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SPACE SHUTTLE

Solid Rocket Motors
Thiokol Corporation

Flight Motor Set 360L008 (STS-32R) Final Report

Volume I – System Overview

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Flight Motor Set
360L008 (STS-32R)
Final Report

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ABSTRACT

Flight motor set 360L008 was launched at approximately 6:35 a.m. CDT (090:009:12:35:00.017 GMT) on 9 Jan 1990 after a 24-hr weather delay due to inclement weather as part of NASA space shuttle mission STS-32R. The primary purposes of this mission were to launch a new Syncom satellite and to retrieve the Long Duration Exposure Facility, which was placed in orbit in 1984. As with all previous redesigned solid rocket motor launches, overall motor performance was excellent. There were no debris concerns from either motor.

All ballistic contract end item specification parameters were verified with the exceptions of ignition interval and rise rates. Ignition interval and rise rates could not be verified due to elimination of developmental flight instrumentation from fourth flight and subsequent, but the low sample rate data that were available showed nominal 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.

All field joint heaters and igniter joint heaters performed without anomalies. Redesigned field joint heaters and the redesigned left-hand igniter heater were used on this flight. The changes to the heaters were primarily to improve durability and reducing handling damage.

Evaluation of the ground environment instrumentation measurements again verified thermal model analysis data and showed agreement with predicted environmental effects. No launch commit criteria violations occurred.

Postflight inspection again verified superior performance of the insulation, phenolics, metal parts, and seals. Postflight evaluation indicated both nozzles performed as expected during flight. All combustion gas was contained by insulation in the field and case-to-nozzle joints.

Recommendations were made concerning improved thermal modeling and measurements. The rationale for these recommendations and complete result details are contained in this report.

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ACRONYMS AND ABBREVIATIONS

ADCAR	Automatic Data Collection and Retrieval
AT	action time
CCP	carbon-cloth phenolic
CDT	central daylight time
CEI	contract end item
cg	center or gravity
deg	degree
DFI	development flight instrumentation
DM	development motor
ECP	engineering change proposal
EDT	eastern daylight time
EPDM	ethylene-propylene-diene monomer
ET	external tank
ETM	evaluation test motor
FBMBT	flex bearing mean bulk temperature
FEC	field engineering change
FEWG	Flight Evaluation Working Group
FMEA	Failure Modes and Effects Analysis
FSEC	Florida Solar Energy Center
FTIR	Fourier transform infrared
GCP	glass-cloth phenolic
GEI	ground environmental instrumentation
GFE	government furnished equipment
GMT	Greenwich mean time
GN_2	gaseous nitrogen
GOX	gaseous oxygen
HOSC	Huntsville Operations Support Center
HPM	high-performance motor
hr	hour
ICD	interface control document
IFA	in-flight anomalies
in.	inch
IPR	interium problem report
ips	inches per second
IR	infrared
I_{sp}	specific impulse
IVBC-3	integrated vehicle baseline configuration
JPS	joint protection system
kn	knot
KSC	Kennedy Space Center
LAT	lot acceptance test
lb	pound
lbf	pounds force
lbm	pounds mass
LCC	launch commit criteria
LDEF	Long Duration Exposure Facility
LH	left-hand
LRU	line replaceable unit
LSC	linear shaped charge

ACRONYMS AND ABBREVIATIONS (cont)

Max Q	maximum dynamic pressure
MBT	mean bulk temperature
min	minute
MLP	mobile launch platform
MS	Military Standard
ms	millisecond
MSFC	Marshall Space Flight Center
MSID	measurement stimulation identification
NA	not applicable
NASA	National Aeronautics and Space Administration
NBR	nitrile butadiene rubber
NSTS	National Space and Transportation System
O_2	oxygen
OBR	outer boot ring
OFI	operational flight instrumentation
OMRSD	operations and maintenance requirement document
OPT	operational pressure transducer
P/N	part number
PEEP	postfire engineering evaluation plan
PMBT	propellant mean bulk temperature
PRCB	Program Requirements Control Board
psi	pounds per square inch
psia	pounds per square inch absolute
PVM	production verification motor
QM	qualification motor
RCN	revision change notice
RH	right-hand
RSRM	redesigned solid rocket motor
RSRML	lightweight redesigned solid rocket motor
RTD	resistance temperature detector
S/N	serial number
S&A	safe and arm
sec	second
SF	safety factor
SII	SRM ignition initiators
spm	sample per minute
sps	sample per second
SRB	solid rocket booster
SRM	solid rocket motor
SSME	space shuttle main engine
STI	shuttle thermal imager
STS	space transportation system
TEM	technical evaluation motor
TPS	thermal protection system
TPTA	transient pressure test article
TWR	Thiokol Wasatch report
USBI	United Space Boosters, Inc.
VAB	vehicle assembly building
°F	degree Fahrenheit

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INTRODUCTION

Solid rocket booster (SRB) ignition command for flight motor set 360L008 was given at 090:009:12:35:00.017 GMT (approximately 6:35 a.m. CDT) on 9 Jan 1990 at Kennedy Space Center (KSC), Florida. This flight was the 33rd space shuttle mission (mission designation STS-32R) and the eighth redesigned solid rocket motor (RSRM) flight. The individual motor identification numbers were 360L008A (left-hand (LH)) and 360L008B (right-hand (RH)), indicating the cases were both lightweights. 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-RPR-1580). 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. TWR-60064 is a flow report which starts from the receipt of 360L008 hardware at KSC, documenting aft booster buildup, RSRM stacking, including processing milestones and highlights, stacking configuration, significant DRs, PRs, etc.

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	Description/ Component	Interim Release	Final Release
I	Systems overview	NA	60 working days after launch
II	Case/seals	NA	60 days after washout of last segment at Clearfield, UT (H-7 facility)
III	Internal insulation	60 days after last joint demate at KSC	60 days after washout of last segment at H-7
IV	TPS/JPS/heaters/ systems tunnel	NA	60 days after hydrolase is complete at KSC
V	Nozzle	NA	60 days after nozzle phenolic sectioning is complete
VI	Igniter	NA	60 days after washout of last igniter chamber at H-7
VII	Performance/ mass properties	NA	60 days after launch

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OBJECTIVES

The eighth Thiokol RSRM flight objectives were intended to satisfy the requirements of CPW1-3600A as listed in parenthesis below. A one-to-one correlation of conclusions by objectives (and CEI paragraphs) is included in Section 3.2 of this report.

Qualification Objectives

A. The ignition interval shall be between 202 and 262 ms with a 40-ms environmental delay after ignition command to the solid rocket motor (SRM) ignition initiators (SII) in the safe and arm (S&A) device up to a point at which the headend chamber pressure has built up to 563.5 psia (3.2.1.1.1.1).

B. The maximum rate of pressure buildup shall be 115.9 psi for any 10 ms interval (3.2.1.1.1.2).

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

D. 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 II).

E. 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 the PMBT range of +40° to +90°F (3.2.1.1.2.3).

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

G. Certify that specified temperatures are maintained in the case-to-nozzle joint region during the countdown launch commit criteria (LCC) time period (3.2.1.2.1.f).

H. The case segment mating joints shall contain a pin retention device (3.2.1.3.g).

I. Certify the performance of the igniter heater so it maintains the igniter gasket rubber seals between 64° and 130°F (3.2.1.5.3).

J. Verify that the S&A devices perform as required using the specified power supply (3.2.1.6.1.2).

K. 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).

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

M. The ground environment instrumentation (GEI) shall monitor the temperature of the SRBs while on the ground at the pad. It is not required to function during flight. These instruments will be monitored on the ground through cables with lift-off breakaway connectors (3.2.1.6.2.3).

N. When exposed to the thermal environments of 3.2.7.2, the systems tunnel floor-plates and cables will be maintained at a temperature at or below that specified in ICD 3-44002 (3.2.1.10.1).

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

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

Q. Demonstrate isolation of subsystem anomalies if required on eighth flight (360L008) hardware (3.2.3.3).

R. Demonstrate the RSRM capability of vertical disassembly if required (3.2.5.1).

S. The RSRM and its components will be adequately protected, by passive means, against natural environments during transportation and handling (3.2.8.c).

T. Demonstrate the remove and replacement capability of the functional line replaceable unit (3.4.1).

Objectives by Inspection

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 operate 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 ignitions system seals operates within the specified temperature range (3.2.1.2.4.b).

J. Verify that the nozzle 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 flex bearing for damage due to water impact (3.2.1.4.6).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

AD. Inspect the hardware for damage or anomalies as identified by the failure mode and effects analysis (FMEAs) (3.2.3).

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

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

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

AH. Verify the structural SF of the case-to-insulation bond (3.3.6.1.1.2.a).

AI. 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).

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

AK. Verify the nozzle SF (3.3.6.1.2.8).

AL. 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

Two in-flight anomalies (IFA) relating to RSRM motor set 360L008 were identified and are summarized below.

MSFC IFA No.	Problem Title/Description	Corrective Action Closure
STS-32-M-1	Depression (low crown) found on secondary seal of the S&A gasket of 360L008B at 0 deg, aft face (0.050 in. circumferential by 0.026 in. radial and 0.0025 in. deep.	360L009 (STS-36) S&A gaskets for both motors were replaced with gaskets which were inspected to the proper criteria. To preclude the use of gaskets already accepted to old requirements, a new S&A gasket number was created for 360T010 (STS-31R) and subsequent.
STS-32-M-2	Bumps or blister were found in the void and cushion areas of 360L008B igniter inner gasket.	A new baseline has been implemented, controlling the molding process and adhesive application. The process requires mold bumping to reduce the possibility of trapping air. An improved venting process has also been added.

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3.1.2 Mass Properties

All SRM weight values were well within the CEI specification limits, as 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 VII of this report.

3.1.3 Propulsion Performance (Ballistics)

3.1.3.1 Propellant Burn Rates/Specific Impulse. The delivered burn rate (at 64°F and 625 psia) for flight motor set 360L008 was 0.371 ips for the LH motor (which matched the prediction) and 0.372 ips for the RH motor (0.001 ips higher than predicted). The reconstructed vacuum specific impulse values were 267.0 lbf*sec/lbm for the LH motor and 266.7 lbf*sec/lbm for the RH motor at 64°F, which were within 0.56 and 0.67 percent, respectively of the predicted value of 268.5 lbf*sec/lbm. The impulse values for the RH motor were the lowest experienced by a HPM/RSRM. It is believed that the low performance was actually due to pressure measurement system data loss.

3.1.3.2 CEI Specification Values. All impulse values, time parameters, and pressure 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 3σ variation. Thrust imbalance was also well within the specification limits for the required time periods.

Due to elimination of development flight instrumentation (DFI) on STS-30R (360T004) and subsequent, 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 prelaunch functional tests and the actual launch. The S&A device is discussed in Section 4.10.4.

3.1.5 Ascent Loads and Structural Dynamics

Due to elimination of DFI after STS-29R (360L003), 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 six redesigned field joint heaters performed adequately and as expected throughout the required operating periods. Prior to launch, a contingency field joint LCC redline was approved which reduced the LCC from 85° to 68°F as a precaution in the event that both primary and secondary heater failed on a given field joint. 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 ambient temperatures ranged from 51° to 81°F. The normal temperature range for the month of January is 55° to 67°F. Windspeeds were lower than the historical conditions. Wind direction was from the west during the LCC timeframe.

No extreme outward cooling effects from external tank (ET) cryogenic loading were noted.

3.1.7.2 Launch Commit Criteria/Infrared Readings. No LCC thermal violations were noted, but the igniter heaters were activated at L-18 hr instead of at L-24 hr as had occurred prior to this launch. The deactivation time was also changed with this launch, from T-4 hr to T-9 min. Had this change not occurred, given the cold temperatures prior to launch, an igniter joint temperature violation would have occurred with the igniter sensors predicted to read 62° to 63°F. All redesigned field and igniter joint heaters performed adequately, including the LH redesigned igniter joint heater. The SRB aft skirt purge operation was activated at approximately L-38 hr prior to the aborted launch on January 8. The SRB aft skirt purge, prior to the successful launch of January 9, was activated at L-14 hr and 20 min. The total operation time for the aft skirt purge system was 45.5 hr.

Infrared (IR) measurements taken by the IR gun during the T-3 hr ice/debris pad inspection were found to be inconsistent with GEI and shuttle thermal imager (STI) readings. Due to this inconsistency, which has been noted during previous countdowns the data were not used or recorded by the ice team. The STI temperature measurements were used along with GEI measurements to monitor SRM surface temperatures.

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

3.1.8 Instrumentation

All 108 GEI measurements performed properly throughout the prelaunch phase, with the exception of B06T7020A (a systems tunnel bondline temperature sensor which was damaged during the stacking operation). 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. However, a pressure measurement system data loss resulted in a low I_{sp}. 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. Two of the 14 weatherseals on this flight set exhibited unbonds. 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 recordable clevis edge separations (over 0.1 in.). No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns were identified. Complete insulation performance evaluation is in Section 4.11.1 of this volume and Volume III of this report.

3.1.9.2 Case. The case field joint surface conditions were as expected. Field joint fretting on this flight ranged from light to heavy. All joints had some fretting. The left center and aft field joints had the worst fretting (0.007 in. deep) and the right aft field joint had a 0.006-in.-deep fret. There were no new frets found in the old fret indications. All new fretting occurred in previously unfretted areas.

Complete case evaluation results are in Section 4.11.2 of this volume and Volume II of this report.

3.1.9.3 Seals. All internal seals performed well, with no heat effects, erosion, or hot gas leakage evident. No motor pressure reached the field or case-to-nozzle joint seals. Evaluation of the field joints indicated the internal seals performed as expected during flight. An impression was found on the crown of the secondary seal on the RH S&A gasket aft face at 0 deg. Approximate dimensions were 0.050 in. circumferential length by 0.0025 in. in depth. No contamination was observed on the seal surface adjacent to the impression. A complete evaluation of seals performance is in Section 4.11.3 of this volume and Volume II of this report.

3.1.9.4 Nozzle/Thrust Vector Control Performance. Postflight evaluation indicated both nozzles performed as expected during flight, with typical smooth and uniform erosion profiles. Complete evaluation 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 the 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).

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 (Table 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 percent Action time (AT) = 293.8 minimum	Certified. The nominal thrust-time curve values are listed below. Time (sec) — Value LH / RH 20 — 65.42 / 65.43 60 — 174.25 / 174.40 AT — 295.38 / 294.97 (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° to 115°F)	Certified. Temperature ranges in the case-to-nozzle joint region are listed below. RH 78° to 82°F LH 78° to 82°F (Table 4.8-2).
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. 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. DFI elimination (high sample rate pressure transducers).

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.	Partially Certified. Ignition transient is unavailable due to DFI elimination, but steady state transition and tailoff were within the imbalance limits (Table 4.4-2)
Certify the performance of the igniter heater so it maintains the igniter gasket rubber seals between 64° and 130°F.	3.2.1.5.3 The igniter heater shall maintain the igniter gasket rubber seals between 64° and 130°F.	Certified. The igniter heater maintained the igniter sensors between 89° and 95°F (RH) and 89° and 96°F (LH) during the prelaunch period. Sensor temperatures between 66° and 123°F ensure O-ring temperatures between 64° and 130°F (Table 4.8-2).
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 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 1050 ±/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 systems tunnel properly: 1) attaches to the case, 2) accommodates the government furnished equipment (GFE) and linear shaped charge (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 was also verified (the field joint heater sensor strip was slightly rotated circumferentially to increase the wire bend radii going to the strip and performed with no anomalies). Detailed systems tunnel evaluation is in Volume IV 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 130°F at launch...	Certified. The joint heaters maintained all field joint sensors between 93° and 108°F during the prelaunch period. Sensor temperatures between 85° and 122°F ensure O-ring temperatures of between 75° and 130°F (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 require-ments... as defined in ICD 3-44005.	Certified. The redesigned field joint external heaters met all the performance requirements (Section 4.8.3).

Demonstrate isolation of subsystem anomalies if required on eighth flight (360L008) 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 360L008.
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 position. 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 (VAB) prior to pad rollout. No vertical disassembly was required. Postflight horizontal disassembly was accomplished at Hangar AF (KSC) facilities.
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.	There were no anomalous readings from the transportation modular units, demonstrating that the RSRM and its components are protected against environments during transportation and handling.
Demonstrate remove and replace capability to the functional line replaceable unit (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.	Both igniter gaskets on motor set 360L008 were removed and replaced with gaskets that had been inspected to the proper criteria.

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 (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).
Certify that at least one virgin ply of insulation is 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 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 the natural and induced environments.	3.2.1.2.1.b Field and Nozzle-to-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. (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 Clearfield, UT (H-7 facility). Detailed results in Volume III of this report.
Verify by inspection 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 positive seal within its internal components. Detailed inspection to be completed during flex bearing acceptance testing.
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 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 pin retention device on all 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 to the 360L008A or 360L008B flex bearing.

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 shutdown was required during the actual launch sequence.
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: 1) Pockets greater than 0.250 in. deep (as measured from the adjacent nonpocketed areas), 2) wedgeouts greater than 0.250 in. deep, and 3) 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.	All ignition system seals, gaskets, and sealing surfaces showed no evidence of heat effects, erosion, or blowby (Section 4.11.3).
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. 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 polysulfide 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 and Volume III of this report).
Inspect the TPS to ensure that there was no environmental damage to the RSRM components.	3.2.1.8.2 TPS shall ensure 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 lack of insulation functionality (igniter details 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 360L008B (RH) or 360L008A (LH). Reuse criteria is not established until after refurbishment (detailed case component inspection results 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 are determined not to be reusable are discussed in Volume V of this report.

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. No apparent anomalies were observed with the 360L008A (LH) or 360L008B (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... S&A 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 is established after refurbishment and calibration by the metrology lab.
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. Two of the 14 factory joint weatherseals showed signs of unbonds. Detailed weatherseal evaluation is in Volume III of this report.
Inspect the hardware for damage or anomalies as identified by the FMEAs.	3.2.3 The design shall minimize the probability of failure taking into consideration the potential failure modes identified and defined by FMEA.	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 SF, 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 SFs, relief provisions, fracture control, and safe life and/or fail safe characteristics.	Postflight inspections verified adequate design SFs, 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.
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 is provided, and are maintained in the Automatic Data Collection and Retrieval (ADCAR) computer system. The past history of all RSRM parts used is in Section 4.2.
Verify the structural SF of the case-to-insulation bond.	3.3.6.1.1.2.a The structural SF for the case-to-insulation bonds shall be 2.0 minimum during the life of the RSRM.	Verification of a 2.0 SF cannot be done by inspection. Flight performance verified a SF of at least 1. Case-to-insulation bond and adhesive bond SF of 2.0 are verified by analysis and 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 SF of 1.5, assuming normal motor operation, and 1.2, assuming loss of a castable inhibitor.	Preliminary insulation thickness measurements indicate adequate thermal SFs near the igniter boss. A final evaluation will be made after the internal insulation thicknesses are measured at the Clearfield H-7 facility. Results and verification of SFs are in Volume III of this report.

Verify by inspection the remaining insulation thickness of the case insulation.	3.3.6.1.2.3 Case insulation adjacent to metal part field joints, case-to-nozzle joints, and extending over factory joints shall have a minimum SF of 2.0.	Preliminary insulation thickness measurements indicate adequate thermal SFs near the igniter boss. A final evaluation will be made after the internal insulation thicknesses are measured at the Clearfield H-7 facility. Results and verification of SFs are in Volume III of this report.
Verify by inspection the remaining insulation thickness of the case insulation.	3.3.6.1.2.4 Case insulation in sandwich construction regions (aft dome and center segment aft end) shall have a minimum SF of 1.5.	Preliminary insulation thickness measurements indicate adequate thermal SFs near the igniter boss. A final evaluation will be made after the internal insulation thicknesses are measured at the Clearfield H-7 facility. Results and verification of SFs are in Volume III of this report.
Verify by inspection the remaining insulation thickness of the case insulation.	3.3.6.1.2.6 Insulation performance shall be calculated using actual premotor and postmotor operation insulation thickness measurements.	Standard measurement techniques were used for final evaluation, as discussed in Volume III of this report.
Verify by inspection the remaining nozzle ablative thicknesses.	3.3.6.1.2.7 The minimum design SF for the nozzle assembly primary ablative materials shall be as listed below... (Values not included here, as detailed results are not available at this writing.)	Preliminary inspections indicate nozzle ablative thicknesses were within design SF (Section 4.11.4). Detailed results are in Volume V of this report.
Verify the nozzle SF.	3.3.6.1.2.8 The nozzle performance margins of safety shall be zero or greater...	Verification of SFs cannot be done by inspection. Nozzle margins of safety will be 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.	Inspection of metal parts for the presence of stress corrosion cannot be done visually but will be accomplished during refurbishment. Any stress corrosion found will be reported in Volume II of this report.

3.3 RECOMMENDATIONS

The following is a summary of the recommendations made concerning flight set 360L008. Additional background information can be found in the referenced sections.

3.3.1 Aero/thermal Recommendations

(Additional information in Section 4.8.4)

3.3.1.1 GEI Accuracy. Gage range has been reduced on all joint heater sensors resulting in better data resolution. It is recommended that the data collection accuracy of all GEI be increased by reducing the gage range and increasing the digital word length. The real fidelity of the KSC ground support equipment could then be quantified and conceivably replaced if determined to be inadequate.

3.3.1.2 IR Measurements. STI data continues 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. Future efforts should be made in specifying locations for additional stationary STI cameras to assist in the eventual replacement of the outboard GEI (inboard GEI will need to be maintained since the STI cannot reach these blind regions.

3.3.2 Handling Ring/Field Joint Fretting

A problem has been observed in almost all RSRM flight sets following shipment to KSC. Fretted surfaces on the field joint tang outer diameter of the center and forward segments have occurred. The degradation which occurs to the hardware justifies immediate attention. Various approaches are being investigated at this time to eliminate metal-to-metal contact between the handling rings and tang outer diameter. A test is currently underway to investigate grease additives in addition to special coatings that will eliminate fretting. It is recommended that implementation occur as soon as the proper resolution is determined.

4

FLIGHT EVALUATION RESULTS AND DISCUSSION

4.1 RSRM IFAs (FEWG Report Paragraph 2.1.2)

Two IFAs pertaining to flight set 360L008 were identified. The summary sheets follow. The IFA description, discussion, conclusion, corrective actions, and closeout signature of the Level II Program Requirements Control Board (PRCB) chairman are included. No IFA was considered to be a flight constraint, but the STS-32-M-1 IFA resulted in the inspection and changeout of the gaskets on 360L009 (STS-36).

4.2 RSRM CONFIGURATION SUMMARY (FEWG Report Paragraph 2.1.3.2)

4.2.1 SRM Reuse Hardware

The case segment reuse history for Flight Motors 360L008A and 360L008B are in Figures 4.2-1 and 4.2-2, respectively. Figures 4.2-3 through 4.2-6 show the left and right igniter and nozzle part reuse, respectively. Nozzle snubber segments were new. Stiffener ring reuse is in Figures 4.2-7 through 4.2-10.

4.2.2 Approved RSRM Changes and Hardware Changeouts

A summary of the changes made since 360L007 (STS-33R) follows. Complete descriptions of these changes are documented in Thiokol document TWR-50167 (Redesigned Solid Rocket Motor Flight Readiness Review - Level III)

Five Class I Hardware Changes for 360L007 (STS-33R):

a. Igniter and field joint heater redesign (ECP SRM-2034) done to prevent a recurrence of STS-29R joint heater anomaly
b. Add MS connector as an alternate to NB connector for all heater power cables (ECP SRM-2065) use of MS connectors is desirable since procurement of NB connectors in a timely fashion has been difficult
c. Increase slot length of the systems tunnel splice plate assembly (ECP SRM-2090R1) this change will reduce processing time by eliminating/reducing the

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Component	S/N	Previous Use	360L008 Total Pressurizations	Inventory Leader Total Pressurizations
Forward Dome P/N 1U51473-03	S/N 0000044	TPTA Pathfinder	3	13
Cylinder P/N 1U50131-13	S/N 0000019R5	DM-3, QM-3, SRM-5A, SRM-14B, SRM-24A	17	17
Capture Cylinder, Standard Weight P/N 1U52983-02	S/N 0000003R1	RSRM-1A	5	7
Cylinder, Lightweight P/N 1U50717-05	S/N 0000004R2	SRM-6A, SRM-16A	6	13
Capture Cylinder, Lightweight P/N 1U52982-03	S/N 0000026R1	PVM-1	5	7
Cylinder, Lightweight P/N 1U50717-05	S/N 0000034R2	SRM-8B, SRM-18	6	13
Capture Cylinder, Lightweight P/N 1U52982-03	S/N 0000046	New	3	7
Attach, Lightweight P/N 1U50716-08	S/N 0000037	New	3	20
Stiffener, Lightweight P/N 1U50715-06	S/N 0000055	New	3	11
Stiffener, Lightweight P/N 1U50715-06	S/N 0000057	New	3	11
Aft Dome P/N 1U50129-11	S/N 0000045R1	RSRM-1A	6	18

Denotes inventory leader status

Conclusion: P/N 1U50131-13, S/N 0000019R5 is an inventory leader. There is no fretted hardware on this motor

Figure 4.2-1. Hardware Reuse Summary—LH (A) Case

A026036a

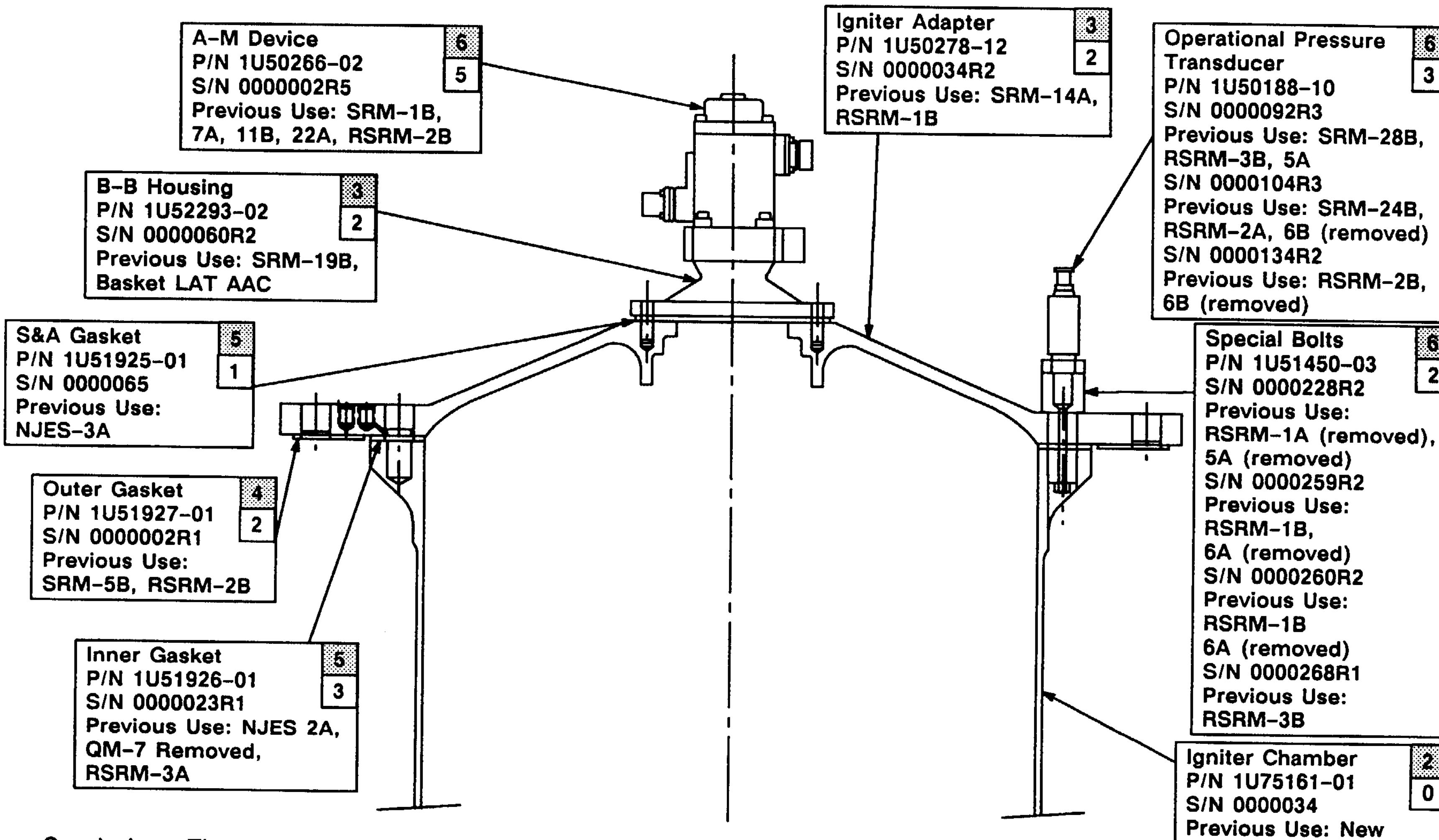
Component	S/N	Fretting	Previous Use	360L008 Total Pressurizations	Inventory Leader Total Pressurizations
Forward Dome P/N 1U51473-03	S/N 0000041R1		RSRM-1B	5	13
Cylinder P/N 1U50131-13	S/N 0000078R4		SRM-2A, SRM-9B, SRM-22B, RSRM-1A	11	17
Capture Cylinder, Standard Weight P/N 1U52983-02	S/N 0000004R1	fretting	RSRM-1B	7	7
Cylinder, Lightweight P/N 1U50717-05	S/N 0000051R3	fretting	SRM-10A, SRM-20A, RSRM-1B	8	13
Capture Cylinder, Lightweight P/N 1U52982-03	S/N 0000021R1	fretting	RSRM-1A	5	7
Cylinder, Lightweight P/N 1U50717-05	S/N 0000054R3		SRM-12A, SRM-23A, PVM-1	8	13
Capture Cylinder, Lightweight P/N 1U52982-03	S/N 0000016R1		PVM-1	5	7
Attach, Lightweight P/N 1U50716-08	S/N 0000040		New	3	20
Stiffener, Lightweight P/N 1U50715-06	S/N 0000061		New	3	11
Stiffener, Lightweight P/N 1U50715-06	S/N 0000058		New	3	11
Aft Dome P/N 1U50129-11	S/N 0000030R2		SRM-20A, TEM-1	5	18

▒ Denotes inventory leader status

Conclusion: P/N 1U52983-02, S/N 0000004R1 is an inventory leader.
Fretting has occurred where indicated all fretting has been repaired

Figure 4.2-2. Hardware Reuse Summary—RH (B) Case

A026037a

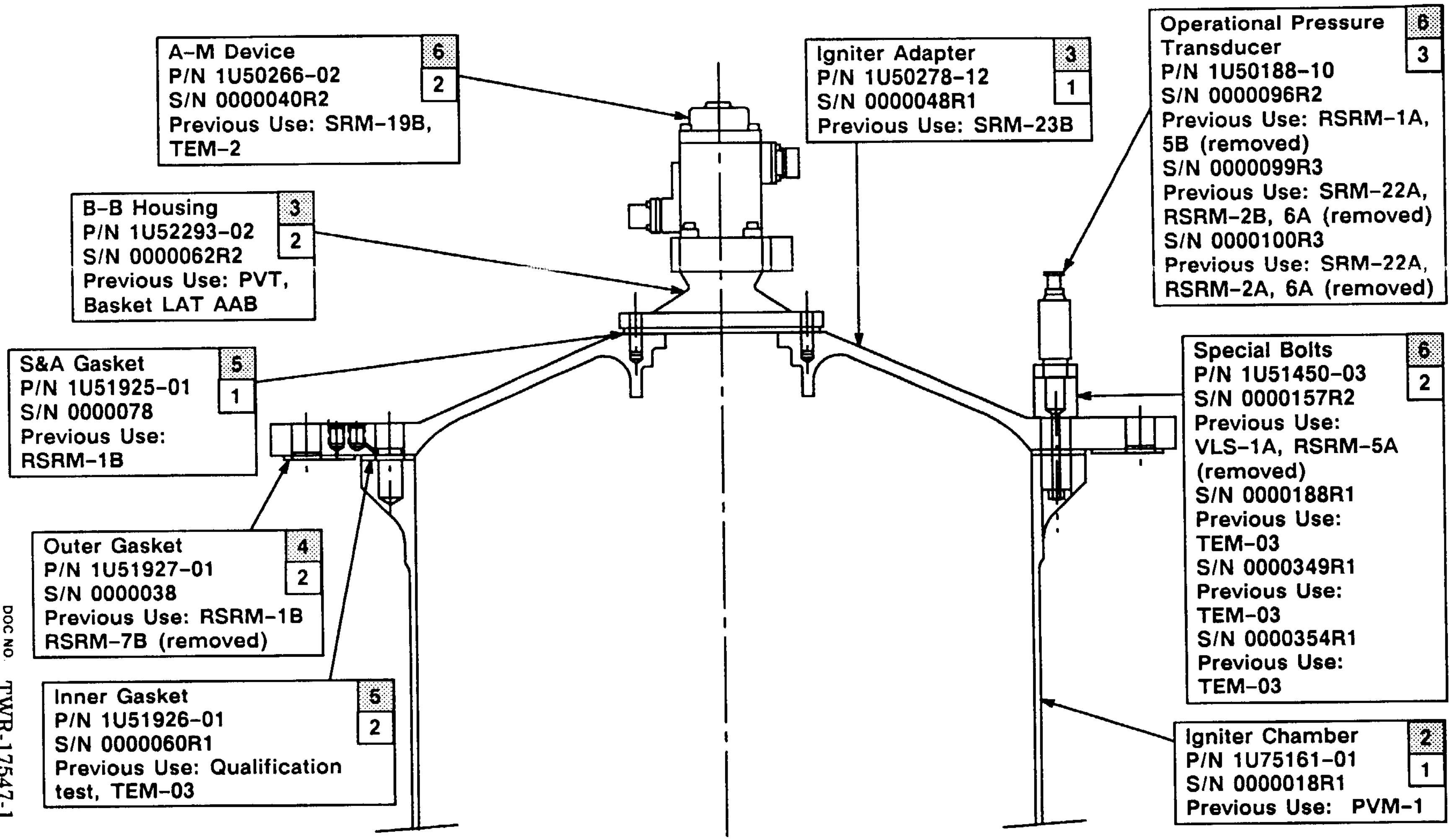


Conclusion: There are no inventory leader components in this assembly

☐ Previous uses ▩ Denotes inventory leader status

Figure 4.2-3. Hardware Reuse Summary—LH (A) Igniter

A026040a



Conclusion: There are no inventory leader components in this assembly

☐ Previous uses ▒ Denotes inventory leader status

Figure 4.2-4. Hardware Reuse Summary—RH (B) Igniter

A026099a

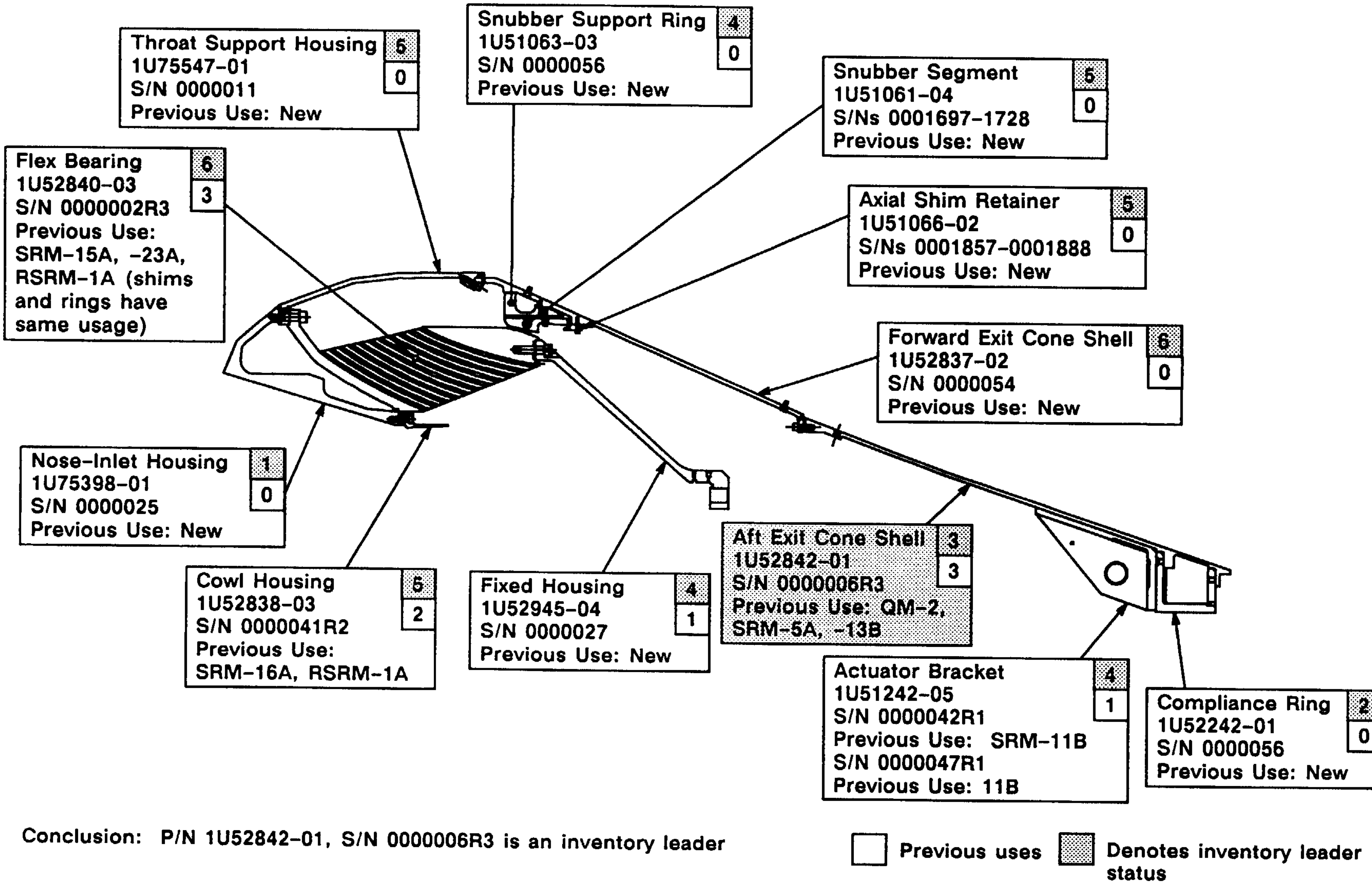
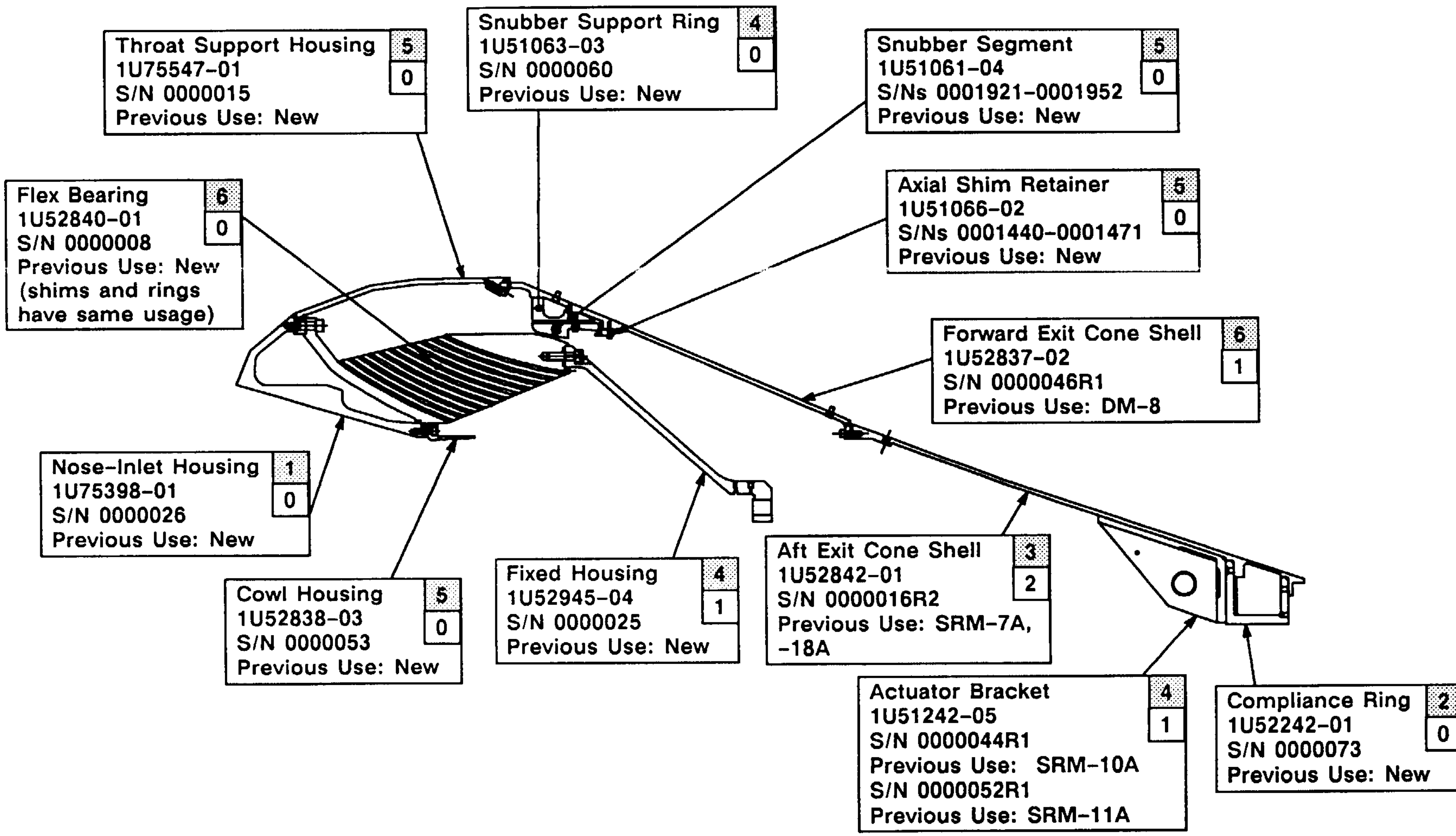


Figure 4.2-5. Hardware Reuse Summary—LH (A) Nozzle

A026038a



Conclusion: There are no inventory leader components in this assembly

☐ Previous uses ▨ Denotes inventory leader status

Figure 4.2-6. Hardware Reuse Summary—RH (B) Nozzle

A026039a

Plate (3 / 0)
1U52505-02
S/N 0000173
Previous Use: New
S/N 0000174
Previous Use: New
S/N 0000175
Previous Use: New
S/N 0000176
Previous Use: New
S/N 0000177
Previous Use: New
S/N 0000178
Previous Use: New

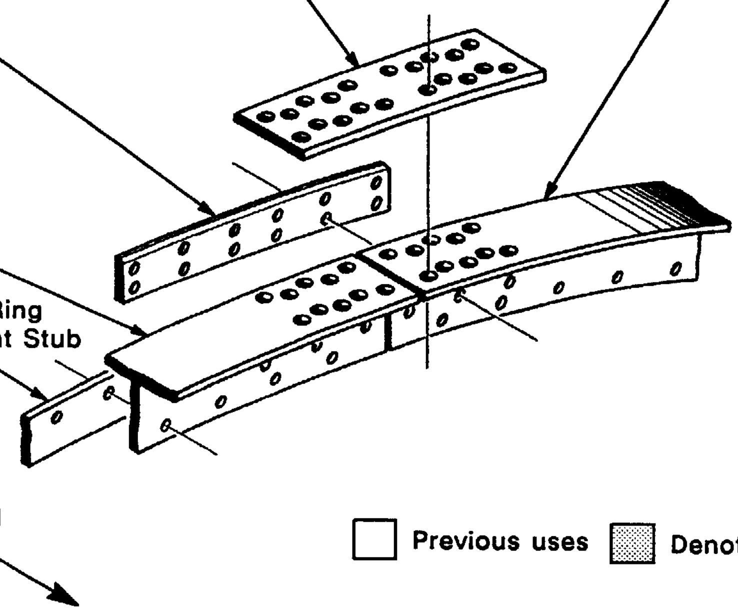
Splice Plate (3 / 2)
1U52503-04
S/N 0000014R2 Previous Use: SRM-15, -23
S/N 0000107R1 Previous Use: SRM-24
S/N 0000108R1 Previous Use: SRM-24
S/N 0000176 Previous Use: New
S/N 0000177 Previous Use: New
S/N 0000179 Previous Use: New

Tee Section (4 / 3)
1U52502-07
S/N 0000012R3
Previous Use: SRM-15, -24, RSRM-2
S/N 0000051R2
Previous Use: SRM-18, RSRM-2
S/N 0000062R1
Previous Use: RSRM-3

Tee Section (3 / 3)
1U52502-01
S/N 0000006R3
Previous Use: SRM-11, -16, -24

1U52502-04 (4 / 2)
S/N 0000056R2
Previous Use: SRM-22, RSRM-2
S/N 0000095R1
Previous Use: RSRM-2

1U52502-08 (3 / 3)
S/N 0000007R3
Previous Use: SRM-14, -24, RSRM-1
S/N 0000043R2
Previous Use: SRM-20, RSRM-2
S/N 0000048R2
Previous Use: SRM-20, RSRM-2



☐ Previous uses ▒ Denotes inventory leader status

Conclusion: There are two inventory leader components in this assembly

Figure 4.2-7. Hardware Reuse Summary—LH (A) Stiffener Rings at Normal Joints

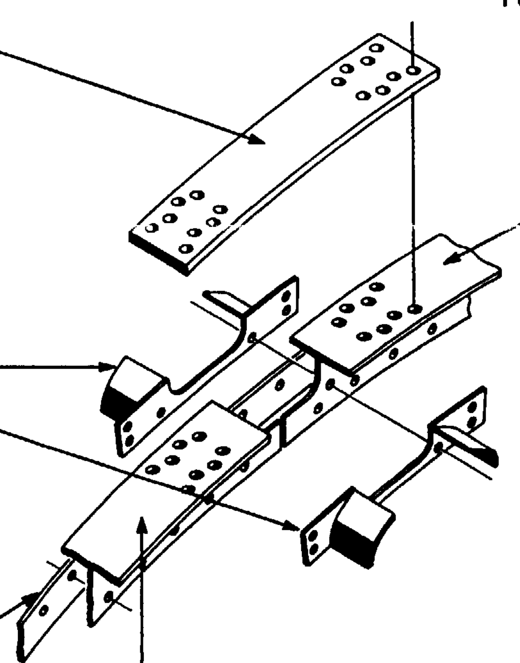
A026100a

Splice Plate
1U52503-05
S/N 0000006R1
Previous Use: RSRM-1
S/N 0000046
Previous Use: New
S/N 0000047
Previous Use: New

2 | 1

Adapter Plate
1U52504-05
S/N 0000085R2
Previous Use: SRM-18, RSRM-1
S/N 0000091R2
Previous Use: SRM-19, RSRM-1
S/N 0000092R2
Previous Use: SRM-19, RSRM-1
S/N 0000095R2
Previous Use: SRM-20, RSRM-1
S/N 0000096R2
Previous Use: SRM-20, RSRM-1
S/N 0000097R2
Previous Use: SRM-20, RSRM-1

4 | 2



Previous uses
Denotes inventory leader status

Conclusion: There are no inventory leader components in this assembly

Figure 4.2-8. Hardware Reuse Summary—LH (A) Stiffener Rings at Systems Tunnel Joint

A026101a

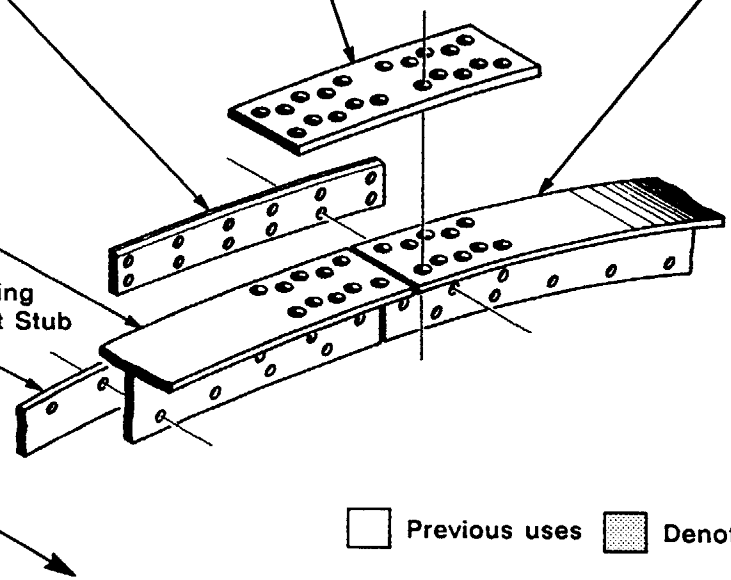
Plate
1U52505-02 — [3] [0]
S/N 0000157
Previous Use: New
S/N 0000158
Previous Use: New
S/N 0000159
Previous Use: New
S/N 0000160
Previous Use: New
S/N 0000171
Previous Use: New
S/N 0000172
Previous Use: New

Splice Plate
1U52503-04 — [3] [2]
S/N 0000013R2 Previous Use: SRM-15, -23
S/N 0000109R1 Previous Use: SRM-24
S/N 0000110R1 Previous Use: SRM-24
S/N 0000117R1 Previous Use: SRM-24
S/N 0000118R1 Previous Use: SRM-24
S/N 0000178 Previous Use: New

Tee Section
1U52502-07 — [4] [3]
S/N 0000013R3
Previous Use: SRM-16, -24, RSRM-2
S/N 0000014R3
Previous Use: SRM-16, -24, RSRM-2
S/N 0000072
Previous Use: New

Tee Section
1U52502-04 — [4] [2]
S/N 0000047R1
Previous Use: SRM-18
S/N 0000049R2
Previous Use: SRM-19, RSRM-1
S/N 0000064R1
Previous Use: RSRM-1

1U52502-08 — [3] [2]
S/N 0000047R2
Previous Use: SRM-20, RSRM-2
S/N 0000055R2
Previous Use: SRM-22, RSRM-2
S/N 0000065R1
Previous Use: SRM-22



☐ Previous uses ▨ Denotes inventory leader status

Conclusion: There are no inventory leader components in this assembly

Figure 4.2-9. Hardware Reuse Summary—RH (B) Stiffener Rings at Normal Joints

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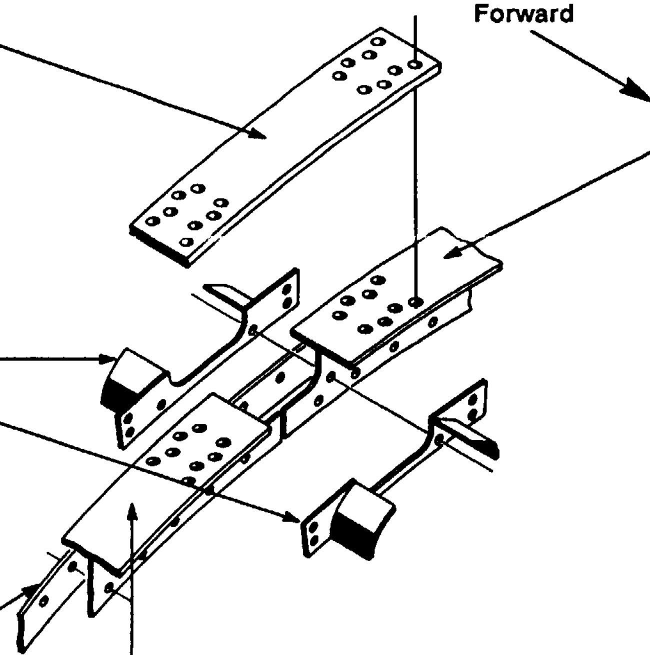

Conclusion: There are no inventory leader components in this assembly

Figure 4.2-10. Hardware Reuse Summary—RH (B) Stiffener Rings at Systems Tunnel Joint

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need to file out the attach slot due to tolerance buildup at the forward bridge splice plate (interface of systems tunnel and forward skirt/SRM)

d. Extend heater cable cork runs an additional 13 in. (cork previously installed at KSC) (ECP SRM-2130) to reduce KSC processing time and provide additional free cable length for mating operations

e. Reduce wire band radii going to the field joint temperature sensor assembly (ECP SRM-2268 FEC RSRM-078) to reduce the possibility of cracks in the wire insulation by increasing bend radii

4.2.3 LCC Changes

ECP 2180--Add note to igniter joint temperature LCC which indicates heater operation from L-18 hr to T-9 min. This is an editorial change only. Add note concerning heater operation to igniter LCC. There is a similar note already in the field joint LCC. This note is added for information only. Heater operation is controlled by operations and maintenance requirement document (OMRSD) and was revised (RCN MS9226).

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 360L008 (STS-32R) LH and RH reconstructed sequential mass properties, respectively. Those mass properties sequential times reported after separation reflect delta times from actual separation.

4.3.2 Predicted Data Versus Postflight Reconstructed Data

Table 4.3-3 compares the LH lightweight redesigned solid rocket motor (RSRML) predicted sequential weight and center of gravity (cg) data with the postflight reconstructed data. Table 4.3-4 compares the RH predicted sequential weight and cg data with the postflight reconstructed data. Actual 360L008 (STS-32) mass properties may be obtained from Mass Properties History Log Space Shuttle 360L008-LH (TWR-17348 dated 12 Sep 1989), and 360L007-RH (TWR-17349 dated 12 Sep 1989). Some of the mass properties data used has been taken from average actual data presented in the 5 Sep 1989 Mass Properties Quarterly Status Report (TWR-10211-92). Postflight reconstructed data reflects ballistics mass flow data from the 12.5 sps measured pressure traces and a predicted slag weight of 2,000 lb.

Table 4.3-1. 360L008-LH Sequential Mass Properties

Events/Times	Weight (lb)	cg Longitude	cg Latitude	cg Vertical	Moment of Inertia Pitch	Moment of Inertia Roll	Moment of Inertia Yaw
Prelaunch Time = 0.00	1,255,255.0	1,171.465	0.059	0.006	42,390.650	878.884	42,391.527
Lift-Off Time = 0.23	1,254,558.5	1,171.597	0.059	0.006	42,347.272	877.564	42,348.149
Intermediate Burn Time = 20.00	1,010,907.2	1,208.748	0.074	0.008	30,569.865	759.230	30,570.740
Intermediate Burn Time = 40.00	788,905.2	1,231.814	0.094	0.010	21,553.935	623.960	21,554.804
Max Q Time = 54.00	658,125.8	1,229.153	0.112	0.012	17,873.544	546.247	17,874.407
Intermediate Burn Time = 60.00	602,607.3	1,226.485	0.122	0.013	16,442.589	508.458	16,443.446
Intermediate Burn Time = 80.00	408,123.4	1,214.590	0.178	0.019	11,726.656	372.757	11,727.503
Max Q Time = 87.00	343,479.6	1,214.297	0.210	0.022	10,346.227	321.470	10,347.069
Intermediate Burn Time = 100.00	237,573.6	1,229.258	0.302	0.032	8,354.986	231.670	8,355.821
Web Burn Time = 109.00	174,507.4	1,265.737	0.409	0.043	7,279.736	173.642	7,280.563
End of Action Time Time = 121.88	143,736.7	1,315.663	0.495	0.053	6,549.454	146.012	6,550.277
Separation Time = 125.75	143,120.2	1,317.293	0.498	0.053	6,519.472	145.561	6,520.298
Max Re-entry Q Time = 320.75	142,776.8	1,317.140	0.499	0.052	6,502.093	145.255	6,502.919
Nose Cap Deployment Time = 350.75	142,724.6	1,317.121	0.499	0.052	6,499.328	145.209	6,500.155
Drogue Chute Deployment Time = 351.35	142,723.5	1,317.121	0.499	0.052	6,499.273	145.208	6,500.100
Frustum Release Time = 372.45	142,686.8	1,317.108	0.499	0.052	6,497.316	145.175	6,498.143
Main Chute Line Stretch Time = 373.75	142,684.5	1,317.107	0.499	0.052	6,497.196	145.173	6,498.023
Main Chute First Disreefing Time = 383.85	142,666.9	1,317.101	0.499	0.052	6,496.255	145.158	6,497.082
Main Chute Second Disreefing Time = 389.75	142,656.6	1,317.098	0.499	0.052	6,495.704	145.149	6,496.531
Nozzle Jettisoned Time = 390.45	140,429.6	1,306.881	0.497	0.052	6,296.283	140.565	6,297.090
Splashdown Time = 415.75	140,384.2	1,306.851	0.497	0.052	6,293.713	140.524	6,294.520

Table 4.3-2. 360L008-RH Sequential Mass Properties

Events/Times	Weight (lb)	cg Longitude	cg Latitude	cg Vertical	Moment of Inertia Pitch	Moment of Inertia Roll	Moment of Inertia Yaw
Prelaunch Time = 0.00	1,255,486.8	1,171.304	0.059	0.006	42,402.173	879.197	42,403.050
Lift-Off Time = 0.23	1,254,790.8	1,171.435	0.059	0.006	42,358.867	877.877	42,359.744
Intermediate Burn Time = 20.00	1,010,764.2	1,208.628	0.074	0.008	30,563.644	759.341	30,564.519
Intermediate Burn Time = 40.00	787,910.3	1,231.692	0.094	0.010	21,523.338	623.523	21,524.206
Max Q Time = 54.00	656,832.9	1,228.957	0.112	0.012	17,843.284	545.621	17,844.146
Intermediate Burn Time = 60.00	601,345.8	1,226.259	0.122	0.013	16,410.964	507.536	16,411.822
Intermediate Burn Time = 80.00	407,272.6	1,214.417	0.178	0.019	11,710.001	372.225	11,710.848
Max Q Time = 87.00	343,234.3	1,214.164	0.211	0.022	10,344.370	321.393	10,345.213
Intermediate Burn Time = 100.00	238,092.2	1,228.944	0.301	0.032	8,367.466	323.241	8,368.300
Web Burn Time = 110.01	171,757.7	1,268.349	0.416	0.044	7,232.700	171.172	7,233.528
End of Action Time Time = 121.46	144,059.0	1,314.948	0.494	0.053	6,562.178	146.401	6,563.001
Separation Time = 125.75	143,396.1	1,316.675	0.497	0.053	6,531.009	145.906	6,531.835
Max Re-entry Q Time = 320.75	143,056.5	1,316.531	0.497	0.052	6,513.513	145.605	6,514.340
Nose Cap Deployment Time = 350.75	143,004.2	1,316.512	0.498	0.052	6,510.748	145.559	6,511.574
Drogue Chute Deployment Time = 351.35	143,003.2	1,316.512	0.498	0.052	6,510.692	145.558	6,511.519
Frustum Release Time = 372.45	142,966.4	1,316.499	0.498	0.052	6,508.734	145.526	6,509.561
Main Chute Line Stretch Time = 373.75	142,964.2	1,316.498	0.498	0.052	6,508.614	145.524	6,509.441
Main Chute First Disreefing Time = 383.85	142,946.6	1,316.492	0.498	0.052	6,507.673	145.508	6,508.500
Main Chute Second Disreefing Time = 389.75	142,936.3	1,316.488	0.498	0.052	6,507.122	145.499	6,507.949
Nozzle Jettisoned Time = 390.45	140,707.1	1,306.261	0.497	0.052	6,306.809	140.913	6,307.615
Splashdown Time = 415.75	140,663.9	1,306.242	0.497	0.052	6,304.449	140.875	6,305.256

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Table 4.3-3. Sequential Mass Properties Predicted/Actual Comparisons 360L008-LH

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	1,255,255	1,255,255	0	0.00	1,171.465	1,171.465	0.000	0.00
Lift-Off	1,254,620	1,254,559	-61	0.00	1,171.591	1,171.597	+0.006	0.00
Action Time	144,040	143,737	-303	0.21	1,314.788	1,315.663	+0.875	0.07
Separation**	143,307	143,120	-187	0.13	1,316.772	1,317.293	+0.521	0.04
Nose Cap Deployment	142,725	142,725	0	0.00	1,317.129	1.317.121	-0.008	0.00
Drogue Chute Deployment	142,724	142,724	0	0.00	1,317.128	1,317.121	-0.007	0.00
Main Chute Line Stretch	142,685	142,685	0	0.00	1,317.115	1,317.107	-0.008	0.00
Main Chute First Disreefing	142,667	142,667	0	0.00	1,317.109	1,317.101	-0.008	0.00
Main Chute Second Disreefing	142,657	142,657	0	0.00	1,317.105	1,317.098	-0.007	0.00
Nozzle Jettison	140,427	140,430	+3	0.00	1,306.871	1,306.881	+0.010	0.00
Splashdown	140,384	140,384	0	0.00	1,306.851	1,306.851	0.000	0.00

*Based on Mass Properties History Log Space Shuttle 360L008-LH, 12 Sep 1989 (TWR-17348)
**The separation longitudinal cg of 1,317.293 is 66% of the vehicle length

Table 4.3-4. Sequential Mass Properties Predicted/Actual Comparisons 360L008-RH

Event	Weight (lb) Predicted*	Actual	Delta	Error (%)	Longitudinal cg (in.) Predicted*	Actual	Delta	Error (%)
Preignition	1,255,487	1,255,487	0	0.00	1,171.304	1,171.304	0.000	0.00
Lift-Off	1,254,852	1,254,791	-61	0.00	1,171.430	1,171.435	+0.005	0.00
Action Time	144,320	144,059	-261	0.18	1,314.180	1,314.948	+0.768	0.06
Separation**	143,587	143,396	-191	0.13	1,316.158	1,316.675	+0.517	0.04
Nose Cap Deployment	143,004	143,004	0	0.00	1,316.511	1,316.512	+0.001	0.00
Drogue Chute Deployment	143,003	143,003	0	0.00	1,316.511	1,316.512	+0.001	0.00
Main Chute Line Stretch	142,964	142,964	0	0.00	1,316.497	1,316.498	+0.001	0.00
Main Chute First Disreefing	142,947	142,947	0	0.00	1,316.491	1,316.492	+0.001	0.00
Main Chute Second Disreefing	142,936	142,936	0	0.00	1,316.487	1,316.488	+0.001	0.00
Nozzle Jettison	140,707	140,707	0	0.00	1,306.262	1,306.261	-0.001	0.00
Splashdown	140,664	140,664	0	0.00	1,306.242	1,306.242	0.000	0.00

*Based on Mass Properties History Log Space Shuttle 360L008-RH, 12 Sep 1989 (TWR-17349)
**The separation longitudinal cg of 1,316.675 is 66% of the vehicle length

4.3.3 CEI Specification Requirements

Tables 4.3-5 and 4.3-6 presents CEI specification requirements, predicted, and actual weight comparisons. Mass properties data for both RSRMs complies with the CEI specification requirements (CPW1-3600A, Addendum G, Part I).

4.4 RSRM PROPULSION PERFORMANCE (FEWG Report Paragraph 2.3.0)

4.4.1 HPM-RSRM Performance Comparisons

The reconstructed thrust-time traces of flight motor set 360L008 (STS-32R) at standard conditions were averaged with the HPM/RSRM population and compared to the CEI specification limits. The results are shown in Figure 4.4-1.

4.4.2 SRM Propulsion Performance Comparisons

The reconstructed RSRM propulsion performance is compared to the predicted performance in Table 4.4-1. The impulse values for the RH motor were the lowest experienced by a HPM/RSRM. It is believed that the low performance was actually due to pressure measurement system data loss. 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 NSIs in the S&A device. The ignition interval ends when the head end chamber pressure has increased to a value of 563.5 psia. The maximum rate of head end chamber pressure build up during the ignition transient is required to be less than 115.9 psia for any 10 ms interval. No high sample rate ignition data was 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 the SRM headend chamber pressure has decayed to 59.4 psia to the time corresponding to 85,000 lb of thrust.

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. The thrust values used for the assessment were reconstructed at the delivered conditions of each SRM.

Table 4.3-5. Predicted/Actual Weight (lb) Comparisons 360L008-LH

Item	Minimum	Maximum	Predicted*	Actual	Delta	Error (%)	Notes
Inerts							
Prefire, Controlled		151,076	149,003	149,003	0	0.00	**
Propellant	1,104,714		1,106,252	1,106,252	0	0.00	**
Usable			1,105,393	1,105,680	+287	0.03	***
To lift-off			535	596	+61	10.23	
Lift-off to action			1,104,858	1,105,084	+226	0.02	***
Unusable			859	572	-287	50.17	
Action to separation			669	551	-118	21.42	
After separation			190	21	-169	804.76	
Slag			2,000	2,000	0	0.00	***

*Based on 12 Sep 1989, Mass Properties History Log Space Shuttle 360L008-LH (TWR-17348)
**Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI specification)
***Slag included in usable propellant, lift-off to action

Table 4.3-6. Predicted/Actual Weight (lb) Comparisons 360L008-RH

Item	Minimum	Maximum	Predicted*	Actual	Delta	Error (%)	Notes
Inerts							
Prefire, Controlled		151,076	149,274	149,274	0	0.00	**
Propellant	1,104,714		1,106,213	1,106,213	0	0.00	**
Usable			1,105,355	1,105,599	+244	0.02	***
To lift-off			535	595	+60	10.08	
Lift-off to action			1,104,820	1,105,004	+184	0.02	***
Unusable			858	614	-244	39.74	
Action to separation			668	596	-72	12.08	
After separation			190	18	-172	955.56	
Slag			2,000	2,000	0	0.00	***

*Based on 12 Sep 1989, Mass Properties History Log Space Shuttle 360L008-RH (TWR-17349)
**Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI specification)
***Slag included in usable propellant, lift-off to action

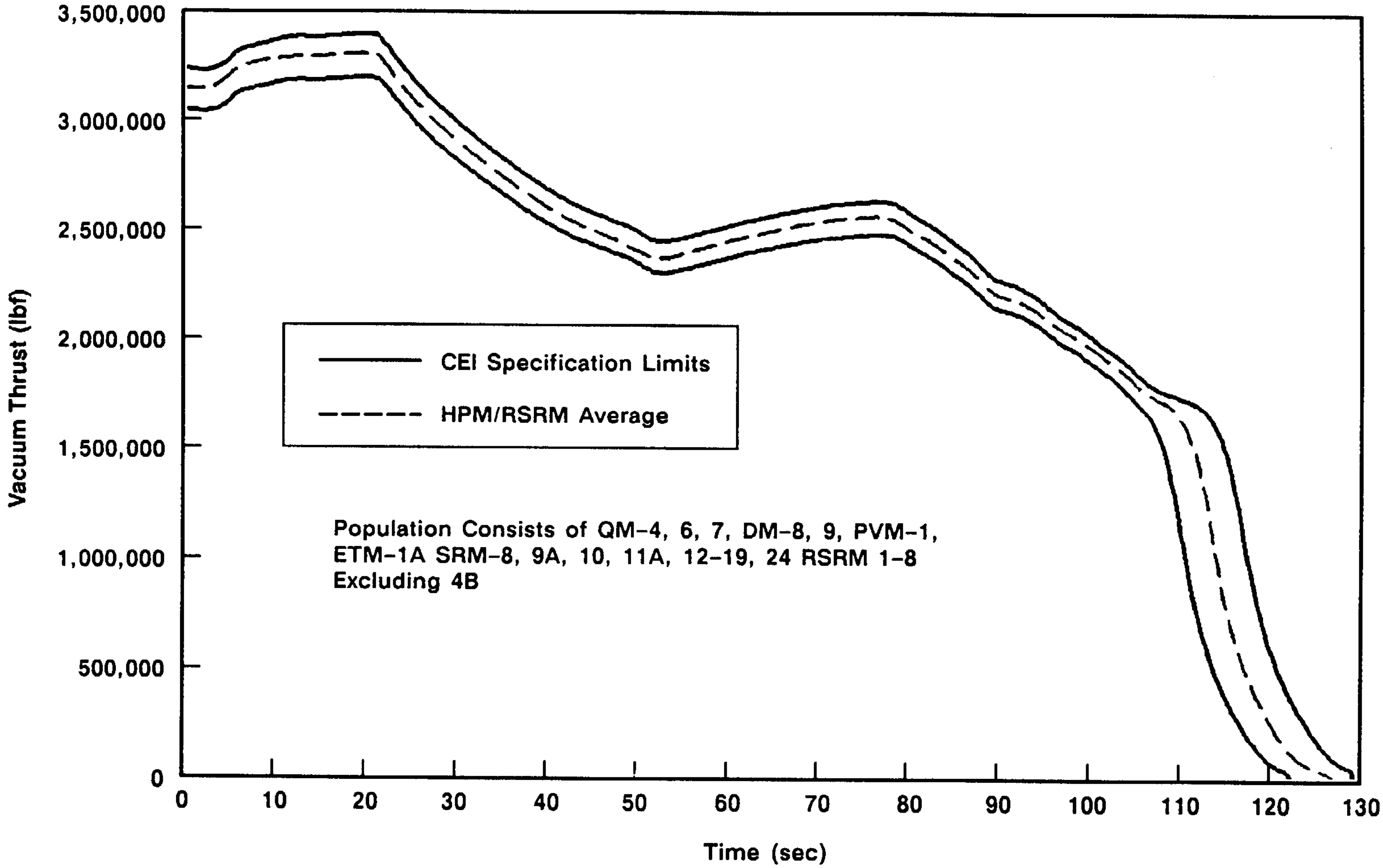

Figure 4.4-1. HPM/RSRM Average Thrust Versus CEI Specification Limits

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Table 4.4-1. RSRM Propulsion Performance Assessment

Impulse Gates	Left Motor 64 deg Predicted	Left Motor 64 deg Actual	Right Motor 64 deg Predicted	Right Motor 64 deg Actual
I-20 (10^6 lbf-sec)	66.0	65.42	65.96	65.43
I-60 (10^6 lbf-sec)	175.84	174.25	175.73	174.40
I-AT (10^6 lbf-sec)	296.98	295.38	296.97	294.97
Vacuum I_{sp} (lbf*sec/lbm)	268.5	267.0	268.5	266.7
Burn Rate (ips)	0.372	0.371	0.372	0.372
Event Times (sec)*				
Ignition Interval	0.232	NA	0.232	NA
Web Time*	109.1	109.2	109.2	109.8
Time of 50 psi Cue	118.7	119.9	118.8	119.9
AT	120.8	121.6	120.9	121.2
Separation Command (sec)	123.6	124.8	123.7	124.8
PMBT (°F)	65.0	64.0	65.0	64.0
Maximum Ignition Rise Rate (psia/10 ms)	91.9	NA	91.9	NA
Decay Time (sec) (59.4 psia to 85 k)	2.8	2.5	2.8	2.6

Tailoff Imbalance	Predicted	Actual
Impulse Differential (klbf-sec)	NA	+799

Note: Impulse imbalance = Left SRM - Right SRM
*All times are referenced to ignition command time except where noted by an *. These times are referenced to lift-off time (ignition interval)

Table 4.4-2. SRM Thrust Imbalance Assessment

Event	Imbalance Specification (klbf)	Maximum Imbalance (klbf)	Time of Maximum Imbalance (sec)
Steady State (1.0 sec to first web time -4.5 sec, lbf, 4 sec average)	85	+34.4	100.5
Transition (first web time -4.5 sec to first web time, lbf)	85 to 268 Linear	-59.2	109.3
Tailoff (first web time to last AT)	710	-127.8	112.4

Thrust imbalance = Left SRM - Right SRM

4.4.4 Performance Tolerances

A comparison of the left and right SRM calculated and reconstructed parameters at PMBT of 60°F with respect to the nominal values and the SRM CEI Specification maximum 3-σ requirements is given in Table 4.4-3.

4.4.5 Igniter Performance

Due to the elimination of DFI on 360T004 (STS-30R) and subsequent, no evaluation of the igniter performance is possible. Also, no evaluation of the ignition interval, pressure rise rate, and ignition thrust imbalance requirements was possible.

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

No RSRM nozzle torque calculations for motor set 360L008 was possible due to DFI elimination on 360T004 (STS-30R) and subsequent. This section is reserved pending the availability of DFI on future flights. The nozzle char and erosion performance is discussed in Section 4.11.4 of this volume, and Volume V of this report.

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

Motor set 360L008 did not have any DFI installed to evaluate the SRM structural performance. This section is reserved pending any future SRMs that incorporate DFI.

4.7 RSRM STRUCTURAL DYNAMICS (FEWG Report Paragraph 2.6.2)

No accelerometer data was available due to the elimination of DFI on 360T004 (STS-30R) and subsequent. This section is reserved pending the installation of accelerometers on future flight SRMs.

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 360L008 (STS-32R) SRM external components and TPS determined by postflight hardware inspection. Assessments of debris, mean bulk temperature (MBT) predictions, on-pad ambient/local induced environments, LCC, and GEI/joint heater sensor data are also included.

Table 4.4-3. SRM Performance Comparisons

Parameter	SRM CEI (+/-) Max 3-σ Variable (%)	Nominal Value *	Left RSRM 360L008A (60°F)	Left RSRM 360L008A Variable (%)**	Right RSRM 360L008B (60°F)	Right RSRM 360L008B Variable (%)**
Web Time (sec)	5.0	111.7	109.6	-1.88	110.2	-1.34
Action Time (sec)	6.5	123.4	122.1	-1.05	121.7	-1.38
Web Time Average Pressure (psia)	5.3	660.8	668.9	+1.23	666.0	+0.79
Max Head End Pressure (psia)	6.5	918.4	920	+0.17	920	+0.17
Max Sea Level Thrust (mlbf)	6.2	3.06	3.09	+0.98	3.10	+1.31
Web Time Average Vacuum Thrust (mlbf)	5.3	2.59	2.62	+1.16	2.61	+0.77
Vacuum Delivered I_{sp} (lbf*sec/lbm)	0.7	267.1	267.0	-0.04	266.6	-0.19
Web Time Vacuum Total Impulse (mlbf*sec)	1.0	288.9	287.1	-0.62	287.4	-0.52
Action Time Vacuum Total Impulse (mlbf*sec)	1.0	296.3	295.1	-0.04	294.7	-0.54

*QM-4 static test and SRM-8A and B, SRM-9A, SRM-10A and B, SRM-11A, SRM-13A and B flight average at standard conditions

**Variation = ((RSRM-8A - nominal)/nominal) * 100
((RSRM-8B - nominal)/nominal) * 100

Performance of SRM internal components (insulation, case components, seals and nozzles) is reported in Paragraph 4.11.

4.8.2 Summary

4.8.2.1 Postflight Hardware Inspection. Postflight inspection of the TPS revealed no anomalies or unexpected problems due to flight heating environments. The condition of both SRMs were similar to that of previous flight sets. Table 4.8-1 provides an overall summary of SRM TPS condition. Nozzle erosion is discussed in Section 4.11.4.

4.8.2.2 Debris Assessment. No SRM violations of NSTS debris criteria were noted. All missing TPS cork pieces (generally small) are due to nozzle severance debris and/or splashdown loads and debris. During ascent film review of previous flights, indications suggest that there were debris particles coming out of the SRM nozzle prior to and following separation. The Debris team is questioning the likelihood of these being chunks of propellant and/or insulation. A complete SRM debris assessment is given in Section 4.8.3.2.

4.8.2.3 MBT Predictions. These temperature predictions were made at different times during the countdown. A discussion of these predictions is presented in Section 4.8.3.3. The final postflight predictions from reconstructed data yielded a PMBT of 64°F and a flex bearing mean bulk temperature (FBMBT) of 78°F.

4.8.2.4 On-Pad Environment Evaluations. The ambient temperature recorded during a 112 hr period prior to launch varied from 51° to 81°F. The normal temperature range experienced during the month of January is from a low of 55° to a high of 67°F. The 51°F temperature, which occurred prior to launch, is within the -1-σ temperature range of the historical January ambient. The wind speeds during this same timeframe were lower than historical conditions. Table 4.8-2 shows the environmental conditions prior to launch.

4.8.2.5 LCC. No LCC thermal violations were noted. Measured GEI and heater sensor data, as compared with the LCC requirements, are discussed in Section 4.8.3.5. Highlights of the heating operations are summarized as follows.

The igniter heaters were activated at L-18 hr and deactivated at T-9 min during both countdown procedures. The redesigned igniter heater was used on the LH SRM

Table 4.8-1. STS-32R SRM External Performance Summary
(left and right SRMs)

Component	TPS Material	Performance	Recovered Hardware Performance Assessment
Field Joints	Cork	Typical	All joint protection system (JPS) in excellent condition; slight paint blistering, pitting on aft edge of JPS K5NA closeout (largest of JPS K5NA/extruded cork missing was 2.25 in.^{3} due to severance debris impact); all K5NA repairs intact over trunnion/vent valve 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; forward edge unbonds on two weather seals with no evidence of sooting, indicating that the separation occurred at or after splashdown
Systems Tunnel JPS Heater Cable	Cork/K5NA	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; insta-foam ramps chunked out on all rings of both motors from 100 to 35 deg due to water impact; insta-foam compressed on LH center stiffeners; cracks observed in the K5NA of several stiffeners: crack through EPDM on RH center stiffener ring
GEI Closeout	Cork/K5NA	Typical	Very good condition, with slight paint blistering; a few small cork pieces missing on GEI cable runs--All within established NSTS debris criteria and all caused by nozzle severance and/or splashdown loads and debris
Aft Kickring Joint	Cork	Typical	Good condition from thermal perspective; shielded from joint radiation by kickring; several small cracks in K5NA bead on aft skirt kick ring - caused by splashdown loads
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

Table 4.8-2. STS-32R Actual GEI Countdown and Historically Predicted On-Pad January Temperatures (°F) (LCC timeframe temperatures also included)

	Daily Cycling		T-6 hr to T-5 min		
Component	January Historical	Actual GEI	January Historical	Actual GEI	LCC
Igniter Joint					
RH	61 to 67	63 to 68	90 to 100	89 to 95	66 to 123
LH	61 to 67	65 to 70	90 to 100	89 to 96	66 to 123
Field Joint					
RH Forward	56 to 71	65 to 76	97 to 102	93 to 104	85 to 122*
LH Forward	56 to 70	65 to 78	93 to 103	94 to 103	85 to 122
RH Center	56 to 71	67 to 76	96 to 103	94 to 108	85 to 122
LH Center	56 to 70	65 to 76	97 to 103	96 to 106	85 to 122
RH Aft	56 to 71	67 to 76	97 to 103	93 to 104	85 to 122
LH Aft	56 to 70	65 to 75	94 to 102	94 to 104	85 to 122
Case-to-Nozzle Joint					
RH	58 to 65	65 to 68	67 to 68	78 to 82	75 to 115
LH	58 to 66	66 to 69	67 to 68	78 to 82	75 to 115
Flex Bearing Aft End Ring					
RH	58 to 65	62 to 64	67 to 68	78 to 80	NA to 115
LH	58 to 66	63 to 64	67 to 68	78 to 82	NA to 115
Case Acreage (deg)					
RH 45	56 to 66	54 to 74	56 to 58	54 to 64	--
135	57 to 68	54 to 80	57 to 61	54 to 64	--
215	57 to 71	54 to 77	57 to 59	54 to 66	--
270	57 to 68	54 to 70	57 to 59	54 to 67	35 to NA
325	57 to 68	53 to 72	57 to 58	53 to 66	--
LH 45	57 to 70	51 to 73	57 to 59	51 to 66	--
135	57 to 66	51 to 73	57 to 59	51 to 64	--
215	57 to 66	54 to 73	57 to 59	54 to 66	--
270	57 to 67	53 to 72	57 to 61	53 to 66	35 to NA
325	57 to 70	53 to 72	57 to 62	51 to 66	--
Local Environment					
Temperature	55 to 67	51 to 81	55 to 59	51 to 59	38 to 99
Wind speed (kn)	12	3 to 20	12	3 to 12	24
Wind direction	N	S to W	North	West	SW to SE
Cloud cover	Clear to Cloudy			Clear	

*Field joint sensor lower limit will drop from 85° to 68°F in the case of a complete heater failure and performed with no anomalies occurring. The igniter heater operation maintained temperatures between 90° and 95°F during the LCC timeframe.

The six field joint heaters performed as expected. All field joint heaters operated on their primary circuits and maintained temperatures between 93° and 108°F. The redesigned heaters introduced on this flight had several changes to the insulation system which did not affect the heating function of the units. The primary purpose of the redesign was to strengthen the heater, especially in the ground tab and cable egress areas. A problem encountered with the redesigned heaters was that the Kapton tab covering the ground tab at 100-deg now interferes with the pin retainer clip. A change is in work to move the location of the ground tab. In the meantime, the Kapton tab is bent out of the way of the pin retainer clip to properly position the heater unit.

The SRB aft skirt purge operation was activated at approximately L-38 hr prior to the aborted launch. This early activation, an extended purge operation, was the result of a FBMBT prediction of 59°F for January 2. During this operation, a GN_2 leak occurred which resulted in an OMSRD violation requiring an IPR to be written. See Section 4.8.2.7 for more detail. The SRB aft skirt purge, prior to the successful launch of January 9, was activated at L-14 hr and 20 min. All case-to-nozzle joint and flex bearing aft end ring temperatures were between 78° and 82°F during the entire LCC timeframe. The total operation time for the aft skirt purge system was 45.5 hr.

4.8.2.6 Prelaunch Thermal Data Evaluation. **IR Temperature Measurements**--The portable STI data collected during the T-3 hr pad walkdown was verbally reported to be between 53° and 56°F for the RH SRM and between 53° and 57°F for the LH SRM. GEI data for this timeframe was between 53° and 58°F for the RH SRM and between 53° and 58°F for the LH SRM. Stationary STI measurements throughout the countdown remained consistent with the GEI, being generally within ±2°F for the RSS location and within ±4°F for the Camera Site No. 2 location.

4.8.2.7 Prelaunch Hardware Anomalies. A GN_2 leak occurred downstream of the GN_2 supply during the aborted countdown. This hardware problem resulted in the deactivation of the aft skirt purge operation which remained off for 6 hr and 9 min. There were no other prelaunch hardware anomalies.

4.8.3 Results Discussion

4.8.3.1 Postflight Hardware Inspection. Following the recovery of the STS-32R 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 4.8-3). Predictions due to the worst-case design trajectory environments (Table 4.8-4) will be documented in the SRB Thermal Design Data Book, SE-019-068-2H.

Table 4.8-3. STS-32R RSRM External Performance Summary (TPS erosion) (left and right SRMs)

Component	Maximum Erosion (in.) TPS Material	Predicted	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

The condition of both SRMs appeared to be similar to previous flight motors, with most of the heat effects seen on the aft segments on the inboard side 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 4.8-1.

Table 4.8-4. SRB Flight-Induced Design Thermal Environments

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

Field Joints--All field joints on both SRMs were in excellent condition. There were no signs of ablation on any of the 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 the result of aft edge hits from water impact and nozzle severance debris. All K5NA repair locations, due to field engineering changes, were intact over the trunnion/vent valve locations. There was a piece of K5NA/extruded cork missing, approximately 2.5 in. by 1.8 in. by 0.5 in. or 2.25 in.^{3}. It was located on the LH forward JPS at about 25 deg. It was a nozzle severance debris scrape, evidenced by a black mark on the case just aft of the missing K5NA/extruded cork.

Factory Joints--The factory joints on each of the SRMs were in very good condition. The only signs of heat effect experienced on the factory joints were located on the aft segments of each SRM. There was only slight ablation, charring, and discoloration on the inboard regions of the aft segment factory joints. This occurred approximately between 220 and 320 deg circumferentially on each SRM. Again, these are all normal occurrences that have been consistently observed on previous flight motors. Weather seals unbonds were evident at three locations (230 and 280 deg on the LH SRM stiffener/stiffener joint - forward edge; and 45 deg on the RH stiffener/stiffener forward edge). 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 one small debris impact or handling scrape on the LH aft segment (1 in. by 1.75 in. with some cork remaining over substrate). There was very little paint blistering. All K5NA closeouts over cables and tunnel seams were in excellent condition. The dimensioning on the slotted holes on the systems tunnel field joint splice plate was changed from 0.500 in. total length of the hole to 0.050 in. slotting on either end of the hole.

Stiffener Rings--The stiffener ring TPS was generally in very good condition with only slight thermal degradation. The major heat-effected 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 insta-foam ramps were chunked out at both SRMs, predominantly at 100 to 135 deg, due to splashdown loads. Compressed insta-foam was evident on the LH center stiffener ring in this region due to the splashdown loads. The K5NA on several stiffener rings was cracked in this same region. An additional crack, in this splashdown load region, was found through the EPDM on the RH center stiffener ring.

GEI Closeout--The cork and K5NA TPS covering the GEI and cableways was 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 re-entry, splashdown loads, and handling problems. There were a total of 17 aft edge hits on GEI cork runs or systems tunnel cork, six on the LH SRM and 11 on the RH SRM.

Aft Kickring 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 during ascent is shielded from adjacent SRB plume radiation by the kickring.

A crack (4 to 5 in. long) was found at the kickring cork-to-K5NA bead interface in the systems tunnel/kickring corner at approximately 88 to 90 deg circumferentially on the LH aft segment. The crack was due to a stress-related occurrence (splashdown or handling). It was found to penetrate into the cork at a 45 deg angle with a depth roughly 0.25 to 0.50 in. at the center. The majority of the splashdown loads occurred in this vicinity as evidenced by the stiffener ring insta-foam chunk out and cracks in K5NA from about 95 to 135 deg.

4.8.3.2 Debris Assessment. NSTS debris criteria for missing TPS was not violated. The missing TPS cork pieces were generally less than the established criteria of 0.70 in.[3] and were all caused by nozzle severance debris, splashdown loads/debris, or handling problems. There were a total of 17 aft edge hits on GEI cork runs or systems tunnel cork, six on the LH SRM and 11 on the RH SRM. The largest TPS piece missing was K5NA/extruded cork approximately 2.5 in. by 1.8 in. by 0.5 in. or 2.25 in.^{3}. It was located on the LH forward JPS at about 25 deg. It was a nozzle severance debris scrape, evidenced by a soot mark on the case just aft of the missing K5NA/extruded cork.

4.8.3.3 MBT Predictions. MBT predictions were performed at various times with respect to the launch of STS-32R. They were predicted for the time of launch and are summarized as follows:

	Historical	L-9 Days 2 Jan 90	L-2 Days 6 Jan 90	L-1 Day 7 Jan 90	L-1 Day 8 Jan 90	Post
PMBT	61	64	65	65	65	64
FBMBT	61	77	--	--	--	78

The final postflight predictions from reconstructed data yield a PMBT of 64°F and a FBMBT of 78°F.

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

a. Thiokol LSS office--Faxed weather data
b. KSC weather station--Modem transmission
c. Florida Solar Energy Center (FSEC)--Modem transmission

The data from the Thiokol LSS office was used, wherever possible, and was the primary source of environmental data. The ambient temperature from the KSC weather station was used as the next source along with wind speed and direction from the FSEC. The ambient temperature data from the FSEC was used only when the other sources were unavailable. Sky temperature and solar flux were received from the FSEC.

Flex bearing temperature predictions were not performed at the same times or frequencies as PMBT predictions. The uncertainty of predicting ambient conditions 7 days in advance, along with the question of how the aft skirt purge system will be operated, make it difficult to accurately predict FBMBT in advance. Required FBMBT calculations are usually performed to determine the current bulk temperature from which aft skirt purge operations can be based.

4.8.3.4 On-Pad Environment Evaluations. The ambient temperature dropped below -4-σ historical values while the vehicle was on the pad. This occurred during the afternoon hours of December 23 and 24. The recorded low temperatures for December 23 through 26 were 23°, 22°, 25°, and 34°F, respectively.

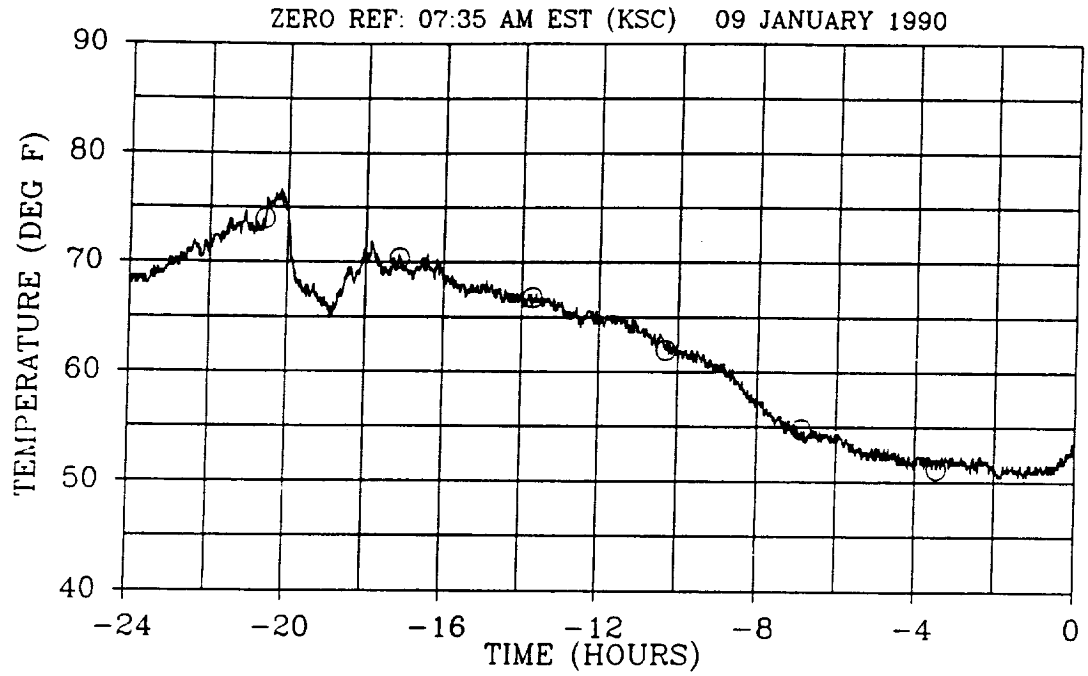
The ambient temperature recorded from L-114 to L-24 hr varied from 61° to 81°F. The ambient temperature for this four day period were higher than normal. The normal temperature range experienced during the month of January is from a low of 55°F to a high of 67°F with the ±1-σ temperature ranging from 45° to 77°F.

Actual environmental data for the final 24 hr prior to launch (51° to 76°F) can be visualized in Figures 4.8-1 through 4.8-5 and summarized together with GEI in Table 4.8-2. The low 50°F readings experienced prior to launch are well within the ±1-σ historical temperature range for January. The wind speeds from L-24 to L-12 were normal (≈13 kn), whereas the wind speeds from L-12 up through launch were below normal (≈7 kn).

The local on-pad environment due to January historical predictions suggest an average 1°F depression while the ET is loaded and when winds are from the north. The actual wind direction during the LCC time frame was from the west. The 7-kn wind from the west provided a situation where a significant temperature depression could be experienced by the SRBs due to GOX venting and ET chill. The GOX, however, was directed up and over the shuttle system. In the past, winds from the east have caused chilling on the inboard side of the west SRB (STS-30R) and winds from the west have caused chilling on the inboard side of the east SRB (STS-29R and STS-28R). From GEI assessments, there is no evidence of temperature suppression on the east SRB due to ET chill effects.

4.8.3.5 <u>LCC</u>. No LCC thermal violations were noted. Measured GEI and heater sensor data for the end of the LCC time frame (T-5 min) are presented in Table 4.8-5 and are compared with the LCC requirements.

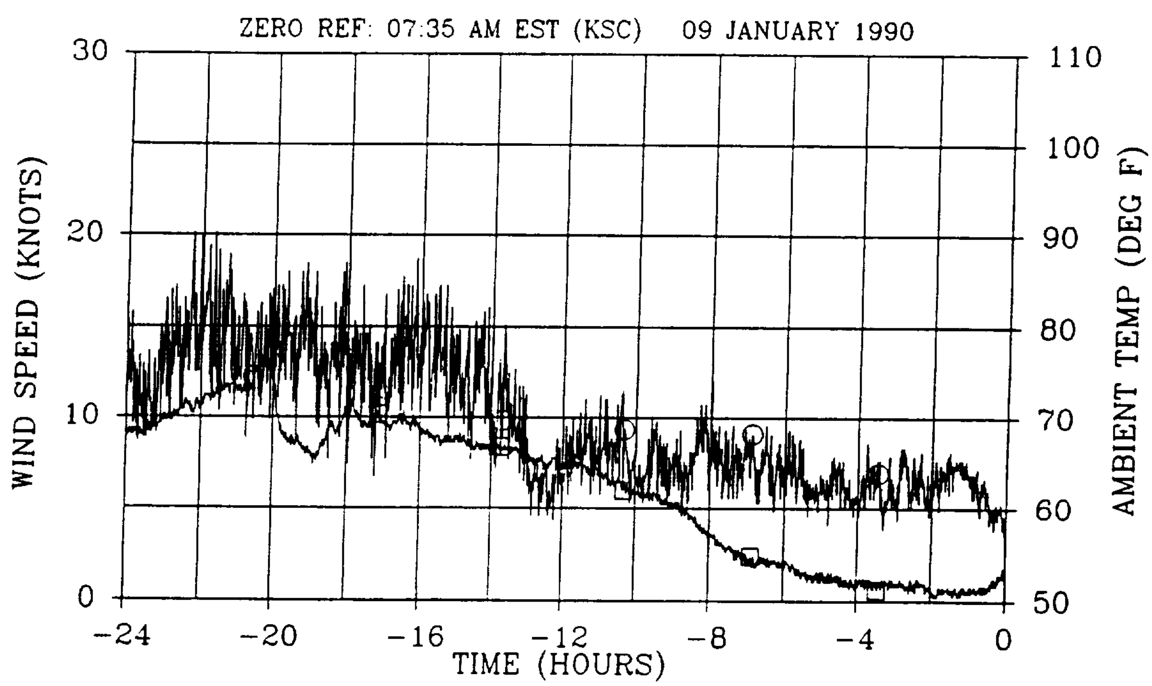
The igniter heaters were activated at L-18 hr instead of at L-24 hr as had occurred prior to this launch. The deactivation time was also changed with this launch, from T-4 hr to T-9 min. Had this change not occurred, given the cold temperatures prior to launch, an igniter joint temperature LCC violation would have occurred with the igniter sensors predicted to read 62° to 63°F. With the later deactivation time the igniter seal temperatures at T-5 min were 90° to 91°F.



*NOTE: T−0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

LEGEND
KMTTA001A (AMBIENT)

Figure 4.8-1. Ambient Temperature at Camera Site No. 3



*NOTE: T−0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

LEGEND
KMTLA002A (WIND SPD)
RIGHT−AXIS LEGEND
KMTTA001A (AMBIENT)

Figure 4.8-2. Wind Speed at Camera Site No. 3 Overlaid With Ambient

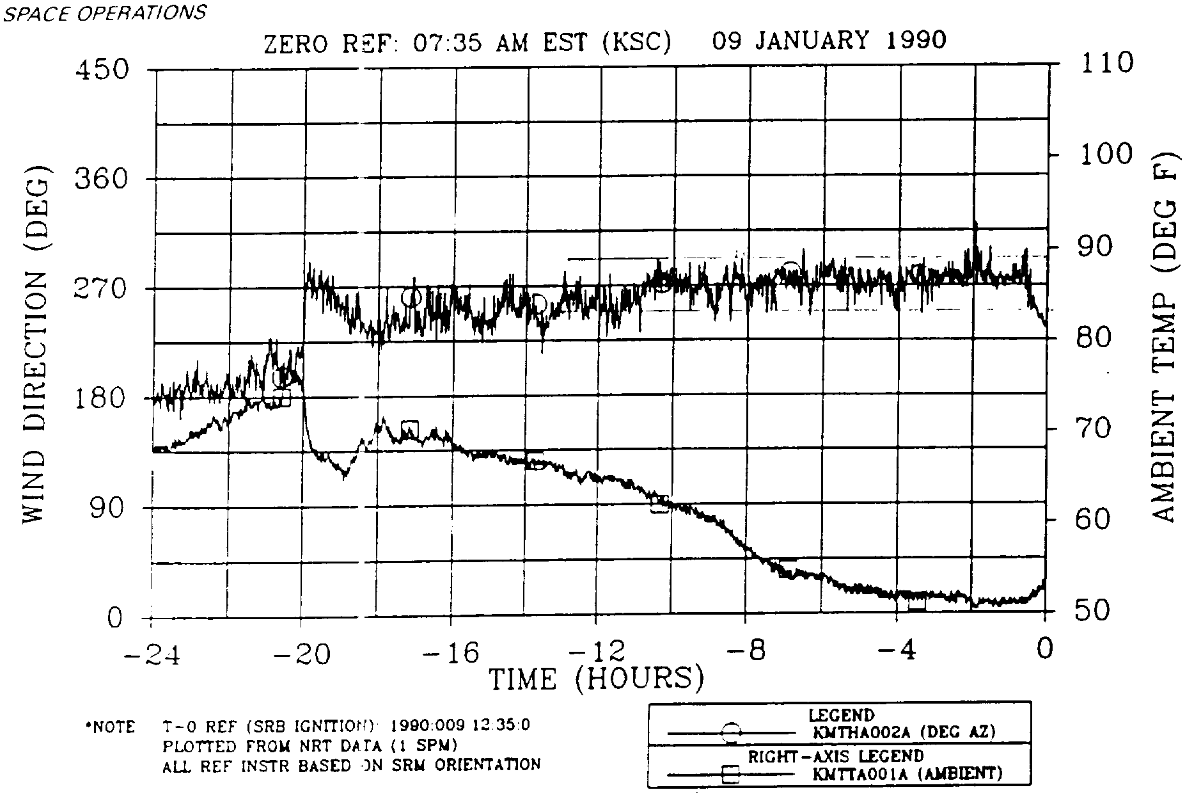


Figure 4.8-3 Wind Direction at Camera Site No. 3 Overlaid With Ambient

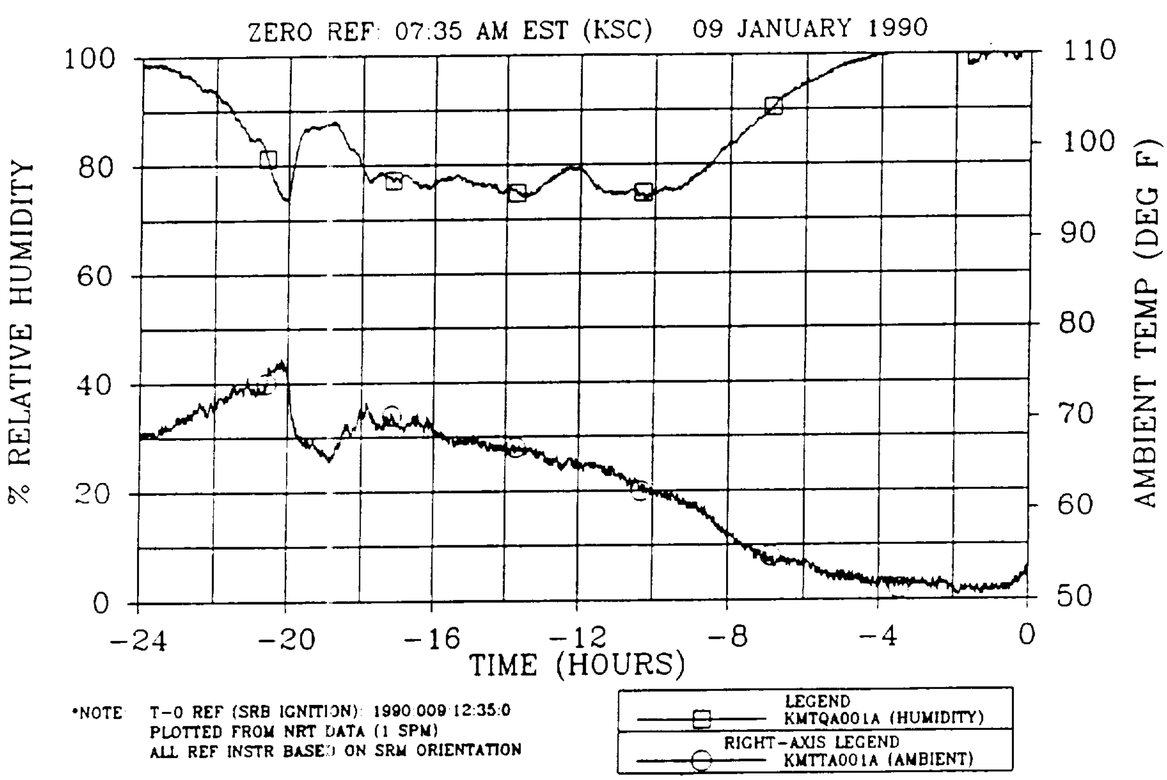


Figure 4.8-4. Humidity at Camera Site No. 3 Overlaid With Ambient

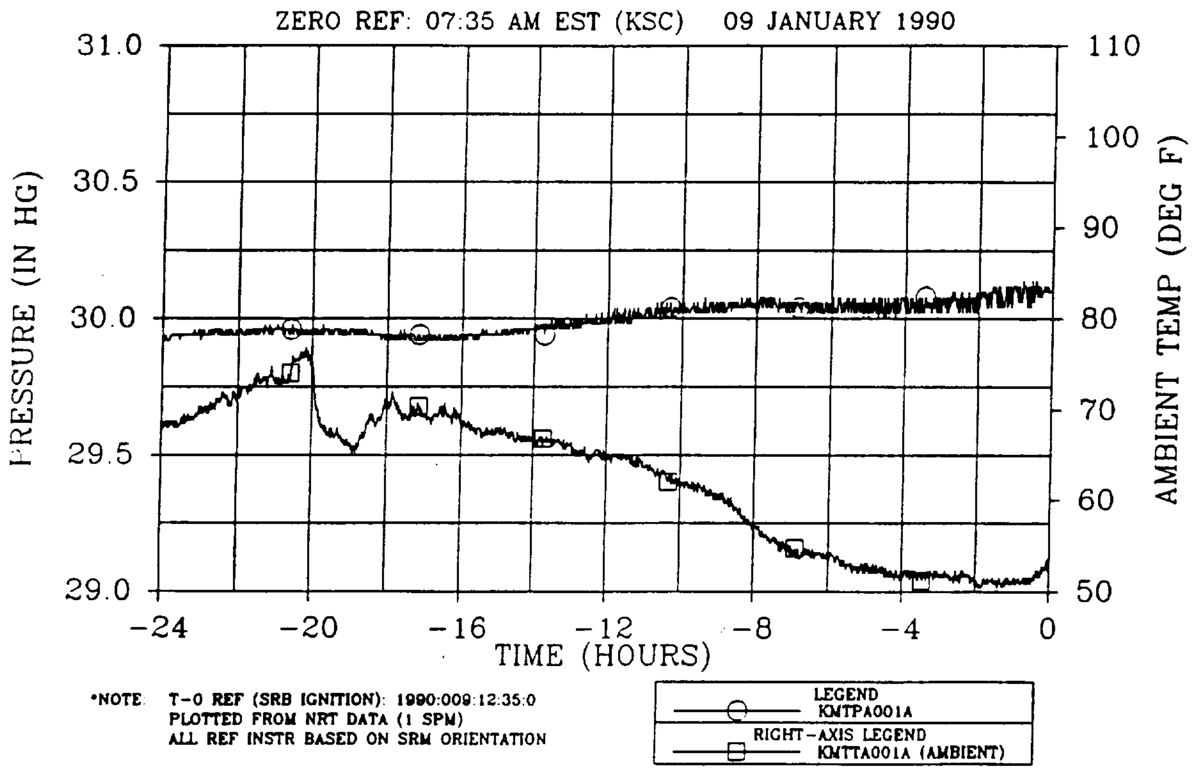


Figure 4.8-5. Barometric Pressure at Camera Site No. 3 Overlaid With Ambient

Table 4.8-5. STS-32R T-5 min On-Pad Temperatures (represents end of LCC timeframe)

Component	T-12 hr Predictions*	January Historical	Actual GEI	Actual LCC
Igniter Joint				
RH	88 to 95	92 to 93	90 to 91	66 to 123
LH	88 to 95	92 to 93	90 to 91	66 to 123
Field Joint				
RH Forward	96 to 102	93 to 97	97 to 102	85 to 122**
LH Forward	96 to 102	93 to 97	99 to 102	85 to 122
RH Center	96 to 102	97 to 100	97 to 99	85 to 122
LH Center	96 to 102	97 to 100	99 to 104	85 to 122
RH Aft	96 to 102	94 to 97	96 to 98	85 to 122
LH Aft	96 to 102	94 to 97	97 to 100	85 to 122
Case-to-Nozzle Joint				
RH	78 to 84	67 to 68	78 to 82	75 to 115
LH	78 to 84	67 to 68	78 to 82	75 to 115
Flex Bearing Aft End Ring				
RH	78 to 84	67 to 68	78 to 80	NA to 115
LH	78 to 84	67 to 68	78 to 80	NA to 115
Case Acreage (deg)				
RH 45	--	56 to 58	56 to 58	--
135	--	57 to 59	56 to 58	--
215	--	56 to 58	54 to 58	--
270	58 to 64	56 to 58	54 to 58	35 to NA
325	--	56 to 58	54 to 58	--
LH 45	--	56 to 58	51 to 59	--
135	--	56 to 58	51 to 58	--
215	--	56 to 58	51 to 59	--
270	58 to 64	58 to 60	54 to 61	35 to NA
325	--	58 to 60	51 to 59	--
Local Environment				
Temperature	58	56	52	38 to 99
Wind speed (kn)	--	12	4 to 5	24
Wind direction	--	North	SW	SW to SE
Cloud cover			Clear	

*Predictions for anticipated launch window at T-5 min
**Field joint sensor lower limit will drop from 85°to 68°F in the event of a complete heater failure

IPR 32RV-0231 was written when an audio alarm was sounded in error. First indications, when the alarm sounded, were that a heater had failed, and that message was given over the network. After monitoring heater operations for a few minutes it became obvious that all heaters were functional. It was later determined that the alarm was the result of a sampling sequence error in the software. The IPR was then written so the problem could be corrected. The heater associated with this problem was the left igniter heater.

The six redesigned field joint heaters performed adequately and as expected with a 15°F sensor temperature range from 93° to 108°F during the LCC timeframe. All 24 field joint sensors recorded temperatures in the expected range. Prior to launch, an LCC contingency was created to lower the minimum redline temperature, at a given field joint, from 85° to 68°F in the event of a complete heater failure. This modification was a change unique to STS-32R and was a precaution taken in the event both primary and redundant heaters fail on a given field joint.

Flex bearing temperature sensor data was not available for approximately 8 days during the holiday (pad) shutdown at KSC. This resulted in an exception being written to the OMRSD on the FBMBT method of calculation. A 59°F FBMBT was then predicted at the time of pad power up on January 2 requiring the early activation of the GN_2 purge. The GN_2 purge was activated at approximately L-38 hr prior to the aborted launch of January 8 as per the OMRSD requirement. Early in the countdown a GN_2 leak was discovered resulting in the deactivation of the purge system. This leak occurred when a seal, downstream of the GN_2 purge supply, either leaked or had been inadvertently left out. With the purge system off at L-35 hr an OMRSD violation occurred requiring IPR 32RV-02221 to be written against the aft skirt purge operation. An exception (EK1581) was written against this violation stating that the 27 hr required operation time would be accomplished by extending the purge beyond T-6 hr to T-0. During the later stages of the countdown, with a scrub likely, the FBMBT was conservatively approximated to be 78°F. With this information it was determined that the aft skirt GN_2 purge could be deactivated and then operated in the normal manner during the subsequent countdown. This was done and the temperature range at the case-to-nozzle joint and flex bearing sensors was 78° to 82°F during the LCC timeframe. A timetable of aft skirt purge operation events is shown in Table 4.8-6.

Table 4.8-6. STS-32R Aft Skirt Purge Operation Timetable

Time (GMT)	Time (EST)	Launch Time	Event
006:23:03	18:03	L-38	Aft skirt purge system activated at high temperature and flow rate (pressure) 114°F, 108 psi
007:00:35	19:35	L-36:28	Aft skirt purge system deactivated after low O_2 reading indicated GN_2 leak. Area evacuated and fire, safety, and other personnel enter MLP compartment to determine and correct problem
007:06:44	1:44	L-30:19	Aft purge system reactivated at high temperature and pressure
007:12:51	7:51	L-24:12	First aft skirt region temperature sensor attains 95°F. Operation temperature dropped to 95°F and pressure dropped to 46 psi
007:21:25	16:25	L-15:38	Purge system deactivated according the OMI to allow personnel to remove the exhaust plug, vent drain, and line scrubber
007:22:18	17:18	L-14:45	Purge system reactivated
(purge system again taken down for less than an hour, actual times not noted)			
008:12:45	7:45	L-1:18	Purge pressure increased to 104 psi
008:13:57	8:57		Launch scrubbed
008:14:30	9:40		Purge deactivated. Technical discussion prior to scrub determined that FBMBT would not drop below the 60°F OMRSD required temperature
008:22:55	17:55	L-13:40	Purge activated at low flow rate, 106°F, and 45 psi. Temperature levels off at 96°F
009:12:10	7:10	L-0:25	Purge flow rate increased. Pressure rises to 106 psi

4.8.3.6 Prelaunch Thermal Data Evaluation. **IR Temperature Measurements**--The portable STI data collected during the T-3 hr pad walkdown (3:00 to 5:00 a.m. EDT) was verbally reported to be between 53° and 56°F for the RH SRM and between 53° and 57°F for the LH SRM. GEI data for this timeframe was between 53° and 58°F for the RH SRM and between 53°F and 58°F for the LH SRM. No IR gun data was reported. Stationary STI measurements throughout the countdown remained consistent with the GEI, being generally within ±2°F for the RSS location and within ±4°F for the Camera Site No. 2 location (the latter location failed to transmit data during final countdown - cause unknown).

GEI Temperature Measurements--Figures 4.8-6 through 4.8-10 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 4.8-11 through 4.8-40 present January historical predictions. These predictions are based on event sequencing, as specified in Table 4.8-7. Figures 4.8-41 through 4.8-97 show actual STS-33R countdown data. Despite the difference between actual and historical ambient temperatures, during the days and weeks prior to launch, the temperatures during the LCC timeframe were similar. Only in the ET attach and nozzle regions did the historical predictions differ significantly from the actual GEI data. This was a result of joint heater affects being incorrectly evaluated at the ET attach location and an unpredictable purge operation in the nozzle region. The T-5 min historical versus actual temperature comparisons were in close agreement except for the actual case-to-nozzle joint and flex bearing aft end ring temperatures which were 11° to 14°F higher lower than the historical predictions (see Table 4.8-5). The L-12 hr predictions of launch time conditions, which incorporate an environmental update for the last 24 hr prior to launch, were in good agreement with the GEI.

Postflight reconstructed predictions of GEI and igniter-to-field joint heater response were performed using the actual environmental data from the 24 hr prior to launch. A few examples of the predictions, compared with actual measured sensor data, are found in Figures 4.8-98 through 4.8-113. Reasonable agreement is apparent in all areas except the ET attach ring and the left SRB systems tunnel. In the future, modeling improvements (environment and detail) need to be made in these regions.

Figure 4.8-114 shows the postflight FBMBT prediction created from reconstructed ambient temperature and aft skirt purge data.

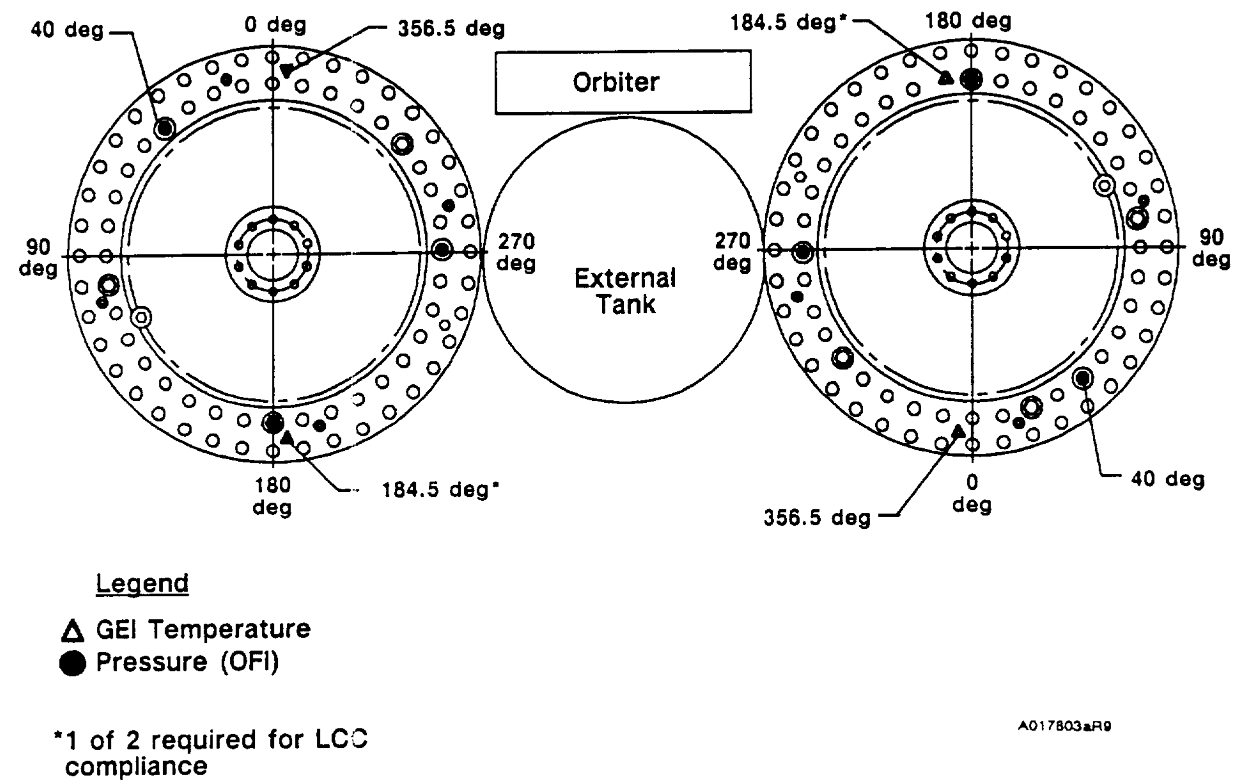


Figure 4.8-6. Forward Dome GEI

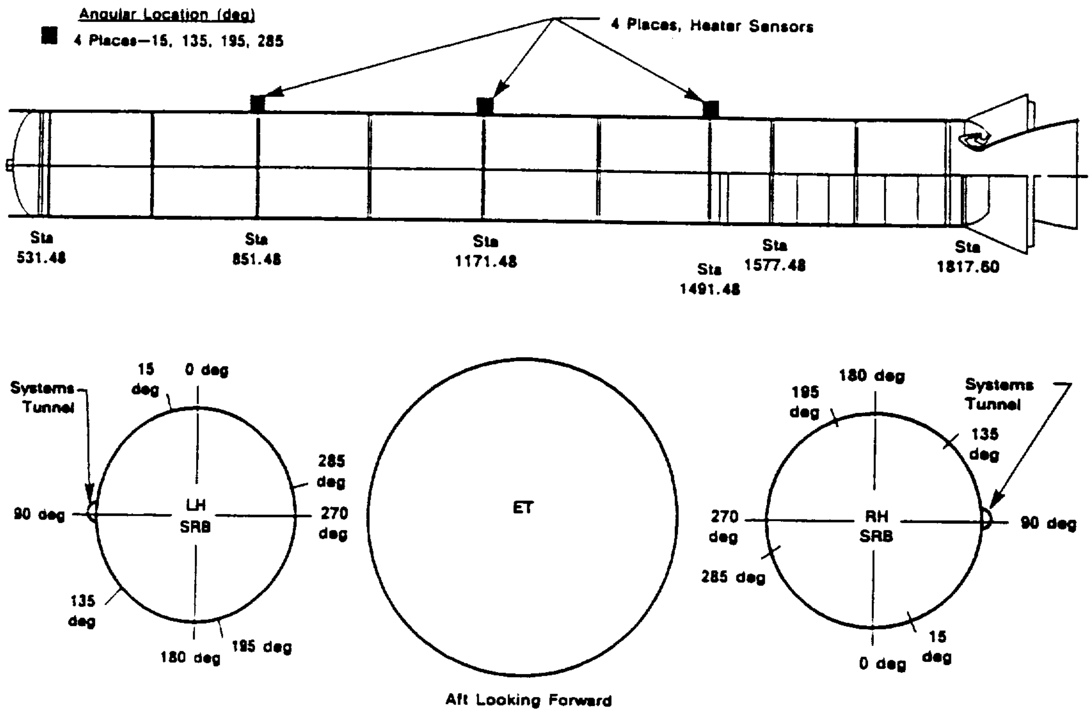


Figure 4.8-7. Field Joint Heater Temperature Sensors

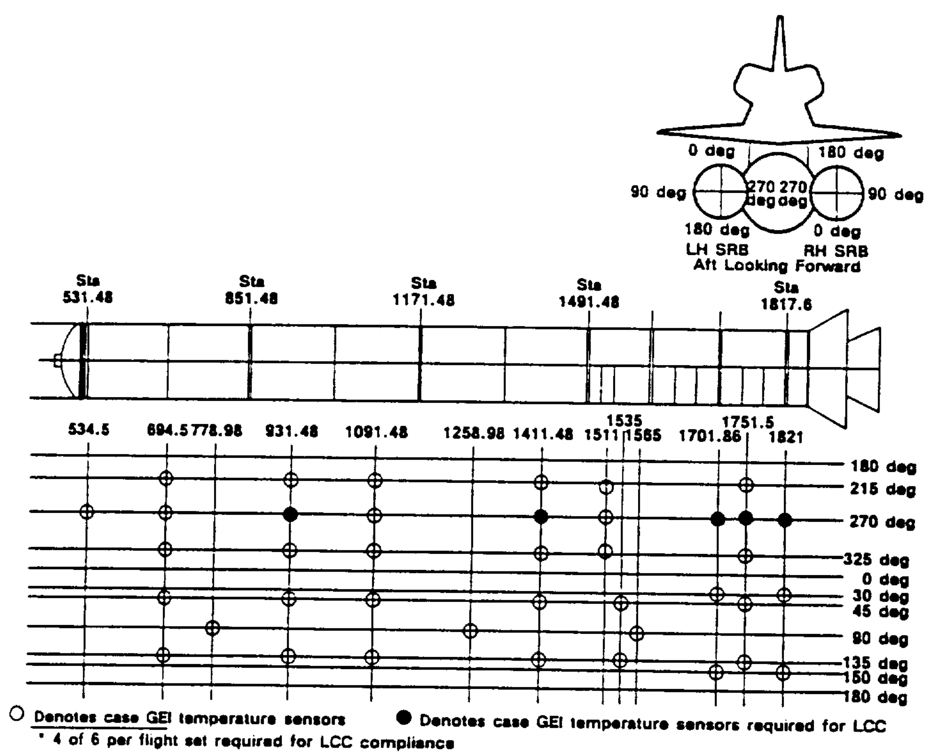


Figure 4.8-8. Case GEI

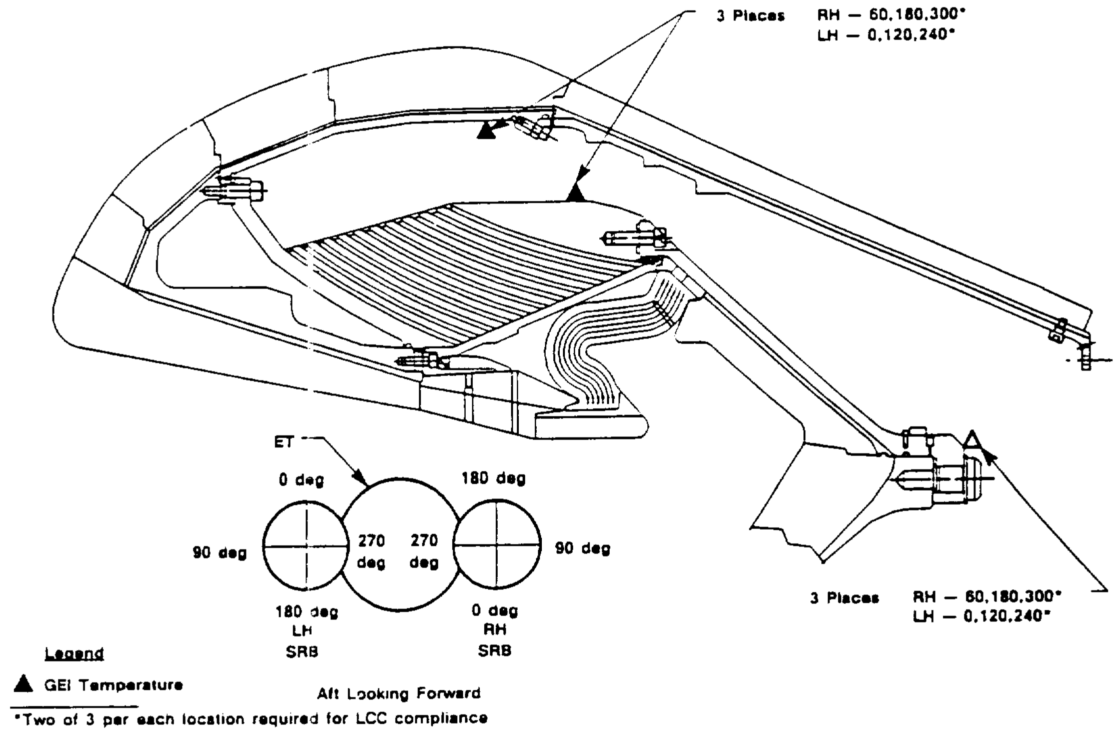


Figure 4.8-9. Nozzle GEI

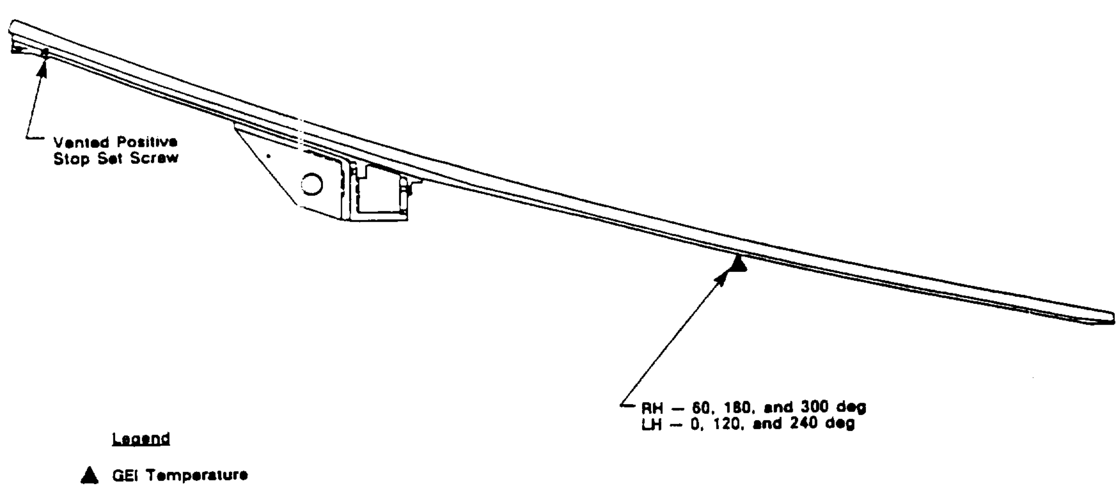


Figure 4.8-10. Aft Exit Cone GEI

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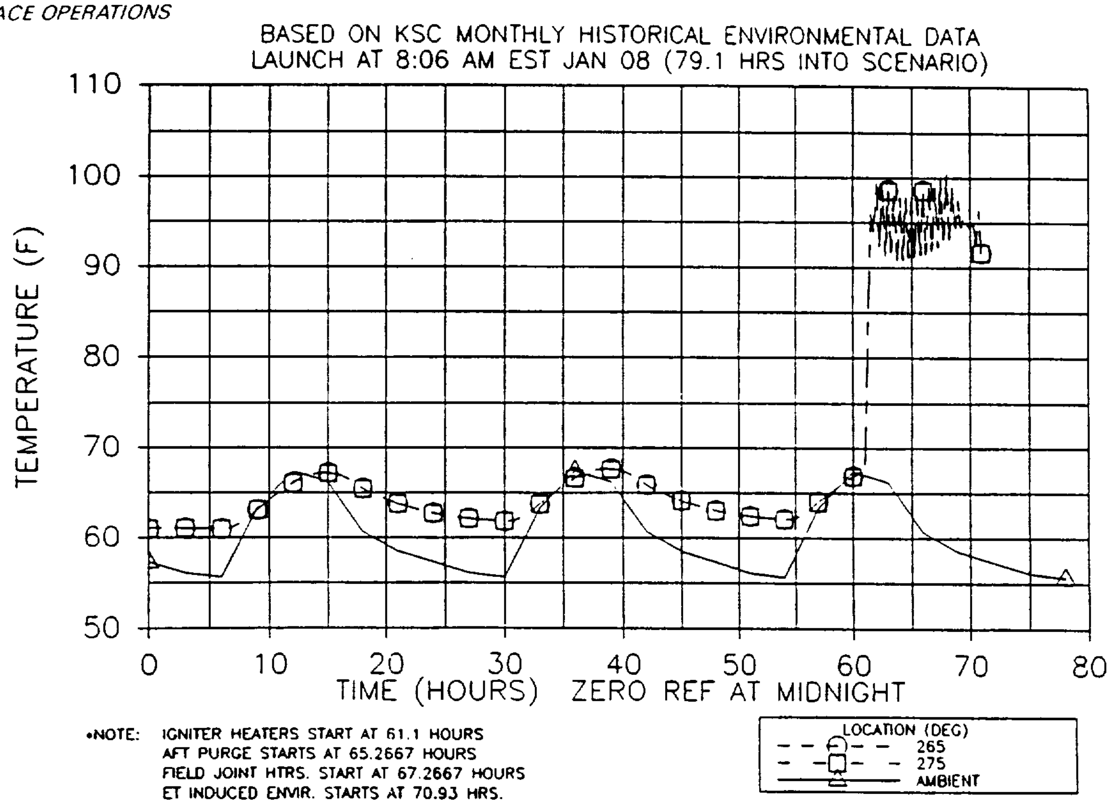


Figure 4.8-11. Right SRM Ignition System Region--Heater and GEI Sensor Temperature Prediction

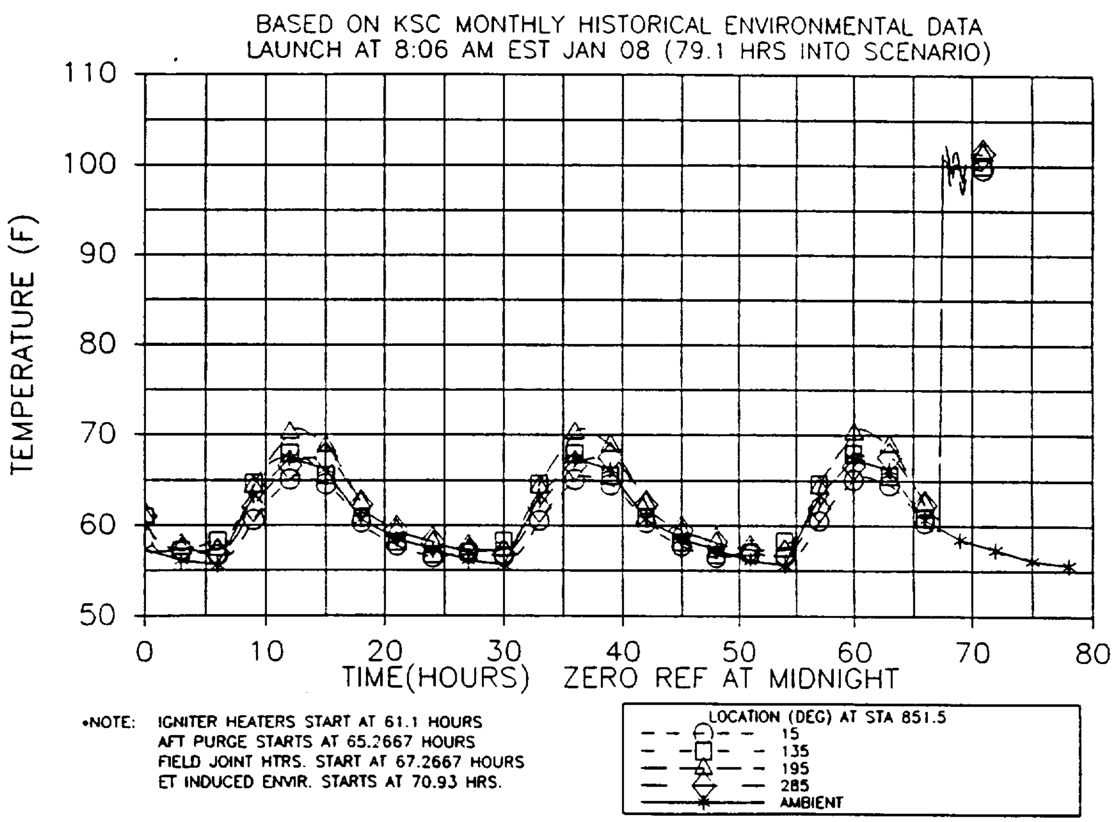


Figure 4.8-12. Right SRM Forward Field Joint--Heater Sensor Temperature Prediction

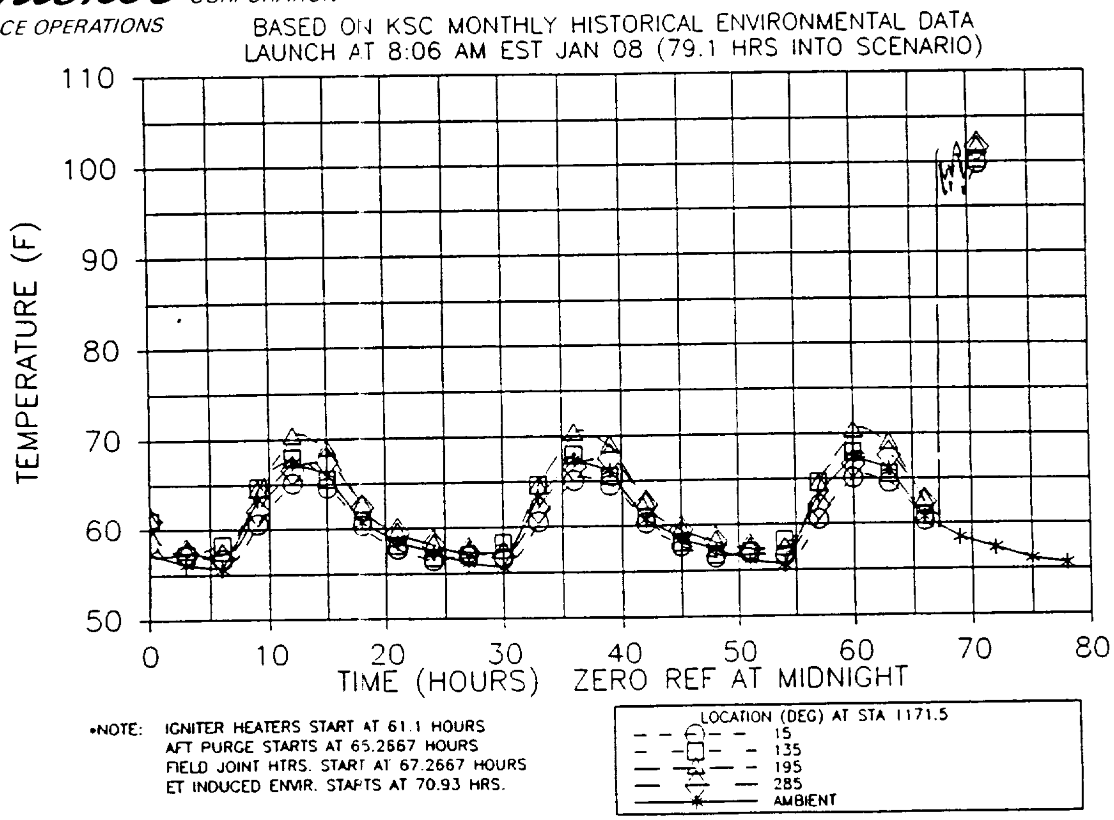


Figure 4.8-13. Right SRM Center Field JOint--Heater Sensor Temperature Prediction

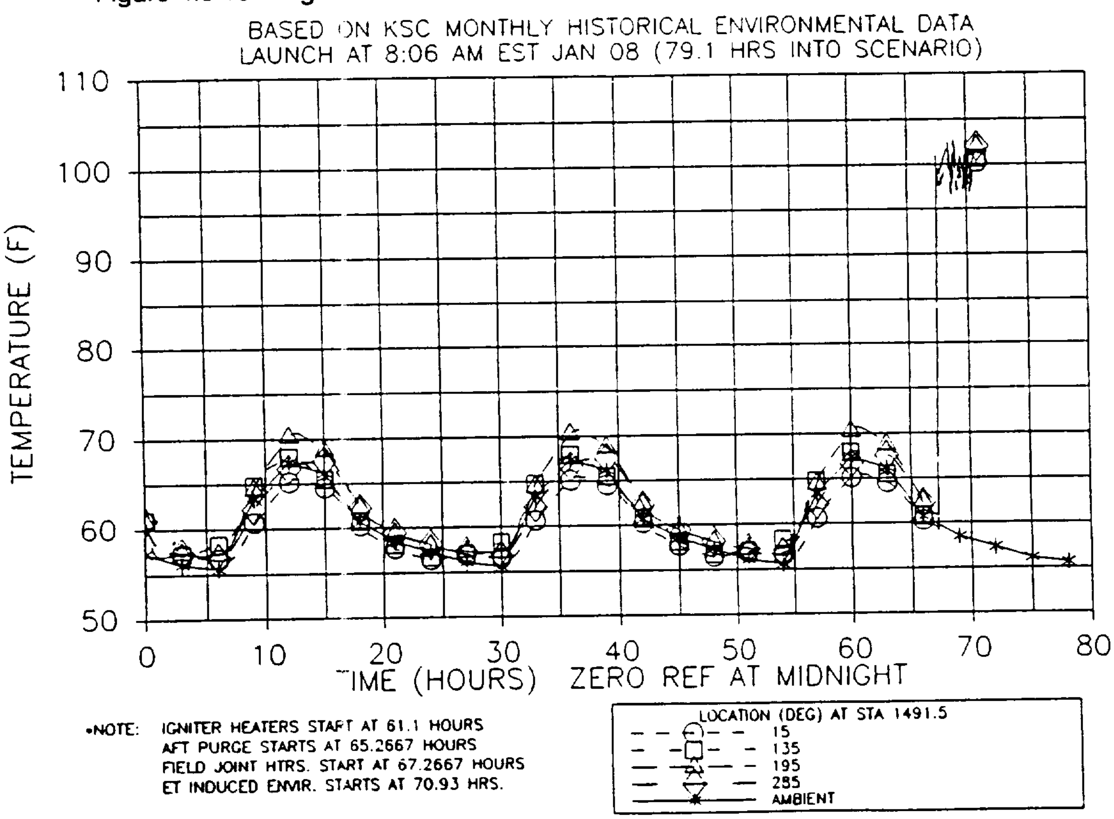


Figure 4.8-14. Right SRM Aft Field Joint--Heater Sensor Temperature Prediction

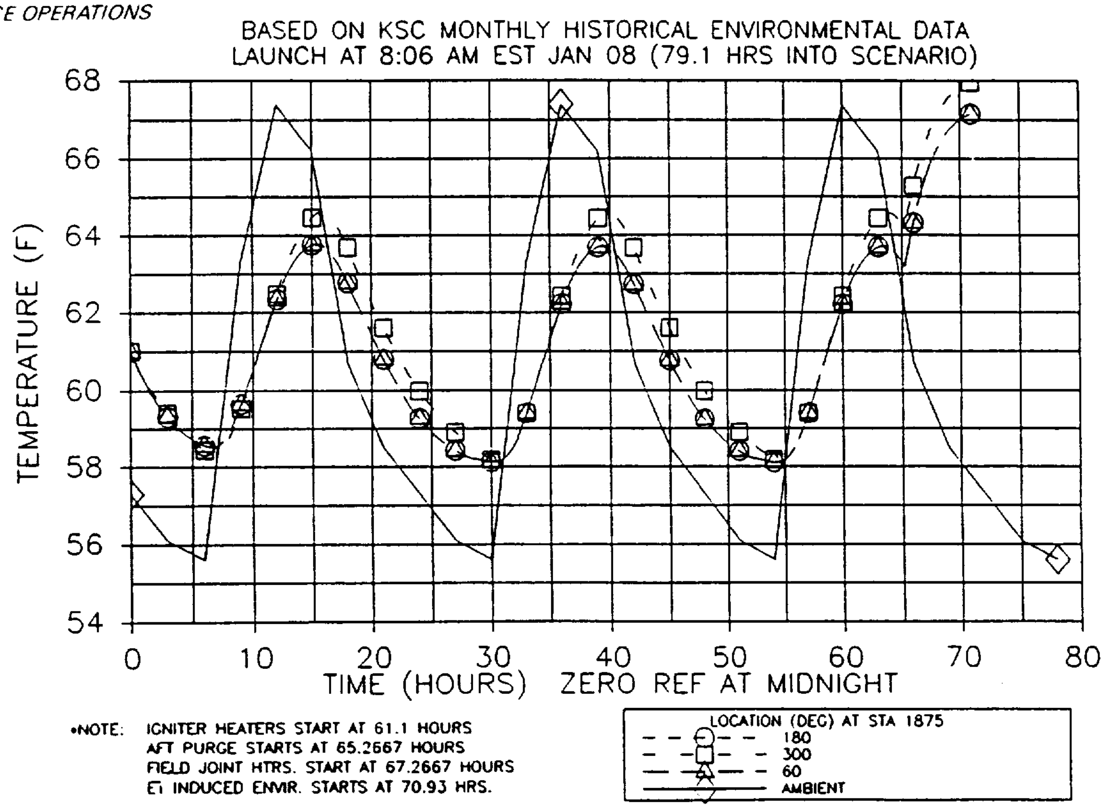


Figure 4.8-15. Right SRM Nozzle Region--GEI Sensor Temperature Prediction

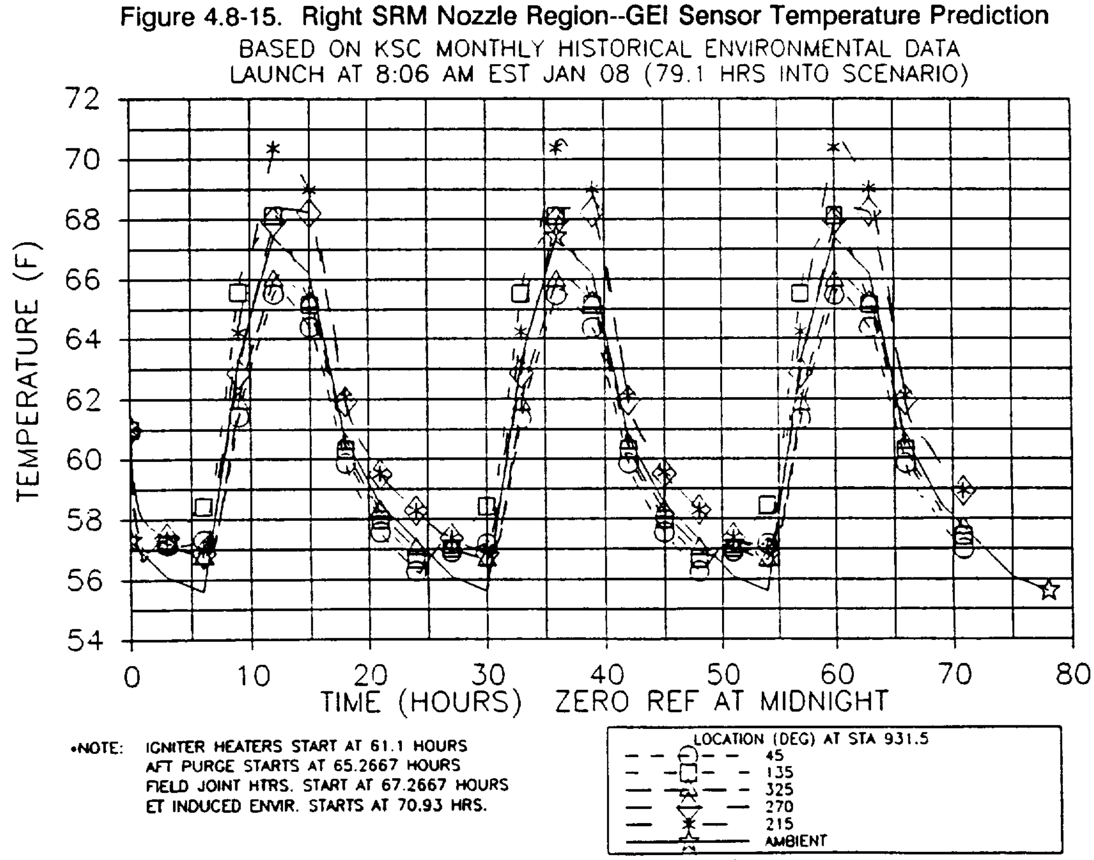


Figure 4.8-16. Right SRM Forward Case Acreage--GEI Sensor Temperature Prediction

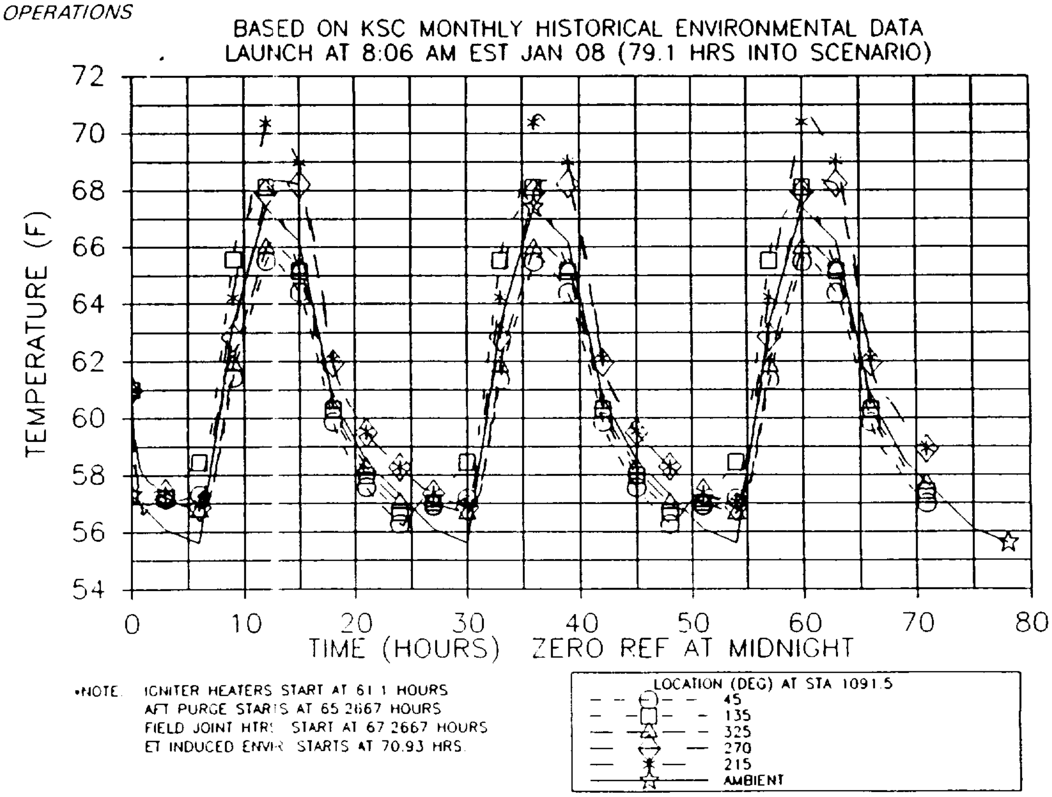


Figure 4.8-17. Right SRM Forward Center Case Acreage--GEI Sensor Temperature Prediction

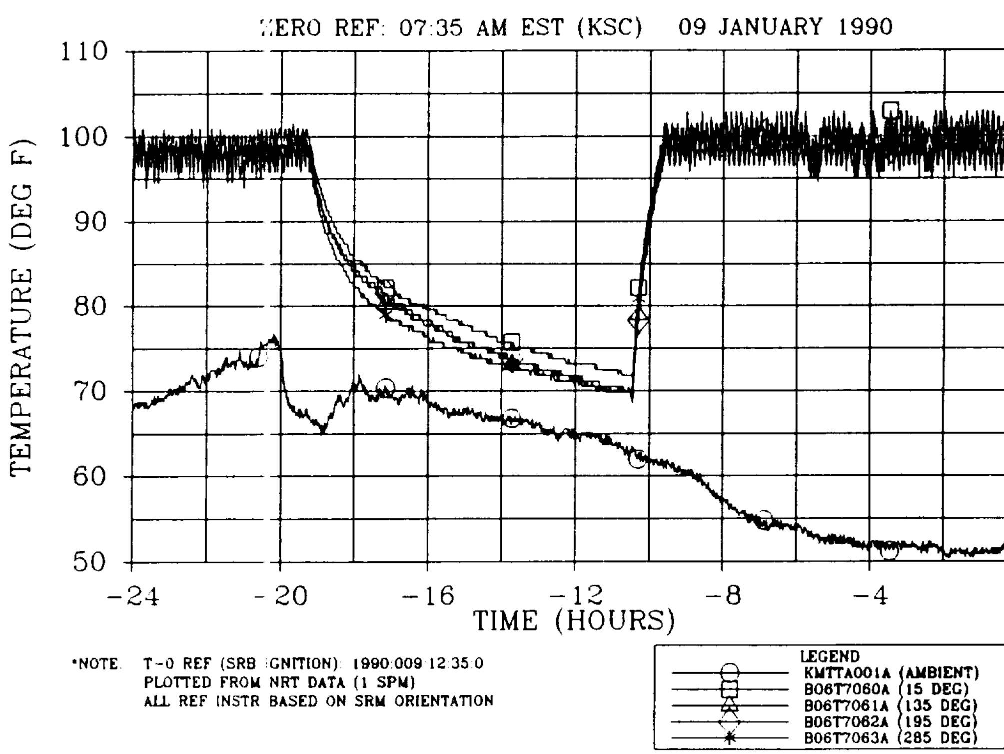


Figure 4.8-18. Left SRM Field Joint Temperature--Overlaid With Ambient

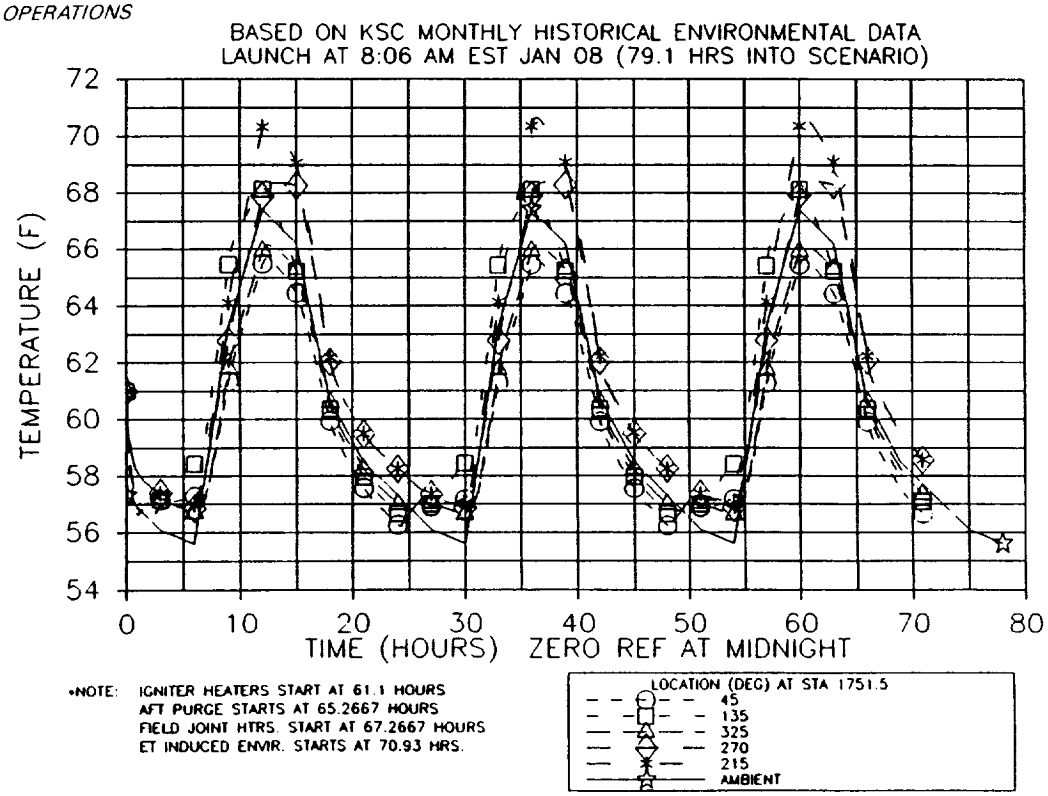


Figure 4.8-19. Right SRM Aft Case Acreage--GEI Sensor Temperature Prediction

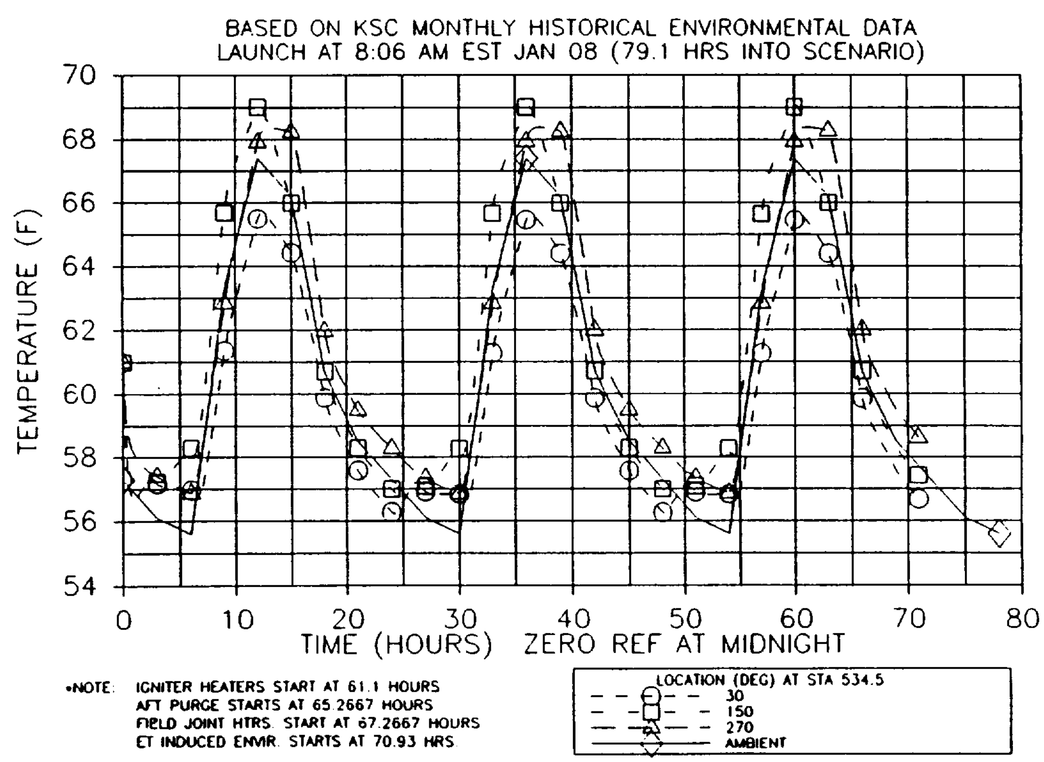


Figure 4.8-20. Right SRM Forward Dome Factory Joint--GEI Sensor Temperature Prediction

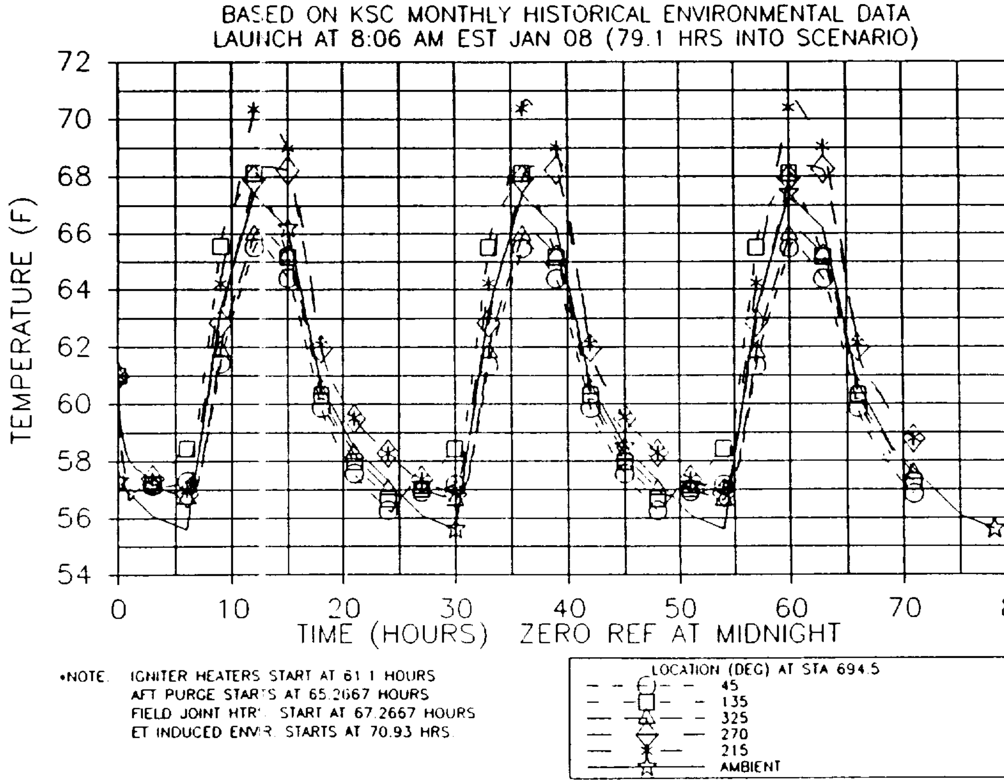


Figure 4.8-21. Right SRM Forward Factory Joint--GEI Sensor Temperature Prediction

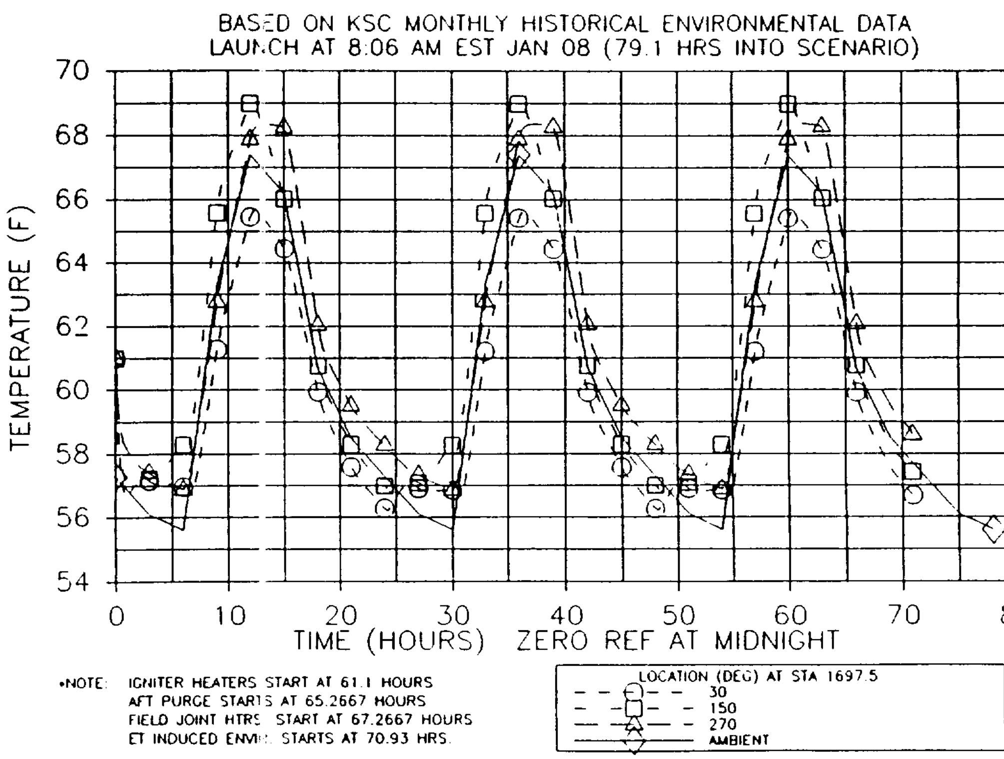


Figure 4.8-22. Right SRM Aft Factory Joint--GEI Sensor Temperature Prediction

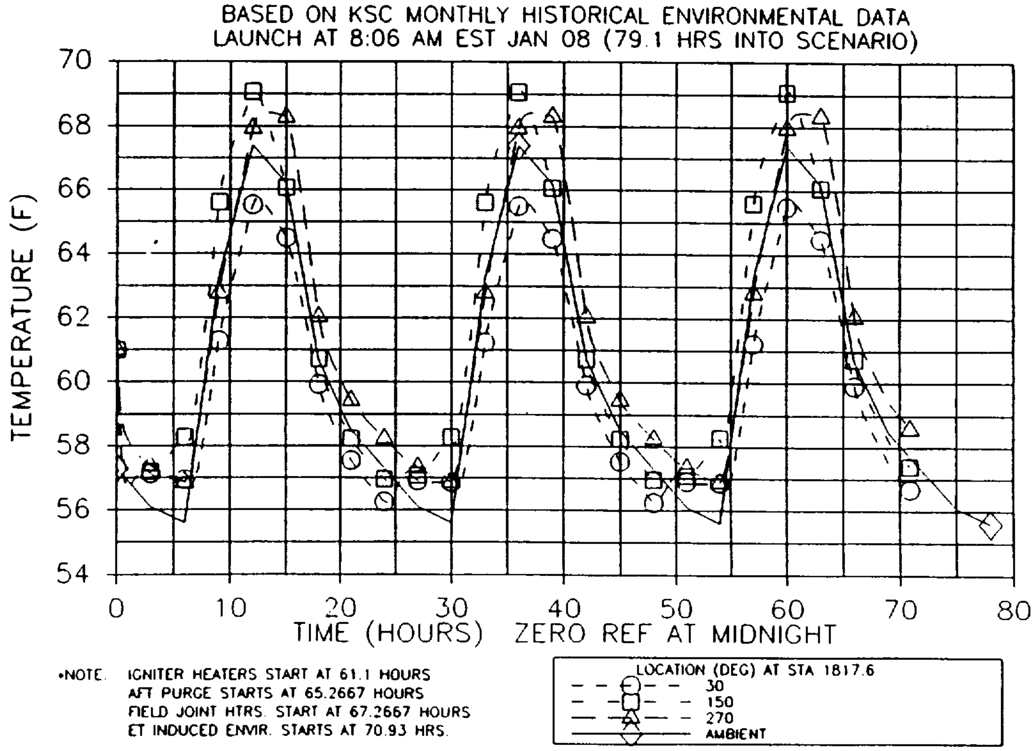


Figure 4.8-23. Right SRM Aft Dome Factory Joint--GEI Sensor Temperature Prediction

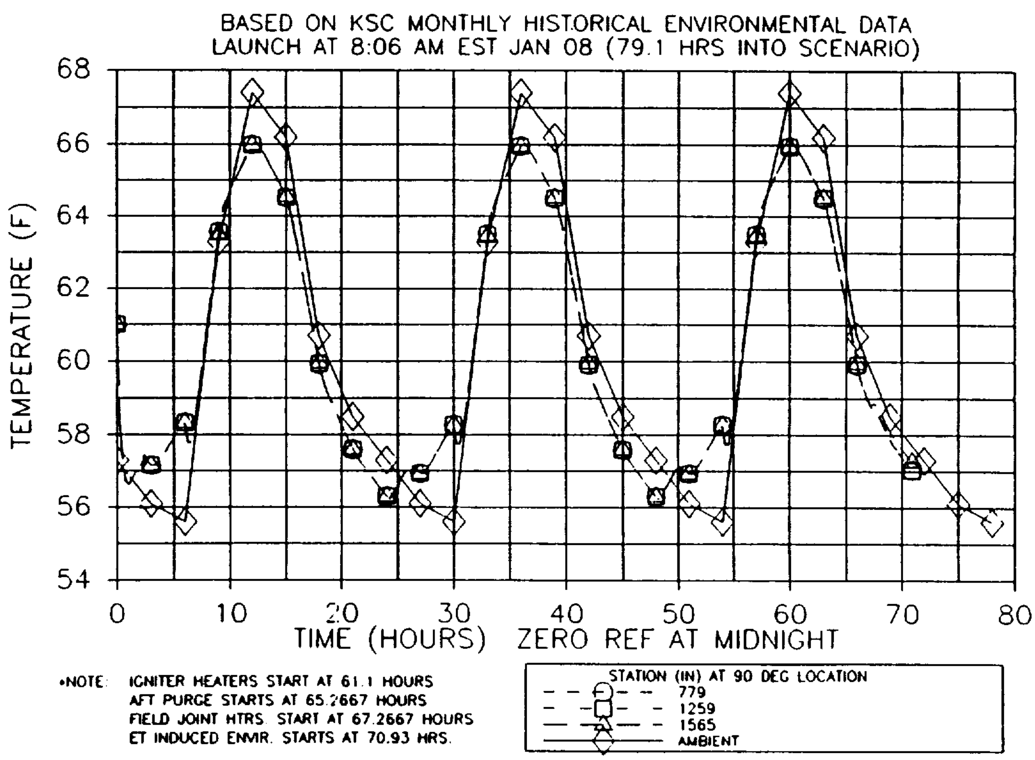


Figure 4.8-24. Right SRM Tunnel Bondline--GEI Sensor Temperature Prediction

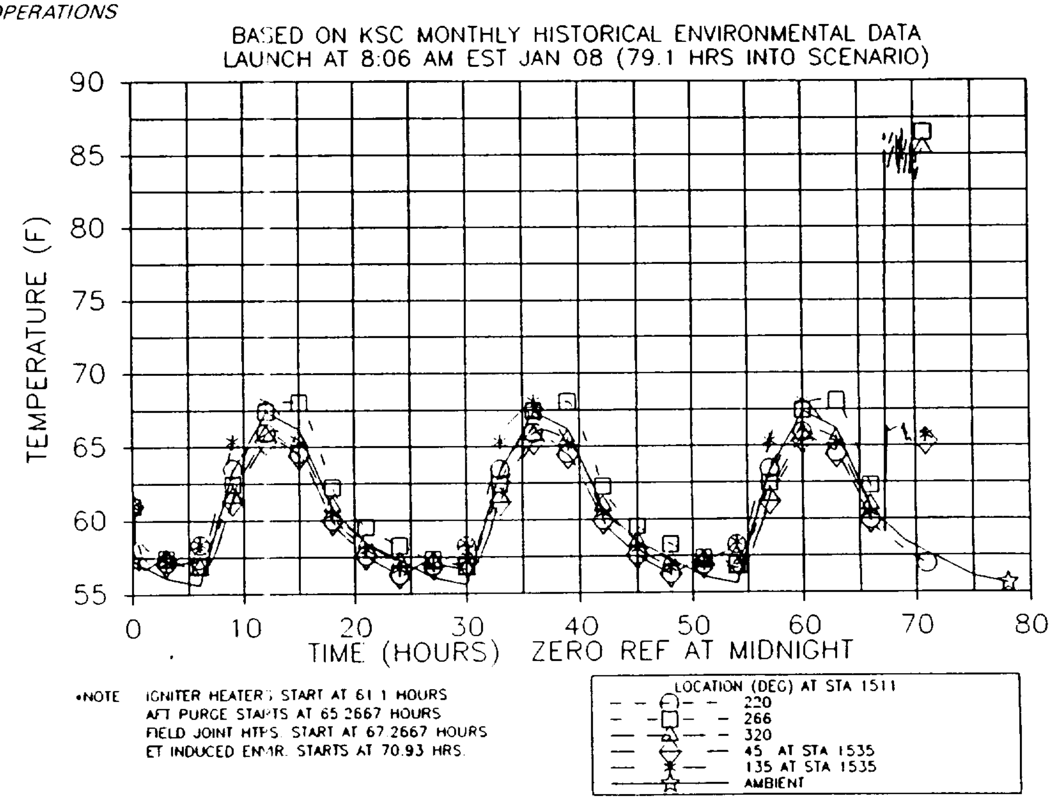


Figure 4.8-25. Right SRM ET Attach Region--GEI Sensor Temperature Prediction

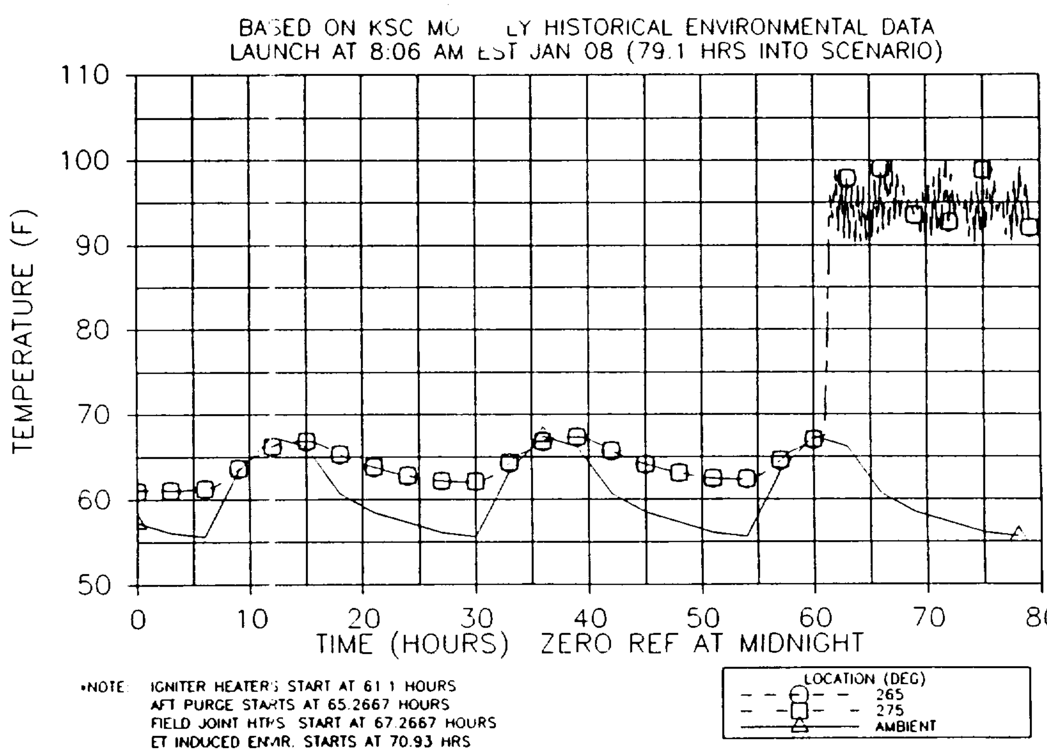


Figure 4.8-26. Left SRM Ignition System Region--Heater and GEI Sensor Temperature Prediction

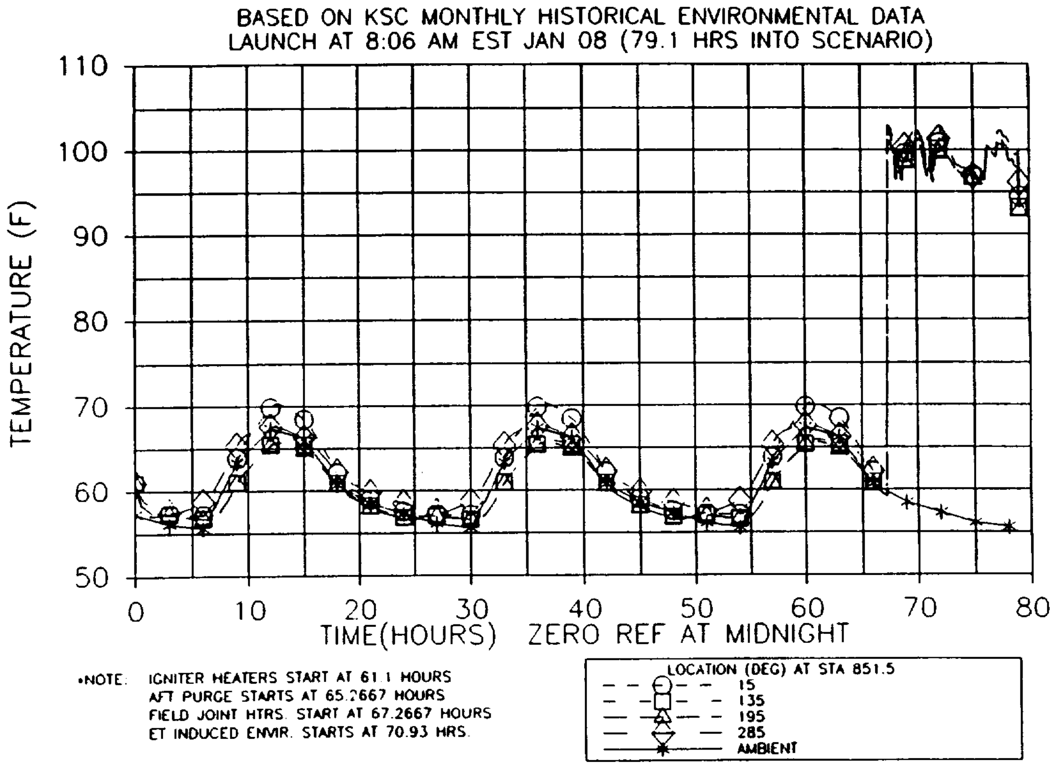


Figure 4.8-27. Left SRM Forward Field Joint--Heater Sensor Temperature Prediction

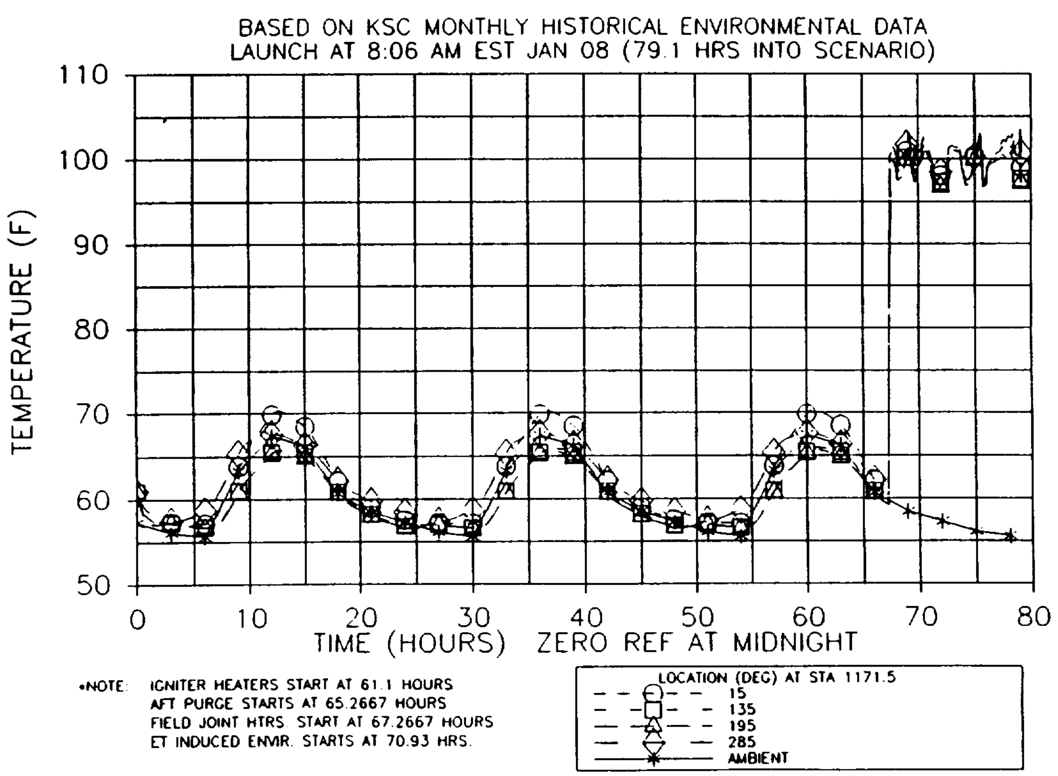


Figure 4.8-28. Left SRM Center Field Joint--Heater Sensor Temperature Prediction

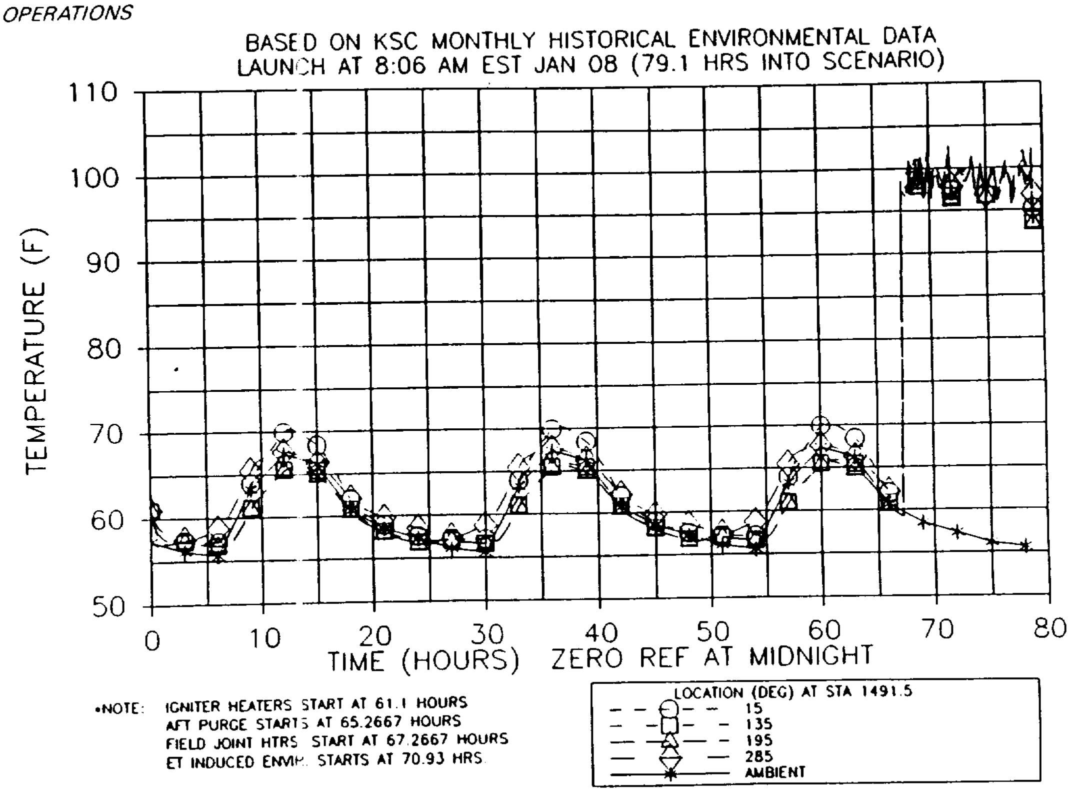


Figure 4.8-29. Left SRM/Aft Field Joint--Heater Sensor Temperature Prediction

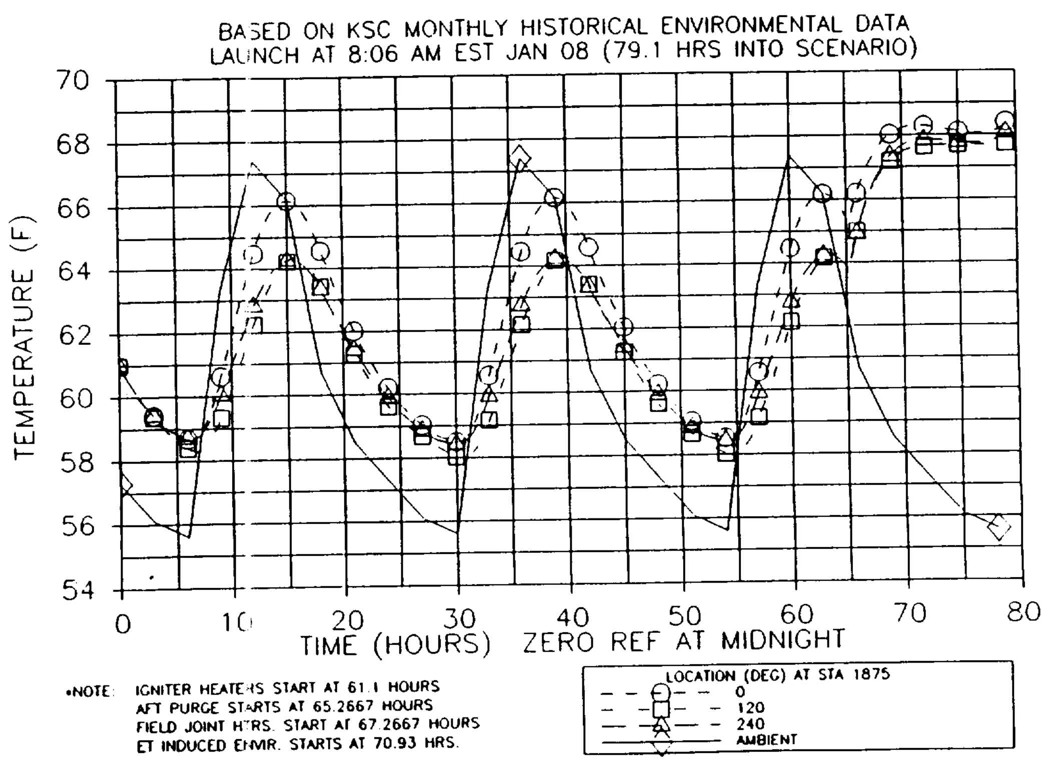


Figure 4.8-30 Left SRM Nozzle Region--GEI Sensor Temperature Prediction

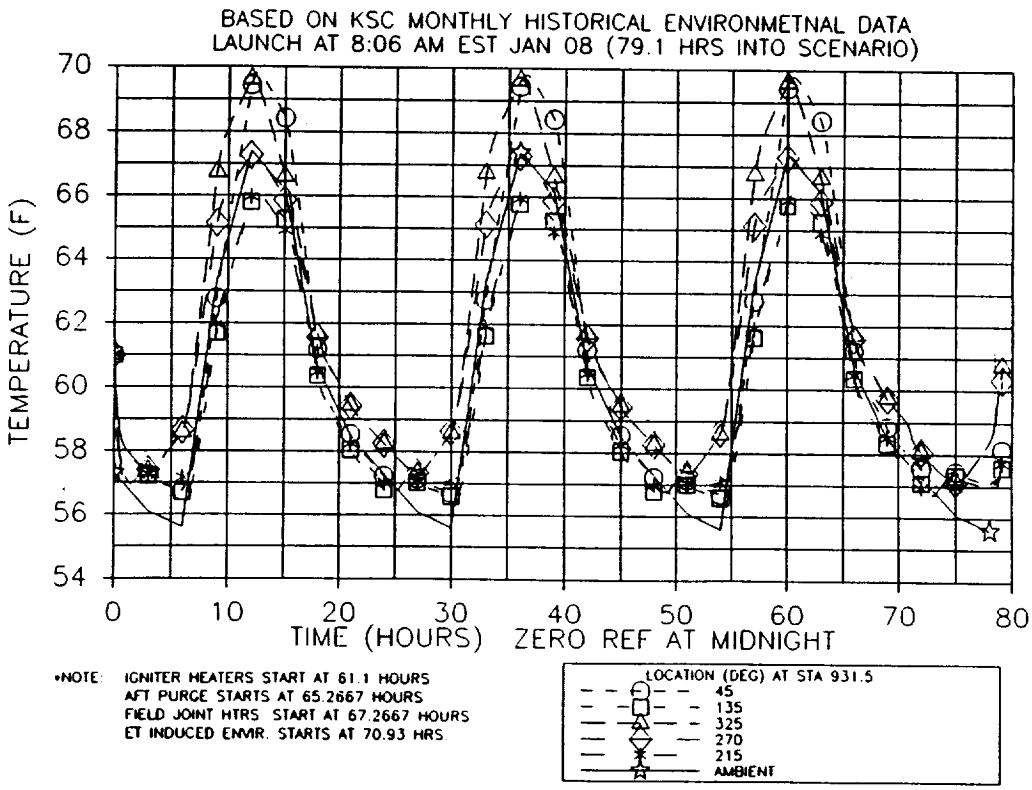


Figure 4.8-31. Left SRM Forward Case Acreage--GEI Sensor Temperature Prediction

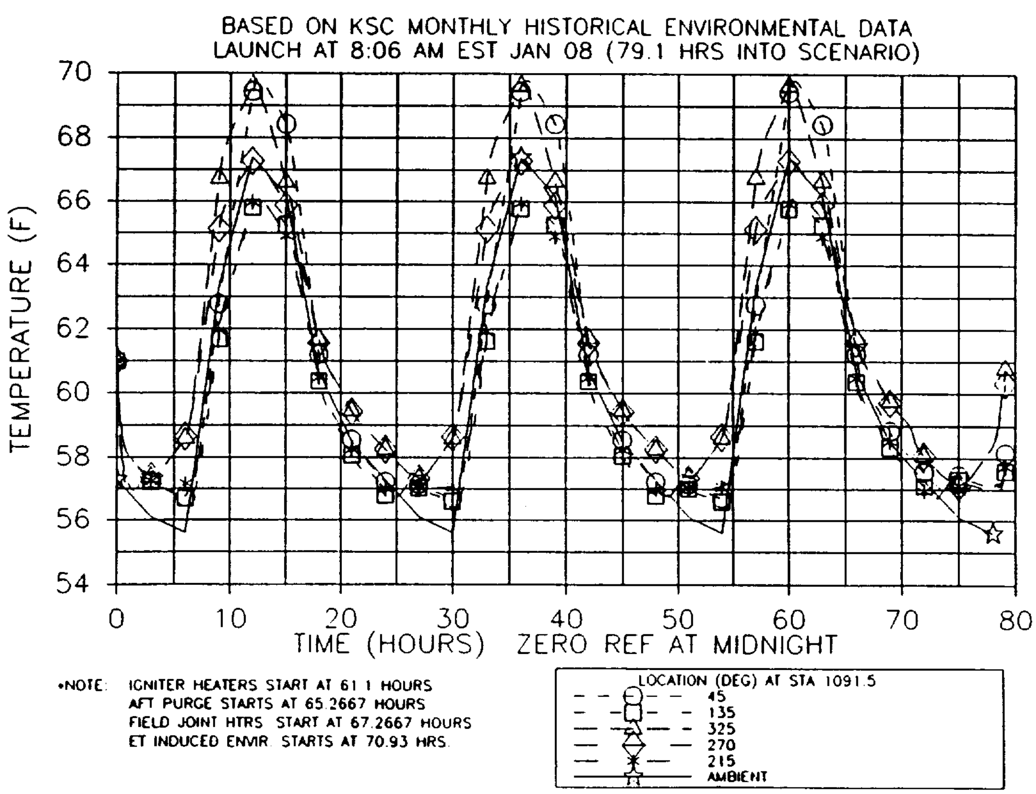


Figure 4.8-32. Left SRM Forward Center Case Acreage--GEI Sensor Temperature Prediction

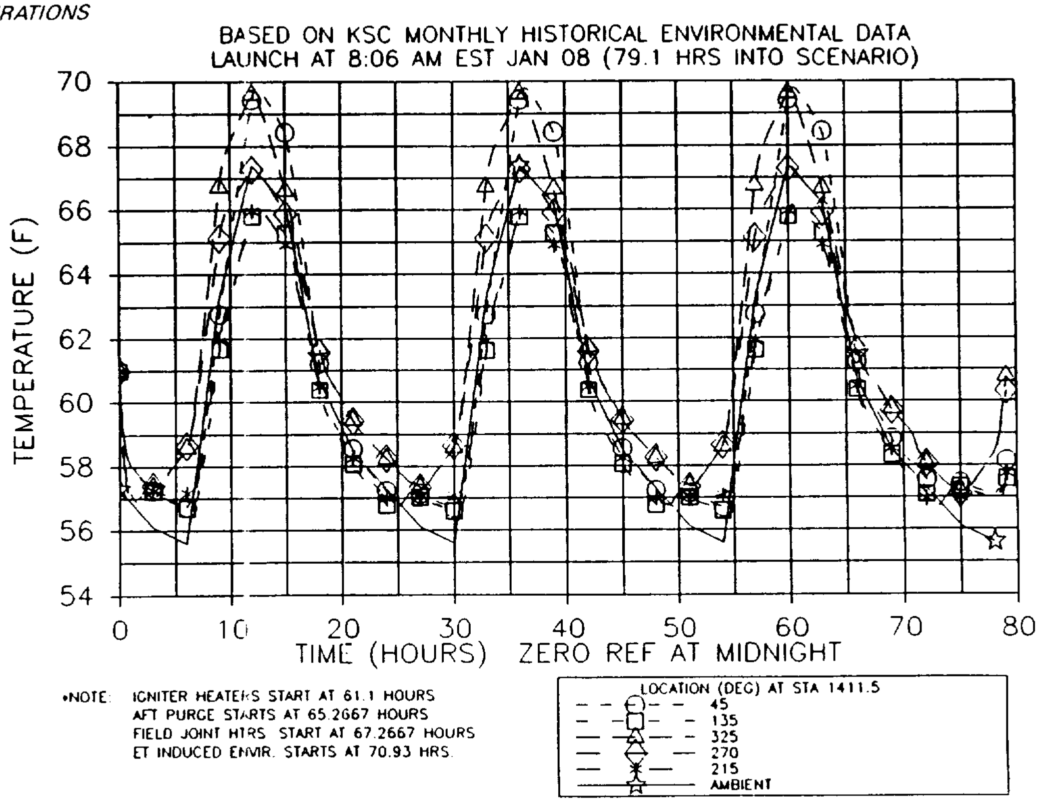


Figure 4.8-33. Left SRM Aft Center Case Acreage--GEI Sensor Temperature Prediction

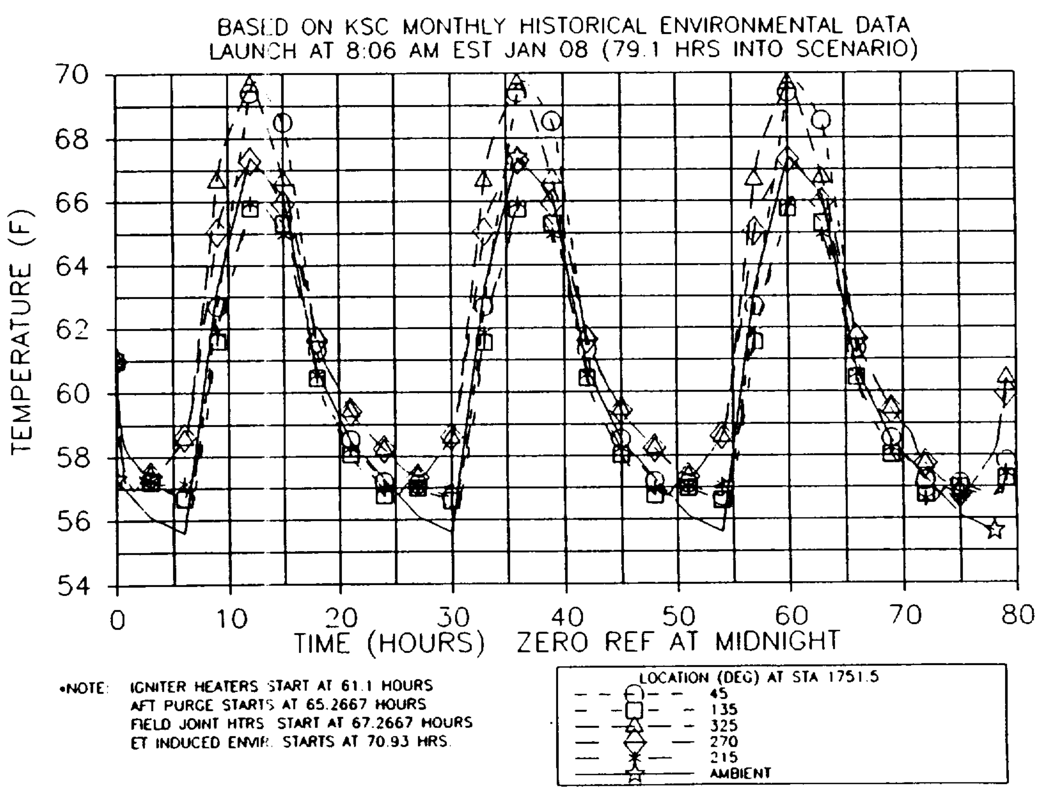


Figure 4.8-34. Left SRM Aft Case Acreage--GEI Sensor Temperature Prediction

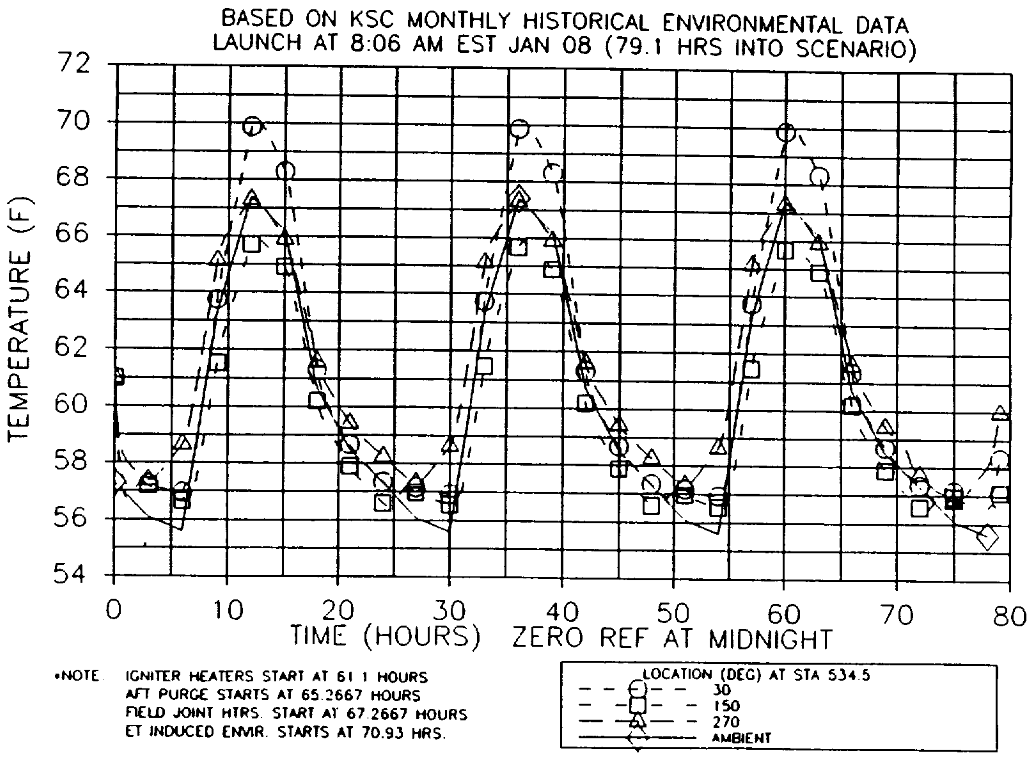


Figure 4.8-35. Left SRM Forward Dome Factory Joint--GEI Sensor Temperature Prediction

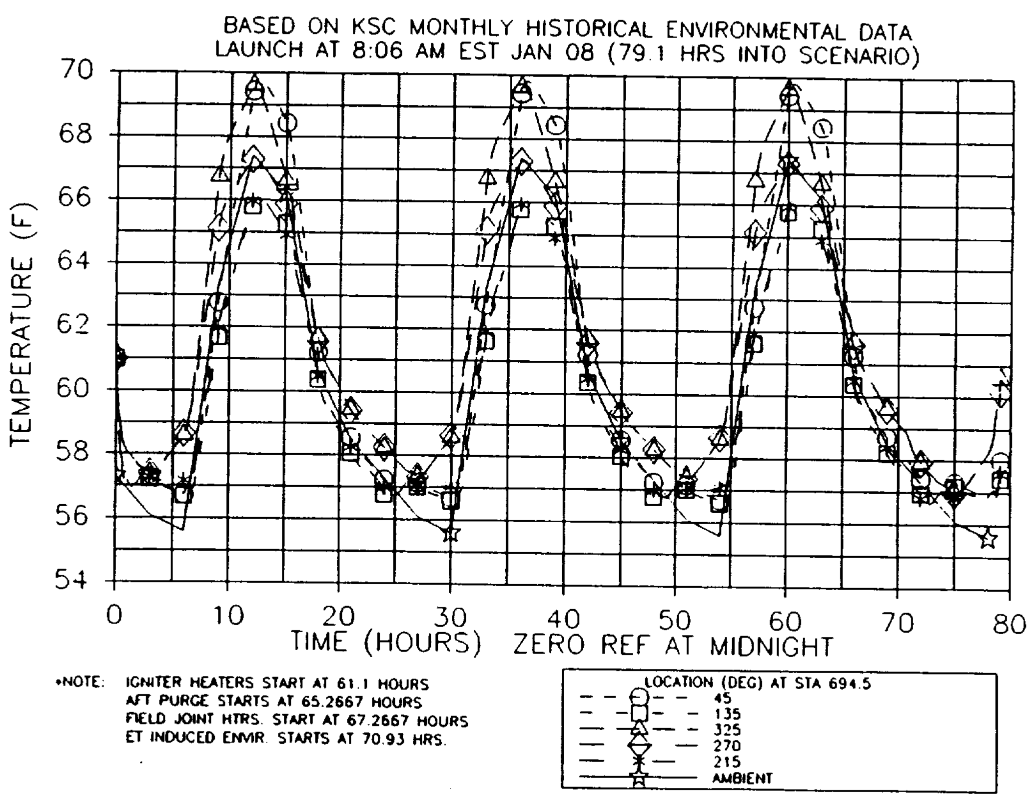


Figure 4.8-36. Left SRM Forward Factory Joint--GEI Sensor Temperature Prediction

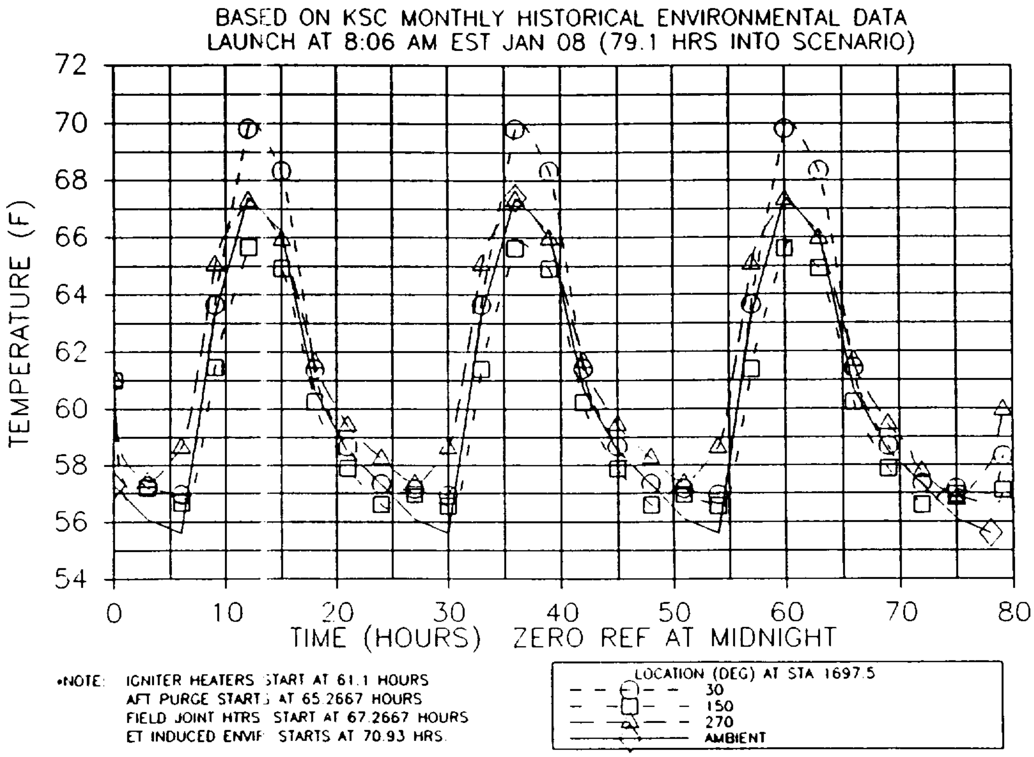


Figure 4.8-37. Left SRM Aft Factory Joint--GEI Sensor Temperature Prediction

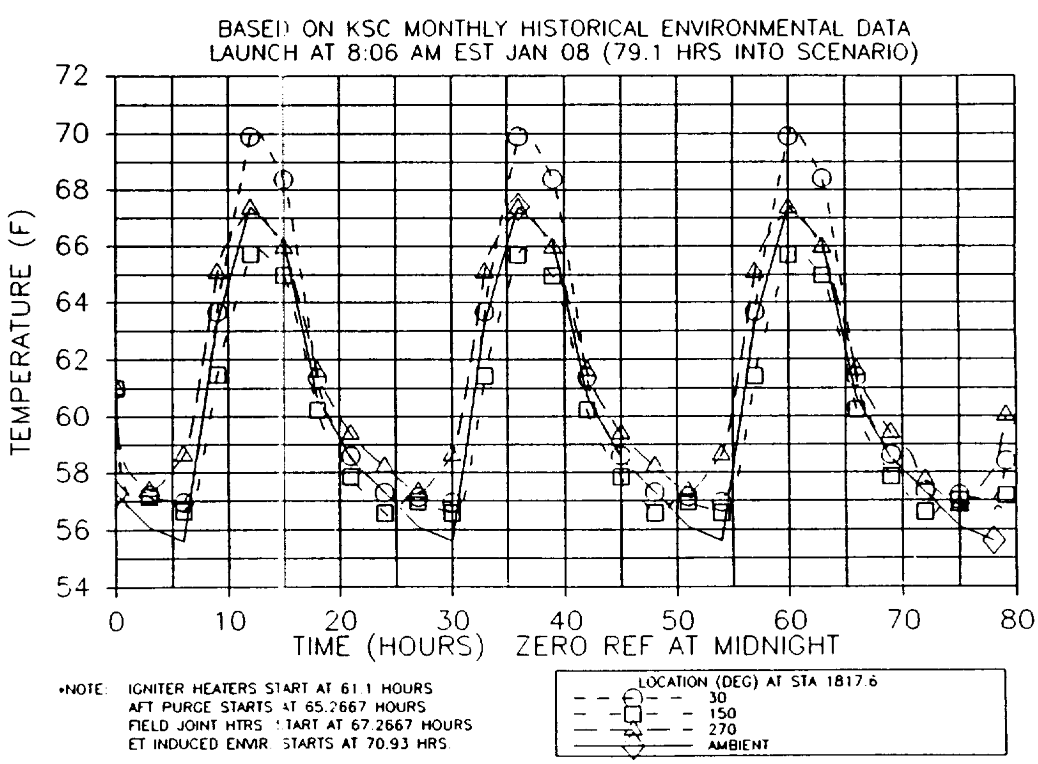


Figure 4.8-38. Left SRM Aft Dome Factory Joint--GEI Sensor Temperature Prediction

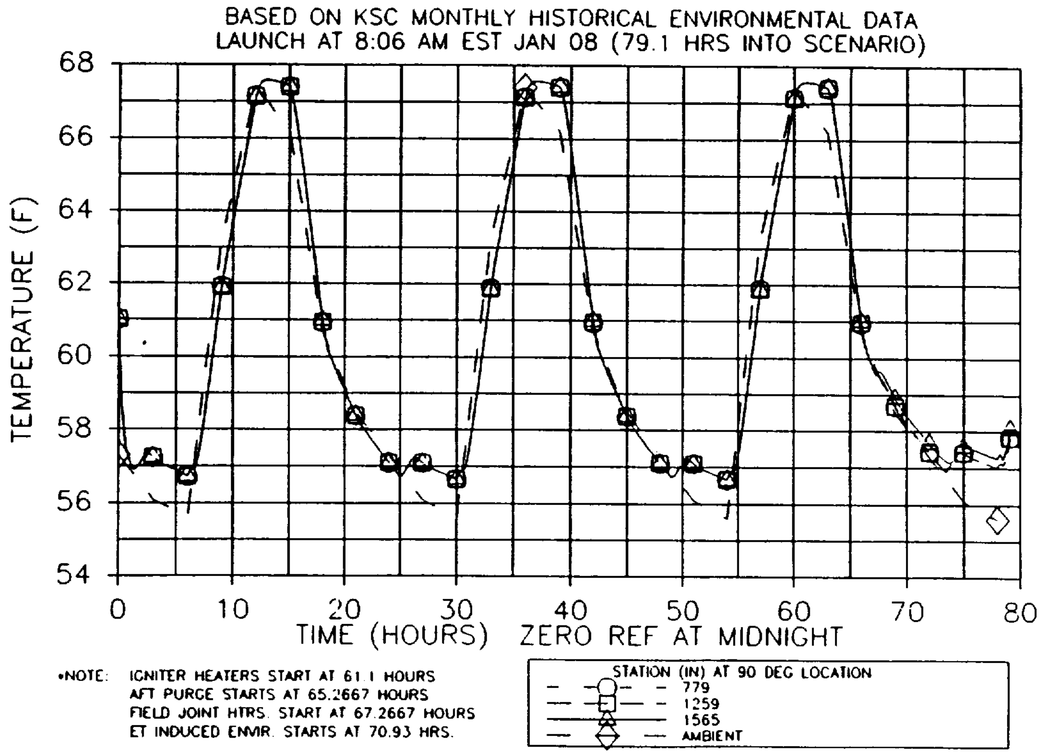


Figure 4.8-39. Left SRM Tunnel Bondline--GEI Sensor Temperature Prediction

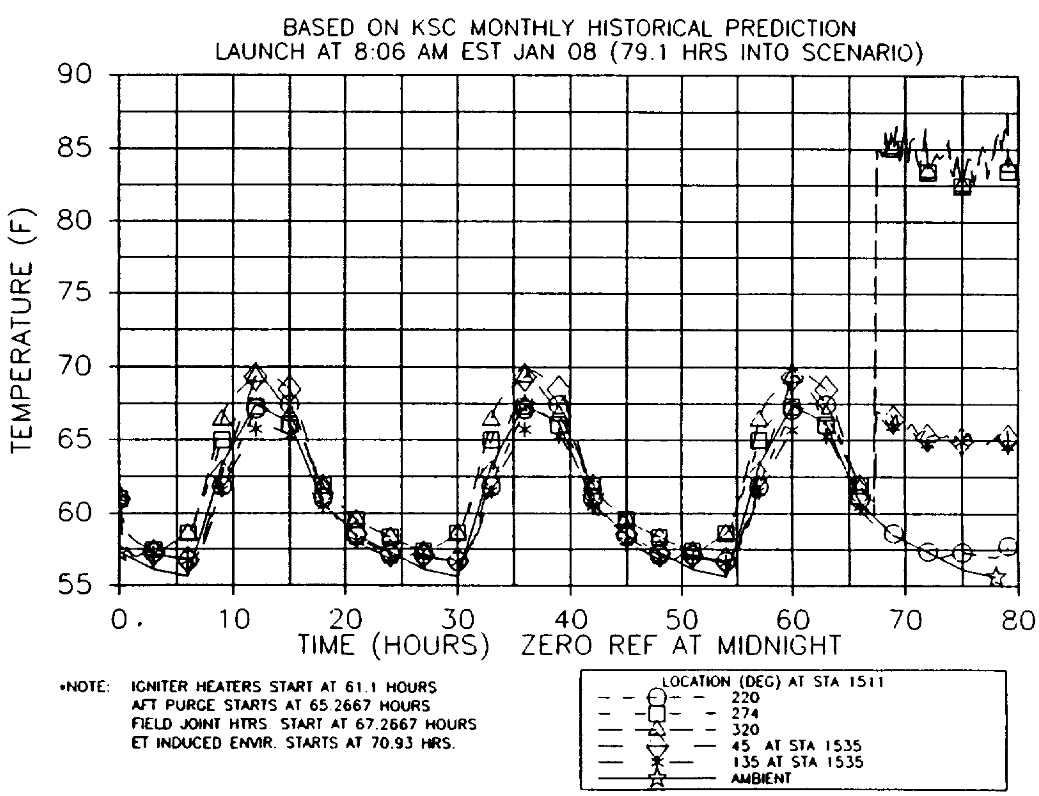


Figure 4.8-40. Left SRM ET Attach Region--GEI Sensor Temperature Prediction

Table 4.8-7. STS-32R Analytical Timeframes for Estimating Event Sequencing of January Historical Joint Heater and GEI Sensor Predictions

Time (hr)	Countdown Events in Analysis
0:01	12:01 a.m. KSC EST (6 Jan 1990)
61:35	Igniter joint heater operation begins on 8 Jan 1990 (L-18 hr)
66:15	Aft skirt conditioning operation begins on 8 Jan 1990 (T-13 hr 20 min)
68:15	Field joint heater operation begins on 8 Jan 1990 (L-11 hr 50 min)
71:25	Induced environments due to ET refrigeration effects begins on 8 Jan 1990 (approximately L-8 hr 10 min)
79:26	Igniter heaters shutoff on 9 Jan 1990 (T-9 min)
79:34	Field joint heaters shutoff on 9 Jan 1990 (T-9 min)
79:35	Assumed time of launch 22 Nov 1989 7:35 a.m. KSC EST

Figures 4.8-11 through 4.8-40 consist of a 3 day plus 8 hr scenario

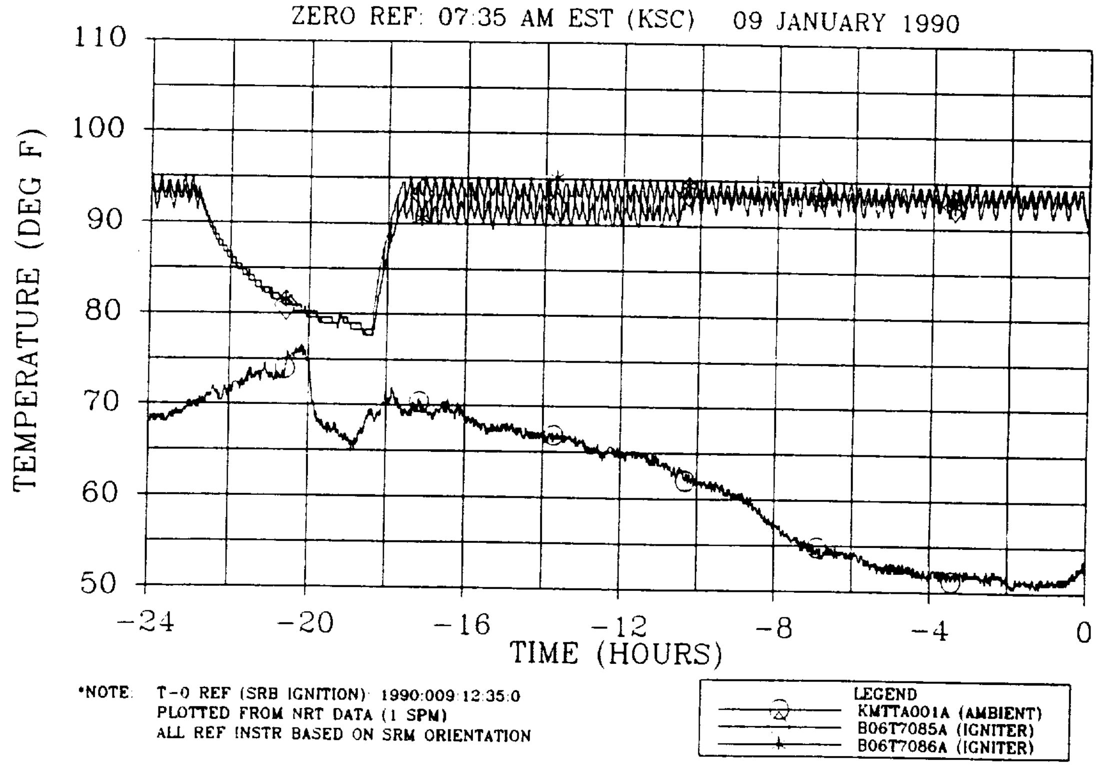


Figure 4.8-41. Left SRM Igniter Joint Temperatures Overlaid With Ambient

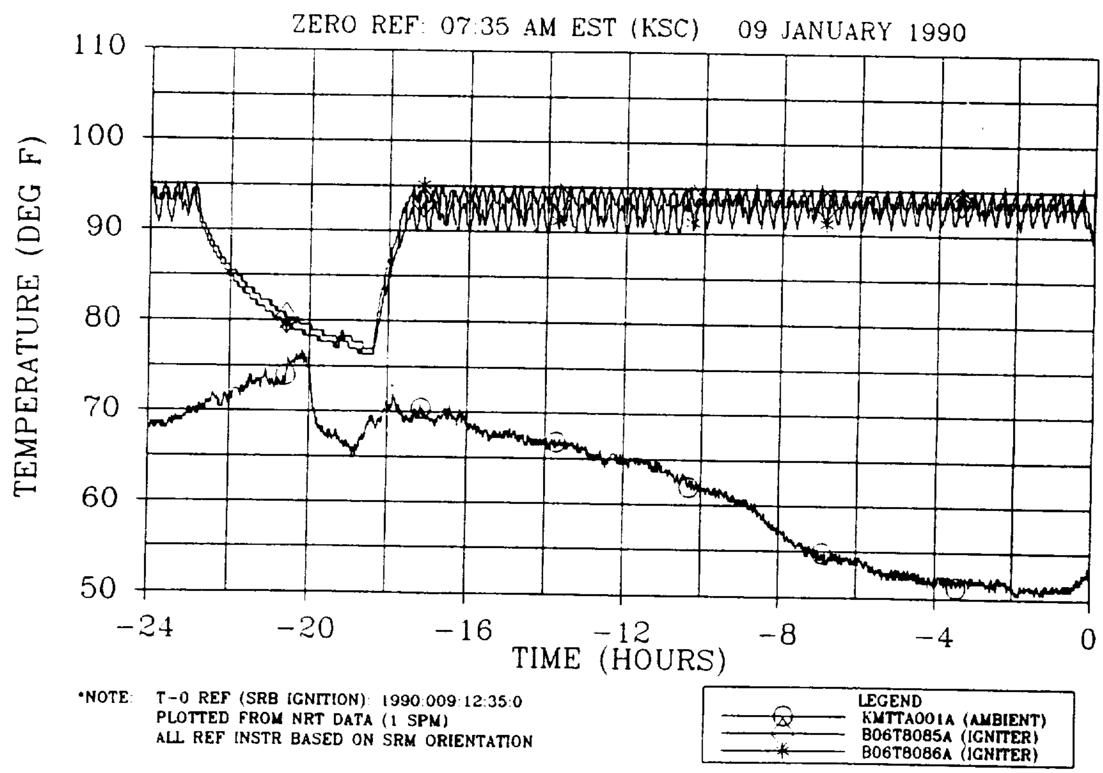


Figure 4.8-42. Right SRM Igniter Joint Temperatures Overlaid With Ambient

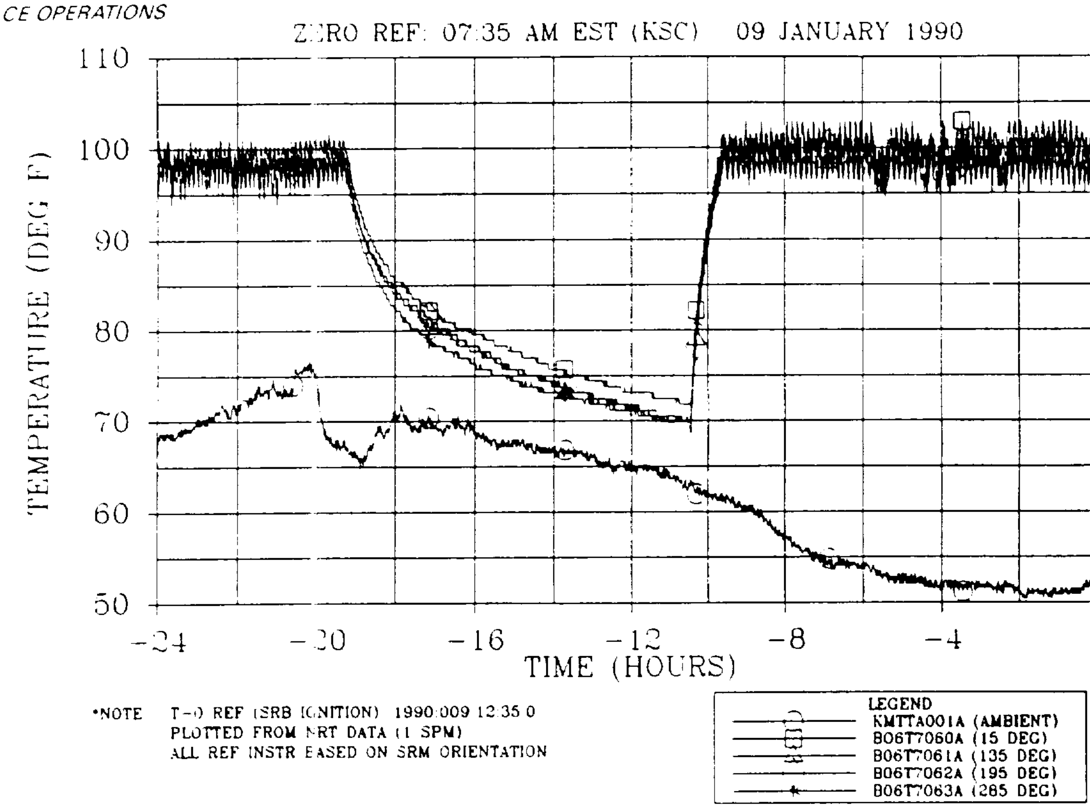


Figure 4.8-43. Left SRM Forward Field Joint Temperature Overlaid With Ambient

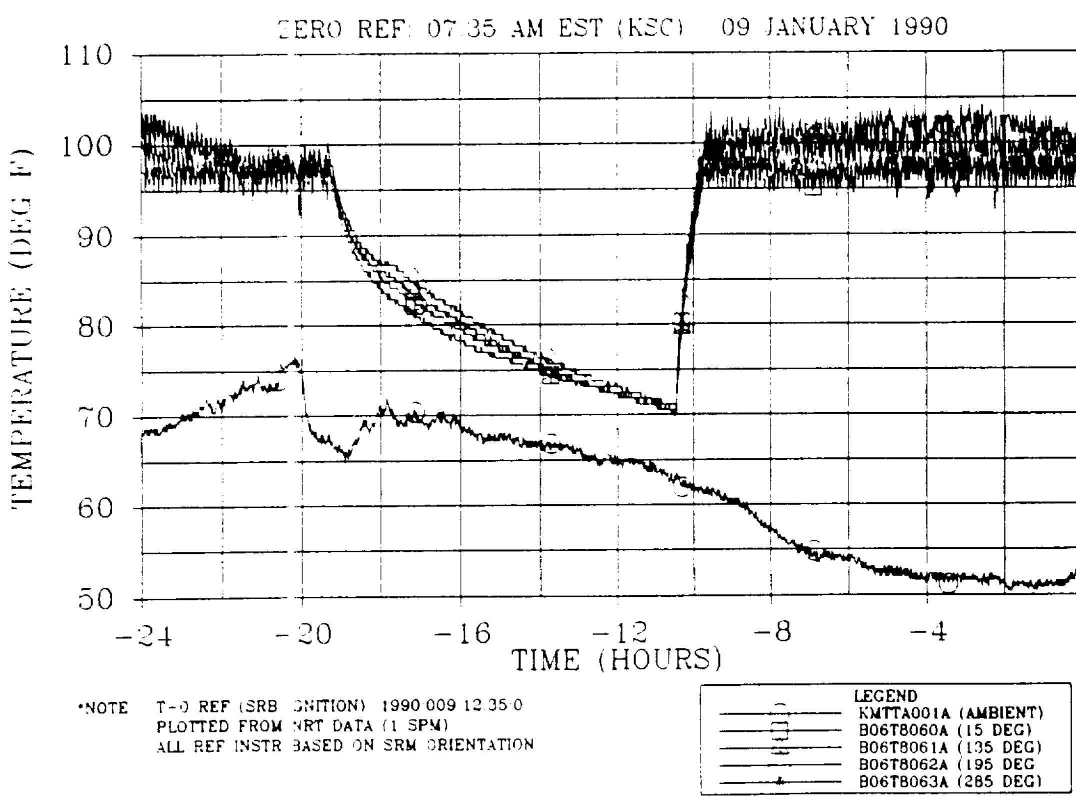


Figure 4.8-44. Right SRM Forward Field Joint Temperature Overlaid With Ambient

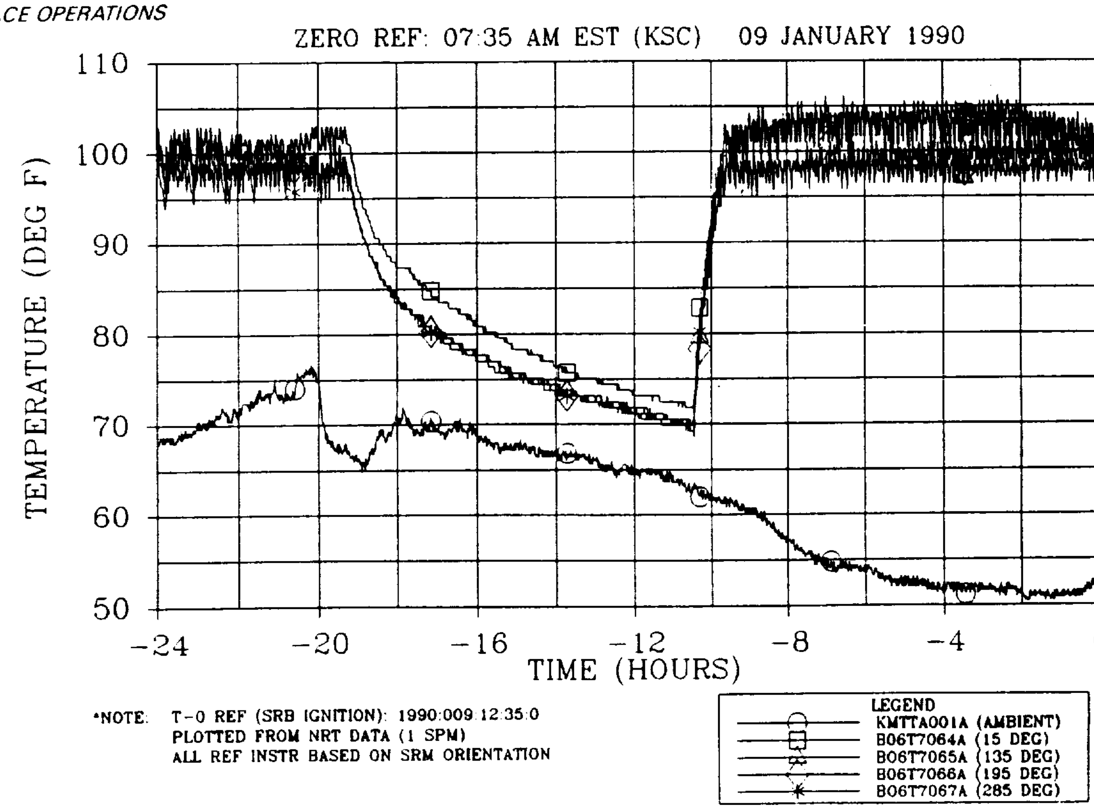


Figure 4.8-45. Left SRM Center Field Joint Temperature Overlaid With Ambient

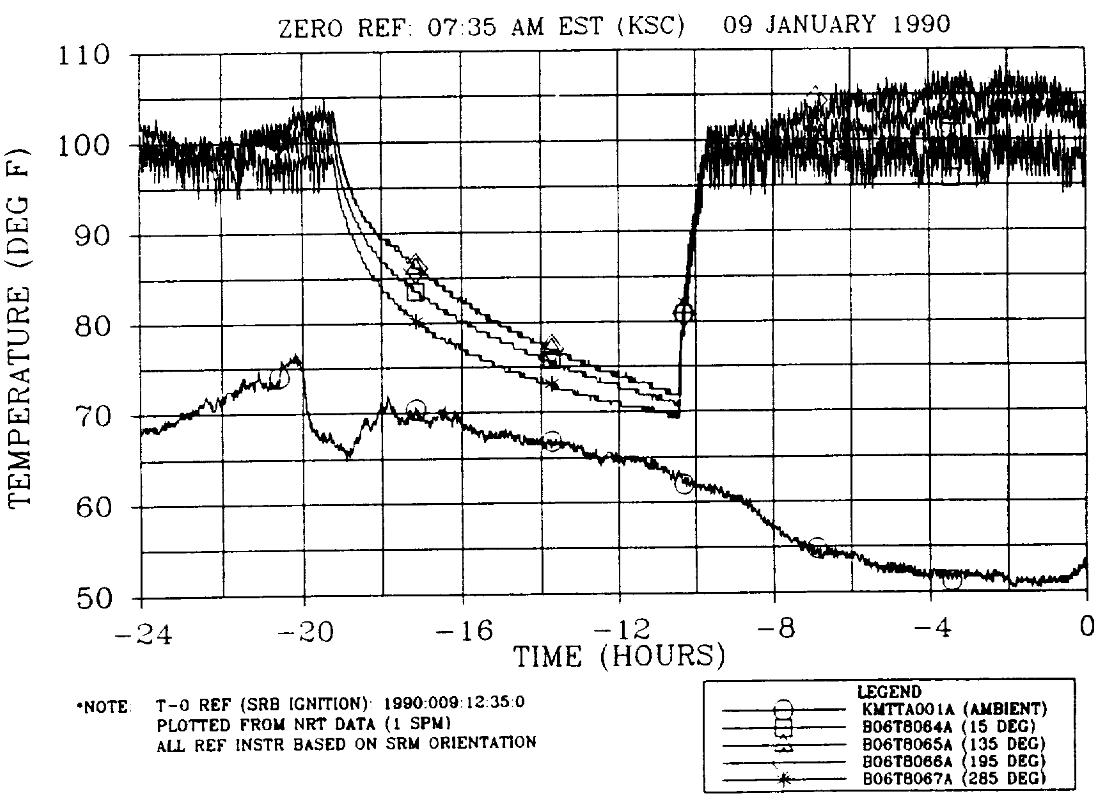


Figure 4.8-46. Right SRM Center Field Joint Temperature Overlaid With Ambient

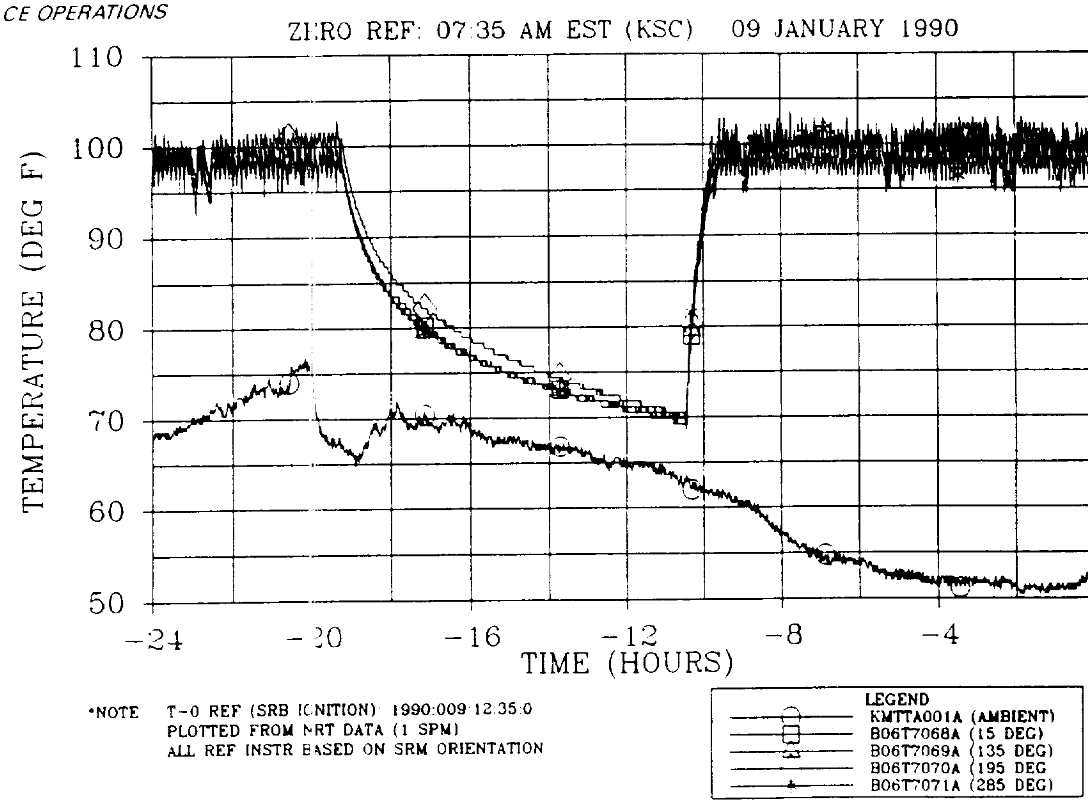


Figure 4.8-47. Left SRM Aft Field Joint Temperature Overlaid With Ambient

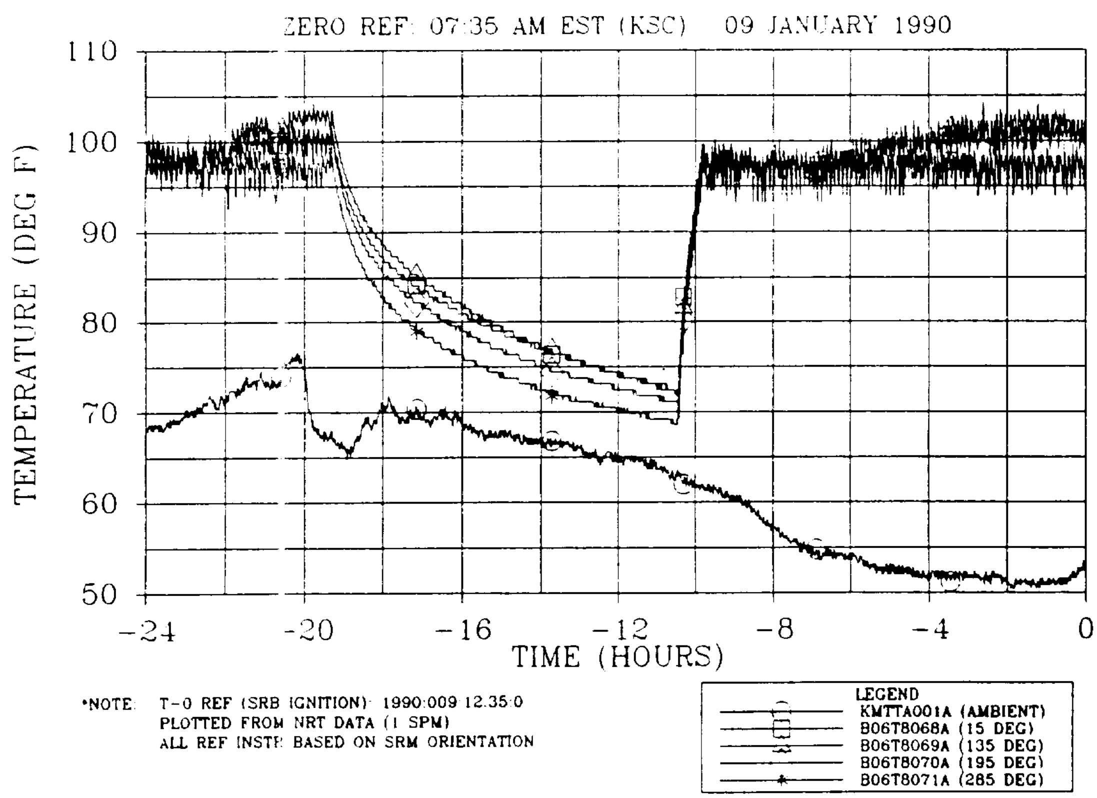


Figure 4.8-48. Right SRM Aft Field Joint Temperature Overlaid With Ambient

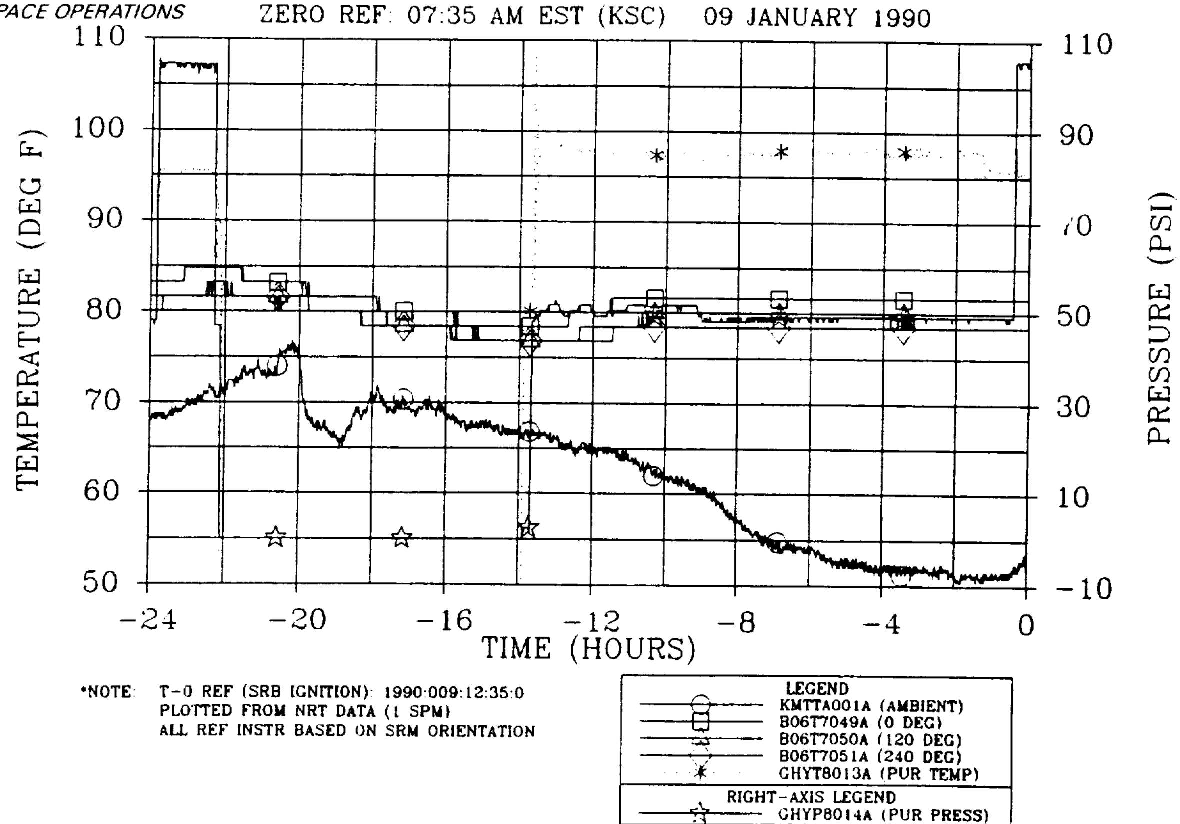


Figure 4.8-49. Left SRM Case-to-Nozzle Joint Temperature Overlaid With Ambient

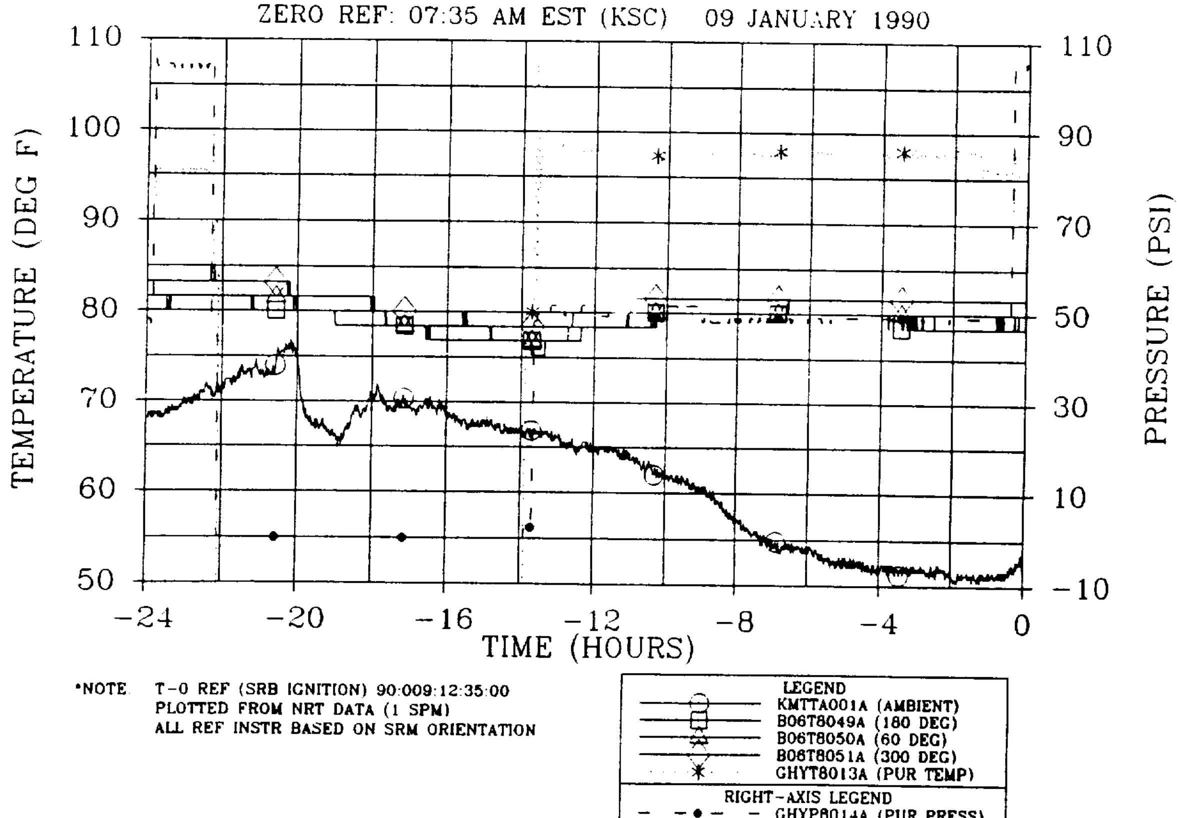


Figure 4.8-50. Right SRM Case-to-Nozzle Joint Temperature Overlaid With Ambient

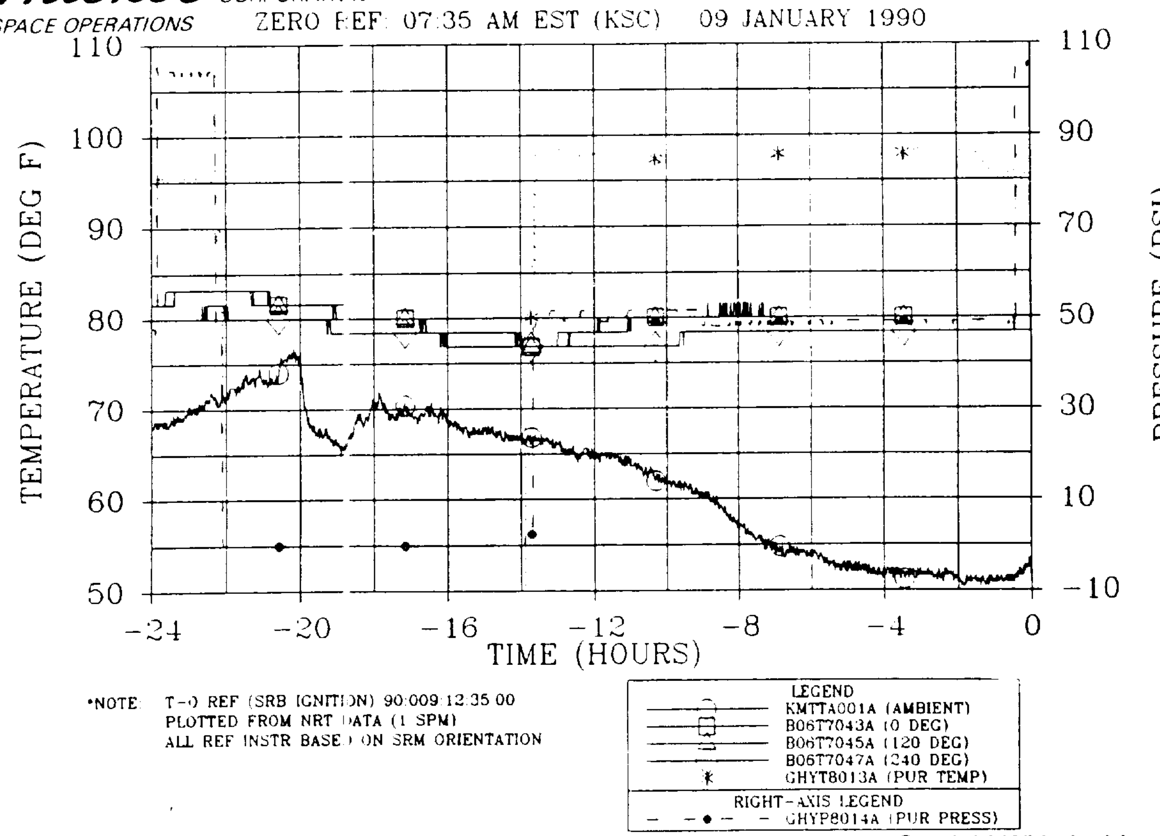


Figure 4.8-51. Left SRM Flex Bearing Aft End Ring Temperature Overlaid With Ambient

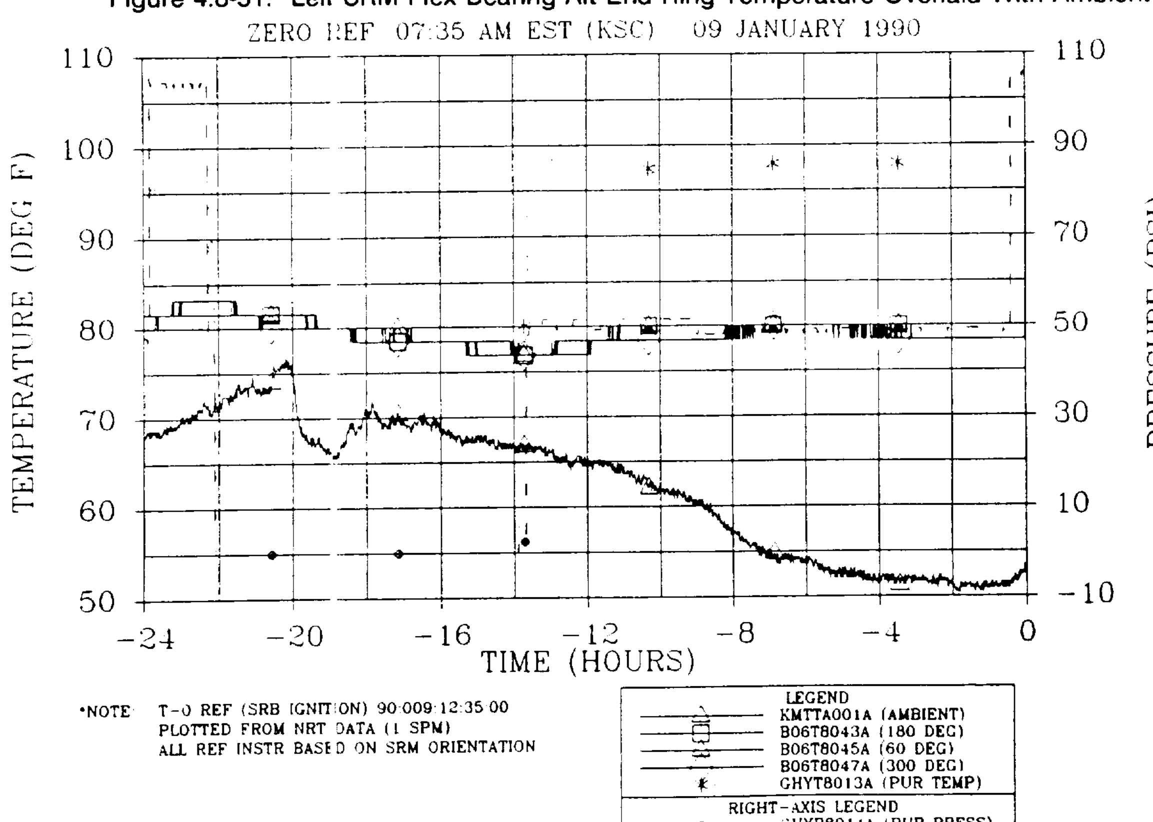


Figure 4.8-52. Right SRM Flex Bearing Aft End Ring Temperature Overlaid With Ambient

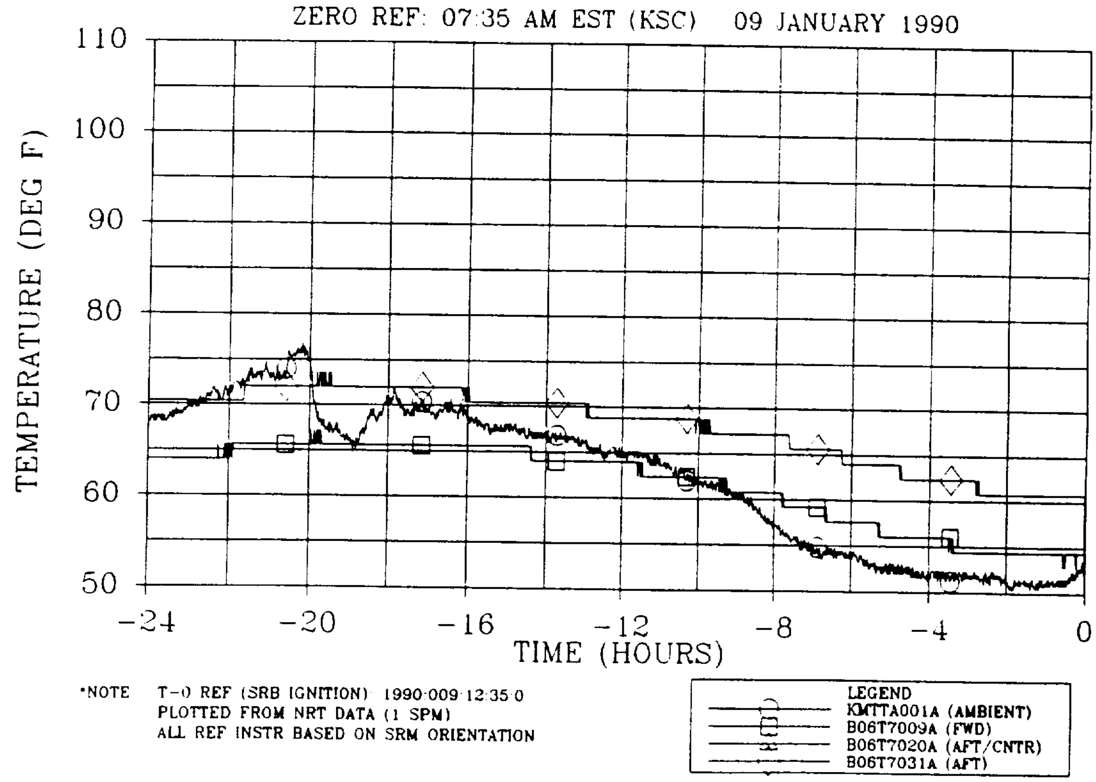


Figure 4.8-53. Left SRM Tunnel Bondline Temperature Overlaid With Ambient

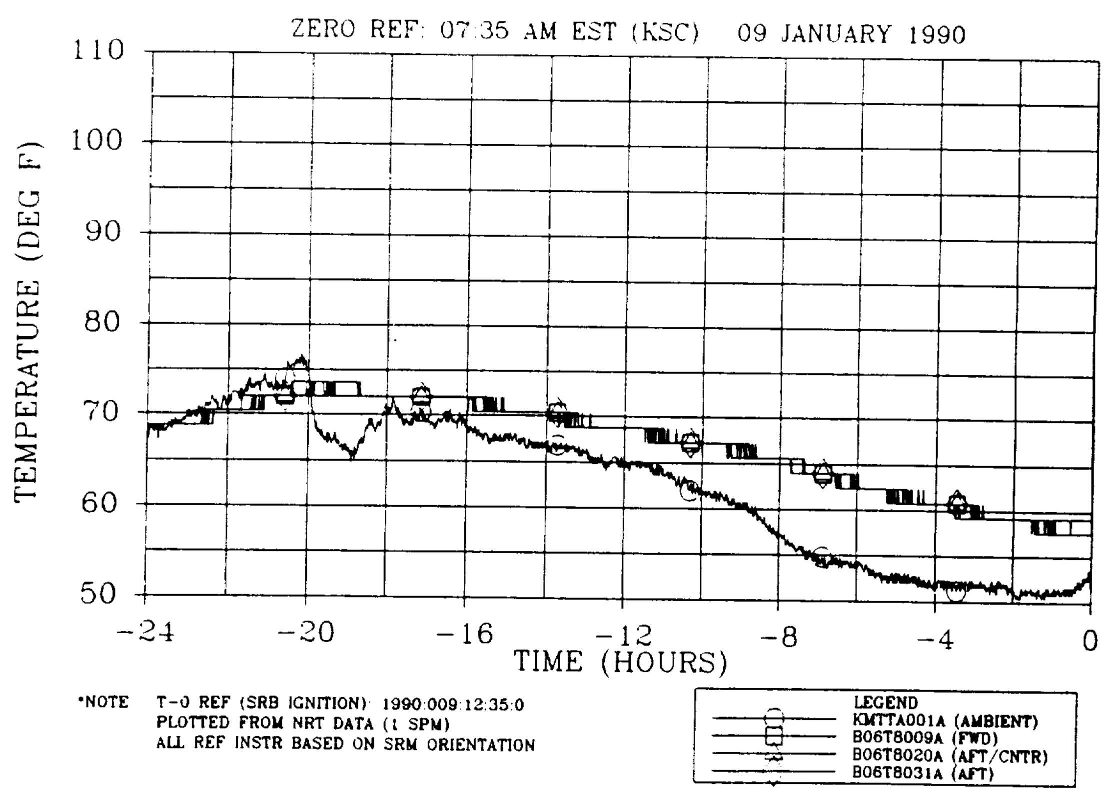


Figure 4.8-54. Right SRM Tunnel Bondline Temperature Overlaid With Ambient

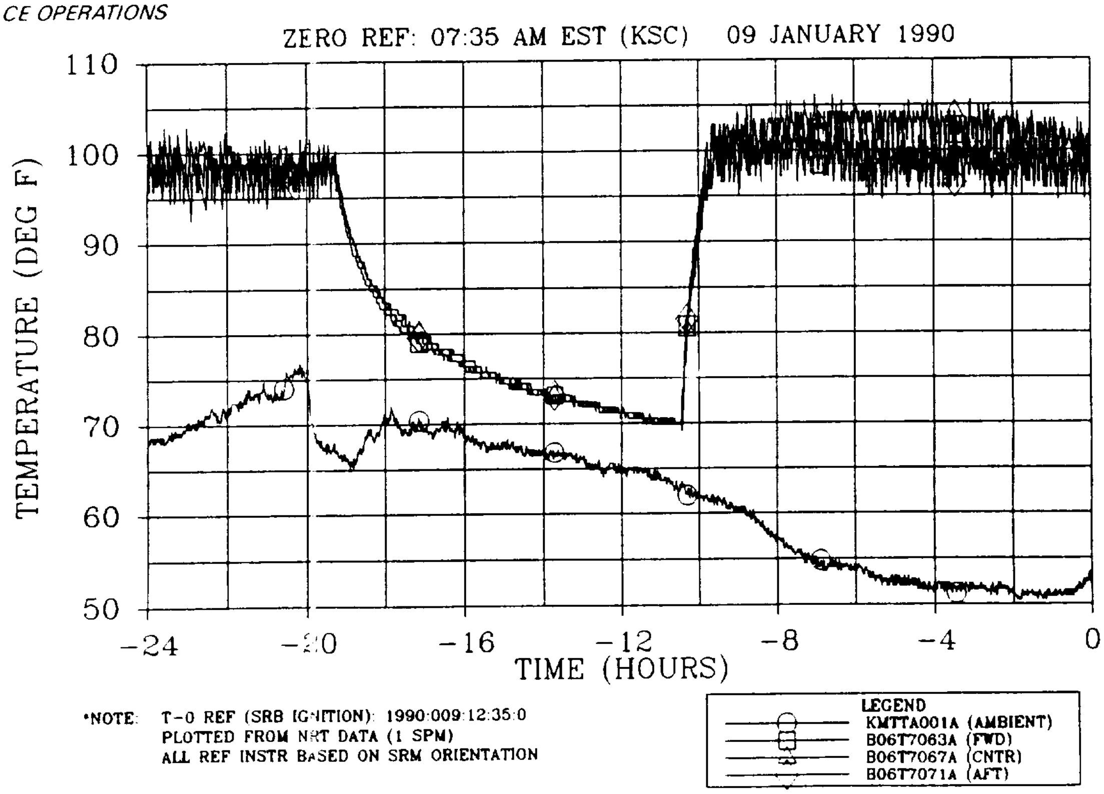


Figure 4.8-55. Left SRM Field Joint Temperature at 285-deg Location Overlaid With Ambient

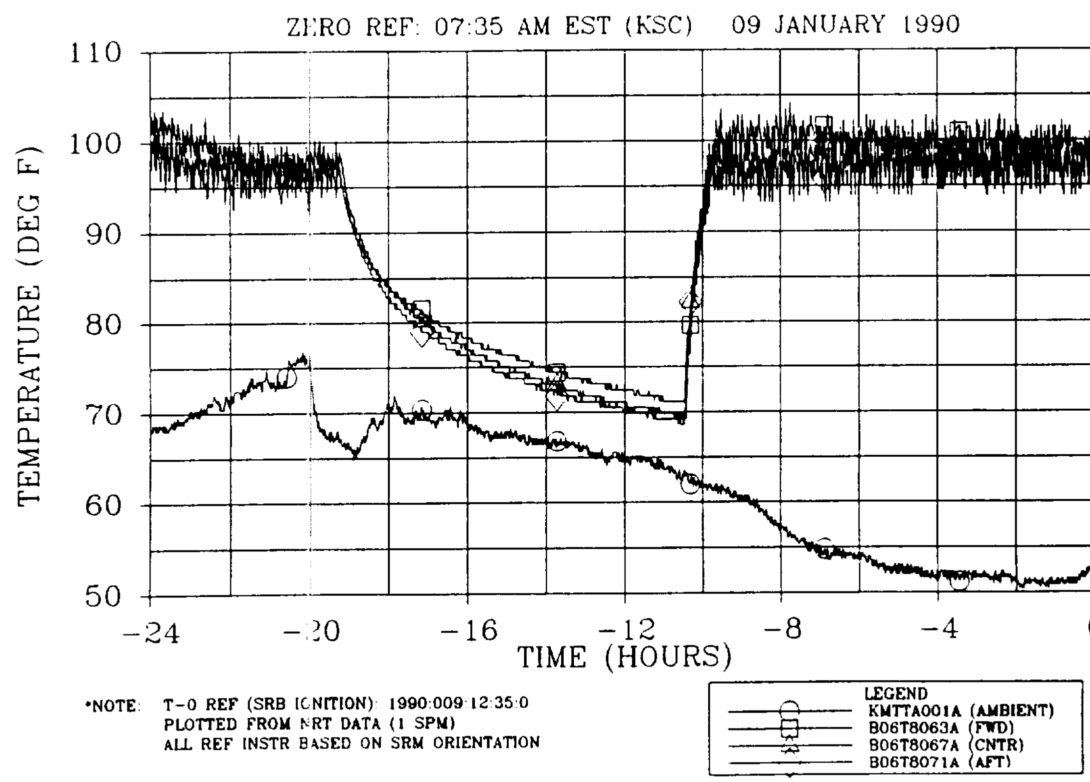


Figure 4.8-56. Right SRM Field Joint Temperature at 285-deg Location Overlaid With Ambient

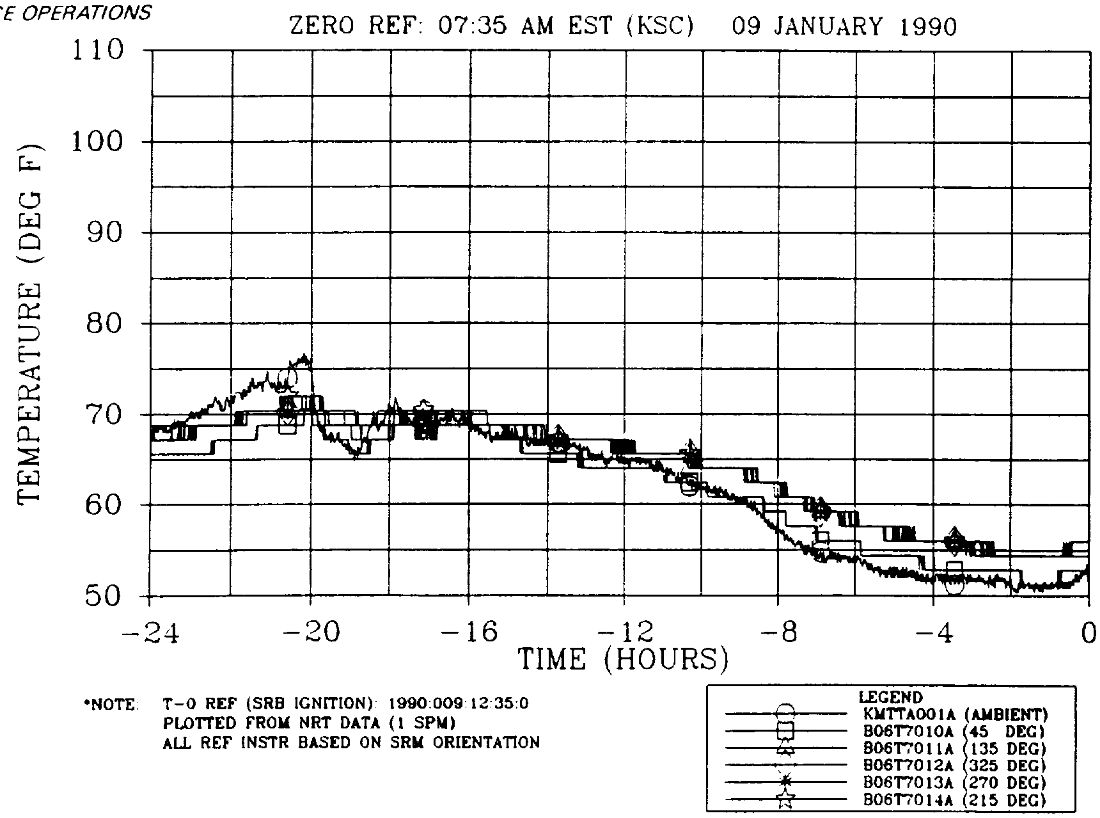


Figure 4.8-57. Left SRM Case Acreage Temperature at Station 931.5 Overlaid With Ambient

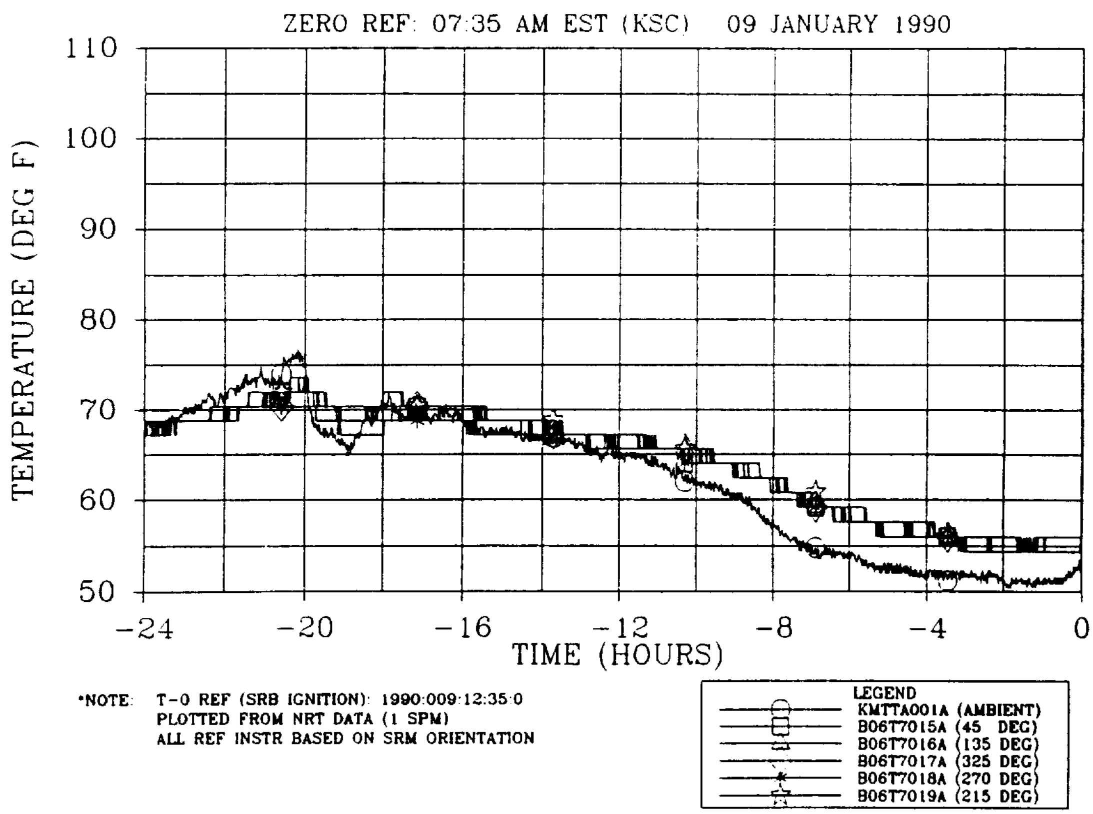


Figure 4.8-58. Left SRM Case Acreage Temperature at Station 1091.5 Overlaid With Ambient

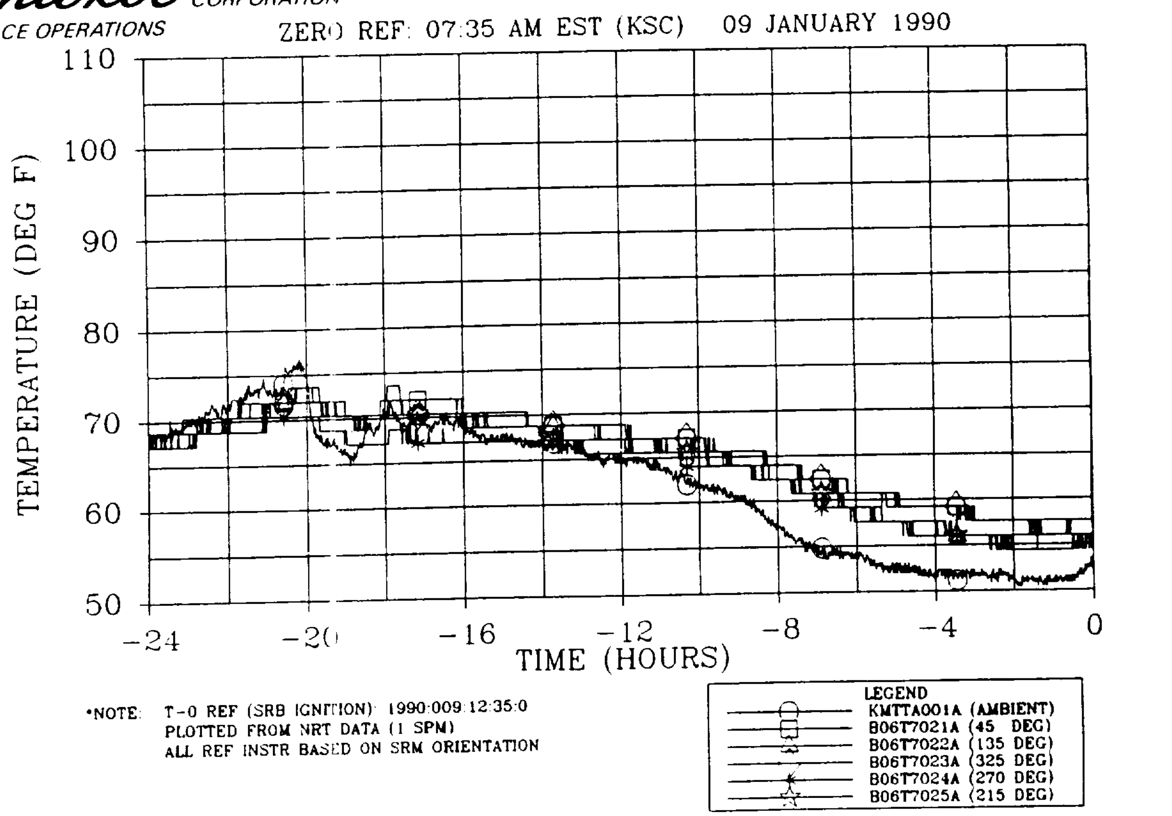


Figure 4.8-59. Left SRM Case Acreage Temperature at Station 1411.5 Overlaid With Ambient

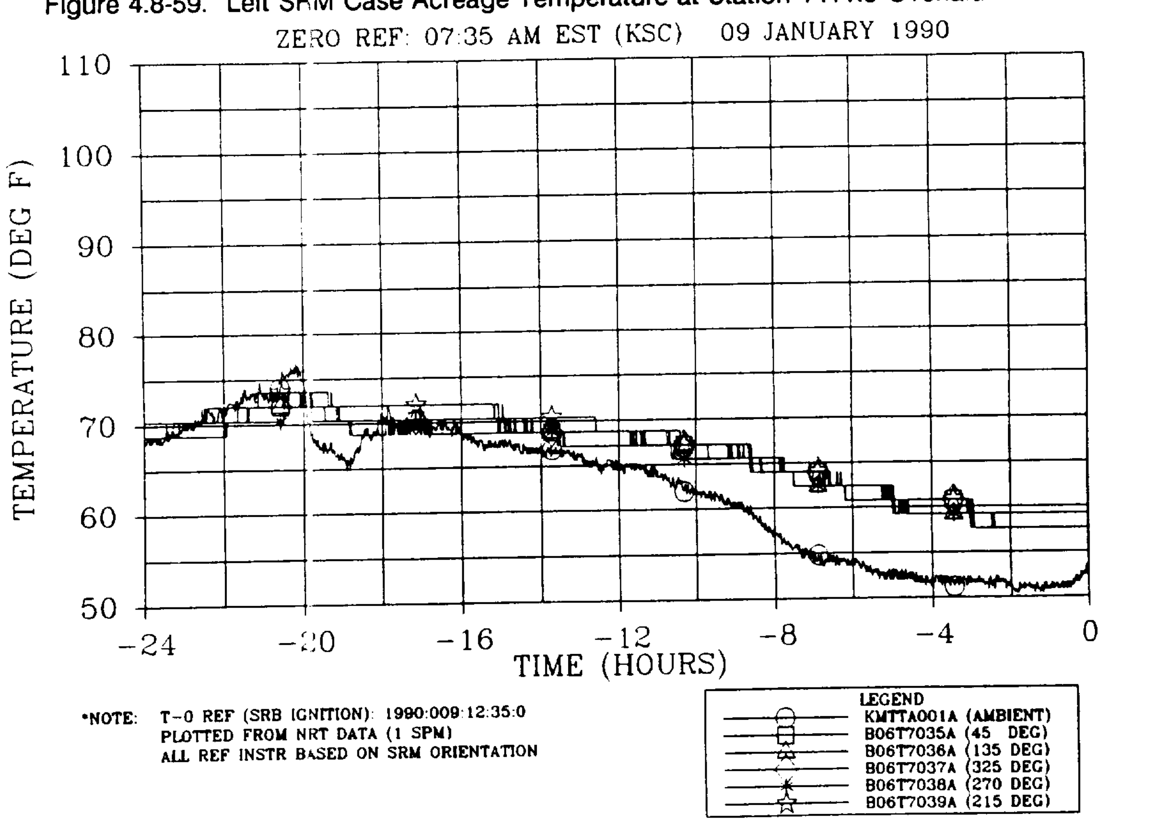


Figure 4.8-60. Left SRM Case Acreage Temperature at Station 1751.5 Overlaid With Ambient

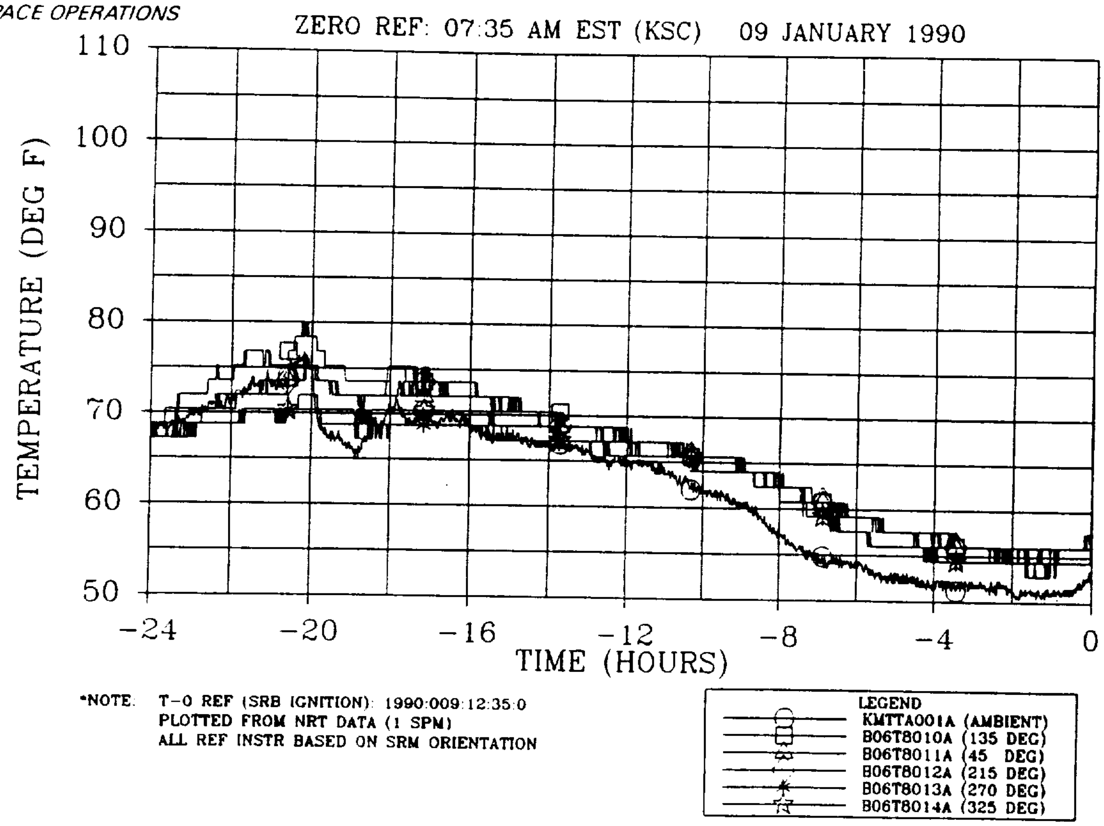


Figure 4.8-61. Right SRM Case Acreage Temperature at Station 931.5 Overlaid With Ambient

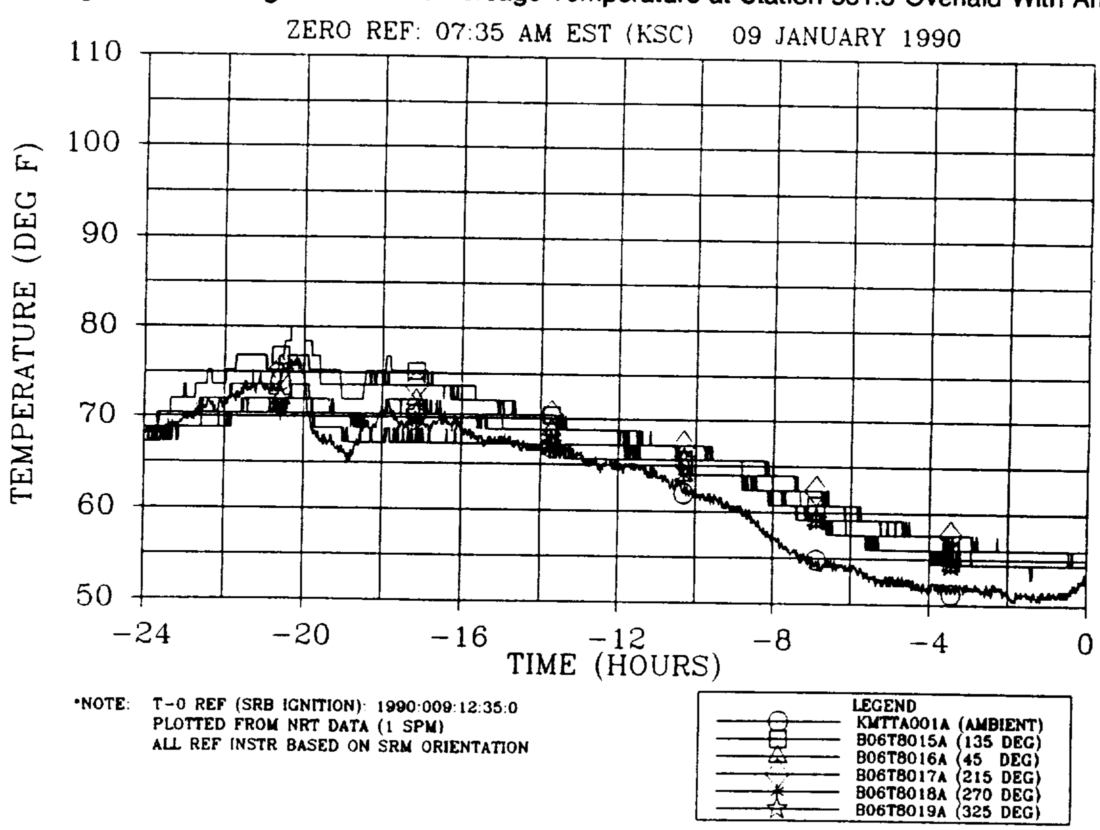


Figure 4.8-62. Right SRM Case Acreage Temperature at Station 1091.5 Overlaid With Ambient

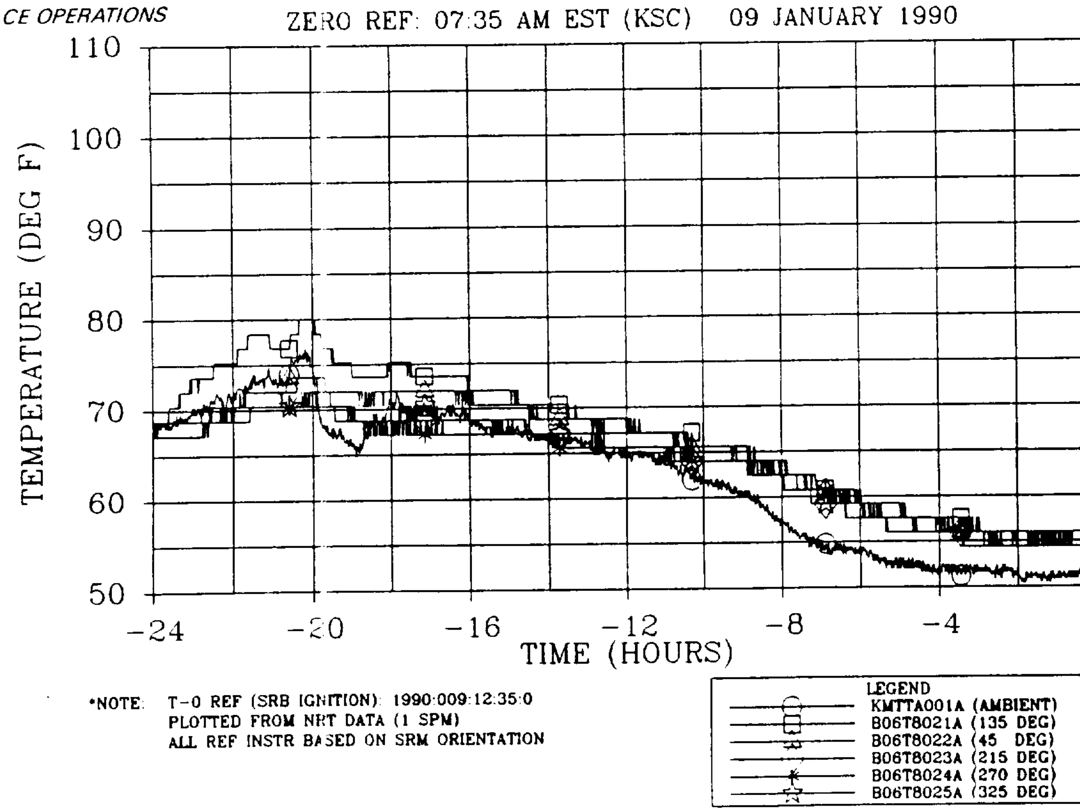


Figure 4.8-63. Right SRM Case Acreage Temperature at Station 1411.5 Overlaid With Ambient

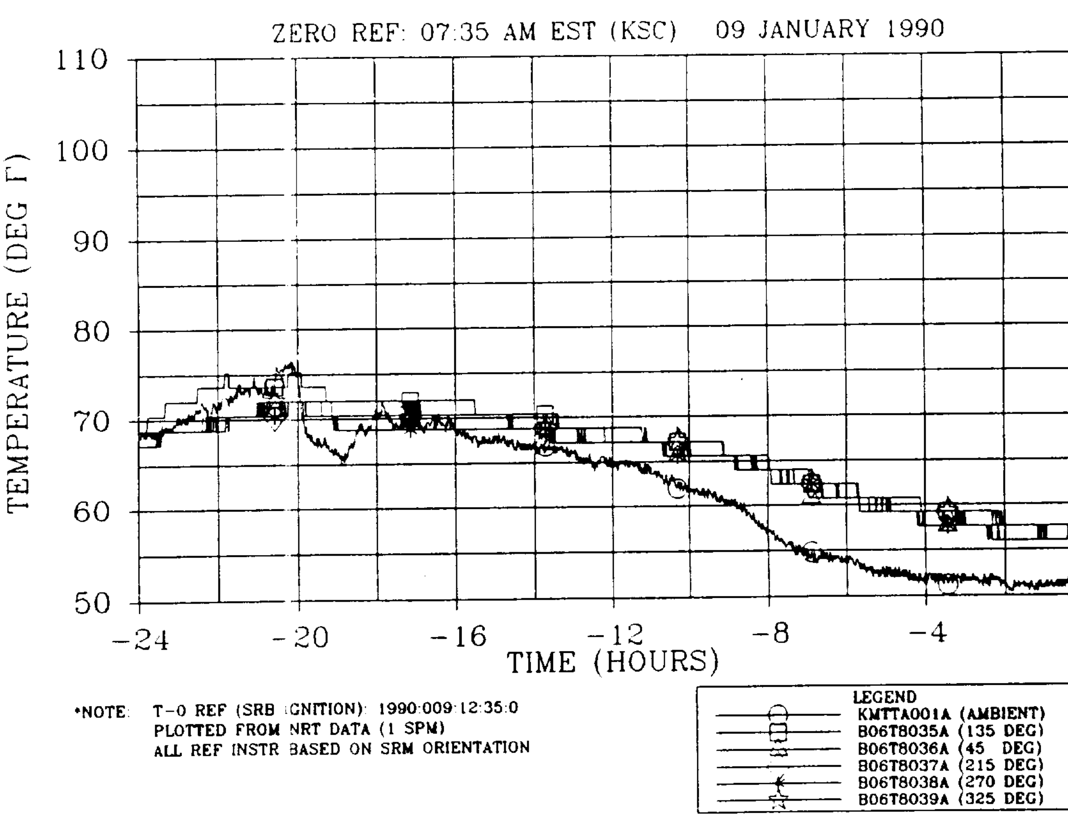


Figure 4.8-64. Right SRM Case Acreage Temperature at Station 1751.5 Overlaid With Ambient

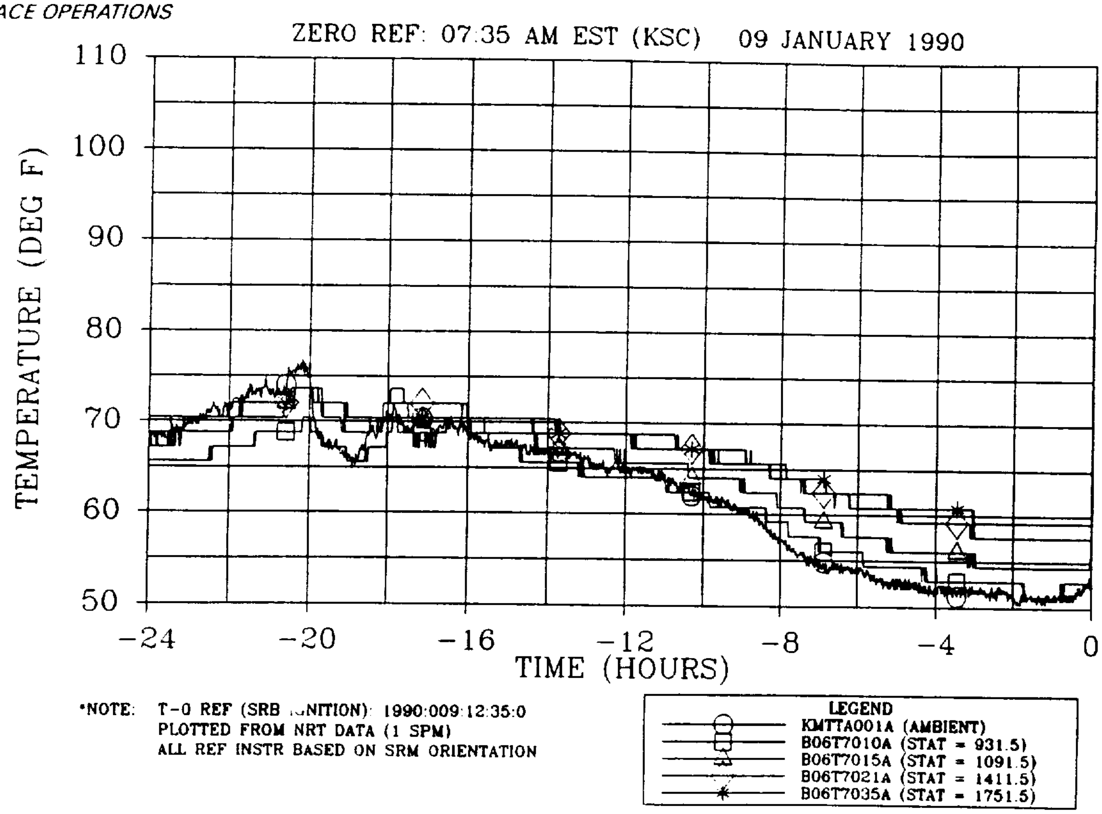


Figure 4.8-65. Left SRM Case Acreage Temperature at 45-deg Location Overlaid With Ambient

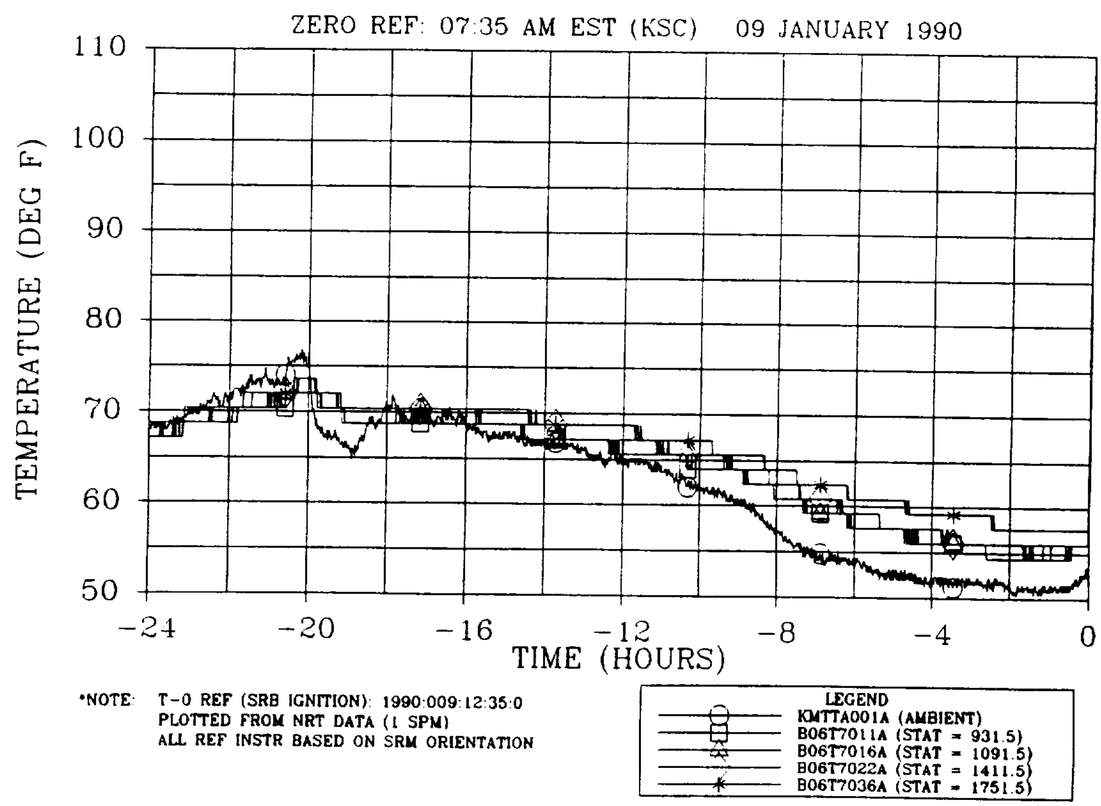


Figure 4.8-66. Left SRM Case Acreage Temperature at 135-deg Location Overlaid With Ambient

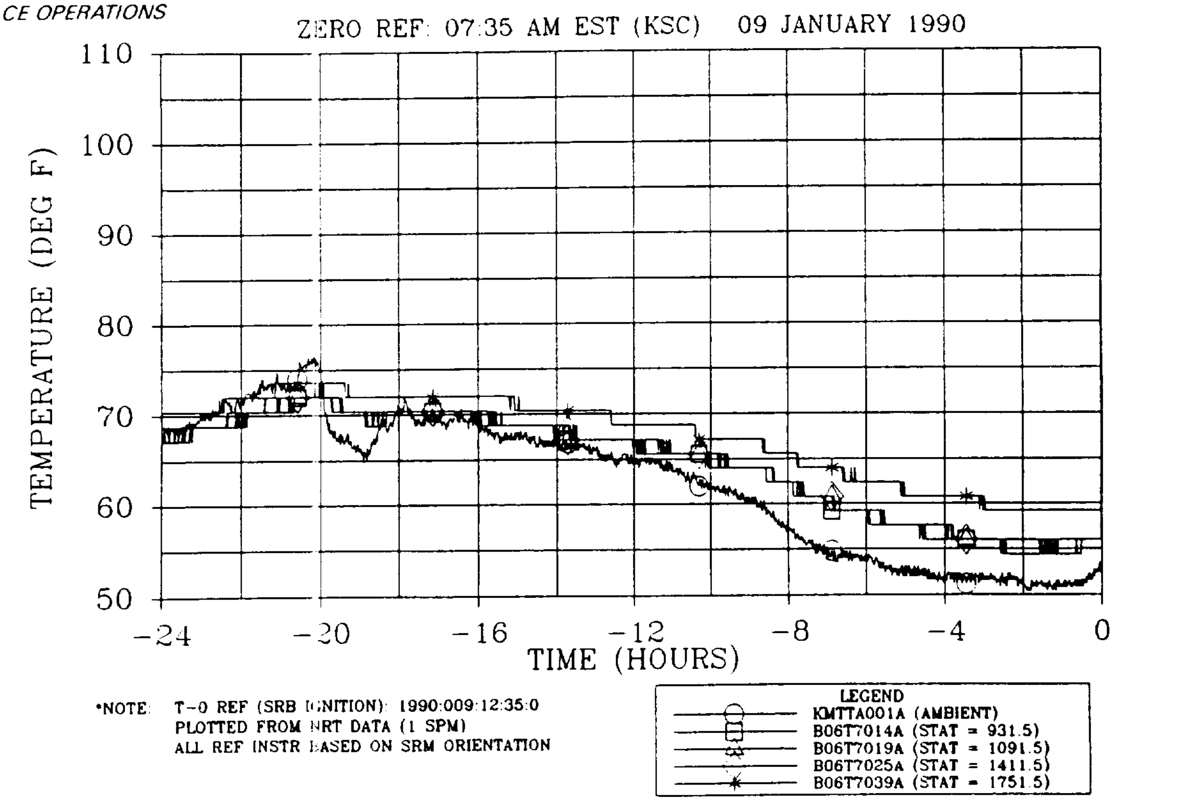


Figure 4.8-67. Left SRM Case Acreage Temperature at 215-deg Location Overlaid With Ambient

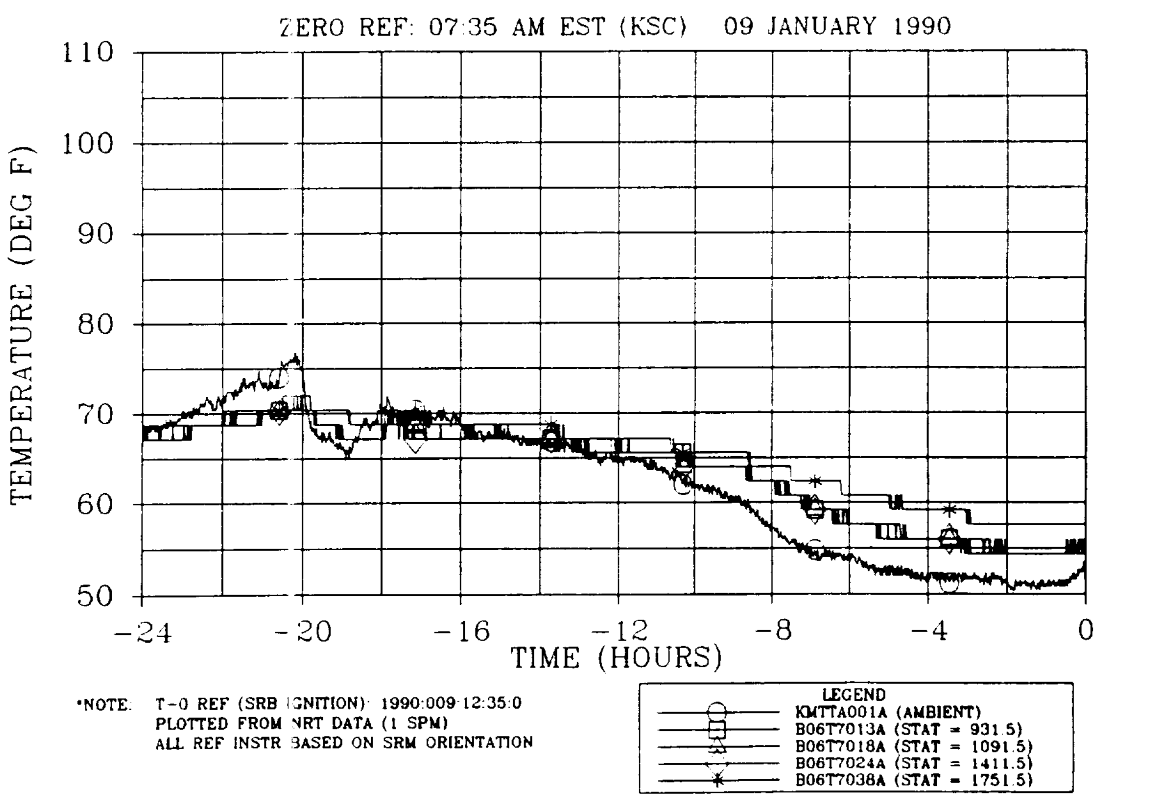


Figure 4.8-68. Left SRM Case Acreage Temperature at 270-deg Location Overlaid With Ambient

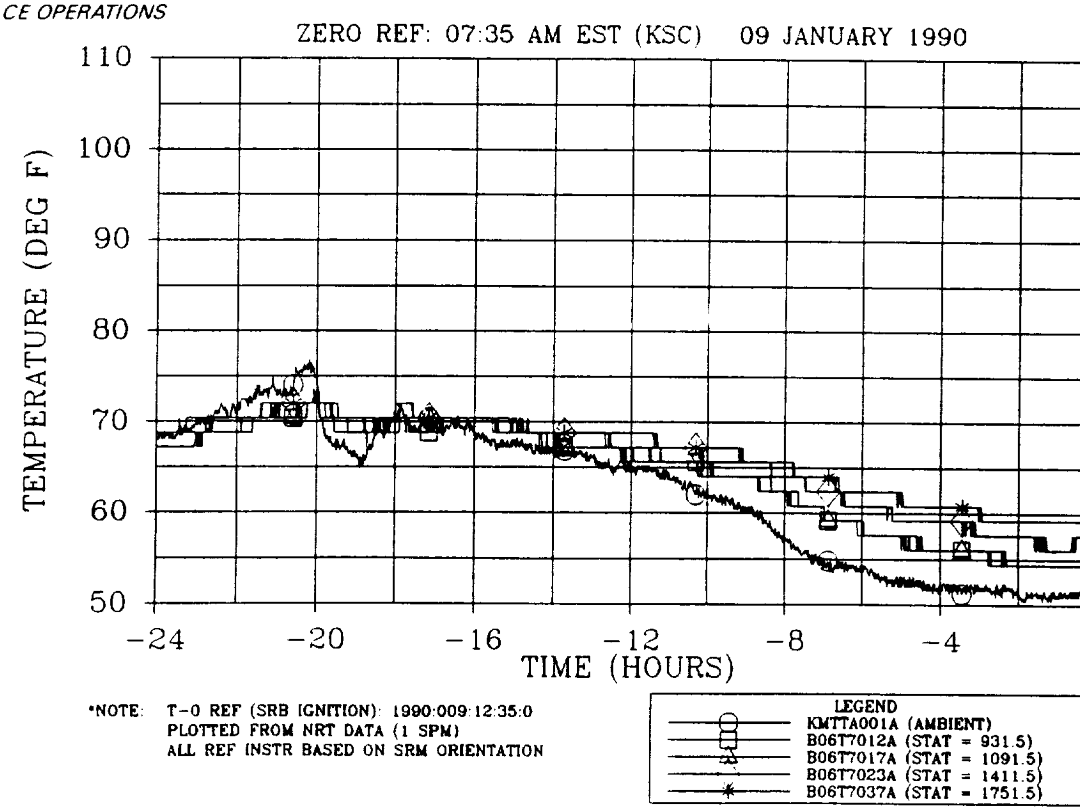


Figure 4.8-69. Left SRM Case Acreage Temperature at 325-deg Location Overlaid With Ambient

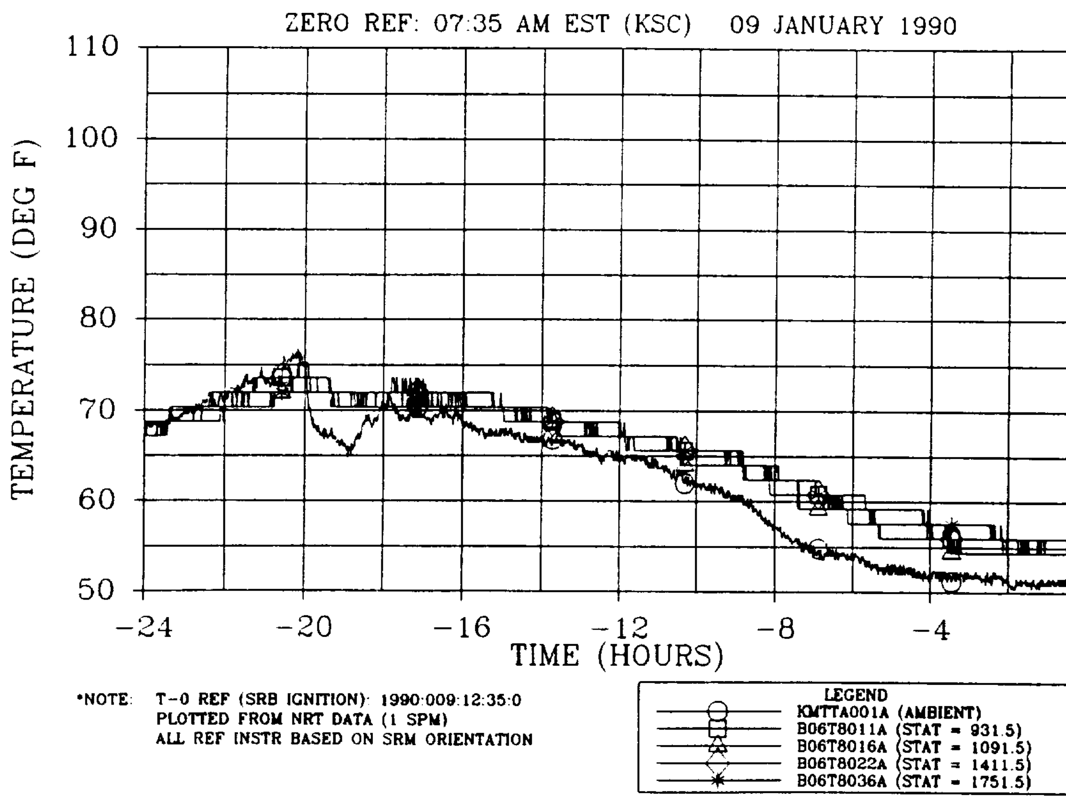


Figure 4.8-70. Right SRM Case Acreage Temperature at 45-deg Location Overlaid With Ambient

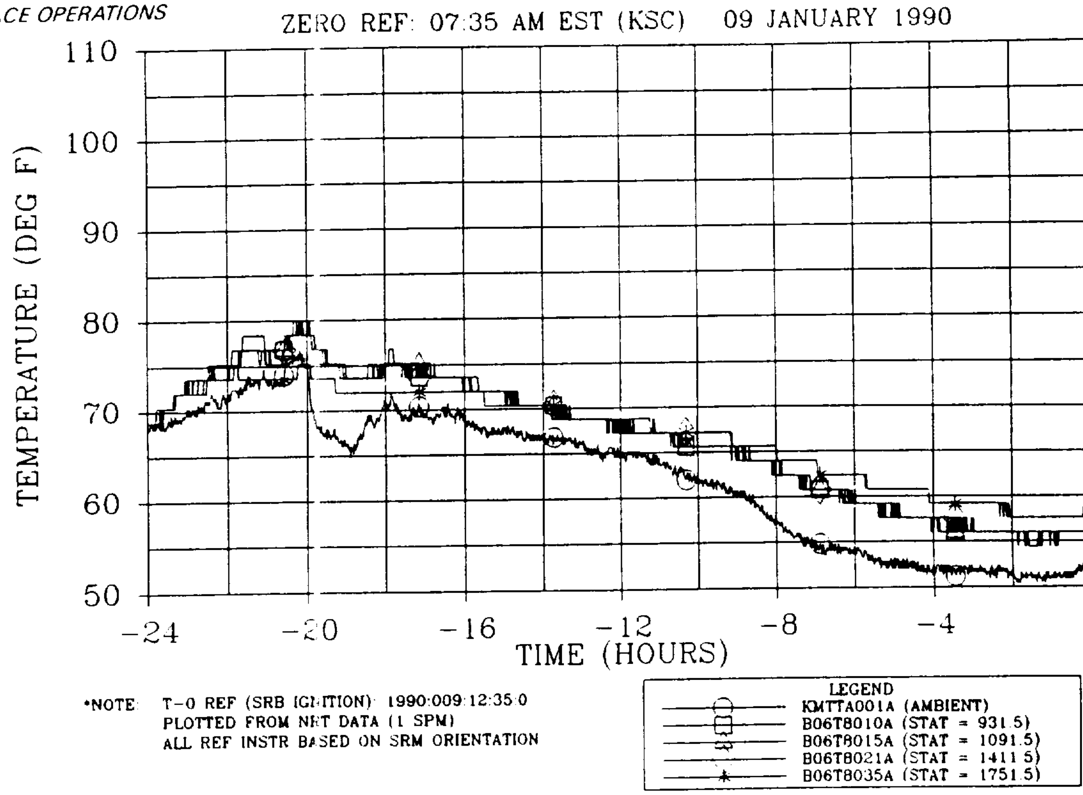


Figure 4.8-71. Right SRM Case Acreage Temperature at 135-deg Location Overlaid With Ambient

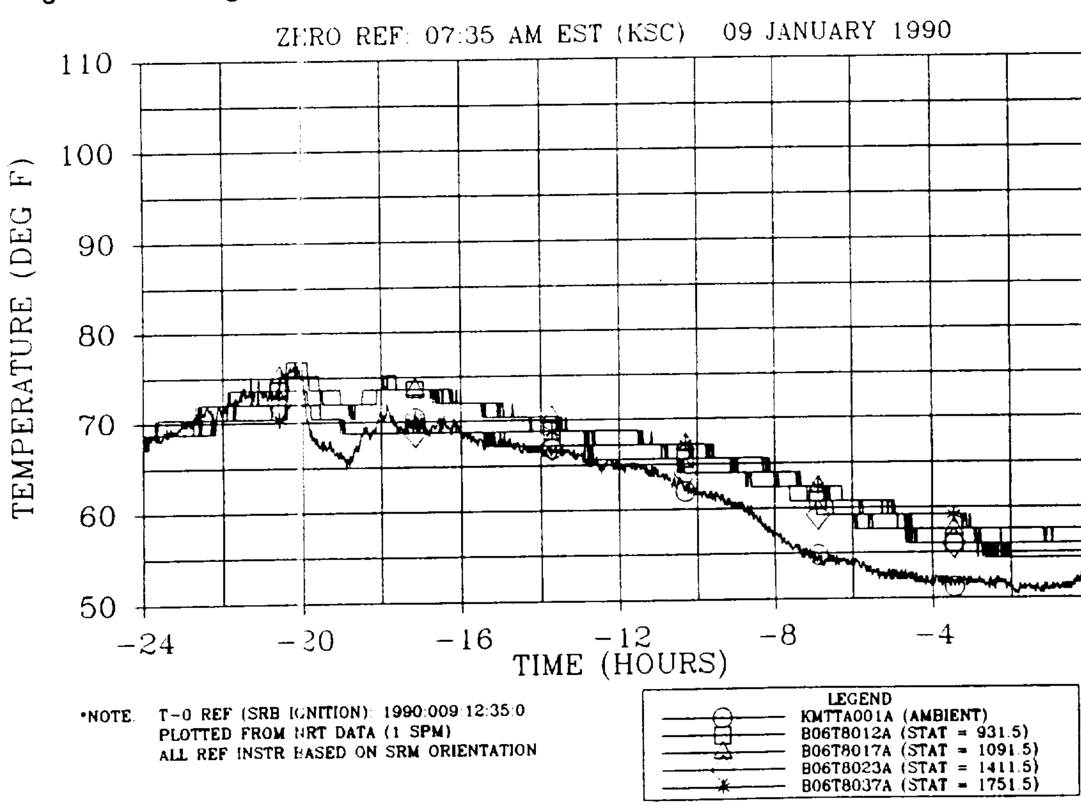


Figure 4.8-72. Right SRM Case Acreage Temperature at 215-deg Location Overlaid With Ambient

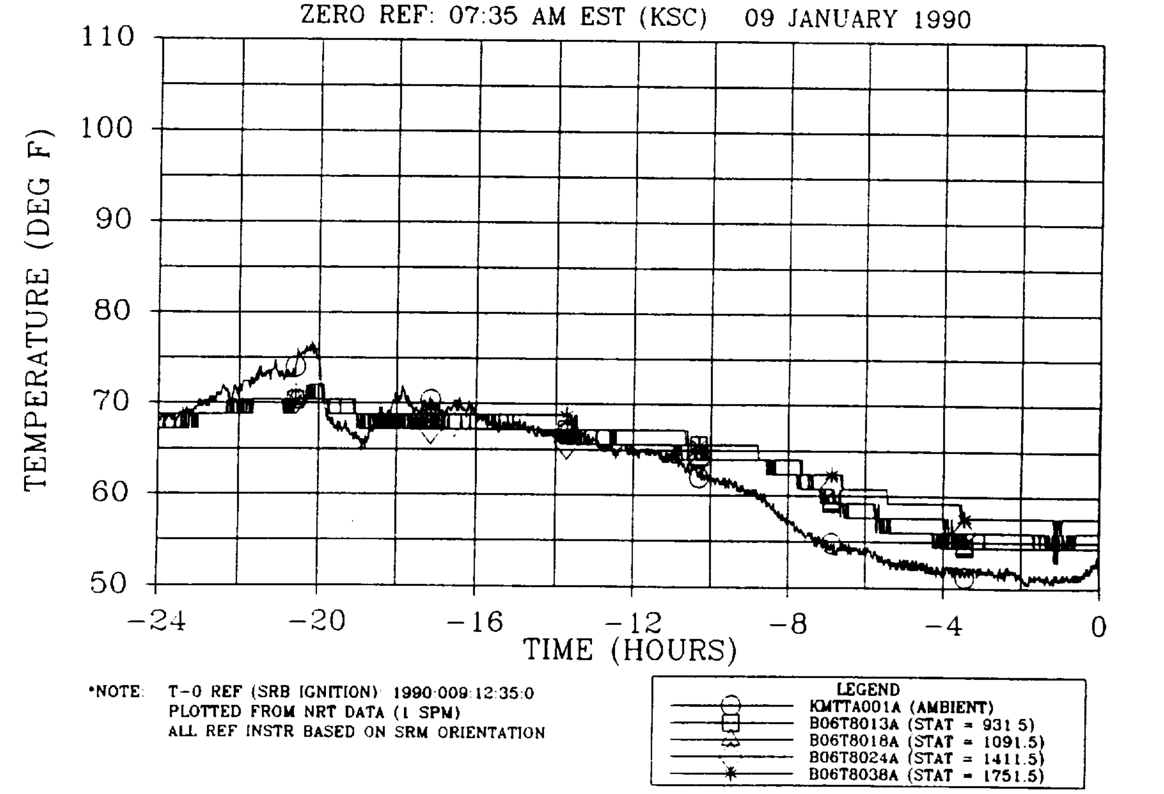


Figure 4.8-73. Right SRM Case Acreage Temperature at 270-deg Location Overlaid With Ambient

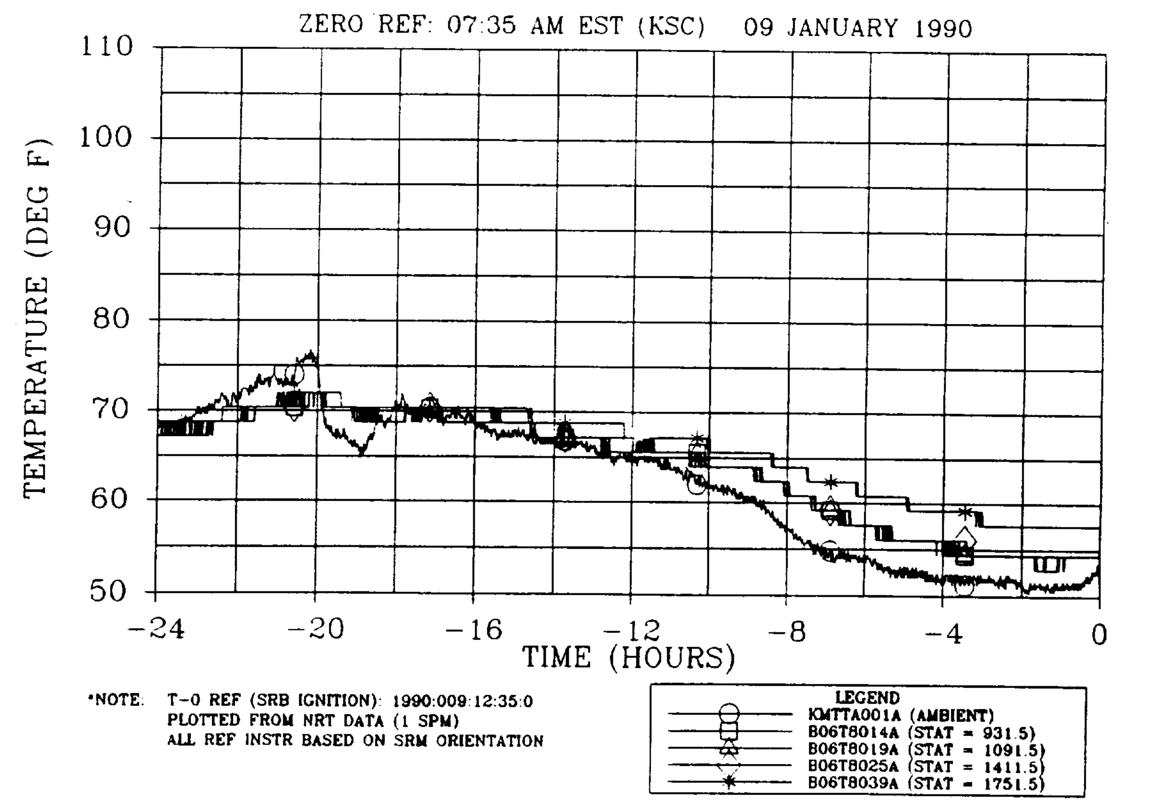


Figure 4.8-74. Right SRM Case Acreage Temperature at 325-deg Location Overlaid With Ambient

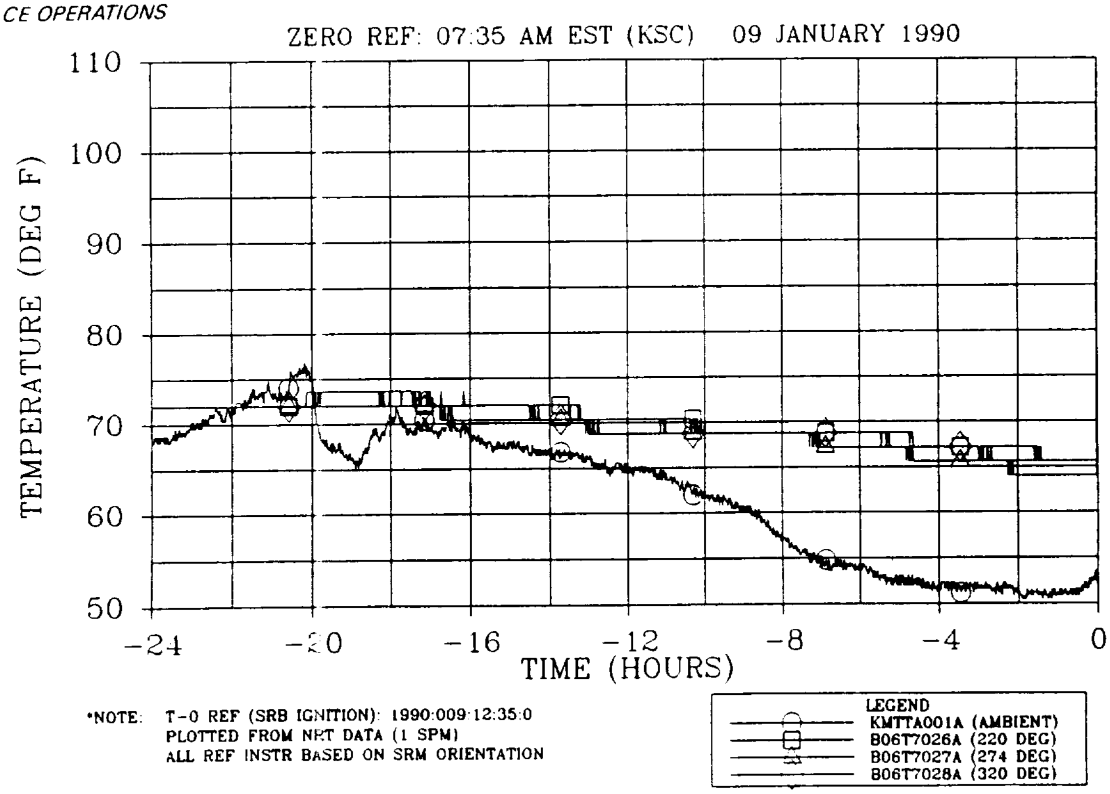


Figure 4.8-75. Left SRM ET Attach Region Temperature at Station 1511.0 Overlaid With Ambient

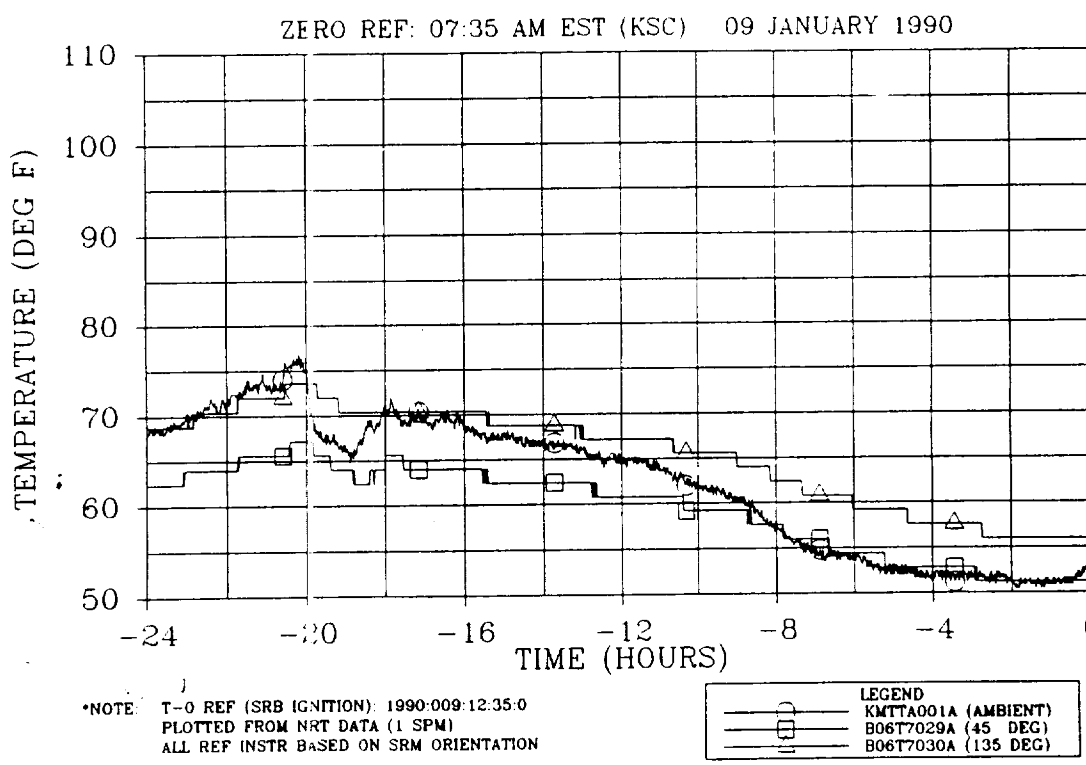


Figure 4.8-76. Left SRM ET Attach Region Temperature at Station 1535.0 Overlaid With Ambient

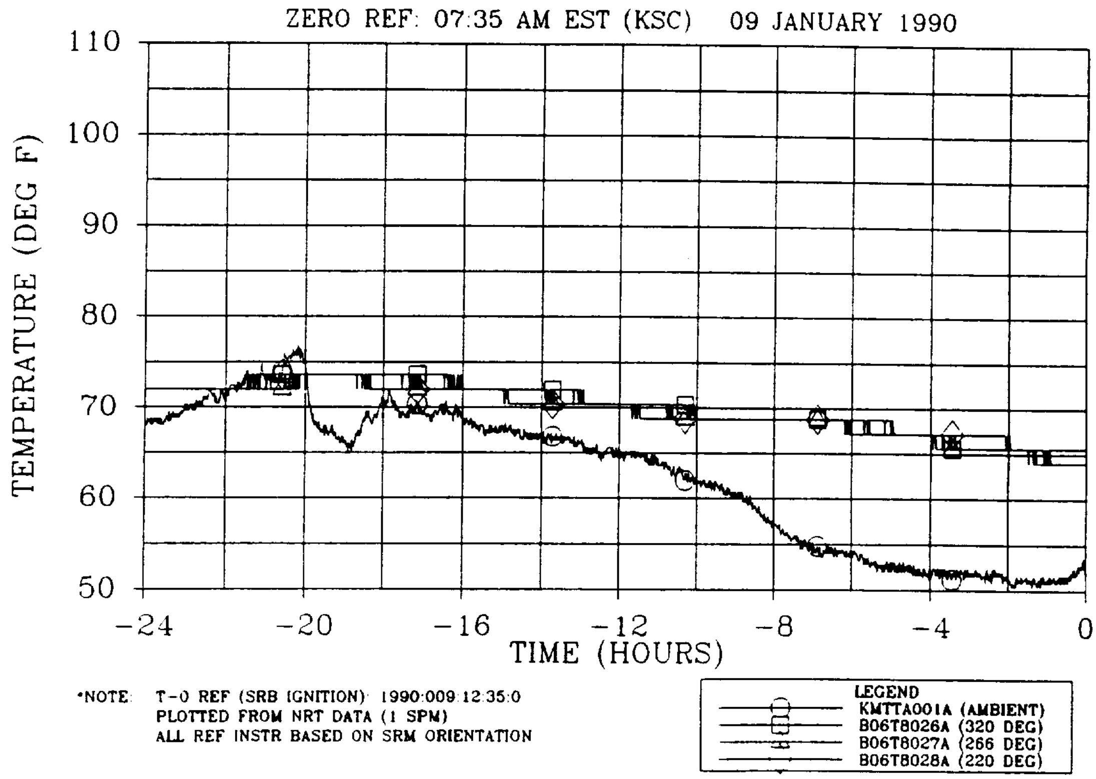


Figure 4.8-77. Right SRM ET Attach Region Temperature at Station 1511.0 Overlaid With Ambient

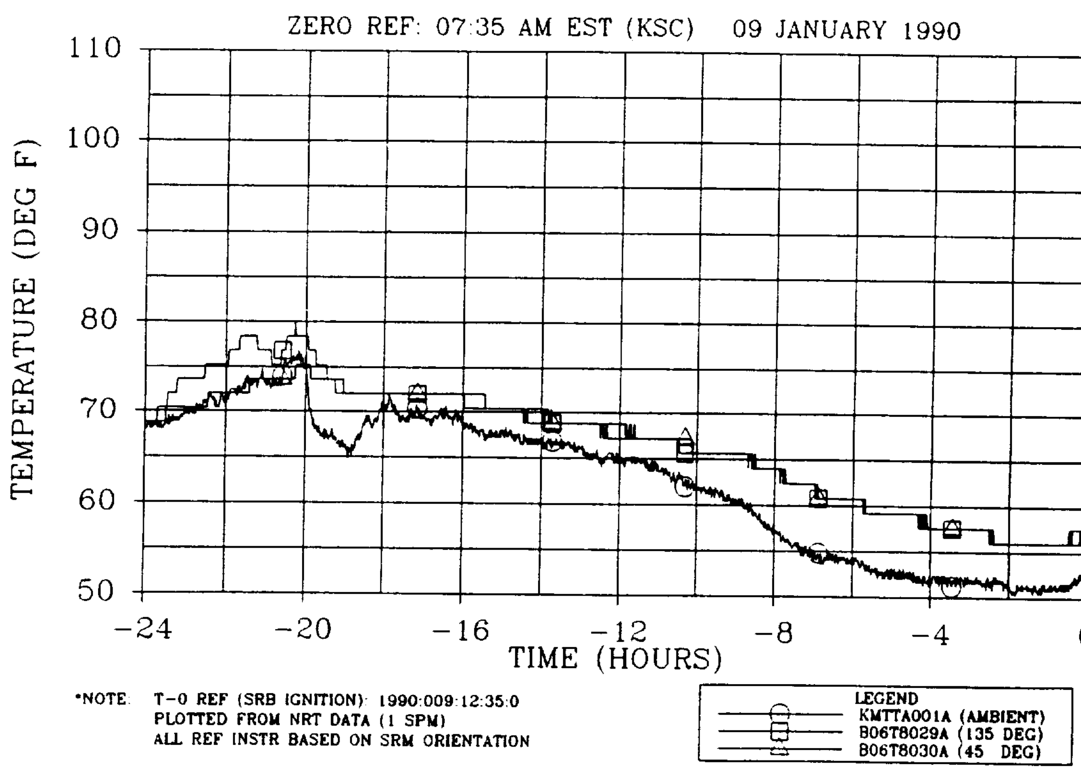


Figure 4.8-78. Right SRM ET Attach Region Temperature at Station 1535.0 Overlaid With Ambient

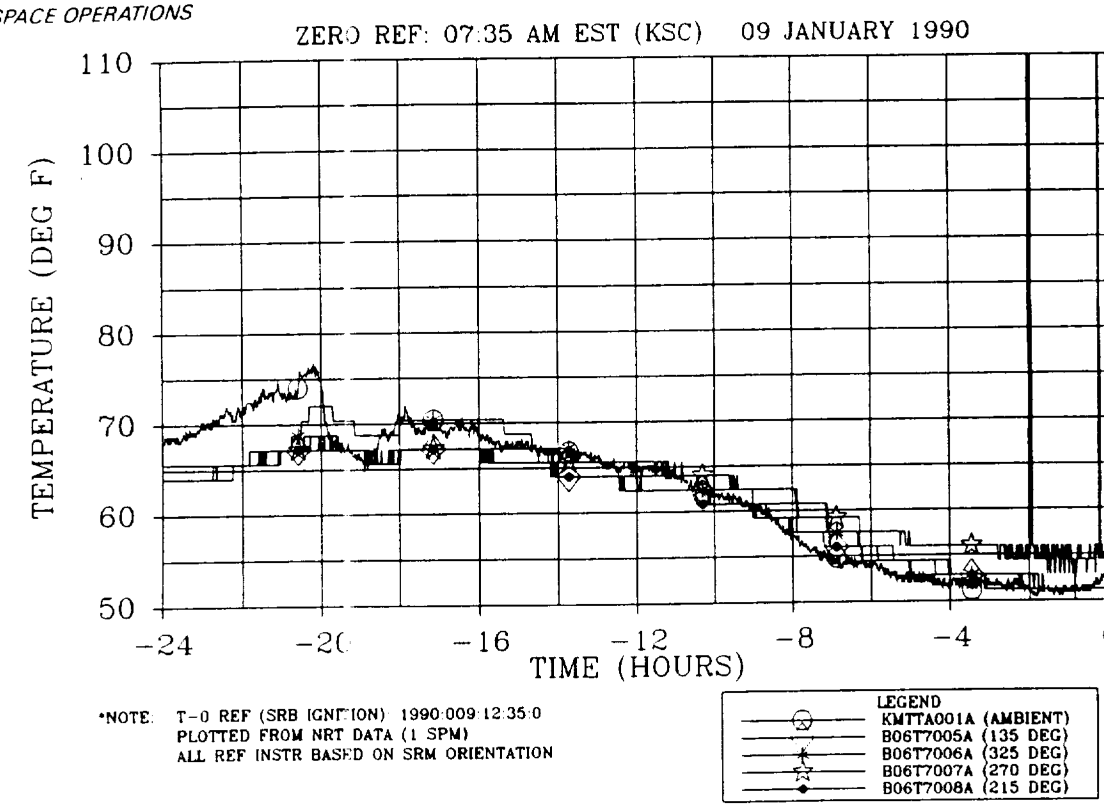


Figure 4.8-79. Left SRM Forward Factory Joint Temperature Overlaid With Ambient

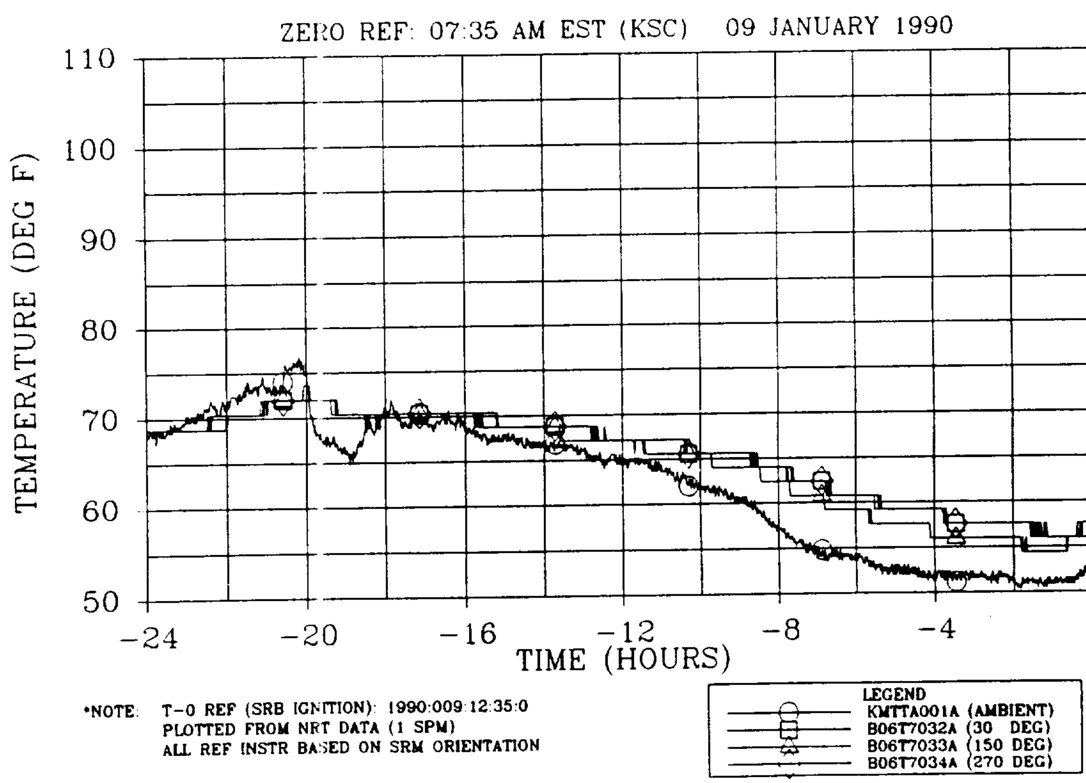


Figure 4.8-80. Left SRM Aft Factory Joint Temperature at Station 1701.9 Overlaid With Ambient

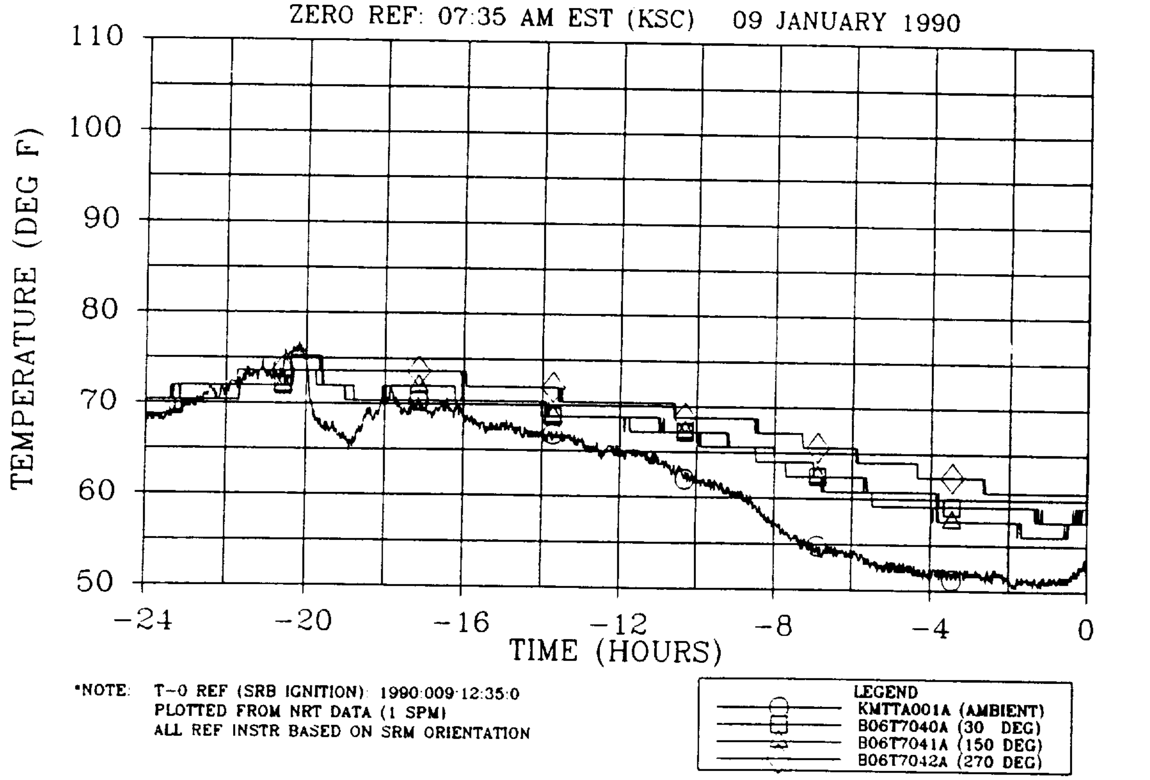


Figure 4.8-81. Left SRM Aft Factory Joint Temperature at Station 1821.0 Overlaid With Ambient

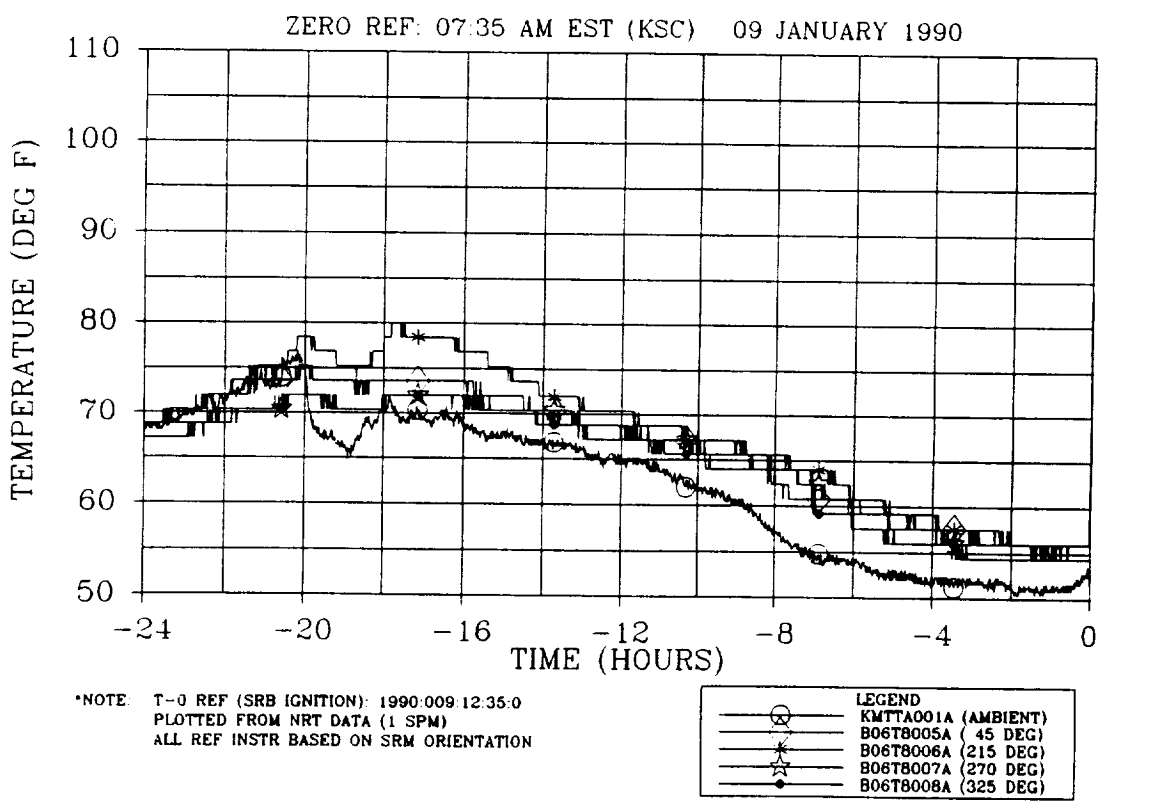


Figure 4.8-82. Right SRM Forward Factory Joint Temperature Overlaid With Ambient

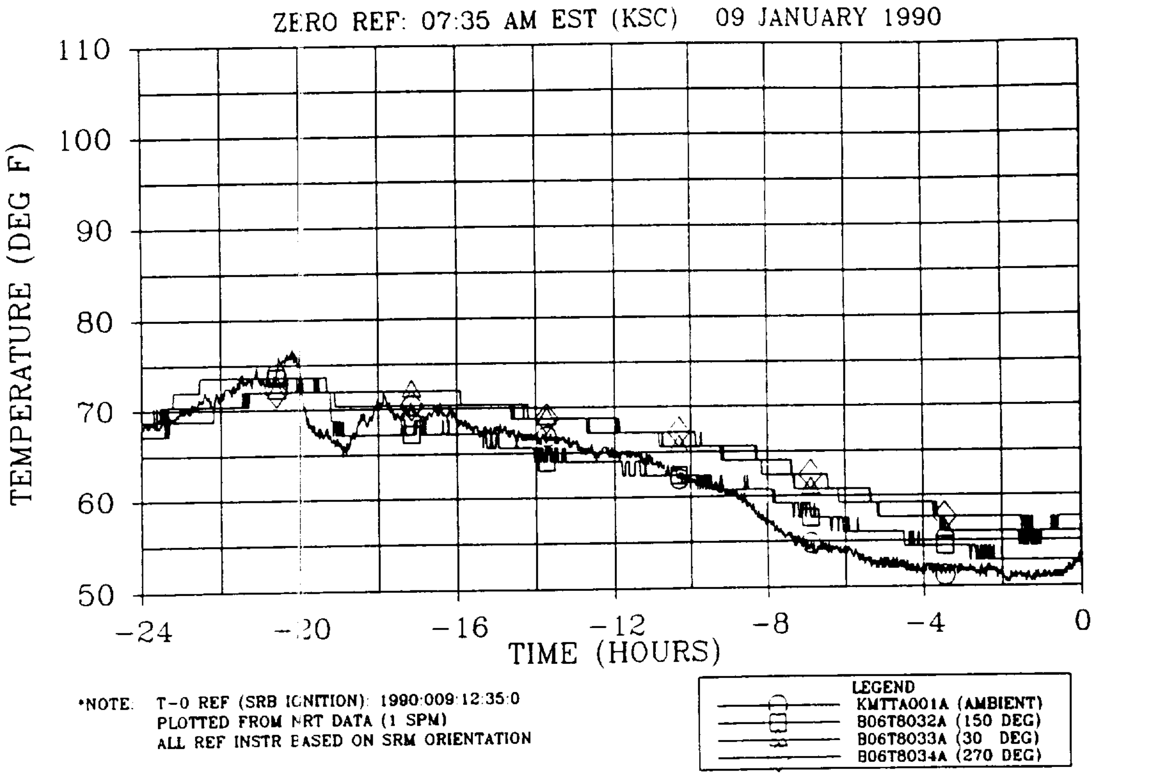


Figure 4.8-83. Right SRM Aft Factory Joint Temperature at Station 1701.9 Overlaid With Ambient

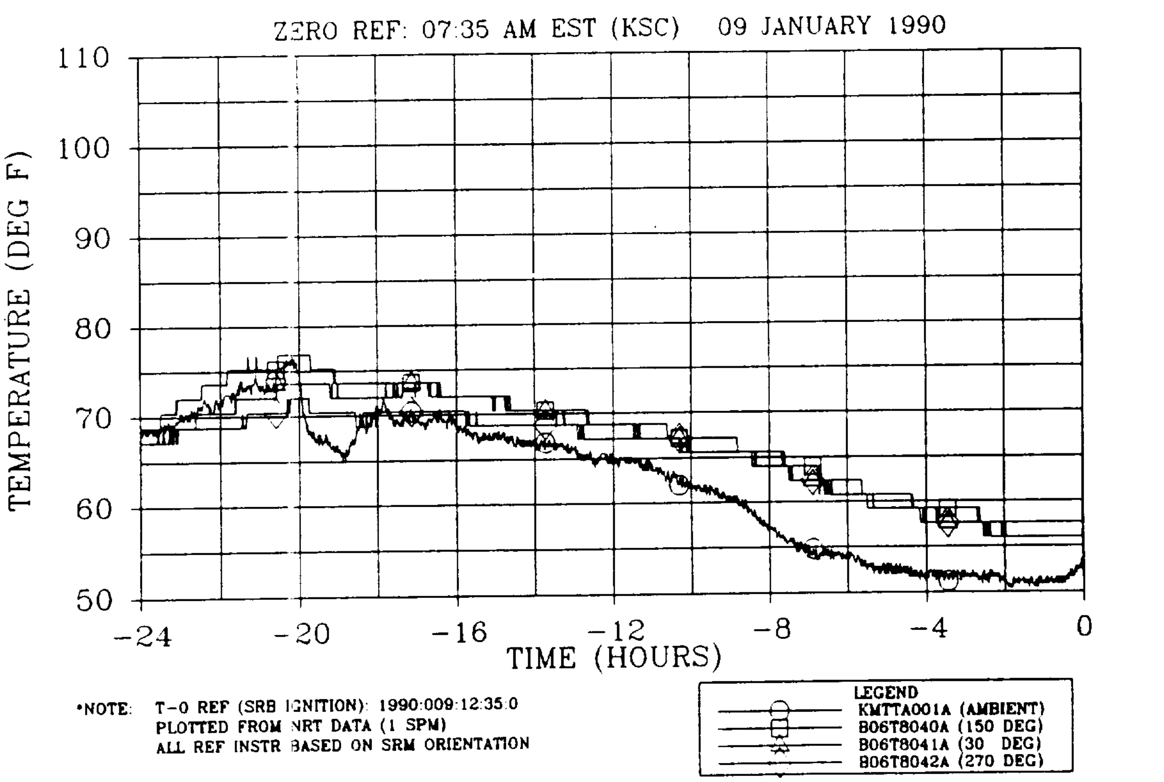


Figure 4.8-84. Right SRM Aft Factory Joint Temperature at Station 1821.0 Overlaid With Ambient

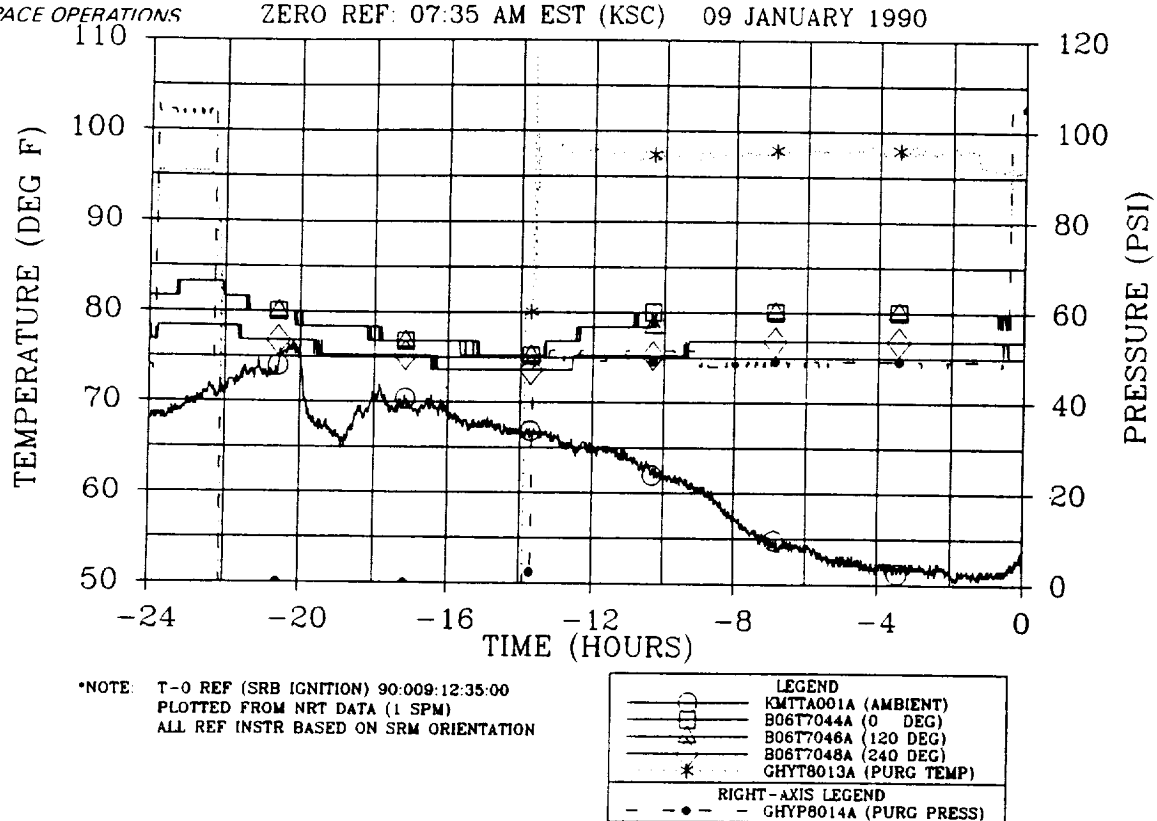


Figure 4.8-85. Left SRM Nozzle Region Temperature at Station 1845.0 Overlaid With Ambient

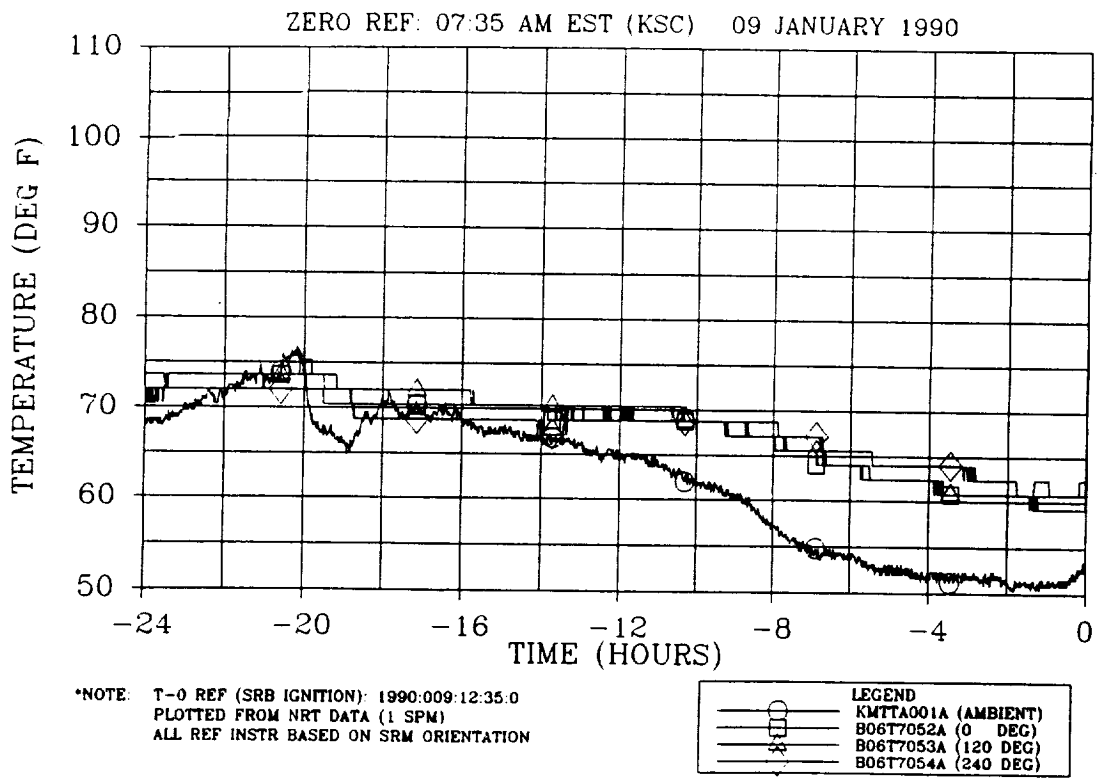


Figure 4.8-86. Left SRM Nozzle Region Temperature at Station 1950.0 Overlaid With Ambient

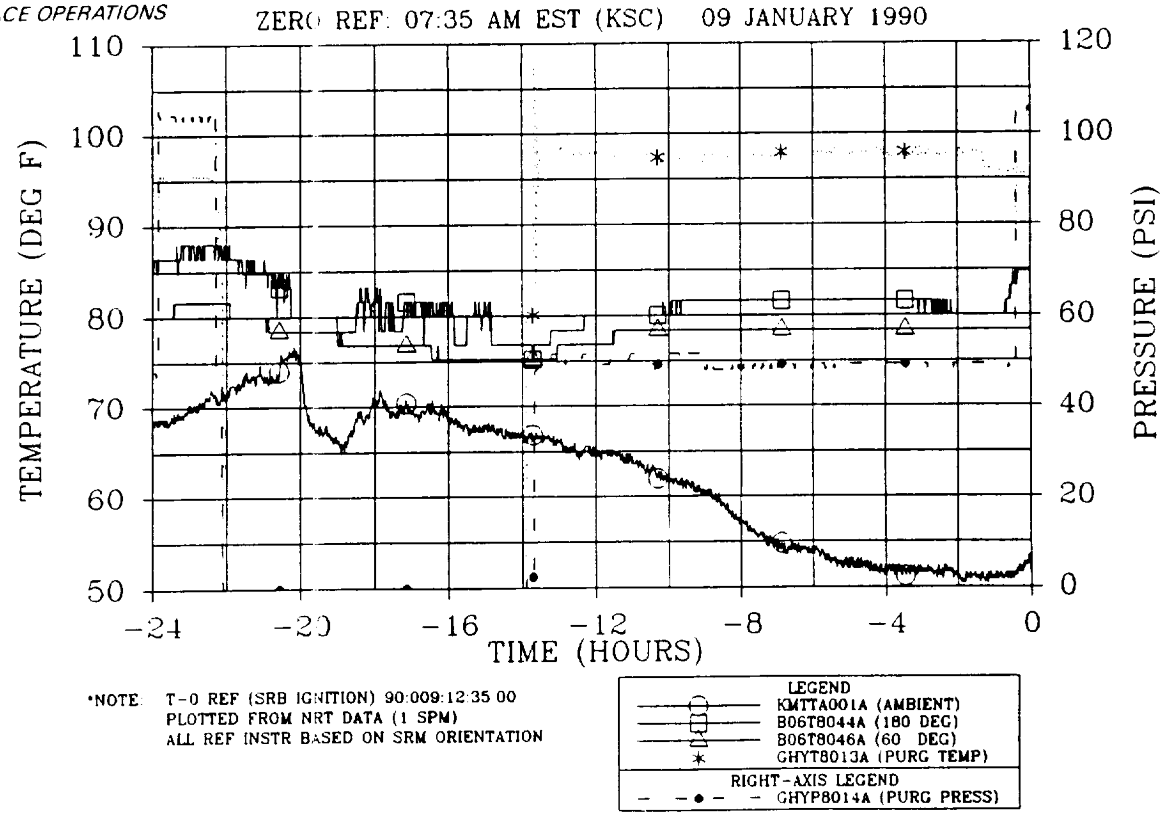


Figure 4.8-87. Right SRM Nozzle Region Temperature at Station 1845.0 Overlaid With Ambient

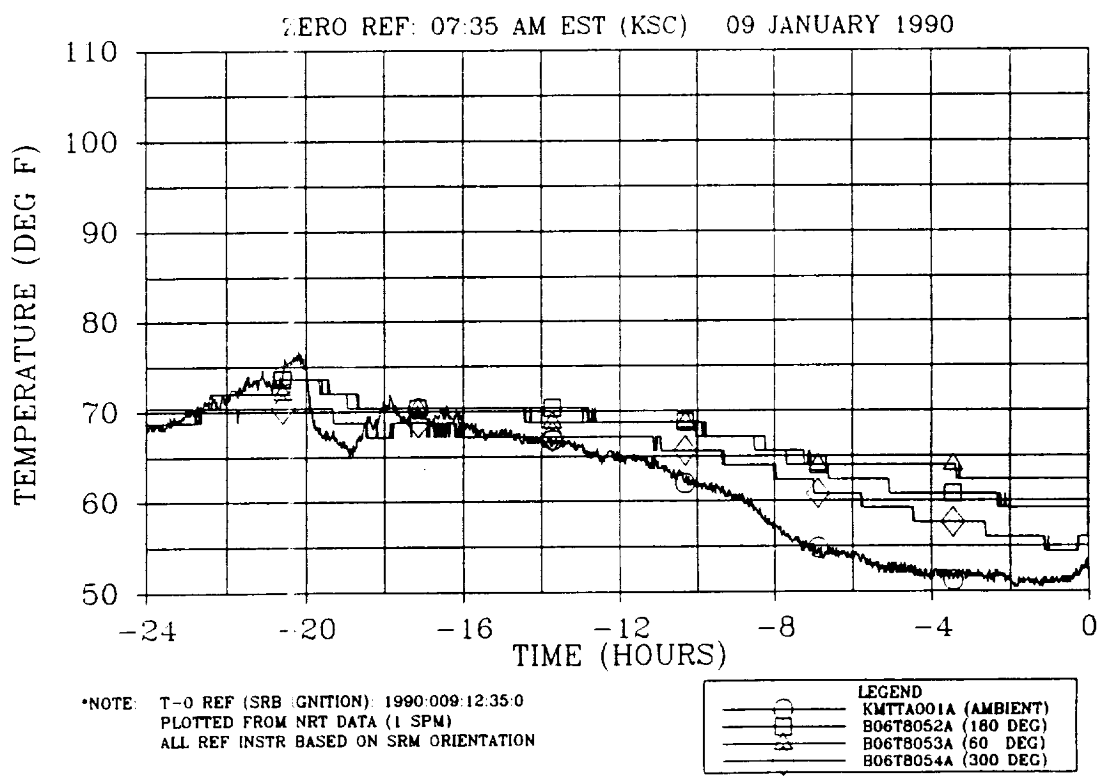
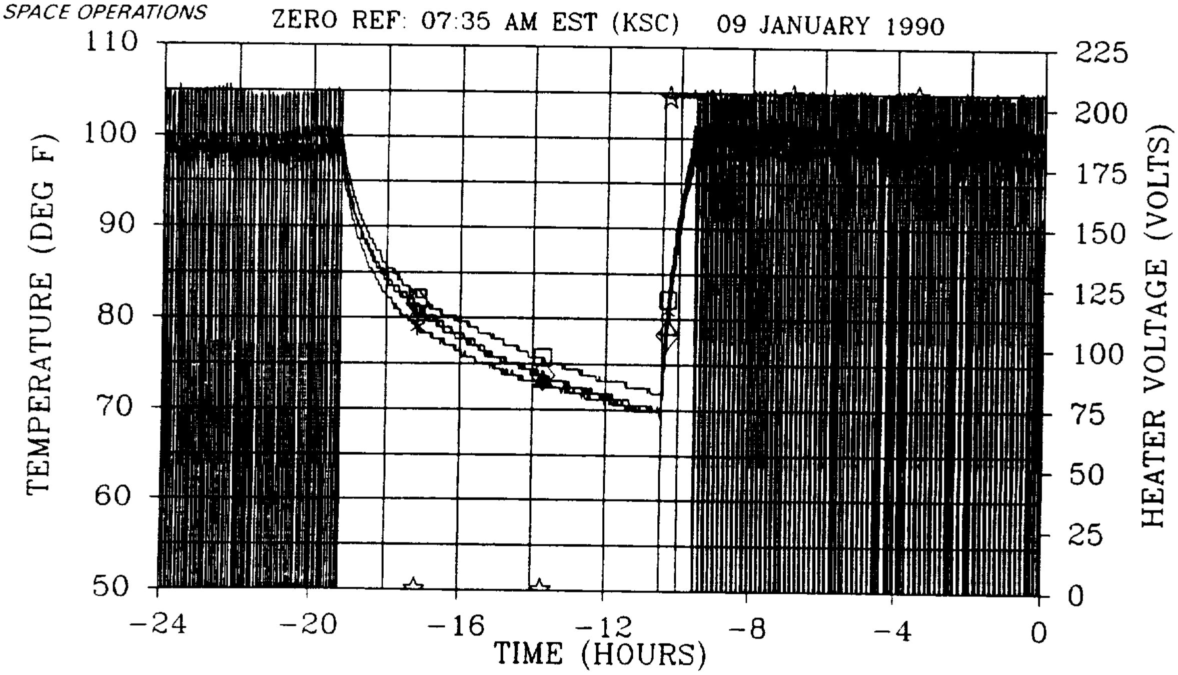


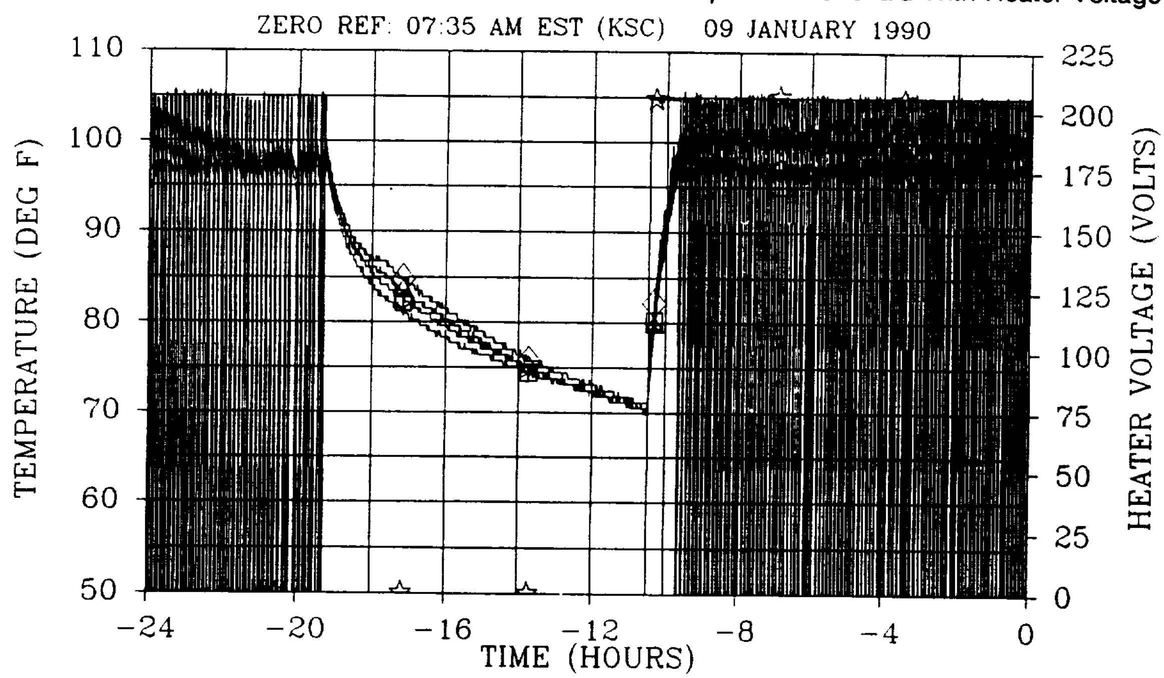
Figure 4.8-88. Right SRM Nozzle Region Temperature at Station 1950.0 Overlaid With Ambient



*NOTE. T−0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

LEGEND
B06T7060A (15 DEG)
B06T7061A (135 DEG)
B06T7062A (195 DEG)
B06T7063A (285 DEG)
RIGHT-AXIS LEGEND
B06V7010A (HTR VOLT)

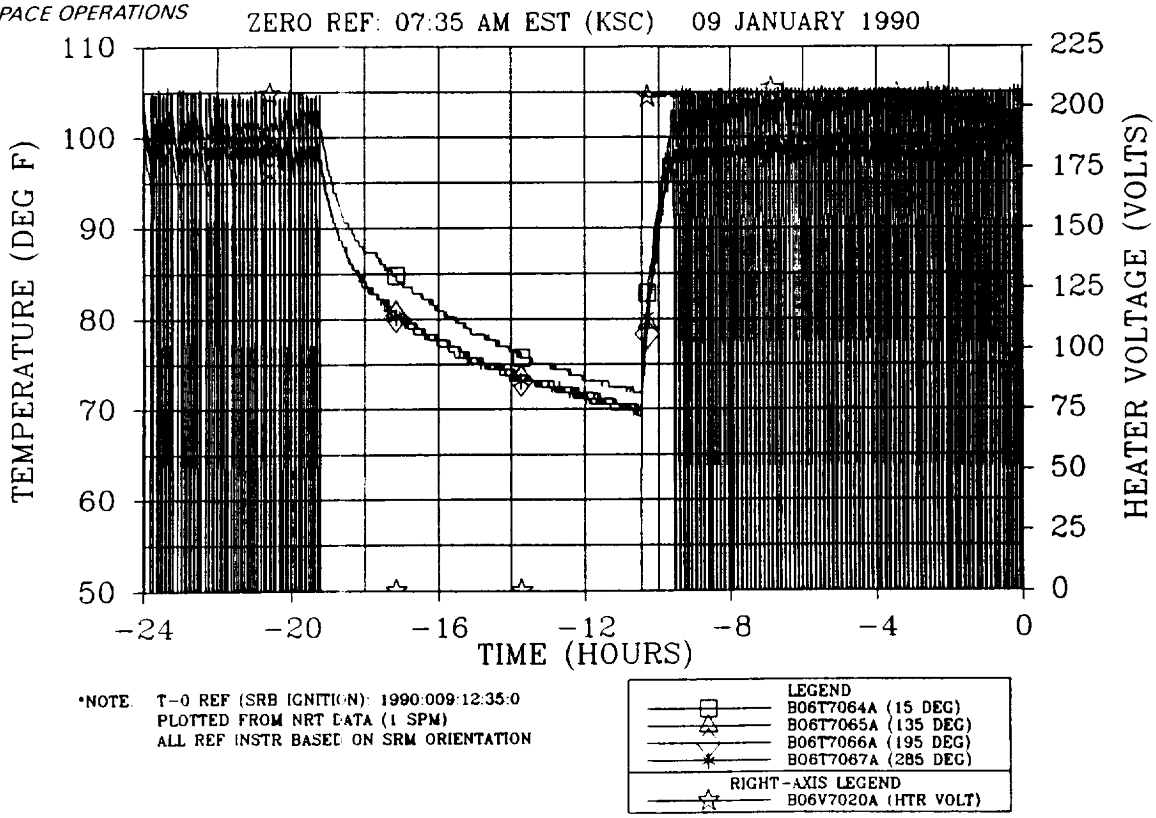
Figure 4.8-89. Left SRM Forward Field Joint Temperature Overlaid With Heater Voltage



*NOTE: T−0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

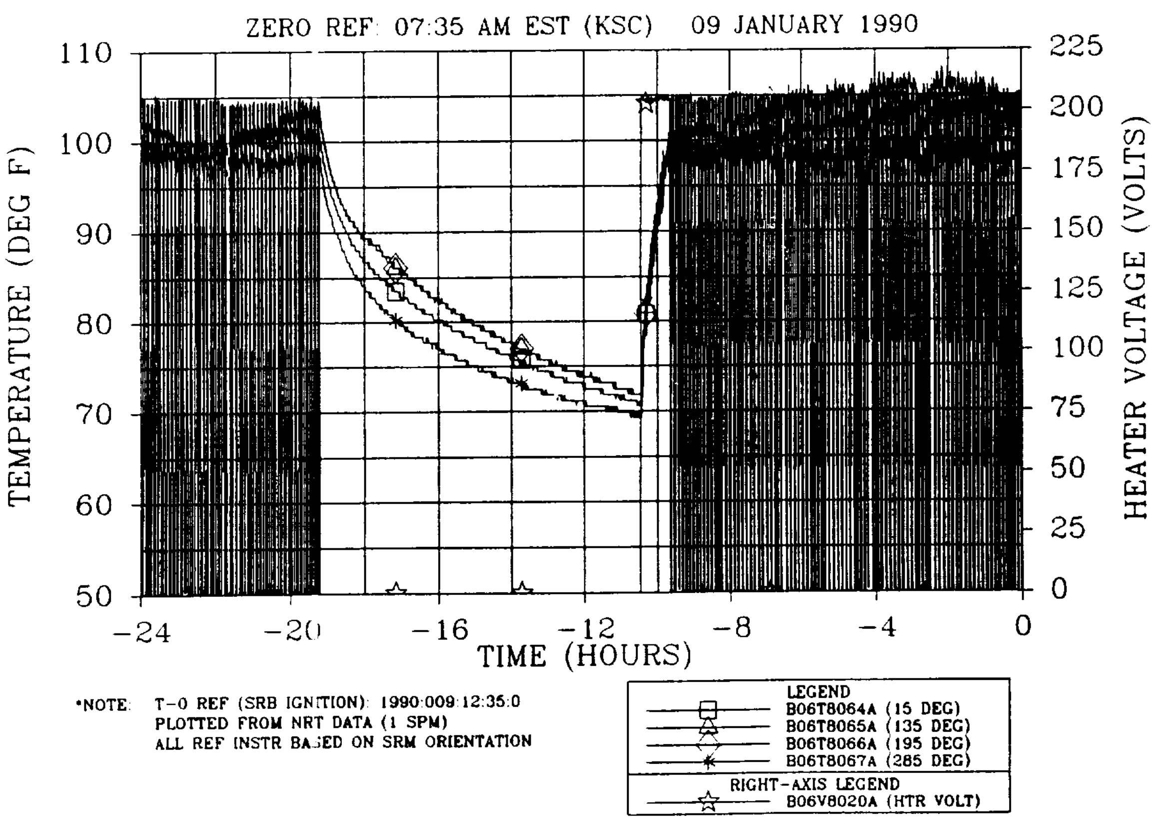
LEGEND
B06T8060A (15 DEG)
B06T8061A (135 DEG)
B06T8062A (195 DEG
B06T8063A (285 DEG)
RIGHT-AXIS LEGEND
B06V8010A (HTR VOLT)

Figure 4.8-90. Right SRM Forward Field Joint Temperature Overlaid With Heater Voltage



*NOTE: T-0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

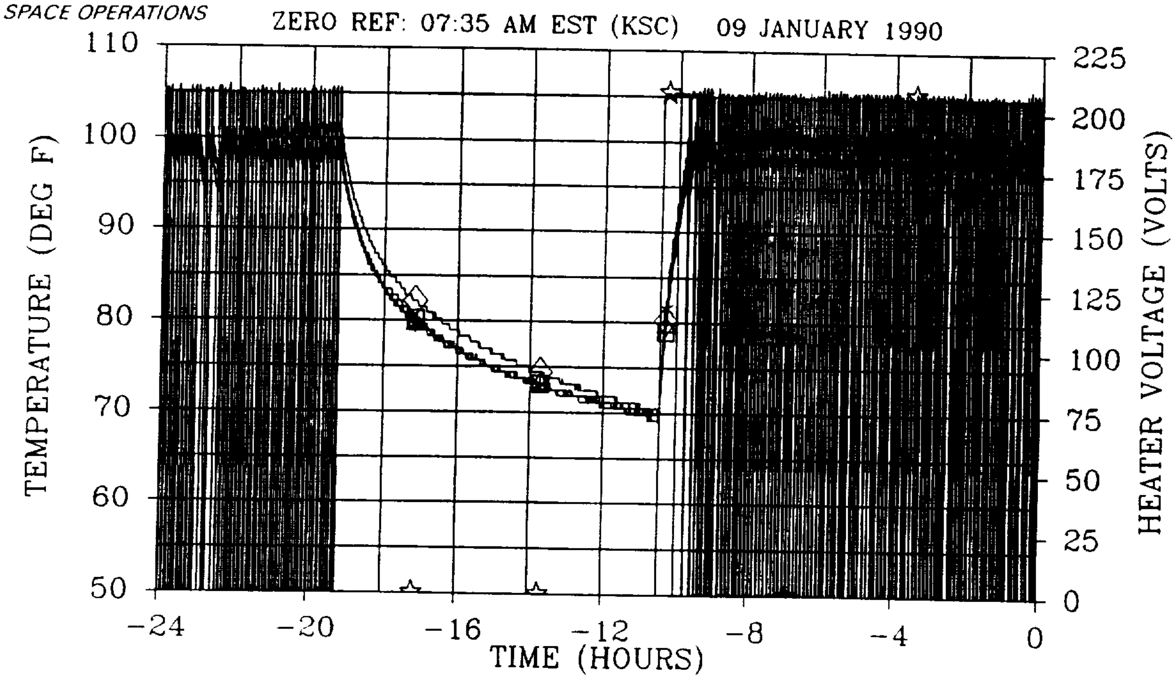
Figure 4.8-91. Left SRM Center Field Joint Temperature Overlaid With Heater Voltage



*NOTE: T-0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

Figure 4.8-92. Right SRM Center Field Joint Temperature Overlaid With Heater Voltage

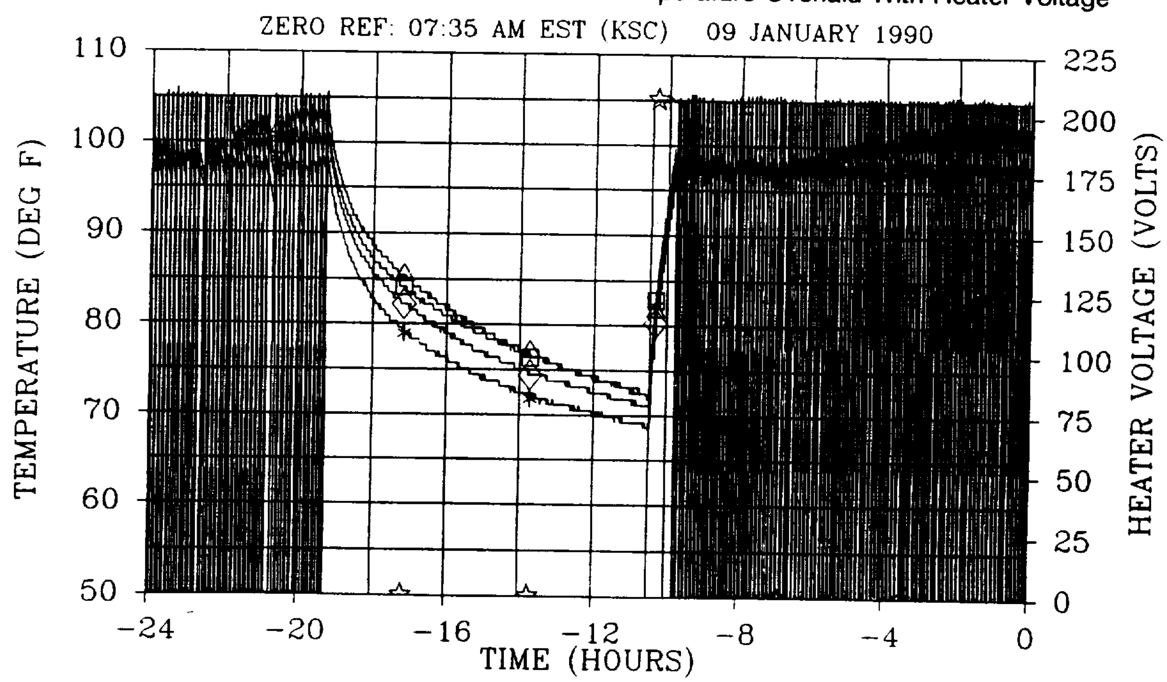
Thiokol CORPORATION
SPACE OPERATIONS



*NOTE: T-0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

LEGEND
B06T7068A (15 DEG)
B06T7069A (135 DEG)
B06T7070A (195 DEG
B06T7071A (285 DEG)
RIGHT-AXIS LEGEND
B06V7030A (HTR VOLT)

Figure 4.8-93. Left SRM Aft Field Joint Temperature Overlaid With Heater Voltage



*NOTE: T-0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

LEGEND
B06T8068A (15 DEG)
B06T8069A (135 DEG)
B06T8070A (195 DEG)
B06T8071A (285 DEG)
RIGHT-AXIS LEGEND
B06V8030A (HTR VOLT)

Figure 4.8-94. Right SRM Aft Field Joint Temperature Overlaid With Heater Voltage

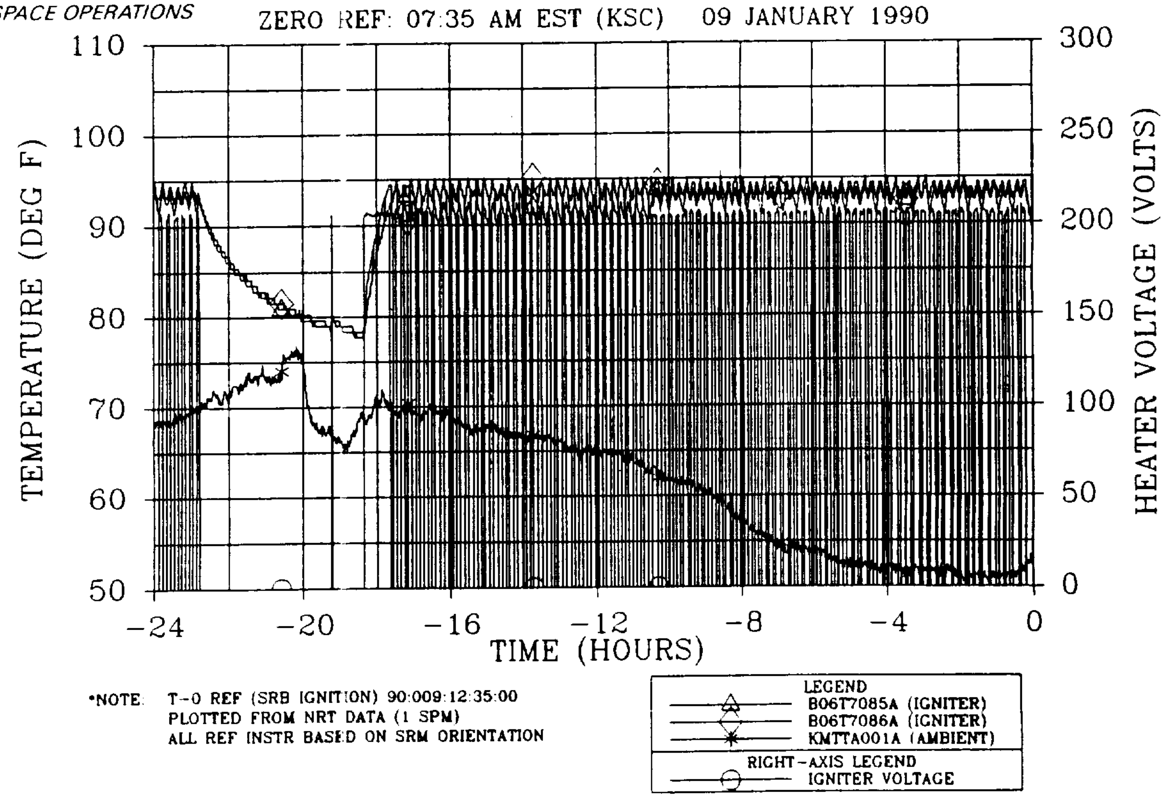


Figure 4.8-95. Left SRM Igniter Joint Temperatures Overlaid With Ambient

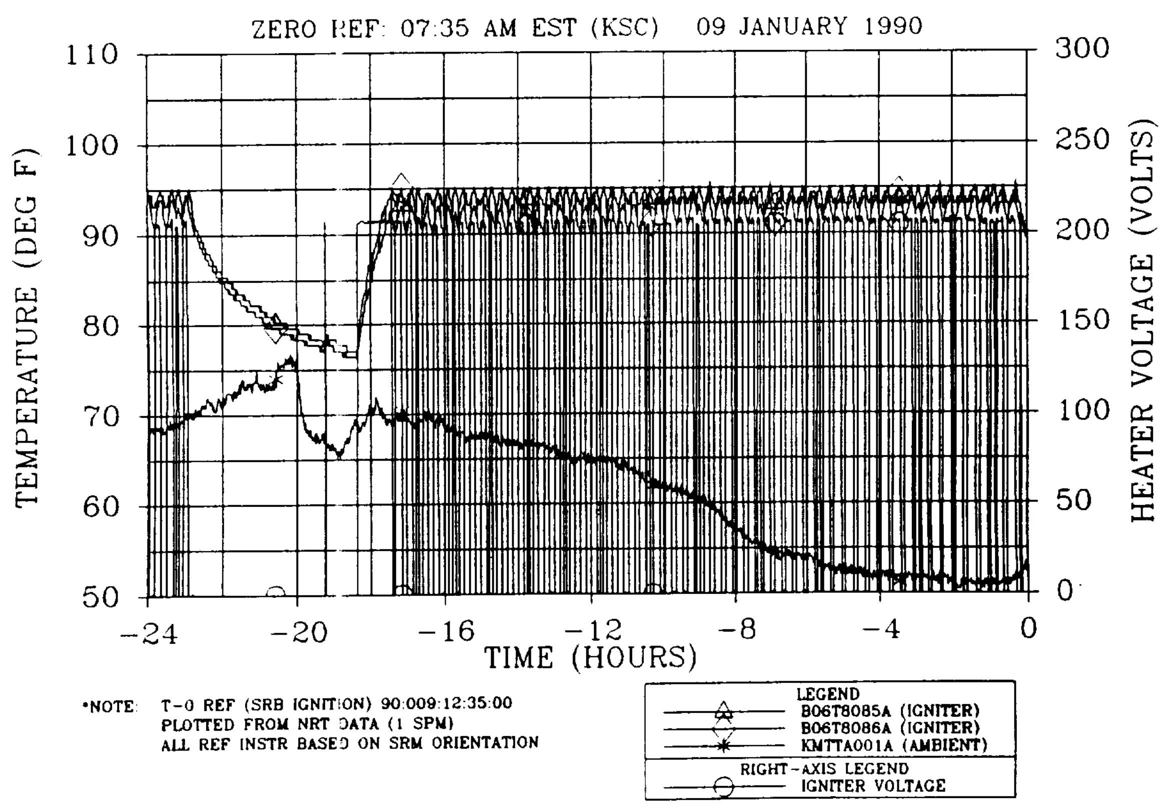
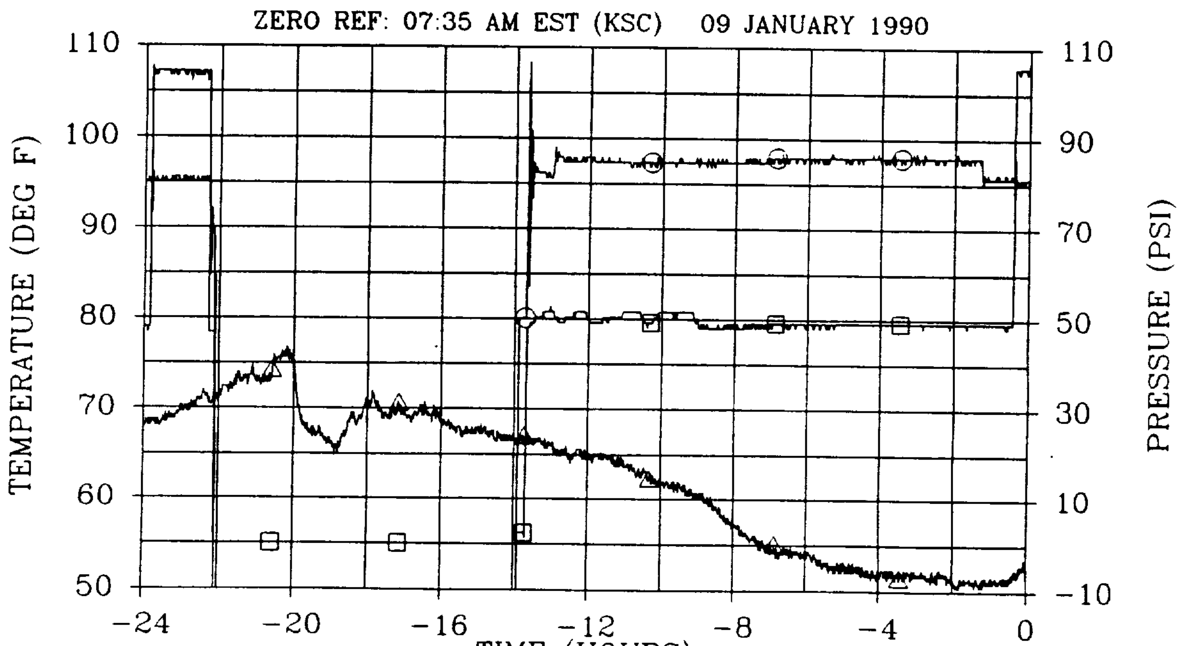


Figure 4.8-96. Right SRM Igniter Joint Temperatures Overlaid With Igniter Voltage



*NOTE: T-0 REF (SRB IGNITION): 1990:009:12:35:0
PLOTTED FROM NRT DATA (1 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

Figure 4.8-97. Aft Skirt Purge Temperature and Pressure Overlaid With Ambient

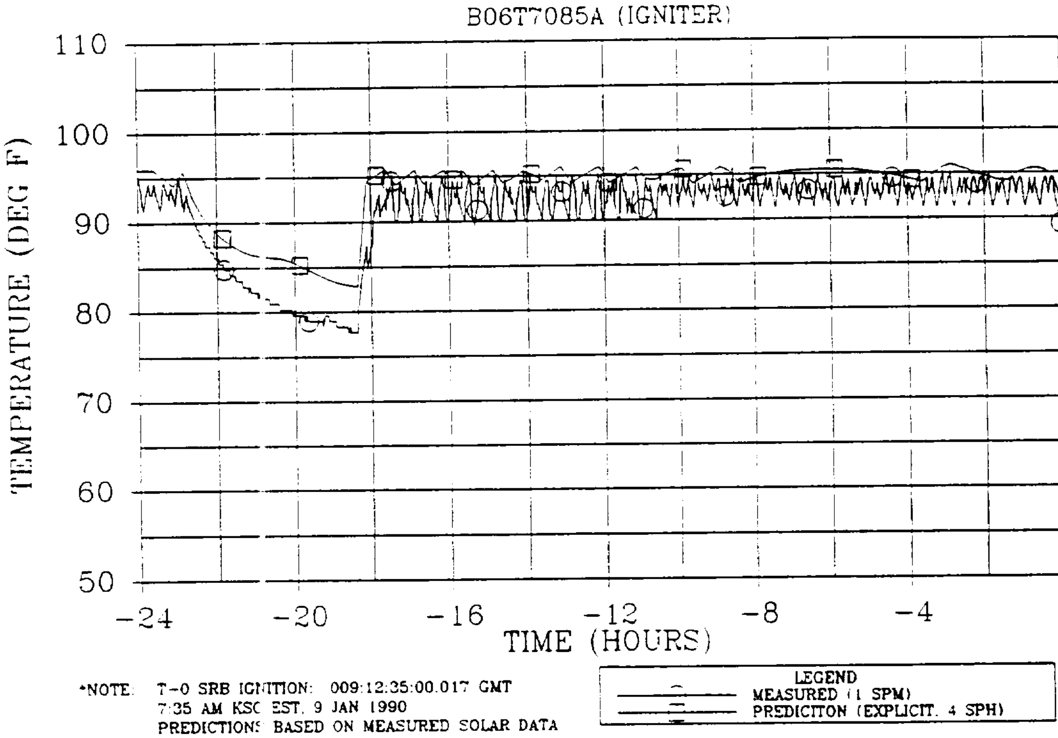


Figure 4.8-98. Measured Versus Postflight Prediction--Left SRM Igniter Joint Temperatures

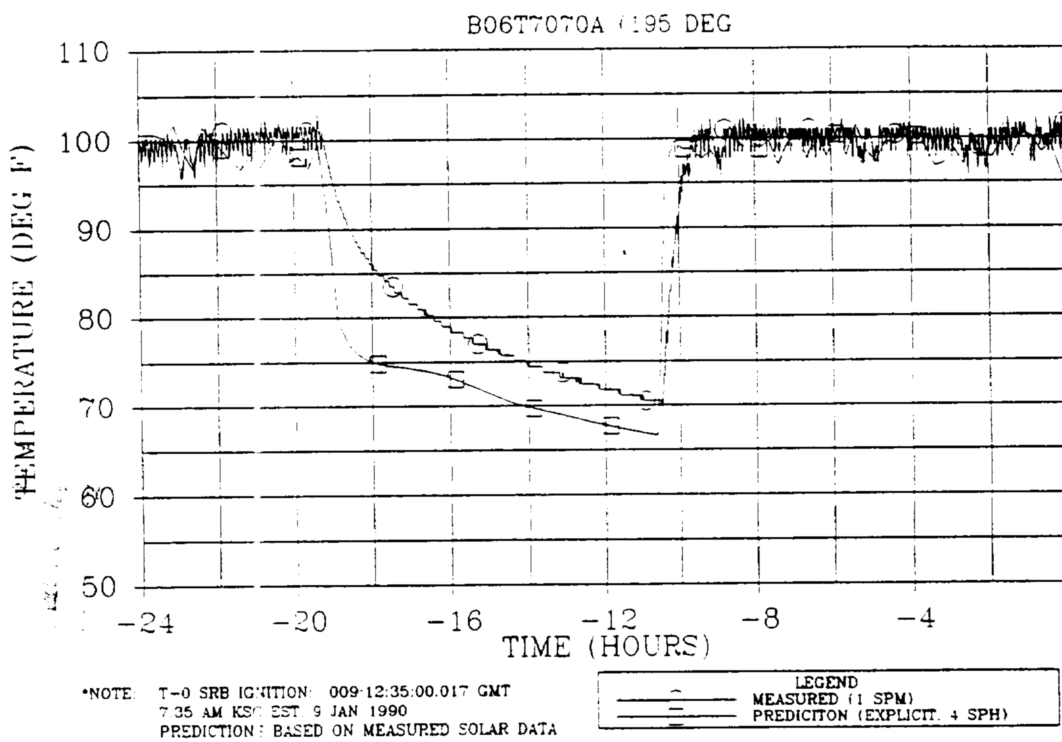


Figure 4.8-99. Measured Versus Postflight Prediction--Left SRM Aft Field Joint Temperature (195 deg)

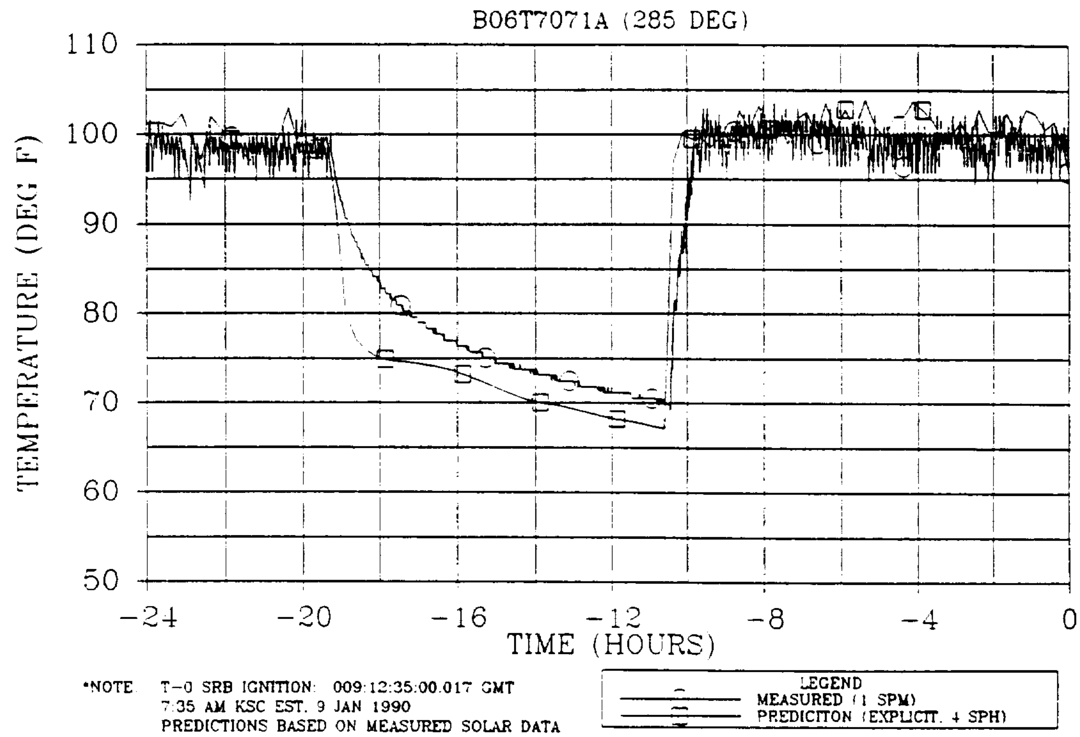


Figure 4.8-100. Measured Versus Postflight Prediction--Left SRM Aft Field Joint Temperature (285 deg)

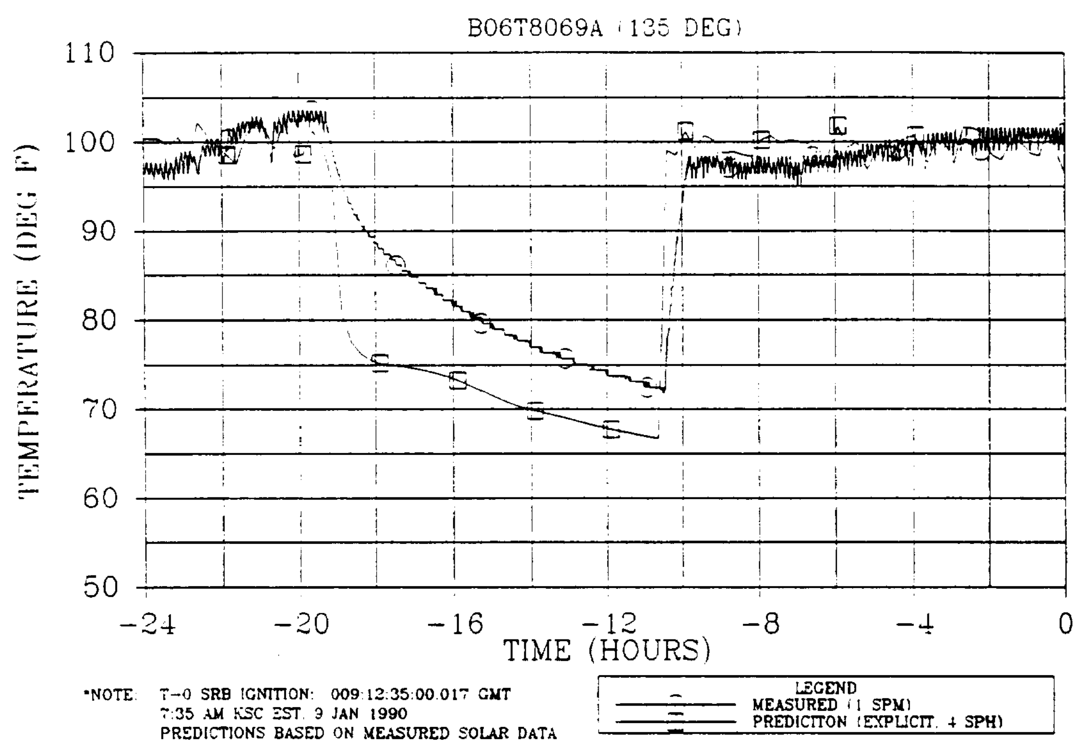


Figure 4.8-101. Measured Versus Postflight Prediction--Right SRM Aft Field Joint Temperature (135 deg)

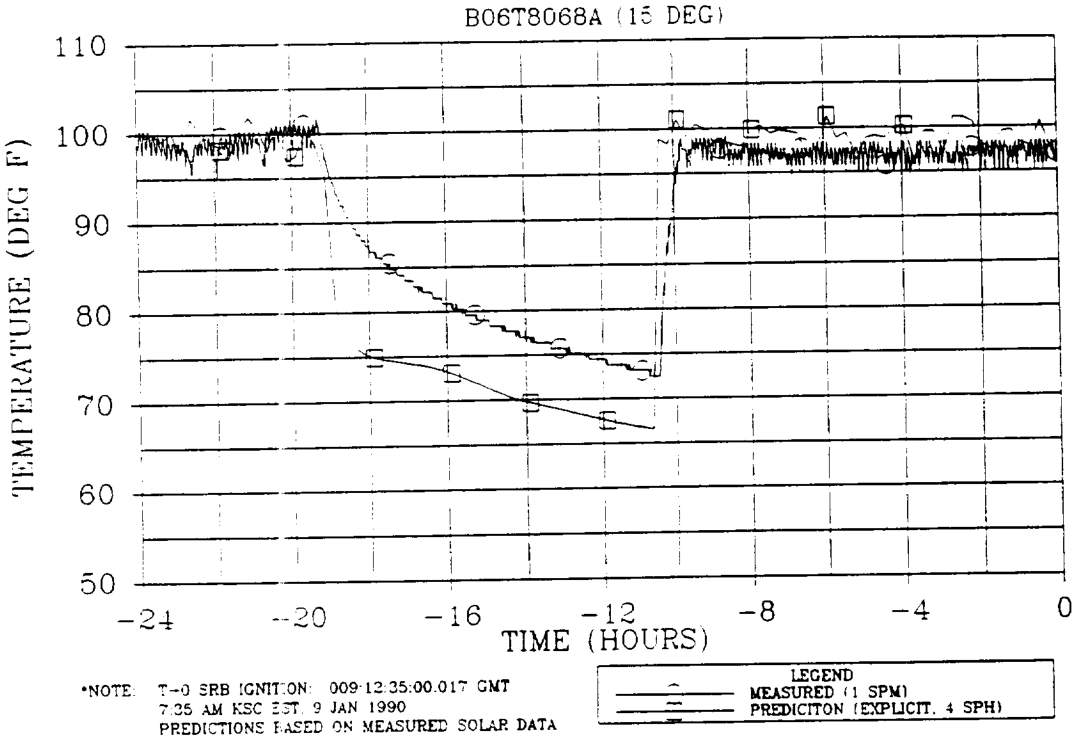


Figure 4.8-102. Measured Versus Postflight Prediction--Right SRM Aft Field Joint Temperature (15 deg)

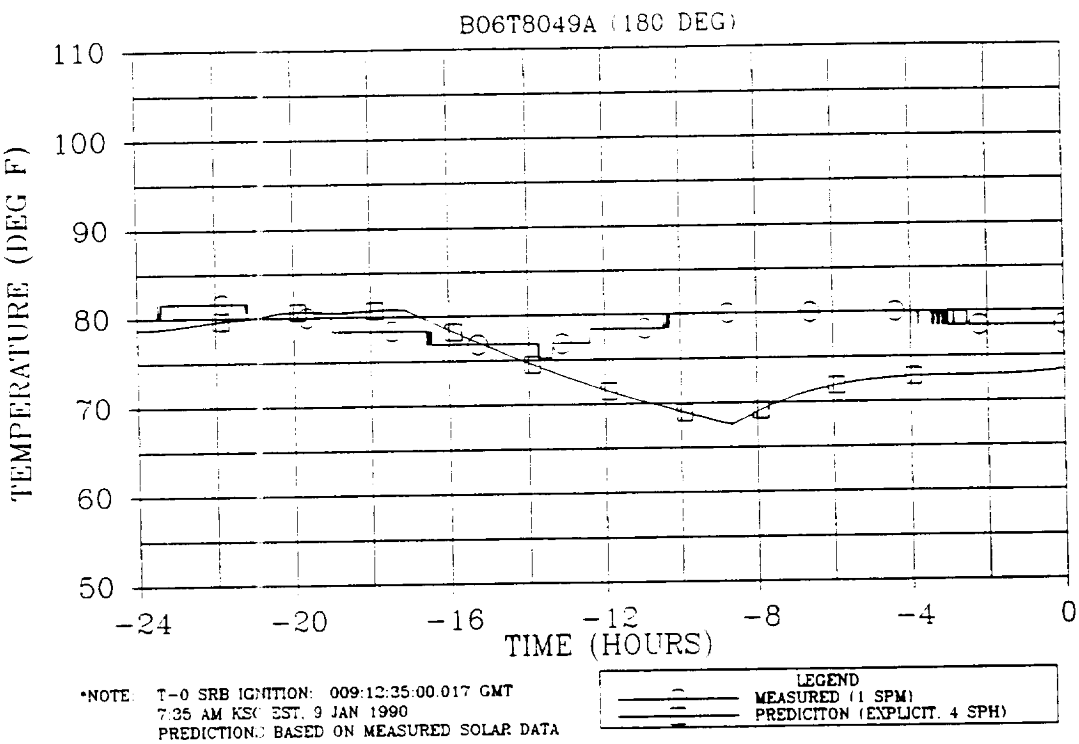
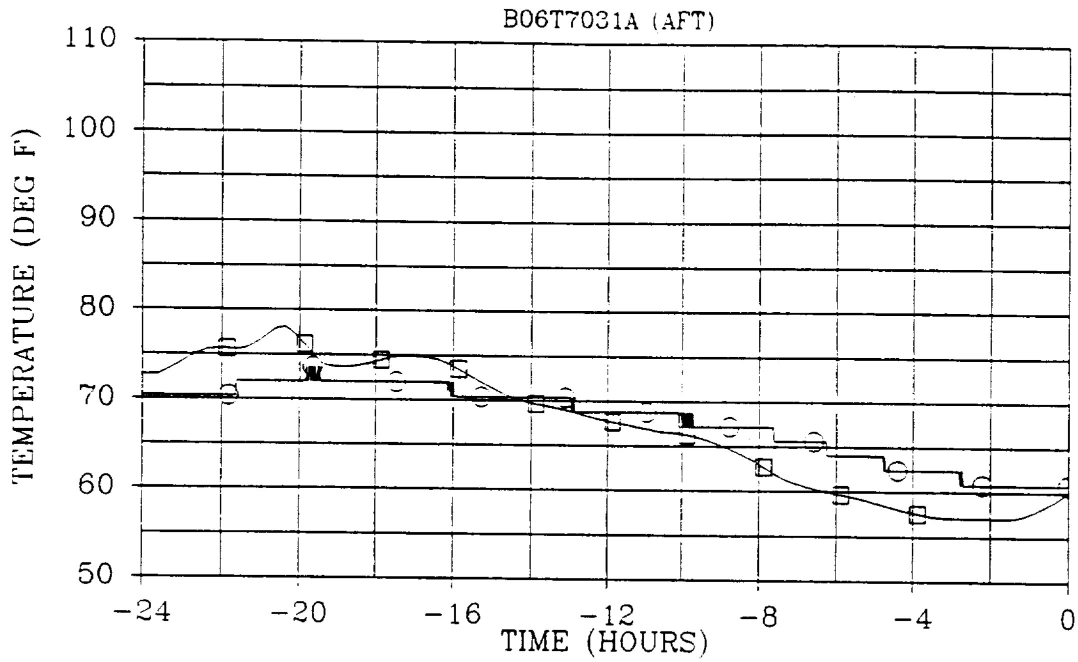


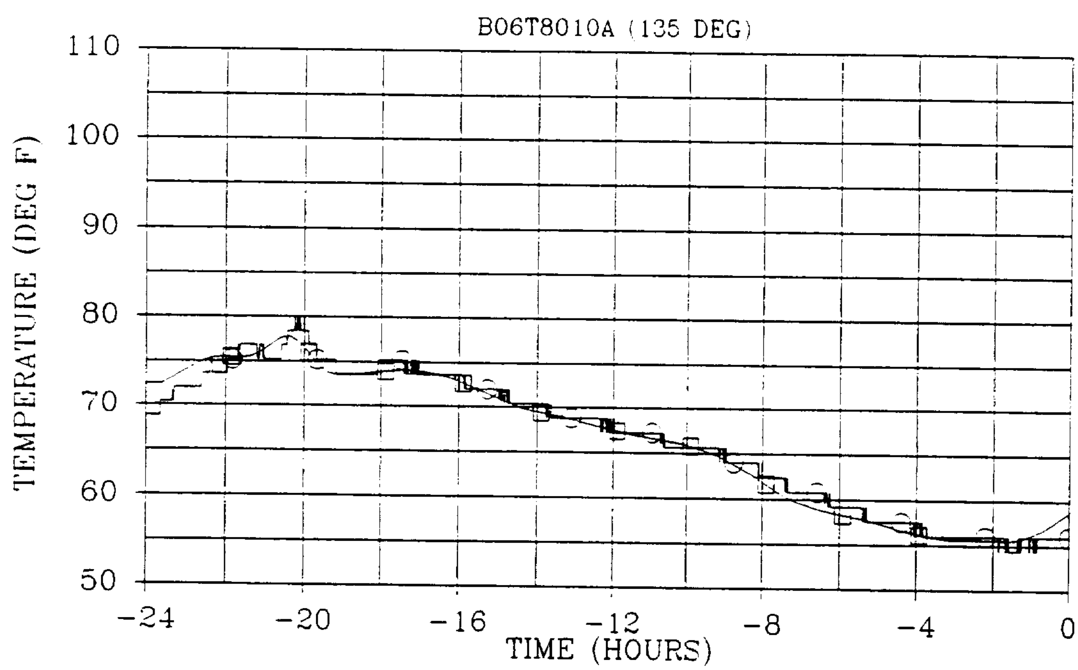
Figure 4.8-103. Measured Versus Postflight Prediction--Right SRM Case-to-Nozzle Joint Temperature (180 deg)



*NOTE: T-0 SRB IGNITION: 009:12:35:00.017 GMT
7:35 AM KSC EST, 9 JAN 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT, 4 SPH)

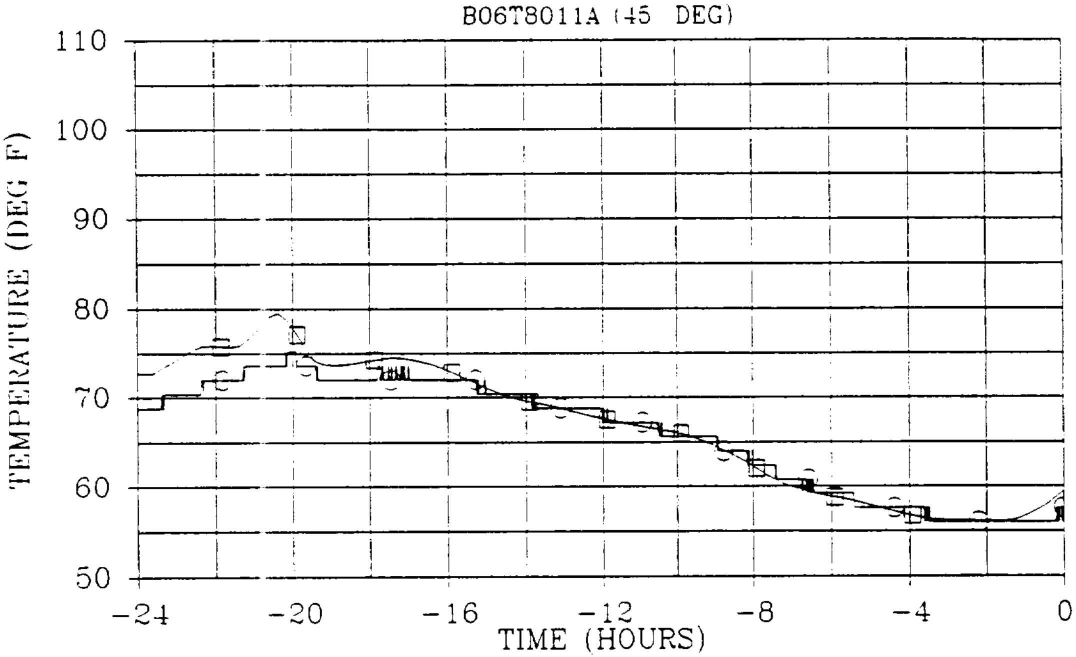
Figure 4.8-104. Measured Versus Postflight Prediction--Left SRM Tunnel Bondline Temperature



*NOTE: T-0 SRB IGNITION: 009:12:35:00.017 GMT
7:35 AM KSC EST, 9 JAN 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT, 4 SPH)

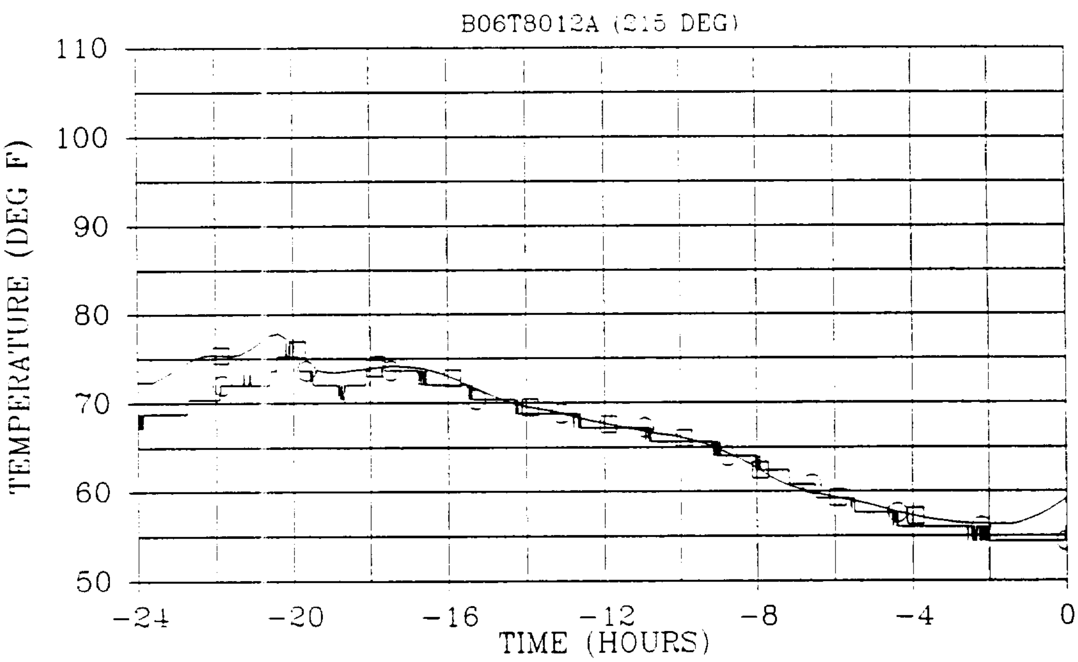
Figure 4.8-105. Measured Versus Postflight Prediction--Right SRM Case Acreage Temperature at Station 931.5 (135 deg)



*NOTE: T-0 SRB IGNITION: 009:12:35:00.017 GMT
7:35 AM KSC EST, 9 JAN 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT, 4 SPH)

Figure 4.8-106. Measured Versus Postflight Prediction--Right SRM Case Acreage Temperature at Station 931.5 (45 deg)



*NOTE: T-0 SRB IGNITION: 009:12:35:00.017 GMT
7:35 AM KSC EST, 9 JAN 1990
PREDICTIONS BASED ON MEASURED SOLAR DATA

LEGEND
MEASURED (1 SPM)
PREDICITON (EXPLICIT, 4 SPH)

Figure 4.8-107. Measured Versus Postflight Prediction--Right SRM Case Acreage Temperature at Station 931.5 (215 deg)

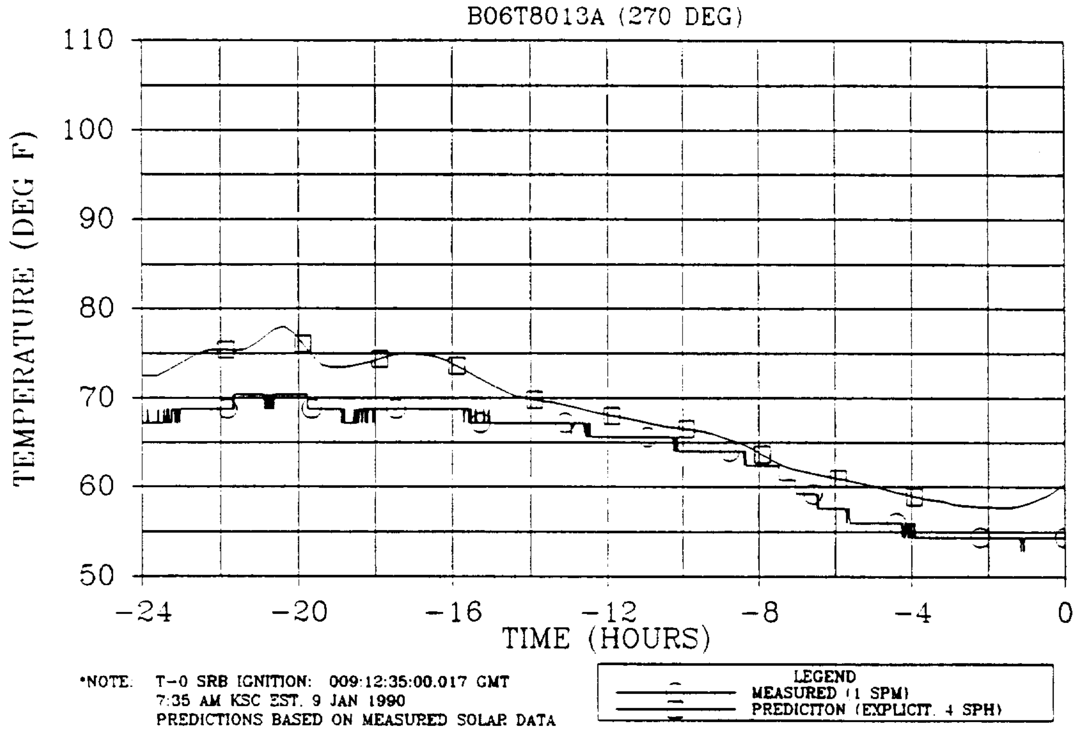


Figure 4.8-108. Measured Versus Postflight Prediction--Right SRM Case Acreage Temperature at Station 931.5 (270 deg)

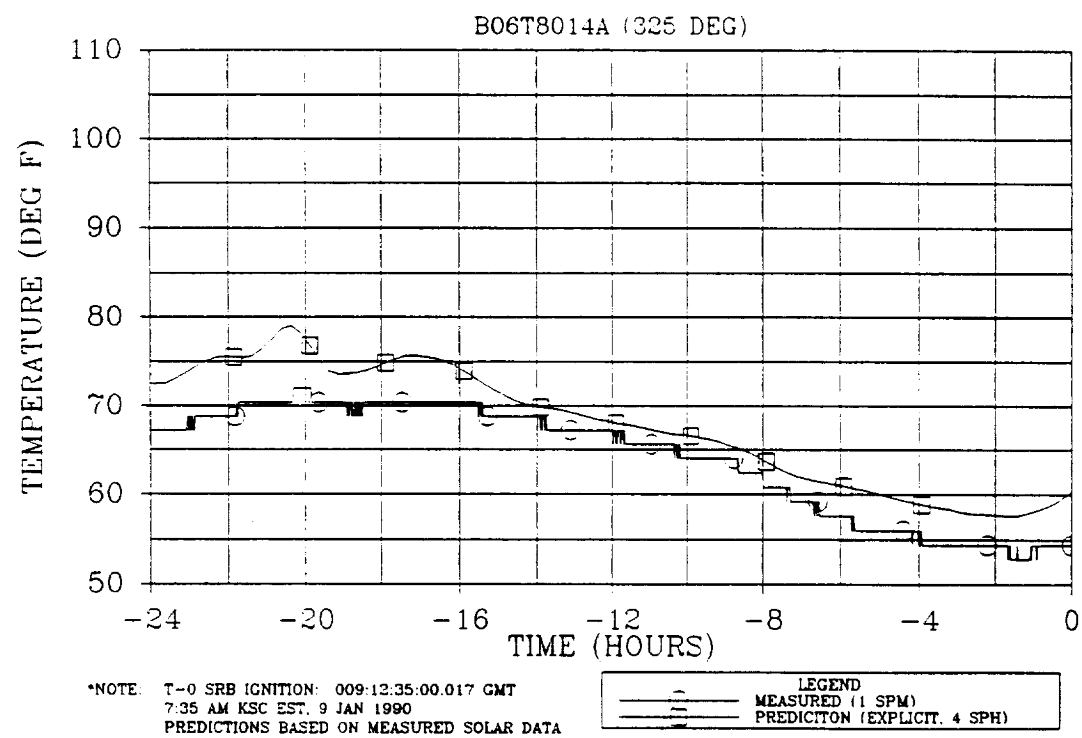


Figure 4.8-109. Measured Versus Postflight Prediction--Right SRM Case Acreage Temperature at Station 931.5 (325 deg)

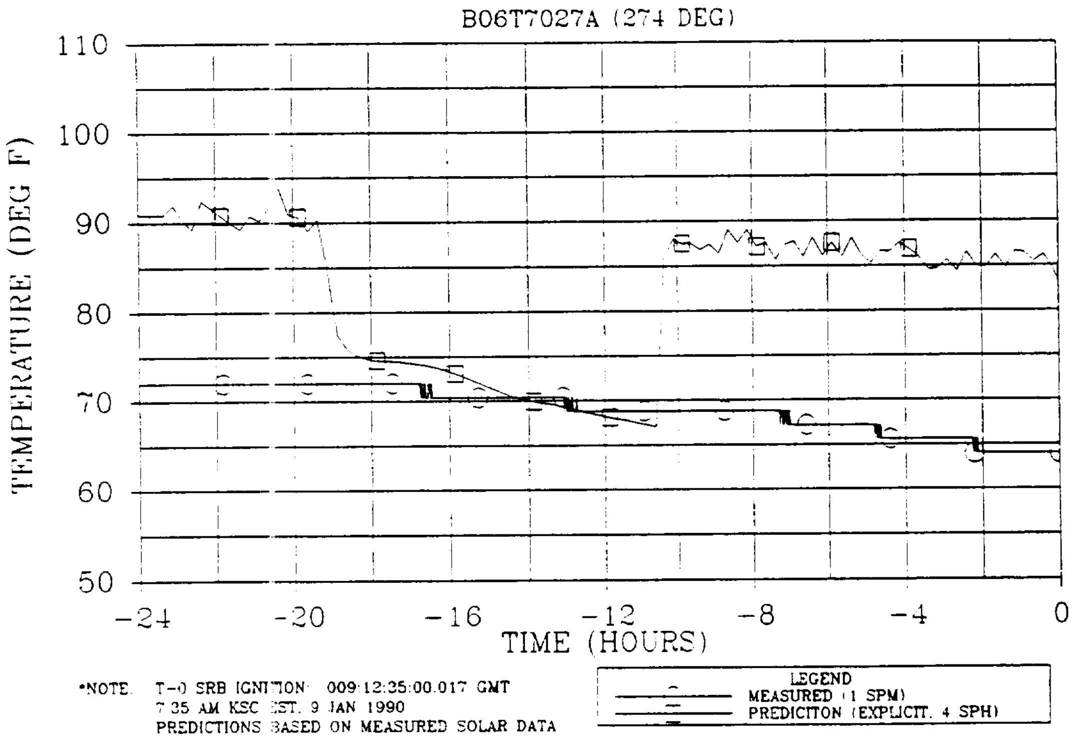


Figure 4.8-110. Measured Versus Postflight Prediction--Left SRM ET Attach Region Temperature at Station 1511.0 (274 deg)

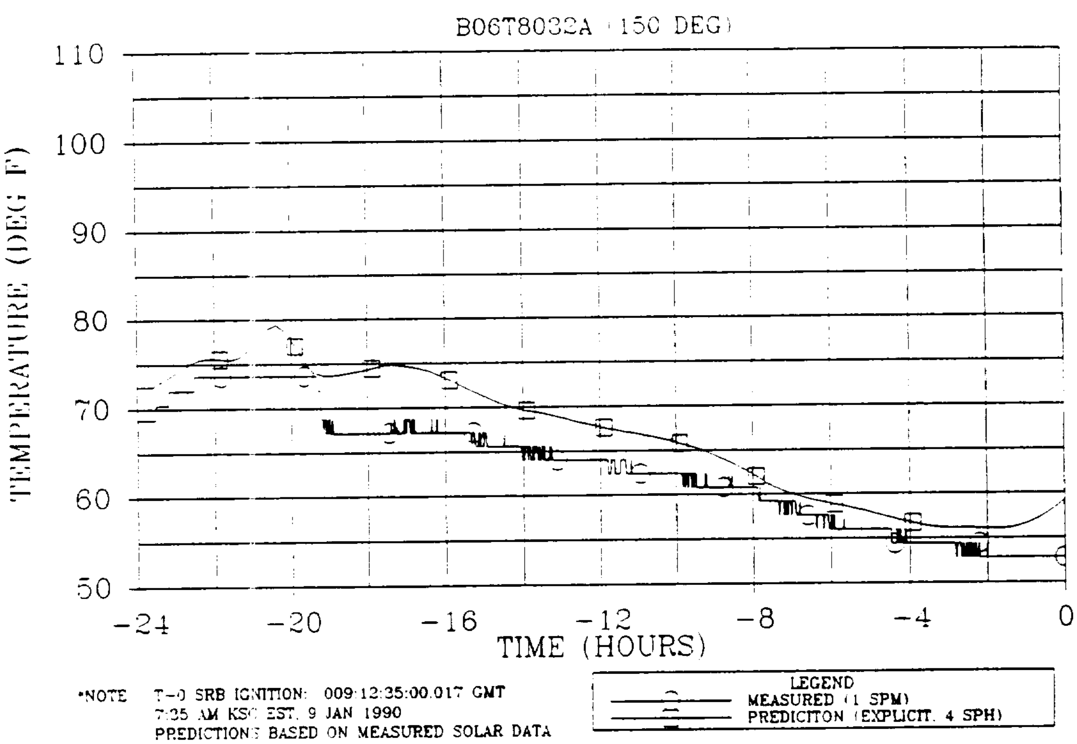


Figure 4.8-111. Measured Versus Postflight Prediction--Right SRM Aft Factory Joint Temperature at Station 1701.9 (150 deg)

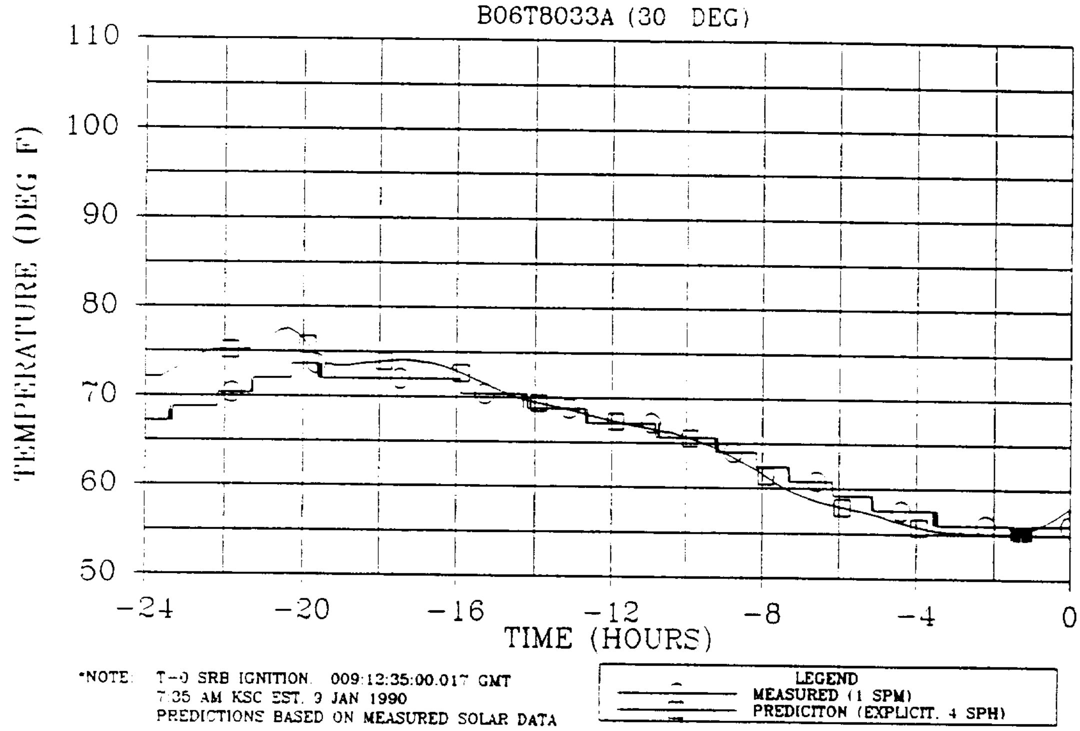


Figure 4.8-112. Measured Versus Postflight Prediction--Right SRM Aft Factory Joint Temperature at Station 1701.9 (30 deg)

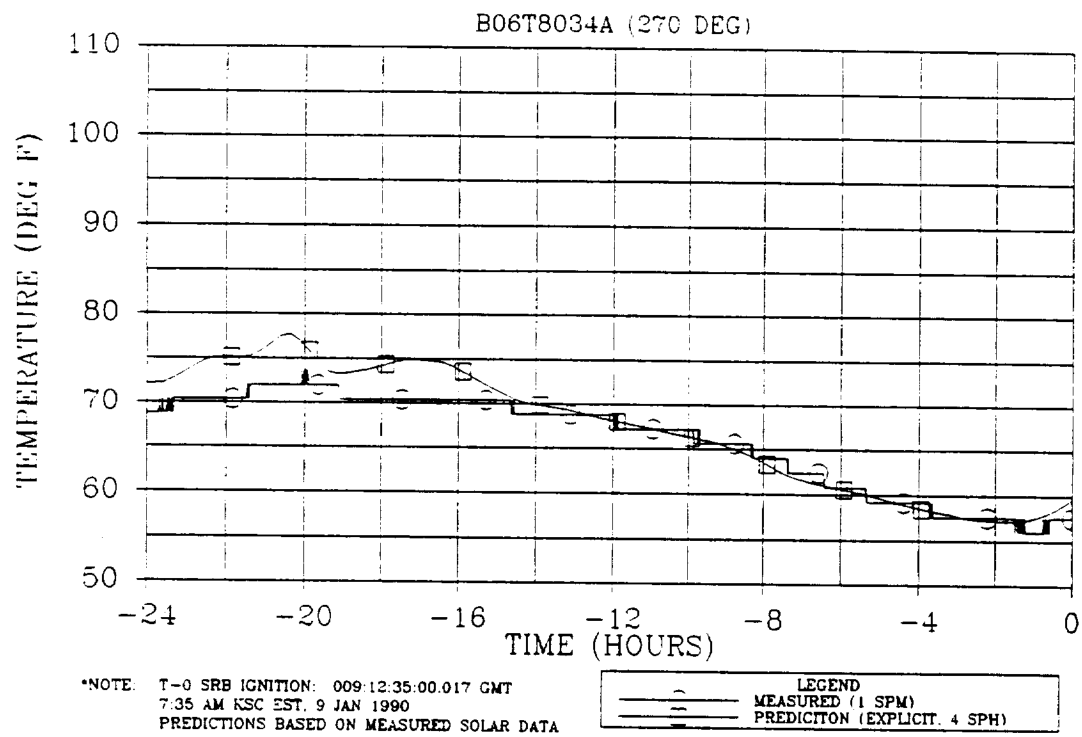


Figure 4.8-113. Measured Versus Postflight Prediction--Right SRM Aft Factory Joint Temperature at Station 1701.9 (270 deg)

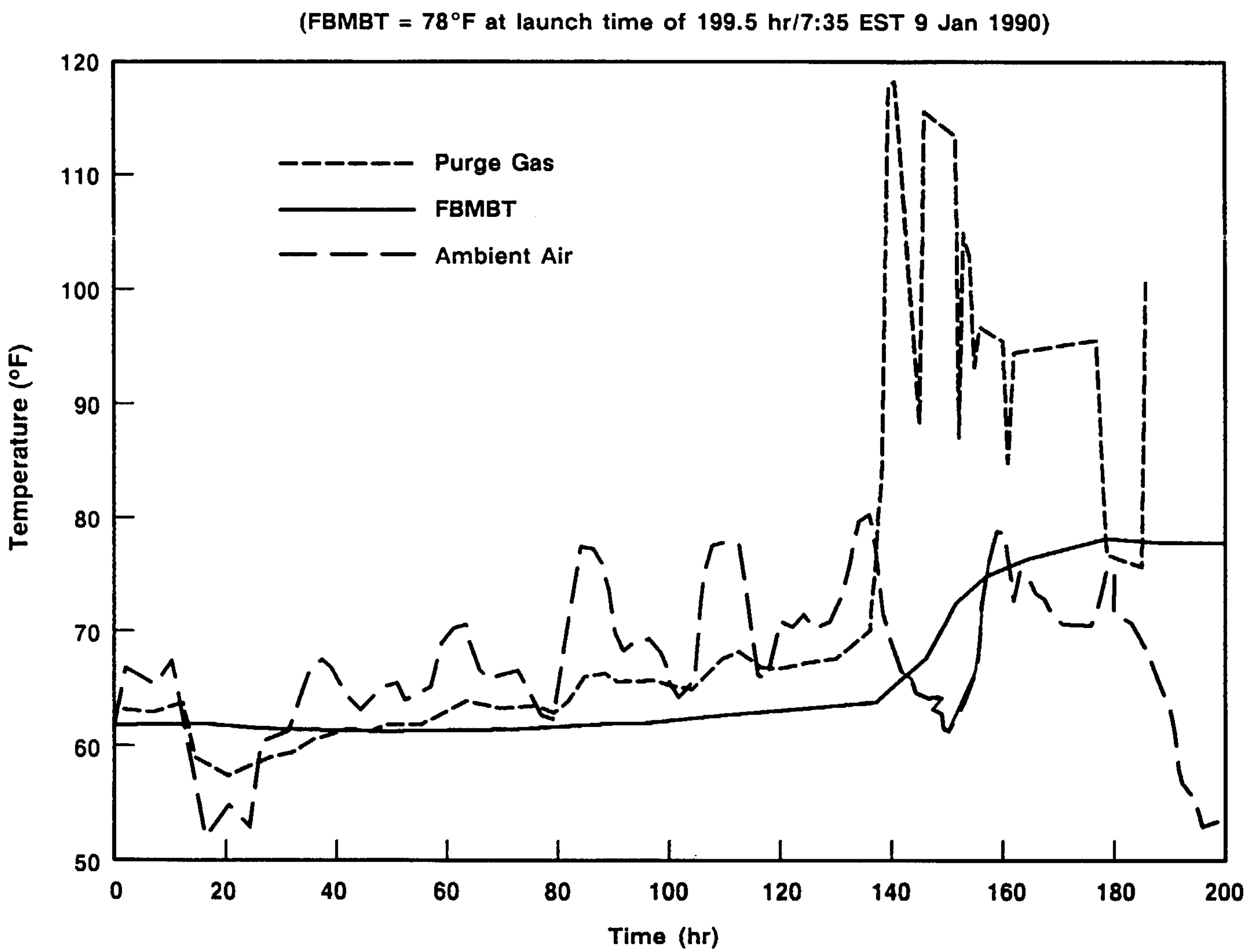


Figure 4.8-114. STS-32 RSRM FBMBT Postprediction

4.8.3.7 Prelaunch Hardware Anomalies. At 19:35 EST on January 6 the aft skirt purge system was deactivated when a low O_2 reading indicated a GN_2 leak. This occurred when a seal, downstream of the GN_2 supply, either leaked or had inadvertently been left out. This hardware problem was corrected and purge operation resumed 6 hr and 9 min later. There were no other prelaunch hardware anomalies.

4.8.4 Conclusions and Recommendations

A summary of these recommendations was previously presented in Section 3.3. A more detailed explanation is provided here.

4.8.4.1 Postflight Hardware Inspection. Based on the quick look external inspection, the SRM TPS performed adequately on STS-32R. No unexpected heating effects were noted. The SRM TPS 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 re-entry are for the most part overly conservative. An exception to this is the environment in the nozzle base region during re-entry when hydrazine fires and excessive nozzle flame heating are present (see 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 the 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 continues to perform excellently as expected. All TPS cork pieces (generally small) are due to nozzle severance debris and/or splashdown loads and debris.

Stencils marking the GEI MSID locations have replaced the original labels with epoxy closeout. This has eliminated epoxy closeout as a debris concern.

4.8.4.3 GEI Prediction. Additional model enhancement is recommended for certain SRM regions in order to improve predictions. It should be noted that the attainment of actual solar radiation data for recent STS flights has improved postflight predictions significantly. Submodel development effort for the areas of the ET attach ring, factory joint, and systems tunnel regions is anticipated. These tasks would be encompassed by the global model. It is recommended that the nodes be made smaller to refine the model. It is also recommended that all these models, including the 3-D SRM model, be made available for use at MSFC. This would allow Thiokol thermal personnel to support launch countdowns at the HOSC with prediction update capability.

4.8.4.4 Aft Skirt Purge Operation. During the early stages of the STS-32R purge operation, up to a 10°F circumferential temperature differential existed between the case-to-nozzle joint sensors and between the aft end ring sensors. This occurred under high flow and temperature conditions. This represents a good data point from which to base a 3-D skirt region flow analysis. This effort would be of special value if the GN_2 heating system fails and a GN_2 cold purge is required in the last stages of the count.

4.8.4.5 GEI Accuracy. Gage range has been reduced on all field joint and igniter heater sensors resulting in better data resolution. It is recommended that the data collection accuracy of all GEI be increased by reducing the gage range and increasing the digital word length. The real fidelity of the KSC ground support equipment could then be quantified and conceivably replaced if determined to be inadequate.

4.8.4.6 Local Chilling. Based on data from STS-28 (360H005), STS-29R (360L003) and STS-30R (360T004), local cooling does occur. Cooling should have occurred on this flight, based on similar wind conditions when comparing this flight with the three previously mentioned. There was no evidence of local chilling for this flight. Methods are currently being examined (a joint effort between Thiokol and MSFC) which can be used to accurately quantify and predict the chill effect. It is recommended that this effort continue

4.8.4.7 IR Measurements. STI data continues 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. Future efforts should be made in specifying locations for additional stationary STI cameras to assist in the eventual replacement of the outboard GEI (inboard GEI will need to be maintained since the STI cannot reach these blind regions).

4.8.4.8 Ice/Debris Team Support. Consideration should be given to provide consistent flight to flight ice/debris support. The present amount of team involvement should be maintained and built upon at opportune times.

Thiokol should give a formal response to the Ice/Debris team concerning debris particles coming out of the SRM nozzle prior to and following separation.

4.8.4.9 SRM Hardware Thermal Assessment. The SRM TPS design from a thermal perspective continues to suggest that the worst-case flight design environments of the IVBC-3 and SRB re-entry are for the most part overly conservative. An exception to this is the environment in the nozzle base region during re-entry when excessive nozzle flame heating and hydrazine fires are present (see STS-29R Final Report, TWR-17542, Vol I). USBI is in the process of updating thermal environments for the base region. Followthrough is being made concerning the request.

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

DFI has been eliminated on STS-30R (360T004) and subsequent flights. This section is reserved pending any future SRMs 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 360L008 (STS-32R). 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. 360L008 (STS-32R) Instrumentation

	LH			RH			
Parameter	OFI	GEI	Heater	OFI	GEI	Heater	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 360L008 consisted of 108 temperature sensors, resistance temperature devices (RTDs) which monitor SRM case temperature while the SRM is on the pad. OFI consists of three OPTs on each forward dome. All GEI gages were functioning and all were within the allowable variation before launch, with the exception of B06T7020A (a systems tunnel bondline temperature sensor which was damaged during the stacking operation). (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 instrumentation list and include gages which consistently read differently from surrounding gages. Figures 4.8-6, 4.8-8, 4.8-9, and 4.8-10 show GEI/OFI locations.

The OFI consists of three OPTs on each forward dome. All OPTs functioned properly during flight and successfully passed the prelaunch calibration checks. However, a pressure measurement system data loss resulted in a low I_{sp}. The results of the 75 percent calibration (performed at T-1.5 hr) verified readings were well within the 740 to 804 psia allowable range and are listed below as follows.

Gage	Reading	Gage	Reading
B47P1300C	767.8	B47P2300C	759.8
B47P1301C	761.8	B47P2301C	765.8
B47P1302C	763.8	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/ and Figure 4.8-7 list the joint heater sensors and show the gage locations, respectively.

4.10.4 S&A Device Rotation Times

Table 4.10-5 includes the S&A delta times for the S&A Functional Test performed prior to the 360L008 (STS-32R) countdown. Table 4.10-6 lists the arm and safe times during the actual launch sequence (at T-5 min). As with the functional test, all values are less that 2.0 sec.

Table 4.10-6. S&A Device Activity Times for 360L008 (STS-32R)

9 Jan 1990 (at T-5 min)

Rotation times	LH	0.844 sec*
(arm command to arm indication)	RH	0.884 sec*

*The data sample rate is five times per second; therefore, the actual rotation times could be ±0.200 sec sooner.

Table 4.10-2. GEI List--LH SRM (360L008A)

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	
B06T7011A	135	931.48	±200	Forward center segment	
B06T7012A	325	931.48	±200	Forward center segment	
B06T7013A	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)	Damaged during stacking--Inoperable
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	
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	

Table 4.10-2. GEI List--LH SRM (360L008A) (cont)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
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	-4 to +158	Igniter	
B06T7086A	355.5	486.4	-4 to +158	Igniter	

Table 4.10-3. GEI List--RH SRM (360L008B)

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	
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	
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	Installed at 108 deg instead of 180 deg due to error on drawing. No adverse effect on LCC
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	

Table 4.10-3. GEI List--RH SRM (360L008B) (cont)

Instrument No.	Location (deg)	Station	Range (°F)	Case Location	Comments
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	-4 to +158	Igniter	Sensor installed properly at correct location, but sensor cable is incorrectly oriented. No effect on RTD performance
B06T8086A	184.5	486.4	-4 to +158	Igniter	

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Table 4.10-4. Field Joint Heater Temperature Sensor Lists (both SRMs)

Instrument No.	Location (deg)	Station	Range (°F)	Required Accuracy (%)	Digital*	Remarks	Comments
			LH SRM Heater Temperature Sensor List				
B07T7060	15	851.5	-4 to 158	±1	1	Forward heater	
B07T7061	135	851.5	-4 to 158	±1	1	Forward heater	
B07T7062	195	851.5	-4 to 158	±1	1	Forward heater	
B07T7063	285	851.5	-4 to 158	±1	1	Forward heater	
B07T7064	15	1171.5	-4 to 158	±1	1	Center heater	
B07T7065	135	1171.5	-4 to 158	±1	1	Center heater	
B07T7066	195	1171.5	-4 to 158	±1	1	Center heater	
B07T7067	285	1171.5	-4 to 158	±1	1	Center heater	
B07T7068	15	1491.5	-4 to 158	±1	1	Aft heater	
B07T7069	135	1491.5	-4 to 158	±1	1	Aft heater	
B07T7070	195	1491.5	-4 to 158	±1	1	Aft heater	
B07T7071	285	1491.5	-4 to 158	±1	1	Aft heater	
			RH SRM Heater Temperature Sensor List				
B07T8060	15	851.5	-4 to 158	±1	1	Forward heater	
B07T8061	135	851.5	-4 to 158	±1	1	Forward heater	
B07T8062	195	851.5	-4 to 158	±1	1	Forward heater	
B07T8063	285	851.5	-4 to 158	±1	1	Forward heater	
B07T8064	15	1171.5	-4 to 158	±1	1	Center heater	
B07T8065	135	1171.5	-4 to 158	±1	1	Center heater	
B07T8066	195	1171.5	-4 to 158	±1	1	Center heater	
B07T8067	285	1171.5	-4 to 158	±1	1	Center heater	
B07T8068	15	1491.5	-4 to 158	±1	1	Aft heater	
B07T8069	135	1491.5	-4 to 158	±1	1	Aft heater	
B07T8070	195	1491.5	-4 to 158	±1	1	Aft heater	
B07T8071	285	1491.5	-4 to 158	±1	1	Aft heater	

*Sampling rate is given in samples per minute (spm)

Table 4.10-5. S&A Delta Times for the S&A Functional Test

SRB IGNITION S&A ROTATION - STS-32R 18-Dec-89
(B47SA0.070 - IGNITION S&A FUNCTIONAL TEST)

ROTATE #	GMT	COMMAND	GMT	RESPONSE	DELTA	ARM LEFT	ARM RIGHT	SAFE LEFT	SAFE RIGHT
	82450.661	B55K3000X1-LH ARM	82451.528	B55X1842X1-LH ARM	0.867	0.867			
1	82450.901	B55K4000X1-RH ARM	82451.848	B55X2842X1-RH ARM	0.947		0.947		
	82458.301	B55K3002X1-LH SAFE	82459.128	B55X1843X1-LH SAFE	0.827			0.827	
	82458.541	B55K4002X1-RH SAFE	82459.448	B55X2843X1-RH SAFE	0.907				0.907
	82732.262	B55K3000X1-LH ARM	82733.128	B55X1842X1-LH ARM	0.866	0.866			
2	82732.501	B55K4000X1-RH ARM	82733.448	B55X2842X1-RH ARM	0.947		0.947		
	82739.981	B55K3002X1-LH SAFE	82740.728	B55X1843X1-LH SAFE	0.747			0.747	
	82740.221	B55K4002X1-RH SAFE	82741.048	B55X2843X1-RH SAFE	0.827				0.827
	82835.381	B55K3000X1-LH ARM	82836.128	B55X1842X1-LH ARM	0.747	0.747			
3	82835.622	B55K4000X1-RH ARM	82836.448	B55X2842X1-RH ARM	0.826		0.826		
	82842.821	B55K3002X1-LH SAFE	82843.528	B55X1843X1-LH SAFE	0.707			0.707	
	82843.061	B55K4002X1-RH SAFE	82843.848	B55X2843X1-RH SAFE	0.787				0.787
	82926.182	B55K3000X1-LH ARM	82926.928	B55X1842X1-LH ARM	0.746	0.746			
4	82926.423	B55K4000X1-RH ARM	82927.248	B55X2842X1-RH ARM	0.825		0.825		
	82933.742	B55K3002X1-LH SAFE	82934.528	B55X1843X1-LH SAFE	0.786			0.786	
	82933.982	B55K4002X1-RH SAFE	82934.848	B55X2843X1-RH SAFE	0.866				0.866
	83005.382	B55K3000X1-LH ARM	83006.127	B55X1842X1-LH ARM	0.745	0.745			
5	83005.623	B55K4000X1-RH ARM	83006.448	B55X2842X1-RH ARM	0.825		0.825		
	83013.062	B55K3002X1-LH SAFE	83013.928	B55X1843X1-LH SAFE	0.866			0.866	
	83013.302	B55K4002X1-RH SAFE	83014.248	B55X2843X1-RH SAFE	0.946				0.946
	83047.741	B55K3000X1-LH ARM	83048.528	B55X1842X1-LH ARM	0.787	0.787			
6	83047.981	B55K4000X1-RH ARM	83048.848	B55X2842X1-RH ARM	0.867		0.867		
	83055.341	B55K3002X1-LH SAFE	83056.128	B55X1843X1-LH SAFE	0.787			0.787	
	83055.621	B55K4002X1-RH SAFE	83056.448	B55X2843X1-RH SAFE	0.827				0.827
	83130.781	B55K3000X1-LH ARM	83131.528	B55X1842X1-LH ARM	0.747	0.747			
7	83131.021	B55K4000X1-RH ARM	83131.848	B55X2842X1-RH ARM	0.827		0.827		
	83138.301	B55K3002X1-LH SAFE	83139.128	B55X1843X1-LH SAFE	0.827			0.827	
	83138.542	B55K4002X1-RH SAFE	83139.448	B55X2843X1-RH SAFE	0.906				0.906
	83244.221	B55K3000X1-LH ARM	83244.928	B55X1842X1-LH ARM	0.707	0.707			
8	83244.461	B55K4000X1-RH ARM	83245.248	B55X2842X1-RH ARM	0.787		0.787		
	83251.821	B55K3002X1-LH SAFE	83252.528	B55X1843X1-LH SAFE	0.707			0.707	
	83252.061	B55K4002X1-RH SAFE	83252.848	B55X2843X1-RH SAFE	0.787				0.787
	83323.381	B55K3000X1-LH ARM	83324.128	B55X1842X1-LH ARM	0.747	0.747			
9	83323.622	B55K4000X1-RH ARM	83324.448	B55X2842X1-RH ARM	0.826		0.826		
	83330.981	B55K3002X1-LH SAFE	83331.728	B55X1843X1-LH SAFE	0.747			0.747	
	83331.221	B55K4002X1-RH SAFE	83332.048	B55X2843X1-RH SAFE	0.827				0.827
	83446.221	B55K3000X1-LH ARM	83446.928	B55X1842X1-LH ARM	0.707	0.707			
10	83446.461	B55K4000X1-RH ARM	83447.248	B55X2842X1-RH ARM	0.787		0.787		
	83453.701	B55K3002X1-LH SAFE	83454.528	B55X1843X1-LH SAFE	0.827			0.827	
	83453.942	B55K4002X1-RH SAFE	83454.848	B55X2843X1-RH SAFE	0.906				0.906
					AVERAGE :	0.767	0.846	0.783	0.85

Table 4.10-5. S&A Delta Times for the S&A Functional Test (Run No. 2)

S&S [illegible] S&A ROTATION [illegible] (RUN 2)
[illegible] - IGNITION S&A FUNCTIONAL TEST)

ROTATE #	GMT	COMMAND	GMT	RESPONSE	DELTA	ARM LEFT	ARM RIGHT	SAFE LEFT	SAFE RIGHT
1	224652.669	B55K3000X1-LH ARM	224653.456	B55X1842X1-LH ARM	0.787	0.787			
	224652.909	B55K4000X1-RH ARM	224653.776	B55X2842X1-RH ARM	0.867		0.867		
	224700.389	B55K3002X1-LH SAFE	224701.256	B55 [illegible]843X1-LH SAFE	0.867			0.867	
	224700.629	B55K4002X1-RH SAFE	224701.576	B5[illegible] 2843[illegible]-RH SAFE	0.947				0.947
2	225012.470	B55K3[illegible]0X1-LH ARM	225013.256	B55X1842X1-LH ARM	0.786	0.786			
	225012.710	B55K4000X1-RH ARM	225013.576	B55X2842X1-RH ARM	0.866		0.866		
	225[illegible]0.070	B55K3002X1-LH SAFE	225020.856	B55X1843X1-LH SAFE	0.786			0.786	
	225020.310	B55K4002X1-RH SAFE	225021.176	B55X284[illegible]-RH SAFE	0.866				0.866
3	22[illegible]43.069	B55K3000X1-LH ARM	225143.856	B55X1842X1-LH ARM	0.787	0.787			
	22514[illegible]309	B55K4[illegible]00X1-RH ARM	225144.176	B55X2842X1-RH ARM	0.867		0.867		
	2251[illegible].669	B55K3002X1-LH SAFE	225151.456	B55X1843X1-LH SAFE	0.787			0.787	
	225150.949	B55K4002X1-RH SAFE	225151.775	B55X2843X1-RH SAFE	0.827				0.827
4	225219.469	B55K3000X1-LH ARM	225220.256	B55X1842X1-LH ARM	0.787	0.787			
	225219.709	B55K4000X1-RH ARM	225220.576	B55X2842X1-RH ARM	0.867		0.867		
	225226.989	B55K3002X1-LH SAFE	2[illegible]227.856	B55X1843X1-LH SAFE	0.867			0.867	
	225227.229	B55K4002X1-RH SAFE	2[illegible]228.176	B55X2843X1-RH SAFE	0.947				0.947
5	225250.829	B55K3000X1-LH ARM	225251.656	B55X1842X1-LH ARM	0.827	0.827			
	225251.109	B55K4000X1-RH ARM	225251.976	B55X2842X1-RH ARM	0.867		0.867		
	225258.549	B55K3002X1-LH SAFE	225259.255	B55X1843X1-LH SAFE	0.706			0.726	
	225258.789	[illegible]55K4002X1-RH SAFE	225259.576	B55X2843X1-RH SAFE	0.787				0.797
	[illegible]324.309	B55K3000X1-LH ARM	225325.056	B55X1842X1-LH ARM	0.747	0.747			
	[illegible]324.549	B55K4000X1-RH ARM	225325.376	B55X2842X1-RH ARM	0.827		0.827		
	225331.789	B55K3002X1-LH SAFE	225332.656	B55X1843X1-LH SAFE	0.867			0.867	
	225332.030	[illegible]55K4002X1-RH SAFE	225332.976	B55X2843X1-RH SAFE	0.946				0.946
7	225357.389	B55K3000X1-LH ARM	225358.256	B55X1842X1-LH ARM	0.867	0.867			
	225357.629	B55K4000X1-RH ARM	225358.576	B55X2842X1-RH ARM	0.947		0.947		
	22540[illegible].149	B55K3002X1-LH SAFE	225405.656	B55X1843X1-LH SAFE	0.707			0.707	
	22540[illegible].389	B55K4002X1-RH SAFE	225406.176	B55X2843X1-RH SAFE	0.787				0.787
8	225424.190	B55K3000X1-LH ARM	225425.056	B55X1842X1-LH ARM	0.866	0.866			
	225424.429	B55K4000X1-RH ARM	225425.376	B55X2842X1-RH ARM	0.947		[illegible]		
	225431.869	B55K3002X1-LH SAFE	225432.656	B55X1843X1-LH SAFE	0.787			0.787	
	225432.109	B55K4002X1-RH SAFE	225432.976	B55X2843X1-RH SAFE	0.867				0.867
9	225451.349	B55K3000X1-LH ARM	225452.055	B55X1842X1-LH ARM	0.706	0.706			
	225451.629	B55K4000X1-RH ARM	225452.576	B55X2842X1-RH ARM	0.947		0.947		
	225458.989	B55K3002X1-LH SAFE	225459.856	B55X1843X1-LH SAFE	0.867			0.867	
	225459.229	B55K4002X1-RH SAFE	225500.176	B55X2843X1-RH SAFE	0.947				0.947
10	225521.590	B55K3000X1-LH ARM	225522.456	B55X1[illegible]2X1-LH ARM	0.866	0.866			
	[illegible]521.829	B55K4000X1-RH ARM	225522.776	B55X[illegible]-RH ARM	0.947		0.947		
	[illegible]529.429	B55K[illegible]-LH SAFE	225530.256	B55X[illegible]-LH SAFE	0.827			0.827	
	[illegible]529.670	B55K4[illegible]-RH SAFE	225530.576	B55X[illegible] SAFE	0.906				0.906
				AVERAGE :		0.803	0.895	0.807	0.883

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4.11 RSRM HARDWARE ASSESSMENT (FEWG Report Paragraph 2.11.2)

4.11.1 Insulation Performance

4.11.1.1 Summary. 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 recordable clevis edge separations (over 0.1 in.). No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns were identified. Complete insulation performance evaluation is in Volume III of this report.

4.11.1.2 External Insulation. **Factory Joint Weatherseals**--Two of the 14 factory joint weatherseals exhibited unbonds.

Two forward edge unbonds were found on the LH aft stiffener-to-stiffener factory joint weatherseal: one at 230 deg, 3.2 in. circumferentially by 1.0 in. maximum depth and the second at 280 deg, 3.0 in. circumferentially by 1.25 in. maximum depth. Both unbonds exhibited adhesive failure between the Chemlok® 236A and the EPDM rubber. Fourier transform infrared (FTIR) swabs were taken for contamination analysis. No visible corrosion was present.

One unbond was found on the forward edge of the RH stiffener-to-stiffener factory joint weatherseal at 45 deg, 2.7 in. circumferentially by 0.70 in. maximum depth. The unbond exhibited adhesive failure between the Chemlok® 205 and the case. Corrosion was present underneath this weatherseal unbond, but there was no evidence of moisture in the LH or RH joints. An FTIR swab was also taken for analysis.

What appeared to be surface cracks were found at seven locations randomly on the factory joint weatherseals. The cracks at all locations were on the Teflon tape impression marks. The maximum condition occurred on the RH aft center, measuring 4.8 in. long by 0.08 in. maximum depth. These were determined to be inherent to the manufacturing process where several Teflon tape pieces are used to hold the rubber in place. During the cure process, the tape edges or folded areas are pulled by vacuum into the rubber. When the tape is removed, impressions, creases and cuts remain. The apparent cracks found at postfire would not have violated Thiokol's prefire engineering criteria (STW7-2831). The limits in the PEEP will be updated to address this as an acceptable condition.

Some small debris impact damage from re-entry was evident intermittently on the aft edges of the weatherseals. Normal heat effects and discoloration were evident on both aft segment weatherseals. No significant areas of missing EPDM insulation were noted. The K5NA closeouts over the thermocouple wires were in good condition, with no evidence of water leaking from any of these locations.

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 in the 220 to 320 deg region. 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. The K5NA repair on the outboard edge of the forward stiffener stubs showed normal erosion and some small missing chunks intermittently around the circumference. There was a crack in the EPDM insulation on the RH center stiffener (forward face) at 120 deg at the flange web interface due to splashdown damage. The crack was caused by water impact. All other stiffener-to-stub EPDM was nominal.

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 were identified. The disassembled joints showed the failure mode was 95 percent cohesive in the LH polysulfide bondline, while the RH motor failed 80 percent cohesive. Several small voids were identified in the polysulfide adhesive on the LH case-to-nozzle joint. The largest was located at 74 deg and measured 1.05 in. longitudinally by 0.25 in. wide. The void started at, but did not reach, the wiper O-ring and was not penetrated by hot gas. Several small voids were also found on the RH joint. Porosity was evident on both joints in the step region. The polysulfide vent slot fill on the LH motor was 45 percent on the LH motor and 50 percent on the RH motor.

4.11.1.4 Field Joints. The internal insulation in all six field joints performed as designed, and no anomalous conditions were noted. J-leg tip contact was evident full circumference at each joint. Wet soot deposits extending down the bondline were noted on all of the field joints, generally to a depth of 0.2 to 0.55 in. radially into the bondline (outboard from the remaining material). The maximum depth of the wet soot was 1.3 in. on the RH center field joint. No heat effects were evident under the soot. Similar wet sooting has been noted on previous RSRM field joints and is believed to occur at reentry or splashdown during joint flexing.

There were no clevis edge separations that were recordable (over 0.10 in. deep).

4.11.1.5 Ignition System Insulation. The igniter chamber insulation, as well as the igniter-to-case joint insulation for both igniter joints, showed normal erosion.

One blowhole through the putty of the LH igniter-to-case joint at 238 deg was present. The blowhole measured 2.95 in. wide at the aft edge of the putty and 0.60 in. wide at the adapter aft face. A band of soot was present on the putty next to the adapter (0.3 in. wide maximum) from 160 through 238 to 290 deg. Intermittent light sooting was present on the putty next to the adapter over the rest of the circumference.

Another blowhole through the putty was found in the RH igniter-to-case joint starting at 325 deg and ending at the adapter at 338 deg. The blowhole measured 0.40 in. wide at the aft edge of the putty and 0.35 in. wide at the adapter. A soot band was on the putty adjacent to the adapter from 45 through 270 to 338 deg. Lighter soot was found on the putty intermittently on the remaining circumference.

There were no blowholes in either adapter-to-chamber joint. The putty in all joints exhibited constant light olive green color, nominal tack and 100 percent cohesive failure on left SRM, 95 percent on right SRM.

Intermittent missing/peeling primer coat was observed on the forward 0.8 in. of the igniter chamber adjacent to the adapter. The missing primer was found on the forward dome putty in locations corresponding to the chamber. Swab samples and primer samples taken for lab analysis indicated that no contamination was present. Surface finish requirements will be changed to ensure adequate bonding.

4.11.1.6 Internal Acreage Insulation. The acreage insulation, including the internal insulation over each of the factory joints, appeared in good condition. No evidence of hot gas penetration through the insulation was identified. Minor debris damage was evident in both aft segments.

Forward Segments--The stress relief flap was present full circumference on both forward segments but was heat effected and eroded. The castable inhibitors were completely missing full circumference. The flaps had a scalloped appearance similar to that seen on previous RSRM flight forward segment flaps. The acreage insulation was in normal condition. The 11-point star pattern was easily distinguishable in the liner.

Both forward domes near the igniter boss were extensively inspected for excessive erosion and thin insulation. No gas paths or areas of abnormal erosion were identified. Preliminary insulation thickness measurements indicated adequate thermal SFs near the igniter boss. The insulation in this area was also removed and three folds in the insulation next to the case were found on the LH sample with a maximum depth of 0.09 inch. Seven folds were found on the RH with a maximum depth of 0.18 inch. Two voids in the right sample insulation were also detected.

A final evaluation of the thermal performance of the insulation will be accomplished after internal thicknesses are measured at the Clearfield H-7 facility.

Center Segments--Only four inhibitor tears greater than 3 in. radially were noted in either aft center segment inhibitor stub. Both were noted on the LH aft center segment and measured 3.2 and 3.7 in. in length.

Some radial tears were noted in the forward center segment NBR inhibitor stubs (seven on the LH motor and six on the RH motor). The tears in the forward center segments ranged from 3.4 to 15.5 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, indicating that the tears occurred after motor burn.

The flap and acreage insulation exhibited normal erosion. The castable inhibitor was completely missing on all four center segments. The flap and carbon-filled/EPDM was completely eroded to the flap bulb on the aft center segments and partially eroded on the forward center segments.

Aft Segments--The aft segment NBR inhibitor stubs exhibited fairly uniformed erosion around the circumference. There were no tears in either inhibitor. The aft segment acreage insulation was in normal condition. Minor gouges and cuts were found due to debris.

4.11.2 Case Component Performance

4.11.2.1 Summary. Evaluation of the steel case indicated the hardware performed as expected during flight. There was no increase in fretting magnitude in the previously fretted hardware. The new fretting occurred in previously unfretted areas. Complete case evaluation results are in Volume II of this report.

4.11.2.2 Stiffener Stubs, Stiffener Rings, and ET Attach Stubs. Eight bolts were missing from the RH center stiffener from 122 to 136 deg.

The RH center stiffener ring was warped between 120 and 122 deg. The flange was cracked at 138 deg, extending to the web. The flange was torn away from the web from 138 to 141 deg (3.6 in.). The bolt holes at 120 and 122 deg were elongated at an angle of 60 deg to the web. All other stiffener rings were nominal as were the stiffener and external attach stubs.

Based on missing insta-foam, the cavity collapse load centerline for the RH and LH SRMs were estimated to be at 140 and 135 deg, respectively.

4.11.2.3 Field Joints. The case field joint surface conditions were as expected. Fretting ranged from light to heavy. All joints had some fretting. The LH center and aft field joints had the worst fretting at 0.007 in. deep. The RH aft joint had a 0.006 in. deep fret. The RH forward field joint had previously been fretted, but no new frets were found in the old fret indications. Figure 4.11-1 provides a subjective summary of the fretting.

4.11.2.4 Case-to-Nozzle Joint. The case-to-nozzle joint on both motors were in excellent condition. There were no signs of metal damage to any of the sealing surfaces; bolt holes or heat effected metal; or corrosion or damaged bolts.

4.11.2.5 Igniter-to-Forward Dome. The igniter-to-forward dome joint on both motors was in excellent condition. There were no signs of metal damage to any sealing surface; bolt holes or heat effected metal; or corrosion or damaged bolts.

4.11.2.6 Factory Joint External Surface. Medium corrosion was found intermittently on the RH center forward factory joint, around and between the pin holes from 135 to 220 deg. No pitting was observed. The other factory joints were nominal.

4.11.2.7 Miscellaneous Case Surfaces. All cork, K5NA, cables and gauges associated with the GEI were removed at Hangar AF because of corrosion pits observed on previous case segments from an instrumentation spot bond. These spot bonds are for lightning protection and use silver-filled epoxy (Eccobond 56C). The instrumentation is then covered with K5NA and Hypalon® paint. During SRB re-entry, the Hypalon® paint blisters, allowing seawater to soak into the K5NA, producing a galvanic cell between the case and the silver-filled epoxy. Some of the case surfaces under the

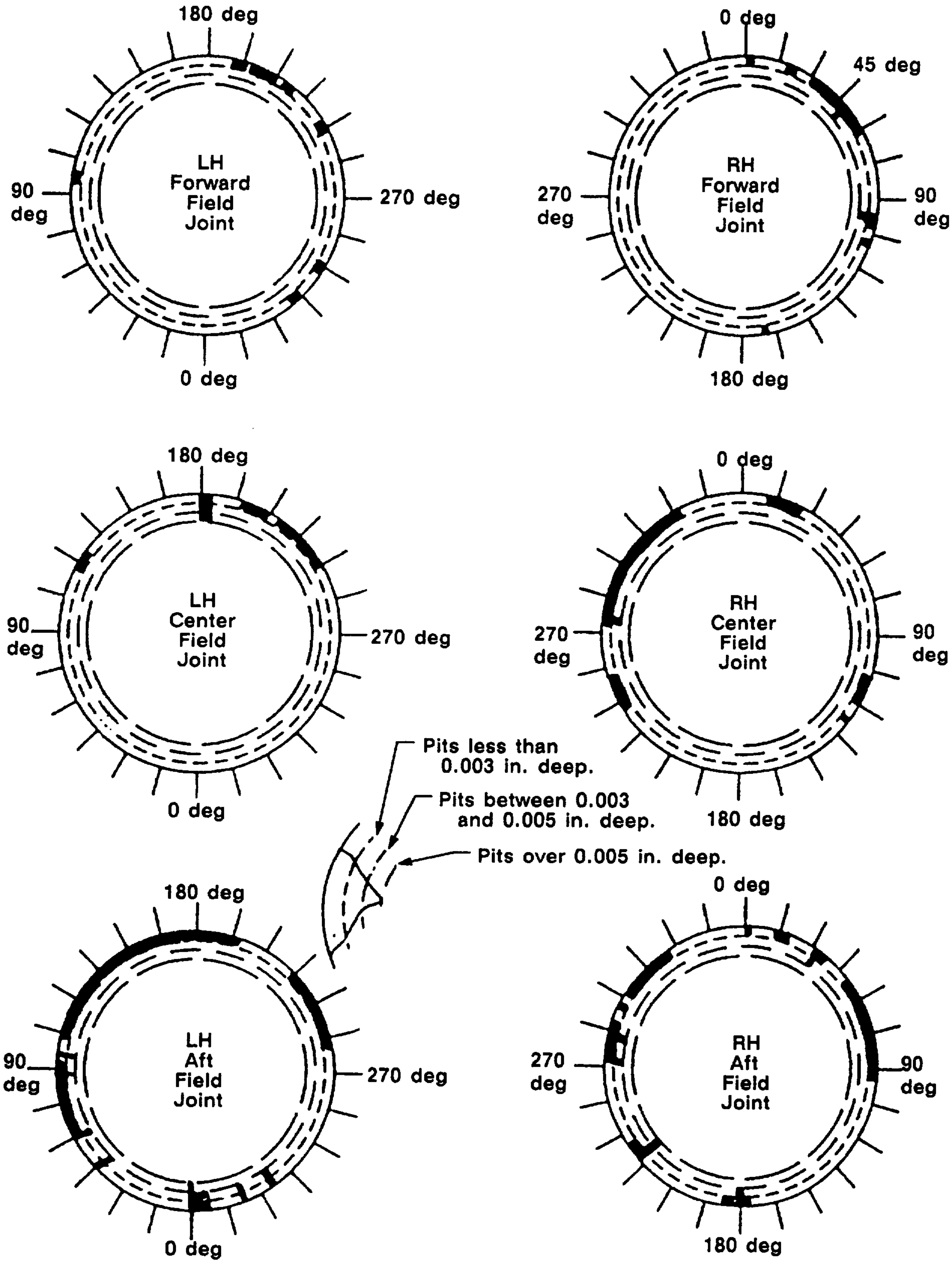

Figure 4.11-1. Field Joint Fretting 360L008 (STS-32R)

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removed GEI runs had light corrosion. Very few minor pits were observed on a few GEI spot bond locations.

4.11.2.8 OPTs, Special Bolts, and Special Bolt Plugs. There was no evidence of any gas leakage past the primary seals on any of the OPTs. The LH and RH primary seals saw pressure. Soot deposits were observed on the threads on the tip of the OPTs and up to the primary seals. The physical condition of the OPTs was excellent.

All LH and RH igniter special bolts experienced typical light sooting up to the primary O-ring and on the end of the special bolts.

4.11.2.9 Vent Port and Leak Check Port Plugs. The metal surfaces of the plugs were free of soot, debris, and corrosion.

4.11.2.10 Joint Heaters. Both RH and LH igniter heaters were evaluated before and after removal. No discoloration or warping was noted, indicating proper installation and nominal performance.

4.11.3 Seals Performance

4.11.3.1 Summary. Evaluation of the field, nozzle-to-case, and forward exit cone-to-aft exit cone joints indicated the internal seals performed as expected during flight. All internal seals, including the redesigned field joint seals and case-to-nozzle joint seals, appeared to have performed well with no hot gas leakage evident. Complete evaluation will be documented in Volume II of this report.

4.11.3.2 Case Field Joint. Inspection of the field joint seals revealed no anomalous conditions. All motor pressure was contained by the insulation J-joint. There was no corrosion or damage 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 was nominal. There was typical light to medium corrosion.

4.11.3.3 OPT, Special Bolts, 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. Soot deposits were observed on the tips of the transducer threads and up to the primary seals. All of the seals performed nominally.

Special bolt primary seals were in excellent condition and performed as expected. Special bolt plug seals were also in excellent condition. All LH and RH igniter special bolts experienced typical light soot up to the primary O-ring and on the end of the special bolts.

4.11.3.4 Ignition System Joint. The igniter removal on this flight set was the second performed using dynamometers and guide pins in order to monitor the loads involved and minimize the putty disturbance during disassembly.

The seals of the S&A, igniter outer, and igniter inner gaskets revealed no erosion or heat effect. An impression was found on the crown of the secondary seal on the RH S&A gasket aft face at 0 deg. Approximate dimensions were 0.050 in. circumferential length by 0.0025 in. in depth. No contamination was observed on the seal surface adjacent to the impression. Most of the impression had recovered by the morning of 11 Jan 1990 (about 9 hr later).

The LH igniter outer putty had a blowhole through it at 238 deg. Very light intermittent soot was observed on the forward dome boss, the igniter adapter face, and both sides of the outer gasket to the primary seal around the full circumference. Light soot was on the gasket primary seal from 247 to 255 deg. No soot was observed past the primary seal on either face and there was no putty on either side of the gasket.

Inspection of the LH inner joint showed no blowholes and all sealing components were nominal.

A blowhole through the RH outer joint was observed at 338 deg. Very light intermittent soot was observed around the full circumference of the dome boss, the igniter adapter face and both sides of the outer gasket to the primary seal. Medium sooting was to the primary seal on the forward face of the gasket from 324 to 330 deg. No soot was observed past the primary seal on either face and there was no putty on either side of the gasket.

There were raised areas of rubber found in the void and cushion area on all seals on both sides of the RH inner gasket intermittently around the circumference. The largest area measured approximately 0.20 in. circumferentially. A detailed inspection revealed raised areas on both primary seals on both faces. Other than the raised areas, the seals were nominal as were the sealing surfaces of the RH inner joint.

The LH and RH igniter inner joint packing with retainers (Stat-O-Seals) were in good condition. None had any apparent damage.

4.11.3.5 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. No obvious disassembly damage was noted on the primary or wiper O-rings.

Three of the radial bolt hole disassembly plugs were damaged during the RH case-to-nozzle joint disassembly. The damaged plugs were the old style plug.

The LH and RH case-to-nozzle joint Stat-O-Seals were in good condition, with no disassembly damage.

4.11.3.6 Vent Port Plugs. The case field joint and case-to-nozzle joint vent port plugs and seals on each motor were in excellent condition. 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 (except for the RH case-to-nozzle joint vent port plug).

4.11.3.7 Leak Check Port Plugs. The leak check port plugs and seals on the LH and RH motors in the case field joints, case-to-nozzle joints, aft exit cone joints, and the ignition system joints were in good condition. None of the leak check port 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.

4.11.4 Nozzle Performance

4.11.4.1 Summary. Postflight evaluation indicated both nozzles performed as expected during flight. Phenolic erosion was smooth and normal. Complete evaluation is in Volume V of this report.

4.11.4.2 360L008A (LH) Nozzle. **Aft Exit Cone**--The 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 carbon-cloth phenolic (CCP) liner was totally missing. These are typical postflight observations, and occur during exit cone severance and at splashdown. The exposed GCP plies showed no signs of heat effect.

Thirty-two helicoils were backed out of the compliance ring about 1-to-4 turns during thermal curtain disassembly.

The actuator brackets showed only minor paint scratches, scrapes, and chips due to actuator removal. The primer remained intact and no metal damage or loose bolts were observed.

Light to medium oxidation was found on the land between the O-ring grooves on the aft exit cone from 26 to 48 deg. Numerous polysulfide voids were observed at 86 to 94, 268, and 296 deg. The polysulfide extended onto the GCP but did not enter the primary O-ring groove. These were probably repair areas. The polysulfide shrank a maximum of 0.10 inch. There were no separations between the polysulfide and the aft exit cone shell.

Forward Exit Cone Assembly--The center 19 in. (about 60 percent) of CCP liner was missing due to splashdown. There was typical dimpled erosion on the aft end approximately 0.1 in. deep radially. The forward 8 in. eroded smoothly.

Throat Assembly--The throat assembly had smooth erosion on the throat inlet and the forward 9 in. of the throat ring, with typical rippled erosion on the aft 6 in. measuring a maximum of 0.05 in. deep. There were no wedgeouts, pop-ups, or wash areas found.

Nose Inlet Assembly--The 503 and 504 rings eroded smoothly. One wash area on the 503 ring was found at 310 to 340 deg and measured 0.11 inch. The margins of safety will be verified at these locations.

The nose cap had smooth erosion with typical minor wash areas on the forward portion. Slag deposits were noted on the forward 8 to 10 in. from 90 to 260 deg. Typical postburn impact marks on the 504 ring were noted intermittently around the circumference. One postburn wedgeout of charred CCP were found on the aft 1.5 in. at 50, 88, and 118 deg.

Cowl Ring--The cowl ring showed the typical ridged erosion (0.06 in. deep). This is due to the low ply angle. One postburn wedgeout of charred CCP was observed on the aft 1.4 in. from 300 to 330 deg measuring about 0.5 in. deep radially.

Outer Boot Ring--The outer boot ring (OBR) had postburn pop-ups on the forward 2 in. of the ring intermittently around the circumference. There were typical postburn delaminations in the aft end along the 35 deg ply wraps. These were 1.0 to 1.5 in. deep axially. The aft tip adjacent to the flex boot was typically fractured and wedged out the full circumference except for a 6-in. section at 19 deg.

Fixed Housing Assembly--The fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing showed typical postburn wedgeouts of charred CCP intermittently around the circumference with some slag deposits on exposed plies. The radial depth of the wedgeouts ranged from 0.2 to 0.8 in. deep radially.

Exit Cone Field Joint--RTV backfill reached the LH primary O-ring everywhere except at 97.5 deg, where there was an unfilled void area on the axial portion of the joint. There was no soot past the char line and no evidence of pressure to the primary O-ring. There was no seal or seal surface damage on the joint.

4.11.4.3 <u>360L008B (RH) Nozzle</u>. **Aft Exit Cone**--The aft exit cone was severed by the LSC during parachute descent. The radial cut through the GCP appeared nominal, with no anomalies observed. The CCP liner was missing everywhere except on the forward 8 in. from about 225 through 0 to 45 deg. These are typical postflight observations, and occur during exit cone severance and at splashdown. The exposed GCP plies showed no signs of heat effect.

Two helicoils were backed out of the compliance ring about 1-to-2 turns during thermal curtain disassembly.

The actuator brackets showed no damage or paint scratches.

Light to medium oxidation was found on the land between the O-ring grooves on the aft exit cone intermittent around the circumference. The polysulfide shrank a maximum of 0.08 in., but there were no void or repair areas observed. There were no separations between the polysulfide and the aft exit cone shell.

Forward Exit Cone Assembly--The center 19 in. (about 60 percent) of CCP liner was missing due to splashdown. There was typical dimpled erosion on the aft end approximately 0.1 in. deep radially. The forward 8 in. eroded smoothly.

Throat Assembly--The throat assembly had smooth erosion on the throat inlet and the forward 9 in. of the throat, with typical rippled erosion (0.10 in. radial depth) on the aft 6 in. of the throat ring. There were no wedgeouts, wash areas, or pop-ups.

Nose Inlet Assembly--The 503 and 504 rings eroded smoothly. The nose cap had smooth erosion with typical minor wash areas on the forward 8 to 13 in. (about 0.08 in. deep radially). Typical postburn wedgeouts of charred CCP were found on the aft 2 in. intermittently around the circumference.

Cowl Ring--The cowl ring showed the typical ridged erosion (0.06 in. deep). One wedgeout was found on the aft 3 in. from 230 through 0 to 160 degrees. They measured 0.9 in. deep radially.

OBR--The OBR had popped plies on the forward 2 in. of the ring at 115 and 197 deg. No wedgeouts were noted. There were typical postburn delaminations in the aft end along the 35 deg ply wraps measuring 1.6 in. deep axially. The aft tip adjacent to the flex boot was fully intact.

Fixed Housing Assembly--The fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing showed typical postburn wedgeouts of charred CCP intermittently around the circumference with some slag deposits on exposed plies. The wedgeouts were typically 0.2 to 0.8 in. deep radially.

Exit Cone Field Joint--RTV backfill was below the RH joint charline and reached the primary O-ring the full circumference. There were no voids in the RTV and no soot past the char line. There was no seal or seal surface damage.

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