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Fire Endurance Tests on Walls and Plumbing Chases Containing Either Metallic or Nonmetallic Drain Waste and Vent Systems

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

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Interim Report

Prepared for
Office of Policy Development and Research
Department of Housing and Urban Development
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary
NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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FIRE ENDURANCE TESTS ON WALLS AND PLUMBING CHASES CONTAINING EITHER METALLIC OR NONMETALLIC DRAIN WASTE AND VENT SYSTEMS

William J. Parker

Two full scale non-load bearing ASTM E-119 fire endurance tests were performed on plumbing chase and wall assemblies containing polyvinyl chloride (PVC) drain, waste, and vent (DWV) systems typical of installations serving two or more stories. For the systems tested which were typical of kitchen sink drain systems constructed and installed according to typical plans, the PVC piping did not contribute to the spread of fire through the plumbing chase to the adjoining dwelling during the test which lasted 50 minutes. A test failure not associated with the plastic piping aborted the test but there was no indication that there would have been a failure due to the piping if the test had continued for one hour.

Three full scale non-load bearing ASTM E-119 fire endurance tests were also run on walls with enclosed DWV systems of acrylonitrile butadiene styrene (ABS), PVC, copper, and iron.

Neither PVC nor ABS piping contributed to fire spread in a plumbing system consisting of 2-inch stacks and 1-1/2-inch back-to-back laterals in a 2 x 6 fir-stud-and-gypsum-board wall. In one test in which the stacks and laterals were 4 inches in diameter and in another test in which the distance between wall surfaces was decreased by using 2 x 4 studs, the effective fire endurance rating of the wall assembly was reduced by the installation of the plastic plumbing.

This progress report on the fire endurance evaluation of five plumbing chase and wall assemblies is limited to construction assemblies in which the openings around the laterals were carefully sealed with plaster spackling. Additional tests are in progress to examine the effect of leaving the openings unsealed.

Key words: ABS; cast iron; copper; drain; fire endurance; fire spread; fire test; Operation BREAKTHROUGH; plastic pipe; PVC; smoke; toxic gases; vent; waste; plumbing.

1. INTRODUCTION

The use of plastic pipe in the plumbing systems of multi-story and multiple occupancy buildings raises two important questions in regard to its behavior in fire. Will the plastic pipe serve to spread fire to other floors and dwelling units when the fire 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? The National Bureau of Standards, under the sponsorship of the Department of Housing and Urban Development, established a research and test program to help answer these questions.

The contribution of plastic plumbing to the fire spread potential between floors and dwelling units may be of three types:

1. The fire could spread from the room of origin along the burning pipe inside the wall or inside the chase[1/] cavity.

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

3. Hot gases from the burning room could enter the chase or cavity through the hole left by the burning of the plastic pipe. The rate of movement through such a hole would depend largely on the difference between the pressure in the room and in the cavity. The pressure difference could be large, especially when considering stack effect in the case of high-rise buildings.

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

To evaluate the potential severity of the fire problems, five full scale non-load bearing fire tests involving plastic and metal plumbing systems have been performed in this research and test program. The results of these tests, and subsequent tests being planned, should provide the technical data necessary to develop guidelines for the use of plastic plumbing systems and to suggest criteria for their acceptances 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 and chase, or shaft construction; the pressure

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[1/] In recent years, the term "chase" in plumbing usage had connoted a shaft constructed specifically to enclose the plumbing piping in a fire resistant construction.

in the chase in the case of highrise buildings, the particular plastic material, the pipe size, the type of fittings, and the details of installation, particularly the manner in which the pipe penetrates the wall.

The full scale fire tests described in this report were designed to simulate the construction of a typical kitchen sink or lavatory drain system made of either plastic or metal. Fires in such locations could be very intense in the vicinity of the trap due to the common use of wood cabinets and the common practice of storing household chemicals and other combustibles under the sink. The configuration chosen represents the typical condition involving exposure to one side of a straight wall, although a potentially more severe condition could result if the piping enclosure extended into a room to give exposure to two or three sides. The design test duration was taken as 1 hour since this is a normal requirement for an interdwelling wall to protect the occupants of an adjacent apartment.

Earlier full scale fire tests were performed at NBS on ABS DWV[2/] in cooperation with the ABS Institute, Inc. in 1970 (Reference 1). The experimental procedures used in the present tests are similar to those employed in the earlier ones.

2. TEST PROCEDURE

2.1 Construction

2.1.1 Test 1

A wall assembly 10 feet high by 16 feet long nominally listed to have a onehour fire endurance rating was built into a test frame of the NBS wall furnace. The wall was constructed of 2 x 4 fir studs with one layer of 5/8 inch type X gypsum board on each side and with nailing and joints taped according to the descriptions in the listing (Reference 2). Four plumbing chases with interior plan dimensions of 20 x 20 inches and heights of 12 feet were attached to the side of the wall opposite the furnace. As may be seen in figure 1, the interior of each chase was lined with 5/8 inch type X gypsum board likewise were the outer walls of the chases and the portion of the firerated wall alongside the chases. This type of chase construction complies with the performance recommendations of Operation BREAKTHROUGH (Reference 3) for an interdwelling wall. All chases were closed at the top and bottom. The side of the wall opposite the chases formed the closure of the NBS wall furnace and was subjected to the fire exposure.

The arrangement of the chases on the test wall permitted the simultaneous testing of four chases. Only one side of the chase was exposed since this would be the typical case in a real room fire. Chase 1, shown in Figure 2, had a 4 inch PVC stack and three 11/2inch PVC laterals[3/]. One lateral near the bottom of the chase passed through the wall into

[1/] DWV refers broadly to drain, waste, and vent piping.

[2/] Throught the report the word "lateral" is synonymous with "Fixture drain" or "trap arm" passing through the chase wall.

furnace. The furnace pressure at the point of penetration of the lateral was +0.02 inches of water. This represents a maximum fire generated pressure which might be expected 20 inches above the floor in a room involved in fire. The other laterals passed through the opposite wall of the chase, one at the same elevation and one 8 feet above. 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 either on the same floor or on the floor above. The openings around all of the laterals in this and succeeding tests were sealed with plaster spackling and covered with escutcheon plates. An expansion joint in the 4 in. stack was located at the simulated second floor level. The traps were filled with water and held in place by wires to simulate the attachment ment 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 arrangement permitted an appreciable induced air flow 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 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.

In chases 2 and 3 modifications of the installation in Chase 1 were tested for possible improvement in 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 sleeves were short lengths cut from 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 against fire penetration.

The installation in chase 3 which is shown in figure 4 was similar to that in chase 1 except that the PVC laterals were replaced by laterals of galvanized iron. The laterals penetrated the chase wall at the same elevation but the connections of the laterals to the stack were made at a point below the neutral pressure plane in the furnace which was the simulated floor level in the chase. This necessitated the incorporation of a vertical length of a 2-inch galvanized-iron pipe and a change from a reducing double sanitary tee to a reducing double upright wye with a similar change at the upper lateral as may be 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.

2.1.2 Test 2

The construction of the wall and chase assembly was revised 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. This single layer protection is permitted within dwelling units when plumbing is run in a partition wall instead of inside a chase. In such construction, the burning of either the plastic plumbing stack or the wood studs could supplement the other, since there was only one layer of gypsum board separating the furnace and the stacks. This construction 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. In chase 7 a hubless cast iron stack was used with PVC laterals, as seen in the sketch and photograph in figures 9 and 10, to simulate a configuration that has been employed in Operation BREAKTHROUGH. 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 galvanized-iron DWV systems installed inside a typical dwelling separation wall was made in the third test. The basic DWV configurations of chases 1 and 5 were repeated except that 2-inch stacks were used, which 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 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 may be seen in figure 14.

2.1.4 Test 4

The construction of the wall and the ABS, PVC, copper and galvanized-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 the same materials and configurations as Test 3, but the stacks were 4-inch instead of 2-inch and a hubless cast-iron stack was used instead of the galvanized iron stack. The galvanized iron lateral was still used with this stack. 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. For ABS and PVC the 1-1/2-inch laterals were connected to a 4-inch double sanitary tee at the lower part of the stack and to a 4-inch 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. This protrusion is shown in the sketch in figure 15. While this type of installation is not typical, it does occur occasionally in housing construction and represents a very severe case. The copper and iron DWV systems used the appropriate reducing tees and consequently their hubs did not protrude. 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. The construction details for these 5 tests are summarized in table 1.

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 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 16. The thermocouple locations for tests 3, 4 and 5 are described in Table 3. ASTM thermocouples, (under felted asbestos pads) were used on the unexposed surfaces. 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 the first test. The light source was a tungsten filament lamp and the detector was a phototube with a type S-4 surface. Concentrations of CO and HCl in the chases and in the comparable wall cavities were determined with commercial colorimetric detector tubes. Additionally, CO and CO_2 concentrations were recorded continuously using commercial infrared gas analyzers. Pads of cotton were occasionally placed in contact with the unexposed surface of the chase wall in order to test for the possibility of ignition from the passage of hot gases through cracks or openings in the wall. The cotton pads were USP absorbent cotton[4/]. The velocity of the air entering the bottom of the stacks was monitored periodically with an anemometer.

2.3 Conduct of the Tests

The test frame containing the wall with the installed DWV or the combination wall and chase assembly was placed in position in the NBS wall furnace and 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 help regulate the pressure inside of the furnace, and the open area under the test frame was adjusted during the test to keep the pressure at the lateral into the furnace equal to +0.02 inches of water. The natural gas flow to the furnace was controlled during the test in order to follow the prescribed ASTM standard E-119 time-temperature curve

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[4/] Also called cotton wool.

(Reference 4) which is shown in figure 17. Temperature and smoke readings were recorded at one minute intervals on punched paper tape and gas concentrations were sampled by hand pump approximately every five minutes. The presence of flames or temperatures hot enough to ignite a cotton pad on the unexposed surface of the chase was noted. Color photos were taken at frequent intervals during the test.

Although the tests were planned to run for one hour, they were stopped when the heat or flame penetration of the wall 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 while the last two tests were run for the full 60 minutes. 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

The fire tests were run between June 1972 and May 1973.

3.1 Visual Observations During the Tests

The visual observations made during these five tests are recorded in the appendix.

3.2 Thermocouple Data

Figure 18 compares the temperatures of the unexposed surface of the chase walls, the temperatures of the laterals measured at the point where they come through the wall surface on chase 5, and the maximum unexposed surface temperature permitted by the ASTM E-119 test procedure. The temperatures at similar locations for the other chases in this test were nearly the same and in no case exceeded 100°C. The highest temperature recorded on the unexposed wall of chase 1 was 43°C and the highest temperature recorded on the laterals outside of this wall and 31°C. Figure 19 through 30 make the same comparison for each of the DWV systems examined in test 3, 4, and 5.

3.3 Cotton Pad Test

There was no ignition of the cotton pad in contact with the unexposed surface of any of the chases or in contact 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. The cotton in contact with the copper lateral was charred but the pyrolysis gases were able to escape without igniting. There was no ignition of the cotton pads for any of the DWV systems in Test 4. In Test 5, flames came out at the ABS lateral at 27 minutes and at the PVC lateral at 58 minutes. There were no cotton pads placed on the laterals in this case. There was no ignition of the cotton in contact with the metal laterals in Test 5.

3.4 Gas Concentrations

The gas concentrations measured with 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 volume cavity (2 x 4 wood-stud wall). The CO and CO_2 concentrations measured with the infrared analyzers are shown in figure 31 for chase 1. The CO concentration for chase 5 is shown in figure 32, and for the PVC installation of test 3 in figure 33, up to the time the measurements had to be stopped due to the buildup of water in the inlet piping to the infrared analyzer. HCl is a very reactive gas that tends to be adsorbed on surfaces very rapidly. This may explain why some HCl readings are lower than expected.

3.5 Smoke Density

The transmission of light through the upper section of the chases in Test 1 is compared in figure 34. There was a malfunction in the recording system for the smoke meters in the second test and they were not used in any of the subsequent tests because the wall cavities were too small to accomodate the instrumentation. Furthermore it was decided that it was not possible at the present time to relate the smoke density in the cavity to the penetration of smoke into the room on the unexposed side of the wall.

3.6 Visual Observations After the Test

3.6.1 Test 1

Chase 1 is shown after the test in figure 35. The collapse of the stack took place after the test was over. The charring of the stack was due to some debris which fell on it. The lateral leading to the furnace was burned off 5-1/2 inches from the tee at the point of attachment of the number 2 thermocouple. The burning of the lateral did not extend beyond the inside layer of gypsum board. The inside of the remaining lateral was partially closed off due to char formation leaving a 1 inch diameter passage through it. The damage inside chase 1 could be regarded as slight.

Figure 36 shows chases 2 and 3. In chase 2 the lateral burned a distance of about 2 inches into the sleeve and closed the remainder of the lateral off by char formation. The scorch on the stack just above the lower lateral in chase 3 is probably also due to the presence of hot debris which fell on it after the test. The damage in these two chases could also be regarded as slight.

3.6.2 Test 2

The unexposed side of the chases can be seen in figure 37. The P-trap hanging down along the wall was removed from its lateral after the test. Although the P-traps sagged on the unexposed side of the chases (due to inadequate wire support), they remained in place and did not pass flame or hot gases sufficient to ignite cotton pads during the test. The upper laterals pulled out of the stacks in chases 5, 6, and 7 and then sagged on the inside of the chases making it impossible for the P-traps to fall. The lower laterals on the unexposed side of the stack in chases 5 and 7 remained intact. In chase 6 the lower laterals remained in the sleeves attached to the walls. In chases 5 and 7 the laterals on the exposed side of the stack burned past the wall into the chase, pulled out of the reducing double sanitary tee and fell to the bottom of the chase. The stacks in chases 5 and 6 melted down into a mass about 4 feet long, and congealed around the thermocouple wires used to measure the temperature in the gas stream. The damage in chase 5 can be seen in figure 38. Although there was a considerable amount of charring of this mass there was no evidence of flaming. The hubless cast iron stacks in chases 7 and 8 remained in place and the neoprene gaskets in the clamps appeared to be in good condition after the test.

3.6.3 Test 3

The condition of the DWV installations after Test 3, which was stopped at 55 minutes, can be seen in figure 39. The copper and galvanized iron stacks were still standing. The ABS stack was completely consumed and the PVC stack had some fragments left which amounted to less than 10 percent of the original pipe. Figure 40 shows the lower PVC trap on the unexposed side of the wall about 15 minutes after the test was terminated. The paper on the gypsum board wall was charred by the penetration of high temperatures through the wall, yet the PVC P-trap remained undamaged.

3.6.4 Test 4

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, and were completely sealed off at this point due to char formation in the interior of the pipe.

3.6.5 Test 5

The ABS pipe in the wall ignited and was extinguished by an internal sprinkler system in the ABS cavity at 33 minutes. The furnace was shut down after 60 minutes terminating the test of the other three sections. 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 about 5 minutes after the test was terminated.

4. DISCUSSION

4.1 Fire Performance of DWV in Plumbing Chases

The first two fire tests were designed to determine whether some typical PVC DWV systems could be a potential source, or 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 might be. The tests showed that the systems installed with the openings around the lateral sealed were generally satisfactory and hence modifications were not recommended. No flames and only a minor amount of smoke penetrated into the "adjacent dwelling unit" areas during the test period. The highest temperature recorded on the unexposed wall of chase 1 was 43°C and the highest temperature recorded on the laterals at the unexposed side of this chase was 31°C. The highest temperatures at the equivalent locations on chase 5 were 95°C and 64°C 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. 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.

The gas supply to the furnace had to be shut down in 45 minutes in the first test due to a breakthrough of flames between the wall and the test frame. 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 and was rising rapidly. Figure 41 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 rise of the unexposed surface of the walls between the other chases were well below 181°C at the time the test was terminated.

During the first test the concentration of HCl measured in the chases was an order of magnitude lower than the CO concentration. In the later tests involving the walls it was found that the CO levels in the cavities containing the metal DWV was as high as that in the cavities 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 threshold limit values (Reference 5) 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 ppm of CO will produce unconsciousness in about 30 minutes

(Reference 6). After one half hour the indicated concentrations of HCl in the chases included in Test 2 were beyond the range of the measurement system which was 2000 ppm. In an actual installation it is possible that the HCl would have been essentially confined to the chase and much of it absorbed in the moist walls.

During the tests 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 penetration holes. Although this source would be present in practice, it did not appear to be a serious factor from these tests.

A suggested test procedure and set of acceptance criteria with respect to fire spread which were met by all of the DWV installations in the first two tests are given in Appendix II.

4.2 Fire Performance of DWV in Wood Stud Walls

In the third test, PVC was compared with ABS and two metal DWV systems installed within a 2 x 4 wood stud wall. There was a flamethrough at 42 minutes around the lower ABS lateral. Because of this early failure the condition of the wall was such that the test had to be terminated after 55 minutes. Except for the case of the ABS system, flame did not spread to the unexposed side of the wall, but a 181°C 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 rise in the PVC pipe at the same location was 120°C at 55 minutes and was rising very slowly. The mechanisms for these high temperature rises were simply heat conduction through the metal laterals and heat conduction, in conjunction with flame spread, in the case of the ABS lateral.

The failure due to a 181°C temperature rise at one of the three ASTM thermocouples located on each section of the unexposed surface of the wall occurred at 48 minutes for ABS and 53 minutes for PVC. The highest temperatures were at the highest elevations on the wall. There were no failures due to 181°C temperature rises on the sections 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. Where the gypsum board panels associated with the plastic DWV fell away from the adjacent wall sections, the temperature rises recorded were as high as those for the wall sections containing the plastic pipe. Those panels protecting the metal plumbing did not break up and the adjacent empty wall sections were not approaching failure at the end of the test. 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 the damage to the part of the wall containing the PVC piping.

The construction used in the fourth test was the same as that in the third test except that the 2 x 4 studs were replaced by 2 x 6 studs thereby providing a larger 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 rise 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 the fifth test 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 created an especially severe situation in which flames came out of the lower ABS lateral on the unexposed side of the wall in 27 minutes. An excessive temperature rise was recorded in 55 minutes by one ASTM thermocouple on the section of wall containing the PVC. At the same time, the paper in one area of the unexposed surface of the gypsum board burst into flame. At 58 minutes flames came out of the lower PVC lateral on the same side of the wall.

When the lower part of the plastic stacks started to soften the upper sections began to descend and pull in the laterals. This caused the seals around the lateral penetrations to rupture which then allowed large quantities of smoke to escape. If this smoke were confined in a normal sized room, the conditions 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 is illustrated in Table 6. Although a 1-1/2 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 to be located totally within the wall. If this space is provided, it appears that both PVC and ABS can be used safely; if it is not, both are susceptible to failure. One lesson learned in these tests is the importance of using reducing double sanitary tees instead of using double sanitary tees fitted with reducers, at least in those cases where the space is severely restricted. Although it would appear that there would be an economical advantage to using the reducing tees, it is not uncommon for a supplier to fill orders for reducing tees by substituting regular tees with reducer inserts. (The number of items in his inventory is reduced by such practice.) If the space provided within the wall or chase is only adequate to enclose a reducing tee, the use of a regular tee with inserts could result in a serious reduction in fire endurance time. This point cannot be over emphasized.

Whereas the metal plumbing in these tests was not responsible for any failures of the wall with regard to flame-through or temperature rise on the unexposed surface of the wall in excess of 181°C, there were temperature rises on the surface of the copper lateral well over 181°C due to its high thermal conductivity. Should the maximum permitted rise on the unexposed surface specified by the E-119 criteria 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 this temperature from the specification. If the surface of the lateral is permitted to rise more than 181°C, why should this restriction still apply to the surface of the wall? For a wall with pipe openings the restriction on the surface temperature rise could hardly be relaxed without removing the requirements for walls in general. But 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 which could be applied to the pipe on the unexposed side of the wall, however, is that of determining whether materials in contact with the pipe will ignite. 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. Although the copper lateral reached 500°C in Test 3, the cotton pad in contact with the pipe only browned and charred without igniting. Thus there was no failure of the wall sections containing the copper DWV according to this criterion.

4.3 Fire Performance of DWV in General

Gas concentrations were measured inside the chase or wall cavities during these tests. This location was chosen to give a comparison between the toxic gases peculiar to burning plastic and the CO generated by the burning of wood and paper in a well defined space. However, the actual concentrations of the gases in these spaces is not the important consideration 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 therein, made the measurement problem so difficult with the colorimetric tubes that the measurements were terminated early in all but the first test.

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

In order to provide exhaustive guidelines for the use of plastic pipe in DWV systems in buildings it will be necessary to examine many more conditions than were covered in these initial tests. There are many variables which need to be considered in connection with the location of DWV within walls and chases and the nature of the penetrations of these vertical enclosures. These include the type of piping material, size of piping, wall material, construction and dimensions, pressure differences and lateral protection. The effect of unsealed holes around the lateral is probably very important. Ceiling penetrations and location of DWV in the space between the floor and ceiling are other important problems that need to be investigated.

5. CONCLUSIONS

The following conclusions may be drawn based on the five fire tests just completed. These apply to constructions in which the openings around the laterals where they penetrate the walls are sealed.

1. A PVC DWV system in a plumbing chase, similar to that used in a residential construction did not spread fire from one side of the construction to the other for a period of 50 minutes and would not be expected to fail within 60 minutes. (Premature failure of wall was not directly related to the DWV installations in the chase.)

2. Under the design conditions applicable to these tests the HCl contributed by the PVC DWV did not reach concentration levels as high as those of CO. However, further measurements of the toxic gas concentrations extended over the duration of the tests are needed to prove this point.

3. The fire endurance of a one hour fire rated 2 x 4 wood-stud-and-gypsum-board wall will be reduced to less than one hour when PVC or ABS DWV is installed within it using the common plumbing configuration and construction details described for test 3 of this report. Under the conditions of this test the section of the wall containing the ABS failed by direct flame penetration to the unexposed surface, whereas the assembly containing the PVC failed by excessive temperature rise (at a later time).

4. Because of their high thermal conductivities, the temperature rise on the unexposed copper and galvanized iron laterals in Test 3 exceeded 181°C within one hour when tested in the same way as the plastic pipes. A 181°C temperature rise at any point on the unexposed surface of the wall constitutes a failure by the ASTM E-119 acceptance criteria. There is however no requirement in ASTM E-119 placed on the surface temperatures of pipes penetrating through the surface.

5. The fire endurance of a one-hour fire-rated 2 x 6 wood-stud and gypsum-board wall was not reduced below one hour with PVC and ABS DWV installed within it using the common plumbing configuration and construction details described in this report.

6. In order to maintain the fire endurance rating of a wall with back-to-back plumbing fixtures, it is important that reducing double sanitary tees be used rather than double sanitary tees fitted with reducing bushings. This is particularly true if the hubs of the double sanitary tees protrude through the gypsum board on each side of the wall.

7. The openings around the laterals where they pass through the wall must be completely sealed off with an adequate packing material such as spackling.

8. Support of the stack at each floor level will eliminate some of the strain on the laterals at the point of wall penetration when the stack begins to soften under heat. Excessive strain on the laterals can break the seal at the wall and permit the passage of large amounts of smoke out of the wall cavity.

ACKNOWLEDGEMENT

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7. APPENDIX I

Visual Observations During the Tests

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.

*The P-trap, resembling an inverted siphon, is one of several designs of devises used in drains to provide a water seal.

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).

3.1.2 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 exposed 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 the 5 chase.
20:00	Smoke is now coming from the north joint between chase 7 and wall.
21:00	Still smoke emanating from the top P-traps of chase 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 2/3 the way up chase 5.
23:00	Much smoke out top P-traps of all 4 chases. Also smoke out bottoms of all chases and all 4 bottom P-traps.
24:00	There are cracks (visible openings) at the joint facing the room at chase 7.
25:00	There is a crackling sound caused by burning studs in the wall. There are flames at all 3 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 1/2 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 on exposed side of chase 8 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 on 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 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, apparently 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-trap are hot while at the end of the P-trap the temperature appears to be ambient.
45:00	Top P-traps for chase 5, 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 3 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.

3.1.3 Test 3

Time Min:Sec	Observations
03:00	The ABS P-trap fell off in the furance. 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	Air flow: 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 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 air flow 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 PVC molten 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 some charring of cotton but not ignition around the lower ABS lateral.
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	Air flow is 200 feet per minute into the copper stack

	200 feet per minute into 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 extention 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 thru 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 thru 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 thru 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 both laterals for the copper and charring around lower PVC lateral. Slight charring at the top PVC lateral. No charring around the laterals for the galvanized iron. 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.

3.1.4 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 top of test frame not 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.

3.1.5 Test 5

Time Min:Sec	Observations
01:00	ABS trap is gone.
02:00	PVC trap 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 lateral. This could easily fail test based on 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 cast 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 3/4 height. Flame out around PVC lateral. Test is over. Gas is turned off.

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

Suggested Test Procedure

1. Construct a simulation of the actual assembly, preserving all of the essential features such as pipe material, pipe size, piping configuration, chase dimensions, installation details, etc. Place two thermocouples under felted asbestos pads on the unexposed surface at 3 feet above the simulated floor level and 1 foot below the simulated ceiling level.

2. Fire-expose the side of the chase for which the fire rating is required to the prescribed ASTM E119 timetemperature exposure in a standard wall test furnace. If the exposed wall includes a lateral penetration, the furnace pressure relative to the adjacent test area at the level of lateral 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. Neither of the two ASTM thermocouples located on the unexposed surface of the chase wall shall exceed 181°C temperature rise during the fire rating period. (This is in accordance with the ASTM standard E119 test criteria.)

2. There shall be no passage of flame or heat sufficient to ignite cotton pads at any point on the unexposed surface of the chase within the fire rated period.

At present, there is no standard or established method for measuring thesmoke and gas passing out through any lateral, through the area adjacent to the lateral, or through the hole left by the lateral.

Table 1.

Summary of Construction Details

Test Number	Chase or Wall Cavity Location: Far North	North of Center	South of Center	Far South
1	20 x 20 in. enclosure formed with 2 x 4 in. fir studs and 5/8 in. type X gypsum board on both inside and outside of the chases			
	Chase 1	Chase 2	Chase 3	Chase 4
	4 in. PVC stack and 1-1/2 in PVC laterals	Same as Chase 1 but with steel sleeves on laterals	4 in. PVC stack and 1-1/2 galvanized iron laterals	No piping or penetration
2	Same construction as for Test 1 except that 5/8 in. type X gypsum board was not put inside of the chases			
	Chase 5	Chase 6	Chase 7	Chase 8
	Plumbing same as in Chase 1	Plumbing same as in Chase 2	4 in. hubless cast iron stack with 1-1/2 in. PVC laterals	4 in. hubless cast iron stack with 1-1/2 in. galvanized iron laterals
3	Wall constructed of 2 x 4 in. fir studs 16 in. on center with 5/8 in. type X gypsum board on each side			
	PVC	Copper	ABS	Iron
	2 in. stack and 1-1/2 in. laterals	Same as PVC	Same as PVC	Same as PVC
4	Identical to Test 3 except that the 2 x 4 in. studs were replaced by 2 x 6 in. studs.			
5	Similar to Test 3 except that the wall was formed by a double row of 2 x 4 studs mounted on a 2 x 10 in. plate providing a separation of 9.5 in. between the 5/8 in. type X gypsum board on each side of the wall			
	PVC	Copper	ABS	Iron
	4 in. stack and 1-1/2 in. laterals. Hubs of 4 to 1-1/2 in. reducers protruded through the wall board	4 in. stack and 1-1/2 in. laterals	Same as PVC	4 in. hubless cast iron stack with 1-1/2 in. galvanized iron laterals

Table 2.

Thermocouple Locations in Test 1 and 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 on the unexposed surface of the exposed wall of the chase and one foot below the upper lateral.

13.* ASTM thermocouple on the inside surface of the chase wall away from the furnace and one foot below the upper lateral.

14. ASTM thermocouple on the outside surface of the chase wall away from the furnace and one foot above the lower lateral.

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 outside 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.

(These thermocouple locations are shown in figure 16.)

---

*Not used in Test 2.

Table 3

Thermocouple Locations in Tests 3, 4, and 5

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.

(These locations are shown in figure 13.)

TABLE 4

GAS CONCENTRATIONS IN TEST 1

Time Min:Sec	Phase	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

VARIABLES EXAMINED DURING THE FIRST FIVE FULL SCALE FIRE TESTS

Test Number	DWV Material	Cavity Depth (Inches)	Stack Diameter (Inches)	Lateral Diameter (Inches)	Layers of 5/8 in Gypsum Board Insulation	Failure Mode	Failure Time (Minutes)
1	PVC	20.0	4	1 1/2	2	None	---
2	PVC	20.0	4	1 1/2	1	None	---
3	PVC	3.5	2	1 1/2	1	Temperature Rise	53
	ABS	3.5	2	1 1/2	1	Flame Through	42
4	PVC	5.5	2	1 1/2	1	None	---
	ABS	5.5	2	1 1/2	1	None	---
5	PVC	9.5	4	4	1	Temperature Rise	55
	ABS	9.5	4	4	1	Flame Through	27

* Test run for 45 min.

** Test run for 50 min.

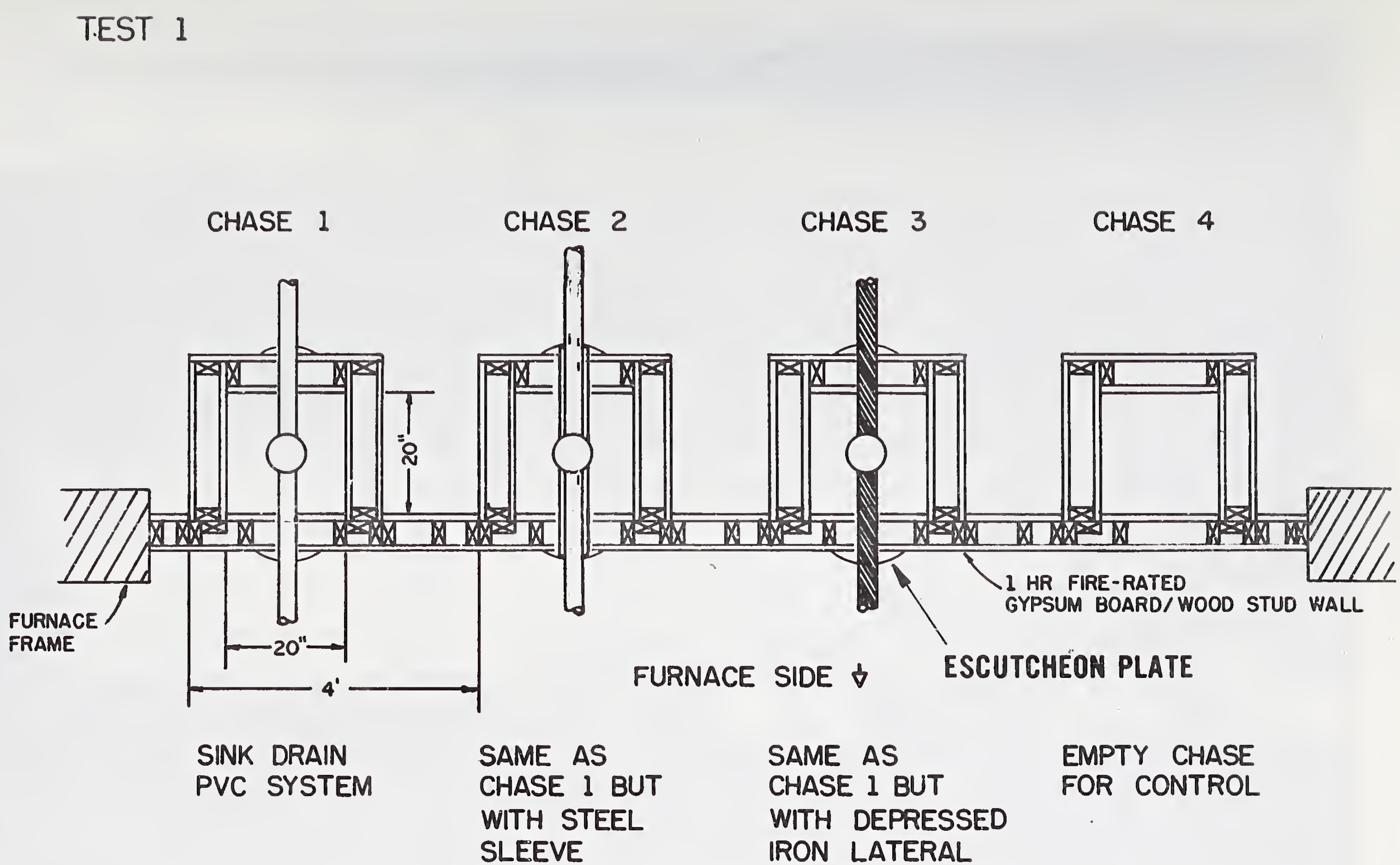


Fig. 1 Plan View of Wall and Pipe Chases for Test 1.

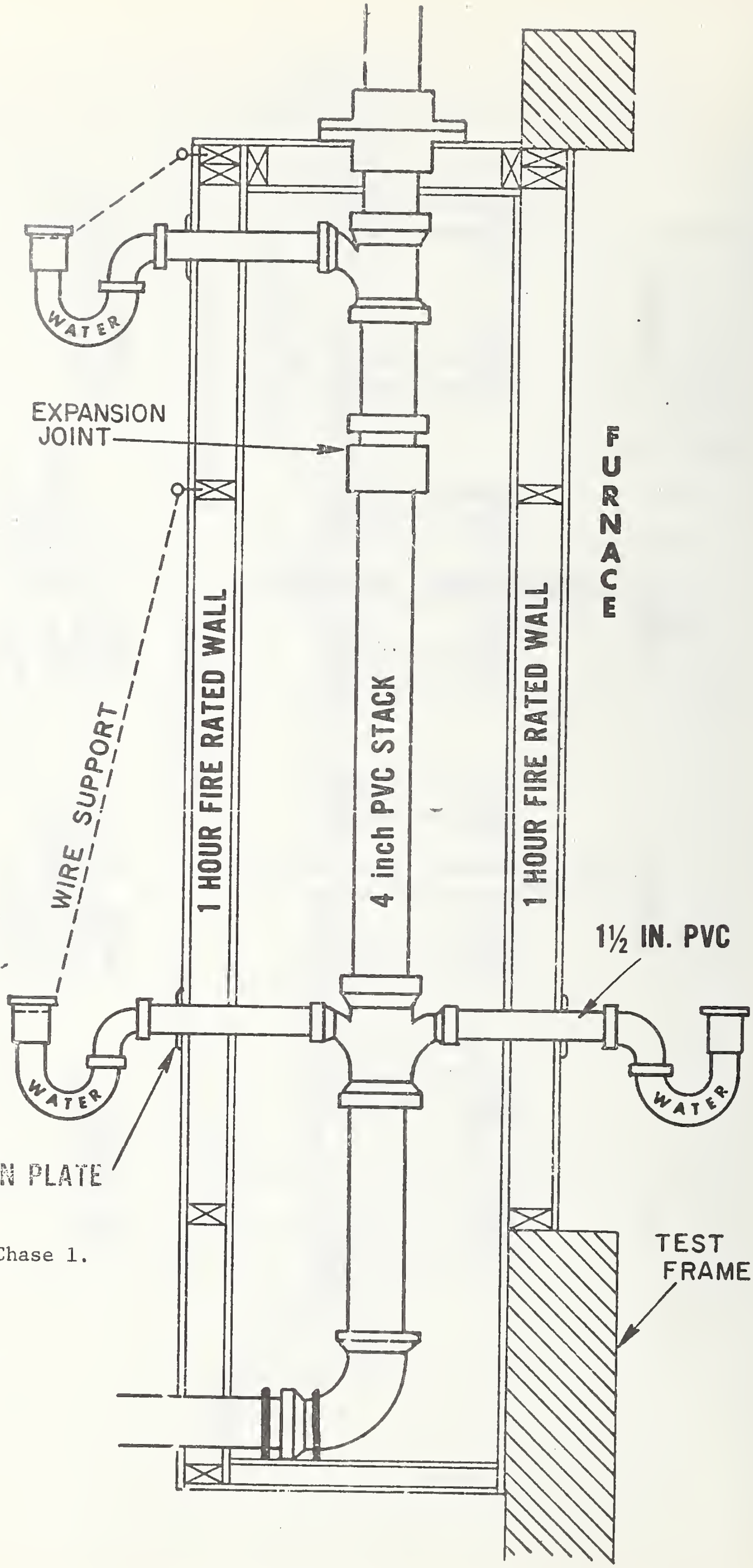


Fig. 2 Sketch of Chase 1.

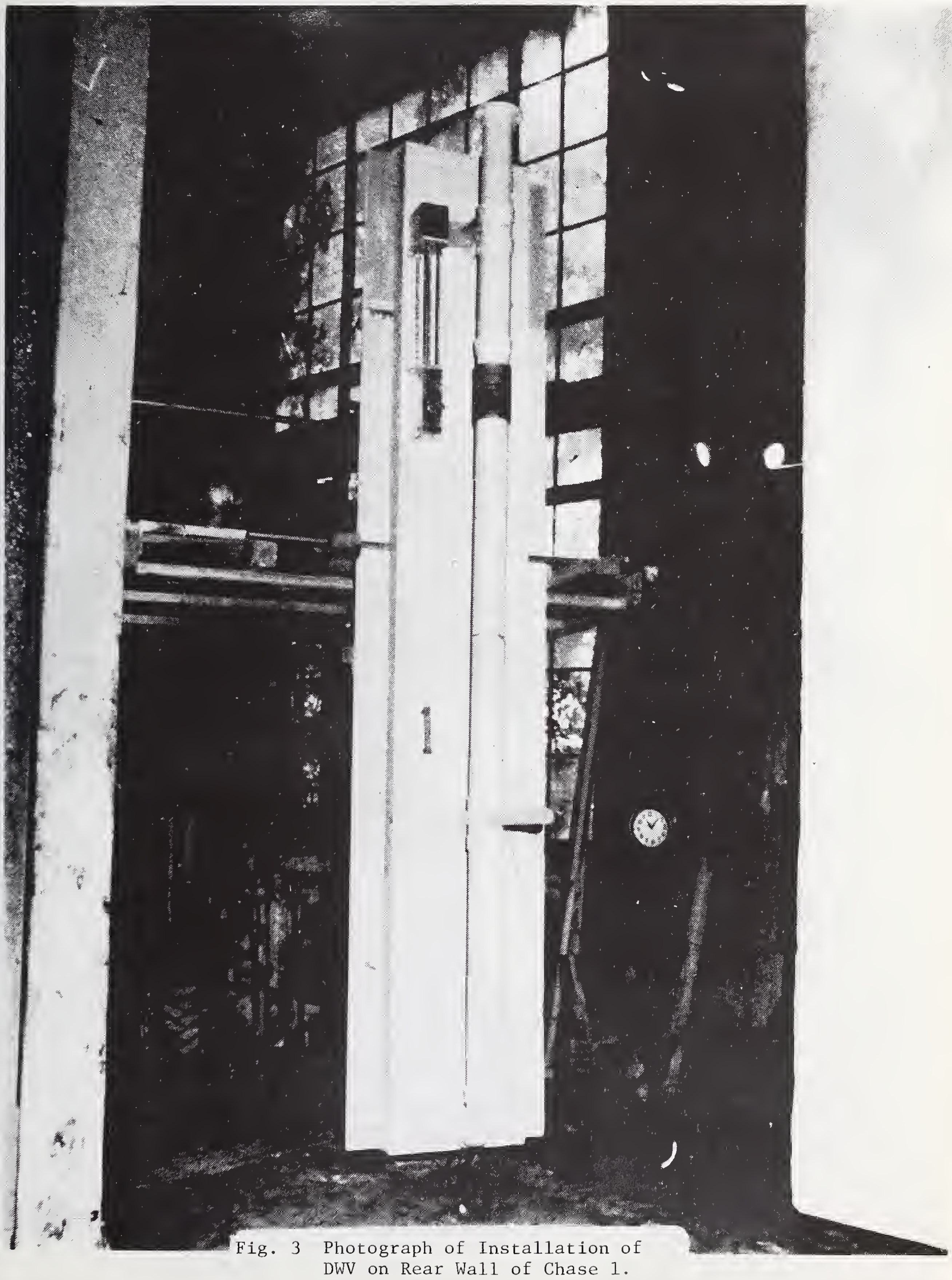


Fig. 3 Photograph of Installation of DWV on Rear Wall of Chase 1.

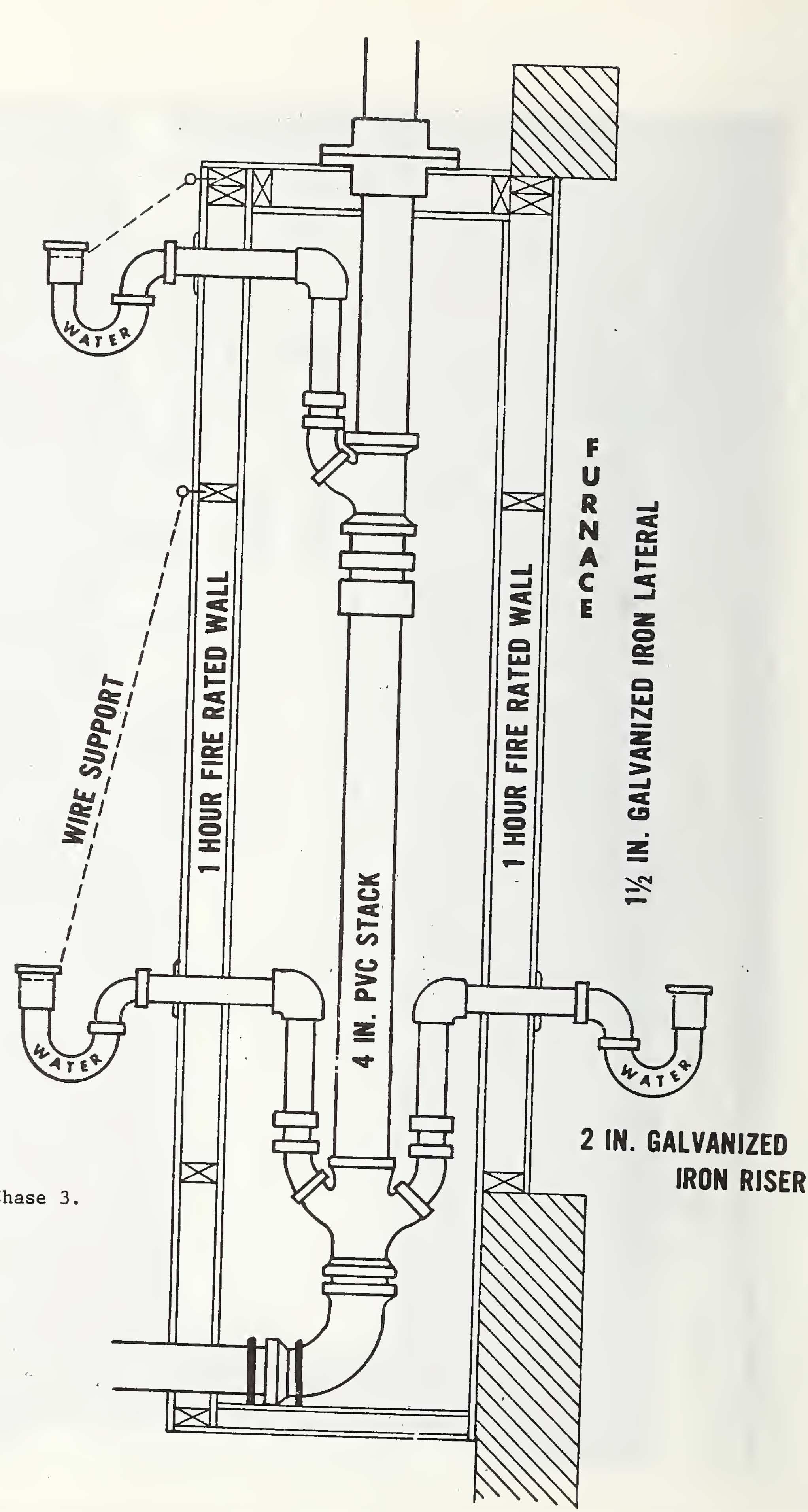


Fig. 4 Sketch of Chase 3.

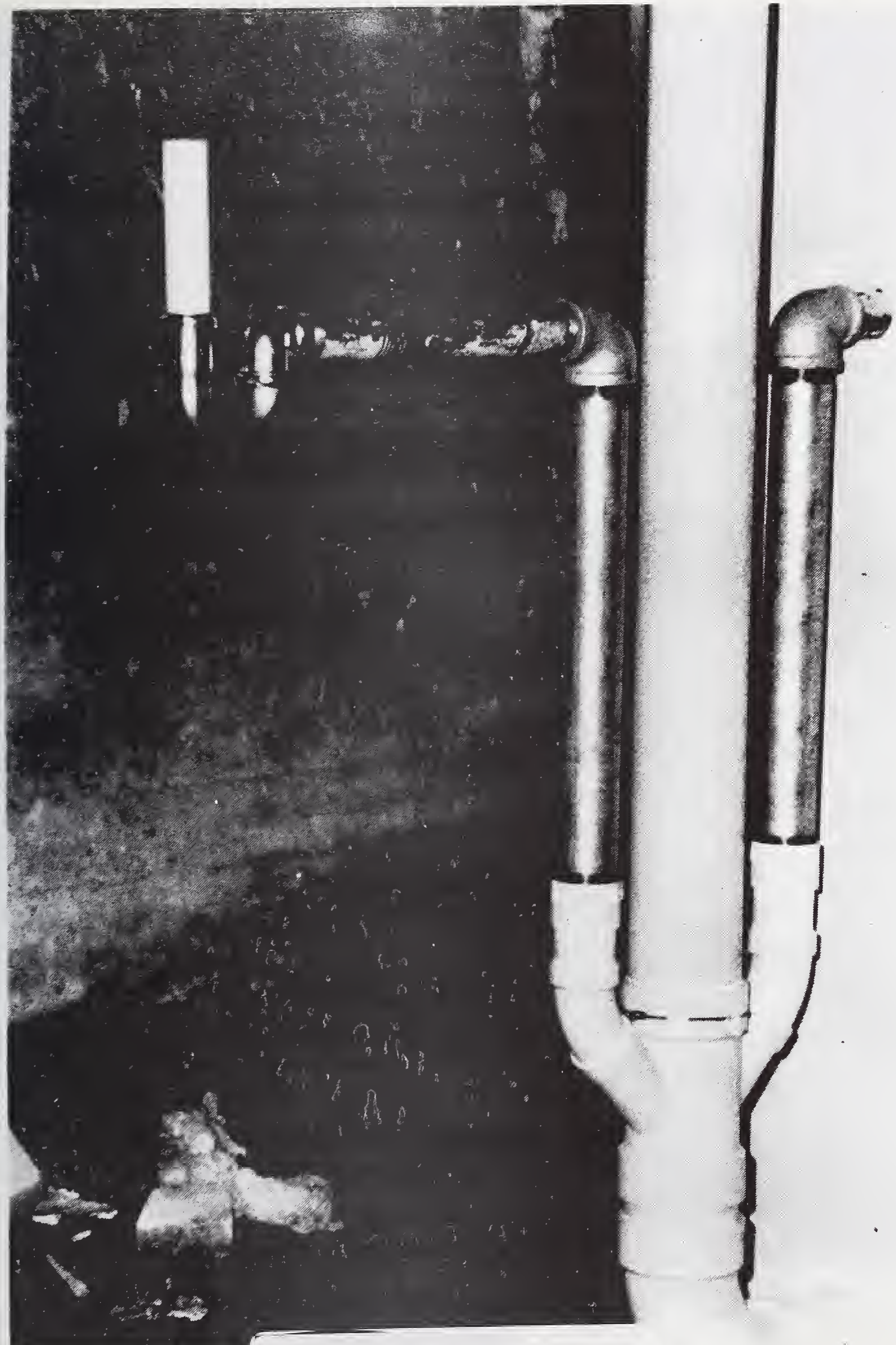


Fig. 5 Photograph of Lower Laterals in Chase 3.

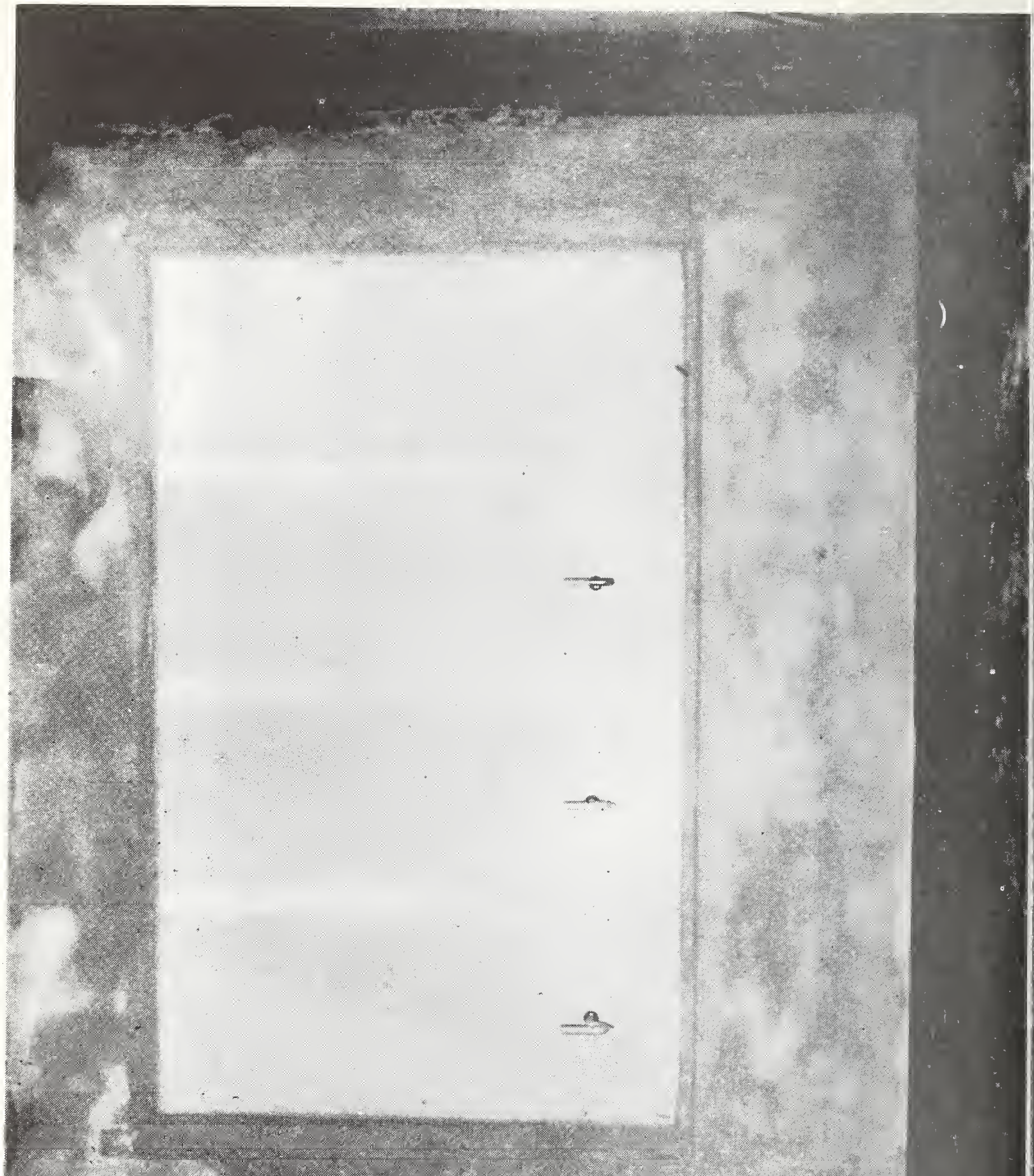


Fig. 6 Photograph of Exposed Wall on Test 1.

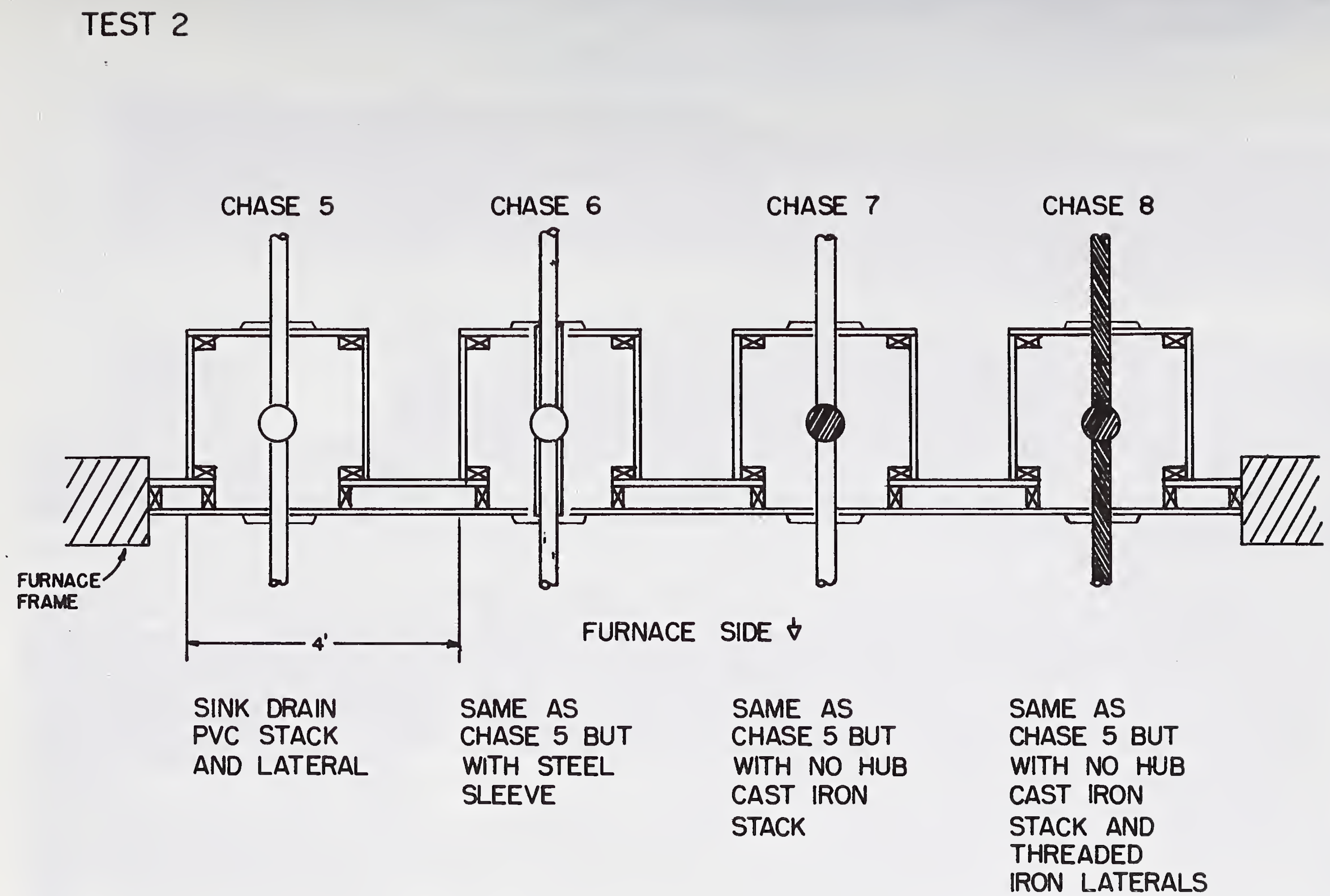


Fig. 7 Plan View of Wall and Pipe Chases for Test 2.

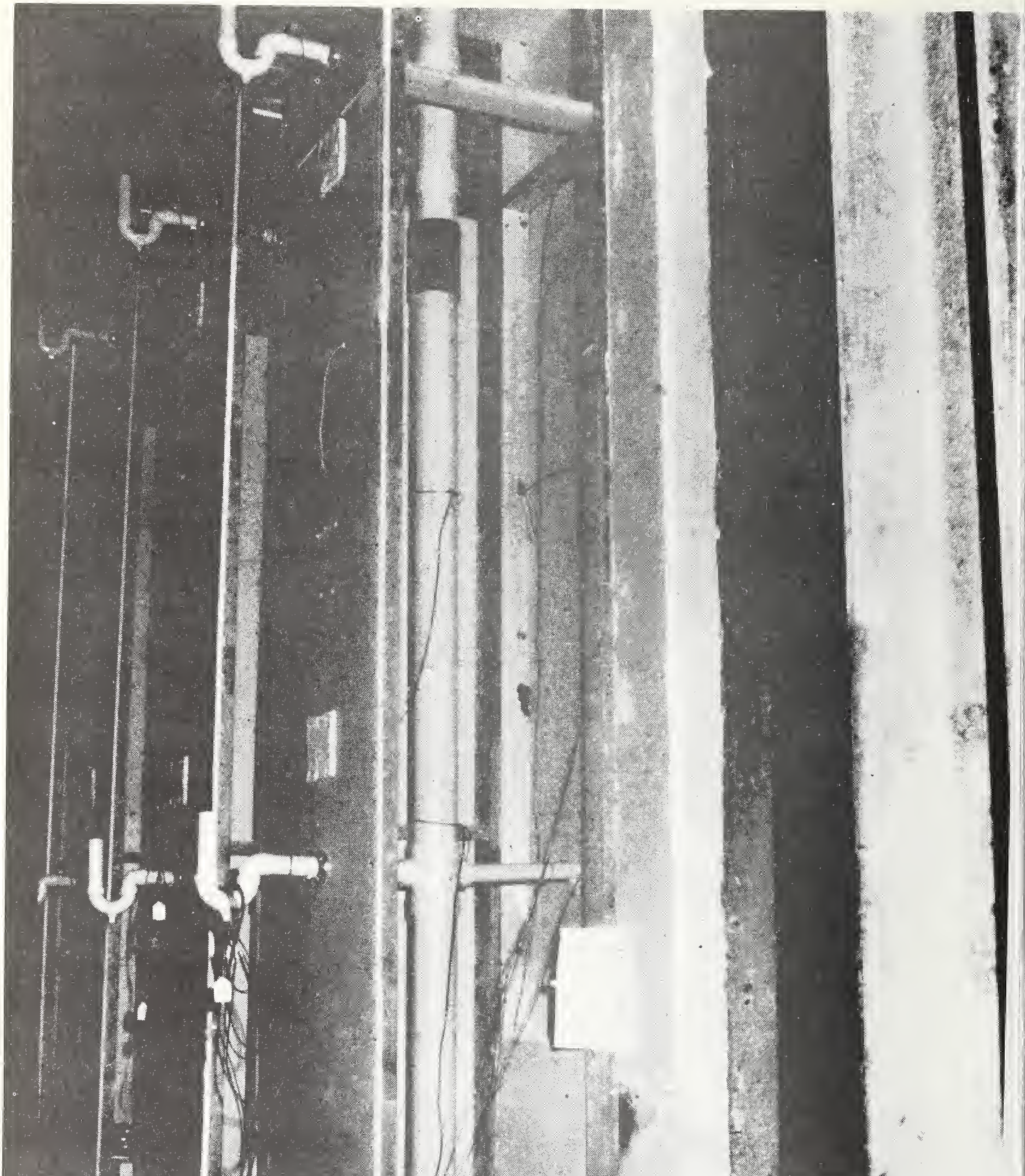


Fig. 8 Photograph of Chase 5 with Side Removed.

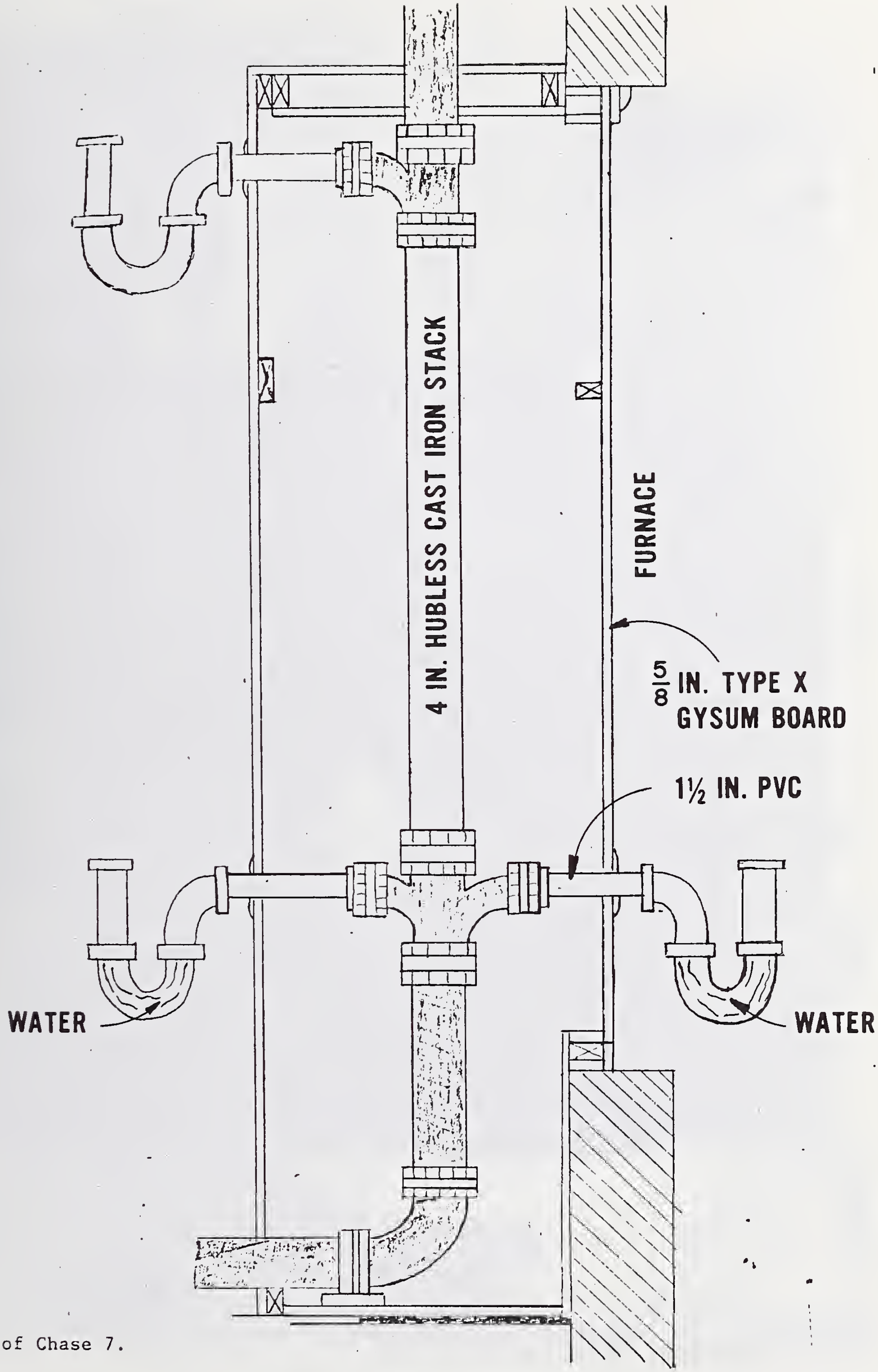


Fig. 9. Sketch of Chase 7.

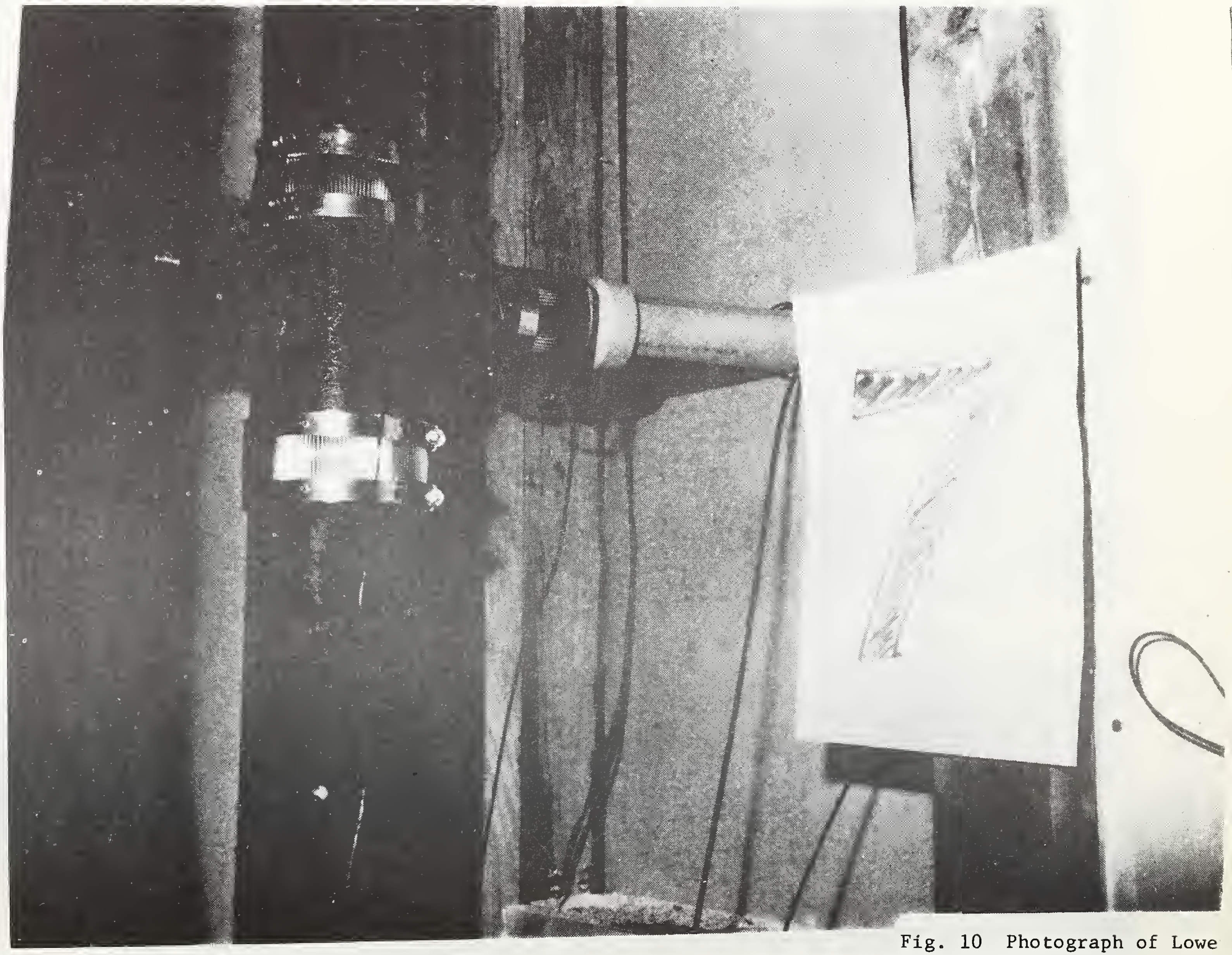


Fig. 10 Photograph of Lowe on Chase 7.

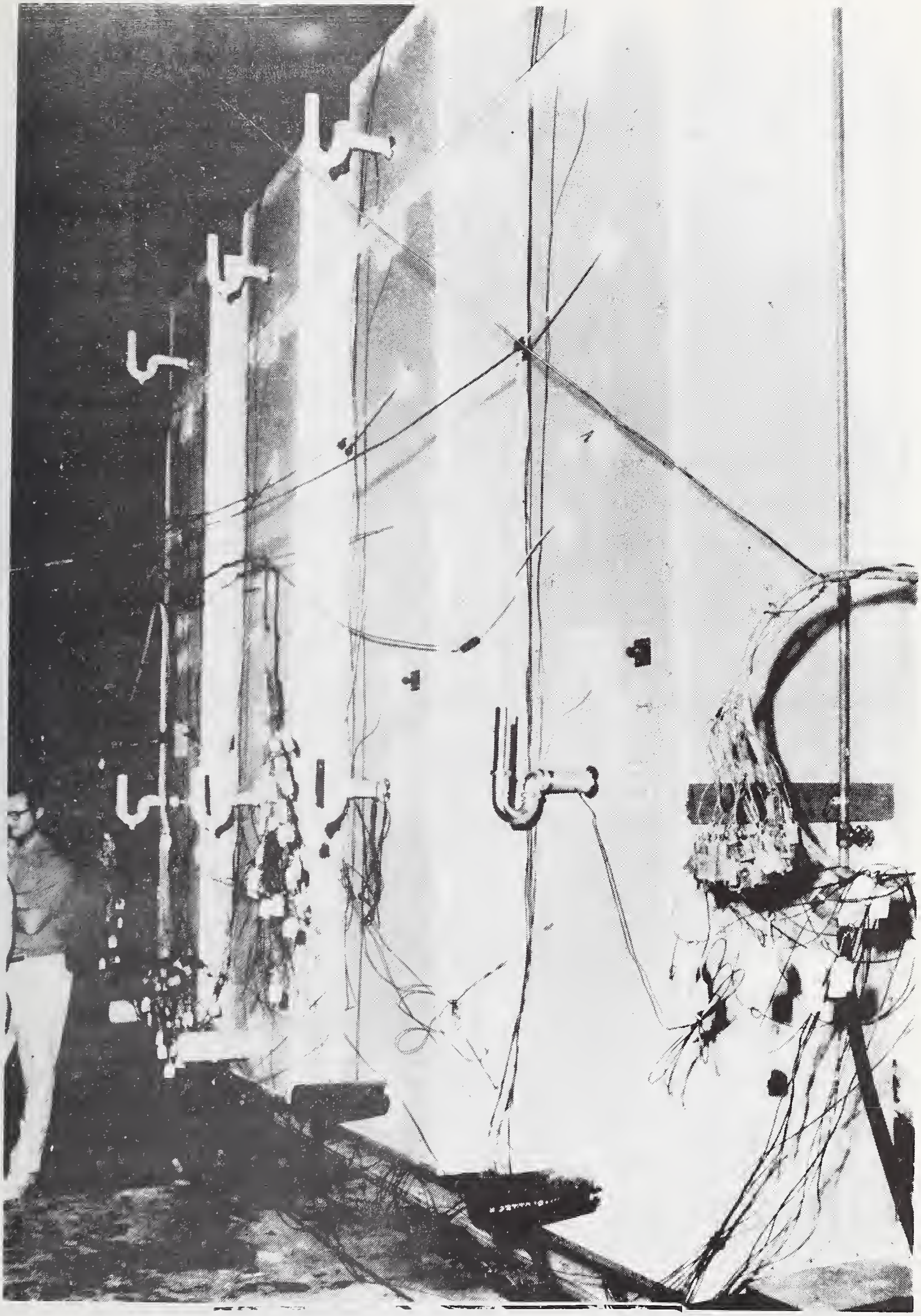


Fig. 11 Photograph of Chases in Test 2.

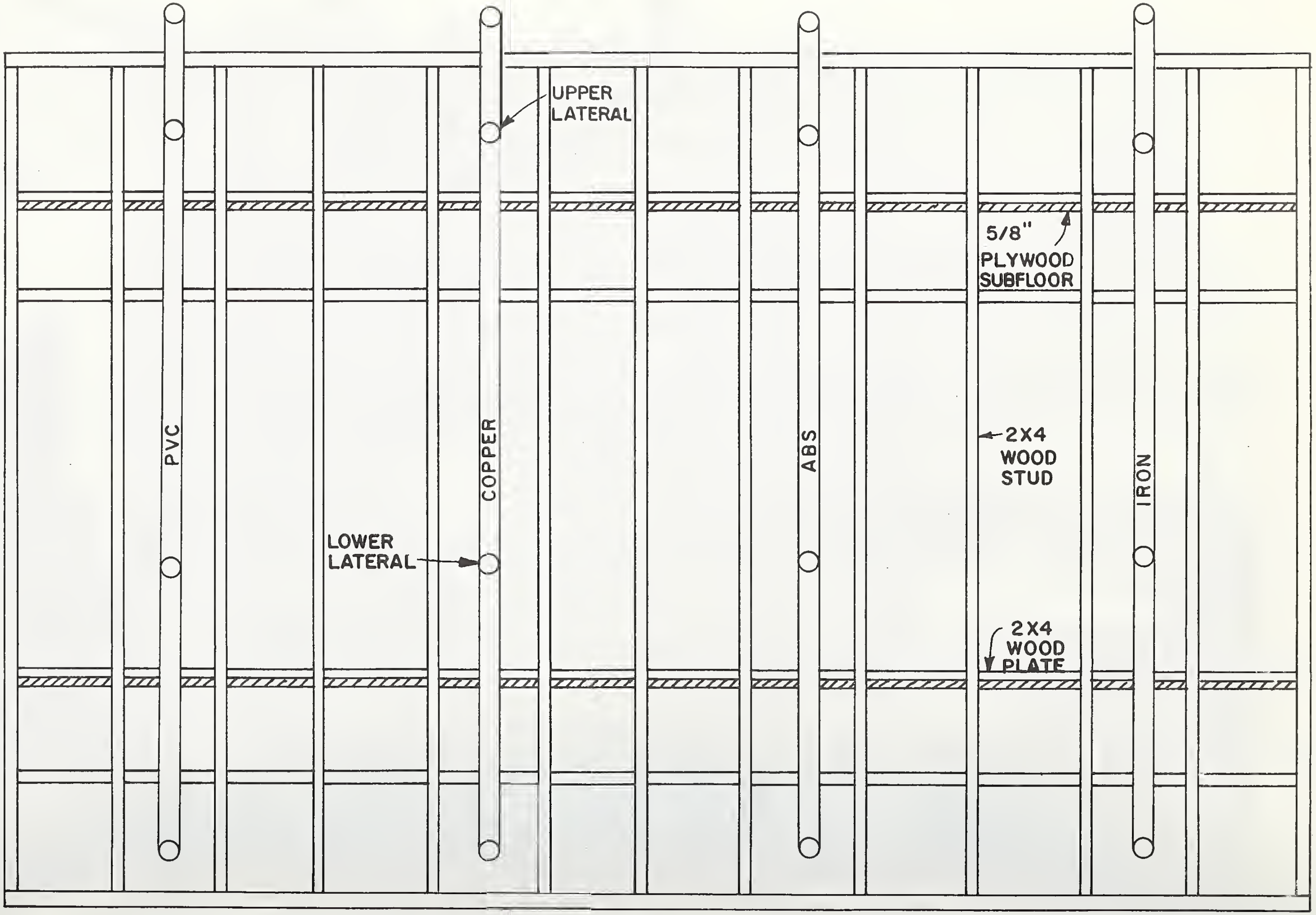


Fig. 12 Wall Construction and Location of Stacks on Test 3.

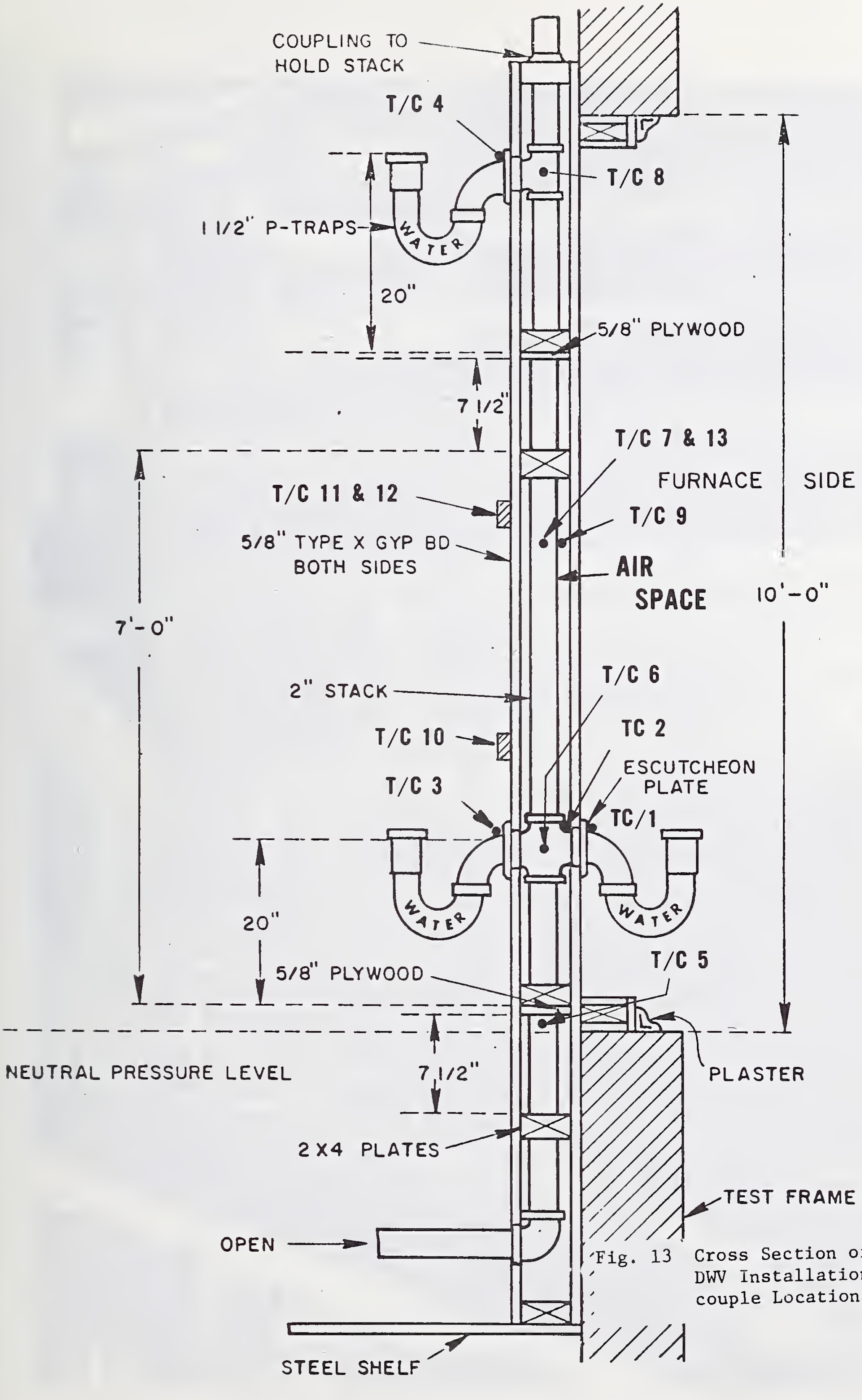
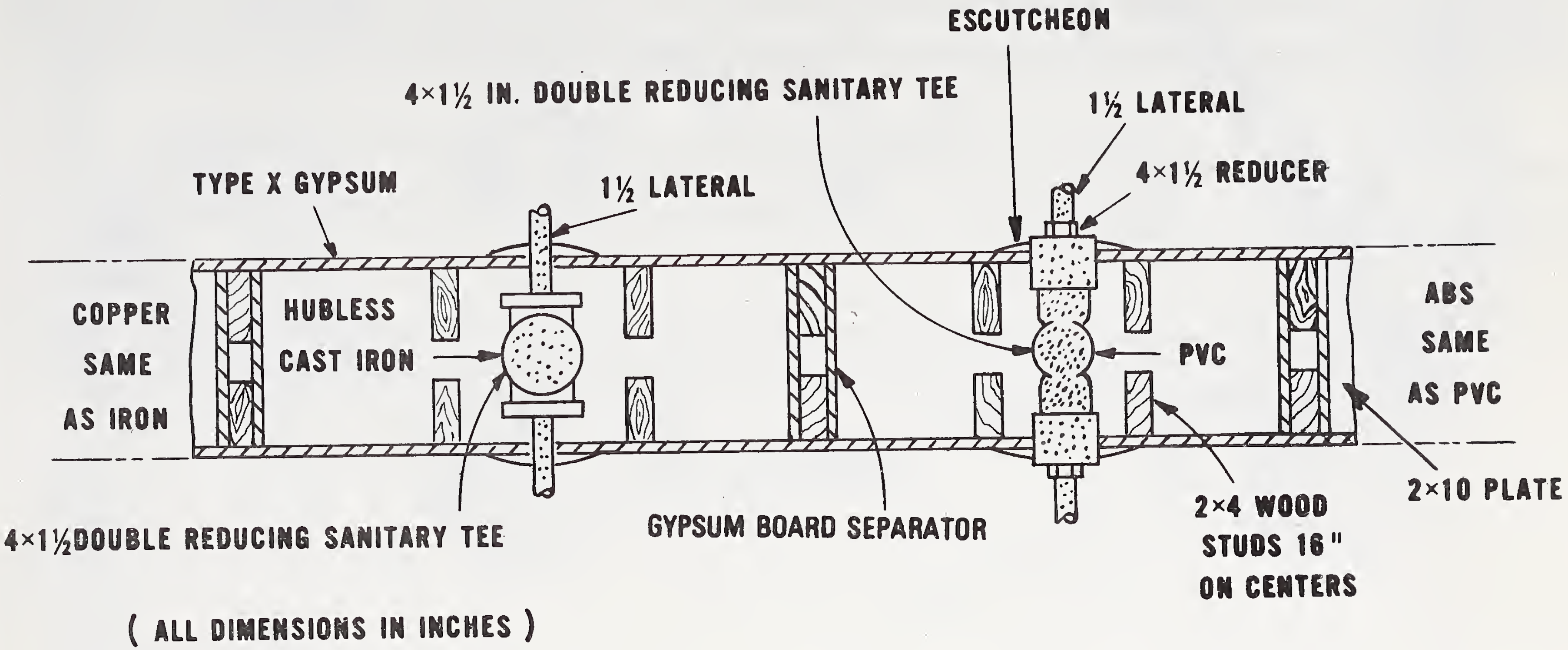


Fig. 13 Cross Section of Wall Showing DWV Installation and Thermocouple Locations on Test 3.

Fig. 14 Photograph of Wall Construction on Test 3.

Fig. 15 Wall Construction in Test 5.



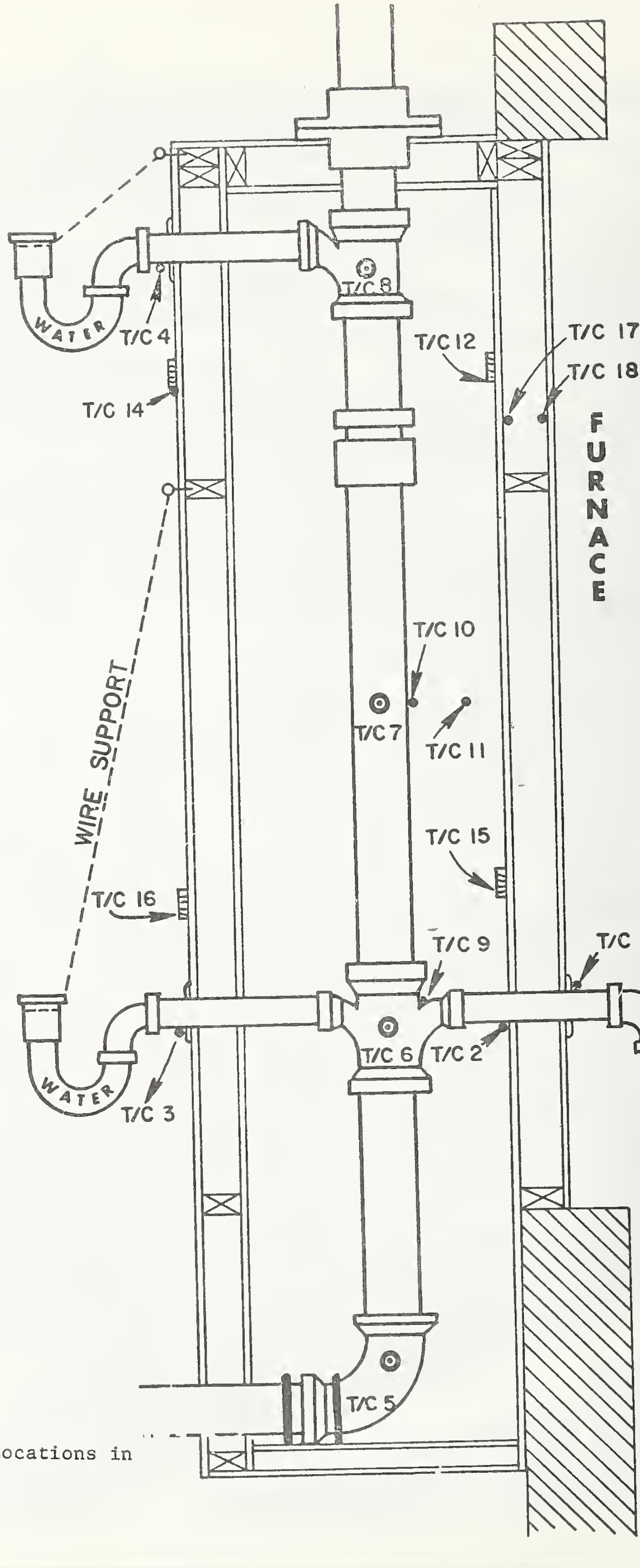


Fig. 16 Thermocouple Locations in Chase 1.

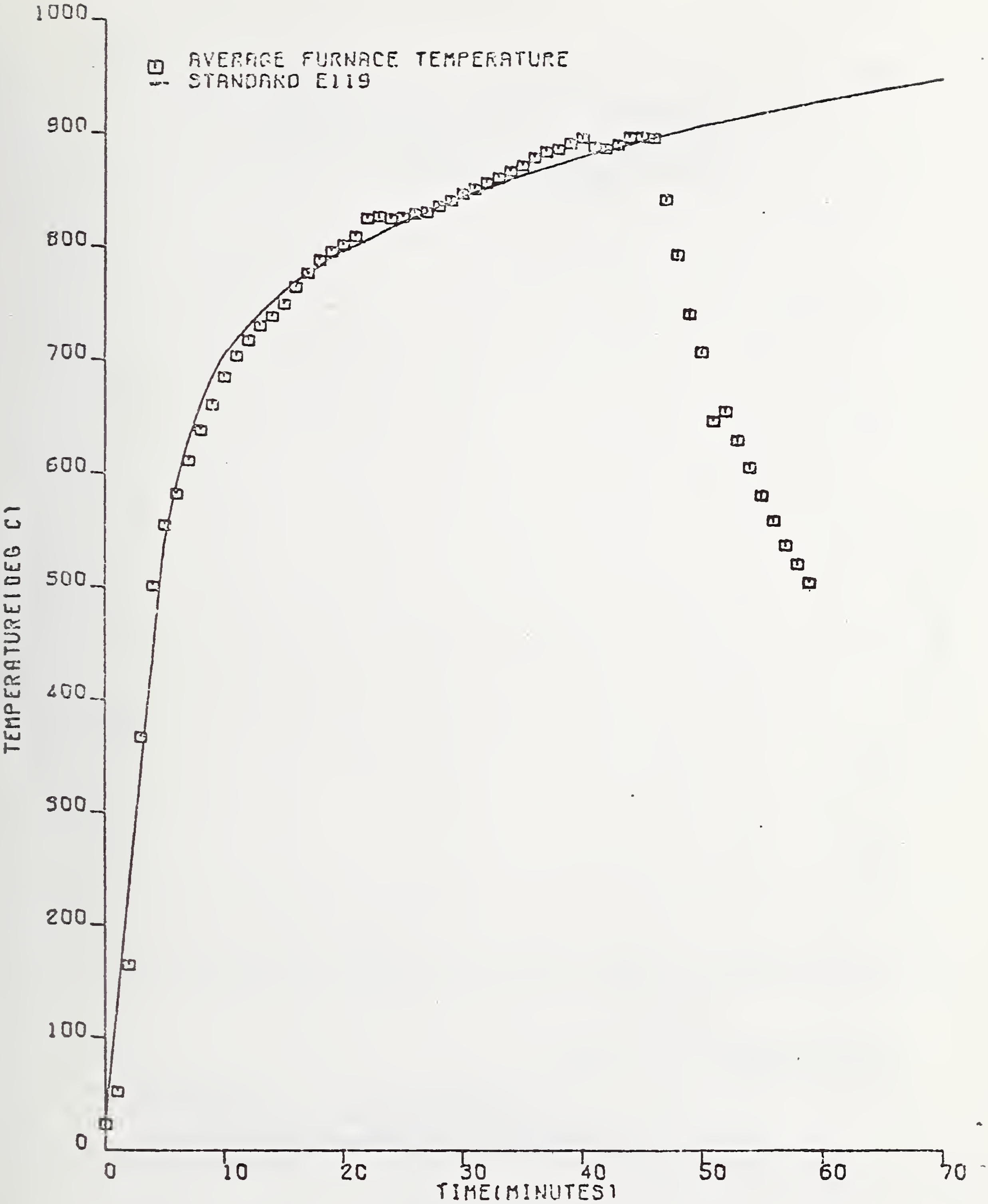


Fig. 17 Average Furnace Temperatures for Test 1 Compared with E119 Curve.

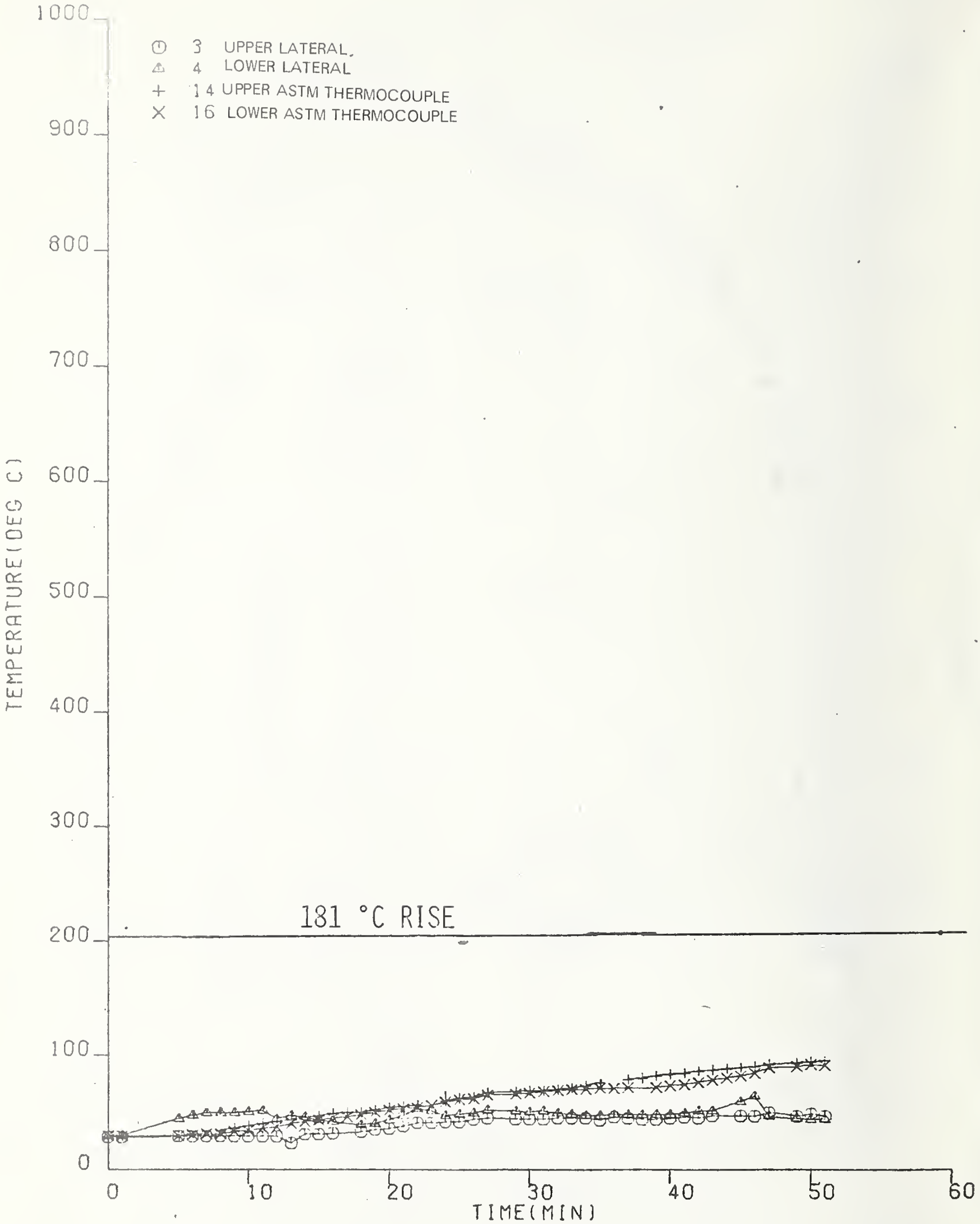


Fig. 18 Unexposed Lateral and ASTM Surface Temperatures for Chase 5.

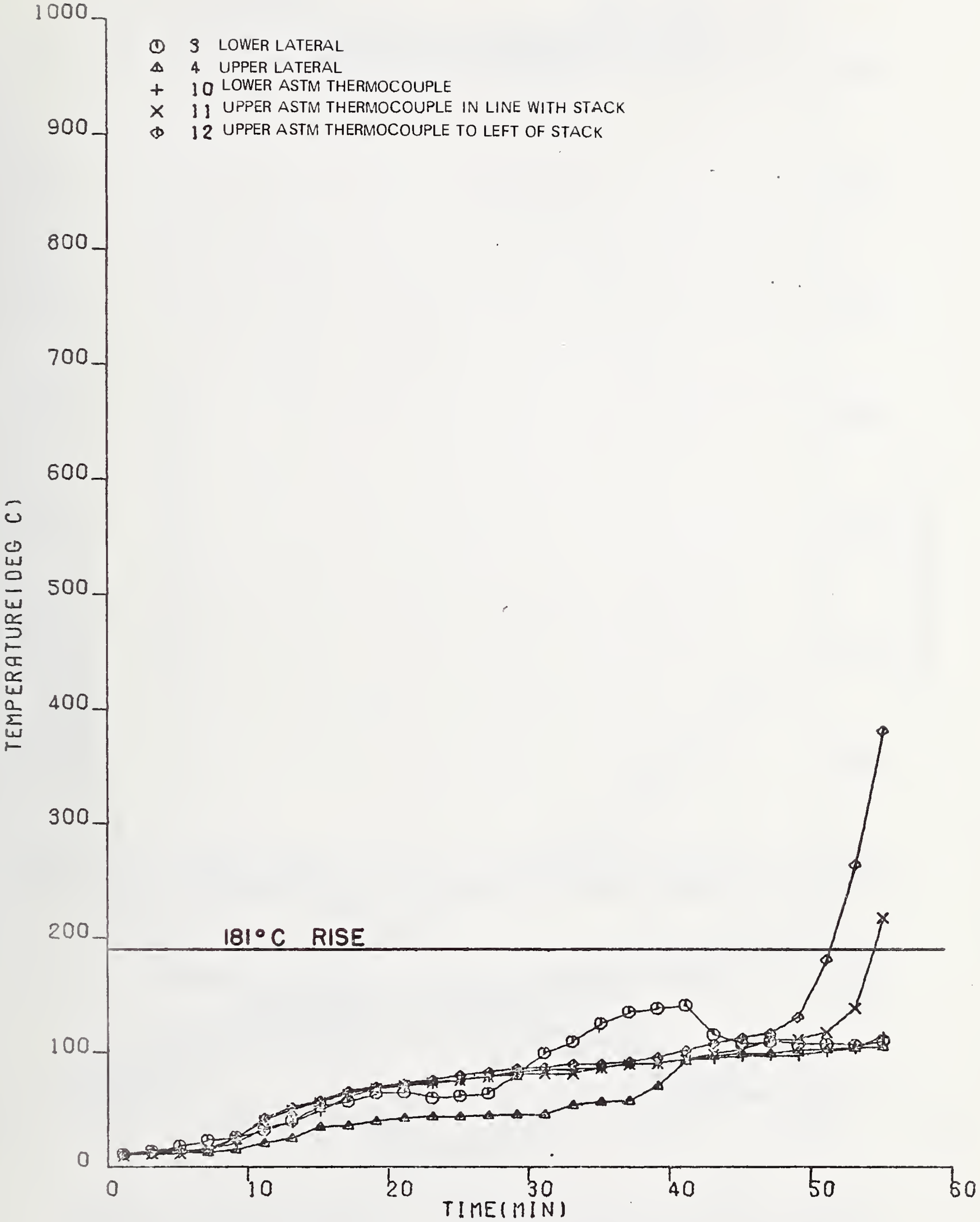


Fig. 19 Unexposed Lateral and ASTM Surface Temperatures in PVC Installation in Test 3.

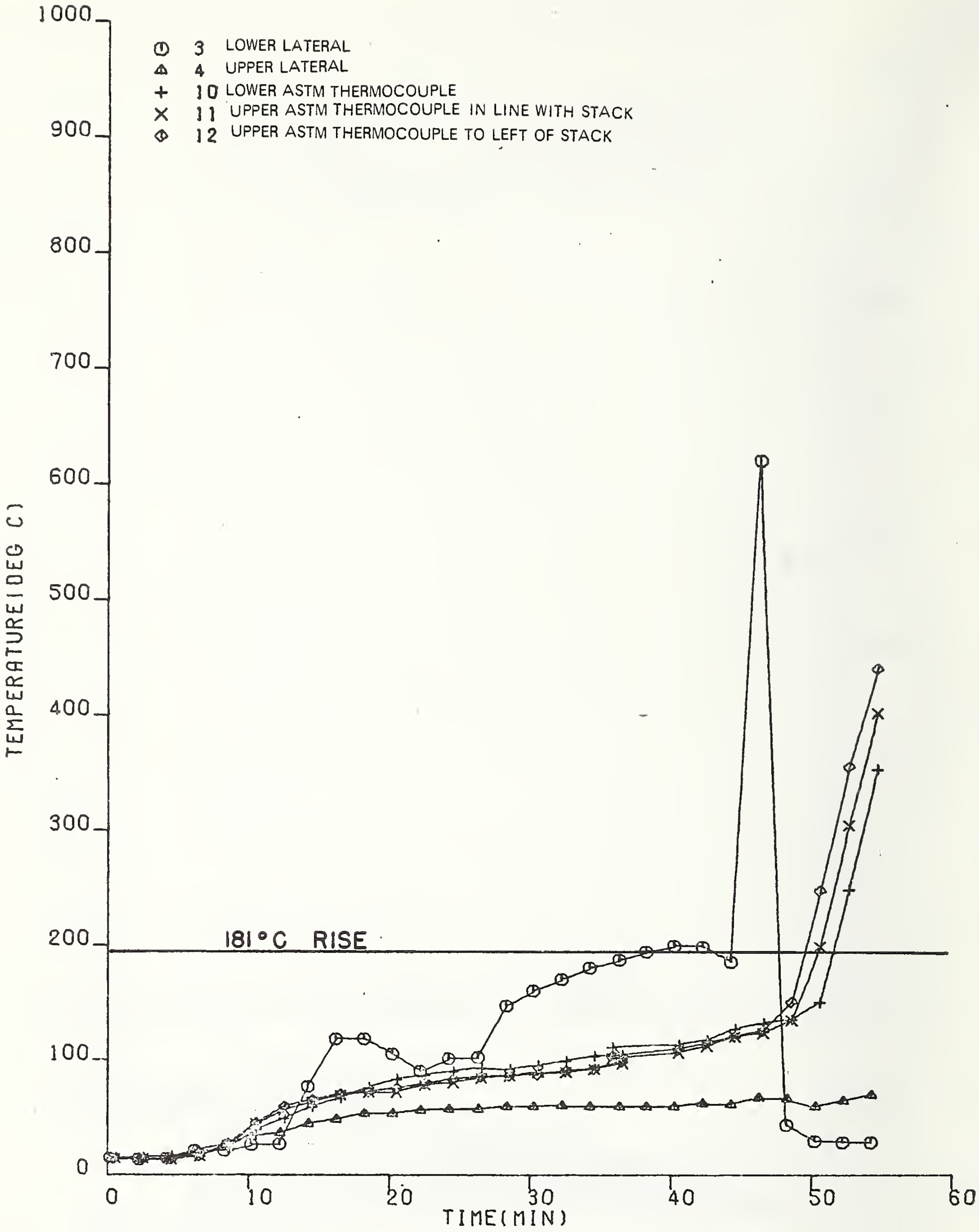


Fig. 20 Unexposed Lateral and ASTM Surface Temperatures in ABS Installation in Test 3.

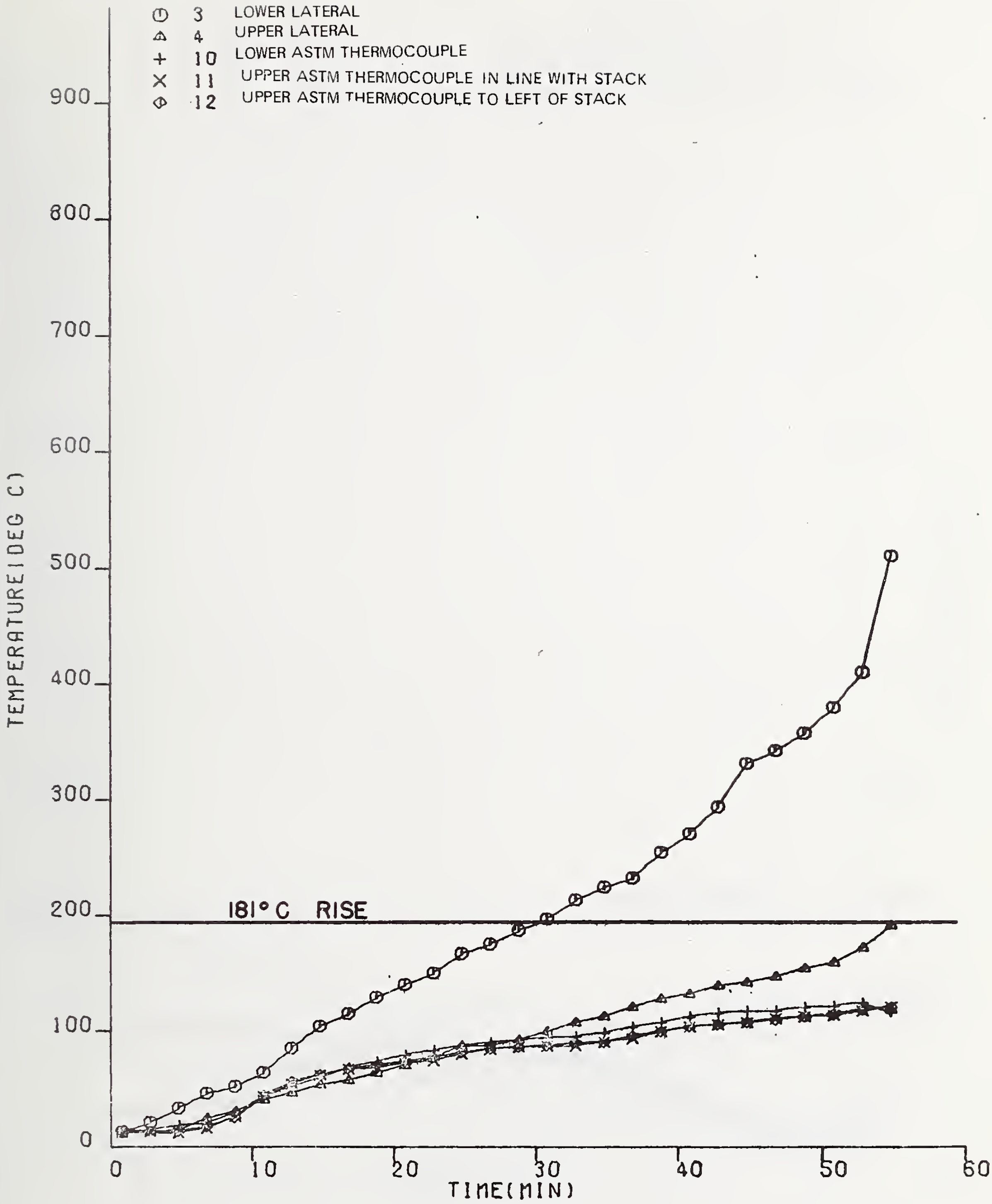


Fig. 21 Unexposed Lateral and ASTM Surface Temperatures in Copper Installation in Test 3.

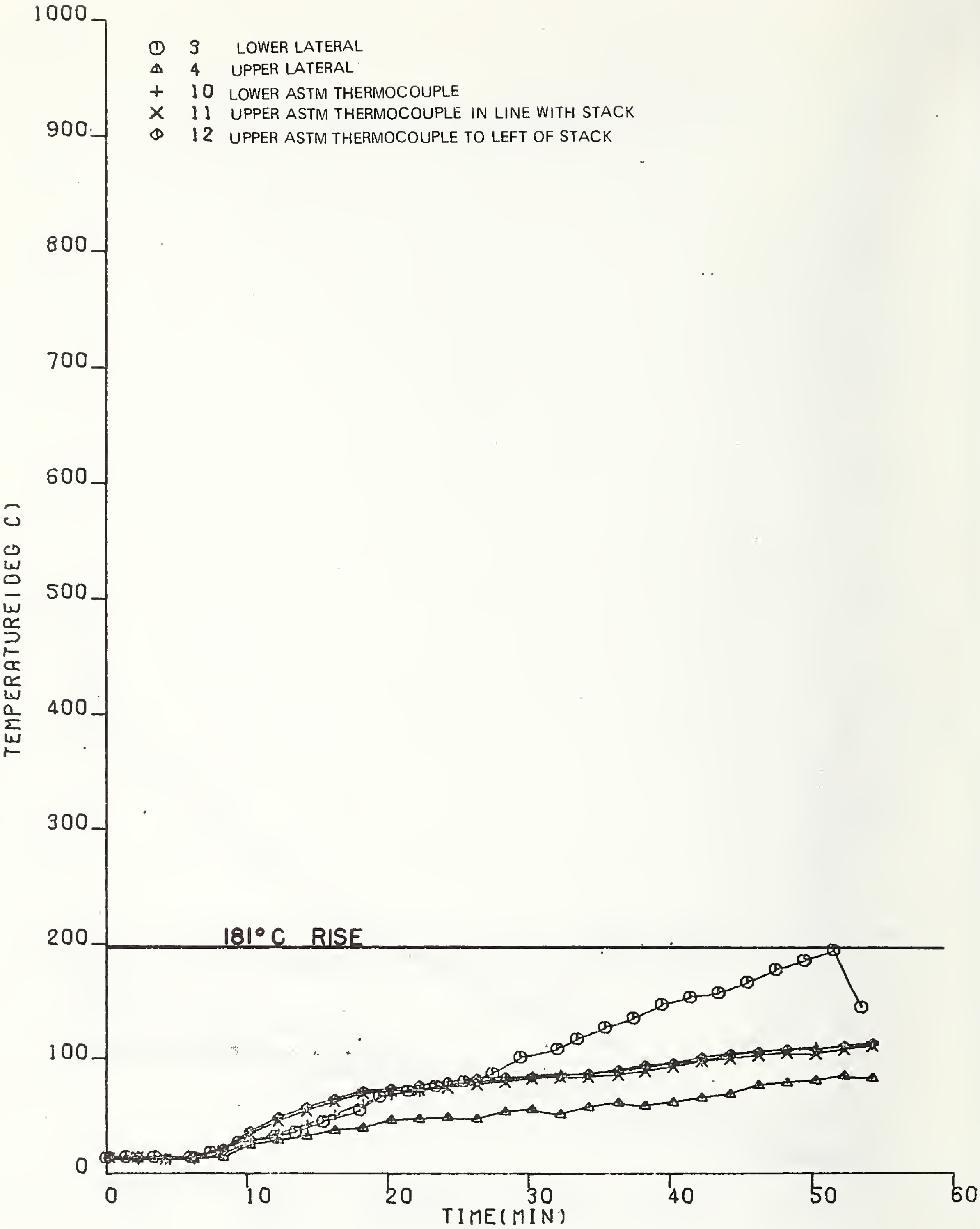


Fig. 22 Unexposed Lateral and ASTM Surface Temperatures in Galvanized Iron Installation in Test 3.

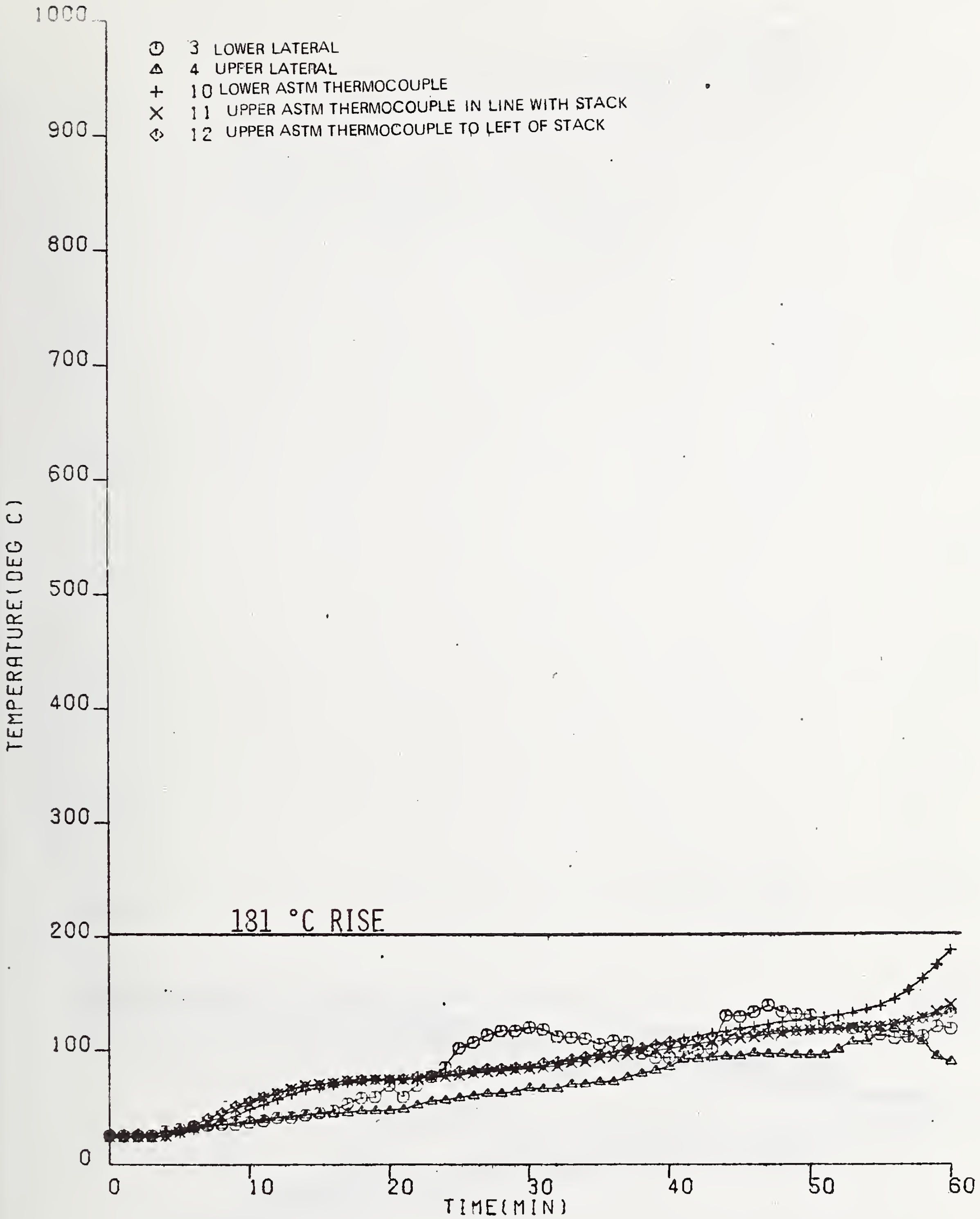


Fig. 23 Unexposed Lateral and ASTM Surface Temperatures in PVC Installation in Test 4.

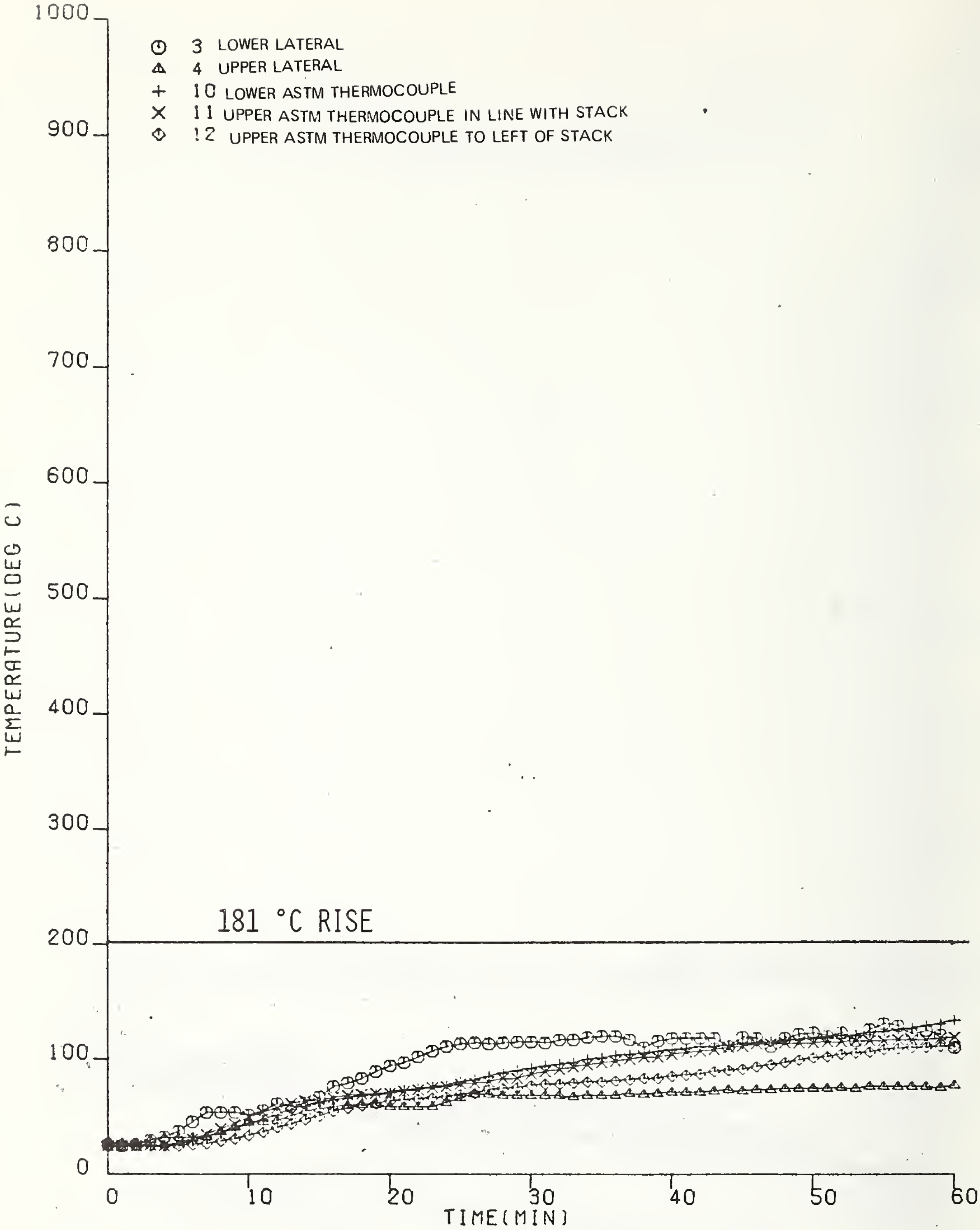


Fig. 24 Unexposed Lateral and ASTM Surface Temperatures in ABS Installation in Test 4.

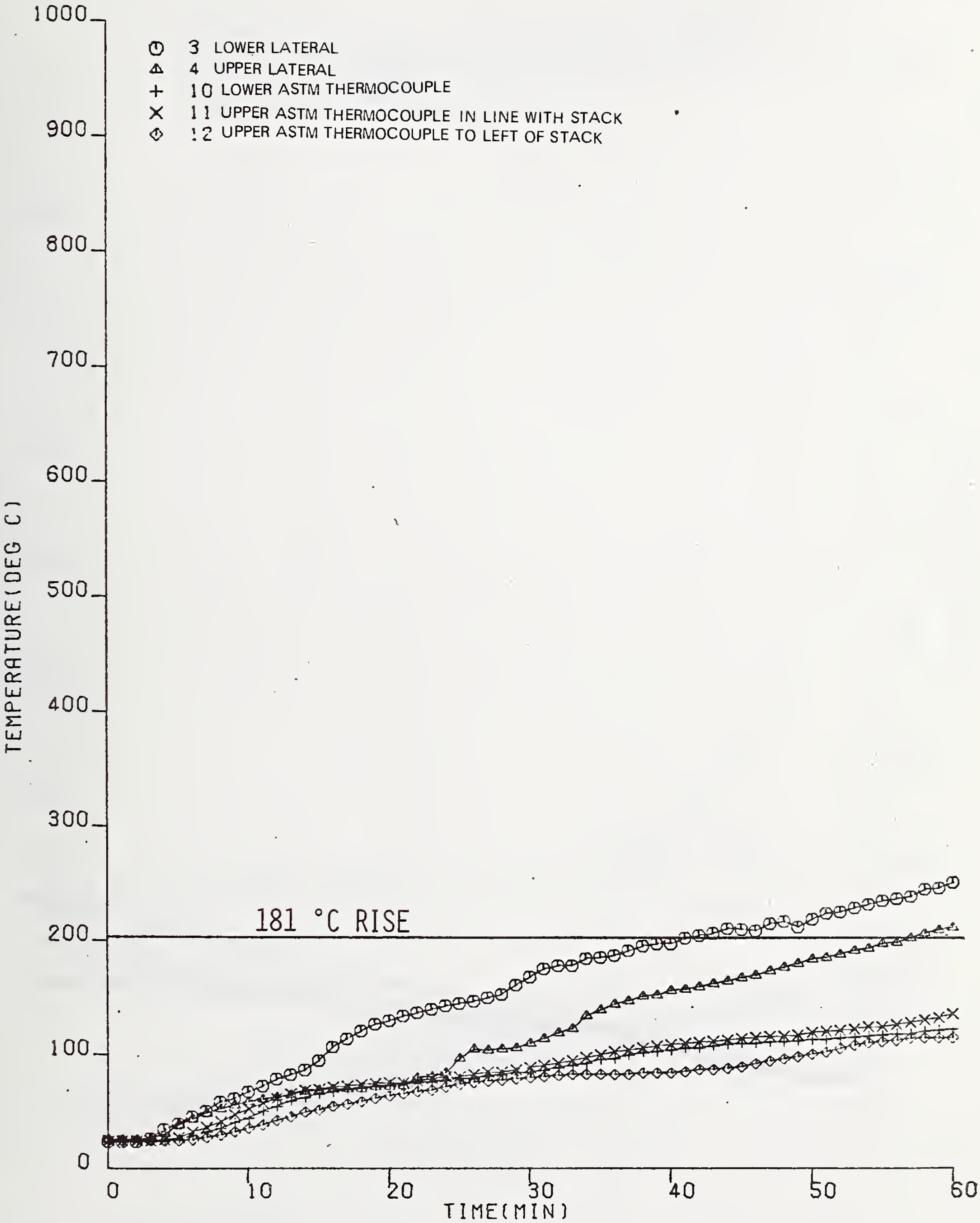


Fig. 25 Unexposed Lateral and ASTM Surface Temperatures in Copper Installation in Test 4.

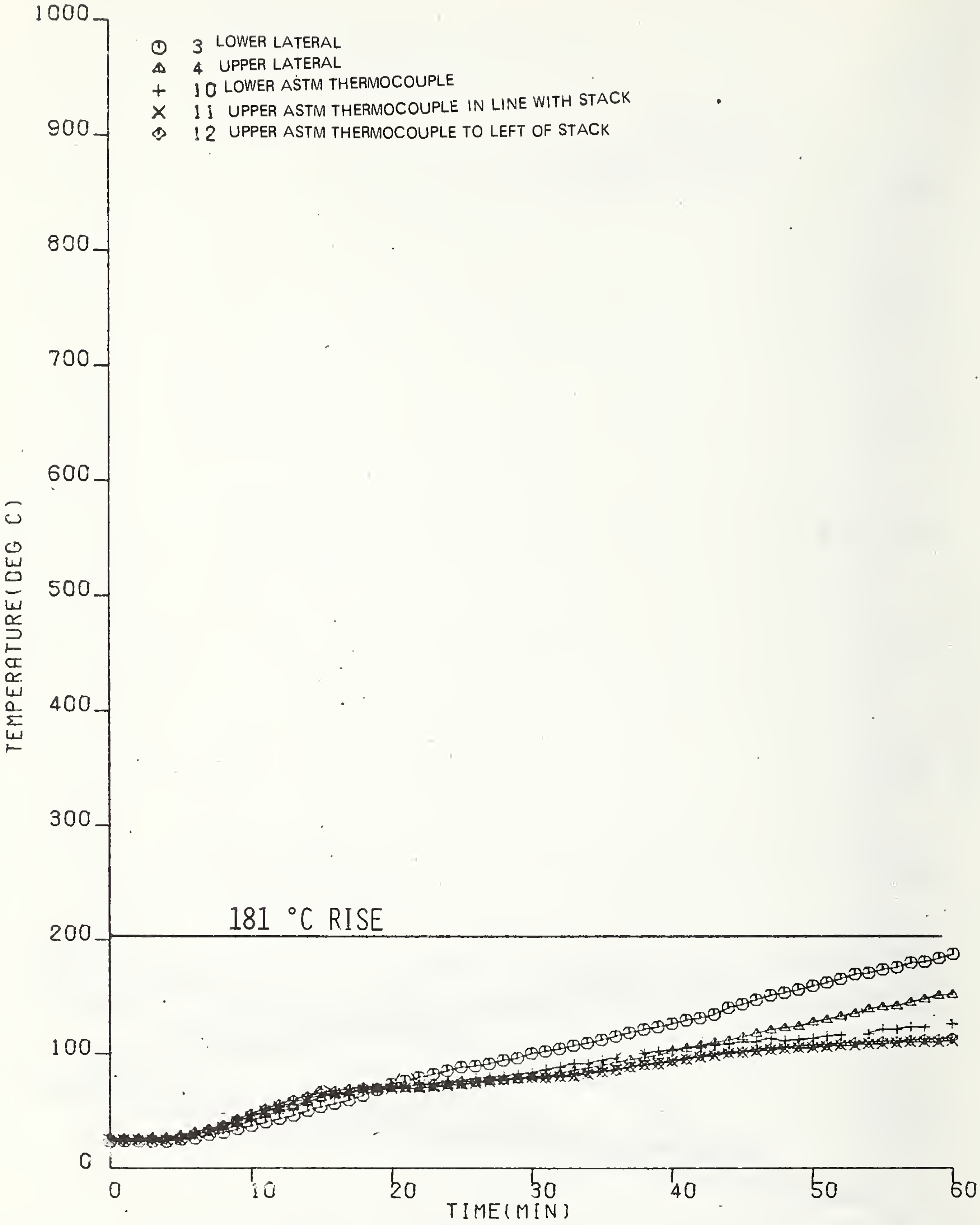


Fig. 26 Unexposed Lateral and ASTM Surface Temperatures in Galvanized Iron Installation in Test 4.

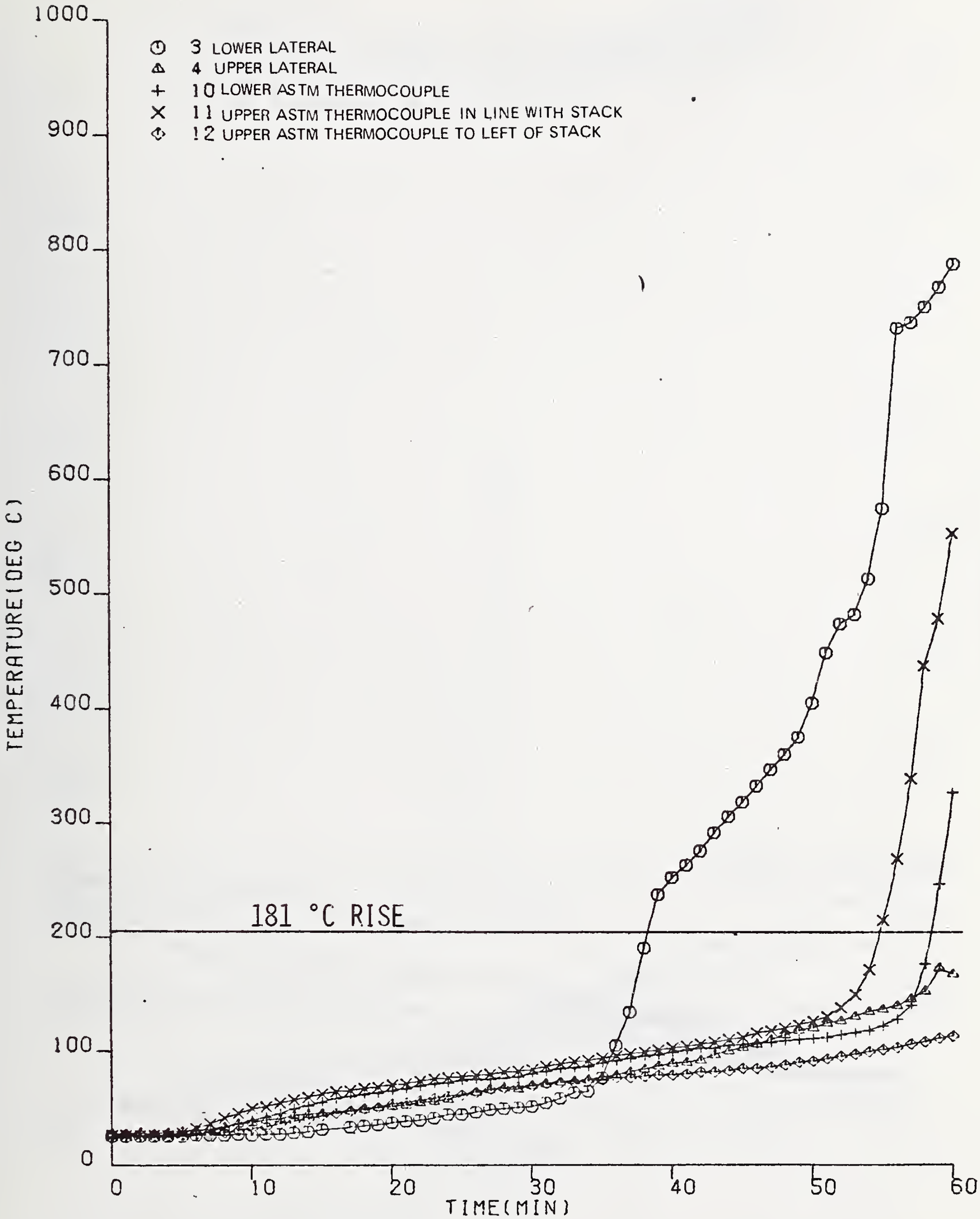


Fig. 27 Unexposed Lateral and ASTM Surface Temperatures in PVC Installation in Test 5.

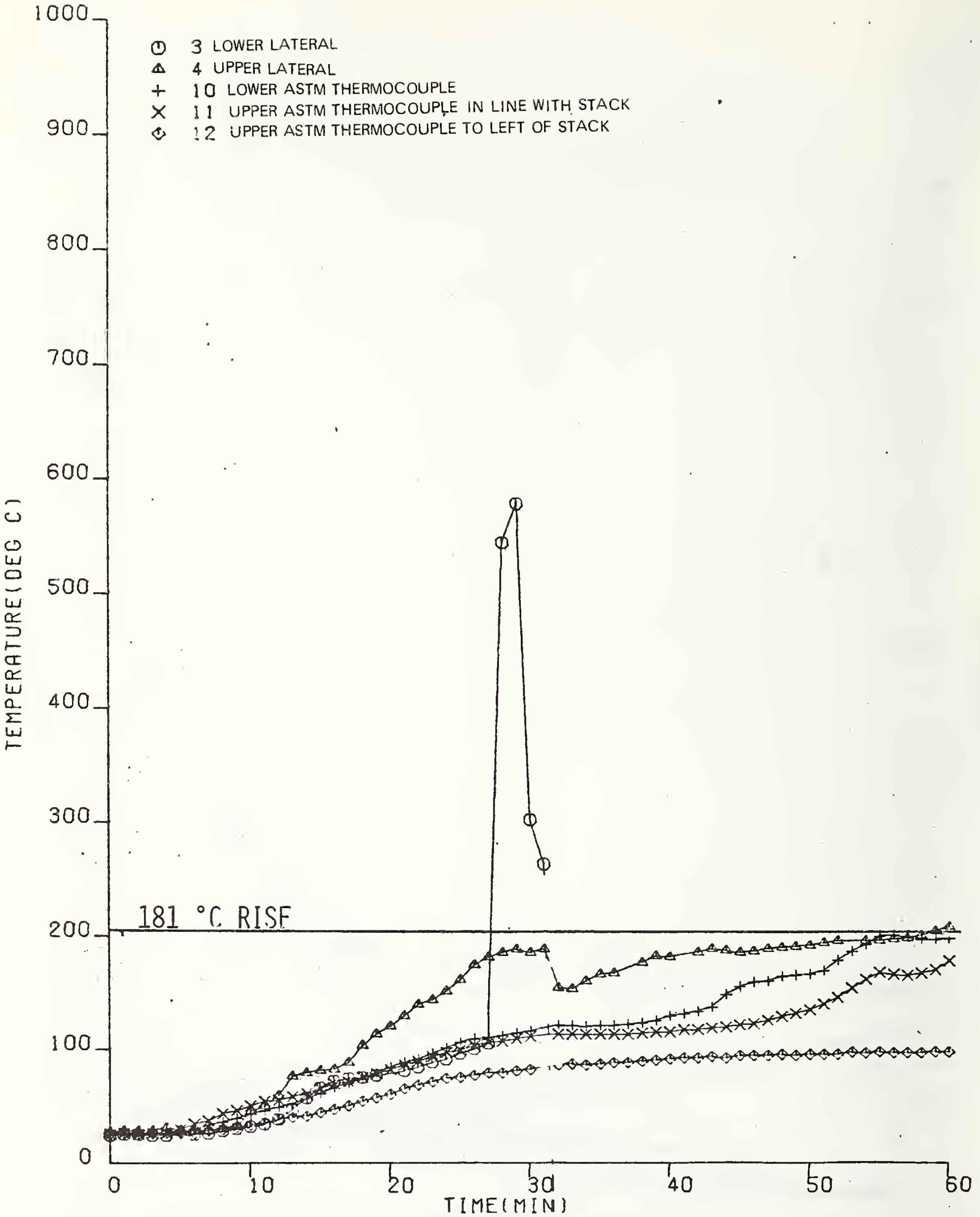


Fig. 28 Unexposed Lateral and ASTM Surface Temperatures in ABS Installation in Test 5.

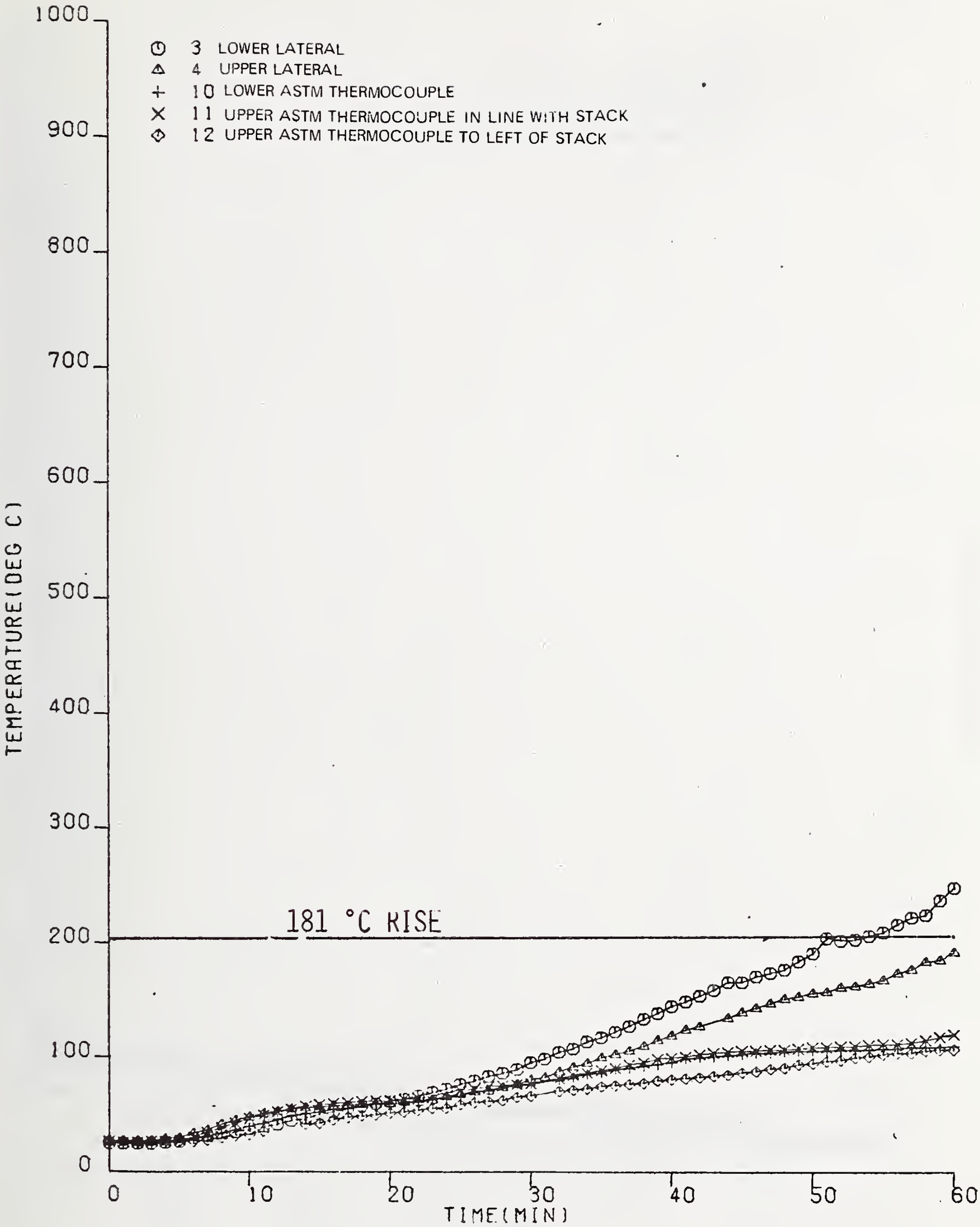


Fig. 29 Unexposed Lateral and ASTM Surface Temperatures in Copper Installation in Test 5.

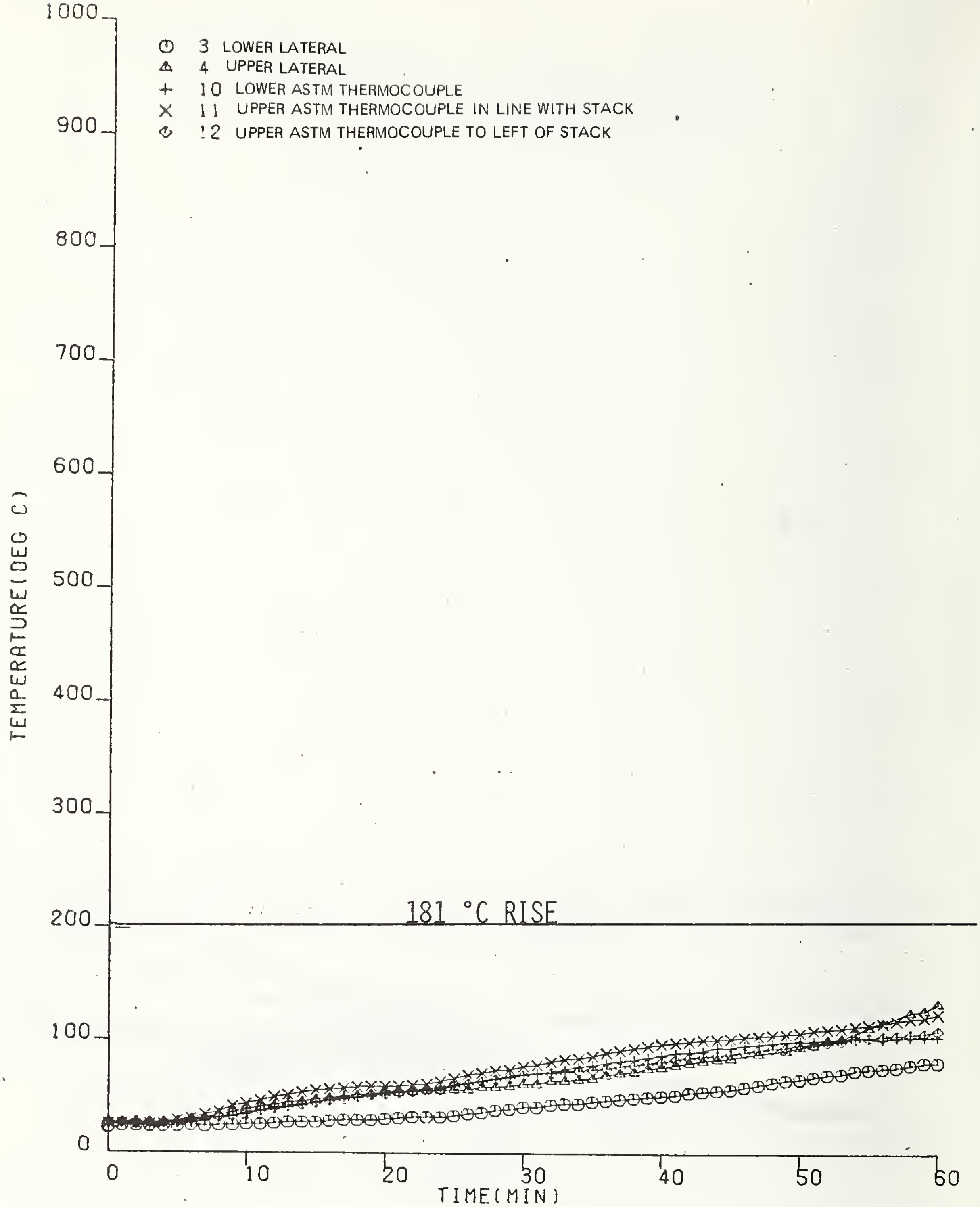


Fig. 30 Unexposed Lateral and ASTM Surface Temperatures in Hubless Cast Iron Installation in Test 5.

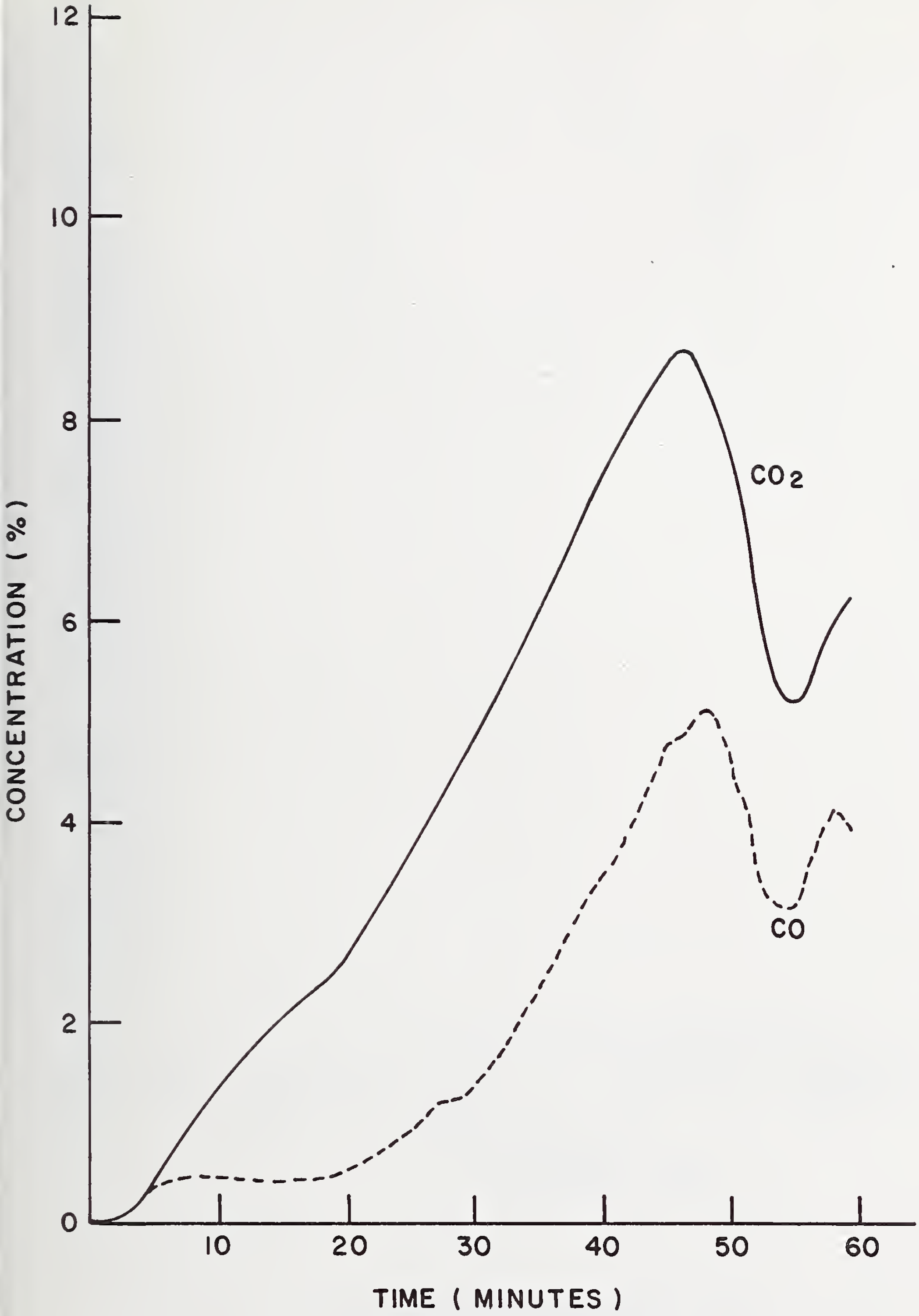


Fig. 31 Carbon Monoxide and Carbon Dioxide Concentrations in Chase 1.

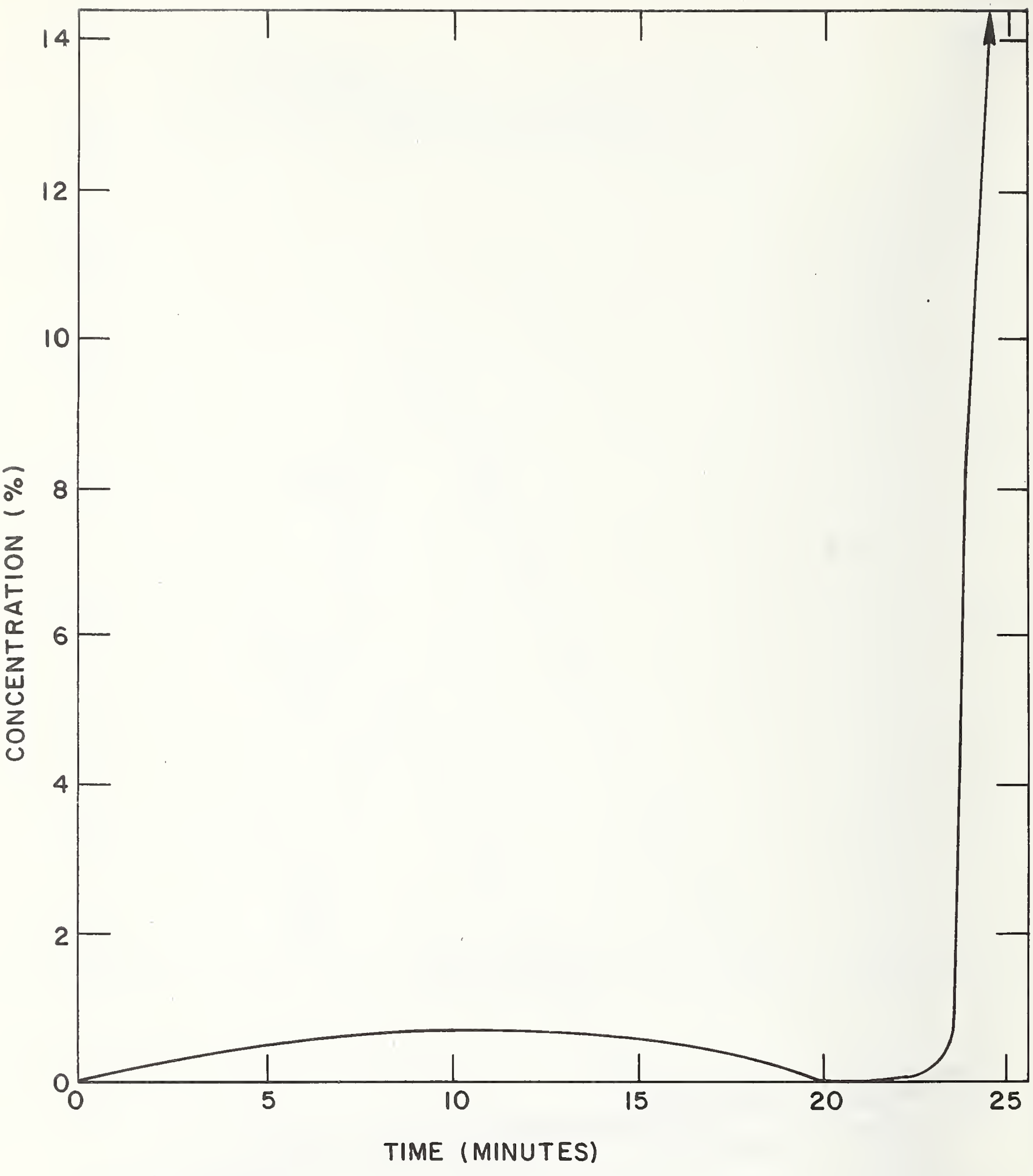


Fig. 32 Carbon Monoxide Concentration in Chase 5 in Test 2.

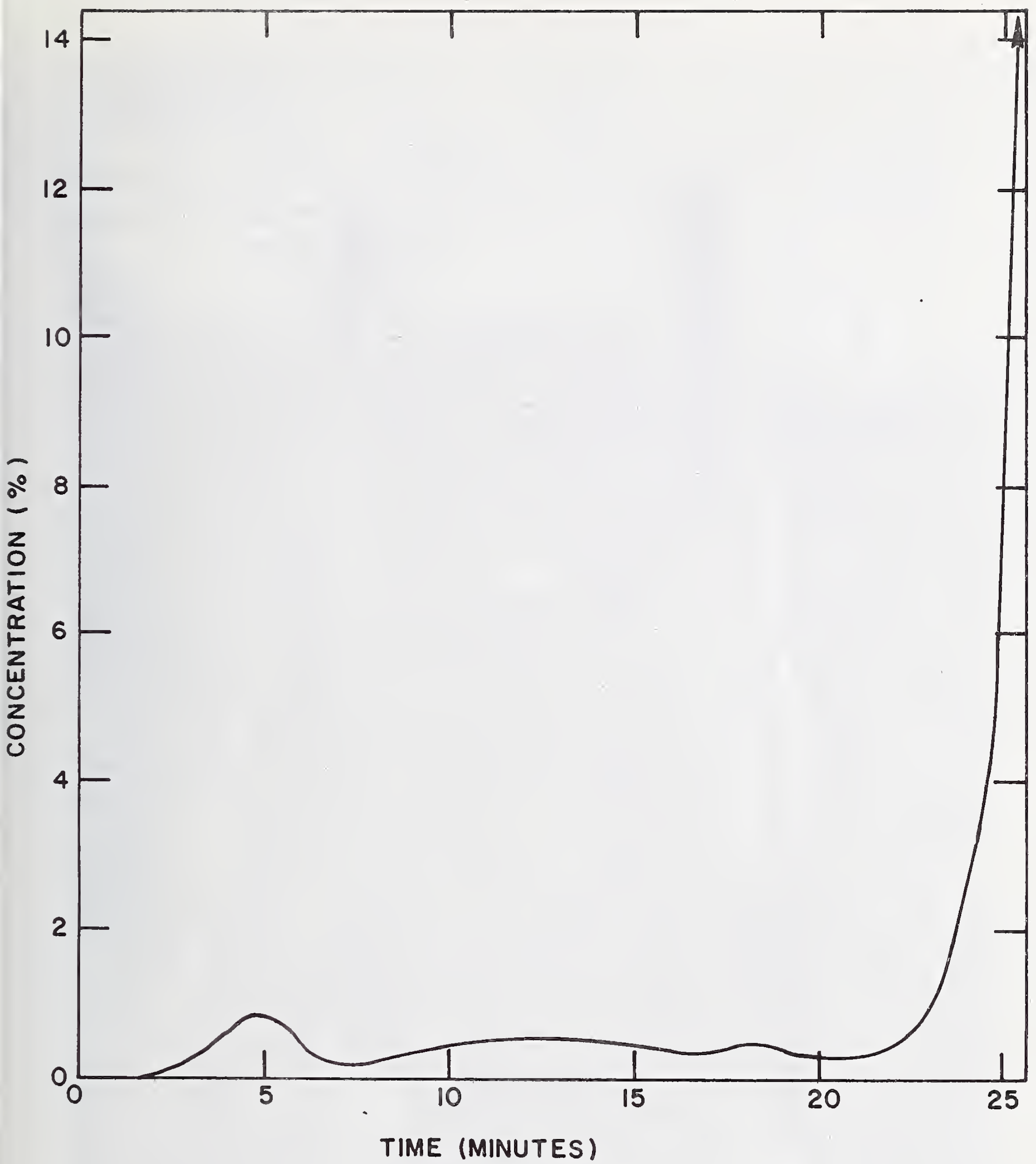


Fig. 33 Carbon Monoxide Concentration in Wall Cavity Containing PVC in Test 3.

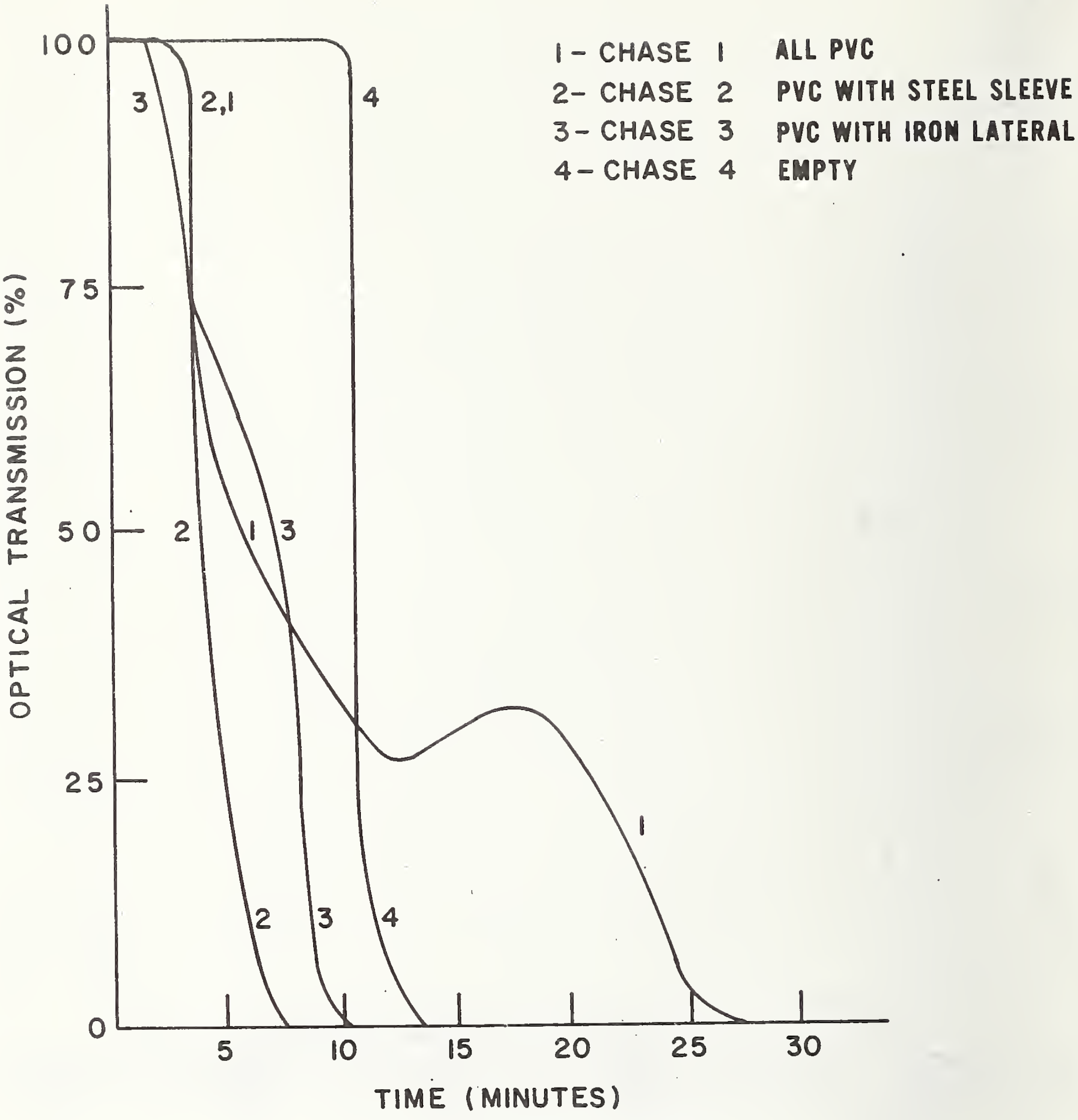


Fig. 34 Smoke Transmission in Test 1.

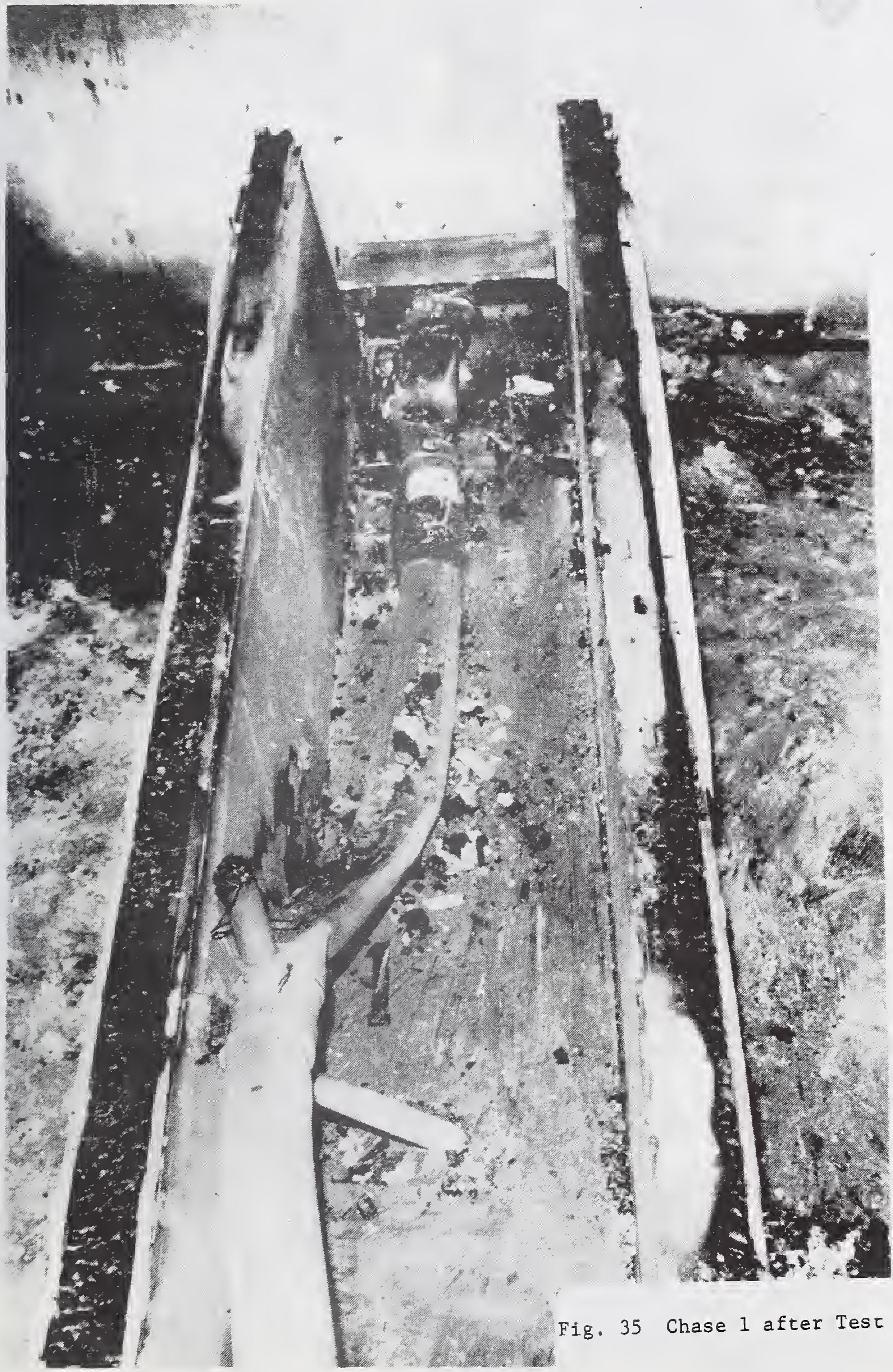


Fig. 35 Chase 1 after Test 1.

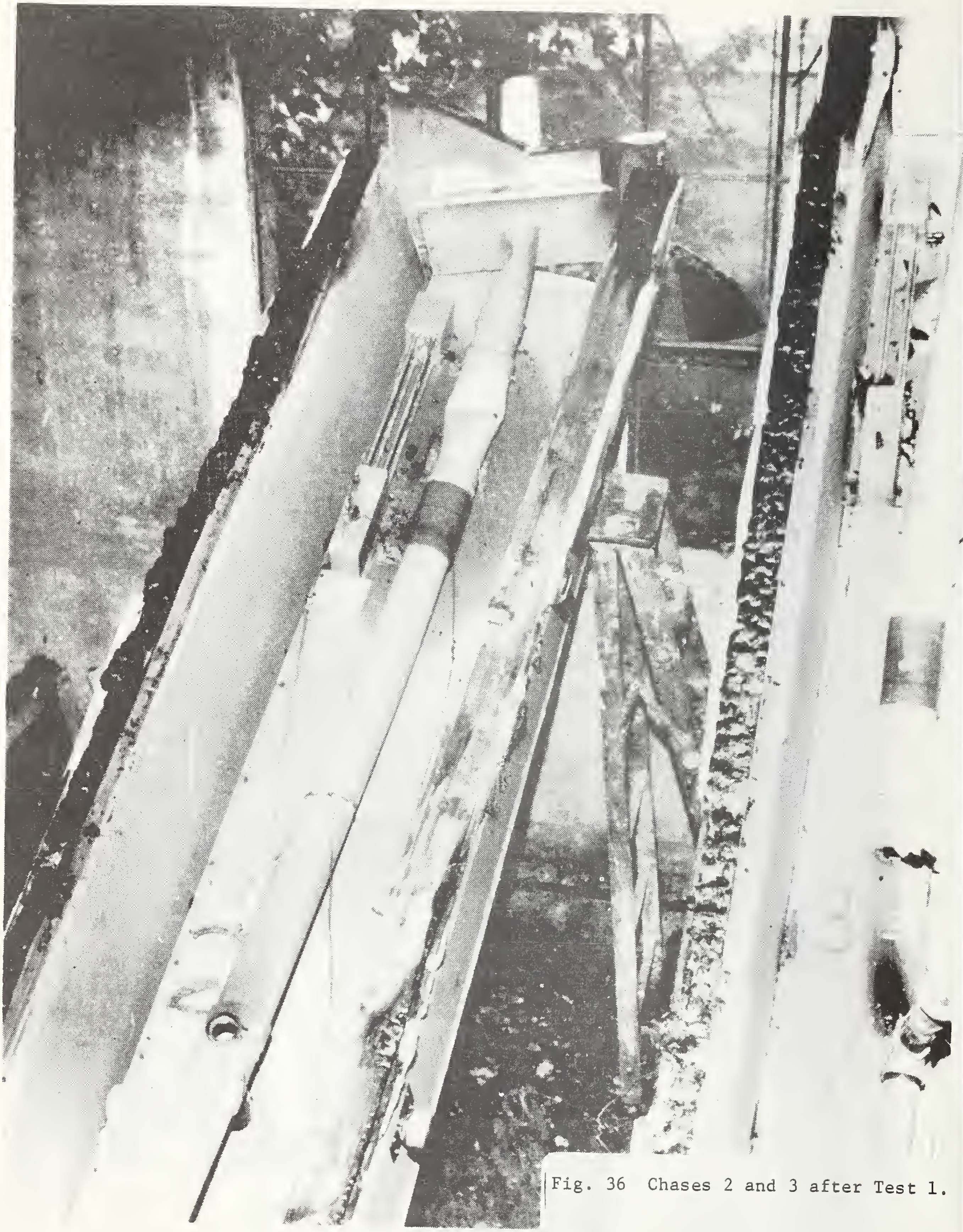


Fig. 36 Chases 2 and 3 after Test 1.

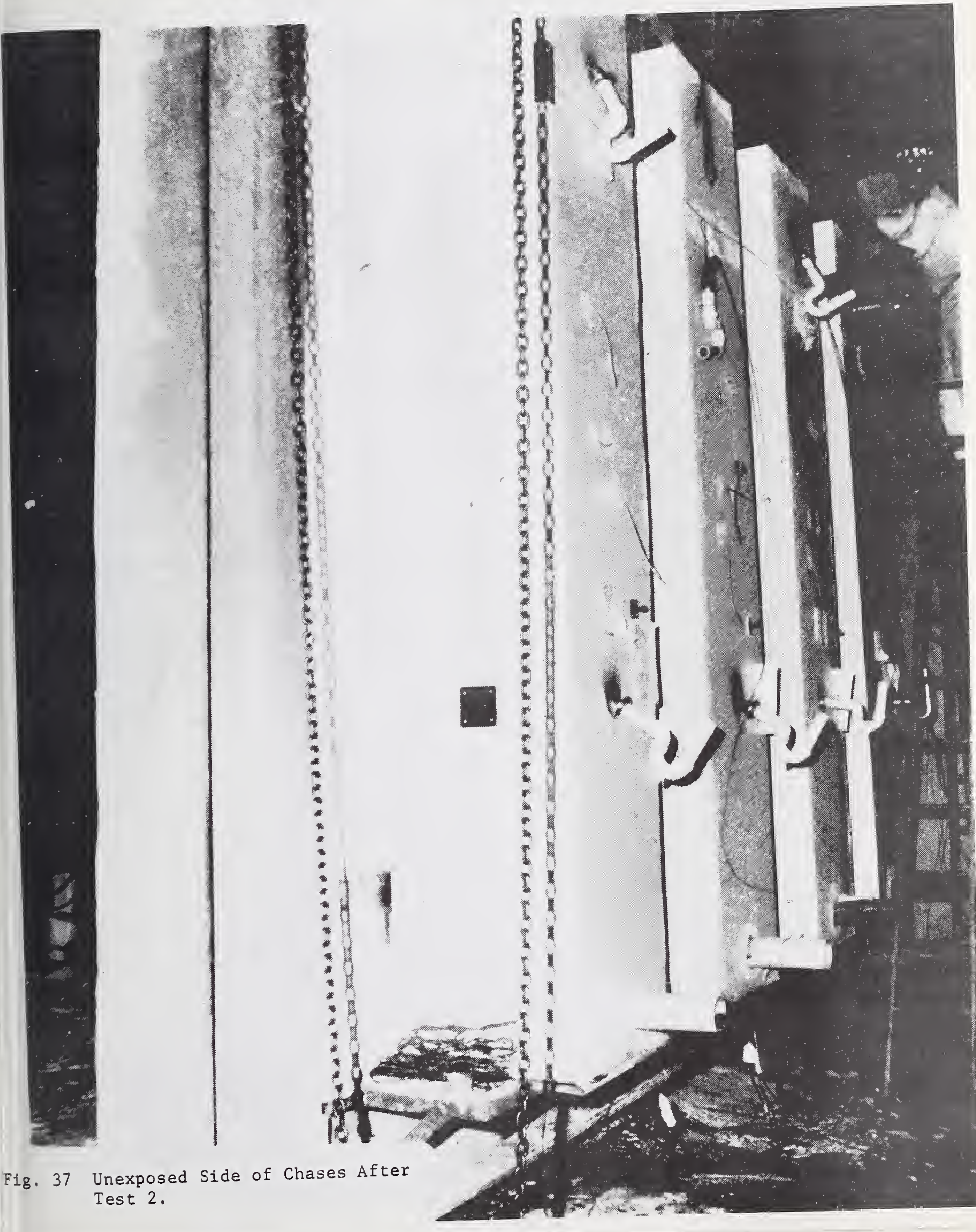


Fig. 37 Unexposed Side of Chases After Test 2.

Fig. 38 Chase 5 after Test 2.

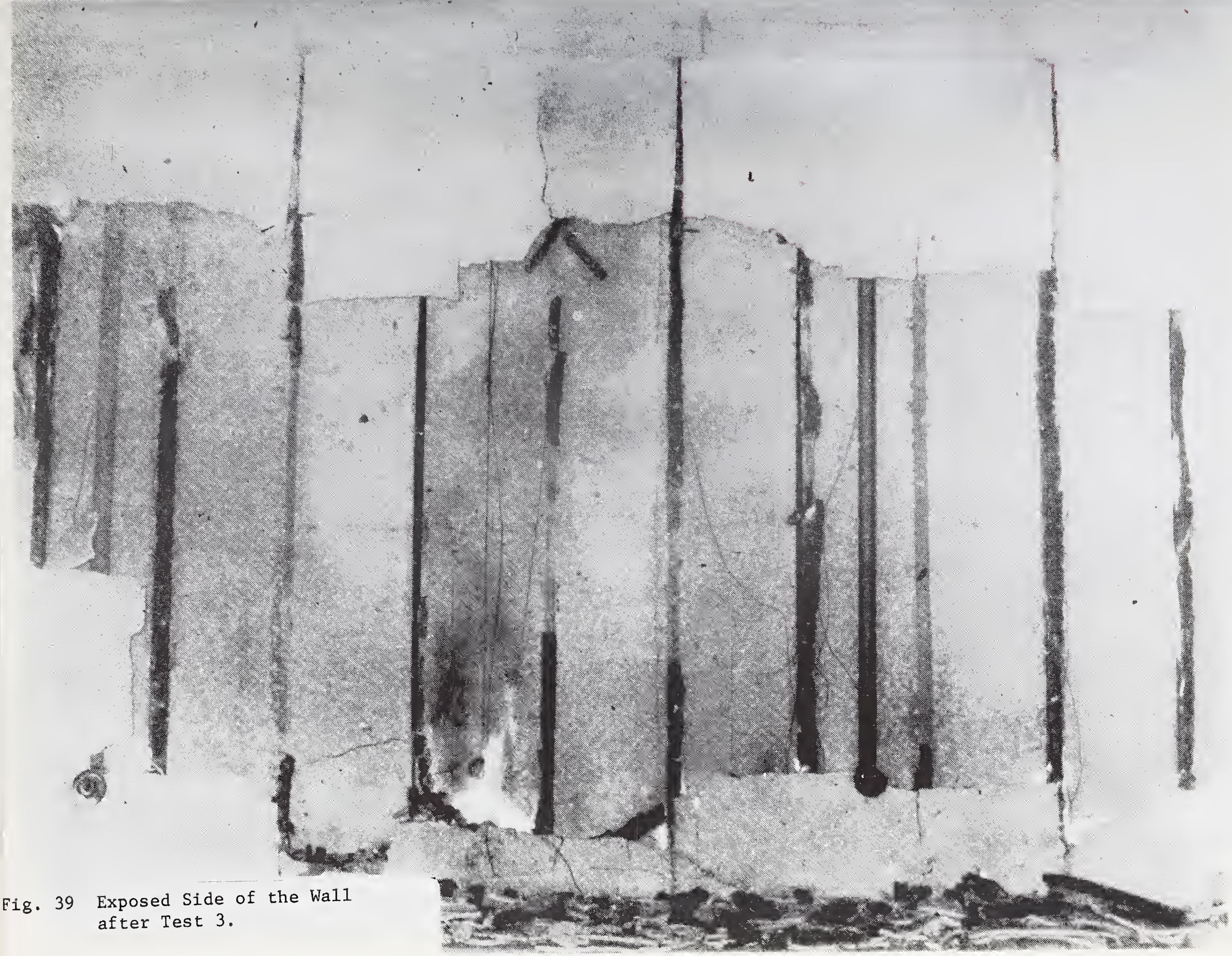


Fig. 39 Exposed Side of the Wall after Test 3.

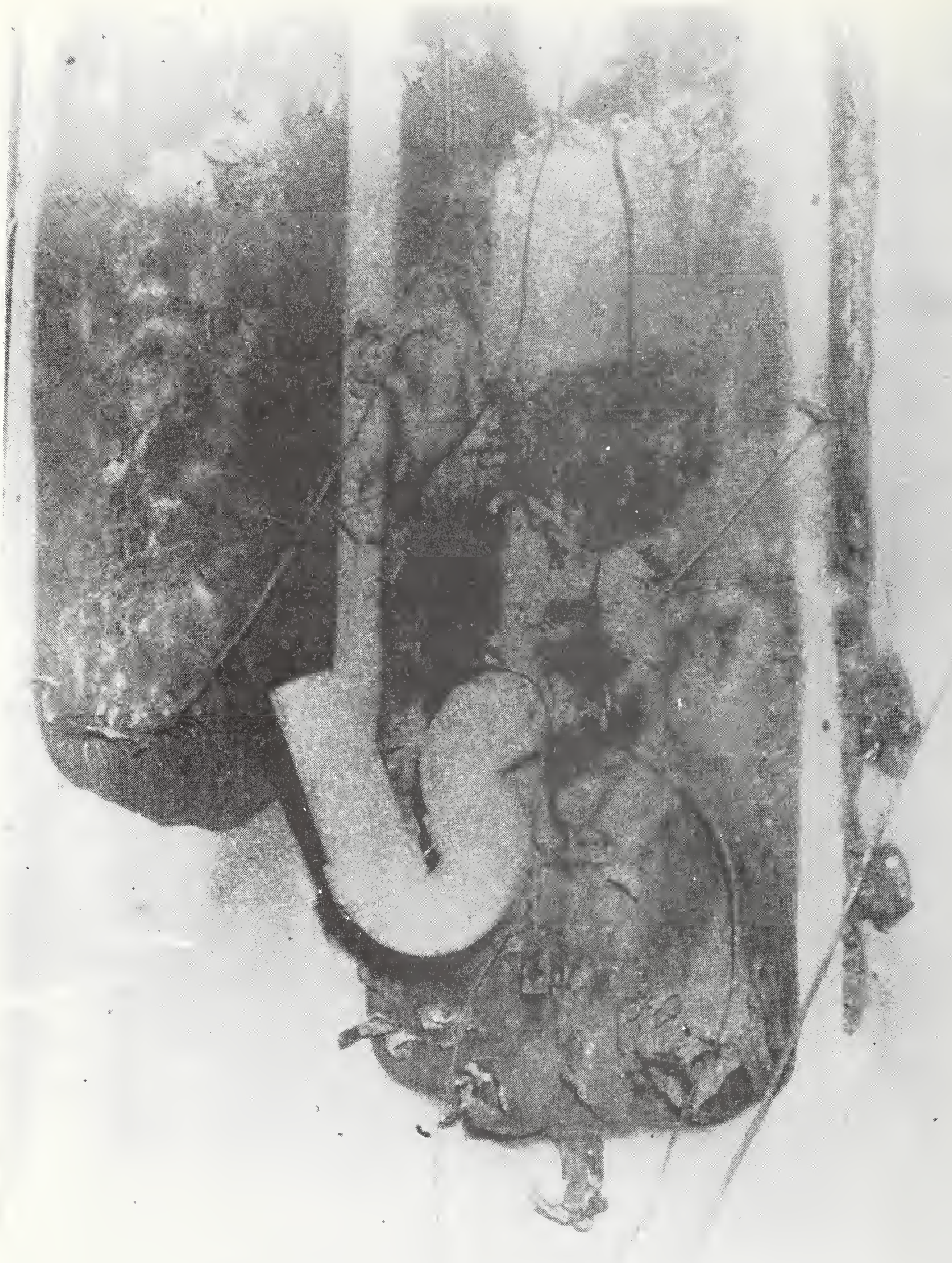


Fig. 40 Lower PVC Trap on the Unexposed Side of the Wall after Test 3.

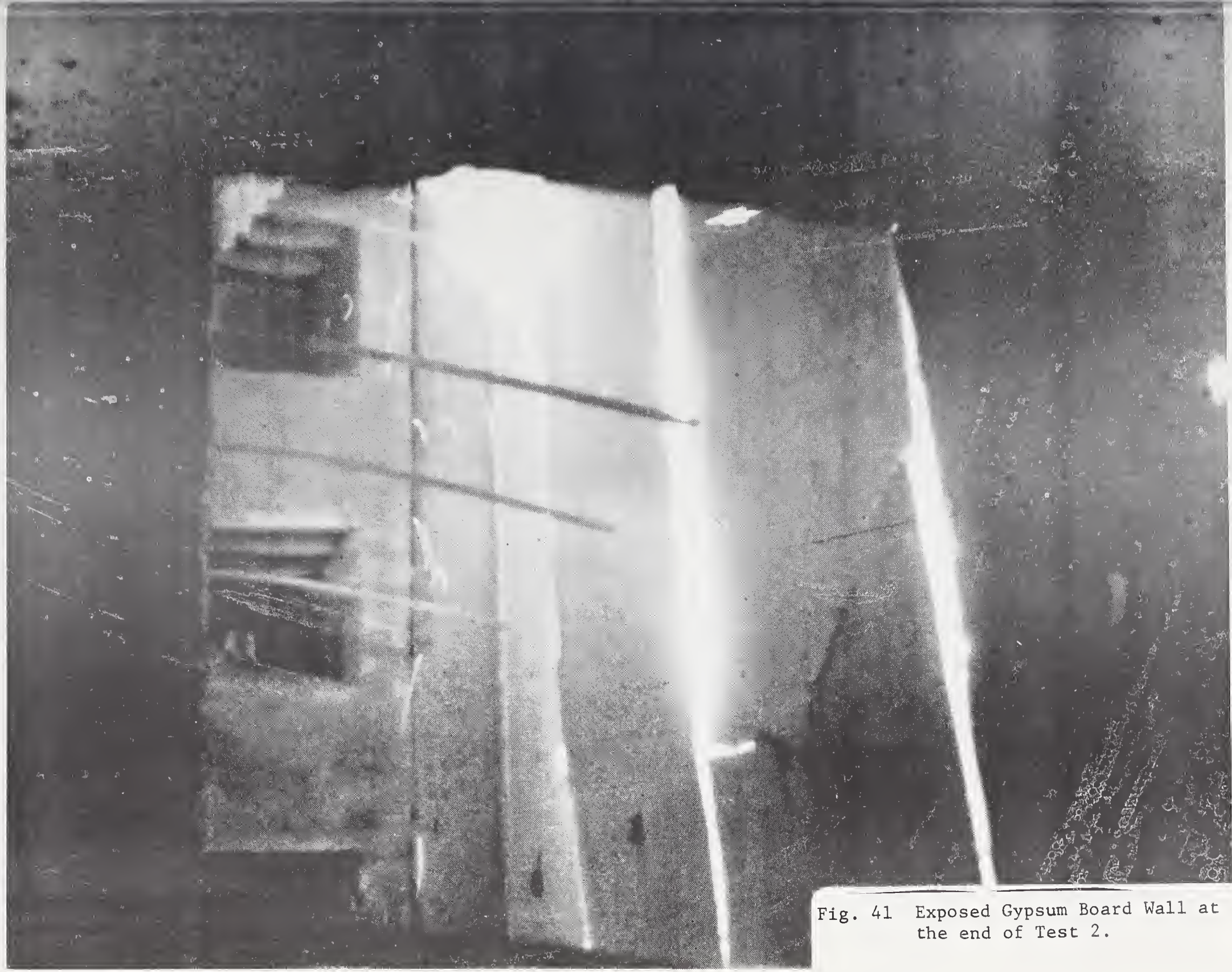


Fig. 41 Exposed Gypsum Board Wall at the end of Test 2.

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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.)*

Two full scale non-load bearing ASTM E-119 fire endurance tests were performed on plumbing chase and wall assemblies containing polyvinyl chloride (PVC) drain, waste, and vent (DWV) systems typical of installations serving two or more stories. For the systems tested which were typical of kitchen sink drain systems constructed and installed according to typical plans, the PVC piping did not contribute to the spread of fire through the plumbing chase to the adjoining dwelling during the test which lasted 50 minutes. A test failure not associated with the plastic piping aborted the test but there was no indication that there would have been a failure due to the piping if the test had continued for one hour.

Three full scale non-load bearing ASTM E-119 fire endurance tests were also run on walls with enclosed DWV systems of acrylonitrile butadiene styrene (ABS), PVC, copper, and iron.

Neither PVC nor ABS piping contributed to fire spread in a plumbing system consisting of 2-inch stacks and 1-1/2-inch back-to-back laterals in a 2 x 6 fir-stud-and-gypsum-board wall. In one test in which the stacks and laterals were 4 inches in diameter and in another test in which the distance between wall surfaces was decreased by using 2 x 4 studs, the effective fire endurance rating of the wall assembly was reduced by the installation of the plastic plumbing.

This progress report on the fire endurance evaluation of five plumbing chase and wall assemblies is limited to construction assemblies in which the openings around the laterals were carefully sealed with plaster spackling. Additional tests are in progress to examine the effect of leaving the openings unsealed.

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; cast iron; copper; drain; fire endurance; fire spread; fire test; Operation BREAKTHROUGH; plastic pipe; PVC; smoke; toxic gases; vent; waste.

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A fair amount of experimental work during the past 6 months dealt with the bottom closure for the manometer columns. This problem has been solved by using specially prepared titanium disks, which are chemically and acoustically compatible with the mercury.

An alternate method for the ultrasonic length measurement has been investigated. It is known as the exact or excess fractions methods and provides a length measurement that does not have to rely on the integrity of the fringe count.

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)*

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