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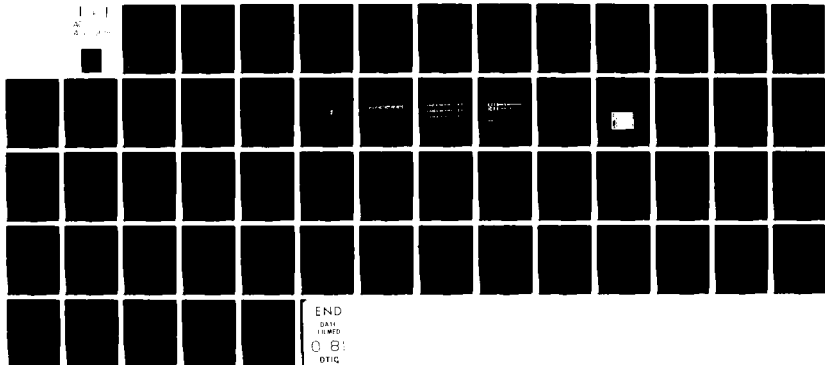
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MEASURING SLEEP BY WRIST ACTIGRAPH

ANNUAL REPORT

Daniel F. Kripke, John B. Webster,
Daniel J. Mullaney, Sam Messin, and William Mason

APRIL 1980

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20. Abstract, continued.

We have investigated methods of artifact rejection and digital preprocessing in converting analog activity data to a digital activity score. A simple digital filtering technique was effective in cancelling 60 Hz electrical noise, a persistent artifact in our analog data. A method of enhancing as well as compressing activity data by summing changes in activity over a 2-second data epoch yields the best discrimination between sleep and wake.

A computer program to recognize sleep from the digital activity score is being refined. Once an optimal algorithm for retrospective sleep recognition has been derived, its success in prospectively recognizing sleep from wrist activity will be evaluated.

A portable model of a wearable prototype digital actigraphic recorder has also been manufactured.

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SUMMARY

We report the second year (ten months) of what is conceived as a three-year effort. Results from the first year of our contract (1978-79) indicated that sleep can be identified from recordings of wrist activity, eliminating the need for costly EEG or unreliable observational sleep recognition procedures. In the next two years, we proposed a technical definition of a miniature digital actigraphic recorder capable of measuring and storing activity information, yet compact enough to be worn on a wrist.

To perfect this system in the current year we have explored alternative activity transducers, transducer placements, and orientations. Results indicate that a crystal transducer is superior to alternative activity transducers, and it responds adequately in any orientation. We have also demonstrated that wrist activity measures are superior to head or ankle measures.

We have investigated methods of artifact rejection and digital pre-processing in converting analog activity data to a digital activity score. A simple digital filtering technique was effective in cancelling 60 Hz electrical noise, a persistent artifact in our analog data. A method of enhancing as well as compressing activity data by summing changes in activity over a 2-second data epoch yields the best discrimination between sleep and wake.

A computer program to recognize sleep from the digital activity score is being refined. Our current efforts utilize the computer to evaluate the contribution of a number of potential discriminators between sleep and wake. Given knowledge of actual sleep/wake status of an activity record, the weighting of each discriminator is adjusted until a maximum percent agreement is reached. Once an optimal algorithm for retrospective sleep recognition has been derived, its success in prospectively recognizing sleep from wrist activity will be evaluated.

A portable model of a wearable prototype digital actigraphic recorder has also been manufactured.

FORWORD

For the protection of human subjects the investigator has adhered to policies of applicable Federal Law 45CFR46.

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INTRODUCTION

Sleep loss and combat fatigue are increasing concerns for the modern army. A future war is likely to be extremely brief and intense, with victory and defeat determined in a few days or weeks. Soldiers using technically sophisticated modern weaponry will have little time for sleep, and plans must be made to enable personnel to perform effectively throughout the duration of a combat of unprecedented intensity. American troops may have to enter combat immediately after airlift to remote parts of the world, and plans must be developed to minimize the effects of jet lag on personnel performance.

Military medicine therefore needs a practical method of quantifying sleep both to design personnel strategies and for potential monitoring of troops in actual field deployments.

Traditional physiologic methods for monitoring sleep through EEG-EOG-EMG recordings are completely impractical in actual or simulated combat settings, and subjective monitoring has been shown to be unreliable (1). In addition, both physiologic measures and observational methods for measuring sleep are costly, and considerable time is necessary to quantify sleep by scoring polygraph records.

We are developing a wrist activity monitoring technique as a solution to these problems.

Employing Delgado's (2) telemetric activity recording device, Kupfer et al (3) and Foster et al (4, 5) described the use of activity data for quantifying sleep and assessing sleep quality in humans. Encouraged by the high correlations between EEG and actigraphic estimates of sleep -- 0.84 and 0.88 in two separate studies (6, 7) -- Kripke et al (8) developed a system in which a piezoelectric crystal worn on a watchband recorded wrist activity onto a Medilog cassette tape recorder worn on a belt (Figure 1). With this crystal actigraph, Kripke et al (8) obtained a correlation of 0.98 between sleep duration determined from wrist activity and the EEG in five subjects.

A more exhaustive study of 63 normal subjects and 39 hospital patients with various sleep disorders was conducted under the first year of our contract (DAMD-17-78-C-8040, 1978-79). All-night recordings of wrist activity, EEG, EMG and EOG were collected simultaneously on a 4-channel cassette. Each minute was scored as either sleep or wake by one rater using only activity data, and a second rater using only EEG-EOG-EMG data. The raters agreed on 94.5% of the minutes (96.3% for non-patients). Estimates of each subject's total sleep time with the two methods were correlated 0.89 (0.95 for non-patients). These results indicate that the wrist actigraphic analog recording contains sufficient information to produce a highly reliable scoring of sleep.

On a cost-benefits basis, the wrist activity method was shown to supply greater precision than EEG for equal expense (because more subjects could be studied) and better applicability to non-laboratory settings. Nevertheless, further development is needed to perfect a device which adequately estimates sleep and is small enough to be worn in combat.

To meet this need, in 1979 we proposed a two-year contract to perform technical design definition of a digital wrist activity recorder which would be suitable for combat use. Our basic concept envisions a two-part system. The first part, to be worn entirely on the wrist, would consist of an activity transducer, microprocessor-based signal preprocessor, and read/write digital memory. The second part, to be field-deployable but not wearable (perhaps the size of a suitcase), would consist of a microprocessor-based readout device which would perform sleep-wake recognition, statistical summarization, and print out a summary report.

In the 1979-1980 year, we planned to define the optimal transducer design, the optimal transducer placement, and the hardware-software requirements of such a device, at the same time developing a breadboard design of a testable portable digital activity monitoring device. In the 1980-1981 year, we plan to program and test a prototype portable device and verify its performance, concluding with definition of technical requirements of a microminiaturized device which would be field-deployable. In 1981, we could then propose actual construction and deployment of combat-applicable sleep monitoring devices.

Here we summarize ten months of the 1979-1980 work.

GOALS OF THIS YEAR'S WORK

1. Determine the optimal activity transducer design.
2. Determine the requirements for omnidirectionality.
3. Determine optimal transducer placement on the body.
4. Develop a digital activity preprocessing algorithm for use in the wearable device.
5. Develop a sleep/wake recognition program.
6. Develop in breadboard form a wearable prototype digital activity monitor to verify design principles before microminiaturization.

TRANSDUCER OPTIMIZATION

Since conversion of mechanical motion to an electrical signal is the basis of actigraphic recording, we believe that optimization of the recording transducer is extremely important to the final goal. Although our current piezoelectric transducer has performed admirably, we wished to test other forms of accelerometers and motion detectors before settling on any transducer design. In general, since we found most of our failures to discriminate sleep and wake were due to failures to detect motion during wake, maximal sensitivity to motion is the major design criterion. Several prototypes of our own design including water- or mercury-filled spheres were rejected because they failed to respond reliably. A number of commercially available transducers were considered, and two were selected for comparison. A single-plane accelerometer ordered from Grass Instruments was delivered in late April, 1980, so testing of this device is still being completed. Testing of an activity transducer consisting of six mercury tilt switches (Vitalog Corp.) is described here.

Method

The Vitalog transducer was mounted in a small box (3.7 x 3.5 x 5.6 mm) along with a crystal actigraph. A 1.35 V battery and resistive voltage divider was placed in series with the Vitalog device so that the voltage switched by the tilt switches matched the input requirements of the Medilog cassette recorder. The two devices were connected to two channels of the Medilog and four subjects wore the box on their wrists for a total of six nights. The two channels were played back simultaneously on a polygraph at an effective rate of 32 mm/minute, relative to real time.

Results

In general, the crystal actigraph measured activity at many times when the Vitalog did not. Figure 2 shows a representative example of the polygraph writeout of the simultaneous Vitalog and actigraph signals. In our entire sample, there were no examples where the Vitalog transducer detected activity not recorded by the crystal. In summary, the tilt switch array missed much of the activity which was detected by the crystal transducer, and it would often have made recognition of wakefulness impossible.

Discussion

The crystal actigraph is clearly more sensitive to wrist activity than the tilt switch activity transducer. One reason for this difference may be fundamental to the design of the two devices. The Vitalog transducer features an array of six mercury tilt switches distributed around the major axes, and consequently measures changes in attitude, or rotation. It is possible to move the transducer without rotating it around any axis,

and without closing any of the switches. The frequency of the signal is a function of the number of axes rotated through and the magnitude of rotation in each axis. The crystal actigraph, on the other hand, is sensitive to any acceleration. The results of this study indicate that wrist activity is better described by acceleration than by rotation. We expect to compare the crystal actigraph and accelerometer in a similar design. It is unlikely that the accelerometer will prove advantageous, however, for it is not omnidirectional.

TRANSDUCER OMNIDIRECTIONALITY

The axial design of the crystal actigraph can be expected to make it most sensitive to one axis of acceleration and one axis of rotation. The eccentrically spring-mounted weight which excites our piezoelectric crystal allows the transducer to respond to accelerations or rotations in any axis, but its directional sensitivity is not equal in every axis. It was therefore important to determine the directional sensitivity of the actigraph, and if significant directionality was found, to specify the orientation which best detected activity.

Methods

Three crystal actigraphs were mounted in each major axis within a single small box (3.7 x 3.5 x 5.6 mm) and connected to three channels of a Medilog recorder. Six subjects wore this 3-axis actigraph on a wrist for a total of ten nights. The three channels were replayed simultaneously onto the polygraph at an effective rate of 32 mm/minute.

Results

An example of the 3-axis actigraph recording is presented in Figure 3. This example is representative of the entire sample, and reveals that although the recorded activity signal was frequently somewhat larger in one axis than another, there were virtually no instances in which activity detected in one axis was not registered by all three transducers. No orientation seemed superior.

Discussion

Although of axial design, the crystal actigraph shows adequate omnidirectionality. The orientation of the actigraph on the wrist does not seem critical.

TRANSDUCER PLACEMENT

Although we have typically mounted actigraphs on the non-dominant wrist, this decision was based on Kupfer's procedure and lacked experimental validation. To determine which placement would register the most activity, and therefore be most likely to discriminate sleep and wake, we surveyed several possible placements. We chose the head rather than any placement on the body trunk because we reasoned the trunk could not be displaced without moving the head, while the reverse was not true. We had also observed respiratory artifacts when the wrist was near the abdomen or ribs, and we wished to minimize these. We also explored the other limbs.

Methods

Four crystal actigraphs were mounted in separate boxes (3.5 x 4.4 x 1.7 mm) and connected to the four channels of a Medilog recorder. Nine subjects completed 22 recordings with the actigraphs worn simultaneously on each wrist, the forehead and the right or left ankle. The assignment of actigraphs to locations was counterbalanced to control for variation in the sensitivity of individual crystals. The four channels were replayed simultaneously to four channels of the polygraph at an effective rate of 32 mm/minute.

Results

Figure 4 shows a typical 4-channel activity record. In order to evaluate the measure of activity from each site in the entire sample, a rater ranked the four channels for the amount of activity measured, without knowledge of which location corresponded to which channel. Results of this ranking are presented in Table 1. Of the 19 records judged adequate for scoring, a wrist was judged best in 18 cases. Furthermore, the best ranking was equally distributed between left and right wrists (all subjects were right-handed).

Discussion

This study showed that wrist placement often detects activity that head or ankle placement fails to detect. The reverse was rarely true, although a few instances were observed in some of the subjects. Other recordings of tibialis EMG in sleep disorders patients have taught us that ankle motion during sleep is common among some subjects, providing a further reason to prefer the wrist. It was also found that there is little difference between wrists. Either wrist may be chosen at the preference of the subject.

DIGITAL PREPROCESSING

In our laboratory, analog activity records are scored by replaying the cassette tape at approximately twice the recording speed to a polygraph, then visually scoring the polygraph record. The procedure is therefore time-consuming (about one-half of the actual time of the sleep recording for the writeout alone) and requires sophisticated apparatus and a trained scorer. The Medilog recorders themselves, while suitable for ambulatory subjects, are too delicate and bulky for field use or actual combat deployment. Our current method also records data with a resolution on the order of 8 bits and a bandwidth of approximately 0.1-100 Hz, that is, approximately 70,000,000 bits of information in a 24-hour recording. It is obvious that to realize a practical digital activity storage device, some form of data compression must be utilized.

Data compression should also incorporate a measure of artifact rejection, for our current actigraphic analog recordings are sometimes contaminated by low-voltage 60 Hz electrical noise, by other kinds of electronic artifact, or by the small movements which occur when the wrist is placed on the chest and is displaced by respiration. The digital actigraphs currently employed at Walter Reed and NIMH are sensitive to vehicular vibrations. While a human judge may recognize this activity as artifact, a computer would not unless specifically programmed to recognize and ignore such activity patterns.

To find an optimal data compression approach, we played back a series of activity records into the A/D converter of our HP 2100 computer system. Ten data compression algorithms combining filtering, summing, squaring, differencing and threshold detection were utilized, and the effectiveness of these algorithms in discriminating sleep and wake (as scored by hand analysis of actigraph) and rejecting 60 Hz noise was compared.

Methods

Figure 5 illustrates the procedure in block diagram form. Activity recordings on Medilog tape were played back at 60 times recording speed to a Sangamo instrumentation recorder running at 30 ips. The Sangamo tape was then rewound and played back at 15/16 ips. The resulting actigraph signal was therefore $60 \times (15/16) / 30$, or 1.875 times actual recording speed. This analog signal was written out on one channel of the polygraph running at 60 mm/minute, for an effective rate of 32 mm/minute relative to real time. At the same time, the analog signal was fed to the analog-to-digital converter (A/D) operating at an actual rate of 450 Hz, or an effective rate of $450 / 1.875$ or 240 Hz relative to real time. The digital output of the A/D converter was then processed by the computer (details will follow) and the output stored on disc. The computer also generated a time code representing one minute of real time which was written on the polygraph record to allow the disc and polygraph records to be compared.

The program for processing and storing digital activity scores explored ten digital preprocessing algorithms and tested a simple digital filtering technique for rejecting 60 Hz electrical interference. A listing of the program is included in Appendix 1. The first stage of the program is the digital filter. The conversion rate of 240 Hz (real time) is exactly four times the frequency of 60 Hz electrical noise (which might come from an electric blanket or clock near the bed during sleep). Since this 60 Hz signal alternates between positive and negative, four (or any even integer) regular samples of voltage per cycle will sum to zero. Thus if every four conversions are summed, 60 Hz interference will cancel. Evidence will be presented indicating the effectiveness of this simple filtering technique. A 120 Hz artifact would also be cancelled and 50 Hz artifact and most high frequencies would be at least partially attenuated.

In addition to the simple sum of every four conversions ($\sum y$) the sum of every four squared conversions ($\sum y^2$) was also calculated and 120 of each of the two sums ($\sum y$ and $\sum y^2$) were accumulated for each two-second data epoch. A total of ten transformations of $\sum y$ and $\sum y^2$ were calculated and stored on disc for each two-second epoch. The ten transformations were: 1) The simple sum of the simple sums $\sum \sum y$, 2) The simple sum of the squared sums $\sum \sum y^2$, 3) The sum of the simple sums squared $\sum (\sum y)^2$, 4) The sum of the squared sums squared $\sum (\sum y^2)^2$. The next four transformations summed a "difference score" on the same four quantities. This difference score is ten times the value of a given item minus the value of the preceding and following five items: $\sum f(x_i)$, where

$$f(x_i) = 10 * x_i - (x_{i-5} + x_{i-4} + x_{i-3} + x_{i-2} + x_{i-1} + x_{i+1} + x_{i+2} + x_{i+3} + x_{i+4} + x_{i+5}).$$

Transformations 5 through 8 replace x in the above expression with 5) $\sum y$, 6) $\sum y^2$, 7) $(\sum y)^2$, 8) $(\sum y^2)^2$. Finally, transformation 9 counts the number of $\sum y$'s per epoch exceeding 90% of the maximum $\sum y$, and transformation 10 counts the number of $\sum y^2$'s exceeding 90% of the maximum $\sum y^2$. The most significant 16 bits of each transformation were then stored on disc for each 2-second epoch.

Seven all-night wrist activity records were digitized according to the procedure described above. Portions of the digitized records were displayed visually on our plotter to examine the behavior of the 10 transformations during different forms of activity. (One such plot is presented in Figure 6 along with the polygraph record of the same five-minute interval.) A more rigorous analysis of the adequacy of each transformation was obtained by first visually scoring each of the seven polygraph activity records for sleep/wake and merging the sleep/wake score to the digitized data. A separate analysis program was then written (Appendix 2) to recognize sleep from the digitized activity data and determine the maximum percent agreement between the computed and known sleep/wake status. It

should be pointed out that this sleep recognition program is not the ultimate sleep recognition program currently under development but a simpler procedure which decides that a minute is "wake" if the activity score in x of the 30 epochs exceeded a threshold of y . The x , y parameter space was then searched and the maximum percent agreement determined for each record and each transformation. This result served to compare the discriminating power of the ten preprocessing algorithms. The thresholds producing the best agreement were calculated individually for each record and therefore differed from record to record. In practice, a transformation would have to discriminate sleep from wake using the same threshold for all records. The procedure was thus repeated except that the maximum percent agreement was calculated using the single best threshold for all records taken together.

Results

Figure 6 shows the plotter display and polygraph writeout of a five-minute portion of a record contaminated with 60 Hz noise from an electric blanket. The ten horizontal traces on the plot represent the ten digital transformations of the analog activity displayed on the polygraph. The vertical lines on the plot separate minutes, which are also marked and labelled with a binary code on the polygraph paper. Of particular interest in this figure is the contrast between traces 1, 3, 5 and 7 and traces 2, 4, 6, 8, 9 and 10 during periods of electric blanket noise. Since even-numbered transformations square voltage prior to summation, all values are positive and cancellation of 60 Hz noise cannot occur. Transformations 1, 3, 5 and 7 do not square voltage prior to summation and cancellation of noise can and does occur. The absence of noise in these latter traces indicates the effectiveness of the simple digital filtering technique.

The potential of each of the ten methods of digital preprocessing was evaluated by calculating the maximum percent agreement between known sleep/wake status and sleep/wake status computed using each of the ten transformations. Table 2 summarizes the maximum percent agreement when the optimal threshold was found for each record individually. Table 3 presents the rank order of maximum percent agreement for each record. Despite some variability, the indication from these data is that transformations 5 and 6 were superior to the others. Maximum percent agreement using the single best threshold for all records is presented in Table 4, and rankings are presented in Table 5. (Transformations 1, 2 and 10 were not tested since they were judged inadequate after the first procedure.) Transformation 5 emerged as the best overall. Although this was a retrospective procedure not strictly comparable to prospective scoring, it was encouraging that the median percent agreement obtained for the best algorithm was 0.91.

Discussion

Since the volume of data generated by frequent A/D conversions of analog activity records could not possibly be stored or managed in its entirety, strategies for data compression were evaluated. In order to preserve some resolution, the basic data epoch was set at two seconds. To utilize the simple 60 Hz noise filter resulting from summation in even integer multiples of 60 Hz, an A/D conversion rate of 240 Hz was selected. Within these constraints, ten algorithms for preprocessing the analog voltage reading were evaluated and it was concluded that a measure of voltage change was preferable to simple or squared summation, or threshold detections. The 60 Hz noise rejection filter was also effective and is an important feature of the transformation finally selected.

SLEEP RECOGNITION

Our experience with scoring activity records suggests that a judgement whether the subject is asleep or awake can be based on reasonably simple and definable criteria with reasonable reliability. If there is no movement at all for several minutes, the subject is judged asleep. The exact number of minutes quiescent required for scoring sleep depends on the previous and subsequent evidence of wakefulness, and it is here that some complex judgements are required. Periods when only occasional brief movements are detected in the record are also difficult to score. Nevertheless, we feel scoring criteria can be reduced to a logical decision system and implemented in a field-transportable computerized read-out device.

We have decided to attack the problem of discerning the optimal rules for sleep recognition by constructing an expression with a number of potential discriminators, then allowing the computer to vary the weighting of each factor in an adaptive search procedure. The expression presently being tested is:

$$D = s * (c_1 T_1 + c_2 T_2 + c_3 T_3 + c_4 T_4 + c_5 T_5 + c_6 T_6)$$

where s is a scale factor, c_1 to c_6 are weights, and T_1 to T_6 are the factors. T_1 is the sum of the activity scores in all 30 epochs in a minute, T_2 is the sum of the activity scores in the 8 most active epochs, T_3 is the activity score in the single most active epoch, and T_4 is the sum of the activity scores in the two most active epochs per minute separated by at least 30 seconds. T_5 and T_6 are context factors which are themselves weighted sums of activity in the preceding and following 3 minutes. For example, T_5 may be six times the sum of activity scores in the last minute plus 3 times the sum of activity in the next-to-last minute plus the sum of activity scores in the third-to-last minute:

$$T_5 = T_{1, i-3} + 3 * T_{1, i-2} + 6 * T_{1, i-1}, \quad \text{and}$$

$$T_6 = T_{1, i+3} + 3 * T_{1, i+2} + 6 * T_{1, i+1}.$$

(The activity score in each 2-second epoch is transformation 5.) A minute is judged "wake" if $D \geq 1.0$, with scale factors adjusted to the best discriminating point. The maximum percent agreement within this range of scale values is determined over an entire file containing data of over 3000 minutes from the 7 sleep/wake records tested above. The computer then varies the weighting of one term at a time, searching for the combination of weights which produces the highest percent agreement. It is entirely possible that weights of zero will be assigned to some of these factors, or that other factors will be desirable. For example, we hope to add a term for respiration artifact. We are confident that this approach will reveal an optimal technique for recognizing sleep in a minute of activity data.

The implementation of this sleep recognition program is not yet complete. A version of the program in which weights of 0 or 1 were assigned each term factorially has been run, and a maximum percent agreement of 0.93 has been obtained. A listing of this program is included in Appendix 3. Modifications to increase the flexibility of the program are the focus of our efforts for the final two months of this contract year.

Although still a retrospective test and as yet referenced to hand-scoring of activity (not yet EEG), this percent agreement is also extremely encouraging and suggests our efforts will ultimately be comparable to hand-staging. Completion of this program and definition of the staging procedure should be complete as planned by the end of this contract year.

In order to provide a larger data base for testing the sleep recognition program in which careful referencing against EEG scoring is possible, two further sets of programs have been implemented. The first set performs the 240 Hz preprocessing in real time, so that the program can be run during on-going sleep recordings in our laboratory. We are currently accumulating a data base of such recordings which have been both digitized directly from the real-time polygraphic recording and which have also been carefully hand-scored by EEG. The second set of programs collects a data base of hand-staging decisions, plots the sleep stage histogram, and computes sleep stage statistics. Listings of these programs are included in Appendix 4.

A PROTOTYPE DIGITAL ACTIVITY MONITOR

When the 1979-1980 year's contract work was proposed, we believed it would require the full year to develop a working breadboard model of a wearable actigraphic recorder, and a packaged model which could be worn could only be constructed in the 1980-81 year. After extensive negotiations with Mr. Bruce Rule of the Vitalog Corp. we jointly developed a design which could be constructed by them during the 1979-80 year, and which has actually been constructed and checked out in response to our purchase order, although we have not yet received delivery. This device, based on the IM6100 microprocessor (as planned), will have an 8-channel A/D converter, 500 x 12 bit words of EPROM monitor memory, and 6000+ words of 12-bit RAM memory, accessible by our Apple computer system. Most important, it will be packaged in a wearable form. Thus, by the end of this contract year, we expect to be slightly ahead of plan in our hardware development, because we will have gone from a breadboard to a packaged device. Nevertheless, debugging the packaged configuration and installation of the preprocessing software in the portable microprocessor is not likely to be commenced before the 1980-81 contract year, as had been originally planned.

PLAN FOR 1980-1981 IN BRIEF

In the 1980-81 year, as previously planned, we propose to install our sleep staging software in the portable digital recorder and test, refine, and validate its performance in actual sleep recording. At the end of 1981, we plan to submit a technical definition of requirements for a microminiaturized version which would be suitable for field or combat use.

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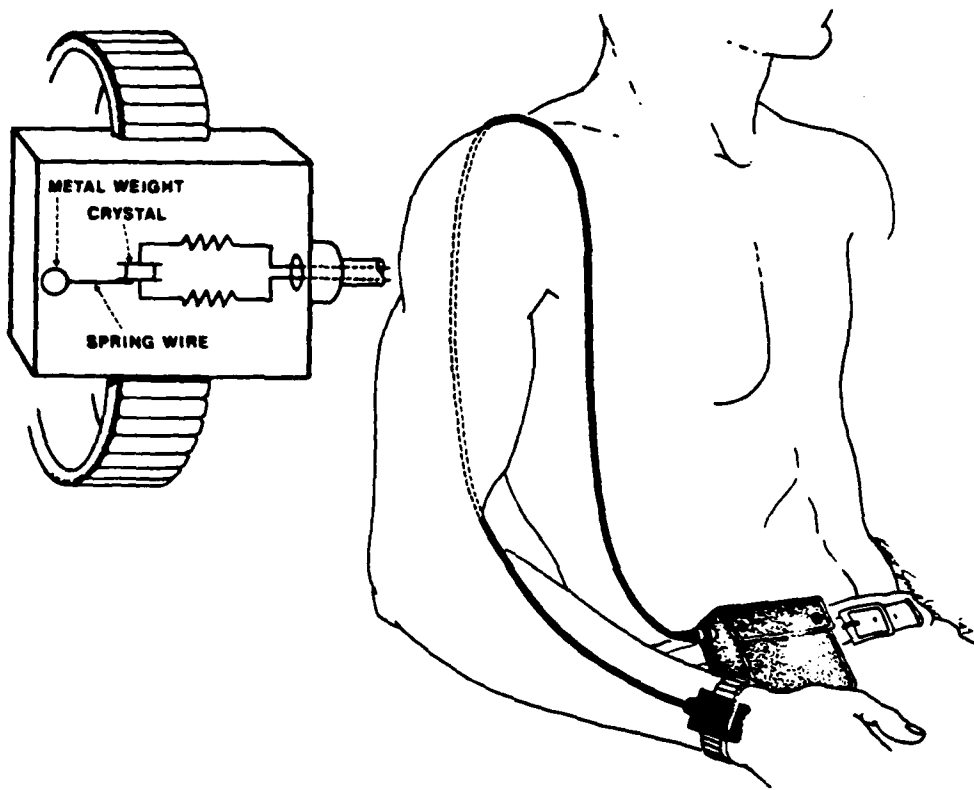


Figure 1. Our current actigraph system, consisting of a piezoelectric crystal transducer connected to a Medilog recorder capable of recording for about 30 hours on a C120 cassette. At left is stylized representation of transducer.

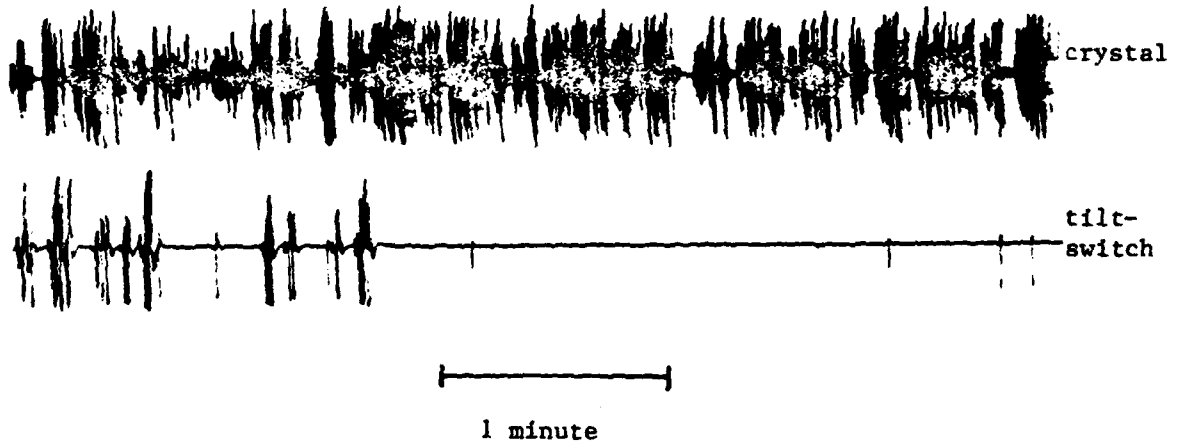


Figure 2. Representative polygraph writeout of activity recorded simultaneously from crystal actigraph (Channel 1, top) and Vitalog tilt-switch activity transducer (Channel 2). Although the crystal measures activity throughout the record, the tilt-switch fails to detect much of this activity.

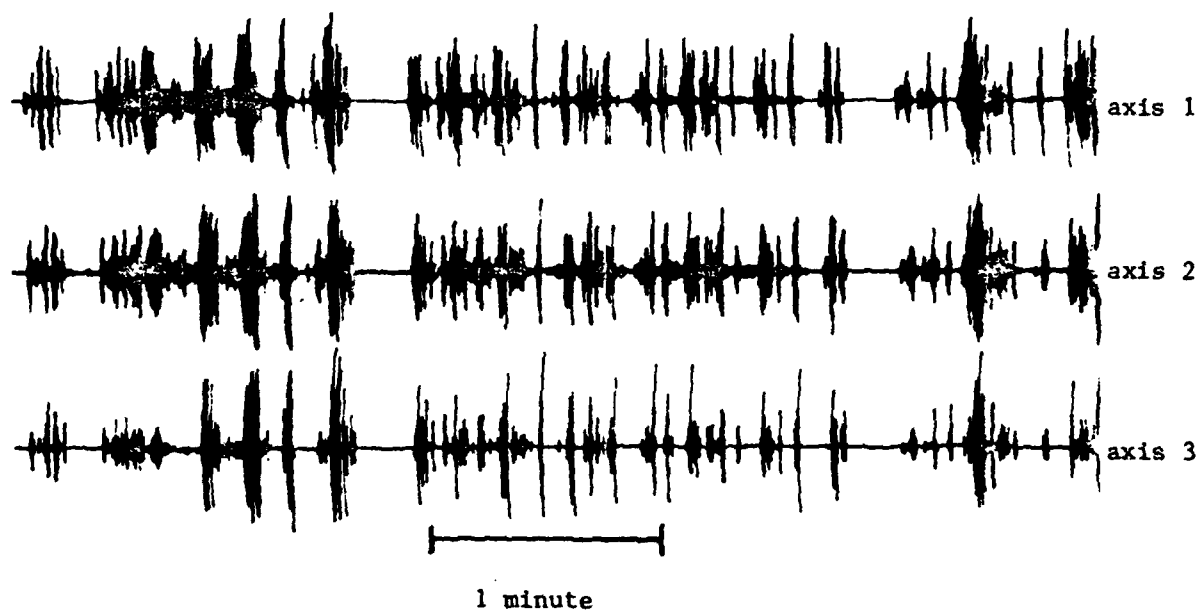


Figure 3. Representative polygraph writeout of 3 crystal actigraphs mounted at the 3 major axes within a single box and worn on the wrist. Although differences in amplitude occur between the 3 channels, there are no failures to detect activity in any channel.

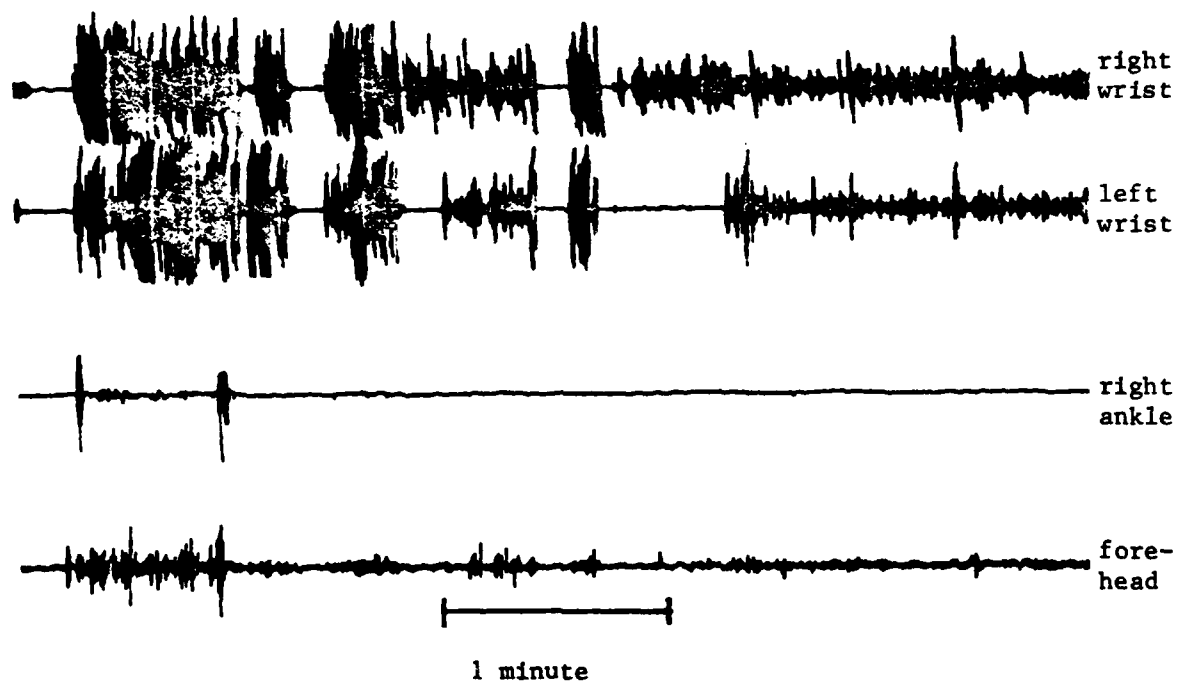


Figure 4. Representative polygraph writeout of activity detected by actigraphs mounted on the right wrist (Channel 1), left wrist (Channel 2), right ankle (Channel 3) and forehead (Channel 4). Bilateral wrist activity frequently occurs in the absence of head or ankle motion.

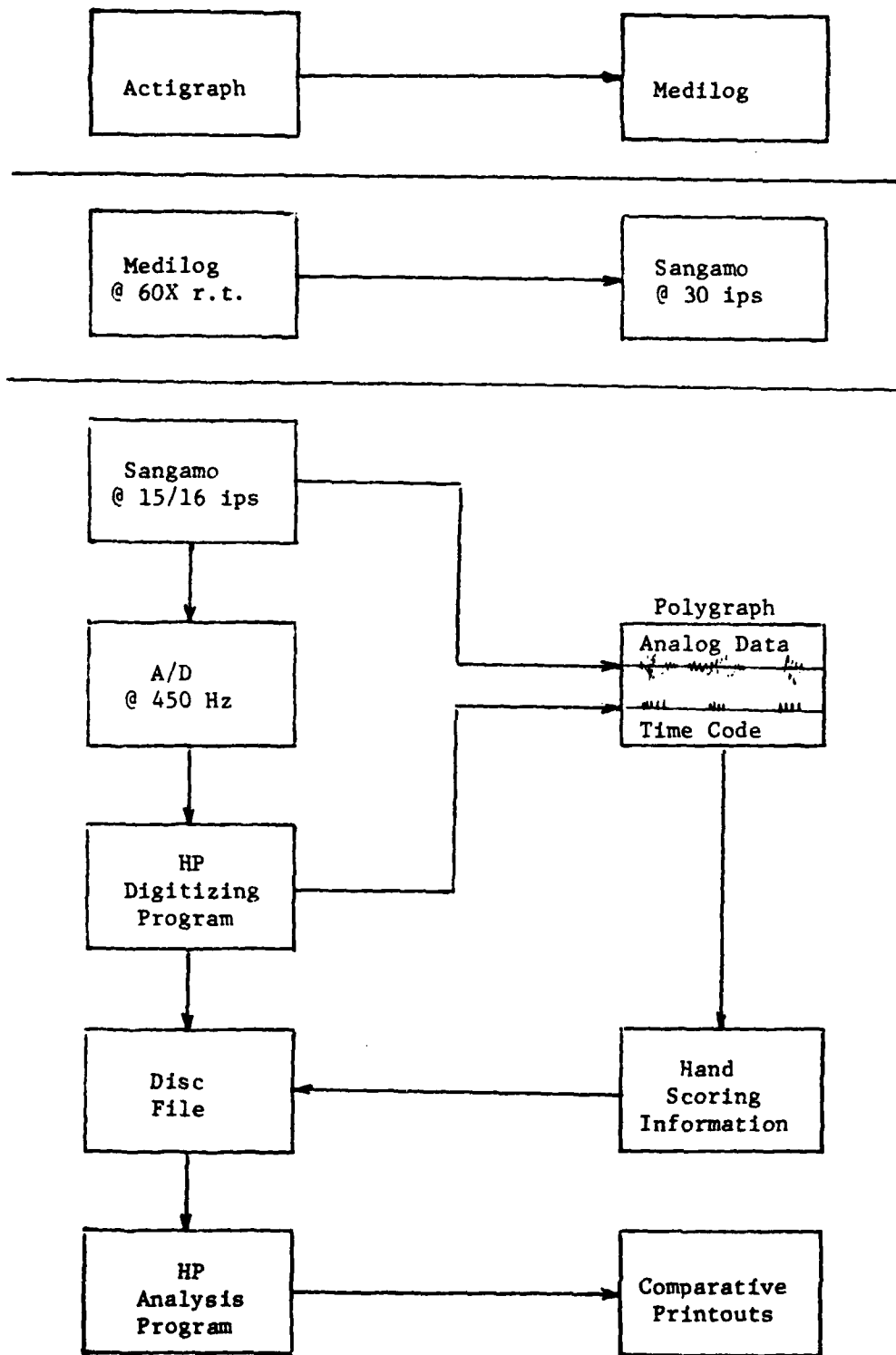


Figure 5. Block diagram illustrating procedure used to determine optimal digital preprocessing algorithm. See text for details.

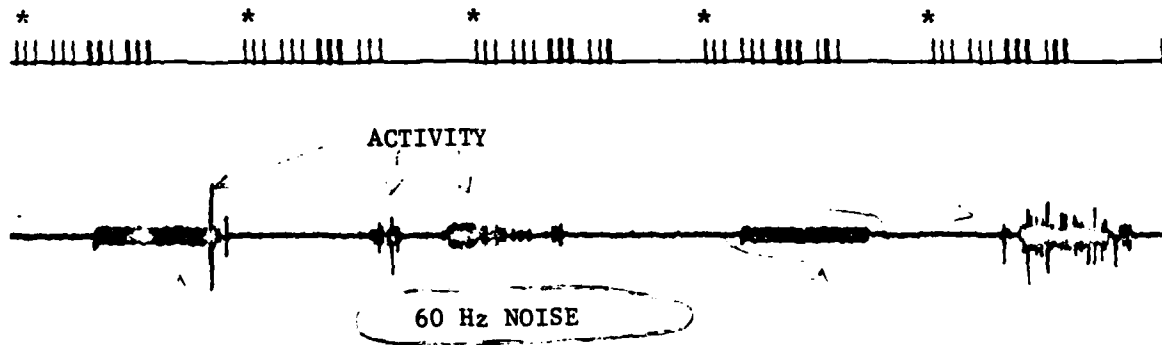


Figure 6a. Polygraph record. Channel 1 is time code. Asterisks indicate beginning of a minute. Channel 2 is analog recording illustrating activity mixed with 60 Hz noise caused by electric blanket.

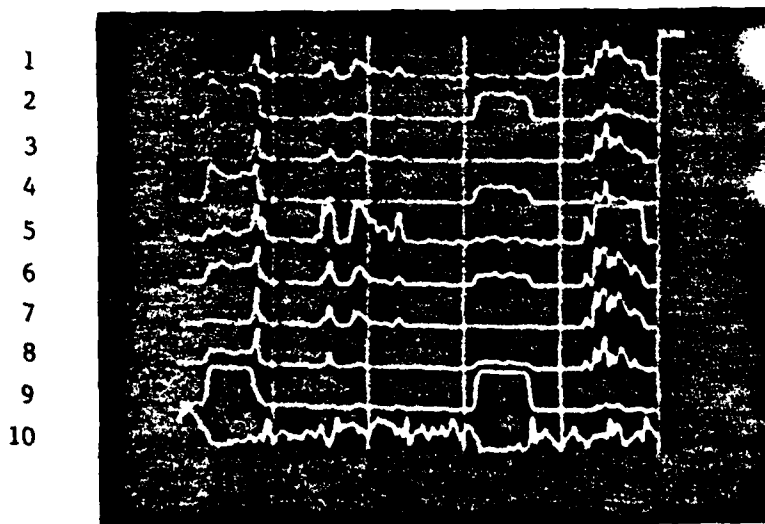


Figure 6b. Photograph of CRT display of 10 digital transformations of the same data. Vertical lines indicate beginning of a minute. Note the absence of noise in traces 1, 3, 5 and 7.

Location	Rating			
	(Best)			(Worst)
	1	2	3	4
Left Wrist	9	7	3	0
Right Wrist	9	7	2	1
Forehead	1	4	12	2
Ankle	0	1	2	16

Table 1. Frequency distribution of ratings (or rankings) of activity measured at the left and right wrist, head and ankle. Ratings reflect the relative amount of activity detected from the 4 transducers in each record (n=19).

Table 2. Maximum percent agreement between known sleep/wake status and sleep/wake status computed for each record and each transformation individually.

		Transform Number										
		1	2	3	4	5	6	7	8	9	10	
Record Number	1	.85	.87	.86	.89	.90	.90	.89	.90	.90	.83	
	2	.91	.93	.92	.93	.93	.93	.93	.93	.93	.85	
	3	.77	.82	.81	.84	.87	.85	.84	.83	.83	.79	
	4	.92	.96	.94	.94	.94	.95	.95	.94	.96	.83	
	5	.83	.83	.83	.84	.83	.84	.84	.84	.84	.85	.78
	6	.96	.97	.96	.97	.97	.97	.97	.97	.97	.95	.89
	7	.91	.89	.91	.88	.91	.90	.91	.89	.87	.80	
	Mean	.88	.90	.89	.90	.91	.91	.90	.90	.90	.82	
	Median	.91	.89	.91	.89	.91	.90	.91	.90	.90	.83	

Table 3. Rank ordering of percent agreement scores (Table 2) within each record.

		Transform Number									
		1	2	3	4	5	6	7	8	9	10
Record Number	1	9	7	8	6	1	3	5	3	1	10
	2	9	1	8	5	4	1	7	5	3	10
	3	10	7	8	4	1	2	3	5	5	9
	4	9	1	8	6	5	3	4	6	1	10
	5	9	7	7	4	6	2	4	2	1	10
	6	8	3	7	3	1	2	3	3	9	10
	7	1	7	1	8	1	5	4	6	9	10
	Mean	7.9	4.7	6.7	5.1	2.7	2.6	4.3	4.3	4.1	9.9
	Median	9	7	8	5	1	2	4	5	3	10

Table 4. Maximum percent agreement between known sleep/wake status and sleep/wake status computed for each transformation with all records taken together.

		Transform Number						
		3	4	5	6	7	8	9
Record Number	1	.75	.84	.74	.82	.66	.85	.80
	2	.89	.90	.91	.90	.90	.90	.90
	3	.72	.75	.84	.76	.78	.75	.71
	4	.91	.93	.94	.92	.92	.93	.94
	5	.74	.74	.56	.71	.56	.74	.83
	6	.96	.96	.97	.96	.95	.96	.94
	7	.90	.88	.91	.88	.91	.88	.87
	Mean	.84	.86	.84	.85	.81	.86	.86
	Median	.89	.88	.91	.88	.90	.88	.87

Table 5. Rank ordering of percent agreement scores (Table 4) within each record for all records taken together.

		Transform Number						
		3	4	5	6	7	8	9
Record Number	1	5	2	6	3	7	1	4
	2	7	2	1	2	2	2	2
	3	6	5	1	3	2	4	7
	4	7	3	1	5	5	3	1
	5	2	2	6	5	6	2	1
	6	2	2	1	2	6	2	7
	7	3	4	1	4	1	4	7
	Mean	4.6	2.9	2.4	3.4	6.6	2.6	4.1
	Median	5	2	1	3	5	2	4

APPENDIX 1

\$D5610 T=00004 IS ON CR00011 USING 00014 BLKS R=0132

```

0001 FTN4,L
0002     PROGRAM D5610,3
0003 C
0004 C-----LAST ALTERED: 12/13/79
0005 C
0006 C-----ACTIGRAPH DIGITIZER (PART 2)
0007 C
0008 C---THIS PRGM DIRECTS THE CONVERSION OF ANALOG
0009 C--ACTIVITY DATA INTO 10 DIGITAL TRANSFORMATIONS
0010 C--WHICH ARE STORED ON DISC. "D5610" IS CALLED
0011 C--FROM "C5610", AND BEGINS DUMPING DATA AT
0012 C--SECTOR 4 OF TRACK SPECIFIED IN CALLING PRGM. (JBW)
0013 C
0014     INTEGER BUFFER(512),IOUT(256),RMP(5),SECTOR,TRACK
0015     INTEGER DFSCR,FLAG,XCDSMA,XCDSMB
0016     INTEGER SUMA,SUMB,SUMASQ,SUMBSQ
0017     INTEGER SUMAPL(11),SUMBPL(11),SMA2PL(11),SMB2PL(11)
0018     INTEGER SUMADF,SUMBDF,SMA2DF,SMB2DF
0019     DATA IAPool,IBPool,I3Pool,I4Pool/4*0/
0020     DATA SUMAPL,SUMBPL,SMA2PL,SMB2PL/44*0/
0021 C
0022 C GET START TRACK FROM RMPAR
0023 C
0024     CALL RMPAR(RMP)
0025     ISTART=RMP
0026     TRACK=ISTART
0027     ITRACK=TRACK
0028     KPTS=1
0029     SECTOR=4
0030 C
0031 C READ IN 1 EPOCH OF DATA
0032 C
0033     FLAG=-1
0034     LL = 11
0035     CALL DMA1J(BUFFER,FLAG)
0036     10 IF (TRACK.GT.190) GO TO 10001
0037     9   IF(ISSW(0)) 1001,8
0038     8   IF(FLAG) 9,12
0039     12  IPTR=FLAG
0040     FLAG=-1
0041 C
0042 C INITIALIZE THE SUMS FOR THIS EPOCH
0043 C
0044     11  SUMA=0
0045     SUMB=0
0046     SUMASQ=0
0047     SUMBSQ=0
0048     SUMADF=0
0049     SUMBDF=0
0050     SMA2DF=0
0051     SMB2DF=0

```

```

0052      ISMAX=0
0053      ISBMX=0
0054 C
0055 C COMPUTE THE SUMS OVER THE LAST EPOCH
0056 C
0057      DO 100 J = 1,240,2
0058      IB=BUFFER(J+IPTR)
0059      IA=BUFFER(J+IPTR+1)
0060      CALL JSHFT(IA, IB, IA2, IB2)
0061      IF (SUMA+IA.LT.0) GO TO 20
0062      SUMA=SUMA+IA
0063      GO TO 25
0064 20 SUMA=32767
0065 25 IF (SUMB+IB.LT.0) GO TO 30
0066      SUMB=SUMB+IB
0067      GO TO 35
0068 30 SUMB=32767
0069 35 IF (SUMASQ+IA2.LT.0) GO TO 40
0070      SUMASQ=SUMASQ+IA2
0071      GO TO 45
0072 40 SUMASQ=32767
0073 45 IF (SUMBSQ+IB2.LT.0) GO TO 50
0074      SUMBSQ=SUMBSQ+IB2
0075      GO TO 55
0076 50 SUMBSQ=32767
0077 55 CONTINUE
0078 C
0079 C COMPUTE J+5 MODULO 11
0080 C
0081      LL = LL - LL/11*11 + 1
0082      MM = LL + 4
0083      MM = MM - MM/11*11 + 1
0084      IF (ISMAX.LT. IA) ISMAX=IA
0085      IF (ISBMX.LT. IB) ISBMX=IB
0086 C
0087 C COMPUTE DIFFERENCE SCORES
0088 C
0089      IQ=DFSCR(IA, LL, SUMAPL, IAPOL, MM)
0090      IF (SUMADF+IQ.LT.0) GO TO 60
0091      SUMADF=SUMADF+IQ
0092      GO TO 65
0093 60 SUMADF=32767
0094 65 IQ=DFSCR(IB, LL, SUMBPL, IBPOOL, MM)
0095      IF (SUMBDF+IQ.LT.0) GO TO 70
0096      SUMBDF=SUMBDF+IQ
0097      GO TO 75
0098 70 SUMBDF=32767
0099 75 IQ=DFSCR(IA2, LL, SMA2PL, I3POOL, MM)
0100      IF (SMA2DF+IQ.LT.0) GO TO 80
0101      SMA2DF=SMA2DF+IQ
0102      GO TO 85
0103 80 SMA2DF=32767
0104 85 IQ=DFSCR(IB2, LL, SMB2PL, I4POOL, MM)
0105      IF (SMB2DF+IQ.LT.0) GO TO 90

```

```

0106      SMB2DF=SMB2DF+IQ
0107      GO TO 100
0108      90 SMB2DF=32767
0109      100  CONTINUE
0110      C
0111      C  COUNT THE PEAKS
0112      C
0113      XCDSMA=0.9*ISMAX
0114      XCDSMB=0.9*ISMBMX
0115      NCTA=0
0116      NCTB=0
0117      DO 200 J=1,240,2
0118      IA=BUFFER(J+IPTR)
0119      IB=BUFFER(J+IPTR+1)
0120      IF(IA.GE.XCDSMA) NCTA=NCTA+1
0121      IF(IB.GE.XCDSMB) NCTB=NCTB+1
0122      200  CONTINUE
0123      C
0124      C  FILL THE OUTPUT BUFFERS
0125      C
0126      L=KPTS
0127      IOUT(L)=SUMA
0128      IOUT(L+1)=SUMB
0129      IOUT(L+2)=SUMASQ
0130      IOUT(L+3)=SUMBSQ
0131      IOUT(L+4)=SUMADF
0132      IOUT(L+5)=SUMBDF
0133      IOUT(L+6)=SMA2DF
0134      IOUT(L+7)=SMB2DF
0135      IOUT(L+8)=NCTA
0136      IOUT(L+9)=NCTB
0137      KPTS=KPTS+10
0138      IF(KPTS.LT.250) GO TO 1000
0139      C
0140      C  WE'RE READY TO WRITE
0141      C
0142      CALL EXEC(2,2107B,IOUT,256,TRACK,SECTOR)
0143      KPTS=1
0144      SECTOR = SECTOR+4
0145      IF(SECTOR.LT.95) GO TO 1000
0146      TRACK=TRACK+1
0147      SECTOR = 0
0148      1000 GO TO 10
0149      10001 WRITE (1,10002)
0150      10002 FORMAT (" DISC FULL ")
0151      1001  CALL STP56
0152      WRITE(1,10010) ITRACK,TRACK,SECTOR
0153      10010 FORMAT("END OF DATA REDUCTION AND TRANSFER"/
0154      1," DATA ORIGIN"," TRACK :",I8/,
0155      2" AND CONCLUSION TRACK :",I8," SECTOR :",I8)
0156      C
0157      C
0158      C
0159      STOP

```

0160
0161

END
END\$

\$DMA1J T=00004 IS ON CRO0011 USING 00034 BLKS R=0347

```
0001 ASMB,L,R
0002     NAM DMA1J,3
0003 *** THIS PRGM READS A/D THRU DMA1, ACCUMULATES
0004 * SUMS & SUMS OF SQUARES, GENERATES TIME CODE,ETC
0005 * MODIFIED BY JBW 11/26/79
0006     ENT P5610,DMA1J,BUFFR
0007     ENT STP56
0008     EXT $LIBR,$LIBX,.ENTR,JP561
0009 BUFFR NOP
0010 FLAG  NOP
0011 DMA1J NOP
0012     JSB .ENTR
0013     DEF BUFFR
0014     JSB $LIBR
0015     NOP
0016     LDA DMA1J
0017     STA SVALV
0018     CLF 0
0019     CLC 7B
0020     LDA JP561
0021     STA 6B
0022     LDA DMA1J
0023     STA P5610
0024     LDA BUFFR
0025     STA PTBF
0026     CLA
0027     STA 10B
0028     LDA CW1
0029     OTA 6B
0030     CLC 2B
0031     LDA DBUF
0032     IOR =B100000
0033     OTA 2B
0034     STC 2B
0035     LDA CW3
0036     OTA 2B
0037     LDA MODE
0038     OTA SC
0039     STC SC,C
0040     STC 6B,C
0041     LDA CLC6,I
0042     STA CLSAV
0043     LDA STC6,I
0044     STA STSAV
0045     CLA
0046     STA CLC6,I
0047     STA STC6,I
0048     LDB INTBA
0049     INB
0050     LDA 1,I
0051     SZA
0052     STC 7B
```



```

0053     LDA STF0
0054     STA XXLNK
0055     LDA STC
0056     STA XXLNK+1
0057     LDA =B124774
0058     STA XXLNK+2
0059     JSB $LIBX
0060     DEF P5610
0061 P5610 NOP
0062     CLF 0
0063     CLF 6
0064     CLC 6B
0065     STA XA
0066     STB XB
0067     ERA,ALS
0068     SOC
0069     INA
0070     STA XEO
0071 *
0072 * ALLOW PRIVILEGED INTERRUPTS WITH THIS DRIVER
0073 *
0074     LDA MPTFL SAVE STATE OF MP ON ENTRY
0075     STA MPFSV
0076     INA MPTFL INDICATE TO ALL OTHERS MP OFF
0077     STA MPTFL
0078     STC 12B ENABLE PRIVILEGED INTERRUPTS
0079     STF 12B
0080     CLC 7B DISABLE DMA CH2
0081     CLC 10B,C CLEAR FLAG ON 5610 IF ANY
0082     STF 00B ALLOW OTHERS THEIR CHANCE
0083     LDA CW1
0084     OTA 6B
0085     CLC 2B
0086     LIA 01B
0087     SLA
0088     JMP HALT
0089     IOR =B4
0090     OTA 01B
0091     LDA DBUF
0092 GO IOR =B100000
0093     OTA 2B
0094     STC 2B
0095     JSB RESET RESTART DMA+5610
0096     JSB CHECK HAVE WE MADE OURSELVES RE-ENTRANT?
0097     LIA 01B ELSE SIGNAL HERE
0098     IOR =B10
0099     OTA 01B
0100 *
0101 * PROCESS INPUT FROM A/D
0102 *
0103     CLA ZERO SUMA & SUMB
0104     STA SUMA
0105     STA SUMB
0106     LDA DBUF INIT. PNTR FOR INPUT BUF

```

```

0107      STA PTR
0108      LDA =D-4  SET UP CNTR TO SUM 4 VAL.S
0109      STA CTR
0110  L.XX  LDA PTR,I  GET VAL. FROM BUF (X)
0111      CLB
0112      SSA          IS X NEG?
0113      JMP XNEG
0114      LSR 6          NO, SHIFT 6 BITS OF JUNK
0115      JMP AHEAD      AND JUMP AHEAD
0116  XNEG  CMA,INA      YES, MAKE POS.,
0117      LSR 6          THEN SHIFT 6 BITS
0118      CMA,INA      THEN NEGATE AGAIN
0119  AHEAD  LDB 0
0120      ADA SUMA
0121      STA SUMA      ADD X TO SUMA
0122      LDA 1
0123      MPY 0  SQUARE X & TRUNCATE TO 9 BITS
0124      LSR 9
0125      ADA SUMB      ADD X-SQ TO SUMB
0126      STA SUMB
0127      ISZ PTR
0128      ISZ CTR      HAVE WE DONE 4 RPTS?
0129      JMP L.XX     NO, LOOP BACK
0130      STA PTBF,I   YES, PACK SUMB IN OUT BUF
0131      ISZ PTBF
0132      LDA SUMA      PACK SUMA IN NEXT BUF LOC
0133      STA PTBF,I
0134      ISZ PTBF
0135      CLA
0136      ISZ EPOCH    HAVE WE DONE AN EPOCH YET?
0137      JMP GTM      NO, EXIT
0138  *
0139  *  AN EPOCH HAS BEEN ACCUMULATED IF HERE
0140  *
0141      LDA FLAG,I
0142      SSA,RSS      DATA RATE EXCESSIVE
0143      JMP HALT      IF BRANCH TAKEN
0144      LDA OR
0145      XOR MASK
0146      STA MASK      OUT BUF READY TO WRITE
0147      STA FLAG,I
0148      XOR OR        SWITCH TO THE NEXT OUT BUF
0149      ADA BUFR
0150      STA PTBF
0151      LDA =D-120   SET UP FOR ANOTHER EPOCH
0152      STA EPOCH
0153  *
0154  *  SET UP TIME CODE PULSE TRAIN
0155  *
0156      ISZ PM30     COUNT 30 EPOCHS BEFORE
0157      JMP GTM      INCREMENTING TIME CODE
0158      LDA =D-30    REPRESENTING MINUTES
0159      STA PM30     IN REAL TIME
0160      LDA XBITS

```

```

0161      STA GOFLG
0162      LDA =D-3
0163      STA OCNT
0164      LIA 01B
0165      AND =B17
0166      LDB TCTR
0167      BLF
0168      IOR 1
0169      AND =B77777
0170      OTA 01B      SET THE COUNT FOR ALL TO SEE
0171      LDA TCTR
0172      INA
0173      STA TCTR
0174      ALF
0175      STA OTWRD      SAVE IN TEMP STORAGE
0176      JMP GOP11
0177  GTM   CLA
0178      ISZ DELAY      COUNT TO 40
0179      JMP ZERO        BEFORE SENDING
0180      LDA =D-40      TIME CODE BIT
0181      STA DELAY      TO RELAY
0182      LDA GOFLG      JUMP OUT IF
0183      SSA,RSS        ALL BITS HAVE
0184      JMP GO1         BEEN SENT.
0185      LDA TCNT       INCREMENT SEQUENCER
0186      INA            AND EVALUATE
0187      STA TCNT
0188      SSA,RSS
0189      JMP NZERO
0190      CLA            MINUS: SEND A ZERO
0191      JMP ZERO
0192  NZERO SZA,RSS      ZERO: SEND DATA
0193      JMP NTWO
0194      LDB =D-3       ONE: SEND A ONE &
0195      STB TCNT       RESET SEQUENCER
0196      ISZ GOFLG
0197      NOP
0198      JMP ZERO
0199  NTWO  ISZ OCNT     LEAVE A GAP BETWEEN
0200      JMP NONE       EACH OCTAL DIGIT
0201      LDA =D-4
0202      STA OCNT
0203      LDA =D-3
0204      STA TCNT
0205      CLA
0206      JMP ZERO
0207  NONE  LDA OTWRD
0208  GOP11 RAL
0209      STA OTWRD
0210  ZERO  AND =B1      SAVE ONLY ONE BIT OF THE WORD
0211      LIB MICRO      GET CURRENT RELAY STATUS
0212      SWP            EXCHANGE A, B REGISTERS
0213      AND =B17770    SAVE ALL BUT TOGGLE BIT
0214      IOR B          RECONSTRUCT AND

```

```

0215      OTA MICRO      LOAD REGISTERS ON RELAY CARD
0216      STC MICRO,C    NOW LATCH REGISTERS
0217      JMP GO1        NOW EXIT
0218      *
0219      DELAY DEC -40
0220      PM30 DEC -30   30 EPOCHS PER MINUTE CNTR
0221      XBITS DEC -11  12 BITS TO BE OUTPUT
0222      TCNT DEC -3
0223      OCNT DEC -3
0224      TCTR OCT 4000  TIME PULSE COUNT;
0225      OTWRD NOP      TEMPORARY STORAGE FOR TIME CODE
0226      GOFLG NOP      FLAG TO INDICATE NO. OF BITS LEFT
0227      MICRO EQU 21B  RELAY CARD I/O SLOT ADDRSS
0228      B EQU 1        B REGISTER
0229      A EQU 0        A REGISTER
0230      GO1 LDA CW3     LOAD COUNT FOR DATA INPUT
0231      OTA 2B
0232      LDA MODE
0233      OTA SC
0234      STC SC,C
0235      STC 6B,C
0236      OUT CLF OOB    PREPARE FOR EXIT
0237      CLA
0238      STA TFLAG
0239      LDA MPFSV RESTORE STATE OF MEMORY
0240      STA MPTFL PROTECT TO WHAT IT WAS ON ENTRY
0241      SZA,RSS
0242      JMP POUT IT WAS ON
0243      LDB XB
0244      LDA XEO
0245      CLO
0246      SLA,ERA
0247      STF 1B
0248      LDA XA
0249      STF 0
0250      JMP P5610,I
0251      POUT LDA P5610
0252      STA XLINK
0253      CLC 12B ALLOW ALL INTERRUPTS AGAIN
0254      STF 12B PREPARE FOR NEXT TIME AND $CIC
0255      DLD INTBA,I EXAMINE INTERRUPT TABLES
0256      SSB SKIP IF BUSY BIT NOT ON
0257      STC 07B OTHERWISE, ALLOW DMA CH2 TO INTERRUPT
0258      *
0259      * THE ABOVE CODE IS NEARLY IDENTICAL TO THAT IN
0260      * $IRT AND $CIC
0261      *
0262      LDB XB
0263      LDA XEO
0264      CLO
0265      SLA,ERA
0266      STF 1B
0267      LDA XA
0268      JMP XLINK+1

```

```

0269 PTBF OCT 0 POINT TO THE USER OUT BUFFER AREA
0270 DBUF DEF DMA1J USE THE CODE FOR A BUFFER!!!!
0271 SUMA OCT 0
0272 SUMB OCT 0
0273 CTR OCT 0
0274 PTR NOP
0275 SC EQU 10B
0276 STFO STF 0B
0277 XLINK EQU 774B
0278 XXLNK EQU 775B
0279 XA OCT 0
0280 XB NOP
0281 XEO NOP
0282 MPFSV NOP TEMPORARY REGISTER FOR FLAG(MP)
0283 EPOCH DEC -120
0284 MASK DEC 256
0285 OR DEC 256
0286 MPTFL EQU 1770B
0287 CW1 OCT 120010
0288 CW3 DEC -4
0289 CLC6 OCT 003531 MODIFIED BY GW,7 78
0290 STC6 OCT 003667 MODIFIED BY GW, 7 78
0291 STSAV OCT 0
0292 CLSAV OCT 0
0293 MODE OCT 10000
0294 INTBA EQU 1654B
0295 STF STF 0B
0296 STC STC 5B
0297 *
0298 HALT CLC 06B,C
0299 LIA 01B
0300 IOR =B2
0301 OTA 01B
0302 JMP OUT
0303 STP56 NOP
0304 *
0305 *
0306 * THIS ROUTINE MUST BE ENTERED WHEN THROUGH
0307 * WITH THE 5610 OR ELSE YOU'LL BE SORRY.
0308 *
0309 *
0310 ISZ STP56
0311 JSB $LIBR
0312 NOP
0313 CLC 06B,C STOP
0314 CLA
0315 OTA 01B CLEAR DISPLAY REGISTER
0316 STA 06B PREVENT ANY MORE INTERRUPTS
0317 JSB $LIBX RETURN TO NORMAL
0318 DEF STP56 AND TO THE USER
0319 *
0320 *
0321 * RESTART DMA & 5610 A/D HERE
0322 *

```

```
0323 *
0324 RESET NOP
0325 LDA CW3
0326 OTA 02B LOAD NEGATIVE COUNT WORD
0327 LDA MODE SET CONTROL ON 5610
0328 OTA SC
0329 STC SC,C SET CONTROL LINE LOGIC
0330 STC 06B,C RESTART DMA
0331 JMP RESET,I DONE!
0332 *
0333 *
0334 *
0335 *
0336 *
0337 *
0338 BAD CLC 06B,C STOP,STOP,STOP!
0339 LDA SVALV LOCATE LAST GOOD LINK
0340 STA P5610
0341 CLC 10B,C
0342 LDA =B777 SIGNAL WE'RE OUT OOF LUCK
0343 OTA 01B SET SWITCH PANEL
0344 JMP GO1 TRY IT AND HOPE FOR THE BEST
0345 *
0346 *
0347 * HERE MAKE SURE WE HAVE'NT INTERRUPTED OURSELVES
0348 *
0349 *
0350 *
0351 CHECK NOP
0352 LDA TFLAG IF ZERO, WE'RE IN LUCK
0353 SZA
0354 JMP BAD TOO BAD!
0355 INA
0356 STA TFLAG
0357 LDA P5610 SAVE THE GOOD LINK
0358 STA SVALV
0359 JMP CHECK,I NOW WE HAVE A SAFETY VALVE
0360 SVALV NOP
0361 TFLAG NOP
0362 END
```

\$DFSCR T=00004 IS ON CRO0011 USING 00004 BLKS R=0000

```

0001 ASMB, L, R
0002     NAM DFSCR, 3
0003     ENT DFSCR
0004     EXT .ENTR
0005 XJ   NOP
0006 J    NOP
0007 SUM  NOP
0008 SMPL NOP
0009 K    NOP
0010 DFSCR NOP
0011     JSB .ENTR
0012     DEF XJ
0013     LDA XJ, I
0014     LDB SMPL, I
0015     ADA 1     SMPL=SMPL+XJ
0016     LDB K, I
0017     ADB SUM   ADDRESS OF SUM(K)
0018     ADB =D-1
0019     CMA, INA
0020     ADA 1, I   -SMPL+SUM(K)
0021     CMA, INA
0022     STA SMPL, I
0023     LDA XJ, I   SUM(K)<- XJ
0024     STA 1, I
0025     LDA J, I
0026     ADA =D-1
0027 *   XK <- SUM(J)
0028     ADA SUM   A(SUM(J)) -> A
0029     LDA 0, I   A<-SUM(J)
0030     MPY =D11   XK*11
0031     CMA, INA
0032     ADA SMPL, I -XK*11+SMPL
0033     SSA           TAKE ABSOLUTE VALUE
0034     CMA, INA
0035     JMP DFSCR, I RETURN
0036     END

```

APPENDIX 2

?JSRCH T=00004 IS ON CRO0011 USING 00023 BLKS R=0200

```

0001 FTN4,L
0002     PROGRAM JSRCH,3
0003 C-----
0004 C     2/7/80
0005 C
0006 C     "JSRCH" EVALUATES CRITERIA FOR RECOGNIZING
0007 C     SLEEP FROM DIGITIZED ACTIVITY DATA. RECORD
0008 C     HAS BEEN SCORED VISUALLY & SLEEP PERIODS
0009 C     ARE IDENTIFIED ON DISK (USING "SCORE"
0010 C     PROGRAM).     JBW
0011 C
0012 C     CALL IS: *"ON,SLEEP,ST,LT,LS,AL" WHERE 'ST' IS
0013 C     START TRACK, 'LT' & 'LS' ARE LAST TRACK & SECTOR
0014 C     AND 'AL' IS STARTING ALGORITHM #
0015 C
0016 C     NOTE: "STOP 6666" MEANS RECORD HAS NOT
0017 C     BEEN SCORED. RUN "SCORE", THEN TRY AGAIN
0018 C     "STOP 7777" IS NORMAL TERMINATION
0019 C-----
0020     DIMENSION NBUF(3072),IBUF(256),FPO(4),IPRM(5)
0021     EQUIVALENCE (IPRM,IT1),(IPRM(2),IT2),(IPRM(3),IS2)
0022     EQUIVALENCE (IPRM(4),ITR),(IPRM(5),IC)
0023     CALL RMPAR(IPRM)
0024 C-----
0025 C     CHECK FOR CORRECT DISC
0026 C-----
0027     CALL EXEC(1,113B,IBUF,256,0,0)
0028     IF (IBUF(2).NE.3828) STOP 1111
0029 C-----
0030 C     SET UP FIRST PASS: INTERPRET SCORED D5610-FORMAT
0031 C     DATA & STORE IN TEMPORARY SCRATCH-PAD AREA
0032 C     REPEAT FOR EACH ALGORITHM
0033 C-----
0034     IF (ITR.EQ.0) GO TO 100
0035     ITR=ITR-1
0036 100 ITR=ITR+1
0037     SMAX=0.
0038     NS=(IT2-IT1)*96+IS2-4
0039     IT=IT1
0040     IS=4
0041     KEP=0
0042     IMAX=0
0043     IMIN=32767
0044     NTR=1
0045     NSEC=0
0046     JSLP=0
0047     SLPN=0.
0048 C-----
0049 C     READ D5610 DATA 4 SECTORS AT A TIME
0050 C-----

```



```

0051      DO 800 I=1,NS,4
0052      CALL EXEC(1,113B,IBUF,256,IT,IS)
0053      IS=IS+4
0054      IF (IS.LT.95) GO TO 700
0055      IT=IT+1
0056      IS=0
0057 C-----
0058 C MAKE SURE DATA IS SCORED
0059 C-----
0060      700 IF (IBUF(256).EQ.9999) GO TO 750
0061      WRITE (4,720)
0062      720 FORMAT (" RECORD HAS NOT BEEN SCORED")
0063      STOP 6666
0064 C-----
0065 C DETERMINE RANGE OF ACTIVITY SCORES
0066 C-----
0067      750 DO 800 J=ITR,ITR+240,10
0068      IMIN=MINO(IMIN,IBUF(J))
0069      IMAX=MAXO(IMAX,IBUF(J))
0070 C-----
0071 C COMPRESS DATA & PLACE IN SCRATCH-PAD AREA
0072 C-----
0073      KEP=KEP+1
0074      NBUF(KEP)=IBUF(J)
0075      IF (MOD(KEP,30).NE.0) GO TO 800
0076 C-----
0077 C TRANSFER SLEEP/WAKE SCORE TO END OF SCRATCH-PAD
0078 C-----
0079      NBUF(2971+KEP/30)=IBUF(251+(J-1)/50)
0080 C-----
0081 C SUM MINS OF SLEEP & TOTAL MINS
0082 C-----
0083      JSPL=JSPL+IBUF(251+(J-1)/50)
0084      SLPN=SLPN+1.
0085      IF (KEP.LT.2970) GO TO 800
0086 C-----
0087 C WRITE WHEN BUFFER FULL
0088 C-----
0089      CALL EXEC(2,2113B,NBUF,3072,NTR,NSEC)
0090 C-----
0091 C REINITIALIZE & UPDATE FOR NEXT BUFFER
0092 C-----
0093      KEP=0
0094      DO 790 M=1,3072
0095      790 NBUF(M)=-1
0096      NSEC=NSEC+48
0097      IF (NSEC.LT.95) GO TO 800
0098      NTR=NTR+1
0099      NSEC=0
0100      800 CONTINUE
0101 C-----
0102 C END FIRST PASS: PRINT SUMMARY
0103 C-----
0104      PSLP=JSPL/SLPN

```

```

0105      WRITE (6,1060) IT1,IT2,IS2,ITR,IMIN,IMAX,PSLP,SLPN
0106 1060 FORMAT (IHI/" START: TRACK "I3" SECTOR 0"/
0107      -" STOP: TRACK "I3" SECTOR "I2/
0108      -" TRANSFORM#"I3/" MIN ="I6/
0109      -" MAX ="I6/" % SLEEP ="F4.3/
0110      -" # MINUTES SCORED ="F5.0/)
0111      WRITE (6,1070)
0112 C-----
0113 C SET UP SECOND PASS:
0114 C-----
0115      NSECS=NSEC+(NTR-1)*96
0116 1080 WRITE (4,1085)
0117 1085 FORMAT (" ENTER E/M CRIT., INIT. CRIT.,
0118      -TERM. CRIT., & STEP SIZE")
0119      READ (4,*) IC,CPR,CPS,CSTEP
0120      IF (IC.EQ.99) GO TO 1700
0121      IF (IC.LT.0) GO TO 2000
0122      ICR=IC
0123      WRITE (4,1070)
0124 1070 FORMAT (/14X"% CORR"6X"CRIT"3X"E/M"5X"" W'/W"
0125      -5X"" W'/S"5X"" S'/W"5X"" S'/S"/)
0126      KSEQ=1
0127      PMAX=0.
0128 1090 NTR=1
0129      NSEC=0
0130      MDV=0
0131      PO=0.
0132      NEP=0
0133      DO 1092 I=1,4
0134 1092 FPO(I)=0.
0135 C-----
0136 C READ DATA FROM SCRATCH-PAD
0137 C-----
0138      DO 1099 I=1,NSECS,48
0139      CALL EXEC(1,113B,NBUF,3072,NTR,NSEC)
0140      NSEC=NSEC+48
0141      IF (NSEC.LT.95) GO TO 1095
0142      NTR=NTR+1
0143      NSEC=0
0144 C-----
0145 C SET CRITERION & COUNT NUMBER OF EPOCHS
0146 C PER MINUTE EXCEEDING CRITERION
0147 C-----
0148 1095 DO 1099 J=1,2970
0149      IF (NBUF(J).EQ.-1) GO TO 1099
0150      MDV=MDV+1
0151      IF (FLOAT(NBUF(J)-IMIN).GE.(IMAX-IMIN)*CPR) NEP=NEP+1
0152      IF (MDV.LT.30) GO TO 1099
0153 C-----
0154 C DETERMINE TRUE SLEEP OR WAKE FOR THIS MIN.
0155 C-----
0156      KS=NBUF(2971+J/30)
0157 C-----
0158 C COMPUTE ESTIMATE OF SLEEP OR WAKE

```

```

0159 C FOR THIS MIN.
0160 C-----
0161     LS=2
0162     IF (NEP.GE.ICR) LS=0
0163 C-----
0164 C UPDATE CONTINGENCY ARRAY
0165 C-----
0166     1098 FPO(KS+LS+1)=FPO(KS+LS+1)+1.
0167     PO=PO+1.
0168     NEP=0
0169     MDV=0
0170     1099 CONTINUE
0171 C-----
0172 C COMPUTE PERCENT CORRECT & DISPLAY RESULTS
0173 C-----
0174     1100 PC=(FPO(1)+FPO(4))/PO
0175     DO 1150 I=1,4
0176     1150 FPO(I)=FPO(I)/FO
0177     GO TO (1160,1170),KSEQ
0178     1160 WRITE (4,1200) PC,CPR,ICR,(FPO(I),I=1,4)
0179     GO TO 1250
0180     1170 WRITE (6,1200) PC,CPR,ICR,(FPO(I),I=1,4)
0181     GO TO 1080
0182     1200 FORMAT (10X,2F10.4,16,4F10.4)
0183     1250 SMAX=AMAX1(SMAX,PC)
0184     PMAX=AMAX1(PMAX,PC)
0185     IF (PMAX.EQ.PC) CPMEM=CPR
0186     CPR=CPR+CSTEP
0187     IF (CPR.LE.CPS) GO TO 1090
0188     GO TO 1080
0189 C-----
0190 C PRINT MAX PC
0191 C-----
0192     1700 KSEQ=KSEQ+1
0193     CPR=CPMEM
0194     GO TO 1090
0195     2000 WRITE (6,2500) ITR,SMAX
0196     2500 FORMAT (/15X" OVERALL MAX % CORRECT FOR
0197     - TRANSFORM# "I2" = "F5.4)
0198     STOP 7777
0199     END
0200     ENDS

```

40
APPENDIX 3

?POLLY T=00004 IS ON CRO0011 USING 00021 BLKS R=0186

```

0001 FTN4,L
0002 PROGRAM POLY1,3
0003 C-----
0004 C 3/27/80
0005 C
0006 C "POLY1" READS ANY NUMBER OF PACKED ACTIVITY
0007 C RECORDS & CALCULATES A SERIES OF TERMS REPRESENTING
0008 C POTENTIAL DISCRIMINATORS BETWEEN SLEEP & WAKE.
0009 C THESE TERMS ARE WEIGHTED & COMBINED TO YIELD
0010 C A DECISION (SLEEP OR WAKE) & COMPARED TO KNOWN
0011 C SLEEP/WAKE STATUS. JBW
0012 C
0013 C CALL IS: (*)ON,POLY1,TR,SEC,NF
0014 C WHERE 'TR' & 'SEC' ARE STARTING TRACK & SECTOR
0015 C REFERENCES & 'NF' IS THE NUMBER OF FILES TO BE
0016 C READ (0 IF ALL)
0017 C-----
0018 DIMENSION NBUF(3072),IPRM(5),IPO(100,4),HIST(5,7),C(6),W(6)
0019 INTEGER A2,A3(8),IFLG,EPOCH(30)
0020 DATA C/6*1./
0021 CALL RMPAR(IPRM)
0022 IT=IPRM
0023 IS=IPRM(2)
0024 NF=IPRM(3)
0025 IF (IT.LT.20) IT=20
0026 IF (NF.EQ.0) NF=1000
0027 IFLG=0
0028 ICC=0
0029 C-----
0030 C ENTER PARAMETERS
0031 C-----
0032 40 WRITE (4,50)
0033 50 FORMAT (/ " ENTER WEIGHTS FOR CONTEXT")
0034 READ (4,*) (W(I),I=1,6)
0035 60 SCLO=0.
0036 SCLIM=1.
0037 STEP=.01
0038 PMAX=0.
0039 SMAX=0.
0040 C-----
0041 C ANALYZE DATA FILE WITH EACH SCALE VALUE
0042 C-----
0043 75 NTR=IT
0044 NSEC=IS
0045 NFILE=0
0046 MNSLP=0
0047 TOTMIN=0.
0048 DO 78 I=1,100
0049 DO 78 J=1,4
0050 78 IPO(I,J)=0
0051 80 NFILE=NFILE+1
0052 MINIT=0

```

```

0053         MDV=0
0054 C-----
0055 C READ A BLOCK OF 48 SECTORS
0056 C INTO CORE & SET UP FOR NEXT BLOCK
0057 C-----
0058     100 CALL EXEC(1,113B,NBUF,3072,NTR,NSEC)
0059         NSEC=NSEC+48
0060         IF (NSEC.LT.95) GO TO 120
0061         NTR=NTR+1
0062         NSEC=0
0063 C-----
0064 C BUFFER DATA BY EPOCHS
0065 C-----
0066     120 DO 200 I=1,2970
0067         IF (NBUF(I).EQ.-32767) GO TO 400
0068         IF (NBUF(I).EQ.-1) GO TO 300
0069         MDV=MDV+1
0070         EPOCH(MDV)=NBUF(I)
0071         IF (MDV.LT.30) GO TO 200
0072         MDV=0
0073         MINIT=MINIT+1
0074 C-----
0075 C COMPUTE TERMS BY MINUTES
0076 C-----
0077         A1=0.
0078         A2=0
0079         DO 130 J=1,8
0080         A3(J)=0
0081     130 CONTINUE
0082         DO 185 NMBR=1,30
0083 C-----
0084 C TERM 1: TOTAL ACTIVITY
0085 C-----
0086         A1=A1+FLOAT(EPOCH(NMBR))
0087 C----
0088 C TERM 2: MAXIMAL EPOCH
0089 C-----
0090         A2=MAXO(A2,EPOCH(NMBR))
0091 C-----
0092 C TERM 3: SUM OF 8 BEST EPOCHS
0093 C-----
0094         DO 170 K=1,8
0095         IF (EPOCH(NMBR).LT.A3(K)) GO TO 170
0096         DO 160 L=8,K+1,-1
0097         A3(L)=A3(L-1)
0098     160 CONTINUE
0099         A3(K)=EPOCH(NMBR)
0100         GO TO 180
0101     170 CONTINUE
0102     180 A30=0.
0103         DO 185 K=1,8
0104         A30=A30+FLOAT(A3(K))
0105     185 CONTINUE
0106 C-----

```

```

0107 C TERM 4: SUM OF 2 BEST DISPERSED EPOCHS
0108 C-----
0109     A4=0.
0110     DO 190 K=1,15
0111     DO 190 L=K+15,30
0112     SUM=FLOAT(EPOCH(K))+FLOAT(EPOCH(L))
0113     A4=AMAX1(A4,SUM)
0114     190 CONTINUE
0115 C-----
0116 C INCREMENT HISTORY ARRAYS
0117 C-----
0118     DO 195 J=1,5
0119     DO 195 K=7,2,-1
0120     HIST(J,K)=HIST(J,K-1)
0121     195 CONTINUE
0122 C-----
0123 C UPDATE HISTORY ARRAY
0124 C-----
0125     196 HIST(1,1)=A1/983010.
0126     HIST(2,1)=A2/32767.
0127     HIST(3,1)=A30/262136.
0128     HIST(4,1)=A4/65534.
0129     HIST(5,1)=FLOAT(NBUF(2971+I/30))
0130     IF (MINIT.LT.7) GO TO 200
0131 C-----
0132 C EVALUATE POLYNOMIAL THRU RANGE OF SCALE VAL.S
0133 C-----
0134     198 FRWRD=HIST(1,3)*W(3)+HIST(1,2)*W(2)+HIST(1,1)*W(1)
0135     BKWRD=HIST(1,5)*W(4)+HIST(1,6)*W(5)+HIST(1,7)*W(6)
0136     SCALE=SCLO+STEP
0137     199 D=SCALE*(C(1)*HIST(1,4)+C(2)*HIST(2,4)+C(3)*HIST(3,4)
0138     &+C(4)*HIST(4,4)+C(5)*FRWRD+C(6)*BKWRD)
0139 C-----
0140 C DECIDE SLEEP OR WAKE
0141 C-----
0142     LS=2
0143     IF (D.GE.1.) LS=0
0144 C-----
0145 C LOOK UP ACTUAL SLEEP OR WAKE
0146 C-----
0147     KS=IFIX(HIST(5,4))
0148 C-----
0149 C UPDATE CONTINGENCY ARRAY
0150 C-----
0151     ISCL=ISCL+1
0152     IPO(ISCL,KS+LS+1)=IPO(ISCL,KS+LS+1)+1
0153     SCALE=SCALE+STEP
0154     IF (ISCL.GE.100) GO TO 1999
0155     IF (SCALE.LE.SCLIN) GO TO 199
0156     1999 MNSLP=MNSLP+KS
0157     TOTMN=TOTMN+1.
0158     ISLIM=ISCL
0159     ISCL=0
0160     200 CONTINUE

```

```

0161      GO TO 100
0162      300 IF (NFILE.LT.NF) GO TO 80
0163 C-----
0164 C  FIND MAX. % CORR
0165 C-----
0166      400 SCALE=SCLO
0167      DO 450 I=1,ISLIM
0168      PC=(IPO(I,1)+IPO(I,4))/TOTMN
0169      PMAX=AMAX1(PMAX,PC)
0170      IF (PMAX.EQ.PC) SMAX=SCALE
0171      SCALE=SCALE+STEP
0172      450 CONTINUE
0173 C-----
0174 C  ADJUST SCALE RANGE & REPT
0175 C-----
0176      RANGE=SCLIM-SCLO
0177      SCLO=SMAX-RANGE/20.
0178      IF (SCLO.LT.0.) SCLO=0.
0179      SCLIM=SMAX+RANGE/20.
0180      IF (SCLIM.GT.1.) SCLIM=1.
0181      STEP=STEP/10.
0182      IF (STEP.GE.0.00001) GO TO 75
0183 C-----
0184 C  PRINT RESULTS
0185 C-----
0186      IF (IFLG.GT.0) GO TO 525
0187      PSLP=MNSLP/TOTMN
0188      IFLG=1
0189      WRITE (6,500) NFILE,TOTMN,PSLP
0190      500 FORMAT (5X"TOTAL RECORDS:"I4,5X"TOTAL MINUTES:"F6.0,
0191      &5X"% SLEEP:"F6.3// "PERCENT"20X"TERM WEIGHTS"31X
0192      &"CONTEXT WEIGHTS"19X
0193      &"SCALE"/" CORRECT"8X"C1"5X"C2"5X"C3"5X"C4"5X"C5"5X"C6"
0194      &8X"W1"5X"W2"5X"W3"5X"W4"5X"W5"5X"W6"7X"FACTOR")
0195      525 WRITE (6,530) PMAX,(C(J),J=1,6),(W(J),J=1,6),SMAX
0196      530 FORMAT (F8.4,2(3X,6F7.3),5X,F8.6)
0197 C-----
0198 C  ADJUST WEIGHTS & REPT
0199 C-----
0200      ICC=ICC+1
0201      IF (ICC.GT.6) GO TO 540
0202      C(ICC)=0.
0203      IF (ICC.GT.1) C(ICC-1)=1.
0204      GO TO 60
0205      540 WRITE (4,550)
0206      550 FORMAT (/"MORE?")
0207      READ (4,*) KKK
0208      IF (KKK.NE.0) GO TO 40
0209      STOP
0210      END
0211      END$

```

APPENDIX 4

\$INPUT T=00004 IS ON CRO0011 USING 00020 BLKS R=0180

```

0001 FTN4,L
0002     PROGRAM INPUT,3
0003 C
0004 C-----LAST ALTERED: 3/28/80
0005 C
0006 C---'INPUT' ACCEPTS ID INFO & 'PAGE & STAGE'
0007 C--DATA FOR STORAGE ON DISC.      JBW
0008 C
0009 C-----CALL IS: "ON,INPUT,TR,SEC,ED", WHERE 'TR'
0010 C--IS TRACK #, 'SEC' IS SECTOR #, & 'ED' INDICATES
0011 C--WHETHER DATA IS TO BE ENTERED (0) OR EDITED (1).
0012 C
0013     DIMENSION IBUF(1280),IPRM(5)
0014     EQUIVALENCE (IPRM(1),ITR),(IPRM(2),ISEC),(IPRM(3),IRW)
0015     CALL RMPAR(IPRM)
0016 C
0017 C--CHECK FOR CORRECT DISC
0018     CALL EXEC(1,107B,IBUF,1280,0,0)
0019     IF (IBUF(1).EQ.3881) GO TO 10
0020     WRITE (4,1020)
0021     1020 FORMAT (" WRONG DISC")
0022     STOP 1111
0023 C
0024 C--CHECK FOR VALID SECTOR
0025     10 IF (MOD(ISEC,24).EQ.0) GO TO 20
0026     WRITE (4,1040)
0027     1040 FORMAT (" INVALID SECTOR")
0028     STOP 2222
0029 C
0030 C--ENTER NEW DATA OR EDIT EXISTING DATA???
0031     20 IF (IRW.EQ.1) GO TO 300
0032 C
0033 C--NEW DATA ENTRY---
0034 C--CHECK AVAILABILITY OF INDICATED DISC SEGMENT
0035     CALL EXEC(1,107B,IBUF,1280,ITR,ISEC)
0036     IF (IBUF(35).NE.3465) GO TO 40
0037     WRITE (4,1030)
0038     1030 FORMAT (" DISC SEGMENT FULL"
0039     -/" ENTER '1' TO ERASE, '0' TO HALT")
0040 C
0041 C--NOT AVAILABLE (ALREADY USED) -
0042 C--WRITE OVER EXISTING DATA???
0043     READ (4,*) SLOP1
0044     J=1*SLOP1
0045     IF (J.NE.0) GO TO 40
0046 C
0047 C--NO, ABORT

```



```

0048      STOP 3333
0049  C
0050  C--COMPOSE ID RECORD
0051      40 J=0
0052      IBUF(35)=3465
0053      50 WRITE (4,2000)
0054      2000 FORMAT (" SUBJECT: ")
0055      READ (4,2010) (IBUF(I),I=1,30)
0056      2010 FORMAT (30R1)
0057      WRITE (4,2030)
0058      2030 FORMAT (" DATE (MO,DA,YR): ")
0059      READ (4,*) SLOP1,SLOP2,SLOP3
0060      IBUF(31)=1*SLOP1
0061      IBUF(32)=1*SLOP2
0062      IBUF(33)=1*SLOP3
0063      WRITE (4,2040)
0064      2040 FORMAT (" SPEED (PAGES/MIN): ")
0065      READ (4,*) SLOP1
0066      IBUF(34)=1*SLOP1
0067      IF (J.NE.0) GO TO 400
0068  C
0069  C--READ 'PAGE & STAGE' DATA
0070      DO 90 I=65,1408
0071      90 IBUF(I)=0
0072      WRITE (4,2020)
0073      2020 FORMAT (" ENTER STAGE, STOP PAGE, START PAGE, TIME")
0074      I=0
0075      100 I=I+1
0076      IF (I.LT.304) GO TO 200
0077      WRITE (4,1045)
0078      1045 FORMAT (" NO MORE ROOM")
0079      SLOP1=7.
0080      GO TO 250
0081      200 SLOP1=0.
0082      SLOP2=0.
0083      SLOP3=0.
0084      SLOP4=0.
0085      READ (4,*) SLOP1,SLOP2,SLOP3,SLOP4
0086      250 IBUF(I*4+61)=1*SLOP1
0087      IBUF(I*4+62)=1*SLOP2
0088      IBUF(I*4+63)=1*SLOP3
0089      IF (IBUF(I*4+63).NE.0) MSTOP=IBUF(I*4+63)
0090      IBUF(I*4+64)=1*SLOP4
0091      IF (IBUF(I*4+61).EQ.7) GO TO 400
0092      IF (IBUF(I*4+62).GT.0.AND.MSTOP.LT.0) GO TO 260
0093      IF (IBUF(I*4+62).GT.MSTOP) GO TO 275
0094      260 WRITE (4,2045)
0095      2045 FORMAT (" PAGE # OUT OF SEQUENCE - REENTER")
0096      GO TO 200
0097      275 MSTOP=IBUF(I*4+62)
0098      GO TO 100
0099      300 CALL EXEC(1,107B,IBUF,1280,ITR,ISEC)
0100      IF (IBUF(35).EQ.3465) GO TO 400
0101      WRITE (4,1050)

```

```

0102 1050 FORMAT (" NO DATA")
0103      STOP 4444
0104 C
0105 C--DISPLAY ID INFO
0106     400 WRITE (6,2050) (IBUF(I),I=1,30)
0107     2050 FORMAT (/ " SUBJECT: "30R1)
0108     WRITE (6,2060) (IBUF(I),I=31,33)
0109     2060 FORMATS
           0110      WRITE (6,2070) IBUF(34)
0111     2070 FORMAT (" PAPER SPEED: "11" PAGES/MIN")
0112     WRITE (4,2075)
0113     2075 FORMAT (" CORRECTIONS? (YES=1, NO=0)_"")
0114 C
0115 C--CORRECTIONS???
0116     READ (4,*) SLOP1
0117     J=1*SLOP1
0118     IF (J.NE.0) GO TO 50
0119     I=-1
0120     IF (IRW.EQ.0) GO TO 450
0121 C
0122 C--NO, DISPLAY 'PAGE & STAGE' DATA
0123     425 WRITE (4,2078)
0124     2078 FORMAT (" LIST ENTIRE FILE (-1) OR LINE #:_"")
0125     READ (4,*) SLOP1
0126     I=1*SLOP1
0127     IF (I.EQ.0) GO TO 650
0128     450 WRITE (6,2080)
0129     2080 FORMAT (/ " LINE# STAGE STOP START TIME"/)
0130     J=0
0131     IF (I)475,500
0132     475 DO 600 I=1,336
0133     500 WRITE (6,2090) I,IBUF(I*4+61),IBUF(I*4+62),
0134     -IBUF(I*4+63),IBUF(I*4+64)
0135     2090 FORMAT (I5":"4I6)
0136     IF (IBUF(I*4+61).EQ.7) GO TO 650
0137     IF (J.NE.0) GO TO 700
0138     IF (SLOP1.GT.0.) GO TO 425
0139     600 CONTINUE
0140 C
0141 C--CORRECTIONS???
0142     650 WRITE (4,2075)
0143     READ (4,*) SLOP1
0144     J=1*SLOP1
0145     IF (J.EQ.0) GO TO 1000
0146 C
0147 C--YES, ENTER CORRECT DATA
0148     700 WRITE (4,3000)
0149     3000 FORMAT (" ENTER LINE#, CORRECT DATA")
0150     WRITE (6,3100)
0151     3100 FORMAT (/)
0152     SLOP1=0.
0153     SLOP2=0.
0154     SLOP3=0.
0155     SLOP4=0.

```

```
0156      SLOP5=0.
0157      READ (4,*) SLOP1,SLOP2,SLOP3,SLOP4,SLOP5
0158      I=1*SLOP1
0159      IF (SLOP2.GE.0.) GO TO 800
0160      ND=-1*SLOP2
0161      DO 900 JK=1,304
0162      DO 900 KK=61,64
0163      IBUF(JK*4+KK)=IBUF(JK*4+KK+ND*4)
0164      IF (IBUF(JK*4+61).EQ.7) GO TO 500
0165      900 CONTINUE
0166      800 IBUF(I*4+61)=1*SLOP2
0167      IBUF(I*4+62)=1*SLOP3
0168      IBUF(I*4+63)=1*SLOP4
0169      IBUF(I*4+64)=1*SLOP5
0170      IF (I.NE.0) GO TO 500
0171      C
0172      C--WRITE TO DISC
0173      1000 CALL EXEC(2,2107B,IBUF,1280,ITR,ISEC)
0174      WRITE (6,1010) ITR,ISEC
0175      1010 FORMAT (/ " DISC FILE: TRACK "13" SECTOR "12)
0176      STOP 7777
0177      C
0178      END
0179      ENDS
```

\$\$STAGE T=00004 IS ON CRO0011 USING 00013 BLKS R=0124

```

0001 FTN4,L
0002     PROGRAM STAGE,3
0003 C
0004 C-----LAST ALTERED: 2/1/80
0005 C
0006 C--'STAGE' READS 'PAGE & STAGE' DATA FROM DISC
0007 C--AND PLOTS STANDARD SLEEP STAGE CHART ON AJ
0008 C--PRINTER/PLOTTER.                JBW
0009 C
0010 C--CALL IS: "ON,STAGE,TR,SEC" WHERE 'TR' & 'SEC'
0011 C--ARE TRACK & SECTOR # RESPECTIVELY.
0012 C
0013 C
0014     INTEGER ESCP,ESCA,ESCN,ESCX,ESCW,ES CZ,ESCY
0015     INTEGER DOT,DASH
0016     INTEGER STAGE(240),PAGES(240),CHAR
0017     DIMENSION IPRM(5),IBUF(64)
0018     EQUIVALENCE (IPRM,ITR),(IPRM(2),ISEC)
0019     DATA ESCP/15520B/,ESCN/15516B/,ESCA/15501B/
0020     DATA ESCX/15530B/,ESCW/15527B/,ES CZ/15532B/
0021     DATA DOT/56B/,DASH/137B/,ESCY/15531B/
0022     DATA MO/0/,M1/1/,M2/2/,M3/3/,M5/5/
0023     CALL RMPAR(IPRM)
0024 C
0025 C--CHECK FOR CORRECT DISC
0026     CALL EXEC(1,107B,IBUF,64,0,0)
0027     IF (IBUF(1).EQ.3881) GO TO 10
0028     WRITE (4,3000)
0029     3000 FORMAT (" WRONG DISC")
0030     STOP 1111
0031 C
0032 C--CHECK FOR VALID SECTOR
0033     10 IF (MOD(ISEC,16).EQ.0) GO TO 20
0034     WRITE (4,3010)
0035     3010 FORMAT (" WRONG SECTOR")
0036     STOP 2222
0037 C
0038 C--MAKE SURE THERE IS DATA
0039     20 CALL EXEC(1,107B,IBUF,64,ITR,ISEC)
0040     IF (IBUF(35).EQ.3465) GO TO 30
0041     WRITE (4,3020)
0042     3020 FORMAT (" NO DATA")
0043     STOP 3333
0044 C
0045 C--WRITE ID INFO
0046     30 WRITE (6,2050) (IBUF(I),I=1,30)
0047     2050 FORMAT (/30X"SUBJECT: "30R1)
0048     WRITE (6,2060) (IBUF(I),I=31,33)
0049     2060 FORMAT (30X"DATE: "12"/"12"/"12)
0050     IPM=IBUF(34)
0051     WRITE (6,2070) IPM
0052     2070 FORMAT (30X"PAPER SPEED: "11" PAGES/MIN")

```

```

0053      WRITE (6,2080) ITR,ISEC
0054 2080 FORMAT (30X"DISC FILE: TRACK "I3" SECTOR "I2)
0055      IPM=IBUF(34)
0056      LINES=0
0057      J=0
0058 C
0059 C--FILL DATA ARRAYS
0060      100 ISEC=ISEC+1
0061      CALL EXEC(1,107B,IBUF,64,ITR,ISEC)
0062      DO 200 I=1,64,4
0063      IF (IBUF(I).EQ.7) GO TO 300
0064      J=J+1
0065      STAGE(J)=IBUF(I)
0066      IF (J.EQ.1) MSTRT=IBUF(I+3)
0067      IF (IBUF(I+2).NE.0) ISTRT=IBUF(I+2)
0068      PAGES(J)=IBUF(I+1)-ISTRT
0069      ISTRT=IBUF(I+1)
0070      LINES=LINES+PAGES(J)
0071      200 CONTINUE
0072      GO TO 100
0073 C
0074 C--PLOT DATA
0075      300 J=1
0076      WRITE (6,1999) MSTRT
0077 1999 FORMAT (30X"START TIME: "I4)
0078      MINS=MSTRT-1
0079      NPGS=0
0080      WRITE (6,2000)
0081 2000 FORMAT (/62X"STAGE"//30X"TIME"12X"4"5X"3"
0082      -5X"2"5X"1"4X"REM"3X"MOVE"2X"WAKE"/)
0083 C
0084 C--DETERMINE STAGE FOR EACH PAGE
0085      DO 1500 I=1,LINES
0086      IF (STAGE(J).EQ.0) LOC=410
0087      IF (STAGE(J).EQ.1) LOC=320
0088      IF (STAGE(J).EQ.2) LOC=290
0089      IF (STAGE(J).EQ.3) LOC=260
0090      IF (STAGE(J).EQ.4) LOC=230
0091      IF (STAGE(J).EQ.5) LOC=350
0092      IF (STAGE(J).EQ.6) LOC=380
0093 C
0094 C--EXIT IF '7' (EOF)
0095      IF (STAGE(J).EQ.7) GO TO 1800
0096 C
0097 C--PRINT HOURS
0098      NPGS=NPGS+1
0099      IF (MOD(NPGS,IPM).EQ.0) MINS=MINS+1
0100      IF (MINS-MINS/100*100.EQ.30.AND.MOD(NPGS,IPM).EQ.0) GO TO 50
0101      IF (MINS-MINS/100*100.NE.60) GO TO 1000
0102      MINS=MINS+40
0103      IF (MINS.EQ.2400) MINS=0
0104      500 WRITE (6,2150) ESCA,M1,M5,M0
0105      WRITE (6,2100) ESCN
0106      WRITE (6,2400) MINS

```

```

0107      WRITE (6,2100) ESCP
0108      N1=LOCM/100
0109      N2=MOD(LOCM,100)/10
0110      N3=MOD(MOD(LOCM,100),10)
0111      WRITE (6,2150) ESCA,N1,N2,N3
0112      C
0113      C--INITIALIZE PLOT:
0114      C--SEND 'ESC P' TO ENTER PLOT MODE
0115      1000 IF (I.NE.1) GO TO 1200
0116      WRITE (6,2100) ESCP
0117      2100 FORMAT (R2" ")
0118      GO TO 1250
0119      C
0120      C--DRAW HORIZ LINE IF TRANS BETW STAGES
0121      1200 IF (LOC-LOCM)1215,1250,1210
0122      C
0123      C--(TO RIGHT)
0124      1210 WRITE (6,2150) ESCY,MO,MO,M3
0125      DO 1212 N=LOCM,LOC-1,6
0126      WRITE (6,2200) ESCX,MO,MO,M3,DASH,ESCX,MO,MO,M3
0127      1212 CONTINUE
0128      GO TO 1245
0129      C
0130      C--(TO LEFT)
0131      1215 WRITE (6,2150) ESCY,MO,MO,M3
0132      DO 1217 N=LOC,LOCM-1,6
0133      WRITE (6,2200) ESCW,MO,MO,M3,DASH,ESCW,MO,MO,M3
0134      1217 CONTINUE
0135      1245 WRITE (6,2150) ESCZ,MO,MO,M3
0136      C
0137      C--PRINT EXTRA DOT FOR REM
0138      1250 IF (STAGE(J).NE.5) GO TO 1260
0139      N1=(LOC-1)/100
0140      N2=MOD(LOC-1,100)/10
0141      N3=MOD(MOD(LOC-1,100),10)
0142      WRITE (6,2125) ESCA,N1,N2,N3,DOT
0143      C
0144      C--PRINT DOT & LF FOR EACH PAGE
0145      1260 N1=LOC/100
0146      N2=MOD(LOC,100)/10
0147      N3=MOD(MOD(LOC,100),10)
0148      WRITE (6,2200) ESCA,N1,N2,N3,DOT,ESCZ,MO,MO,M1
0149      2125 FORMAT (R2,3I1,R1" ")
0150      2150 FORMAT (R2,3I1" ")
0151      2200 FORMAT (R2,3I1,R1,R2,3I1" ")
0152      2400 FORMAT (I4" ")
0153      C
0154      C--INCR STAGE PNTR WHEN NUMBER OF
0155      C--PAGES IN CURRENT STAGE EXCEEDED
0156      1300 L=L+1
0157      IF (L.GE.PAGES(J)) L=0
0158      IF (L.EQ.0) J=J+1
0159      LOCM=LOC
0160      1500 CONTINUE

```

```
0161 C
0162 C--RETURN TO PRINT MODE
0163 C--WHEN FINISHED PLOTTING
0164 1800 WRITE (6,2150) ESCA,MO,MO,MO
0165     WRITE (6,2100) ESCN
0166     WRITE (6,2000)
0167     WRITE (6,2500) MINS
0168 2500 FORMAT (////30X"STOP TIME: "I4)
0169     STOP 7777
0170     END
0171     ENDS
```

IS ON CRO0011 USING 00017 BLKS R=0157

```

0001 FTN4,L
0002     PROGRAM STATS,3
0003 C-----
0004 C 3/19/80
0005 C
0006 C "STATS" COMPUTES SUMMARY STATISTICS FROM SLEEP
0007 C RECORDS. RECORDS MUST HAVE BEEN ENTERED ON DISC
0008 C USING "INPUT" PROGRAM.           JBW
0009 C
0010 C CALL IS: (*)ON,STATS,TR,SEC, WHERE 'TR' & 'SEC'
0011 C ARE TRACK & SECTOR REFERENCES OF DISC FILE
0012 C-----
0013     DIMENSION IBUF(64),IPRM(5),NX(7),NY(7)
0014     INTEGER PAGES(7,150)
0015     CALL RMPAR(IPRM)
0016     ITR=IPRM
0017     ISEC=IPRM(2)
0018 C-----
0019 C INITIALIZATIONS
0020 C-----
0021     DO 10 I=1,7
0022         NX(I)=0
0023         NY(I)=0
0024     DO 10 J=1,150
0025         PAGES(I,J)=0.
0026     10 CONTINUE
0027     NNY=0
0028     WASA=0.
0029     WASO=0.
0030     TOT=0.
0031     TOTS=0.
0032 C-----
0033 C CHECK FOR CORRECT DISC
0034 C-----
0035     CALL EXEC(1,107B,IBUF,64,0,0)
0036     IF (IBUF(1).EQ.3881) GO TO 50
0037     WRITE (4,40)
0038     40 FORMAT (" WRONG DISC")
0039     STOP 1111
0040 C-----
0041 C CHECK FOR VALID SECTOR
0042 C-----
0043     50 IF (MOD(ISEC,24).EQ.0) GO TO 70
0044     WRITE (4,60)
0045     60 FORMAT (" WRONG SECTOR")
0046     STOP 2222
0047 C-----
0048 C MAKE SURE THERE IS DATA
0049 C-----
0050     70 CALL EXEC (1,107B,IBUF,64,ITR,ISEC)

```



```

0051     IF (IBUF(35).EQ.3465) GO TO 100
0052     WRITE (4,90)
0053     90 FORMAT (" NO DATA")
0054     STOP 3333
0055 C-----
0056 C WRITE ID INFO
0057 C-----
0058     100 WRITE (6,110) (IBUF(1),I=1,30)
0059     110 FORMAT (/ " SUBJECT: "30R1)
0060     WRITE (6,120) (IBUF(1),I=31,33)
0061     120 FORMAT (" DATE: "I2"/"I2"/"I2)
0062     IPM=IBUF(34)
0063     WRITE (6,130) IPM
0064     130 FORMAT (" PAPER SPEED: "I1" PAGES/MIN")
0065     WRITE (6,140) ITR, ISEC
0066     140 FORMAT (" DISC FILE: TRACK "I3" SECTOR "I2)
0067     PM=FLOAT(IPM)
0068 C-----
0069 C READ PAGE & STAGE DATA
0070 C-----
0071     150 ISEC=ISEC+1
0072     CALL EXEC (1,107B,IBUF,64,ITR,ISEC)
0073     DO 200 I=1,64,4
0074     IF (IBUF(I).EQ.7) GO TO 201
0075     ISTG=IBUF(I)+1
0076     IF (IBUF(I+2).NE.0) ISTRT=IBUF(I+2)
0077     IX=IBUF(I+1)-ISTRT
0078     NY(ISTG)=NY(ISTG)+1
0079     NNY=NNY+1
0080     NX(ISTG)=NX(ISTG)+IX
0081     PAGES(ISTG,NY(ISTG))=IX
0082     TOT=TOT+IX/PM
0083     WASO=WASO+WASA
0084     IF (ISTG.GT.1) TOTS=TOTS+IX/PM
0085     IF (NNY.GT.1.AND.ISTG.EQ.1) WASA=IX/PM
0086     IF (ISTG.NE.1) WASA=0.
0087     ISTRT=IBUF(I+1)
0088     200 CONTINUE
0089     GO TO 150
0090     201 WRITE (6,202)
0091     202 FORMAT (/ " STAGE      N      DUR  MN DUR    % TOT    % SLP"
0092     -" 25%ILE  MEDIAN  75%ILE  I.Q.R."/)
0093 C-----
0094 C RANK DURATIONS IN EACH STAGE
0095 C-----
0096     I=1
0097     205 N1=NY(I)-1
0098     207 DO 210 J=1,N1
0099     J1=J+1
0100     IF (PAGES(I,J).LT.PAGES(I,J1)) GO TO 210
0101     ITEMP=PAGES(I,J)
0102     PAGES(I,J)=PAGES(I,J1)
0103     PAGES(I,J1)=ITEMP
0104     210 CONTINUE

```

```

0105      N1=N1-1
0106      IF (N1.GE.1) GO TO 207
0107      I=I+1
0108      IF (I.LT.8) GO TO 205
0109      C-----
0110      C  COMPUTE ORDER STATS
0111      C-----
0112      DO 300 I=1,7
0113      IF (NY(I).EQ.0) GO TO 265
0114      IM=NY(I)/2+1
0115      IP=NY(I)/2
0116      IF (MOD(NY(I),2).EQ.0) GO TO 220
0117      QMED=PAGES(I,IM)/PM
0118      GO TO 225
0119      220 QMED=((PAGES(I,IP)+PAGES(I,IM))/2.)/PM
0120      225 IF (NY(I).LT.4) GO TO 255
0121      IQ1=IP/2+1
0122      IQ3=NY(I)-IQ1+1
0123      IF (MOD(IP,2).EQ.0) GO TO 230
0124      Q1=PAGES(I,IQ1)/PM
0125      Q3=PAGES(I,IQ3)/PM
0126      GO TO 250
0127      230 IP1=IP/2
0128      Q1=((PAGES(I,IP1)+PAGES(I,IQ1))/2.)/PM
0129      IQ3=NY(I)-IQ1+1
0130      IP3=NY(I)-IP1+1
0131      Q3=((PAGES(I,IP3)+PAGES(I,IQ3))/2.)/PM
0132      250 RI=(Q3-Q1)/2
0133      GO TO 260
0134      255 Q1=0.
0135      Q3=0.
0136      RI=0.
0137      C-----
0138      C  COMPUTE SUMMARY STATS
0139      C-----
0140      260 DUR=NX(I)/PM
0141      TMEAN=DUR/TOT
0142      SMEAN=DUR/TOTS
0143      IF (I.EQ.1) SMEAN=0.
0144      DMEAN=DUR/NY(I)
0145      GO TO 270
0146      C-----
0147      C  ENTER ZEROS IF NO OCCURRENCES
0148      C  OF THIS STAGE
0149      C-----
0150      265 DUR=0.
0151      TMEAN=0.
0152      SMEAN=0.
0153      DMEAN=0.
0154      Q1=0.
0155      Q3=0.
0156      QMED=0.
0157      RI=0.
0158      C-----

```

```
0159 C PRINT SUMMARY
0160 C-----
0161 270 JSTG=I-1
0162 WRITE (6,295) JSTG, NY(1), DUR, DMEAN, TMEAN, SMEAN, Q1, QMED, Q3, RI
0163 295 FORMAT (I4, 1X, I6, 2F8.2, 2F8.3, 4F8.2)
0164 300 CONTINUE
0165 TSP=TOTS+WASO
0166 WRITE (6,350) NNY, TOT, TOTS, TSP, WASO
0167 350 FORMAT (/ " TOTAL" I5, F8.2 /// 12X "TST= " F8.2
0168 -" TSP= " F8.2" WASO= " F8.2)
0169 STOP
0170 END
0171 ENDS
```

