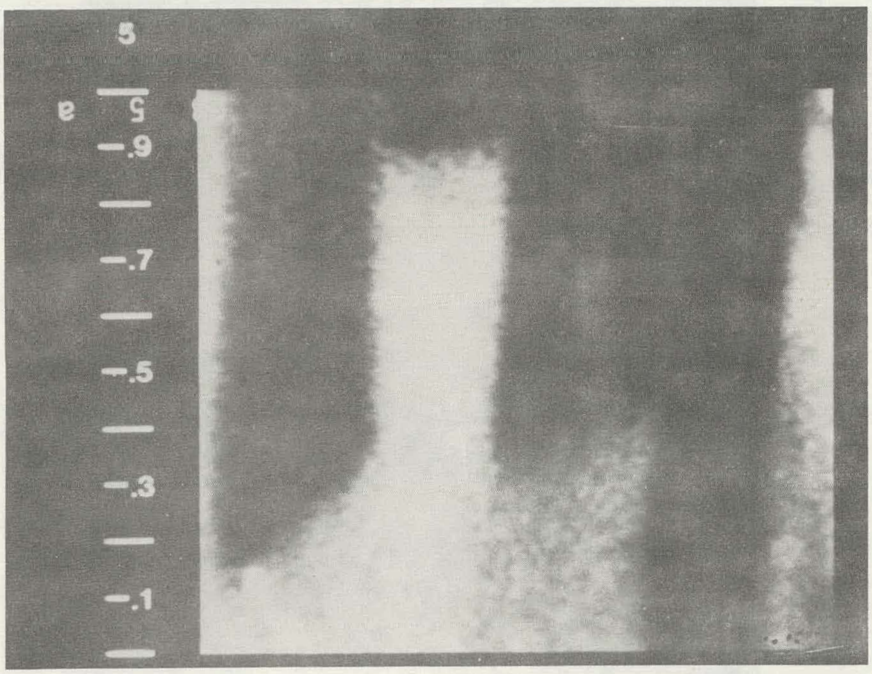

Fig. 13. Thermogram of inside of 23WX area showing numerous voids.

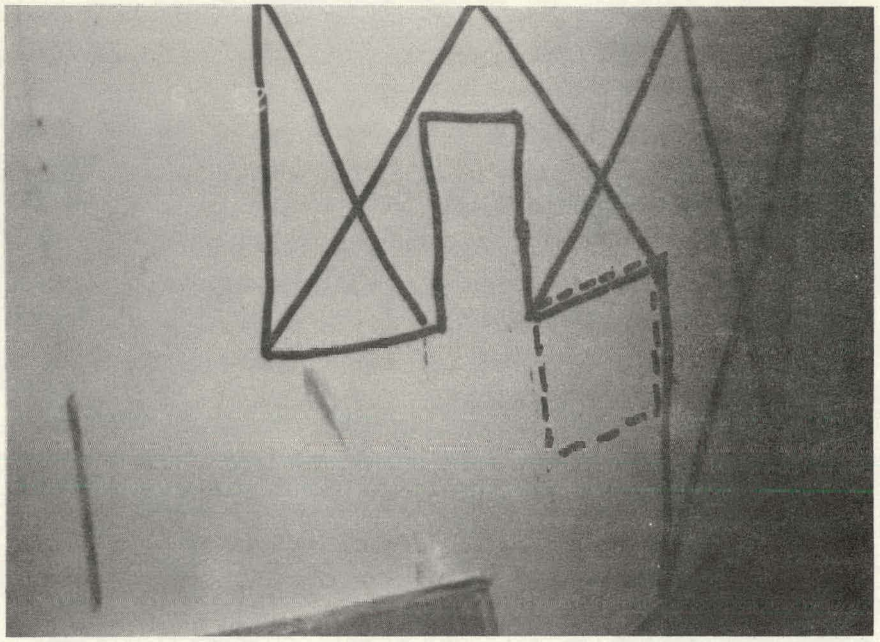

Fig. 14. Photograph of inside of 23WX marking void areas. Dotted line shows approximate location of 23WX1 opening.

Fig. 15. Thermography equipment.

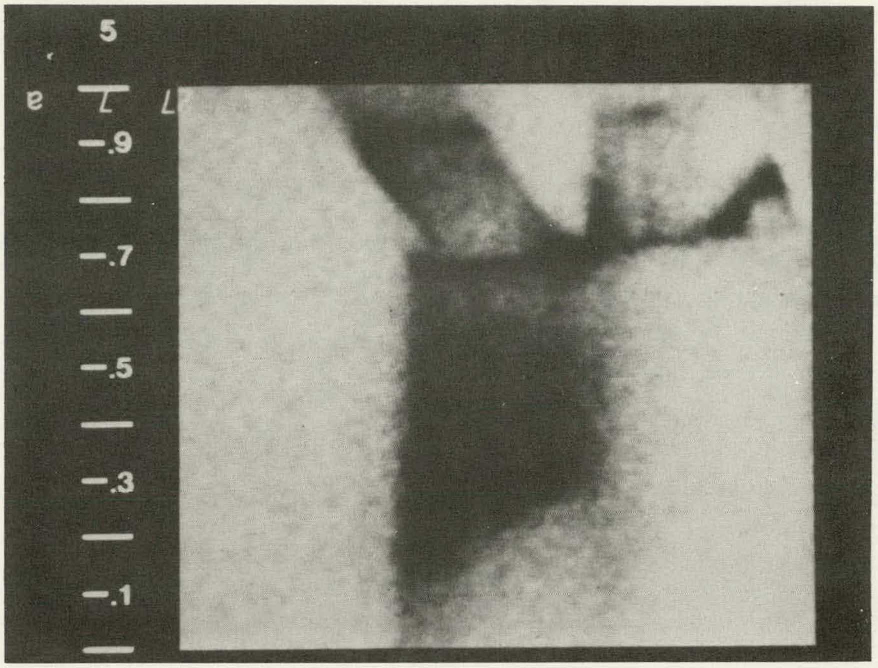

Fig. 16. Thermogram of inside of 27WX showing voids.

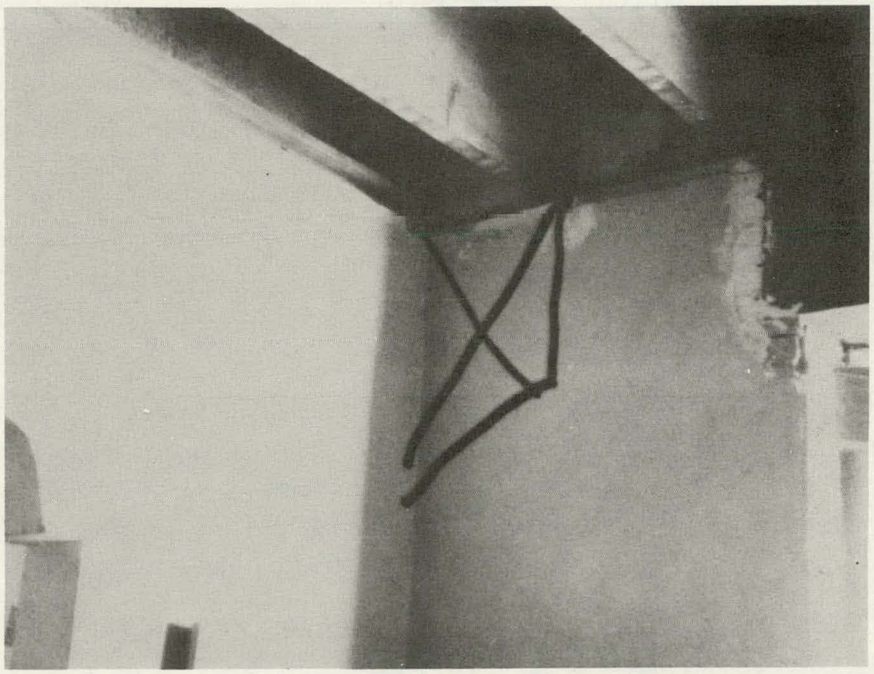

Fig. 17. Photograph of inside of 27WX marking void area.

REFERENCES

1. USDA Forest Service Research Paper, FPL 132, "Condensation Problems: Their Prevention and Solution", 1972.

2. D. M. Burch; C. I. Siu; and F. J. Powell, "Comparison of the Thermal Performance of Three Insulating Materials Commonly Used to Retrofit Exterior Frame Walls in Existing Residences", September 1976.

3. Brookhaven National Laboratory with the Assistance of Dynatech R/D Company, "An Assessment of Thermal Insulation Materials and Systems for Building Applications", June 1978.

4. Dr. Jay McGrew, "Is Your Insulation What It Shouldn't Be?", <u>Home Energy Digest - Wood Burning Quarterly</u>, Summer, 1978.

APPENDIX 1

LABORATORY EXPERIMENTAL PROCEDURES

Density

The density of the loose-fill materials, both cellulose and mineral fiber, were determined from the volume of the sample measured and recorded during sample removal. A cross-sectional area of either wall or ceiling was marked off and measured. The average thickness of the area was then determined by a depth gauge. The sample was placed in double polyethylene bags and sent to a commercial testing laboratory. At the laboratory, the sample material was weighed and the density calculated from the mass and the volume given by the *in situ* recorded length, width and depth as shown below:

$$D = \frac{M}{(l)\ (w)\ (d)}$$

where D = density
m = mass of material submitted in polyethylene bags
l = length of selected cavity section
w = width of cavity
d = average depth of insulation section

Thermal Resistance

The thermal resistance of the loose-fill cellulosic and mineral fiber insulations was determined in accordance with ASTM C518-76, "Steady-State Thermal Transmission Properties by Means of a Heat Flow Meter", using a commercially available heat flow meter apparatus. The upper and lower plates of the instrument were 24 x 24 inch blackened aluminum sinks, containing heaters which were temperature controlled with proportional/reset temperature controllers. Both plates were instrumented with a calibrated integrating heat flow transducer. The temperature of the upper and lower plates were controlled at 50 and 100 Deg. F respectively. The samples were placed within insulating containment rings, 3.5 inches thick for wall materials and 6 inches thick for ceiling materials. At equilibrium, the thermal resistance per inch was calculated as above.

Moisture Content

Duplicate 100 gram samples of the loose-fill insulation were placed in tared evaporating dishes and weighed. The sample was placed in an air circulating oven at 110 Deg. C for 48 hours, removed, placed in a dessicator until cool and reweighed. The percent mass loss assumed to be moisture content was calculated as:

$$\% \text{ moisture content} = \frac{(m_i - m_f)\ (100)}{m_i}$$

where m_i = initial mass

m_f = final weight

APPENDIX 2

ERRATA SHEET FOR HCP/W2843-01

Stu Spinney, Dynatech R/D Company; John Weidt, John Weidt Associates

October 1979

PAGE	**ITEM**	**CHANGE**
iii	Tbl. of Contents, 7.3, Moisture Control	from Control to Content
15	Section 7.3, MOISTURE CONTROL	from CONTROL to CONTENT
21	Table 8.3, Attic Venting,Sample 17c,none	from none to average
34	Table 8.12, Sample 9C, 1% Moisture Content	from 1% to <1%
	Sample 16C, 1% Moisture Content	from 1% to <1%
	Sample 18C, 1% Moisture Content	from 1% to <1%
	Sample 20C, 1% Moisture Content	from 1% to <1%
	Sample 22C, 1% Moisture Content	from 1% to <1%
	Sample 29C, 1% Moisture Content	from 1% to <1%
	Sample 30C, 1% Moisture Content	from 1% to <1%
	Sample 31C, 1% Moisture Content	from 1% to <1%
	Sample 35C, 1% Moisture Content	from 1% to <1%
	Sample 36C, 1% Moisture Content	from 1% to <1%
	Sample 37C, 1% Moisture Content	from 1% to <1%
	Sample 38C, 1% Moisture Content	from 1% to <1%
	Sample 39C, 1% Moisture Content	from 1% to <1%
	Sample 43C, 1% Moisture Content	from 1% to <1%
35	Table 8.12, Sample 47C, 1% Moisture Content	from 1% to <1%
	Sample 50C, 1% Moisture Content	from 1% to <1%
	Sample 52C, 1% Moisture Content	from 1% to <1%
37	Table 8.15, Sample 42C,	Delete - Add to Table 8.11
38	Table 8.16, Sample 8C, 1% Moisture Content	from 1% to <1%
	Sample 42C, 1% Moisture Content	from 1% to <1%
	Sample 42C,	Delete - Add to Table 8.12
40	Table 8.18, Sample 24C, 1% Moisture Content	from 1% to <1%
	Sample 28C, 1% Moisture Content	from 1% to <1%

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