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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

FURTHER EXPERIMENTS ON THE TRANSMISSION OF HEAT FROM FLUE PIPES

by

H. L. Malhotra

Summary

Some experiments have been carried out to determine the effect of providing a metal sleeve round a flue pipe where it passed through a brick wall and filling the gap between the pipe and the sleeve with asbestos rope. There was a significant reduction in the heat transmission as measured by the temperature rise of a timber wall plate compared with the results obtained when no sleeve was used.

Some tests were also performed to find the effect of interposing a noncombustible shield between the ceiling of a timber joist floor and a horizontal flue pipe. The use of a metal shield led to a reduction of the temperature of the ceiling and the joists.

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1. Introduction

In an installation where a flue pipe from a domestic type of fire or boiler passes through a wall, it is necessary to pay special attention to the placing of combustible materials near to the flue pipe. In April, 1954, a fire occurred in the Nursery of Dellwood Maternity Home at Reading, which was presumed to have started in the structural timber immediately above the flue pipe of a solid fuel boiler used for the supply of hot water. An experiment (1) was carried out reproducing the flue pipe installation at Dellwood Maternity Home and it was shown that the fire could have been initiated in the timber construction above the flue pipe, if the pipe were operating continuously at temperatures of the order of 600°C.

A British Standard Code of Practice (2) recommends for small boiler systems using solid fuel that "where a flue pipe passes through brickwork or concrete, a metal sleeve should be provided, the space between the pipe and the sleeve being caulked with asbestos string or rope". The London County Council require according to their building byelaws (3) that "no structural timber, woodwork ...... or other combustible material is placed ...... within 9 in. of any flue pipe fitted to a gas fired appliance unless that pipe, where it is in proximity to combustible material, is carried in a metal sleeve with a space of 1 inch between the sleeve and the pipe and that the space is packed with asbestos packing or other suitable non-heat-conducting material".

Tests were made to study the effectiveness of such a metal sleeve by measuring the temperature of a timber wall plate placed at known distances above the flue pipe.

Where a flue pipe runs horizontally below a timber floor, it should be fixed at such a distance that the joists are not likely to attain temperatures which may lead to progressive charring and ignition. Some tests were carried out to study the protection afforded by non-combustible shields attached to the ceiling above a flue pipe.

2. Technique

The technique employed was similar to that used in the flue pipe experiment relating to Dellwood Maternity Home (1). Figure 1 shows the mock-up used, which represented a corner of a brick-walled room with the boiler close to the walls and its flue pipe passing horizontally through one wall.

A 16 S.W.G. sheet steel sleeve 8 in. inside diameter and 9 in. long was built in a 9 in. brick wall. A 6 in. diameter flue pipe was placed centrally in the sleeve leaving a uniform gap of 1 in. between the pipe and the sleeve. A 3 in. x 4 in. timber wall plate, 36 in. long, was fixed in two alternative positions, either 9 or 6 in. from the top of the flue pipe (see Figs. 2 and 5) and was bedded in cement/sand mortar. The floor unit which consisted of 2 in. x 8 in. timber joists with 1 in. nominal boarding, had a ½ in. plaster board ceiling nailed direct to the joists. The soffit of the ceiling was 12 in. from the top of the pipe.

The ceiling shields, which consisted of either 18 S.W.G. sheet steel or ½ in. asbestos board, were held in position by means of screws, one at each corner with appropriate distance pieces between the ceiling and the shield.

Thermocouples were fixed to the flue pipe, the metal sleeve, the wall plate, and between the plasterboard and the timber joist above the flue pipe, at positions shown in Figures 2, 5, 8 and 11; and a continuous record of the temperatures kept. It was intended to perform the tests with the temperature of the flue pipe before it entered the sleeve at 600°C, which was assumed to be the maximum temperature for continuous running. It was not found possible to keep this temperature constant in all the tests on account of variations in the gas supply.

3. Description of the tests

For the first two tests the space between the sleeve and the pipe was fully packed with 1 in. diameter asbestos rope and the wall plate positioned 9 and 6 in. respectively from the pipe. In the remaining two tests the effect of providing only partial insulation, such as might occur in practice due either to carelessness or to gradual disintegration of the insulation, was investigated. The partial insulation consisted of sealing only the ends of the sleeve with asbestos rope.

No ceiling shield was used in the first test, in the second test a steel sheet measuring 20 in. x 12 in. was fixed $\frac{1}{2}$ in. from the soffit to protect an area above the flue pipe. The size of the shield was increased to 20 in. x 32 in. in the next test when it was 1 in. away from the soffit. In the final test the shield was of the same size and similarly fixed but consisted of $\frac{1}{2}$ in. asbestos board.

The tests carried out are summarized in the table below.

Table 1

Test No.	Duration of test hr.	Distance between wall plate and flue pipe in.	Insulation between flue pipe and the sleeve	Size and type of ceiling shield
1	114	9	Fully packed	None
2	114$\frac{1}{2}$	6	"	Sheet steel 18 G x 20 in. x 12 in. $\frac{1}{2}$ in. from soffit
3	120	9	Partially packed	Sheet steel 18 G x 20 in. x 32 in. 1 in. from soffit
4	121	6	"	Asbestos board $\frac{1}{2}$ in. x 20 in. x 32 in. 1 in. from soffit

4. Test results

The test results in the form of temperature curves together with sectional views showing the location of thermocouples and photographs showing the appearance of the wall plate and the ceiling after the various tests are presented in Figures 2 to 14 and amplified in the following notes.

Test No. 1

It was not found possible to maintain the flue pipe temperature constant due to fluctuations in the gas supply. Referring to Figure 2, it will be seen that the pipe attained a maximum temperature of 600°C at 20 hours as measured at location 1. The temperature of the pipe where it passed through the wall was 800°C at the same time, and the corresponding sleeve temperature was 500°C. The floor joist above the pipe had practically reached a steady state at 10 hours whereas the temperature of the wall plate was not steady until 31 hours when it attained a value of 140°C at position 4. For the rest of the test the temperature fluctuations of wall plate and the joist corresponded to those in the pipe and at 114 hours when the test was stopped both were at a temperature of 155°C.

At the end of the test there was no significant charring of the wall plate (Figure 4) or the ceiling joist, but the lower paper face of the plasterboard in the area above the flue pipe was charred and the board had become brittle (Figure 3).

Test No. 2

The flue pipe temperature, as measured at location 1, was fairly constant for the duration of this test. The rise in temperature of the wall plate was more rapid than in the previous test whereas the joist temperature rose more slowly due to the provision of the shield. Both the wall plate and the ceiling joist reached steady state condition at times corresponding to those in the previous test. When the test was stopped at 114½ hours the wall plate temperature was 200°C and had been fairly constant for 80 hours (Figure 5). This resulted in the slight amount of charring shown in Figure 7. The joist temperature at the end of the test was 110°C, a reduction of 45°C, from the previous test. The provision of the shield had reduced the charring of the plasterboard (Figure 6) but had not protected a sufficiently large area.

Test No. 3

Provision of partial insulation only between the flue pipe and the sleeve raised the temperature of the sleeve and increased the rate of rise of temperature of the wall plate as shown by temperature curves in Figure 8. The wall plate temperature was 160°C compared with 150°C in test No. 1 where it occupied a similar position with respect to the flue pipe. Figure 10 shows that at the end of the test, after 120 hours, no significant charring of the wall plate had occurred.

The increase in the air gap between the shield and the ceiling did not afford any greater protection to the ceiling joist.

Test No. 4

The temperature of the wall plate rose rapidly in this test and at 50 hours, when it was steady, it had attained a value of 250°C. At 117 hours glowing at the central portion of the wall plate was observed and this was accompanied by emission of slight amount of smoke. After two hours a length of approximately 6 in. had charred and flaming started on the outside of the wall plate, accompanied by a sudden temperature rise to 387°C as shown by thermocouple No. 4. The test was stopped at 121 hours, and Figure 14 shows the remains of the wall plate with the middle 12 in. totally consumed.

The temperature of the ceiling joist at the end of the test was 150°C. Figure 12 shows the appearance of the ceiling after test.

5. Discussion of results

The test results show that where it passed through the wall the flue pipe attained a higher temperature than outside the wall; the rise in temperature being about 150°C. The temperature of the sleeve depended upon the insulation used between it and the pipe and, with well packed insulation the temperature of the sleeve was lower. This in turn reflected upon the temperature rise of the timber wall plate.

The use of the metal sleeve resulted in a lowering of the temperature of the wall plate; with no sleeve the temperature of the (1)
wall plate when at a distance of $8\frac{7}{8}$ in. from the flue pipe was 180°C after 72 hours, the temperatures at the corresponding time when the sleeve was used were 140°C when well insulated and 160°C when only partially insulated. With the wall plate 6 in. from the flue pipe and the sleeve fully insulated the temperature of the wall plate rose to 200°C after 31 hours and then remained fairly constant. On the other hand with only partial insulation the temperature after 31 hours was 245°C and attained a maximum value of 270°C after 50 hours. This resulted in progressive charring and spontaneous ignition of the wall plate after approximately 5 days of continuous operation of the flue pipe at a temperature of 600°C. It would therefore appear that a temperature of about 250°C is critical for timber under these conditions.

The provision of a mild steel sheet ceiling shield reduced the temperature between the plasterboard and the timber joist as well as decreasing the charring of the plasterboard. The larger size of shield provided better protection, but increasing the gap between the ceiling and the shield from $\frac{1}{2}$ to 1 in. did not have any significant effect. The larger air gap may have led to increased heat transmission by convection. The use of asbestos board on the other hand provided slightly poorer protection.

6. Conclusions

A few tentative conclusions can be drawn from this work:-

1. The use of a metal sleeve as recommended in the British Standard Code of Practice 403 : 101 (1952) and Building Byelaws (1952) of the London County Council reduces the heat transmission from a flue pipe where it passes through a wall. Even when a metal sleeve is used combustible material such as timber wall plates etc. should be not less than 9 in. from a flue pipe and the space between the metal sleeve and the flue pipe should be tightly packed with insulating material such as asbestos if the temperature of the timber is not to exceed 150°C. To keep the temperature of the timber lower than 100°C under these conditions it should be not less than $10\frac{1}{2}$ in. from the flue pipe.

2. Provision of a ceiling shield above a flue pipe would reduce the temperature of the floor joists. The width of this shield at right angles to the pipe should be not less than five times its diameter. Steel sheet of 18 S.W.G. provides an effective shield in conjunction with an air gap of $\frac{1}{2}$ in.

7. Acknowledgments

Mr. P. Smith assisted in carrying out the tests.

8. References

(1) "A Flue Pipe Experiment Relating to Dellwood Maternity Home, Reading". Malhotra, H. L. Department of Scientific and Industrial Research and Fire Offices' Committee Joint Fire Research Organization. F.R. Note 119/1954.

(2) "Small Boiler Systems Using Solid Fuel". British Standard Code of Practice CP 403.101 (1952). p. 21, Clause 502.

(3) "London Building (Constructional) Bye-Laws, 1952". London County Council. p. 36, Bye-Law 10.04.

PC.

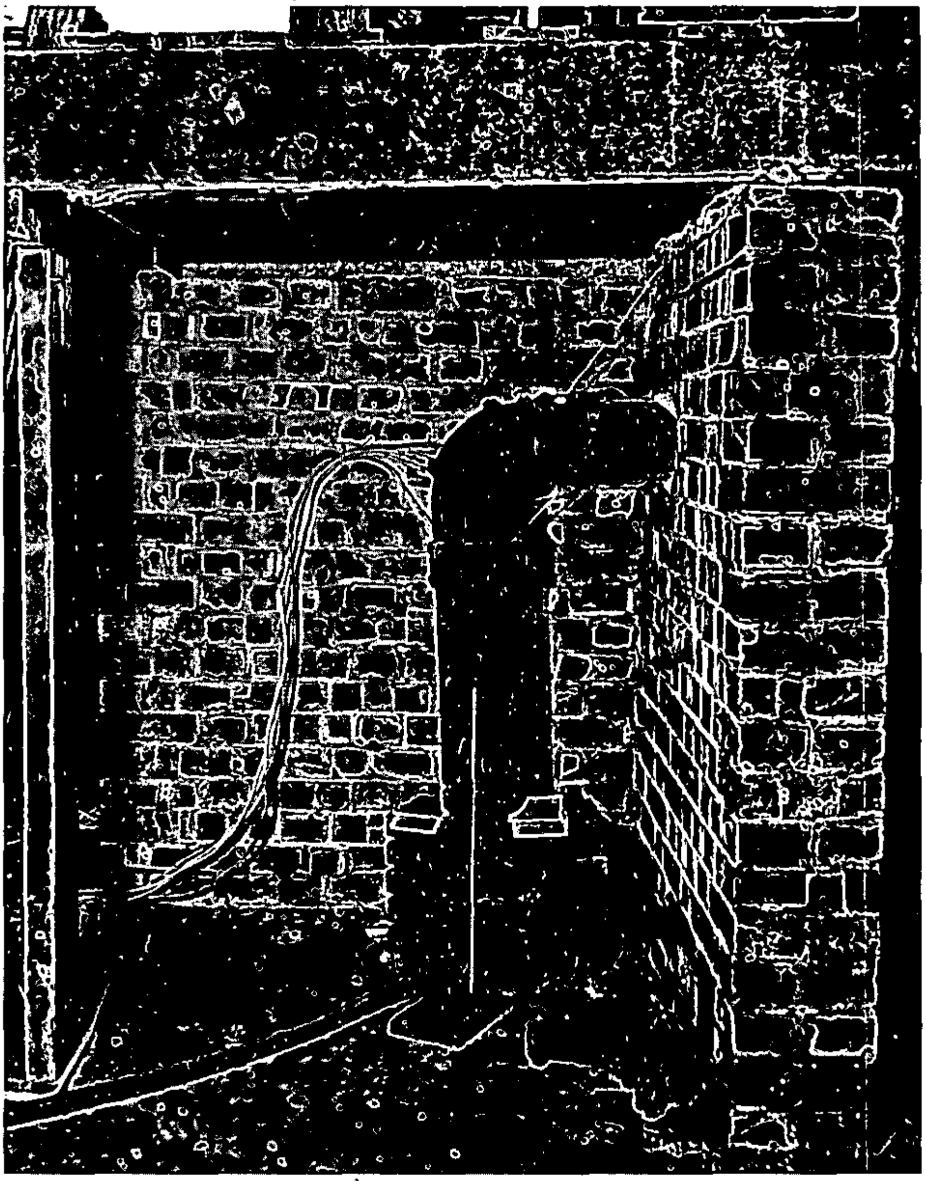
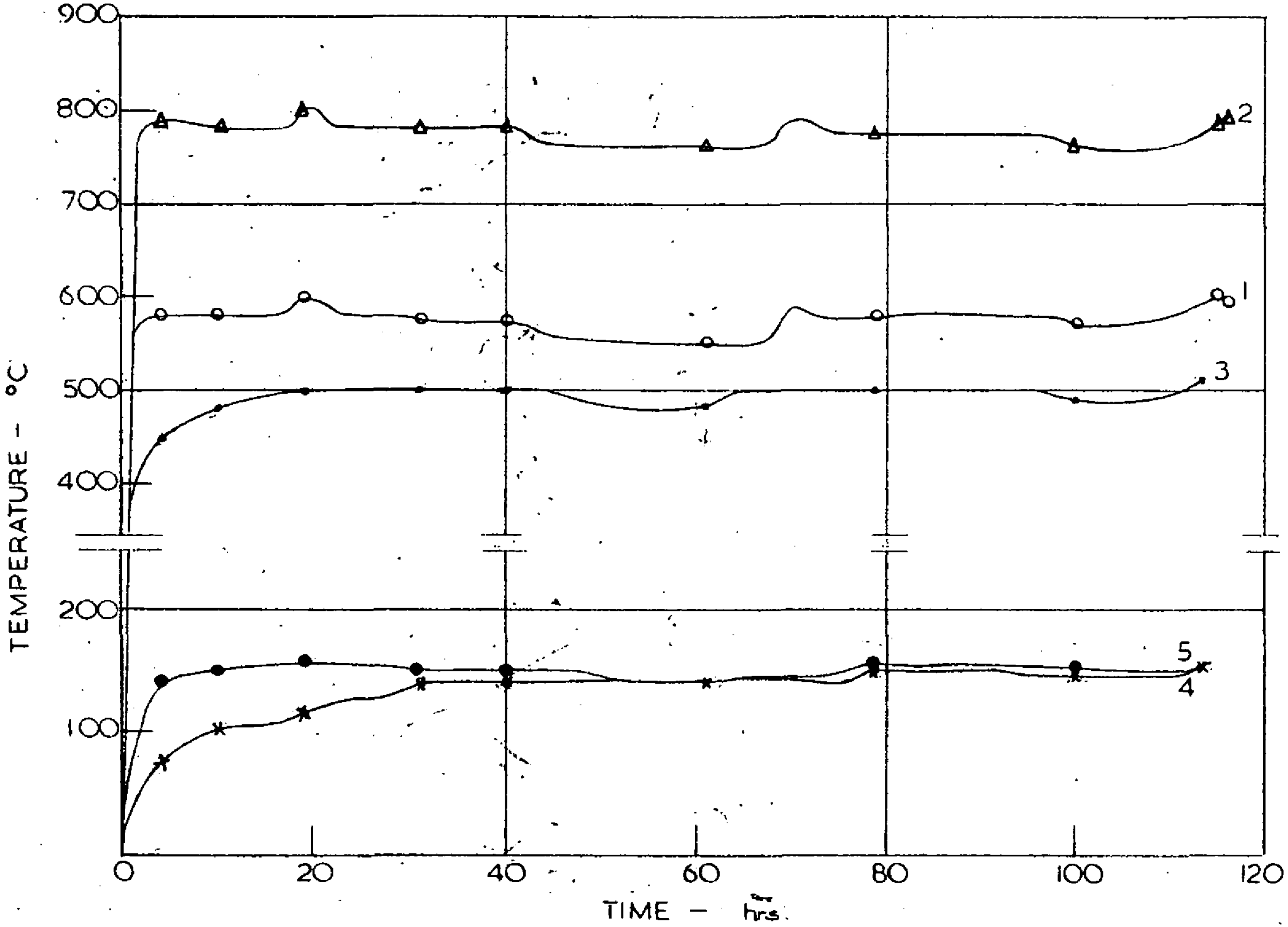


FIG.1. GENERAL ARRANGEMENT OF FLUE PIPE TESTS



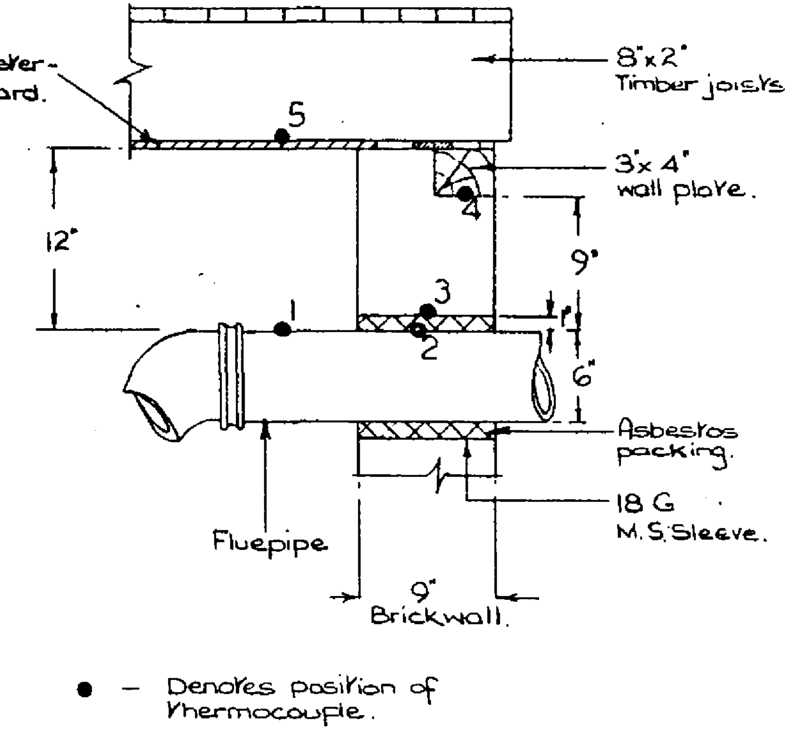


FIG. 2. TEST No. 1. POSITION OF THERMOCOUPLES AND TEMPERATURE CURVES.

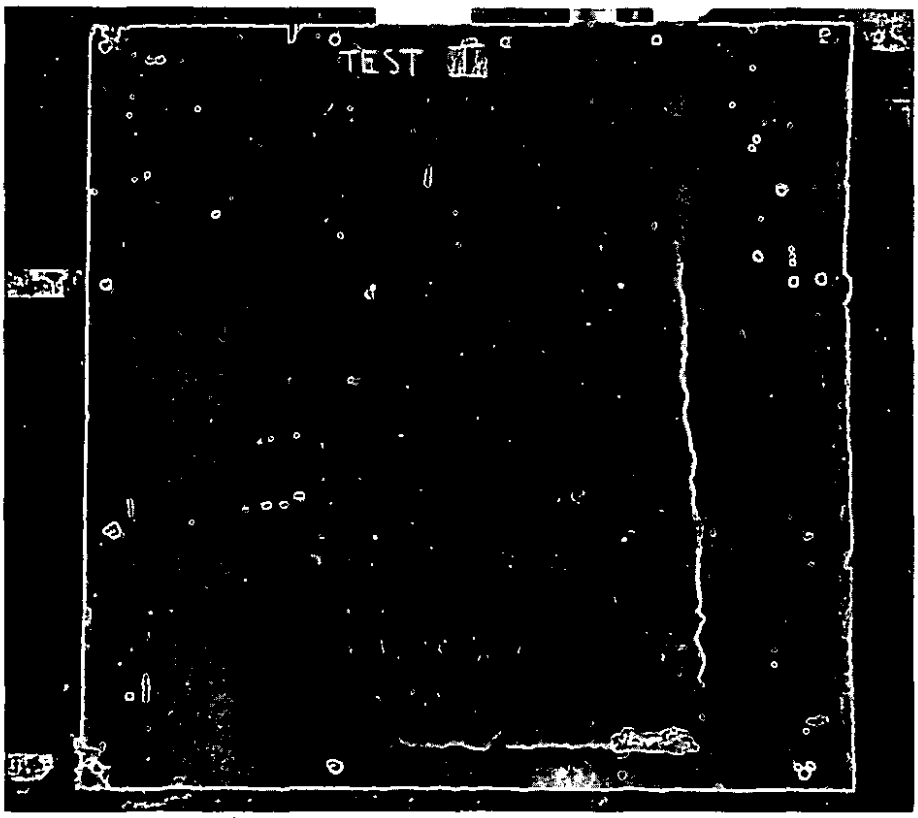


FIG 3 APPEARANCE OF CEILING AFTER TEST I

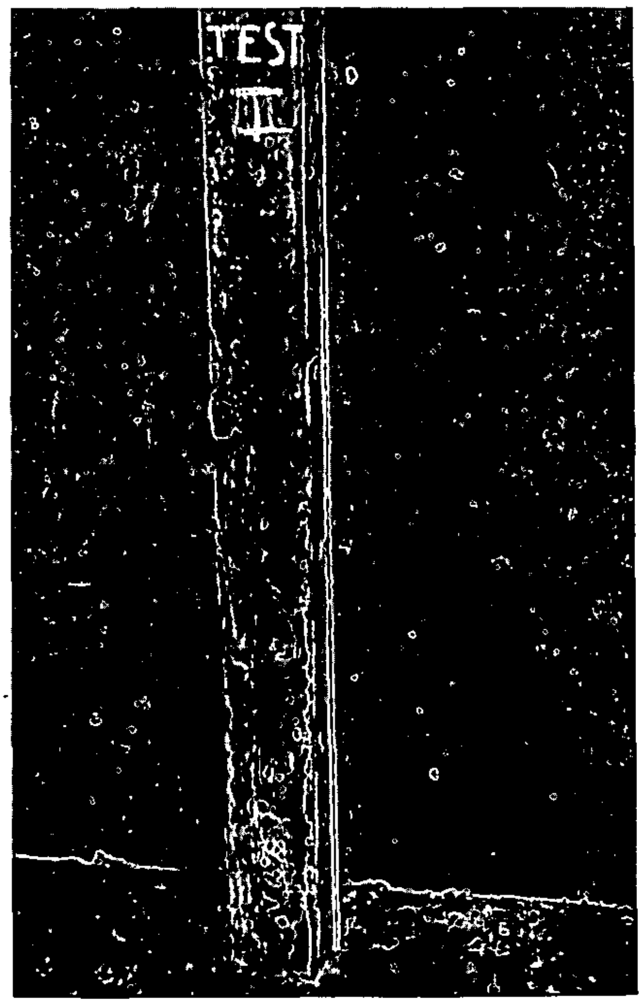


FIG. 4. APPEARANCE OF WALL PLATE AFTER TEST I

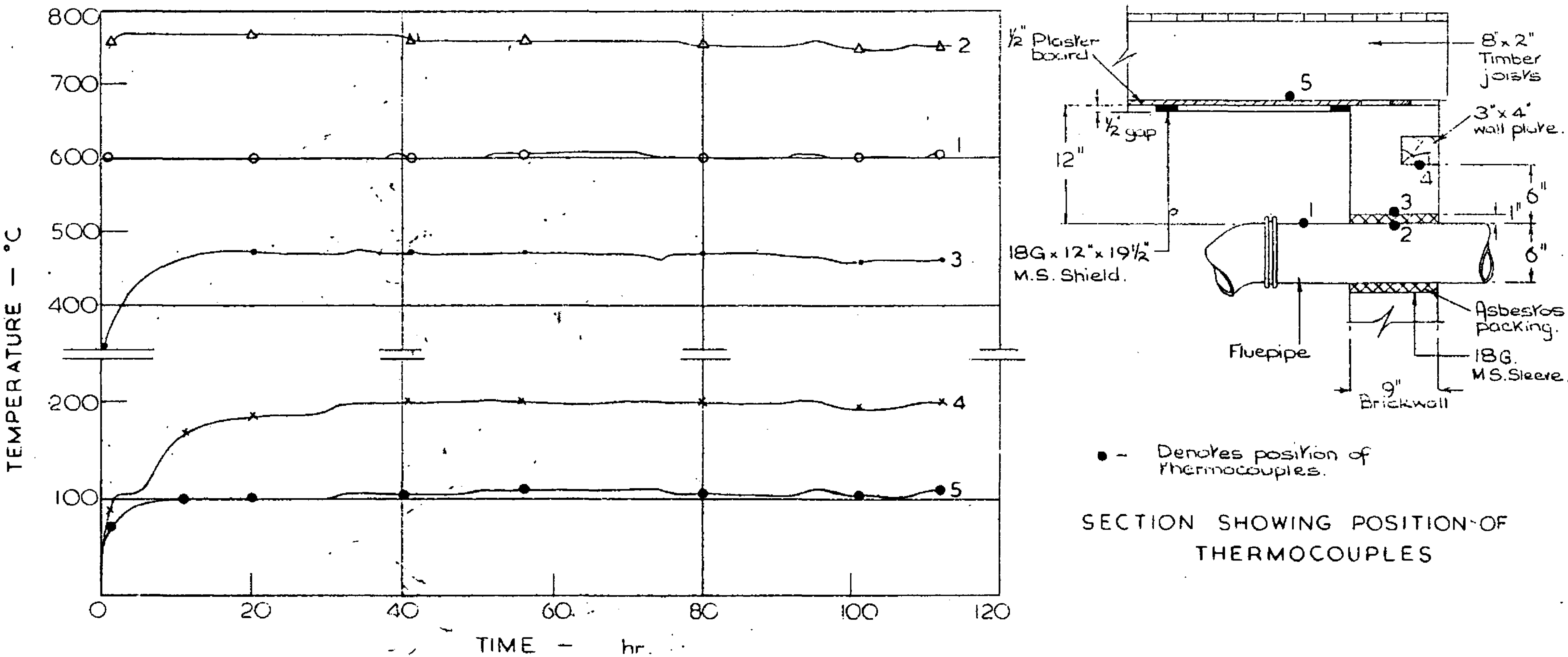


FIG. 5. TEST No. 2. POSITION OF THERMOCOUPLES AND TEMPERATURE CURVES

FIG. 6. APPEARANCE OF CEILING AFTER TEST 2.

FIG. 7. APPEARANCE OF WALL PLATE AFTER TEST 2

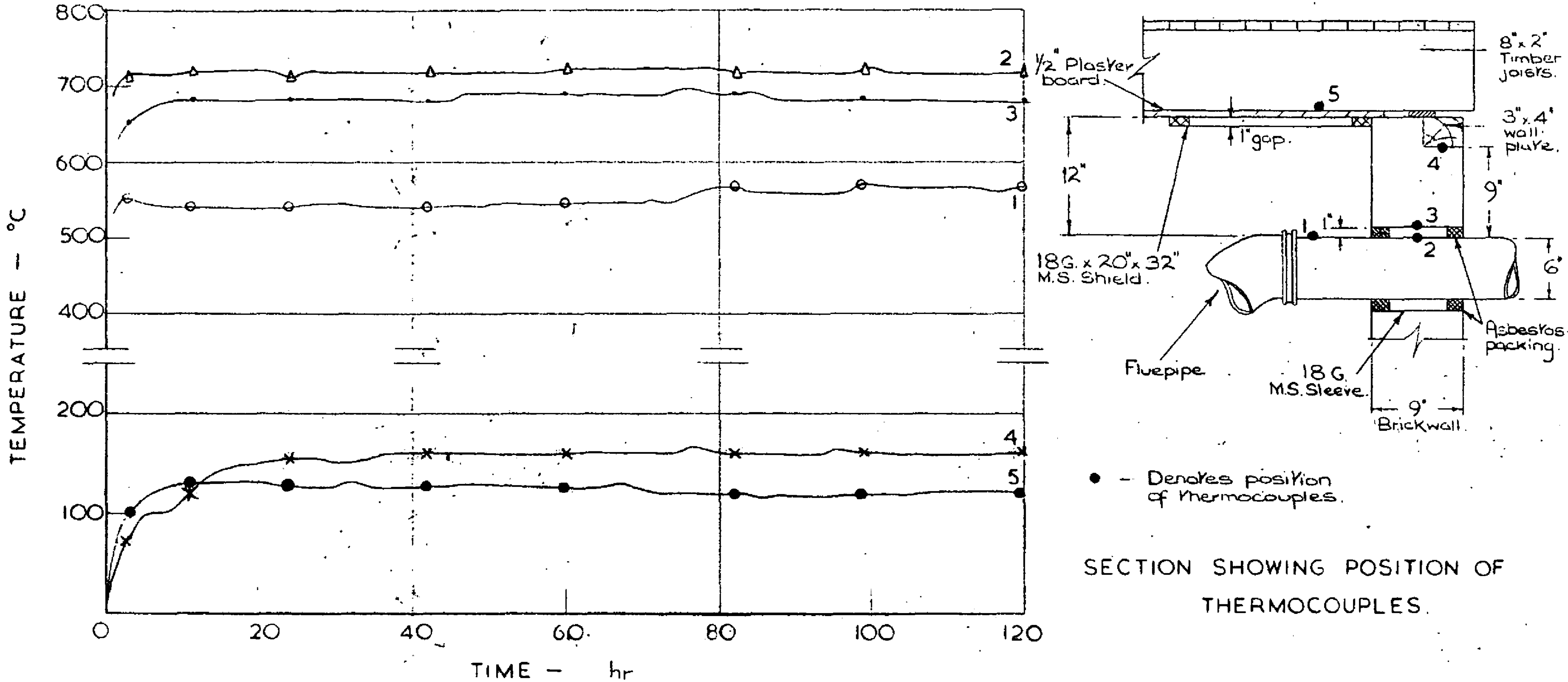


FIG. 8. TEST No. 3. POSITION OF THERMOCOUPLES AND TEMPERATURE CURVES.

FIG. 9. APPEARANCE OF CEILING AFTER TEST 3

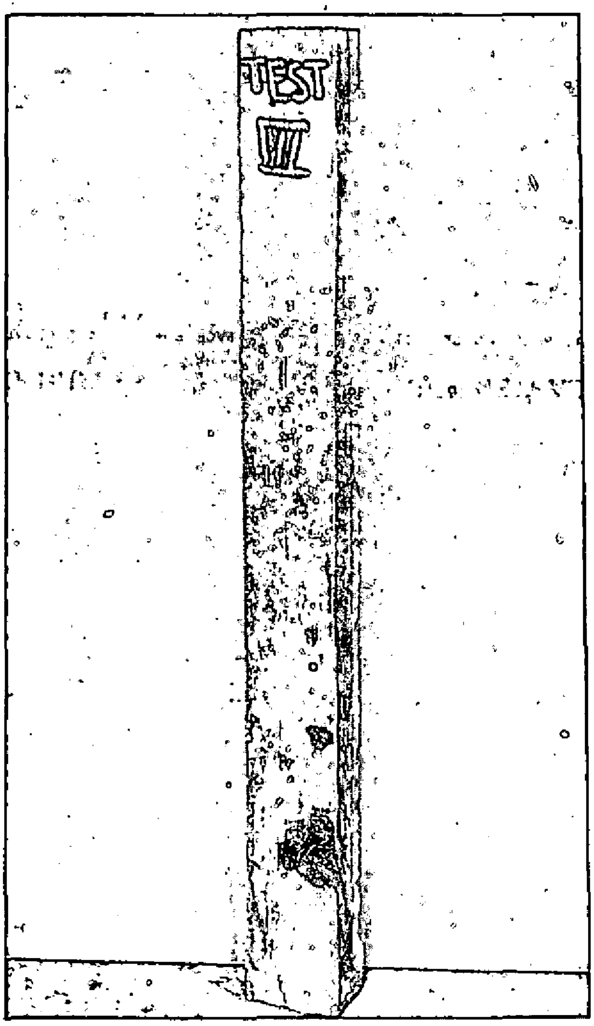


FIG. 10. APPEARANCE OF WALL PLATE AFTER TEST 3

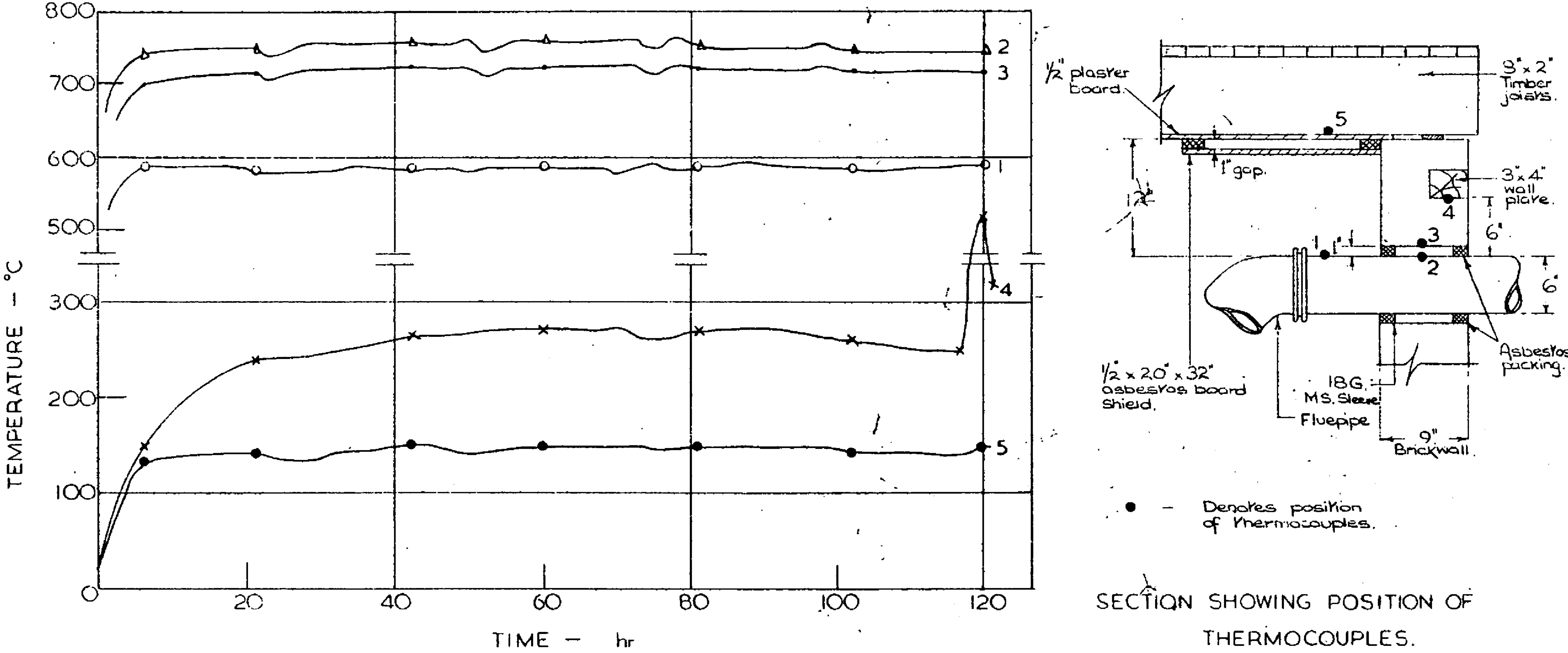


FIG. 11. TEST No. 4. POSITION OF THERMOCOUPLES AND TEMPERATURE CURVES.

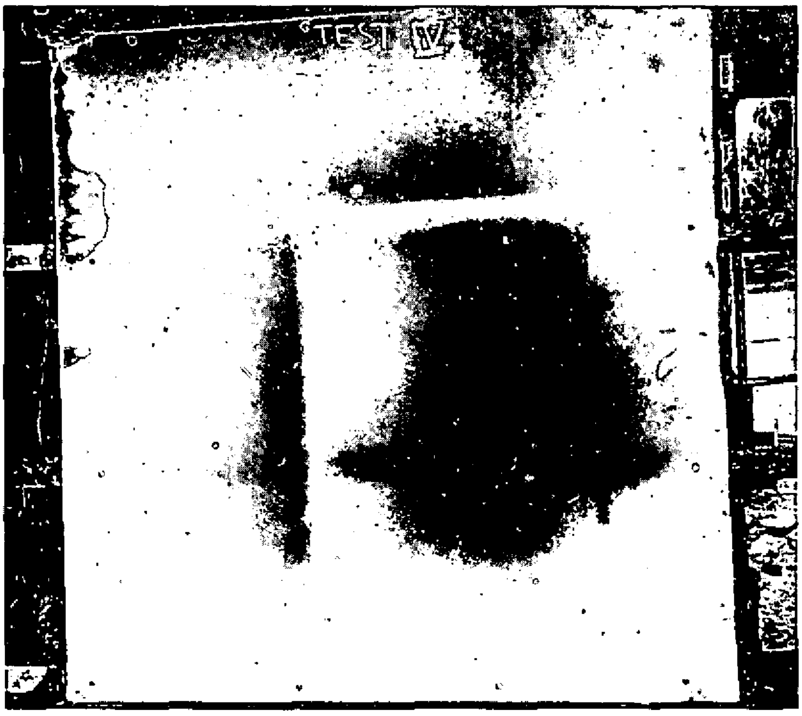


FIG.12. APPEARANCE OF CEILING AFTER TEST 4

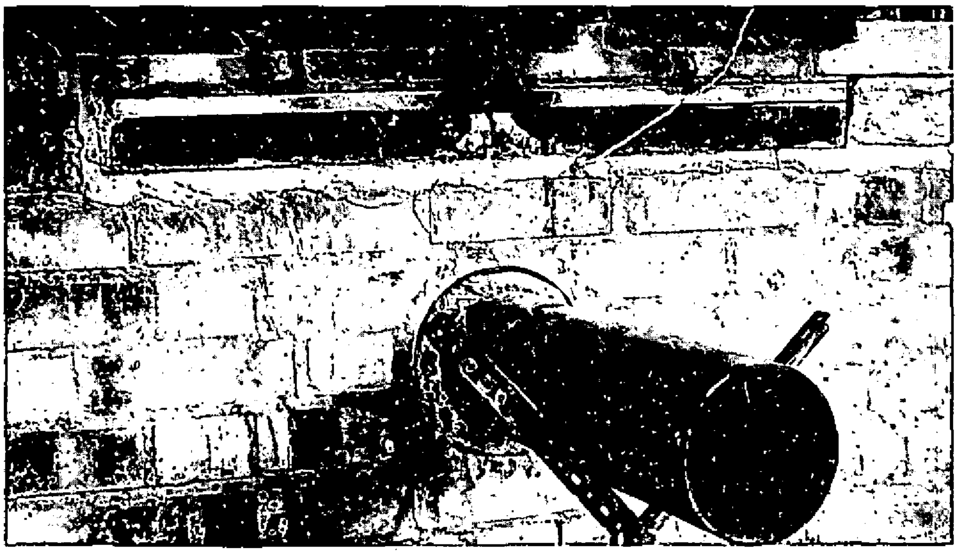


FIG.13. WALL PLATE GLOWING AT 118 HOURS. TEST 4

FIG.14. WALL PLATE AFTER TEST 4