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Compendium of UK Standard Fire Resistance Test Data Unprotected Structural Steel - 3

Supplementary Thermal Data on Floor Beams

British Steel Technical

Research Organisation

COMPENDIUM OF UK STANDARD FIRE RESISTANCE TEST DATA UNPROTECTED STRUCTURAL STEEL - 3

SUPPLEMENTARY THERMAL DATA ON FLOOR BEAMS

D.E. Wainman R.R. Preston

SYNOPSIS

This compendium is the third in a series of such documents in which data from standard fire resistance tests to BS476 are presented. The document is intended as a supplement to the two earlier compendia and contains additional thermal data for standard fire resistance tests on simply supported floor beams. The report is concerned principally with demonstrating and quantifying the longitudinal thermal gradients which are developed along members during the course of standard fire resistance tests.

KEY WORDS

26	Beams
Fire Resistance	Sections(Structural)
+BS 476	Lab Reports
Thermal Properties	Building Floors

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COMPENDIUM OF UK STANDARD FIRE RESISTANCE TEST DATA UNPROTECTED STRUCTURAL STEEL - 3

SUPPLEMENTARY THERMAL DATA ON FLOOR BEAMS

1. INTRODUCTION

This compendium is the third in a series of such documents in which data from British standard fire resistance tests are presented.

The first compendium[1], published in March 1987, covered all the fire resistance tests which had been carried out in the UK up to that time, according to BS476:Part 8:1972, on unprotected, hot rolled, structural steel sections. This was followed at the end of 1988 by the second volume[2], in which data from a further ten tests were presented.

The main purpose of both documents was to provide detailed information for research workers in the field of structural fire engineering and to aid the development of accurate calculation methods for the determination of high temperature performance and fire resistant design. Since their publication, both compendia have been used extensively by many groups of workers, principally for the purpose of validating mathematical modelling techniques. Whilst most computer simulations of the standard fire resistance test acknowledge the existence of a temperature gradient through the depth of the steel section, it has generally been assumed, for modelling purposes, that no such gradient exists along the length of the section.

During the preparation of the two compendia referred to earlier it was noted that additional thermal data were available for some, but not all, of the tests carried out on floor beams. The data referred to thermocouples which were located at one end of the steel beam, adjacent to the furnace wall. At the time it was decided, in the interests of clarity, to omit these data from the compendia. However, in response to requests for further information concerning longitudinal thermal gradients these data are now being made available. The data are presented in a similar format to that adopted for the earlier publications. When using the information presented in this document, reference should be made to the appropriate data sheets in either Compendium No. 1 or No. 2 for details describing the design, construction and test procedures of each assembly.

2. SOURCES OF ADDITIONAL DATA

In the case of the floor beam tests covered by data sheets 1-31 of Ref. 1, the British Steel reports prepared in connection with each particular test include, where available, data from the thermocouples located near one end of the beam. Examination of these reports has revealed additional thermal data for the tests described in data sheets 12, 13 and 17-31 inclusive and these data are presented in Appendix A. The numbering system maintains that used in Ref. 1, i.e. data sheet 12C in Appendix A, should be read in conjunction with data sheets 12A/B of Compendium No. 1.

No additional data exist for any of the floor beam tests reported in the second compendium (data sheets 89-95).

In the case of the six shelf angle floor beam tests covered by data sheets 32-37 of Ref. 1 it has been necessary to interrogate the original COMPULOG printouts to ascertain whether any additional data are available. Data have been revealed for five of these tests, (the exception being No. 37), and these are also presented in Appendix A.

No additional data exist for the two shelf angle floor beam tests reported in data sheets 96 and 97 of Compendium No. 2.

No additional data have been found for the two slim floor beam tests reported in the first compendium (data sheets 38 and 39).

3. THERMOCOUPLE LOCATIONS

Thermocouple positions were generally recorded with reference to one end of the test beam. Figures 1 and 2 show, schematically, the layout of all the thermocouples used on both simply supported and shelf-angle floor beam tests respectively. The dimensional data are presented in Table 1, from which it may be seen that the thermocouples which are of particular interest in this report were, in the majority of cases, located approximately 700 mm from the furnace wall.

For convenience this group of thermocouples has been designated the 'end' group, whilst all the remaining thermocouples will be referred to as the 'centre' group.

4. DATA ANALYSIS

4.1 Simply Supported Floor Beams

4.1.1 254 × 146 mm × 43 kg/m Serial Size Beams

Of the seventeen separate floor beam tests for which data are presented in Appendix A, nine involve beams of serial size 254 × 146 mm × 43 kg/m. Although the grade of steel, the applied load and the test configuration are variables for each test, none of these factors has any influence on the thermal response of the member. It is therefore considered permissible to group all nine beams together for the purpose of data analysis.

Table 2 presents thermal data for these nine beams. The overall mean upper flange, web, and lower flange values were obtained by taking the mean of the data presented in the appropriate data sheets of Ref. 1. The mean F10, F11 and W5 values are from the data given in Appendix A. Table 2 also records the differences between the two values, these being an indication of the magnitude of the longitudinal thermal gradient in each of the three elements of the beam. The table shows that the greatest temperature differences occur as follows:-

Upper Flange	:	171°C after 30 min
Web	:	140°C after 15 min
Lower Flange	:	124°C after 15 min

Figures 3-5 are plots of the mean temperature data given in Table 2 for the upper flange, web and lower flange positions respectively. Figure 6 shows the magnitude of the longitudinal thermal gradient for the same positions.

It is interesting to note that even after considerable reduction of the data sets by averaging it is still possible to detect the temperature plateau associated with the endothermic ferrite/pearlite to austenite transformation. This is illustrated particularly well in Fig. 5, where both the 'end' and 'centre' plots show the feature.

The shape of the difference curves in Fig. 6 may be explained by considering the effect of the ferrite/pearlite to austenite transformation. Initially, both the centre and end regions of the beam begin to heat up, but the end tends to lag progressively further behind the centre due to the chilling effect of the furnace wall. The temperature gradient therefore rises during this period. Eventually the centre of the

beam undergoes the transformation to austenite, as a consequence of which its rate of temperature rise diminishes. However, the end of the beam has not yet reached the transformation temperature and so its temperature continues to rise. The net result of this is therefore to reduce the difference in temperature between the two parts of the beam. Having passed through the phase transformation the temperature of the centre part of the beam starts to increase again. The rate of temperature rise at the end of the beam now diminishes as it undergoes transformation, thereby resulting in a net increase in the temperature difference again.

4.1.2 Other Serial Size Beams

Additional thermal data have been found for eight tests involving beams of serial sizes other than 254 × 146 mm × 43 kg/m. The table below gives a summary of these.

Data Sheet Number	Serial Size of Member mm × mm × kg/m
12	356 × 171 × 67 Beam
20/21/22	203 × 133 × 30 Beam
24/25/26/27	203 × 203 × 52 Column

Data for the tests involving 203 × 133 mm × 30 kg/m beams have been analysed in a similar manner to that described for the 254 × 146 mm × 43 kg/m beams. Table 3 presents thermal data for these three beams. No data were obtained from thermocouple F11, located in the upper flange position, in any of the tests. The table shows that the greatest temperature differences occurred as follows:-

Web	:	157°C after 12 min
Lower Flange	:	146°C after 12 min

Figure 7 is a plot showing the magnitude of the thermal gradient for web and lower flange positions.

Examination of the data presented in sheet 12C of Appendix A indicates an atypical thermal response from the thermocouples located at the end of the beam. These temperatures are considered to be abnormally low and the reader is advised to regard these data as being unreliable. The data are included here for the sake of completeness only.

No analysis has been carried out on the 203 × 203 mm × 52 kg/m column sections used as beams.

4.2 Shelf Angle Floor Beams

Table 4 gives a summary of selected data for all the shelf angle floor beams tested. Of these, additional data exist for only the first five (Nos. 32-36). From Table 4 it may be seen that three tests in particular (Nos. 32, 34 and 36), are similar in as much that the beam serial size is 406 × 178 mm × 54 kg/m and the height of the exposed web is nominally 182 mm. Whilst other factors such as steel grade and loading conditions are different these again should not have any bearing on the thermal response of the member. It is therefore considered valid to group these three beams together for the purposes of data analysis.

Reference to the appropriate data sheets in Compendium 1 indicates that the time intervals between 20 and 30 min at which the data are presented for Test 32 are different to those used for the other two tests. This has been remedied by interrogating the original COMPULOG data printouts and extracting new data at times of 18, 21, 24 and 27 min. These data are given in Table 5.

Table 6 presents thermal data for the three beams. The overall mean temperature values at the six locations have been obtained in the manner described for simply supported floor beams. The mean F13,

F14, F15, W13, W14, W15 values are from the data in Appendix A. The differences between the two values are also given in Table 6.

Figures 8-13 are plots of the mean temperature data given in Table 6 for the six thermocouple locations. Figures 14-19 show the variation in the difference values at the same locations.

Figure 8 is of particular interest since it again shows quite well the plateau associated with the phase change to austenite.

As expected the unexposed elements of the structure exhibit only relatively small longitudinal thermal gradients. That in the unexposed flange angle is still increasing slowly even after one hour. In the case of the exposed elements the gradients are more pronounced; the greatest temperature differences occurring as follows:-

Exposed web	:	180°C between 21 & 24 min
Lower flange	:	185°C after 21 min
Exposed flange angle	:	190°C between 45 & 50 min

5. SUMMARY

Additional thermal data have been obtained from BS476:Part 8 fire resistance tests carried out on seventeen simply supported floor beams and six shelf angle floor beams.

The data relate to thermocouples located near one end of the beam approximately 700 mm from the furnace wall.

Analysis of the data gives an indication of the longitudinal thermal gradients which are developed during standard fire resistance tests.

6. REFERENCES

1. Wainman, D.E. and Kirby, B.R., 'Compendium of UK Standard Fire Test Data - Unprotected Structural Steel (1)', British Steel Report RS/RSC/S10328/1/87/B.

2. Wainman, D.E. and Kirby, B.R., 'Compendium of UK Standard Fire Test Data - Unprotected Structural Steel (2)', British Steel Report RS/R/S1199/8/88/B.

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TABLE 1
DIMENSIONAL DATA FOR
THERMOCOUPLE POSITIONS SHOWN IN FIGS. 1 AND 2

Dimension Code	Test Data Sheets			
	12/17-18	13/19-27	28-31	32-36
A	0.50	1.56	1.25	0.57
B	1.50	2.56	2.23	1.57
C	1.81	2.87	2.54	1.88
D	2.11	3.17	2.84	2.17
E	2.43	3.49	3.16	2.50
F	2.73	3.79	3.46	2.80
G	3.05	4.11	3.78	3.12
H	3.35	4.41	4.08	3.42
I	4.84	6.90	6.30	5.00
J	0.32	0.32	0.32	0.33
K	0.30	0.30	0.30	0.30
L	0.62	0.62	0.62	0.62
M	0.62	0.62	0.62	0.62
N	0.93	0.93	0.93	0.93
O	0.92	0.92	0.92	0.92
P	1.93	1.93	1.91	1.93
Q	4.00	4.00	4.00	4.00
R	4.50 4.53 (18)	4.50 4.53 (21/22)	4.50	4.50
S	0.07	0.07	0.09	0.07

All dimensions are in metres

TABLE 2
OVERALL MEAN TEMPERATURE DATA FOR 254 × 146 mm × 43 kg/m SERIAL SIZE BEAMS
(DATA SHEETS:- 13/17/18/19/23/28/29/30/31)

	Temperature Deg. C After Various Times (minutes)															
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Overall Mean Upper Flange	69.0	116.8	169.3	217.0	274.0	331.0	386.8	436.2	482.4	525.4	563.8	600.2	634.0	662.5	688.3	722.5
Mean T/C F11	50.0	75.3	105.3	131.6	163.4	202.2	239.0	278.2	316.0	354.4	393.8	430.8	466.6	508.3	543.7	595.0
Difference	19.0	41.5	64.0	85.4	110.6	128.8	147.8	158.0	166.4	171.0	170.0	169.4	167.4	154.2	144.6	127.5
Overall Mean Web	127.7	253.9	374.3	467.9	544.0	599.0	639.6	673.0	701.3	721.4	741.0	755.9	775.3	788.0	804.8	841.7
Mean T/C W5	101.7	180.7	263.9	334.6	404.1	462.4	511.5	555.1	592.6	620.1	651.1	675.1	699.7	719.6	734.3	760.7
Difference	26.0	73.2	110.4	133.3	139.9	136.6	128.1	117.9	108.7	101.3	89.9	80.8	75.6	68.4	70.5	81.0
Overall Mean Lower Flange	106.5	221.4	342.0	450.9	538.6	604.0	650.8	686.1	715.0	733.4	754.6	771.3	791.9	806.8	822.0	859.3
Mean T/C F10	106.5	182.1	261.9	336.5	415.1	482.1	536.5	583.8	622.6	651.6	678.3	704.4	725.0	733.0	746.8	775.3
Difference	Nil	39.3	80.1	114.4	123.5	121.9	114.3	102.3	92.4	81.8	76.3	66.9	66.9	73.8	75.2	84.0

TABLE 3
OVERALL MEAN TEMPERATURE DATA FOR 203 × 133 mm × 30 kg/m SERIAL SIZE BEAMS (DATA SHEETS:- 20/21/22)

	Temperature Deg. C After Various Times (minutes)										
	3	6	9	12	15	18	21	24	27	30	33
Overall Mean Upper Flange Mean T/C F11 Difference	No data available										
Overall Mean Web	148.7	297.0	426.3	528.0	595.3	641.3	675.3	703.0	724.3	744.7	759.7
Mean T/C W5	101.0	196.0	285.7	371.0	441.0	496.7	541.3	578.3	610.7	639.7	661.0
Difference	47.7	101.0	140.6	157.0	154.3	144.6	134.0	124.7	113.6	105.0	98.7
Overall Mean Lower Flange	113.0	264.3	412.3	532.7	612.3	663.3	697.7	722.3	741.7	761.3	777.0
Mean T/C F10	88.0	186.3	286.0	386.3	469.7	534.0	581.0	617.3	656.3	674.3	693.0
Difference	25.0	78.0	126.3	146.4	142.6	129.3	116.7	105.0	85.4	87.0	84.0

TABLE 4
SELECTED DATA FOR SHELF ANGLE FLOOR BEAM SYSTEMS

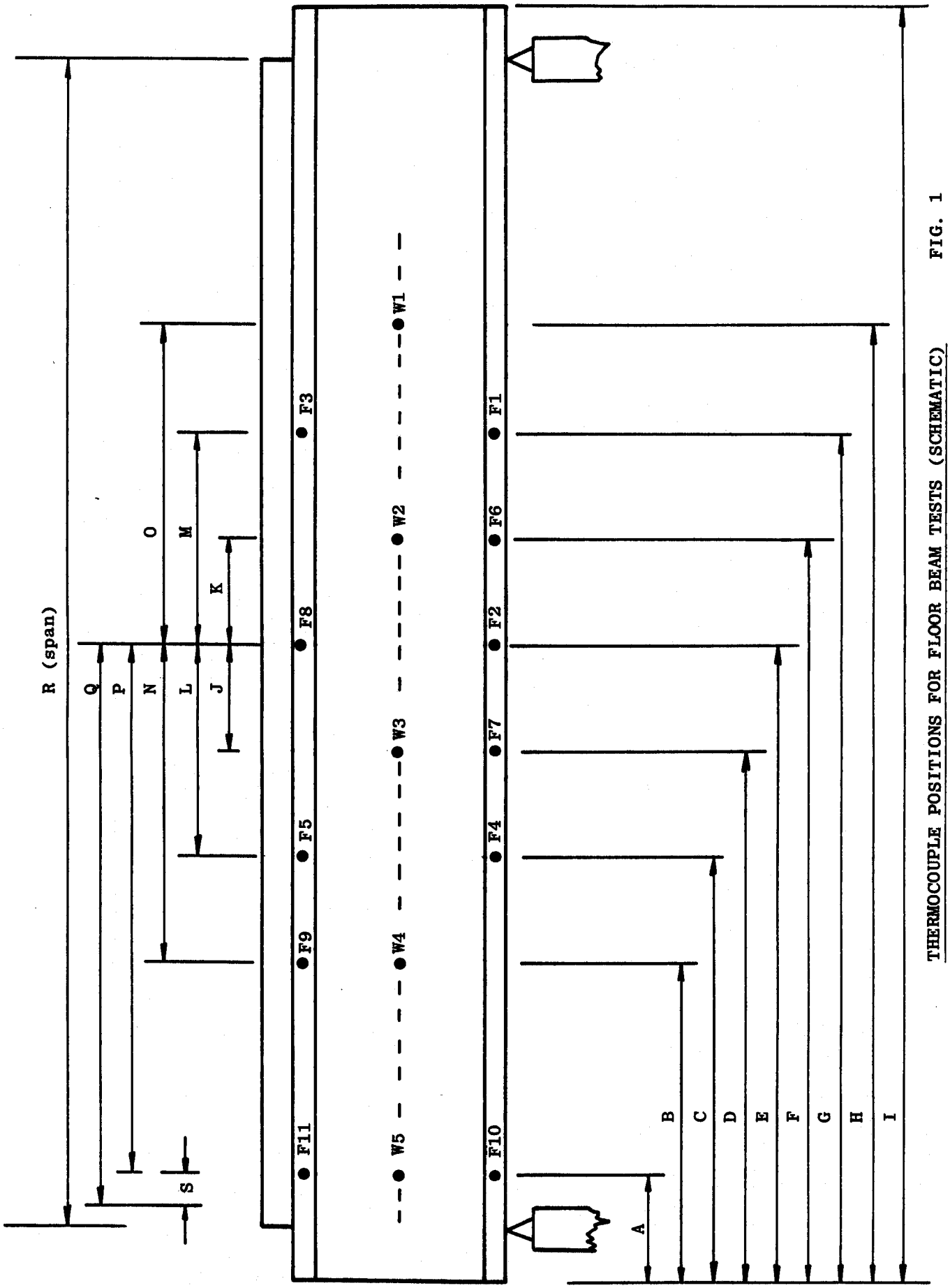
Data Sheet Number	Beam Serial Size mm × mm × kg/m	Steel Grade	Concrete Floor Slab Thickness mm	Proportion of BS449 Design Load %	Height of Exposed Web mm	Additional Data
32	406 × 178 × 54	43A	Solid, 200 mm	106	181.1	Yes
33	305 × 165 × 40	43A	Solid, 200 mm	107	84.0	Yes
34	406 × 178 × 54	50B	Solid, 200 mm	46.2	182.0	Yes
35	406 × 178 × 54	43A	Solid, 150 mm with 50 mm deep × 300 mm long taper at one end.	105.2	282.0	Yes
36	406 × 178 × 54	43A	Solid, 200 mm	85.2	182.0	Yes
37	406 × 178 × 54	43A	Solid, 150 mm with 50 mm deep × 300 mm long taper at one end.	60.9	282.0	No
96	254 × 146 × 43	43A	Solid, 150 mm	110.7	82.0	No
97	254 × 146 × 43	43A	Solid, 150 mm with 50 mm deep × 300 mm long taper at one end.	105.5	114.0	No

TABLE 5
SUPPLEMENTARY THERMAL DATA FOR DATA SHEET 32B OF REFERENCE 1

Thermocouple Location		Temperature Deg. C After Various Times (minutes)			
		18	21	24	27
Upper Flange	F3	25	26	27	28
	F8	27	28	29	31
	F9	27	28	29	30
	Mean	26	27	28	30
Unexposed Web	W5	52	61	72	83
	W6	53	63	74	86
	W7	54	64	76	90
	W8	51	60	70	81
	Mean	52	62	73	85
Exposed Web	W1	551	596	633	663
	W2	573	617	655	685
	W3	553	595	633	663
	W4	522	563	603	629
	Mean	550	593	631	660
Lower Flange	F2	607	652	690	716
	F4	570	617	656	685
	F6	602	652	690	718
	F7	586	635	674	703
	Mean	591	639	677	705
Exposed Flange Angle	F10	397	445	492	527
	F11	370	418	468	508
	F12	395	447	496	539
	Mean	387	437	485	525
Unexposed Flange Angle	W9	169	208	246	282
	W10	198	241	282	320
	W11	182	227	269	309
	W12	189	229	268	305
	Mean	184	226	266	304
Angle Root	R1	237	285	331	373
	R2	263	312	359	402
	R3	251	301	349	392
	Mean	250	299	346	389
Mean Furnace Gas		760	778	796	808
Standard Curve		769	792	812	829

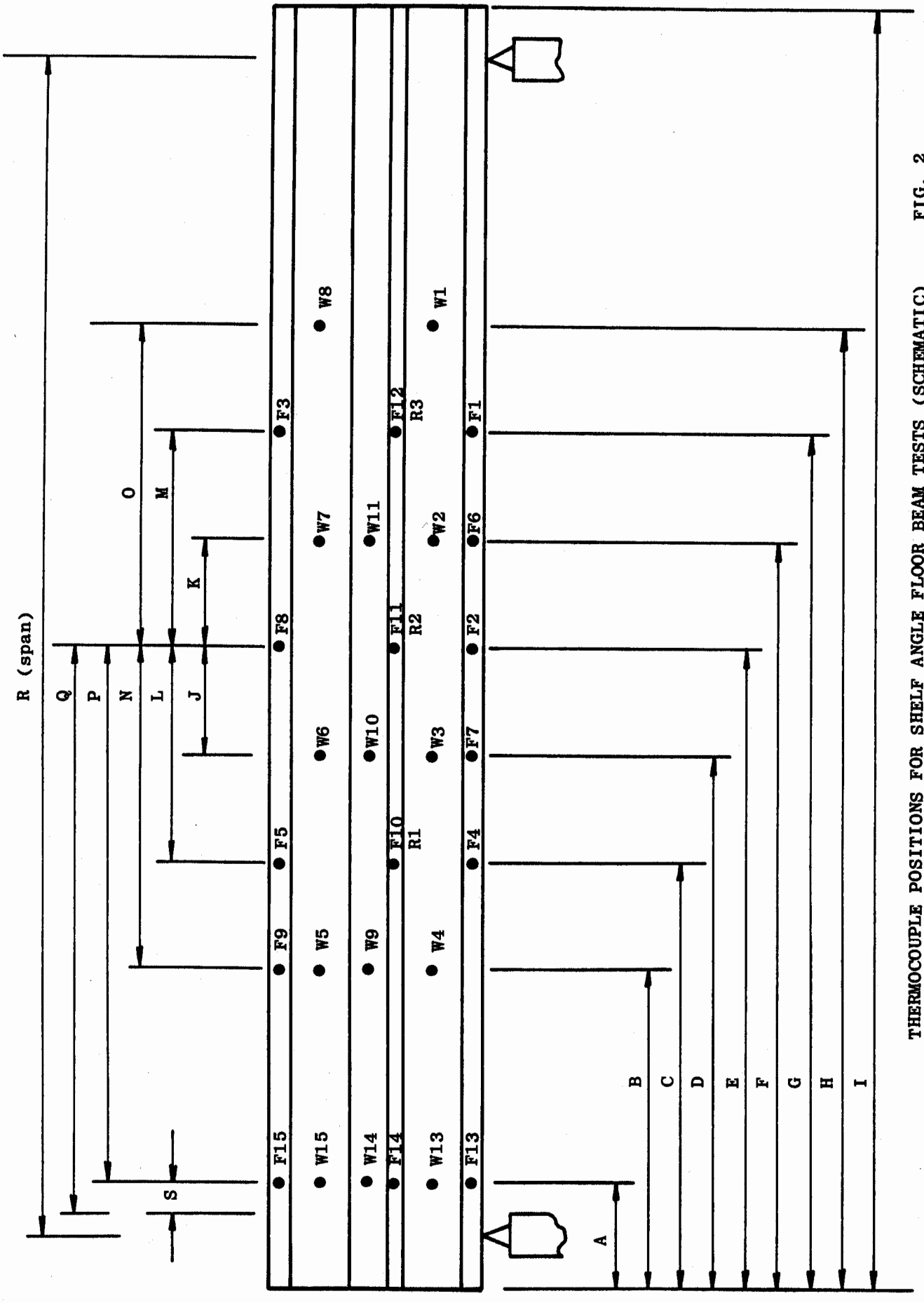
TABLE 6
OVERALL MEAN TEMPERATURE DATA FOR 406 × 178 mm × 54 kg/m SHELF ANGLE FLOOR BEAMS
(FLOOR THICKNESS = 200 mm)
(DATA SHEETS:- 32/34/36)

	Temperature Deg. C After Various Times (min)															
	3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60
Overall Mean Upper Flange	20.0	20.7	21.3	21.7	22.3	23.3	23.3	25.3	29.0	32.7	38.7	44.7	50.0	59.0	67.3	79.0
Mean T/C F15	21.7	22.0	23.0	23.3	23.7	25.7	26.0	27.7	30.7	33.0	37.3	42.0	44.7	52.7	59.7	67.0
Difference	-1.7	-1.3	-1.7	-1.6	-1.4	-2.4	-2.7	-2.4	-1.7	-0.3	1.4	2.7	5.3	6.3	7.6	12.0
Overall Mean Unexposed Web	20.7	22.7	26.7	32.3	39.3	47.7	57.3	67.3	78.7	91.0	108.0	118.7	128.3	136.7	145.3	155.0
Mean T/C W15	21.7	22.7	26.3	29.3	32.3	39.3	44.3	50.7	59.0	66.7	80.0	93.7	101.3	113.0	119.0	124.3
Difference	-1.0	Nil	0.4	3.0	7.0	8.4	13.0	16.6	19.7	24.3	28.0	25.0	27.0	23.7	26.3	30.7
Overall Mean Exposed Web	106.3	196.7	301.0	391.3	475.7	536.3	585.3	625.3	656.0	681.7	716.3	741.3	770.0	800.7	829.0	854.7
Mean T/C W13	77.0	134.7	197.7	254.3	311.0	363.0	405.3	445.3	479.3	508.7	550.3	586.3	616.3	648.0	676.7	704.0
Difference	29.3	62.0	103.3	137.0	164.7	173.3	180.0	180.0	176.7	173.0	166.0	155.0	153.7	152.7	152.3	150.7
Overall Mean Lower Flange	82.0	179.7	306.7	419.0	516.7	586.0	635.0	673.7	702.0	724.3	747.3	777.3	807.7	834.7	861.0	883.3
Mean T/C F13	76.0	144.7	216.0	281.0	343.7	402.0	449.7	492.0	528.0	557.0	596.3	629.7	656.7	684.0	709.0	731.3
Difference	6.0	35.0	90.7	138.0	173.0	184.0	185.3	181.7	174.0	167.3	151.0	147.6	151.0	150.7	152.0	152.0
Overall Mean Exposed Flange Angle	69.0	118.3	180.0	238.7	304.3	364.7	418.7	466.0	507.7	545.0	597.0	644.0	687.3	724.7	756.7	782.3
Mean T/C F14	61.0	92.7	126.7	160.7	197.3	234.0	269.3	306.0	341.3	373.0	419.7	461.0	497.3	534.3	568.7	600.7
Difference	8.0	25.6	53.3	78.0	107.0	130.7	149.4	160.0	166.4	172.0	177.3	183.0	190.0	190.4	188.0	181.6
Overall Mean Unexposed Flange Angle	26.3	42.7	69.7	99.7	137.3	178.7	220.3	261.3	299.3	334.0	383.0	424.7	462.3	497.0	530.0	560.7
Mean T/C W14	25.7	37.3	53.3	72.0	94.0	119.3	144.0	170.7	199.3	225.0	264.3	296.0	324.0	357.7	388.0	418.0
Difference	0.6	5.4	16.4	27.7	43.3	59.4	76.3	90.6	100.0	109.0	118.7	128.7	138.3	139.3	142.0	142.7



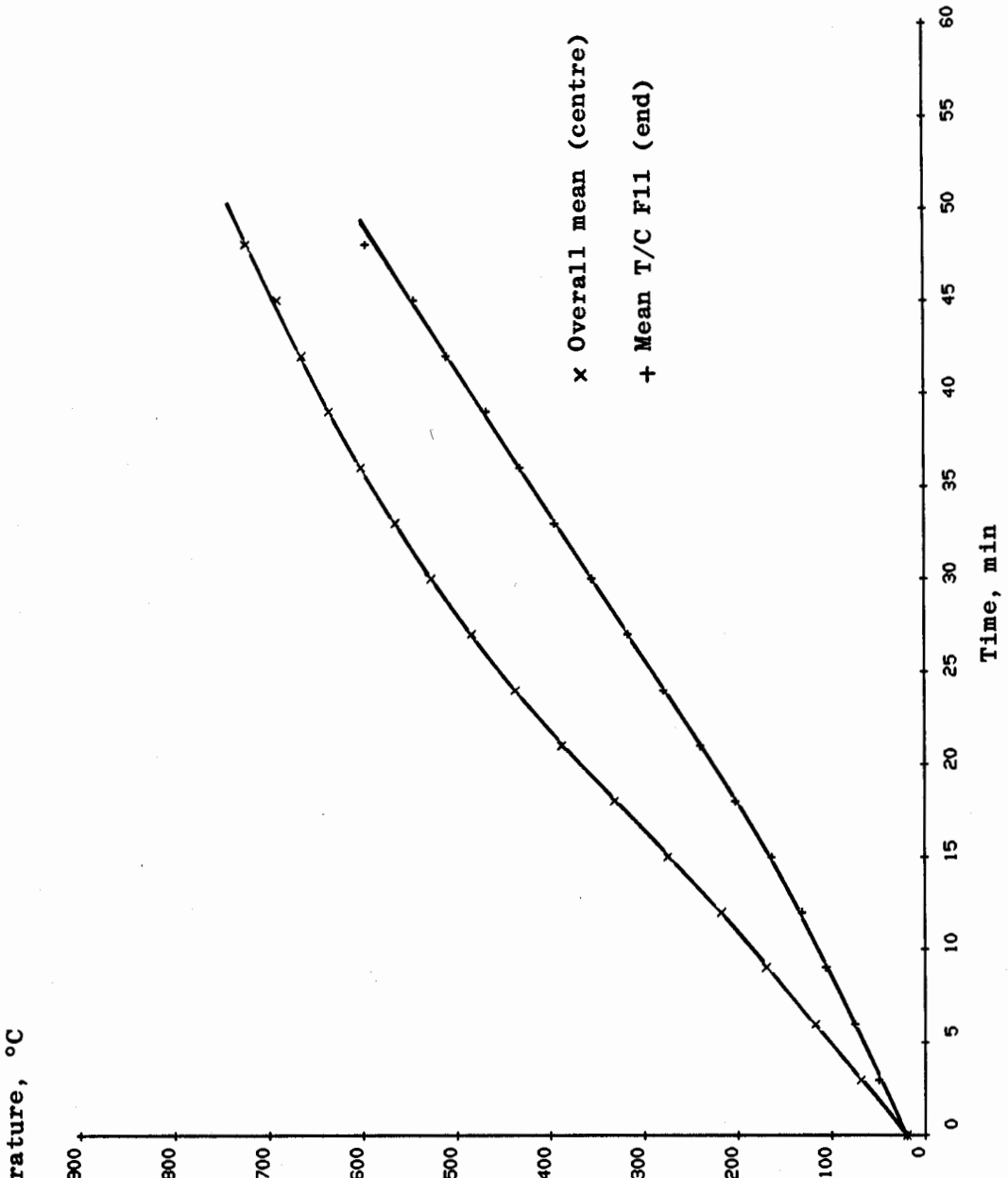
THERMOCOUPLE POSITIONS FOR FLOOR BEAM TESTS (SCHEMATIC)

FIG. 1
(R3/4565)



THERMOCOUPLE POSITIONS FOR SHELF ANGLE FLOOR BEAM TESTS (SCHEMATIC)

FIG. 2
(R3/4566)



MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE UPPER FLANGE OF 254 x 146 mm x 43 kg/m BEAMS

FIG. 3

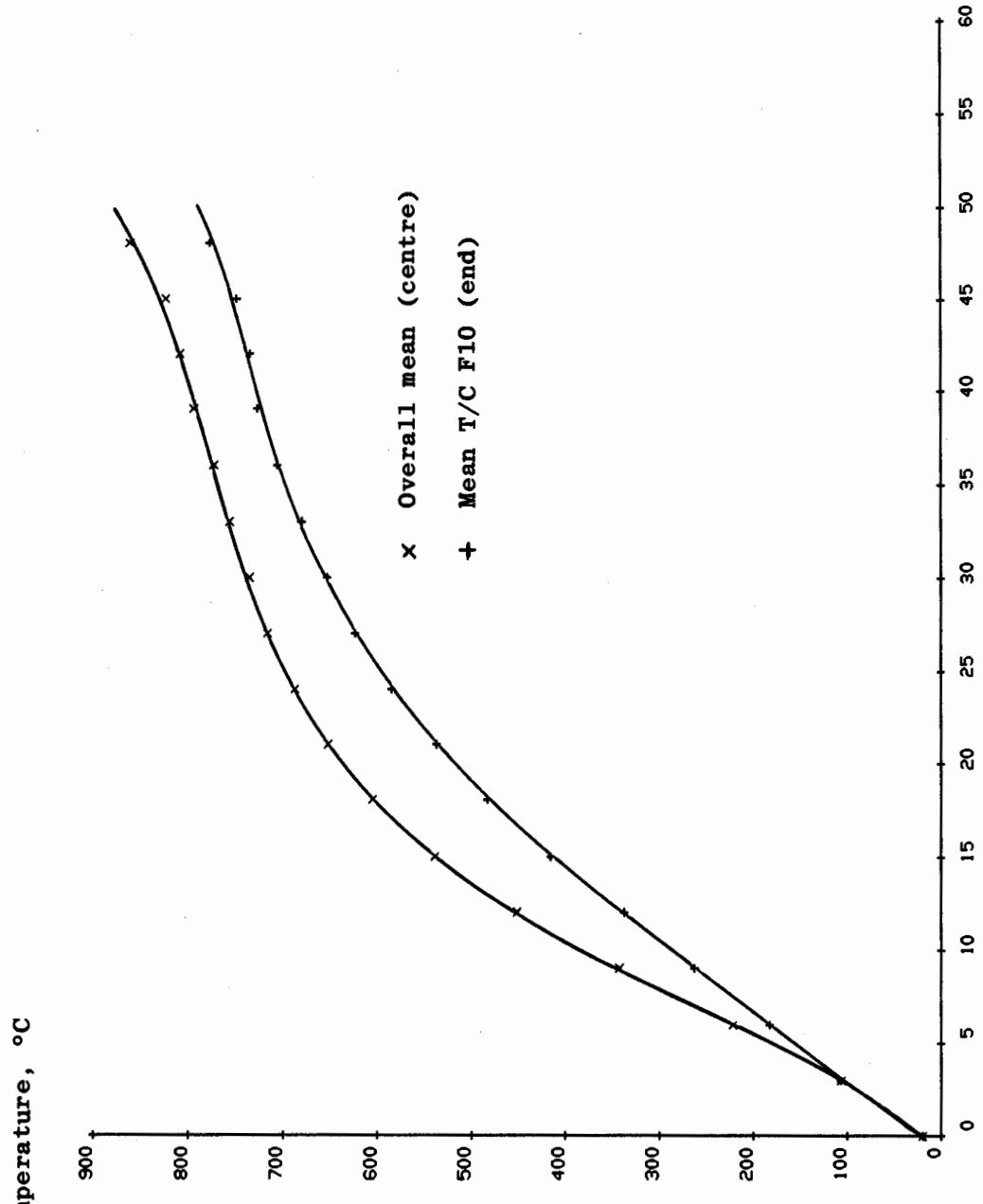
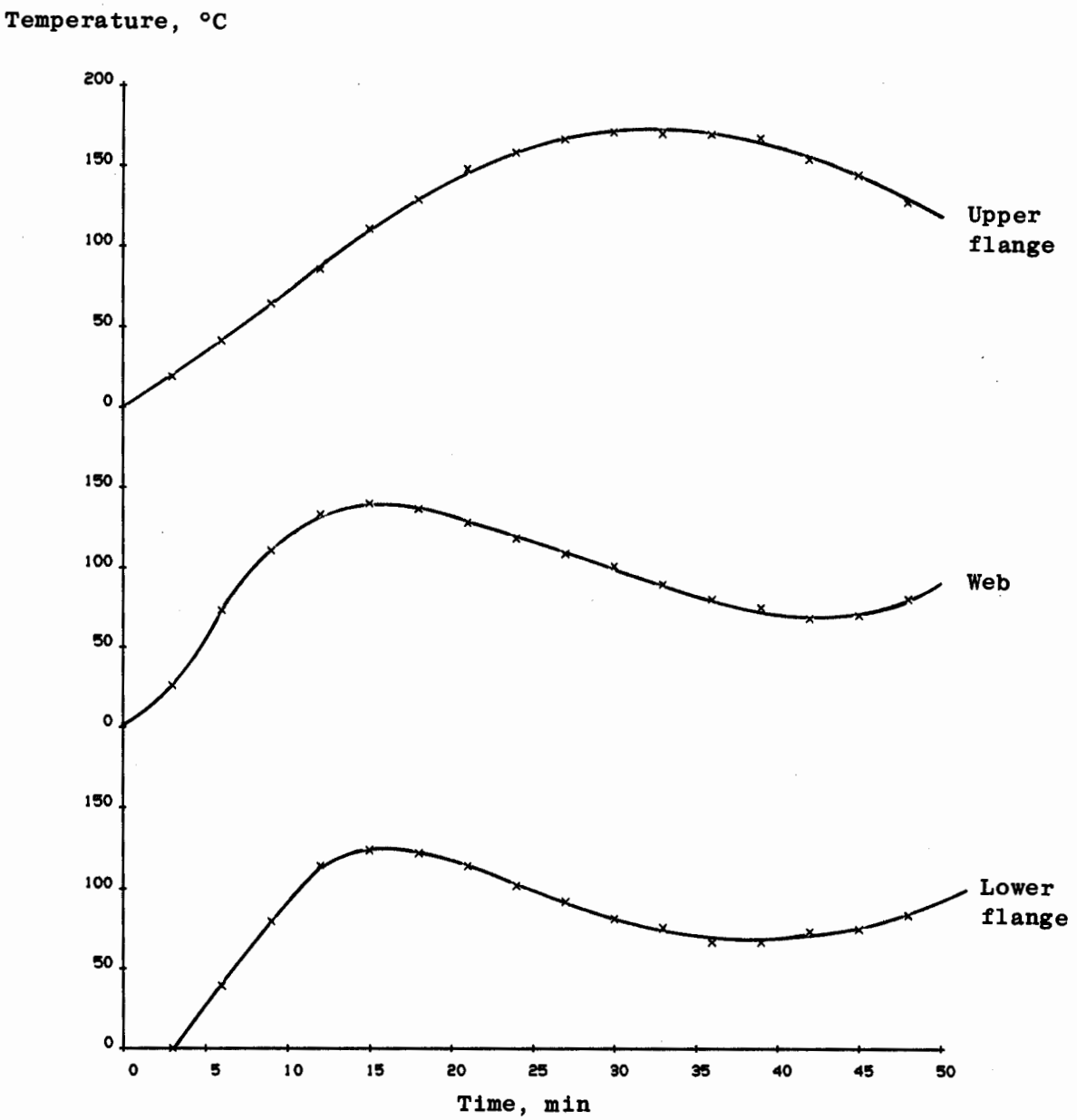


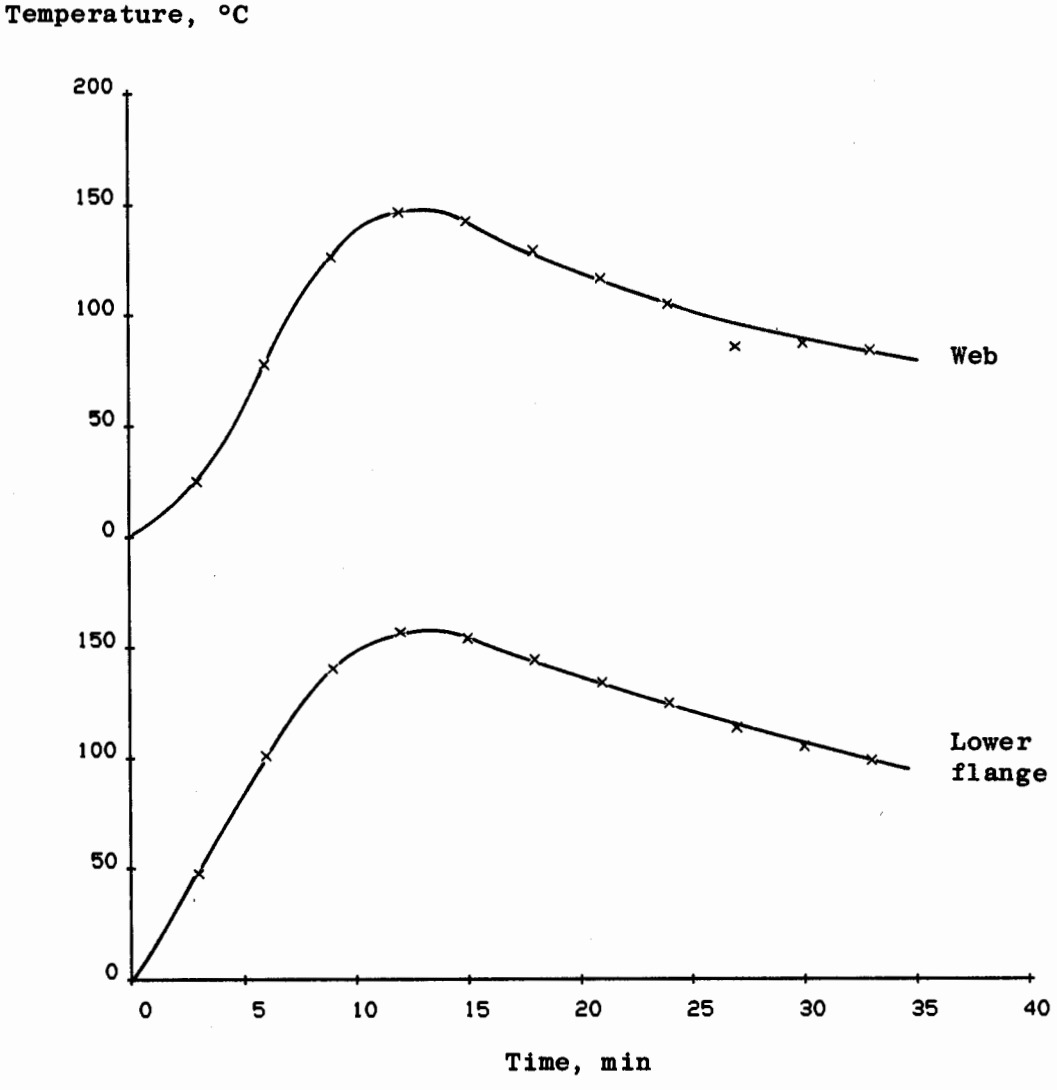
FIG. 5

MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE LOWER FLANGE OF 254 x 146 mm x 43 kg/m BEAMS



DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA FOR 254 x 146 mm x 43 kg/m BEAMS

FIG. 6



DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA FOR 203 x 133 mm x 30 kg/m BEAMS

FIG. 7

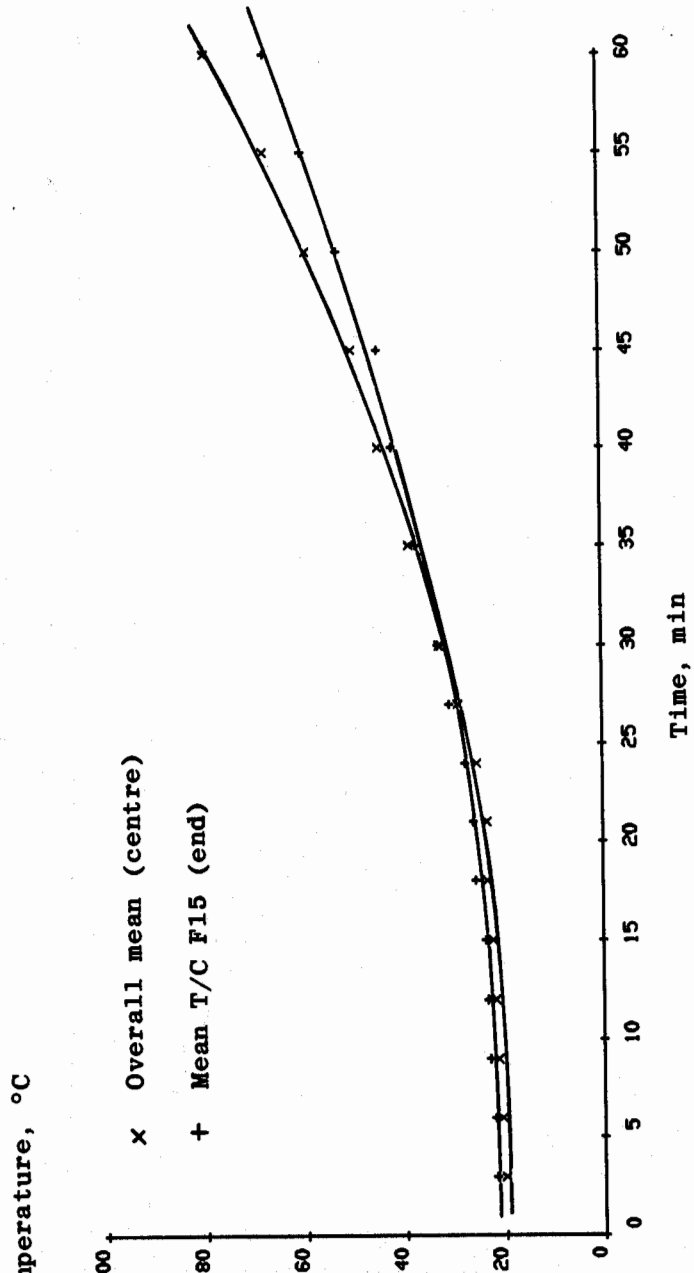
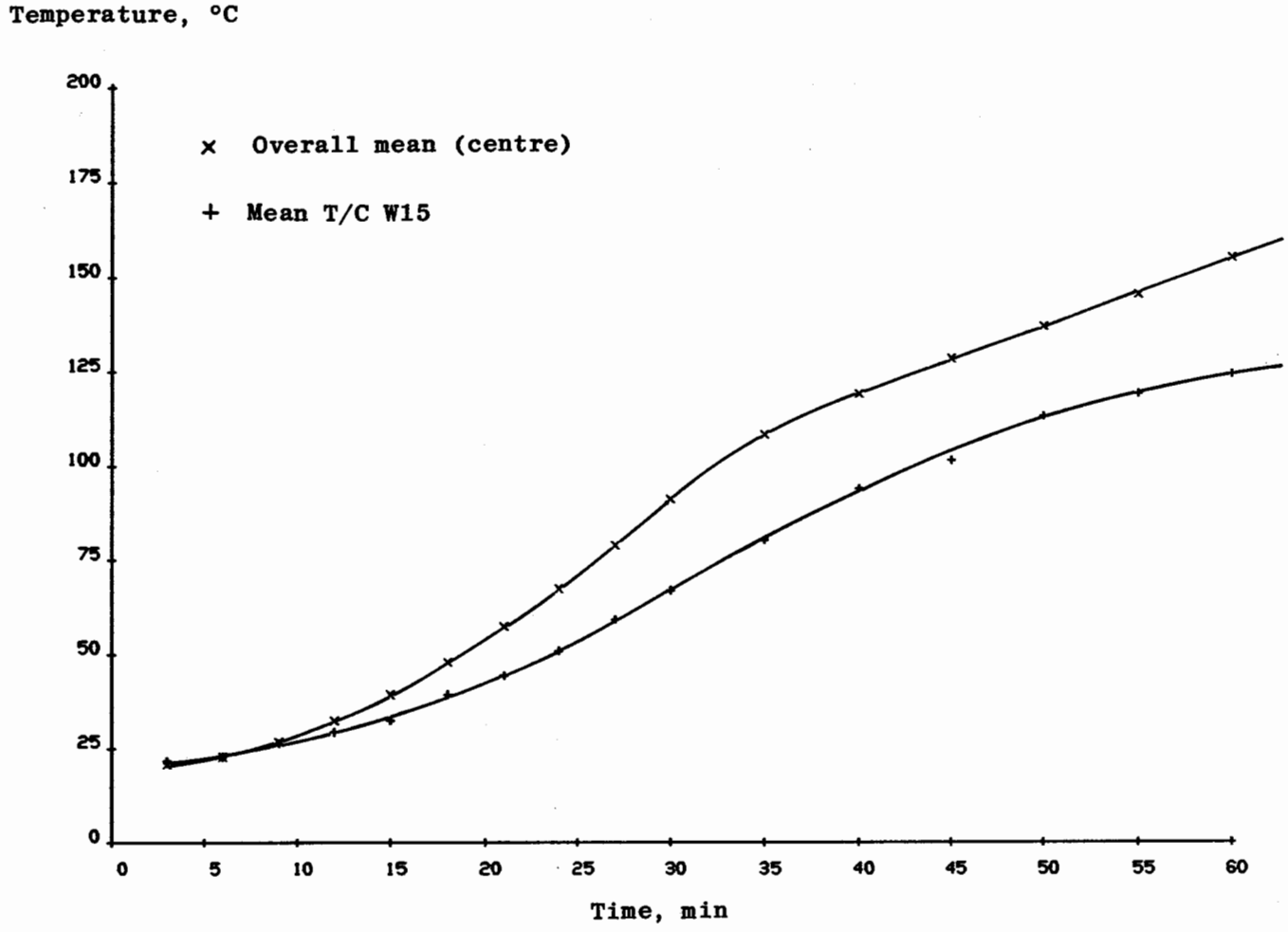


FIG. 8

MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE UPPER FLANGE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)



MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE UNEXPOSED WEB OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

FIG. 9

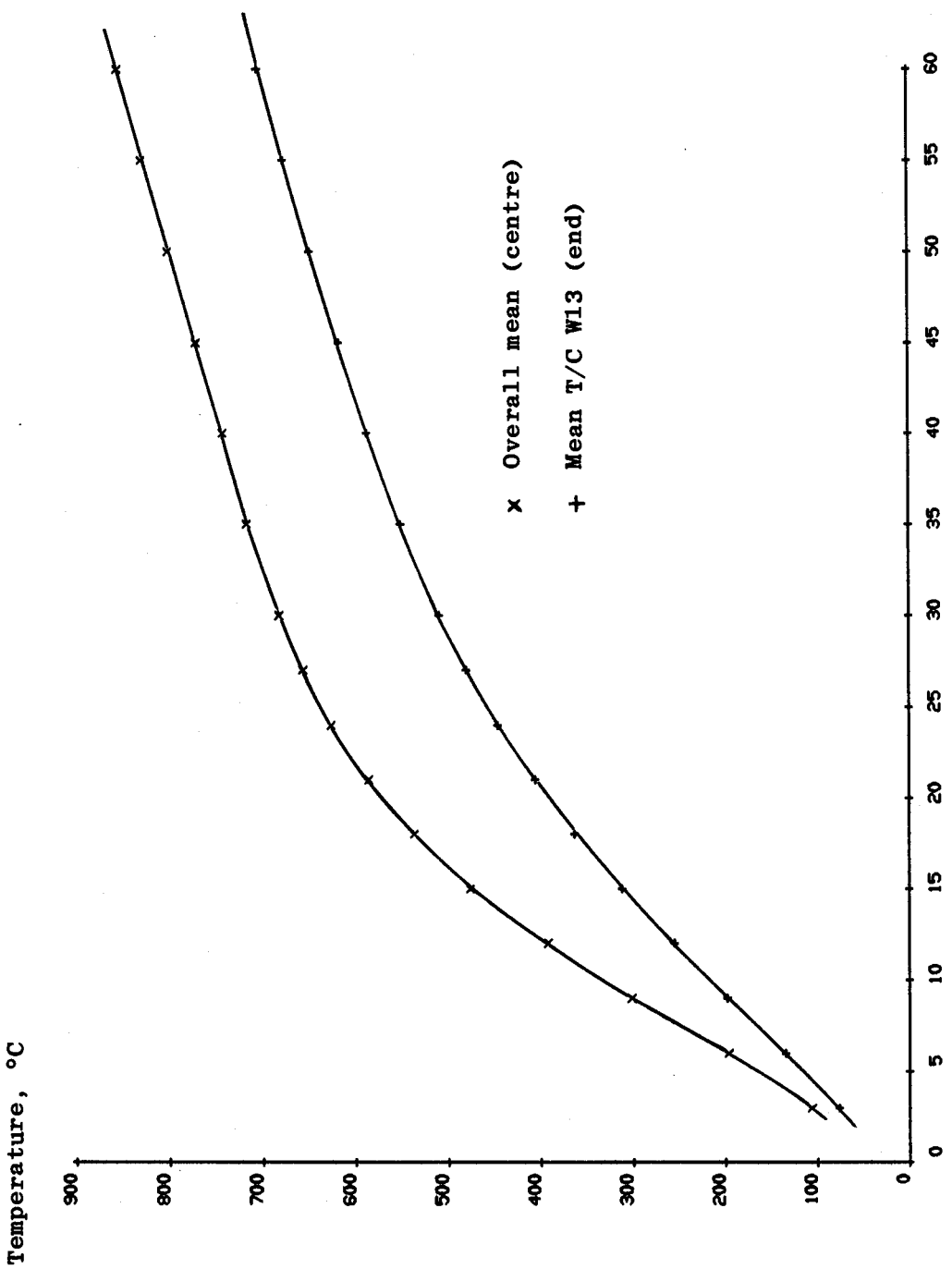


FIG. 10

MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE EXPOSED WEB OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

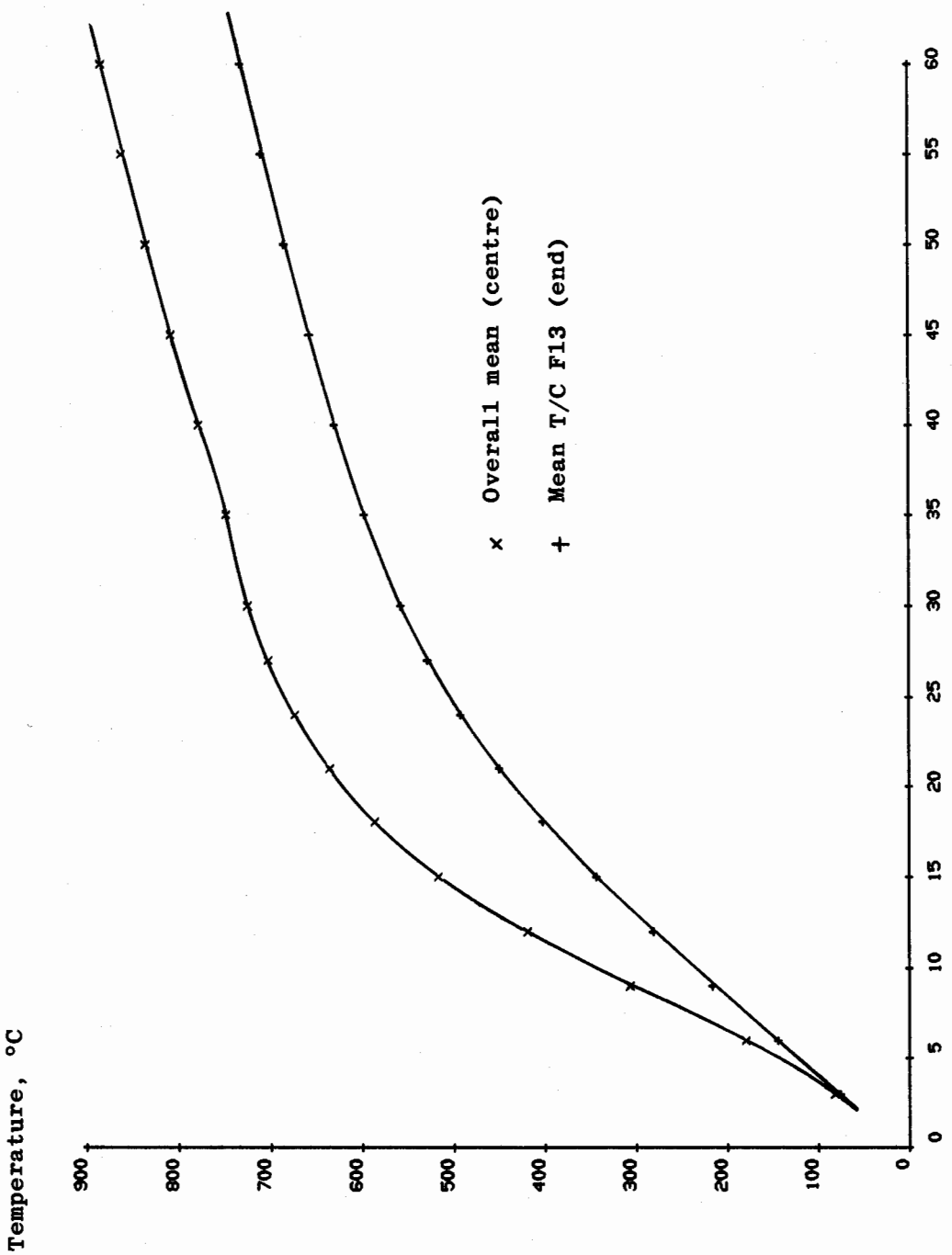


FIG. 11

MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE LOWER FLANGE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

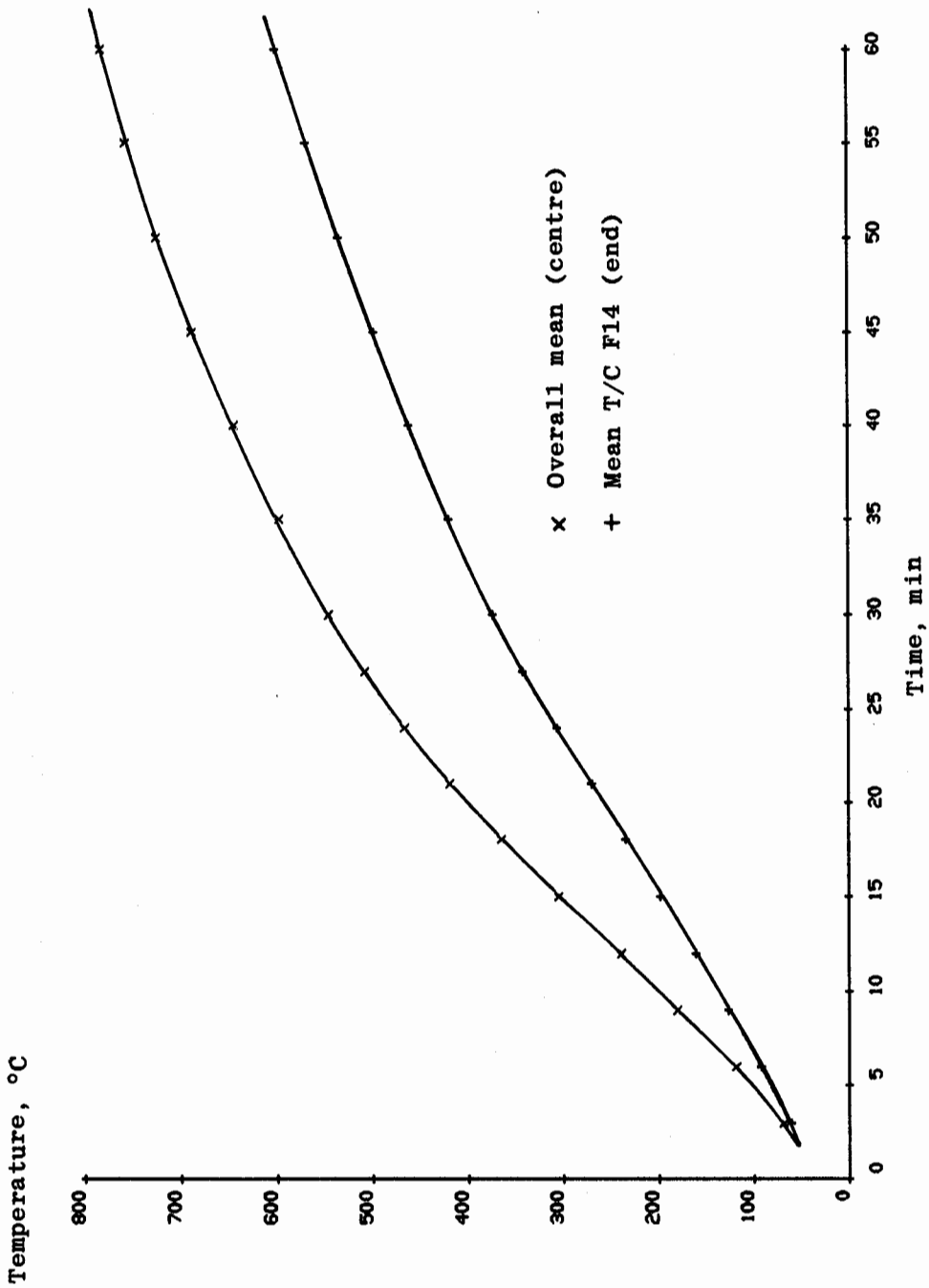


FIG. 12

MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE EXPOSED FLANGE ANGLE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

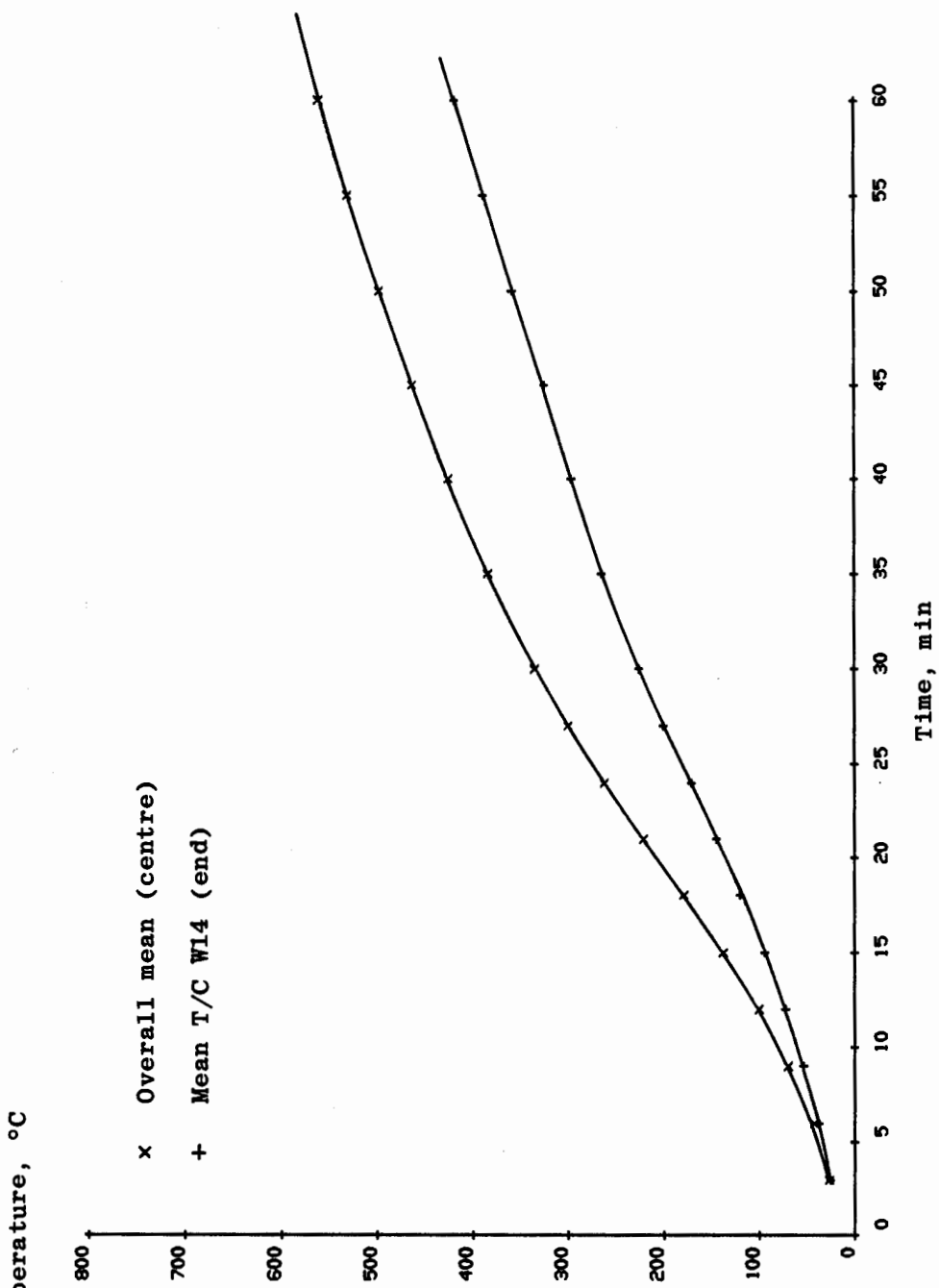


FIG. 13

MEAN TEMPERATURE DATA AT THE 'CENTRE' AND 'END' OF THE UNEXPOSED FLANGE ANGLE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

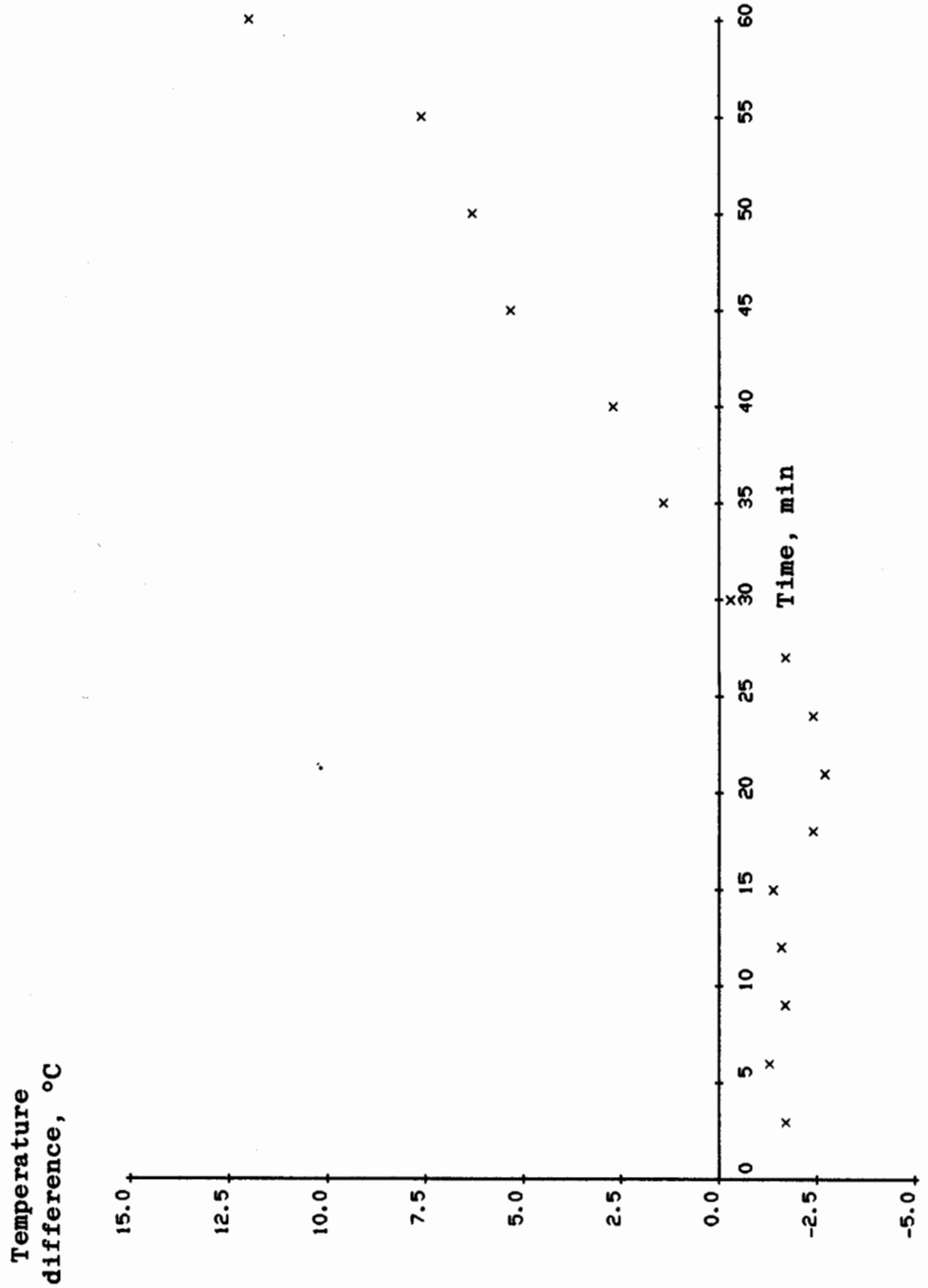
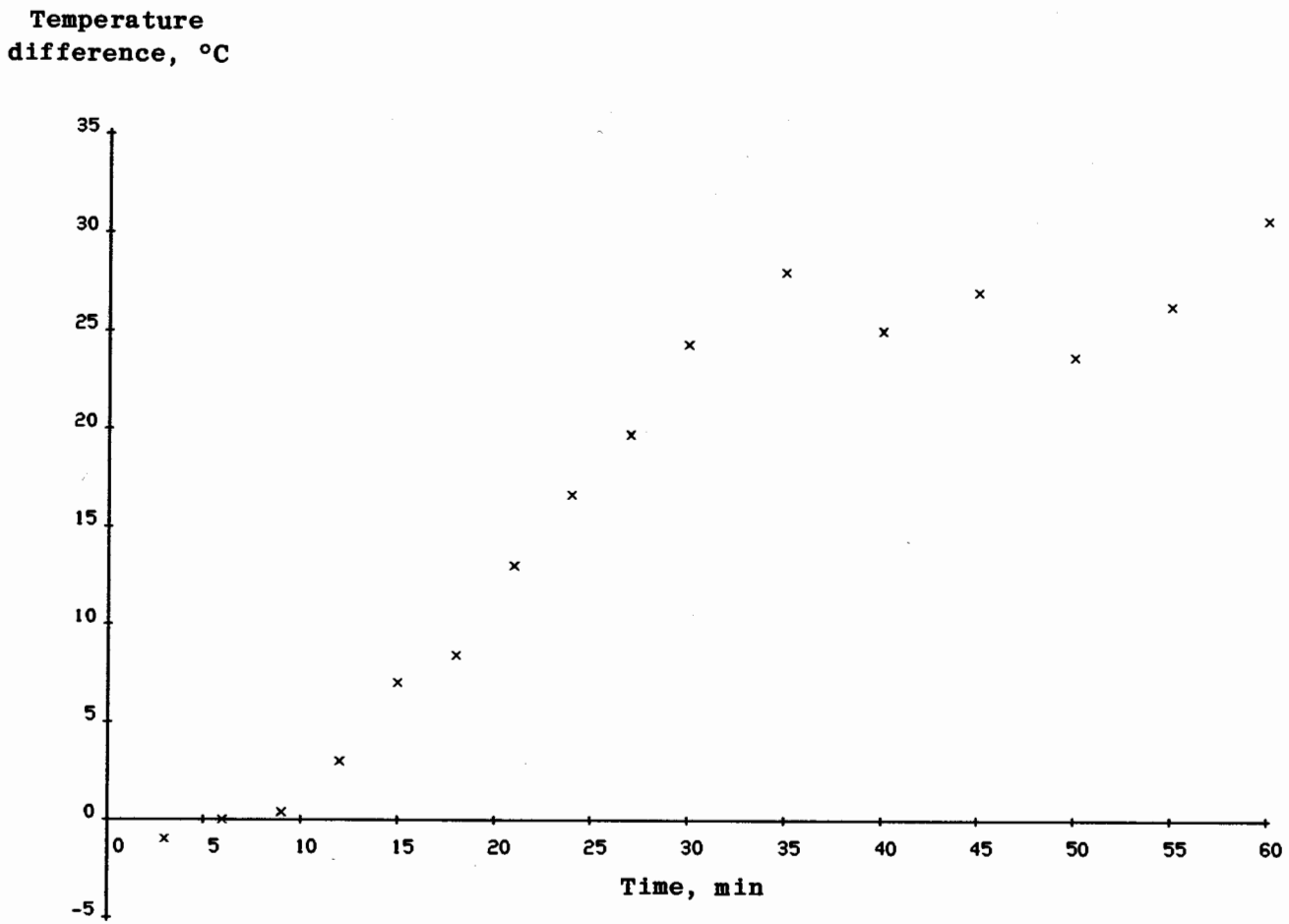


FIG. 14

DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA
FOR THE UPPER FLANGE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS
(FLOOR THICKNESS = 200 mm)



DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA FOR THE UNEXPOSED WEB OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

FIG. 15

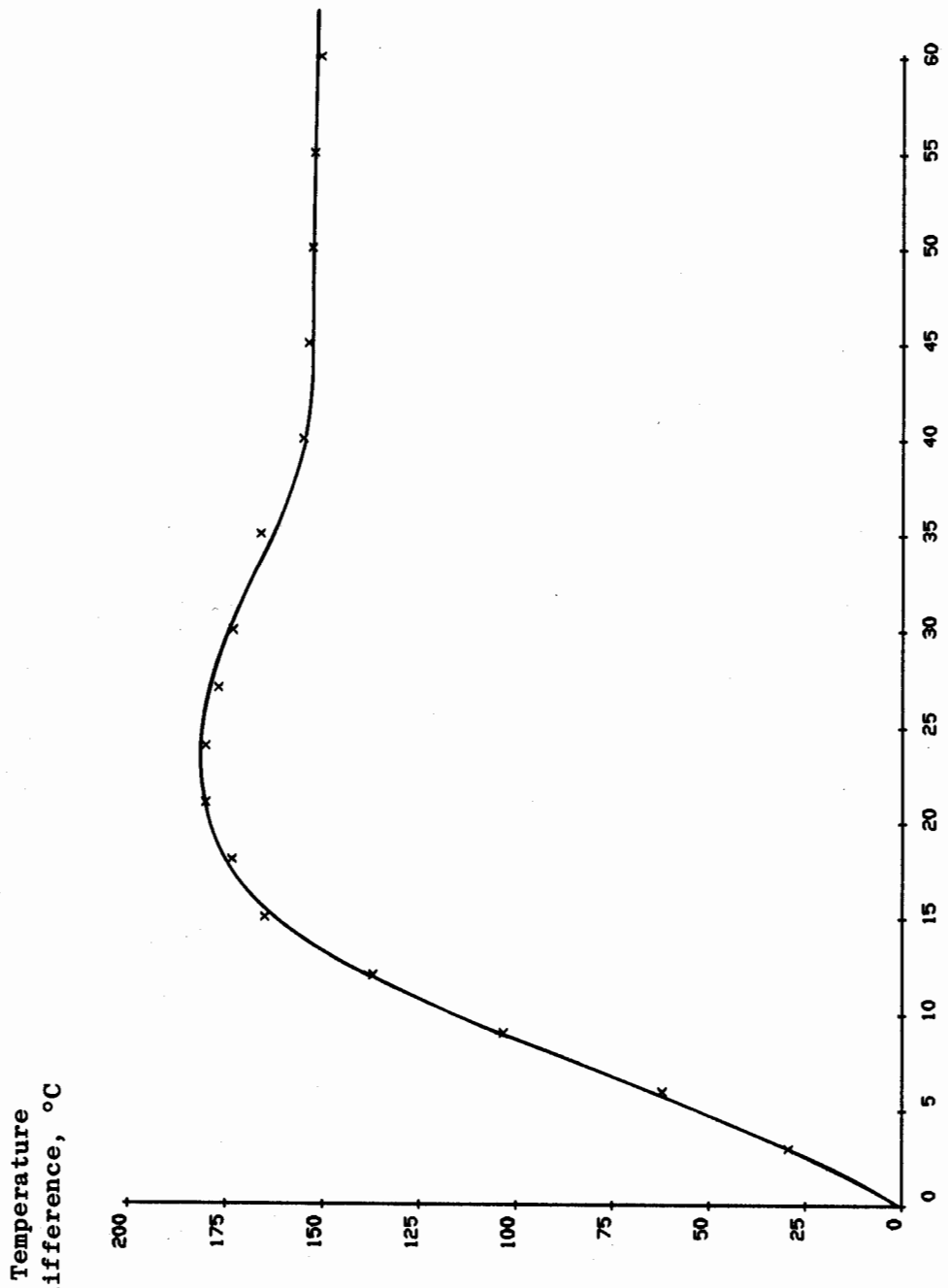


FIG. 16

DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA FOR THE EXPOSED WEB OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

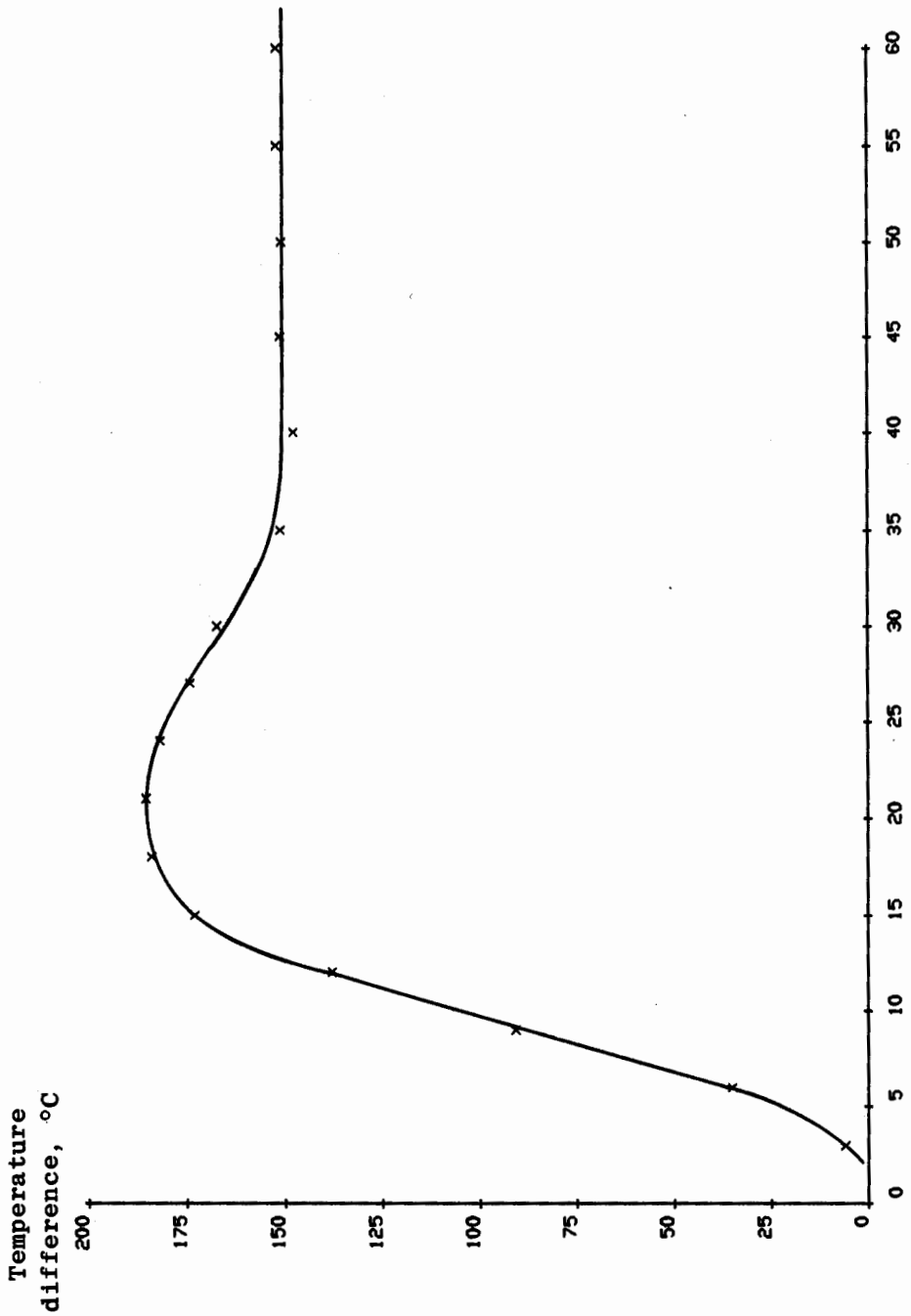
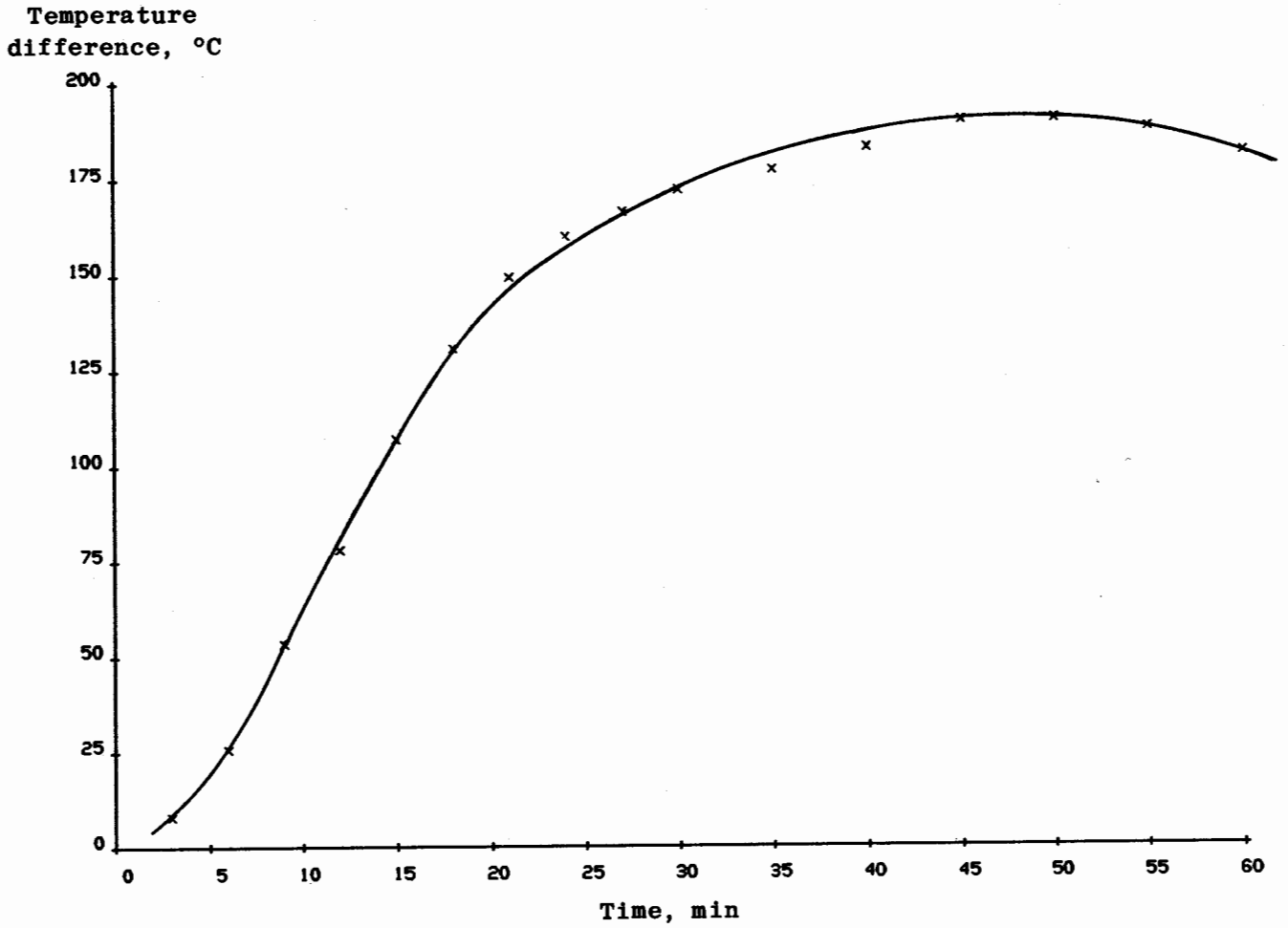


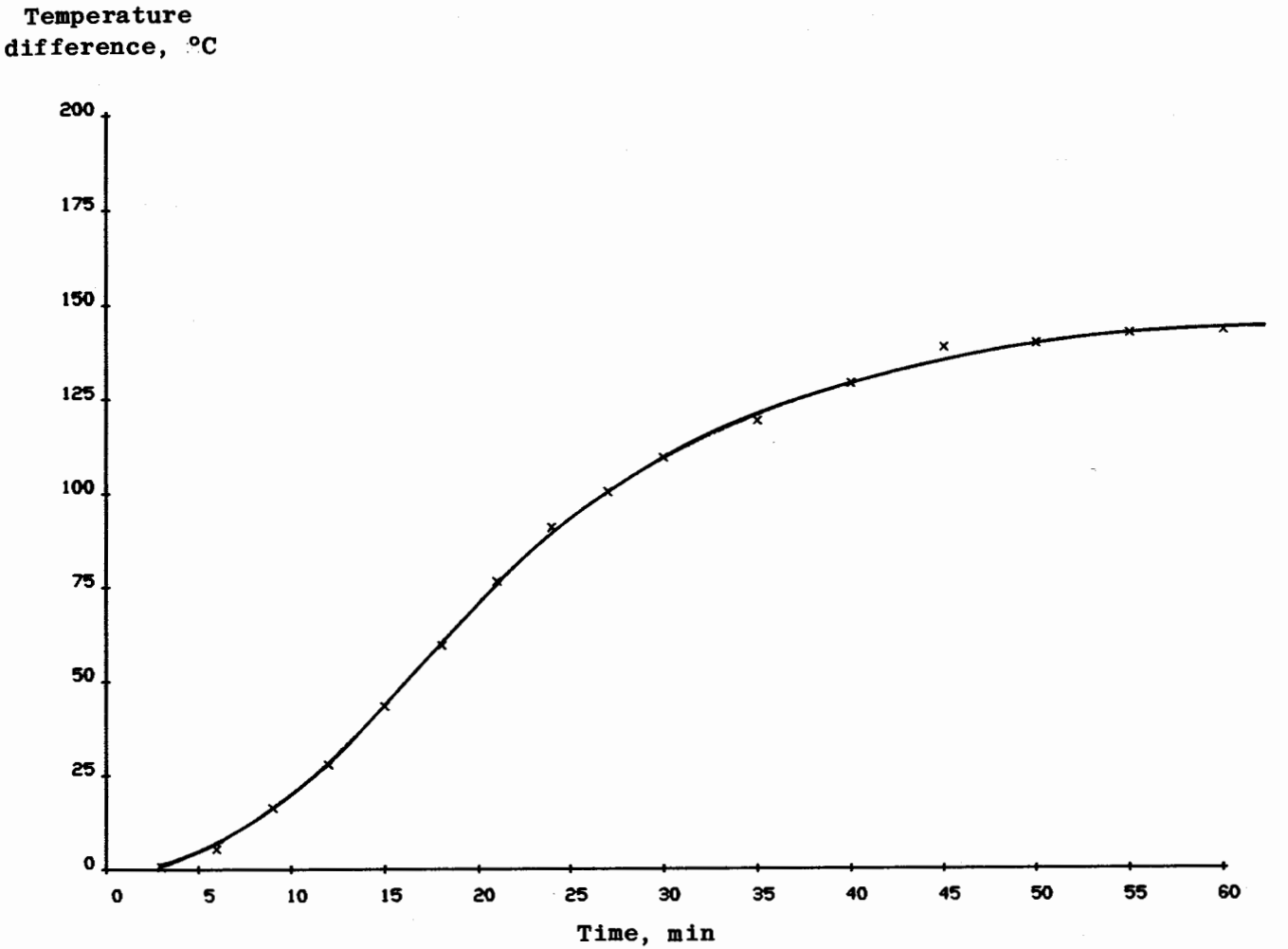
FIG. 17

DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA FOR THE LOWER FLANGE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)



DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA FOR THE EXPOSED FLANGE ANGLE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

FIG. 18



DIFFERENCE BETWEEN 'CENTRE' AND 'END' MEAN TEMPERATURE DATA FOR THE UNEXPOSED FLANGE ANGLE OF 406 x 178 mm x 54 kg/m SHELF ANGLE FLOOR BEAMS (FLOOR THICKNESS = 200 mm)

FIG. 19

APPENDIX A BS476:PART 8:1972 FIRE RESISTANCE TESTS

	Test Configuration	Data Sheet No.
I	Simply supported floor beam	12-13
II	Floor beam with applied rotational end restraining moments	17-28
III	Floor beam with applied rotational and longitudinal thermal restraint	29-31
IV	Shelf angle floor beam	32-36

DATA SHEET NUMBER **12C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)									
	3	6	9	12	15	18	21	24	27	29
Mean Upper Flange Thermocouple F11	No Data Recorded									
Mean Web Thermocouple W5	185 38	325 71	436 99	507 124	550 148	571 166	600 184	632 204	659 226	680 242
Mean Lower Flange Thermocouple F10	118 51	234 81	340 102	427 104	490 156	539 183	586 220	626 255	659 291	681 313

DATA SHEET NUMBER **13C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)									
	3	6	9	12	15	18	21	24	26	27
Mean Upper Flange Thermocouple F11	No Data Recorded									
Mean Web Thermocouple W5	159 121	287 211	408 305	499 392	566 458	614 517	651 561	681 595	703 619	713 630
Mean Lower Flange Thermocouple F10	130 129	245 208	372 298	480 391	562 467	622 536	664 585	696 625	716 649	727 660

DATA SHEET NUMBER **17C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)														
	3	6	9	12	15	18	21	24	27	30	33	36	37½	39	41
Mean Upper Flange Thermocouple F11	No Data Recorded														
Mean Web Thermocouple W5	126	257	387	488	567	623	668	700	725	739	758	780	790	799	811
	108	200	299	386	456	511	558	597	632	661	684	706	717	727	735
Mean Lower Flange Thermocouple F10	113	228	353	465	559	624	674	708	732	746	767	791	800	810	823
	81	164	268	371	459	528	580	625	658	689	711	729	733	739	752

DATA SHEET NUMBER **18C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)															
	3	6	9	12	15	18	21	24	27	30	33	36	39	40	42	45
Mean Upper Flange Thermocouple F11	No Data Recorded															
Mean Web Thermocouple W5	96 100	207 170	344 265	449 348	522 415	583 469	614 518	646 558	674 593	697 624	719 665	735 676	748 700	755 707	767 720	787 735
Mean Lower Flange Thermocouple F10	98 75	196 142	321 233	432 325	516 400	588 466	624 520	658 565	687 603	711 635	729 653	742 689	759 711	765 718	779 728	799 739

DATA SHEET NUMBER **19C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																				
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	59	60
Mean Upper Flange	100	151	205	258	321	376	431	481	524	563	596	627	654	678	701	722	741	758	774	783	788
Thermocouple F11	64	87	122	163	204	243	280	318	356	393	430	463	495	525	556	583	610	636	661	679	688
Mean Web	131	248	359	449	529	585	627	660	686	710	731	748	763	782	801	817	830	845	858	867	872
Thermocouple W5	106	182	271	358	437	499	546	588	622	652	678	700	720	737	752	767	786	803	818	829	834
Mean Lower Flange	104	207	321	427	521	589	638	674	703	727	744	758	778	797	814	830	845	859	872	880	884
Thermocouple F10	95	152	236	329	417	489	546	593	632	664	691	712	732	746	759	777	795	812	827	837	842

DATA SHEET NUMBER **20C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																			
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
Mean Upper Flange Thermocouple F11	No Data Recorded																			
Mean Web Thermocouple W5	156 98	311 196	448 290	542 374	601 439	641 490	673 532	700 567	722 597	742 629	750 642	776 673	794 695	811 716	825 733	841 750	855 769	867 787	879 803	890 818
Mean Lower Flange Thermocouple F10	115 116	276 218	431 311	548 402	620 474	665 530	697 572	722 607	738 635	758 664	768 675	794 703	811 722	826 736	841 754	855 773	868 791	880 808	890 824	900 839

DATA SHEET NUMBER **21C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)															
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Mean Upper Flange Thermocouple F11	No Data Recorded															
Mean Web Thermocouple W5	165 127	313 216	445 302	552 384	618 448	663 499	696 541	722 578	741 612	762 640	783 667	804 691	820 712	838 731	854 748	872 770
Mean Lower Flange Thermocouple F10	127 83	278 175	431 279	557 384	636 469	686 534	719 582	739 618	760 649	785 676	804 699	823 721	840 735	858 753	871 772	887 794

DATA SHEET NUMBER **22C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)										
	3	6	9	12	15	18	21	24	27	30	33
Mean Upper Flange Thermocouple F11	No Data Recorded										
Mean Web Thermocouple W5	125 78	267 176	386 265	490 355	567 436	620 501	657 551	687 590	710 623	730 650	746 674
Mean Lower Flange Thermocouple F10	97 65	239 166	375 268	493 373	581 466	639 538	677 589	706 627	727 685	741 683	759 705

DATA SHEET NUMBER **23C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)								
	5	8	33	37	48	50	53		
Mean Upper Flange Thermocouple F11	No Data Recorded								
Mean Web Thermocouple W5	228 129	345 210	757 652	792 691	853 762	863 727	878 798		
Mean Lower Flange Thermocouple F10	170 109	292 185	776 670	813 707	875 778	885 794	899 814		

DATA SHEET NUMBER **24C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)													
	3	6	9	12	15	18	21	24	27	30	33	37	40	44
Mean Upper Flange Thermocouple F11	No Data Recorded													
Mean Web Thermocouple W5	114 63	262 147	394 243	506 312	591 394	644 459	686 516	718 567	738 607	756 642	781 672	815 705	835 726	858 746
Mean Lower Flange Thermocouple F10	74 116	225 212	380 293	512 357	611 444	668 509	708 566	731 614	751 648	778 679	802 704	831 726	854 744	874 772

DATA SHEET NUMBER **25C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)										
	3	6	9	12	15	18	21	24	27	30	32
Mean Upper Flange Thermocouple F11	73 39	108 61	161 84	213 115	266 144	320 176	372 211	421 254	468 303	517 359	551 400
Mean Web Thermocouple W5	152 81	237 135	337 194	428 253	500 307	561 360	609 410	645 455	677 498	704 539	721 566
Mean Lower Flange Thermocouple F10	129 60	221 124	329 193	432 265	515 334	583 400	633 459	671 509	702 552	727 590	741 613

DATA SHEET NUMBER **26C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																	
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	53
Mean Upper Flange	94	150	199	253	313	372	432	489	537	580	619	653	685	712	737	759	777	790
Thermocouple F11	44	76	100	130	159	189	224	261	299	338	376	413	450	486	521	555	584	600
Mean Web	120	234	336	429	509	571	624	668	703	730	750	773	796	817	835	851	864	873
Thermocouple W5	64	127	183	242	304	361	418	471	517	556	590	623	653	679	703	724	740	750
Mean Lower Flange	98	219	333	446	538	606	661	702	733	755	778	802	823	841	858	873	884	892
Thermocouple F10	52	116	187	261	334	398	460	513	558	597	630	662	689	714	735	751	772	785

DATA SHEET NUMBER **27C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																	
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	55
Mean Upper Flange	64	105	153	203	265	330	391	446	497	545	588	625	656	689	708	730	751	771
Thermocouple F11	51	79	111	145	179	214	247	284	321	359	397	436	471	515	542	573	602	636
Mean Web	115	208	315	412	502	570	616	651	679	710	737	755	778	799	817	833	849	868
Thermocouple W5	63	111	166	219	277	333	384	431	473	515	555	591	622	657	677	700	720	745
Mean Lower Flange	93	186	301	412	514	590	641	677	704	731	751	776	800	820	836	852	868	886
Thermocouple F10	61	120	194	266	341	412	470	519	559	597	633	665	692	720	735	751	768	791

DATA SHEET NUMBER **28C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)													
	3	6	9	12	15	18	21	24	27	30	33	36	39	41
Mean Upper Flange Thermocouple F11	57 39	101 64	152 86	205 114	263 148	319 184	369 215	408 250	456 281	507 318	555 357	598 393	635 427	659 450
Mean Web Thermocouple W5	124 87	239 150	358 209	459 268	544 333	599 396	638 442	669 487	695 524	729 566	743 604	767 638	796 667	815 684
Mean Lower Flange Thermocouple F10	102 161	211 243	330 291	443 341	538 416	605 490	649 541	682 590	710 628	734 671	753 707	782 736	804 753	814 766

DATA SHEET NUMBER **29C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																		
	5	8	10	12	15	18	21	24	27	30	33	36	39	42	45	46	49	52	55
Mean Upper Flange	65	112	153	197	246	306	368	422	470	512	549	582	611	639	664	671	692	712	730
Thermocouple F11	44	69	86	104	124	176	217	256	293	326	363	396	429	462	495	506	538	577	616
Mean Web	150	258	349	445	520	579	626	662	690	713	729	739	754	774	795	801	819	837	854
Thermocouple W5	104	172	226	282	356	416	475	526	566	601	630	655	677	696	713	718	731	743	763
Mean Lower Flange	134	241	338	446	521	587	642	680	709	730	743	760	780	799	818	824	842	859	873
Thermocouple F10	89	158	218	282	368	434	500	556	600	635	664	683	710	727	736	738	755	773	793

DATA SHEET NUMBER **30C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)															
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Mean Upper Flange	50	96	151	206	265	323	380	433	485	531	567	604	642	672	700	723
Thermocouple F11	47	75	108	141	174	210	247	288	334	382	430	478	522	553	580	607
Mean Web	130	245	369	471	553	608	651	685	717	733	749	764	784	811	836	855
Thermocouple W5	88	163	242	320	392	452	503	550	592	620	649	677	707	726	737	753
Mean Lower Flange	92	203	329	448	544	611	662	698	728	748	768	789	811	836	857	873
Thermocouple F10	98	200	273	347	417	477	527	571	611	641	672	696	720	737	753	771

DATA SHEET NUMBER **31C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)														
	2	6	9	12	15	18	21	24	27	30	33	36	39	42	44
Mean Upper Flange	81	119	169	219	275	331	386	437	477	514	552	590	628	661	685
Thermocouple F11	53	75	105	136	167	198	236	279	316	353	389	424	460	493	522
Mean Web	199	294	395	483	551	601	642	681	710	729	742	758	783	806	825
Thermocouple W5	132	189	256	323	386	439	489	540	582	617	647	674	700	719	734
Mean Lower Flange	154	260	368	466	548	606	653	693	724	738	757	777	801	823	841
Thermocouple F10	89	166	234	306	377	437	493	545	589	626	658	686	710	727	737

DATA SHEET NUMBER **32C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																	
	3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	67½
Mean Upper Flange	24	24	24	25	28	26	27	28	30	32	36	42	49	58	68	78	89	94
Thermocouple F15	26	26	27	28	30	32	35	38	40	44	49	55	61	68	75	83	93	98
Mean Unexposed Web	25	27	30	36	44	52	62	73	85	97	110	114	118	124	131	140	151	158
Thermocouple W15	27	28	31	35	40	47	54	62	70	79	95	111	125	139	152	163	174	179
Mean Exposed Web	129	224	327	416	493	550	593	631	660	685	720	746	777	806	834	858	879	889
Thermocouple W13	81	138	199	255	310	359	398	436	467	496	537	573	608	640	670	699	726	737
Mean Lower Flange	88	189	314	429	522	591	639	677	705	728	752	781	812	839	865	887	908	915
Thermocouple F13	57	108	173	240	303	360	407	449	485	515	557	593	625	654	680	706	726	736
Mean Exposed Flange Angle	93	149	208	264	330	387	437	485	525	562	613	655	697	728	758	784	810	824
Thermocouple F14	74	109	143	180	220	255	290	326	359	389	435	475	515	551	584	616	648	662
Mean Unexposed Flange Angle	32	48	74	106	144	184	226	266	304	338	386	429	469	505	538	569	598	611
Thermocouple W14	31	43	60	81	107	135	164	192	220	247	289	326	362	396	427	456	484	498

DATA SHEET NUMBER **33C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																				
	3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	70	75	80	83
Mean Upper Flange	9	9	11	11	12	11	12	15	14	16	23	29	37	40	52	57	68	78	83	88	92
Thermocouple F15	12	12	14	14	14	13	13	16	14	15	20	22	25	25	32	33	45	49	58	66	92
Mean Unexposed Web	12	12	15	19	23	26	33	43	51	60	78	90	99	102	110	110	121	130	136	142	146
Thermocouple W15	12	13	16	17	20	21	25	31	33	39	50	60	70	77	91	96	112	111	115	118	142
Mean Exposed Web	60	124	186	238	286	349	408	458	493	525	571	610	644	672	708	735	770	802	827	851	864
Thermocouple W13	42	80	122	155	185	222	258	292	318	344	387	424	461	494	532	560	599	626	657	683	721
Mean Lower Flange	76	176	273	348	413	500	567	611	639	664	697	724	746	770	803	826	855	878	896	913	924
Thermocouple F13	56	119	186	237	282	335	386	430	460	487	524	558	592	621	655	679	715	735	760	787	823
Mean Exposed Flange Angle	44	88	133	165	191	245	308	355	402	448	518	575	625	665	708	737	771	806	834	863	878
Thermocouple F14	49	82	113	137	162	193	226	265	292	321	367	410	451	488	529	559	602	634	670	700	739
Mean Unexposed Flange Angle	14	27	46	68	92	120	156	195	225	254	300	342	381	413	451	482	518	551	577	603	617
Thermocouple W14	15	22	36	49	63	78	96	118	137	158	195	228	260	286	319	342	376	401	430	457	494

DATA SHEET NUMBER **34C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																			
	3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	70	80	90	94
Mean Upper Flange	19	20	22	22	20	24	21	22	27	29	34	39	41	53	61	79	88	102	103	103
Thermocouple F15	20	21	23	23	21	25	22	23	29	31	36	41	39	52	61	70	84	94	100	101
Mean Unexposed Web	19	21	26	31	37	45	53	62	72	84	104	118	131	141	150	160	181	206	232	243
Thermocouple W15	20	21	26	28	28	37	39	44	55	62	74	88	88	101	103	105	115	113	155	164
Mean Exposed Web	80	169	272	372	453	512	567	615	651	681	719	745	775	806	834	859	899	934	964	974
Thermocouple W13	70	130	196	258	311	363	405	449	490	523	567	605	628	661	688	714	757	805	847	860
Mean Lower Flange	67	160	283	402	494	562	614	660	696	722	749	782	813	840	865	886	922	955	976	992
Thermocouple F13	96	183	256	318	368	421	464	507	549	580	619	653	673	700	724	745	791	833	873	883
Mean Exposed Flange Angle	47	86	147	208	264	322	379	439	490	532	592	641	685	723	756	781	842	894	933	945
Thermocouple F14	47	77	110	145	176	213	246	283	325	359	408	452	485	525	561	592	654	707	756	770
Mean Unexposed Flange Angle	22	39	68	92	127	167	206	246	284	320	370	412	450	486	521	553	609	658	701	716
Thermocouple W14	23	35	51	69	87	111	130	155	186	211	249	280	301	341	372	403	461	515	563	581

DATA SHEET NUMBER **35C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)								
	3	6	9	12	15	18	21	24	29
Mean Upper Flange	22	23	24	28	34	44	55	70	97
Thermocouple F15	23	23	24	26	29	34	40	47	65
Mean Unexposed Web	23	28	39	52	69	89	109	130	167
Thermocouple W15	23	26	31	39	48	60	73	88	116
Mean Exposed Web	88	236	347	475	555	605	645	676	715
Thermocouple W13	76	167	225	327	406	465	514	553	602
Mean Lower Flange	83	227	347	486	576	631	673	703	733
Thermocouple F13	53	144	189	313	397	462	516	559	608
Mean Exposed Flange Angle	81	161	218	294	358	416	465	509	571
Thermocouple F14	57	112	135	196	243	288	334	376	435
Mean Unexposed Flange Angle	27	47	77	120	168	216	261	304	368
Thermocouple W14	26	38	54	77	108	141	175	209	265

DATA SHEET NUMBER **36C**

THERMOCOUPLE LOCATION	TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																	
	3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	70
Mean Upper Flange	17	18	18	18	19	20	22	26	30	37	46	53	60	66	73	80	86	94
Thermocouple F15	19	19	19	19	20	20	21	22	23	24	27	30	34	38	43	48	54	60
Mean Unexposed Web	18	20	24	30	37	46	57	67	79	92	110	124	136	145	155	165	176	191
Thermocouple W15	18	19	22	25	29	34	40	46	52	59	71	82	91	99	102	105	110	118
Mean Exposed Web	110	197	304	386	481	547	596	630	657	679	710	733	758	790	819	847	869	890
Thermocouple W13	80	136	198	250	312	367	413	451	481	507	547	581	613	643	672	699	723	745
Mean Lower Flange	91	190	323	426	534	605	652	684	705	723	741	769	798	825	853	877	896	914
Thermocouple F13	75	143	219	285	360	425	478	520	550	576	613	643	672	698	723	743	769	798
Mean Exposed Flange Angle	67	120	185	244	319	385	440	474	508	541	586	636	680	723	756	782	811	839
Thermocouple F14	62	92	127	157	196	234	272	309	340	371	416	456	492	527	561	594	624	655
Mean Unexposed Flange Angle	25	41	67	101	141	185	229	272	310	344	393	433	468	500	531	560	588	613
Thermocouple W14	23	34	49	66	88	112	138	165	192	217	255	282	309	336	365	395	426	457