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PHYSIOLOGICAL EFFECTS OF SUITED VERSUS UNSUITED OPERATIONS IN THE GEMINI SPACECRAFT

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SUMMARY

The use of pressure suits in space missions is, at present, a requirement during launch and reentry and, obviously, during any extravehicular activity. In order to compare suited and unsuited operations during inflight periods other than those noted, an evaluation of Gemini VII flight data and crew reports has been conducted. The results generally support the contention that future long-duration space flights should be conducted to the degree possible outside the pressure suits. Analysis of the physiological data revealed minor differences between the suited and unsuited condition which may reflect the presence of greater physiological stress affecting the response of each crew member during those flight segments when the pressure suit was worn. Clinical reports of postflight medical examiners established that the Gemini VII crew was in as good physical condition at the end of their 14-day mission as was the Gemini V crew after their 8-day mission. There exists a general impression, based on the flight experience accumulated during the Gemini Program, that the postflight physical condition of the Gemini VII crew was significantly better than expected. It is believed that a very important contribution to this surprisingly good condition was the fact that the Gemini VII crewmen performed a significant portion of their flight outside the pressure suits.

Crew preferences are strongly in favor of unsuited flight. The limitations and restrictions imposed by the pressure suit and the associated spacecraft compromises required by the suited configuration have resulted in significant compromises by the crew in terms of mobility, comfort, and efficiency. The advantages of unsuited operations in terms of physical mobility are obvious.

There is no evidence of any advantage in suited operations over unsuited operations within the cabin. Differences in the cabin environment were small, and the data clearly show that the cabin environment with crewmen unsuited was satisfactory for unsuited flight. In over 600 hours of United States' manned flights to date, there has been no evidence of cabin environment problems which would preclude the accomplishment of flight operations outside the pressure suit.

INTRODUCTION

The 14-day Gemini VII flight included extensive periods during which the crew was outside the pressure suits. The flight was of sufficient duration to obtain data contrasting crew physiological conditions with the pressure suits on and off. A procedure was devised and included in the flight plan to determine the relative comfort and utility of the two environments and to evaluate unsuited flight operations in support of Apollo planning. This report is based primarily on the observations and data obtained on the Gemini VII flight. Details of the plan together with modifications thereof made during the flight are included as an appendix to this report.

This report is an evaluation of:

(a) Physiological effects of suited compared with unsuited orbital flight on the Gemini VII flight crew

(b) Pressure suit comfort and utility from a crew standpoint

(c) Effects of suited and unsuited flight on the cabin environment

(d) Characteristics of the G5C lightweight pressure suit

PHYSIOLOGICAL EFFECTS OF SUITED COMPARED WITH UNSUITED ORBITAL FLIGHT ON THE GEMINI VII FLIGHT CREW

The Gemini VII mission presented biomedical observers with their first opportunity to evaluate the responses of crewmen flying in space without pressure suits, and to make direct comparisons with the responses from the same crewmen while flying with their pressure suits on. It was also the first opportunity to evaluate the relative physiological cost, if any, extracted from the astronauts as a consequence of their being required to wear pressure suits.

Evaluation of Inflight Biomedical Telemetry Data

Telemetry records were systematically reviewed for a difference between responses of either crewman when suited and unsuited. Table I is a partial list of the numerous ways in which the physiological data were plotted, cross-plotted, and compared in attempts to detect significant trends relative to the suit configuration. The differences noted were slight. The respiration rate was fairly constant from both astronauts. Similarly, body temperature showed no tendency to vary in relation to suited or unsuited flight. Therefore, no detailed study of these measurements was undertaken.

Table II is a list of statistical averages computed from Gemini VII physiological data taken on each crew member, both in and out of the pressure suits. No rigorous statistical test for significance has been accomplished. Most of the differences noted in the averages are small, and few will individually support an interpretation. It is noted, however, that the pattern of these differences consistently tends to favor the unsuited state. Of the parameters listed, heart rates during exercise and all direct and derived measurements of blood pressure show a consistent variation with a change in the suited status of the crewmen. Changes in peak heart rate and the product of heart rate and pulse pressure during exercise periods reveal a tendency in both crewmen toward increased cardiovascular response to a standard exercise when unsuited compared to suited. At first glance, it appeared that the same exercise imposed a greater demand on the cardiovascular system when the crew member was unsuited than the demand when he was suited. After further analysis, it appeared more likely that the responses reflect the fact that each crewman accomplished the exercise more vigorously when out of his suit than when suited. One of the shortcomings in using the bungee exerciser device for calibrated work is that the user can expend more force and energy than is required to stretch the elastic to its predetermined length. The values in question are therefore interpreted as a valid reflection of the movement-inhibiting effect of the pressure suit; that is, when the astronaut was suited he apparently pulled the exerciser more deliberately, and consequently he pulled with less expended energy than was the case when he exercised unsuited. The product of heart rate and pulse pressure is also higher, systolic pressure tends to be higher, and diastolic pressure tends to be lower in the unsuited condition than in the suited condition during other than exercise periods. This may be indicative of an inclination toward greater vigor and activity in the unsuited state. Whether this physical manifestation is primarily the result of a physiological or psychological reaction is not evident, but in either case it is in no way unfavorable to unsuited flight.

During the flight, it was observed that the heart rate and blood pressure appeared to vary in a different way depending on whether a crewman was in or out of his pressure suit. Specifically, heart rate and blood pressure response to measured exercise during the first 6 days of the mission were vigorous and consistent with ground-based control values in the pilot, who was out of his suit from the second through the sixth day. The same responses from the command pilot, who remained suited, showed a gradual departure from his ground-based control responses, with failure of his blood pressure to respond to exercise in a normal fashion by the end of the sixth day. On the seventh and eighth days of the mission, pilot heart rate and blood pressure responses showed a similar tendency to depart from preflight normal values while he was in his suit. Command pilot responses were much nearer normal during this period, and he was out of his suit during that time. The normal response to measured exercise with the inflight bungee exerciser is a moderate increase in heart rate during exercise, along with a widening of pulse pressure. At the midpoint of the mission, each crew member showed generally normal responses when unsuited, but showed little or no widening of pulse pressure following exercise when wearing the pressure suit. During the twelfth day of the mission, after both crew members had donned their suits for the Gemini VI-A rendezvous, heart rate and blood pressure responses of each crew member to this measured exercise remained normal or slightly higher in comparison to preflight exercise response. This departure from the trend which was evident in the midportion of the mission is thought to represent a reflection in the cardiovascular system of a general "keying up" of all body systems in anticipation of the rendezvous activity. On the thirteenth day of the mission, the exercise response of both crewmen diminished, but the last data point on the fourteenth day was again essentially normal for both crew members. In summary, heart rate and blood pressure responses to exercise, if considered throughout the mission, failed to show a consistent relationship to the suited or unsuited status of either crewman. However, if the high tension periods of the Gemini VI-A rendezvous and the reentry preparation are viewed as special cases, then the heart rate and blood pressure responses to exercise were characteristically normal for each crewman while he was out of his suit, and showed a tendency toward degraded response by each crewman while wearing the pressure suit. Figure 1 shows the measured heart rates and blood pressures obtained during the Gemini VII mission.

Heart rate data obtained during sleep periods were examined to see if differences in resting heart rate were apparent between the suited and unsuited conditions. Mean resting heart rate values revealed no significant differences. Figure 2 shows the high and low heart rates reported at each tracking station pass during which the Gemini VII crewmen were asleep. Figure 3 shows the sleep period heart rate data averaged over the period of flight prior to rendezvous. The figures reveal that heart rate variations about the mean were slightly greater during sleep periods when the suit was worn. Additionally they suggest a tendency toward more rapid relaxation into a deeper and a less disturbed sleep during unsuited flight.

It appeared about halfway through the mission that the rate of water consumption during suited periods was different from the rate during unsuited periods. Records of water intake over the entire mission (see fig. 4) failed to bear out this relationship. However, the difference between water consumption and urine excretion strongly indicates that the insensible water loss was definitely correlated to the suited status of the crewmen. Table III shows water intake and urine output during periods for which preliminary urine excretion data were available. Assuming that water balance was generally maintained over the major portion of the flight, relative rates of water loss through sweating may be calculated from the difference between oral intake and urine output (insensible water loss). The reduced urine volume voided by each astronaut while suited, and the correspondingly greater amount of water given off through other avenues almost certainly indicate a greater output of water as perspiration by each astronaut while suited than while unsuited. Even though these preliminary values may not be too accurate, the data clearly show that more water was used by each astronaut to maintain thermal comfort when in the suit than when unsuited.

Comparative Results of Postflight Medical Examinations

Throughout the Gemini Program, one of the most consistent medical observations has been the initial postflight response of crew members to the tilt-table test. From GT-3 through Gemini VI-A, the astronauts exhibited postflight changes in heart rate and blood pressure, as compared to their preflight responses, which were directly proportional to the duration of the mission. The tilt-table test is believed to be a good measurement of the ability of the cardiovascular system to respond to the challenge imposed by the presence of gravity when body posture is passively changed from a reclining to an upright attitude. The magnitude of this cardiovascular system response after each Gemini flight, showing a generally linear increase of heart rate change in response to tilting, is shown in figure 5 as a function of mission duration. Had the Gemini VII crew experienced cardiovascular reflex changes in relation to mission duration comparable to the changes which had been measured in their colleagues, their heart rates during initial postflight tilt tests should either have risen to the exceedingly high values indicated by extrapolating the trend line in figure 5 out to 14 days, or else the crew members should have experienced cardiovascular syncope because of an inability of the circulatory system to compensate for this magnitude of change. In the actual postflight examination, one crew member did exhibit a tendency toward syncope, although this occurred without the prior dramatic rise in heart rate which would be expected. The other Gemini VII crew member showed a rise in heart rate on his initial postflight tilt which was considerably less than that seen in either astronaut following the Gemini V flight of 8 days duration. Because of the tendency toward syncope indicated by the pilot during the first tilt-table tests, the second tilt-table test results were also examined. These tests on GT-3 through Gemini VI-A gave evidence of the same increasing heart rate response as a function of the duration of flight as is evident in the first tilt-table series, but the rate of increase is less. For both series the data for the Gemini VII flight demonstrate a divergence from the consistent trend exhibited by the small group of Gemini crewmen who preceded them in orbital flight. This divergence appears to favor the unsuited mode of operation.

The clinical impressions of the physicians who performed the preflight and postflight medical examinations of the Gemini V and Gemini VII crewmen form another basis for comparison. With the exception of the specialist in internal medicine, the same physicians formed the medical evaluation team used in these two flights. They reported that the postflight condition of both Gemini VII crew members was at least as good as the postflight condition which they had observed in the Gemini V crew members. In some respects, the Gemini VII crew clearly fared better. There was far less scaling of their scalps and desquamation of skin over their bodies. The following statement is a narrative report by the Manned Spacecraft Center (MSC) Flight Surgeon who was on the recovery ships for the Gemini V and Gemini VII missions. It succinctly summarizes the main findings of the examining physicians.

> "After recovery of the Gemini VII crew aboard the U.S.S. Wasp, both astronauts walked unassisted to the sick bay where an extensive medical examination was conducted. It was noted at the time of space suit doffing that the crew's underwear was soaked with perspiration and that body odor was only mild. Upon removal of the underwear, the skin appeared to be in remarkably good condition. There was minimal scalp scaling and this was in marked contrast to the considerable dandruff present in the Gemini V crew. The skin, although wet with perspiration, did not produce the moist, somewhat greasy desquamation that had been present with both members of the Gemini V crew. Like the Gemini V crew, there was no evidence of skin irritation except at the sites of biosensor application. The reaction at these sites was moderate and of approximately the same degree on both crews. Neither infection nor cyst formation occurred. The erythematous reaction at the sensor sites cleared at approximately the same rate as the similar reaction in the Gemini V crew and was completely clear in about five days. The Gemini VII crew reported that these sensor sites did not itch at the time of suit removal and that the itching they had experienced in flight was remarkably mild. Both crew members commented spontaneously that the opportunity to remove the space suits during the flight had significantly increased their personal comfort. Moreover, the pilot stated that his comfort was greater than the command pilot because he had been out of his suit for a longer period of time during the inflight phase of the mission. As noted following previous missions, there was no evidence of pressure points on either crew member's body. Likewise, areas where one might expect to find skin irritation, e.g. the axillae and the perineum, were notably clear at the time of immediate postflight examination. Skin turgor was good and there was no evidence of drying or epilation. In summary, the excellent condition of the Gemini VII crew members' skin and skin

appendages is quite possibly attributable to the time that each of them spent out of his space suit during the mission. Other factors contributing to this finding, such as individual variation, skin temperature, sweating, and bacterial flora, must also be considered to have influenced the ultimate postflight condition of the crew."

PRESSURE SUIT COMFORT AND UTILITY FROM A CREW STANDPOINT

The following subjective evaluation of the use of pressure suits is based primarily on comments by the Gemini VII flight crew.

The main topics to be discussed are:

(a) Crew comfort as related to efficiency

(b) Mobility and level of effort associated with movement in the cockpit

(c) Visibility

(d) Personal hygiene

(e) Comparison of suit-on and suit-off operations

Crew Comfort as Related to Crew Efficiency

After spending 7 days in the G4C suit, the Gemini V crew reported that, in their opinion, it would be difficult to complete a 14-day mission in that suit and next to impossible to perform the desired experiments and operational tests. The G4C suit was designed for the rigorous environment of extravehicular activity and to provide optimum mobility in a pressurized state. The G5C suit was developed to provide comfort and utility during a 14-day flight, retaining sufficient safety for emergencies. To a great extent this goal was met. However, living within a rubber bladder, which is basic to the concept of a pressure suit, is in itself the source of the discomfort problem. The effect of this discomfort on crew efficiency can be evaluated in only a very qualitative manner because of the many contributing factors.

The Gemini V crew reported considerable discomfort near the end of the mission, but there was no outward indication of degraded efficiency. This result is to be expected because of the adaptability of the human body combined with the obvious motivation of the flight crew. The same phenomenon has been observed many times during aircraft flight tests when the pilot rated a particular control or flying characteristic as completely unacceptable, yet he would do very well in overcoming the unacceptable characteristic and be able to control the aircraft. The difference is one of pilot effort involved. However, it is only reasonable to expect that, after a sustained period of working with an unacceptable system, a rapid decline in human efficiency will result. Logic requires that over a sustained period, the crew must be kept at an acceptable comfort level to maintain overall efficiency of operation. Crew experience during the Gemini VII mission indicates that an acceptable comfort level is best obtained in a shirtsleeve environment having a reasonable cabin temperature and a level of humidity which will rapidly dissipate peak body-heat loads.

Mobility and the Level of Effort Associated with Movement in the Cockpit

While the crew was wearing the G5C suit used in the Gemini VII mission, their mobility was superior to that achieved when using previously designed suits. The principle of a pressure suit involves a limitation of mobility. The pilot must expend effort in bending the suit. This does not sound difficult, but it adds an increment to the work required for every movement. The fixed suit torso length has a discomforting effect. As an example, the Gemini VI-A pilot experienced a backache and a sore spot on his forehead, incurred as a result of the constant strain against his suit while leaning forward to accomplish operational tasks.

In addition, there was the encumbrance of the wrist rings which constantly hindered motion and resulted in difficult access to tight places such as the aft food boxes in the Gemini spacecraft. The crew objected to the encumbrance of the wrist rings during normal controller and switch operations, and in particular they were constantly concerned over inadvertently actuating switches with the wrist rings. Again, the suit caused compromises in the spacecraft which placed an added burden on the crew to make the system workable.

Visibility

Crew visibility has not been seriously affected by the pressure suit. The G5C suit as originally designed was particularly good from the standpoint of an absence of visual restrictions. The command pilot's hood was modified with a smaller, hard visor, the end result of which was a restriction of vision when looking up or through the top of the window.

There is, however, the problem of using optical instruments with the visor closed. The long eye relief required of optical instruments results in added bulk and greater difficulty in maintaining eye alignment with the optical axis.

Personal Hygiene

The problems of personal hygiene are a basic limitation to the use of a pressure suit because of limited access to wash the body and its extremities. This problem is aggravated by the higher heat level and the resulting greater perspiration when suited. The problem of defecation has been reported in each Gemini flight and, although great improvements have been made, the problem still exists; and the restrictions imposed by the pressure suit are the real problem. Again, the added burden required to overcome equipment limitation is placed on the flight crew.

Comparison of the Suit-on and Suit-off Configuration

On the second day of Gemini VII the pilot doffed his suit completely and observed a marked improvement in comfort, mobility, ability to manipulate controls, vision, and personal hygiene. The ventilation over the body was good and the skin felt more comfortable. The pilot was able to perform biosensor repair functions readily and it was much easier and more efficient for him to exercise and conduct flight plan activities than it was for the command pilot.

On approximately the sixth day the command pilot removed his suit, and the pilot donned his suit. On the eighth day both crew members were in the unsuited configuration. At this time the cabin comfort level improved markedly due to increased humidity evidenced by less dryness of the skin and decreased stuffiness of the nose. It was possible to maintain this comfort level with only one coolant pump operating.

Toward the end of the flight, engineering data relative to suit-off operation were obtained in accordance with instructions transmitted from the ground. (See part II of the appendix.) In the forced convection mode, one blue (inlet) suit hose was positioned at each crewman's shoulder area, while one red (outlet) suit hose was located near the outboard knee of each crewman. Both suit flow valves were placed in the full open position and the coolant circuit flow was adjusted to the full cold position. Crew comfort in this mode was excellent. A flow pattern developed from the shoulder across the body to the knee. The main stream of the cooling air did not impinge on either crewmen's body and comfort was maintained without the sensation of direct flow cooling. This mode of operation was preferred and was used for the majority of the mission.

An attempt was made to evaluate pilot comfort in the free convection mode. The suit air flow on the pilot's side was shut off and the pilot's suit outlet hose was placed in the left footwell which effectively removed the pilot from the area of forced convection. The pilot comfort in this mode was not as good as in the forced convection mode. After 5 minutes, the pilot felt a lack of air circulation; however, the command pilot was very comfortable. The pilot's temperature did not become a serious problem, but there was a greater tendency to perspire and a general awareness of a lack of circulation. After 21 minutes, the pilot was still cool enough, but described the environment as a little stuffy. After 30 minutes, the environment was still stuffy. At 31 minutes, the cabin fan was activated and the cabin recirculation valve was placed to the 45-degree position. This action was effective in producing enough circulation in the right footwell to materially increase the pilot's comfort.

From a crew standpoint, suits-off operation is far superior in terms of crew comfort, mobility, controls manipulation, visibility, communication, and personal hygiene. These factors contributed to increased crew efficiency and reduced demand on the spacecraft systems for cooling and ventilation.

CHARACTERISTICS OF THE LIGHTWEIGHT PRESSURE SUIT

Lightweight Pressure Suit Configuration

The G5C pressure suit was designed to remove the encumbrances and restrictions inherent in the G4C pressure suit while maintaining a pressurization capability for emergency situations. From tests, training, and previous missions, it had been determined that the helmet neck ring, wrist rings, and basic thickness of the garment had been the areas of greatest restriction.

Hood and Visibility

The helmet and neck ring were replaced with a removable hood with visor and a standard flight helmet. A zipper was used which permitted separation of the hood and suit everywhere except directly behind the head. The zipper also allowed the separation plane of the hood and suit to be lower on the chest than had been possible with the neck ring. The standard flight helmet was found to be very good from an operational standpoint, and the absence of the neck ring on the G5C suit gave the Gemini VII crew more freedom for head movement than was possible in the G4C suit.

Stowage and visor visibility degradation provided some inconveniences and concern to the Gemini VII crew. The stowed position of the hood was behind the head, and the bulkiness of the hood and visor caused minor discomfort. Scratches and dirt accumulated on the visor as the mission progressed and impaired visibility during the reentry phase. Prior to the hood being scratched, the visibility was adequate, but the field of view was restricted when looking either up or down.

Mobility

The internal net material used in the G4C suit was not included in the G5C suit, except in the shoulder area. The thickness of the garment was considerably reduced by elimination of this material. The net does provide better mobility in a pressurized suit, but the G5C was to be pressurized only during emergency conditions. The net was kept in the shoulder area of the G5C suit to maintain reasonable mobility for the arms in the event of an emergency.

The wrist rings were the same configuration as those on the G4C suit. No suitable replacement for the ring configuration could be found in the time available. The primary problem with the wrist ring configuration was incurred during recovery of stowed items. The large ring was difficult or impossible to get through some of the storage doors. The problem was overcome by sliding the ring up on the arm as far as possible.

The Gemini VII crew found that reach and movement in the G5C suit were superior to that of the G4C suit. Though the difference was not great, the reduced thickness did provide easier movement. Operations to be accomplished in the back of the cabin were still difficult, and any function which required reaching aft or turning around proved to be quite strenuous. These same operations were very easy in the unsuited configuration.

In summary, the G5C suit performed the function for which it was designed by providing better mobility and easier doffing and donning than would have been possible with the G4C or G3C suits.

EFFECTS OF SUITED AND UNSUITED FLIGHT ON THE CABIN ENVIRONMENT

According to a plan included as part I of the appendix, the crew frequently measured the dry bulb and dew point temperatures at various points in the cabin. Temperature variations within the cabin at any given time were small. Typical values of cabin temperatures and relative humidity are presented in figure 6. Figure 7 shows the zone of comfortable conditions while wearing normal street clothing. The information was extracted from the NASA Life Sciences Data Book. Conditions within the cabin were generally within or near this zone.

An analysis of the relative humidity measurements in the cabin indicates a tendency for relative humidity to stabilize at values between 40 and 55 percent under various conditions of suited and unsuited flight. The values at which stabilization occurred could not be correlated with changes in the suited condition because of the differences in control settings of the environmental control system. The relative humidity increased as expected with the removal of a suit at 45, 147, and 191 hours ground elapsed time.

A special cabin-ventilation test was performed, starting at approximately 250 hours g.e.t., according to a procedure included as part II of the appendix. The cabin air temperatures and dew points measured during this test are shown in table IV. Crew comments concerning these tests were included under the section "Comparison of the Suit-on and Suit-off Configuration."

The differences in the effects of suited compared with unsuited operations on the cabin environment were small. During the early phase of the Gemini Program, there were many unknown characteristics associated with the performance of the environmental control system such as heat losses from the cabin walls. Because of the uncertainties, considerable discretion was justified in qualifying the demands upon the system. During the ensuing Gemini flights it has been shown that the cabin environment can be maintained within acceptable limits. The characteristics of this environment offer no impediment to out-of-suit crew operations. The observed differences in cabin environment during in-suit and out-of-suit operations tend to verify the statements of the crew, attesting to greater comfort in the unsuited configuration.

CONCLUDING REMARKS

Based on all available data used in the preparation of this report, the following statements may be presented.

1. Greater mobility, more sensitive responses, ease of physical activity, et cetera, are obvious characteristics of the unsuited configuration and are desirable characteristics in any environment in which they can be safely achieved.

2. The restrictive nature of a pressure suit results in an inclination toward less vigorous activity by the flight crew.

3. Differences in physiological measurements were not marked, but indicated that the effects of a suits-off configuration on the flight crew is not adversely different from, and may be slightly better than, the effects of a suits-on configuration.

4. The crew's excellent general physical condition postflight may be due in part to the unsuited operations.

5. Crew preferences are for unsuited operations.

TABLE I.- STATISTICAL PLOTS USED TO DETECT SIGNIFICANT DIFFERENCES BETWEEN SUITED AND UNSUITED OPERATIONS

Change in pulse pressure as a result of exercise	versus	Pre-exercise pulse pressure
Change in systolic pressure as a result of exercise	versus	Pre-exercise systolic pressure
Change in systolic pressure as a result of exercise	versus	Pre-exercise pulse pressure
Change in diastolic pressure as a result of exercise	versus	Pre-exercise diastolic pressure
Change in diastolic pressure as a result of exercise	versus	Pre-exercise pulse pressure
Change in pulse pressure as a result of exercise	versus	Pre-exercise heart rate
Pre-exercise heart rate	versus	Pre-exercise pulse pressure
Change in pulse pressure as a result of exercise	versus	Pre-exercise range of heart rate
Pre-exercise range of heart rate	versus	Pre-exercise pulse pressure
Change in pulse pressure as a result of exercise	versus	Peak heart rate during exercise
Peak heart rate during exercise	versus	Pre-exercise pulse pressure
Change in pulse pressure as a result of exercise	versus	Pre-exercise maximum heart rate
Pre-exercise minimum heart rate	versus	Pre-exercise pulse pressure
Pre-exercise mean heart rate	versus	Pre-exercise body temperature
Change in heart rate as a result of exercise	versus	Pre-exercise heart rate
Pre-exercise mean heart rate	versus	Pre-exercise pulse pressure
Daily water intake	versus	Elapsed time from lift-off
Average heart rate	versus	Elapsed time from exercise period

TABLE I.- STATISTICAL PLOTS USED TO DETECT SIGNIFICANT DIFFERENCES

BETWEEN SUITED AND UNSUITED OPERATIONS - Concluded

Change in heart rate as a result of exercise	versus	Change in pulse pressure as a result of exercise
Mean heart rate	versus	Elapsed time from beginning of sleep period
Mean maximum heart rate	versus	Elapsed time from beginning of sleep period
Mean minimum heart rate	versus	Elapsed time from beginning of sleep period
Range of heart rate (mean maximum minus mean minimum)	versus	Mean heart rate
Maximum heart rate during sleep periods	versus	Elapsed time from lift-off
Minimum heart rate during sleep periods	versus	Elapsed time from lift-off
Change in pulse pressure as a result of exercise	versus	Elapsed time from lift-off
Cumulative change in pulse pressure as a result of exercise	versus	Elapsed time from lift-off
Cumulative water consumption	versus	Elapsed time from lift-off

TABLE II.- AVERAGE PHYSIOLOGICAL MEASUREMENTS DURING

SUITED AND UNSUITED FLIGHT

Measurement	Pilot (a)		Command pilot (a)	
	Suited	Unsuited	Suited	Unsuited
Peak heart rate during exercise	84	94	94	103
Heart rate X pulse pressure (pre-exercise)	3797	4471	5159	5660
Heart rate X pulse pressure (post-exercise)	4351	5222	4705	7131
Change in heart rate X pulse pressure (post-exercise, pre-exercise)	554	751	546	1471
Maximum heart rate (other than exercise periods)	71	69	79	78
Minimum heart rate (other than exercise periods)	57	57	64	64
Range of heart rate (other than exercise periods)	14	13	15	14
Range of heart rate (sleep periods)	11	9	15	14
Heart rate (other than exercise periods)	64	62	71	70
Pulse pressure (pre-exercise)	62	67	57	68
Pulse pressure (post-exercise)	67	71	58	76
Change in pulse pressure (post-exercise, pre-exercise)	5	4	1	8
Systolic pressure (pre-exercise)	129	131	129	137
Systolic pressure (post-exercise)	131	133	135	148
Diastolic pressure (pre-exercise)	67	64	72	69
Diastolic pressure (post-exercise)	64	62	78	72
Change in systolic pressure (post-exercise, pre-exercise)	2	2	5	11
Change in diastolic pressure (post-exercise, pre-exercise)	-3	-2	6	3
Respiration rate	16.1	15.5	14.9	14.0

[a]Based on 260 hours of data from insertion to rendezvous.

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TABLE III.- COMPARISON OF INSENSIBLE WATER LOSS DURING SUITED AND UNSUITED OPERATIONS

	Time involved, hr (a)	Water intake		Urine output		Insensible water loss (b)	
		Quantity, oz	Rate, oz/hr	Quantity, oz	Rate, oz/hr	Quantity, oz	Rate, oz/hr
Command pilot							
Suited	148	486	3.3	164	1.1	322	2.2
Unsuited	112	405	3.6	203	1.8	202	1.8
Pilot							
Suited	89	247	2.8	62	0.7	185	2.1
Unsuited	171	498	2.9	183	1.1	315	1.8

[a] Based on 260 hours of data from insertion to rendezvous.

[b] Measured as the difference between water intake and urine output. This is a crude measurement but the correlation is valid.

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TABLE IV.- RESULTS OF SPECIAL VENTILATION TESTS

Measurement	Force convection mode test at 275 hours, g.e.t.	Free convection mode test at 304 hours, g.e.t.			Force convection mode test at 308 hours, g.e.t.
		Reference	Command pilot	Pilot	
Cabin air temperature, °F					
Between seats	79	78			76
12 inches from chest			77	76	
Suit inlet hose	65		66	(a)	66
Suit outlet hose	76		69	(b)	76
Wall	79				77
Cabin dew point, °F					
Between seats	62	66			65
12 inches from chest			64	68	
Suit inlet hose	52		56	(a)	55
Suit outlet hose	60		63	(b)	64

NOTES: (a) Suit airflow was shut off during this test.

(b) Outlet hose located in the command pilot's footwell and no measurements were taken.

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TABLE IV.- RESULTS OF SPECIAL VENTILATION TESTS

Measurement	Force convection mode test at 275 hours, g.e.t.	Free convection mode test at 304 hours, g.e.t.			Force convection mode test at 308 hours, g.e.t.
		Reference	Command pilot	Pilot	
Cabin air temperature, °F					
Between seats	79	78			76
12 inches from chest			77	76	
Suit inlet hose	65		66	(a)	66
Suit outlet hose	76		69	(b)	76
Wall	79				77
Cabin dew point, °F					
Between seats	62	66			65
12 inches from chest			64	68	
Suit inlet hose	52		56	(a)	55
Suit outlet hose	60		63	(b)	64

NOTES: (a) Suit airflow was shut off during this test.

(b) Outlet hose located in the command pilot's footwell and no measurements were taken.

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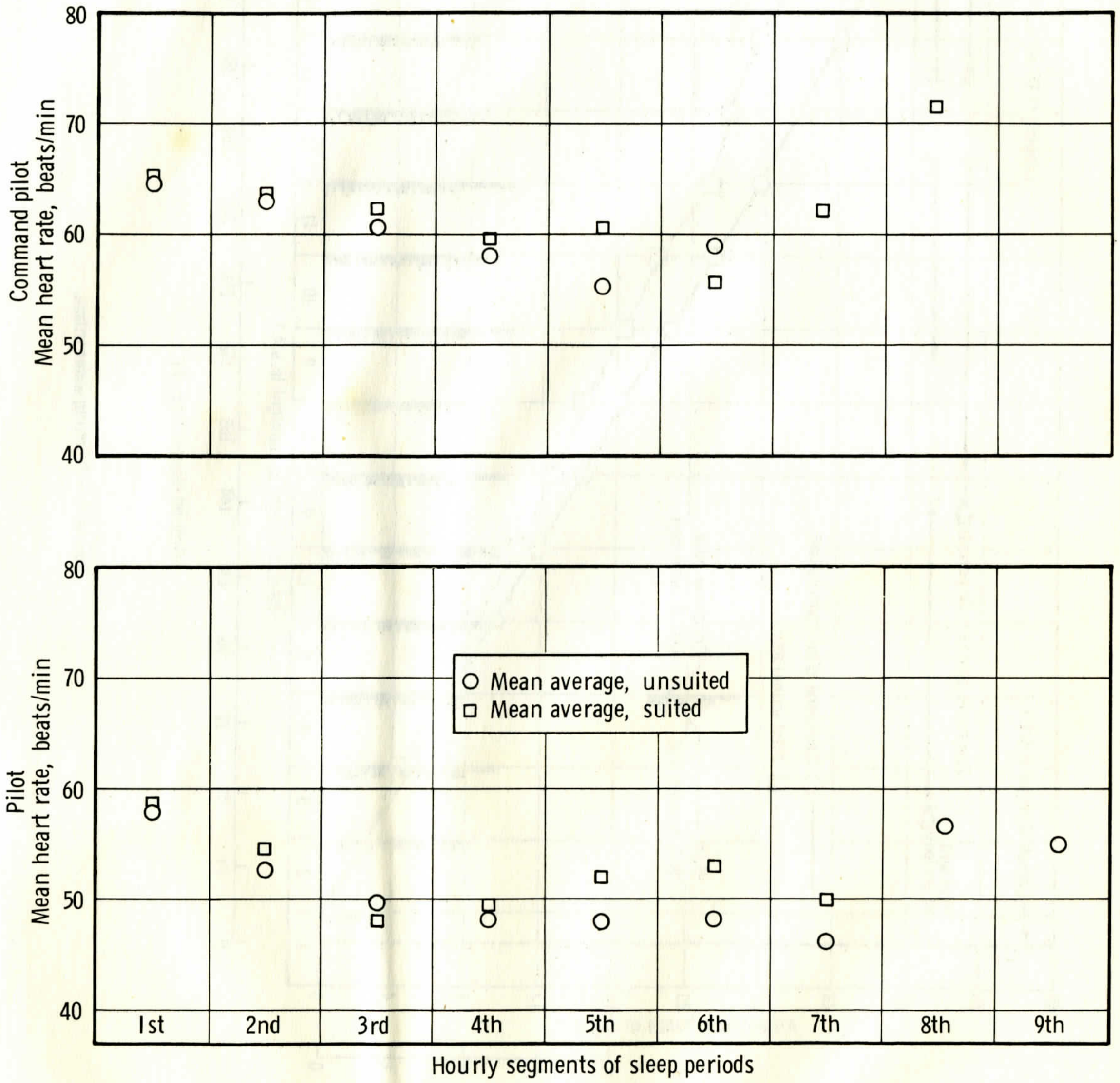

Figure 3. - Heart rate variation (averaged over sleep periods from insertion to rendezvous).

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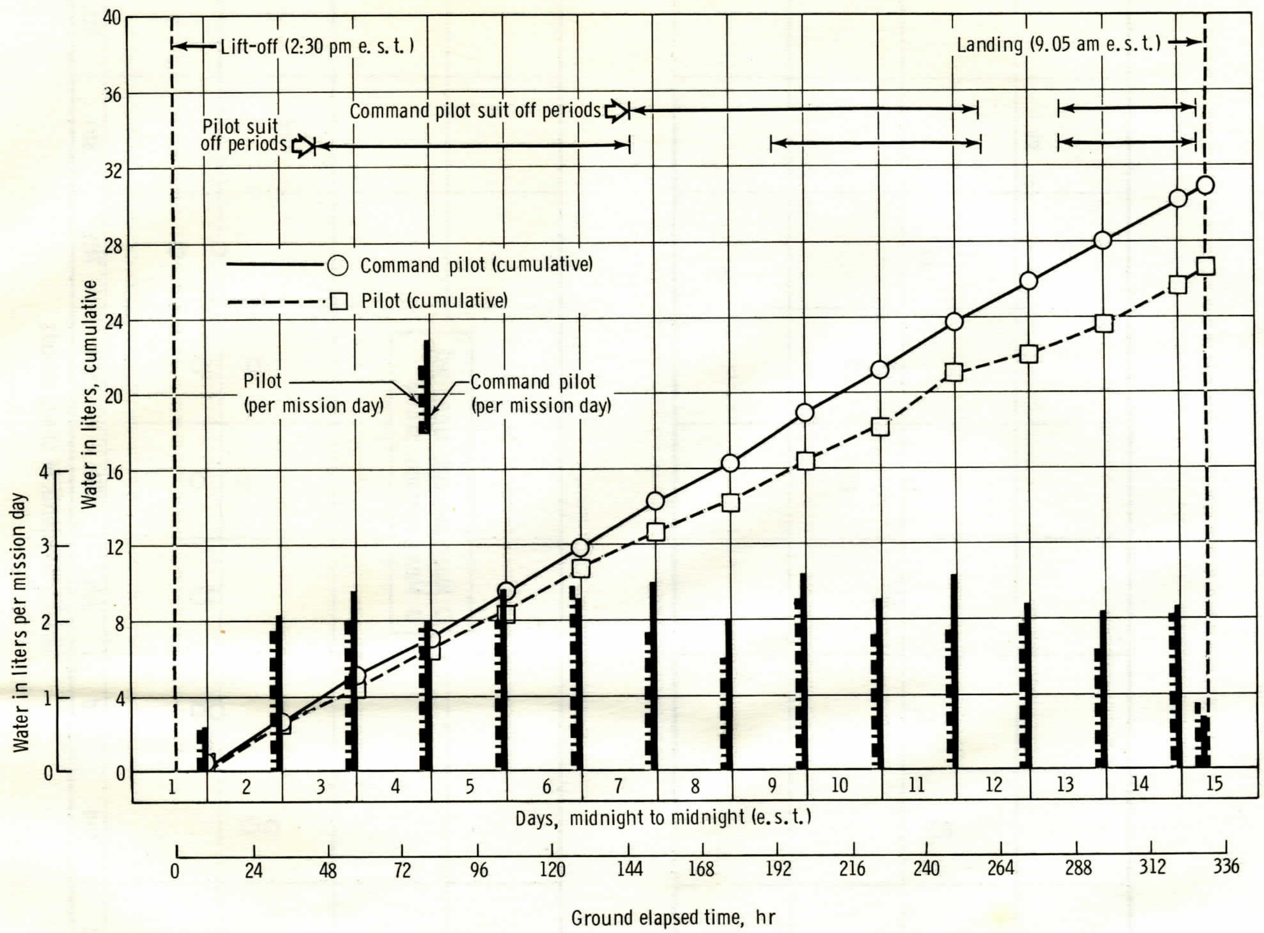

Figure 4. - Drinking water intake.

NASA-S-66-153 JAN

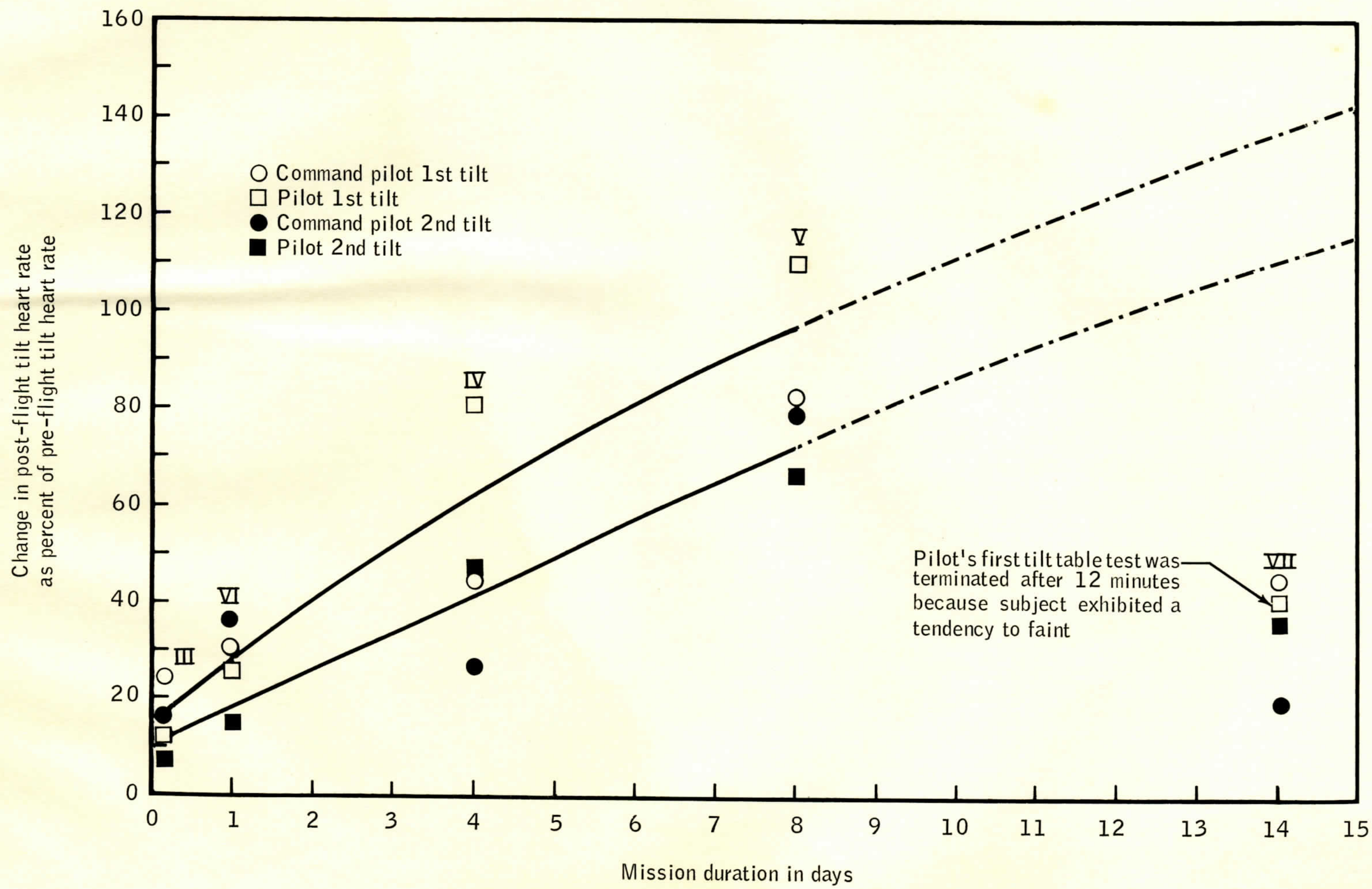

Figure 5. - Heart rate tilt response compared with mission duration.

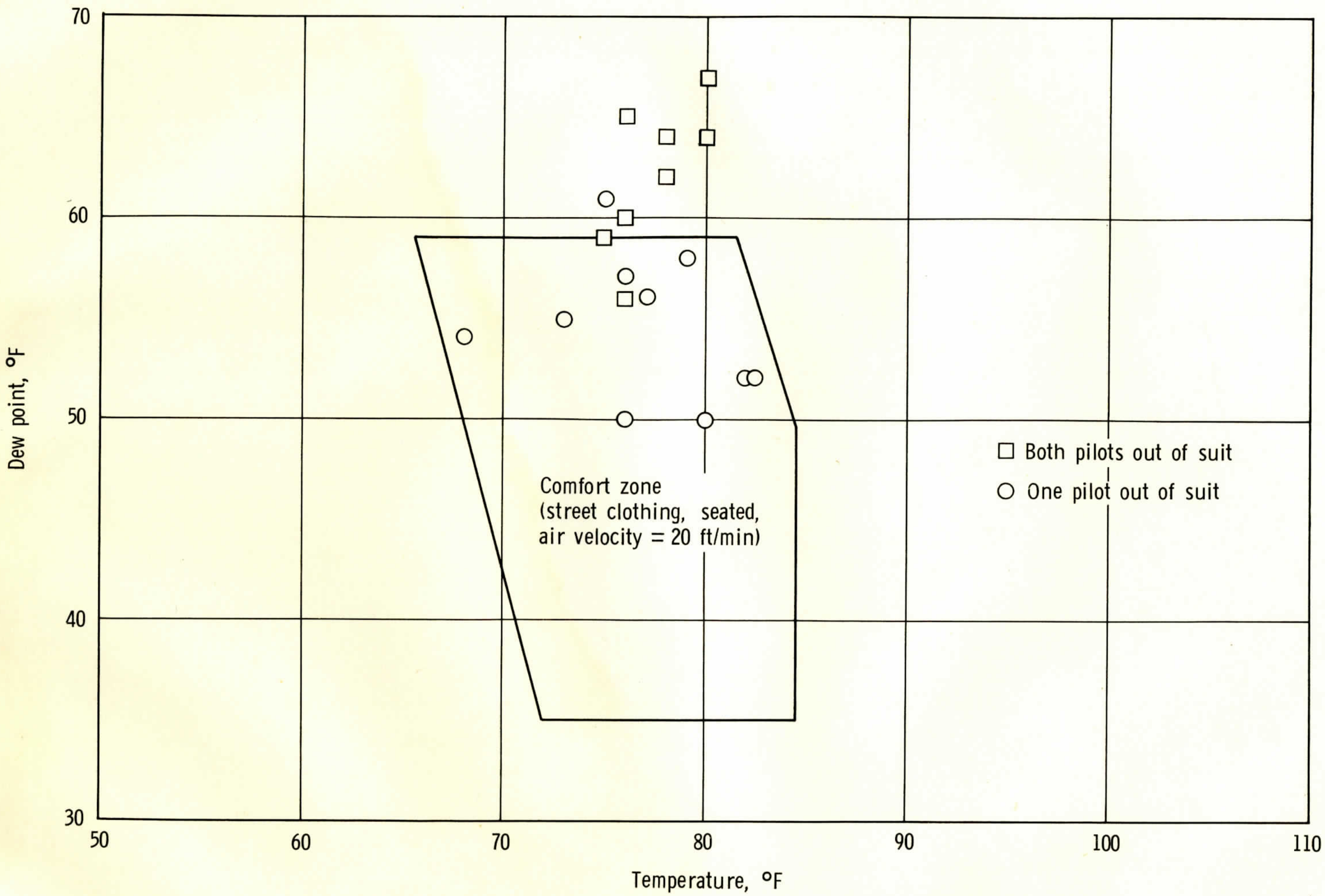

Figure 7. - Actual environment compared to thermal comfort zone.

APPENDIX

PROCEDURES FOR EVALUATION OF UNSUITED OPERATIONS DURING THE GEMINI VII MISSION

Part I

Prior to the Gemini VII mission, a test plan was developed to provide both objective and subjective data on the relative merits of suited and unsuited operations during orbital flight.

The purposes in obtaining these data are for an evaluation of the following:

(a) Unsuited environment

(b) Effects of various suit configurations on relative humidity

(c) Relative comfort suited versus unsuited

(d) Apollo unsuited operation

The data which will be gained from this evaluation are as follows:

(a) Thermal comfort and control (subjective)

(b) Mobility (subjective)

(c) Regional wall temperature - dew point hygrometer (measured)

(d) Regional cabin temperature (measured)

(e) Body temperature (telemetry only) (measured)

The preflight planned and actual procedures for conducting this evaluation are shown in the following table.

UNCLASSIFIED

Time	Planned configuration	Actual configuration
Launch through 2 - 1 Go—no-go	Both pilots fully suited	As planned
After Go—no-go	Command pilot and pilot go to partial suit configuration	As planned
Launch + 3 days (after second sleep period)	Pilot removes suit for 24-hour evaluation (orbital suit optional)	As planned
Launch + 4 days	Pilot dons suit and command pilot removes suit	As planned except on launch + 6 days
Launch + 5 days	Alternate suit on and off between astronauts as desired, provided one astronaut is in suit at all times (partial)	Pilot removed suit on launch plus 8 days. Both pilots remained unsuited until rendezvous period
Spacecraft 6 rendezvous	Four hours prior to rendezvous until after final separation – both astronauts fully suited. (suit integrity check immediately after returning to full suit configuration)	As planned
After final separation from spacecraft 6	Alternate suit configuration as desired by crew	Both men out of suits
Sleep period prior to reentry	Return to full suit configuration (perform integrity check	Both pilots donned suits after sleep period

Humidity measurements are to be taken once each 12 hours during suit-on operations and once each 6 hours while the suit was off. The reading locations are as follows:

(a) Head area

(b) Footwell area

(c) Each hatch - dry bulb to be surface temperature

(d) Each window sill - dry bulb to be surface temperature

(e) Each side wall - dry bulb to be surface temperature

(f) Between seats as low as possible

The crewmen should mark points on the hatches, side walls, and window sills where readings are taken. The same location for each reading is satisfactory.

Record the ambient and dew point reading.

Note: The ambient reading should be made first. (Three times a day during meals)

Part II

During the Gemini VII mission, an additional evaluation was made by the crew with their suits off to determine the relative merits of the forced and free convection modes of cabin-air ventilation. Procedures were transmitted to the crew to establish the proper configuration and to identify data points required. The procedure to be followed to place both crewmen in the forced convection mode was as follows:

1. Position red (outlet) suit hose nozzle at knee of each crewman, and blue (inlet) suit hose nozzle at shoulder of each crewman.

2. Place both suit flow valves to full open.

3. Turn cabin fan off.

4. Turn cabin heat exchanger coolant flow off.

5. Adjust suit coolant flow as desired.

6. While in this configuration, make and record the following measurements over a minimum of a 24-hour period:

(a) Cabin temperature, wall temperature, and cabin dew point upon awakening and about 4 hours later. The data should be obtained during the daylight side of a revolution and the ground elapsed time at which the measurements are made should be noted.

(b) The position of the coolant flow valves for the cabin and suit heat exchangers should be recorded.

(c) The dry bulb temperature and dewpoint of the suit gas at the inlet of the red and blue suit hoses should be recorded upon awakening and about 4 hours later. This should be done over a station and on the daylight side.

(d) The recirculation valve position at that time should be recorded.

(e) Any subjective comments concerning the thermal comfort on the daylight and night side should be recorded.

The procedure to be followed with the command pilot in the forced convection mode and the pilot in the free convection mode was as follows:

1. Pilot attach his suit hose nozzles together with hose nozzle interconnect. (The pilot shut the suit airflow off and placed his outlet hose in the command pilot's footwell to accomplish this step of the procedure.)

2. Command pilot place red nozzle at his knee and blue nozzle at his shoulder with nozzles located for minimum disturbance to the pilot's air.

3. Turn off cabin fan, but turn back on if mode is unacceptable.

4. Command pilot select airflow he requires for comfort.

5. Adjust suit heat exchanger flow as desired, and turn off cabin heat-exchanger coolant flow (full hot).

6. Repeat steps 6(a) through 6(e) in the first procedure.