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Fire Endurance of Gypsum Board Walls and Chases Containing Plastic and Metallic Drain, Waste and Vent Plumbing Systems

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Fire Endurance of Gypsum Board Walls and Chases Containing Plastic and Metallic Drain, Waste and Vent Plumbing Systems

W. J. Parker, M. Paabo, J. T. Scott
D. Gross and I. A. Benjamin

Center for Fire Research
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

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CONTENTS

	Page
LIST OF FIGURES	iv
LIST OF TABLES	vi
1. INTRODUCTION	1
1.1. General	1
1.2. Performance Criteria	2
2. TEST PROCEDURE	3
2.1. Construction	3
2.1.1. Test 1	3
2.1.2. Test 2	4
2.1.3. Test 3	4
2.1.4. Test 4	6
2.1.5. Test 5	6
2.1.6. Test 6	6
2.1.7. Test 7	6
2.1.8. Test 8	7
2.1.9. Test 9	7
2.1.10. Test 10	7
2.2. Instrumentation	7
2.3. Conduct of Tests	10
3. RESULTS	10
3.1. Temperature Measurements	10
3.2. Cotton Pad Test and Flame-Through Time	10
3.3. Gas Concentrations	11
3.4. Airflow Measurements	11
3.5. Smoke Density	11
4. DISCUSSION	17
4.1. DWV in Plumbing Chases	17
4.2. DWV in Wood-Stud Walls	17
4.3. DWV in Steel-Stud Walls	20
5. SUMMARY	20
6. ACKNOWLEDGMENT	22
7. REFERENCES	22
APPENDIX A. VISUAL OBSERVATIONS DURING THE TESTS	23
APPENDIX B. SUGGESTED MODIFICATIONS TO THE ASTM E 119 STANDARD FIRE ENDURANCE TEST PROCEDURE AND ACCEPTANCE CRITERIA FOR DWV PLUMBING CHASES AND WALLS	39
APPENDIX C. SI CONVERSION UNITS	40

LIST OF FIGURES

Page

Figure 1. Cross section of wall and pipe chases for test 1. 41

Figure 2. Sketch of chase 1 showing thermocouple (T/C) locations. 42

Figure 3. Photograph of installation of DWV on rear wall of chase 1 43

Figure 4. Sketch of chase 3 44

Figure 5. Photograph of lower laterals in chase 3 45

Figure 6. Photograph of exposed wall in test 1. 46

Figure 7. Plan view of wall and pipe chases for test 2. 47

Figure 8. Photograph of chase 5 with side removed 48

Figure 9. Sketch of chase 7 49

Figure 10. Photograph of lower lateral in chase 7. 50

Figure 11. Photograph of chases in test 2. 51

Figure 12. Wall construction and location of stacks in test 3. 52

Figure 13. Cross section of wall showing DWV installation and thermocouple locations in test 3 53

Figure 14. Photograph of wall construction in test 3 54

Figure 15. Wall construction in test 5 55

Figure 16. Wall construction and location of thermocouples for test 6. 56

Figure 17. Wall construction and location of thermocouples inside wall space for test 7. 57

Figure 18. Details of wall construction and piping for test 9. 58

Figure 19. ASTM thermocouples on unexposed surface 59

Figure 20. Average furnace temperatures for test 1 compared with E 119 curve . . 60

Figure 21. Unexposed lateral and ASTM surface temperatures for chase 5 61

Figure 22. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 1) in test 3. 62

Figure 23. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 3) in test 3. 63

Figure 24. Unexposed lateral and ASTM surface temperatures in copper installation (cavity 2) in test 3. 64

Figure 25. Unexposed lateral and ASTM surface temperatures in galvanized iron installation (cavity 4) in test 3 65

Figure 26. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 7) in test 4. 66

Figure 27. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 3) in test 4. 67

Figure 28. Unexposed lateral and ASTM surface temperatures in copper installation (cavity 2) in test 4. 68

Figure 29. Unexposed lateral and ASTM surface temperatures in galvanized iron installation (cavity 4) in test 4 69

Page

Figure 30. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 1) in test 5. 70

Figure 31. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 3) in test 5. 71

Figure 32. Unexposed lateral and ASTM surface temperatures in copper installation (cavity 2) in test 5 72

Figure 33. Unexposed lateral and ASTM surface temperatures in hubless cast iron installation (cavity 4) in test 5 73

Figure 34. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 1) in test 6. 74

Figure 35. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 2) in test 6. 75

Figure 36. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 3) in test 6. 76

Figure 37. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 4) in test 6. 77

Figure 38. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 1) in test 7. 78

Figure 39. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 2) in test 7. 79

Figure 40. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 3) in test 7. 80

Figure 41. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 4) in test 7. 81

Figure 42. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 1) in test 8 82

Figure 43. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 2) in test 8 83

Figure 44. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 3) in test 8 84

Figure 45. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 4) in test 8 85

Figure 46. Unexposed lateral and ASTM surface temperature readings in copper installation (cavity 1) in test 9 86

Figure 47. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 2) in test 9 87

Figure 48. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 3) in test 9 88

Figure 49. Readings in ABS installation (cavity 4) in test 9 89

Figure 50. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 1) in test 10. 90

Figure 51. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 2) in test 10. 91

Figure 52. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 3) in test 10. 92

Page

Figure 53. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 4) in test 10. 93

Figure 54. Carbon monoxide and carbon dioxide concentration in chase 1, test 1 94

Figure 55. Carbon monoxide concentration in chase 5, test 2. 95

Figure 56. Carbon monoxide concentration in PVC installation (cavity 1) in test 3. 96

Figure 57. Gas concentrations in ABS installation (cavity 1) in test 6 97

Figure 58. Gas concentrations in ABS installation (cavity 2) in test 7 98

Figure 59. Gas concentrations in PVC installation (cavity 4) in test 7 99

Figure 60. Gas concentrations in ABS installation (cavity 3) in test 8 100

Figure 61. Gas concentrations in PVC installation (cavity 4) in test 8 101

Figure 62. Gas concentrations in ABS installation (cavity 3) in test 10. . . . 102

Figure 63. Gas concentrations in PVC installation (cavity 4) in test 10. . . . 103

Figure 64. Smoke transmission in test 1. 104

Figure 65. Exposed gypsum board wall at the end of test 2. 105

LIST OF TABLES

Table 1. Construction Details and Summary of Test Results. 5

Table 2. Thermocouple Locations for Each Chase in Tests 1 and 2. 8

Table 3. Selected Thermocouple Locations in Tests 3 through 10 9

Table 4. Gas Concentrations in Test 1. 12

Table 5. Gas Concentrations in Test 2. . . . . ı3

Table 6. Gas Concentrations in Test 6. 14

Table 7. Gas Concentrations in Test 8. 15

Table 8. Air Velocities into the Bottom of Stacks. 16

FIRE ENDURANCE OF GYPSUM BOARD WALLS AND CHASES CONTAINING PLASTIC AND METALLIC DRAIN, WASTE AND VENT PLUMBING SYSTEMS

W. J. Parker, M. Paabo, J. T. Scott, D. Gross, and I. A. Benjamin

The use of plastic pipe in plumbing systems of multiple-occupancy buildings has raised considerations regarding fire safety. To provide needed data, ten full-scale fire endurance tests were performed involving a total of 39 plumbing chase and wall assemblies containing plastic and metal drain, waste, and vent (DWV) systems typical of installations serving one or two story buildings.

Two tests were conducted using plumbing chase configurations simulating kitchen sink drain systems. The PVC DWV piping in these installations did not contribute to spread of fire from one side of the construction to the other.

Six fire endurance tests were conducted in which the performance of ABS, PVC, copper, and iron was compared directly in kitchen sink drain systems as installed in wood-stud and gypsum-board walls. The stacks ranged from 2 inch to 4 inch in diameter and the laterals from 1-1/2 inch to 4 inches. In these tests it was noted that the plumbing configuration and wall construction details, particularly the sealing of plumbing penetrations, seriously affected the fire endurance of the barrier. Satisfactory performance was achieved when certain conditions were met.

In the two tests involving nominal 2 by 4 steel-stud-and-gypsum-board walls it was determined that the one-hour fire resistance rating of the wall was reduced considerably when ABS or PVC DWV was installed within it using the construction details described in this report. These details included back to back 1-1/2-in diameter laterals feeding directly into 2-in diameter stacks.

Key words: ABS; DWV; fire endurance; fire spread; fire test; gases; plastic pipe plumbing; PVC; smoke.

1. INTRODUCTION

1.1. General

The use of plastic plumbing systems is growing in the residential housing market. Availability, ease of handling and installation, and economics are playing a part in the transition from the conventional materials of copper, steel and cast iron to plastics. These same factors are also playing an important role in the introduction of plastics into the multiple-occupancy building.

The use of plastic pipe in the DWV[1] plumbing systems of multiple-occupancy buildings raises two important questions in regard to its involvement in fire. Will the plastic pipe serve to spread fire to other dwelling units when it might otherwise be contained? Will there be a serious life hazard introduced due to the smoke and toxic gases generated by the burning of the pipe? To help answer these questions, the National Bureau of Standards, with the support of the Department of Housing and Urban Development, established a research and test program.

When plastic DWV piping is incorporated in fire-rated construction, the following possibilities must be considered.

1. The fire could spread from the room of origin along the burning pipe inside the wall or chase cavity, and thus into an adjacent residential unit.

2. The additional heat generated in the shaft, chase,[2] or wall cavity due solely to the burning of the pipe could cause a premature failure of the wall.

[1]DWV refers broadly to drain, waste and vent piping.
[2]The term "chase" in plumbing usage connotes a shaft constructed specifically to enclose the plumbing piping in a fire resistant construction.

3. Smoke and gaseous combustion products from the burning room could enter the chase or wall cavity through the hole left by the burning of the plastic pipe and penetrate into adjacent living areas. The rate of movement through such a hole would depend largely on the difference between the pressures in the room and in the cavity.

In addition to their fire spread potential, the common plastic plumbing materials, polyvinyl chloride (PVC) and acrylonitrile-butadiene-styrene (ABS) when they burn, generate a considerable amount of smoke (particulates) and toxic gases. Besides carbon monoxide, PVC releases hydrogen chloride and ABS generates small amounts of hydrogen cyanide.

It must be realized that in a burning room, those furnishings made of organic material may release great quantities of toxic gases and smoke. The quantities could be many times greater than that which would result from the complete burning of installed plastic plumbing pipe. Even when plastics are not involved in the fire, carbon monoxide from the incomplete combustion of other materials in the burning room could spread and reach excessively high levels in adjacent rooms. Building codes and plumbing codes can place limits on kinds of materials used in construction and installation, but not on materials that subsequently become the furnishings and content of the dwelling. The basic question addressed here is to what extent does a plumbing system compromise the integrity of a partition or a pipe chase with respect to the role of either as a fire (and smoke) barrier.

To evaluate the extent of these potential problems, ten full-scale fire tests involving 39 plastic and metal plumbing configurations have been performed in this program. The results of these tests are being used to provide technical background data necessary to prescribe guidelines for the use of plastic plumbing systems and to suggest criteria for acceptance of such systems in building and plumbing codes. From the standpoint of fire safety, the suitability of the plastic plumbing will depend on: the type of application, including the details of the wall, chase, or shaft construction; the pressure in the shaft in the case of high-rise buildings; the particular plastic material; the pipe size, the type of fittings; and the manner in which the pipe penetrates the wall.

The full-scale fire tests described in this report apply to kitchen sink or lavatory drain systems made of either plastic or metal. The kitchen is the more likely room in the house to have a fire involving drain, waste, and vent pipe. Such a fire could be very intense in the vicinity of the trap due to the common use of wooden base cabinets and the practice of storing household chemicals and other combustibles under the sink. The test duration was arbitrarily taken as 1 hour in accordance with the fire endurance requirement in many building codes for an interdwelling wall in a garden-type apartment.

Full-scale fire tests were performed on ABS DWV piping in two-hour pipe chases in cooperation with the ABS Institute in 1970 [1].[3] The experimental procedures used in the present tests are similar to those employed in the earlier ones.

1.2. Performance Criteria

There are no established performance criteria for evaluating the acceptability of DWV pipe in a wall assembly, other than the general statement that the piping should not decrease the fire resistance of that assembly. The first phase of this project has been directed towards the evaluation of 1-hour fire resistive wall constructions containing DWV. These walls are commonly used between dwelling units in multi-family buildings which may contain DWV systems.

The fire resistance of a wall assembly, under test conditions, should be sufficient to prevent the spread of the fire from one dwelling unit to another for the designated time -- in this case, 60 minutes. The limitations on the spread of fire would restrict the passage of flame through the wall assembly and would prevent the development of an unacceptable temperature rise on the unexposed surface of the wall and the loss of structural integrity. These limitations would prevent open flame from coming through and igniting objects in an adjacent room and would prevent self-ignition or smoldering

[3]Numbers in brackets correspond with the literature references listed at the end of this paper.

of combustible objects in contact with a high temperature wall surface. The critical range for self-ignition would be about 163 to 204 °C (325 to 400 °F). The ASTM E 119 test standard [2] also mentions preventing the passage of hot gases without specific reference to smoke. However, there has been increasing evidence in recent years of the need to consider the regulation of smoke coming through the walls as part of the criteria for containing the fire. The passage of excessive smoke into an adjacent dwelling unit would endanger the occupants of the adjacent unit. In view of the above, the standard ASTM E 119 time-temperature curve was used in this test program, and performance criteria were adopted as follows:

1. There should be no passage of flame through the wall as a result of the DWV installation.

2. The temperature rise on the unexposed surface of the wall should not be affected by the DWV installation and should not exceed 181 °C (325 °F) at any measured point. This corresponds to the highest temperature allowed at any point on the surface according to the ASTM test standard. The temperatures recorded on the laterals are not regarded as wall surface temperatures.

3. Large quantities of smoke should not pass through the unexposed face. This last criterion is not defined in quantitative terms but was based on observations during the test which indicated when heavy smoke was seen to be issuing from the construction.

The above three criteria were used to judge the extent to which the wall assembly tested had met the requirements for the one-hour fire endurance. No hose stream tests (optional in ASTM E 119) were conducted.

2. TEST PROCEDURE

2.1. Construction

2.1.1. Test 1

A one-hour fire-rated wall 10 feet high by 16 feet long, constructed of nominal[4] 2 x 4 fir studs with one layer of 5/8-inch type X gypsum board on each side was built into a test frame for the NBS wall furnace. Four plumbing chases with interior cross sections of 20 x 20 inches and heights of 12 feet were attached to one side of the wall. This wall served as a common wall for each of the chases as seen in figure 1.

The other three side walls of each chase were also constructed with 2 x 4 fir studs with 5/8-inch type X gypsum board on each side. The chases were closed at the top and bottom. The side of the common wall opposite the chases formed the closure to the NBS wall furnace and was subjected to the standard ASTM E 119 fire exposure applicable to construction assemblies [2]. This arrangement permitted the simultaneous testing of four plumbing chases.

Chase 1, sketched in figure 2, had a 4-inch PVC stack and three 1-1/2-inch PVC laterals.[5] One lateral near the bottom of the chase penetrated the wall into the furnace. The furnace pressure at the point of penetration was +0.02 inches of water relative to the pressure in the chase. This represents a pressure which would likely be found about 20 inches above the floor in a room involved in fire, with no building stack effect.

Two laterals passed through the opposite wall of the chase, one at the same elevation as the lateral entering the furnace and one 8 feet above it. The lateral into the furnace represented a kitchen sink or lavatory drain in the room of fire origin. The other two laterals represented locations where the fire could pass from the chase into other dwelling unit rooms on the same floor or on the floor above. The openings around all of the laterals were sealed with plaster spackling and covered with escutcheon plates. An expansion joint in the 4-inch stack was located at the simulated second

[4]All lumber sizes refer to nominal dimensions in inches.
[5]Throughout the report the word "lateral" is synonymous with "fixture drain" or "trap arm" passing through the chase wall.

floor level. Water-filled PVC P traps were located at the end of each lateral. Except for the ones in the furnace, these traps were held in place by wires to simulate the attachment support represented by a sink. The bottom of the stack was attached to a 90-degree elbow which led out through the unexposed chase wall to the atmosphere. This configuration represented an attachment to a vented sewer line. The top of the stack extended 1 foot above the top of the chase and opened into the upper part of the test building. Although the chase was sealed the stack was open at the top and bottom. This permitted an appreciable induced airflow through the stack when the chase became hot. A photograph of the installation attached to the rear wall of the chase is shown in figure 3.

The DWV piping and the chase construction were nominally identical to the construction being used in the multi-family units of some experimental factory built homes. However, the chase did not contain other piping (e.g., copper hot and cold water supply) or wiring. The kitchen sink drain system was chosen because it was deemed to be more critical both in terms of the likelihood of a fire exposure and the potential fire severity.

Chases 2 and 3 tested modifications of the construction in chase 1 which might improve its fire performance.

Chase 2 was identical to chase 1 except that each of the laterals was enclosed in a sleeve from the hub of the tee to a point 1/4 inch outside of the chase wall where it was covered with an escutcheon plate. The sleeve was a section of 2-inch standard weight galvanized iron water pipe. The intended purpose of the sleeve was to restrict the burning and collapse of the lateral, and thus to protect the wall penetration.

The installation in chase 3 as shown in figure 4 was similar to that in chase 1 except that the PVC laterals were replaced by laterals of galvanized iron. They penetrated the chase wall at the same elevation but the connections of the laterals to the stack were made at a location below the neutral pressure plane in the furnace which was the simulated floor level in the chase. This necessitated the incorporation of a vertical section of a 2-inch galvanized iron pipe as seen in the photograph in figure 5. This modification was intended to counter the pressure-induced flow of hot furnace gases into the stack.

Chase 4 contained no plumbing and had no penetration holes. It served as a control to determine how much of the temperature rise in the chase was due to heat transmitted directly through the walls. The exposed side of the wall before the test is shown in figure 6. The principal construction features of this wall and chase arrangement and all other assemblies are summarized in table 1.

2.1.2. Test 2

The construction of the wall and chase assembly was changed for the second test. The wall segments enclosing the chases consisted of only a single layer of 5/8-inch type X gypsum board nailed to the outside of the studs as illustrated schematically in figure 7. In this arrangement, the plumbing stacks inside of the chases would be exposed directly to burning studs, and there was only one layer of gypsum board separating the furnace and the stacks. This can be seen in the photograph of chase 5 in figure 8.

The DWV installation in chases 5 and 6 were duplicates of those in chases 1 and 2 of Test 1. In chase 7 a hubless cast iron stack was used with PVC laterals, as seen in figures 9 and 10. The hubless cast iron stack was used again in chase 8 with galvanized iron laterals to provide an all metal system for comparison. The unexposed sides of the chases before the test are shown in figure 11.

2.1.3. Test 3

A comparison of the fire performance of PVC, ABS, copper, and cast iron DWV systems installed inside of a typical dwelling separation wall was made in the third test. The basic DWV configurations were repeated except that 2-inch stacks were used and they were confined within a 2 x 4 fir stud wall with one layer of 5/8-inch type X gypsum board on each side. Holes of sufficient size were cut into the board to accommodate the hubs of the 2 x 1-1/2-inch reducing sanitary tees. The termination of the stacks at the top and bottom of the wall was the same as it was when installed in the chases. The wall construction was such that the 5/8-inch plywood subfloor and the top and bottom 2 x 4 plates which would be present in an actual building installation were properly simulated

Table 1. Construction Details and Summary of Test Results

Test No.	Construction Details	Stack Materials	Lateral Materials	Wall Penetration	Time to Failure (Minutes) Flame-through	Surface Temp. Rise (181 °C)	Heavy Smoke
1-1	20" X 20" Chases of 2" X	4" PVC	1-1/2" PVC	Sealed	> 60[a]	> 60[a]	> 60[a]
1-2	4" Wood Studs Covered with	4" PVC	1-1/2" PVC/Steel Sleeve	Sealed	> 60[a]	> 60[a]	> 60[a]
1-3	5/8" Type X Gypsum Board	4" PVC	1-1/2" Galvanized Iron[b]	Sealed	> 60[a]	> 60[a]	> 60[a]
1-4	Both Inside and Outside	None	None	None	> 60[a]	> 60[a]	> 60[a]
2-1	Same as for Test No. 1	4" PVC	1-1/2" PVC	Sealed	> 60[a]	> 60[a]	> 60[a]
2-2	Except 5/8" Gypsum Board	4" PVC	1-1/2" PVC/Steel Sleeve	Sealed	> 60[a]	> 60[a]	> 60[a]
2-3	Not on Inside of Chases	4" Cast Iron, Hubless	1-1/2" PVC	Sealed	> 60[a]	> 60[a]	> 60[a]
2-4		4" Cast Iron, Hubless	1-1/2" Galvanized Iron	Sealed	> 60[a]	> 60[a]	> 60[a]
3-1	2" X 4" Wood Stud Wall	2" PVC	1-1/2" PVC	Sealed	> 60[a]	> 51	> 60[a]
3-2	16" on Centers with 5/8"	2" Copper	1-1/2" Copper	Sealed	> 60[a]	> 60[a]	> 60[a]
3-3	Gypsum Board on each Face[c]	2" ABS	1-1/2" ABS	Sealed	42	48	45
3-4	(3-1/2" Cavity)	2" Galvanized Iron	1-1/2" Galvanized Iron	Sealed	> 60[a]	> 60[a]	> 60[a]
4-1	2" X 6" Wood Stud Wall	2" PVC	1-1/2" PVC	Sealed	> 60	> 60	> 60
4-2	16" on Centers with 5/8"	2" Copper	1-1/2" Copper	Sealed	> 60	> 60	> 60
4-3	Gypsum Board on each Face	2" ABS	1-1/2" ABS	Sealed	> 60	> 60	> 60
4-4	(5-1/2" Cavity)	2" Galvanized Iron	1-1/2" Galvanized Iron	Sealed	> 60	> 60	> 60
5-1	Wood Stud Wall Formed with	4" PVC[d]	1-1/2" PVC	Sealed	55	55	42
5-2	Double Row of 2" X 4" Studs	4" Copper	1-1/2" Copper	Sealed	> 60	> 60	> 60
5-3	On 10" Plate. See fig. 15	4" ABS[d]	1-1/2" ABS	Sealed	27	----	23
5-4	(9-1/2" Cavity)	4" Cast Iron, Hubless	1-1/2" Galvanized Iron	Sealed	> 60	> 60	> 60
6-1	2" X 4" Steel Stud Wall	2" ABS	1-1/2" ABS	Sealed	28	----	----
6-2	16" on Centers See fig. 16	2" ABS	1-1/2" ABS	Not Sealed[f]	19	----	----
6-3	Gypsum Board on each Face	2" ABS[e]	1-1/2" ABS	Sealed	25	----	25
6-4	(3-1/2" Cavity)	2" PVC	1-1/2" PVC	Sealed	56	51	40
7-1	2" X 6" Wood Stud Wall	3" ABS	1-1/2" ABS	Sealed	> 60	> 60	> 60
7-2	16" on Centers, See fig. 17	2" ABS	1-1/2" ABS	Not Sealed[f]	29(27)[j]	----	----
7-3	Gypsum Board on each Face	3" PVC	1-1/2" PVC	Sealed	> 60	60	> 60
7-4	(5-1/2" Cavity)	2" PVC	1-1/2" PVC	Not Sealed[f]	30(28)[j]	----	----
8-1	Construction of Wall is	4" ABS	1-1/2" ABS	Sealed	44	----	17
8-2	Similar to that of Test 5	4" PVC	1-1/2" PVC	Sealed	> 60	> 60	> 60
8-3	(9-1/2" Cavity)	4" ABS	2" ABS	Sealed	> 60	> 60	> 60
8-4		4" PVC	2" PVC	Sealed	> 60	> 60	> 60
9-1	Construction of Wall is	2" Copper	1-1/2" Copper	Not Sealed[g]	> 60	> 60	> 60
9-2	Similar to that of Tests	2" PVC	1-1/2" PVC[h]	Not Sealed[g]	> 60	> 60	34
9-3	4 and 7	2" ABS	1-1/2" ABS[h]	Not Sealed[g]	> 60	> 60	34
9-4	(5-1/2" Cavity)	2" ABS	1-1/2" ABS[i]	Not Sealed[g]	21	----	5
10-1	Construction is Similar	2" ABS	1-1/2" ABS	Sealed	25	----	----
10-2	To that of Test 6, with	2" PVC	1-1/2" PVC	Sealed	55	----	----
10-3	Glass Fiber Insulation	2" ABS	1-1/2" ABS	Not Sealed[g]	22	----	9
10-4	(3-1/2" Cavity)	2" PVC	1-1/2" PVC	Not Sealed[g]	16	----	----

[a]Estimated. Gas off at 45 min (Test 1), 50 min (Test 2), and 56 min (Test 3).

[b]With a drop in elevation before joining a double upright wye on the stack.

[c]Holes in gypsum board for hub of a 2" X 1-1/2" reducing sanitary tee.

[d]Hub of 4" double sanitary tee penetrated gypsum wall board.

[e]Stack bottom closed. [f]1/2 " oversized hole. [g]1" oversized hole. [h]Lateral offset from stack but located in same stud space.

[i]Lateral offset from stack but located in adjacent stud space. [j]Corrected (and uncorrected) time to failure due to slight departure from standard exposure.

at the "floor" locations. The wall construction and location of the stacks are shown in figure 12. The cross section of the wall showing the DWV installation can be seen in figure 13. A photograph of the wall under construction is seen in figure 14. The walls did not contain other piping (e.g., copper hot and cold water supply) or wiring.

2.1.4. Test 4

The construction of the wall and the ABS, PVC, copper and iron DWV system in Test 4 was identical to that of Test 3 except that 2 x 6 fir studs were used instead of 2 x 4 fir studs.

2.1.5. Test 5

In Test 5 the DWV systems used in the same materials and configurations as Test 3, but the stacks were 4 inches instead of 2 inches. The wall construction was similar to the other two wall tests except that it was made up of a double row of 2 x 4 studs attached to a 2 x 10 plate as shown in the sketch in figure 15. The 1-1/2-inch laterals were connected to the 4-inch double sanitary tee at the lower part of the stack and to the 4-inch single sanitary tee near the top of the stack by means of appropriate reducers. The hubs of the 4-inch tees protruded slightly through the holes in the gypsum board at each side of the wall. While reducing double sanitary tees would normally be used for this type of installation, the more space-consuming combination used in this test does occur occasionally in the field and represents a very severe case. The penetration holes were sealed with spackling compound. The plates and the 5/8-inch plywood subfloor at the floor and ceiling elevations were simulated in this test in the same manner as they were for the previous wall tests.

2.1.6. Test 6

A wall assembly was constructed of 2 x 4 steel studs with one layer of 5/8-inch type X gypsum board on each side. The steel studs were placed 16 inches on centers and the wall was divided into four isolated plumbing cavities by four double steel studs with gypsum board strips attached to each stud lining the cavity. A ceiling-floor assembly was simulated at the 9-foot level by the use of steel runner tracks and 6-inch asbestos floor blocks. A ground floor assembly was simulated at the 2-foot level by the use of steel runner tracks and one layer of gypsum board. Details and dimensions of the wall construction are shown in figure 16.

The basic DWV configuration previously used was repeated except that 2-inch stacks were installed in each wall cavity. ABS was used in three wall cavities and PVC pipe and fittings were used in the fourth cavity. Except for ABS installation No. 2, the penetrations around all laterals were sealed with a plaster spackling compound and covered with metal escutcheon plates. In installation No. 2, the hole in the gypsum board was cut 1/2 inch oversize in diameter and was covered with an escutcheon plate without sealing. The bottoms of all vertical stacks were left open except ABS installation No. 3. In this case the bottom was closed with a cap to simulate a clogged sewer line.

Individual water sprinkling systems were installed at the upper level of each plumbing cavity. The arrangement permitted flooding of an individual cavity in the case of an early flame-through[6] failure without disruption of the test for the remaining DWV installations.

2.1.7. Test 7

This assembly, consisting of 2 x 6 wood studs was similar to that used in Test 4. A 5/8-inch plywood subfloor with 2 x 6 upper and lower wood plates were installed at two levels. Details and dimensions of the wall construction and the location of the DWV installations are shown in figure 17. The DWV plumbing configurations were the same as in Test 6. In wall cavities Nos. 1 and 2, ABS installations were used, with

[6] "Flame-through indicates the passage of flame through some region of the unexplored wall.

3-inch and 2-inch stack sizes respectively. In wall cavities Nos. 3 and 4, PVC assemblies were used with 3-inch and 2-inch stack sizes, respectively. All laterals were 1-1/2 inches in diameter. The penetrations in the gypsum board around the laterals of assemblies Nos. 1 and 3 were sealed with spackling compound and were covered with escutcheon plates while the penetrations for No. 2 and No. 4 were left unsealed and were covered only with escutcheon plates. All stacks were left open to the atmosphere at the top and bottom.

2.1.8. Test 8

The wall construction for Test 8 was similar to that used in Test 5. The DWV configurations were similar to those of other tests as shown in figure 13. ABS was used in wall cavities Nos. 1 and 3 and with 1-1/2-inch and 2-inch lateral sizes, respectively. In wall cavities Nos. 2 and 4, PVC assemblies were used with 1-1/2-inch and 2-inch lateral sizes, respectively. All stacks were 4 inches in diameter and all penetrations in the walls were sealed with spackling compound and covered with escutcheon plates. Reducing sanitary tees were used so that the hubs did not penetrate through the wall as they did in Test 5.

2.1.9. Test 9

Variations in the stack configurations were introduced in Test 9. A comparison with Test 4 showed the effects of sealing penetrations. The wall construction remained identical to Tests 4 and 7 using 2 x 6 fir studs. All the DWV installations maintained the same features of 2-inch stacks with 1-1/2-inch laterals. Where laterals penetrated the gypsum board holes were cut 1 inch oversize in diameter, left unsealed, and covered with escutcheon plates. Wall cavity No. 1 contained copper piping using the basic DWV configuration as shown in figure 13. A kitchen cabinet with sink was installed on the unexposed side of the wall assembly for this configuration. ABS was used in wall cavities 3 and 4 while PVC was used in wall cavity No. 2. Laterals made a right angle turn into the vertical stack, but were included in the same stud space in installations Nos. 2 and 3. In wall cavity No. 4 the laterals and stack were in adjacent stud spaces connected by a pipe running through a stud. Details of the piping assembly and wall construction can be seen in figure 18. The top and bottom of all vertical stacks were left open to the atmosphere.

2.1.10. Test 10

The construction of the wall for Test 10 was identical to that of Test 6 except that a glass fiber insulation batt was installed in the stud cavities. ABS was used in wall cavities Nos. 1 and 3 while PVC was used in wall cavities Nos. 2 and 4. The basic DWV configuration was repeated for all assemblies except that 2-inch stacks with 1-1/2-inch laterals were used. All lateral penetrations of the gypsum wall were cut 1 inch oversize in diameter. The openings were sealed with spackling compound and covered with escutcheon plates for installations Nos. 1 and 2. The openings around the laterals to installations Nos. 3 and 4 were left unsealed and covered with escutcheon plates. All stacks were left open at the bottom, and in an effort to control smoke buildup in the test building, the open stacks were extended at the top to exhaust outside the building.

2.2. Instrumentation

The temperatures were monitored with chromel-alumel thermocouples at various points on the surface of the pipes and tees, in the air inside of the pipe, and on the surfaces of the walls and chases. The thermocouple locations for Tests 1 and 2 are described in table 2 and are illustrated for chase 1 in figure 2. Selected thermocouple locations for Tests 3 through 10 are described in table 3 and are illustrated in figure 13. Additional thermocouples within the stud spaces are shown in figures 16 and 17. Figure 19 shows the location of the unexposed surface thermocouples mounted under 6 x 6 x 0.4-inch felted asbestos pads as prescribed in appendix 2 of ASTM E 119. These are designated in this report as "ASTM thermocouples."

Gas concentrations in the wall cavities were measured by several techniques at a point 1 foot above the lower lateral. Concentrations of CO, HCl, and HCN in the chases and in the wall cavities were determined with commercial colorimetric detector tubes. Non-dispersive infrared gas analyzers were used for continuous monitoring of CO and CO_2 and liquid diffusion cell oxygen meters were used for O_2. Sampling lines between the instruments and the wall cavities were trapped at room and dry ice temperatures to remove water and other condensable combustion products. In Test 6 HCl was also determined by collecting grab samples of gas with evacuated bulbs and subsequently analyzing the water rinsings for chloride content with a chloride ion-selective electrode.

Additional instrumentation included the use of an anemometer for measuring airflow through the vertical stacks. Pads of cotton were occasionally placed in contact with the exposed surface of the chase wall in order to test for possible ignition from the passage of hot gas through cracks or openings in the wall. The cotton pads were USP absorbent, sterilized, surgical cotton.

Table 2. Thermocouple Locations for Each Chase in Tests 1 and 2 (cf fig. 2)

1. On surface of lateral just inside of furnace.
2. On surface of lateral just inside of the exposed wall at the chase.
3. On surface of lower lateral just outside of unexposed wall of chase.
4. On surface of upper lateral just outside of unexposed wall of chase.
5. Centered inside the upper portion of the 90° bend at the bottom of the stack.
6. Centered inside of the double sanitary tee.
7. Centered inside of the stack midway between the laterals.
8. Centered inside of the upper tee.
9. On the surface at the crotch of the double sanitary tee.
10. On the surface of the stack midway between the laterals.
11. In the air space between the stack and the exposed wall of the chase midway between the laterals.
12.* ASTM thermocouple near the top of the unexposed side of the exposed wall of the chase.
13.* ASTM thermocouple near the top of the inside surface of the chase wall away from the furnace.
14. ASTM thermocouple near the top of the outside surface of the chase wall away from the furnace.
15.* ASTM thermocouple on the unexposed surface of the exposed wall of the chase one foot above the lower lateral.
16. ASTM thermocouple on the unexposed surface of the chase wall away from the furnace and one foot above the lower lateral.
17.* Inside of the exposed wall on the surface of the unexposed layer of gypsum board near the top.
18. Inside of the exposed wall on the surface of the exposed layer of gypsum board near the top.
19. Same as 18 but in wall between chases.
20. Same as 17 but in wall between chases.
21. Same as 12 but in wall between chases.

*Not used in Test 2.

Table 3. Selected Thermocouple Locations in Tests 3 through 10 (cf. figures 13, 16, 17, and 19)

1. On surface of lateral just inside of furnace.
2. On surface at the crotch of the double sanitary tee.
3. On surface of lower lateral just outside of the wall on the unexposed side.
4. On surface of upper lateral just outside of the wall.
5. Centered inside of the stack at the simulated lower floor level.
6. Centered inside the double sanitary tee.
7. Centered in the stack midway between the laterals.
8. Centered inside the upper tee.
9. On the outside surface of the stack at the same elevation as thermocouple 7.
10. ASTM thermocouple 1 foot above the lower lateral.
11. ASTM thermocouple 1 foot below simulated ceiling level.
12. ASTM thermocouple 6 inches to the left of thermocouple 11.
13. On the surface of the stud closest to the stack, midway between the two layers of gypsum board, and at the same elevation as thermocouple 7.
14. On the surface of the adjacent stud (not containing DWV stack).

Smoke meters which measured light transmission through the smoke over an 18-inch vertical path were installed in the upper part of the chases in Test 1. The light source was a tungsten filament lamp and the detector was a phototube with a type S-4 surface.

2.3. Conduct of Tests

Except for the placement of the thermocouples which were aligned with the stacks, the hose stream test was not performed. These tests were conducted in accordance with the fire endurance test procedure prescribed in ASTM E 119.

The test frame containing the wall assembly with the DWV installed or the combination wall and chase assembly were moved in front of the NBS wall furnace. The joints between the test frame and the furnace were plastered to provide a seal. Two of the five furnace exhaust vents were closed off in order to increase positive pressure inside the furnace. The open area under the test frame through which secondary air passes into the furnace was adjusted during the test to keep the furnace pressure at the level of the lateral equal to +0.02 inches of water relative to the pressure at the same elevation in the test room. The flow rate of natural gas to the furnace was controlled during the test in order to follow the prescribed ASTM standard E 119 furnace time-temperature curve as shown in figure 20. Instantaneous temperature readings were recorded using a fast-scan data logging system. The duration between readings for a given channel was 2 minutes or less. Gas samples for indicator tubes were collected about every 10 minutes. The presence of flames or temperatures hot enough to ignite the cotton pad on the unexposed surface of the chase was considered to be an indication of a failure as far as fire penetration was concerned. The time at which these events occurred was recorded. Visual observations (see appendix A) and color photographs were taken throughout the tests. Although all tests were planned to last for one hour, some tests were stopped when the heat or flame penetration reached a point where it was unsafe to continue. This occurred in 45 minutes, 50 minutes, and 55 minutes in the first, second and third tests, respectively. The remaining tests all lasted for at least one hour. In Tests 6 through 9, the fire test for a particular DWV installation was terminated by sprinkler flooding whenever there was obvious flame-through. After completion of each test, the wall was pulled away from the furnace and photographs were taken of the exposed wall and DWV systems.

3. RESULTS

3.1. Temperature Measurements

Figure 20 provides a comparison of the average furnace temperature for Test 1 with the ASTM E 119 standard time-temperature curve. Furnace control was closely maintained in all tests except one; in Test 7 it was necessary to add a correction factor to the recorded failure times according to the procedure described in ASTM E 119. The correction required an adjustment of 2 minutes on the times to failure.

The highest temperature recorded in Test 1 on the unexposed wall of chase 1 was 43 °C (109 °F) and the highest temperature recorded on the laterals outside of this wall was 31 °C (88 °F). For Test 2 the temperatures at similar locations for the other chases were nearly the same and in no case exceeded 100 °C (212 °F). Figure 21 compares both the temperature of the unexposed surface of the chase walls and the temperatures of the laterals at the point where they come through the surface with the maximum temperature allowable on the unexposed surface, according to the ASTM E 119 test procedure. The temperatures at similar locations for the other chases were nearly the same.

Figures 22 through 53 provide a record of the temperature data for Tests 3 through 10. Thermocouples Nos. 3 and 4 recorded the temperatures on the lower and upper laterals at the point where they come through the unexposed surface of the chase walls. The horizontal lines indicate the allowable temperature rise (181 °C or 325 °F) for a thermocouple on the unexposed surface of a rated fire wall and indicate when the temperature exceeded one of the criteria.

3.2. Cotton Pad Test and Flame-Through Time

There was no ignition of the cotton pad in contact with the unexposed surface of any of the chases or with the laterals passing through the unexposed chase walls at any time during the first two tests. In the third test the cotton pad in contact with the lower

ABS lateral ignited in 42 minutes. There was no ignition of the cotton pad associated with any of the other DWV systems during the 55 minutes of this test even though the surface temperature of the copper lateral was up to 500 °C. There was no ignition of the cotton pads for any of the DWV systems in Test 4. In Test 5, flames came through around the ABS lateral at 27 minutes and around the PVC lateral at 55 minutes. In this test the 4-inch hubs of the PVC and ABS tees penetrated the wall. There was no ignition of the cotton in contact with the metal laterals in Test 5. In Test 6, flames came out through the laterals of all three ABS systems at 19, 25 and 28 minutes, respectively, and through the PVC lateral at 56 minutes. In Test 7 flames came out around the unsealed penetration at the ABS and PVC laterals at 27 and 28 minutes, respectively. In Test 8, flames came through around the ABS lateral at 44 minutes and ignited a cotton pad. A cotton pad was ignited at the lower ABS lateral in 21 minutes during Test 9. Although the copper lateral reached 500 °C there was no ignition of the cotton pad. All four DWV systems ignited the cotton pad during Test 10. Failure by flame-through or ignition occurred at 22 and 25 minutes for the two ABS systems and at 16 and 55 minutes, respectively, for the two PVC systems.

3.3. Gas Concentrations

The gas concentrations measured with the colorimetric tubes during Tests 1 and 2 are tabulated in tables 4 and 5. The concentrations of HCl and CO quickly went out of range of the detecting tubes in the third test, which involved the smallest cavity volume (2 x 4 wood-stud wall). The CO and CO_2 concentrations measured with the infrared analyzers are shown in figure 54 for chase 1. The CO concentration for chase 5 is shown in figure 55. For the PVC installation in Test 3 the CO concentration is presented in figure 56 up to the time the measurements had to be stopped due to the buildup of water in the inlet piping to the infrared analyzer. The results of gas concentrations measured in the wall cavities for Tests 6 through 9 by colorimetric indicator tubes are presented in tables 6 and 7. Some measurements in Test 6 using ion-selective electrodes indicated HCl concentrations as high as 30 percent which is not inconsistant with the amount of PVC in the cavity, but the method was not thoroughly checked out for this application. The detector tubes for HCl and HCN had insufficient ranges for the concentrations encountered within the wall cavities. The results of continuous monitoring of CO, CO_2 and O_2 are shown in figures 57 through 63 for Tests 6 through 10. In all ABS installations in which a measurement was made, the curves show the typical increase of CO_2 as the O_2 concentration decreased and the final buildup of CO as the O_2 content neared depletion. No continuous monitoring data could be obtained for the PVC installation in Tests 6 and 9 because the sampling line had a tendency to clog with smoke particulates and tarry condensates. During Test 7 the same problem was encountered between 3 and 13 minutes.

In test 10, the following gas concentration readings were taken in the test building at the 6-foot level at 30 minutes into the test: CO - 2,000 ppm, HCl - 25 ppm, HCN - 15 ppm. Due to the increased buildup of smoke and toxic gases, the observers left the area and no further readings were taken.

3.4. Airflow Measurements

The anemometer readings of air velocity through vertical stacks are presented in table 8. These readings were taken at the bottom of all open stacks in Tests 6 through 9. The zero air velocity readings are indicative of the times when vertical stacks deformed in a manner to prevent passage of air through them.

3.5. Smoke Density

The transmission of light through the smoke in the upper section of the four chases in Test 1 is compared in figure 64. Smoke meters were not used in any of the subsequent tests.

Table 4. Gas Concentrations in Test 1

Time min:sec	Chase	HCl (ppm)	CO (ppm)
4:15	1	8	
6:50	1	12	
8:00	1		2000
9:45	1		2500
10:00	1	0	
11:10	2	100	
12:30	1	0	
13:00	2	60	
14:25	2		>4000
15:40	1	0	
18:45	2	0	
20:35			
33:30	1	0	
36:00	2	15	
40:20	1	10	
44:30	1	10	
47:00	1	0	

Table 5. Gas Concentrations in Test 2

Time min:sec	Chase	HCl (ppm)	CO (ppm)
3:43	7	10	
4:50	5	90	
5:30	6	90	
6:15	5		2800
7:15	6		3000
8:05	7		3200
9:00	8		>4000
10:15	5	600	
15:15	6		3000
16:30	8	0	
17:30	6	40	
18:20	7	0	
19:20	8	0	
21:30	5	320	
22:50	6	225	
29:40	5		>4000
30:40	6		>4000
34:25	5	>500	

Table 6. Gas Concentrations

Test 6

	time	ABS #1	time	ABS #2	time	ABS #3	time	PVC #4
CO ppm	3:00	5,000	4:15	5,000	5:00	5,000	7:10	5,000
	8:00	5,000	7:45	5,000	13:30	5,000	10:10	5,000
	12:14	5,000	9:00	5,000	19:10	40.000	33:00	
	17:30	20,000	13:15	5,000	21:40	30,000		
	19:30	40,000	17:50	50,000				
	23:00	40,000						
	28:00	30,000						
HCl ppm							5:00	
							8:00	trace
							15:00	
							20:10	~2,000
							25:00	>2,000
							35:00	
							45:00	
							55:00	
HCN ppm	14:00	>150	14:15	>150	15:15	>150	18:00	~ 1
							24:10	>30
							26:40	>50
							38:00	>150

Test 7

	time	ABS #2	time	PVC #4
CO ppm	5:00	10,000	7:45	1,300
	8:30	10,000	11:00	1,300
	13:00	2,500	16:45	1,300
	17:00	32,500	22:00	>40,000
	22:00	>40,000	26:00	>70,000
HCl ppm			4:00	150
			6:30	100
			12:00	225
			15:30	340
			23:30	> 1,000
			24:30	> 2,000

Table 7. Gas Concentrations

Test 8

	time	ABS #1	time	PVC #2
CO ppm	5:45	3,000	8:30	3,000
	11:45	3,000	14:15	2,500
	17:15	4,000	20:00	2,000
	24:30	25,000	28:00	5,000
	30:45	30,000	34:00	4,000
	36:00	40,000	39:30	3,700
	43:00	50,000	50:00	2,000
HCN ppm	7:30	2		
	13:00	10		
	19:00	30		
	27:00	>180		
	33:00	>180		
	38:15	>300		
	45:00			
HCl ppm			10:10	100
			15:30	200
			22:00	220
			29:00	450
			35:00	800
			41:30	1,200
			51:30	~2,000

Test 9

	time	ABS #3	time	PVC #2
CO ppm	3:50	10,000	5:10	10,000
	9:20	2,000	10:30	5,000
	14:30	2,000	16:00	5,000
	20:00	12,000	30:00	55,000
	29:00	25,000		
	57:00	60,000		
HCN ppm	6:00	15		
	11:30	10		
	17:10	10		
	27:30	>30		
	33:00	>>30		
	58:00	30		
HCl ppm			7:15	100
			13:30	300
			17:50	550
			21:40	1,120
			24:20	1,400
			26:45	1,400
			28:50	2,000
			31:00	>2,000

Table 8. Air Velocities into the Bottom of Stacks (ft/min)

Time (min)	Test 6				Test 7			
	ABS #1	ABS #2	ABS #3	PVC #4	ABS #1	ABS #2	PVC #3	PVC #4
3	140	230	*		550	200	490	100
6	0	0		120				
10				140	340	100	480	100
13				195	0	0	500	180
19							500	0
22				0				
25							520	
30							0	

* Bottom of stack capped.

Time (min)	Test 8				Test 9			
	ABS #1	PVC #2	ABS #3	PVC #4	Cu #1	PVC #2	ABS #3	ABS #4
0	0	0	0	0	0	0	0	0
5	160	520	240	380	0	0	0	0
7	560	580	360	490	125	135	110	120
10	560	460	380	460	180	160	140	140
15	560	510	400	550	160	170	145	180
18	50				165	170	160	180
20	0	460	350	550	170	175	145	180
23	200				180	50	50	200
25	100	50	480	600	100	50	50	190
30	50	50	520	620	90	30	50	185
35	100	50	380	560	75	20	60	160
40	0	0	500	0	0	0	70	145
45			70		80	60	70	120
50			0		0	0	40	60
55							0	0

4. DISCUSSION

4.1. DWV in Plumbing Chases

The first two fire tests were designed to determine whether PVC DWV systems could be a potential factor in the spread of fire or smoke through a plumbing chase to other dwelling units on the same floor or to the floor above; and if there were a fire spread problem, how effective certain counter-measures would be. All openings around laterals were sealed. The tests showed that the systems as installed were generally acceptable and hence, modifications were not needed. No flames and only a minor amount of smoke penetrated into the "adjacent dwelling unit" areas during the test period. The maximum temperature recorded on the unexposed wall of chase 1 was 43 °C (109 °F) and the highest temperature recorded on the laterals at the unexposed side of this chase was 31 °C (88 °F). The maximum temperatures at the equivalent locations in chase 5 were 95 °C (203 °F) and 64 °C (147 °F), respectively. These temperatures were rising very slowly when the test was terminated at 45 minutes in the first test and 50 minutes in the second test. It was not possible to ignite the cotton pads at any point on the unexposed surface of the chases in either of these tests.

Neither of the first two tests could be continued for the full hour. The gas supply to the furnace had to be shut off in 45 minutes due to a breakthrough of flames between the wall and the test frame on the first test. This had nothing to do with the chases or the plumbing and was corrected in the succeeding tests by adding additional protection at these joints. The test assembly remained in place after the gas was shut down and the chases were exposed to the burning studs for the remainder of the hour. The second test was stopped (gas off) at 50 minutes when the unexposed surface of the wall between chases 1 and 2 indicated a temperature of 483 °C (901 °F) and was rising rapidly. Again, this was not due to the DWV installation. Figure 65 shows the vertical crack in the third gypsum board panel which permitted a high heat transfer rate to the back wall. The reason why the crack developed as early as it did is not known. The test was stopped to examine the condition of the pipe at this time. Sprinklers which had been installed in the chase were turned on as soon as the gas supply to the furnace was turned off. The temperature rises of the unexposed surfaces of the walls between the other chases were well below 181 °C (325 °F) at the time the test was terminated. It is presumed that the satisfactory performance would have continued to at least 60 minutes from the beginning of the test in the absence of a premature failure of furnace frame seal in the first test and a wall failure not associated with the DWV in the second test.

During the first test the concentration of HCl measured in the chases was an order of magnitude lower than the CO concentration. In an actual installation it is likely that the HCl will be essentially confined to the chase and much of it absorbed in the moist walls. In the second test it was found that the CO levels in the chases containing the metal DWV was as high as that in the chases containing plastic DWV due to the contribution of the burning wood studs.

There are obviously different physiological and toxic effects of HCl and CO on people. The suggested threshold limit values [3] are 5 ppm for HCl and 50 ppm for CO. These are safe limits at which a worker can perform 8 hours a day, 5 days a week. A person can tolerate considerably higher values than these over the shorter exposure times encountered in fires. Concentrations of 1,000 ppm of HCl are considered dangerous if breathed from 30 to 60 minutes and concentrations of 2,000 of CO will produce unconsciousness in about 30 minutes [4].

Most of the smoke present in the observation room came out of the top of the stacks which were vented into the top of the room and eventually descended to the level of the observers. A lesser amount came from the leakage between the test wall and the furnace test frame which would not have been a source in actual construction. There was a minor contribution of smoke and toxic gases due to leakage around the lateral penetrations due to cracks developing in the plaster seal. Although this source would be present in practice, it did not appear to be a serious factor in these tests.

4.2. DWV in Wood-Stud Walls

Six full-scale tests were conducted on wood-stud walls with various DWV systems in three basic types of wall construction. The principle variables were the depth of the wall, the type and size of DWV and the sealing of the penetrations. The effect of an offset stack was also investigated. These tests were designed for the purpose of studying these test parameters and correlating test results within the group. Table 1 provides a summary of the results for the entire ten tests.

In Test 3, PVC was compared with ABS and two metal DWV systems installed within a 2 x 4 wood-stud wall. The ABS pipe caused fire to spread to the unexposed side of the wall in 42 minutes. Because of this early failure the condition of the wall was such that the test had to be terminated after 56 minutes. For the other DWV systems, flame did not spread to the unexposed side of the wall. A 181 °C (325 °F) temperature rise of the pipe just outside of the unexposed wall occurred in 30 minutes for the copper, 37 minutes for the ABS, and 52 minutes for the galvanized iron. The temperature increases were due simply to heat conduction through the metal laterals and heat conduction in conjunction with flame spread in the case of the ABS lateral. The temperature in the PVC pipe at the same location had increased only 120 °C (216 °F) after 55 minutes and was rising very slowly.

The failure based on the 181 °C (325 °F) temperature-rise criterion at any one of the three ASTM thermocouples located on each section of the unexposed surface of the wall, occurred at 48 minutes for ABS and 51 minutes for PVC. The highest temperatures were at the highest elevations on the wall. There were no failures of the section of the wall containing the metal piping systems. The sequence of events leading to the fire penetration failures seemed to be: (1) flaming of the wood studs behind all of the fire-exposed gypsum board joints in the furnace, (2) burning of the pipe inside the wall cavity, and (3) disintegration and collapse of the exposed gypsum board.

The entrance of hot furnace gases into the wall cavity left by the burnout of the pipe did not appear to be a major factor because the temperatures at 30 minutes at mid-height were essentially the same for all the cavities. The damage to the section of the wall containing the ABS piping occurred sooner and was more severe than it was for the part of the wall containing the PVC piping. Those panels protecting the metal plumbing did not break up, and the empty wall cavities adjacent to them were not approaching failure at the end of the test.

The construction used in Test 4 was the same as that in Test 3 except that the 2 x 4 studs were replaced by 2 x 6 studs thereby providing a deeper wall cavity. In this test the hubs of the sanitary tees did not protrude through the gypsum board. There were no failures due to excessive temperature rises or flame-through for either of the plastic or metal DWV systems. The fire-exposed gypsum board remained intact almost to the end of the test.

In Test 5, the 4-inch stacks were enclosed in a double 2 x 4 wood-stud wall with the studs secured to 2 x 10 plates. Four-inch sanitary tees were used, and their hubs protruded through the gypsum board on each side of the wall. This simulated a 4-inch diameter lateral penetrating the wall and created an especially severe situation. Flames came out of the lower ABS lateral on the unexposed side of the wall in 27 minutes. An excessive temperature rise was recorded by one ASTM thermocouple on the section of wall containing the PVC in 55 minutes. At the same time, the paper in one area of the unexposed surface of the gypsum board burst into flame. At 55 minutes flames came out of the lower PVC lateral on the same side of the wall. A large amount of smoke penetrated the ABS upper lateral at 23 minutes and the PVC lower lateral at 42 minutes.

When the lower part of the plastic stacks started to soften, the upper sections began to sag pulling the laterals down with them. This caused the seals around the lateral penetrations to rupture and allowed large quantities of smoke to escape. If this smoke were confined in a normal sized room, the conditions there would be untenable in a short time. This demonstrates one aspect of the importance of adequately supporting the plastic stacks along their length.

The effect of cavity depth, stack diameter, and lateral diameter are illustrated in table 1. Although a 1-1/2-inch lateral was actually used in Test 5, the 4-inch hub penetrated the gypsum wall board so that the lateral was effectively slightly over 4 inches in diameter at the point of wall penetration. The comparison of the results of Test 3 and 5 with Test 4 indicates the importance of providing adequate space for the stack and the fittings. If this space is provided, it appears that both PVC and ABS may be used with no serious decrease in fire performance; if it is not, the fire performance may degrade appreciably. One lesson learned in these tests is the importance of using reducing sanitary tees instead of using regular sanitary tees with reducers, at least in those cases where the space is severely restricted. Although it appears logical that there would be an economical advantage to using the reducing tees, it is possible for a supplier to fill orders for reducing tees by substituting regular tees with inserts. If the space provided is only adequate for a reducing tee, the acceptance of a regular tee with inserts could result in a serious deficiency from a fire standpoint.

In Test 7 was studied the effect of variations in installation parameters, increased vertical stack diameter and open penetrations around laterals, in a 2 x 6 wood-stud wall as compared with a similar wall assembly in Test 4. When the distance between the vertical stack and the wall was decreased in this test by increasing the stack diameter from 2 to 3 inches, the 2 x 6 wall with sealed penetrations barely passed the 181 °C (325 °F) temperature-rise acceptance criteria. At 60 minutes, failure due to excessive temperature rise was recorded for PVC on the unexposed wall surface of thermocouple No. 10. The open penetrations around the laterals for the 2-inch stack ABS and PVC DWV installations caused the fire to penetrate the wall at 27 and 28 minutes, respectively, whereas no failure occurred for the corresponding DWV installations with sealed penetrations in Test 4. A correction of +2 minutes was applied to the times in Test 7 to account for a slight departure from the standard exposure.

Test 8 repeated the double 2 x 4 wood-stud wall construction with the studs secured to 2 x 10 plates. In the prior test, the sanitary tees had protruded through the gypsum wall resulting in a 4-inch penetration in the wall. In this test reducing sanitary tees were used which did not protrude through the gypsum wall and therefore a less severe and more typical arrangement was tested. At 17 minutes, heavy smoke was coming out around the upper P trap to stack 1. At 44 minutes flame-through occurred on ABS cavity No. 1 at the lower lateral. Cavity No. 1 had included a reducing bushing from the tee to the 1-1/2-inch lateral whereas cavity No. 3 had a 2-inch lateral connected to the reducing tee.

In Test 9 the DWV systems were enclosed in a 2 x 6 wood-stud wall assembly as in Tests 4 and 7. Offset stack-piping configurations were used in cavities 2, 3 and 4 and all systems had unsealed lateral penetrations through the gypsum wall. The introduction of the different DWV configuration with the stack offset from the lateral resulted in no flame-through in cavities 2 and 3. When the direct stack-lateral configuration had been used with unsealed penetrations in Test 7 with both ABS and PVC piping, flame-through occurred.

Whereas the metal plumbing in these tests was not responsible for any failures of the wall with regard to flame-through or excessive temperature rises on the unexposed surface of the wall, there were temperature rises on the surface of the copper lateral well over 181 °C (325 °F) due to its high thermal conductivity.

Should the ASTM E 119 maximum temperature-rise criterion on the unexposed surface include the surface of the lateral? Until there is some demonstration that these high lateral temperatures significantly increase the fire hazard, it would seem reasonable to exclude the lateral temperature from the specification. However, if the surface of the lateral is permitted to rise more than 181 °C (325 °F), this relaxation must be defined in relation to the extensive surface area of the wall. The restriction on the surface temperature rise of a wall with one or more pipe openings can hardly be relaxed without rethinking the requirements for walls in general. Furthermore, there is some justification for providing a larger margin of safety for the wall surface, in that materials stored against it could substantially increase its temperature due to heat trapping. On the other hand, heat conduction along the lateral to the water filled trap would reduce this heat trapping effect on the surface of the pipe.

A fair test that should be applied to the pipe on the unexposed side of the wall, however, is to determine whether it can ignite materials in contact with it. One can easily imagine times when there may be cloth draped over the drain pipe under a sink, and other combustibles stored within an enclosed closet or vanity. Even though the copper lateral reached 500 °C (932 °F) in Tests 3 and 9, the cotton pad in contact with the pipe only browned and charred without igniting. In Test 9 the cabinet on the unexposed side was filled with crumpled newspapers without ignition. Thus, there was no failure of the copper DWV according to the flame-through criterion.

The smoke and gas concentrations were measured inside of the wall cavities during these tests. This location (1 ft above the lower lateral) was chosen to give a comparison between selected toxic gases characteristic of the burning plastics and the CO generated by the burning of wood and paper in a well defined space. However, the actual concentrations of gases in these spaces is not the important consideration from a life-safety standpoint, but rather the levels that would be built up in adjacent occupied rooms. Furthermore, the high levels in the confined spaces, along with the high temperature there, made the measurement problem difficult and often the measurements had to be terminated early in a test.

To the extent a comparison could be made, the CO levels were about an order of magnitude higher than HCl levels in the cavities containing PVC piping. Since the level of CO present in the other cavities due to the burning of the wood studs was of the same order of magnitude, the burning of the PVC only added to the potential toxic gas hazard already in existence. The additional hazard should be considered in terms of the protected location of the pipe, and the confinement of the pyrolysis products during burning.

4.3. DWV in Steel-Stud Walls

Two full-scale fire tests were performed to examine the effect of plastic DWV systems on the fire endurance of a wall constructed with 2 x 4 steel studs. Two of the variables studied were the effects of sealed versus unsealed penetrations for the laterals coming through the wall and the effect of adding insulation batting to the stud spaces which was done in the Test 10.

Test 6 had three ABS and one PVC DWV installations. In ABS cavity No. 1, the fire penetrated the steel-stud wall at 28 minutes, which is earlier than a comparable wood-stud wall (42 minutes: Test 3). Flame-through occurred at 19 minutes in ABS cavity No. 2 which had the unsealed penetrations around the laterals. Although the ABS stack in cavity No. 3 was capped at the bottom to minimize the airflow, no significant difference in the failure time between cavity No. 1 and cavity No. 3 was observed. An unexposed-surface temperature-rise failure was recorded at 51 minutes on the PVC installation. Additionally, flame-through at the lower PVC lateral occurred at 56 minutes.

In Test 10 glass fiber batt insulation was installed in the stud spaces. One ABS and one PVC DWV installation were left unsealed, while two comparable installations were sealed. There was only a 3minute differential between the failure times for the unsealed (22 min) and sealed (25 min) penetrations for the two ABS installations. The results of Test 10 correlated with Test 6 wherein the failure due to flame-through occurred at the same time (25 min) for the ABS DWV installation with the bottom of the stack sealed off. Comparing the PVC DWV installations, there was a significant time differential in the failure time as a result of the unsealed penetration (16 vs 55 min). With the sealed penetration, the test results correlated well with Test 6 with only a one-minute difference in the failure times (55 vs 56 min). No improvement in the wall performance was measurable as a result of adding the insulation, as failure times of the wall due to flame-through correlated with the previous test on a wall without insulation.

The indicated gas concentrations reported for Test 6 (also other tests) may not be representative of actual gas concentrations in the wall cavities because of measurement difficulties as mentioned earlier. The HCl and HCN values obtained with colorimetric indicator tubes are to be considered semi-quantitative only, since the high temperatures within the wall cavities exceeded the prescribed operating temperature limits for the indicator tubes.

Based on the tests described, involving DWV plumbing systems in fire-rated chases and wall assemblies, a suggested test procedure and set of acceptance criteria with respect to fire spread are given in appendix B.

5. SUMMARY

The following observations were drawn from the series of 10 full-scale fire tests involving 39 piping assemblies within wall cavities and pipe chases. These observations are based on the performance of the iron, copper, ABS and PVC drain, waste and vent pipe in both walls and chases using the plumbing configuration and construction details described in this report. The observations are predicated on three failure criteria which were established for the purpose of this research: flames coming through the wall; excessive temperature rise at selected locations on the unexposed wall surface; or heavy smoke coming through the wall prior to a one-hour exposure time for the test. It should be emphasized that these were research tests rather than rating tests.

5.1. The PVC DWV systems with 4-inch stacks and 1-1/2-inch laterals in 20-inch by 20-inch chases met the criteria for 60 minutes fire endurance (see Tests 1-1 and 2-1). The annular openings around the laterals were sealed for these tests. Although not tested, it appears likely that a similar ABS installation would also meet the criteria.

5.2. The one-hour fire-rated walls containing ABS and PVC pipe with back-to-back laterals in line with the stack met the 60-minute criteria when all of the following conditions were satisfied:

1. The annular openings around the laterals were sealed.

2. The wall cavity depth was 5-1/2 in or more.

3. The stack was limited to 2- or 3-in diameter. (See Tests 4-1, 4-3, 7-1 and 7-3.) A 4-in diameter PVC stack in a 9-1/2-in deep wall cavity also met the criteria when the annual opening around the lateral was sealed. (See Tests 8-2 and 8-4.)

5.3. The fire endurance of the wall containing PVC or ABS pipe with back-to-back laterals in line with the stack was reduced when any of the following conditions existed:

1. The plumbing fittings (e.g., tees, wyes) penetrated the gypsum board. (See Tests 8-1 vs 5-3 and 8-2 vs 5-1.) (See also Tests 3-1 and 3-3).

2. The annular hole around the PVC or ABS lateral was not sealed. (See Tests 4-3 vs 7-2 and 4-1 vs 7-4.)

3. The PVC or ABS pipe was used in a 3-1/2-in deep wall cavity with either wood or steel studs. (See Tests 3-1, 3-3, 6-1, 6-2, 6-3, 6-4, and 10-1, 10-2, 10-3, 10-4.)

5.4. Offsetting the lateral from the stack in the same stud space for a 2 x 6 wood-stud wall increased the time to flame passage. However, when the annular openings around the lateral was not sealed, a considerable quantity of smoke was released into the room at 34 minutes and the ABS and PVC systems failed this criterion (see Tests 9-2 and 9-3). When the lateral was offset from the stack in an adjacent stud space, the heavy smoke criterion was reached at 5 minutes and failure by flame-through occurred at 21 minutes (see Test 9-4). The effect of offsetting the laterals in 2 x 4 wood-or steel-stud walls was not examined in these tests.

5.5. The performance of the PVC system was superior to the ABS type, both in time to flame-through and in time to heavy smoke development in almost all the tests where a direct comparison was possible, (see Tests 3-1 vs 3-3, 5-1 vs 5-3, 6-1 vs 6-4, 8-1 vs 8-1 vs 8-2, 10-1 vs 10-2). These tests covered a variety of wall-cavity depths and stack sizes. However, in each of the above cases, the comparison is based on the condition where the annular hole around the lateral was completely sealed off with plaster spackling. When the annular hole was not sealed, the performance was difficult to compare since the times to failure were short in both cases.

5.6. All copper, galvanized iron and cast iron systems installed in wall cavities, a total of seven constructions, met the criteria for 60 minutes in every case. In six tests, the openings around the lateral were sealed, (see Tests 3-2, 3-4, 4-2, 4-4, 5-2, 5-4); and in one test the opening around the lateral was not sealed (Test 9-1). The wall cavities in these tests were of three depths, 3-1/2 in, 5-1/2 in, and 9-1/2 in. While the wall-surface temperature-rise did not exceed 181 °C (325 °F) the temperature of the copper lateral reached 500 °C (932 °F) just outside of the wall.

5.7. Based on the results from this series of tests, plastic DWV Systems with lateral sizes of 2 inches or less would not be expected to reduce the 1-hour fire endurance rating of wood-stud-and-gypsum board walls and chases in one- and two-story buildings provided that:

1. the annular hole in the wall around the lateral is sealed (an adequate inspection system may be required), and

2. the stud space depth is sufficient to obviate the need for the hubs of any tees or wyes in the vertical stack to penetrate the wall.

5.8. There was a quantitative difference in the fire performance of ABS and PVC DWV systems. However, neither system degraded the one-hour fire rating of wood-stud-and-gypsum board walls where the above conditions were followed.

5.9. This investigation covered only the fire performance of plastic (and metallic) pipe in one-hour fire-rated chases and walls. It did not address the fire performance of DWV in "high-rise" buildings nor DWV penetrating floor-ceiling assemblies. Further studies may be needed to determine whether pressure differences due to the stack effect in high-rise buildings will contribute to rapid fire and smoke spread. Also, there is a need for developing a procedure for quantitative measurements of smoke and gas accumulation in adjacent dwelling areas.

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7. REFERENCES

[1] Benjamin, I. A. and Parker, W. J., Fire Spread Potential of ABS Plastic Plumbing, Fire Technology, Vol. 8, No. 2, 104-119 (May 1972).

[2] Standard Methods of Fire Tests of Building Construction and Materials, ASTM Designation E 119-73, 1972 Annual Book of ASTM Standards, Part 14, 508-525.

[3] Threshold Limit Values of Airborne Contaminants Adopted by ACG-121 for 1972, American Conference of Governmental Industrial Hygenists, P. O. Box 1937, Cincinnati, Ohio 45201.

[4] Sax, I. N., Dangerous Properties of Industrial Materials, Third Edition (Van Nostrand Reinhold Co., New York, 1969).

APPENDIX A. VISUAL OBSERVATIONS DURING THE TESTS

Test 1

Time min:sec	Observations
02:00	P-traps at chases 1, 2 and 3 have fallen away inside of the furnace. The laterals of all three chases are flaming in the furnace.
03:30	Smoke is issuing copiously from the top of the stack in chase 1.
04:00	All of the paper burned off the exposed gypsum board wall.
05:00	Smoke and steam are issuing from the bottom of the stack in chase 2.
06:00	Considerable water coming out of the bottom of chase 3.
08:00	Flaming stopped at the lateral on the furnace side of chase 1.
10:00	Flaming still persists in the furnace at the lateral to chase 2. Smoke and steam is appearing around the lower lateral where it penetrates the unexposed wall of chase 2.
10:30	The chrome plated brass P-trap from chase 3 fell into the furnace.
13:30	The furnace lateral to chase 2 is no longer flaming.
20:00	Smoke is leaking out along the south edge of the wall. Smoke is coming out of the bottom of the empty chase. There is flaming of the studs along all three gypsum board joints in the furnace. There are popping noises caused by the burning of the studs in the wall.
25:00	Smoke is issuing from all of the gypsum board joints on all of the chases.
27:00	Wall between chases is warm.
30:30	Popping continues. The burning studs are expelling sparks and cinders into the furnace.
32:00	Flame is issuing from the upper joint between the wall and the frame on the unexposed side between chases 3 and 4 (not associated with fire penetration through chase). Smoke is continuing to issue from the top of the stack in chase 1 but not in the others. The air velocities into the bottom of the stacks were 400 ft/min in chase 1, 200 ft/min in chase 2, and 300 ft/min in chase 3.
35:00	More water draining from bottom of stack in chase 3. Gypsum board is separating on the furnace side of chase 4.
40:00	Smoke continues to issue from the top of stack in chase 1 and from leaks between the wall construction and the frame.
41:00	Flames at joint between wall and test frame on the unexposed side are now 6 to 8 inches high. The gypsum board is separating along the whole length of the upper wall in the furnace.
45:00	Flames are now 2 feet high at the joint between the wall and the frame. Frame is being threatened. Embers are falling in the observation room. Gas to the furnace is cut off. Wall is permitted to burn for another 25 minutes.
55:00	The gypsum board is burning on the unexposed surface between chases 1 and 2. (This is due to premature failure of seal at joint of furnace frame.) There is considerable water draining from the bottom of the stack in chase 1.

70:00	The wall was moved away from the furnace and hit with a spray of water from the fire hose. The wall collapsed and fell. The stacks were observed to be fairly straight at the time when the wall was giving away. (The collapsed state seen after the test was a result mostly of the fall.)

Test 2

Time min:sec	Observations
00:30	The number 5 P-trap on the exposed side is flaming.
01:30	Approximately at this time numbers 5, 6, and 7 P-traps on the unexposed side fell into the furnace leaving molten flaming PVC at the exposed openings.
03:00	Smoke is emanating from the top of the stack of chase 7.
03:30	Visible combustion products coming out of the bottom drain of chase 5. By its yellowish color and its smell, it appears to be HCl.
05:00	The gypsum board on the exposed side is completely charred. Smoke is emanating out of the stack at the top of chase 5.
06:00	Smoke is emanating around the lower P-trap (on the unexposed side) for chase 7. There is still smoke out the stack at the top of chase 7.
07:00	There is flaming at the P-trap on the exposed side of chase 8.
09:00	Smoke is now emanating around the top of P-trap of chase 7 (unexposed side).
10:00	Smoke coming out of the tops of stacks 5, 6 and 7. Most of the smoke is coming from stacks 5 and 7, and the most smoke of all appears to come from 5.
11:00	There is still quite a bit of smoke around both unexposed P-traps on chase 7. The lateral on the exposed side of chase 7 is sealed off.
12:00	P-trap 8 is the only one still standing on the furnace side. Smoke emanating out around unexposed laterals on chase 7 and also at the bottom of the chase.
12:30	There is still quite a bit of smoke coming from the tops of 5, 6 and 7 chases. No smoke out the top of chase 8.
13:00	Plastic has for the most part fallen out from the exposed side but has effectively stopped up the openings.
14:00	The number 8 P-trap is still standing (from the exposed side). The gypsum board to this point appears to have held its integrity on the exposed side, but a red glow is visible at the vertical joints as viewed from the inside of the furnace.
15:00	Smoke is emanating around the top P-trap of chase 6. Smoke is emanating from the vertical joint between the wall and chase 5 on the south side.
17:00	Smoke is coming from behind chase 8 at the wall as viewed from the unexposed side.
17:30	Most smoke out the stacks is now coming from the chase 6 stack.
18:00	There is still a red glow at the vertical joints as viewed from the exposed side and also a red glow where the P-trap connections were (at the opening).

19:00 Smoke is coming from the bottom of chase 5.

20:00 Smoke is now coming from the north joint between chase 7 and wall.

21:00 Still smoke emanating from around the upper laterals of chases 6, 7 and 8.

22:00 Smoke appears to be coming from behind chases 6, 7 and 8 at the wall behind the chases. Smoke is coming from the hole two-thirds the way up chase 5.

23:00 Much smoke out around the upper laterals of all four chases. Also smoke out bottoms of all chases and around all four bottom laterals.

24:00 There are cracks (visible openings) at the joint between chase 7 and the wall.

25:00 There is a crackling sound caused by burning studs in the wall. There are flames at all three vertical joints visible on the exposed side.

26:00 Smoke is coming out around all of the laterals (top and bottom) and at the bottoms of the chases (especially 6).

27:00 There is a crack at the joint between chases and the wall about one-half way up. The top P-trap for chase 5 is drooping as viewed from the outside. We neglected to use the wire supports for the traps on this test.

28:00 The bottom P-trap for chase 5 is now drooping. The top P-trap for chase 6 is drooping. There is a brownish ring at all of the upper laterals (unexposed side) where the smoke is emanating.

29:00 Crackling sound from the inside of the wall.

30:00 There is still flames at the vertical joints on the exposed side. There is still smoke out the tops of all chases and around the lower laterals, but very little from the bottom of the stacks. The chase 6 bottom P-trap is now sagging.

31:00 There is a visible opening (hole) where the P-trap was on the exposed side for chase 7, but there is still PVC at the exposed side openings for P-traps of chases 5 and 6. Flame at P-trap opening is still intact. There is no smoke coming from around the bottom lateral on the unexposed side of chase 7.

32:00 There is no smoke coming from around the top lateral, chase 5, unexposed side. There is more loud crackling from the inside of the wall.

33:00 The only lateral that does not have a brown ring around it is the bottom lateral for chase 8.

34:00 Still flaming at the vertical joints as viewed from the inside of the furnace. The holes for chase 5 and 6 still appear to be stopped up on the exposed side; there is no PVC remaining at the exposed lateral hole on chase 7. The P-trap of chase 8 inside the furnace is OK.

35:00 The vertical joint of the unexposed wall between chases 5 and 6 is cracking.

36:00 The vertical joint of the unexposed wall between chases 5 and 6 is cracking.

36:00 Much crackling from inside the wall or chases (especially 7). Cotton wool test was run, on chase 7, just browning the cotton.

37:00 There is now nothing in the lateral holes on the exposed side except the lateral and P-trap for chase 8 which is still intact.

38:00 There is still smoke out the bottoms of all chases. (A lot of crackling noise on the inside of chases or wall.)

39:00	There is burning at the P-trap on chase 8, exposed side. There is still flaming at the vertical joints.
40:00	The chase 7 P-trap is drooping at the top; the bottom P-trap is drooping slightly. There is a blue flame at the iron pipe as viewed from the exposed side. The gypsum board is opening at the vertical joints on the exposed side, appparently due to shrinkage.
41:00	The top P-trap for chase 7 is apparently about to fall.
43:00	Smoke is beginning to fill the room.
44:00	For chase 8 the wall and P-traps are hot while at the end of the P-trap the temperature appears to be ambient.
45:00	Top P-traps for chases 5 and 7 appear to be about to fall.
45:30	There is smoke out the top of stacks for chases 5, 6 and 7 but not chase 8.
46:00	Smoke is really puffing out the tops of stacks 6 and 7 while some smoke is coming from 5. There is still a blue flame at the P-trap at the furnace side of chase 8.
47:00	Smoke is coming out of the bottom of the stack in chase 6.
48:00	At the joint at the wall between chases 5 and 6, a cotton pad ignition test was performed and just a little browning occurred although there was a red glow visible in the joint.
49:00	All PVC top P-traps appear about to fall.
50:00	Smoke is coming out the drains at the bottoms of chases 5 and 6. The glow at the crack in the wall (vertical) between chases 5 and 6 is about 6 inches long. At this time the test was terminated. At the termination of the test all three PVC P-traps 5, 6 and 7 top and bottom were drooping. The top P-traps appear to be ready to fall. The bottom P-traps are drooping somewhat less; 5 a lot, 6 not too much and 7 very little. After the sprinkling of the chases, there was still burning at the tops of the chases when the wall was pulled out. The vertical pipes for 5 and 6 have melted and congealed around the thermocouple wires in the lower third of the chase.

Test 3

Time min:sec	Observations
03:00	The ABS P-trap fell off in the furnace. The exposed ABS lateral into the chase is sagging. The PVC P-trap is falling off. The PVC lateral into the chase is sagging. The escutcheon plates around the ABS and PVC have pulled slightly away from the wall. The ABS lateral coming out of the escutcheon plate in the furnace is sagging. The copper and steel are still in place.
05:10	Smoke is coming around the lower PVC lateral on the unexposed side.
05:30	The paper on the gypsum board has ignited in the furnace. There is burning at the ABS penetration. The escutcheon plate is falling off.
06:20	Flame is coming out of the ABS stack and smoke out of the PVC stack. Slight smoke coming out of copper and cast iron stacks.
07:30	Scorching around PVC P-trap on unexposed side around the escutcheon plate. Evidence that ABS piping is burning inside the chase.

09:00	Airflow: 160 feet per minute in galvanized iron stack, 100 in the ABS riser, 150 feet per minute in the copper stack, 150 feet per minute in the PVC stack. Flames coming out of chrome plated brass P-trap on the galvanized iron lateral, on the exposed side.
13:30	More smoke coming around the escutcheon plate on the PVC lateral on unexposed side. Slight smoke coming around the ABS lateral. These are the lower laterals on the unexposed side.
14:20	Smoke continues to pour out of the top of the ABS stack, but not out of the PVC stack.
15:00	The joint treatment on the gypsum board is still in place for the most part, but starting to flake off. This is tape compound joint treatment. The P-traps attached to the copper and galvanized iron laterals on exposed side are red hot in appearance but still staying in place, no apparent deflection. The opening into the exposed side of the wall has closed off for the PVC whereas the ABS has burned off.
16:00	Smoke coming around the lower unexposed lateral on the ABS and continuing to pour out of the top of the stack.
16:30	Gas analysis was shut down for the ABS wall cavity. Water was pulled into the sample receiving tubing.
17:20	Smoke is starting to come out of the bottom of ABS stack.
17:30	No airflow through the galvanized iron stack. On the copper stack we have 180 feet per minute, on PVC stack 180 feet per minute.
18:20	The PVC penetration on the exposed side is still melted over tending to close off the penetration whereas the ABS is completely open.
19:30	The escutcheon plate around the galvanized iron lateral on the exposed side has started to pull away from the wall. The escutcheon plate on the copper lateral on the exposed side is still tight to the gypsum board.
20:00	Smoke is coming out of the top of the PVC stack as well as the ABS stack now. Areas around the PVC and ABS lower laterals are scorching.
22:30	Ignition test at lower ABS lateral. No ignition of the cotton as yet.
24:30	Some burning at the joints between the gypsum board sheets on the exposed side. The molten PVC stem going into the wall cavity is burning. The P-traps on the copper and galvanized iron laterals are still in place although they appear to be red hot, the escutcheon plates are still in place on the copper, and slightly away from the wall on the galvanized iron. There is flaming at all joints on the gypsum board.
24:30	Starting to hear wood burning inside chase.
25:30	Getting smoke around the upper lateral for the copper. This is the only smoke coming out around any of the top laterals.
26:00	Paper on gypsum board around the escutcheon plate on the lower copper lateral is charring. No charring is evident around the galvanized iron lateral. The lateral at the top of the copper stack is charring the paper. There is no other charring occurring at the other laterals.
28:30	The gas analysis equipment is shut down for the wall cavity containing the PVC.
29:15	Getting smoke around the upper lateral for the copper. This is the only smoke coming out around any of the top laterals.
30:30	Continuing to burn at the gypsum board joints, no breakup of any of the board as yet. The P-traps for the galvanized and copper are still in place. The escutcheon plate on the copper is still tight against the gypsum board on the exposed side.

39:00	Airflow is 200 feet per minute into the copper stack, 200 feet per minute into the galvanized iron stack. Smoke is coming out of bottom of both plastic stacks.
39:45	An ignition check is being made with the cotton pad at the top copper lateral again. This is the only upper lateral that shows any indication of smoke penetration and charring around the paper.
41:30	The extension of ABS stack above the wall fell off. Horizontal cracking of the gypsum board at the south end of furnace on exposed side.
42:00	The PVC is burning pretty heavily at the lateral opening inside the furnace. The gypsum board on the south side is opening up inside the furnace. A piece fell out around the PVC penetration. The gypsum near the ABS opening inside the furnace is tending to pull away from the studs. Flame-through at the lower ABS lateral on the unexposed side. Trap was still filled with water.
44:15	The wall board on the exposed side of the ABS stack has fallen into the furnace. There is heavy burning inside the wall.
45:00	Heavy smoke around the lower ABS lateral. Again the only charring at the upper part of the unexposed wall seems to be around the copper lateral.
52:00	The studs are burning, gypsum board is falling off considerably on the exposed side. Still no flame-through at any of the penetrations other than the previously reported lower ABS lateral. All other unexposed laterals are in good shape. There is still smoke and heat coming around the top and bottom escutcheon plates for the copper and at the lower escutcheon plate for the PVC.
52:30	Flame-through at gypsum board joint on unexposed wall north of ABS trap.
56:00	Gas off, end of test. Continued flaming on gypsum board joint, no other flame penetration at any of the P-traps other than the previously reported ABS. Charring around lower PVC lateral. Slight charring at the top PVC lateral. No charring around the laterals for the galvanized iron.
Post fire analysis:	After pulling the wall frame out of the furnace the PVC stack is still in place burning, and the ABS stack has been completely consumed. The copper and galvanized iron are still standing.

Test 4

Time min:sec	Observations
01:30	PVC P-trap on the exposed side is scorched.
01:35	ABS P-trap has fallen off on the exposed side.
02:05	The paper on the gypsum board on the exposed side has ignited.
03:00	The PVC P-trap has fallen away from the wall on the exposed side.
03:30	The ABS lateral on the exposed side has melted and closed at the escutcheon plate.
05:15	The PVC lateral on the exposed side has also melted and closed off the opening into the stack.
07:30	Smoke is coming out of the top of the ABS stack. Exposed ABS lateral has burned away completely.

14:00	Smoke is continuing to come out the top of the ABS stack.
16:30	There are flames at the openings to the PVC and ABS cavities in the furnace; the escutcheon plates are still in place at both entrances.
18:00	The pump is shut down to the gas analysis equipment for the ABS.
21:00	Steam or light smoke is coming out of the top of the PVC stack.
23:00	The joint compound on the exposed side is starting to flake off and some flaming of the paper is occurring at the joints.
25:00	Flaming is noted at the joints of the gypsum board on the exposed side.
27:00	There is burning inside the cavity containing the copper.
34:45	The escutcheon plate fell away from the opening left by the PVC lateral on the exposed side. Flaming is noted at this penetration. The escutcheon plate at the ABS opening is still in place.
37:00	Heavy flaming at the opening to the PVC stack on the exposed side.
42:00	The joints are burning badly on the exposed side. The joint compound treatment has fallen away.
45:00	There is no breakup of the gypsum board on the exposed side.
47:00	A piece of gypsum board at the top fell down and knocked the tail piece off the P-trap attached to the copper lateral on the exposed side. (Note: gypsum board which fell was from protected wood molding at the top of test frame <u>not</u> from the wall itself.)
50:00	Flame broke through at the edge of the test frame on south side.
52:45	The gypsum board is starting to break away from the studs at the joints near the PVC stack.
62:00	The most severe scorching on the unexposed side is at the upper copper lateral.
64:00	Test shut down.
Post fire analysis:	The plastic stacks were completely burned out at the end of the test which was run for 65 minutes. The laterals were intact where they penetrated the unexposed side of the wall, but they were completely sealed off at this point due to char formation in the interior of the pipe.

Test 5

Time min:sec	Observations
01:00	ABS trap in the furnace is gone.
02:00	PVC trap in the furnace is gone.
03:00	Smoke coming around upper ABS lateral.
04:00	Smoke out top of PVC stack.
04:30	Smoke out through south joint between wall and test frame.
08:00	Flames out of top of PVC stack.
08:30	Metal traps are gone.

10:00	Flames out top of ABS stack.
12:00	Joints OK on gypsum board.
12:30	Trap being pulled inward by the stack.
13:00	Flames out ABS hole in the furnace.
16:00	Can see flames in cavity through the cracks in the spackle around ABS lower lateral.
20:00	Flame appears to be sucked into hole left by ABS lateral in the furnace.
23:00	Voluminous quantities of smoke coming out upper ABS lateral. This could easily fail test based on limiting smoke criterion.
24:00	Lower ABS trap being pulled in.
25:00	Smoke out of bottom of ABS stack.
26:00	Sparks issuing from top of wall where hubless case iron stack passes through the top plate.
27:00	Flames broke out through lower ABS lateral.
29:00	Lower ABS trap and lateral were removed and hole boarded up.
30:00	HCl concentration greater than 2,000 ppm at bottom of stack. Water was applied to ABS cavity for 30 seconds. This effectively stopped the fire in the cavity.
35:00	Cracking of spackling plaster around lower PVC trap. Tape has fallen away from gypsum board joints but joints are still intact.
38:00	HCl concentration greater than 2,000 around lower ABS lateral. Lower PVC trap being pulled inward.
42:00	Tremendous smoke out around lower PVC lateral.
48:00	Gypsum board between PVC and furnace breaking up.
52:00	Gypsum board falling into furnace around PVC.
53:00	Gypsum board between PVC and furnace has essentially all fallen in.
55:00	Paper on unexposed wall in front of PVC burst into flame at three-quarters height. Flame out around PVC lateral.
60:00	Test over. Gas turned off.
Post fire analysis:	The fire in the ABS section of the wall was effectively stopped by an internal sprinkler system at 33 minutes. The test was stopped at 60 minutes. Both plastic stacks had been consumed as well as the lower laterals and traps. The upper laterals had been pulled inward but were still intact. The upper PVC lateral caught fire and burned about 5 minutes after the test was over.

Test 6

Time min:sec	Observations
00:35	Inlet P-trap at stacks 1, 2 and 3 are aflame.
02:00	White smoke (possibly steam) issuing from the vicinity of the top of stack 1.

03:00	P-traps at stacks 1, 2 and 3 have fallen away inside of the furnace.
03:15	Smoke is emanating from the top of stack 2 and from the vicinity of the lower P-trap of stack 2.
03:20	Smoke from top of stack 3.
04:00	Smoke coming out at the bottom of stack. Smoke issuing from the tops of stacks 2, 3 and 4.
04:30	Flames appeared momentarily at the top stack 2.
04:30	Opening around lower lateral of stack 2 smoke.
05:00	Paper surface of the exposed gypsum board wall has turned black.
06:00	Smoke coming out at the bottom of stack 1 only.
06:30	Smoke is still issuing from the bottom of stacks 1 and 2. No smoke is observed at the bottoms of the other two stacks. Smoke is also emanating from the tops of stacks 1, 2 and 3. No smoke is coming from the top of stack 4.
09:00	Along the bottom of the stacks, only stack 2 is still issuing smoke. No smoke is present around all four lower P-traps. Some smoke is observed around the upper P-traps of stacks 1, 2 and 3. No smoke is noticed at the upper P-trap of stack 4. (#4 stack stops smoking at top.) Smoke is issuing copiously from the tops of stacks 1, 2 and 3. No smoke is coming out of stack 4.
12:20	Much smoke is coming from the bottoms of stacks 1 and 2. Only a glowing red stub remains of the inlet P-trap for stack 4. Gypsum wall below the inlets of stacks 2 and 4 are aflame.
13:00	Top of stack 4 starts smoking again.
14:00	Gypsum wall around the lower escutcheon plate for stack 2 is turning brown. The P-trap is sagging. Smoke is issuing from the wall around the lower escutcheon plate for stack 3 and the P-trap is also sagging.
15:30	Wall area around the upper escutcheon plate for stack 3 is now turning brown.
16:15	Smoke is observed around the lower escutcheon plate for stack 1. Wall areas around the lower and upper escutcheon plates for stack 4 have not been affected.
19:00	Flame broke through around the lower P-trap of stack 2 and is extinguished with a water spray.
20:00	Furnace inlet for stack 2 appears dark. The other three inlets are reddish yellow in color. Wall area around the upper escutcheon plate for stack 4 has burned brown. Only the wall surfaces around the lower P-traps for stacks 1 and 4 and the upper P-trap for stack 1 have not been affected.
24:30	Smoke is issuing copiously from the area around the lower escutcheon plate for stack 3.
25:10	Flame is coming through around the lower escutcheon plate for stack 3.
26:30	Flaming around the lower plate for stack 3 is extinguished with a water spray. Furnace inlets for stacks 2 and 3 appear dark. The other two inlets are yellowish in color.
28:00	Lower P-trap for stack 1 has just dropped out. Flames are shooting out. Flames are also re-emerging at the lower escutcheon plate areas of stacks 2 and 3.

28:30	Flames extinguished at all three locations. Glass wool is used to plug the breakthrough area around the lower plate of stack 1.
29:15	Flames emerging periodically around the lower plates of stacks 2 and 3.
30:30	Paper joints between the exposed panels of gypsum board have peeled off. Breakthrough area around the lower plate for stack 1 is restuffed with glass fiber. The flame through areas for stacks 2 and 3 are being filled with glass fiber.
32:30	PVC stub at the inlet is still there and is still glowing yellow in color. Wall surface around the lower escutcheon plate for stack 4 has not been affected. Wall areas around all four upper escutcheon plates have burned brown. Exposed surface of the gypsum boards still appear to be in good condition.
37:35	Smoke is coming from a break-through hole near the bottom of stack 4. Gypsum charred around upper lateral of stack 4.
40:00	PVC stub at the inlet to stack 4 has dropped off. Much smoke is issuing from the area around the lower escutcheon plate of stack 4.
45:30	Paper has blackened and has lifted around the lower escutcheon plate of stack 4.
47:30	Exposed gypsum board above the inlet of stack 3 is buckling slightly towards the furnace.
53:00	Lower escutcheon plate for stack 4 is red hot on its north side. A smaller glowing red area is also present a short distance above the plate.
55:30	Cotton pad is applied to the glowing red areas.
55:55	Flaming occurs in the cotton pad on the lower plate of stack 4.
57:00	Test terminated.
Post fire analysis:	Water is sprayed on the unexposed wall surface. Wall assembly is wheeled into the open. Entire exposed surface is cracked, but otherwise looks in good condition. Both upper corners on the exposed side are still flaming. Flames are still present within the walls originally containing stacks 1, 2 and 3. Water is sprayed over the furnace side of the wall. No ABS piping residue remains. Little PVC ash is seen near the lower part of the assembly. Several of the steel studs were twisted.

Test 7

Time min:sec	
00:25	Crackling noise.
00:40	Inlet P-trap to stacks 1 and 4 are aflame. Smoke issuing from vicinity of lower P-trap to stacks 2 and 4.
01:20	Looking back into furnace, all four inlets now aflame.
01:35	Inlet trap to stack 2 has completely come off. Inlet trap to stack 4 has also dropped, leaving a stud. Inlet P-trap for stacks 1 and 3 are drooping severely.
03:15	Only inlet trap to stack 3 still attached. Heavy smoke was emanating from top of stack 4.
04:00	Smoke issuing copiously from top of stacks 1, 2 and 3. Only a little smoke now coming from top of stack 4.

04:20	Inlet trap to stack 3 has come off.
05:00	Heavy smoke from top of stack 1. Only a little smoke now issuing from the other three stacks. Smoke observed from the vicinity of the lower escutcheon plates for stacks 2 and 4. No smoke seen at corresponding locations for stacks 1 and 3.
05:15	Gypsum boards inside furnace have turned brown. Joints between boards are still intact.
07:30	Smoke continuing to come from lower escutcheon plate areas of stacks 2 and 4. No smoke yet observed around lower plates of stacks 1 and 3.
08:30	Reflection of flames seen at bottom of stack 1. Loud roar also heard at that location.
09:40	Flames observed several times from top of stack 1.
10:00	Cotton pad applied at vicinity of lower plate of stack 4. No ignition.
11:30	Inside the furnace the inlet stub to stack 4 still there. Inlets 1, 3 and 4 are brightly lit while inlet to stack 2 appears dark.
12:40	Smoke issuing from bottom of stack 1. Area around escutcheon plate of upper P-trap to stack 4 is turning brown.
13:40	Looking inside furnace, inlets to stacks 1 and 2 appear dark. Inlets to stacks 3 and 4 appear yellowish in color.
14:30	Areas around upper escutcheon plates for stacks 2 and 4 are brown in color. There is no discoloring of the upper plate areas for stacks 1 and 3.
15:30	Paper joints between gypsum boards inside furnace are still intact.
16:40	Smoke coming from bottoms of stacks 1 and 2. Only little smoke from bottom of stacks 3 and 4.
17:45	Cotton pad applied at vicinity of lower plate of stack 4. No ignition.
18:15	Escutcheon plate areas around lower traps to stacks 2 and 4 turned brown. No discoloring around the other lower escutcheon plates.
19:00	At escutcheon plate areas around upper traps, only those for stacks 2 and 4 have discolored.
19:45	Cotton pad applied to plate area at lower trap to stack 4. Pad turned brown, but no ignition.
21:05	Condition unchanged inside furnace. Cotton pad applied around lower plate to stack 4.
21:45	Cotton pad applied to plate area at lower trap to stack 2. No ignitions at either location.
22:45	Cotton pad again applied at lower plate of stack 4. No ignition.
24:00	Looking inside furnace, paper joints between gypsum boards for stacks 1 and 2 are flaming.
26:00	Heavy brown smoke issuing from bottom of stack 3. Light smoke coming from bottoms of stacks 1, 2 and 4.
27:08	Flames emerging from vicinity of escutcheon plate on lower P-trap to stack 2.
27:45	Flame-through near plate on lower trap to stack 4. Water being sprinkled inside wall sections housing stacks 2 and 4.

28:35	Conditions unchanged inside furnace.
31:00	Flame coming out lateral (inlet) 1 into furnace stub on inlet to stack 4 still present.
32:35	Flame issuing from lateral (inlet) 3 into furnace.
32:55	Crackling of studs. Inlet to stack 3 has widened. Flames emerging from inlets 2 and 3 into furnace.
38:00	Paper joints flaming between gypsum board for stacks 3 and 4. Flames coming out from all four inlets into furnace.
41:30	Inlet stub to stack 4 almost gone.
50:00	Gypsum boards between stacks 3 and 4 have pulled away from studding.
59:45	Cotton pad applied at browned area adjacent upper plate of stack 1. No ignition.
62:00	Test terminated.
70:00	Wall section wheeled out into the open and hosed down with water.
Post fire analysis:	Large sections of gypsum boards for stack 3 and 4 fallen off. Pieces of gypsum board for stack 1 have just fallen off exposing the studding. Gypsum board for stack 2 is intact. All exposed wood studding severely charred. Much of studding only partially standing.

Test 8

Time min:sec	Observations
01:00	Exposed P-traps to stacks 1 and 3 are aflame.
01:15	All exposed P-traps are now aflame.
02:00	Steam and smoke emanating from stacks 2 and 4.
02:30	All traps have fallen into furnace.
03:00	Heavy black smoke coming from stacks 1 and 3.
03:10	Yellow smoke coming from stacks 2 and 4.
04:30	Paper face to gypsum board igniting.
05:45	Smoke emanating from around edges of wall.
07:30	Heavy smoke pouring from stacks of all four stacks.
08:00	Spackling tape loosening from exposed wall joints.
09:00	Light smoke emanating from stacks 2 and 4. Heavy smoke still coming from stacks 1 and 3. Large door was opened to clear smoke from test room.
09:30	Escutcheon plates to laterals 1 and 3 of exposed wall have fallen inside furnace.
11:00	Light smoke coming from around lower P-trap to stack 4.
12:00	Inside the furnace, plugs remain of molten PVC laterals to stacks 2 and 4.

14:00	Viewing into the furnace it appears that interior studding is now burning in stacks 1 and 3.
14:30	Heavy smoke still coming from stacks 1 and 3. Upper P-traps to stacks 1, 2 and 4 have smoke coming from around escutcheon plate.
15:00	Smoke emanating around edges of stack 4.
15:30	Flames observed from top of stack 1.
17:00	Thick black smoke pouring out from upper P-trap to stack 1.
18:00	Continued dripping of ABS in stack 1.
20:00	Molten plugs remain in place in laterals 2 and 4. Holes where laterals penetrated walls are clear for stacks 1 and 3.
22:30	Thick black smoke continuing to pour out stacks 1 and 3. Only light smoke from stacks 2 and 4.
23:00	Smoke coming from bottom of stack 3. Smoke coming from around lower P-traps to stacks 1, 2 and 4.
27:00	Spackling tape has pulled away from exposed wall along most joints.
28:00	Cotton pad applied to lower P-trap cavity 2. Pad turned brown, but no ignition.
28:40	Only a light white smoke now coming from stacks 1 and 3.
29:00	Continued dripping of ABS particles in stack 1.
30:00	Exposed gypsum wall is now buckling inward towards furnace.
32:10	Smoke coming from bottom of stack 4.
33:40	Heavy smoke coming from stacks 1, 3 and 4.
35:10	Blackening around escutcheon plate to lower P-trap of stack 1.
40:00	Moderate amount of smoke coming out stack 2. Heavy smoke coming from stack 4.
40:30	Bottom pads tested on lower P-traps to stacks 2 and 4. No ignition.
41:00	Crackling of studs and loud popping sounds coming from interior of wall.
44:00	Lower P-trap to stack 1 has fallen away and interior of furnace can be seen. Cotton pad applied and ignited by flames.
45:00	Water sprinkled inside wall sections housing stack 1.
47:15	Charring to upper P-trap stack 2 apparent.
48:00	Exposed wall to stack 4 has failed by falling into furnace.
49:00	Exposed wall to stack 2 has failed by falling into furnace (lower half).
53:30	Cotton pads tested on lower P-traps to stacks 2, 3 and 4. No ignition.
59:00	Stack 2 fell into the furnace.
65:00	Test terminated.
75:00	Wall wheeled out into the open and hosed down with water.
Post fire analysis:	Fire had destroyed interior wall to all stacks. All exposed wood studding was charred and no plastic pipe remained in stacks. Hose stream broke through unexposed wall.

Test 9

Time min:sec	Observations
01:15	Exposed P-traps for stacks 2, 3 and 4 are aflame.
02:30	Exposed P-traps to stacks 2 and 3 have fallen into the furnace.
02:45	P-trap to stack 4 fell into the furnace.
04:00	All of the paper burned off the exposed gypsum board wall.
05:00	Heavy black smoke emanating from around escutcheon plate to stack 4. There is smoke charring to the wall.
06:00	Charring is evident around all of the escutcheon plates.
06:45	Smoke and steam are issuing from cavity 4.
09:10	Unexposed lower P-trap to stack 4 is starting to deform.
10:00	Continuous gas sampling was stopped.
10:45	Light white smoke coming from cavities 2, 3 and 4.
12:00	Looking into the furnace it was noted that a clear hole is left where the ABS laterals were whereas the PVC lateral has melted and formed a molten plug where the pipe penetrates the wall.
14:45	The copper P-trap is turning red.
17:00	Smoke and steam issuing around the edges of the test frame and wall.
19:00	Unexposed P-traps to stack 4 is melting and smoking heavily.
21:00	P-traps to stack 4 has dropped off wall and flame-through occurred igniting cotton pad.
24:50	Active burning of the interior wall is evident. Popping sounds and heavy smoke coming from stacks.
26:00	Popping continues. All studs seen to be burning.
27:00	P-traps to stacks 2 and 3 are deforming.
30:00	Furnace room filling with smoke.
31:15	Cabinet to stack 1 was open--pipe was very hot and cabinet was smoke filled.
34:00	Heavy smoke coming from P-traps to stacks 2 and 3.
39:00	Copper P-traps inside furnace has dropped off wall.
46:00	Copper pipe in cabinet to stack 1 is at 481 °C. Crumpled newspaper in cabinet has charred, but not ignited.
48:45	P-traps to stacks 2 and 3 are severely deforming.
54:00	Smoke continuing to emanate from cavities 1, 2 and 3.
60:00	P-traps to cavities 2 and 3 are still intact.
65:00	Test concluded.
Post fire analysis:	Fire destroyed sections of exposed wall. All of the studs were severely charred and only minor amounts of plastic pipe remained in PVC cavity 2. However, the copper piping remained intact.

Time min:sec	
01:45	Light gray smoke coming out of smoke box.
02:00	P-traps on exposed wall surface are aflame.
02:25	All P-traps have fallen into furnace.
04:00	Some smoke coming out P-traps to stacks 1 and 4. Some additional water was added to these P-traps as they were apparently not full.
05:00	Thick gray smoke pouring out the smoke box.
06:00	Some smoke coming out the top of ABS stacks 1 and 3.
07:30	Smoke leaking out the lower P-trap to stack 1 through the sealed penetration.
08:45	Heavy smoke coming from smoke box and from around upper P-trap to stack 3.
09:30	Heavy thick smoke coming out the bottom of stack 1.
10:10	Viewing into furnace, flames can be seen inside cavities 1 and 3.
10:30	Brown staining of the paper around the upper P-trap to stack 3.
14:00	Smoke leaking out the side of the steel studs through the penetration holes.
15:30	Flaming of upper P-trap to PVC stack 4.
16:30	A molten plug of PVC can be seen where the lateral penetrates the wall to stacks 2 and 4.
17:00	Thick gray smoke continuing to come from ABS stacks 1 and 3. Light white smoke coming from PVC stack 4 P-traps.
19:00	ABS P-traps to stack 3 have severely deformed. Scorching around PVC to stack 4.
22:00	ABS upper P-trap to stack 3 dropped off and flame-through occurred. Failure in cavity 3 by cotton pad test.
25:00	Lower ABS P-trap to stack 1 dropped off wall and flame-through occurred. Reading of 2,000 ppm CO.
26:00	Upper P-trap to stack 1 dropped off.
31:00	Readings of 2,000 ppm CO at the 6-foot level continue. Cotton pad test for cavity 4 failed to ignite pad.
35:00	Flame-through occurred igniting cotton pad at lower P-trap to PVC stack 4.
36:00	Upper P-trap to stack 4 dropped off wall. There is a horizontal crack at about the center of the gypsum board to ABS cavity 3 on the exposed side.
40:00	Technicians are all wearing smoke masks or air-packs at this time. Room is filled with dense smoke.
48:00	Upper PVC P-trap to stack 2 is deforming.
50:00	A one-foot vertical crack in the gypsum board above the penetration to the furnace has occurred in cavity 2.
55:00	Upper PVC P-trap to stack 2 dropped off and we have flame-through the penetration.

56:00	The unexposed wall has bowed and deflected about 2 inches at the center between cavities 1 and 2 and also between cavities 3 and 4.
57:00	Lower PVC P-trap to stack 2 dropped off.
58:00	The exposed wall to cavity 1 cracked and pieces dropped out into the furnace.
60:00	End of test.
Post fire analysis:	The wall was pulled out from the furnace at 65 minutes. In cavities 1 and 3 the pipe had burned and dripped to the bottom of the cavity and continued to burn. A small amount of insulation remained at the bottom of the cavity. In cavities 2 and 4 the exposed wall had cracked but remained in place. Using a pike pole the wall was pulled apart. Charred remains of the skeleton of a PVC pipe were in place along with most of the insulation which had charred, but not completely burned as in cavities 1 and 3.

APPENDIX B. SUGGESTED MODIFICATIONS TO THE ASTM E 119 STANDARD FIRE ENDURANCE TEST PROCEDURE AND ACCEPTANCE CRITERIA FOR DWV PLUMBING CHASES AND WALLS

Suggested Test Procedure

1. Construct a mock-up of the actual installation preserving all of the essential features such as pipe material, pipe size, piping configuration, chase and wall cavity dimensions, inlet pressure, etc. For a chase assembly up to 30 inches in width, place a thermocouple under a felted asbestos pad on the unexposed surface at 3 feet above simulated floor level, at 1 foot below simulated ceiling level, and at two equally spaced distances in between. For wall assemblies 9 or more feet in width, place a minimum of 9 thermocouples under felted asbestos pads on the unexposed surface. Place four thermocouples at the centers of the quarter sections, place one thermocouple at the center of the specimen and place four thermocouples in line with each of the vertical stacks, and one thermocouple 1 foot above each of the laterals.

2. Fire-expose the side of the assembly for which the fire rating is required to the prescribed ASTM E 119 time-temperature exposure in a standard wall test furnace. If the exposed wall includes a lateral penetration, the lateral must enter the furnace, and the furnace pressure relative to the adjacent test area at the inlet must be equal to the product of 0.001 inches of water times the intended height of the lateral above the floor of the room in inches. (This pressure is applicable to cases where stack effect is not appreciable.)

Suggested Acceptance Criteria

1. None of the ASTM thermocouples located on the unexposed surface of the chase or wall may exceed 181 °C (325 °F) temperature rise during the fire rating period. The average temperature rise of all of the ASTM thermocouples on the unexposed surface must not exceed 139 °C (250 °F). (This is similar to the ASTM Standard E 119 test criteria.)

2. No flaming and no hot gases which could ignite a cotton pad at any point on the unexposed surface of the chase or wall shall occur within the fire-rated period.

   At present, there is no standard or established method for quantitative measurement of the smoke passing out through any lateral, through the area adjacent to the lateral, or through the hole left by the lateral.

APPENDIX C. SI CONVERSION UNITS

In view of the present accepted practice in this country in building technology, common U.S. Units of measurement have been used throughout this report. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measurements which gave official status to the metric SI system of units in 1960, we assist the readers interested in making use of the coherent system of SI units by giving conversion factors applicable to the U.S. units used in this report.

Length

1 in = 0.0254 metre
1 ft = 0.3048 metre

Pressure

1 in of water = 249.08 $newtons/metre^2$

Velocity

1 ft/min = 0.00508 metres/s

Temperature*

Temperature in °F = 9/5 (temperature in °C) + 32 °F

*Both temperatures are presented together in the text.

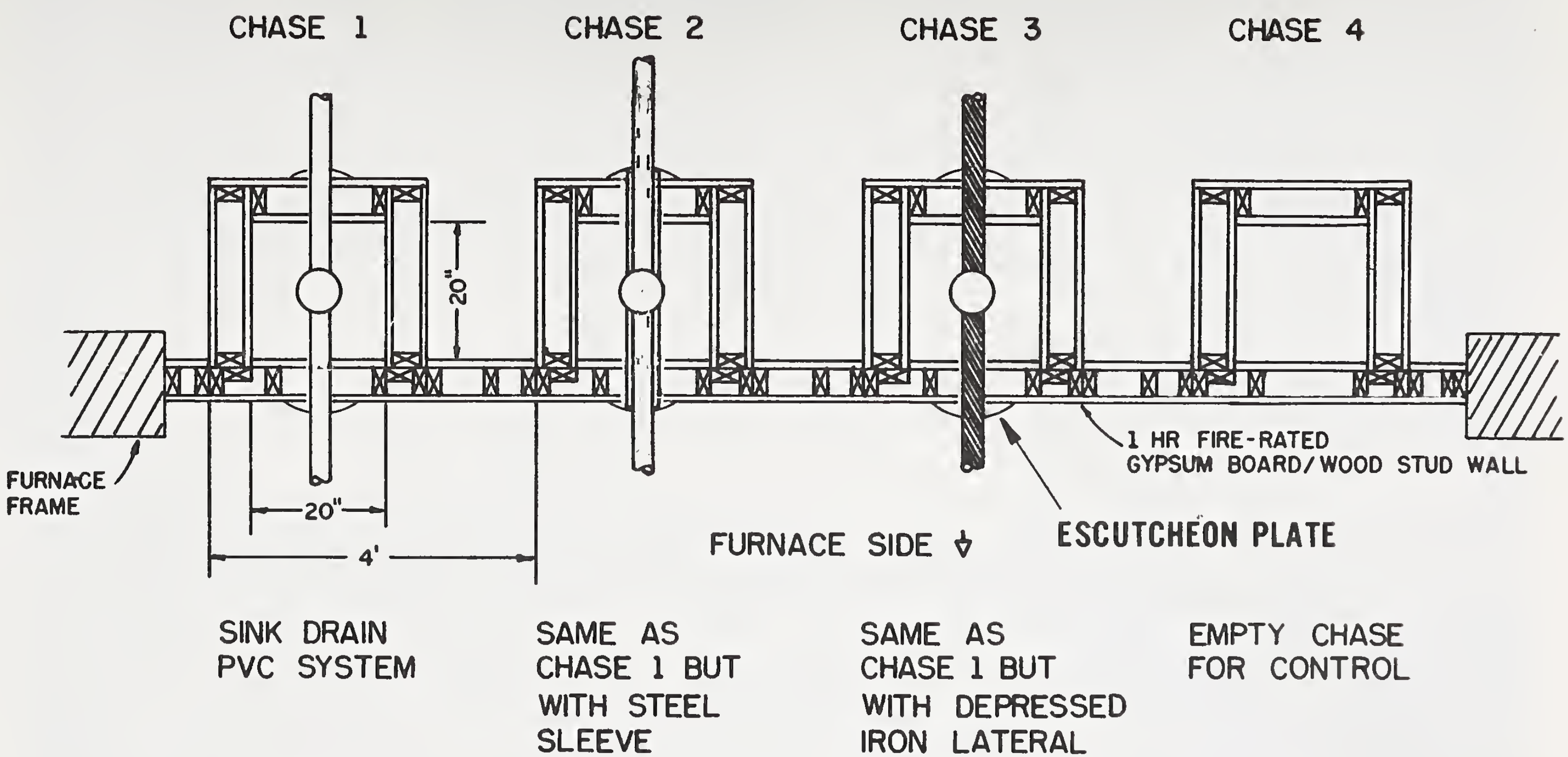


Figure 1. Cross section of wall and pipe chases for test 1.

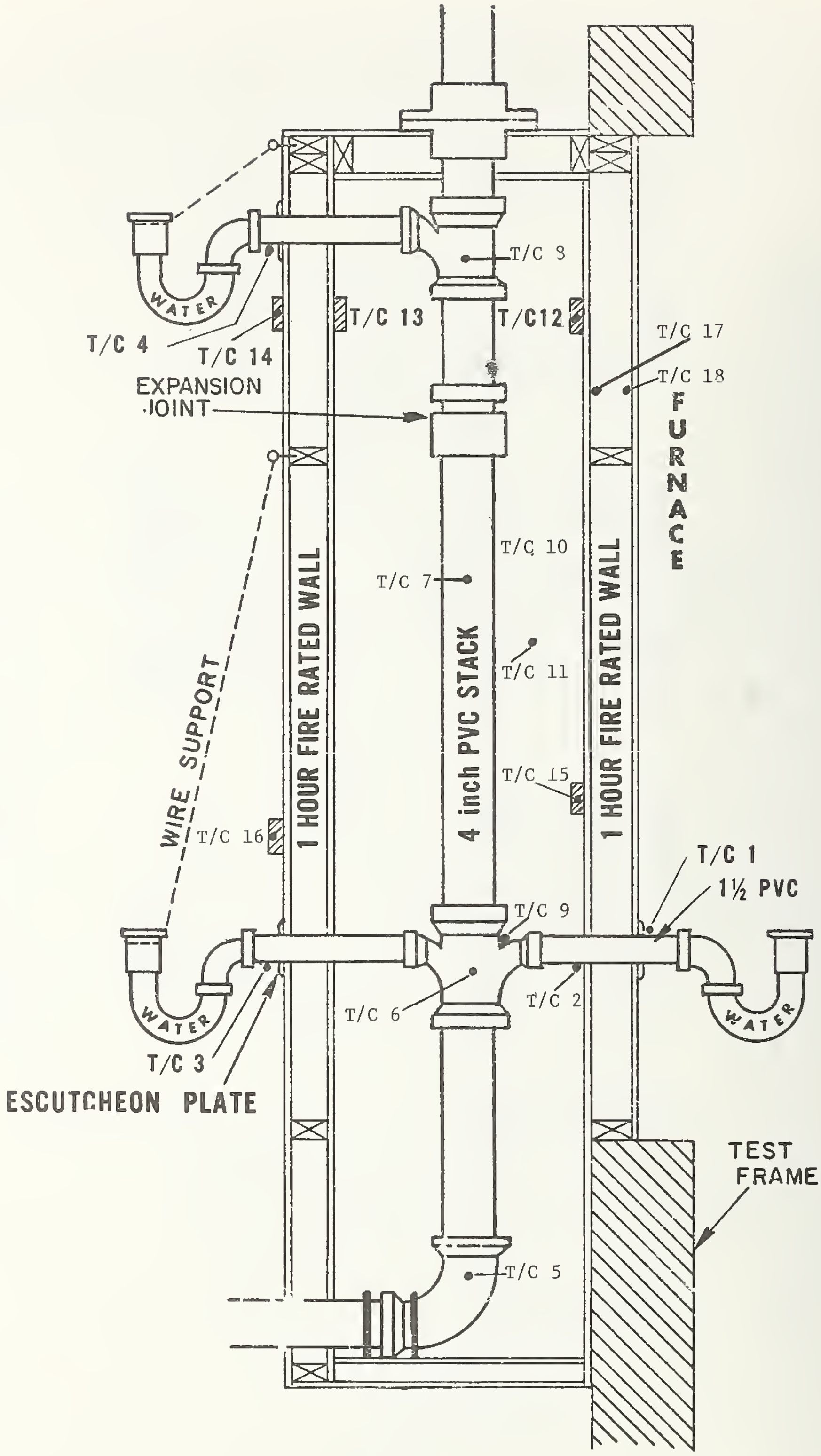


Figure 2. Sketch of chase 1 showing thermocouple (T/C) locations.

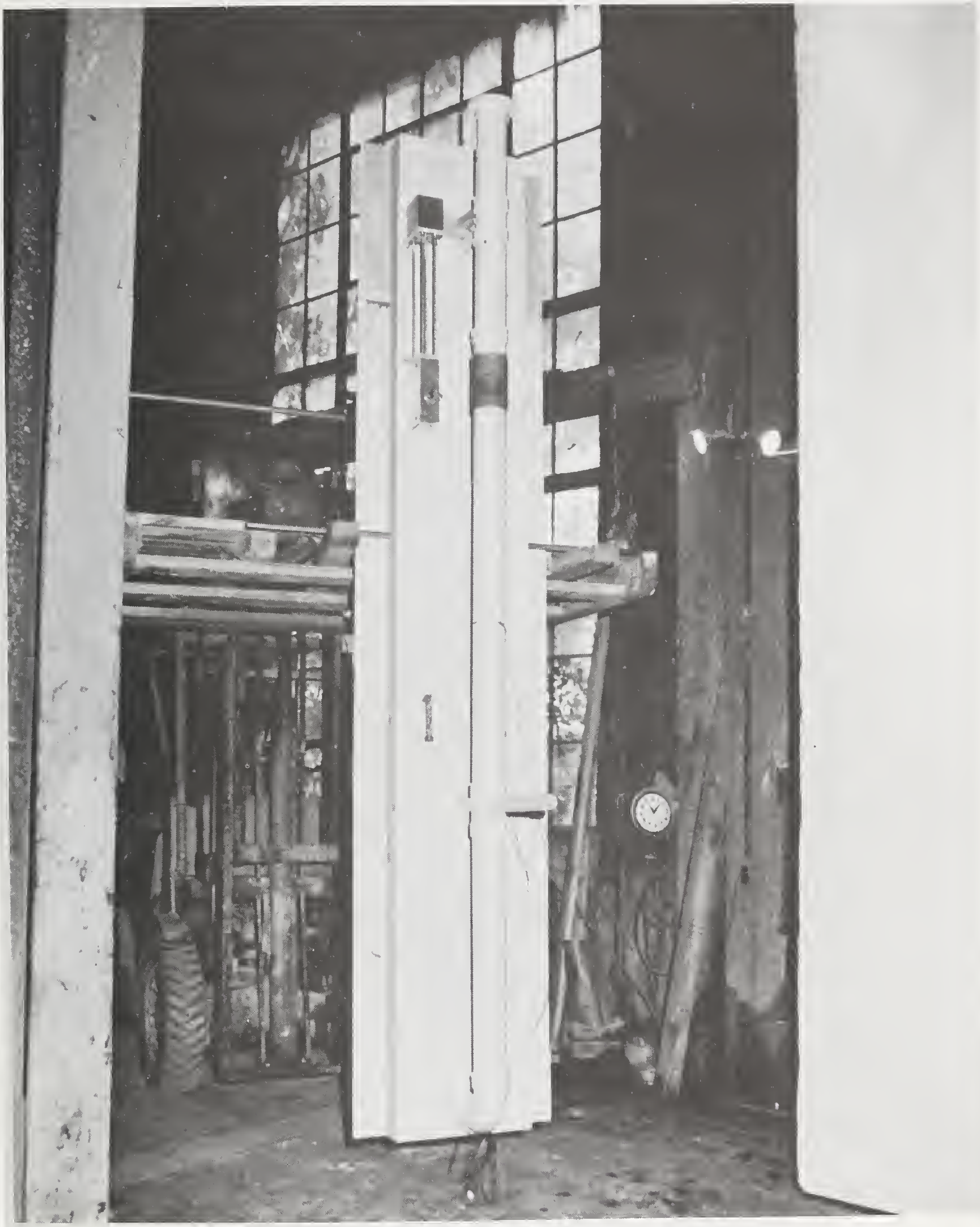


Figure 3. Photograph of installation of DWV on rear wall of chaşe 1.

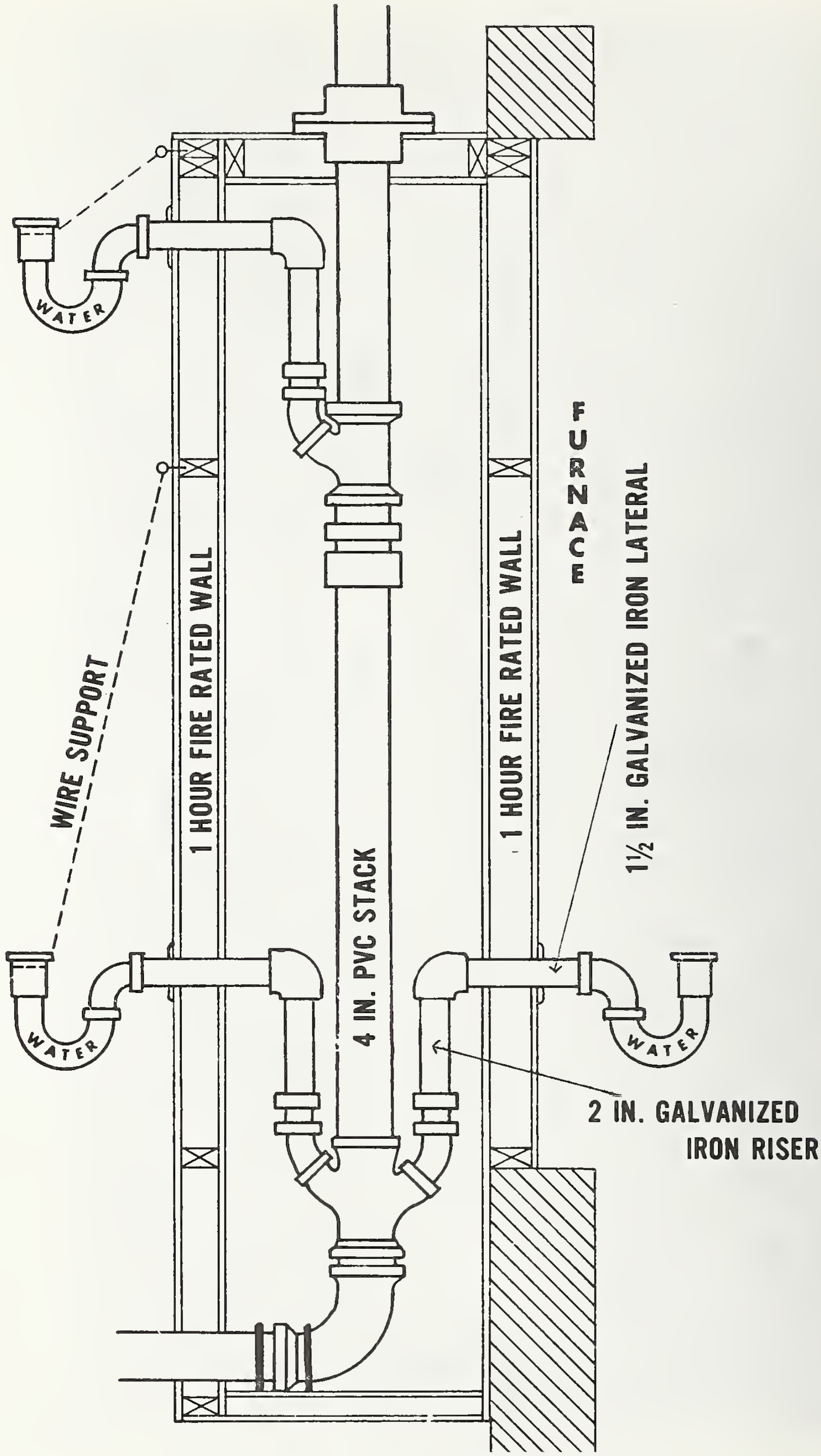


Figure 4. Sketch of chase 3.

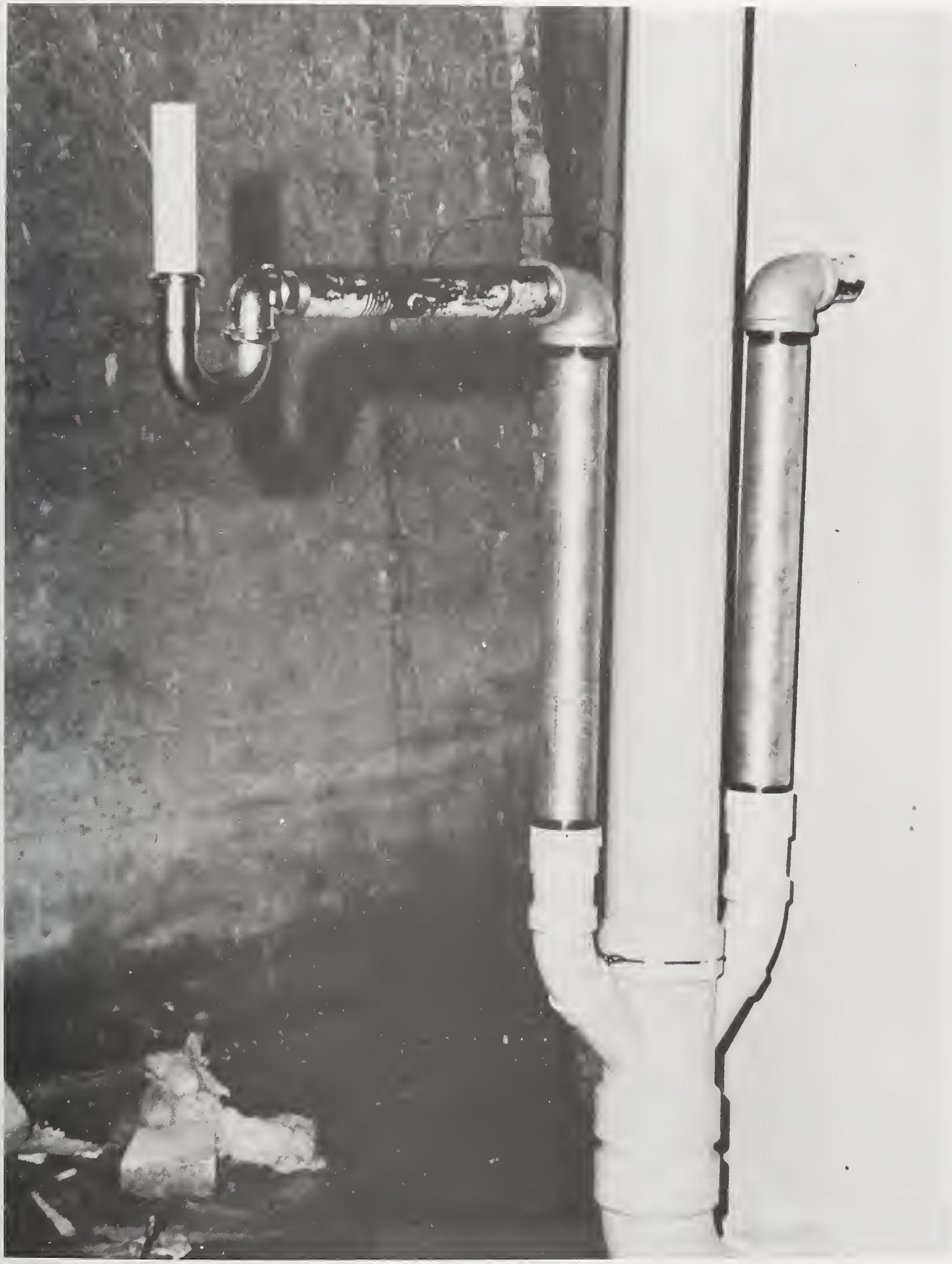


Figure 5. Photograph of lower laterals in chase 3.

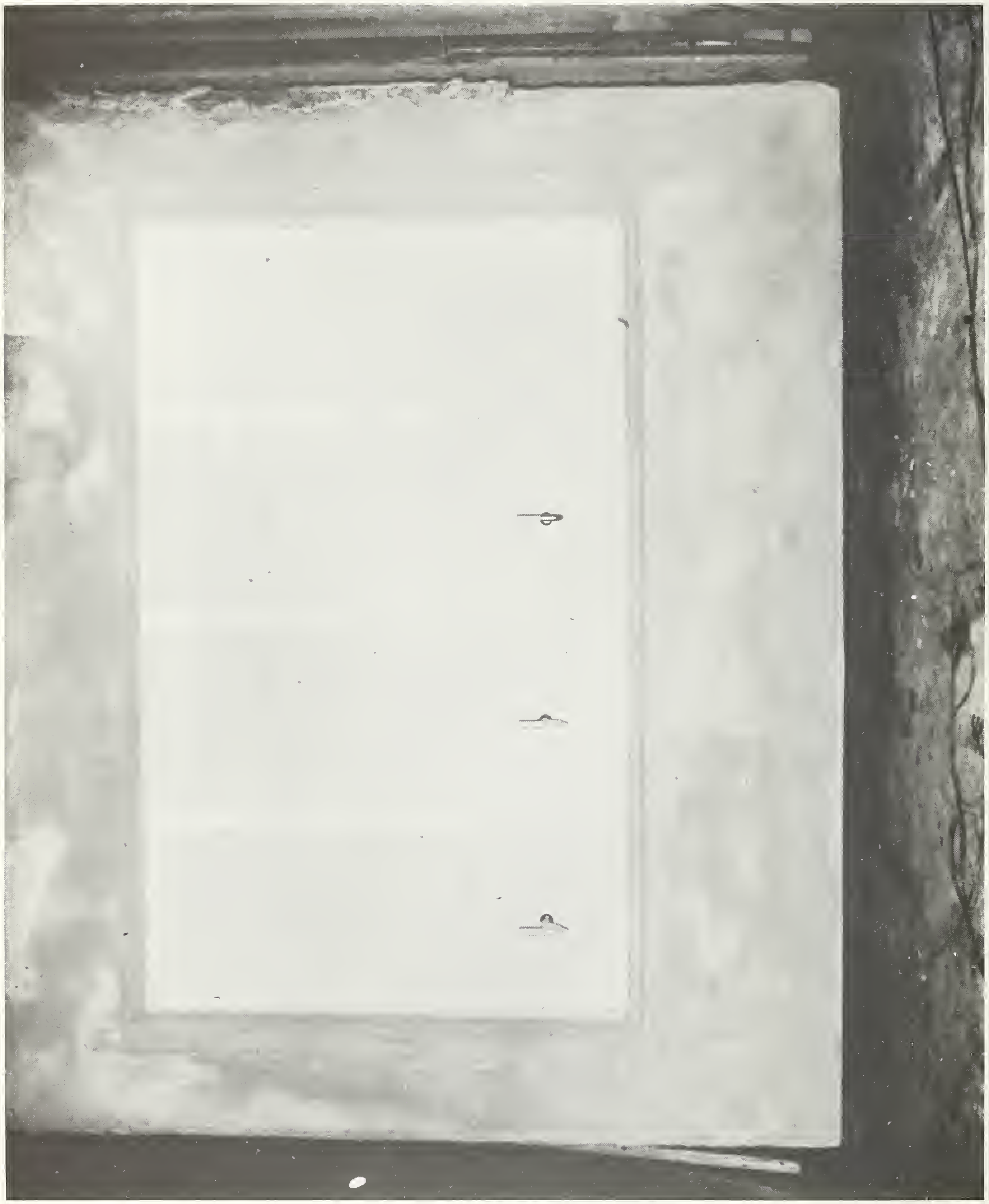


Figure 6. Photograph of exposed wall in test 1.

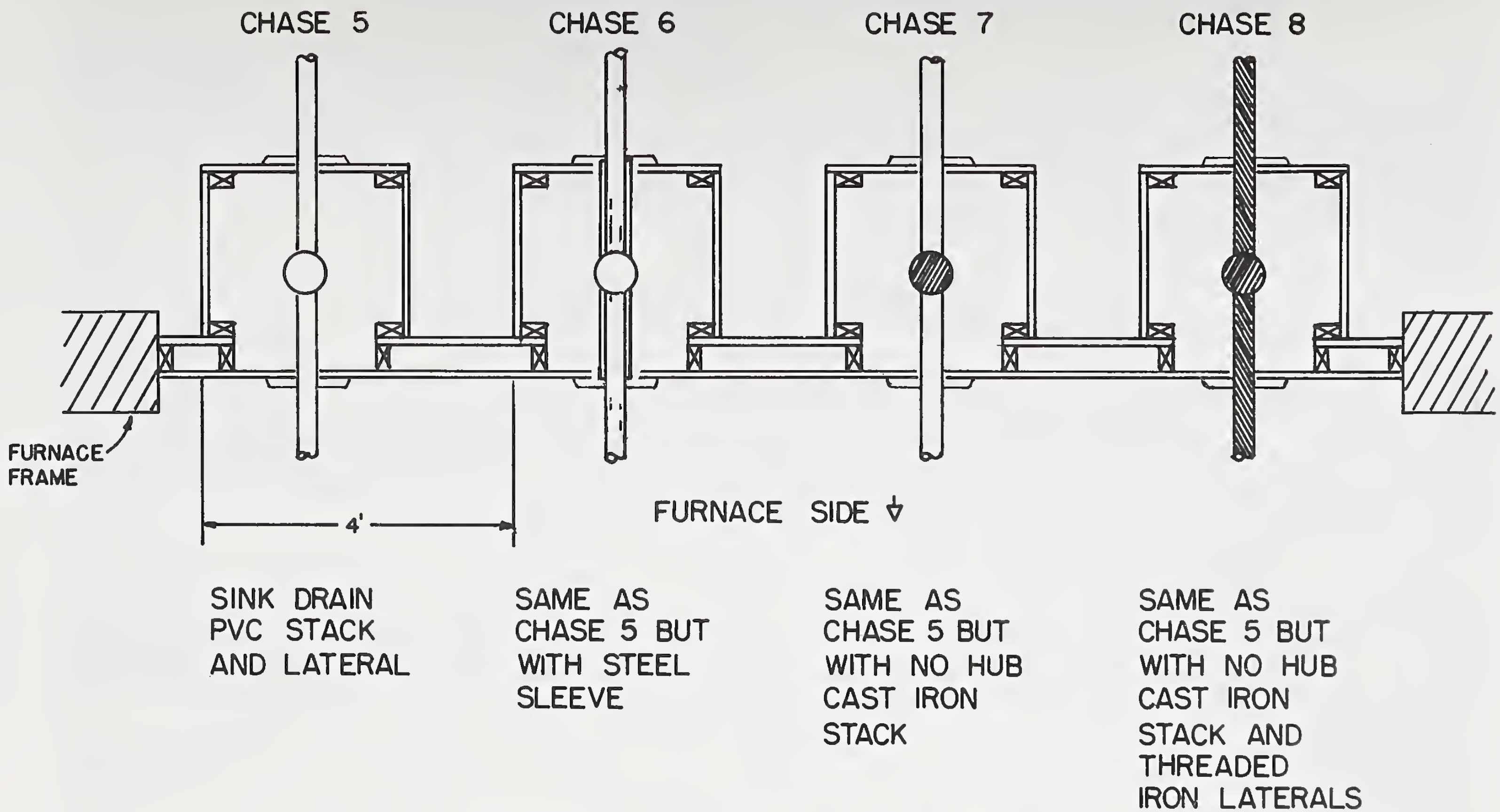


Figure 7. Plan view of wall and pipe chases for test 2.

Figure 8. Photograph of chase 5 with side removed.

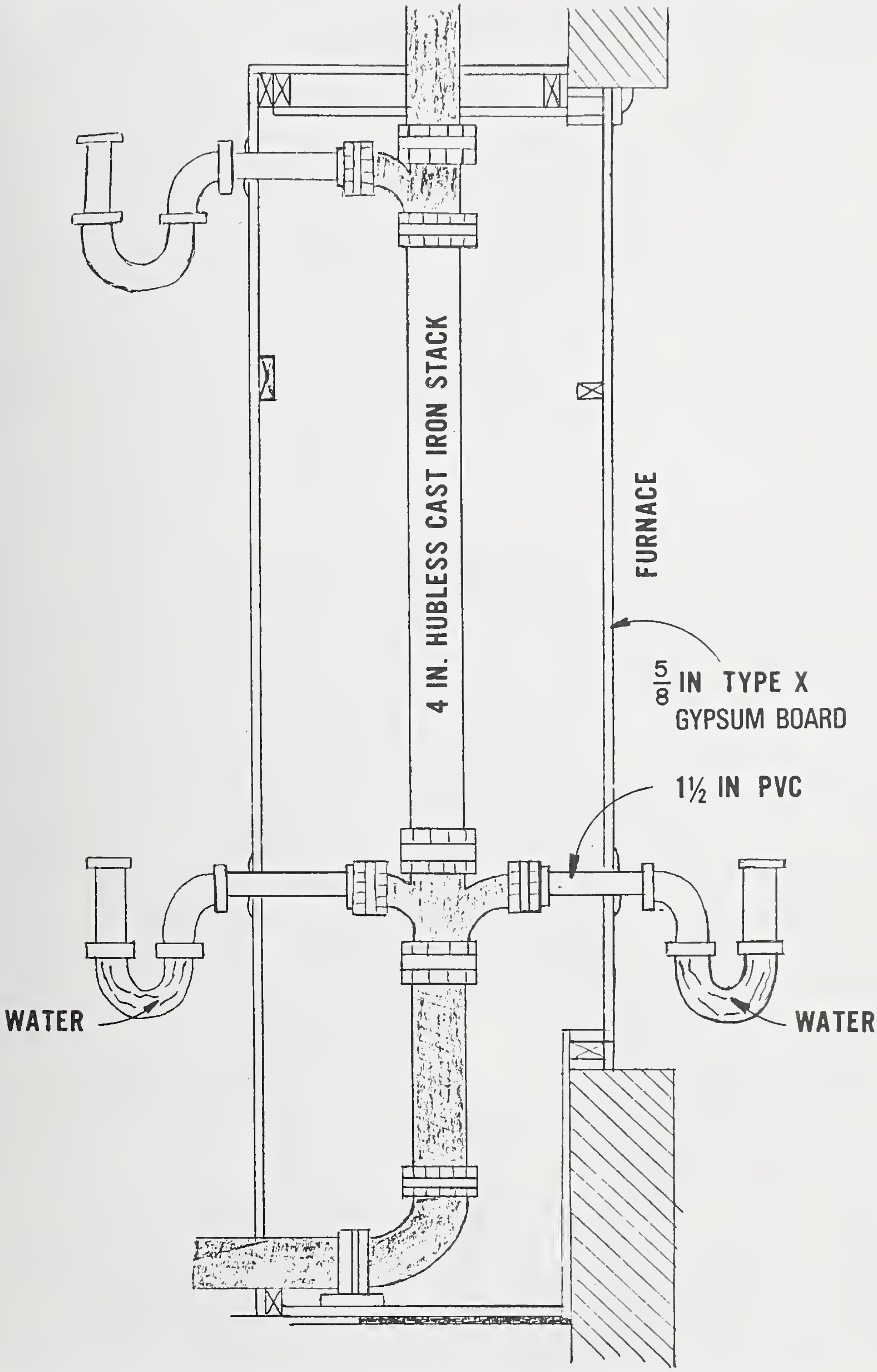


Figure 9. Sketch of chase 7.

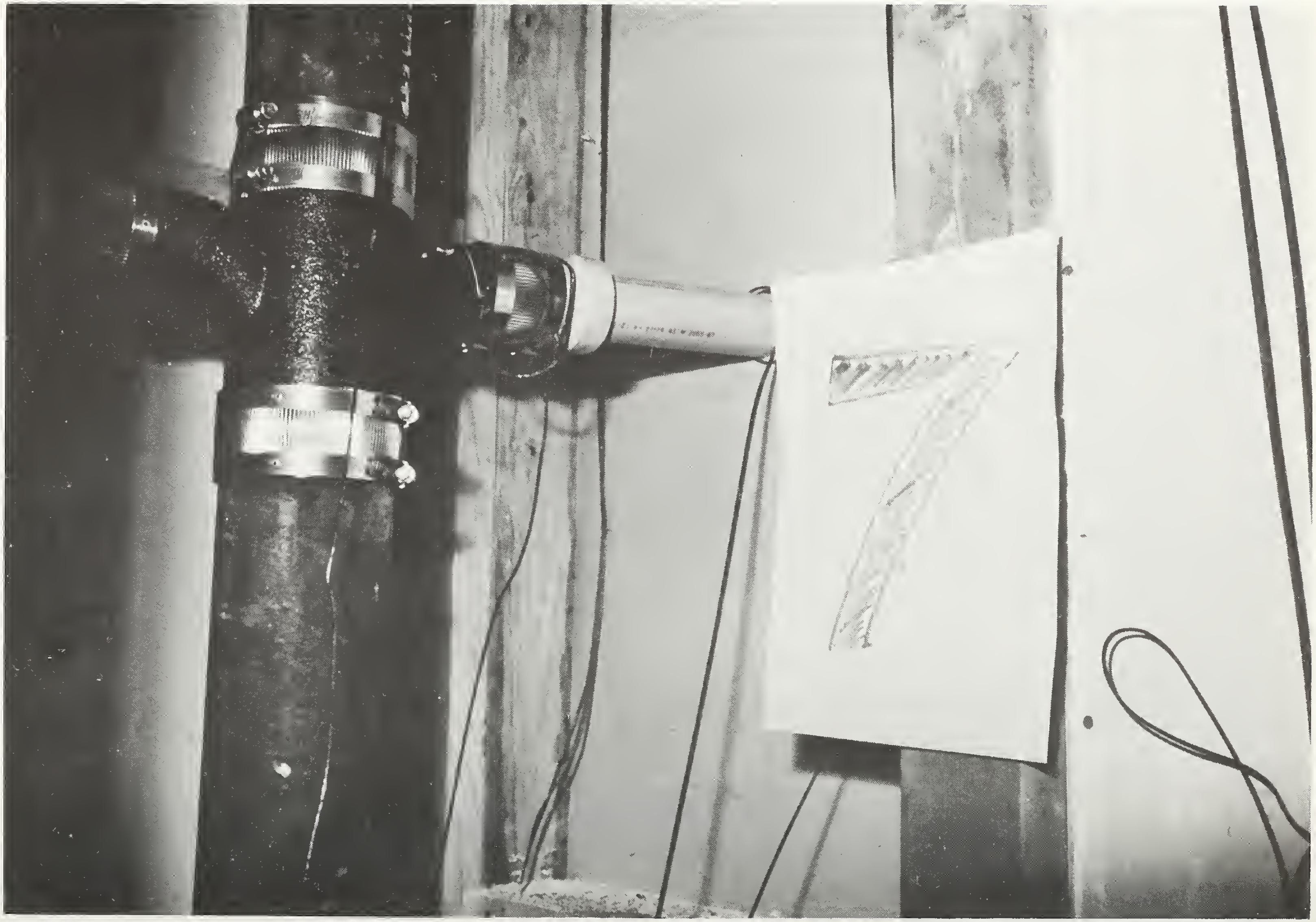


Figure 10. Photograph of lower
lateral in chase 7.

Figure 11. Photograph of chases in test 2.

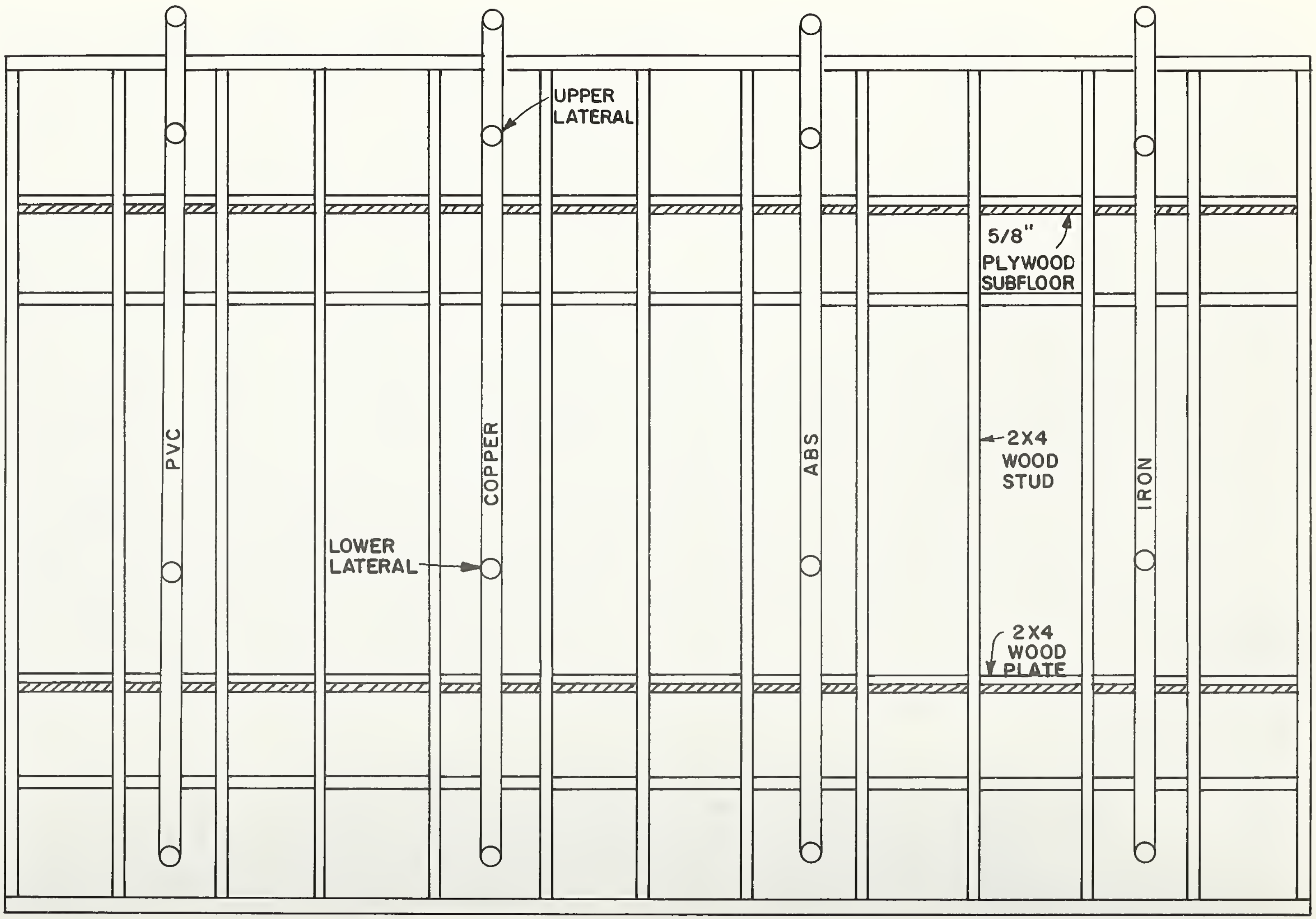


Figure 12. Wall construction and location of stacks in test 3.

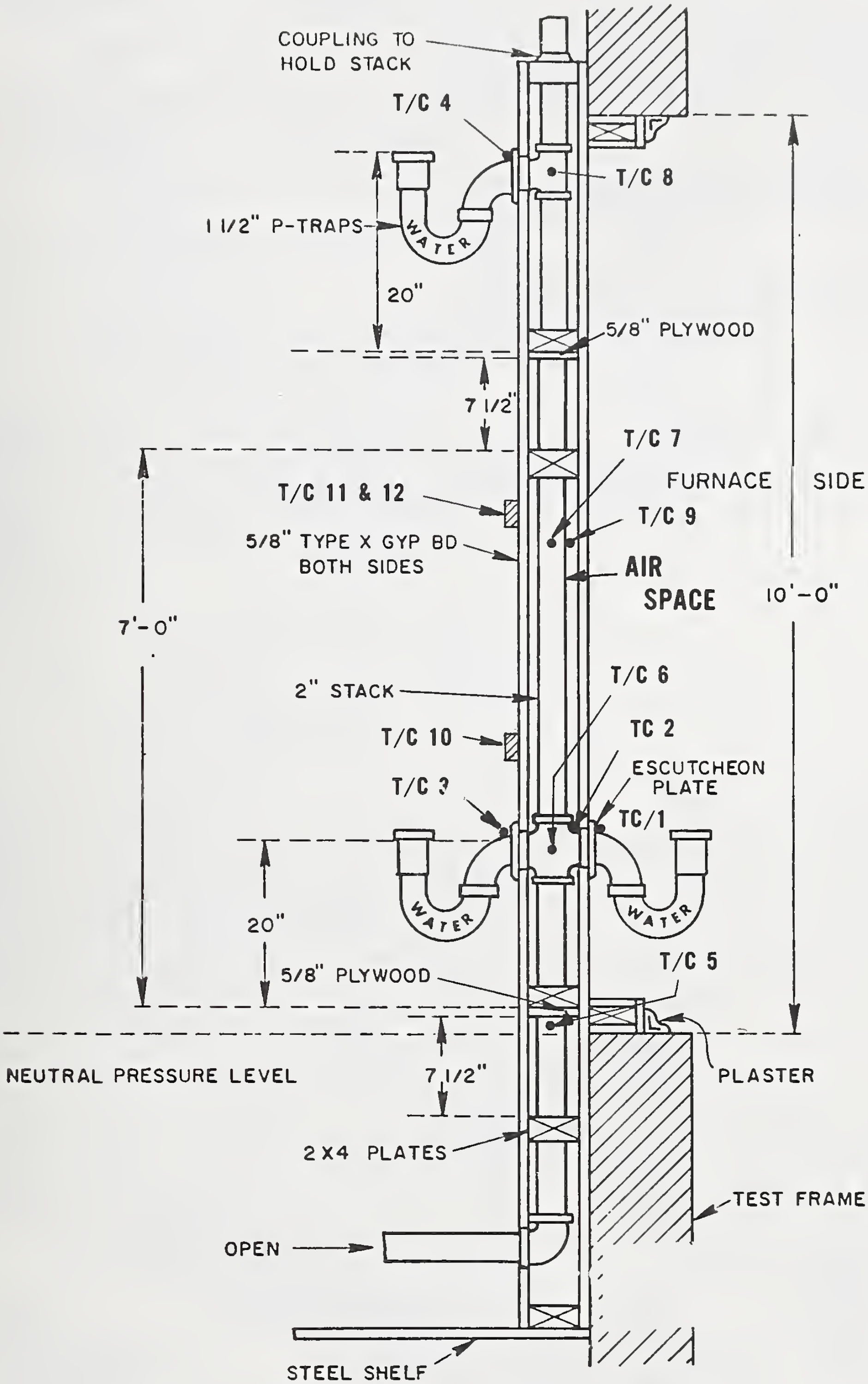


Figure 13. Cross section of wall showing DWV installation and thermocouple locations in test 3.

Figure 14. Photograph of wall construction in test 3.

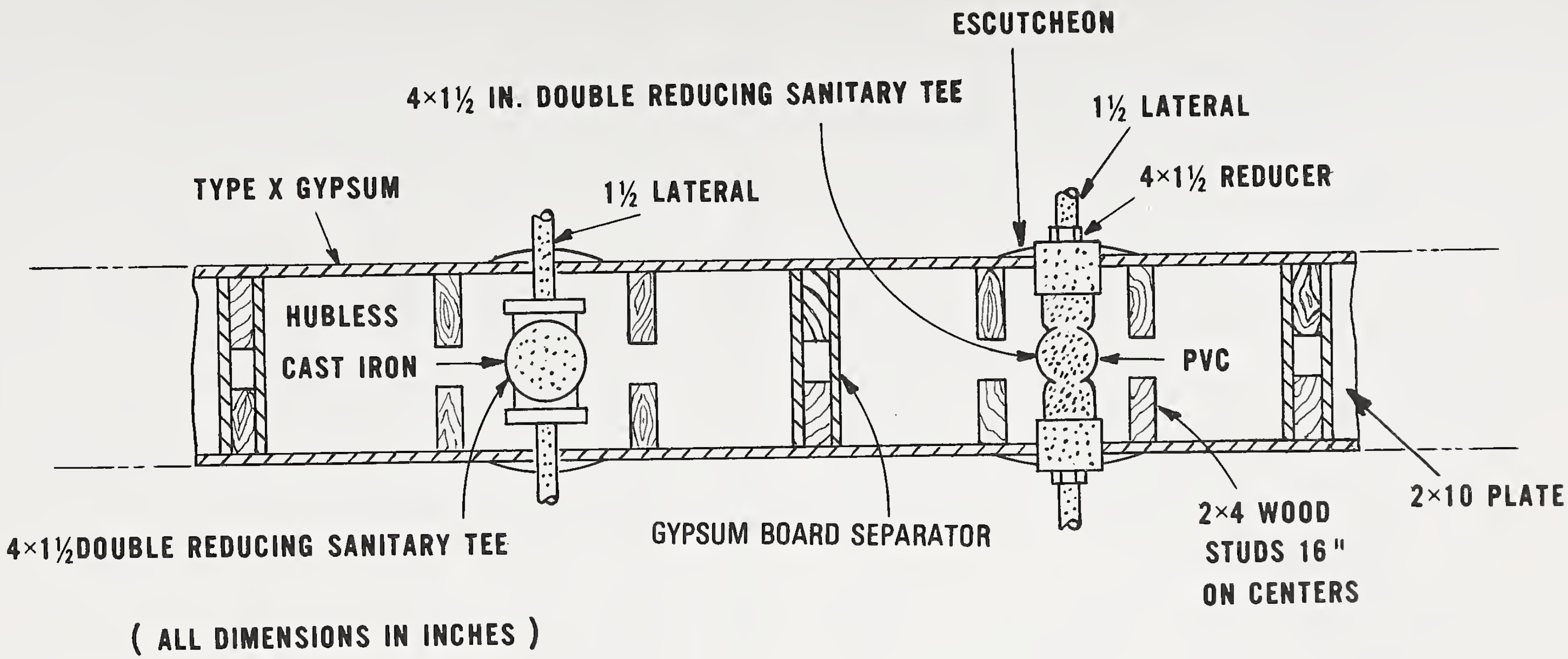


Figure 15. Wall construction in test 5.

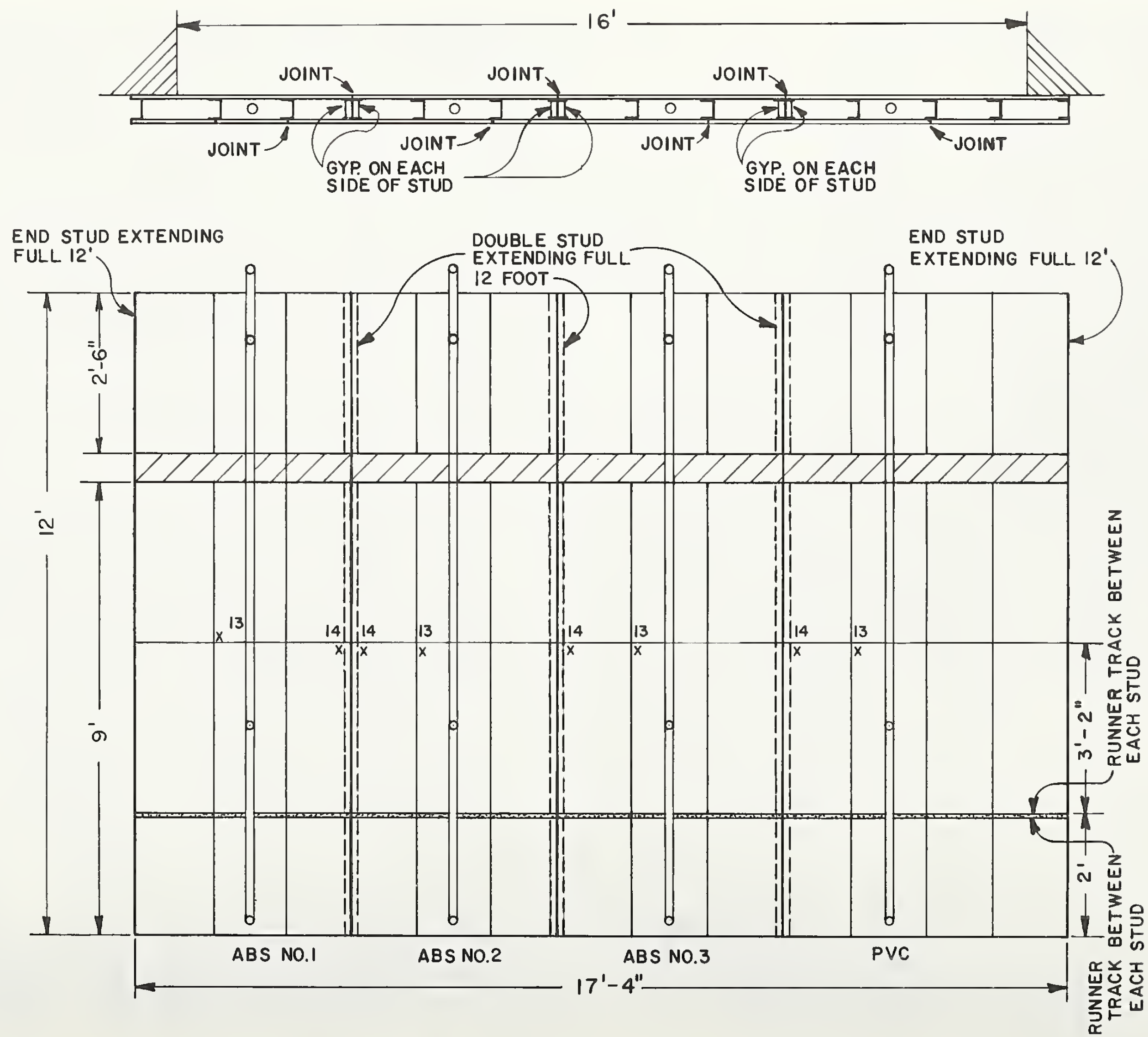


Figure 16. Wall construction and location of thermocouples for test 6.

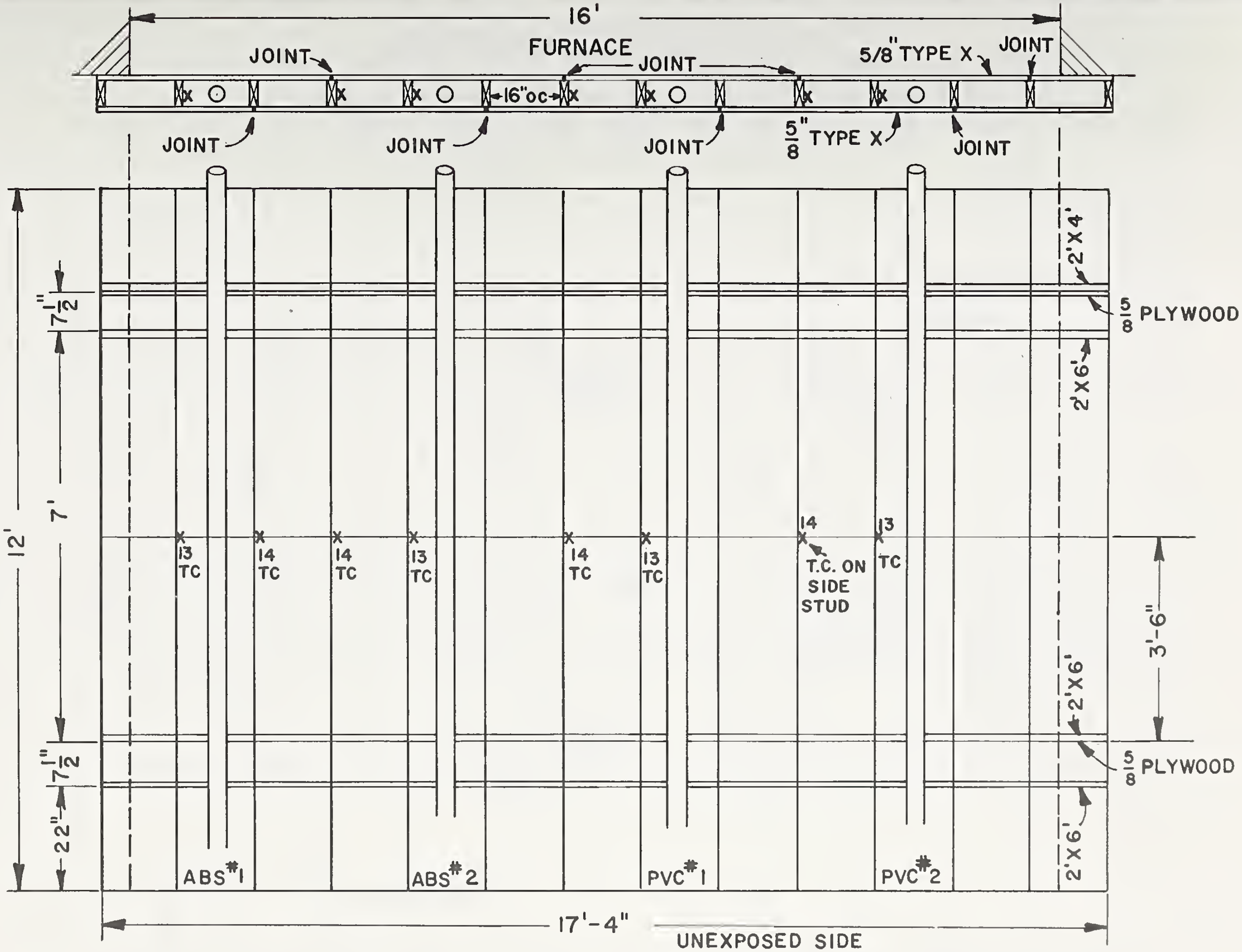


Figure 17. Wall construction and location of thermocouples inside wall space for test 7.

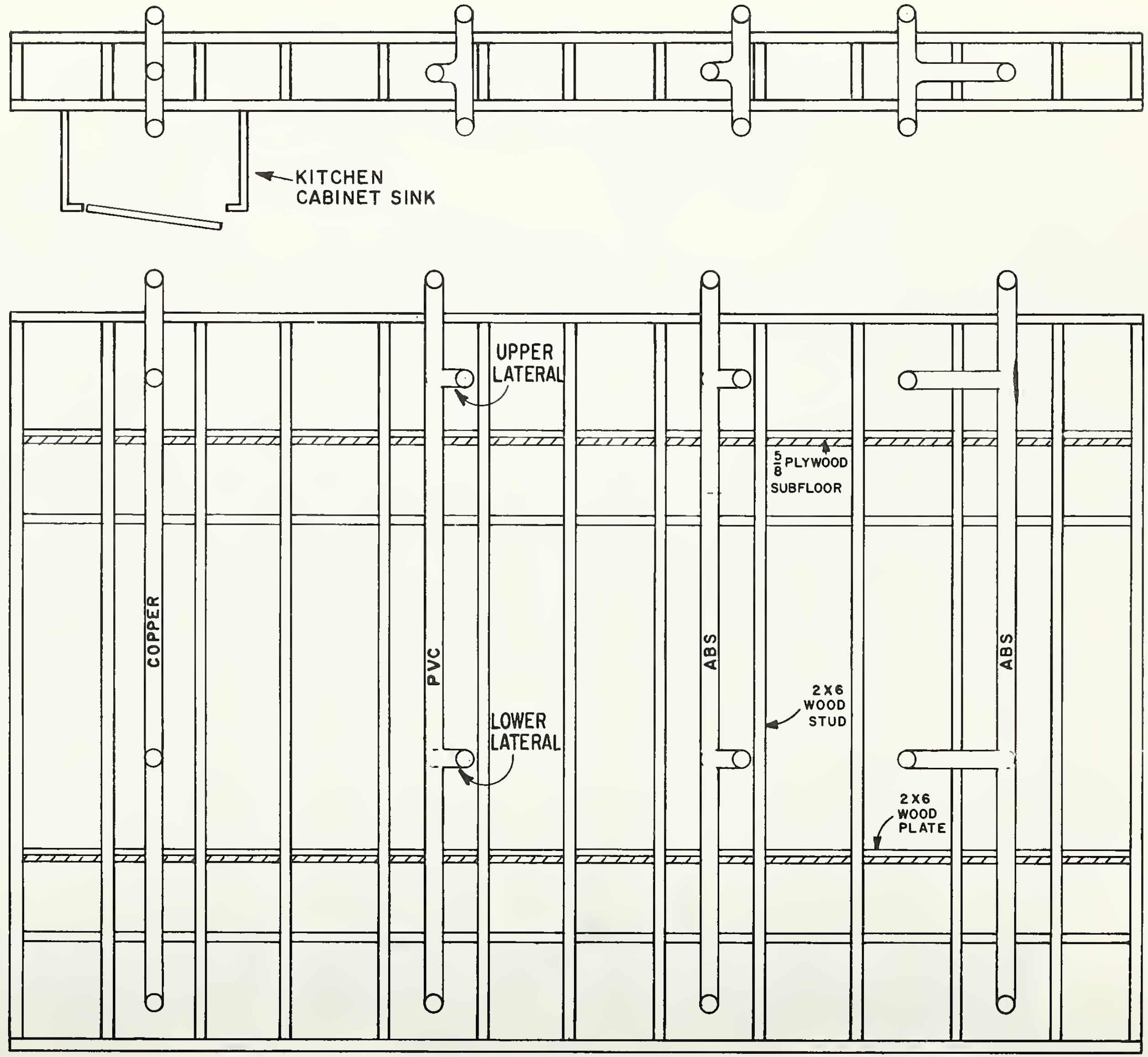


Figure 18. Details of wall construction and piping for test 9.

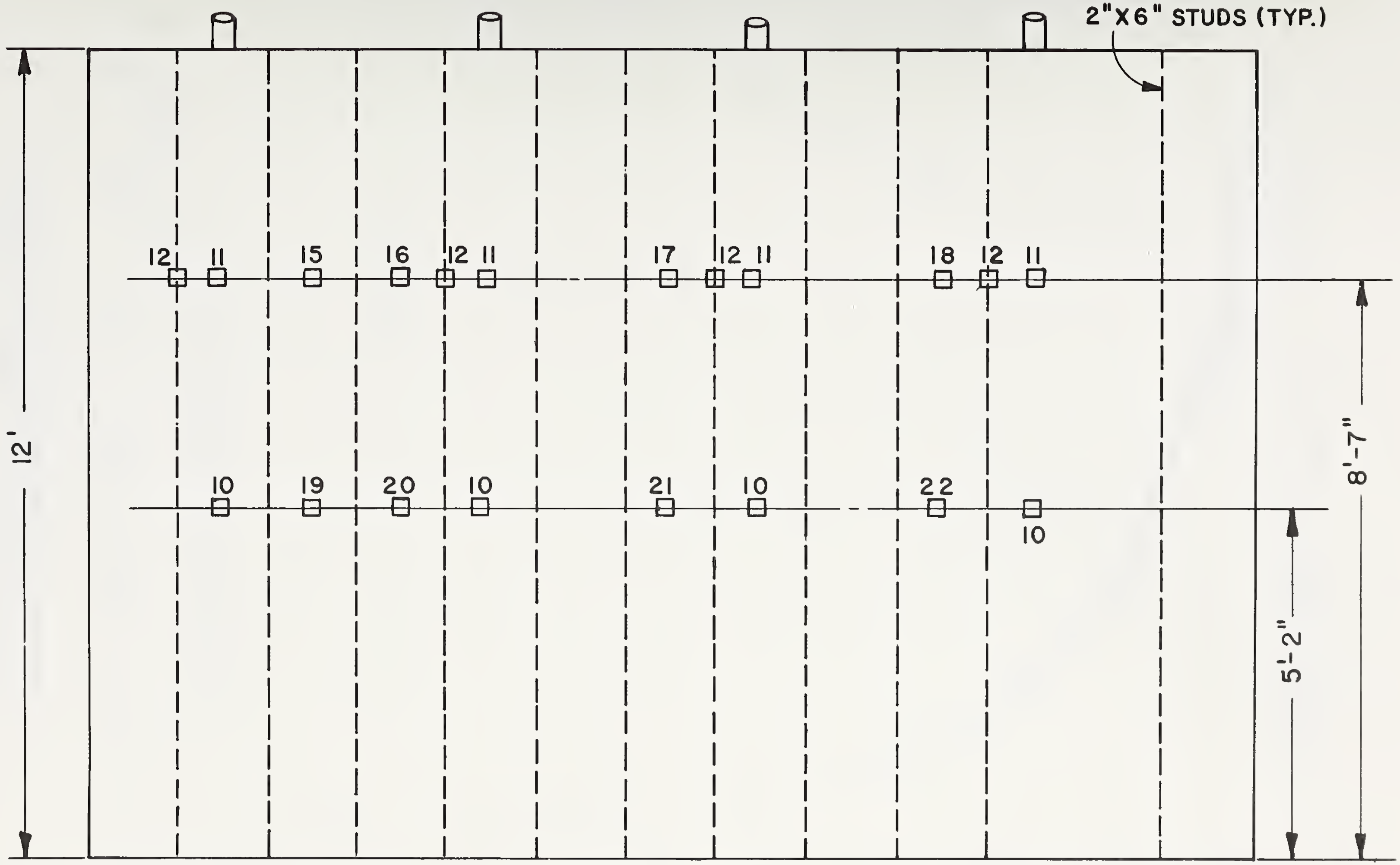


Figure 19. ASTM thermocouples on unexposed surface.

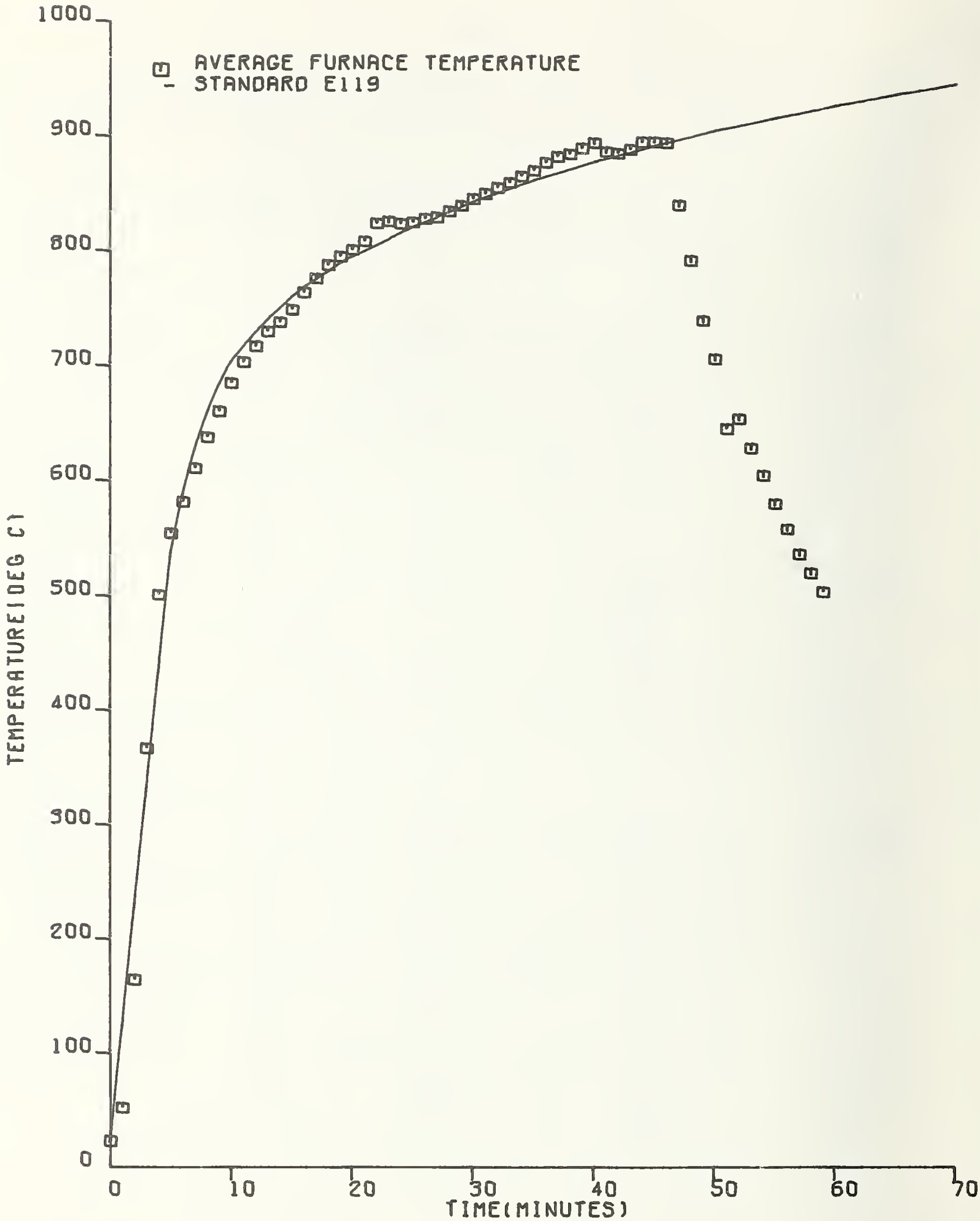


Figure 20. Average furnace temperatures for test 1 compared with E 119 curve.

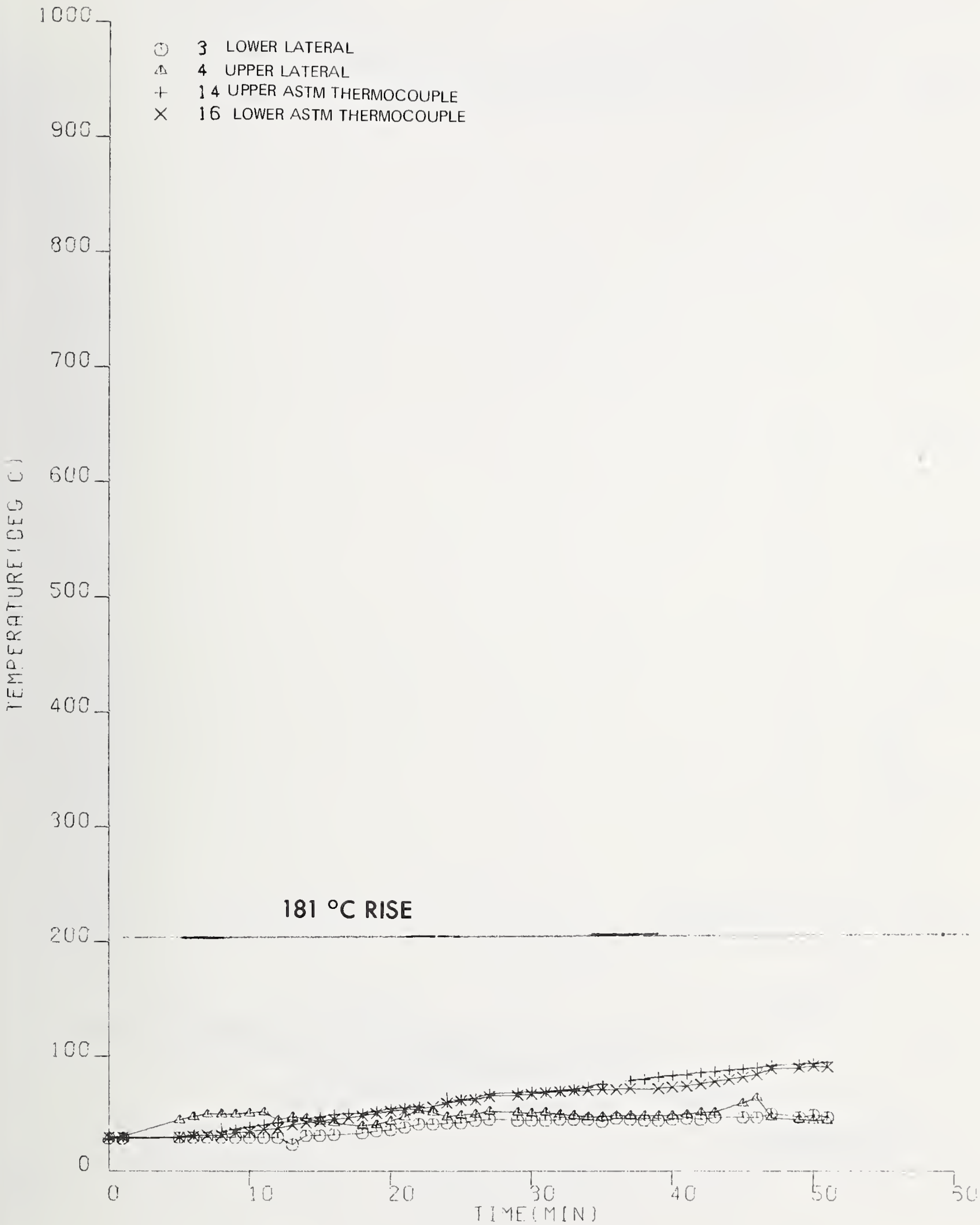


Figure 21. Unexposed lateral and ASTM surface temperatures for chase 5.

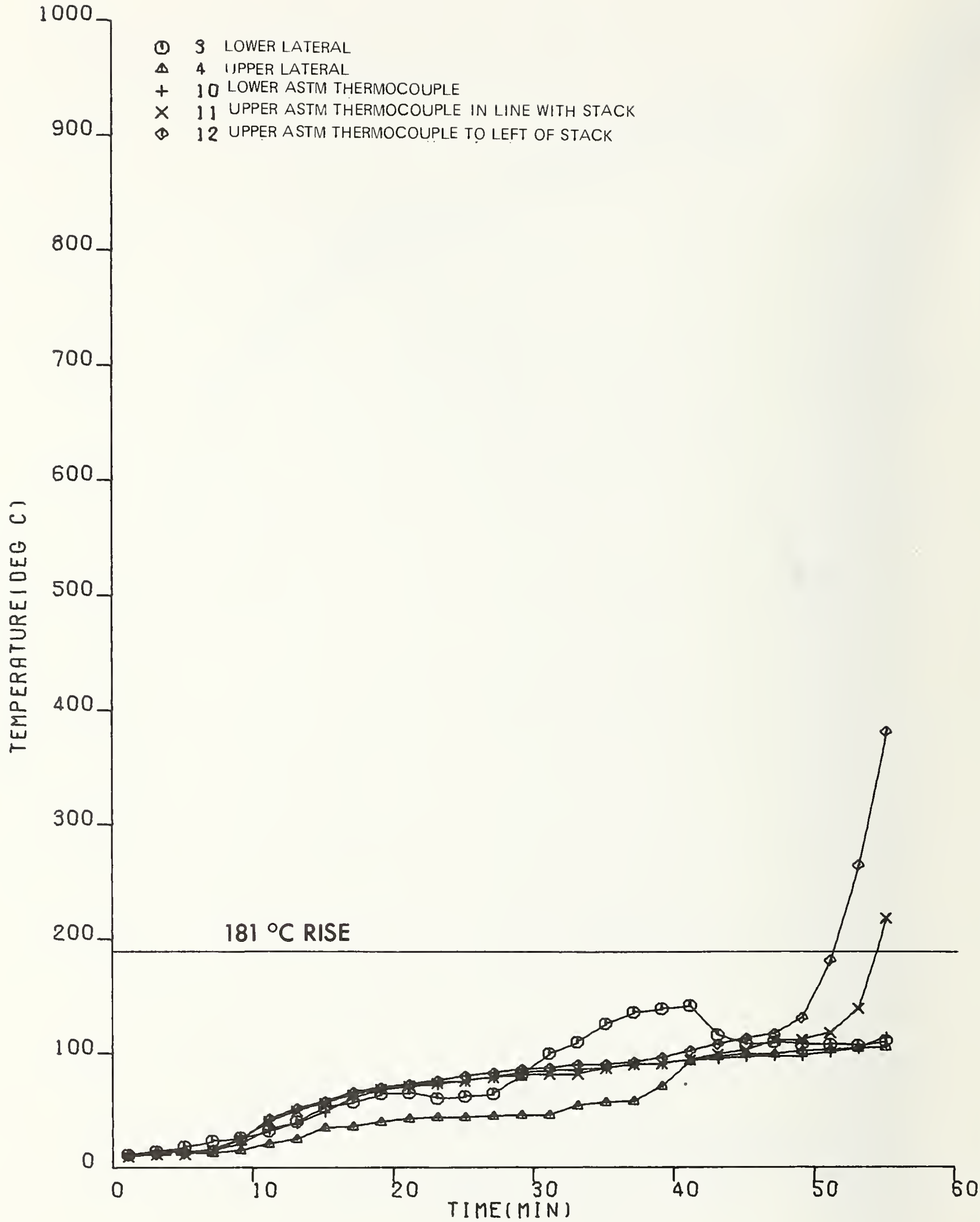


Figure 22. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 1) in test 3.

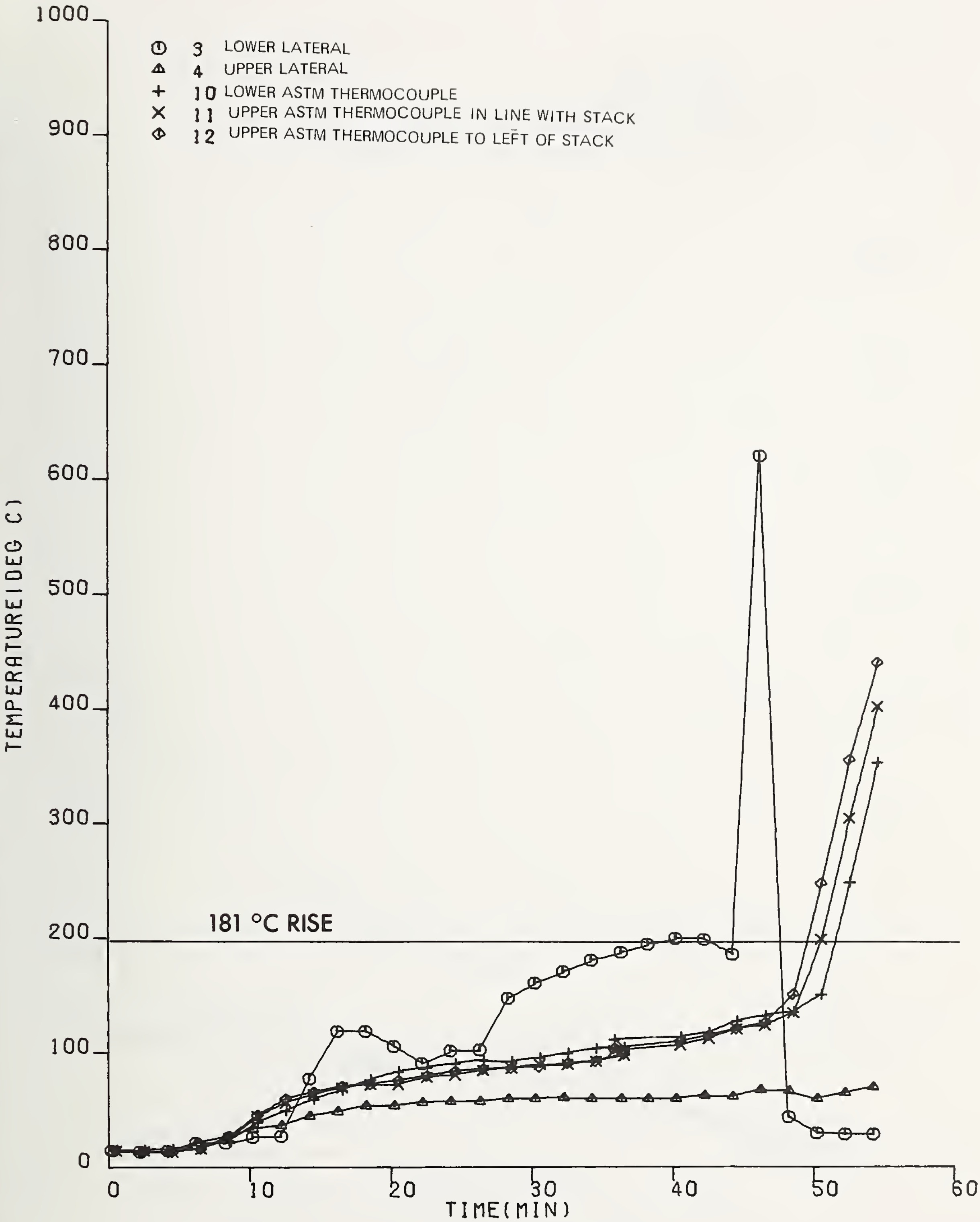


Figure 23. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 3) in test 3.

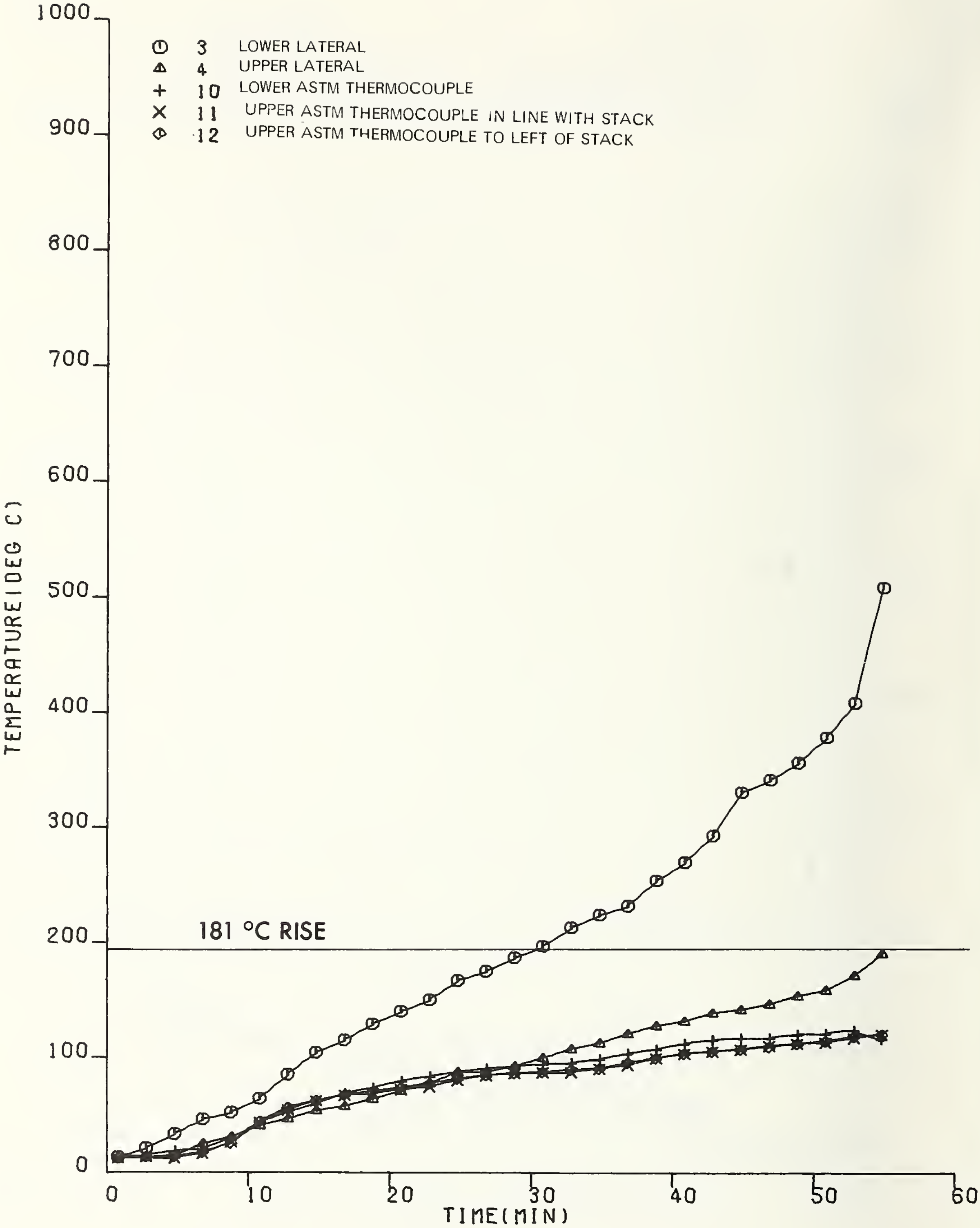


Figure 24. Unexposed lateral and ASTM surface temperatures in copper installation (cavity 2) in test 3.

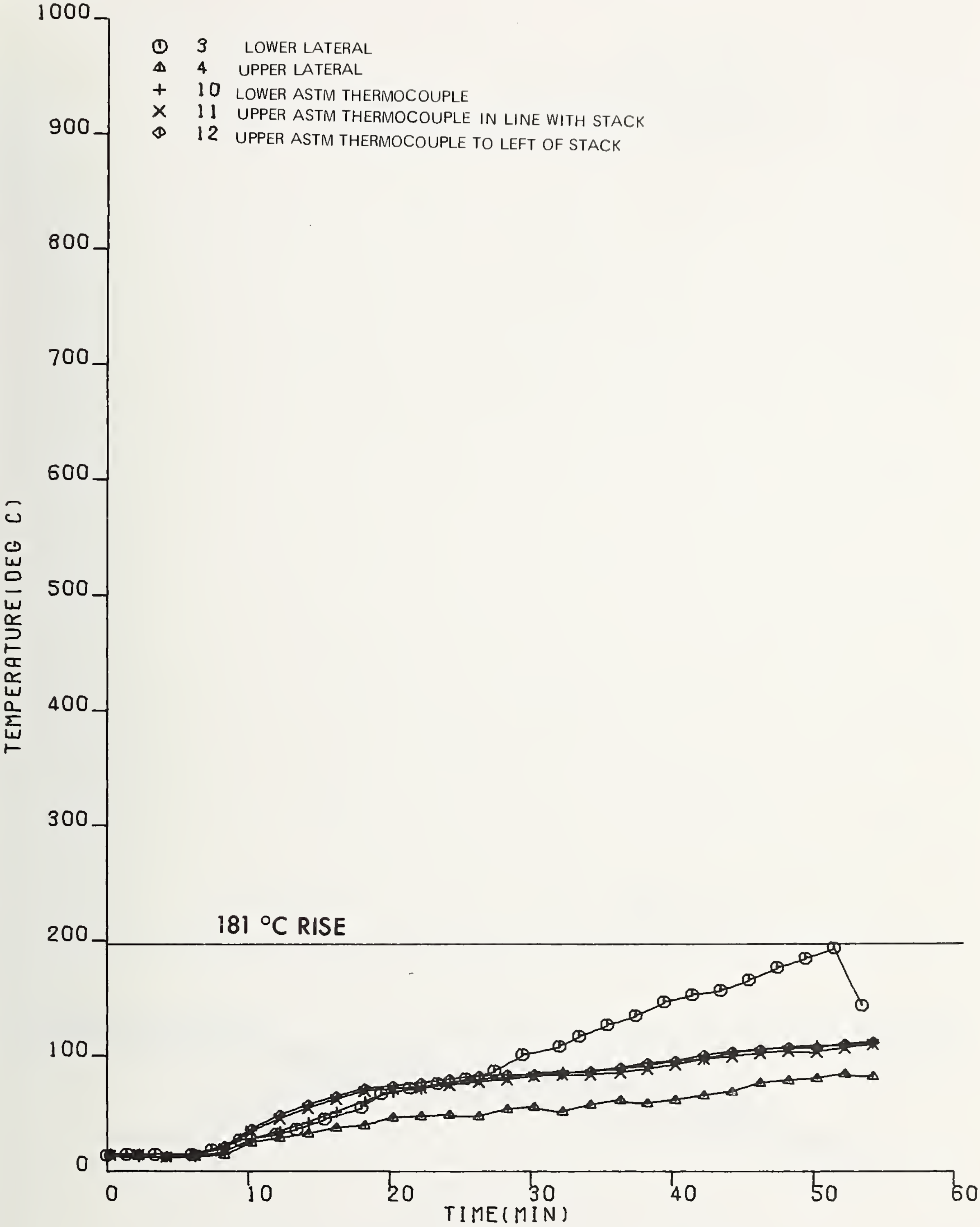


Figure 25. Unexposed lateral and ASTM surface temperatures in galvanized iron installation (cavity 4) in test 3.

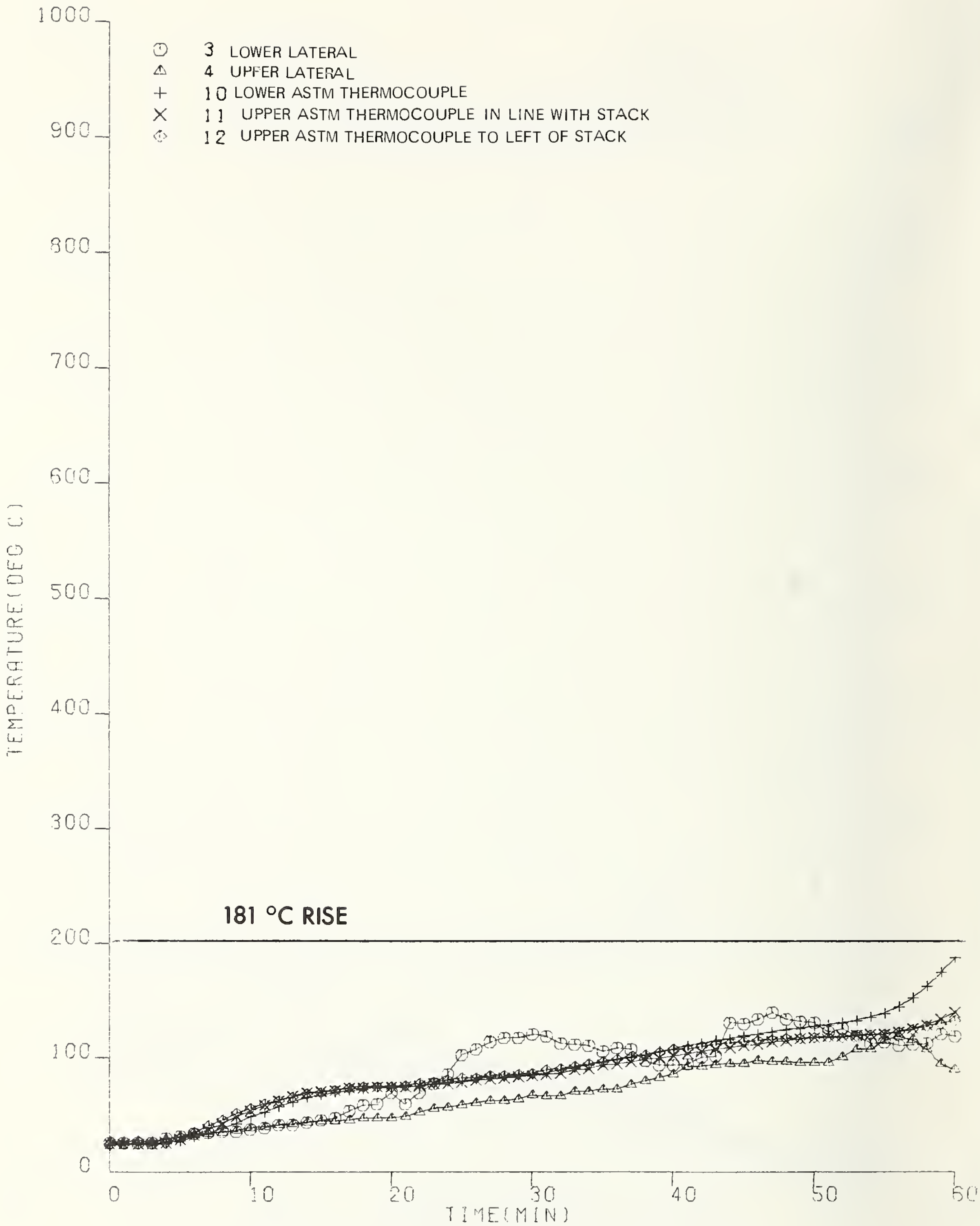


Figure 26. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 7) in test 4.

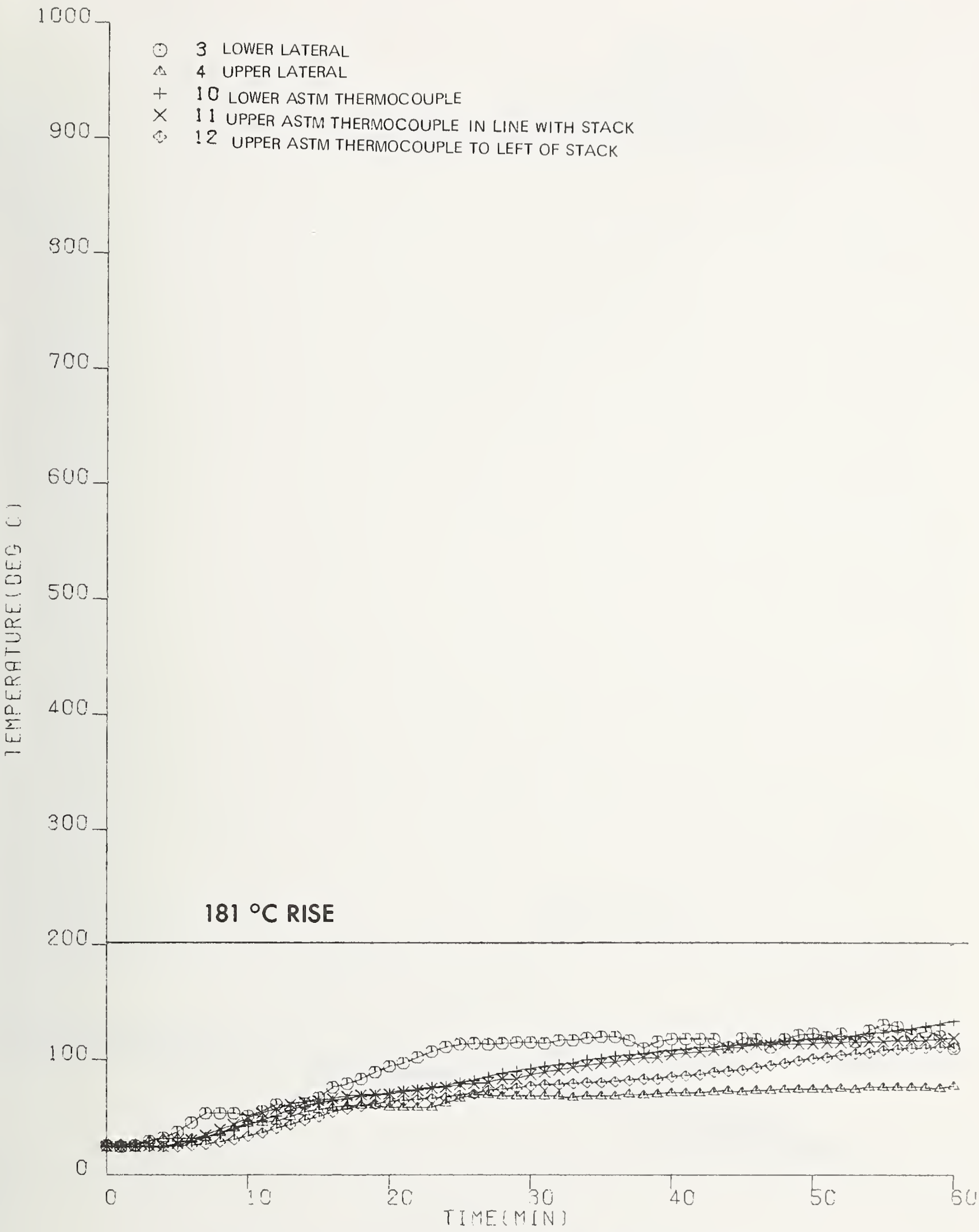


Figure 27. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 3) in test 4.

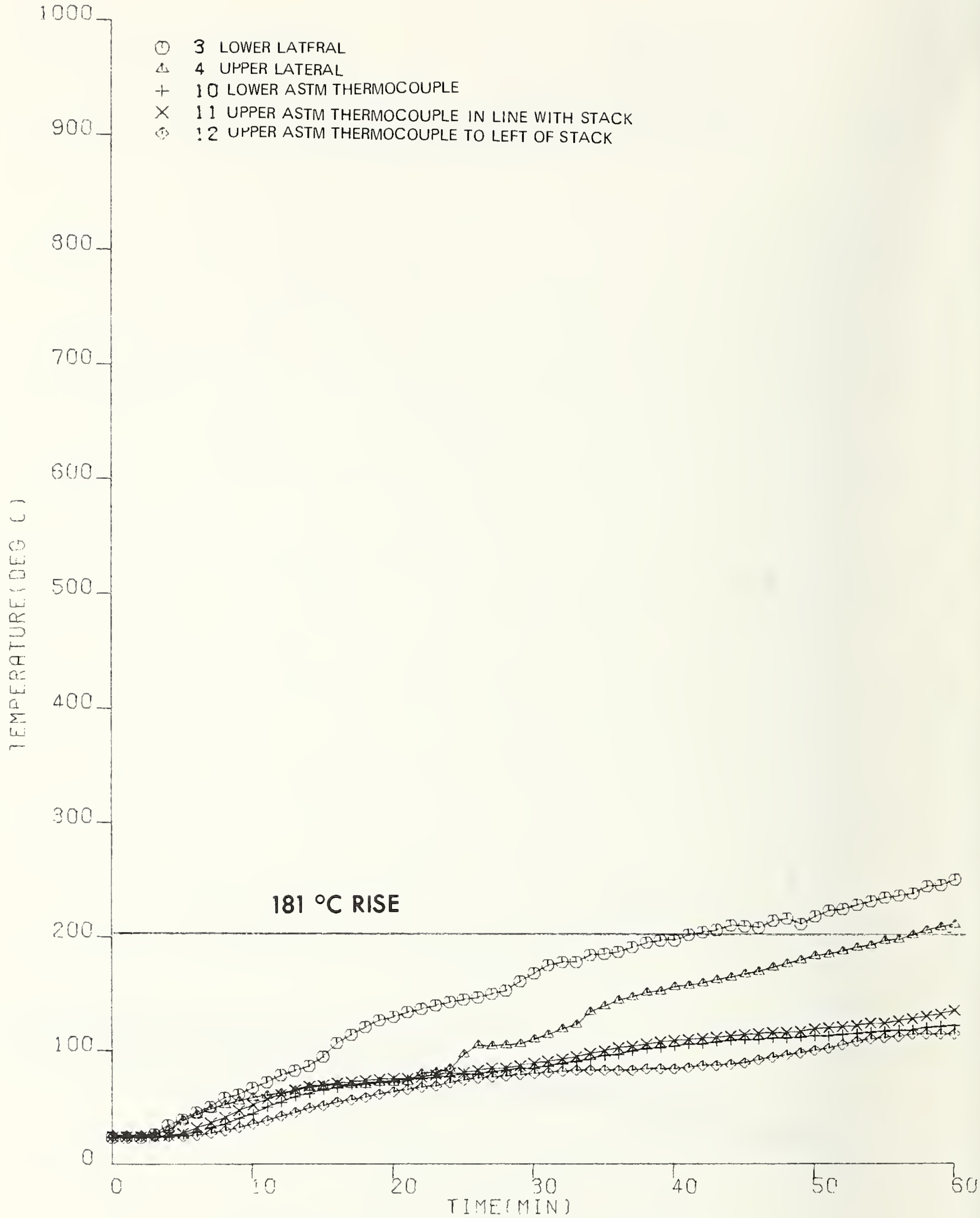


Figure 28. Unexposed lateral and ASTM surface temperatures in copper installation (cavity 2) in test 4.

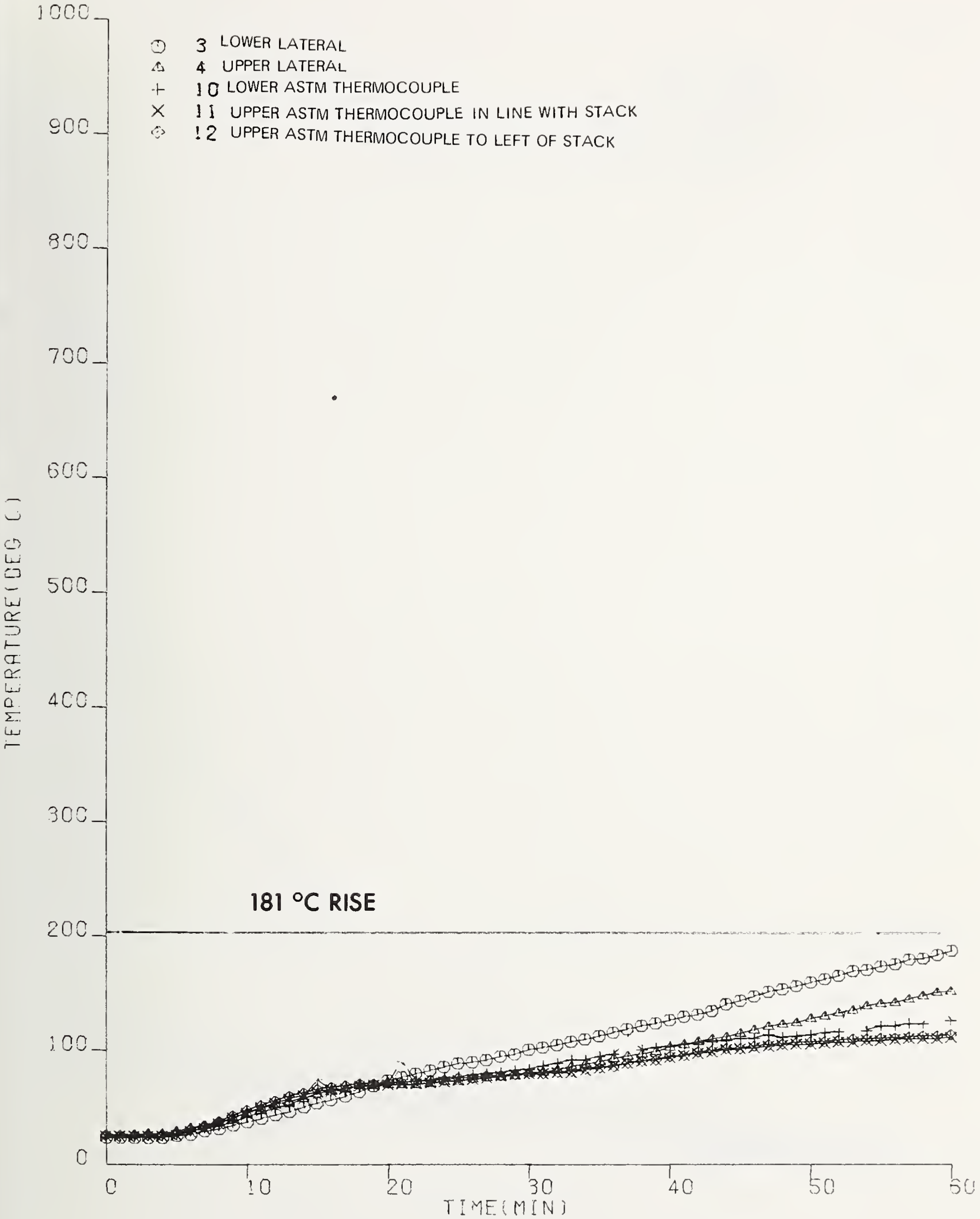


Figure 29. Unexposed lateral and ASTM surface temperatures in galvanized iron installation (cavity 4) in test 4.

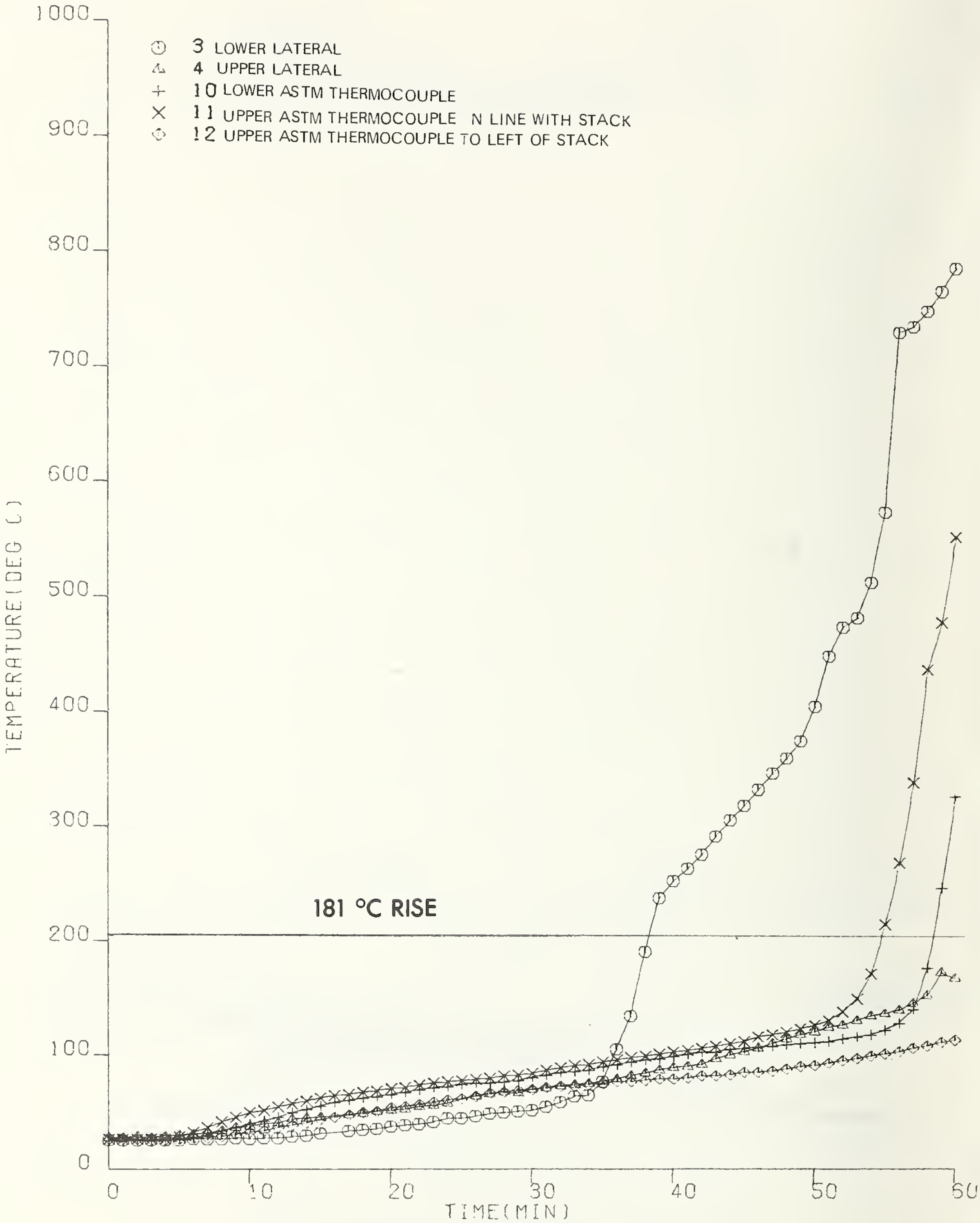


Figure 30. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 1) in test 5.

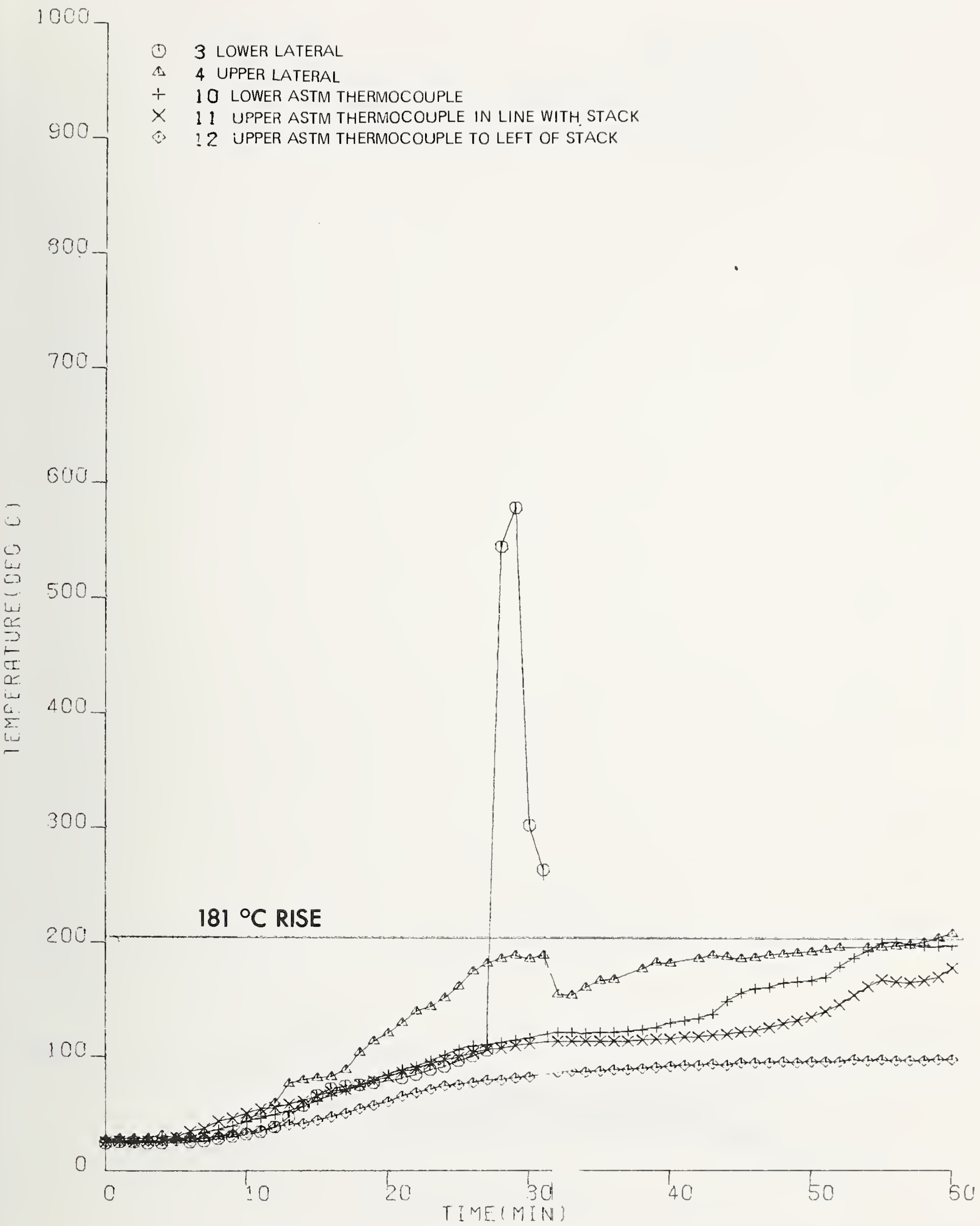


Figure 31. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 3) in test 5.

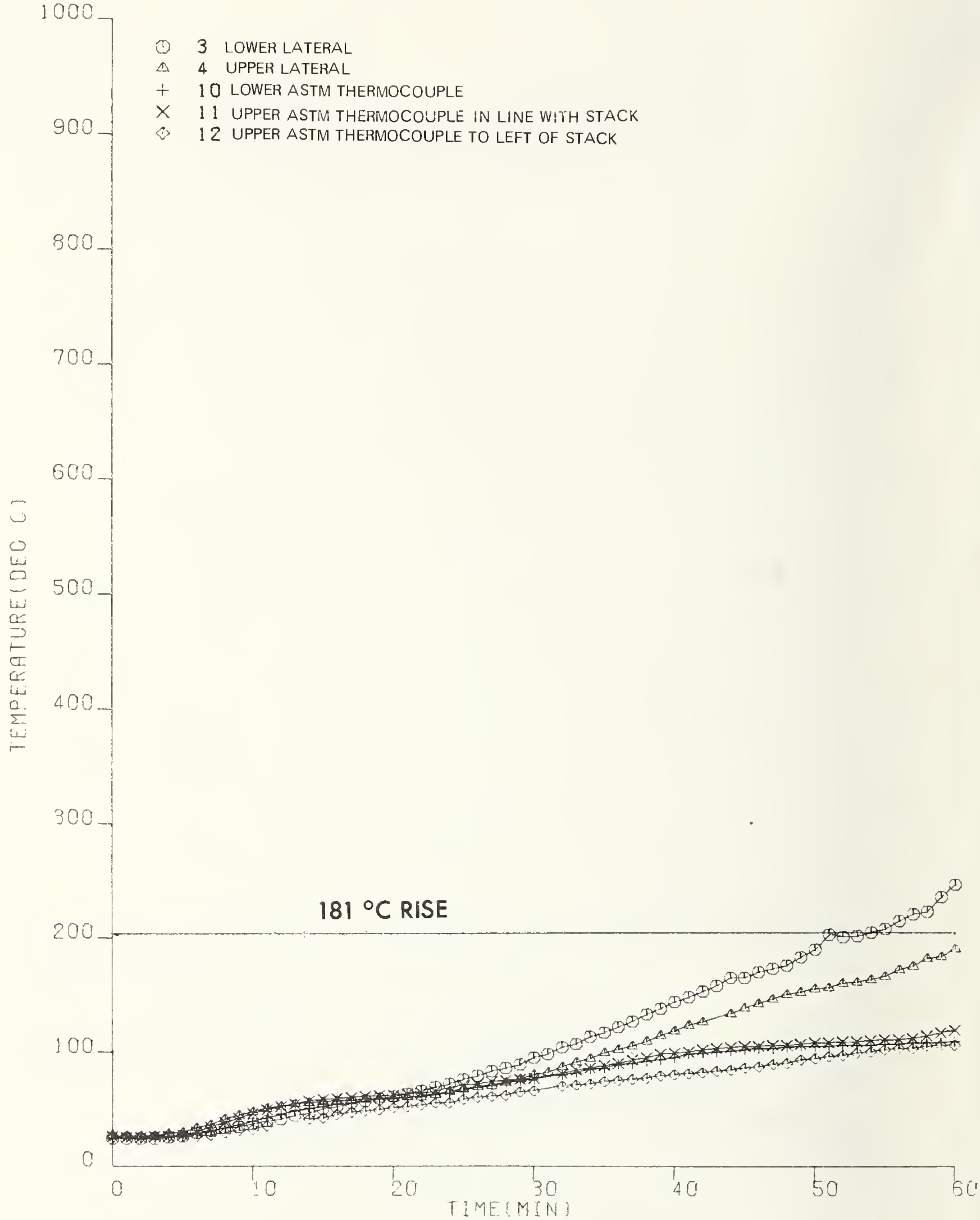


Figure 32. Unexposed lateral and ASTM surface temperatures in copper installation (cavity 2) in test 5.

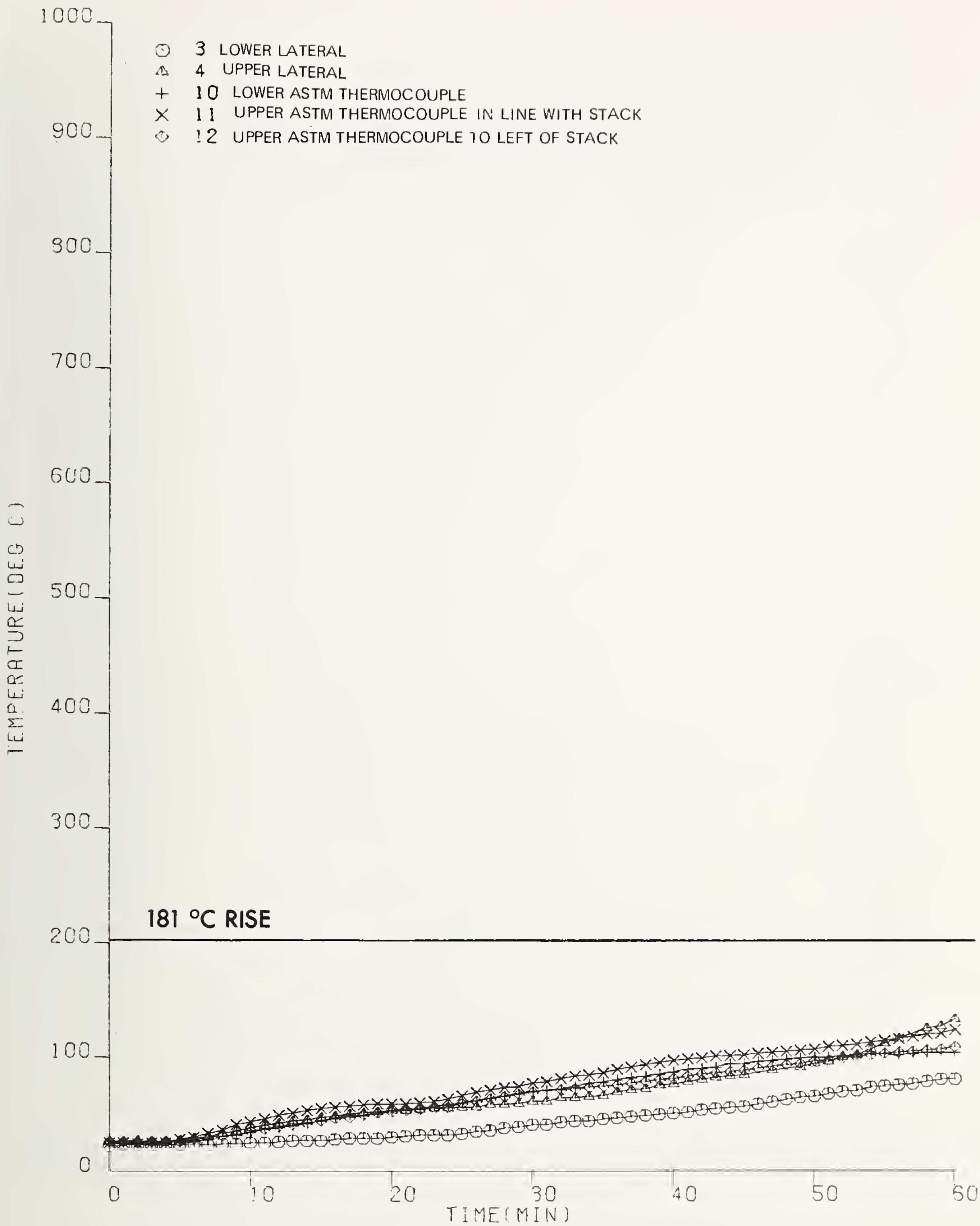


Figure 33. Unexposed lateral and ASTM surface temperatures in hubless cast iron installation (cavity 4) in test 5.

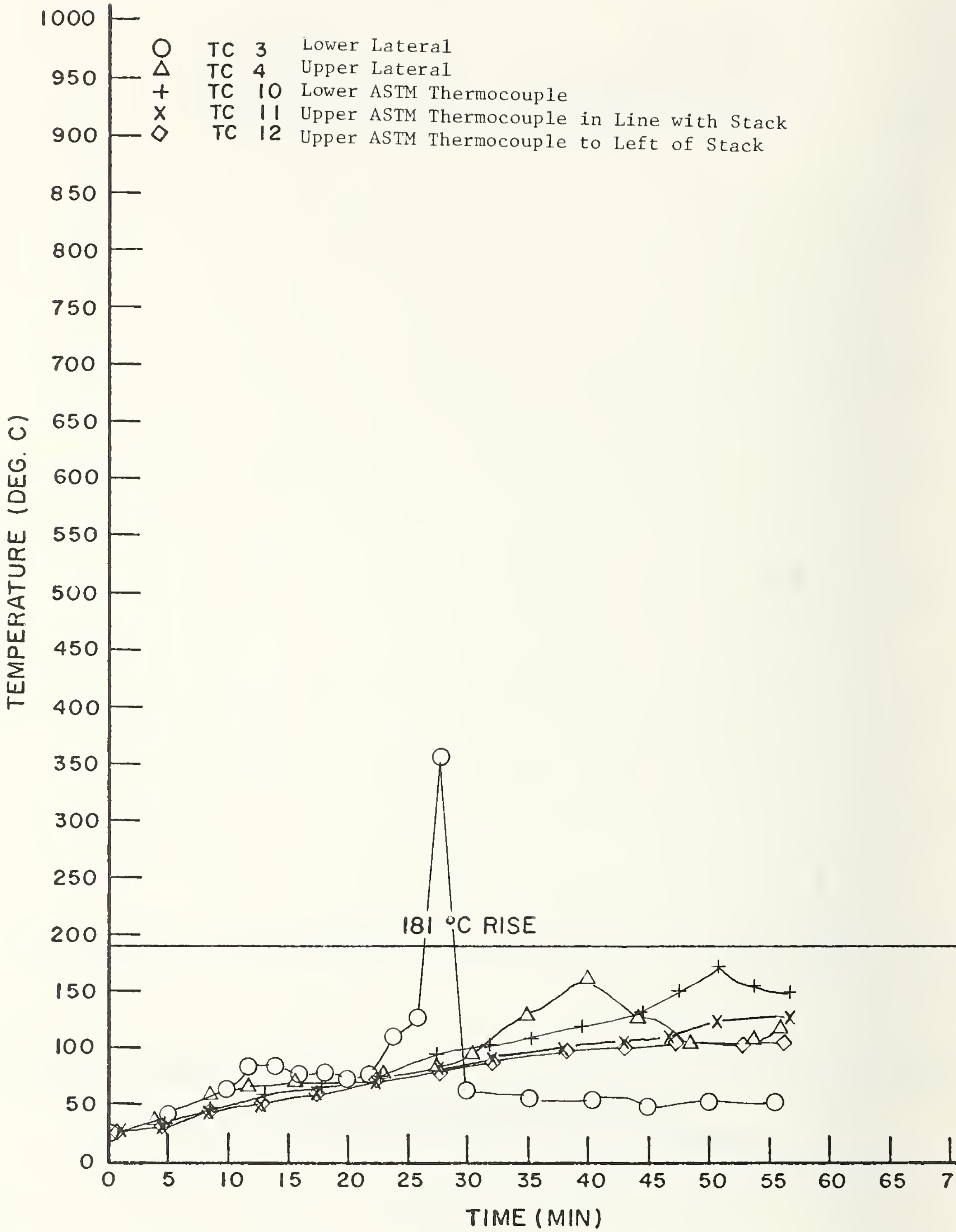


Figure 34. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 1) in test 6.

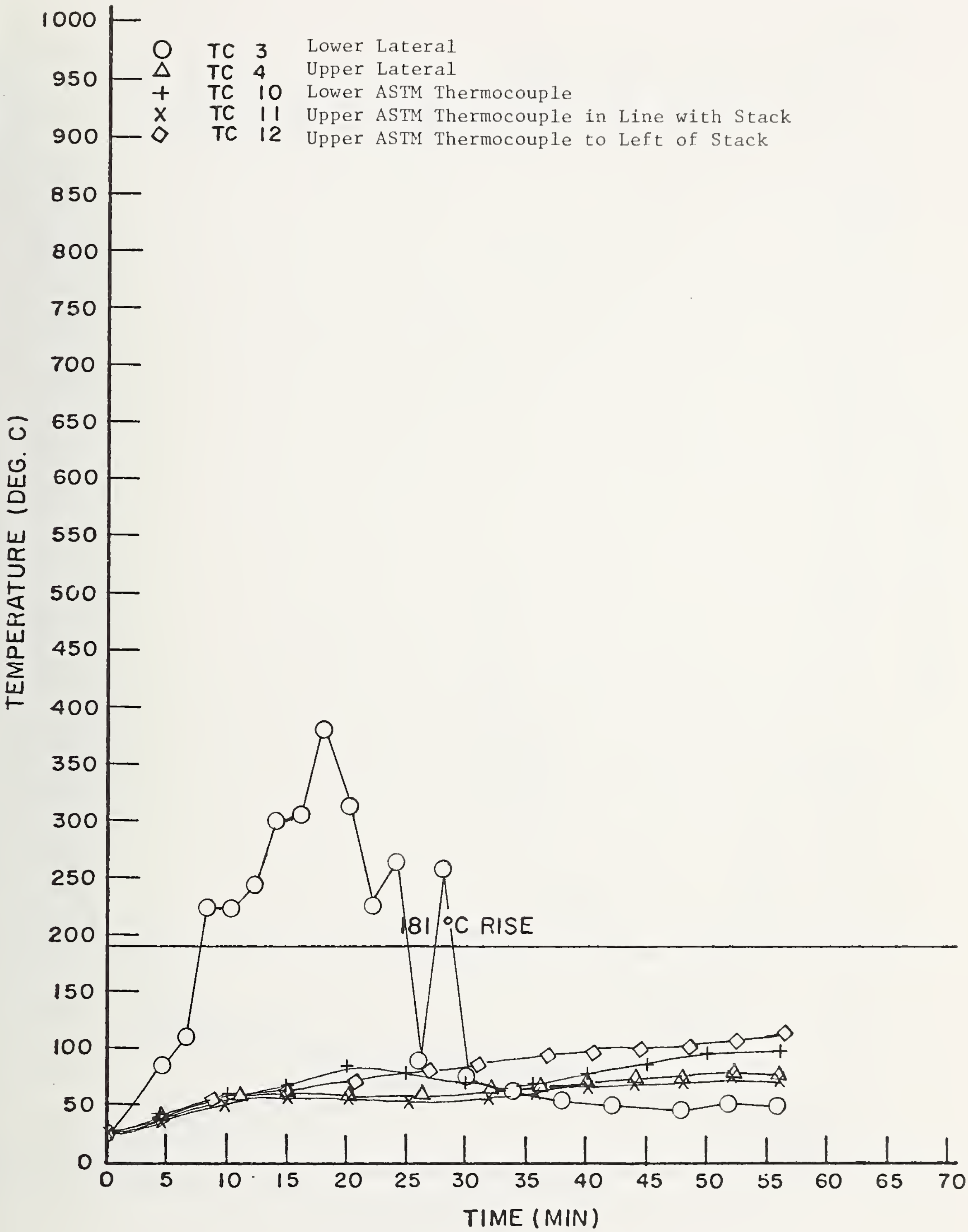


Figure 35. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 2) in test 6.

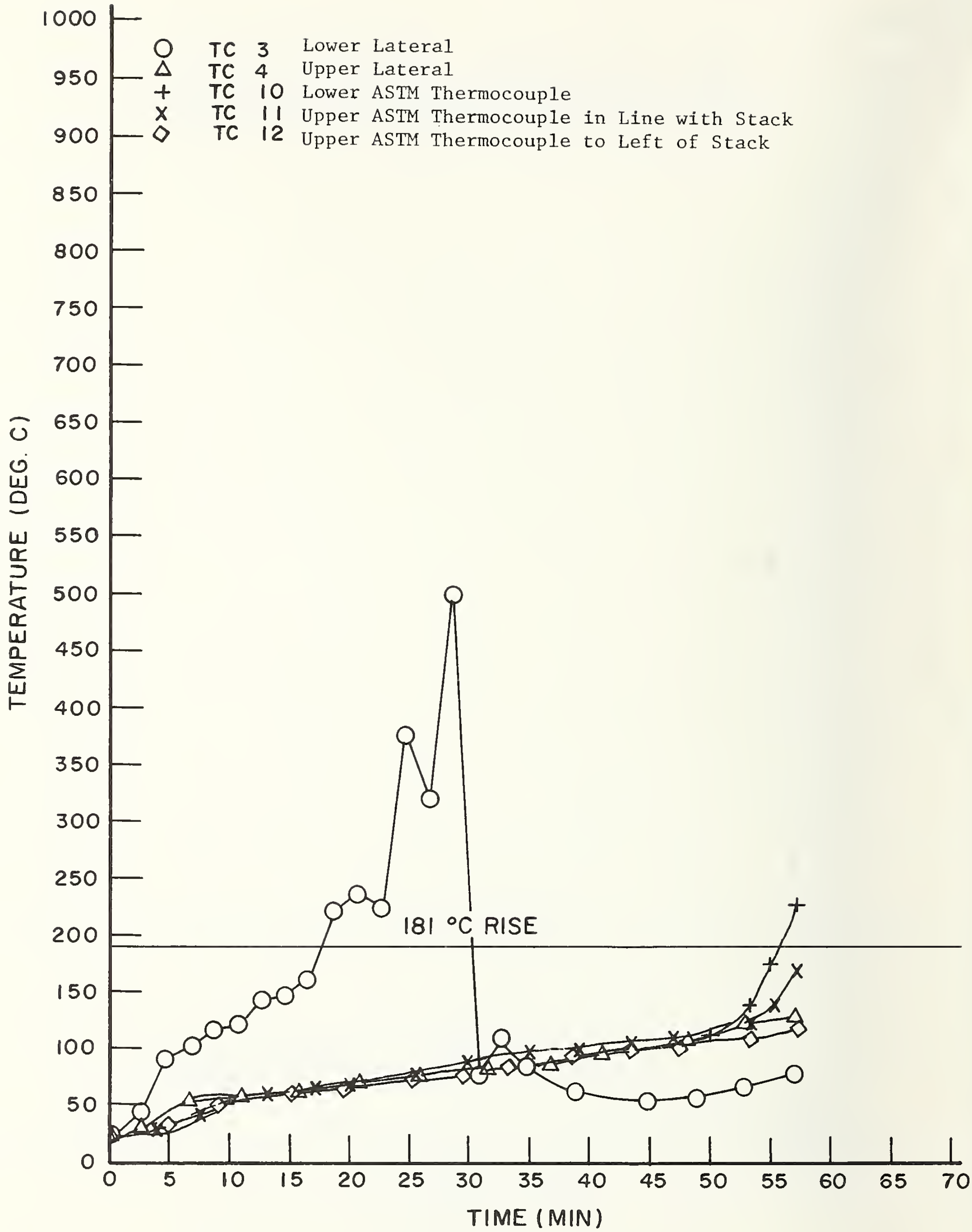


Figure 36. Unexposed lateral and ASTM surface temperature in ABS installation (cavity 3) in test 6.

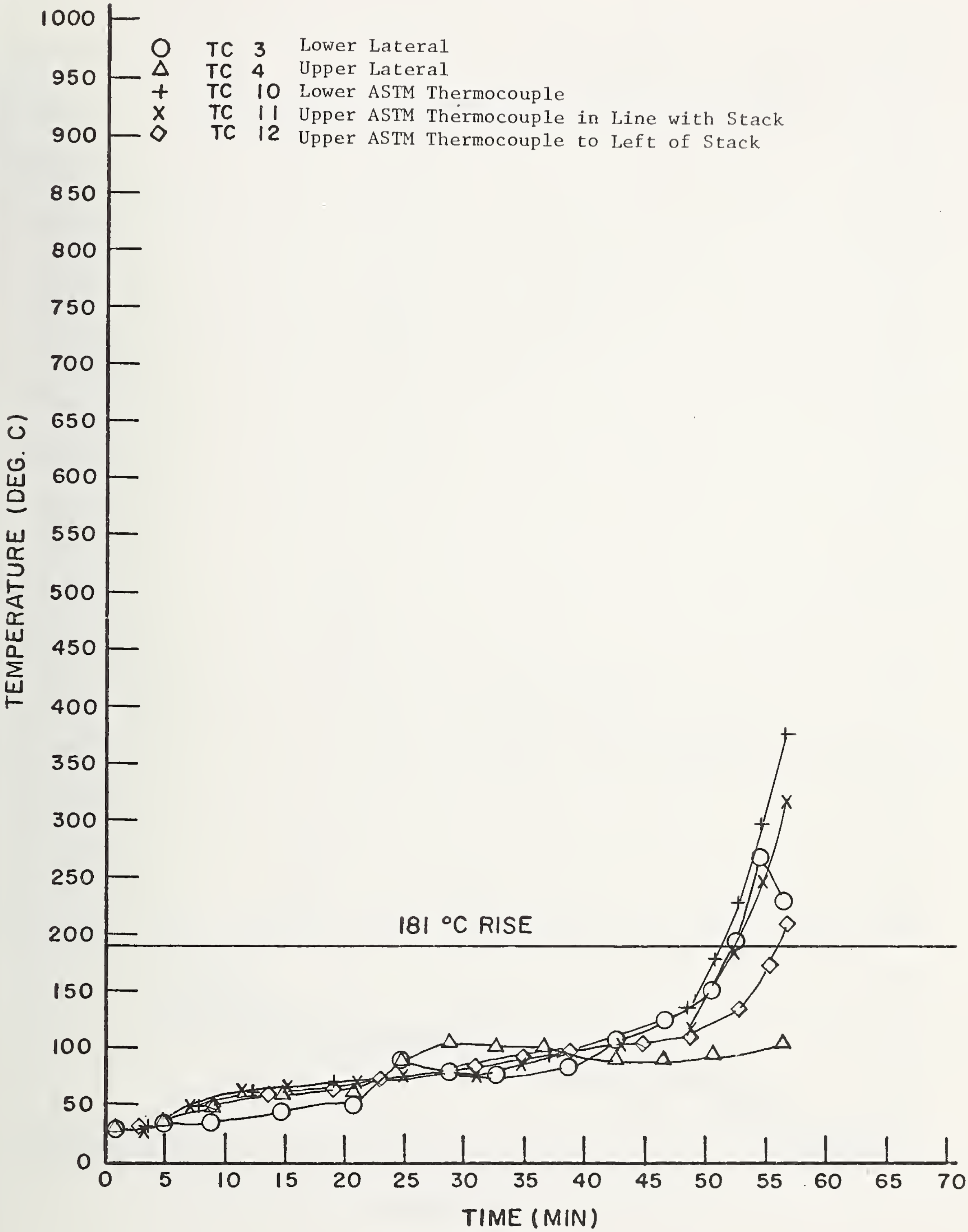


Figure 37. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 4) in test 6.

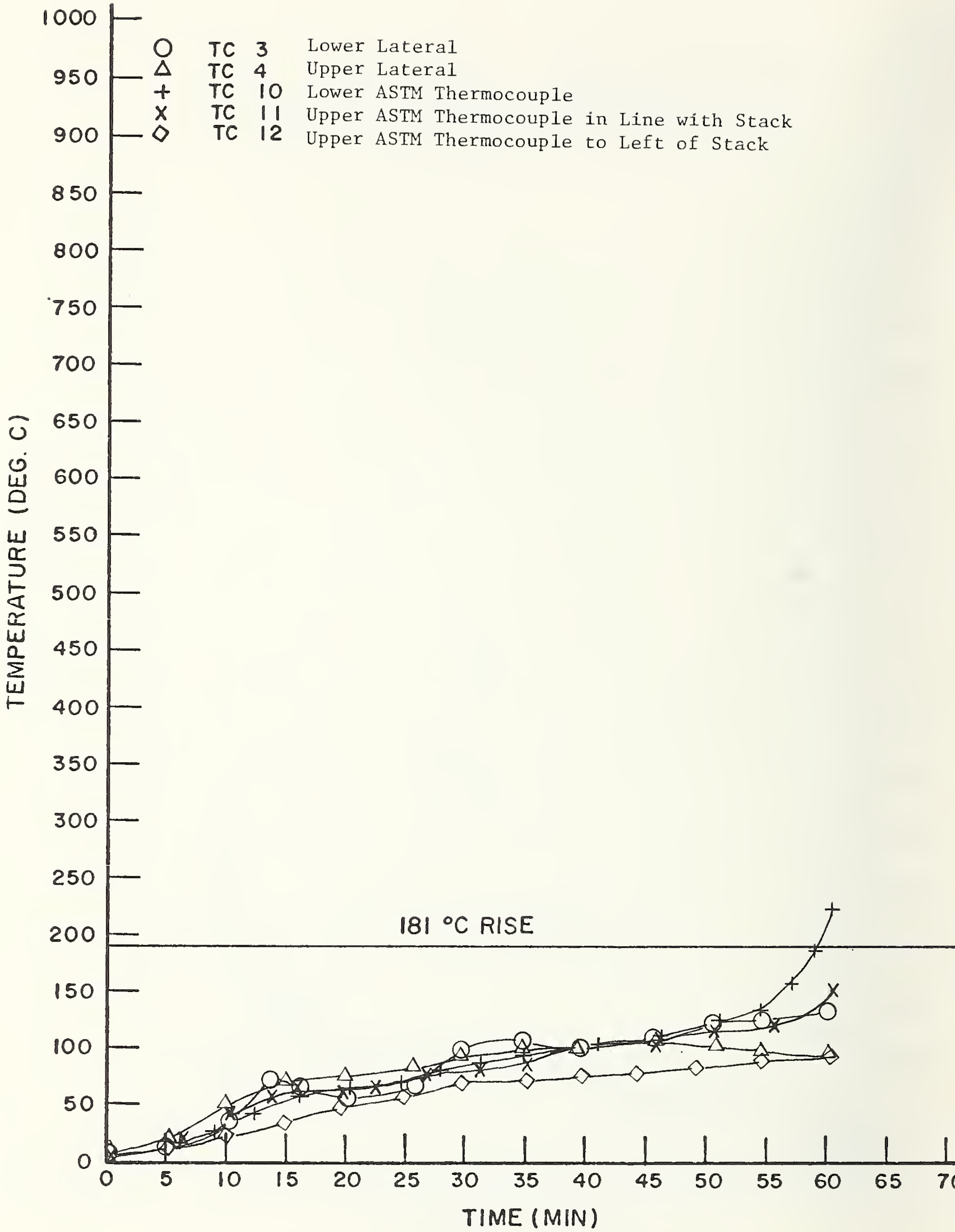


Figure 38. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 1) in test 7.

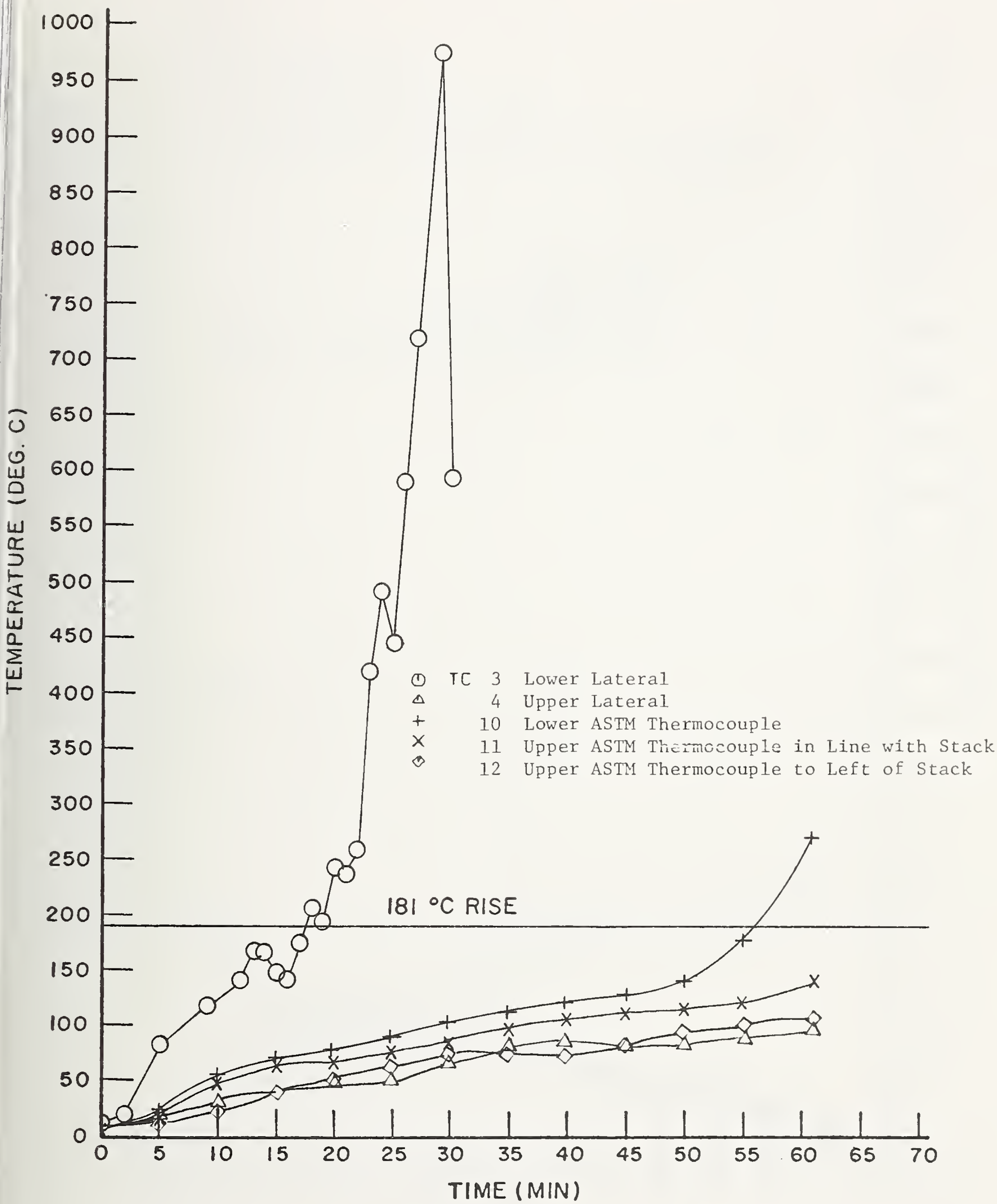


Figure 39. Unexposed lateral and ASTM surface temperatures in ABS installation (cavity 2) in test 7.

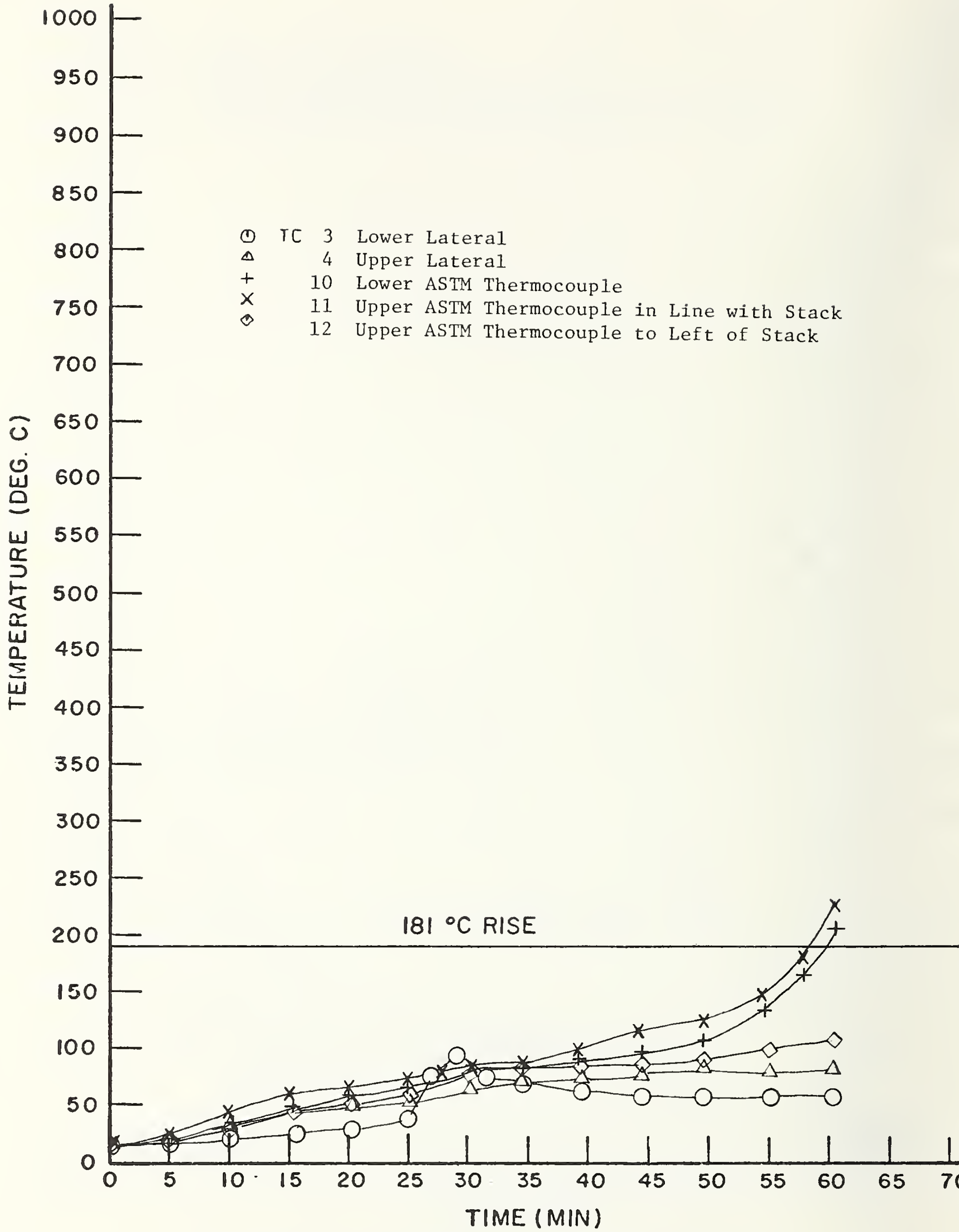


Figure 40. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 3) in test 7.

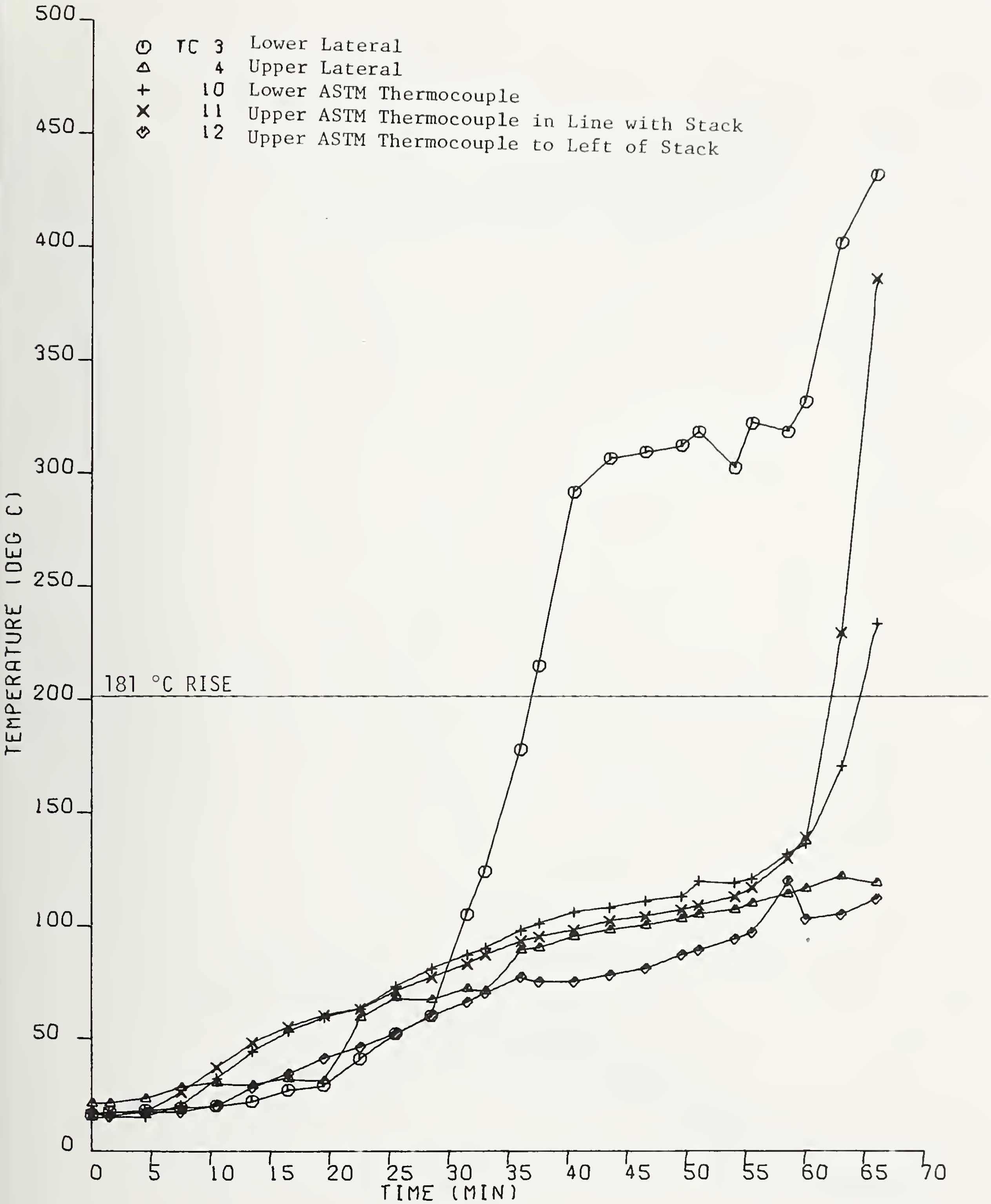


Figure 41. Unexposed lateral and ASTM surface temperatures in PVC installation (cavity 4) in test 7.

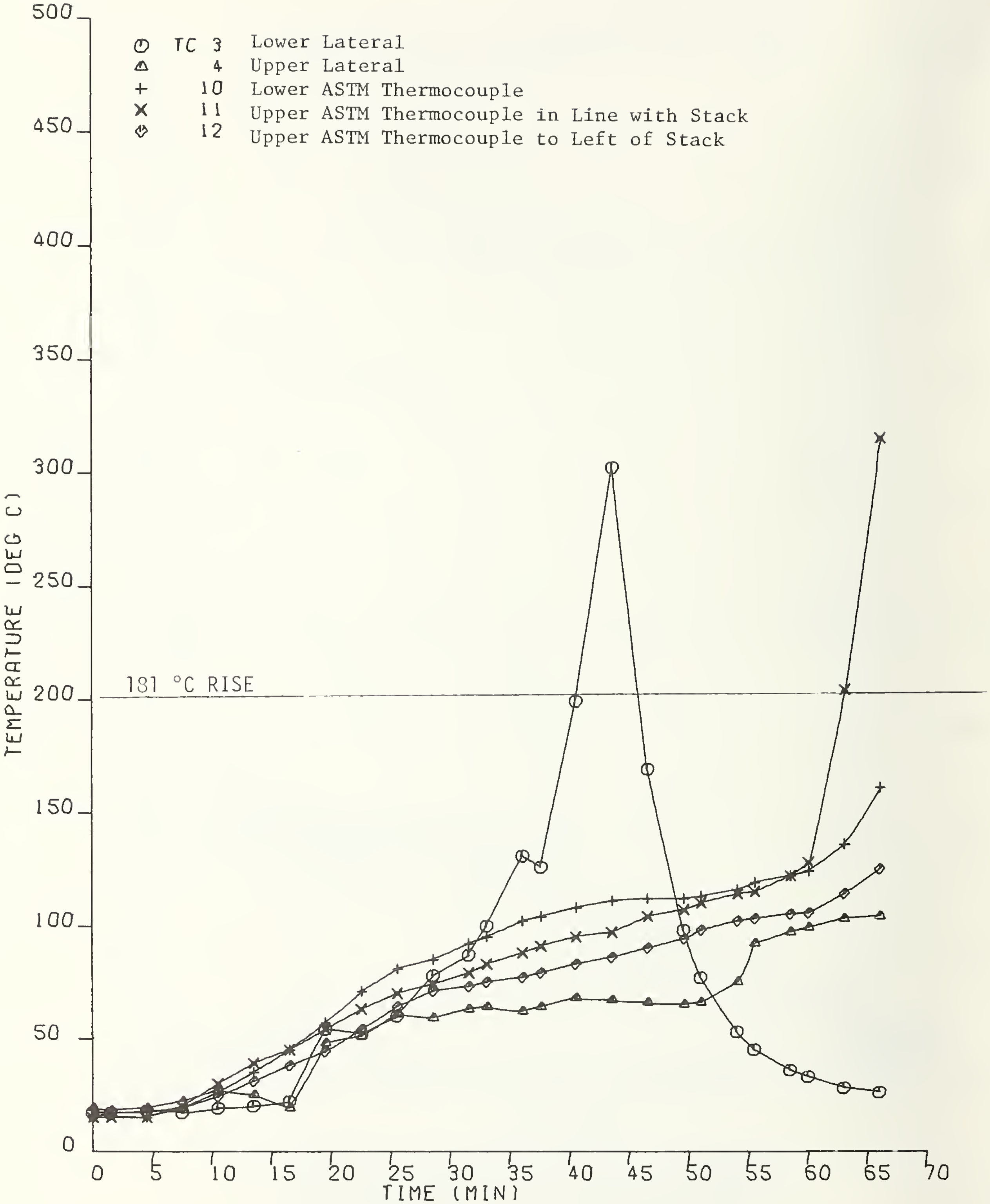


Figure 42. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 1) in test 8.

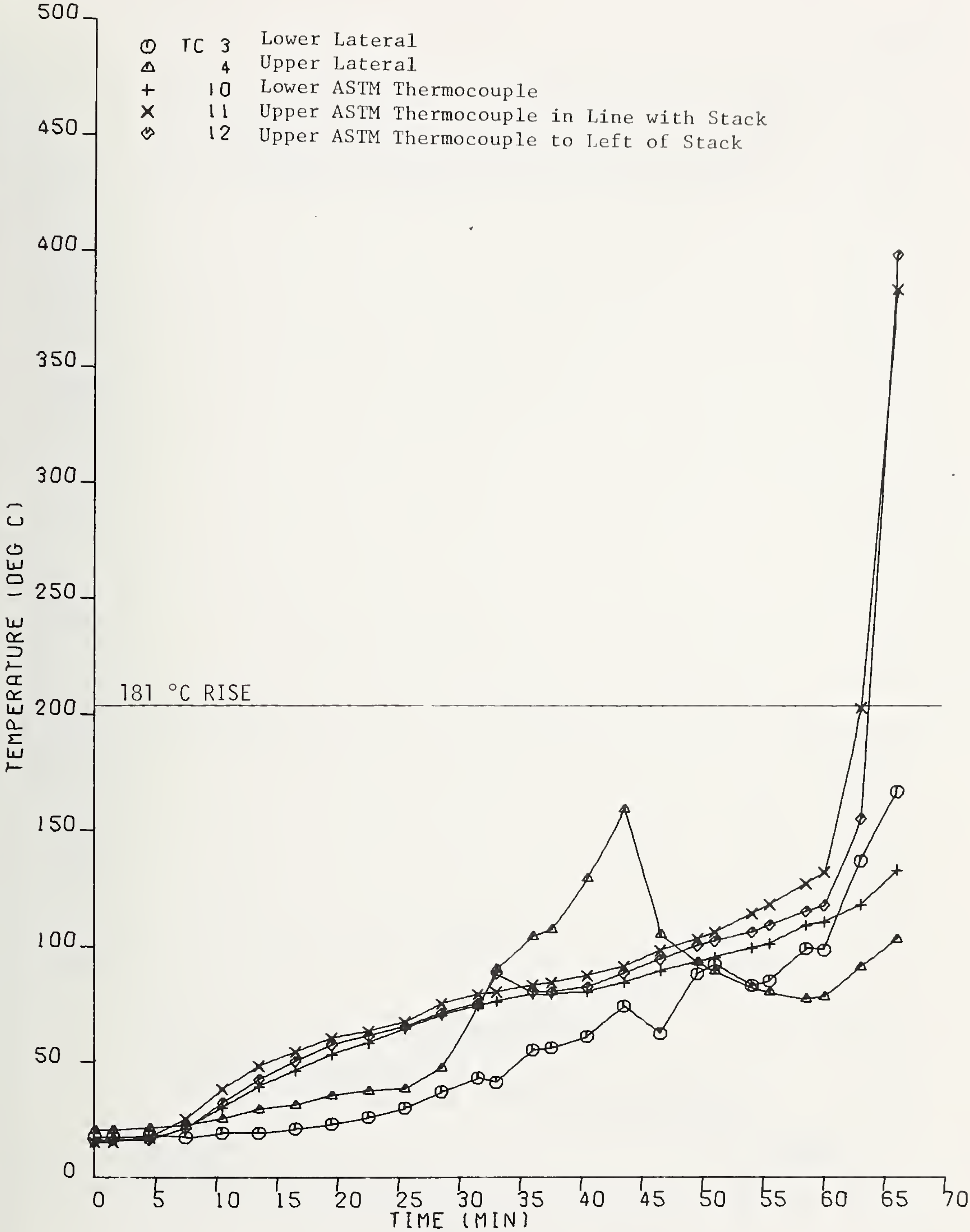


Figure 43. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 2) in test 8.

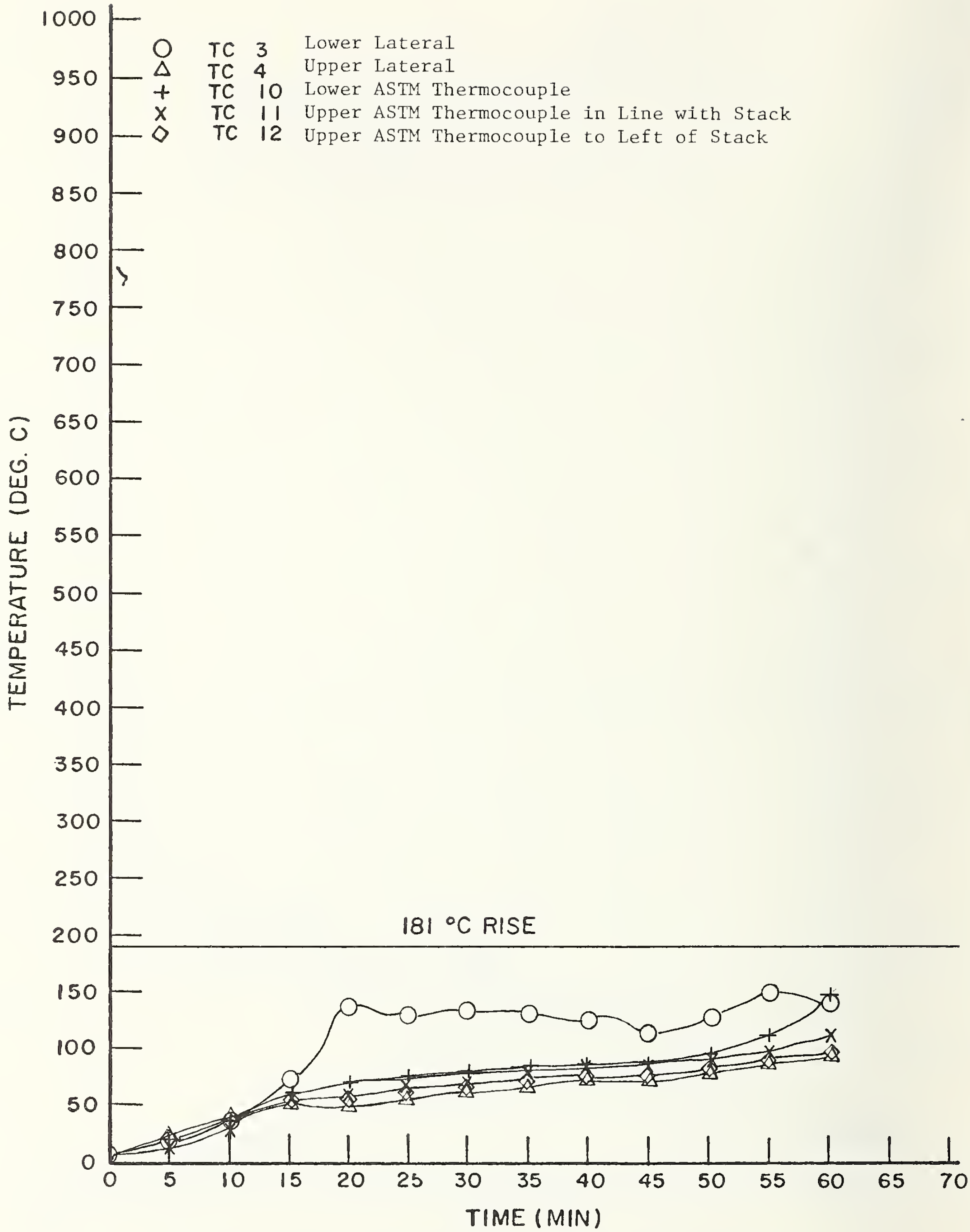


Figure 44. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 3) in test 8.

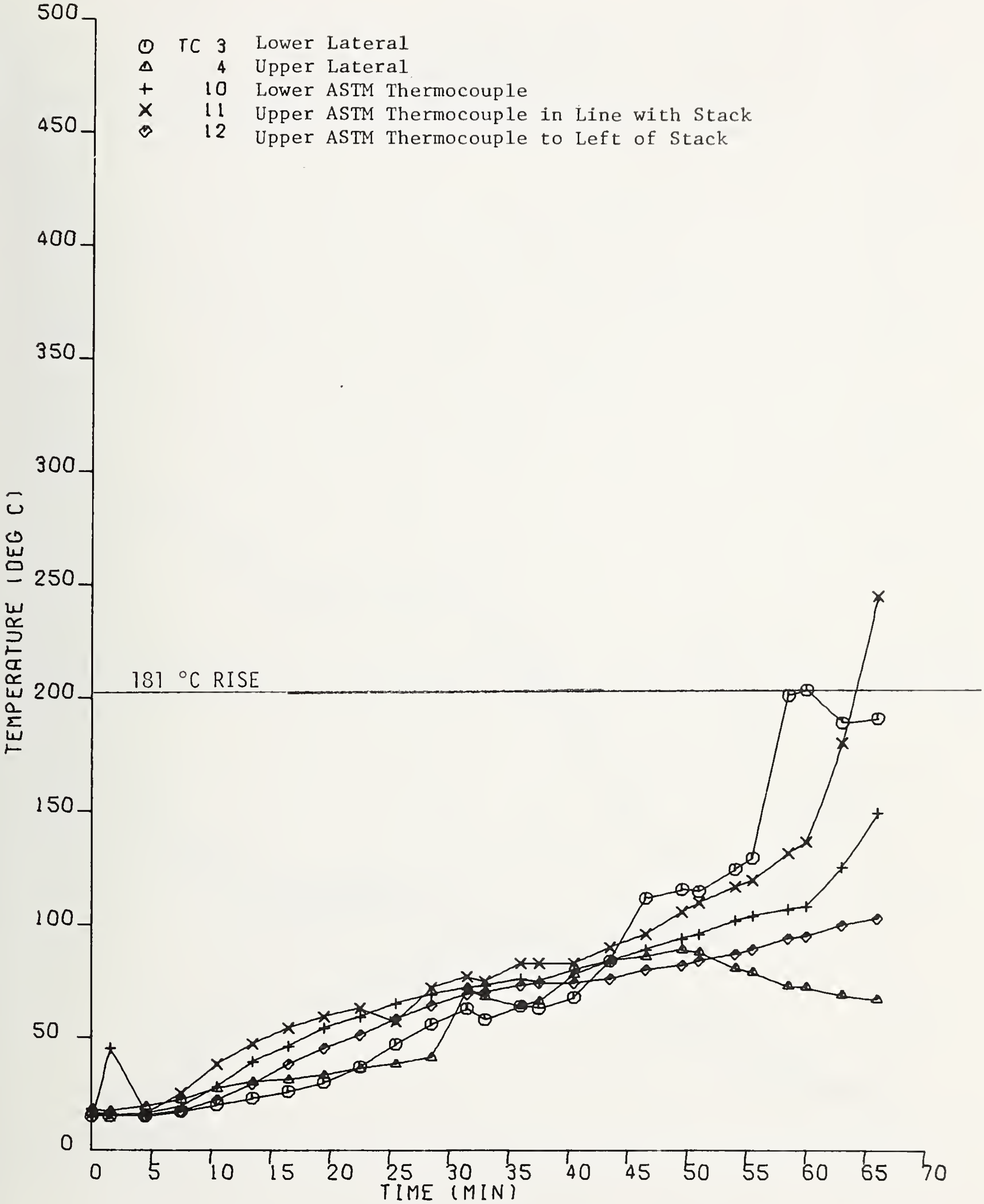


Figure 45. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 4) in test 8.

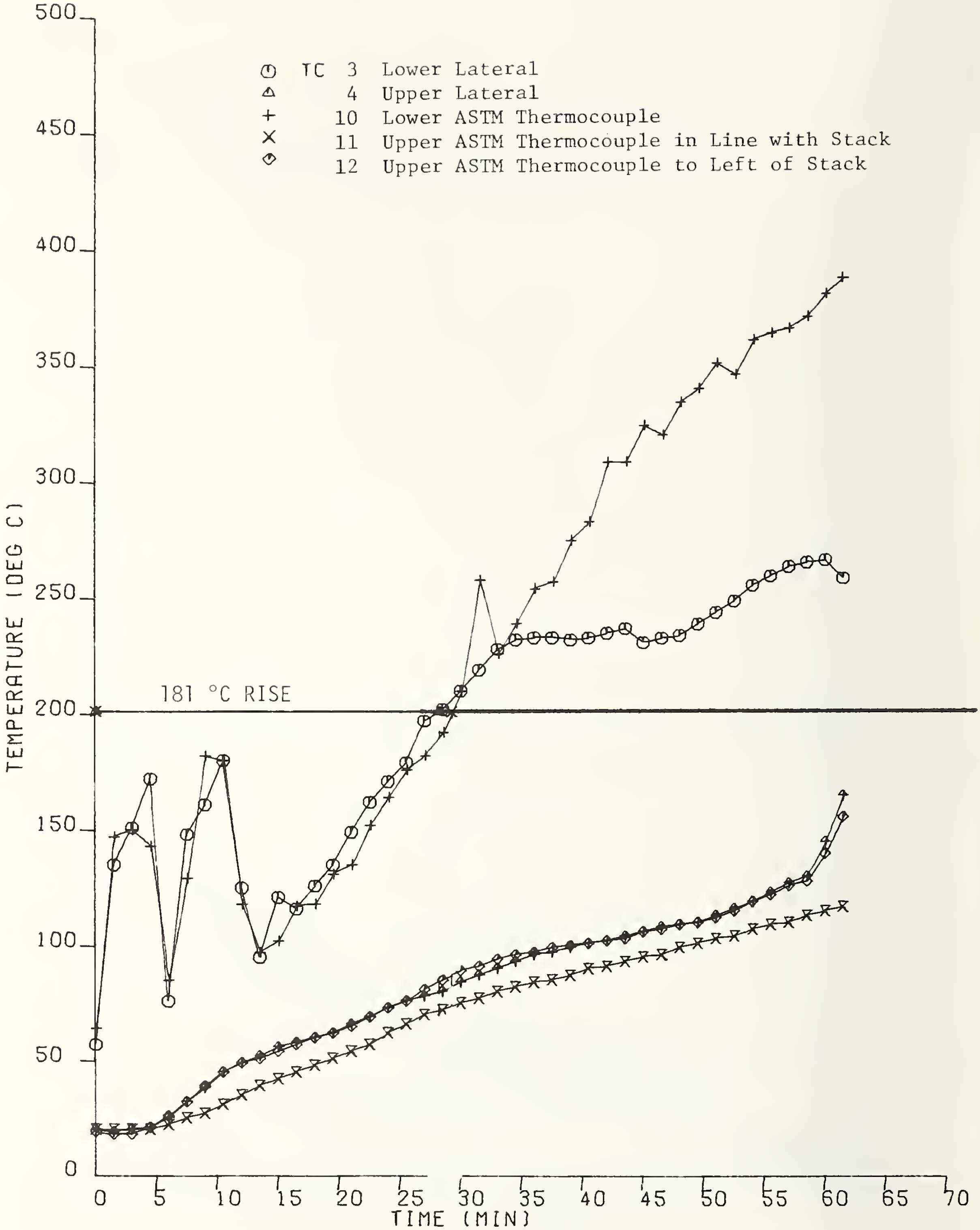


Figure 46. Unexposed lateral and ASTM surface temperature readings in copper installation (cavity 1) in test 9.

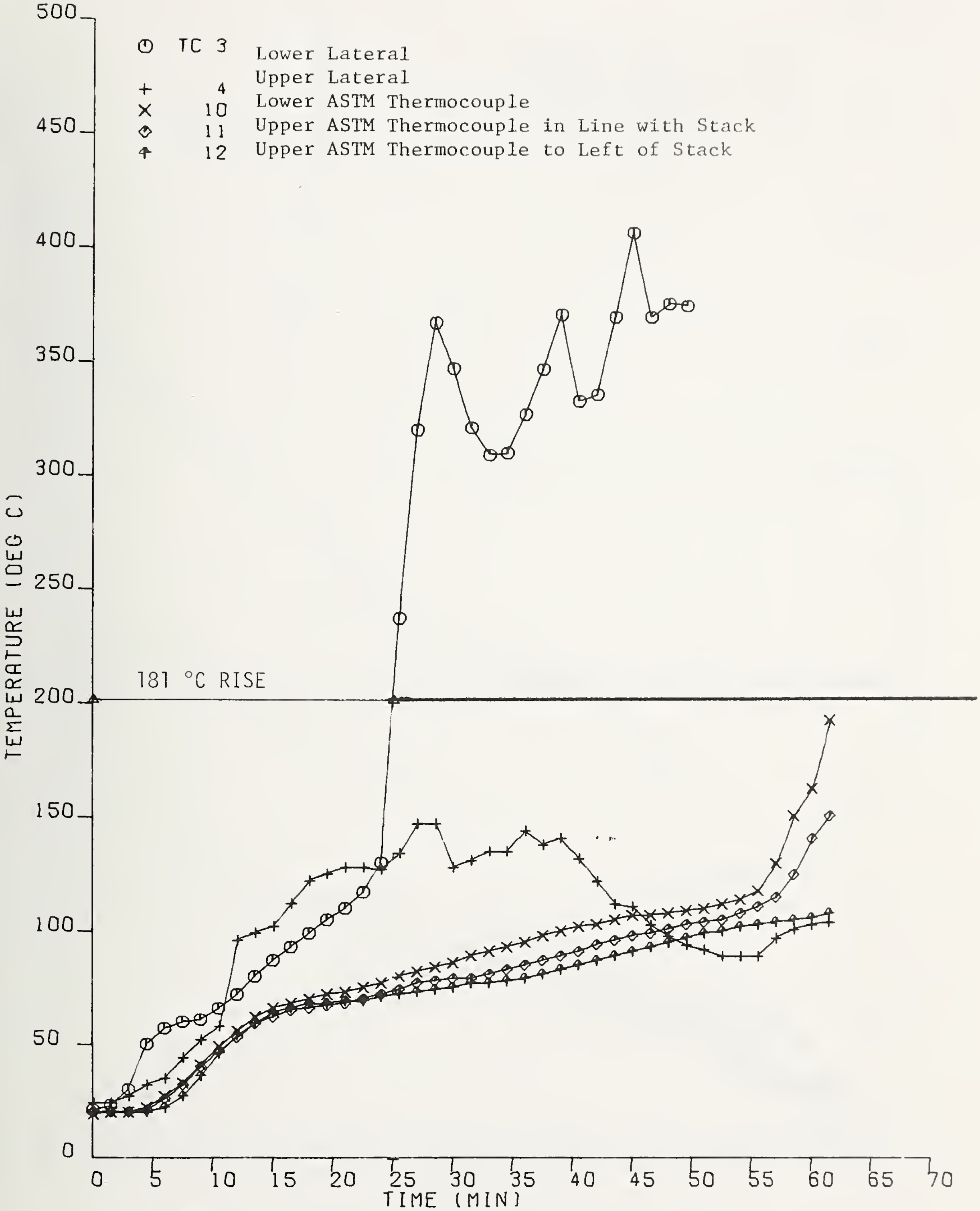


Figure 47. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 2) in test 9.

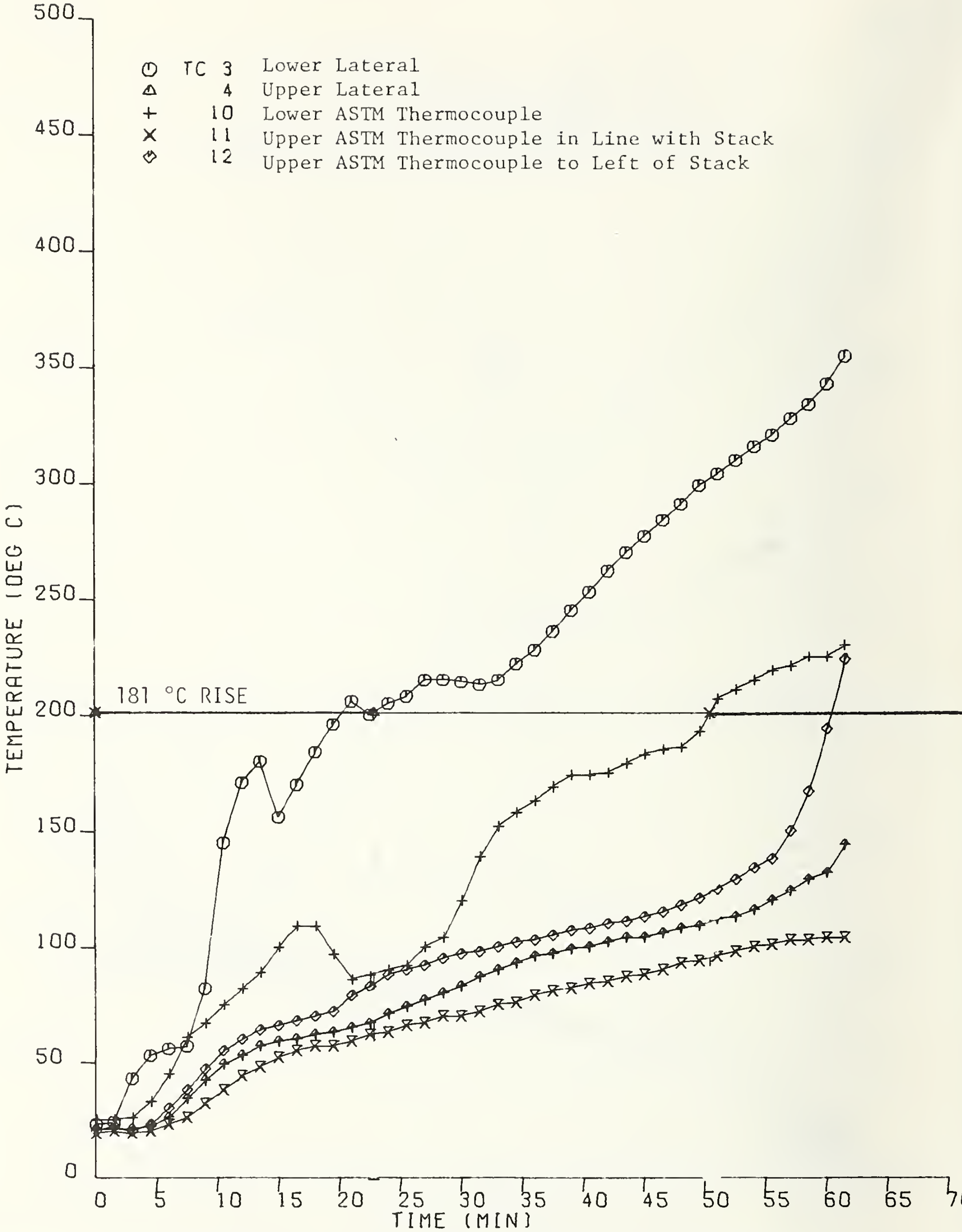


Figure 48. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 3) in test 9.

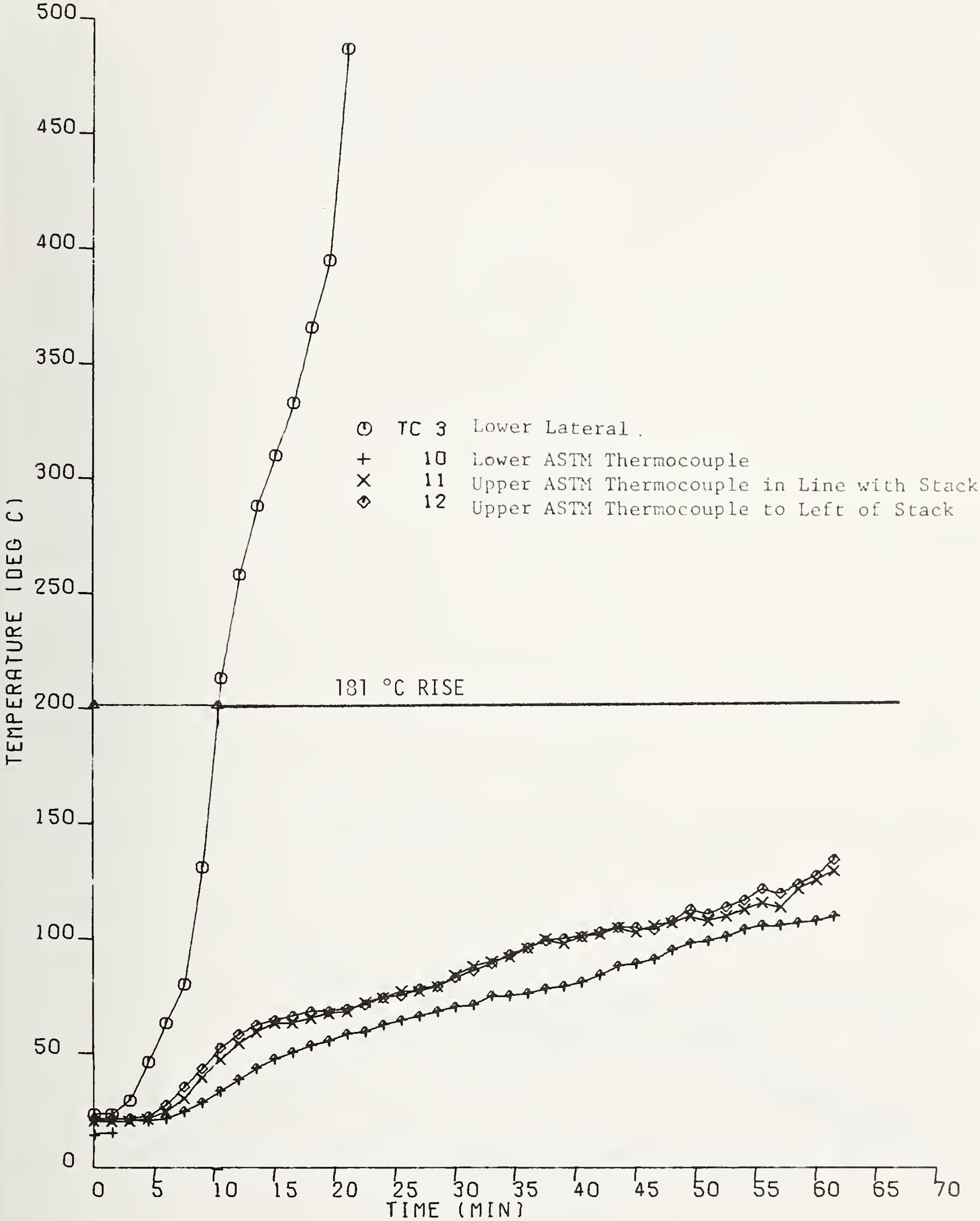


Figure 49. Readings in ABS installation (cavity 4) in test 9

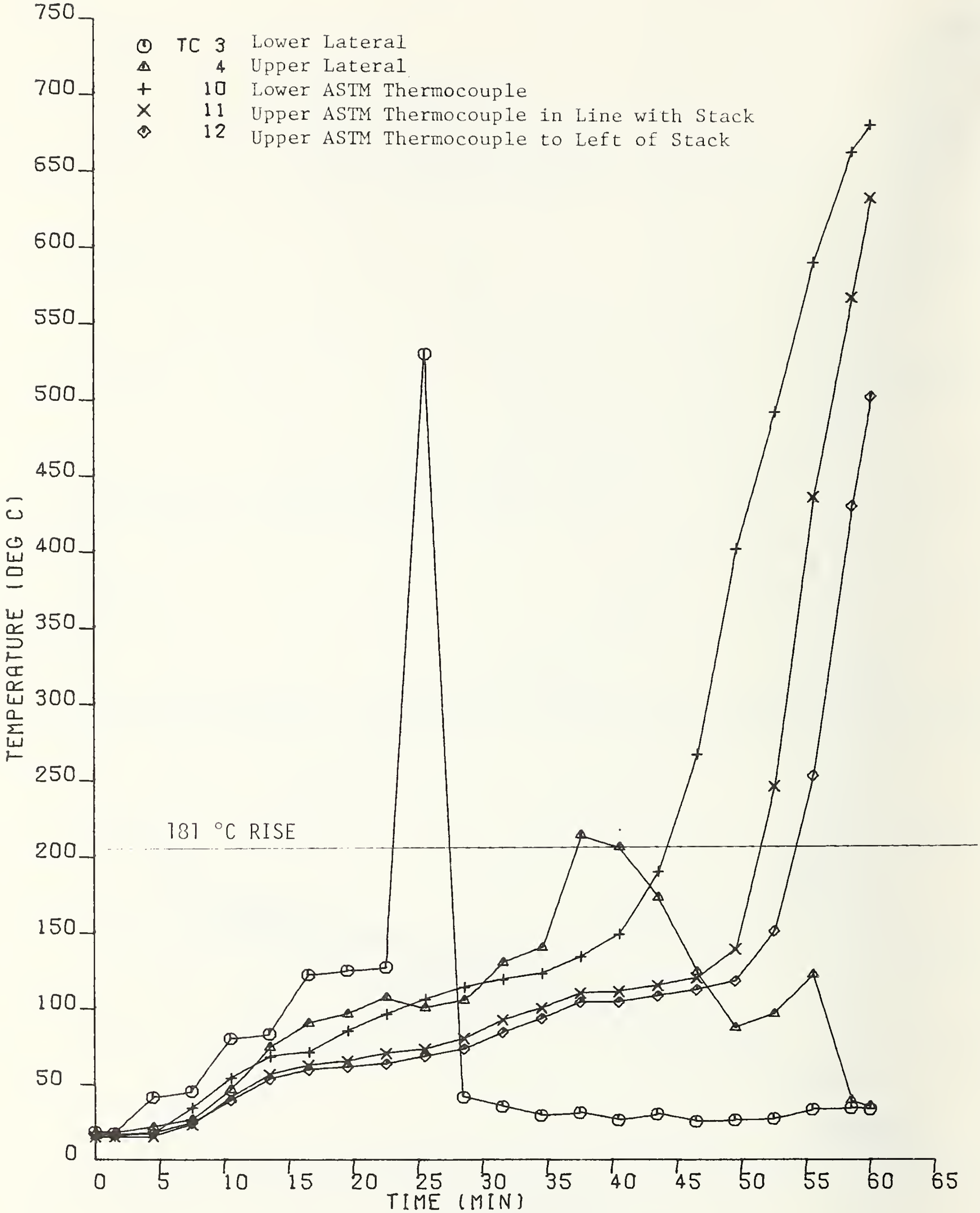


Figure 50. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 1) in test 10.

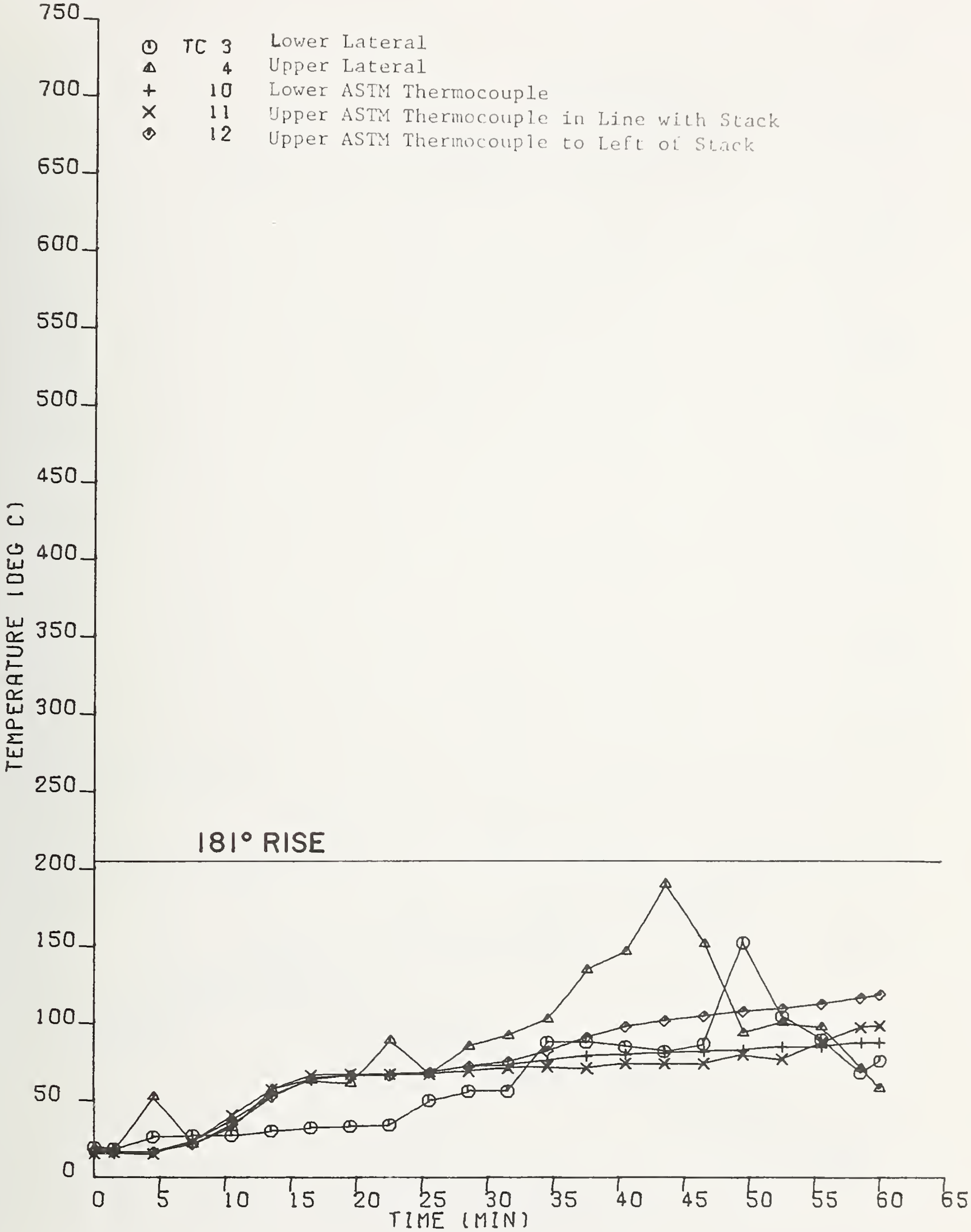


Figure 51. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 2) in test 10.

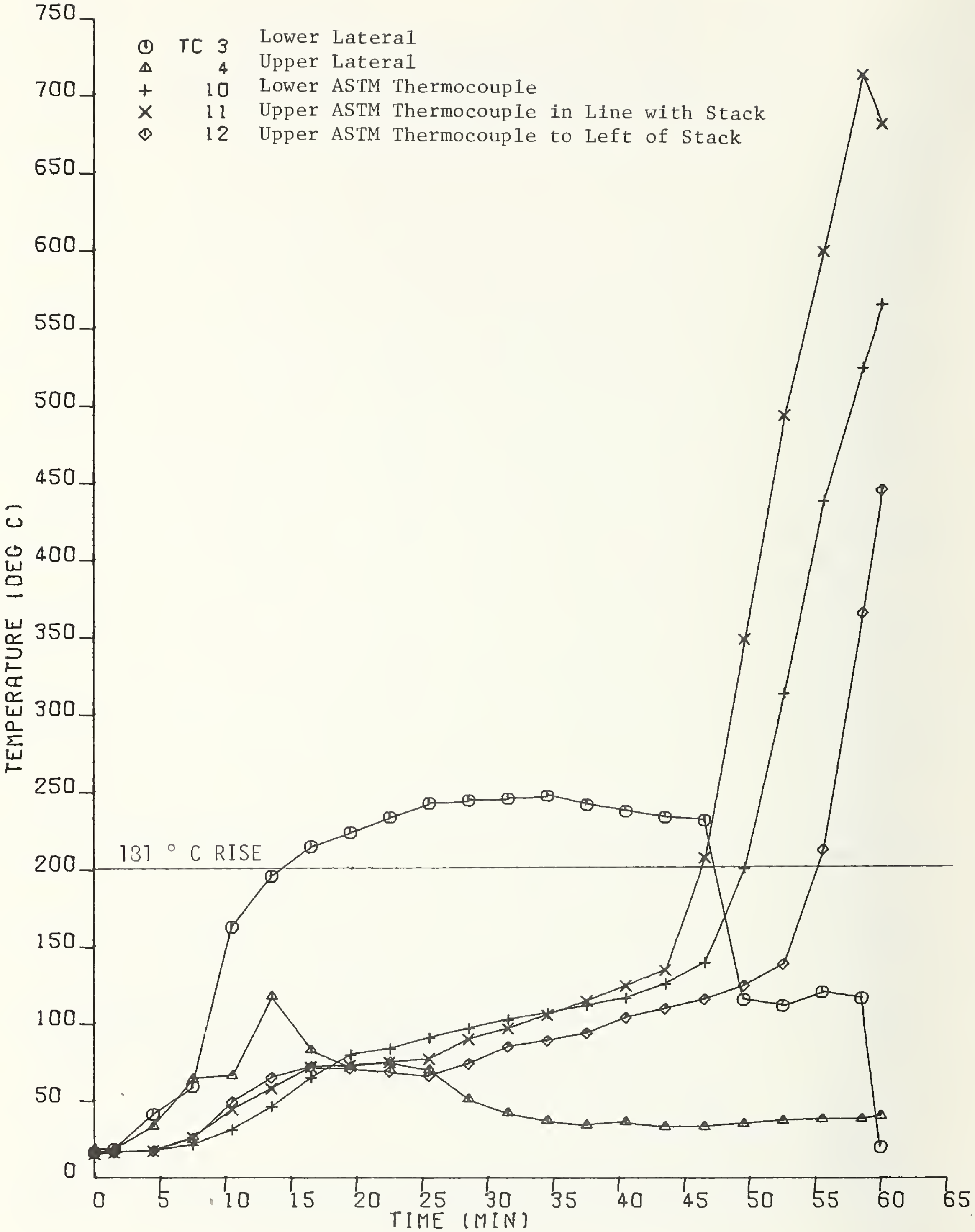
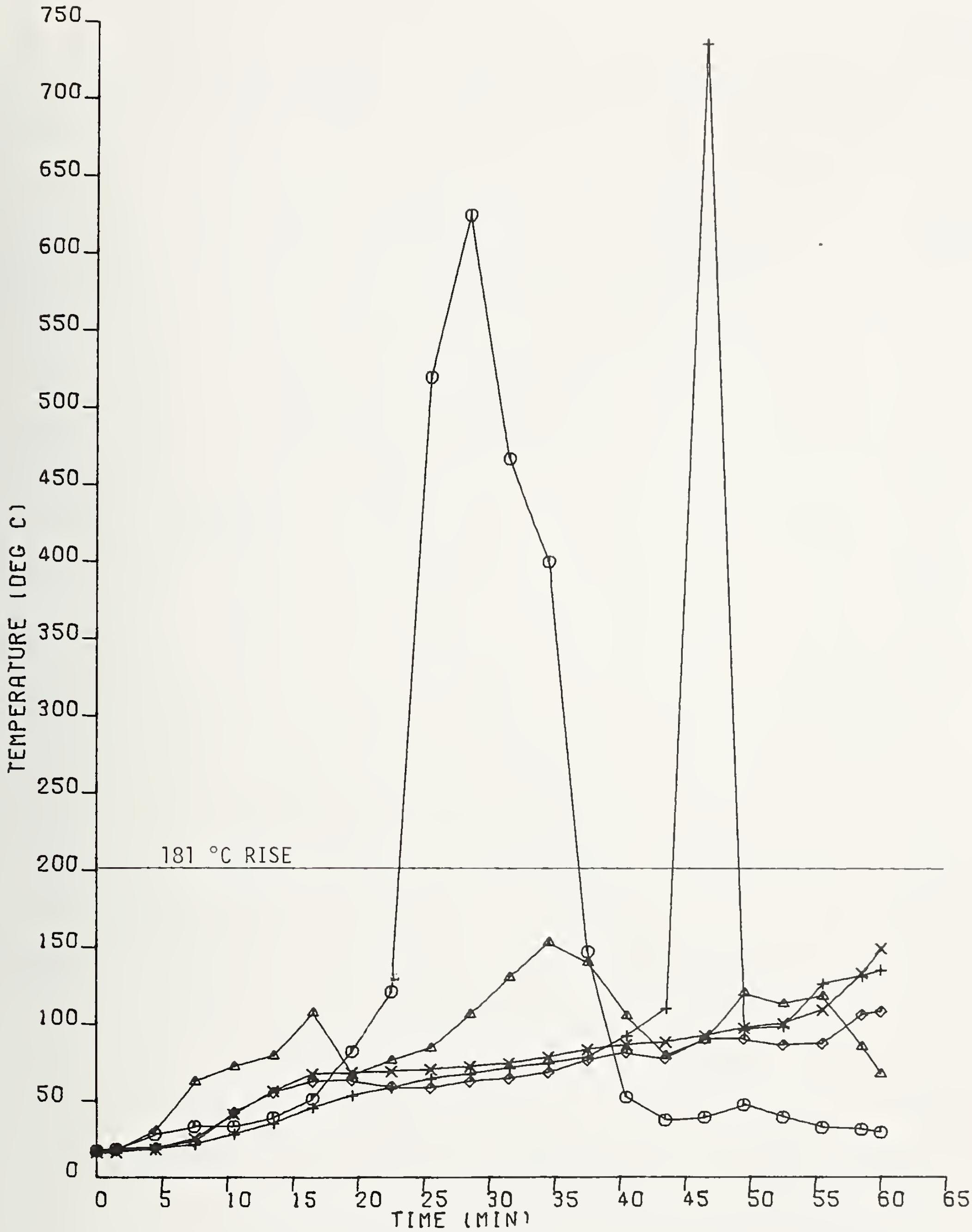


Figure 52. Unexposed lateral and ASTM surface temperature readings in ABS installation (cavity 3) in test 10.



⊕	TC 3	Lower Lateral
△	4	Upper Lateral
+	10	Lower ASTM Thermocouple
×	11	Upper ASTM Thermocouple in Line with Stack
◇	12	Upper ASTM Thermocouple to Left of Stack

Figure 53. Unexposed lateral and ASTM surface temperature readings in PVC installation (cavity 4) in test 10.

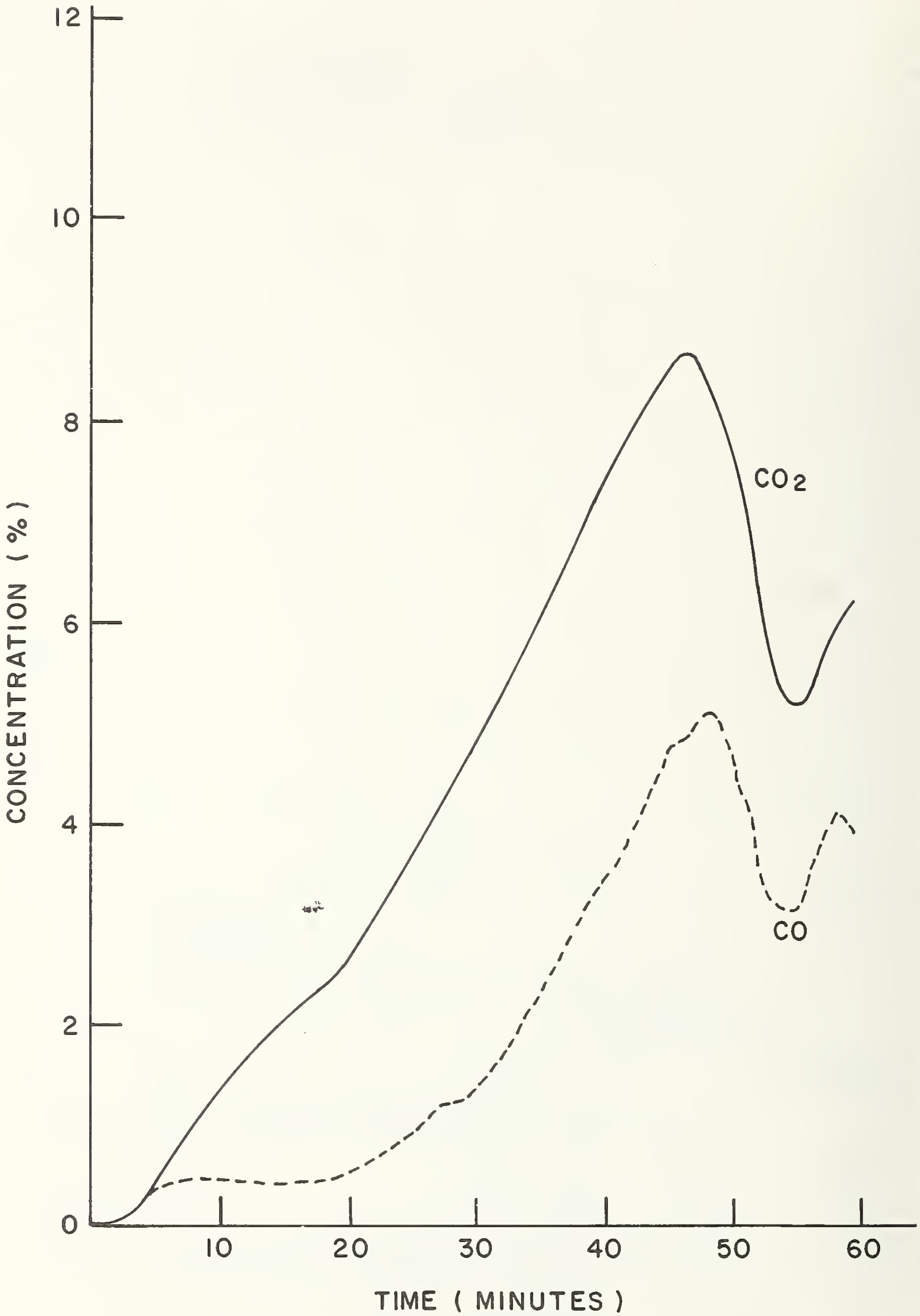


Figure 54. Carbon monoxide and carbon dioxide concentration in chase 1, test 1.

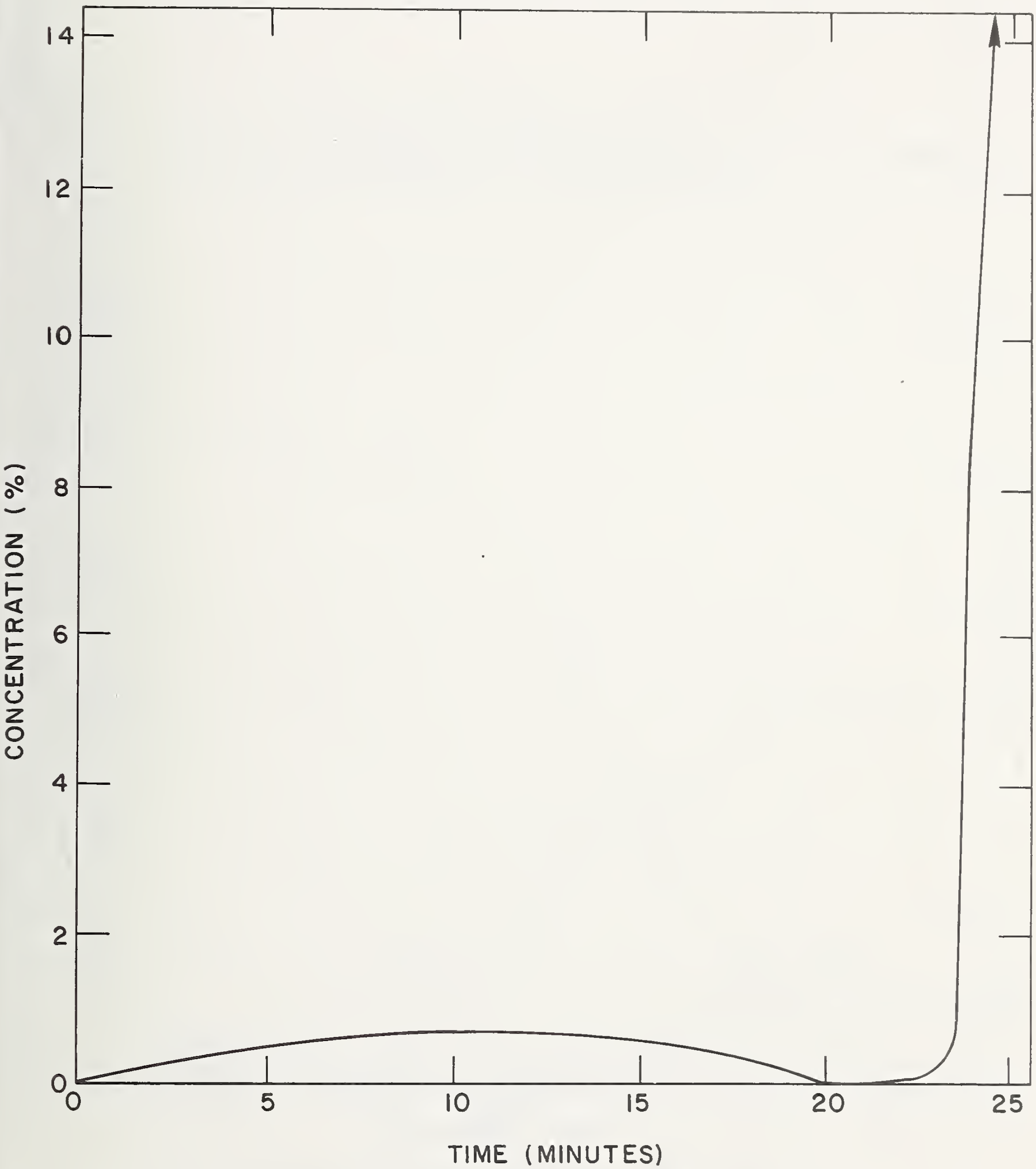


Figure 55. Carbon monoxide concentration in chase 5, test 2.

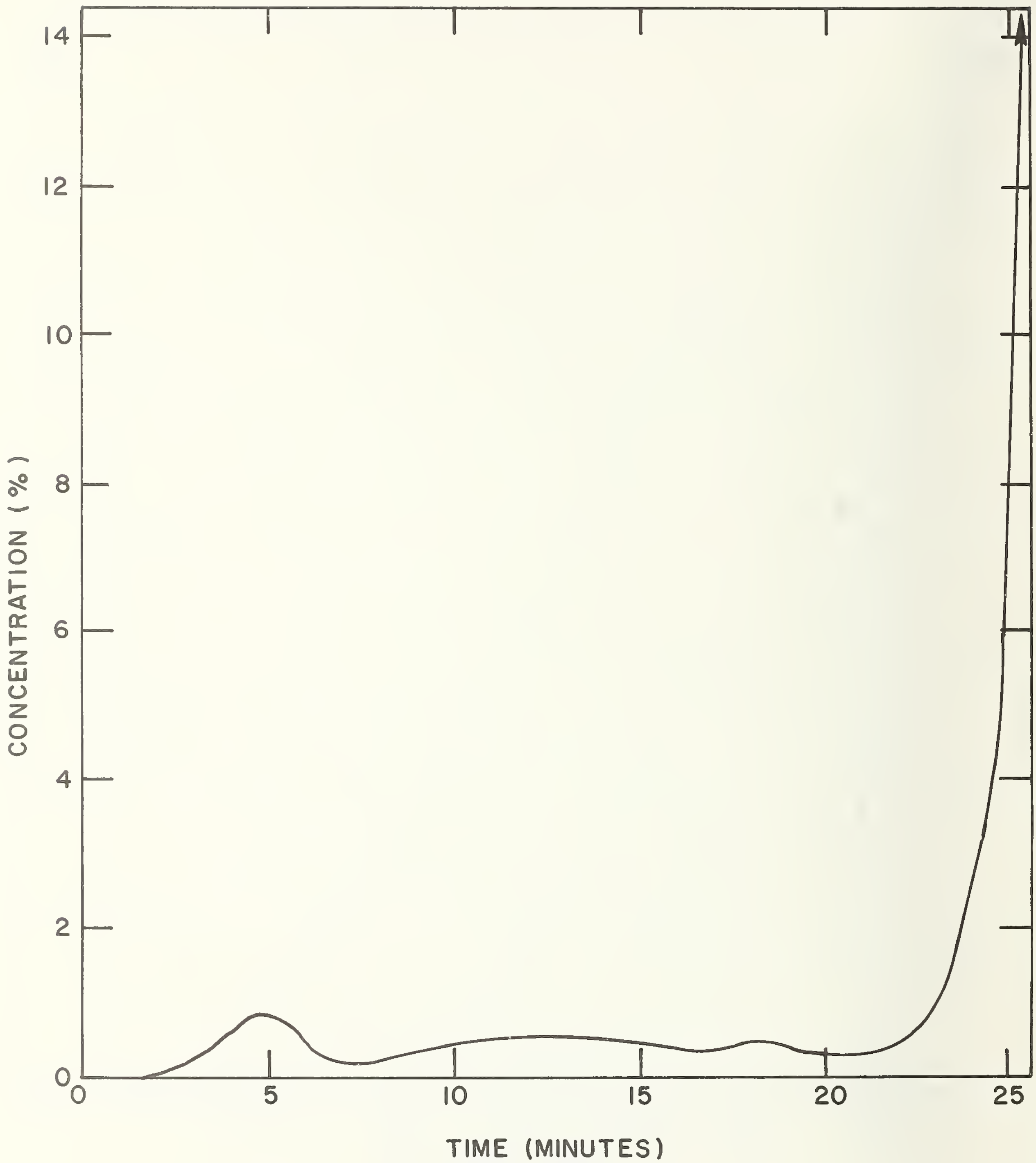


Figure 56. Carbon monoxide concentration in PVC installation (cavity 1) in test 3.

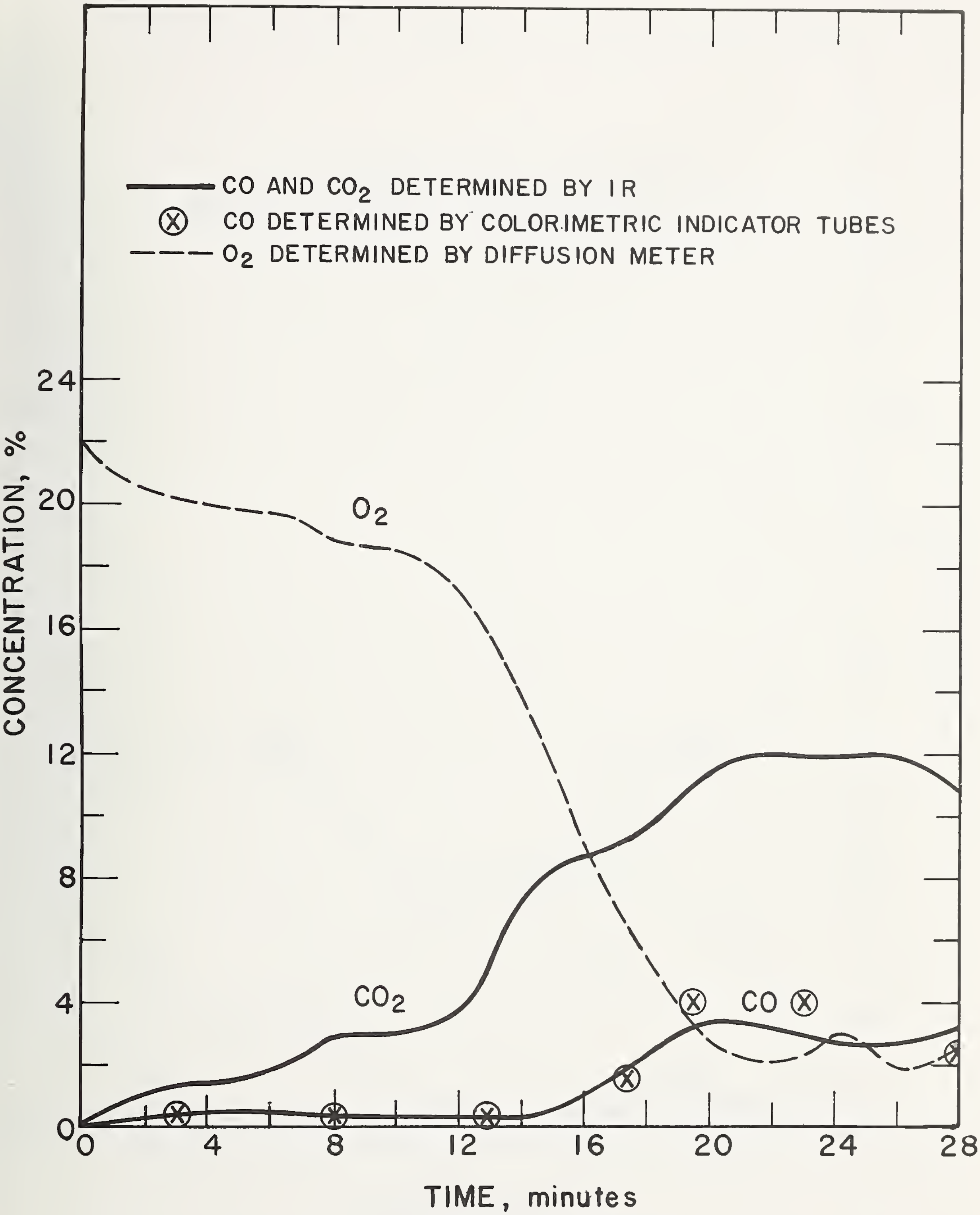


Figure 57. Gas concentrations in ABS installation (cavity 1) in test 6.

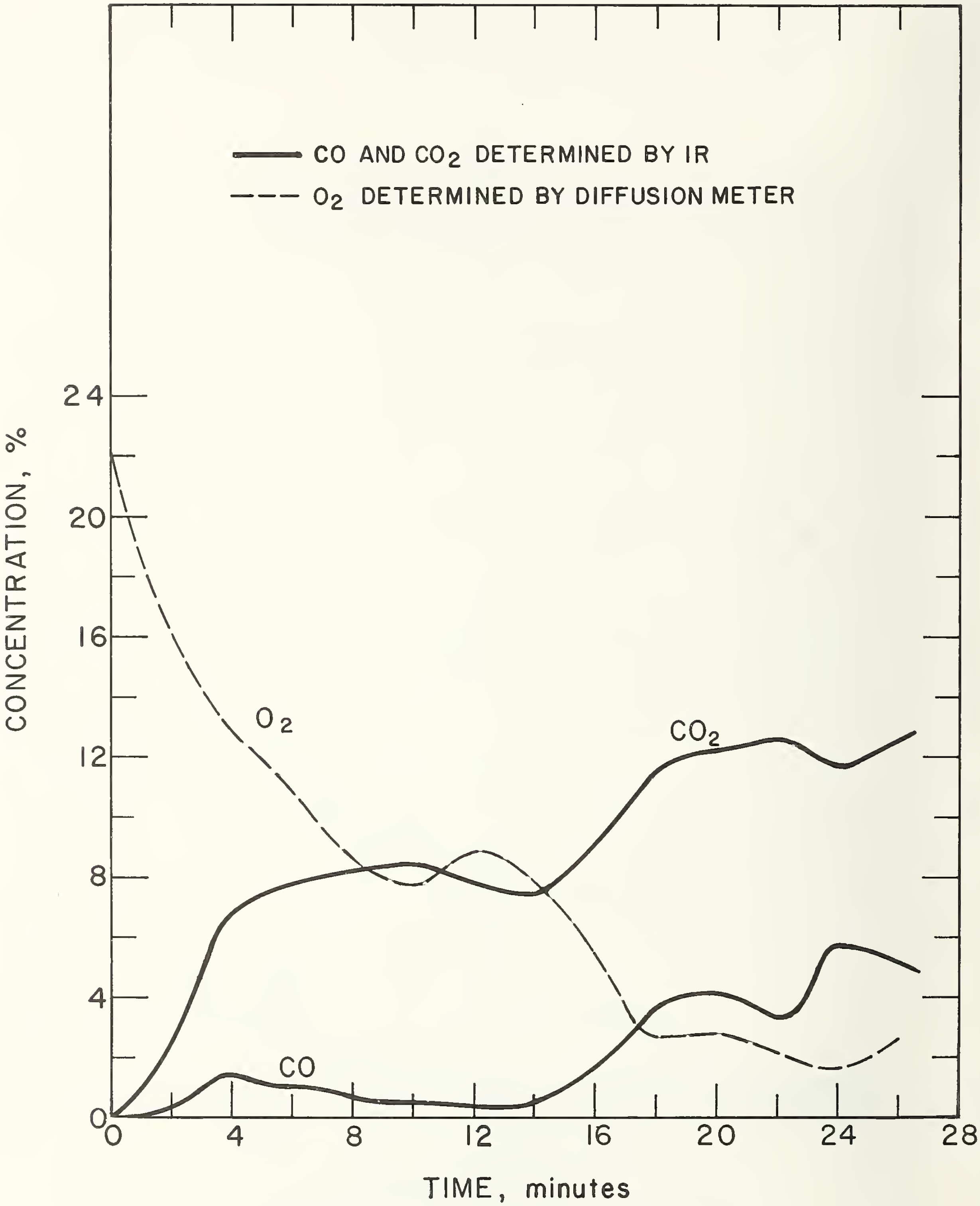


Figure 58. Gas concentrations in ABS installation (cavity 2) in test 7.

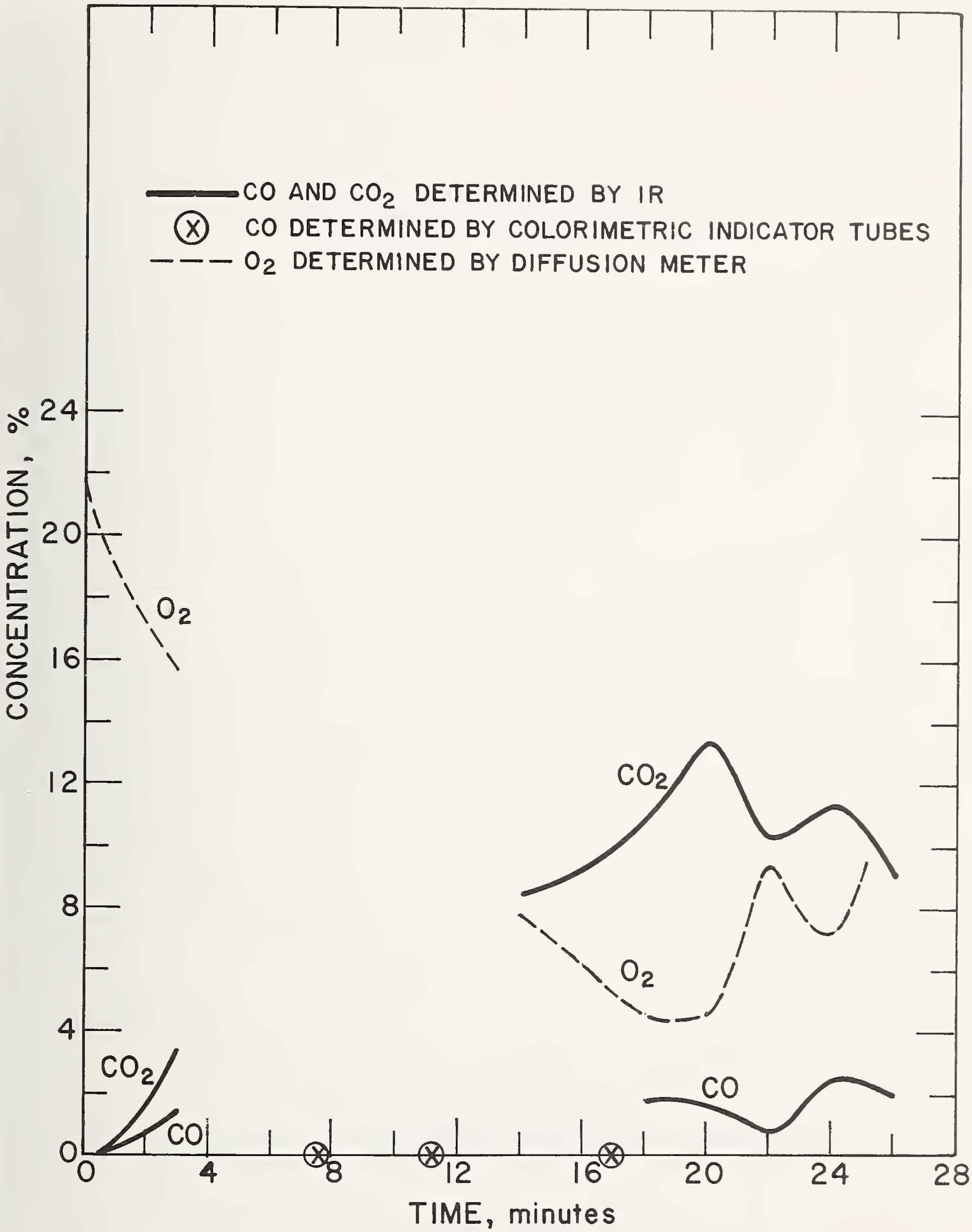


Figure 59. Gas concentrations in PVC installation (cavity 4) in test 7.

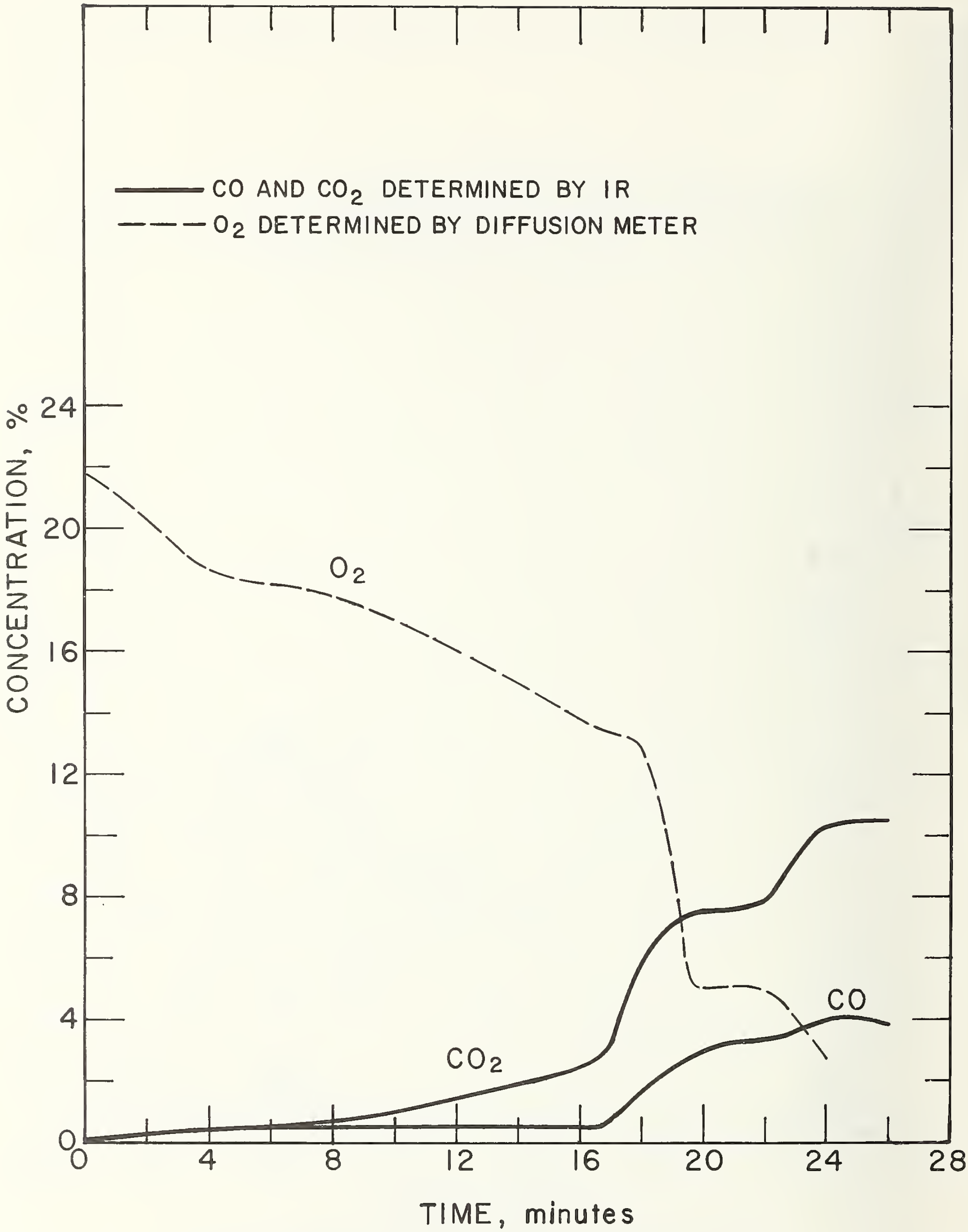


Figure 60. Gas concentrations in ABS installation (cavity 3) in test 8.

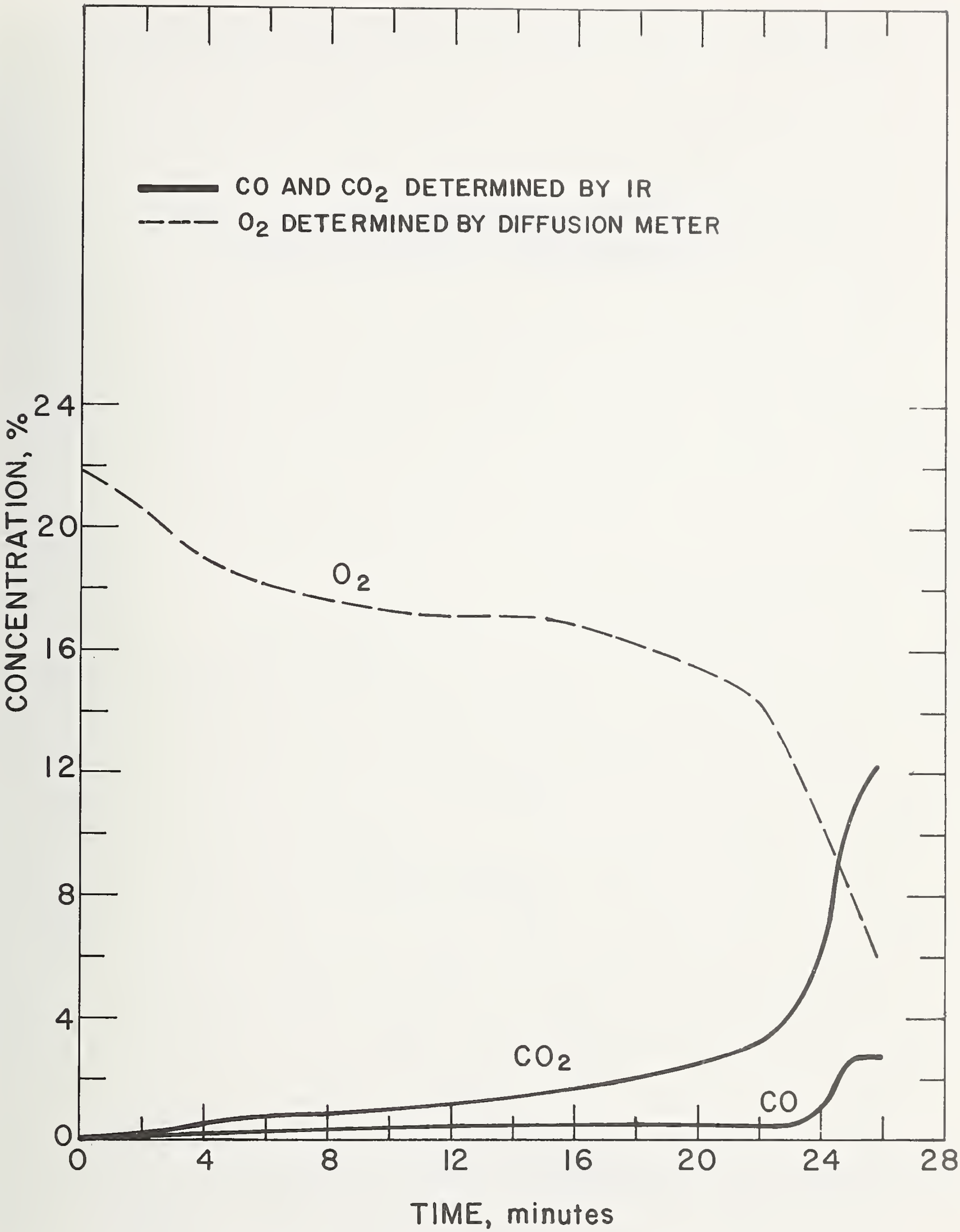


Figure 61. Gas concentrations in PVC installation (cavity 4) in test 8.

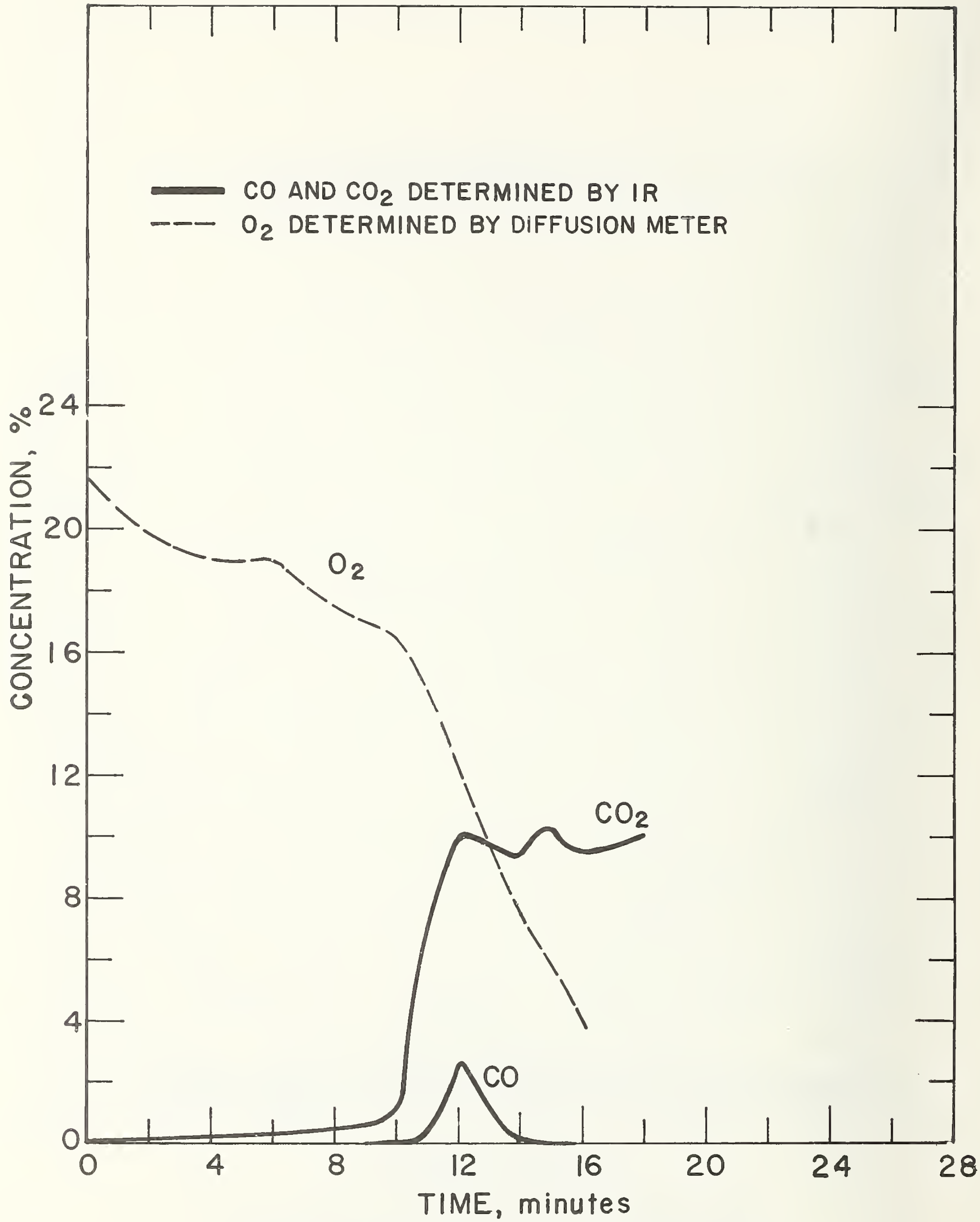


Figure 62. Gas concentrations in ABS installation (cavity 3) in test 10.

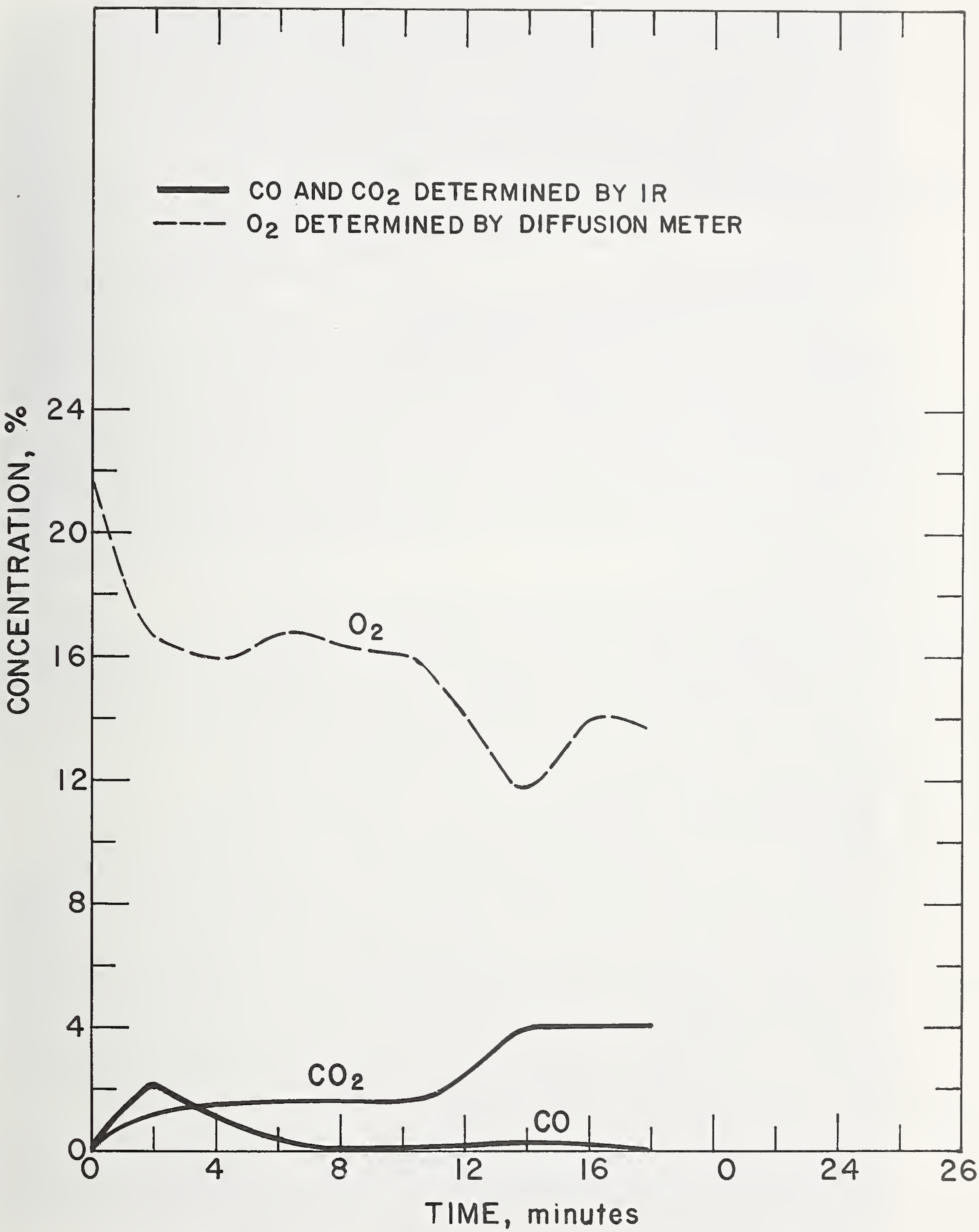


Figure 63. Gas concentrations in PVC installation (cavity 4) in test 10.

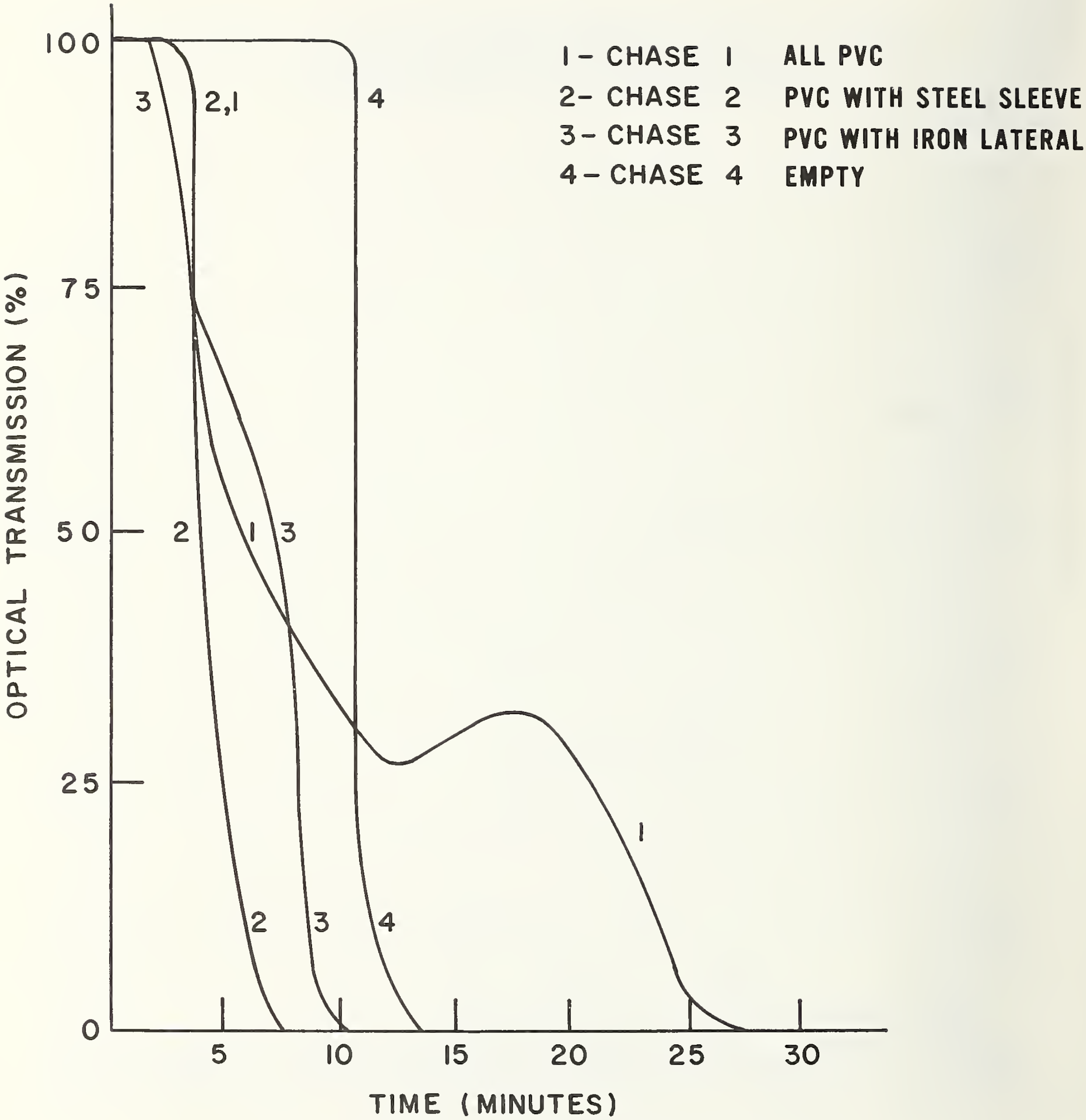


Figure 64. Smoke transmission in test 1.

Figure 65. Exposed gypsum board wall at the end of test 2.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The use of plastic pipe in plumbing systems of multiple-occupancy buildings has raised considerations regarding fire safety. To provide needed data, ten full-scale fire endurance tests were performed involving a total of 39 plumbing chase and wall assemblies containing plastic and metal drain, waste, and vent (DWV) systems typical of installations serving one or two story buildings.

Two tests were conducted using plumbing chase configurations simulating kitchen sink drain systems. The PVC DWV piping in these installations did not contribute to spread of fire from one side of the construction to the other.

Six fire endurance tests were conducted in which the performance of ABS, PVC, copper and iron was compared directly in kitchen sink drain systems as installed in wood-stud and gypsum-board walls. The stacks ranged from 2 inch to 4 inch in diameter and the laterals from 1-1/2 inch to 4 inches. In these tests it was noted that the plumbing configuration and wall construction details, particularly the sealing of plumbing penetrations, seriously affected the fire endurance of the barrier. Satisfactory performance was achieved when certain conditions were met.

In the two tests involving nominal 2 by 4 steel-stud-and-gypsum-board walls it was determined that the one-hour fire resistance rating of the wall was reduced considerably when ABS or PVC DWV was installed within it using the construction details described in this report. These details included back to back 1-1/2-in diameter laterals feeding directly into 2-in diameter stacks.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

ABS; DWV; fire endurance; fire spread; fire test; gases; plastic pipe plumbing; PVC; smoke.

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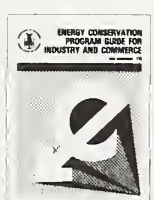

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