PHYSIOLOGICAL MONITORING

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Physiological monitoring could be defined as the process of obtaining information on the function of various body systems while the human being responds to a particular environmental situation. Accepting this definition, I would like to limit this discussion to physiological monitoring as applied to man in the space environment and further to emphasize that I am not going to linger on a discussion of hardware involved in doing this task but will emphasize overall philosophy including the need for monitoring, what has been monitored, brief results of this monitoring, and our plans for the future.

The difficulties encountered in attempting to provide meaningful measurements of physiologic function are present in our space activities as they are in any laboratory situation. In fact, the situation encountered in the operational spaceflight program is decidedly more difficult than that encountered in the laboratory. The problem of relating the many environmental input factors acting on the astronaut with the many output factors evidencing behavior is complicated. The usual laboratory approach of isolating a particular variable, exposing the subject to that one variable and measuring the physiologic response is not possible in the operational environment. We are unable to control the many environmental variables and thus the astronaut is exposed to a number of simultaneous environmental variables or stresses. While we have very excellent selection information, and, indeed, a select group of flight crew personnel in the astronauts, they are still human beings. As such they may be described as follows: "From the engineer's standpoint the human subject is jammed full of nonlinear devices and inter-connecting subsystems with multiple feed-back loops. It also has a self-adapting programmer and tremendous information storage capability. The output from the subject is often governed by the events of hours, days, or years past."[1]

WHY DO WE PHYSIOLOGICALLY MONITOR SPACE CREWS?

In assessing why we are physiologically monitoring men in a space environment, it might be well to review the medical objectives of the Manned Spaceflight Program. They could be simply stated as follows: To provide medical support for man, enabling him to fly safely in order to answer the following questions:

(1) How long can man be exposed to the spaceflight

environment without producing significant physiologic or performance detriment?

(2) What is the cause of changes which are observed?

(3) Are preventive measures or treatment needed, and, if so, what is best?

In order to attain these objectives and answer the questions listed, we find it necessary to conduct physiological monitoring for flight safety purposes, and for research purposes. In the area of flight safety, the astronaut is considered as a complex of body subsystems which are integrated into a single major subsystem in the spacecraft...the human. The monitoring of this most important group of systems, if we are to look at man in an engineering context, is necessary to evaluate his status as to possible deterioration of function and effective operation; provide information to assist in real time decision making concerning the accomplishment of the various flight plan activities for the mission itself or altering the course of this activity in order to increase the chances of accomplishing the mission objectives. This type of monitoring is of ever greater importance as we give more control to the man in these complex vehicles. Our attitude is strongly influenced by the fact that man is not capable of determining his own capacity to continue. Numerous examples of the lack of ability to recognize and heed warning signs of fatigue when one is highly task-oriented, of the effects of hypoxia, carbon dioxide, etc., have been seen in aircraft flight experience and are no less applicable to the spaceflight experience. It is obvious that the physical and mental status of the crewmen is a strong determinate in the ground control's ability to rely on other reported data and actions.

The procurement of data from physiologic monitoring for research purposes is necessary to allow us to predict the effect of extended duration flight upon man. Actual inflight experience is vital for we still lack high fidelity simulation producing the same effects as those seen from the flight experience. It is hoped that the collection of information will document man's reactions to what is admittedly a complex environment and assist us in determining the methods that the body is using to maintain homeostasis. It should be remembered that prior to the launching of the first man into orbit, many competent investigators felt that there was a question about his survival in such an environment. While we have seen from Project Gemini that he can obviously survive and perform for 14 days it must be emphasized that our data points are few in number and due to the large amount of human variability, there is need to document a great deal of data to add confidence to our predictions. Such data are also necessary for application to future design concepts for advanced programs. There have been questions raised on occasion concerning the obtaining of data on animals versus obtaining it on man. It is my feeling that man provides us the most directly applicable data and that his use can thus be most economical in giving us the data in the minimum number of flights and in the minimum time. We have chosen the method of doubling man's exposure as a safe method of projecting the flight program and we must document it with data.

PHYSIOLOGIC MONITORING IN THE MANNED SPACEFLIGHT PROGRAM TO DATE

In asking ourselves the question how do we monitor man in the spaceflight situation, the first decision to be made is what to monitor. Almost every measurable physiological parameter has been considered at one time or another. There are several parameters which were selected and have been utilized in both the Mercury and Gemini Program. These represent a compromise between the simplest system which could provide some means of recognition of viability only and some of the complex laboratory type data collection systems which have been used to good effect for cross-referencing of physiological parameters.[2] Every group concerned with a system aboard the spacecraft, whether it be machine or man, has demands for varying amounts of data. There is strong competition for the telemetry channels which are available but obviously are limited and operational compromises must be made. Some requirements concerning instrumentation to be used inflight have been established as follows:

(1) Usefulness of the measurement in the flight program.

(2) Demonstrated reliability of the measurement in simulated flight conditions.

(3) Adequate background of biological validation of the measurement and the accumulation of data under various conditions allowing reference interpretation of the spaceflight data.

(4) The measurements should present no hazard to crew performance and in so far as possible should be noninterfering to crew comfort.

(5) The procurement of data should be virtually automatic, requiring little or no action on the part of the crewmen.

The physiologic outputs which have been monitored during Mercury and Gemini are shown in Table 1.

In addition to the physiologic outputs noted, we have used voice as a most important monitoring parameter and on one occasion, MA-9, we had an opportunity to use inflight television for some very limited monitoring experience. There are certain physiologic outputs, such as urine and feces which assist in assessing the status of the crew in a postflight analysis situation but they are obviously not monitored as the organism is responding to the environmental situation. They are of no real-time value. Film of onboard and extravehicular EVA operations falls in the same category in that it is extremely helpful in postflight analysis, but offers no real-time monitoring capability. For comparison, the physiologic parameters monitored by the Russians may be seen by referring to Table 2. It will be noted that they have utilized a number of parameters which we might call experimental, such as seisma- and vibro-cardiograms.

The details of the bioinstrumentation utilized in Project Mercury[4-8] have been previously described. The Mercury biosensor harness is shown in Figure 1. The Gemini biosensor harness is shown in Figure 2. This system has been arranged in such a way that the outputs from the biosensor harness are carried to an onboard biomedical tape recorder (Figure 3) for postflight analysis and simultaneously to the telemetry system allowing the data to be monitored in real time as the spacecraft is over a station. The configuration of the network is such that the real-time station coverage varies between 12 and 52 minutes per revolution depending upon the particular orbital path. The Gemini network and Mission Control Center arrangement has allowed us to receive real-time data whenever the spacecraft is over any station except the two ships. Data from the ships may be received immediately postpass at the Control Center via tape replay and thus the entire range can be monitored from a central point. This simplifies the use of the physiological monitoring for real-time decision making at a central location.

In order to interpret properly the physiologic data obtained by monitoring techniques, it is necessary to have a compendium of control or base line data on the given crewmen in as many situations analogous to the actual flight conditions as possible. This requirement will discussed in greater detail in the extra-vehicular activity areas.

RESULTS OF PHYSIOLOGICAL MONITORING

In general the quality of all the data received during both programs has been excellent. There have been occasional minor technical problems, but these have all been handled without any real compromise in the monitoring capability. We have been very gratified by the performance of our sensors through a

14-day flight. Electrocardiograph sensors were replaced by the crewmen inflight during the 14-day mission. Excellent data were received in both instances after the sensors were replaced.

We might comment upon what has been learned through the various types of monitoring of body systems utilized thus far. Detailed reports of the effects of spaceflight on the body appear elsewhere.[9] The central nervous system has been generally monitored only by observing the performance of the astronauts in the duties which they were assigned. The successful conduct of these missions and the many evidences of precise performance accomplished in the face of various flight difficulties attest to the excellent function of this system. Voice was certainly an invaluable aid in determination of this performance. The postflight evaluation of inflight film was also helpful. The EEG was utilized in one instance and a total of 54 hours and 43 minutes of interpretable EEG data were obtained. These were used to evaluate depth of sleep during the first portion of the 14-day mission.

The respiratory system has been monitored through the use of the impedance pneumograph which principally gives rate information.

Some idea of depth may also be obtained by careful monitoring. The respiratory responses have been appropriate to the various activities in which the crew has been engaged and it will be noted that we have had some markedly elevated respiratory rates during some of the hard work of extravehicular activity.

The cardiovascular system has been monitored by the use of two leads of electrocardiogram and blood pressure. Phonocardiogram has been recorded on board for postflight analysis. We have observed some interesting peak heart rates at the time of launch and reentry and normal physiologic responses to workloads induced during flight. The blood pressure responses have been perfectly normal and as expected even during the special provisions made for obtaining them just prior to and following the reentry sequence on the 4- and 8-day flights. The phonocardiographic data through the 14-day flights has shown no evidence of electromechanical delay and the variations in electromechanical systole have been related directly to heart rate changes. Information concerning the excretory and endocrine systems has been obtained only for postflight analysis.

Metabolic information has been obtained during our preflight base-line runs, but not inflight other than body temperature.

EXTRAVEHICULAR ACTIVITY (EVA)

In our initial planning for extravehicular activity (EVA), it was realized that the EVA astronaut would be placed in a position where for the first time his suit was no longer a backup but his prime method of protection. We expected that there would be a certain amount of emotional response to this activity outside the spacecraft and that we should approach the experience cautiously with the crewman performing actions slowly and deliberately. Again, we faced the problem of what to monitor during this activity. The umbilical which was to be used had a limited number of channels of data which could be returned to the spacecraft for transmission to the ground. It was decided that the minimum amount of biological data should be the sternal lead of the electrocardiogram (which would also give us heart rate, respiration rate, and voice). The GT-4 was planned to occur during a stateside pass where we would have total real-time data coverage. The astronaut would thus egress and reenter the spacecraft while being constantly monitored. Astronaut White was to evaluate extravehicular activity by means of slow and deliberate movements allowing himself to roll or tumble slowly as the situation directed. He also evaluated a hand-held maneuvering unit for a brief period and was able to move about by pulling on the tether. The physiologic data obtained may be seen in Figure 4. The heart rates varying between 140 and 160 with what was minimal directed activity caused us some concern as we planned for future extravehicular activity.

The duration of the next step precluded continuous real-time telemetry coverage and some more responsibility was placed on the command pilot for monitoring the physiologic state of the pilot during his extravehicular excursion. He always has a responsibility, but this lack of station coverage meant that he would have no help from the ground in discharging this responsibility. The only data available to him was the respiration rate as determined over the voice loop and the voice responses themselves. The training experiences were extremely valuable in allowing the command pilot to become familiar with the work responses of the pilot as he conducted the programmed tasks in a hard suit, either in an altitude chamber or in spacecraft mockups. The EVA experience on Gemini 8 was not obtained due to the development of a thruster problem which caused abort of the mission prior to the EVA. In our preparation for GT-9 we were faced with another problem in that the astronaut maneuvering unit (AMU) which was to be stored in the adapter section and donned by the pilot, had no capability for the transmission of real-time biomedical data. The one lead of ECG and respiration were telemetered to the spacecraft and recorded onboard but could not be transmitted to the ground. This placed a requirement on us as monitors to obtain the necessary data to evaluate the physiologic state of the crewman for a "GO" decision prior to his donning the AMU. The astronaut command pilot/pilot team on this flight did a superb job in handling their monitoring responsibilities and the problems encountered. The umbilical EVA experience was aborted due to the development of a visor fogging which resulted from excessive heat loads in the suit-chest pack combination. The activity and resulting heart rates which produced this heat load may be seen in Figure 5. We concluded that the work involved in maintaining body position to do the tasks assigned had produced excessive heat and resulted in overwhelming the heat removal capability of the extravehicular life support system, (ELSS). Tests had shown it was capable of handling 2000 BTU/hr. with peaks to 3000 BTU/hr. for short periods. The Gemini 10 umbilical EVA produced only moderate increases in heart rate and what we felt to be work loads. It was a reassuring experience following that of Gemini 9.

In preparing for Gemini 11 a good deal of training was done on the ground in a 1-G suited condition particularly aimed at the task of connecting a tether from the spacecraft to the Agena. This task required removal of a clamp and its positioning on an upright rod in order to hold the tether in place. Details of this task may be seen in the film. Numerous zero-G flights were made in the aircraft to also practice this task. Astronaut Gordon found that he could accomplish the task within a 30- to 40-second parabola when he managed to position himself properly on the nose of the spacecraft and had both hands free to accomplish the task. Chamber runs of the flight plan, EVA timelines were also done and monitored preflight.

A Bicycle ergometry test was done to maximum exercise capacity during the immediate preflight period. This test gave us some idea of the crewman's capability of work performance and the status of his cardiovascular and respiratory systems. The carbon dioxide and oxygen samples obtained at intervals during the run also allowed us to plot a curve of BTU's output versus heart rate in a laboratory situation. An example of this plot for the pilot on Gemini 11 is shown in Figure 6. Some increase in heat load within the suit due to early preparation for EVA and the use of the ELSS in a 5 psi cabin where the water boiler would not operate, and the work load created immediately prior to EVA by the attempts to attach the extravehicular visor combined with the initial activity of attempting to attach the tether caused an early abort of this umbilical EVA due to astronaut fatigue. The heart rates observed during this experience may be seen in Figure 7 and our postflight analysis would indicate that the inability of the astronaut to secure himself in such a way that he could perform the task with both hands as he had done in training, produced work loads of the order of 3400 BTU's per hour lasting up to 10 minutes and resulted in the fatigue noted. There were also extremely high respiratory rates and it was our feeling that our problem involved basic laws of physics concerning action and reaction and the need to stop an action once begun as the source of the difficulty in trying to maintain a body position in order to accomplish a specific task. These difficulties were enhanced by the work load produced by moving against a 3.5 to 3.7 psi suit, some increased heat load within the suit system and an indeterminate increase in carbon dioxide level in the helmet. The intense task orientation of the extravehicular crewmen on our missions has led us to believe that the emotional response has been at a low level in relation to the other factors active in producing increased heart and respiratory rates.

In preparing for Gemini 12 it was decided that we must provide the crewman adequate tie down by various means, such as waist tethers and foot restraints, hand holds, etc. and some method of getting to the task where he could be tethered and then utilize both hands in its accomplishment. While we were aware that both suit temperature and CO_2 level within the helmet were of importance in the production of the results noted, no additional physiologic monitoring parameters could be obtained within the flight schedule time frames. Instead, it was decided that the tasks to be done would be outlined in such a way that man could be carefully evaluated based upon a series of preflight tests which would be monitored from a physiologic point of view and this information then applied to the real-time situation. Table 3 summarizes the number of these tests which were conducted. Again, it will be noted that bicycle ergometry was performed pre- and postflight and the results may be seen in Figure 8. In addition, an exercise consisting of moving the arms against the 3.5 to 3.7 psi suit and touching the helmet once every second for 60 times was performed both preflight and four times inflight. The purpose of this exercise was to give us some general idea of the importance of the other factors, such as heat load, CO_2, and emotional response in producing the heart rates observed during the actual extravehicular activity. We had prepared plots of heart rate versus BTU's expended per hour and in attempting to apply these to the actual inflight situation realized that there are many unknowns involved. The arm exercise was an additional attempt to get some quantitation of this difference. Figure 9 illustrates the heart rate and BTU response to the arm exercises conducted preflight and inflight. It can be seen that there is little difference between the preflight and the inflight determinations. The GT-12 umbilical EVA heart rates actually observed are shown in Figure 10. Underwater tests had provided an excellent time line of the projected EVA activity which would allow us to follow the inflight activity very closely. In addition the heart and respiration rates obtained during all of these activities preflight were graphed and available to use for comparison during real-time monitoring. We had tried to integrate these data and determine a heart rate which could be utilized as a warning and another higher rate which could be an indicator to stop the activity in which the astronauts was engaged and rest. The figures which we used worked very well in this particular mission and we were surprised by the closeness with which the inflight heart rates followed those observed in the underwater simulation. Some interesting physiologic data were obtained preflight concerning the respiratory response of the pilot. He could increase his heart rate to 140 by the work involved and still maintain a respiratory rate of 20. He had, however, doubled his ventilation within this time period and this made respiratory rate a very unreliable method of monitoring for the command pilot. The results of the extravehicular activity are beautifully shown in the inflight film. Our total EVA experience in hours is summarized in Table 4, and we feel that the flight results have shown that if man is provided a means to reach the task, fixation at the task, and proper flight planning of the activity, he can work very well in the extravehicular environment.

PROJECT APOLLO MONITORING

In a paper on the application of our experience to Apollo planning some two years ago at an AIAA session,[10] the requirements for physiologic monitoring in Apollo were outlined. At this point in time it is interesting to review our status. In the Block I spacecraft we will have three channels of biomedical telemetry available. On the command pilot these will consist of two leads of ECG and respiration. On the senior pilot and pilot they will consist of one lead of ECG, respiration and phonocardiogram. The biomedical data will be obtained on only one astronaut at a time and this is controlled through a switching function aboard the spacecraft. A problem in identification of the biomedical data arose due to switching technique. Since data on a particular astronaut is not being commended from the ground, an onboard switch is necessary to select the source. An interim fix for the first Block I mission has involved a switching of the signal conditioners for the phonocardiogram and the electrocardiogram, thus positively identifying two of the crewmen. The Command Pilot is identified by the presence of the 2 ECG's. A permanent solution to this problem is under consideration and involves the use of a coder to be placed on one of the EKG signal conditioners. In addition to the physiologic parameters to be monitored, we will have a medical kit consisting of a thermometer, a blood pressure cuff, and a stethescope available. The astronauts will record the body temperature and pass it to the ground by voice. They will also utilize the blood pressure cuff and stethescope in the standard manner ordinarily used in the doctor's office and pass this information to the ground. The biosensor equipment is shown in Figure 11 and the onboard instruments for use by the crew in obtaining medical data are shown in Figure 12. We are continually evaluating our equipment in the hopes of making it easier to wear and easier to apply and we certainly anticipate the donning and doffing of this equipment in the Apollo flights. A word should be said about the blood pressure determination as used in the Block I spacecraft. In the paper previously mentioned it was stated that we had requested a method of blood pressure determination which would not involve the wearing of a cuff and the most likely method seemed to be finger plethysmography. Our biomedical engineers have been unable to obtain a satisfactory system which will give us accurate diastolic readings and therefore we have regressed in our blood pressure systems from Mercury to Gemini to Apollo as shown in Figure 13. Work must continue in the development of an adequate blood pressure system.

In the Block II spacecraft there will be two channels of biomedical telemetry and in all three crewmen they will consist of the sternal lead of the ECG and respiration. Our stated requirement for data on the extravehicular astronaut on the lunar surface has been one lead of ECG and voice. We maintain this position in current operational studies which are underway to determine the feasibility of a 2-astronaut lunar surface operation. While it is frequently necessary to develop compromises and operational tradeoffs, this can never be done by compromising the ultimate safety of the crewmen, nor can it preclude the obtaining of historical information vital to answering the question, "What happened?"

In addition to the procurement of the physiologic information, there must be an adequate method for its real-time use and its processing for future use. There are a number of modifications which we have programmed for the Mission Control Center for Apollo flights which will aid us in this regard. These modifications will provide for computer processing of digitized biomedical data to allow real-time computation of heart rate data for mean, maximum, minimum, standard variation, and variance, and will provide a summary format of each pass.

CONCLUSIONS

It has been possible to monitor space crew physiological parameter in orbital flight without undue interference with crew performance and comfort. In most instances the crew has not been aware of the presence of sensors as they perform their duties. Collection of data on crew status each A.M. and P.M. has included blood pressure and sleep, water and food reporting. The physiological information available has been adequate and timely enough to allow decision making on crew physiologic capability during various mission phases. It has also provided data for evaluating the effects of flight on various body systems and planning future missions.

EVA has been effectively monitored from a safety standpoint, but information concerning temperature and carbon dioxide levels would be valuable in assessing the cause of heart and respiratory rate increases.

Efforts should be continually directed at eliminating the need for a biomedical umbilical and for easily donned and doffed sensors as well as a blood pressure method which does not require the wearing of a cuff. Long duration flights in the orbital workshop and other Apollo applications missions will require such developments if we are to obtain the wealth of medical information possible on such missions.

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Apollo 7 11 Oct 68 Schirra *
Eisele
Cunningham
260:09:45

Apollo 8 21 Dec 68 Borman *
Lovell *
Anders
147:00:11

22 men flown 18 missions for 32 man exposures. The totaling of
— hours of manned spaceflight. See Table.

6 6
10 20
2 6
32

24 × 4 = 96
24 × 7 = 168; + 22 = 190
24 × 13 = 72 / 312; 24; 18 = 330
24 × 3 = 72; 22 = 94
24 × 2 = 48; 22 = 70
48 + 23 = 71

40710:56
3
1261:30

1 astro in 1-2 + 3 man s/c.
2 " in 1 + 2 man s/c.
2 " in 2 + 3 man s/c.
4 " flown twice in 2 man s/c.

Details of findings by systems - all programs to date.

Hazards mentioned early   Table : Predicted - actual.

Oslo paper.. -

TABLE 1 — PHYSIOLOGIC PARAMETERS MONITORED DURING MERCURY AND GEMINI

Data Retrieval System	Parameters	Instrumentation
MERCURY		
Telemetry	ECG, sternal lead	Bipolar electrodes
	ECG, axillary lead	Bipolar electrodes
	Blood pressure	Automatically inflated cuff, microphone pickup of Korotkow sounds.
	Body temperature	Rectal thermistor (changed to oral thermistor for MA9)
	Respiratory rate	Heated wire bridge replaced by impedance pneumograph on MA8 and MA9
GEMINI		
Telemetry	ECG, sternal lead	Bipolar electrodes
	ECG, axillary lead	Bipolar electrodes
	Blood pressure	Manually inflated cuff, microphone pickup of Korotkow sounds
	Body temperature	Oral thermistor
	Respiratory rate	Impedance pneumograph
On-Board Recorder	EEG, 2 leads[1]	Electrodes cemented to scalp
	Phonocardiogram[2]	Parasternal microphone

1. Gemini VII, Command Pilot
2. Gemini IV, V, VII, Pilot

add APOLLO —

TABLE 2

Physiologic Parameters	Spaceship						
	Vostok 1	Vostok 2	Vostok 3	Vostok 4	Vostok 5	Vostok 6	Voskhod
Electrocardiogram with MX, DS Leads	+	−	−	−	−	−	−
Seismocardiogram	+	+	+	+	+	+	+
Kinetocardiogram	−	+	−	−	−	−	−
Pulse Rate	+	+	+	+	+	+	+
Pulse Rate and Respiratory Rate	−	−	−	−	−	−	+
Pneumogram	+	+	+	+	+	+	+
Electroencephalogram	−	−	+	+	+	+	+
Electrooculogram	−	−	+	+	+	+	+
Galvanic Skin Reaction	−	−	+	+	+	+	−
Dynamogram	−	−	−	−	−	−	+
Motor Coordination	−	−	−	−	−	−	+

TABLE 3

SOURCES OF PREFLIGHT PHYSIOLOGICAL DATA

GEMINI XII PILOT

Treadmill

Centrifuge

Spacecraft Altitude Chamber Test - McDonnell

Altitude Chamber Checkout of EVA Equipment - MSC

Underwater Zero-G Simulations

EVA Walk-Throughs

Bicycle Ergometry

Simultaneous Launch Demonstration

Simulated Flight

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TABLE IV

GEMINI EVA TIME

	STANDUP		UMBILICAL	
	HRS	MIN	HRS	MIN
GEMINI IV				23
GEMINI IXA			2	08
GEMINI X		49 04		38
GEMINI XI	2	11 03		36
GEMINI XII	2	29 59	2	09
TOTAL EVA TIME: 12:29				

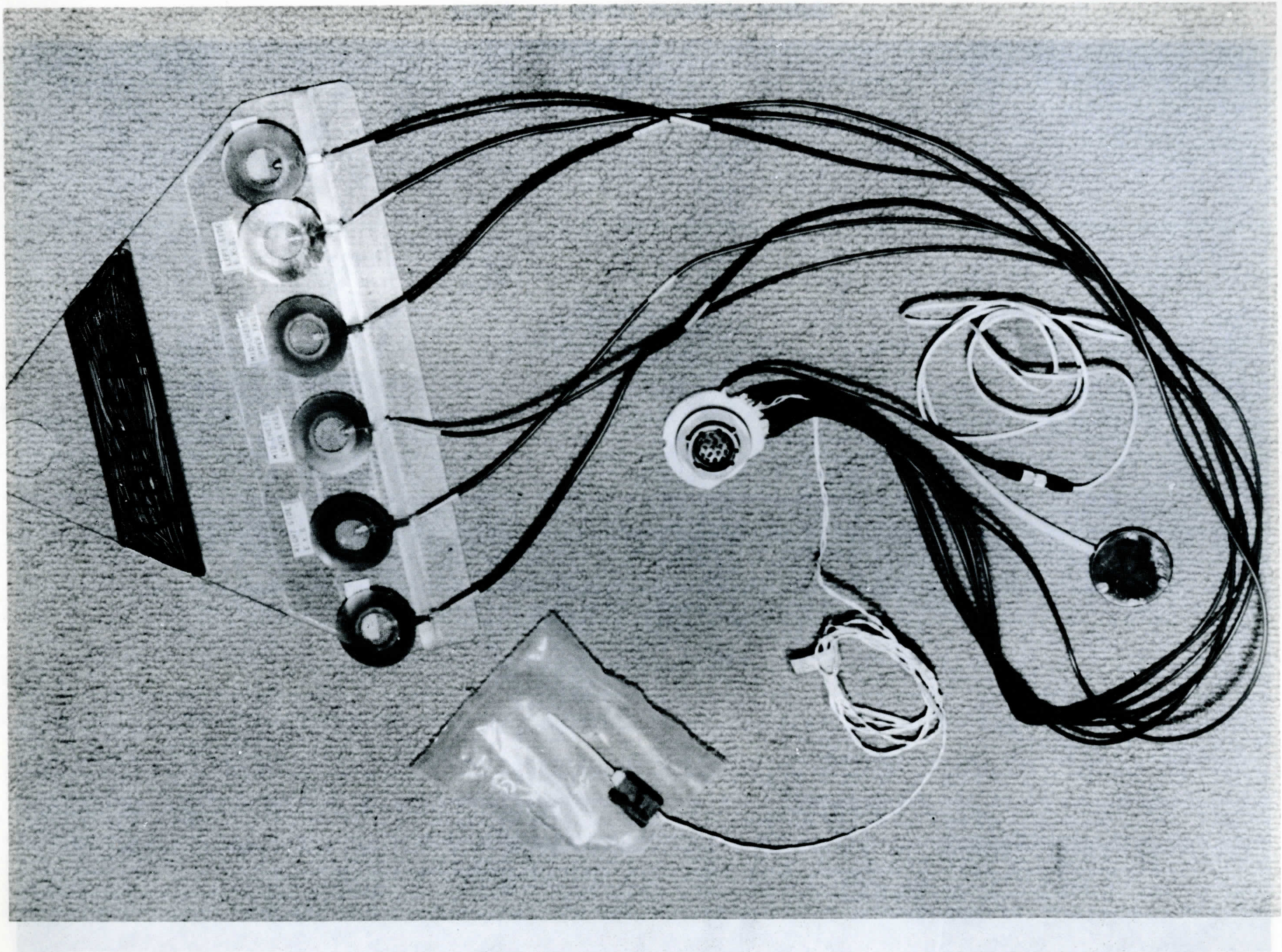

FIGURE 1.- MERCURY BIOSENSOR HARNESS

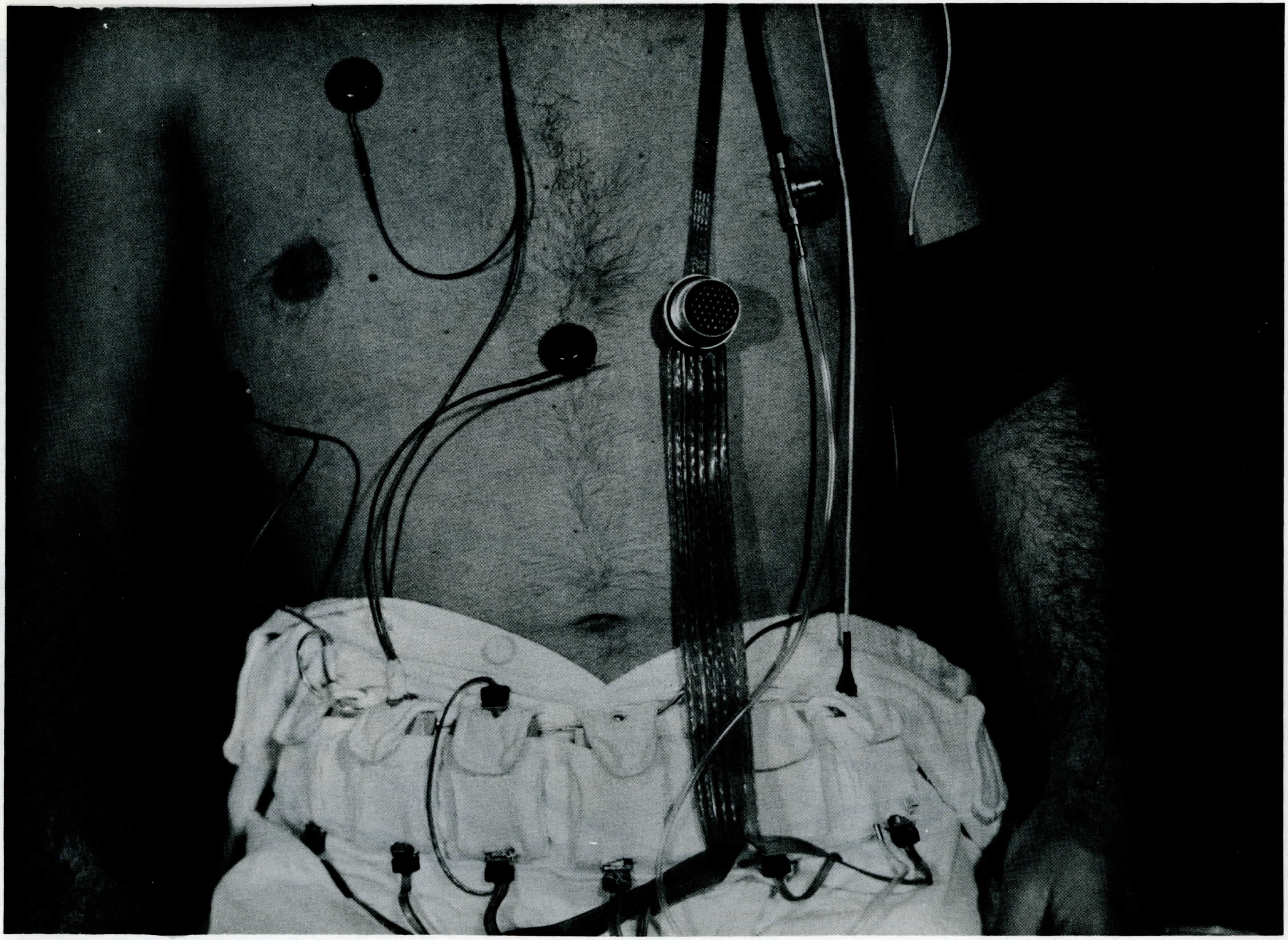

FIGURE 2.- GEMINI BIOSENSOR HARNESS

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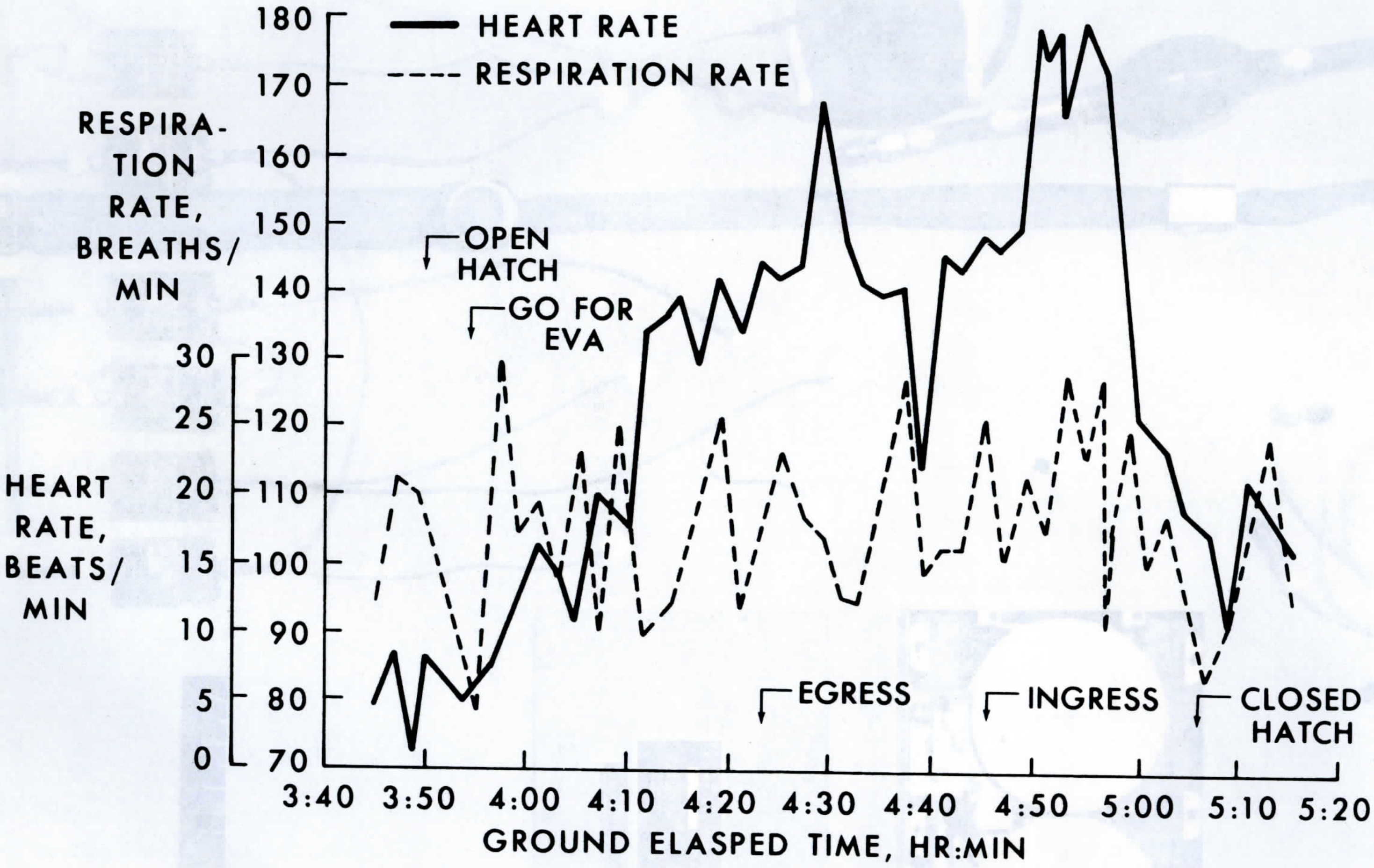

FIGURE 4.- GEMINI IV UMBILICAL EVA

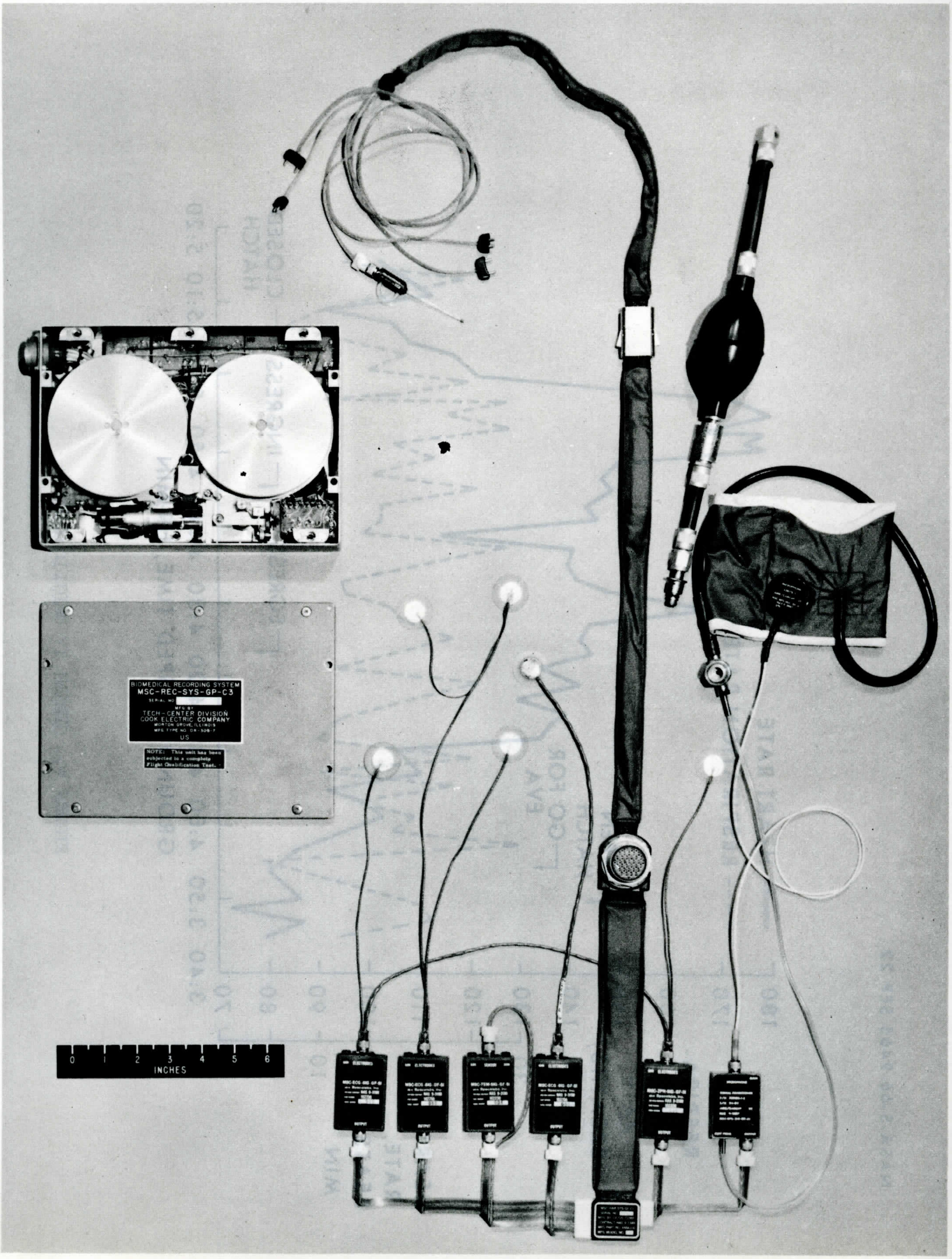

FIGURE 3.- GEMINI HARNESS AND BIOMEDICAL TAPE RECORDER.

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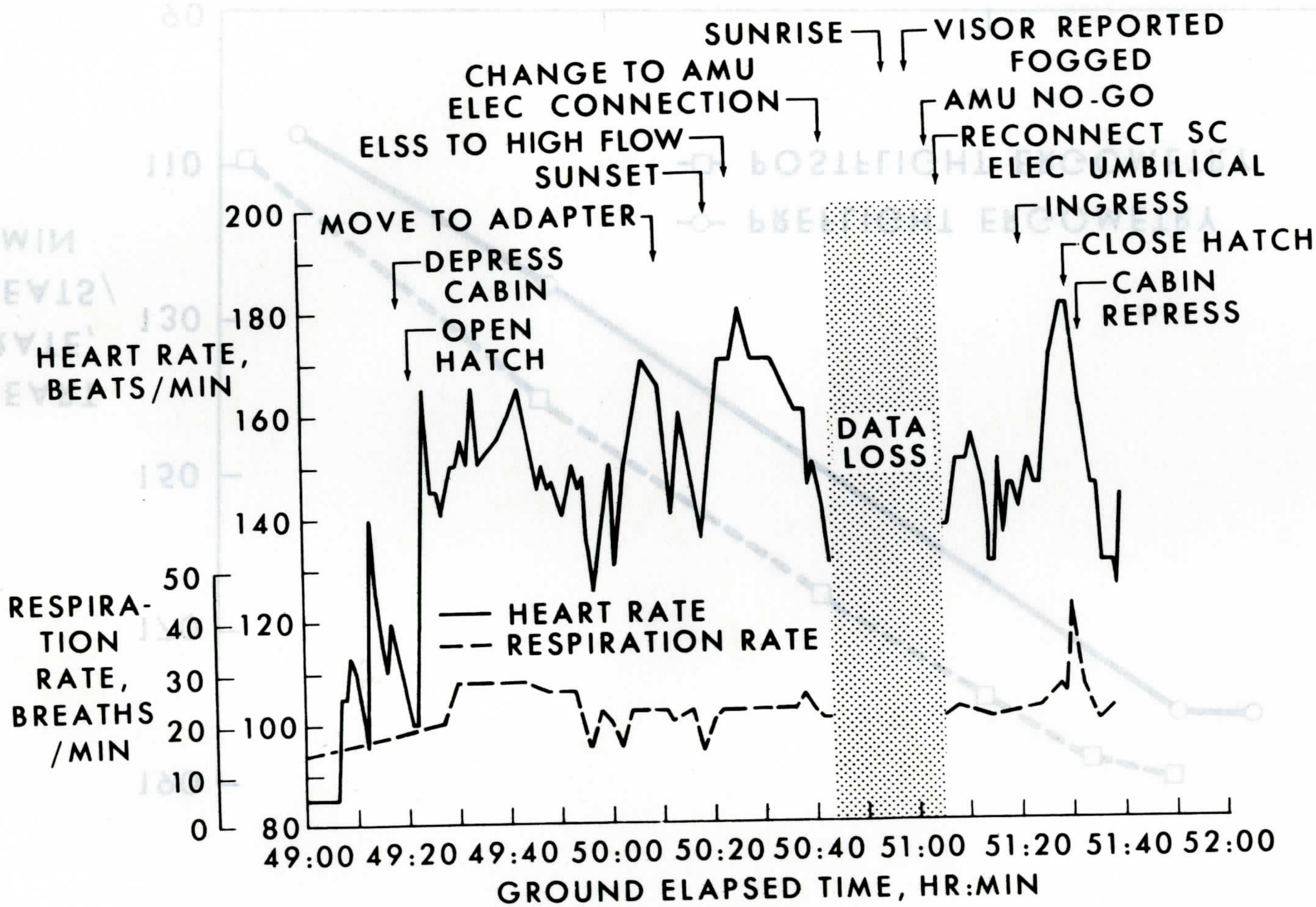

FIGURE 5.- GEMINI IXA PHYSIOLOGICAL DATA DURING EVA

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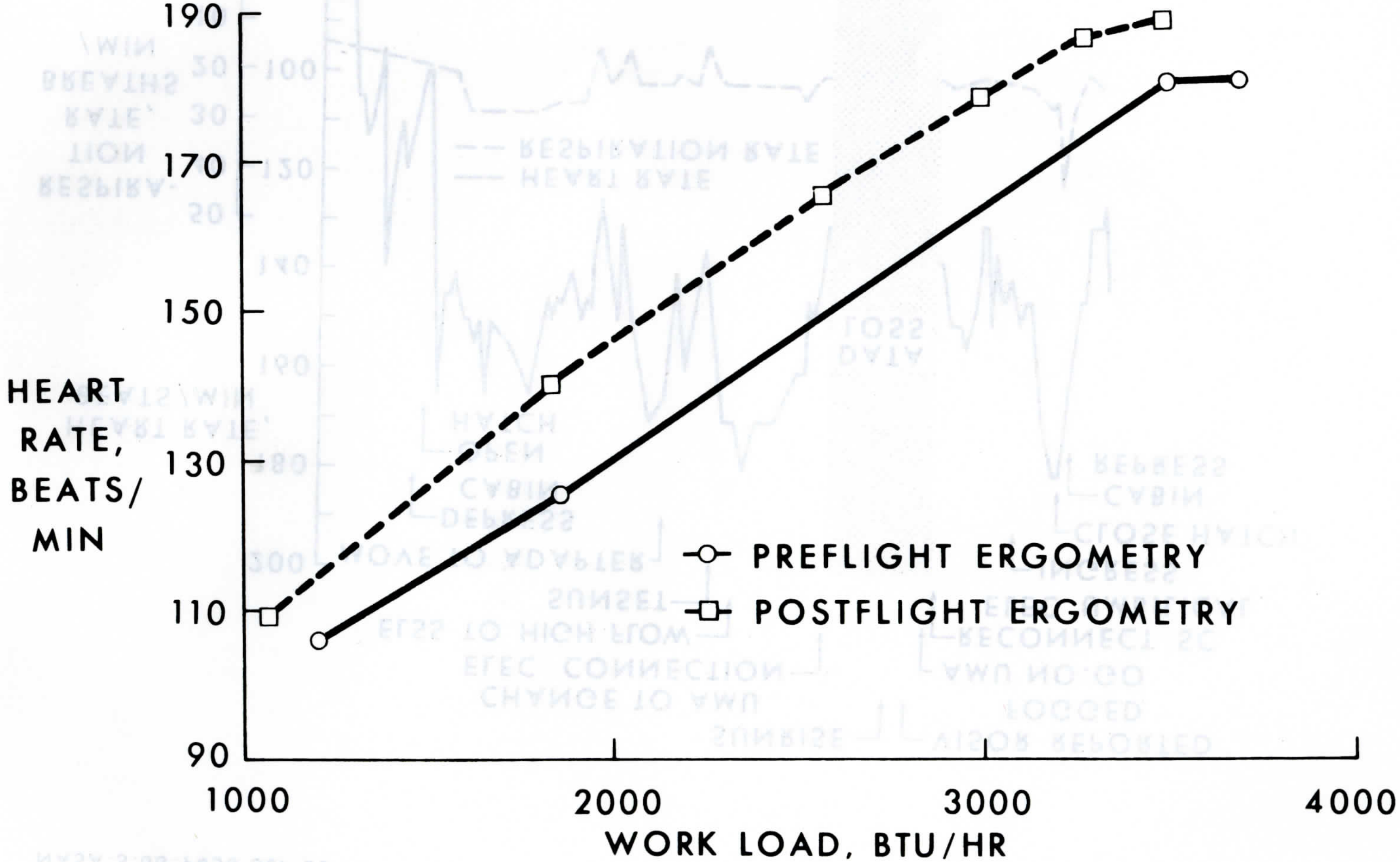

FIGURE 6.- EXERCISE STUDIES ON THE GEMINI XI PILOT

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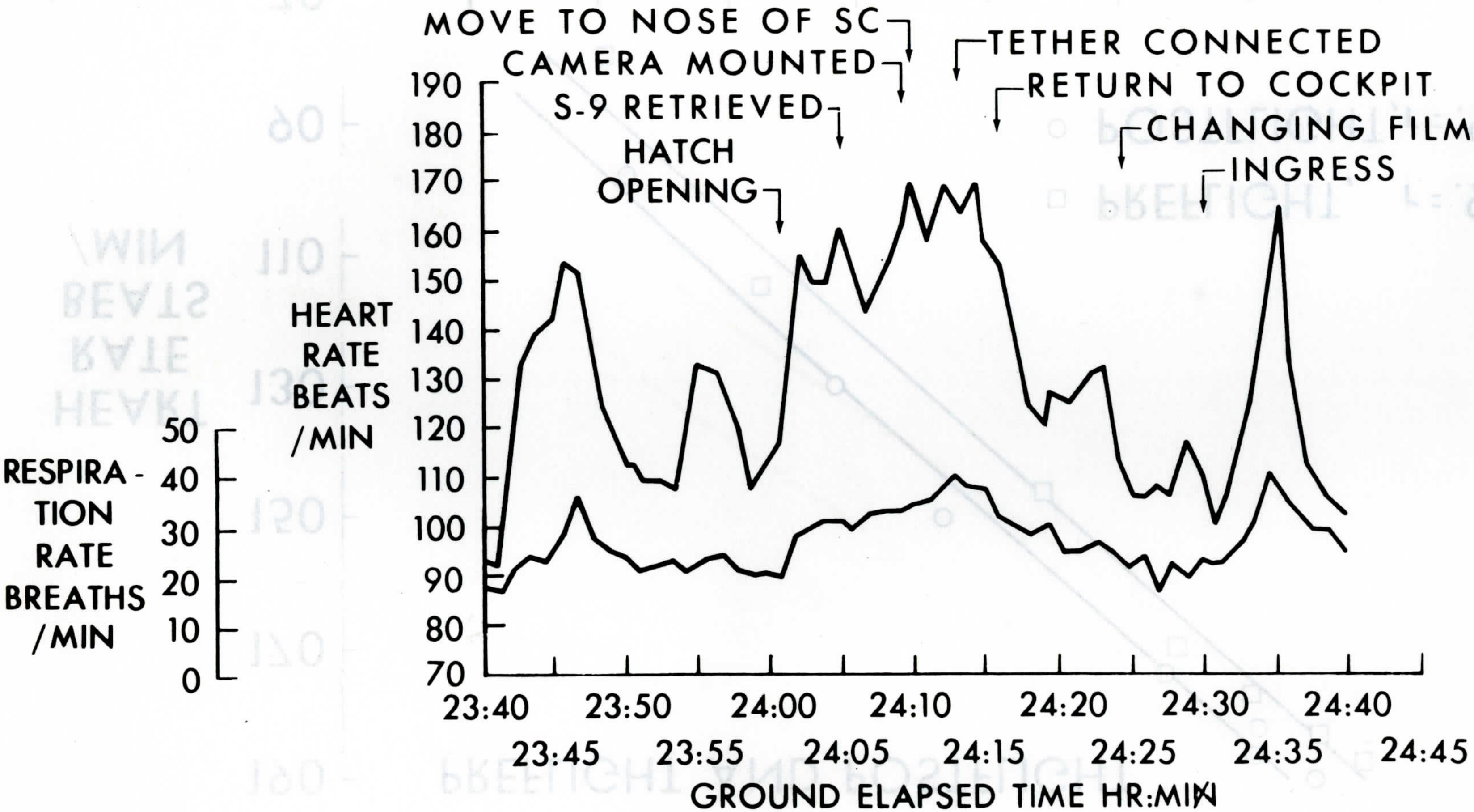

FIGURE 7.- UMBILICAL EVA XI

NASA-S-66-11527 NOV 26

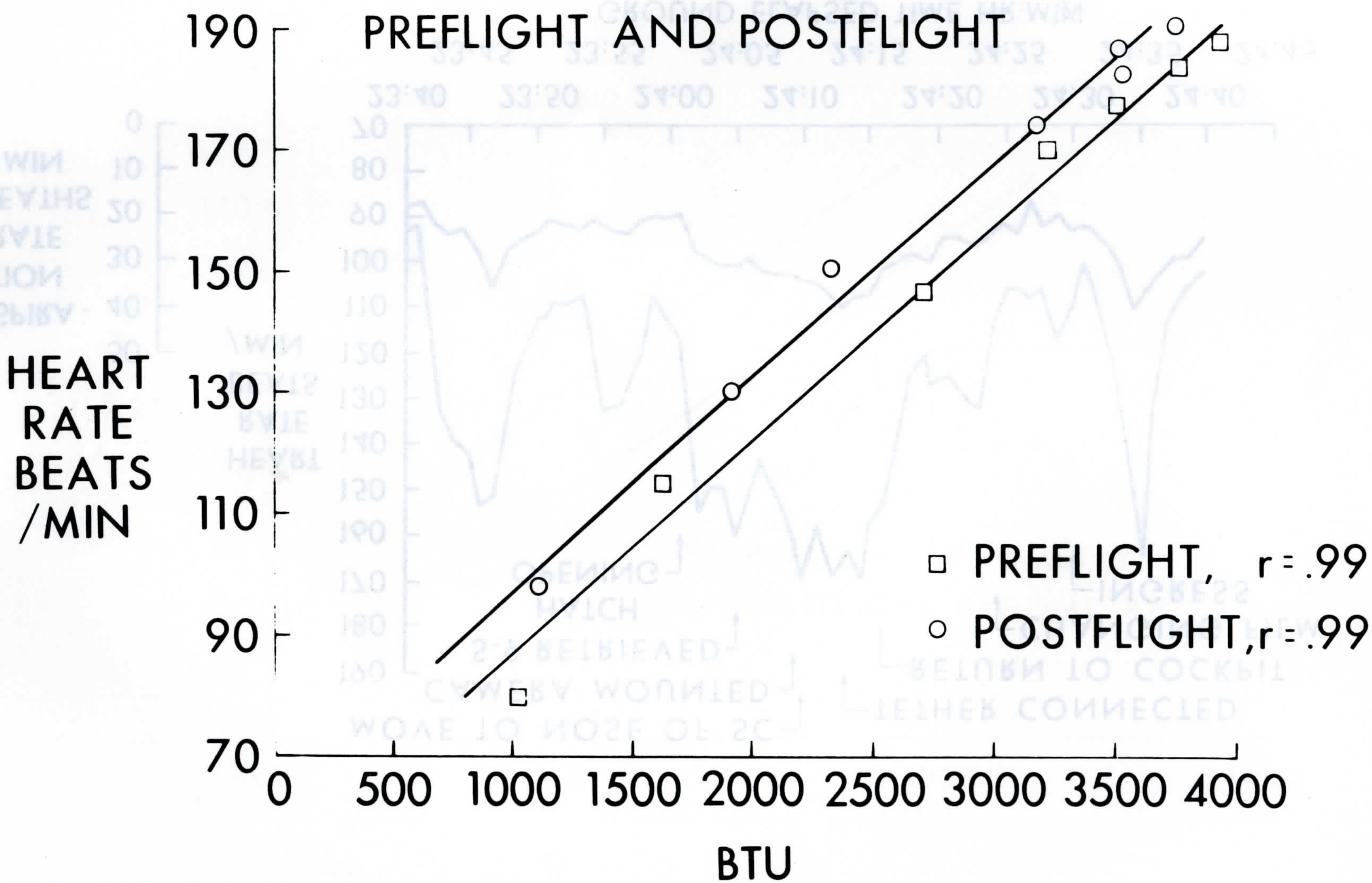

FIGURE 8.- HEART RATE VS BTU'S

NASA-S-66-11522 NOV 26

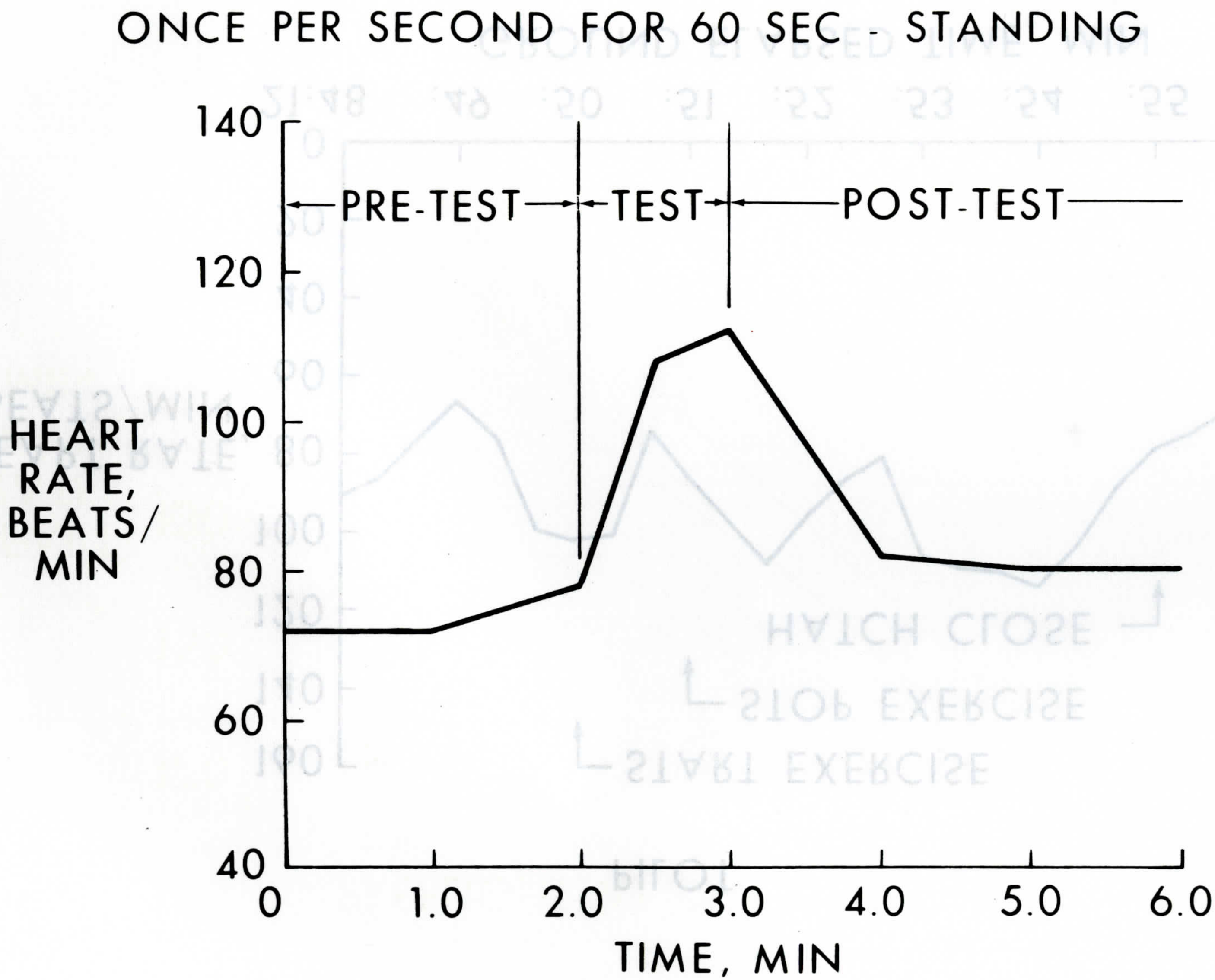

FIGURE 9(a).- 1g EXERCISE--HANDS UP AND DOWN.

NASA-S-66-11529 NOV 26

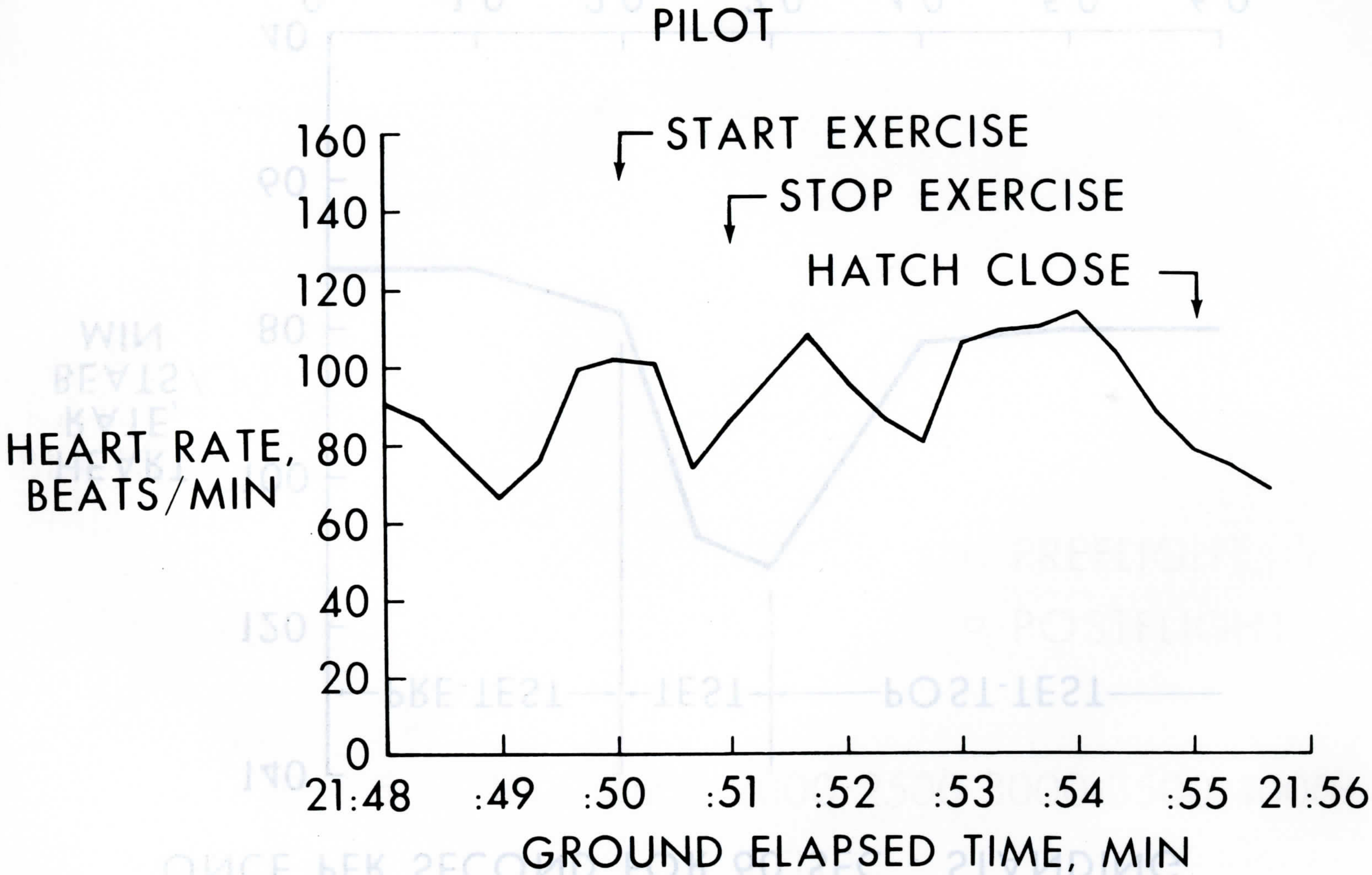

FIGURE 9(b).- GEMINI XII FIRST STANDUP EVA EXERCISE.

NASA-S-66-11524 NOV 26

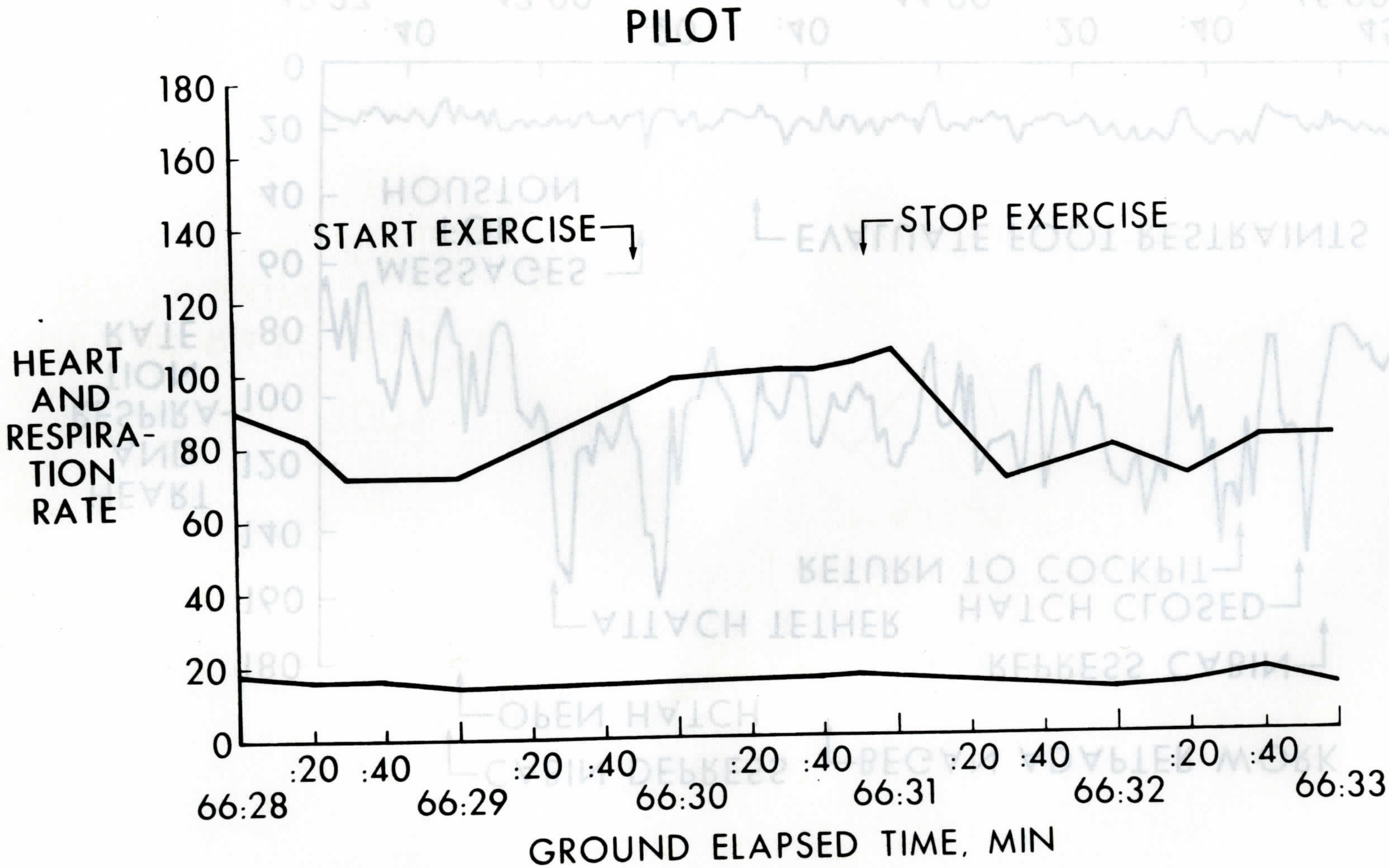

FIGURE 9(c).- GEMINI XII STANDUP EVA EXERCISE PERIOD.

NASA-S-66-11528 NOV 26

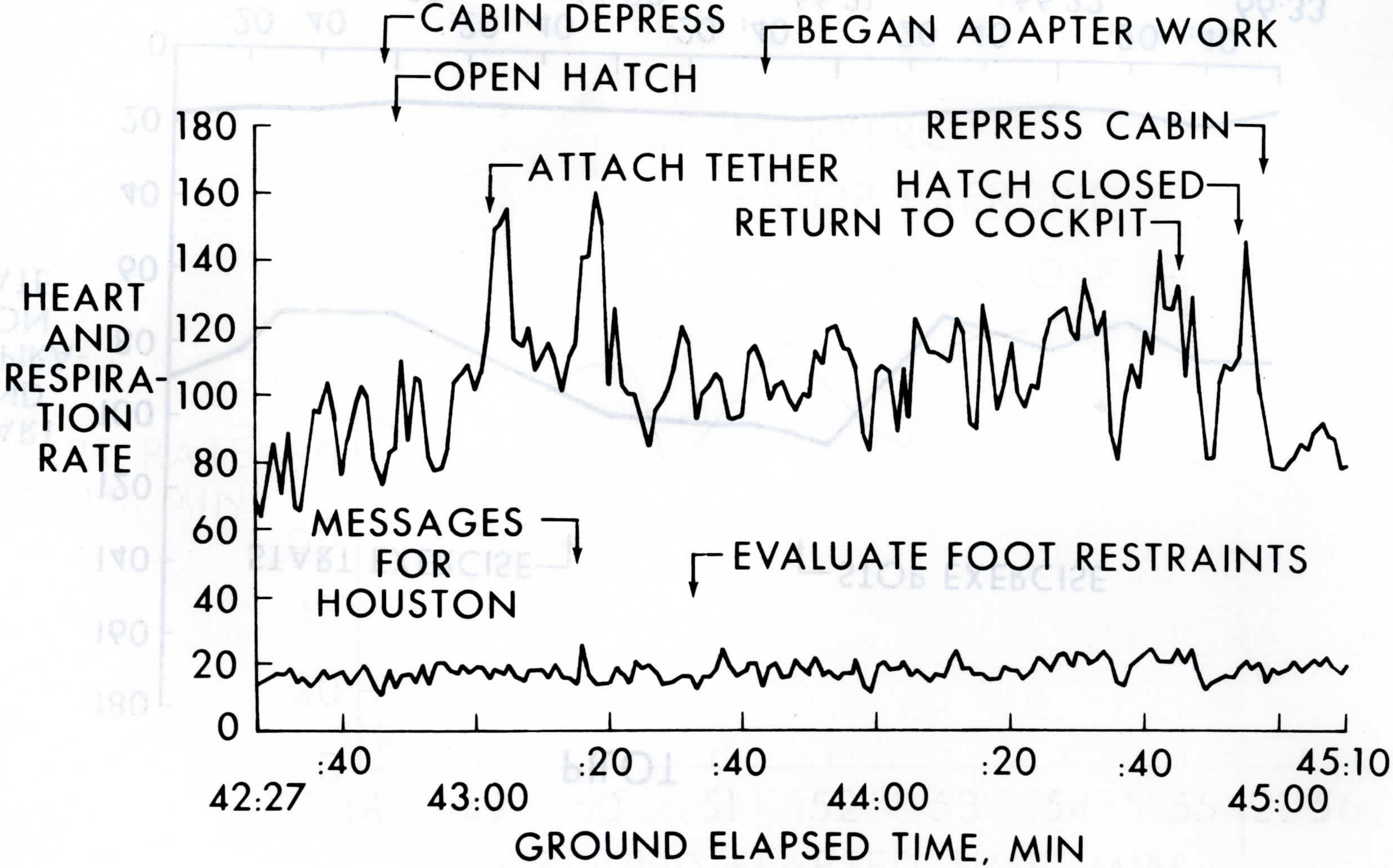

FIGURE 10.- GEMINI XII UMBILICAL DATA--PILOT.

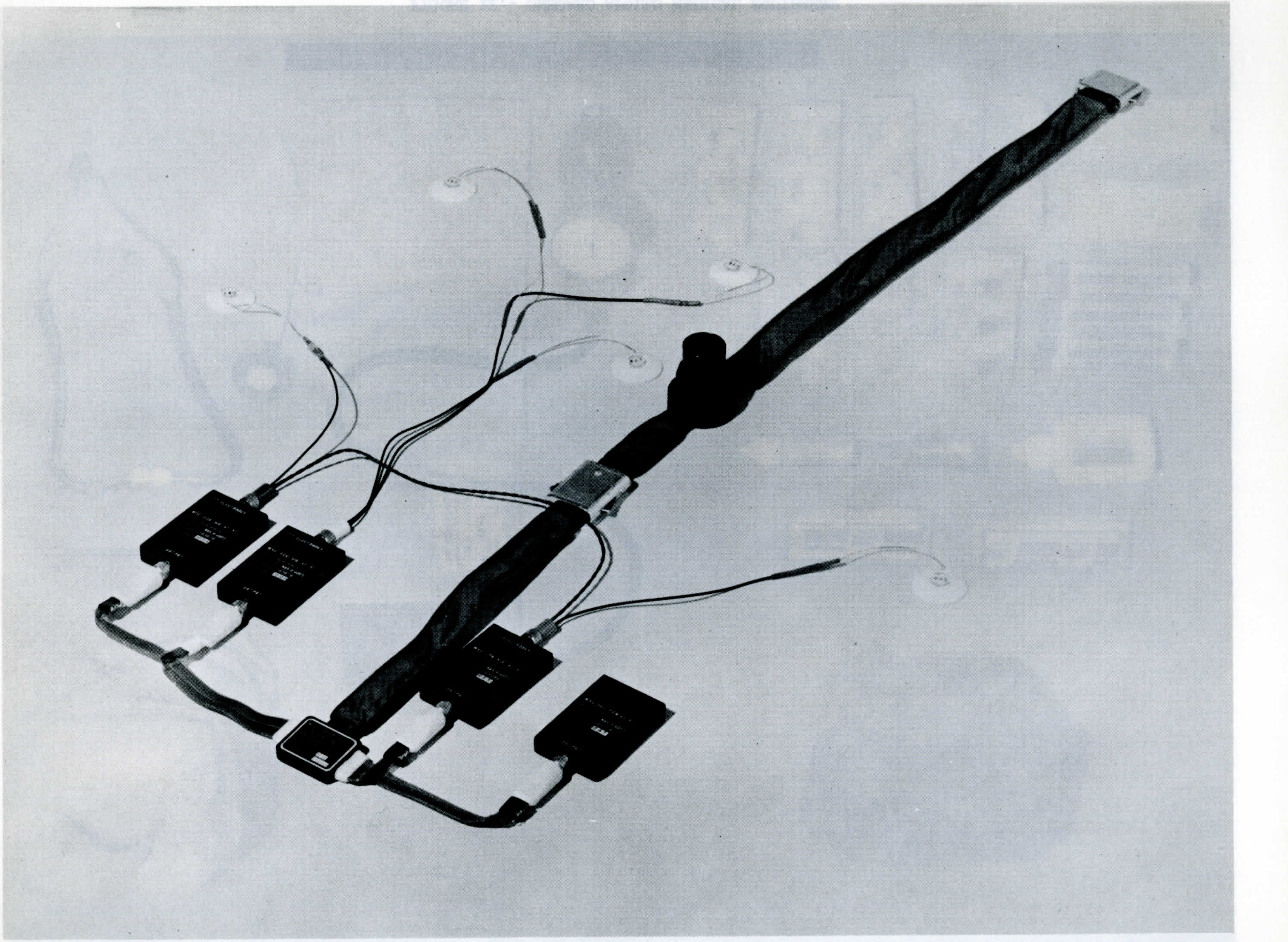

FIGURE 11

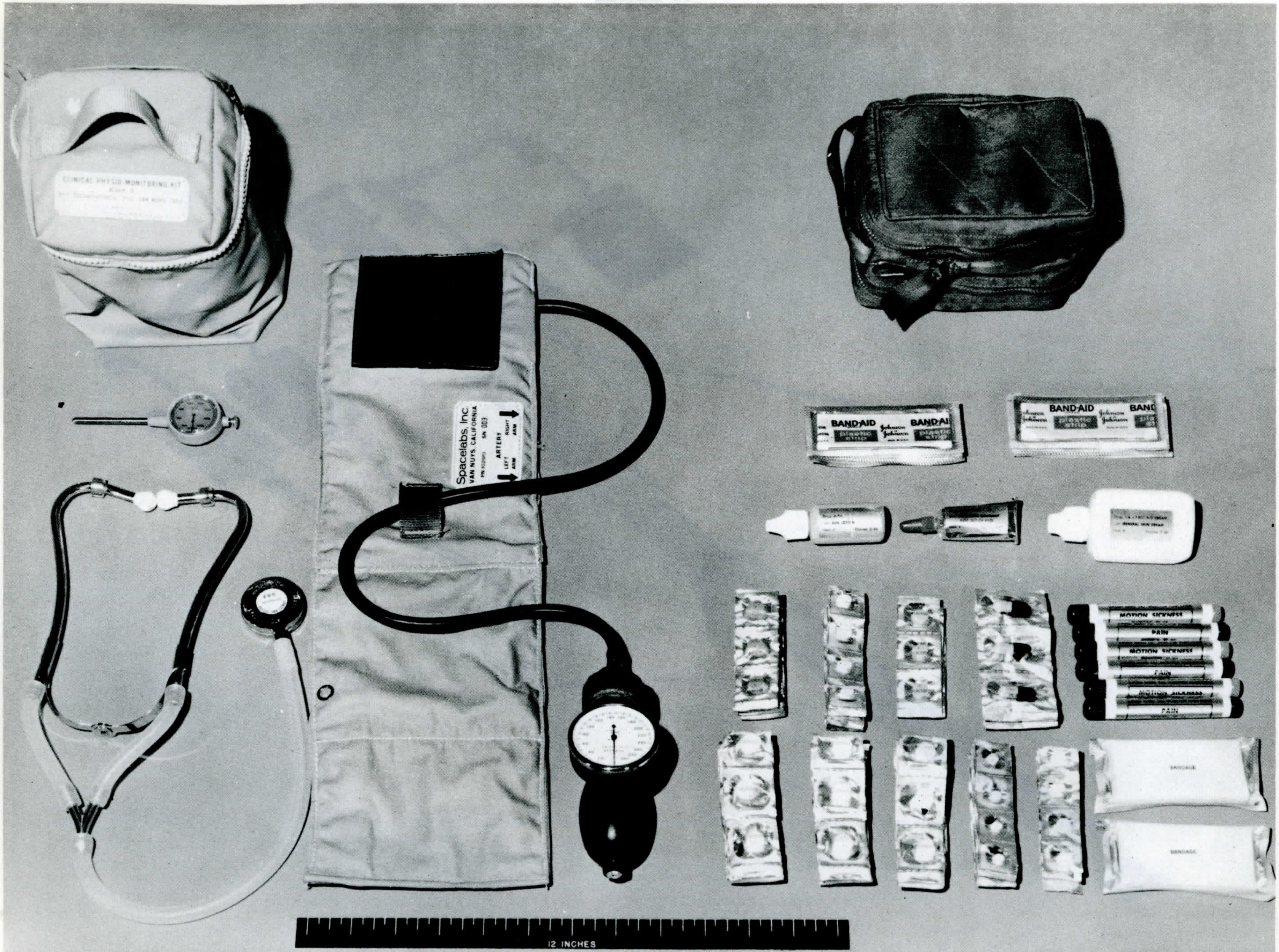

FIGURE 12.- ONBOARD APOLLO MEDICAL EQUIPMENT

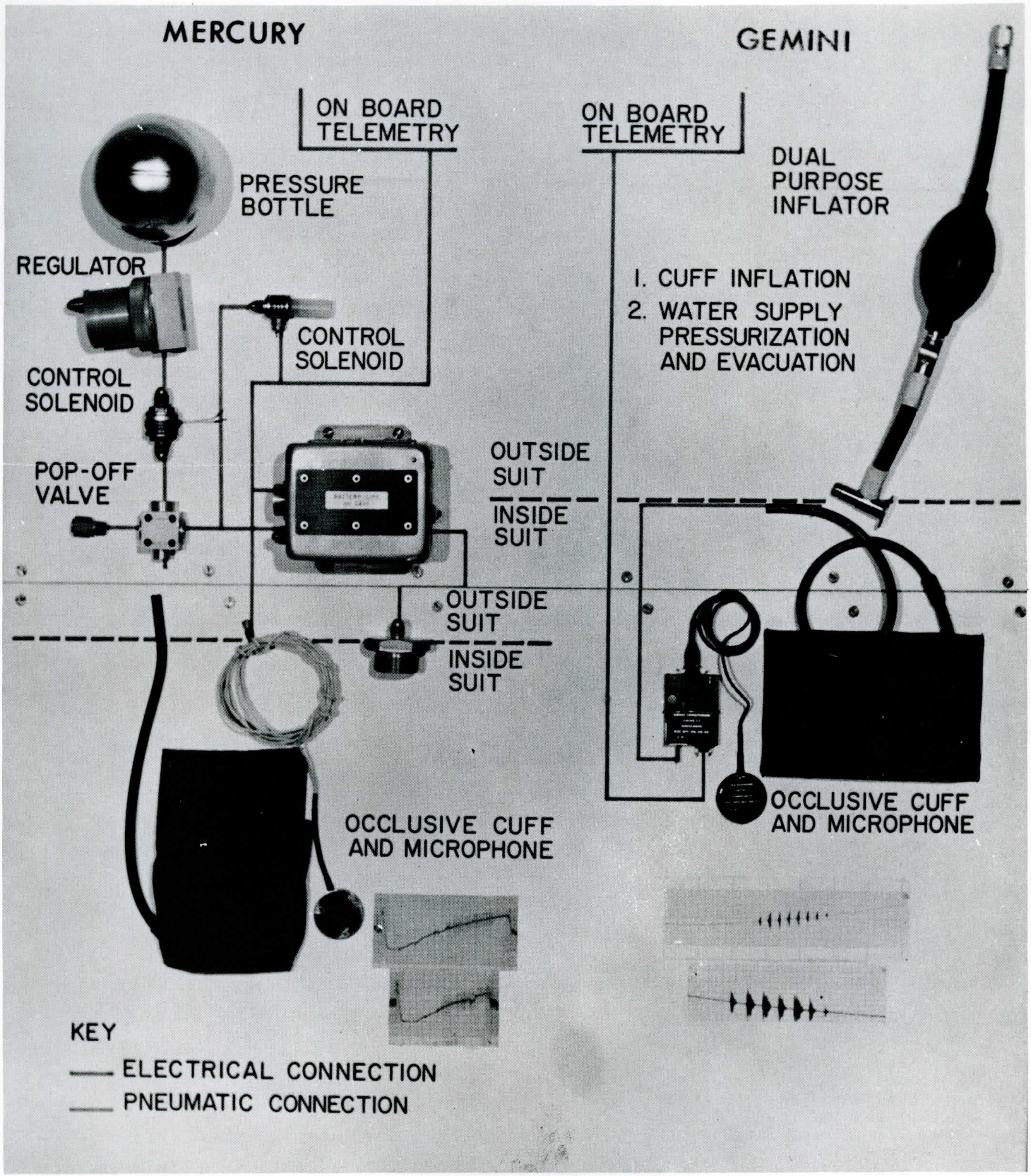

FIGURE 13.- BLOOD PRESSURE MEASURING SYSTEMS FOR USE IN SPACEFLIGHT.