10. MEDICAL ASPECTS OF GEMINI EXTRAVEHICULAR ACTIVITIES

By G. Fred Kelly, *M.D., Medical Operations Office, NASA Manned Spacecraft Center; and* D. Owen Coons, *M.D., Medical Operations Office, NASA Manned Spacecraft Center*

Introduction

The medical aspects of Gemini extravehicular activities are principally concerned with the physiological responses to high workloads, high thermal stresses, and low fatigue tolerance. Analysis of physiological instrumentation data from extravehicular flights and training operations contributed significantly to the understanding of extravehicular workloads and the means of controlling these workloads.

Background

The success of the Gemini IV extravehicular activity provided the initial confidence that man could accomplish extravehicular operations easily and with a minimum of physiological constraints. The Gemini IV mission also tended to indicate that elaborate physiological instrumentation would not be required. Accordingly, medical instrumentation requirements for future extravehicular activities were kept to a minimum. The requirements included one lead for an electrocardiogram and one lead for obtaining respiration rate. Because the pilot was able to monitor the suit pressure, this measurement was deleted for Gemini IX-A and subsequent flights. Other instrumentation which would have been desirable included carbon-dioxide concentration and body temperatures; however, feasible means of measuring these parameters were not readily available.

Medical Evaluation of Extravehicular Activities

During the extravehicular portions of Gemini IX-A and XI, excessive workload appeared to be a limiting factor. An evaluation of flight data indicated that there may have been an excessive thermal load imposed upon the extravehicular pilot during these activities. The high respiration rates encountered during Gemini XI indicated that a buildup in the carbon-dioxide level may have been a problem. Since there were no actual data on thermal conditions, oxygen, or carbon-dioxide levels, and no direct measure of metabolic load, a quantitative evaluation of the potential problem areas was not possible.

Although there was no direct measure of metabolic load, the electrocardiogram and impedance pneumogram provided some useful information, but only if certain limitations and inaccuracies were considered. These parameters have been monitored during a great many physiological and psychological tests under widely varying conditions. This information reconfirms that heart rate responds to psychological, physiological, and pathological conditions. There is considerable individual variation in these responses. However, in the absence of a more scientific approach to the problem, and because a quantitative indication of the workload actually experienced in flight appeared to be of primary importance, the feasibility of using heart rate as a quantitative indication of workload was investigated.

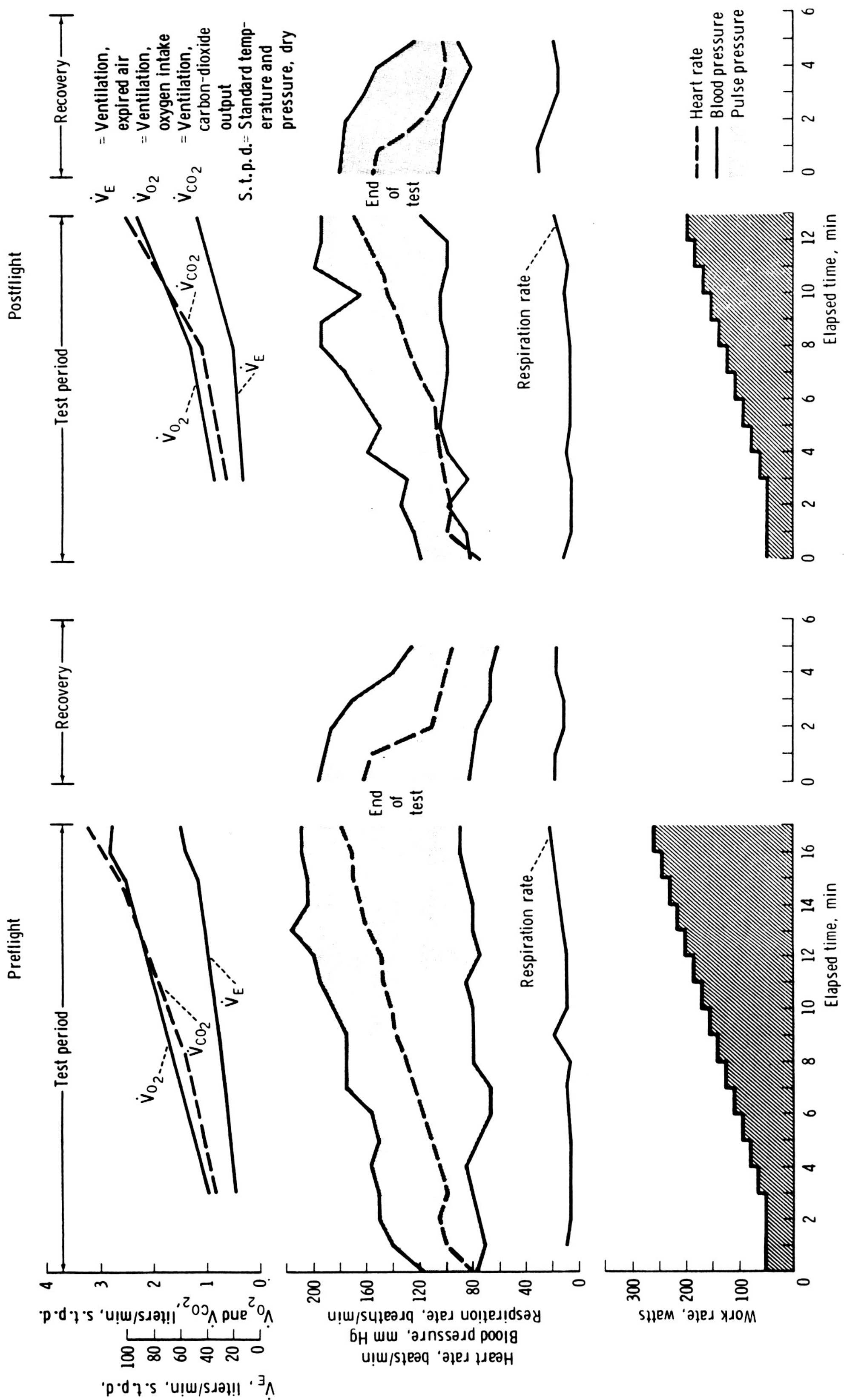
On Gemini IX–A, X, XI, and XII, preflight and postflight exercise tests using the bicycle ergometer were performed on the pilots. During the tests, the subject performed a measured amount of work in increasing increments while heart rate, blood pressure, and respiration rate were monitored; periodic samples of expired gas were collected for analysis. The data were translated into oxygen utilization curves and heat-energy plots (fig. 10–1). Using the plots and the heart-rate data obtained during each flight (figs. 10–2 and 10–3), an approximate workload curve was plotted against the time line for the extravehicular activity. The derived data were not entirely believable, since there is no method to account for the effect on heart rate resulting from thermal or other environmental variations. Also, the psychogenic effect of a new and different environment could certainly increase the heart rates without a corresponding change in metabolic rate. The plots were useful in evaluating the workloads for the Gemini XII extravehicular activity. The accuracy of the plots may be expected to increase as the oxygen consumption increases toward maximum oxygen utilization. This value varies with individuals and with the degree of physical conditioning, and is dependent upon the amount of oxygen which can be transported from the environment to the body tissues.

The area of major interest in evaluating workloads during extravehicular activities is during high workload periods. Furthermore, any error introduced by unknown factors would increase the observed heart rate for a given workload level. This tends to increase the usefulness of such a plot for preflight planning and for inflight monitoring of extravehicular activities. When data from previous flights, altitude chamber tests, 1g walk-throughs, and underwater zero-g simulations are examined in this manner, a quantitative indication may be derived of work expended on various tasks (fig. 10–4). This is important in the postflight assessment of the relative physiological cost of various tasks, and in determining acceptable tasks and realistic time lines during simulations and preflight planning. The use of heart-rate and respiration-rate data, when coupled with voice contact and an understanding of programed activities, proved an extremely important and useful method for real-time monitoring of extravehicular pilots.

The major factors which apparently produced the highest workload prior to Gemini XII were high suit forces, insufficient body-position restraints, and thermal stress. This was indicated when the Gemini XI pilot expended an exceptionally high effort in attaching the spacecraft/target-vehicle tether to the docking bar. Difficulties in maintaining body position in the weightless environment made the task much more difficult than had been expected.

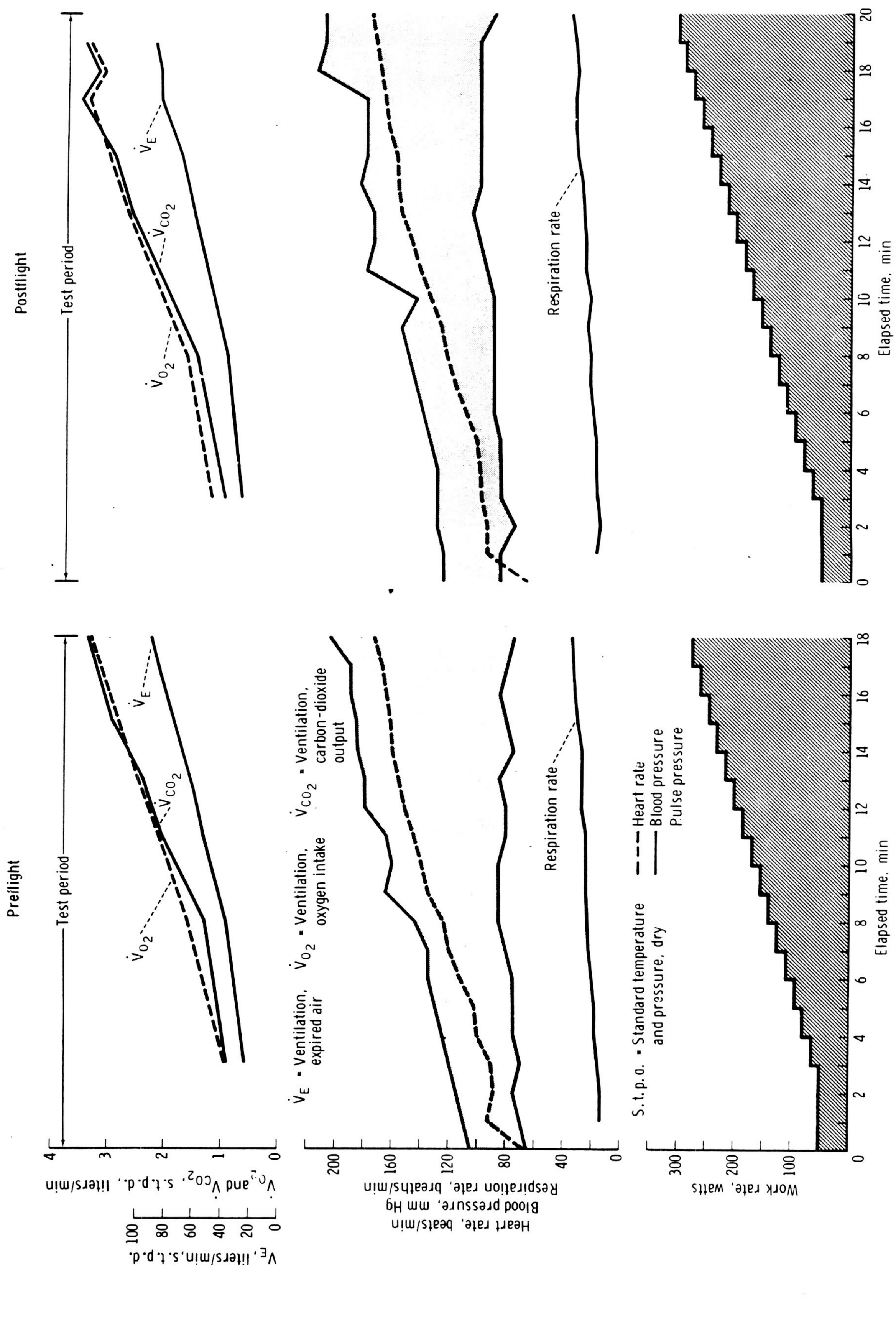
The pilot used the large torso and leg muscles in attempting to straddle the spacecraft nose and found that he had to work against the pressurized space suit in order to force his legs into an unnatural position. The high workload subjectively described by the pilot was confirmed by heart and respiration rates (fig. 10–2(*d*)). The high respiration rates also indicate the possibility of increased carbon-dioxide level. The Extravehicular Life-Support System was not designed to handle workloads of the magnitude indicated by these rates in terms of either thermal control or carbon-dioxide removal. It is probable that the thermal and carbon-dioxide buildup, along with psychogenic factors which were certainly present, contributed to the high heart rates recorded. However, this would make heart rate and respiration rate data no less useful in the real-time monitoring of a crew during flight if stress or potential danger were in fact present.

In planning for Gemini XII, it was deemed important to avoid workloads which would exceed the capacity of the Extravehicular Life-Support System. It had been determined that the Extravehicular Life-Support System was capable of handling 2000 Btu/hr while maintaining a carbon-dioxide level equal to approximately 6 mm of mercury. During the



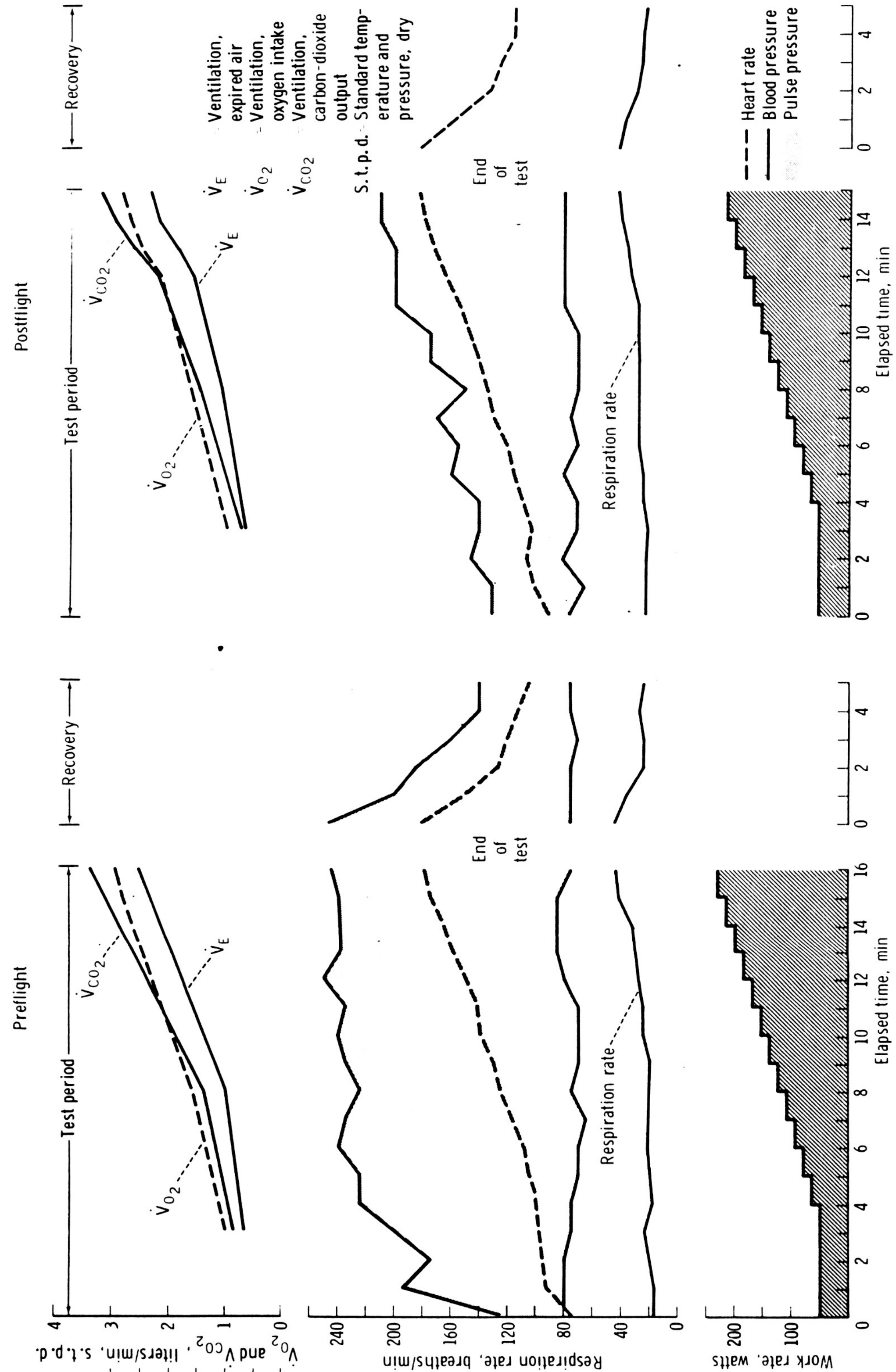
(*a*) Gemini IX-A pilot.

FIGURE 10-1.—Ergometry studies.



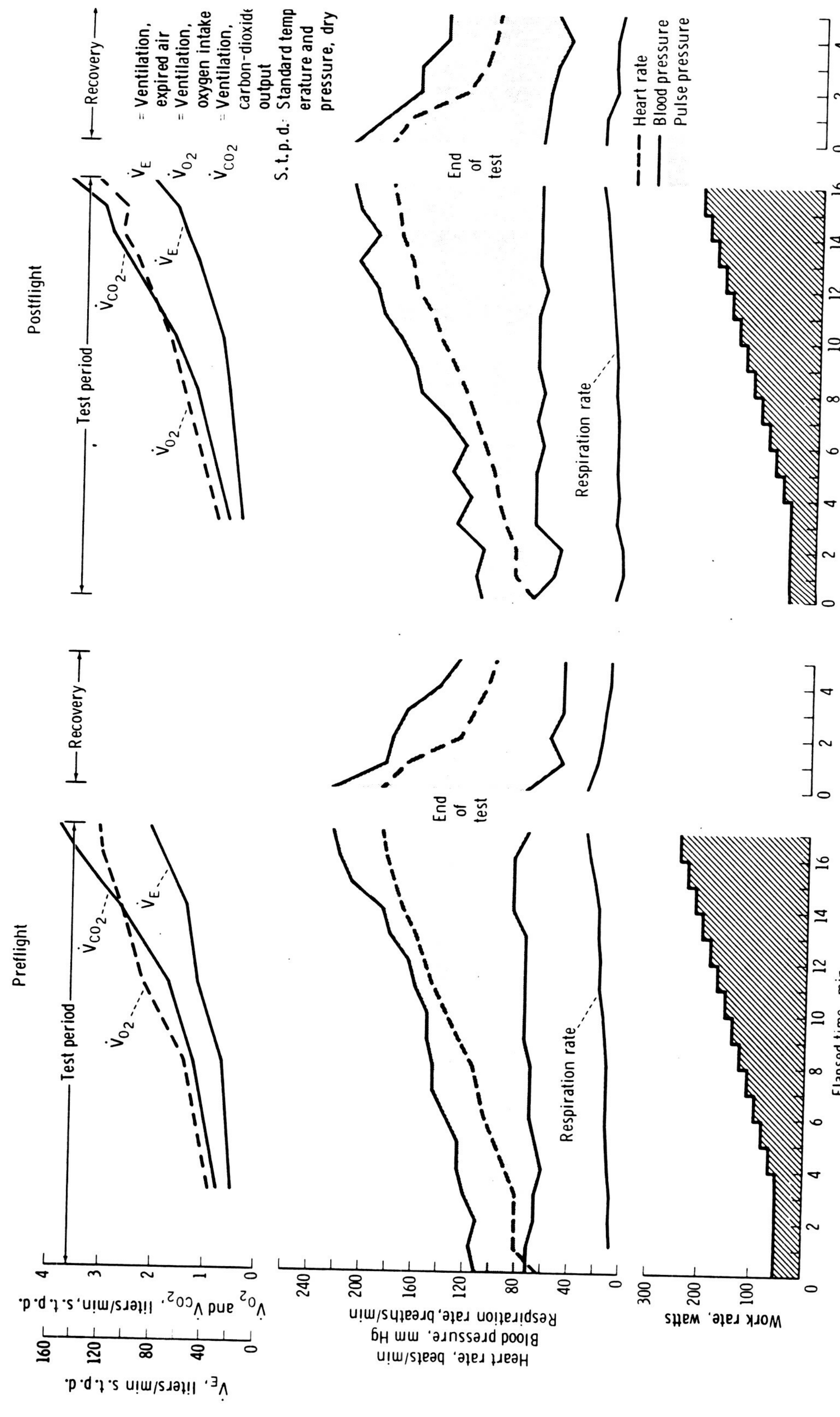
(*b*) Gemini X pilot.

FIGURE 10-1.—Continued.



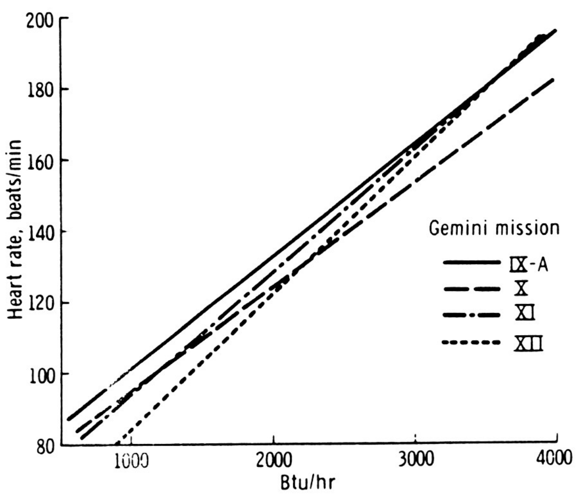
(c) Gemini XI pilot.

FIGURE 10-1.—Continued.



(*d*) Gemini XII pilot.

FIGURE 10-1.—Continued.



(*e*) Gemini IX-A through XII preflight studies.

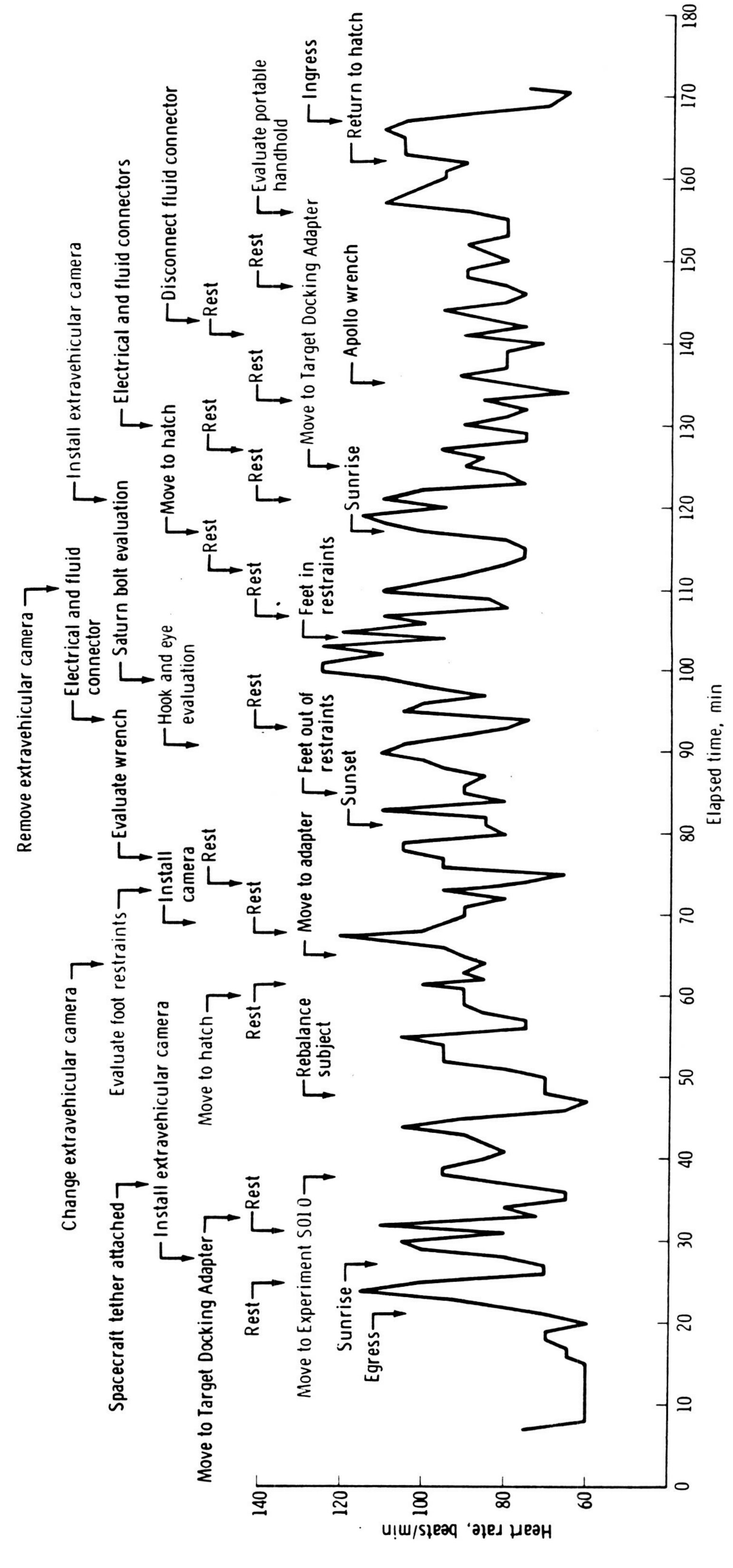
FIGURE 10-1.—Concluded

preflight ergometer studies (fig. 10-5), the pilot heart rate was 122 beats per minute when the workload was 2000 Btu/hr. It should be noted that a total heat capacity higher than 2000 Btu/hr was possible for short periods of time, and that sustained heat dissipation of a percentage of thermal load produced by higher levels of work was also within the capabilities of the Extravehicular Life-Support System. Because of these and other factors which are known to cause increases, heart rates above 122 beats per minute were expected and observed during the planned extravehicular activities on Gemini XII. Figure 10-3(*e*) is a graph of heart rate related to events during the Gemini XII umbilical extravehicular activity. Only once did the pilot's heart rate exceed expected levels. This occurred during a period of unscheduled activities when psychogenic factors contributed heavily to the heart rate. When the pilot was asked to decrease the activities, heart rates returned to a resting level in less than 1 minute.

During each period of standup extravehicular activity in Gemini XII, two sessions of programed exercise were performed. The exercises consisted of moving the arms against the restrictive forces of the pressurized space suit. Both arms were brought from the neutral position to the sides of the helmet once each second for 60 seconds. An attempt was made to correlate heart rate during these inflight exercise periods with preflight exercise tests (fig. 10-5). When compared in this manner, there appeared to be no significant difference between the heart-rate data for the exercises performed before flight and those performed in flight. Only qualitative conclusions, however, can be drawn from these data. Quantitative and scientifically valid conclusions must await the results of more detailed and precisely implemented inflight medical experimentation in which controlled conditions are possible and adequate data collection is feasible.

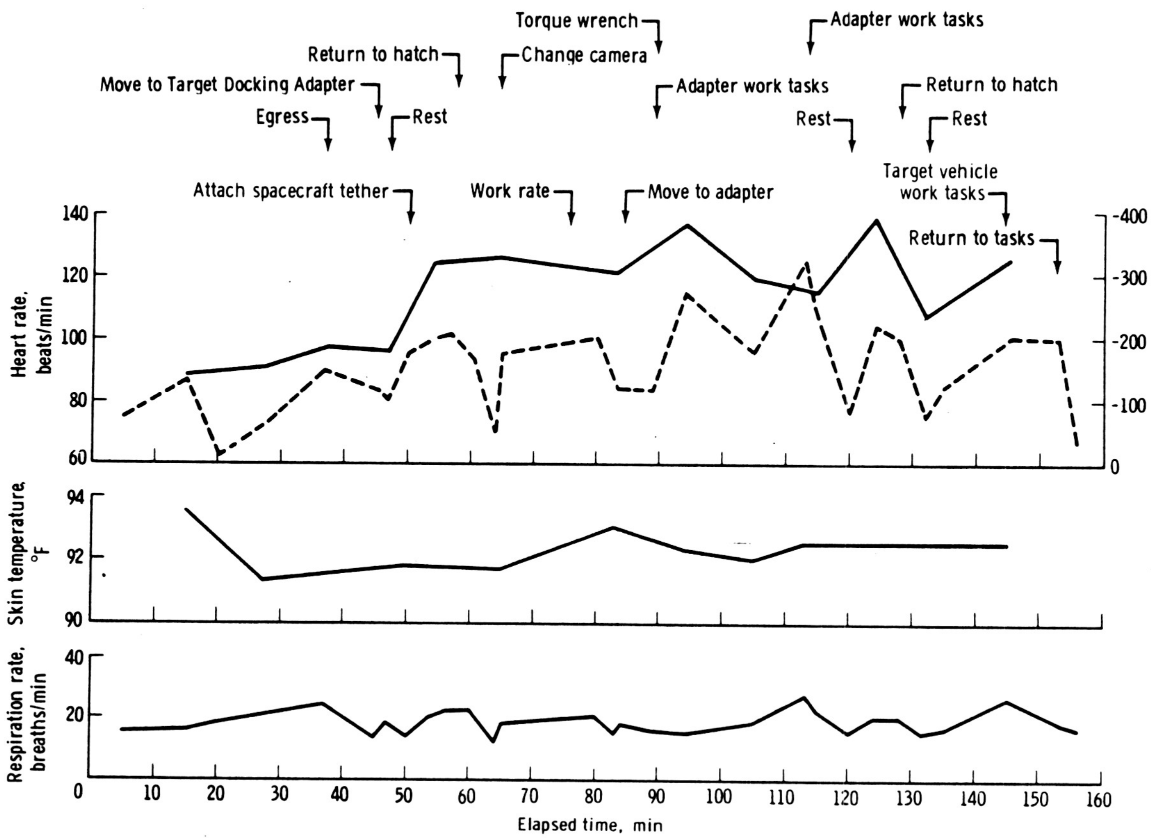
Certain other factors are considered significant in the medical aspects of the Gemini extravehicular activities. One of these factors, the art of conserving energy, has been briefly mentioned, and was demonstrated by the pilot of Gemini XII. The pilot of Gemini XII was able to condition himself to relax completely within the neutral position of the suit. He consciously tried to determine when a group of muscles was found to be tense while performing no useful work, and then tried to subjectively relax these muscles. All movements were slow and deliberate. When small movement of the fingers was sufficient to perform a task, the pilot used only the necessary muscles. If a restraint strap would substitute for muscle action, the pilot would rely on the restraint strap to maintain position, and would relax the muscles which would otherwise have been required for this task.

Chronic fatigue and degraded physical condition may have been a problem during extravehicular activity. Sleep during the first night of each flight was inadequate, and preparation activities for extravehicular maneuvers were detailed and fatiguing. Furthermore, the pace of preflight activities and the pressures of planning, training, and preparation to meet a flight schedule predisposed the crew to fatigue. During the final weeks of preparation for a flight, each crew found that time



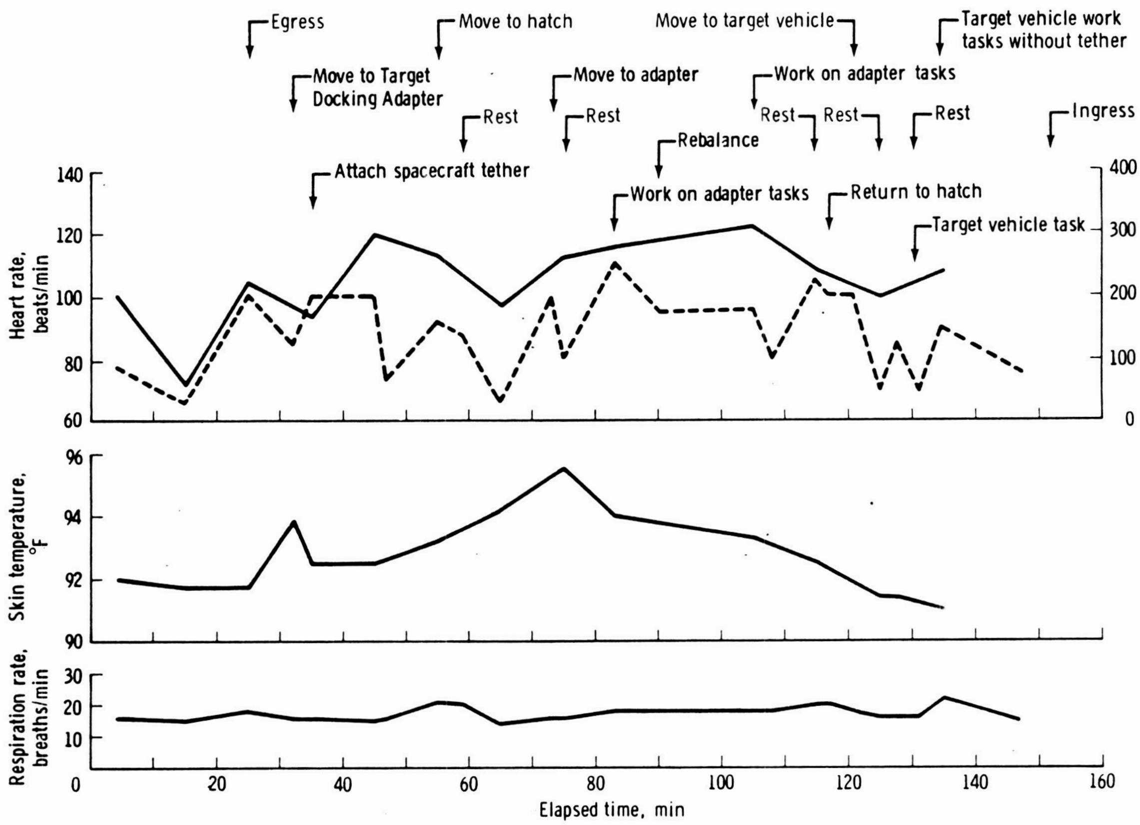
(*a*) Gemini XII pilot.

FIGURE 10-2.—Heart rates from underwater simulations.



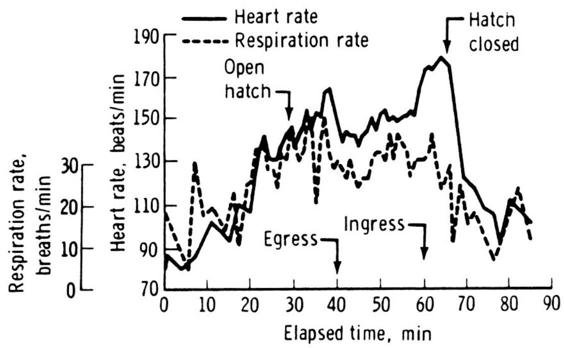
(*b*) Gemini XII pilot.

FIGURE 10-2.—Continued.



(*c*) Gemini XII pilot.

FIGURE 10-2.—Concluded.



(*a*) Gemini IV pilot.

FIGURE 10–3.—Physiological data during umbilical extravehicular activity.

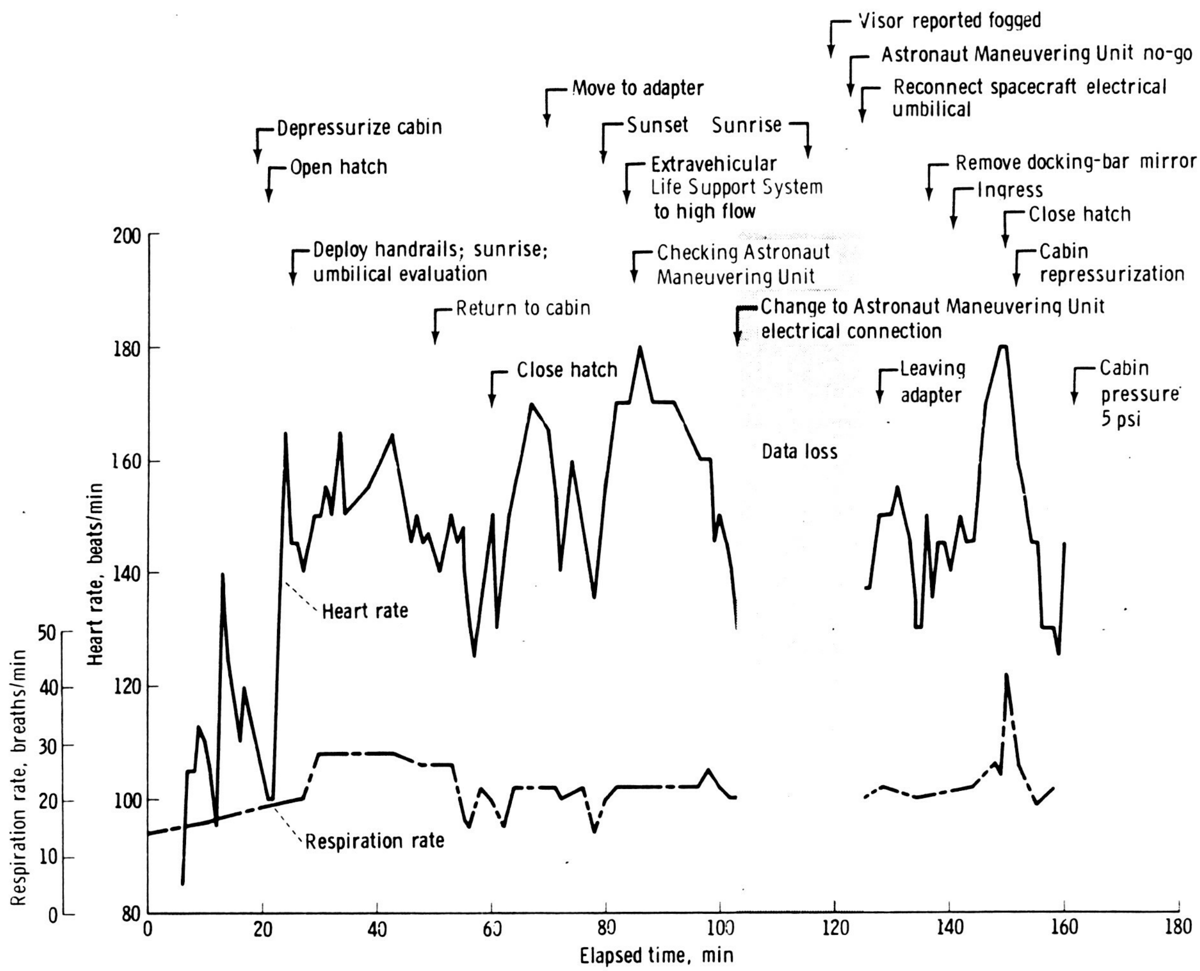
for rest, relaxation, and even physical conditioning was at a premium, and often these activities were omitted.

The possibility exists that hematological or cardiovascular changes observed in weightless flight decrease the metabolic efficiency of man during the extravehicular activities requiring a relatively high workload. Until more detailed information is available from well-founded medical experimentation during flight, the relative importance of such factors cannot be assessed.

Conclusions

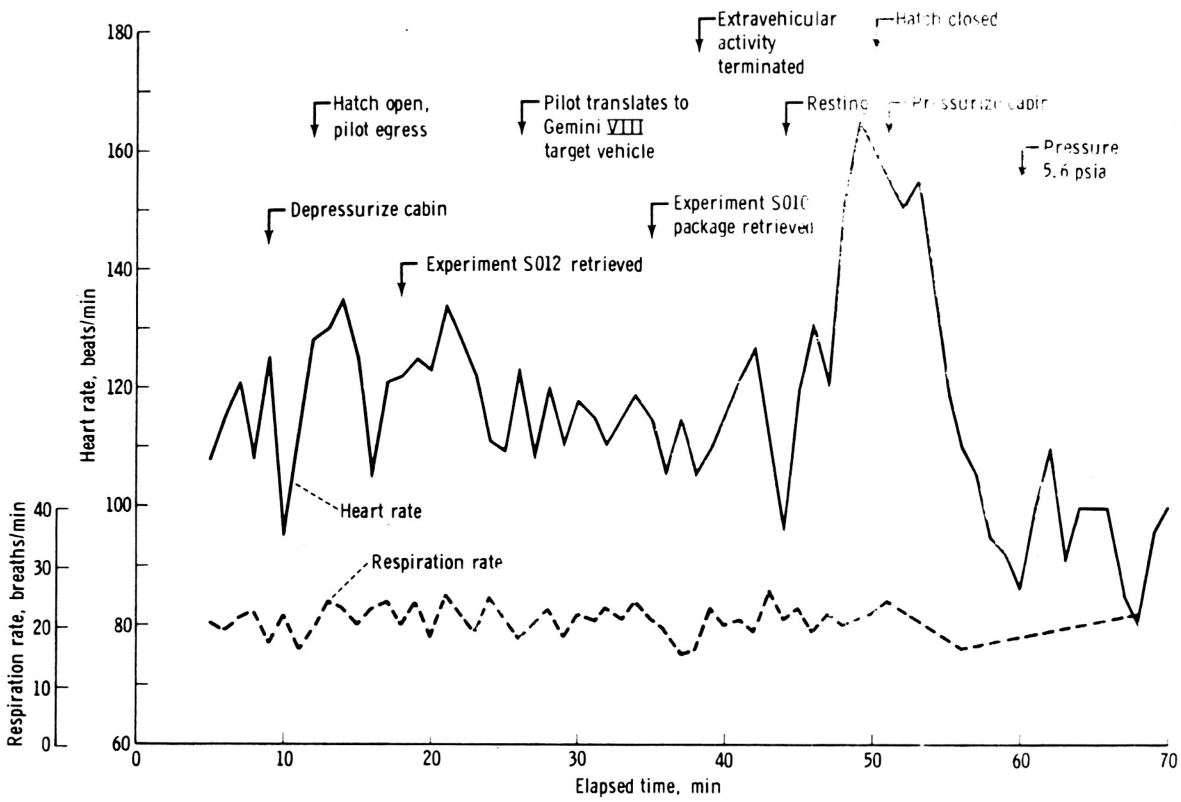
The experience gained from the Gemini extravehicular activities has provided information which will be invaluable in planning future missions. There have been no indications that the efficiency of man during extravehicular activities is significantly altered. The major factors which appear to have produced the highest workload during the extravehicular activity are high suit forces, insufficient body-position aids, and thermal stress. The success of Gemini XII conclusively demonstrated that these factors can be minimized through careful planning. Evaluation of physiological factors during the extravehicular activity has been significantly compromised by the lack of adequate instrumentation. Much can be learned about the physiological responses to extravehicular activities from simulations in the zero-g aircraft and in an underwater mockup. Without specific knowledge of the thermal and environmental conditions, however, a realistic simulation of extravehicular activities will be incomplete and possibly misleading.

The successful completion of the Gemini extravehicular activities indicates that life-support planning has been essentially sound. The success of Gemini XII indicates that within the limitations of the experience gained, time lines and work tasks can be tailored so that flight objectives can be accomplished. There are no medical contraindications to presently planned extravehicular activities.



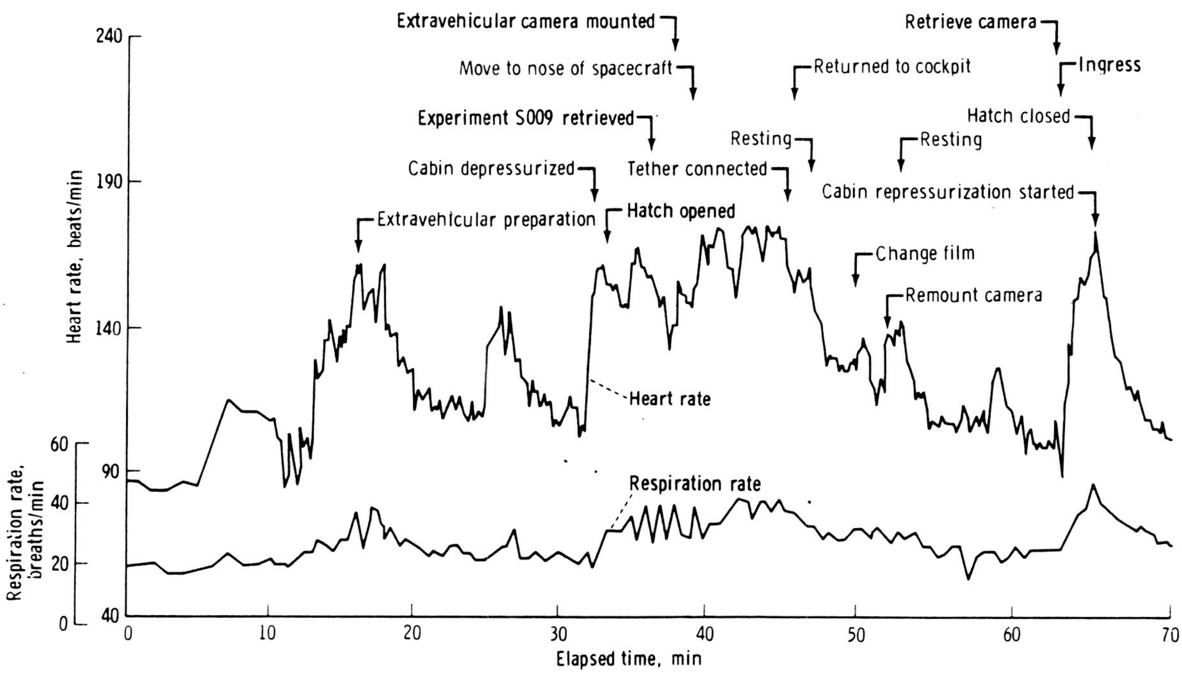
(*b*) Gemini IX–A pilot.

FIGURE 10–3.—Continued.



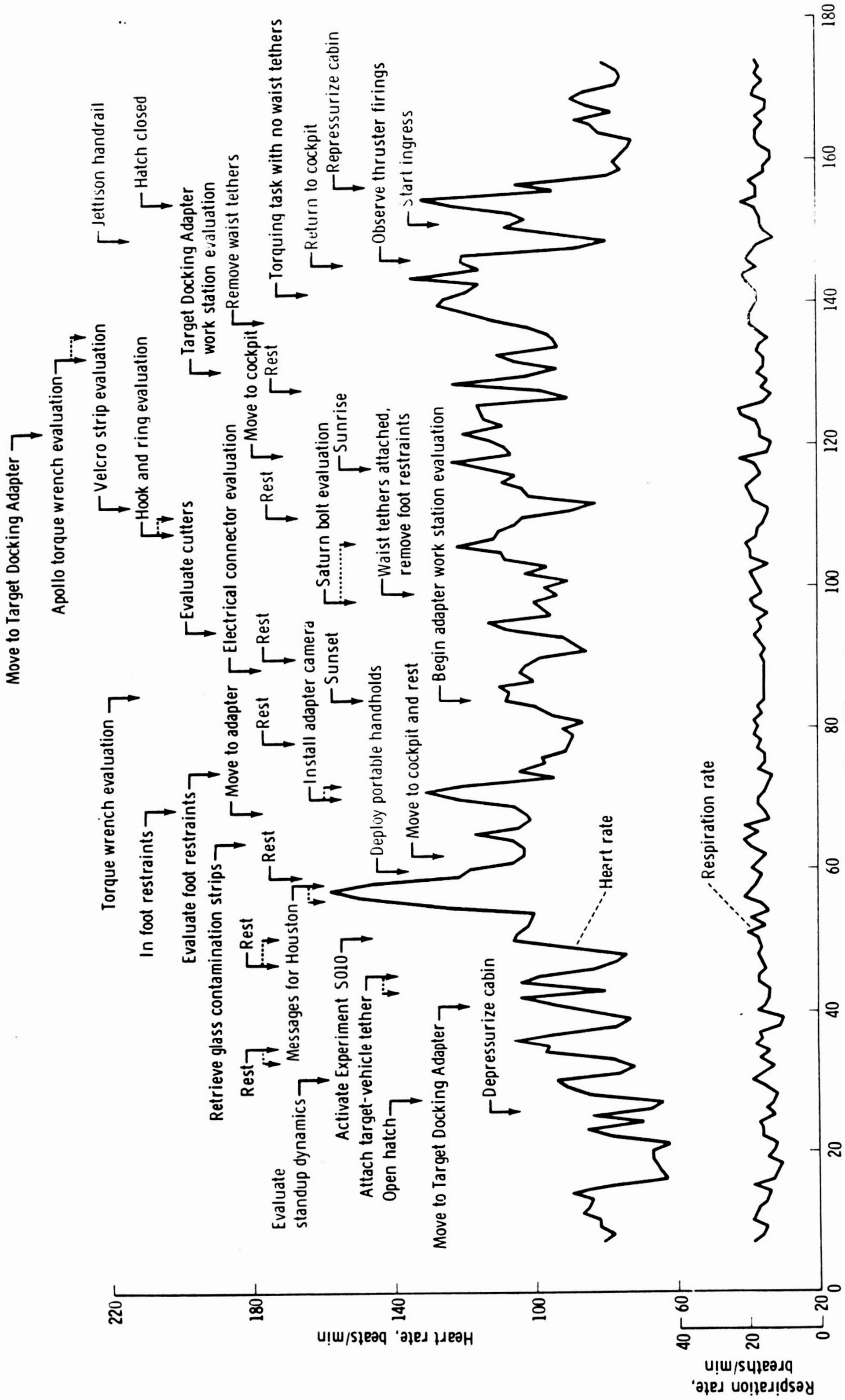
(*c*) Gemini X pilot.

FIGURE 10-3.—Continued.



(*d*) Gemini XI pilot.

FIGURE 10-3.—Continued.



(e) Gemini XII pilot.

FIGURE 10-3.—Concluded.

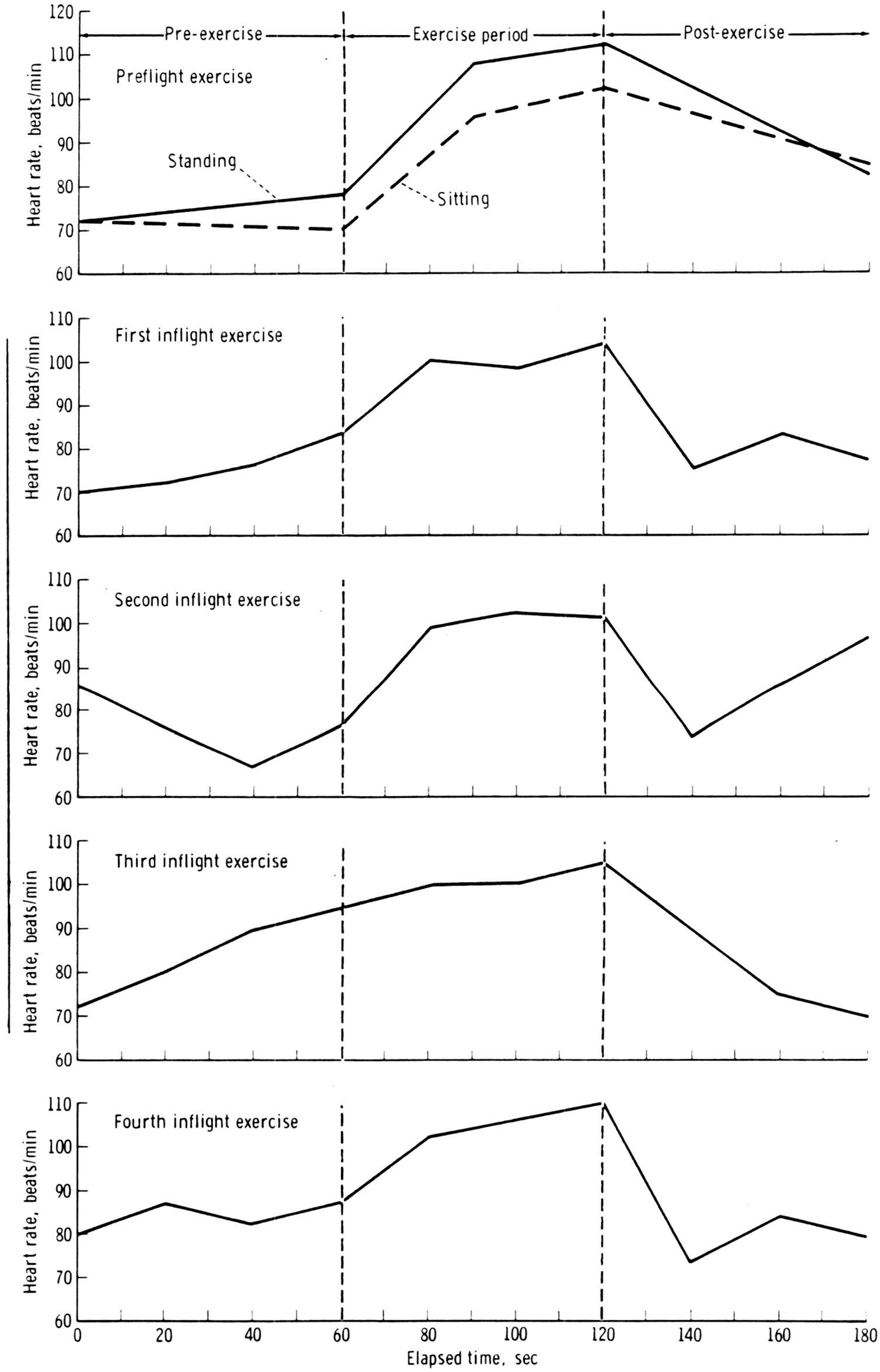
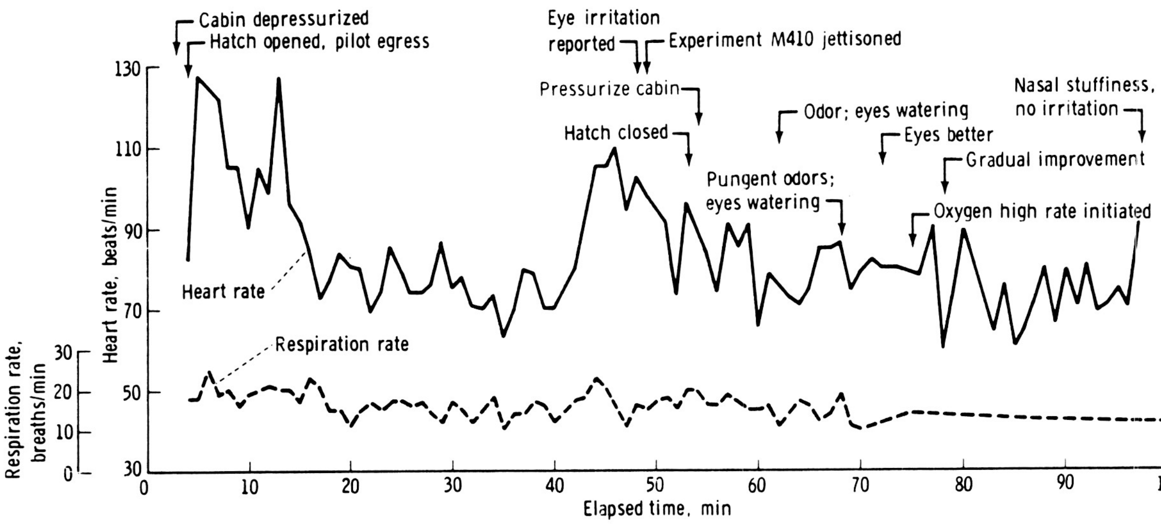
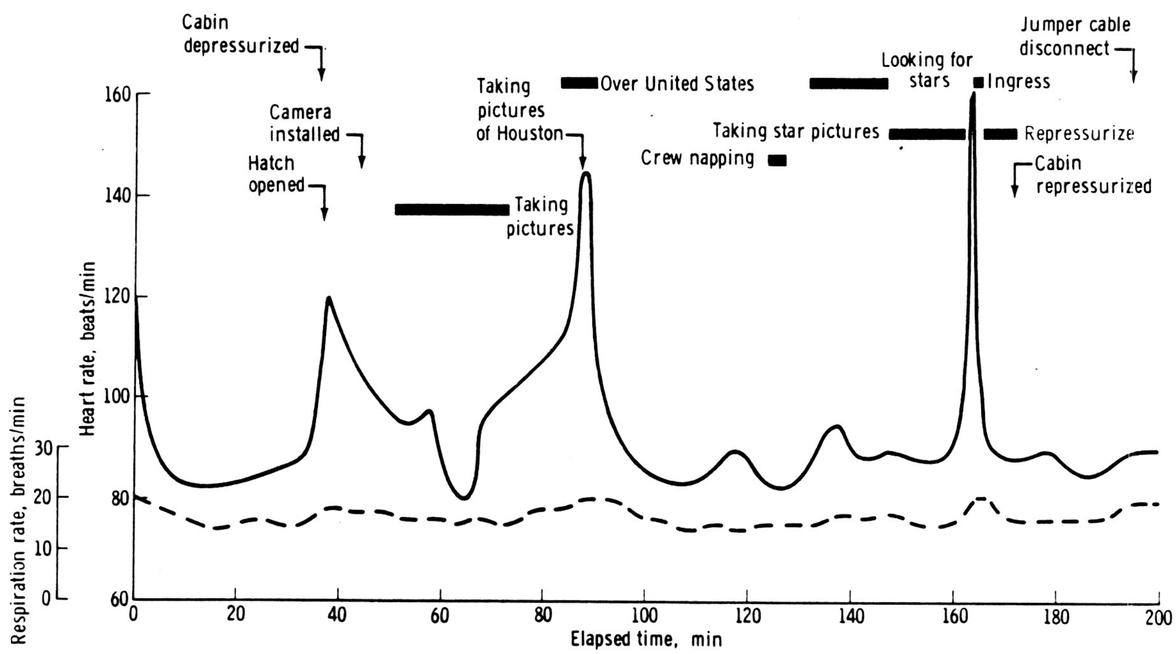


FIGURE 10-4.—Preflight and inflight exercise test, Gemini XII pilot.



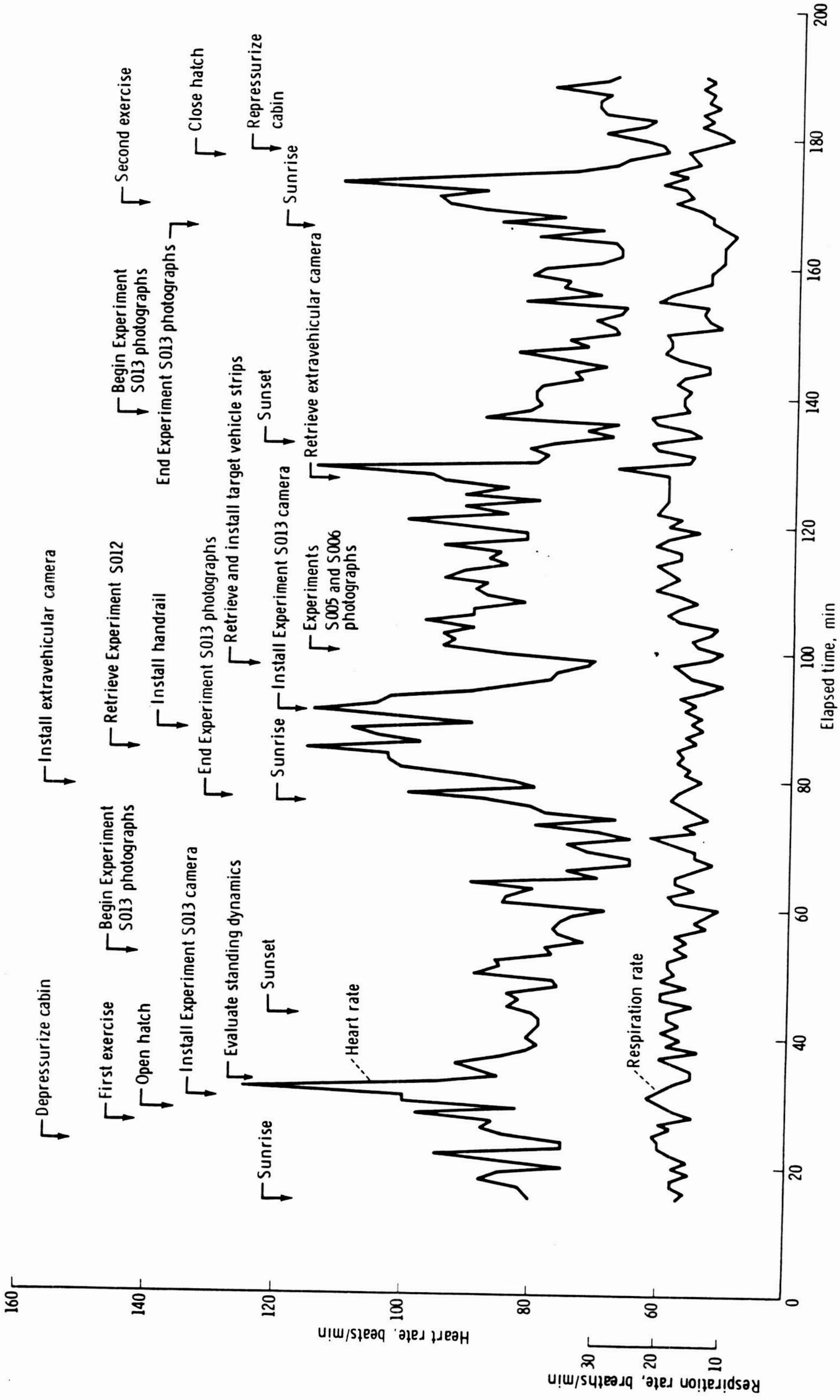
(*a*) Gemini X pilot.

FIGURE 10-5.—Physiological data during standup extravehicular activity.



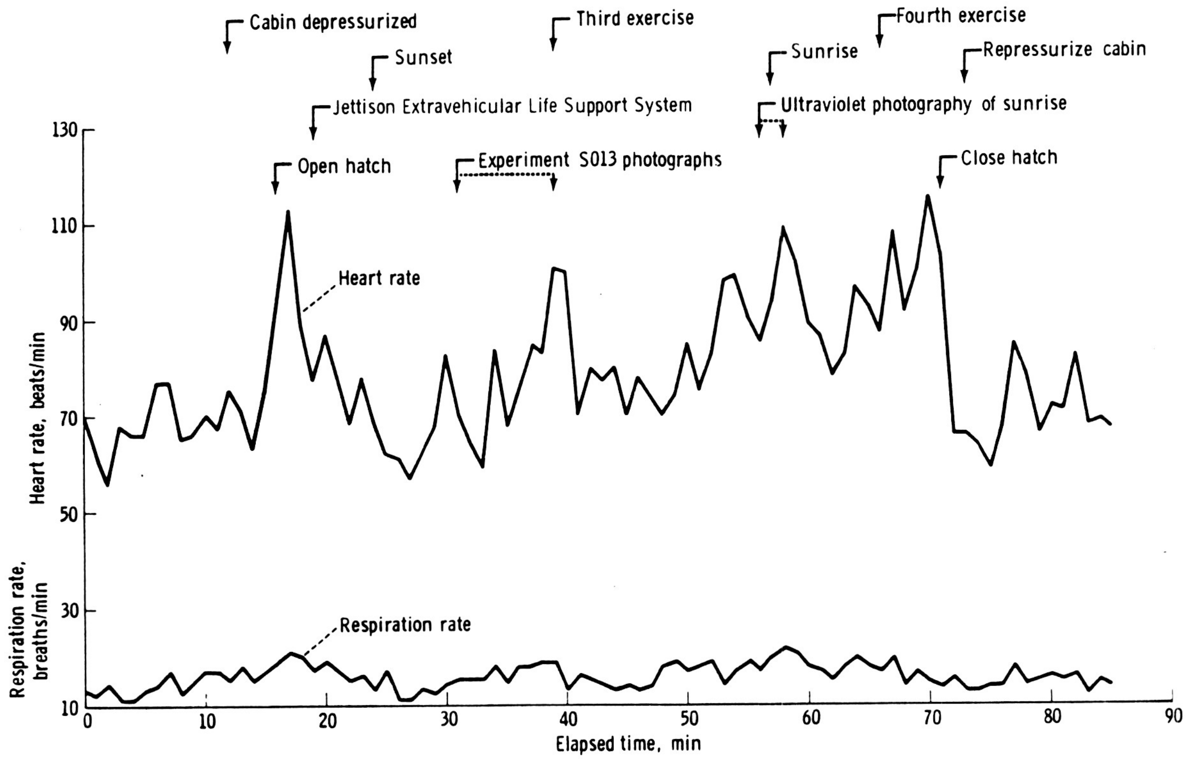
(*b*) Gemini XI pilot.

FIGURE 10-5.—Continued.



(c) First standup extravehicular activity of the Gemini XII pilot.

FIGURE 10-5.—Continued.



(*d*) Second standup extravehicular activity of the Gemini XII pilot.

FIGURE 10-5.—Concluded.