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FIRE TESTS ON INSULATED SHEET STEEL WALLS

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K.H. Bardell

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Ottawa, August 1984

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FIRE TESTS ON INSULATED SHEET STEEL WALLS

by

K.H. Bardell

INTRODUCTION

The National Building Code of Canada (NBCC) requires that insulated sheet steel walls commonly used on the exterior of commercial and industrial buildings have a fire resistance rating of 1 h or more. In certain situations this requirement may be waived for exterior walls located 1.2 m or further from adjacent structures (NBCC 3.2.3.9) (1). For such walls, the temperatures, T_u, on the unexposed face during a specified time under fire test conditions governs the required spatial separation.

A series of ten small-scale fire tests of insulated sheet-steel walls had previously been conducted (2) to study thermal performance. The present report describes the results of two full-scale fire resistance tests designed to verify small-scale test results and determine fire resistance values and spatial separation requirements for insulated sheet-steel walls. The results of a cavity wall test are also reported.

DESCRIPTION OF SPECIMENS

Details of the test specimens are shown in Figures 1 and 2, item numbers below corresponding to the part numbers.

1. Steel liner sheet; 0.46 mm thick, 610 mm wide panels; lip_type caulked vertical seam; #12 sheet metal screws through the lip at 300 mm o.c.; Test No. 1 - lips inside wall, Test No. 2 - lips outside wall.

2. Sheet metal z-bars; 150 mm wide; screwed to liner at 300 mm o.c.; Test No. 1 - 1.22 mm thick, five bars of 606 mm lengths and two bars of 303 mm length. There is a space of 4 mm between the bars (see Figure 1 item 2). Test No. 2 - 1.91 mm thick, one continuous bar of 3630 mm length.

3. Ceramic paper; 3.2 mm thick, glued to both z-bar flanges; Test No. 1 - 1 layer, Test No. 2 - 2 layers.

4. Rock wool insulation; 128 kg m^3 density; two layers of 75-mm thick batts; 610 by 1220 mm square; vertical joints staggered.

5. Exterior steel sheet; 0.46 mm thick, 762 mm wide painted panels; lap-type vertical-joint sheet metal screwed at 410 mm o.c. through the lap; screwed to z-bar at 410 mm o.c.; Test No. 1 - "V-beam" profile, Test No. 2 - "Panel-Rib" profile (Figure 2).

6. Sheet steel channels; 1.52 mm thick, 150 mm wide; screwed to liner and exterior sheet at 310 mm o.c. top and bottom and 410 mm o.c. on sides; ramset to concrete restraining frame at 410 mm o.c.

(The following items were not part of the test specimen.)

7. Reinforced concrete restraining frame.

8. Red clay bricks and mortar used as a filler between the frame (item No. 7) and the test specimen.

Wall construction was carried out by commercial sheet steel erectors. Figures 3 and 4 show the walls before test.

TEST PROCEDURE

The specimens were subjected to fire test in accordance with ULC S101-M1980 (3), following the prescribed time-furnace temperature curve for a period of 2 h. The furnace temperature was measured by nine symmetrically distributed thermocouples enclosed in inconel tubes. The hot junction of each was placed 150 mm from the exposed surface of the specimen. Both individual temperature at the nine points in the furnace and the average of the nine temperatures were recorded. The fuel input into the furnace was automatically controlled. A detailed description of the fire test facilities of the National Research Council is available (4).

The temperature of the unexposed surface of the specimens was measured by nine fixed thermocouples and a roving one (Figure 5). Numbers 3, 5, 6 and 8 plus the roving thermocouple were placed in the valleys of the corrugations; the others were placed on the ridges. All were covered with 12-mm thick asbestos pads measuring 50 mm by 50 mm. The pads were smaller than standard in order that they would fit in the corrugations. In Test No. 1 the roving thermocouple was fixed in a valley at z-bar level near thermocouple 1 at 1 h and remained there for the duration of the test. In Test No. 2 it was in place from the beginning of the test. The lateral deflection of the specimen was measured at the wall centrepoint with an LVDT (linearly varying displacement transducer).

OBSERVATIONS

Test No. 1

For the first 20 min, smoke issued from the top of the corrugations on the unexposed side, accompanied by flaming at the linear seams on the exposed side, indicating combustion of the organic liner lip caulking. Steam continued to issue from the top of the corrugations for the duration of the test. The liner sheet underwent significant deformation during the first 40 min, including buckling and seam opening between screws (Figure 6). At $1\frac{1}{2}$ h, 75-mm diam hot spots, indicated by paint charring on the unexposed face, appeared at a corrugation ridge near the top centreline and near the z-bar screws. From Figure 6 it is evident that there was little or no deterioration of the insulation near the unexposed surface nor of the exterior sheet. The centreline of the wall deflected inward throughout the test.

Test No. 2

Wall No. 2 behaved the same as wall No. 1 with the following exceptions: the continuous z-bar bent in an s-shape at 1 h 10 min; a hot spot developed at thermocouple No. 2, caused by opening of the liner seam at this location; the centreline of the wall deflected outward as the test began and returned toward the furnace near the end of the test. Figure 7 shows the wall after test.

RESULTS

The average furnace temperature, average-unexposed surface temperature, and temperatures of the nine fixed thermocouples and one roving one are given in Tables I and II and shown in Figures 8 and 9 for both tests. Deflections of the centreline are plotted in Figures 10 and 11.

Test No. 1

The fire resistance of the wall was 1 h, 40 min; failure was due to the fact that the temperature (measured by the roving thermocouple) on the unexposed surface exceeded the allowable limit, 26 + 163 = 189°C, according to ULC-S101 (3). The test was terminated after 2 h.

Test No. 2

The fire resistance of the wall was 1 h and 30 min; failure was due to the fact that the temperature (measured by the roving thermocouple) on the unexposed surface exceeded the allowable limit. The test was terminated after 2 h. Immediately following the tests the furnace was opened and the specimens were subjected to a 180-s hose stream test in which the water pressure was 205 kPa (Figure 12). The specimens showed no further deterioration as a result of the hose stream test.

COMMENTS

The National Building Code, section 3.2.3.9 (1), dictates the spatial separation requirements for walls that do not pass the insulation requirements of the fire resistance test but remain intact for a given fire resistance period. An equivalent opening factor, F_{eo}, is calculated for the wall at the given period according to:

$$F_{eo} = \frac{(T_u + 273)^4}{(T_e + 273)^4}$$

where T_u = average temperature, in degrees Celsius, of the unexposed wall surface at the time the required fire-resistance rating is reached under test conditions

T_e = 892°C for a 3/4-h fire-resistance rating,
927°C for a 1-h fire-resistance rating,
1010°C fore a 2-h fire-resistance rating.

Equivalent unprotected openings are thus increased by this factor and the required distance between the wall and the lot line is increased according to the NBC, Section 3.2.3.1 (1). Table III summarizes the F_{eo} values for the test walls calculated for periods greater than their fire resistance. Also listed are the corresponding spatial separation values.

Figure 13 compares the average unexposed surface temperature determined in the full-scale and small tests and that determined by a calculation procedure described in Reference (2). The full-scale walls showed superior performance, probably due to a stack effect that developed in the corrugations and cooled the unexposed surface. This effect was not present in the small-scale tests, nor was it taken into account in the calculation procedure.

REFERENCES

1. National Building Code of Canada, Associate Committee on the National Building Code, National Research Council of Canada, NRCC 17303, 1980.

2. Bardell, K., Thermal Performance of Sheet Steel Walls Exposed to Fire, To be published.

3. ULC-S101-M1980, Standard Methods of Fire Endurance Tests of Building Construction and Materials, Underwriters' Laboratories of Canada, Scarborough, Ontario.

4. Shorter, G.W. and T.Z. Harmathy, Fire Research Furnaces at the National Research Council, National Research Council of Canada, Division of Building Research, NRC 5732, 1960.

ACKNOWLEDGEMENT

This work was carried out under a program approved by a joint committee of the Canadian Steel Construction Council and the National Research Council of Canada (CSCC/NRCC).

TABLE I

TEST NO. 1, TEMPERATURES °C

Time (min)	Furnace Temperature		Temp. of Unexposed Surface of Specimen	Thermocouple Readings									
	Prescr.	Av.	Av.	1	2	3	4	5	6	7	8	9	Rov.
0	20	26	26	25	27	24	24	15	27	33	22	25	
5	538	512	26	26	27	24	24	14	27	33	22	25	
10	704	670	26	27	28	24	23	13	28	34	23	27	
15	760	791	26	29	27	24	23	11	29	34	22	28	
20	795	777	27	30	27	24	22	11	31	34	21	30	
25	821	797	27	32	27	23	22	10	34	35	21	32	
30	843	840	28	33	27	23	21	9	35	35	21	33	
35	862	**	28	35	27	23	22	9	36	35	21	36	
40	878	892	29	38	27	23	22	44	36	36	21	38	
45	892	892	29	39	28	23	21	42	36	36	21	40	
50	905	890	29	40	28	23	21	41	36	37	21	43	
55	916	899	31	43	29	23	22	41	39	38	22	46	
60	927	918	32	46	30	24	22	42	44	40	22	49	70
65	937	939	34	49	32	25	23	41	50	42	23	51	
70	946	956	36	52	37	26	23	42	57	44	25	53	
75	955	963	40	56	44	31	23	42	67	48	27	56	
80	963	963	47	63	59	45	24	42	80	55	32	59	
85	971	962	60	73	88	68	25	43	100	67	43	63	
90	978	962	73	88	120	82	27	45	125	96	64	68	
95	985	974	89	110	118	114	31	48	155	96	98	75	
100	991	989	106	134	113	151	39	53	173	112	135	86	198*
105	996	1002	109	150	118	150	54	63	177	115	123	98	
110	1001	1009	114	158	137	**	89	81	178	121	114	113	
115	1006	1003	116	183	146	**	106	116	192	122	114	120	
120	1010	1018	121	215	149	**	105	119	216	128	110	128	

* Failure

** Measurement not reliable

TABLE II

TEST NO. 2, TEMPERATURES °C

Time (min)	Furnace Temperature		Temp. of Unexposed Surface of Specimen	Thermocouple Readings									
	Prescr.	Av.	Av.	1	2	3	4	5	6	7	8	9	Rov.
0	20	32	34	34	36	33	33	35	36	36	33	34	25
5	538	488	33	34	35	33	33	35	35	36	33	33	25
10	704	694	34	34	35	33	33	35	35	36	34	34	26
15	760	782	34	36	36	33	33	35	35	37	33	37	28
20	795	786	35	39	36	33	32	35	35	38	34	39	33
25	821	801	35	42	36	33	32	35	35	38	34	41	38
30	843	829	37	46	37	33	32	36	36	39	34	44	43
35	862	863	38	49	39	33	32	36	36	40	35	47	49
40	878	889	39	53	40	34	32	37	37	42	36	49	55
45	892	903	41	57	41	34	32	38	39	43	37	52	61
50	905	907	42	61	43	34	33	40	41	45	38	54	68
55	916	906	44	64	47	34	33	42	43	47	38	57	72
60	927	914	47	69	55	35	33	44	46	49	37	62	79
65	937	926	50	76	70	36	33	47	47	53	38	64	92
70	946	941	56	85	96	38	34	49	50	58	39	67	108
75	955	954	62	94	127	43	35	41	42	54	30	71	125
80	963	966	72	109	159	60	37	53	55	74	43	74	148
85	971	974	93	125	184	106	44	54	64	124	52	80	170
90	978	979	110	140	189	138	58	55	89	171	83	89	182
95	985	980	127	155	198	140	81	56	126	144	156	102	193*
100	991	983	157	177	203	154	121	57	175	204	213	130	218
105	996	989	186	204	204	154	146	61	232	219	269	202	262
110	1001	998	210	232	200	150	149	89	282	218	297	282	311
115	1006	1008	229	266	198	144	173	124	305	227	287	343	363
120	1010	1014	234	294	195	139	180	146	313	231	262	354	395

* Failure

TABLE III

SUMMARY OF TEST RESULTS

Wall	Fire Resistance	Average Unexposed Temp., °C	Time	F_{eo}	Spatial Separation
1	1 h, 40 min	121	2 h	0.0089	1.2 m for wall less than 500 sq m
2	1 h, 30 min	234	2 h	0.024	1.2 m for wall less than 250 sq m

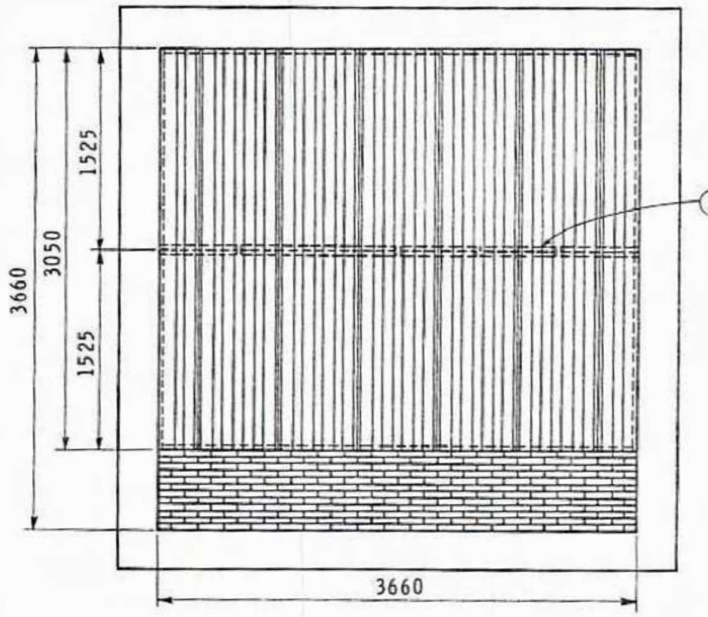


Figure 1

Test specimen

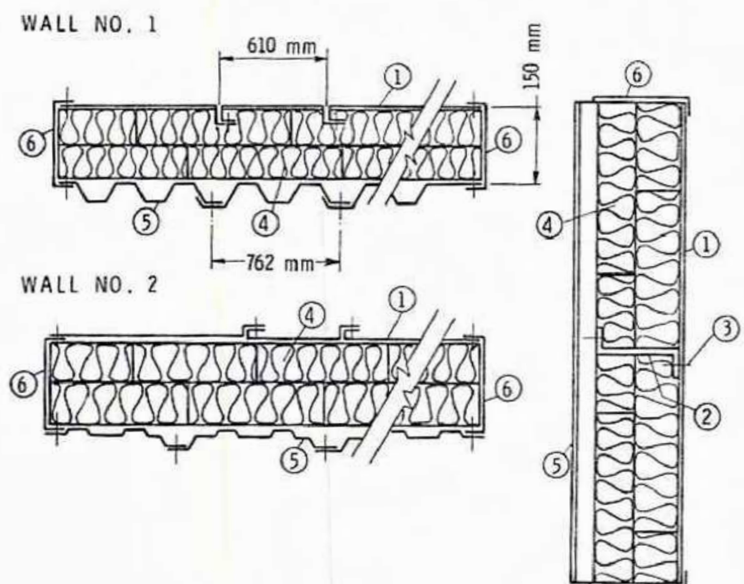
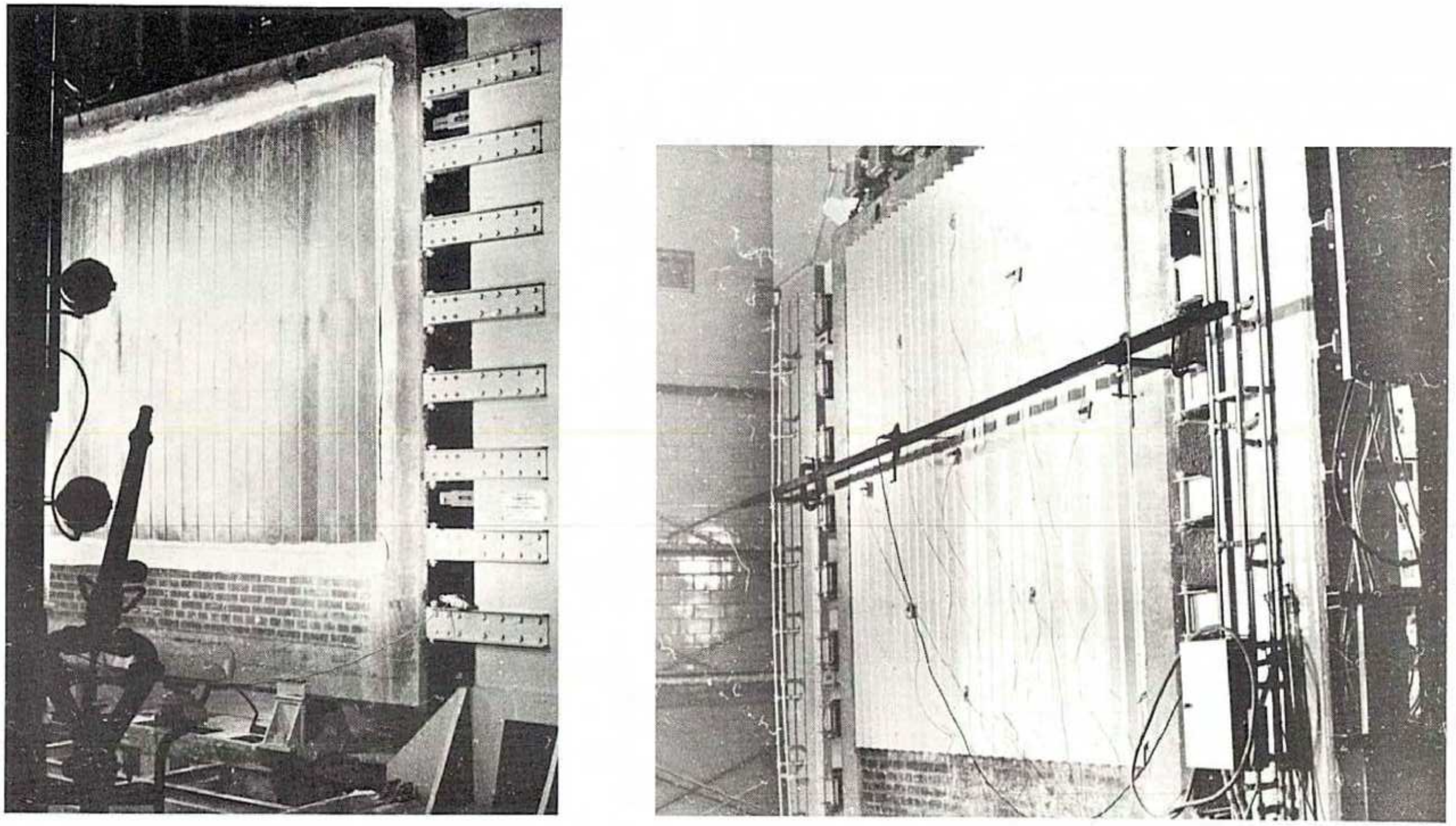


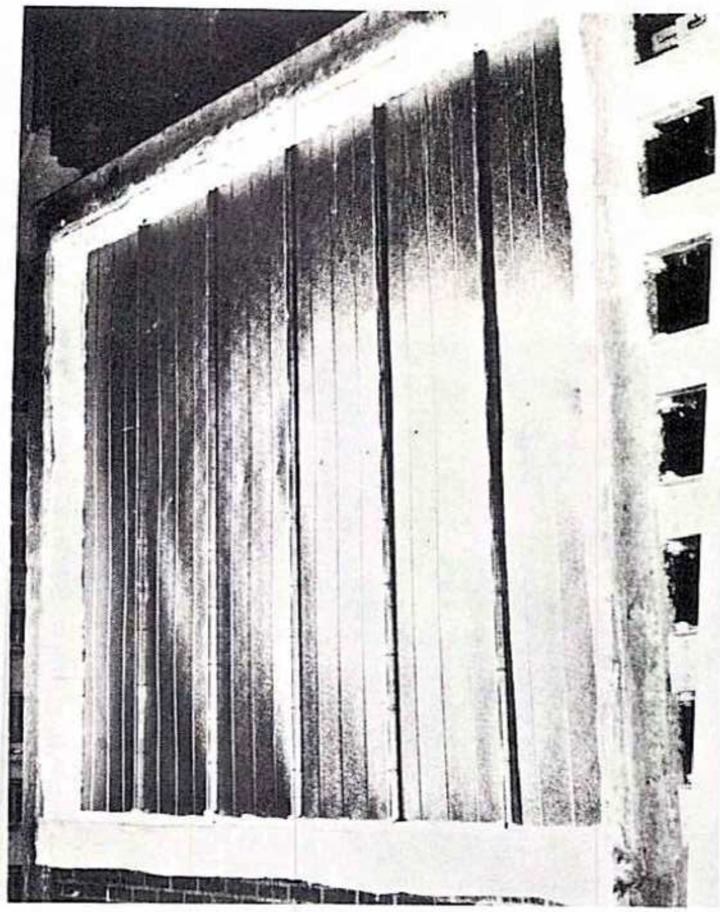
Figure 2

Sections through wall specimens



(a) Exposed Side (b) Unexposed Side

Figure 3 Wall No. 1, before Test



Exposed Side

Figure 4 Wall No. 2, before Test

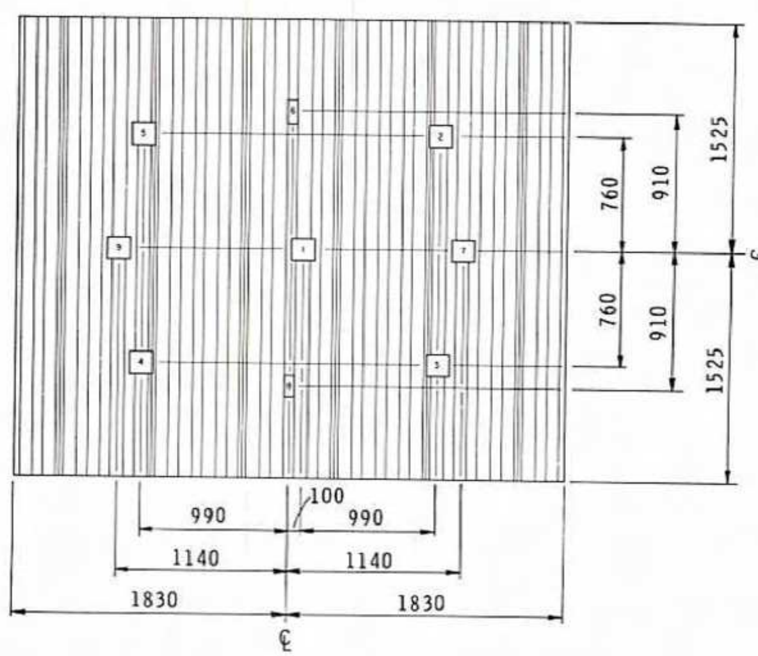
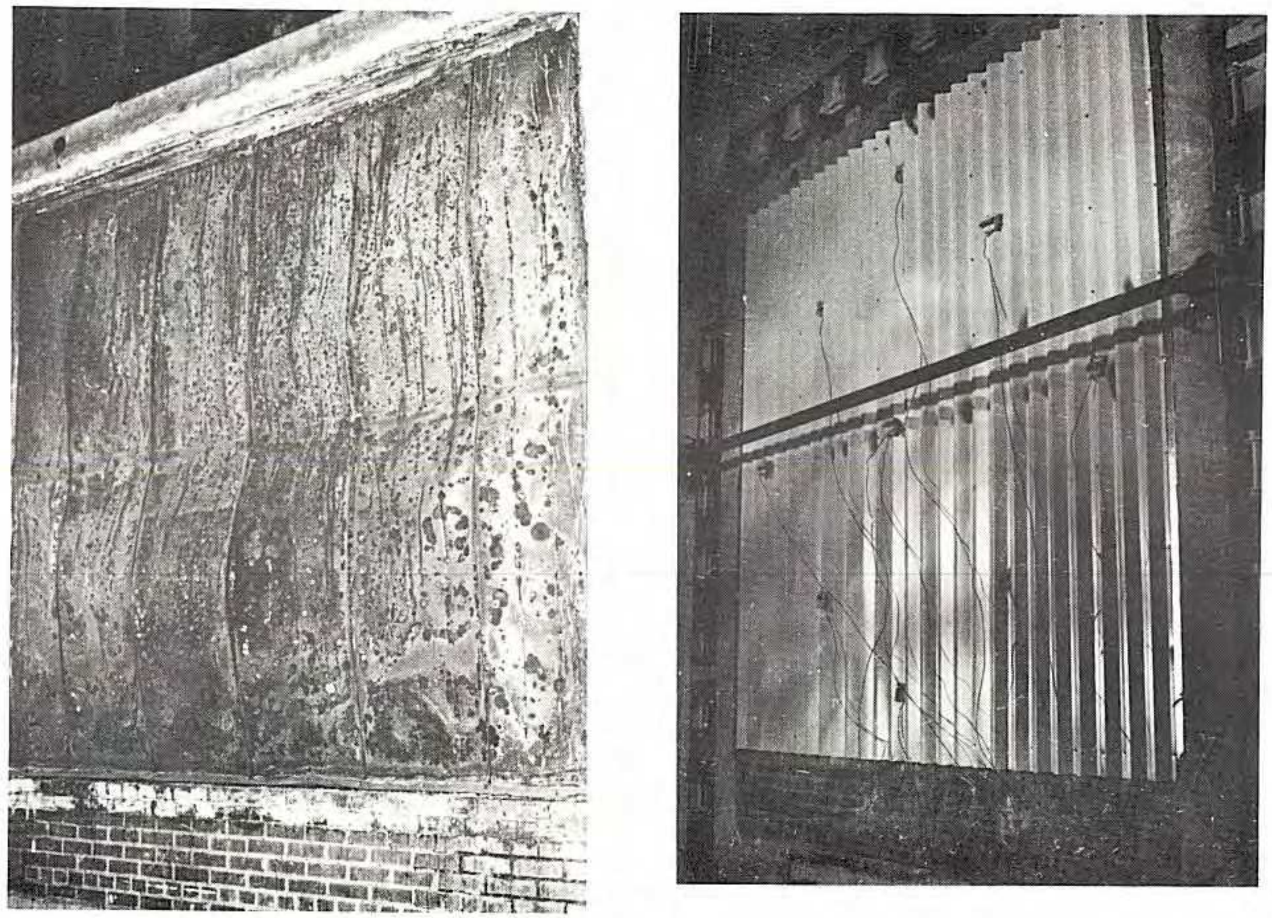


Figure 5

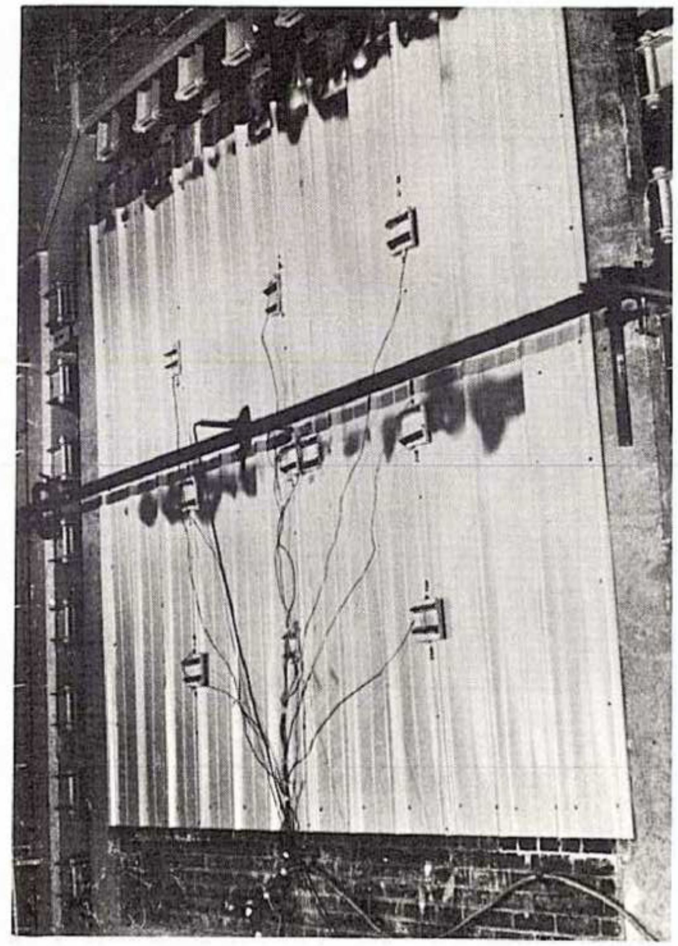
Location of thermocouples on unexposed surface



(a) Exposed Side (b) Unexposed

Figure 6 Wall No. 1, after Test

(a) Exposed Side



(b) Unexposed Side

Figure 7 Wall No. 2, after Test

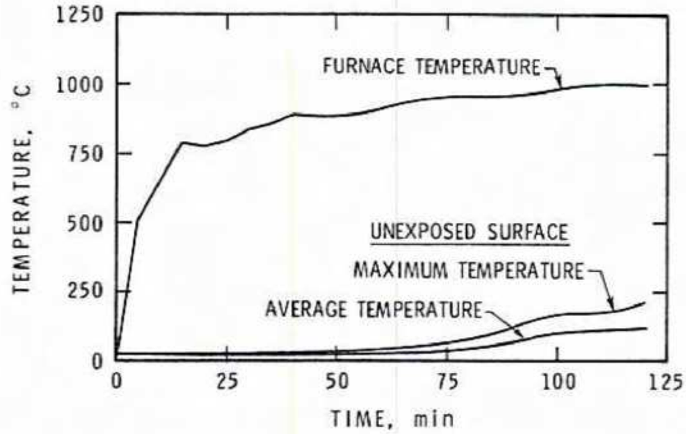


Figure 8

Average temperatures, Test No. 1

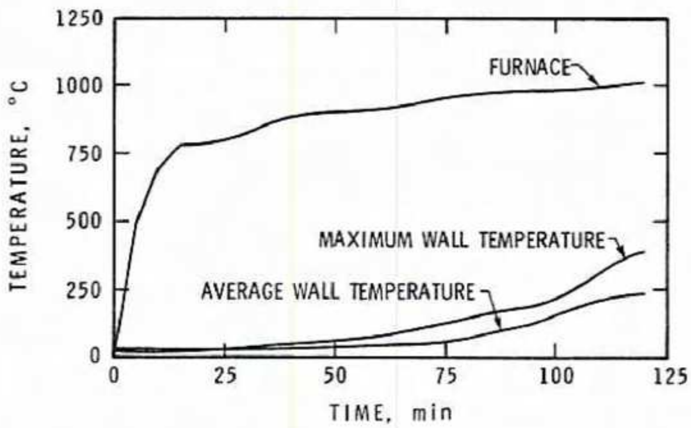


Figure 9

Average temperatures, Test No. 2

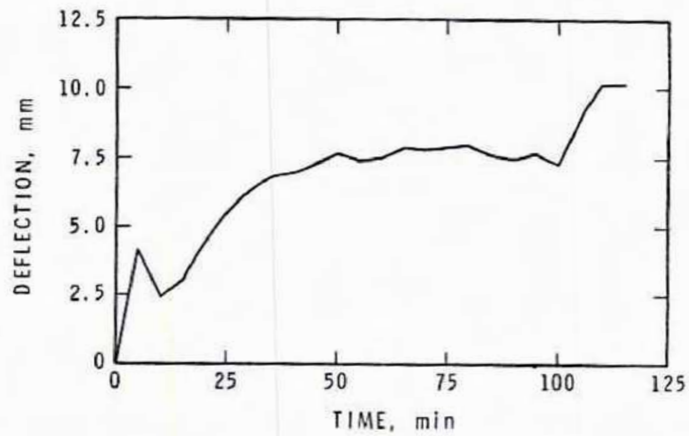


Figure 10

Deflection of centreline, Test No. 1

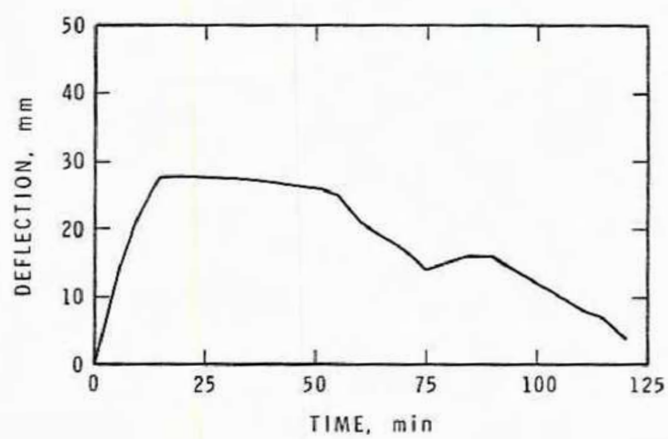


Figure 11

Deflection of centreline, Test No. 2

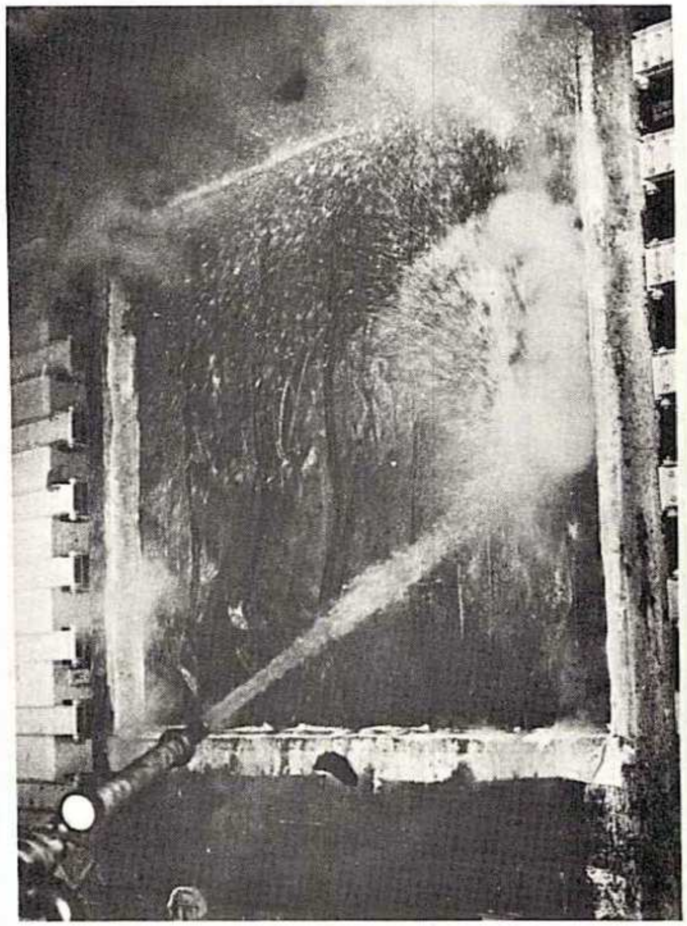


Figure 12

Hose Stream Test

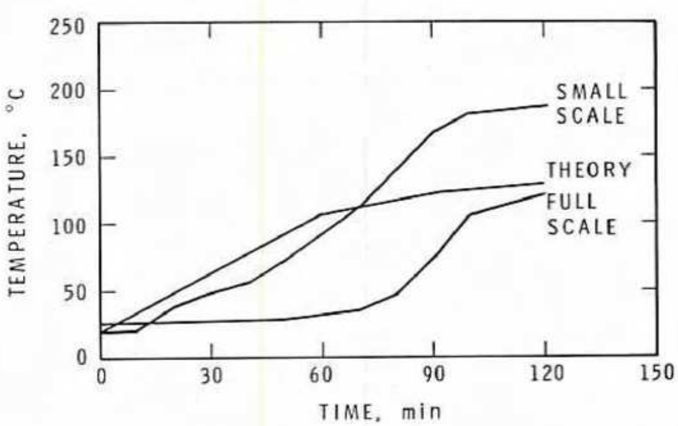


Figure 13

Comparison of predicted and actual temperatures