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SPACE SHUTTLE

Solid Rocket Motors
Thiokol Corporation

Flight Motor Set 360T004 (STS-30R) Final Report

Volume I (System Overview)

September 1989

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ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Secured in the shuttle orbiter Atlantis' cargo bay, the interplanetary probe Magellan begins its journey toward Venus during the STS-30R mission launch on 4 May 1989. Thiokol flight motor set 360T004 again verified the exceptional performance of the redesigned solid rocket motors.

Flight Motor Set 360T004 (STS-30R)
Final Report

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ABSTRACT

The fourth NASA space shuttle flight incorporating redesigned solid rocket motors began on 4 May 1989, at 2:47 p.m. EDT, following an aborted launch attempt on 28 April. The flight motors were designated 360Q004A (left-hand) and 360H004B (right-hand); the mission was designated STS-30R. As has been the case on all previous redesigned solid rocket motor launches, overall motor performance was excellent.

As a result of the elimination of developmental flight instrumentation, complete verification of all ballistic contract end item specification parameters could not be accomplished. However, the low sample rate data that were available showed exceptional propulsion performance. All ballistic and mass property parameters closely matched the predicted values and were well within the required contract end item specification levels that could be assessed. No strain, vibration, or aft skirt heating environments could be addressed due to developmental flight instrumentation deletion.

Evaluation of the ground environment instrumentation showed that on-pad local environments were more indicative of April conditions than of May. Some outward cooling effects were noticed (2.5° to 3.5°F) and were attributed to external tank cryogenics and the easterly wind condition. No launch commit criteria thermal violations were observed, and all field and igniter joint heaters performed adequately and as expected. Also, no evidence of circumferential temperature gradients in the aft skirt region (which had previously been seen on 360L003 and 360L002) was detected.

Infrared readings from the shuttle thermal imager were considered very good when compared to ground environment instrumentation readings taken during both the aborted and actual countdowns. However, hand-held infrared gun reading/ground environment instrumentation comparisons were considered poor during both countdowns, with the exception of the T - 3-hr timeframe during the actual launch.

Postflight inspection again verified superior performance of the insulation, phenolics, metal parts, and seals. All combustion gas was contained by the insulation in the field and case-to-nozzle joints. Inadequate parachute performance on the left-hand booster caused high splashdown loads, which resulted in a displaced nozzle and factory joint weatherseal unbond anomalies. Recommendations were made concerning improved thermal modeling and measurements, as well as to incorporate developmental flight instrumentation on future flights. The rationale for these recommendations, the dispositions of all anomalies, and complete result details are contained in this report.

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ACRONYMS

AT	action time
CCP	carbon-cloth phenolic
CEI	contract end item
cg	center of gravity
D&V	design and verification
DWV	dielectric withstanding voltage
EPDM	ethylene-propylene-diene monomer
EST	eastern standard time
ET	external tank
FBMBT	flex bearing mean bulk temperature
FEWG	Flight Evaluation Working Group
FMEA	Failure Modes and Effects Analysis
GCP	glass-cloth phenolic
GEI	ground environment instrumentation
GFE	government-furnished equipment
GMT	Greenwich mean time
GSE	ground support equipment
HOSC	Huntsville Operations Support Center
HPM	high performance motor
ID	inside diameter
IFA	in-flight anomaly
ips	inches per second
IR	infrared
JPS	joint protection system
KSC	Kennedy Space Center
LCC	launch commit criteria
LRU	line-replaceable unit
LSC	linear shaped charge
MLP	mobile launch platform
ms	millisecond
MSFC	Marshall Space Flight Center
NBR	nitrile butadiene rubber
OBR	outer boot ring

ACRONYMS (cont)

OD	outside diameter
OFI	operational flight instrumentation
OPT	operational pressure transducer
PMBT	propellant mean bulk temperature
PR	problem report
QM	qualification motor
RSRM	redesigned solid rocket motor
RSS	rotating service structure
RTD	resistance temperature device
S&A	safety and arming device
SII	SRM ignition initiator
SRB	solid rocket booster
SSME	space shuttle main engine
STI	shuttle thermal imager
TPS	thermal protection system
USBI	United Space Boosters, Inc.

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INTRODUCTION

Solid rocket booster (SRB) ignition command time for flight motor set 360T004 was given at 89:124:18:46:59.011 GMT (approximately 2:47 p.m. EST) on 4 May 1989 at Kennedy Space Center (KSC), Florida. This flight was the 29th space shuttle mission (mission designation STS-30R) and the fourth redesigned solid rocket motor (RSRM) flight. The individual motor identification numbers were 360Q004A (left-hand (LH)) and 360H004B (right-hand (RH)), indicating the cases were quarter and half weights, respectively. The aft segment that was originally scheduled to fly on the RH motor was switched with the Qualification Motor No. 8 (QM-8) static test motor aft segment due to insulation-to-insulation unbonds that were determined to be excessive for flight but not for static testing. Additional case configuration details are addressed in Section 4.2.

This volume (Volume I) of this report contains the Thiokol Flight Evaluation Working Group (FEWG) inputs submitted to United Space Boosters, Inc. (USBI) for incorporation into the shuttle prime contractors' FEWG report (Document MSFC-RPT-1576). An executive summary of the entire RSRM flight set performance and a one-to-one correlation of conclusions by objectives (and contract end item (CEI) paragraphs) are also included in this report. The detailed component volumes of this report (and the approximate timeline for volume release from the launch date) are listed in Table 1-1.

The subsections of this report volume that were submitted to USBI as part of the FEWG report are so designated with the FEWG report paragraph number.

Table 1-1. Component Volume Release Schedule

Volume	Component Description	Interim Release	Final Release
I	System overview	NA	Approximately 60 working days after launch
II	Case	45 days after last field joint demate at KSC Hangar AF	45 days after washout of last segment at Clearfield H-7
III	Insulation	45 days after last field joint demate at KSC Hangar AF	45 days after last factory joint disassembly at Clearfield H-7
IV	Seals	45 days after last internal nozzle joint demate	45 days after last factory joint disassembly at Clearfield H-7
V	Nozzle	45 days after final nozzle joint disassembly	90 days after final nozzle liner char and erosion measurements
VI	Igniter	NA	30 days after igniter disassembly at Clearfield H-7
VII	Joint protection system (heater)	NA	60 days after launch
VIII	Systems tunnel	NA	60 days after launch
IX	Instrumentation*	NA	60 days after launch
X	Performance and mass properties	NA	60 days after launch
XI	Dynamics** (reconstructed loads evaluation)	NA	60 days after receipt of reconstructed loads

*There is no component instrumentation volume (Volume IX) for motor set 360T004. All instrumentation information is contained in Volume I (this volume)
**Dynamics volume applicable only to DFI flights (360L001 through 360L003)

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OBJECTIVES

The fourth Thiokol RSRM flight test objectives were derived from the fourth flight test summary sheet of the Design and Verification (D&V) Plan (TWR-15723C), and are listed here as contained in the engineering requirements document for RSRM fourth flight (TWR-19071). They are intended to satisfy the requirements of CPW1-3600A (including Addendum G) as listed in parentheses below:

Qualification Test Objectives

A. Verify that the thrust-time performance falls within the requirements of the nominal thrust-time curve (3.2.1.1.2.1, Table 1).

B. Certify that the measured motor performance parameters, when corrected to a 60°F propellant mean bulk temperature (PMBT), fall within the nominal value, tolerance, and limits for individual flight motors (3.2.1.1.2.2, Table 2).

C. Certify that the thrust-time curve complies with impulse requirements (3.2.1.1.2.4).

D. Certify that specified temperatures are maintained in the case-to-nozzle joint region (3.2.1.2.1.f).

E. Verify that the safety and arming (S&A) devices perform as required using the specified power supply (3.2.1.6.1.2).

F. Verify that the operational flight instrumentation (OFI) is capable of launch readiness checkout after the ground system has been connected on the launch pad (3.2.1.6.2).

G. Certify the proper operation of the operational pressure transducer (OPT) during flight (3.2.1.6.2.1).

H. Verify that the flex bearing system is reusable (3.2.1.9.c).

I. Verify that the systems tunnel properly: 1) attaches to the case, 2) accommodates the government-furnished equipment (GFE) and linear shaped charge (LSC), and 3) provides OFI, ground environmental instrumentation (GEI) and heater cables (3.2.1.10.1).

J. Certify the performance of the field joint heater and the sensor assembly so it maintains the case field joint at 75°F minimum. Field joints shall not exceed 130°F (3.2.1.11.a).

K. Certify that each field joint heater assembly meets all performance requirements (3.2.1.11.1.2).

L. Demonstrate isolation of subsystem anomalies if required on fourth flight (360T004) hardware (3.2.3.3).

M. Demonstrate the RSRM capability of assembly/disassembly in both the vertical and horizontal positions (3.2.5.1).

N. Demonstrate assembly and verification of the SRB prior to external tank (ET) mating (3.2.5.4).

O. Demonstrate that the RSRM and its components are capable of being transported to and from fabrication, test, operational launch, recovery/retrieval, and the refurbishment sites (3.2.8).

P. Demonstrate the remove and replace capability of the functional line replaceable unit (LRU) (3.4.1).

Q. Certify that the ignition interval is between 202 and 262 ms with a 40-ms environmental delay after ignition command (3.2.1.1.1.1).

R. Certify that the pressure rise rate meets specification requirements (3.2.1.1.1.2).

S. Certify that the motor thrust differential meets specification requirements (3.2.1.1.2.3).

<u>Test Objectives by Inspection</u>

Perform the following required postflight inspections and demonstrations:

A. Inspect all RSRM seals for performance (3.2.1.2).

B. Inspect the seals for satisfactory operation within the specified temperature range that results from natural and induced environments (3.2.1.2.1.b).

C. Inspect the factory joint insulation for accommodation to structural deflections and erosion (3.2.1.2.2.a).

D. Inspect the factory joint insulation for operation within the specified temperature range (3.2.1.2.2.b).

E. Verify that at least one virgin ply of insulation exists over the factory joint at the end of motor operation (3.2.1.2.2.d).

F. Verify that no leakage occurred through the insulation (3.2.1.2.2.e).

G. Verify that the flex bearing seals operates within the specified temperature range (3.2.1.2.3.b).

H. Verify that the flex bearing maintained a positive gas seal between its internal components (3.2.1.2.3.d).

I. Verify that the ignition system seals operate within the specified temperature range (3.2.1.2.4.b).

J. Verify that the internal seals and exit cone field joint seals operate within the specified temperature range (3.2.1.2.5.b).

K. Inspect the risers for damage or cracks that would degrade the pressure holding capability of the case (3.2.1.3.c).

L. Inspect the case segment mating joints for the pin retention device (3.2.1.3.g).

M. Inspect the flex bearing for damage due to water impact (3.2.1.4.6).

N. Inspect the nozzle for the presence of the environmental protection plug (3.2.1.4.7.a).

O. Verify that the environmental protection plug will withstand space shuttle main engine (SSME) shutdown, if incurred (3.2.1.4.7.b).

P. Inspect the aft exit cone severance ordnance ring for the presence of the government-furnished detonator cartridge (3.2.1.4.12.1).

Q. Inspect the aft exit cone severance ordnance cable and brackets for installation (3.2.1.4.12.4)

R. Verify the performance of the nozzle liner (3.2.1.4.13).

S. Inspect the ignition system seals for evidence of hot gas leakage (3.2.1.5.a).

T. Verify that the S&A device has the capability to provide direct visual position indication in both the safe and armed positions (3.2.1.5.1.f).

U. Verify the use of two GFE solid rocket motor (SRM) ignition initiators (SII) in the S&A device (3.2.1.5.1.l).

V. Inspect the igniter for evidence of debris formation or damage (3.2.1.5.2).

W. Verify that the GEI can monitor the temperature of the SRBs while on the ground at the pad (3.2.1.6.2.3).

X. Inspect the seals for visible degradation from motor combustion gas (3.2.1.8.1.1.d).

Y. Verify by inspection that the insulation met all performance requirements (3.2.1.8.1.1.e).

A. Inspect insulation material for shedding of fibrous or particulate matter (3.2.1.8.1.1.f).

AA. Inspect the joint insulation for evidence of slag accumulation (3.2.1.8.1.1.g).

AB. Inspect the thermal protection system (TPS) to insure that there was no environmental damage to the RSRM components (3.2.1.8.2).

AC. Inspect for thermal damage to the igniter chamber and the adapter metal parts (3.2.1.8.3).

AD. Verify that the case components are reusable (3.2.1.9.a).

AE. Verify that the nozzle metal parts are reusable (3.2.1.9.b).

AF. Verify through flight demonstration and a postflight inspection that the flex bearing is reusable (3.2.1.9.c).

AG. Verify that the igniter components are reusable (3.2.1.9.d).

AH. Verify by inspection that the S&A device is reusable (3.2.1.9.e).

AI. Verify by inspection that the OPTs are reusable (3.2.1.9.f).

AJ. Inspect the case factory joint external seal for moisture (3.2.1.12).

AK. Inspect the hardware for damage or anomalies as identified by the failure modes effects analyses (FMEA) (3.2.3).

AL. Determine the adequacy of the design safety factors, relief provisions, fracture control, and safe-life and/or fail-safe characteristics (3.2.3.1).

AM. Determine the adequacy of subsystem redundancy and fail-safe requirements (3.2.3.2).

AN. Verify that storage/age control monitoring of the RSRM and its subsystems is being accomplished (3.2.9.2).

AO. Inspect the identification numbers of each reusable RSRM part and material for traceability (3.3.1.5).

AP. Verify the structural safety factor of the case-to-insulation bond (3.3.6.1.1.2.a).

AQ. Verify by inspection the remaining insulation thickness of the case insulation (3.3.6.1.2.2, 3.3.6.1.2.3, 3.3.6.1.2.4, 3.3.6.1.2.6).

AR. Verify by inspection the remaining nozzle ablative thicknesses (3.3.6.1.2.7).

AS. Verify the nozzle safety factors (3.3.6.1.2.8).

AT. Inspect metal parts for presence of stress corrosion (3.3.8.2.b).

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RESULTS SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

3.1 RESULTS SUMMARY

This section contains an executive summary of the key results from the flight data evaluation and postflight inspection. Additional information and details can be found in the referenced report sections or in the separate component volumes of this report.

3.1.1 In-Flight Anomalies

Three in-flight anomalies (IFA) relating to RSRM motor set 360T004 were identified. They are summarized below.

MSFC IFA No.	Problem Title/ Description	Corrective Action Closure
STS-30-M-1	Factory joint weatherseal adhesive unbonds between the case and Chemlok® 205 primer on the: a) LH aft stiffener-to-stiffener, b) LH aft stiffener-to-dome, and c) LH forward center factory joints.	Adhesive strength was reduced due to unusual case smoothness--contamination was not a contributing factor--actual unbonding was a result of splashdown loads. Verify a minimum 70 μin. R case surface roughness on future motors to ensure optimum adhesive strength.
STS-30-M-2	Nick and/or gouge at 285 deg on LH igniter outer gasket secondary seal. Noted during postflight hardware inspection. No history on this type of anomaly.	Cut believed to have occurred during final assembly from inadequate gasket handling/packaging/ storage and inspection. Improved handling/ assembly procedures and tighter inspections will eliminate future occurrence.
STS-30-M-3	LH SRM nozzle support ring was displaced forward and wedged into snubber assembly, preventing nozzle from returning to null position.	Damage was caused by higher than normal water impact loads due to excessive SRB descent/ splashdown velocity (as a result of SRB parachute anomaly).

The dispositions and closeout statements of all the IFAs are included in Section 4.1. None were considered to be flight constraints.

3.1.2 Mass Properties

All actual propellant weights varied by less than 0.13 percent from the predicted values, with the average variation being 0.02 percent. All SRM weight values were well within the CEI specification limits, as also has been the case on all previous RSRM motor sets. Complete mass property values are included in Section 4.3 of this volume and Volume X of this report.

3.1.3 Propulsion Performance (ballistics)

3.1.3.1 Propellant Burn Rates/Specific Impulse. The delivered burn rate for flight motors 360Q004A and 360H004B was 0.3713 in./sec and 0.3714 in./sec (at 71°F and 625 psia), respectively, which was 0.0003 in.\sec greater than predicted for the LH and 0.0011 less than predicted for the RH. The reconstructed vacuum specific impulse value was 267.6 lbf*sec/lbm at 71°F for both motors, which was within 0.3 percent of the predicted value of 268.3 lbf*sec/lbm.

3.1.3.2 CEI Specification Values. All impulse values, time parameters, and pressure and thrust levels (all corrected to 60°F) again showed excellent agreement with the motor nominal performance requirements. Actual value variations from the allowable CEI specification limits were all within 2 percent, significantly less than the allowable 3-sigma variation. Thrust imbalance was also well within the specification limits for the required time periods.

Due to the elimination of DFI, no high sample rate pressure data were available. Therefore, the CEI specification requirement to verify ignition interval, pressure rise rate, and ignition time thrust imbalance could not be addressed. A complete evaluation of all ballistic parameters is included in Section 4.4.

3.1.4 S&A Device

The S&A device safe-to-arm rotation times were all within the minimum 2-sec requirement during both the actual and aborted launch attempts. (The arm-to-safe rotation times during the abort were also within the required time period.) The actual times, as recorded on the S&A device gages, are included in Section 4.10.4.

3.1.5 Ascent Loads and Structural Dynamics

Due to the elimination of DFI on motor set 360T004, no evaluation of the RSRM loading or vibration characteristics is possible.

3.1.6 External TPS/Joint Heater Evaluation

Postflight assessment results stated all TPS components to be in very good to excellent condition, with typical flight heat effects and erosion. National Space and Transportation System (NSTS) debris criteria for all missing TPS was not violated.

All heaters performed as expected throughout the required operating periods, including the LH forward field joint primary heater. (The LH forward secondary heater was not to be activated, as it had previously failed the dielectric withstanding voltage (DWV) test.) A detailed TPS and heater evaluation is in Section 4.8 of this volume.

3.1.7 Aero/Thermal Evaluation

3.1.7.1 On-Pad Local Environments/Thermal Model Verification. The on-pad local environments were more indicative of April conditions (64° to 78°F) than of May (69° to 81°F), with the ambient temperatures ranging from 62° to 78°F. Windspeeds were close to predicted values, with the direction primarily from the east-southeast--close to the historical southeast direction.

No extreme outward cooling effects from ET cryogenic loading were noted--only minor chilling (2.5° to 3.5°F) on the inboard region of 360H004B (RH).

3.1.7.2 Launch Commit Criteria/Infrared Readings. No launch commit criteria (LCC) thermal violations were noted; all field and igniter joint heaters performed adequately and as expected. No evidence of circumferential temperature gradients in the aft skirt region, which had previously been seen on 360L003 and 360L002 (STS-29R and -27R), was noted.

Infrared (IR) readings from the shuttle thermal imager (STI) were considered very good when compared to GEI readings taken during both the aborted and actual countdowns. Variation was less than 2°F using the portable and rotating service structure (RSS) stationary STI. However, hand-held IR gun reading/GEI comparisons were considered poor during both countdowns, with the exception of the T - 3-hr timeframe during the actual launch.

No thermal evaluation of the aft skirt area (as has been done on RSRM Flights 1 through 3) was possible due to DFI elimination. A complete aero/thermal evaluation is in Section 4.8.

3.1.8 Instrumentation

Of the 108 GEI measurements, 106 (98 percent) performed properly throughout the prelaunch phase. (All GEI are disconnected by breakaway umbilicals at SRB ignition and are not operative during flight.) All OPTs functioned properly during flight and successfully passed the prelaunch calibration checks. A complete discussion of GEI and all instrumentation is in Section 4.10 of this report.

3.1.9 Postflight Hardware Assessment

3.1.9.1 Insulation. Postflight evaluation again verified excellent insulation performance, showing that the insulation effectively contained the motor combustion gas in the two case-to-nozzle joints and six field joints. None of the internal acreage insulation showed evidence of gas paths or other severe erosion. No clevis edge separations of recordable size were detected. Some factory joint weatherseals on the LH aft segment and forward center segment were damaged at splashdown (see IFA STS-30-M-1); all remaining external insulation was in good condition. A complete insulation evaluation is in Section 4.11.1 of this volume and Volume III of this report.

3.1.9.2 Case. Overall, this flight exhibited fretting of a lesser magnitude than 360L003 (STS-29), although fretting was observed on five of the six field joints. The deepest pit measured was 0.007 inch.

All three LH motor stiffener stubs and segments experienced some outer ligament cracks and missing or broken bolts. (There were four cracks prior to this flight, and four new cracks formed during this flight.) Excessive splashdown loads due to improper parachute operation may have contributed to the cracking of the LH stub. The RH stiffener rings revealed no noticeable damage upon removal of the stiffener stubs.

No damage to the ET attach stubs on either motor was observed. A complete evaluation of the case components can be found in Section 4.11.2 of this volume and Volume II of this report.

3.2.9.3 Seals. All internal seals performed well, with no heat effects, erosion, or hot gas leakage evident. Some assembly damage to the LH igniter outer gasket secondary seal did occur (see IFA STS-30-M-2). No motor pressure reached the field or case-to-nozzle joint seal. A complete seals evaluation is in Section 4.11.3 of this volume and Volume IV of this report.

3.2.9.4 Nozzle/Thrust Vector Control Performance. Both nozzles performed as expected during flight, and postflight evaluation showed typical smooth and uniform erosion profiles. The 360Q004A (LH) nozzle experienced high impact loads due to improper parachute deployment (see IFA STS-30-M-3). The snubber assembly was displaced about 10 in. forward, with portions wedged against the bearing aft end ring. Attempts to "de-snub" the nozzle at KSC were unsuccessful; disassembly was completed at Clearfield H-7. A complete evaluation of both RSRM nozzles is in Section 4.11.4 of this volume and Volume V of this report.

3.2 CONCLUSIONS

Listed below are the conclusions as they relate specifically to the objectives and CEI paragraphs. Also included with the conclusion is the report section (in parenthesis) where additional information can be found.

Objective	CEI Paragraph	Conclusions
Certify that the thrust-time performance falls within the requirements of the nominal thrust-time curve.	3.2.1.1.2.1 (see nominal thrust-time curve)	Certified. The thrust-time performance was within the nominal thrust-time curve (Figure 4.4-1.).

Objective	CEI Paragraph	Conclusions
Certify that the measured motor performance parameters, when corrected to a 60°F PMBT, fall within the nominal value, tolerance, and limits for individual flight motors.	3.2.1.1.2.2 The delivered performance values for each individual motor when corrected to a 60°F PMBT shall not exceed the limits specified...	Partially certified. All measurable motor performance values were well within the specification requirements. (Tables 4.4-2 and 4.4-3.) The ignition interval and rise rates could not be measured due to DFI elimination.
Certify that the thrust-time curve complies with impulse requirements.	3.2.1.1.2.4 Impulse Gates. Time (sec) / Total Impulse (10E6 lb-sec) 20 / 63.1 minimum 60 / 172.9 -1% +3% Action time (AT) 293.8 minimum	Certified. The nominal thrust-time curve values are listed below. Time (sec) / Value LH / RH 20 / 65.42 / 65.42 60 / 174.71 / 174.73 AT / 296.20 / 296.10 (Table 4.4-1)
Certify that specified temperatures are maintained in the case-to-nozzle joint region.	3.2.1.2.1.f Case-to-nozzle joint O-rings shall be maintained within the temperature range as specified in ICD 2-0A002 (75°-120°F).	Certified. Temperature ranges in the case-to-nozzle joint region are listed below. RH 82° - 90°F LH 80° - 85°F (Table 4.8-4)
Certify that the ignition interval is between 202 and 262 ms, with a 40 ms environmental delay after ignition command.	3.2.1.1.1.1 The ignition interval shall be between 202 and 262 ms with a 40 ms environmental delay after ignition command to the SII in the S&A device up to a point at which the headend chamber pressure has built up to 563.5 psia.	Unable to certify due to DFI elimination (high sample rate pressure transducer).
Certify that the pressure rise rate meets specification requirements.	3.2.1.1.1.2 The maximum rate of pressure buildup shall be 115.9 psi for any 10-ms interval.	Unable to certify due to DFI elimination (high sample rate pressure transducers).

Objective	CEI Paragraph	Conclusions
Certify that the motor thrust differential meets specification requirements.	3.2.1.1.2.3 With a maximum PMBT difference of 1.4°F between the two RSRMs on a shuttle vehicle, the differential thrust between the two RSRMs shall not be greater than the values given in Table III at any time during the periods shown. These differentials are applicable over PMBT range of +40° to +90°F.	Unable to certify due to DFI elimination (high sample rate pressure transducers).
Certify that the S&A devices perform as required using the specified power supply.	3.2.1.6.1.2 Power Supply. The S&A device shall meet all performance requirements....in accordance with ICD 3-44005.	Certified. The rotation and arming times of both S&A devices were within the required limits. (Section 4.10).
Certify that the OFI is capable of launch readiness checkout after the ground system has been connected on the launch pad.	3.2.1.6.2 Instrumentation. The OFI shall be capable of launch readiness checkout after ground system connection on the launch pad.	Certified. The 0 percent and 75 percent calibration checks of the OFI verified launch readiness after ground system connection on the launch pad (Section 4.10).
Certify proper operation of the OPT during flight.	3.2.1.6.2.1 The OPT shall monitor the chamber pressure of the RSRMs over the range from 0 to 1,050 ±/15 psi. They shall operate in accordance with ICD 3-44005...	Certified. The OPTs properly monitored the chamber pressure and operated in accordance with ICD 3-44005. Recorded pressure data and values are discussed in Section 4.4.
Certify that the flex bearing system is reusable.	3.2.1.9.c Flex bearing system--Reinforced shims and end rings, elastomer materials.	Cannot be completely certified (at this time). All flex bearing previous use history is in Section 4.2. The 360Q004A (LH) nozzle suffered high splashdown loads due to improper chute deployment. Detailed evaluation is not possible until after flex bearing acceptance testing is completed. Preliminary evaluation indicated no anomalies with the 360H004B (RH) flex bearing system.

Objective	CEI Paragraph	Conclusions
Certify that the systems tunnel properly: (1) attaches to the case, (2) accommodates the GFE and LSC, and (3) provides OFI, GEI, and heater cables.	3.2.1.10.1 When exposed to the thermal environments of 3.2.7.2, the tunnel floorplates and tunnel cables will be maintained at a temperature at or below that specified in ICD 3-44002.	Certified. Postflight evaluation showed no evidence of heat damage to the systems tunnel or adjacent cork, cables, and seams (Table 4.8.3). Proper case attachment and accommodation of the GFE, LSC, and cabling were also verified. A detailed systems tunnel evaluation is in Volume VIII of this report.
Certify the performance of the field joint heater and the sensor assembly so it maintains the case field joint at 75°F minimum. Field joints shall not exceed 130°F.	3.2.1.11.a The case field joint external heater and sensor assembly shall maintain the case field joint O-ring seals between 75° and 120°F at launch...	Certified. The joint heaters maintained all field joints between 89° and 108°F during the prelaunch period (Table 4.8.4).
Certify that each field joint heater assembly meets all performance requirements.	3.2.1.11.1.2 Power Supply. Each field joint external heater assembly shall meet all performance requirements... as defined in ICD 3-44005.	Certified. All the field joint external heaters met all the performance requirements (Section 4.8.3).
Demonstrate isolation of subsystem anomalies if required on fourth flight (360T004) hardware.	3.2.3.3 Isolation of anomalies of time-critical functions shall be provided such that a faulty subsystem element can be deactivated without disrupting its own or other subsystems.	No subsystem anomalies of time-critical functions were detected on flight set 360T004.
Demonstrate RSRM capability of assembly/disassembly in both the vertical and horizontal positions.	3.2.5.1 The RSRM shall be capable of assembly/disassembly in both the vertical and horizontal positions. The RSRM shall be capable of vertical assembly in a manner to meet the alignment criteria of USBI-10183-0022 without a requirement for optical equipment.	RSRM vertical assembly in accordance with USBI-10183-0022 was demonstrated in the vehicle assembly building prior to pad rollout. No vertical disassembly was required. Postflight horizontal disassembly was accomplished at the Hangar AF and H-7 (Clearfield, Utah) facilities.

Objective	CEI Paragraph	Conclusions
Demonstrate assembly and verification of the SRB prior to ET mating.	3.2.5.4 The RSRM assembly and verification on the mobile launch platform (MLP) shall be required prior to mating to the ET.	Flight motor set 360T004 was success-fully assembled on the MLP prior to being mated to the ET.
Demonstrate that the RSRM and its components are capable of being transported to and from fabrication, test, operational launch, recovery/retrieval, and refurbishment sites.	3.2.8 The RSRM and its component parts.... shall be capable of being handled and transported by rail or other suitable means to and from fabrication, test, operational launch, recovery/retrieval, and refurbishment sites.	Flight set 360T004 and its associated components demonstrated transportability from fabrication in Utah to launch in Florida, were the motor set components were recovered, retrieved, and transported back to the refurbishment sites in Utah.
Demonstrate that the RSRM and its components are protected against environments during transportation and handling.	3.2.8.c The RSRM and its components...are adequately protected, by passive means, against natural environments during transportation and handling.	Pre- and postflight inspection results demonstrated no damage to motor set 360T004 and its components as a result of environmental exposure during transportation.
Demonstrate remove and replace capability of the functional LRU.	3.4.1 The maintenance concept shall be to "remove and replace"...in a manner which will...prevent deterioration of inherent design levels of reliability and operating safety at minimum practical costs.	No LRU anomalies were detected on motor set 360T004; therefore, no LRU changeouts were required.
Certify by inspection all RSRM seals performance.	3.2.1.2 Redundant, verifiable seals shall be provided for each pressure vessel leak path. Both the primary and secondary seals shall provide independent sealing capability through the entire ignition transient and motor burn without evidence of blowby or erosion.	Certified. No motor pressure reached any of the field or case-to-nozzle joint seals. All seals that did have motor pressure reach them showed no evidence of heat effect, erosion, or blowby (Section 4.11.3).
Inspect the factory joint insulation for accommodation to structural deflections and erosion.	3.2.1.2.2.a Sealing shall accommodate any structural deflections or erosion which may occur.	The factory joint insulation remained sealed and accommodated all deflection and erosion (Section 4.11.1).

Objective	CEI Paragraph	Conclusions
Certify that at least one virgin ply of insulation remains over factory joint at end of motor operation.	3.2.1.2.2.d The insulation shall provide one or more virgin ply coverage at end of motor operation. The design shall perform the seal function throughout SRM operation.	Certified. Preliminary inspections indicate adequate factory joint insulation ply coverage. (Section 4.11.1) Detailed insulation inspection results are in Volume III of this report.
Certify that the field and case-to-nozzle joint seals, factory joint insulation, flex bearing seals, ignition system seals, and nozzle internal seals operate within the specified temperature range resulting from natural and induced environments.	3.2.1.2.1.b Field and Nozzle/Case Joint Seals... 3.2.1.2.2.b Factory Joint Insulation... 3.2.1.2.3.b Flex Bearing Seals... 3.2.1.2.4.b Ignition System Seals... 3.2.1.2.5.b Nozzle Internal Seals... shall be capable of operating within a temperature range resulting from all natural and induced environments ...all manufacturing processes, and any motor-induced environments.	Certified. All field joint and case-to-nozzle joint seals, ignition system seals, and internal nozzle seals operated within all induced environments and showed no evidence of heat effects, erosion, or blowby. (Section 4.11.3.) Evaluation indicates no anomalies with the factory joint insulation (Section 4.11.1) or the flex bearing internal seals. A detailed flex bearing evaluation is in Volume V of this report.
Certify that no leakage occurred through the insulation.	3.2.1.2.2.e The insulation used as a primary seal shall be adequate to preclude leaking through the insulation.	Certified. Preliminary inspections showed no evidence of leakage through the factory joint insulation (Section 4.11.1) Detailed postflight evaluations are completed at the H-7 (Clearfield, Utah) facility. Detailed results are in Volume III of this report.
Verify by inspection that no gas leaks occurred between the flex bearing internal components.	3.2.1.2.3.d The flex bearing shall maintain a positive gas seal between its internal components.	Partially verified. Preliminary inspection indicates the flex bearing maintained a positive seal within its internal components. Detailed inspection to be completed during flex bearing acceptance testing.

Objective	CEI Paragraph	Conclusions
Inspect the risers for damage or cracks that would degrade the pressure holding capability of the case.	3.2.1.3.c The case shall contain risers for attaching the ET/SRB aft attach ring as defined in ICD 3-44004. The risers shall be part of the pressurized section of the case and shall not degrade the integrity of the case.	No damage or adverse effects to the ET attach risers were noted during post-test inspection. Preliminary case inspection results are in Section 4.11.2, and the final case evaluation is in Volume II of this report.
Inspect the case segment mating joints for the pin retention device.	3.2.1.3.g The case segment mating joints shall contain a pin retention device.	The 360Q004A (LH) aft factory joint pin retainer band was stretched due to high splashdown loads; however, no pins were lost. The pin retention devices on all other joints performed as designed (Section 4.11.2). Detailed results are in Volume II of this report.
Inspect the flex bearing for damage due to water impact.	3.2.1.4.6 The nozzle assembly shall incorporate a nozzle snubbing device suitable for preventing flex bearing damage resulting from water impact and shall not adversely affect the nozzle assembly vectoring capability.	Preliminary inspections indicate no anomalous conditions on the 360H004B (RH) flex bearing. However, the 360Q004A (LH) snubbing assembly was damaged and the flex bearing suffered excessive splashdown loads due to SRB parachute failure. Final damage assessment (for both flex bearings) will not be known until after acceptance testing is completed.
Inspect the nozzle for the presence of the environmental protection plug.	3.2.1.4.7.a The nozzle assembly shall contain a covering and/or plug to protect the RSRM... during storage after assembly.	Both nozzle assemblies contained an environmental protection plug, which burst into multiple pieces upon motor ignition.
Certify that the environmental protection plug will withstand SSME shutdown, if incurred.	3.2.1.4.7.b The nozzle assembly shall contain a covering and/or plug to protect the RSRM... in the event of an on-pad SSME shutdown prior to SRB ignition.	Not required to certify. No SSME ignition occurred during the aborted countdown, and no SSME shutdown was required during the actual launch sequence.

Objective	CEI Paragraph	Conclusions
Inspect the aft exit cone severance ordnance ring for the presence of the government-furnished detonator cartridge.	3.2.1.4.12.1 The aft exit cone severance ordnance ring shall use one government-furnished detonator cartridge...	A government-furnished detonator cartridge was present on the aft exit cone severance ring. Nominal severance of the nozzle aft exit cone occurred prior to splashdown (Section 4.11.4).
Inspect the aft exit cone severance ordnance cable and brackets for installation.	3.2.1.4.12.4 The aft exit cone severance ordnance cable and brackets shall be installed in accordance with the requirements referenced in ICD 3-44005.	The aft exit cone cable and bracket assembly was inspected and verified to be in accordance with ICD-44005 when the aft exit cone drawing (1U76039 for motor set 360T004) was bought off in the shop traveller by Quality Assurance.
Certify the performance of the nozzle liner. Note: SCN 49 proposes to change the CEI paragraph wedgeout requirement from "greater than 0.250 in. deep" to "yield a positive margin of safety".	3.2.1.4.13 The nozzle flame front liners shall prevent the formation of: a. pockets greater than 0.250 in. deep (as measured from the adjacent non-pocketed areas), b. wedgeouts greater than 0.250 in. deep, c. prefire anomalies except as allowed by TWR-16340.	Certified. No nozzle flame front liner erosion pockets greater than 0.25 in. were noted. All wedgeouts observed occurred postburn and do not affect liner performance. No prefire anomalies were found (Section 4.11.4).
Inspect the ignition system seals for evidence of hot gas leakage.	3.2.1.5.a The ignition system shall preclude hot gas leakage during and subsequent to motor ignition.	The 360Q004A (LH) adapter-to-igniter outer gasket forward face sustained a cut on the secondary seal at 285 deg (see IFA STS-30-M-2 in Section 4.1). However, no pressure reached this seal, and no ignition system seals, gaskets, or sealing surfaces showed evidence of heat effects, erosion, or blowby (Section 4.11.3).
Certify that the S&A device has the capability to provide direct visual position indication in both the safe and armed positions.	3.2.1.5.1.f The S&A device shall... provide direct visual position indication in both the safe and armed positions.	Certified. The S&A device is designed so that direct visual position verification is possible in both the safe and armed position.

Objective	CEI Paragraph	Conclusions
Verify the use of two GFE SIIs in the S&A device.	3.2.1.5.1.1 The S&A device shall...use two GFE SIIs.	Two GFE SIIs were used in each S&A device, as specified in the S&A device drawings.
Inspect the igniter for evidence of debris formation or damage.	3.2.1.5.2 ...the igniter hardware and materials shall not form any debris...	Preliminary indications show no evidence of any igniter debris formation. A complete evaluation is in Volume VI of this report.
Certify that the GEI can monitor the temperature of the SRBs while on the ground at the pad.	3.2.1.6.2.3 The GEI shall monitor the temperature of the SRBs while on the ground...	Certified. Extensive monitoring of the GEI was done during the countdown to access the SRM thermal environment and LCC. Detailed results are discussed in Section 4.8.
Inspect the seals for visible degradation from motor combustion gas.	3.2.1.8.1.1.d Insulation shall protect primary and secondary seals from visible degradation from motor combustion gas.	All motor combustion gas was contained by the insulation J-leg on the six field joints and the poly-sulfide adhesive on the two case-to-nozzle joints. No seals showed evidence of motor combustion gas degradation (Section 4.11.1).
Certify by inspection that the insulation met all performance requirements.	3.2.1.8.1.1.e The insulation shall...meet all performance requirements under worst manufacturing tolerances and geometry changes during and after assembly and throughout motor operation.	Certified. Preliminary inspection indicates the insulation met all the performance requirements (Section 4.11.1). Detailed inspection results are in Volume III of this report.
Inspect insulation material for shedding of fibrous or particulate matter.	3.2.1.8.1.1.f Insulation materials shall not shed fibrous or particulate matter during assembly which could prevent sealing.	No shedding of fibrous or particulate matter during assembly was detected (Section 4.11.1 of this volume and Volume III of this report).
Inspect the joint insulation for evidence of slag accumulation.	3.2.1.8.1.1.g The joint insulation shall withstand slag accumulation during motor operation.	No evidence of insulation damage due to slag accumulation was observed (Section 4.11.1 of this volume and Volume III of this report).

Objective	CEI Paragraph	Conclusions
Inspect the TPS to ensure that there was no environmental damage to the RSRM components.	3.2.1.8.2 TPS shall insure that the mechanical properties of the RSRM components are not degraded when exposed to the environments...	Postflight inspection revealed excellent TPS condition with no violation of any NSTS debris criteria. No thermal degradation of any RSRM component was noted (Section 4.8.3).
Inspect for thermal damage to the igniter chamber and the adapter metal parts.	3.2.1.8.3 The igniter insulation shall provide thermal protection for the main igniter chamber and adapter metal parts to ensure that RSRM operation does not degrade their functional integrity or make them unsuitable for refurbishment.	Preliminary investigation revealed no thermal damage to the igniter due to lack of insulation functionality. Igniter details are in Volume VI of this report.
Certify that the case components are reusable.	3.2.1.9.a Reusability of...Case--Cylindrical segments, stiffener segments, attach segments, forward and aft segments (domes), stiffener rings, clevis joint pins.	Cannot be completely certified at this time. All case component previous use history is in Section 4.2. No damage was noted to any cylindrical segments, attach segments, forward and aft domes, clevis joint pins, or the stiffener rings and segments on 360H004B (RH). The 360Q004A (LH) stiffener segments and rings suffered damage due to splashdown loads (Section 4.11.2). Reuse criteria are not established until after refurbishment. Detailed case component inspection results are in Volume II of this report.
Certify that the nozzle metal parts are reusable.	3.2.1.9.b Reusability of...Nozzle metal parts--boss attach bolts.	Cannot be completely certified at this time. All nozzle metal part previous use history is in Section 4.2. Preliminary observations showed no damage or corrosion to any nozzle reusable metal parts (Section 4.11.4). Any nozzle metal parts that were determined not to be reusable are discussed in Volume V of this report.

Objective	CEI Paragraph	Conclusions
Certify through flight demonstration and a postflight inspection that the flex bearing is reusable.	3.2.1.9.c Reusability of...flex bearing system--Reinforced shims and end rings, elastomer materials.	Cannot be completely certified at this time. The flex bearing previous use history is in Section 4.2. The 360Q004A (LH) flex bearing experienced high splashdown loads due to SRB parachute anomalies and remained in the snubbed position. No apparent anomalies were observed with the 360H004B (RH) flex bearing (Section 4.11.4). Final reuse criteria cannot be determined until after flex bearing acceptance testing.
Certify that the igniter components are reusable.	3.2.1.9.d Reusability of...igniter--Chamber, adapter, igniter port, special bolts.	Cannot be completely certified at this time. All igniter component previous use history is in Section 4.2. Preliminary postflight inspection revealed nothing that would adversely affect reuse of any igniter part. Detailed inspection results are in Volume VI of this report.
Certify by inspection that the S&A device is reusable.	3.2.1.9.e Reusability of...safe & arm device	Cannot be completely certified at this time. The S&A device previous use history is in Section 4.2. Preliminary postflight inspection revealed nothing that would adversely affect reuse of any S&A device part. Detailed inspection results are in Volume VI of this report.
Certify by inspection that the OPTs are reusable.	3.2.1.9.f Reusability of...Transducers	Cannot be completely certified at this time. The OPT previous use history is in Section 4.2. All pressure data and preliminary postflight inspection indicate no issues that would adversely affect OPT reuse. Final OPT reuse criteria are established after refurbishment and calibration by the metrology lab.

Objective	CEI Paragraph	Conclusions
Inspect the case factory joint external seal for moisture.	3.2.1.12 The factory joint external seal shall prevent the prelaunch intrusion of rain into the factory joints from the time of assembly of the segment until launch... The factory joint seal shall remain intact through flight and, as a goal, through recovery.	The external weatherseal protected the case adequately from assembly until launch. Damage to the aft segment stiffener-to-stiffener and stiffener-to-dome weatherseals (IFA STS-30-M-1) occurred at splashdown. A detailed weatherseal evaluation is in Volume III of this report.
Inspect the hardware for damage or anomalies as identified by the FMEA.	3.2.3 The design shall minimize the probability of failure, taking into consideration the potential failure modes identified and defined by failure modes effects analyses.	No hardware damage or anomalies identified by FMEA were found. Specific inspection results are in the individual component volumes of this report.
Determine the adequacy of the design safety factors, relief provisions, fracture control, and safe-life and/or fail-safe characteristics.	3.2.3.1 The primary structure, thermal protection, and pressure vessel subsystems shall be designed to preclude failure by use of adequate design safety factors, relief provisions, fracture control, and safe-life and/or fail-safe characteristics.	Postflight inspections verified adequate design safety factors, relief provisions, fracture control, and safe-life and/or fail-safe characteristics for the primary structure, thermal protection, and pressure vessel subsystems as documented in this volume and the component volumes of this report.
Determine the adequacy of subsystem redundancy and fail-safe requirements.	3.2.3.2 The redundancy requirements for subsystems...shall be established on an individual subsystem basis, but shall not be less than fail-safe...	No primary subsystem failure was noted; thus, subsystem redundancy and fail-safe requirements were not determined.
Verify that storage/age control monitoring of the RSRM and its subsystems is being accomplished.	3.2.9.2 Storage monitoring of the RSRM and its subsystems shall require only electrical grounding and visual inspection.	Electrical grounding of the RSRM and its subsystems is verified through the OMRSD requirement B47 GEN 70.

Objective	CEI Paragraph	Conclusions
Inspect the identification numbers of each reusable RSRM part and material for traceability.	3.3.1.5 Traceability shall be provided by assigning a traceability identification to each RSRM part and material and providing a means of correlating each to its historical records...	Inspection numbers for traceability of each RSRM part and material are provided and are maintained in the Automatic Data Collection and Retrieval computer system. The past history of all RSRM parts used is in Section 4.2.
Verify the structural safety factor of the case-to-insulation bond.	3.3.6.1.1.2.a The structural safety factor for the case/insulation bonds shall be 2.0 minimum during the life of the RSRM.	Verification of a 2.0 safety factor cannot be done by inspection; however, flight performance verified a safety factor of at least 1. Case-to-insulation bond and adhesive bond safety factor of 2.0 are verified by analysis, documented in TWR-16961.
Verify by inspection the remaining insulation thickness of the case insulation.	3.3.6.1.2.2 The case insulation shall have a minimum design safety factor of 1.5, assuming normal motor operation, and 1.2, assuming loss of a castable inhibitor.	Detailed postflight insulation inspections are performed at the Clearfield H-7 facility. Results and verification of safety factors are in Volume III of this report.
(Objective continued)	3.3.6.1.2.3 Case insulation adjacent to metal part field joints, nozzle/case joints, and extending over factory joints shall have a minimum safety factor of 2.0.	See above statement.
(Objective continued)	3.3.6.1.2.4 Case insulation in sandwich construction regions (aft dome and center segment aft end) shall have a minimum safety factor of 1.5.	See above statement.
(Objective continued)	3.3.6.1.2.6 Insulation performance shall be calculated using actual pre- and post-motor operation insulation thickness measurements.	Standard measurement techniques were used for final evaluation, as discussed in Volume III of this report.

Objective	CEI Paragraph	Conclusions
Verify by inspection the remaining nozzle ablative thicknesses.	3.3.6.1.2.7 The minimum design safety factors for the nozzle assembly primary ablative materials shall be as listed below...(Values not included here because detailed results are not available at this writing.)	Preliminary inspections indicate nozzle ablative thicknesses were within design safety factors (Section 4.11.4). Detailed results are in Volume V of this report.
Verify the nozzle safety factors.	3.3.6.1.2.8 The nozzle performance margins of safety shall be zero or greater...	The nozzle performance margins of safety are discussed in Volume V of this report.
Inspect metal parts for presence of stress corrosion.	3.3.8.2.b The criteria for material selection in the design to prevent stress corrosion failure of fabricated components shall be in accordance with MSFC-SPEC-522 and SE-019-094-2H.	No evidence of stress corrosion was found during post-test case inspection. Details are in Volume II of this report.

3.3 RECOMMENDATIONS

Following are the recommendations made concerning flight set 360T004. Additional background information can be found in the referenced sections.

3.3.1 General Recommendations

It is recommended to continue the use of DFI on future RSRM flight motors. The DFI will be used to verify safety margins, verify CEI specification requirements, validate models, and provide additional data for engineering evaluation.

3.3.2 Aero/Thermal Recommendations

(Additional information in Section 4.8.4.)

3.3.2.1 Debris Problem. The ice/debris team recommended either removing the GEI labels (which are covered with a thick layer of epoxy) or replacing them with stencils on future flights.

3.3.2.1 GEI Prediction Model Improvement. Additional model enhancement is recommended for the ET attach ring, field joint, factory joint, systems tunnel, igniter, and nozzle regions. These tasks would be encompassed by the global model effort.

3.3.2.3 GEI Prediction Model Availability. It is recommended that all above-mentioned models (including the three-dimensional SRM model) be made available for use at Marshall Space Flight Center (MSFC). This would allow Thiokol thermal personnel the opportunity to support launch countdowns at the Huntsville Operations Support Center (HOSC) with real-time PMBT, GEI, and component predictions updates. This would also allow MSFC thermal personnel the same modeling capabilities.

3.3.2.4 Aft Skirt Conditioning. It is recommended that the aft skirt conditioning gas temperature be monitored as it enters the aft skirt compartment. During cold weather this would allow the use of a higher operating temperature and, at the same time, not violate the 115°F maximum within the compartment.

3.3.2.5 GEI Accuracy. It is recommended that the GEI data collection accuracy be increased by reducing the gage range and increasing the digital word length. The real fidelity of the KSC ground support equipment (GSE) could then be quantified and conceivably replaced if determined to be inadequate.

3.3.2.6 Local Chilling. Based on data from 360L003 and 360T004 (STS-29R and -30R), local cooling is minimal. It is recommended that a method be developed to accurately quantify the chill effect.

3.3.2.7 IR Measurements. It is recommended that in future flights half-hour STI-versus-GEI direct comparisons be made and documented. (Comparisons with GEI are within acceptable margins for STI data but are questionable and unpredictable for IR gun data.)

4

FLIGHT EVALUATION RESULTS AND DISCUSSION

4.1 RSRM IN-FLIGHT ANOMALIES (FEWG report Paragraph 2.1.2)

The summary sheets for the three IFAs pertaining to flight set 360T004 follow. The IFA description, discussion, conclusion, corrective actions, and closeout signature of the Level II PCRB chairman are included. No IFA was considered to be a flight constraint.

4.2 RSRM CONFIGURATION SUMMARY (FEWG report Paragraph 2.1.3.2)

4.2.1 SRM Reuse Hardware

The case segment reuse history for 360Q004A and 360H004B is shown in Figures 4.2-1 and 4.2-2, respectively. Figures 4.2-3 through 4.2-6 show the LH and RH igniter and nozzle part reuse history, respectively. Tables 4.2-1 and 4.2-2 list nozzle snubber segment reuse. Stiffener ring reuse is detailed in Figure 4.2-7 and Table 4.2-3.

4.2.2 Approved RSRM Changes and Hardware Changeouts

A summary of the changes made since 360L003 (STS-29) is below. Complete descriptions of these changes are documented in Morton Thiokol document TWR-19395a (Redesigned Solid Rocket Motor Flight Readiness Review--Level III)

Seven Class I hardware changes since 360L003 (STS-29):

- Stiffener stub ethylene-propylene-diene monomer (EPDM) rubber elimination--ECP SRM-1645. Thermal analysis shows the K5NA which is applied over the stiffener stubs is an adequate insulator. Postflight inspection has verified no EPDM thermal erosion.
- Vent port plug replacement--ECP SRM-1632R5. Replaced adjustable vent port plug with a custom fit vent port plug to ensure proper sealing due to discrepant condition in the LH center field joint. (Discrepancy noted in DR 169706.)
- DFI elimination--ECP SRM-1737. 360T004 designated as nondevelopmental flight. No DFI required.
- Internal insulation thickness increase--ECP SRM-1739. Minor increase to case insulation thickness to raise safety factor from 1.45 to 1.5; greatest increase was 0.17 inch.
- New heater element material--ECP SRM-1848. Old material no longer available; new material is essentially the same. Certified on QM-8 and Technical Evaluation Motor No. 1.

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CONCLUSIONS:

. BONDING SURFACE CONTAMINATION WAS NOT THE CAUSE OF THE FACTORY
. JOINT WEATHERSEAL UNBONDS. DATA RECENTLY COLLECTED INDICATE THAT
. THE TENSILE ADHESION VALUES OF STRUCTURAL ADHESIVE BONDS ARE
. SIGNIFICANTLY REDUCED WHEN THE BONDING SURFACES ARE TOO SMOOTH
. (REFERENCE MTI DOCUMENT TWR-19301). CASE SURFACE SMOOTHNESS,
. COMBINED WITH THE EXCESSIVE SPLASHDOWN VELOCITY, CONTRIBUTED TO
. REDUCED WEATHERSEAL BOND STRENGTH AND THE SUBSEQUENT ADHESIVE
. FAILURES SEEN ON THE LEFT SRM FACTORY JOINTS.

CORRECTIVE ACTION:

. PLANNING BEING IMPLEMENTED TO VERIFY AND ENFORCE MINIMUM
. SURFACE ROUGHNESS OF 70-MICROINCHES R SUBSCRIPT A TO
. PROVIDE THE SURFACE TEXTURE NECESSARY TO ENSURE OPTIMUM
. TENSILE ADHESION STRENGTH. PLANNED EFFECTIVITY IS FOR
. RSRM-10. CASE REFURBISHMENT SPECIFICATION (STW7-2744)
. CHANGE ALLOWING GRITBLAST OF ENTIRE BONDING SURFACE IS IN
. SIGN-OFF. REQUIREMENTS FOR MINIMUM CONSCAN READINGS VALUES ON
. THESE SURFACES ARE CURRENTLY IN PLACE.

EFFECTIVITY: STS-30

LEVEL II IMPACTS AUTHORIZED BY THIS DIRECTION: --WEIGHT: NONE,
--SCHEDULE: NONE, --COST: NONE.

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CHANGE TITLE
LEFT SRM IGNITER OUTER GASKET SECONDARY SEAL NICK/GOUGE (IFA)

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
STS-30 ANOMALY TRACKING LIST FLIGHT PR STS-30-M-2	
INITIATED BY: MSFC-EP73/E.CARRASQUILLO	SUBMITTED BY: MSFC-SA01/G.P. BRIDWELL

LEVEL II BASELINE CHANGE DIRECTION: OPR: WA MBE/AR
BOARD:DAILY

THIS PRCBD IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-30 ANOMALY NUMBER STS-30-M-2 PER THE FOLLOWING RATIONALE:

DISCUSSION:
POSTFLIGHT HARDWARE INSPECTION OF THE LEFT SRM IGNITER REVEALED A NICK/GOUGE AT 285 DEGREES ON THE SECONDARY SEAL OF THE OUTER GASKET. THE DAMAGE IS LOCATED ON THE GASKET FORWARD FACE, PASSING ACROSS ABOUT 50% OF THE CROWN SURFACE AND EXTENDING RADIALLY (AT A DIAGONAL) INBOARD. DIMENSIONS OF THE NICK/GOUGE ARE APPROXIMATELY 0.10" LONG X 0.01" WIDE X 0.03" DEEP. THIS PARTICULAR GASKET (S/N 000061), IS A REUSED ITEM (PREVIOUSLY USED ON JOINT ENVIRONMENT SIMULATOR, JES-3B). THE GASKET ACCEPTANCE WAS IN ACCORDANCE WITH THE CORRECT IGNITER INSPECTION CRITERIA, STW7-2790. THE IGNITER OUTER JOINT SEAL PASSED BOTH THE HIGH AND LOW PRESSURE LEAK TESTS. DURING ASSEMBLY TWO SEPARATE GOUGES IN THE METAL RETAINER OF THE GASKET AT 230 DEGREES AND 284 DEGREES WERE NOTED AND WRITTEN ON A DISCREPANCY REPORT (DR), HOWEVER, NO INDICATION OF A NICK OR GOUGE IN THE SEAL SURFACES WERE OBSERVED. THE DR ENGINEERING DISPOSITION WAS TO "USE AS IS". THE "SEALS" INVESTIGATION TEAM BELIEVES THE CUT PROBABLY OCCURRED BEFORE INSTALLATION AT MTI FINAL ASSEMBLY AND RESULTED FROM COMBINED EFFECTS OF INADEQUATE GASKET HANDLING/PACKAGING/STORAGE PROCEDURES AND INADEQUATE FINAL ASSEMBLY INSPECTION.

AUTHORIZATION: Douglas R Cooke — 06/27/89

CHAIRMAN, LEVEL II PRCB — DATE

BARS RPT 8020 BARS NSTS FORM 4003

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CONCLUSIONS:
. ALTHOUGH THE EXACT SOURCE OF THE O-RING DAMAGE CANNOT BE
. PINPOINTED, THE FOREMENTIONED ASSEMBLY/HANDLING SCENARIO
. IS THE MOST REASONABLE/ACCEPTED CONCLUSION. NO HISTORY
. EXISTS ON THIS TYPE OF ANOMALY.

CORRECTIVE ACTION:
. THE DISCUSSED INADEQUACIES HAVE BEEN CORRECTED BY IMPLEMENTING
. IMPROVED HANDLING/PACKAGING/STORAGE PROCEDURES PREVENTING
. GASKET DAMAGE AFTER RECEIVING INSPECTION AND TIGHTENING
. PREASSEMBLY INSPECTION REQUIREMENTS, EFFECTIVE 360H005
. (STS-28) AND SUBSEQUENT FLIGHTS. THE RE-INSPECTION OF ALL
. EXISTING MTI GASKETS HAS SHOWN NO DISCREPANT PARTS SINCE
. IMPLEMENTATION OF THESE CORRECTIVE ACTION. UPDATED SHIPPING,
. HANDLING, PACKAGING, STORAGE AND INSPECTION OPERATIONS FOR
. NEW AND REFURBISHED GASKETS RECEIVED FROM VENDOR ARE ALSO
. IN PLACE.

EFFECTIVITY: STS-30

LEVEL II IMPACTS AUTHORIZED BY THIS DIRECTION: --WEIGHT: NONE,
--SCHEDULE: NONE, --COST: NONE.

PCIN 62057 PRCBD S62057	NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 02 PRCB DATE 06/27/89

CHANGE TITLE
LEFT SRM NOZZLE SNUBBER ASSEMBLY DISPLACED INTO THE FLEX BEARING/THROAT HOUSING CAVITY (IFA)

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
STS-30 ANOMALY TRACKING LIST FLIGHT PR# STS-30-M-3	
INITIATED BY: MSFC-EP73/E.CARRASQUILLO	SUBMITTED BY: MSFC-SA01/G.P. BRIDWELL

LEVEL II BASELINE CHANGE DIRECTION: OPR: WA MBE/AR
BOARD:DAILY

THIS PRCBD IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-30 ANOMALY NUMBER STS-30-M-3 PER THE FOLLOWING RATIONALE:

DISCUSSION:

. POSTFLIGHT HARDWARE INSPECTION REVEALED THAT THE LEFT SRM NOZZLE SNUBBER SUPPORT RING WAS DISPLACED FORWARD AND WEDGED INTO THE AFT END RING, PREVENTING THE NOZZLE FROM RETURNING TO THE NULL POSITION. EFFORTS TO MOVE/DE-SNUB THE NOZZLE AT KSC PROVED FUTILE. FOLLOWING DEMATE OF THE LEFT NOZZLE-TO-CASE FIELD JOINT, THE NOZZLE ASSEMBLY WAS PREPARED TO BE RETURNED TO THE H7 FACILITY IN CLEARFIELD, UTAH. ALL BOLTS CONNECTING THE SNUBBER SUPPORT RING TO THE FORWARD EXIT CONE ARE SHEARED-OFF. THE SUPPORT RING IS DISPLACED TEN INCHES FORWARD AT 248 DEGREES AND IS POSITIONED NORMALLY AT 68 DEGREES. SNUBBER SUPPORT RING AND SNUBBER SEGMENTS ARE WEDGED BETWEEN THE FORWARD EXIT CONE AND THE BEARING END RING, CAUSING THE FLEX-BEARING TO BE STRETCHED FORWARD APPROXIMATELY 3/4 INCH. ONE SNUBBER AXIAL SHIM RETAINER IS MISSING AT 217 DEGREES. BOLT HEADS ON AXIAL SHIM RETAINERS ARE SHEARED FROM 191 TO 334 DEGREES DUE TO CONTACT WITH THE FLEX BEARING AFT END RING. FINAL ASSESSMENT OF FLEX-BEARING ASSEMBLY DAMAGE AND NOZZLE PARTS REUSABILITY WILL BE MADE UPON COMPLETION OF DISASSEMBLY/ INSPECTION AT CLEARFIELD.

AUTHORIZATION: Douglas R Cooke

CHAIRMAN, LEVEL II PRCB

06/27/89
DATE

BARS RPT 8020 BARS NSTS FORM 4003

PCIN 62057	NATIONAL SPACE SHUTTLE PROGRAM DOCUMENT CONTINUATION SHEET	PAGE 02 OF 02
S62057		OFFICE:
DOCUMENT: S62057		DATE 06/27/89

CONCLUSIONS:
. THE STS-30 LEFT SRM NOZZLE HARDWARE DAMAGE WAS CAUSED BY
. HIGHER THAN NORMAL WATER IMPACT LOADS DUE TO EXCESSIVE
. SRB DESCENT/SPLASHDOWN VELOCITY, RESULTING FROM ANOMALOUS
. LEFT SRB PARACHUTE BEHAVIOR (REFER TO STS-30-B-1).

CORRECTIVE ACTION:
. NO SRM CORRECTIVE ACTI-N IS BEING CONSIDERED. MTI AND SPC
. DE-SNUB TOOLING AND PF CEDURES CALLED OUT IN THE KSC DIS-
. ASSEMBLY MANUAL ARE TO BE OMITTED. ALL FUTURE NOZZLE
. DE-SNUBBING OPERATION WILL BE ACCOMPLISHED AT CLEARFIELD.

EFFECTIVITY: STS-30

LEVEL II IMPACTS AUTHORIZED BY THIS DIRECTION: --WEIGHT: NONE,
--SCHEDULE: NONE, --COST: NONE.

PCIN 62055	NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 02
PRCBD S62055		PRCB DATE 06/27/89

CHANGE TITLE
LEFT SRM FACTORY JOINT WEATHERSEAL AFT EDGE UNBONDS (IFA)

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
STS-30 ANOMALY TRACKING LIST FLIGHT PR# STS-30-M-1	
INITIATED BY: MSFC-EP73/E.CARRASQUILLO	SUBMITTED BY: MSFC-SA01/G.P. BRIDWELL

LEVEL II BASELINE CHANGE DIRECTION: OPR: WA MBE/MLB
BOARD:DAILY

THIS PRCBD IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-30 ANOMALY NUMBER STS-30-M-1 PER THE FOLLOWING RATIONALE:

DISCUSSION:
POSTFLIGHT HARDWARE INSPECTION AT KSC SHOWS LEFT SRM AFT SEGMENT STIFFENER-TO-STIFFENER FACTORY JOINT WEATHERSEAL EXHIBITED INTERMITTENT AFT EDGE UNBONDS AROUND THE CIRCUMFERENCE. ALSO EXHIBITING A SINGLE, LOCALIZED DEBOND ALONG THE WEATHERSEAL AFT EDGE WERE THE AFT SEGMENT STIFFENER-TO-DOME FACTORY JOINT AND THE FORWARD CENTER SEGMENT FACTORY JOINT. ALL OF THE UNBONDS WERE CAUSED BY AN ADHESIVE FAILURE BETWEEN THE CHEMLOK 205 (PRIMER) AND THE CASE SURFACE. MOST OF THE AFT SEGMENT UNBONDS EXTENDED AXIALLY TO THE PIN RETAINER BAND, HOWEVER THE FORWARD CENTER UNBOND DID NOT EXTEND TO THE PIN RETAINER BAND. NO HEAT EFFECTS OR SOOTING WERE FOUND UNDER THE DISPLACED WEATHERSEAL AFT EDGES, BUT MILD RUST CORROSION WAS SEEN ON METAL SURFACE EXPOSED TO SEAWATER. INVESTIGATION HAS RULED OUT CONTAMINATION AS THE CAUSE FOR UNBONDS. CONSCAN READINGS FOR ALL UNBONDED JOINTS WERE WITHIN CURRENT PLANNING REQUIREMENTS. REVIEW OF LEFT AFT AND FORWARD CENTER SEGMENT INSULATED CASE LOGS REVEALED NO DISCREPANT OR ANOMALOUS CONDITIONS, ALTHOUGH FACTORY JOINT AFT SURFACE FINISH READINGS ON THE LEFT SRM AFT SEGMENT ARE AMONG THE LOWEST OBSERVED. WEATHERSEAL DAMAGE OCCURRED ONLY ON THE LEFT SRM, KNOWN TO HAVE EXPERIENCED SIGNIFICANTLY GREATER THAN NORMAL WATER IMPACT DUE TO EXCESSIVE DESCENT/SPLASHDOWN VELOCITY RESULTING FROM ANOMALOUS PARACHUTE BEHAVIOR (REFER TO STS-30-B-1).

AUTHORIZATION:
Douglas R Cooke
CHAIRMAN, LEVEL II PRCB

06/27/89
DATE

BARS RPT 8020 BARS NSTS FORM 4003

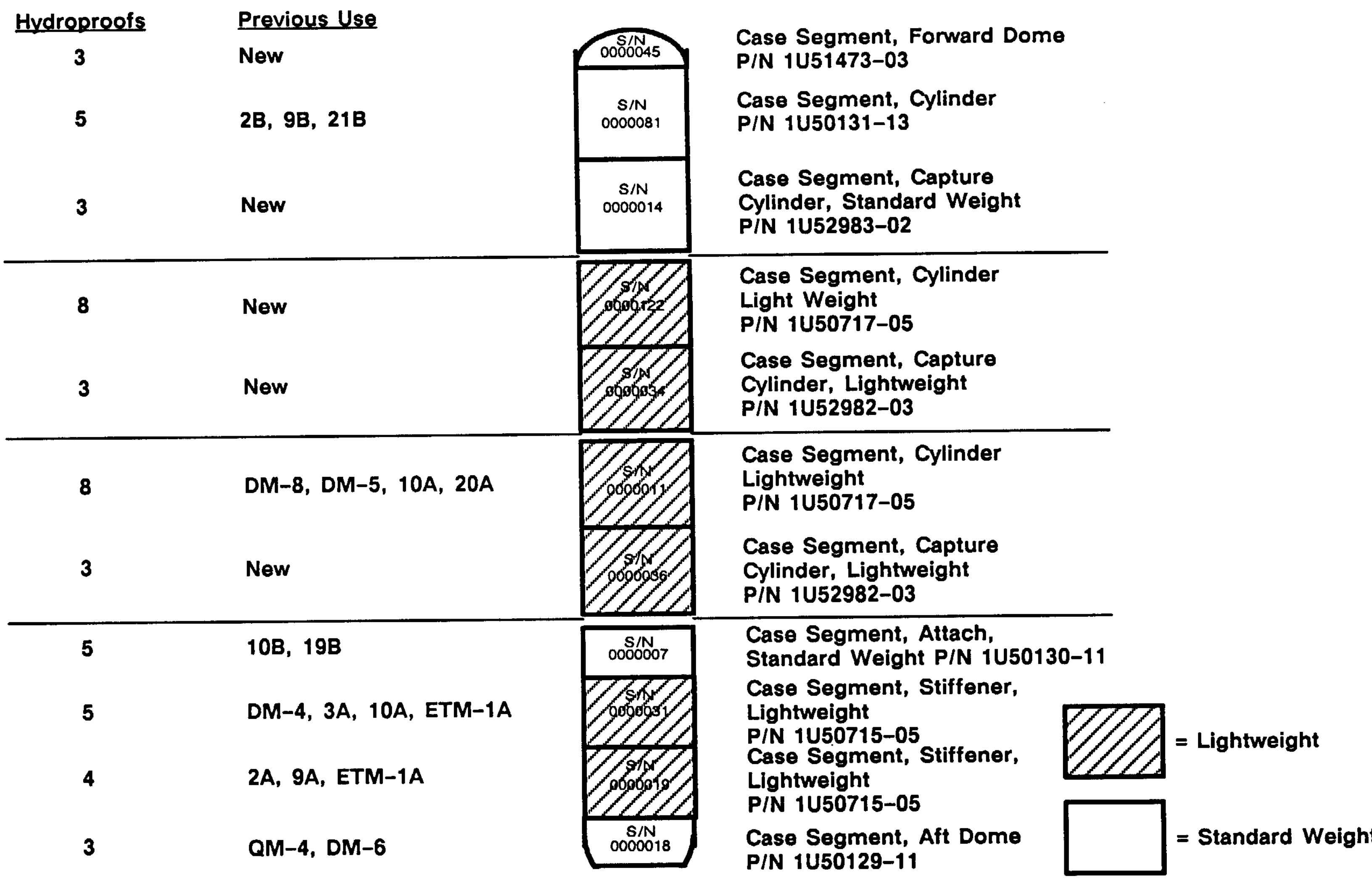
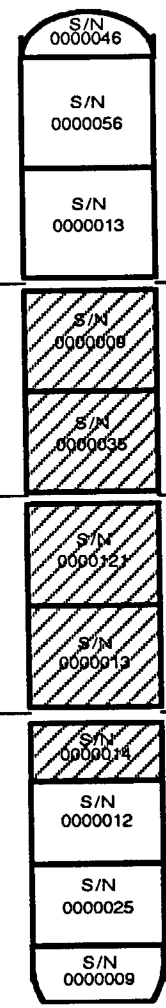


Figure 4.2-1. Case Segment Reuse History—360Q004A (LH motor)

A023173a



Hydroproofs	Previous Use		
3	New	S/N 0000046	Case Segment, Forward Dome P/N 1U51473-03
6	QM-1, 3B, 13A, 22A	S/N 0000056	Case Segment, Cylinder P/N 1U50131-13
4	New	S/N 0000013	Case Segment, Capture Cylinder, Standard Weight P/N 1U52983-02
4	6B, 16B, ETM-1A	S/N 0000008	Case Segment, Cylinder Lightweight P/N 1U50717-05
3	New	S/N 0000035	Case Segment, Capture Cylinder, Lightweight P/N 1U52982-03
10	QM-6	S/N 0000121	Case Segment, Cylinder Lightweight P/N 1U50717-05
4	QM-6	S/N 0000013	Case Segment, Capture Cylinder, Lightweight P/N 1U52982-03
5	14B, 24B, DM-9	S/N 0000014	Case Segment, Attach, Lightweight P/N 1U50130-11
5	21A, DM-9	S/N 0000012	Case Segment, Stiffener, Standard Weight P/N 1U50185-08
4	13A, 22B	S/N 0000025	Case Segment, Stiffener, Standard Weight P/N 1U50185-08
14	1A, 10A	S/N 0000009	Case Segment, Aft Dome P/N 1U50129-11

(hatched) = Lightweight
(open) = Standard Weight

Figure 4.2-2. Case Segment Reuse History—360H004B (RH motor)

A023174a

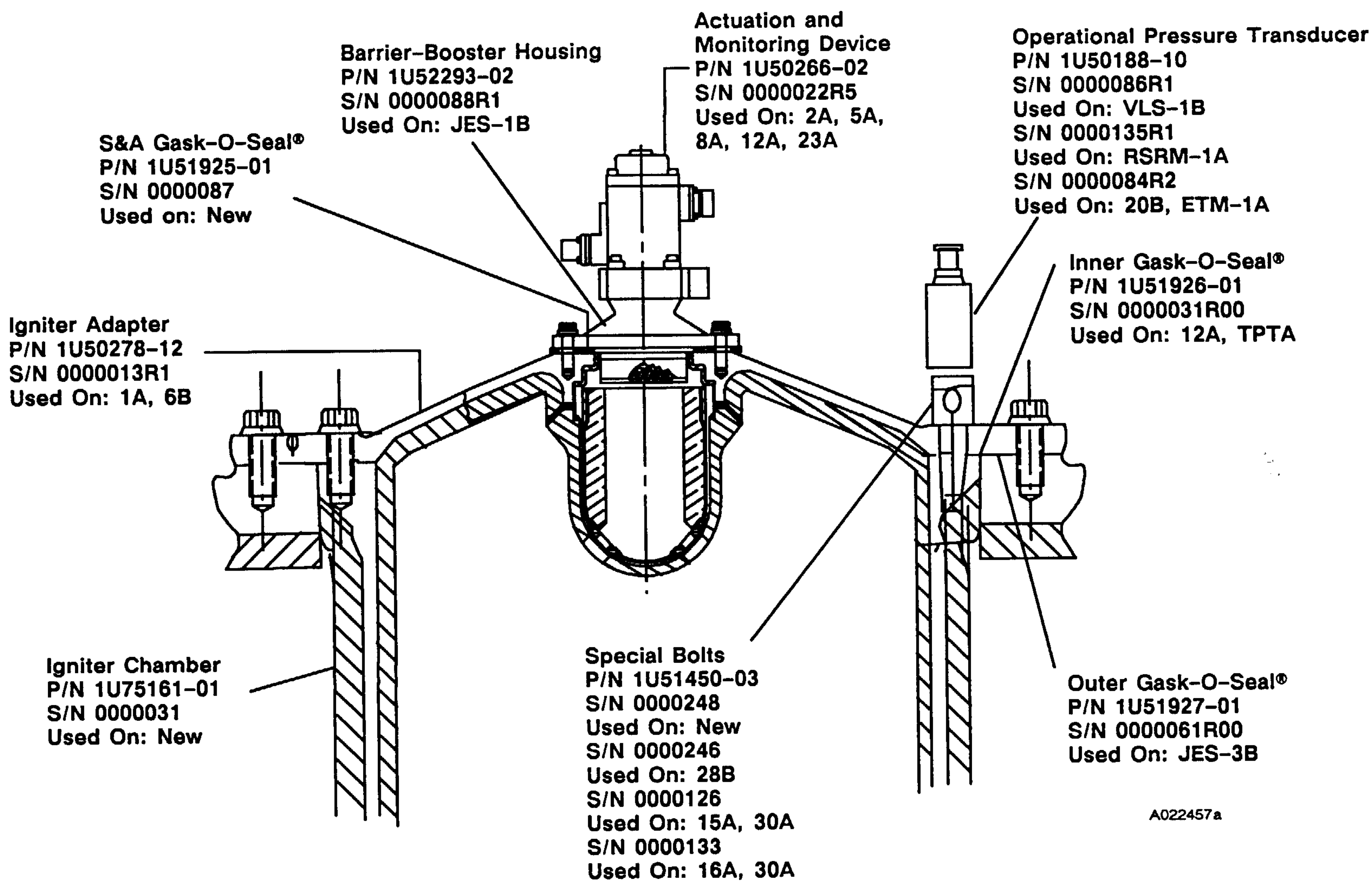


Figure 4.2-3. Previous Use History—LH Igniter

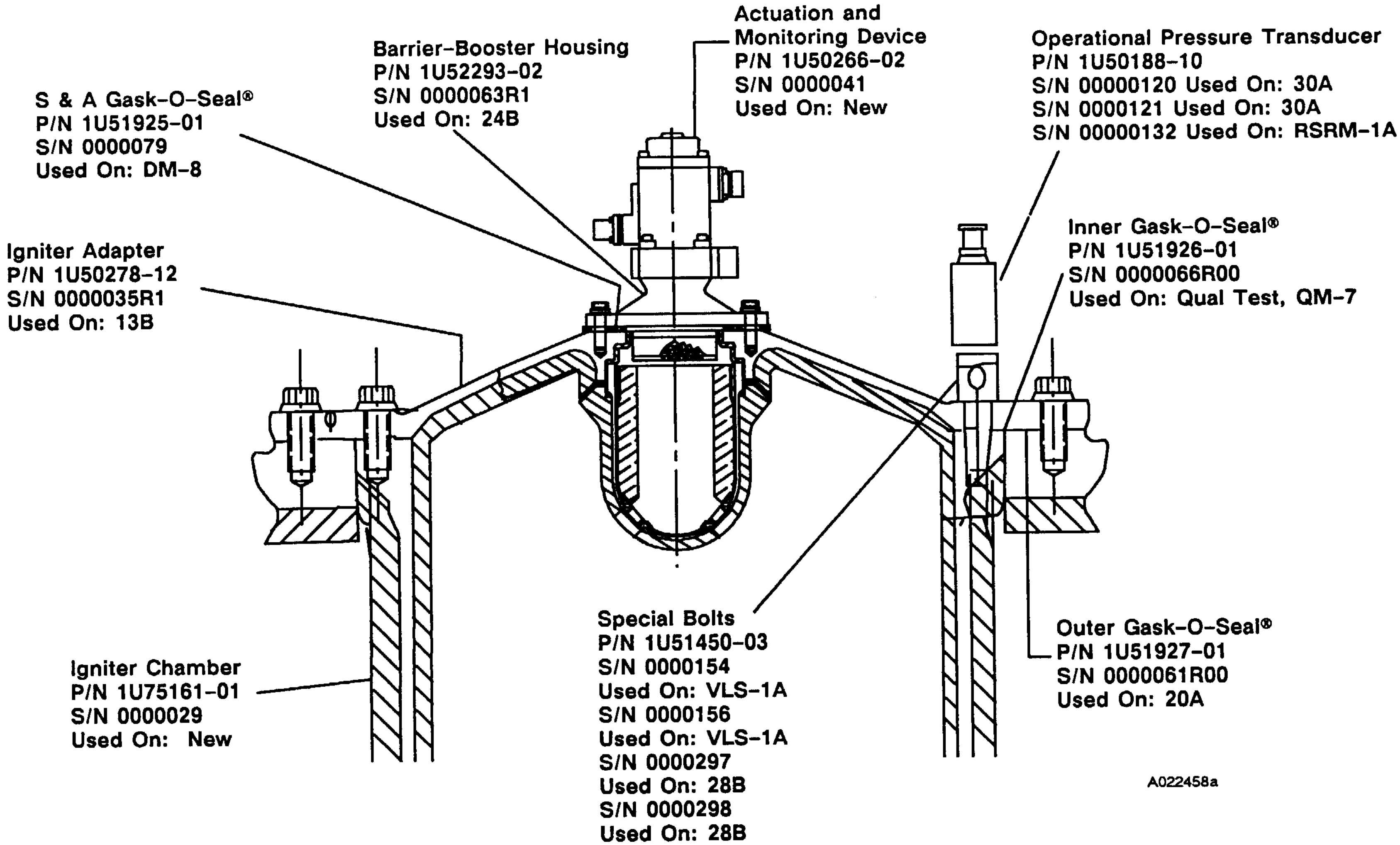
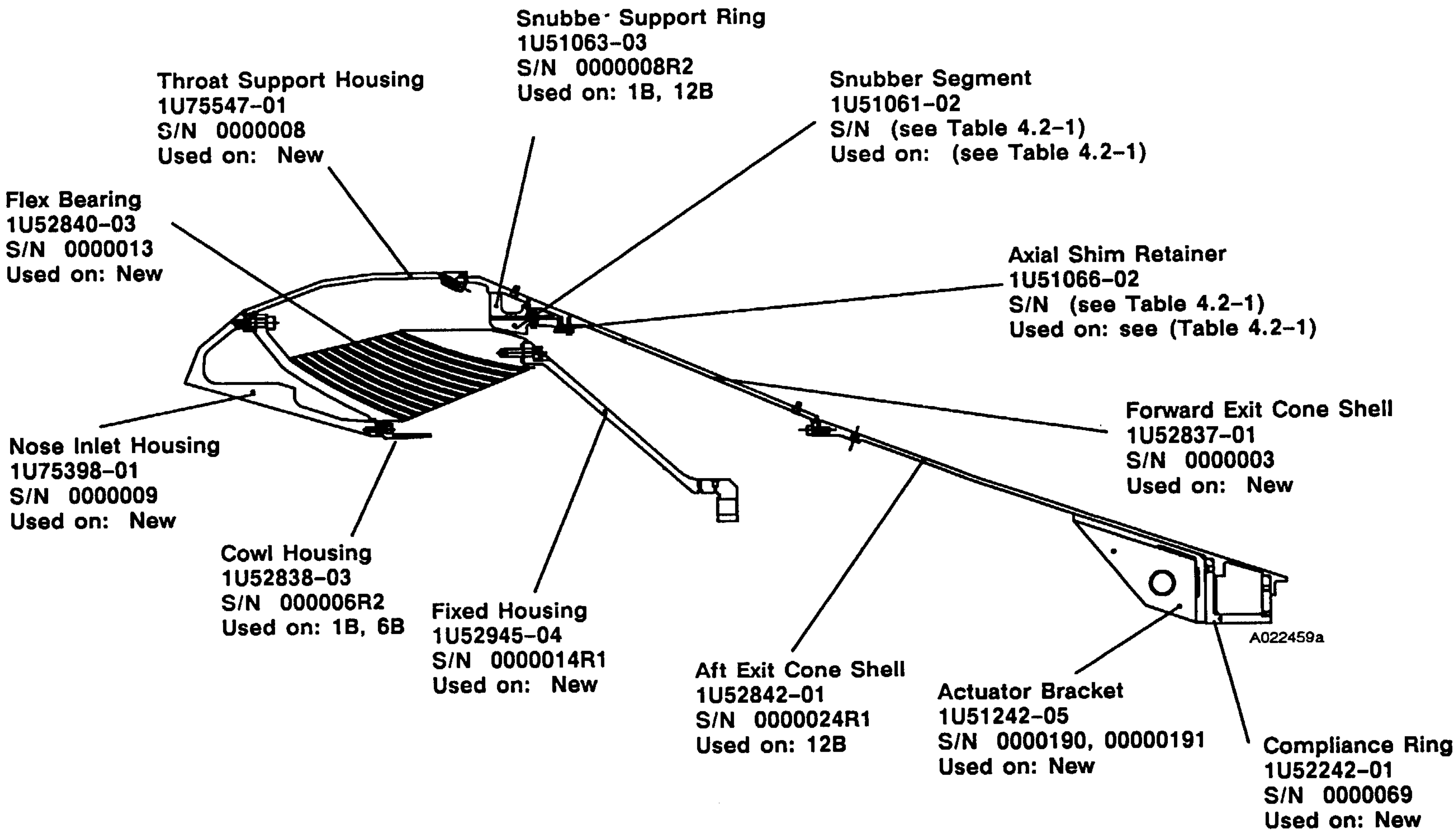
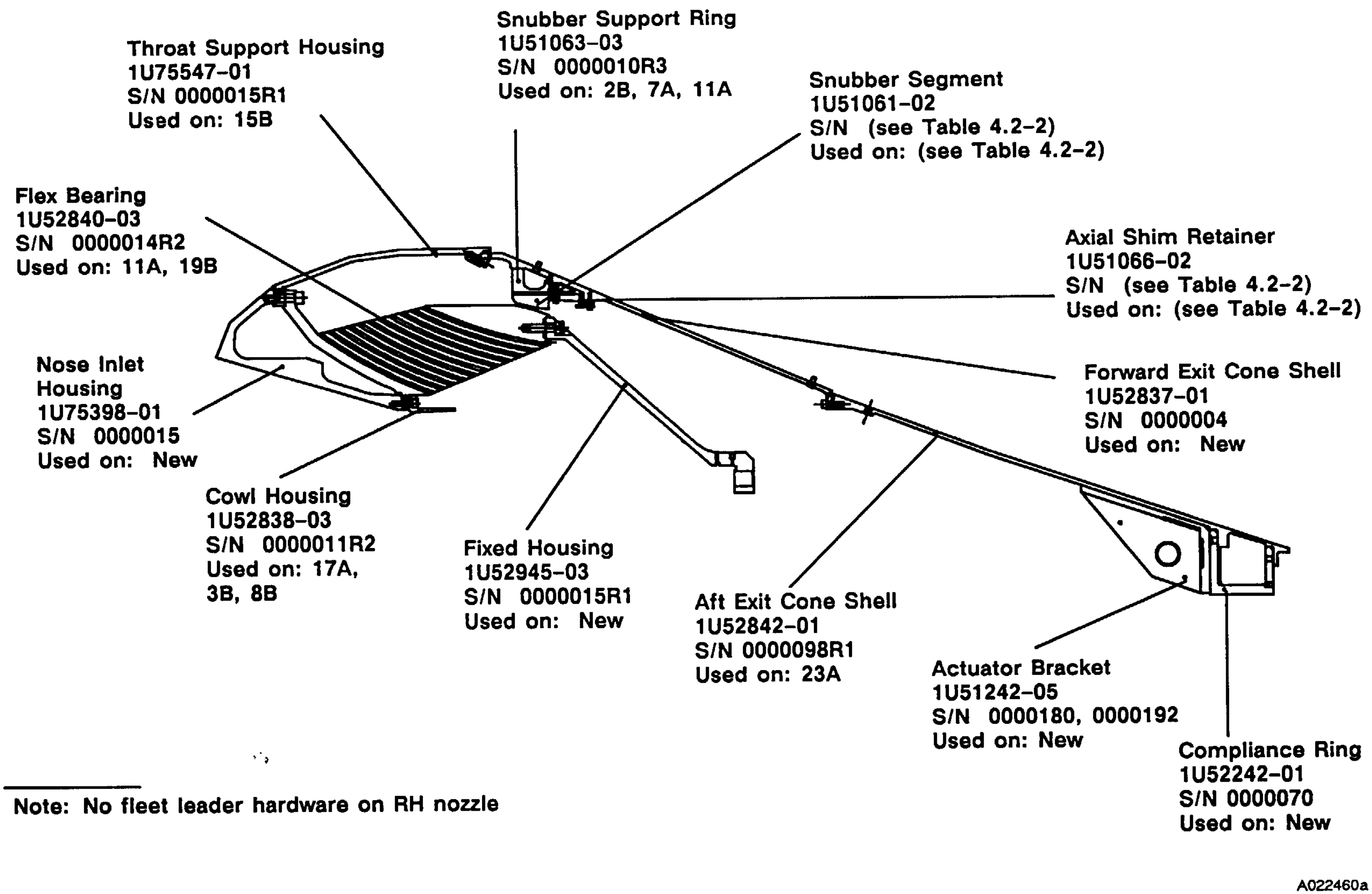


Figure 4.2-4. Previous Use History—RH Igniter



Note: No fleet leader hardware on LH nozzle

Figure 4.2-5. Previous Use History—LH Nozzle



Note: No fleet leader hardware on RH nozzle

Figure 4.2-6. Previous Use History—RH Nozzle

Table 4.2-1. Previous Use History--LH Nozzle (360Q004A)

Part No.	Serial No.	Previous Use
1U51061-02, Snubber Segment	0000091R3	QM-1, 3A, 10B
	0000091R3	QM-1, 3A, 10B
	0000061R3	1B, 7A, 10A
	0000061R4	QM-1, 3A, 10B, 20A
	0000062R4	QM-1, 3A, 10B, 20A
	0000063R4	QM-1, 3A, 10B, 20A
	0000064R4	QM-1, 3A, 10B, 20A
	0000065R4	QM-1, 3A, 10B, 20A
	0000066R4	QM-1, 3A, 10B, 20A
	0000067R4	QM-1, 3A, 10B, 20A
	0000068R4	QM-1, 3A, 10B, 20A
	0000069R4	QM-1, 3A, 10B, 20A
	0000070R4	QM-1, 3A, 10B, 20A
	0000072R4	QM-1, 3A, 10B, 20A
	0000073R4	QM-1, 3A, 10B, 20A
	0000074R4	QM-1, 3A, 10B, 20A
	0000075R4	QM-1, 3A, 10B, 20A
	0000076R4	QM-1, 3A, 10B, 20A
	0000077R4	QM-1, 3A, 10B, 20A
	0000078R4	QM-1, 3A, 10B, 20A
	0000079R4	QM-1, 3A, 10B, 20A
	0000080R4	QM-1, 3A, 10B, 20A
	0000081R4	QM-1, 3A, 10B, 20A
	0000082R4	QM-1, 3A, 10B, 20A
	0000083R4	QM-1, 3A, 10B, 20A
	0000084R4	QM-1, 3A, 10B, 20A
	0000085R4	QM-1, 3A, 10B, 20A
	0000086R4	QM-1, 3A, 10B, 20A
	0000087R4	QM-1, 3A, 10B, 20A
	0000088R4	QM-1, 3A, 10B, 20A
	0000089R4	QM-1, 3A, 10B, 20A
	0000090R4	QM-1, 3A, 10B, 20A
1U51066-02, Axial Shim Retainer	0001736	New
	0001762 through	New
	0001792	New

Table 4.2-2. Previous Use History--RH Nozzle (360L004B)

Part No.	Serial No.	Previous Use
1U51061-02, Snubber Segment	0000341R1	11A
	0000455R1	11A
	0000461R1	11A
	0000468R1	11A
	0000475R1	11A
	0000479R1	11A
	0000480R2	11A, 24A
	0000321R2	11A, 24A
	0000340R2	11A, 24A
	0000425R2	11A, 24A
	0000454R2	11A, 24A
	0000456R2	11A, 24A
	0000457R2	11A, 24A
	0000458R2	11A, 24A
	0000459R2	11A, 24A
	0000460R2	11A, 24A
	0000462R2	11A, 24A
	0000463R2	11A, 24A
	0000465R2	11A, 24A
	0000466R2	11A, 24A
	0000467R2	11A
	0000464R2	11A, 24A
	0000470R2	11A, 24A
	0000471R2	11A, 24A
	0000472R2	11A, 24A
	0000473R2	11A, 24A
	0000474R2	11A, 24A
	0000477R2	11A, 24A
	0000478R2	11A, 23B
	0000545R2	14B, 23B
	0000546R2	14B, 23B
	0000176R3	1B, 7A, 10A
1U50166-02, Axial Shim Retainer	0001349 through 0001380	New New

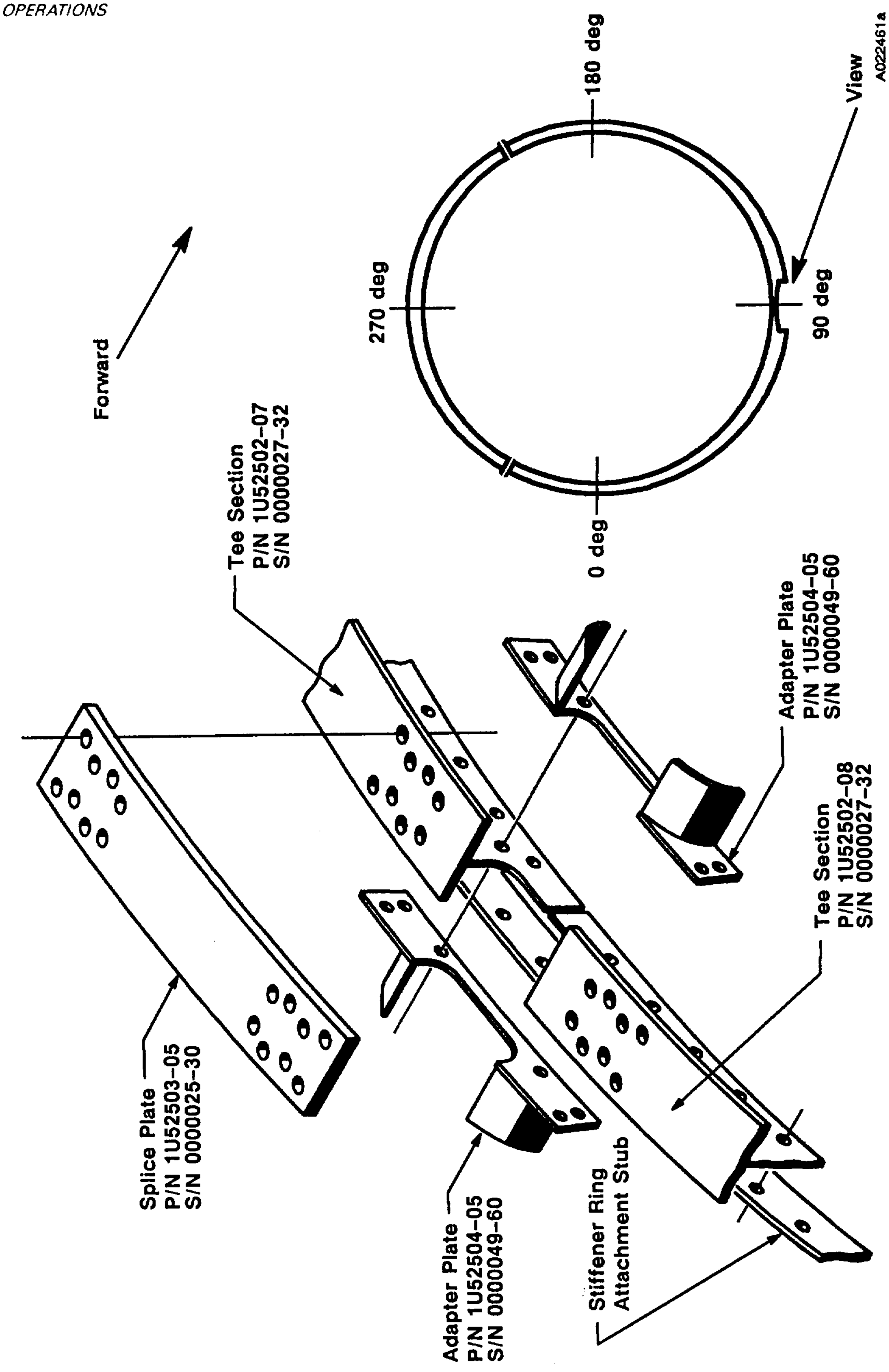


Figure 4.2-7. Previous Use History—Stiffener Rings

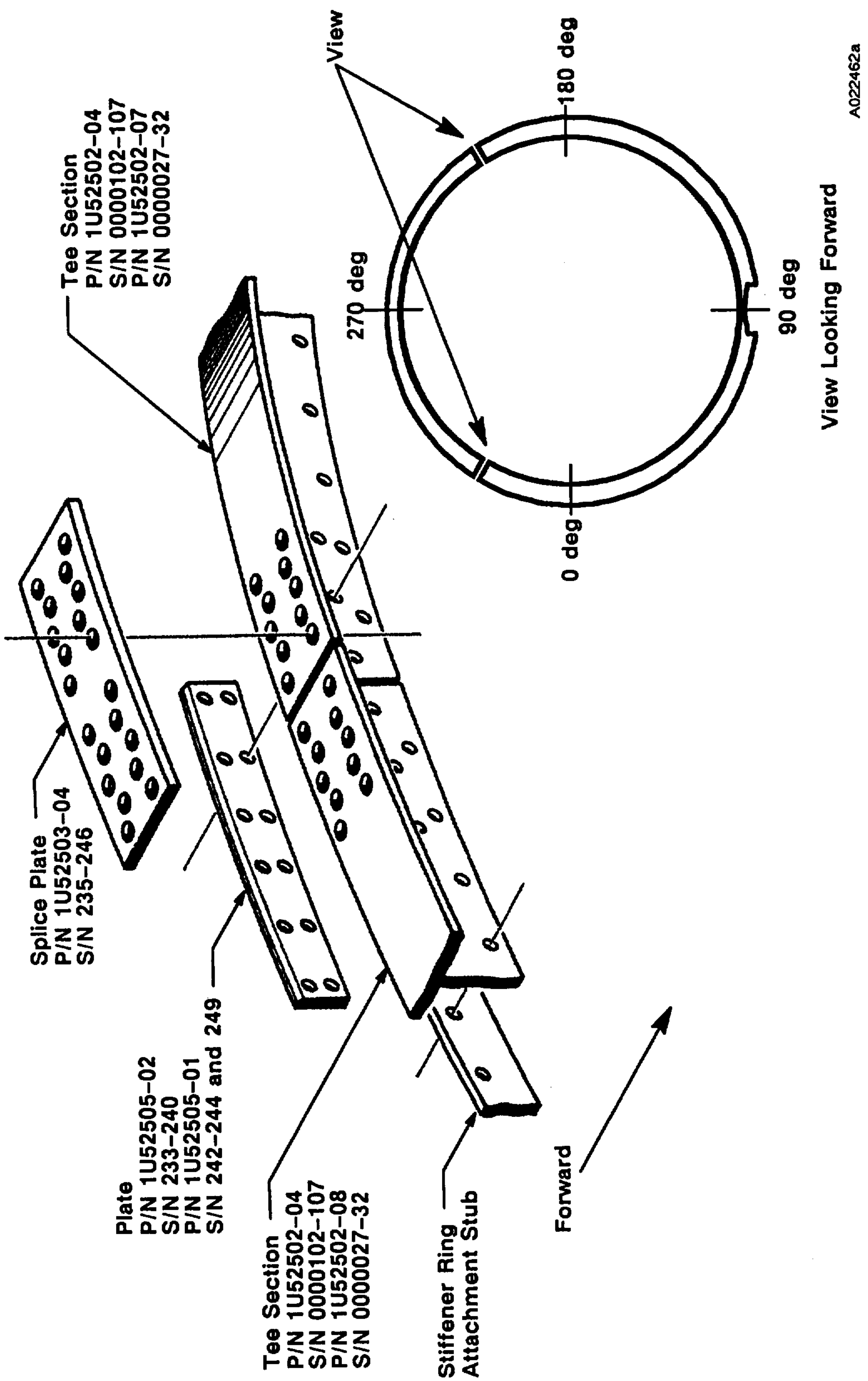


Figure 4.2-7. Previous Use History—Stiffener Rings (cont)

Table 4.2-3. Previous Use History--Stiffener Rings

Part No.	Serial No.	Previous Use
1U52502-04, Stiffener Ring	0000102	New
	0000103	New
	0000104	New
	0000105	New
	0000106	New
	0000107	New
1U52502-07, Stiffener Ring	0000027	New
	0000028	New
	0000029	New
	0000030	New
	0000031	New
	0000032	New
1U52502-08, Stiffener Ring	0000027	New
	0000028	New
	0000029	New
	0000030	New
	0000031	New
	0000032	New
1U52503-04, Splice Plate	0000235	New
	0000236	New
	0000237	New
	0000238	New
	0000239	New
	0000240	New
	0000241	New
	0000242	New
	0000243	New
	0000244	New
	0000245	New
	0000246	New
1U52503-05, Splice Plate	0000025	New
	0000026	New
	0000027	New
	0000028	New
	0000029	New
	0000030	New

Table 4.2-3. Previous Use History--Stiffener Rings (cont)

Part No.	Serial No.	Previous Use
1U52504-05, Adapter Plate	0000049	New
	0000050	New
	0000051	New
	0000052	New
	0000053	New
	0000054	New
	0000055	New
	0000056	New
	0000057	New
	0000058	New
	0000059	New
	0000060	New
1U52505-02, Plate, Stiffener Ring	0000233	New
	0000234	New
	0000235	New
	0000236	New
	0000237	New
	0000238	New
	0000239	New
	0000240	New
1U52505-02, Plate, Stiffener Ring	0000242	New
	0000243	New
	0000244	New
	0000249	New

- Relocation of moisture seal vent valve test hole--FEC RSRM-048. Relocated test hole allows splice plate installation in parallel with field joint closeout; no impact on other related system components.
- Lengthen forward joint protection system (JPS) Kevlar® strap--ECP SRM-1952. One-in. length increase will lower GSE installation load to within rated limits and maintain minimum required tension after installation.

One Class I hardware changeout to 360T004:

- Aft segment exchange--ECP SRM-1857. Original RSRM-04B aft segment exchanged with QM-8 aft segment due to insulation unbonds being outside experience data base.

4.2.3 Critical Process and Operations and Maintenance Requirements and Specification Document (OMRSD) Changes

Two critical process changes:

- Nozzle installation--OCR 141723. a) Nozzle seating weight increased from 2,000 to 5,000 lbf to properly seat nozzle. b) Polywipe diaper placed under leveling pin to catch any metal particles that could contaminate sealing area. c) Four leveling pins reduced to three to eliminate uneven installation loads.
- Insulation layup change--OCR 132998. Changed EPDM layup strip dimensions to reduce stress concentrations.

Six OMRSD changes:

- RCN MB8522--Allows field joint mating with crane only if hydrosets are inoperable.
- RCN MB8626--Do not allow weight of RSRM segments to bear on alignment pins during engagement.
- RCN MB8358--Reduced leak test time of nozzle exit cone, reducing GSE serial time.
- RCN MB8358--Reduced leak test time of nozzle/aft segment joint, reducing GSE serial time.
- RCN MB8510--Reduces number of internal insulation J-joint profile measurements.
- RCN MB8771--S&A device rotation time requirement changed from 1 to 2 sec during the preinstallation test.

4.3 SRB MASS PROPERTIES (FEWG report Paragraph 2.2.0)

4.3.1 Sequential Mass Properties

Tables 4.3-1 and 4.3-2 provide 360T004 (STS-30) LH and RH reconstructed sequential mass properties, respectively.

Table 4.3-1. Sequential Mass Properties (LH SRM)

Event Time (sec)	Weight (lb)	Center of Gravity			Moment of Inertia		
		Long	Lat	Vert	Pitch	Roll	Yaw
Prelaunch = 0.00	1,256,224.2	1171.186	0.058	0.006	42481.747	873.019	42482.561
Lift-Off = 0.23	1,255,482.9	1171.341	0.058	0.006	42435.700	871.366	42436.514
Intermediate Burn = 20.00	1,012,465.3	1208.516	0.071	0.007	30689.580	753.307	30690.391
Intermediate Burn = 40.00	789,649.0	1231.895	0.091	0.009	21634.024	617.565	21634.829
Max Q = 54.00	658,677.7	1229.351	0.108	0.011	17952.501	539.892	17953.299
Intermediate Burn = 60.00	603,531.4	1226.763	0.118	0.012	16530.869	502.329	16531.665
Intermediate Burn = 80.00	410,397.0	1215.277	0.172	0.018	11846.599	367.955	11847.382
Max G = 87.00	346,521.7	1215.019	0.202	0.022	10477.867	317.422	10478.646
Intermediate Burn = 100.00	241,309.4	1229.650	0.289	0.031	8491.205	228.570	8491.976
Web Burn = 110.06	173,669.6	1267.846	0.399	0.043	7315.657	167.022	7316.423
End of Action Time = 122.42	143,901.6	1314.710	0.480	0.052	6605.726	140.693	6606.486
Separation = 125.00	143,231.5	1316.169	0.483	0.052	6582.883	140.107	6583.646
Max Reentry Q = 320.00	142,780.7	1316.027	0.484	0.051	6560.380	139.698	6561.144
Nose Cap Deployment = 335.03	142,751.9	1316.017	0.484	0.051	6558.840	139.672	6559.604
Drogue Chute Deployment = 335.63	142,750.8	1316.016	0.484	0.051	6558.779	139.671	6559.543
Frustum Release = 356.73	142,710.3	1316.002	0.484	0.051	6556.606	139.636	6557.370
Main Chute Line Stretch = 358.03	142,707.8	1316.001	0.484	0.051	6556.472	139.633	6557.236
Main Chute First Disreefing = 368.13	142,688.4	1315.995	0.484	0.051	6555.427	139.616	6556.191
Main Chute Second Disreefing = 374.03	142,677.1	1315.991	0.484	0.051	6554.816	139.606	6555.580
Nozzle Jettison = 374.73	140,465.5	1305.781	0.482	0.051	6354.589	134.182	6355.334
Splashdown = 386.45	140,443.0	1305.772	0.482	0.051	6353.368	134.162	6354.113

90089-8.4

Table 4.3-2. Sequential Mass Properties (RH SRM)

Event Time (sec)	Weight (lb)	Center of Gravity			Moment of Inertia		
		Long	Lat	Vert	Pitch	Roll	Yaw
Prelaunch = 0.00	1,256,695.3	1171.305	0.058	0.006	42471.998	879.786	42472.841
Lift-Off = 0.23	1,256,040.9	1171.434	0.058	0.006	42431.498	878.479	42432.341
Intermediate Burn = 20.00	1,012,939.9	1208.545	0.071	0.008	30679.197	760.601	30680.037
Intermediate Burn = 40.00	790,245.3	1231.813	0.091	0.010	21625.742	624.857	21626.576
Max Q = 54.00	659,232.7	1229.261	0.108	0.012	17937.746	546.858	17938.574
Intermediate Burn = 60.00	603,875.6	1226.642	0.118	0.013	16508.842	508.919	16509.666
Intermediate Burn = 80.00	410,859.0	1215.156	0.171	0.019	11831.607	374.559	11832.420
Max G = 87.00	347,176.1	1214.928	0.202	0.022	10469.086	324.097	10469.894
Intermediate Burn = 100.00	242,561.5	1229.335	0.287	0.032	8496.556	235.596	8497.357
Web Burn = 110.40	172,854.3	1269.030	0.401	0.045	7283.814	172.013	7284.607
End of Action Time = 122.86	144,610.1	1315.556	0.478	0.054	6581.540	147.433	6582.329
Separation = 125.00	143,996.9	1317.410	0.480	0.054	6550.490	147.070	6551.282
Max Reentry Q = 320.00	143,503.0	1317.601	0.481	0.053	6521.886	146.660	6522.679
Nose Cap Deployment = 350	143,449.3	1317.582	0.481	0.053	6519.035	146.612	6519.827
Drogue Chute Deployment = 350.60	143,448.2	1317.582	0.481	0.053	6518.977	146.611	6519.770
Frustum Release = 371.70	143,410.5	1317.570	0.482	0.053	6516.958	146.578	6517.751
Main Chute Line Stretch = 373.00	143,408.1	1317.569	0.482	0.053	6516.834	146.576	6517.627
Main Chute First Disreefing = 383.10	143,390.1	1317.563	0.482	0.053	6515.864	146.560	6516.657
Main Chute Second Disreefing = 389.00	143,379.5	1317.560	0.482	0.053	6515.296	146.550	6516.089
Nozzle Jettison = 389.70	141,179.6	1307.380	0.480	0.052	6316.978	141.255	6317.752
Splashdown = 406.89	141,148.9	1307.368	0.480	0.052	6315.314	141.228	6316.087

90089-8.5

4.3.2 Predicted Data Versus Postflight Reconstructed Data

Table 4.3-3 compares the LH quarter-weight RSRM (360Q004A) predicted sequential weight and center of gravity (cg) data with the postflight reconstructed data. Table 4.3-4 compares the RH half-weight RSRM (360H004B) predicted sequential weight and cg data with the postflight reconstructed data. Actual 360T004 (STS-30) mass properties may be obtained from Mass Properties History Log Space Shuttle 360Q004-LH (TWR-17340, dated 9 Jan 1989) and 360H004-RH (TWR-17341, dated 9 Jan 1989). Some of the mass properties data used have been taken from average actual data presented in the 5 Dec 1988 Mass Properties Quarterly Status Report (TWR-10211-89). Postflight reconstructed data reflect ballistics mass flow data from the 12.5 sample per second measured pressure traces and a predicted slag weight of 1,518 lb. Those mass properties reported after separation reflect delta times previously used on earlier flights.

4.3.3 CEI Specification Requirements

Tables 4.3-5 and 4.3-6 present CEI specification requirements predicted and actual weight comparisons. Mass properties data for both RSRMs comply with the CEI specification requirements.

4.4 RSRM PROPULSION PERFORMANCE (FEWG report Paragraph 2.3.0)

4.4.1 High Performance Motor/RSRM Performance Comparisons

The reconstructed thrust-time traces of flight motor set 360T004 at standard conditions were averaged with the high performance motor (HPM)/RSRM population and compared to the CEI specification limits. The results are shown in Figure 4.4-1. 360H004B (RH) is not included in the average because the aft segment of this motor was originally cast for QM-8.

4.4.2 SRM Propulsion Performance Comparisons

The reconstructed RSRM propulsion performance is compared to the predicted performance in Table 4.4-1. The following comments are to explain the table values. The RSRM ignition interval is to be between 202 and 302 ms after ignition command to the NASA standard initiator in the S&A device. The ignition interval ends when the headend chamber pressure has increased to a value of 563.5 psia. The maximum rate of headend chamber pressure buildup during the ignition transient is required to be less than 115.9 psia for any 10-ms interval. However, no high sample rate ignition data were available for this flight (due to the elimination of DFI). Therefore, no rise rate or ignition interval is reported.

Separation is based upon the 50-psia cue from the last RSRM, plus 4.9 sec, plus a time delay between the receipt and execution of the command to separate. No time delay is assumed in the prediction. The decay time intervals are measured from the time motor headend chamber pressure has decayed to 59.4 psia to the time corresponding to 85,000 lb of thrust.

Table 4.3-3. Sequential Mass Properties--Predicted Versus Actual Comparisons (LH SRM)

Event	Weight (lb) Predicted*	Weight (lb) Actual	Weight (lb) Delta	Weight (lb) Error (%)	Longitudinal cg (in.) Predicted*	Longitudinal cg (in.) Actual	Longitudinal cg (in.) Delta	Longitudinal cg (in.) Error (%)
Preignition	1,256,224	1,256,224	0	0.00	1,171.186	1,171.168	0.000	0.00
Lift-off	1,255,589	1,255,483	-106	0.01	1,171.313	1,171.341	+0.028	0.00
Action Time	144,086	143,902	-184	0.13	1,313.766	1,314.710	+0.944	0.07
Separation**	143,352	143,232	-120	0.08	1,315.747	1,316.169	+0.422	0.03
Nose Cap Deployment	142,774	142,752	-22	0.02	1,316.097	1,316.017	-0.080	0.01
Drogue Chute Deployment	142,759	142,751	-8	0.01	1,316.091	1,316.016	-0.075	0.01
Main Chute Line Stretch	142,731	142,708	-23	0.02	1,316.081	1,316.001	-0.080	0.01
Main Chute First Disreefing	142,720	142,688	-32	0.02	1,316.077	1,315.995	-0.082	0.01
Main Chute Second Disreefing	142,713	142,677	-36	0.03	1,316.075	1,315.991	-0.084	0.01
Nozzle Jettison	140,541	140,465	-76	0.05	1,305.771	1,305.781	+0.010	0.00
Splashdown	140,443	140,443	0	0.00	1,305.772	1,305.772	0.000	0.00

*Based on Mass Properties History Log--Space Shuttle 360Q004-LH, 9 Jan 1989 (TWR-17340)
**The separation longitudinal cg of 1,316.169 is 66 percent of the vehicle length

90089-11.1

Table 4.3-4. Sequential Mass Properties--Predicted Versus Actual Comparisons (RH SRM)

Event	Weight (lb) Predicted*	Weight (lb) Actual	Weight (lb) Delta	Weight (lb) Error (%)	Longitudinal cg (in.) Predicted*	Longitudinal cg (in.) Actual	Longitudinal cg (in.) Delta	Longitudinal cg (in.) Error (%)
Preignition	1,256,695	1,256,695	0	0.00	1,171.305	1,171.305	0.000	0.00
Lift-off	1,256,060	1,256,041	-19	0.00	1,171.431	1,171.434	+0.003	0.00
Action Time	144,784	144,610	-174	0.12	1,315.322	1,315.556	+0.234	0.02
Separation**	144,050	143,997	-53	0.04	1,317.302	1,317.410	0.108	0.01
Nose Cap Deployment	143,471	143,449	-22	0.02	1,317.657	1,317.582	-0.075	0.01
Drogue Chute Deployment	143,456	143,448	-8	0.01	1,317.652	1,317.582	-0.070	0.01
Main Chute Line Stretch	143,428	143,408	-20	0.01	1,317.642	1,317.569	-0.073	0.01
Main Chute First Disreefing	143,417	143,390	-27	0.02	1,317.638	1,317.563	-0.075	0.01
Main Chute Second Disreefing	143,410	143,379	-31	0.02	1,317.636	1,317.560	-0.076	0.01
Nozzle Jettison	141,157	141,180	+23	0.02	1,307.367	1,307.380	+0.013	0.00
Splashdown	141,149	141,149	0	0.00	1,307.368	1,307.368	0.000	0.00

*Based on Mass Properties History Log--Space Shuttle 360H004-RH, 9 Jan 1989 (TWR-17341)
**The separation longitudinal cg of 1,317.410 is 66 percent of the vehicle length

90089-11.2

Table 4.3-5. Predicted Versus Actual Weight Comparisons (lb)--LH SRM

Item	Minimum	Maximum	Predicted***	Actual	Delta	Error (%)
Inerts						
Prefire, Controlled*		151,380	149,521	149,521	0	0.00
Propellant*	1,103,730		1,106,703	1,106,703	0	0.00
Usable**			1,105,844	1,106,021	+177	0.02
To Lift-Off			534	555	+21	3.78
Lift-Off to Action**			1,105,310	1,105,466	+156	0.01
Unusable			859	682	-177	25.95
Action to Separation			669	605	-64	10.58
After Separation			190	77	-113	146.75
Slag**			1,518	1,518	0	0.00

*Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI specification)
**Slag included in usable propellant, lift-off to action
***Based on Mass Properties History Log--Space Shuttle 360Q004-LH, 9 Jan 1989 (TWR-17340)

Table 4.3-6. Predicted Versus Actual Weight Comparisons (lb)--RH SRM

Item	Minimum	Maximum	Predicted***	Actual	Delta	Error (%)
Inerts						
Prefire, Controlled*		151,975	150,188	150,188	0	0.00
Propellant*	1,103,560		1,106,477	1,106,477	0	0.00
Usable**			1,105,618	1,105,784	+166	0.02
To Lift-Off			534	556	+22	3.96
Lift-Off to Action**			1,105,084	1,105,228	+144	0.01
Unusable			859	693	-166	23.95
Action to Separation			669	548	-121	22.08
After Separation			190	145	-45	31.03
Slag**			1,518	1,518	0	0.00

*Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI specification)
**Slag included in usable propellant, lift-off to action
***Based on Mass Properties History Log--Space Shuttle 360H004-RH, 9 Jan 1989 (TWR-17341)

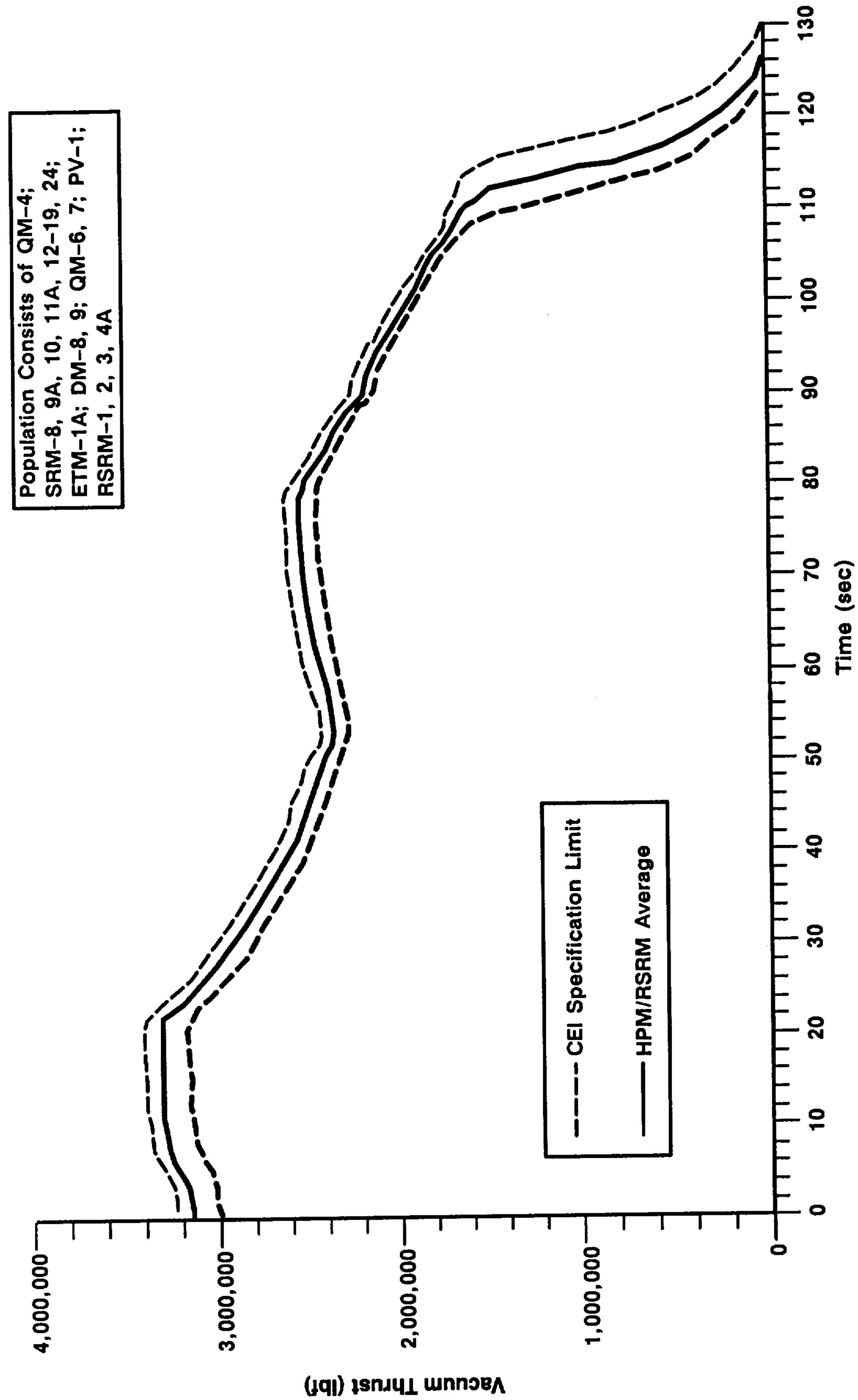


Figure 4.4-1. HPM/RSRM Population Nominal Vacuum Thrust Compared to CEI CPW1-3600 Specification Limits

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4.4.3 Matched Pair Thrust Differential

Table 4.4-2 shows the thrust differential during steady state and tailoff. All the thrust differential values were near the nominal values experienced by previous flight SRMs and were well within the CEI specification limits. It should be noted that, because of the 360H004B aft segment exchange with QM-8, a waiver was written for this flight set to remove the thrust imbalance requirements. The thrust values used for the assessment were reconstructed at the delivered conditions of each motor.

Table 4.4-1. RSRM Propulsion Performance Assessment

	LH Motor (71°F)		RH Motor (71°F)	
	Predicted	Actual	Predicted	Actual
Impulse Gates				
I-20 (10^6 lbf-sec)	65.73	65.42	66.15	65.42
I-60 (10^6 lbf-sec)	174.63	174.71	175.21	174.73
I-AT (10^6 lbf-sec)	296.88	296.20	296.82	296.10
Vacuum I_{sp} (lbf x sec/lbm)	268.3	267.6	268.3	267.6
Burn Rate (in./sec) (at 71°F, 625 psia)	0.3710	0.3713	0.3725	0.3714
Event Times (sec)*				
Ignition Interval	0.232	NA**	0.232	NA**
Web Time*	109.7	109.8	109.1	110.2
Time of 50-psia Cue	118.7	119.7	118.6	120.1
Action Time*	120.8	122.2	120.7	122.6
Separation Command (sec)	123.6	125.0	123.6	125.0
PMBT (°F)	71.0	71.0	71.0	71.0
Maximum Ignition Rise Rate (psia/10 ms)	91.9	N/A*	91.9	N/A*
Decay Time (sec) (59.4 psia to 85 K)	2.9	3.2	2.9	3.6
Tailoff Imbalance Impulse Differential (lbf-sec)	Predicted +248 K		Actual -77 K	

Note: Impulse imbalance = LH motor - RH motor
*All times are referenced to ignition command time except where noted by an asterisk. These times are referenced to lift-off time
**Data not available due to DFI elimination

Table 4.4-2. RSRM Thrust Imbalance Assessment

Event	Imbalance Specification (Klbf)	Maximum Imbalance (Klbf)	Time of Maximum Imbalance (sec)
Ignition (0 to 1.0 sec)	300	NA*	NA*
Steady State (1.0 sec to first web time minus 4.5 sec, lbf, 4 sec average)	85	+22.6	94.5
Transition (First web time minus 4.5 sec to first web time, lbf)	85-268 Linear	+44.2	109.5
Tailoff (first web time to last action time)	710	+53.5	112.0

Note: Thrust imbalance = LH motor - RH motor
*Data not available due to DFI elimination

4.4.4 Performance Tolerances

A comparison of the LH and RH motor calculated and reconstructed parameters at a PMBT of 60°F with respect to the nominal values and the SRM CEI specification maximum 3-sigma requirements is given in Table 4.4-3.

4.4.5 Igniter Performance

Due to the elimination of DFI, no evaluation of igniter performance is possible. Also, no evaluation of the ignition interval, pressure rise rate, and ignition thrust imbalance requirements is possible.

4.5 RSRM NOZZLE THRUST VECTOR CONTROL PERFORMANCE (FEWG report Paragraph 2.4.3)

The nozzle torque values for motor set 360T004 could not be determined due to DFI elimination. This section is reserved pending any future motors that incorporate DFI.

4.6 RSRM ASCENT LOADS--STRUCTURAL ASSESSMENT (FEWG report Paragraph 2.5.2)

Motor set 360T004 did not have any DFI installed to evaluate motor structural performance. This section is reserved pending any future motors that incorporate DFI.

Table 4.4-3. RSRM Performance Comparison

Parameter	SRM CEI (±) Max 3-Sigma Variation (%)	Nominal Value*	LH RSRM 360Q004A (60°F)	LH RSRM 360Q004A Variation (%)**	RH RSRM 360H004B (60°F)	RH RSRM 360H004B Variation (%)**
Web Time (sec)	5.0	111.7	111.1	-0.54	111.5	-0.18
Action Time (sec)	6.5	123.4	123.5	+0.08	124.0	+0.49
Web Time Avg Pressure (psia)	5.3	660.8	662.5	0.26	661.2	+0.06
Max Headend Pressure (psia)	6.5	918.4	909	-1.02	907	-1.24
Max Sea Level Thrust (Mlbf)	6.2	3.06	3.08	+0.65	3.07	+0.33
Web Time Avg Vac Thrust (Mlbf)	5.3	2.59	2.59	0.00	2.59	0.00
Vac Del Specific Impulse (lbf*sec/lbm)	0.7	267.1	267.5	0.15	267.4	0.11
Web Time Vac Total Impulse (Mlbf*sec)	1.0	288.9	288.4	-0.17	288.6	-0.10
Action Time Vac Total Impulse (Mlbf*sec)	1.0	296.3	296.0	-0.10	295.9	-0.13

*QM-4 static test and SRM-8A and B, SRM-9A, SRM-10A and B, SRM-11A, SRM-13A and -13B flight average at standard conditions
**Variation = ((360Q004A - nominal)/nominal) * 100
((360H004B - nominal)/nominal) * 100

4.7 RSRM STRUCTURAL DYNAMICS (FEWG report Paragraph 2.6.2)

No accelerometer data were available due to the elimination of DFI on flight set 360T004. This section is reserved pending the installation of accelerometers on future flight motors.

4.8 RSRM TEMPERATURE AND TPS PERFORMANCE (FEWG report Paragraph 2.8.2)

4.8.1 Introduction

This section documents the thermal performance of the 360T004 (STS-30R) SRM external components and TPS, determined by postflight hardware inspection. Assessments of mean bulk temperature predictions, on-pad ambient/local induced environments, LCC, and GEI/joint heater sensor/thermal imaging data are also included. Performance of SRM internal components (insulation, case components, seals, and nozzles) is reported in Section 4.11 of this volume.

4.8.2 Summary

4.8.2.1 Postflight Hardware Inspection. Postflight inspection revealed no unexpected problems due to flight heating environments. The condition of both SRMs was similar to that of previous flight motors. A complete external heating evaluation of postflight hardware is given in Section 4.8.3.1 of this volume. Nozzle erosion is discussed in Section 4.11.4 of this volume.

4.8.2.2 Debris Assessment. NSTS debris criteria for missing TPS were not violated. A complete SRM debris assessment is given in Section 4.8.3.2 of this volume. Highlights are described below:

Missing TPS cork pieces were generally less than the established criteria of 0.70 $in.^3$ and were all caused by nozzle severance debris and/or splashdown loads and debris.

Numerous GEI MSID labels were missing. The epoxy closeouts over these labels, generally up to 1/8 in. thick, are a questionable debris concern. Action is underway to either remove these labels or replace them with stencils on future flights. Currently, these labels with the epoxy closeout are attached to 360H005 and 360L006 flight hardware.

4.8.2.3 Mean Bulk Temperature Predictions. These temperature predictions were made at different timeframes during the countdown. A discussion of these predictions is presented in Section 4.8.3.3 of this volume. Final postflight predictions from reconstructed data are: 1) PMBT was 71°F and 2) the flex bearing mean bulk temperature (FBMBT) was 80°F.

4.8.2.4 On-Pad Environment Evaluations. A complete environment evaluation is given in Section 4.8.3.4 of this volume. A summary of key observations follows.

Ambient Conditions. Ambient temperature data recorded during a 55-hr period prior to launch varied from 62° to 78°F. This temperature range is more indicative of normal April conditions (64° to 78°F) than of normal May conditions (69° to 81°F). Windspeeds during this same timeframe were close to historical conditions.

SRM Local. The local prelaunch environment due to April-May historical predictions suggests as much as a 1°F temperature suppression while the ET is loaded for winds from the southeast direction. Actual winds were from the east by southeast direction for 6 hr prior to launch. From GEI assessments, there was no outward indication of extreme temperature suppression due to ET cooling effects. There was evidence, however, of 2.5° to 3.5°F chilling on the inboard region of the LH SRM.

4.8.2.5 Launch Commit Criteria. No LCC thermal violations occurred. Measured GEI and heater sensor data, as compared to the LCC requirements, are discussed in Section 4.8.3.5 of this volume. Highlights of heating operations are summarized as follows.

The igniter heaters performed as expected, with the cooldown occurring over an approximate 7-hr period. At T - 5 min, the RH SRM igniter had dropped to 78°F while the LH SRM igniter dropped to 84°F. The lower reading on the RH SRM igniter was due to a gage which read 8° to 10°F low from the beginning of gage monitoring.

The six field joint heaters performed adequately and as expected, with a sensor temperature range of 89°F occurring at only one sensor which had read up to 7°F low from the beginning of instrumentation monitoring. Prior to this the minimum field joint LCC redline was reduced from 85° to 73°F. This modification was a change unique to 360T004 (STS-30R) and was a precaution taken in the event of a primary heater failure on the LH forward field joint. The secondary heater on this field joint (LH forward) was not to be used, as explained in Section 4.8.3.5 of this volume.

The SRB aft skirt purge operation performed satisfactorily and as expected. There was no evidence of circumferential temperature gradients in the aft skirt compartment, which had been seen in earlier launches.

4.8.2.6 Prelaunch Thermal Data Evaluation. IR temperature measurements from both the IR gun and the STI were compared with GEI. A complete evaluation is found in Section 4.8.3.6 of this volume. Highlights are summarized as follows.

IR gun/GEI comparison was poor for the L - 1-day and T - 3-hr ice/debris team pad inspection of the aborted countdown, but was considered good during the T - 3-hr period prior to the successful launch. STI real-time comparisons with GEI were considered very good during both countdowns. Verbally reported STI readings were within ±2°F of the GEI for the portable and the RSS stationary STI and they were within +4°F of the GEI for the camera Site 2 stationary STI.

4.8.3 Results Discussion

4.8.3.1 Postflight Hardware Inspection. Following the recovery of the STS-30R SRBs, a postflight inspection of the external hardware was conducted at the SRB Disassembly Facility (Hangar AF). The TPS performance was considered to be excellent in all areas, with external heating and recession effects being less than predicted (Table 4.8-1). Predictions due to the worst-case design trajectory environments (Table 4.8-2) will be documented in the SRB Thermal Design Data Book, SE-019-068-2H.

The condition of both motors appeared to be similar to previous flight motors, with most of the heat effects seen on the aft segments on the inboard sides of the SRBs. The aft segment inboard regions facing the ET experience high aerodynamic heating normal to protuberance components. They also receive the high plume radiation and recirculation heating induced by the adjacent SRB and SSMEs to aft-facing surfaces. In this area there was slight charring to the TPS over the factory joints, the stiffener rings and stubs, and GEI cabling runs. A concise summary of the external hardware condition is shown in Table 4.8-3.

Field Joints. All field joints on both motors were in excellent condition. There were no signs of ablation on any of the joint protection systems (JPS), with only slight paint blistering on the cork cover. The paint on the K5NA closeout aft of the cork was also slightly darkened and blistered, with occasional pitting. This was probably due to aerodynamic heating and aft edge hits from water impact and nozzle severance debris. All K5NA repair locations were intact where preflight bond tests were conducted.

Factory Joints. The factory joints on each of the motors were in very good condition. The only signs of heat effect experienced on the factory joints were located on the aft segments of each motor. There was only sight ablation, charring, and discoloration on the inboard regions of the aft segment factory joints. This occurred between approximately 220 and 320 deg circumferentially on each motor. Again, these are all normal occurrences that have been consistently observed on previous flight motors. Three weatherseals on the LH motor showed signs of aft edge unbond regions. No evidence of sooting was found under these unbonds, indicating that the separation occurred at or after splashdown due to adhesive failure.

Systems Tunnel. The cork TPS adjacent to the systems tunnel floor plate was in excellent condition. There was very little paint blistering. All K5NA closeouts over cables and tunnel seams were in excellent condition.

Stiffener Rings. The stiffener ring TPS was generally in very good condition, with only slight thermal degradation. The major heat-affected area was again predominantly in the 220- to 320-deg sector, with the EPDM on the outer flange showing signs of brown charring. This region was subjected to aeroheating along the outboard tip forward face, while the aft face and top surfaces experienced radiant heating. The K5NA TPS on the top surfaces of the stubs was also slightly charred in the same regions, with intermittent pitting around the whole circumference. The Instafoam ramps were "chunked out" from approximately 240 to 280 deg on the LH motor and 320 to 360 deg on the RH motor due to water impact. The three stiffener rings on the LH SRB were fractured during water impact, typically near the 260-deg location.

Table 4.8-1. STS-30R RSRM External Performance Summary (TPS erosion)--Both Motors

Component	TPS Material	Maximum Erosion (in.) Predicted	Maximum Erosion (in.) Measured
Field Joints	Cork	0.003	None
Factory Joints	EPDM	0.014	Not measurable*
Systems Tunnel	Cork	0.014	None
Stiffener Rings	EPDM	0.009	Not measurable*
GEI Closeout	Cork	0.036	Not measurable*
Nozzle Exit Cone	Cork	0.104	NA**

*All evidences of minor erosion were apparent only on the inboard region of the aft segment, where the flight-induced thermal environments are the most severe
**Nozzle exit cones are not recovered

Table 4.8-2. SRB Flight-Induced Thermal Environments

Thermal Environment	Related Document
Ascent Heating	Document No. STS 84-0575, dated 24 May 1985
	Change Notice 2, SE-698-D, dated 30 Apr 1987
	Data on computer tapes No. DN 4044 and DN 9068
	Change Notice 3, SE-698-D, dated 30 October 1987. Tape No. DP 5309
Base Recirculation Heating	Document No. STS 84-0259, dated October 1984
	Change Notice 1, SE-698-D, dated 30 Sep 1987
SSME and SRB Plume Radiation	Document No. STS 84-0259, dated October 1984
	Change Notice 1, SE-698-D, dated 30 Sep 1987
SSME Plume Impingement After SRB Separation	Document No. STS 84-0259, dated October 1984
	Change Notice 1, SE-698-D, dated 30 Sep 1987
Reentry Heating	Document No. SE-0119-053-2H, Rev D, dated August 1984, and Rev E, dated 12 Nov 1985

Table 4.8-3. STS-30R RSRM External Performance Summary (both motors)

Component	TPS Material	Performance	Recovered Hardware Performance Assessment
Field Joints	Cork	Typical	All JPS in excellent condition; slight paint blistering; pitting on aft edge of JPS K5NA closeout; all K5NA repairs intact for preflight bond test locations
Factory Joints	EPDM	Typical	All factory joints in very good condition; typical heat-affected areas on aft segment joints on inboard side of both motors; multiple aft edge unbonds on three LH motor weatherseals, with no evidence of sooting, indicating that the separation occurred at or after splashdown
Systems Tunnel	Cork	Typical	Cork TPS adjacent to tunnel floor plate in excellent condition; very little paint blistering; K5NA closeout in excellent condition on both cables and seams
Stiffener Rings	EPDM	Typical	Good condition--no deviations from normal postflight appearance; charring and discoloration on all edges and inboard top surfaces; Instafoam ramps chunked out due to water impact--this occurred at approximately 240 to 280 deg on LH motor and 320 to 360 deg on RH motor. Cracks and bulges observed in the K5NA and EPDM of all three LH rings, indicating moderate to severe hardware damage
GEI Closeout	Cork	Typical	Very good condition, with slight paint blistering; a few small cork pieces missing on GEI cable runs--all less than established NSTS debris criteria and all caused by nozzle severance and/or splashdown loads and debris; numerous MSID labels with up to 1/8-in.-thick epoxy closeout missing. Some of the missing labels showed signs of sooting, causing debris concerns

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Table 4.8-3. STS-30R RSRM External Performance Summary (both motors) (cont)

Component	TPS Material	Performance	Recovered Hardware Performance Assessment
Aft Kick Ring Joint	Cork	Typical	Good condition from thermal perspective; one 11-in. cork piece on RH kick ring joint damaged due to splashdown loads--5 in. of this piece missing, with little adhesive evident on pin retainer band
Nozzle Exit Cone	Cork	Unknown	Aft exit cones not recovered
Motor Case	NA	Typical	No hot spots or abnormal discoloration of the case paint due to external or internal heating; aft segments extensively sooted

90089-8.2

GEI Closeout. The cork and K5NA TPS covering the GEI and cableways were generally in good condition. Very little heat effect was observed, consisting of only slight paint discoloration and blistering. Some of the GEI cable runs had small areas of missing cork on the aft edges of the runs at intermittent regions. These minor cork losses were all attributed to aft edge hits caused by nozzle severance debris impact during reentry or at splashdown. There was a total of nine aft edge hits on the LH motor and three on the RH motor. The largest GEI cork piece missing was approximately 2.5 by 0.75 by 0.25 in., or 0.47 $in.^3$.

Aft Kick Ring Joint. The TPS cork strip over the pin retainer band was in good condition from a thermal perspective. This strip, as well as the case region vicinity, was heavily sooted, with no unexpected heating effects. This strip is shielded from adjacent SRB plume radiation during ascent by the kick ring. One 11-in. cork piece was damaged due to splashdown loads on the RH aft kick ring joint, and a 5-in. section of this piece was missing (approximately 5 by 1.5 by 0.5 in., or 3.75 $in.^3$). Little adhesive was evident on the pin retainer band.

4.8.3.2 Debris Assessment. NSTS debris criteria for missing TPS were not violated. The TPS cork pieces that were missing were generally less than the established criteria of 0.70 $in.^3$ and were all caused by nozzle severance debris and/or splashdown loads and debris. There was a total of nine aft edge hits on the LH motor and three on the RH motor. The largest GEI cork piece missing was approximately 2.5 by 0.75 by 0.25 in., or 0.47 $in.^3$. One 11-in. cork piece was damaged due to splashdown loads on the RH aft kick ring joint, and a 5-in. section of this piece was missing (approximately 5 by 1.5 by 0.5 in., or 3.75 $in.^3$). Little adhesive was evident on the pin retainer band.

Numerous GEI MSID labels were missing. The epoxy closeouts over these labels, generally up to 1/8 in. thick, are a questionable debris concern. Action is underway to either remove these labels or replace them with stencils on future flights. Currently, these labels with the epoxy closeout are attached to fifth and sixth flight hardware. Of the 40 labels on the LH SRM, 27 were totally missing (15 showed signs of sooting), 8 were partially missing (3 showed signs of sooting), and 5 were still intact. Of the 40 labels on the RH SRM, 15 were totally missing (7 showed signs of sooting), 14 were partially missing (2 showed signs of sooting), and 11 were still intact.

4.8.3.3 PMBT AND FBMBT Predictions. Temperature predictions (°F) were performed at various times with respect to the launch of STS-30R. They are predicted for the time of launch and are summarized as follows:

	Historical	L - 8 Days 4-20-89	L - 2 Days 4-26	L - 2 Days 5-2	L - 24 Hr 4-27	L - 24 Hr 5-3	Post
PMBT	70	71	71	--	71	--	71
FBMBT	72	76	--	76	--	77	80

As can be seen, the PMBT did not change from the beginning of the first countdown to the day of launch following the second countdown. The reason the PMBT calculation did not change was that the predicted daily temperatures used in that calculation were higher than the actual daily temperatures that replaced them in the updates. The average predicted daily temperature from 20 April to 4 May was 72.2°F, whereas the actual average daily temperature during the same timeframe was 71.6°F.

All predictions were based on the following three sources of data:

1. Tapes sent to Thiokol from KSC
2. Data from the KSC weather station
3. USA Today newspaper (daily high and low temperatures)

The data from the tapes were used wherever possible. However, due to the limited availability of the tapes, the data from the KSC weather station became the primary source of environmental data.

Figure 4.8-1 shows the reconstructed FBMBT predictions for both SRMs by impressing the GEI flex bearing aft end ring temperature data as a boundary condition in the Supertab/SINDA model. The increase of the FBMBT from the final prediction to the post calculation can be attributed principally to the residual effect of the initial aft end conditioning operation, for which adequate accounting was not given.

4.8.3.4 On-Pad Environmental Evaluations. Actual environmental data for the final 24 hr prior to launch is shown in Figures 4.8-2 through 4.8-6 and summarized together with GEI in Table 4.8-4. Ambient temperature data recorded during a 55-hr period prior to launch varied from 62° to 78°F. This temperature range is more indicative of normal April conditions (64° to 78°F) than of normal May conditions (69° to 81°F). Windspeeds during this same timeframe were similar to historical conditions.

The local prelaunch environment due to April-May historical predictions suggests as much as a 1°F temperature suppression while the ET is loaded for winds from the southeast direction. Actual winds were from the east by southeast direction for 6 hr prior to launch. From GEI assessments, there was no outward indication of extreme temperature suppression due to ET cooling effects. There was evidence, however, of 2.5° to 3.5°F chilling on the inboard region of the left SRM.

This chilling effect occurred on the three forwardmost 270-deg GEI locations--Stations 931.5, 1091.5, and 1411.5. This determination was made by first noting that the temperatures on the RH and LH motors at these three locations were identical during nonfilled conditions. Next, a comparison was made to determine the temperature change (relative to ambient) of these six locations during and following ET loading. It was seen that the LH motor, at these locations,

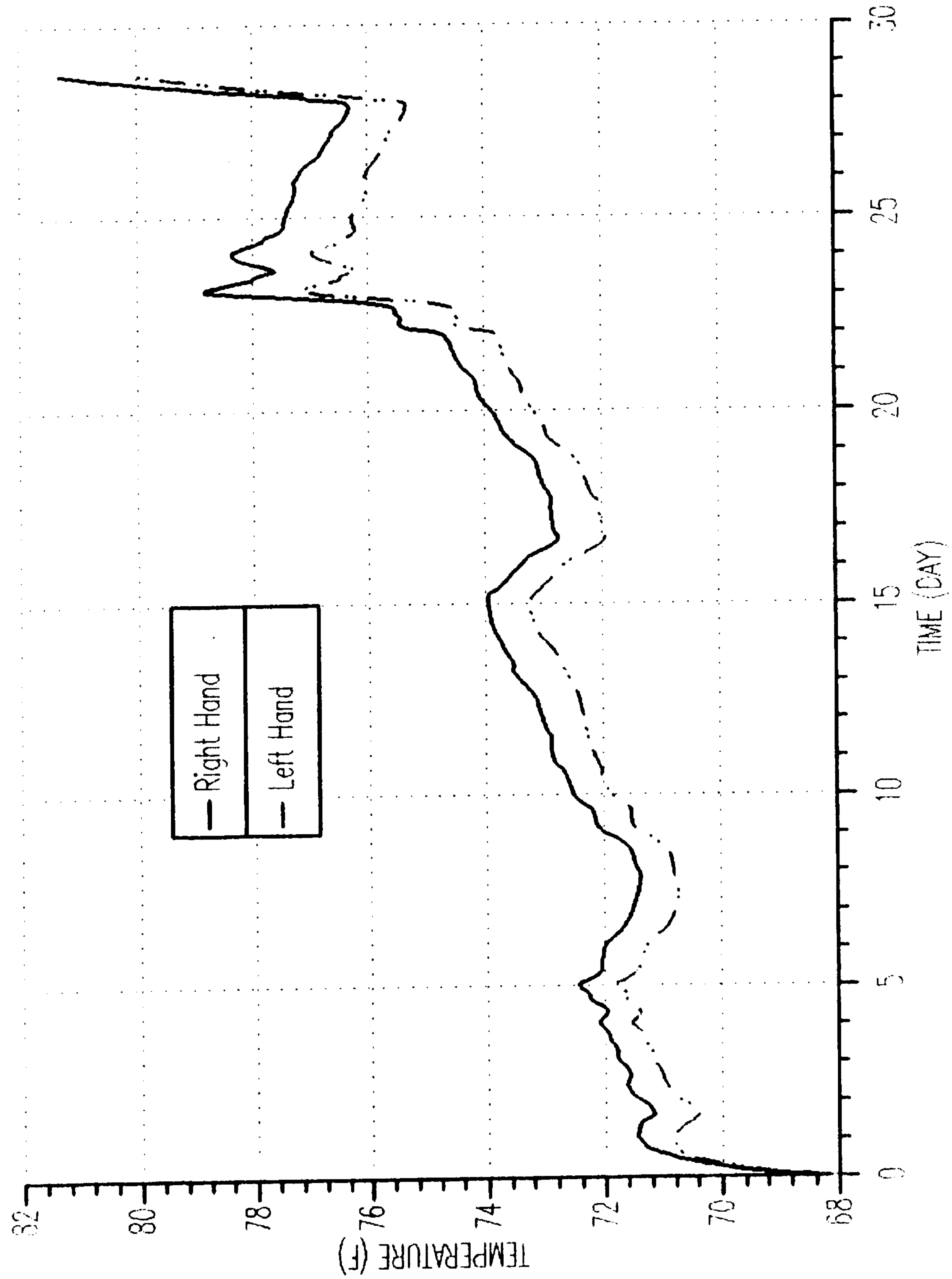


Figure 4.8-1. RSRM Flex Bearing Mean Bulk Temperature

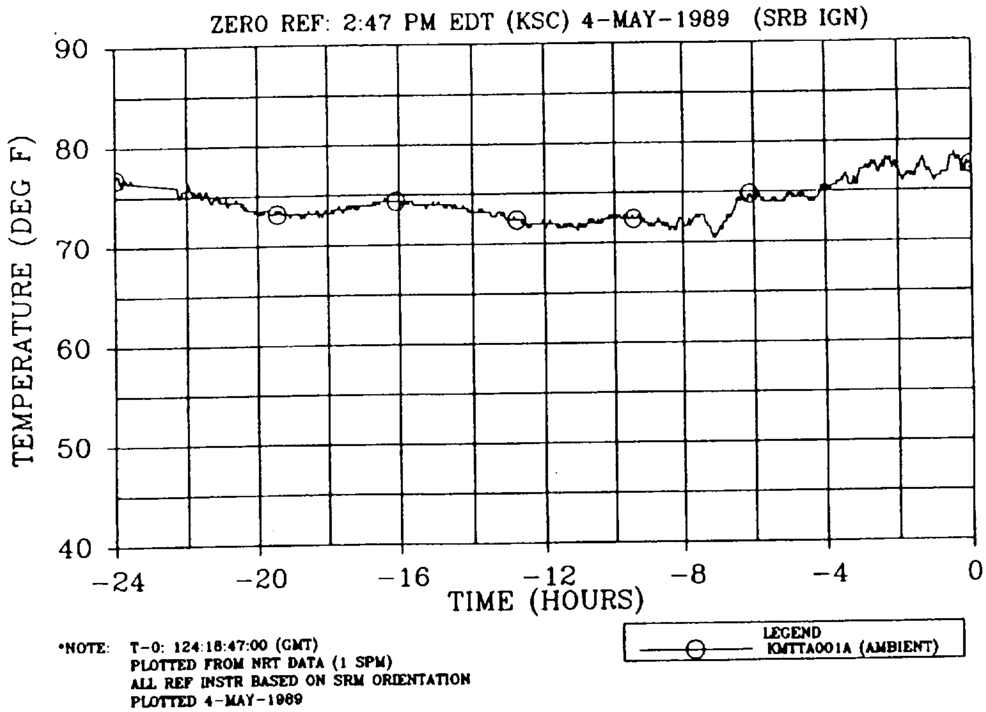


Figure 4.8-2. Prelaunch Ambient Temperatures at Camera Site No. 3

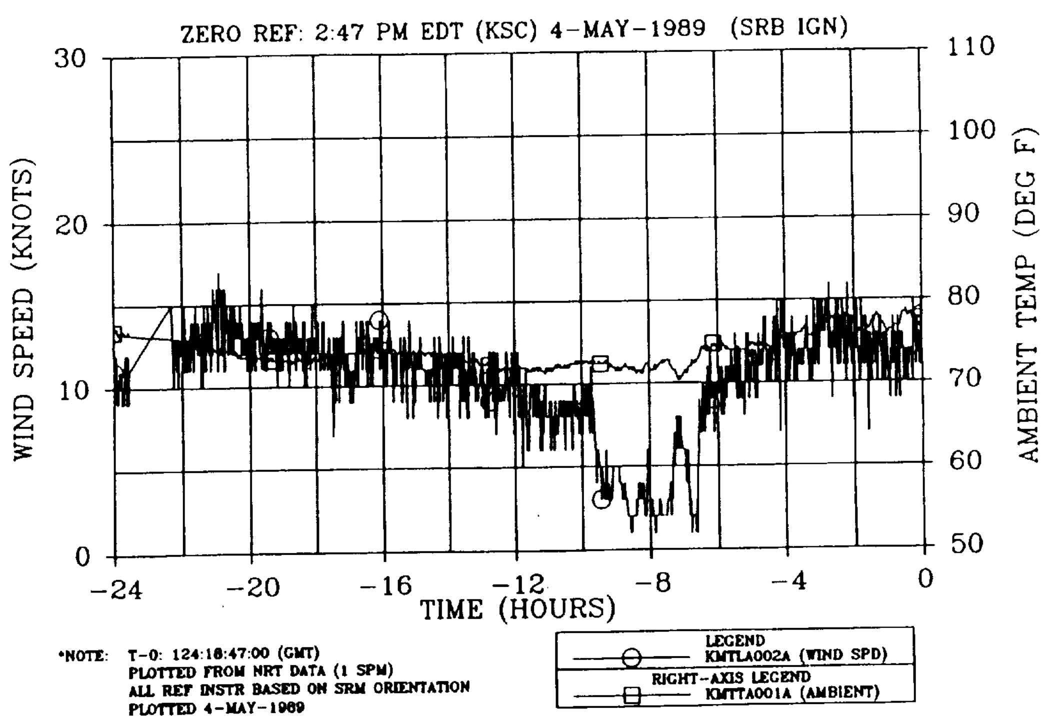


Figure 4.8-3. Prelaunch Ambient Temperatures at Camera Site No. 3
(overlaid with ambient)

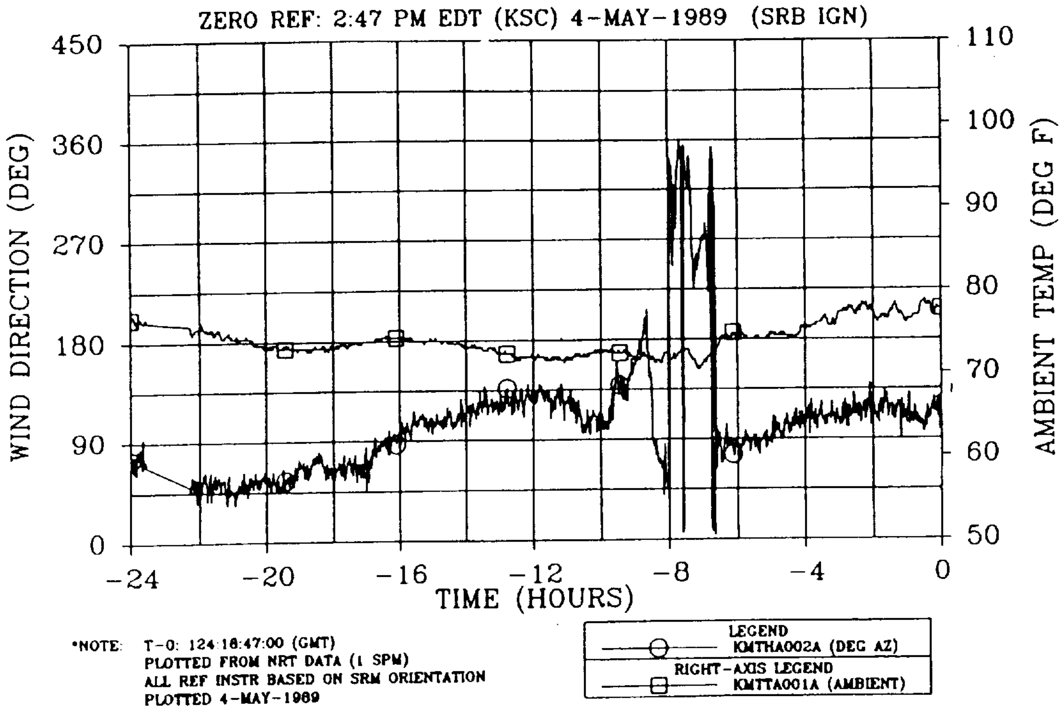


Figure 4.8-4. Prelaunch Wind Direction at Camera Site No. 3 (overlaid with ambient)

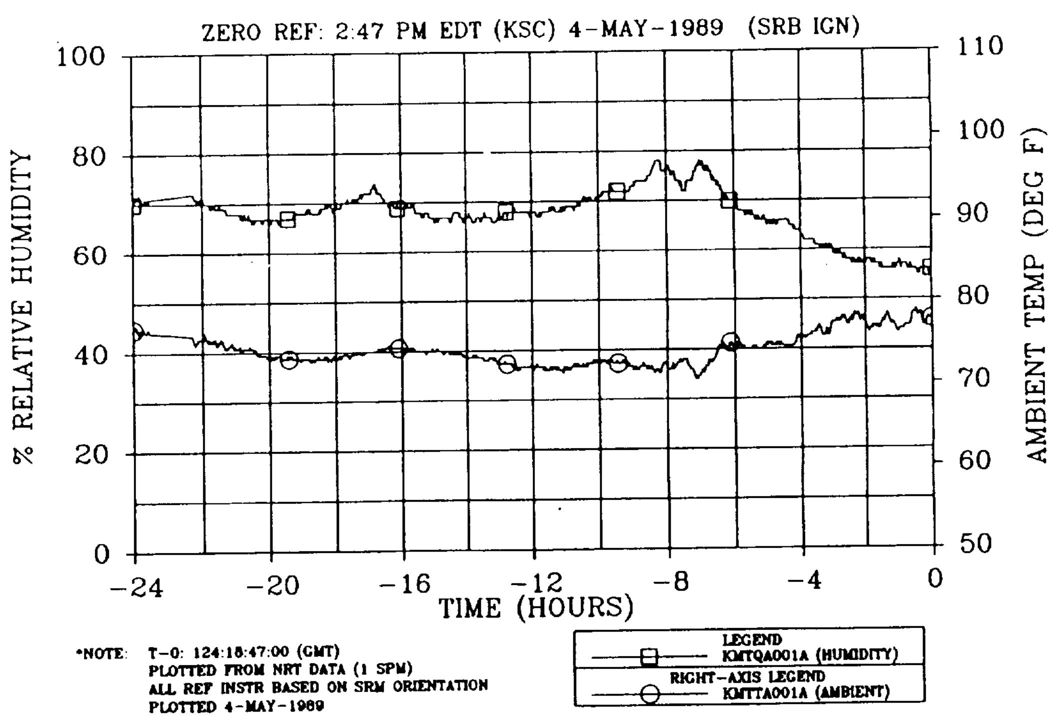


Figure 4.8-5. Prelaunch Humidity at Camera Site No. 3 (overlaid with ambient)

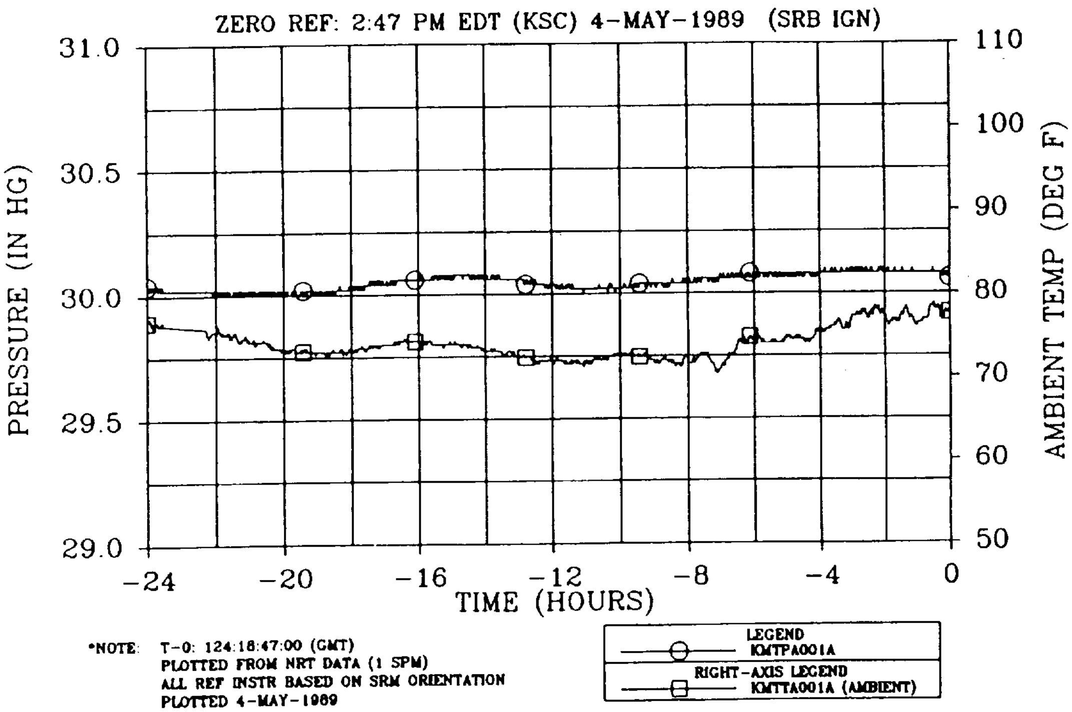


Figure 4.8-6. Prelaunch Barometric Pressure at Camera Site No. 3
(overlaid with ambient)

Table 4.8-4. STS-30R April Historical On-Pad Temperature Predictions Versus Actual GEI/Joint Heater Sensor Data (°F)

Component	Daily Cycling Historical	Daily Cycling Actual	T - 6 Hr to T - 5 Min Historical	T - 6 Hr to T - 5 Min Actual	T - 5 Min Historical	T - 5 Min Actual
Igniter Joint						
RH	71-80	59-66*	80-100	78-110	83-84	78-91*
LH	71-80	70-85	80-100	83-104	83-84	83-86
Field Joint						
RH Forward	65-83	75-88	97-105	95-103	103-107	95-101
LH Forward	64-83	75-82	96-105	94-104	102-106	95-104
RH Center	64-83	71-87	97-107	94-108	97-105	95-107
LH Center	64-82	74-80	96-105	93-103	97-105	95-104
RH Aft	64-82	71-86	97-107	93-107	97-107	96-107
LH Aft	64-82	64-79**	97-103	89-105**	98-102	95-101**
Case-to-Nozzle Joint						
RH	67-77	74-80	75-83	82-90	82-83	85-90
LH	67-77	72-76	75-83	80-85	82-83	82-85
Flex Bearing Aft End ring						
RH	67-77	75-77	75-83	82-88	82-83	85-88
LH	67-77	75-77	75-83	82-86	82-83	85-86
Case Acreage (deg)						
RH 45	64-80	70-86	65-80	75-83	79-80	78-83
135	65-84	67-91	65-83	70-86	82-83	76-86
215	65-82	70-81	67-81	74-84	80-81	76-83
270	65-82	70-84	66-80	73-84	79-80	76-83
325	65-82	69-80	65-80	74-80	79-80	77-80
LH 45	65-84	69-79	65-83	72-84	82-84	77-83
135	65-81	69-80	65-81	74-82	80-81	77-82
215	64-80	70-79	65-80	72-80	78-80	78-80
270	65-82	70-79	66-81	74-78	80-81	75-78
325	65-83	70-78	66-83	74-80	81-83	75-80
Local Environment						
Temperature***	64-78	62-78	68-77	72-78	77	77
Windspeed (kt)	13	2-15	13	2-15	13	11-15
Wind Direction†	SE	S-NE	SE	E-SE	SE	E-SE
Cloud Cover	Clear/cloudy		Clear/cloudy		Clear	

*Sensor B06T8085A 10°F low during all monitoring periods
**Sensor B06T7070A 7°F low during all monitoring periods
***Actual temperatures are representative of April historical conditions
†Predominant wind direction

dropped 2.5° to 3.5°F lower than the corresponding sensor locations on the RH motor. The cooling occurred on the RH motor at 270 deg. If cooling did occur at this location on the RH motor, a determination which could not be made, then the net cooling effect would be even greater.

This cooling should not be considered serious because the actual case surface temperature was never more than 3°F lower than the ambient temperature. It should also be noted that the GOX venting played no part in this LH motor inboard location cooling occurrence.

From the cooling which occurred on this flight set and from that which occurred on STS-29R, a general conclusion can be made. The conclusion is that a consistent wind from the east will cause cooling on the inboard side of the west motor and a consistent wind from the west will cause cooling on the inboard side of the east motor. This occurrence is a consequence of air cooling as it is blown around the ET, resulting in regions of subcooling at inboard locations.

4.8.3.5 Launch Commit Criteria. No LCC thermal violations were noted. Measured GEI and heater sensor data, as compared to the LCC requirements, are presented in Table 4.8-5.

The igniter heaters performed as expected, with cooldown occurring over an approximate 7-hr period. At T - 5 minutes, the RH SRM igniter had dropped to 78°F while the LH SRM igniter dropped to 84°F. The lower reading on the RH SRM igniter was due to a gage which read 10°F low from the beginning of gage monitoring.

The six field joint heaters performed adequately and as expected, with a sensor temperature range of 89° to 108°F during the LCC timeframe. The lower value of 89°F occurred at only one sensor, which had read up to 7°F low from the beginning of instrumentation monitoring. Prior to this the minimum field joint LCC redline was reduced from 85° to 73°F. This modification was a change unique to STS-30R and was a precaution taken in the event of a primary heater failure, as explained below.

The LH forward secondary heating element, which had previously failed a DWV test, was inadvertently activated at about L - 24 hr during the automatic heater functionality test. (This test applies power to each heating element in turn, beginning with the left forward primary and ending with the right aft secondary.) The heater appeared to function properly, producing a 3°F rise in temperature with no excess current flow. However, disassembly inspection revealed an excessively heated pin on the connector plug. An IPR was written concerning this incident because the activation of the heater was an operator error. The IPR was upgraded to a problem report (PR), then upgraded again to a preliminary IFA. Upon review, however, this was downgraded and not elevated to IFA status.

The SRB aft skirt purge operation performed as expected. There was no evidence of circumferential temperature gradients in the aft skirt compartment, which had been seen in earlier launches.

Table 4.8-5. STS-30R LCC Time Period (T - 6 Hr to T - 5 Min)
On-Pad Temperature Predictions Versus Actual
GEI/Joint Heater Sensor Data (°F)*

Component	T - 6 Hr to T - 5 Min Prediction	T - 6 Hr to T - 5 Min Actual	T - 5 Min LCC	T - 5 Min Actual
Igniter Joint				
RH	80-95	78-110	66-123	78-91
LH	80-87	83-104	66-123	83-86
Field Joint				
RH Forward	94-106	95-103	85-122	95-101
LH Forward	94-104	94-104	85-122	95-104
RH Center	94-110	94-108	85-122	95-107
LH Center	94-104	93-103	85-122	95-104
RH Aft	94-110	93-107	85-122	96-107
LH Aft	94-110	89-105	85-122	95-101
Case-to-Nozzle Joint				
RH	85-91	82-90	75-115	85-90
LH	80-90	80-85	75-115	82-85
Flex Bearing Aft End Ring				
RH	85-91	82-90	NA-115	85-88
LH	82-88	82-88	NA-115	85-86
Case Acreage (deg)				
RH 45	--	75-83	35-NA	78-83
135	--	70-86	--	76-86
215	--	74-84	--	76-83
270	79-86	73-84	35-NA	76-83
325	--	74-80	--	77-80
LH 45	--	72-84	35-NA	77-83
135	--	74-82	--	77-82
215	--	72-80	--	78-80
270	80-86	74-78	35-NA	75-78
325	--	74-80	--	75-80
Local Environment				
Temperature**	84-87***	72-78	38-99	77
Windspeed (kt)	13	2-15	24	11-15
Wind Direction†	SE	E-SE	SW-SE	E-SE
Cloud Cover	Clear/cloudy		Clear	

*Predictions for anticipated launch window at T - 5 min
**Actual temperatures representative of April historical conditions
***Predictions based upon this projected ambient from GWEN JASPAR/MSFC
†Predominant wind direction

4.8.3.6 Prelaunch Thermal Data Evaluation. Figures 4.8-7 through 4.8-11 show locations of the GEI and joint heater sensors for the igniter adapter, field joints, case acreage, nozzle region, and aft exit cone, respectively. Figures 4.8-12 through 4.8-41 present April historical predictions. These predications are based on event sequencing, as specified in Table 4.8-6. Figures 4.8-42 through 4.8-98 show actual STS-30R countdown data.

Actual GEI and joint heater sensor data were in agreement, for the most part, with April historical on-pad predictions. The deviations which occurred were largely a result of comparing actual May data with historical April data. The actual minimum temperatures were 4° to 8°F warmer than the historical average minimum temperatures for the month of April.

The LCC time period (T - 6 hr to T - 5 min) real-time predictions, which incorporate an environmental update for the last 24 hr prior to launch, were somewhat in agreement with GEI. The GEI deviated on the lower side due to lower than anticipated ambient temperatures (Table 4.8-5).

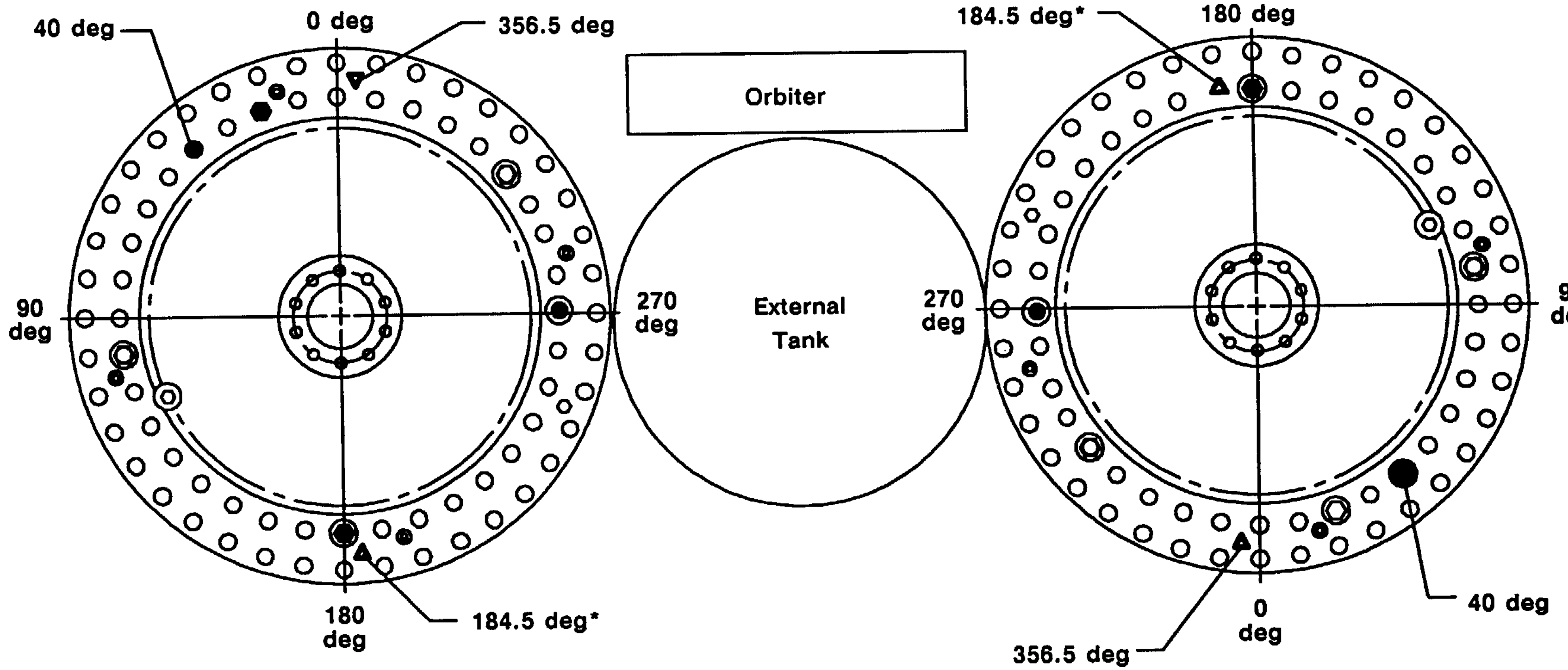
Postflight reconstructed predictions of GEI and igniter/field joint heater response have been performed using the actual environmental data from the 24 hr prior to launch. A few examples of these predictions, compared with actual measured sensor data, are found in Figures 4.8-99 through 4.8-114. Reasonable agreement is apparent in all areas except the ET attach ring, systems tunnel, and case-to-nozzle joint regions. In the future, modeling improvements (environment and detail) need to be made in these regions.

IR temperature measurements were taken for three different timeframes. During the L - 1-day pad inspection of the aborted countdown, IR gun measurements were recorded and compared with GEI (Table 4.8-7). During the T - 3-hr timeframe of the aborted countdown, comparisons were made of GEI versus collected IR measurements from the IR gun (Table 4.8-8), the portable STI, and the two stationary STIs. During the T - 3-hr timeframe of the successful countdown, comparisons were made of GEI versus collected IR measurements of the IR gun (Table 4.8-9), the portable STI, and the two stationary STIs.

IR gun data compared with GEI were poor for the L - 1-day and T - 3-hr ice/debris team pad inspection of the aborted countdown, but were considered good during the T - 3-hr period of the successful launch. STI real-time comparisons with GEI were considered very good during both countdowns. STI readings were within ±2°F of the GEI for the portable and the RSS stationary STI and they were within +4°F of the GEI for the camera Site 2 stationary STI.

4.8.4 Conclusions and Recommendations

4.8.4.1 Postflight Hardware Inspection. Based on the quick-look external inspection, the SRM TPS performed adequately on STS-30R. No unexpected heating effects were noted. The SRM TPS



Legend

- △ GEI Temperature
- ● Pressure (OFI)

*One of two per booster required for LCC compliance

Figure 4.8-7. Forward Dome GEI

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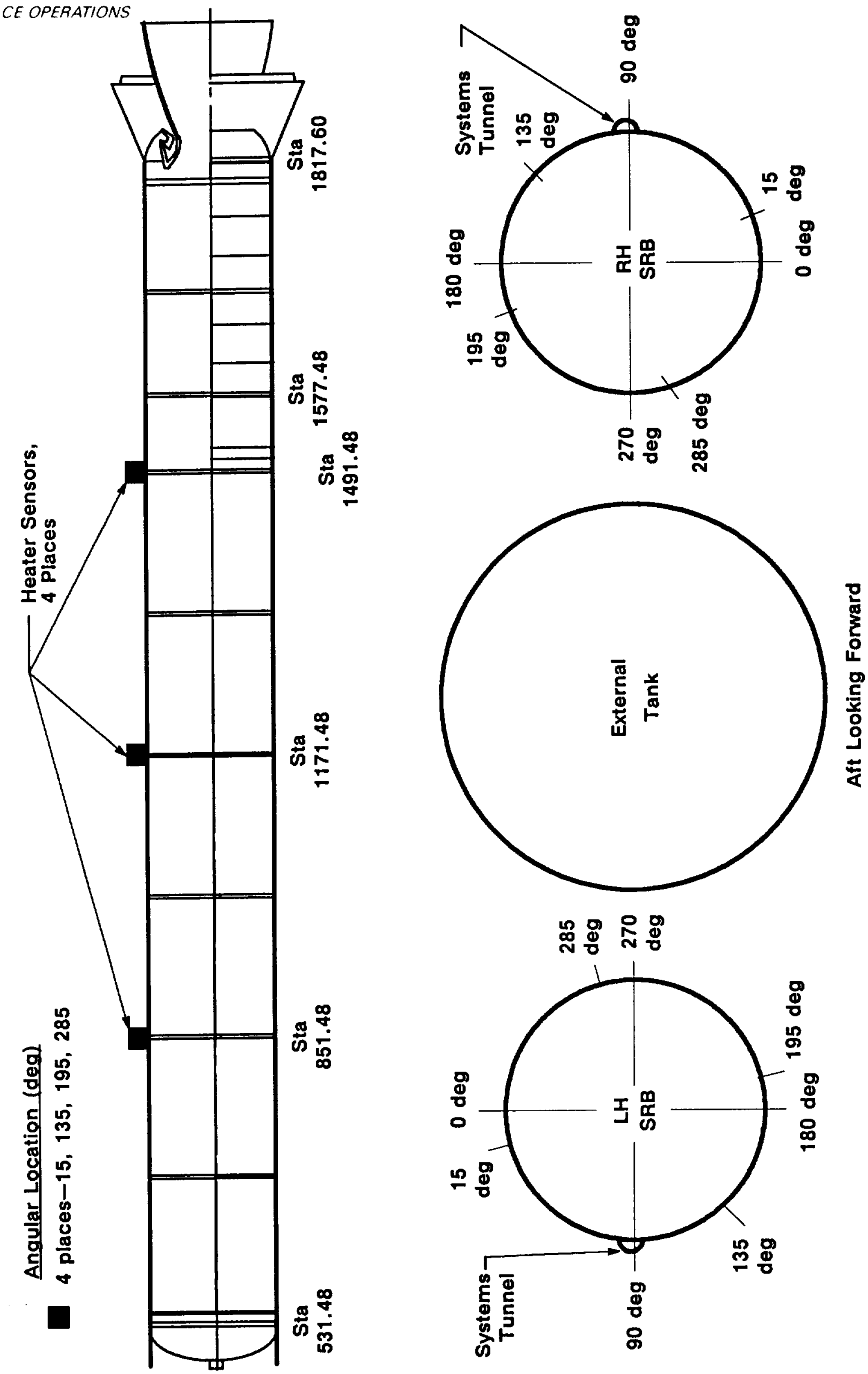

Figure 4.8-8. Field Joint Heater Temperature Sensors

A023172a

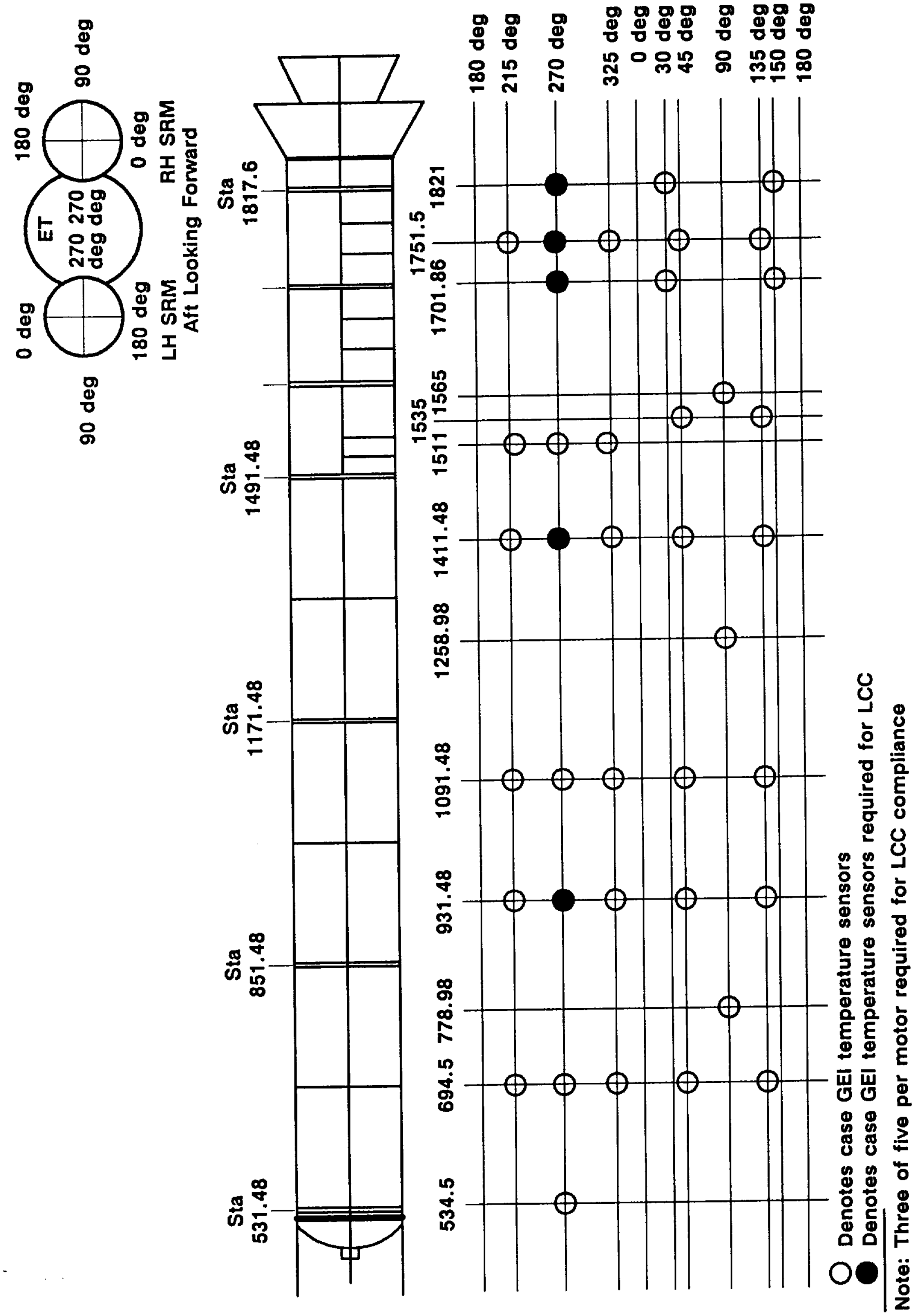

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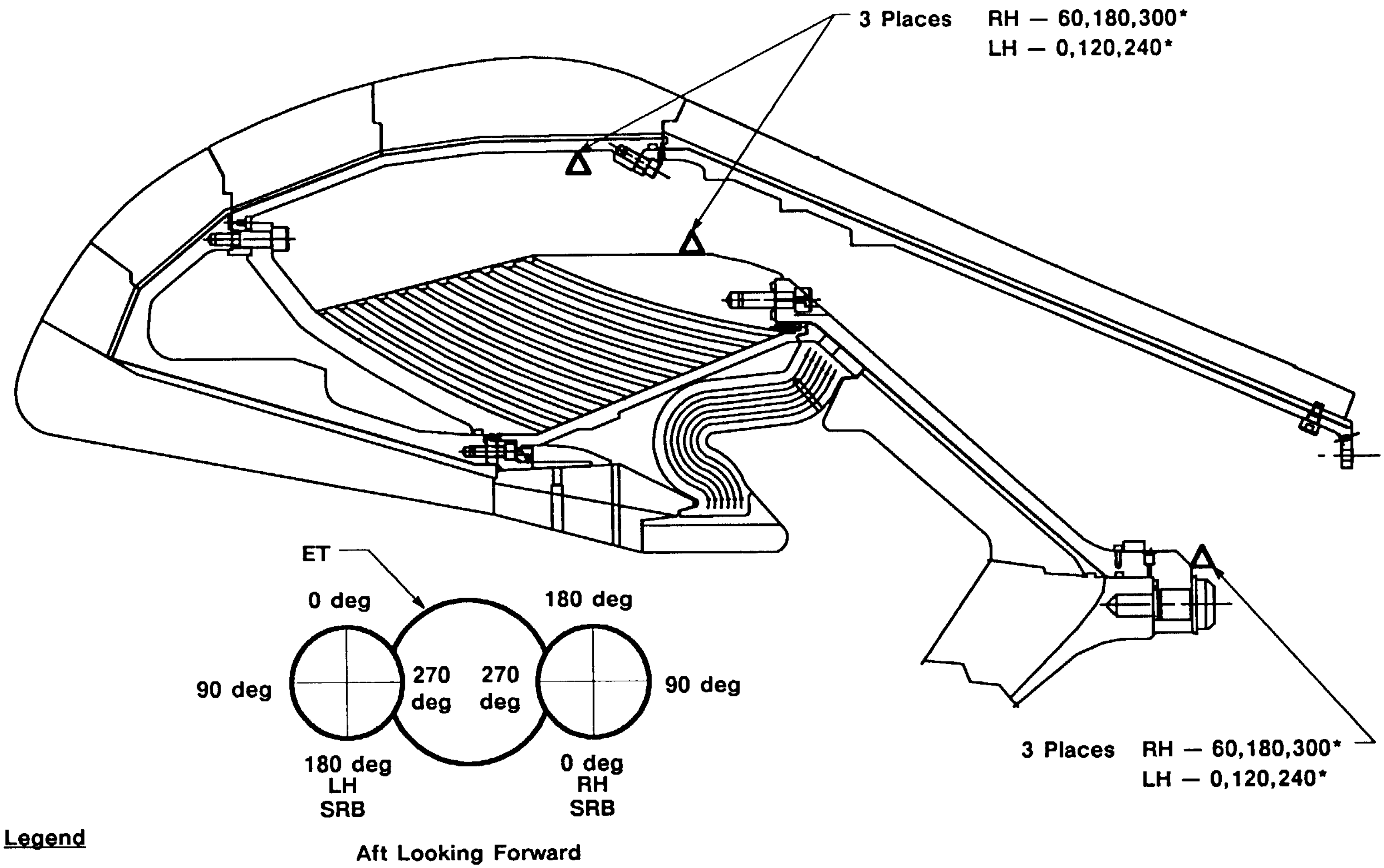
Figure 4.8-9. Case Acreage GEI



Legend

△ GEI Temperature

*Two of three per each location required for LCC compliance

Figure 4.8-10. Nozzle/Exit Cone GEI

A023169a

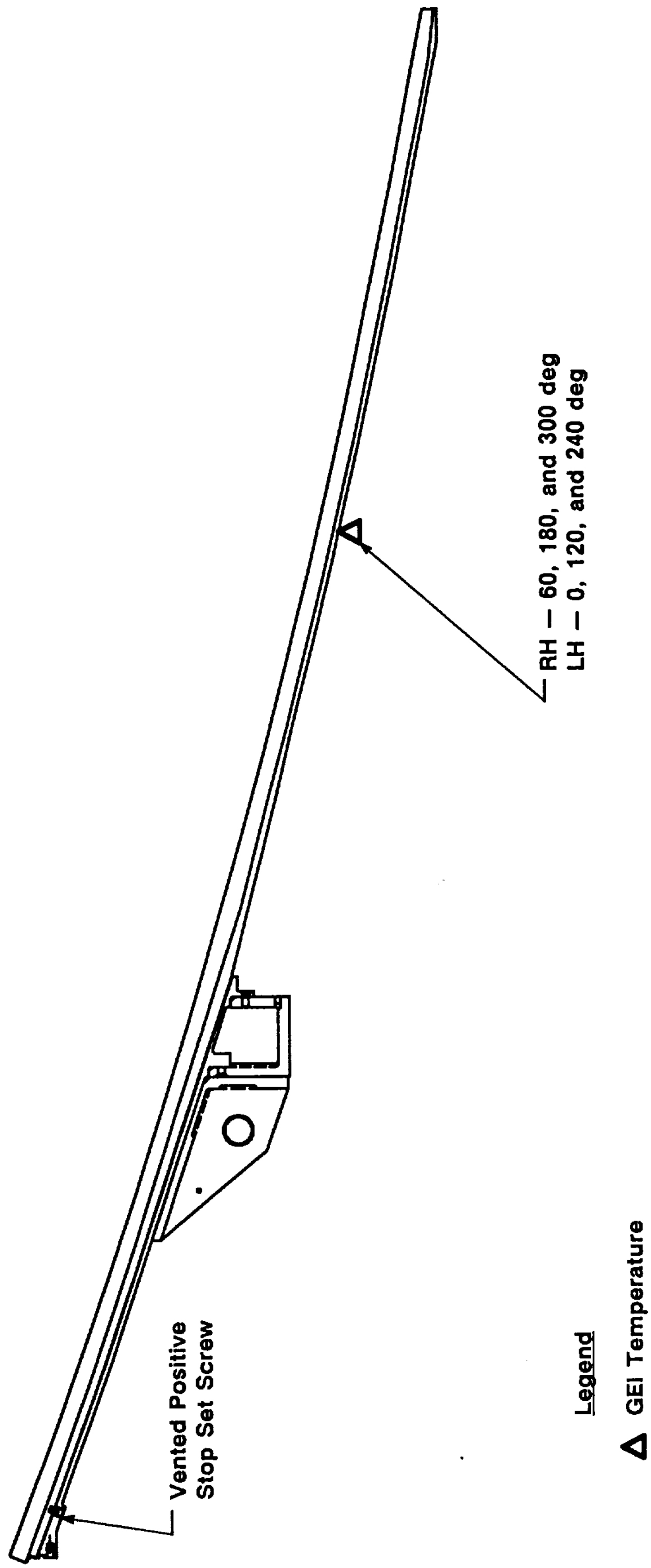


Figure 4.8-11. Aft Exit Cone GEI

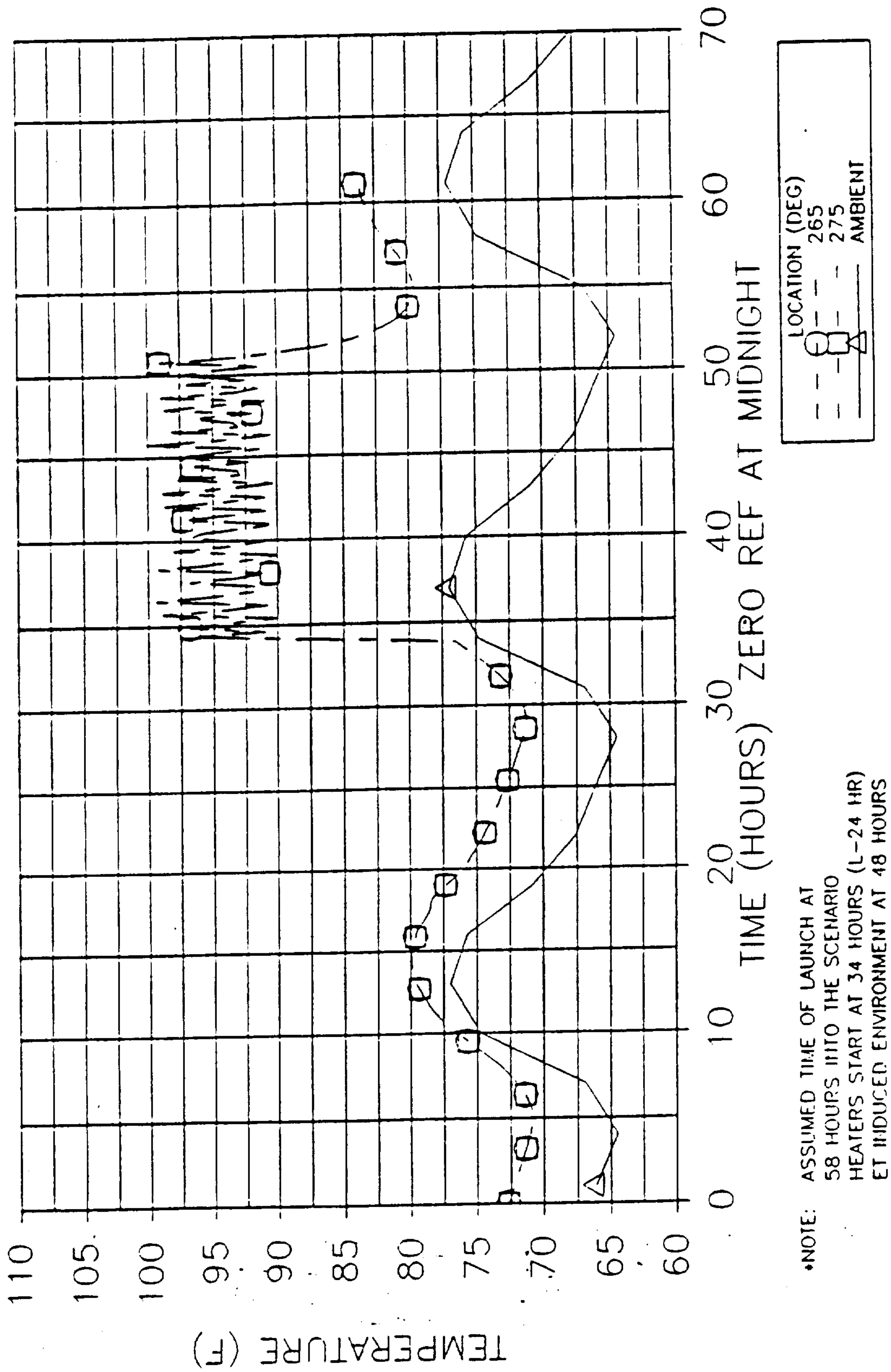


Figure 4.8-12. RH SRM Ignition System Region-Heater and GEI Sensor Temperature Prediction

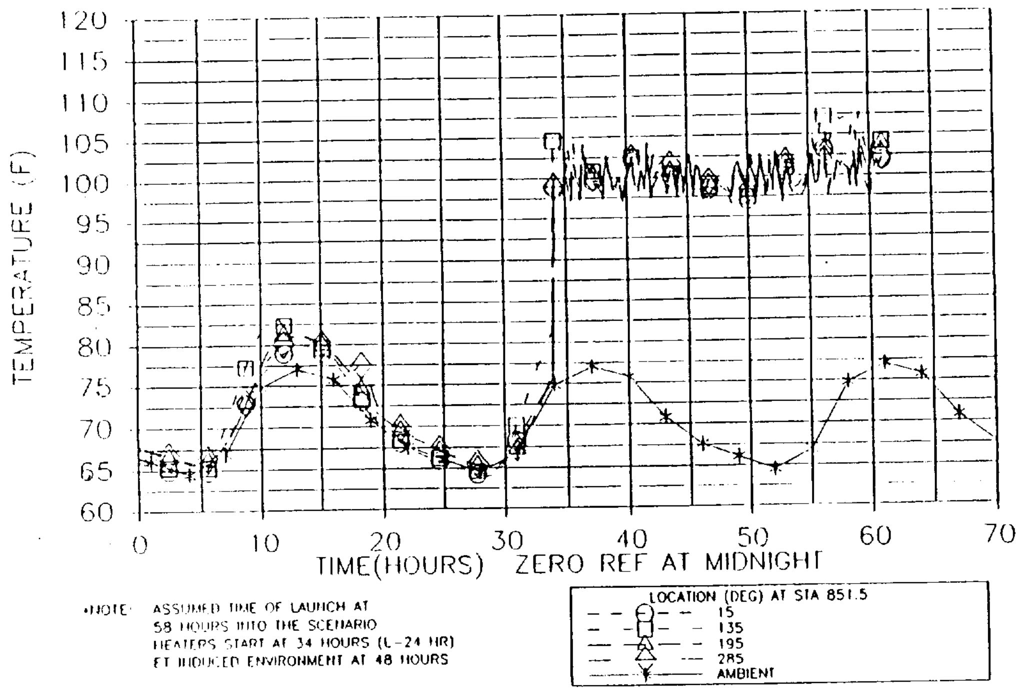


Figure 4.8-13. RH SRM Forward Field Joint--Heater Sensor Temperature Prediction

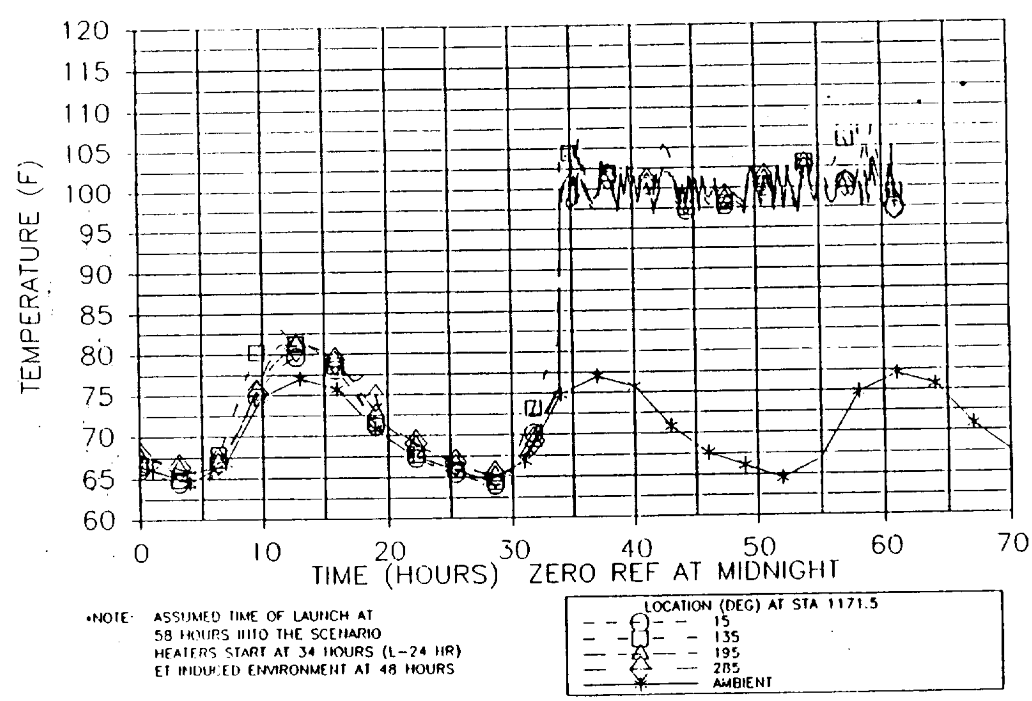


Figure 4.8-14. RH SRM Center Field Joint--Heater Sensor Temperature Prediction

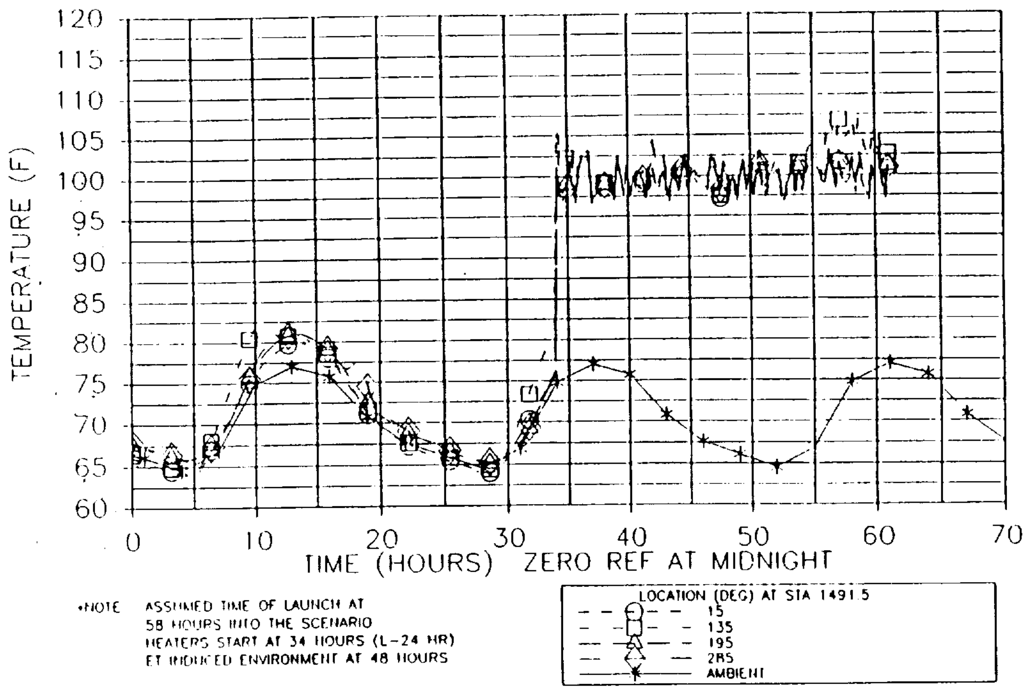


Figure 4.8-15. RH SRM Aft Field Joint--Heater Sensor Temperature Prediction

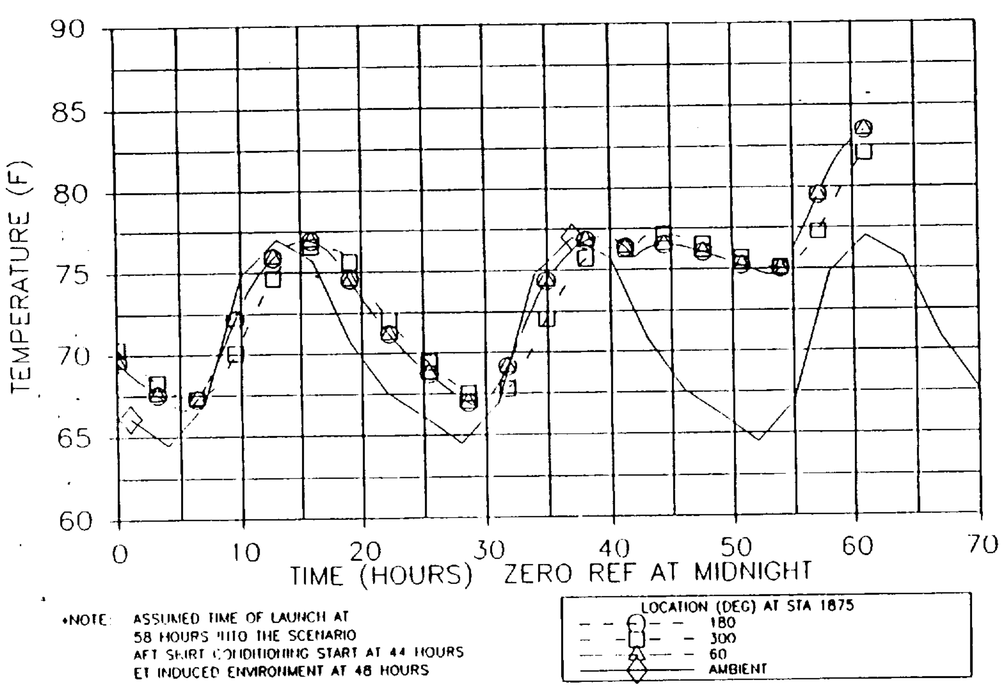


Figure 4.8-16. RH SRM Nozzle Region--GEI Sensor Temperature Prediction

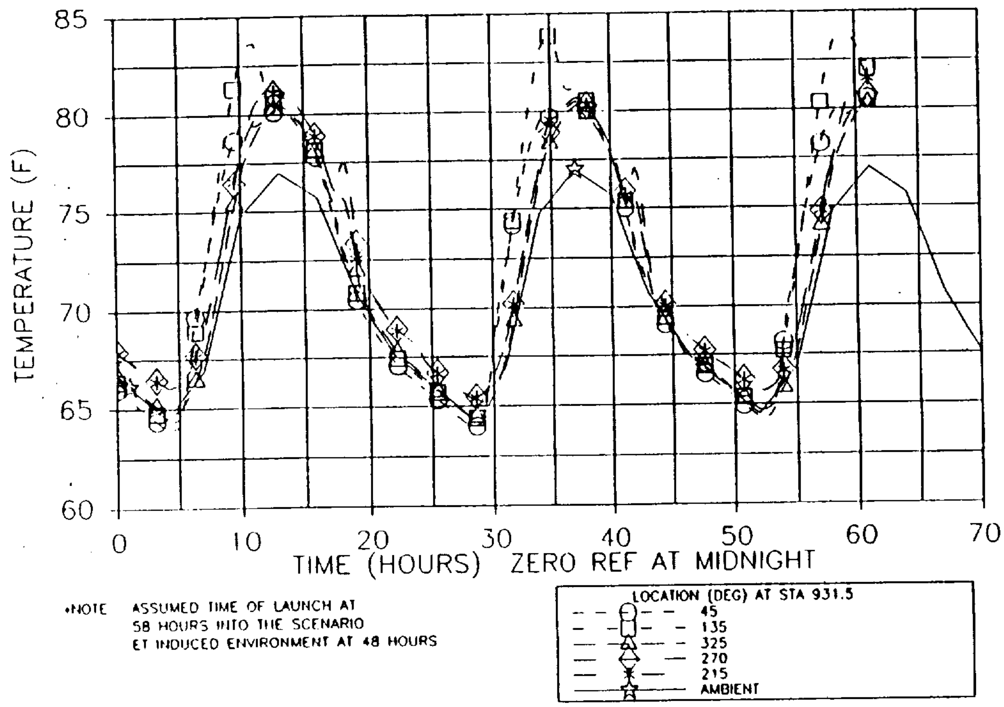


Figure 4.8-17. RH SRM Forward Case Acreage--GEI Sensor Temperature Prediction

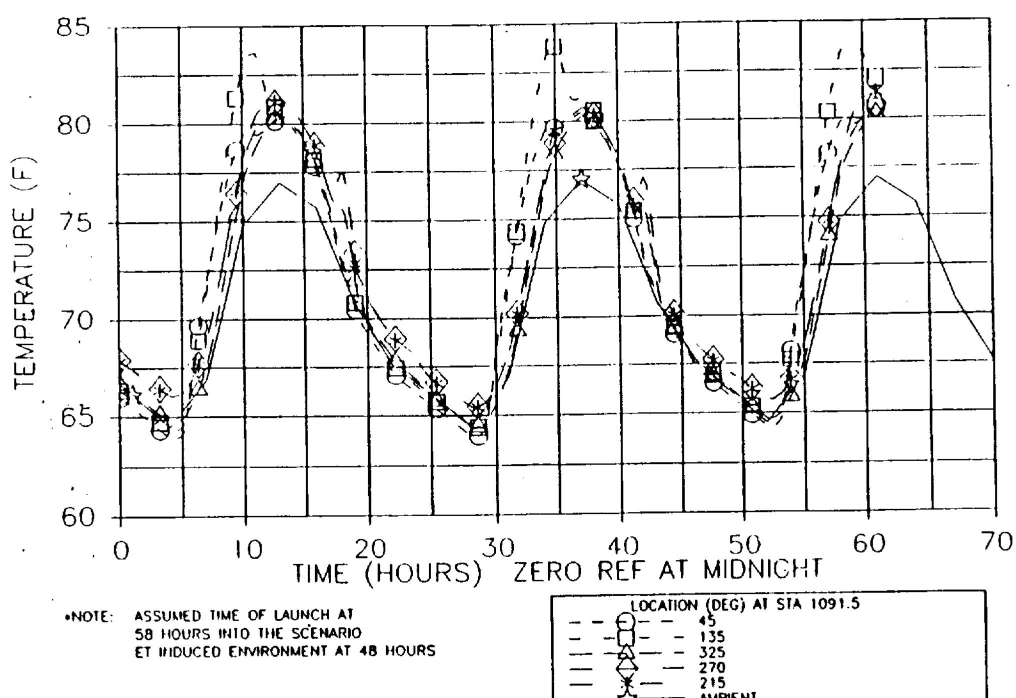


Figure 4.8-18. RH SRM Forward Center Case Acreage--GEI Sensor Temperature Prediction

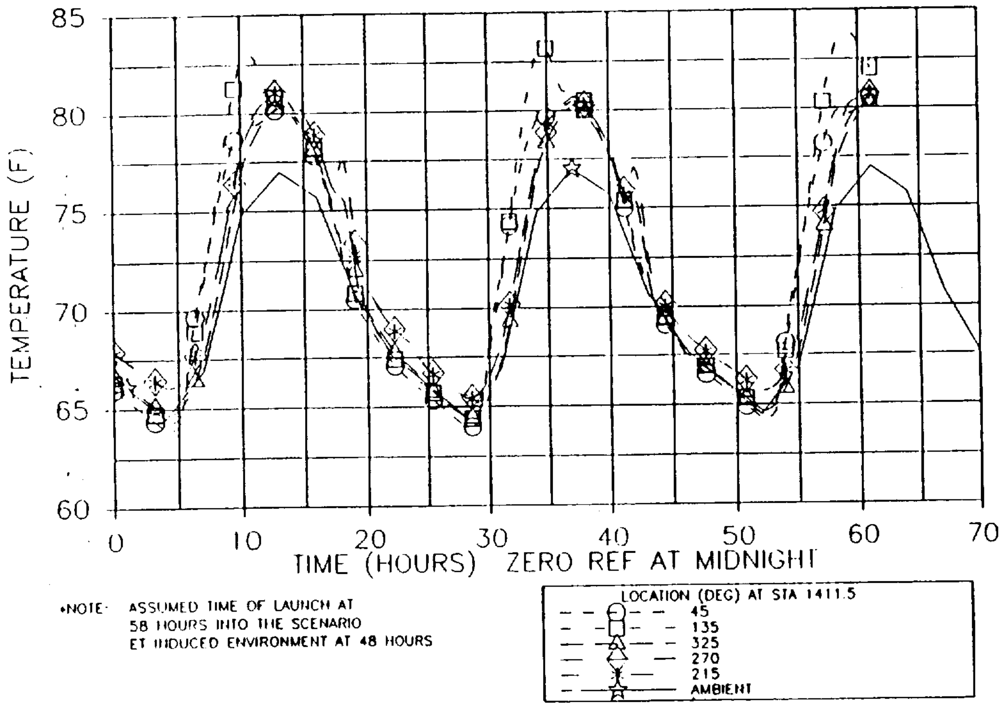


Figure 4.8-19. RH SRM Aft Center Case Acreage--GEI Sensor Temperature Prediction

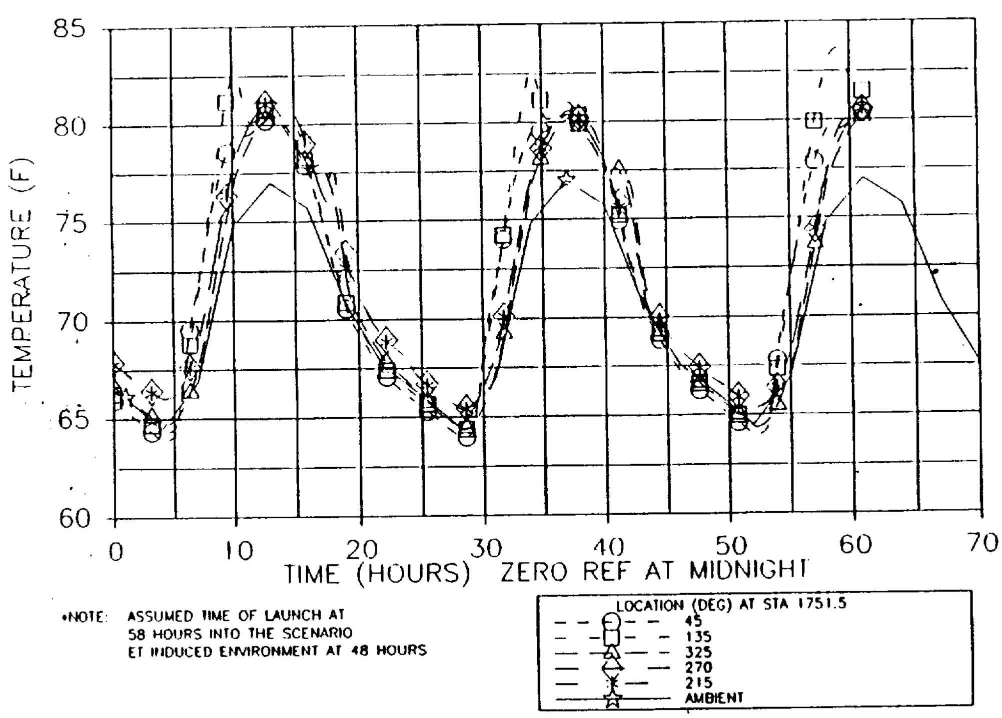


Figure 4.8-20. RH SRM Aft Case Acreage--GEI Sensor Temperature Prediction

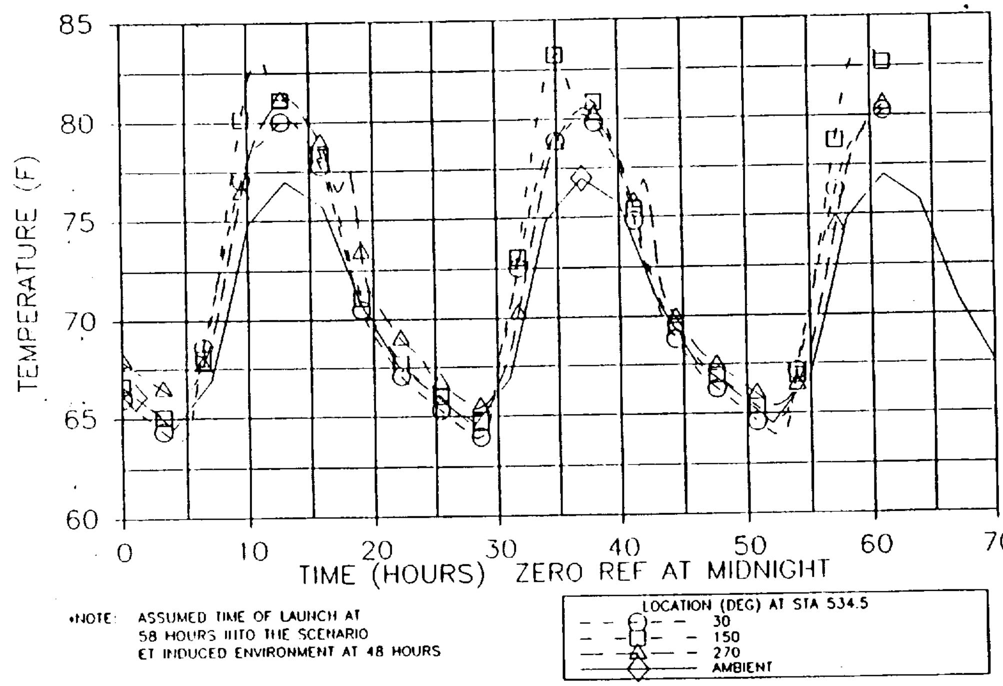


Figure 4.8-21. RH SRM Forward Dome Factory Joint--GEI Sensor Temperature Prediction

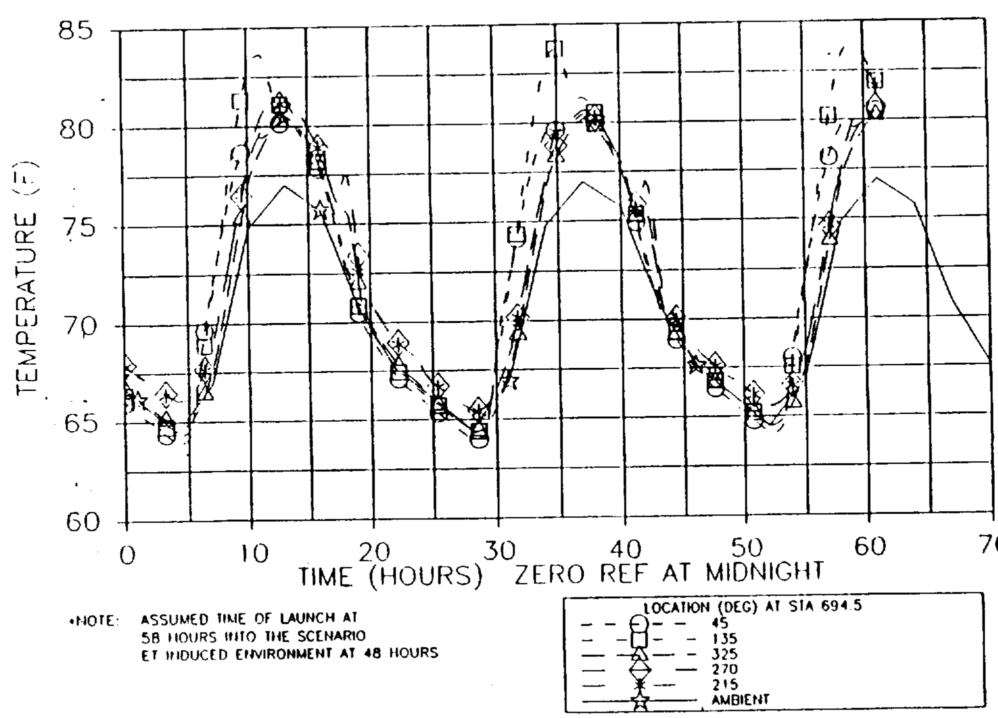


Figure 4.8-22. RH SRM Forward Factory Joint--GEI Sensor Temperature Prediction

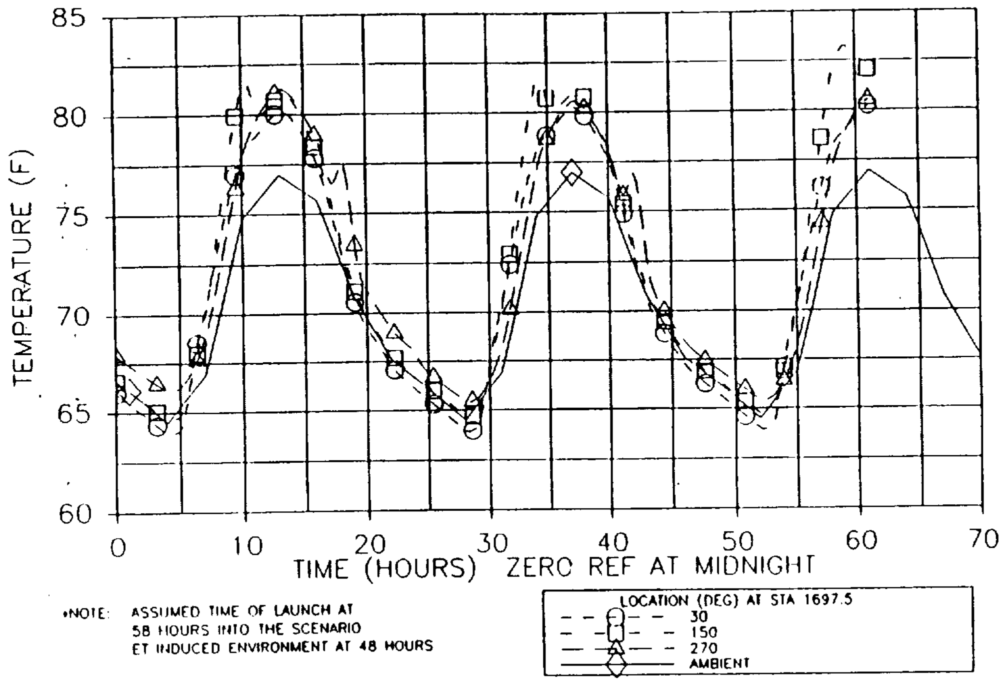


Figure 4.8-23. RH SRM Aft Factory Joint--GEI Sensor Temperature Prediction

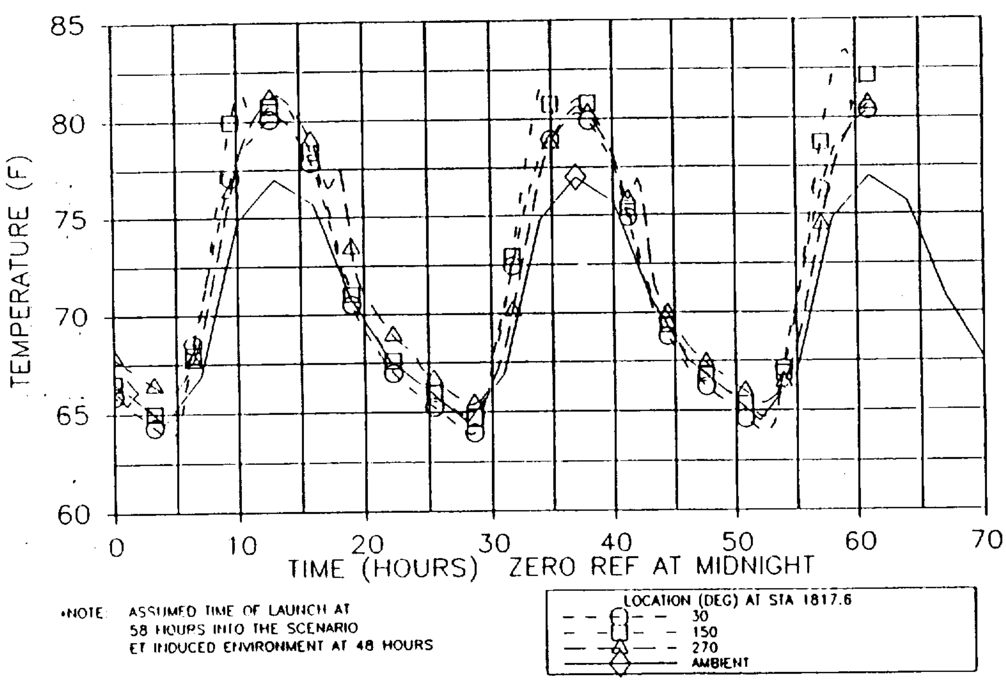


Figure 4.8-24. RH SRM Aft Dome Factory--GEI Sensor Temperature Prediction

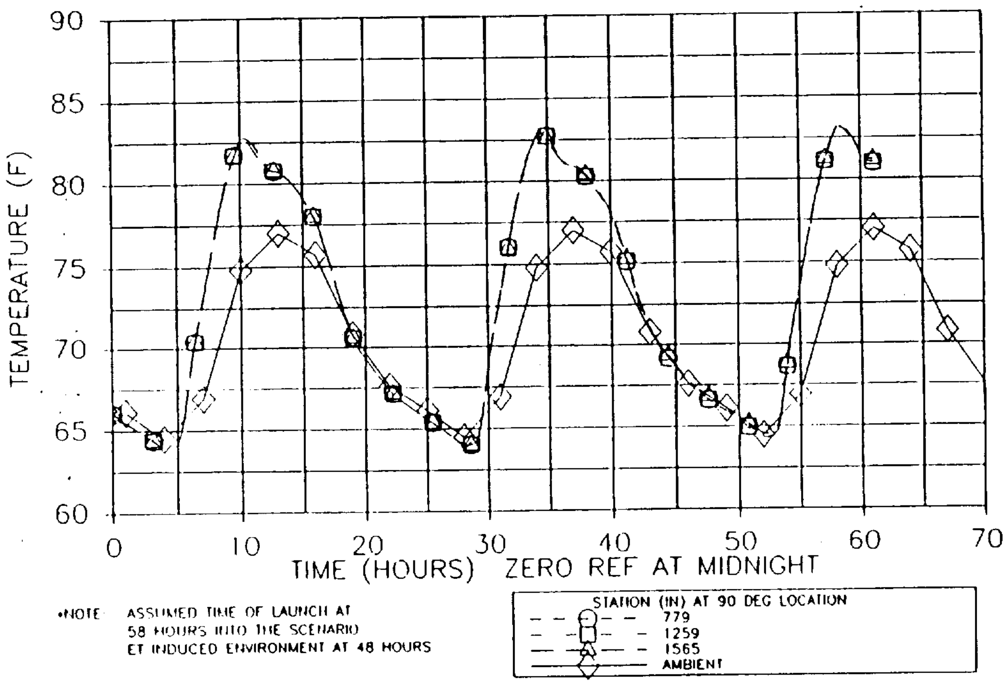


Figure 4.8-25. RH SRM Systems Tunnel Bondline--GEI Sensor Temperature Prediction

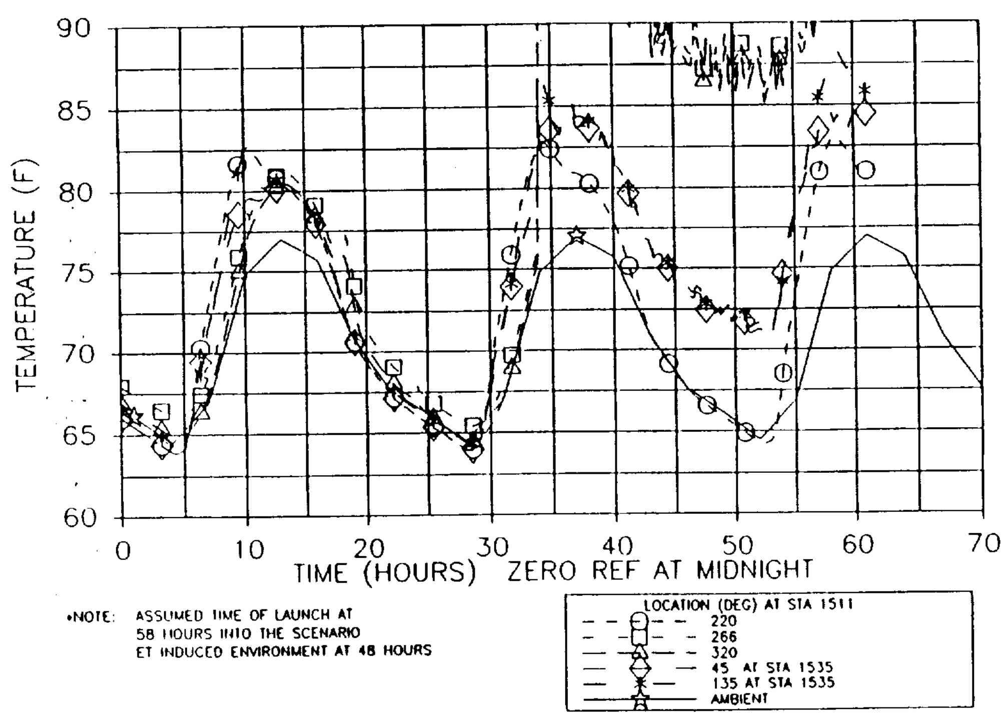


Figure 4.8-26. RH SRM ET Attach Region--GEI Sensor Temperature Prediction

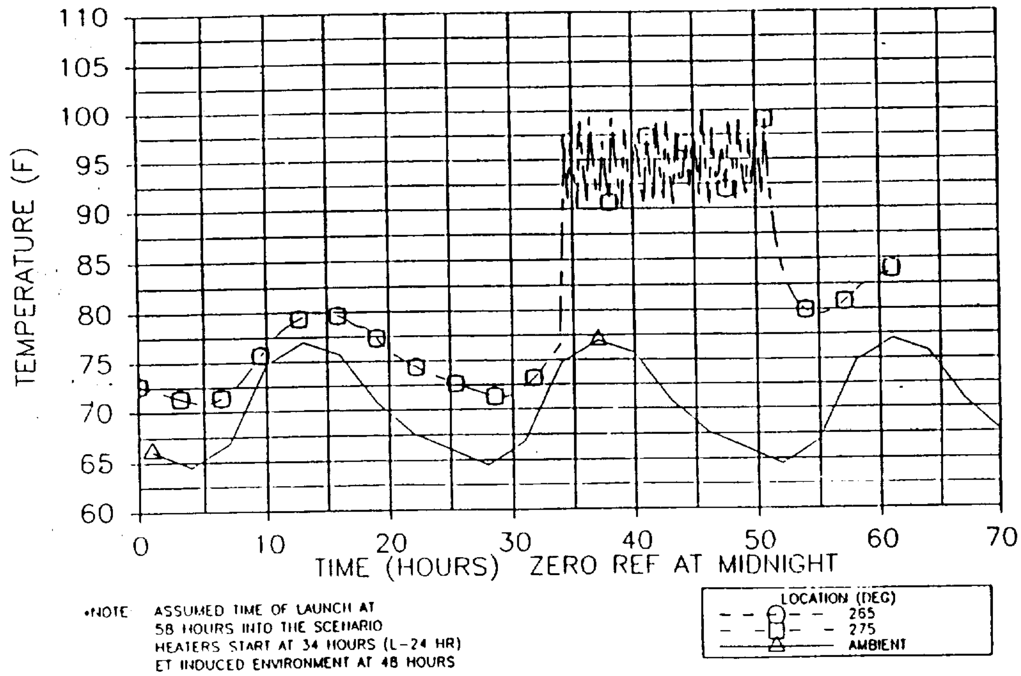


Figure 4.8-27. LH SRM Ignition System Region--Heater and GEI Sensor Temperature Prediction

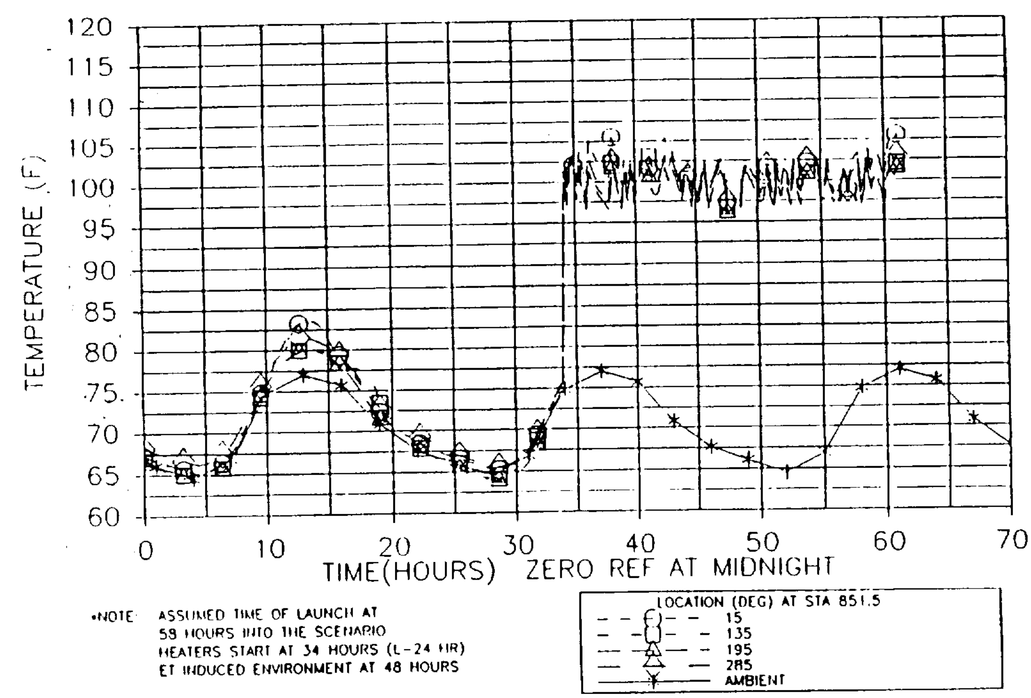


Figure 4.8-28. LH SRM Forward Field Joint--Heater Sensor Temperature Prediction

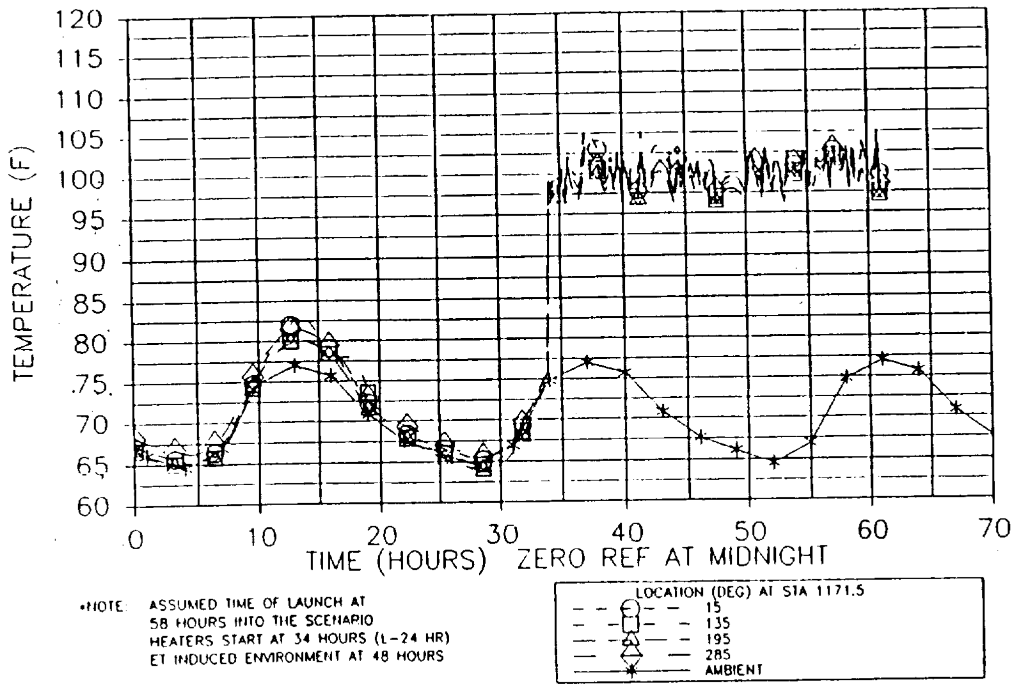


Figure 4.8-29. LH SRM Center Field Joint--Heater Sensor Temperature Prediction

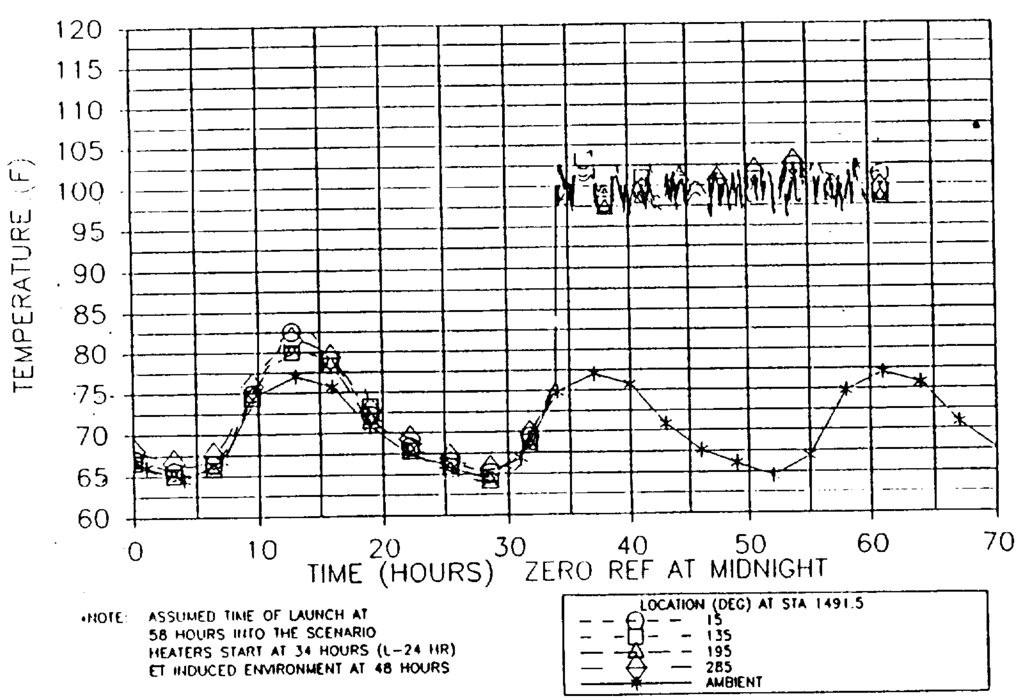


Figure 4.8-30. LH SRM Aft Field Joint--Heater Sensor Temperature Prediction

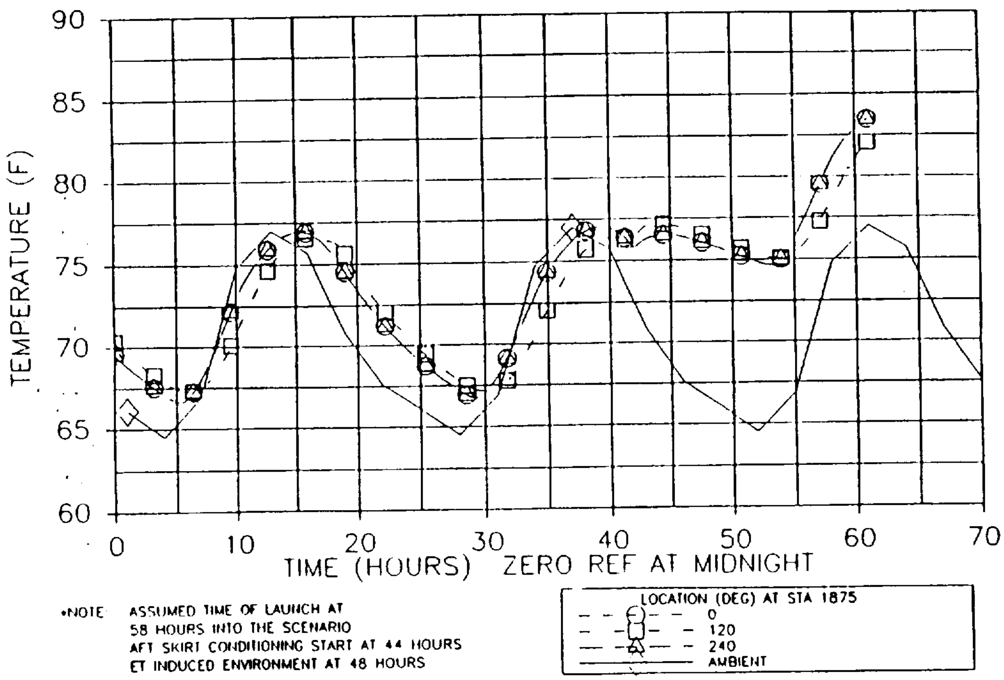


Figure 4.8-31. LH SRM Nozzle Region--GEI Sensor Temperature Prediction

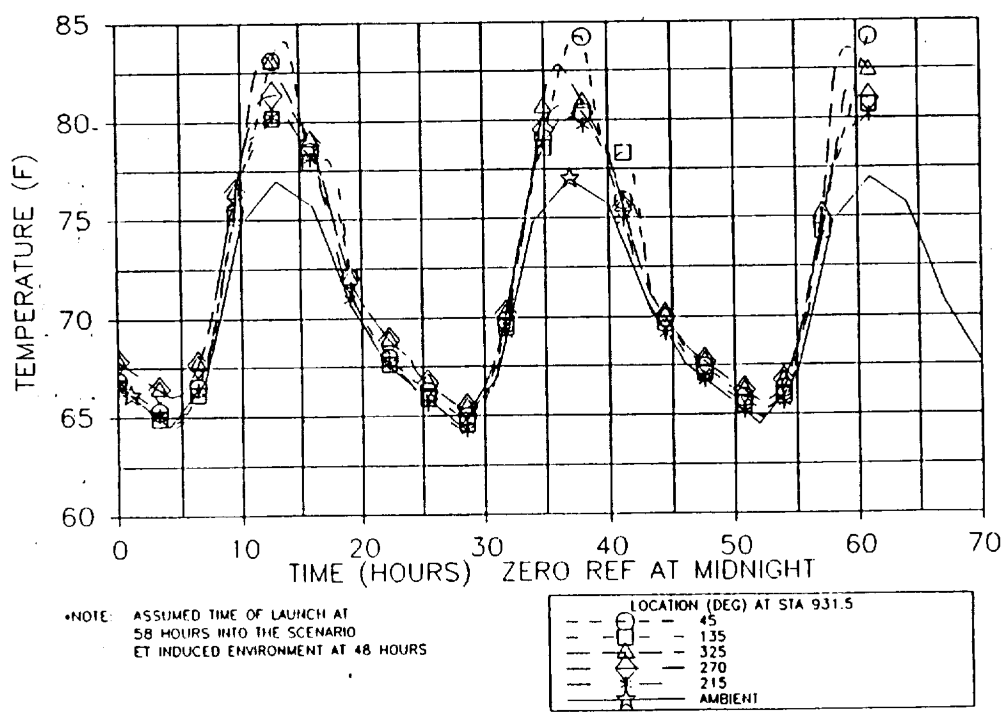


Figure 4.8-32. LH SRM Forward Case Acreage--GEI Sensor Temperature Prediction

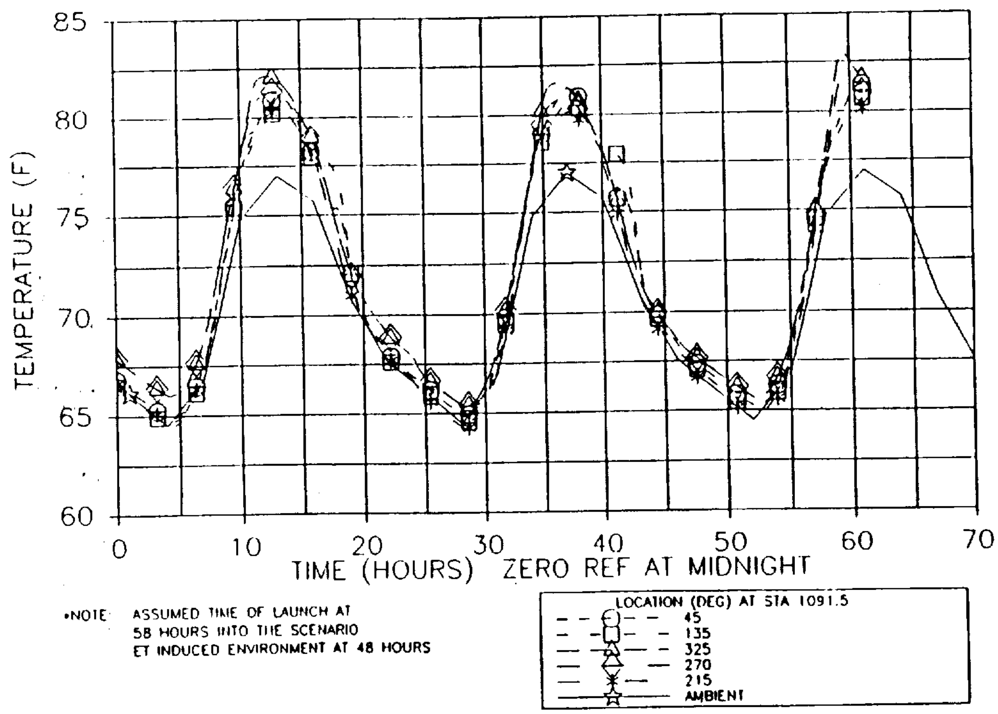


Figure 4.8-33. LH SRM Forward Center Case Acreage--GEI Sensor Temperature Prediction

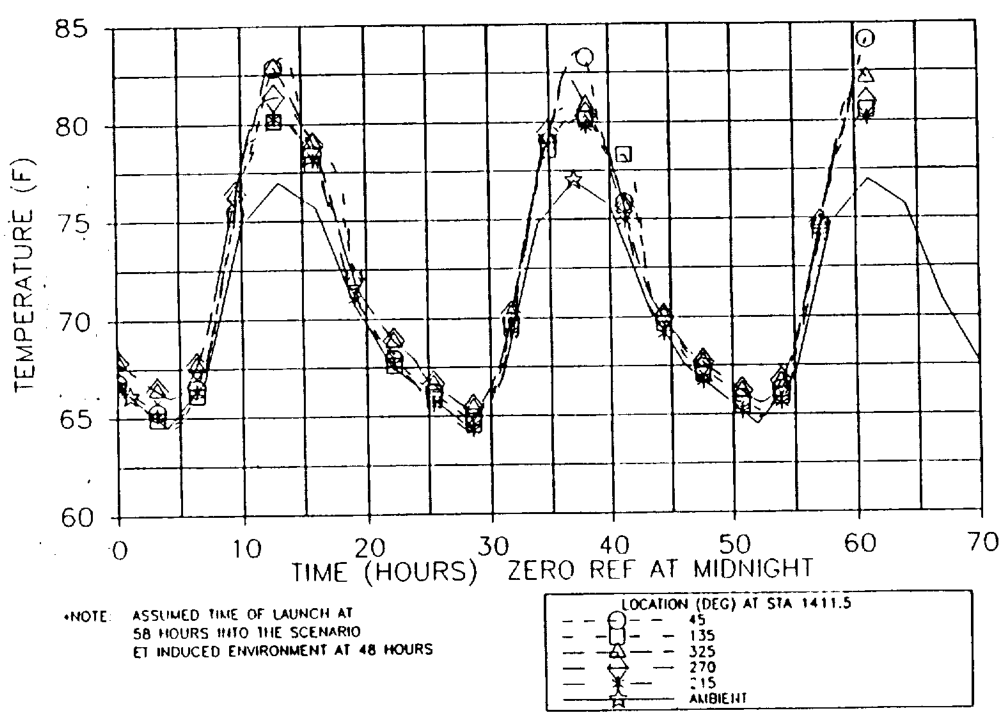


Figure 4.8-34. LH SRM Aft Center Case Acreage--GEI Sensor Temperature Prediction

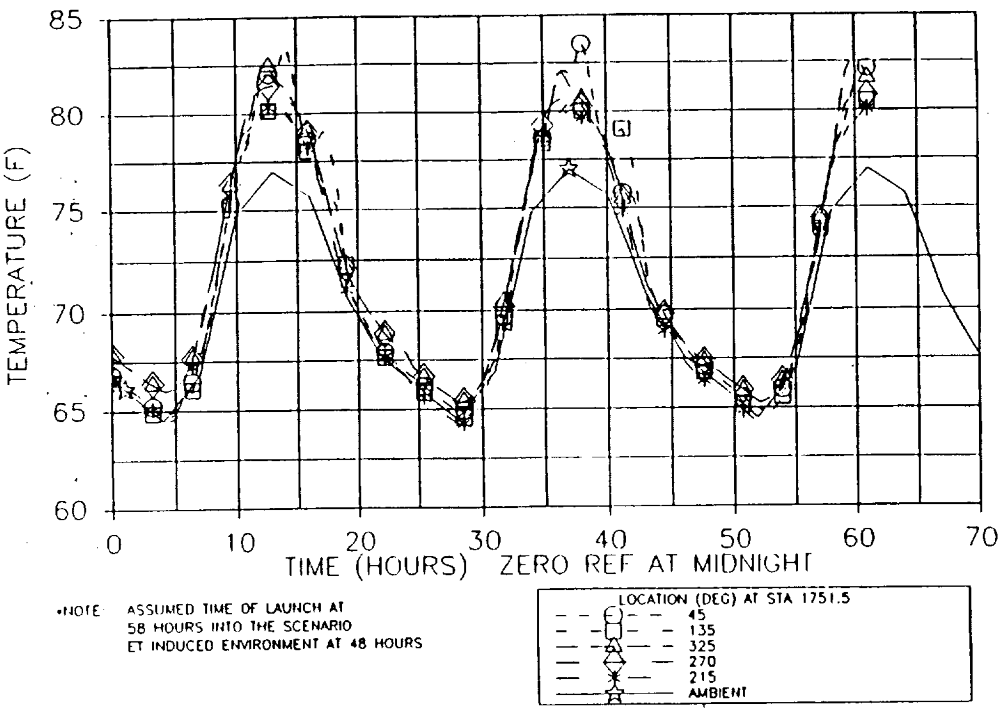


Figure 4.8-35. LH SRM Aft Case Acreage--GEI Sensor Temperature Prediction

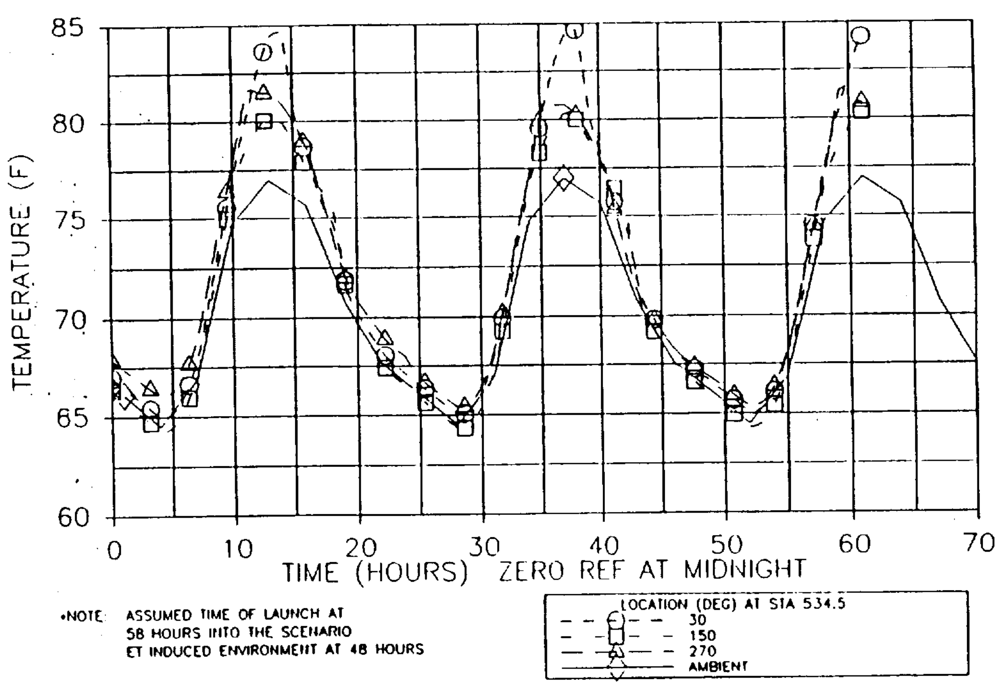


Figure 4.8-36. LH SRM Forward Dome Factory Joint--GEI Sensor Temperature Prediction

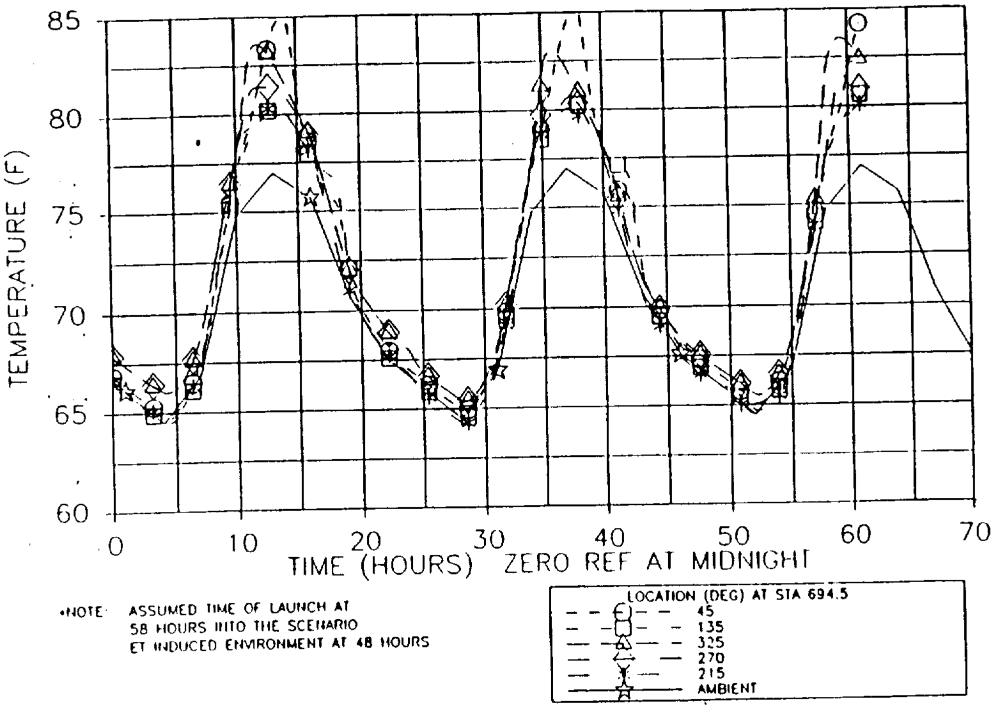


Figure 4.8-37. LH SRM Forward Factory Joint--GEI Sensor Temperature Prediction

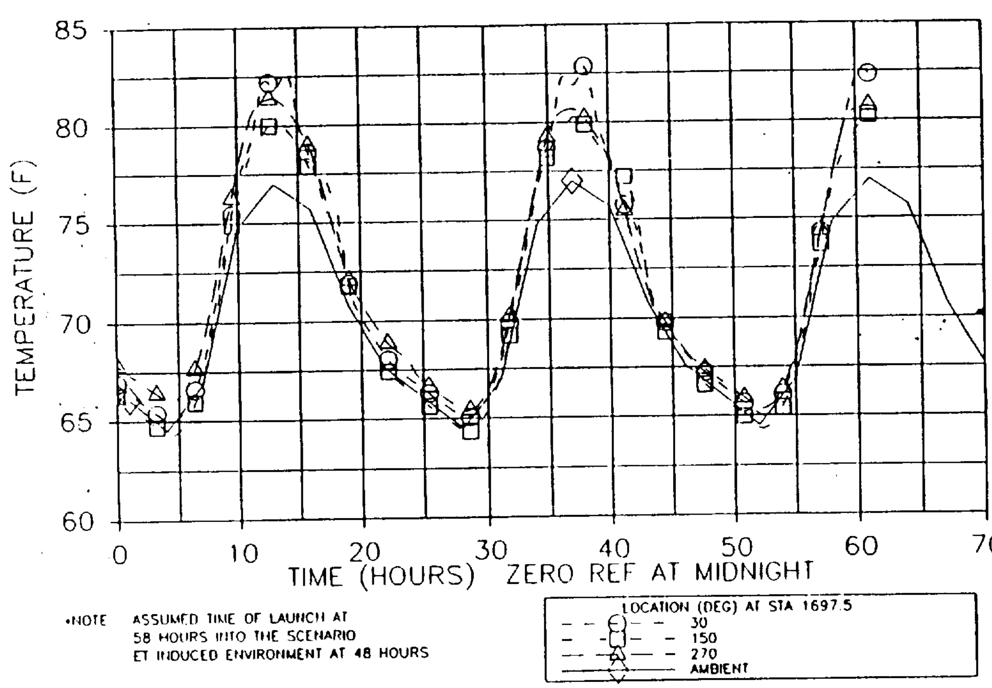


Figure 4.8-38. LH SRM Aft Factory Joint--GEI Sensor Temperature Prediction

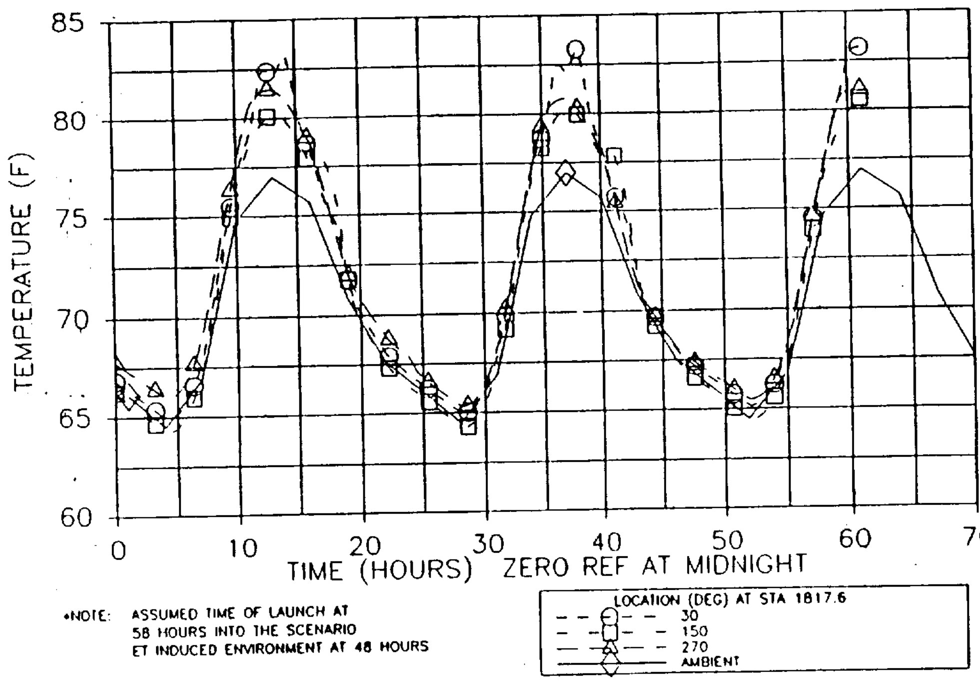


Figure 4.8-39. LH SRM Aft Dome Factory Joint--GEI Sensor Temperature Prediction

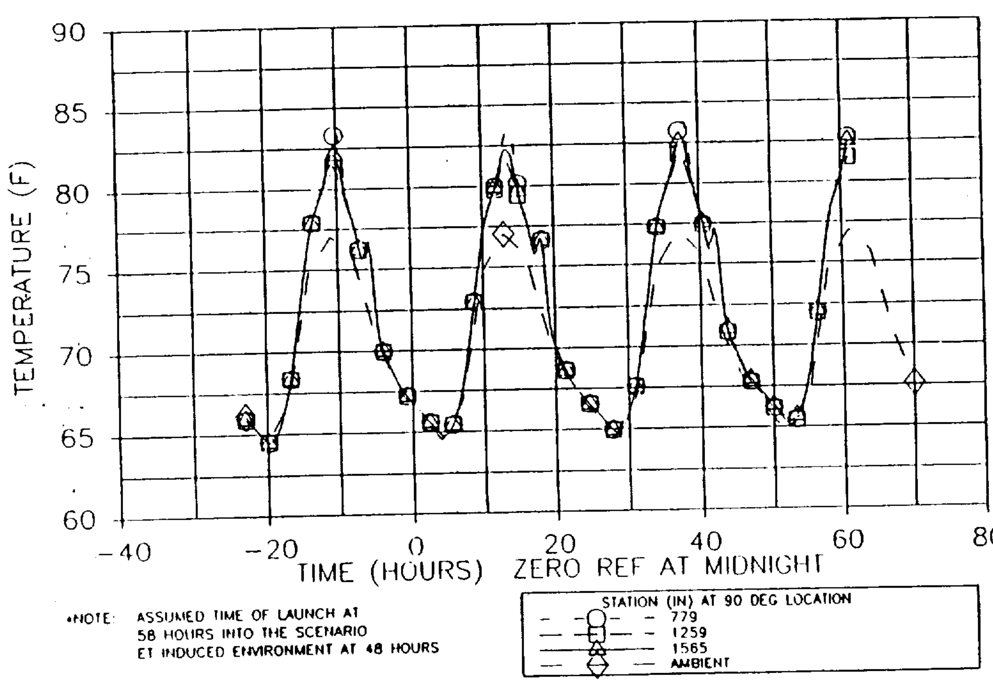


Figure 4.8-40. LH SRM Systems Tunnel Bondline--GEI Sensor Temperature Prediction

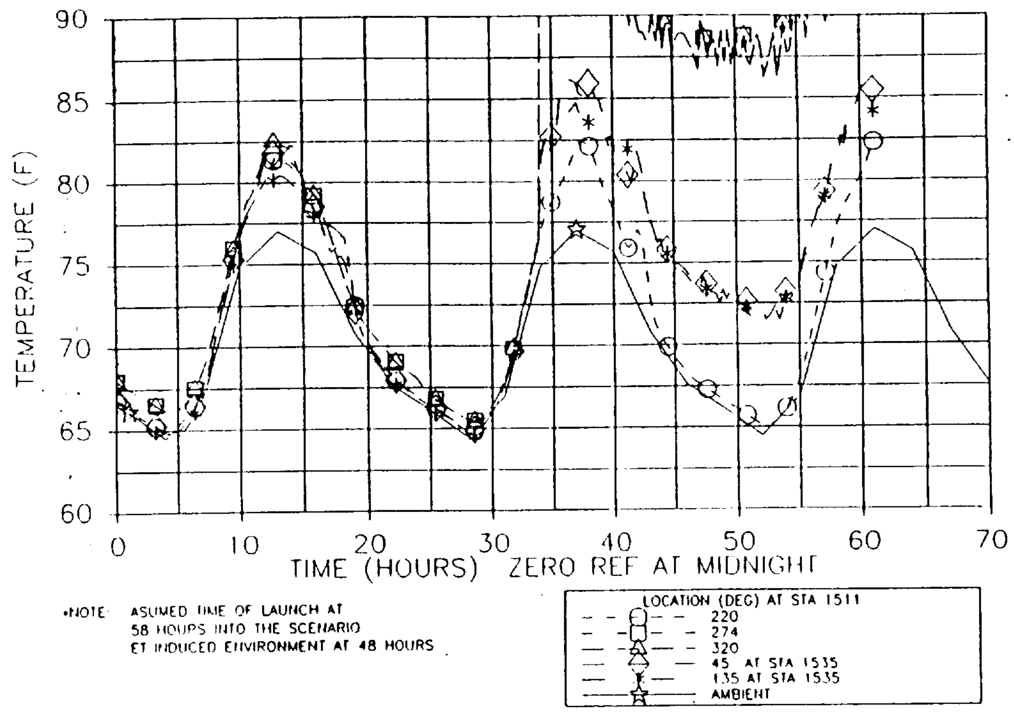


Figure 4.8-41. LH SRM ET Attach Region--GEI Sensor Temperature Prediction

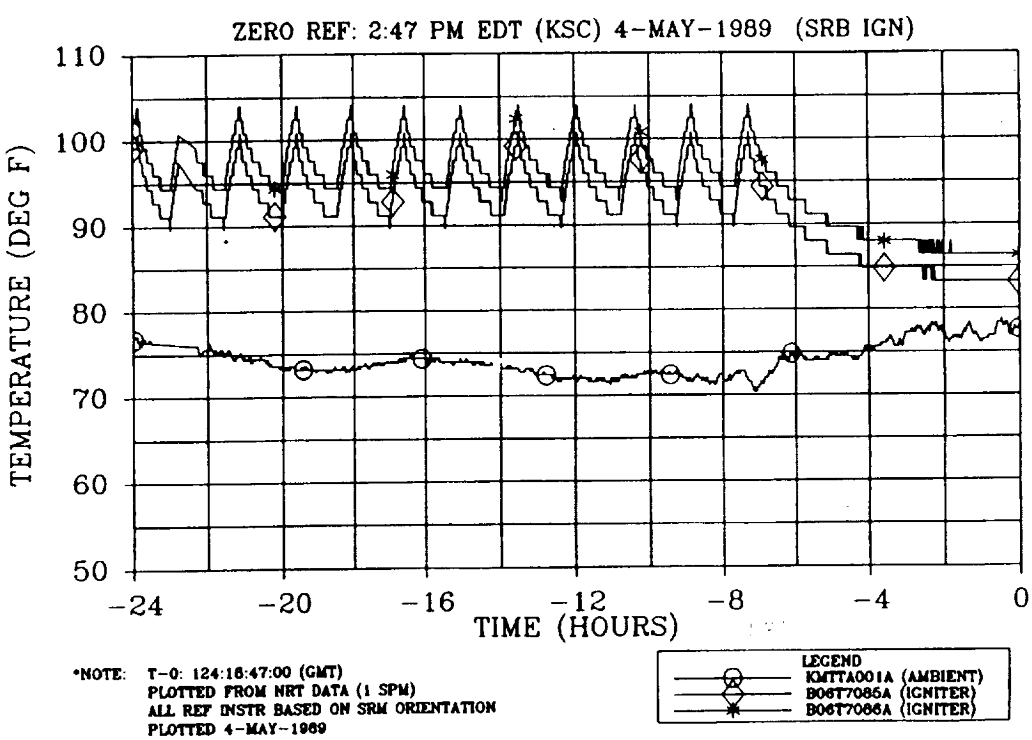


Figure 4.8-42. LH SRM Prelaunch Igniter Joint Temperatures
(overlaid with ambient)

Table 4.8-6. STS-30R Analytical Timeframes for Estimating Event Sequencing of April Historical Joint Heater and GEI Sensor Predictions

Time (hr)	Countdown Events in Analysis
0	Midnight KSC EST (2 May 1989)
38	Igniter heater operation begins on 3 May 1989 (L - 24 hr)
46	Aft skirt conditioning operation begins on 4 May 1989 (T - 12 hr plus 4 hr for holds)
50	Field joint heater operation begins on 4 May 1989 (T - 8 hr plus 4 hr for holds)
55	Igniter heater shutoff/start cooldown (T - 4 hr plus 3 hr for holds)
62	Assumed time for launch (4 May 1989)
63	Up to a 1-hr allowable launch delay

Note: Figures 4.8-12 through 4.8-41 consist of a 2-day plus 13-hr scenario

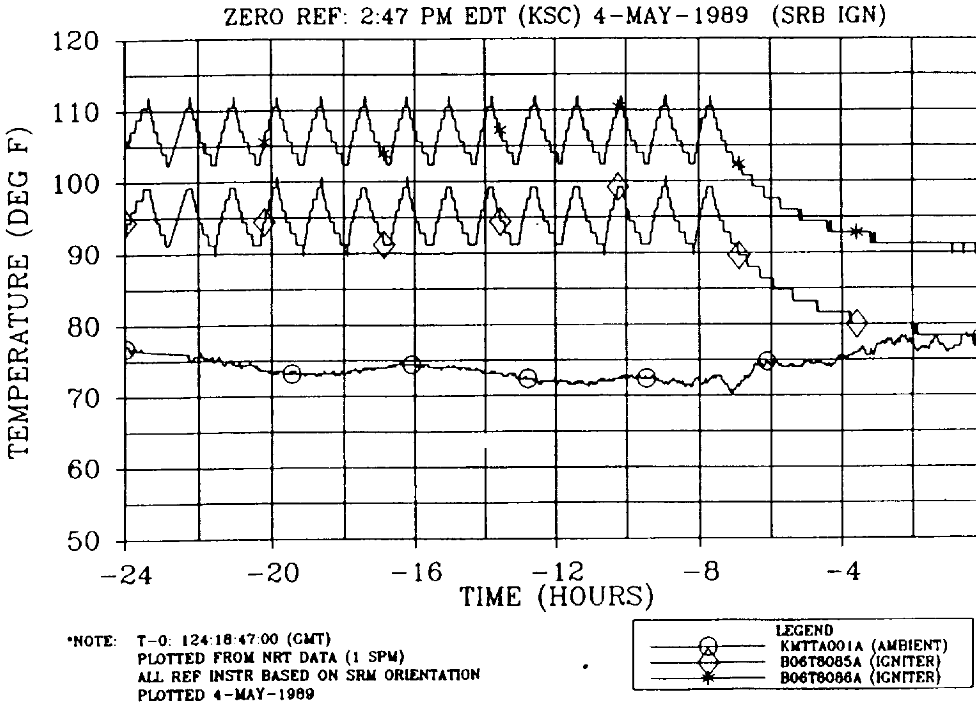


Figure 4.8-43. RH SRM Prelaunch Igniter Joint Temperatures (overlaid with ambient)

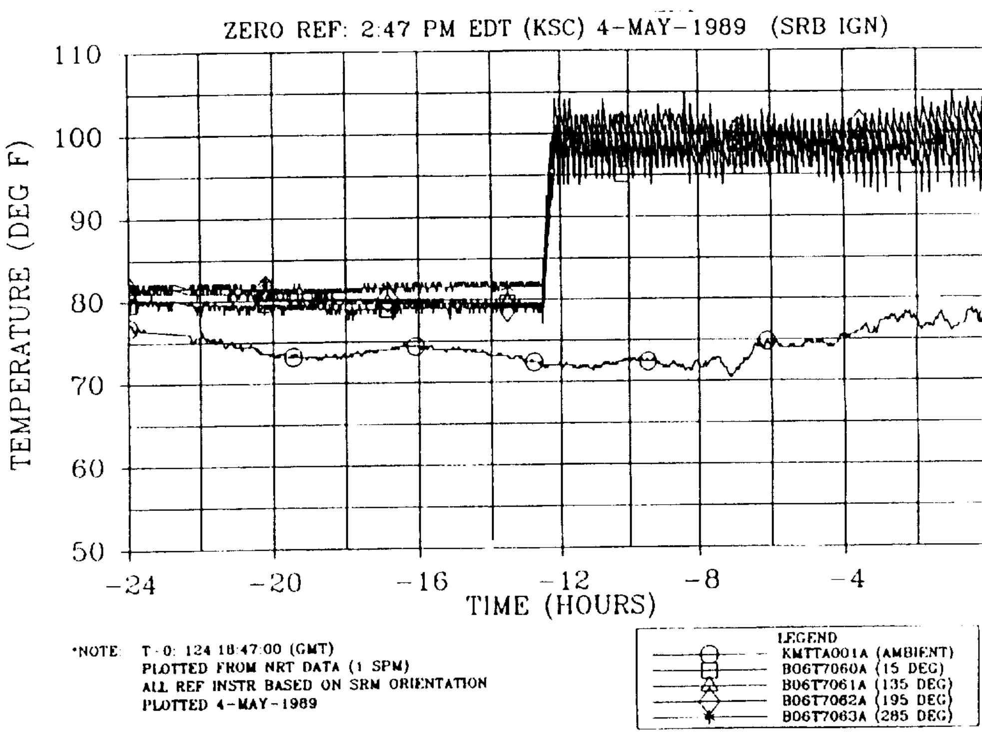


Figure 4.8-44. LH SRM Prelaunch Forward Field Joint Temperature (overlaid with ambient)

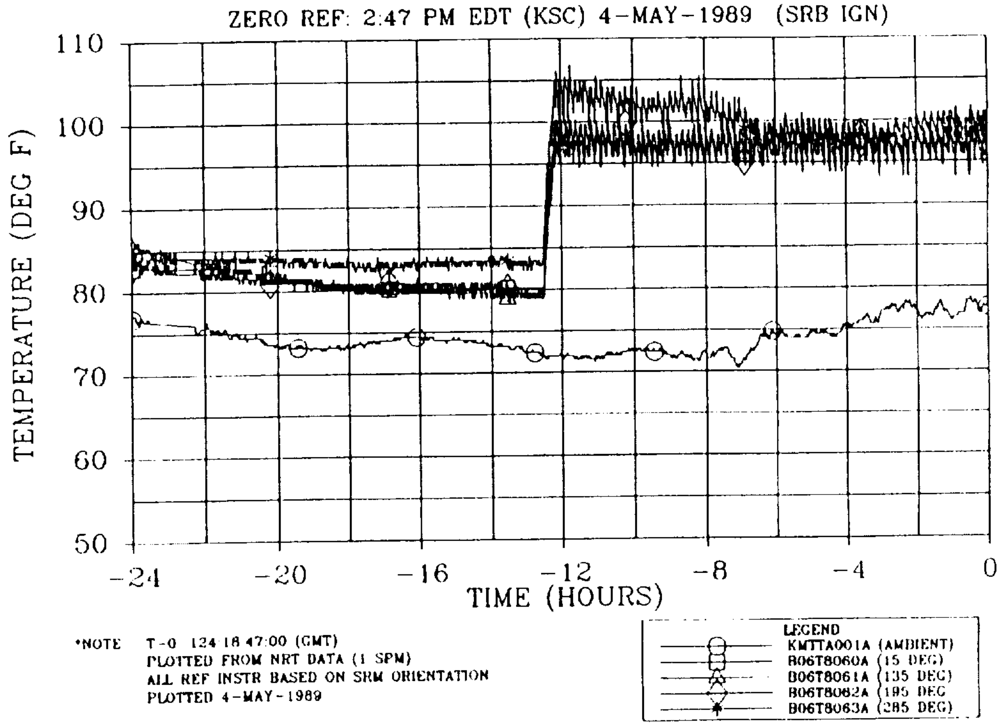


Figure 4.8-45. RH SRM Prelaunch Forward Field Joint Temperature (overlaid with ambient)

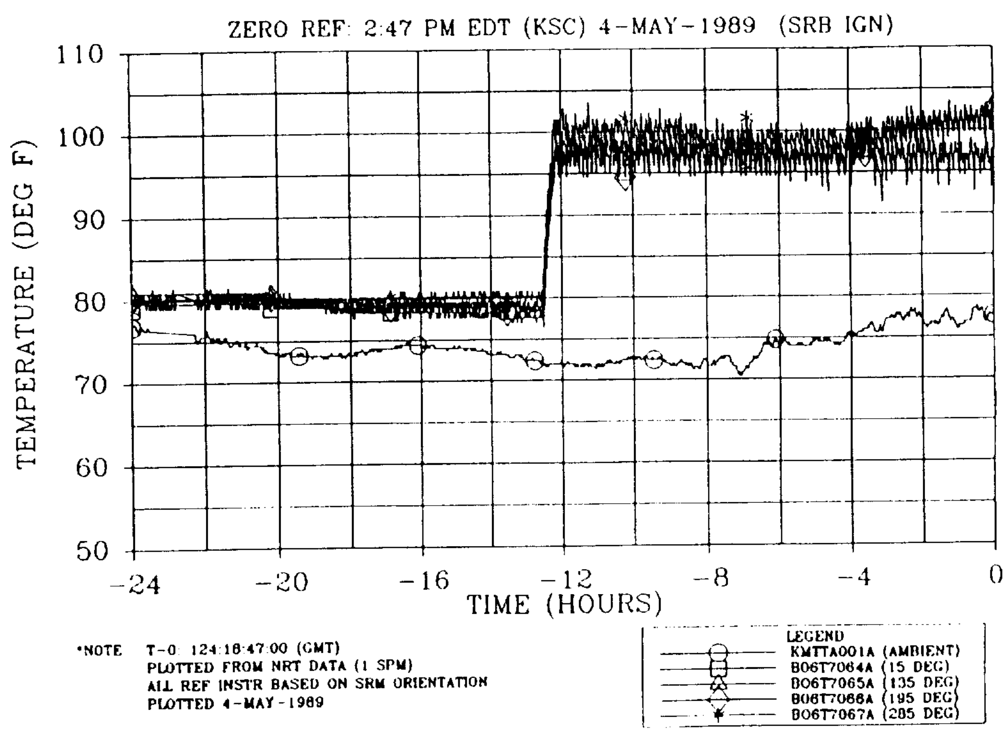


Figure 4.8-46. LH SRM Prelaunch Center Field Joint Temperature (overlaid with ambient)

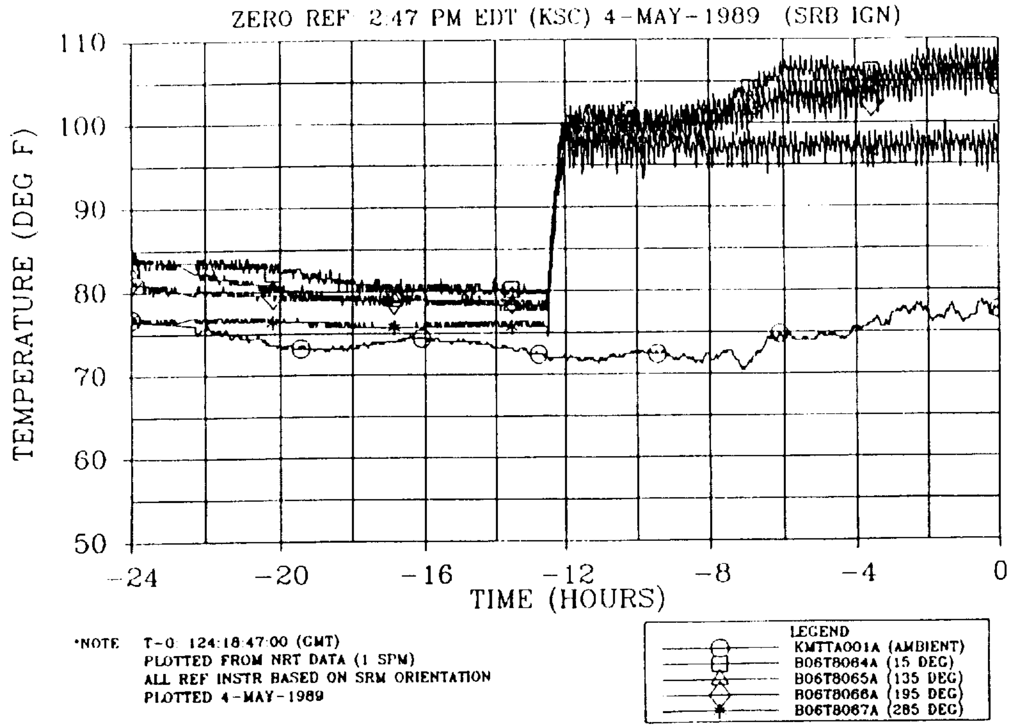


Figure 4.8-47. RH SRM Prelaunch Center Field Joint Temperature (overlaid with ambient)

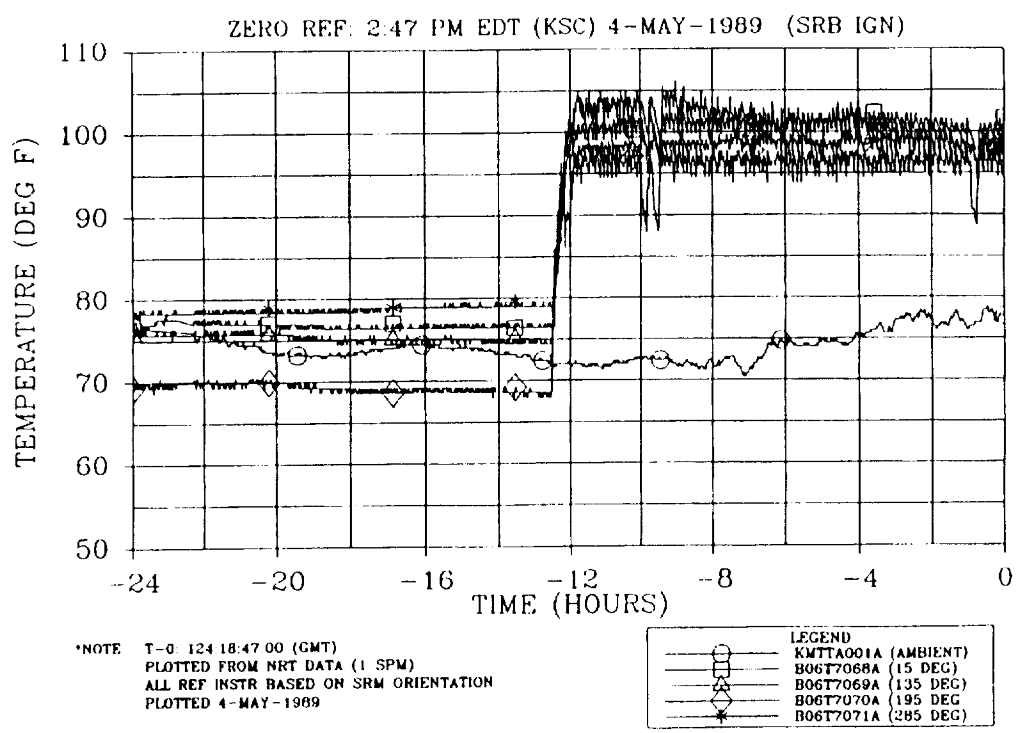


Figure 4.8-48. LH SRM Prelaunch Aft Field Joint Temperature (overlaid with ambient)

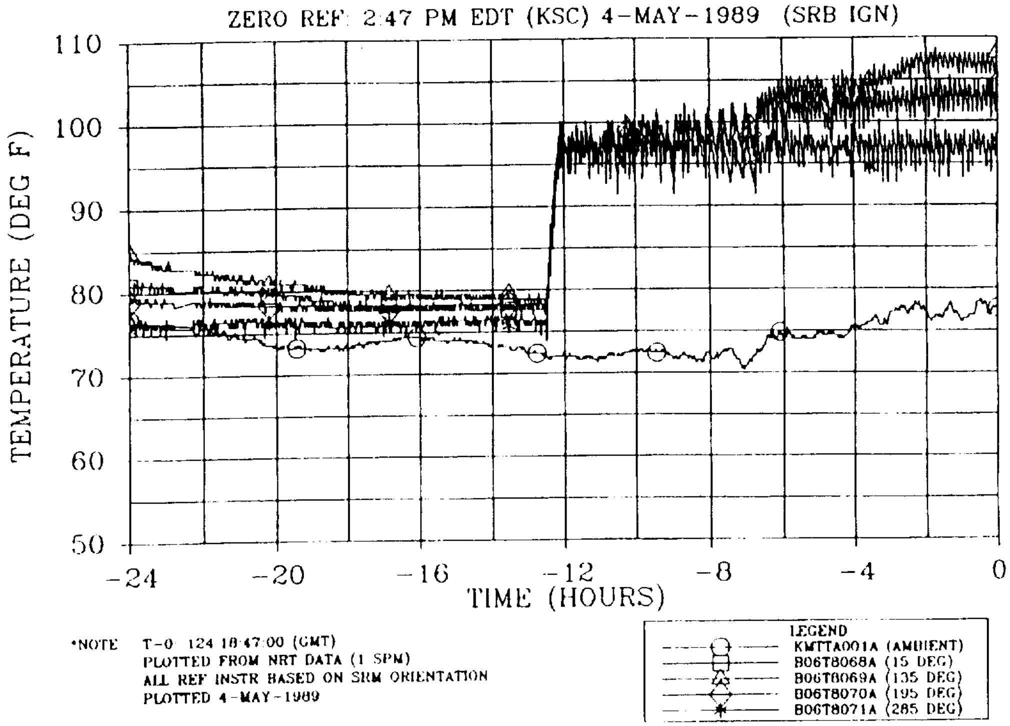


Figure 4.8-49. RH SRM Prelaunch Aft Field Joint Temperature (overlaid with ambient)

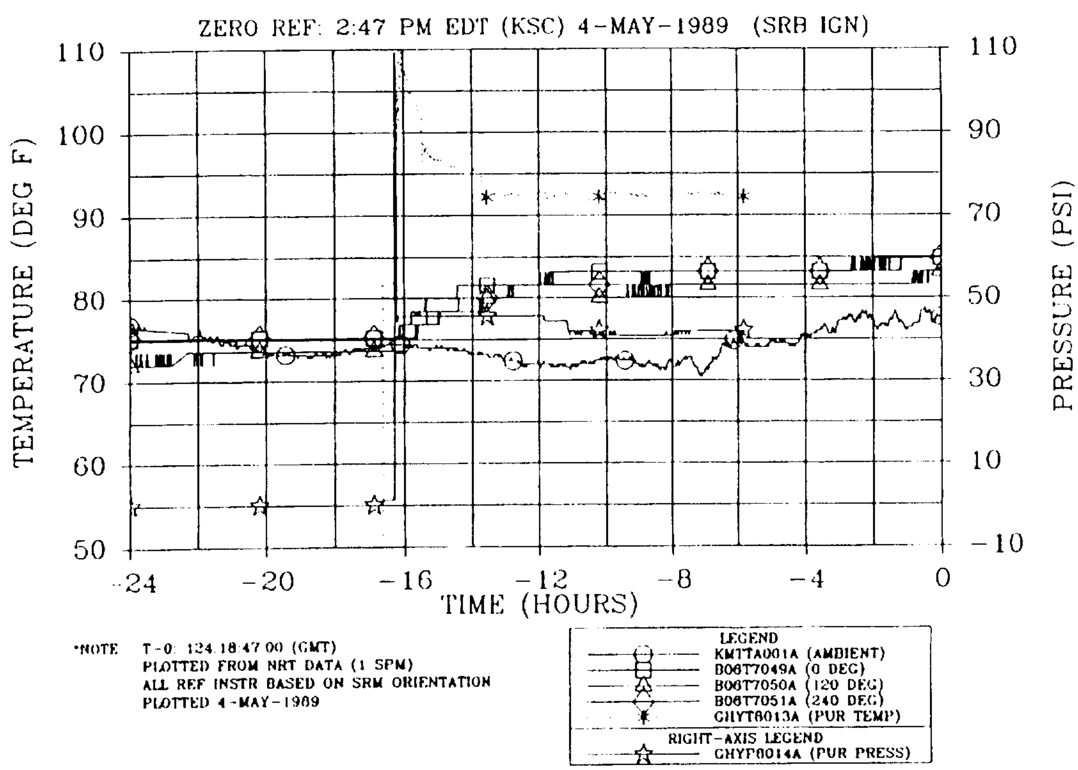


Figure 4.8-50. LH SRM Prelaunch Case-to Nozzle Joint Temperature (overlaid with ambient)

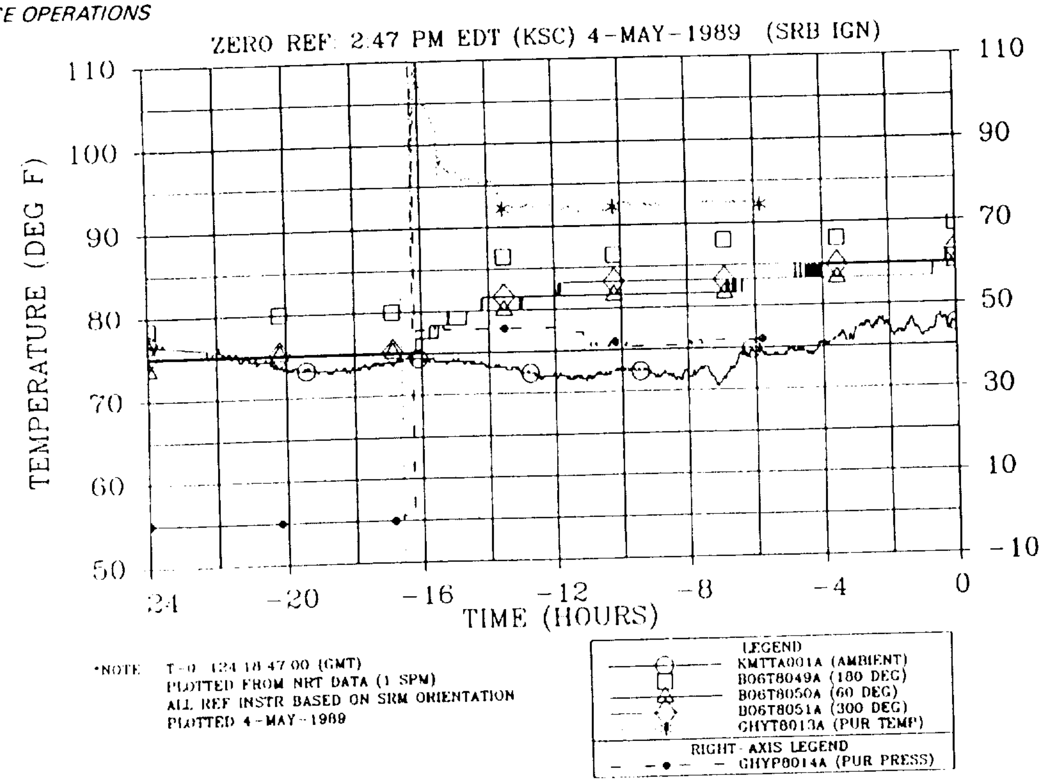


Figure 4.8-51. RH SRM Prelaunch Case-to-Nozzle Joint Temperature (overlaid with ambient)

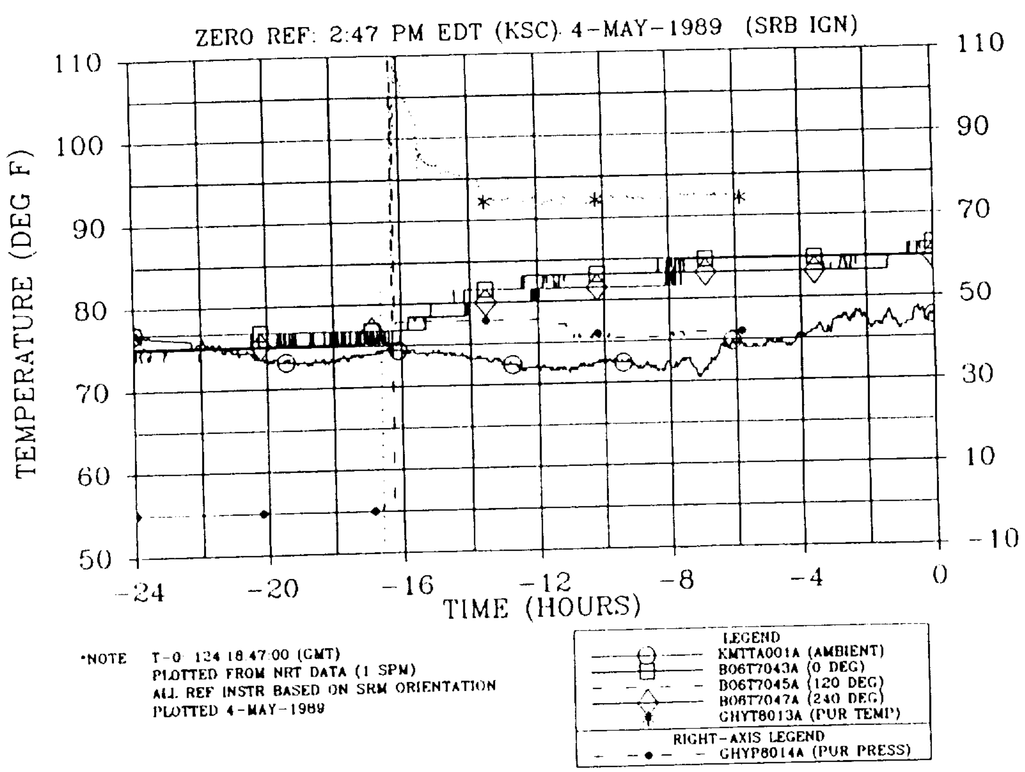


Figure 4.8-52. LH SRM Prelaunch Flex Bearing Aft End Ring Temperature (overlaid with ambient)

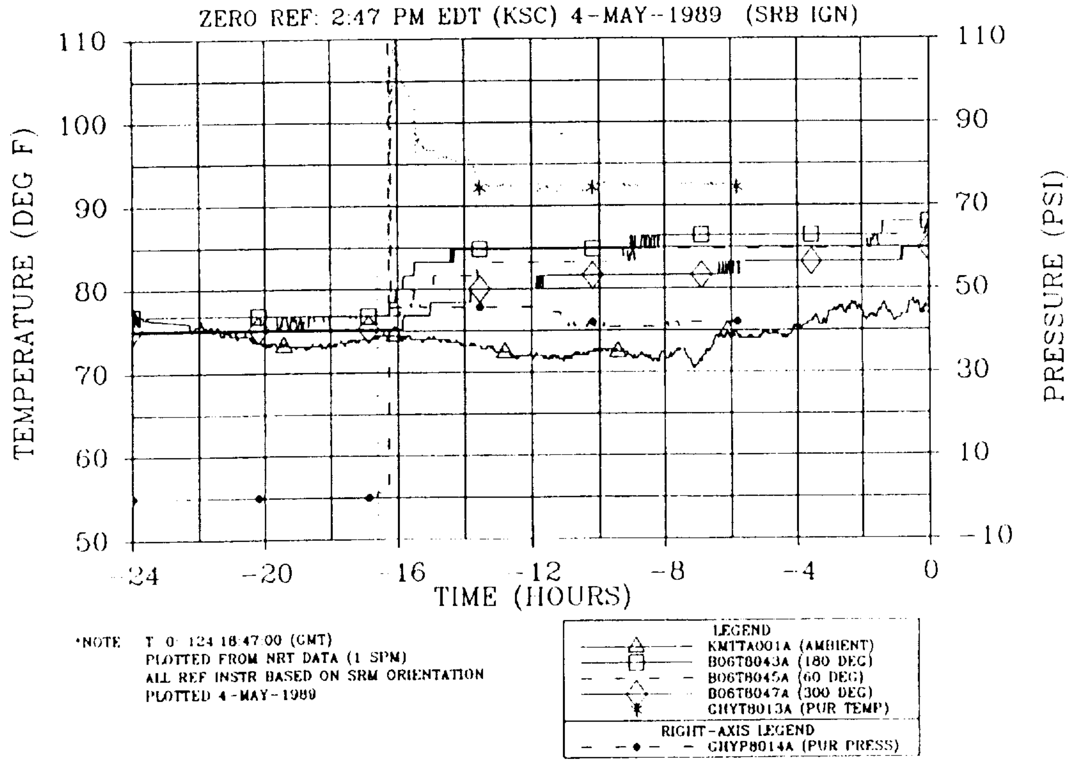


Figure 4.8-53. RH SRM Prelaunch Flex Bearing Aft End Ring Temperature (overlaid with ambient)

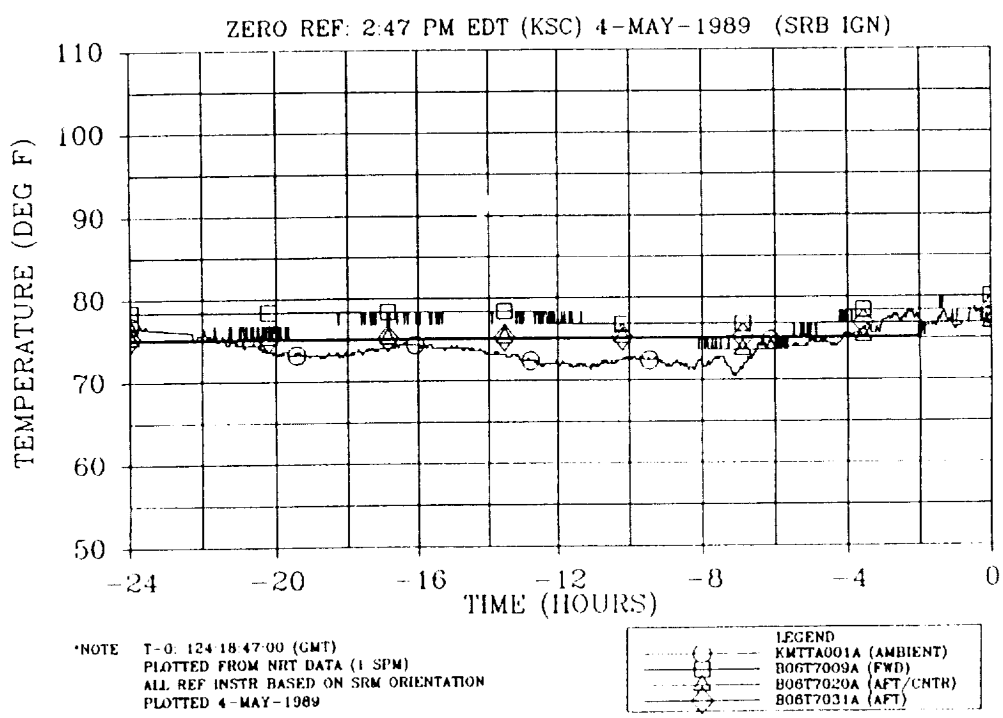


Figure 4.8-54. LH SRM Prelaunch Systems Tunnel Bondline Temperature (overlaid with ambient)

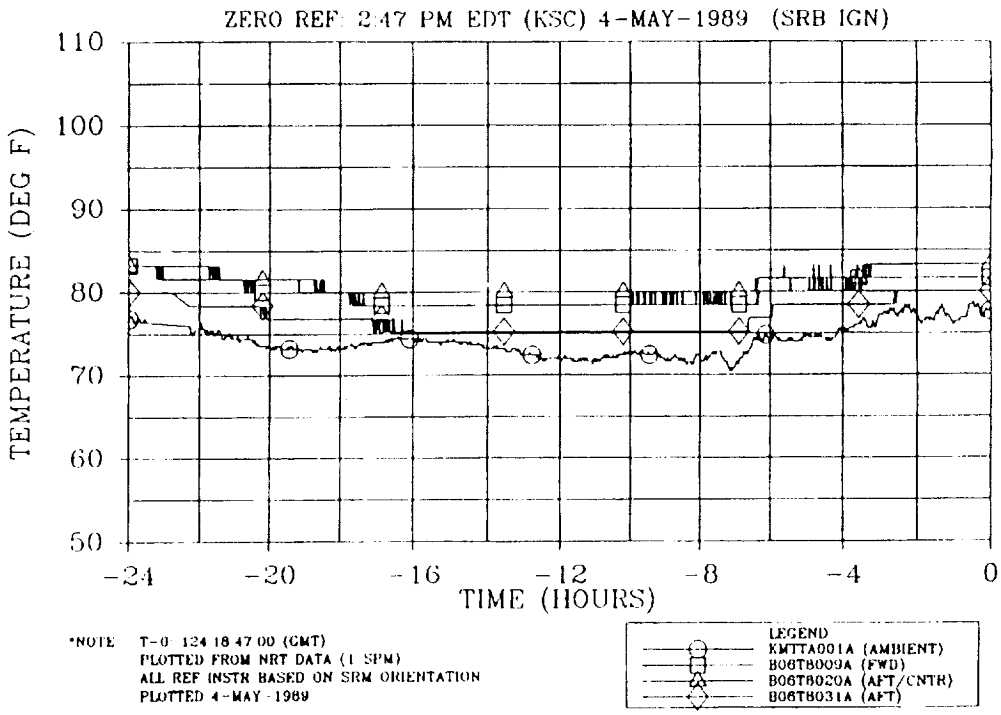


Figure 4.8-55. RH SRM Prelaunch Systems Tunnel Bondline Temperature (overlaid with ambient)

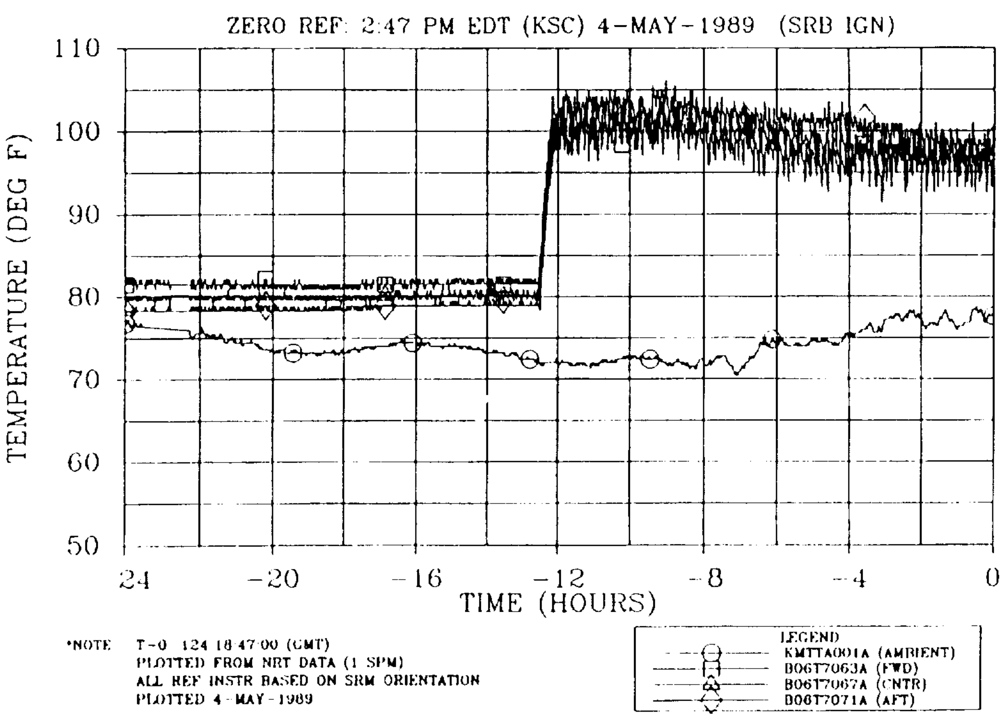


Figure 4.8-56. LH SRM Prelaunch Field Joint Temperature at 285 Deg (overlaid with ambient)

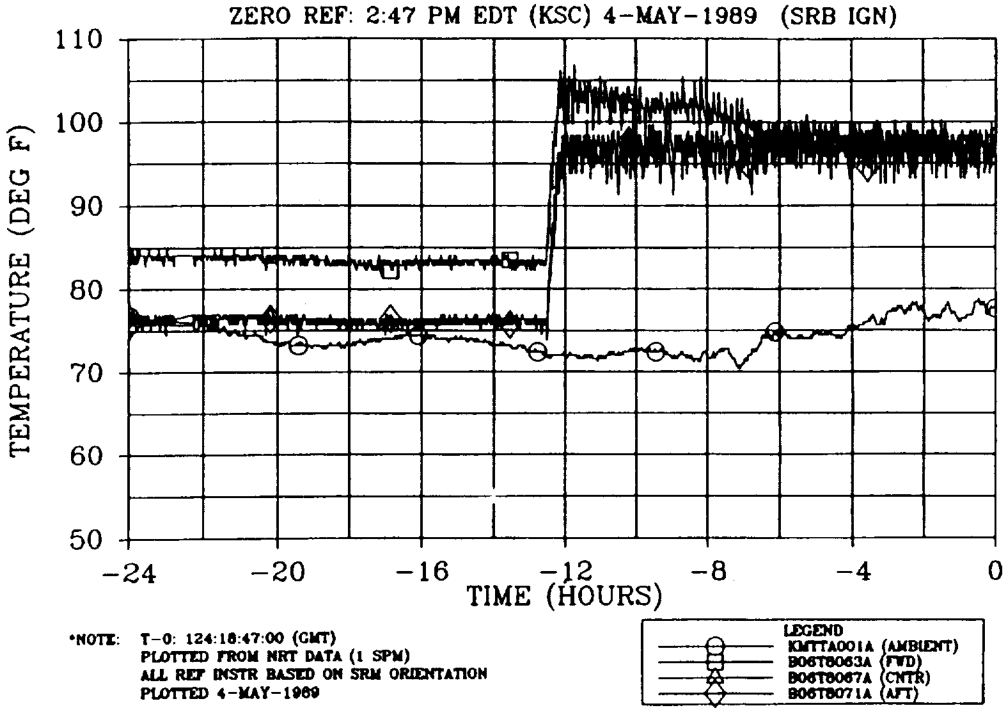


Figure 4.8-57. RH SRM Prelaunch Field Joint Temperature at 285 Deg (overlaid with ambient)

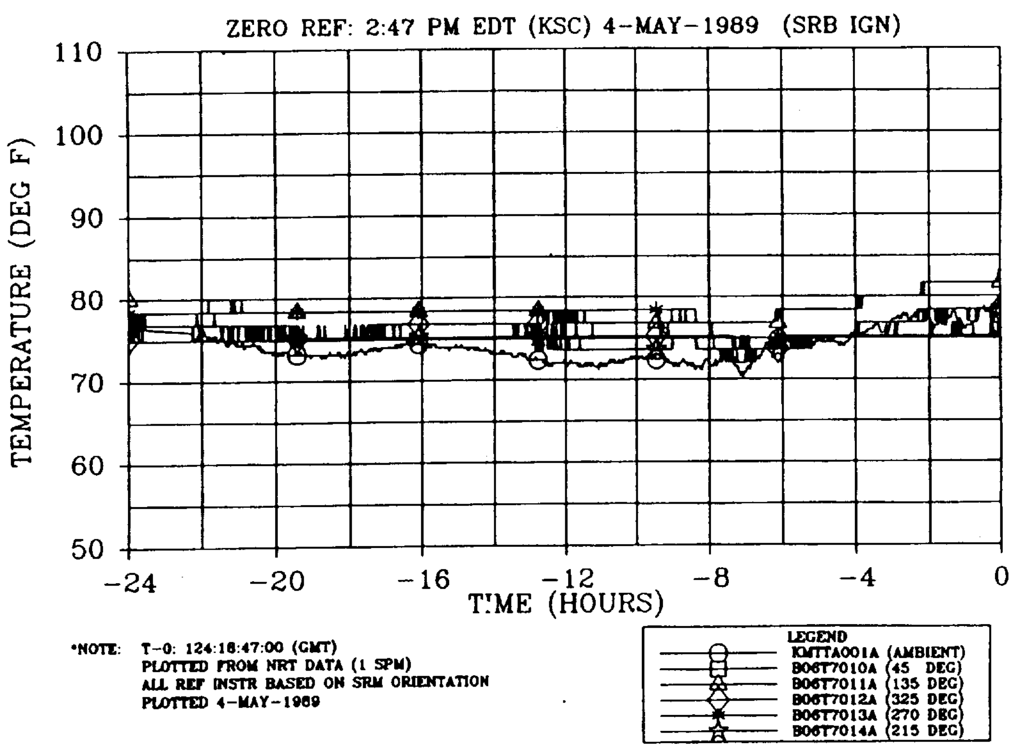


Figure 4.8-58. LH SRM Prelaunch Case Acreage Temperature at Station 931.5 (overlaid with ambient)

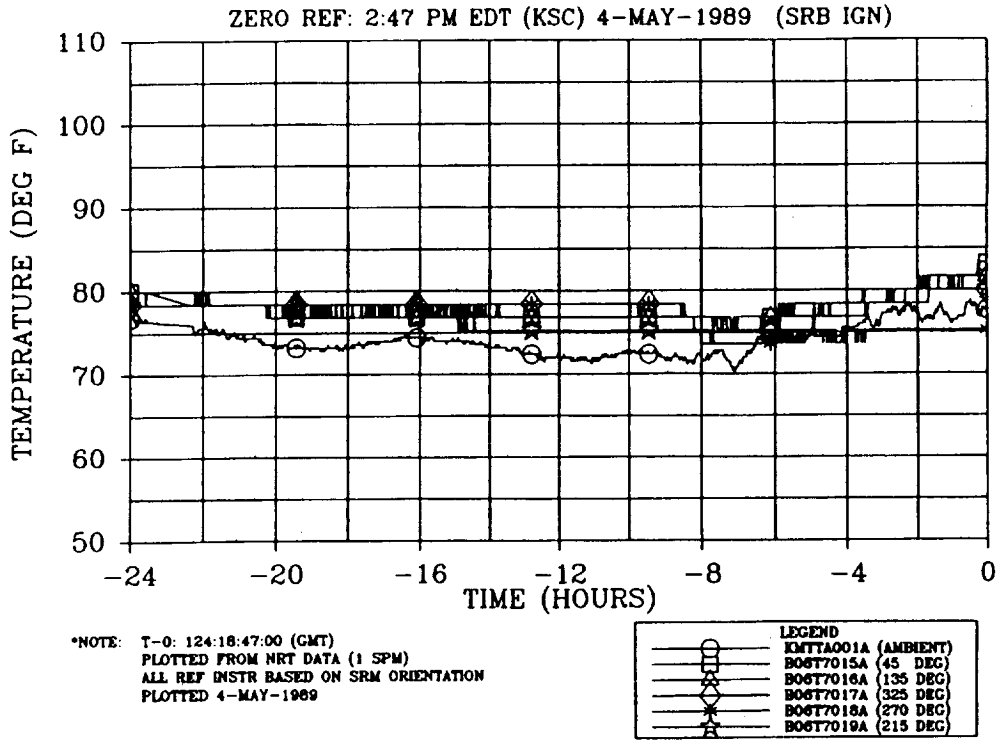


Figure 4.8-59. LH SRM Prelaunch Case Acreage Temperature at Station 1091.5 (overlaid with ambient)

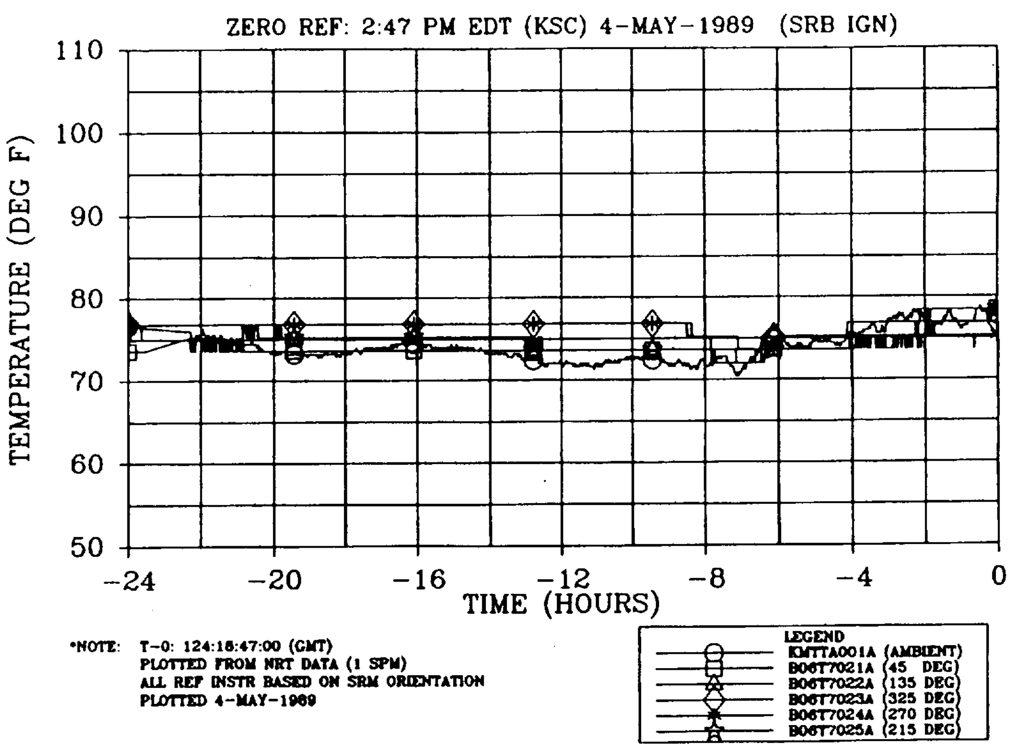


Figure 4.8-60. LH SRM Prelaunch Case Acreage Temperature at Station 1411.5 (overlaid with ambient)

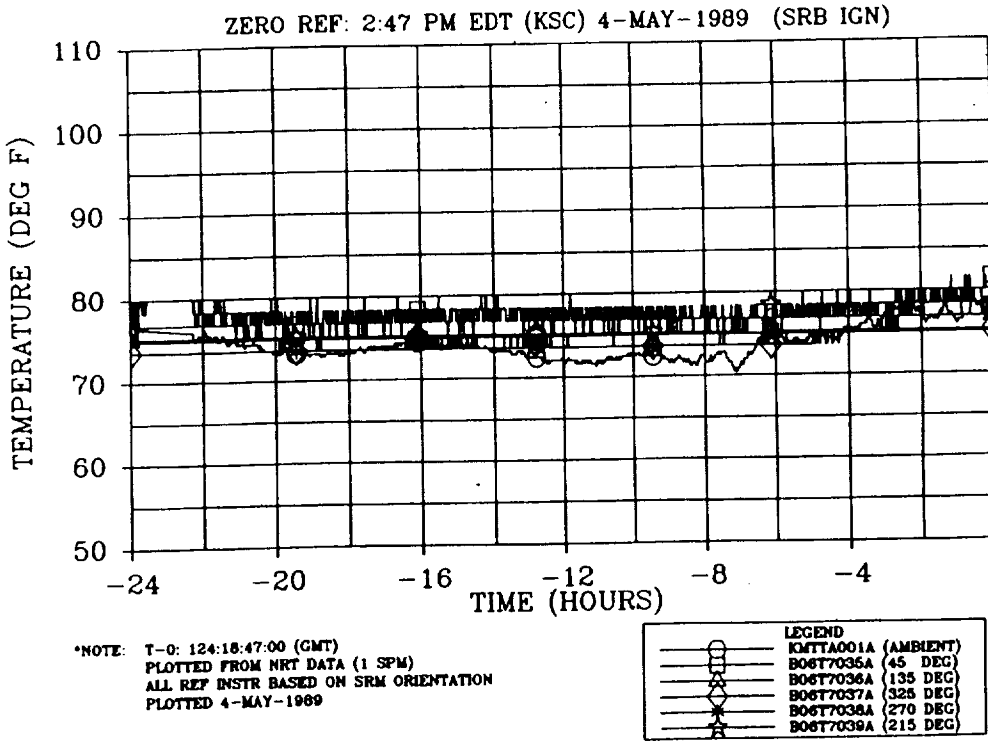


Figure 4.8-61. LH SRM Prelaunch Case Acreage Temperature at Station 1751.5 (overlaid with ambient)

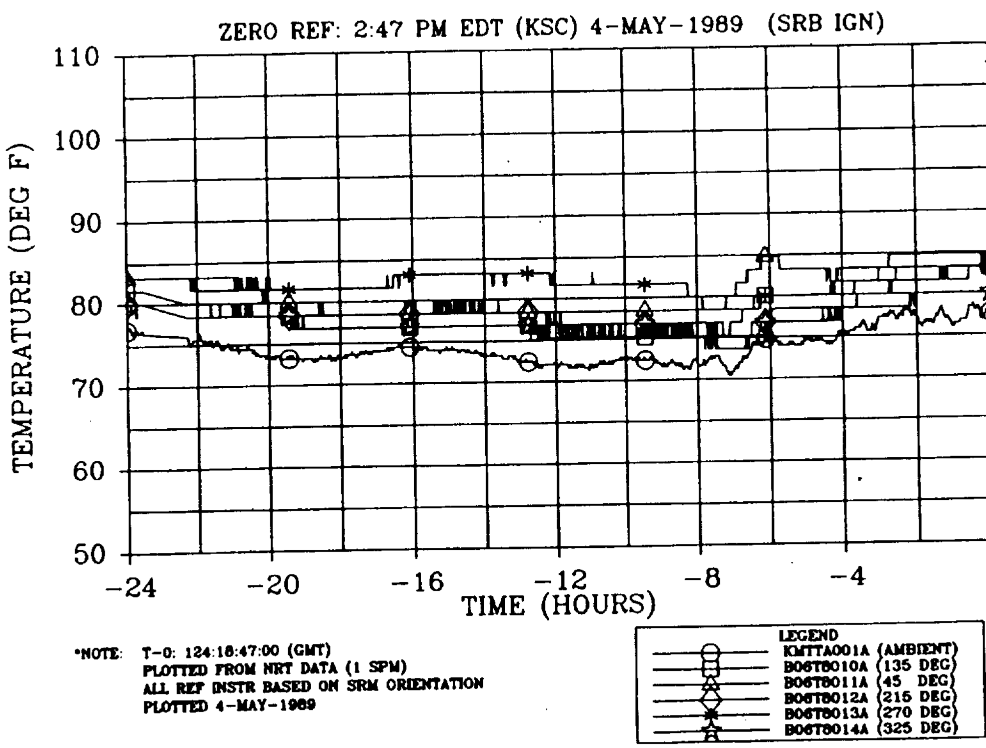


Figure 4.8-62. RH SRM Prelaunch Case Acreage Temperature at Station 931.5 (overlaid with ambient)

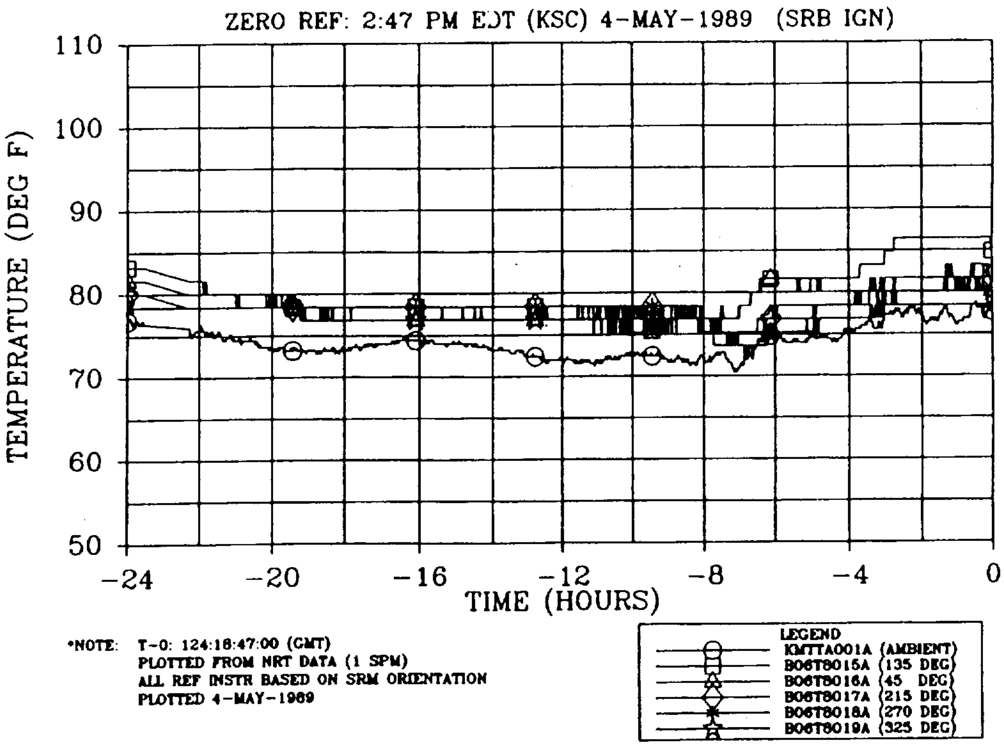


Figure 4.8-63. RH SRM Prelaunch Case Acreage Temperature at Station 1091.5 (overlaid with ambient)

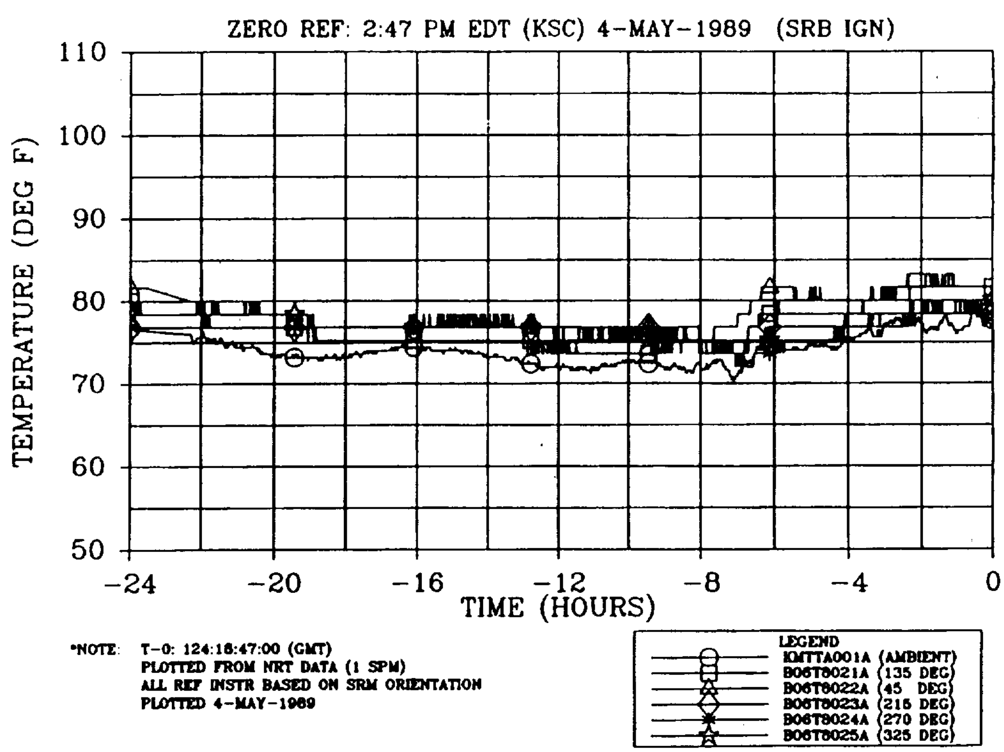


Figure 4.8-64. RH SRM Prelaunch Case Acreage Temperature at Station 1411.5 (overlaid with ambient)

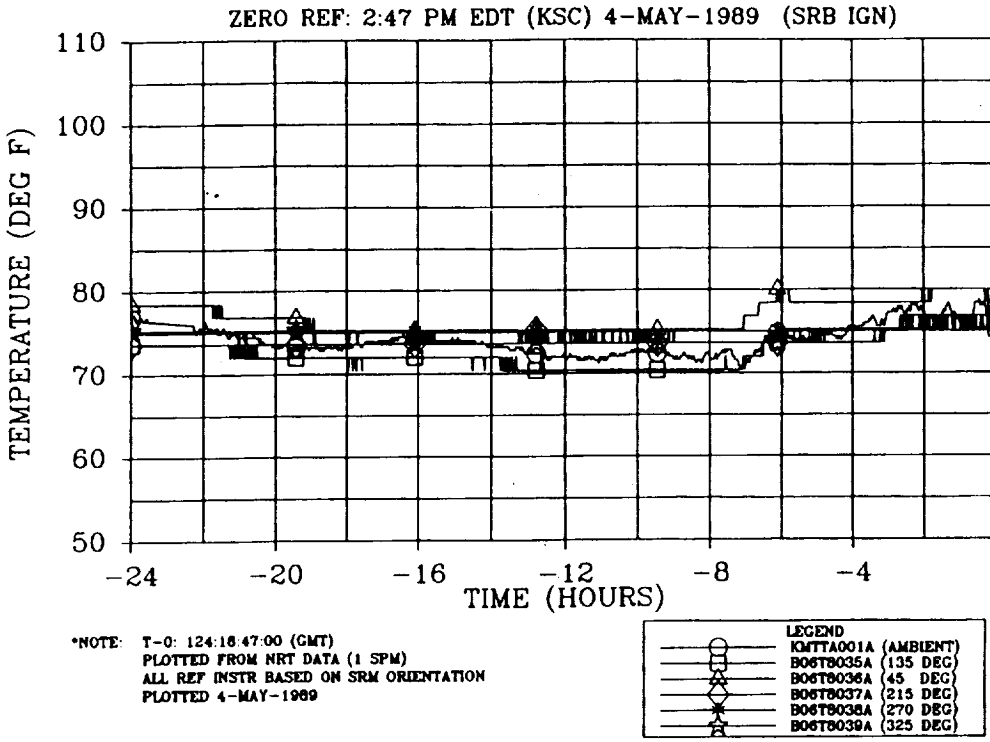


Figure 4.8-65. RH SRM Prelaunch Case Acreage Temperature at Station 1751.5 (overlaid with ambient)

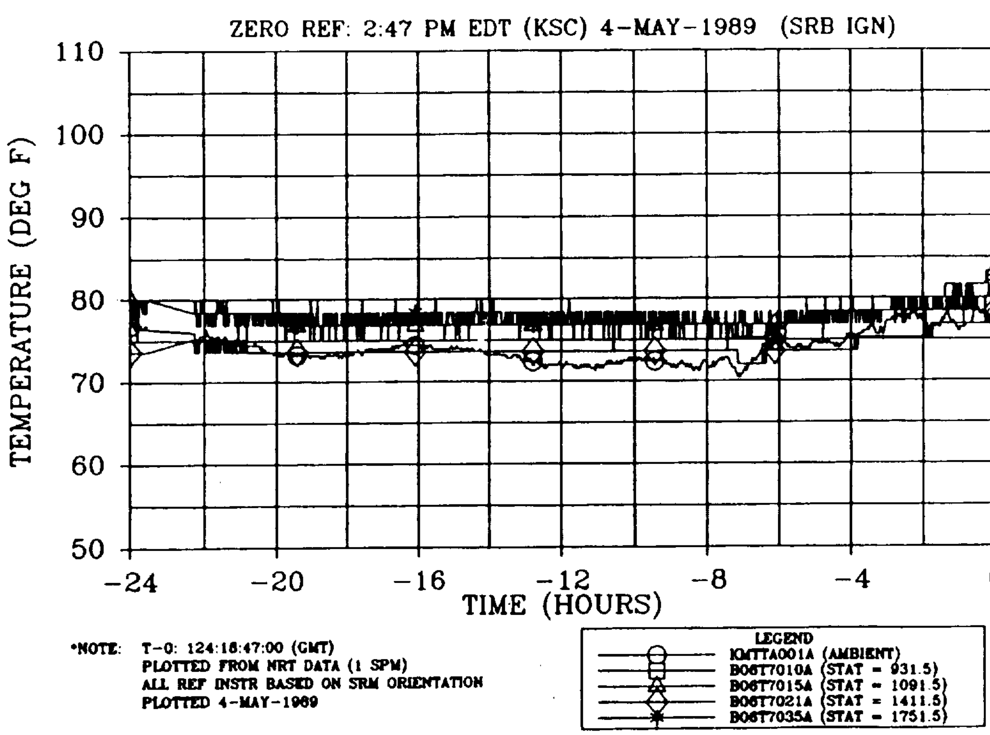


Figure 4.8-66. LH SRM Prelaunch Case Acreage Temperature at 45 Deg (overlaid with ambient)

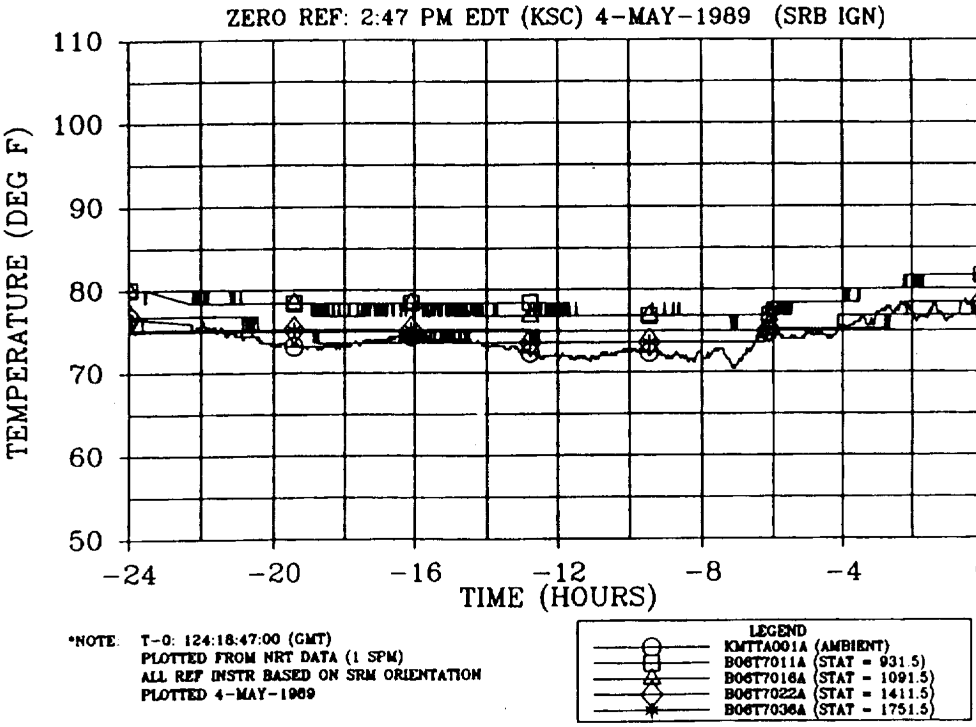


Figure 4.8-67. LH SRM Prelaunch Case Acreage Temperature at 135 Deg (overlaid with ambient)

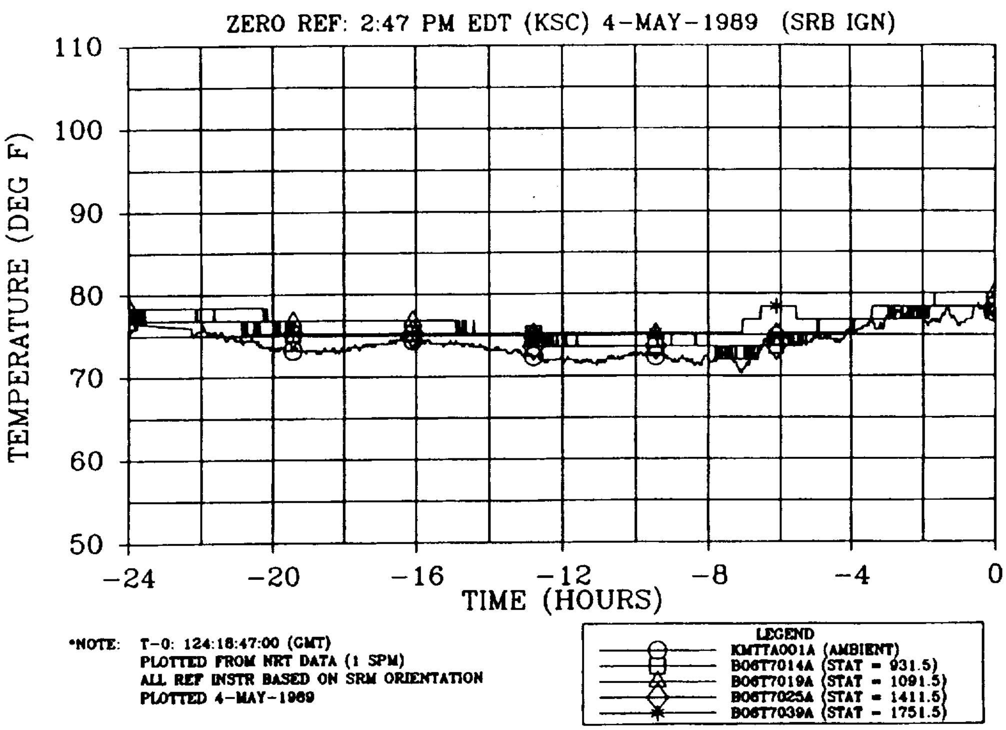


Figure 4.8-68. LH SRM Prelaunch Case Acreage Temperature at 215 Deg (overlaid with ambient)

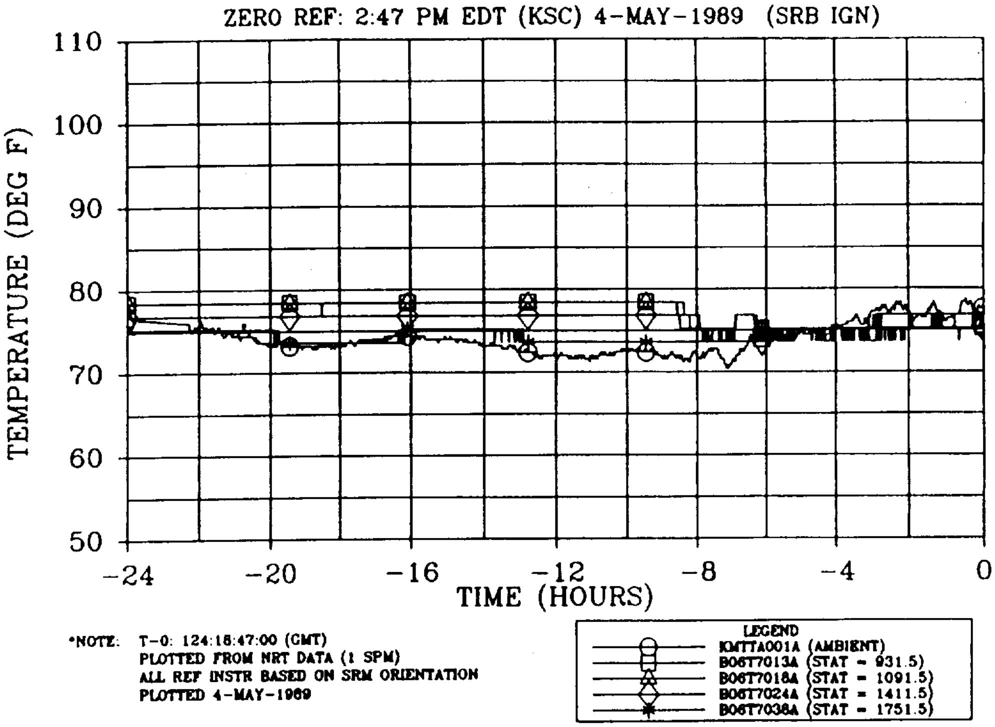


Figure 4.8-69. LH SRM Prelaunch Case Acreage Temperature at 270 Deg (overlaid with ambient)

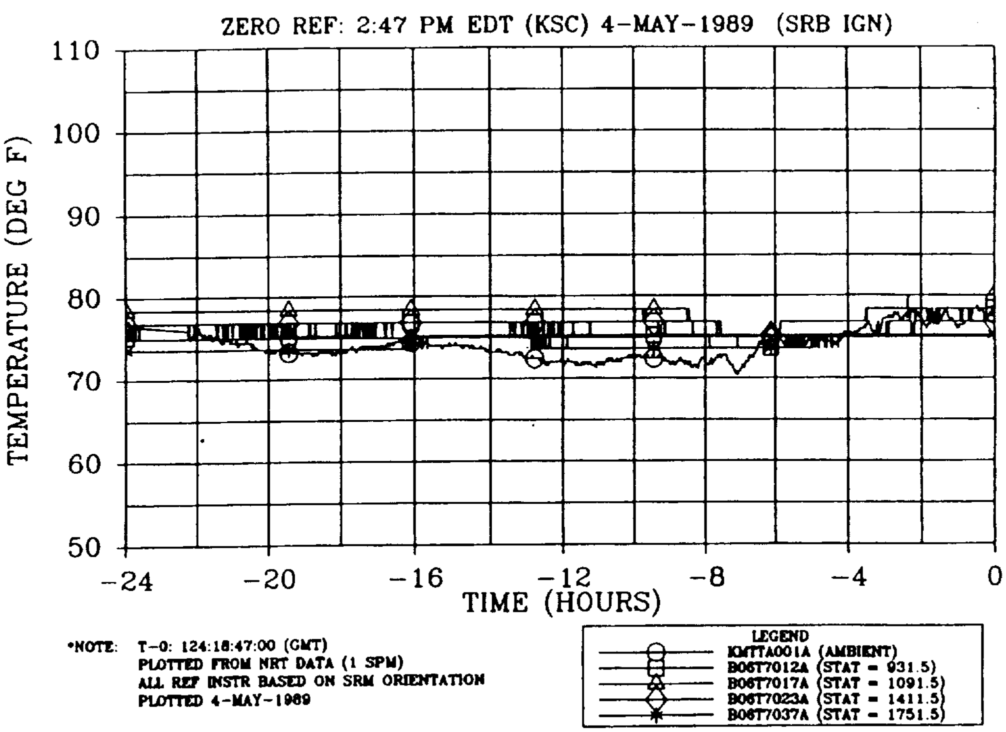


Figure 4.8-70. LH SRM Prelaunch Case Acreage Temperature at 325 Deg (overlaid with ambient)

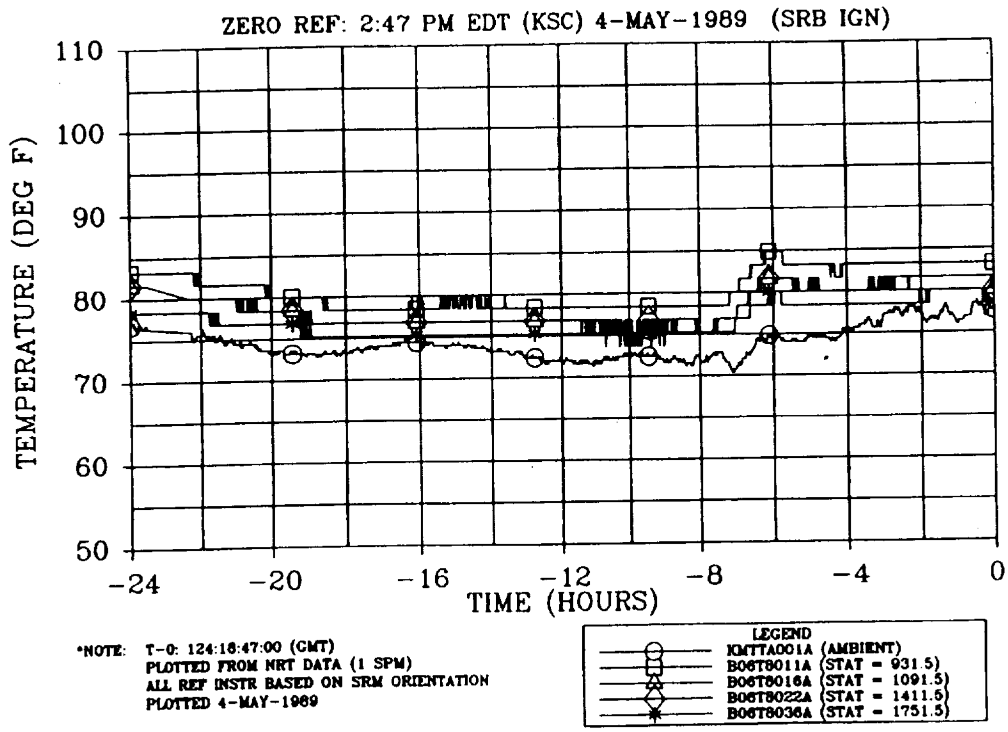


Figure 4.8-71. RH SRM Prelaunch Case Acreage Temperature at 45 Deg (overlaid with ambient)

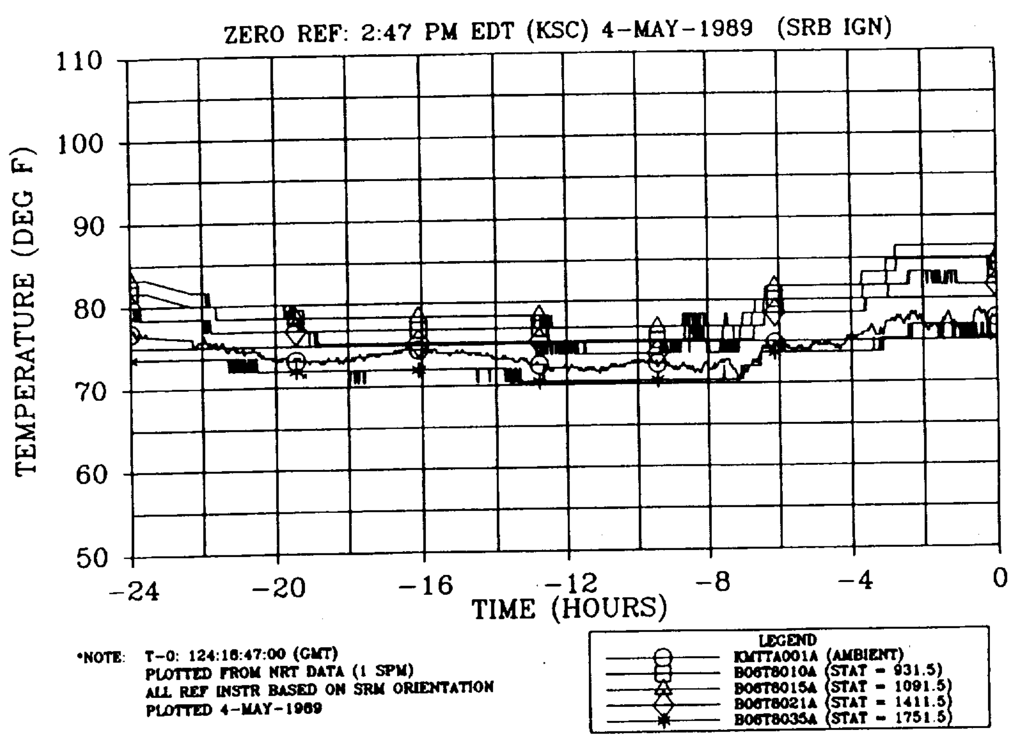


Figure 4.8-72. RH SRM Prelaunch Case Acreage Temperature at 135 Deg (overlaid with ambient)

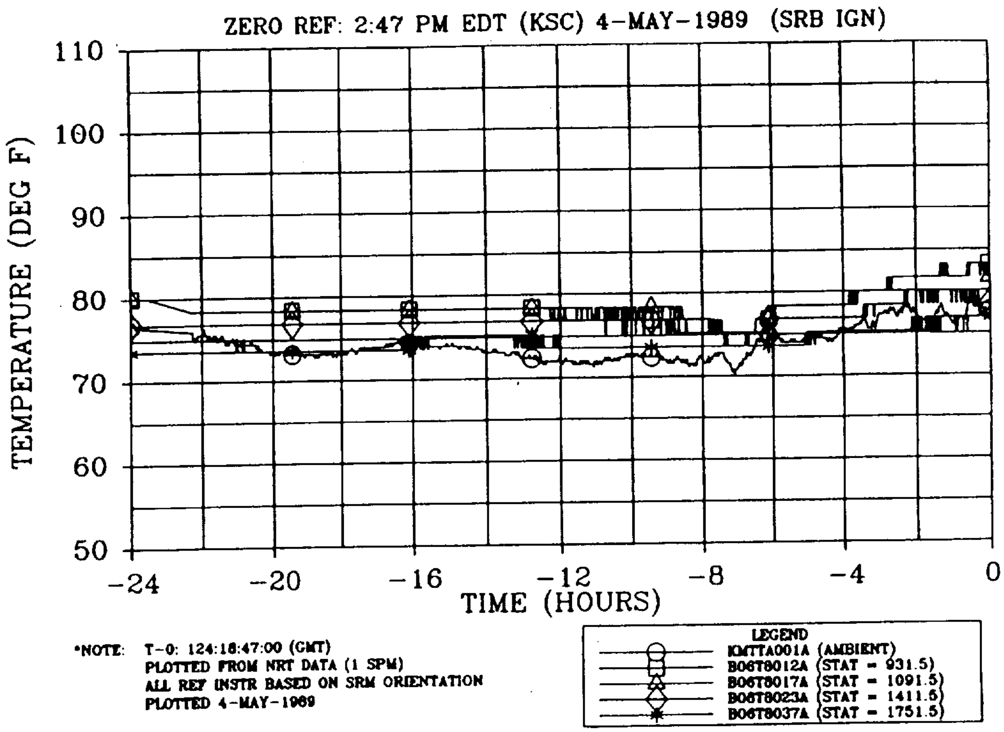


Figure 4.8-73. RH SRM Prelaunch Case Acreage Temperature at 215 Deg (overlaid with ambient)

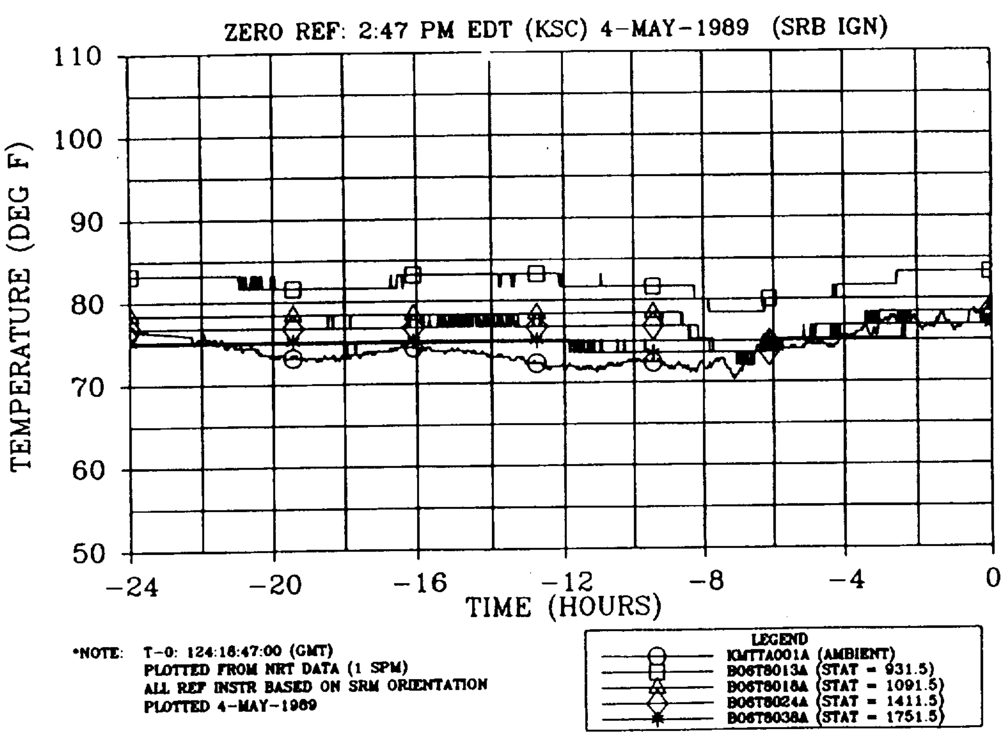


Figure 4.8-74. RH SRM Prelaunch Case Acreage Temperature at 270 Deg (overlaid with ambient)

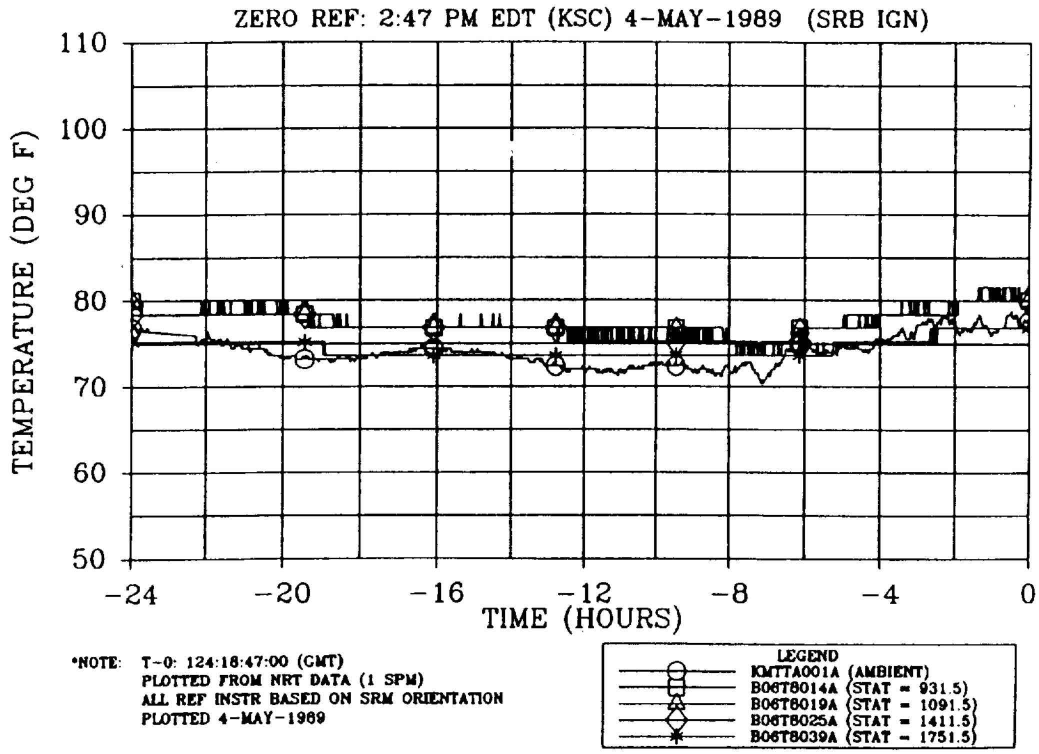


Figure 4.8-75. RH SRM Prelaunch Case Acreage Temperature at 325 Deg (overlaid with ambient)

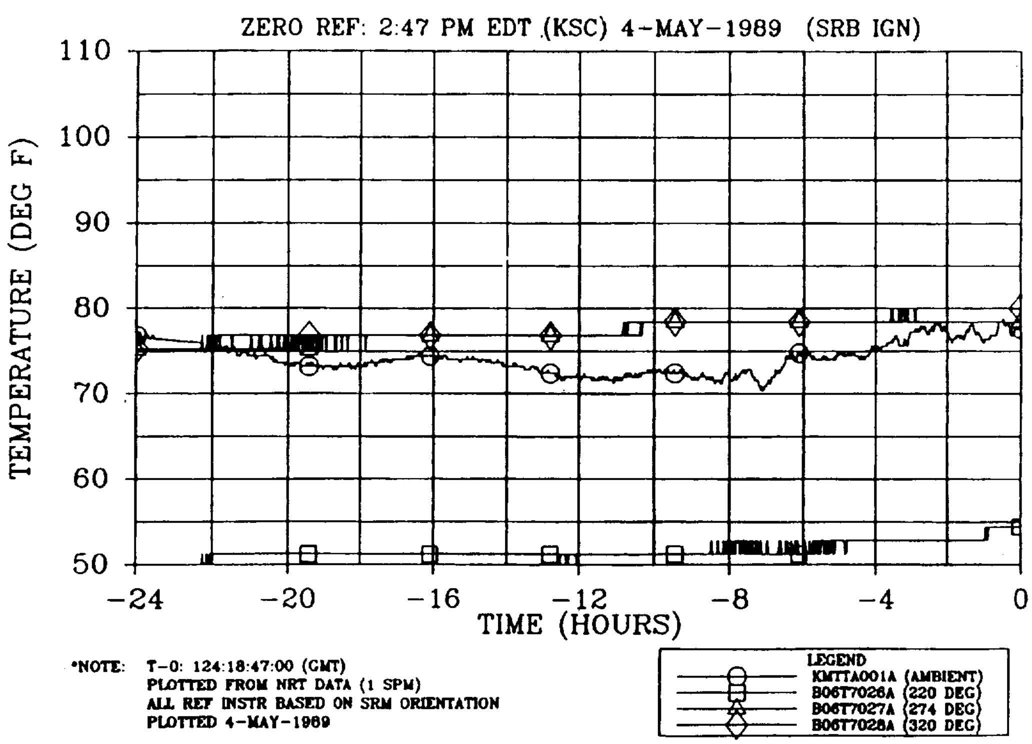


Figure 4.8-76. RH SRM Prelaunch Case Acreage Temperature at Station 1511.0 (overlaid with ambient)

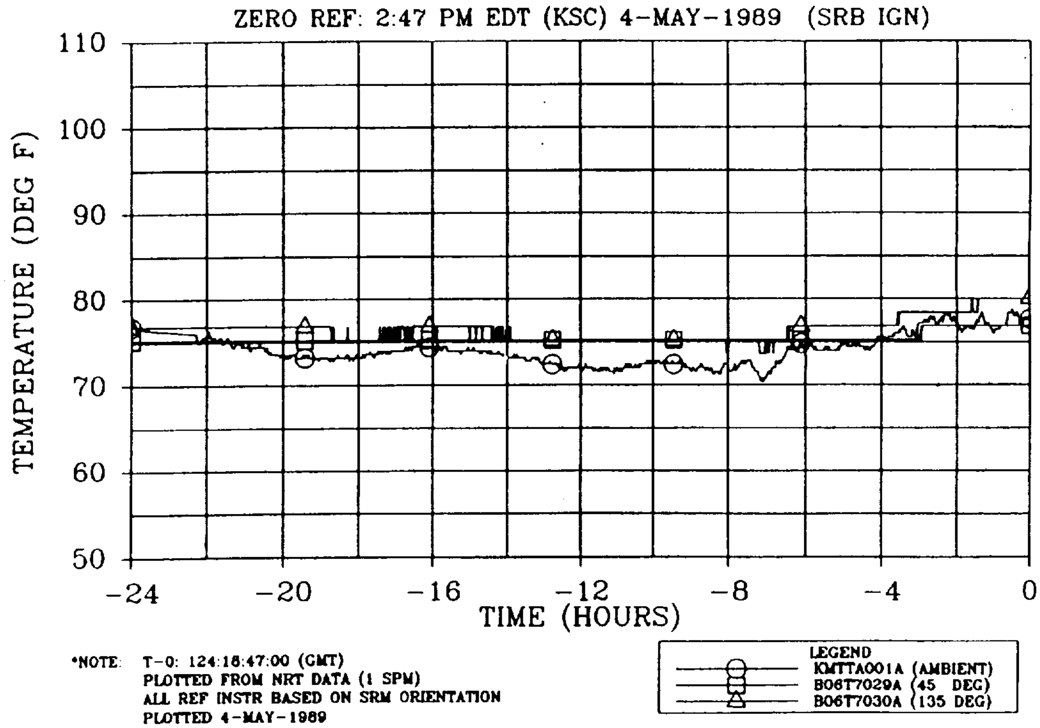


Figure 4.8-77. RH SRM Prelaunch Case Acreage Temperature at Station 1535.0 (overlaid with ambient)

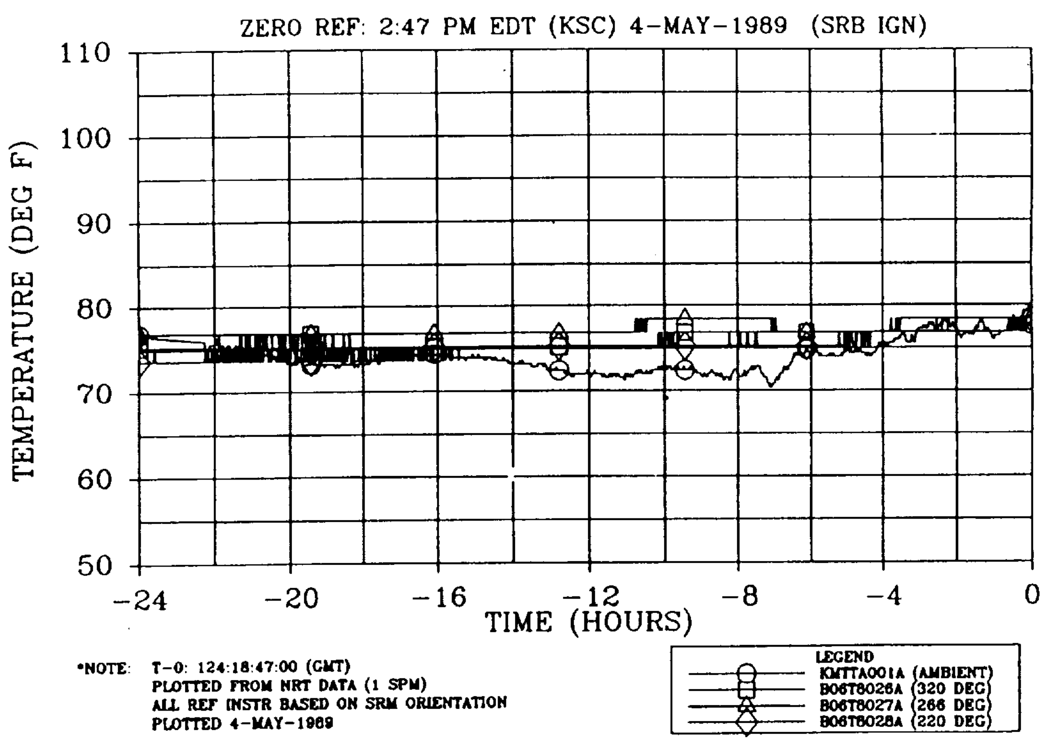
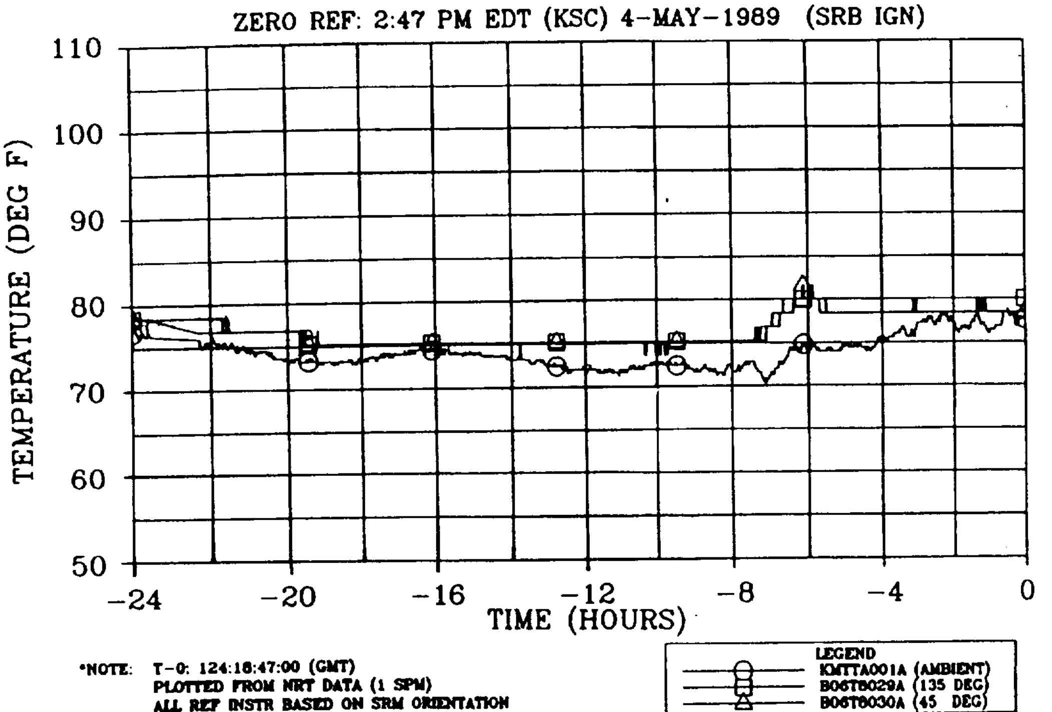
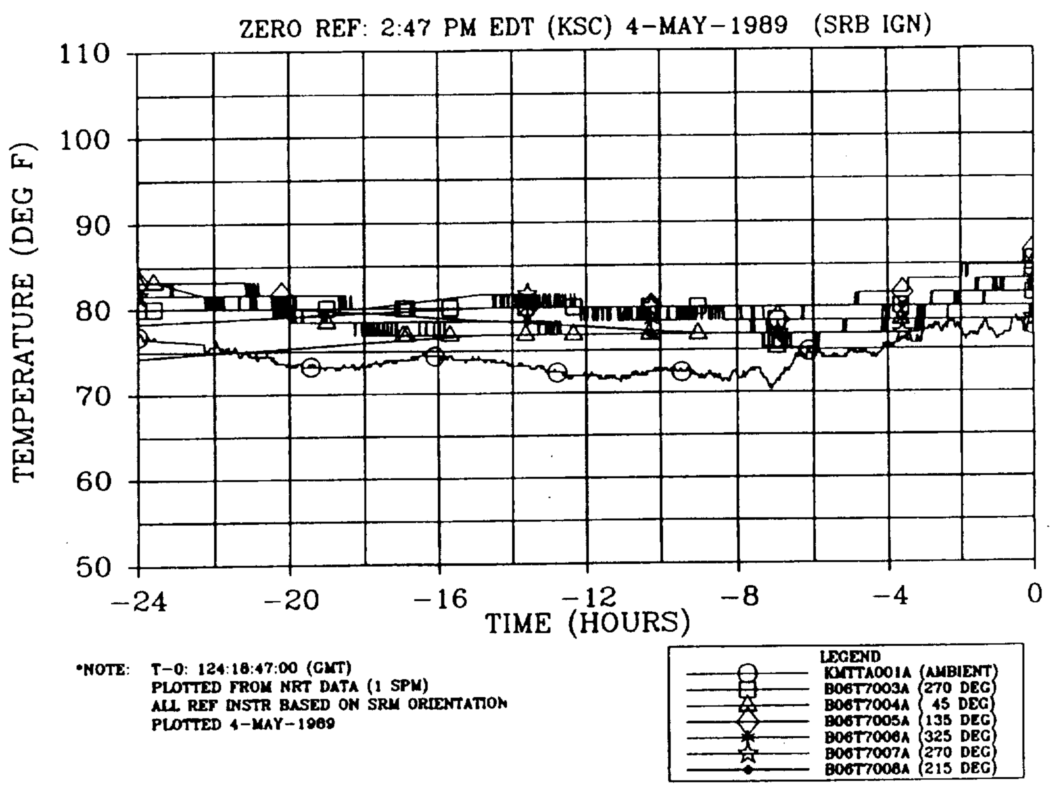


Figure 4.8-78. RH SRM Prelaunch ET Attach Region Temperature at Station 1511.0 (overlaid with ambient)



*NOTE: T-0: 124:18:47:00 (GMT)
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION
PLOTTED 4-MAY-1989

Figure 4.8-79. RH SRM Prelaunch ET Attach Region Temperature at Station 1535.0 (overlaid with ambient)



*NOTE: T-0: 124:18:47:00 (GMT)
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION
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Figure 4.8-80. LH SRM Prelaunch Forward Factory Joint Temperature (overlaid with ambient)

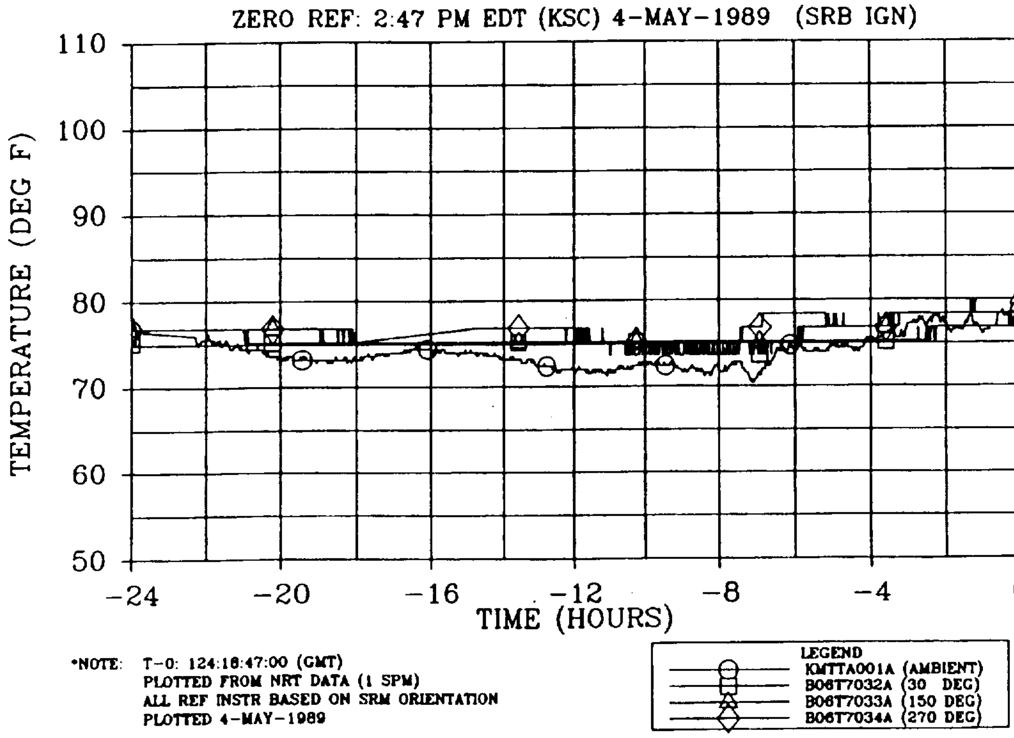


Figure 4.8-81. LH SRM Prelaunch Aft Factory Joint Temperature at at Station 1701.9 (overlaid with ambient)

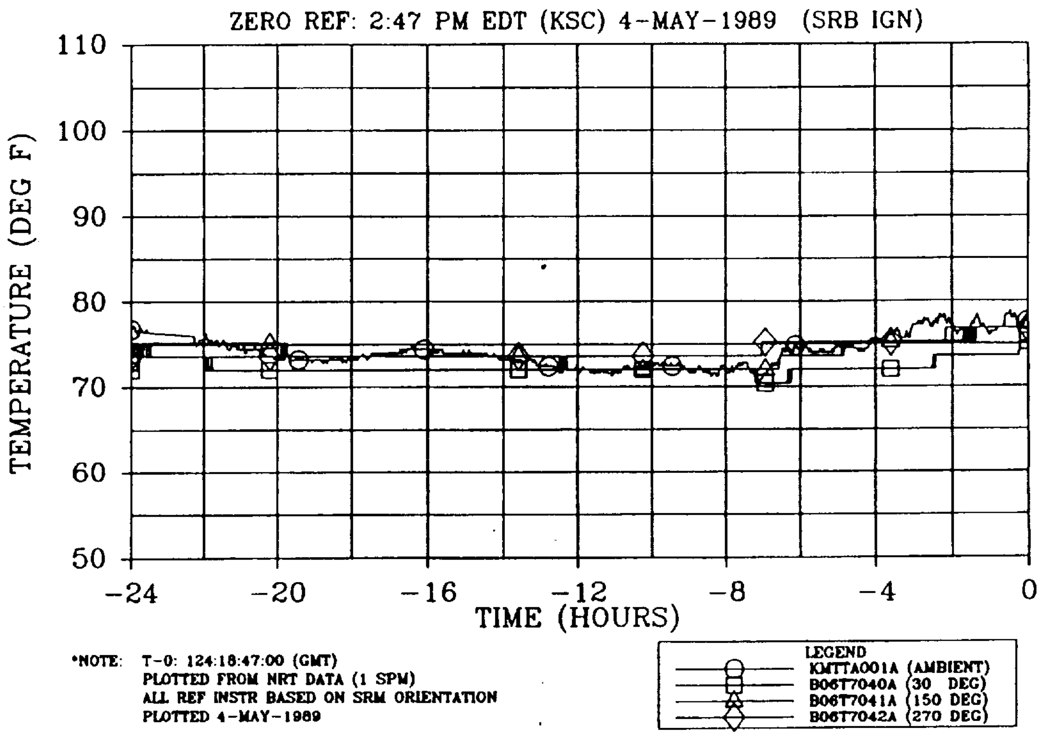


Figure 4.8-82. LH SRM Prelaunch Aft Factory Joint Temperature at Station 1821.0 (overlaid with ambient)

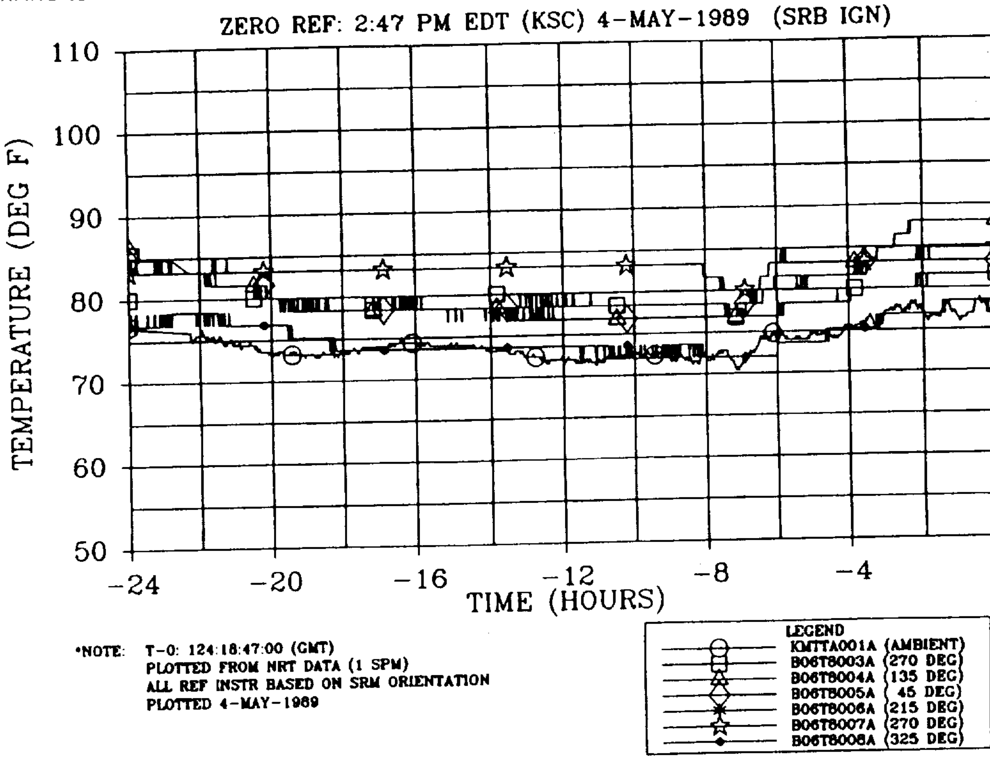


Figure 4.8-83. RH SRM Prelaunch Forward Factory Joint Temperature (overlaid with ambient)

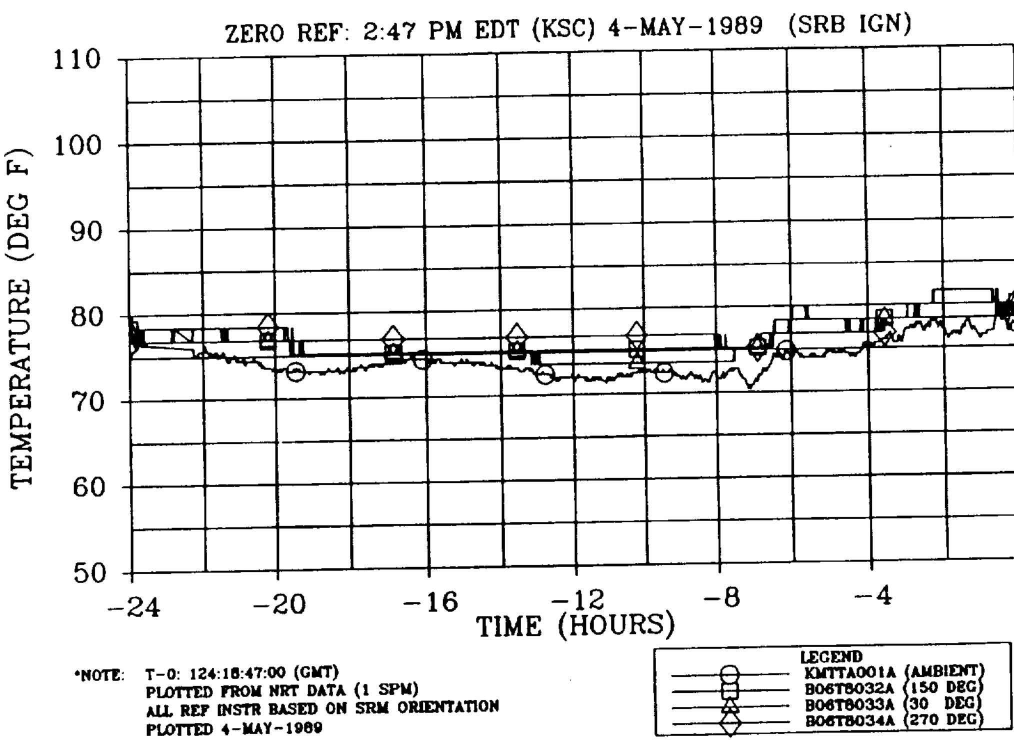


Figure 4.8-84. RH SRM Prelaunch Aft Factory Joint Temperature at Station 1701.9 (overlaid with ambient)

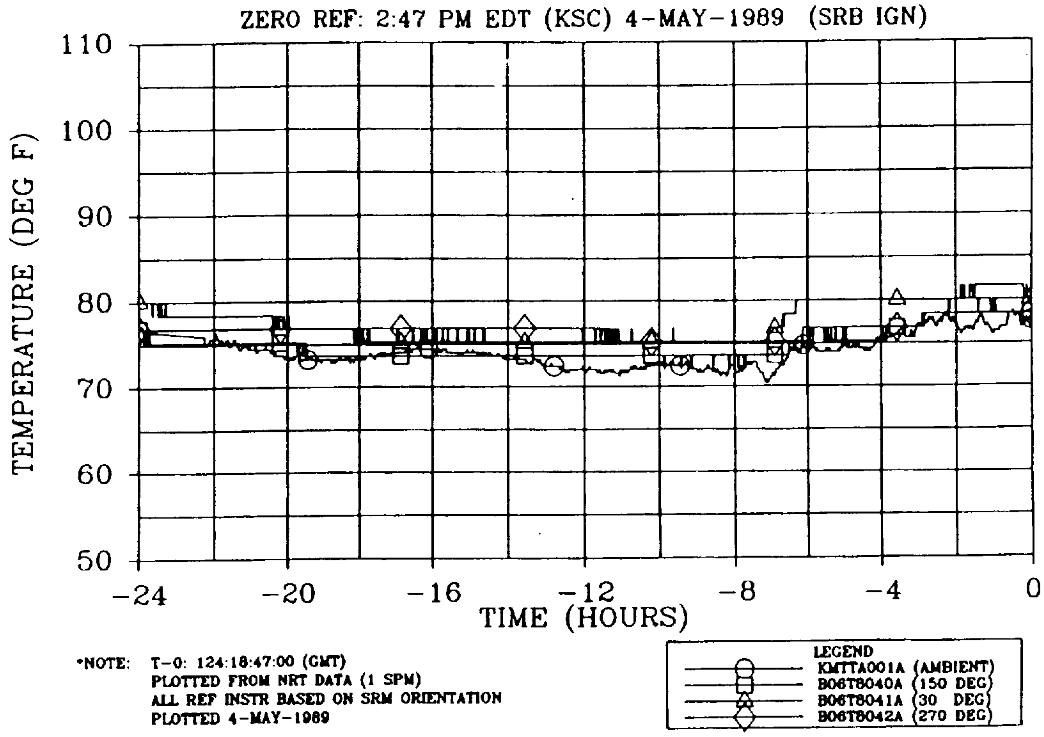


Figure 4.8-85. RH SRM Prelaunch Aft Factory Joint Temperature at Station 1821.0 (overlaid with ambient)

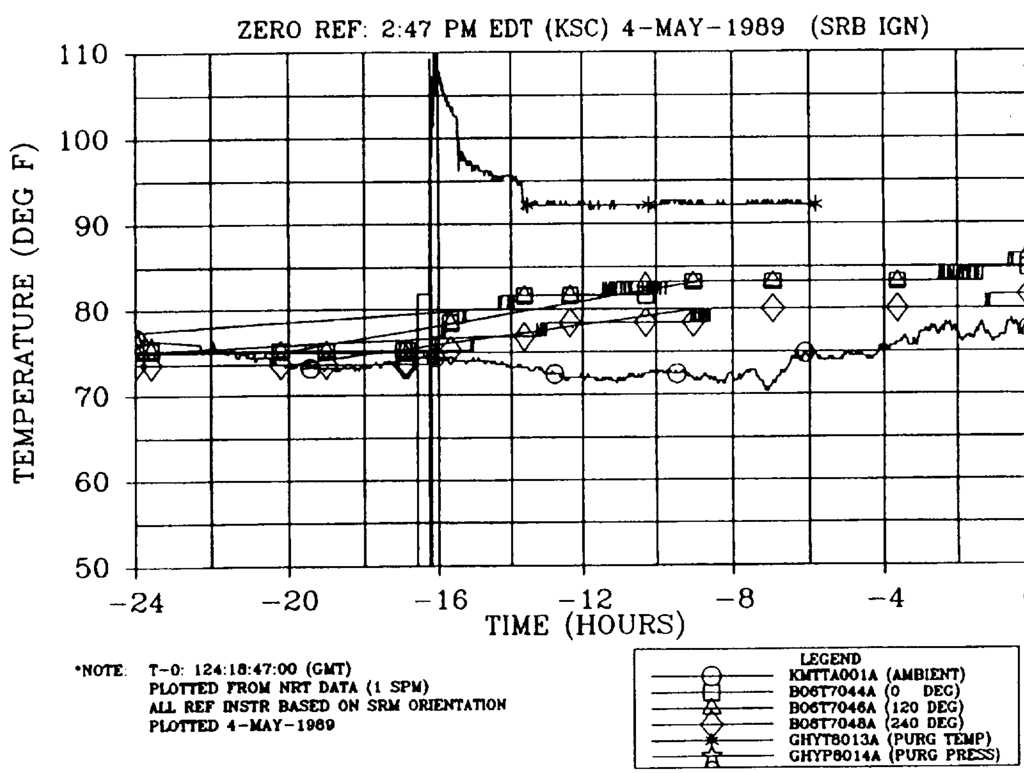
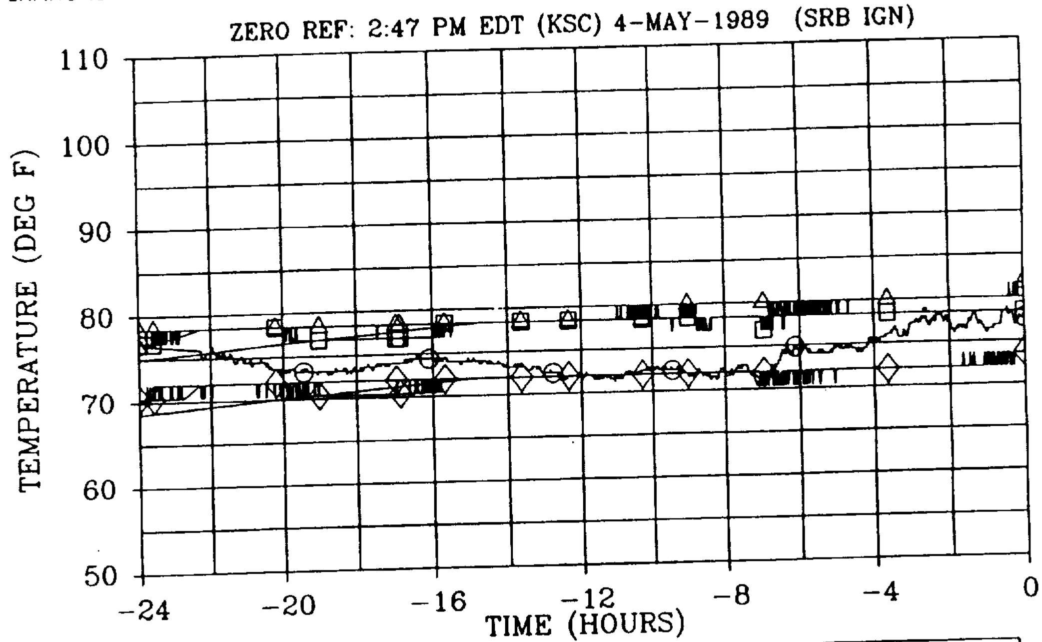
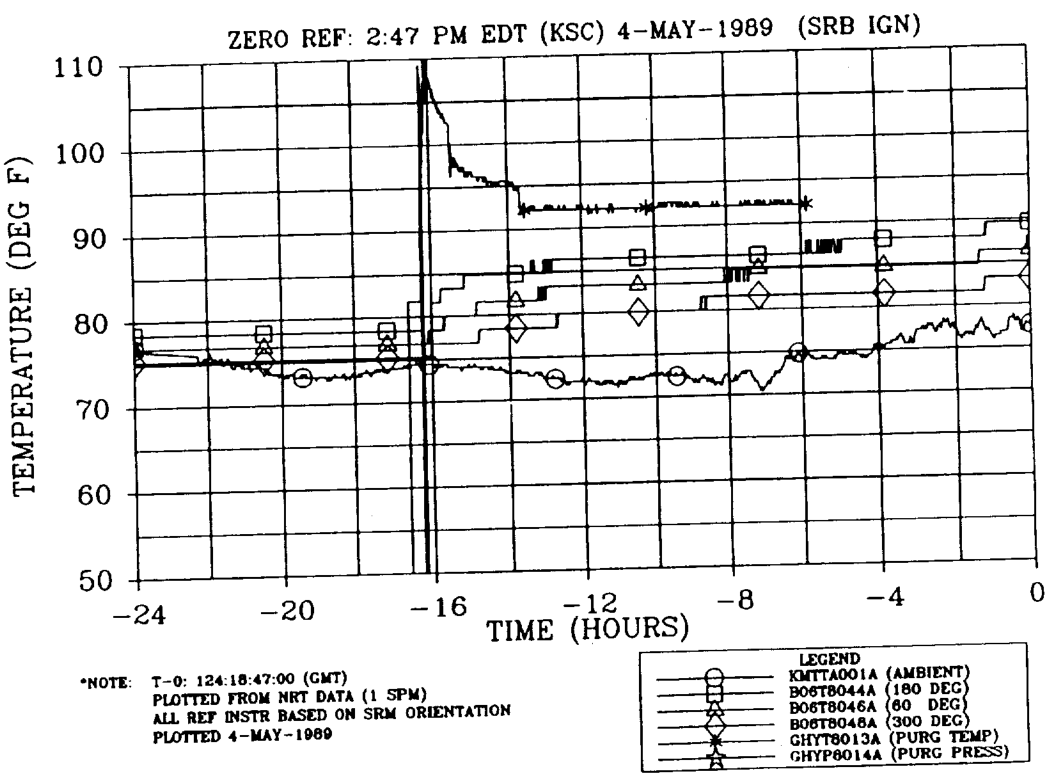


Figure 4.8-86. LH SRM Prelaunch Nozzle Region Temperature at Station 1845.0 (overlaid with ambient)



*NOTE: T-0: 124:18:47:00 (GMT)
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION
PLOTTED 4-MAY-1989

Figure 4.8-87. LH SRM Prelaunch Nozzle Region Temperature at Station 1950.0 (overlaid with ambient)



*NOTE: T-0: 124:18:47:00 (GMT)
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION
PLOTTED 4-MAY-1989

Figure 4.8-88. RH SRM Prelaunch Nozzle Region Temperature at Station 1845.0 (overlaid with ambient)

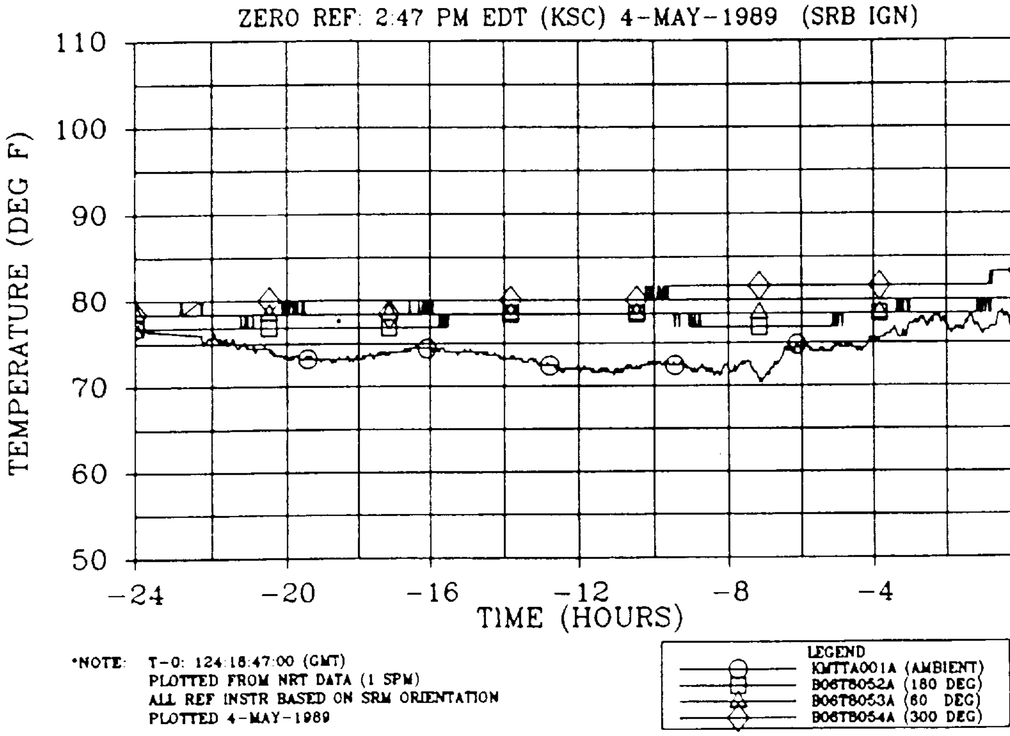


Figure 4.8-89. RH SRM Prelaunch Nozzle Region Temperature at Station 1950.0 (overlaid with ambient)

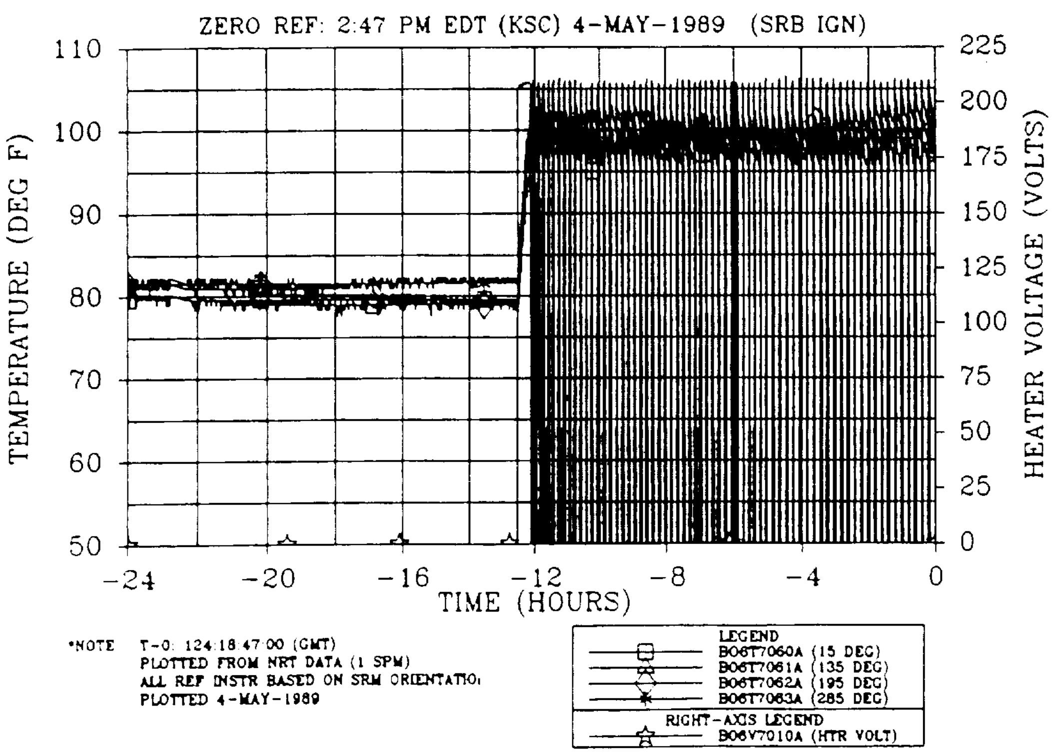


Figure 4.8-90. LH SRM Prelaunch Forward Field Joint Temperature (overlaid with heater voltage)

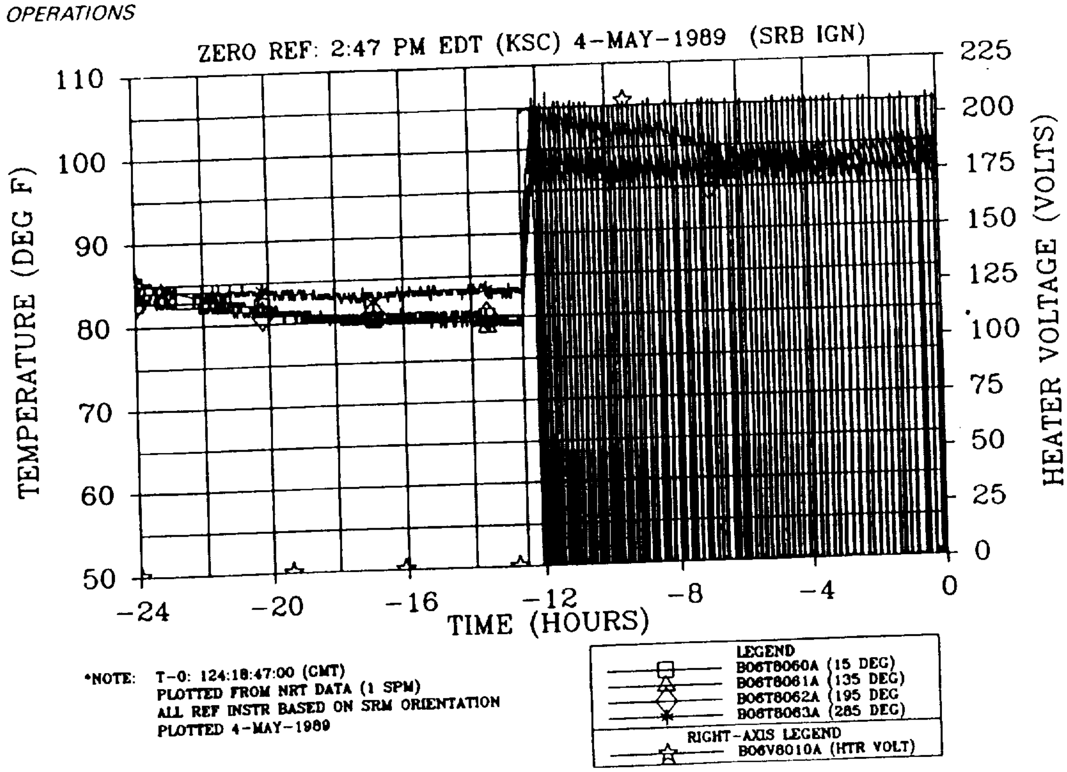


Figure 4.8-91. RH SRM Prelaunch Forward Field Joint Temperature (overlaid with heater voltage)

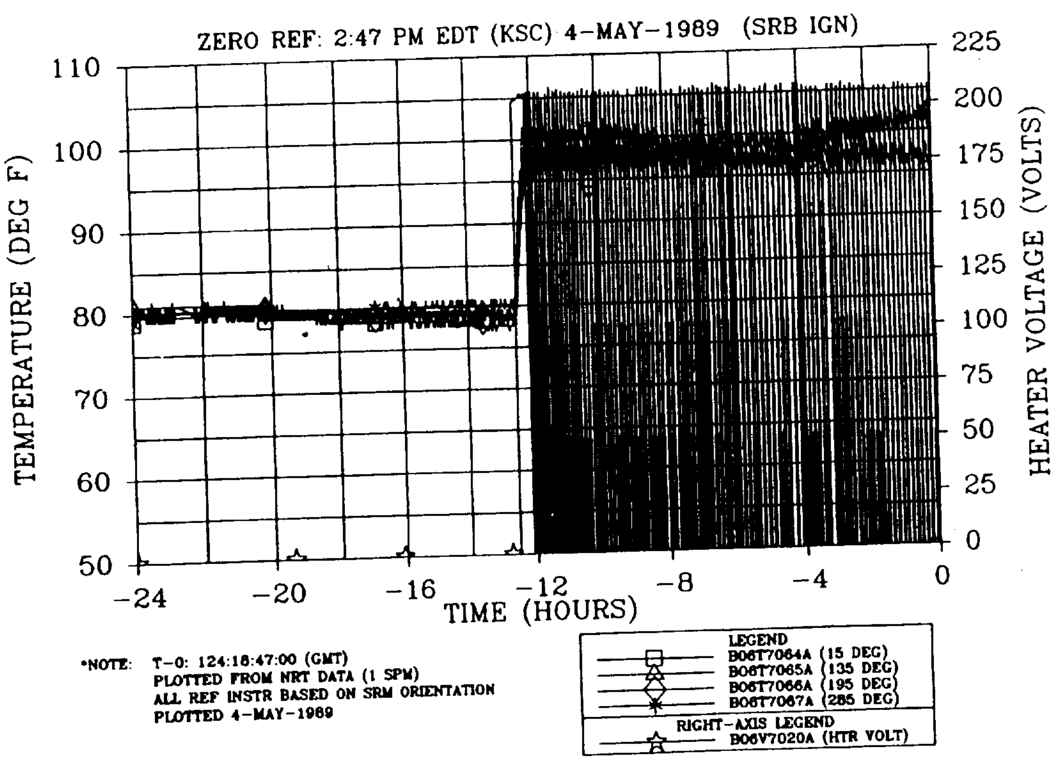


Figure 4.8-92. LH SRM Prelaunch Center Field Joint Temperature (overlaid with heater voltage)

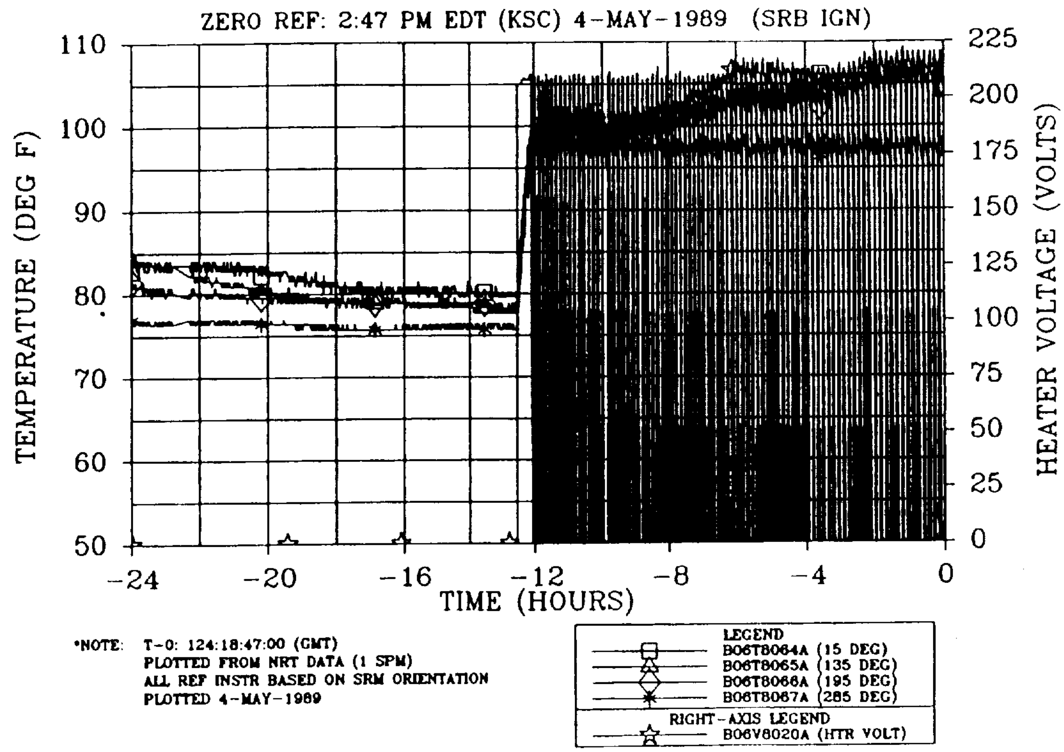


Figure 4.8-93. RH SRM Prelaunch Center Field Joint Temperature (overlaid with heater voltage)

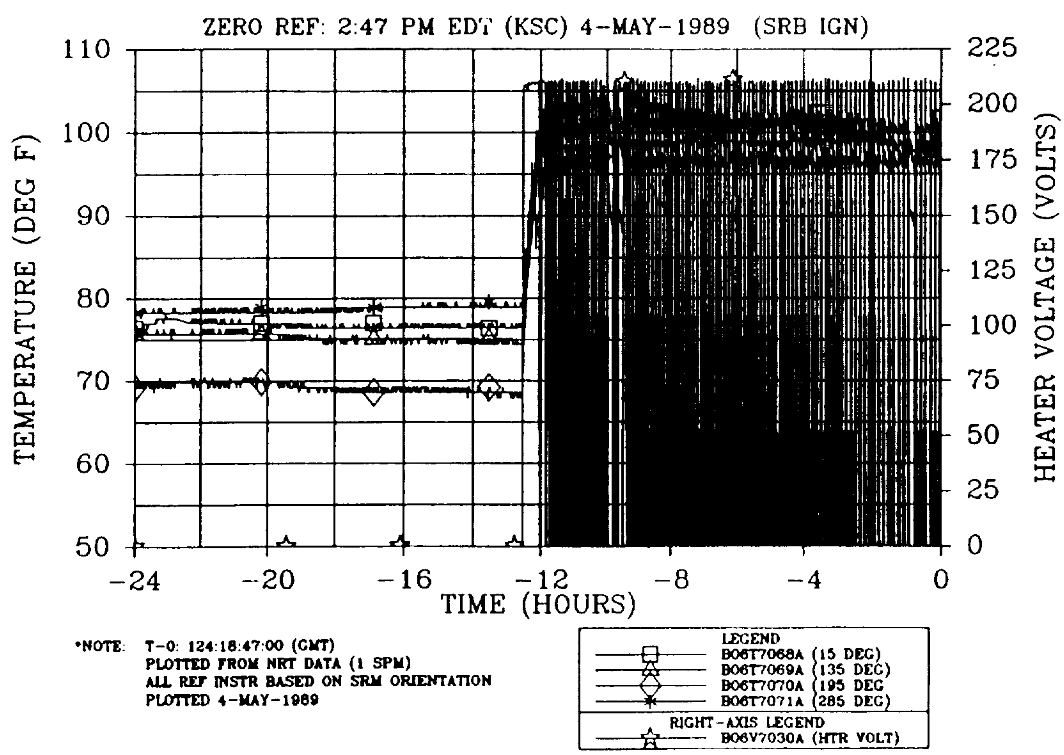


Figure 4.8-94. LH SRM Prelaunch Aft Field Joint Temperature (overlaid with heater voltage)

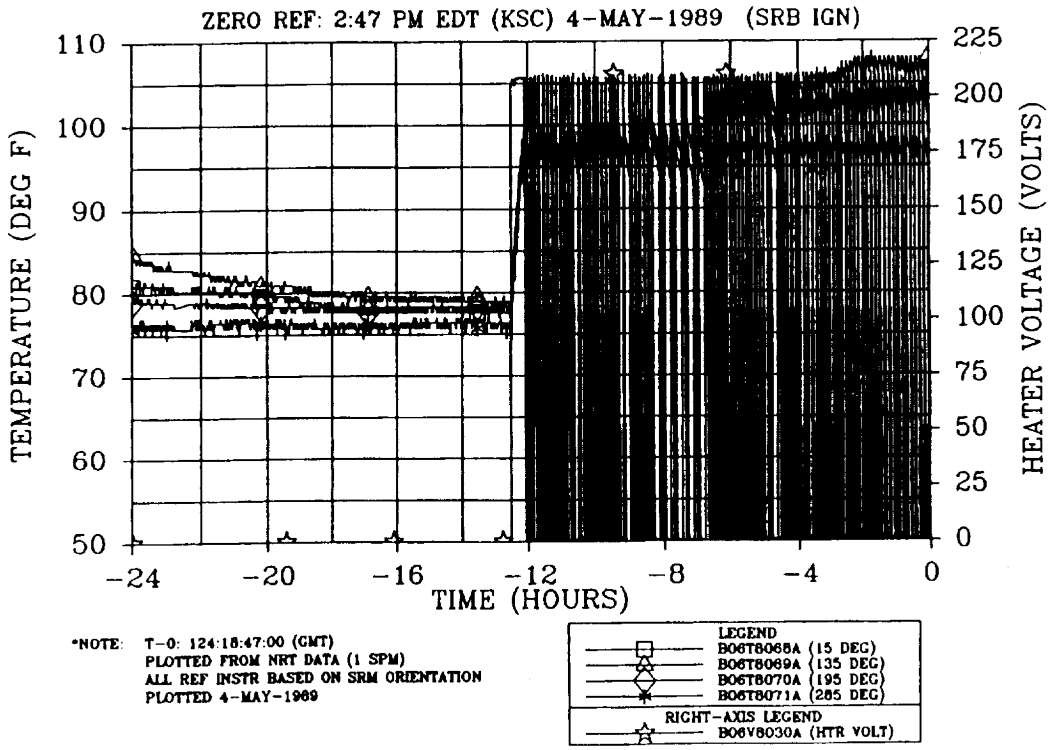


Figure 4.8-95. RH SRM Prelaunch Aft Field Joint Temperature (overlaid with heater voltage)

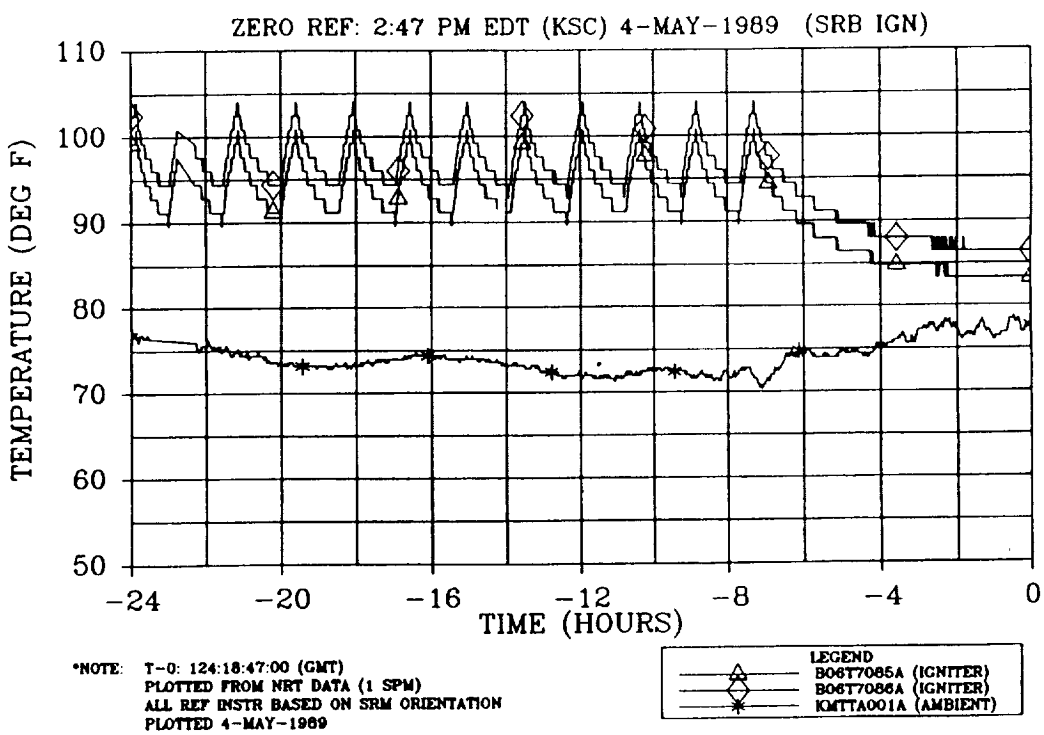


Figure 4.8-96. LH SRM Prelaunch Igniter Joint Temperature (overlaid with ambient)

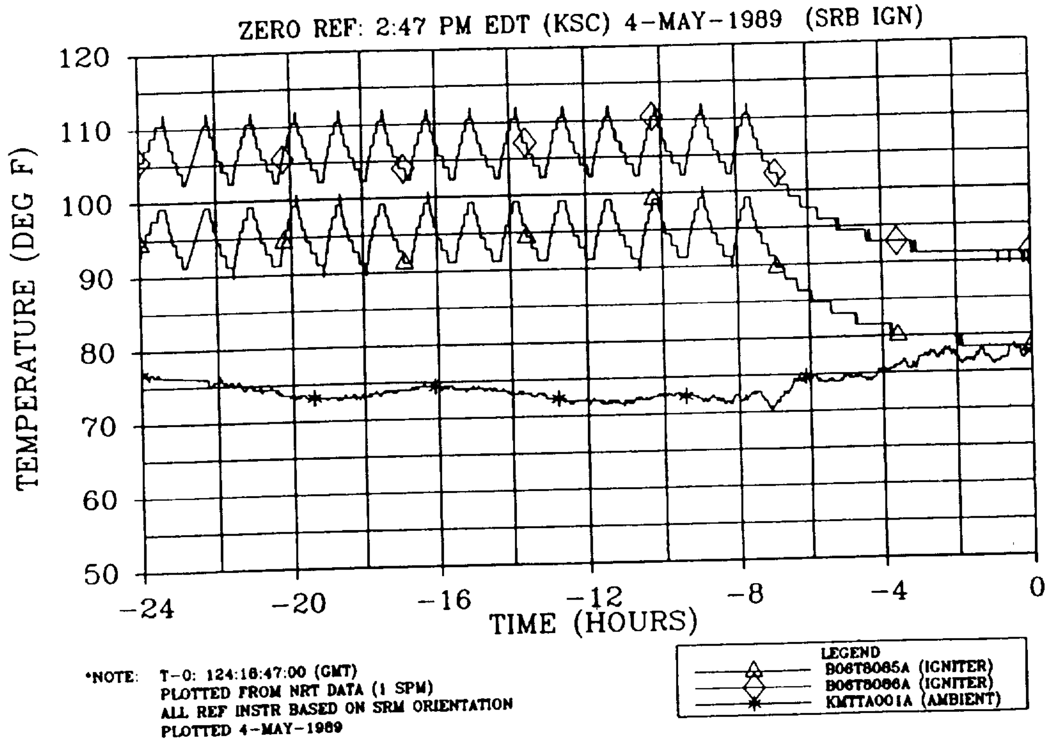


Figure 4.8-97. RH SRM Prelaunch Igniter Joint Temperature (overlaid with ambient)

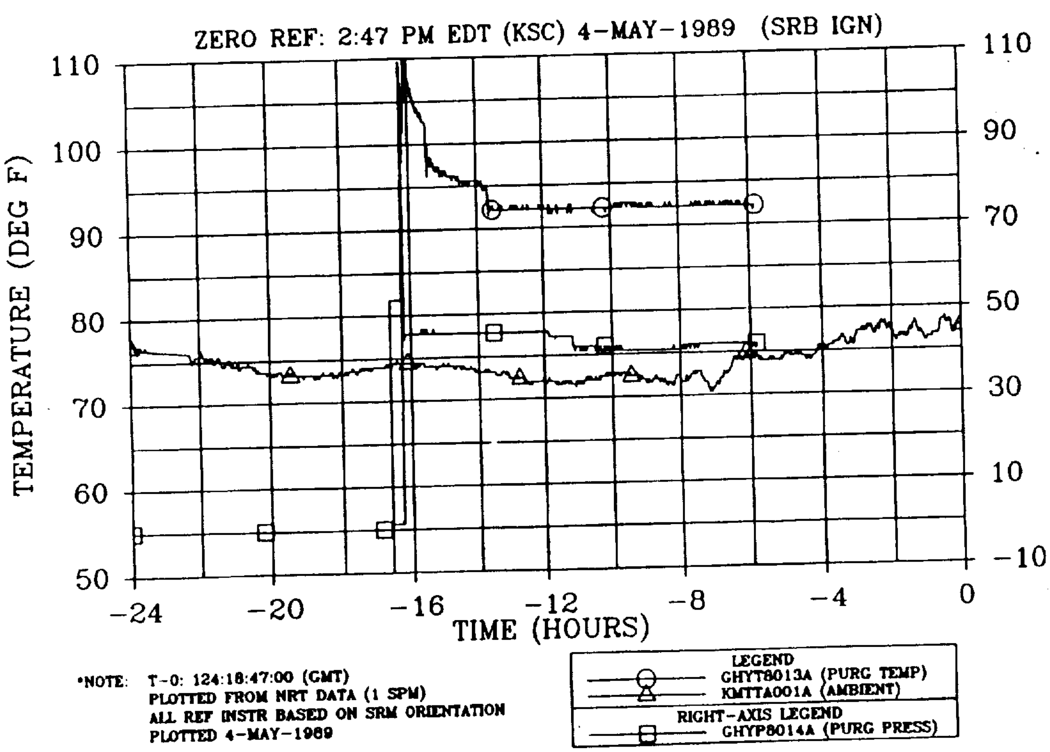


Figure 4.8-98. Prelaunch Aft Skirt Purge Temperature and Pressure (overlaid with ambient)

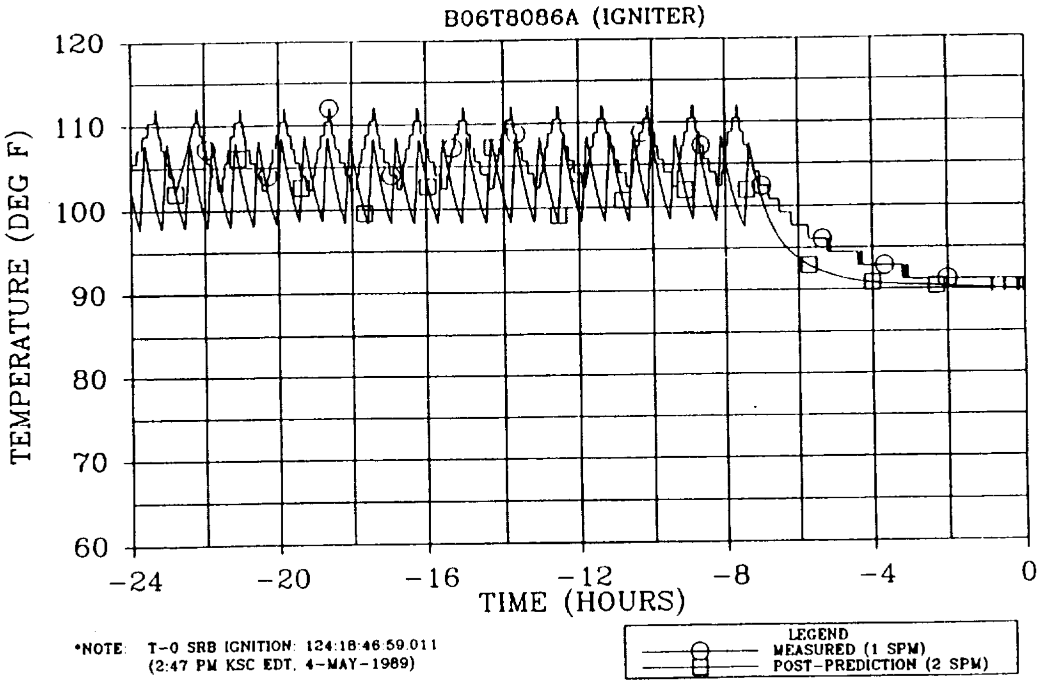


Figure 4.8-99. GEI Data Comparison--RH SRM Igniter Joint Temperature (measured versus postflight prediction)

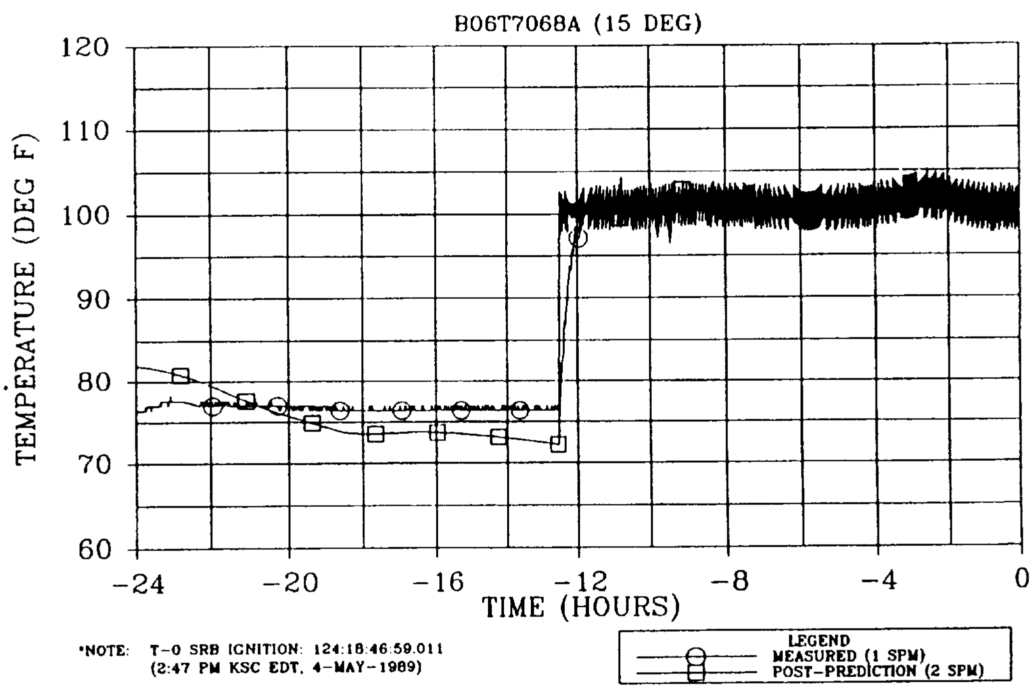


Figure 4.8-100. GEI Data Comparison--LH SRM Aft Field Joint Temperature at 15 Deg (measured versus postflight prediction)

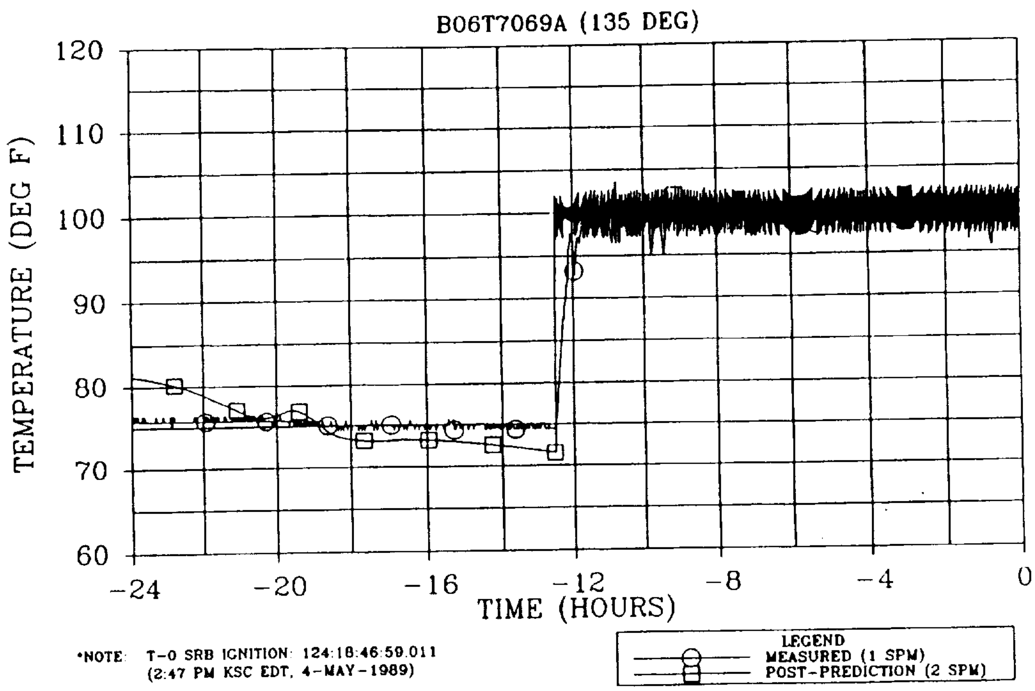


Figure 4.8-101. GEI Data Comparison--LH SRM Aft Field Joint Temperature at 135 Deg (measured versus postflight prediction)

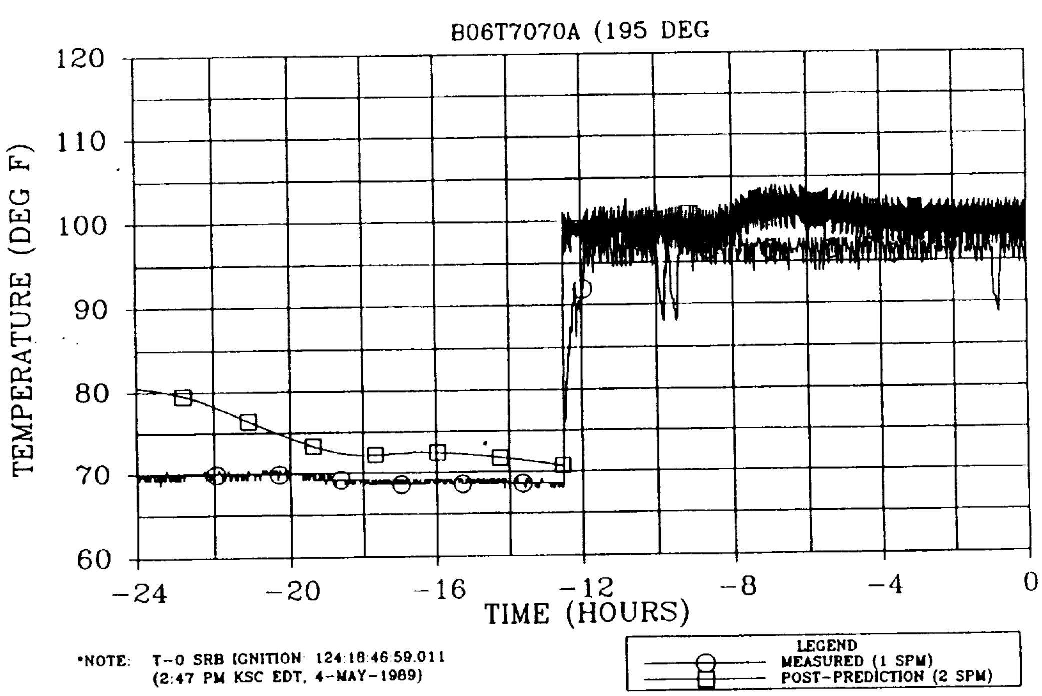


Figure 4.8-102. GEI Data Comparison--LH SRM Aft Field Joint Temperature at 195 Deg (measured versus postflight prediction)

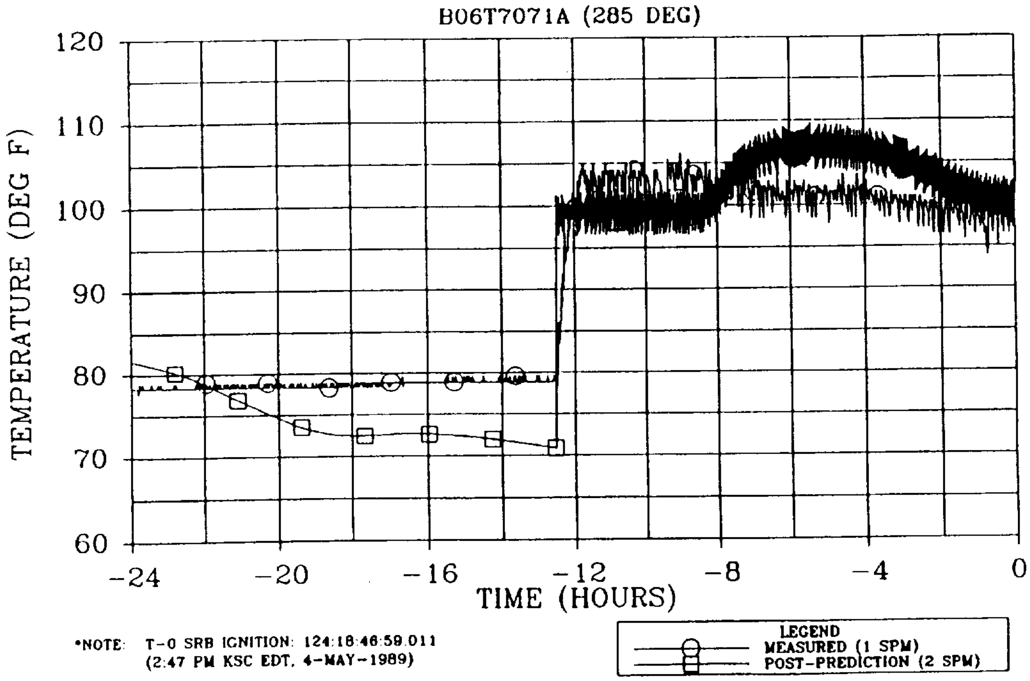


Figure 4.8-103. GEI Data Comparison--LH SRM Aft Field Joint Temperature at 285 Deg (measured versus postflight prediction)

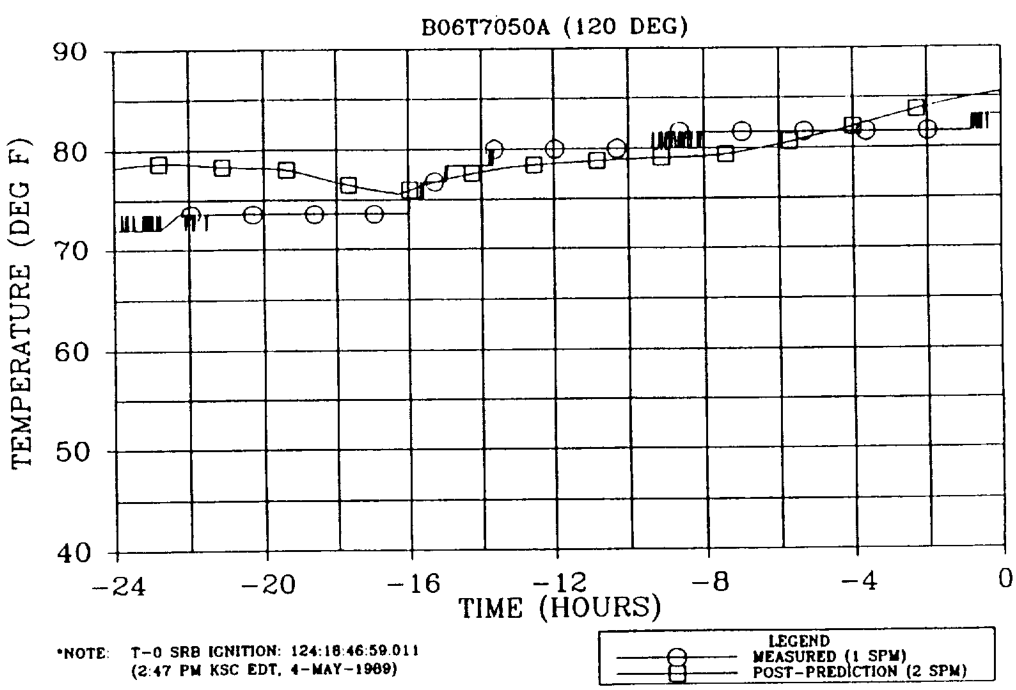


Figure 4.8-104. GEI Data Comparison--LH SRM Case-to-Nozzle Joint Temperature at 120 Deg (measured versus postflight prediction)

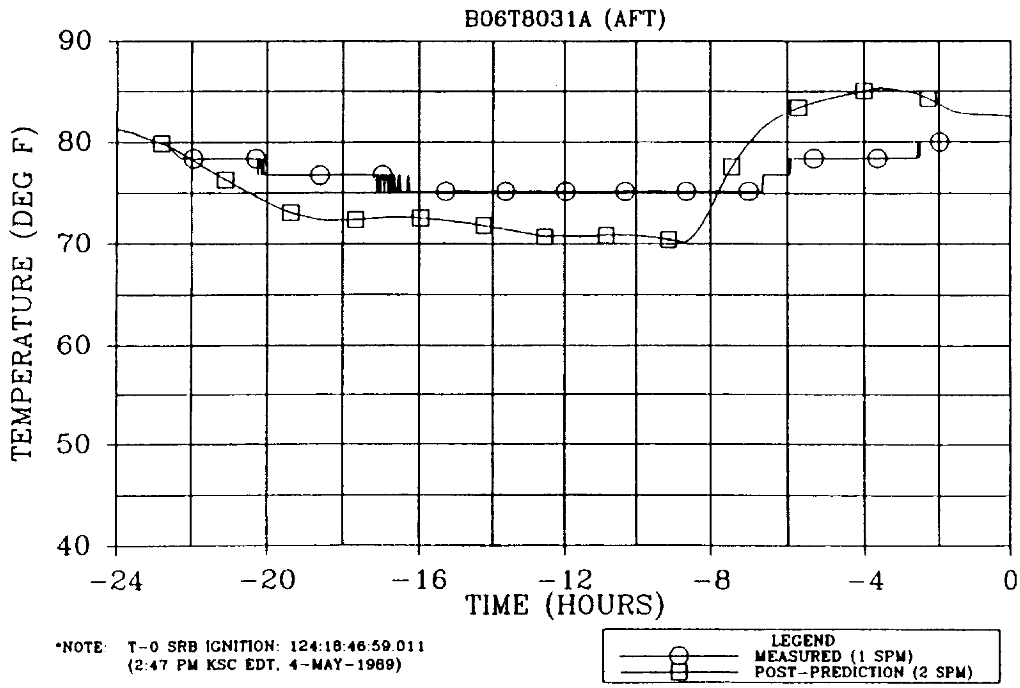


Figure 4.8-105. GEI Data Comparison--RH SRM Systems Tunnel Bondline Temperature (measured versus postflight prediction)

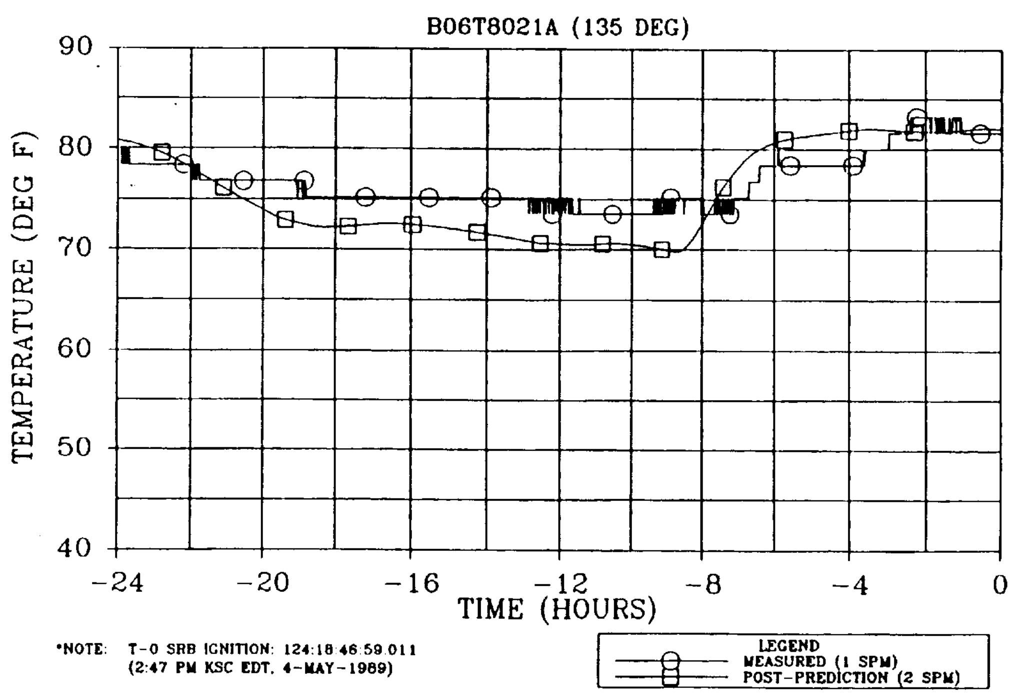


Figure 4.8-106. GEI Data Comparison--RH SRM Case Acreage Temperature at Station 1411.5, 135 Deg (measured versus postflight prediction)

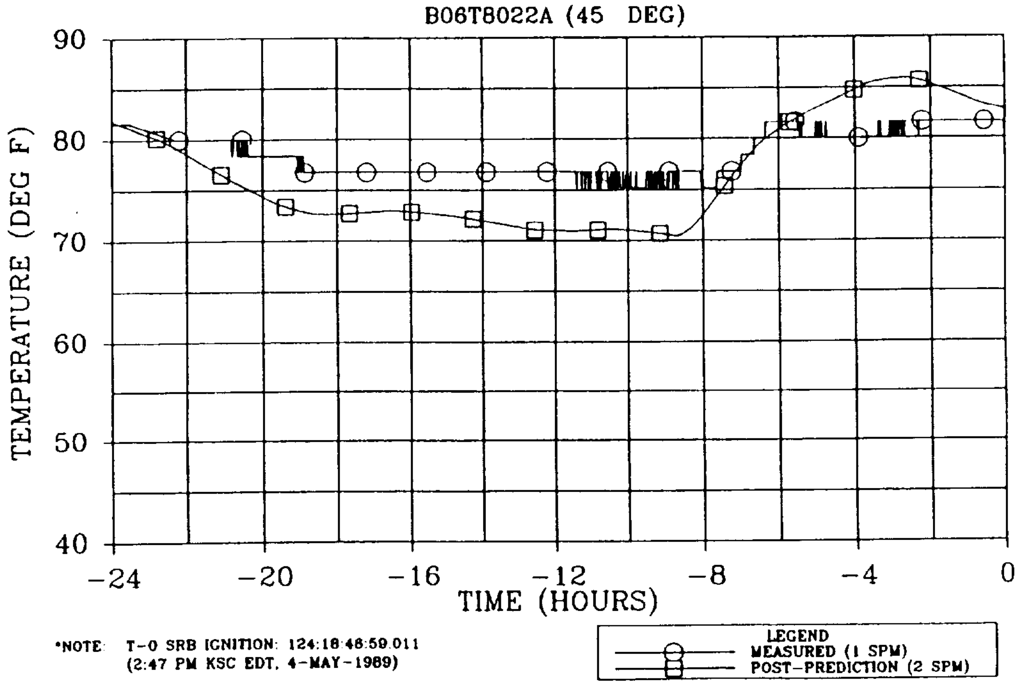


Figure 4.8-107. GEI Data Comparison--RH SRM Case Acreage Temperature at Station 1411.5, 45 Deg (measured versus postflight prediction)

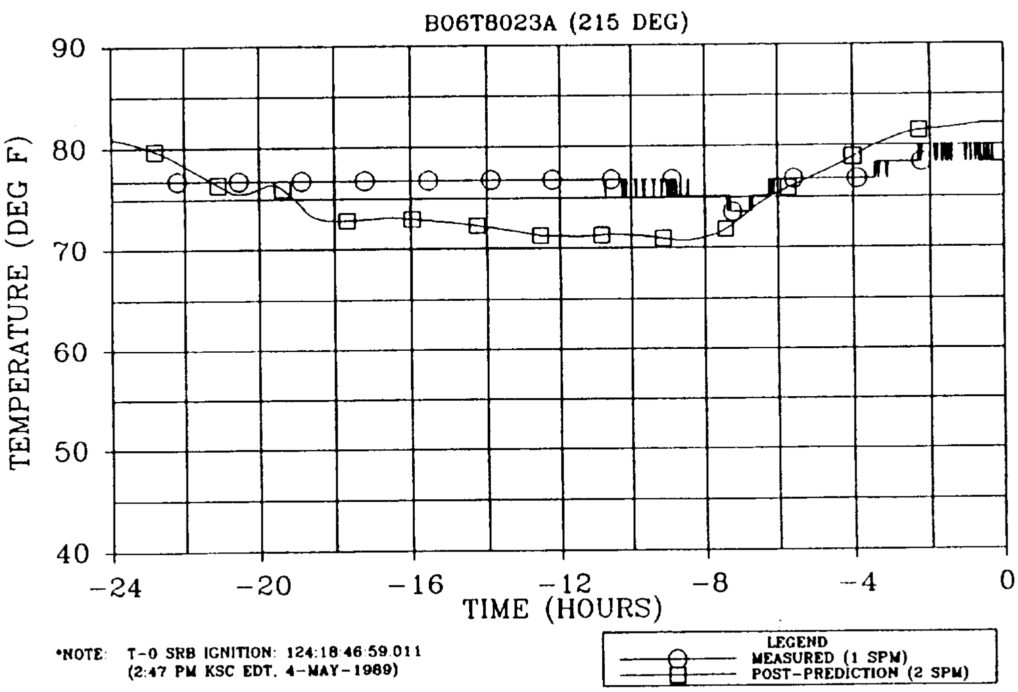


Figure 4.8-108. GEI Data Comparison--RH SRM Case Acreage Temperature at Station 1411.5, 215 Deg (measured versus postflight prediction)

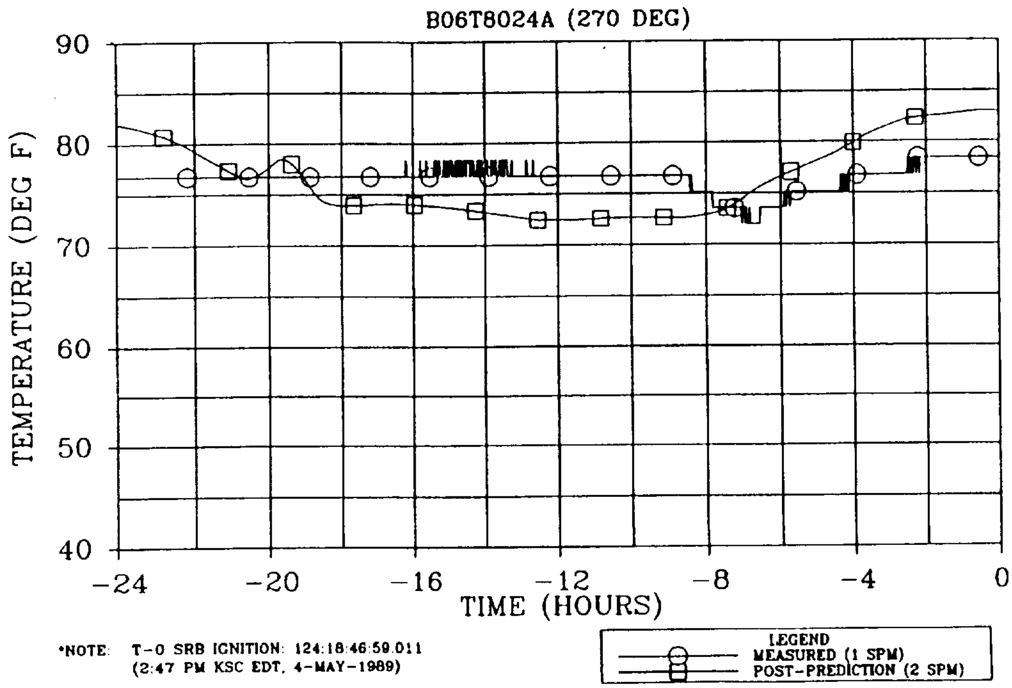


Figure 4.8-109. GEI Data Comparison--RH SRM Case Acreage Temperature at Station 1411.5, 270 Deg (measured versus postflight prediction)

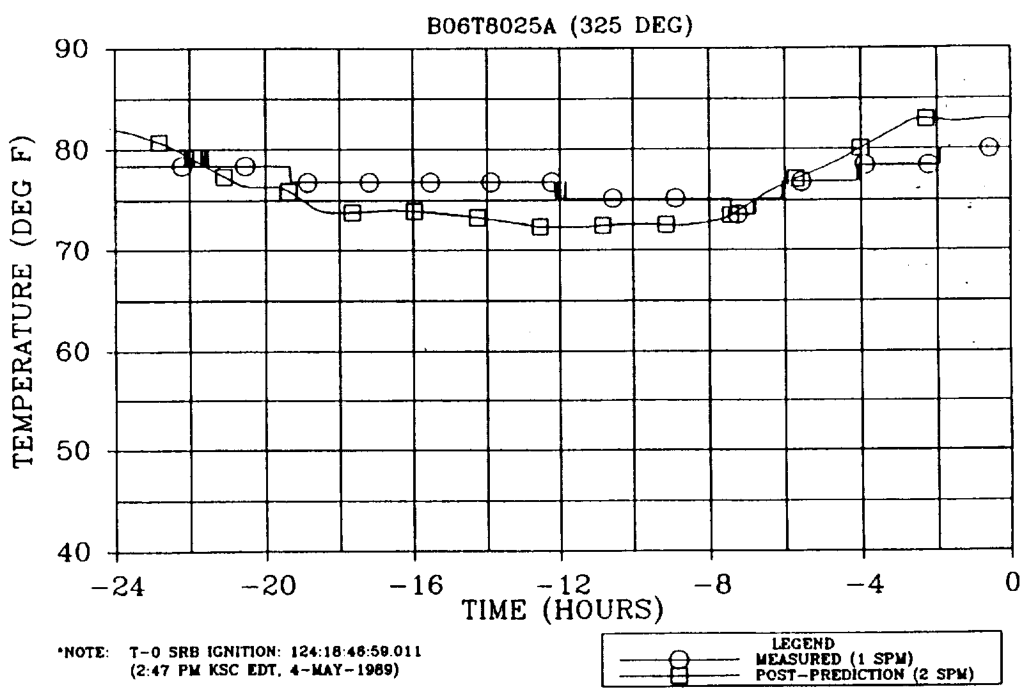


Figure 4.8-110. GEI Data Comparison--RH SRM Case Acreage Temperature at Station 1411.5, 325 Deg (measured versus postflight prediction)

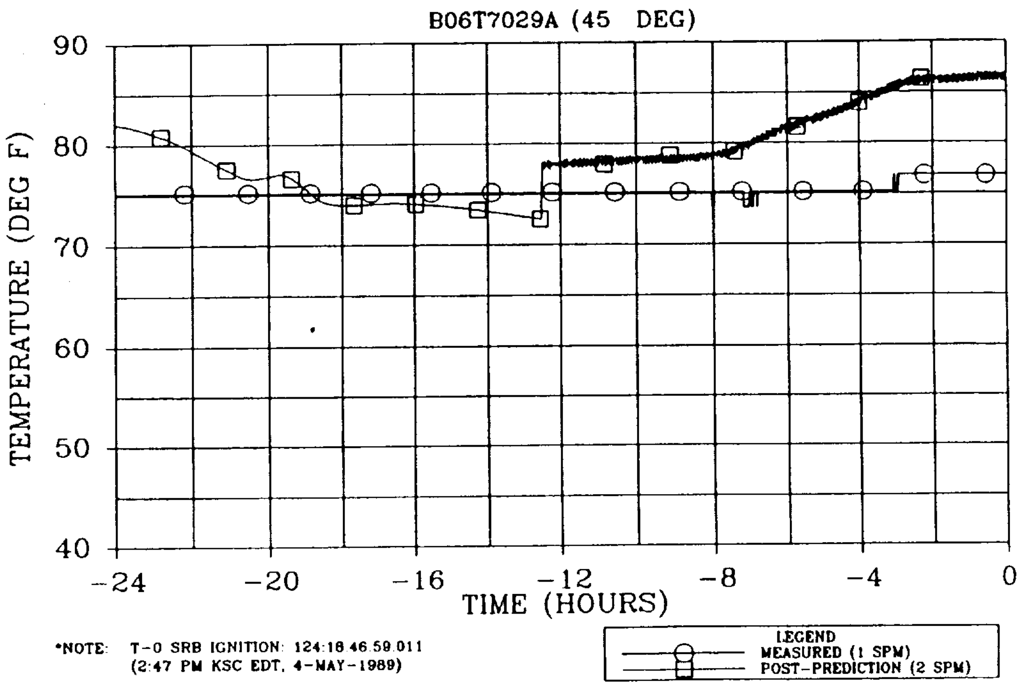


Figure 4.8-111. GEI Data Comparison--LH SRM ET Attach Region Temperature at Station 1535.0, 45 Deg (measured versus postflight prediction)

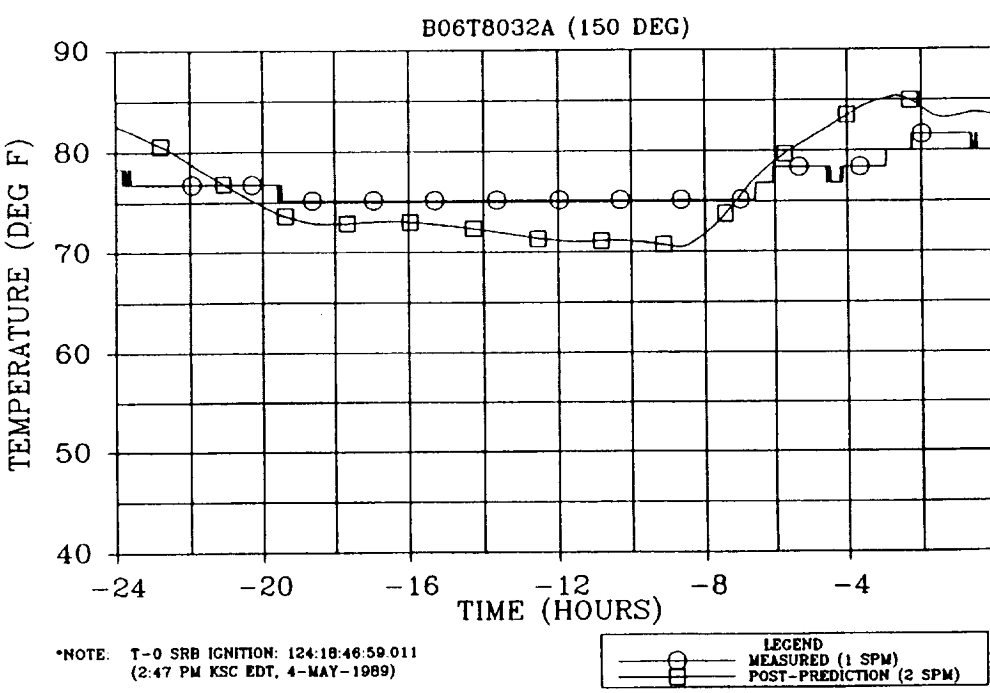


Figure 4.8-112. GEI Data Comparison--RH SRM Aft Factory Joint Temperature at Station 1701.9, 150 Deg (measured versus postflight prediction)

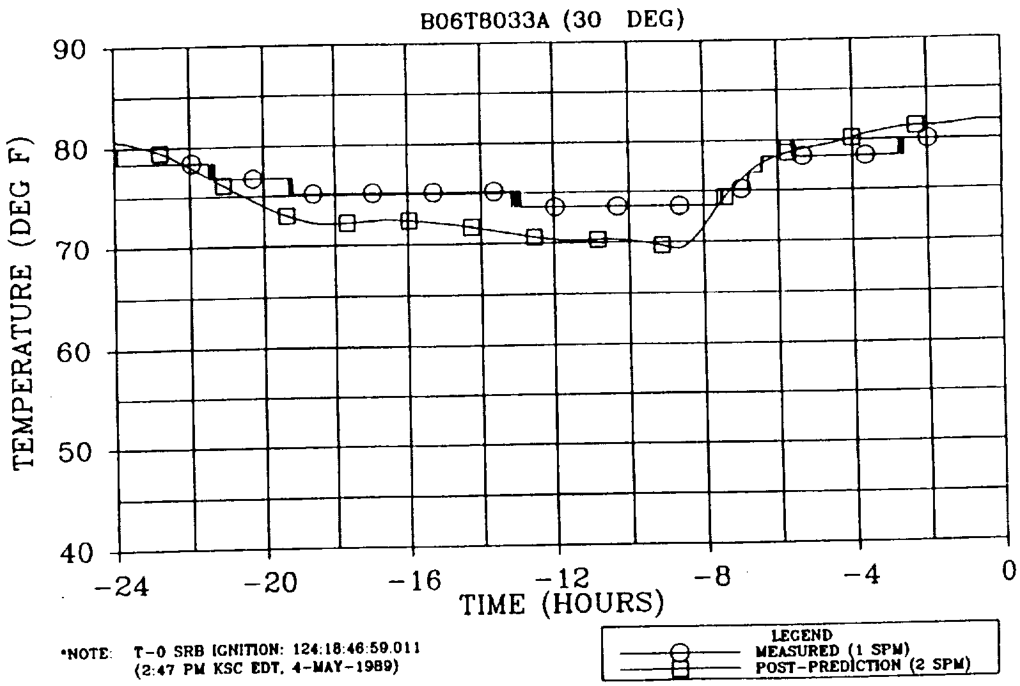


Figure 4.8-113. GEI Data Comparison--RH SRM Aft Factory Joint Temperature at Station 1701.9, 30 Deg (measured versus postflight prediction)

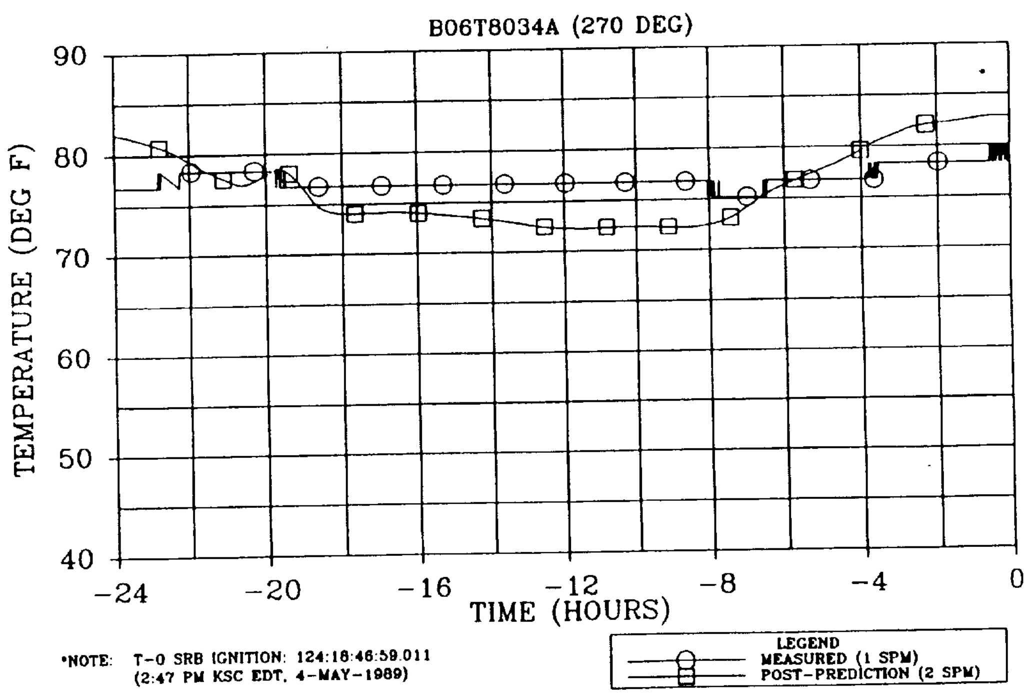


Figure 4.8-114. GEI Data Comparison--RH SRM Aft Factory Joint Temperature at Station 1701.9, 270 Deg (measured versus postflight prediction)

Table 4.8-7. STS-30R Infrared (IR gun) On-Pad Measurements Versus Actual GEI Sensor Data (°F) at L - 1 Day (1:30 to 2:30 p.m.) on 27 Apr 1989

	Infrared*		Actual GEI	
Component	Location** (deg)	Temperature*** (°F)	Location (deg)	Temperature*** (°F)
Case Acreage				
LH Aft	45	73	45	76
	135	72	135	74
RH Aft	45	69	45	79
	135	71	135	82
LH Aft Center	45	74	45	75
	135	77	135	77
LH Forward Center	45	75	45	78
	135	77	135	81
LH Forward	45	75	45	85
	135	72	135	80

*No measurements were taken on the RH booster above the aft segment because IR gun measurements taken at a steep angle from the MLP have always read low and are questionable when compared with GEI
**Measurements were taken of case surface next to GEI sensor labels
***Two or three axial locations were measured and averaged per segment

Table 4.8-8. STS-30R Infrared (IR gun) On-Pad Measurements Versus Actual GEI Sensor Data (°F) at T - 3 Hr (9:00 to 10:00 a.m.) on 28 Apr 1989

	Infrared*		Actual GEI	
Component	Location** (deg)	Temperature*** (°F)	Location (deg)	Temperature*** (°F)
Case Acreage				
LH Aft	45	64	45	70
	135	65	135	70
RH Aft	45	77	45	79
	135	78	135	79
LH Aft Center	45	67	45	70
	135	67	135	70
LH Forward Center	45	67	45	73
	135	67	135	74
LH Forward	45	66	45	74
	135	66	135	77
Forward Skirt†	70	70	--	--
LH	110	70	--	--
Aft Skirt†				
LH	90	68	--	--
	180	66	--	--
RH	90	77	--	--
	0	66	--	--

*No measurements were taken on the RH booster above the aft segment because IR gun measurements taken at a steep angle from the MLP have always read low and are questionable when compared with GEI
**Measurements were taken of case surface next to GEI sensor labels
***Two or three axial locations were measured and averaged per segment
†No GEI are available for these regions

Table 4.8-9. STS-30R Infrared (IR gun) On-Pad Measurements Versus Actual GEI Sensor Data (°F) at T - 3 Hr (9:00 to 10:00 a.m.) on 4 May 1989

	Infrared*		Actual GEI	
Component	Location** (deg)	Temperature*** (°F)	Location (deg)	Temperature*** (°F)
Case Acreage				
LH Aft	45	71	45	75
	135	71	135	74
RH Aft	45	77	45	78
	135	76	135	76
LH Aft Center	45	72	45	74
	135	72	135	75
LH Forward Center	45	71	45	76
	135	71	135	76
LH Forward	45	70	45	75
	135	69	135	77
Forward Skirt†				
LH	70	71	--	--
	110	71	--	--
Aft Skirt†				
LH	90	72	--	--
	180	68	--	--
RH	90	76	--	--
	0	69	--	--

*No measurements were taken on the RH booster above the aft segment because IR gun measurements taken at a steep angle from the MLP have always read low and are questionable when compared with GEI
**Measurements were taken of case surface next to GEI sensor labels
***Two or three axial locations were measured and averaged per segment
†No GEI are available for these regions

design, from a thermal perspective, continues to suggest that the worst-case flight design environments of the integrated vehicle baseline configuration (IVBC-3) and SRB reentry are for the most part overly conservative. An exception to this is the environment in the nozzle base region during reentry when hydrazine fires are present. (Refer to STS-29R final report, TWR-17542, Vol I.)

4.8.4.2 Debris. No SRM violations of NSTS debris criteria were noted. The problem of losing TPS cork caps covering the GEI cables due to poor cork bonds appears to have been alleviated. The K5NA closeout in place of the cork caps is performing excellently and as expected. All missing TPS cork pieces (generally small) are due to nozzle severance debris and/or splashdown loads and debris.

A potential debris problem was acknowledged during 360T004 open assessment concerning the GEI labels which are covered with a thick layer of epoxy. Numerous labels were missing and some of the areas showed signs of sooting, indicating that they occurred during flight. The ice/debris team recommended either removing these labels or replacing them with stencils on future flights. Currently these labels, with epoxy closeouts, are attached to both the 360H005 and 360L006 flight hardware.

4.8.4.3 GEI Prediction. Additional model enhancement is recommended for certain motor regions in order to improve predictions. Submodel development effort for the areas of the ET attach ring, field joint, factory joint, systems tunnel, igniter, and nozzle regions is anticipated. These tasks would be encompassed by the global model effort. It is also recommended that all these models, including the 3-D SRM model, be made available for use at MSFC. This will allow Thiokol thermal personnel the opportunity to support launch support countdowns at the HOSC with real-time PMBT, GEI, and component predictions updates. This would also allow MSFC thermal personnel the same modeling capabilities.

4.8.4.4 Aft Skirt Conditioning. It is apparent, based on the cold environment experienced by 360L003 (STS-29R), that substantial gas cooling occurs in the ducting system before the gas enters the aft skirt. It is recommended that the gas temperature be monitored as it enters the aft skirt compartment. During cold weather this would allow the use of a higher operating temperature and at the same time not violate the 115°F maximum within the compartment.

4.8.4.5 GEI Accuracy. It is recommended that the GEI data collection accuracy be increased by reducing the gage range and increasing the digital word length. The real fidelity of the KSC GSE could then be quantified and conceivably replaced if determined to be inadequate.

4.8.4.6 Local Chilling. Based on data from 360L003 (STS-29R) and 360T004 (STS-30R), local cooling does occur. It is recommended that a method be developed to accurately quantify the chill effect.

4.8.4.7 IR Measurements. STI data continue to be much more reliable than IR gun measurements. Comparisons with GEI are within acceptable margins for STI data but are questionable and unpredictable for IR gun data. It is recommended for future flights that 1/2-hr STI versus GEI direct comparisons be made and documented.

4.9 MEASUREMENT SYSTEM PERFORMANCE (DFI) (FEWG report Paragraph 2.9.5)

Motor set 360T004 did not have any DFI installed. This section is reserved pending any future motors that incorporate DFI.

4.10 MEASUREMENT SYSTEM PERFORMANCE (FEWG report Paragraph 2.9.7)

4.10.1 Instrumentation Summary

Table 4.10-1 shows the location and number of instrumentation for 360T004. Note that the igniter heater sensors are classified as GEI, whereas the field joint heater sensors are listed under a separate category. The OFI consists of the three OPTs which are used to determine the SRB separation time.

Table 4.10-1. 360T004 (STS-30R) Instrumentation

	LH			RH			
Parameter	OFI	GEI	HTR	OFI	GEI	HTR	Total
Pressure	3			3			6
Temperature		54*	12		54*	12	132
							138

*Includes igniter heater sensors

4.10.2 GEI/OFI Performance

The GEI instrumentation on flight set 360T004 consisted of 108 resistance temperature devices (RTD), which monitor motor case and igniter temperature while the motor is on the pad. The gage locations were previously shown in Figures 4.8-7 and 4.8-9 through 4.8-11. Of the 108 GEI gages, 106 (98.2 percent) were functioning before launch. (All GEI are disconnected by breakaway umbilicals at SRB ignition and are not operative during flight). Tables 4.10-2 and 4.10-3 are the GEI lists, and also include the gage losses and those that consistently read differently from surrounding gages.

Table 4.10-2. GEI List--LH SRM (360Q004)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T7003A	270	534.5	±200	Forward segment	
B06T7004A	45	694.5	±200	Forward segment	
B06T7005A	135	694.5	±200	Forward segment	
B06T7006A	325	694.5	±200	Forward segment	
B06T7007A	270	694.5	±200	Forward segment	
B06T7008A	215	694.5	±200	Forward segment	
B06T7009A	90	778.98	±200	Forward segment (systems tunnel)	
B06T7010A	45	931.48	±200	Forward center segment	Gage lost--no data
B06T7011A	135	931.48	±200	Forward center segment	
B06T7012A	325	931.48	±200	Forward center segment	
B05T7013A	270	931.48	±200	Forward center segment	
B06T7014A	215	931.48	±200	Forward center segment	
B06T7015A	45	1091.48	±200	Forward center segment	
B06T7016A	135	1091.48	±200	Forward center segment	
B06T7017A	325	1091.48	±200	Forward center segment	
B06T7018A	270	1091.48	±200	Forward center segment	
B06T7019A	215	1091.48	±200	Forward center segment	
B06T7020A	90	1258.98	±200	Aft center segment (systems tunnel)	
B06T7021A	45	1411.48	±200	Aft center segment	
B06T7022A	135	1411.48	±200	Aft center segment	
B06T7023A	325	1411.48	±200	Aft center segment	
B06T7024A	270	1411.48	±200	Aft center segment	
B06T7025A	215	1411.48	±200	Aft center segment	
B06T7026A	220	1511	±200	ET attach ring	
B06T7027A	274	1511	±200	ET attach ring	
B06T7028A	320	1511	±200	ET attach ring	
B06T7029A	45	1535	±200	Aft segment	
B06T7030A	135	1535	±200	Aft segment	
B06T7031A	90	1565	±200	Aft segment (systems tunnel)	
B06T7032A	30	1701.86	±200	Aft segment	
B06T7033A	150	1701.86	±200	Aft segment	
B06T7034A	270	1701.86	±200	Aft segment	
B06T7035A	45	1751.5	±200	Aft segment	
B06T7036A	135	1751.5	±200	Aft segment	
B06T7037A	325	1751.5	±200	Aft segment	

90089-11.5

Table 4.10-2. GEI List--LH SRM (360Q004) (cont)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T7038A	270	1751.5	±200	Aft segment	
B06T7039A	215	1751.5	±200	Aft segment	
B06T7040A	30	1821	±200	Aft segment	
B06T7041A	150	1821	±200	Aft segment	
B06T7042A	270	1821	±200	Aft segment	
B06T7043A	0	1847	±200	Flex bearing	
B06T7044A	0	1845	±200	Nozzle throat	
B06T7045A	120	1847	±200	Flex bearing	
B06T7046A	120	1845	±200	Nozzle throat	
B06T7047A	240	1847	±200	Flex bearing	
B06T7048A	240	1845	±200	Nozzle throat	
B06T7049A	0	1876.6	±200	Case-to-nozzle joint	
B06T7050A	120	1876.6	±200	Case-to-nozzle joint	
B06T7051A	240	1876.6	±200	Case-to-nozzle joint	
B06T7052A	0	1950	±200	Exit cone	
B06T7053A	120	1950	±200	Exit cone	
B06T7054A	240	1950	±200	Exit cone	
B06T7085A	184.5	486.4	±200	Igniter	
B06T7086A	355.5	486.4	±200	Igniter	

90089-11.6

Table 4.10-3 GEI List--RH SRM (360H004)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T8003A	270	534.5	±200	Forward segment	
B06T8004A	135	694.5	±200	Forward segment	
B06T8005A	45	694.5	±200	Forward segment	
B06T8006A	215	694.5	±200	Forward segment	
B06T8007A	270	694.5	±200	Forward segment	
B06T8008A	325	694.5	±200	Forward segment	Gage lost--No data
B06T8009A	90	778.98	±200	Forward segment (systems tunnel)	
B06T8010A	135	931.48	±200	Forward center segment	
B06T8011A	45	931.48	±200	Forward center segment	
B06T8012A	215	931.48	±200	Forward center segment	
B06T8013A	270	931.48	±200	Forward center segment	
B06T8014A	325	931.48	±200	Forward center segment	
B06T8015A	135	1091.48	±200	Forward center segment	
B06T8016A	45	1091.48	±200	Forward center segment	
B06T8017A	215	1091.48	±200	Forward center segment	
B06T8018A	270	1091.48	±200	Forward center segment	
B06T8019A	325	1091.48	±200	Forward center segment	
B06T8020A	90	1258.98	±200	Aft center segment (systems tunnel)	
B06T8021A	135	1411.48	±200	Aft center segment	
B06T8022A	45	1411.48	±200	Aft center segment	
B06T8023A	215	1411.48	±200	Aft center segment	
B06T8024A	270	1411.48	±200	Aft center segment	
B06T8025A	325	1411.48	±200	Aft center segment	
B06T8026A	320	1511	±200	ET attach ring	
B06T8027A	266	1511	±200	ET attach ring	
B06T8028A	220	1511	±200	ET attach ring	
B06T8029A	135	1535	±200	Aft segment	
B06T8030A	45	1535	±200	Aft segment	
B06T8031A	90	1565	±200	Aft segment (systems tunnel)	
B06T8032A	150	1701.86	±200	Aft segment	
B06T8033A	30	1701.86	±200	Aft segment	
B06T8034A	270	1701.86	±200	Aft segment	
B06T8035A	135	1701.86	±200	Aft segment	
B06T8036A	45	1751.5	±200	Aft segment	
B06T8037A	215	1751.5	±200	Aft segment	
B06T8038A	270	1751.5	±200	Aft segment	

90089-11.7

Table 4.10-3 GEI List--RH SRM (360H004) (cont)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
B06T8039A	325	1751.5	±200	Aft segment	
B06T8040A	150	1821	±200	Aft segment	
B06T8041A	30	1821	±200	Aft segment	
B06T8042A	270	1821	±200	Aft segment	
B06T8043A	180	1847	±200	Flex bearing	
B06T8044A	180	1845	±200	Nozzle throat	
B06T8045A	60	1847	±200	Flex bearing	
B06T8046A	60	1845	±200	Nozzle throat	
B06T8047A	300	1847	±200	Flex bearing	
B06T8048A	300	1845	±200	Nozzle throat	
B06T8049A	180	1876.6	±200	Case-to-nozzle joint	
B06T8050A	60	1876.6	±200	Case-to-nozzle joint	
B06T8051A	300	1876.6	±200	Case-to-nozzle joint	
B06T8052A	180	1950	±200	Exit cone	
B06T8053A	60	1950	±200	Exit cone	
B06T8054A	300	1950	±200	Exit cone	
B06T8085A	355.5	486.4	±200	Igniter	Reads 10°F low
B06T8086A	184.5	486.4	±200	Igniter	

90089-11.8

The OFI consists of three OPTs on each forward dome, as shown previously in Figure 4.8-7. The results of the 75-percent calibration (performed at T - 1.5 hr) verified all readings were well within the 740- to 804-psia allowable range and are listed below.

360Q004A (LH)		360H004B (RH)	
Gage	Reading	Gage	Reading
B47P1300C	767.8	B47P2300C	769.8
B47P1301C	767.8	B47P2301C	769.8
B47P1302C	761.8	B47P2302C	761.8

4.10.3 Heater Sensor Performance

Evaluation of the field joint heaters and heater sensor performance was discussed previously in Section 4.8.3. Table 4.10-4 lists the joint heater sensors. The gage locations were shown previously in Figure 4.8-8.

4.10.4 S&A Device Rotation Times

Table 4.10-5 includes the arm and safe delta times for the S&A device functional test performed prior to the STS-30 countdown. It can be seen that all values are less than the required 2.0 sec. Table 4.10-6 lists the arm and safe times during the aborted and actual launch sequence (at T - 5 min). As was the case with the functional test, all values are less that 2.0 sec.

4.11 RSRM HARDWARE ASSESSMENT (FEWG report Paragraph 2.11.2)

4.11.1 Insulation Performance

4.11.1.1 Summary. The factory joint weatherseals appeared to be in good condition with the exception of the 360Q00A aft segment stiffener-to-stiffener joint, aft segment stiffener-to-dome joint, and forward center factory joint weatherseal unbonds. All weatherseal unbonds resulted from splashdown loads. No gas paths through the case-to-nozzle joint polysulfide adhesive or any other anomalous joint conditions were identified. The internal insulation in all six of the case field joints also performed as designed, with no anomalous conditions. There were no clevis edge separations that were recordable (over 0.1 in.). This was the first flight hardware set yielding no edge separations upon disassembly at KSC. No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns was identified. A complete insulation performance evaluation is in Volume III of this report.

4.11.1.2 External Insulation

Factory Joint Weatherseals. The factory joint weatherseals appeared to be in good condition. Normal heat effects and discoloration were evident on both aft segment weatherseals.

Table 4.10-4. Field Joint Heater Temperature Sensors

LH SRM Heater Temperature Sensor List

Instrument No.	Location (deg)	Station	Range (deg)	Req ACC (%)	Dig (SPM)	Remarks	Comments
B06T7060	15	851.5	0 to 200	±1	1	Forward heater	
B06T7061	135	851.5	0 to 200	±1	1	Forward heater	
B06T7062	195	851.5	0 to 200	±1	1	Forward heater	
B06T7063	285	851.5	0 to 200	±1	1	Forward heater	
B06T7064	15	117.15	0 to 200	±1	1	Center heater	
B06T7065	135	1171.5	0 to 200	±1	1	Center heater	
B06T7066	195	1171.5	0 to 200	±1	1	Center heater	
B06T7067	285	1171.5	0 to 200	±1	1	Center heater	
B06T7068	15	1491.5	0 to 200	±1	1	Aft heater	
B06T7069	135	1491.5	0 to 200	±1	1	Aft heater	
B06T7070	195	1491.5	0 to 200	±1	1	Aft heater	Reads 7 deg low
B06T7071	285	1491.5	0 to 200	±1	1	Aft heater	

RH SRM Heater Temperature Sensor List

Instrument No.	Location (deg)	Station	Range (deg)	Req ACC (%)	Dig (SPM)	Remarks
B06T8060	15	851.5	0 to 200	±1	1	Forward heater
B06T8061	135	851.5	0 to 200	±1	1	Forward heater
B06T8062	195	851.5	0 to 200	±1	1	Forward heater
B06T8063	285	851.5	0 to 200	±1	1	Forward heater
B06T8064	15	1171.5	0 to 200	±1	1	Center heater
B06T8065	135	1171.5	0 to 200	±1	1	Center heater
B06T8066	195	1171.5	0 to 200	±1	1	Center heater
B06T8067	285	1171.5	0 to 200	±1	1	Center heater
B06T8068	15	1491.5	0 to 200	±1	1	Aft heater
B06T8069	135	1491.5	0 to 200	±1	1	Aft heater
B06T8070	195	1491.5	0 to 200	±1	1	Aft heater
B06T8071	285	1491.5	0 to 200	±1	1	Aft heater

90089-8.3

Attachment B

Table 4.10-5. S&A Device Arm and Safe Delta Times

SRB IGNITION S&A ROTATION - STS-30
(B47SAO.070 - IGNITION S&A FUNCTIONAL TEST)

						ARM		SAFE	
ROTATE #	GMT	COMMAND	GMT	RESPONSE	DELTA	LEFT	RIGHT	LEFT	RIGHT
	112405.520	B55K3000X1-LH ARM	112406.267	B55X1842X1-LH ARM	0.747	0.747			
1	112405.800	B55K4000X1-RH ARM	112406.786	B55X2842X1-RH ARM	0.986		0.986		
	112413.320	B55K3002X1-LH SAFE	112414.067	B55X1843X1-LH SAFE	0.747			0.747	
	112413.560	B55K4002X1-RH SAFE	112414.386	B55X2843X1-RH SAFE	0.826				0.826
	112916.560	B55K3000X1-LH ARM	112917.466	B55X1842X1-LH ARM	0.906	0.906			
2	112916.840	B55K4000X1-RH ARM	112917.786	B55X2842X1-RH ARM	0.946		0.946		
	112924.240	B55K3002X1-LH SAFE	112925.067	B55X1843X1-LH SAFE	0.827			0.827	
	112924.521	B55K4002X1-RH SAFE	112925.386	B55X2843X1-RH SAFE	0.865				0.865
	112956.400	B55K3000X1-LH ARM	112957.267	B55X1842X1-LH ARM	0.867	0.867			
3	112956.640	B55K4000X1-RH ARM	112957.587	B55X2842X1-RH ARM	0.947		0.947		
	113004.080	B55K3002X1-LH SAFE	113004.866	B55X1843X1-LH SAFE	0.786			0.786	
	113004.320	B55K4002X1-RH SAFE	113005.186	B55X2843X1-RH SAFE	0.866				0.866
	113041.720	B55K3000X1-LH ARM	113042.466	B55X1842X1-LH ARM	0.746	0.746			
4	113041.960	B55K4000X1-RH ARM	113042.786	B55X2842X1-RH ARM	0.826		0.826		
	113049.240	B55K3002X1-LH SAFE	113050.067	B55X1843X1-LH SAFE	0.827			0.827	
	113049.482	B55K4002X1-RH SAFE	113050.386	B55X2843X1-RH SAFE	0.904				0.904
	113120.561	B55K3000X1-LH ARM	113121.266	B55X1842X1-LH ARM	0.705	0.705			
5	113120.801	B55K4000X1-RH ARM	113121.786	B55X2842X1-RH ARM	0.985		0.985		
	113128.360	B55K3002X1-LH SAFE	113129.067	B55X1843X1-LH SAFE	0.707			0.707	
	113128.600	B55K4002X1-RH SAFE	113129.386	B55X2843X1-RH SAFE	0.786				0.786
	113148.880	B55K3000X1-LH ARM	113149.666	B55X1842X1-LH ARM	0.786	0.786			
6	113149.120	B55K4000X1-RH ARM	113149.986	B55X2842X1-RH ARM	0.866		0.866		
	113156.600	B55K3002X1-LH SAFE	113157.466	B55X1843X1-LH SAFE	0.866			0.866	
	113156.840	B55K4002X1-RH SAFE	113157.587	B55X2843X1-RH SAFE	0.747				0.747
	113240.640	B55K3000X1-LH ARM	113241.466	B55X1842X1-LH ARM	0.826	0.826			
7	113240.880	B55K4000X1-RH ARM	113241.786	B55X2842X1-RH ARM	0.906		0.906		
	113248.240	B55K3002X1-LH SAFE	113249.067	B55X1843X1-LH SAFE	0.827			0.827	
	113248.480	B55K4002X1-RH SAFE	113249.386	B55X2843X1-RH SAFE	0.906				0.906
	113341.840	B55K3000X1-LH ARM	113342.667	B55X1842X1-LH ARM	0.827	0.827			
8	113342.080	B55K4000X1-RH ARM	113342.987	B55X2842X1-RH ARM	0.907		0.907		
	113349.440	B55K3002X1-LH SAFE	113350.267	B55X1843X1-LH SAFE	0.827			0.827	
	113349.680	B55K4002X1-RH SAFE	113350.587	B55X2843X1-RH SAFE	0.907				0.907
	113417.080	B55K3000X1-LH ARM	113417.866	B55X1842X1-LH ARM	0.786	0.786			
9	113417.320	B55K4000X1-RH ARM	113418.186	B55X2842X1-RH ARM	0.866		0.866		
	113424.600	B55K3002X1-LH SAFE	113425.466	B55X1843X1-LH SAFE	0.866			0.866	
	113424.840	B55K4002X1-RH SAFE	113425.587	B55X2843X1-RH SAFE	0.747				0.747
	113506.880	B55K3000X1-LH ARM	113507.667	B55X1842X1-LH ARM	0.787	0.787			
10	113507.120	B55K4000X1-RH ARM	113507.987	B55X2842X1-RH ARM	0.867		0.867		
	113514.440	B55K3002X1-LH SAFE	113515.267	B55X1843X1-LH SAFE	0.827			0.827	
	113514.720	B55K4002X1-RH SAFE	113515.587	B55X2843X1-RH SAFE	0.867				0.867
					AVERAGE :	0.798	0.910	0.811	0.842

Table 4.10-6. S&A Device Activity Times for 360T004 (STS-30R)--
28 Apr 1989 (aborted launch attempt)

Command	GMT	Response	GMT	Delta (sec)
LH Arm Command B55K3000X1	182402.214	LH Arm B55K1842X1	182402.979	0.765
RH Arm Command B55K4000X1	182402.374	LH Arm B55K2842X1	182403.419	1.045
LH Safe Command B55K3002X1	182940.613	LH Safe B55K1843X1	182941.579	0.966
RH Safe Command B55K4002X1	182940.853	LH Safe B55K2843X1	182941.820	0.967

4 May 1989 (at T - 5 min)

Rotation	LH	0.400 sec
	RH	0.600 sec
Command to Arm	LH	0.765 sec
	RH	1.245 sec

The weatherseal on the 360Q00A aft segment stiffener-to-stiffener joint was unbonded on the aft edge in 14 separate places. The largest unbond extended 35.0 in. circumferentially. Most of the unbonds extended axially to the pin retainer band, and all of the unbonded areas exhibited adhesive failure at the Chemlok® 205-to-case interface. The pin retainer band was also stretched and displaced, leaving the pins visible in several locations. The total unbond area covered approximately 31 percent of the circumference on the aft edge. One similar unbond was present on the 360Q004A aft segment stiffener-to-dome factory joint weatherseal. It was located at 278 deg and measured 3.75 in. circumferentially and extended axially to the pin retainer band.

Another unbond was found on the aft edge of the 360Q004A forward center factory joint weatherseal. It was located at 28 deg and measured 1.2 in. circumferentially and 0.40 in. axially. The unbonding occurred at splashdown and appears to be the result of a surface finish that was too smooth.

Moisture was found dripping from under the weatherseal on the 360Q004A forward center segment factory joint. The water appeared to have entered the weatherseal at the locations where insulation cure thermocouple wires were routed between the weatherseal and the case. The unbond described above was adjacent to the wires; however, the unbond was small and did not extend to the pin retainer band. The weatherseal was very well bonded in all other areas. This same condition was noted on multiple segments of the 360L002 flight set and one segment of the 360L003 flight set. The closeout of the wire exit locations has been changed to eliminate problems on future flights. No significant areas of missing EPDM insulation were noted on any factory joint weatherseal.

Stiffener Stubs and Rings. The insulation over the stiffener stubs and rings was in good condition. Normal heat effects and discoloration were evident on all surfaces, and there were no significant areas of missing material. The EPDM was well bonded to the stiffener stubs and appeared to be well bonded to the stiffener rings, as evidenced by the tap test of all exposed surfaces prior to and after hydrolazing. The only exceptions were on the 360Q004A motor, where the stiffener rings were buckled due to splashdown loads and the insulation was visibly unbonded. K5NA was present on the ends of the ring segments after removal, indicating that hydrolazing was less severe than on previous flights.

4.11.1.3 Case-to-Nozzle Joints. Based on the visual evaluation, both case-to-nozzle joints performed well. No gas paths through the polysulfide adhesive or any other anomalous conditions were identified. The polysulfide adhesive on the 360Q004A joint had only two measurable voids; both were aft of the insulation step. The largest void was 1.02 in. axially by 0.40 in. circumferentially. There were approximately 10 to 15 smaller (0.15 in. axial by 0.10 in. circumferential) voids on the 360H004B joint; all were aft of the insulation step. None of the voids on either joint received hot gas.

The 360Q004A and 360H004B polysulfide bondlines exhibited good cohesive failure of the polysulfide bondline upon disassembly (360Q004A--70 percent; 360H004B--85 percent). The average polysulfide vent slot fill was 68 percent on 360Q004A and 64 percent on 360H004B. These are within the expected range.

4.11.1.4 Field Joints. The internal insulation in all six of the case field joints performed as designed, and no anomalous conditions were identified. J-leg tip contact was evident over the full circumference at each joint. Wet soot deposits extending down the bondline were noted on all of the 360T004 field joints to a fairly uniform depth 0.3 to 0.4 in. into the bondline (outboard from the remaining material). Similar wet sooting was noted further into the bondline on the 360L001 forward field joints and extended to the radius region. Wet sooting was also noted on 360L002 and 360L003. This sooting is believed to occur at reentry or splashdown during joint flexing.

There were no clevis edge separations that were recordable (over 0.1 in.). This hardware was the first flight set yielding no edge separations upon disassembly at KSC. It is also the second flight set to incorporate grit blasting of the inner clevis leg. The process appears to have significantly improved the postfire edge separation condition. Some tang edge separations were visible on two field joints. These will be further evaluated when the segments reach the Clearfield H-7 facility.

Clevis insulation cracks and crazing were noted on the radius region insulation of both aft segments and both aft center segments. The noted conditions did not have any effect on the function of the joint. Cracks and crazing will be further evaluated when the segments reach the Clearfield H-7 facility.

4.11.1.5 Igniter-to-Case Joints. The condition of the igniter boss insulation was excellent. An evaluation of both 360Q004A and 360H004B insulation-to-case interfaces revealed no edge separations. The molded insulation surface was in good condition, and both joints exhibited normal erosion on the inboard surface. One blowhole through the putty on each igniter was present. No adverse effects on the performance of the joint resulted from either of the blowholes.

4.11.1.6 Internal Acreage Insulation. The acreage insulation, including the internal insulation over each of the factory joints, appeared in good condition during the preliminary evaluation. No evidence of hot gas penetration through the insulation or severe erosion was identified.

Aft Segments. The aft segment nitrile butadiene rubber (NBR) inhibitor stubs exhibited normal erosion over approximately half of the circumference, but there was an area of uneven erosion on each. These areas had a very short inhibitor stub with intermittent inhibitor pieces taller than adjacent areas. A similar condition was also noted on the 360L002 and 360L003 aft segments. There was one circumferential tear (3.20 in. long) and one radial tear (3.1 in. long) in the 360Q004A inhibitor. No charring or erosion was evident in the tear, indicating that the tear occurred after motor burn.

Center Segments. One inhibitor tear greater than 3 in. radially was noted in the 360H004B aft center segment inhibitor stub. Some radial tears were also noted in the forward center segment NBR inhibitor stubs (six on 360Q004A and five on 360H004B). The tears in the forward center segments ranged from 5.5 to 14.4 in. radially. The radial extent and frequency of the tears identified in the inhibitor stubs are within the range of tears noted on past flight motors. The edges of the tears demonstrated no material loss or erosion. This indicated that the tears occurred after motor burn.

Forward Segments. The stress relief flap was present over the full circumference on both forward segments but was heat affected and eroded. The castable inhibitors were completely missing over the full circumference. Some axial tears were identified on the remaining heat-affected flaps of both segments, similar to 360L001 and 360L003B forward segments, which had numerous flap tears. The edges of the tears demonstrated no material loss or erosion. This indicated that the tears occurred after motor burn. A final evaluation of the thermal performance of the insulation will be accomplished after the internal insulation thicknesses are measured at the Clearfield H-7 facility.

4.11.2 Case Component Performance

4.11.2.1 Summary. Evaluation of the steel case indicated the hardware performed as expected during flight. The 360H004B (RH) stiffener rings revealed no noticeable damage upon removal of the stiffener stubs during postflight assessment. However, all three 360Q004A (LH) motor stiffener stubs and segments experienced some outer ligament cracks and missing or broken bolts as a result of splashdown loads. Complete case evaluation results are in Volume II of this report.

4.11.2.2 Stiffener Stubs, Stiffener Rings, and ETA Stubs. The cavity collapse load was centered at approximately 260 deg for the LH motor. Cracks and bulges were observed in the K5NA and EPDM of all three LH stiffener rings prior to their removal. (Coincidentally, the previous damage overlapped with this flight's cavity collapse loading.) The cavity collapse load was centered at approximately 330 deg for the RH motor.

Stiffener Stubs. A total of eight stiffener stub outer ligament cracks were observed on the LH forward stiffener stub ring, four of which were identified during prefire inspections. These older LH forward stiffener stub outer ligament cracks are located at 174, 236, 238, and 342 deg. The LH center stiffener stub had three new outer ligament cracks at 238, 284, and 286 deg. The aft stiffener stub had one new outer ligament crack at 256 deg.

Stiffener Rings. The forward stiffener ring segments had a web crack at 256 deg and a total of 10 missing or broken bolts. The center stiffener ring had web buckles at 240, 246 and 285 deg, web cracks at 256 and 264 deg, and a total of 19 missing or broken bolts. A total of 20 bolts were missing or broken from the aft stiffener ring.

The RH stiffener rings revealed no noticeable damage upon removal from the stiffener stubs. The aft side of the RH forward stiffener ring experienced one K5NA hairline crack.

ETA Stubs. There was no apparent damage to the ET attach stubs on either motor.

4.11.2.3 Forward Dome Boss. Both igniter-to-case joint forward dome bosses appeared in good condition after igniter removal. No metal damage was apparent. Intermittent light corrosion was found on the forward dome boss inboard of the primary seal footprint 360 deg.

4.11.2.4 Field Joints. The case field joint surface conditions were as expected. There was intermittent minor corrosion on the unpainted surfaces of the outer clevis leg outside surface on all of the case field joints. The corrosion was much less severe than on previous flights. Debris from hydrolase operations was observed in most of the joints. Once again, fretting was observed on the interference surfaces of the field joints. Only those indications which could be felt with the fingernail test were reported as frets.

Fretting was found on all field joints except the LH aft joint. Overall, this flight exhibited fretting of a lesser magnitude than the last flight (360L003). The deepest pit measured was 0.007 inch. Figure 4.11-1 provides a subjective summary of the fretting.

4.11.2.5 Case-to-Nozzle Joint. The case-to-nozzle joint of both motors was in excellent condition. There were no signs of metal damage to any of the sealing surfaces or boltholes and no heat-affected metal, corrosion, or damaged bolts.

4.11.2.6 Aft Dome Boss. The case-to-nozzle joint aft dome boss metal of both motors was free of corrosion and damage. The axial and radial bolts were detorqued without incident. The ultrasonic bolt preload inspection revealed that most bolts remained within ±10 percent of preflight values. Radial bolts on the LH motor showed an average increase in preload of 10 percent, while axial bolts on the LH motor showed little or no change in preload values. Radial bolts on the RH motor showed an average increase in preload of 12 percent, while axial bolts on the RH motor showed a preload average decrease of 10 percent.

4.11.3 Seals Performance

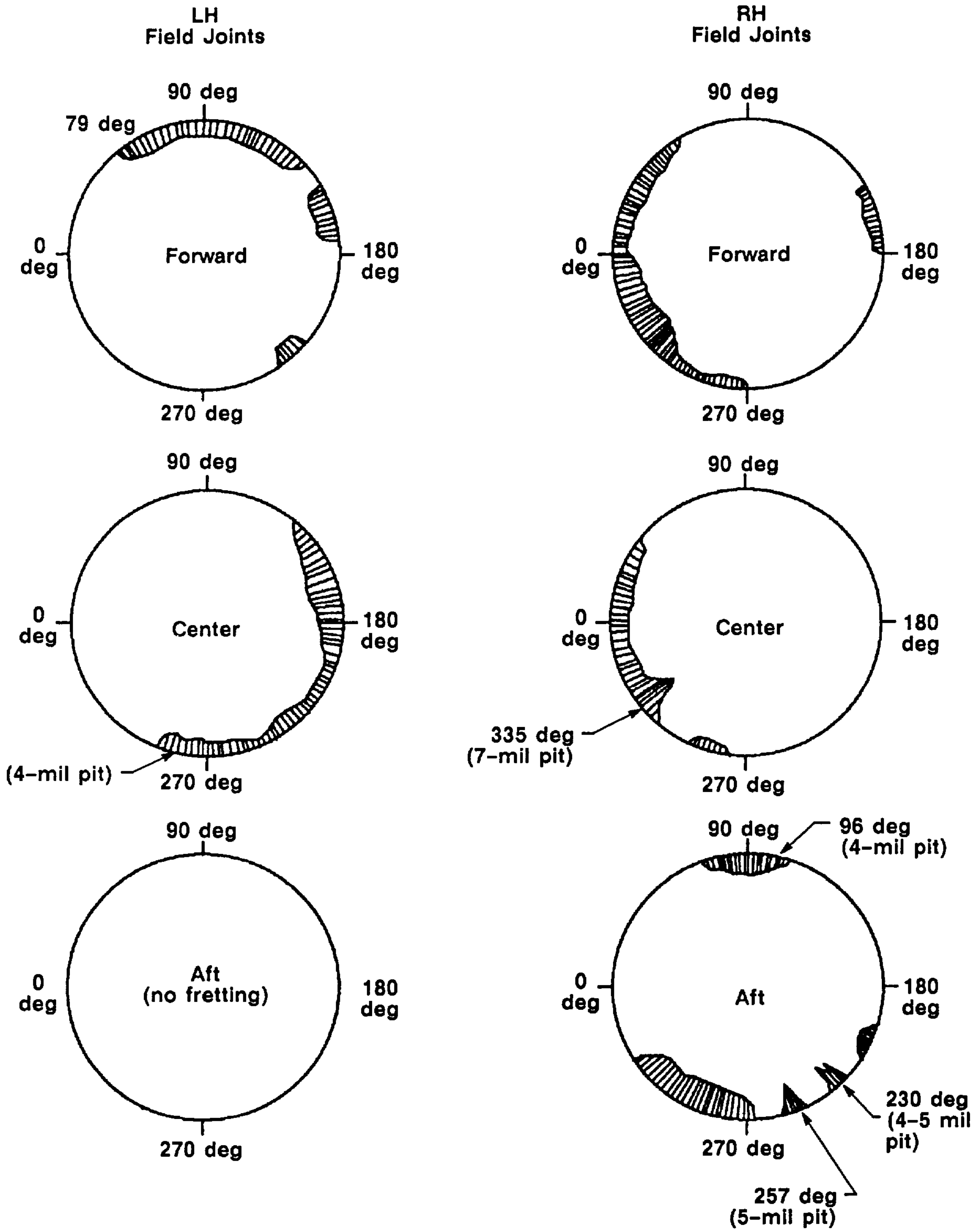
4.11.3.1 Summary. Evaluation of the field and factory joints indicated the internal seals performed as expected during flight. All internal seals clearly appeared to have performed well, with no hot gas leakage evident. A complete evaluation is in Volume IV of this report.

4.11.3.2 External Factory and Field Joints. There was no evidence of combustion product leakage from any joint.

4.11.3.3 Aft Exit Cone Field Joint. All aft exit cone field joint components on both motors were in good condition. The O-rings were free from erosion, heat effect, or any other damage and the sealing surfaces and O-ring glands were devoid of soot, debris, or damage. The grease condition was nominal. No RTV pressure paths or soot past the RTV were observed. Light, intermittent oxidation was observed on the forward face of the aft exit cones between the O-ring grooves. All other metal surfaces were in good condition.

4.11.3.4 Case Field Joints. Inspection of the field joint seals revealed no anomalous conditions. All motor pressure was contained by the insulation J-joint. No corrosion or damage was found on any of the O-ring sealing surfaces. The V_2 filler was also found to be in excellent condition. None of the vent ports were obstructed by the V_2 filler. The grease application appeared to be per design. Typical corrosion was noted on unpainted surfaces of the joints outside of the sealing areas; however, the corrosion was light and less severe than observed on the three previous RSRM flights.

4.11.3.5 OPT Special Bolt and Special Bolt Plug Seals. There was no evidence of gas leakage past the primary seals on any of the OPTs. The LH and RH primary seals saw pressure but there was



Note: Line length indicates relative severity of observed fretting

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Figure 4.11-1. Number and Location of Clevis Scratches (360T004)

no soot observed on them. Soot deposits were observed on the tips of the transducer threads. All of the seals performed nominally.

All four LH igniter special bolts experienced typical light soot up to the primary O-ring and on the ends of the special bolts. All four RH igniter special bolts experienced typical light soot up to the primary O-ring and on the ends of the special bolts. The igniter special bolt at 40 deg had medium corrosion on the end of the bolt and around through the hole. Special bolt primary seals were in excellent condition and performed as designed. Special bolt plug seals were also in excellent condition.

4.11.3.6 Ignition System Joint. The S&A and inner igniter gasket seals revealed no erosion, heat effect, debris, soot, or damage. The S&A primary gasket seals did see pressure. Soot was observed on both the forward and aft face of the RH gasket faces up to the primary seal. No soot was observed past the primary seal of either S&A gasket. Corrosion was observed inboard of the primary seals on both sides of each S&A gasket intermittently around the circumference. The putty in the adapter-to-igniter chamber joint was free of blowpaths on both motors; thus, there were no pressure paths or soot to the inner gasket primary seals.

The LH adapter-to-igniter outer gasket forward face sustained a cut on the secondary seal at 285 deg (also discussed in Section 4.1 as IFA STS-30-M-2). The cut was approximately 0.100 in. long by 0.010 in. wide by 0.030 in. deep and started at the center of the crown, extending radially inward. Corrosion due to hot gas impingement was found on the inner edge of the LH outer gasket at 225 deg. Intermittent light corrosion was observed on both forward dome bosses inboard of the primary seal footprints and medium corrosion was found on the interior bare surface of the forward dome boss intermittently over 360 deg. There was no soot to the primary seal of the LH gasket. Soot was observed to the aft face primary seal of the RH gasket but not past. The LH igniter inner joint Stat-O-Seals® experienced typical disassembly damage; however, a flow line was found on the 100-deg special bolt Stat-O-Seal®. (Flow line is a minor imperfection formed when the Stat-O-Seal® is compressed from bolt torquing. This anomaly was identified to occur only on a select lot of Stat-O-Seals®, which have all been replaced.)

The RH igniter inner joint Stat-O-Seals® experienced typical disassembly damage.

4.11.3.7 Case-to-Nozzle Joint. The overall joint condition was excellent on both motors. Motor pressure was halted at the polysulfide adhesive, leaving the fluorocarbon O-rings untouched. The RH nozzle wiper O-ring was cut in half at 210 deg. During disassembly the O-ring caught on the GSE jack screw.

4.11.3.8 Vent Port Plugs. The case field joint and case-to-nozzle joint vent port plugs and seals on both motors were in excellent condition. All but one LH vent port plug showed typical primary O-ring extrusion damage caused by assembly. The LH center joint secondary vent port plug O-ring experienced some assembly extrusion damage. This was caused by a discrepant port. The secondary seal surface was too shallow. The LH aft field joint vent port plug had some light hex marring. The vent port plug O-rings showed no evidence of heat effect, and the fluorocarbon O-rings, glands, and metal surfaces of the plugs were free of soot, debris, and corrosion.

All RH vent port plugs showed typical primary O-ring extrusion damage caused by assembly. The RH aft field joint vent port plug had some intermittent medium corrosion on the plug hex head. The vent port plug O-rings showed no evidence of heat effect. The fluorocarbon O-rings, glands, and metal surfaces of the plugs were free of soot, debris, and corrosion.

4.11.3.9 <u>Leak Check Port Plug</u>. The case field joint and case-to-nozzle joint leak check port plugs and seals on both motors were in good condition. None of the leak test plug O-rings showed any evidence of heat effect. The fluorocarbon O-rings, glands, and metal surfaces of the plugs were free of soot, debris, and corrosion. Both LH and RH igniter joint plug and plug holes were in excellent condition in the adapter-to-case and adapter-to-chamber joints.

4.11.4 <u>Nozzle Performance</u>

4.11.4.1 <u>Summary</u>. Postflight evaluation indicated both nozzles performed as expected during flight, with typical smooth and uniform erosion profiles. The 360Q004A (LH) nozzle experienced high impact loads due to improper chute deployment, which resulted in a snubbed nozzle (as discussed in IFA STS-30-M-3, Section 4.1). A complete evaluation is in Volume V of this report.

4.11.4.2 <u>360Q004A (LH) Nozzle</u>

<u>Splashdown Damage</u>. The LH nozzle experienced high impact loads due to improper parachute deployment. Examination of the nozzle showed that it was in a snubbed position. Most of the snubber assembly (both the snubber segments and the snubber support ring) was detached from the forward exit cone housing. At 248 deg, the snubber ring and segments were displaced forward approximately 10 in. (forward of the throat-to-forward exit cone internal nozzle joint). Portions of the snubber assembly were wedged against the bearing aft end ring. One snubber retainer was observed missing, and the sheared snubber retainer boltheads were observed intermittently around the circumference. Attempts were made to desnub the nozzle by placing radial loads on the aft exit cone assembly. Loads up to 8,000 lb were used unsuccessfully. The forward nozzle assembly was removed from the aft dome and shipped to the Clearfield facility with the nozzle in the snubbed position.

<u>Aft Exit Cone</u>. The 360Q004A aft exit cone was severed by the LSC during parachute descent. The radial cut through the glass-cloth phenolic (GCP) appeared nominal, with no anomalies observed. The entire carbon-cloth phenolic (CCP) liner was missing and portions of the GCP insulator were torn and delaminated. These are typical postflight observations, and occur during exit cone severance and at splashdown. The exposed GCP plies showed no signs of heat effect.

The 45-deg actuator bracket showed gouge marks on the inside diameter (ID) of one of the bushings. This occurred during actuator pin removal. The other bushing was removed from the bracket during actuator demate. Minor paint scratches were also observed. None of the screws appeared loose.

The 135-deg actuator bracket also showed gouges on the ID of both bushings due to actuator pin removal. Paint scrapes and minor metal gouges were observed along the center portion of the bracket. None of the screws appeared loose.

There were no separations observed between the polysulfide and the aft exit cone shell. Postflight measurements of the polysulfide groove radial width showed that the GCP insulator did not pull away from the aluminum shell during cooldown. The average postflight radial width of the polysulfide groove was 0.19 inch. The polysulfide appeared to shrink axially aft up to 0.05 inch. A layer of polysulfide (approximately 0.015 in. thick) was found lying loose on top of the polysulfide groove intermittently around the circumference. It was determined that these were standard repaired areas to which polysulfide was added after the initial groove fill. Portions of the repaired areas were still bonded to the base material.

<u>Forward Exit Cone Assembly</u>. The STS-30 LH forward exit cone CCP liner was intact and did not exhibit the typical missing CCP along the center portion. A postburn wedgeout of charred CCP was observed on the forward 0.7 in. from 225 to 280 deg. Other postburn wedgeouts and impact marks were observed intermittently along the length and on the aft 2 in. of the cone. Many delaminations along the CCP plies extended all the way to the GCP, but there were no indications of flow or heat effects. These delaminations are attributed to postburn cooldown liner shrinkage. Typical dimpled erosion was observed on the aft 12 in. and measured approximately 0.1 in. deep radially.

Bondline separations on the aft end between the CCP and GCP were observed from 180 to 300 deg (0.40 in. maximum radial width) and between the steel shell and the EA 913NA adhesive at 195 deg (0.03 in. radial width). These are typical observations which occur postburn.

The forward exit cone housing outside diameter (OD) impacted against the fixed housing/aft end ring screw heads from 217.5 to 303.75 deg at splashdown. Paint scraped off at these locations, but there was no apparent metal damage to the forward exit cone housing. Closer inspections will take place during nozzle internal joint demate at Clearfield.

<u>Throat Assembly</u>. Erosion of the 360Q004A throat and throat inlet rings was smooth and uniform, with no wedgeouts or popped-up, charred CCP material observed. Intermittent postburn impact marks were noted on the throat ring. Throat diameter measurements will be taken at Clearfield during internal joint disassembly operations.

Nose Inlet Assembly. The 360Q004A forward nose (-503) and aft inlet (-504) rings showed smooth erosion, with no pockets or wash areas observed. One postburn wedgeout was found on the forward 1.3 in. of the -504 ring at 355 deg and measured 5.3 in. circumferentially. Slag deposits were noted on the -503 ring and the forward tip of the nose cap from 90 to 210 deg.

The nose cap exhibited typical minor wash areas on the forward 12 in. (0.10 in. maximum radial depth). Postburn popped-up CCP was observed on the aft 2 in. intermittently around the circumference. Postburn wedgeouts on the aft 2 in. occurred from 6 to 32 deg and 126 to 205 deg, and measured 0.75 in. deep radially.

Cowl Ring. The 360Q004A cowl ring showed the typical erratic erosion seen on previous postburn RSRM cowl rings. The forward 6 in. of the ring eroded a maximum of 0.10 in. more than the aft end. There were no wedgeouts or popped-up CCP observed. All cowl ventholes were plugged with soot and slag.

Outer Boot Ring. The 360Q004A outer boot ring (OBR) showed smooth erosion, with no wedgeouts. Impact marks (most likely from loose debris inside the motor at splashdown) were noted intermittently on the aft end of the OBR. Typical delaminations into charred CCP were found on the aft tip. The aft tip adjacent to the flex boot was fractured and wedged-out intermittently around the circumference. The cowl/OBR bondline remained intact.

Fixed Housing Assembly. The 360Q004A fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing showed typical postburn radial depth of the wedgeouts was 0.5 inch. There were no bondline separations observed on the aft end of the fixed housing.

The fixed housing/aft end ring screw heads from 217.5 to 303.75 deg were flattened on the sides due to impact with the forward exit cone housing at splashdown.

The fixed housing aft flange showed no damage to the metal surfaces, boltholes, or O-ring grooves. No corrosion of the flange surface was observed.

Aft Exit Cone Field Joint. The RTV was below the joint char line and reached the primary O-ring 360 deg circumferentially. The primary O-ring did not see pressure. Light aluminum oxide corrosion was observed on the aft exit cone forward end between the primary and secondary O-ring grooves intermittently around the circumference, but no pitting was observed.

4.11.4.3 360H004B (RH) Nozzle

Splashdown Damage. The RH nozzle was in very good condition and did not exhibit any indications of abnormal splashdown loads.

Aft Exit Cone. The 360H004B aft exit cone was severed by the LSC during parachute descent. The radial cut through the GCP appeared nominal, with no anomalies observed. The aft 18 in. of the CCP liner was missing and portions of the GCP insulator were torn and delaminated. The exposed GCP plies showed no signs of heat effect. The forward 28 in. of the CCP liner was still intact and exhibited postburn wedgeouts typically 0.5 in. deep radially on most of its surface. The forward 1 to 2 in. also showed wedgeouts 360 deg circumferentially. These are typical postflight observations and occur during exit cone severance and at splashdown.

The aft exit cone forward end showed separations (0.09 in. maximum radial width) at the GCP/CCP interface from 24 to 65, 90 to 116, 174 to 199, and 240 to 335 deg. Minor metal disassembly damage was observed on the aft exit cone shell forward end 281-deg bolthole (0.01 in. raised metal), and on the OD surface centered at 109 deg (0.02 in. deep radially).

The 45-deg actuator bracket showed minor metal gouges and paint scrapes along the bottom center portion. There was no other damage to the bracket or bushings. None of the screws appeared loose.

The 135-deg actuator bracket also showed paint scrapes on the bottom center portion, but there was no metal damage to the bracket or bushings. None of the screws appeared loose.

There were no separations observed between the polysulfide and the aft exit cone shell. Postflight measurements of the polysulfide groove radial width showed the GCP insulator did not pull away from the aluminum shell during cooldown. The average postflight radial width of the polysulfide groove was 0.16 inch. The polysulfide appeared to shrink axially aft up to 0.06 in. No loose layers of polysulfide were observed in the groove.

Forward Exit Cone Assembly. The 360H004B forward exit cone CCP liner was intact and did not exhibit the typical missing CCP along the center portion. A postburn wedgeout of charred CCP was observed 10 in. aft of the forward end from 80 to 140 deg and measured 4 in. long axially and 1.5 in. deep radially. One other postburn wedgeout centered at 170 deg was located 1 in. forward of the aft end and measured 0.5 in. axially, 0.6 in. radially, and 8.5 in. circumferentially. Many delaminations along the CCP plies extended all the way to the GCP, but there was no indication of flow or heat effects. These delaminations are attributed to postburn cooldown liner shrinkage. Typical dimpled erosion was observed on the aft 15 in. and measured approximately 0.1 in. deep radially.

Bondline separations on the aft end were noted between the CCP and GCP at 345 deg (0.02 in. wide radially) and between the EA 913NA adhesive and GCP at 75 deg (0.02 in. wide radially). These are typical observations which occur postburn.

Throat Assembly. Erosion of the 360H004B throat and throat inlet rings was smooth and uniform, with no wedgeouts or popped-up, charred CCP material observed. Intermittent postburn impact marks were noted on the throat ring. The largest was at 180 deg and measured 1.8 in. circumferentially, 1.9 in. axially, and 0.1 in. radially. Throat diameter measurements will be taken at Clearfield during internal joint disassembly operations.

Nose Inlet Assembly. The 360H004B forward nose (-503) and aft inlet (-504) rings showed smooth erosion, with no pockets or wash areas, wedgeouts, or popped-up material observed. Intermittent small impact marks (postburn) were found intermittently on the -504 ring. These were typically 0.2 in. in diameter. Slag deposits were noted on the -503 ring and the forward tip of the nose cap from 90 to 0 to 290 deg.

The nose cap exhibited typical minor wash areas on the forward 12 in. (0.20 in. maximum radial depth). Postburn popped-up CCP was observed on the aft 2 in. intermittently around the circumference. Postburn wedgeouts on the aft 2 in. occurred from 62 to 93, 105 to 116, 138 to 176, and 273 to 322 deg, and measured 0.50 in. deep radially.

Cowl Ring. The 360H004B cowl ring showed the typical erratic erosion seen on previous postburn RSRM cowl rings, although not as pronounced in some areas. The forward 4 in. of the ring eroded a maximum of 0.10 in. more than the aft end. There were no wedgeouts or popped-up CCP observed. All cowl ventholes were plugged with soot and slag.

Outer Boot Ring. The 360H004B OBR showed smooth erosion, with no wedgeouts. Many delaminations of charred CCP along the 35-deg plies occurred on the flow surface. Typical delaminations into charred CCP were found on the aft tip. The aft tip adjacent to the flex boot was fractured and wedged out 360 deg circumferentially. The cowl/OBR bondline remained intact.

Fixed Housing Assembly. The 360H004B fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing showed typical postburn radial depth of the wedgeouts was 0.5 inch. There were no bondline separations observed on the aft end of the fixed housing. During case-to-nozzle demate, the GCP on both sides of the wiper O-ring groove was chipped at 209 and 336 deg. The wiper O-ring was also cut at these locations.

The fixed housing aft flange showed no damage to the metal surfaces, boltholes, or O-ring grooves. No corrosion of the flange surface was observed.

Aft Exit Cone Field Joint. The RTV was below the joint char line 360 deg circumferentially and reached the primary O-ring from 214 to 0 to 139 deg. There were no blow paths in the joint, and the primary O-ring did not see pressure. Light aluminum oxide corrosion was observed on the aft exit cone forward end between the primary and secondary O-ring grooves intermittently around the circumference. No pitting was observed.

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