ISS TEST DESCRIPTION AND ANALYSIS

JDC's 00050, 00051, 15053, 15057, 00059, and 00060

TEMPERATURE CONTROL TESTS

1. SCOPE

This document is intended to complement and support the Block I-100 ISS Temperature Control Tests released with ATP 1015497. Described herein are the reason for the test, description of test procedures, derivation of tolerances, and possible effects of ground support equipment.

2. APPLICABLE DOCUMENTS

XDE 34-S-516	Preliminary Performance Specification, Apollo IMU Temperature Control System, Block I Systems
XDE 34-T-25	Design Criteria for the Temperature Monitor and Control (Apollo Series 100 Ground Support Equipment)
XDE 34-T-44	Signal Identification and Test Point Location for Series 100, Block II and LEM GSE
AP-M No. 4792	Block I Temperature Control - ISS Testing
JDC 09202	Heater Control Calibration (Part of ATP 1000001)
FON-AT-65-66	Temperature Loop Investigation at ACSP/NAA ETR 022
FON-AT-65-134	ETR 022 Report
AP-M No. 7648	TMC Monitor Meter Error Analysis
AP-M No. 8839	Analysis - Proportional, Backup and Emergency ISS Operate Temperature Control Data
AP-M No. 7937	ISS Backup Operate Temperature Control JDC Limits
SK-47527	Apollo - GSE Signal Monitoring Flow Diagrams, Series 100 GSE and Series 100 Airborne
SK-47514	Apollo - GSE Auxiliary Heat Control (Series 100)
SK-47515	Apollo - GSE PSA Heat Control (Series 100)
SK-47516	Apollo - GSE Temperature Monitor Circuits (Series 100)

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SK-47517	Apollo - GSE Temperature Monitor Alarm Circuits (Series 100)
1010039	Apollo IMU Temperature Control System Schematic Block I
1017510	Apollo IMU Temperature Control System, Block I Two-Wire Mechanization
1901997	Temperature Monitor and Control Schematic Diagram
ND 1002213	Design Criteria Specification for Apollo Ground Support Equipment.

3. PURPOSE OF TESTS

3.1 JDC 00050. IRIG INDICATING CIRCUITRY TESTS

The purpose of this JDC is to verify the accuracy of the IRIG temperature indicating circuitry in the PSA and to determine its error with specified inputs. The IRIG fail circuitry is also exercised, and the fail temperatures determined.

3.2 JDC 00051. PIP INDICATING CIRCUITRY TESTS

The purpose of this JDC is to verify the accuracy of the accelerometer temperature indicating circuitry and to determine its error with specified inputs. The accelerometer fail circuitry is also exercised, and the fail temperatures determined.

3.3 JDC 15053. TEMPERATURE CONTROL AND CIRCUITRY TESTS

The first part of this JDC is identical to JDC's 00050 and 00051 above. When JDC 15053 is performed, JDC's 00050 and 00051 need not be performed. In addition, this JDC is used to adjust the temperature of the accelerometers to 130.0°F. in PROPORTIONAL OPERATE, and to determine the IRIG and accelerometer temperatures during BACKUP, and EMERGENCY OPERATE.

3.4 JDC 15057. STANDBY AND OPERATE TEMPERATURE CONTROL TESTS

The purpose of this JDC is to make functional checks in BACKUP and PROPORTIONAL, while in STANDBY, and to observe and record the temperatures. The inertial component temperature response is then determined by switching from STANDBY to OPERATE in the PROPORTIONAL Mode. The temperature is recorded after 15 minutes, 30 minutes and 90 minutes. Checks are then made in BACKUP, EMERGENCY, and AUTO-OVERRIDE while in OPERATE.

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3.5 JDC 00059. HIGH POWER CONDITION TEST

The purpose of this JDC is to test the IMU temperature control system in PROPORTIONAL and BACKUP, while in OPERATE, with the coolant lowered from 45°F. to 30°F., thereby increasing the temperature control system heat requirements.

3.6 JDC 00060. LOW POWER CONDITION TEST

The purpose of this JDC is to test the IMU temperature control system in PROPORTIONAL, BACKUP and EMERGENCY, while in OPERATE, with the coolant raised from 45°F. to 90°F., thereby decreasing the temperature control system heat requirements.

4. <u>TEST PROCEDURE</u>

4.1 TEST CONFIGURATION

The IMU is mounted on the test stand in the ISS configuration for which the GSE mechanization is as shown in SK Drawings 47527, 47514, 47515, 47516 and 47517. The temperature control modes and tests are controlled by the Temperature Monitor and Control Panel (TMC) described in XDE 34-T-25 and Schematic 1901997. The TMC front panel layout is shown in ND 1002213. The operation of the airborne temperature control is described in XDE 34-S-516. Airborne temperature control circuitry is illustrated on Schematic 1017510.

4.2 DESCRIPTION OF PROCEDURE

4.2.1 JDC 00050

This JDC contains a procedure for testing the accuracy of the IRIG temperature indicating amplifier and its associated circuitry, and for determining the average IRIG temperature at which an IMU temperature fail indication would be detected and produced by the alarm detection circuitry in the PSA. The Inertial Subsystem is placed in STANDBY with temperature control maintained by the GSE TMC panel (AUX HTR PWR) through use of the IRIG control sensors. The PROPORTIONAL temperature control mode is used. Various resistance values are then substituted into the IRIG indicating bridge which simulate the resistance of the IRIG indicating sensors at 133.5°F., 128.5°F., and 138.5°F., and the response of the IRIG indicating circuitry is determined. The output of the IRIG indicating amplifier is monitored on the IRIG TEMP meter on the TMC panel which is calibrated to indicate +5° and -5° deviation from the nominal IRIG temperature of 133.5°F. The MONITOR METER is also used to determine this temperature directly from the IRIG indicating bridge unbalance. The final portion of this JDC specifies substitution of a potentiometer into the IRIG indicating bridge that has the capability of simulating sensor resistances at temperatures from 122.5°F. to 138.5°F. By varying this potentiometer and observing the indicated temperature on the IRIG TEMP meter or on the MONITOR METER, the temperature at which a high or low IRIG temperature would cause an alarm can be determined.

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4.2.2 JDC 00051

This JDC contains a procedure for testing the accuracy of the accelerometer temperature indicating amplifier and its associated circuitry, and for determining the average accelerometer temperature at which an IMU temperature fail indication would be detected and produced by the alarm detection circuitry in the PSA. Procedures of this JDC are similar to 00050, above, except that selected resistance values are now substituted for the accelerometer temperature indicating sensors to simulate accelerometer temperatures of 130°F., 125°F., and 135°F. A potentiometer is used to simulate accelerometer temperatures ranging from 122.9°F. to 137.1°F. in order to test the alarm circuitry.

4.2.3 JDC 15053

The procedures contained in the first part of this JDC are identical to those contained in JDC's 00050 and 00051 which verify the operation and accuracy of the IRIG and accelerometer indicating and alarm circuitry prior to performing other temperature control tests.

As part of the preparation for performing operational temperature control tests, the IMU gimbals are set to 0° ± 1°, and the table is set to 0° tilt angle (Ø), and 60° rotary angle (Θ). This places the X input axis West, the Y input axis North, and the Z input axis down. These conditions are established in order to minimize the effects of changes in gimbal angles on inertial component temperatures, permitting better correlation of test results.

The average indicated accelerometer temperature is set to 130.0°F. ± 0.1°F. as indicated on the MONITOR METER by adjusting the temperature set pot control in Tray 7 after the inertial component temperatures have been allowed to stabilize in ISS OPERATE and in the PROPORTIONAL temperature control mode. Other things determined at this time are the average indicated IRIG temperature, the average heater current, and the IRIG and ACCEL TEMP meter indications. Sealing compound is then applied to the temperature set pot control, after final adjustment, to insure that this setting remains unchanged.

The final portion of this JDC is used to determine inertial component temperatures, blower current, heater current, heater current on-time, and heater current duty cycle during BACKUP and EMERGENCY OPERATE conditions. Maximum and minimum temperatures are determined in BACKUP to verify the temperature limit cycle in this mode.

4.2.4 JDC 15057

The gimbal angles are initially positioned to the same standard conditions specified in JDC 15053 procedures with the system in ISS STANDBY. Maximum and minimum IRIG and accelerometer temperatures are determined when temperature control has stabilized in BACKUP. PROPORTIONAL temperature control is then established and the temperatures allowed to stabilize while still in STANDBY. The inertial subsystem is then switched to ISS OPERATE and the IRIG temperature, accelerometer temperature, heater current and blower

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current measured 15 minutes, 30 minutes and 90 minutes after switching from STANDBY to OPERATE. In this manner, the time response of the system is determined.

Temperature control is then switched to the BACKUP Mode and allowed to stabilize after which the following is determined: maximum and minimum IRIG and accelerometer temperatures, heater current, blower current, heater current on-time, and heater current duty cycle.

Temperature control is then switched to the EMERGENCY Mode and its operation allowed to stabilize. The following are determined: IRIG and accelerometer temperatures, heater current, blower current, heater current on-time, and heater current duty cycle.

The final portion of this JDC is intended to test the AUTO-OVERRIDE temperature control mode circuitry. A simulated alarm condition is induced, while in this mode, which de-energizes the temperature alarm relays in Tray 7. This switches control to the emergency thermostat in the IMU during which the emergency heater current on-time and duty cycle are determined. Operation at this time should be identical to the EMERGENCY temperature control mode.

4.2.5 JDC 00059

This JDC contains procedures for testing the temperature control system in OPERATE for conditions of high required heater current obtained by lowering the IMU coolant from 45°F. to 30°F. Readings are obtained for IRIG temperature, accelerometer temperature, heater current, and blower current after the system has stabilized in the PROPORTIONAL mode. BACKUP is then selected and temperature and current readings again made after allowing the system to stabilize. The maximum and minimum temperatures and the heater current duty cycle are obtained here to verify the temperature limit cycle.

4.2.6 JDC 00060

This JDC contains procedures for testing the temperature control system in OPERATE for conditions of low required heater current obtained by raising the IMU coolant from 45°F. to 90°F. Procedures here are identical to those in JDC 00059 with the addition of tests to determine the temperatures, currents, and heater current duty cycle in EMERGENCY.

5. <u>TEST TOLERANCES</u>

5.1 ATP AND JDC REQUIREMENTS

5.1.1 GENERAL

All ATP and JDC test limits are identical except those for the PIP and IRIG Indicating and Alarm Tolerances (See Tables I and II). A comparison of the differences is tabulated below.

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		TEMP METER		MONITOR METER	
		ATP	JDC	ATP	JDC
IRIG +5°	min	4.2°F	4.3°F	4.8°F	4.55°F
	max			5.2°F	N/A
IRIG -5°	min			-5.2°F	N/A
	max			-4.8°F	-4.55°F
PIP +5°	min	4.2°F	4.3°F	4.8°F	4.7° F
	max			5.2°F	N/A
PIP -5°	min			-5.2°F	N/A
	max			-4.8°F	-4.7° F

These differences result from GSE metering circuitry errors; See Section 5.2.

5.1.2 IRIG AND PIP INDICATING AND ALARM TOLERANCES

See Tables I and II.

5.1.3 TEMPERATURE SET (PROPORTIONAL - OPERATE)

	ATP	JDC
PIP Temperature	130.0°F ± 0.1°F	-0.1°F to +0.1°F
IRIG Temperature	134.5°F ± 1.5°F	-0.5°F to +2.5°F
Heater Current	None	0.7a to 1.3a

5.1.4 IMU STANDBY

5.1.4.1 PROPORTIONAL

	ATP	JDC
PIP Temperature	N/A	N/A
IRIG Temperature	N/A	N/A
Heater Current	1.2a ± 0.3a	0.9a to 1.5a

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TABLE I

IRIG INDICATING AND ALARM CIRCUITRY

SIMULATED TEMPERATURE	TEMP METER INDICATION		INDICATING AMPLIFIER OUTPUT VOLTAGE		BRIDGE VOLTAGE		MONITOR METER INDICATION	
	ATP	JDC	ATP	JDC	ATP	JDC	ATP	JDC
133.5° F.	0 ± 0.3°F	0 ± 0.3°F	2.5 ± 0.15 VDC		0 ± 7 mv		0 ±0.2 °F	0 +0.2 °F
138.5° F.	4.7 ± 0.5°F	4.3°F. min	4.85 ± 0.25 VDC	5.10V max	-144 ± 7 mv		5.0 ±0.2 °F	4.55°F. min
128.5° F.	-4.8 ± 0.5°F	-4.3°F. max	0.1 ± 0.25 VDC	-0.15V min	147 ± 7 mv		-5.0 ±0.2 °F	-4.55°F. max
High Fail	3.7 ± 1.0°F	3.7 ± 1.0°F	4.35 ± 0.5 VDC		-119 ± 33 mv		4.05±1.15°F	2.9° F. min
High Reset	1.6 ± 1.1°F	1.6 ± 1.1°F	3.3 ± 0.55 VDC		-52.5±37.5 mv		1.75±1.25°F	1.75±1.25°F
Low Fail	-3.8 ± 1.0°F	-3.8 ± 1.0°F	0.6 ± 0.5 VDC		119 ± 32 mv		-4.05±1.15°F	-2.9° F. max
Low Reset	-1.9 ± 1.1°F	-1.9 ± 1.1°F	1.55 ± 0.55 VDC		53 ± 37 mv		-1.75±1.25°F	-1.75±1.25°F

TABLE II

PIP INDICATING AND ALARM CIRCUITRY

SIMULATED TEMPERATURE	TEMP METER INDICATION		INDICATING AMPLIFIER OUTPUT VOLTAGE		BRIDGE VOLTAGE		MONITOR METER INDICATION	
	ATP	JDC	ATP	JDC	ATP	JDC	ATP	JDC
130.0° F.	0 ± 0.3°F	0 ± 0.3°F	2.5 ± 0.15 VDC		0 ± 2 mv		0. ± 0.2 °F	0. ± 0.2 °F
135.0° F.	4.7 ± 0.5°F	4.3° F. min	4.85 ± 0.25 VDC	5.1 V max	45 ± 2 mv		5.0 ± 0.2 °F	4.7° F. min
125.0° F.	-4.8 ± 0.5°F	-4.3° F. max	0.1 ± 0.25 VDC	-0.15V min	-45 ± 2 mv		-5.0 ± 0.2 °F	-4.7° F. max
High Fail	3.7 ± 1.0°F	3.7 ± 1.0°F	4.35 ± 0.5 VDC		36 ± 10 mv		4.05 ± 1.15°F	2.9° F. min
High Reset	1.6 ± 1.1°F	1.6 ± 1.1°F	3.3 ± 0.55 VDC		16 ± 11 mv		1.75 ± 1.25°F	1.75 ± 1.25°F
Low Fail	-3.8 ± 1.0°F	-3.8 ± 1.0°F	0.6 ± 0.5 VDC		-36 ± 10 mv		-4.05 ± 1.15°F	-2.9° F. max
Low Reset	-1.9 ± 1.1°F	-1.9 ± 1.1°F	1.55 ± 0.55 VDC		-16 ± 11 mv		-1.75 ± 1.25°F	-1.75 ± 1.25°F

5.1.4.2 BACKUP

	ATP	JDC
PIP Temperature	132.25°F ± 1.25°F	+1.0°F to +3.5°F
IRIG Temperature	133.5° F ± 1.5° F	-1.5°F to +1.5°F

NOTE: Tolerances include limit cycle.

5.1.5 IMU OPERATE CONTROL

5.1.5.1 STANDBY TO OPERATE RESPONSE TIME (PROPORTIONAL OR AUTO-OVERRIDE)

5.1.5.1.1 <u>After 15 Minutes</u>

	ATP	JDC
PIP Temperature	N/A	N/A
IRIG Temperature	N/A	N/A
Heater Current	N/A	N/A
Blower Current	N/A	N/A

5.1.5.1.2 <u>After 30 Minutes</u>

	ATP	JDC
PIP Temperature	130.°F ± 0.5°F	0 ± 0.5°F
IRIG Temperature	Within ±0.5°F of actual value obtained during temperature set	Within ±0.5°F of actual value obtained during temperature set
Heater Current	N/A	N/A
Blower Current	N/A	N/A

5.1.5.1.3 <u>After 90 Minutes</u>

	ATP	JDC
PIP and IRIG Temperatures	Within ±0.2°F of actual value obtained during temperature set	Within ±0.2°F of actual value obtained during temperature set
Heater Current	1.00a ± 0.30a	0.7a to 1.3a
Blower Current	0.35a ± 0.15a	0.2a to 0.5a

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5.1.5.2 BACKUP

	ATP	JDC
PIP Temperature	131.75°F ± 1.75°F	0.0°F to +3.5°F
IRIG Temperature	136.00°F ± 1.00°F	+1.5°F to +3.5°F

NOTE: Tolerances include limit cycle.

Heater Current Duty Cycle	N/A	N/A
Heater Current	None	N/A
Blower Current	Shall change inversely with heater current	Shall change inversely with heater current
Heater Current On-Time	None	N/A

5.1.5.3 EMERGENCY

	ATP	JDC
PIP and IRIG Temperatures	Within ±2.0°F of temperature obtained in PROPORTIONAL after 90 minutes in OPERATE	Within ±2.0°F of temperature obtained in PROPORTIONAL after 90 minutes in OPERATE
Heater Current Duty Cycle	N/A	N/A
Heater Current	None	N/A
Heater Current On-Time	None	N/A
Blower Current	Shall change inversely with heater current	Shall change inversely with heater current

5.1.5.4 AUTO-OVERRIDE (DURING ALARM)

	ATP	JDC
Heater Current On-Time	None	N/A
Heater Current Duty Cycle	None	N/A

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5.1.6 HIGH HEATER POWER REQUIREMENTS IN ISS OPERATE

5.1.6.1 PROPORTIONAL OR AUTO-OVERRIDE

	ATP	JDC
PIP and IRIG Temperatures	Within ±0.5°F of temperature obtained in PROPORTIONAL after 90 minutes in OPERATE at standard conditions	Within ±0.5°F of temperature obtained in PROPORTIONAL after 90 minutes in OPERATE at standard conditions
Heater Current	N/A	N/A
Blower Current	N/A	N/A

5.1.6.2 BACKUP OPERATE

	ATP	JDC
PIP Temperature	131.75°F ± 1.75°F	0.0°F to +3.5°F
IRIG Temperature	136.00°F ± 1.00°F	+1.5°F to +3.5°F

NOTE: Tolerances include limit cycle

	ATP	JDC
Heater Current	N/A	N/A
Heater Current Duty Cycle	N/A	N/A
Blower Current	Shall change inversely with heater current	Shall change inversely with heater current

5.1.7 LOW HEATER POWER REQUIREMENTS

5.1.7.1 PROPORTIONAL OPERATE

	ATP	JDC
PIP and IRIG Temperatures	Within ±0.5°F of temperature obtained in PROPORTIONAL after 90 min in OPERATE at standard conditions	Within ±0.5°F of temperature obtained in PROPORTIONAL after 90 min in OPERATE at standard conditions
Heater Current	N/A	N/A
Blower Current	N/A	N/A

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5.1.7.2 BACKUP OPERATE

	ATP	JDC
PIP Temperature	131.75°F ± 1.75°F	0.0°F to +3.5°F
IRIG Temperature	136.00°F ± 1.00°F	+1.5°F to +3.5°F

NOTE: Tolerances include limit cycle.

Heater Current	N/A	N/A
Heater Current Duty Cycle	N/A	N/A
Blower Current	Shall change inversely with heater current	Shall change inversely with heater current

5.1.7.3 EMERGENCY OPERATE

	ATP	JDC
PIP and IRIG Temperatures	Within ±2.0°F of temperature obtained under these conditions in PROPORTIONAL	Within ±2.0°F of temperature obtained under these conditions in PROPORTIONAL
Heater Current Duty Cycle	N/A	N/A
Heater Current	None	N/A
Blower Current	Shall change inversely with heater current	Shall change inversely with heater current

5.2 ERROR CONSIDERATIONS

5.2.1 GENERAL

To eliminate indicating errors caused by the temperature indicating amplifiers, the IMU temperature set and all subsequent temperature measurements are made with the MONITOR METER connected directly to the indicating bridges.

5.2.2 MONITOR METER

An Error Analysis of the MONITOR METER circuitry was presented in Memorandum AP-M No. 7648, dated 13 July 1965, and is summarized here. During ±5° checks of the indicating circuitry, the following should be expected.

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	Bridge Voltage		Monitor Meter Deflection		JDC	
	With Monitor Meter	Without Monitor Meter	Nom	Tol	Max	Min
IRIG +5°	-125.3 mv	-144.1 mv	4.87°	±.30	5.3°	4.55°
IRIG -5°	126.7 mv	147.3 mv	-4.96°	±.30	-4.55°	-5.3°
PIP +5°	32.96 mv	44.73 mv	4.96°	±.28	5.3°	4.7°
PIP -5°	- 33.51 mv	- 45.42 mv	-5.04°	±.28	-4.7°	-5.3°

The tolerances were derived for near full scale deflection as follows:

	IRIG	PIP
Diode Tolerances	±.02°	±.017°
Monitor Meter Accuracy (±1% of F.S.)	±.10°	±.10°
Meter Resolution	±.05°	±.05°
Test Voltage Tolerance	±.005°	±.017°
Series Resistor Tolerance (±.1%)	±.005°	±.003°
Bridge Excitation Tolerance (±2%)	±.10°	±.10°
Gain Resistor Symmetry	±.045°	±.041°
Total Possible Deviation	±.325°	±.328°
≅	±.33°	±.33°
Nominal ± 5° Deviation	4.92°	5.00°
Limits	4.59° to 5.25°	4.67° to 5.33°
Rounded Off	4.55° to 5.30°	4.70° to 5.30°

5.2.3 IRIG AND ACCEL TEMP METERS

These meters provide a readout of the IRIG and accelerometer temperature telemetry output. Their tolerance is derived as follows:

	VOLTAGE	DEFLECTION
Ideal Indicating Amplifier Output Voltage for +5° Dummy Bridge Input Resistor and 500K Load (disregarding alarm circuitry load).	5.0 VDC	
Actual Output Voltage and Tolerance at Module Level for +5° Test (including alarm circuitry load)	4.92 ± 0.08 VDC (± 1.7%)	
Apparent Source Voltage for +5° Test	5.05 V	
Calculated Output Voltage with TEMP METER attached	4.67V (± 1.7%)	
Meter Deflection for 4.67V ± 1.7% (Ideal)		4.75°F ± 0.08°F
Meter Calibration Tolerance (± 1%)		± 0.2°
Bridge Voltage Excitation Tolerance (±2%)		± 0.10°
TEMP METER Resolution		± 0.05°
Total TEMP METER Tolerance		± 0.43° or ≅ ± 0.45°
Applicable TEMP METER Limits are then:		4.75°F ± 0.45°F or 4.30°F to 5.20°F

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