NATIONAL BUREAU OF STANDARDS REPORT

10 482

FIRE SAFETY STUDY OF AIR DUCTS AND FIRE DAMPERS
EFFECT OF HANGAR SPACING, HANGAR SIZE, AND WALL THICKNESS
FIRST PROGRESS REPORT

Sponsored by:

American Iron and Steel Institute

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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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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FIRST PROGRESS REPORT

by
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Washington, D. C. 20234

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Introduction

In order to develop information on the performance of air conditioning ducts constructed of sheet steel the present program was initiated under the sponsorship of the American Iron and Steel Institute. Phase I of this program is a study of the feasibility and the nature of the penetration of fire into a duct, either by breakthrough of the fire through the wall or by collapse of the duct.

The penetration of fire into a duct is probably a function of the size, shape, thickness of material, type of material and type of joints used in the duct construction. The possibility of collapse of a duct exposed to fire is believed to be a function of the hangar size spacing and type of joints used and the structural properties of the duct. For discussion we have used two terms: "collapse of the duct" which means an overall structural failure, including tearing apart of the steel or opening of the joints; and "buckling of the duct" which means an accordion type of collapse without rupture of the

steel or opening of the joints.

As the first phase of the program, on March 10, 1971, five air ducts constructed of galvanized steel sheet were subjected to a test following the standard time-temperature curve used in fire tests of building constructions (ASTM E119). This fire test was performed in the floor test furnace facility of the National Bureau of Standards in Washington, D.C. The object of this program was to study the effects of hangar size, hangar spacing, duct wall thickness and joint technique on the structural behavior of steel ducts exposed to a fire.

1.0 Construction

1.1 Duct Set-up

The test specimens were suspended on hangars and trapeze angles in accordance with the recommendations of SMACNA (1). At the time of test it was not possible to obtain, locally, No. 8 gauge wire, and so wire guage No. 9 was used for ducts A, B and C. The difference in cross sectional area of No. 8 and 9 SWG is only about 15%. For ducts D and E, ¼ inch diameter rods were used for the hangars. Quasi continuity to simulate a horizontal run of duct resting on several supports, was simulated by having the ducts overhang the supports and placing blocking at the ends of the duct between the top of the ducts and the furnace closure. This also served to restrain any upward deflections of the ends during the initial part of the test. See Figure 1 and 2 for erection and construction details.

1.2 Instrumentation

Each duct and hangar was instrumented with 16 thermocouples (B & S 24 guage, 0.020 in diameter, chromel-alumel). Two groups of three thermocouples each had the thermocouples connected together in parallel, making a total of 12 thermocouple channels on each duct. See Figure 3 for the locations of the thermocouples.

Deflections were measured at the hangar and at the midspan of each duct. However since the deflection points were located on the top of the ducts, these measurements were of limited value since localized buckling of the ducts occurred during the test. In future tests of this kind, the deflection points will be referenced differently.

The locations of the thermocouples are shown in Figure 3 The deflections at the duct hangars are shown in Figure 4, the uncorrected deflections at midspan of the ducts are shown in Figure 5, and the net deflections at midspan are shown in Figure 6.

2.0 Stresses in Ducts and Hangars

The stresses in the ducts and the hangars at the start of the test were low. The approximate stresses are summarized in Table 1:

Table 1

Duct	Max Bending Stress Support psi	Center psi	Max Shear Stress Support psi	Hangar Stress psi	Wall Thickness
A	173	1938	47	3780	24ga
B	323	864	36	3360	24ga
C	173	370	24	2360	24ga
D	293	680	39	3340	20ga
E	323	864	36	2770	24ga

A stability analysis indicates that for the 24 gauge ducts the critical shear stress for buckling is of the order of 1400 psi, and for the 20 gauge ducts the critical shear stress is of the order of 3200 psi.

3.0 Behavior of the Ducts During the Tests

3.1 Temperature Response

The average furnace temperatures are shown in Figure 7. The difficulty with the furnace temperature at the beginning of the test was due to a defective thermocouple circuit. However, this does not affect the results of this preliminary test. Generally, the temperature of the ducts and hangars followed the adjacent furnace temperature. See figures 8 to 12 for a comparison of the duct temperatures and the adjacent furnace temperatures. During this test the south end of the furnace was somewhat hotter than the north subsequently the furnace controls were adjusted to provide a more uniform temperature.

3.2 Structural Response

As the temperature of the ducts rose during the test, the sheet steel softened and the ducts sagged at midspan and over the trapeze supports. This sagging over the supports destroyed the simulated continuity and the ducts were simply supported for the rest of the test.

The ducts failed in the order of E, B, D, and A. Duct C did not fail during the test.

Duct E failed at 26 minutes by buckling collapse over the hangar supports.

Duct B failed at 28 minutes test time by generalized buckling of the sides of the duct.

Duct D, which was made of 20 gauge steel, failed at 51 minutes by failure of the joints. Because of the heavier gauge of this duct, the joints were made with pop rivets rather than slip joints. These pop rivets allowed the metal on each side of the joint to separate.

Duct A collapsed at 66 minutes.

Duct C showed only moderate bowing and sagging during the test. This duct had the shortest span between supports.

In general, the structural behavior improved with reduced span.

3.3 Joints

In every case, except duct C which did not fail, the ducts ultimately failed at the joints. Thus the joint construction is an important factor governing the performance of the duct.

4.0 Discussion and Recommendations

4.1 Discussion of Results

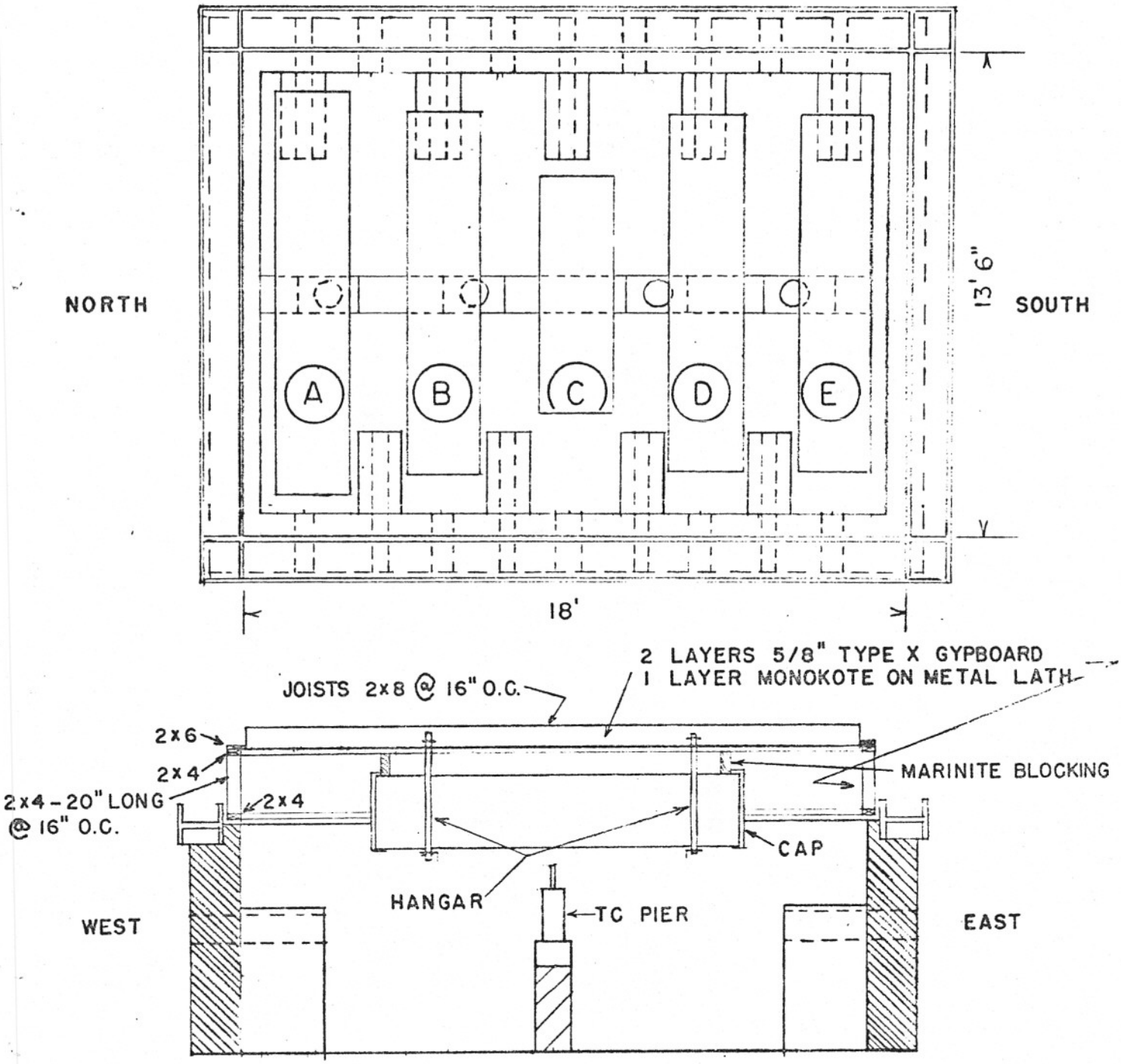
The behavior of the ducts indicated that with reduced hangar spacing and adequate joints a sheet steel metal duct can probably be designed to withstand a fire exposure of up to 2 hours without failure. Failure in this case meaning the inability of the duct to maintain its structural integrity and permitting fire to enter the duct.

4.2 Recommendation For Additional Research

The optimum spacing of the hangars, and the optimum design of the joints and ducts for these specified fire resistances can be determined only by additional tests. These additional tests should

include tests of joint strength and tests of other shapes, such as circular ducts, and insulated ducts. This test phase did not examine other significant factors such as the transfer of heat from a fire to air moving in the duct, the ability of a duct to transmit a fire from one compartment to another, and methods for preventing a fire from being transmitted from one compartment to another.

Figure 1



TYPICAL ERECTION DETAILS
DUCT PROGRAM

Figure 2

DUCTS-ASSEMBLY DETAILS

TEST UNIT	SPAN "L" FT	OVERHANG-M	HANGAR*	GA
A	10.0	1.0	9 GA	24
B	7.5	1.5	9 GA	24
C	5.0	1.0	9 GA	24
D	7.5	1.5	$\frac{1}{4}$	20
E	7.5	1.5	$\frac{1}{4}$	24
	* TRAPEZE SHELF ANGLE - 1"x1"x $\frac{1}{8}$"			
	ALL DUCTS GALVANIZED			

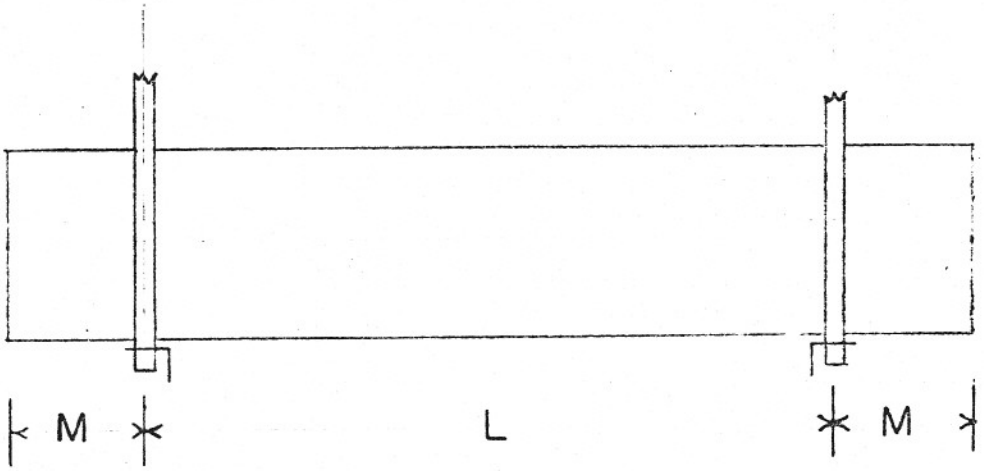
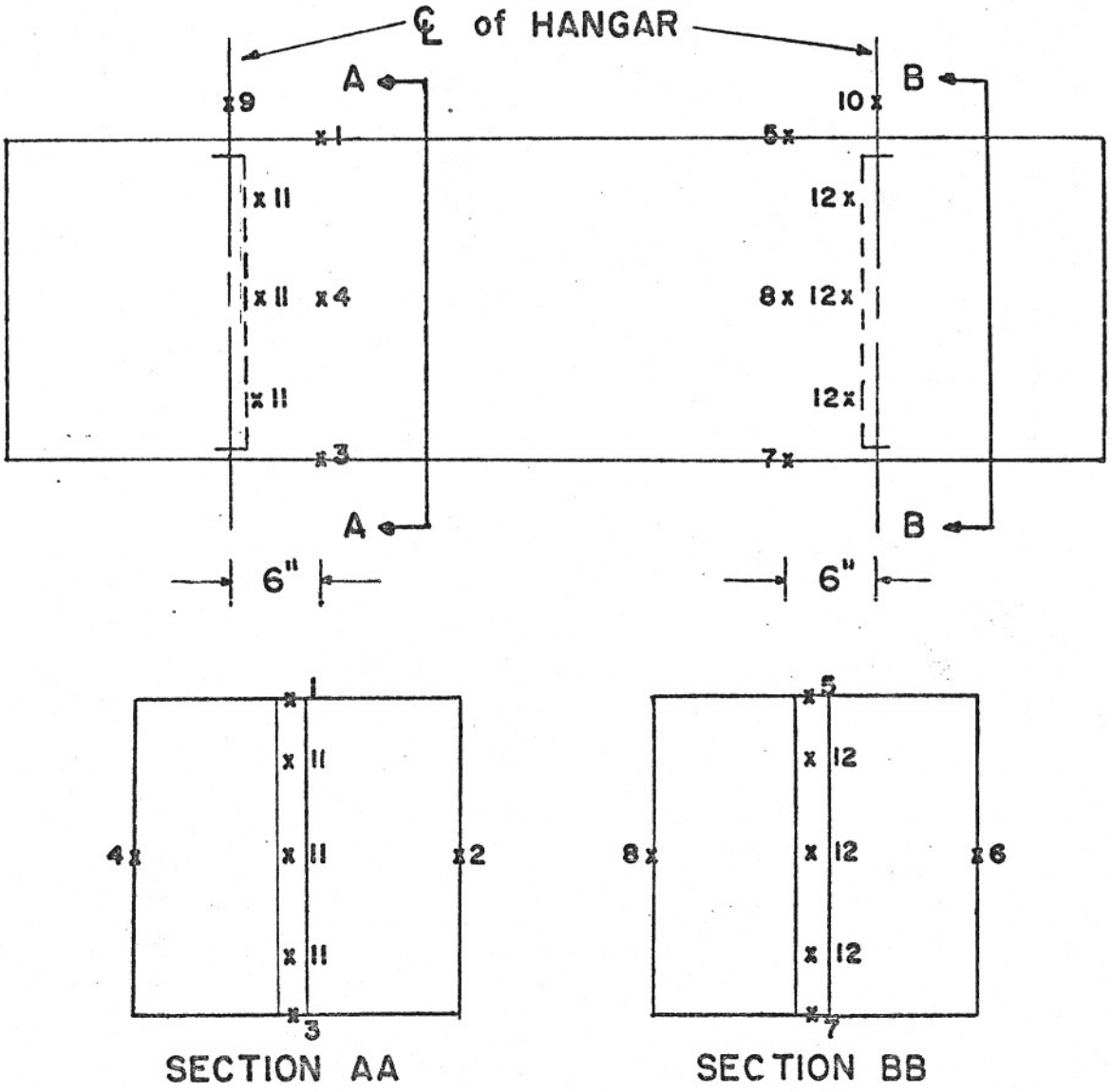


Figure 3

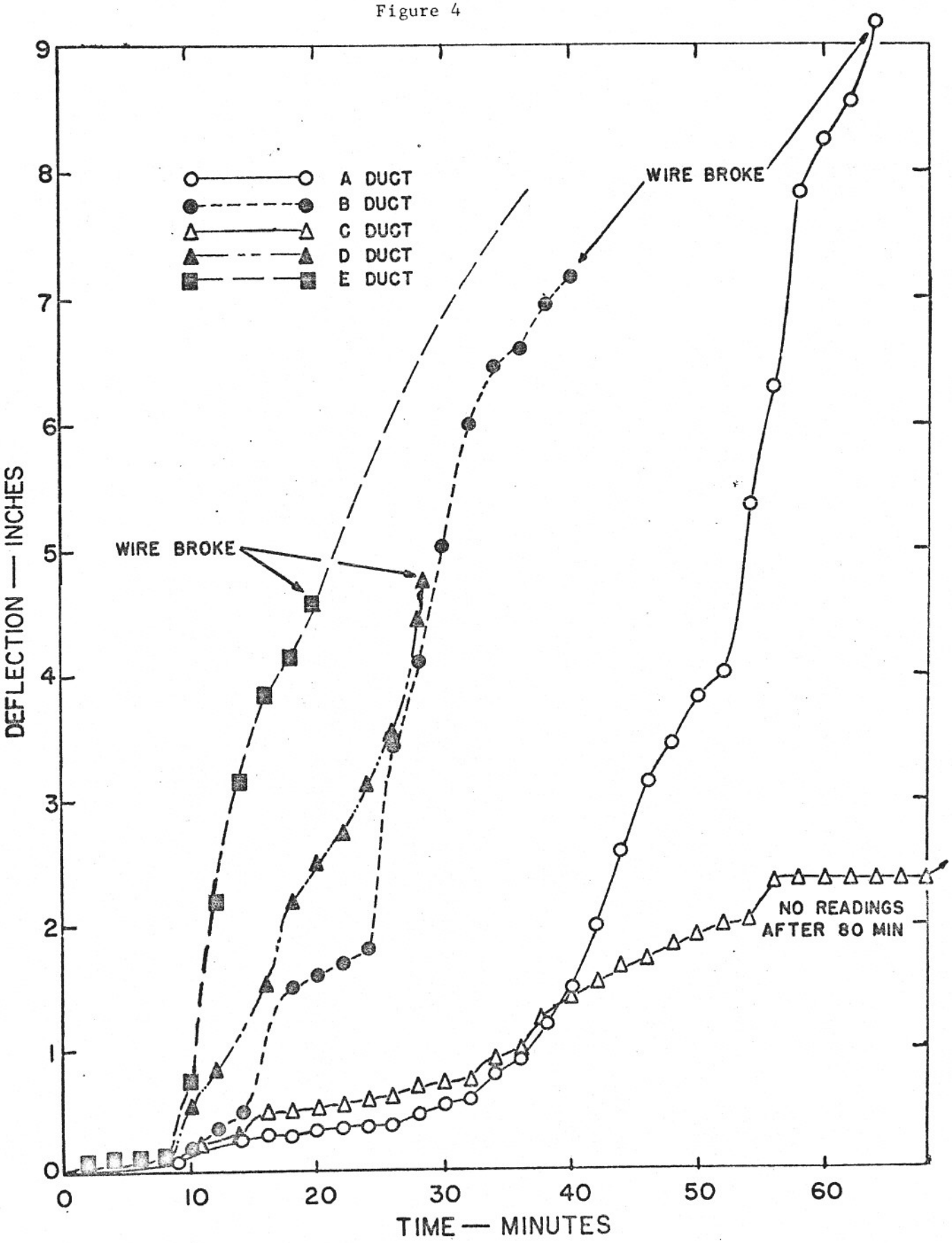


THREE THERMOCOUPLES MARKED NO. 11
AND THREE MARKED NO. 12 ARE
CONNECTED IN PARALLEL

DUCT TEST NO. 1

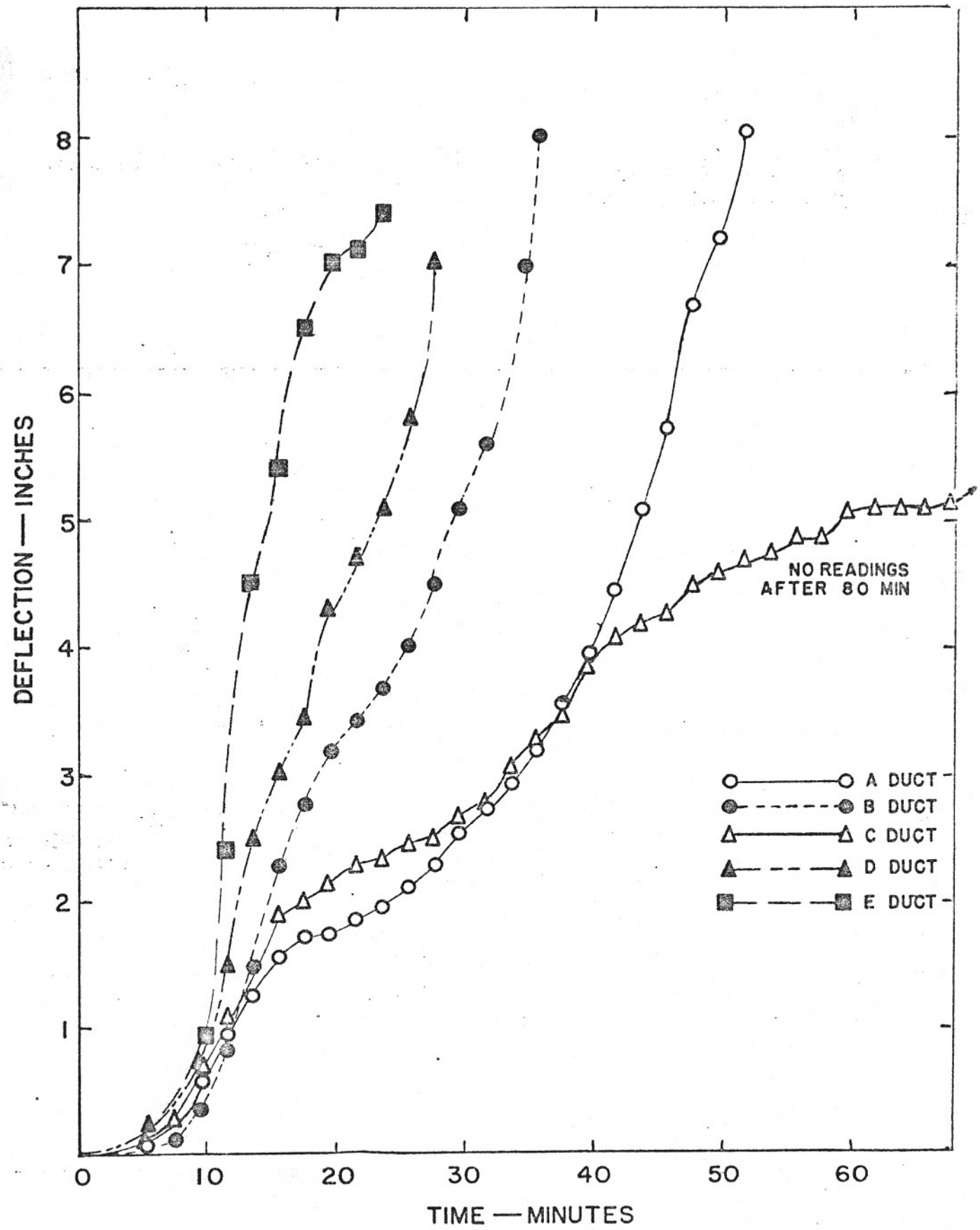
THERMOCOUPLE LOCATIONS

Figure 4



DEFLECTION AT DUCT HANGAR vs. TIME

Figure 5



DEFLECTION AT CENTER OF DUCTS vs. TIME

Figure 6

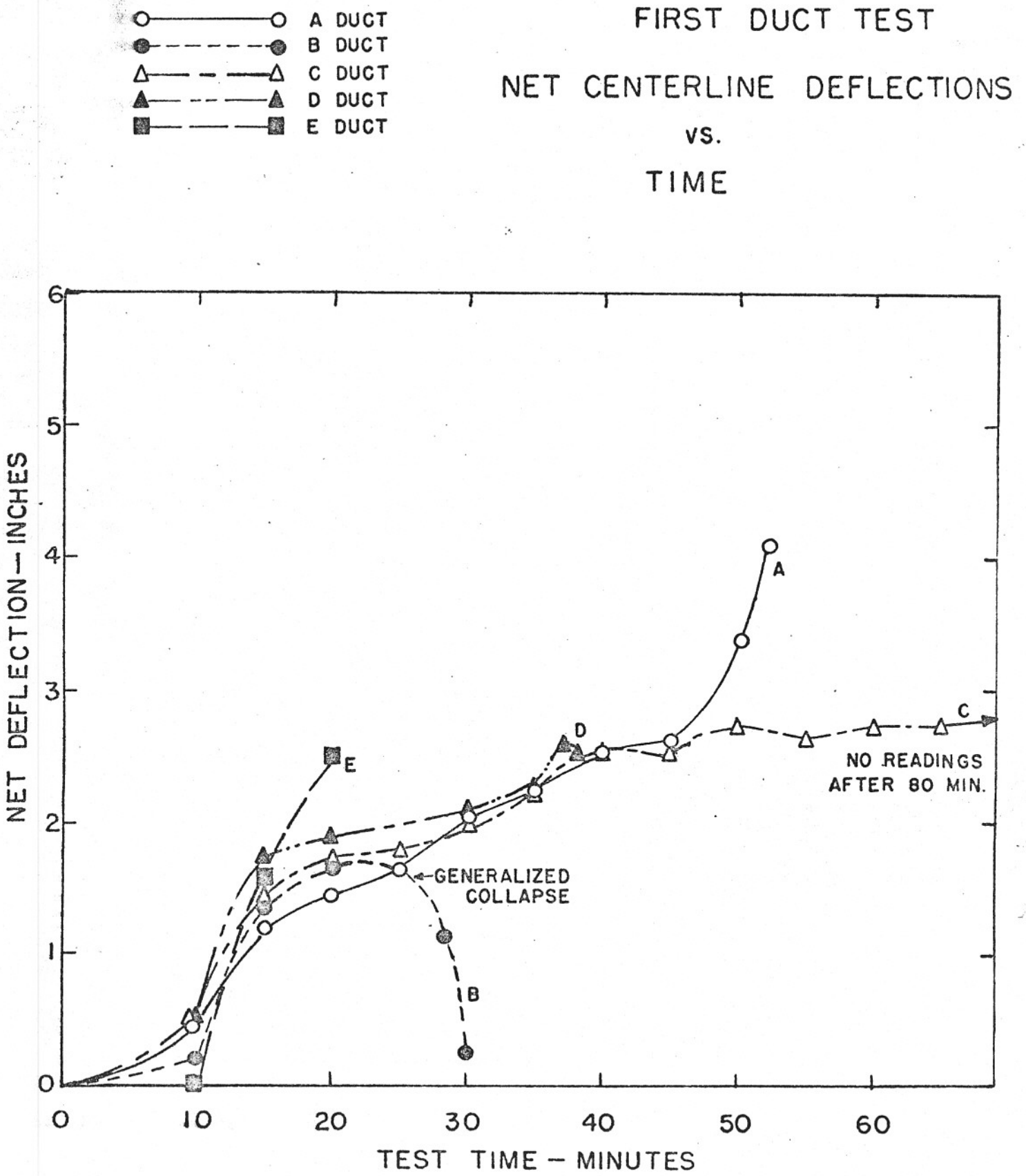

A DUCT
B DUCT
C DUCT
D DUCT
E DUCT
FIRST DUCT TEST
NET CENTERLINE DEFLECTIONS
VS.
TIME
NET DEFLECTION — INCHES
TEST TIME — MINUTES
0
1
2
3
4
5
6
0
10
20
30
40
50
60
A
B
C
D
E
GENERALIZED COLLAPSE
NO READINGS AFTER 80 MIN.

Figure 7

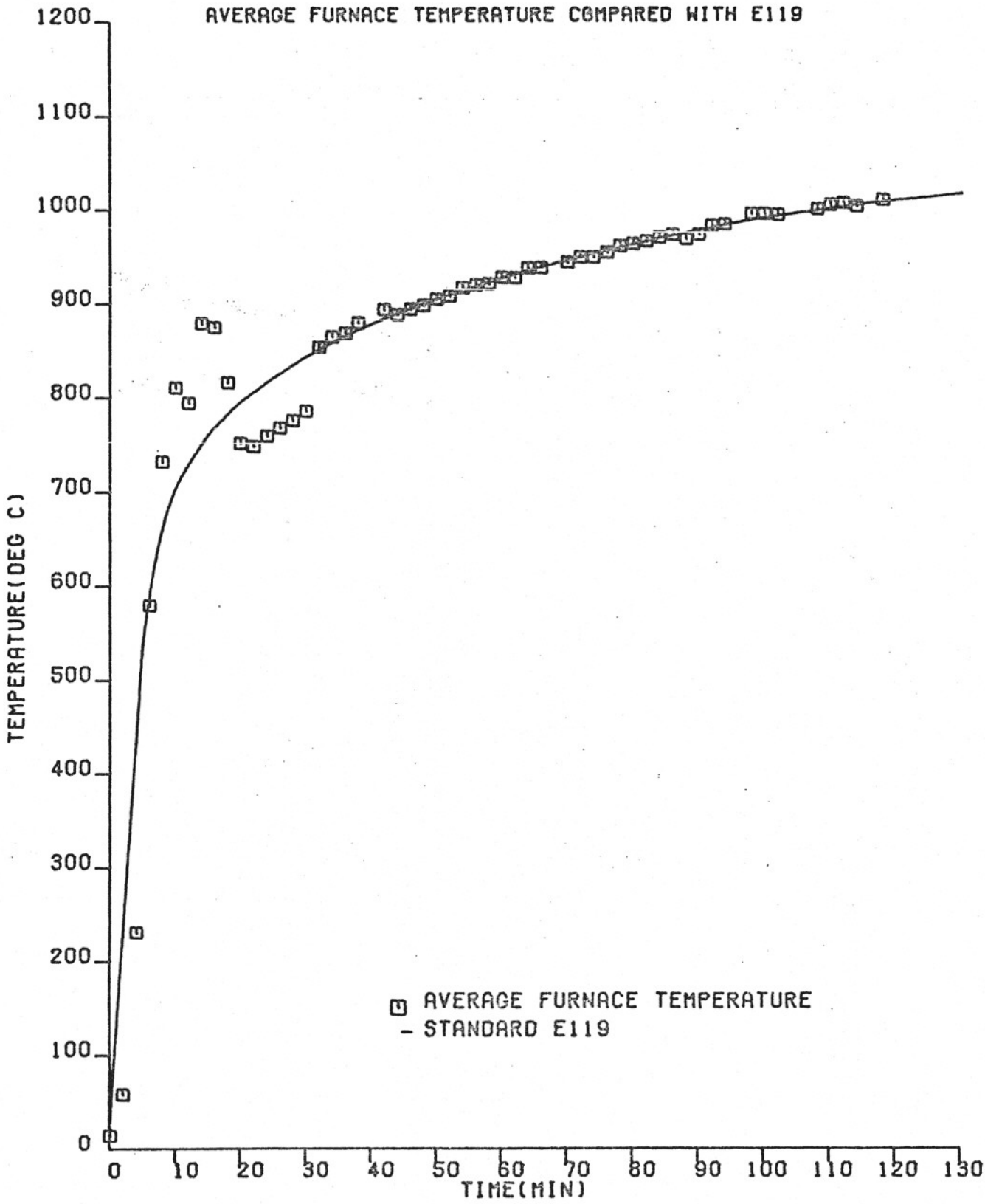

AVERAGE FURNACE TEMPERATURE COMPARED WITH E119
TEMPERATURE(DEG C)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
TIME(MIN)
AVERAGE FURNACE TEMPERATURE
STANDARD E119

Figure 8

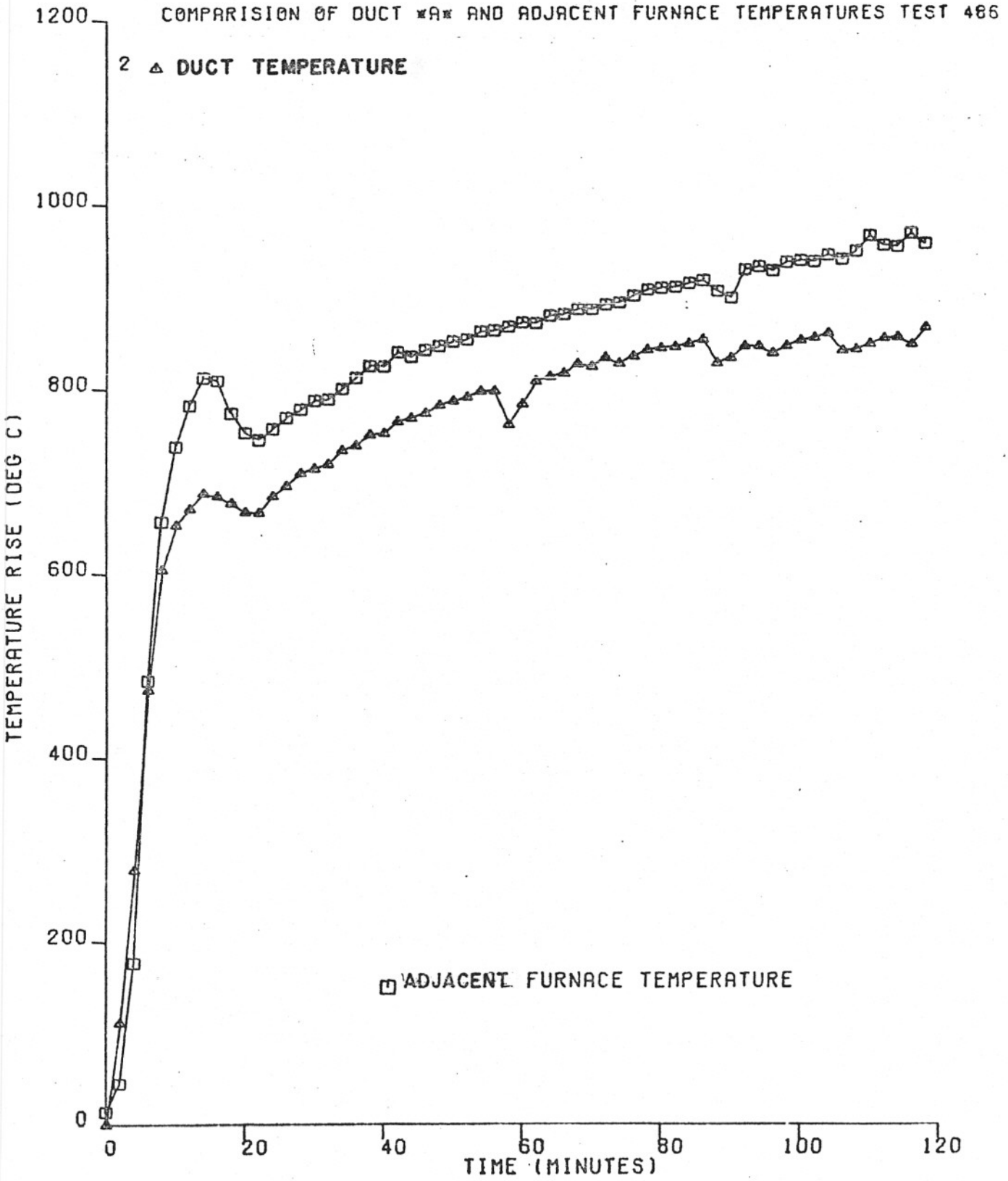

COMPARISION OF DUCT "A" AND ADJACENT FURNACE TEMPERATURES TEST 486
2 △ DUCT TEMPERATURE
□ ADJACENT FURNACE TEMPERATURE
TEMPERATURE RISE (DEG C)
TIME (MINUTES)
0
200
400
600
800
1000
1200
0
20
40
60
80
100
120

Figure 9

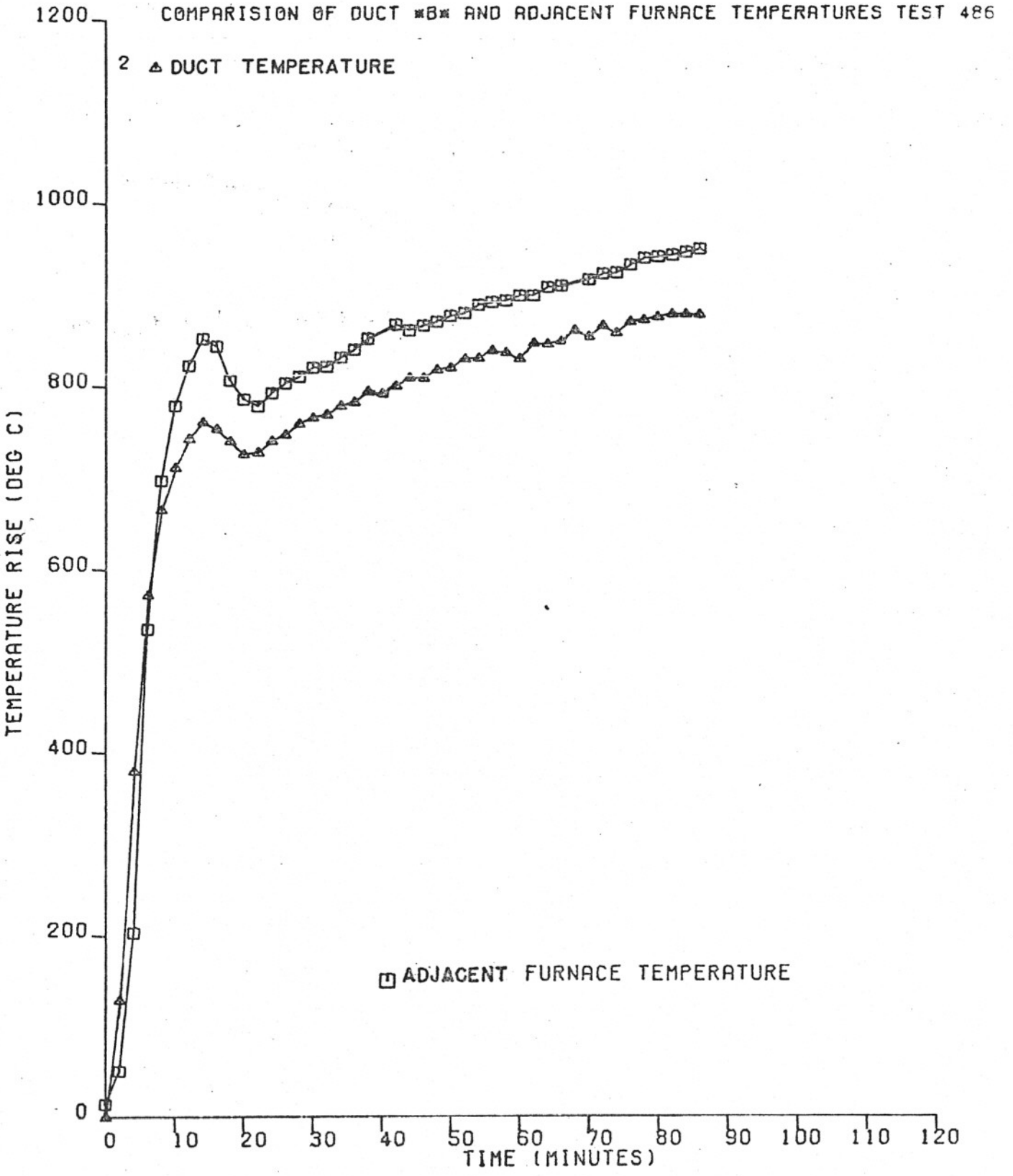

COMPARISION OF DUCT *B* AND ADJACENT FURNACE TEMPERATURES TEST 486
2 △ DUCT TEMPERATURE
□ ADJACENT FURNACE TEMPERATURE
TEMPERATURE RISE (DEG C)
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)

Figure 10

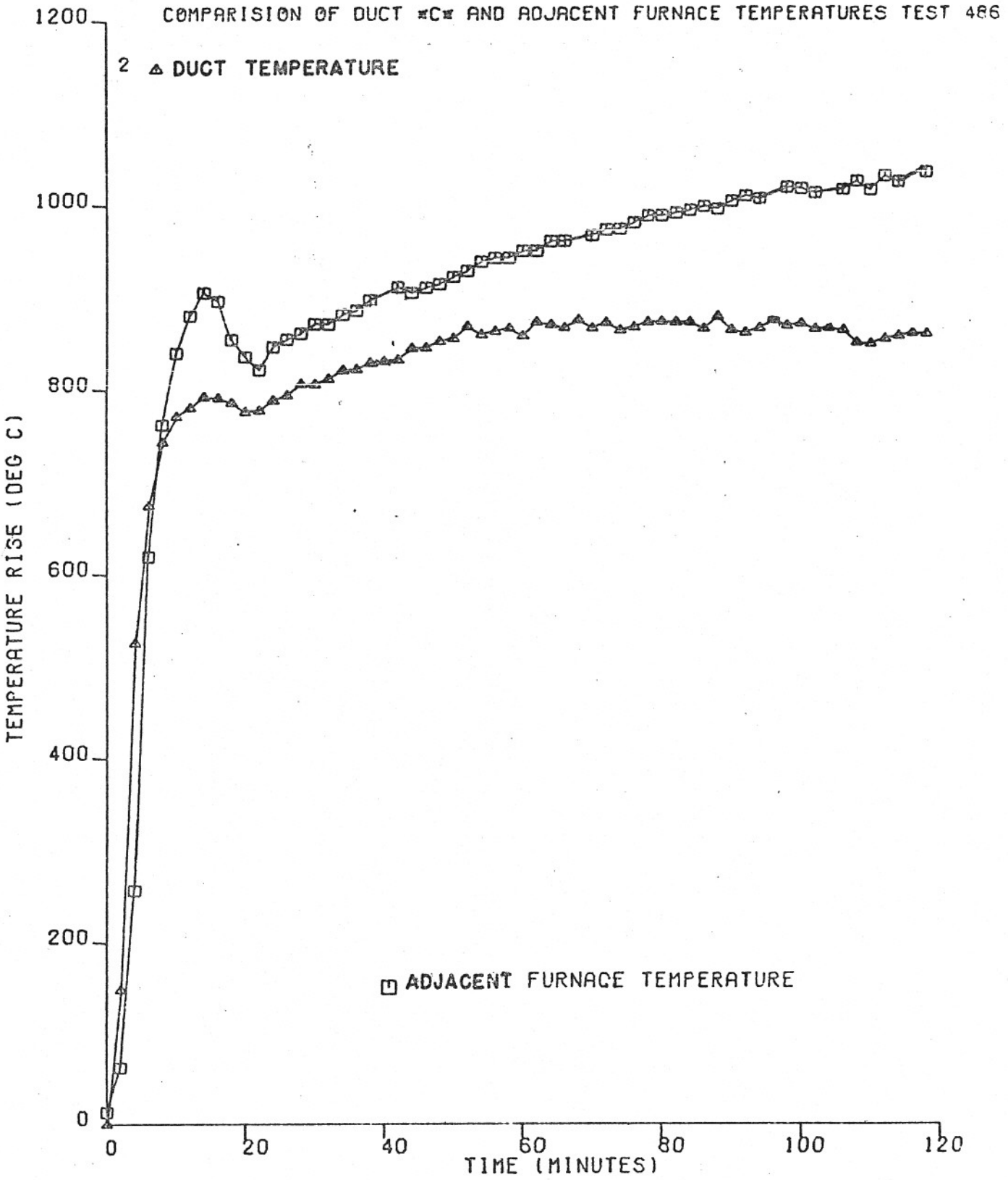

COMPARISION OF DUCT #C# AND ADJACENT FURNACE TEMPERATURES TEST 486
2 △ DUCT TEMPERATURE
□ ADJACENT FURNACE TEMPERATURE
TEMPERATURE RISE (DEG C)
TIME (MINUTES)
0
200
400
600
800
1000
1200
0
20
40
60
80
100
120

Figure 11

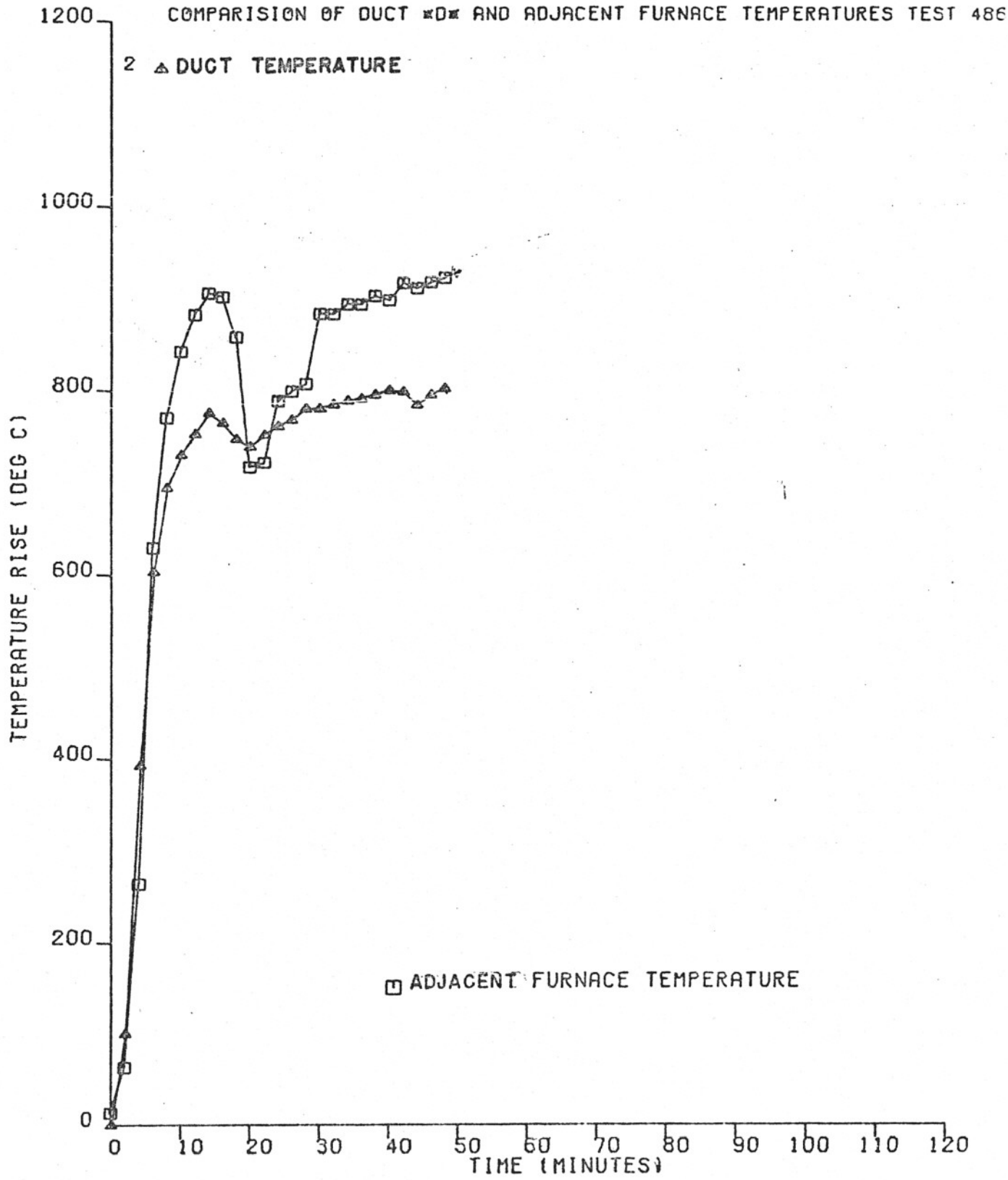
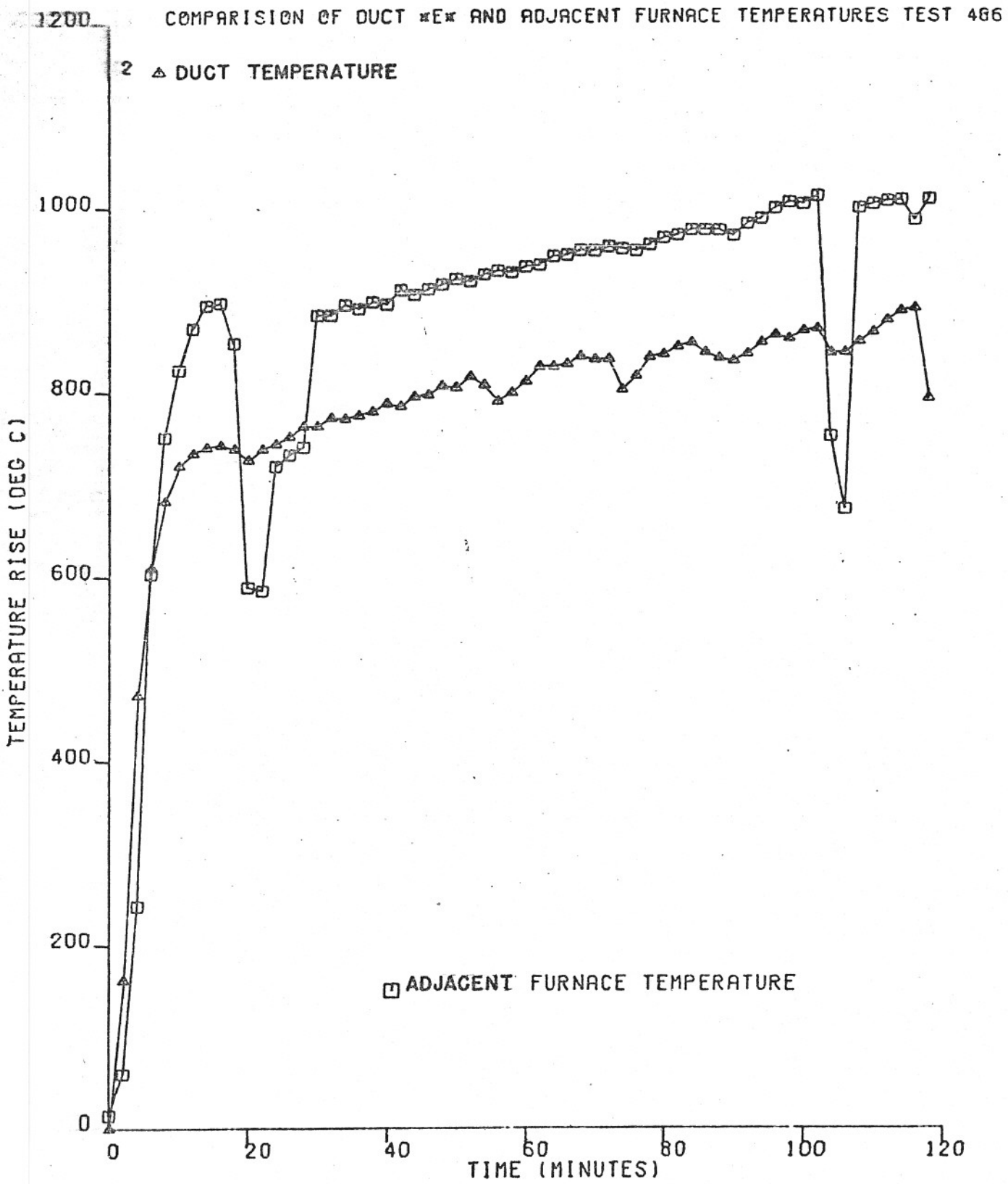

COMPARISION OF DUCT "D" AND ADJACENT FURNACE TEMPERATURES TEST 486
2 △ DUCT TEMPERATURE
□ ADJACENT FURNACE TEMPERATURE
TEMPERATURE RISE (DEG C)
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
90
100
110
120
TIME (MINUTES)

Figure 12


COMPARISION OF DUCT *E* AND ADJACENT FURNACE TEMPERATURES TEST 486
2 △ DUCT TEMPERATURE
□ ADJACENT FURNACE TEMPERATURE
TEMPERATURE RISE (DEG C)
TIME (MINUTES)
0
200
400
600
800
1000
1200
0
20
40
60
80
100
120