6(a). EXPERIMENT M-1, CARDIOVASCULAR CONDITIONING

Lawrence F. Dietlein, M.D. and William V. Judy
NASA Manned Spacecraft Center

SUMMARY

Intermittent venous occlusion of the extremities of man, during weightlessness simulation studies, has been demonstrated to be effective in preventing or mitigating the orthostatic hypotension observed following such simulations (refs. 1-3). A similar preventive measure was employed on the pilot of Gemini V with a view to determining the efficacy of pulsatile leg cuffs in preventing or lessening the orthostatic hypotension observed following previous space flights (refs. 4 and 5). Unfortunately, the cuff device was operative continuously during only the first 4 days of the 8-day mission. Postflight tilt-table responses of the command pilot and the pilot were considerably different, but the data cannot be construed as a conclusive demonstration that the observed differences were the result of the action of the pulsatile cuffs. The differences in the tilt responses of the Gemini V flight crew may be only a reflection of individual variability so commonly observed in biological experimentation. More data shall be required before a judgment can be rendered as to the efficacy of the pulsatile-leg-cuff technique in lessening postflight postural or orthostatic hypotension.

INTRODUCTION

Ground baseline studies in support of Experiment M-1 indicated that leg cuffs alone, inflated to 70-75 mm Hg for 2 minutes out of every 6, provided protection against cardiovascular deconditioning resulting from 6 hours of water immersion (ref. 6). Four healthy male subjects were immersed in water to neck level for a 6-hour period on two separate occasions, 2 days apart. Leg cuffs were utilized during the second immersion period. Referral to figures 6(a)-1 through 6(a)-4 reveals that 6 hours of water immersion did indeed result in cardiovascular deconditioning, as evidenced by cardio-acceleration in excess of that observed during the control tilt and by the occurrence of syncope in two of the four subjects. The tilt responses after the second period of immersion, during which leg cuffs were utilized, revealed that a definite protective effect was achieved; cardio-acceleration was lessened, and no syncope resulted.

During the postflight tilts, both crewmen sustained an increased pulse rate and a narrowed pulse pressure. The command pilot exhibited an increase of 78 beats/min in heart rate above his postflight resting level during the first tilt (4-hours postflight), and a 54 beat/min increase during the second tilt (8-hours postflight). The pilot exhibited a 46 beat/min increase during the first tilt and a 33 beat/min increase on the second tilt. Both crewmen revealed a marked decrease in both supine and upright heart rates 24 hours after recovery (supine rate decrease - 22 beats/min; upright rate decrease - 34 beats/min for each crew member). During the third, fourth, and fifth day after recovery, both crew members exhibited progressively decreasing supine and upright pulse rates, although these were still above preflight values.

During the first postflight tilts, the pulse pressure of each crew member exhibited narrowing as compared with preflight tilt and postflight resting values. During the second, third, and fourth postflight tilts, the command pilot continued to maintain a lower systolic pressure during tilt, whereas the pilot had returned to his normal preflight levels.

During the first postflight tilts, the command pilot and pilot exhibited an 89 and 87 percent increase, respectively, in leg blood volume. During the second tilt, however, the command pilot had increased this value to 149 percent over the preflight reading and the pilot to only 73 percent. Table 6(a)-II indicates the postflight changes in leg volume observed in the crews of Gemini IV and V:

TABLE 6(a)-II.- POSTFLIGHT LEG PLETHYSMOGRAPHIC VALUES

Days post recovery	Postflight change in volume per minute percent (a)			
	GEMINI V		GEMINI IV	
	Command pilot	Pilot	Command pilot	Pilot
1	[b]+119	+80	+22	+131
2	+44	+25	+27	+61
3	+73	+57	-38	+126
4	+78	+117		
5	+111	+97		

[a]Percent change in volume = cc/100 cc tissue/minute.

[b]+ indicates percent above preflight value; - indicates percent below.

The physiological mechanism responsible for the observed efficacy of the cuff technique remains evasive. One might postulate that the cuffs prevent thoracic blood volume overload, thus not activating the so-called Gauer-Henry reflex with its subsequent diuresis and diminished effective circulating blood volume. Alternatively, or perhaps additionally, one might postulate that the cuffs induce an intermittent artificial hydrostatic gradient across the walls of the leg veins by increasing venous pressure distal to the cuffs during inflation. This action simulates the situation that occurs in a one g environment and thereby maintains venomotor reflexes or "tone." Theoretically, this action should aid in preventing the pooling of blood in the lower extremities and increase the effective circulating blood volume in a subject standing upright in a one g environment. The precise mechanism or mechanisms of action must await further study.

EQUIPMENT AND METHODS

The cardiovascular-conditioning experiment equipment consisted of a pneumatic timing or cycling system and a pair of venous pressure cuffs (figs. 6(a)-5 through 6(a)-7). The cycling system was entirely pneumatic and alternately inflated and deflated the leg cuffs attached to the pilot's thighs to approximately 80 mm Hg pressure. The system consisted of three basic components:

(1) A pressurized storage vessel charged with oxygen to 3500 psig.

(2) A pneumatic control system for monitoring the pressurized storage vessel.

(3) A pneumatic oscillator system for periodically inflating and deflating the cuffs.

The pneumatic venous pressure cuffs were form-fitted to the proximal thigh area of the pilot. These consisted essentially of a 3 in. by 6 in. bladder enclosed in a soft nonstretchable fabric. The bladder was positioned on the dorsomedial aspect of each thigh. The lateral surface of the cuff consisted of a lace-type adjustor to insure proper fit.

Only the pilot wore the leg cuffs during the Gemini V mission. Upon activation of the manual shutoff valve, the cuffs were automatically pressurized to 80 mm Hg for 2 minutes of each 6-minute time interval. The system could operate continuously during flight, but it could be switched off for sleep periods. The experiment imposed no operational requirements other than activation of the device after insertion into orbit and deactivation prior to reentry.

RESULTS

The cardiovascular responses to three preflight 70-degree tilts for each crew member are summarized in table 6(a)-I (mean values):

TABLE 6(a)-I.- CARDIOVASCULAR RESPONSES TO PREFLIGHT 70-DEGREE TILTS

Pretilt, supine			70-degree tilt		
	Heart rate, beats/min	Blood pressure, mm Hg	Heart rate, beats/min	Blood pressure, mm Hg	Percent blood volume change in legs (cc/100 cc tissue/min)
Command pilot	58	109/72	75	111/79	3.01
Pilot	59	117/68	78	120/79	2.70

Thus, during tilt, a slight increase in heart rate, a relatively constant blood pressure with a slight increase in diastolic values, and a slight increase in leg volume were noted. These values reverted to the pretilt levels following return to the horizontal position.

The cuffs were programed in the flight plan to operate continuously for the full 8-day mission. After 4 days, however, the pneumatic programer stopped cycling when the oxygen pressure of the storage vessel dropped below operational levels.

The results of six consecutive postflight tilt procedures are indicated in figures 6(a)-8 through 6(a)-13 for the command pilot and in figures 6(a)-14 through 6(a)-19 for the pilot. Both crew members exhibited increased resting pulse rates during the first 2 days after recovery. Maximum increases in resting pulse rate over preflight resting values were observed on the first day after recovery (command pilot increase - 27 beats/min; pilot increase - 50 beats/min). Postflight resting blood pressure was below preflight values for the command pilot. His systolic pressure remained 10 mm Hg below preflight values for 3 days after recovery. His diastolic pressure readings were 8 mm Hg below preflight resting values for 4 days after recovery. The pilot exhibited an increased resting diastolic pressure (3 to 9 mm Hg) for 4 days postflight, whereas his systolic values were essentially identical with the preflight readings.

CONCLUSIONS

(1) The pilot's pulse rate and pulse pressure returned to normal within 2 days after recovery, whereas the command pilot required a somewhat longer period to return to preflight values.

(2) The pilot's narrowing of pulse pressure was less pronounced than that of the command pilot.

(3) The pilot's decrease in measured plasma volume was -5 percent; the command pilot's was -9 percent.

(4) The pilot's body weight loss was 8 1/2 pounds; the command pilot lost 7 1/2 pounds.

(5) The pilot's pooling of blood in the legs generally was less than that observed in the command pilot.

On the basis of the preflight and postflight data presented, one is tempted to conclude that the pulsatile cuff device was at least partially successful in lessening the severity of the postflight orthostatic responses observed in the pilot. But individual variation in response must be reckoned with when dealing with biological systems, and, although the data appear attractive and perhaps reflect a measure of protective "trend" in the use of the cuff technique, we cannot make such a conclusion on the basis of the data available from a single experiment. The differences observed in the tilt responses of the Gemini V crew may well be only a reflection of physiological variance in human subjects. More conclusive data shall be required before the pulsatile leg cuff can be judged a useful device or technique in mitigating the cardiovascular-deconditioning effects of space flight.

REFERENCES

1. Graveline, D. E.; and Balke, B.: The Physiologic Effects of Hypodynamics Induced by Water Immersion. USAF School of Aviation Medicine Report No. 60-88, Sept. 1960.

2. Graybiel, A.; and Clark, B.: Symptoms Resulting from Prolonged Immersion in Water: The Problem of Zero G Asthenia. Aerospace Medicine, vol. 32, 1961, p. 181.

3. Vogt, F. B.: Effect of Extremity Cuff-Tourniquets on Tilt Table Tolerance after Water Immersion. Aerospace Medicine, vol. 36, 1965, p. 442.

4. Berry, C. A.; Minners, H. A.; McCutcheon, E. P.; and Pollard, R. A.: Aeromedical Analysis. Results of the Third United States Orbital Space Flight, NASA SP-12, Oct. 3, 1962.

5. Catterson, A. D.; McCutcheon, E. P.; Minners, H. A.; and Pollard, R. A.: Aeromedical Observations. Mercury Project Summary Including the Results of the Fourth Manned Orbital Flight, NASA SP-45, May 15-16, 1963.

6. Vogt, F. B.: Personal Communication. Study to be published.

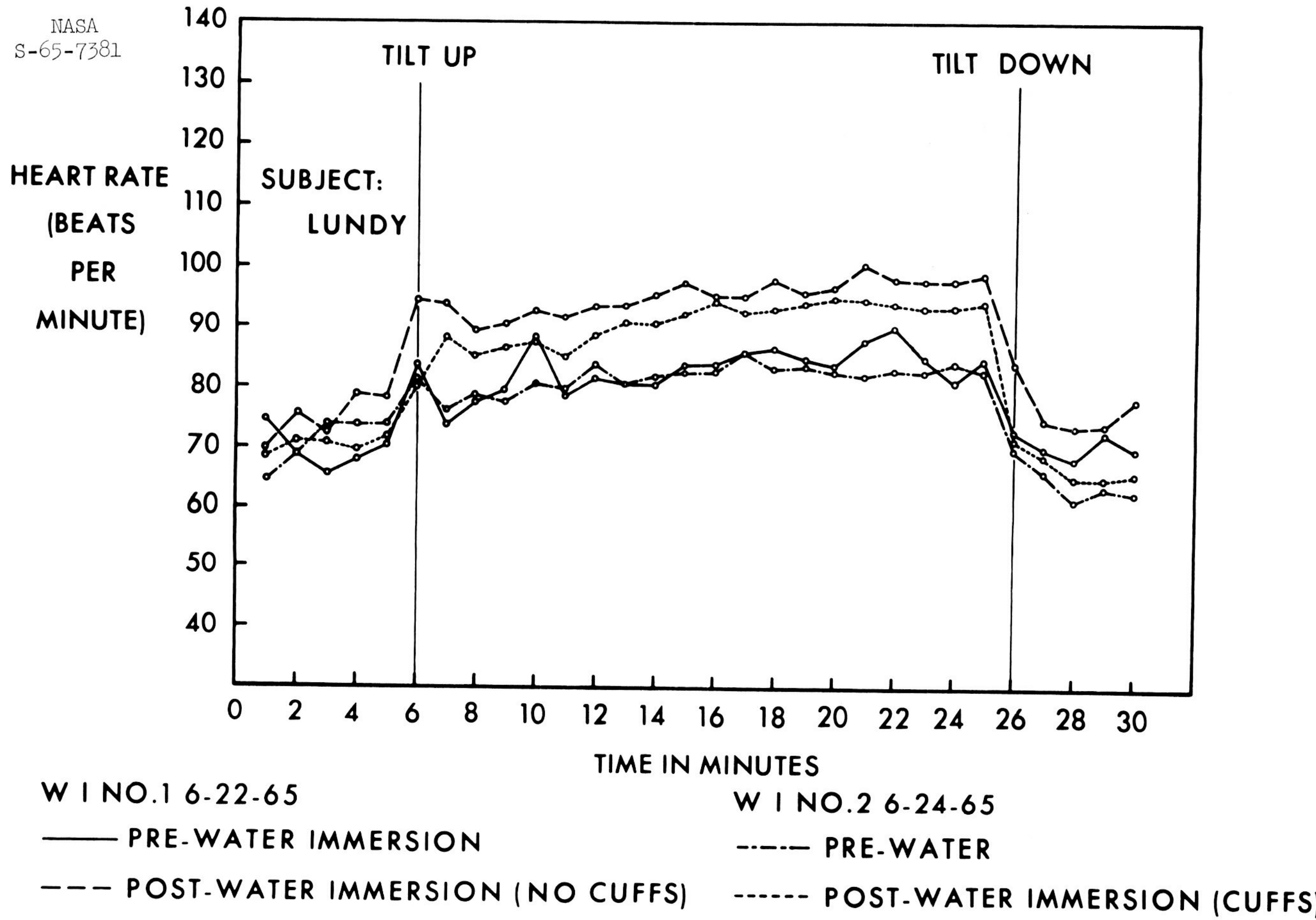

Figure 6(a)-1.- Six-hour water immersion study, test subject Lundy.

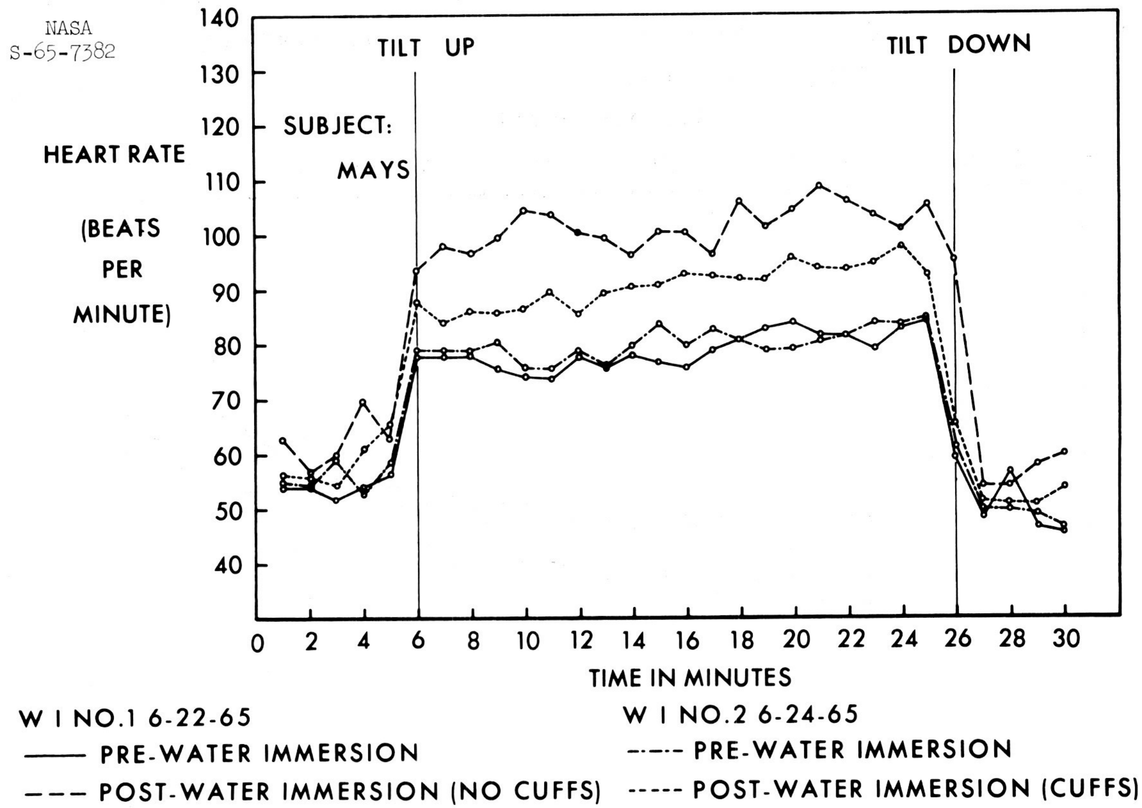

Figure 6(a)-2.- Six-hour water immersion study, test subject Mays.

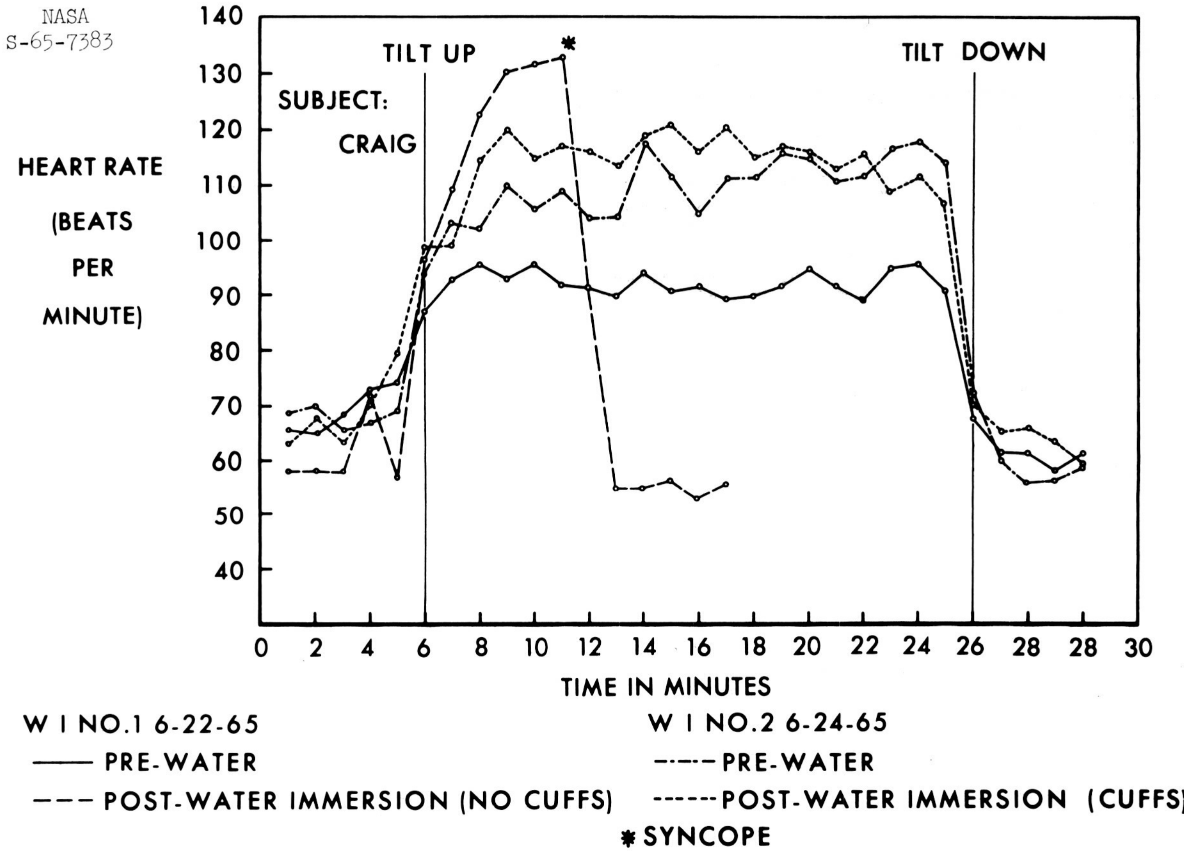

Figure 6(a)-3.- Six-hour water immersion study, test subject Craig.

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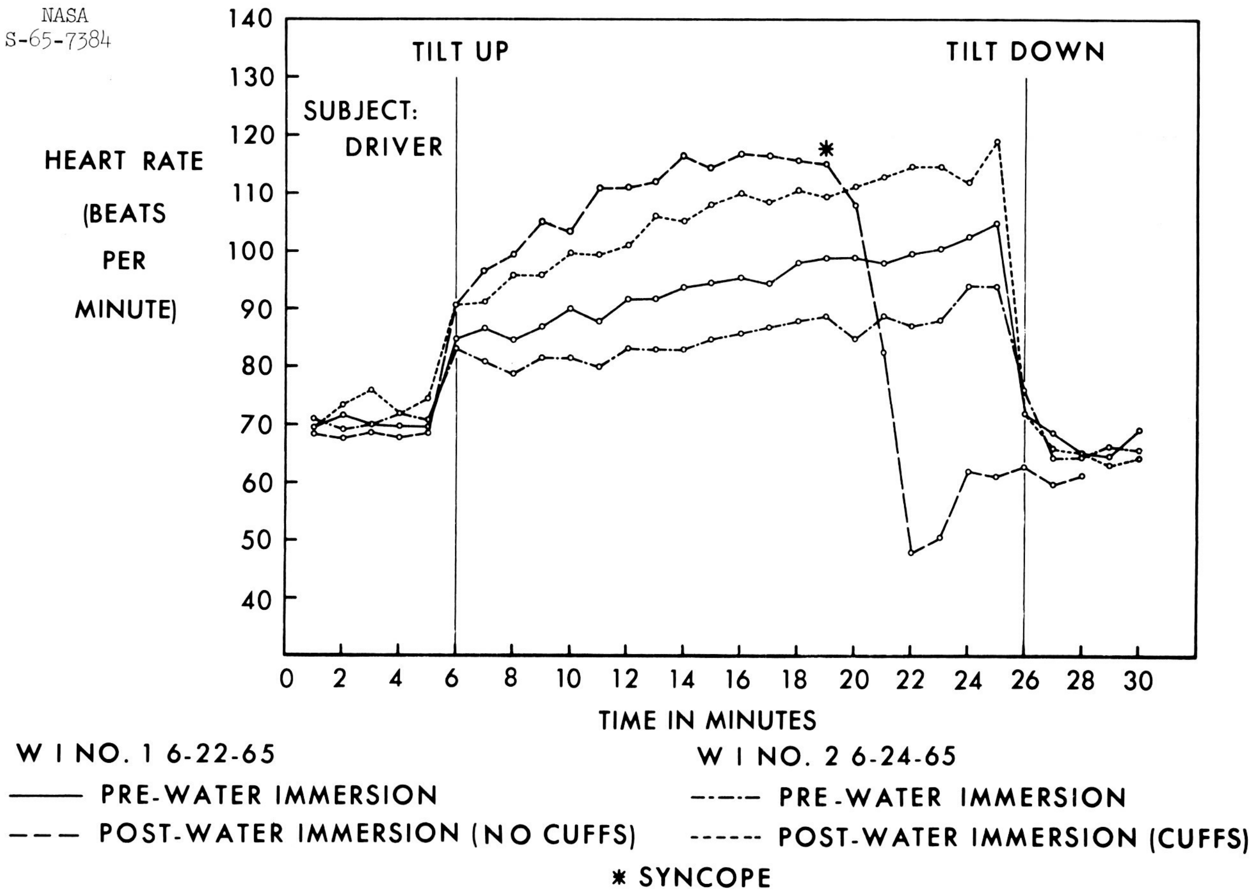

Figure 6(a)-4.- Six-hour water immersion study, test subject Driver.

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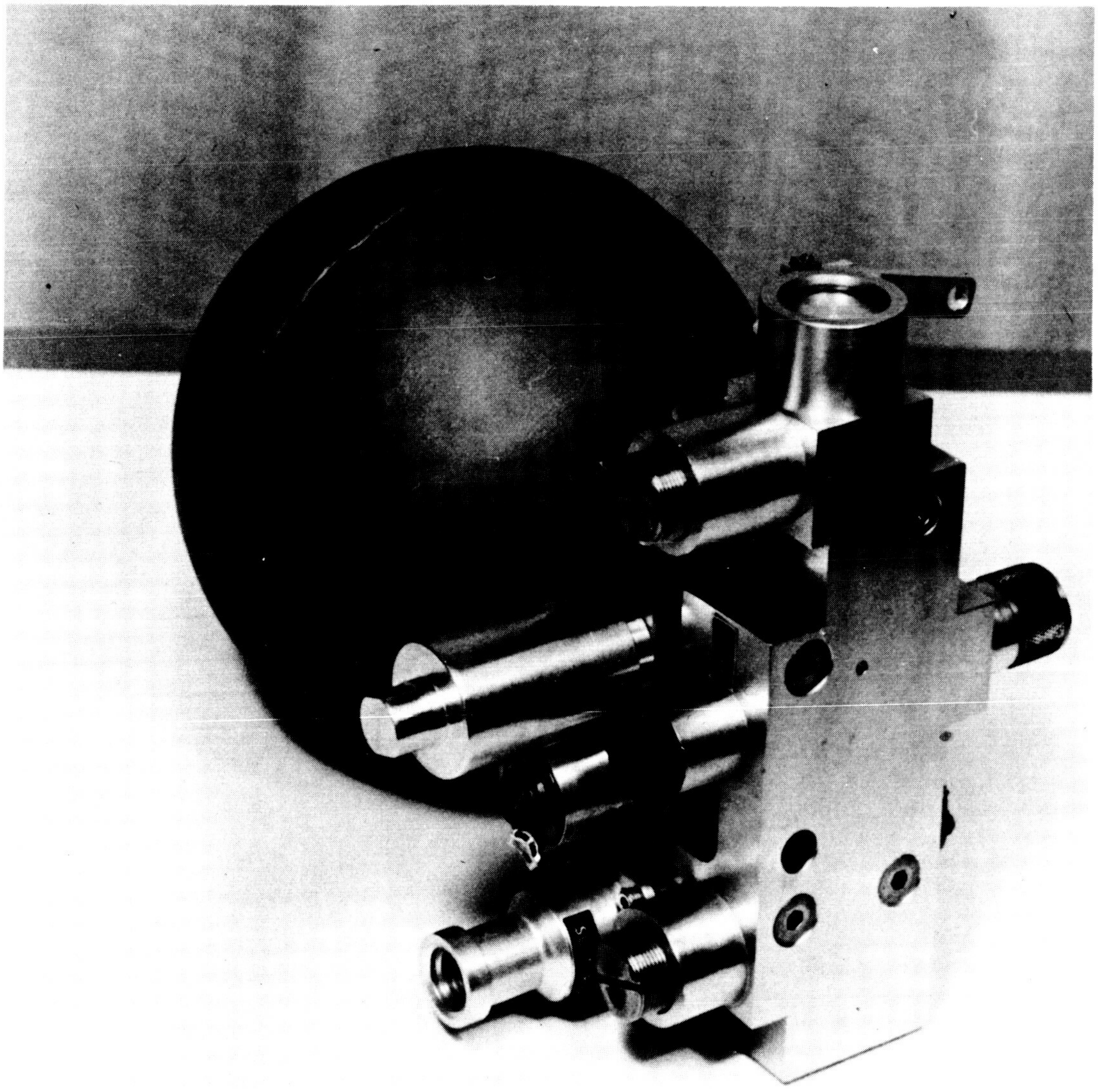

Figure 6(a)-5.- Cardiovascular reflex conditioning system.

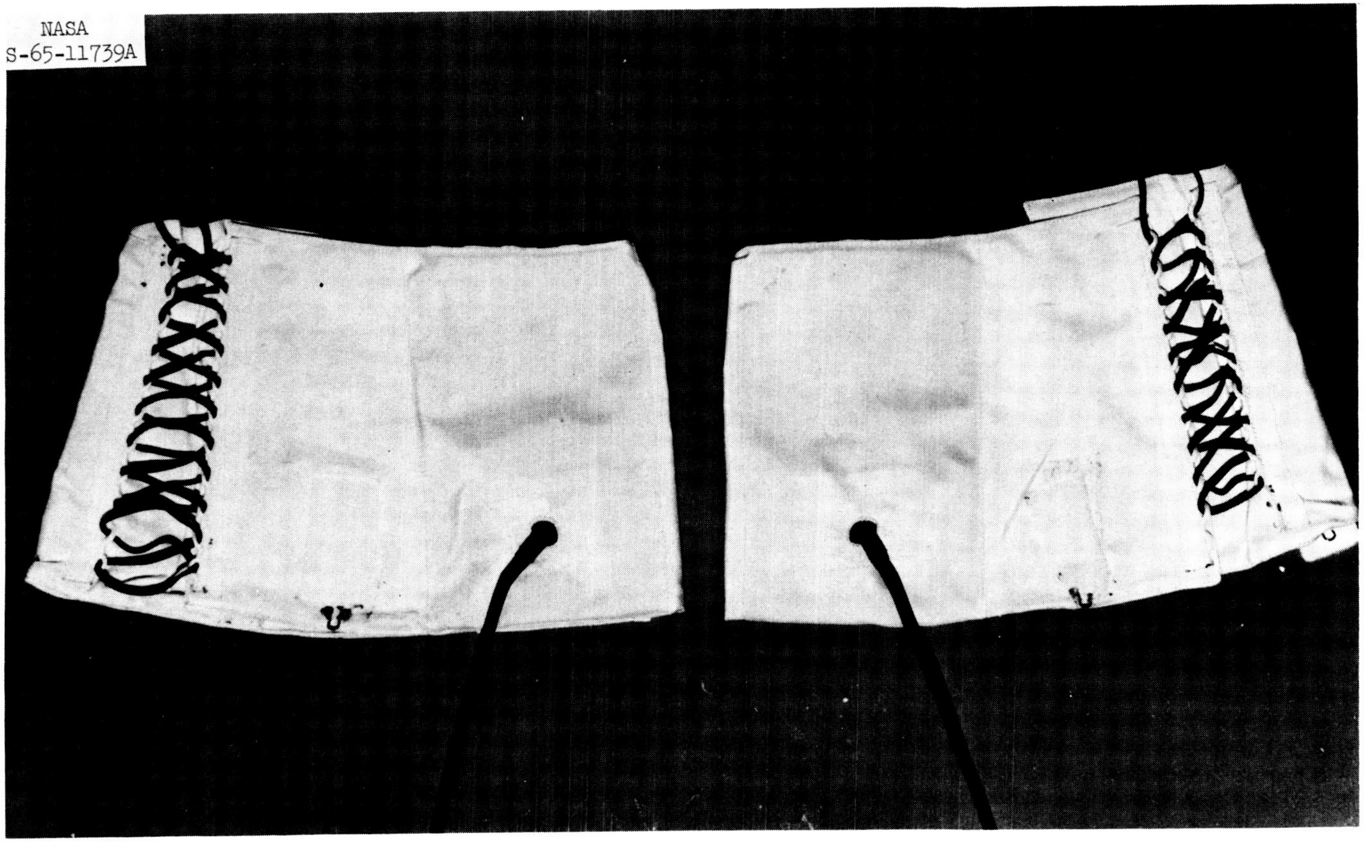

Figure 6(a)-6.- Pneumatic cuffs, cardiovascular continuing.

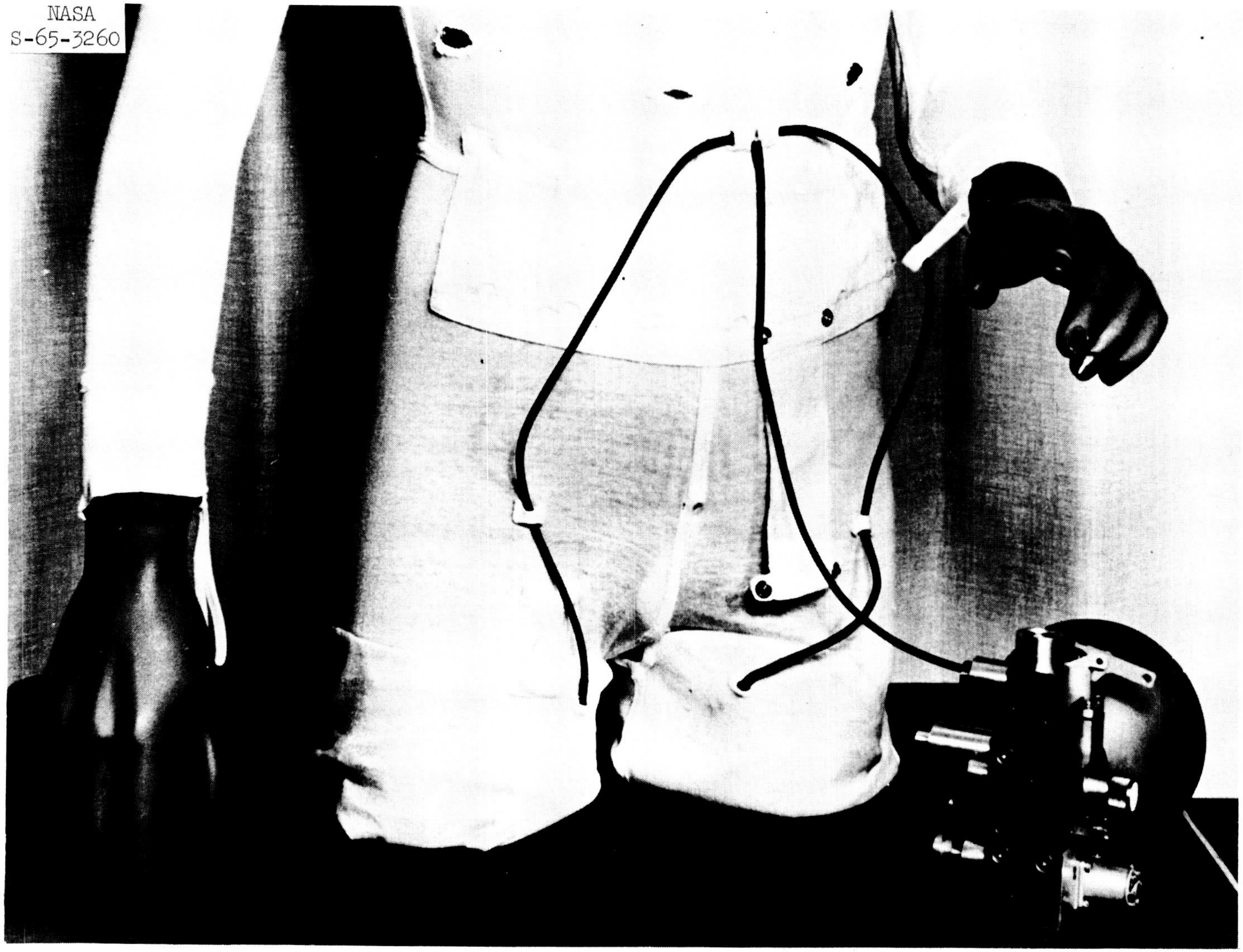

Figure 6(a)-7.- Cardiovascular reflex conditioning system and suit undergarment with pressure cuffs.

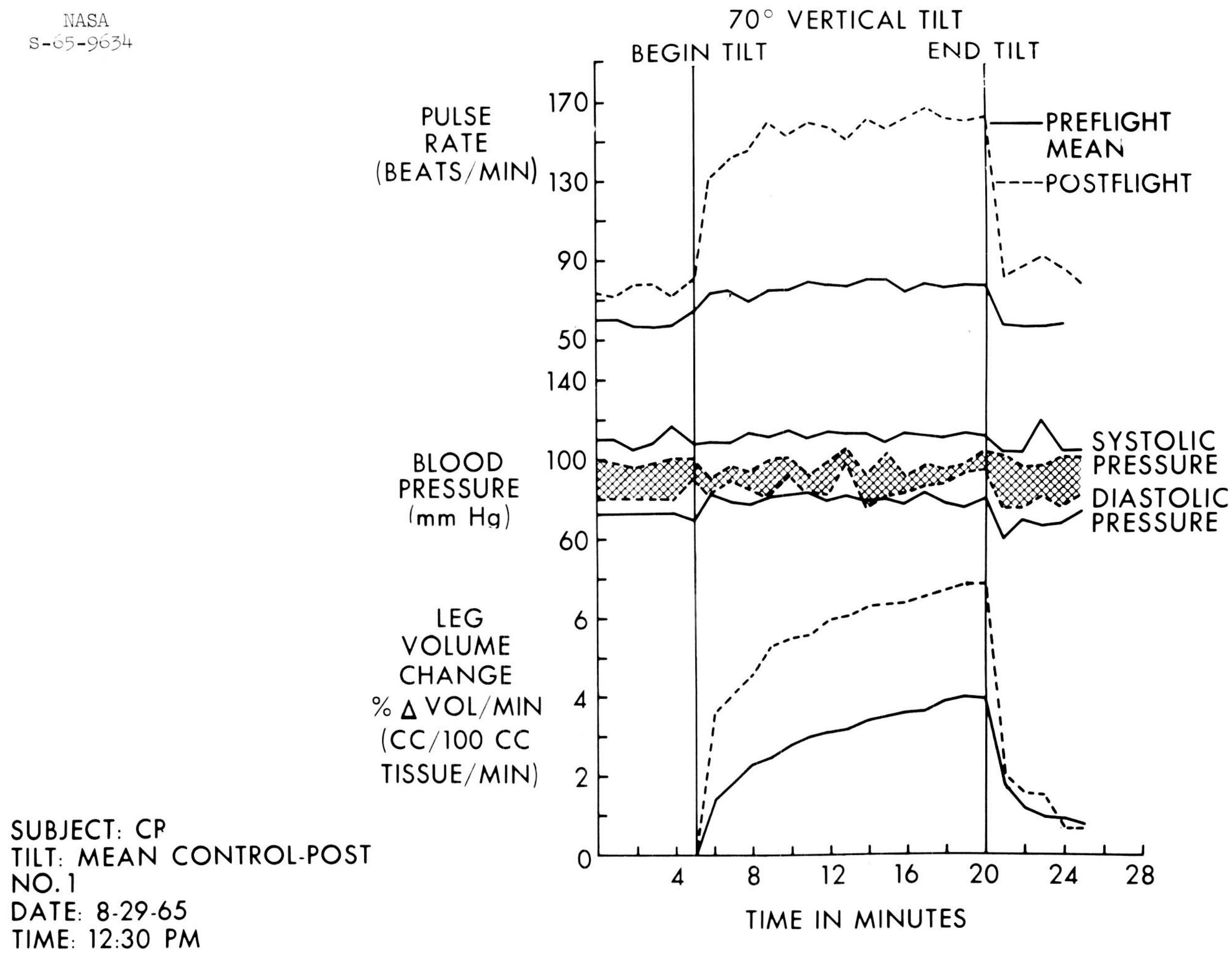

Figure 6(a)-8.- Command pilot tilt-table data.

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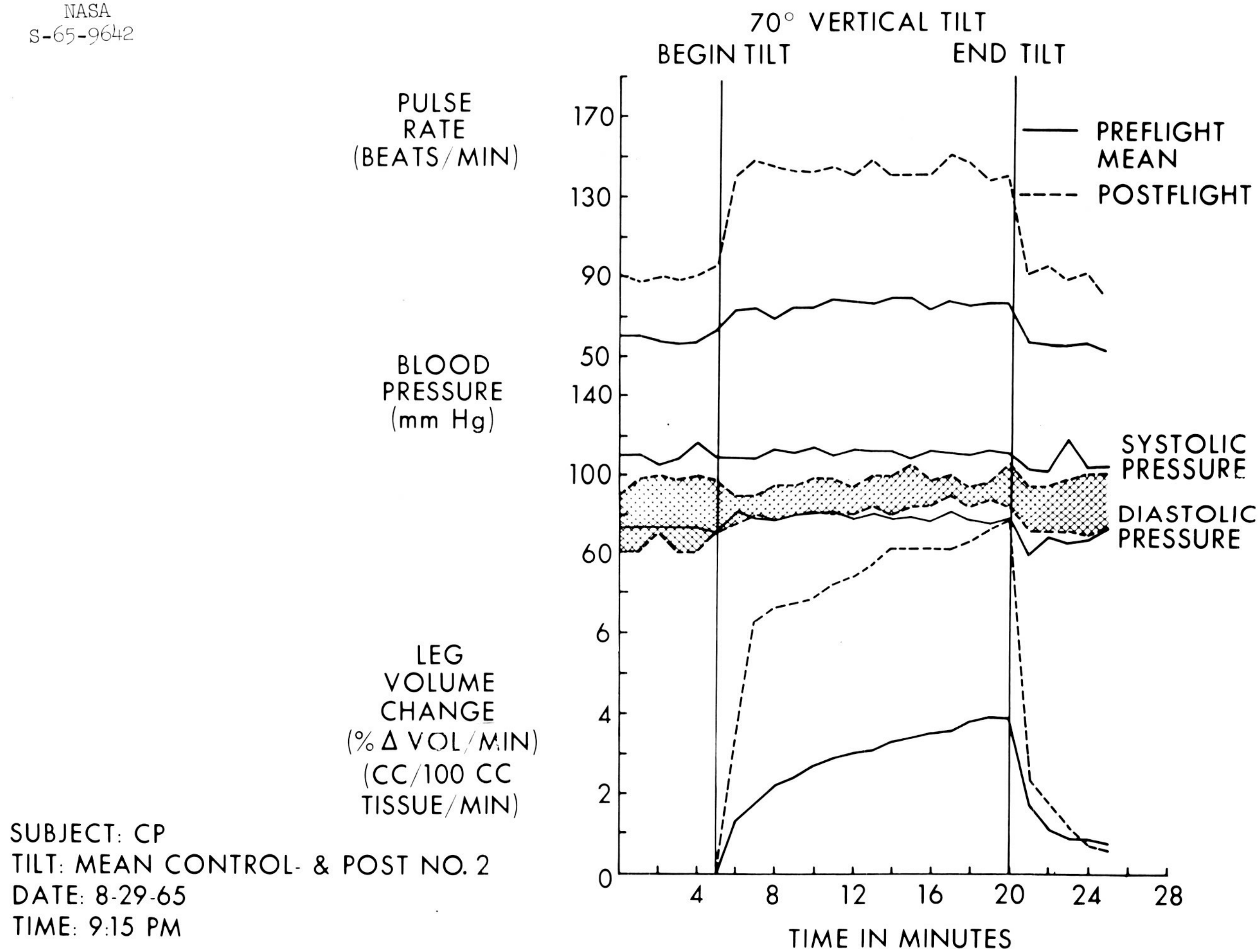

Figure 6(a)-9.- Command pilot tilt-table data.

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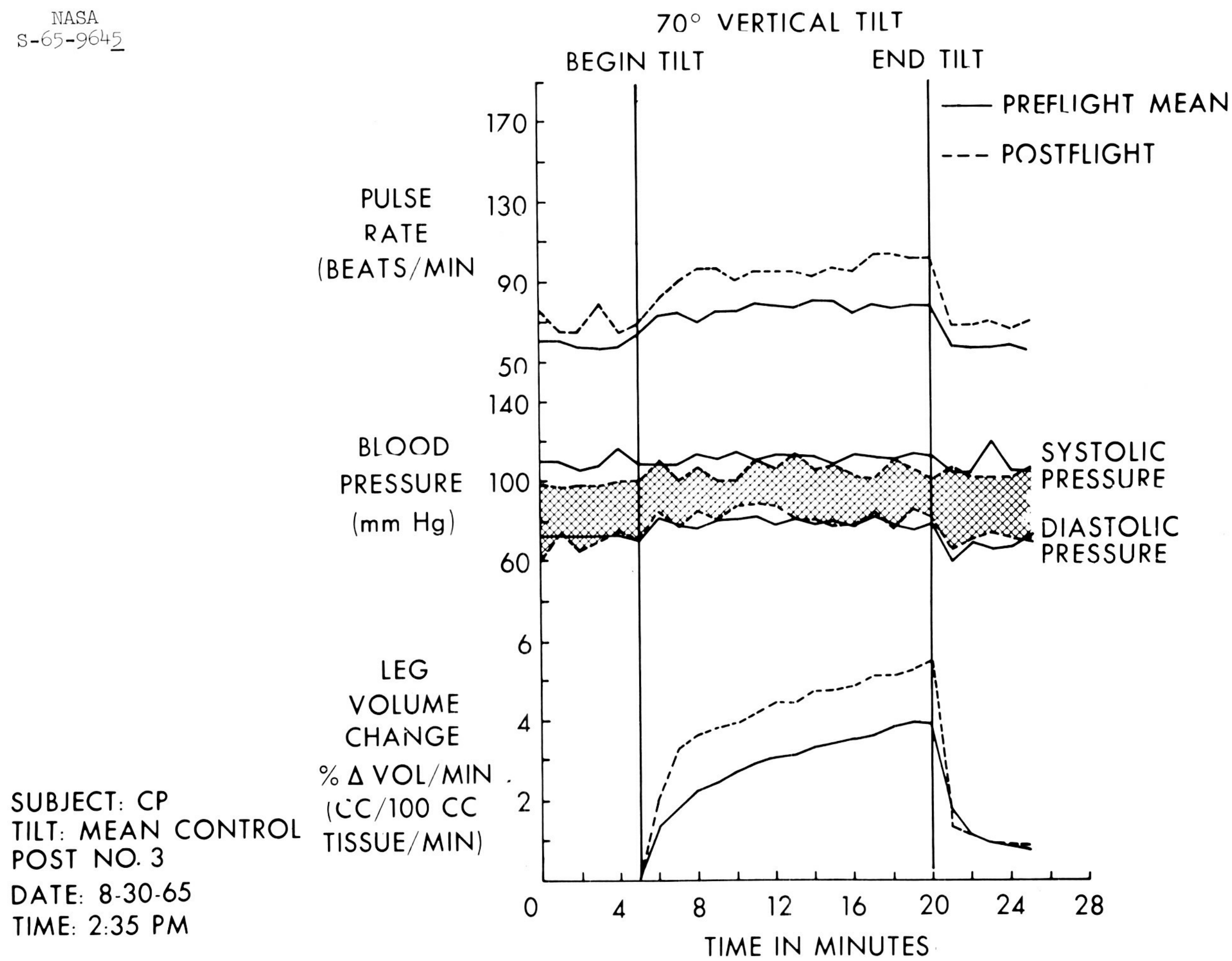

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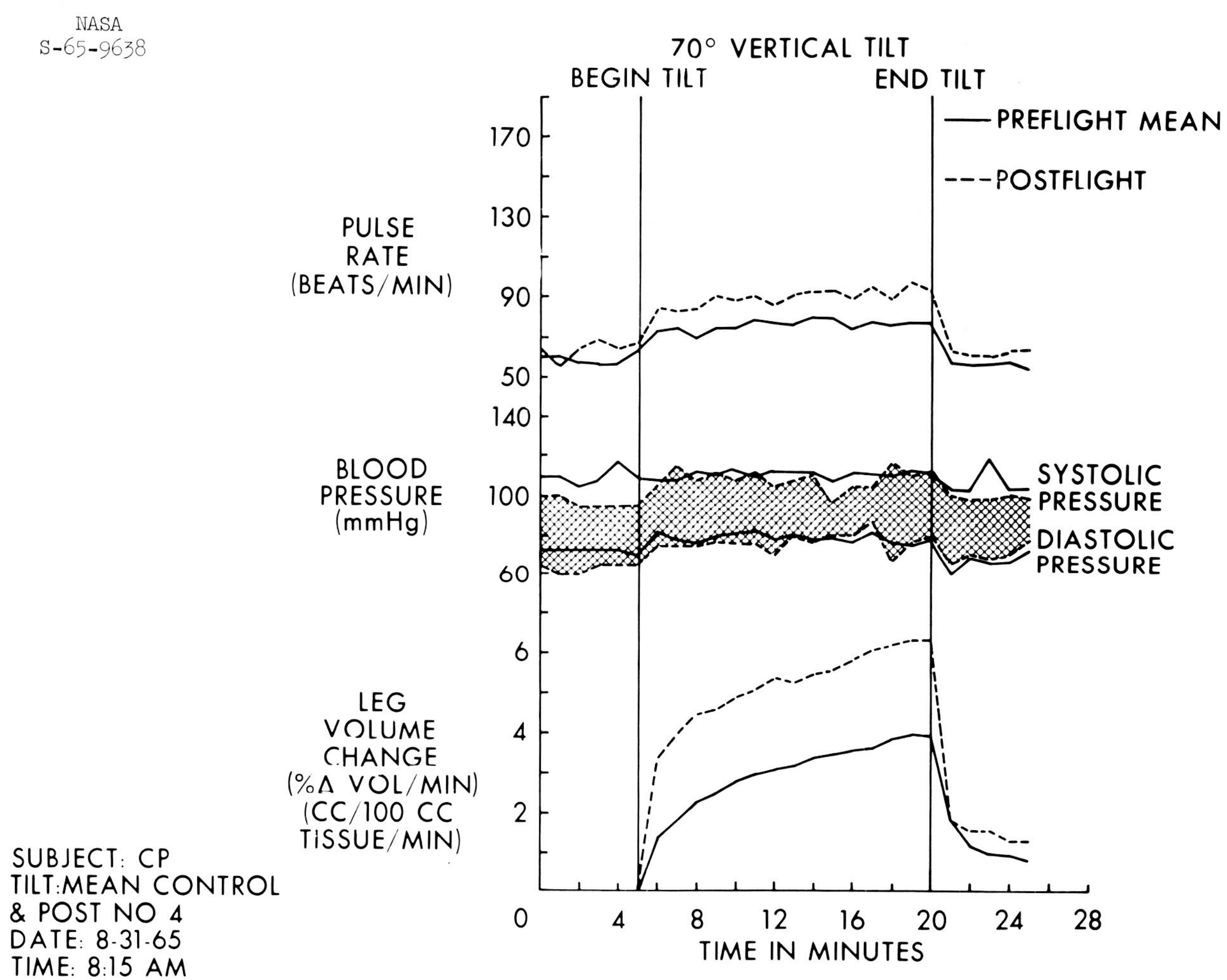

Figure 6(a)-11.- Command pilot tilt-table data.

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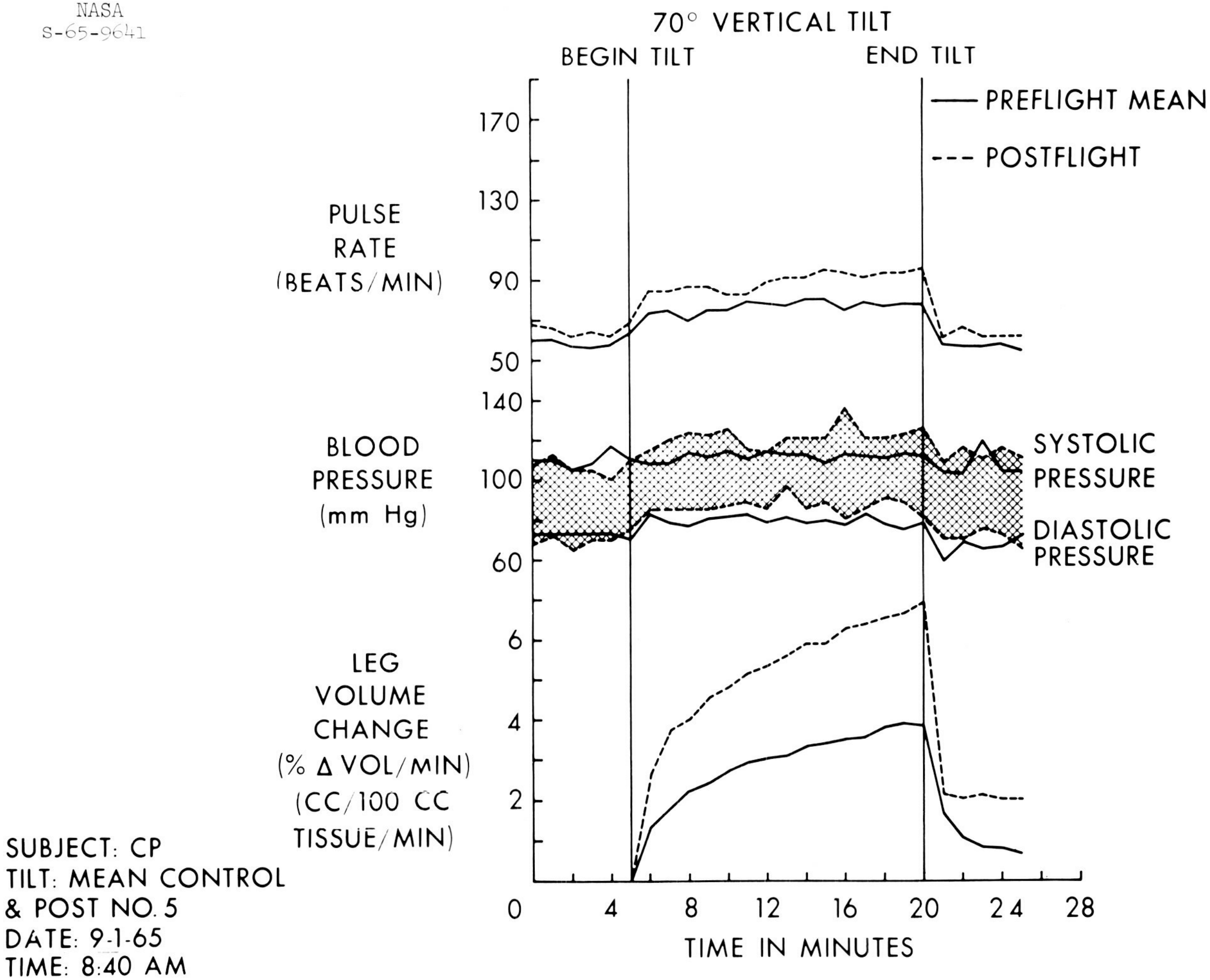

Figure 6(a)-12.- Command pilot tilt-table data.

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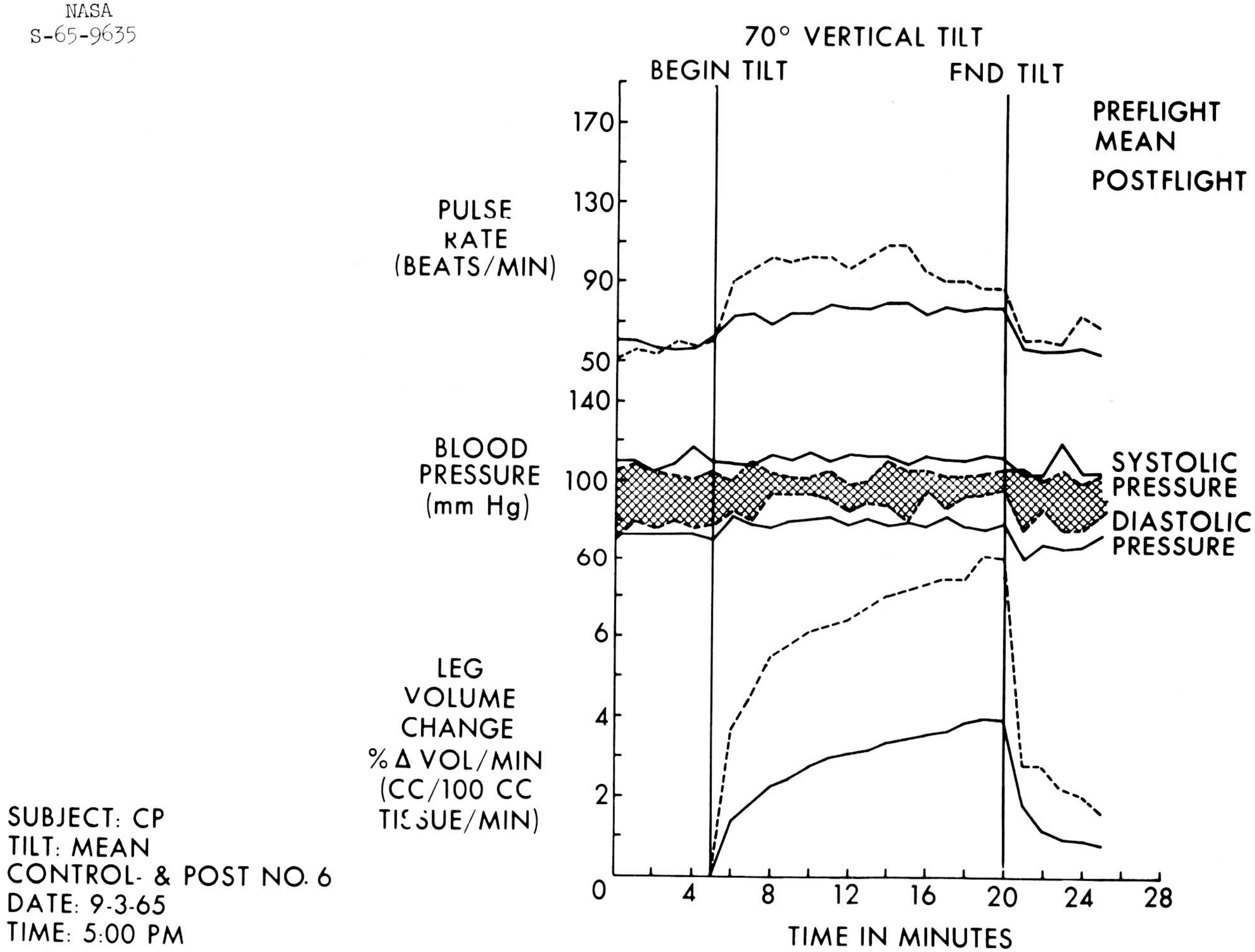

Figure 6(a)-13.- Command pilot tilt-table data.

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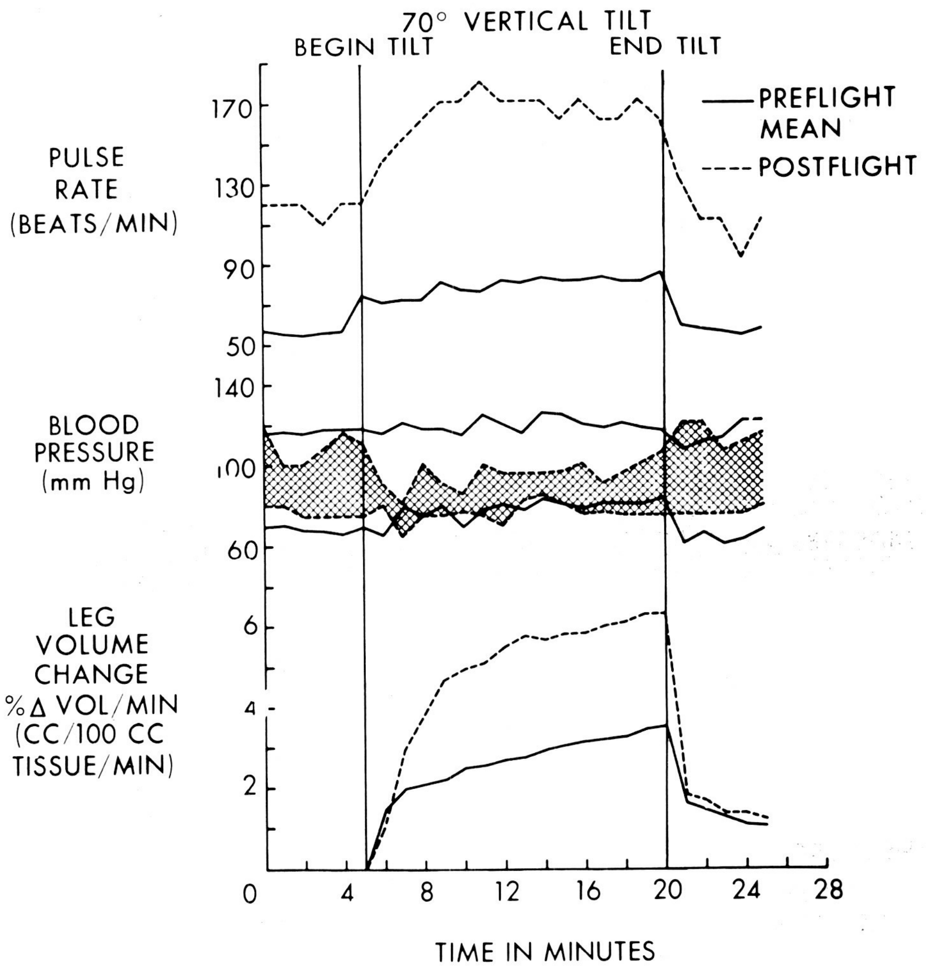

SUBJECT: P
TILT: MEAN CONTROL
& POST NO. 1
DATE: 8-29-65
TIME: 10:55 AM

Figure 6(a)-14.- Pilot tilt-table data.

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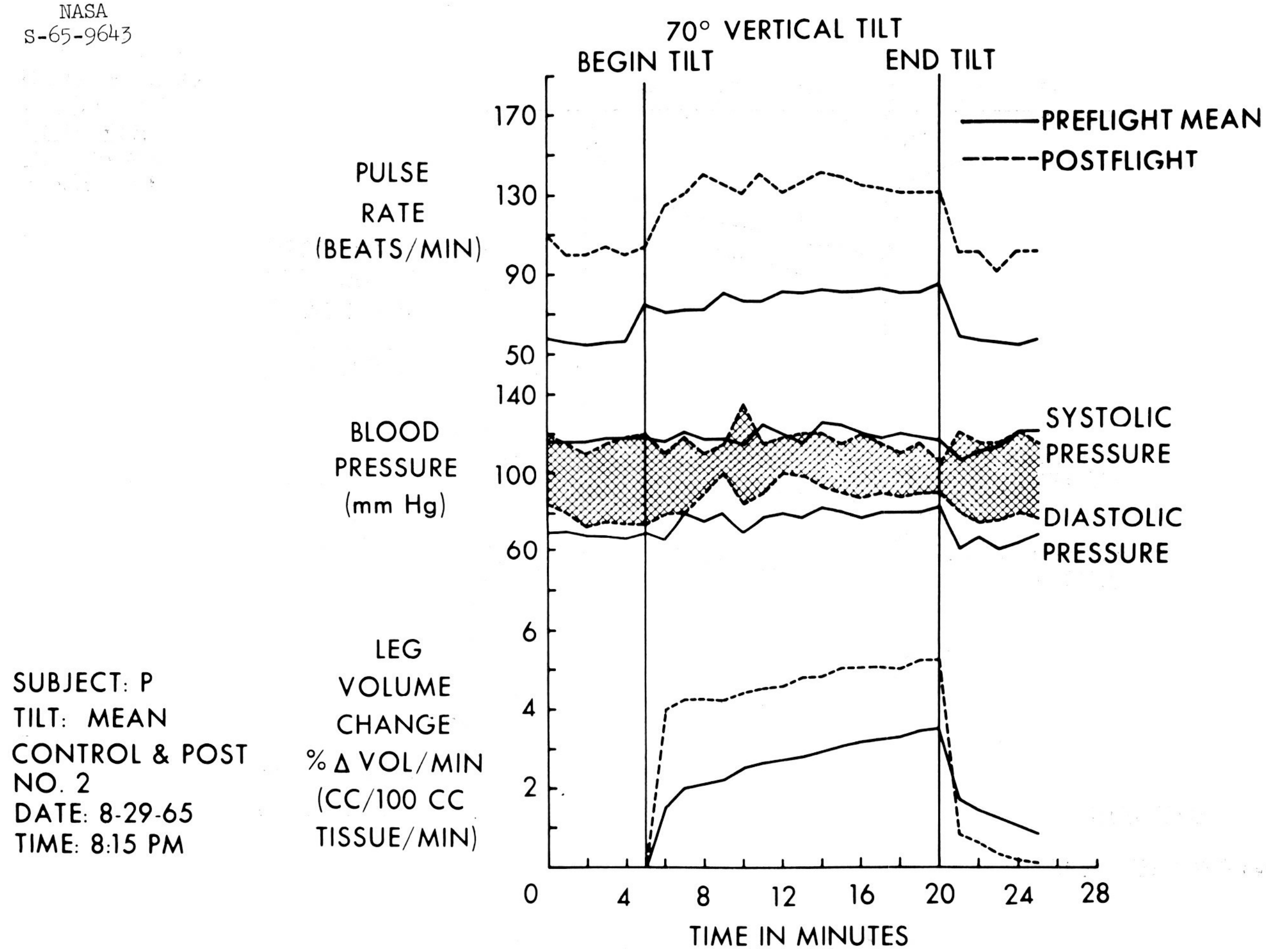

Figure 6(a)-15.- Pilot tilt-table data.

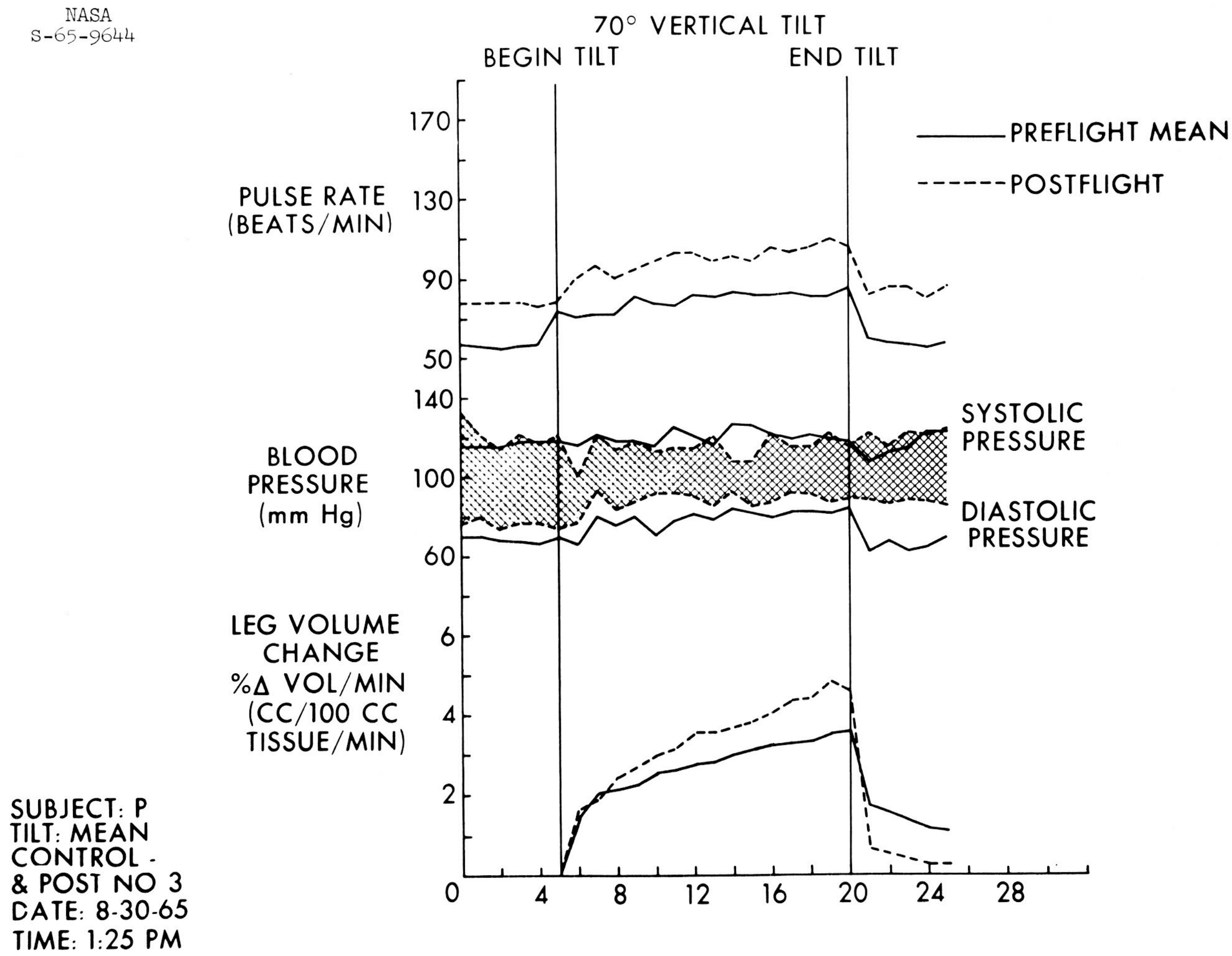

Figure 6(a)-16.- Pilot tilt-table data.

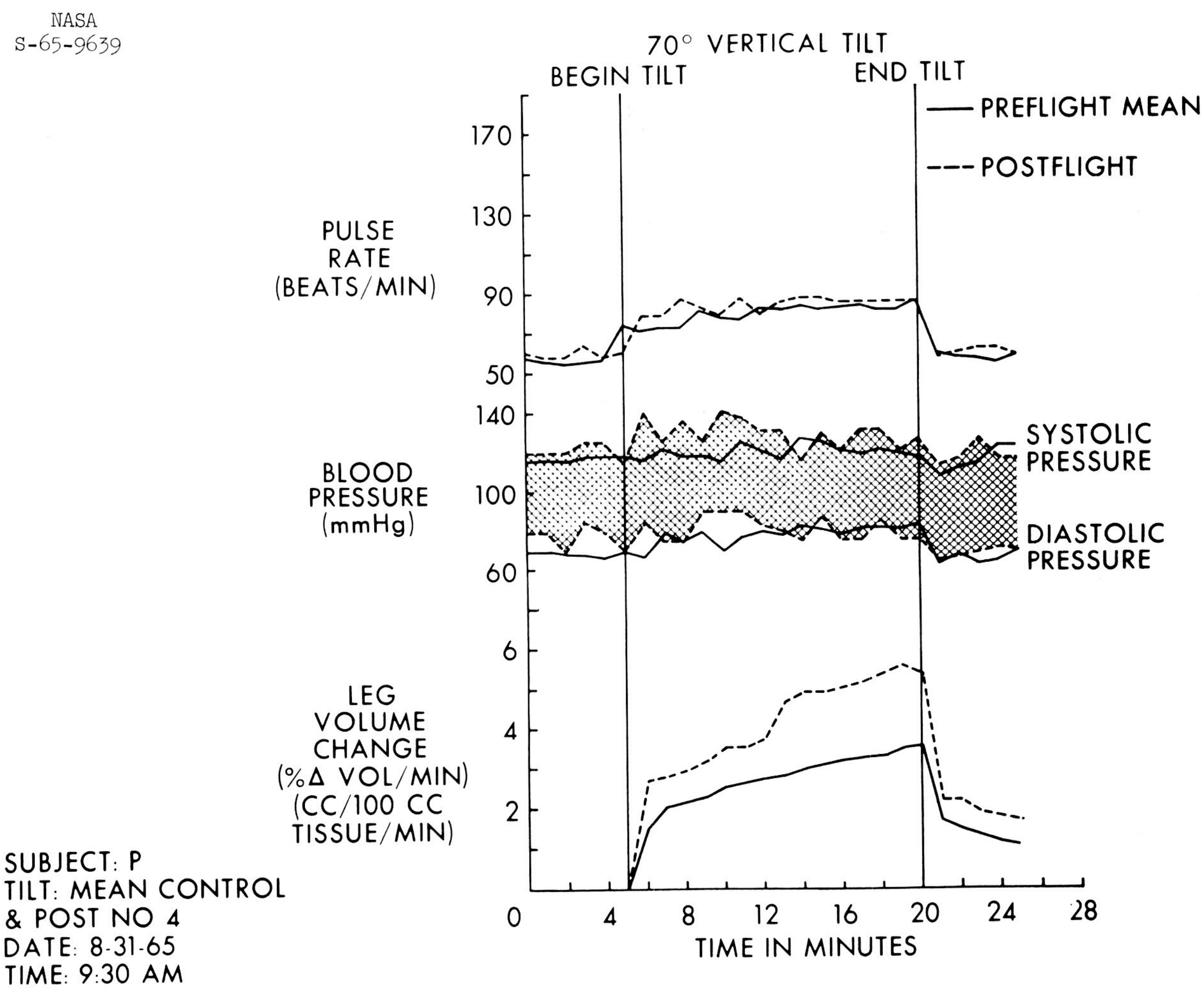

Figure 6(a)-17.- Pilot tilt-table data.

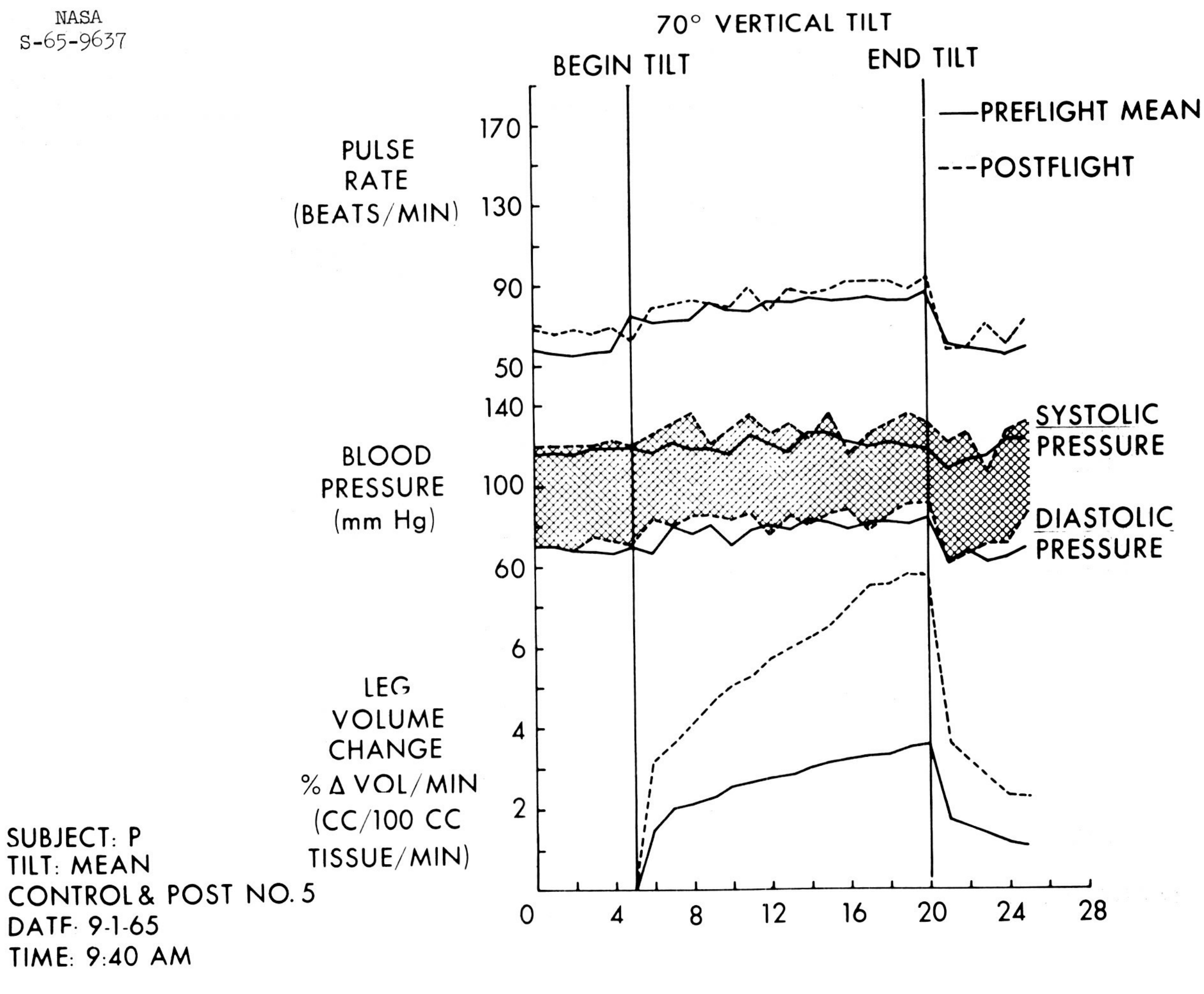

Figure 6(a)-18.- Pilot tilt-table data.

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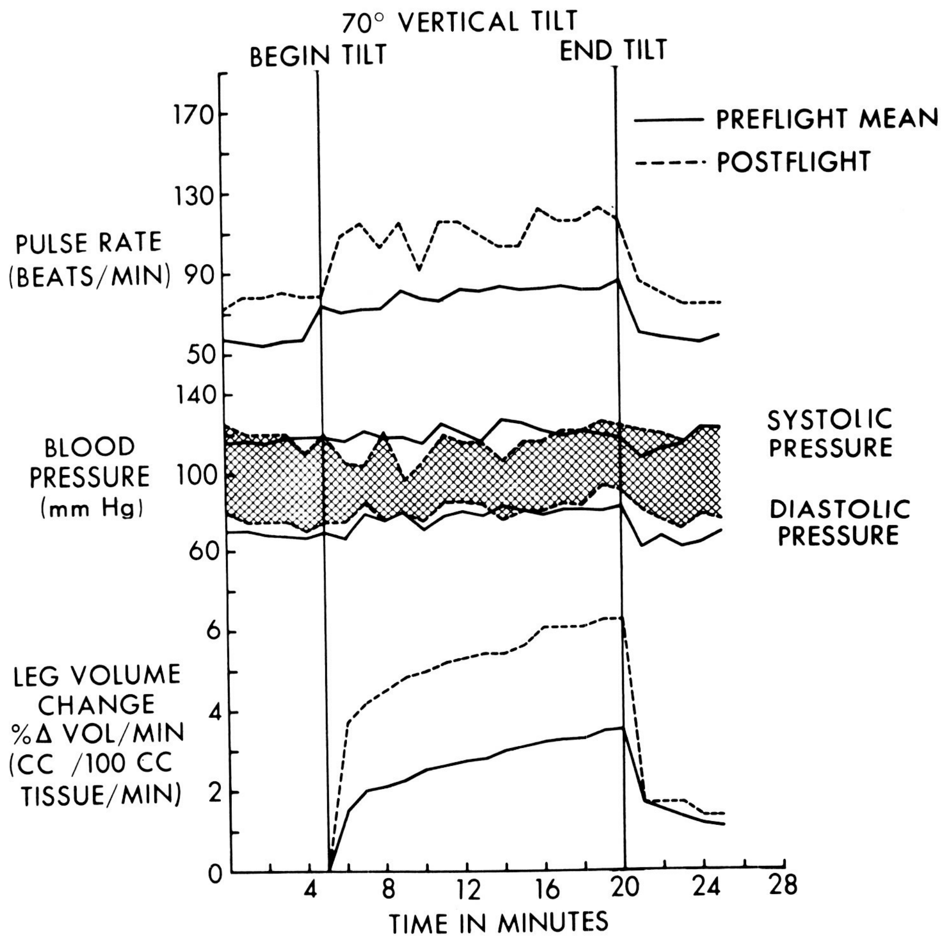

Figure 6(a)-19.- Pilot tilt-table data.