4.0 EXTRAVEHICULAR ACTIVITY

The planned use of two vehicles for the lunar landing mission requires development of hardware and procedures for extravehicular transfer from the lunar module to the command module in the event the transfer tunnel becomes unusable. Demonstration of this capability was at one time an Apollo 9 objective, and since the hardware was the same as that for lunar surface exploration, evaluation of its operation was included in the transfer demonstration.

The planned extravehicular operation provided the opportunity to support other developmental objectives, such as photographing the exterior of both vehicles and retrieval of thermal samples. It was originally intended that the Lunar Module Pilot egress from the lunar module, transfer to the open hatch in the command module, then return to the lunar module. However, the plan was abbreviated because of a minor inflight illness experienced by the Lunar Module Pilot on the day preceding the extravehicular operation as well as concern for the crowded timeline required for rendezvous the following day.

As a result of the extravehicular activity performed during the Apollo 9 mission, the extravehicular transfer capability was demonstrated and is considered satisfactory for future missions. Further, successful operational experience with the procedures and equipment has provided additional confidence in the capability to perform successful lunar surface operations. The guidelines for planning and conduct of extravehicular activity as defined in the "Summary of Gemini Extravehicular Activity," NASA SP-149, continue to be valid.

4.1 FLIGHT PLAN

The plan called for the Lunar Module Pilot to egress, mount the 16-mm camera on the lunar module forward platform, transfer to and partially ingress the command module, retrieve thermal samples, transfer back to the lunar module, evaluate lighting aids during a dark side pass, obtain 70-mm still photography from the platform area, provide television transmission from the platform area, retrieve lunar module thermal sample, and ingress the lunar module. The entire operation was planned for 2 hours 15 minutes outside the spacecraft.

The vehicle attitude during extravehicular activity was constrained primarily by the limitation that no direct solar illumination could impinge on the command module interior through the open hatch. The lunar module had a less stringent thermal requirement in that the forward hatch could remain open up to 45 degrees for any sun position for the entire activity. The plan was to start with the command module minus Z axis pointed at the sun, pitch down 15 degrees, and roll left 80 degrees. This attitude would satisfy the command module thermal constraint and provide good lighting for command module photography.

4.2 ACTUAL TIMELINE

The Lunar Module Pilot donned and checked the extravehicular mobility unit, depressurized the lunar module, and began his egress to the forward platform at 72:59:02. Egress was completed at 73:07:00. The command module was depressurized and the side hatch opened at 73:02:00.

During the first 20 minutes, the Lunar Module Pilot and Command Module Pilot photographed each other's activities. The Command Module Pilot discovered the thermal sample was missing from the side of the command module, but at 73:26:00 he retrieved the service module thermal samples. The Lunar Module Pilot retrieved the lunar module thermal sample at 73:39:00, and 3 minutes later, began an abbreviated evaluation of translation and body-attitude-control capability using the extravehicular transfer handrails.

The Lunar Module Pilot began his ingress at 73:45:00 and completed it at 73:46:03. The command module hatch was closed and locked at 73:49:00, and the lunar module hatch was locked a minute later. Both vehicles were repressurized, and the two crewmen in the lunar module returned to the command module.

4.3 FLIGHT CREW ACTIVITIES

4.3.1 Preflight Preparation

There are specific advantages to each of the three types of crew training. These types of training are: one-g mockup training, zero-gravity training, and altitude chamber training.

The one-g mockups are high fidelity representations of the flight vehicles without operational subsystems. One-g mockup training enables a detailed review of procedures and equipment interfaces with emphasis on the operations during the preparation and post-extravehicular activity periods. One-g mockup training accomplished was: Commander, 4 exercises, 15 hours; Command Module Pilot, 7 exercises, 18.5 hours; Lunar Module Pilot, 7 exercises, 19.5 hours.

Zero-gravity training was conducted in the Water Immersion Facility and in the zero-gravity aircraft. Neutral buoyancy simulations in the Water Immersion Facility training were used for total extravehicular activity timeline evaluations. The Water Immersion Facility training accomplished was: Commander, 5 exercises, 5 hours; Command Module Pilot, 1 exercise, 1 hour; Lunar Module Pilot, 11 exercises, 12.5 hours.

Further refinement of specific tasks was accomplished in the true zero-gravity field provided by the zero-gravity aircraft. The training accomplished was: Commander, 59 parabolas; Command Module Pilot, 27 parabolas; Lunar Module Pilot, 71 parabolas. Each parabola provided about 30 seconds of zero-gravity.

Altitude chamber familiarization included testing of the portable life support system and the oxygen purge system with the Lunar Module Pilot and of the oxygen purge system with the Commander, as well as testing of the intravehicular pressure garment assembly with the Command Module Pilot. Testing for the Lunar Module Pilot and Command Module Pilot included one run each at thermal vacuum conditions. The testing for the Commander and for two additional Lunar Module Pilot chamber runs were conducted in an 8-foot altitude chamber. The Lunar Module Pilot spent a total of 9 hours, the Commander 2 hours, and the Command Module Pilot 1 hour training in the altitude chamber. First-time flight usage of equipment required additional chamber test time on the part of the Lunar Module Pilot and the Commander.

Additional information on the extravehicular mobility unit was obtained from formal briefings and informal discussions, the Apollo Operations Handbook, and briefings in support of altitude-chamber testing.

4.3.2 Procedures

The nominal extravehicular activity plan called for the Lunar Module Pilot to spend 2 hours 15 minutes outside the spacecraft during the fourth mission day. However, the minor sickness experienced by this pilot on the third day required a revised extravehicular activity plan that would accomplish only those items that had the greatest priority: donning and checkout of the extravehicular mobility units, cabin depressurization and hatch opening for both the command module and the lunar module. While the command module side hatch was open, the Command Module Pilot was to retrieve the thermal samples from the command module. The Lunar Module Pilot was not to egress but was to remain connected to the lunar module support hoses even though using the portable life support system. The condition of the Lunar Module Pilot just prior to extravehicular activity was sufficiently improved to permit further modification of the plan to more nearly approach the preflight plan (fig. 4-1). Returning entirely to the preflight timeline was considered in view of the pilot's improved condition, but was rejected in favor of terminating the activity at the end of one daylight pass to provide adequate preparation time for the next day's rendezvous activities.

After the Lunar Module Pilot donned the portable life support system and oxygen purge system and connected the extravehicular lifeline to the lunar module cabin interior, he egressed and moved to the foot restraints (fig. 4-2) on the forward platform. While restrained, he retrieved the lunar module thermal sample and performed 16-mm and 70-mm photography of the Command Module Pilot's activities and the exterior of both spacecraft.

The initial extravehicular activities by the Lunar Module Pilot were recorded by the Command Module Pilot on both 16-mm and 70-mm film (see figure 4-3). The Command Module Pilot retrieved thermal samples from the service module but the command module sample was missing. The Command Module Pilot's life support came from the spacecraft environmental control system hoses, which also served as his restraint during partial egress to retrieve the samples (fig. 4-4). The Command Module Pilot was wearing an intravehicular suit with minimal thermal insulation; however, he had participated in a thermal vacuum test of this suit and was familiar with its reaction to the space environment. The upper part of his body, down to slightly above his waist, was exposed to the extravehicular environment for about 70 percent of the hatch-open time, and he experienced no thermal extremes.

The Lunar Module Pilot conducted an evaluation of the extravehicular transfer handrails by translating along the lunar module rail to the point where the rail turned and crossed the top surface of the lunar module (fig. 4-5). Translation capability and body attitude control were both evaluated as excellent. After the handrail evaluation, the Lunar Module Pilot returned to the forward hatch and ingressed the lunar module. The hatches of both spacecraft were closed and the spacecraft were repressurized. The post-extravehicular activity procedures were conducted according to plan.

Both oxygen purge systems were checked at the start of each day of lunar module activity. A check of the Commander's oxygen purge system heater showed it to be intermittent on the day of extravehicular activity, and the unit was not operable on the rendezvous day. A discussion of this failure is contained in section 17.

4.3.3 Crew Performance

The modified extravehicular plan accomplished all the principal extravehicular test objectives; however, extravehicular transfer between the two spacecraft and various communications checks were not performed. No problems were encountered in performing any of the planned tasks.

Body control by the extravehicular crewman was excellent in the foot restraints and on the handrail. All translations, lunar module egress and ingress, and stability evaluation were performed satisfactorily with a minimum of effort. Inflight capabilities were found to be similar to that experienced during reduced gravity training. The primary difference was that some tasks were easier to perform inflight. These differences are attributed to the external perturbing forces occasionally experienced in the Water Immersion Facility and zero-gravity aircraft. Data from the extravehicular mobility unit show a very low metabolic expenditure during extravehicular activity. The extravehicular crewman's heart rate ranged from 66 to 88 beats/minute during the period outside the spacecraft. The spacecraft and crew performance during extravehicular activity was sufficiently good that the crew stated that extravehicular transfer from one spacecraft to the other would pose no problem.

4.4 EXTRAVEHICULAR MOBILITY UNIT

The extravehicular mobility unit used for Apollo 9 is described in Appendix A. The performance of the extravehicular mobility unit was nominal, and most telemetry data closely parallelled that obtained during crew training. The extravehicular mobility unit could not be evaluated under design heat loads and work-rate conditions because of time limitations on the extravehicular activity. Both the Lunar Module Pilot and the Command Module Pilot reported they were comfortable and experienced no visual problems with the extravehicular visor assembly. The Command Module Pilot wore one extravehicular glove and one intravehicular glove. The hand with the intravehicular glove became warm but was not uncomfortable. After the extravehicular activity, the portable life support system was successfully recharged with oxygen and water for possible contingency reuse.

There were three minor discrepancies in the operation of the extravehicular mobility unit. As indicated in figure 4-6, the liquid cooling garment inlet temperature did not reach equilibrium. Equilibrium of the inlet temperature was reached during ground tests under similar workload conditions. Several conditions, either separately or combined, could have caused this deficiency. The extravehicular activity was performed at a low metabolic rate; therefore, the portable life support system was operating with the diverter valve set in the minimum-cool position at the low end of the performance range. In this idling state, system performance was difficult to evaluate and normal telemetry inaccuracies preclude detection of small performance shifts. The Lunar Module Pilot had donned the liquid cooling garment on the third day and left it on for the extravehicular activity on the fourth day.

The crewman stated that the liquid cooling garment kept him cool and operated satisfactorily at all times during extravehicular activity, however, the garment was saturated with air after it was used. The cooling garment differential temperature indicated that performance of the sublimator was degraded. This is attributed to the entrapped air in the system. Previous tests indicate that air would pocket in the sublimator when the diverter valve is in the minimum position which restricts the liquid flow through the sublimator.

If the extravehicular activity had been accomplished as planned, it was anticipated that the diverter valve would be in minimum position at startup and would be moved to intermediate and then cycled to either minimum or maximum depending upon the crewman comfort. However, because the Lunar Module Pilot did work at a very low rate for the complete time, the minimum position would be expected.

The second problem concerned the portable life support system feedwater pressure transducer which normally indicates sublimator startup by a tone to the crewman and sublimator performance through telemetry. The transducer indicated a 17-percent downward shift on the third day, but on the fourth day just prior to extravehicular activity, the level had risen to a downward shift of only 8 percent. Data during the extravehicular activity, however, were normal, and no shift was evidenced.

The third discrepancy was an indicated failure of one of the two heater circuits in the oxygen purge system during checkout on the fifth day. It had been intermittent during checkout on the fourth day. The problem most likely resulted from a failed-open power switch which was cam-operated and controlled by an actuator and cable mechanism on the crewman's chest. See section 17 for further details.

A plot of performance parameters for the portable life support system is shown in figure 4-6. The oxygen supply pressure decreased from 960 to approximately 830 psia during system operation, indicating a usage of about 0.2 pound. A rate of 900 to 1000 Btu/hr was originally predicted for the extravehicular activity; however, the readjusted plan did not require the crewman to be as active as originally planned. During the 47-minute extravehicular activity, the Lunar Module Pilot produced approximately 500 Btu which indicates a rate of about 600 Btu/hr. This determination was based on heart rate, oxygen consumption, and liquid cooling garment thermodynamics. Based on a postflight analysis of the lithium hydroxide element, a total of 90.6 grams of carbon dioxide, corresponding to 1170 Btu, were produced during the 28-minute preparation time for extravehicular activity, the 47 minutes of extravehicular activity, and the 34-minute period after extravehicular activity when returning to the normal spacecraft oxygen environment. However, the 1170-Btu determination could have been compromised to some degree because the lithium hydroxide container was not sealed for the postflight return to the Manned Spacecraft Center. Figure 4-7 shows inflight oxygen usage compared with preflight predictions.

4.5 SPACECRAFT INTERFACES

The extravehicular transfer subsystem consisted of a series of handrails leading from the lunar module forward hatch to the command module side hatch. Lighting was provided by a deployable extravehicular pole lamp at the vehicle interface, the service module docking spotlight, and radioluminescent discs imbedded in the handrails (fig. 4-2). The lunar module handrail was rigid and continuous from near the forward hatch to near the docking interface. The command module handrails were rigid but discontinuous because of constraints imposed by vehicle structure. All handrails and lighting aids were adequate for the extravehicular activity. Photographs taken during flight verified proper deployment of the extravehicular pole lamp and the uppermost handrail on the command module; both were spring-loaded to deploy at escape tower jettison.

The crew reported that when the lunar module forward hatch was opened for extravehicular activity, it tended to bind on top and had to be pushed downward to be opened. Additionally, the forward hatch had a tendency to close during extravehicular activity, and the hatch friction device had no noticeable effect. See section 17 for a discussion of the hatch problems. A slight delay between closing and locking the forward hatch occurred when the Commander had difficulty in getting into position to operate the handle. Closing and locking of the command module side hatch took only 23 seconds, and this hatch operated without incident. Communications were excellent between the command module/lunar module/extravehicular crewmen and the network during most of the extravehicular activity. The communication configuration used was command module one-way relay with the portable life support system mode-select in positon 1.

A preflight analysis indicated that with the portable life support system operating inside the lunar module cabin, relay of the portable life support system data to the Manned Space Flight Network through the command module might not be possible. During the flight, however, excellent data and voice were received at the Manned Space Flight Network when the portable life support system antenna was erected inside the lunar module and also between the command module and lunar module during the extravehicular activity. Therefore, it was shown that radio frequency radiation leakage from the closed lunar module cabin to the closed command module cabin is sufficient to establish a good communication link.

A ground test of a lunar module test article (LTA-8) and the portable life support system in the anechoic chamber demonstrated that during extravehicular activity, the Lunar Module Pilot's electrocardiograph data would be degraded if the Lunar Module Pilot was within 4 feet of the antenna when the development flight instrumentation B-transmitter was operating. Examination of the flight data shows that the transmitter was on but did not degrade the electrocardiogram. The reason for the lack of interference is unknown. However, on future flights no development flight instrumentation will be installed.

The extravehicular lifeline secured the crewman to the lunar module at all times. The vehicle end of the lifeline was attached to the minus Y overhead attach point and the crewman end to the lunar module left restraint attach point on the pressure garment assembly. The lifeline was fabricated of Polybenzimidozole webbing 1-inch wide and 1/16-inch thick (fig. 4-8). Three hooks were provided, one permanently attached at each end and one positionable to any point along the 25-foot length of the tether for transfer of cameras and thermal samples. Each hook was provided with a locking-type keeper, which a crewman in a pressurized suit could easily operate. The entire assembly was designed for an ultimate tensile strength of 600 pounds and was packed in a Teflon-coated beta cloth bag that provided for orderly management of the webbing as the lifeline was deployed for use.

The thermal sample tether (fig. 4-9) was fabricated from the same material as the lifeline assembly. Two hooks were provided, one permanently attached to the end of the webbing and the other adjustable to any point along the 14-foot length of the tether. One hook was identical in design to the nonadjustable lifeline hook, and the other was a basic waist tether hook. The assembly was packed in a Teflon-coated beta cloth bag which acted as a container while the assembly was stowed and provided a means of managing the webbing during deployment and use. This tether could also have been used as an aid in closing the command module side hatch, if necessary.

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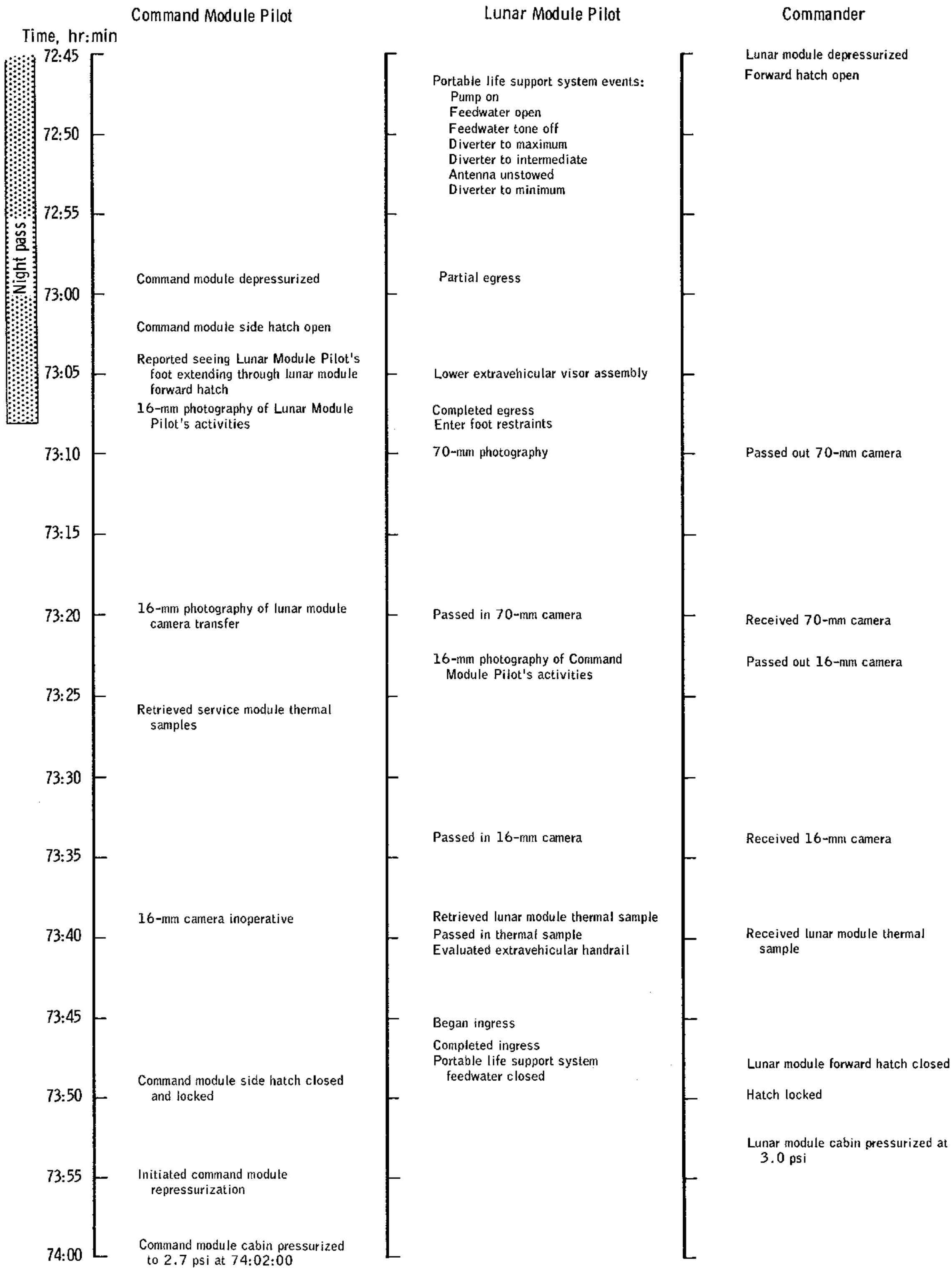

Figure 4-1. - Timeline for extravehicular activity.

NASA-S-69-1943

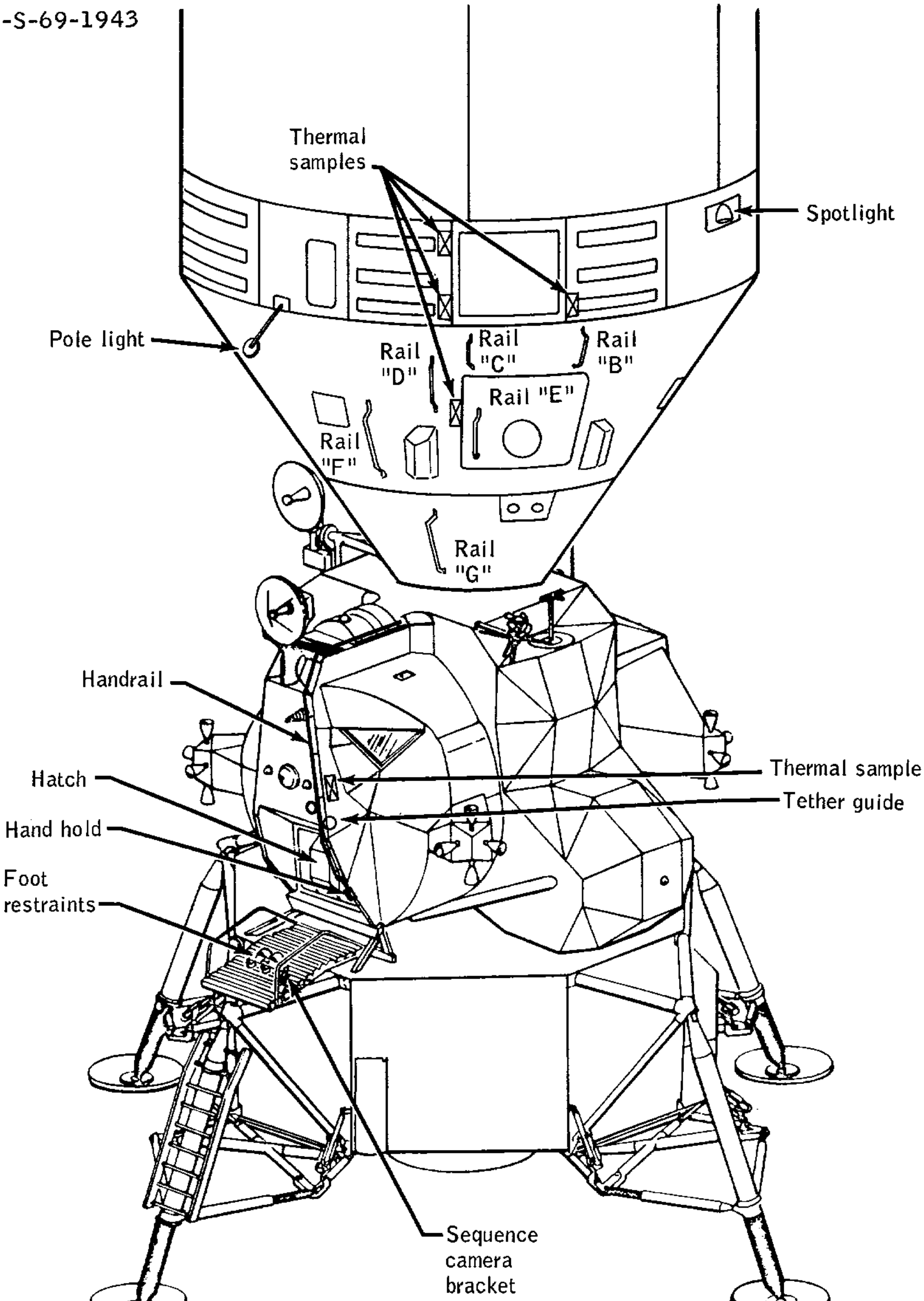

Figure 4-2.- Relative spacecraft positions and location of handrails and thermal samples.

Figure 4-3.- Lunar Module Pilot on forward platform.

NASA-S-69-1945

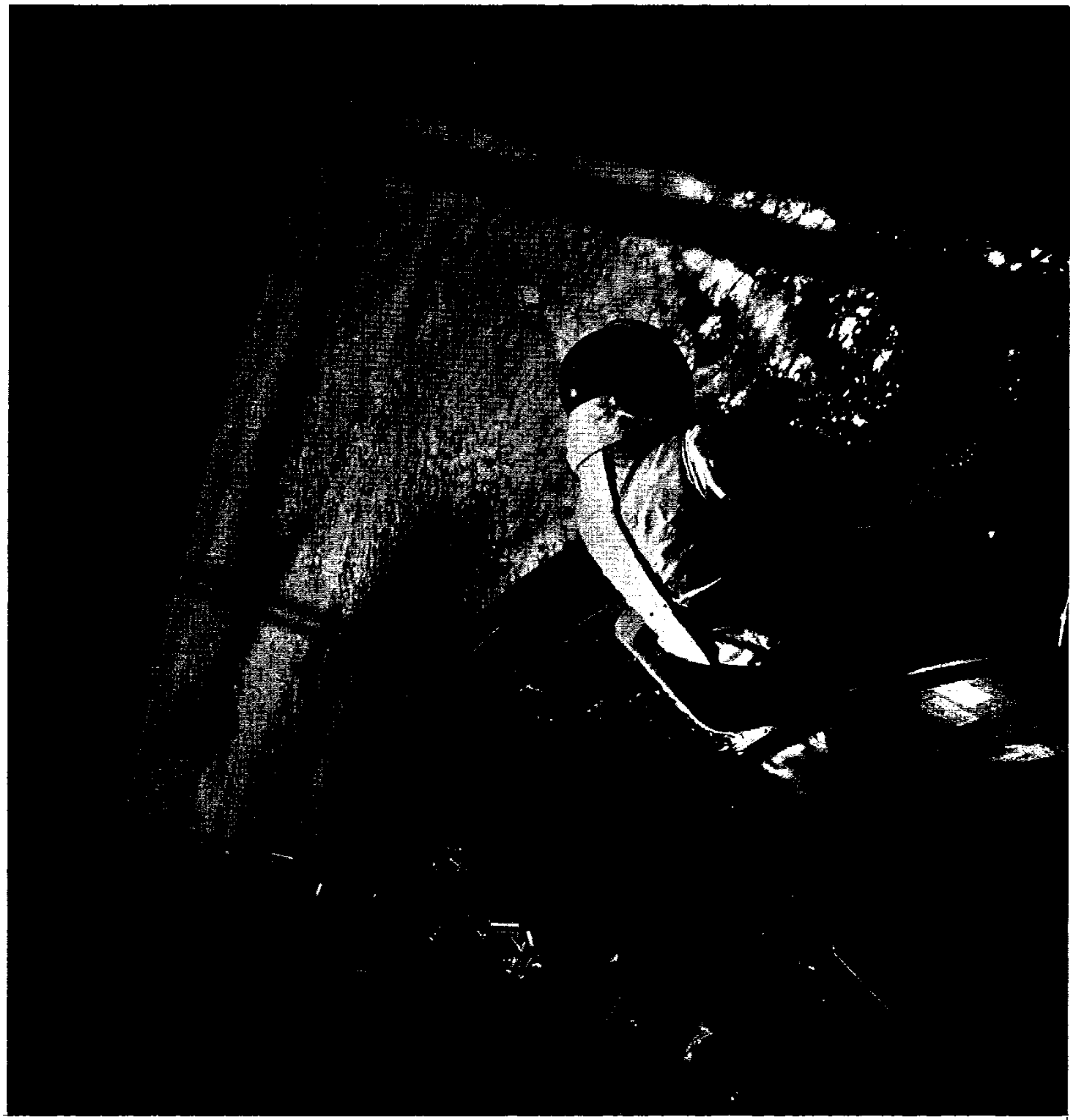

Figure 4-4.- Command Module Pilot retrieving thermal samples.

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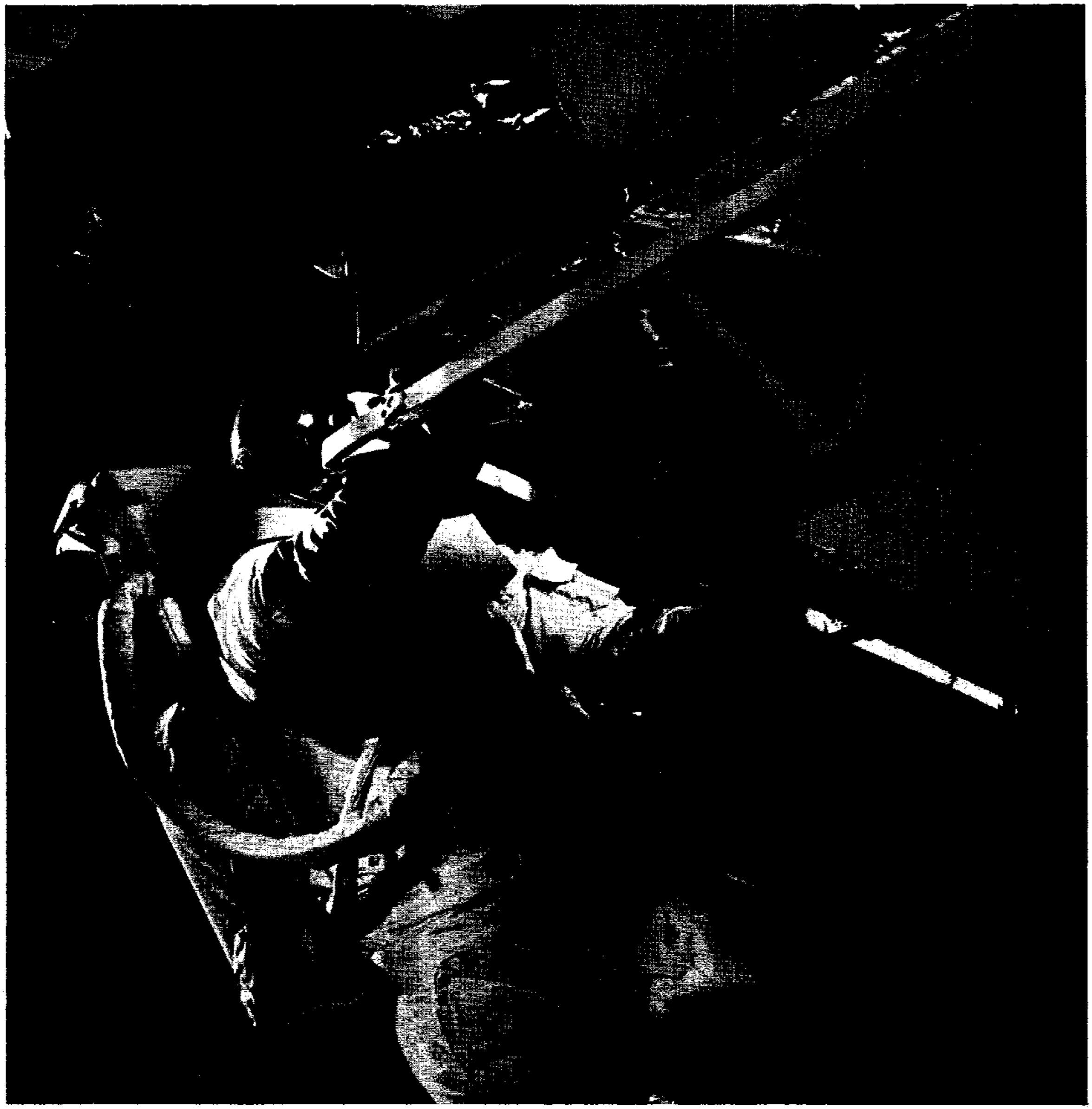

Figure 4-5.- Lunar Module Pilot evaluating handrails.

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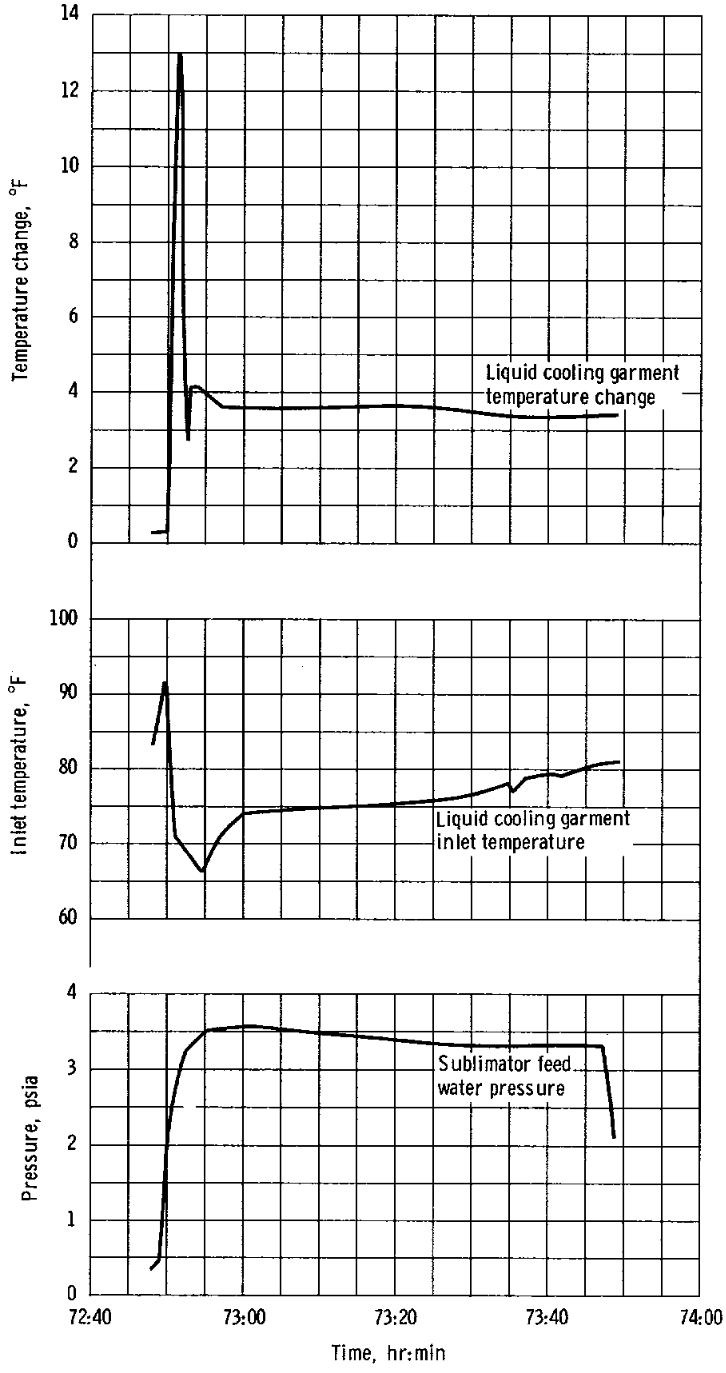

Figure 4-6. - Portable life support system operational parameters.

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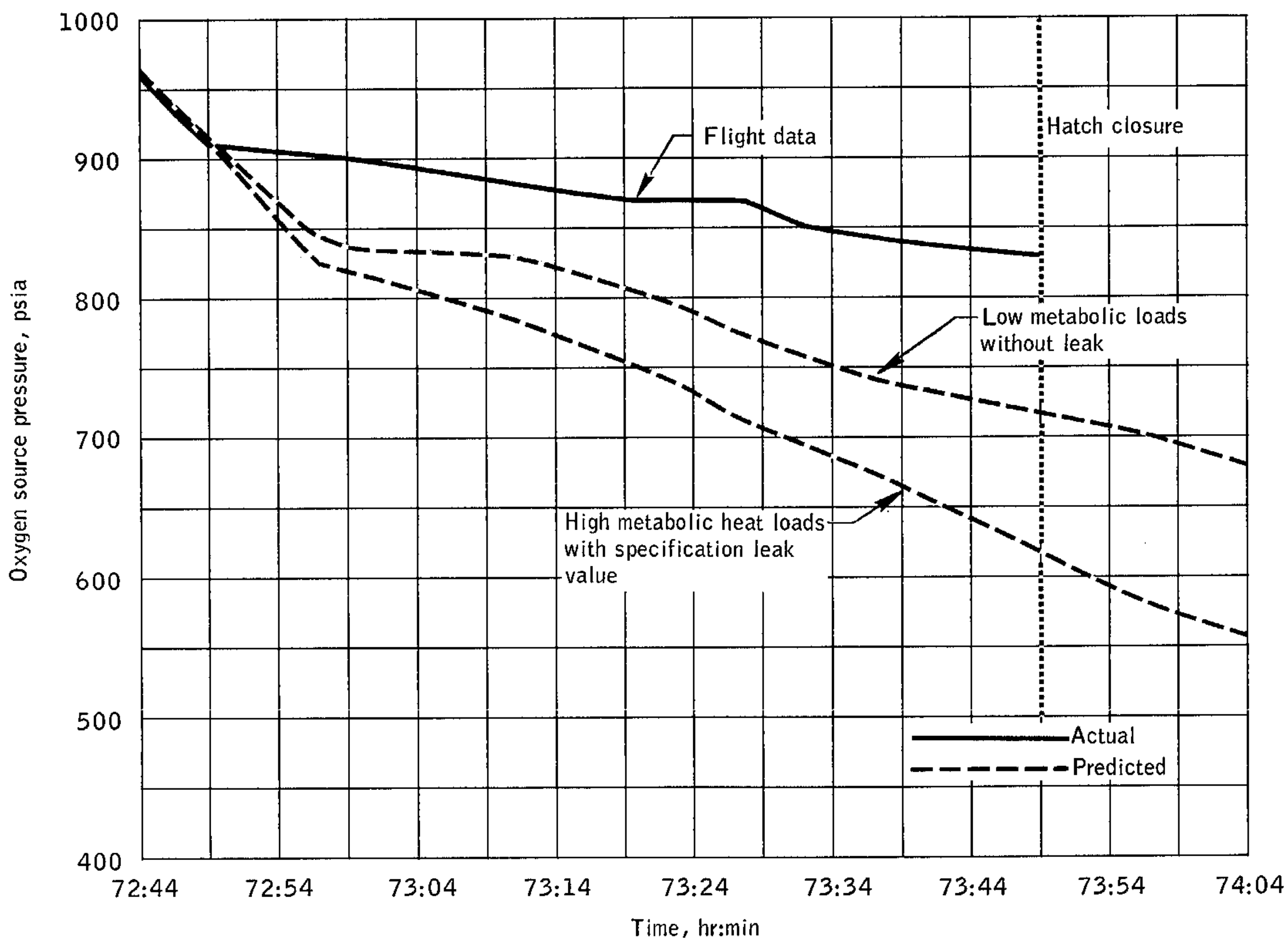

Figure 4-7.- Oxygen usage during extravehicular activity.

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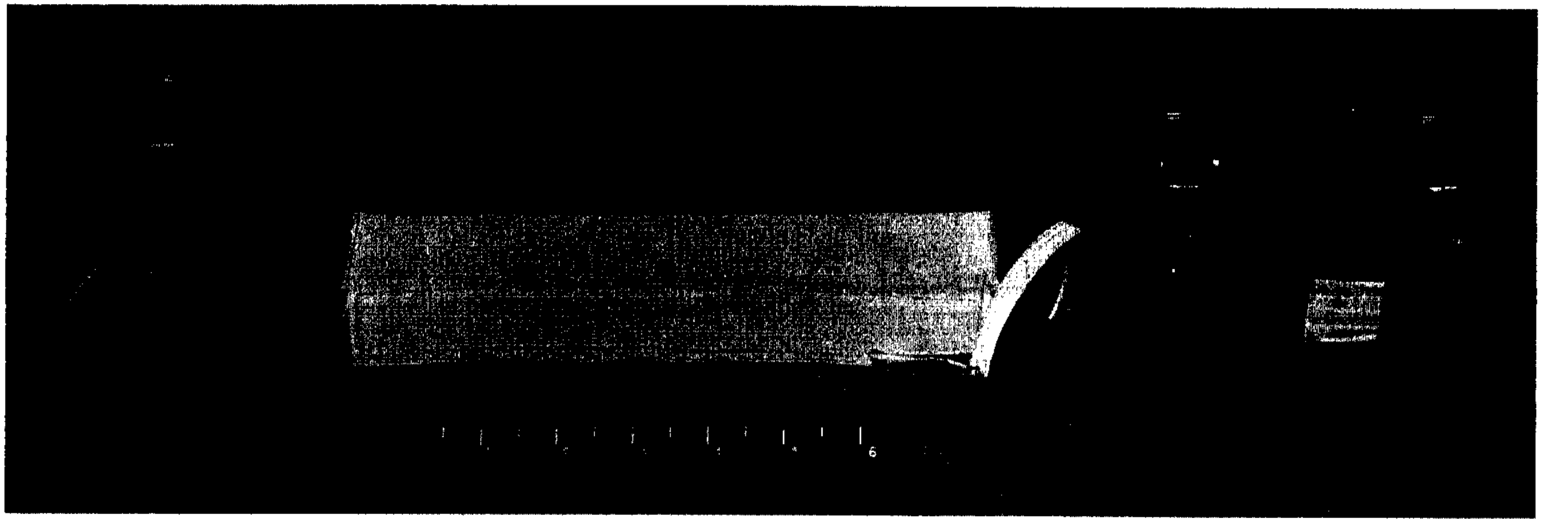

Figure 4-8.- Extravehicular lifeline.

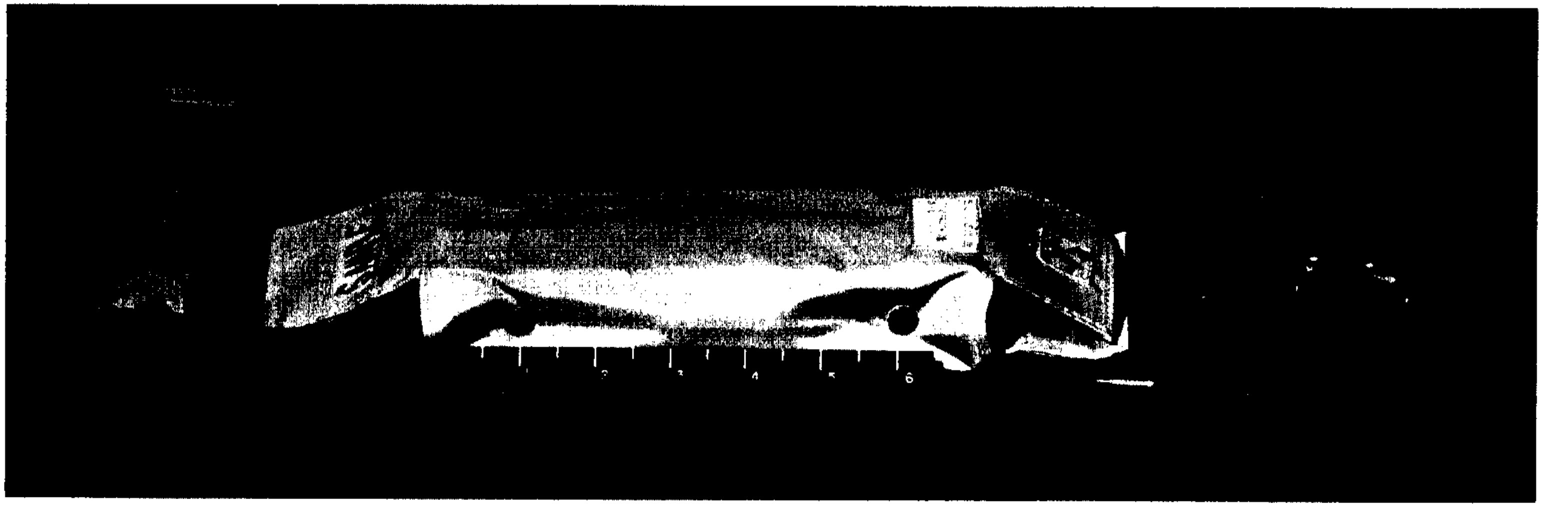

Figure 4-9.- Thermal sample tether.