1.0 Purpose

The purpose of this report is to provide a record of the performance of the CSD (Crew Systems Division) furnished equipment during the Apollo 11 mission. This report will include preflight, inflight, and post-flight problems, activities, and performance.

2.0 Apollo 11 EMU Hardware and Crew Provisions GFE (Government-furnished equipment)

The following lists include all CSD supplied hardware either carried onboard the CM or stowed in the CM and LM for earth launch.

2.1 Apollo 11 Walk-On Equipment List

ITEM	P/N	S/N Armstrong	S/N Collins	S/N Aldrin
PGA	A7L-100000-83	056	—	077
	A7L-100000-85	—	033	—
TLSA	A7L-100002-45	056	—	077
	A7L-100004-10	—	033	—
Helmet	A7L-102043-03	028	030	027
IV Gloves	A7L-103000-18/19	131	070	141
Comfort Gloves and Wristlets		(1)	(2)	(3)
	A7L-103056-07/08			
	SDB 13100133-301			
Checklist Pocket	A7L-201121-03	006	—	—
	A7L-201047-06	—	077	—
	A7L-201121-01	—	—	020

Preliminary

2.1 (Cont'd)

ITEM	P/N	S/N Armstrong	S/N Collins	S/N Aldrin
Checklist and Scissors Pocket	A7L-201123-01	004	—	—
	A7L-201049-03	—	058	—
	A7L-201123-02	—	—	019
Donning Lanyard	A7L-101033-01/02	056	N/A	055
Donning Lanyard Pocket	A7L-201051-07	084	N/A	100
Neck Dam	A7L-101067-03	125	052	114
Bio-harness	A7L-101054-03	086	060	119
Pressure Gage	A6L-104025-04	249	248	247
Electrical Harness	A7L-101038-04	091	118	099
Dual Life Vest	SEB40100165-203	1155	1163	1167
Scissors	SDB42100059-202	1013	1014	1015
Scissors Lanyards	SDB42100118-702	1031	1033	1032
Penlight	ACR-FA-5	1065	1066	1067
Roll-on Cuff	14-283	-4	-4	-5
Bioinstrumentation System	SEB42100083-306	013	014	015
Comm. Carrier	16536G-04	142	143	144
UCTA	14-0108-02	3359	3366	3361
CWG	SEB13100061-208	1225	1249	1265
Bio-belt	SEB13100084-202	1232	1234	1236

(1) Armstrong took comfort gloves A7L-103056-07/08 sewn to wristlets P/N SDB 13100133-301. Items were carried in check list pocket.

Preliminary

2.1 (Cont'd)

(2) Collins took neither the comfort gloves nor wristlets.

(3) Aldrin wore wristlets SDB 13100133-301 for launch and carried comfort gloves A7L-103056-07/08, S/N 035.

2.2 CM Earth Launch Stowage List

2.2.1 Personalized Hardware

ITEM	P/N	S/N		
		Armstrong	Collins	Aldrin
C/M Utility Towel Ass'y (Red)	SEB42100079-204	1107		
C/M Utility Towel Ass'y (White)	SEB42100079-205		1110	
C/M Utility Towel Ass'y (Blue)	SEB42100079-206			1108
Inflight Helmet Stowage Bag	SEB13100077-206	1168	1170	1169
CWG	SEB13100061-208	1223	1251	1227
Liquid Cooled (1) Garment	A6L-400000-11	077		079
Oxygen Mask and Hose	651-400-07	1046		1047
Oxygen Mask and Hose	651-400-08		1064	
ICG Jacket Ass'y	BW-1060-002	1038	1041	1039
ICG Trouser Ass'y	BW-1061-001	1038	1041	1039
ICG Boot Ass'y Right	BW-1062-002	1038	1041	1039
ICG Boot Ass'y Left	BW-1062-001	1038	1041	1039
Fecal Containment Subsystem	A6L-501000-05	076	—	078
Urine Transfer System	14-0133-01	3743	3744	3745

2.2.1 (Cont'd)

ITEM	P/N	S/N Armstrong	S/N Collins	S/N Aldrin
Roll On Cuff Stowage Bags Ass'y (Red)	SEB42100112-201	1031		
Roll On Cuff Stowage Bags Ass'y (White)	SEB42100112-202		1037	
Roll On Cuff Stowage Bags Ass'y (Blue)	SEB42100112-203			1043
Accessory Bag	SEB13100114-701	1131	1132	1133
Head Rest Pads	BW-1052-001	1019	1020	1021
Heel Restraint	BW-1053-001/002	1019	1920	1021
PGA Elec. Conn. Proctective Cover	A7L-101118-01	N/A	N/A	N/A
UCTA Flange W/Cuffs	14-202	2952-10	2952-4	410-8

(1) Athletic suspensory stowed with each LCG.

2.2.2 Unassigned Hardware (CM Stowed)

ITEM	P/N	S/N
Medical Accessories Kit	SEB42100082-212	1211
Survival Rucksack Kit No. 1	SEB40100151-202	1116
Survival Rucksack Kit No. 2	SEB40100152-202	1110
Tissue Dispenser	SEB42100086-203	1145,1147,1148,1149,1150
EMU Maintenance Kit	A6L-503000-07	034
Water Disp./Fire Ext. Ass'y	14-0131	4137
Penlight	ACR-FA-5	1068,1069,1070,1071,1072
UCTA Clamp	14-149-01	2611, 2612, 2613

2.2.2 (Cont'd)

ITEM	P/N	S/N
Urine Receiver Ass'y (Spare)	14-02051	3486
Helmet Protective Shield	A7L-502003-03	048
UCTA Transfer Adapter	SEB12100083-301	1003
Eyepatch	SEB12100084-301	1001
CWG Elec. Adapter	A6L-507000-03	009,010, 011,018
Vacuum Brush	BW-1079-001	1104, 1105
Hyd. Gas Separator Assembly	SEB39104353-301	1005, 1007
Hyd. Gas Separator Drying Adapter	SDB39104492-301	1001

2.3 LM Earth Launch Stowage List

2.3.1 Personalized Hardware

Item	P/N	S/N Armstrong	S/N Aldrin
PLSS/EVCS Ass'y	SEB11100066-319	00015	
PLSS/EVCS Ass'y	SEB11100066-320		00014
PLSS	SV706100-6-14	00015	00014
PLSS Remote Control Unit	SV721783-08	008	010
OPS	SV730101-2-12	013	008
Helmet Stowage Bag	A6L-502000-07	054	055
LEVA	A7L-205000-02	005	006
EV Gloves	A7L-203025-13/10	073	074

2.3.1 (Cont'd)

ITEM	P/N	S/N Armstrong	S/N Aldrin
Purge Fitting	A6L-505000-04	155	157
Lunar Overshoes	A7L-106043-05/06	050	043

2.3.2 Unassigned Hardware (LM Stowed)

ITEM	P/N	S/N
PLSS LiOH Cartridge (In LM ECS)	SV710854-9	00135
COAS Light Bulb Ass'y	B50258-1	152
COAS	ME331-0018-0021	0741 (BKA)
LM Medical Package	SEB40100185-301	1002
LM Utility Towel Assembly	SEB42100080-202	1115
Def. Coll. Device	14-0111-01	2324,2325,2326,2327
Water Disp/Fire Ext. Assembly	14-0131	4153
LEC- Waist Tether Kit	SJB33100199-310	1007
Eyepatch	SEB12100084-301	1007
Camera Bracket	SV742170-2	005,006
PLSS Feedwater Coll. Bag Ass'y	BW1080-001	1106
COAS Filter	ME331-0018-0023	1275
Jettison Stowage Bag	SEB13100134-301	1001
EMU Maintenance Kit (1)	A6L-503000-07	027

(1) Item stowed in HSB S/N 054

Preliminary

3.0 Preflight Performance

3.1 EMU

A final crew fit and function, and inflight donning procedures verification exercises was conducted on June 25, 1969 at KSC in accordance with TPS No. EVA-MST-026. All prime EMU flight hardware was evaluated by the Apollo 11 crew and found satisfactory for flight.

3.1.1 PGA and Accessories

The prime PGA's (S/N 033, 056, 077) were worn for CDDT and then PIA'd for flight. One significant problem occurred during CDDT. Collins' UCTA flange created a painful pressure point which resulted from the suit being too tight in the abdomen and crotch. This problem was again noted in flight.

The PIA consisted of a complete breakdown and cleaning of all PGA hardware and functional testing of equipment as specified in the flight PIA document. The results of the pertinent functional tests during PIA are as follows:

ITEM	PGA S/N		
	056	033	077
Relief Valve			
Crack	4.90 psi	N/A	4.80
Reseat	4.75	N/A	4.81
Flowrate at 5.5 psig	Not Recorded	N/A	1.9 SCFM
Leakage			
0.18 psi	5 scc/min	60 scc/min	

Preliminary

3.1.1 (Cont'd)

ITEM	PGA S/N 056	PGA S/N 033	PGA S/N 077
4.2 in. H_2O			8 scc/min
3.75 psi (IV Gloves)	33 scc/min	60 scc/min	95 "
3.75 psi (EV Gloves)	50 "	N/A	78 "
Pressure Gage Cross Check			
3.0 psi ± .15	3.10 psi	3.0 psi	3.02 psi
3.5 " " "	3.58	3.5	3.55
4.0 " " "	4.08	4.0	4.0
4.5 " " "	4.60	4.5	4.5
5.0 " " "	5.10	5.0	5.0
6.0 " " "	6.10	6.0	6.0
4.0 " " "	4.10	4.03	4.0
3.5 " " "	3.60	3.53	3.5

ITEM	PURGE VALVE S/N 155	PURGE VALVE S/N 157
Flow Rate (lb/hr)	~~not required~~	~~not required~~
Leakage (3.7 psig)	<4 scc/m	< 4 scc/m

Verified 8.0 ± .1 #/

The LCG's were PIA'd and then charged in accordance with TCP EVA-K1006. Significant data is listed on the next page.

ITEM	LCC S/N	
	077	079
Dry Weight	3.89	4.02 lb
Wet Weight	4.88	5.13 lb
Charge Time/Date	0207/7-14-69	2220/7-12-69
Pressure Drop (PSI)		
at 3.0 lb/min	1.3	1.3
" 3.5 lb/min	1.8	1.7
" 3.8 "	1.95	2.0
" 4.0 "	2.35	2.1
" 4.3 "	2.5	2.4
" 4.5 "	2.6	2.6
" 5.0 "	3.4	3.1

Crew suiting for the Apollo 11 flight began at 0540 on July 16, 1969. Suiting was completed at 0617 with an O_2 concentration check at 0621 indicating 100 $^0/_0$ O_2 in the suit. The crew departed the ILCI Suit Lab at 0625. Results of the PGA integrity checks conducted with the suited crewman are listed below:

ITEM	PGA S/N		
	056	033	077
Relief Valve			
Crack	4.85 psi	N/A	5.1 psi
Reseat	4.65 psi	N/A	4.69 psi
Flow rate	3.0 CFM	N/A	3.0 CFM
Pressure Decay	0 psi	0 psi	0.05 psi

3.1.1 (Cont'd)

ITEM	PGA S/N 056	033	077
Pressure Drop			
at 12 scfm and 1.5 psig suit press.	10.5 in. H_2O		
at 12 scfm and 3.5 psig suit press	8.6 in. H_2O	10.0 in. H_2O	9.5 in. H_2O
at 6 scfm and 3.9 psig suit press	3.4 in. H_2O		3.3 in H_2O
at 12 scfm and 0.75 psig suit press.		11.0 in H_2O	
at 12 scfm and 1.1 psig suit press.			11.5 in H_2O

3.1.2 PLSS/OPS

PLSS's 00014 and 00015/OPS's 008 and 013 were used both during the CF[2] on June 25 and during CDDT. S/N 009 OPS developed an internal leak in the regulator early in PIA and was replaced by S/N 013. Pertinent data for both the PLSS's and OPS's are as follows:

ITEM	ARMSTRONG		ALDRIN	
	PLSS 00015	OPS 013	PLSS 00014	OPS 008
Dry Weight (lbs) (1)	55.17	29.56	54.94	29.63
Charged Weight (IBS) (2)	79.63	40.0	79.62	40.25
O_2 Pressure (PSIA)	1022	5950 at 74°F	1024.7	5950 at 74°F
Battery Activiation Date	7/13/69	7/11/69	7/13/69	7/10/69
Lanyard Slide (in)	N/A	0.62	N/A	0.62

3.1.2 (Cont'd)

ITEM	ARMSTRONG		ALDRIN	
	PLSS 00015	OPS 013	PLSS 00014	OPS 008
Switch Overtravel (in)	N/A	0.012	N/A	0.01
F/W Quantity (lbs)	8.63	N/A	8.56	N/A
T/W Quantity (lbs)	1.25	N/A	1.44	N/A
LiOH Weight (lbs)	4.69	N/A	4.60	N/A
RCU Weight (lbs)	5.19	N/A	5.13	N/A
Battery Shelf Life (3)	9/68	1/69	9/68	1/69
RCU Serial No.	010	N/A	008	N/A
Battery Serial No.	S-139	S-46	S-147	S-47
LiOH Cartridge S/N	138	N/A	136	N/A

(1) Less RCU, thermal cover, harness, battery and cartridge

(2) Completely flight configured, less RCU

(3) Dry shelf life one year from date shown.

The flight PIA's were completed on all above listed equipment on approximately 7/13/69. Functional testing resulted in the following data for the PLSS's.

ITEM	PLSS S/N	
	00014	00015
Low Pressure O_2 Loop Leakage	4.0 scc/min	4.5 scc/min
POS Leakage	0.405 psi/hr	0
Regulator Internal Leakage	0	0
OPS Backflow Check Valve Leakage	0.06 lb/hr	0.06 lb/hr

3.1.2 (Cont'd)

ITEM	PISS S/N	
Feedwater Loop External Leakage	0.018 $\frac{\text{in of } H_2O}{\text{minute}}$	0.004 $\frac{\text{in of } H_2O}{\text{minute}}$
Feedwater to O_2 Loop Leakage	0	0
Feedwater and Transport Loop Leakage	1.07 cc/hr	1.61 cc/hr
Transport Loop Leakage	0.107 cc/hr	0.21 cc/hr
Water Shutoff and Relief Valve		
Relief	56.0 psig	57 psig
Reseat	54.0 psig	54 psig
Feedwater Quantity	8.5 lb	8.5 lb
Low Vent Flow Sensor		
Actuation	4.78 ACFM	4.68 ACFM
Deactivation	5.00 ACFM	4.92 ACFM
Low PGA Pressure Switch		
Actuation	3.17 Psid	3.20 Psid
Deactivation	3.30 Psid	3.27 Psid
Low Feedwater Pressure Switch		
Activation	1.40 Psia	1.38 Psia
Deactivation	1.52 Psia	1.52 Psia

3.1.2 (Cont'd)

PLSS O_2 REGULATOR PERFORMANCE					
S/N 00014			S/N 00015		
BOTTLE PRESSURE (PSIG)	FLOW (lb/hr)	REGUALTED PRESSURE (PSID)	BOTTLE PRESSURE (PSIG)	FLOW (lb/hr)	REGULATED PRESSURE (PSID)
86	0.07	3.84	85	0.07	3.90
86	0.36	3.80	88	0.36	3.87
89	0.07	3.86	90	0.07	3.92
235	0.07	3.90	238	0.07	3.96
235	0.70	3.85	235	0.07	3.93
1105	0.07	3.90	1105	0.07	3.99
1104	2.00	3.72	1102	1.97	3.83
1105	0.07	3.85	1110	0.07	3.97

The PIA's for OPS's 008 and 013 resulted in the following:

ITEM	OPS S/N	
	013	008
Checkout Gage Accuracy Indicated ΔP at 3.5 psi	3.45 psi	3.43 psi
3.8 psi	3.75 psi	3.57 psi
High Pressure External Leakage at 6750 psi ΔP	1.03×10^{-4} cc/sec	0.14×10^{-4} cc/sec
Internal Leakage Across Regulator	24 cc/min	0

3.1.2 (Cont'd)

ITEM	OPS S/N	
	013	008
Purge Flow Performance Regulated ΔP variation at the following conditions thirty min. flow at 8 lb/hr bottle decay 6000 to 1200 psig	3.655 to 3.45 psid	—
Purge Flow Performance Regulated ΔP variation at the following conditions thirty min. flow at 8 lb/hr bottle decay 6400 to 1700 psig	—	3.68 to 3.45 psid
Make-up Flow (ΔP Range) at 6750 psig bottle pressure at flow of 0.08 lb/hr	3.785 to 3.80 psid	—
at 5750 psig bottle pressure at flow of 0.08 lb/hr	—	3.63 to 3.775 psid

3.2 Crew Provisions

All crew provisions hardware was reviewed by the crew at the bench check on February 6, 1969. An additional bench check was performed just prior to launch stowage. Crew compartment Fit and Functional (C^2F^2) exercises were performed in conjunction with the altitude chamber runs at KSC. A Δ C^2 F^2 was performed in conjunction with CDDT.

3.2 (Cont'd)

Minor modification to some of the crew provisions hardware was made during pre-launch preparations. These include the following:

a. Communications carrier sizing for Armstrong.

b. Stowage of spare UCTA flanges with roll-on-cuff installed. The crew could then install the complete flange/cuff ass'y prior to lunar surface operations rather than replacing just the cuff.

c. Armstrong's and Aldrin's CWG's were modified to increase the size of the buttocks port. Velcro was installed to provide a closure.

d. Alignment dots were added to the 61 pin connector of the CWG electrical adapter.

e. Athletic suspensories were stowed with the LCG's for use by Armstrong and Aldrin while wearing the LCG's.

f. The EMU maintenance kits were modified to provide IVCL and LITMG repair capability.

g. The LEC was modified to include a continueous Chromel thread to prevent static charge buildup.

4.0 Inflight Performance

4.1 EMU

The EMU performance was nominal throughout the mission, both while intravehicular and during lunar surface operations. Crew mobility was good during EVA and analysis of the inflight data shows good correlation with data from the SESL altitude chamber training exercises.

4.1 (Cont'd)

EVA preparations went very smoothly, however, the crew stated that additional time should be added to the timeline to account for deltas such as check lists and other items which are unstowed and must be dealt with which are not considered in training exercises.

No problems of significance were noted at LM egress. The crew stated that they were comfortable while waiting for the cabin to depressurize even though the LCG inlet temperature went above 90° F prior to sublimator startup. No thermal changes were noted at egress. The crew stated that the PLSS/OPS was quite comfortable and that the mass was not objectionable.

The flight crew commented that EMU operation, while EVA, was uneventful which indicated proper operation. There were no requirements to operate any of the PLSS controls other than the diverter valves which they both changed at their option for comfort.

The maximum range traversed was approximately 200 feet. Crewman commented that this left him a little tired. However, this was toward the end of the EVA and crewmen had not rested prior to EVA.

Crewman mobility and balance in the EMU was adequate to allow stable movement while performing lunar surface tasks. Aldrin demonstrated capability to walk, run, change direction while running, and to stop movement without difficulty. One foot in front of the other with a fairly long stride was found to be the most satsifactory method of locomotion.

4.1 (Cont'd)

Aldrin reported a tendency to tip backward in the soft lunar material and noted that he had to be careful to compensate for the different location of the center of mass. The crewmen were observed to kneel down and contact the lunar surface while retrieving objects. The crew stated that adapting to 1/6 "G" was easy and that 1/6 "G" was very easy to work in. They felt that the EMU hardware was fairly comfortable in 1/6 "G".

4.1.1 PGA and Accessories

The PGA's (including helmet and IV gloves) were worn during launch. The flight crew reported that they had no problems of "elbowing" each other. The PGA's of the CDR and LMP incorporated arm bearings but the total bulk was within the acceptable envelope for all operations.

Astronaut Collins had a fit problem in the lower abdomen and crotch of his PGA. The problem was due to the Urine Collection and Transfer Assembly (UCTA) flange causing pressure points which resulted from insufficient size in the PGA. He recommends that future fit checks be performed with the crewman wearing the UCTA, Fecal Containment Subsystem (FCS), and Liquid Cooling Garment (LCG) as applicable. In addition, he recommends that the fit check include a position simulating that which the crewman experience prelaunch.

Astronaut Armstrong commented that the contingency sample pocket of his PGA interfered with the abort handle and that although they repositioned it as much as possible toward the inner thigh, it was still a matter of concern. The pocket was installed on the upper thigh for launch as

4.1.1 PGA and Accessories Cont'd

well as for lunar surface operation. It is recommended that for future missions the pocket be strapped to the other thigh or to the calf for launch.

Helmets and gloves were removed and stowed approximately 15 minutes after launch and the remainder of the PGA was removed and stowed at approximately 5 hours 15 minutes elapsed time. The flight crew reported no problem in doffing and stowing the PGA's. All three PGA's were stowed in the PGA bag.

The PGA's (and LCG's for the CDR and LMP) were donned at approximately 97 hours elapsed time in preparation for the lunar landing and lunar surface operations. Donning was accomplished with the help of the other crewmen as required.

The suit integrity check prior to undocking was performed with the suit pressures decaying approximately 0.1 psi. The crew commented that the integrity check is fairly involved and for this reason should be performed on the earth side where communication and telemetry are available rather than on the back side of the moon.

Astronaut Aldrin had problems with the PGA wrist rings rubbing his wrists. He had decided not to wear the protective wristlets (sock tops) which he had carried on board, however in retrospect, he feels that he should have worn them.

4.1.1 PGA and Accessories cont'd

Preliminary

Astronaut Aldrin developed a pressure point in the instep of his right foot after attachment of the LM restraint. The restraint tended to pull him forward and outboard rather than straight down. He compensated for this by moving his right foot forward and to the right. His right foot was taking the majority of the load. A possible wrinkle in his LCG sock or a fold in the foot of the PGA comfort liner became apparent.

The crew recommended that the helmets be identified per crewman. Interim stowage in the LM is accomplished by use of Velcro hook installed on the helmet feedport cover, not by stowage in identifiable helmet stowage bags as in the CM. They were, however, able to identify individual helmets by the scratches. It is recommended that the individual helmets be marked with the crewman's name during flight PIA. Helmets are switched too often prior to flight PIA to make earlier identification practical.

The LEVA visors were observed to be raised in various positions throughout the EVA by each crewmen. One comment made was about a back reflection of the face from the visors, and another on the fact that there was a short eye adaptation time required when moving from sunlight to shadow.

The reflection was greatest with the sun shining approximately 90° degrees from the front of the LEVA. With this reflection it was difficult to see into shaded areas. As soon as the helmet entered the shadow the crewman began dark adapting. Continually moving back and forth from sunlight into shadow and back to sunlight should be avoided

Preliminary

4.1.1 (Cont'd)

as much as possible because it costs time in dark adapting. Proper use of the blinders on the LEVA could alleviate this problem to some extent.

The crew stated that getting down on the knees to retrieve samples and allow closer inspection of the lunar surface should be a normal operating mode. They feel that the PGA should be fully qualified to allow kneeling. The PGA, in fact, is fully qualified for kneeling on the lunar surface. The only restriction to kneeling is that care should be taken to avoid sharp rocks. They also feel that additional waist mobility is highly desirable which would ease the ability to get closer to the lunar surface and in addition would increase downward visibility.

There were no thermal problems while EVA, however, astronaut Armstrong's hands sweated inside the EV gloves. He did not wear comfort gloves, therefore, his hands tended to slip inside the gloves thereby decreasing dexterity and the ability to handle objects.

LCG (Liquid Cooling Garment) cooling was adequate although temperature data is much higher (warmer) for Astronaut Armstrong than for Astronaut Aldrin. This correlates with previous chamber experience which shows a strong preference for Armstrong to maintain a warmer body temperature than Aldrin. This parameter is controlled by the crewman to meet his comfort requirements.

4.1.1 (Cont'd)

Two additional problems were noted by the crew and will be further discussed in Section V. Collins stated that the elbow of his PGA frayed rather badly and Aldrin stated that his urine connector came loose from the ITMG mounting flange.

4.1.2 PLSS/OPS

Analysis of the EVA data (See Figure 1 thru 12) shows a good correlation with data from previous training runs conducted in the SESL Chamber B facility. (NOTE: Quantitative data, i.e., pressures, voltages, etc., quoted in the following paragraphs is from tabulated data rather than the curves of Figure 1 thru 12.) As expected, the feedwater pressure was slightly higher than that indicated in chamber data. The difference is probably due to the lunar gravitational effect on the head of water at the sublimator and transducer which is the high point in the system. The only other discernible differences were in temperature readouts which generally indicated better performance (more cooling) than expected.

Analysis of remaining expendables on the Armstrong PLSS S/N 0015 indicates a good correlation between oxygen and water usage. Measured water remaining in S/N 00015 was approximately 5.7 lbs. Comparison of water and oxygen usage on the Aldrin PLSS S/N 00014 cannot be made directly as no water measurement was taken. Two problems were encountered during pre-egress activities; mating of the RCU connector and bumping the LM breaker and two circuit breakers to be switched. The crew recommends very deliberate careful motions in the future.

4.1.2 PLSS/OPS cont'd

Astronaut Armstrong estimated that it took 10 minutes to make each RCU connector. The problem was that each time the crewman thought he had the connector lined up and began to rotate the lever, the connector would cock off to one side. Investigations are being conducted to replace or modify the RCU connector to ease installation and/or stow the RCU mated to the PLSS.

The crew discovered a PLSS control with which they were not familiar. They stated that it looked like a press-to-test button or relief valve. During the debriefing the crew was shown a photograph of the PLSS and identified the control as the battery release mechanism. They weren't familiar with this item because the Apollo 11 mission didn't include a battery change; therefore, none of their training exercises included operation of this mechanism.

Armstrong had trouble installing the camera on the RCU camera mount. Binding occurred during initial engagement of the bracket to the mount. This had never been a problem prior to flight.

4.1.2.1 Communications Check

(From power on at 108:07:20 CDR and LMP to fan on at 108:30:10 LMP; 108:32:48 CDR)

During the PLSS communication check there was no noticable difference in the quality of the telemetry and voice transmissions being received in the various mode switch positions. The initial PLSS O_2 quantity was 1020 psia from both PLSS's (See Figure 1 and Figure 2). This compares favorably to the preflight 1024.7 psia for PLSS S/N 00014 and 1022 psia for PLSS S/N 00015. Communications broke up several times during PLSS checkout. At the time it was thought to be due to PLSS antenna position, however, it was determined by the crew that the condition would occur regardless of antenna position. The problem was not a serious one but is presently under investigation by SESD. Preliminary results indicate the possibility of an improperly set LM VOX sensitivity switch causing the disturbance. All warning tones and flags were normal, all telemetry channels indicated properly and current and voltage values were nominal for this mode.

4.1.2.2 PLSS Startup

(From fan on to feedwater tone off 109:13:18 CDR; 109:13:24 LMP.) PLSS fan startup was normal for both the CDR and LMP. The total time without cooling was somewhat longer than had been expected. The LM-192 pump was shut down at 108:37 and effective cooling didn't begin again until 109:13 for both crewmen. This amounts to 36 minutes without cooling as compared to 21 minutes each during the LM-5 crew training at SESL. In the debriefing, the crew said that they did not notice any undue discomfort due to the lack of cooling. The pump startup traces were normal (See Figure 3 and Figure 4). The total current drain with all systems running and with high suit pressures of just under 5.0 psi for both crewmen was 3.0 Amps for the CDR and 3.4 Amps for the LMP. This was also the lowest voltage point with 16.2 volts for both crewmen. Current eventually stabilized out at vacuum at 2.4 Amps for the CDR and 2.5 Amps for the LMP. During the initial PLSS pressurization of the PGA, the PLSS O_2 bottle lost 71 psi (1031 psia to 960 psia) for the CDR (See Figure 2) and 55 psi (1035 psia to 980 psia) for the LMP (See Figure 1). The LMP's data compares favorably with the 48 psi which he used at SESL but the CDR's 71 psi does not compare well with the 54 psi used during SESL. Analysis indicates that this disparity is probably due to the design of the transducer which results in about a 40 psi error band. The CDR's PGA relief valve relieved at just under 5.0 psid (See Figure 5) and reseated at about 4.7 psid. This is a good correlation with the preflight pia data of 4.90 and 4.75 for relief and reseat respectively. The LMP's valve relieved above 5.0 psid (See Figure 6) and reseated at 4.68 psid. This also compares favorably with the preflight pia data of 5.1 psid and 4.69 psid for relief and reseat respectively. The CDR's feedwater warning deactuated 3 min. 27 sec. after turning the feedwater valve on; the LMP's deactuated 4 min. 52 sec. after turning the valve on. SESL times for these events were 3:28 and 3:44 for CDR and LMP respectively. The longer sublimator startup time for the LMP was probably due to his relatively higher heat storage prior to sublimator startup. The CDR's suit pressure decayed from relief valve reseat at 4.7 psid to regulator unlock at 3.9 psid in 10 minutes (0.08 psi/min.). The LMP's suit pressure decayed from 4.7 psid to 3.85 psid in 6 minutes (0.14 psi/min.).

4.1.2.3 <u>EVA</u>

(From feedwater tone off to feedwater valve closed 111:39:38 CDR; 111-39:50 LMP.)

The CDR used MIN or MIN/INT diverter valve position throughout the EVA until just prior to ingress. The performance of the PLSS was slightly better than that which was seen at SESL with the diverter valve in minimum, which gave rise to speculation that the CDR was between detents (MIN/INT) during EVA. If the CDR was between detents he was not aware of it and thought he was in MIN. At 111:32:45, about six minutes prior to ingress the CDR went to INT to prepare for the ingress (See Figure 7). At 111:39:06, during ingress, the CDR's inlet temperature was down to 61.7°F, which was too cool for his liking. In an attempt to go to MIN, he inadvertantly went to MAX at this point and remained there for 12 seconds before going to MIN. During this 12 second interval, the inlet dropped another 10°F to 51.4°F. The CDR remained in MIN for the duration of the PLSS operation. The LMP went to MAX right after his feedwater warning flag deactuated at 109:13:24 (See Figure 8). He remained in MAX and then at 109:54:52, went to INT for the remained of the EVA. Feedwater pressure remained higher than SESL data during the EVA (See Figure 9 and Figure 10). This could be caused by the lower gravity field on the lunar surface acting on the negative water head at the feedwater pressure transducer. Regulator performance for both crewmen was exactly the same as in SESL. The CDR used 320 psi of O_2 during the EVA from relief valve reseat at 109:00:00 to start of repress at 111:42 (from 960 psia to 640 psia in 2 hours 42 minutes). The LMP used 375 psi of O_2 over the same period (from 980 psia to 605 psia in 2 hours 42 minutes).

4.1.2.4 PLSS Shut Down

(From feedwater valve closed to power off 111:56:09 LMP; 111:57:20 CDR) In the two minutes between the closing of the feedwater valves and the start of cabin repress at 111:42:00, there was no loss of cooling performance. Neither crewman's suit went negative during the repress; in fact, neither went below 2.5 psid. The CDR's minimum suit pressure was 2.85 psid and the POS bottle lost 44 psi (from 640 psia to 596 psia) during repress. The minumum suit pressure for the LMP was 2.74 psid and the POS bottle lost 55 psi (from 605 psia to 550 psia) during repress. At 111:44:00, the CDR closed his O_2 valve just as the cabin pressure was leveling off. His pressure stabilized at about 3.0 psid. At 111:45:42, the CDR depressurized his suit in about three seconds, probably by opening his purge valve. The LMP closed his O_2 valve at 111:44:25 and his suit pressure stabilized at 3.4 psid. At 111:45:25, the LMP depressurized his suit, probably by the same method. Feedwater pressure dropped off nominally for both crewmen. Fan and pump shut downs were normal and the CDR turned his mode switch to "O" at 111:57:20 and the LMP at 111:56:09.

4.1.2.5 Feedwater Collection

After the EVA, the crew measured the feedwater remaining in the CDR's PLSS (S/N 00015). The procedure used was to place the empty feedwater collection bag on the scale and adjust the scale to zero. Then the empty bag was removed and the RCU from the CDR's PLSS (a known earth weight of 5.19 lbs.) was placed on the scale and the measurement recorded. The crew then placed the filled feedwater bag on the scale and recorded the result. The calculation is contained on page 27. In order to determine

FEEDWATER COLLECTION BAG CALCULATIONS

Given: 1. 0.75 scale pounds (12.5 scale ounces) of collected feedwater.
2. A feedwater collection bag of 0.47 earth pounds (empty)
3. An RCU of 5.19 earth pounds

Problem: To determine the earth/scale ratio so that the 0.78 scale pounds of water can be converted into earth pounds of water.

Calculations: Let us take the crew procedure and results and perform them at earth gravity mathematically. We will then compare the earth result to the scale result and obtain the desired ratio.

Step #1. Place bag on scale and zero scale
Step #2. Remove bag
Step #3. Place RCU on scale

Scale result 0.75lbs. Earth result

$$\begin{array}{r} 5.19 \\ -0.47 \\ \hline 4.72\text{lbs.} \end{array}$$

Therefore 4.72 earth pounds equals 0.75 scale pounds. The ratio then is:

$$\frac{4.72}{0.75} = \frac{6.29}{1}$$

Result: Earth lbs. = scale lbs. x 6.29
Earth lbs. = 0.78 (6.29)
Earth lbs. = 4.90 lbs.

the total feedwater remaining, that which was collected (4.90 lbs.) must be added to the amount of unmeasurable water left in the PLSS (0.83 lbs.). This results in a total of 5.73 lbs. of feedwater remaining in PISS S/N 00015. The PLSS pre-EVA feedwater weight was 8.62 lbs. Therefore, 2.89 lbs. of feedwater were used by the CDR.

In future missions, it is suggested that no lunar measurement of the feedwater bag be made. The crew should simply zero the scale, weight the RCU, and then weight the filled feedwater bag.

4.1.2.6 Metabolic Determination

Metabolic data on the EVA was obtained in two separate and distinct ways. First, the LCG delta and inlet temperatures were used and the second method was to measure the oxygen consumption. The results were judged to be accurate because of close correlation with the post EVA feedwater measurement.

The results of the two methods are contained in pages 29 through 33, which shows the rationale with which the numbers are arrived at. Assuming a negligible heat leak, the delta temperature method indicates that the CDR's total metabolic load was 2330 BTU. If the time period from the -192 pump off (isolation from LM cooling) to cabin repress (end of PLSS cooling), which is about 3.0 hrs., is considered then the CDR's metabolic rate was 777 BTU/hr. The LMP's total was 3356 BTU and, utilizing the same time period, the rate was 1118 BTU/hr.

The O_2 consumption method yields 2456 BTU total and a rate of 910 BTU/hr for the CDR over a period from releif valve reseat to cabin repress (2.7 hrs.). For the LMP, the metabolic load was 2762 BTU and the metabolic rate was 1023 BTU/hr

METABOLIC DETERMINATION

ARMSTRONG

Δ T Method

TRANSPORT LOOP ANALYSIS

Metabolic Heat Load = Metabolic Rate X Time

Metabolic Rate = LCG Δ Temp. X LCG Flowrate

Armstrong used min. or min/int. for 2.4 hours with an average Δ temp. of 2.0°F, followed by 0.13 hours in max. which, due to its transient nature, can be added to the min. calculation at a Δ temp. of 2.0°F the flowrate for min. per pre-flight PIA was 4.8 PPM or 288.0 PPH.

Rate = 2.0 X 288 = 576 BTU/hr

Load = 576 X 2.53 = 1457.3 BTU

OXYGEN VENTILATION LOOP ANALYSIS

Neglecting Sensible Heat Load

Metabolic Heat Load = Metabolic Rate X Time

Metabolic Rate = Change in Enthalpy X Flowrate

Assume a 68°F PLSS inlet dewpoint
(This is based on the actual transport loop heat load)

Assume a flow of 6.0 CFM (7.34PPH)

For a 68°F inlet dewpoint and a 42°F PLSS outlet dewpoint (Sublimator gas outlet temp. is the same as dewpoint out) The change in enthalpy is 47 BTU/lb.

Rate = 47 BTU/lb X 7.34 lb/hr = 345 BTU/hr

Load = 345 BTU/hr X 2.53 hr = 872.8 BTU

O_2 Consumption Method

- O_2 used during EVA (from PGA relief valve reseat to start of repress; 2.7 hrs) — 320 psi (.393 lbs.)
- Assumed R/Q factor — 1
- Assumed suit leakage — 0 psi/hr
- Load * $= \dfrac{(O_2 \text{ used} - O_2 \text{ leak})}{0.0001708 - \left(\dfrac{R/Q - 0.707}{0.293}\right)(0.000123)}$

Preliminary

ARMSTRONG (Cont.)

- Load = $\frac{0.393 - 0}{0.00016}$ = 2456 BTU
- Rate = 2456/2.7 = .910 BTU/Hr

* Formula from RTCC metabolic load simulator program J154

Preliminary

ALDRIN

Δ T Method

TRANSPORT LOOP ANALYSIS

Metabolic Heat Load = Metabolic Rate X Time

Metabolic Rate = LCG Δ temp. X LCG Flowrate

Aldrin used max. for .68 hrs. with an average LCG Δ temp. of 6.7°F. The pre-flight PIA indicated a flow of 4.20 PPM or 252.00 PPH thru the LCG. He then went to INT. for the remaining 1.78 hrs. with an average Δ temp. of 3.00°F; flowrate per pre-flight PIA was 4.5 PPM or 270 PPH.

Rate max. = 6.70 X 252.00 = 1688.4 BTU/hr

Load max. = 1688 X 0.68 = 1148.1 BTU

Rate INT. = 3.00 X 270.00 = 810.0 BTU/hr

Load INT. = 810.0 X 1.78 = 1441.8 BTU

Total transport loop head load = 1148.1 + 1441.8 = 2589.9

OXYGEN VENLATION LOOP ANALYSIS

Negelect Sensible Heat Load

Metabolic Heat Load = Metabolic Rate X Time

Metabolic Rate = C Change in Enthaply X Flowrate

Assume a 66°F dewpoint into the PLSS for max. and a 65°F dewpoint for INT. (these are based on the actual transport loop heat load).

Assume a flow of 6.0 CFM (7.34 PPH)

For a 66°F inlet dewpoint and a 41°F outlet dewpoint (sublimator gas out is same as dewpoint out) the change in enthalpy is 41 BTU/lb for a 65°F inlet dewpoint and 41°F outlet dewpoint the change in enthaply is 43 BTU/lb.

Rate max. = 41 BTU/lb X 7.34 lb/hr = 300.9 BTU/hr

Load max. = 300.9 BTU/hr X .68 hr = 204.6 BTU

Rate INT. = 43 BTU/lb X 7.34 lb/hr = 315.6 BTU/hr

Load INT. = 315.6 BTU/hr X 1.78 hr = 561.7

Aldrin Continued

Total Oxygen Heat Load = 204.6 + 561.7 = 766.3

O_2 Consumption Method

- O_2 used during EVA — 360 psi (.442 lbs)
  (from PGA relief valve reseat to start of repress; 2.70 hrs)
- Assumed R/Q factor — 1
- Assumed suit leakage — 0 psi/Hr
- Load = $\dfrac{(O_2 \text{ used} - O_2 \text{ leakage})}{0.0001708 - \dfrac{(R/Q - 0.707)}{0.293}(0.0000123)}$
- Load = $\dfrac{0.442-0}{0.00016}$ = 2762 BTU
- Rate = 2762/2.7 = 1023 BTU/Hr

TOTALS

Metabolic

Armstrong	Transport Loop	1457.3 BTU
	Oxygen Loop	872.8 BTU
	Total Metabolic	2330.1 Over 3.00 hrs**
	Metabolic Rate	776.7 BTU/hr
Aldrin	Transport Loop	2589.9 BTU
	Oxygen Loop	766.3 BTU
	Total Metabolic	3356.2 Over 3.00 hrs**
	Metabolic Rate	1118.7 BTU/hr

LiOH Heat Load

Armstrong	(Assuming R/Q of 0.9)	=	590 BTU
Aldrin	(Assuming R/Q of 0.9)	=	850 BTU

Electrical Heat Load

Armstrong	38.4 watts for 2.58 hrs.*	=	336.8
Aldrin	41.2 watts for 2.58 hrs.*	=	361.4

*Time is from depress to repress

**Three hours is including the time prior to feedwater startup and after the crewman was on the PLSS transport loop.

Total Heat Load

Armstrong	Metabolic	2330.1
	LiOH	590.0
	Electrical	336.8
		3256.90 BTU
Aldrin	Metabolic	3356.2
	LiOH	850.0
	Electrical	361.4
		4567.6 BTU

O_2 Consumption Method

Armstrong	Metabolic Load	2456 BTU
	Metabolic Rate	910 BTU/HR
Aldrin	Metabolic Load	2762 BTU
	Metabolic Rate	1023 BTU/Hr

for the same period. The data indicates that the O_2 method yields higher loads and rate for the CDR and lower loads and rates for the LMP. This disparity results because the O_2 method does not measure any change in the physiological heat balance of the crewman. As a further explanation, consider that previous test data indicates that Armstrong prefers higher skin temperatures than Aldrin does. It can be assumed that either or both of the crewmen started their PLSS activity with something other than a "zero heat storage." This is because the -192 package, which is the crew's primary cooling source in the LM, only puts out one temperature. Consequently, it can be assumed that the CDR was on the cool side (slight negative heat storage) of balance or that the LMP was on the warm side (slight positive heat storage) or both, just prior to the beginning of PLSS activity. This was evident from a comparison of the LMP and CDR LCG inlet temperature profiles. The LMP's inlet temperature rose approximately twice as fast as the CDR's just after transferring to the PLSS. In addition, there is evidence that the crewmen finished the EVA just the opposite, with CDR storing positive and the LMP sub-cooled. This is because the individual crewman selected his own cooling on the PLSS early in the EVA. Past profiles have shown that the crewman usually "over selects" his preference (e.g., a crewman who likes to run warm does not select enough cooling). In chamber tests where the crewman is acutely aware of his temperature situation, he usually corrects this situation as required during the chamber run. On actual flights, the crew does not correct for nominal amounts of positive or negative heat storage, simply because they are not thinking about it, as evidenced by R. Schweickart's heat storage during Apollo 9 EVA. It should be noted that the positive or negative levels discussed here are not of a critical nature.

In summary, a portion of the CDR's metabolic load was absorbed by his body and the LMP's metabolic load was suplemented by stored heat being rejected from his body. These numbers show up in the delta T method and not in the oxygen consumption method. Therefore, the delta T method is essential in predicting feedwater reserves since it shows the actual overall heat rejection; the O_2 consumption method is essential in determining the physiological metabolic rate.

4.1.2.7 Expendables

None of the four expendables - oxygen, LiOH, feedwater and battery - was near depletion at the end of the EVA for either crewman. (See data on page 37.)

The CDR's initial oxygen pressure was 1030 psia; he used 320 psi for metabolic and suit leakage during the 2:42 EVA. 115 psi was used for the two suit pressurizations. There was 596 psia remaining of which 461 psi was usable (596 psi less 85 psi ullage and 50 psi gage/TM inaccuracy). Since the CDR's metabolic rate was relatively constant, at this usage rate of 118.5 psi/hr., the CDR's oxygen would have lasted another 3:53. The LMP used 375 psi over the same time interval (138.9 psi/hr.) and metabolic rate was relatively constant; there was 550 psia remaining of which 415 was usable. At this rate, the LMP's oxygen would have lasted another 2:58.

Although there is no direct way to check the amount of LiOH remaining, since neither of the cartridges were returned, it is possible to make a conservative estimate. Extensive testing by HSD, in qualification of the LiOH cartridge, has indicated that, at an input of 1250 BTU/hr., the LiOH cartridge reaches the specification limit of 15.0 mm/Hg $PPCO_2$ at 6.5 to 8.8 hours. Since both crewmen averaged below this rate and Aldrin was the only one to ever exceed it and then for only a short period, these numbers can be confidently used. The LiOH usage time for both crewmen was from helmets on at about 108:36 to fan shutdown at 111:52 or 3:16 total time on LiOH. Using the conservative figure of 6:30 for total usage, both crewmen had 3:14 of LiOH cartridge left. The specification minimum for electrical power is 240 watt hours; however, extensive testing has shown that all PLSS batteries exceed 270 watt hours. The CDR used 133 watt hours, and, therefore, had at least 135 watt hours remaining. At the LMP's full power usage rate of 41.2 watts, there was another 3:16 of power remaining.

The initial feedwater fill for the CDR's PLSS S/N 00015 was 8.62 lbs. The post EVA feedwater measurement showed that he had 5.73 lbs. remaining, and that he therefore used 2.89 lbs. A conservative assumption is that 0.5 lbs. of feedwater is unusable and that the CDR had 5.23 lbs. of usable feedwater remaining. The CDR's PLSS rejected 3256 BTU's in three hours. At this rate of 1085.3 BTU/hr., the remaining 5.23 lbs. of feedwater would have lasted 5:00 (using 1041 BTU/lb.) longer. The LMP started with 8.56 lbs. of feedwater and it was calculated that he used 4.38 lbs. and had 4.18 lbs. remaining (3.68 lbs. usable). The LMP's PLSS rejected 4567 BTU's over the three hour period. At this rate of 1522.3 BTU/hr, the remaining 3.68 lbs. of feedwater would have lasted 2:30 longer.

4.2 <u>Crew Provisions</u>

All CSD GFE Crew Provisions operated satisfactorily throughout the mission with the following exceptions:

APOLLO 11 EVA DATA

EXPENDABLES	ARMSTRONG	ALDRIN
OXYGEN	2+56 Hrs - Min	2+56 Hrs - Min.
POWER	3+45	3+49
LiOH	3+18	3+21
FAN	3+18	3+21
FEED H_2O	2+30	2+31
PUMP	3+05	3+05
CONSUMABLE DATA		
OXYGEN PRESSURE INITIAL	1030 psi	1030 psi
OXYGEN USED (METABOLIC)	320	360
OXYGEN USED (SUIT PRESSURATION	120	130
OXYGEN PRESSURE REMAINING	590	540
FEEDWATER INITIAL	8.62 lbs.	8.56 lbs.
FEEDWATER USED	2.89	4.38 *
FEEDWATER REMAINING	5.73	4.18 *
POWER INITIAL	270 watt hours**	270 watt hours**
POWER USED	133	135
POWER REMAINING	137	135
METABOLIC DATA		
OXYGEN	2456 BTU 910 BTU/hr ****	2762 BTU 1023 BTU/hr ****
LCG THERMAL BALANCE		
TOTAL METABOLIC	2330	3356
LiOH	590	850
POWER	336	361
TOTAL HEAT LOAD	3256 BTU	4567 BTU
METABOLIC RATE	777 BTU/hr ***	1118 BTU/hr ***

**** Based on 2.7 hrs from PGA relief valve reseat to cabin repress

* Calculated
** Nominal Battery Charge
*** Based on approximately 3 hours of isolation on PLSS.

(a) The IMP's ECG became erratic during the mission. A spare sternal harness was installed with new electrode paste and acceptable ECG signals were established. The CMP's ZPN later became erratic, but nothing was done to re-establish good data.

(b) The Medical Accessories Kit pill packages expanded during ascent. As a result, the kit was overstuffed and very difficult to unstow. The handle was ripped off while unstowing the kit.

(c) The crew reported repeated fogging of the LM windows while the sunshades were installed. They had transferred two of the CM tissue dispensers to the LM and made use of them in cleaning the windows. They recommend that tissue dispensers be added to the LM stowage list.

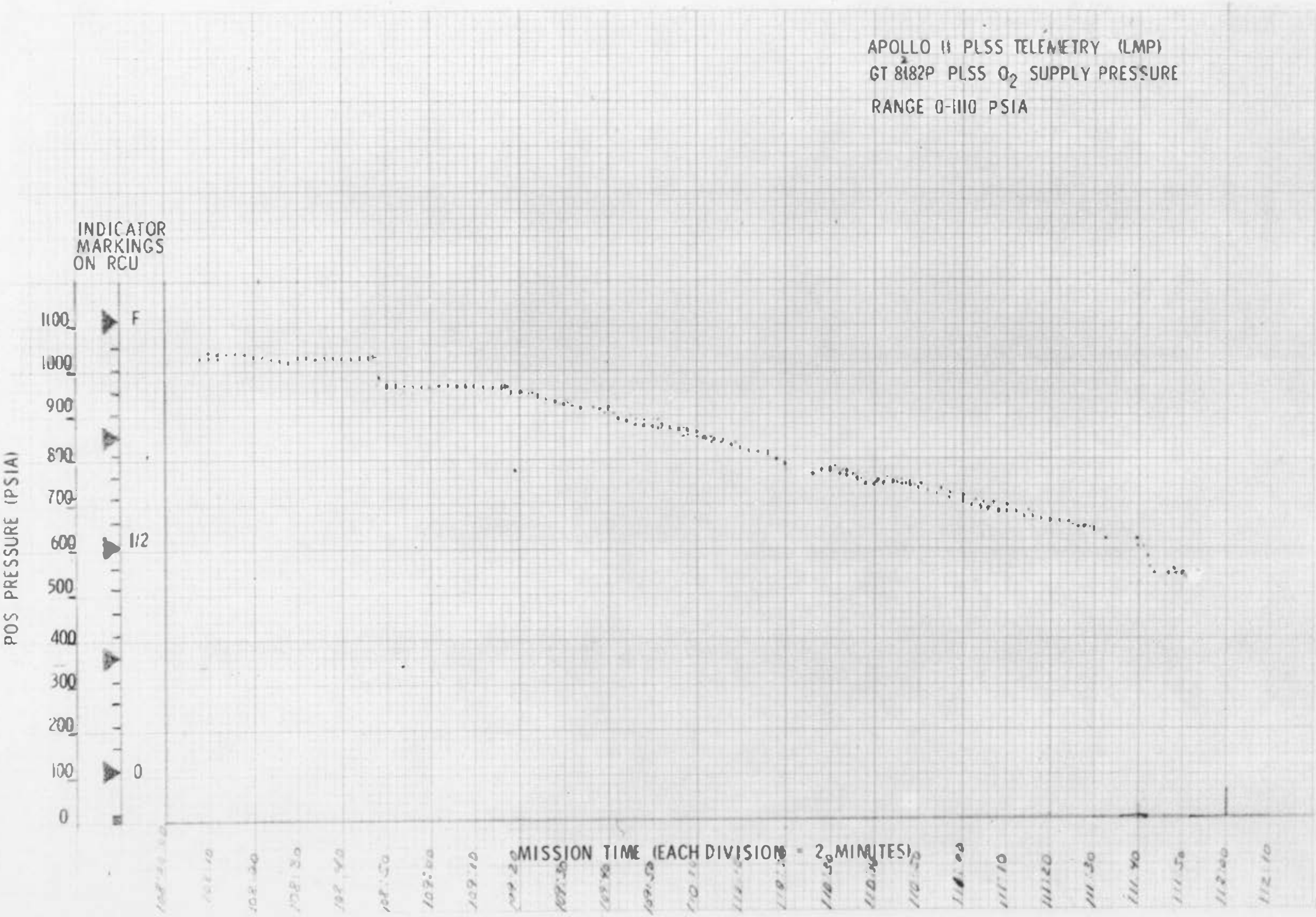
(d) The Lunar Equipment Conveyor (LEC) attracted and collected a large quantity of lunar dust, which tended to shake loose and fall over the crewmen. It also caused the pulley to bind.

(e) The crew commented that the Inflight Coverall Garments (ICG's) would be more utilitarian if they were patterned after the one-piece summer flying suit. More pockets with a better method of closure, i.e., zippers, were recommended.

(f) The molded ear pieces become painful when worn in conjunction with the comm. carriers. Armstrong didn't carry any at launch because of previous problems. Aldrin wore his for lunar landing but removed them after landing because of the discomfort.

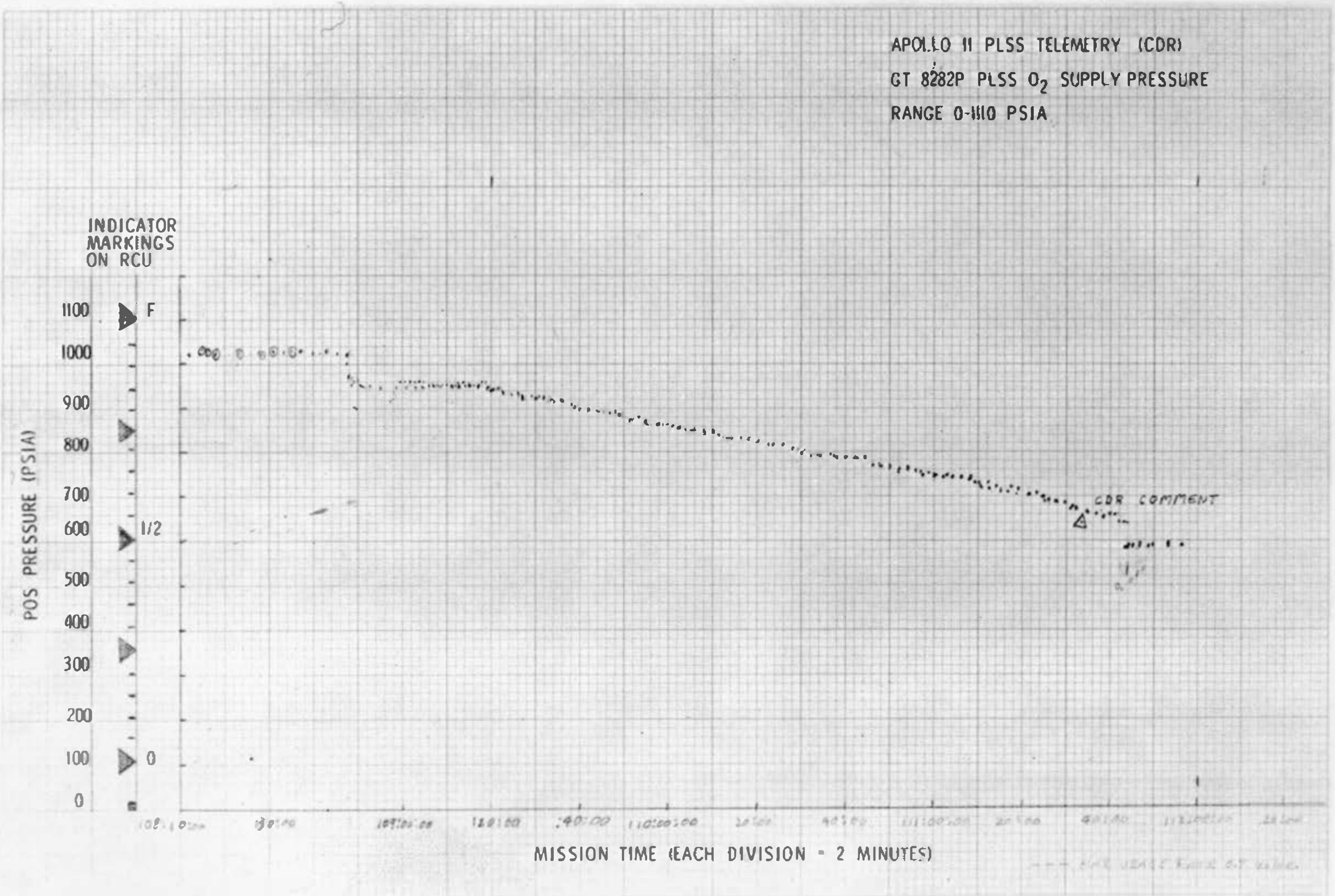
NASA
S-69-44876

Figure 1



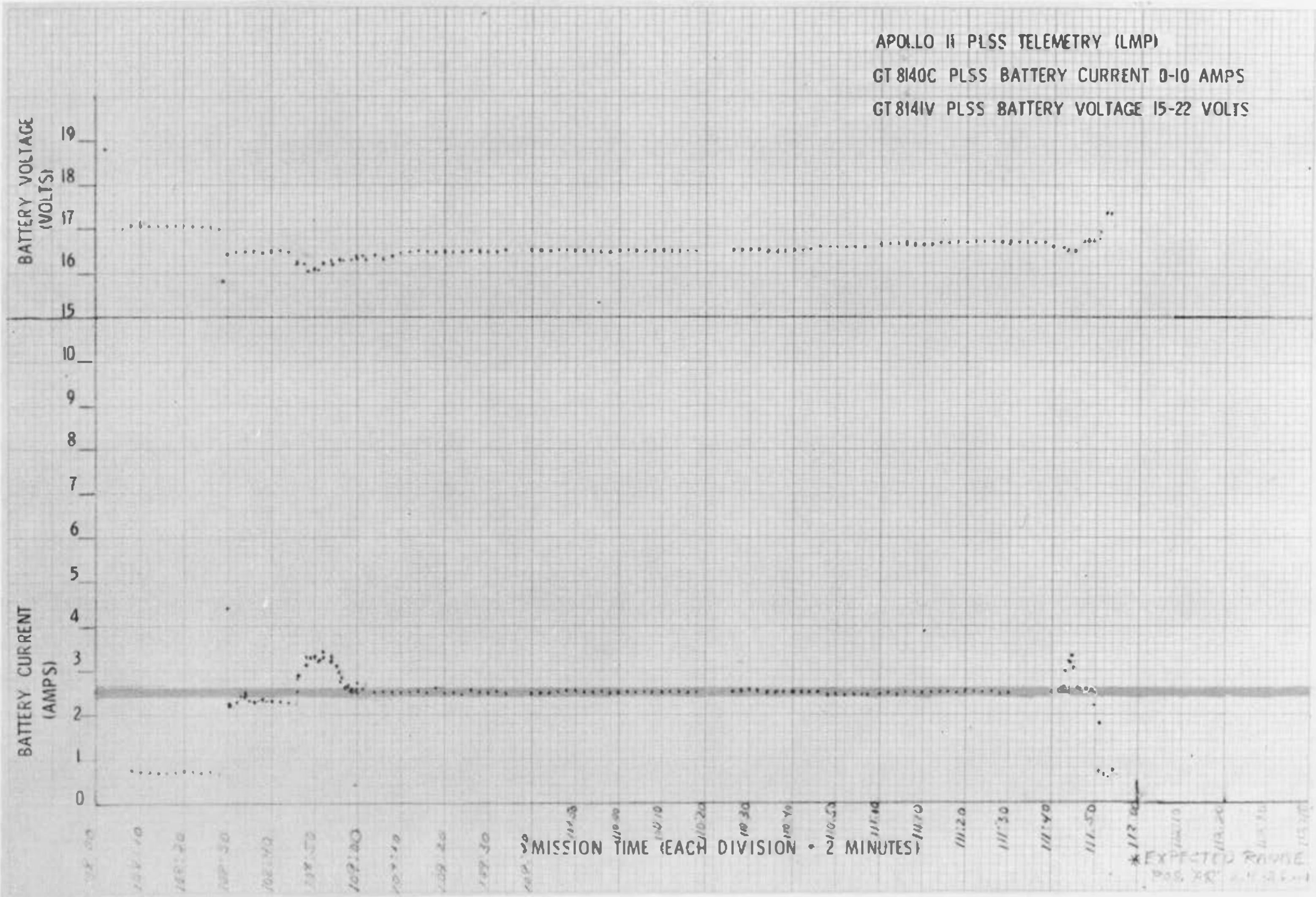
NASA
S-69-44825

Figure 2



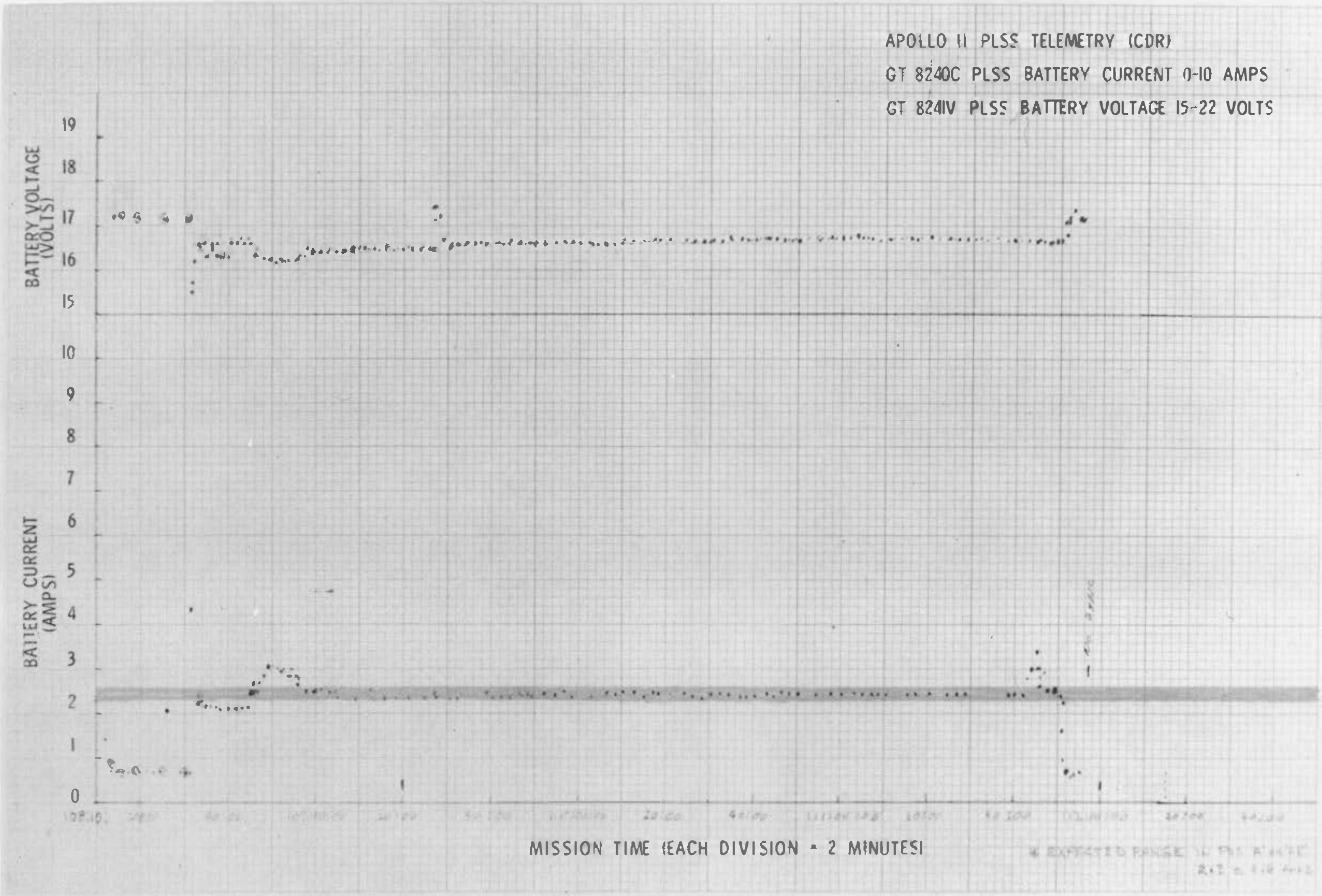
NASA
S-69-44827

Figure 3



NASA
S-69-44819

Figure 4

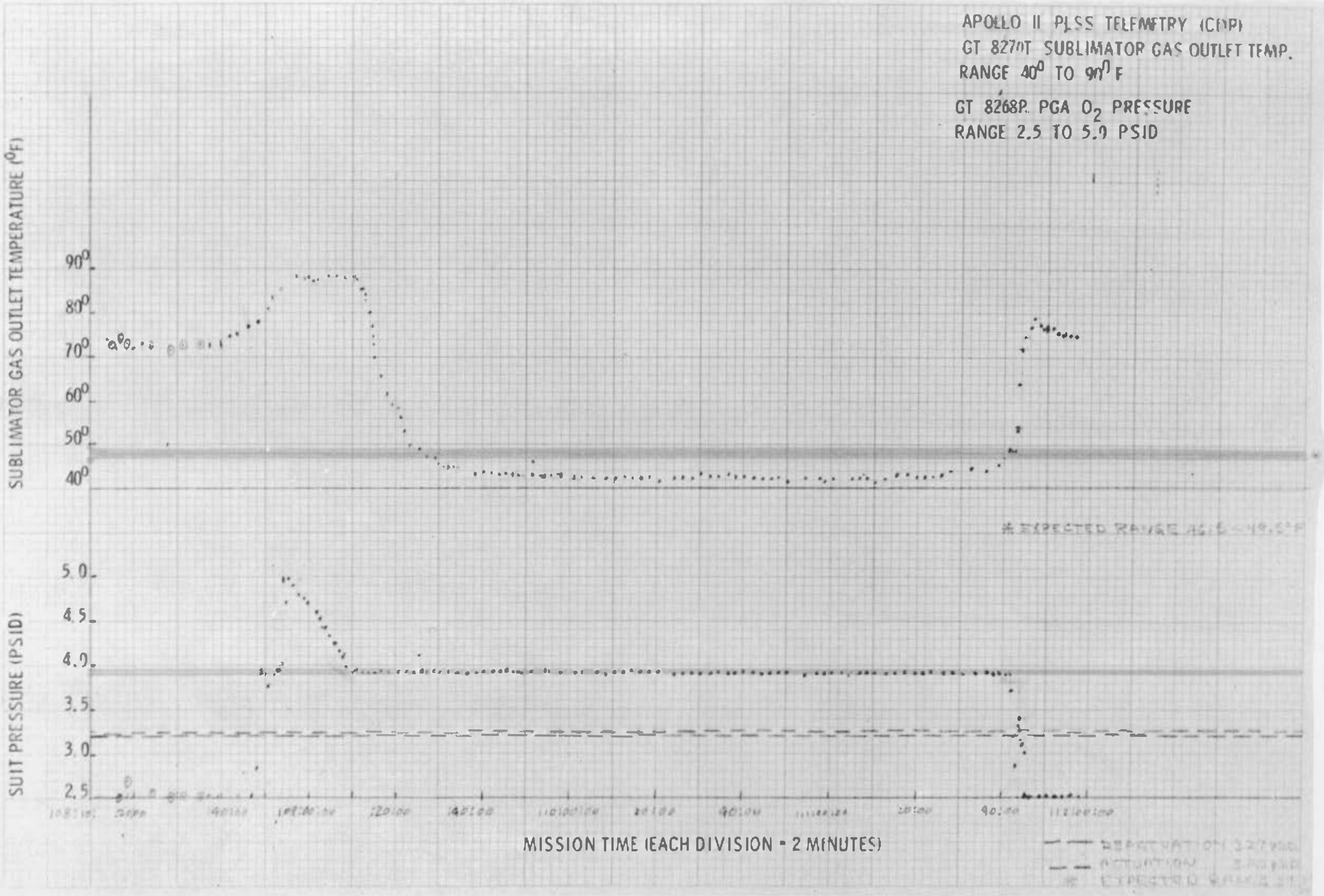


Preliminary

Preliminary

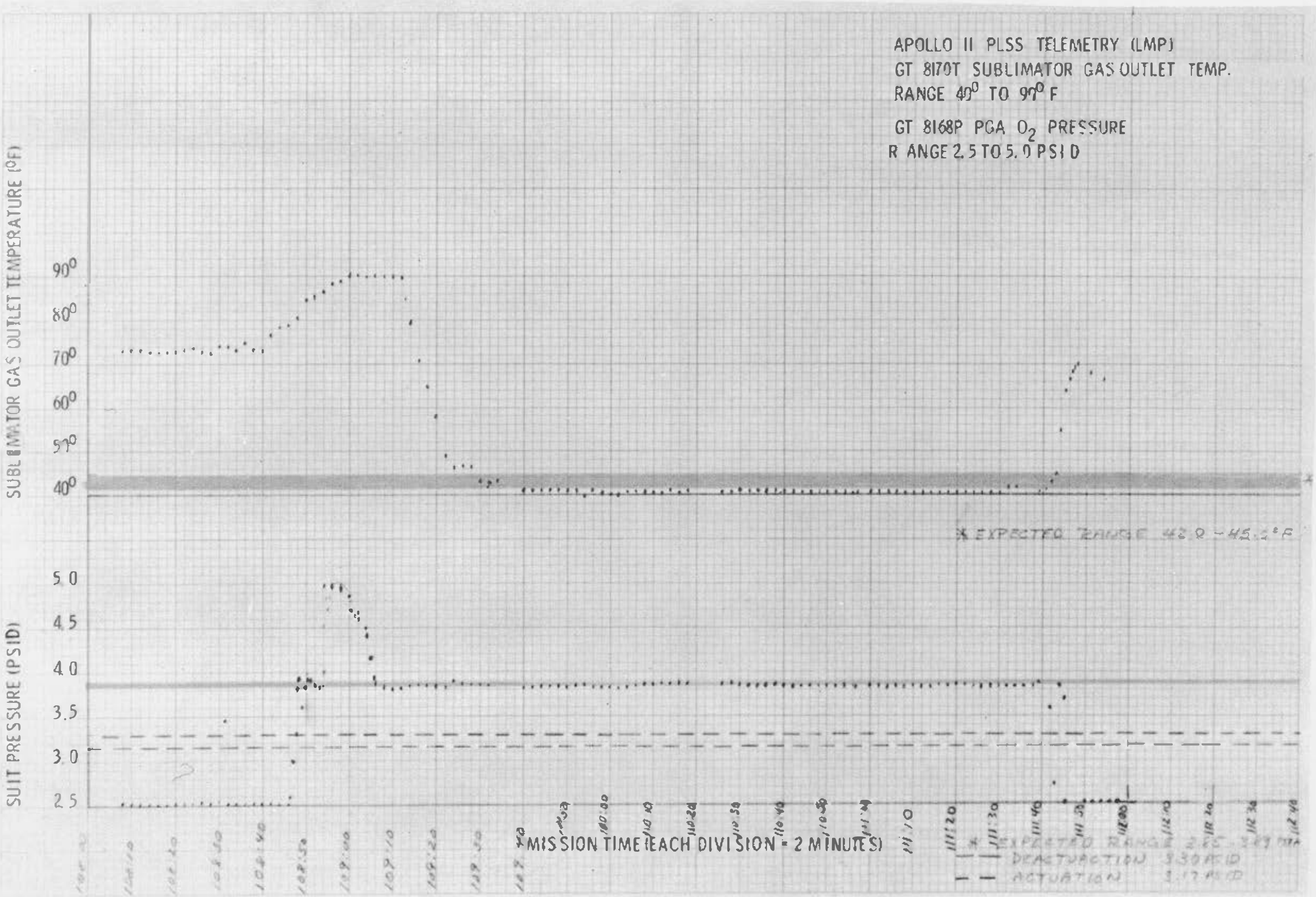
NASA
S-69-44823

Figure 5



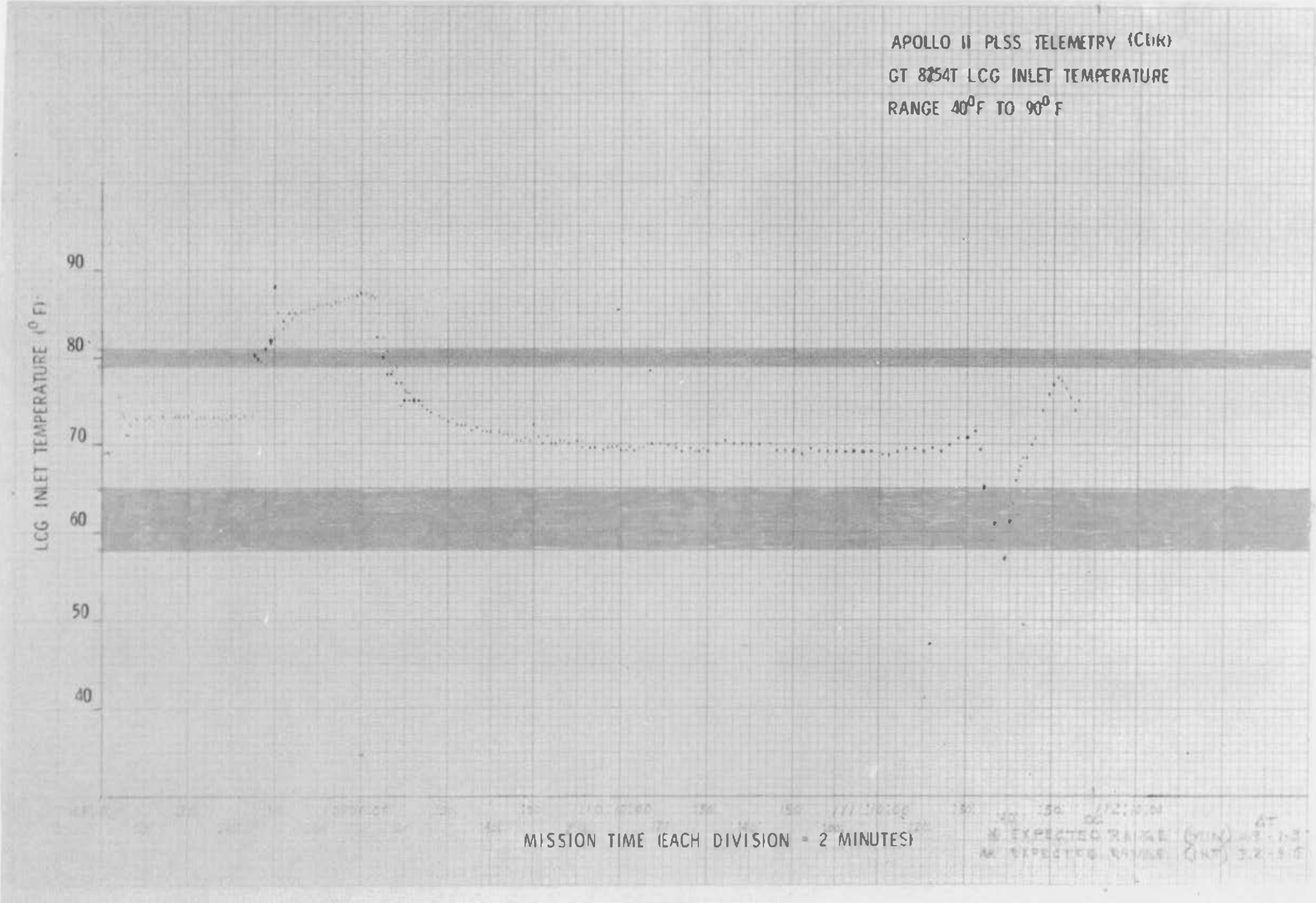
NASA
S-69-44828

Figure 6



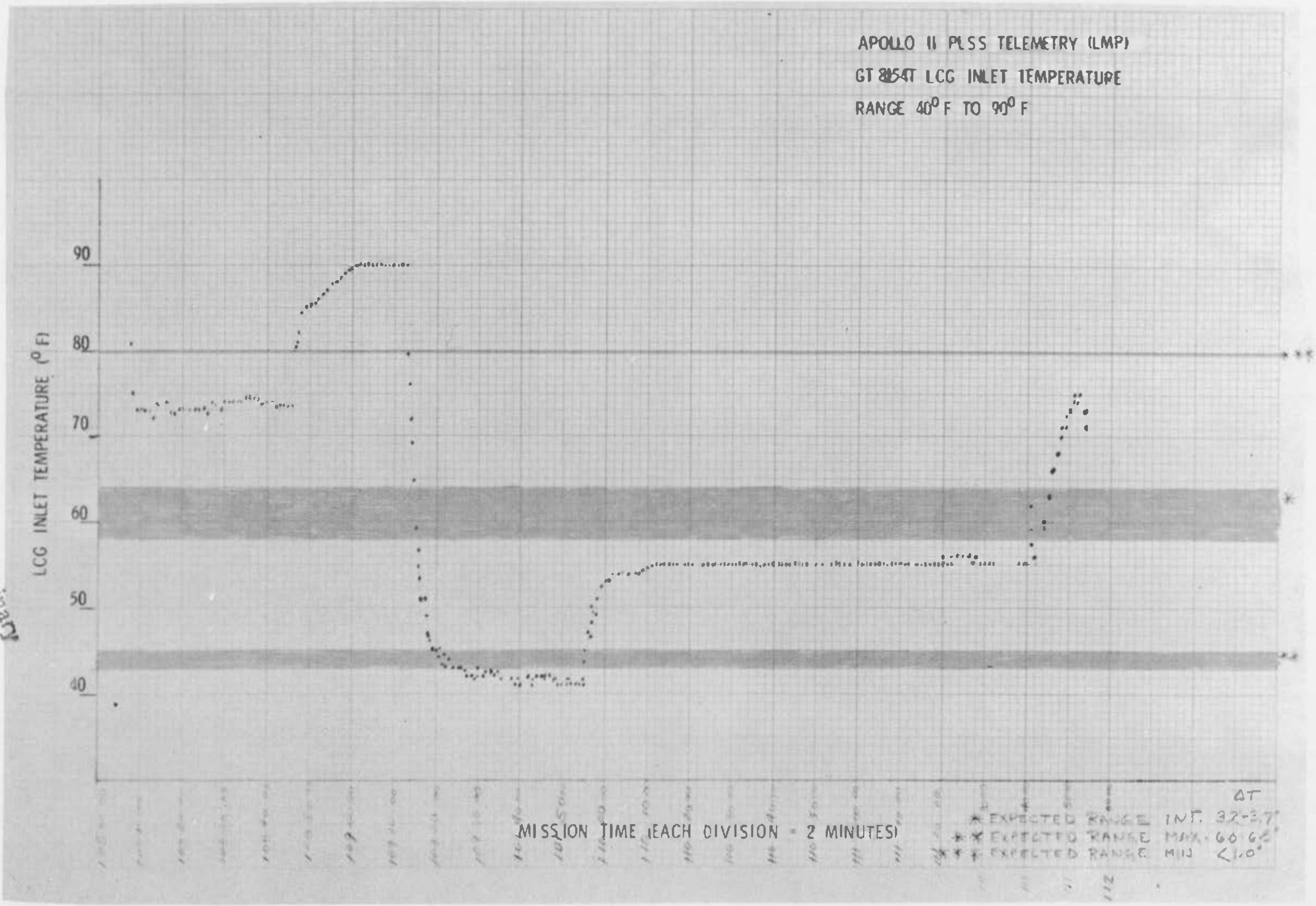
NASA
S-69-44820

Figure 7



NASA
S-69-44???

Figure 8

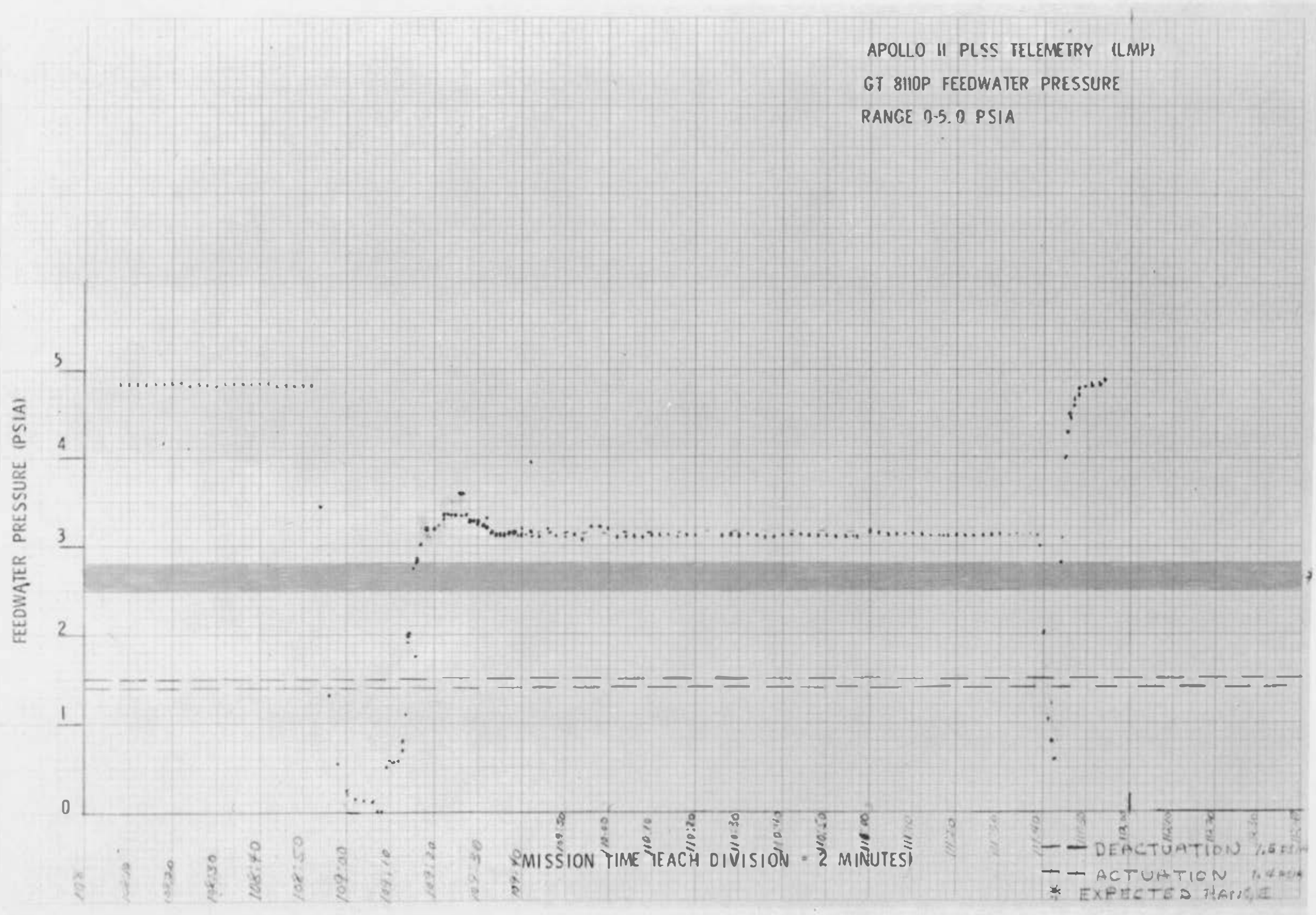


Preliminary

Preliminary

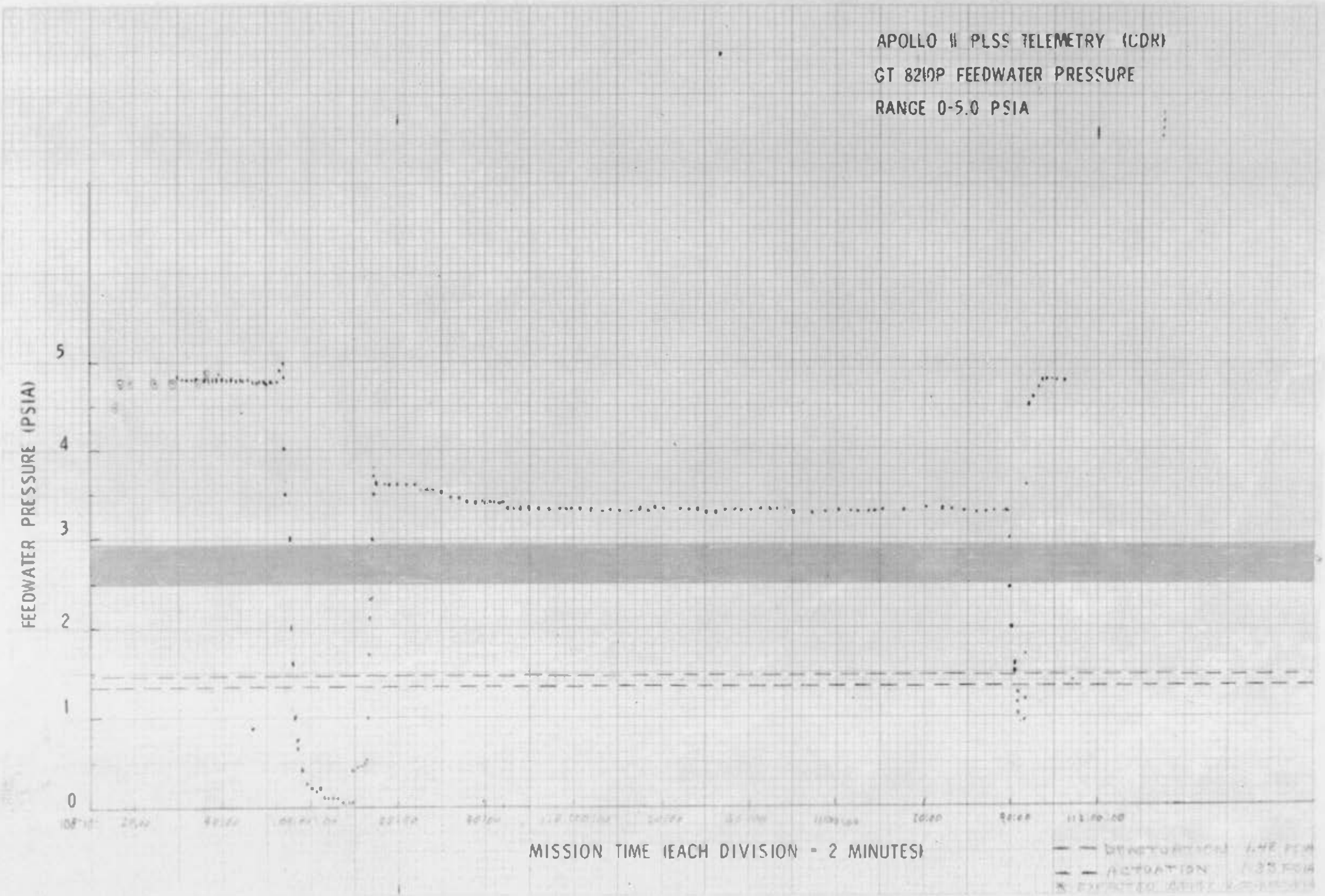
NASA
S-69-44822

Figure 9



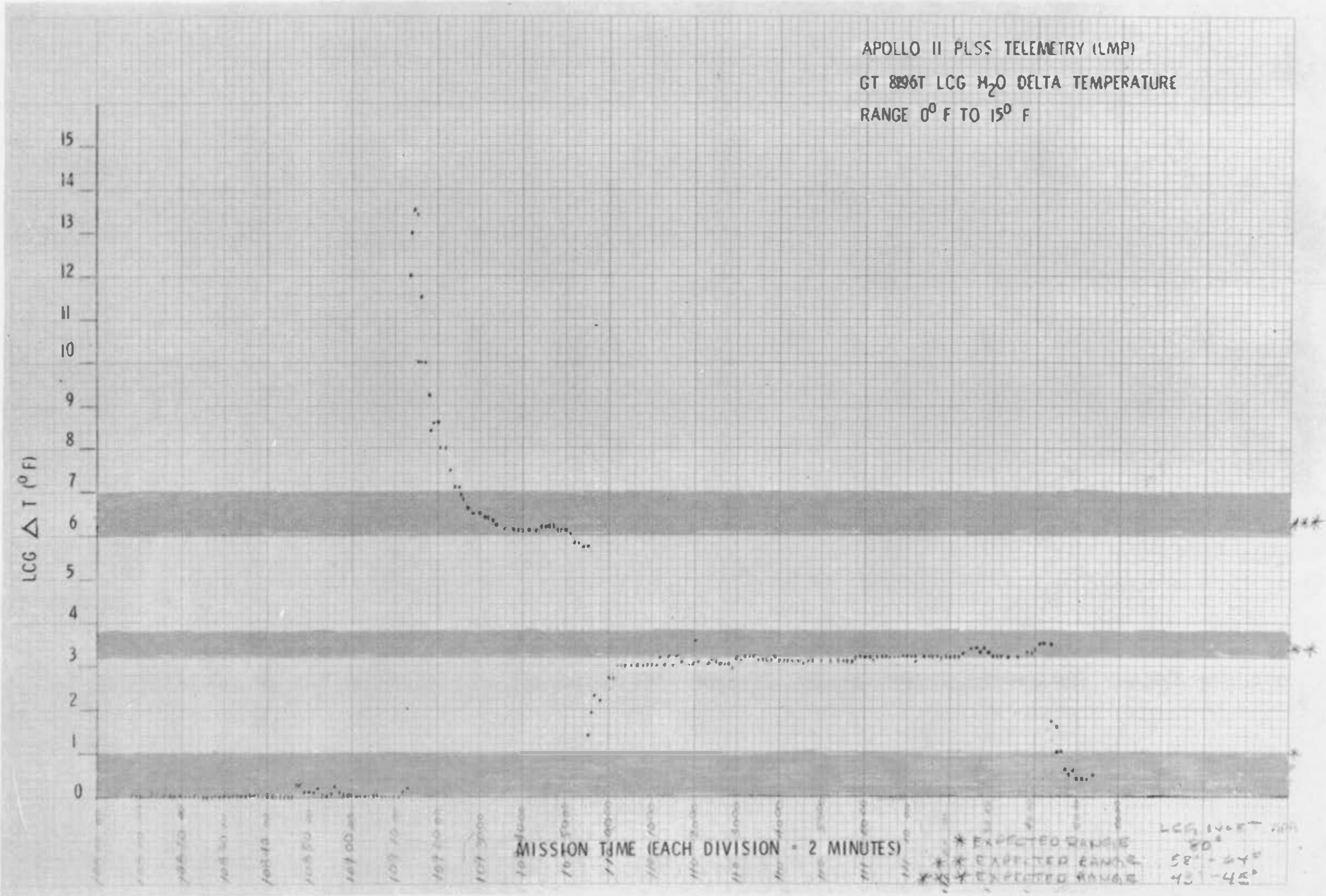
NASA
S-69-44821

Figure 10



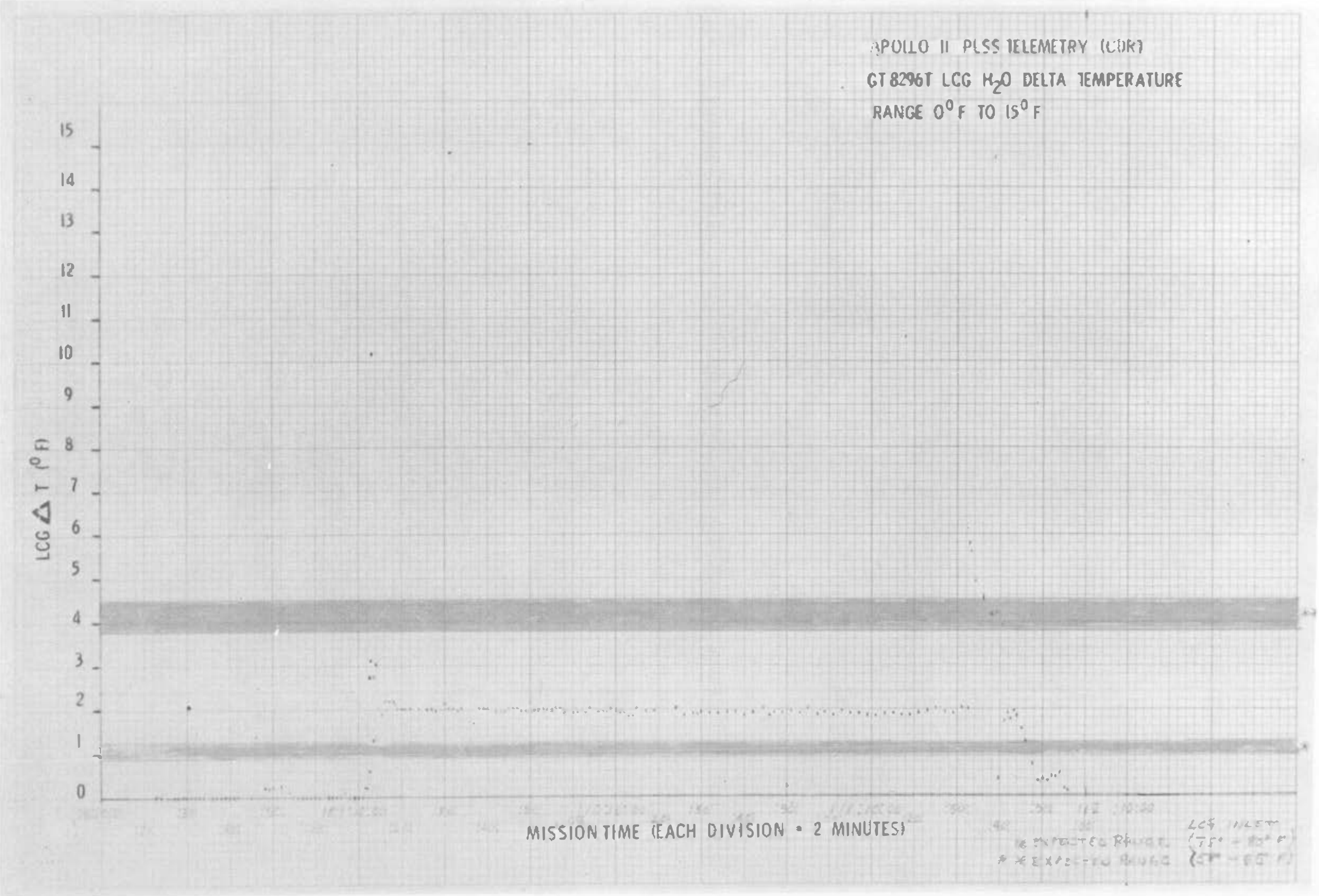
NASA
S-69-44818

Figure 11



NASA
S-69-44824

Figure 12



5.0 Problems, Conclusions, and Recommendation

In this section will be discussed the significant problems encountered during the preflight phase, i.e. simulator runs, EVA exercises, 0 and 1/6 "G" flight C^2F^2, CF^2, and CDDT. Also, problems encountered during flight and those resulting from post flight testing will be discussed.

5.1 Preflight

The significant problems encountered during the preflight phase include such items as hardware delivery schedules, adequacy of training equipment and discrepancies/failures.

5.1.1 EMU

5.1.1.1 PGA and Accessories

5.1.1.1.1 Problem

The outer Beta shell of the ITMG and beta covering on the insuit electrical harness was continually fraying and separating at the seams.

Conclusions — Without exception DR's were written after every exercise for fraying of beta. Approximately 70 o/o of the maintenance effort was contributed to this area alone. Those areas of the suit where teflon is used showed only slight wearing effects. The electrical harnesses showed this same fraying and seam separation to the extent the sheaths required repair after almost every use. Repair consisted of either patching, CNR coating or installation of a complete sheath.

Static Action Taken

5.1.1.1.1 (Cont'd)

Recommendations — Even with a weight and flammability penalty the entire ITMG and sheath should be fabricated with teflon. The electrical harness has been ~~could be~~ retrofitted for Apollo 12 and sub ~~in the field~~ with a teflon sheath over the existing beta sheath.

5.1.1.1.2 Problem — Astronaut Aldrin's hands partially retract from gloves when he bends his arm.

Conclusions — Due to large biceps on E. Aldrin, when the arms were bent to work in the RCU area the biceps would interfere with the arm bearings thereby forcing the hands out of the gloves. The flight suit was adjusted to the extent the total reach was affected. However, the finger tips were still approximately 3/8" out of the gloves during RCU operation. ILCI/Dover, during fit check on the 036 suit, recommended pads on the elbows to prevent the elbows from moving outboard. This was tried during simulator runs by installing pads on the elbows of the LCG. However, the total build up of the arms and pads would not pass thru the arm bearing, therefore, the pads had to be removed.

Recommendation — During the Apollo 11 debriefing, Aldrin stated that this problem did not affect the mission, therefore, no corrective action is recommended for Apollo 12. However, close attention should be emphasized during fit checks of EV crewmembers with large biceps and evaluated at that time. Further investigation ~~A check~~ into this problem should ~~could possibly~~ be initiated for future flights ~~after Apollo 12 or 13.~~

5.1.1.1.3 Problem — Pressure points in the crotch area of Astronaut Collins PGA's caused by the UCTA flange.

Conclusions — In discussing this problem with M. Collins it was evident that both his 033 and 034 suits did not have enough relief in the crotch/hip area. Collins indicated during the fit check of the 034 suit at KSC that he called attention to this problem while at ILCI for the fit of the 033 suit several months earlier and that he could not understand why it had not been corrected. Collins was bothered by pressure points both during CDDT and prior to launch on launch day. As a matter of record and worthy of note here, is that when J. Lovell was originally an IV crewmember his first comment when he fit checked the 055 suit was the excessive pressure points in the crotch area due to lack of relief.

add ILC's comments

Recommendation — M. Collins has requested that in future fit checks, all flight required equipment (i.e. FCS, UCTA, w/flange and cuff, LCG, etc.) be used and that the fit check include a check in the CM couch launch position. Also, ILCI should be requested to revalidate the patterns for proper size in this area.

5.1.1.1.4 Problem — Upper PLSS/tie-down buckle webbing stitches failed during PGA proof pressure at PIA.

Conclusion — While the PGA S/N 077 was being proof tested during flight PIA, stitches could be heard giving way but coud not be located until after the pressure was released. Upon examination it was discovered that approximately 1/3 of the stitches holding the upper PLSS/tie-down buckle

5.1.1.1.4 (Cont'd)

to the PGA had given way. ILCI/Dover was immediatly notified of the problem. A review of historical data revealed that during the retrofit to relocate the "D" ring, it was discovered that the buckle was still to low and rather than remove the entire structure the webbing was lifted on the lower portion and as the seamstress resewed it, the webbing was continually gathered. This resulted in loading of the lower stitches only and not the entire area. The suit was immediately shipped to ILCI/ Dover, repaired overnight, and returned to KSC within 24 hours.

Recommedation —— No recommendation is required since this ~~was an error in manufacturing.~~

5.1.1.1.5 Problem —— Pressure points just above wrist at wrist disconnect interface with forearm causes irritation.

Conclusion —— A combination of two problems has caused excessive irritation in this area. The first problem is that the vent tube connecting at the wrist disconnect lies directly beneath the pressure gage mounting flange. This has reduced the free area opening of the wrist disconnect. The second problem is the sharp inner ridge of the suit half wrist disconnect irritates the forearm. When the arms are bent in toward the chest the load on the arm for movement contacts the wrist and the arms are actually bent with the forearm against the wrist disconnect. Wristlets have retarded this irritation but has not eliminated the problem entirely.

5.1.1.1.5 (Cont'd)

add ILC,I

Recommendation — The vent tube needed to be moved and the sharp of the wristed ring eliminated, also large wrist disconnects would correct this since the lower arm of the suit would assist in bending the arm without undue pressure on the wrist disconnect.

5.1.1.1.6 Problem — Comfort pads not installed on liner prior to shipment of PGA's from ILCI/Dover.

add ILC,I

Conclusion — Comfort pads are a crew preference item which can be installed throughout the suit at the option of the crew. Locations for the pads are normaly identified during training exercises, however, certain locations were identified at Dover during suit fit checks. As crew preference items the pads were not installed prior to shipment.

Recommendation — Comfort pads which are identified of original suit fit checks, should be installed prior to shipment. This would reduce considerable effort in modification kit installation in the field.

5.1.1.1.7 Problem — ITMG mobility cords not being adjusted and cut to proper length at ILCI/Dover.

Conclusion — During the fit checks at Dover the ITMG lacing cords are to be adjusted for maximum mobility and cut accordingly. However, the suits are being delivered without this being accomplished which increases the workload in the field. In addition, these cords can hang in the zipper or crotch pulleys prior to adjustment.

5.1.1.1.7 (Cont'd)

Recommendation — ILCI should be notified to implement in their fit check summary sheets and require a waiver if this operation cannot be performed prior to shipment.

5.1.1.1.8 Problem — Availability of suit mounted urine connectors at ILCI/Dover for timely suit deliveries.

Conclusions — Toward the latter phase of the program suits were being delivered without the suit mounted urine connectors. ILCI stated on several occasion that they had notified NASA of the lack of connectors.

Recommendation — A way must be worked out with HSD to provide flight hardware on a more timely basis.

Corrective action and problems identified

5.1.1.1.9 Problem — ~~Information noted~~ on the PGA fit check summary

are not bein adequately implemented

sheets ~~is not being passed to~~ production or the retrofit area for incorporation of changes required.

Conclusions — Many changes agreed on at the fit checks are not incorporated into the equipment prior to shipment. When a crewman is fit checked in one suit, many times the very next suit he has fit checked will have the same changes required.

Recommendation — As part of the PDA, the fit check summary sheets should be reviewed and concurred on by DCASR - not only summary sheets for this suit but previous suits fitted by the crewman to make sure that

5.1.1.1.9 (Cont'd)

identical problems do not occur.

5.1.1.1.10 Problem — Incorrect sizes on lunar boots allocated to crewman.

Talk with Ralph & Wayne

Conclusion — Three of the four pair of lunar boots fit checked during the CF^2 did not fit. Lunar boots S/N 049 assigned to F. Haise were 1 1/2" too long. The S/N 035 boots assigned to J. Lovell were too short and fitted F. Haise satisfactory. Lunar boots 032 assigned to N. Armstrong were too large and had to be reallocated.

Recommendation — ILCI should be directed to reconfirm future lunar boots for proper sizing.

5.1.1.1.11 Problem — LCG sizing incorrect for N. Armstrong.

Conclusion — Astronaut Armstrong was allocated 3 LCG's of 2 different sizes; S/N 058 - large and S/N's 084 and 085 both medium. The medium sized LCG, S/N 084 and S/N 085, were too tight in the arm. Another large LCG, S/N 077 was reallocated to Armstrong.

Recommendation — Insure correct fit of LCG's by proper fit checks.

5.1.1.1.12 Problem — EV glove mounting fixtures pulled loose from the base of the LM helmet stowage bags.

CONCLUSION -- Whenever the crew removed the EV gloves from the LM helmet stowage bags, the receptacles tended to be pulled loose from the base. Due to the tight fit and the lightweight of the receptacles it was difficult to prevent breaking of the bond.

RECOMMENDATIONS --

5.1.1.1.13 PROBLEM - LCG lower arm interfering with connecting the PGA wrist disconnect as experienced on Apollo 10.

CONCLUSION - At no time during the training program nor flight did the LCG material on the wrist get caught in the wrist disconnect upon engaging. In fact, the crew felt that this was an added feature that helped retard abrasion of the wrist disconnect on the forearm.

RECOMMENDATION - No recommendation is required.

5.1.1.1.14 PROBLEM - Arm length could not be adjusted short enough for E. Aldrin's suits.

CONCLUSION - During the fit check at Dover, Delaware, it was discovered that Aldrin's suits were too long in the arms. The arms were able to be pulled almost to a satisfactory length, but this resulted in the pressure gage and relief valve being tilted forward approximately 30°. As a result, ILCI started manufacture of a 6" long elbow convolute to replace the standard 7" convolute. This resulted in considerable delay in an adequate training or flight suit. Also, due to retrofit schedules, only the flight suits were full-up flight configuration with respect to arm bearings for both suits and short elbow convolutes on Aldrin's suit.

RECOMMENDATIONS - In the future, both the prime and back-up suit, as well as training suits, should have the arm bearings. If either of the back-up suits had to be used, the EVA would have been affected. Also, ILCI should re-evaluate all future crew members to ascertain the requirements for the shorter convolutes.

5.1.1.1.15 PROBLEM - Athletic suspensories worn with the LCG and FCS were for crew comfort but were stowed illegally in the CM with the LCG's.

CONCLUSION - The crew requested that the supports be stowed aboard the CM with the LCG's because they did not need them until they donned the LCG's. The stowage list did not provide for this stowage since they had originally been walk-on equipment. The reason a CCBD was not written at KSC was because all necessary documentation was not available at the time to adequately cover same as well as a part number was not on the supports.

RECOMMENDATION - The supports should be issued a part number and included on the stowage list as crew preference.

5.1.1.1.16 PROBLEM - Configuration of flight and training hardware and modification kit incorporation.

CONCLUSION - During the course of the training program, a continual problem existed with adequate training equipment. On several occasions, the crew, as well as the monitors, questioned whether the training exercises were beneficial enough with the equipment being used. On many occasions, part of the exercise was skipped over because mockups were being used which would not function properly. In order to train as rapidly as possible, it was necessary to accomplish this with uncontrolled hardware which by nature did not have the latest authorized changes approved for this equipment. This does not say that all equipment was not updated, but that the contractors were not set up to supply uncontrolled flight configuration equipment. Flight configuration mock-ups were produced, but by the time full utilization was accomplished, they would be outdated. Usually, training equipment had been handed down from past missions without adequate update. Modification kits seem to be considerably excessive, which would not have been the case with proper planning. Usually it was not known what shortages would be delivered with each end item until the paperwork for shipment was reviewed and then it was too late. Precedence should be established for a design freeze and mod kit incorporation so many weeks prior to launch.

RECOMMENDATION - Consideration should be given, on a new design change, to adequate crew training, time required for incorporation into crew check lists, incorporation into the mission timeline, and delivery of training and flight hardware. Therefore, it is recommended that all of the above consideration be made and the responsible project engineers be in charge on all modification kits up until the time of incorporation into the particular CEI. Also, that prime training equipment be monitored by Program Control and all changes incorporated on flight equipment be also imposed on training even if uncontrolled.

5.1.1.1.17 PROBLEM - Arm rotation in excess of 180° without stops on the arm bearings.

CONCLUSION - Contrary to several discussions over the past few months, at not time during preflight training nor the mission, did the lower arm section ever get out of phase so that the arm could be bent to cause failure of the ITMG or impact on the mission. However, it is true that during the fit check at ILCI Dover, Delaware, the arm did get into a position for which it was not designed, but in all cases the ITMG had not been installed.

RECOMMENDATION - An additional stop should be considered in the A7LB program.

5.1.1.2 PLSS/OPS

5.1.1.2.1 PROBLEM - Pressure gages used on PLSS cryo packs not sensitive enough for suit pressurization.

CONCLUSION - Time and again during the crew training, the crewmen were over pressurized due to the small pressure gage scale and the sensitivity of the pressurization valve.

RECOMMENDATION - A better method of indicating suit pressure and regulating suit pressure should be incorporated into the mockup PLSS's.

5.1.1.2.2 PROBLEM - Flight PLSS straps were not available until just prior to flight.

CONCLUSION - The present philosophy for PLSS straps is to build a set of fixed length straps for use in crew training and in chamber runs. The flight set was fabricated just prior to flight and were made to be identical to the training set. This can result in flying a set of straps which have never interfaced with the PGA or crewman nor been through SESL runs.

RECOMMENDATION - Fabricate the flight strap early enough to use in SESL chamber runs. Fabricate another set for crew training. Replace the flight set with new straps only if the flight set become damaged.

5.1.2 CREW PROVISIONS

5.1.2.1 PROBLEM - Several instances of UCTA leakage occurred during preflight activities.

CONCLUSION - Astronaut Collins' UCTA leaked during altitude chamber runs at KSC. The UCTA was inspected and tested after the first instance and no discrepancy was found. It was assumed that the check valve had been reversed which caused the leak. The UCTA was shipped to MSC after the second instance. The cause of the leakage was determined to be a buildup of salts on the check valve. The UCTA was properly cleaned per CSD-A-470 and then functioned properly.

RECOMMENDATION - Insure that the cleaning procedures are properly followed.

5.1.2.2 PROBLEM - CWG's were delivered with the biobelt snap patches not installed, with the bioharness "button-hole" not opened, and with damaged snaps which would not retain the biobelt snap.

CONCLUSION - The proper people were informed of the discrepancies and tighter controls were to be initiated to insure that the discrepancies were not repeated.

RECOMMENDATION - Tighter controls should be imposed on delivery of CWG's.

5.1.2.3 PROBLEM - Discoloration to the head of crewmembers after wearing the comm. carriers.

CONCLUSIONS - It was noted that the crew received yellow stains around the ears as a result of the comm carriers during exercises resulting in considerable sweating. Apparently the treatment of the material used in the earcup pads has not been fully investigated.

RECOMMENDATIONS - Investigation into this problem should be undertaken to insure that the leather material is properly treated.

5.2 FLIGHT

No major problems were encountered during flight. The majority of these problems have been discussed in Section 4.0, "Inflight Performance." Additional information concerning some of the more important problems will be presented in this section.

5.2.1 EMU

5.2.1.1 PGA and ACCESSORIES

5.2.1.1.1 PROBLEM - N. Armstrong had difficulty installing the camera bracket on the RCU mount.

CONCLUSION - During the final CF^2 at KSC, the flight RCU, flight bracket, and flight camera were interfaced and found to be acceptable for flight. At no time during the CF^2 did the problem occur as noted during the lunar surface activity. From all indications the camera bracket was misaligned on the RCU mount, which made it difficult to lock in.

RECOMMENDATION - Apollo 12 equipment has been evaluated at KSC. This item should be monitored during Apollo 12, and if further difficulties exist, then a different mounting technique should be investigated.

5.2.1.1.2 PROBLEM - Back reflection inside helmet made it difficult to see into shaded areas and hindered dark adaptation

CONCLUSION - Crew reported that the reflection was greatest with the sun shining approximately 90° from the front of the LEVA's.

RECOMMENDATION - Proper use of the blinders on the LEVA should alleviate the problem of reflection. In addition, the crew should minimize dark adaptation requirements by minimizing the number of times they go from sunlit to shaded areas. "Tests at Lockheed ~~Perkin~~-Elmer have shown that the reflection problem is caused primarily by excessive reflection of the PGA helmet. ~~ILCI has submitted a PECP to coat the PGA helmets to minimize reflection.~~"

5.2.1.1.3 PROBLEM - The urine connector, mounted in the PGA, became dislodged and had dropped back through the LITMG mounting flange on Aldrin's PGA.

CONCLUSION - Investigation into this problem revealed that the connector on Aldrin's suit was indeed easy to push back through the mounting flange. Armstrong's suit was then tried, and the connector could be pushed out of the mounting flange. However, it took considerable more effort than for Aldrin's. The PIA Procedures used to install this connector specified two to three in.-lbs. torque for the clamp screw. The screw used in this flange is a size 4-40, and the recommended torque for this size screw is 5 to 7 in.-lbs. The torque was increased to 5 in.-lbs, and the connector could not be pushed out. ILCI was contacted and confirmed that this was in error in the PIA procedures would be changed to 5-7 in.-lbs.

RECOMMENDATIONS - Followup only is required to assure that all documentation has been changed to reflect the 5 to 7 in.-lbs. in leiu of 2 to 3 in.-lbs.

5.2.1.1.4 PROBLEM - The contingency sample pocket worn by Armstrong interfered with the abort handle during launch.

CONCLUSION - Armstrong wore the contingency sample pocket right side up on the lower left leg for CDDT. However, for better utilization of the pocket at launch and immediately thereafter, he requested that the pocket be placed on the upper thigh in an inverted position for launch day.

RECOMMENDATION - The contingency sample pocket can be located in four different places - either the left or right lower leg and either the left or right thigh. Therefore, three places are available for the contingency sample pocket, which would not interfer with the abort handle. The crewman should decide where he wants to wear each pocket for launch and verify these locations during CDDT.

5.2.1.1.5 Problem - Crew commented that the suits did not allow enough waist mobility which made it difficult to bend over, knell, and pick up material from the lunar surface.

Conclusions - Although the crew was able to collect almost all the samples desired they stated that the collecting would have been easier and faster if better waist mobility were available. Without the additional weight available as under 1 g, it is very difficult to overcome the knee and ankle torque to a point where objects at ground level are accessible. This does not mean to say that better knee and ankle mobility is required because with perfect mobility in these two areas would not accomplish the desired results without the capability of bending at the waist.

Recommendations - Implement waist mobility as soon as practicable.

5.2.1.1.6 Problem - Armstrong had difficulty in handling objects due to sweating hands.

Conclusion - Armstrong carried a pair of comfort gloves on Apollo 11 but chose at the last minute not to wear them for the lunar surface portion of the mission. However, during the debriefing he stated that he would definitely wear them if he had it to do over again. Although he had been wearing the comfort gloves during training, he stated that he thought it would not create the problem he experienced. Sweating of the hands is normal with non-porus material as that used in the EV gloves; therefore, this produces a slippery effect inside the gloves which makes it difficult to grasp and

and handle objects.

Recommendations: Comfort gloves should be recommended to the crewmen for all EVA missions.

5.2.1.1.7 Problem - Aldrin experienced discomfort due to the suit wrist disconnects rubbing on forearm.

Conclusion - This is a continuing problem especially with those crewmen with large forearms and wrists. Both EVA crewmen carried protective wristlets to minimize irritation of the wrists but did not wear them during the lunar surface operation. Aldrin stated during the debriefing that he should have worn his wristlets.

Recommendation - All crewmen be advised of the potential problem and to evaluate the wristlets to minimize the problem.

5.2.1.1.10 Problem - The TV cable became hooked on the lunar boot donning tab.

Conclusion - During the lunar excursion as Armstrong passed close to the TV cable, the lunar boot doning tab snagged the cable. The crewman could not see this nor feel it and could have fallen or disrupted the TV transmission. However, if the cable had been laying flat on the lunar surface this would not have occurred. Also, to establish a ground rule to prevent items of this nature from being up off the surface is not feasible.

Recommendation - It is recommended that a cuff be incorporated on the ITMG that could be pulled down over the lunar boots and just cover the donning tabs. This seems to be the most feasible since it would also prevent dust from filtering down the tops of the lunar boots which was also noted by the crewmen.

5.2.1.2 PLSS/OPS

5.2.1.2.1 Problem - The RCU Electrical Connector was difficult to mate to the PLSS.

Conclusion - Armstrong estimated that it took 10 minutes each to make the connections. The problem was that each time the crewman thought the connector was lined up for proper engagement and began to rotate the lever, the connector would move off to one side and bind. This problem occurred several times during training but was not corrected.

Recommendations - This connector is presently being redesigned. The redesigned connector will be available for Apollo 12.

5.2.1.2.2 Problem - Bumping around inside the LM prior to egress with the suit pressurized and PLSS donned caused tripping of two circuit breakers and breakage of another.

Conclusions - Although this is not considered a PLSS problem it will be discussed here because the PLSS did cause this problem. Whenever a suit is pressurized with PLSS donned, it is impossible to feel or hear objects being bumped with the PLSS and quite a force can be exerted without the subject knowing or sensing this.

5.2.2 CREW PROVISIONS

5.2.2.1 PROBLEM - Communications broke up several times during PLSS checkout.

CONCLUSIONS - The crew established during the mission that this problem was not a function of the antenna position. During the mission it was suspected to be the sensitivity setting on the LM VOX switch.

RECOMMENDATIONS - This problem is still under investigation and the results will be presented in Section 5.3 of this report.

5.2.2.2 PROBLEM - The PLSS feedwater bag took considerable time to zero to obtain a tare weight of the remaining PLSS condensate water.

CONCLUSION - During crew training at KSC, Armstrong requested that the scale be set in a closer proximity to zero so that the thumb screw would not have to be turned as many times as had been required in training. The reason for the excessive turns required was that there was some concern as to launch vibrations producing an error with a free spring. Therefore, the spring was bottomed out which locked the spring in place. After discussing this vibration with the project engineer at MSC approval was given to free float the spring. A TPS was generated to approximate the lunar gravity effects on the weight. This was accomplished by obtaining the earth weight of the internal hardware inside the scale that would be affected by lunar weight and the weight of the empty bag. These weights were then equated to lunar weight which was then hung on the scale and the scale zeroed. However, when Armstrong unpacked this measuring equipment he commented that it still took a considerable number of turns to zero the scale with the empty bag attached. The procedure he followed was to attach the empty bag, zero the scale, remove the bag and attach the RCU and record the weight, then weigh the filled

Recommendations - It is recommended that the mission timeline be reviewed to make sure that the PLSS's are donned as late as possible in the mission and that protective covers be installed on the LM controls and displays in the critical areas of PLSS interface and on critical components.

Preliminary

bag and record. There was considerable controversy at KSC during training over the accuracy of this measurement. However, when lunar weights are used the scale is very sensitive which was demonstrated to the crew. The accuracy of the scale is not affected by moving the thumb screw to zero the scale. Even if the scale would have been left in the locked position, it would only have taken longer to zero than was the case. Therefore, the measurements taken were correct and an effort to closer approximate the zero setting under lunar weight should be employed on future flights to reduce the time required to obtain these measurements.

RECOMMENDATIONS - The scale should be set as close to zero as possible under the predicted lunar weights. Also, the lunar surface procedures should be changed to zero the scale without the bag attached, weigh the RCU, and then weigh the filled feedwater bag. This would then give the required weights in the shortest time period.

5.2.2.3 PROBLEM - The medical accessories kit pill packages expanded during the mission making it almost impossible to unstow the contents.

CONCLUSION - The packages containing the pills were not vacuum packed for flight and expanded during pressure reduction.

RECOMMENDATIONS - The medical kit is under failure analysis and will be discussed in detail in Section 5.3.2 of this report.

5.2.2.4 PROBLEM - EKG signal was lost on E. Aldrin and the ZPN signal was lost on M. Collins during flight.

CONCLUSION - First indications as analyzed during the mission was not electrical problems but a drying out of the electrode paste on both crewman. A spare sternal harness was installed with new electrode paste which produced an acceptable ECG signal. The ZPN was not changed nor was new paste applied.

RECOMMENDATION - A full systems check is presently under way to determine that only the electrode paste caused signal failure and will be presented in Section 5.3.2 of this report.

5.2.2.5 PROBLEM - Crew reported repeated fogging of the LM windows with the sunshades installed.

CONCLUSIONS - Although this is not a problem within CSD control it is being presented here because of the crew recommendation requires additional hardware allocations by CSD.

RECOMMENDATION - The crew transferred two of the CM tissue dispensers to the LM. These were used to control the water vapor on the windows and worked quite satisfactory as reported by the crew. Therefore, the crew has suggested that two tissue dispensers be added to the LM stowage list.

5.2.2.6 PROBLEM - The lunar equipment conveyor (LEC) attracted and collected a large quantity of lunar dust, which tended to shake loose and fall over the lower end of the LEC). The lunar dust also caused the pulley to partially bind. Furthermore, it is suspected that the LEC contributed to an increase in lunar dust inside the LM.

CONCLUSIONS - The rock boxes were transferred to the LM from the lunar surface by use of the LEC. It was during this time that the lunar dust caused some concern. However, the procedures did not require a deviation and all equipment was satisfactorily transferred. The rock boxes as well as the LEC transfer cable were covered with lunar dust and when the crew started transferring, it was shaken loose and began to fall on N. Armstrong.

RECOMMENDATION - The LEC has been changed for Apollo 12 to a single strap system whereby the crewman inside the LM will provide the force required to hoist the equipment with the crewman on the lunar surface acting as an anchor point only. Also, it was suggested and should be included in the flight procedures to shake the lunar dust from the LEC prior to each transfer. GAEC has also been tasked to provide a different type system for future flights.

5.2.2.7 PROBLEM - The crew requested a more utilitarian inflight coverall garment (ICG) than that flown.

CONCLUSION - The crew were never quite satisfied, even during training, with the two-piece ICG's. They were accustomed to the regular one piece flying suits which had different pocket arrangements as well as different closures. Largest objection was with the Velcro closures on the leg pockets. The pockets seemed to work satisfactory with large objects but when small objects were placed inside they would come out each corner of the pockets.

RECOMMENDATION - A CCBD has been approved, as crew preference, to install zippers on the LCG pockets. The CCBD to tailor the ICG's similar to the lightweight flying suits and make them one piece was disapproved.

5.2.2.8 PROBLEM - The molded ear pieces became painful when worn in conjunction with the communication carriers.

CONCLUSIONS - E. Aldrin wore the ear pieces for the lunar landing but removed them shortly after landing because of the discomfort. N. Armstrong did not carry ear pieces aboard because of this same problem noted during training. The ear pieces are hard plastic molded to fit individual crew members. Apparently the pressure produced by the ear cups against the ear pieces produce pressure around the entrance to the ear making them impossible to wear for even short periods of time. N. Armstrong commented that there were loud noises during lunar landing but that he was still able to hear enough not to interfere with the landing of the LM.

RECOMMENDATION - A special earcup should be supplied those crewmen requiring ear pieces, or better attenuation of LM systems should be provided.

5.3 POST FLIGHT EVALUATION

Post flight testing, inspection and cleaning have been performed on certain returned items. This section will deal only with problem areas, i.e., if no problem was noted during the post flight inspection or test of an item, then there is no mention of that item in this section.

5.3.1 PGA and Accessories

Twenty-nine (29) discrepancy reports (DR's) were written against the PGA and accessory items. Of these twenty-nine DR's, twenty-five concern wear and tear which is to be expected and is typical of what has been experienced in previous missions. These twenty-five DR's covered scuffs and scratches on the helmets and LEVA's, frayed and torn Beta cloth at various points on the ITMG's, IVCL, LEVA's, gloves, electrical harnesses and bio harnesses; stains and discolorations on the LEVA's, water connectors, diverter valves, zipper flap and comfort liner; and condensation and foreign substances inside the gas connectors. Some of these discrepancies are shown in the attached photographs, S-69-54743 through S-69-54746, S-69-54748 through S-69-54750, and S-69-54754 through S-69-54758. The five remaining DR's are of a more serious nature and are discussed in succeeding paragraphs.

The PGA's were leak tested prior to any cleaning or lubrication of "o" rings and zippers. The relief valves and pressure gages were also functionally checked. All leakages, crack and reseat pressures and pressure gage readings were within preflight PIA specification requirements. These values are recorded in TPS 11924519 and its associated modification sheets and in the following tables.

ITEM	PGA S/N		
	056	033	077
Leakage			
4.2 in. H_2O	68 scc/min	24 scc/min	32 scc/min
3.75 psi (IV gloves)	117 scc/min	85 scc/min	115 scc/min
3.75 psi (EV gloves)	85 ssc/min		87 scc/min
Pressure Gage Cross Check			
3.0 psi	3.04	3.01	3.03
3.5 psi	3.54	3.53	3.53
4.0 psi	4.04	4.03	4.03
4.5 psi	4.52	4.52	4.52
5.0 psi	5.03	5.02	5.04
5.5 psi	5.52	5.53	5.54
6.0 psi	6.03	6.02	6.02
6.0 psi	6.04	6.00	6.02
5.5 psi	5.52	5.50	5.54
5.0 psi	5.02	5.01	5.02
4.5 psi	4.53	4.52	4.53
4.0 psi	4.03	4.02	4.03
3.5 psi	3.53	3.53	3.52
3.0 psi	3.03	3.03	3.01
Relief Valve			
Crack	4.85 psi		4.95 psi
Reseat	4.80 psi		4.80 psi
Flow rate @ 5.5 psig	1.635 cfm		2.3 scfm

Preliminary

5.3.1.1 LCG S/N 079

The LCG's were cleaned and functionally tested as a part of the post flight evaluation. LCG S/N 079 (Aldrin's) failed during the 31.5 psig structural test. The short silicon rubber riser ruptured after six minutes, nine seconds, at 31.5 psig. Photograph S-69-54742 shows the rupture of the external silicon rubber sleeve of the hose. Photograph S-69-54840 shows the cut in the internal sleeve which precipitated the failure. Failure Analysis and Corrective Action Report MSC-03904 (Attachment 1) describes the cause of the failure and the corrective action to be taken.

5.3.1.2 GSE Nametag on PGA S/N 033

The IVCL was removed from PGA S/N 033 during post flight evaluation. At this time, a GSE nametag was found installed on one arm of the TLSA. These nametags consist of a rectangular cardboard plate with the crewman's name and the serial number of the PGA and an elastic band to secure the tag around the arm. They are used at both MSC and KSC to ease in identification of the individual suits. The IVCL was removed for flight PIA and the tag installed on the arm of the TLSA. The tag was inadvertently left on the TLSA when the IVCL was installed.

A memoranda has been sent to the appropriate personnel to insure that this type oversight is guarded against. Although this was an error at PIA, the chances of causing an operational problem are almost non-existent.

Preliminary

5.3.1.3 EMU Maintenance Kits

During post flight inspection of the maintenance kits, it was determined that some of the anti-fog wipe had dried out in both kits and that the lubricant had leaked out inside kit S/N 027. Photograph S-69-54751 shows heat seal separations which resulted in the drying. Photograph S-69-54752 shows the lubricant leakage as the discolored area of nylon in the center of the picture.

Failure Analysis and Corrective Action Report MSC-03812 (Attachment 2) describes the cause of the failures and the corrective action to be taken.

5.3.1.4 PGA S/N 056 Crotch Cable

It was discovered that the left-hand crotch cable was installed 180° out-of-phase at the rear "D" ring on PGA S/N 056. Photograph S-69-54747 shows the right-hand cable properly installed. The discrepant cable was twisted 180° clockwise from that shown. This twist has very little effect while the PGA is unpressurized but can, in effect, shorten the crotch area when pressurized. The seriousness if the problem is not in the result but in the fact that the cable was not installed per design requirements.

5.3.2 <u>Crew Provisions</u>

No problems were noted during inspection of the crew provisions hardware other than those discrepancies or possible anomalies which occurred during flight.

5.3.2.1 Communications Carriers

Communications broke up several times during PLSS checkout and donning prior to LM egress. It was thought, at the time, to be due to antenna position; however, it was determined by the crew that the condition could occur regardless of antenna position. Post flight testing of the communications carriers found no out-of-specification conditions, failures or anomalies.

5.3.2.2 Medical Accessories Kit

The medical accessories kit was difficult to unstow during flight. The handle was ripped while unstowing. Post flight analysis revealed that the difficulty was due to interference from snaps, screw heads, etc., in the stowage compartment and due to the pill packages ballooning due to reduced ambient pressure. Further investigation has resulted in two actions which will be taken to eliminate this problem. It was determined that if, in unstowing the kit, it is pulled out and down, then unstowing is rather easy. In addition, the pill packages will be punctured during flight PIA. This will eliminate ballooning of the packages.

5.3.2.2 Bio Instrumentation

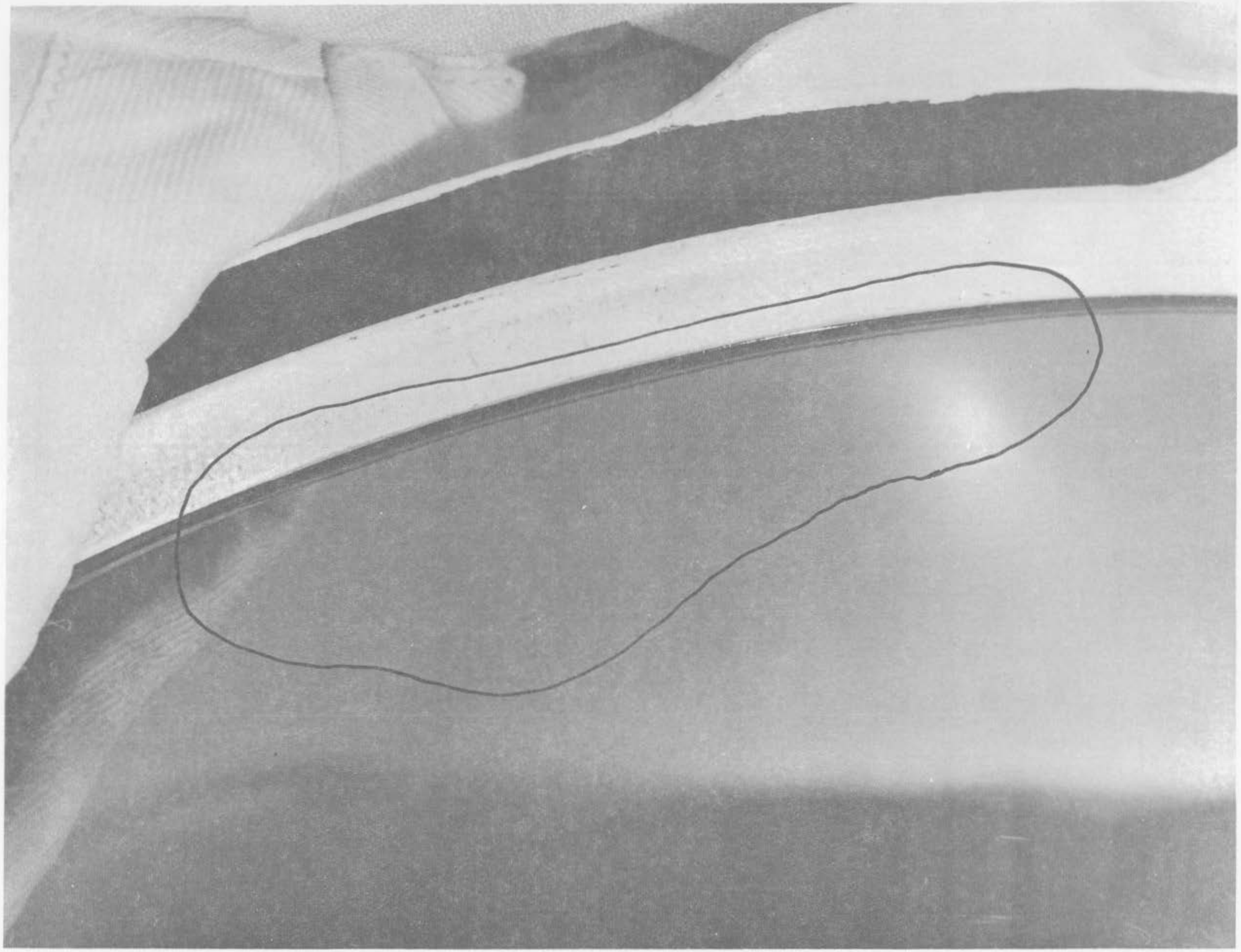
Aldrin's ECG became erratic during the mission, and it was thought, at the time, that the problem was due to dried electrode paste. A spare sternal harness was installed with new electrode paste and acceptable ECG signals were established.

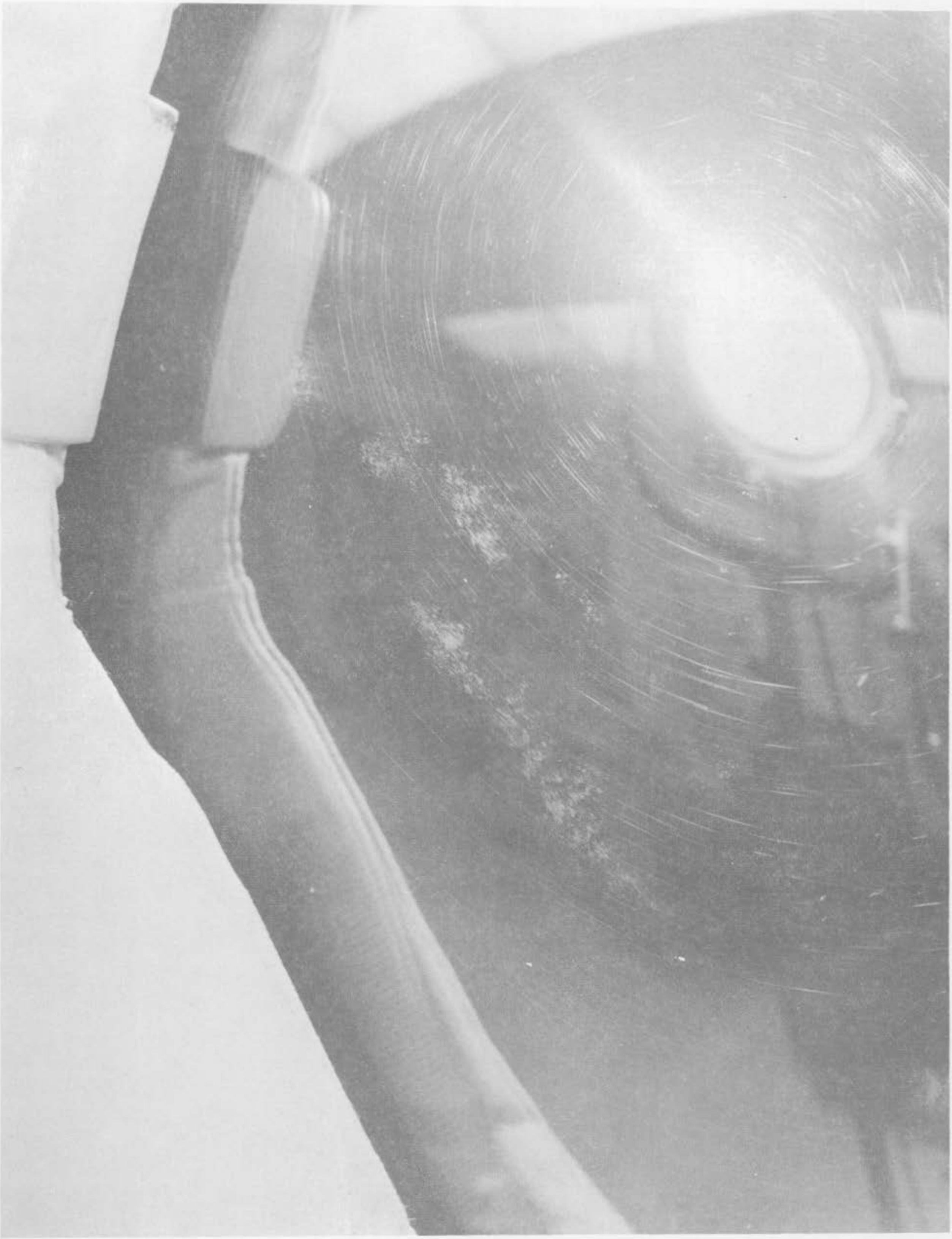
Collins' ZPN later became erratic, but nothing was done to re-establish good data. Post flight evaluation of the bio instrumentation systems revealed that Collins' ZPN dropout was, in fact, the result of paste dryout. However, it was discovered that the ECG failure in Aldrin's harness was due to the harness breaking at the resistor.

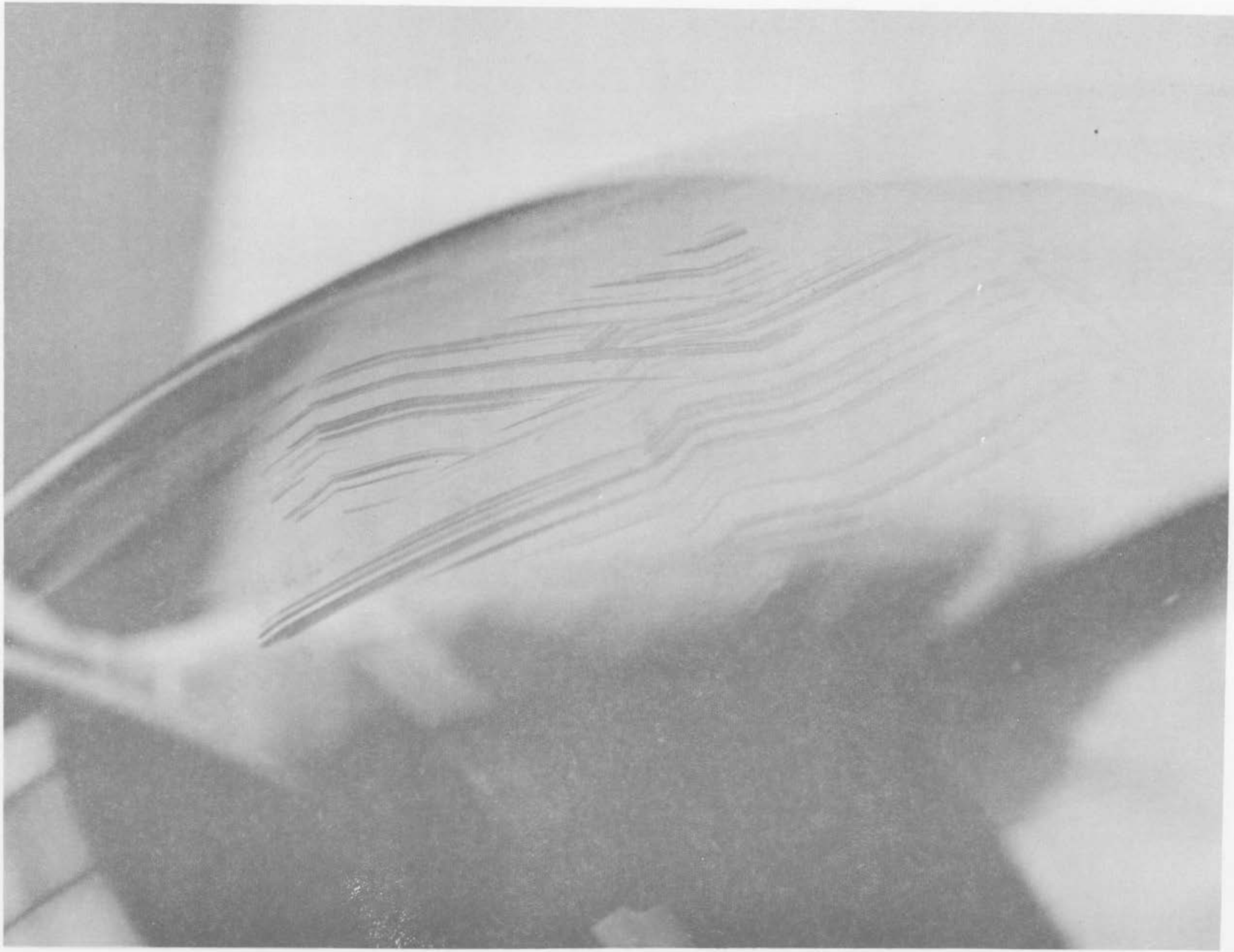
It is an established fact that the harnesses can be damaged rather easily and that the paste will probably dry out prior to the end of the mission. Spare harnesses and paste are carried for this reason.

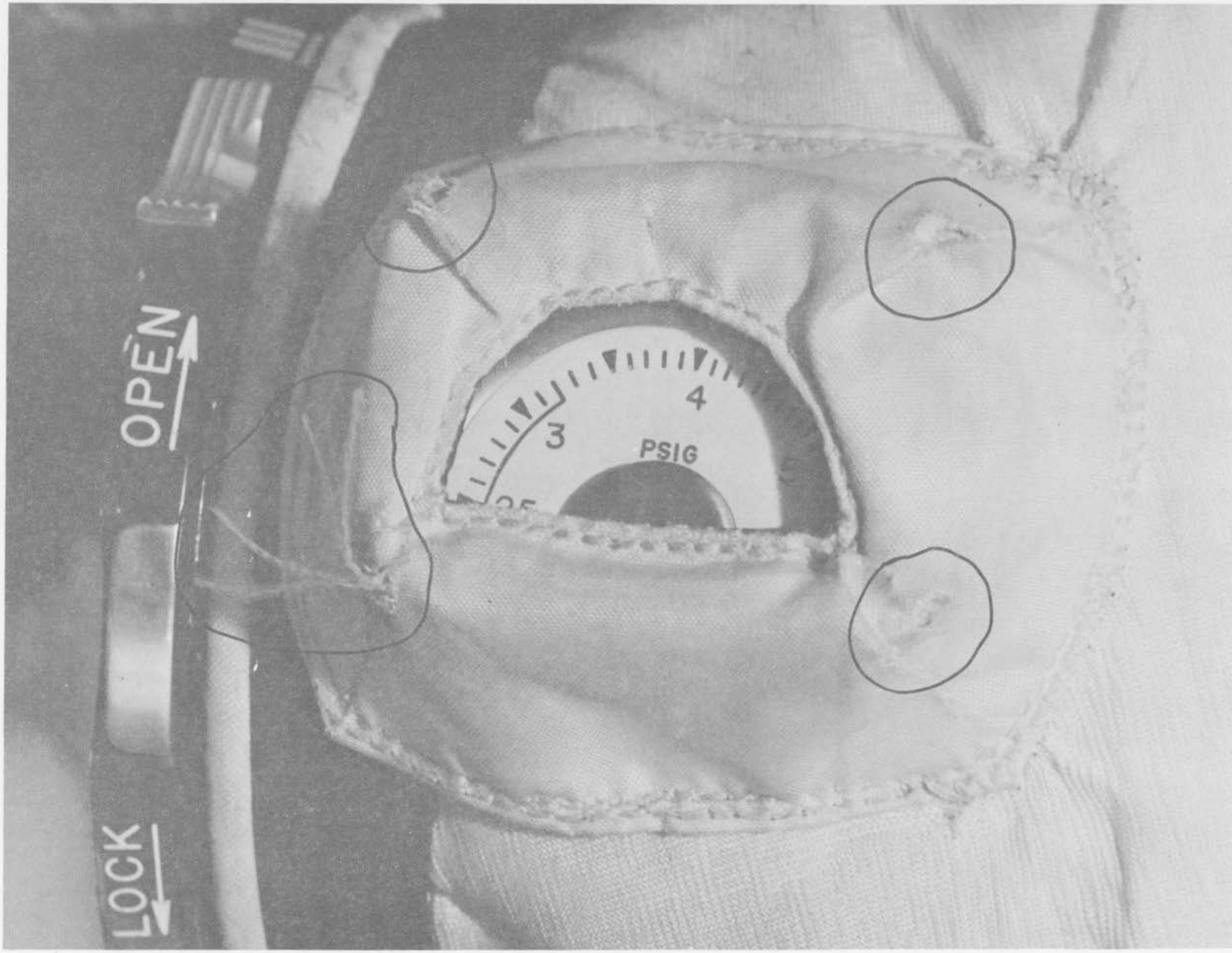
6.0 DETAILED TEST OBJECTIVES

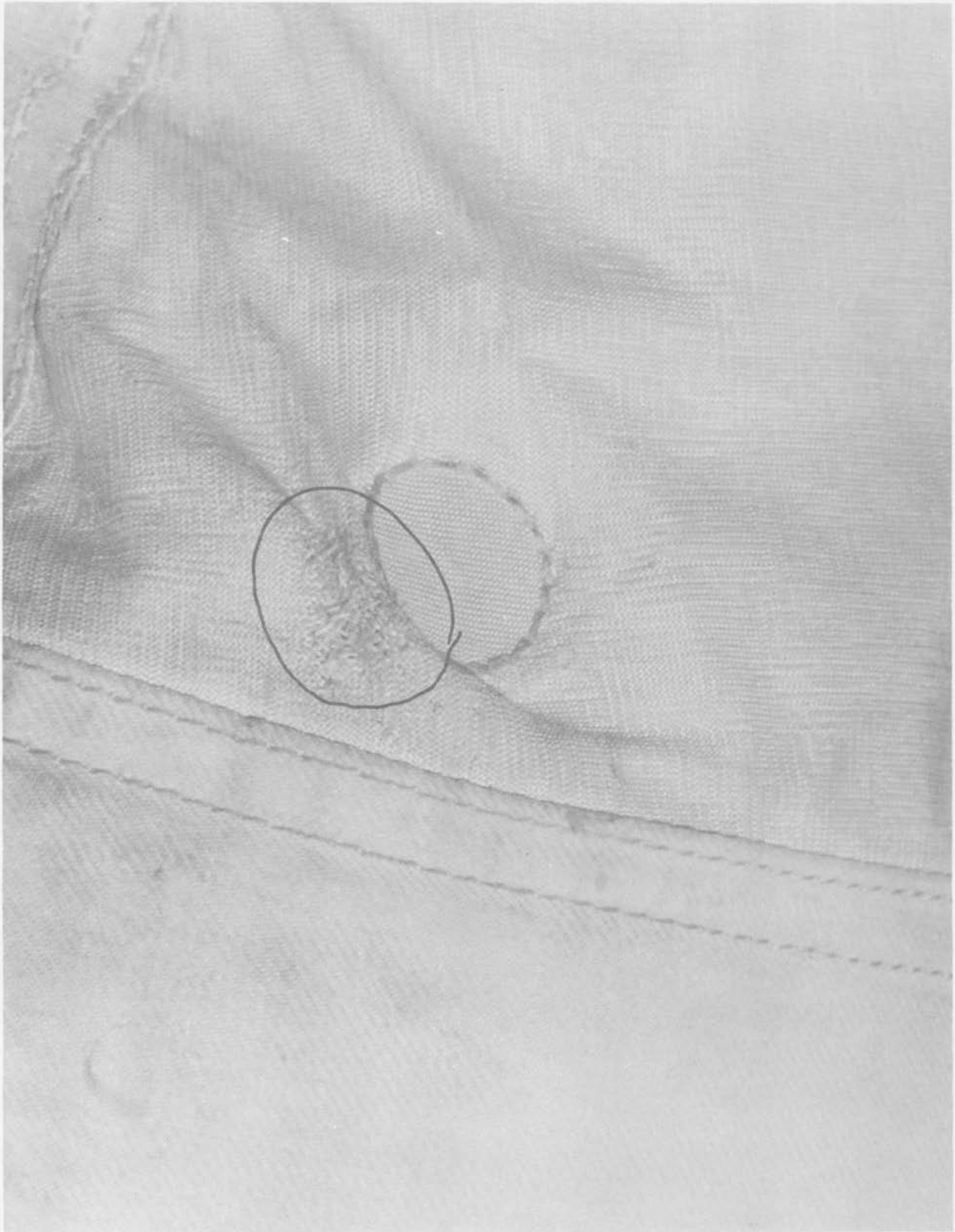
The report of the detailed test objectives has previously been submitted. A copy of this report is included as Attachment 3.

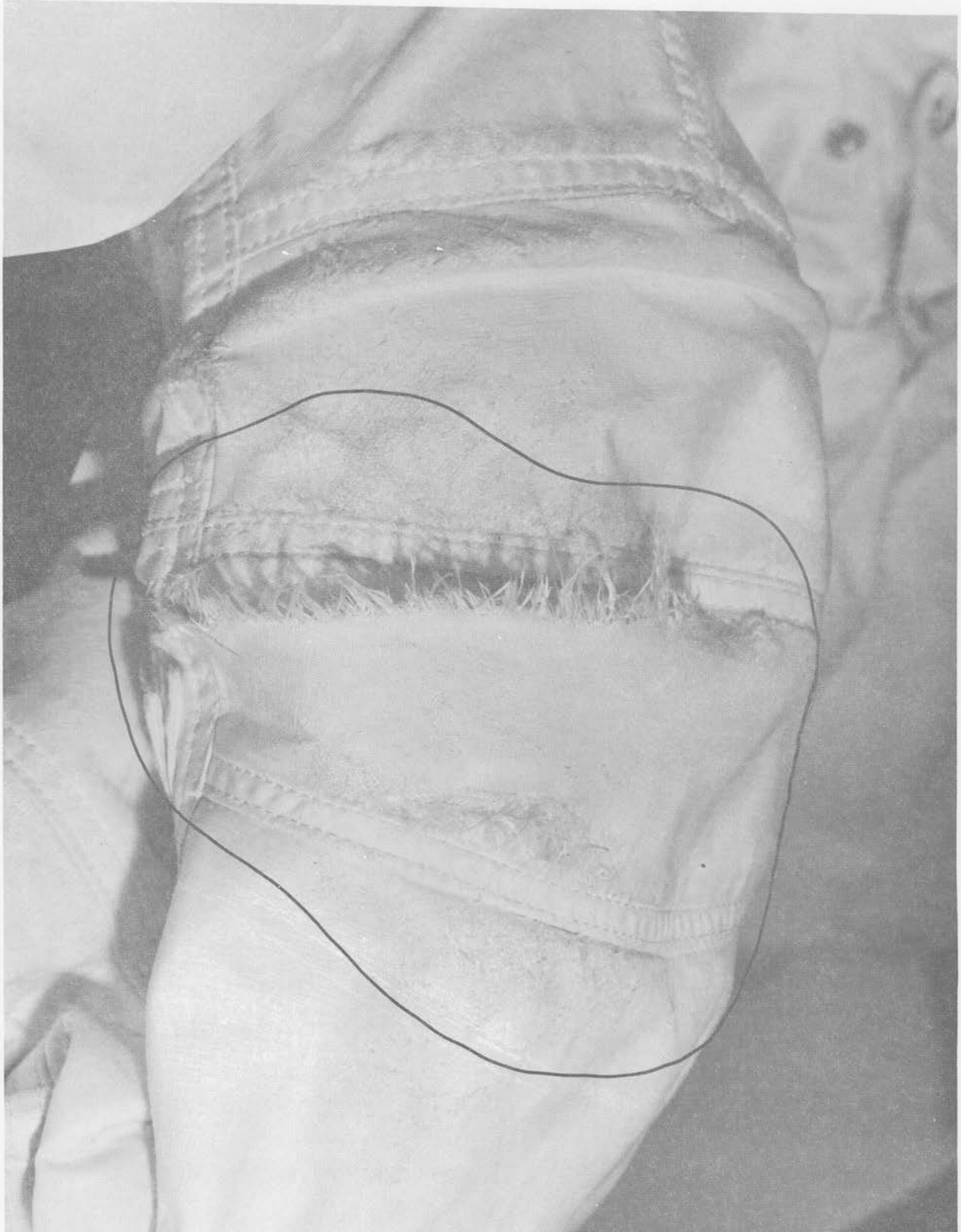


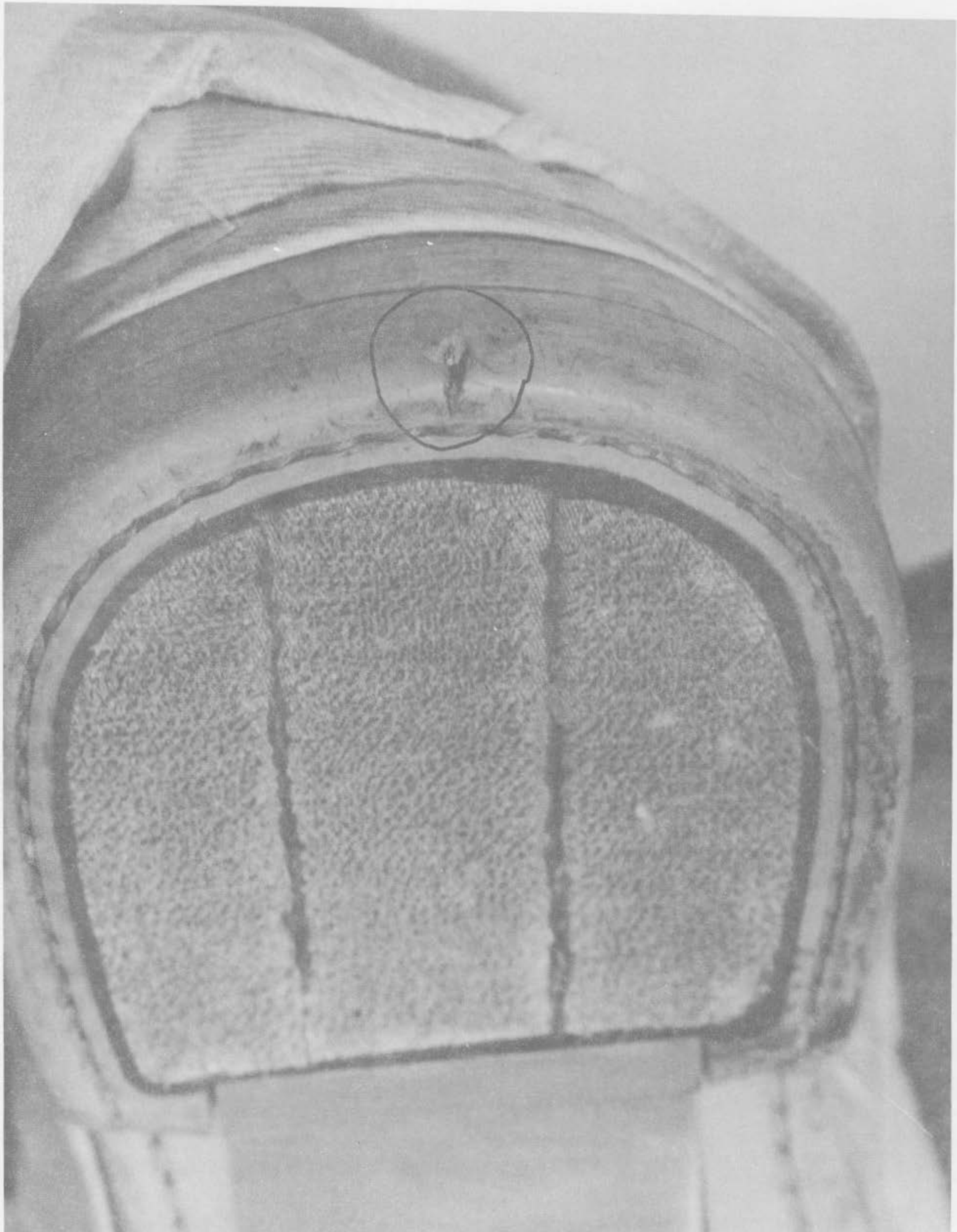


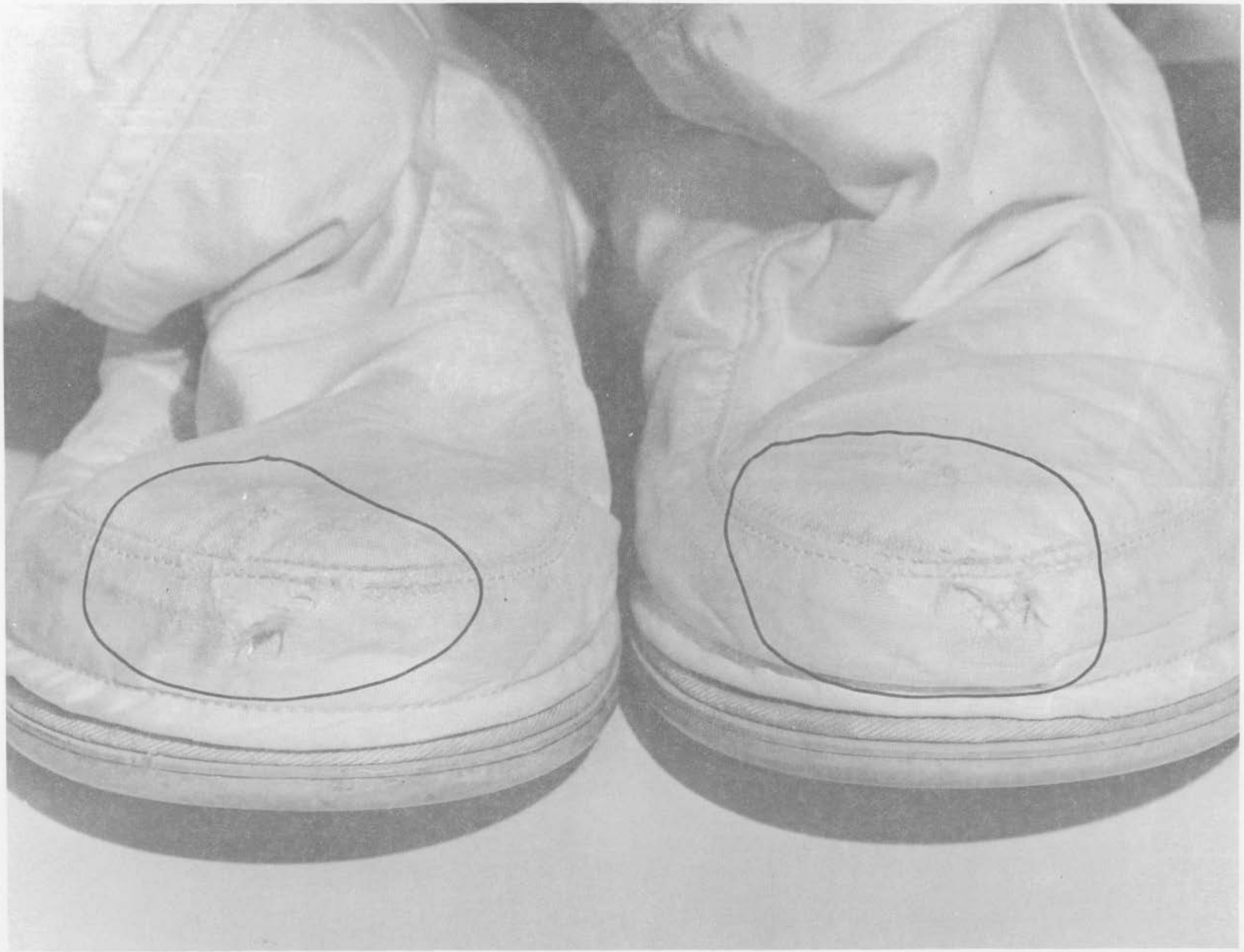


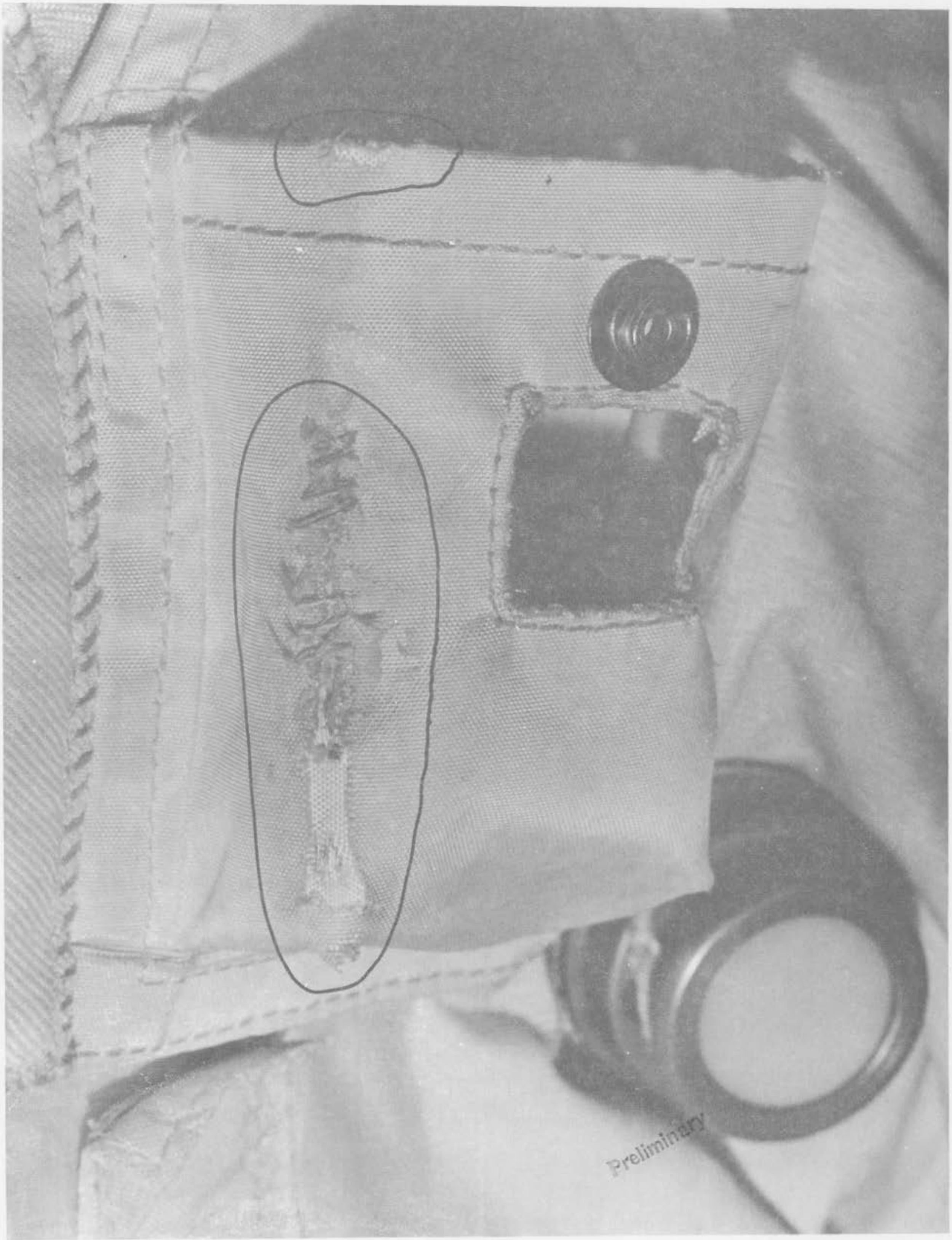

OPEN
LOCK
3
4
PSIG

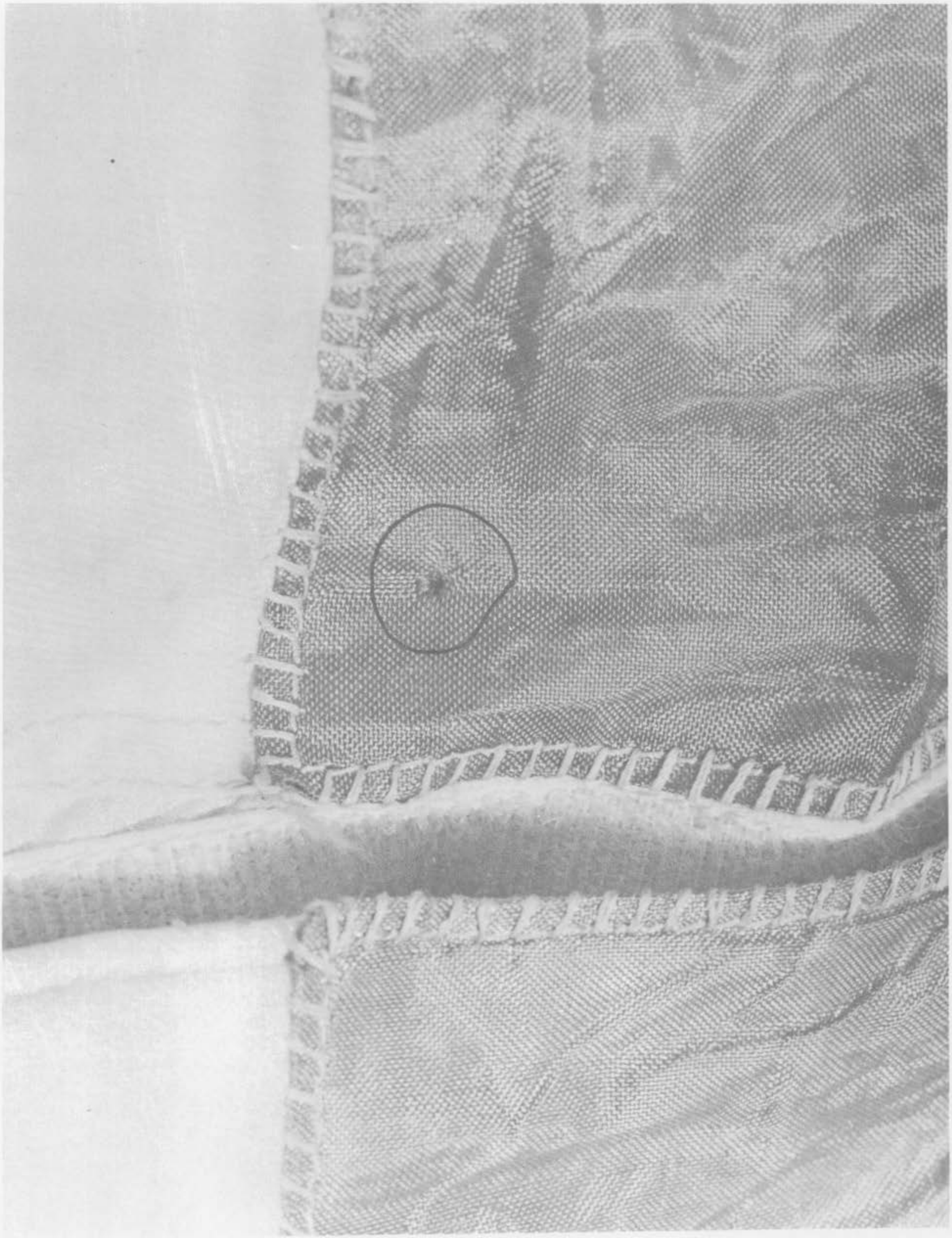


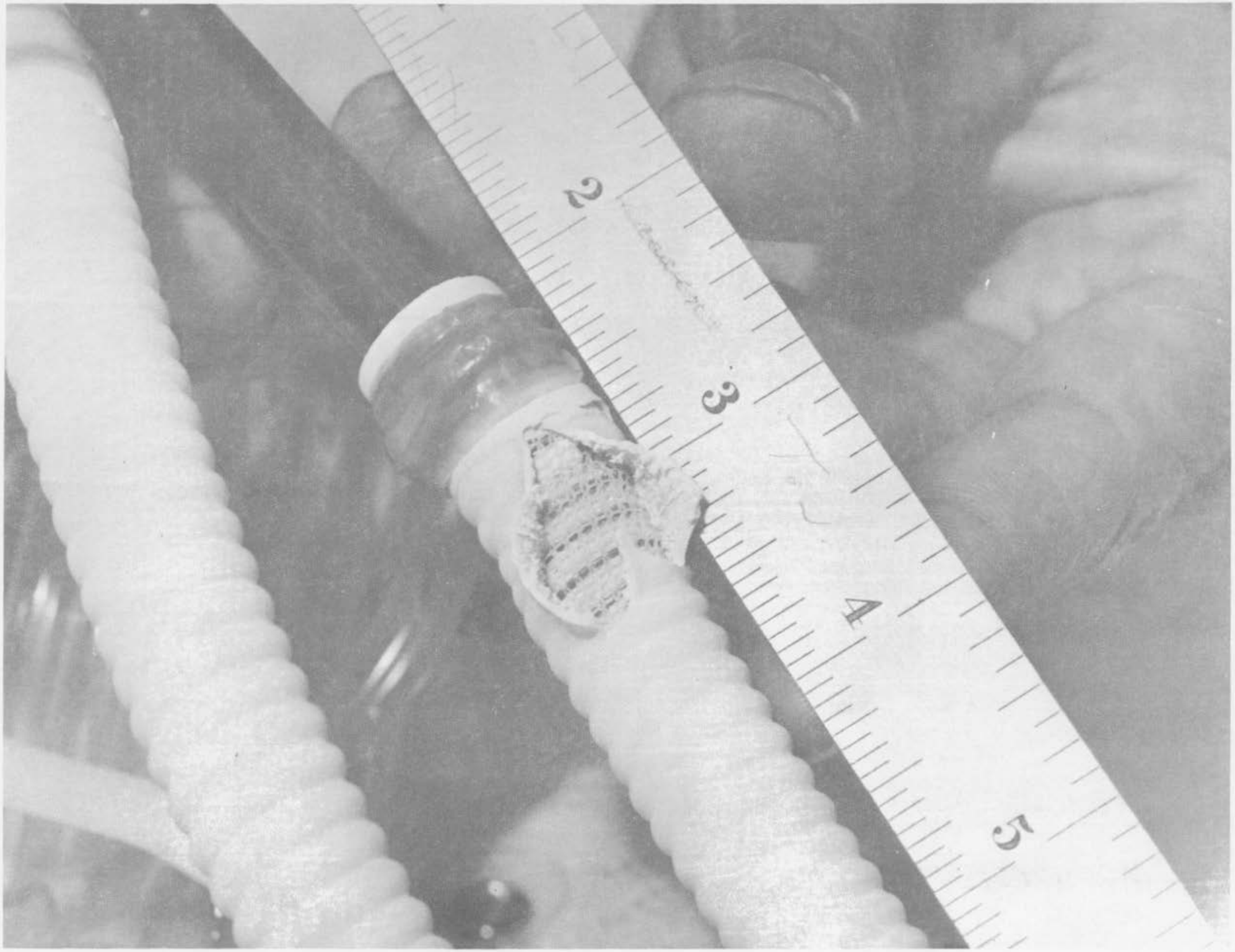







Preliminary

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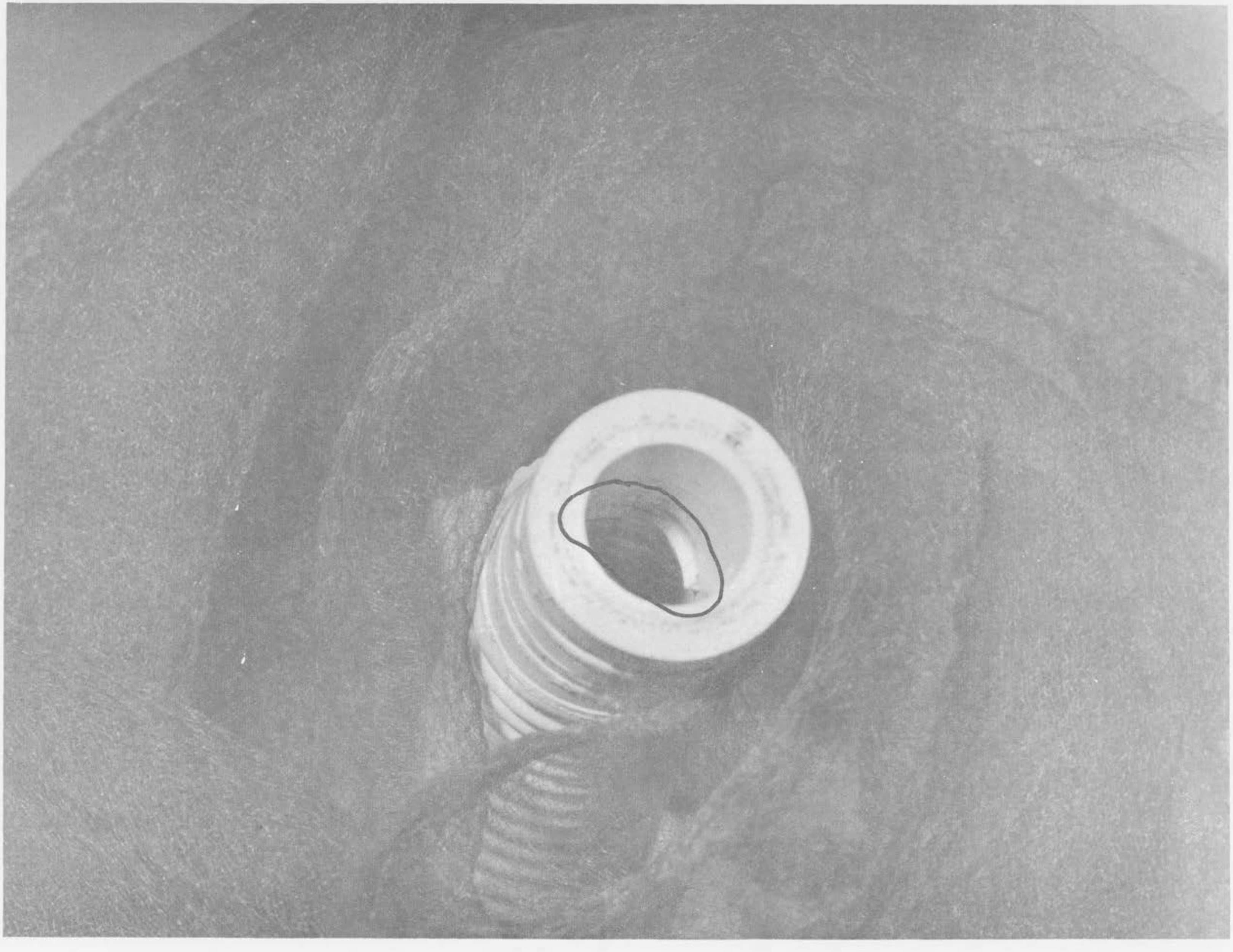

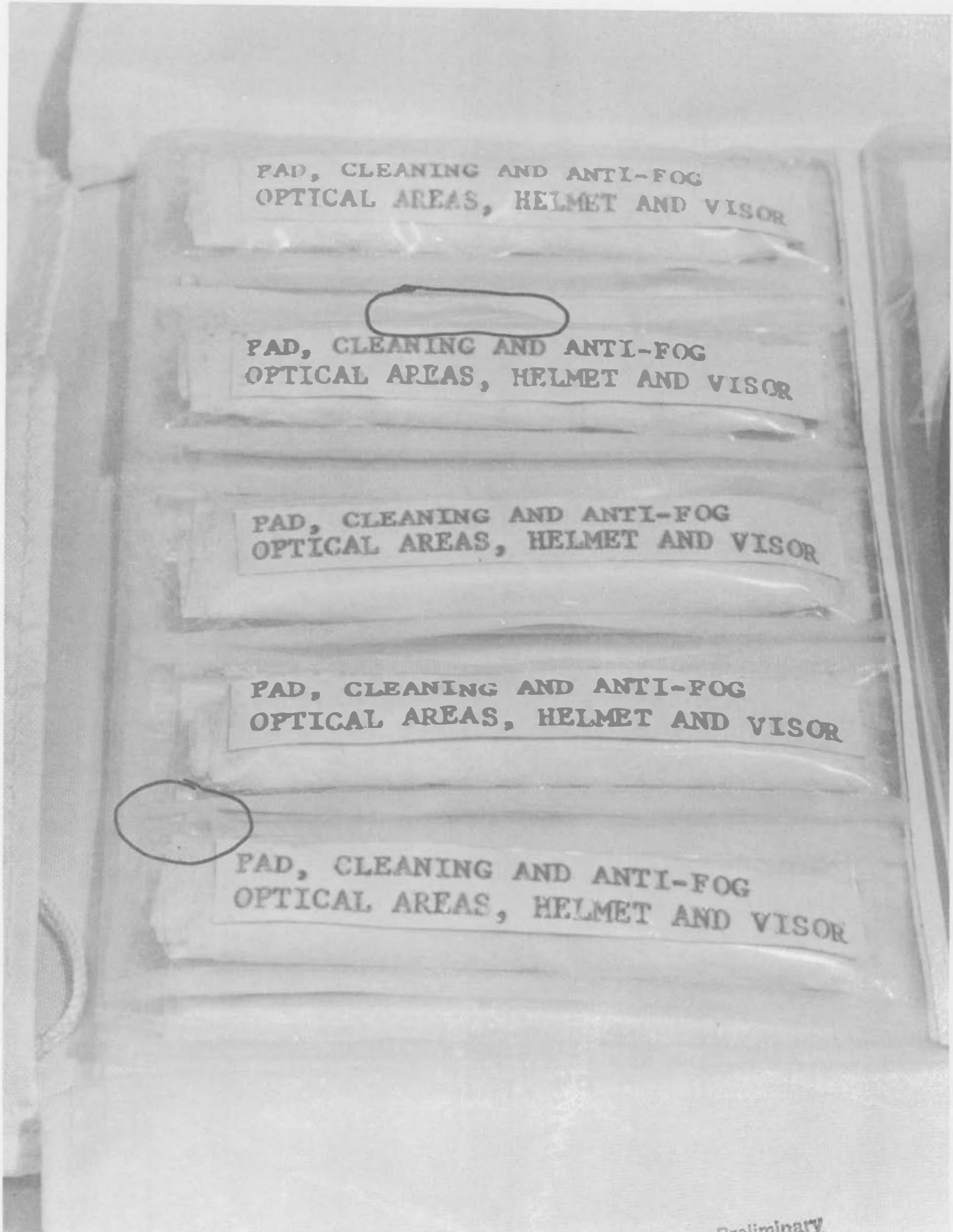

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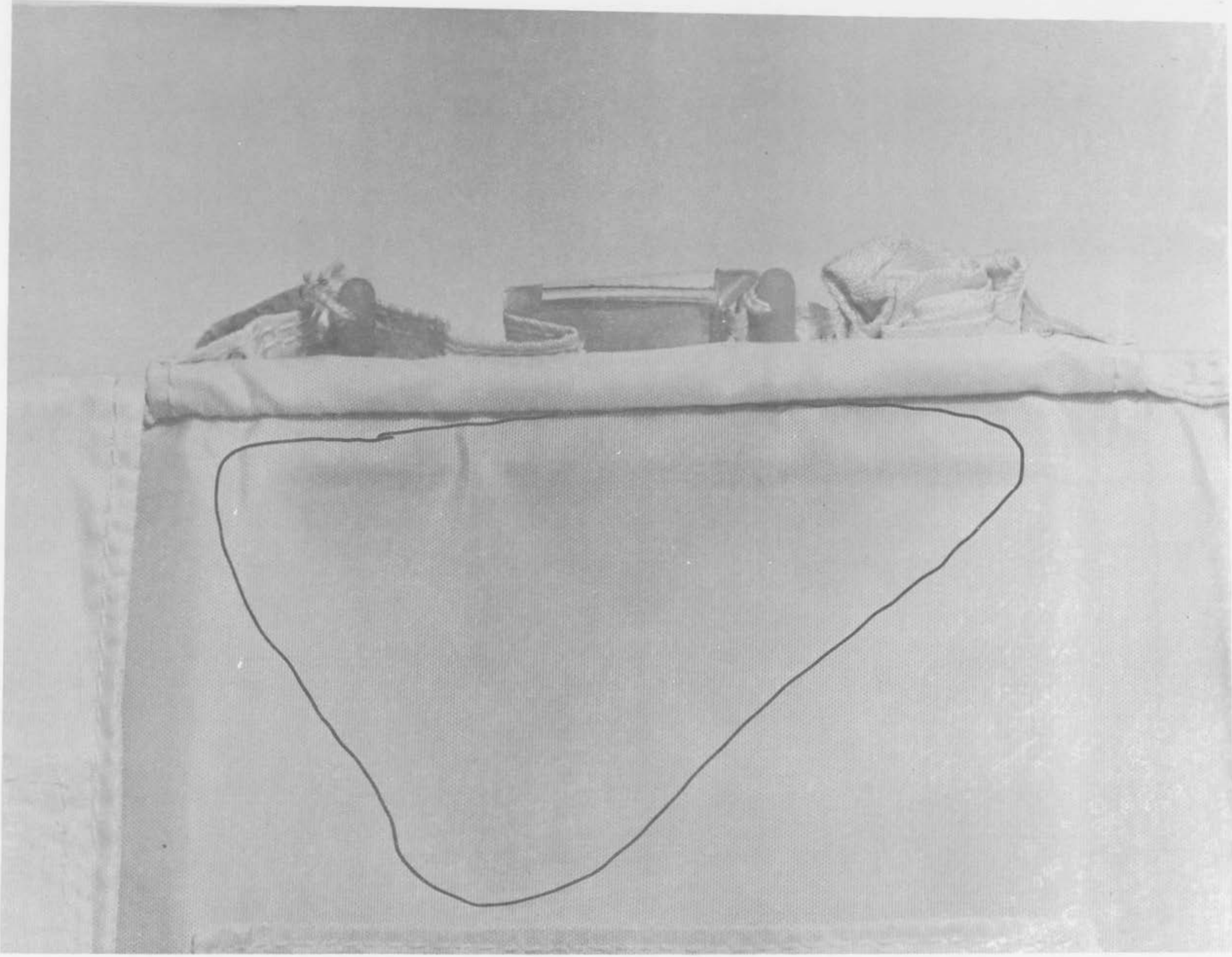


ATCH. 1

ILC INDUSTRIES, INC.
MALFUNCTION REPORT

1. DATE OF MALFUNCTION	2. REPORT NO.
10-13-69	MSC-03904

3. REPORTING AGENCY	4. PROJECT	5. EMU MODEL #	6. EMU SIZE	7. EMU/CEI SERIAL #
ILCI / MSC	AP01-L.O-11	A6L-400000-11	ALDRIN	079

8. FAILED P/N	9. FAILED PART S/N	10. FAILED PART NAME	11. FAILED PART MANUFACTURER
A6L-4Z1032	PROTYPE	HOSE, WATER	R.E. DARLING Co. TUCSON, ARIZ

12. REPLACEMENT P/N	13. REPLACEMENT S/N	14. REF. LOG SHEET/TEST	15. SIGNATURE OF REPORT INITIATOR

16. MALFUNCTION/FAILURE DISCOVERED DURING

- [ ] Inspection - MFG-USER-PDA-PIA-FLIGHT
- [ ] Testing - MFG-USER-PDA-PIA-FLIGHT
- [ ] Maintenance - MFG-USER-PDA-PIA-FLIGHT
- [x] Other (Specify) POST-FLIGHT PIA

17. REPAIR ACTION

- [ ] Repaired in Place
- [ ] Repaired & Re-installed
- [ ] Replaced

18. FAILED ITEM DISPOSITION

- [ ] Return for Analysis
- [ ] Continued Use "AS IS"
- [ ] Destroyed During Test

19. TEST ENVIRON. AT MALFUNCTION

Temp. - High 72° Low
Humid - High N/A Low
Pressure 31.5 PSIG.
Flow Rate 4 PPM
Type of Gas WATER

20. NO. OF CLOSURES (USE CYCLES)

A. Closure (Main) N/A
B. Right Wrist
C. Left Wrist
D. Neck Ring N/A
E. Feedport
F. Vent Inlet L R
G. Vent Exhaust R N/A
H. Telemetry
I. Restraint Cable Shoulder

21. CUMULATIVE USAGE OF CEI AT FAILURE OR REMOVAL

A. 5 PSI		B. 3.7 PSI		C. VENT. PRESS.		D. # DONS & DOFFS
HRS.	HUND.	HRS.	HUND.	HRS.	HUND.	

22. TEST SUBJECT N/A

HGT. WGT. N/A

23. DESCRIPTION OF MALFUNCTION

WATER HOSE RUPTURED AT 31.5 PSIG AFTER 6 MIN. AND 9 SEC. OF OPERATION. RUPTURE OCCURRED 1/2 INCH FROM MANIFOLD CLAMP.

(DR 11932832)

24. REMARKS

25. ASSOCIATED TEST EQUIPMENT

Was test equipment used as intended? YES
Was the test equipment within its required tolerance and/or its accuracy calibrated? YES
T at Console Serial Number NAS 9-3535
Test Conductor T. J. TIRADO & T. HAIG
Test Procedure Document Number 8 812 4G 0050
Test Procedure Paragraph Number 20.3.4 SEC. E

26. NASA & ILC INDUSTRIES, INC. ENGINEERING REVIEW SIGNATURES

COGNIZANT NASA ENGINEER James H. O'Kane DATE 10/14/69
ILC INDUSTRIES FIELD Q&R ENGINEER Len Grayson DATE 10-13-69
ILC INDUSTRIES RELIABILITY (HOME OFFICE)

FORM NO. 1262 (1/68) PRINTED IN USA

ILC INDUSTRIES, INC.
350 PEAR STREET DOVER, DELAWARE 19901

FAILURE ANALYSIS AND CORRECTIVE ACTION REPORT

1. GENERAL	
CALIBRATION REPORT NUMBER: MSC #03904	DATE OF ANALYSIS: 14 October 1969
FACILITY: MSC	ADDRESS: Houston, Texas

2. IDENTIFICATION		
NAME: Hose, Water	PART NUMBER: A6L-421032	TYPE OR MODEL:
MANUFACTURER: R. E. Darling Co.		SERIAL NUMBER: Prototype

HISTORY:

The Apollo 11 LCG A6L-400000-11, S/N 079 was being subjected to post flight testing per TPS 11924519 when a rupture in the short riser tube occurred. The unit was being proof pressure tested per 88124G0050, Section E, Paragraph 20.3.4, Rev. A, and ruptured after 6 min. 9 seconds at 31.5 psig. The discrepant hose (P/N A6L-421032) is a prototype assembly and was connected to manifold assembly P/N 2992-01, S/N 1004.

ANALYSIS:

An initial visual examination of the ruptured LCG riser tube revealed a 3/4" long tear in the outer silicone cover at the manifold end of the tube exposing the fabric mesh and reinforcement wire. The tear was located in the convoluted portion of the tube starting at the point where the convolutes interface with the molded end. It was also observed that the end of the tube was butted against the shoulder at the base of the manifold nipple. Prior to disassembly of the tube from the manifold, X-ray photographs of the discrepant area were taken to ~~xx~~ determine the location of the reinforcement wire coil relative to the manifold lip. These photographs indicated that the end of the coil was located over the lip. The tube was then carefully disassembled from the manifold per TPS 11924929. Visual examination revealed a leakage path through the inner tube located at the coil wire end. Direct measurements of the manifold and hose confirmed that with the tube butted against the manifold shoulder, the coil end was in fact over the nipple lip. As mentioned previously, the discrepant hose assembly is a prototype unit and does not conform to the A6L-421032 drawing. The drawing now controls the dimension from the end of the tube molded end to the first wire coil at 9/16 +0/-1/16 inch. This dimension was 45/64 inch on the discrepant hose. In addition, the latest manifold configuration is a P/N 2992-02 assembly which controls the nipple length at 9/16 ± .010 inch. This length was 48/64 inch on the -01 assembly.

To determine if the same problem existed with Armstrong's A6L-400000-11, S/N 077 LCG an ~~XX~~ X-ray photograph of the manifold/tube interface was taken. The X-ray indicated that the reinforcing wire was located over the nipple lip as in the S/N 079 LCG. The tube was then removed from the manifold per TPS 11924519 revealing a cut in the ~~xxxxx~~ inner silicone tube at the wire coil end. This LCG, however, did not incur an external leak during the 31.5 psig proof pressure test.

LCG A6L-400000-11, S/N 072 was inspected to determine if this condition existed in an LCG in which the riser tubes were installed onto the manifold with the wire coil not over the nipple lip. X-ray photographs of the manifold/tube interface indicated the coil wire to be outside the nipple lip. The riser tubes were removed from the manifold and inspected per TPS 11924971. No damage to the inner silicone tubes of the long and short ~~xxxxxx~~ risers was visible.

FAILURE ANALYSIS
AND
CORRECTIVE ACTION REPORT
(Continuation Sheet)

#03904		DATE OF ANALYSIS: 14 October 1969
Hose, Water	FAILED PART NUMBER: A6L-421032	Prototype

CONCLUSIONS:

As a result of the analysis, it is concluded that the rupture was caused by the compression of the silicone inner tube between the wire reinforcement coil and the manifold nipple lip. Due to tube flexure at this point and under the ~~xxx~~ loading induced during the 31.5 psig proof pressure test, the tube ruptured.

In order to preclude reoccurrence of this failure in the future the riser tube must be installed on the manifold nipple such that the wire coil is not over the nipple lip. Since the length ~~xx~~ of the nipple is controlled at 9/16 ± .010 ~~xx~~ inch and length from the wire coil to the tube end is controlled at 9/16 +0/-1/16 inch, ~~x~~ a maximum interference distance of 5/64 inch could be encountered.

RECOMMENDATIONS (CORRECTIVE ACTION):

(1) Revise the LCG assembly drawing and maintenance procedures to control the dimension between the manifold shoulder and the tube end at 5/64 +1/16/-0 inch.

(2) X-ray inspect all existing silicone riser LCG's to verify that the coil wire is not over the nipple end.

(3) Revise Flight P.I.A. procedures to require inspection verification of the 5/64" +1/16/-0 assembly dimension.

Robert C. Ewart

Prepared by: R. C. Ewart, ILCI

APPROVAL SIGNATURES	DATE
ILCI QUALITY: J. Scott Brown	10/16/69
ILCI RELIABILITY: Ken Grayson	10/16/69
ILCI ENGINEERING: R.C. Ewart for R. Robbins per telecon	10/16/69
ILCI QSR MANAGER: John V. Lund by Ken Grayson per telecon	10/16
NASA QUALITY: D. B. Wells / CF	10/16
NASA RELIABILITY: R. H. Steele NB5	10/16
NASA ENGINEERING: Frank A. C. Yane	10/16

ATCH 2

ILC INDUSTRIES, INC.
MALFUNCTION REPORT

1. DATE OF MALFUNCTION	2. REPORT NO.
10-8-[illegible]	MSC 03812

3. REPORTING AGENCY	4. PROJECT	5. EMU MODEL #	6. EMU SIZE	7. EMU/CEI SERIAL #
[illegible]/MSC	Apollo-11	[illegible]	N/A	[illegible]

8. FAILED P/N	9. FAILED PART S/N	10. FAILED PART NAME	11. FAILED PART MANUFACTURER
[illegible]	[illegible]7	EMU Maint Kit	ILC

12. REPLACEMENT P/N	13. REPLACEMENT S/N	14. REF. LOG SHEET/TEST	15. SIGNATURE OF REPORT INITIATOR
N/A	N/A	N/A	[illegible]

16. MALFUNCTION/FAILURE DISCOVERED DURING

- [ ] Inspection - MFG-USER-PDA-PIA-FLIGHT
- [ ] Testing - MFG-USER-PDA-PIA-FLIGHT
- [ ] Maintenance - MFG-USER-PDA-PIA-FLIGHT
- [x] Other (Specify) Post [illegible] PIA

17. REPAIR ACTION

- [ ] Repaired in Place
- [ ] Repaired & Re-installed
- [ ] Replaced

18. FAILED ITEM DISPOSITION

- [ ] Return for Analysis
- [ ] Continued Use "AS IS"
- [ ] Destroyed During Test

19. TEST ENVIRON. AT MALFUNCTION

Temp. - High ______ Low ______
Humid - High ______ Low ______
Pressure ______
Flow Rate ______
Type of Gas ______

20. NO. OF CLOSURES (USE CYCLES)

A. Closure (Main) N/A
B. Right Wrist N/A
C. Left Wrist N/A
D. Neck Ring N/A
E. Feedport N/A
F. Vent Inlet L N/A
G. Vent Exhaust L [illegible] R
H. Telemetry [illegible]
I. Restraint Cable Shoulder ______

21. CUMULATIVE USAGE OF CEI AT FAILURE OR REMOVAL

A. 5 PSI		B. 3.7 PSI		C. VENT. PRESS.		D. # DONS & DOFFS
HRS.	HUND.	HRS.	HUND.	HRS.	HUND.	
N/A						

22. TEST SUBJECT N/A HGT. WGT.

23. DESCRIPTION OF MALFUNCTION REF DR 1193 2746

1. LUBRICANT HAS LEAKED OUT OF LUBRICANT PAD

2. CLEANING & ANTI FOG PADS, & [redacted] ARE OUT.

24. REMARKS

25. ASSOCIATED TEST EQUIPMENT

Was test equipment used as intended? ______
Was the test equipment within the required tolerance and/or its accuracy calibrated? ______
Test Console Serial Number ______
Test Conductor ______

26. NASA & ILC INDUSTRIES, INC. ENGINEERING REVIEW SIGNATURES

COGNIZANT NASA ENGINEER [illegible signature] DATE
ILC INDUSTRIES FIELD Q&R ENGINEER [illegible signature] DATE

ATCH. 3

EMU OBJECTIVES ASSESSMENT REPORT

APOLLO 11

Scope

Three functional test objectives, (FTO), were contained in the EMU lunar surface operations of the Mission Requirement Document for Apollo 11. The purposes were to demonstrate satisfactory performance of the EMU (FTO 1 and FTO 2) and to demonstrate the satisfactory operation of the EVA-LM-MSFN communication links (FTO 3). FTO 1 and FTO-2 assessments are presented in this report.

Objectives

The functional test objectives (FTO) were as follows:

FTO 1. Demonstrate the capability of the EMU to provide a habitable environment.

FTO 2. Demonstrate the capability of the EMU to provide sufficient mobility, dexterity and comfort to allow the crew to egress/ingress the LM and perform useful work on the lunar surface.

Data Requirements

1. Telemetry Measurements:

Measurement Number	Description	TM
GT 8100	EVCS No. L Sync	FM/FM*
GT 8101 V	Volt, EVCS No. 1 Calib 0 Pct	FM/FM*
GT 8102 V	Volt, EVCS No. 1 Calib 100 Pct	FM/FM*
GT 8110 P	Press, PLSS Feed No. 1 H20	FM/FM*
GT 8124 J	Electrocardiogram No. 1	FM/FM*
GT 8140 C	PLSS Batt Current No. 1	FM/FM*
GT 8141 V	Volt, PLSS No. Battery	FM/FM*
GT 8154 T	Temp, LCG H_2O Inlet No. 1	FM/FM*
GT 8168 P	Press, PGA O_2 No. 1	FM/FM*
GT 8170 T	Temp, PLSS No. 1 Subl O2 Outlet	FM/FM*
GT 8182 P	Press, PLSS O_2 Supply No. 1	FM/FM*
GT 8196 T	Delta Temp, LCG H_2O In/Out No. 1	FM/FM*

Measurement Number	Description	TM
GT 8200	EVCS No. 2 Sync	FM/FM*
GT 8201 V	Volt, EVCS No. 2 Calib 0 Pct.	FM/FM*
GT 8202 V	Volt, EVCS No. 2 Calib 100 Pct	M/FM*
GT 8210 P	Press, PLSS No. 2 Feed H_2O	FM/FM*
GT 8224 J	Volt, PLSS No. 2 EKG	FM/FM*
GT 8240 C	Curr, PLSS No. 2 Battery	FM/FM*
GT 8241 V	Volt, PLSS No. 2 Battery	FM/FM*
GT 8254 T	Temp, LCG No. 2 H_2O Inlet	FM/FM*
GT 8268 P	Press, PGA No. 2	FM/FM*
GT 8270 T	Temp, PLSS No. 2 Subl O_2 Outlet Deleted	FM/FM*
GT 8282 P	Press, PLSS No. 2 O_2	FM/FM*
GT 8296 T	Delta Temp, LCG No. 2 H_2O In/Out	FM/FM*
GT 9991 U	EMU TM Outputs	FM/FM*

*Measurements GT 8100 through GT 8296 T are all parts of measurement GT 9991 U.

2. Astronaut Logs or Voice Records:

   a. The crew were to notify MSFN of the initial and final positions of the PLSS water diverter valve, primary oxygen shutoff valve, and water shutoff/relief valve each time the valves were changed. (M)
   b. The crew were to notify MSFN whenever the following PLSS remote control unit status indicators and audible warning tone came on. (M)
      (1) High O_2 flowrate
      (2) Low vent flow
      (3) Low feedwater pressure
      (4) PGA pressure low
   c. The crew were to record EMU radiation dosimeter readings just prior to and after completion of the extravehicular activities. (M)
   d. The crew were to notify MSFN whenever the following occurred (HD)
      (1) Noxious odors, if any
      (2) Condensation, if any, on the visor assembly.
   e. The crew were to comment on the adequacy of procedures and difficulties encountered during donning and doffing EMU equipment; i.e., PLSS, EV visor, gloves and boots. (HD)
   f. The crew were to comment on time required and adequacy of the EMU checkout procedures. (HD)
   g. The crew were to comment at least one time on the adequacy of EMU thermal environment when walking from a sunlit area to shadow and vice versa. (M)
   h. The crew were to comment on their estimated energy expenditure and comfort as compared to their simulation experience. (HD)
   i. The crew were to comment on voice quality for EVA-EVA and EVA-LM-MSFN communications. (M)
   j. The crew were to record the weight of the feedwater collection bag prior to and after collection of water drained from the PLSS at the end of the EVA period. (M)

3. MSFN recording of EVA-LM-MSFN conference voice. (M)

Evaluation to be Accomplished

FTO 1. The adequacy of the EMU to provide a habitable environment was to be assessed. (Astronaut records, MSFN recording of EVA-LM-MSFN conference voice and GT 9991 U)

The quantity of water used during EVA was to be determined. (Astronaut records)

FTO 2. Mobility, dexterity and comfort of the crew were to be assessed. (Astronaut records)

Results of the Evaluation

FTO 1. The EMU adequately provided a habitable environment for the Apollo 11 extravehicular activities (EVA).

a. As a result of a slow lunar module cabin depressurization, both crewmen operated on the EMU approximately 32 minutes without cooling from the PLSS sublimator. The crew indicated they did not feel uncomfortable during this period. The Commander's sublimator gas outlet temperature ranged from 72.5°F to a buildup of 88°F in about 20 minutes, then held constant at about 88°F until sublimator startup. Reference Figure 1, Page 7.

The lunar module pilot's sublimator gas outlet temperature ranged from 74°F to a buildup of 90°F in about 18 minutes where instrumentation goes off scale until about 4 minutes after sublimator start-up. Reference Figure 2 , Page 8.

b. The cooling performance of the LCG/LTL (liquid cooling garment/liquid transport loop) for both crewmen exhibited slightly higher efficiencies than were obtained from the ground manned altitude chamber tests which were conducted at approximately 10^{-6} mm Hg.

The lunar surface environment exhibits vacuum of 10^{-12} to 10^{-14} mm Hg; therefore, the PLSS sublimators had better sublimation because of the lower ambient pressure. Sublimator oxygen outlet temperatures, Figures 1 and 2 , Pages 7 and 8, were observed to be below 45°F at stabilization which substantiates the higher performance. Both crewmen reported good cooling after sublimator start-up.

The Commander stayed in minimum PLSS diverter position throughout the EVA until preparations for ingress at which time he switched to intermediate diverter position for approximately 6.5 minutes. He then returned the diverter to minimum position.

The lunar module pilot switched to the maximum diverter valve position immediately after sublimator startup, and operated at maximum position for about 42 minutes before switching to the intermediate diverter position. He remained in the intermediate position for the duration of the EVA. LCG inlet and LCG delta temperature curves are provided for both crewmen in figures 3 through 6 pages 9 through 12.

During the lunar surface activities there were no thermal problems with the EMU's and the crew observed no difference in temperature between the shade and the sun.

The lunar surface activities were as planned in the "Apollo 11 Lunar Surface Plan" dated 27 June 1969 with the exceptions as follows:

1. The United States Flag Ceremony

2. Telephone call from President Nixon

3. Documented sample activity curtailed after 18 minutes. Planned activity was for 34 minutes.

c. The duration of the EMU habitable environment was 2 hours 56 minutes for each crewman. The consumables remaining in each PLSS were measured with the exception of the unreacted LiOH and the LMP feedwater. The consumables analysis are presented in figure 7 page 13.

d. The low vent warning tone did not sound nor did the low vent indicator appear, which provides a basis for sufficient CO_2 washout in the oral-nasal area.

FTO 2. The capability of the EMU to provide sufficient mobility, dexterity and comfort to allow the crew to egress/ingress the LM and perform useful work on the lunar surface was demonstrated by the Apollo 11 EVA crewmen. The operation in the suits was very pleasant. There was little hindrance to mobility except when getting down to the surface to pick up objects with the hands which was very difficult. Moving in and out through the hatch was no trouble. Climbing up and down the ladder was a simple task and was very much like ground simulations. This included the first rung of the ladder from the lunar surface. During motivation forward a lope was very comfortable. When they started to move sideways they just hopped. Moving around was very natural and easier than 1/6 G simulations. The crew adapted rapidly and easily to 1/6 G. The kangaroo hop worked for forward movement but the mobility was not quite as good as the conventional one foot after the other.

After getting off balance, it was very easy to recover. The LMP had to be rather careful to maintain his center of mass. Sometimes it took two to three paces to be certain his feet were under him. To change directions like a football player he had to stretch one of his feet out to the side and cut a little bit. Traction was observed to be quite good, however, the rocks were rather slippery.

With the sun shining on the LEVA from approximately 90o to the front, reflections got on the face. At this point it was difficult to see in the shadow. As the crewman inserted his helmet into the shadow he began to see and started dark adaptation. Continually moving back and forth from sunlight into shadows should be avoided because it costs time in dark adaptation.

The Commander did not wear comfort gloves and his hands sweated. He found that wet hands degraded his ability to handle objects and get a firm grip on things.

Major work activities which were successfully conducted were as follows:

1. Solar wind composition deployment.
2. Television deployment
3. Bulk sample collection
4. The United States Flag Installation
5. EASEP deployment
6. Documented Sample deployment

These activities are delineated in the Apollo 11 Lunar Surface Plan dated 27 June 1969.

Conclusions:

FTO 1. a. Sufficient cooling to the LMP was borderline during the EMU checkout just prior to and immediately after cabin depress as observed from the sublimator outlet oxygen temperature, Figure 2 page 8.

This potential situation of insufficient cooling can be preempted by at least two methods as follows:

1. Depress the LM cabin (<1000 microns) faster than the LM-5 cabin was depressed so that the PLSS sublimator startup can be realized within the thirty minute limitation.

2. Provide cooling from the LM 192 package to the crew until the cabin has been depressurized completely (<1000 microns) where the PLSS sublimator is effective. his procedure is not conducive to good management in that it requires serial time for

the PLSS water connection to be connected to the suit after the LM 192 package water connector has been disconnected. Each crewman is needed to aid the other crewman during the connection and disconnection of the water connectors.

b. Predicted and estimated metabolic rates were higher than the actual metabolic rates, therefore, the lunar surface excursion was curtailed based on projected consumables remaining. Sufficient consumables remained in both PLSS to plan for a 3.5 hour mission based on a work rate of 1200 BTU/hr.

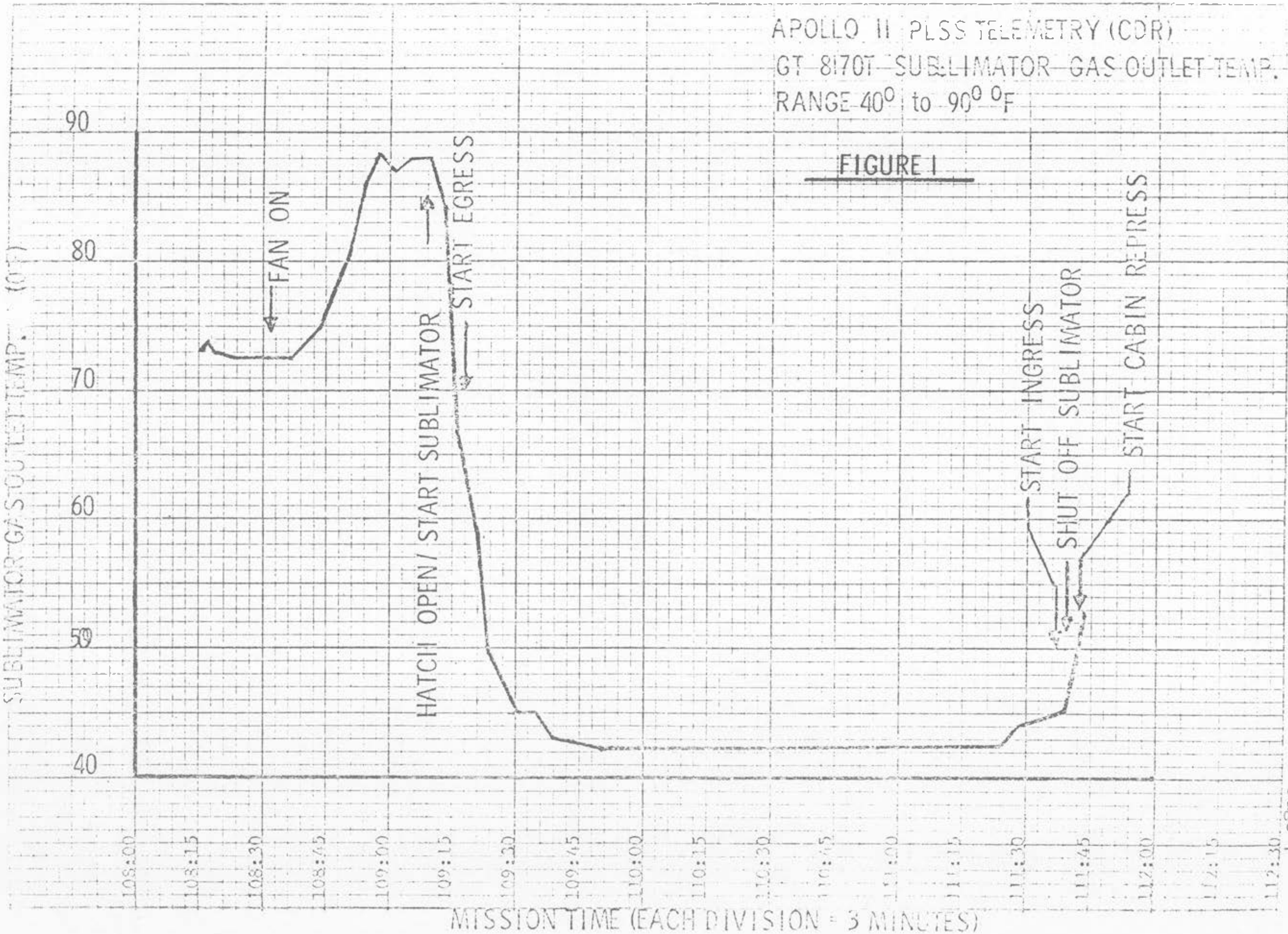
c. The feedwater extracted confirmed the metabolic load of the commander, however, the feedwater was not extracted from the LMP PLSS leaving the metabolic loads to analysis and speculation.

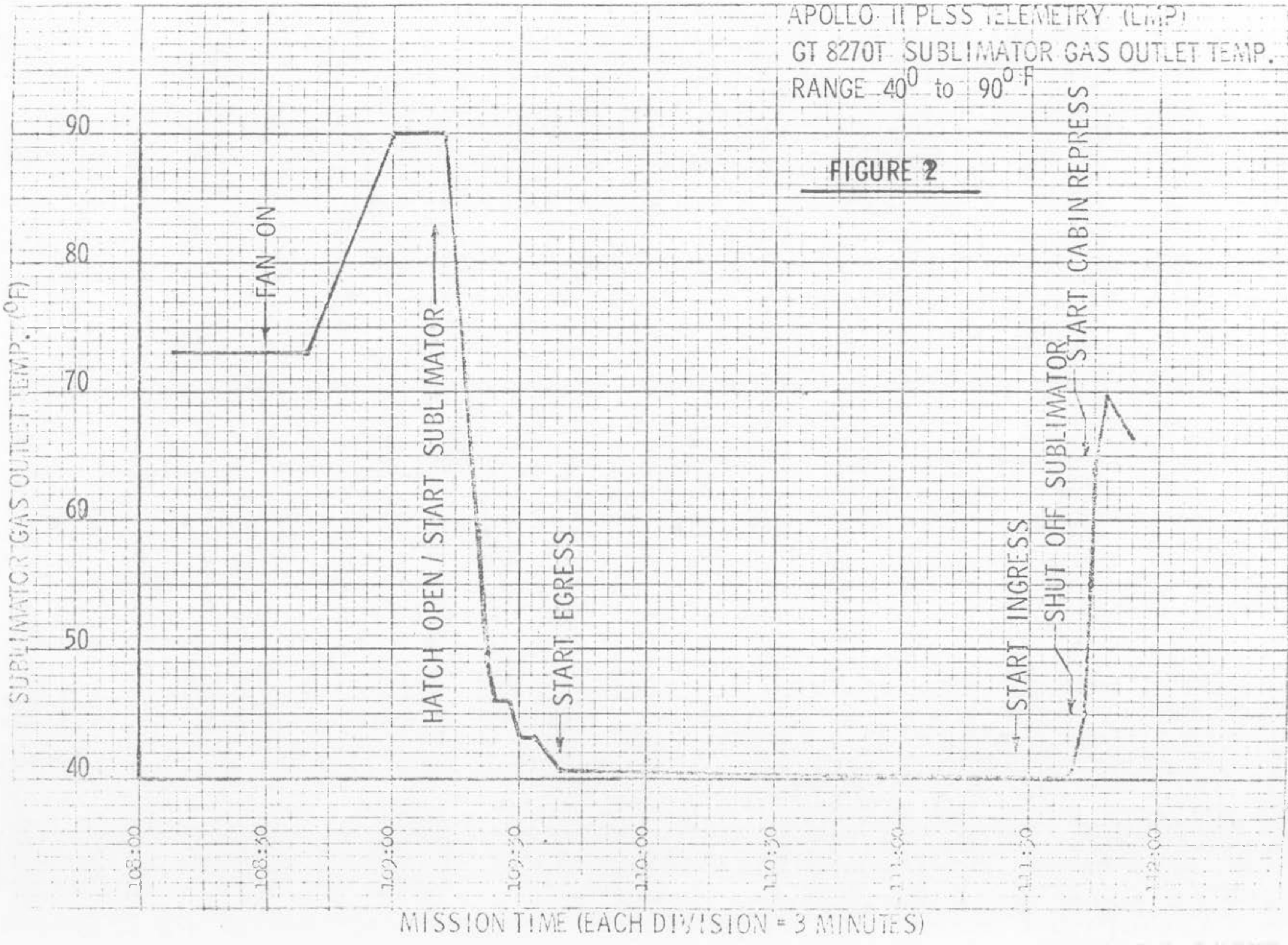
Feedwater measurement will be obtained from each PLSS after each excursion for Apollo 12 for metabolic load confirmation and projected mission planning, approved by the Apollo Program Manager August 15, 1969.

Finally, the EMU adequately provided a habitable environment for the EVA.

FTO 2. a. The EMU provided sufficient mobility, dexterity and comfort to allow the crew to egress/ingress the lunar module and perform useful work on the lunar surface.

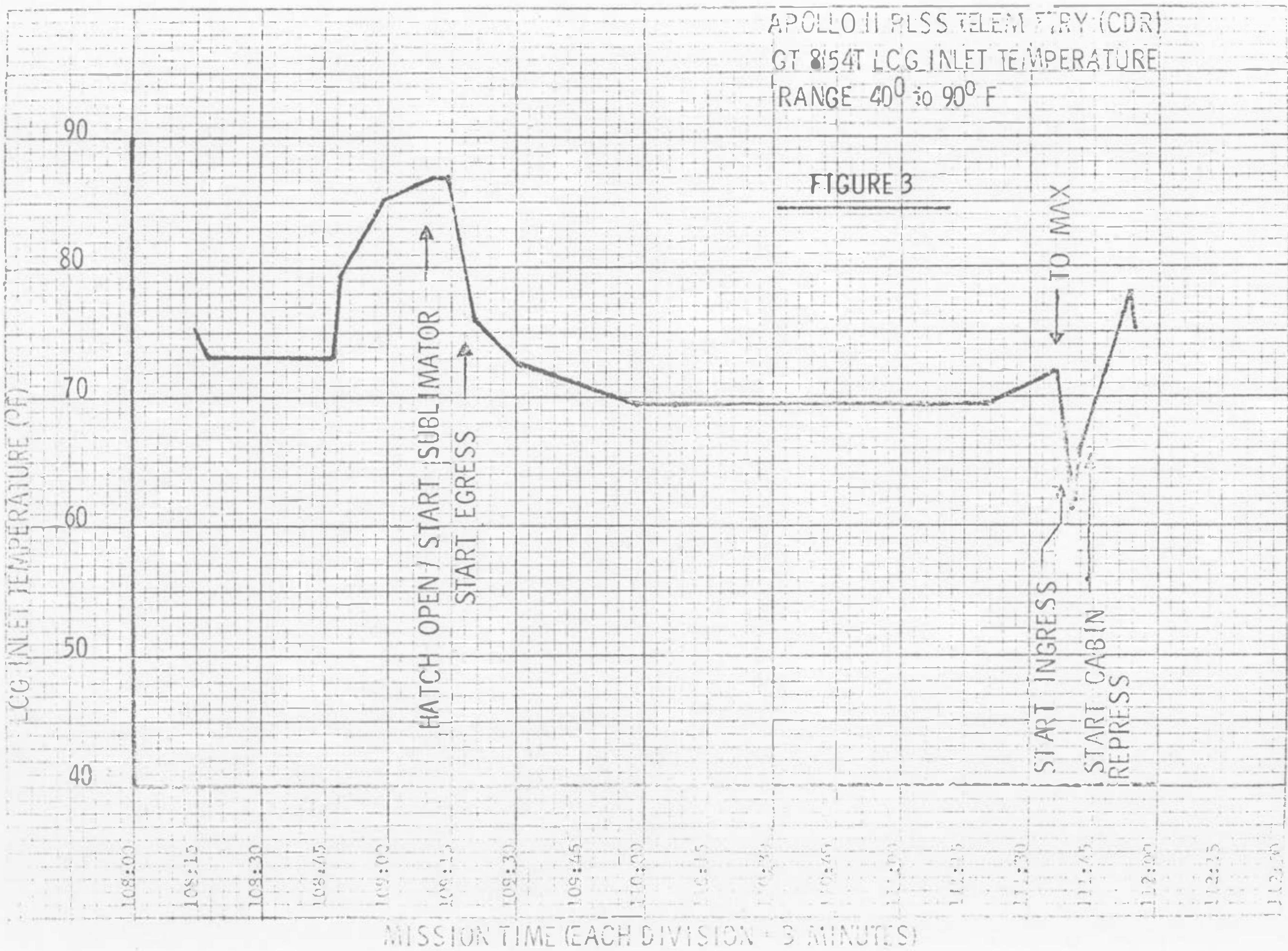
b. The commander had difficulty picking up or handling objects because of moist hands interfering with the glove bladder. The comfort gloves should be worn to absorb the moisture and reduce the slipping.

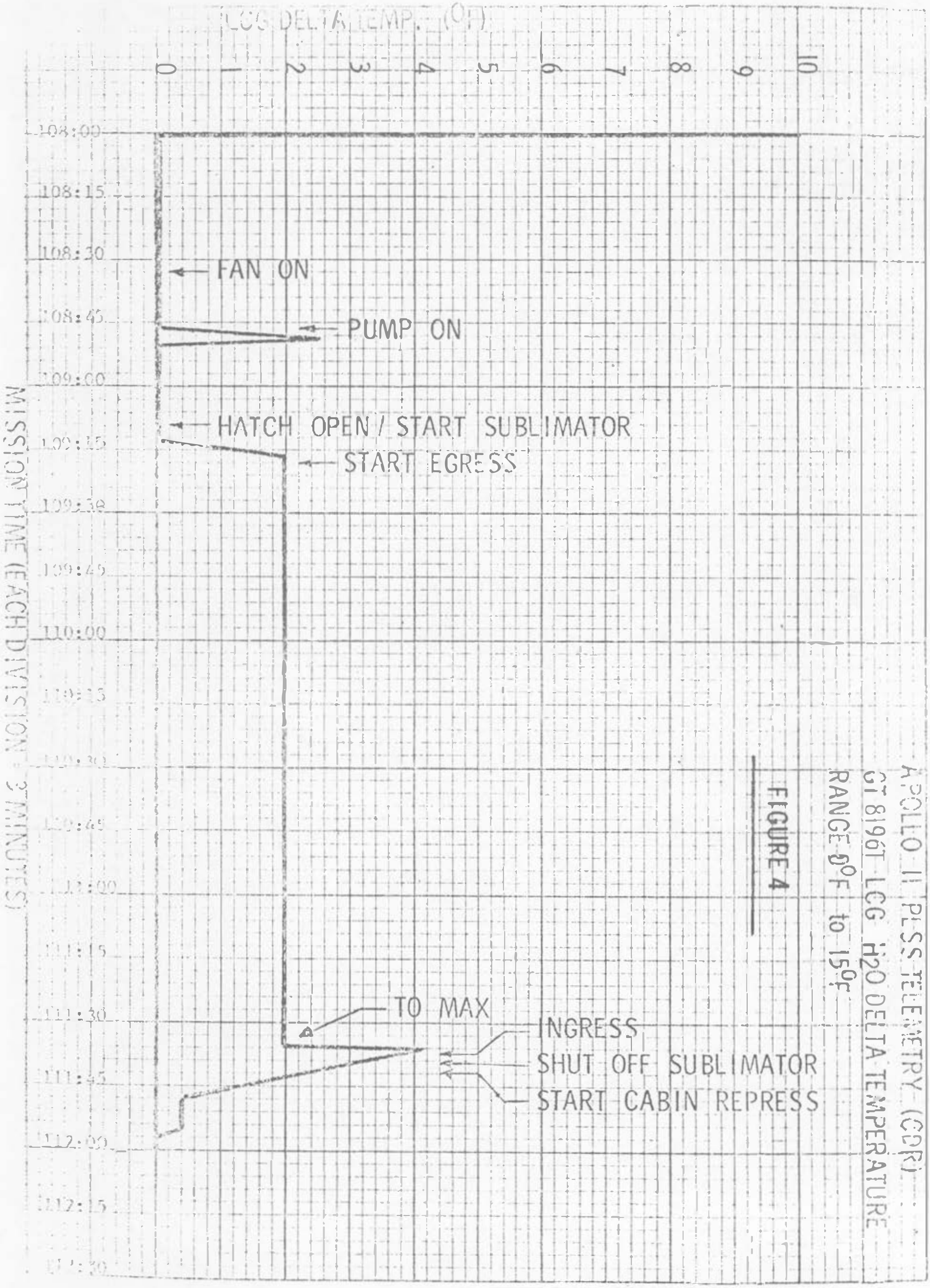

APOLLO 11 PLSS TELEMETRY (CDR)
GT 8170T SUBLIMATOR GAS OUTLET TEMP.
RANGE 40° to 90° °F
FIGURE I
SUBLIMATOR GAS OUTLET TEMP. (°F)
90
80
70
60
50
40
FAN ON
HATCH OPEN / START SUBLIMATOR
START EGRESS
START INGRESS
SHUT OFF SUBLIMATOR
START CABIN REPRESS
108:00
108:15
108:30
108:45
109:00
109:15
109:30
109:45
110:00
110:15
110:30
110:45
111:00
111:15
111:30
111:45
112:00
112:15
112:30
MISSION TIME (EACH DIVISION = 3 MINUTES)

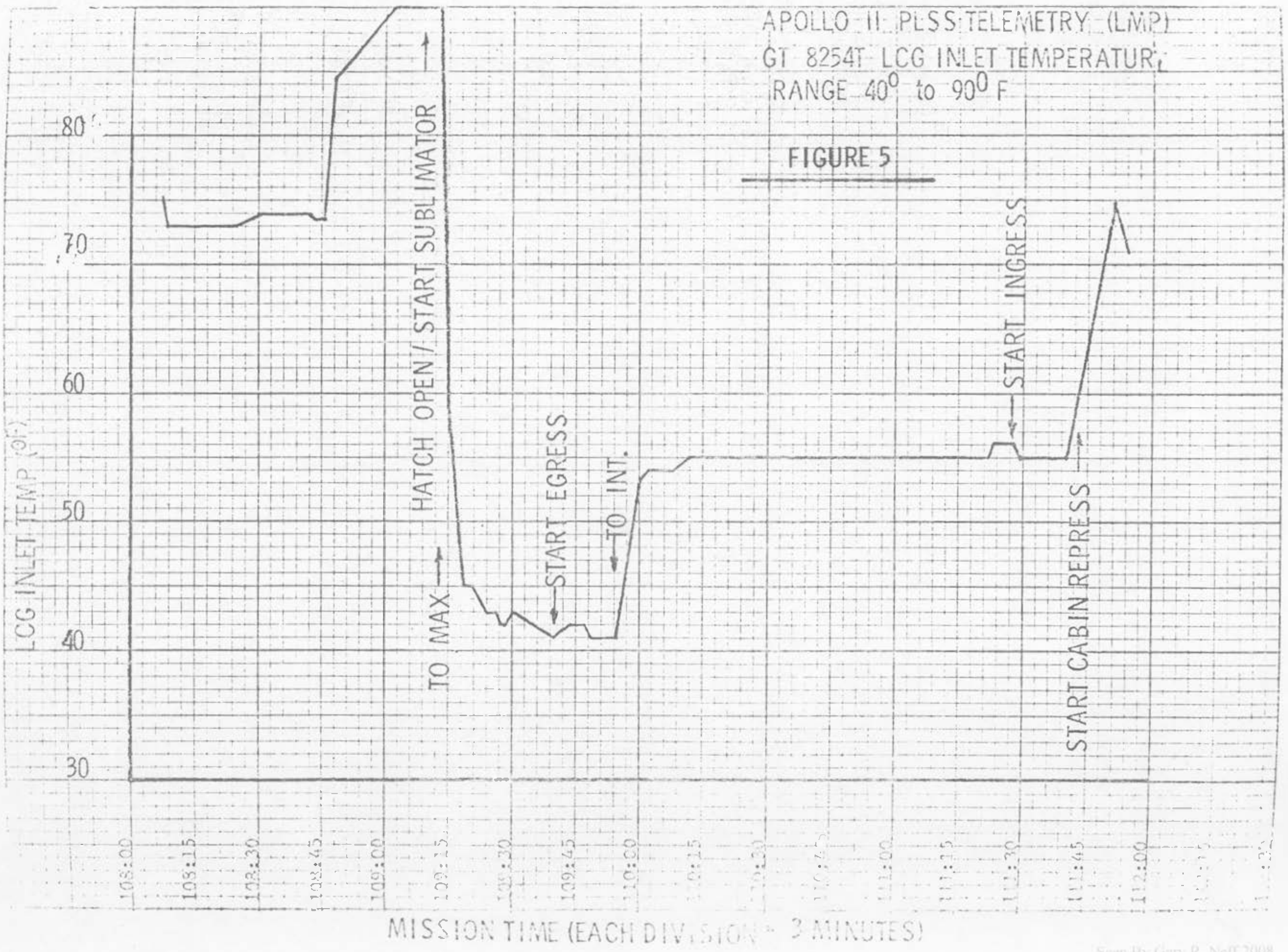

APOLLO 11 PLSS TELEMETRY (LMP)
GT 8270T SUBLIMATOR GAS OUTLET TEMP.
RANGE 40^0 to 90^0 F
FIGURE 2
SUBLIMATOR GAS OUTLET TEMP. (°F)
90
80
70
60
50
40
FAN ON
HATCH OPEN / START SUBLIMATOR
START EGRESS
START INGRESS
SHUT OFF SUBLIMATOR
START CABIN REPRESS
108:00
108:30
109:00
109:30
110:00
110:30
111:00
111:30
112:00
MISSION TIME (EACH DIVISION = 3 MINUTES)

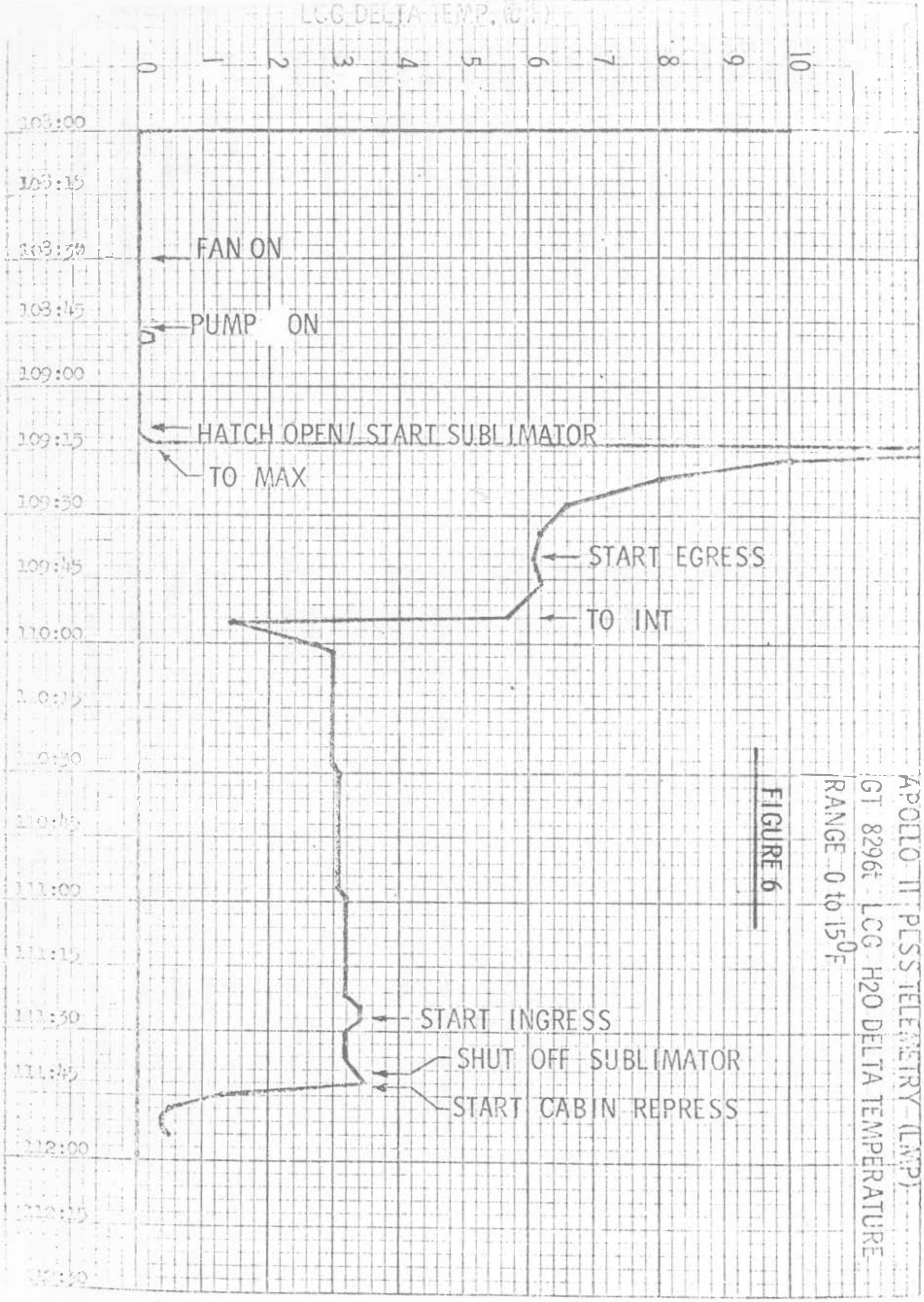
APOLLO 11 PLSS TELEMETRY (CDR)
GT 8154T LCG INLET TEMPERATURE
RANGE 40^0 to 90^0 F

FIGURE 3




APOLLO 11 PLSS TELEMETRY (CDR)
GT 8196T LCG H2O DELTA TEMPERATURE
RANGE 0°F to 15°F
FIGURE 4
LCG DELTA TEMP. (°F)
0
1
2
3
4
5
6
7
8
9
10
MISSION TIME (EACH DIVISION = 3 MINUTES)
108:00
108:15
108:30
108:45
109:00
109:15
109:30
109:45
110:00
110:15
110:30
110:45
111:00
111:15
111:30
111:45
112:00
112:15
112:30
FAN ON
PUMP ON
HATCH OPEN / START SUBLIMATOR
START EGRESS
TO MAX
INGRESS
SHUT OFF SUBLIMATOR
START CABIN REPRESS


APOLLO 11 PLSS TELEMETRY (LMP)
GT 8254T LCG INLET TEMPERATURE
RANGE 40° to 90° F
FIGURE 5
LCG INLET TEMP (°F)
30
40
50
60
70
80
HATCH OPEN / START SUBLIMATOR
TO MAX
START EGRESS
TO INT.
START INGRESS
START CABIN REPRESS
108:00
108:15
108:30
108:45
109:00
109:15
109:30
109:45
110:00
110:15
110:30
110:45
111:00
111:15
111:30
111:45
112:00
MISSION TIME (EACH DIVISION = 3 MINUTES)



APOLLO 11 PLSS TELEMETRY (LMP)
GT 8296t LCG H2O DELTA TEMPERATURE
RANGE 0 to 15°F
LCG DELTA TEMP. (°F)
0
1
2
3
4
5
6
7
8
9
10
MISSION TIME (EACH DIVISION - 3 MINUTES)
108:00
108:15
108:30
108:45
109:00
109:15
109:30
109:45
110:00
110:15
110:30
110:45
111:00
111:15
111:30
111:45
112:00
112:15
112:30
FAN ON
PUMP ON
HATCH OPEN/ START SUBLIMATOR
TO MAX
START EGRESS
TO INT
START INGRESS
SHUT OFF SUBLIMATOR
START CABIN REPRESS

FIGURE 6

EMU CONSUMABLES ANALYSIS
APOLLO 11

EXPENDABLES	COMMANDER	LUNAR MODULE PILOT
OXYGEN	2+56 Hrs - Min	2+56 Hrs - Min.
POWER	3+45	3+49
LIOH	3+18	3+21
FAN	3+18	3+21
FEED H_2O	2+30	2+31
PUMP	3+05	3+05
CONSUMABLE DATA		
OXYGEN PRESSURE INITIAL	1030 psi	1030 psi
OXYGEN USED (METABOLIC)	320	360
OXYGEN USED (SUIT PRESSURATION	120	130
OXYGEN PRESSURE REMAINING	590	540
FEEDWATER INITIAL	8.62 lbs.	8.56 lbs.
FEEDWATER USED	2.89	4.38 *
FEEDWATER REMAINING	5.73	4.18 *
POWER INITIAL	270 watt hours**	270 watt hours**
POWER USED	133	135
POWER REMAINING	137	135
METABOLIC DATA		
OXYGEN	2456 BTU 818 BTU/hr	2762 BTU 920 BTU/hr
LCG THERMAL BALANCE		
TOTAL METABOLIC	2330	3356
LiOH	590	550
POWER	336	361
TOTAL HEAT LOAD	3256 BTU	4567 BTU
METABOLIC RATE	777 BTU/hr ***	1118 BTU/hr ***

* Calculated
** Nominal Battery Charge
*** Based on approximately 3 hours of isolation on PLSS

FIGURE 7