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FINAL REPORT TM6

Contract NAS 9-11127

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Contract No. NAS 9-11127

Title:

Operational Testing of System for Automatic Sleep Analysis

Submitted by:

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Introduction

The objective of this contract was to test thoroughly, under operational conditions, a complete system for monitoring sleep. This was undertaken at the sleep laboratories of the Neurophysiology Department of the Baylor/ Methodist program. It was the original intention to make some tests at the operational site for the Tektite II project also, but due to the long delays in the development of the Tektite II, it was not possible to carry out the tests in the underwater habitat within the time framework of this contract.

In consultation with the scientific monitor of the contract and the responsible offices at the Manned Spacecraft Center, it was decided to substitute a study in which recordings would be made from patients undergoing surgery of the heart and great vessels in the operating rooms of the Cardiovascular Institute at Baylor/Methodist. It was thought that this would constitute a rigorous trial of the latest prototype sensors and the preamplifier system, because once the patient is on the operating-room table, no further opportunity to make any adjustments to the cap are afforded, in spite of the fact that the patient may be moved or turned to different positions, and vigorous manipulations of the head, neck, and trunk are made by the surgeon and the anesthesiologist. Such procedures permit testing of cap fit and electrode contact under rigorous conditions for periods up to seven hours. The study afforded important information that resulted in significant improvement in the cap, the electrodes, and the preamplifiers, especially those used for recording the EOG.

For testing the sleep analyzer and the medical console write-out unit, forty children were each studied for three consecutive nights. It was thought that children would constitute a unique test of the equipment because of the very considerable differences in the frequency/amplitude characteristics of children's records as compared to adults' and the marked differences that there are between children of various ages. This study yielded important information which resulted in the development of the automatic voltage-control circuit in the sleep analyzer. It also resulted in the development of special circuitry for obviating the possibility of incorrect sleep staging due to the presence of movement artifact. These modifications of the sleep analyzer have been described in the December, 1971, progress report of Contract NAS 9-11855.

Surgical Operating-Room Tests

Thirty-four patients were studied, undergoing surgical procedures averaging about four hours in length but varying in duration from one hour and eighteen minutes to six hours and fifty-five minutes. Table I summarizes

Table I

	Patient	Type of Surgery	Comments	Time	Anesthetics Used
1.	W.R.H.	Aorta, right coronary bypass		3 hr 8 min	Pentothal, Innovar, morphine Demerol, halothane
2.	H.S.P.	Aortic aneurysm resection and replacement with graft		2 hr 10 min	Pentothal, Demerol, halothane, morphine
3.	A.M.P.	Total correction of tetralogy of Fallot		4 hr 38 min	Pump, Innovar, morphine, Pentothal
4.	R.C.	Double coronary bypass	Poor electrode contacts	3 hr 28 min	Innovar, morphine, N_2O, Pentothal
5.	W.B.	Right aorta-femoral bypass	Poor electrode contacts; EOG amp blown	2 hr 16 min	Halothane, N_2O, morphine, Pentothal
6.	W.McD.	Resection, aneurysm at abdominal aorta	Poor electrode contacts; EOG amp blown	1 hr 18 min	Halothane, morphine, Demerol, Pentothal
7.	W.McF.	Aorta, right and left descending coronary arteries bypass		4 hr 20 min	morphine, Pentothal, Innovar, halothane
8.	M.M.Y.	Aorta, left anterior descending coronary bypass	Poor electrode contacts	3 hr 24 min	morphine, Pentothal, Innovar
9.	A.G.	Bypass, right and left descending coronary arteries	Poor electrode contacts	6 hr 55 min	Pentothal, halothane, morphine
10.	L.A.L.	Aortic valve replacement	Poor electrode contacts (pump case)	3 hr 22 min	Innovar, morphine, Pentothal

	Patient	Type of Surgery	Comments	Time	Anesthetics Used
11.	C.A.H.	Resection of aneurysm, descending thoracic aorta	(Pump case)	4 hr 29 min	Pentothal, halothane, morphine
12.	C.R.S.	Resection of aneurysm, abdominal aorta		2 hr 54 min	halothane, Pentothal, morphine, Demerol
13.	P.F.McH.	Aorto-femoral bypass and femoral endarterectomy		3 hr 5 min	Innovar, halothane, N_2O, morphine, Pentothal
14.	G.E.B.	Right coronary artery, gas endarterectomy, and left anterior descending coronary bypass		5 hr 26 min	halothane, morphine, N_2O, Pentothal
15.	J.W.B.	Aorta, right coronary artery bypass		3 hr 31 min	halothane, morphine, Pentothal
16.	M.T.	Mitral valve replacement	(Pump case)	5 hr	Innovar, morphine, N_2O, Pentothal
17.	M.M.P.	Resection of aneurysm, descending aorta	EOG amp blown	3 hr 33 min	halothane, Pentothal, Innovar, N_2O, morphine
18.	M.S.T.	Coarctation of aorta (graft)	EEG #2 amp blown in preamp	3 hr 10 min	Innovar, halothane, morphine, Pentothal
19.	J.W.P.	Aorta, left anterior descending coronary artery bypass	(Pump case)	4 hr 9 min	N_2O, Pentothal, morphine, pump
20.	I.I.	Mitral valve replacement	(Pump case)	5 hr 17 min	Innovar, morphine, Pentothal
21.	R.T.G.	Aorta to left descending coronary artery bypass	Diodes blown in EOG amp	2 hr 16 min	N_2O, Pentothal, Innovar, Demerol

	Patient	Type of Surgery	Comments	Time	Anesthetics Used
22.	S.M.M.	Closure of arterial septal defect		3 hr 47 min	Innovar, N_2O, morphine, Pentothal
23.	S.S.	Aorta, left anterior descending coronary artery bypass	Poor electrode contacts	4 hr 3 min	Innovar, N_2O, morphine, Pentothal
24.	B.R.D.	Mitral valve replacement	(Pump case)	4 hr	Innovar, N_2O, morphine, Pentothal
25.	E.J.D.	Resection, aneurysm of abdominal aorta		1 hr 27 min	Innovar, Demerol, Pentothal
26.	E.L.G.	Aorta to left anterior descending artery bypass	(Pump case)	3 hr 53 min	Innovar, N_2O, morphine, Pentothal
27.	R.S.P.	Mitral valve replacement	Poor electrode contacts (pump case)	4 hr 15 min	Innovar, morphine, Pentothal
28.	M.F.	Abdominal aorta to mesenteric and celiac axis bypass		4 hr 57 min	Innovar, morphine, Pentothal
29.	J.F.	Aorta to right circumflex coronary arteries bypass	(Pump case)	4 hr 36 min	Innovar, N_2O, morphine, Valium, Pentothal
30.	B.K.	Mitral valve replacement	(Pump case)	3 hr 48 min	Innovar, morphine, Pentothal
31.	R.B.	Aortic valve replacement	(Pump case)	3 hr 55 min	Innovar, N_2O, morphine, Pentothal

	Patient	Type of Surgery	Comments	Time	Anesthetics Used
32.	A. L. G.	Aortic and mitral valve replacement	(Pump case)	4 hr 23 min	Innovar, N_2O, morphine, Pentothal
33.	J. T. H.	Aorta to right and left anterior descending coronary arteries bypass	(Pump case)	3 hr 57 min	Innovar, N_2O, morphine, Pentothal
34.	P. S.	Aorta to right and left anterior descending and circumflex coronary arteries bypass	(Pump case)	4 hr 41 min	Innovar, N_2O, morphine, Pentothal

these studies. Recording difficulties were encountered in ten of these cases, mostly in the first patients in the series. Most of these difficulties were associated with dislodgment of the cap position due to manipulation of the patient's head or trunk, resulting in poor electrode contact. These difficulties were corrected subsequently, as indicated in the summary which follows (page 4). The experience in the operating room also indicated that the transistors used in the input circuit of the EOG electrodes were inadequate for the purpose, and this resulted in a modification of the circuit, after which no further problems were encountered.

All the problems with the caps relating to electrodes and the breaking of connector wires were a consequence of the movement of the head against the operating table, etc., as a consequence of the manipulation of the patient by surgeons, nurses, and anesthesiologists. These conditions are not likely to be encountered during space flight, due to weightlessness, but they constitute an important testing procedure for evaluation of the general reliability, consistency, and operational stability of the electrodes, cap, and preamplifiers.

All-Night Sleep Studies in Children

Forty children, ages 6 to 17 years, were each studied for three consecutive nights, using the prototype sensors, including the prefilled sponge electrodes, the sleep analyzer, and the medical console write-out equipment. This series of subjects constituted a major test of the sleep-staging analyzer because of the marked inter-subject variation in the voltage/frequency characteristics of the electrical activity of sleep.

Each night's sleep was staged by the sleep analyzer and recorded, using a Beckman Type R graphic write-out for subsequent visual analysis and comparison with the analyzer output. The visual analysis of these records indicated a general concordance with the automatic analysis, but two conditions which resulted in inaccuracies were identified. The first of these was the large amplitude differences of the brain waves of children as compared to adults and the marked inter-subject variation, as mentioned above. In order to correct for such inter-subject differences, an automatic voltage-control circuit was developed and incorporated in the latest version of the sleep analyzer. An example of staging problems that can result from the high voltages encountered in the various sleep stages of children, particularly young children, is indicated in the sample comparisons of the visual and automatic analyses shown in Fig. 1. The second condition, the problem that ocular and other artifacts may introduce when the patient is awake, the analyzer interpreting this largely as REM sleep, is illustrated by this same figure. This problem has been largely obviated with the development of a new circuit for registering prolonged movement

SUMMARY OF PROBLEMS WITH CAPS

PROBLEM: Cap slipping on head and hiking up in back.

SOLUTION: Made back straps for cap. Sewed a piece of Velcro 2" by 1$\frac{1}{2}$" in center back of cap, 9 cm from bottom seam. Attached two chin straps to Velcro in back and pulled to desired fit and fastened to front Velcro.

RESULT: Worked O.K., but not very comfortable; too much trouble and time.

PROBLEM: Cap slipping on head and hiking up in back.

SOLUTION: Took three tucks in the back seams, about $\frac{1}{2}$ cm each.

RESULT: Better fit. Fit most.

PROBLEM: Frontal and EOG electrodes not making good contact.

SOLUTION: Took tucks in front three seams, about $\frac{1}{2}$ cm each.

RESULTS: Better contact. Fit most.

PROBLEM: Connector wires breaking just above the solder joint. These are Teflon wires, and wires were damaged when stripping insulation from wire.

SOLUTION: Stripped insulation from wire electronically.

RESULT: Practically no broken wires.

PROBLEM: Solder joints breaking due to stress on wires when cap was stretched.

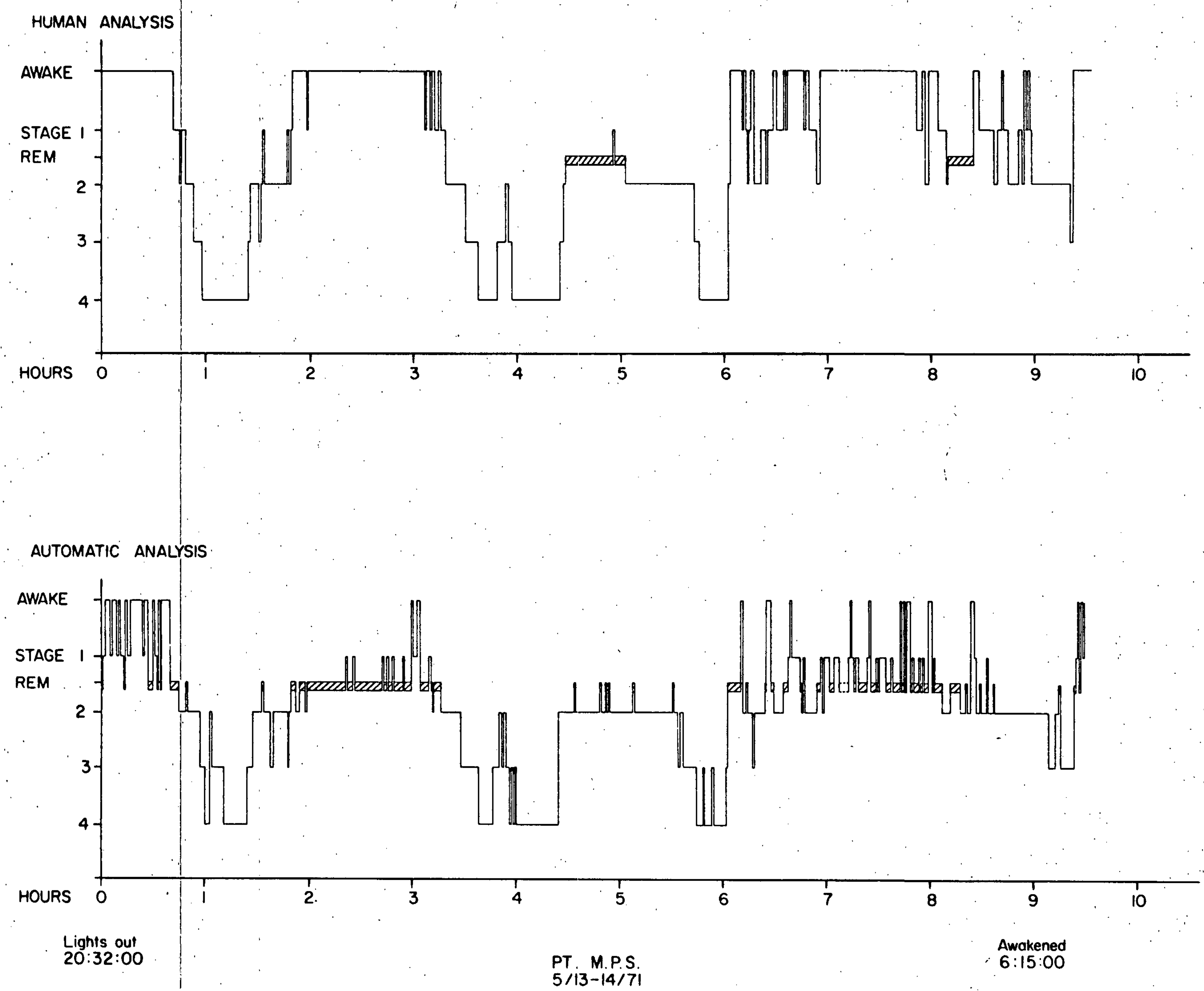
SOLUTION: Left about 5" of slack on all connector wires. Sewed the wire down in curves or snakes so that the wire would stretch with the cap. Sewed down on inside of curve.

RESULT: Good.

PROBLEM: Broken wires inside electrodes.

SOLUTION: Changed to silver-coated cable, because the copper would corrode into and wire would break.

RESULT:	Good.
PROBLEM:	Occipital and temporal electrodes not making good contact.
SOLUTION:	Took in two side seams across from occipitals and temporals, about $\frac{1}{2}$ cm each.
RESULT:	Good.
PROBLEM:	Temporal wires breaking.
SOLUTION:	Rerouted wire around side of head instead of up over the head.
RESULT:	Good.
PROBLEM:	Electrodes hard and brittle. Uncomfortable and tending to split.
SOLUTION:	Changed vinyl coating.
RESULT:	Good; much improved.
PROBLEM:	Chin straps sometimes too small or large.
SOLUTION:	Modified chin strap by sewing a longer piece of Velcro on each end. Started it closer to center and let it extend out equally from each end. Velcro 7 cm long x 2 1/4 cm wide. Changed position of ground electrode from central position to 3 cm from left side seam on front of cap, next to EOG electrodes. Changed position of temporal electrodes from just above ear to just behind ear. Made a super small and $\frac{1}{2}$ (S. S. $\frac{1}{2}$) cap for in between super small (S. S.) and super-super small (S. S. S.) S. S. S. cap made for children that occasionally come for surgery. There has been no occasion to use it since it has become available. S. S. $\frac{1}{2}$ cap made for a few patients that have unusually small heads.
RESULT:	Good.



HUMAN ANALYSIS
AWAKE
STAGE 1
REM
2
3
4
HOURS 0 1 2 3 4 5 6 7 8 9 10
AUTOMATIC ANALYSIS
AWAKE
STAGE 1
REM
2
3
4
HOURS 0 1 2 3 4 5 6 7 8 9 10
Lights out
20:32:00
PT. M.P.S.
5/13-14/71
Awakened
6:15:00

Fig. 1

artifact as "awake." Figs. 2 and 3 are examples of subsequent automatic staging of all-night sleep in children compared to human analysis of the same data.

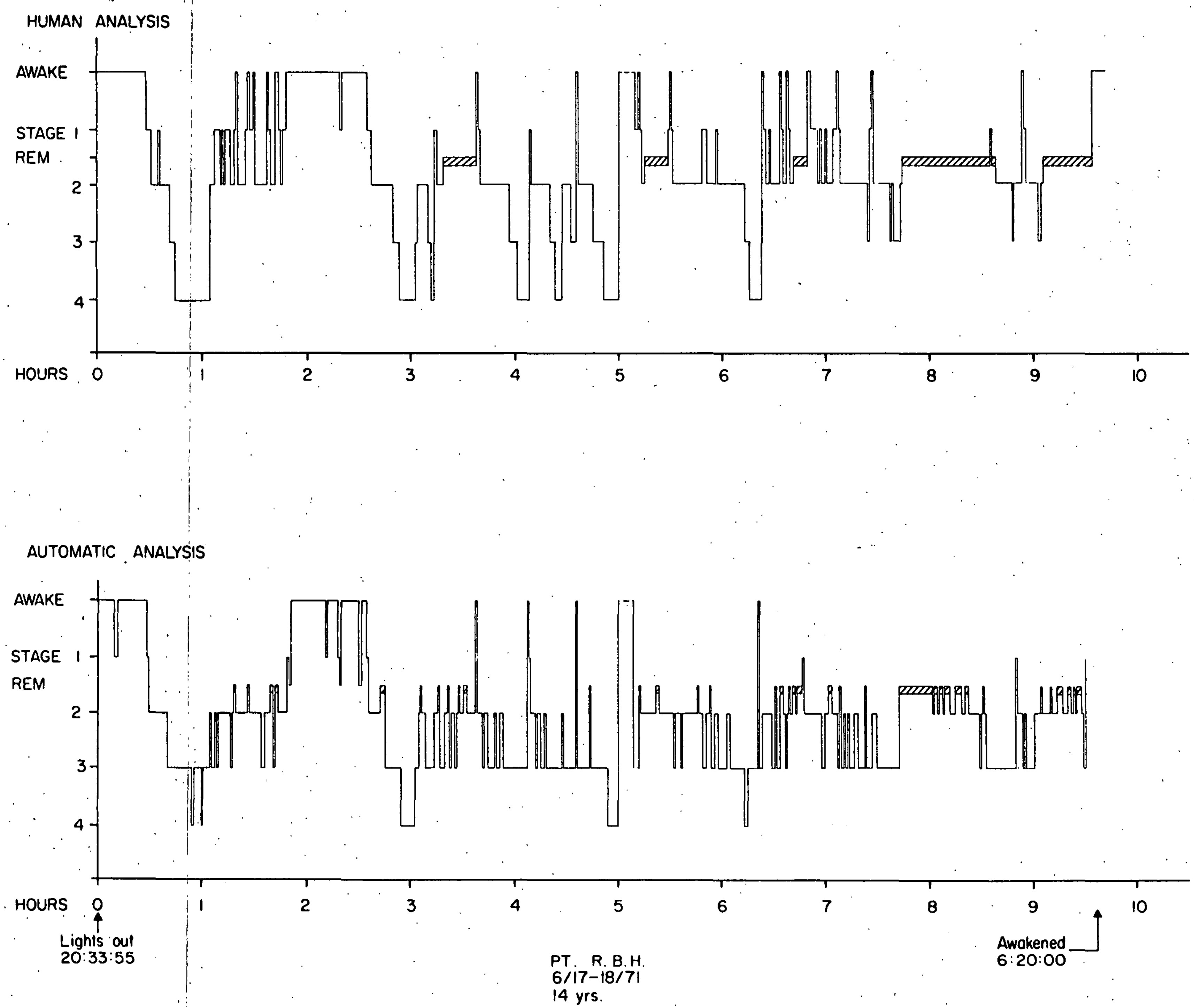

HUMAN ANALYSIS
AWAKE
STAGE I
REM
2
3
4
HOURS
0
1
2
3
4
5
6
7
8
9
10
AUTOMATIC ANALYSIS
AWAKE
STAGE I
REM
2
3
4
HOURS
0
1
2
3
4
5
6
7
8
9
10
Lights out
20:33:55
PT. R. B. H.
6/17-18/71
14 yrs.
Awakened
6:20:00

Fig. 2

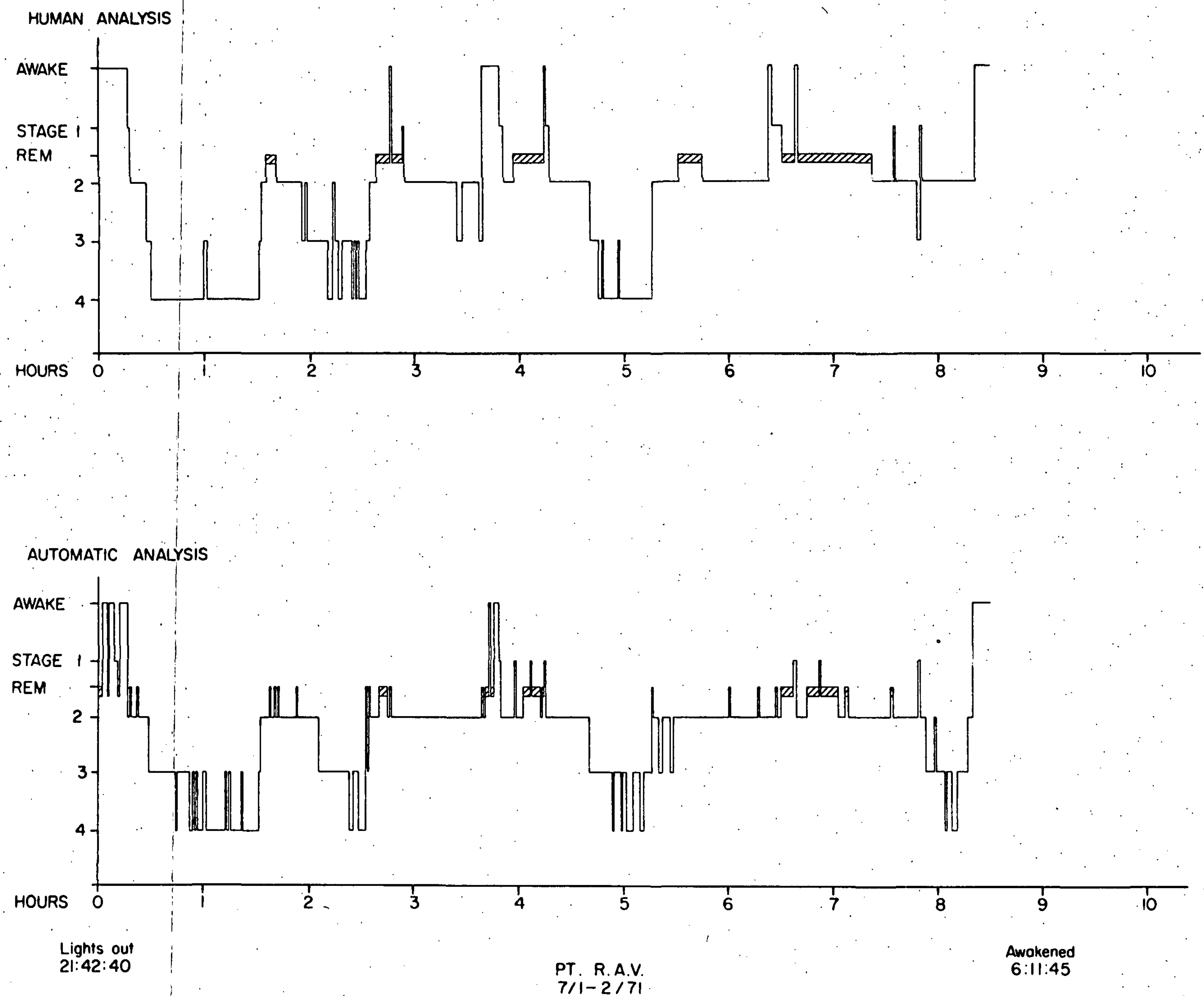

HUMAN ANALYSIS
AWAKE
STAGE 1
REM
2
3
4
HOURS
0
1
2
3
4
5
6
7
8
9
10
AUTOMATIC ANALYSIS
AWAKE
STAGE 1
REM
2
3
4
HOURS
0
1
2
3
4
5
6
7
8
9
10
Lights out
21:42:40
PT. R.A.V.
7/1-2/71
Awakened
6:11:45

Fig. 3