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NATIONAL BUREAU OF STANDARDS REPORT

10 342

AN INVESTIGATION ON THE FIRE SPREAD POTENTIAL OF PLASTIC PIPE INSTALLATIONS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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AN INVESTIGATION ON THE FIRE SPREAD POTENTIAL OF PLASTIC PIPE INSTALLATIONS

by

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Prepared for:

ABS Institute Incorporated

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

AN INVESTIGATION ON THE FIRE SPREAD POTENTIAL OF ABS PLASTIC DWV PIPE INSTALLATIONS

by

I.A. Benjamin and W.J. Parker

SUMMARY

Fire tests were conducted on two panels, both containing four ABS pipe installations in separate protected chases. The chases were exposed in the wall furnace to the ASTM E 119 standard time-temperature curve. Positive pressures of 0.01 and 0.03 inches of water were maintained in the furnace at the elevation of the pipe inlets during the first and second tests respectively. The duration of the tests was 77 minutes for the first panel and 124 minutes for the second. Each of the eight chases enclosed a vertical ABS pipe stack 4 inches in diameter, sealed at the bottom of the chase and open to the atmosphere at the top. Tees or 45° wyes near the top and bottom of the stack received three inch diameter laterals. The lower lateral passed through the fire exposed wall of the chase into the furnace while the upper lateral passed through the opposite wall into the room. In two cases there were two lower laterals with the second one passing through the unexposed wall into the room.

The protected chase is designed to prevent a fire from spreading from one floor to the next in a building. If any combustible material, such as ABS plastic pipe, passes through the wall of the chase, the possibility of fire spread exists. The tests were designed to determine the best method of preventing fire from entering the chase via the ABS pipe or through the hole in the chase left after the pipe burns out and emerging from the chase at the floor above during a two hour fire exposure.

The first test panel served to demonstrate that the 45° wye connection was superior to the standard tee; and that using ABS pipe enclosed in a steel sleeve, where the lateral penetrates the chase wall, was better than using a galvanized iron nipple at that point. The test with the second panel in which all of the laterals used ABS pipe showed that double 45° wyes could be used as well as single 45° wyes and that the steel sleeve is essential in either case.

In the second test panel the most severe damage occurred in the chase with the double 45° wye and the ABS laterals without the steel sleeves. The plastic pipe was completely burned out, the studs were actively burning prior to the end of the test, and the ignition temperature of ABS was exceeded at the level of the upper 45° wye.

In the chases with the steel sleeves 20% of the plastic pipe remained at the top of the chase and about 1/3 of a cubic foot remained as melted material at the bottom of the chase. Minimal damage occurred to the studs and the gypsum board was not charred. Except for peaks of short duration at the beginning of the test the temperatures at the level of the upper wye never exceeded 160°C. There was essentially no difference between the performance of the chase with the single 45° wyes and the chase with the double 45° wye at the lower level, when the steel sleeves were used.

There was a copious amount of smoke released through the tops of the stacks of all the chases tested. There were small amounts of smoke leaking through the mineral wool packing around the pipes and through the untaped joints of the gypsum board. It is essential that the chases be reasonably air-tight, including the wall joints and the openings in the chase wall which accept the laterals. These seals should be of a type that will not be damaged by the temperatures encountered in the chases during the two hour fire exposure.

The increase in furnace pressure in the second test was accompanied by significantly higher temperatures in the chase. This illustrates the importance of furnace pressure in evaluating a particular piping arrangement.

From the results of these tests we suggest that four inch ABS pipe in a protected chase with connecting three inch ABS laterals penetrating the walls will not spread either fire or significant quantities of smoke from one floor to the next during a two hour fire provided that:

1. The connection of the lateral to the riser is made with a 45° wye so that the lateral passes through the wall at an angle of 45°.

2. The lateral is enclosed in a steel sleeve and penetrates the lower 1/3 of the wall height.

3. The chase is of 2 hour non-combustible construction. (This condition is a matter of judgment since a two hour non combustible chase was not tested).

4. The top of the chase is sealed, except for the penetration of the pipe. (This was the condition used in all of the chases tested).

5. The joints in the wall and the openings where the laterals penetrate the shaft wall are sealed with materials which will contain the smoke throughout the two hour period.

Further tests with both 2 hour combustible and 2 hour non combustible construction and higher furnace pressures are needed for a more precise definition of the requirements regarding the use of ABS DWV systems in all types of pipe chases with closed tops. Additional tests beyond these would be necessary to consider chases with open tops.

AN INVESTIGATION OF THE FIRE SPREAD
POTENTIAL OF ABS PLASTIC DWV PIPE INSTALLATIONS

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1.0 INTRODUCTION

ABS resins are thermoplastic copolymers. By ASTM Standard D2661-68 they have a minimum of 13% acrylonitrile, 5% butadiene, and 15% styrene. These resins are being used to make pipe and pipe fittings for drain, waste, and vent installations in the plumbing systems of many types of buildings. Since they are combustible their use in building construction depends on meeting the requirements of local building codes to safeguard the structures against spread of fire.

Buildings above a certain height require that the pipe stacks be confined in a vertical pipe chase (or plumbing shaft), except for lateral connections to a room. Because ABS Plastic pipe is combustible, it may release a certain amount of smoke, gaseous products and heat inside the chase. More seriously the consumption of the pipe in the room of fire origin leaves a hole through which flames and hot combustion gases can penetrate into the chase. If the fire can travel vertically inside the chase and through the lateral at the floor above, the protected chase does not serve its purpose.

Two exploratory tests were run in May and July of 1970 at the National Bureau of Standards for the ABS Institute to examine the potential hazard due to the combustible material in a chase with a two hour fire endurance rating; and to determine the best way of making the lateral connection through the chase wall to prevent the passage of flames and hot gases.

Each test was set up to simulate a protected chase in a building with lateral connections to the stack at two floor levels 8 feet apart. Assuming a burnout fire exposure of 2 hour duration (with its attendant positive pressure) in one room, the following general performance criteria were examined:

1. No flames, hot gases or smoke shall pass through the chase to the unexposed side representing other rooms.

2. Temperatures at any upper lateral shall not exceed the decomposition temperature of the plastic pipe outside of the chase.

2.0 DESCRIPTION OF EXPERIMENT

2.1 Chase and Pipe Arrangement

Four chases were built on each panel as shown in figure 1. Each chase had two layers of 5/8" type "X" gypsum board on each side of the 2 x 4 fir stud framing. This is a construction comparable to "Design No. 4 - 2 hour Combustible" fire resistance classification in the Underwriter's Laboratories Building Materials List. The chases were 12 feet high and were supported at the bottom by a steel shelf. The cross sections were 20 x 14 inches on the first panel, and 18 x 13 inches on the second panel. There was a strip 1 x 13 inches inadvertently left open at the bottom of the chases in the second test. Otherwise, the chases were closed, but the joints on the gypsum board were not taped. The gypsum board surface exposed to the furnace was unfinished in the first panel and was protected by a layer of sprayed fireproofing over metal lath on the second panel.

Chase 1

The pipe installation used in chase 1 is shown in figure 2A. The vertical pipe, four inches in diameter, was terminated at the top and bottom of the chase by ABS stack restrainers. The lower stack restrainer rested on two 3/8 inch thick sheets of asbestos cement board which sealed off the bottom of the pipe. For the first panel test the pipe opened into a double sanitary tee above the chase, which was used for smoke measurements. This tee was not used with the four chases on the second panel.

A 3 inch diameter galvanized iron pipe 19 inches long was attached to each wye with an adaptor and was terminated at the other end by a galvanized iron elbow. At the lower lateral the total projection of the elbow into the furnace was about 8 inches. The iron elbow at the end of the top lateral was fitted to a closet bend by means of another adapter. A closet ring was attached to the closet bend and a cap was inserted inside the closet ring to represent the seal of a water trap. There were about eight feet between the upper and lower branches, to represent the minimum distance between floor levels in a building.

Chase 2

Chase 2 differed from Chase 1 in that the galvanized iron pipe laterals were replaced by ABS pipes sheathed in 5 inch O.D. steel sleeves 17 1/2 inches long, as shown in figure 2B. The iron elbows were replaced by ones of ABS and the adapters were not needed.

Chase 3

In Chase 3 single sanitary reducing tees replaced the 45° wyes and the 3 inch diameter galvanized iron pipes were connected to the tees by adapters. The iron pipes passed horizontally through the chase walls. This is shown in figure 2C. There was no fitting at the end of the pipe which projected into the furnace. The upper lateral iron pipe was terminated with an iron coupling connected to an identical set of fittings as that used in Chase 1.

Chase 4

The installation in Chase 4 which is shown in figure 2D was the same as in Chase 3 except that ABS pipes with steel sleeves were used as in Chase 2. The adapters and the iron coupling were not needed.

Chases 5 - 8

The next four chases were built for the tests with the second panel. Chase 8 which includes the details of the other three chases is shown in figure 2E. A wye connection, a 3 inch lateral, a 45° ell which projects about 10 inches into the furnace at the lower level. And a combination of a 45° ell, a closet bend, a closet ring, and a cap at the upper level were common to all the chases tested with the second panel. The differences between the chases was in the number of lower laterals and the presence or absence of a steel sleeve.

Chase 5 had one lower lateral with a single 45° wye and a steel sleeve. Chase 6 had one lower lateral and no steel sleeve. Chase 7 had two lower laterals with a double 45° wye and no steel sleeves. Chase 8 had two lower laterals with a double 45° wye and steel sleeves. A photograph of the lower lateral of Chase 8 is shown in figure 3.

The variations in the installations are summarized in Table I.

The panel with the four chases was moved in front of the wall furnace shown in figure 4.

Figure 4 shows the furnace set up to measure the fire endurance time of a loaded wall specimen. In the ABS pipe tests the loading beam (O), hydraulic jacks (P) and the surface thermocouples (R) were not used. The test wall (Q) was replaced by the panel shown in figure 1.

2.2 INSTRUMENTATION

2.2.1 Temperature

To follow the temperature history at critical points in the installation there were nine chromel alumel thermocouples located in each chase. The locations and numbered designations are indicated in figures 5 and 6 and in Table 2. During the installation it was necessary to change the location of thermocouple 1 and Chases 1 and 2 and thermocouple 9 on Chase 2 to the position shown in figure 4, from that designated in Table 2.

In the second panel there were five additional thermocouples located in the partition between the middle chases to evaluate fire penetration of the partition. Their placement is shown in figure 7. Twelve standard ASTM thermocouples sheathed in iron pipes were used to monitor the temperature inside the furnace. The average furnace temperature was made to follow the standard ASTM E 119 time-temperature curve by controlling the flow of gas to the burners.

The extent to which it followed the curve can be seen in figure 8 for the tests with the second panel. The average rate of fuel consumption was about 8,000 cubic feet per hour of natural gas.

All of the above thermocouples were connected to a data logger which printed the temperatures at each location at two minute intervals. These numbers were subsequently punched on cards and fed into the NBS computer which produced a magnetic tape record suitable for Cal Comp plotting. The computer program generated the graphs presented in this report for the second panel test. Data from the first panel test were reduced manually.

2.2.2 Smoke

Optical densities of the smoke leaving each chase were obtained with laboratory smoke meters which consisted of a light source and a detector located at opposite ends of the double sanitary tee above each chase. Thus a measurement was made of the attenuation of the light beam by smoke rising through the chase. These meters can be seen at the top of figure 9 which is a photograph of upper portion of the chases before the first test. The light source consisted of a 30 watt tungsten lamp located at the focal point of a glass lens. The detector was a IP 39 single stage phototube located behind a 1/8 inch diameter aperature plate positioned at the focal point of another lens. Glass windows at each end of the double sanitary tee restricted the collimated light path through the smoke to 11 5/16 inches. The output of each phototube was connected to a recorder.

3.0 FURNACE PRESSURE

Critical to the performance of the chase is the passage of flame through the hole left by the melting and burning of the pastic pipe. In a real fire a positive pressure will always exist in the room of the fire origin. Therefore, a realistic simulation of the fire spread hazard required positive pressure to be present in the furnace at the opening of the lateral.

In the NBS furnace, the magnitude of the furnace pressure and its variation with height depends on the gas pressure, the temperature, and the relative size of the openings for air inlet and hot gas exhaust. The pressure increases linearly with height in the furnace and the neutral pressure plane (where inside and outside pressures are equal) normally occurs about 4 to 8 feet above floor level. Above the neutral pressure plane furnace pressures are higher than outside, and below the neutral pressure plane they are lower than the outside.

Secondary combustion air is admitted to the furnace by natural draft through the space between the floor and the lower edge of the frame into which the panel is built. This opening was approximately 2 1/2 inches high and 16 feet long. The hot gases normally exhaust through a flue served by five 10 inch square furnace vents.

During the test the pressure in the furnace was measured at two elevations, 53 and 144 inches above the floor. The pressure at the lateral inlet, 61 inches above the floor, was obtained by linear interpolation.

In the just test the positive pressure at the pipe inlet was 0.01 inches of water which was considered to be too low. To determine the maximum amount of positive pressure that could be generated in the lower portion of the furnace two supplementary pressure tests were conducted after the first panel test, An available wall mounted in a test frame was used to close up the front of the furnace. The highest pressures in the furnace are generated with a small exhaust vent opening and a relatively large air inlet at the base of the test frame. On these tests the maximum opening below the test wall was maintained while the number of vents opening into the furnace stack was varied.

As a result of these supplementary tests it was decided to run the second panel with two vents open. A positive pressure of 0.03 inches of water was attained. This is in the range of pressures expected in a real fire situation for the lateral coming through the lower third of the wall height.

4.0 TEST RESULTS

The results of each test are presented as visual observations along with photographs, temperature histories, and, in the case of the first test, smoke measurements. The visual observations during each test are included as appendices.

4.1 Condition of the Chases After the First Test (77 minute fire exposure)

General:

Although the panel on which the chases were built for the first test is of comparable construction to those given a two hour fire rating in UL

Reexamination List Design No. 4-2HR, the studs had begun to burn and flames had broken through the joint at the top of the panel so that the test had to be terminated after 77 minutes. Figure 10 shows the partition with the exposed gypsum board removed. Note that charring was not limited to the studs associated with the chases. Also the magnitude of the charring of the studs associated with a particular chase was not in proportion to the damage suffered by the piping or gypsum board within the chase. The gypsum board on the back of the studs was intact. The holes seen in figure 10 were broken through after the test for observation purposes. The temperature on the unexposed surface of the gypsum board was not measured so it is not known whether the panel would have failed a fire endurance test if the upper joint had been better protected.

Figure 11 shows all four chases with their rear panels removed. All of the upper laterals were intact. The lateral in chase 3 had to be held up by a board for the photograph because the vertical stack was destroyed during the test.

The chase with the horizontal iron pipe for a lateral suffered the greatest damage and the highest temperature rises in the first test. The ABS pipe was partially burned and the remainder was left as a melted mass at the bottom of the chase. The lower portion of the gypsum board interior wall was charred.

The chase with the horizontal ABS pipe sheathed in a steel sleeve suffered the second greatest amount of damage. The lower tee was burned out and most of the remaining pipe was drawn down and collapsed flat. Although the ignition temperature of ABS was never attained at the level of the upper tees in these two chases, the temperatures were considerably higher near the end of the test than they were for the other two chases, and the duration of the test was considerably less than two hours. By contrast the damage suffered by the two chases with the 45° wye connections was much smaller. The lower wyes softened and collapsed. The iron pipe used as a lateral into the furnace for one of the chases fell back into the chase leaving an unprotected hole. The steel sleeve used in the other chase remained in place and supported what remained of the plastic pipe in the lateral. Except for peaks of short duration at the beginning of the test, the temperatures recorded in these two chases were quite low.

4.1.1 Chase 1

The lower 45° wye softened and collapsed as shown in figure 12. The vertical pipe was hanging free approximately 3/4 inches above the base board. There was no damage or discoloration to the gypsum board interior surfaces. The vertical pipe softened approximately one foot above the lower wye and was drawn down. The side facing the partition had a coarse rippled surface due to the heat from the partition. The lower iron nipple fell into the chase.

4.1.2 Chase 2

The condition of chase 2 was similar to that of chase 1, except that the lower 45° wye fitting was held in place by the steel sleeve. This is shown in figure 13.

4.1.3 Chase 3

The pipe inside of chase 3 was completely destroyed. There was a melted mass of plastic pipe approximately 14 x 14 x 5 inches and the cast iron nipple at the bottom of the chase as shown in figure 14. There was a small piece of plastic solidified to the thermocouple wire approximately 2 inches in diameter and 10 inches long about 1 foot below the upper wye. This can be seen in figure 15. The interior surfaces of the gypsum board were charred and burned from the base up to about the 5 foot height. The upper surfaces were black but this appeared to be mainly due to soot deposition rather than paper charring.

4.1.4 Chase 4

The upper branch of chase 4 was intact from the tee down approximately one foot as seen in figure 16. The remainder of the plastic pipe was drawn down and collapsed flat. The lower end was hanging free approximately 3/4 of an inch above the base. The lower 1 1/2 foot of vertical pipe was intact. See figure 17. The ramainder was deformed and sagging. The tee connector appeared to be almost 100% burned out. The interior surfaces of the gypsum board were about 80% covered with soot.

4.2 Temperatures During the First Panel Test

Figures 18 through 25 show the temperature histories during the first test for thermocouples 1,2,3,5 and 6 for all four chases. Since thermocouple 1 was just inside the furnace its temperature was very close to the furnace temperature for all four chases.

Thermocouple 2 located at the junction of the wye or tee indicated the temperature of the lower fitting. In chases 1 and 2, with the 45° wye fittings it never exceeded 135°C whereas in chases 3 and 4 with the tee fittings it went to 740°C and 425°C respectively. The lower tee burned completely in chase 3, partially burned in chase 4 and merely softened and collapsed in chases 1 and 2. Thermocouples 3, 5 and 6 indicate the gas temperature at different levels inside the pipe. There was a rise in these temperatures due to the passing of high temperature furnace gases and combustion products from burning plastic pipe near the inlet to the furnace. These temperatures dropped when the lower fittings burned up and the pipe collapsed and blocked the flow. In chase 4 there was a second temperature peak when the fitting was burning.

There were high values for thermocouple 3 throughout the test in chase 3 where the whole pipe installation melted or burned and the paper on the gypsum board interior caught fire.

Thermocouples 5 and 6 reflect the air temperature in the stack midway between the floors and at the junction of the lateral at the floor above respectively. These temperatures are tabulated in table 3 for comparison between the wye and tee connections and can be viewed in light of the fact that the ignition temperature of the ABS pipe is about 465°C.

Although all nine thermocouple readings were recorded for all of the chases on the strip chart recorder, only the most pertinent are plotted here because the data logger became defective during the test so that the more tedious manual data reduction procedures were necessary.

4.3 Smoke Measurements During the First Test

The record of optical density of smoke versus time for each meter is shown in figures 26 and 27. Because of a defect in the electrical circuit which developed during the test the results for chases 3 and 4 respectively were limited to the early part of the test. The deposits formed on the windows of the smoke meters for chases 1 and 2 during the test had optical densities of less than 1.

The presence of smoke was noted in chase 3 within 1 minute. The other meters showed a sudden indication of high smoke levels at about 6 minutes. The highest smoke level recorded was in chase 2. This was an optical density of over 4.5 occurring between 14 and 24 minutes. This occurred at the same time as the maximum gas temperature in the pipe. The maximum gas temperature in chase 4 was higher and occurred during the period in which that smoke meter was defective. It is possible that higher smoke densities might have occurred in chase 4.

In this test and in the second test the smoke issuing from the open stacks was very heavy and filled the panel test building, which had a single roof vent without mechanical exhaust. The presence of dense smoke and the possible buildup of CO and HCN gases required that test observers leave the building for a time during test 2.

4.4 Condition of the Chases After the Second Panel Test (124 min.fire exposure)

In testing the second panel a coating of fireproof plaster was applied to the exposed surface of the gypsum board and to its junction with the panel frame. This permitted the panel to last for the full two hours. In this case the only studs which were severely charred were in the chases, and the severity of the charring was in proportion to the damage to the piping and gypsum board in the interior of the chase. This damage was also in proportion to the temperatures observed in the chase during the later part of the test. By contrast with the first panel the failure of the second panel after two hours could be laid directly to the high temperatures inside the chases.

Figure 28 shows the wood stud framing after the second test with the exposed gypsum board removed. The chases are 8, 5, 7, and 6 starting at the left. The charring of the studs not associated with the chases is minimal and the amount of charring or burning of the studs associated with the chases is in proportion to the interior damage in the chase. The fire stop and the lower portions of the studs burned out completely in chase 7, as seen in figure 29, resulting in moderate involvement of the upper framing of this chase as shown in figure 30. The gypsum board in the interior of the chases was intact in chases 5 and 8, (the chases with the steel sleeve on the lateral) 20% destroyed in chase 6 and 100% destroyed in chase 7.

The most severe damage occurred in the chase with the double 45° wye and the ABS lateral without the steel sleeve. The plastic pipe was completely burned out, the studs were actively burning prior to the end of the test, and the ignition temperature of ABS was exceeded at the level of the upper 45° wye.

The chase with the single 45° wye and the ABS lateral without the steel sleeve also suffered a considerable amount of damage to the gypsum board and the studs in the lower portion. The pipe was completely burned out. The ignition temperature of ABS was reached midway between the upper and lower wyes, but the temperatures at the level of the upper wye only reached 240°C.

In the chases with the steel sleeves 20% of the plastic pipe remained at the top of the chase and about 1/3 of a cubic foot remained as melted material at the bottom of the chase. Minimal damage occurred to the studs and the gypsum board was not charred. Except for peaks of short duration at the beginning of the test the temperatures at the level of the upper wye never exceeded 160°C.

The top of chase 5 can be seen from the furnace side in figure 31. The gypsum board was broken away after the test in order to view the pipe. There was about 1/3 of a cubic foot of pipe remaining as melted material at the bottom of chases 5 and 8 and none at the bottom of chases 6 and 7. The upper stack restrainers softened and separated in chases 5 and 8. The unexposed side of chases 7, 5 and 8 are shown in figure 32 with the burned out holes visible in chase 7.

4.5 Temperatures During the Second Panel Test

The temperature histories of all nine thermocouples in each chase are presented for the second pipe test in figures 33 through 40. A comparison of thermocouples 5,6,7 and 8 for each of the chases is shown in figures 41 through 44. In addition, the temperatures in the partition between the two middle chases is shown in figure 45.

Thermocouple 1 is located inside the furnace and has a temperature close to that of the furnace. Thermocouple 2 gives the temperature of the lower wye until it is destroyed and then it gives the general gas temperature in the lower chase. Thermocouple 3 gives the temperature of the gas passing through the lower wye as long as the pipe remains intact.

Thermocouple 4 yields the temperature in the pipe at the bottom of the chase. It stayed near ambient temperature until melted material fell on it, which occurred at about 24 minutes for chases 5 and 8. Peak temperatures in thermocouple 4 occurred when the melted material or the paper on the gypsum board is flaming. The extremely slight rise in temperature of thermocouple 4 in chase 6 would indicate that the pipe must have burned in place without falling to the bottom of the chase. There was no flaming noted at the bottom of chase 6. Prior to 40 minutes there was very little rise in temperature of thermocouple 4 in chase 7.

Thermocouples 5,6 and 7 indicate the temperature of the gas passing through the upper part of the pipe as long as it remains intact. High temperatures in chase 7 at later times in the test were due to the burning of the wood and the paper on the gypsum board. The temperatures near the end of the test were much lower in chase 6 and lower yet in chases 5 and 8 reflecting the amount of fire damage reported for the chases. Figures 33 and 34 show the temperatures for T5 and T6, the critical temperatures for evaluating the spread of fire in the stack. The temperatures for stacks 5 and 8, which had steel sleeves in the laterals, were much lower than those for the other two stacks and never exceeded 300°C.

Thermocouple 9 indicates the temperature of the upper lateral pipe outside of the unexposed chase wall. This is critical in regard to fire spread into a room on the upper floor. In no case did this temperature exceed 130°C.

The thermocouple on the stud in the partition between the middle chases barely reached 170°C by the end of the test. However, its rate of temperature rise at that time was quite high.

5.0 DISCUSSION OF RESULTS

5.1 Fire Containment

The first test served to illustrate the superiority of the 45° wye over the horizontal tee. This was most dramatic in chase 3 which had the horizontal iron nipple and yet suffered considerable damage. Chases 1 and 2 with 45° wyes both had lower temperatures in the later part of the test than their counterparts 3 and 4, as indicated in table 3. This test also shows that a lateral of ABS pipe enclosed in a steel sleeve performs better than plain iron pipe. The amount of damage was greater and the temperatures near the end of the test were higher for chase 2 than for chase 1. Chase 2 used an iron pipe and chase 1 used an ABS pipe with a steel sleeve.

Chases 7 and 8 both had double 45° wye fittings at the lower level to investigate passage of flame through the chase with this arrangement. Without the sleeve the lateral on the unexposed side of chase 7 collapsed at 36 minutes and fire passed through the chase. On chase 8, where the steel sleeve was used the fire did not pass through. At the end of the test the sleeve on the unexposed face of the chase could be touched by hand.

In chases 5,7 and 8 there were temperatures in the range of 700 to 900°C in the lower areas from the passage of hot gas from the furnace into the pipe and burning of the lower section of the pipe. These temperatures in chases 5 and 8, the ones with sleeves, had peaks of two to three minute duration, occurring in the first 30 minutes, probably associated in some cases with burning of material at the bottom of the chase. In chase 7 the high temperatures were of extended duration and continued to the end of the test.

To investigate the possibility of fire being transmitted to the floor above--and out of the upper lateral--the temperatures T6 and T8, the gas temperature inside the upper wye and the surface temperature of the upper wye must be examined. These temperatures are shown in figures 42 and 44. For the sleeved laterals in stacks 5 and 8 the air temperature T6 was highest during the first part of the test, but never exceeded 300°C except for a 2 minute peak at 400° in chase 8. At the end of the test the temperatures were below 200°C.

For chases 5 and 8, with sleeves, thermocouple 8, at the wye junction, was below 200°C at its peak and below 150°C at the end of the test. This is well below the ignition point of the ABS pipe. Of importance, at the end of the test the temperature was holding constant for both thermocouples 6 and 8.

In the stacks without sleeves the upper lateral collapsed and fire issued from the unprotected opening. This action showed the great value of the sleeves in holding the pipe assembly in place to prevent passage of fire.

For stacks 5 and 8 the sleeved assemblies prevented the passage of fire through the chase or from one floor to the upper via the stack.

5.2 Smoke Containment

In all chases dense smoke came out from the top of the stack at various times, associated with various stages of burning of the pipe. Since the stack would be going through the roof of a building this smoke would be going to the outside or condensing out as long as the stack remained intact and the joints of the chase were impervious. The joints of the gypsum board framing the chases were tight but not taped and some light amounts of smoke came through the joints of the chase, indicating the need for a reasonably air-tight chase to contain the smoke and gaseous products. Also, some smoke came out through the opening where the lateral came through the chase wall although the space between the wall and the pipe had been filled with mineral wool prior to the test. This passage of smoke indicated that a cementitious packing or other type of air-tight seal of the openings around the laterals is needed. The solid packing chosen must not crack or shrink on heating.

5.3 Effect of Chase Construction

Although the panel for the second series of tests had a layer of plaster over metal lath on the exposed face and the fire endurance rating was well in excess of two hours, the wood studs in chase 7 were burning freely at the end of the test. The thermocouples in the partition between the chases indicated that the wall performed well against exposures from the fire side only. Thus the damage to the studs may be attributed to the additional heat coming through the interior wall of the chase. The primary source of this heat was the hot gas passing through the hole left by the melted pipe. This gas heated the wall directly and also raised the temperature of the ABS pipe to its ignition temperature. The burning pipe contributed additional heat to the wall.

The chase performance indicated that the ABS pipe should only be used in a non combustible chase. Further tests on 2 hour combustible chases are needed to define when the use of ABS DWV systems would be acceptable for use in combustible constructions.

5.4 Pressure Difference

From a comparison of observations and temperature measurements in tests 1 and 2, pressure difference had a considerable effect on the burning of ABS pipe. Pressure difference may also be a factor in the passage of flame and smoke from a fire-involved room to a shaft or pipe chase. Pressure differences on the order of 0.03 in H_2O may be expected to develop in the lower one third of a room due to the fire alone. In addition, where shafts are open, an appreciable stack effect may exist, particularly in tall buildings in winter. For example, a 20°F temperature difference over a height of 100 feet (or an 80°F temperature difference over a height of 20 feet) can produce a pressure head of 0.05 in H_2O. This forms the basis for the requirement that the shaft be closed at the top and bottom in order to prevent indrafts of outside air, thereby maintaining the stack at a temperature close to that of the building interior. Consideration may have to be given to the buildup of combustible or explosive mixtures in tightly closed pipe chases, although no evidence of this was noted in these tests.

6.0 CONCLUSIONS

6.1

The combination of the 45° wye fitting and a steel sleeve enclosing the plastic pipe where it penetrates the chase wall was effective in preventing the passage of flame horizontally through or vertically up a chase with an ABS DWV pipe installation during the 2 hours of fire exposure provided under the conditions of these tests. These conditions include a positive pressure typical of the lower one third of a burning room at the pipe inlet, and a chase sealed off at the top. The downward angle of the sleeve reduced the direct radiation into the chase and restricted the passage of flame and hot gases. The projection of the sleeve into the chase reduced the contact of the remaining hot gases with the chase wall. The steel sleeve also kept the laterals through the unexposed wall from collapsing and thus maintained the smoke tight integrity of the system. A small projection of the steel sleeves through the chase walls was sufficient for the conditions of these tests.

6.2

When the steel sleeve was not used the hot furnace gases entering the chase heated the interior walls and caused the ABS pipe to burn, which further increased the wall temperatures. The high interior temperature tended to bring the combustible studs, now heated from both sides, to their ignition temperature in less time than the indicated fire endurance of the construction. The use of steel sleeves reduces the interior chase temperature but until the problem is studied further the chase should be limited to non combustible construction.

6.3

Since all the tests in this series were performed with the top of the chase sealed, except where the pipe penetrated the top, the performance of a chase with an open top cannot be predicted. The presence of drafts in the chase could make a difference in the burning of the pipe and the tendency to fire spread.

6.4

Since some smoke came through the mineral wool packing around the lateral--where it passed through the chase wall--a cementitious or other air tight packing is indicated for smoke control. A type of packing must be chosen, however, that will not pull away from the openings at high temperature and leave an even more direct path for smoke effusion.

6.5

Further tests with both 2 hour combustible and 2 hour non combustible construction are needed for a satisfactory definition of the requirements regarding the use of ABS DWV systems in pipe chases with closed tops. Additional tests beyond these would be necessary to consider the use of chases with open tops.

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Table 1

CHASE VARIABLES

Chase	Lateral Passage Through Wall	Fitting	No. of Branches at Bottom
1	Iron Nipple	45° wye	1
2	ABS + Steel Sleeve	45° wye	1
3	Iron Nipple	Straight Sanitary Tee	1
4	ABS + Steel Sleeve	Straight Sanitary Tee	1
5	ABS + Steel Sleeve	45° wye	1
6	ABS Alone	Double 45° wye	2
7	ABS Alone	45° wye	1
8	ABS + Steel Sleeve	Double 45° wye	2

Table 2

THERMOCOUPLE LAYOUT

Number	Location
1	Top of nipple, pipe, or sleeve, fire side of partition (lower lateral)
2	Top outside crotch of sanitary tee or wye (lower)
3	Inside center of sanitary tee or wye (lower)
4	Bottom of pipe on asbestos cement base
5	Center of 4 inch pipe equidistant from laterals
6	Inside center of sanitary tee or wye (upper)
7	Inside center of 4 inch pipe near open top
8	Top outside crotch of sanitary tee or wye (lower)
9	Top of pipe nipple, unexposed side of chase (upper lateral)

Table 3

MAXIMUM GAS TEMPERATURES IN THE UPPER STACK

CHASE NO.	T5	T6
1	300°C	275°C
2	400	360
3	440	300
4	500	395

APPENDIX A

Visual Observations During First Panel Test

Test Conducted For 77 Minutes

3 min: Smoke is coming from the stack of chase 3

6 1/2 min: The ABS Projections into the furnace from chase 2 and 4 are on fire. Smoke is still coming from chase 3.

9 min: Flames are going into the furnace from the burning of the plastic pipe in the sleeves in chases 2 and 4. This is especially heavy from chase 2 up the face wall.

10 min: Two puffs of flame emerged from the top of the stack in chase 3. There is heavy smoke from stack 3 and moderate from stack 1.

13 min: Heavy yellow smoke is coming from stack 2, moderate smoke from stack 3, light smoke from stack 1, and none from stack 4. The pipe is gone at the inlet to chase 2. The nipple on chase 3 and the sleeve on chase 4 are red hot.

17 min: There is black smoke from stack 4.

18 min: There is heavy white smoke from stack 2. There is heavy black smoke from stack 4. There is light smoke from stack 3.

20 min: There is a sharp decrease in smoke from stack 4.

23 min: The vent collapsed at the top of chase 4. There is light white smoke coming from stack 2.

24 min: There is heavy white brown smoke coming from stack 3.

28 min: There is no visible change inside of the furnace. There is light brown smoke from stack 2 and heavy brown smoke from stack 3. There is a slight fire from the junction of the gypsum board on the face wall in the furnace.

32 min: There is light smoke from all four stacks. The fire from the joints inside the furnace stopped. There are occasional

lazy puffs of smoke from stack 2. There is flame from the packing around the nipple in class 3.

36 min: The smoke intensity from stack 3 has increased to moderate to heavy.

39 min: There is a fire inside the sleeve of chase 4.

42 min: Nothing is happening inside of the furnace. There is light smoke from stack 2 and moderate smoke from stack 3.

48 min: There is moderate smoke from stack 3. There is nothing happening inside of the furnace.

51 min: There is light smoke from stack 2 and moderate smoke from stack 3.

60 min: There is moderate smoke from stack 2 and from the packing at the top of chase 2. There is light smoke from stacks 1 and 4. There is moderate smoke from stack 3. There are lazy flames out of chase 2 inside the furnace.

72 min: The wood studs are burning.

77 min: The gas is turned off to the furnace. There are flames out of the nipple in chase 2.

83 min: Black smoke is emerging from chase 3 and the top tee has collapsed at some previous time.

APPENDIX B

Visual Observations During the Second Panel Test

Test Conducted For 124 Minutes

1.5 min: The elbows in the furnace are beginning to soften.

1.75 min: There is occasional flaming of these elbows.

2.5 min: There is smoke from the stacks at the top of chase 6 and 7. There is little from the stacks of chase 5 and 8.

3.5 min: There is heavy smoke from stack 8.

4 min: There is heavy smoke from stack 5.

5 min: There is very strong flaming from the fittings of chase 5 and 8 inside of the furnace. This is accompanied by melting and dripping.

6.5 min: There is heavy smoke from stack 7 and a small amount from stacks 5 and 8.

12 min: The lower branch of chase 7 outside of the furnace sagged, possibly due to stack softening. There is heavy smoke from chase 7 from the mid-height to the top.

14 min: There is heavy smoke from stack 5. There is a slight leakage of smoke from the joints of chase 6. There is no plastic pipe left in the furnace.

15 min: There is heavy smoke from stacks 5 and 8 The sprayed gypsum board or metal lath panels are bowing in the furnace.

20 min: There is some smoke from the upper joints of chase 5.

25 min: There is heavy smoke from stack 8. There is slight black smoke near the bottom of the outside of chase 5. This is possibly the paper on the gypsum board.

27 min: There are occasional fires at the bottom of chase 5. The paper from the gypsum board is burning.

30 min: There is smoke from the upper branch of chase 5. There is exceptionally heavy and acrid smoke throughout the test building. This is most severe for about 7 minutes.

31 min: There is flaming in the furnace near the south end.

32.5 min: There are heavily pulsating spurts of flame at the bottom of chase 8 lasting to 34 minutes.

36.5 min: The lower branch of chase 7 fell off.

37.0 min: There are heavy flames through the opening about 2 feet long.

39 min: The hole was boarded up. The upper branch of chase 7 dropped and heavy smoke is coming out.

40 min: There are flaming drips from the bottom of chase 7. The interiors of chases 7 and 8 are flaming at the bottom. Black smoke is coming from the top and bottom of chase 7.

43 min: Chases 6 and 7 show black charring on the upper half due to burning in the chase. This is also noted 2 feet above the bottom on chase 5. There is black soot on top of the lower branch of chase 8 from burning at earlier times.

45 min: There is heavy smoke still issuing from around the upper branches of chases 5,6 and 7 The steel sleeve on chase 8 is warm to the touch.

50 min: Flaming is observed from under chase 7. Black soot is dropping out from heavy smoke from chase 7. The upper branch of chase 6 has sagged about 10°

52 min: There are short momentary flames out of the bottom of chase 7 Smoke is issuing from the gypsum board extension on the exterior of the frame at the top.

55 min: Lath and plaster are bowed and cracked at several locations but are intact and holding up well.

60 min: There is very heavy black smoke issuing through the opening of the upper branch of chase 7. There is moderately heavy gray smoke issuing through the opening of the upper branch of chase 6. The upper branch of chase 6 has sagged to 45°. There is a small trace of gray smoke from the upper branch of chase 5. The upper branch of chase 5 is still horizontal and intact. This branch is also intact on chase 8 with

barely perceptible wisp of smoke.

64 min: The upper branch of chase 6 has sagged completely down against the chase wall. Bright yellow flames are seen in the furnace due to the burning of soot particles being drawn into the furnace at the bottom.

75 min: There is a flaming mass approximately 6x6 inches below chase 7. Flaming drips continue to burn for 15 minutes. There is charring of the gypsum board at the upper corner of chase 6.

87 min: There are flames out of the upper branch opening of chase 7 where the lateral fell off. These flames occasionally extend out about 1 foot and indicate that the paper on the gypsum board is burning.

90 min: There is heavy gray smoke through the joints at the top seal of chase 7.

95 min: The studs are burning in chase 7.

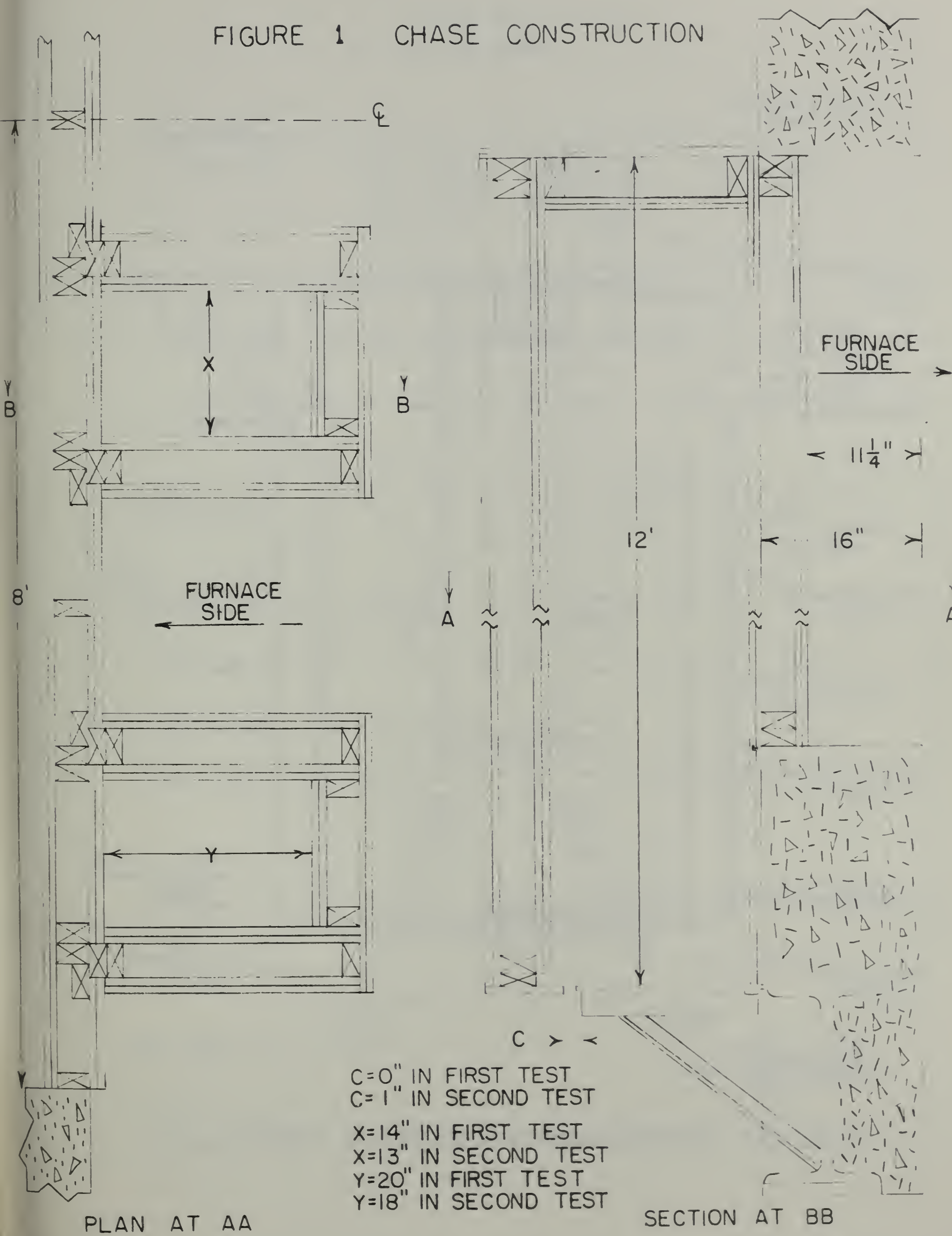
100 min: There is heavy gray wood smoke emerging from chase 7.

108 min: The thermocouples whose leads pass through the arm near the top of chase 7 were disconnected

120 min: All of the stack tops are still in place above the chases. They are held on by collars. There is moderately heavy gray smoke through the branch opening in chase 6. There is moderately heavy gray black smoke through the separation between the sleeved branch and opening in chase 5.

124 min: The gas is turned off to the furnace. Chases 5 and 6 are still producing heavy black smoke. There is heavy smoke from chases 5 and 6 into the furnace. In addition there is a strong flame from chase 6 into the furnace.

FIGURE 1 CHASE CONSTRUCTION



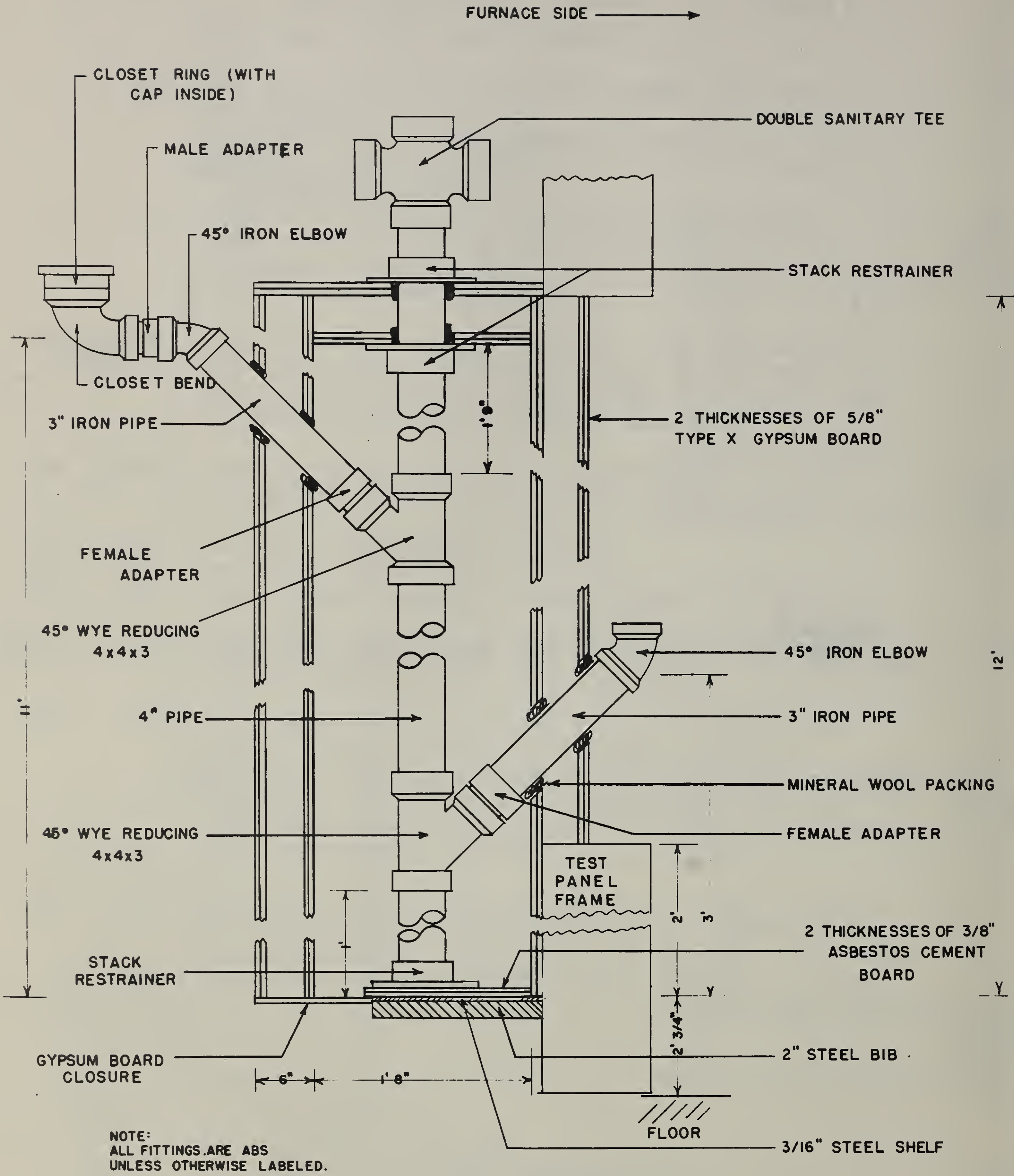


FIGURE 2A PIPING ARRANGEMENT IN CHASE 1

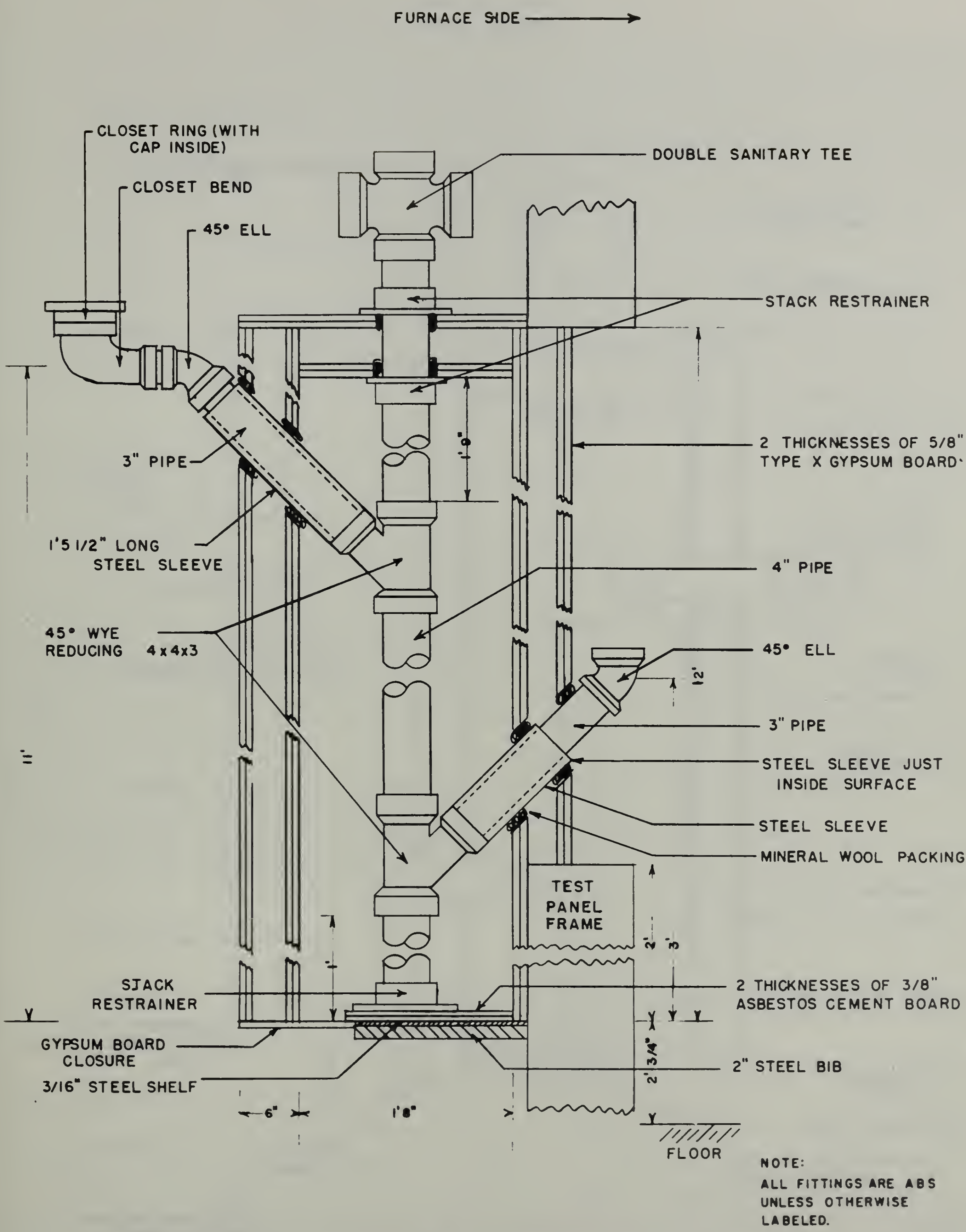


FIGURE 2B PIPING ARRANGEMENT IN CHASE 2

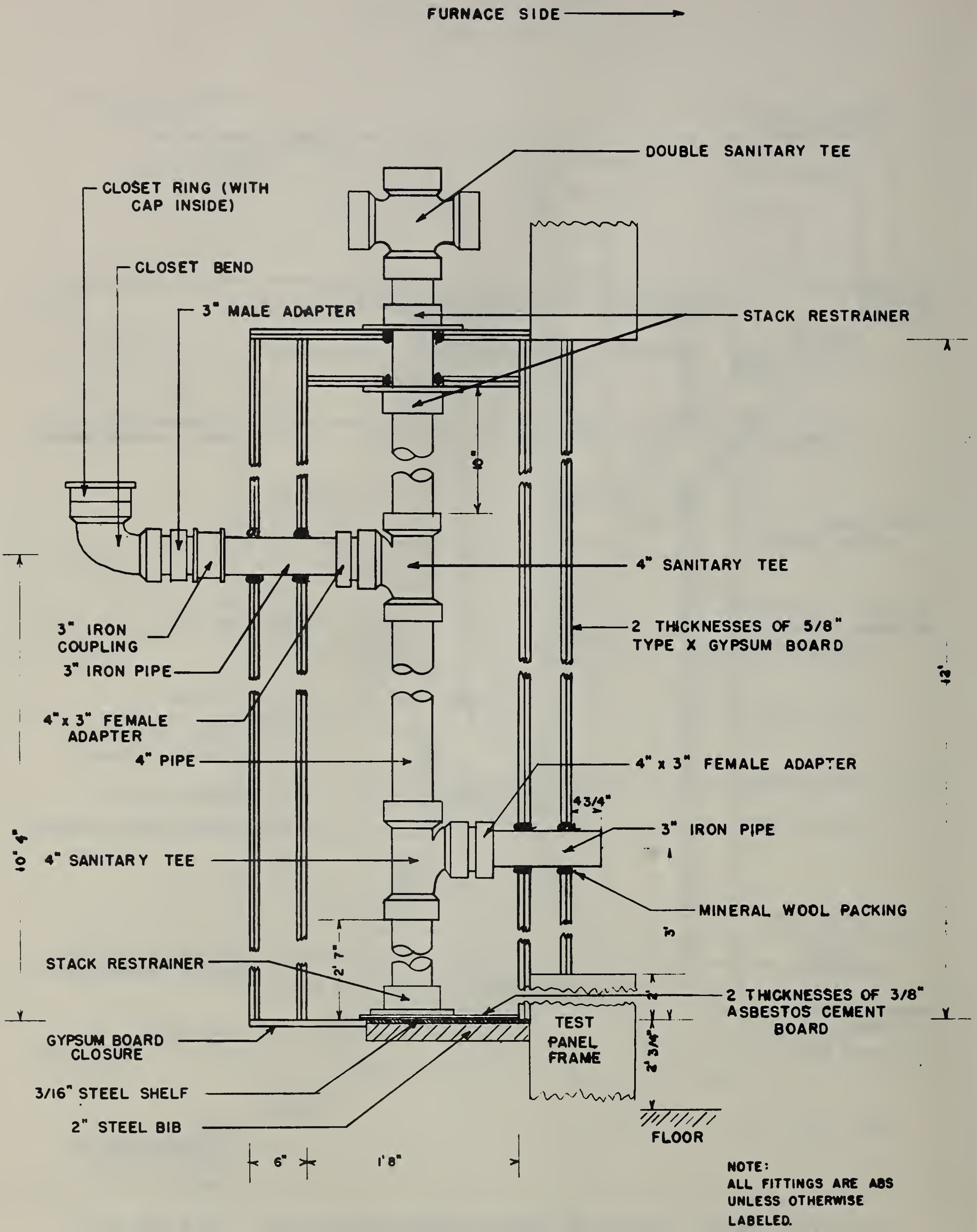


FIGURE 2C PIPING ARRANGEMENT IN CHASE 3

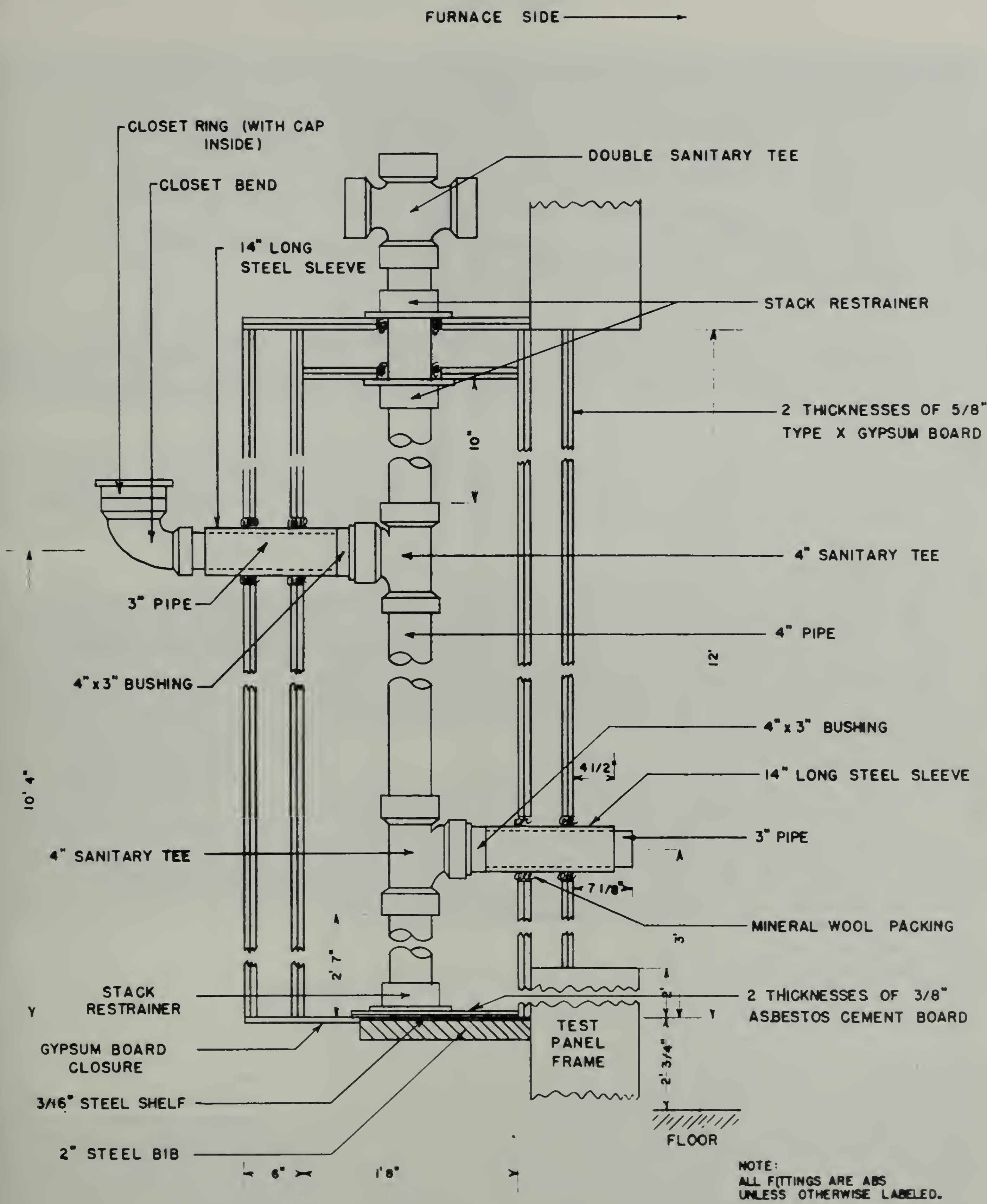


FIGURE 2D PIPING ARRANGEMENT IN CHASE 4

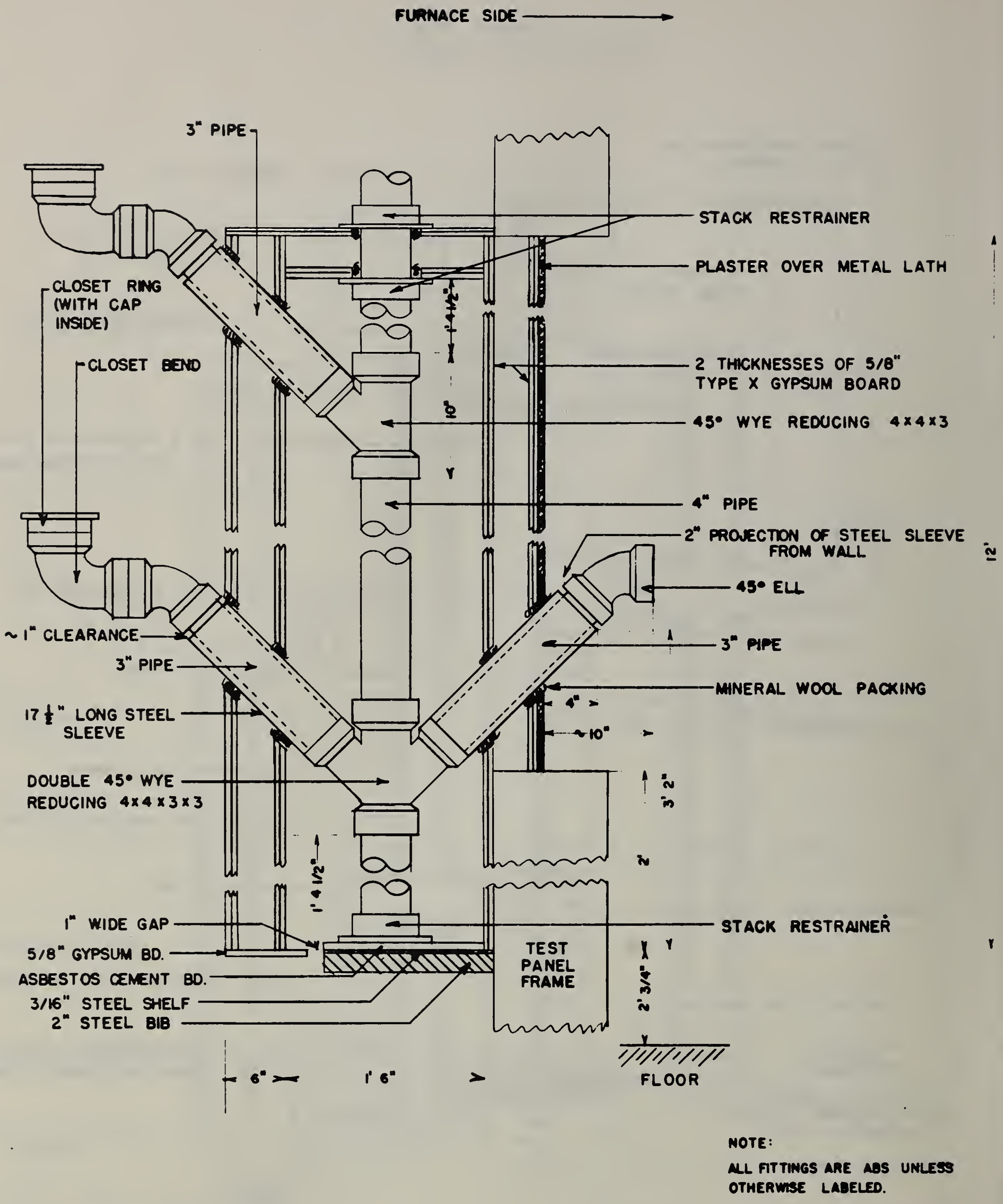


FIGURE 2E PIPING ARRANGEMENT FOR CHASE 8

Fig. 3. Lower Branch of Chase 8

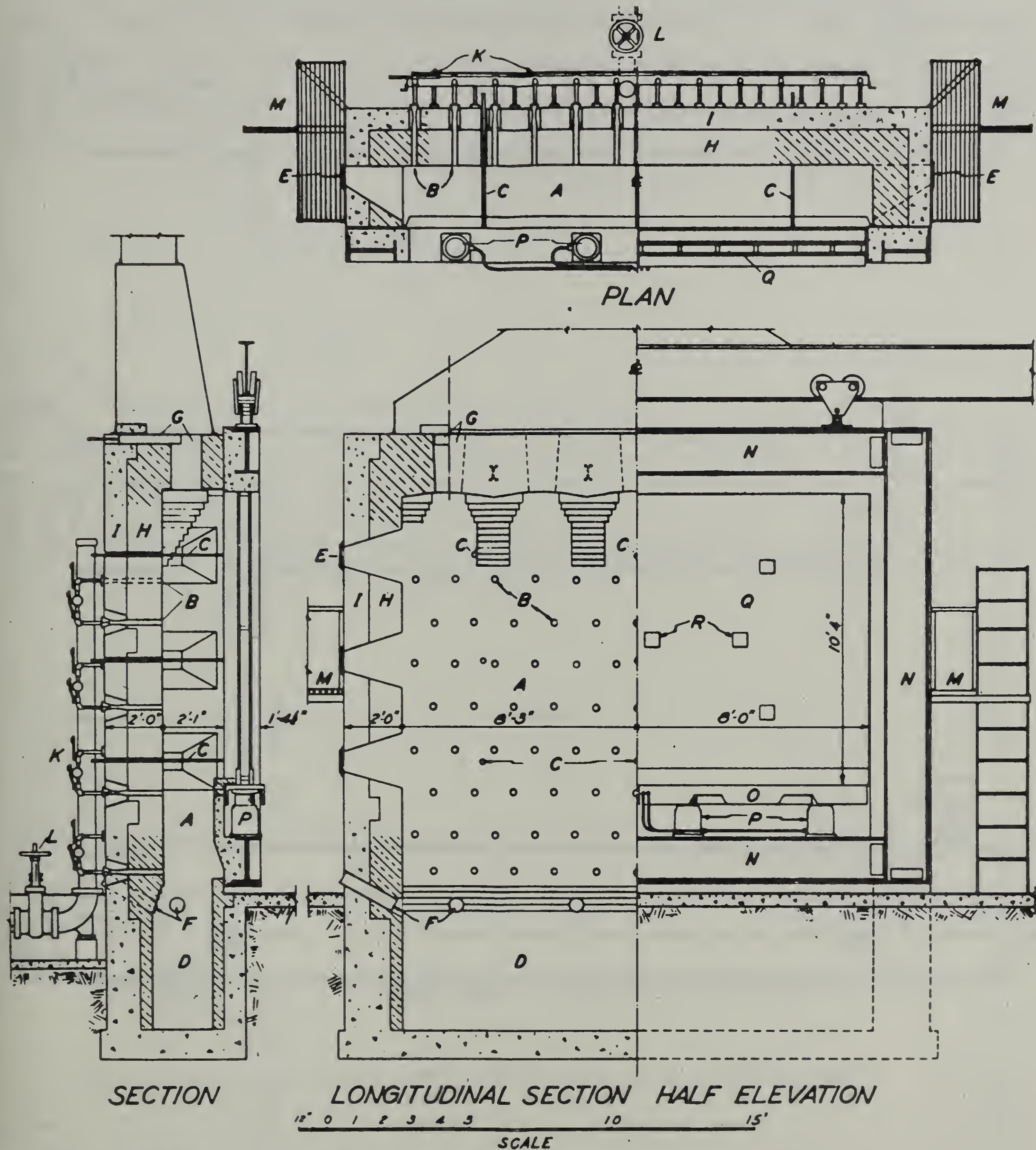


FIGURE 4 DETAILS OF WALL-TESTING FURNACE.

A, FURNACE CHAMBER; B, BURNERS; C, THERMOCOUPLE PROTECTION TUBES; D, PIT FOR DEBRIS; E, OBSERVATION WINDOWS; F, AIR INLETS; G, FLUE OUTLETS AND DAMPERS; H, FIREBRICK FURNACE LINING; I, REINFORCED CONCRETE FURNACE-SHELL; K, GAS COCKS; L, CONTROL VALVE; M, LADDERS AND PLATFORMS TO OBSERVATION WINDOWS; N, MOVABLE FIREPROOFED TEST FRAME; O, LOADING BEAM; P, HYDRAULIC JACKS; Q, TEST WALL; R, ASBESTOS FELTED PADS COVERING THERMOCOUPLES ON UNEXPOSED SURFACE OF TEST WALL.

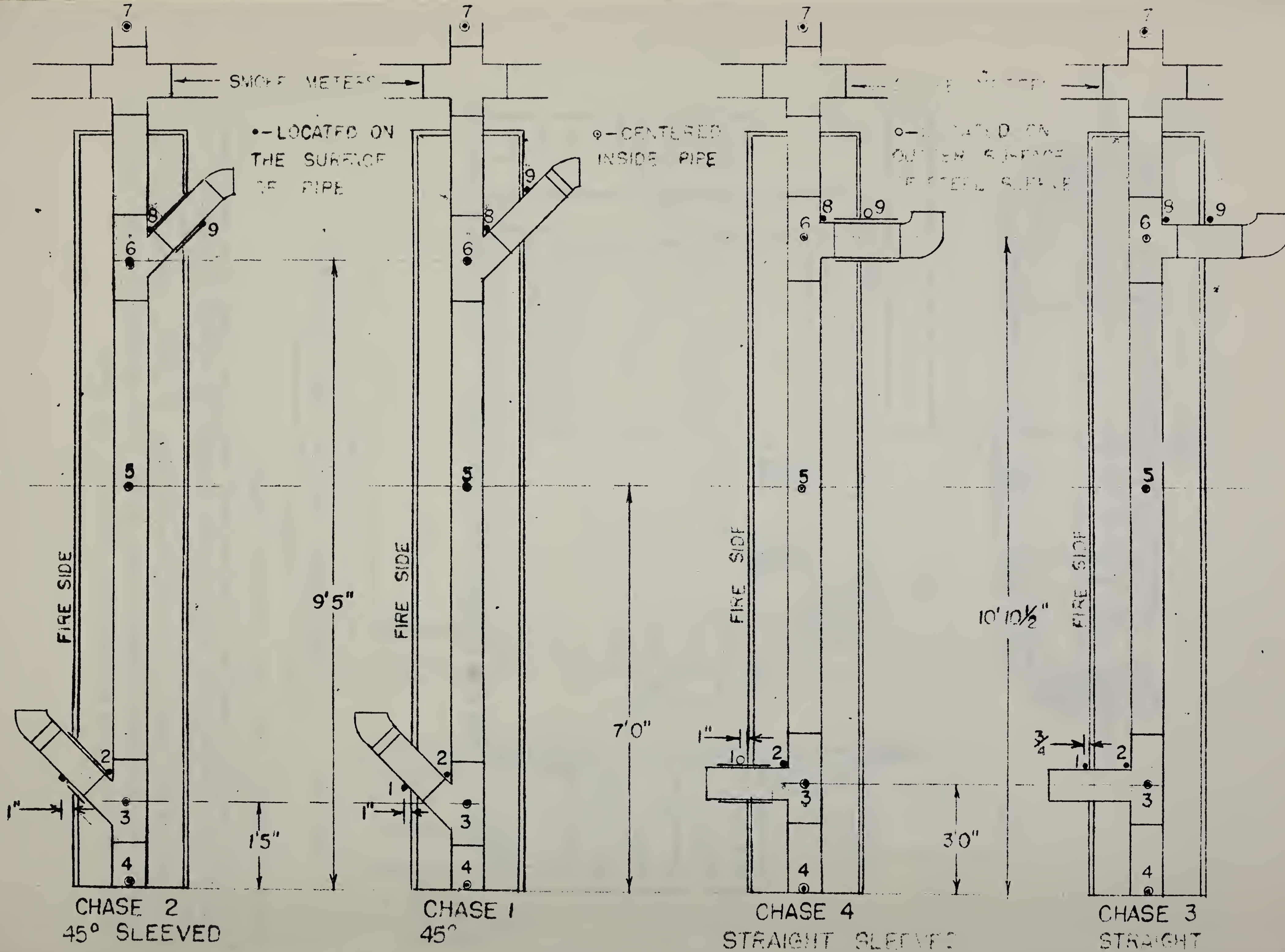


FIGURE 5 THERMOCOUPLE LOCATIONS ON ABS PIPE TEST 466

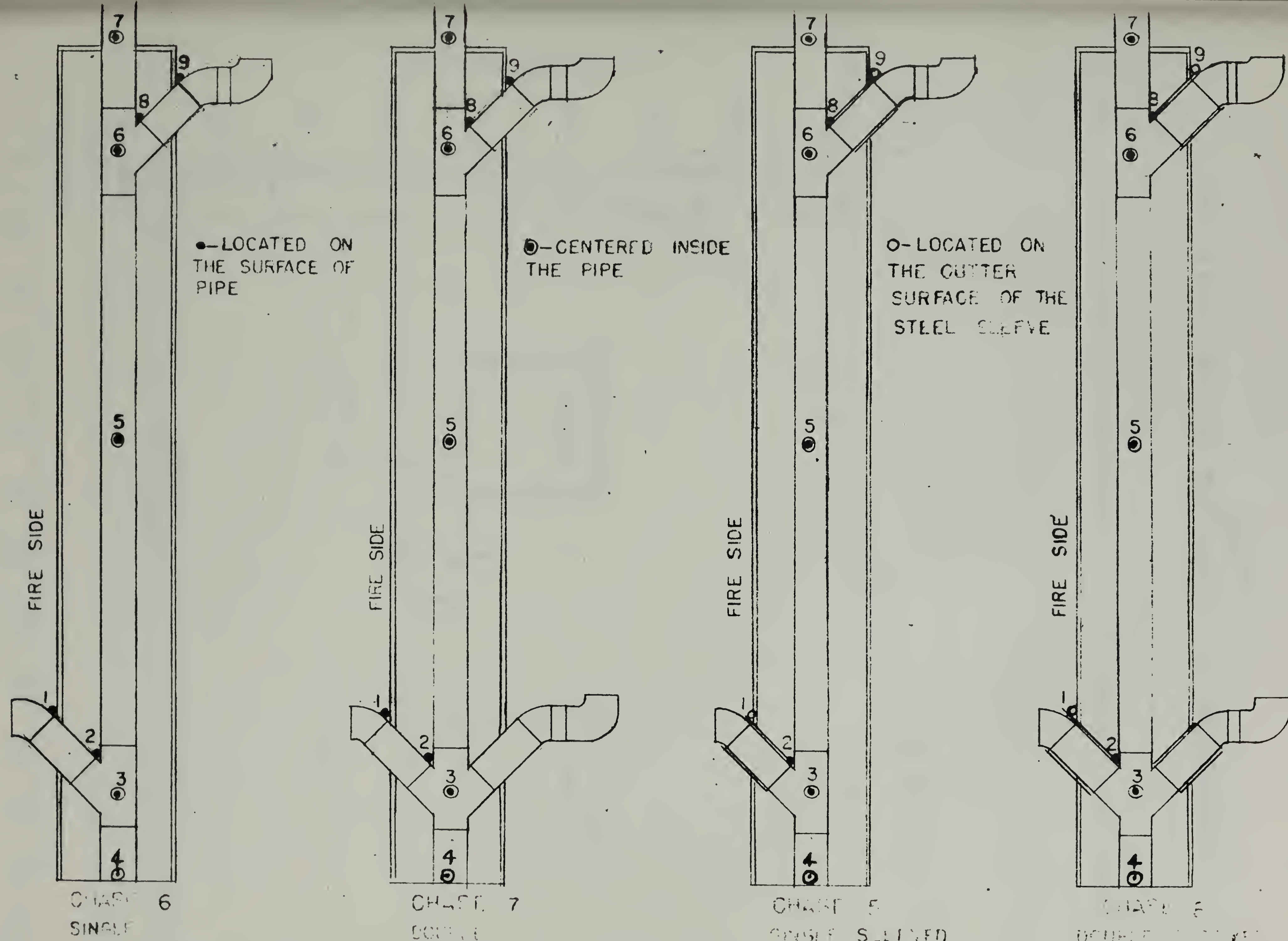


FIGURE 6 THEROMCOUPLE LOCATIONS ON ABS PIPE IN TEST 471

FIGURE 7
THERMOCOUPLE LOCATIONS IN THE PARTITION

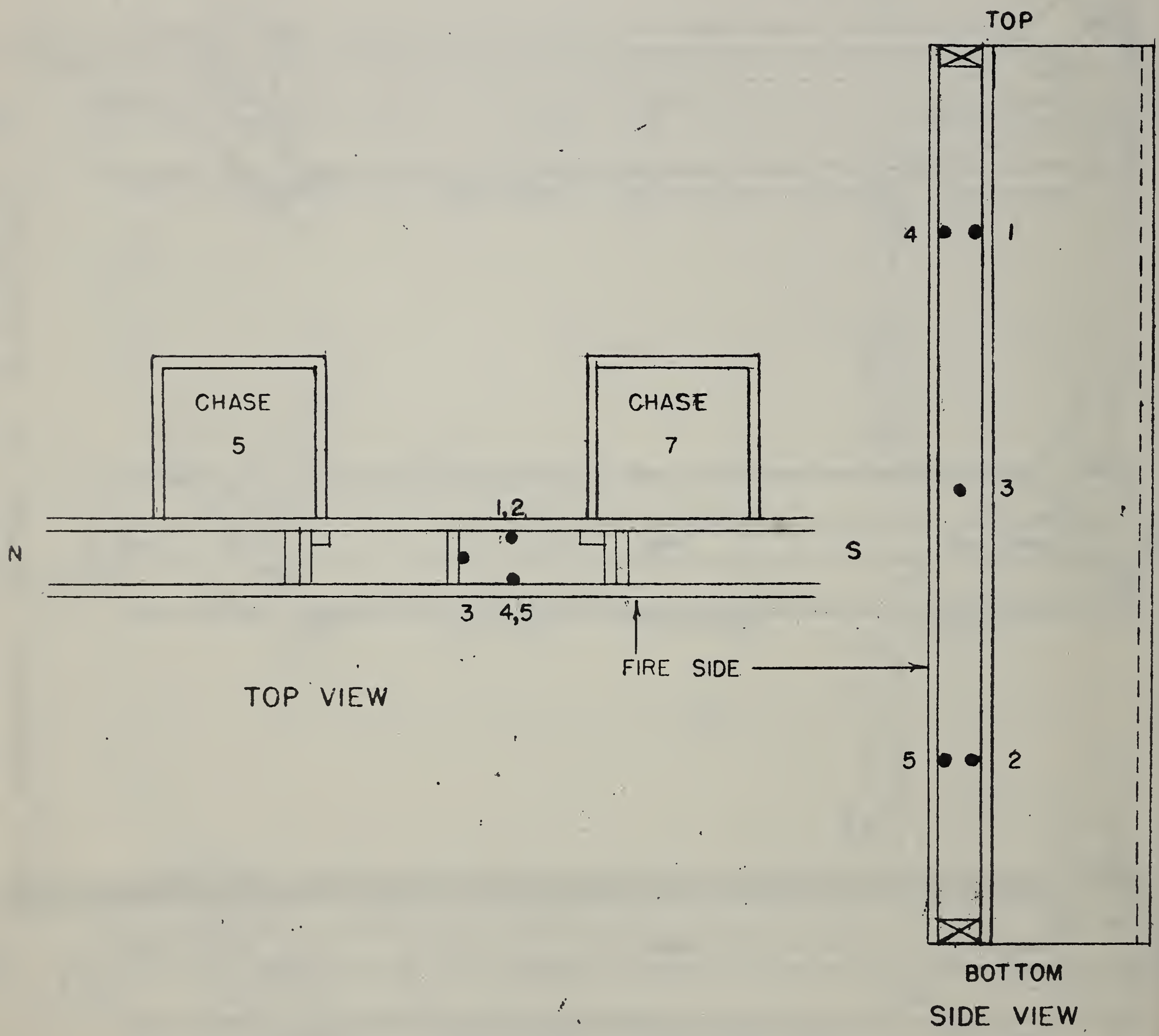
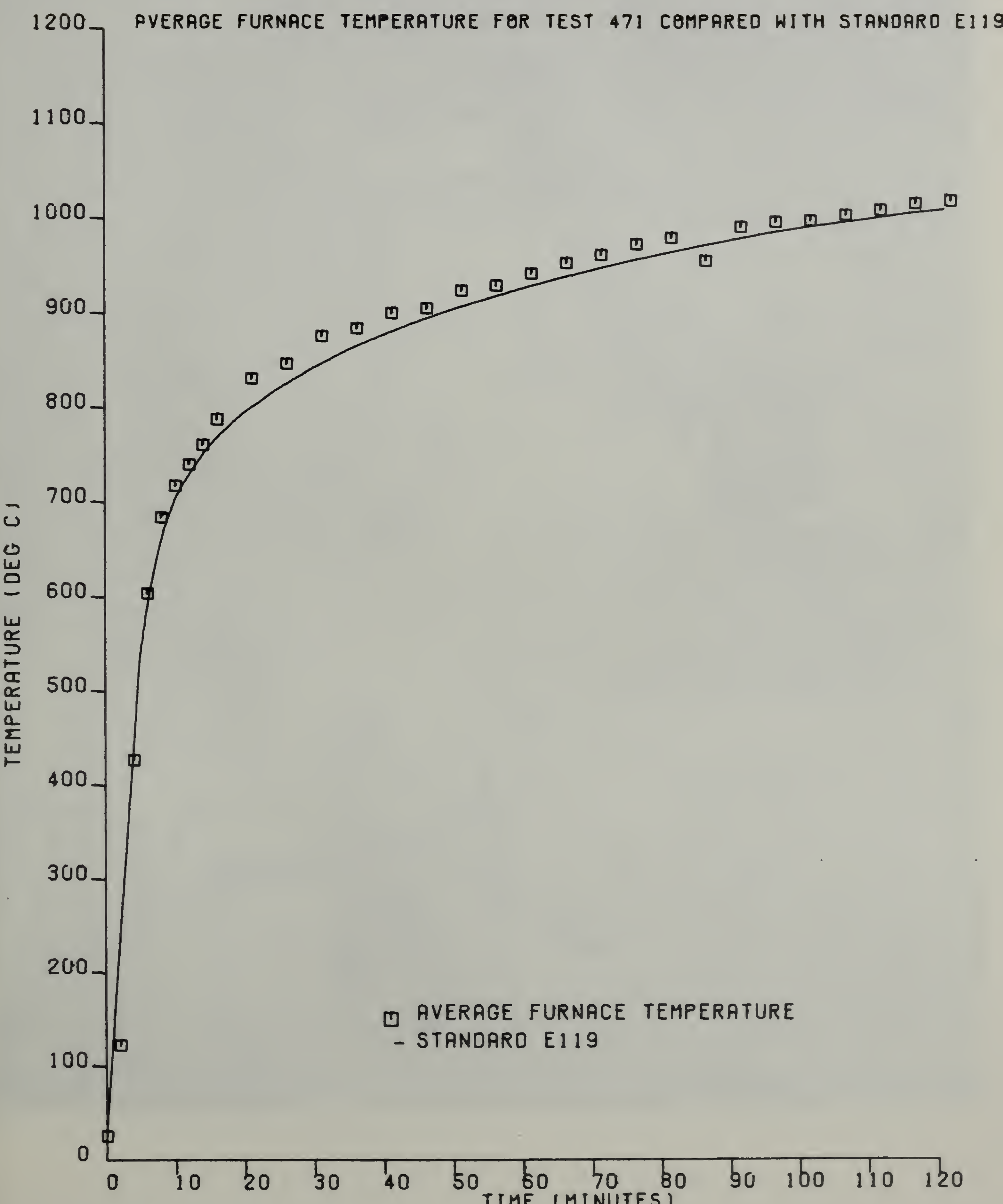


FIGURE 8



AVERAGE FURNACE TEMPERATURE FOR TEST 471 COMPARED WITH STANDARD E119
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
AVERAGE FURNACE TEMPERATURE
STANDARD E119
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)

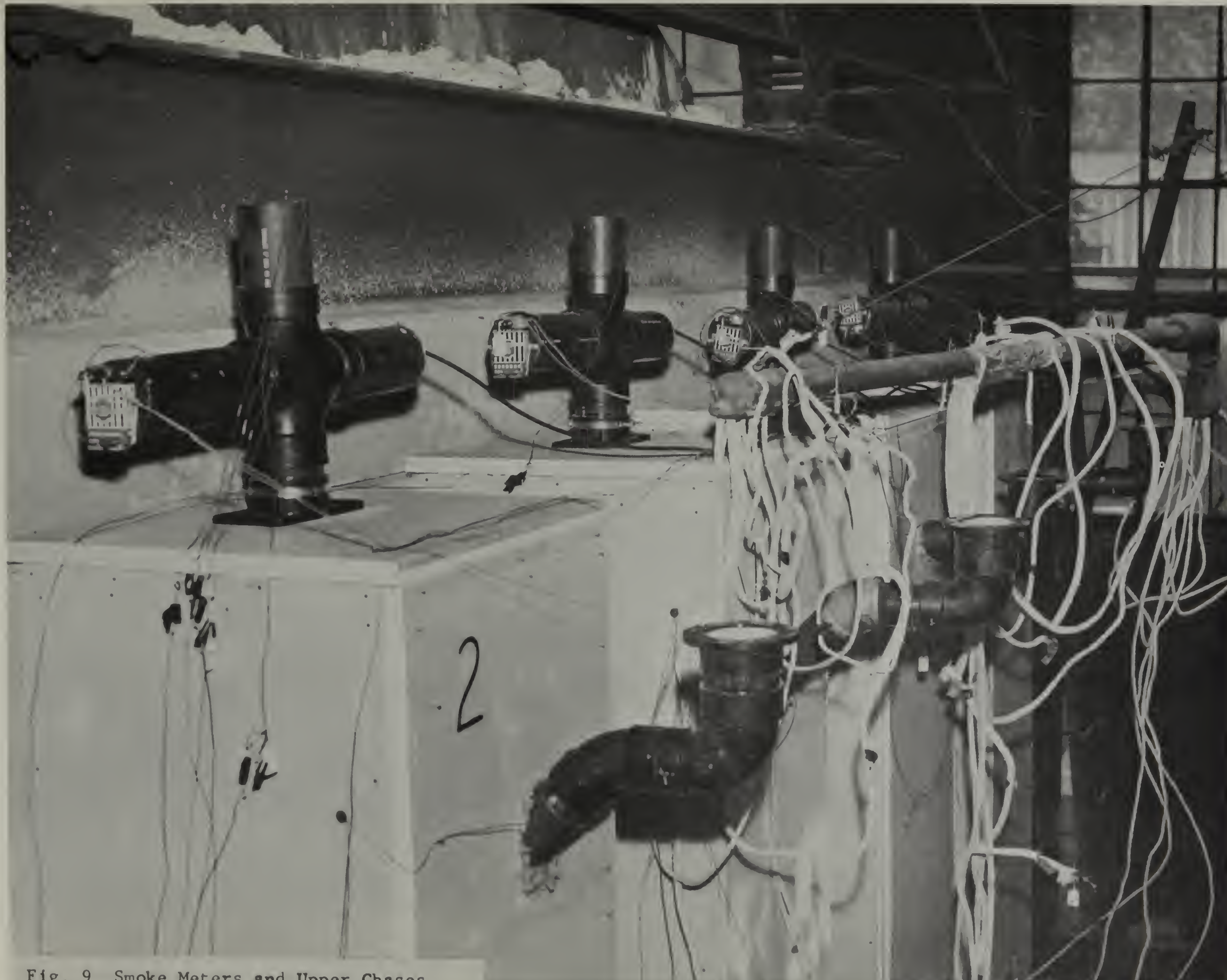


Fig. 9 Smoke Meters and Upper Chases
2, 1, 4 and 3

Fig. 10 Fire Side of Partition After the First Test (Holes in Gypsum Board Were Made After the Test)

Fig. 11 Chases 2, 1, 4 and 3 After Test

Fig. 12 Lower Part of Chase 1 After Test

Fig. 13 Lower Part of Chase 2 After Test

Fig. 14 Lower Part of Chase 3 After Test

Fig. 15 Upper Part of Chase 3 After Test

Fig. 16 Upper Part of Chase 4 After Test

Fig. 17 Lower Part of Chase 4 After Test

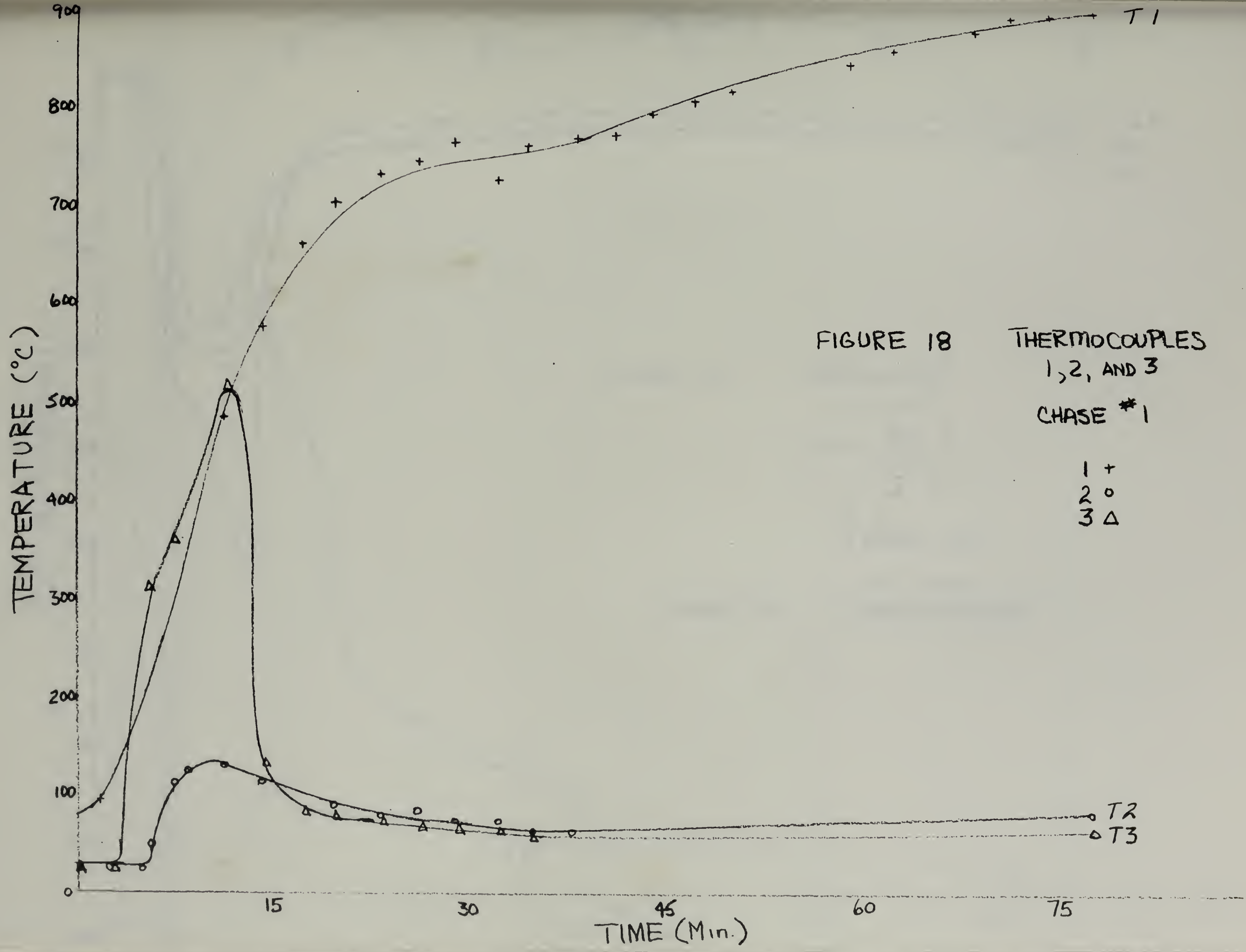


FIGURE 18
THERMOCOUPLES
1, 2, AND 3
CHASE #1
1 +
2 o
3 Δ
T1
T2
T3
TEMPERATURE (°C)
TIME (Min.)
0
100
200
300
400
500
600
700
800
900
15
30
45
60
75

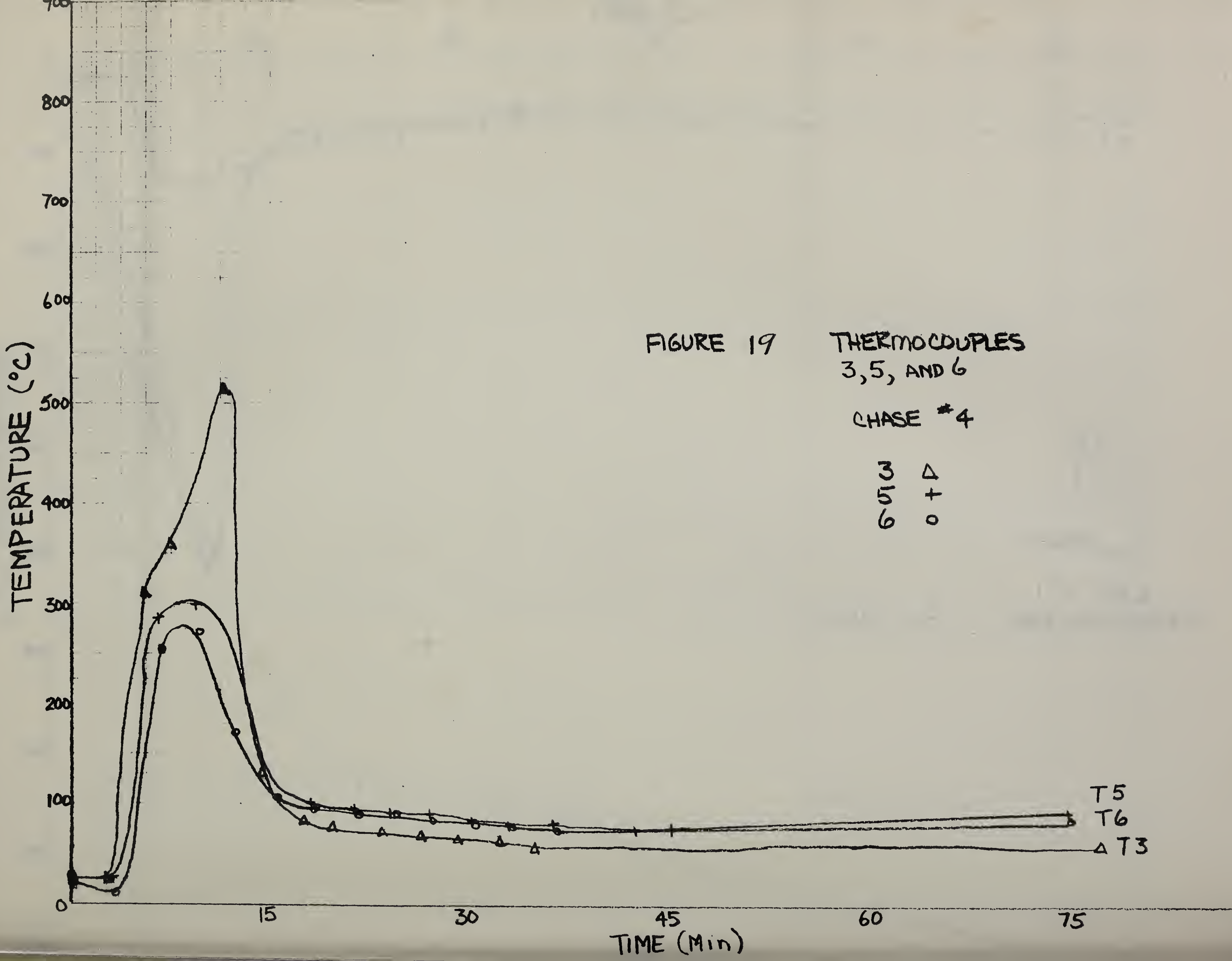


FIGURE 19
THERMOCOUPLES
3,5, AND 6
CHASE #4
3 Δ
5 +
6 o
T5
T6
T3
TEMPERATURE (°C)
TIME (Min)
0
100
200
300
400
500
600
700
800
15
30
45
60
75

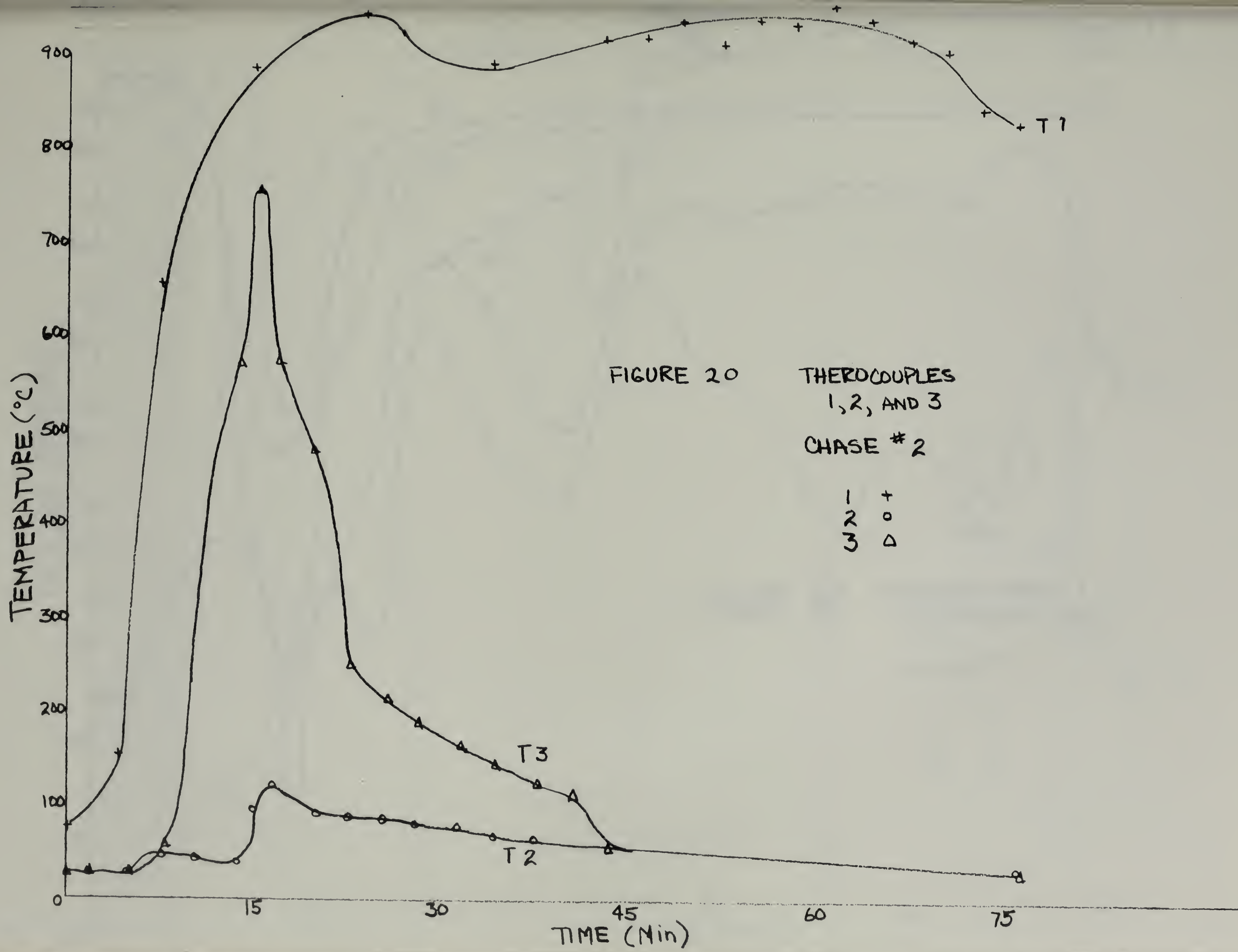

THEROCOUPLES
1, 2, AND 3
CHASE # 2
1 +
2 o
3 Δ
T 1
T 2
T 3
TEMPERATURE (°C)
TIME (Min)
0
100
200
300
400
500
600
700
800
900
15
30
45
60
75

FIGURE 20

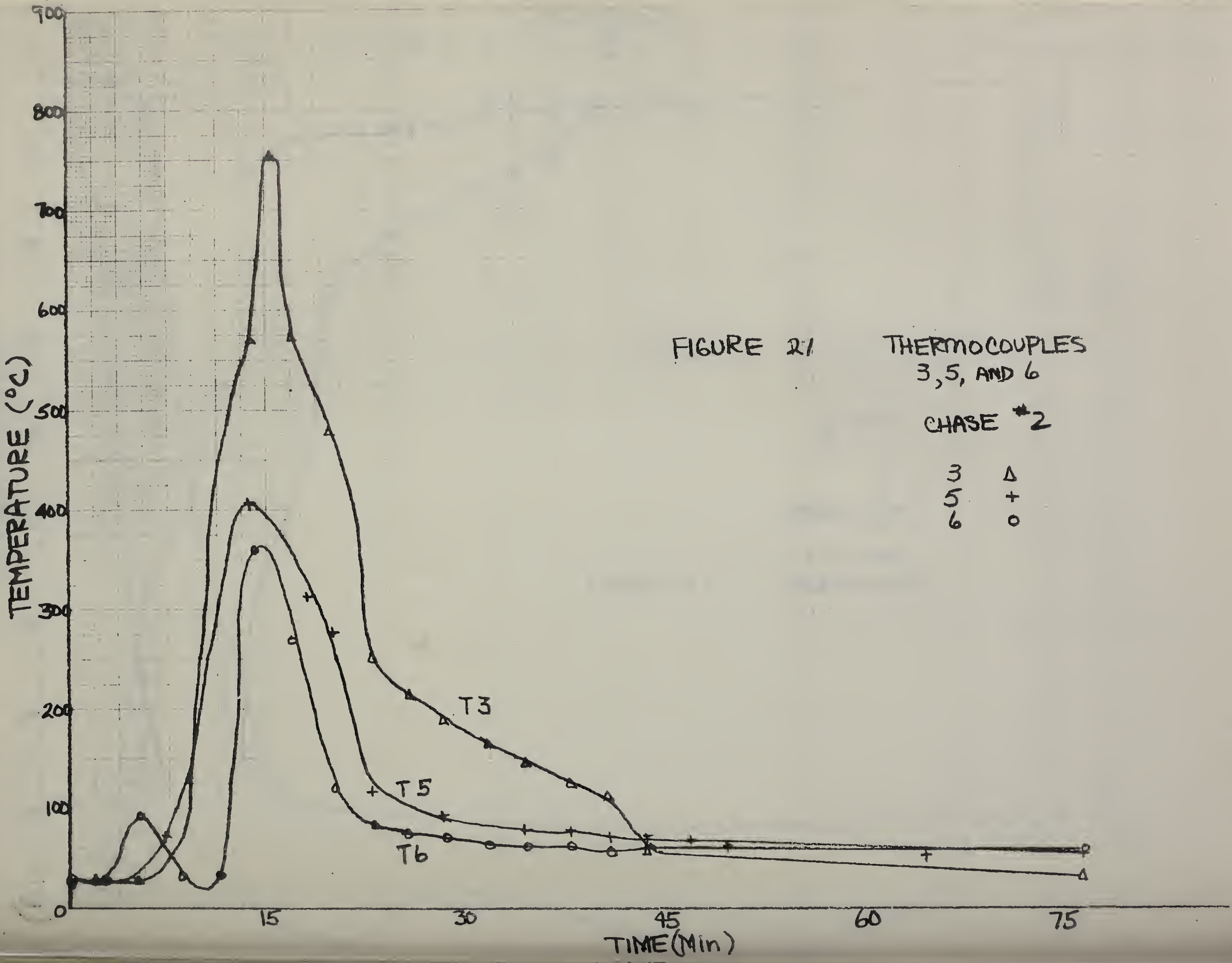


FIGURE 21 THERMOCOUPLES 3, 5, AND 6 CHASE #2

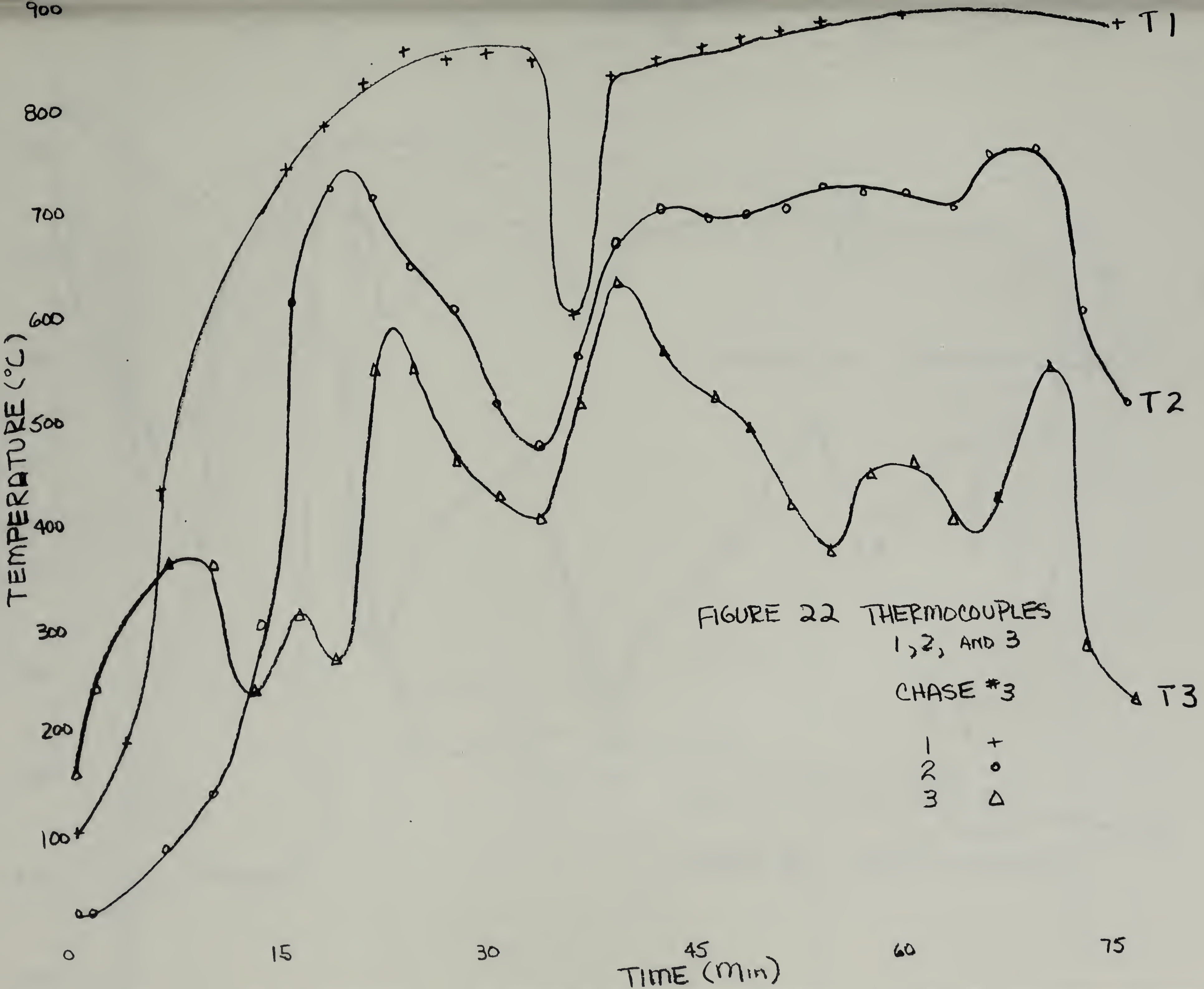


FIGURE 22 THERMOCOUPLES 1, 2, AND 3

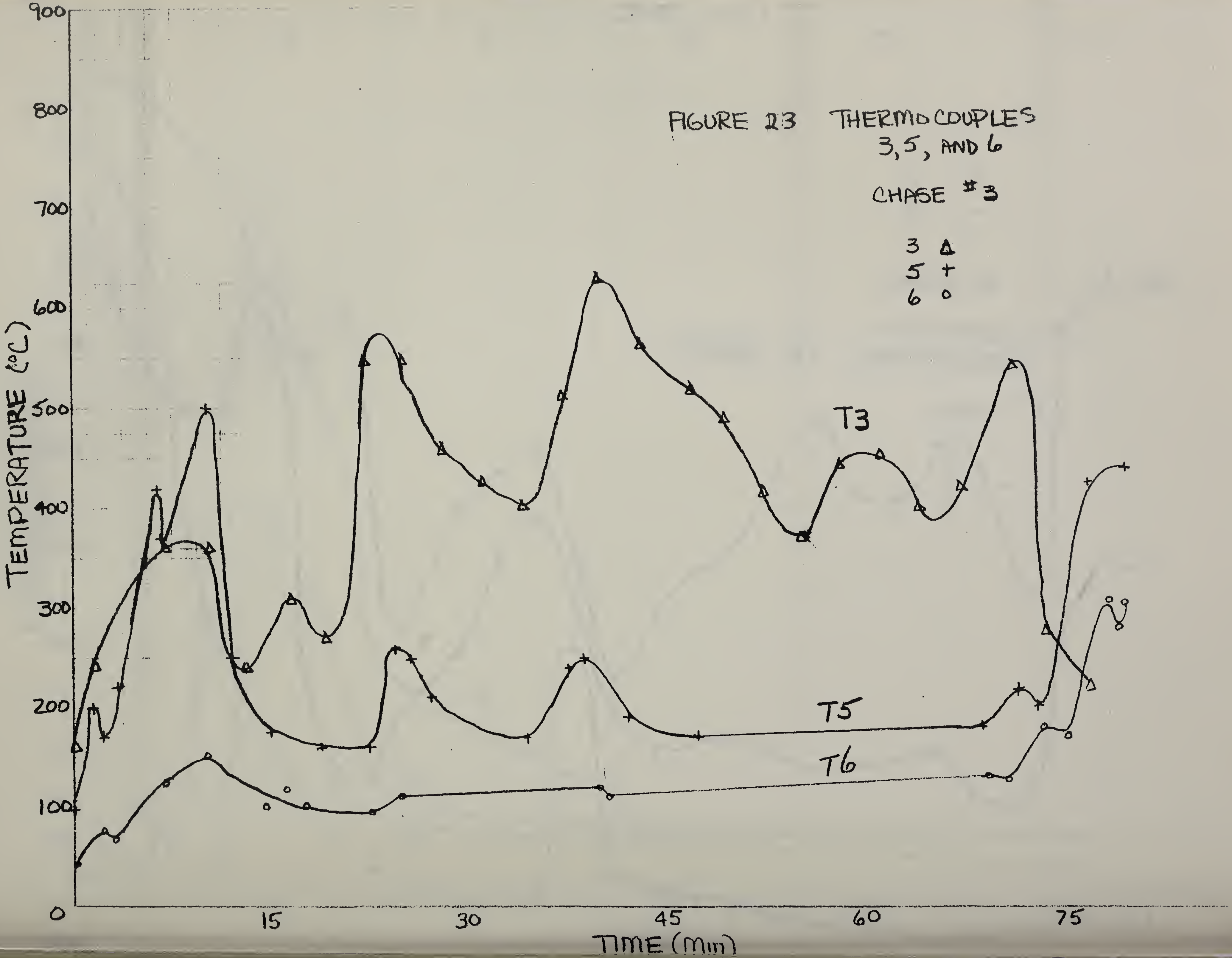


FIGURE 23 THERMOCOUPLES 3,5, AND 6

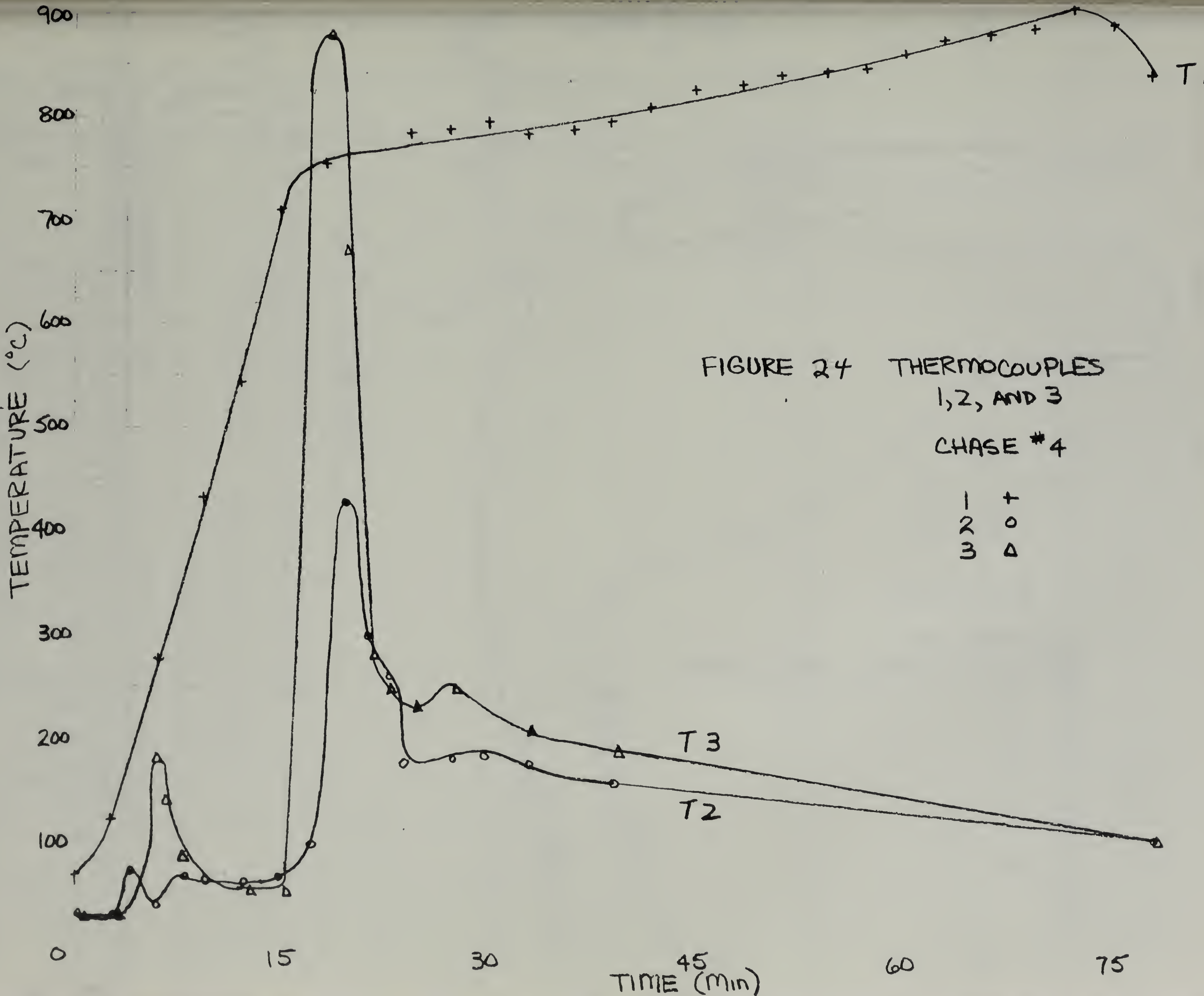
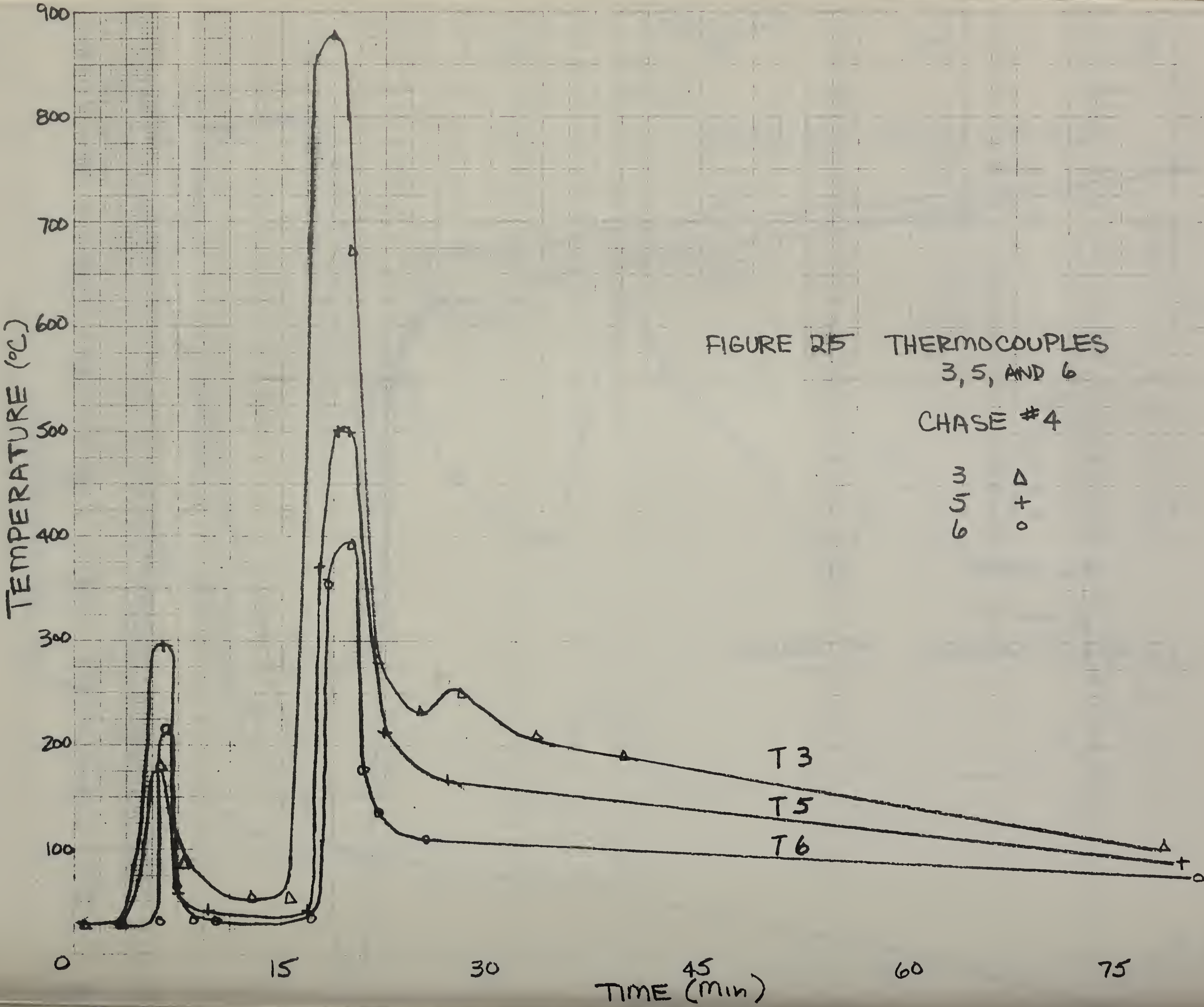


FIGURE 24 THERMOCOUPLES 1,2, AND 3
CHASE #4

1 +
2 o
3 Δ



THERMOCOUPLES
3, 5, AND 6
CHASE #4
3 Δ
5 +
6 o
T 3
T 5
T 6
TEMPERATURE (°C)
900
800
700
600
500
400
300
200
100
0
15
30
45
60
75
TIME (min)

FIGURE 25

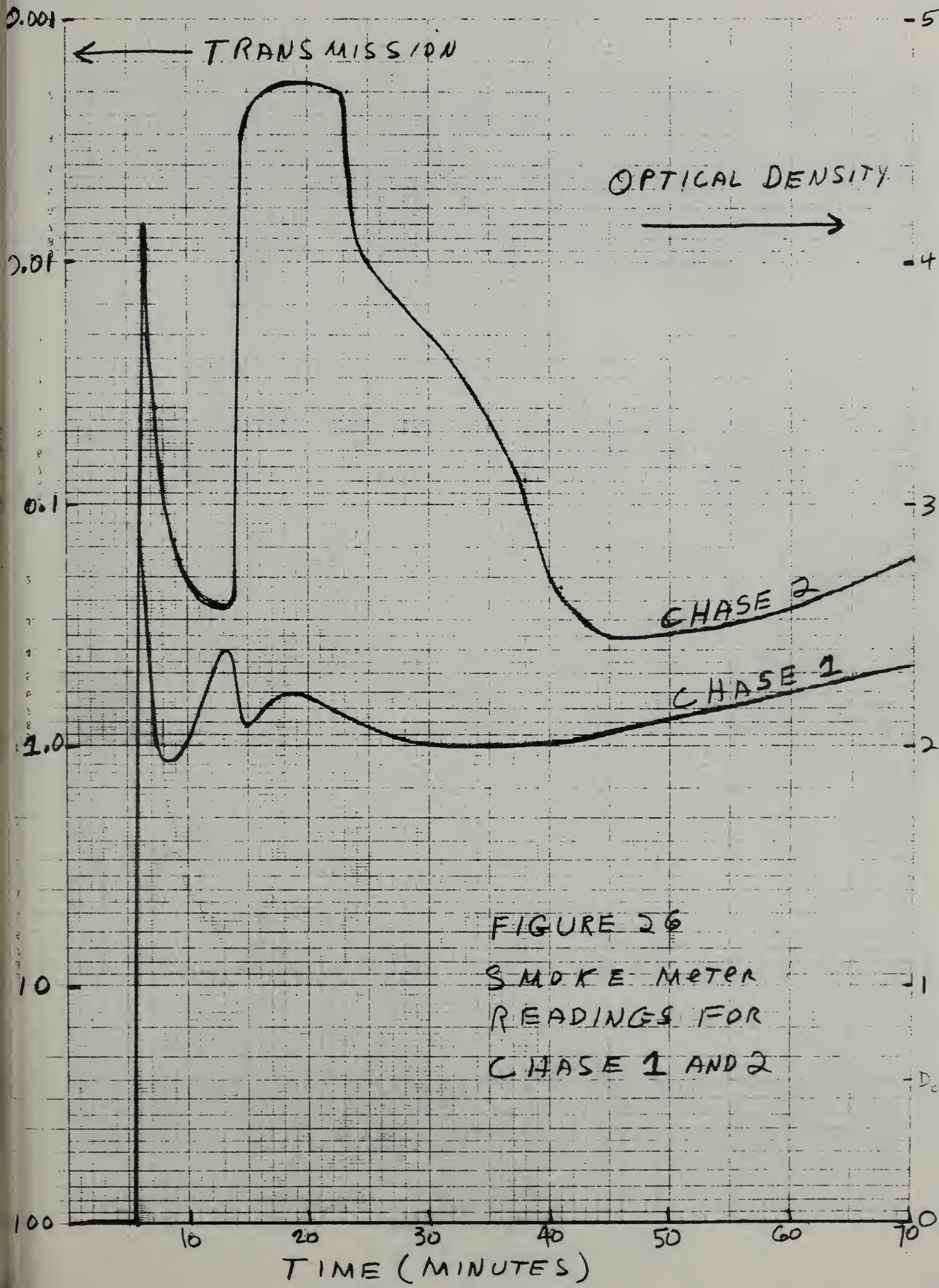


FIGURE 26
SMOKE METER READINGS FOR CHASE 1 AND 2

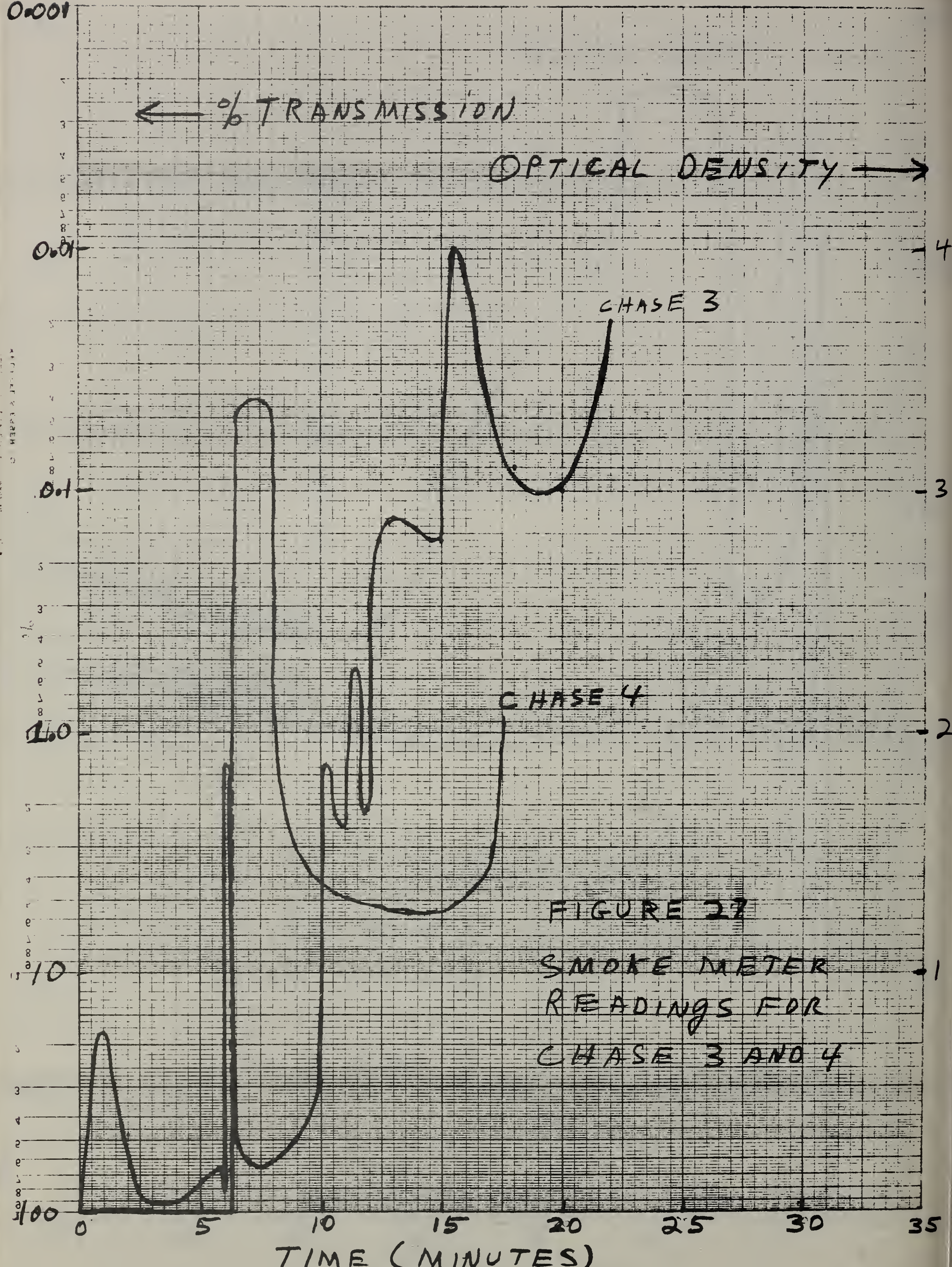


FIGURE 27

SMOKE METER READINGS FOR CHASE 3 AND 4

Fig. 28 Fire Side of Partition After the Second Test (Holes in Gypsum Board Were Made After Test)

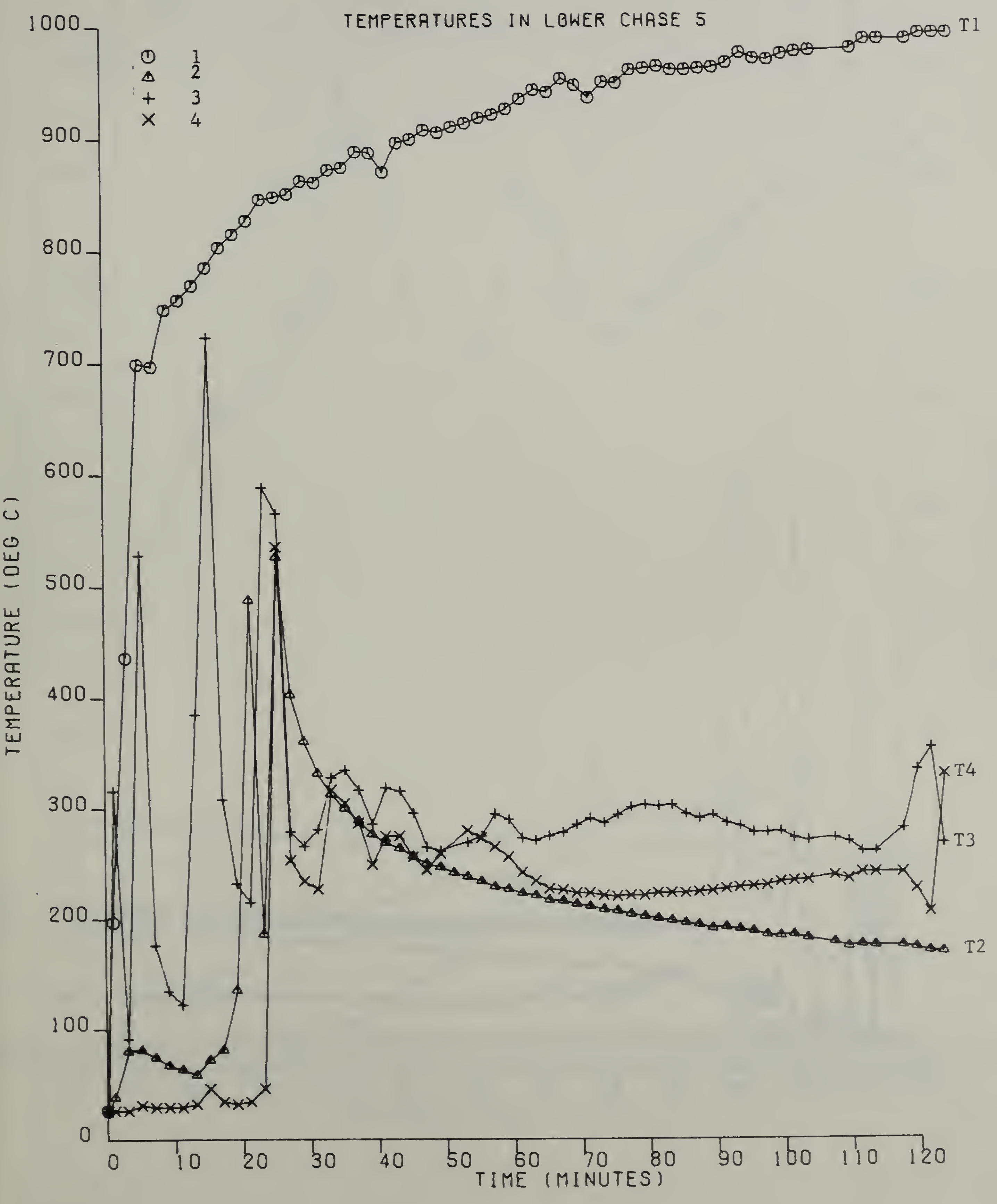
Fig. 29 Lower Stud Framing on Chase 7
After Test

Fig. 30 Upper Part of Chase 7 After Test

Fig. 31 Upper Part of Chase 5 After Test

Fig. 32 Front View of Chases 7, 5, and 8
After Test

FIGURE 33



TEMPERATURES IN LOWER CHASE 5
1
2
3
4
T1
T2
T3
T4
TEMPERATURE (DEG C)
TIME (MINUTES)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100
110
120

FIGURE 34

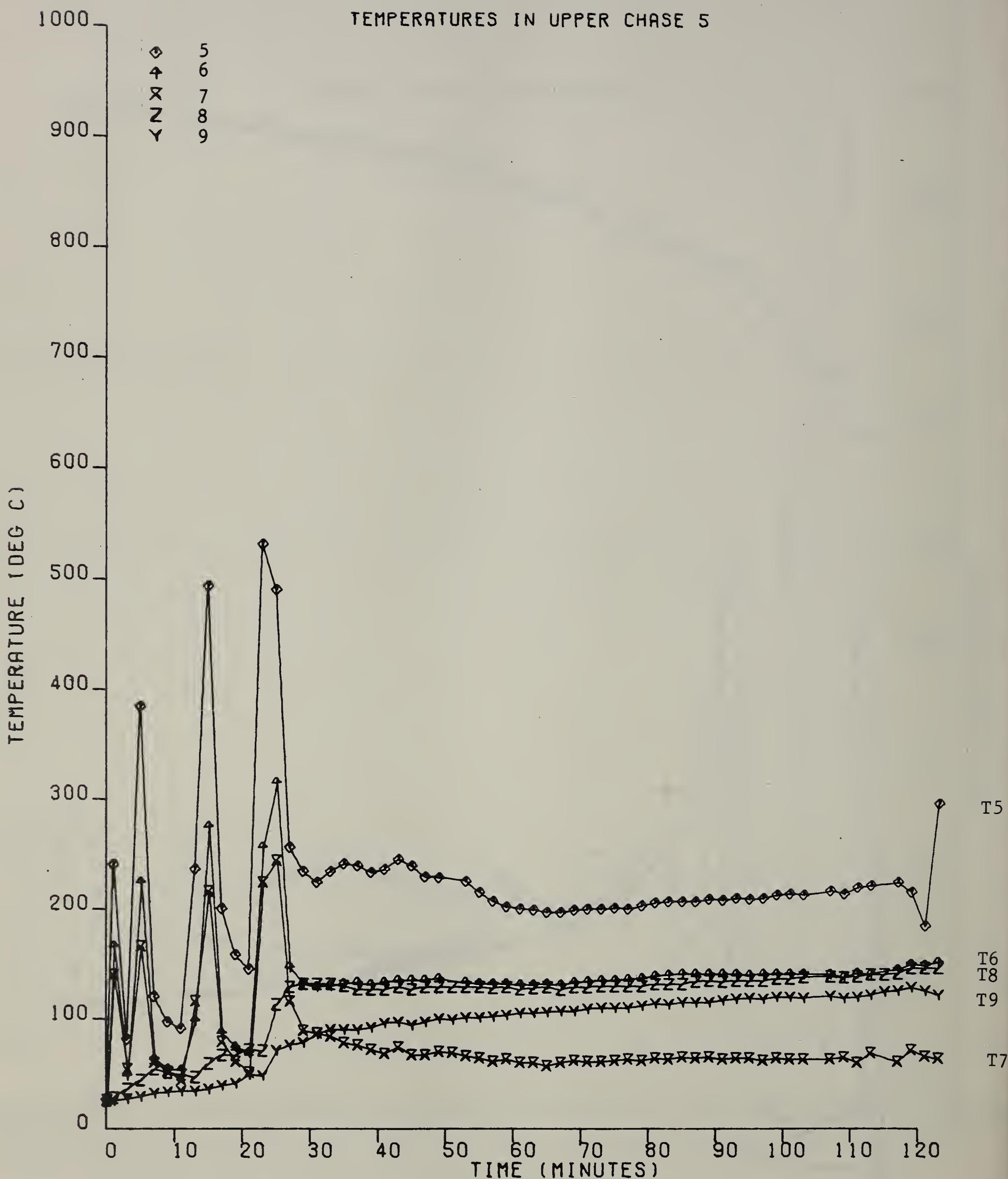

TEMPERATURES IN UPPER CHASE 5
5
6
7
8
9
TEMPERATURE (DEG C)
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)
T5
T6
T8
T9
T7

FIGURE 35

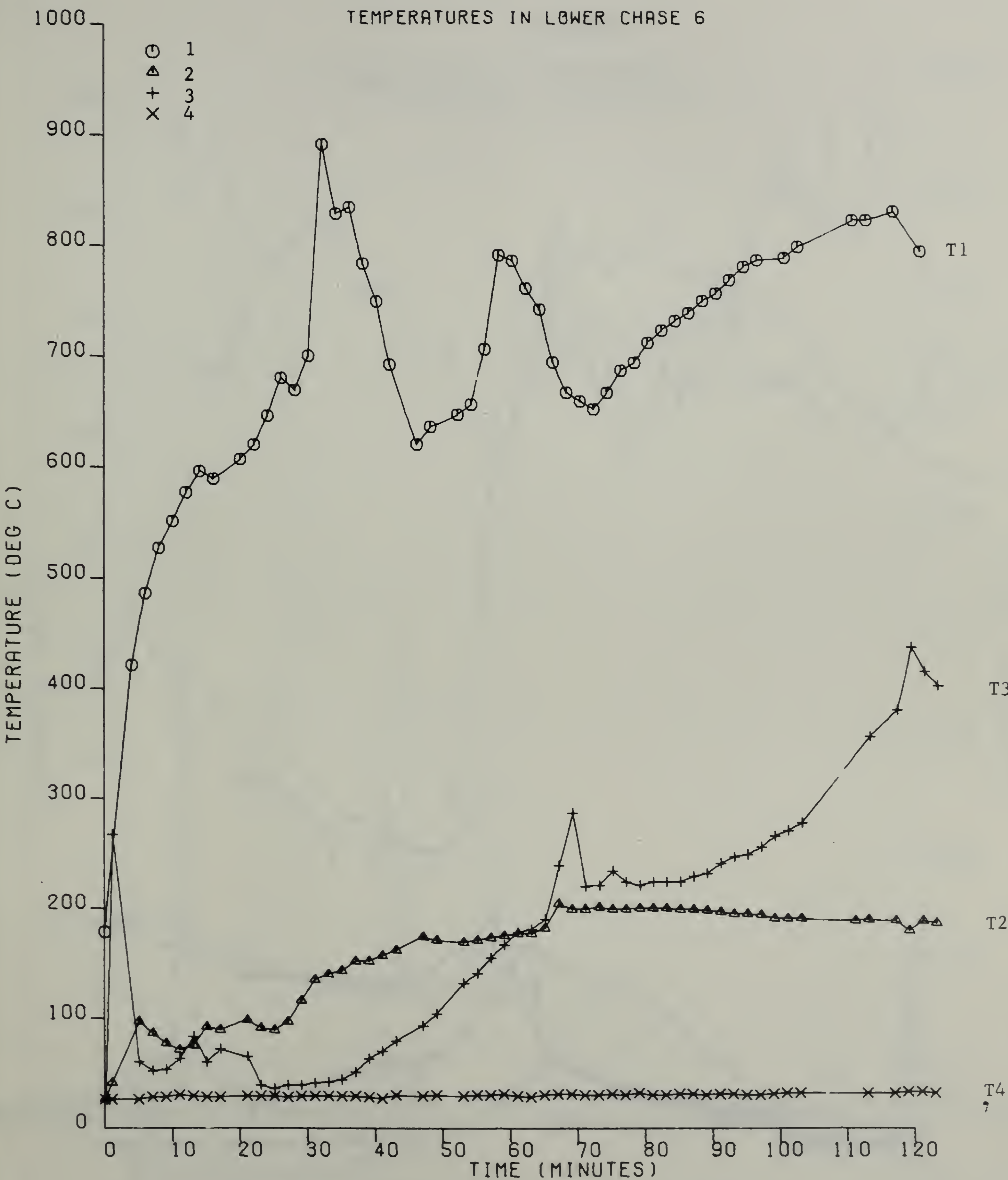

TEMPERATURES IN LOWER CHASE 6
1
2
3
4
TEMPERATURE (DEG C)
1000
900
800
700
600
500
400
300
200
100
0
TIME (MINUTES)
0
10
20
30
40
50
60
70
80
90
100
110
120
T1
T3
T2
T4

FIGURE 36

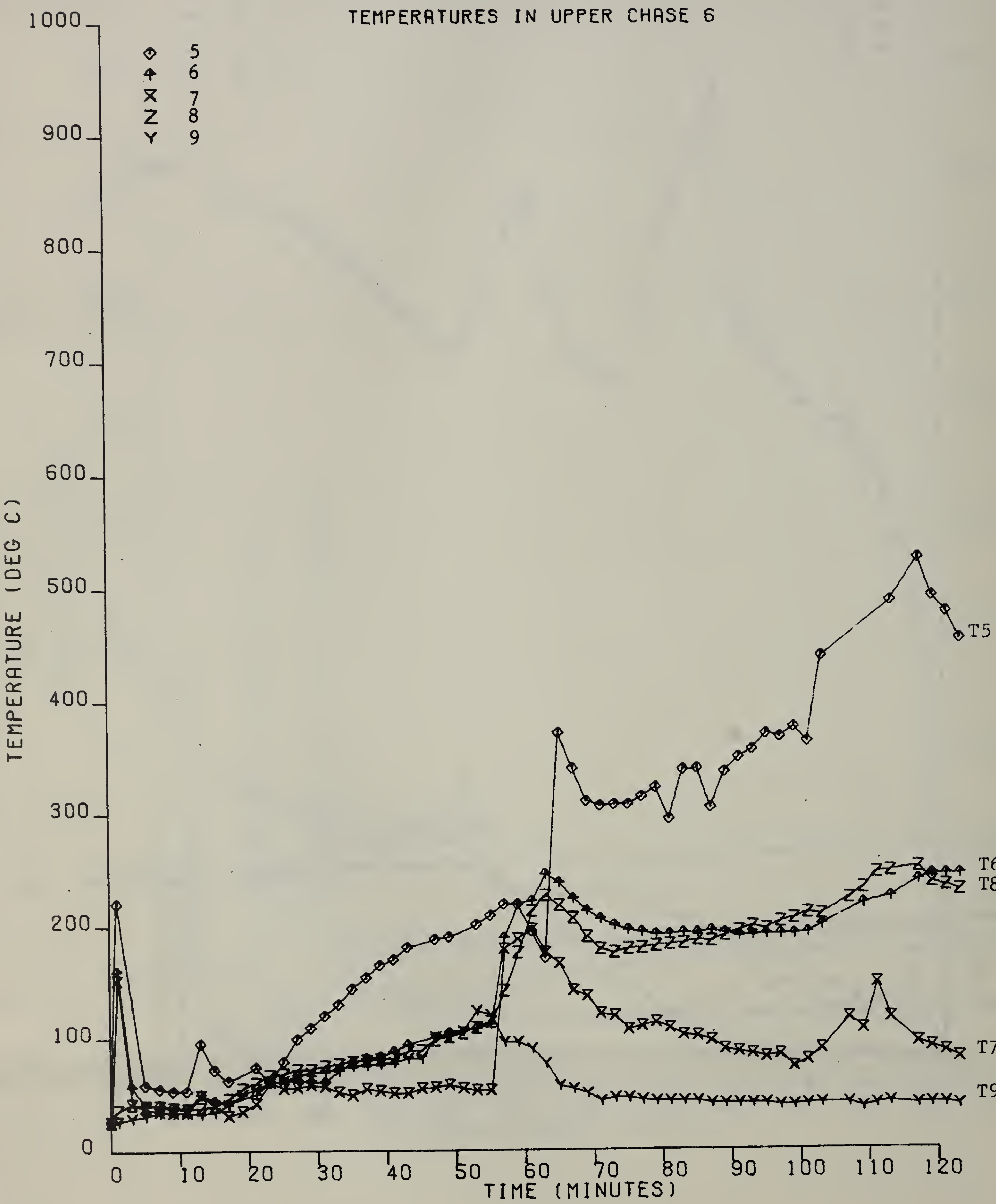

TEMPERATURES IN UPPER CHASE 6
5
6
7
8
9
TEMPERATURE (DEG C)
1000
900
800
700
600
500
400
300
200
100
0
TIME (MINUTES)
0
10
20
30
40
50
60
70
80
90
100
110
120
T5
T6
T8
T7
T9

FIGURE 37

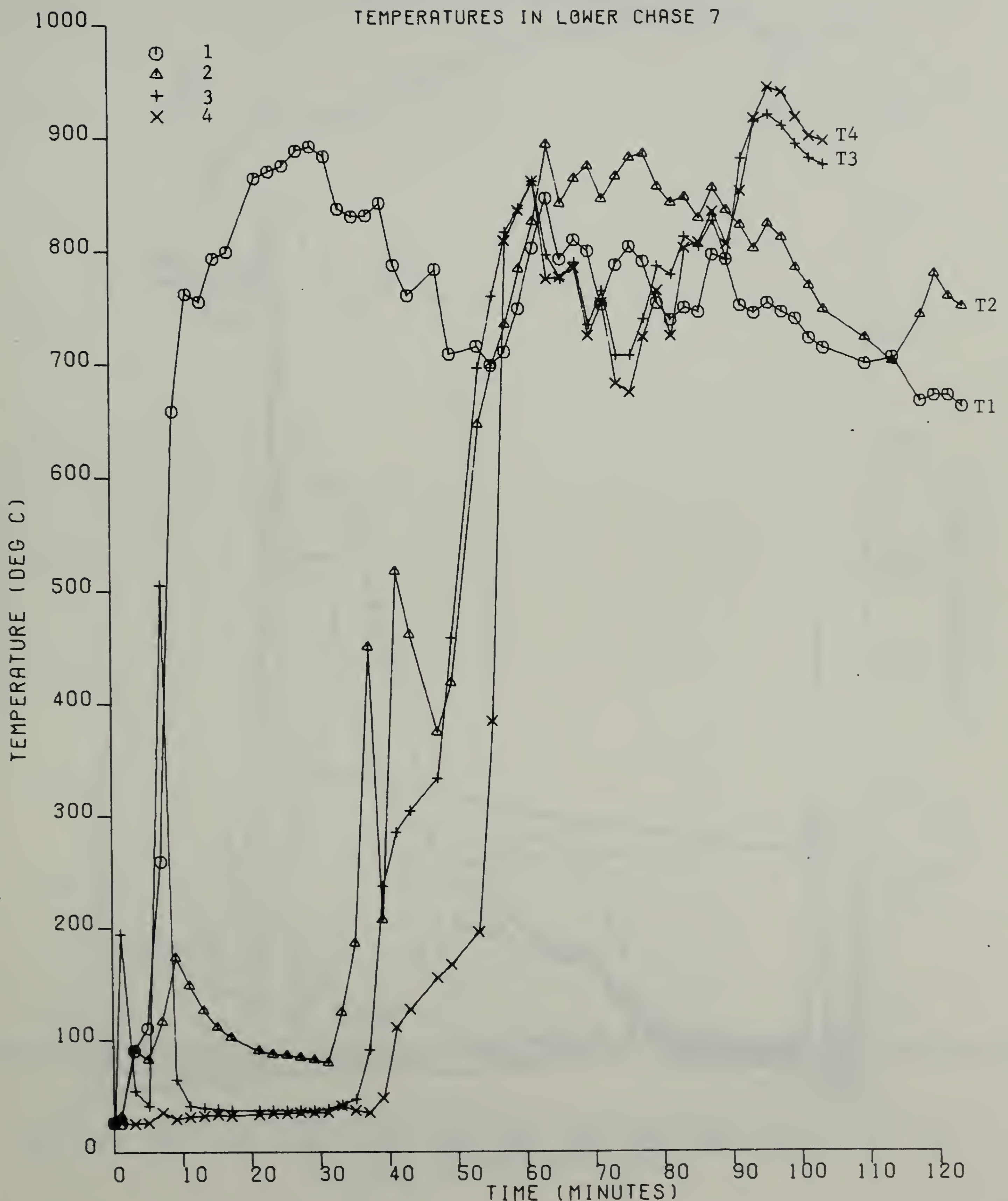
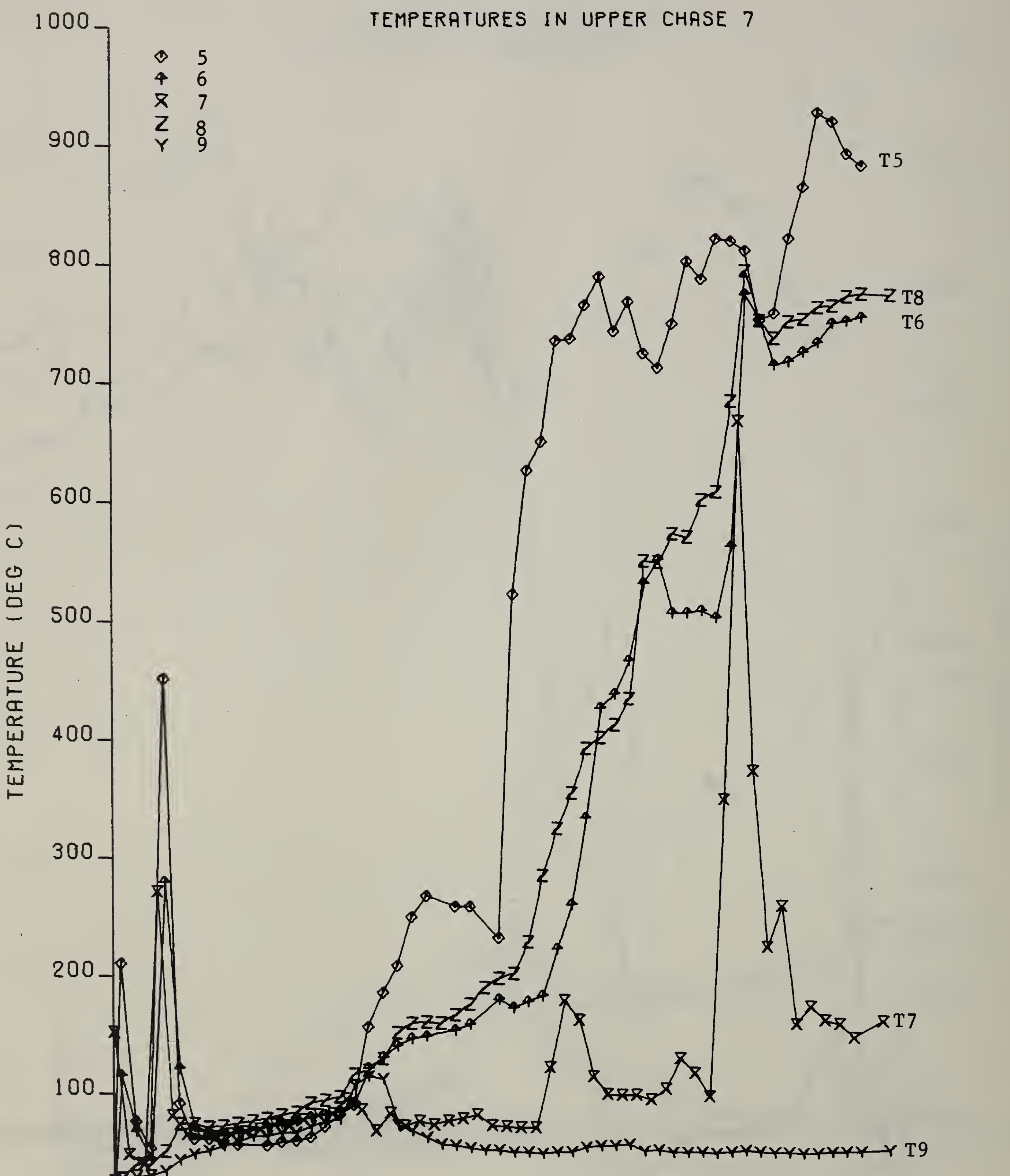

TEMPERATURES IN LOWER CHASE 7
1
2
3
4
T4
T3
T2
T1
TEMPERATURE (DEG C)
TIME (MINUTES)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100
110
120

FIGURE 38



TEMPERATURES IN UPPER CHASE 7
5
6
7
8
9
T5
T8
T6
T7
T9
TEMPERATURE (DEG C)
TIME (MINUTES)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100
110
120

FIGURE 39

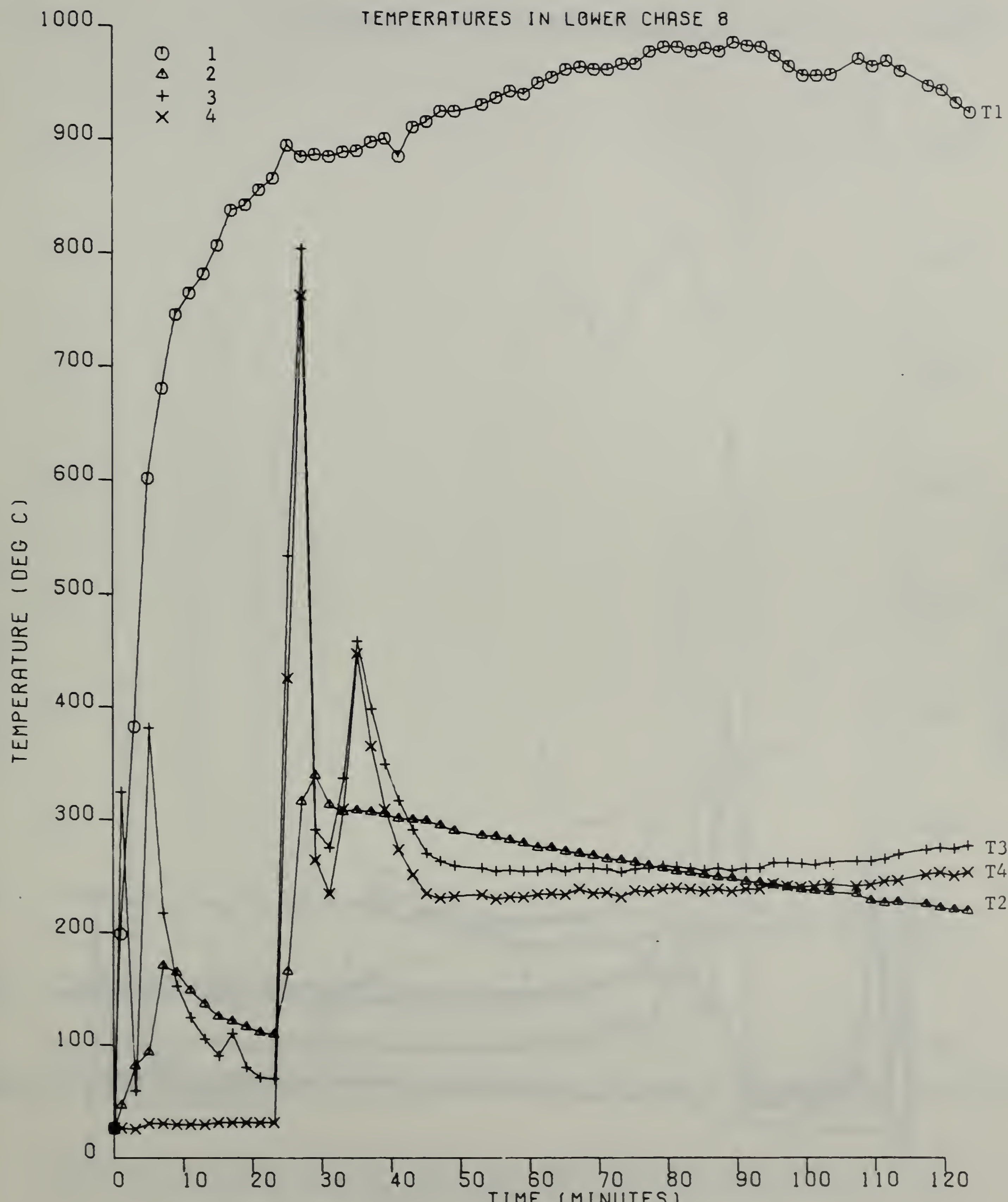

TEMPERATURES IN LOWER CHASE 8
1
2
3
4
T1
T2
T3
T4
TEMPERATURE (DEG C)
0
100
200
300
400
500
600
700
800
900
1000
TIME (MINUTES)
0
10
20
30
40
50
60
70
80
90
100
110
120

FIGURE 40

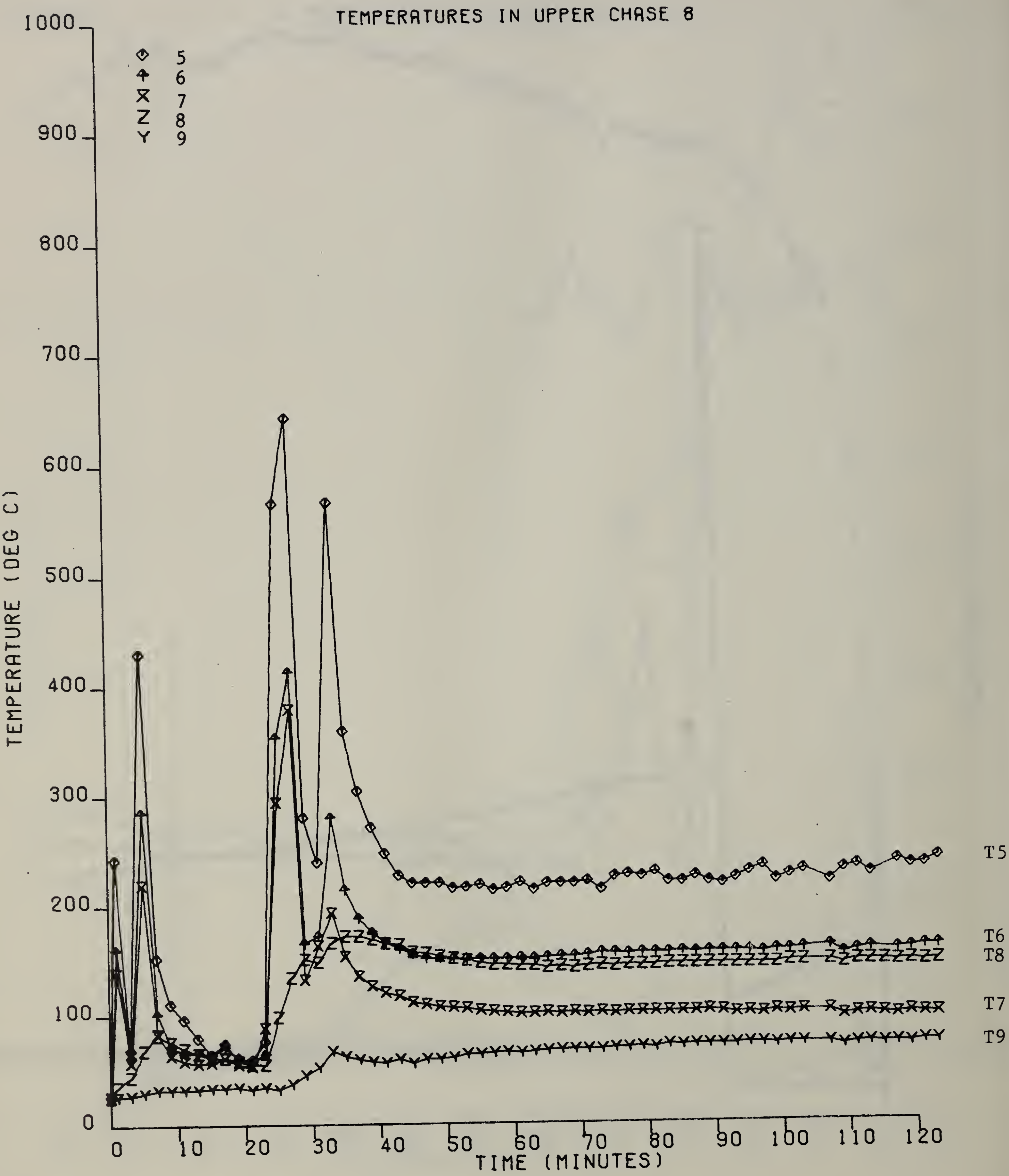

TEMPERATURES IN UPPER CHASE 8
5
6
7
8
9
1000
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)
T5
T6
T8
T7
T9

FIGURE 41

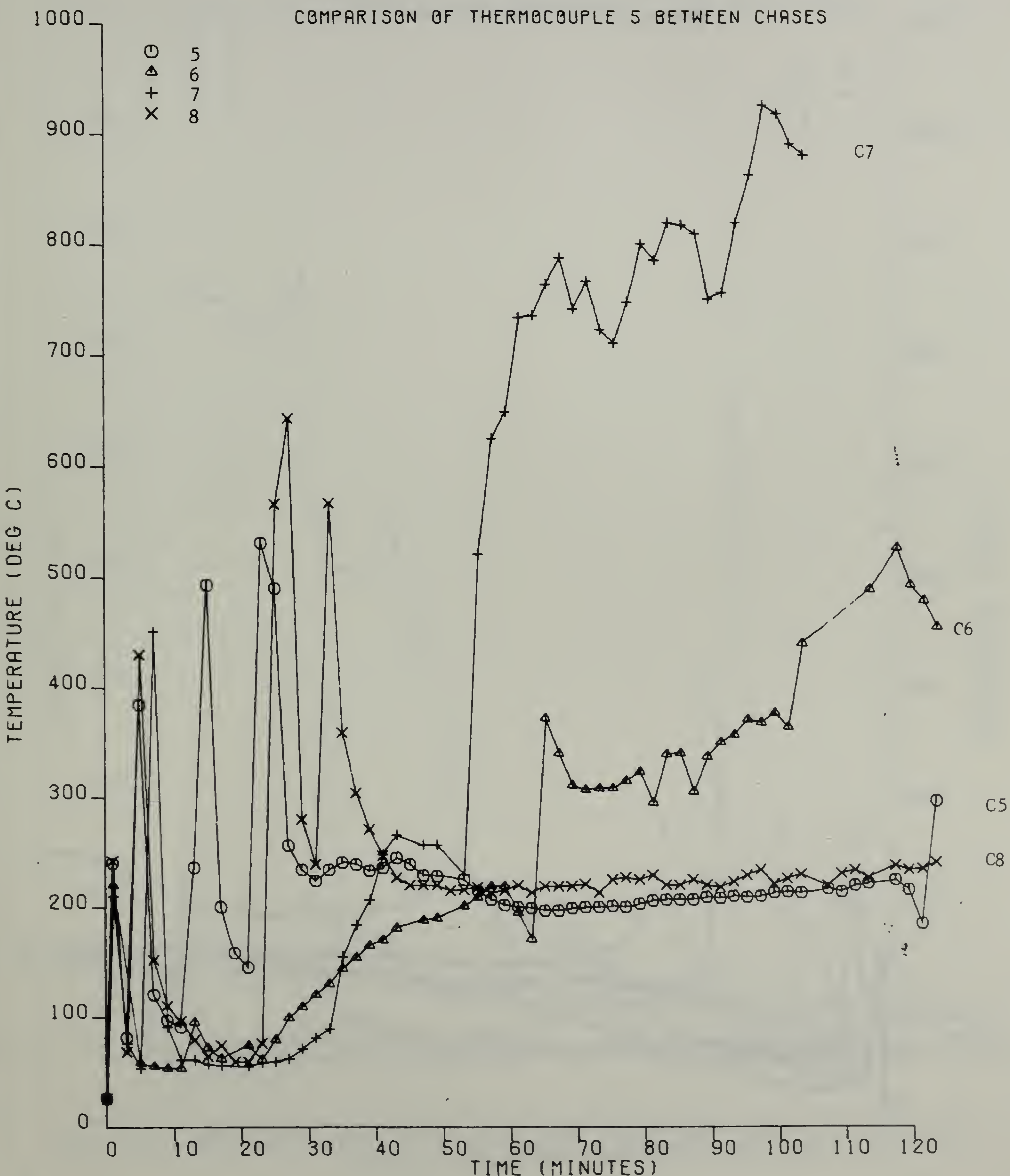

COMPARISON OF THERMOCOUPLE 5 BETWEEN CHASES
5
6
7
8
1000
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)
C7
C6
C5
C8

FIGURE 42

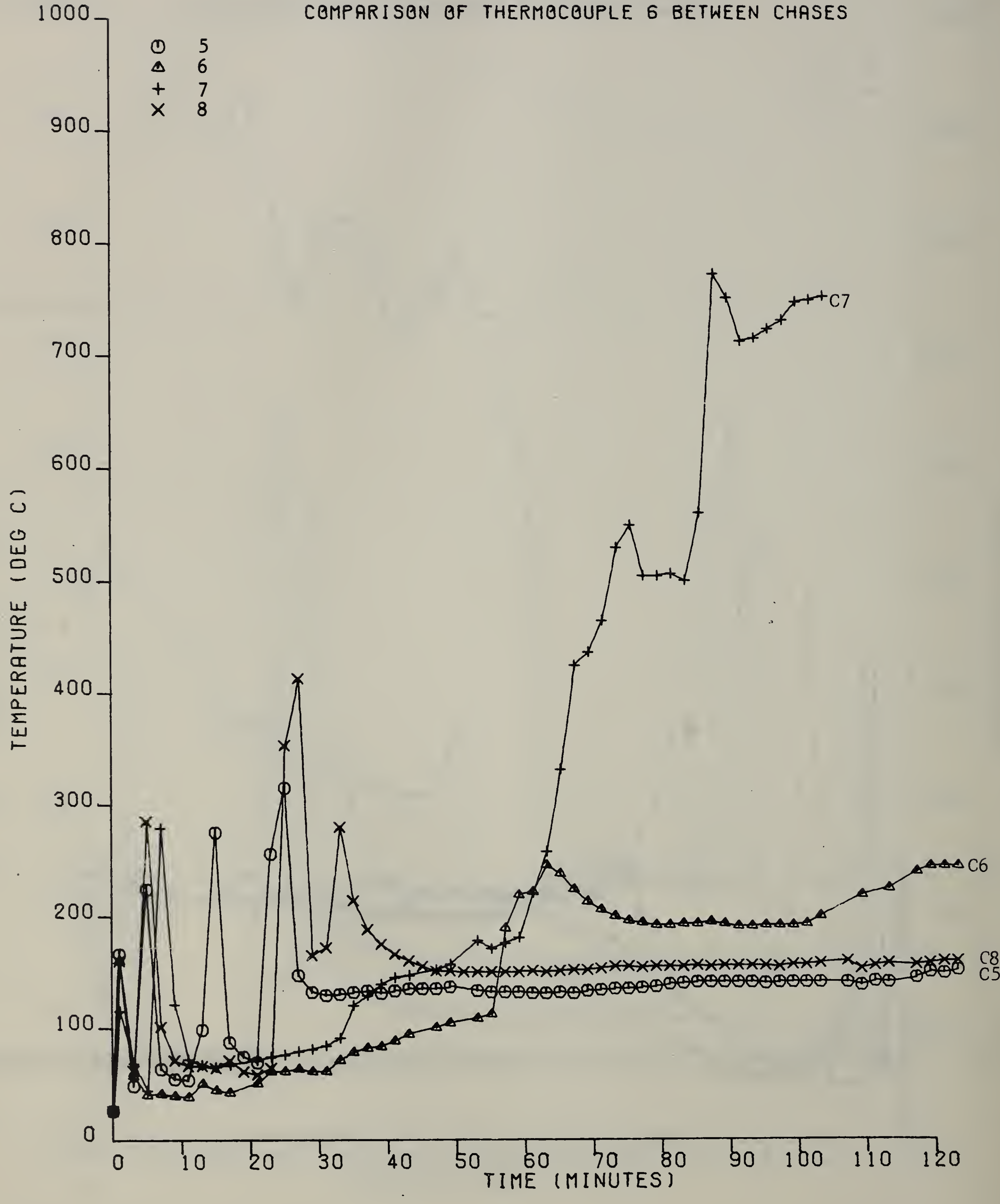

COMPARISON OF THERMOCOUPLE 6 BETWEEN CHASES
5
6
7
8
TEMPERATURE (DEG C)
TIME (MINUTES)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100
110
120
C7
C6
C8
C5

FIGURE 43

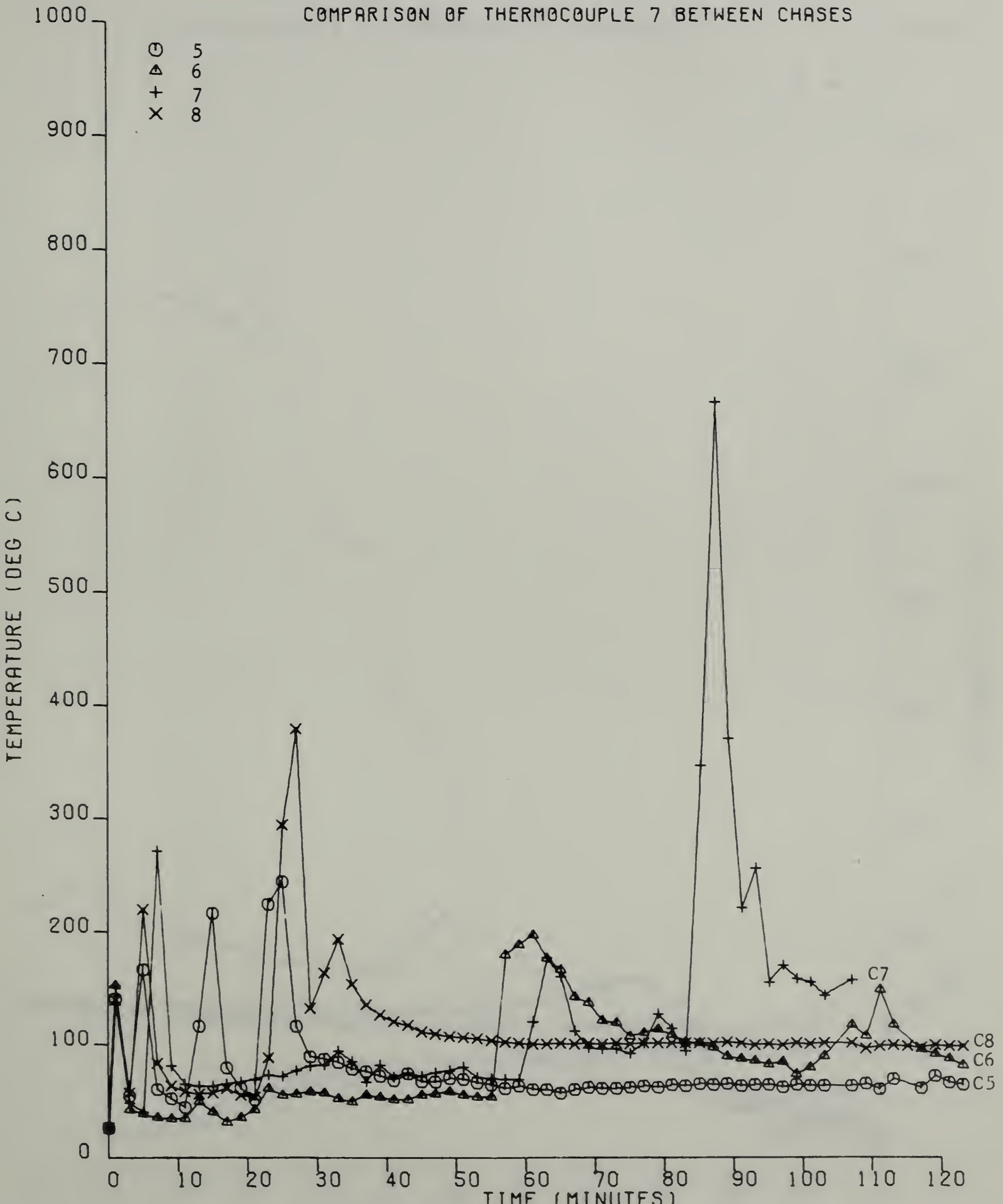
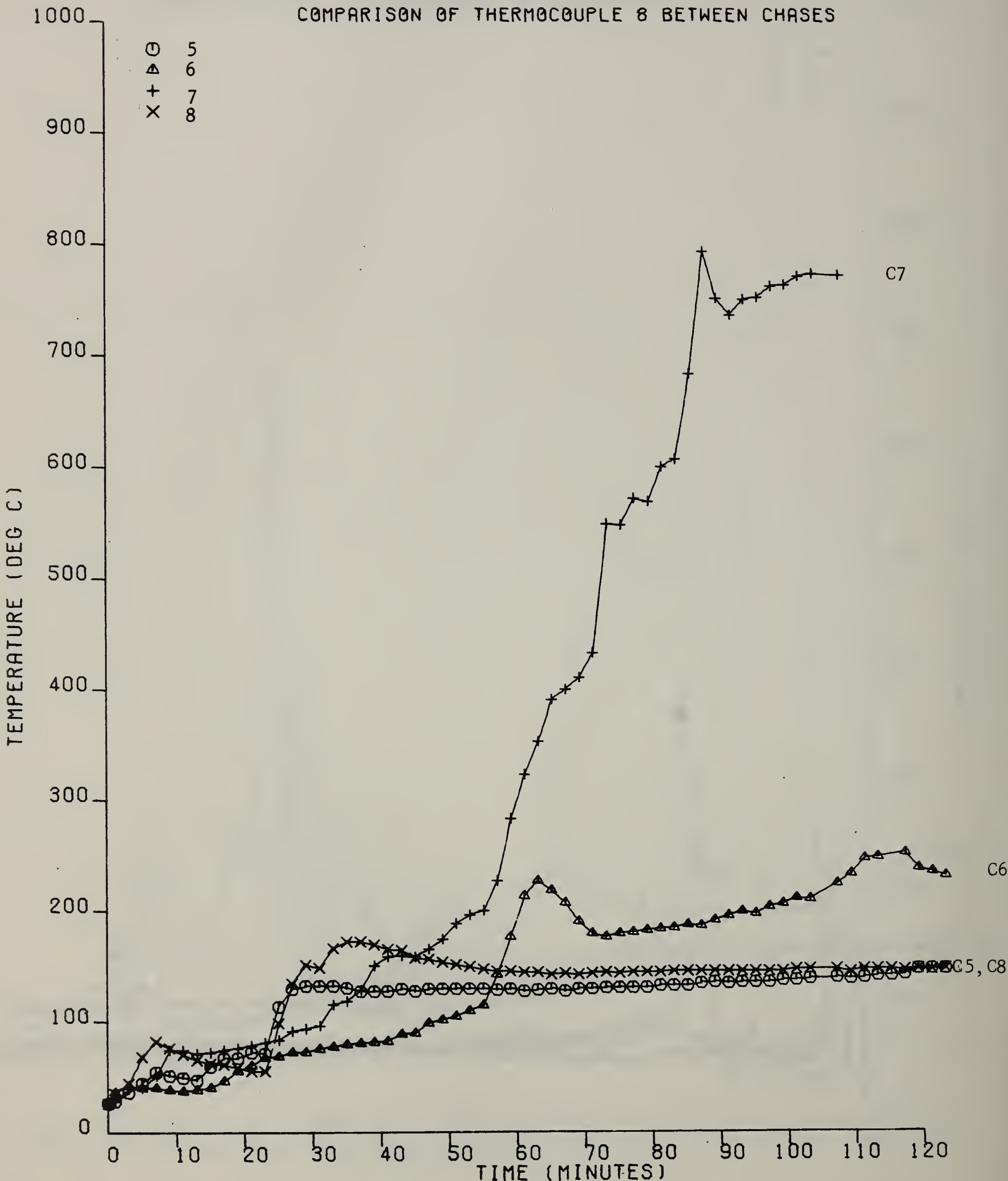
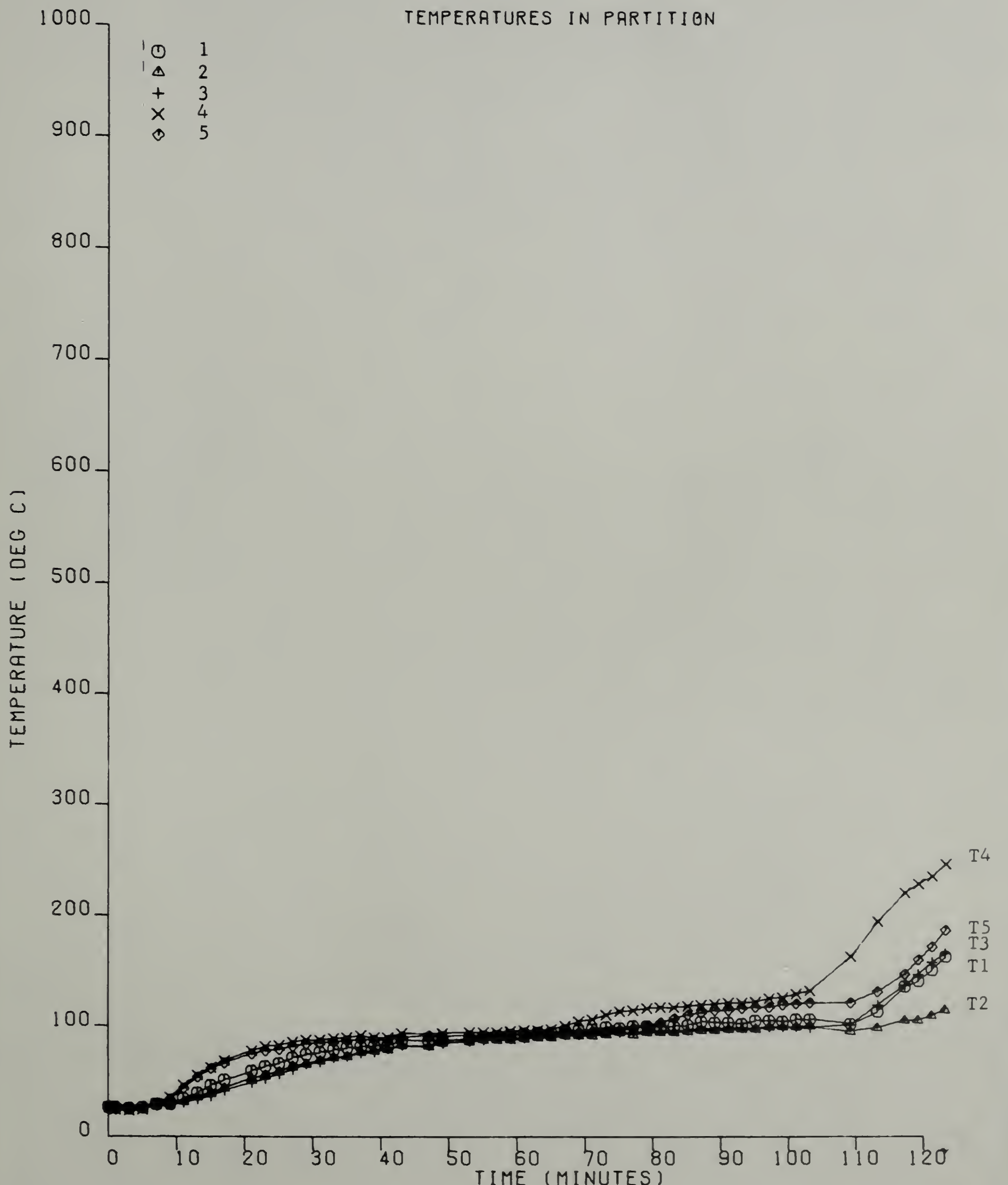

COMPARISON OF THERMOCOUPLE 7 BETWEEN CHASES
5
6
7
8
TEMPERATURE (DEG C)
1000
900
800
700
600
500
400
300
200
100
0
TIME (MINUTES)
0
10
20
30
40
50
60
70
80
90
100
110
120
C7
C8
C6
C5

FIGURE 44



COMPARISON OF THERMOCOUPLE 8 BETWEEN CHASES
5
6
7
8
1000
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)
C7
C6
C5, C8

FIGURE 45



TEMPERATURES IN PARTITION
1
2
3
4
5
1000
900
800
700
600
500
400
300
200
100
0
TEMPERATURE (DEG C)
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)
T4
T5
T3
T1
T2