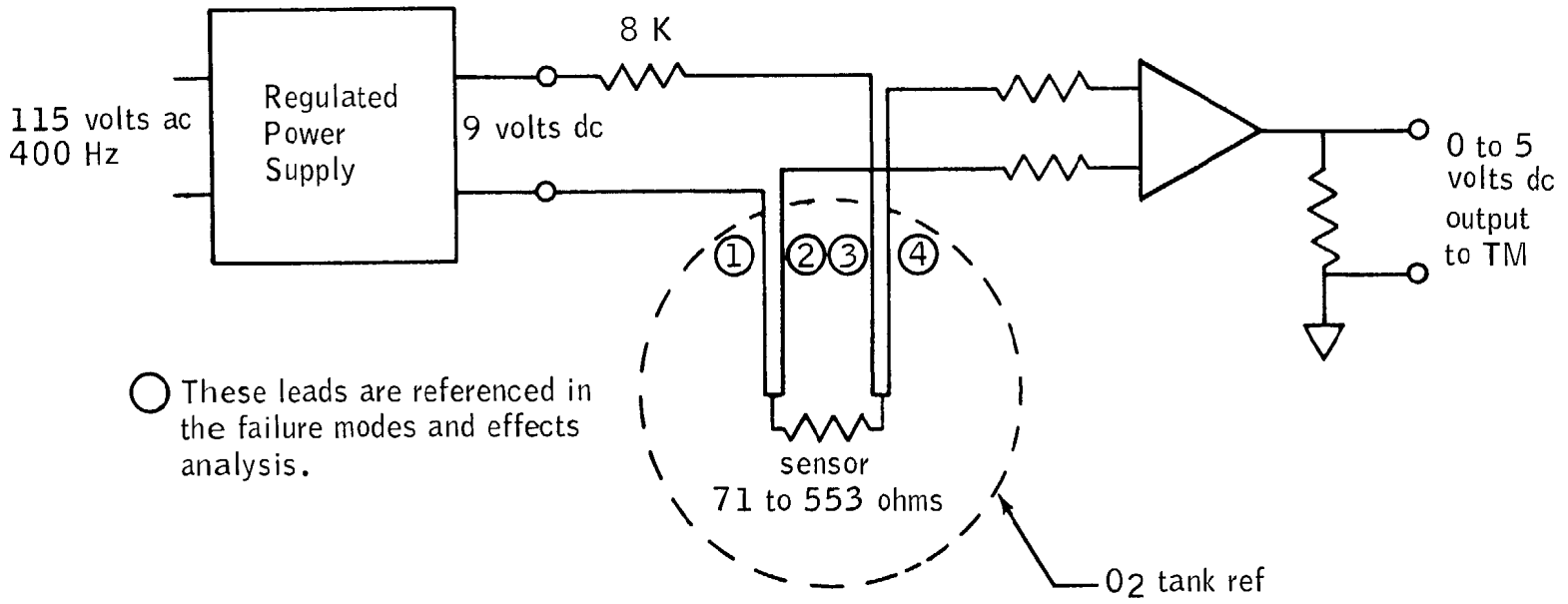


Figure B7-2.- Oxygen tank temperatures sensing circuit.

Power	1.25 watts, 115 V ac, 400 cps
Time constant in liquid nitrogen or alcohol	Approximately 20 seconds

The 20-second time constant was measured by plunging the sensor first into liquid nitrogen at -317° F and then into dry ice/alcohol at -91° F. Tests were made under one-g and 1 atmosphere and are not applicable to supercritical oxygen and zero-g.

Telemetry would indicate the temperature of the sensor itself, but under rapidly changing conditions the sensor could remain almost unaffected by local temperature changes in other parts of the tank. The effect of various failure modes on the transducer and its output signal are presented in table B7-I.

OXYGEN TANK QUANTITY INSTRUMENTATION

The oxygen tank quantity gage is shown in figure B7-1. This gage senses the average dielectric constant of oxygen in the cylindrical annular volume between two concentric aluminum tubes. The dielectric constant is proportional to density, which in turn is proportional to the quantity of oxygen in the tank. The gage is approximately 2 feet long; the outer tube is about 0.85-inch ID and the inner tube is about 0.65-inch OD to form two plates of a capacitor with 0.10-inch spacing. The gage mounts in the center of the tank.

The gage capacitance is connected in series with a reference capacity to form a capacitive 400-cycle ac voltage divider as shown in figure B7-3 and is adjusted to apply zero volts input to the amplifiers when the tank is empty. As the tank is filled, the gage capacity increases, applying a voltage to the amplifier input. This voltage is amplified and rectified to provide an output signal voltage which increases to 5 volts dc when the tank is full.

The reactive voltage developed across the probe capacitance will change as rapidly as capacitance changes. The rectifier filter on the output of the signal conditioner introduces a time constant of about 0.022 second in the instrument response.

TABLE B7-I.- FAILURE MODES OF THE OXYGEN TANK TEMPERATURE TRANSDUCER

Failure mode	Indication	Resulting damage
Any of the four temperature sensor leads shorted to 115 V ac line (1, 2, 3, 4)	Full scale output followed by zero output	Would fail signal conditioner amplifier, sensor element, and pulse code modulation gate
Temperature sensor shorted to the density probe element	*No change in output	Probably no circuit element damage
Temperature sensor shorted to ground (either side)	*Zero output signal	No circuit damage
Dc power shorted to temperature sensor	Full scale output	Would fail signal conditioner output
Either or both sensor leads open	Full scale output	None
400 Hz power input to power supply disconnected.	Output drifts to zero as charge in power supply filter capacitors discharge.	None
Temperature sensor leads shorted to each other	*Zero output	None
Any one of leads 1, 3, or 4 broken (open) (fig. B7-2)	Zero output	No circuit damage
Open lead 2 (fig. B7-1)	*Immediate rise to full scale followed by a linear decay to zero in approx. 10 msec	No circuit damage

*Indication verified by test

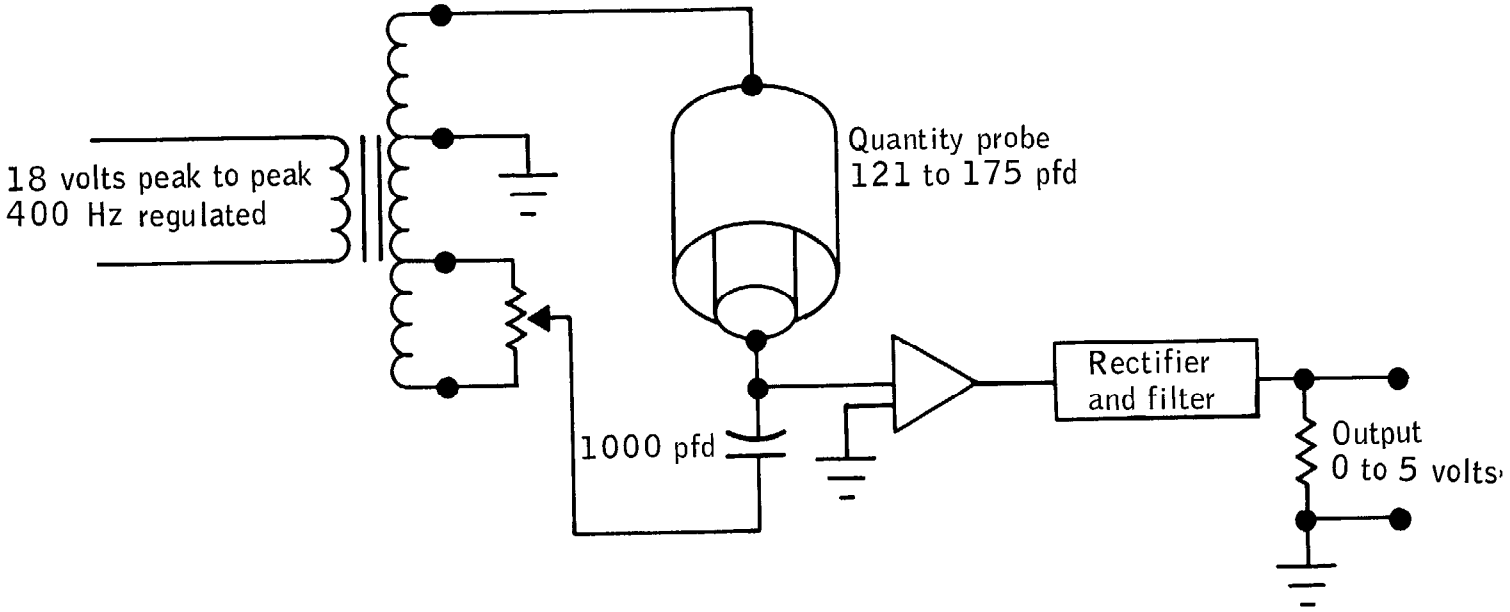


Figure B7-3.- Oxygen quantity gage block diagram.

Gage parameters are as follows:

Tank condition	Empty	Full
Density	0	69.5 lb/ft^3
Dielectric Constant	1.0	1.45
Capacitance	121	175 picofarads
Output voltage	0	5 V dc
Output impedance	500 ohms	
Power	2-1/2 watts	
Supply voltage	115 V, 400 cycles	
Accuracy	2.68 percent full scale	
Value of fixed capacitance	1000 picofarads	
Data sampled	Once per second	

This method of gaging works well for single-phase fluids in any gravity environment so long as the fluid is uniformly mixed with no significant density variations. But under zero-g, density and temperature variations can exist in the fluid, especially when heat is added without any fluid movement (convection). Under these conditions, the gage measures the average density of the oxygen between the two tubes which may or may not be representative of the average density in the tank.

If the gage is either opened or shorted, the signal conditioner is overdriven and a greater-than-100-percent quantity is indicated. Other malfunction characteristics follow.

	Failure Mode	Effect
1.	Elements of probe shorted to each other	Full scale output
2.	Wire to either element disconnected from probe	Full scale output
3.	Outside element of probe or its lead wire shorted to ground	Measurement indicates some value between zero and full scale
4.	Inside element of probe or its lead shorted to ground	Random output tending towards zero
5.	Clear shorted probe	Output decreases to zero, remains 0.7 second, then increases to correct value in about 1-1/2 second
6.	Clear open probe fault	Output assumed correct value within 1/2 second
7.	Intermittent shorts, any combination	Output becomes irregular sawtooth

OXYGEN TANK 2 PRESSURE INSTRUMENTATION

The location of the oxygen tank pressure measuring instrumentation is shown schematically in figure B7-4. Pressure transducers for both tanks are located in a valve module assembly along with the pressure switches and pressure relief valves as shown in figure B7-5. The valve module assembly is connected to the oxygen tanks by 19-foot lengths of 1/4-inch and 3/16-inch OD tubing.

The pressure transducer consists of a diaphragm 0.2 inch in diameter and 0.015 inch thick to which are attached 4 chips of strain-sensitive semi-conductor materials electrically connected into a bridge circuit. When pressure is applied, deflection of the diaphragm changes the electrical resistance of the semi-conductor clips to unbalance the bridge and develop an electrical output proportional to the applied pressure. This output is amplified so that full-scale pressure of 1050 psia gives a 5 V dc output which is indicated on the CM instrument panel and telemetered to the ground through the PCM telemetry system.

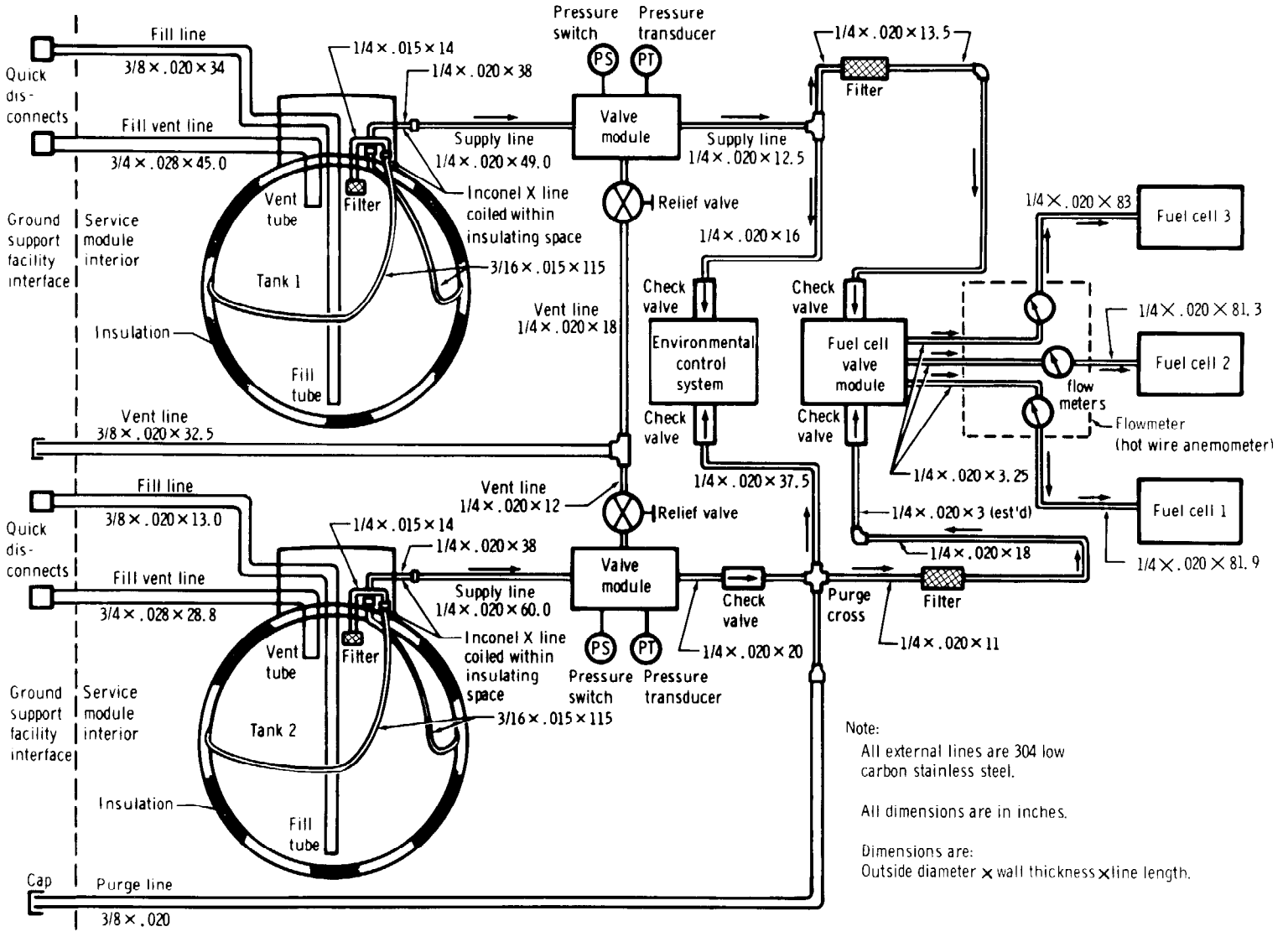


Figure B7-4.- Oxygen system.

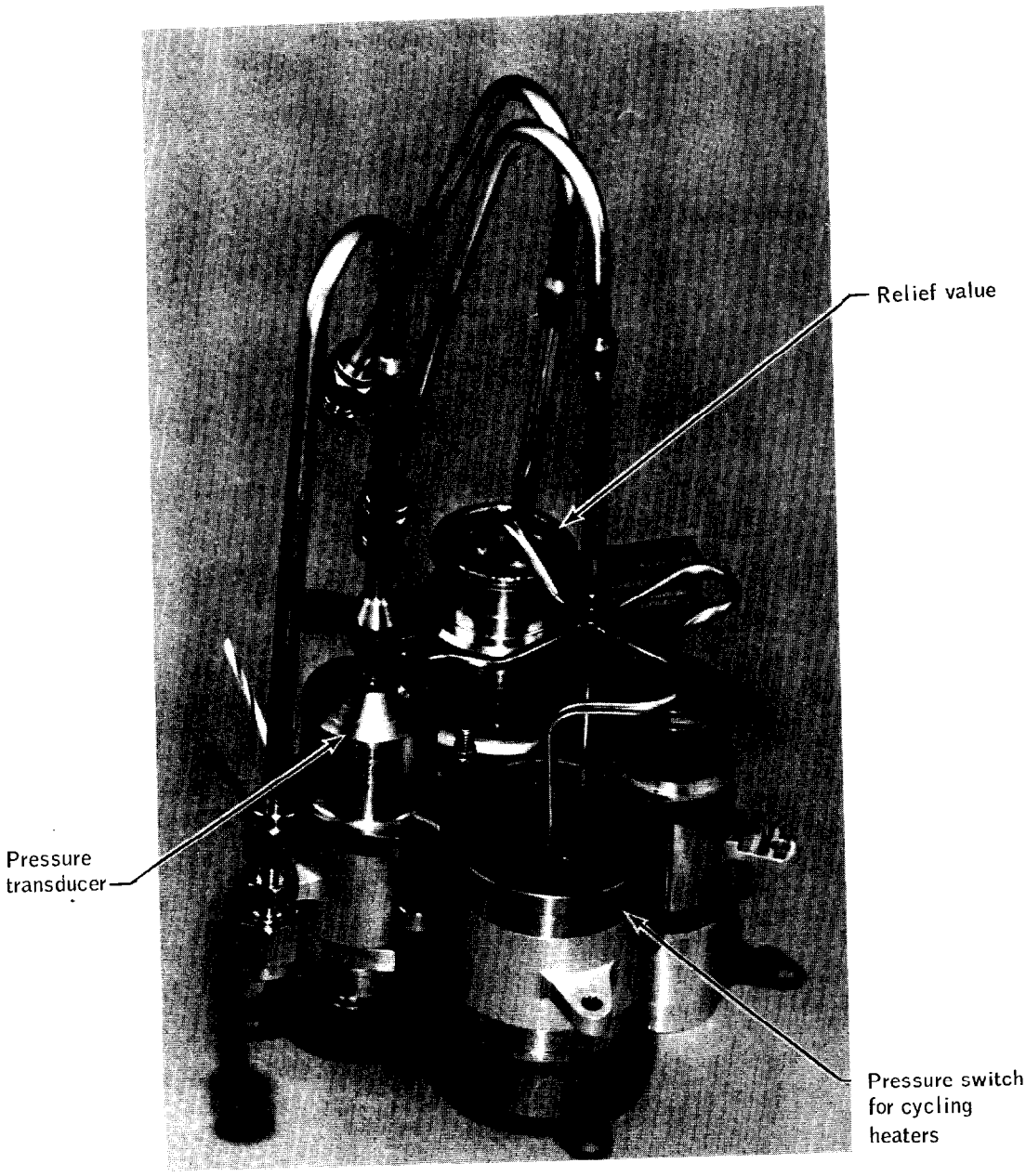


Figure B7-5.- Pressure transducer, relief valve, and pressure switch.

Other pressure transducer parameters are as follows:

Range	19 to 1080 psia
Accuracy	±2.68 percent fuel range
Output voltage	0 to 5 V dc
Output impedance	500 ohms
Power	1.5 watts
Voltage supply	28 V dc
Data sampled	Once per second

Under normal operating conditions oxygen flow through the 19 feet of tubing is about 1.5 pounds per hour and the pressure drop through the line is negligible.

The physical dimensions and electronic characteristics of the pressure transducer are such that its time lags are negligible as compared with acoustical lags of the tubing. If the relief valve opens (normally set at 1008 psia) or if the pressure in the tank changes suddenly, the delta P is communicated through the tube at sonic velocity (813 fps at 288° R) so that a delay of about 23 msec would be expected exclusive of pressure drops due to flow through the tubing. Tests run at MSC show that when a step pressure increase is applied at the tank end of the system, pressure indicated by the transducer begins to change in about 16 msec and reaches 63 percent of the pressure change in about 40 msec.

PULSE CODE MODULATION SYSTEM DESCRIPTION

The instrumentation system on the Apollo spacecraft interfaces with a pulse code modulation (PCM) telemetry system. In such a system, measurements are not presented continuously, but are sampled in time and quantitized in amplitude. Signal conditioners standardize the outputs from all sensors to a range of 0 to 5 volts. This voltage is fed into the PCM system where it is sampled and encoded for transmission to the ground.

The PCM system basically consists of a number of electronic input switches and an analog-to-digital encoder, all of which are controlled by a programmer. The analog switches, through programmer control, are sampled sequentially with a sample period of 40 microseconds for each

input. The sampled voltage is then converted by the encoder into an 8-bit binary word which is subsequently transmitted to the ground. The sampling rate for each channel is selected on the basis of the rapidity with which that channel value changes under normal operation. Programmer sampling rates are 200, 100, 50, 10, and 1 sample per second. The end result of this operation when the system is in the high-bit-rate mode is a serial stream of data consisting of 128 eight-bit words in each frame with 50 frames transmitted each second. This corresponds to a bit rate of 51,200 bits per second. In the low-bit-rate mode, 1600 bits per second are transmitted and the measurements are made at a reduced sampling rate.

In evaluating telemetry data, consideration must be given to the fact that the system samples data in time and quantitizes in amplitude.

Figure B7-6 depicts an analog signal and its equivalent digital representation to illustrate several limitations of PCM telemetry systems.

1. Fast transients which happen to occur between the sample times will not be recorded.

2. A long transient whose peak amplitude occurs between sample times will be recorded with an incorrect peak amplitude.

3. A low-amplitude transient may go completely unrecorded even if its peak amplitude occurs at a sample time.

4. A change of one count in a parameter does not necessarily mean that the analog quantity has changed by an amount equal to the difference in count values. If the analog quantity happens to be very close to the switchover point between counts, a small change can cause the count to change.

5. If the analog quantity remains for a long time close to the switchover point from one count to the next, the output may toggle (jump back and forth) from one count to another. This does not indicate that the analog value is actually changing this rapidly but is characteristic of the system when noise is present.

6. In addition to the phenomena illustrated in figure B7-6, it must be recognized that noise in the RF link may cause erroneous data to be received on the ground. Such errors usually appear in the data as values which differ greatly from adjacent outputs from the same channel.

Table B7-II lists the measurements telemetered from the Apollo 13 command and service modules as well as their ranges, sampling rates, and value of one count.

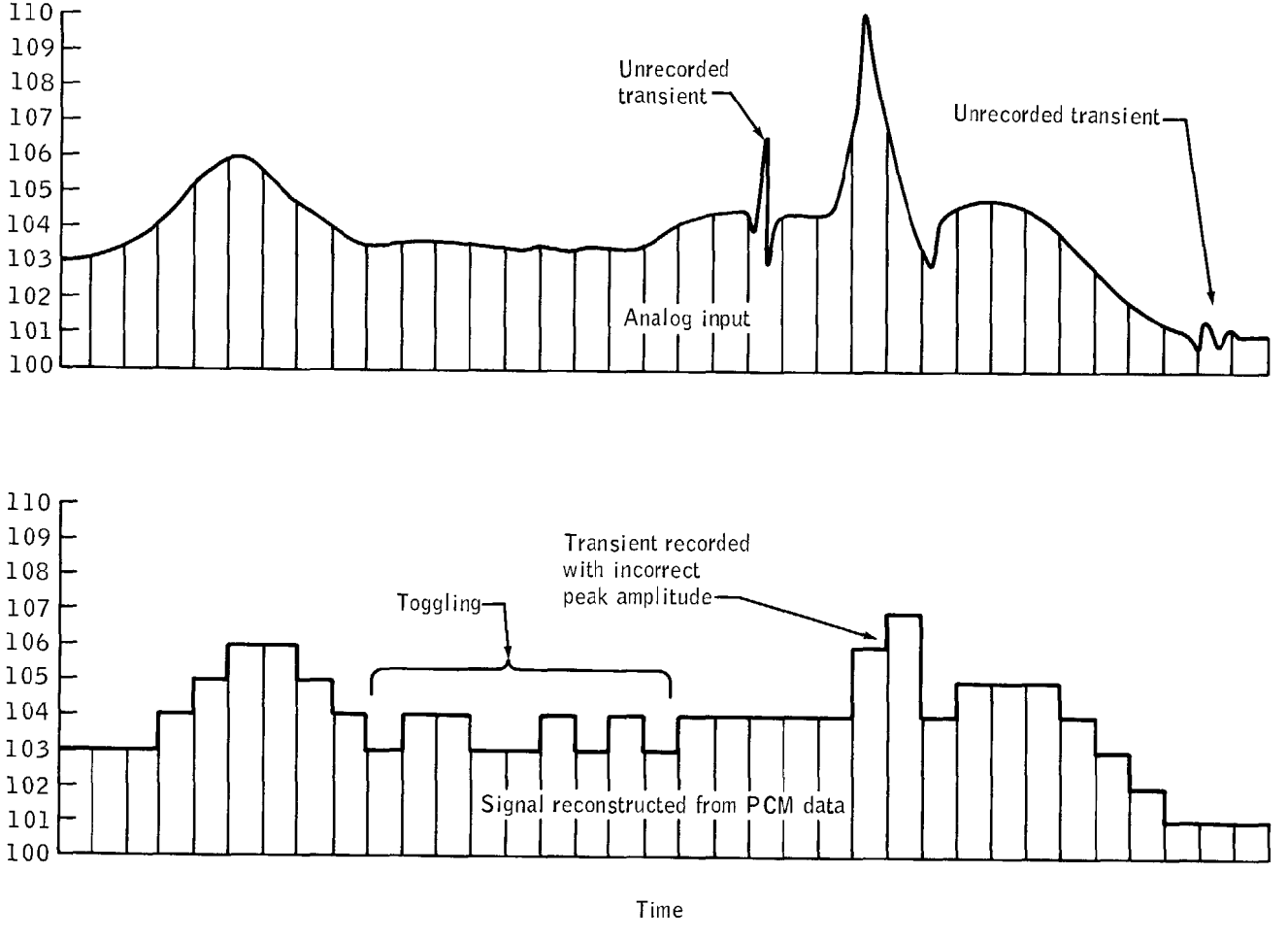


Figure B7-6.- Digital coding and reconstruction of analog signal.

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CA1820T	TEMP CREW HS ABL SUR LOC 1A	°F	-300	+850	1	-	4 - *NL
CA1821T	TEMP CREW HS ABL SUR LOC 4A	°F	-300	+850	1	-	4 - NL
CA1822T	TEMP CREW HS ABL SUR LOC 7A	°F	-300	+850	1	-	4 - NL
CA1823T	TEMP CREW HS ABL SUR LOC 10A	°F	-300	+850	1	-	4 - NL
SA1830T	TEMP SM SKIN SURF LOC 1A	°F	-120	+270	1	-	1.5 - NL
SA1831T	TEMP SM SKIN SURF LOC 4A	°F	-120	+270	1	-	1.5 - NL
SA1832T	TEMP SM SKIN SURF LOC 7A	°F	-120	+270	1	-	1.5 - NL
SA1833T	TEMP SM SKIN SURF LOC 10A	°F	-120	+270	1	-	1.5 - NL
SA2377T	TEMP BAY 2 OX TANK SURFACE	°F	-100	+200	1	-	1.2
SA2378T	TEMP BAY 3 OX TANK SURFACE	°F	-100	+200	1	-	1.2
SA2379T	TEMP BAY 5 FUEL TANK SURFACE	°F	-100	+200	1	-	1.2
SA2380T	TEMP BAY 6 FUEL TANK SURFACE	°F	-100	+200	1	-	1.2
SC0030Q	QUANTITY H2 TANK 1	PCT	0	100	1	1	0.4
SC0031Q	QUANTITY H2 TANK 2	PCT	0	100	1	1	0.4
SC0032Q	QUANTITY O2 TANK 1	PCT	0	100	1	1	0.4
SC0033Q	QUANTITY O2 TANK 2	PCT	0	100	1	1	0.4
SC0037P	PRESS O2 TANK 1	PSIA	20	1080	1	1	4.0
SC0038P	PRESS O2 TANK 2	PSIA	20	1080	1	1	4.0
SC0039P	PRESS H2 TANK 1	PSIA	0	350	1	1	1.5
SC0040P	PRESS H2 TANK 2	PSIA	0	350	1	1	1.5
SC0041T	TEMP O2 TANK 1	°F	-325	+80	1	1	1.6
SC0042T	TEMP O2 TANK 2	°F	-325	+80	1	1	1.6
SC0043T	TEMP H2 TANK 1	°F	-425	-200	1	1	1.0
SC0044T	TEMP H2 TANK 2	°F	-425	-200	1	1	1.0
CC0175T	TEMP STATIC INVERTER 1	°F	+32	+248	1	-	1
CC0176T	TEMP STATIC INVERTER 2	°F	+32	+248	1	-	1
CC0177T	TEMP STATIC INVERTER 3	°F	+32	+248	1	-	1 - NL
CC0200V	AC VOLTAGE MAIN BUS 1 PHASE A	VAC	0	+150	10	1	0.6
CC0203V	AC VOLTAGE MAIN BUS 2 PHASE A	VAC	0	+150	10	1	0.6
CC0206V	DC VOLTAGE MAIN BUS A	VDC	0	+45	10	1	0.18
CC0207V	DC VOLTAGE MAIN BUS B	VDC	0	+45	10	1	0.18

NL - Non Linear

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CC0210V	DC VOLTAGE BAT-TERY BUS A	VDC	0	+45	10	1	0.18
CC0211V	DC VOLTAGE BAT-TERY BUS B	VDC	0	+45	10	1	0.18
CC0215C	DC CURRENT BATT CHARGER OUT	AMP	0	+5	10	1	0.02
CC0222C	DC CURRENT BATTERY A	AMP	0	+100	10	1	0.4
CC0223C	DC CURRENT BATTERY B	AMP	0	+100	10	1	0.4
CC0224C	DC CURRENT BATTERY C	AMP	0	+100	10	1	0.4
CC0232V	DC VOLTAGE BAT-TERY RELAY BUS	VDC	0	+45	10	1	0.18
SC2060P	N2 PRESSURE FC 1 REGULATED	PSIA	0	75	10	-	0.3
SC2061P	N2 PRESSURE FC 2 REGULATED	PSIA	0	75	10	-	0.3
SC2062P	N2 PRESSURE FC 3 REGULATED	PSIA	0	75	10	-	0.3
SC2066P	O2 PRESSURE FC 1 REGULATED	PSIA	0	75	10	-	0.3
SC2067P	O2 PRESSURE FC 2 REGULATED	PSIA	0	75	10	-	0.3
SC2068P	O2 PRESSURE FC 3 REGULATED	PSIA	0	75	10	-	0.3
SC2069P	H2 PRESSURE FC 1 REGULATED	PSIA	0	75	10	-	0.3
SC2070P	H2 PRESSURE FC 2 REGULATED	PSIA	0	75	10	-	0.3
SC2071P	H2 PRESSURE FC 3 REGULATED	PSIA	0	75	10	-	0.3
SC2081T	TEMP FC 1 COND EXHAUST	°F	+145	+250	1	1	0.4
SC2082T	TEMP FC 2 COND EXHAUST	°F	+145	+250	1	1	0.4
SC2083T	TEMP FC 3 COND EXHAUST	°F	+145	+250	1	1	0.4
SC2084T	TEMP FC 1 SKIN	°F	+80	+550	1	1	2
SC2085T	TEMP FC 2 SKIN	°F	+80	+550	1	1	2
SC2086T	TEMP FC 3 SKIN	°F	+80	+550	1	1	2
SC2087T	TEMP FC 1 RADIATOR OUTLET	°F	-50	+300	1	1	1.4
SC2088T	TEMP FC 2 RADIATOR OUTLET	°F	-50	+300	1	1	1.5
SC2089T	TEMP FC 3 RADIATOR OUTLET	°F	-50	+300	1	1	1.5
SC2090T	RAD INLET TEMP FC 1	°F	-50	+300	1	-	1.5
SC2091T	RAD INLET TEMP FC 2	°F	-50	+300	1	-	1.5
SC2092T	RAD INLET TEMP FC 3	°F	-50	+300	1	-	1.5
SC2113C	DC CURRENT FC 1 OUTLET	AMP	0	+100	10	1	0.4

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
SC2114C	DC CURRENT FC 2 OUTPUT	AMP	0	+100.0	10	1	0.4
SC2115C	DC CURRENT FC 3 OUTPUT	AMP	0	+100.0	10	1	0.4
SC2139R	FLOW RATE H2 FC 1	LB/HR	0	.2	10	-	.001 - NL
SC2140R	FLOW RATE H2 FC 2	LB/HR	0	.2	10	-	.001 - NL
SC2141R	FLOW RATE H2 FC 3	LB/HR	0	.2	10	-	.001 - NL
SC2142R	FLOW RATE O2 FC 1	LB/HR	0	1.7	10	-	.005 - NL
SC2143R	FLOW RATE O2 FC 2	LB/HR	0	1.7	10	-	.005 - NL
SC2144R	FLOW RATE O2 FC 3	LB/HR	0	1.7	10	-	.005 - NL
SC2160X	PH FACTOR WATER COND FC 1		NORM	HIGH	10	1	
SC2161X	PH FACTOR WATER COND FC 2		NORM	HIGH	10	1	
SC2162X	PH FACTOR WATER COND FC 3		NORM	HIGH	10	1	
CC2962C	CSM TO LEM CURRENT MONITOR	AMP	0	+10	10	1	0.04
CD0005V	DC VOLTAGE PYRO BUS A	VDC	0	+40	10	-	0.15
CD0006V	DC VOLTAGE PYRO BUS B	VDC	0	+40	10	-	0.15
CD0023X	CM-SM RELAY CLOSE A			SEP	10	1	
CD0024X	CM-SM SEP RELAY CLOSE B			SEP	10	1	
CD0123X	SLA SEPARATION RELAY A			SEP	10	1	
CD0124X	SLA SEPARATION RELAY B			SEP	10	1	
CD0130X	HAND CONTROLLER INPUT A			ABORT	10	1	
CD0131X	HAND CONTROLLER INPUT B			ABORT	10	1	
CD0132X	EDS ABORT LOGIC INPUT NO 1		VOTE/ OFF	ARM	10	1	
CD0133X	EDS ABORT LOGIC INPUT NO 2		VOTE/ OFF	ARM	10	1	
CD0134X	EDS ABORT LOGIC INPUT NO 3		VOTE/ OFF	ARM	10	1	
CD0135X	EDS ABORT LOGIC OUTPUT A			ABORT	10	1	
CD0136X	EDS ABORT LOGIC OUTPUT B			ABORT	10	1	
CD0170X	RCS ACTIVATE SIG A			ENABLE	10	1	
CD0171X	RCS ACTIVATE SIG B			ENABLE	10	1	
CD0173X	CM RCS PRESS SIG A			PRESS	10	1	
CD0174X	CM RCS PRESS SIG B			PRESS	10	1	
CD0200V	DC VOLTAGE LOGIC BUS A	VDC	0	+40	10	-	0.15

NL - Non Linear

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CD0201V	DC VOLTAGE LOGIC BUS B	VDC	0	+40	10	-	0.15
CD0230X	FWD HS JETTISON A			JETT	10	1	
CD0231X	FWD HS JETTISON B			JETT	10	1	
CD1154X	CSM-LEM LOCK RING SEP RELAY A			SEP	10	1	
CD1155X	CSM-LEM LOCK RING SEP RELAY B			SEP	10	1	
CE0001X	DROGUE DEPLOY RELAY CLOSE A			DEPLOY	10	1	
CE0002X	DROGUE DEPLOY RELAY CLOSE B			DEPLOY	10	1	
CE0003X	MAIN CHUTE DEPL DRG REL RLY A			DEPLOY	10	1	
CE0004X	MAIN CHUTE DEPL DRG REL RLY B			DEPLOY	10	1	
CE0321X	MAIN CHUTE DISCONNECT RELAY A			DISC	10	1	
CE0322X	MAIN CHUTE DISCONNECT RELAY B			DISC	10	1	
CF0001P	PRESSURE CABIN	PSIA	0	17	1	1	0.067
CF0002T	TEMP CABIN	°F	+40	+125	1	1	0.3 - NL
CF0003P	PRESS O2 SUIT TO CABIN DIFF	IN H2O	-5	+5	10	-	0.04
CF0005P	PRESS CO2 PARTIAL	MM HG	0	30.00	1	1	0.12 - NL
CF0006P	PRESS SURGE TANK	PSIA	30	1080	10	1	4
CF0008T	TEMP SUIT SUPPLY MANIF	°F	+20	+95	1	1	0.3
CF0009Q	QUANTITY WASTE WATER TANK	PCT	0	100	1	1	0.4 - NL
CF0010Q	QUAN POTABLE H2O TANK	PCT	0	100	1	1	0.3 - NL
CF0012P	PRESS SUIT DEMAND REG SENSE	PSIA	0	17	10	1	0.07
CF0015P	PRESS SUIT COMPRESSOR DIFF	PSID	0	1.00	10	1	0.0035 - NL
CF0016P	PRESS GLYCOL PUMP OUTLET	PSIG	0	60	10	1	0.24
CF0017T	TEMP GLYCOL EVAP OUTLET STEAM	°F	+20	+95	1	-	0.3
CF0018T	TEMP GLY EVAP OUTLET LIQUID	°F	+25	+75	1	1	0.2
CF0019Q	QUANTITY GLYCOL ACCUM	PCT	0	107	10	1	0.5 - NL
CF0020T	TEMP SPACE RADIATOR OUTLET	°F	-50	+100	1	1	0.6 - NL
CF0034P	BACK PRESS GLYCOL EVAPORATOR	PSIA	0	0.25	1	-	0.0008
CF0035R	FLOWRATE ECS O2	LB/HR	0.16	1	10	-	0.003 - NL
CF0036P	PRESS OUTLET O2 REG SUPPLY	PSIG	0	150	10	1	0.6

NL - Non Linear

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CF0070P	PRESS SEC GLYCOL PUMP OUTLET	PSIG	0	60	10	1	0.24
CF0071T	TEMP SEC EVAP OUTLET LIQUID	°F	+25	+75	10	1	0.2
CF0072Q	QUANTITY SEC GLYCOL ACCUM	PCT	0	100	10	1	0.8 - NL
CF0073P	PR SECONDARY EVAP OUT STEAM	PSIA	0.05	0.25	1	-	0.0008
CF0120P	PRESS H2O AND GLYCOL TANKS	PSIA	0	50	1	-	0.2
CF0157R	RATE GLYCOL FROM THERMAL LOAD	LB/HR	45	330	10	-	0.9 - NL
CF0181T	TEMP GLYCOL EVAP INLET	°F	+35	+100	1	-	0.3
SF0260T	TEMP PRIMARY RADIATOR INLET	°F	+55	+120	1	1	0.25
SF0262T	TEMP SECONDARY RADIATOR INLET	°F	+55	+120	1	1	0.25
SF0263T	TEMP SEC RADIATOR OUTLET	°F	+30	+70	1	1	0.15
SF0266X	RADIATOR FLOW CONT SYS 1 OR 2		SYS 1	SYS 2	10	1	
CF0460T	TEMP URINE DUMP NOZZLE	°F	0	+100	1	1	0.4
CF0461T	TEMP WASTE WATER DUMP NOZZLE	°F	0	+100	1	1	0.4
CG1040V	120 VDC PIPA SUPPLY DC LEVEL	VDC	+84	+135	1	-	0.2
CG1110V	2.5 VDC TM BIAS	VDC	0	5	1	1	0.02
CG1201V	IMU 28V .8KC 1 PCT	VRMS	0	30	1	-	0.12 - NL
CG1331V	3.2KC 28V SUPPLY	VRMS	0	30	1	-	0.12 - NL
CG1513X	28V IMU STANDBY		OFF	STBY	10	1	
CG1523X	28V CMC OPERATE		OFF	OPR	10	1	
CG1533X	28V OPTX OPERATE		OFF	OPR	10	1	
CG2112V	IG 1X RESOLVER OUTPUT SIN	VRMS	-21	+21	10	-	0.17
CG2113V	IG 1X RESOLVER OUTPUT COS	VRMS	-21	+21	10	-	0.17
CG2117V	IGA SERVO ERROR IN PHASE	VRMS	-3	+3	100	-	0.025
CG2142V	MG 1X RESOLVER OUTPUT SIN	VRMS	-21	+21	10	-	0.16
CG2143V	MG 1X RESOLVER OUTPUT COS	VRMS	-20	+40	10	-	0.16
CG2147V	MGA SERVO ERROR IN PHASE	VRMS	-3	+3	100	-	0.024
CG2172V	OG 1X RESOLVER OUTPUT SINE	VRMS	-21	+21	10	-	0.16

NL - Non Linear

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CG2173V	OG 1X RESOLVER OUTPUT COS	VRMS	-21	+21	10	-	0.16
CG2177V	OGA SERVO ERROR IN PHASE	VRMS	-3	+3	100	-	0.025
CG2300T	PIPA TEMPERATURE	°F	+119	+140	1	1	0.08
CG3721V	SHAFT CDU DAC OUTPUT	VRMS	-12	+12	10	-	0.09
CG3722V	TRUNNION CDU DAC OUTPUT	VRMS	-12	+12	10	-	0.09
CG5040X	CMC WARNING		WARN		10	1	
CH3500H	FDAI CM/SM ATT ERROR PITCH	DEG	-5 -15	+5 +15	50	-	MM
CH3501H	FDAI CM/SM ATT ERROR YAW	DEG	-5 -15	+5 +15	50	-	MM
CH3502H	FDAI CM/SM ATT ERROR ROLL	DEG	-5 -50	+5 +50	100	-	MM
CH3503R	FDAI SCS BODY RATE PITCH	DEG/SEC	-1 -5 -10	+1 +5 +10	100	-	MM
CH3504R	FDAI SCS BODY RATE YAW	DEG/SEC	-1 -5 -10	+1 +5 +10	100	-	MM
CH3505R	FDAI SCS BODY RATE ROLL	DEG/SEC	-1 -5 -50	+1 +5 +50	100	-	MM
CH3517H	GIMBAL POSITION PITCH 1 OR 2	DEG	-5	+5	100	-	0.04
CH3518H	GIMBAL POSITION YAW 1 OR 2	DEG	-5	+5	100	-	0.04
CH3546X	RCS SOLENOID ACT C3/13/X		FIRE/OFF	ARM	200	-	
CH3547X	RCS SOLENOID ACT A4/14/X		FIRE/OFF	ARM	200	-	
CH3548X	RCS SOLENOID ACT A3/23/-X		FIRE/OFF	ARM	200	-	
CH3549X	RCS SOLENOID ACT C4/24/-X		FIRE/OFF	ARM	200	-	
CH3550X	RCS SOLENOID ACT D3/25/X		FIRE/OFF	ARM	200	-	
CH3551X	RCS SOLENOID ACT B4/26/X		FIRE/OFF	ARM	200	-	
CH3552X	RCS SOLENOID ACT B3/15/-X		FIRE/OFF	ARM	200	-	
CH3553X	RCS SOLENOID ACT D4/16/-X		FIRE/OFF	ARM	200	-	
CH3554X	RCS SOLENOID ACT B1/11/Z		FIRE OFF	ARM	200	-	
CH3555X	RCS SOLENOID ACT D2/22/Z		FIRE/OFF	ARM	200	-	

MM - Multiple Mode Calibration

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CH3556X	RCS SOLENOID ACT D1/21/-Z		FIRE/ OFF	ARM	200	-	
CH3557X	RCS SOLENOID ACT B2/12/-Z		FIRE/ OFF	ARM	200	-	
CH3558X	RCS SOLENOID ACT A1/Y		FIRE/ OFF	ARM	200	-	
CH3559X	RCS SOLENOID ACT C2/Y		FIRE/ OFF	ARM	200	-	
CH3560X	RCS SOLENOID ACT C1/-Y		FIRE/ OFF	ARM	200	-	
CH3561X	RCS SOLENOID ACT A2/-Y		FIRE/ OFF	ARM	200	-	
CH3574X	TRANSLATIONAL CONTROLLER XC MD		OFF	ON	10	1	
CH3575X	TRANSLATIONAL CONTROLLER-XC MD		OFF	ON	10	1	
CH3576X	TRANSLATIONAL CONTROLLER YC MD		OFF	ON	10	1	
CH3577X	TRANSLATIONAL CONTROLLER -YC MD		OFF	ON	10	1	
CH3578X	TRANSLATIONAL CONTROLLER ZC MD		OFF	ON	10	1	
CH3579X	TRANSLATIONAL CONTROLLER -SC MD		OFF	ON	10	1	
CH3582V	SCS TVC AUTO COMMAND PITCH	VDC	-10	+10	100	-	0.08
CH3583V	SCS TVC AUTO COMMAND PITCH	VDC	-10	+10	100	-	0.08
CH3585H	ROT CONTROL/MTVC PITCH	VDC	-10	+10	50	-	0.078
CH3586H	ROT CONTROL/MTVC YAW CMC	VDC	-10	+10	50	-	0.08
CH3587H	ROT CONTROL/MTVC ROLL CMC	DEG	-11	+11	50	-	0.087
CH3588X	ATTITUDE DEADBAND MINIMUM		MAX	MIN	10	1	
CH3590X	HIGH PRO RATE LIMIT		LOW	HIGH	10	1	
CH3592X	FDAI SCALE ERROR 5, RATE 5		OFF	ON	10	1	
CH3593X	FDAI SCALE ERROR 50/15, RT50/10		OFF	ON	10	1	
CH3600X	SCS DELTA V CG-LM/CSM POS		CSM	LM/ CSM	10	1	
CH3601X	DIR RCS SW NO 1 ENABLE POS		OFF	ENABLE	10	1	
CH3602X	DIR RCS SW NO 2 ENABLE POS		OFF	ENABLE	10	1	
CH3604X	SPS SOLENOID DRIVER NO 1		FIRE/ OFF	ARM	10	1	
CH3605X	SPS SOLENOID DRIVER NO 2		FIRE/ OFF	ARM	10	1	

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CH3606X	LIMIT CYCLE SW OFF POS		ON	OFF	10	1	
CH3607X	SC CONTROL SOURCE SWITCH		CMC	SCS	10	1	
CH3609X	ROLL MAN ATT SW ACCEL CMD POS		OFF	ON	10	1	
CH3610X	R MAN ATT SW MIN IMP CMD POS		OFF	ON	10	1	
CH3612X	PITCH MAN ATT SW ACCEL CMD POS		OFF	ON	10	1	
CH3613X	P MAN ATT SW MIN IMP CMD POS		OFF	ON	10	1	
CH3615X	YAW MAN ATT SW ACCEL CMD POS		OFF	ON	10	1	
CH3616X	YAW MAN ATT SW MIN IMP CMD POS		OFF	ON	10	1	
CH3623X	GYRO 1 COMB SPIN MTRS RUN DET		LOW	NORM	10	1	
CH3624X	GYRO 2 COMB SPIN MTRS RUN DET		LOW	NORM	10	1	
CH3635X	BMAG MODE SW-ROLL ATT 1 RT 2		OFF	ON	10	-	
CH3636X	BMAG MODE SW-ROLL RATE 2		OFF	ON	10	-	
CH3638X	BMAG MODE SW-PITCH ATT 1 RT 2		OFF	ON	10	-	
CH3639X	BMAG MODE SW-PITCH RATE 2		OFF	ON	10	-	
CH3641X	BMAG MODE SW-YAW ATT 1 RT 2		OFF	ON	10	-	
CH3642X	BMAG MODE SW-YAW RATE 2		OFF	ON	10	-	
CH3666C	TVC PITCH DIFF CURRENT	MAMP	-800	+800	200	-	
CH3667C	TVC YAW DIFF CURRENT	MAMP	-800	+800	100	-	
CJ0060J	EKG COMMANDER LH COUCH	MV	NA	NA	200	-	
CJ0061J	EKG COMMANDER CTR COUCH	MV	NA	NA	200	-	
CJ0062J	EKG LM PILOT RH COUCH	MV	NA	NA	200	-	
CJ0200R	RESP RATE CMD, CM/LM PILOT	OHM	NA	NA	50	-	
CJ0201R	RESP RATE CM PILOT CTR COUCH	OHM	NA	NA	50	-	
CJ0202R	RESP RATE LM PILOT RH COUCH	OHM	NA	NA	50	-	
CK0026A	CM ACCEL X-AXIS	G	-2	+10	100	-	0.05
CK0027A	CM ACCEL Y-AXIS	G	-2	+2	100	-	0.016

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CK0028A	CM ACCEL Z-AXIS	G	-2	+2	100	-	0.016
CK1051K	RADIATION DOSIMETER 1	VDC	0	5	10	-	0.02 - NL
CK1052K	RADIATION DOSIMETER 2	VDC	0	5	10	-	0.02 - NL
CK1053R	DOSIMETER RATE CHANGE	VDC	0	5	1	-	0.02 - NL
CK1043	70mm HASSELBLAD		OFF	ON	100	-	
CK1044	70mm LUNAR PHOTOGRAPHY		OFF	ON	100	-	
SP0001P	HE PRESS TANK	PSIA	0.	5000	10	1	21
SP0002T	HE TEMP TANK	°F	-100	+200	1	-	1.2
SP0003P	PRESS OXIDIZER TANKS	PSIA	0	250	10	1	1
SP0006P	PRESS FUEL TANKS	PSIA	0	250	10	1	1
SP0022H	POSITION FUEL/OX VLV 1 POT B	DEG	0	90	10	-	0.46
SP0023H	POSITION FUEL/OX VLV 2 POT B	DEG	0	90	10	-	0.46
SP0024H	POSITION FUEL/OX VLV 3 POT B	DEG	0	90	10	-	0.46
SP0025H	POSITION FUEL/OX VLV 4 POT B	DEG	0	90	10	-	0.46
SP0045T	TEMP ENG VALVE BODY	°F	0	+200	1	-	0.8
SP0048T	TEMP ENG FUEL FEED LINE	°F	0	+200	1	1	0.8
SP0049T	TEMP ENG OX FEED LINE	°F	0	+200	1	1	0.8
SP0054T	TEMP 1 OX DISTRIBUTION LINE	°F	0	+200	1	-	0.8
SP0057T	TEMP 1 FUEL DISTRIBUTION LINE	°F	0	+200	1	-	0.8
SP0061T	ENG INJECTOR FLANGE TEMP NO 1	°F	0	600	1	-	2.3
SP0062T	ENG INJECTOR FLANGE TEMP NO 2	°F	0	600	1	-	2.3
SP0600P	ENG VLV ACT SYS TANK PR PRI	PSIA	0	5000.	1	-	21
SP0601P	ENG VLV ACT SYS TANK PR SEC	PSIA	0	5000.	1	-	21
SP0655Q	QUAN OX TANK 1 PRI-TOTAL AUX	PCT	0	50	1	-	0.2
SP0656Q	QUAN OX TANK 2	PCT	0	60	1	-	0.2
SP0657Q	QUAN FUEL TANK 1 PRI-TOTAL AUX	PCT	0	50	1	-	0.2
SP0658Q	QUAN FUEL TANK 2	PCT	0	60	1	-	0.2
SP0661P	PRESS ENGINE CHAMBER	PSIA	0	150	100	-	0.6
SP0930P	PRESS FUEL SM/ENG INTERFACE	PSIA	0	300	10	-	1.3
SP0931P	PRESS OX SM/ENG INTERFACE	PSIA	0	300	10	-	1.3

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
CR0001P	HE PRESS TANK A	PSIA	0.	5000	1	1	21
CR0002P	HE PRESS TANK B	PSIA	0.	5000	1	1	21
CR0003T	HE TEMP TANK A	°F	0	+300	10	1	1.2
CR0004T	HE TEMP TANK B	°F	0	+300	10	1	1.2
CR0035P	PRESS CM-RCS HE MANIFOLD 1	PSIA	0	400	10	1	1.7
CR0036P	PRESS CM-RCS HE MANIFOLD 2	PSIA	0	400	10	1	1.7
SR5001P	HE PRESS TANK A	PSIA	0	5000	1	1	21
SR5002P	HE PRESS TANK B	PSIA	0	5000	1	1	21
SR5003P	HE PRESS TANK C	PSIA	0	5000	1	1	21
SR5004P	HE PRESS TANK D	PSIA	0	5000	1	1	21
SR5013T	HE TEMP TANK A	°F	0	+100	10	1	0.4
SR5014T	HE TEMP TANK B	°F	0	+100	10	1	0.4
SR5015T	HE TEMP TANK C	°F	0	+100	10	1	0.4
SR5016T	HE TEMP TANK D	°F	0	+100	10	1	0.4
SR5025Q	QUAN SM RCS PRO SYS A	VDC	0	5	1	1	0.02
SR5026Q	QUAN SM RCS PRO SYS B	VDC	0	5	1	1	0.02
SR5027Q	QUAN SM RCS PRO SYS C	VDC	0	5	1	1	0.02
SR5028Q	QUAN SM RCS PRO SYS D	VDC	0	5	1	1	0.02
SR5065T	TEMP ENGINE PACKAGE A	°F	0	+300	1	-	1.2
SR5066T	TEMP ENGINE PACKAGE B	°F	0	+300	1	-	1.2
SR5067T	TEMP ENGINE PACKAGE C	°F	0	+300	1	-	1.2
SR5068T	TEMP ENGINE PACKAGE D	°F	0	+300	1	-	1.2
SR5729P	A HE MANIFOLD PRESS	PSIA	0	400	10	1	1.7
SR5733P	OX MANIFOLD PR SYS A	PSIA	0	300	10	-	1.3
SR5737P	FUEL MANIFOLD PR SYS A	PSIA	0	400	10	1	1.7
SR5776P	B HE MANIFOLD PRESS	PSIA	0	400	10	1	1.7
SR5780P	OX MANIFOLD PR SYS B	PSIA	0	300	10	-	1.3
SR5784P	FUEL MANIFOLD PR SYS B	PSIA	0	400	10	1	1.7
SR5817P	C HE MANIFOLD PRESS	PSIA	0	400	10	1	1.7
SR5820P	OX MANIFOLD PR SYS C	PSIA	0	300	10	-	1.3
SR5821P	OX MANIFOLD PR SYS D	PSIA	0	300	10	-	1.3

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Continued.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
SR5822P	FUEL MANIFOLD PR SYS C	PSIA	0	400	10	1	1.7
SR5823P	FUEL MANIFOLD PR SYS D	PSIA	0	400	10	1	1.7
SR5830P	D HE MANIFOLD PRESS	PSIA	0	400	10	1	1.7
BS0080X	EDS ABORT REQUEST A		NORM	ABORT	10	1	
BS0081X	EDS ABORT REQUEST B		NORM	ABORT	10	1	
CS0150X	MASTER CAUTION-WARNING ON		WARN/OFF	NORM	10	1	
LS0200H	ANGLE OF ATTACK	PSID	0	5	10	-	0.017
CS0220T	TEMP DOCKING PROBE	°F	-100	+300	1	-	1.7
CT0012X	DSE TAPE MOTION MONITOR		OFF	MOTION	10	1	
CT0015V	SIG COND POS SUPPLY VOLTS	VDC	0	22	10	1	0.09
CT0016V	SIG COND NEG SUPPLY VOLTS	VDC	-22	0	10	1	0.09
CT0017V	SENSOR EXCITATION 5 VOLTS	VDC	0	5.5	10	1	0.02
CT0018V	SENSOR EXCITATION 10 VOLTS	VDC	0	11.	10	1	0.04
CT0120X	PCM BIT RATE CHANGE 8 BIT		LOW	HIGH	1	1	
CT0125V	PCM HI LEVEL 85 PERCENT REF	VDC	0	+5	10	1	0.02
CT0126V	PCM HI LEVEL 15 PERCENT REF	VDC	0	+5	10	1	0.02
CT0262V	UDL VALIDITY SIG 4-BIT		NA	NA	50	10	
CT0340X	PCM SYNC SOURCE EXT OR INT		INT	EXT	10	-	
CT0620E	S-BAND REC 1-2 AGC VOLTAGE	COUNTS	1	254	10	1	1 - NL
CT0640F	S-BAND RCVR 1-2 STATIC PH ERR	COUNTS	1	254	10	-	1 - NL
ST0820K	PROTON COUNT RATE CHANNEL 1	KHz	0	100	10	-	0.015 - NL
ST0821K	PROTON COUNT RATE CHANNEL 2	KHz	0	10	10	-	0.0015 - NL
ST0822K	PROTON COUNT RATE CHANNEL 3	KHz	0	10	10	-	0.0015 - NL
ST0823K	PROTON COUNT RATE CHANNEL 4	KHz	0	10	10	-	0.0015 - NL
ST0830K	ALPHA COUNT RATE CHANNEL 1	KHz	0	10	10	-	0.0016 - NL
ST0831K	ALPHA COUNT RATE CHANNEL 2	KHz	0	10	10	-	0.0015 - NL

TABLE B7-II.- COMMAND AND SERVICE MODULE TELEMETRY DATA SUMMARY - Concluded.

Measurement					Samples/Second		Units/Count
Number	Title	Unit	Approx. Range		High Bit Rate	Low Bit Rate	
			Low	High			
ST0832K	ALPHA COUNT RATE CHANNEL 3	KHz	0	10	10	-	0.0015 - NL
ST0838K	PROTON-ALPHA INTEGR COUNT RATE	KHz	0	100	10	-	0.015 - NL
ST0840T	TEMP NUCLEAR PARTICLE DET	°F	-120	+200	1	-	1.2 - NL
ST0841T	TEMP NUCLEAR PARTICLE ANALYZER	°F	-120	+200	1	-	1.2 - NL

NL - Non Linear

MISSION CONTROL

The Flight Director in Mission Control is supported by a team of specialists who are responsible for different aspects of spacecraft operation. These specialists are located in Mission Control and sit in front of console displays which provide real-time telemetry data. Each specialist is in voice contact with a group of support personnel in adjacent rooms who also have access to real-time telemetry data. See Appendix A, Part A4 for a description of the organization of Mission Control.

The display console for the CSM Electrical and Environmental Engineer (EECOM) is shown in figure B7-7 and is representative of the type of displays available to all the specialists in the Mission Control Center. The two television monitors on the console are used to display real-time telemetry data. Although various data formats are available to the EECOM, the two displays most frequently in use are shown in figures B7-8 and B7-9. These displays are updated once per second.

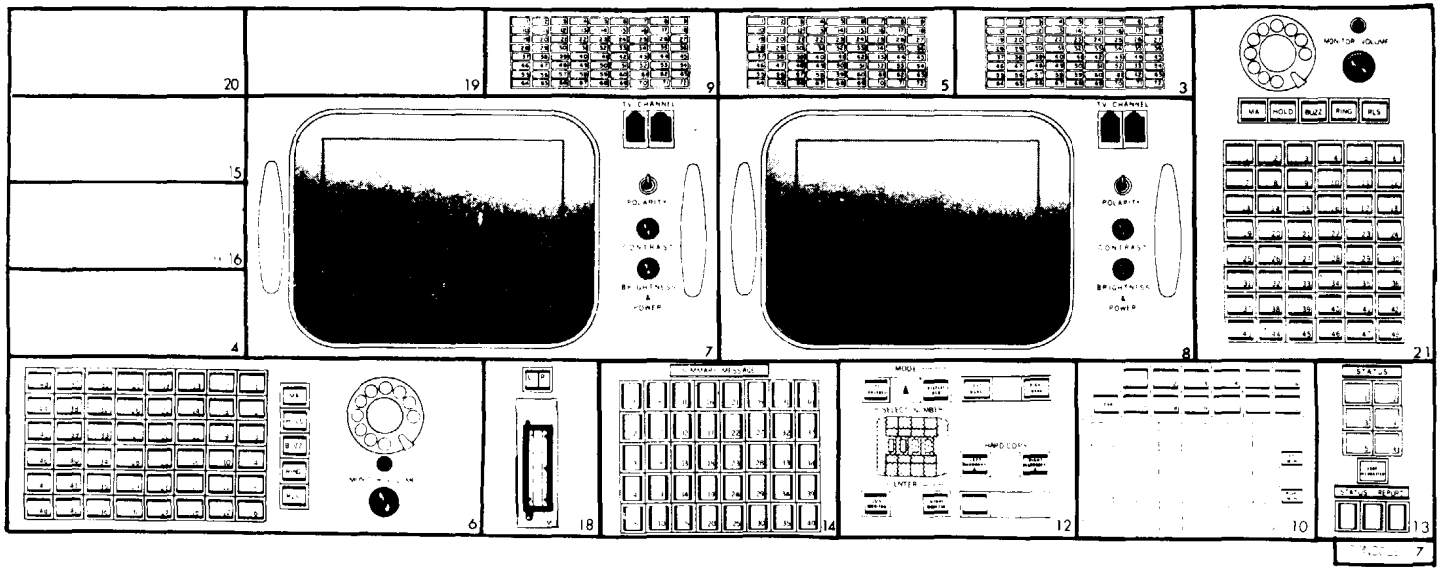
As an aid in recognizing out-of-tolerance parameters and spacecraft events, three groups of event indicators are provided at the top of the console. The lights on these panels which alert the EECOM to out-of-tolerance parameters are referred to as limit sense lights. A limit sense light comes on whenever the parameter in question falls outside of high and low limits which are manually set by the EECOM for that particular parameter. Among the 72 lights on panel 3, there are a total of 12 limit sense lights for pressure, temperature, and quantity in each cryogenic oxygen and hydrogen tank. In normal operation, the EECOM sets fairly tight limits on the limit sense lights in order to get an immediate indication of parameter variations. Consequently, it is not unusual for several limit sense lights to be burning.

Besides the limit sense lights, there are lights which indicate spacecraft events. One of these, located in the upper row of panel 9, indicates the presence of a master caution and warning in the spacecraft.

The following is a list of the system specialists in Mission Control:

(a) Retrofire Officer (RETRO) - responsible for abort planning, deorbit/entry times, and landing point prediction.

(b) Flight Dynamics Officer (FIDO) - responsible for coordinating and participating in mission planning and the control of the trajectory aspects of the mission, including powered flight trajectory, abort, and orbital GO/NO GO decision.



Location	Description	Location	Description
3	Event indicator	10	Display request keyboard
5	Event indicator	12	Manual select keyboard
6	Voice communication position	13	Status/status report
7	Precision TV monitor	14	Summary message inable keyboard
8	Precision TV monitor	18	Analog meter
9	Event indicator	21	Voice communication position

Figure B7-7.- CSM EECOM engineer console.

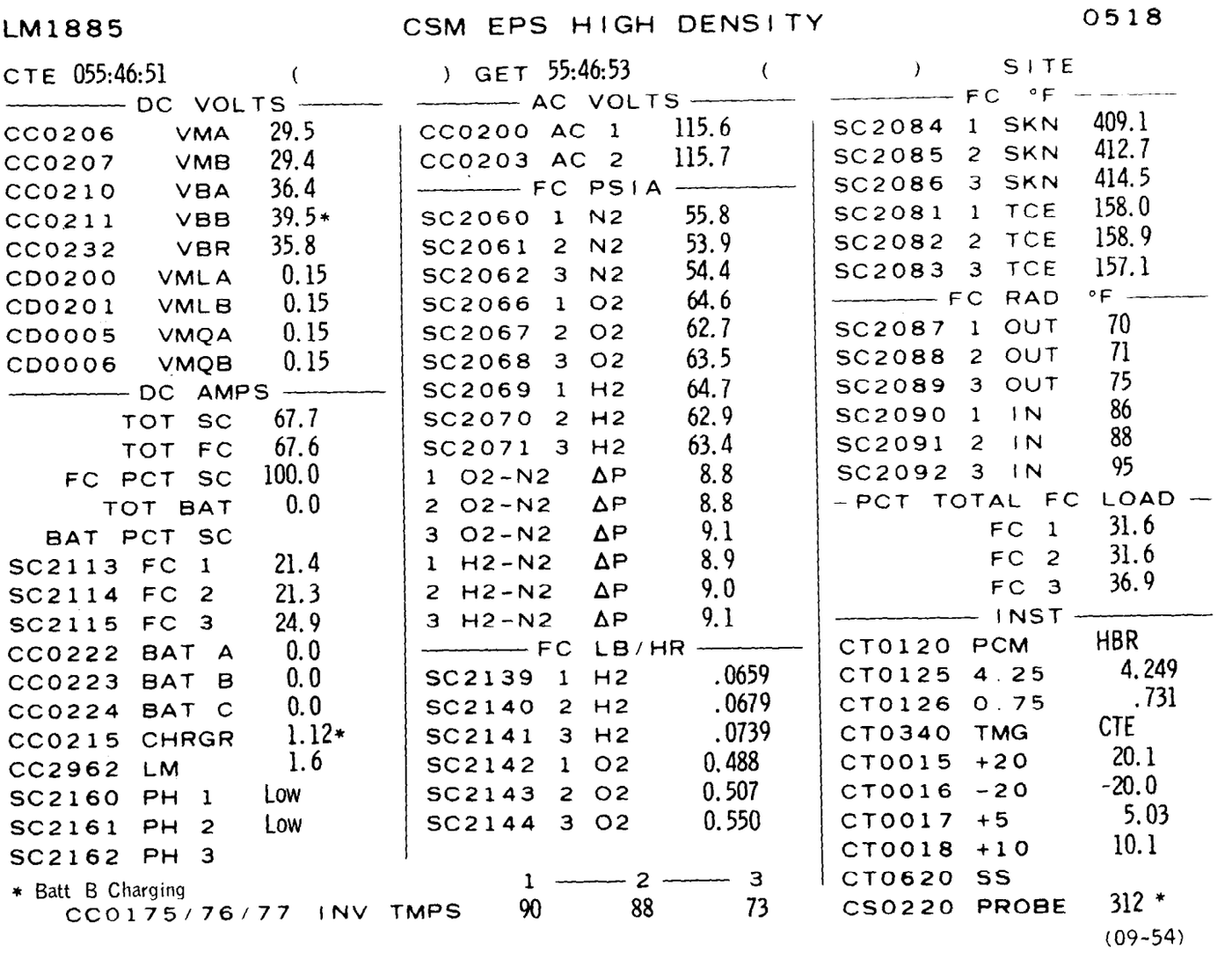


Figure B7-8.- Electrical power system parameters display.

LM1839 CSM ECS-CRYO TAB 0613

CTE 055:46:51 ( ) GET 055:46:53 ( ) SITE

— LIFE SUPPORT —				— PRIMARY COOLANT —	
GF3571	LM CABIN P	PSIA		CF0019	ACCUM QTY PCT 34.4
CF0001	CABIN P	PSIA	5.1	CF0016	PUMP P PSID 45.0
CF0012	SUIT P	PSIA	4.3	SF0260	RAD IN T °F 73.8
CF0003	SUIT ΔP	IN H2O	-1.68		
CF0015	COMP ΔP	P PSID	0.30		
CF0006	SURGE P	P PSIA	891	CF0020	RAD OUT T °F 35
	SURGE QTY	LB	3.67	CF0181	EVAP IN T °F 45.7
	O2 TK 1 CAP ΔP	PSID	21	CF0017	STEAM T °F 64.9
	O2 TK 2 CAP ΔP	PSID	17	CF0034	STEAM P PSIA .161
				CF0018	EVAP OUT T °F 44.2
CF0036	O2 MAN P	PSIA	105		
CF0035	O2 FLOW	LB/HR	0.181		
				SF0266	RAD VLV 1/2 ONE
CF0008	SUIT T	°F	50.5	CF0157	GLY FLO LB/HR 215
CF0002	CABIN T	°F	65	— SECONDARY COOLANT —	
CF0005	CO2 PP	MMHG	1.5	CF0072	ACCUM QTY PCT 36.8
— H2O —				CF0070	PUMP P PSID 9.3
CF0009	WASTE	PCT	24.4	SF0262	RAD IN T °F 76.5
	WASTE	LB	13.7	SF0263	RAD OUT T °F 44.6
CF0010	POTABLE	PCT	104.5	CF0073	STEAM P PSIA .2460
	POTABLE	LB	37.6	CF0071	EVAP OUT T °F 66.1
CF0460	URINE NOZ T	°F	70	CF0120	H2O-RES PSIA 25.8
CF0461	H2O NOZ T	°F	72	TOTAL FC CUR	AMPS

— CRYO SUPPLY —		O2-1	O2-2	H2-1	H2-2
SC0037-38-39-40 P	PSIA	913	908	225.7 (03-1)	235.1
SC0032-33-30-31 QTY	PCT	77.63	01.17	73.24	74.03
SC0041-42-43-44 T	°F	-189	-192	-417	-416
QTY	LBS	251.1	260.0	20.61	20.83

Figure B7-9.- Cryogenic system display.

(c) Guidance Officer (GUIDO) - responsible for the utilization of the guidance and navigation system, correlation of inertial alignment, and evaluation of terminal phase actions in support of rendezvous.

(d) CSM Electrical, Environmental, and Communications Engineer (EECOM) - responsible for monitoring and evaluating the performance of the electrical power, environmental control, instrumentation, and sequential systems of the command and service modules.

(e) CSM Guidance and Navigation Officer (GNC) - responsible for monitoring and evaluating the performance of the guidance and navigation, propulsion, and stabilization and control systems of the command and service modules.

(f) LM Electrical, Environmental, and EMV Officer (TELMU) - responsible for monitoring and evaluating the performance of the primary guidance and navigation, abort guidance, control electronics, ascent propulsion, descent propulsion, and reaction control systems of the lunar module.

(g) LM Control Officer (CONTROL) - responsible for monitoring and evaluating the performance of the electrical, communications, instrumentation, sequential, and environmental control systems of the lunar module.

(h) Instrumentation and Communication Officer (INCO) - responsible for monitoring and evaluating the performance of spacecraft communications systems.

(i) Procedures Officer (PROCEDURES) - responsible for the detailed procedures implementation of Mission Control.

(j) Flight Activities Officer (FAO) - responsible for the detailed implementation of the flight plan and its revision.

(k) Aeromedical Officer (SURGEON) - directs all operational medical activities concerned with the mission.

The following table lists the members of the White and Black Mission Control teams. The White Team was on duty at the time of the accident, and many of the Black Team members were in Mission Control preparatory to their going on duty about an hour later.

Position	White	Black
Flight Director	E. F. Kranz	G. S. Lunney
Asst. Flt. Dir.	J. M. Leeper	L. W. Keyser
RETRO	B. T. Spencer	T. E. Weichel
FIDO	W. M. Stoval	W. J. Boone
GUIDO	W. E. Fenner	J. G. Renick
EECOM	S. A. Liebergot	W. C. Burton
GNC	B. N. Willoughby	J. A. Kamman
TELMU	R. H. Heselmeyer	W. M. Merritt
CONTROL	L. W. Strimple	H. A. Loden
INCO	G. B. Scott	T. L. Hanchett
PROCEDURES	J. R. Fucci	E. W. Thompson
FAO	E. B. Pippert	T. R. Lindsey
SURGEON	W. R. Hawkins	G. F. Humbert

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4. Anon.: Mission Director's Summary Report, Apollo 13. Manned Spacecraft Center, April 20, 1970.

5. Anon.: Apollo 13 Mission Operations Report. Manned Spacecraft Center, April 28, 1970.

6. Anon.: Saturn AS-508 M + 5 Day Report. Marshall Space Flight Center, April 22, 1970.

7. Manned Spacecraft Center: Flight Data File. (The complete set of checklists, procedures, activity timeline books, and flight plan carried on board the spacecraft).

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