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GAS 007
MARSHALL AMATEUR RADIO CLUB EXPERIMENT (MARCE)

Edward F. Stluka, W4QAU
MARCE Principal Investigator

INTRODUCTION

The Marshall Amateur Radio Club Experiment (MARCE), started in 1978, was designed, assembled and tested by the Marshall Space Flight Center Amateur Radio Club (MARC), in Huntsville, Alabama, for supporting the Space Shuttle Get Away Special (GAS), #007 student science experimenters. The Project Explorer, GAS #007 is planned to be launched October 2, 1984, on STS-17 (41G) and is sponsored by the Alabama Space and Rocket Center, Huntsville, who paid the fee, and the Alabama Section of the Institute of Aeronautics and Astronautics (AIAA). The AIAA, with four universities, University of Alabama, Huntsville and Tuscaloosa, the University of Auburn and the Alabama A&M University, selected the student experiment proposals. The MARC was requested to provide a radio experiment when no radio experiment proposal was submitted.

In addition to supporting the student experimenters, the objectives of the MARCE are:

(1) Demonstrate amateur radio data communication from the cargo bay, during a Space Shuttle mission, on a non-interference basis with the Orbiter and its payloads.

(2) Involve educational groups of all ages to emphasize space communication opportunities for like type ventures of volunteer research and creativity.

(3) Encourage broader participation of amateur radio enthusiasts in this space research adventure capitalizing on the pioneering spirit of volunteer amateur radio operators and shortwave listeners around the world.

Design Considerations

1. Integration - As a guest experimenter, the MARC was requested to perform the GAS payload integration task. In addition to providing the primary power, control and distribution networks to electrically integrate the experiments, an instrumentation measuring system, a data system and an RF downlink system were designed.

2. Measurement and Instrumentation - Figure 1 is a review of the MARCE. The measurement inputs were first requested from the student experimenters in 1978 in an attempt to size the design required by the MARCE. Figure 2 shows the voice message formats and calibration data curves for the measurement list in Figure 1 and the GAS #007 health status. The instrumentation conditions the measurement sensors for inputs to the Analog to Digital Converters (ADC). The Digitalker* system changes the ADC signals to voice (English).

The Digitalker* was chosen to appeal to the widest possible segment of the amateur radio community as well as shortwave listeners. The downlinked message output from a 435.033 FM receiver can be recorded on a cassette during an Orbiter pass. During playback, the listener can, by using the data curves, status code and mission timeline, get a firsthand, real time experimentation progress report. Receiving a copy of the cassette at MARC from the ground stations around the world is vital to reconstructing the health of the experiments in flight. Relay of the data by amateur radio would greatly expedite the data flow.

In the event that the Orbiter's cargo bay is facing space during an RF transmission and the OSCAR AO-10 satellite can relay the MARCE data, the 2 meter receiver or scanner set at 145.9720 MHz could possibly receive the data, depending on the AO-10 location, receiver sensitivity, antenna gain and other RF link parameters.

3. Power and Control - The power, control and distribution system likewise was designed with the experimenters' inputs. Tradeoffs were continually required between student requirements and limited power and control methods. The more significant trades are:

a. It was found that one central power source was more efficient than separate experiment power sources. With multiple power sources, long duration relay (300 ohm) loads would consume significant power. The CPU completes the ground circuit of the control relays in accordance with timed sequence. Experiment 3 is the exception. It carries its own flash batteries, however, the 1.5V precision reference voltage provides a continuous power source for the 24-hour crystal growth experiment.

b. Continuous RF transmission would consume enormous power (75 ampere hours), therefore, three 8-hour downlinks were chosen (7 ampere hours). The RF transmission in each 8-hour period is made at the start of 4 minute segments and lasts long enough to transmit the data message. The first 8-hour period starts with GAS 007 initial "Power ON." Each data message (Format A) lasts less than 30 seconds. This data provides knowledge of the

*Trademark

payload health and monitors Experiment #2 heater operation and, at 00400 hours (4 hours after GAS #007 "Power ON), Pump A operation flows nutrient to the radish seeds. The second and third 8-hour downlinks provide Experiments 1 and 3 operational data and lasts about 45 seconds (Format B) every 4 minutes. See Figure 3 for power profile and mission timeline.

c. Continuous operation of I1, the current sensor, likewise would consume significant power (6 ampere hours). Therefore, I1 is turned "ON" for one second every ten minutes, except during the downlinks when it is turned on for ten seconds at the start of each radio transmission. The solid state sensor requires 50 ma.

d. The use of CMOS devices conserves power and allows non-volatile memory by use of alkaline "D" size batteries. The memory will store all MARCE data every ten minutes throughout the 120-hour mission. A less than one microampere drain over the period of several months should assure post-flight data retrieval.

4. Special Problems

a. RF transmission from the GAS container takes the lead in the problems encountered. The most difficult was the approval for lid modification to accommodate the RF coaxial cable feed through connector and approval for RF transmission from the cargo bay.

To date, approval for RF transmission has not been received. The complexity of the STS-17 payload manifest indicates that another flight should be selected; however, there are no other flights with 57° inclination until mid-1986 when a greater than 95° inclination is scheduled for OASTA-5.

Other problems include three notifications to the FCC, 27 months, 15 months and 3 months prior to space operations; RFI, EMI, antenna pattern and other tests required to assure compliance with FCC regulations as well as proper operation in the cargo bay, and to assure non-interference with the Orbiter or the payloads.

b. The lack of STS-17 timelines or Crew Activity Plan (CAP), forced MARCE to generate and use a simulated timeline for simulated flight test, thermal tests and other planning. GAS #007 experiments 1 and 3 desire to operate and MARCE desires to transmit during crew sleep periods and the other STS-17 payload down times. During this time, the lowest "G" levels are expected and the potential for interference, at transmitter full power (approximately 4.5 watts), to the STS-17 payloads is reduced or eliminated.

c. The RF transmitter power level is dependent on the location of the nearest payload component/assembly that is susceptible to RF interference. The SIR-B electronics enclosure is located about 1.6 meters from the GAS #007 container. If there is a possibility that MARCE RF transmissions would occur during the SIR-B radar "ON" times, then the MARCE transmitter RF power would be limited to 0.5 watts.

d. The 23 cell silver zinc battery requires special attention that dry cells do not. Safety requires (1) redundant vent lines from the battery case to the GAS lid relief valve assembly; (2) safety requires absorbent material above the cells to absorb possible electrolyte (KOH) leakage, and Solethane 113 chips placed between the absorbent material and the battery top cover, to displace any H2 expelled by the cells, when the GAS #007 experiments take energy out of the battery; and (3) safety requires a fail safe thermal control circuit that will turn GAS #007 power "OFF" when the battery case temperature reaches about $75^{\circ}C$. Such a high temperature would indicate a critical cell(s) short and/or reversal. This is a most serious safety critical condition because of the potential consequences.

5. Volunteers

MARCE could not have been completed without the help of the many who responded to the request to work on MARCE. The major volunteers are noted here: Data System and Software - Chris Rupp, W4HIY. Antenna - Reggie Inman, design of antenna and lid feed through. Ed Martin helped Reggie with antenna evaluation tests, radiation patterns and balun tuning. Power, Control, Distribution, Instrumentation - Art Davis, WB4KKA. RF System - Leon Bell, WB4LTT, evaluated the transmitter, prepared the RF system test plan, performed the RF link analysis, conducted EMI tests, transmitter stability, transmission line design and VSWR measurements. Fabrication and Planning - Bill Richardson, W4LRE - mechanical, milling, fabrication work on the antenna and electronic support assembly. Battery - Al Henry activated, load tested and coordinated with KSC for flight battery activation at KSC and with GSFC for battery flightworthiness preparations. Flight and Ground Operations - Leigh DuPre, WB4WCX, Ed Clark, K4KFH and Joe Appling, W4WIA - MARC station readiness, OSCAR relay and amateur radio community coordination. Mechanical Design - Ken Anthony and Jerry Hudgins. Stress - Tom Stinson. Assembly and Systems Test - Guy Smith, Chris Rupp, Leon Bell, Leigh DuPre. Payload Inspection, Quality and Documentation Compliance - Wiley Bunn, NO4S.

6. Contributors

MARCE could not have been completed without the companies and individuals contributing hardware and effort. Motorola - Jim Worsham, WA4KXY and the Fort Lauderdale, Florida, Motorola Portable Products Division provided the modified 5-watt transmitter and the handheld receiver (GSE). Zero Corporation - Jay Shorette and the Zero Corporation provided the MARCE electronic support assembly enclosure which houses the MARCE data system, signal conditioning, power distribution and experiment control, and I1, the current sensor. National Semiconductor Corporation - Peter Lami and the Interep Association, Huntsville, Alabama, provided two sets of the CMOS modules for the MARCE data system, one set for the prototype, the other set for the flight unit. RCA - Ivars Lauzuma and the Somerville, New Jersey, RCA Solid State Microsystems facility provided an 1802 CPU data system, A/D converter and related parts. The University of Alabama, Huntsville - The University's Environmental Lab provided space for assembling and testing the GAS #007 package. The UAH machine shop provided the major portion of the GAS #007 structural fabrication, drilling, machining and final fitting work. Space Processing Applications Rocket Project (SPAR) - 28V DC, 20 ampere hour batteries, 7.5V DC regulator, instrumentation sensors, connectors, and related parts were obtained from surplus hardware. Midwest Components, Inc. - John Saling and MCI provided the thermal sensing switches for the battery.

Consultation

The following organizations-persons provided guidance, recommendations and encouragement:

American Radio Relay League (ARRL)
Bernie Glassmeyer, W9KDR; and Dale Clift, WA3NLO.

Radio Amateur Satellite Corporation (AMSAT)
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Jack Gottlieb, Clark Prouty, Jim Barrowman, John Annen, KB3DN, Susan Oldin, Frank Bauer, KA3HDO.

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J. D. Collner, W4GNC, KSC technical representative for MARCE Eric E. Olseen, Andy Wheeler, WB4ZLW.

Jet Propulsion Laboratory (JPL)
Jim Lumsden, WA6MYJ, JPL technical representative for MARCE.

GAS 007 POWER USAGE

0243-84

RADIO DOWNLINKS 1	RADIO DOWNLINKS 2	RADIO DOWNLINKS 3	OTHER	PULSING LOADS	RELAY GCD	GAS 007 RELAY
8 HRS				(2) TX 30 SEC/4 MIN .593 A (INCL K4 AT .093A)	AB, C	K4
30 SEC				(3) EXP 2 PUMP 1 - 120A (PUMP) + .093A (K1) = .213	A	K1
		15 MIN		(5) EXP 1 OVEN 1, 1.75 AMPS	A, C	K2
		*30 MIN		(6) EXP 1 OVEN 1, 1.75 FOLLOWS (5)*	A	K2
		6 HRS		(7) EXP 1 OVEN 1 DATA SYS .250A A+.093A K2=.344A	A	K2
	20 MIN			[5] EXP 1 OVEN 2, 2.0 AMPS	A	K2
	*30 MIN			[6] EXP 1 OVEN 2, 2.0A FOLLOWS [5]*	A	K2
	6 HRS			[7] EXP 1 OVEN 2 .250 A DATA SYS + .093A K2=.344A	A	K2
			(1)	(9) CURRENT SENSOR (CSI) .050 A 1 SEC/10 MIN	A	-
8 HRS	8 HRS	8 HRS		(10) CURRENT SENSOR (CSI) .050 A 10 SEC/4 MIN	A	-
	8 HRS	8 HRS		(11) TX 45 SEC/4 MIN .593 A	A,B,C	K4
			(2)	(12) EXP 2 PUMP 2, 30 SEC .120A + .093A (K5)	A	K5
				CONSTANT LOADS		
X	X	X	120 HRS	(1) EXP 4 DATA SYS .036A 120 HRS	A	-
X	X	X	120 HRS	(4) EXP 2 HEATER .075 MA $\leq$ 60 HRS	A	-
	X		24 HRS	(8) EXP 3 (1.5V) + FLASH CKT .093A (K3)	A	K3

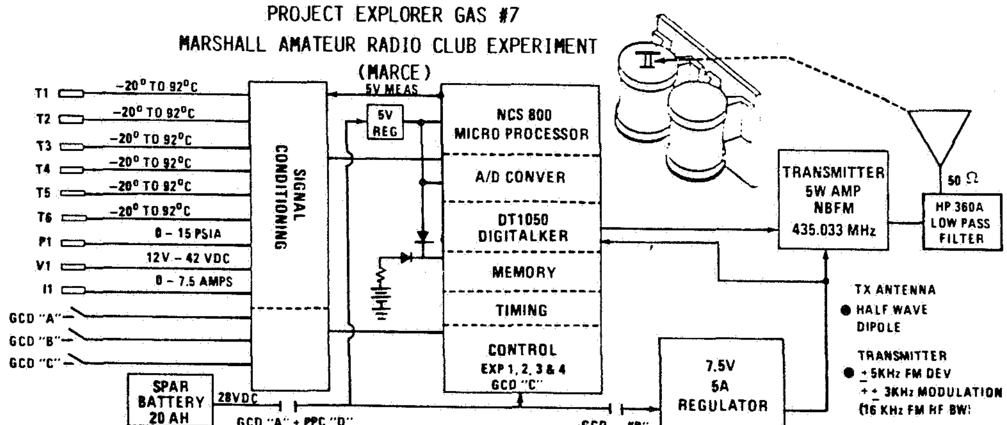
LEGEND:
(X) [X] KEYS FOR POWER PROFILE
SEE FIGURES 2, 2.1 & 2.2

(1) DURING NON TRANSMISSION PERIODS (3-8 HOURS)
(2) IMMEDIATELY PRIOR TO END OF 120 HOURS

TABLE 1 EFS 3-29-84

FIGURE 1

PROJECT EXPLORER GAS #7
MARSHALL AMATEUR RADIO CLUB EXPERIMENT
(MARCE)



EXPERIMENT DATA			MEASUREMENTS	
NO.	NAME	LOCATION	NO.	TYPE
1.	ALLOY SOLIDIFICATION	A&M UNIV HSV, AL	1	T1 OVEN 1
			2	T2 OVEN 2
2.	PLANT PHYSIOLOGY	UNIV OF ALA HSV, AL	3	T3 EXP 2
3.	CRYSTAL GROWTH	UNIV OF ALA HSV, AL	4	T4 EXP 3
4.	AMATEUR RADIO	MARC – MSFC, AL		
A	CONTAINER TEMP		5	T5
B	BATTERY TEMP		6	T6
C	BATTERY VOLTAGE		7	V1
D	BATTERY CURRENT		8	I1
E	CONTAINER PRESSURE		9	P1
F	GCD "A" + PPC "D"	AFT FLIGHT DECK	10	TURN GAS 007 ON/OFF
G	GCD – "B"	AUTONOMOUS	11	RADIO TX PWR
H	GCD – "C"	PAYLOAD CONTROLLER (APC)	12	"ON" SIGNAL FOR EXP 1, 2, 3, & 4

INTEGRATION (A–H)

SAMPLE DATA:

FORMAT A

QST QST QST FROM WA4NZD TIME 00000 (EXP ELAPSED TIME
STATUS 10, DATA 012 014 014 014 015 012 255
135 255, FROM WA4NZD OUT

FORMAT B (WHEN EXPERIMENT 1 IS ON)

QST QST QST FROM WA4NZD TIME 00003
STATUS 1 0 DATA 015 014 013 012 015 013 255
180 255 TIME 0000 STATUS
0A DATA 3F 4A 3B 3C 3D 42 AF A2 FROM WA4NZD OUT

GROUND STATION REQUIREMENTS:

435.033 MHz ANTENNA & FM RECEIVER
ANTENNA: CIRCULAR POLARIZATION $\geq$ 10 DB GAIN
FM RECEIVER $\leq$ 1. μV 20 KHz RF BANDWIDTH
CASSETTE RECORDER – VOICE
FOR OSCAR A8-10 RELAY, 2 METER OSCAR
ANTENNA & RECEIVER

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PROJECT EXPLORER
GAS 007

VOICE MESSAGE FORMATS

FORMAT A:

QST QST QST FROM WA4NZD TIME 00000
STATUS 10 DATA 012 014 014 014 015 012 225
135 255 FROM WA4NZD OUT

FORMAT B: (WHEN EXPERIMENT 1 IS "ON")

QST QST QST FROM WA4NZD TIME 00003
STATUS 10 DATA 015 014 013 012 015 013
255 190 255
TIME 0000 STATUS OF DATA 3F 4A 3B 3C 3D
42 AF A2 FROM WA4NZD OUT

NOTES: 1. DATA, TIME AND STATUS WILL VARY
2. MEASUREMENT LIST, STATUS DICTIONARY AND DATA CURVES REQUIRED TO READ MESSAGES

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GAS007 MESSAGE DESCRIPTION

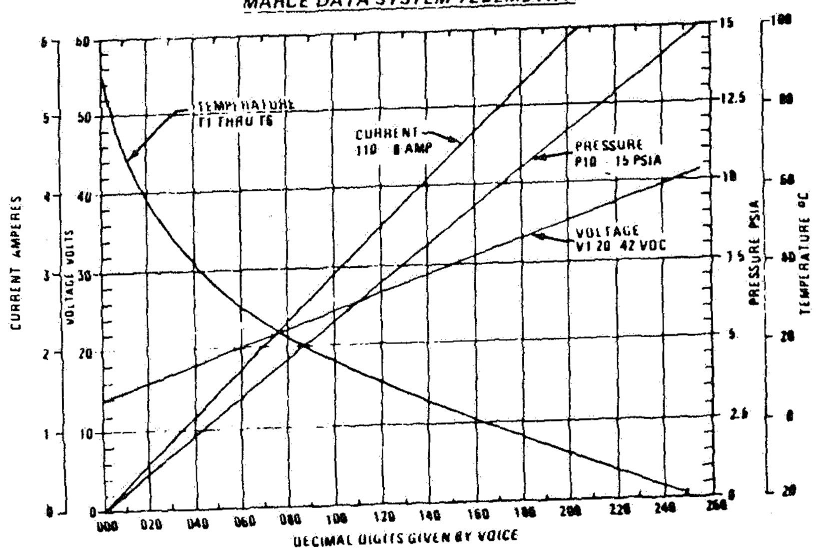
QST QST QST

- GENERAL CALL TO ALL RADIO AMATEURS AND ARRL MEMBERS
  - FROM WA4NZD
    - IDENTIFICATION FOR THE MARSHALL AMATEUR RADIO CLUB
  - HOURS, MINUTES 00000
    - EXPERIMENT ELAPSED TIME, STARTING WITH START OF EXPERIMENTS TURN ON
- STATUS HH
  - A HEXIDECIMAL SYSTEM HAS A BASE OF 16 AND USES 0 THRU 9, A THRU F TO INDICATE THE DECIMAL VALUES 0 THRU 15

CONDITION	STATUS	HEXADECIMAL
A/D CONVERTER FAILURE	0	01
CANISTER PRESSURE TOO LOW	1	02
TRANSMITTER ON TOO LONG	2	04
GCD "B" TRANSMITTER RELAY OFF	3	08
GCD "C" CONTROL RELAY OFF	4	10
EXP # 1 OVER TEMPERATURE	5	20
EXP # 2 OR # 3 ARE ON	6	40
BATTERY VOLTAGE IS TOO LOW	7	80

EXAMPLE OF "STATUS A1"	VALUE
A/D C ERROR	01
EXP # 1 OVER TEMP	20
BATTERY V. TOO LOW	80
	A1

GAS 007
MAHCE DATA SYSTEM TELEMETRY



GAS 007
EXPERIMENT 1 TELEMETRY CONVERSION FORMAT B

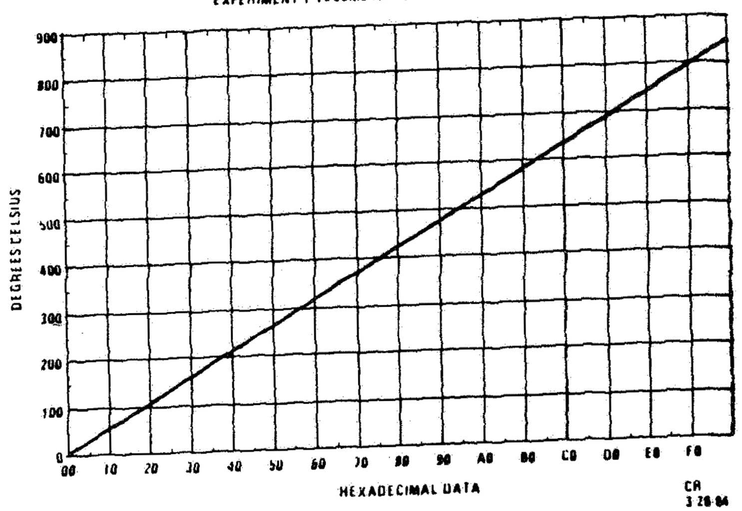
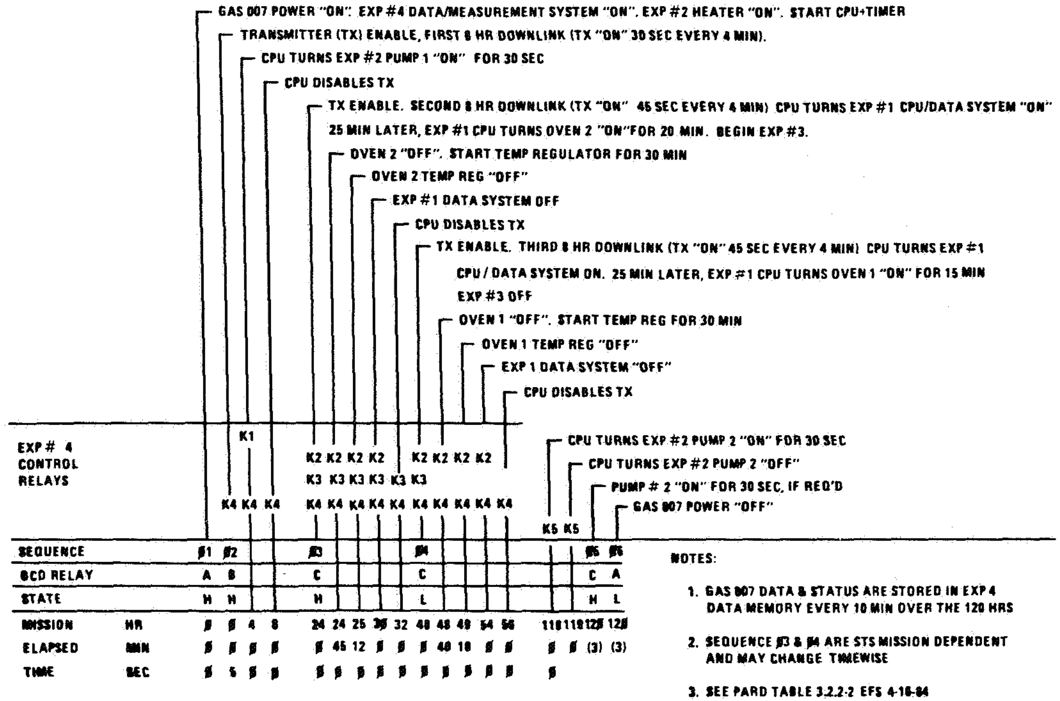


FIGURE 2

GAS 007 MISSION TIMELINE AND PAYLOAD FUNCTIONS



GAS 007 SECOND DOWN LINK POWER PROFILE

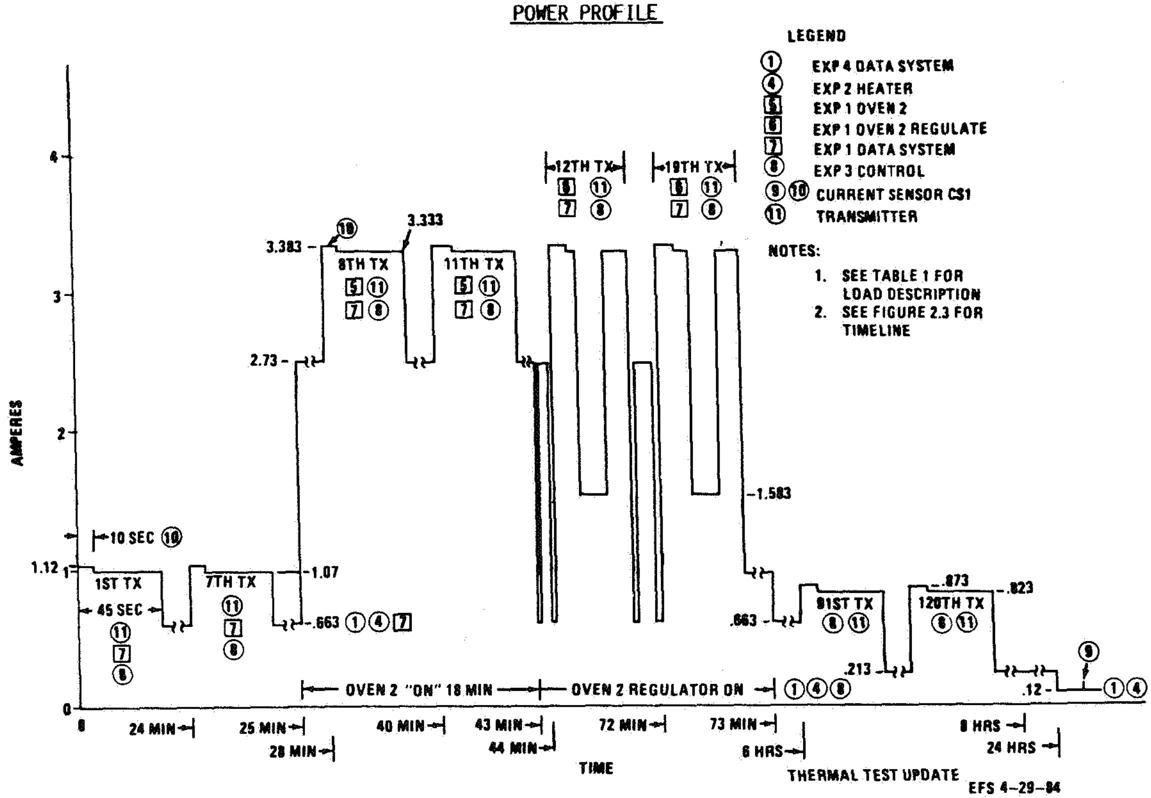


FIGURE 3