FROM: OMNIFAX

[redacted]

TEST PLAN NO. 72-52

[redacted]

MODEL 4HOP PACKAGE TYPE B(U) TRANSPORT TEST (TP72-52)

PRODUCT MODEL: 4HOP

ORIGINATOR: MICHAEL TREMBLAY DATE: 2/[illegible]/99

[redacted]

ENGINEERING APPROVAL: DATE:

QUALITY ASSURANCE APPROVAL: DATE:

MANAGEMENT APPROVAL: DATE:

COMMENTS: SEE COVER SHEET of TP72-52 for approval signatures 2nd 16/FEB/99

[redacted]

TECHNICAL APPROVAL: [signature] DATE: 15 FEB 99

QUALITY ASSURANCE APPROVAL: [signature] DATE: 16 Feb 99

MANAGEMENT APPROVAL: Catherine [signature] DATE: 16 Feb 99

[redacted]

TOTAL P.03

TEST PLAN 72-S2 REPORT

MODEL 680-OP

15FEB99

Prepared By: _____ Date: _____

Reviewed By: _____ Date: _____

Approved By: _____ Date: _____

AEA Technology QSA, Inc.
Burlington, MA

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1.0 PURPOSE

This report describes the results of Model 680-OP tests which were performed in accordance with Test Plan 72, Supplement 2. The tests were conducted from 26JAN99 though 30JAN99. The Test Plan specified testing necessary to satisfy the requirements in 10 CFR Part 71 and IAEA Safety Series No.6 for "Hypothetical Accident Conditions", specifically 10CFR 71.73(c)(4) - Thermal Test Requirements. Evaluation of the compliance of the Model 680-OP with these requirements is provided in the Safety Analysis Report.

2.0 SCOPE OF TESTING

The scope of testing in Test Plan 72-S2 includes the following:

1. Hypothetical Accident Tests per 10 CFR 71.73.

   a) Thermal test in accordance with 10 CFR71.73(c)(4) for the projector alone in worst case orientation (tilted 60° up from horizontal).

   b) Thermal test in accordance with 10 CFR71.73(c)(4) with the projector within an open overpack with the cover removed. (This test allows for an assessment of the impact on projector temperatures of the combustion of the overpack contents.)

For all tests, sufficient margin was included in test parameters to account for measurement uncertainty. These test parameters included weight and temperature[1].

[1] ANSI Standard MC96.1 specifies an allowable deviation of thermocouples and extension wire from the standard emf-temperature tables. For type "K" thermocouples, the tolerance is required to be the greater of ±2.2°C or ±2% for -200 to 0°C or ±2.2°C or ±0.75°C for 0 to 1250°C. Given these tolerances and assuming a tolerance of ±0.1% for typical instrumentation, the total system uncertainty is shown below. Installation errors are not included. The total system uncertainty is the square root of the sum of the squares of each component.

Temperature	Thermocouple Tolerance	Extension Wire Tolerance	Instrument Accuracy	Total Uncertainty
800°C	±6°C	±6°C	±0.8°C	±8.5°C
-100°C	±2.2°C	±2.2°C	±0.1°C	±3.1°C

3.0 FAILURE MODES

For the Model 680-OP, the key function important to safety is the positive retention of the radioactive source in its stored position within the undamaged depleted uranium shield. Excessive displacement of either the source or the shield from the design position or destruction of the shield could cause radiation from the package to increase above regulatory limits. Mechanisms which could cause this mode of failure include:

a) Excessive movement of the shield due to pyrolization of the Vultafoam, weakening of the leveling jig and shell, and deformation of the source tubes while the source is held in position by the locking mechanism.

b) Combustion of the shield due to damage to the projector shell permitting an excessive ingress of oxygen.

Consequently, the package orientations selected for the hypothetical accident thermal tests were intended to challenge the components that prevent these failures.

4.0 TEST UNIT DESCRIPTION

The units tested are shown in the following table. The Model 680-OP units were constructed in accordance with drawing 97013Rev C. The manufacturing route cards for the units document the compliance of these units with the AEA Technology QSA QA program (see TP72,Appendix B). As noted in the table, the test units had previously been subjected to hypothetical accident drop tests as part of Test Plan 72 and Supplement 1.

MODEL	PROJECTOR SERIAL NO.	DRAWINGS		OVERPACK SPECIMEN
		Projector	Overpack Assembly	
680-OP	B198 (NOTE 1.)	R68090 Rev. C	NA	NA
680-OP	B199 (NOTE 2.)	R68090 Rev. C	97013, Rev C	TP72-S1(C)

Notes:
1. Camera S/N B198 was used in Supplement 1 to Hypothetical Accident Test Plan 72. The camera was dropped in overpack test specimen TP72-S1(B).
2. Camera S/N B199 was used in Hypothetical Accident Test Plan 72. The camera was dropped in overpack test specimen TP72(D).

The 680 projector units were radiographed after the drop tests to document the position of the internal components prior to the thermal tests. Also, the position of the "dummy" source used in the projector was measured prior to thermal testing. Specimen B198 was chosen for thermal testing in the 60° orientation, considered worst case, as it had sustained the most damage in the drop tests.

5.0 SUMMARY AND CONCLUSIONS

Results of the tests are summarized in the table below in the sequence in which the tests were completed. Detailed results are provided in the following sections of this report.

As shown in Appendix E, the highest projector temperatures were seen on right of side of camera B198. Temperatures on this exposed camera were greater than 1000°C throughout the 30 minute test period. These temperatures bound those seen on the hottest surface on the camera contained in the overpack during the 30 minute test of 991°C.

Model	Specimen	Tests Done	Test Results
680-OP	Unit B198 Projector only	Set in oven at 60° from horizontal on jig. Total time in oven was 49 minutes.	- Foam pyrolized - Most lead melted. - Side shells and end plates bulged slightly - Posilock in place and undamaged - Shield moved ~ 1" downward. - Radiation levels acceptable.

680-OP	TP72-S1(C)
	Unit B199
	&
	overpack
		Set in over on feet with long side to elements. Cover removed. Total time in oven was 64 minutes.	- Projector
			  - Most foam pyrolized
			  - Most lead melted.
			  - Projector unaffected dimensionally.
			  - Posilock in place and undamaged
			  - Shield did not move.
			  - Radiation levels acceptable.
			- Overpack-
			  - Most wood burned to ashes
			  - Most foam combusted.
			  - Slight bow in box bottom.

The oven door was held open by insulating strips 1" thick on both sides, creating an opening of one inch at the top and bottom of the oven door (total 72 square inches). This opening created a "chimney effect" within the oven, drawing air in through the bottom and exhausting it out the top, as was evidenced by the flames emanating from the oven thought the tests. This natural convection of air into the furnace was sufficient to combust the pyrolization gases from the projectors and the bracing materials of the overpack.

6.0 THERMAL TEST – PROJECTOR AT 60° FROM HORIZONTAL

6.1 Orientation

The projector was placed in the oven orientated as shown in Figure 1. The unit was supported by a jig constructed of ¾" diameter steel rod, which held the unit in position, but afforded minimal insulation from direct radiation. This orientation was selected based on an assessment of which orientation had the potential to result in the largest relative motion between the shield and the source. (Note that as shown in Figure 1, the top 1 inch of the right side plate was cut off prior to the test. This was done to allow the camera to fit in the test oven and has no impact on the test results.)

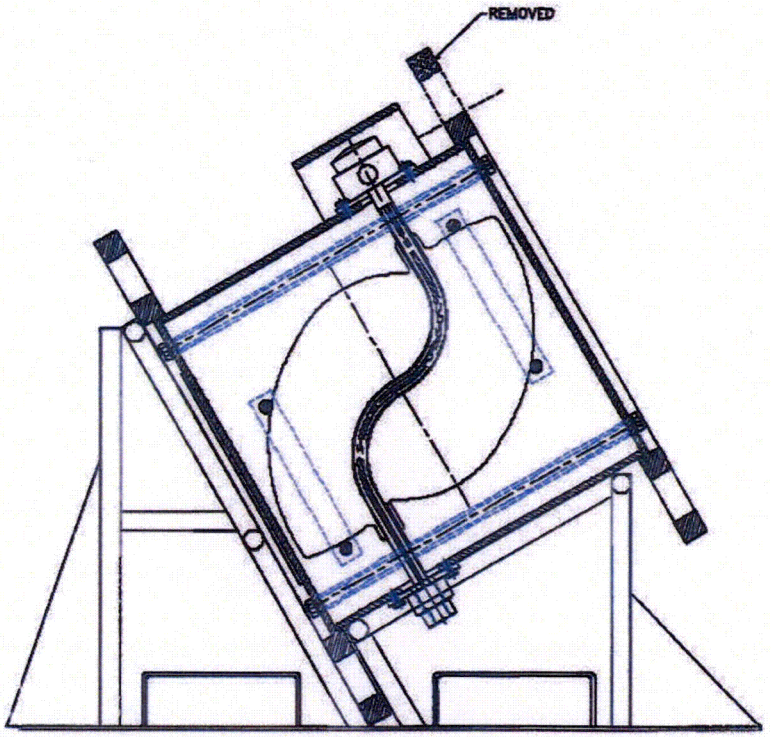


FIGURE 1. SPECIMEN TP72-S1(B) (SN#B198)

6.2 Thermocouples and Temperatures

Thermocouples were placed on the unit as shown in Figure 2. An additional thermocouple was placed within the oven chamber approximately 8 inches away from the left side of the unit. Readings form this thermocouple were used as the actual oven temperature. The temperature read from the oven controller was recorded at various intervals, but used only as an indication of when the oven coils were powered and not as the documented environmental temperature.

Temperatures were recorded from insertion, through burn out, until the unit was moved to temporary storage (Total of 826 minutes). Graphical representation of the data can be found in Appendix E.

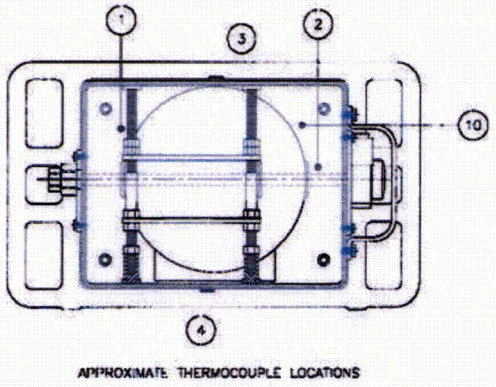


FIGURE 2. THERMOCOUPLE LOCATIONS

The unit was in the oven for 18 minutes before the test time began. It was removed after 49 minutes (total). Initial and final temperatures during the 30 minute test period were as follows. (All temperatures are in °C)

Thermocouple	Initial	Final
3 – Left	800	881
4 – Right	1004	1005
5 – Bottom	804	912
6 – Rear	991	951
7 – Top	912	945
8 – Front	862	924
9 – Source tube	617	924
Oven Ambient	951	800

The temperature of the left side (thermocouple 3) was 800°C when the test time was started, 10° below the stated temperature in the test plan. This side took approximately one (1) minute to reach 810°C. However, the time weighted average of the thermal input to this side far exceeded that required by the regulations, as evidenced by the final temperature. Consistent with the Test Plan, the test time was started when all the shell temperatures (thermocouples # 3,4,5,7) were at 800°C.

Upon removal from the oven, the gas escaping from the unit continued to burn for about 2 hours. Immediately on removal, two (2) white jets of flame were emanating from the small seam between the side plate and shell on the left side of the projector. These jets died down and extinguished in three (3) to four (4) minutes. The unit was left to self-extinguish. This took an additional time of approximately 125 minutes.

6.3Damage Assessment

The initial on site external assessment showed:

a) Most paint vaporized. Radiation labels legible.
b) Lead dripping out of bottom of unit.
c) Outward bow of upper side plate, and the right and lift sides of the shell. This resulted in small 3-4" long by 1/16" wide gaps to form on both sides, at the intersection of the upper side plate and shell.
d) Shipping cover and Posilock in place and undamaged. Plunger lock melted.

After radiographs of the unit were examined, it was determined that:

a) The shield had shifted downward a small amount. The ears of the shield were jammed against the lower side frame and leveling jigs.
b) Lead dispersed in the carbon char matrix obscured views of the source tube on the front end.
c) Measurement of the source through the front source tube connection was not feasible on site due to lead within the source tube and potential buckling of the tube.
d) Some of the lead sheet placed around the shield (to increase weight) remained .

It was not feasible to profile the unit on site within acceptable safety margins. It was therefore decided to remove the top side plate in order to 1) to accurately determine the position of the shield, 2) assess all internal damage and 3) secure the shield in position for shipment.

Upon removal of the top side plate it was noted that the carbon char matrix filled approximately 95% of the space the foam had occupied. Partially melted lead sheet was found near the top and sides of the shield. Some molten lead had percolated down to the lower corner and was dispersed throughout the matrix. The lower source tube and lower leveling jig could not be observed, even after removal of most of the carbon char. The lower rod of the upper jig had disengaged from the cleats due to bowing of the shell. However, both upper rods showed essentially no deformation. The carbon char was removed in sections and replaced with Vultafoam to ensure the shield would not move during shipment.

Upon receipt at Burlington, the front plate securing the shipping plug was removed. The source tube was found to be buckled and jammed against the boss inside the source tube connector.

The rear plate Posilock assembly was also removed. The dummy source was withdrawn from the source tube without much effort. The tope edge of the source tube was 1.063" below the plane of the outside of the shell and 0.212" off center. This translates to a shield movement of approximately 1".

6.4 Profile Results

The unit was profiled with a 83 Ci Co60 source dimensionally identical to the dummy source used in the thermal test (see Appendix B). The source was inserted into the projector and locked into position with the Posilock. This simulated the position of the dummy source in the test. The unit was then profiled. The highest readings, found only in one very small area, were 250 mR/hr at one (1) meter at approximately a 60° angle away and 45° down from the Posilock. When scaled to the maximum capacity of the unit (110 Ci Co60) this translates to a reading of approximately 330 mR/hr at one (1) meter. This is 33% of the regulatory requirement of 1000 mR/hr at one (1) meter for a factor of safety of 3.

7.0 THERMAL TEST – PROJECTOR IN OVERPACK

7.1 Orientation

The projector was placed in the oven orientated as shown in Figure 3. The overpack was placed length-wise with the short sides toward the back and front of the oven. Information from this orientation is being used to quantify the effects of the combustion of the overpack on the projector temperatures. These results will be used in conjunction with the test of the worst case camera orientation discussed in Section 6.0 to assess the potential combination of a projector in an overpack placed in the worst case orientation.

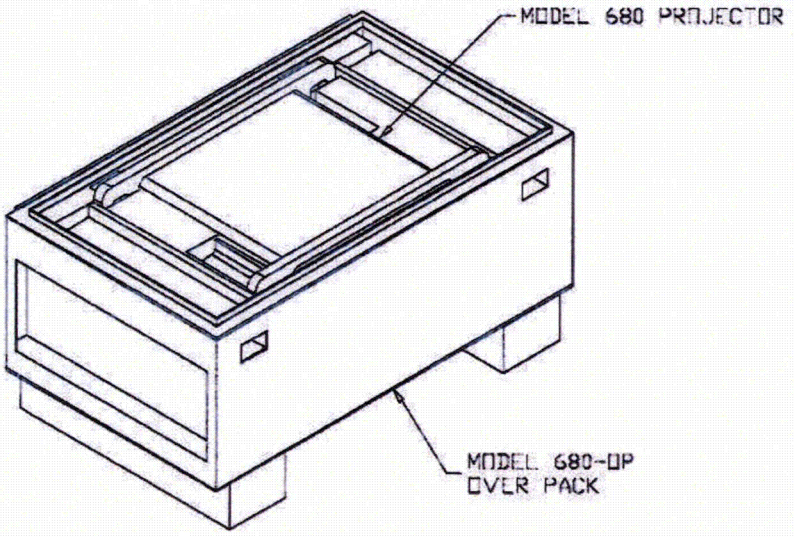


FIGURE 3. SPECIMEN TP72-S1(C) (SN#B199)

7.2 Thermocouples and Temperatures

Thermocouples were placed on the unit as shown in Figure 4. An additional thermocouple was placed within the oven chamber approximately 8 inches away from the left side of the unit. Readings form this thermocouple were used as the actual oven temperature. The temperature read from the oven controller was recorded at various intervals, but used only as an indication of when the oven coils were powered and not as the documented environmental temperature.

Temperatures were recorded from insertion, through burn out, until the unit was moved to temporary storage (Total of 375 minutes). Graphical representation of the data can be found in Appendix E.

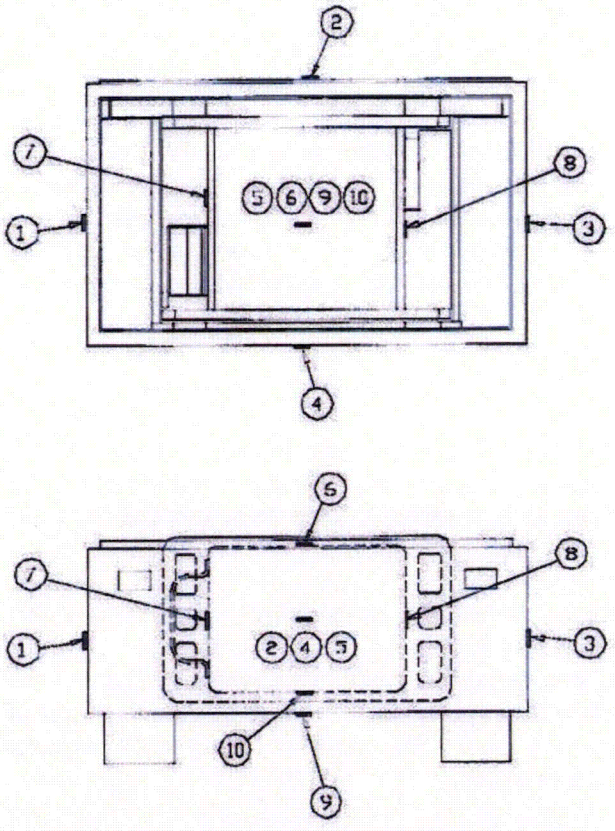


FIGURE 4. THERMOCOUPLE LOCATIONS

The unit was in the oven for 34 minutes before the test time began. It was removed after 64 minutes (total). Initial and final temperatures during the 30 minute test period were as follows.: (All temperatures are in °C)

Thermocouple	Initial	Final
1 – Box Rear	1022	974
2 – Box Right	951	920
3 – Box Front	827	840
4 – Box Left	955	926
5 – Source Tube	1004	979
6 – Projector Top	975	959
7 – Projector Rear	991	972
8 – Projector Front	981	964
9 – Box Bottom	800	816
10 – Projector Bottom	990	967
11 – Projector Left	977	960
12 – Oven Ambient	953	919

The temperature of the Box Bottom (thermocouple 9) was 800°C when the test time was started, 10° below the stated temperature in the test plan. The time weighted average of the thermal input to this side did exceeded that required by the regulations, as evidenced by the final temperature and the area under the graph. Consistent with the Test Plan, the test time was started when all the external surface temperatures (thermocouples # 1,2,3,4,6,9) were at 800°C.

As shown in Appendix E, the temperatures on the bottom and front of the overpack took about 30 minutes to reach 800°C. The slow response of these temperatures is believed to be a result of the air flow patterns within the furnace. In particular, with the furnace door open at the top and bottom, a natural draft was setup which resulted in ambient air entering the bottom of the furnace. This air flow served to keep the bottom and front surfaces of the overpack cooler than the rest of the package.

Upon removal from the oven, the packing materials within the overpack continued to burn. After a short time, the flame was limited to the top of the projector, burning only escaping gases from the foam and smoldering wood within the overpack. The unit was left to self-extinguish. This took approximately 245 additional minutes. During most of this time the flame consisted of a very cool, small diffusion fire on the top of the projector and smoldering char within the overpack.

7.3 Damage Assessment

The initial on site external assessment showed:

a) Some of the paint remained on the labels, especially on the sides of the projector. Radiation labels legible.
b) No lead noticeable at bottom of overpack or any where external to the projector.
c) Projector dimensionally unchanged. No noticeable bulging or sagging.
d) Shipping cover and Posilock in place and undamaged. Plunger lock slightly melted.

After radiographs of the unit were examined, it was determined that:

a) The shield had not moved.
b) Measurement of the source position through the front source tube connection was not feasible on site and would be performed at Burlington.
c) Some of the lead sheet placed around the shield (to increase weight) remained .
d) It was not feasible to profile the unit on site within acceptable safety margins.
e) It was necessary to disassemble the unit to accurately determine, the extend of foam pyrolization and to assess any internal damage. This would be performed at Burlington.

Upon receipt of the units at Burlington, the shipping plug was removed and the source position measured at 9 13/16", essentially unchanged from the original. The rear plate Posilock assembly was removed. The dummy source was withdrawn from the source tube without much effort. The position of the source tube confirmed that the shield had not shifted during transport. A functional test confirmed that all mechanisms operated properly.

The side plates were removed. The carbon char matrix filled approximately 95% of the space the foam had occupied. The density and resistance to probing of the matrix indicated that the foam had not totally pyrolized. Partially melted lead sheet was found near the top and sides of the shield. Some molten lead had percolated down to the bottom of the projector and was dispersed throughout the matrix. All components showed essentially no deformation.

7.4 Profile Results

The unit was profiled with a 83 Ci Co60 source dimensionally identical to the dummy source used in the thermal test (see Appendix B). The source was transferred to the projector using standard loading techniques. This simulated the position of the dummy source in the test. The unit was then profiled. The highest readings were found to be 1.0 to 1.6 mR/hr at one (1) meter at approximately a 45° angle away from the Posilock across the projector. When scaled to the maximum capacity of the unit (110 Ci Co60) this translates to a reading of approximately 2.5 mR/hr at one (1) meter. This is consistent with the pre-test profile readings and shows no significant increase due to the test.

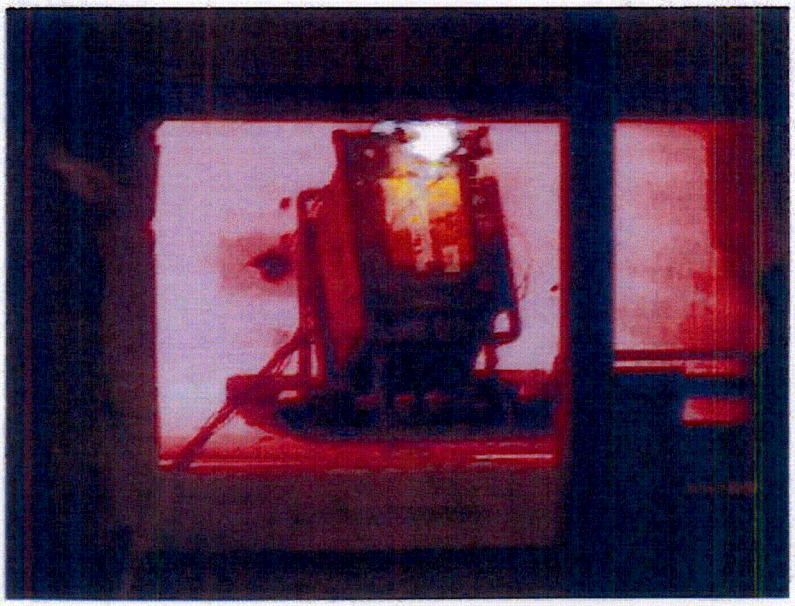
APPENDIX A CALIBRATION RECORDS

APPENDIX B
RADIATION PROFILE DATA SHEETS

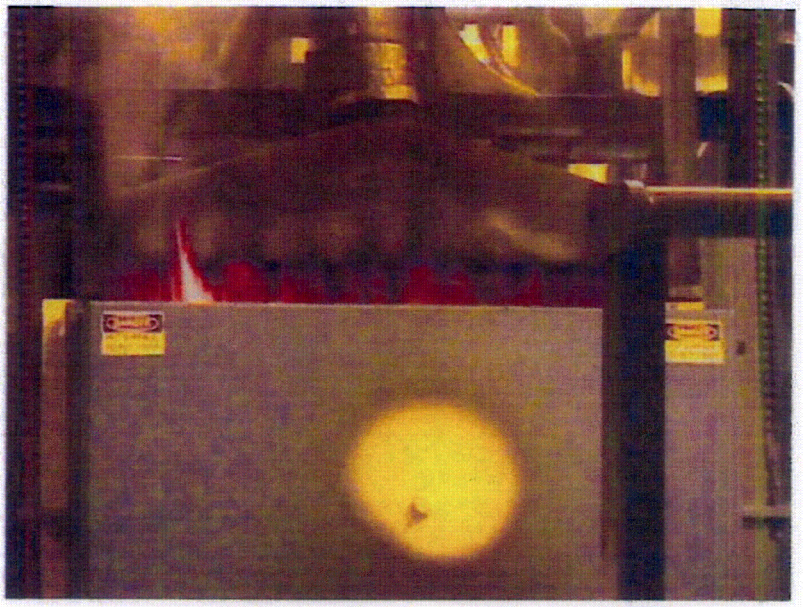
APPENDIX C TEST CHECKLISTS AND DATA SHEETS

APPENDIX D
TEST PHOTOGRAPHS

SPECIMEN B198 ON JIG



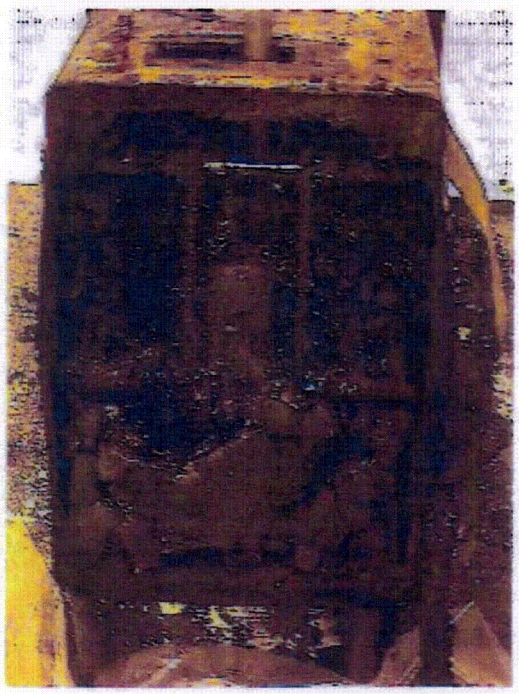
SPECIMEN B198 ENTERING OVEN



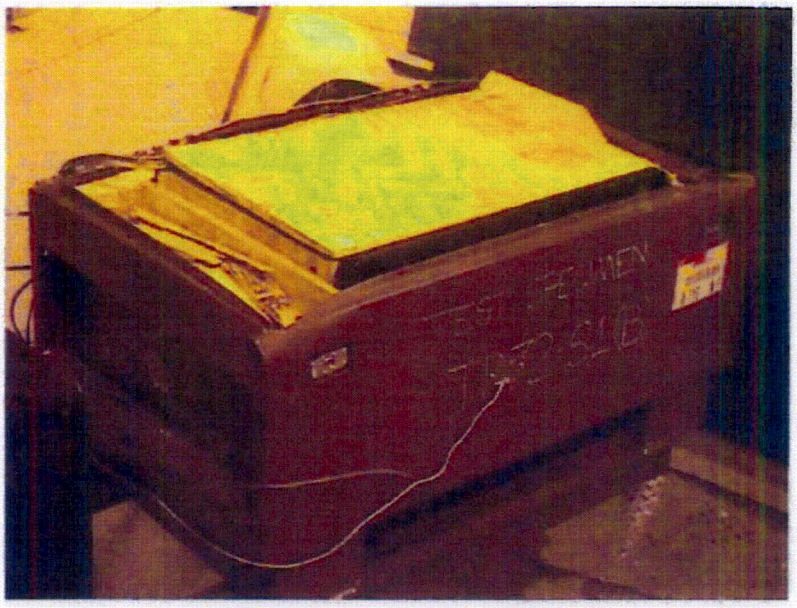
FLAMES FROM SPECIMEN B198 IN OVEN

SPECIMEN B198 BEING REMOVED FROM OVEN

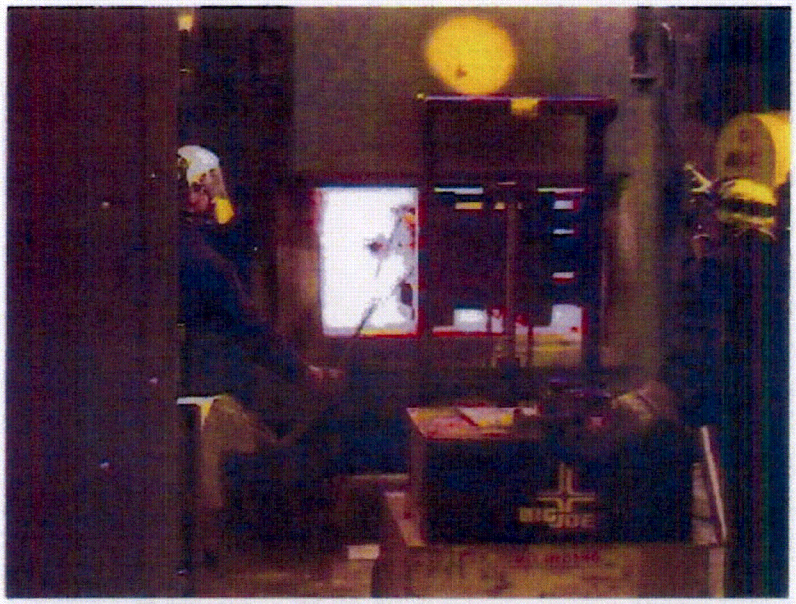
SPECIMEN B198 EXTINGUISHED



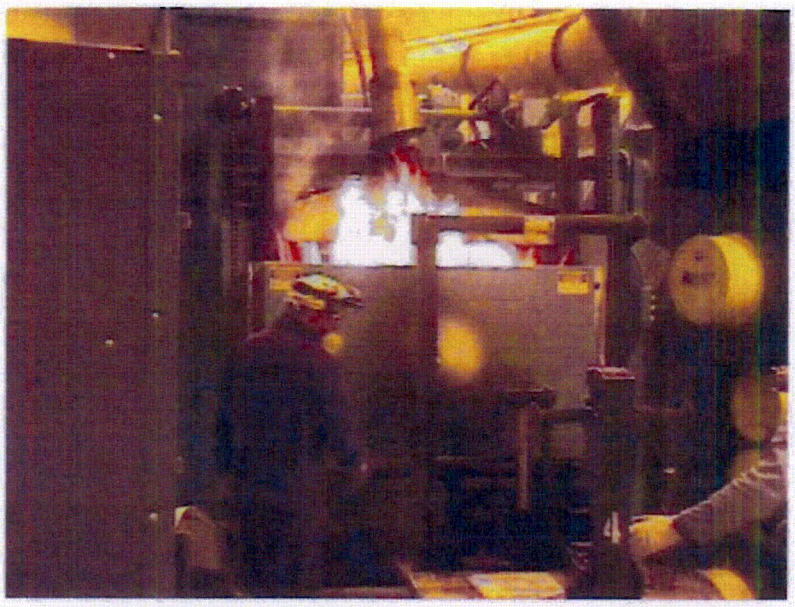
SPECIMEN B198 WITH TOP SIDE PLATE OPEN



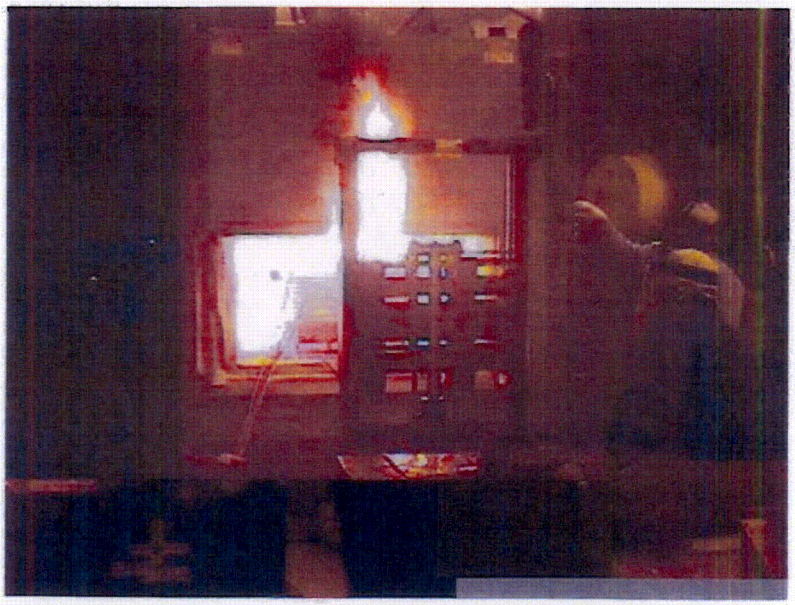
SPECIMEN B201 AND OVERPACK



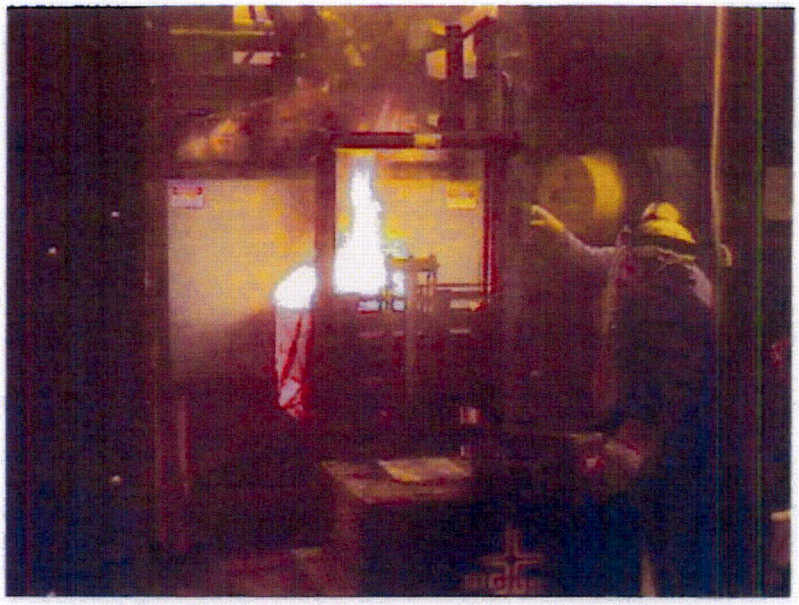
SPECIMEN B201 AND OVERPACK ENTERING OVEN



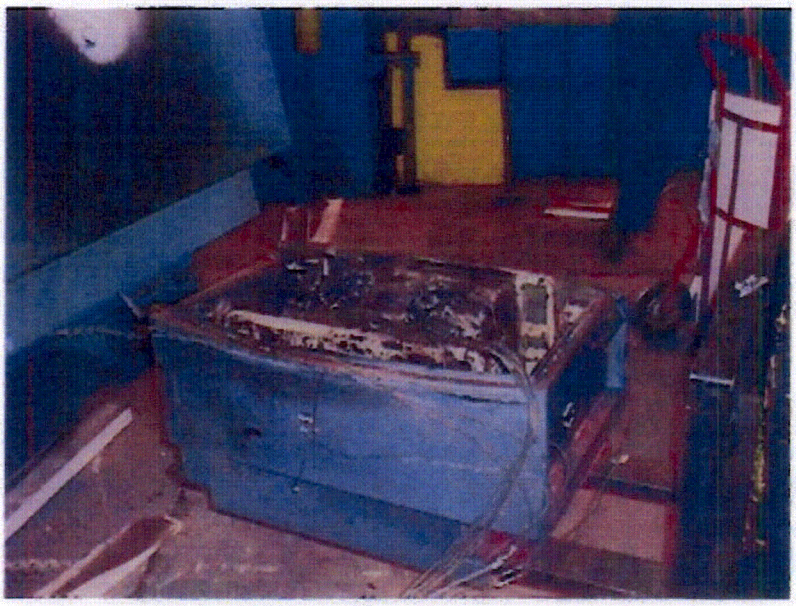
FLAMES FROM SPECIMEN B201 AND OVERPACK



SPECIMEN B201 AND OVERPACK BEING REMOVED

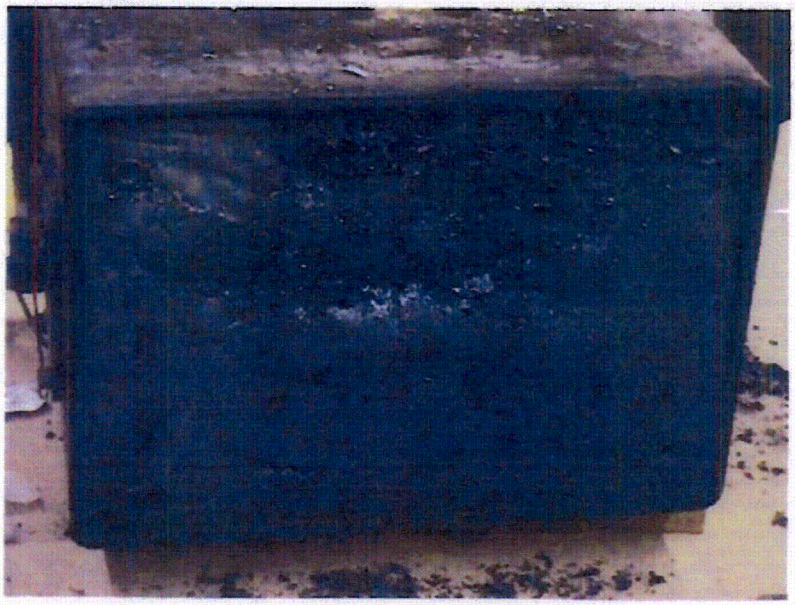


SPECIMEN B201 AND OVERPACK OUT OF OVEN



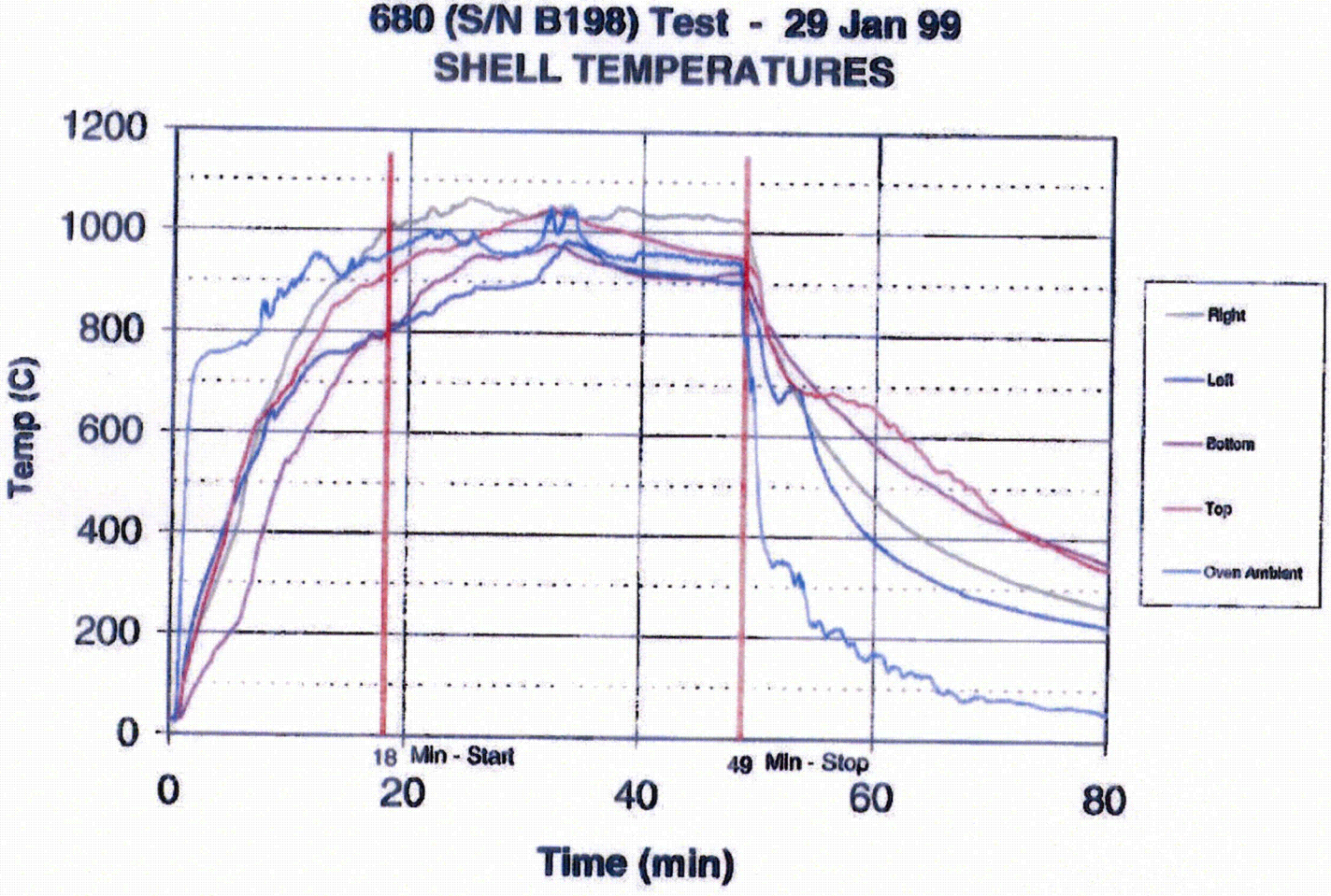
SPECIMEN B201 AND OVERPACK EXTINGUISHED

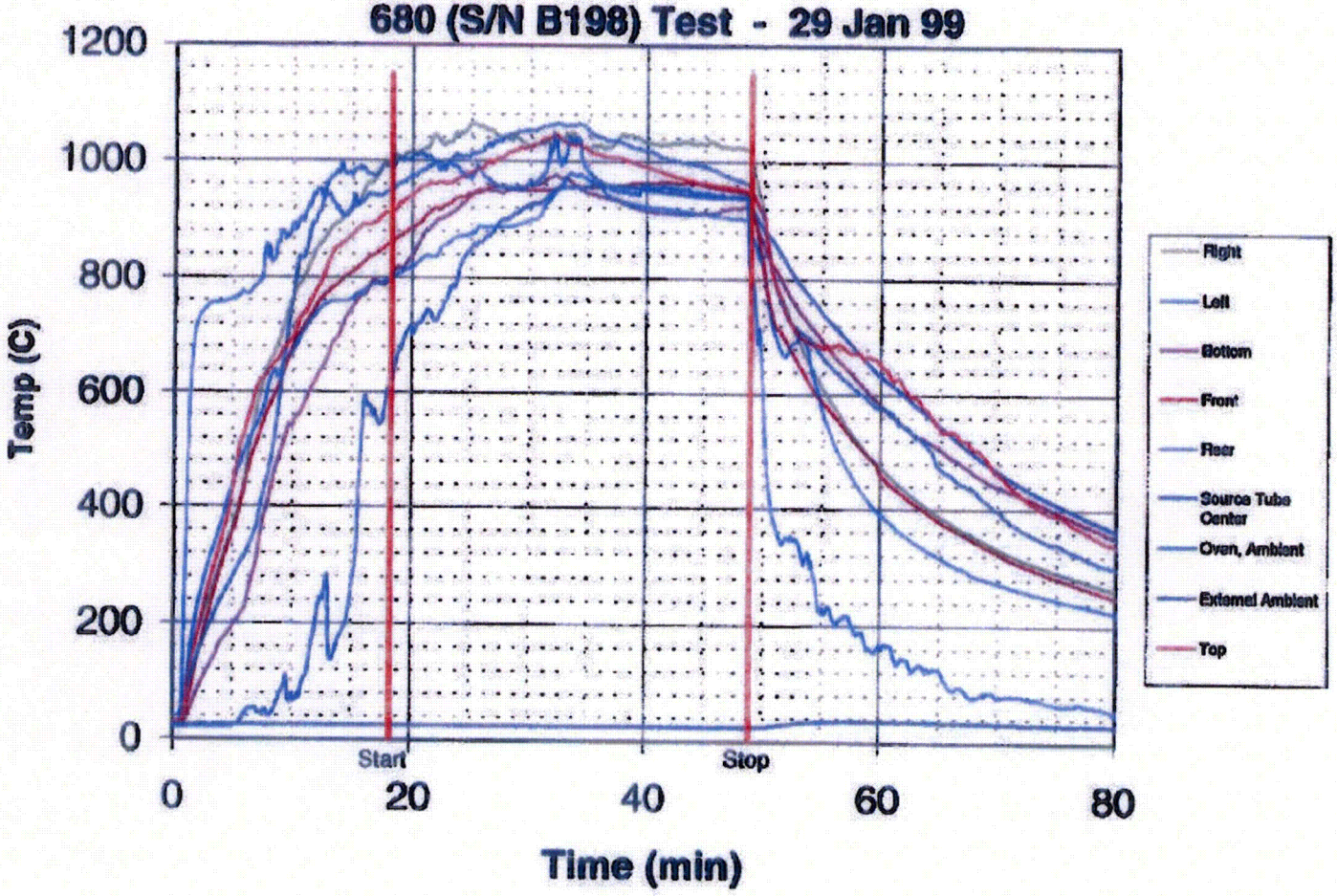
SPECIMEN B201 AND OVERPACK EXTINGUISHED

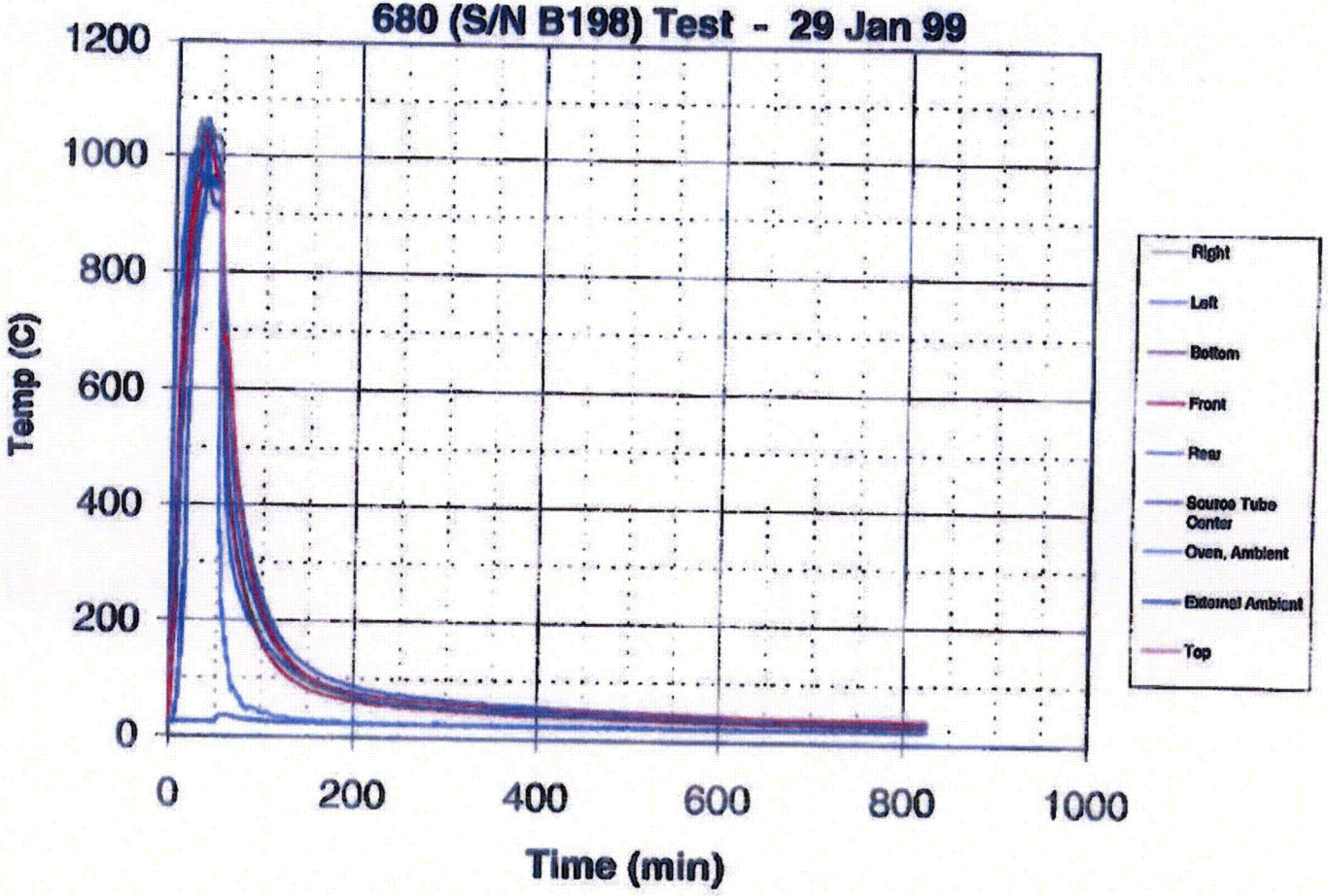


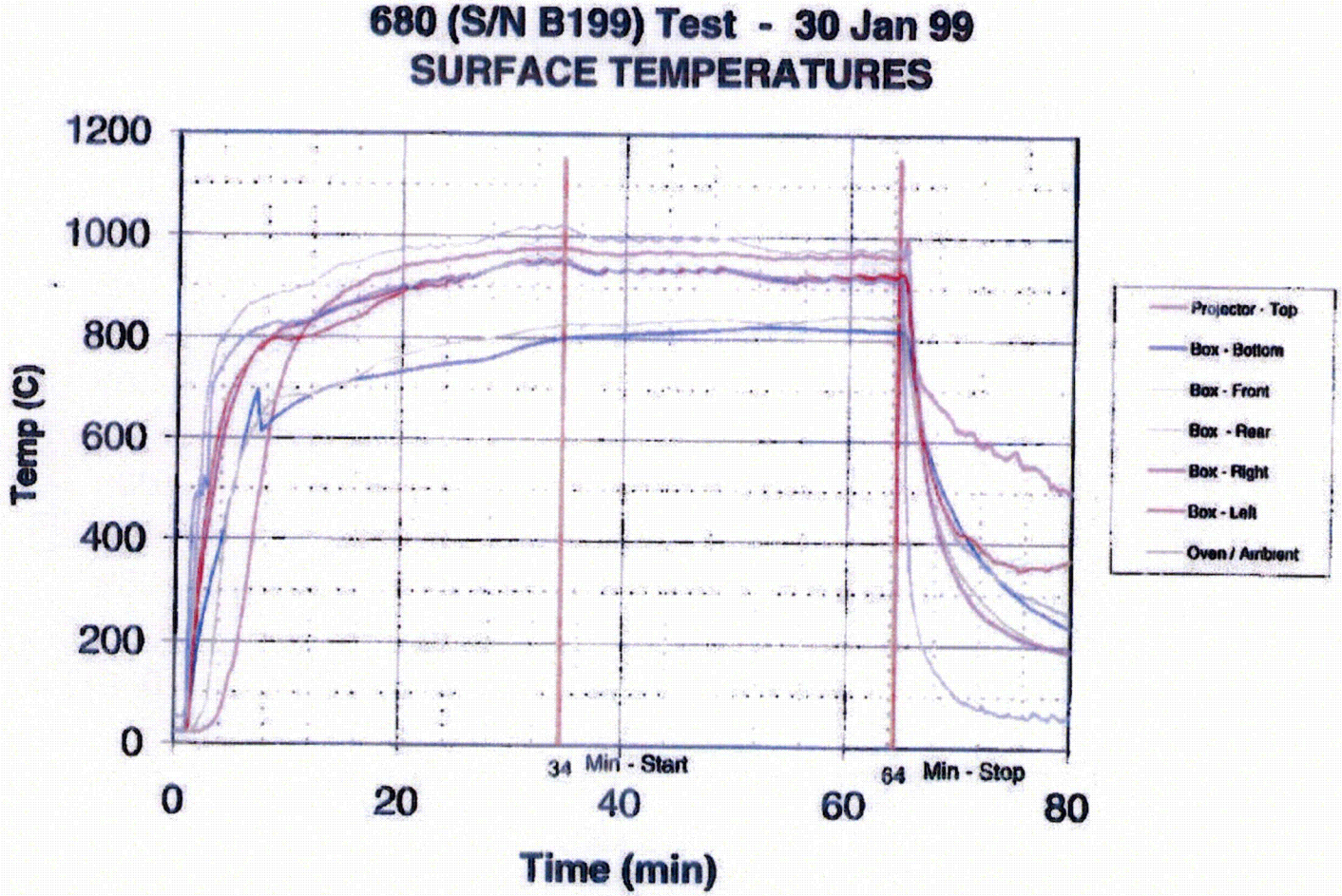
SPECIMEN B201 WITH SIDE PLATE REMOVED

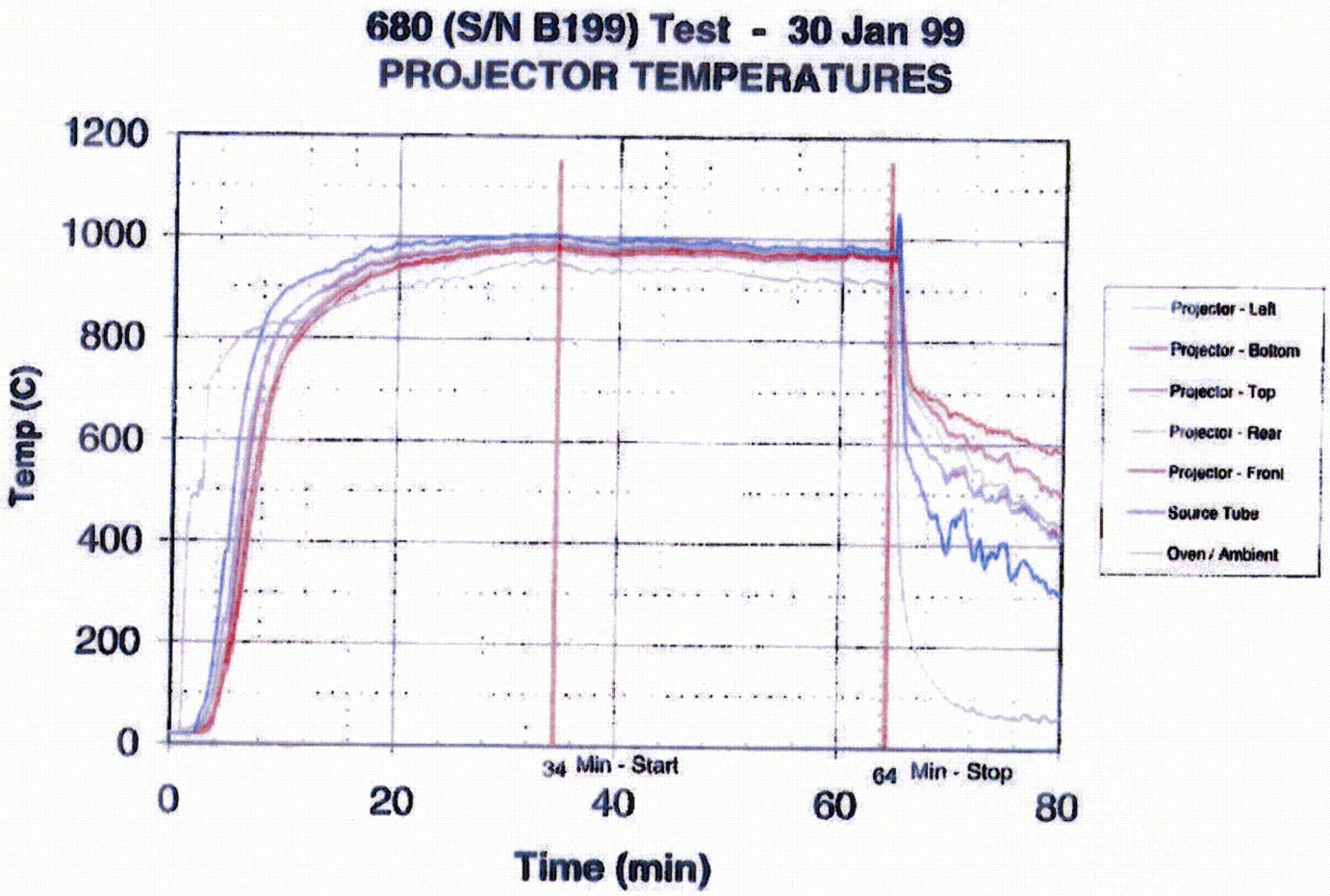
APPENDIX E
THERMAL GRAPHS

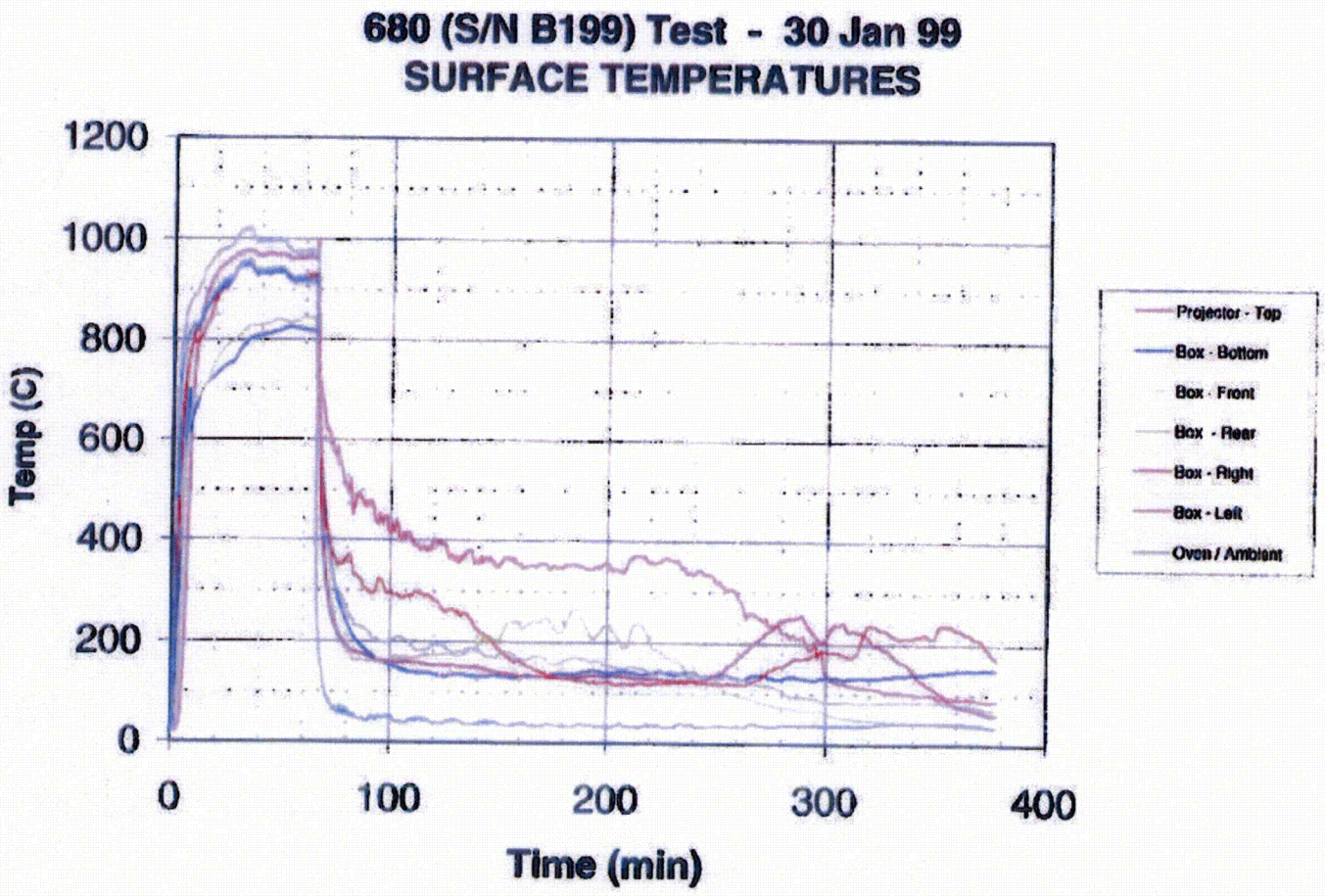

680 (S/N B198) Test - 29 Jan 99
SHELL TEMPERATURES
Temp (C)
1200
1000
800
600
400
200
0
0
20
40
60
80
Time (min)
18 Min - Start
49 Min - Stop
Right
Left
Bottom
Top
Oven Ambient

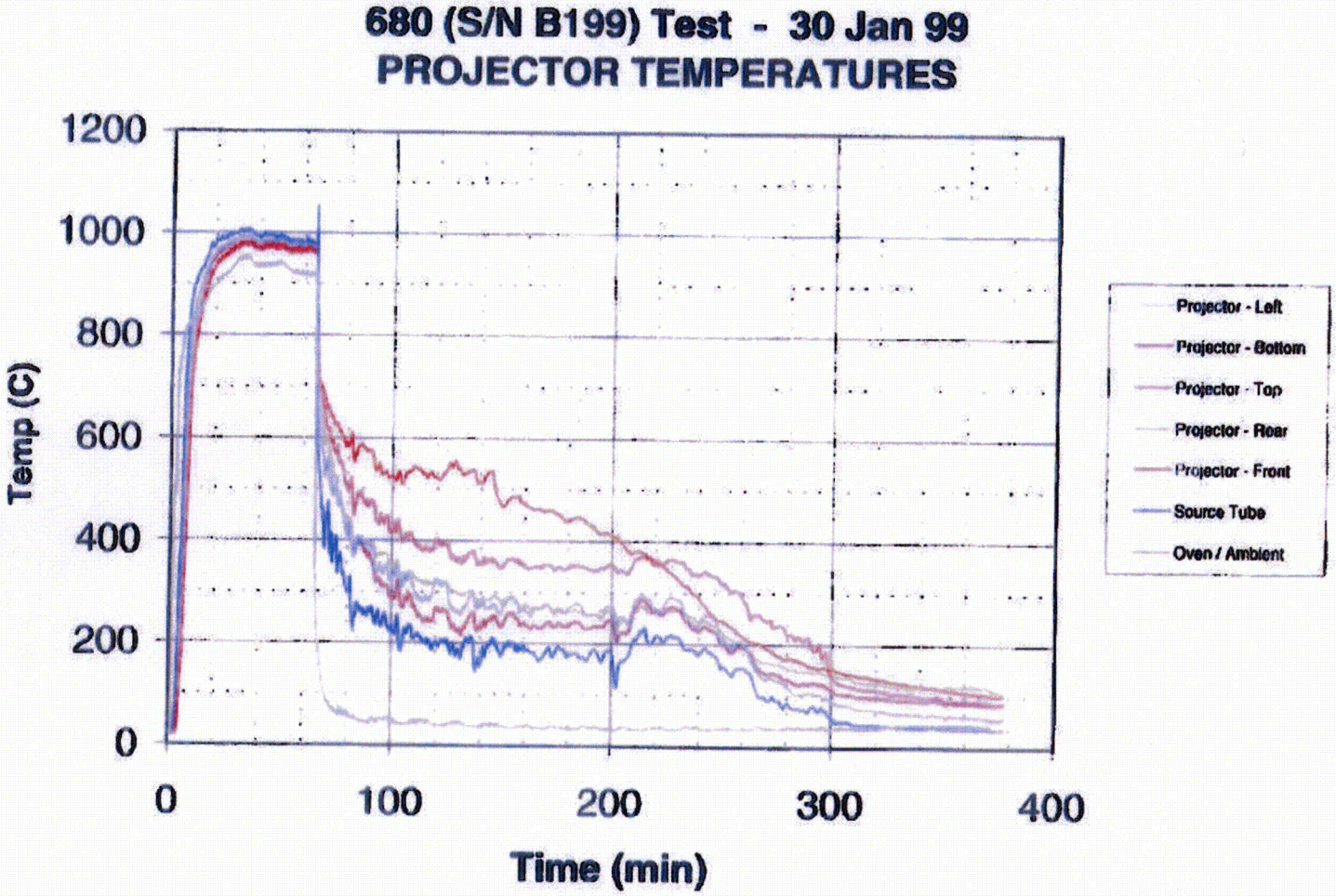

680 (S/N B198) Test - 29 Jan 99
Temp (C)
1200
1000
800
600
400
200
0
Start
Stop
0
20
40
60
80
Time (min)
Right
Left
Bottom
Front
Rear
Source Tube Center
Oven, Ambient
External Ambient
Top


680 (S/N B198) Test - 29 Jan 99
Temp (C)
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
Time (min)
Right
Left
Bottom
Front
Rear
Source Tube Center
Oven, Ambient
External Ambient
Top


680 (S/N B199) Test - 30 Jan 99
SURFACE TEMPERATURES
1200
1000
800
600
400
200
0
Temp (C)
0
20
40
60
80
Time (min)
34 Min - Start
64 Min - Stop
Projector - Top
Box - Bottom
Box - Front
Box - Rear
Box - Right
Box - Left
Oven / Ambient


680 (S/N B199) Test - 30 Jan 99
PROJECTOR TEMPERATURES
1200
1000
800
600
400
200
0
Temp (C)
0
20
40
60
80
Time (min)
34 Min - Start
64 Min - Stop
Projector - Left
Projector - Bottom
Projector - Top
Projector - Rear
Projector - Front
Source Tube
Oven / Ambient


680 (S/N B199) Test - 30 Jan 99
SURFACE TEMPERATURES
Temp (C)
1200
1000
800
600
400
200
0
0
100
200
300
400
Time (min)
Projector - Top
Box - Bottom
Box - Front
Box - Rear
Box - Right
Box - Left
Oven / Ambient


680 (S/N B199) Test - 30 Jan 99
PROJECTOR TEMPERATURES
Temp (C)
1200
1000
800
600
400
200
0
0
100
200
300
400
Time (min)
Projector - Left
Projector - Bottom
Projector - Top
Projector - Rear
Projector - Front
Source Tube
Oven / Ambient

2.12.6 Test Plan Report 80 dated June 1999 (Minus Manufacturing Records)