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SPACE SHUTTLE

Solid Rocket Motors
Thiokol Corporation

Flight Motor Set 360L006 (STS-34) Final Report

Volume I – System Overview

February 1990

Prepared for

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

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SPACE OPERATIONS

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ORIGINAL PAGE
COLOR PHOTOGRAPH

18 October 1989...KSC...Galileo probe is sent on its way to Jupiter...Space Shuttle mission STS-34, launched by Thiokol SRM flight set 360L006, performed successfully.

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ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

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Abstract

Flight motor set 360L006 was launched at approximately 11:54 a.m. CDT (89:291:16:53:40.020 GMT) on 18 October 1989 as part of NASA space shuttle mission STS-34. As with all previous redesigned solid rocket motor launches, overall motor performance was excellent.

All ballistic contract end item (CEI) specification parameters were verified with the exceptions of ignition interval and rise rates. Ignition interval and rise rates could not be verified due to the 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 CEI specification levels that could be assessed, with the exception of the RH-motor vacuum-delivered specific impulse. It exceeds the upper-limit CEI specification due to a bias imposed on the raw data by the OPT/Taber gage measurement differences. Details are in Section 4.4.4.

Evaluation of the ground environment instrumentation measurements again verified thermal model analysis data and showed agreement with predicted environmental effects. No launch commit criteria thermal 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, although splashdown loads tore the left-hand, 45-deg actuator bracket from the nozzle. All combustion gas was contained by insulation in the field and nozzle-to-case joints.

Recommendations were made concerning improved thermal modeling and measurements. The rationale for these recommendations, the disposition of all anomalies, and complete result details are contained in this report.

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Abbreviations and Acronyms

ADCAR . . Automated Data Collection and Retrieval (system)
AT . . . . . action time
avg . . . . . average
CCP . . . . carbon-cloth phenolic
CDS . . . . Central Data System
CDT . . . . Central Daylight Time
CEI . . . . contract end item
CF . . . . . carbon fiber
CFF . . . . carbon fiber-filled
cg . . . . . . center of gravity
CPI . . . . common planning index
deg . . . . . degree
del . . . . . delivery
DFI . . . . development flight instrumentation
DWV . . . dielectric withstanding voltage
ECP . . . . engineering change proposal
EDT . . . . Eastern Daylight Time
EPDM . . ethylene propylene diene monomer
ET . . . . . external tank
F . . . . . . Fahrenheit
FBMBT . flex bearing mean bulk temperature
FEWG . . Flight Evaluation Working Group
FMEA . . failure modes and effects analysis
GCP . . . . glass-cloth phenolic
GEI . . . . ground environment instrumentation
GFE . . . . government-furnished equipment
GMT . . . Greenwich Mean Time
HOSC . . . Huntsville Operations Support Center
HPM . . . high-performance motor
ICD . . . . interface control drawing
ID . . . . . inside diameter
IFA . . . . in-flight anamoly
IPR . . . . interim problem report
I_{sp} . . . . . . specific impulse
IVBC . . . integrated vehicle baseline configuration
JPS . . . . joint protection system
K . . . . . . Kelvin
klbf . . . . kilopound-force
kn . . . . . knot
KSC . . . . Kennedy Space Center
lbf . . . . . pound force
lbm . . . . pound mass
LCC . . . . launch commit criteria
LH . . . . . left hand
LRU . . . . . line replaceable unit
LSC . . . . . linear-shaped charge
LSS . . . . . Launch Support Service (office)
mA . . . . . . milliampere
max . . . . . maximum
Mlbf . . . . . megapound-force
msec . . . . . millisecond
MSFC . . . . Marshall Space Flight Center
NBR . . . . . nitrile butadiene rubber
NE . . . . . . northeast
No. . . . . . . number
NRT . . . . . near real time
NSTS . . . . National Space Transportation System
OBR . . . . . outer boot ring
OCR . . . . . operations change request
OFI . . . . . operational flight instrumentation
OMI . . . . . operations maintenance instruction
OMRSD . . operations and maintenance requirements and specification document
OPT . . . . . operational pressure transducer
PRCB . . . . Program Review Control Board
PMBT . . . . propellant mean bulk temperature
psi . . . . . . pound per square inch
psia . . . . . pound per square inch, absolute
QM . . . . . qualification motor
RH . . . . . . right hand
RSRM . . . redesigned solid rocket motor
RTV . . . . . room temperature vulcanization
S&A . . . . . safe and arm (device)
SCN . . . . . specification change notice
SE . . . . . . southeast
sec . . . . . . second
SF . . . . . . safety factor
SII . . . . . . SRM ignition initiator
SIT . . . . . . shuttle interface test
SRB . . . . . solid rocket booster
SRM . . . . . solid rocket motor
SSME . . . . space shuttle main engine
STI . . . . . . shuttle thermal imager
STS . . . . . Space Transportation System
TPS . . . . . thermal protection system
TVC . . . . . thrust vector control
TWR . . . . Thiokol Wasatch Report
USBI . . . . United Space Boosters, Inc.
UT . . . . . . Utah
V . . . . volt
VAB . . . . . vehicle assembly building

1/Introduction

Solid rocket booster (SRB) ignition command time for flight motor set 360L006 was given at 89:291:16:53:40.020 GMT (approximately 11:54 a.m. CDT) on 18 Oct 1989 at Kennedy Space Center (KSC), Florida, following a weather conditions launch scrub on 17 Oct 1989. This flight was the 31st space shuttle mission (mission designation STS-34) and the sixth redesigned solid rocket motor (RSRM) flight. The individual motor identification numbers were 360L006A (left-hand (LH)) and 360L006B (right-hand (RH)), indicating the cases were both lightweight. Additional case configuration details are addressed in Section 4.2.

This volume, Volume I, of this report contains the Thiokol Corporation Flight Evaluation Working Group (FEWG) inputs submitted to United Space Boosters, Inc., (USBI) for incorporation into the shuttle prime contractors' FEWG report (document MSFC-RPT-1578). An executive summary of 11the 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 schedule from the launch date for volume release) are listed in Table 1-1. TWR-60062 is a flow report which starts from receipt of 360L009 hardware at KSC, documenting aft booster buildup; RSRM stacking, including processing milestones and highlights; stacking configuration; significant discrepancy reports, problem reports, etc.

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

Table 1-1. Component Volume Release Schedule

Volume	Component Description	Interim Release	Final Release
I	System Overview	NA	Approximately 60 working days after launch
II	Case/Seals	NA	45 days after washout of last segment at Clearfield facility (H-7)
III	Insulation/Weatherseals	45 days after last field joint demate at Hangar AF (KSC)	45 days after last factory joint disassembly at H-7
IV	JPS, Systems Tunnel, TPS, Heaters	NA	60 days after launch
V	Nozzle	45 days after last internal nozzle joint demate	90 days after final nozzle liner char and erosion measurements
VI	Igniter	NA	30 days after igniter disassembly at H-7
VII	Performance and Mass Properties	NA	30 days after last factory joint disassembly at H-7

2/Objectives

The sixth Thiokol RSRM flight test objectives were intended to satisfy the requirements of CPW1-3600A, as listed in parentheses 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 milliseconds with a 40 millisecond environmental delay after ignition command to the SRM Ignition Initiators (SII) in the 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 millisecond 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 nozzle to case joint region during the countdown 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. Verify that the S&A devices perform as required using the specified power supply (3.2.1.6.1.2).

J. Verify 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).

K. Certify the proper operation of the Operational Pressure Transducer (OPT) during flight (3.2.1.6.2.1).

L. 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 liftoff breakaway connectors (3.2.1.6.2.3).

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

N. 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).

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

P. Demonstrate isolation of subsystem anomalies if required on fifth flight (360H005) hardware (3.2.3.3).

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

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

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

T. 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).

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 ignition system seals operate 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 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 insure 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 post-flight 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 FMEAs (3.2.3).

AE. Determine the adequacy of the design safety factors, 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 safety factor of the case/insulation bond (3.3.6.1.1.2.a).

AI. Verify by inspection the remaining 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 safety factors (3.3.6.1.2.8).

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

3/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

Five in-flight anomalies (IFA) relating to RSRM flight set 360L006 were identified. They are summarized below.

The disposition and closeout statements of the IFAs are included in Section 4-1.

MSFC IFA No.	Problem Title/ Description	Corrective Action Closure
STS-34-M-1	During postflight inspection of the LH aft exit cone, 45-deg rock actuator bracket was found to be broken/damaged	Problem not considered a flight safety concern, but a reuse issue only. No corrective action planned since this splashdown anomaly is considered a rare occurrence
STS-34-M-2	LH SRM factory joint weatherseal forward edge unbonds	Adhesive failures imply the cause is surface contamination. Additional conscan and surface finish requirements have been added to ensure no future contamination
STS-34-M-3	Putty on RH outer igniter gasket	Tighter putty layup and igniter installation have been implemented based on Thiokol test results
STS-34-M-4	K5NA unbond on aft edge of LH center field joint	Unbond caused by debris hit during splashdown. Since unbond occurred after separation, there is no debris hazard to the orbiter and no impact relative to flight safety for future missions. JPS and K5NA inspections are performed as part of regular preflight assembly activities
STS-34-M-5	LH and RH aft dome EPDM blisters	A review of CFF EPDM records and lab testing shows no condition which could have caused or contributed to this condition. An adequate safety factor is maintained. No corrective action is planned

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 flight sets. Complete mass property values are included in Section 4.3 of this volume and Volume X of this report.

3.1.3 Propulsion Performance (Ballistics)

3.1.3.1 Propellant Burn Rates/ Specific Impulse. The delivered burn rate for flight motor set 360L006 was 0.372 in./sec (at 82°F and 625 psia) for both motors, which was 0.002 in./sec lower than predicted for the LH motor and 0.001 in./sec lower than predicted for the RH motor. The reconstructed vacuum specific impulse values were 268.8 lbf•sec/lbm for the LH motor and 269.6 lbf•sec/lbm for the RH motor at 82°F, which was within 0.2 percent for the LH motor and 0.5 percent for the RH motor of the predicted value of 268.4 lbf•sec/lbm.

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, with the exception that the RH motor, vacuum-delivered specific impulse exceeds the upper limit CEI specification. Current plans are to update the CEI specification to the new HPM/RSRM nominal. The higher values experienced are due to bias which is imposed on the raw data due to OPT/ Taber gage measurement differences. OPT gages (flight transducers) historically have measured lower values than Taber gages (approximately 0.4 percent), and a bias is now imposed on the raw data which causes performance parameters to be higher. Actual value variations from the allowable CEI specification limits were all within 2 percent. Thrust imbalance was also well within the specification limits for the required time periods.

Due to elimination of development flight instrumentation (DFI), no high sample rate pressure data were available. Therefore, the CEI specification requirement to verify ignition interval, pressure rise rate, and ignition thrust-time 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 safe and arm (S&A) device safe-to-arm rotation times were all within the minimum 2-sec requirement during the actual launch. The actual times, as recorded on the S&A device gages, are included in Section 4.10.4.

3.1.5 Ascent Loads and Structural Dynamics

Due to the elimination of DFI on motor set 360L006, no evaluation of the RSRM loading or vibration characteristics is possible.

3.1.6 External TPS/Joint Heater Evaluation

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

All six field joint heaters performed adequately and as expected throughout the required operating periods. The RH center field joint primary heater failed the dielectric withstanding voltage (DWV) test after joint closeout, so the circuit was disabled and the redundant heater was used. A detailed TPS and heater evaluation is in Section 4.8.

3.1.7 Aero/Thermal Evaluation

3.1.7.1 On-Pad Local Environments/ Thermal Model Verification. The on-pad local environments were indicative of October conditions (71° to 80°F), with the ambient temperatures ranging from

69° to 85°F. Windspeeds were slightly lower than the historical conditions, averaging approximately 8 kn. Wind direction began in a northeasterly direction and swung steadily southward to a southerly direction at the time of launch.

No extreme outward cooling effects from external tank (ET) cryogenic loading were noted (2° to 3°F) on the inboard region of 360L006B (RH).

3.1.7.2 Launch Commit Criteria/ Infrared Readings. No launch commit criteria (LCC) thermal violations were noted; all field and igniter joint heaters performed adequately. The aft skirt purge was not activated until T-15 min because of the warm ambient and component temperatures.

Infrared measurements taken by the infrared 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 ground environment instrumentation (GEI) measurements to monitor solid rocket motor (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.

3.1.8 Instrumentation

All 108 GEI measurements performed properly throughout the prelaunch phase. All GEI is disconnected by breakaway umbilicals at SRB ignition and are not operative during flight. All operational pressure transducers (OPT) functioned properly during flight and successfully passed the prelaunch calibration checks.

The LH center field joint sensor at 196 deg was damaged prior to the beginning of the systems integration test (SIT) and provided no data during the countdown. No LCC occurred due to this failure since only two of the four sensors per joint are required.

A complete discussion of GEI and all instrumentation is in Section 4.10.

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. No gas paths through the nozzle-to-case 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 three recordable clevis edge separations (over 0.1 in.). No evidence of hot gas penetration through any of the acreage insulation or severe erosion patterns was 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 extremely light on most of the joints to locally heavy on one joint. The fretting was worst on both center field joints with the RH aft joint having the heaviest.

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 nozzle-to-case joint seal. Evaluation of the field and factory joints indicated the internal seal performed as expected during flight. A complete evaluation of seal 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

The following list is the conclusions as they relate specifically to the objectives and the CEI paragraphs. Also included with the conclusion is the report section (in parentheses) 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 4-9)
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, with the exception of the RH-motor vacuum-delivered specific impulse (Tables 4-9 and 4-10). 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 — 171.2 - 178.1 Action Time (AT) — 293.8 Minimum	*Certified* — The nominal thrust-time curve values are listed below. Time (sec) — Value LH / RH 20 — 66.02 / 66.38 60 — 176.00 / 176.56 AT — 297.73 / 298.25 (Table 4-8)
Certify that specified temperatures are maintained in the nozzle-to-case joint region	3.2.1.2.1.f — Nozzle-to-case joint O-rings shall be maintained within the temperature range as specified in ICD 2-0A002 (75°-120°F)	*Certified* — Temperature ranges in the nozzle-to-case joint region are: RH 80°-85°F LH 80°-83°F (Table 4-15)
Certify that the ignition interval is between 202 and 262 msec with a 40-msec environmental delay after ignition command	3.2.1.1.1.1 — The ignition interval shall be between 202 and 262 milliseconds with a 40-milliseconds environmental delay after ignition command to the SRM Ignition Initiators (SII) in the S&A device up to a point at which the head-end chamber pressure has built up to 563.5 psia	*Unable to Certify* — Due to DFI elimination (high sample rate pressure transducer)

Objective	CEI Paragraph	Conclusions
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 millisecond interval	*Unable to Certify* — Due to 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 3 at any time during the periods shown. These differentials are applicable over PMBT range of +40° to +90°F	*Unable to Certify* — Due to DFI elimination (high sample rate pressure transducers)
Certify that the S&A devices perform as required using the specified power supply	3.2.1.6.1.2 — Power Supply. The S&A device shall meet all performance requirements....in accordance with ICD 3-44005	*Certified* — The rotation and arming times of both S&A devices were within the required limits (Section 4.10)
Certify that the OFI is capable of launch readiness checkout after the ground system has been connected on the launch pad	3.2.1.6.2 — Instrumentation. The OFI shall be capable of launch readiness checkout after ground system connection on the launch pad.	*Certified* — The 0% and 75% calibration checks of the OFI verified launch readiness after ground system connection on the launch pad (Section 4.10)
Certify proper operation of the OPT during flight	3.2.1.6.2.1 — The OPT shall monitor the chamber pressure of the RSRMs over the range from 0 to 1,050 ±15 psi. They shall operate in accordance with ICD 3-44005...	*Certified* — The OPTs properly monitored the chamber pressure and operated in accordance with ICD 3-44005 (Recorded pressure data and values are discussed in Section 4.4)
Certify that the systems tunnel properly: 1) attaches to the case, 2) accommodates the GFE and LSC, and 3) provides OFI, GEI, and heater cables	3.2.1.10.1 — When exposed to the thermal environments of 3.2.7.2, the tunnel floorplates and tunnel cables will be maintained at a temperature at or below that specified in ICD 3-44002	*Certified* — Postflight evaluation showed no evidence of heat damage to the systems tunnel or adjacent cork, cables, and seams (Table 4-13). Proper case attachment and accommodation of the GFE, LSC, and cabling were also verified (Detailed systems tunnel evaluation 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 91° and 109°F during the prelaunch period. Note: Field joint temperature sensors must read between 85° and 122°F to assure O-ring temperatures of 75° to 130°F (Table 4-15)

Objective	CEI Paragraph	Conclusions
Certify that each field joint heater assembly meets all performance requirements	3.2.1.11.1.2 — Power Supply. Each field joint external heater assembly shall meet all performance requirements...as defined in ICD 3-44005	*Certified* — All the field joint external heaters met all the performance requirements (Section 4.8.3). The RH center field joint primary heater failed the DWV test after joint closeout, so the circuit was disabled and the redundant heater was used
Demonstrate isolation of subsystem anomalies if required on sixth flight (360L006) 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	
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 VAB prior to pad rollout. No vertical disassembly was required. Post-flight horizontal disassembly was accomplished at the 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 monitor 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	No LRU anomalies were detected on motor set 360L006, therefore no LRU changeouts were required
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 at 83° to 98°F (RH) and 83° to 102°F (LH). Note: Igniter sensors must read between 66° and 123°F to assure igniter temperatures of 64° to 130°F (Table 4-15)
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 nozzle/case joint seals. All seals that did have motor pressure reach them showed no evidence of heat effect, erosion, or blow-by (Section 4.11.3)

Objective	CEI Paragraph	Conclusions
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 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 in Volume III of this report)
Certify the field and nozzle/case 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/ 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 nozzle-to-case 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 in Volume II of this report)
Certify that no leakage occurred through the insulation	3.2.1.2.2.e — The insulation used as a primary seal shall be adequate to preclude leaking through the insulation	*Certified* — Preliminary inspections showed no evidence of leakage through the factory joint insulation (Section 4.11.1). Detailed postflight evaluations are completed at the H-7 (Clearfield, UT) 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)

Objective	CEI Paragraph	Conclusions
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)
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 360L006A or 360L006B 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 inch deep" to "yield a positive margin of safety"	3.2.1.4.13 — The nozzle flame front liners shall prevent the formation of: a. Pockets greater than 0.250 inches deep (as measured from the adjacent nonpocketed areas), b. Wedgeouts greater than 0.250 inches deep, c. Prefire anomalies except as allowed by TWR-16340	*Certified* — No nozzle flame front liner erosion pockets greater than 0.25 in. were noted. All wedgeouts observed occurred postburn and do not affect liner performance. No prefire anomalies were found (Section 4.11.4)
Inspect the ignition system seals for evidence of hot gas leakage	3.2.1.5.a — The ignition system shall preclude hot gas leakage during and subsequent to motor ignition	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 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 assess the SRM thermal environment and LCC (Detailed results are discussed in Section 4.8)

Objective	CEI Paragraph	Conclusions
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 nozzle-to-case 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)
Inspect the TPS to insure that there was no environmental damage to the RSRM components	3.2.1.8.2 — TPS shall insure that the mechanical properties of the RSRM components are not degraded when exposed to the environments...	Postflight inspection revealed excellent TPS condition with no violation of any NSTS debris criteria. No thermal degradation of any RSRM component was noted (Section 4.8.3)
Inspect for thermal damage to the igniter chamber and the adapter metal parts	3.2.1.8.3 — The igniter insulation shall provide thermal protection for the main igniter chamber and adapter metal parts to ensure that RSRM operation does not degrade their functional integrity or make them unsuitable for refurbishment	Preliminary investigation revealed no thermal damage to the igniter due to lack of insulation functionality (Igniter details in Volume VI of this report)

Objective	CEI Paragraph	Conclusions
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 360L006B (RH). The 360L006A (LH) motor stiffener ring sections and stubs sustained typical water damage (Section 4.11.2). Left 45-deg rock actuator bracket was damaged at the aft exit cone during splashdown. Reuse criteria are 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 parts previous use history is in Section 4.2. Preliminary observations showed no damage or corrosion to any nozzle reusable metal parts, with the exception of the left 45-deg rock actuator bracket which was damaged at the aft exit cone during splashdown (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 360L006A (LH) or 360L006B (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 in Volume VI of this report)

Objective	CEI Paragraph	Conclusions
Certify by inspection that the S&A is reusable	3.2.1.9.e — Reusability of... Safe & Arm Device	*Cannot be Completely Certified (at this time)* — The S&A previous use history is in Section 4.2. Preliminary postflight inspection revealed nothing that would adversely affect reuse of any S&A part (Detailed inspection results in Volume VI of this report)
Certify by inspection that the OPTs are reusable.	3.2.1.9.f — Reusability of...Transducers	*Cannot be Completely Certified (at this time)* — The OPT previous use history is in Section 4.2. All pressure data and preliminary postflight inspection indicate no issues that would adversely affect OPT reuse. Final OPT reuse criteria are established after refurbishment and calibration by the metrology lab
Inspect the case factory joint external seal for moisture	3.2.1.12 — The factory joint external seal shall prevent the pre-launch 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 aft edge unbonds (Detailed weatherseal evaluation 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 Failure Modes Effects Analyses	No hardware damage or anomalies identified by FMEAs were found (Specific inspection results are in the individual component volumes of this report)
Determine the adequacy of the design safety factors, relief provisions, fracture control, and safe life and/or fail/safe characteristics	3.2.3.1 — The primary structure, thermal protection, and pressure vessel subsystems shall be designed to preclude failure by use of adequate design safety factors, relief provisions, fracture control, and safe life and/or fail safe characteristics	Postflight inspections verified adequate design safety factors, relief provisions, fracture control, and safe life and/or fail/safe characteristics for the primary structure, thermal protection, and pressure vessel subsystems (as documented in this volume and the component volumes of this report)
Determine the adequacy of subsystem redundancy and fail/safe requirements	3.2.3.2 — The redundancy requirements for subsystems...shall be established on an individual subsystem basis, but shall not be less than fail safe...	The RH center field joint primary heater failed the DWV test after joint closeout, so the circuit was disabled and the redundant heater was used and functioned properly

Objective	CEI Paragraph	Conclusions
Inspect the identification numbers of each reusable RSRM part and material for traceability	3.3.1.5 — Traceability shall be provided by assigning a traceability identification to each RSRM part and material and providing a means of correlating each to its historical records...	Inspection numbers for traceability of each RSRM part and material are provided, and are maintained in the Automatic Data Collection and Retrieval computer system (The past history of all RSRM parts used is in Section 4.2)
Verify the structural safety factor (SF) of the case/insulation bond	3.3.6.1.1.2.a — The structural SF for the case/insulation bonds shall be 2.0 minimum during the life of the RSRM	Verification of a 2.0 SF cannot be done by inspection, however, flight performance verified an SF of at least 1. Case/insulation bond and adhesive bond SF of 2.0 are verified by analysis (documented in TWR-16961)
Verify by inspection the remaining insulation thickness of the case insulation	3.3.6.1.2.2 — The case insulation shall have a minimum design safety factor of 1.5, assuming normal motor operation, and 1.2, assuming loss of a castable inhibitor	Detailed postflight insulation inspections are performed at the Clearfield H-7 facility (Results and verification of SFs are in Volume III of this report)
Same as 3.3.6.1.2.2	3.3.6.1.2.3 — Case insulation adjacent to metal part field joints, nozzle/case joints, and extending over factory joints shall have a minimum safety factor of 2.0	See above statement
Same as 3.3.6.1.2.2	3.3.6.1.2.4 — Case insulation in sandwich construction regions (aft dome and center segment aft end) shall have a minimum safety factor of 1.5	See above statement
Same as 3.3.6.1.2.2	3.3.6.1.2.6 — Insulation performance shall be calculated using actual pre- and post-motor operation insulation thickness measurements	Standard measurement techniques were used for final evaluation (as discussed in Volume III of this report)
Verify by inspection the remaining nozzle ablative thicknesses	3.3.6.1.2.7 — The minimum design safety factors for the nozzle assembly primary ablative materials shall be as listed below...(Values not included here, as detailed results are not available at this writing)	Preliminary inspections indicate nozzle ablative thicknesses were within design safety factors (Section 4.11.4) (Detailed results are in Volume V of this report)
Verify the nozzle SFs	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.

Objective	CEI Paragraph	Conclusions
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

Following is a summary of the aero/thermal recommendations made concerning flight set 360L006 (also see Section 4.8.4). For additional background information see the referenced sections.

3.3.1 GEI Prediction. Aero/Thermal is anticipating submodel development effort for the areas of the ET attach ring, field joint, factory joint, systems tunnel, igniter, and nozzle regions to improve predictions. These areas would be encompassed by the global model. The nodes need to be made smaller to refine the model. If the model cannot be satisfactorily refined, all systems with heaters will remain a separate model, since at this time these separate models are more accurate.

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

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

3.3.4 Local Chilling. Based on data from STS-28 (360L005), STS-29R (360L003), and STS-30R (360L004), local cooling does occur. A method is being developed by Thiokol personnel to accurately quantify and predict the chill effect.

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

3.3.6 Ice/Debris Team Support. Thiokol personnel currently supporting the ice/debris team should be maintained.

4/Flight Evaluation Results and Discussion

4.1 RSRM In-Flight Anomalies

(FEWG Report Para 2.1.2)

The summary sheets for five IFAs pertaining to flight set 360L006 follow. The IFA description, discussion, conclusion, corrective actions, and closeout signature of the Level II PRCB chairman are included. No IFA was considered to be a flight constraint. As a result of IFA STS-34-M-3 (putty on RH outer igniter gasket), STS-33 (360L007) RH igniter was removed at the pad on 4 Nov 1989 to apply the putty according to the new controls. All subsequent motors are not affected since their igniters were installed with the new putty layup procedures.

4.2 RSRM Configuration Summary

(FEWG Report Para 2.1.3.2)

4.2.1 SRM Reuse Hardware

The case segment reuse history for flight motors 360L006A and 360L006B is in Figures 4-1 and 4-2, respectively. Figures 4-3 through 4-6 show the left and right igniter and nozzle part reuse, respectively. Nozzle snubber segments were new. Stiffener ring reuse is in Figure 4-7 and Table 4-1.

4.2.2 Approved RSRM Changes and Hardware Changouts

A summary of the changes made since 360H005 (STS-28R) follows. Complete descriptions of these changes are documented in Thiokol document TWR-19959 (Redesigned Solid Rocket Motor Flight Readiness Review, Level III).

Four Class I hardware changes since 360H005 (STS-28R):

- Replace existing igniter bolts with new higher strength bolts – ECP SRM-1720R3 Criticality 1. Previous design did not meet CEI specification for safety factors. Previous flights allowed by RDW-0579
- Modify special bolt eddy current acceptable flaw size, surface finish, and storage requirements – ECP SRM-1746R1 Criticality 1. Large number of discrepancy reports due to cosmetic defects
- Change nozzle leak check port plug from a nonlocking plug to one with a locking feature – ECP SRM-1805 Criticality 1R. Requirement to provide locking feature for all fasteners in accordance with CPW1-3600, Para 3.3.6.10
- Change field joint leak check port plug from a nonlocking plug to one with a locking feature – ECP SRM-1940 Criticality 1. Requirement to provide locking feature for all fasteners in accordance with CPW1-3600, Para 3.3.6.10

4.2.3 Critical Process and OMRSD Changes

As a result of studies conducted by the flex bearing process task force, 11 process changes were instituted:

- Reduced size of adhesive and tycement mixes to a quantity which will be entirely held in the spray system reservoir – OCR 139992. Changed to guarantee constant agitation of adhesives and tycement between spray applications, preventing improper suspension of solids
- Added cycling of adhesives through lines into main bucket for a minimum of 30 sec prior to spraying adhesives on each component – Revision 3 to CPI submitted 3 Aug 1989. Ensures proper dispersal of solids in adhesives prior to spraying on components
- Changed rubber sheet end-cut from butt joint to skived overlapped

(STS-33R ISSUE)
FLIGHT PROBLEM REPORT

No. STS-34-M-1

Statement of Problem:
Left SRM rock actuator bracket damage

Discussion:
During postflight inspection of the left SRM aft exit cone, the 45° rock actuator bracket was found to be broken/damaged. Part of the bracket remained on the aft exit cone shell, part on the compliance ring, and part remained with the actuator itself. The part of the bracket remaining on the actuator had a section of the aft exit cone shell (approximately 16" by 6") still attached.

There were no reported functional anomalies during flight associated with the actuator and nozzle vectoring. Visual examination of the actuator bracket by structures engineering indicated that there was no crack growth or stress corrosion growth prior to failure. Also, no soot was observed on the painted surfaces between the bracket and aft exit cone, indicating a splashdown failure.

Conclusions:
It was concluded that the actuator damage resulted from splashdown loads. The actuation system is incapable of producing a load large enough to fail the bracket. The maximum actuation (stall) load is 103,424 lbf. An actuator bracket has been prooftested to 195,132 lbf (tensile load) with an additional 20,000 lbf (side load). A structural integrity analysis of the bracket under flight loads confirms that positive margins of safety are maintained against failures by excessive stress and fracture (0.52 and 0.97 respectively with a S.F. = 1.4). It was concluded that the water impact loads on this motor were the only loads of sufficient magnitude to fracture the bracket. The calm sea state condition may have contributed to the greater water impact loads. In addition, a delay in one of the main chutes may have resulted in a higher horizontal-drift velocity.

Corrective Action:
As a result of the above noted conclusions, this problem is not considered a flight safety concern, but a reuse issue only. No corrective actions are planned since the splashdown anomaly experienced by this segment is considered a somewhat rare occurrence.

Effects on Subsequent Missions:
This failure of the actuator bracket appears to be a materials reuse issue only with no impact on flight operation or flight safety.

Approved: [signature] 11/20/89
SRM Project Manager Date
for Royce Mitchell

Personnel Assigned:

THIOKOL: Jack Leavitt/Craig Russell MSFC: B.Neighbors
BN 11-20-89

Resolution: The SRM Project recommends Level II closure of this IFA. Future failure analysis/recurrence control will be tracked via Significant Problem Report (SPR)# DR4-5/175 in the MSFC PRACA system.

PCIN 44804	NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 01
PRCBD S44804F		PRCB DATE 11/21/89

CHANGE TITLE
LEFT SRM ROCK ACTUATOR BRACKET DAMAGE

CHANGE PROPOSAL(S) NO. AND SOURCE STS-34 ANOMALY TRACKING LIST FLIGHT PR NO. STS-34-M-1	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
INITIATED BY: MSFC-ED35/B. NEIGHBORS	SUBMITTED BY: MSFC-SA43/C. RUTLAND

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

PRCBD S44804F IS ISSUED TO AUTHORIZE CLOSEOUT OF STS-34 ANOMALY NUMBER STS-34-M-1 PER THE ATTACHED PAGE(S). THIS DIRECTIVE LEVIES NO FORMAL PROGRAM ACTIONS.

EFFECTIVITY: STS-34

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

ACTIONS:

...NO FORMAL PROGRAM ACTION REQUIRED.

AUTHORIZATION:
/S/BREWSTER SHAW 11/21/89

CHAIRMAN, LEVEL II PRCB DATE

BARS RPT 8020 BARS NSTS FORM 4003

** TOTAL PAGE.02 **

(STS-33R ISSUE)
FLIGHT PROBLEM REPORT

IFA NO. STS-34-M-2

Statement of Problem:
Left SRM Factory Joint Weatherseal Forward Edge Unbonds

Discussion:
The left SRM forward center segment factory joint weatherseal unbond is located at 0° approximately 6" circumferentially by 1.75" deep. The second unbond was observed on the forward dome-to-cylinder factory joint weatherseal from 225° to 248° with a maximum axial depth of 2.05 inches. Adjacent paint was pulled off from the case and attached to the weatherseal. Both factory joint unbonds are adhesive failures between the Chemlok 205 primer and the motor case. It is considered that the primer underneath the paint adjacent to the EPDM also experienced an adhesive failure. The investigation revealed no evidence of soot or heat effects. Both weatherseals were intact with no missing material. Although weatherseal unbonds (aft edge) have been observed and treated as IFAs on previous flights, this is the first documented instance of forward edge unbonds. Consequently, this problem has been elevated to the IFA category.

Conclusions:
The adhesive failure of the factory joint weatherseals implies the cause is the result of surface contamination. The STS-34 unbonds indicate only localized contamination (worst unbond less than 7% of the total weatherseal). The structural assessment shows that flight loads are not sufficient to create a debris concern (S.F. > 6). Furthermore, a completely unbonded weatherseal would remain in place and intact during flight.

Abnormal splashdown may have applied loads to the forward weatherseal edges. The booster appeared to have had a higher than usual horizontal drift velocity and fell over into the log mode much sooner than typical splashdowns.

Corrective Action:
A team has been established to identify and eliminate contamination sources. As corrective action, additional conscan and surface finish requirements have been added. This will include FTIR swabs and independent monitoring of the manufacturing process to identify and eliminate any possible anomalies. All pin retainer band cleaning will be done prior to assembly to also eliminate potential contaminants.

For the next flight (STS-33R), a visual inspection and 0.005" shim stock edge probing were performed at TC prior to paint closeout of the factory joints. Also, a 100% visual inspection has been performed at KSC. The observed unbroken paint radius between the case and weatherseal is a good indicator of the seal's capability to withstand on-pad moisture entry.

Effects on Subsequent Missions:
STS-34 unbonds indicated only localized contamination. The final assessment indicated unbonds likely occurred at the abnormal splashdown noted above. Preflight inspections, postflight inspections, and improved manufacturing processes should eliminate this condition, although this problem presents no flight operation concern or flight safety issue.

Approved: [signature] 11/20/89
SRB Project Manager — Date
for Royce Mitchell

(STS-33R ISSUE)
FLIGHT PROBLEM REPORT

IFA NO. STS-34-M-2

Personnel Assigned:

THIOKOL: Sally Marsh/Larry Allred MSFC: L. Hanks

Resolution: The SRM Project recommends Level II closure of this IFA. Future failure analysis/recurrence control will be tracked via Significant Problem Report (SPR)# DR4-5/176 in the MSFC PRACA system.

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Thiokol CORPORATION
SPACE OPERATIONS

PCIN 44804	NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 01
PRCBD S44804G		PRCB DATE #

CHANGE TITLE
LEFT SRM FACTORY JOINT WEATHERSEAL FORWARD EDGE UNBONDS (IFA STS-34-M-2)

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
STS-34 ANOMALY TRACKING LIST FLIGHT PR. NO. STS-34-M-2	
INITIATED BY: MSFC-EH44/L. HANKS	SUBMITTED BY: MSFC-SA51/R. MITCHELL

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

PRCBD S44804G IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-34 ANOMALY NUMBER STS-34-M-2 PER THE ATTACHED PAGE(S). IFA STS-34-M-2 IS BEING DISPOSITIONED OUTSIDE THE REGULAR PRCB BASED ON ADEQUATE DISCUSSION AT THE STS-33 FRR ON NOVEMBER 6-7, 1989. THIS DIRECTIVE LEVIES NO FORMAL PROGRAM ACTION.

EFFECTIVITY: STS-34

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

ACTIONS:
NO FORMAL PROGRAM ACTION REQUIRED.

THIS PRCBD WAS PROCESSED OUTSIDE THE FORMAL LEVEL II PRCB.

AUTHORIZATION:

Jay Greene — 12-8-89

CHAIRMAN, LEVEL II PRCB — DATE

BARS RPT 8020 BARS NSTS FORM 4003

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Thiokol CORPORATION
SPACE OPERATIONS

NOV 22 '89 9:22 FROM SRM PROJECT OFFICE TO MTI MAIN PAGE.005

FLIGHT PROBLEM REPORT

No. STS-34-M-3

Statement of Problem:
Putty on STS-34 RH Outer Gasket

Discussion:
Upon removal of the RH igniter after the STS-34 flight, putty was found on the outer gasket aft face. The putty had extruded into the void region upstream of the primary seal from the 234° location through 0° to 5°. The putty did not cross the crown of the primary seal.

Conclusions:
Though there was no leakage or blowby past the seal (there was no blowhole in the putty), the seal is not designed to have putty in it. The concern regarding an anomaly of this nature is that the gasket's sealing capability might be impaired by the embedded putty. The sealing surface should be free of any contaminants. This is regarded as an igniter installation/processing problem and should be corrected.

Corrective Action:
There is potential for putty on the gasket on RH (B) 360L007 (STS-33) as there was on 360L006 (STS-34). Tighter putty layup and igniter installation controls have been implemented based on recent tests performed at Wasatch. A corrective action implementing these improved processes has already been implemented on STS-33 LH and STS-32 at KSC and was also implemented on STS-36 and subsequent igniter installations at Thiokol. STS-33 RH was processed in a similar fashion to STS-34. It was recommended that the STS-33 RH igniter be removed, replaced and reinstalled using the new putty layup.

Effects on Subsequent Missions:
STS-33 RH igniter was removed at the pad on 4 November 1989 to apply the putty according to the new controls. All subsequent motors are not affected since their igniters were installed with the new putty layup procedures.

Approved: [signature] 11/21/89
SRB Project Manager Date
for [signature]

Personnel Assigned:

[initials] 11/21/89

THIOKOL: Dan Cooper/James Seiler MSFC: E. Carrasquillo

Resolution: The SRM Project recommends Level II closure of this IFA. This problem (tracked via Significant Problem Report (SPR)# DR4-5/177) has been DEFERRED in the MSFC PRACA system for STS-33R, STS-32 and STS-36 on 11/16/89.

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PCIN 44804	NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 01
PRCBD S44804H		PRCB DATE #

CHANGE TITLE
. PUTTY ON STS-34 RH OUTER GASKET (IFA STS-34-M-3)

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
STS-34 ANOMALY TRACKING LIST FLIGHT PR NO. STS-34-M-3	
INITIATED BY: MSFC-EP73/E.CARRASQUILLO	SUBMITTED BY: MSFC-SA51/R. MITCHELL

LEVEL II BASELINE CHANGE DIRECTION: OPR: WA MBE/LS
BOARD:OSB

PRCBD S44804H IS ISSUED TO AUTHORIZE CLOSEOUT OF STS-34 ANOMALY NUMBER STS-34-M-3 PER THE ATTACHED PAGE(S). IFA STS-34-M-3 IS BEING DISPOSITIONED OUTSIDE THE REGULAR PRCB BASED ON ADEQUATE DISCUSSION AT THE STS-33 FRR ON NOVEMBER 6-7, 1989. THIS DIRECTIVE LEVIES NO FORMAL PROGRAM ACTION.

EFFECTIVITY: STS-34

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

ACTIONS:

...NO FORMAL PROGRAM ACTION REQUIRED.

THIS PRCBD WAS PROCESSED OUTSIDE THE FORMAL LEVEL II PRCB.

AUTHORIZATION:

J. Greene

CHAIRMAN, LEVEL II PRCB

12-8-89
DATE

BARS RPT 8020 BARS NSTS FORM 4003

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FLIGHT PROBLEM REPORT

No. STS-34-M-4

Statement of Problem:

A K5NA unbond was noted on the aft edge of the 360L006A.

Discussion:

The unbond was located at the 0 degree location and measured 5 inches circumferentially. The K5NA was unbonded from both the motor case wall and JPS cork but remained in place. The aft edge of the K5NA was deformed, indicating contact with some object(s).

Conclusions:

A scrape was found just aft of the K5NA and in line with the 0 degree location, indicating contact was made with some object(s). The scrape was approximately the same width as the unbond. Due to the geometry involved, it is unlikely that potential debris from the ET or orbiter could have caused the noted condition. As a result, both the scrape and the unbond are attributed to debris from the nozzle jettison or possibly water impact.

Corrective Action:

Minor divots to the JPS/K5NA have been observed on previous flights with water impact or nozzle jettison debris being noted as the cause of failure in the closure rationale. (Reference TWR 50050 "Postfire Engineering Evaluation Plan"). Inspections of JPS and K5NA closeout are performed as part of the regular pre-flight assembly activities.

Effects on Subsequent Missions:

Since the unbond occurred after booster separation, there is no debris hazard to the orbiter and no impact relative to flight safety for future missions.

Approved: Royce E. Mitchell 11/21/89
SRB Project Manager / Date

Personnel Assigned:

MTI: Gary Stephens/James Sailer MSFC: L. Xenks LX 11/21/89

Resolution: The SRM Project [illegible] problem (tracked via Significant Problem Report (SPR)# DR4-5/179) has been CLOSED in the MSFC PRACA system for STS-33R and subs on 11/15/89.

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PCIN 44804	NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 01
PRCBD S44804J		PRCB DATE #

CHANGE TITLE
A K5NA UNBOND WAS NOTED ON THE AFT EDGE OF THE 360L006 (IFA STS-34-M-4)

CHANGE PROPOSAL(S) NO. AND SOURCE STS-34 ANOMALY TRACKING LIST FLIGHT PR. NO. STS-34-M-4	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
INITIATED BY: MSFC-EH44/L. HANKS	SUBMITTED BY: MSFC-SA51/R. MITCHELL

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

PRCBD S44804J IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-34 ANOMALY NUMBER STS-34-M-4 PER THE ATTACHED PAGE(S). IFA STS-34-M-4 IS BEING DISPOSITIONED OUTSIDE THE REGULAR PRCB BASED ON ADEQUATE DISCUSSION AT THE STS-33 FRR ON NOVEMBER 6-7, 1989. THIS DIRECTIVE LEVIES NO FORMAL PROGRAM ACTION.

EFFECTIVITY: STS-34

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

ACTIONS:
NO FORMAL PROGRAM ACTION REQUIRED.

THIS PRCBD WAS PROCESSED OUTSIDE THE FORMAL LEVEL II PRCB.

AUTHORIZATION:

Jay Greene — 12-8-89

CHAIRMAN, LEVEL II PRCB — DATE

BARS RPT 8020 BARS NSTS FORM 4003

Thiokol CORPORATION
SPACE OPERATIONS

FLIGHT PROBLEM REPORT

No. STS-34-M-6

Statement of Problem:
Left and Right SRM Aft Dome CFP EPDM Blisters

Discussion:
The right SRM aft dome had approximately 15 blisters in the Carbon Fiber Filled (CFF) EPDM surface located randomly throughout the aft dome. The largest blister measured 5.3" axially x 4.5" circumferentially. The left SRM aft dome had approximately 10 blisters located randomly throughout the aft dome. The largest blister measured 2" axially x 1" circumferentially. The skin of the blisters were ragged and curled and measured approximately 0.030" thick. The bottom surface of the blisters appeared to be virgin CFF EPDM. The blisters were present in a localized area and did not propagate when pulled by hand. FTIR and volatile analysis performed on the blisters showed no evidence of foreign material.

The left SRM aft dome CFF EPDM insulation for 360H005 (STS-28R) was sectioned and inspected by engineering. The sectioning revealed evidence of a similar blister-like condition buried between the insulation plies. The condition detected through sectioning was much less extensive than that observed on 360L006 (STS-34). Samples of sectioned CFF EPDM from STS-34 were submitted to the lab for analysis. Blisters of this size in the CFF EPDM have not been observed in previous postflight hardware inspections at KSC.

Conclusions:
The blister condition did not cause an abnormal erosion in the aft dome CFF EPDM. The CFF EPDM is in compression during firing and the virgin CFF EPDM is separated from chamber gas flow by a thick char layer. The blisters were a localized condition which did not propagate when the edges were pulled.

Corrective Action:
A review of the CFF EPDM records has not identified any condition during fabrication which would have caused or contributed to this condition. Since the thermal evaluation indicates an adequate safety factor is maintained, the blisters are not considered a flight safety issue. Although no corrective actions are planned at the present, complete materials investigation results are pending which may warrant a material process or fabrication change.

Effects on Subsequent Missions:
Condition observed on STS-34 demonstrated no abnormal erosion in CFF EPDM. Through analysis and evaluations that have been performed subsequent to flight, it has been determined that this issue is not considered a flight safety issue for future missions.

Approved: Royce E. Mitchell 11/21/89
SRM Project Manager — Date

Personnel Assigned:

THIOKOL: Sally Marsh/Larry Allred MSFC: ____________

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FLIGHT PROBLEM REPORT

IFA NO. STS-34-M-5

Resolution: The SRM Project Office recommends Level II closure of this IFA. This problem (tracked via Significant Problem Report (SPR)# DR4-5/178) has been Deferred in the MSFC PRACA system for STS-33, STS-32 and STS-36 on 11/16/89.

PCIN 44804	NSTS PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 01 OF 01
PRCBD S44804K		PRCB DATE #

CHANGE TITLE
LEFT AND RIGHT SRM AFT DOME EPDM BLISTERS (IFA STS-34-M-5)

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
STS-34 ANOMALY TRACKING LIST FLIGHT PR. NO. STS-34-M-5 .	. . .
INITIATED BY: MSFC-EH44/L. HANKS	SUBMITTED BY: MSFC-SA51/R. MITCHELL

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

PRCBD S44804K IS ISSUED TO AUTHORIZE THE CLOSEOUT OF STS-34 ANOMALY NUMBER STS-34-M-5 PER THE ATTACHED PAGE(S). IFA STS-34-M-5 IS BEING DISPOSITIONED OUTSIDE THE REGULAR PRCB BASED ON ADEQUATE DISCUSSION AT THE STS-33 FRR ON NOVEMBER 6-7, 1989. THIS DIRECTIVE LEVIES NO FORMAL PROGRAM ACTION.

EFFECTIVITY: STS-34

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

ACTIONS:
. NO FORMAL PROGRAM ACTION REQUIRED.

THIS PRCBD WAS PROCESSED OUTSIDE THE FORMAL LEVEL II PRCB.

AUTHORIZATION:
Jay Greene 12-8-89
CHAIRMAN, LEVEL II PRCB DATE

BARS RPT 8020 BARS NSTS FORM 4003

Component	S/N	Previous Use	Total Pressurizations	
Forward Dome P/N 1U51473-03	0000040R1	QM-7	4	12
Cylinder P/N 1U50131-13	0000012R5	DM-2, SRM-5A -14A, -24B QM-6	14	16
Capture Cylinder, Standard Weight P/N 1U52983-02	0000006R1	QM-6	6	8
Cylinder, Lightweight P/N 1U50717-05	0000040R3	SRM-10B, -20B, QM-7	8	13
Capture Cylinder, Lightweight P/N 1U52982-03	0000008R1	DM-9	5	8
Cylinder, Lightweight P/N 1U50717-05	0000124	New	3	13
Capture Cylinder, Lightweight P/N 1U52982-03	0000022R1	QM-7	5	8
Attach, Lightweight P/N 1U50716-08	0000019R2	SRM-21B, PVM-1	6	19
Stiffener, Lightweight P/N 1U50715-05	0000049R1	QM-7	7	12
Stiffener, Lightweight P/N 1U50715-05	0000035R2	SRM-22A, QM-7	7	12
Aft Dome P/N 1U50129-11	0000049R1	QM-7	6	18

Conclusion: There are no fleet leader components in this assembly

☐ Denotes fleet leader status

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Figure 4-1. Hardware Reuse Summary — LH Case (A)

Component	S/N	Previous Use	Total Pressurizations	
Forward Dome P/N 1U51473-03	0000024R2	SRM-13A, -22A	5	12
Cylinder P/N 1U50131-13	0000007R4	DM-4, SRM-2B, -9A, -20B	13	16
Capture Cylinder, Standard Weight P/N 1U52983-02	0000016	New	3	8
Cylinder, Lightweight P/N 1U50717-05	0000073R2	SRM-14B, -24B	6	13
Capture Cylinder, Lightweight P/N 1U52982-03	0000020R1	QM-7	5	8
Cylinder, Lightweight P/N 1U50717-05	0000072R2	SRM-14A, -24A	6	13
Capture Cylinder, Lightweight P/N 1U52982-03	0000038	New	3	8
Attach, Lightweight P/N 1U50716-08	0000038	New	3	19
Stiffener, Lightweight P/N 1U50715-05	0000037R2	SRM-22B, RSRM-1A	6	12
Stiffener, Lightweight P/N 1U50715-05	0000036R2	SRM-22A, RSRM-1A	6	12
Aft Dome P/N 1U50129-11	0000002R5	DM-3, QM-3, SRM-9B, -20B, PVM-1	12	18

Conclusion: There are no fleet leader components in this assembly

☐ Denotes fleet leader status

006-FRRM 81

Figure 4-2. Hardware Reuse Summary — RH Case (B)

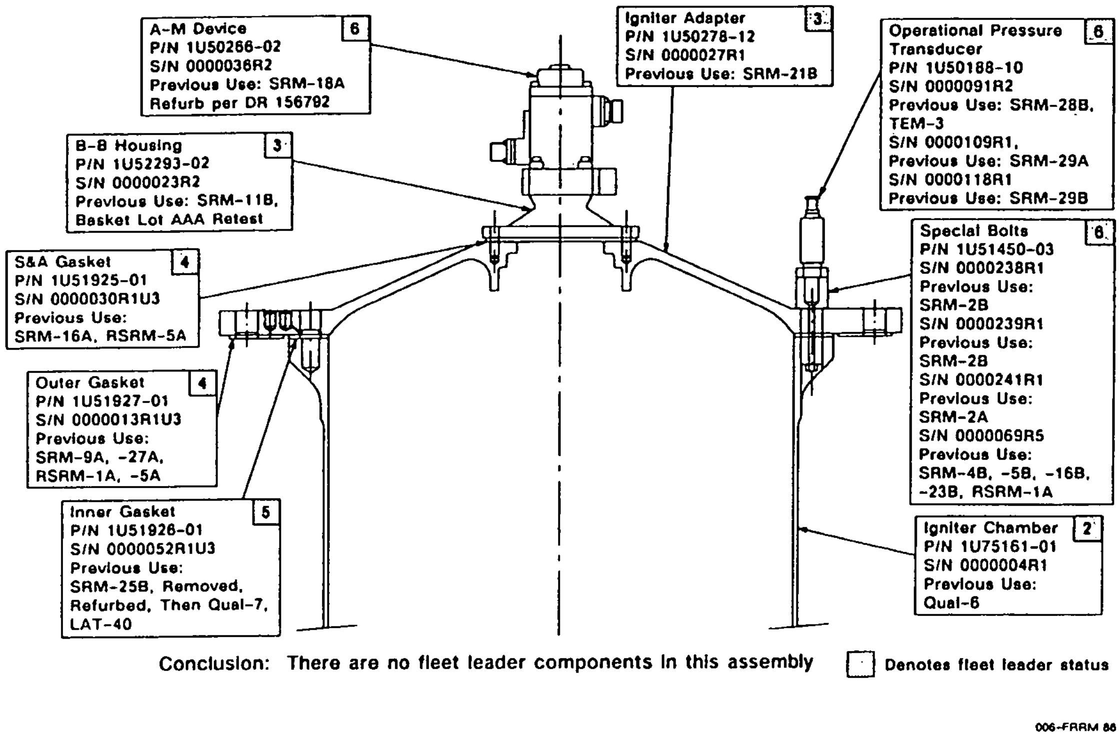


Figure 4-3. Hardware Reuse Summary — LH Igniter (A)

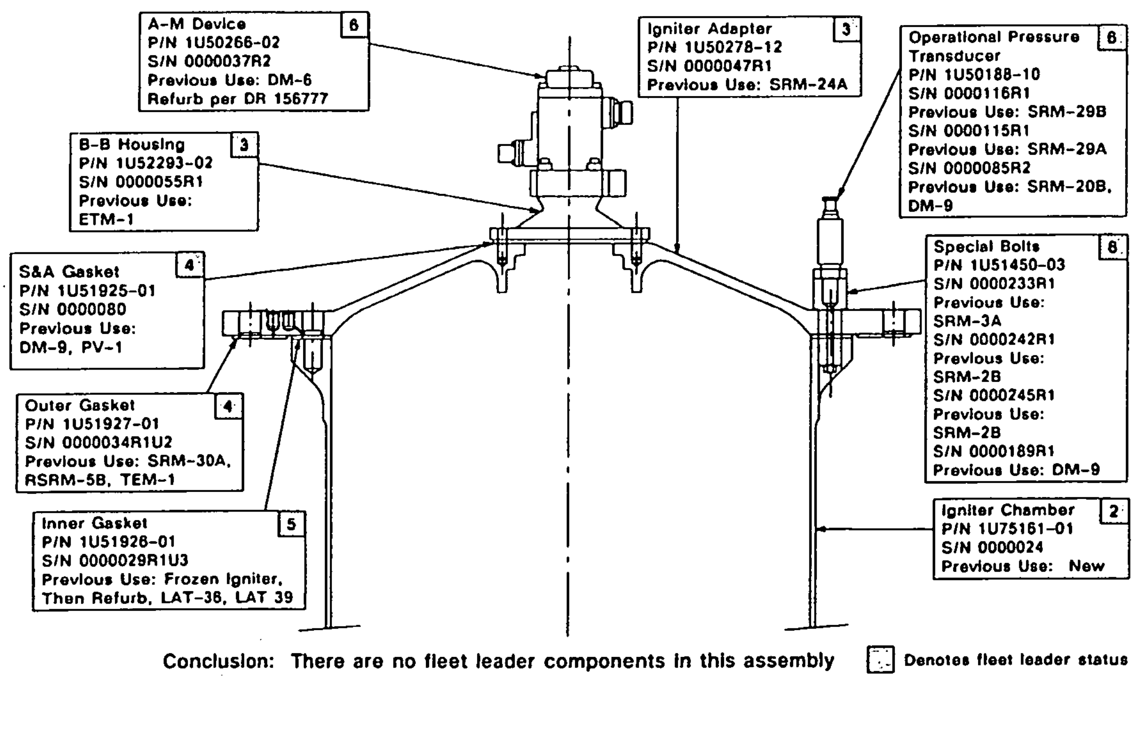
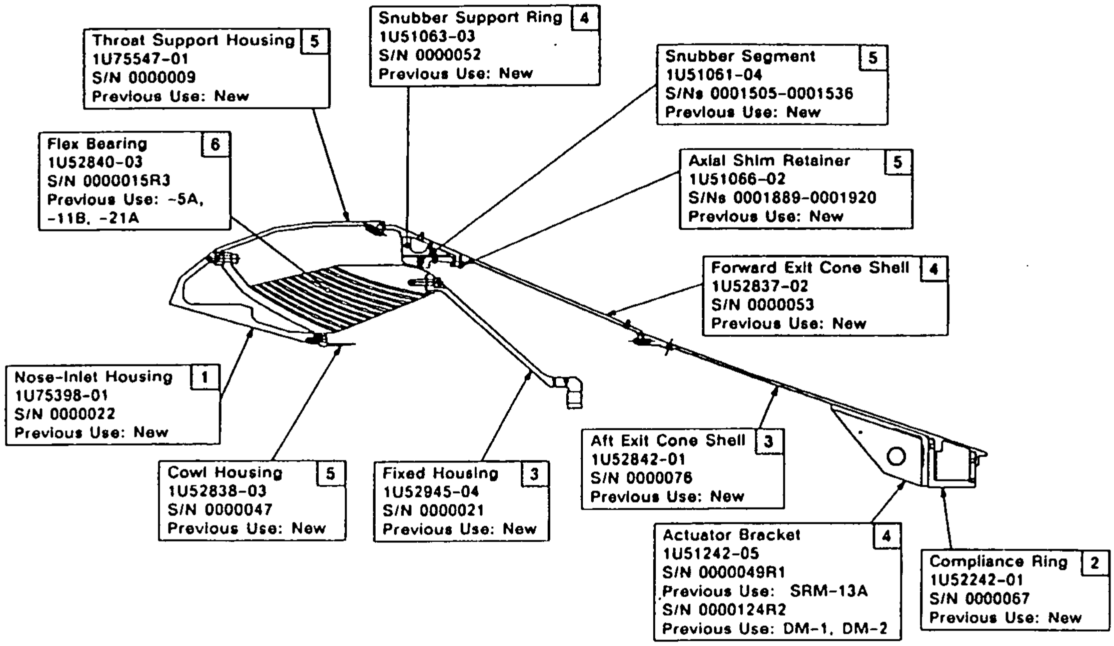


Figure 4-4. Hardware Reuse Summary — RH Igniter (B)



Part No.	Serial No.	Fleet Leader
Flex Bearing, Aft End Ring		
1U50083-02	0000007R2	6
Flex Bearing, Forward End Ring		
1U50085-02	0000007R2	6
Flex Bearing, Shims		
1U50097-01	0000010R2	6
1U50097-02	0000010R2	6
1U50097-03	0000010R2	6
1U50097-04	0000012R1	6
1U50097-05	0000010R2	6
1U50097-06	0000010R2	6
1U50097-07	0000010R2	6
1U50097-08	0000011R2	6
1U50097-09	0000010R2	6
1U50097-10	0000010R2	6

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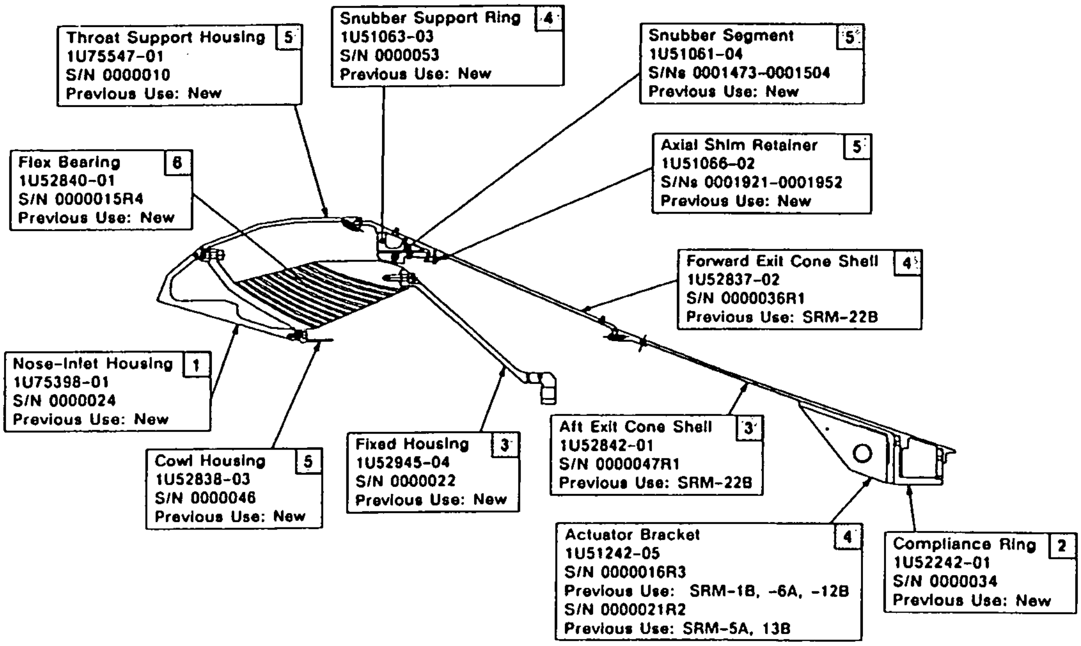
Figure 4-5. Hardware Reuse Summary – LH Nozzle (A)



Conclusion: There are no fleet leader components in this assembly

☐ Denotes fleet leader status

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Part No.	Serial No.	Fleet Leader
Flex Bearing, Aft End Ring		
1U50083-02	0000004	6
Flex Bearing, Forward End Ring		
1U50085-02	0000001	6
Flex Bearing, Shims		
1U50097-01	0000038	6
1U50097-02	0000041	6
1U50097-03	0000036	6
1U50097-04	0000044	6
1U50097-05	0000056	6
1U50097-06	0000040	6
1U50097-07	0000036	6
1U50097-08	0000046	6
1U50097-09	0000044	6
1U50097-10	0000035	6

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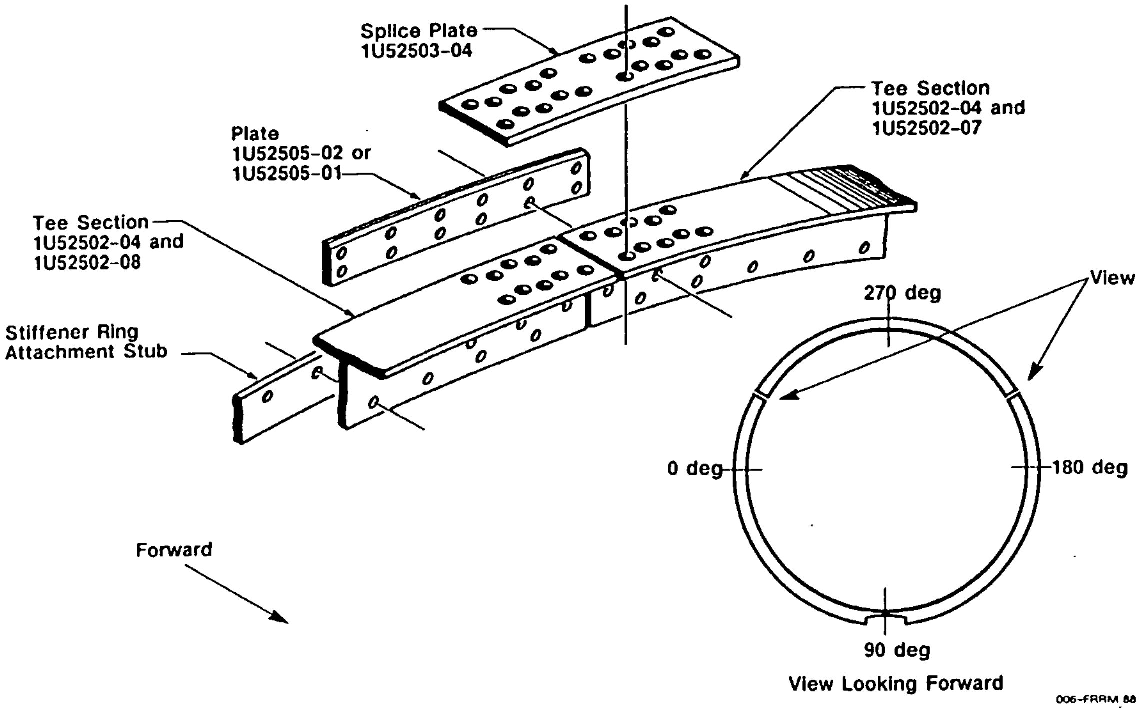
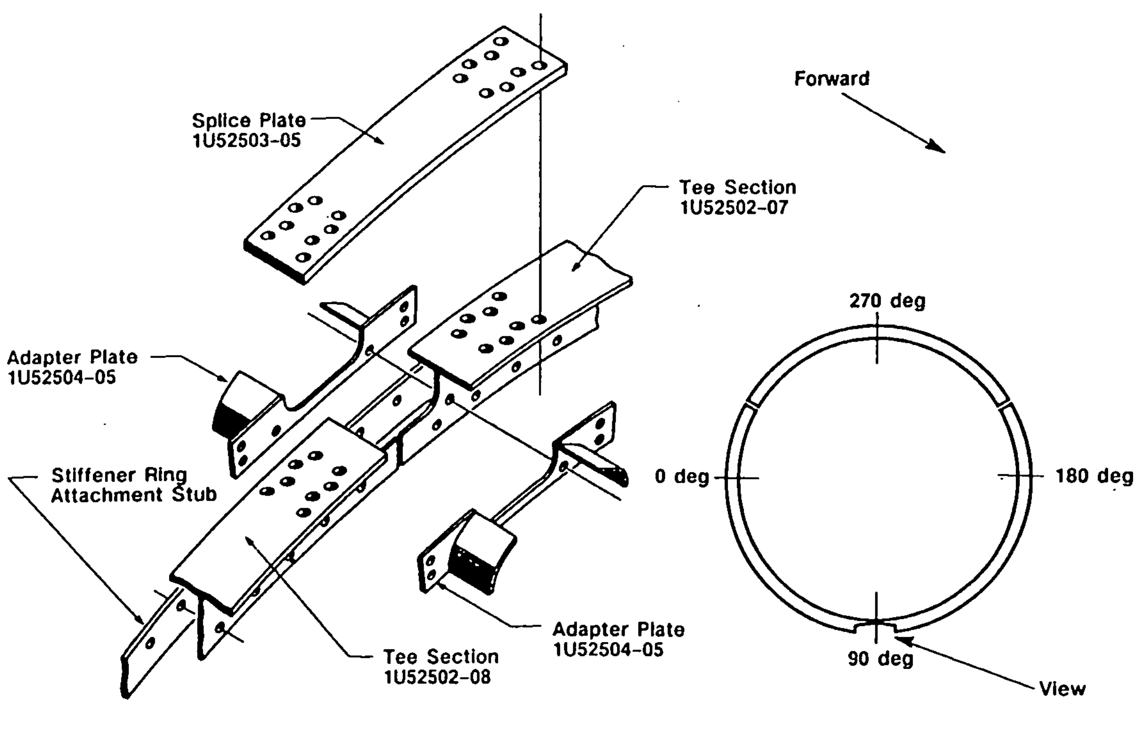
Figure 4-6. Hardware Reuse Summary — RH Nozzle (B)



a. *At Normal Joints*



b. *At Systems Tunnel Joint*

Figure 4-7. Hardware Reuse Summary – Stiffener Rings

Table 4-1. Hardware Reuse Summary — Stiffener Rings

Part No.	LH (A) Serial No.	Previous Use	RH (B) Serial No.	Previous Use	Fleet Leader
1U52502-04	0000001R2	SRM-45, SRM-23	0000008R2	SRM-12, SRM-21	R1*
Stiffener Ring	0000082R1	SRM-20A	0000051R1	SRM-19	
	0000099	New	0000052R1	SRM-19	
1U52502-07	0000075	New	0000078	New	R2
Stiffener Ring	0000080	New	0000082	New	
	0000081	New	0000083	New	
1U52502-08	0000072	New	0000057	New	R2
Stiffener Ring	0000079	New	0000071	New	
	0000081	New	0000077	New	
1U52503-04	0000101R1	SRM-21	0000075R2	SRM-18, RSRM-1	R1*
Splice Plate	0000102R1	SRM-21	0000076R2	SRM-18, RSRM-1	
	0000103R1	SRM-21	0000077R2	SRM-18, RSRM-1	
	0000104R1	SRM-21	0000078R2	SRM-18, RSRM-1	
	0000105R1	SRM-21	0000079R2	SRM-18, RSRM-1	
	0000106R1	SRM-21	0000080R2	SRM-18, RSRM-1	
1U52503-05	0000034	New	0000037	New	New
Splice Plate	0000035	New	0000038	New	
	0000036	New	0000039	New	
1U52504-05	0000125	New	0000126	New	R3
Adapter Plate	0000141	New	0000139	New	
	0000142	New	0000140	New	
	0000144	New	0000143	New	
	0000151	New	0000145	New	
	0000152	New	0000146	New	
1U52505-02 Plate	0000011R2	SRM-14, SRM-22	0000077R2	SRM-18, SRM-26	R1*
Stiffener Ring	0000012R2	SRM-14, SRM-22	0000078R2	SRM-18, SRM-28	
			0000112R1	RSRM-1	
			0000113R1	RSRM-1	
			0000114R1	RSRM-1	
			0000154R1	RSRM-1	
1U52505-01 Plate	0000005R3	STS-8, SRM-12, -23			R2*
Stiffener Ring	0000011R3	STS-9, SRM-15, -23			
	0000019R3	STS-9, SRM-15, -23			
	0000020R3	STS-9, SRM-15, -23			

*Flying fleet leader on this motor set

joint – OCR 141936 submitted 3 Aug 1989. Eliminates gaps in joints and increases joint contact length to prevent sheet separation

- Changed from wiping entire rubber surface using toluene-dampened rymplecloth to removing incidental surface lint and dust from rubber only in affected areas -- OCR 135956. Reduces the possibility of entrapped solvent in rubber pores during cure
- Added use of roller to provide better surface contact between rubber and shim – OCR 142186 submitted 3 Aug 1989. Ensures better surface contact and enhances bond
- Added use of shop vacuum in conjunction with hypodermic needle to remove entrapped air between rubber and shim – OCR 143160. Ensures better surface contact and enhances bond
- Changed method of initial press closure from jack rams to main ram – OCR 133010. Avoids possible loss of contact between bearing components during initial press closure when switching from jack rams to main ram
- Increased initial set point of main ram pressure – OCR 133010. Provide more constant control of ram pressure during initial debulk cycle
- Increased temperature set point in lagging heat zones 5, 7, 8, and 9 (Figure 4-8) – Revision 3 to CPI. Reduces the time at temperature of the leading heat zones to reduce hycar migration
- Moved controlling thermocouples from outer mold rings into rubber pads – Revision 3 to CPI. Thermocouples in the rubber indicate the actual temperature of the flex bearing during cure, which allows for more accurate cure
- Cure terminated when rubber thermocouples exceed 300°F for 2 hr rather than tooling thermocouples at 290°F – Revision 3 to CPI. Ensures component temperature does not exceed limits, which could cause rust

Four OMRSD changes:

- MB8761M Criticality 1 – When shelf life is dependant on conditioned storage, verify from Thiokol acceptance tag rather than from vendor's container tag that conditioned storage requirements have not been exceeded. The Thiokol acceptance tag shall be kept with the material until it is used or discarded. This assures that accurate shelf life information is available prior to material use
- MB8806M Criticality 3 – Incorporate use of new nozzle disassembly tool (8U tool developed to replace 7U prototype tool currently in use)
- RCN MB8816A Criticality 1 – Cannot show evidence that O-ring shipping box has been opened or crushed, ensuring O-ring integrity.
- RCN MS9072 Criticality 1 – Update useful life tables from a 5-year limited life to a 3-year limited life to reflect NSTS 07700 Volume X

4.3 SRB Mass Properties

(FEWG Report Para 2.2.0)

4.3.1 Sequential Mass Properties

Tables 4-2 and 4-3 provide 360L006 (STS-34) 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 4-4 compares the LH lightweight RSRM predicted sequential weight and center of gravity data with the postflight reconstructed data. Table 4-5 compares the RH RSRM predicted sequential weight and center of gravity data with the postflight reconstructed data. Actual

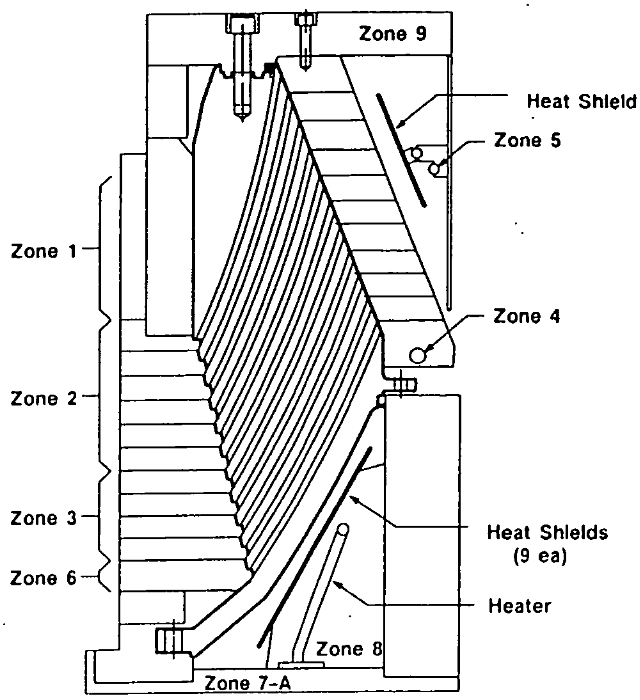


Figure 4-8. Critical Process — Flex Bearing Mold Sketch

Table 4-2. Sequential Mass Properties — LH 360L007

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
PRE-LAUNCH TIME = 0.00	1257084.6	1171.467	0.059	0.006	42457.071	880.317	42457.948
LIFT-OFF TIME = 0.23	1256437.9	1171.593	0.059	0.006	42416.430	879.007	42417.307
INTERMEDIATE BURN TIME = 20.00	1012115.8	1208.778	0.074	0.008	30605.954	760.529	30606.828
INTERMEDIATE BURN TIME = 40.00	789311.4	1231.791	0.094	0.010	21562.291	624.810	21563.159
MAX "Q" TIME = 54.00	658034.7	1229.046	0.112	0.012	17871.972	546.717	17872.833
INTERMEDIATE BURN TIME = 60.00	602293.0	1226.331	0.122	0.013	16433.299	508.510	16434.157
INTERMEDIATE BURN TIME = 80.00	407694.5	1214.388	0.178	0.019	11718.953	372.725	11719.800
MAX "G" TIME = 87.00	343436.5	1214.163	0.211	0.022	10349.787	321.690	10350.629
INTERMEDIATE BURN TIME = 100.00	238369.3	1228.911	0.301	0.032	8376.362	232.510	8377.197
WEB BURN TIME = 109.36	174896.5	1264.444	0.409	0.043	7283.739	174.162	7284.567
END OF ACTION TIME TIME = 121.87	143849.0	1313.164	0.495	0.053	6542.581	146.413	6543.404
SEPARATION TIME = 124.41	143088.3	1315.239	0.498	0.053	6507.683	145.914	6508.509
MAX REENTRY "Q" TIME = 319.41	142666.8	1315.346	0.499	0.052	6482.012	145.543	6482.839
NOSE CAP DEPLOYMENT TIME = 349.41	142614.5	1315.327	0.499	0.052	6479.246	145.497	6480.073
DROGUE CHUTE DEPLOYMENT TIME = 350.01	142613.5	1315.326	0.499	0.052	6479.190	145.496	6480.017
FRUSTUM RELEASE TIME = 371.11	142576.7	1315.313	0.499	0.052	6477.232	145.464	6478.059
MAIN CHUTE LINE STRETCH TIME = 372.41	142574.5	1315.312	0.499	0.052	6477.110	145.462	6477.937
MAIN CHUTE 1ST DISREEFING TIME = 382.51	142556.9	1315.306	0.499	0.052	6476.169	145.446	6476.996
MAIN CHUTE 2ND DISREEFING TIME = 388.41	142546.6	1315.303	0.499	0.052	6475.619	145.437	6476.446
NOZZLE JETTISONED TIME = 389.11	140317.2	1305.028	0.498	0.052	6274.004	140.712	6274.812
SPLASHDOWN TIME = 414.41	140274.0	1305.009	0.498	0.052	6271.648	140.674	6272.455

Table 4-3. Sequential Mass Properties — RH 360L007

EVENTS/TIMES	WEIGHT (LBS)	CENTER OF GRAVITY LONG.	LAT.	VERT.	MOMENT OF INERTIA PITCH	ROLL	YAW
PRE-LAUNCH TIME = 0.00	1255858.1	1171.285	0.059	0.006	42413.669	879.444	42414.546
LIFT-OFF TIME = 0.23	1255210.8	1171.413	0.059	0.006	42372.368	878.151	42373.245
INTERMEDIATE BURN TIME = 20.00	1010239.1	1208.715	0.074	0.008	30532.631	759.080	30533.506
INTERMEDIATE BURN TIME = 40.00	787709.8	1231.561	0.094	0.010	21516.741	623.471	21517.609
MAX "Q" TIME = 54.00	656561.7	1228.725	0.112	0.012	17838.054	545.487	17838.916
INTERMEDIATE BURN TIME = 60.00	600744.5	1225.963	0.122	0.013	16396.052	507.044	16396.910
INTERMEDIATE BURN TIME = 80.00	406116.0	1213.933	0.179	0.019	11684.835	371.264	11685.682
MAX "G" TIME = 87.00	341831.3	1213.764	0.212	0.022	10318.574	320.186	10319.416
INTERMEDIATE BURN TIME = 100.00	236292.3	1228.885	0.304	0.032	8340.955	230.516	8341.789
WEB BURN TIME = 109.29	173528.6	1264.863	0.412	0.044	7261.596	172.785	7262.424
END OF ACTION TIME TIME = 121.31	143912.9	1312.042	0.495	0.053	6550.271	146.393	6551.095
SEPARATION TIME = 124.41	143148.5	1314.119	0.498	0.053	6514.435	145.883	6515.261
MAX REENTRY "Q" TIME = 319.41	142737.8	1314.186	0.499	0.052	6490.645	145.520	6491.471
NOSE CAP DEPLOYMENT TIME = 349.41	142685.5	1314.165	0.499	0.052	6487.877	145.474	6488.703
DROGUE CHUTE DEPLOYMENT TIME = 350.01	142684.5	1314.165	0.499	0.052	6487.822	145.473	6488.648
FRUSTUM RELEASE TIME = 371.11	142647.7	1314.151	0.499	0.052	6485.862	145.441	6486.688
MAIN CHUTE LINE STRETCH TIME = 372.41	142645.5	1314.151	0.499	0.052	6485.741	145.439	6486.568
MAIN CHUTE 1ST DISREEFING TIME = 382.51	142627.9	1314.144	0.499	0.052	6484.799	145.423	6485.626
MAIN CHUTE 2ND DISREEFING TIME = 388.41	142617.6	1314.141	0.499	0.052	6484.249	145.414	6485.076
NOZZLE JETTISONED TIME = 389.11	140388.2	1303.853	0.497	0.051	6282.426	140.827	6283.233
SPLASHDOWN TIME = 414.41	140345.0	1303.833	0.497	0.051	6280.066	140.788	6280.873

Table 4-4. Sequential Mass Properties Predicted/Actual Comparisons — LH 360L007

Event	Weight (lb)				Longitudinal CG (in)			
	Predicted[1]	Actual	Delta	% Error	Predicted[1]	Actual	Delta	% Error
Pre-Ignition	1,257,085	1,257,085	0	0.00	1,171.467	1,171.467	0.000	0.00
Liftoff	1,256,449	1,256,438	-11	0.00	1,171.593	1,171.593	0.000	0.00
Action Time	143,932	143,849	-83	0.06	1,313.005	1,313.164	+0.159	0.01
Separation[2]	143,197	143,088	-109	0.08	1,314.984	1,315.239	+0.255	0.02
Nose Cap Deployment	142,614	142,615	+1	0.00	1,315.334	1,315.327	-0.007	0.00
Drogue Chute Deployment	142,613	142,614	+1	0.00	1,315.334	1,315.326	-0.008	0.00
Main Chute Line Stretch	142,574	142,575	+1	0.00	1,315.320	1,315.312	-0.008	0.00
Main Chute 1st Disreefing	142,557	142,557	0	0.00	1,315.314	1,315.306	-0.008	0.00
Main Chute 2nd Disreefing	142,547	142,547	0	0.00	1,315.310	1,315.303	-0.007	0.00
Nozzle Jettison	140,317	140,317	0	0.00	1,305.029	1,305.028	-0.001	0.00
Splash Down	140,274	140,274	0	0.00	1,305.009	1,305.009	0.000	0.00

Notes:

1. Based on Mass Properties History Log Space Shuttle 360L006-LH, 11 May 1989 (TWR-17344).

2. The separation longitudinal center of gravity of 1,315.239 is 66% of the vehicle length.

Table 4-5. Sequential Mass Properties Predicted/Actual Comparisons — RH 360L007

	Weight (lb)				Longitudinal CG (in)			
Event	Predicted[1]	Actual	Delta	% Error	Predicted[1]	Actual	Delta	% Error
Pre-Ignition	1,255,858	1,255,858	0	0.00	1,171.285	1,171.285	0.000	0.00
Liftoff	1,255,223	1,255,211	-12	0.00	1,171.411	1,171.413	+0.002	0.00
Action Time	144,001	143,913	-88	0.06	1,311.858	1,312.042	+0.184	0.01
Separation[2]	143,268	143,149	-119	0.08	1,313.828	1,314.119	+0.291	0.02
Nose Cap Deployment	142,685	142,686	+1	0.00	1,314.173	1,314.165	-0.008	0.00
Drogue Chute Deployment	142,684	142,685	+1	0.00	1,314.173	1,314.165	-0.008	0.00
Main Chute Line Stretch	142,645	142,646	+1	0.00	1,314.158	1,314.151	-0.007	0.00
Main Chute 1st Disreefing	142,628	142,628	0	0.00	1,314.152	1,314.144	-0.008	0.00
Main Chute 2nd Disreefing	142,617	142,618	+1	0.00	1,314.148	1,314.141	-0.007	0.00
Nozzle Jettison	140,388	140,388	0	0.00	1,303.853	1,303.853	0.000	0.00
Splash Down	140,345	140,345	0	0.00	1,303.833	1,303.833	0.000	0.00

Notes:

1. Based on Mass Properties History Log Space Shuttle 360L006-RH, 25 October 1988 (TWR-17339).

2. The separation longitudinal center of gravity of 1,314.119 is 66% of the vehicle length.

360L006 (STS-34) mass properties may be obtained from Mass Properties History Log Space Shuttle 360L006-LH (TWR-17344, 11 May 1989) and 360L006-RH (TWR-17345, 11 May 1989). Some of the mass properties data used have been taken from average actual data presented in the Mass Properties Quarterly Status Report (TWR-10211-90, 5 Mar 1989). Postflight reconstructed data reflect ballistics mass flow data from the 12.5-samples-per-sec measured pressure traces and a predicted slag weight of 1,518 lb.

4.3.3 CEI Specification Requirements

Tables 4-6 and 4-7 present CEI specification requirements and predicted and actual weight comparisons. Mass properties data for both RSRMs comply with the CEI specification requirements (CPW1-3600A, Addendum G, Part I).

4.4 RSRM Propulsion Performance

(FEWG Report Para 2.3.0)

4.4.1 HPM-RSRM Performance Comparisons

The reconstructed thrust-time traces of flight motor set 360L006 at standard conditions were averaged with the high-performance motor (HPM)/RSRM population and compared to the CEI specification limits. The results are shown in Figure 4-9.

4.4.2 SRM Propulsion Performance Comparisons

The reconstructed RSRM propulsion performance is compared to the predicted performance in Table 4-8. The following comments explain the table values. The RSRM ignition interval is to be between 202 and 302 msec after ignition command to the NASA standard initiators 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 buildup during the ignition transient is required to be less than 115.9 psia for any 10-msec interval. However, no high sample rate ignition data were available for this flight (due to the elimination of DFI); therefore, no rise rate or ignition interval is reported. Separation is based upon the 50-psia cue from the last RSRM, plus 4.9 sec and a time delay between the receipt and execution of the command to separate. No time delay is assumed in the prediction. The decay time intervals are measured from the time motor head-end 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 4-9 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 motor.

4.4.4 Performance Tolerances

A comparison of the LH and RH motors' calculated and reconstructed parameters at propellant mean bulk temperature (PMBT) of 60°F, with respect to the nominal values and the SRM CEI specification maximum 3-sigma requirements, is given in Table 4-10. The RH-motor vacuum-delivered specific impulse exceeds the upper limit CEI specification. Current plans are to update the CEI specification to the new HPM/RSRM nominal. The higher values experienced are due to bias which is imposed on the raw data due to OPT/Taber gage measurement differences. OPT gages (flight transducers) historically have measured lower values than Taber gages (approximately 0.4 percent), and a bias is now imposed on the raw data which

Table 4-6. Predicted/Actual Weight Comparisons (lb) — LH 360L007

Item	Minimum	Maximum	Predicted[3]	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		150,076	149,364	149,364	0	0.00	1
Propellant	1,104,714		1,107,720	1,107,720	0	0.00	1
Usable			1,106,861	1,106,943	+82	0.01	2
To Liftoff			535	546	+11	2.01	
Liftoff to Action			1,106,326	1,106,397	+71	0.01	2
Unusable			859	777	-82	10.55	
Action to Separation			669	695	+26	3.74	
After Separation			190	82	-108	131.71	
Slag			1,518	1,518	0	0.00	2

Notes:

1. Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI Specification).

2. Slag included in usable propellant, liftoff to action.

3. Based on 11 May 1989, Mass Properties History Log Space Shuttle 360L006-LH (TWR-17344).

Table 4-7. Predicted/Actual Weight Comparisons (lb) — RH 360L007

Item	Minimum	Maximum	Predicted[3]	Actual	Delta	% Error	Notes
Inerts							
Prefire, Controlled		150,076	149,436	149,436	0	0.00	1
Propellant	1,104,714		1,106,423	1,106,423	0	0.00	1
Usable			1,105,564	1,105,654	+90	0.01	2
To Liftoff			534	547	+13	2.38	
Liftoff to Action			1,105,030	1,105,107	+77	0.01	2
Unusable			859	769	-90	11.70	
Action to Separation			669	698	+29	4.15	
After Separation			190	71	-119	167.61	
Slag			1,518	1,518	0	0.00	2

Notes:

1. Requirement per CPW1-3600A, Addendum G, Part I, (RSRM CEI Specification).
2. Slag included in usable propellant, liftoff to action.
3. Based on 11 May 1989, Mass Properties History Log Space Shuttle 360L006-RH (TWR-17345).

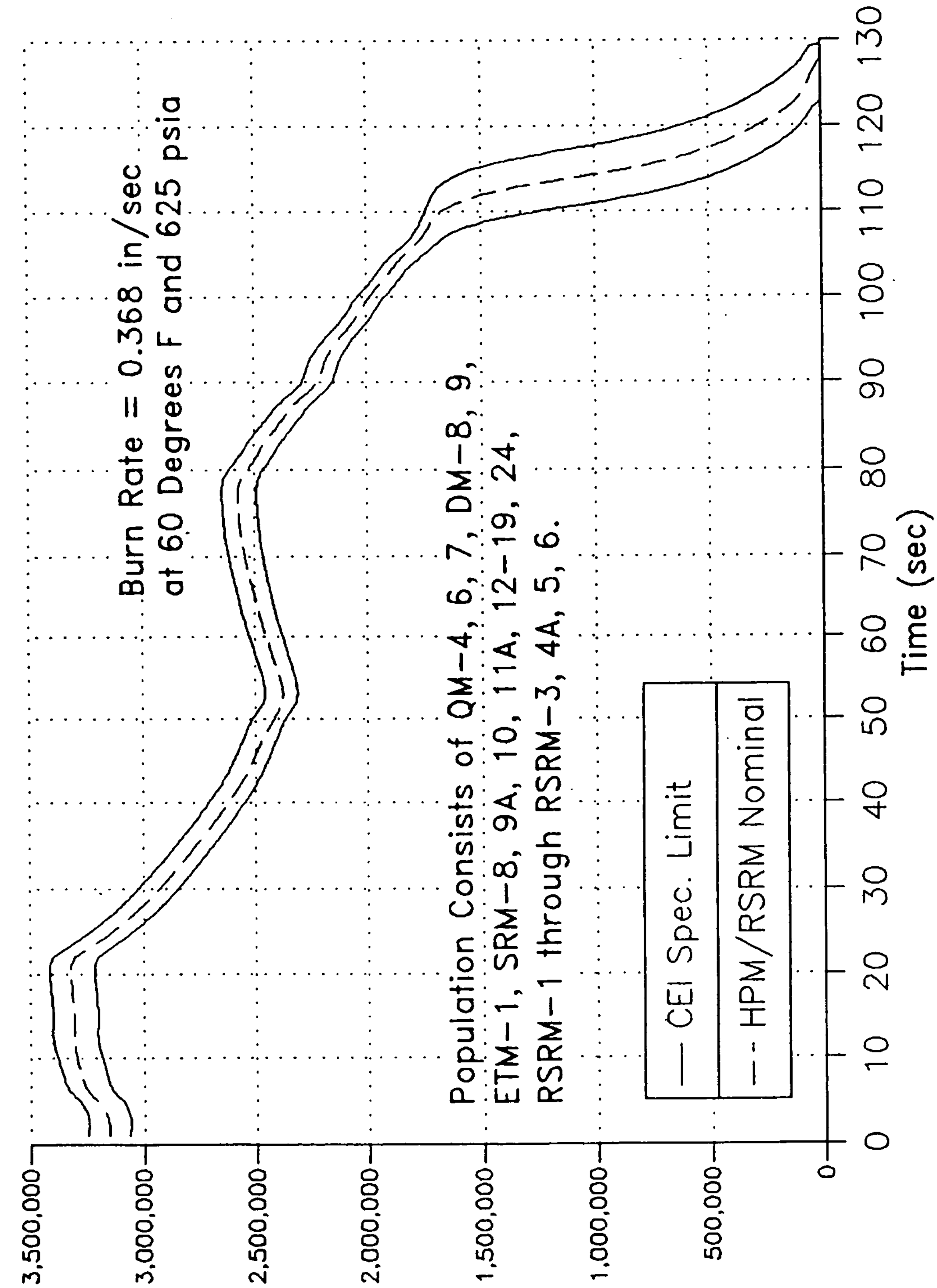


Figure 4-9. HPM/RSRM Nominal Thrust Versus CEI Specification

Table 4-8. RSRM Propulsion Performance Assessment

	82-deg Predicted Actual			
	LH Motor		RH Motor	
	Predicted	Actual	Predicted	Actual
Impulse Gates				
I-20 (10^6 lbf-sec)	66.41	66.02	66.02	66.38
I-60 (10^6 lbf-sec)	176.57	176.00	175.66	176.56
I-AT (10^6 lbf-sec)	297.30	297.73	296.96	298.25
Vacuum I_{sp} (lbf•sec/lbm)	268.4	268.8	268.4	269.6
Burn Rate at 60°F (in./sec)	0.368	0.366	0.367	0.366
Event Times (sec)*				
Ignition Interval	0.232	NA	0.232	NA
Web Time*	108.6	109.4	109.1	109.3
Time of 50-psia Cue	118.6	119.5	119.1	118.9
Action Time*	120.7	121.9	121.2	121.3
Separation Command (sec)	124.0	124.4	124.0	124.4
PMBT (°F)	82.0	82.0	82.0	82.0
Maximum Ignition Rise Rate (psia/10 msec)	91.9	NA	91.9	NA
Decay Time (sec) — (59.4 psia to 85°K)	2.9	3.2	2.8	3.1
Tail-Off Imbalance Impulse Differential (klbf-sec)	Predicted -772		Actual +337	

Impulse Imbalance = LH motor - RH motor

*All times are referenced to ignition command time except where noted by an *. These times are referenced to lift-off time (ignition interval)

Table 4-9. SRM Thrust Imbalance Assessment

Event	Imbalance Specification (klbf)	Max Imbalance (klbf)	Time of Max Imbalance (sec)
Steady State (1.0 sec to first web time -4.5 sec, lbf, 4-sec average)	85	-26.3	12.0
Transition (first web time -4.5 sec to first web time, lbf)	85-268 linear	+45.1	109.5
Tail-Off (first web time to last action time)	710	+50.5	112.0

Thrust Imbalance = LH SRM - RH SRM

Table 4-10. SRM Performance Comparisons

Parameter	SRM CEI Max ±3σ Var (%)	Nominal Value*	360L006A LH RSRM (60 °F)	360L006A LH RSRM Var (%)**	360L006B RH RSRM (60 °F)	360L006B RH RSRM Var (%)**
Web Time (sec)	5.0	111.7	111.9	+0.18	112.0	+0.27
Action Time (sec)	6.5	123.4	124.7	+1.05	124.1	+0.57
Web Time Avg Pressure (psia)	5.3	660.8	660.6	-0.03	662.8	+0.30
Max Head-End Pressure (psia)	6.5	918.4	916.7	-0.19	917.2	-0.13
Max Sea Level Thrust (Mlbf)	6.2	3.06	3.06	+0.00	3.07	+0.33
Web Time Avg Vac Thrust (Mlbf)	5.3	2.59	2.59	+0.00	2.59	+0.00
Vac Del I_{sp} (lbf•sec/lbm)	0.7	267.1	268.6	+0.56	269.3***	+0.82
Web Time Vac Total Impulse (Mlbf•sec)	1.0	288.9	289.7	+0.28	290.5	+0.55
Action Time Vac Total Impulse (Mlbf•sec)	1.0	296.3	297.3	+0.34	297.7	+0.47

*QM-4 static test and SRM-8A and 8B, SRM-9A, SRM-10A and 10B, SRM-11A, SRM-13A and 13B flight average at standard conditions
**Variation = ((RSRM-6A - Nominal)/Nominal) x 100
((RSRM-6B - Nominal)/Nominal) x 100
***High due to OPT-Tabor bias (0.4%). Without bias adjustment, value would 268.22. It has been proposed to update the CEI specification to reflect the bias adjustment

causes performance parameters to be higher.

4.4.5 Igniter Performance

Due to the elimination of DFI on flight set 360L004 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 TVC Performance

(FEWG Report Para 2.4.3)

No RSRM nozzle torque calculations for motor set 360L006 were possible due to DFI elimination on flight set 360L004 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 Para 2.5.2)

Motor set 360L006 did not have any DFI installed to evaluate the motor structural performance. This section is reserved pending any future motors that incorporate DFI.

4.7 RSRM Structural Dynamics

(FEWG Report Para 2.6.2)

No accelerometer data were available due to the elimination of DFI on flight set 360L004 and subsequent. This section is reserved pending the installation of accelerometers on future flight motors.

4.8 RSRM Temperature and TPS Performance

(FEWG Report Para 2.8.2)

4.8.1 Introduction

This section documents the thermal performance of the 360L006 (STS-34) SRM external components and TPS, as determined by postflight hardware inspection. Assessments of debris, mean bulk temperature predictions, on-pad ambient/local induced environments, LCC, and GEI/joint heater sensor data are also included. Performance of SRM internal components (insulation, case components, seals, and nozzles) is reported in Section 4.11.

4.8.2 Summary

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

4.8.2.2 Debris Assessment. NSTS debris criteria for missing TPS were not violated. A complete SRM debris assessment is given in Section 4.8.3.2. The highlights included: missing TPS cork pieces were generally less than the established criteria of 0.70 $in.^3$, and were all caused by nozzle severance debris and/or splashdown loads and debris.

4.8.2.3 Mean Bulk Temperature Predictions. These temperature predictions were made at different timeframes during the countdown. A discussion of these predictions is presented in Section 4.8.3.3. Final postflight predictions from reconstructed data are:

a. **Propellant.** The PMBT was 82°F.

b. **Flex Bearing.** The flex bearing mean bulk temperature (FBMBT) was 80°F.

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

a. **Ambient Conditions.** The ambient temperature recorded during a 60-hr period prior to launch varied from 69° to 85°F. The normal temperature range experienced during the month of October is from a low of 71°F to a high of 80°F. The 85°F temperature represents a $+1\sigma$ deviation from the historical October mean afternoon (1200 to 1400 hr) high temperature. The windspeeds during this same timeframe were slightly lower than the historical conditions, averaging approximately 8 kn, while the historical average is approximately 12.5 kn.

Wind direction began in a northeasterly direction and swung steadily southward to a southerly direction at the time of launch. The historical wind direction is typically northeasterly during the month of October.

b. **SRM Local.** The wind direction during the LCC timeframe was roughly from the south. From GEI assessments, there was no evidence of temperature suppression due to ET cooling effects.

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

The igniter heaters were activated for approximately 12.5 hr during the 18 October launch countdown and performed as expected. Cooldown, after heater shutoff, occurred over an approximate 7.5-hr period and resulted in T-5-min igniter sensor temperatures of 83° to 86°F.

The heaters were deactivated approximately 50 min earlier than specified in the Operations, Maintenance, and Requirements Specification Document (OMRSD) by KSC console operators for an unknown reason. The early deactivation resulted in an interim problem report (IPR) which was dispositioned by a waiver of the OMRS. The result of the early deactivation was negligible, due to the warm ambient temperatures prior to launch.

The six field joint heaters performed adequately and as expected, with a 17°F sensor temperature range from 92° to 109°F during the LCC timeframe. Of the 24 field joint sensors, 23 recorded temperatures in the expected range. The LH center field joint temperature sensor at 195 deg was severed prior to the systems integration test (SIT), and was deleted from the control logic of the field joint heater. The LCC requirement is that two of four sensors be operational; the loss of the single sensor posed no problem from either a heater control or LCC standpoint.

The SRB aft skirt purge operation was not activated until T-15 min because of the warm ambient and component temperatures. This was done in accordance with the operations maintenance instruction (OMI) which instructs the operator to control the "SRB flow rate purge as required to maintain the following limits: Flex Bearing 60°-115°F and Nozzle/Case Joint 75°-115°F."

4.8.2.6 Prelaunch Thermal Data Evaluation. Infrared measurements from both the infrared gun and the STI were compared with GEI. A complete evaluation is found in Section 4.8.3.6. Highlights are as follows: Infrared measurements taken by the infrared gun during the T-3-hr ice/debris pad inspection were found to be anomalous and therefore were not reported. The STI temperature measurements were used along with the GEI measurements to monitor SRM surface temperatures. Temperatures varied between 76° and 80°F during the T-3-hr pad inspection for both STI and GEI temperatures.

4.8.2.7 Prelaunch Hardware Anomalies

a. **RH Center Field Joint Heater DWV Test Failure.** The RH center field joint heater failed the DWV test after installation. Due to the severity of the failure, the heater was disabled by opening the circuit breaker to avoid inadvertent activation of the heater. The redundant heater performed nominally during the launch countdown. A complete discussion of the problem is given in Section 4.8.3.7.

b. **LH Forward Center Segment Heater Cabling Switch.** During the installation of the LH forward field joint heater cabling on the LH forward center segment, the primary and redundant heater cables were inadvertently switched. The cables were switched back prior to rollout. Details are given in Section 4.8.3.7.

4.8.3 Results Discussion

4.8.3.1 Postflight Hardware Inspection. Following the recovery of the STS-34 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 4-11). Predictions due to the worst-case design trajectory environments (Table 4-12) will be documented in the SRB Thermal Design Data Book, SE-019-068-2H.

The condition of both motors appeared to be similar to previous flight motors, with most of the heat effects seen on the aft segments on the inboard 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 space shuttle main engines (SSME) 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 4-13.

a. **Field Joints.** All field joints on both motors were in excellent condition. There were no signs of ablation on any of the joint protection systems (JPS), with only slight paint blistering on the cork cover. The paint on the K5NA closeout aft of the cork was also slightly darkened and blistered, with occasional pitting. This was probably due to aerodynamic heating and 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.

b. **Factory Joints.** The factory joints on each of the motors were in very good condition. The only signs of heat effect experienced on the factory joints were located on the aft segments of each motor. There were only slight ablation, charring, and discoloration on the inboard regions of the aft segment factory joints. This occurred between approximately 220- and 320-deg circumferentially on each motor. These are all normal occurrences which have been consistently observed on previous flight motors. Two weatherseals on the LH motor showed signs of forward and aft edge unbond regions. No evidence of sooting was found under these unbonds.

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

d. **Stiffener Rings.** The stiffener ring TPS was generally in very good condition with only slight thermal degradation. The major heat-affected area was predominantly in the 220- to 320-deg sector, with the ethylene

Table 4-11. RSRM External Performance Summary, TPS Erosion — LH and RH Motors

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

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

Table 4-12. SRB Flight-Induced Design Thermal Environments

Ascent Heating

- Document No. STS 84-0575, 24 May 1985
- Change Notice 2, SE-698-D, 30 April 1987
- Computer tapes No. DN 4044 and DN 9068
- Change Notice 3, SE-698-D, 30 October 1987; Tape No. DP 5309

Base Recirculation Heating

- Document No. STS 84-0259, October 1984
- Change Notice 1, SE-698-D, 30 September 1987

SSME and SRB Plume Radiation

- Document No. STS 84-0259, October 1984
- Change Notice 1, SE-698-D, 30 September 1987

SSME Plume Impingement After SRB Separation

- Document No. STS 84-0259, October 1984
- Change Notice 1, SE-698-D, 30 September 1987

Reentry Heating

- Document No. SE-0119-053-2H, Rev D, August 1984, and Rev E, 12 November 1985

Table 4-13. SRM External Performance Summary—LH and RH Motors

Component	TPS Material	Performance	Recovered Hardware Performance Assessment
Field Joints	Cork	Typical	All JPS in excellent condition. Slight paint blistering. Pitting on aft edge of JPS K5NA closeout. All K5NA repairs intact 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 and aft edge unbonds on two LH motor weatherseals with no evidence of sooting
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 at outboard locations of both motors due to water impact. Cracks observed in K5NA of both middle stiffeners
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 Kick Ring Joint	Cork	Typical	Good condition from thermal perspective. Shielded from radiation by kick ring. No splashdown damage
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

propylene diene monomer (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 on both motors, predominantly at outboard locations, due to splashdown loads. The K5NA on the middle stiffener of both motors was cracked in this same region.

e. **GEI, Cables.** 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 reentry, splashdown loads, and handling problems. There was a total of 16 aft edge hits, eight per motor.

f. **Aft Kick Ring Joint.** The TPS cork strip over the pin retainer band was in good condition from a thermal perspective. This strip, as well as the case region vicinity, was heavily sooted with no unexpected heating effects. This strip during ascent is shielded from adjacent SRB plume radiation by the kick ring.

4.8.3.2 Debris Assessment. NSTS debris criteria for missing TPS were not violated. The TPS cork pieces that were missing were generally less than the established criteria of 0.70 in.^{3}, and were all caused by nozzle severance debris, splashdown loads/debris, or handling problems. There was a total of 16 aft edge hits, eight on each motor. There were six of these pieces which exceeded 0.70 in.^{3}. The largest GEI cork piece missing was approximately 4 by 1.5 by 0.25 inches, or 1.50 in.^{3}. It was located on the LH aft center segment at Station 1410 at 270 deg. It was either a handling or splashdown scrape, leaving a clean substrate.

Based on the quick-look external inspection, the SRM TPS performed adequately on STS-34. The problem of losing TPS cork caps covering the instrumentation cables (a result of poor cork bonds) appears to have been corrected. The K5NA closeouts performed well and as expected.

4.8.3.3 Propellant Mean Bulk Temperature and Flex Bearing Mean Bulk Temperature Predictions. Temperature predictions (°F) were performed at various times with respect to the launch of STS-34. They are predicted for the time of launch and are summarized as follows:

	Historical	L-9 Days 3 Oct 89	L-2 Days 9 Oct 89
PMBT	75	82	82
FBMBT	80	80	--

	L-24 Hours 17 Oct 89	Postlaunch
PMBT	--	82
FBMBT	80	80

As can be seen, the PMBT and FBMBT did not change from the L-9 day prediction to the postlaunch calculation using reconstructed ambient data.

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

a. Thiokol Launch Support Service (LSS) Office (faxed weather data).

b. KSC Weather Station (modem transmission).

c. Florida Solar Energy Center (FSEC) (modem transmission).

d. Central Data System (CDS) data collected at HOSC (faxed weather data).

The data from the Thiokol LSS Office were used wherever possible, and were the primary source of environmental data. The ambient temperature from the KSC Weather Station was used as the next source along with windspeed and direction from the FSEC. The ambient temperature data from the FSEC were used only when the other sources were unavailable. The FSEC, however, was the sole source for sky temperature and solar flux. The CDS data collected at the HOSC during the countdown were the ambient temperature data used during the 69 hr prior to launch.

The FBMBT calculations were not actually conducted since the flex bearing temperature was projected to be above 75°F and the aft skirt purge was not expected to operate. Due to the slow transients in the aft skirt, the aft end ring temperature can be used as a reliable indicator of the FBMBT. The aft end ring temperature and FBMBT were 80°F throughout the prelaunch period.

4.8.3.4 On-Pad Environmental Evaluations. Actual environmental data for the final 24 hr prior to launch can be visualized in Figures 4-10 through 4-14 and summarized together with GEI in Table 4-14. The ambient temperature data recorded during a 61-hr period prior to launch varied from 69° to 85°F. The normal temperature range experienced during the month of October is from a low of 71°F to a high of 80°F. The 85°F temperature represents a $+1\sigma$ deviation from the historical October mean afternoon (1200 to 1400 hr) high temperature. The windspeeds during this same timeframe were slightly lower than the historical conditions, averaging approximately 8 kn, while the historical average is approximately 12.5 kn. Wind direction began in a northeasterly direction and swung steadily southward to a southerly direction at the time of launch. The historical wind direction is typically northeasterly during the month of October.

The local on-pad environment due to October historical predictions suggests an average 1°F temperature suppression while the ET is loaded for winds from the southeast direction. The actual wind direction during the LCC timeframe was roughly from the south. From GEI assessments, there was no evidence of temperature suppression due to ET cooling effects.

4.8.3.5 Launch Commit Criteria. No LCC thermal violations were noted. Measured GEI and heater sensor data for the end of the LCC timeframe (T-5 min) are presented in Table 4-15 and are compared to the LCC requirements.

The igniter heaters were activated for approximately 12.5 hr during the 18 October launch countdown and performed as expected. Cooldown, after heater shutoff, occurred over an approximate 7.5-hr period and resulted in T-5-min igniter sensor temperatures of 83° to 86°F. The igniter temperatures at the time of initial heater activation 48 hr earlier were 77° to 83°F. Since the ambient temperature at the time of heater activation was nearly identical to the ambient temperature at the time of launch, the net effect of the heaters was to raise the igniter temperatures by only 3° to 6°F.

The heaters were deactivated approximately 50 min earlier than specified in the OMRSD. The early deactivation resulted in an IPR which was dispositioned by a waiver of the OMRS. Due to the short duration of the launch window, a concerted effort was made to perform all launch sequence steps earlier than required by the OMI. OMI Steps 16-0083 through 16-0088 provide instructions for igniter heater power removal and the pyrotechnic initiator controller (PIC) resistance test (Go Mode). Although the appropriate OMRSD requirements are referenced in the OMI steps, no actual mention is made of the

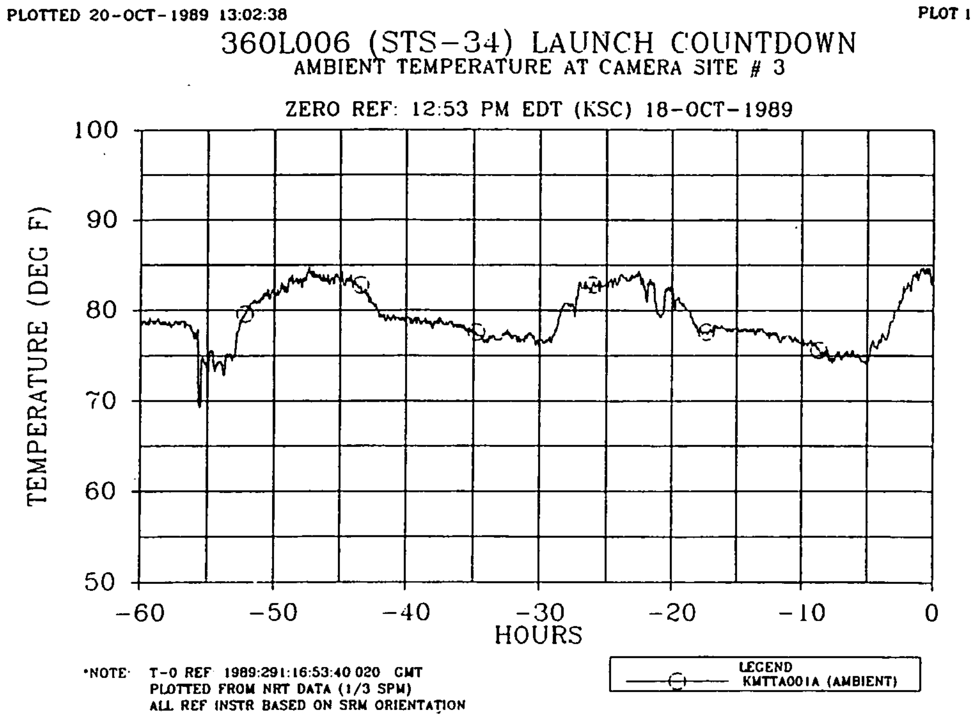


Figure 4-10. Ambient Temperature at Camera Site 3

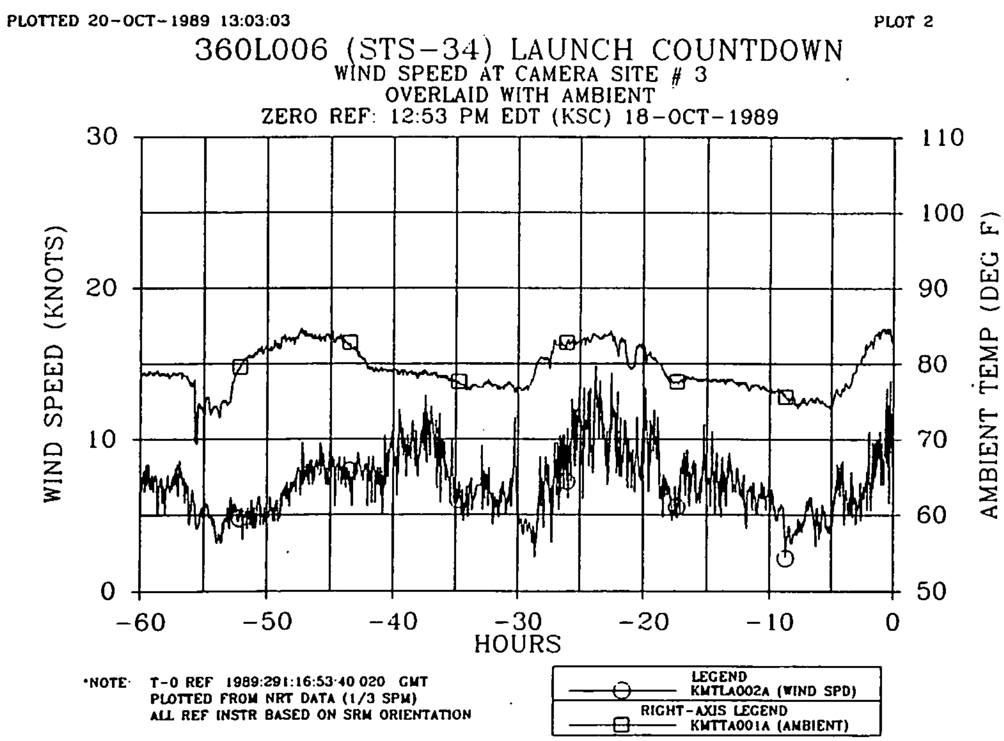


Figure 4-11. Windspeed at Camera Site 3 — Overlaid With Ambient

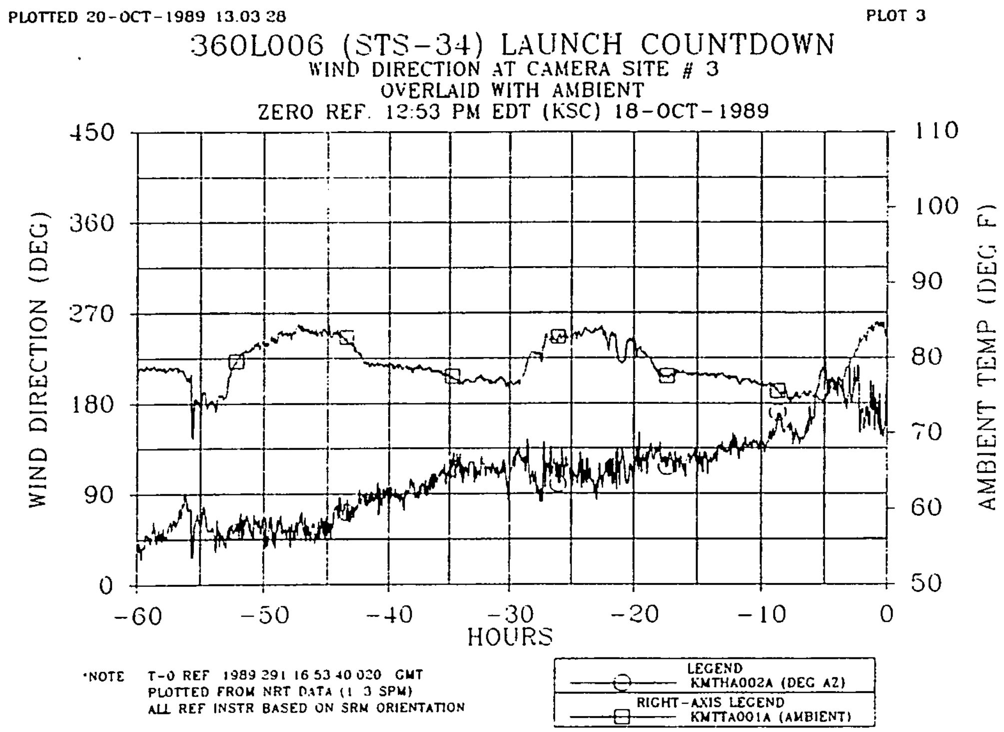


Figure 4-12. Wind Direction at Camera Site 3 – Overlaid With Ambient

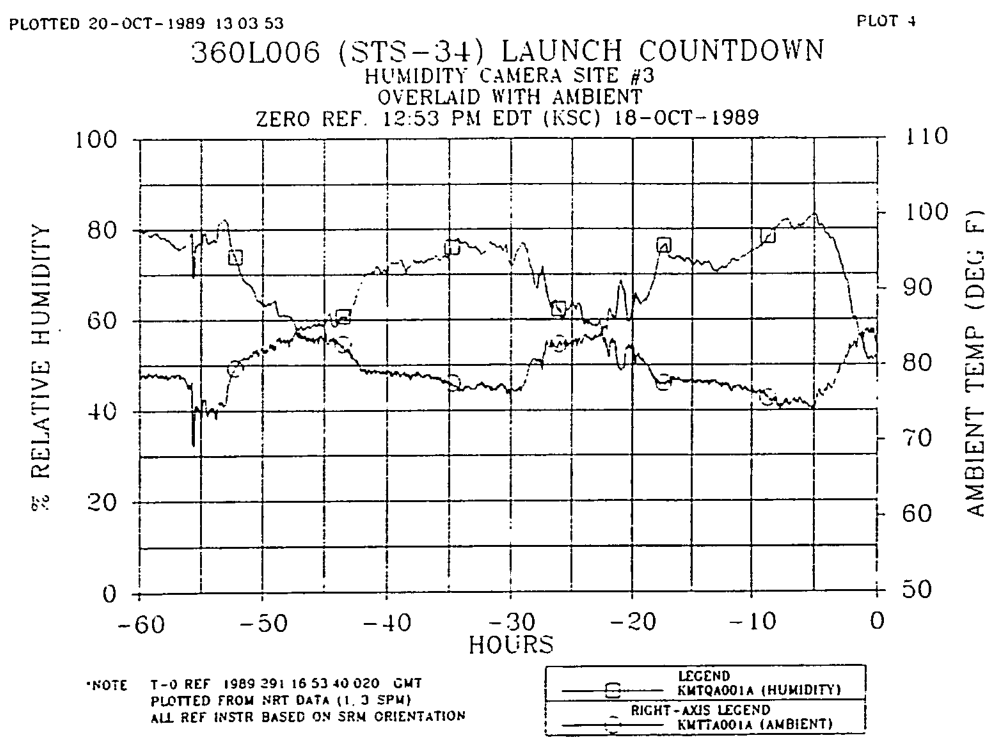


Figure 4-13. Humidity at Camera Site 3 – Overlaid With Ambient

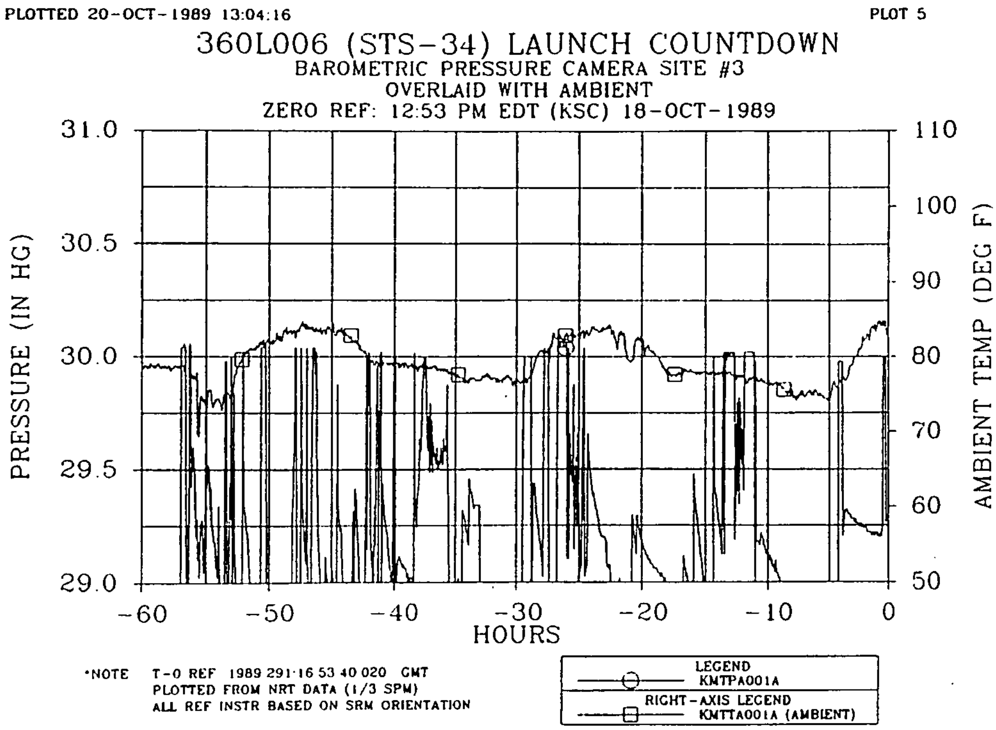


Figure 4-14. Barometric Pressure at Camera Site 3 — Overlaid With Ambient

*Table 4-14. T-5-Minute On-Pad Temperatures**
(represents end of LCC timeframe)

Component	T-12-Hour Predictions*	October Historical	Actual GEI	LCC
Igniter				
RH	88-92	83-83	83-85	66-123
LH	88-92	83-83	83-86	66-123
Field Joint				
RH Forward	96-108	100-102	97-107	85-122
LH Forward	96-104	100-102	98-99	85-122
RH Center	96-108	100-102	97-103	85-122
LH Center	96-104	98-100	97-104	85-122
RH Aft	96-108	97-99	97-108	85-122
LH Aft	96-104	97-99	95-96	85-122
Nozzle-to-Case Joint				
RH	80-85	82-83	83-83	75-115
LH	80-85	82-83	82-83	75-115
Flex Bearing Aft End Ring				
RH	78-82	82-83	82-85	NA/115
LH	78-82	82-83	82-83	NA/115
Case Acreage (deg)				
RH — 45	--	77-78	83-85	--
135	--	76-77	80-93	--
215	--	76-77	80-90	--
270	80-86	77-78	83-87	35-NA
325	--	77-78	80-83	--
LH — 45	--	76-77	80-83	--
135	--	76-77	80-85	--
215	--	77-78	80-82	--
270	80-86	77-78	79-81	35-NA
325	--	76-77	80-82	--
Local Environment				
Temperature	85	80	84	38-99
Windspeed (kn)	--	13	9-12	24
Wind Direction	--	E-NE	S	SW-SE
Cloud Cover		Partly Cloudy		

*In °F
**Predictions for anticipated launch window at T-5 min

*Table 4-15. Actual GEI Countdown and Historically Predicted On-Pad October Temperatures**
(LCC timeframe temperatures also included)

Component	Daily Cycling October Historical	Daily Cycling Actual GEI	T-6 Hour to T-5 Minutes October Historical	T-6 Hour to T-5 Minutes Actual GEI	T-6 Hour to T-5 Minutes LCC
Igniter					
RH	77-80	78-80	83-100	83-98	66-123
LH	77-80	77-80	83-100	83-102	66-123
Field Joint					
RH Forward	70-78	80-94	97-103	92-108	85-122
LH Forward	70-77	79-88	97-103	93-102	85-122
RH Center	70-78	80-97	97-103	93-106	85-122
LH Center	70-77	80-89	97-103	93-106	85-122
RH Aft	70-78	79-89	97-102	91-109	85-122
LH Aft	70-77	78-89	97-102	92-100	85-122
Nozzle-to-Case Joint					
RH	72-77	80-83	78-82	80-85	75-115
LH	72-77	77-80	78-82	80-83	75-115
Flex Bearing Aft End Ring					
RH	72-77	77-78	78-82	82-85	NA-115
LH	72-77	78-78	78-82	80-85	NA-115
Case Acreage (deg)					
RH — 45	70-77	77-86	70-77	78-85	–
135	70-77	74-99	70-77	74-93	–
215	72-78	77-94	72-77	77-90	–
270	72-78	77-88	72-77	77-86	35-NA
325	71-77	75-83	71-77	75-83	–
LH — 45	71-78	77-90	71-77	77-83	–
135	70-78	77-85	70-77	77-85	–
215	70-78	75-82	70-77	75-82	–
270	72-78	75-83	72-77	75-81	35-NA
325	72-78	77-88	72-77	77-82	–
Local Environment					
Temperature	71-80	75-85	71-80	75-85	38-99
Windspeed (kn)	13	3-15	13	3-14	24
Wind Direction	E-NE	E-SW	E-NE	SW-SE	SW-SE
Cloud Cover	Partly Cloudy		Partly Cloudy		

*In °F

requirement that igniter heater deactivation is not to be performed prior to T-4 hr. Therefore, the igniter heater power removal was performed at the earliest possible moment, T-4 hr 50 min. The result of the early deactivation was negligible, due to the warm ambient temperatures prior to launch.

The six field joint heaters performed adequately and as expected with a 17°F sensor temperature range from 92° to 109°F during the LCC timeframe. Of the 24 field joint sensors, 23 recorded temperatures in the expected range. The LH center field joint temperature sensor at 195 deg was severed prior to the SIT, and was deleted from the control logic of the field joint heater. The LCC requirement is that two of four sensors be operational, so the loss of the single sensor posed no problem from either a heater control or LCC standpoint.

The SRB aft skirt purge operation was not activated until T-15 min because of the warm ambient and component temperatures. This was done in accordance with the OMI which instructs the operator to control the "SRB flow rate purge as required to maintain the following limits: Flex Bearing 60°-115°F and Nozzle/Case Joint 75°-115°F."

4.8.3.6 Prelaunch Thermal Data Evaluation. Figures 4-15 through 4-19 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 4-20 through 4-49 present October historical predictions. These predictions are based on event sequencing, as specified in Table 4-16. Figures 4-50 through 4-106 show actual STS-34 countdown data.

The ambient temperature was approximately $+1\sigma$ above the historical value while the vehicle was on the pad. The actual high temperature the day before launch was 5°F warmer than the normal October high temperature. Because of this, the actual GEI and joint heater sensor data were at higher temperatures than the October historical on-pad predictions. The predicted igniter sensor, nozzle-to-case joint, and flex bearing aft end ring temperatures varied more during a daily cycle than the actual GEI temperatures. The LCC time period (T-6 hr to T-5 min) predictions were in good agreement with the actual data given the fact the aft skirt purge system did not operate (see Table 4-14). The T-5 min historical versus actual temperature comparisons were also in close agreement although the actual case acreage temperatures were about 5°F higher than the historical average (see Table 4-15). 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 most of the GEI. The predicted igniter sensor temperatures after cooldown were higher than the actual measured temperatures (see Table 4-14).

Postflight reconstructed predictions of GEI and igniter/field joint heater response have been performed using the actual environmental data from the 24 hr prior to launch. Because of the increased accuracy seen from the STS-28R flight, the postflight predictions were made using the measured solar data, and use of the historical values was discontinued. The historical values can be easily incorporated into the model in the event that measured solar data become unavailable from the FSEC. A few examples of the predictions, compared with actual measured sensor data, are found in Figures 4-107 through 4-122. Reasonable agreement is apparent in all areas except the ET attach ring, the LH SRB systems tunnel, and the nozzle-to-case joint regions. In the future, modeling improvements (environment and detail) need to be made in these regions.

Infrared temperature measurements taken by the infrared gun during the T-3-hr ice/debris pad inspection were found to be anomalous and therefore

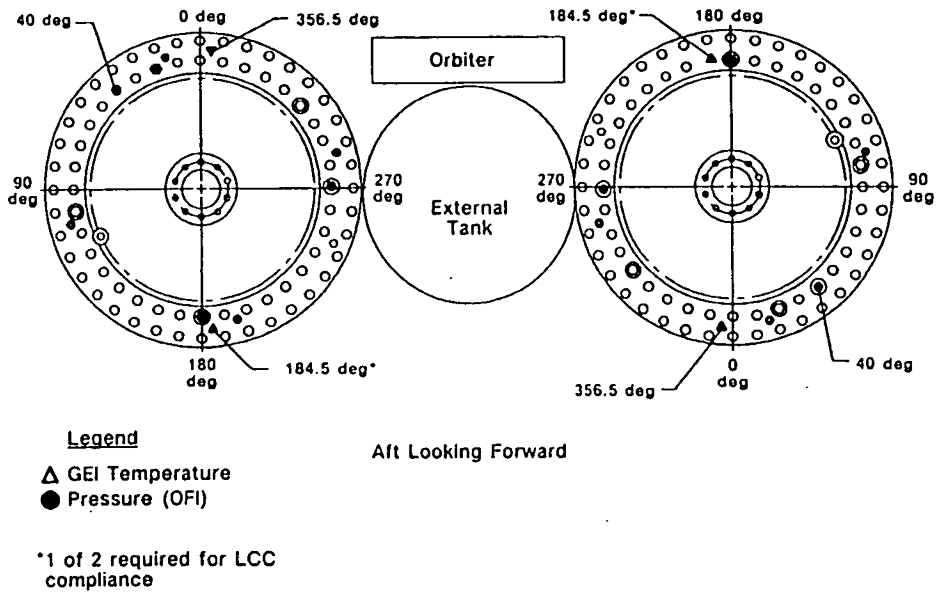


Figure 4-15. Forward Dome GEI

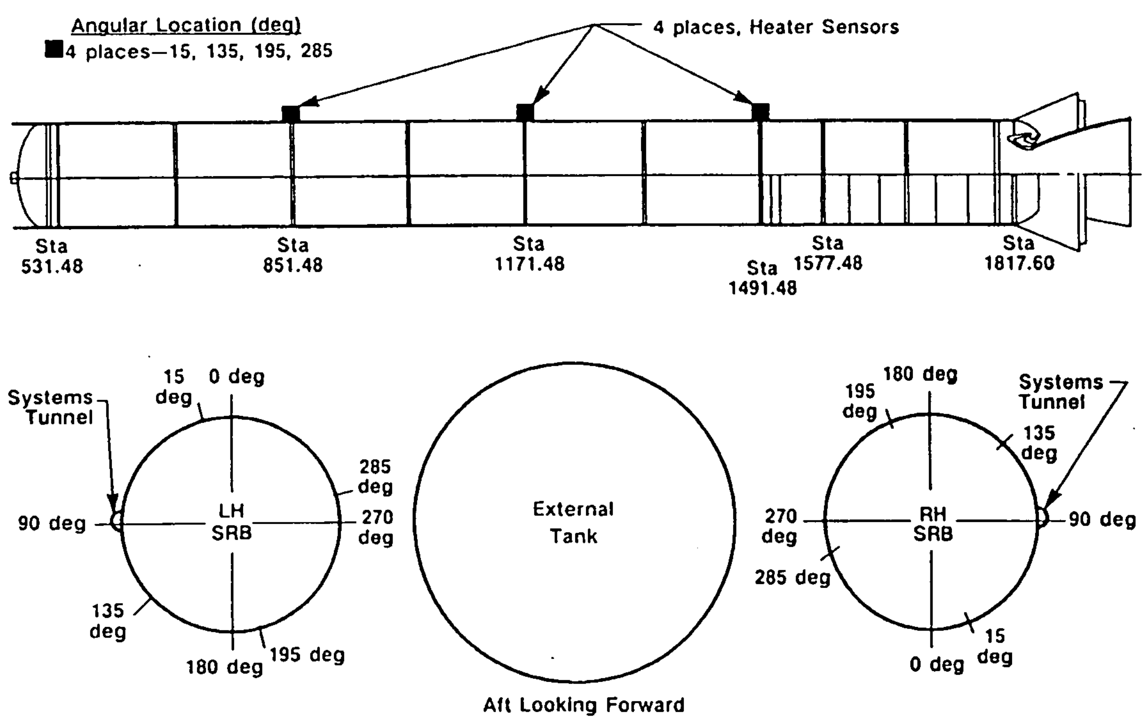


Figure 4-16. Field Joint Heater Temperature Sensors

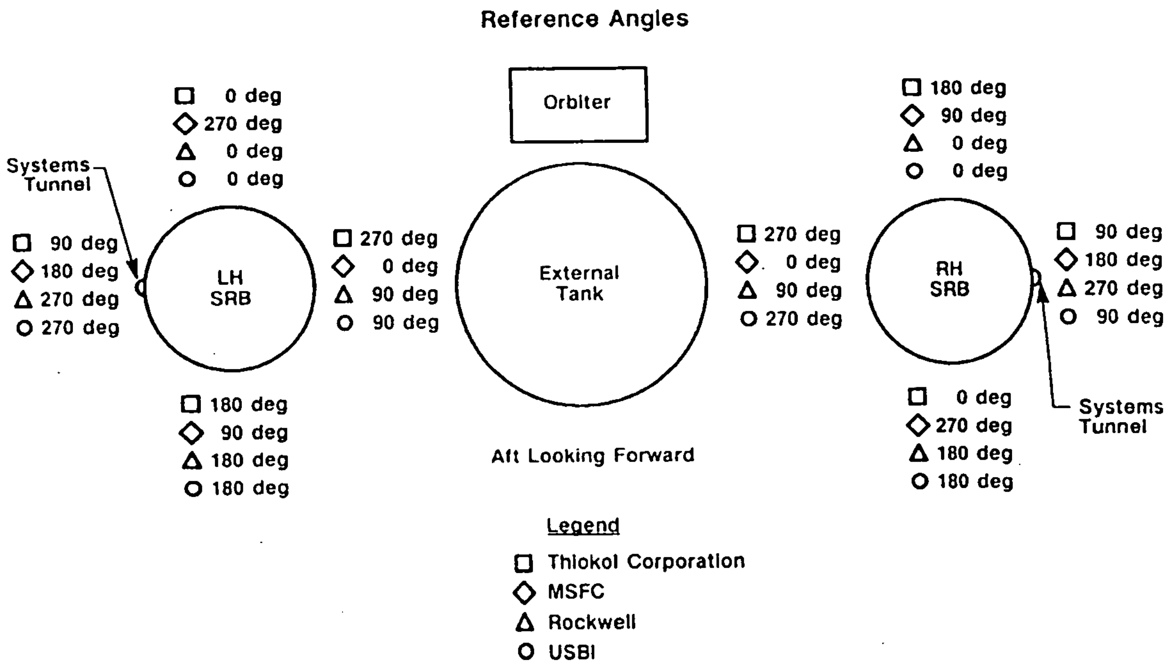


Figure 4-17. Case Ground Environmental Instrumentation (GEI)

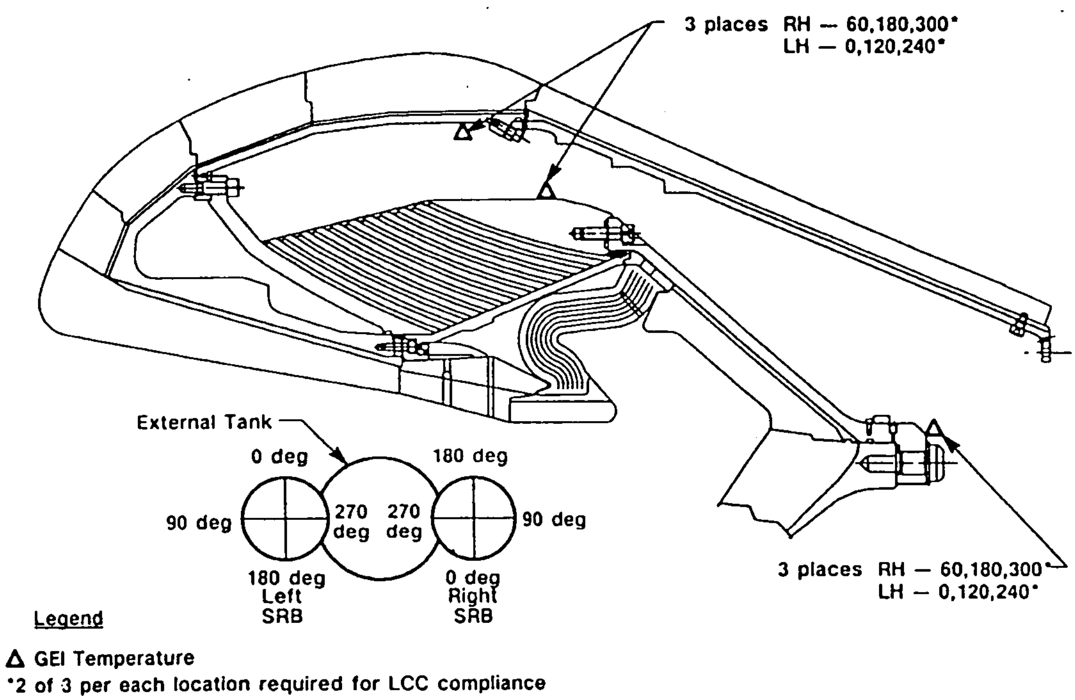


Figure 4-18. Nozzle/Exit Cone

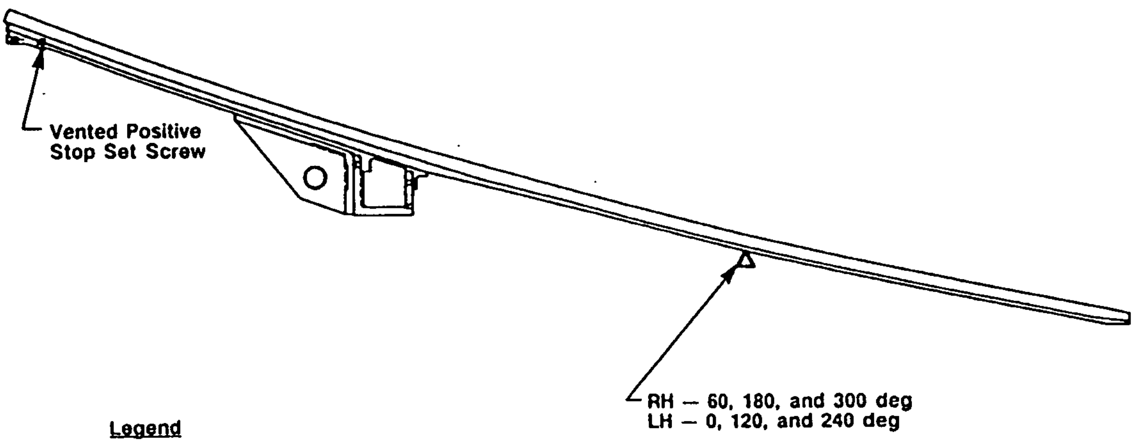


Figure 4-19. Aft Exit Cone GEI

Table 4-16. Analytical Timeframes for Estimating Event Sequencing of October Historical Joint Heater and GEI Sensor Predictions

Time (hr)	Countdown Events in Analysis
0	Midnight KSC EST (16 Oct 89)
37.5	Igniter heater operation begins on 17 Oct 89 (L-24 hr)
45.5	Aft skirt conditioning operation begins on 17 Oct 89 (T-12 hr + 4 hr for holds)
49.5	Field joint heater operation begins on 17 Oct 89 (T-8 hr + 4 hr for holds)
51.5	Induced environments due to ET refrigeration effects begin early on 18 Oct 89 (T-6 + 4 hr for holds)
54.5	Igniter heater shutoff/start cooldown (T-4 hr + 3 hr for holds)
61.5	Assumed time of launch (18 Oct 89)

Note: Figures 4-20 through 4-49 consist of a 2-day plus 13.5-hour scenario

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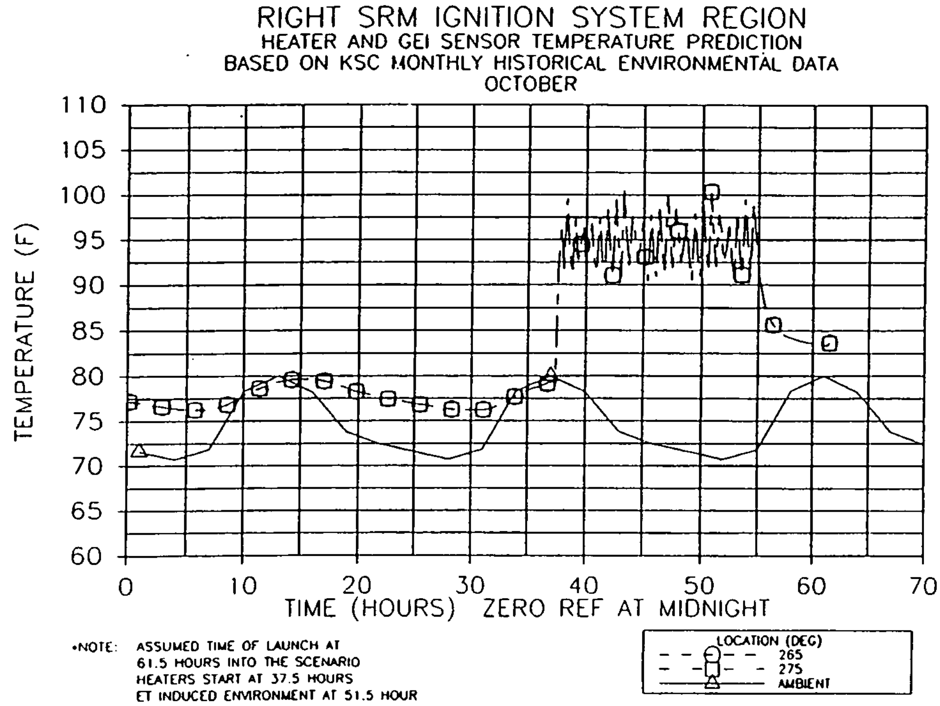

Figure 4-20. RH SRM Ignition System Region — Heater and GEI Sensor Temperature Prediction

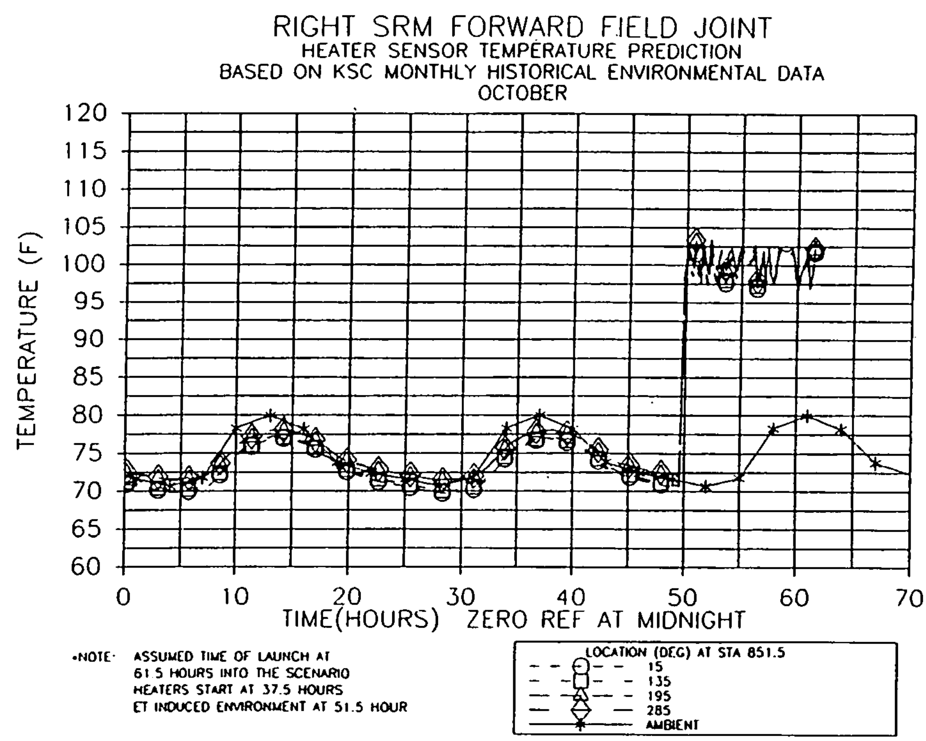

Figure 4-21. RH SRM Forward Field Joint — Heater Sensor Temperature Prediction

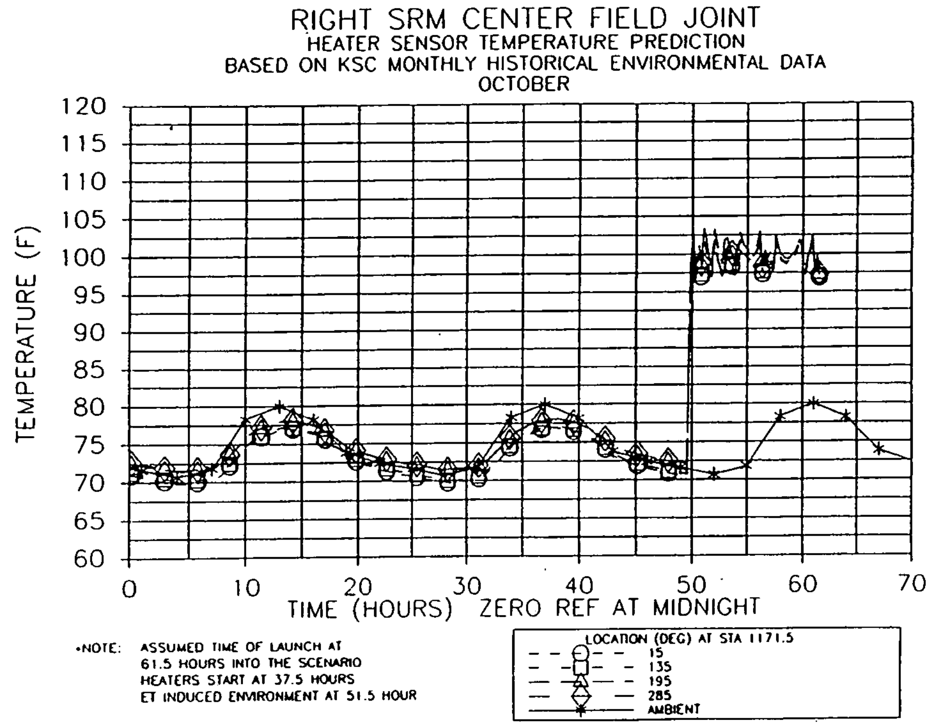

Figure 4-22. RH SRM Center Field Joint – Heater Sensor Temperature Prediction

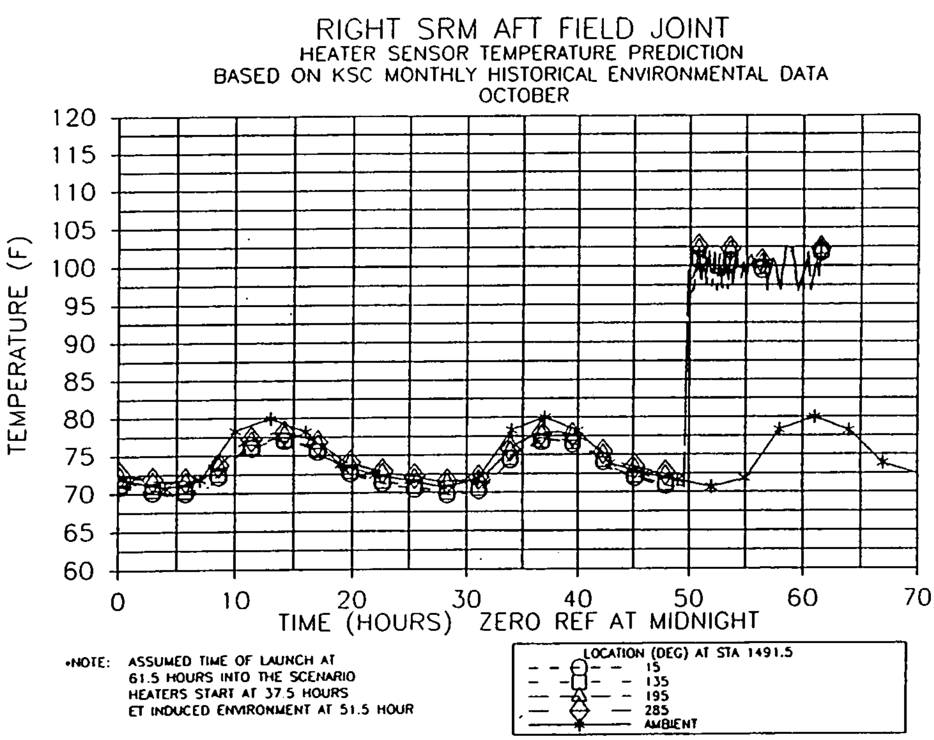

Figure 4-23. RH SRM Aft Field Joint – Heater Sensor Temperature Prediction

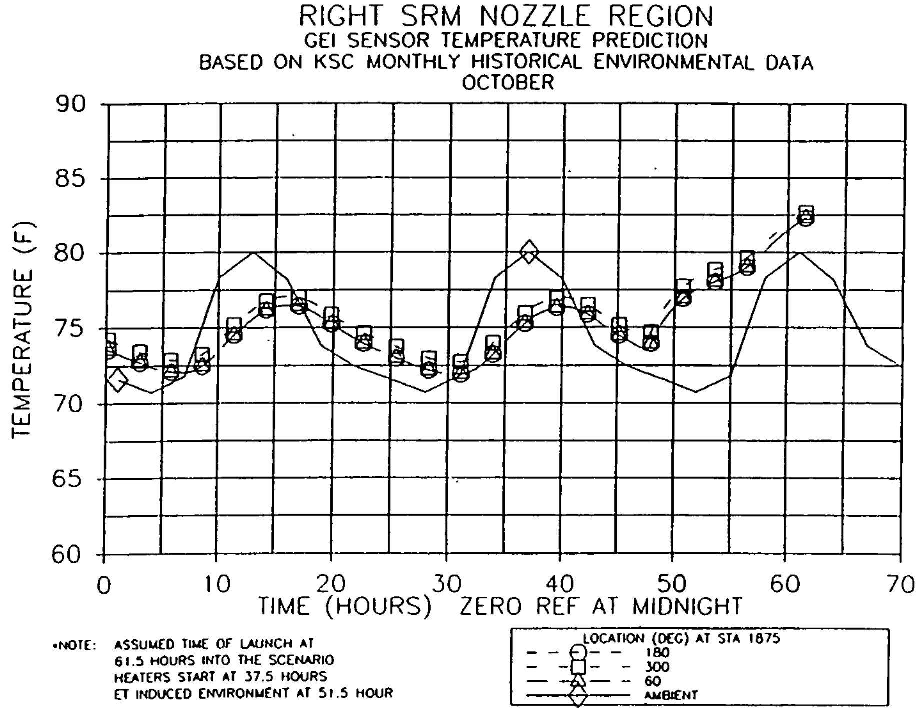

Figure 4-24. RH SRM Nozzle Region — GEI Sensor Temperature Prediction

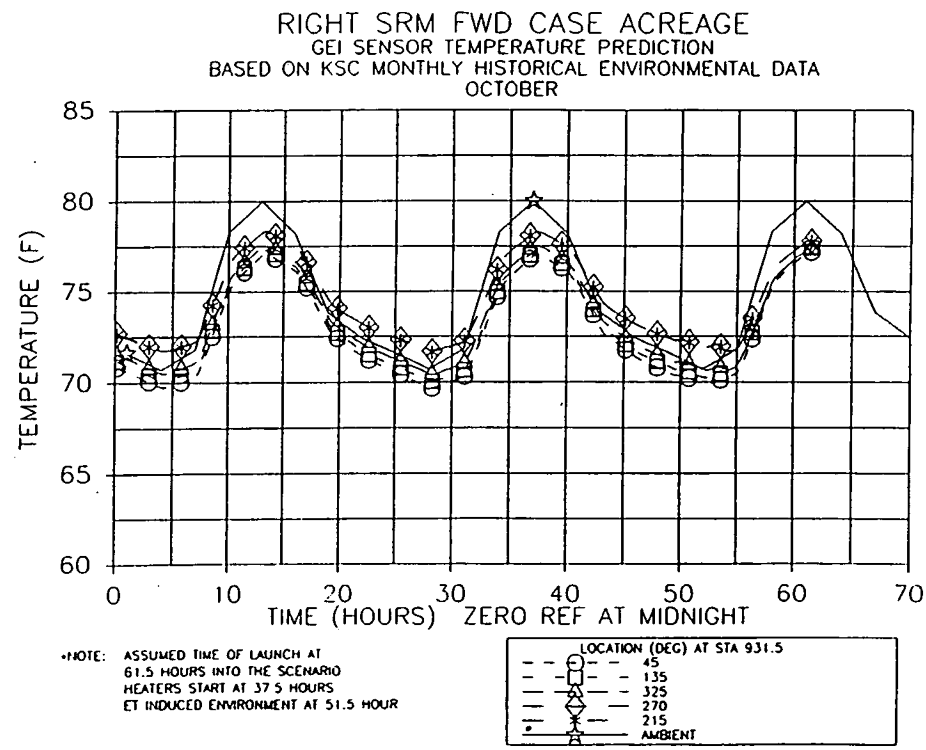

Figure 4-25. RH SRM Forward Case Acreage — GEI Sensor Temperature Prediction

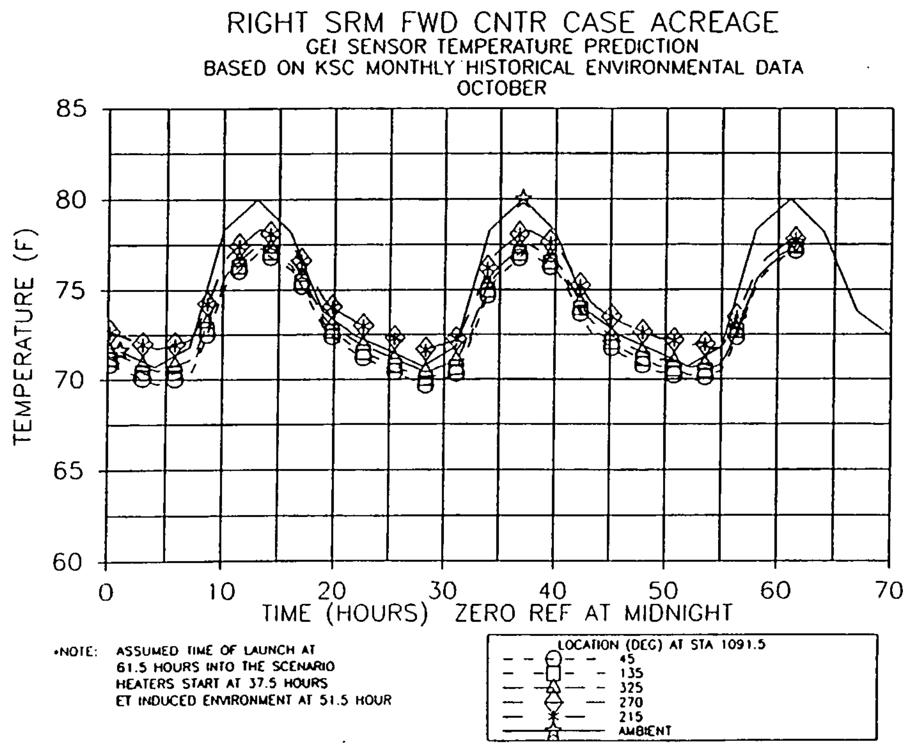

Figure 4-26. RH SRM Forward Center Case Acreage — GEI Sensor Temperature Prediction

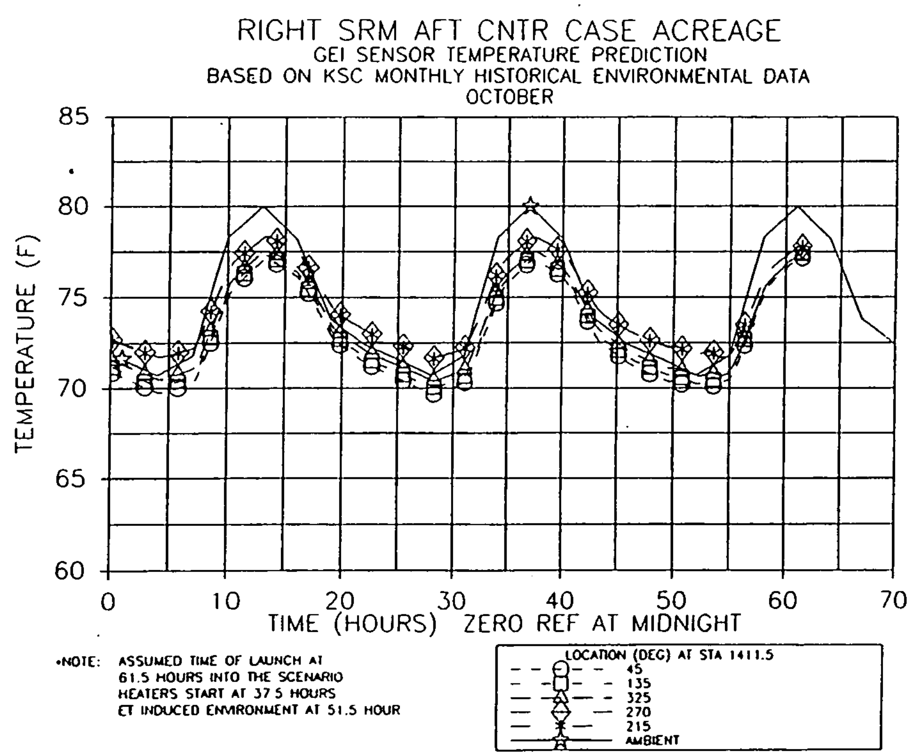

Figure 4-27. RH SRM Aft Center Case Acreage — GEI Sensor Temperature Prediction

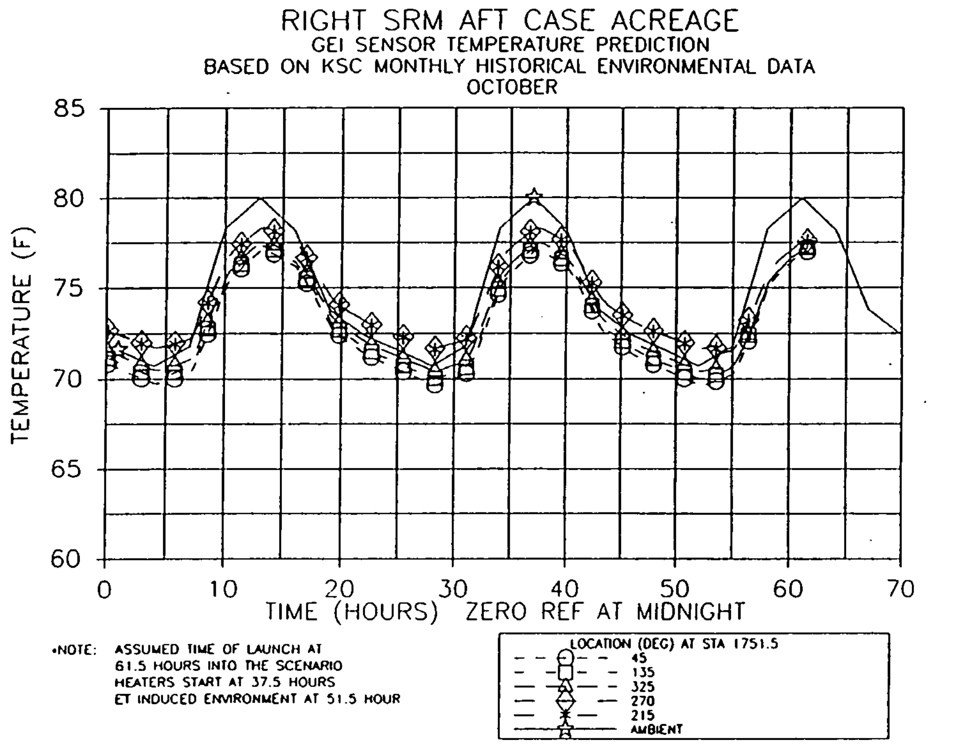

Figure 4-28. RH SRM Aft Case Acreage — GEI Sensor Temperature Prediction

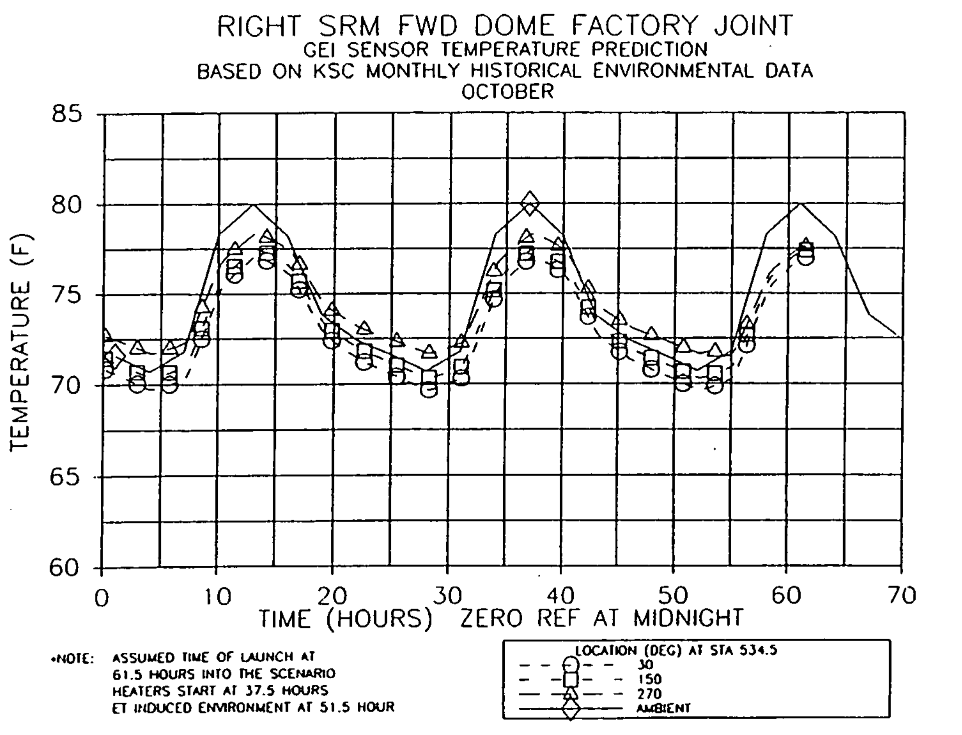

Figure 4-29. RH SRM Forward Dome Factory Joint — GEI Sensor Temperature Prediction

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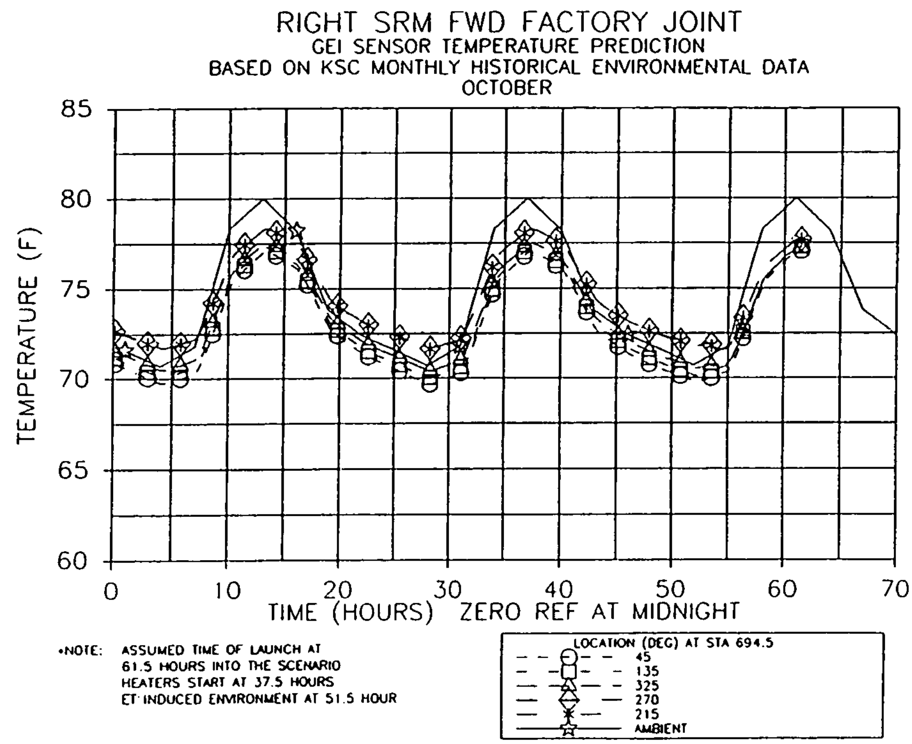


Figure 4-30. RH SRM Forward Factory Joint – GEI Sensor Temperature Prediction

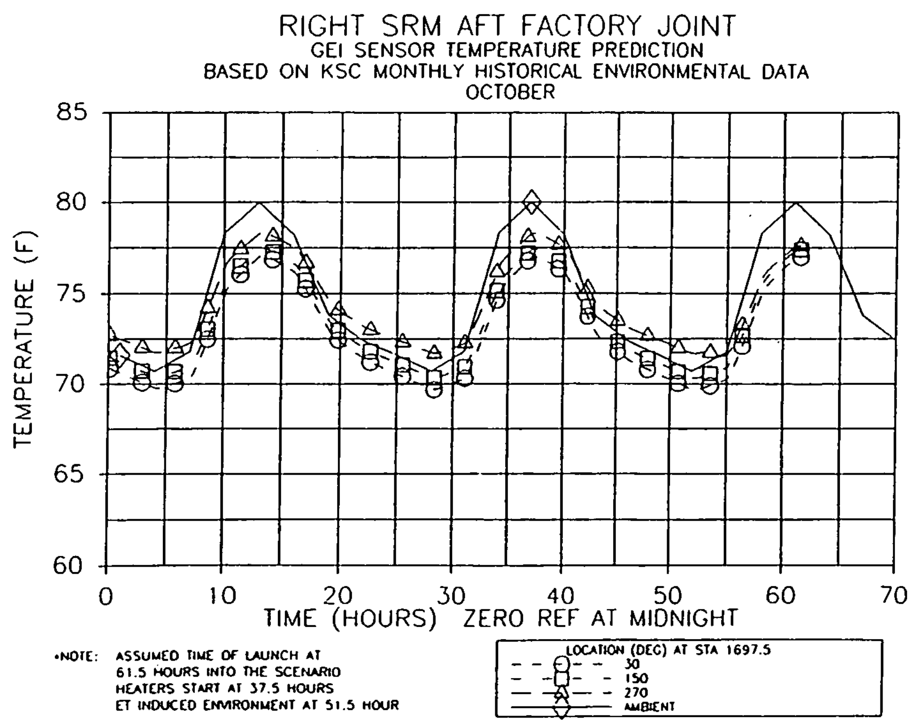


Figure 4-31. RH SRM Aft Factory Joint – GEI Sensor Temperature Prediction

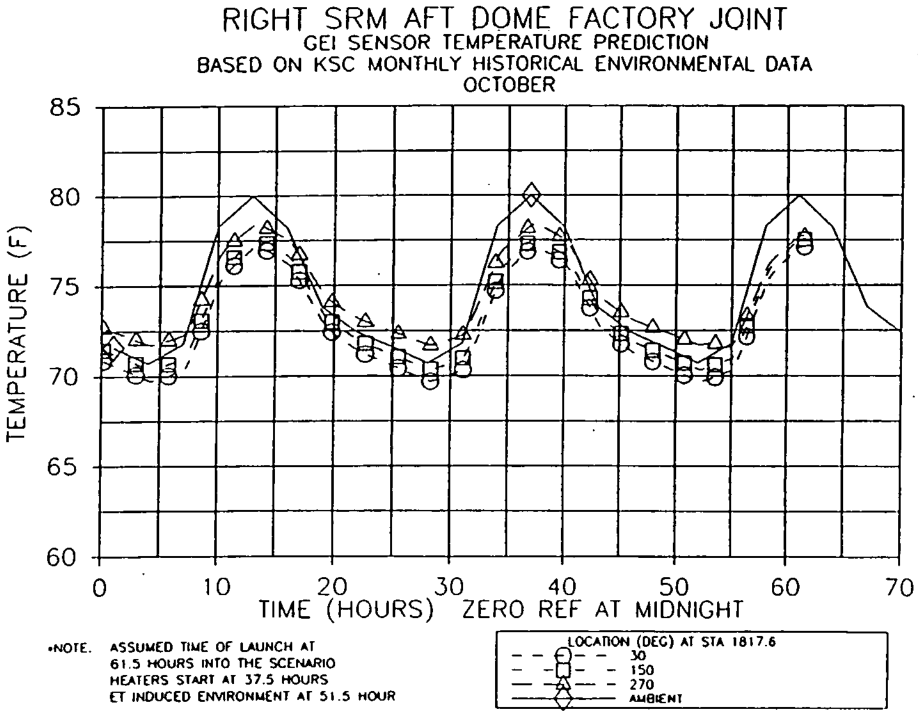


Figure 4-32. RH SRM Aft Dome Factory Joint – GEI Sensor Temperature Prediction

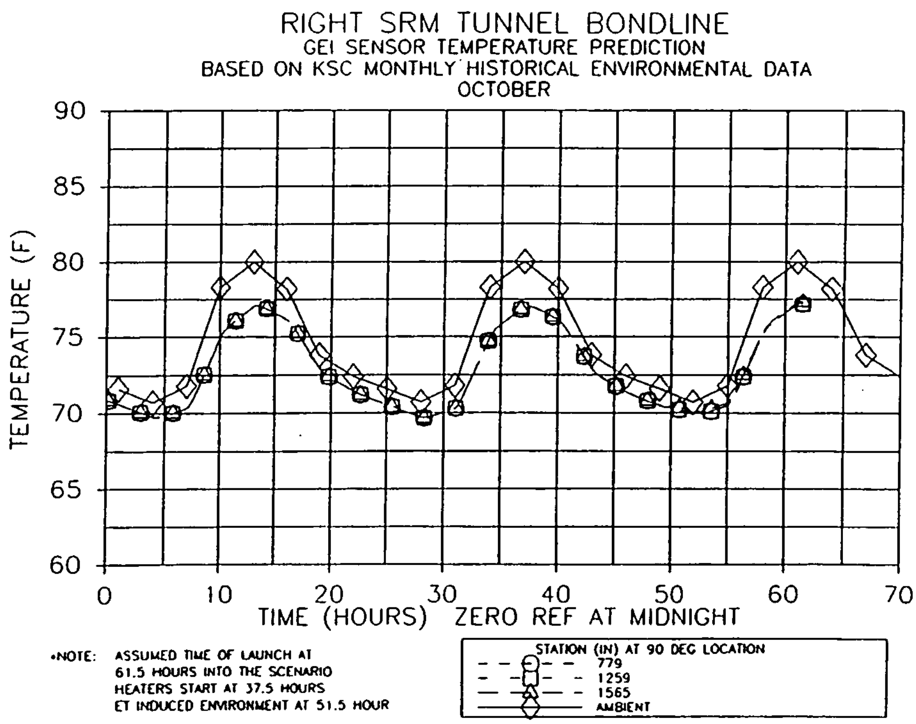


Figure 4-33. RH SRM Tunnel Bondline – GEI Sensor Temperature Prediction

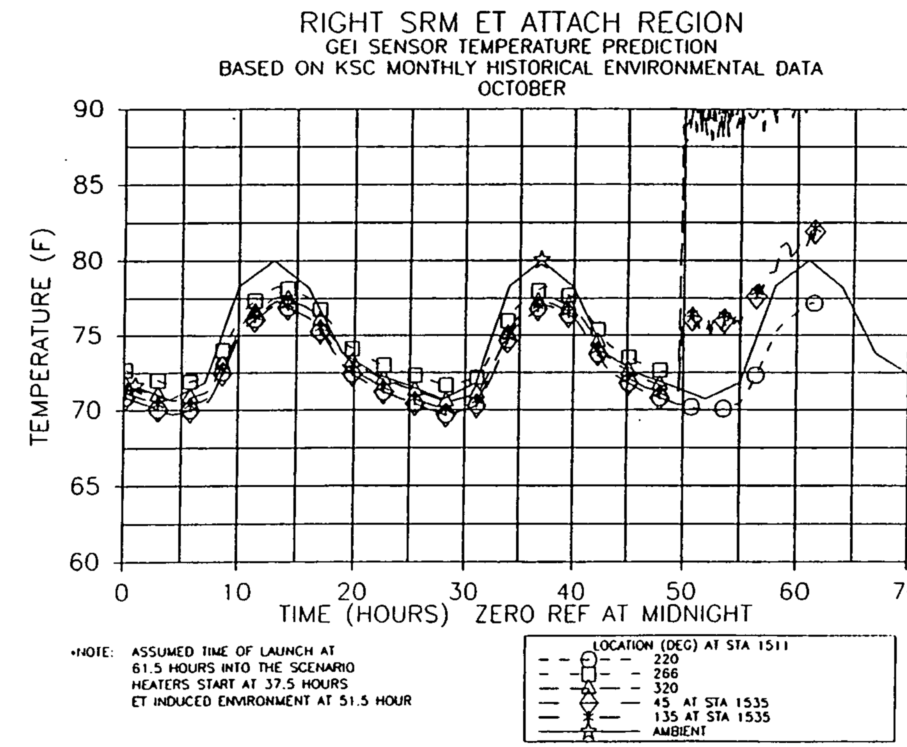


Figure 4-34. RH SRM ET Attach Region — GEI Sensor Temperature Prediction

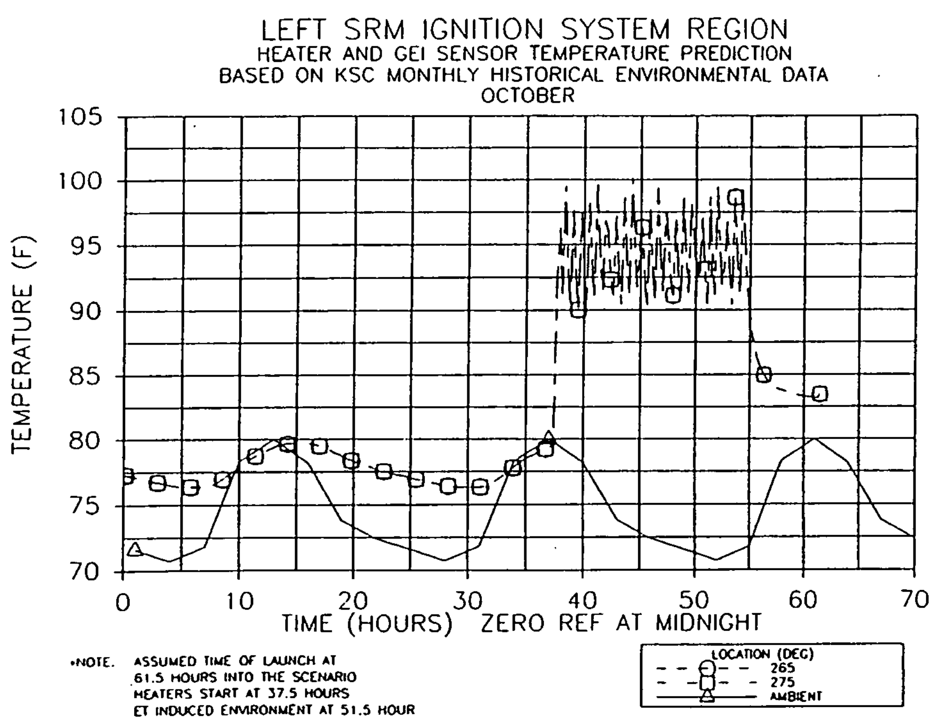


Figure 4-35. LH SRM Ignition System Region — Heater and GEI Sensor Temperature Prediction

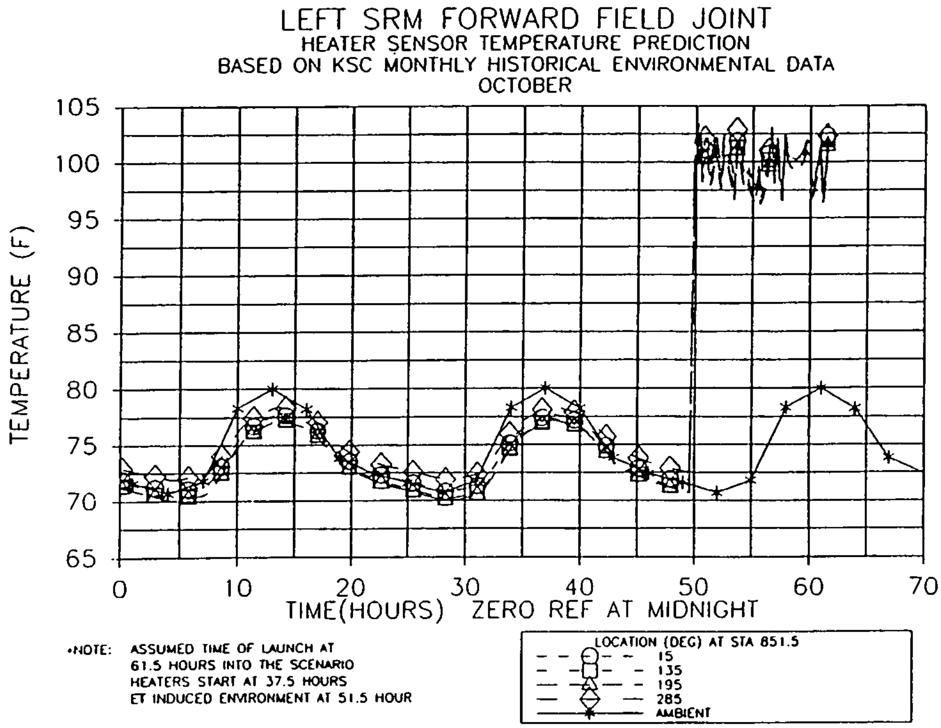


Figure 4-36. LH SRM Forward Field Joint – Heater Sensor Temperature Prediction

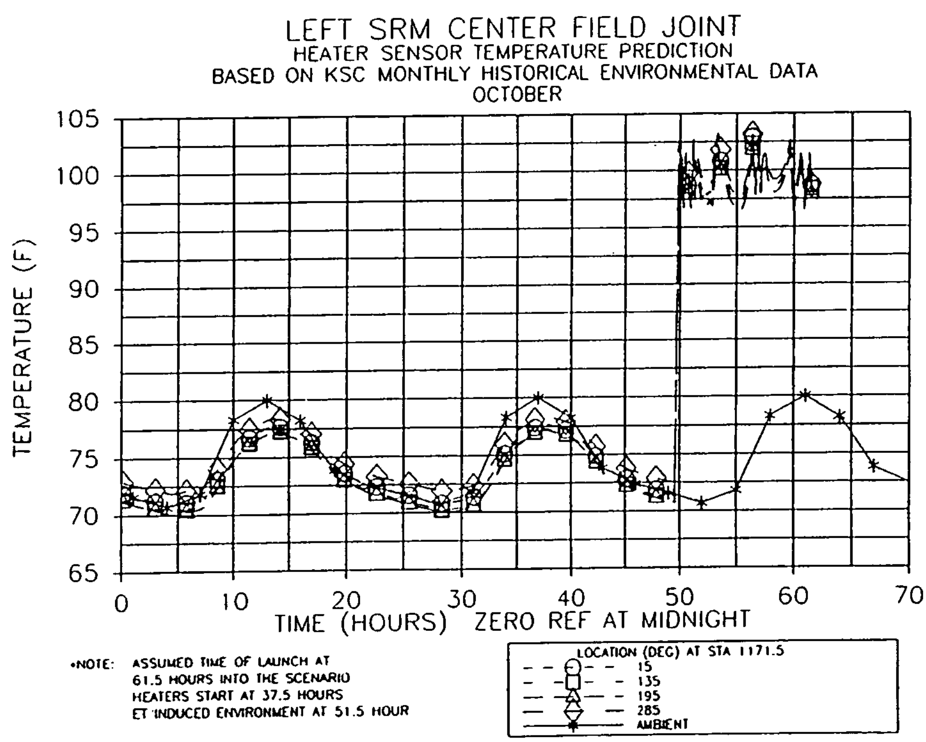


Figure 4-37. LH SRM Center Field Joint – Heater Sensor Temperature Prediction

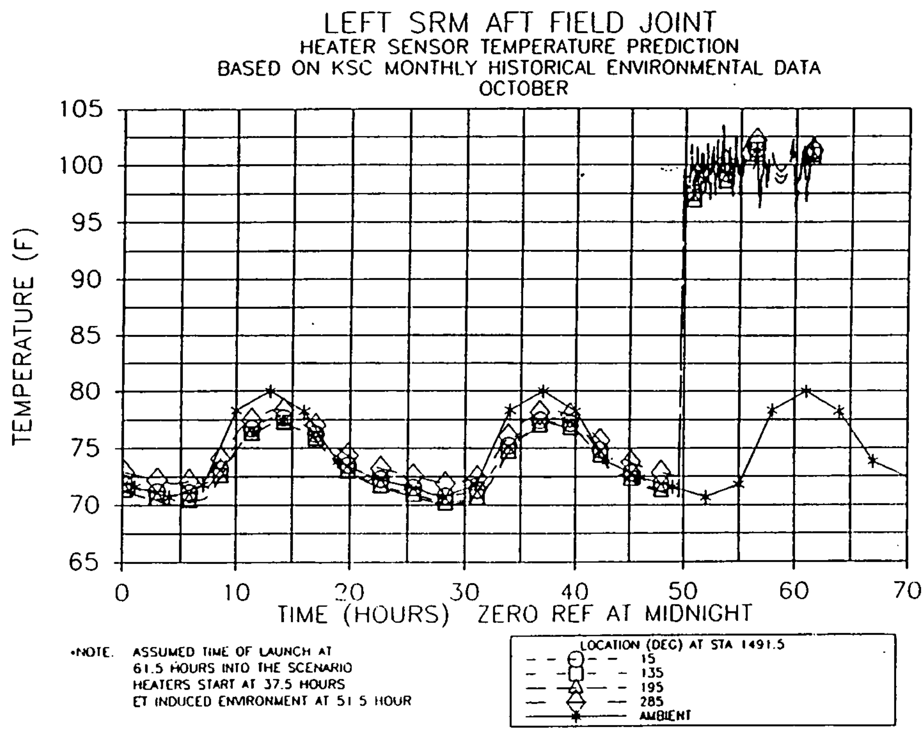


Figure 4-38. LH SRM Aft Field Joint – Heater Sensor Temperature Prediction

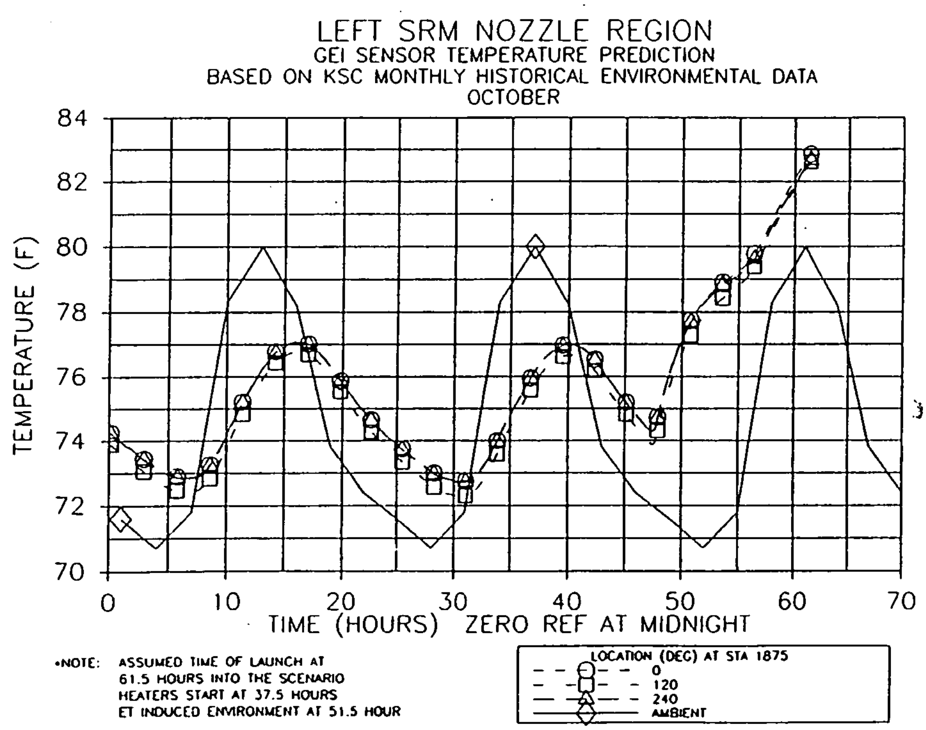


Figure 4-39. LH SRM Nozzle Region – GEI Sensor Temperature Prediction

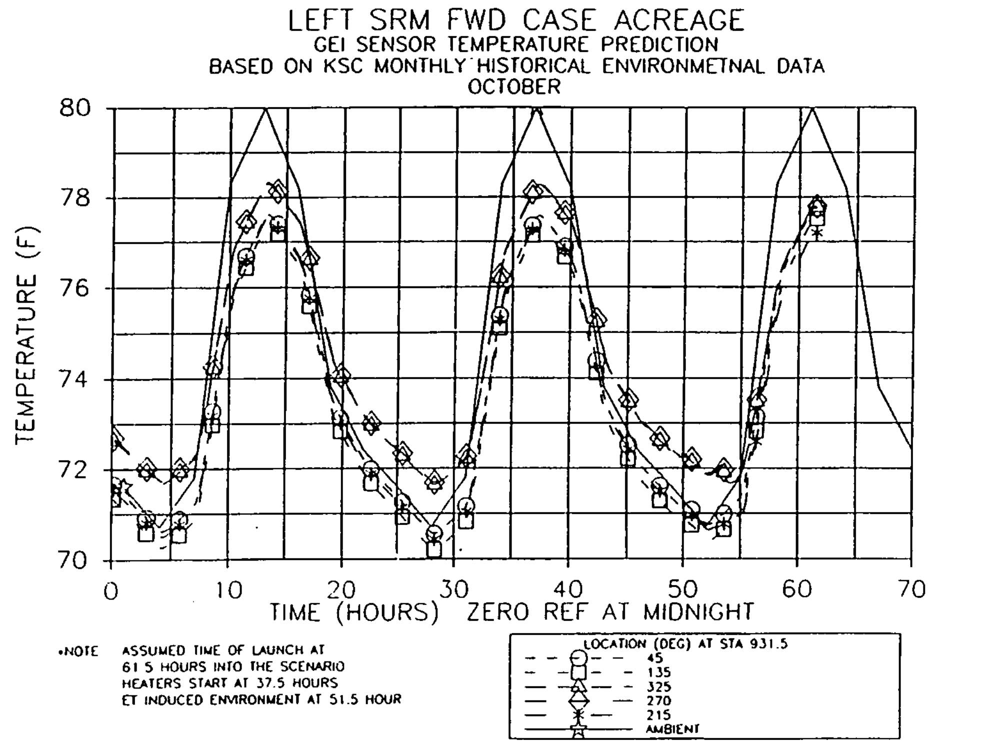


Figure 4-40. LH SRM Forward Case Acreage — GEI Sensor Temperature Prediction

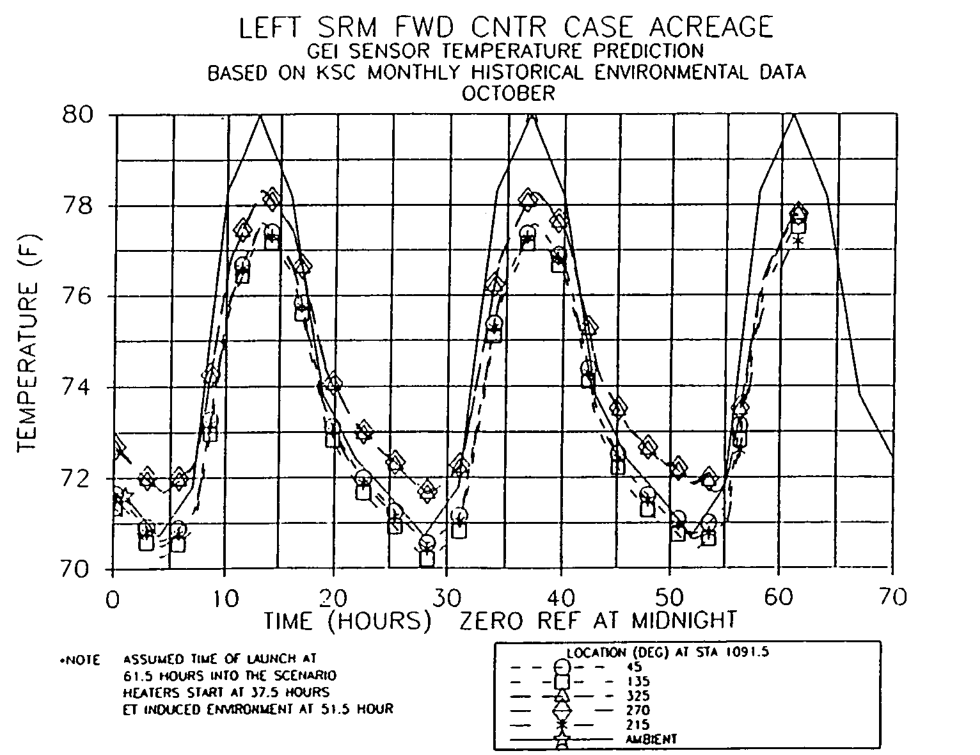


Figure 4-41. LH SRM Forward Center Case Acreage — GEI Sensor Temperature Prediction

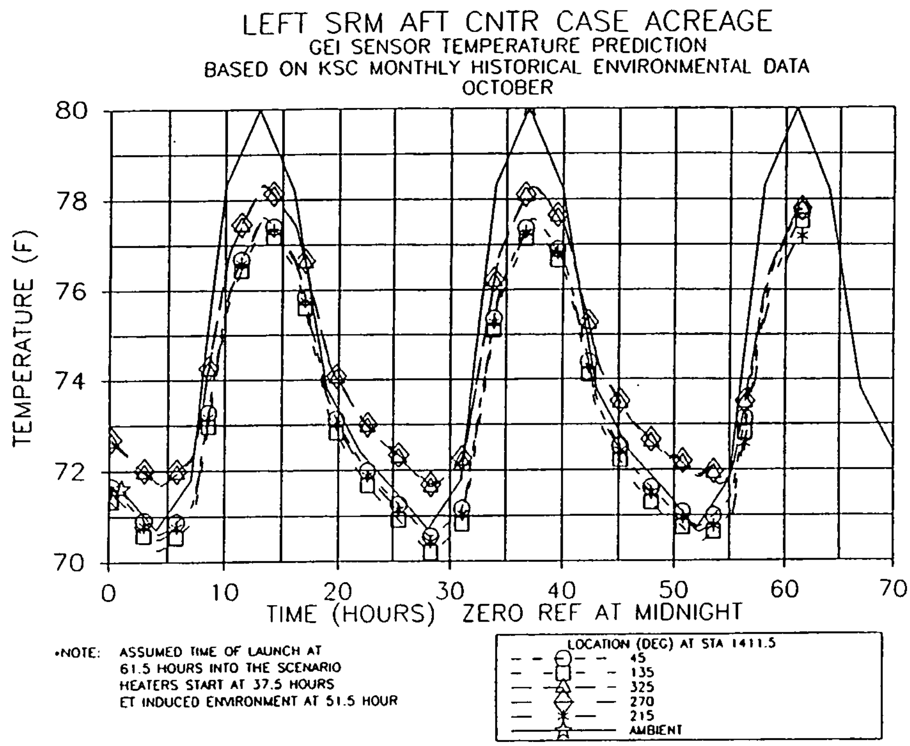


Figure 4-42. LH SRM Aft Center Case Acreage — GEI Sensor Temperature Prediction

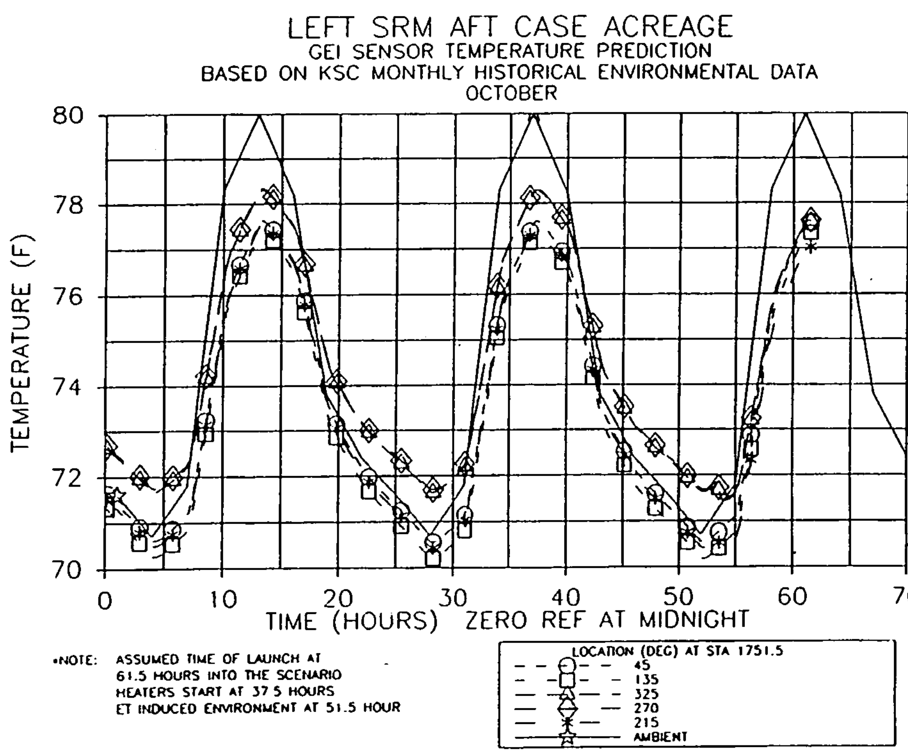


Figure 4-43. LH SRM Aft Case Acreage — GEI Sensor Temperature Prediction

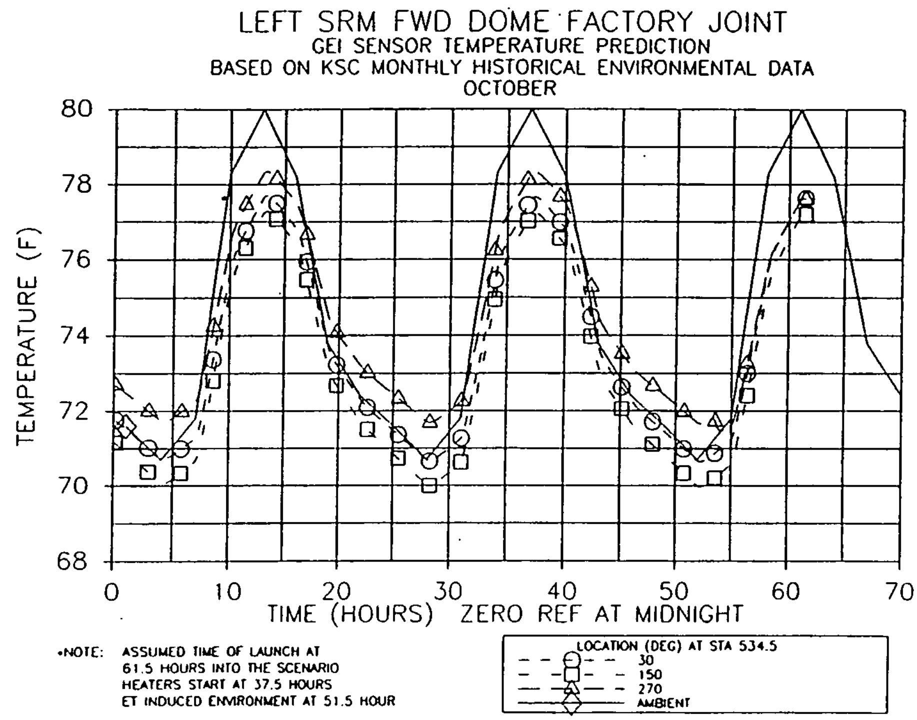


Figure 4-44. LH SRM Forward Dome Factory Joint – GEI Sensor Temperature Prediction

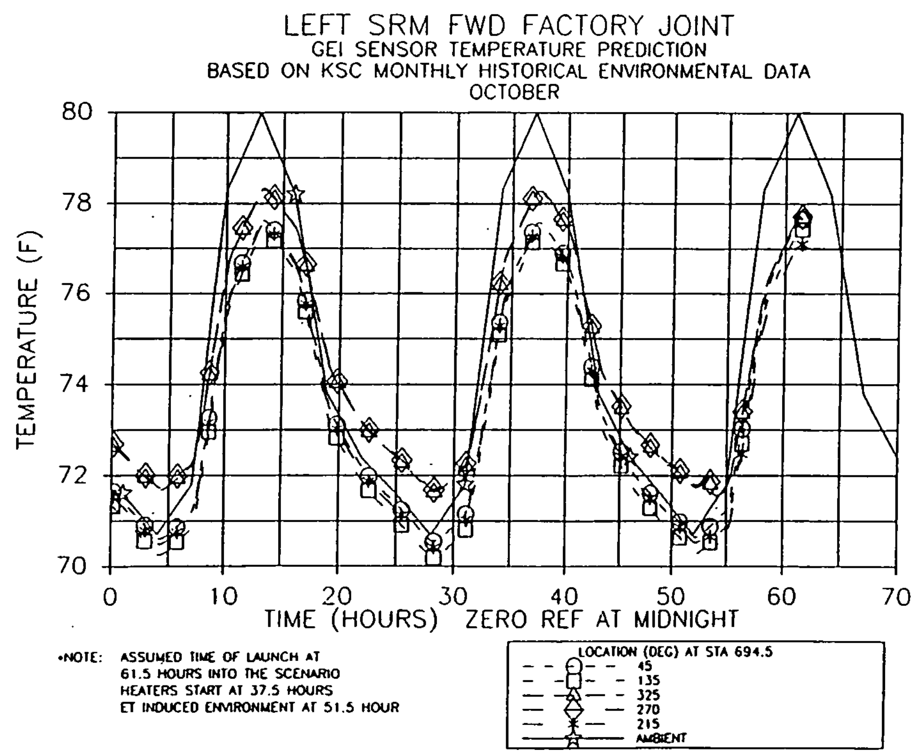


Figure 4-45. LH SRM Forward Factory Joint – GEI Sensor Temperature Prediction

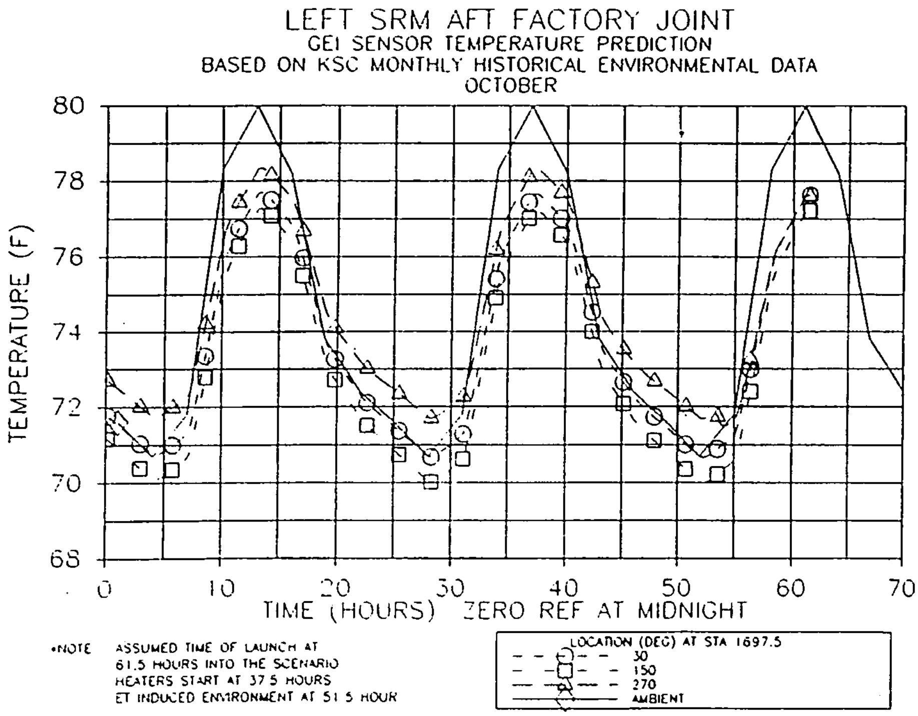


Figure 4-46. LH SRM Aft Factory Joint — GEI Sensor Temperature Prediction

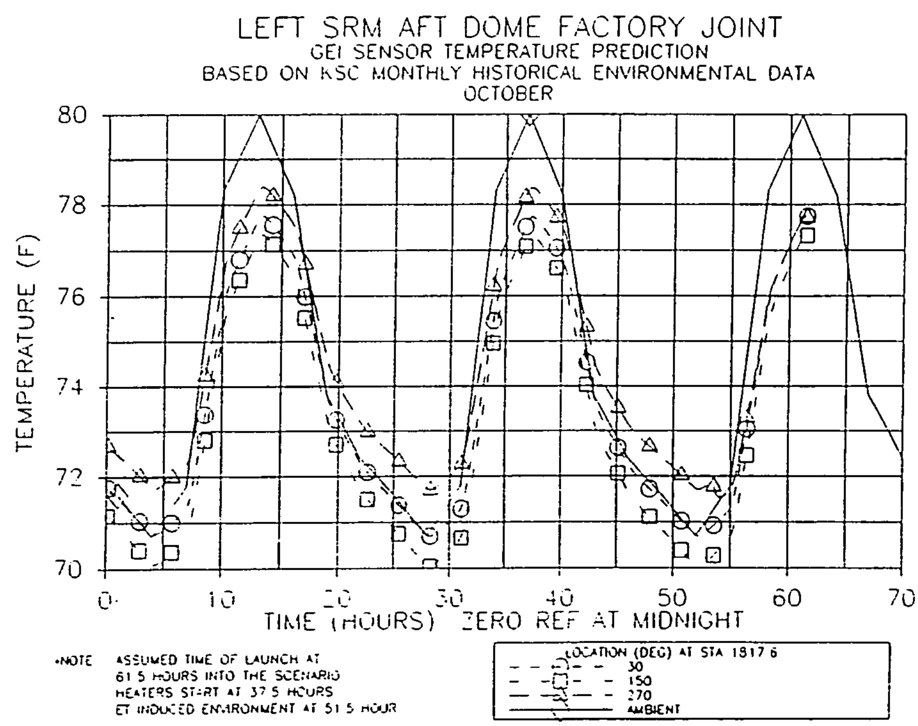


Figure 4-47. LH SRM Aft Dome Factory Joint — GEI Sensor Temperature Prediction

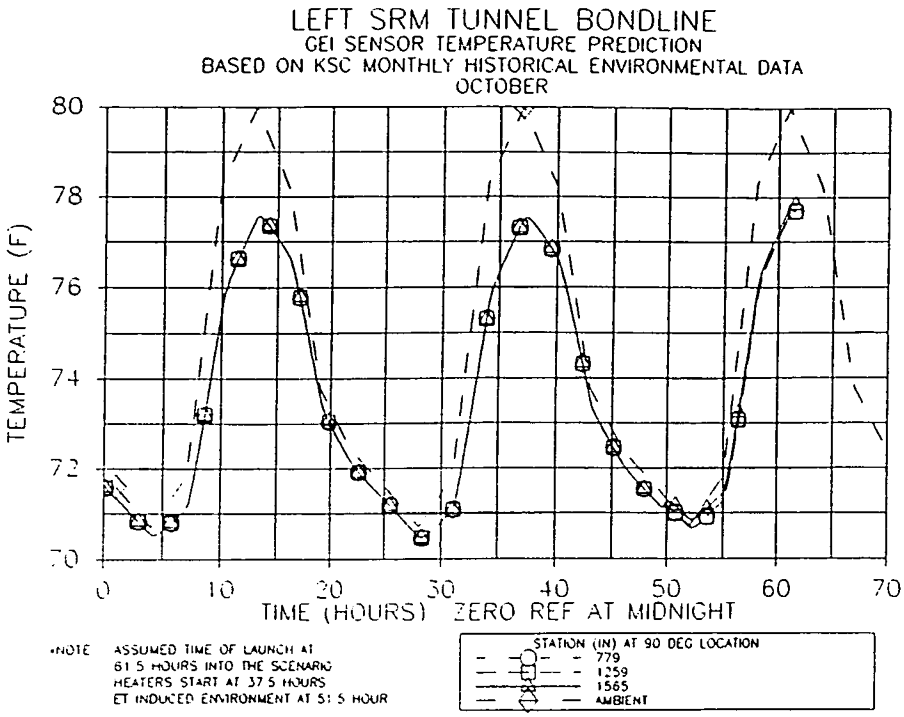


Figure 4-48. LH SRM Tunnel Bondline – GEI Sensor Temperature Prediction

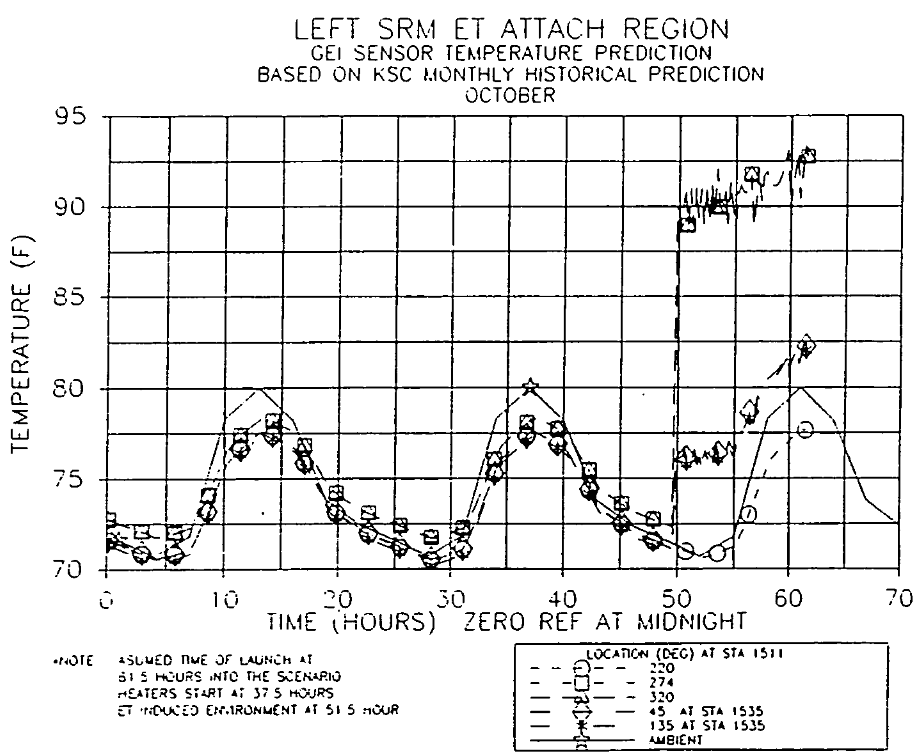


Figure 4-49. LH SRM ET Attach Region – GEI Sensor Temperature Prediction

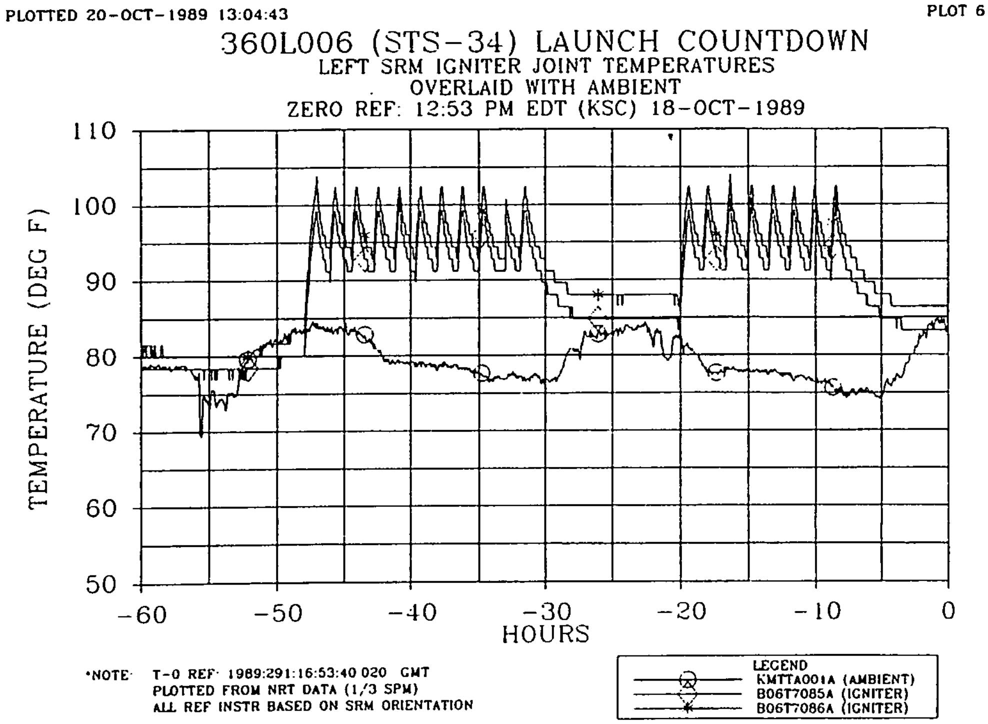


Figure 4-50. LH SRM Igniter Joint Temperatures — Overlaid With Ambient

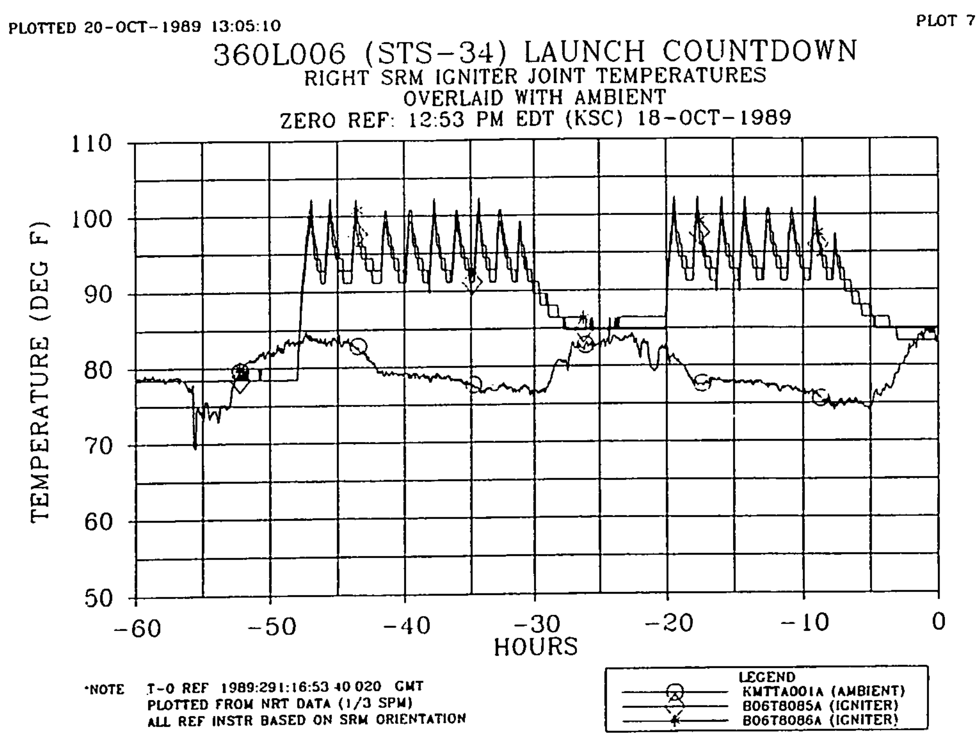


Figure 4-51. RH SRM Igniter Joint Temperatures — Overlaid With Ambient

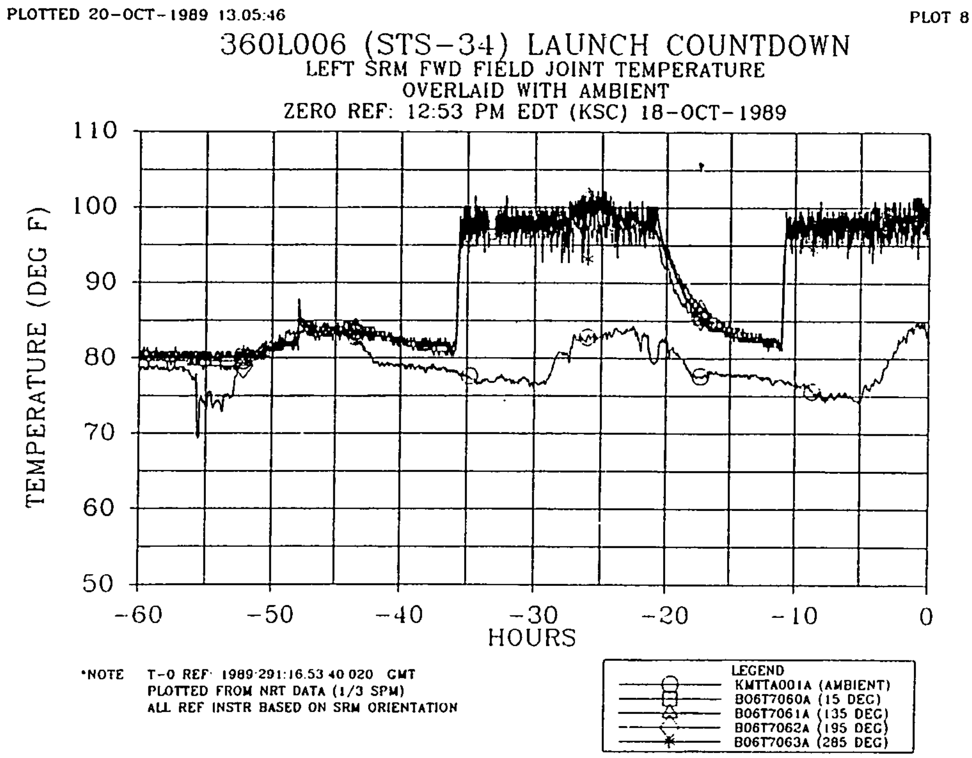


Figure 4-52. LH SRM Forward Field Joint Temperature — Overlaid With Ambient

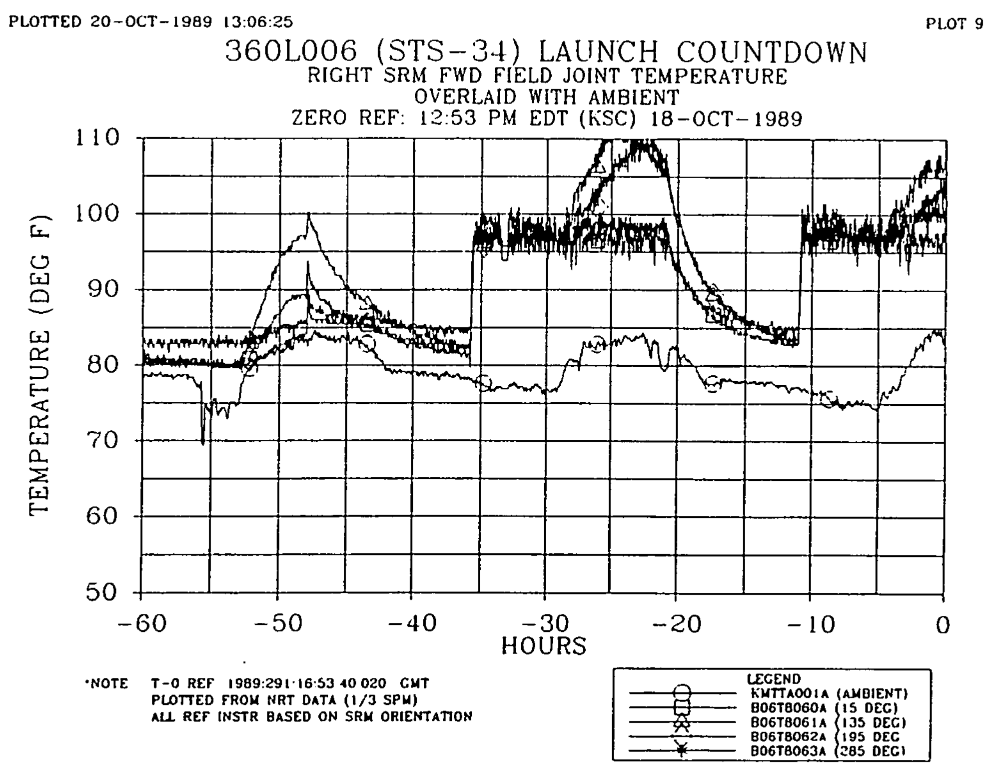


Figure 4-53. RH SRM Forward Field Joint Temperature — Overlaid With Ambient

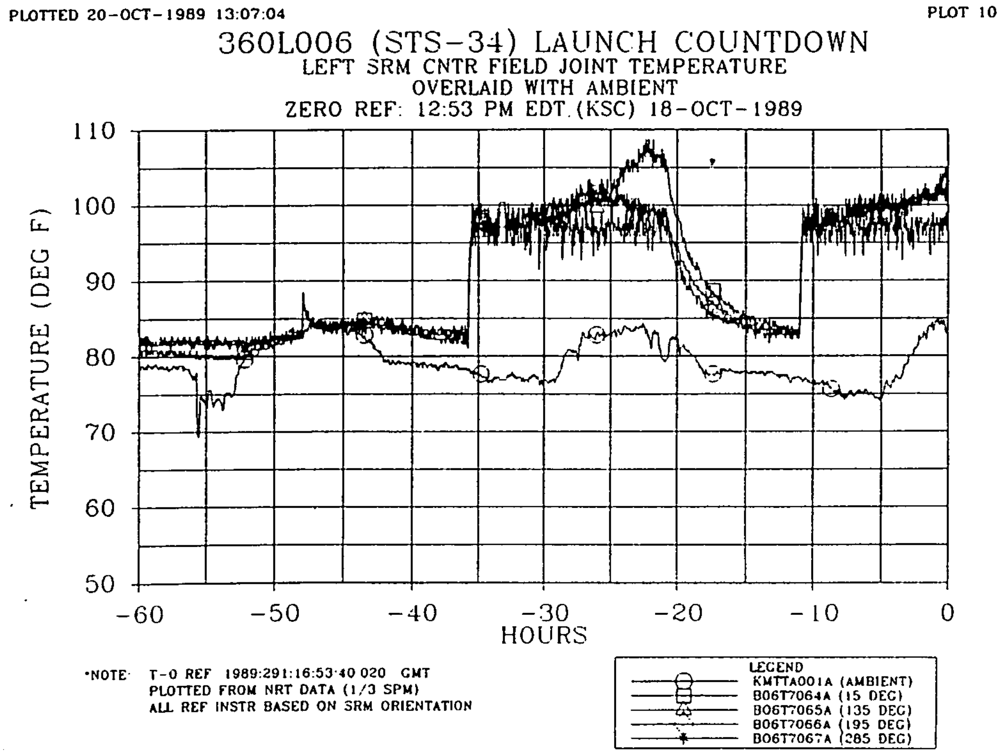


Figure 4-54. LH SRM Center Field Joint Temperature — Overlaid With Ambient

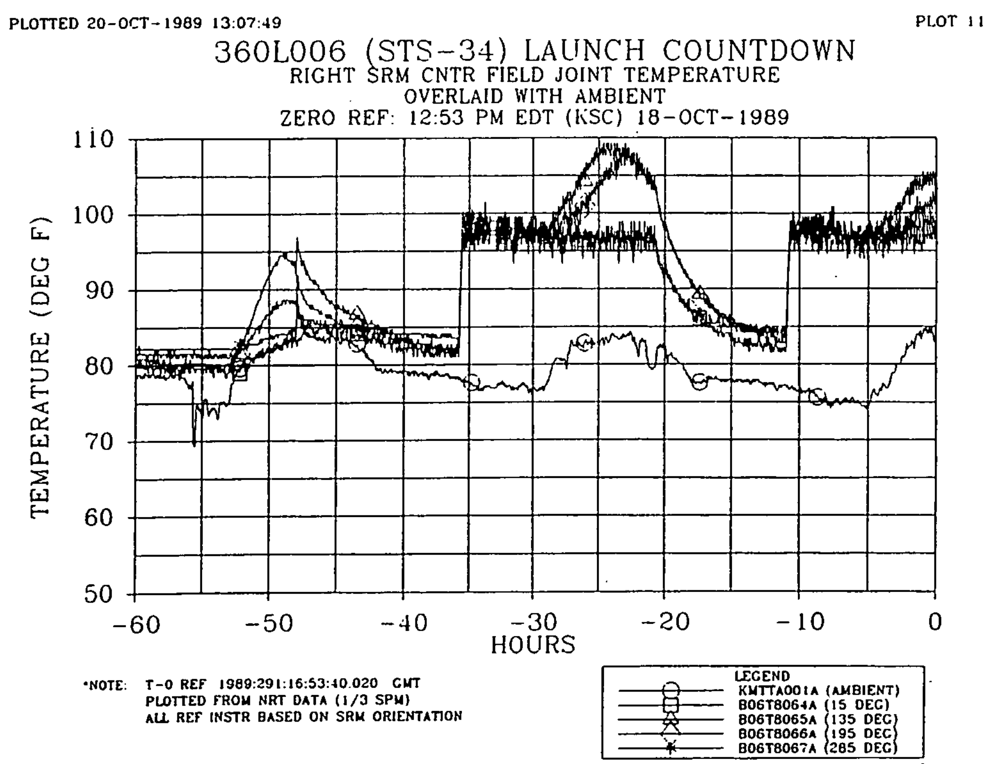


Figure 4-55. RH SRM Center Field Joint Temperature — Overlaid With Ambient

C-2

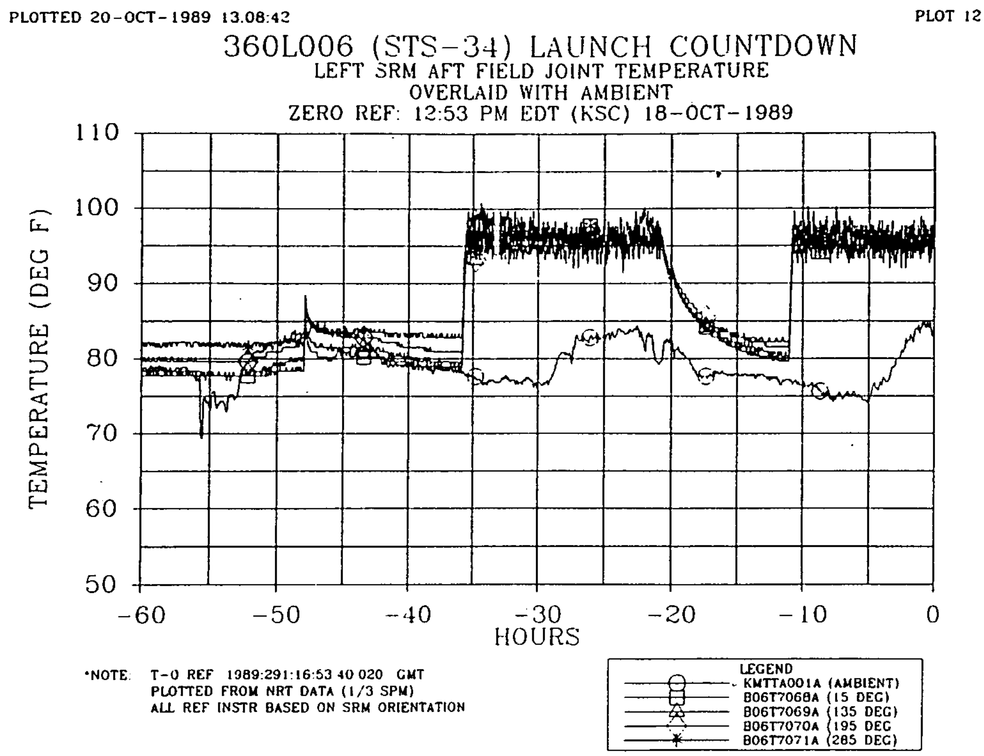


Figure 4-56. LH SRM Aft Field Joint Temperature — Overlaid With Ambient

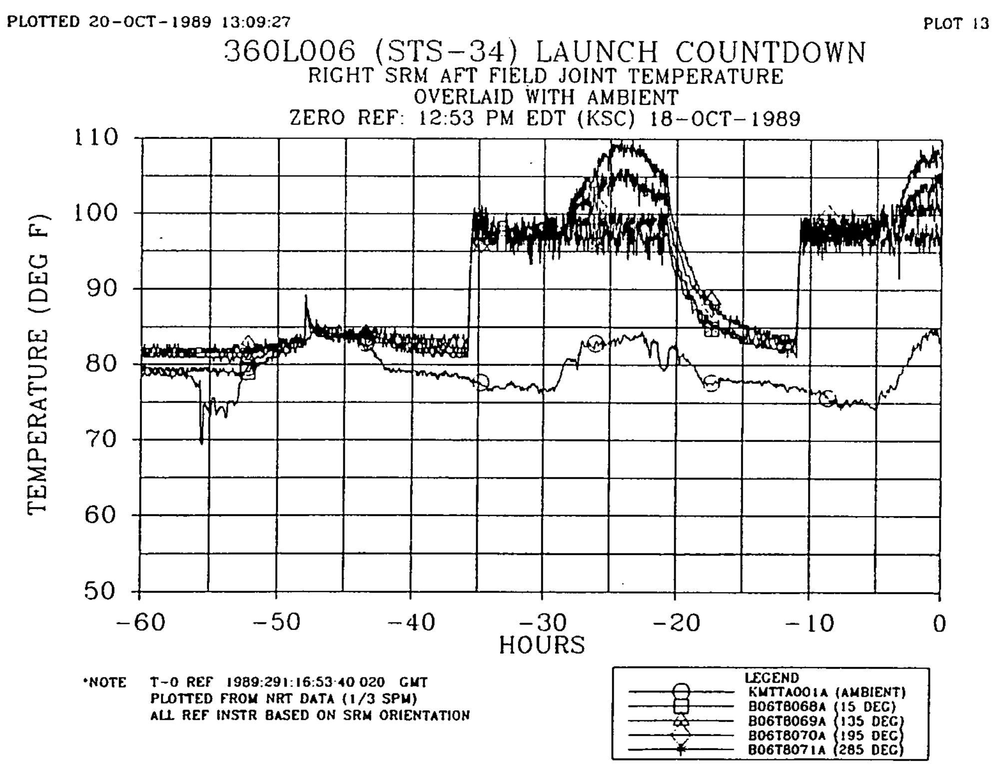


Figure 4-57. RH SRM Aft Field Joint Temperature — Overlaid With Ambient

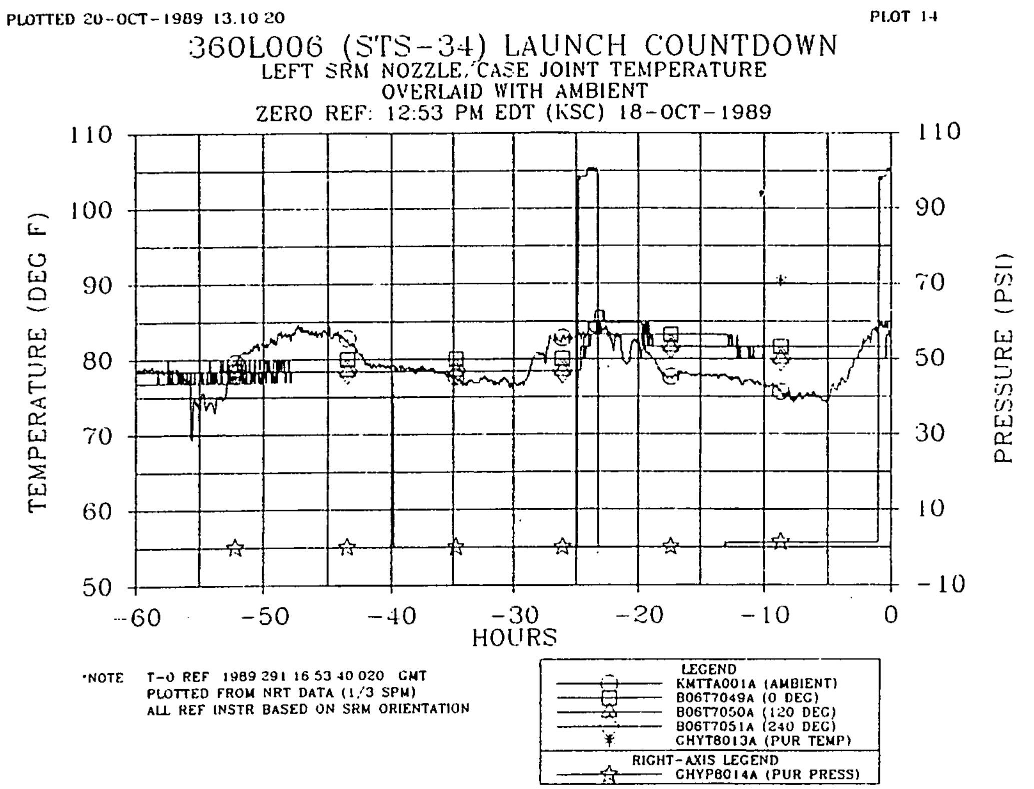


Figure 4-58. LH SRM Nozzle/Case Joint Temperature — Overlaid With Ambient

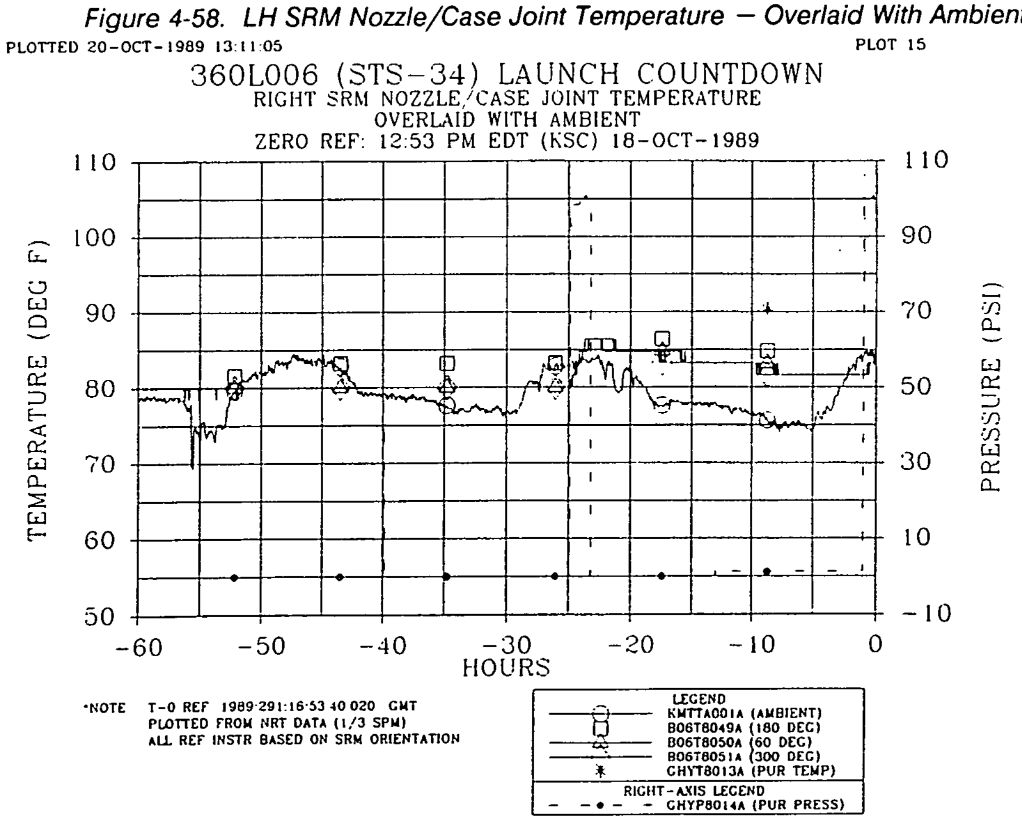


Figure 4-59. RH SRM Nozzle/Case Joint Temperature — Overlaid With Ambient

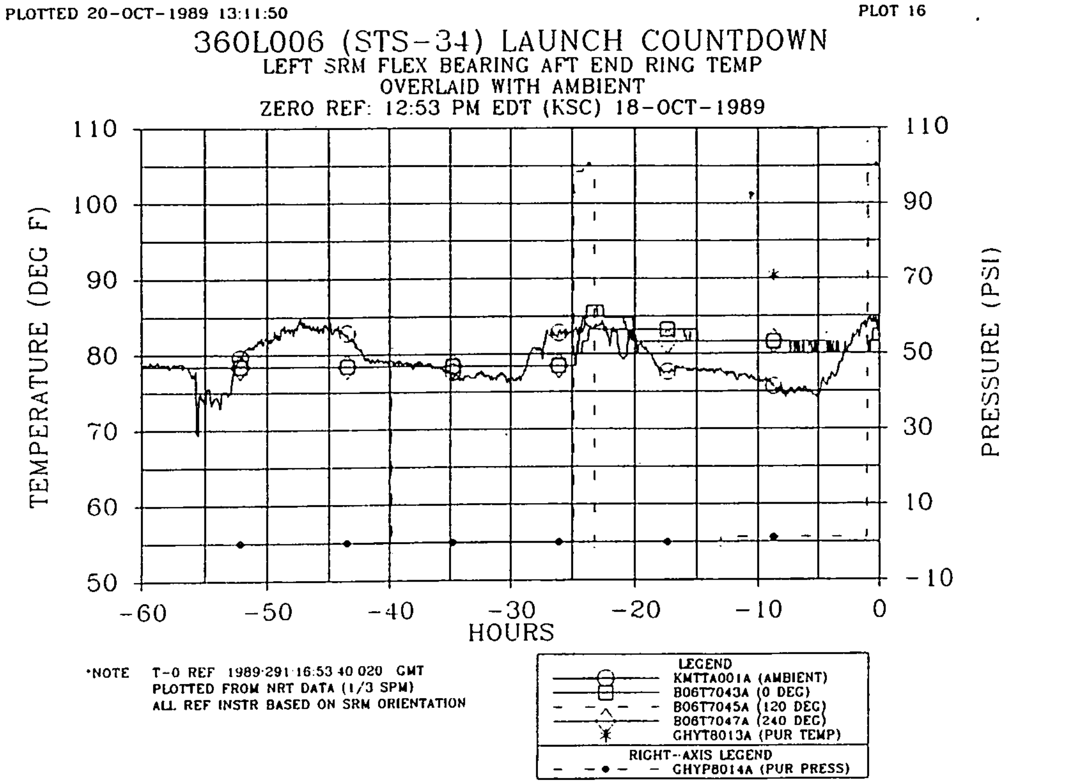


Figure 4-60. LH SRM Flex Bearing Aft End Ring Temperature – Overlaid With Ambient

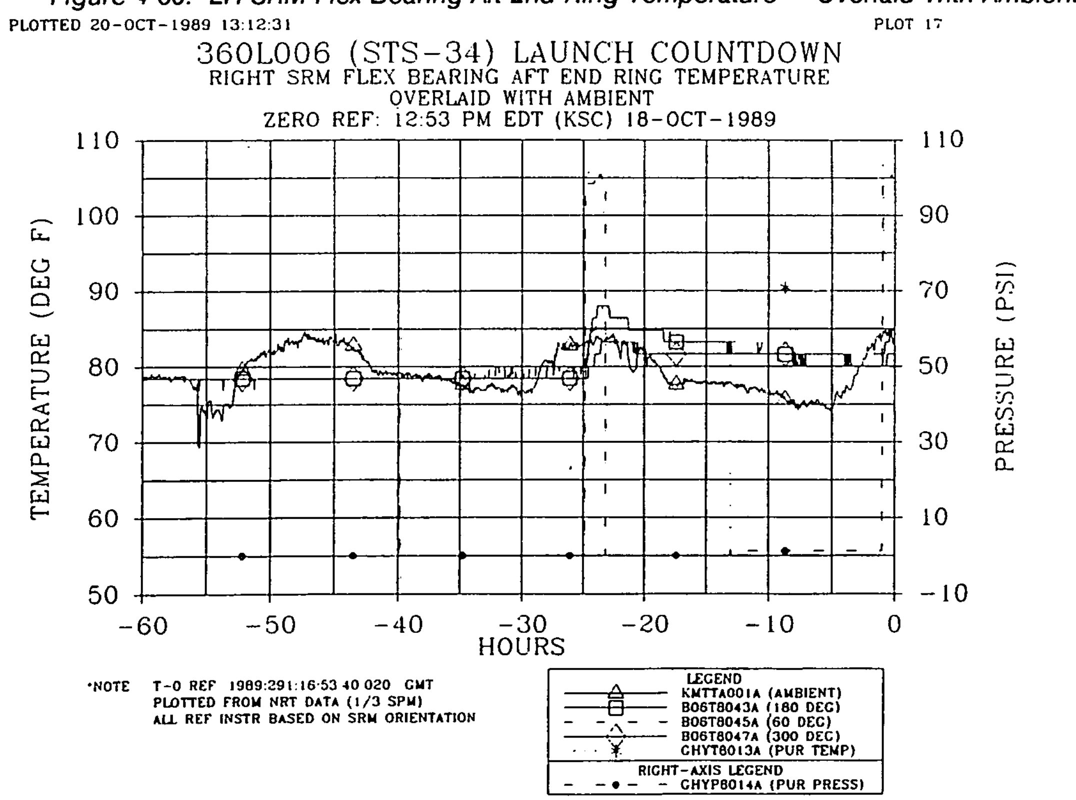


Figure 4-61. RH SRM Flex Bearing Aft End Ring Temperature – Overlaid With Ambient

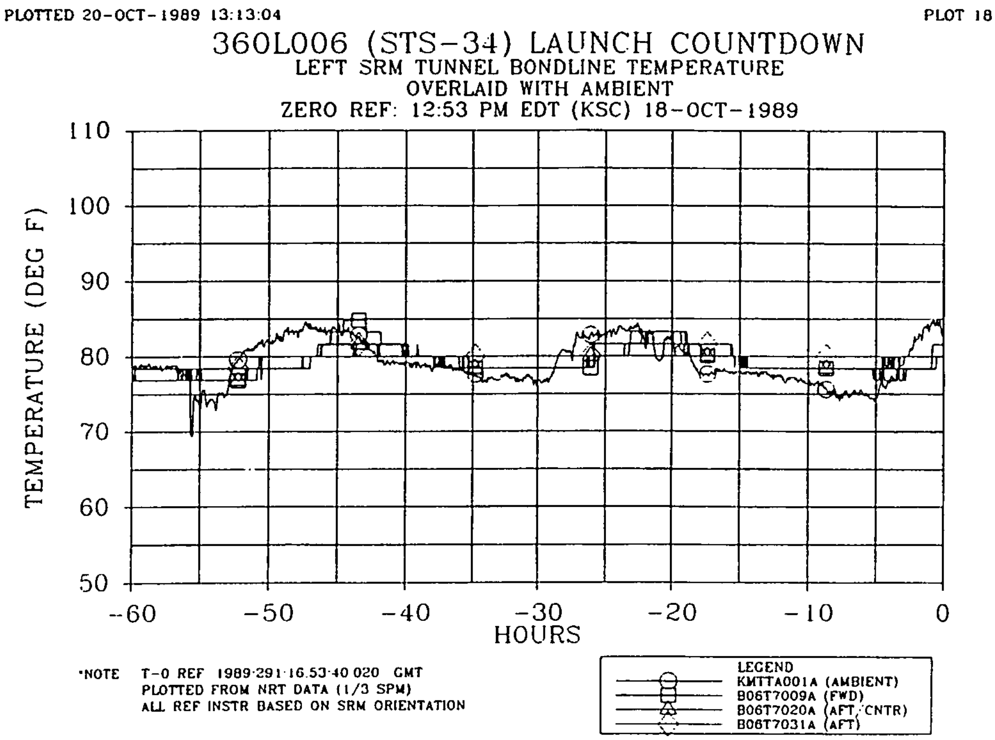


Figure 4-62. LH SRM Tunnel Bondline Temperature — Overlaid With Ambient

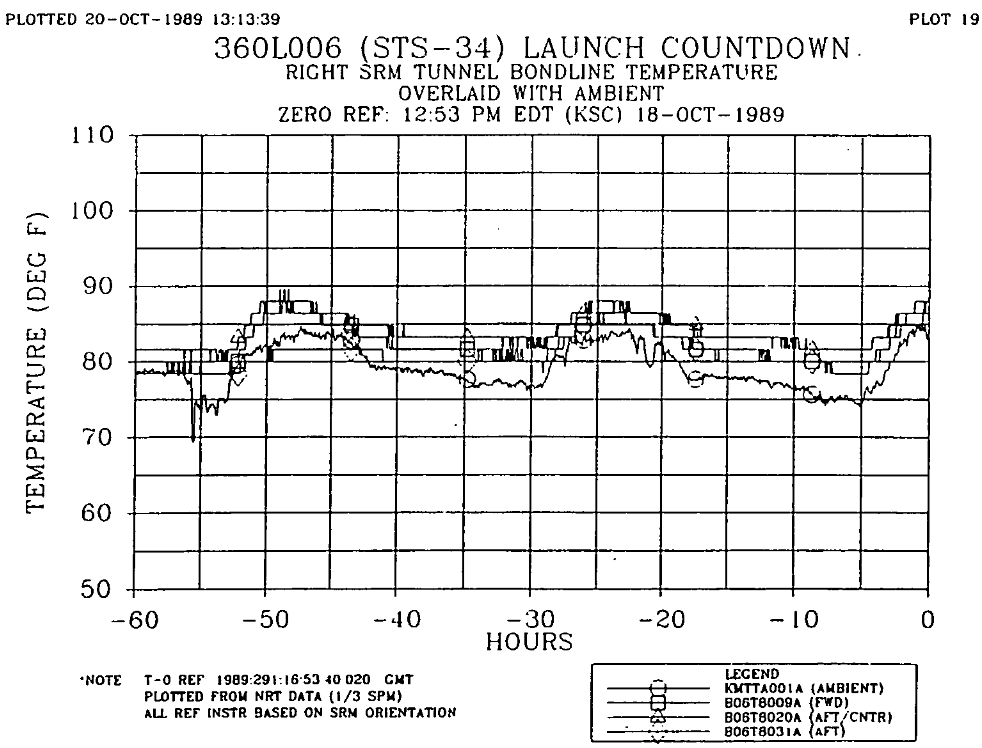


Figure 4-63. RH SRM Tunnel Bondline Temperature — Overlaid With Ambient

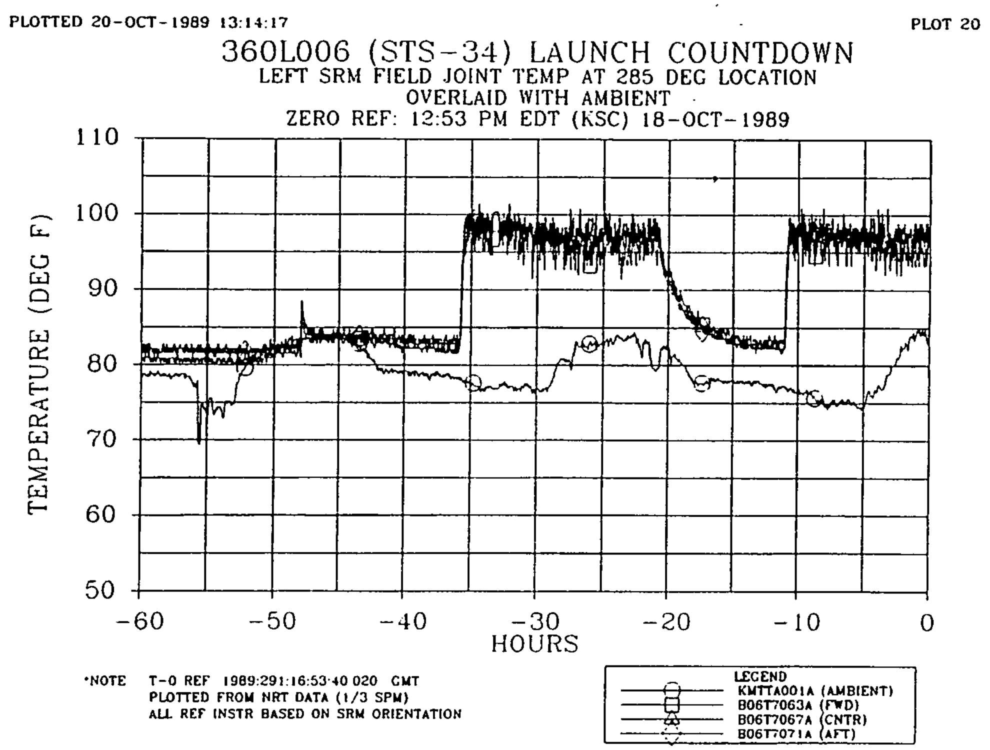


Figure 4-64. LH SRM Field Joint Temperature at 285-Deg Location — Overlaid With Ambient

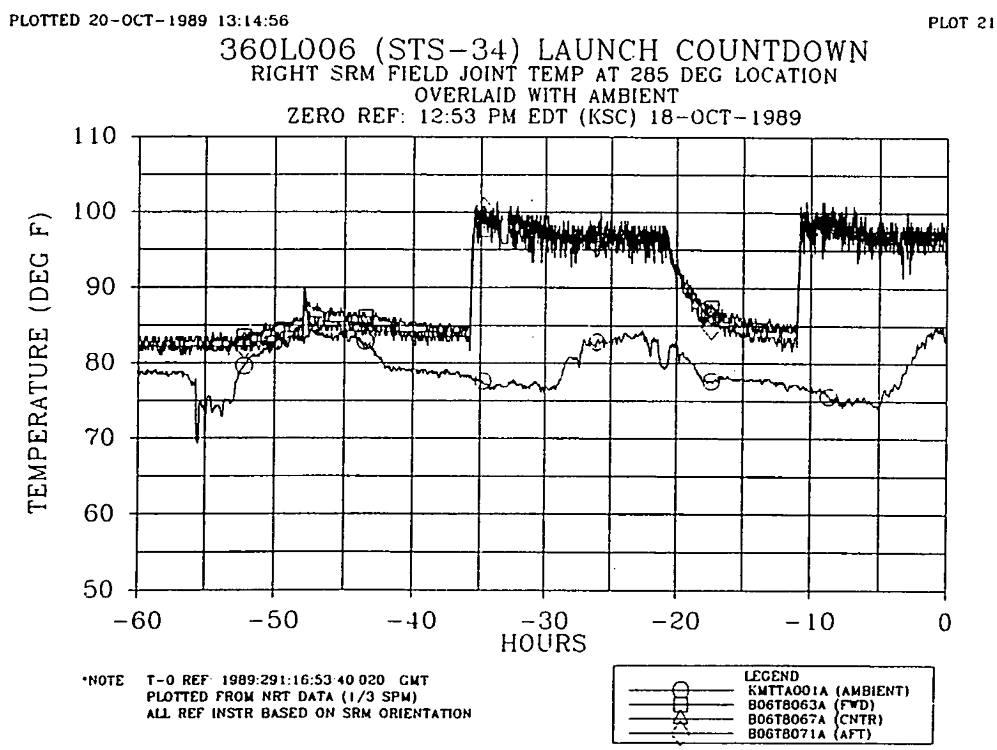


Figure 4-65. RH SRM Field Joint Temperature at 285-Deg Location — Overlaid With Ambient

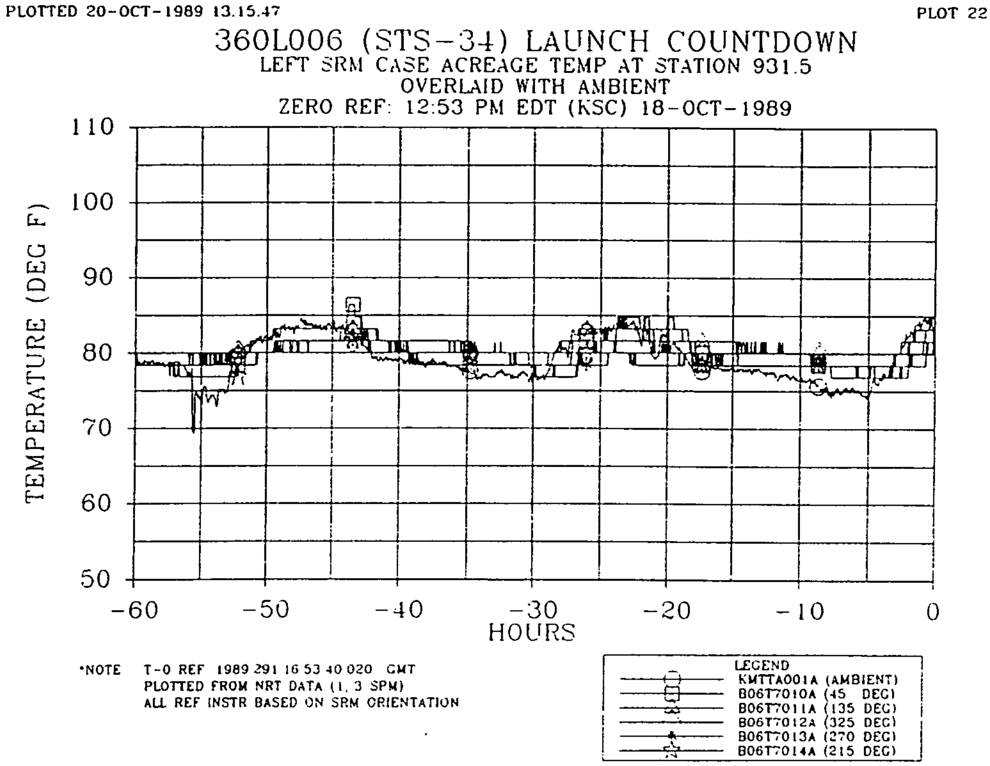


Figure 4-66. LH SRM Case Acreage Temperature at Station 931.5 — Overlaid With Ambient

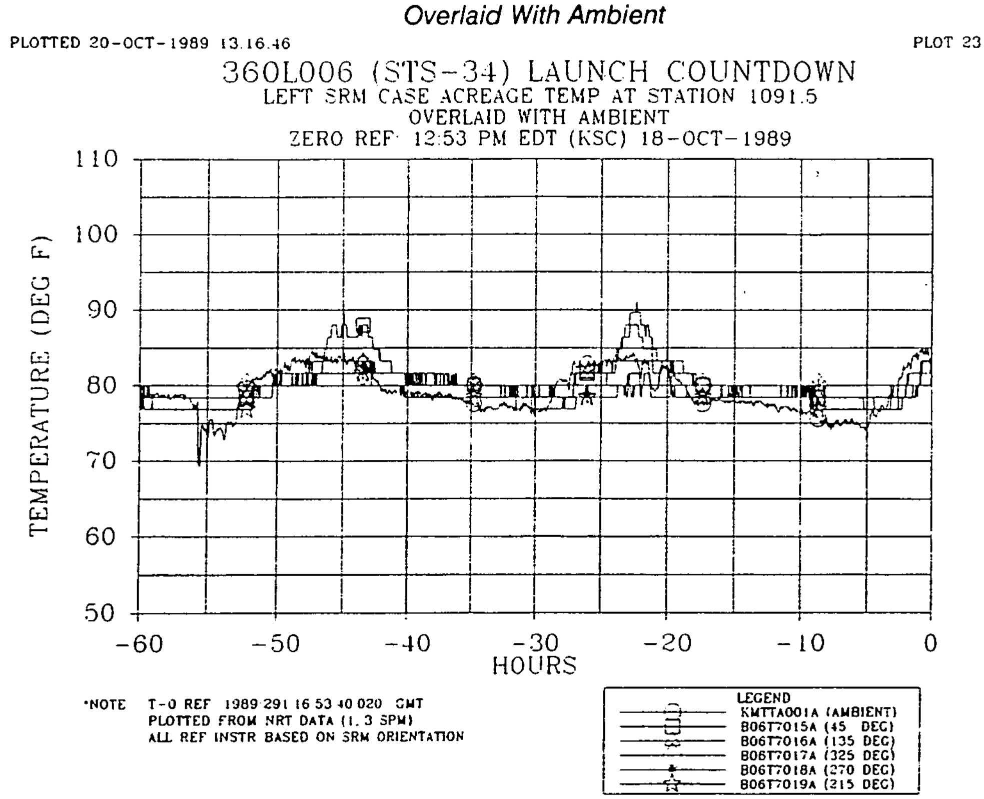


Figure 4-67. LH SRM Case Acreage Temperature at Station 1091.5 — Overlaid With Ambient

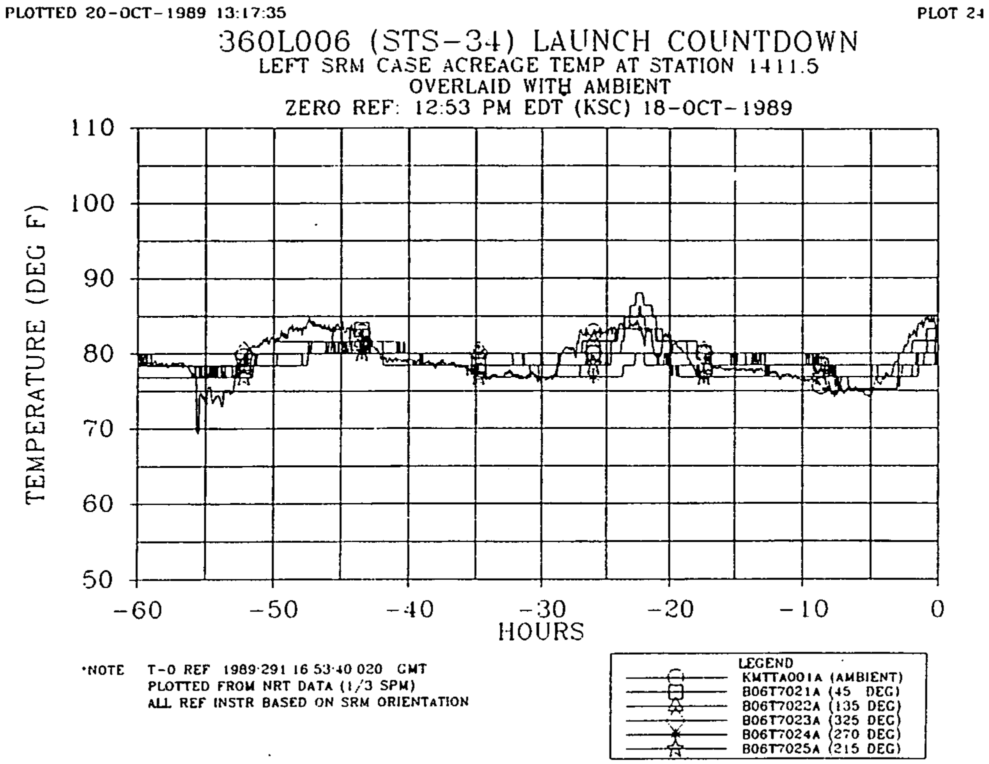


Figure 4-68. LH SRM Case Acreage Temperature at Station 1411.5 — Overlaid With Ambient

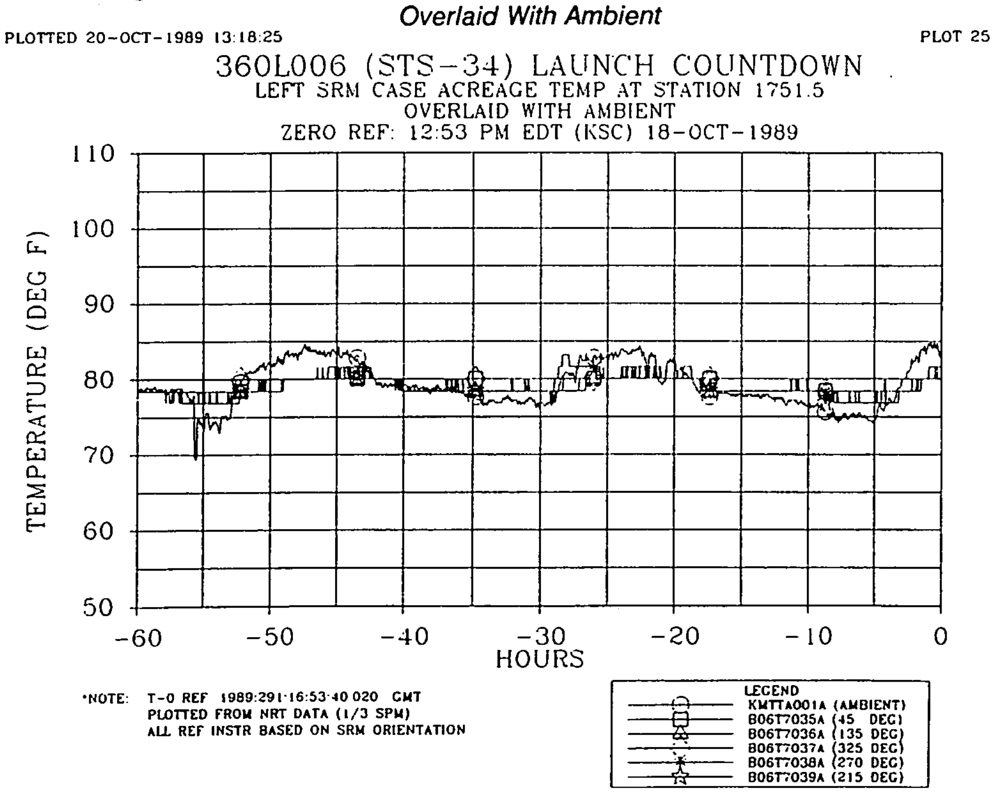


Figure 4-69. RH SRM Case Acreage Temperature at Station 1751.5 — Overlaid With Ambient

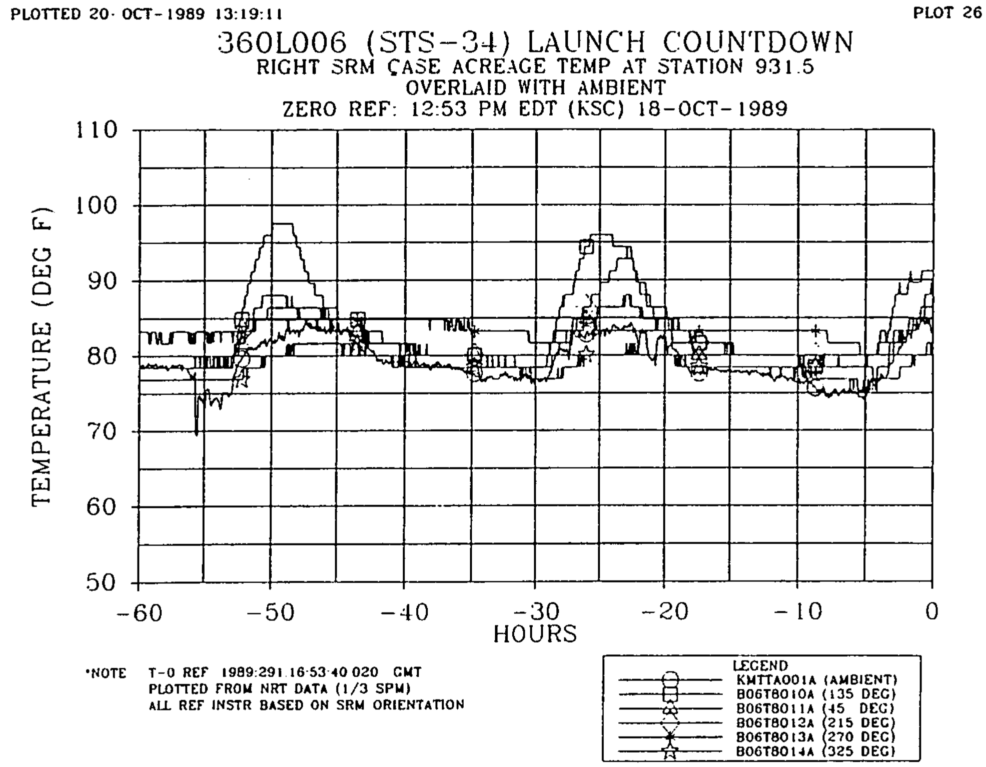


Figure 4-70. RH SRM Case Acreage Temperature at Station 931.5 — Overlaid With Ambient

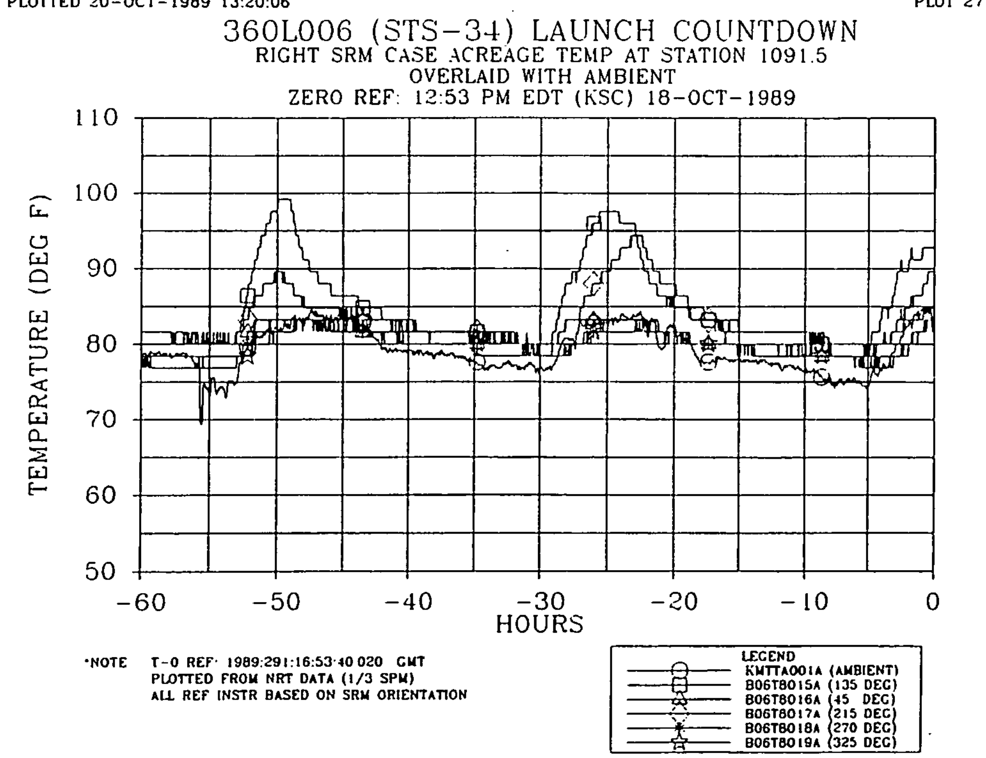


Figure 4-71. RH SRM Case Acreage Temperature at Station 1091.5 — Overlaid With Ambient

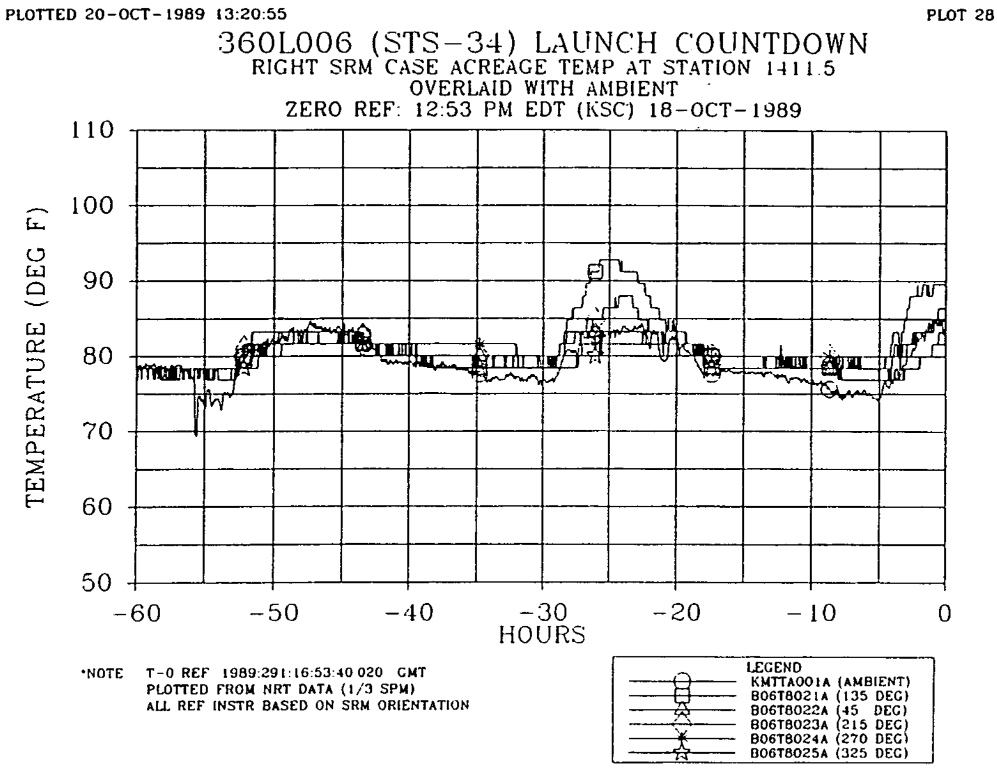


Figure 4-72. RH SRM Case Acreage Temperature at Station 1411.5 — Overlaid With Ambient

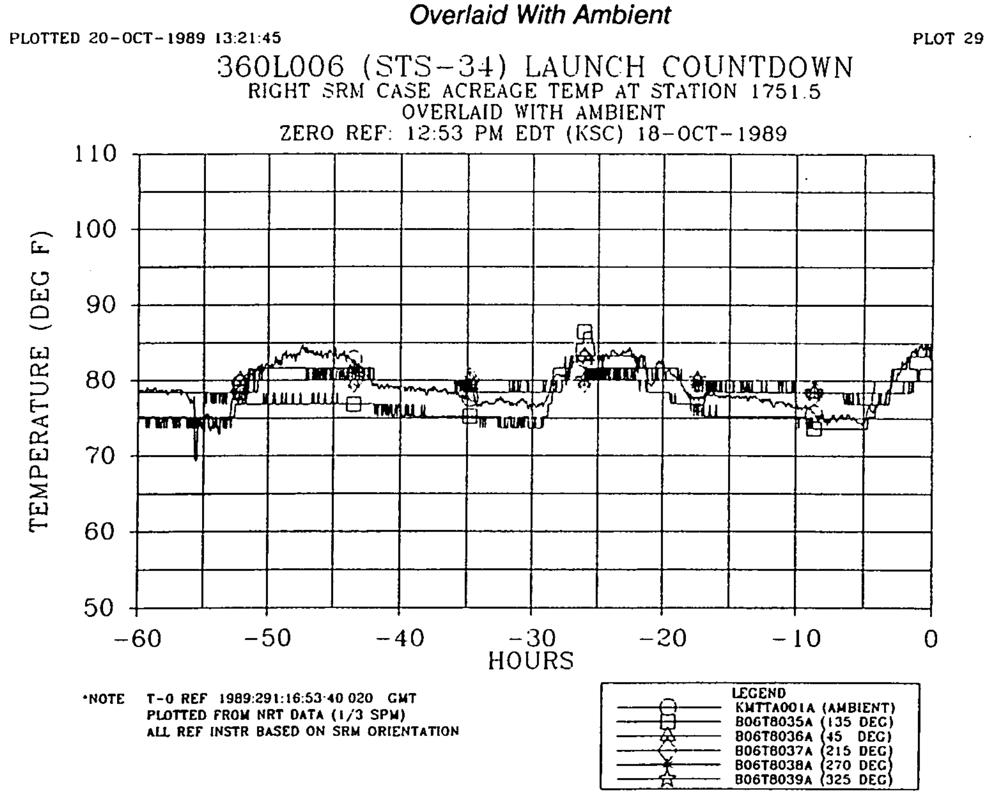


Figure 4-73. RH SRM Case Acreage Temperature at Station 1751.5 — Overlaid With Ambient

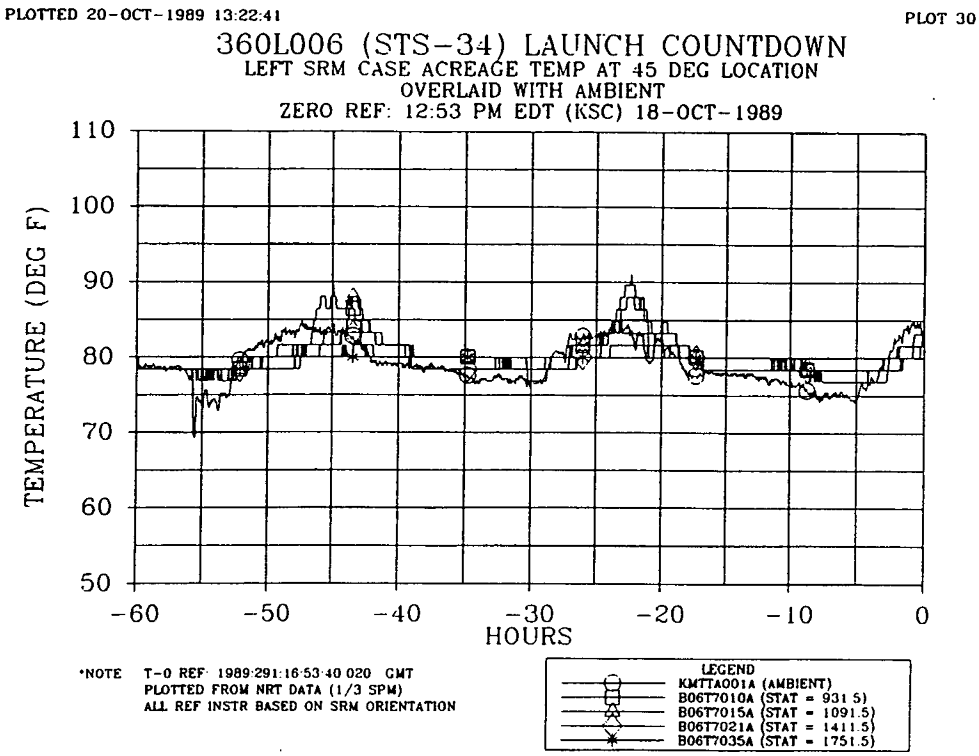


Figure 4-74. LH SRM Case Acreage Temperature at 45-Deg Location — Overlaid With Ambient

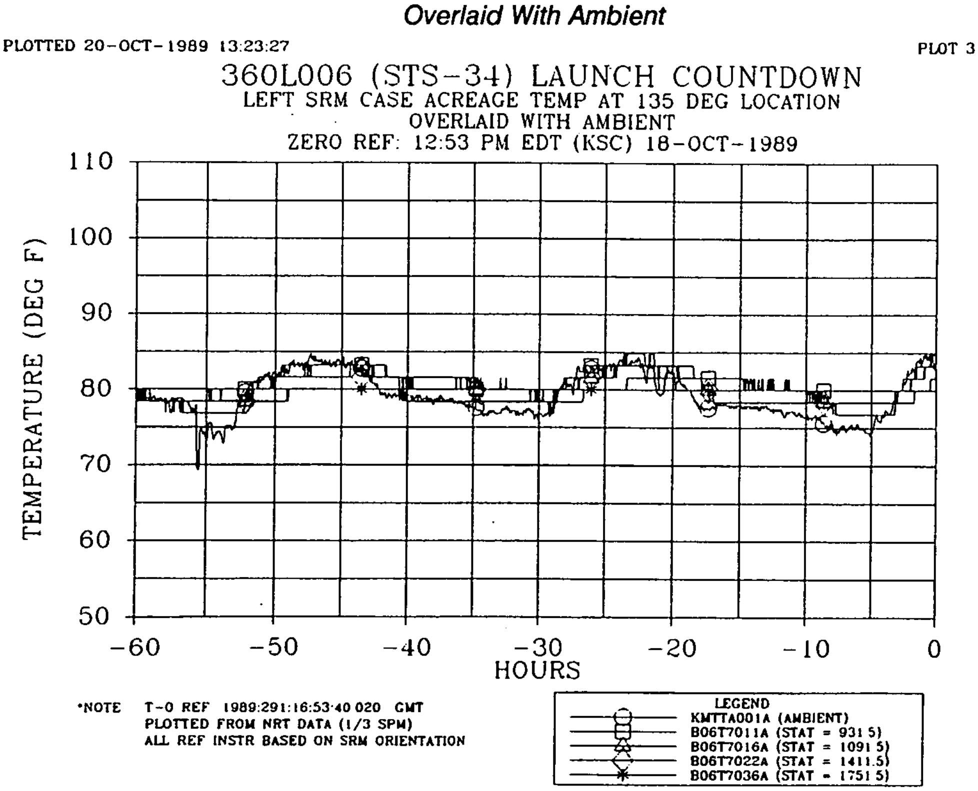


Figure 4-75. LH SRM Case Acreage Temperature at 135-Deg Location — Overlaid With Ambient

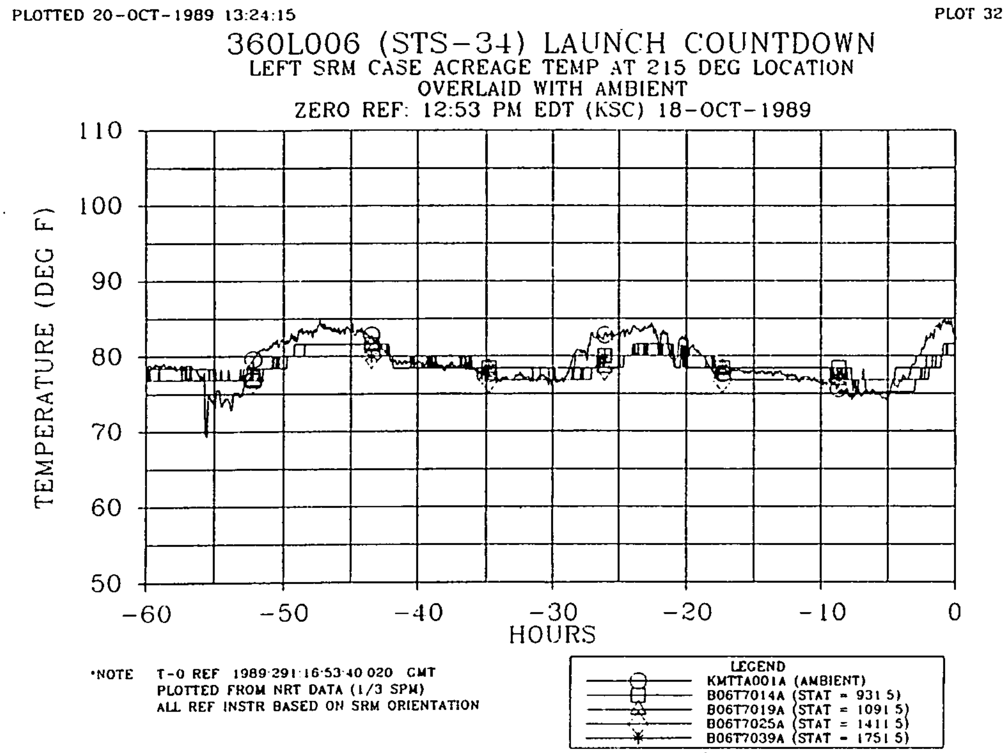


Figure 4-76. LH SRM Case Acreage Temperature at 215-Deg Location — Overlaid With Ambient

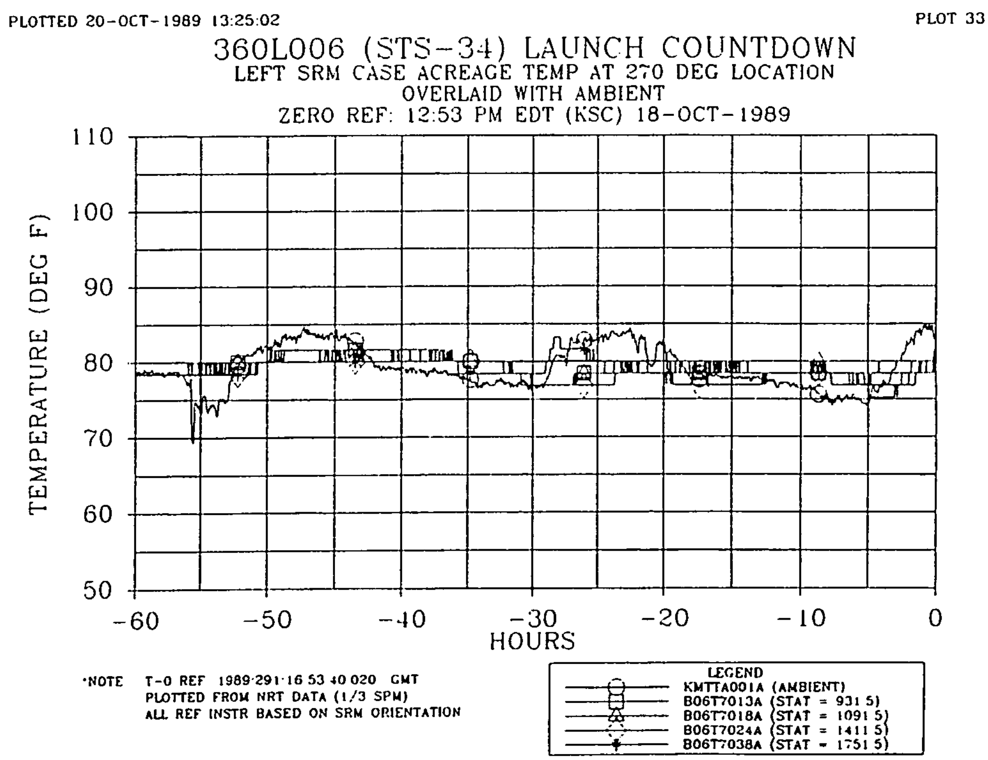


Figure 4-77. LH SRM Case Acreage Temperature at 270-Deg Location — Overlaid With Ambient

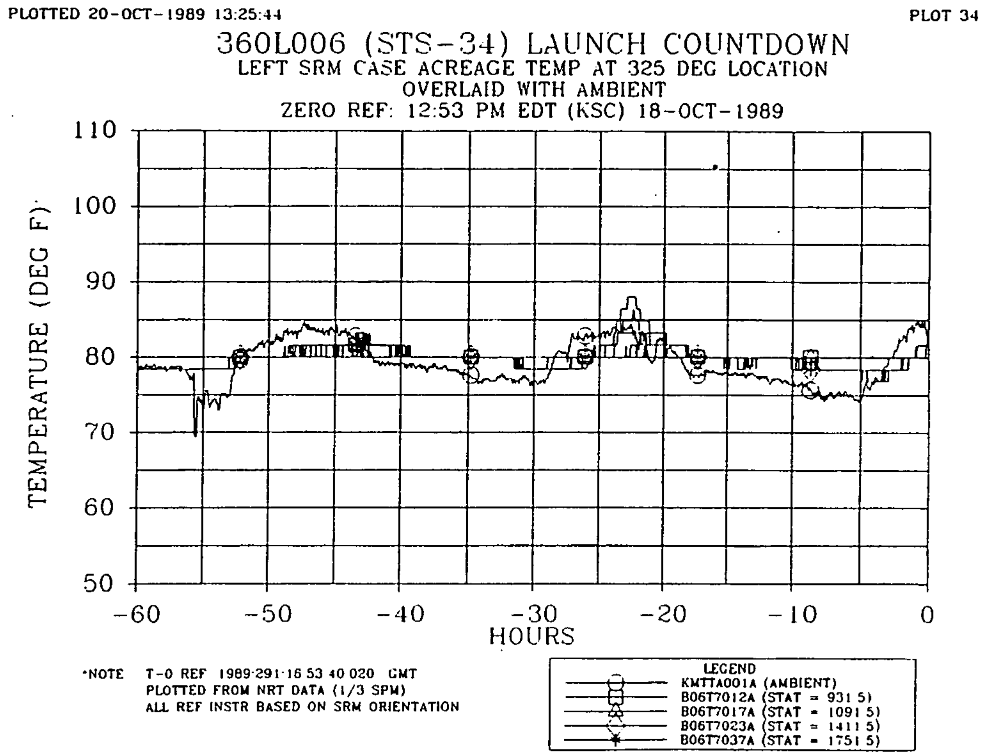


Figure 4-78. LH SRM Case Acreage Temperature at 325-Deg Location — Overlaid With Ambient

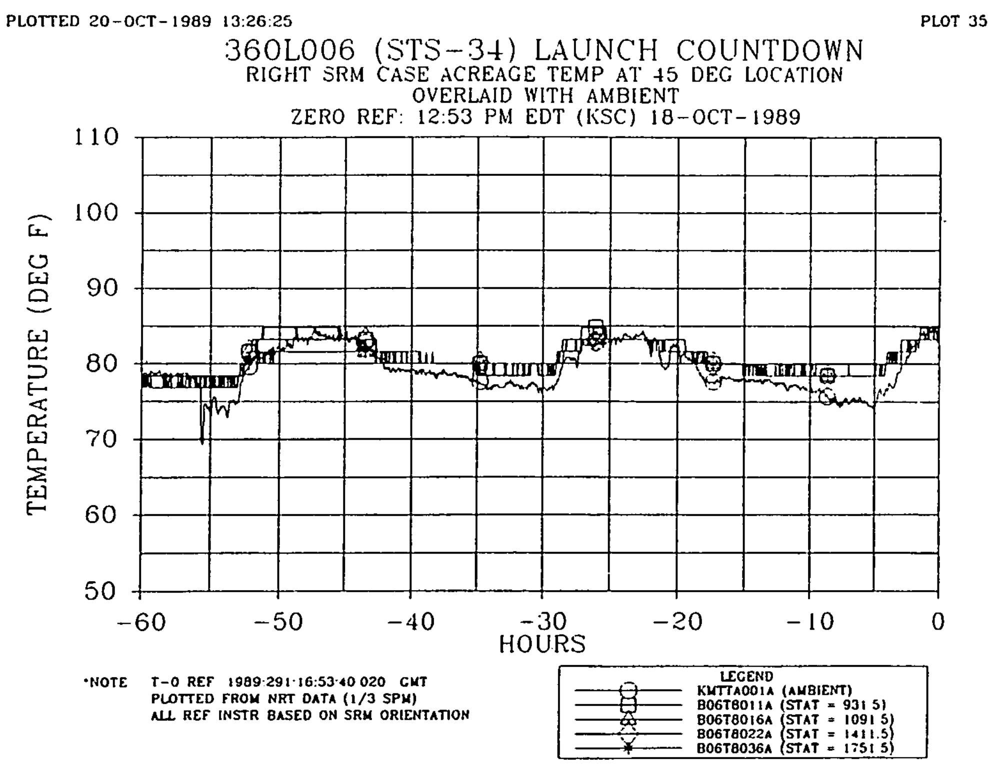


Figure 4-79. RH SRM Case Acreage Temperature at 45-Deg Location — Overlaid With Ambient

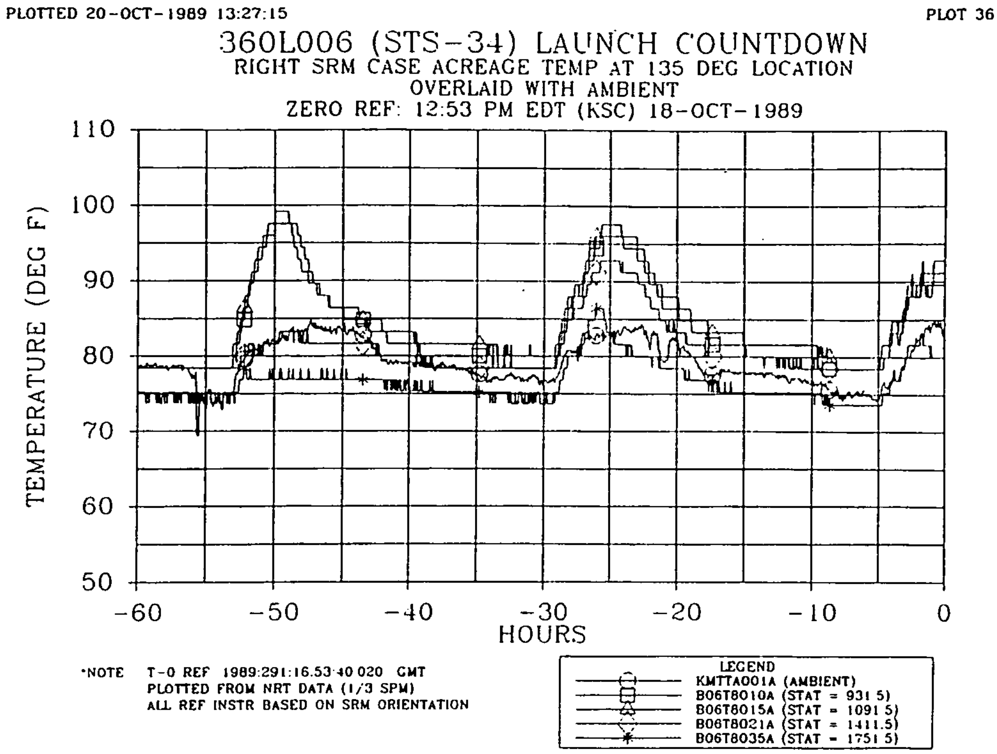


Figure 4-80. RH SRM Case Acreage Temperature at 135-Deg Location — Overlaid With Ambient

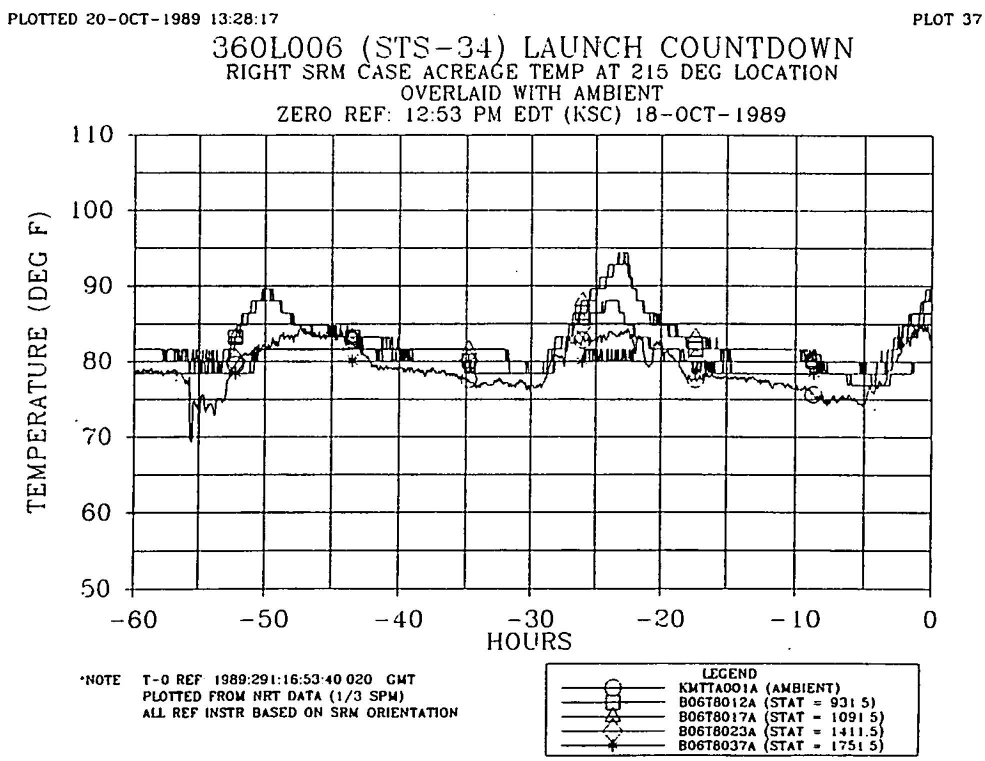
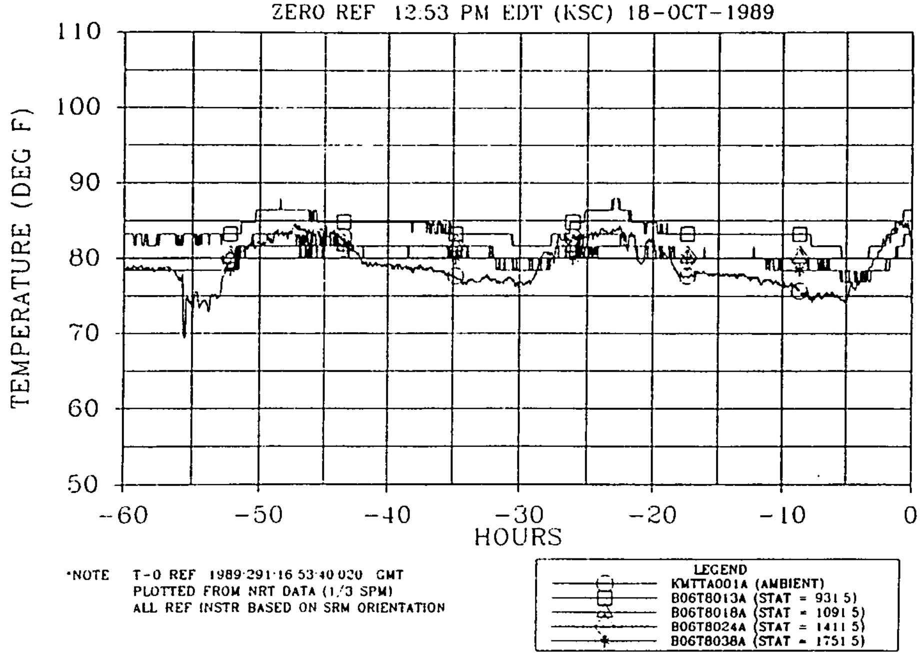


Figure 4-81. RH SRM Case Acreage Temperature at 215-Deg Location — Overlaid With Ambient

PLOTTED 20-OCT-1989 13.29 12 PLOT 38

360L006 (STS-34) LAUNCH COUNTDOWN
RIGHT SRM CASE ACREAGE TEMP AT 270 DEG LOCATION
OVERLAID WITH AMBIENT
ZERO REF 12.53 PM EDT (KSC) 18-OCT-1989

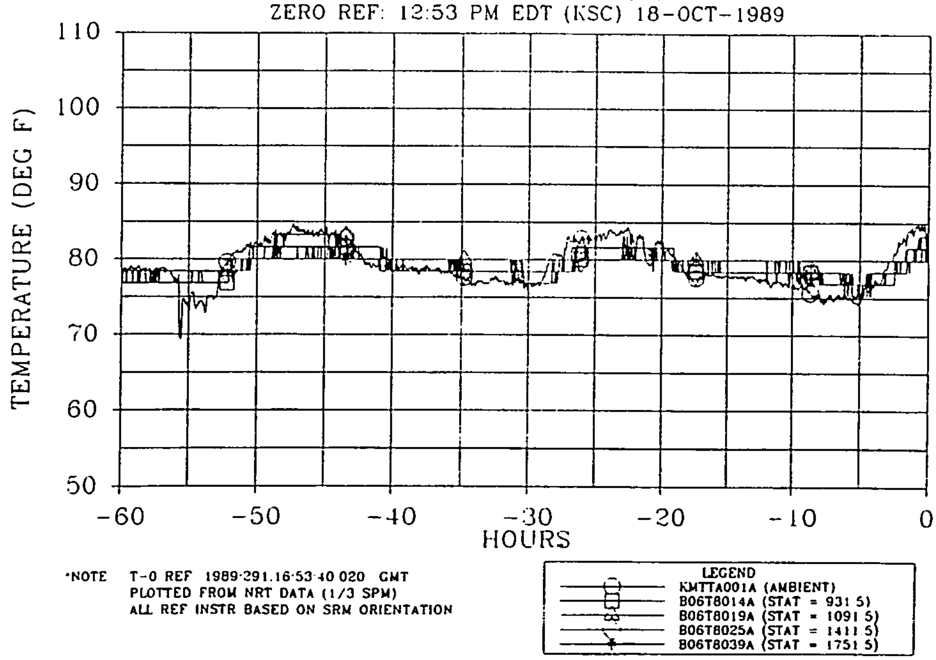


*NOTE T-0 REF 1989·291·16 53·40 020 GMT
PLOTTED FROM NRT DATA (1/3 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

Figure 4-82. RH SRM Case Acreage Temperature at 270-Deg Location — Overlaid With Ambient

PLOTTED 20-OCT-1989 13:30:20 PLOT 39

360L006 (STS-34) LAUNCH COUNTDOWN
RIGHT SRM CASE ACREAGE TEMP AT 325 DEG LOCATION
OVERLAID WITH AMBIENT
ZERO REF: 12:53 PM EDT (KSC) 18-OCT-1989



*NOTE T-0 REF 1989·291.16·53·40 020 GMT
PLOTTED FROM NRT DATA (1/3 SPM)
ALL REF INSTR BASED ON SRM ORIENTATION

Figure 4-83. RH SRM Case Acreage Temperature at 325-Deg Location — Overlaid With Ambient

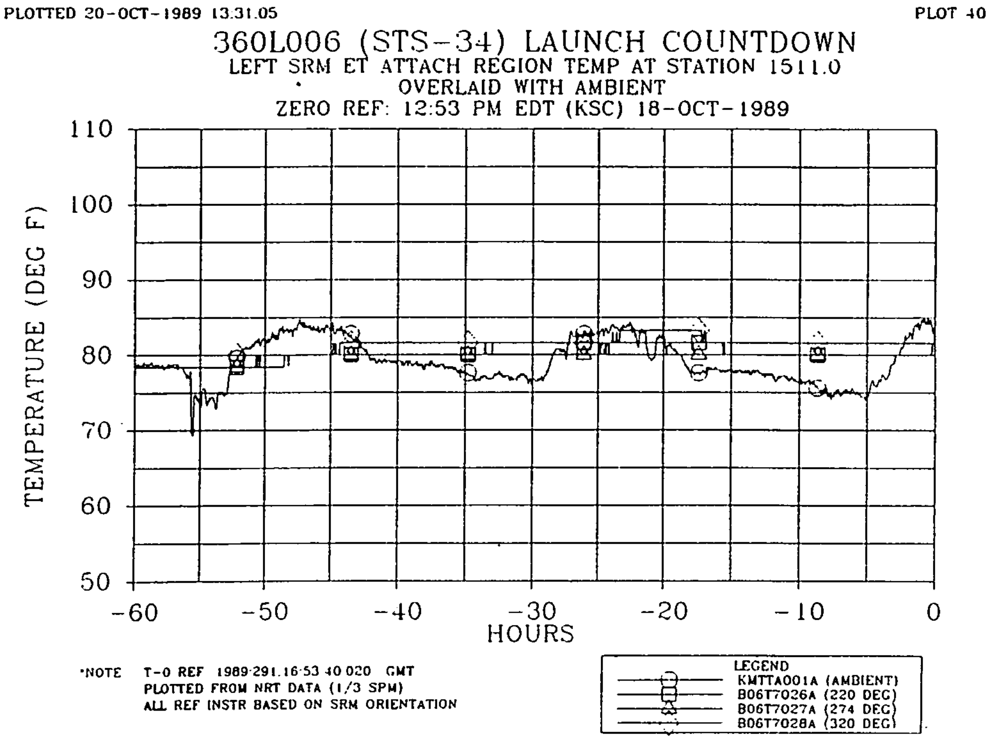


Figure 4-84. LH SRM ET Attach Region Temperature at Station 1511.0 — Overlaid With Ambient

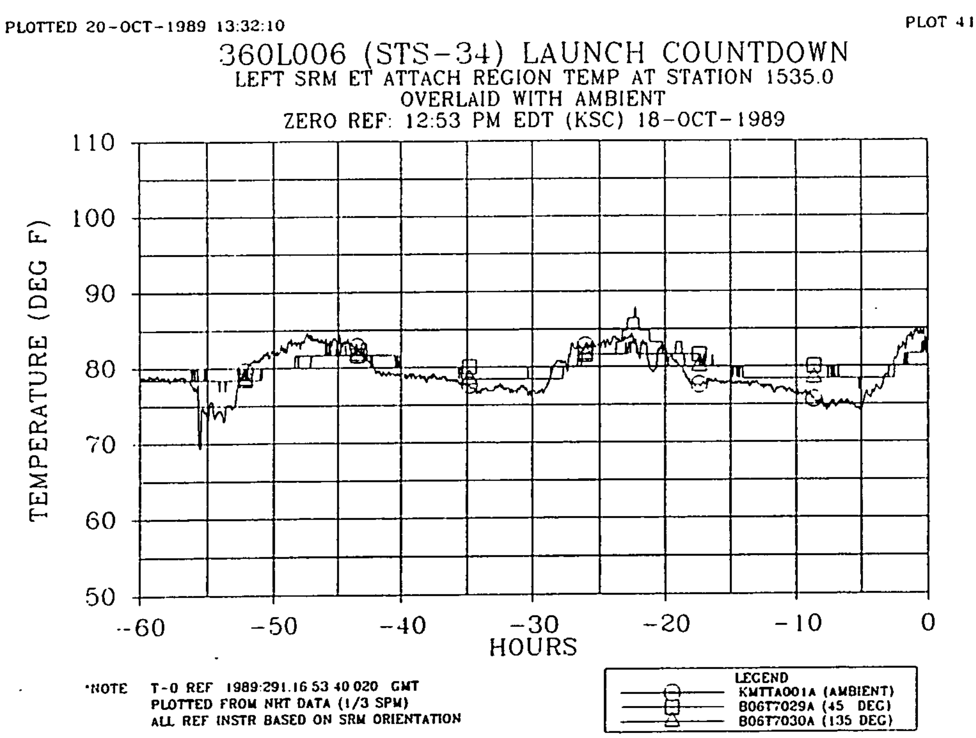


Figure 4-85. LH SRM ET Attach Region Temperature at Station 1535.0 — Overlaid With Ambient

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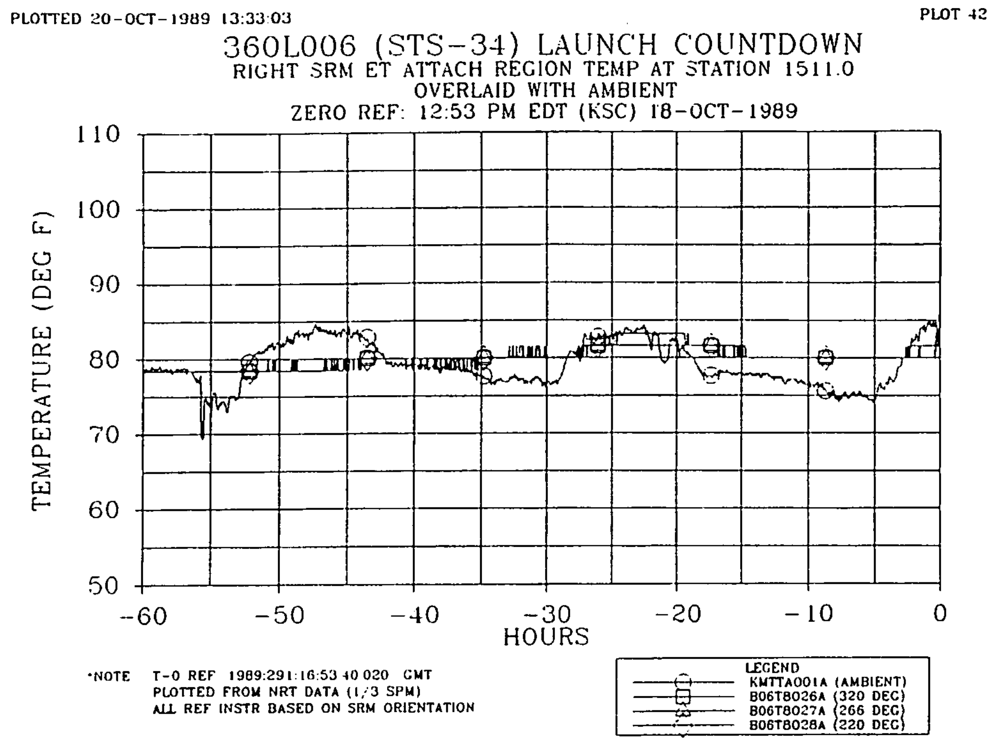

Figure 4-86. RH SRM ET Attach Region Temperature at Station 1511.0 — Overlaid With Ambient

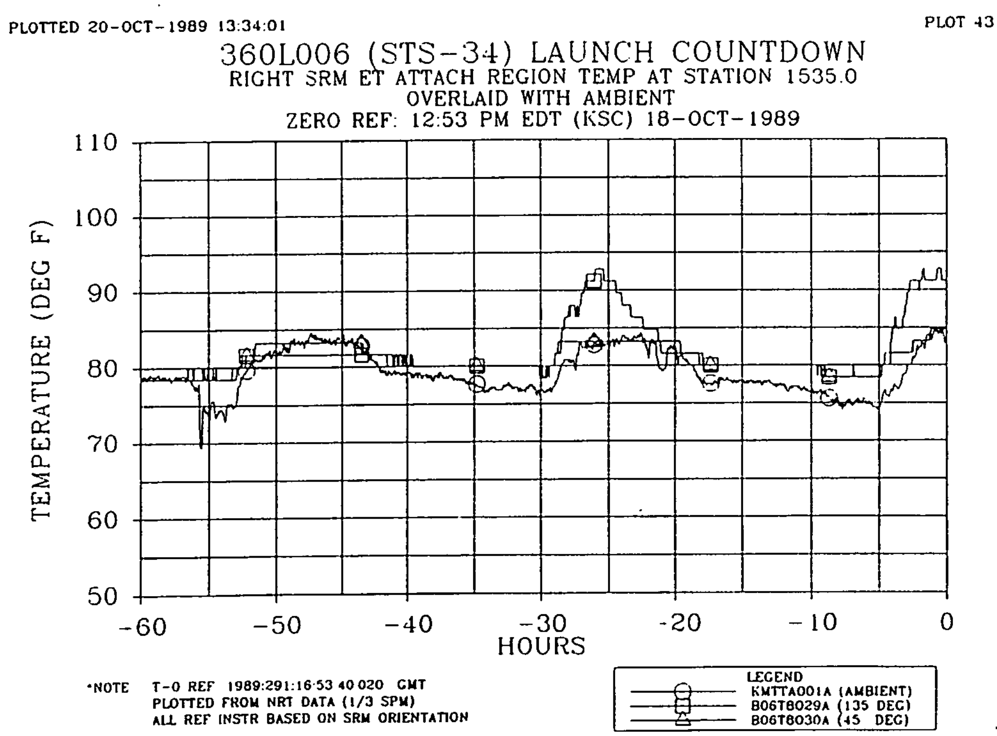

Figure 4-87. RH SRM ET Attach Region Temperature at Station 1535.0 — Overlaid With Ambient

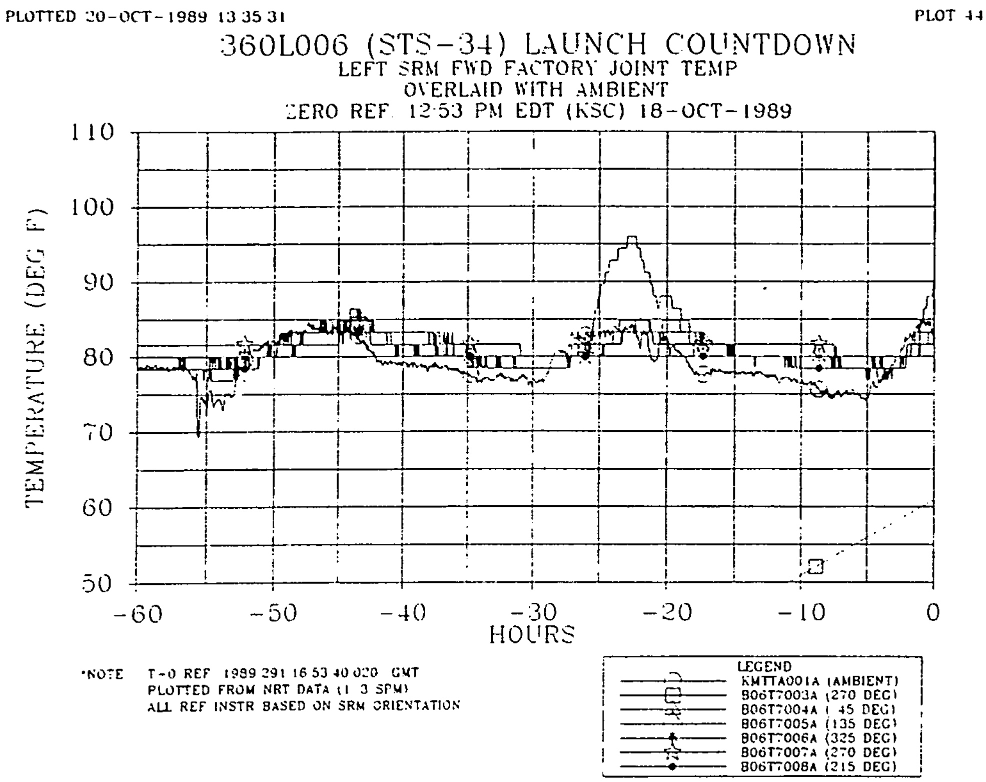

Figure 4-88. LH SRM Forward Factory Joint Temperature — Overlaid With Ambient

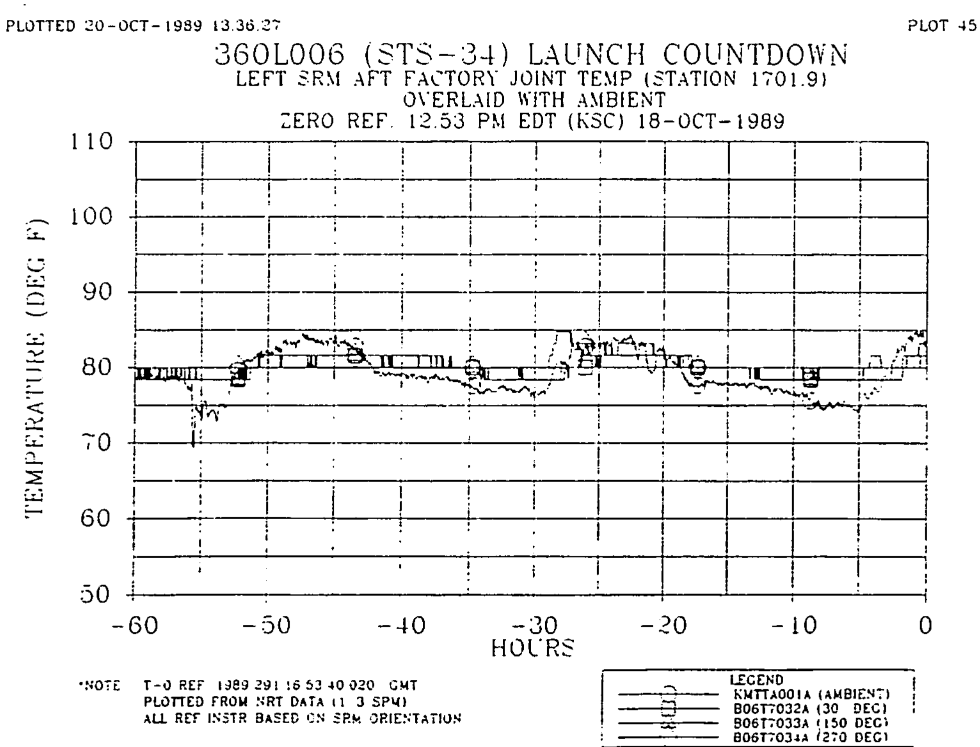

Figure 4-89. LH SRM Aft Factory Joint Temperature at Station 1701.9 — Overlaid With Ambient

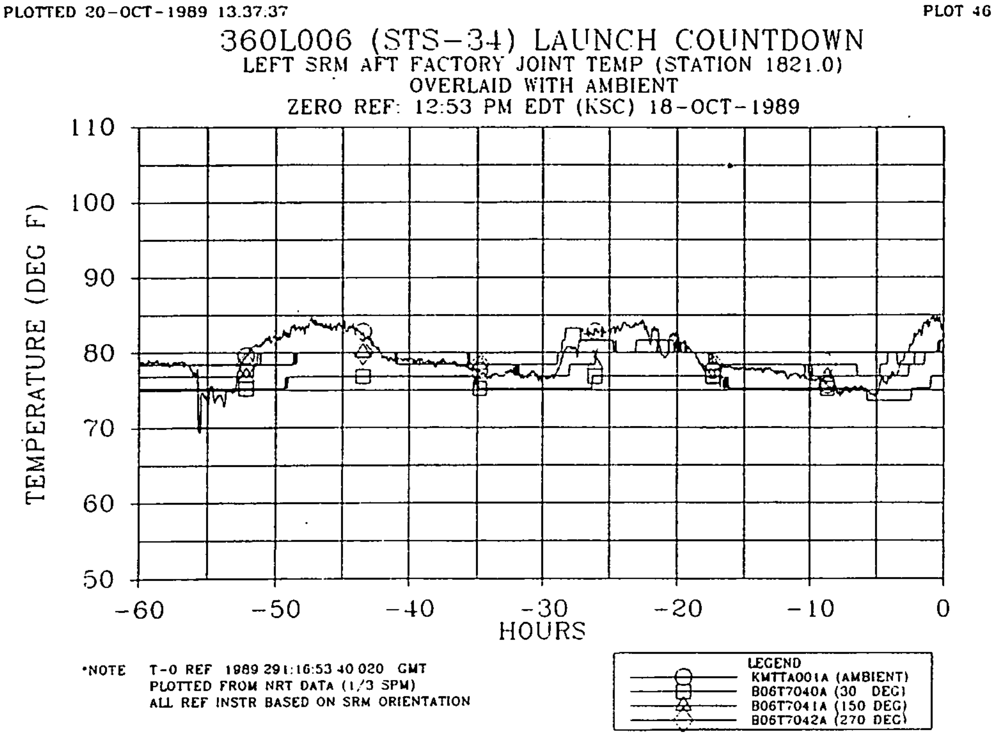

Figure 4-90. LH SRM Aft Factory Joint Temperature at Station 1511.0 — Overlaid With Ambient

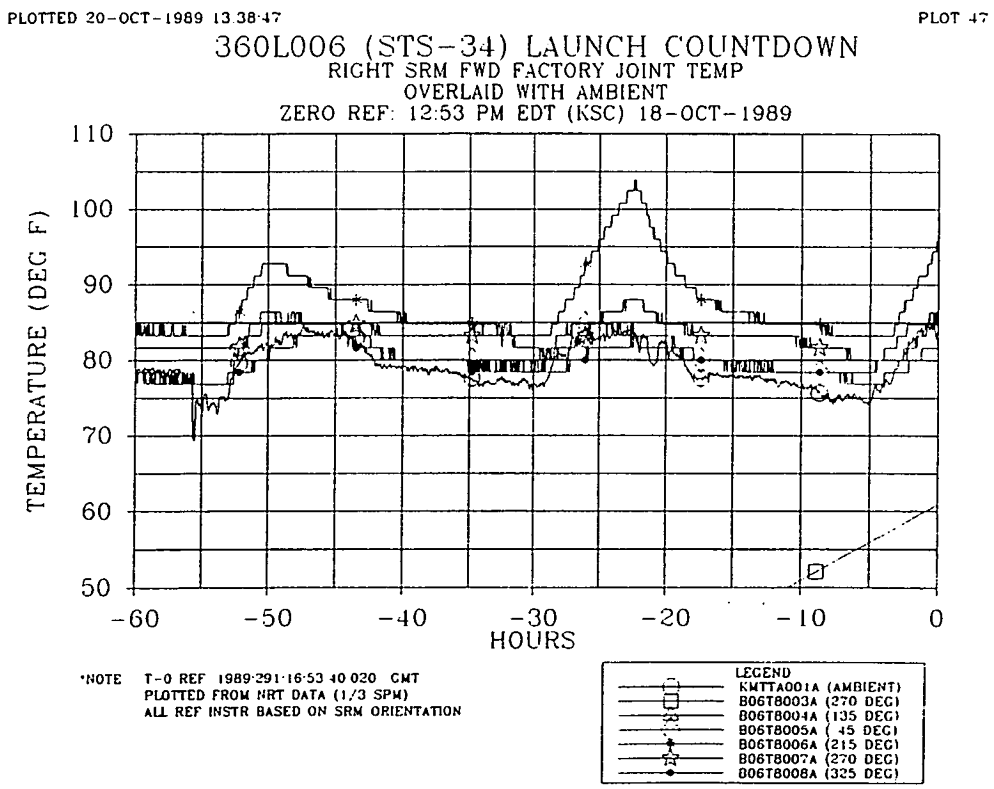

Figure 4-91. RH SRM Forward Factory Joint Temperature — Overlaid With Ambient

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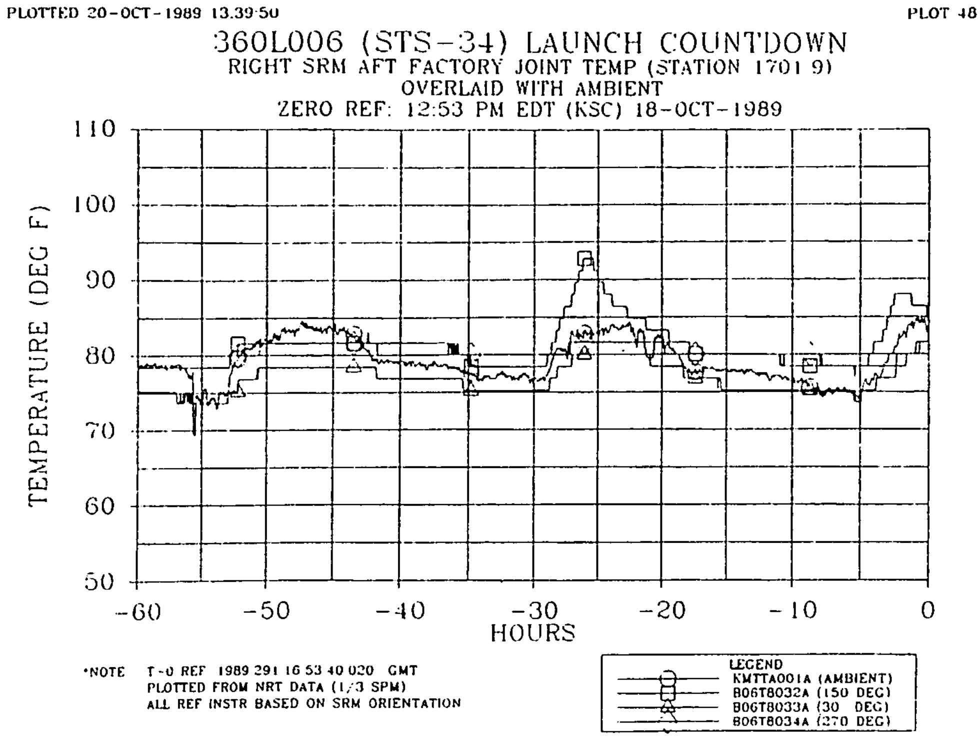

Figure 4-92. RH SRM Aft Factory Joint Temperature at Station 1701.9 — Overlaid With Ambient

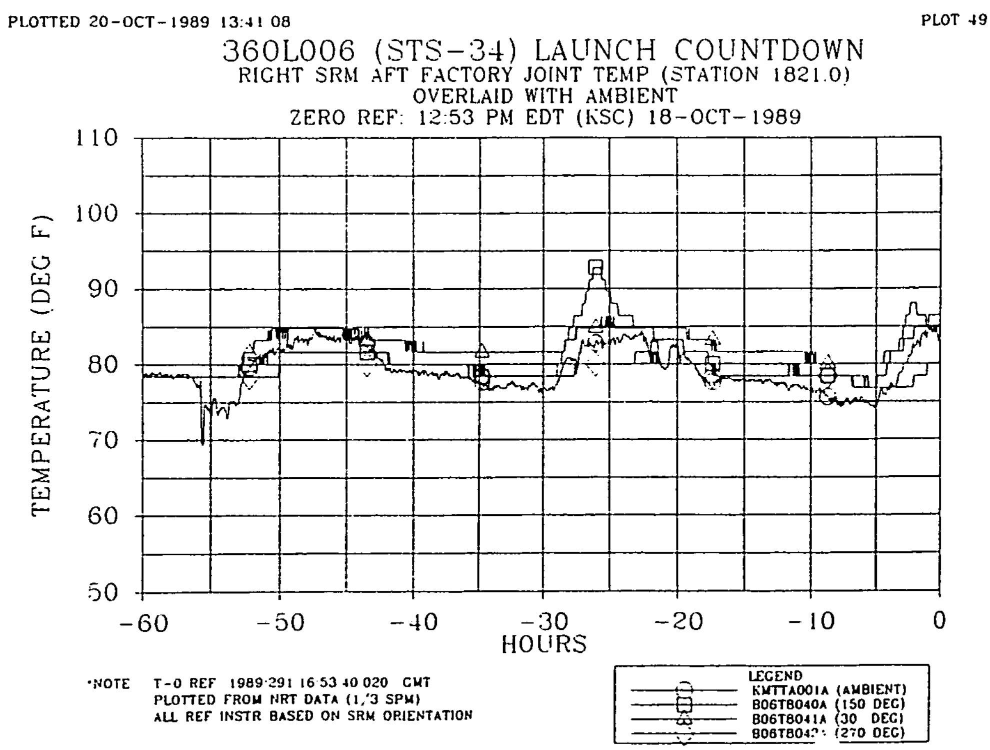

Figure 4-93. RH SRM Aft Factory Joint Temperature at Station 1821.0 — Overlaid With Ambient

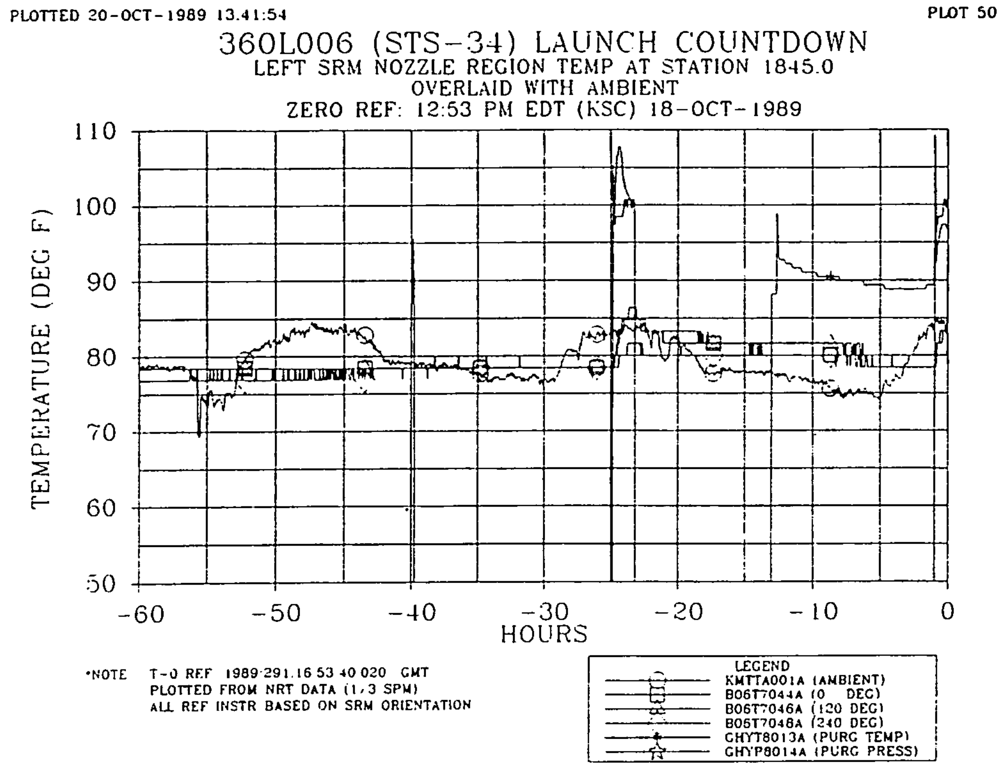

Figure 4-94. LH SRM Nozzle Region Temperature at Station 1845.0 — Overlaid With Ambient

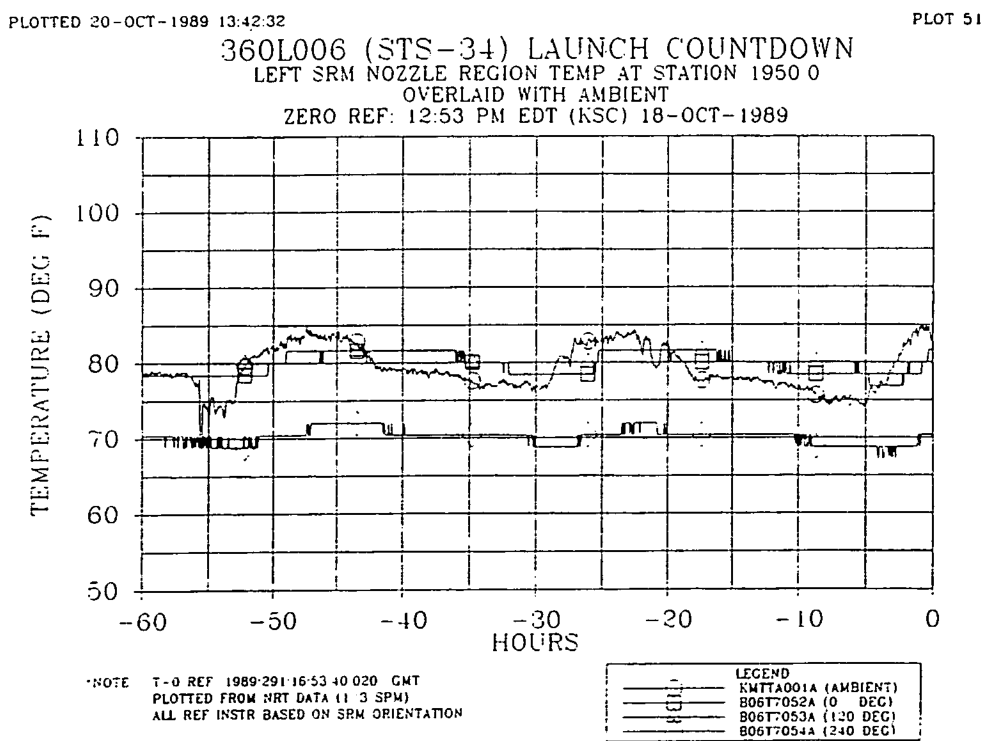

Figure 4-95. LH SRM Nozzle Region Temperature at Station 1950.0 — Overlaid With Ambient

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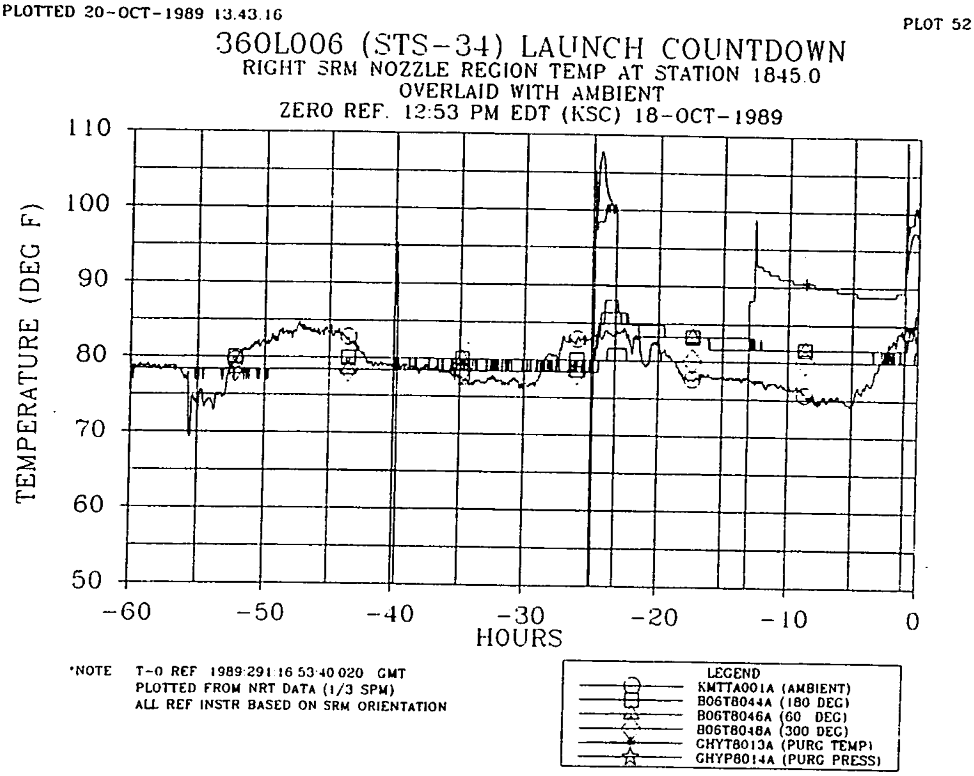

Figure 4-96. RH SRM Nozzle Region Temperature at Station 1845.0 — Overlaid With Ambient

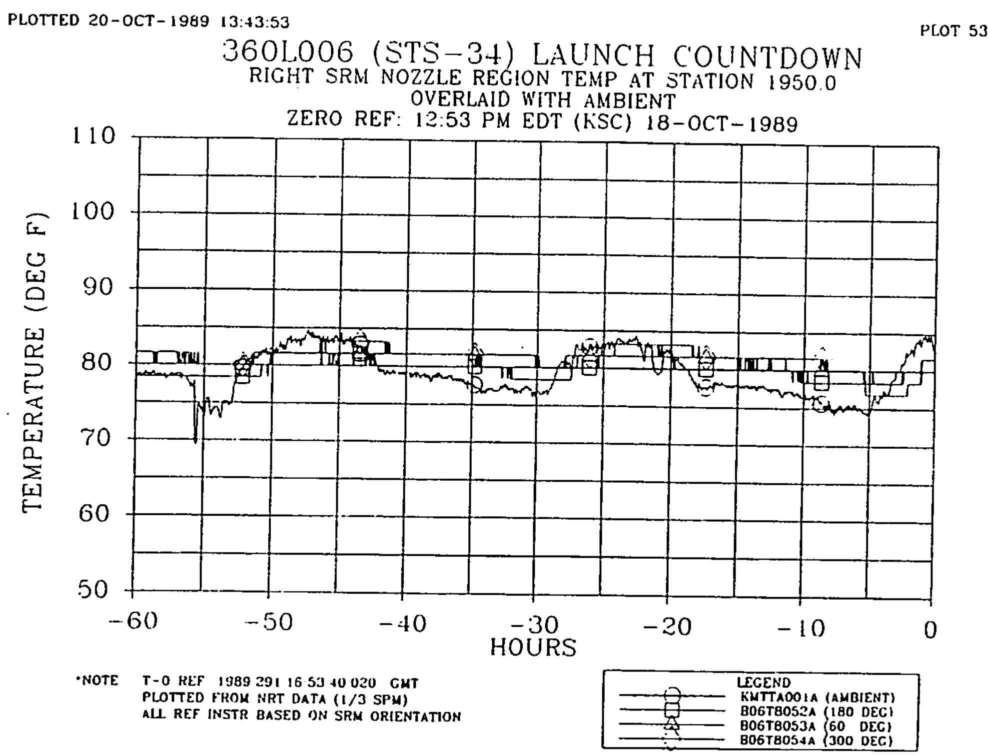

Figure 4-97. RH SRM Nozzle Region Temperature at Station 1950.0 — Overlaid With Ambient

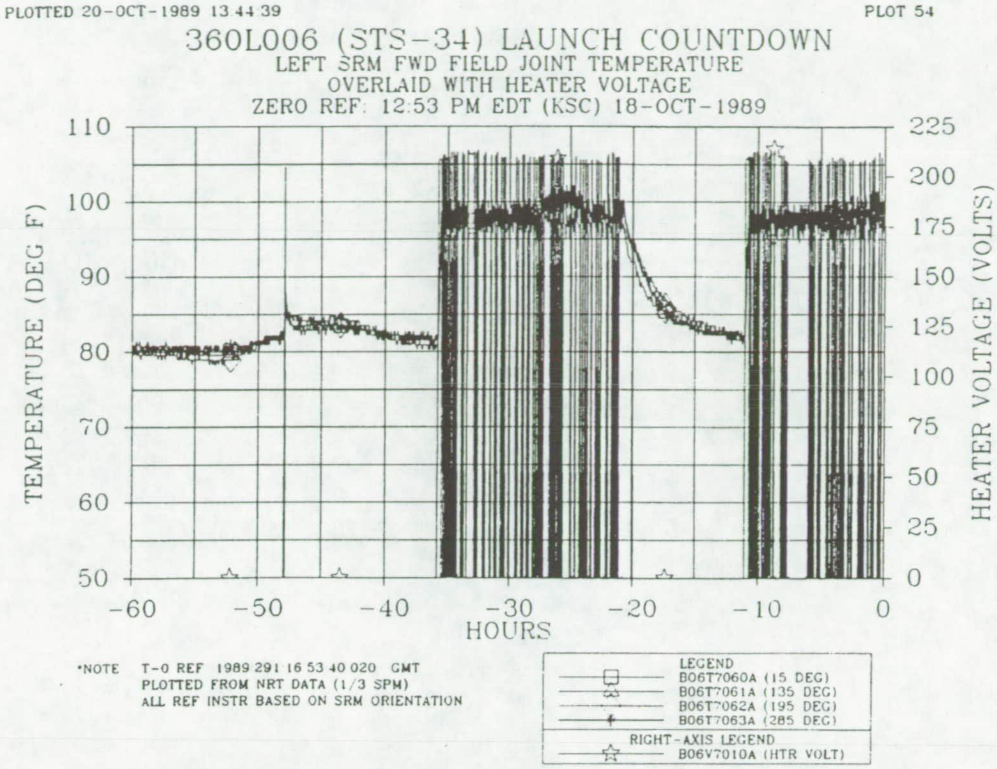

Figure 4-98. LH SRM Forward Field Joint Temperature — Overlaid With Heater Voltage

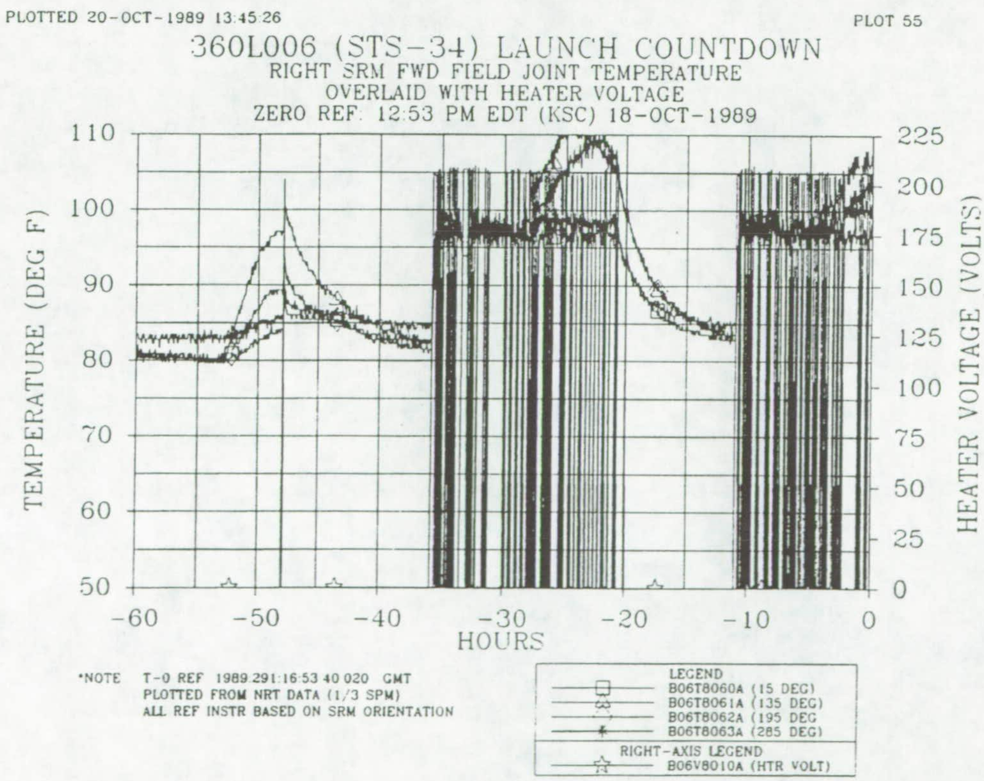

Figure 4-99. RH SRM Forward Field Joint Temperature — Overlaid With Heater Voltage

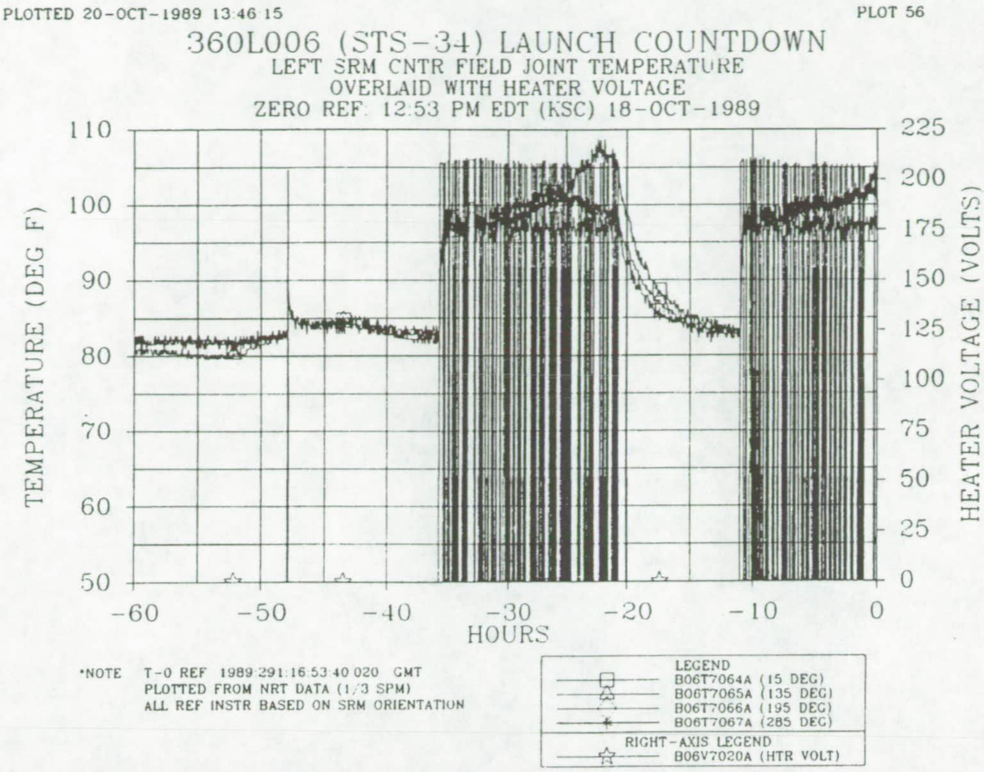

Figure 4-100. LH SRM Center Field Joint Temperature — Overlaid With Heater Voltage

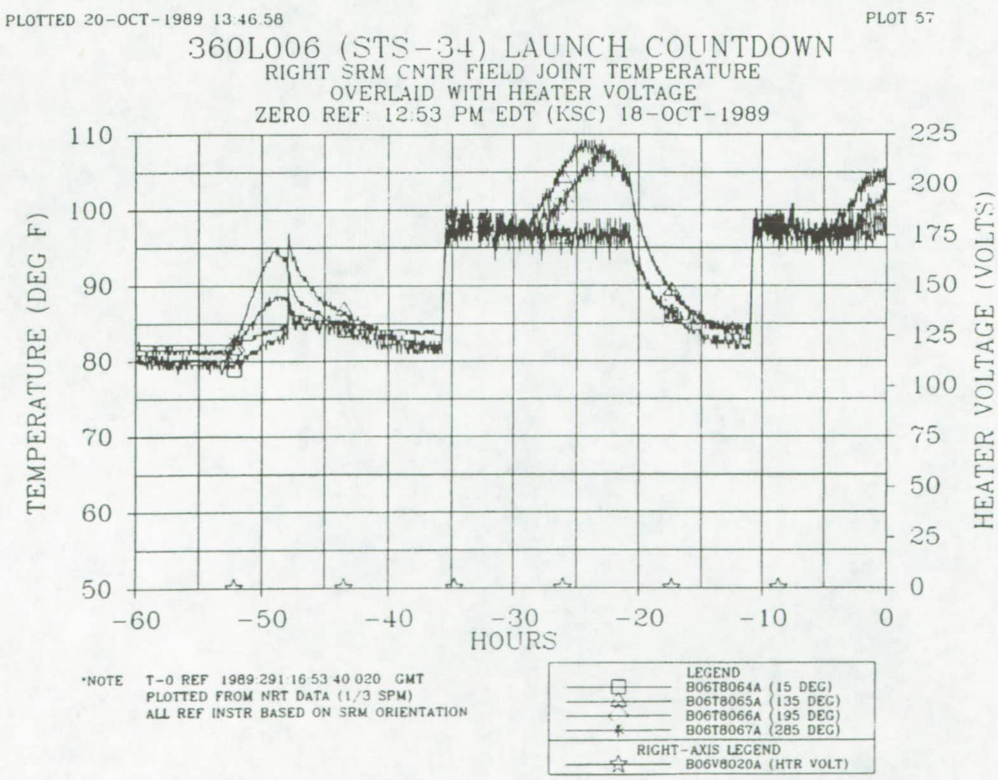

Figure 4-101. RH SRM Center Field Joint Temperature — Overlaid With Heater Voltage

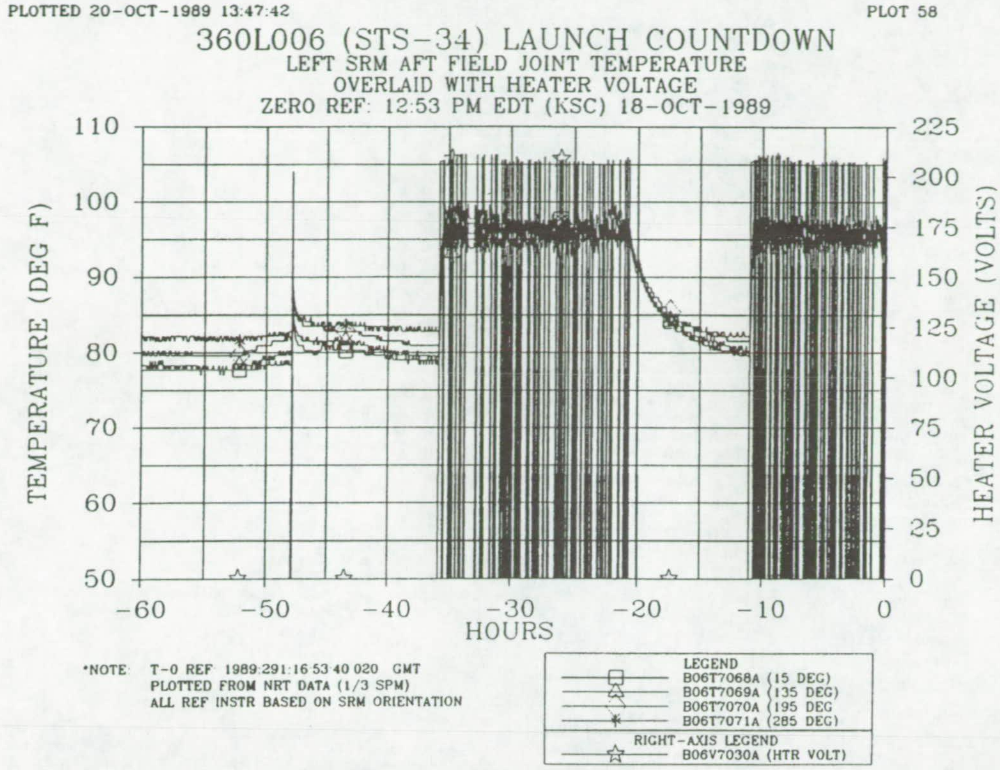

Figure 4-102. LH SRM Aft Field Joint Temperature — Overlaid With Heater Voltage

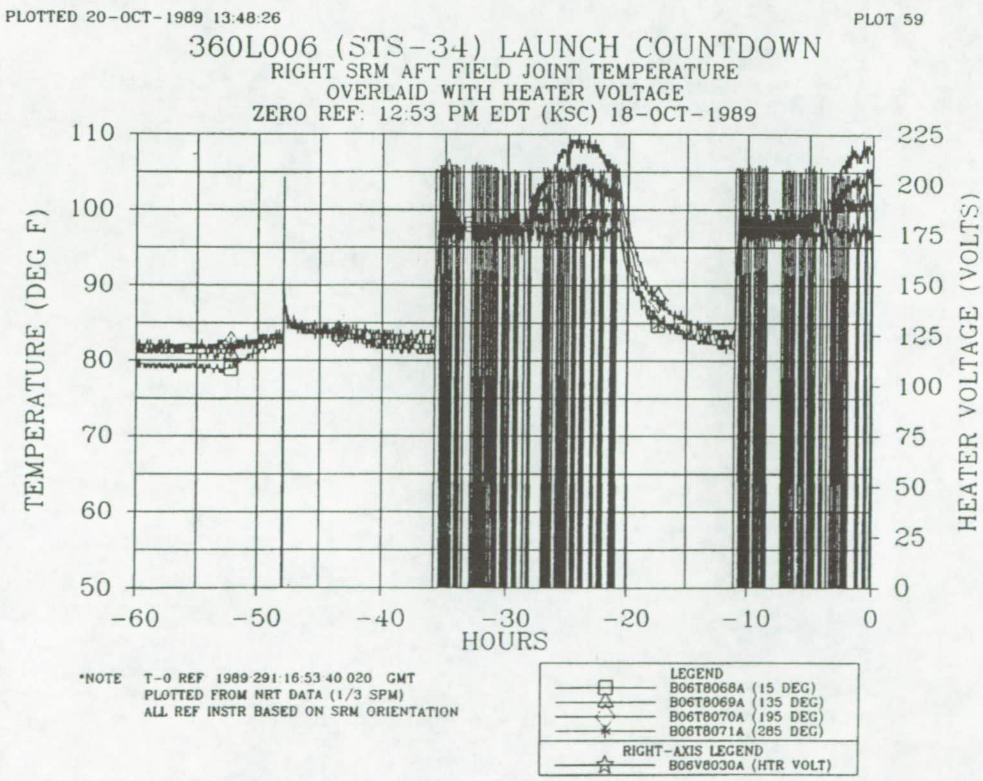

Figure 4-103. RH SRM Aft Field Joint Temperature — Overlaid With Heater Voltage

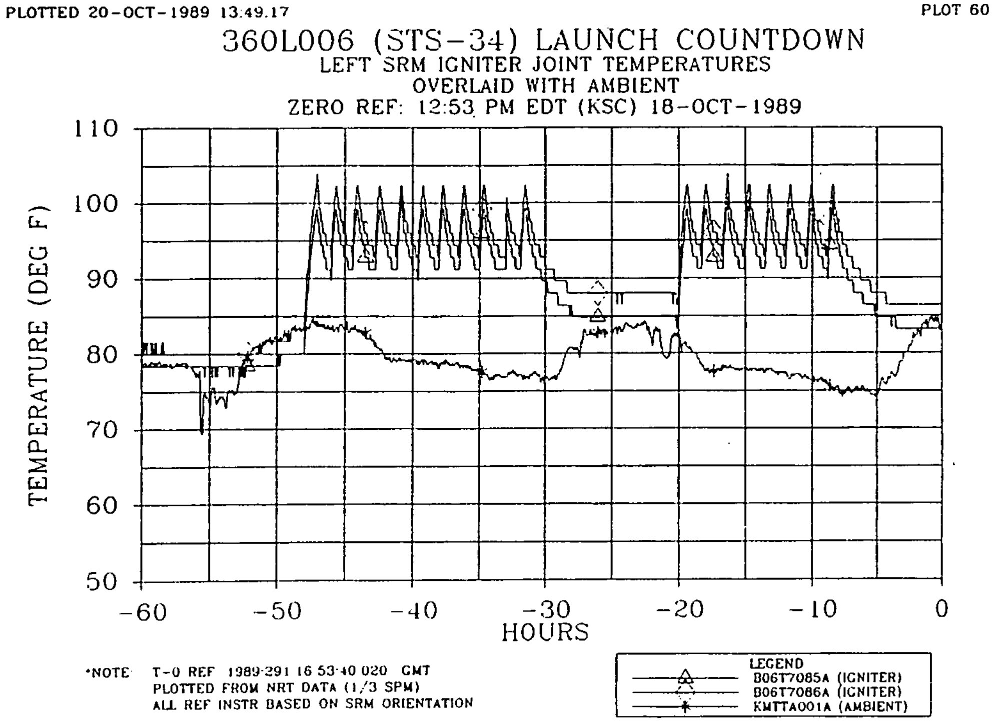

Figure 4-104. LH SRM Igniter Joint Temperature — Overlaid With Ambient

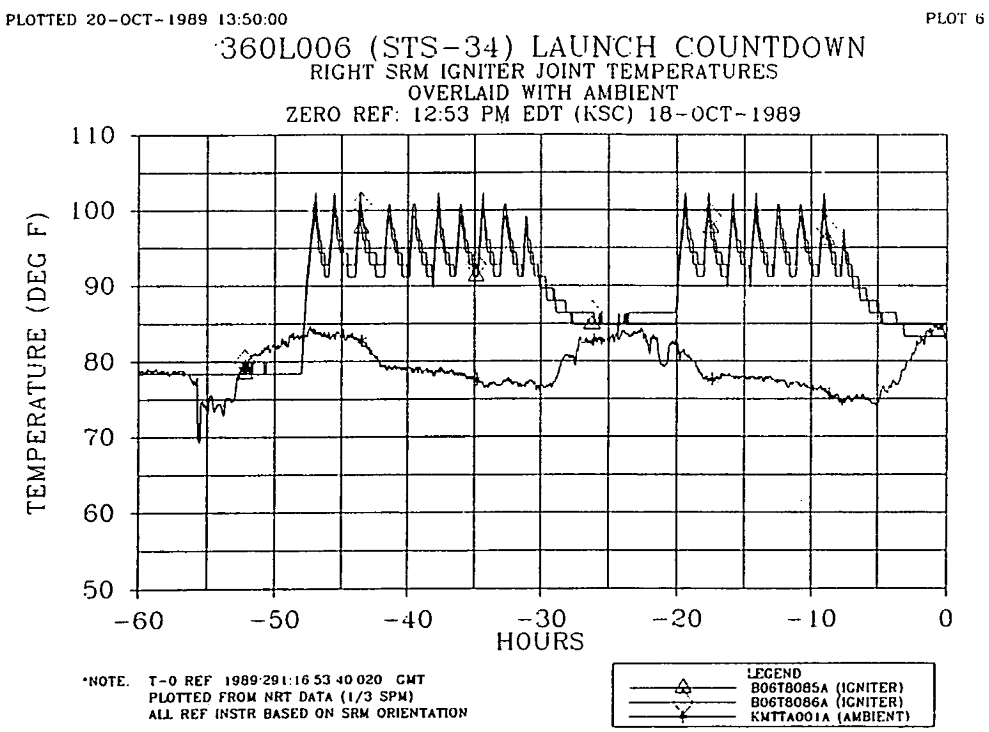

Figure 4-105. RH SRM Igniter Joint Temperature — Overlaid With Ambient

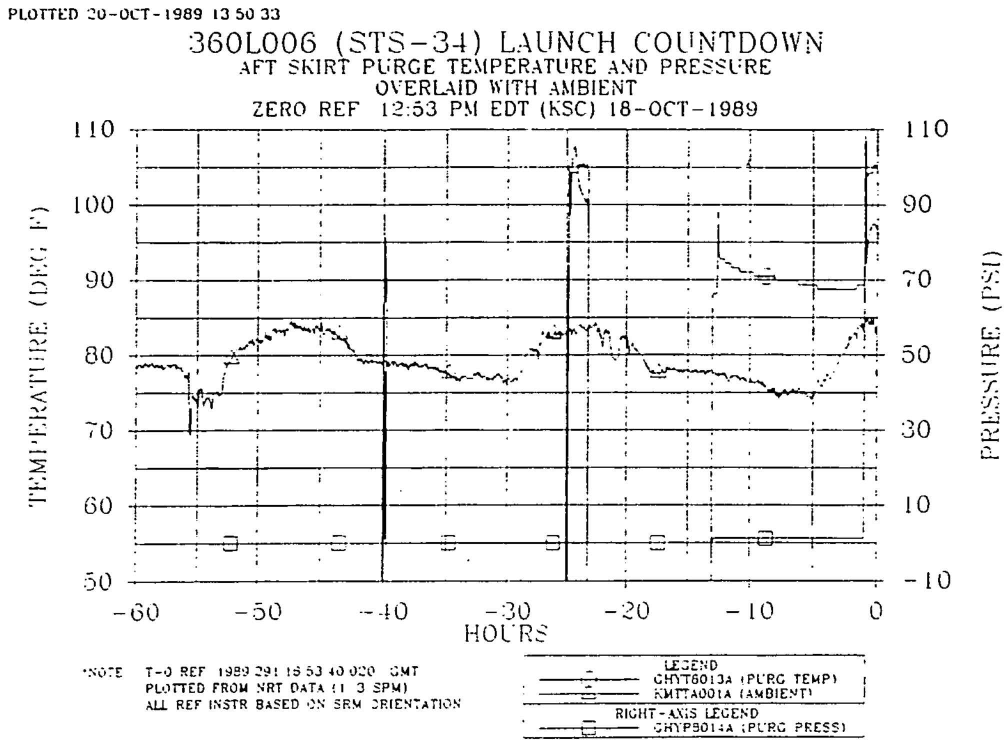

Figure 4-106. Aft Skirt Purge Temperature and Pressure — Overlaid With Ambient

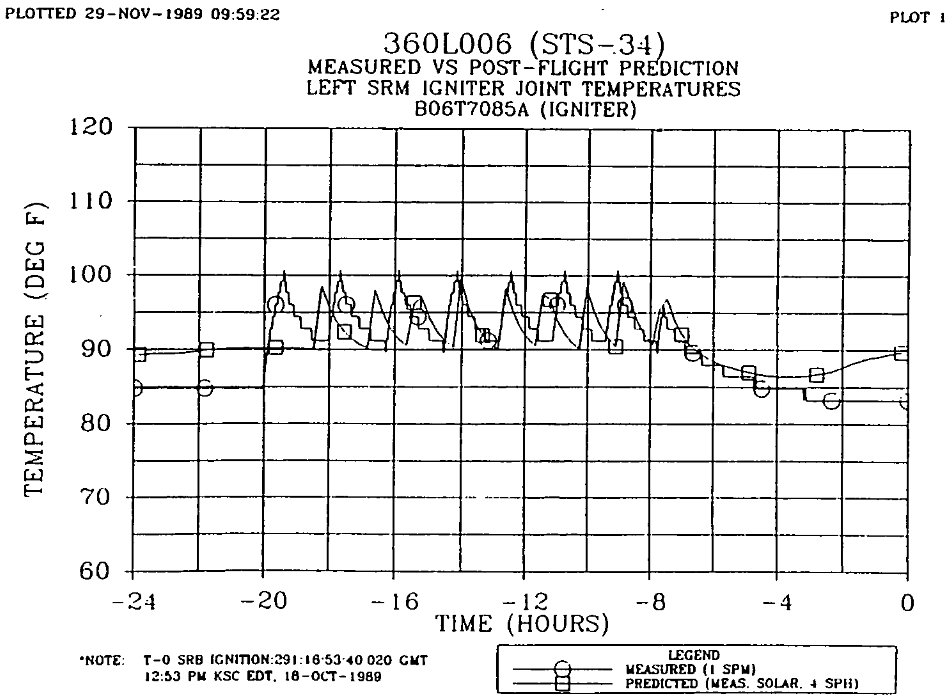

Figure 4-107. LH SRM Igniter Joint Temperature, B06T7085A (Igniter) — Measured Versus Postflight Prediction

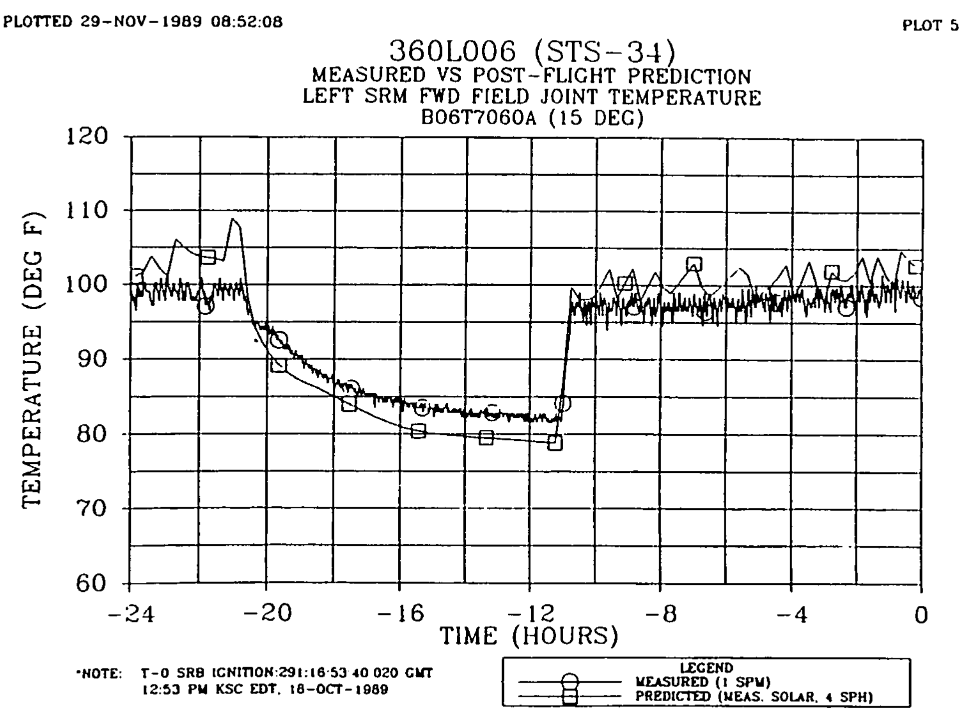

Figure 4-108. LH SRM Forward Field Joint Temperature, B06T7060A (15-Deg) — Measured Versus Postflight Prediction

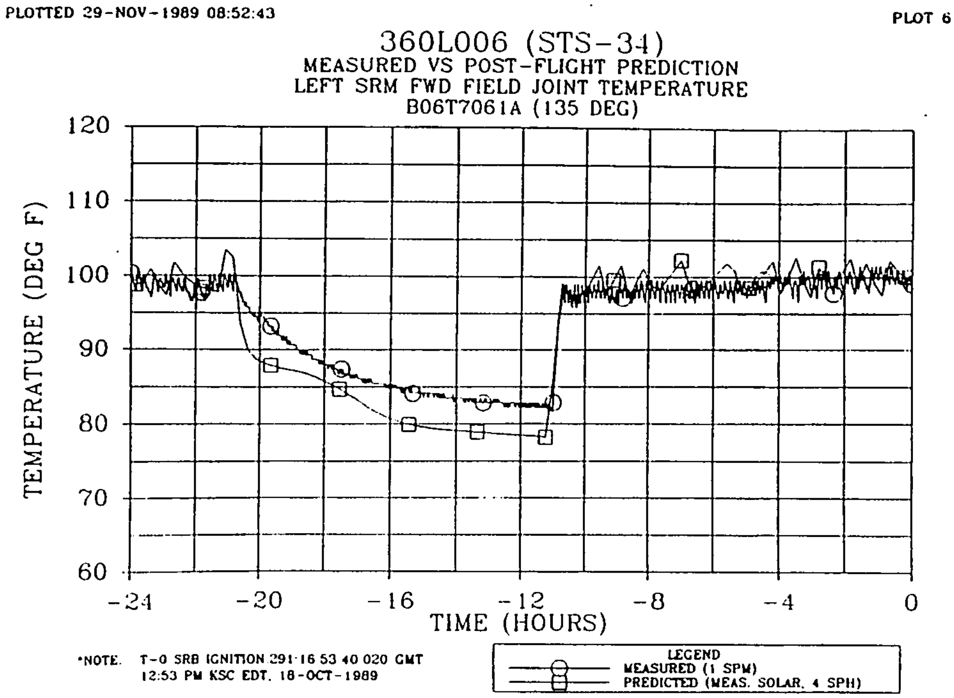

Figure 4-109. LH SRM Forward Field Joint Temperature, B06T7061A (135-Deg) — Measured Versus Postflight Prediction

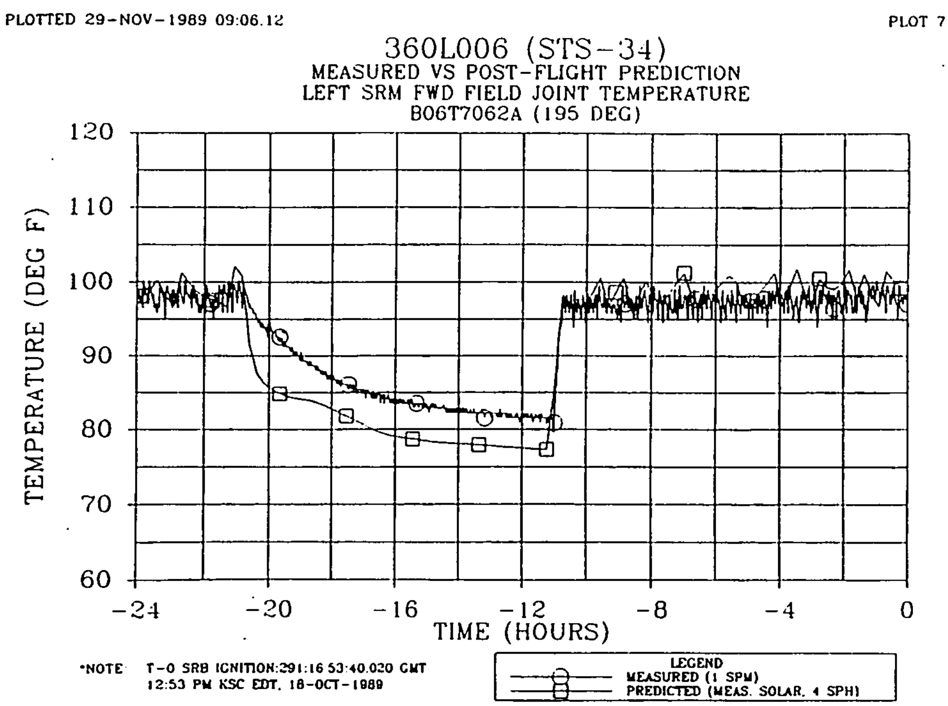

Figure 4-110. LH SRM Forward Field Joint Temperature, B06T7062A (195-Deg) — Measured Versus Postflight Prediction

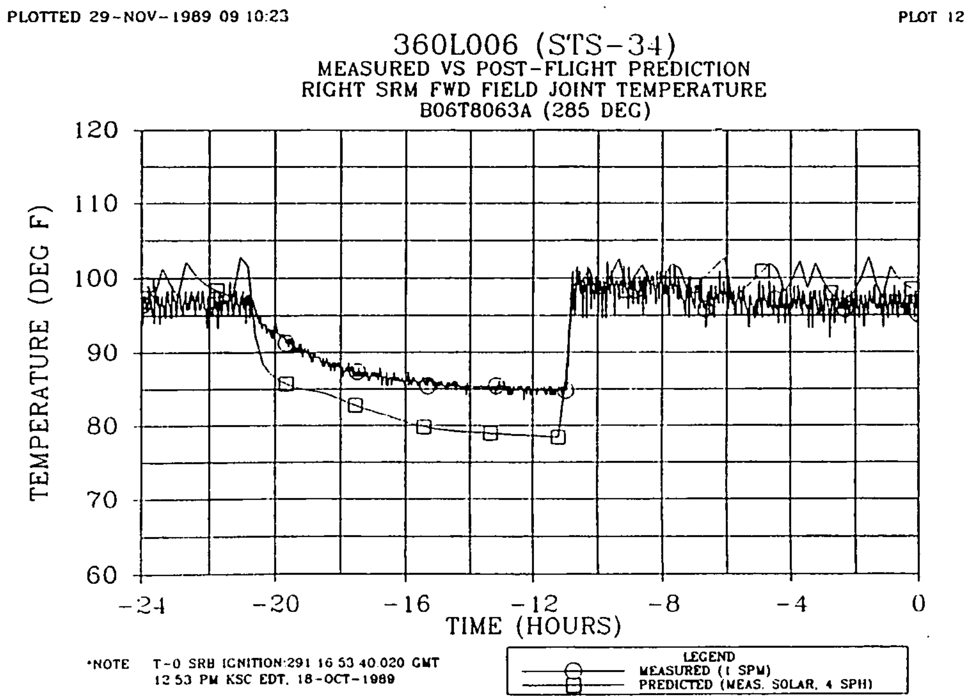

Figure 4-111. RH SRM Forward Field Joint Temperature, B06T8063A (285-Deg) — Measured Versus Postflight Prediction

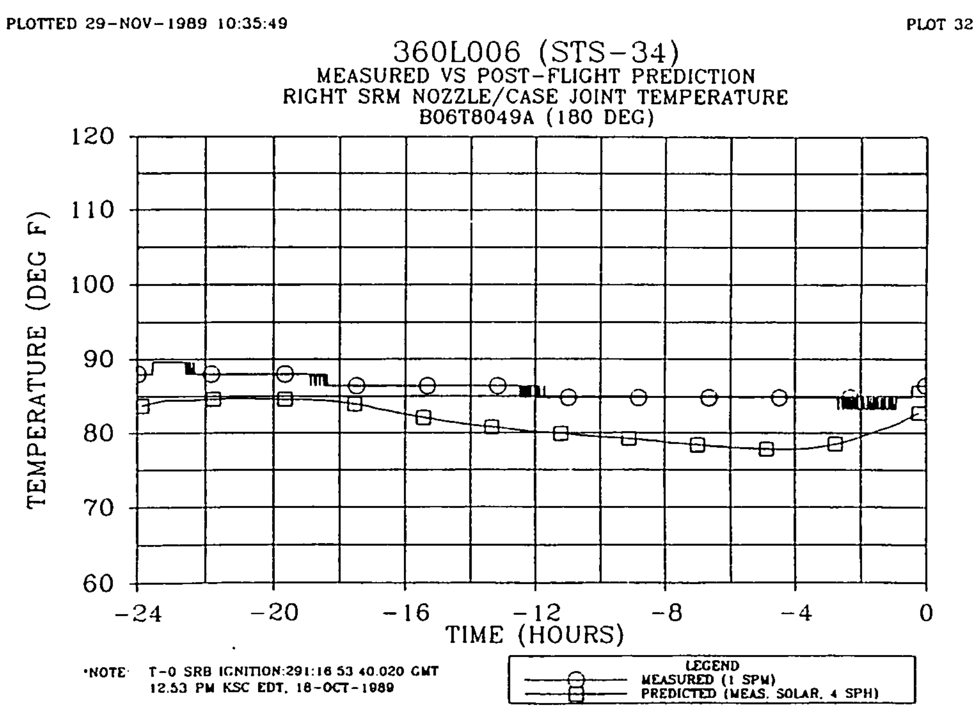

Figure 4-112. RH SRM Nozzle/Case Joint Temperature, B06T8049A (180-Deg) — Measured Versus Postflight Prediction

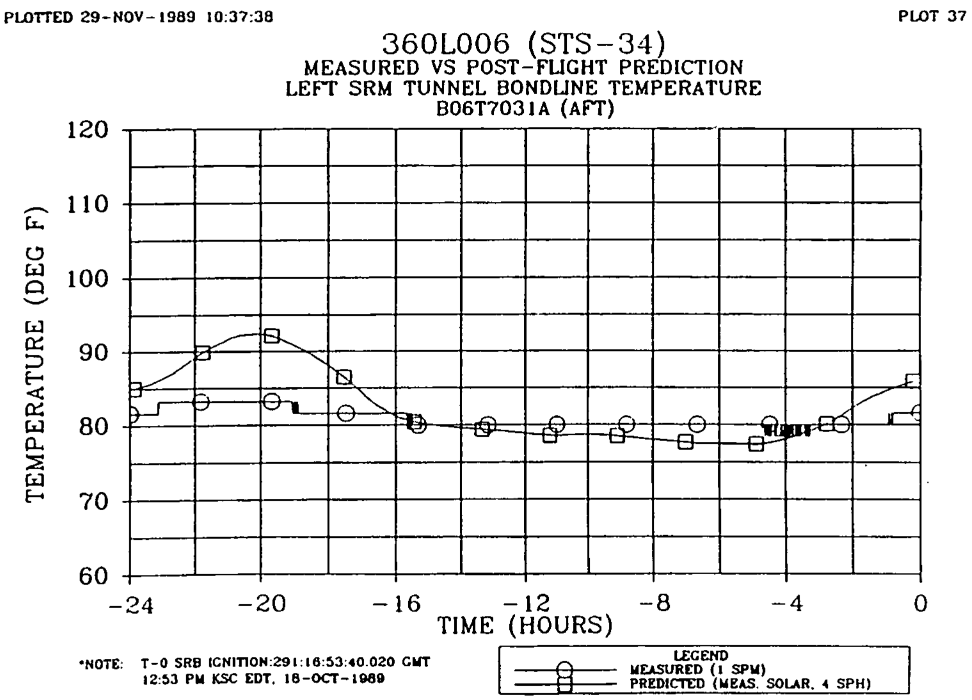

Figure 4-113. LH SRM Tunnel Bondline Temperature, B06T7031A (Aft) — Measured Versus Postflight Prediction

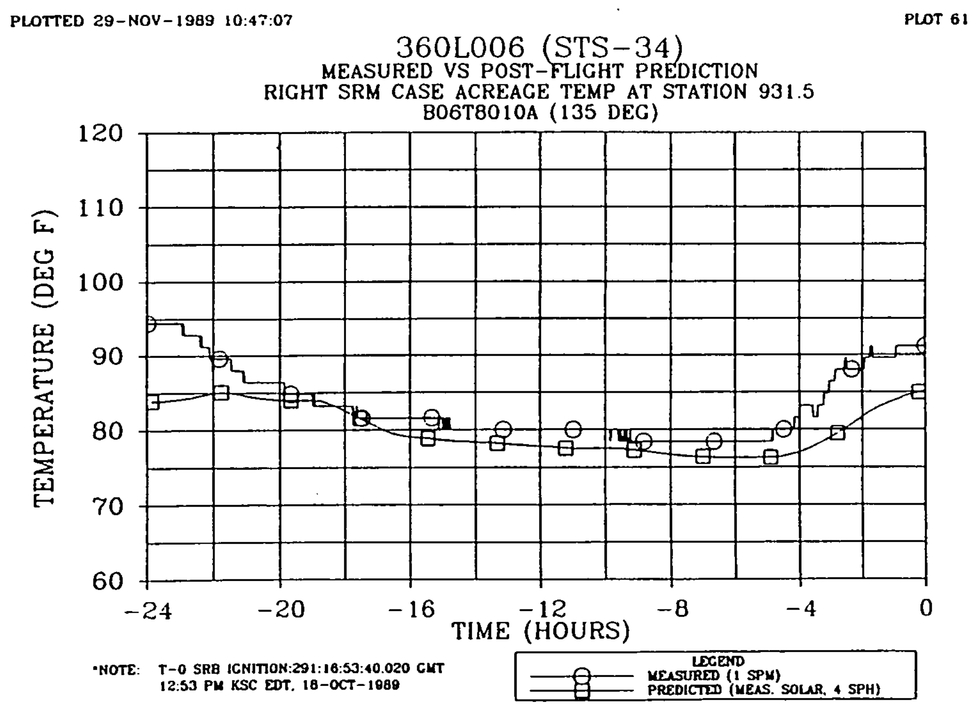

Figure 4-114. RH SRM Case Acreage Temperature at Station 931.5, B06T8010A (135-Deg) — Measured Versus Postflight Prediction

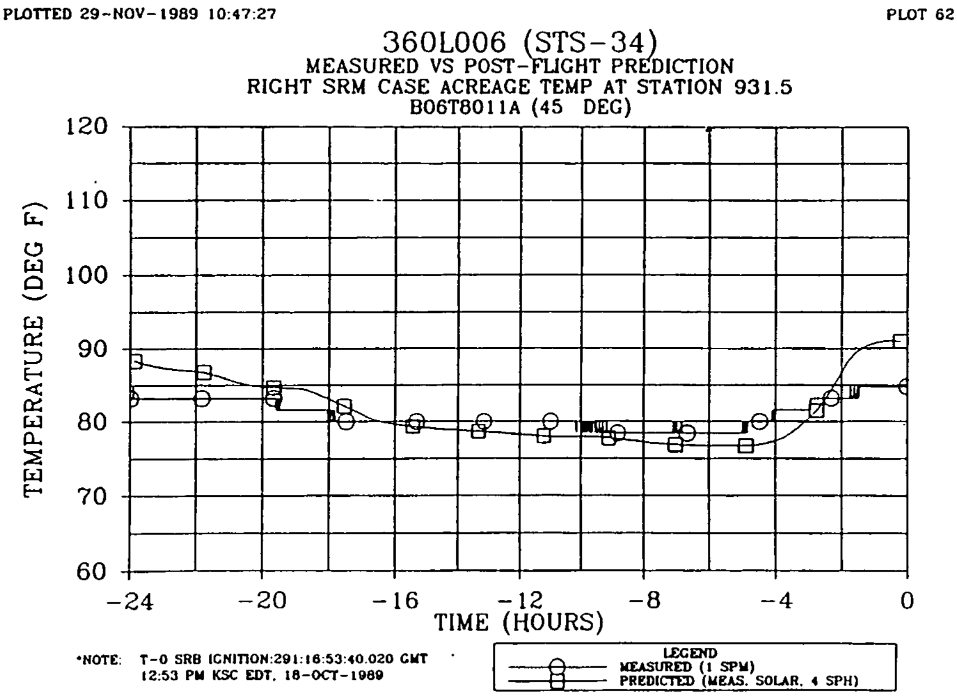

Figure 4-115. RH SRM Case Acreage Temperature at Station 931.5, B06T8011A (45-Deg) — Measured Versus Postflight Prediction

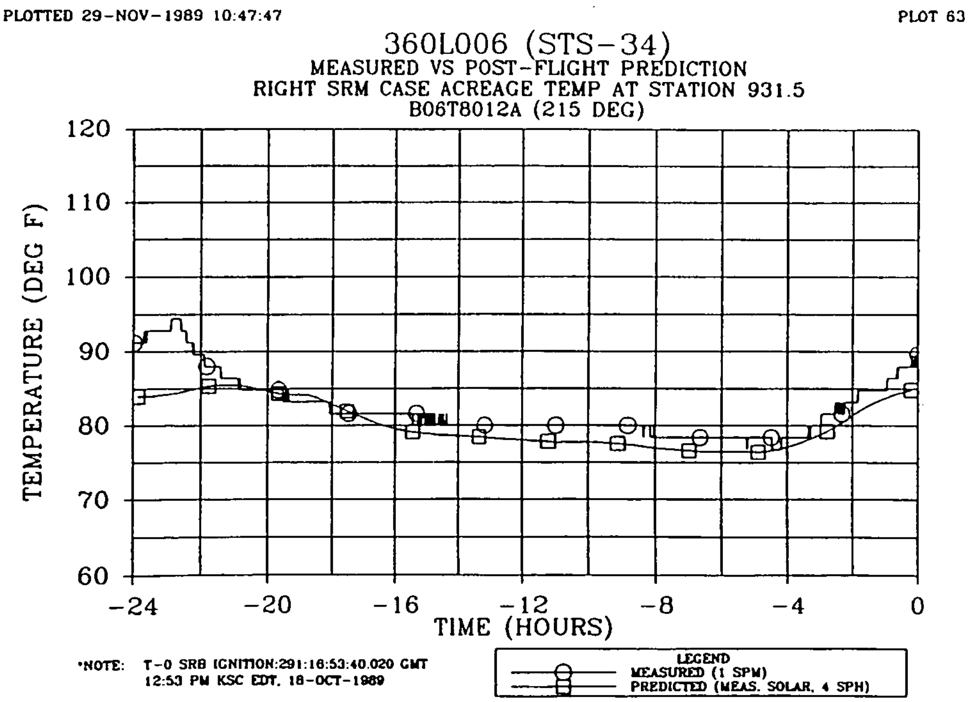

Figure 4-116. RH SRM Case Acreage Temperature at Station 931.5, B06T8012A (215-Deg) — Measured Versus Postflight Prediction

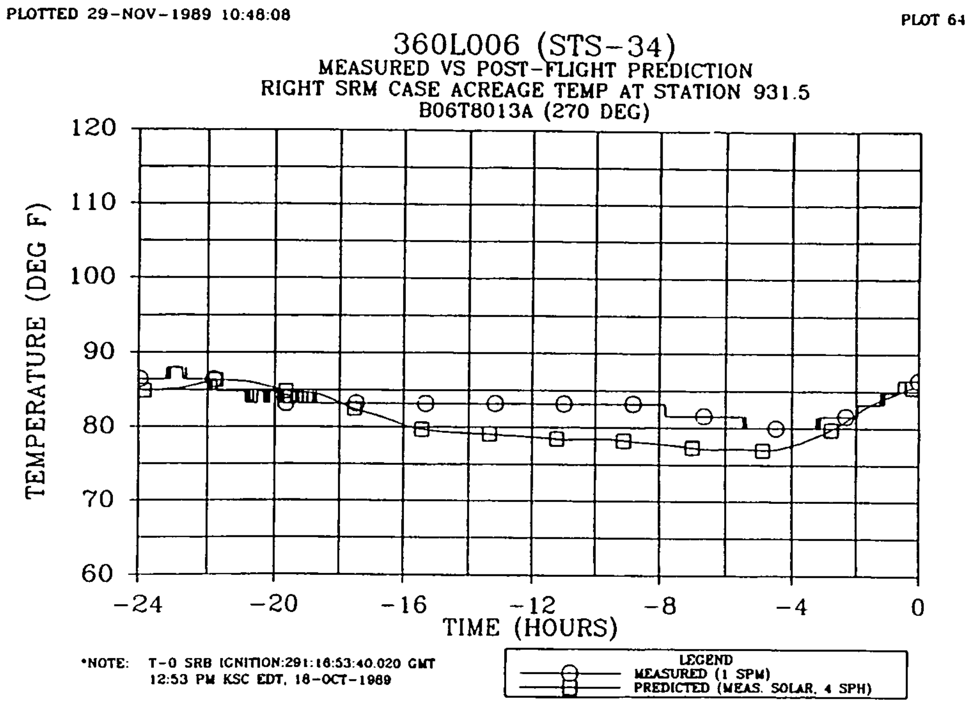

Figure 4-117. RH SRM Case Acreage Temperature at Station 931.5, B06T8013A (270-Deg) – Measured Versus Postflight Prediction

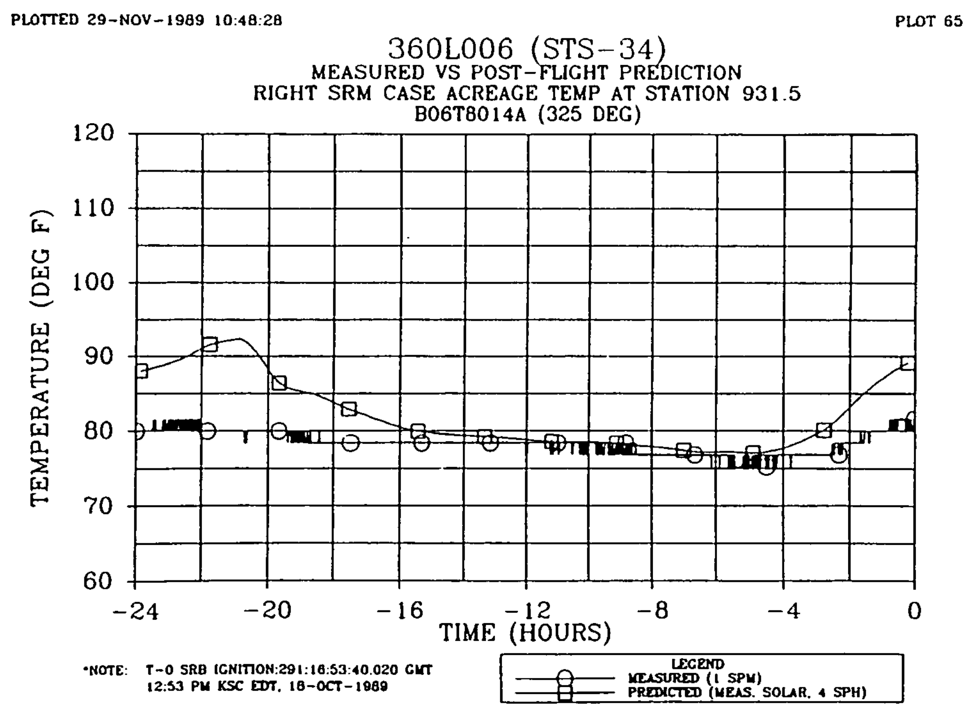

Figure 4-118. RH SRM Case Acreage Temperature at Station 931.5, B06T8014A (325-Deg) – Measured Versus Postflight Prediction

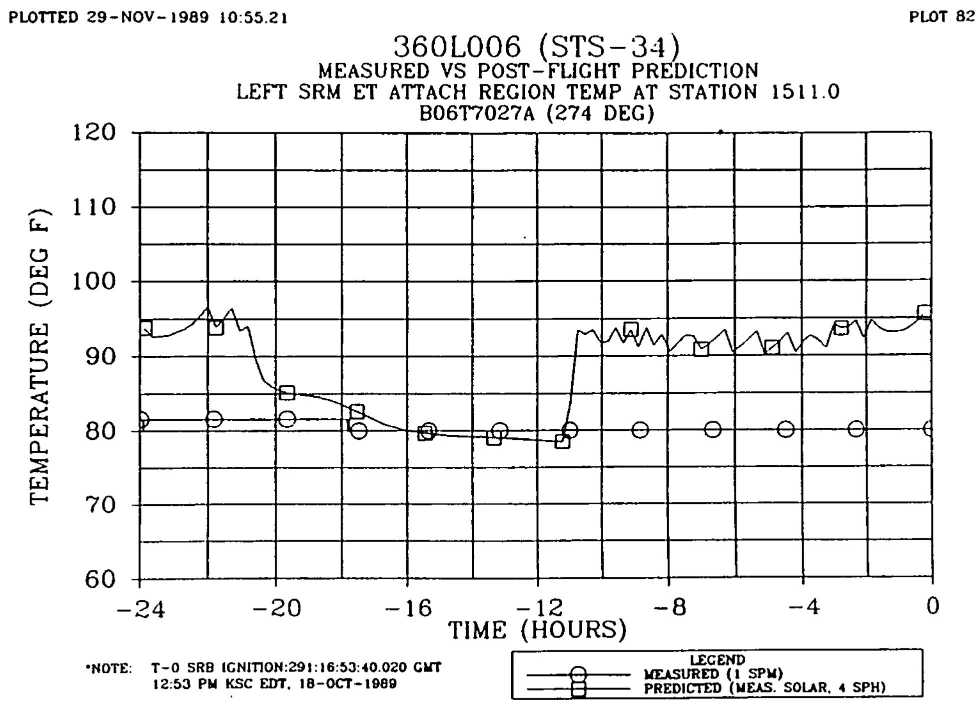

Figure 4-119. RH SRM ET Attach Region Temperature at Station 1511.0, B06T7027A (274-Deg) – Measured Versus Postflight Prediction

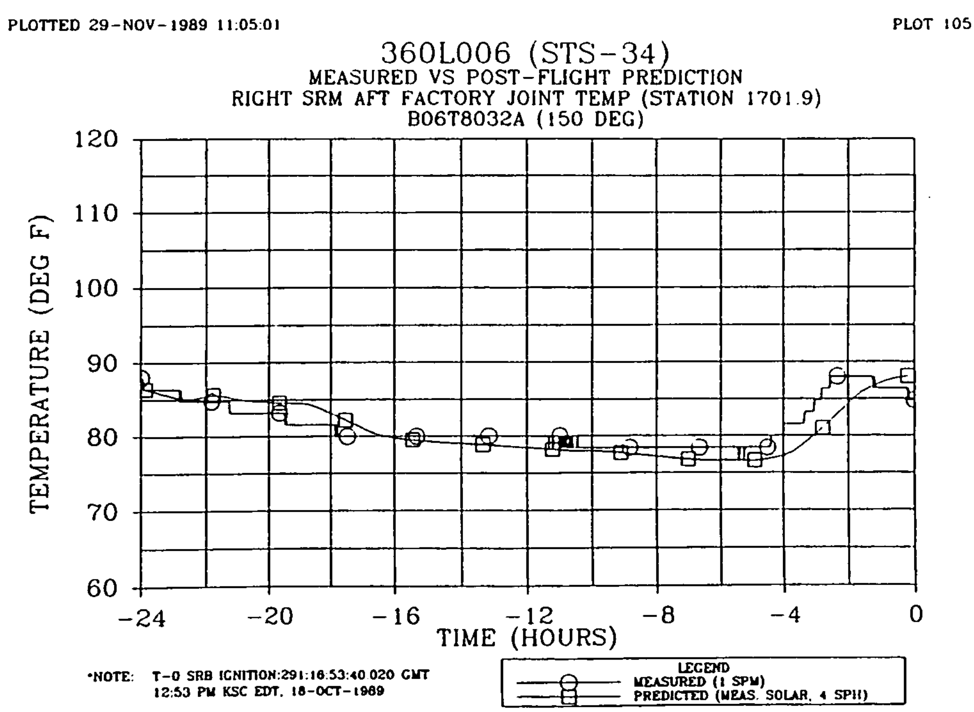

Figure 4-120. RH SRM Aft Factory Joint Temperature at Station 1701.9, B06T8032A (150-Deg) – Measured Versus Postflight Prediction

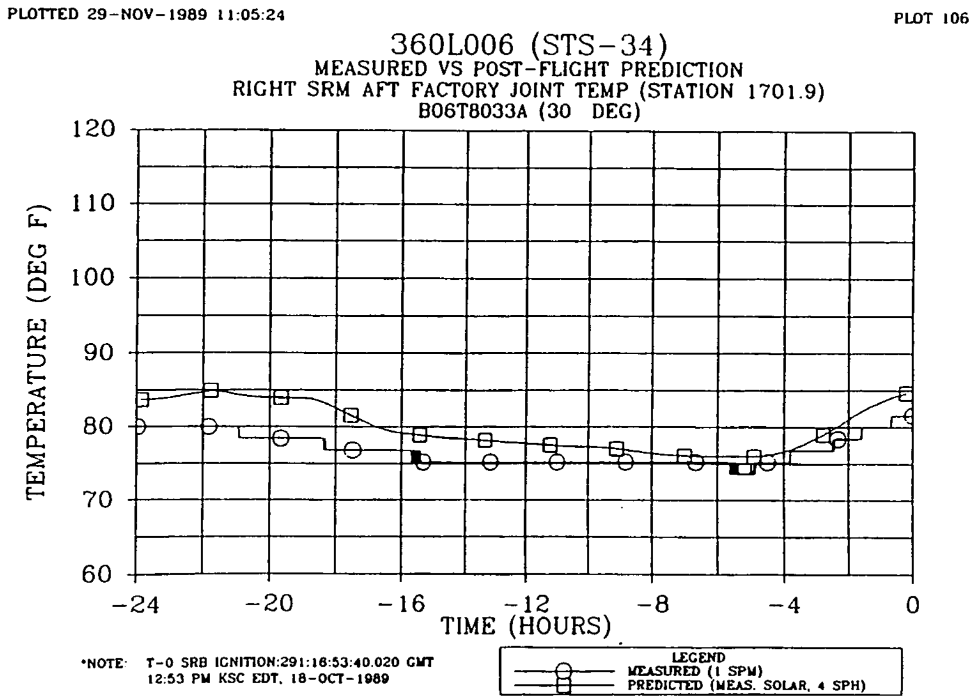

Figure 4-121. RH SRM Aft Factory Joint Temperature at Station 1701.9, B06T8033A (30-Deg) — Measured Versus Postflight Prediction

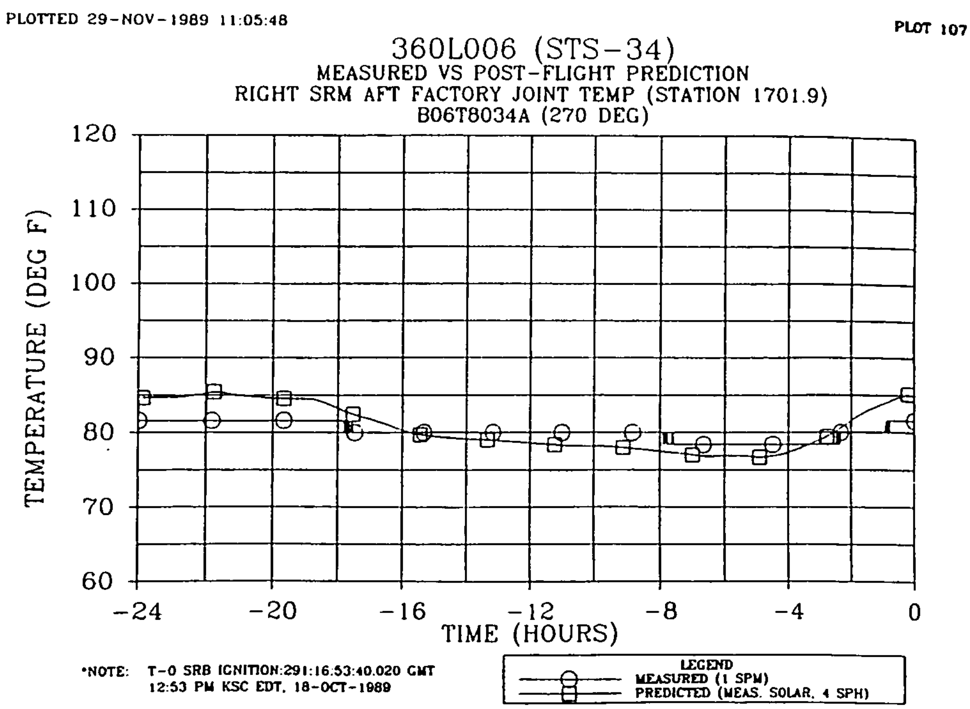

Figure 4-122. RH SRM Aft Factory Joint Temperature at Station 1701.9, B06T8034A (270-Deg) — Measured Versus Postflight Prediction

were not reported. The STI temperature measurements were used along with the GEI measurements to monitor SRM surface temperatures. Temperatures varied between about 76° and 80°F during the T-3-hr pad inspection for both STI and GEI temperatures.

4.8.3.7 Prelaunch Hardware Anomalies

a. **RH Center Field Joint Heater DWV Test Failure.** The requirement of the DWV test is that the heater and cabling exhibit no more than 1-mA current leakage when a 1,500-V electrical potential is applied element to element and element to shield. The RH center joint primary heater and cabling failed the 1-mA requirement when only 100 V was applied. This failure was far more severe than any experienced to date. Due to the severity of the failure, the heater was disabled by opening the circuit breaker to avoid inadvertent activation of the heater. Under no circumstance was the primary heater to be activated. The redundant heater passed the DWV test and was used in place of the primary heater during the launch. The redundant heater performed nominally during the launch countdown. Postflight evaluation of the primary heater showed that the reason for the DWV test failure was a 2900-ohm short between the primary heater and the heater shield. All heater cabling was functional.

b. **LH Forward Center Segment Heater Cabling Switch.** During the installation of the LH forward field joint heater cabling on the LH forward center segment, the primary and redundant heater cables were inadvertently switched. Due to the different connector pin clockings and close tolerances on length of exposed installation on the segment by laying them up in a serpentine fashion. To correct the improper installation, the K5NA closeout material was trimmed back from each end of the segment until enough of the serpentined cable was exposed to give the necessary slack to cross the cables. The cable connectors were then positioned in their correct orientation and the K5NA closeout reapplied. No electrical concerns were identified with the process. Both heaters passed the DWV test, and the LH forward field joint heater performed nominally during the countdown.

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-34. 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 reentry are for the most part overly conservative. An exception to this is the environment in the nozzle base region during reentry when hydrazine fires and excessive nozzle flame heating are present (see STS-29R final report, TWR-17542, Volume 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 is performing excellently and as expected. All TPS cork pieces (generally small) are due to nozzle severance debris and/or splashdown loads and debris.

During ascent film review, indications suggested that there are debris particles coming out of the SRM nozzle prior to separation. The likelihood of these being chunks of propellant and/or insulation is being investigated.

4.8.4.3 GEI Prediction. Additional model enhancement is recommended for certain motor regions in order to improve predictions. It should be noted, however, that the attainment of actual solar radiation data for the STS-28R and STS-34 flights have improved postflight predictions significantly. Submodel development effort for the areas of the ET attach ring, field joint, factory joint, systems tunnel, igniter, and nozzle regions is anticipated. These tasks would be encompassed by the global model. It is also recommended that all these models, including the three-dimensional SRM model, be made available for use at MSFC. This would allow Thiokol thermal personnel the opportunity to support launch countdowns at the HOSC with real-time PMBT, GEI, and component prediction updates. This would also allow MSFC thermal personnel the same modeling capabilities.

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

4.8.4.5 Local Chilling. Based on data from STS-28, STS-29R, and STS-30R local cooling does occur. Although no cooling effect was seen for the STS-34 flight due to the southerly wind direction, it is recommended that a method be developed to accurately quantify the chill effect.

4.8.4.6 Infrared Measurements. STI data continue to be much more reliable than infrared gun measurements. Comparisons with GEI are within acceptable margins for STI data, but are questionable and unpredictable for infrared 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).

4.8.4.7 Ice/Debris Team Support. Consideration should be given to provide consistency in the limited number of Thiokol personnel which support the ice/debris team from flight to flight. The present amount of team involvement should be maintained and built upon at opportune periods.

4.8.4.8 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 reentry are, for the most part, overly conservative. An exception to this is the environment in the nozzle base region during reentry when excessive nozzle flame heating and hydrazine fires are present (see STS-29R final report, TWR-17542, Volume I). USBI is in the process of obtaining updated thermal environments for the base region. However, follow-through needs to be made concerning the request.

4.9 Measurement System Performance (DFI)

(FEWG Report Para 2.9.5)

Motor set 360L006 did not have any DFI installed. This section is reserved pending any future motors that incorporate DFI.

4.10 Measurement System Performance

(FEWG Report Para 2.9.7)

4.10.1 Instrumentation Summary

Table 4-17 shows the location and number of instrumentation for 360L006. 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.

4.10.2 GEI/OFI Performance

The GEI instrumentation on flight set 360L006 consisted of 108 temperature sensors, RTDs which monitor motor case temperature while the motor 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 one exception. The LH center field joint heater sensor at 195-deg was damaged prior to the beginning of the SIT and provided no data during the countdown. One of the lead wires was severed during installation of the heater or the JPS. No LCC violation occurred due to this failure since only two of the four sensors per joint are required. (All GEI is disconnected by breakaway umbilicals at SRB ignition and is not operative during (flight). Tables 4-18 and 4-19 are the GEI list and include gages which consistently read differently from surrounding gages. Figures 4-15 through 4-19 show GEI/OFI locations.

The OFI consists of three OPTs on each forward dome. 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.

360L006A (LH)

Gage	Reading
B47P1300C	763.8
B47P1301C	759.8
B47P1302C	767.8

360L006B (RH)

Gage	Reading
B47P2300C	765.8
B47P2301C	759.8
B47P2302C	767.8

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 4-20 and Figure 4-16 list the joint heater sensors and show the gage locations, respectively.

4.10.4 S&A Device Rotation Times

Table 4-21 includes the arm and safe delta times for the S&A functional test performed prior to the STS-34 countdown. It can be seen that all values are less than the required 2.0 sec. Table 4-22 lists the arm and safe times during the actual launch sequence (at T-5 min). As was the case with the functional test, all values are less than 2.0 sec.

Table 4-17. 360L006 Instrumentation

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

*Includes igniter heater sensors

Table 4-18. GEI List—LH SRM (360L006A)

Instrument No.	Location (deg)	Station	Case Location
B06T7003A	270	534.5	Forward segment
B06T7004A	45	694.5	Forward segment
B06T7005A	135	694.5	Forward segment
B06T7006A	325	694.5	Forward segment
B06T7007A	270	694.5	Forward segment
B06T7008A	215	694.5	Forward segment
B06T7009A	90	778.98	Forward segment (systems tunnel)
B06T7010A	45	931.48	Forward center segment
B06T7011A	135	931.48	Forward center segment
B06T7012A	325	931.48	Forward center segment
B06T7013A	270	931.48	Forward center segment
B06T7014A	215	931.48	Forward center segment
B06T7015A	45	1091.48	Forward center segment
B06T7016A	135	1091.48	Forward center segment
B06T7017A	325	1091.48	Forward center segment
B06T7018A	270	1091.48	Forward center segment
B06T7019A	215	1091.48	Forward center segment
B06T7020A	90	1258.98	Aft center segment (systems tunnel)
B06T7021A	45	1411.48	Aft center segment
B06T7022A	135	1411.48	Aft center segment
B06T7023A	325	1411.48	Aft center segment
B06T7024A	270	1411.48	Aft center segment
B06T7025A	215	1411.48	Aft center segment
B06T7026A	220	1511	ET attach ring
B06T7027A	274	1511	ET attach ring
B06T7028A	320	1511	ET attach ring
B06T7029A	45	1535	Aft segment
B06T7030A	135	1535	Aft segment
B06T7031A	90	1565	Aft segment (systems tunnel)
B06T7032A	30	1701.86	Aft segment
B06T7033A	150	1701.86	Aft segment
B06T7034A	270	1701.86	Aft segment
B06T7035A	45	1751.5	Aft segment
B06T7036A	135	1751.5	Aft segment
B06T7037A	325	1751.5	Aft segment
B06T7038A	270	1751.5	Aft segment
B06T7039A	215	1751.5	Aft segment
B06T7040A	30	1821	Aft segment
B06T7041A	150	1821	Aft segment
B06T7042A	270	1821	Aft segment
B06T7043A	0	1847	Flex bearing
B06T7044A	0	1845	Nozzle throat
B06T7045A	120	1847	Flex bearing
B06T7046A	120	1845	Nozzle throat
B06T7047A	240	1847	Flex bearing
B06T7048A	240	1845	Nozzle throat
B06T7049A	0	1876.6	Case-to-nozzle joint
B06T7050A	120	1876.6	Case-to-nozzle joint
B06T7051A	240	1876.6	Case-to-nozzle joint
B06T7052A	0	1950	Exit cone
B06T7053A	120	1950	Exit cone
B06T7054A	240	1950	Exit cone
B06T7085A	184.5	486.4	Igniter
B06T7086A	355.5	486.4	Igniter

Note: Range = ±200°F

Table 4-19. GEI List—RH SRM (360L006B)

Instrument No.	Location (deg)	Station	Case Location
B06T8003A	270	534.5	Forward segment
B06T8004A	135	694.5	Forward segment
B06T8005A	45	694.5	Forward segment
B06T8006A	215	694.5	Forward segment
B06T8007A	270	694.5	Forward segment
B06T8008A	325	694.5	Forward segment
B06T8009A	90	778.98	Forward segment (systems tunnel)
B06T8010A	135	931.48	Forward center segment
B06T8011A	45	931.48	Forward center segment
B06T8012A	215	931.48	Forward center segment
B06T8013A	270	931.48	Forward center segment
B06T8014A	325	931.48	Forward center segment
B06T8015A	135	1091.48	Forward center segment
B06T8016A	45	1091.48	Forward center segment
B06T8017A	215	1091.48	Forward center segment
B06T8018A	270	1091.48	Forward center segment
B06T8019A	325	1091.48	Forward center segment
B06T8020A	90	1258.98	Aft center segment (systems tunnel)
B06T8021A	135	1411.48	Aft center segment
B06T8022A	45	1411.48	Aft center segment
B06T8023A	215	1411.48	Aft center segment
B06T8024A	270	1411.48	Aft center segment
B06T8025A	325	1411.48	Aft center segment
B06T8026A	320	1511	ET attach ring
B06T8027A	266	1511	ET attach ring
B06T8028A	220	1511	ET attach ring
B06T8029A	135	1535	Aft segment
B06T8030A	45	1535	Aft segment
B06T8031A	90	1565	Aft segment (systems tunnel)
B06T8032A	150	1701.86	Aft segment
B06T8033A	30	1701.86	Aft segment
B06T8034A	270	1701.86	Aft segment
B06T8035A	135	1701.86	Aft segment
B06T8036A	45	1751.5	Aft segment
B06T8037A	215	1751.5	Aft segment
B06T8038A	270	1751.5	Aft segment
B06T8039A	325	1751.5	Aft segment
B06T8040A	150	1821	Aft segment
B06T8041A	30	1821	Aft segment
B06T8042A	270	1821	Aft segment
B06T8043A	180	1847	Flex bearing
B06T8044A	180	1845	Nozzle throat
B06T8045A	60	1847	Flex bearing
B06T8046A	60	1845	Nozzle throat
B06T8047A	300	1847	Flex bearing
B06T8048A	300	1845	Nozzle throat
B06T8049A	180	1876.6	Case-to-nozzle joint
B06T8050A	60	1876.6	Case-to-nozzle joint
B06T8051A	300	1876.6	Case-to-nozzle joint
B06T8052A	180	1950	Exit cone
B06T8053A	60	1950	Exit cone
B06T8054A	300	1950	Exit cone
B06T8085A	355.5	486.4	Igniter
B06T8086A	184.5	486.4	Igniter

Note: Range = ±200°F

Table 4-20. Field Joint Heater Temperature Sensor Lists (both motors)

Instrument No.	Location (deg)	Station	Case Location
LH SRM			
B06T7060	15	851.5	Forward heater
B06T7061	135	851.5	Forward heater
B06T7062	195	851.5	Forward heater
B06T7063	285	851.5	Forward heater
B06T7064	15	1171.5	Center heater
B06T7065	135	1171.5	Center heater
B06T7066	195	1171.5	Center heater
B06T7067	285	1171.5	Center heater
B06T7068	15	1491.5	Aft heater
B06T7069	135	1491.5	Aft heater
B06T7070	195	1491.5	Aft heater
B06T7071	285	1491.5	Aft heater
RH SRM			
B06T8060	15	851.5	Forward heater
B06T8061	135	851.5	Forward heater
B06T8062	195	851.5	Forward heater
B06T8063	285	851.5	Forward heater
B06T8064	15	1171.5	Center heater
B06T8065	135	1171.5	Center heater
B06T8066	195	1171.5	Center heater
B06T8067	285	1171.5	Center heater
B06T8068	15	1491.5	Aft heater
B06T8069	135	1491.5	Aft heater
B06T8070	195	1491.5	Aft heater
B06T8071	285	1491.5	Aft heater

Note: Range = ±200°F
Required accuracy = ±1%
Digital = 1 (sampling rate is given in samples per minute)

4.11 RSRM Hardware Assessment
(FEWG Report Para 2.11.2)

4.11.1 Insulation Performance

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

4.11.1.2 External Insulation

a. **Factory Joint Weatherseals.** Two of the fourteen factory joint weatherseals showed signs of edge unbonds. No evidence of sooting or heat effects was found under any of these unbonds. The weatherseals on the remaining factory joints performed satisfactorily. All K5NA closeouts over weatherseal thermocouple leads were intact with no evidence of bondline failure.

Table 4-21. Ignition S&A Functional Test

ROTATE #	GMT	COMMAND	GMT	RESPONSE	DELTA	LH	RH	LH	RH
	224350.043	B55K3000X1-LH [illegible]	224351.[illegible]	[illegible]X1-LH ARM	0.986	0.986			
1	224350.283	B55K4000X1-RH [illegible]	224351.[illegible]	[illegible]X1-RH ARM	0.867		0.867		
	224357.523	B5[illegible]3002X1-LH SAFE	224358.4[illegible]	B55X1843X1-LH SAFE	0.906			0.906	
	224357.763	B55K4002X1-RH SAFE	224358.749	B55X2843X1-RH SAFE	0.936				0.[illegible]96
	224644.843	B55K3000X1-LH ARM	224645.630	B55X1842X1-LH ARM	0.787	0.787			
2	224645.083	B55K4000X1-RH ARM	224645.949	B55X2842X1-RH ARM	0.866		0.866		
	224652.443	B55K3002X1-LH SAFE	224653.229	B55X1843X1-LH SAFE	0.786			0.786	
	224652.684	B55K4002X1-RH SAFE	224653.549	B55X2843X1-RH SAFE	0.865				0.865
	224739.123	B55K3000X1-LH ARM	224740.029	B55X1842X1-LH ARM	0.906	0.906			
3	224739.363	B55K4000X1-RH ARM	224740.349	B55X2842X1-RH ARM	0.986		0.986		
	224746.883	B55K3002X1-LH SAFE	224747.629	B55X1843X1-LH SAFE	0.746			0.746	
	224747.123	B55K4002X1-RH SAFE	224747.950	B55X2843X1-RH SAFE	0.827				0.827
	224813.363	B55K3000X1-LH ARM	224814.229	B55X1842X1-LH ARM	0.866	0.866			
4	224813.643	B55K4000X1-RH ARM	224814.549	B55X2842X1-RH ARM	0.906		0.906		
	224820.963	B55K3002X1-LH SAFE	224821.829	B55X1843X1-LH SAFE	0.866			0.866	
	224821.203	B55K4002X1-RH SAFE	224822.149	B55X2843X1-RH SAFE	0.946				0.94[illegible]
	224853.163	B55K3000X1-LH ARM	224854.029	B55X1842X1-LH ARM	0.866	0.866			
5	224853.403	B55K4000X1-RH ARM	224854.349	B55X2842X1-RH ARM	0.946		0.946		
	224900.763	B55K3002X1-LH SAFE	224901.630	B55X1843X1-LH SAFE	0.867			0.86[illegible]	
	224901.003	B55K4002X1-RH SAFE	224901.750	B55X2843X1-RH SAFE	0.747				0.747
	224942.763	B55K3000X1-LH ARM	224943.629	B55X1842X1-LH ARM	0.866	0.866			
	224943.003	B55K4000X1-RH ARM	224943.750	B55X2842X1-RH ARM	0.747		0.747		
	[illegible]4950.163	B55K3002X1-LH SAFE	224951.029	B55X1843X1-LH SAFE	0.866			0.866	
	224950.403	B55K4002X1-RH SAFE	224951.149	B55X2843X1-RH SAFE	0.746				0.746
	225006.123	B55K300[illegible]X1-LH ARM	225006.829	B55X1842X1-LH ARM	0.706	0.706			
7	225006.363	B55K4000X1-RH ARM	225007.149	B55X2842X1-RH ARM	0.786		0.786		
	225013.563	B55K3002X1-LH SAFE	225014.429	B55X1843X1-LH SAFE	0.866			0.866	
	225013.803	B55K4002X1-RH SAFE	225014.549	B55X2843X1-RH SAFE	0.746				0.746
	225028.843	B55K3000X1-LH ARM	225029.629	B55X1842X1-LH ARM	0.785	0.786			
8	225029.083	B55K4000X1-RH ARM	225029.950	B55X2842X1-RH ARM	0.867		0.867		
	225036.323	B55K3002X1-LH SAFE	225037.029	B55X1843X1-LH SAFE	0.706			0.706	
	225036.564	B55K4002X1-RH SAFE	225037.350	B55X2843X1-RH SAFE	0.786				0.786
	225048.323	B55K3000X1-LH ARM	225049.029	B55X1842X1-LH ARM	0.706	0.706			
9	225048.564	B55K4000X1-RH ARM	225049.350	B55X2842X1-RH ARM	0.786		0.786		
	225055.724	B55K3002X1-LH SAFE	225056.429	B55X1843X1-LH SAFE	0.705			0.705	
	225055.964	B55K4002X1-RH SAFE	225056.749	B55X2843X1-RH SAFE	0.785				0.785
	225112.684	B55K3000X1-LH ARM	225113.429	B55X1842X1-LH ARM	0.745	0.745			
10	225112.924	B55K4000X1-RH ARM	225113.749	B55X2842X1-RH ARM	0.825		0.825		
	225120.084	B55K3002X1-LH SAFE	225120.830	B55X1843X1-LH SAFE	0.746			0.746	
	225120.324	B55K4002X1-RH SAFE	225121.150	B55X2843X1-RH SAFE	0.826				0.826
				AVERAGE :		0.822	0.859	0.806	0.826

H. Sheppard
6 Oct 89

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Table 4-22. S&A Device Activity Times for 360L006 (STS-34R)

18 Oct 1989 (at T-5 min)	
Rotation times (arm command to arm indication)	LH 0.888 sec*
	RH 0.969 sec*

*The data sample rate is five times per second; therefore, the actual rotation times could be ±0.20 sec

Two unbonds were identified on the aft edge of the weatherseal on the LH forward segment cylinder-to-cylinder factory joint. At 0 deg, the unbond measured 6.6 in. circumferentially and extended to a maximum depth of 1.75 inches. Water was leaking from this unbond and corrosion was observed on the case under the unbond. At 45 deg, an unbond was observed which measured 2.0 in. circumferentially and extended to a maximum depth of 0.75 inch. No leakage or rust was observed at this unbond. Both unbonds on this factory joint failed adhesively between the Chemlok 205 and the case.

One unbond was observed on the forward edge of the weatherseal on the LH forward segment dome-to-cylinder factory joint. This unbond was located from 225 to 248 deg and measured 28.5 in. circumferentially to a maximum depth of 2.05 inches. This unbond also showed adhesive failure between the Chemlok 205 and case. Paint was peeled up from the case and attached to the edge of the weatherseal intermittently along the unbond.

Corrective actions taken to alleviate the unbond problem are:

- Additional conscan and surface finish inspections have been added
- All pin retainer band cleaning will be done before assembly to eliminate potential contaminants
- An investigative team has been established to further assess problem

b. **Stiffener Stubs and Rings.** The insulation over the stiffener stubs and rings was in good condition. The EPDM was well bonded to the stiffener stubs and appeared to be well bonded to the stiffener rings.

4.11.1.3 Nozzle-to-Case Joints. Based on the visual evaluation, both nozzle-to-case joints performed well. No gas paths through the polysulfide adhesive or any other anomalous conditions were identified. The disassembled joints showed the failure mode was 95 percent cohesive in the polysulfide, 5 percent adhesive failure to the fixed housing phenolic on the LH motor. On the RH motor, the failure mode was 100 percent adhesive to the nitrile butadiene rubber (NBR). Inadequate prefire NBR surface preparation was evident on the RH motor. This failure mode did not affect joint function. One void was identified in the polysulfide adhesive on the LH nozzle-to-case joint, measuring 1.5 in. longitudinally by 0.5 in. circumferentially. The polysulfide vent slot fill on these motors was 38 and 57 percent for the LH and RH motors, respectively. One insulation-to-case unbond was noted at the nozzle boss of the LH motor. The unbond occurred in a prefire repair area and measured 2.3 in. circumferentially by 0.23 in. deep.

4.11.1.4 Field Joints. All of the case field joint insulation was in good condition with uniform erosion and heat effects. Good adhesive contact was evident on all field joints. Wet sooting observed outboard from the remaining material on the tang and clevis, due to splashdown, ranged from 0.0 to 1.40 inches. Probing of the clevis insulation bondline revealed no unbonds exceeding the 0.30-in. depth postfire engineering evaluation limits requirement. The maximum observed unbond was 0.22 in. deep, identified on the RH center field joint. Some tang edge separations were visible; however, measurements and further evaluation will be conducted at the Clearfield H-7 facility.

Intermittent crazing/cracking was noted on the radius region on the clevis insulation of the RH forward center segment, measuring approximately 2.0 in. circumferentially. Evaluation showed there was no measurable depth to the crazing/cracks and the condition had no adverse effect on the performance of the joint. No other crazing/cracking was observed on any other joint. Further evaluation will be conducted at the Clearfield H-7 facility.

All NBR inhibitors and stress relief flaps performed as expected with no abnormal erosion or tears.

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, adapter-to-igniter chamber at 70 deg was present. The blowhole measured 0.85 in. circumferentially at its widest point. A blowhole was also observed through the putty of the RH igniter, adapter-to-igniter chamber joint at 0-deg. The blowhole measured 0.45 in. circumferentially at its widest location. No soot was visible on either inner gasket.

Minor insulation flashing was observed on the igniter boss on LH forward dome.

4.11.1.6 Internal Acreage Insulation. Blisters were noted in the carbon fiber-filled (CF)/EPDM of the aft dome region on both motors intermittently around the circumference. The largest blister occurred at 0 deg on the RH aft dome insulation and measured approximately 4.5 in. circumferentially by 5.5 in. axially. The material was separated between plies of virgin insulation. A sample of the CF/EPDM was taken for further analysis where the worst blistering occurred. The overall appearance indicated there was normal erosion with no pocketing and no problem with thermal safety factors.

No abnormal erosion or unusual conditions were noted for the remainder of the internal acreage insulation. Insulation depth measurements and samples were taken from the forward domes of both motors. Initial evaluation revealed no major voids or thin areas. Further evaluation will be conducted at the Clearfield H-7 facility.

4.11.2 Case Component Performance

4.11.2.1 Summary. Evaluation of the steel case indicated the hardware performed as expected during flight. Complete case evaluation results are in Volume II of this report.

4.11.2.2 Stiffener Stubs, Stiffener Rings, and ET Attach Stubs. The stiffener rings and case stubs sustained typical water impact damage. Ten bolts were missing from the LH center stiffener ring assembly, six from the LH aft stiffener ring assembly, and eight from the RH center stiffener ring assembly.

The LH 90- to 210-deg center stiffener ring section had deformed holes from 188 to 208 deg. No cracks or warpage were found. The LH 210- to 330-deg center stiffener ring had one deformed hole at 212 deg. The LH 90- to 210-deg aft stiffener ring section had web cracks at 192 and 206 deg and a web buckle at 193 deg. All other stiffener rings on the LH motor were in good condition. Slight warpage of the LH aft stub was also found at 192 and 194 deg. No outer or inner ligament cracks were found in any of the stubs.

The RH 330- to 90-deg center stiffener ring had a web crack for 40 to 44 deg. All other stiffener rings on the RH motor were in good condition. Three elongated bolt holes were found on the RH center stub between 34 and 38 deg.

Pieces of stiffener ring Insta-Foam were missing on all rings. These were predominantly outboard locations due to splashdown loads, leaving clean substrates. Cracks in the K5NA underneath the foam due to impact damage were noted on the LH aft stiffener ring and both center stiffener rings.

Based on missing Insta-Foam, the cavity collapse load centerlines for the RH and LH motors were estimated to be at 30 and 210 deg, respectively.

4.11.2.3 Field Joints. The case field joint surface conditions were as expected. Fretting ranged from light on most joints to locally heavy on three joints, with the RH aft field joint being the worst (deepest pit was 0.010 in. at 240 deg and a 0.006-in. deep pit at 246 deg. Fretting was moderate from 185 to 202 deg). Figure 4-123 provides a subjective summary of the fretting.

Corrosion pitting was observed on the inner clevis leg inner diameter in the capture feature seal area on the RH center and aft field joints intermittently from 220 to 300 deg. The maximum pit depth was 0.003 inch. Pitting was also observed on the LH center tang field joint inner diameter lead-in ramp at 280 deg.

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

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

4.11.3 Seal Performance

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

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

4.11.3.3 Exit Cone Field Joint. All exit cone field joint components on both motors were in good condition. The O-rings were free from erosion, heat effect, or any other damage, and the sealing surfaces and O-ring glands were devoid of soot, debris, or damage. The grease condition was nominal. Light intermittent oxidation was observed on the forward face of both aft exit cones between the O-ring grooves. All other metal surfaces were in good condition.

4.11.3.4 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 was obstructed by the V-2 filler. The grease application was nominal.

4.11.3.5 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 but there was no soot observed on them. 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.

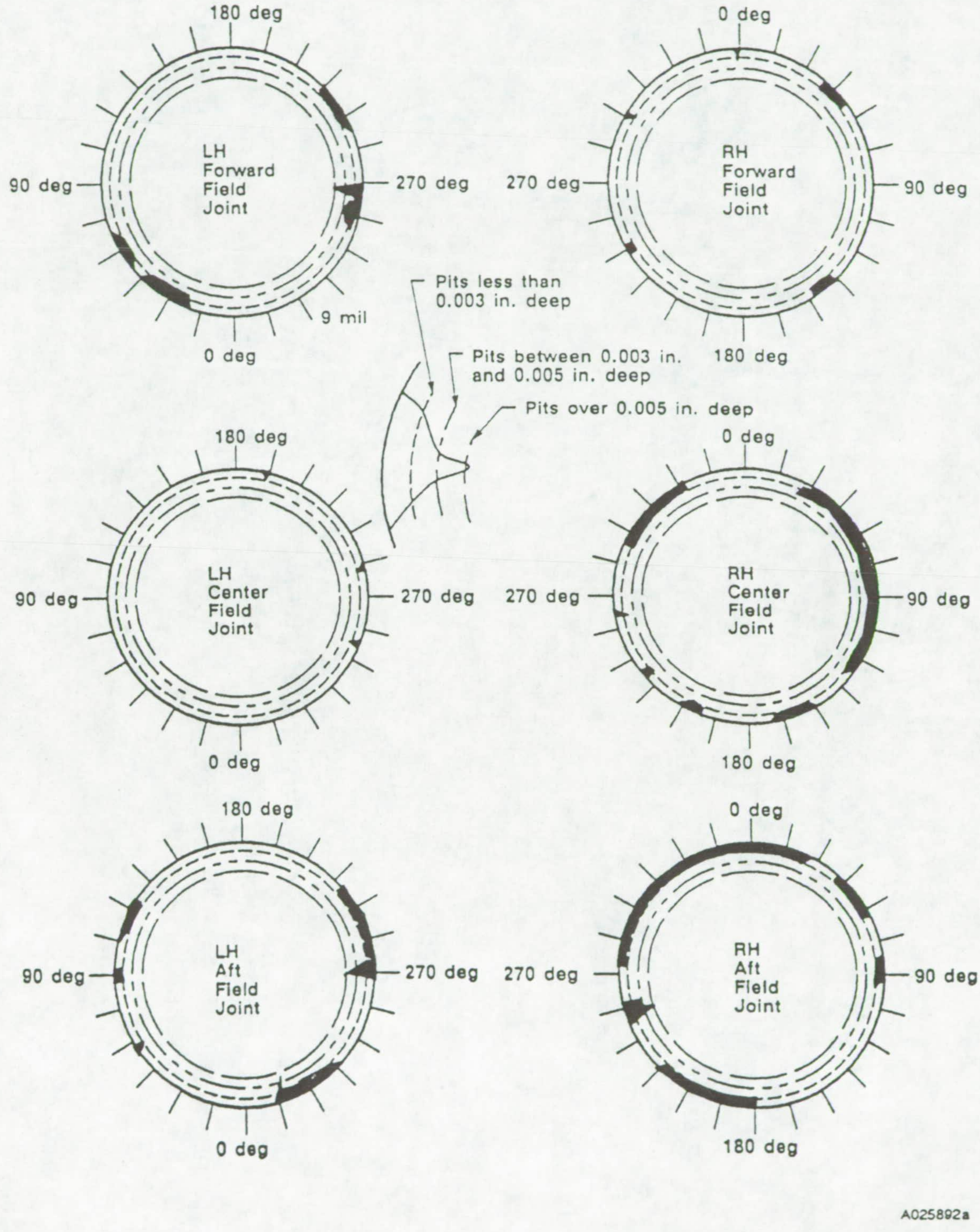

Figure 4-123. Overall Field Joint Fretting Observations

4.11.3.6 Ignition System Joint. The seals of the S&A and igniter outer and inner gasket seals revealed no erosion or heat effect. Pressure did not reach either inner or outer gasket on the LH or RH motors.

Soot was found on the inside diameter (ID) edge of the LH S&A gasket. Soot was found up to the primary seal on the RH S&A gasket from 15 to 25 deg.

Putty was observed up to and in the primary seal void region on the RH outer igniter gasket aft side. A problem report was written against this condition and was elevated to an IFA (STS-34-M-3). Tighter putty layup and igniter installation controls have been implemented based on recent tests performed at Thiokol. A corrective action implementing these improved processes has already been implemented on STS-33 and STS-32 at KSC, and was also implemented on STS-36 and subsequent igniter installations at Thiokol. The RH outer gasket had one small depression on the primary seal forward face at 306 deg. The environmental seal was torn from 175 to 330 deg. The RH inner gasket had one small depression at 160 deg on the aft face inner primary seal. Medium corrosion was also noted on the forward face of the retainer.

Putty was present on the aft face of the LH outer gasket from 261 to 297 deg, extending to a maximum radial distance of 0.11 in. inboard of the ID edge. This gasket also had three small depressions on the aft face of the secondary seal. The forward face had one small nick and a depression on it. The environmental seal was torn intermittently.

The LH and RH igniter inner joint Stat-O-Seals were in good condition. Only one Stat-O-Seal was torn due to disassembly.

4.11.3.7 Nozzle-to-Case 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 wiper O-rings. The LH and RH nozzle-to-case joint Stat-O-Seals were in good condition.

4.11.3.8 Vent Port Plugs. The case field joint and nozzle-to-case joint vent port plugs and seals on each motor were in excellent condition. One out of eight vent port plugs showed typical primary O-ring extrusion damage caused by assembly. The remaining seven primary O-rings had extrusion impressions. The vent port plug O-rings showed no evidence of heat effect. The fluorocarbon O-rings, glands, and metal surfaces of the plugs were free of soot, debris, and corrosion.

4.11.3.9 Leak Check Port Plugs. The leak check port plugs and seals on the LH and RH motors in the case field joints, nozzle-to-case 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, although splashdown loads tore the 45-deg LH actuator bracket from the aft exit cone shell. Phenolic erosion was smooth and normal. Complete evaluation is in Volume V of this report.

4.11.4.2 360L006A (LH) Nozzle

a. **Aft Exit Cone.** The aft exit cone was severed by the linear-shaped charge (LSC) during parachute descent. The radial cut through the glass-cloth phenolic (GCP) appeared nominal, with no anomalies observed. Some carbon-cloth phenolic (CCP) liner was missing and portions of the GCP insulator were torn and delaminated. These are typicalp postflight observations, and occur during exit cone severance and at splashdown. The exposed GCP plies showed no signs of heat effect.

The only observation outside the RSRM nozzle experience was the detached nozzle rock (45-deg) actuator bracket. Splashdown loads caused part of the bracket to remain with the actuator rod end and remnants of the bracket were left on the compliance ring. Part of the aluminum aft exit cone shell and part of a GCP layer remained attached to the bracket. The remaining 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.

There were no separations between the polysulfide and the aft exit cone shell observed. Postflight measurements of the polysulfide groove radial width showed that the GCP insulator did not pull away from the aluminum shell during cooldown.

The room temperature vulcanization (RTV) backfill was below the joint charline 360 deg circumferentially. An RTV void was found at 93.8 deg. There were no blowpaths to the void area. Void size was about 1.0 in. circumferentially by 0.4 in. axially.

b. **Forward Exit Cone Assembly.** The CCP liner was intact and showed smooth erosion for the forward 15 inches. Moving aft, the next 5 in. had missing CCP, but no heat effect to the GCP. The aft 14 in. had CCP intact with typical dimpled erosion approximately 0.1 in. deep radially.

c. **Throat Assembly.** Erosion of the throat and throat inlet rings was smooth and uniform, with no wedgeouts or popups.

d. **Nose Inlet Assembly.** The nose cap had minor wash areas on the forward 12 in. (0.05 in. deep radially). The rest of the nose cap had smooth erosion, except for postburn, popped-up, charred CCP on the aft 2.3 in. intermittently around the circumference. There were also postburn wedgeouts on the aft 2 in. at 20 to 105 and 300 to 360 (zero) deg, with a 0.7-in. radial depth.

The -503 ring had smooth erosion and intermittent minor impact marks, typically 0.3 in. in diameter and 0.05 in. deep. The -504 ring had smooth erosion, no impact marks, and no wedgeouts or popups.

e. **Cowl Ring.** The cowl ring showed the typical ridged erosion (0.06 in. deep). This is due to the low ply angle. A postburn wedgeout of charred CCP was observed along the entire length of the cowl (about 7 in.) from 20 to 60 deg. It had a radial depth of 0.7 inch. Postburn wedgeouts were found on the aft 2.5 in. from 0 to 70 deg (1.3 in. radially), 70 to 140 deg (0.7 in. radially), and 160 to 360 (zero) deg (0.8 in. radially).

The cowl/outer boot ring (OBR) bondline broke during splashdown. The gap between the two rings measured least at 0 deg (0.06 in.) and most at 225 deg (0.58 in.)

f. **Outer Boot Ring.** The OBR had postburn wedgeouts on the forward 1.6 in. of the ring from 50 to 67, 190 to 228, 245 to 276, and 316 to 344 deg. They were 0.7 in. deep radially. There were typical postburn delaminations in the aft end along the 35-deg ply wraps. These were 0.6 to 1.9 in. deep axially. The aft tip adjacent to the flex boot was typically fractured and wedged out.

g. **Fixed Housing Assembly.** The fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing CCP showed typical postburn wedgeouts of charred CCP intermittently around the circumference. The maximum radial depth of the wedgeouts was 0.5 inch.

4.11.4.3 360L006B (RH) Nozzle

a. **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. Some of the CCP liner was missing and portions of the GCP insulator were torn and delaminated due to splashdown and exit cone severance. The exposed GCP plies showed no signs of heat effect.

The 45- and 135-deg actuator brackets showed minor paint scratches resulting from actuator removal. The primer remained intact and there was no metal damage or loose bolts observed.

There were no observed separations between the polysulfide and the aft exit cone shell. Postflight measurements of the polysulfide groove radial width showed the GCP insulator did not pull away from the aluminum shell during cooldown.

The RTV backfill was below the joint charline 360 deg circumferentially. An RTV void was found at 202 deg. A white residue was found on the forward exit cone CCP at this location. Laboratory analysis is under way. There were no blowpaths to the void area. Void size was about 1.4 in. circumferentially by 0.35 in. axially.

b. **Forward Exit Cone Assembly.** The CCP was intact with smooth erosion for the forward 14 inches. Moving aft, the next 6 to 7 in. had CCP missing, but no heat effect to the GCP. The aft 14 in. had CCP intact with typical dimpled erosion 0.1 in. deep. A wedgeout was observed from 10 to 75 deg. It was located 7 in. from the aft edge of the forward exit cone and measured 3.5 in. axially.

c. **Throat Assembly.** Erosion of the throat assembly was smooth and uniform, with no wedgeouts observed. The center 3 in. of the throat ring had typical dimpled erosion (0.05 in. radial depth).

d. **Nose Inlet Assembly.** The nose cap had minor wash areas on the forward 12 in. (0.05 in. deep radially). Slag deposits were noted on the forward 18 in. from 325 to 35 deg (through zero). A postburn impact mark on the outer diameter at 63 deg measured 1.5 in. axially by 1 in. circumferentially by 0.25 in. radially. Another postburn impact mark at 47 deg and 4.5 in. from the aft end measured 1 in. axially by 2 in. circumferentially by 0.1 in. radially. Postburn wedgeouts of charred CCP were found on the aft 2 in. at 20 to 45, 68 to 181, 220 to 262, 283 to 300, and 310 to 350 deg.

The -503 ring had smooth erosion and a large number of impact marks, typically 0.2 to 0.3 in. in diameter and 0.05 to 0.1 in. deep. Some marks had slag in them. One impact mark at 210 deg was 2.1 in. circumferentially, 0.45 in. axially, and 0.09 in. radially, and also had slag. The -504 ring had smooth erosion and a postburn wedgeout at 165 to 170 deg on the forward end. It measured 6.0 in. circumferentially, 0.2 in. axially, and 0.95 in. radially.

e. **Cowl Ring.** The cowl ring showed the typical ridged erosion (0.1 in. deep) on the forward 5 inches. Wedgeouts were found on the aft 2.6 in. at 70 to 90, 100 to 160, and 230 to 260 deg. They were 0.8 in. radially. The cowl/OBR bondline was intact and measured 0.12 in.

f. **Outer Boot Ring.** The OBR had one wedgeout from 230 to 250 deg on the forward end measuring 1.7 in. circumferentially and 0.77 in. deep radially. Typical postburn delaminations were found in the aft end along the 35-deg ply wraps, and were 0.5 in. deep. The aft tip adjacent to the flex boot was typically fractured and wedged out.

g. **Fixed Housing Assembly.** The fixed housing insulation erosion was smooth and uniform. The forward 2 in. of the fixed housing CCP showed typical postburn wedgeouts of charred CCP intermittently around the circumference. The maximum radial depth of the wedgeouts was 0.5 inch.

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