SCI

CR-128733

FINAL REPORT

BIOMEDICAL ENGINEERING TASKS

CONTRACT NAS 9-12597

SUBMITTED TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

BY

SCI SYSTEMS, INC.

HOUSTON DIVISION

8330 BROADWAY ST.

HOUSTON, TEXAS 77017

DECEMBER, 1972

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I

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Foreword

This Final Report documents the work accomplished for the duration of Contract NAS 9-12597 from March 1, 1972 to November 30, 1972. All requirements of the Statement of Work (Exhibit A of the Contract) have been completed within the budget and time allocated.

All technical concepts developed under the contract have been demonstrated to the cognizant NASA-MSC technical personnel. There is no deliverable hardware under this contract.

I. BIOINSTRUMENTATION PROBLEMS

Although no major problems arose during the performance of this program, several small problems were investigated and solved under direction of the Technical Monitor. These problems were largely associated with support of SMEAT testing. Also, specialized measurements of electrodes were performed and the results were reported in support of specific bioinstrumentation problems.

II. ECG/VCG ELECTRODE HARNESS SYSTEM EVALUATION

INTRODUCTION

The following study was undertaken to explore the possibility of selecting a new electrode system for Project Skylab both for experimental and continuous monitoring purposes. The present electrode configuration utilizing the sponge wetted with electrolyte and recessed in the plastic housing has been found to be troublesome and inconvenient in its use. This electrode has exhibited a continuing problem with bacterial contamination of the wetted sponges even though they are sealed in foil packets and treated with Benzoates. The sponges also tend to take a "set" and not provide the necessary thickness for proper skin contact. This electrode was originally chosen over the traditional paste filled electrode because of the messy and time consuming task involved in filling the electrodes.

The selection of an improved electrode system would greatly enhance the efficiency with which the astronauts can conduct their experiments. Three major parameters were measured in the evaluation of various electrode systems: impedance, voltage, and actual recorded EKG waveforms. The impedance and voltage measurements gave an approximation of time required to produce noise free recordings. Actual EKG strip chart recordings were utilized to confirm findings taken in the impedance and voltage measurements.

MATERIALS AND METHODS

For the present electrode study, 20 healthy male subjects were chosen with ages ranging from 30 to 40 with an average age of 32. All subjects were of average complexion and with one exception, average build. The experiment was conducted during the months of May and June. Laboratory conditions were maintained throughout the study. Temperatures ranged from 70° to 74°F and relative humidity ranged from 50% to 80%. All subjects were Caucasian.

Four types of electrode systems were utilized in this study. The ECG/VCG system consists of a recessed silver/silver chloride pellet of approximately 2 sq. cm. in area. The electrolyte wetted sponge is placed in the recessed electrode and attached to the skin with Stomaseal adhesive discs. The second system consists of an electrode with a silver/silver chloride disc mounted flush with the surface of the electrode. It was then wetted with a paste designated KM129B. The third system again consisted of a flush electrode utilizing a paste designated KM136. The fourth system consisted of a flush type electrode and standard flight electrode paste. All flush electrodes had a surface area of 2 sq. cm. They were also held to the skin utilizing stomaseal adhesive discs. Prior to application of the electrodes, the electrode skin site was prepared utilizing the Zephiran Chloride wipes planned for utilization during the VCG experiment. No rough treatment or decornification was utilized in preparation of the skin. The underside of the forearms was utilized as the placement sites for the electrodes extending approximately half way between the elbow and the wrist. This application is shown in Figure 1. For waveform measurements, the electrode sites were the manubrium and V5 placements. For exercise recordings, a friction type ergometer was utilized. Impedance measurements were made using a NASA-designed impedance meter with ranges from 1000 ohms to 1 megohm. This system uses a chopper to reverse polarize the electrodes at the chopper frequency thus preventing any polarity buildup. The voltmeter utilized for voltage measurements was a Hewlett Packard 412A with an input impedance of approximately 10 megohms. The ECG recordings were made utilizing two sets of commercial clinical instrumentation. These were Abbott Medical Electronics, Model EK2 (EKG amplifier) and a CR1 (chart recorder). For a simultaneous recording, the recorders were initiated simultaneously and marked at their initiation point. The set up for the ECG recordings is shown in Figure 2. This recording system has a frequency response (plus or minus 3db) from 0.5 Hz to 100 Hz.

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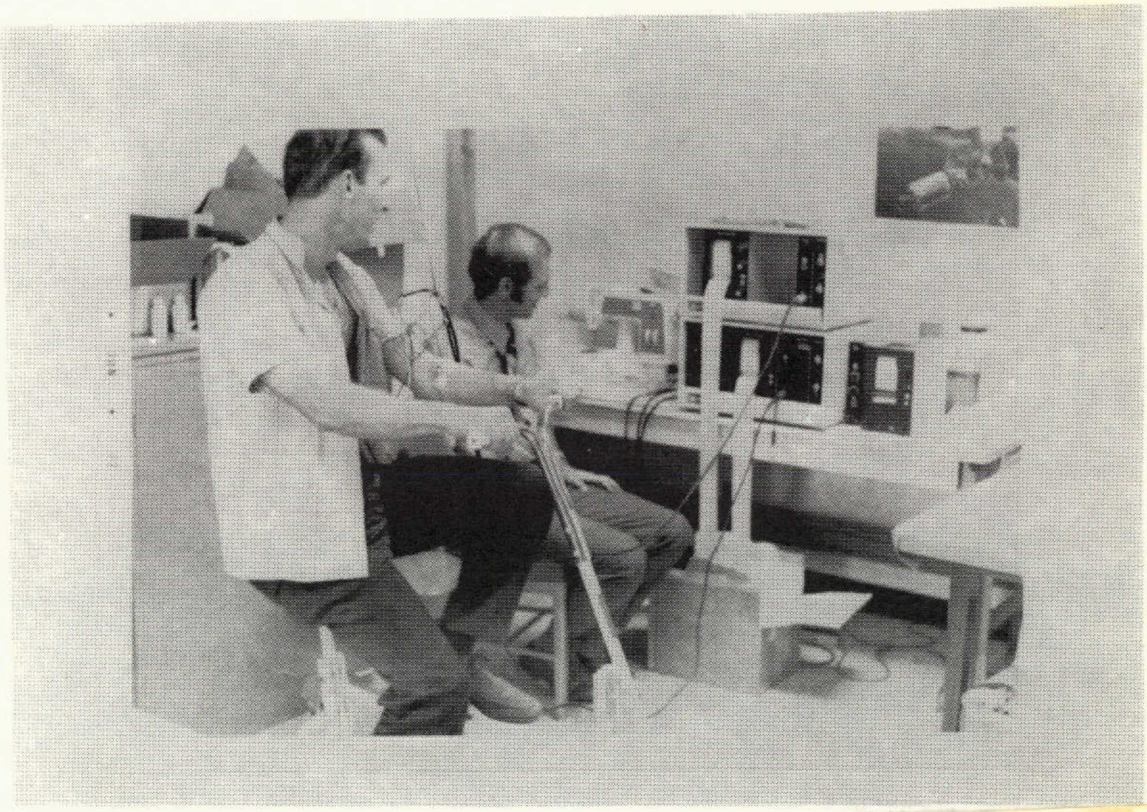
ELECTRODE IMPEDANCE/VOLTAGE
TEST SETUP

FIGURE 1



EXERCISE EKG STRIP CHART
RECORDING SETUP

FIGURE 2

This page is reproduced at the back of the report by a different reproduction method to provide better detail.

With the subject sitting at rest at a table, the electrodes were attached to the underside of the forearm following a brief cleansing of the forearm with Zephiran Chloride wipes. Immediately after application, the electrodes were checked for impedance and voltage. At 4 minute intervals, this data was rechecked. The intervals of measurements consisted of 4, 8, 12, 16, 20, 30, and 40 minutes respectively. After data was taken 45 minutes after appliction, the electrodes were removed and the underlying skin was checked for any irritation. No irritation appeared on any subject for any electrode system. The ECG recordings were taken both at rest and under vigorous exercies on the ergometer. To nullify any effects of instrumentation, the channels were reversed on the two systems and recordings were again taken both at rest and at exercise. The electrodes selected for exercise were the current ECG/VCG electrode with its internal sponge and the electrode that showed the best promise as far as impedance and voltage. The electrodes were placed 1/8" separating the two electrode housings. Approximately 2 minutes of recording were taken on each period of recording.

RESULTS

After all data were taken, graphs were plotted on both impedance and voltage for each subject. Extrapolation was used in many instances where the initial impedance was above 1 Megohm. After all graphs were drawn, the data were averaged as to time and magnitude of impedance and voltage. Figure 3 depicts the average impedance of the four electrode systems tested. As can readily be seen from this graph, the KM129B and KM136 electrode systems were far superior in their performance with impedance versus time. The voltage measurements were also averaged and their plot appears on Figure 4. As can be seen from this graph, the voltage measurements are quite random and centered about 4 millivolts. No particular system seemed to be superior as far as the voltage measurement was concerned. As can be seen from the impedance chart, the two KM-type pastes out-performed both the VCG and standard flight paste. Following the analysis of both the impedance and voltage data, the KM129B was selected as a candidate to compare with the VCG paste. To evaluate the KM129B in reference to the VCG paste, electrodes were attached to both the highest impedance subject and low impedance subject to evaluate the ECG recordings. Figure 5, 6, 7, and 8 depict the results of the ECG chart recordings.

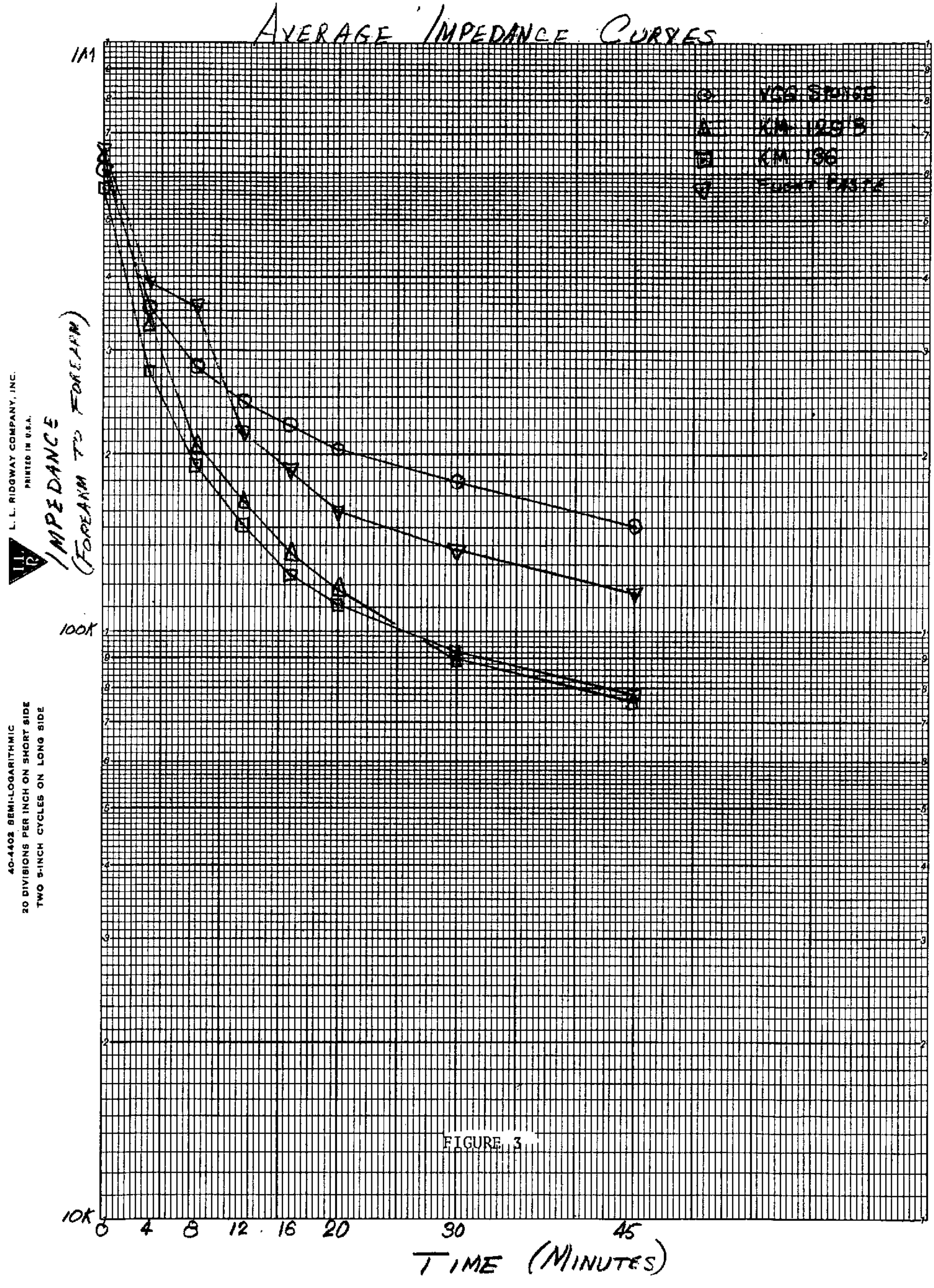

AVERAGE IMPEDANCE CURVES
VCG SPONGE
KM 129'B
KM 136
FLIGHT PASTE
IMPEDANCE
(FOREARM TO FOREARM)
1M
100K
10K
0
4
8
12
16
20
30
45
TIME (MINUTES)
L. L. RIDGWAY COMPANY, INC.
PRINTED IN U.S.A.
40-4402 SEMI-LOGARITHMIC
20 DIVISIONS PER INCH ON SHORT SIDE
TWO 5-INCH CYCLES ON LONG SIDE

FIGURE 3

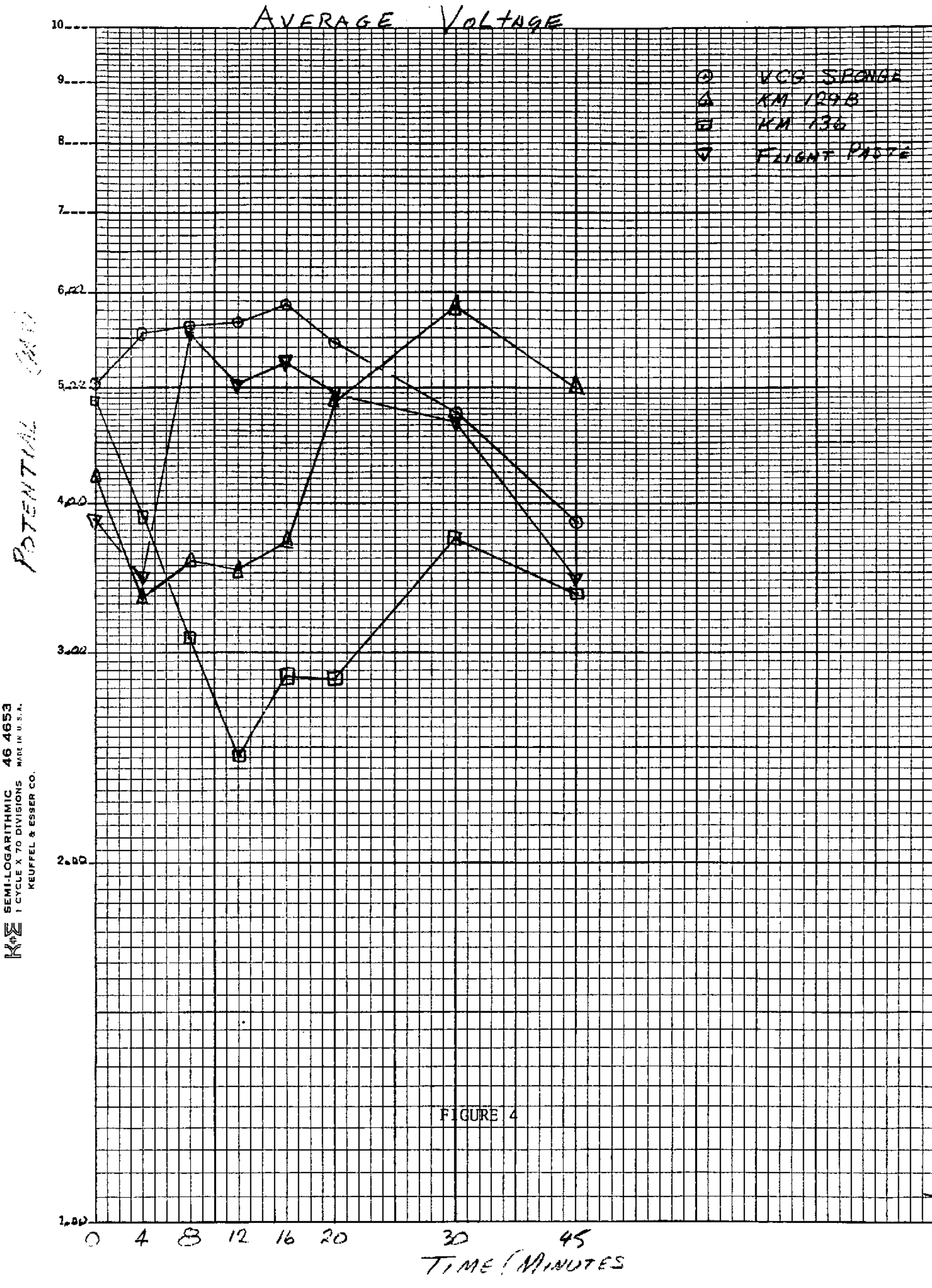
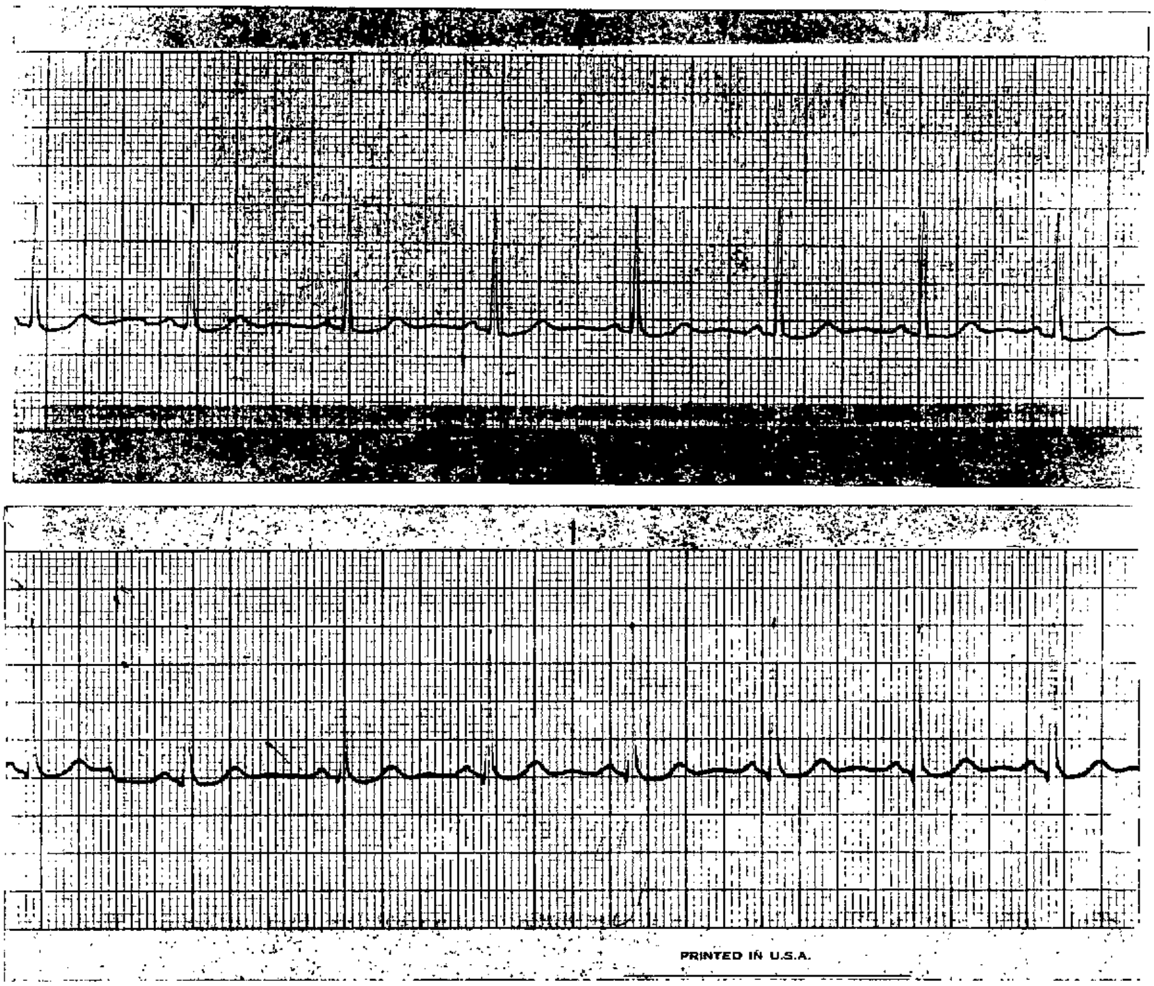

AVERAGE VOLTAGE
VCG SPONGE
KM 129B
KM 136
FLIGHT PASTE
POTENTIAL
10
9
8
7
6.00
5.00
4.00
3.00
2.00
1.00
0
4
8
12
16
20
30
45
TIME / MINUTES
K+E SEMI-LOGARITHMIC 46 4653
1 CYCLE X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 4

FLUSH MOUNTED/KM129B

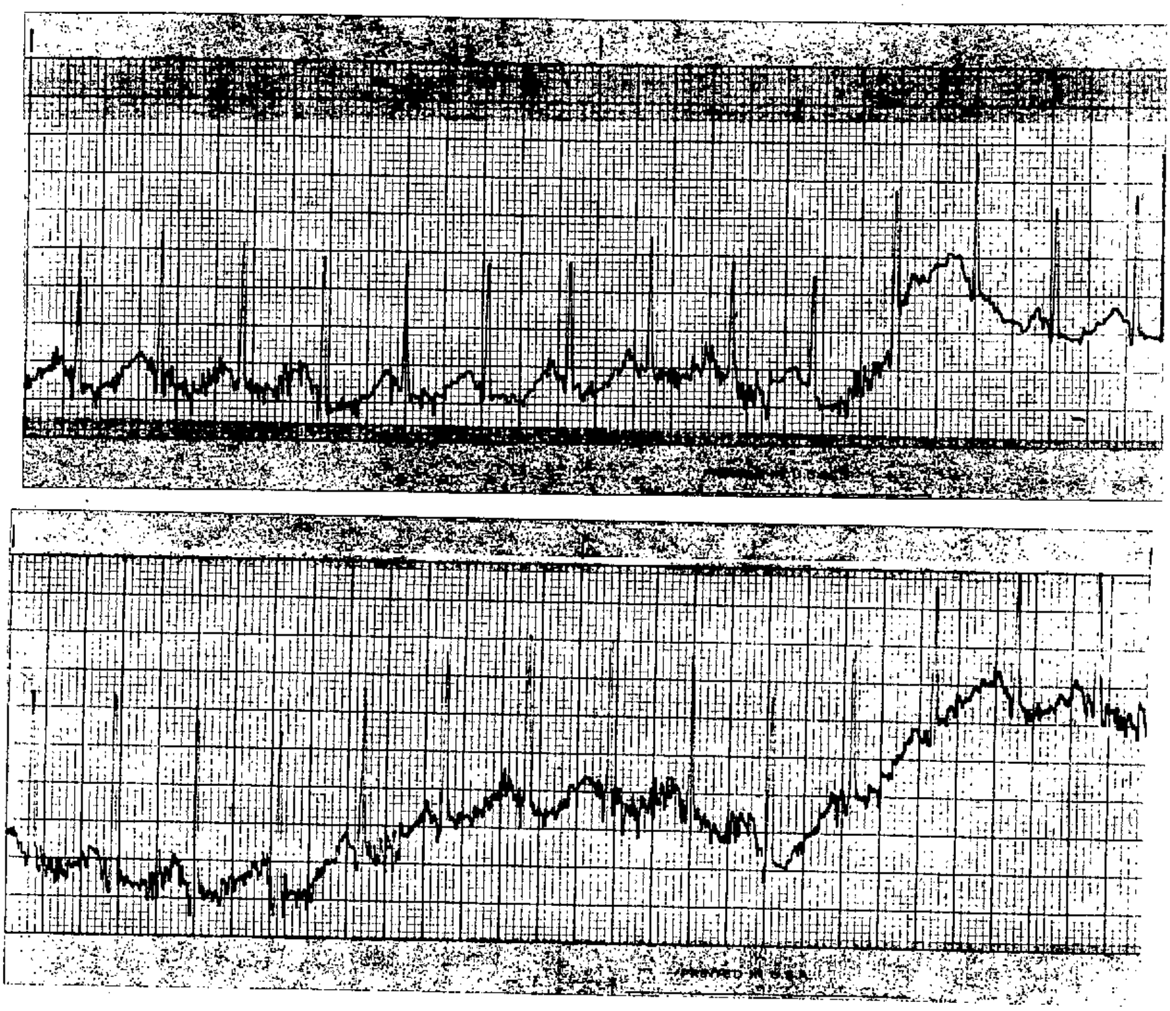


ECG/VCG SPONGE
SIMULTANEOUS RESTING EKG RECORDINGS

(High Impedance Subject #6)

FIGURE 5

FLUSH MOUNTED/KM129B



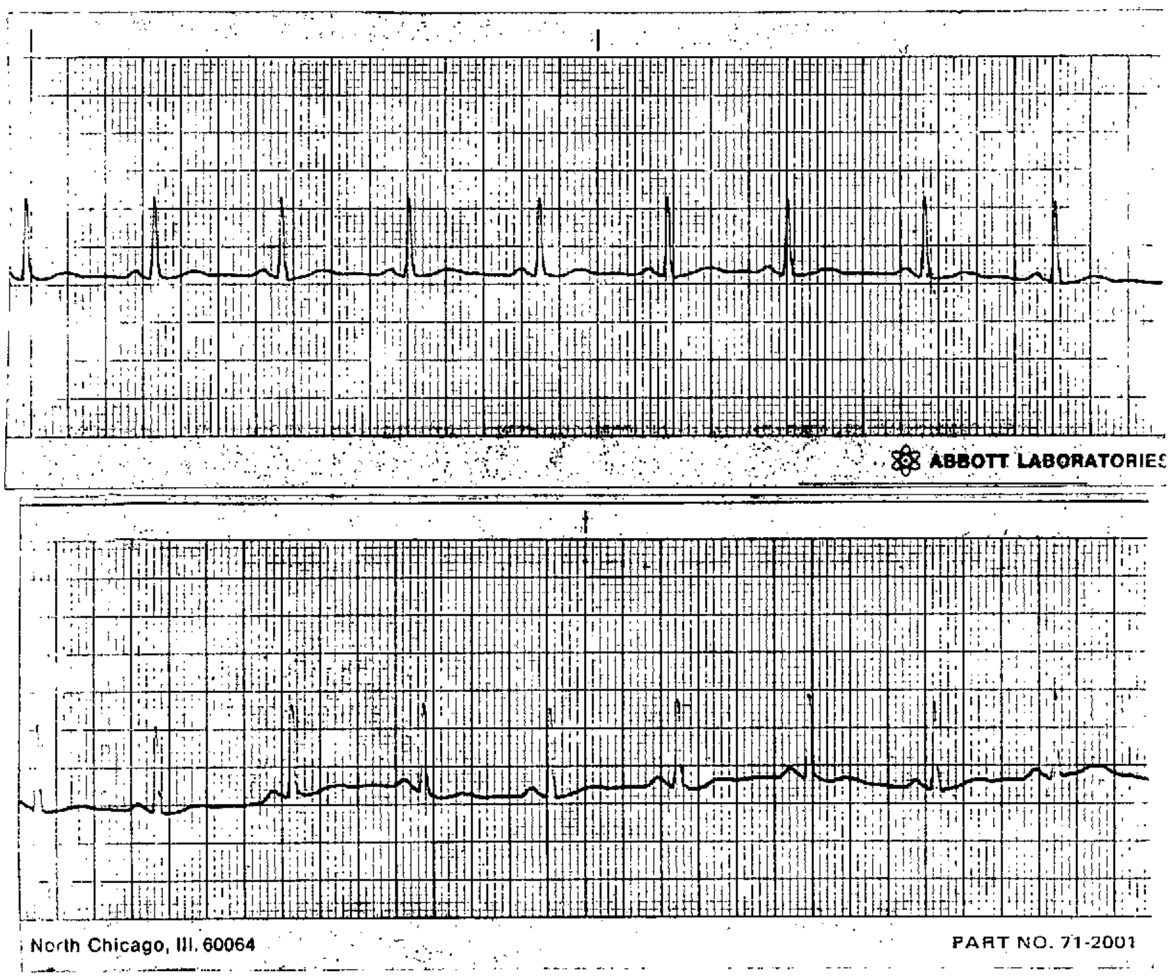
ECG/VCG

SIMULTANEOUS EXERCISE EKG RECORDINGS

(High Impedance Subject #6)

FIGURE 6

FLUSH MOUNTED/KM129B



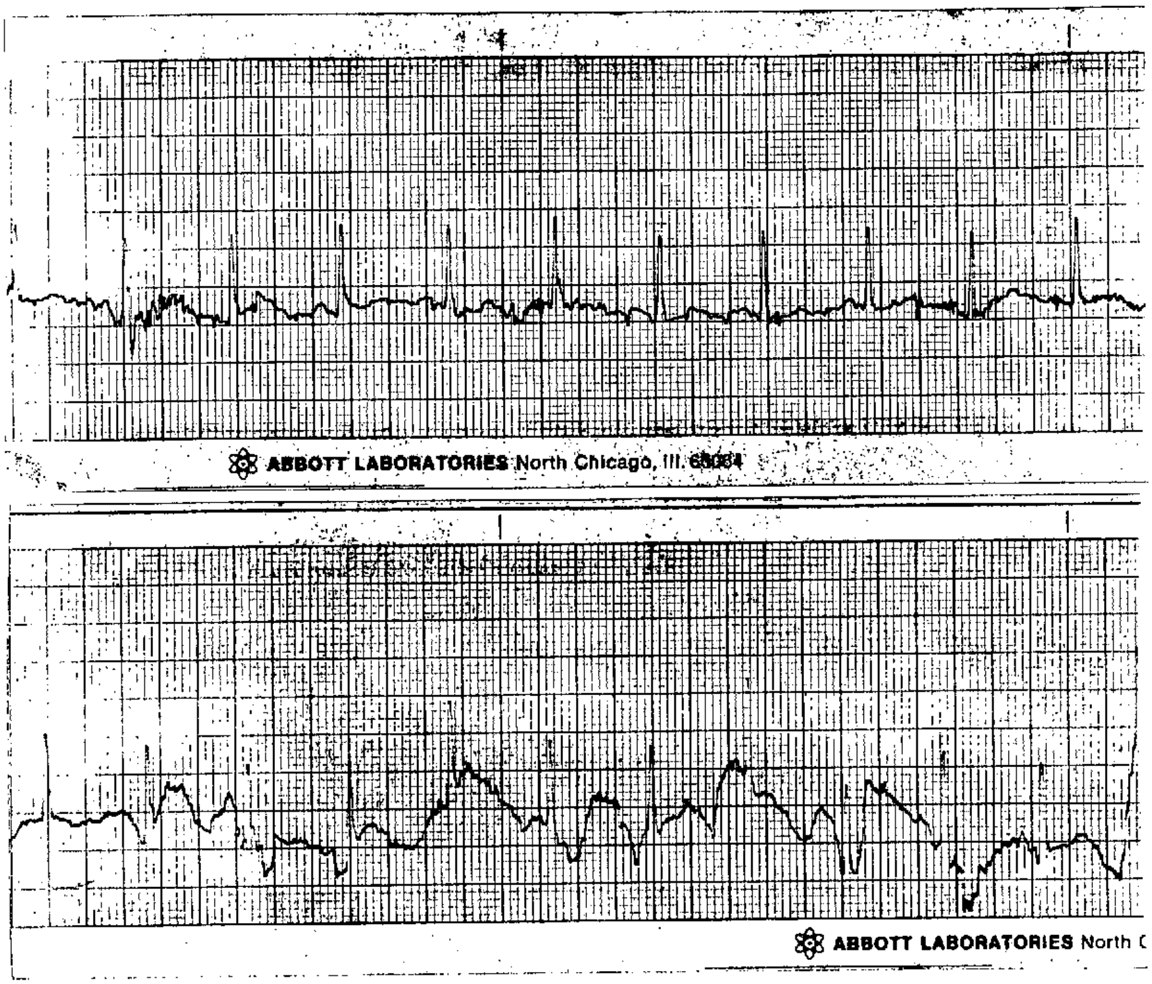
ECG/VCG SPONGE

SIMULTANEOUS RESTING EKG RECORDINGS

(Low Impedance Subject #3)

FIGURE 7

FLUSH MOUNTED/KM129B



ECG/VCG SPONGE

SIMULTANEOUS EXERCISE EKG RECORDINGS

(Low Impedance Subject #3)

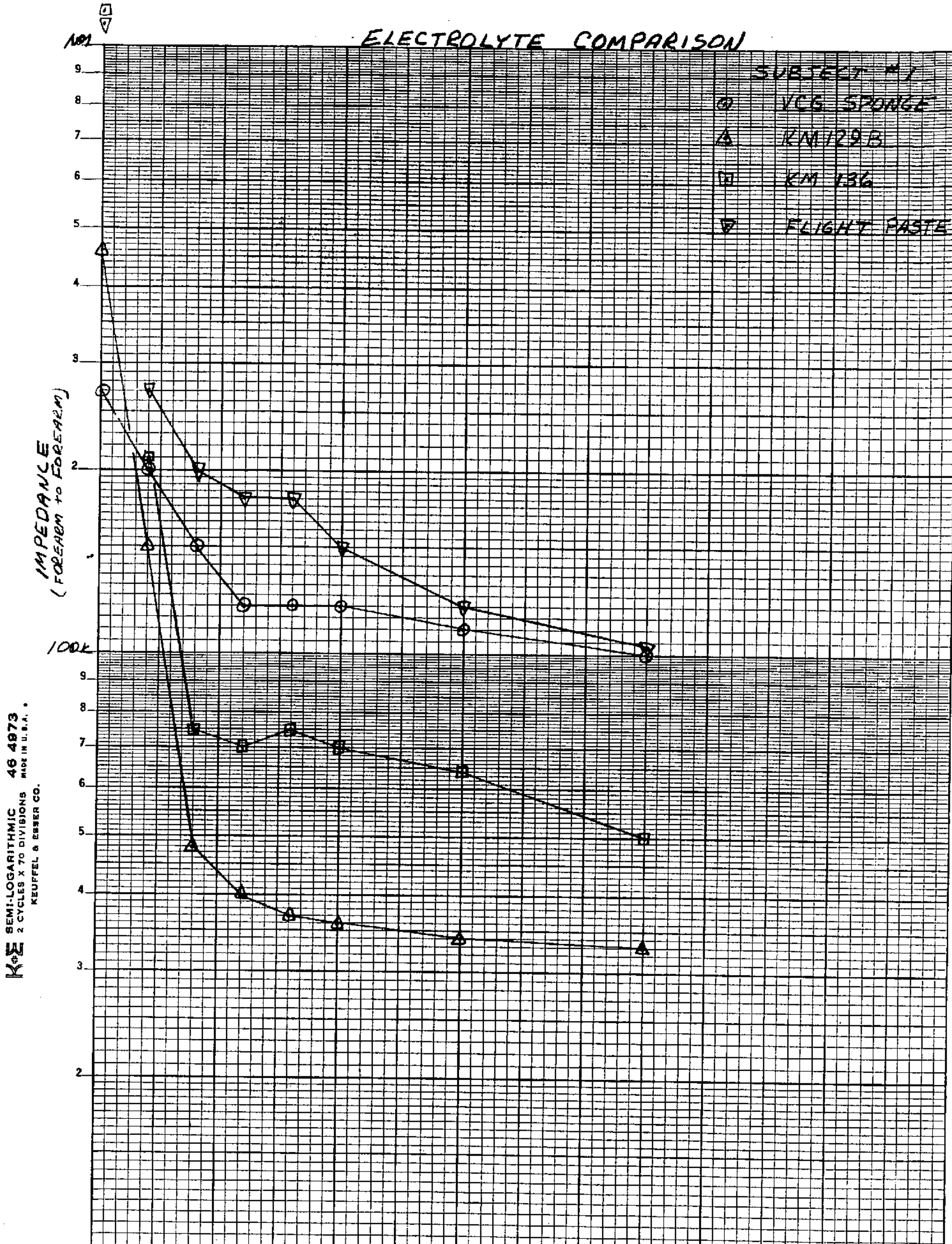
FIGURE 8

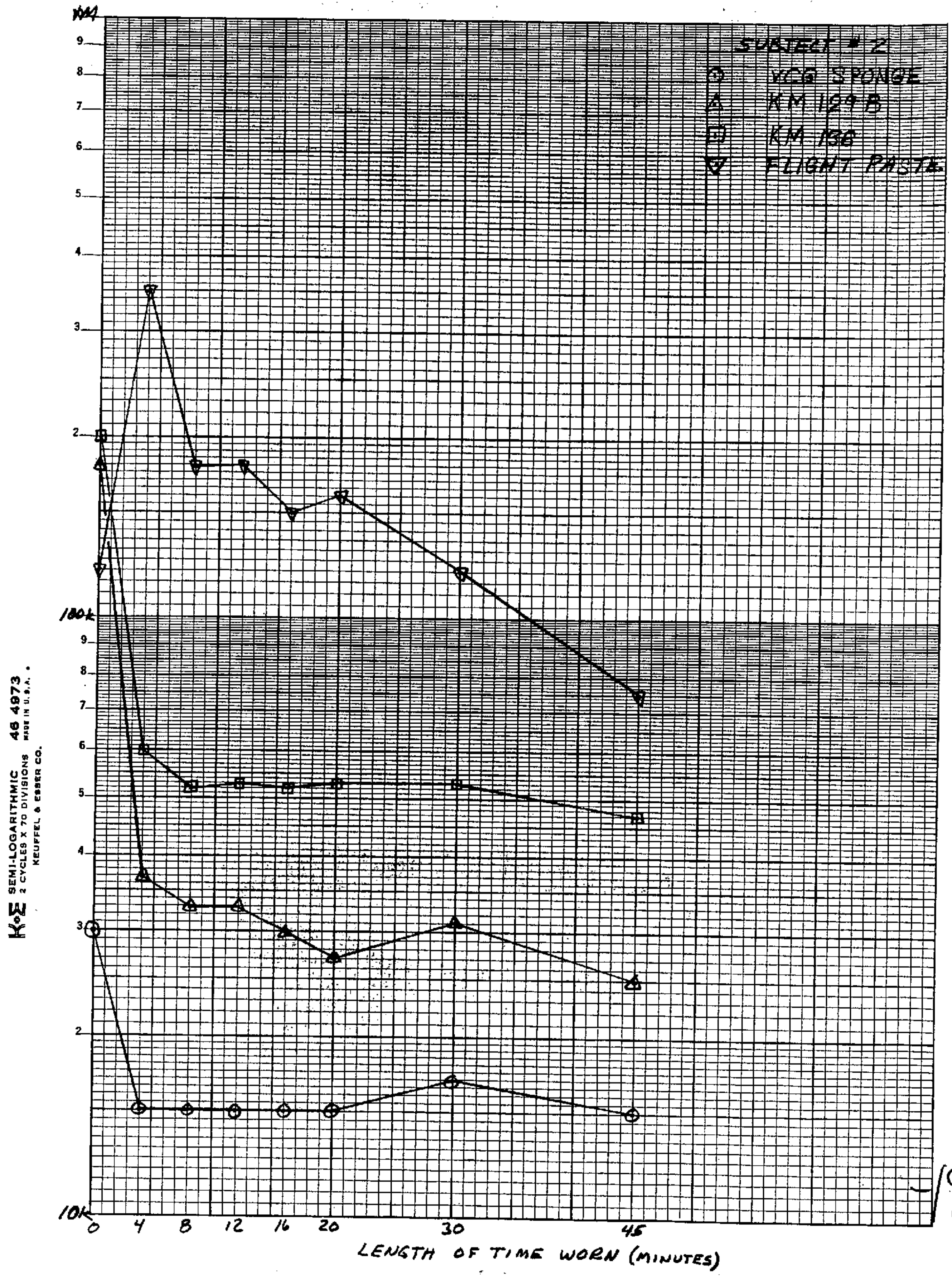
CONCLUSIONS

Test data indicated that the two KM type pastes produced impedances approximately one half the VCG impedance at the end of 45 minutes. The KM129B was selected as a candidate to compare to the VCG because of its consistency and probable ease of dispensing. Analog strip chart recordings from each of the two subjects indicated that the KM129B paste used in conjunction with the flush electrode did not significantly differ in quality from the sponge/recessed electrodes. Therefore, because of the KM129B low impedance characteristics and its apparent ease of application, this electrode system has been found to be far superior to the VCG sponge electrode.

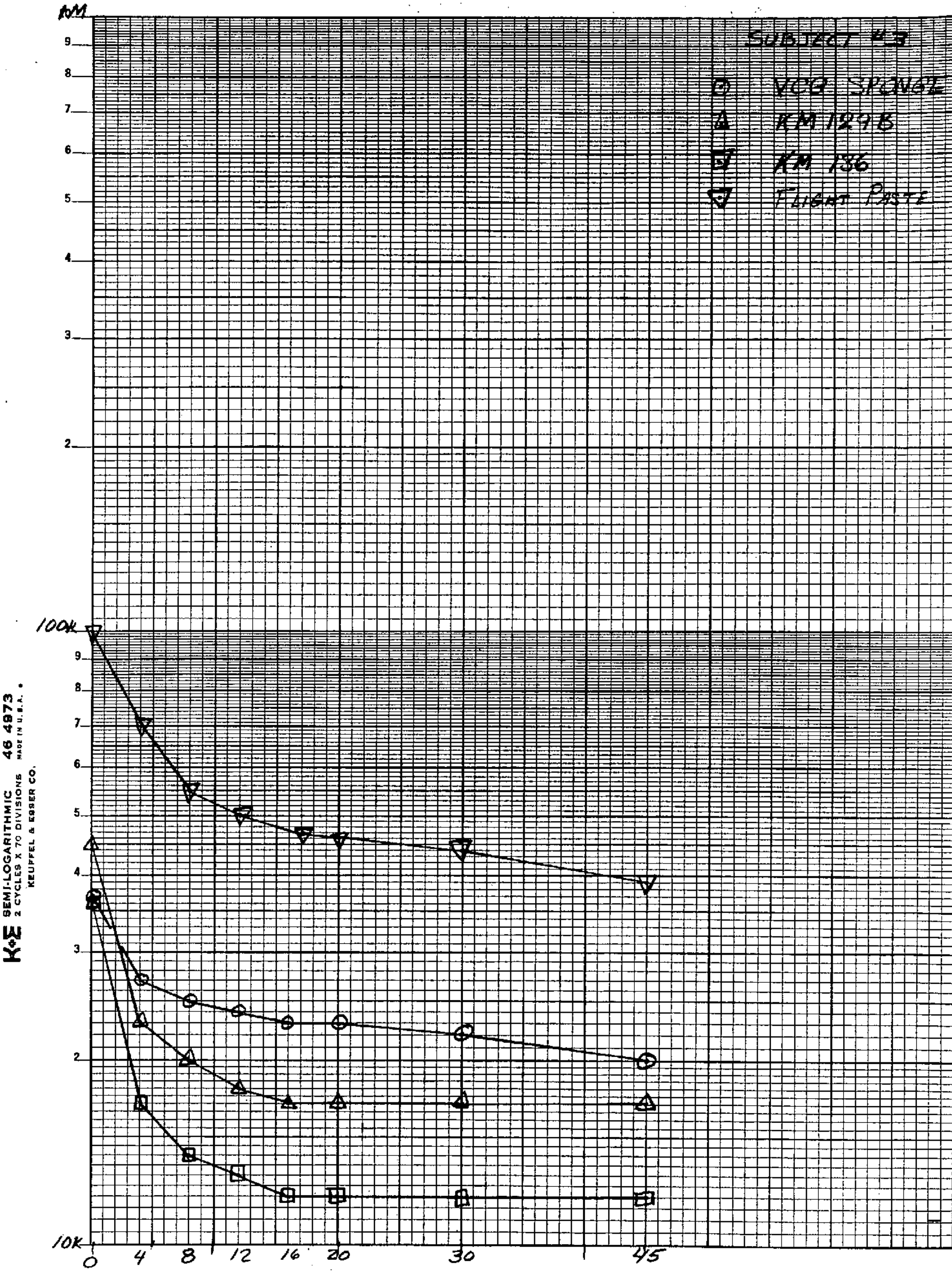
/ge

ELECTROLYTE COMPARISON



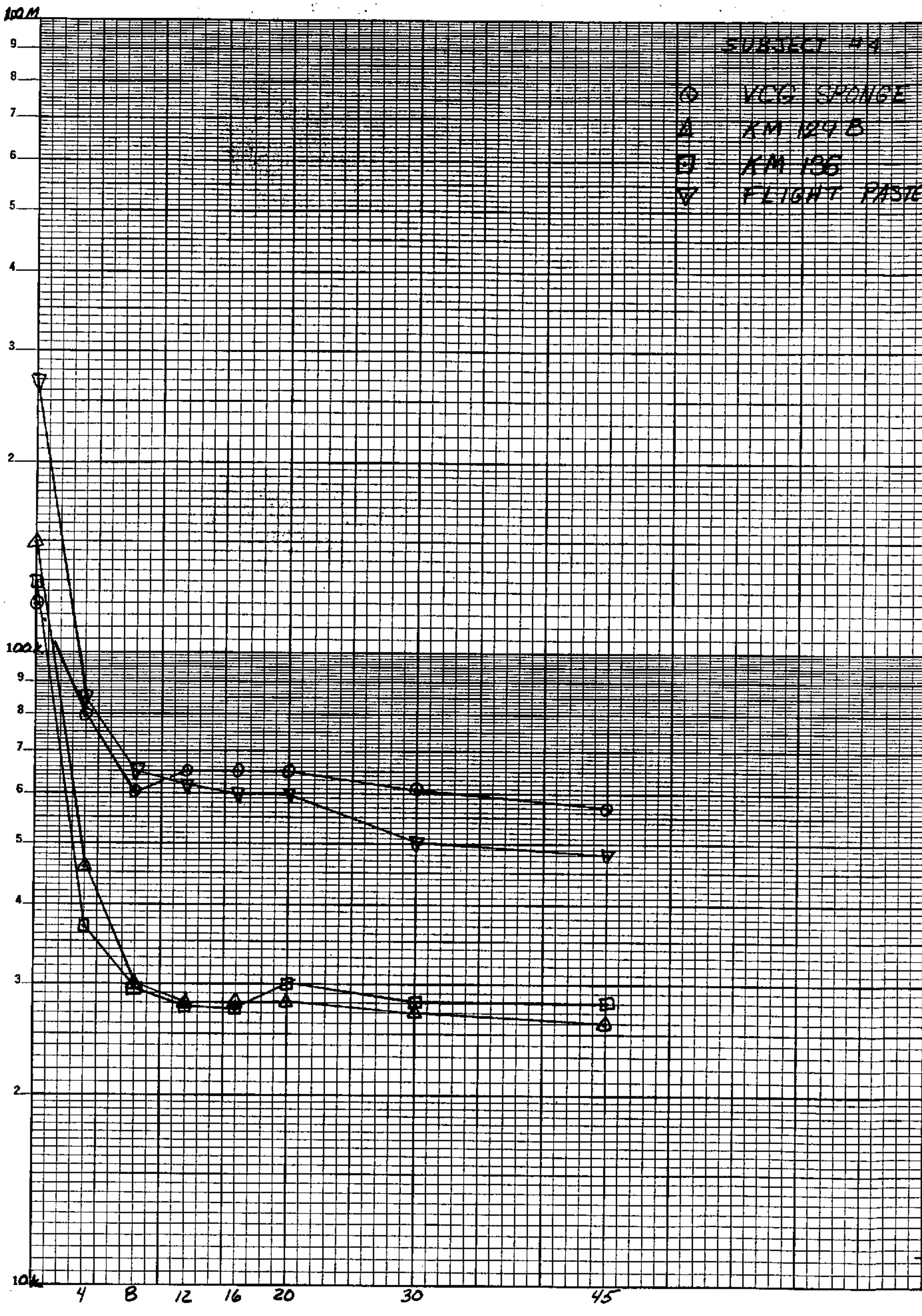


1M
9
8
7
6
5
4
3
2
100k
9
8
7
6
5
4
3
2
10K
0
4
8
12
16
20
30
45
LENGTH OF TIME WORN (MINUTES)
SUBJECT # 2
VCG SPONGE
KM 129 B
KM 138
FLIGHT PASTE
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

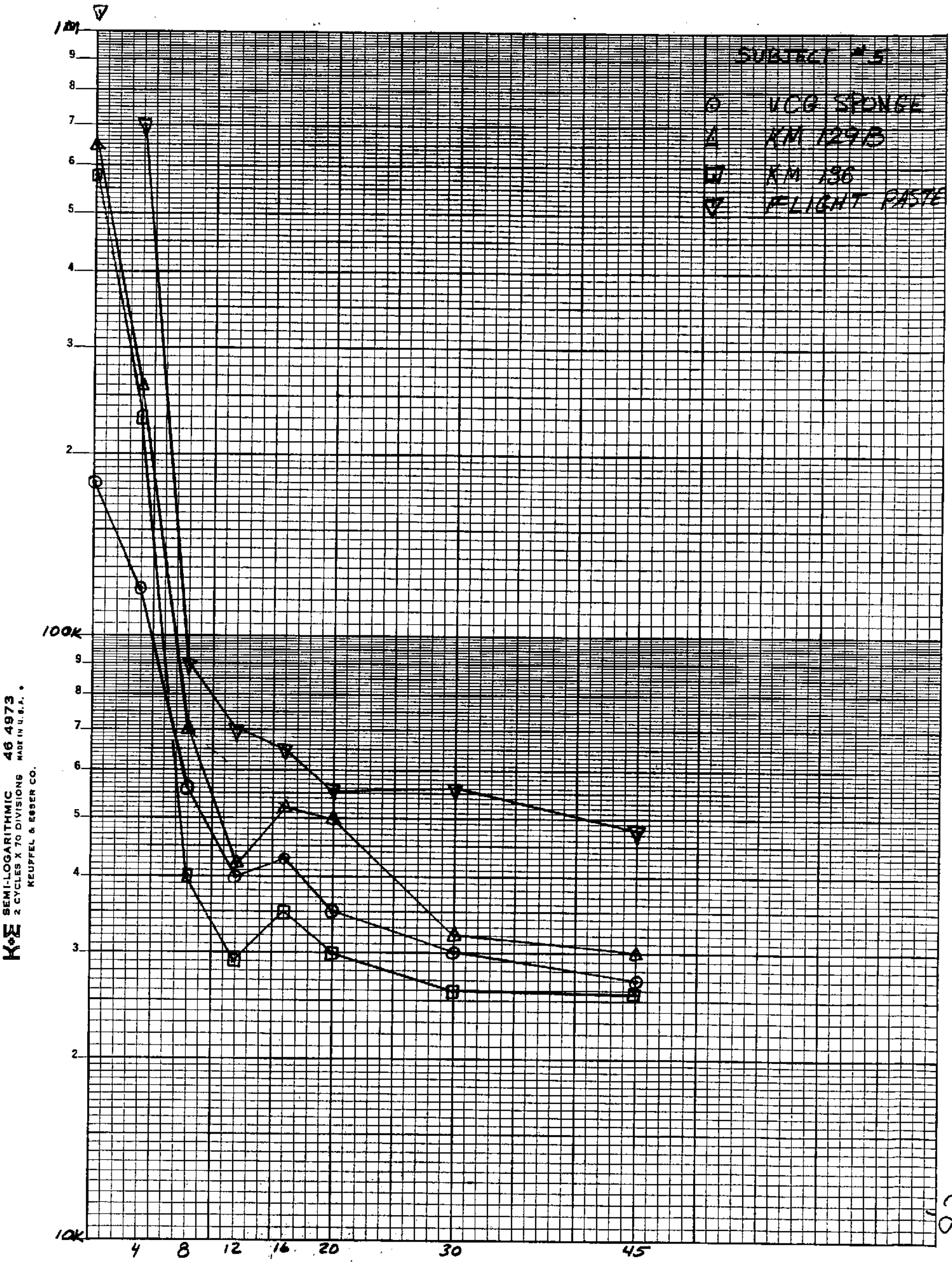


SUBJECT #3
VCG SPONGE
KM 129B
KM 136
FLIGHT PASTE
1M
100K
10K
0
4
8
12
16
20
30
45
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

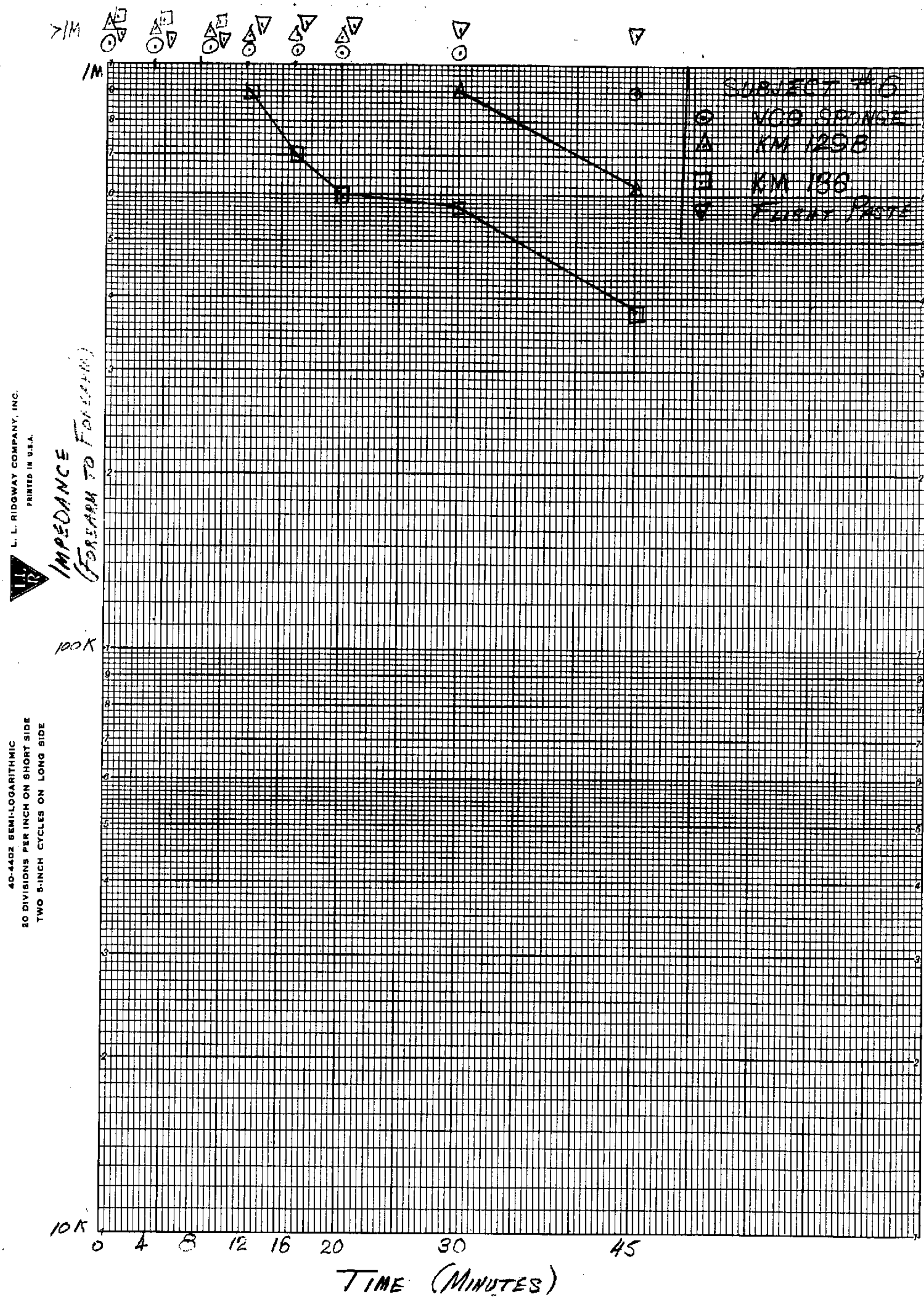
19



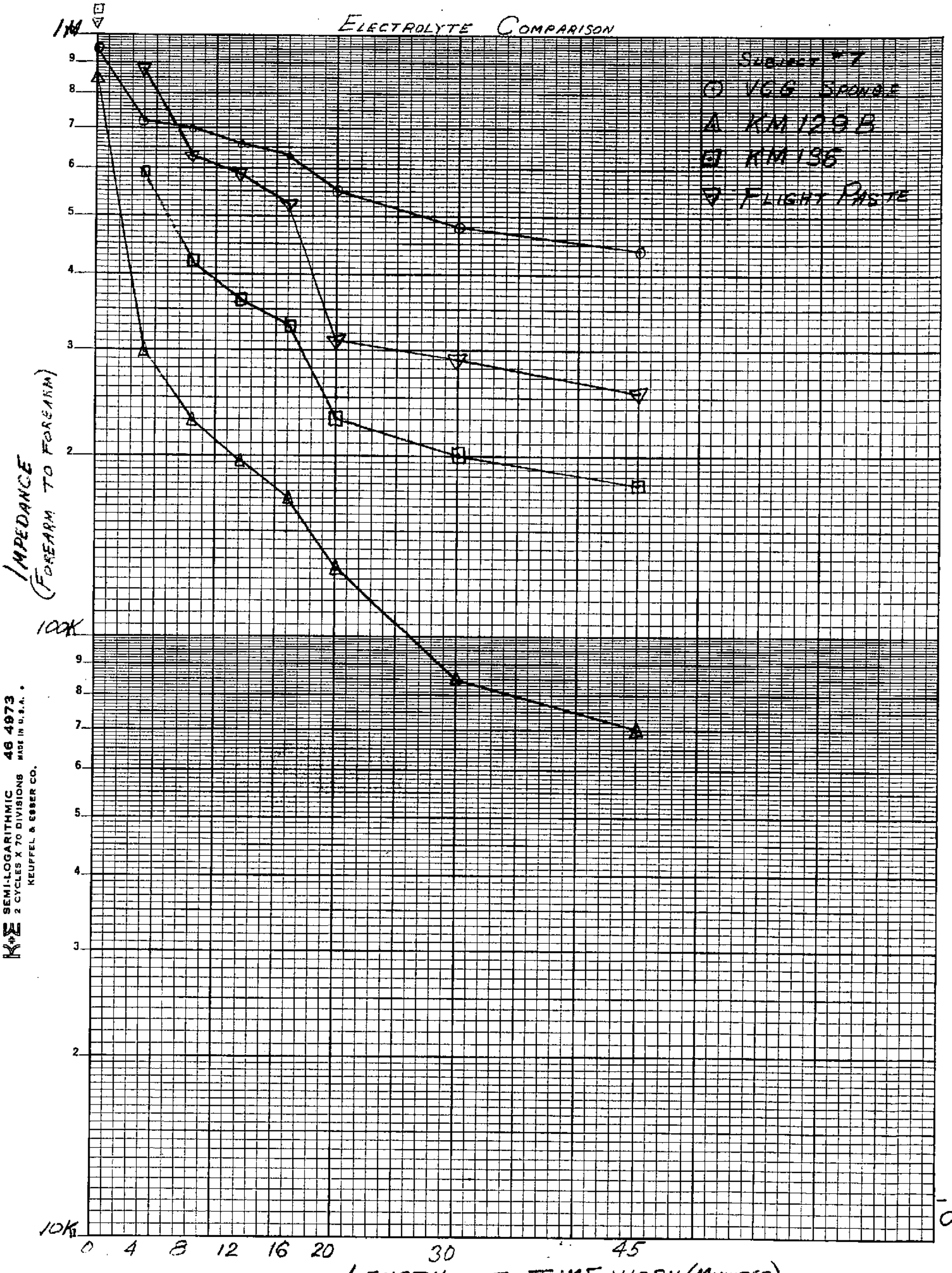
SUBJECT #4
VCG SPONGE
KM 129 B
KM 136
FLIGHT PASTE
100M
10k
100k
4
8
12
16
20
30
45



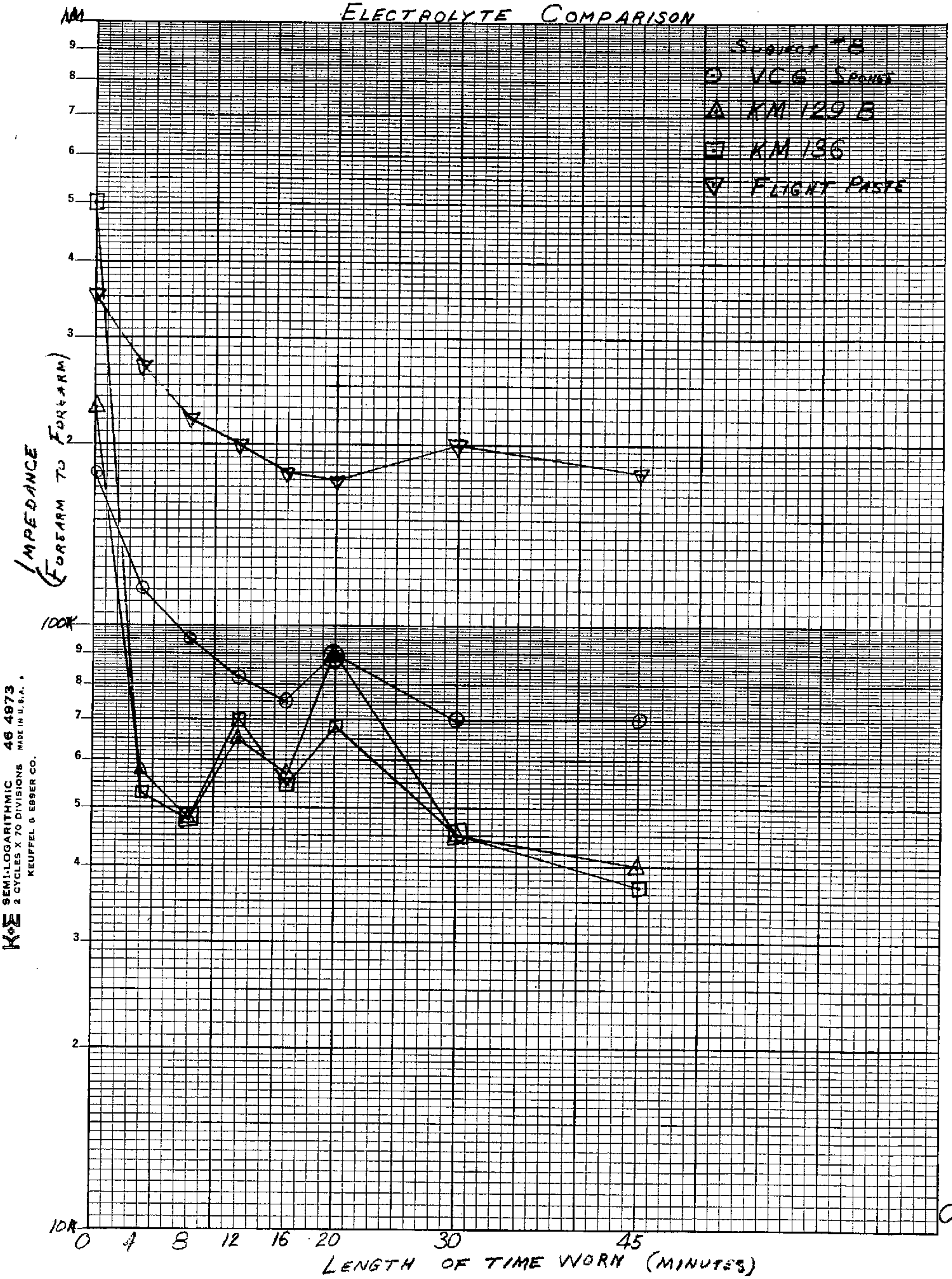
SUBJECT #5
○ VCG SPONGE
△ KM 129B
□ KM 136
▽ FLIGHT PASTE
1M
100K
10K
4
8
12
16
20
30
45
K&E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.



SUBJECT #6
VCG SPONGE
KM 129B
KM 136
FLIGHT PASTE
IMPEDANCE (FOREARM TO FOREARM)
>1M
1M
100K
10K
0
4
8
12
16
20
30
45
TIME (MINUTES)
L. L. RIDGWAY COMPANY, INC.
PRINTED IN U.S.A.
40-4402 SEMI-LOGARITHMIC
20 DIVISIONS PER INCH ON SHORT SIDE
TWO 5-INCH CYCLES ON LONG SIDE

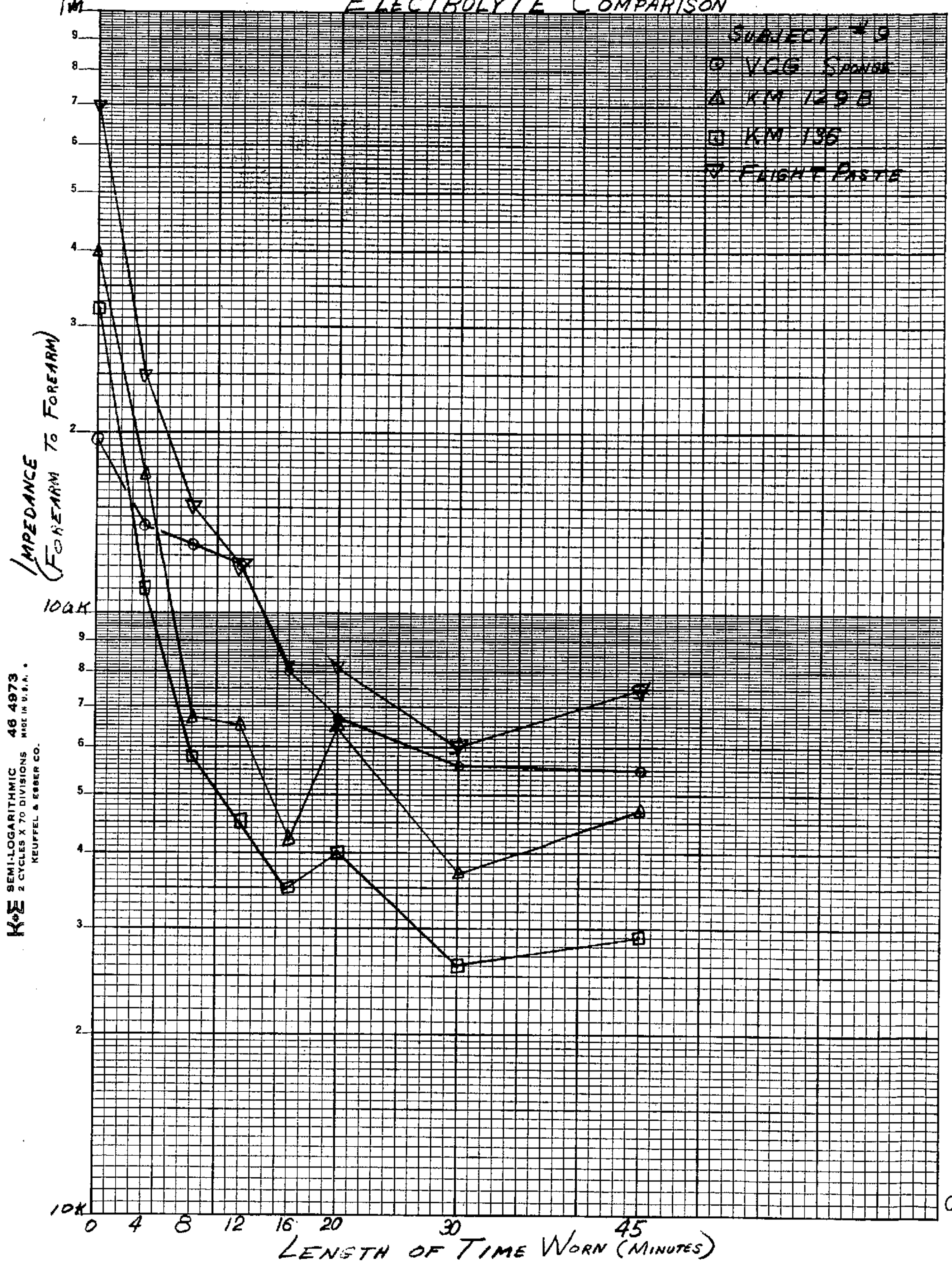


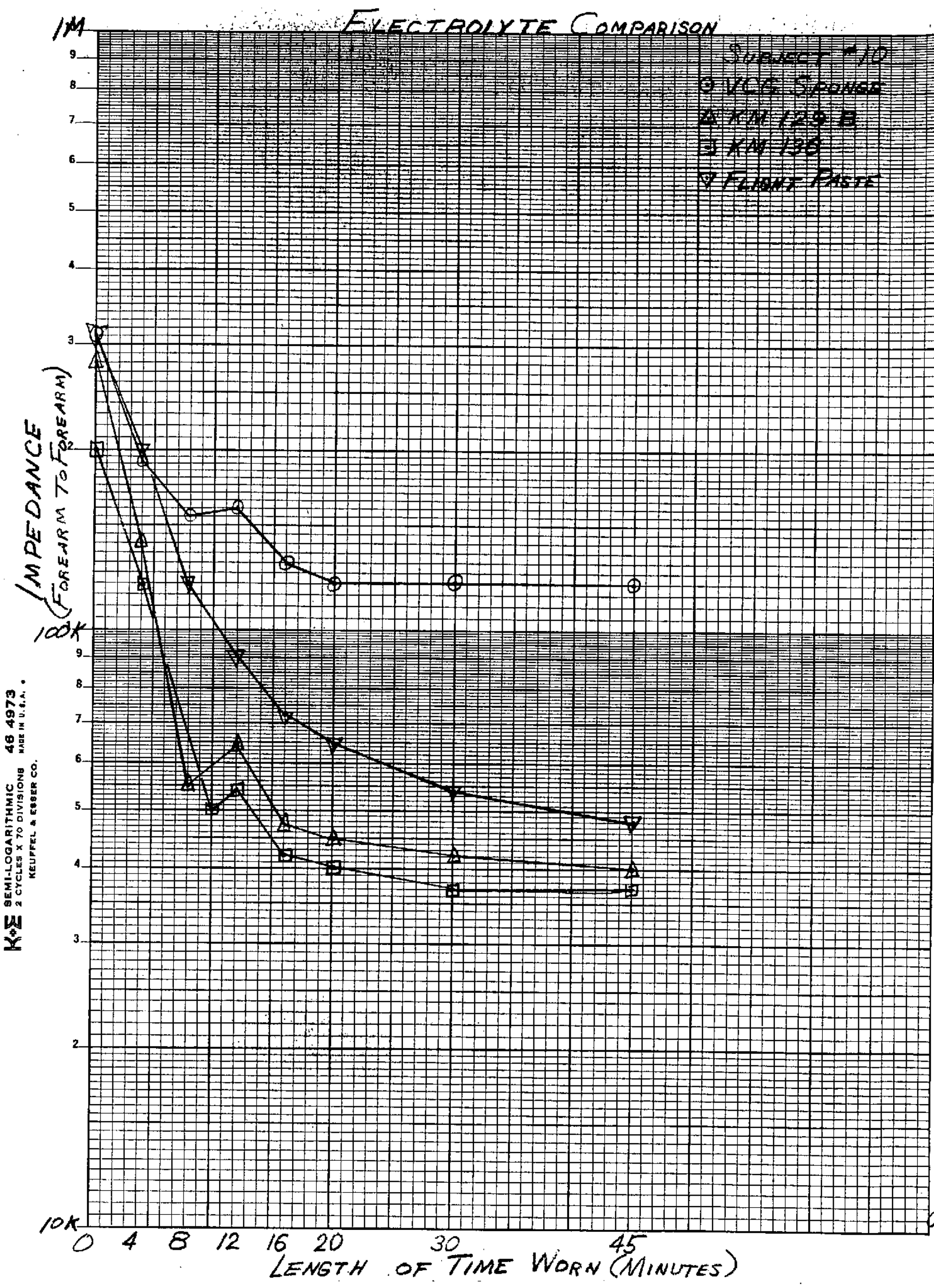
ELECTROLYTE COMPARISON
SUBJECT #7
○ VCG SPONGE
△ KM 129 B
⊡ KM 136
▽ FLIGHT PASTE
1M
9
8
7
6
5
4
3
2
100K
9
8
7
6
5
4
3
2
10K
0
4
8
12
16
20
30
45
IMPEDANCE (FOREARM TO FOREARM)
LENGTH OF TIME WORN (MINUTES)
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

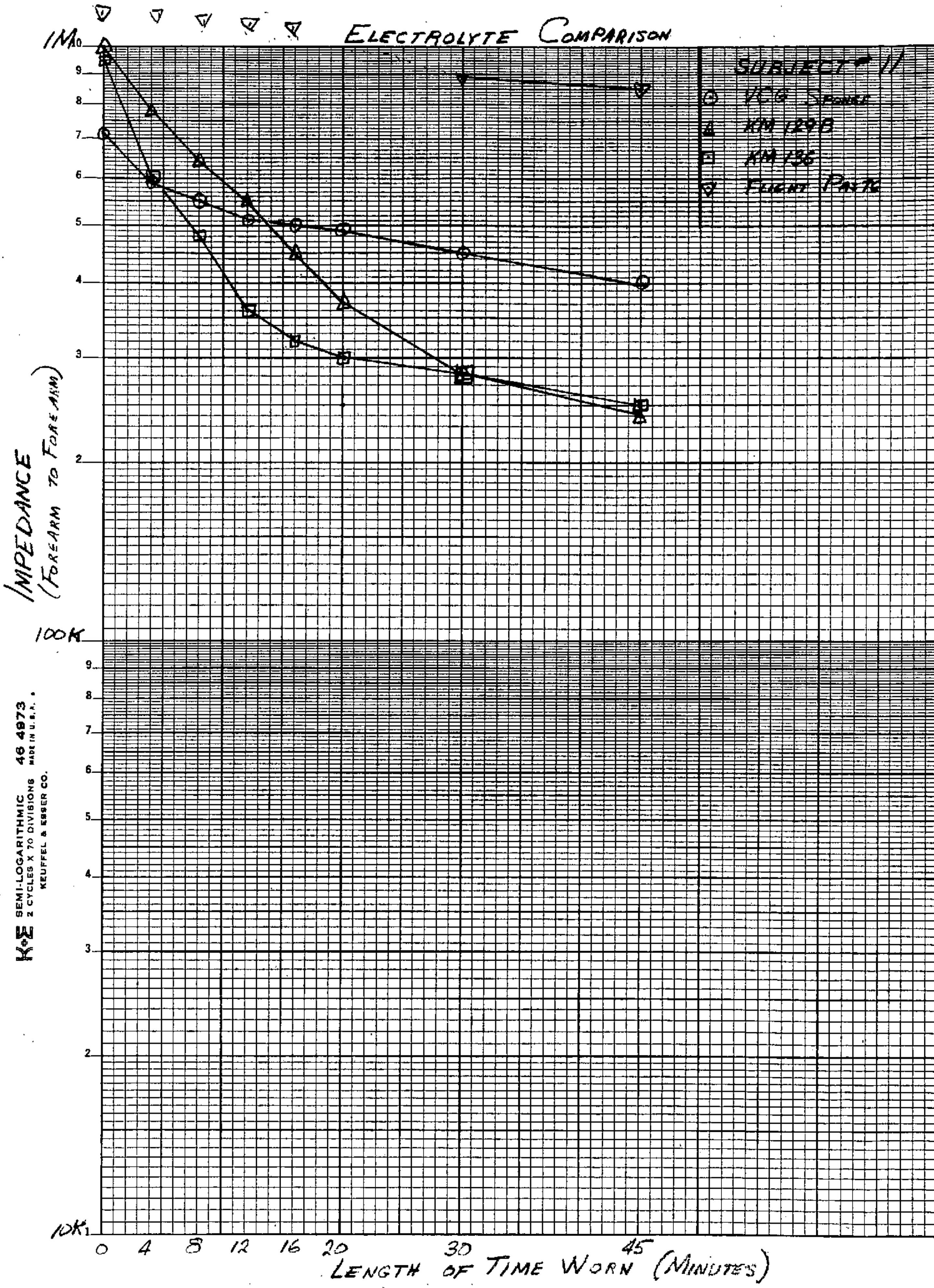


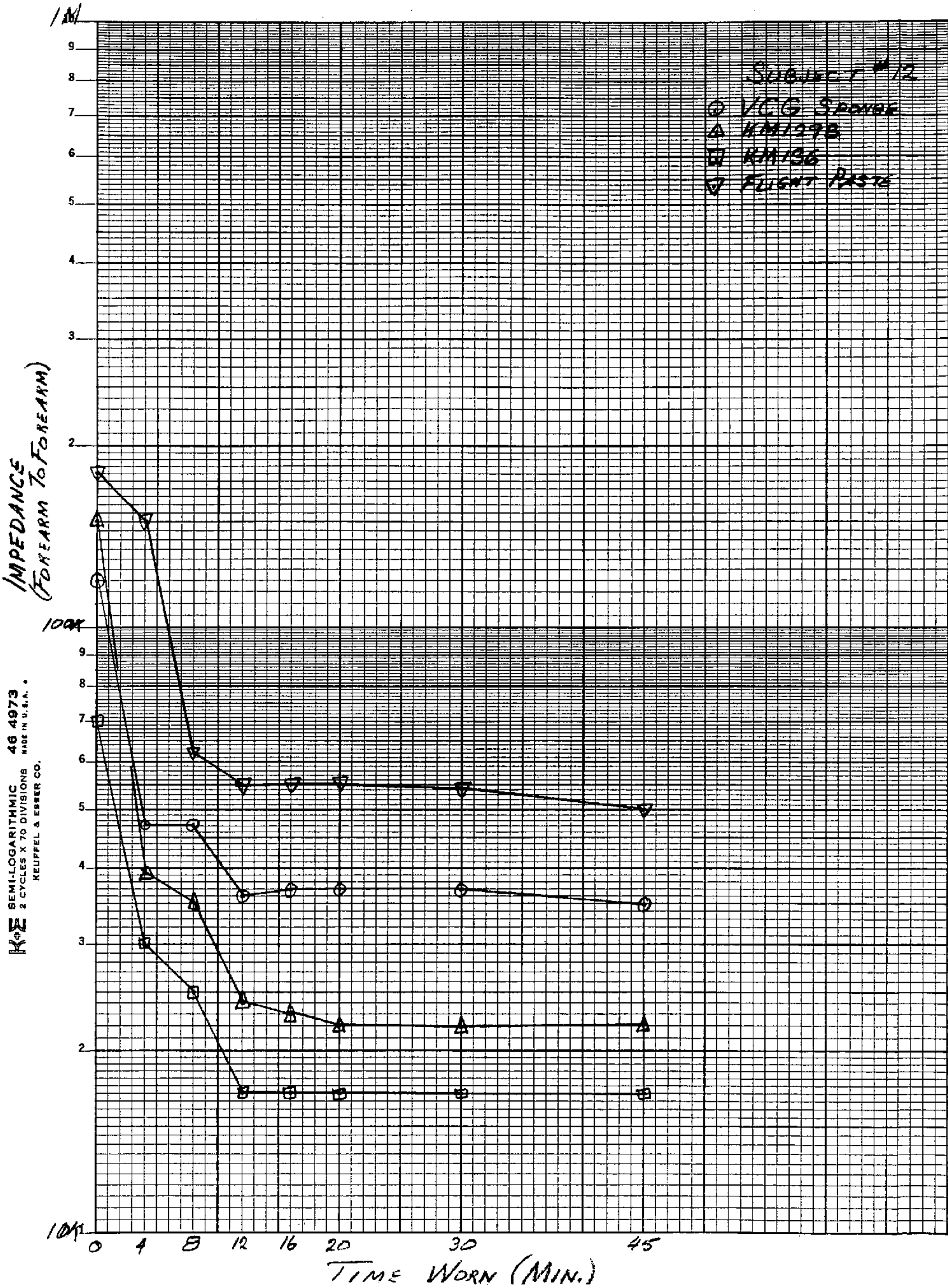
ELECTROLYTE COMPARISON
SUBJECT #8
VCG SPONGE
KM 129 B
KM 136
FLIGHT PASTE
IMPEDANCE (FOREARM TO FOREARM)
MM
9
8
7
6
5
4
3
2
100K
9
8
7
6
5
4
3
2
10K
0
4
8
12
16
20
30
45
LENGTH OF TIME WORN (MINUTES)
K&E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

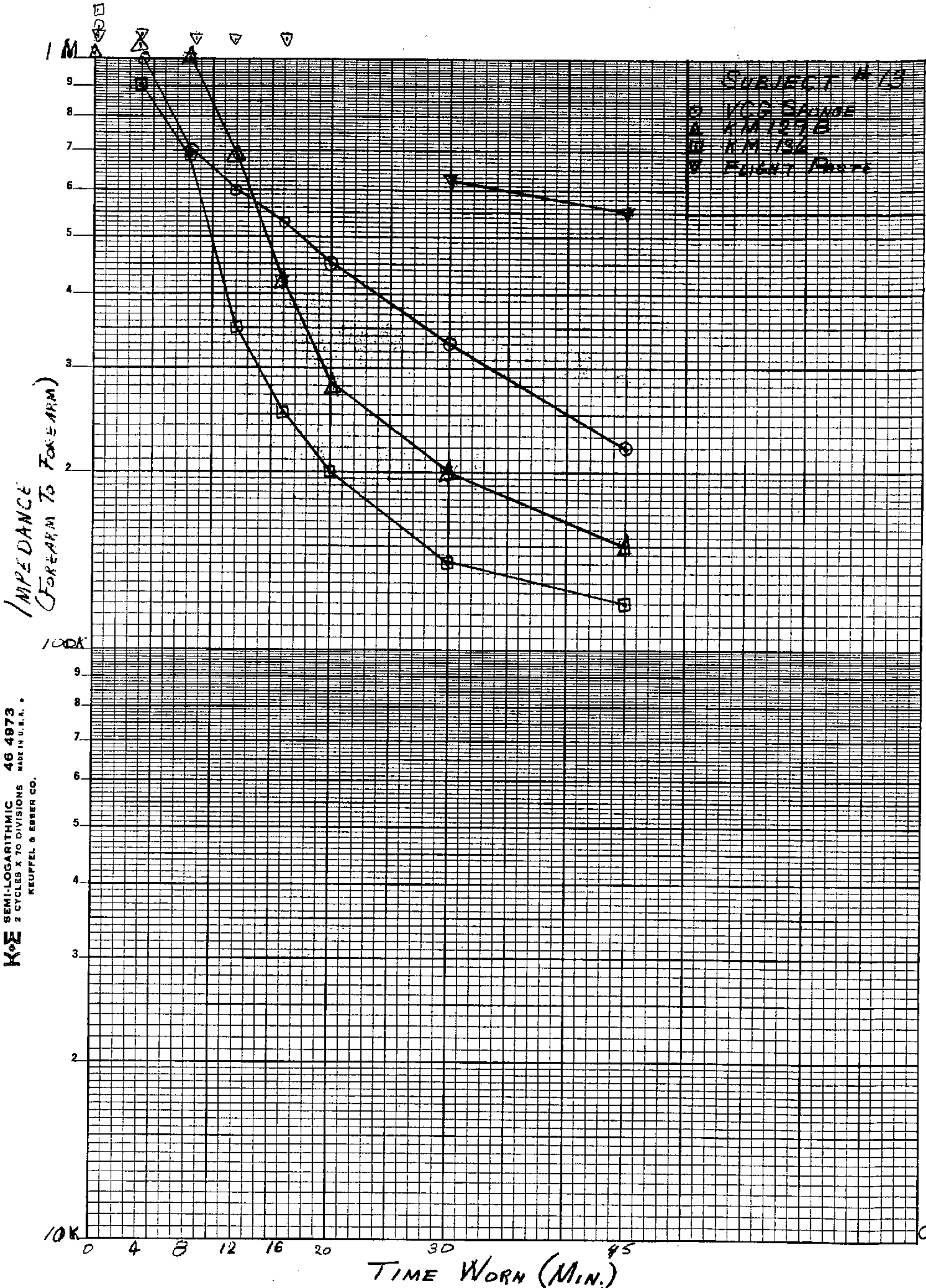
ELECTROLYTE COMPARISON




ELECTROLYTE COMPARISON
SUBJECT #10
⊙ VCG SPONGE
△ KM 129 B
□ KM 138
▽ FLIGHT PASTE
IMPEDANCE
(FOREARM TO FOREARM)
1M
100K
10K
LENGTH OF TIME WORN (MINUTES)
0
4
8
12
16
20
30
45
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

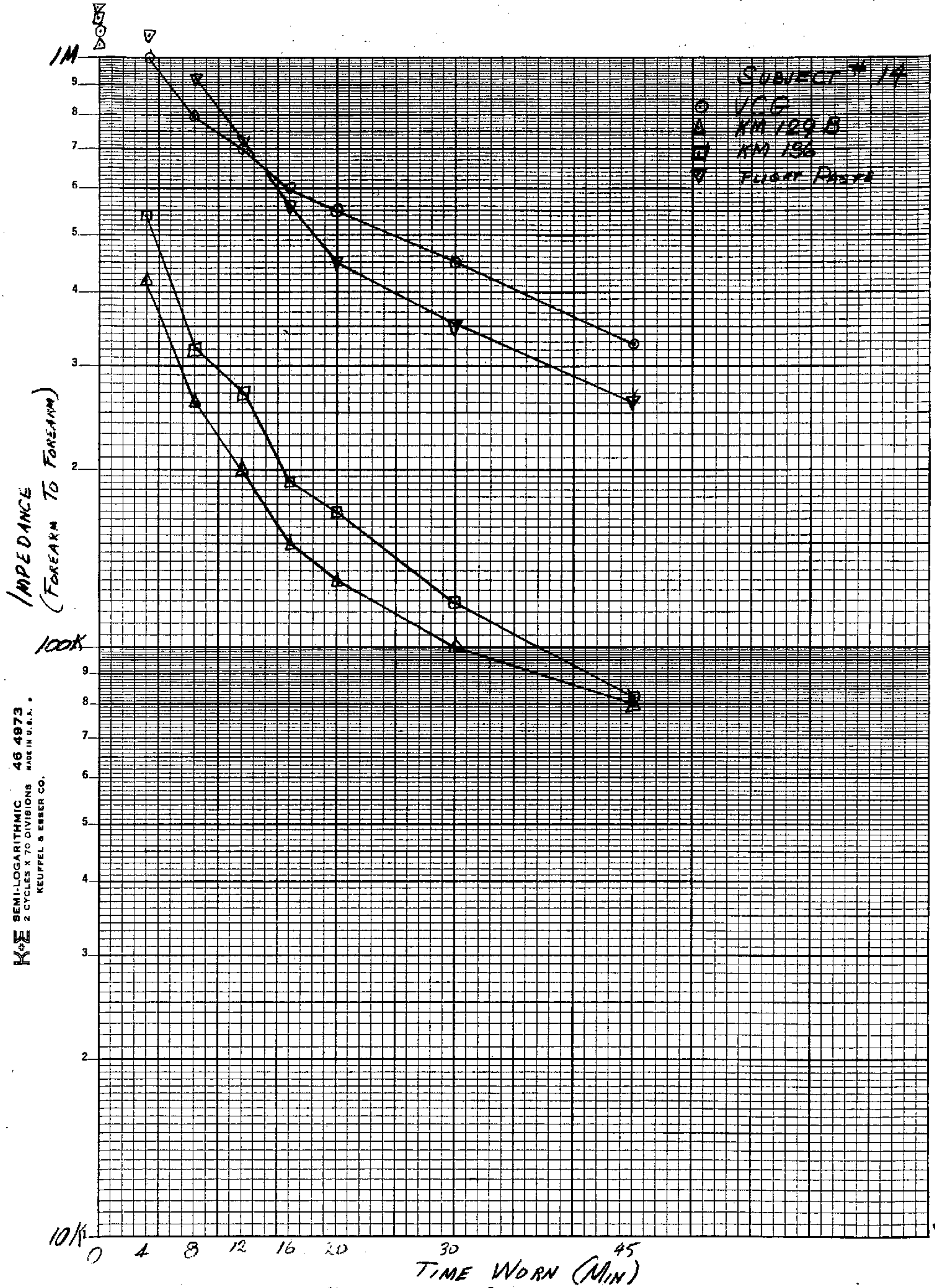

ELECTROLYTE COMPARISON
SUBJECT # 11
VCG SPONGE
KM 129B
KM 136
FLIGHT PASTE
IMPEDANCE (FOREARM TO FORE ARM)
1M
100K
10K
LENGTH OF TIME WORN (MINUTES)
0
4
8
12
16
20
30
45
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


SUBJECT #12
VCG SPONGE
KM129B
KM136
FLIGHT PASTE
IMPEDANCE
(FOREARM TO FOREARM)
1M
100K
10K
0 4 8 12 16 20 30 45
TIME WORN (MIN.)
K&E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.



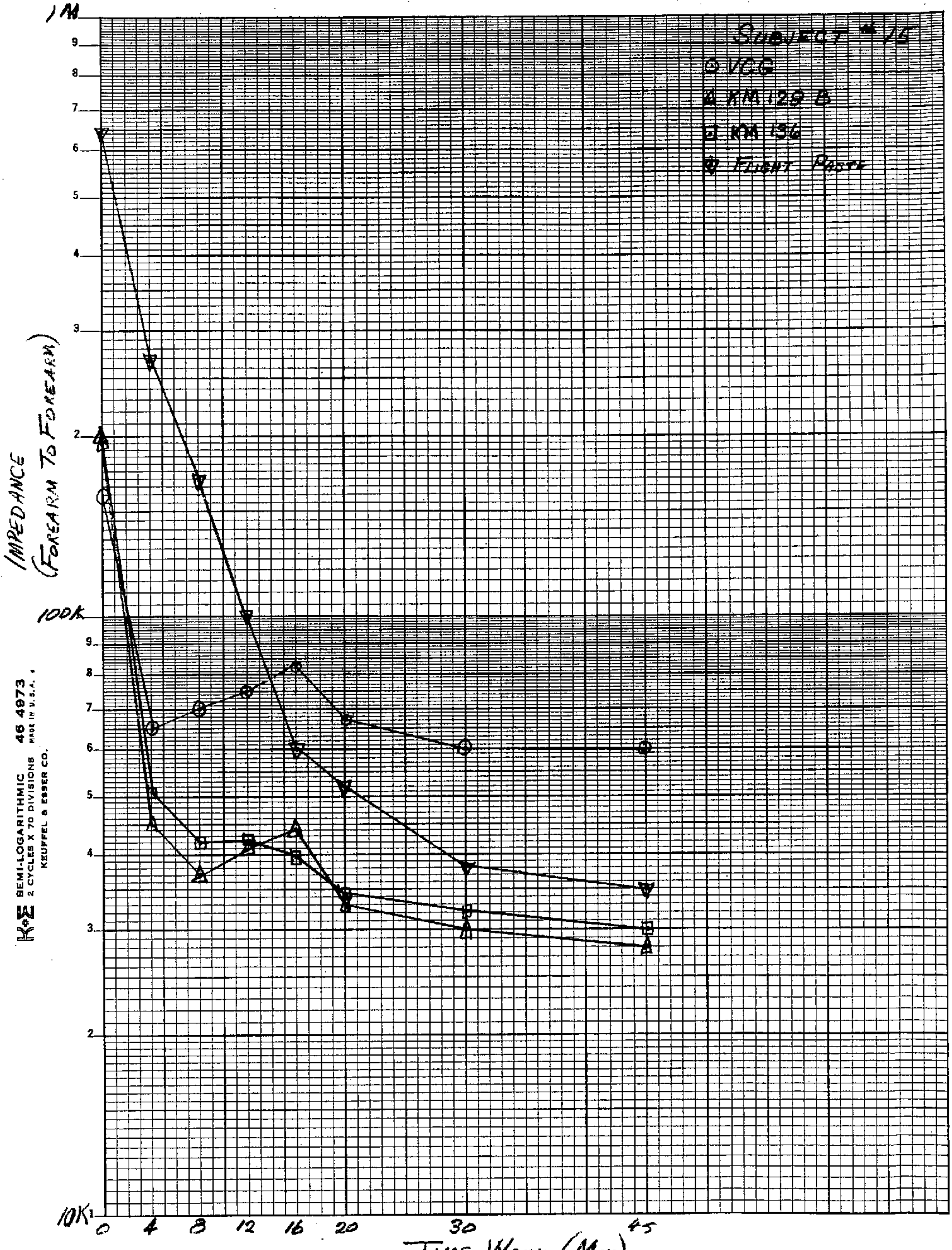
1 M
9
8
7
6
5
4
3
2
100K
9
8
7
6
5
4
3
2
10K
0
4
8
12
16
20
30
45
TIME WORN (MIN.)
IMPEDANCE (FOREARM TO FOREARM)
SUBJECT #13
VCG SPONGE
KM 127 B
KM 134
FLIGHT PROBE
K&E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

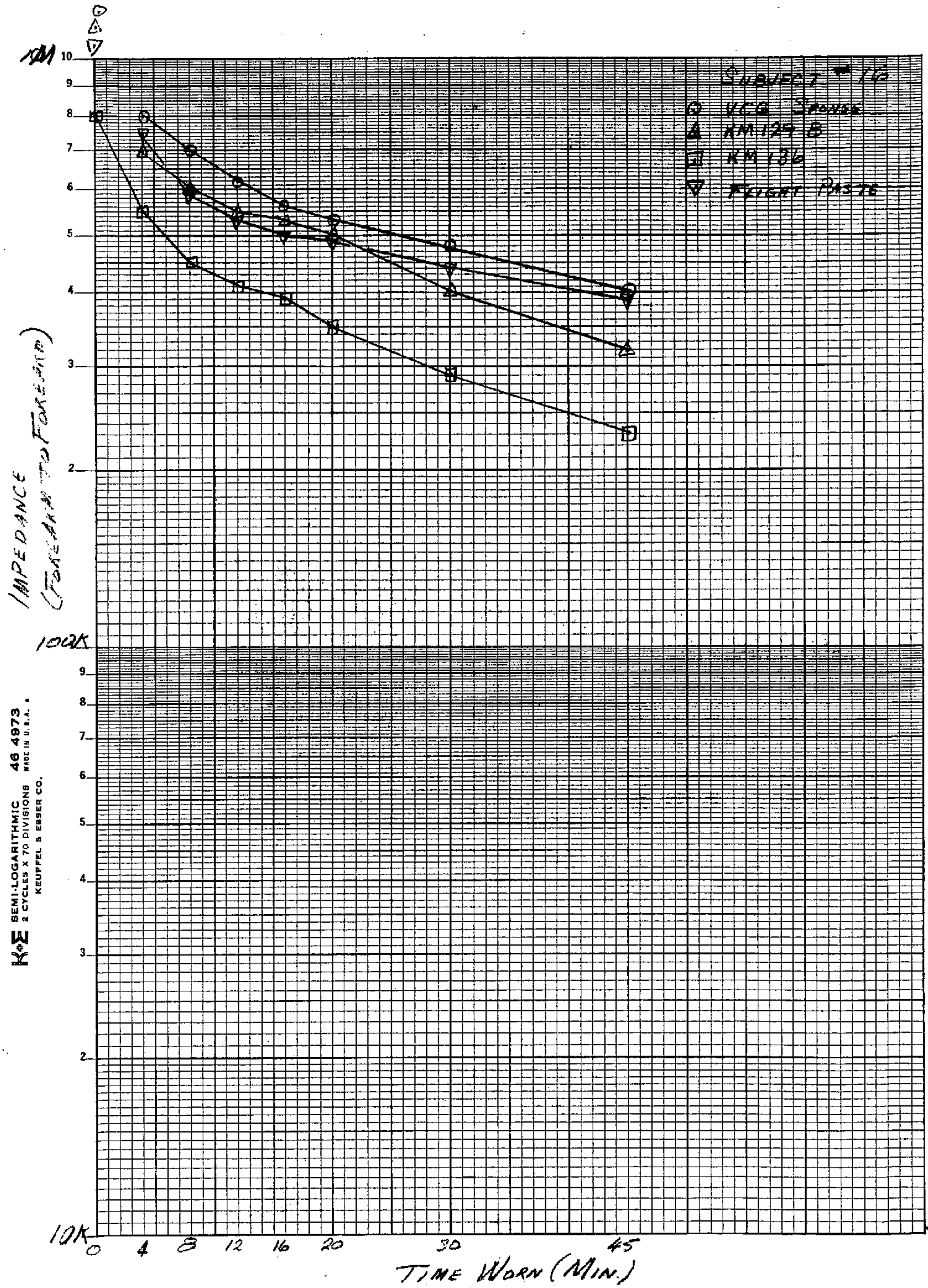
29

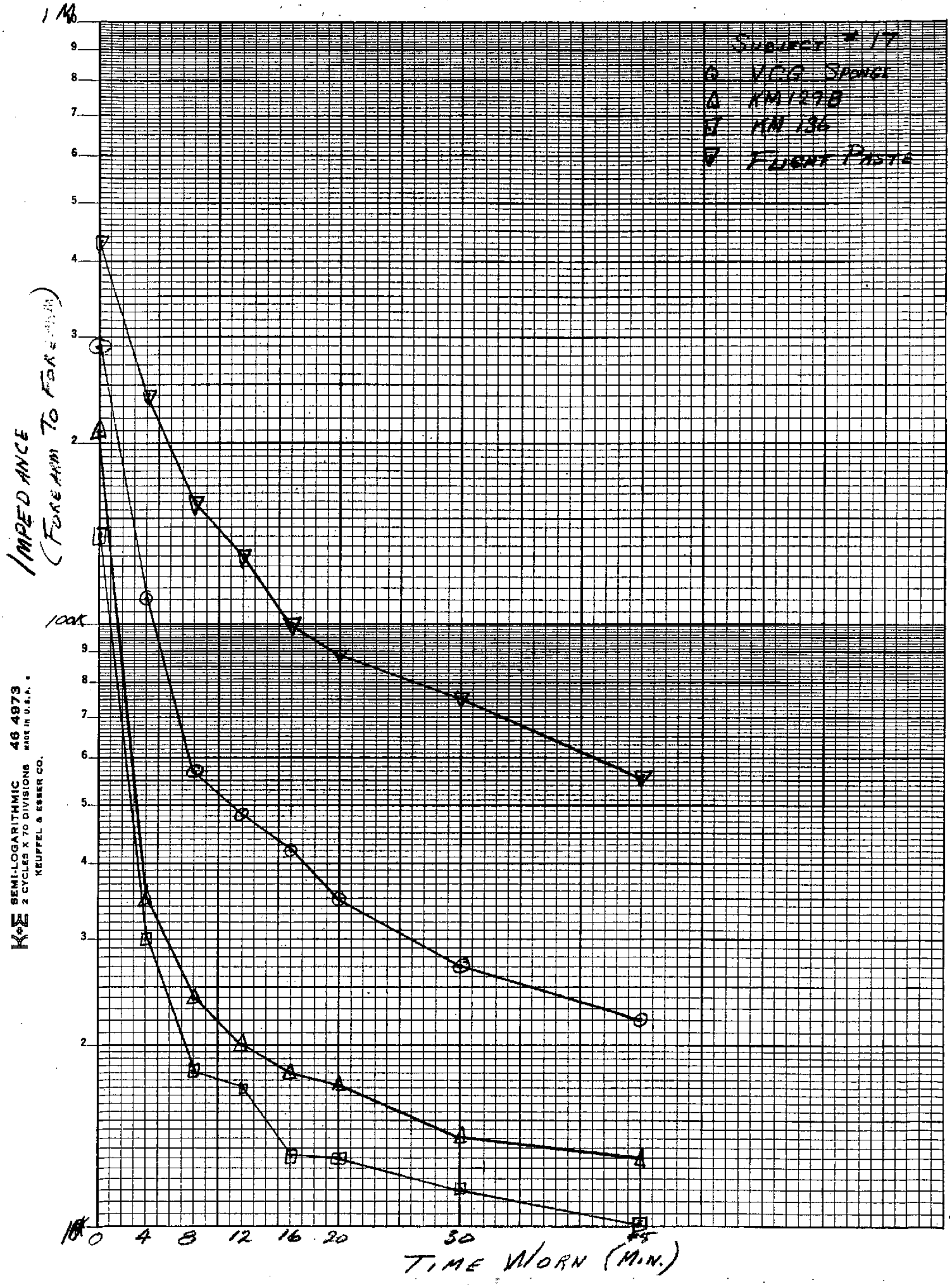


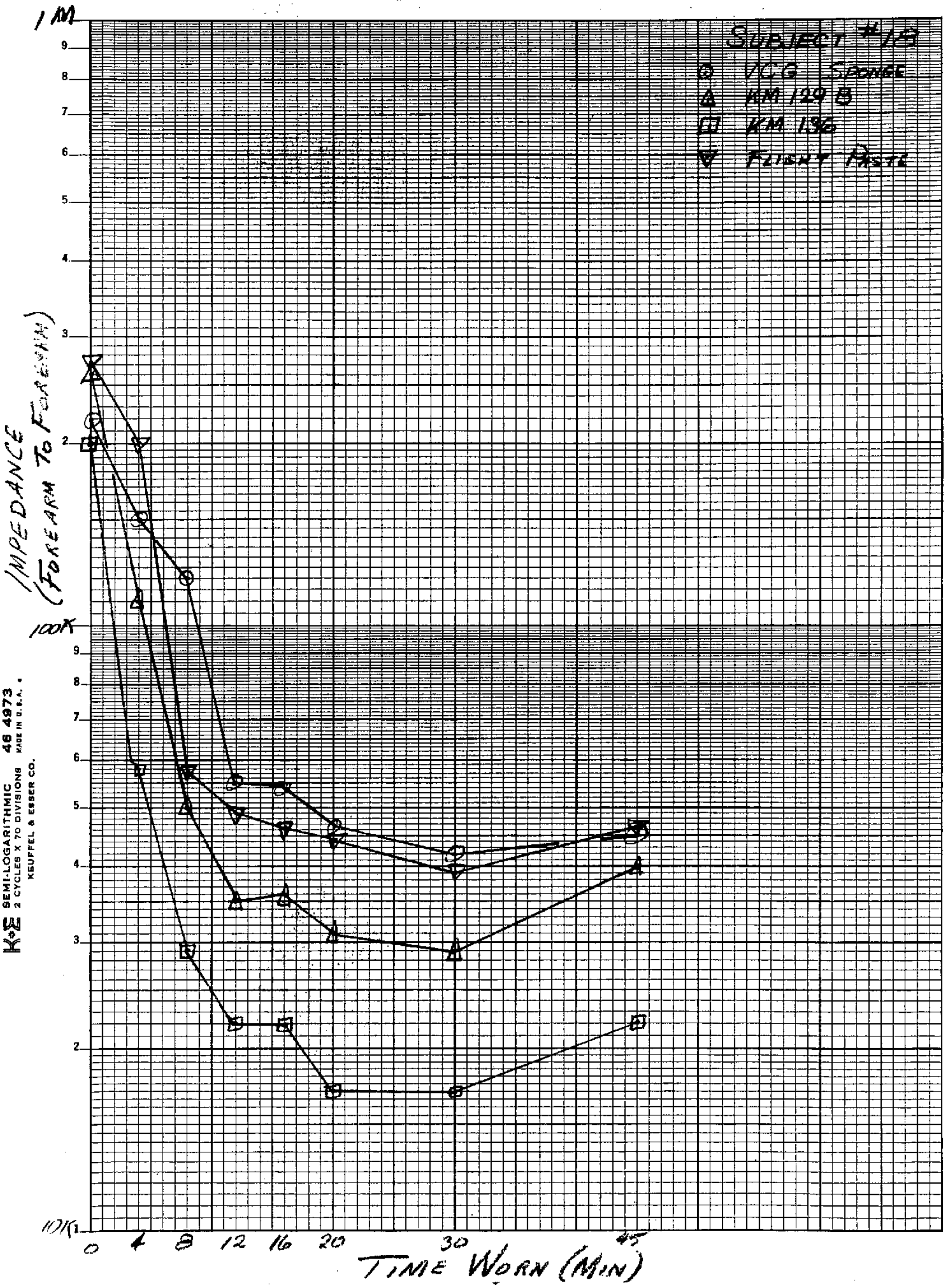
SUBJECT # 14
VCG
KM 129 B
KM 196
FLIGHT PASTE
IMPEDANCE (FOREARM TO FOREARM)
1M
100K
10K
0
4
8
12
16
20
30
45
TIME WORN (MIN)
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS
MADE IN U.S.A.
KEUFFEL & ESSER CO.

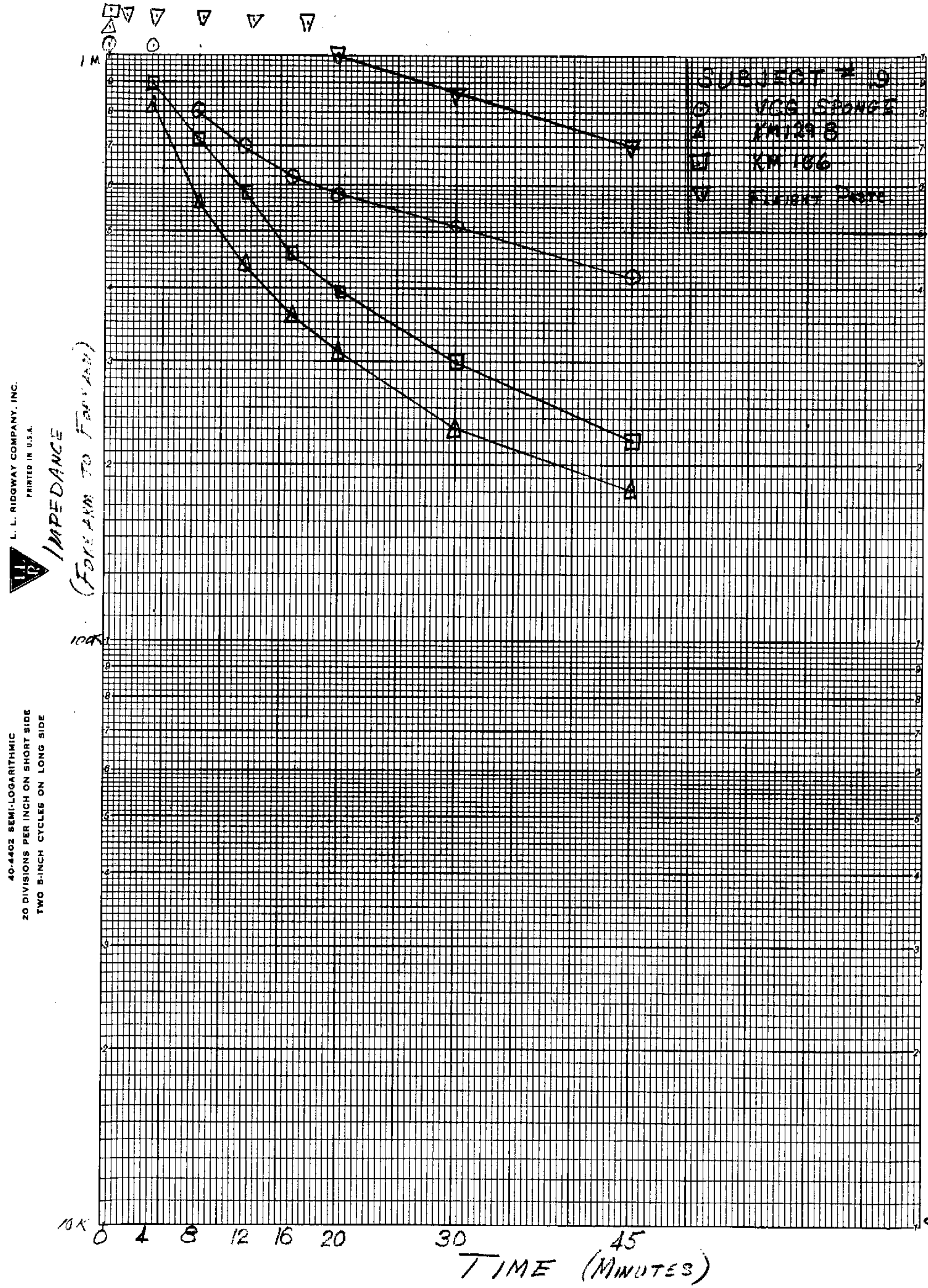
30


SUBJECT #15
VCG
KM 129 B
KM 136
FLIGHT PASTE
IMPEDANCE
(FOREARM TO FOREARM)
1M
100K
10K
TIME WORN (MIN)
0
4
8
12
16
20
30
45
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


SUBJECT # 16
VCG SPONGE
KM 129 B
KM 136
FLIGHT PASTE
IMPEDANCE (FOREARM TO FOREARM)
TIME WORN (MIN.)
100K
10K
0
4
8
12
16
20
30
45
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

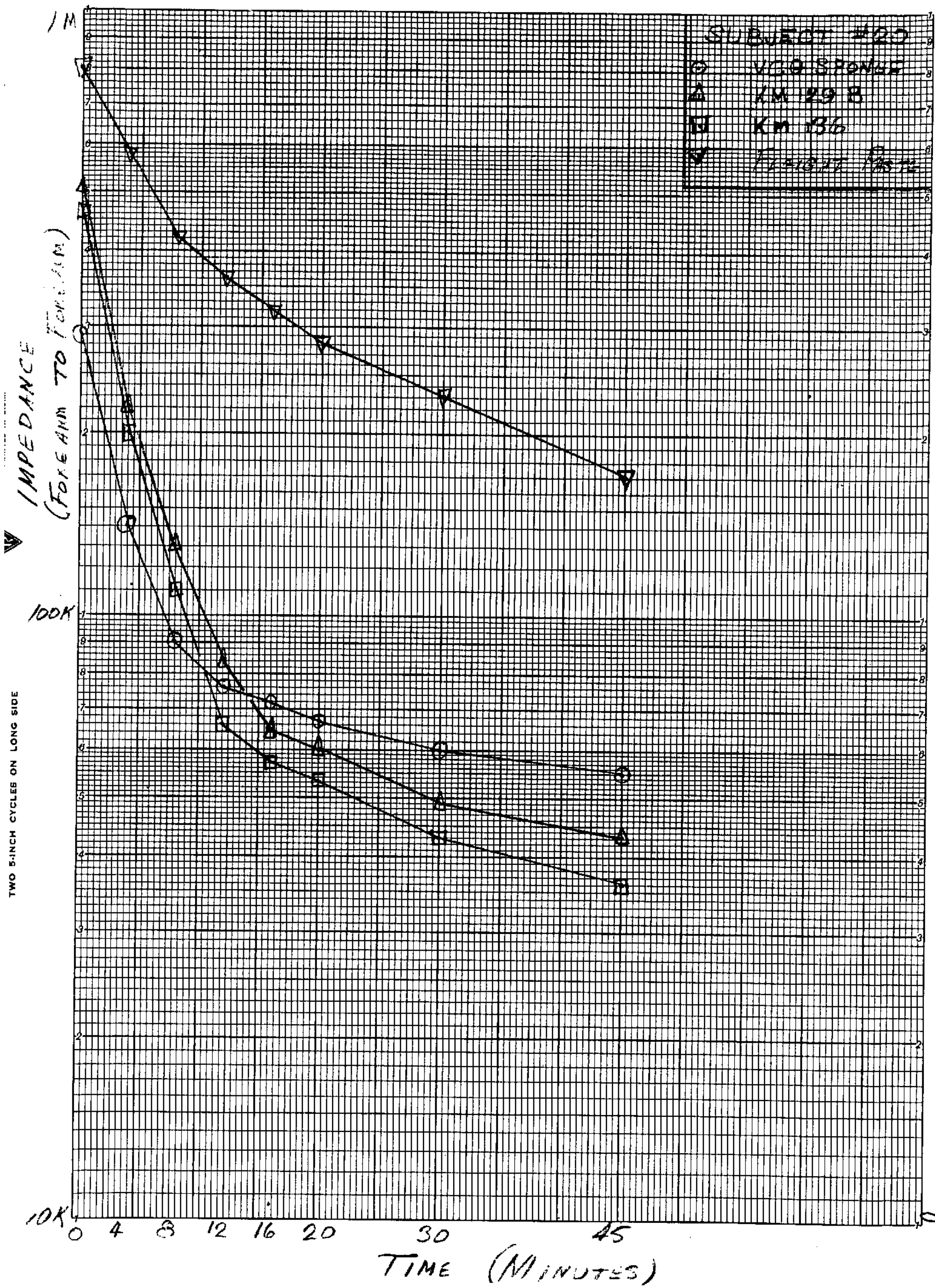

SUBJECT # 17
VCG SPONGE
KM 127B
KM 136
FLIGHT PASTE
IMPEDANCE
(FOREARM TO FORE
1M
100K
10K
0
4
8
12
16
20
30
45
TIME WORN (MIN.)
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


Subject #18
○ VCG Sponge
△ KM 129 B
□ KM 136
▽ Flight Paste
Impedance (Forearm to Forearm)
1M
100K
10K
Time Worn (Min)
0 4 8 12 16 20 30 45
K+E SEMI-LOGARITHMIC 46 4973
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.



SUBJECT # 19
VCG SPONGE
XM129 B
XM 186
FLIGHT PASTE
1 M
100K
10 K
IMPEDANCE
(FOREARM TO FOREARM)
0 4 8 12 16 20 30 45
TIME (MINUTES)
L. L. RIDGWAY COMPANY, INC.
PRINTED IN U.S.A.
40-4402 SEMI-LOGARITHMIC
20 DIVISIONS PER INCH ON SHORT SIDE
TWO 5-INCH CYCLES ON LONG SIDE

35


SUBJECT #20
VCG SPONGE
KM 29 B
Km 136
FLIGHT PASTE
IMPEDANCE
(FOREARM TO FOREARM)
1M
100K
10K
0 4 8 12 16 20 30 45
TIME (MINUTES)
TWO 5-INCH CYCLES ON LONG SIDE

ELECTRODE TEST SHEET

TEST NO. ________

Subject Data:

Name ____________________ Age ________ Weight ________ Height ______ Complexion ____________________

Additional comments or observations on test subject ____

____

IMPEDANCES EXTRAPOLATED TO GET POINTS GREATER THAN 1MEG.

Test No.	Paste Type	Electrode Type	Impedance and Voltage after elapsed time (minutes)																Irritation?
			0		4		8		12		16		20		30		45		
			ohms	mv	ohms	mv	ohms	mv	ohms	mv	ohms	mv	ohms	mv	ohms	mv	ohms	mv	
	XCG		608.5		351		280		247.7		225.		207		179.6		152		
	KM 129B		634.8		334.4		207.2		167.1		135.6		118.		89.6		76		
	KM 136		564.3		278.2		192.7		150.6		124.6		111.2		91.4		77.1		
	Flight Paste		648		392.8		255.6		218.5		187.		160		138		116.6		
	VCG			5.03		5.54		5.61		5.67		5.87		5.43		4.76		3.86	
	KM 129B			4.21		3.34		3.59		3.51		3.72		4.88		5.82		5.00	
	KM 136			4.89		3.90		3.09		2.46		2.86		2.85		3.74		3.36	
	Flight Paste			3.88		3.47		5.52		5.07		5.27		4.94		4.72		3.41	

Comments regarding test ____

____

III. ARRHYTHMIA DETECTION

Project Summary

The purpose of this project was to design and develop hardware/software ECG signal processing techniques suitable for use in a multi-subject real time cardiac arrhythmia detection system. In essence, the work is based on the concepts developed by Cox, Nolle, and Fozzard[1]. This technique reduces the incoming data, in a series of steps, to features essential to the proper classification of each QRS complex.

A portable ECG preprocessor has been designed and a breadboard has been built of the unit. This unit will sample ECG input data at a rate of 500 samples per second. The preprocessor will filter the ECG data input for noise, correct the base line, and provide significant data reduction by supplying the computer with digitized ECG data only when that data exceeds certain adjustable limits which have been set around the base line. When these limits are exceeded, the preprocessor will also provide the computer with information as to the length of time between data samples. In most instances, this will mean that the computer will receive information only during a QRS complex along with data which can be identified as the R-R interval. The programs were also developed for this project to provide for the detection of arrhythmias and the discrimination of probable premature ventricular contractions (PVC's).

The programs which SCI has developed for this project consist of a very fast small multi-programming real-time "executive", a display driver program, a waveform feature processor, and a general multi-dimensional statistical analysis program for analyzing selected QRS features.

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1 Jerome R. Cox, Jr., et.al., "Some Data Transformations Useful in Electrocardiography," Monograph No. 83, Washington University School of Medicine, St. Louis, Missouri, September, 1968.

Initially, it was planned to interface the hardware preprocessor to the Varian 620F Computer and to develop the software for that computer. Because of the work load on available NASA computers, however, it was decided that the concept feasibility could be proved utilizing another computer. SCI therefore offered the use of some existing equipment at no cost to the Government for the development of a breadboard test system. The Data General Nova computer was used for the development of the software and the Ann Arbor CRT display was utilized to display the processed information. It should be emphasized that use was made of available SCI equipment for testing concept feasibility and this equipment does not constitute a final deliverable system. The concepts, however, were kept general so that the programs can be easily translated to operate on another computer.

To date, the system has been given preliminary tests utilizing a QRS simulator and recorded data provided by the Dallas Heart Institute of patients residing in a coronary care ward. These tapes contain most of the classic arrhythmias (PVC's, nodal beats, abnormal rhythms, etc.). The results so far have been very encouraging in that the arrhythmia monitoring system seems to be able to classify the various shapes of the QRS complexes quite accurately and in most cases was able to discriminate the ectopic beats which should be classified as premature ventricular contractions (PVC's). The software has been able to "learn" what is normal or abnormal for a particular individual based on an analysis of the relationship of the current waveform to preceeding data. Much more qualitative work needs to be done in testing this system utilizing additional tapes (preferably those provided by NASA) and utilizing a chart recorder for an in-depth analysis of the quality of the computer's discrimination. The preprocessor has been designed with the ability to output data to a recorder as initiated by the computer.

For test purposes the computer provides only one output display to the CRT (See Figure 1). This allows the display of up to 10 families; a family being a statistically significant group of QRS complexes along with data describing the pertinent features of that family. Among these features are the maximum positive amplitude of the QRS complex, the width of the QRS, the area under the curve, the heart rate in the form of the Q-Q interval, the maximum negative amplitude of the QRS complex, and the maximum slope. Included in this display are the number of members in each family and the amount of time since a member has been added to a particular family. In addition, on the lower part of this display is included information on the number of probable PVC's detected and how many beats have occurred normally during the time that these probable PVC's were indicated. Also, an instantaneous indication comes up on the bottom of this display when a probable PVC is detected or if the information is noisy enough to be classified as chaotic by the computer.

EXECUTIVE ROUTINE

The Executive Routine used on the NOVA computer in this project is a previously-developed proprietary package. It is designed to control the operation of real-time systems while allowing maximum flexibility in application programs.

Associated with each program to be run under executive control is an information list which defines features desired by the program and contains the present status of the program. Thus, by setting one bit the program may request exclusive use of a device when it needs it. It can call for queueing of data to be handled by other programs. The program can be scheduled to be run on a regular basis at given time intervals.

When running, the Executive Routine controls the flow of data throughout the system. It identifies "interrupts" from devices and switches control to the proper handling routine. It keeps track of program priorities and makes best use of available machine time. By spending as little time as possible performing its own bookkeeping chores, it is able to allow quicker response of the system to external events. In this way the system can come ever closer to acting upon the data as the external event occurs.

At the lowest level, the executive program is an assistant to both the program and the programmer. By performing necessary functions such as timekeeping and device coordination it frees the other programs to spend all their energies on the particular application at hand. In this way the Executive Routine reduces programming time, effort, and error.

While this version of the executive is written for the NOVA computer, its philosophy and form are easily adaptable to other dedicated minicomputer systems such as the Honeywell 316's and the Varian 620's. The fact that it is written in the particular machine language of the machine means that it is particularly tailored to that machine rather than a result of a slow, core-devouring, higher level program such as FORTRAN. Furthermore, the general nature of the Executive Routine makes it easily modified to control special or unusual applications.

DISPLAY PROGRAMS

The display package developed to assist in the checkout of this monitoring task is easily adaptable to other systems possessing a similar hardware configuration; that is, a NOVA-family computer and an Ann Arbor Terminal Video Controller.

The package is requested by programs within the system which require display of a particular page. Associated with this page number is a table of formatting instructions which call other display routines to fill a buffer with octal, decimal, or alphabetic information. Since these three basic routines are already available, additional displays may be included merely by adding more table entries.

The numerical display routines are designed to allow tables to be displayed in either rows or columns with only one change required. Alphabetic labels are easily set up and also readily changed. Provision has been made to allow for graphic information to be formatted, although at this time, a graphics-generating program is not being used.

FEATURE PROCESSOR

The Feature Processor program measures the features of the curve. Currently the six features which it measures are Amplitude, Width, Area under the Curve, Q-Q interval, maximum Change in Amplitude for a 2-millisecond (ms) interval, and maximum amplitude of opposite sign of the major amplitude. The program is requested every 2 ms after the preprocessor detects a signal with exits from the baseline aperture. Every 2 ms the Change-In-Amplitude samples are stored in a buffer by the interrupt response code. This code then requests that the feature processor be run at the first opportunity. When the feature processor is called, its first action is to pick up the measured data from the buffer. If this is the first sample for a curve, this first sample is multiplied by a constant to give the initial amplitude of the signal. Subsequent samples are added to the amplitude to give the current amplitude. Each time a sample occurs, a counter is incremented. When this counter exceeds 400 (or .8 second), the curve is considered noise and the "K" aperture is reset. This counter is reset at the beginning of each curve.

The data is exponentially smoothed by the formula: $V_i = S_i + 1/2\ (V_{i-1} - S_i)$ where V_0 = the initial change in amplitude and S_i is the input sample. This removes sharp spikes from the data. The new amplitude value is divided by 2 and added to the area. It is then divided again by 4 to give the criterion for judging when the curve has flattened out and QRS complex is complete. The width is measured by the number of samples required for the QRS to be considered complete. This occurs when a sufficient number of samples have satisfied the flat criterion. Each time the sample is "flat", a counter is incremented. Each time the sample is not flat the counter is decremented to a minimum of zero. When the counter reaches 64, the QRS is considered complete.

Comparison and selection are performed to obtain the maximum positive amplitude and maximum negative amplitude. The sign of the maximum negative amplitude may actually be positive. This is because the signal may be inverted. Then the amplitude of positive sign will be classified as negative. The amplitude with largest absolute value is the positive amplitude and the amplitude of the opposite sign is the negative amplitude.

Each exponentially smoothed change of amplitude sample is compared to the maximum (absolute) value obtained thus far. If the new value is greater, then it replaces the previous maximum. This gives the maximum slope.

The Q-Q interval is calculated by adding the width of the previous curve to the "long-line" length between QRS complexes. This long-line is measured in 16 ms intervals.

When the QRS is complete, the calculated features are stored in a buffer and the statistical processor is requested.

If the sample counter reaches 400 (.8 second), the curve is considered noisy or chaotic and no statistical examination is requested. The "K" aperture is reset and the feature processor quits looking at data for this curve. (This is done by resetting "K". The initial interrupt on K exit always causes all counters to be reset.)

STATISTICAL PROCESSOR

The statistical processor is general in design and thus easily modified to classify different features or numbers of features. It classifies the data given to it into related groups or families. Additionally, there is a section of code which looks for premature ventricular contractions (PVC's) and keeps a record of these. This program is activated by the Executive Routine upon request by the feature processor.

The first action of the program is to retrieve the feature measurements from the buffer of the feature processors. It then compares each feature to a high and low allowable limit value. If any feature is outside its limits, the statistical program rejects this set of features as unusable and terminates itself. If all the features are within these gross limits, a search is make to determine if this curve fits into an active family. A family is called active if it has added a member within the last 20 beats. If it is not an active family, it is an inactive family and the storage is make available for a new family.

There are per cent limits for each feature. Thus, if the percent limit is 30 for amplitude, a new curve must have an amplitude of between 70% and 130% of a family's amplitude to fit in that family. There is also a count value which may override the percent value. If the amplitude is 60, the percent value 30%, and the count value 25, then a new amplitude will fit if it is from 35 to 85, since the 25 is greater than 30% of 60.

Each feature of the new curve is compared to that of the first family. If any feature does not fit, the comparison is repeated for all features on the next active family. This continues until either a family is found into which the curve fits or all the active families are exhausted. If the curve fits, then the family age is reset to the maximum of 20, one is added to the number of members in the family and the family is modified by the new member. This modification is a weighted average of each feature giving a weight of 0.1 to the new member and 0.9 to the previous value to yield the new family value.

If the curve does not fit into any active family, then an inactive family slot is taken and turned into a new active family whose features are those of the new curve. The age is set to 20 and the number of members to 1.

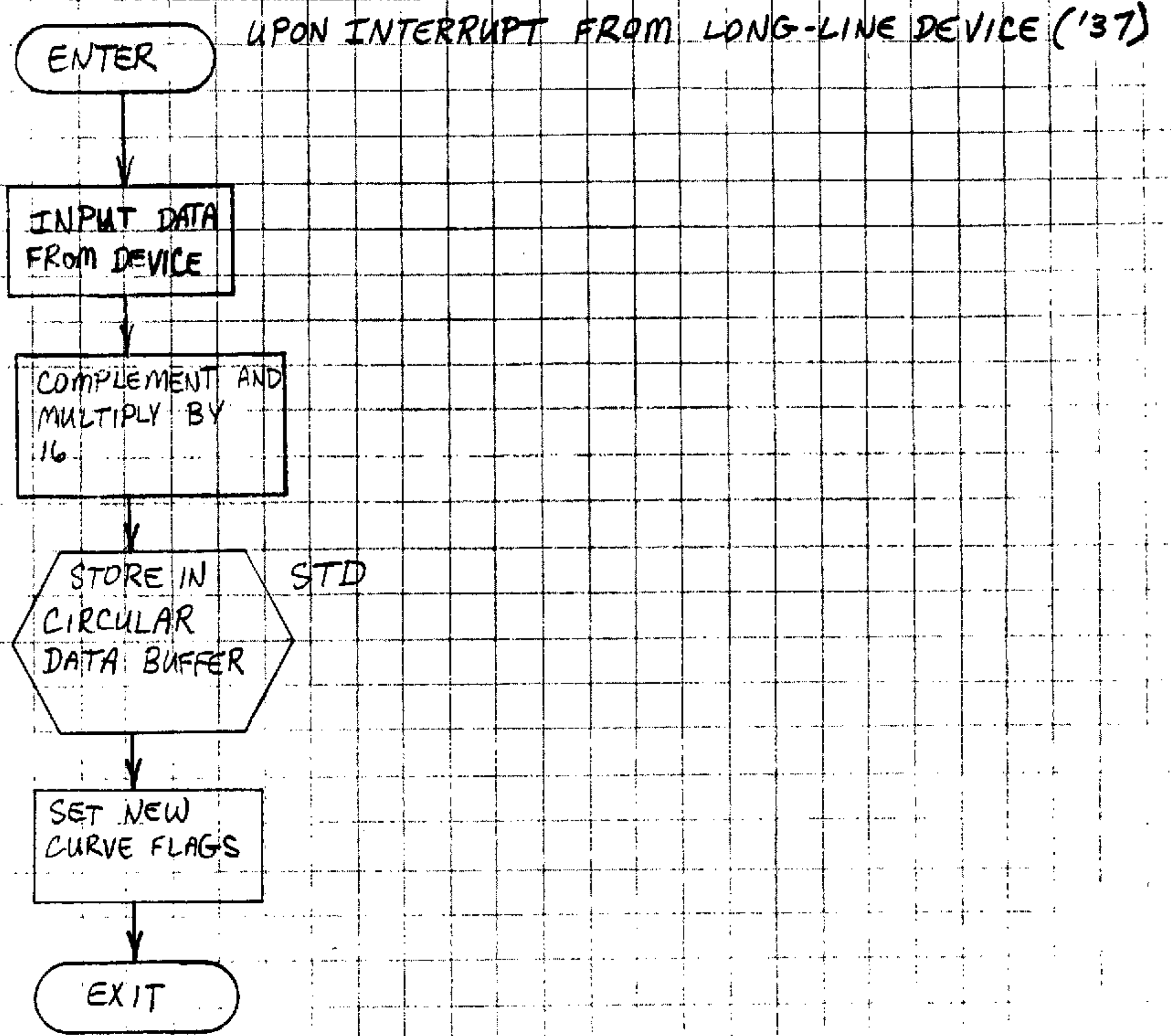
If there are no more slots available, the curve is ignored and all the other families are aged by one. The aging process is performed on each family not receiving a new member after each curve has been placed. After aging is complete, the processor looks for PVC's.

The first step in abnormality classification is determining what is normal. It is assumed that the family with the most members is normal. If the new curve is in this family, it is not a PVC. If it is not in this family, comparisons are made. To be a PVC the new curve's area must be greater than 110% of the normal family's area, Q-Q interval must be less than 93% of normal, and maximum change of slope must be greater than 70% of normal. This last criterion is to eliminate T waves from being called PVC's. If the curve is a probable PVC, a PVC counter is incremented.

Before terminating the NOVA console switches are scanned. If they are set to a value of 177777_8, a display of the families is requested. This includes a report of how many probable PVC's have been spotted in the previous N beats. This display will not be updated until some switch(es) is toggled for one beat's duration to reset the display request (flag). A switch value of 77777_8 will cause the beat and PVC counters to be zeroed. (This also resets the display request flag.) Finally, 37777_8 causes all feature and member tables to be zeroed.

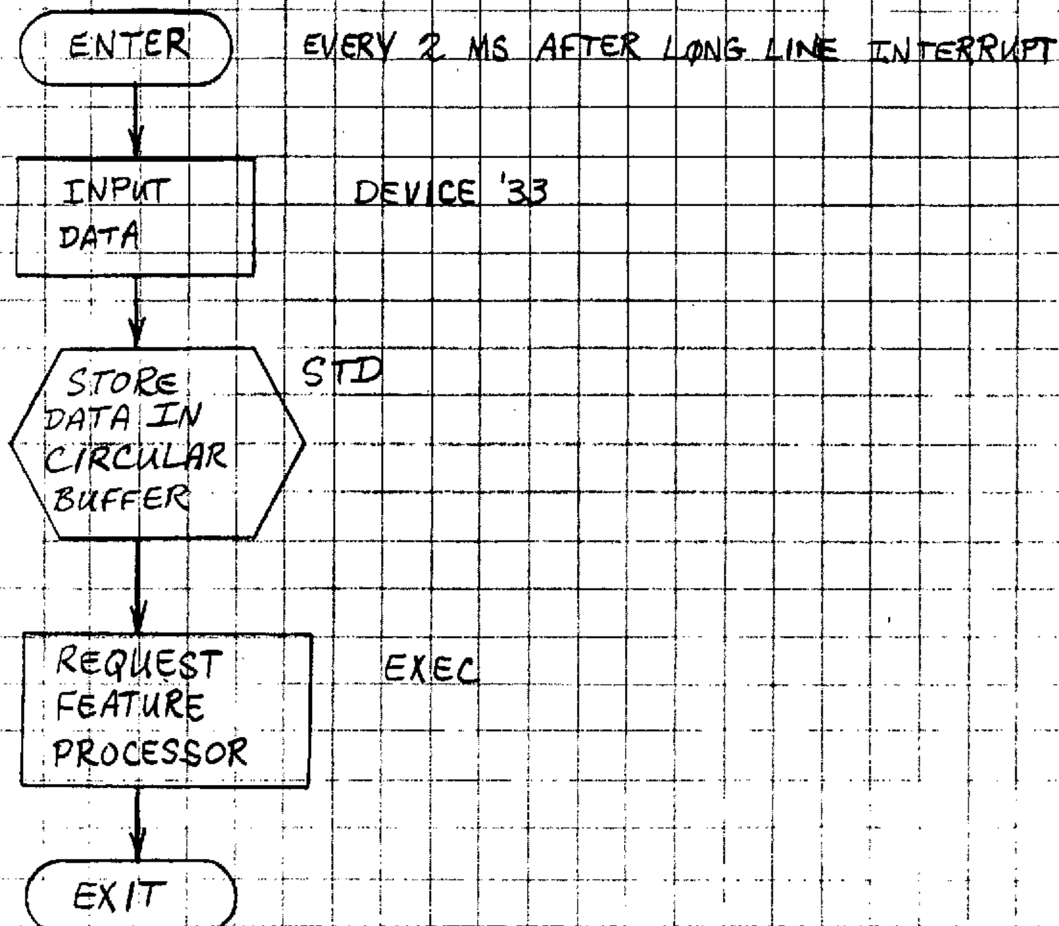
SCI ELECTRONICS, INC.

LONG-LINE INTERRUPT RESPONSE PROGRAM



SCI ELECTRONICS, INC.

AMPLITUDE CHANGE (DELTA V) INTERRUPT RESPONSE PRØGRAM



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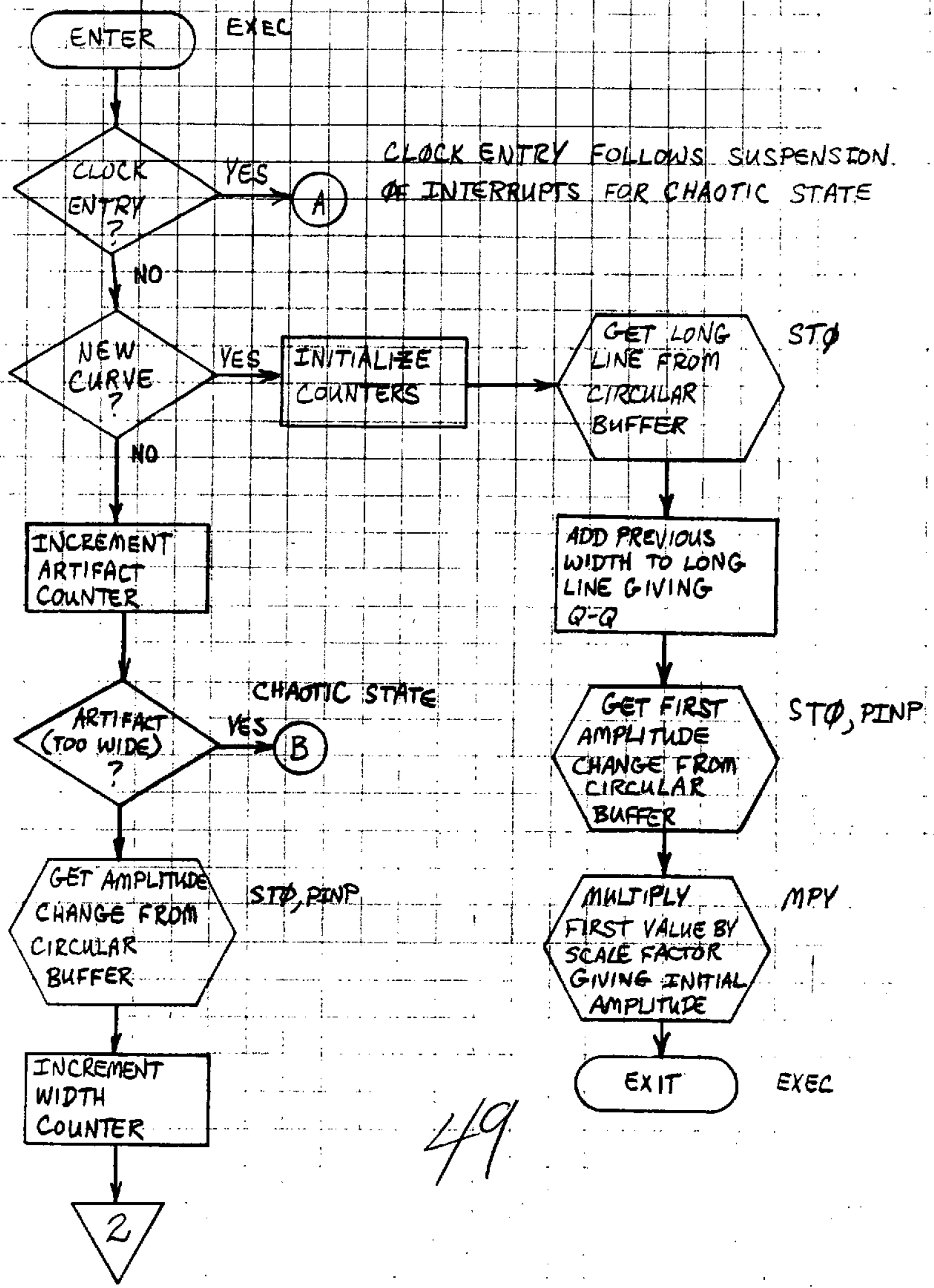
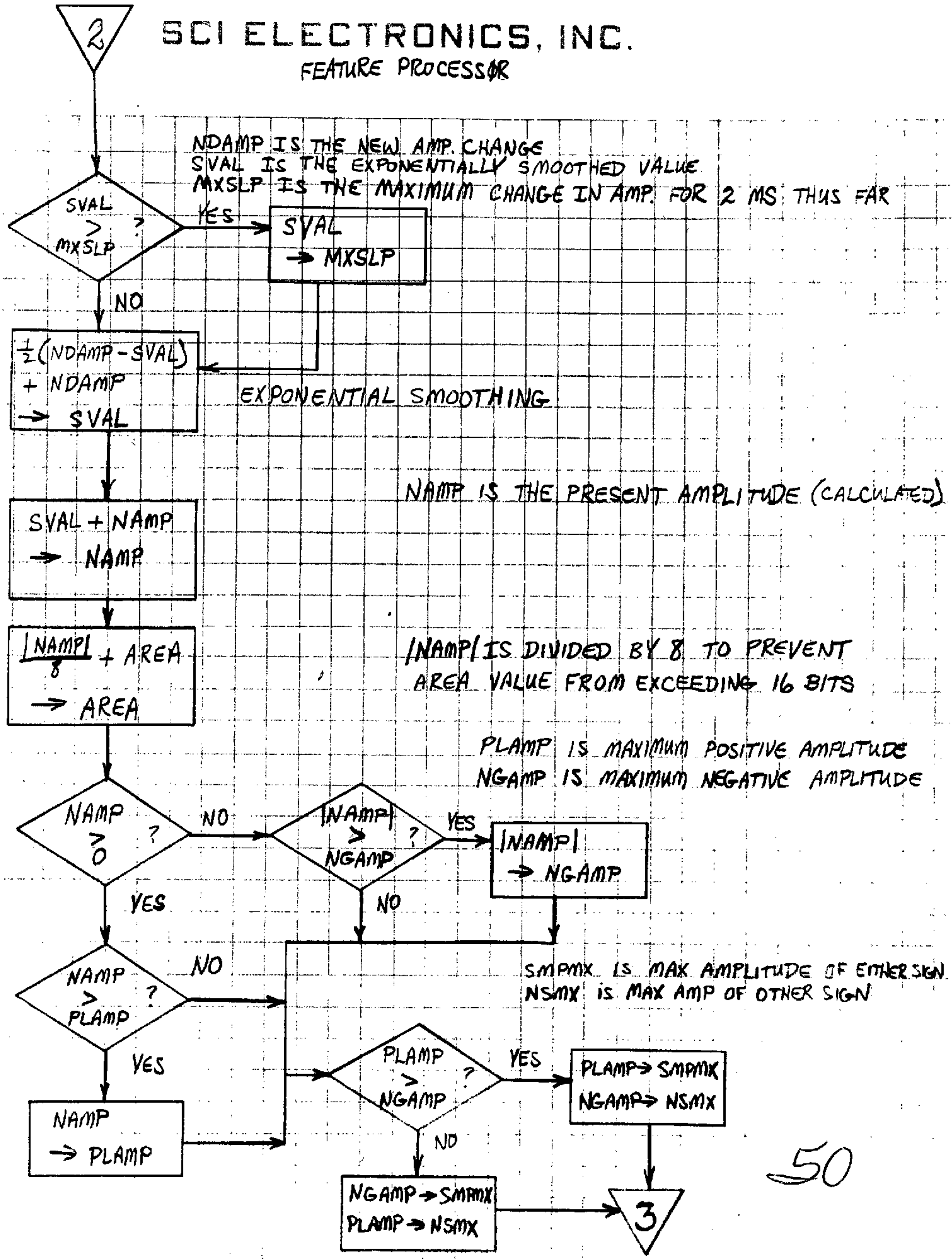
SCI ELECTRONICS, INC.

FEATURE (PRIMITIVE) PROCESSOR



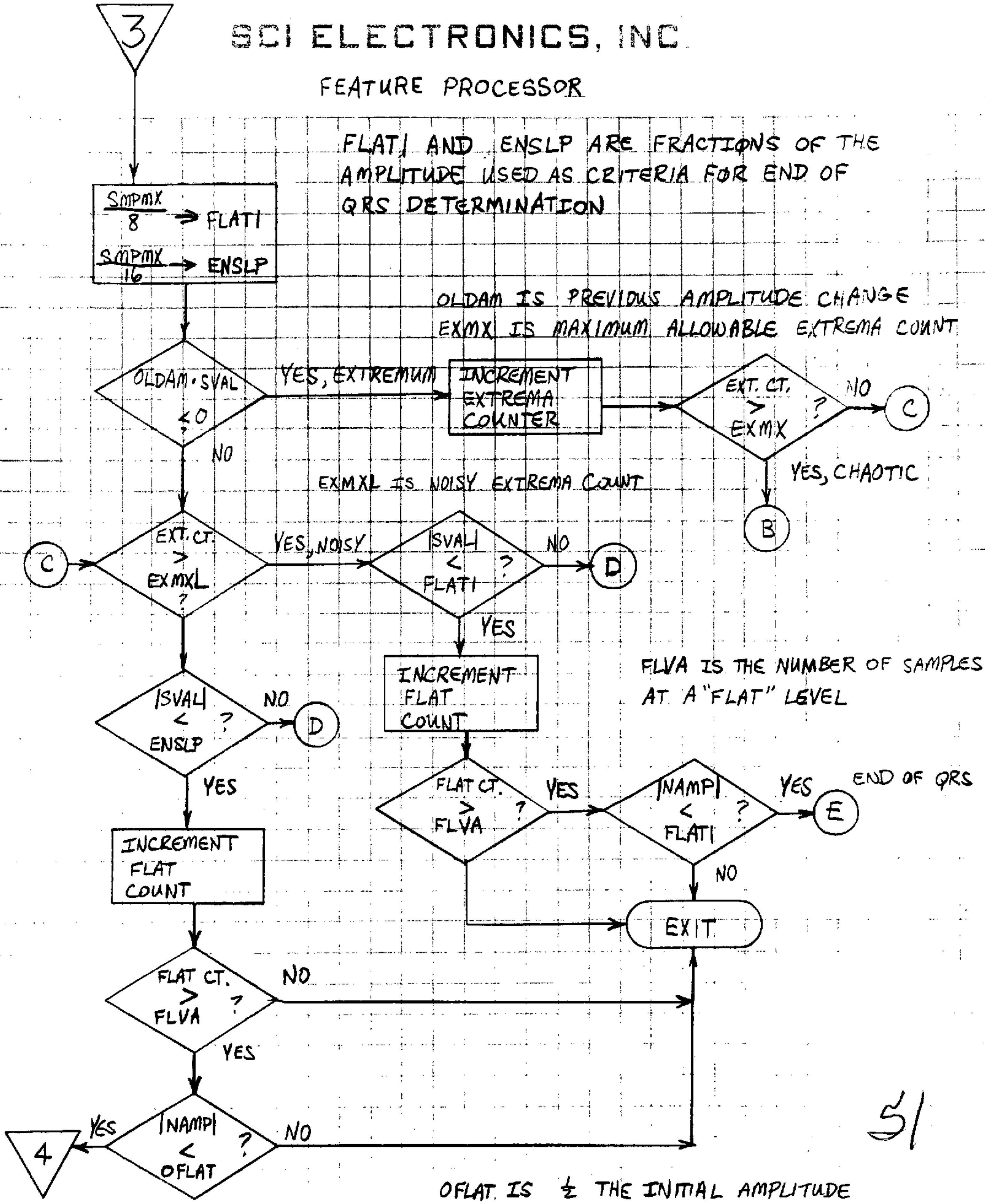
SCI ELECTRONICS, INC.

FEATURE PROCESSOR



SCI ELECTRONICS, INC

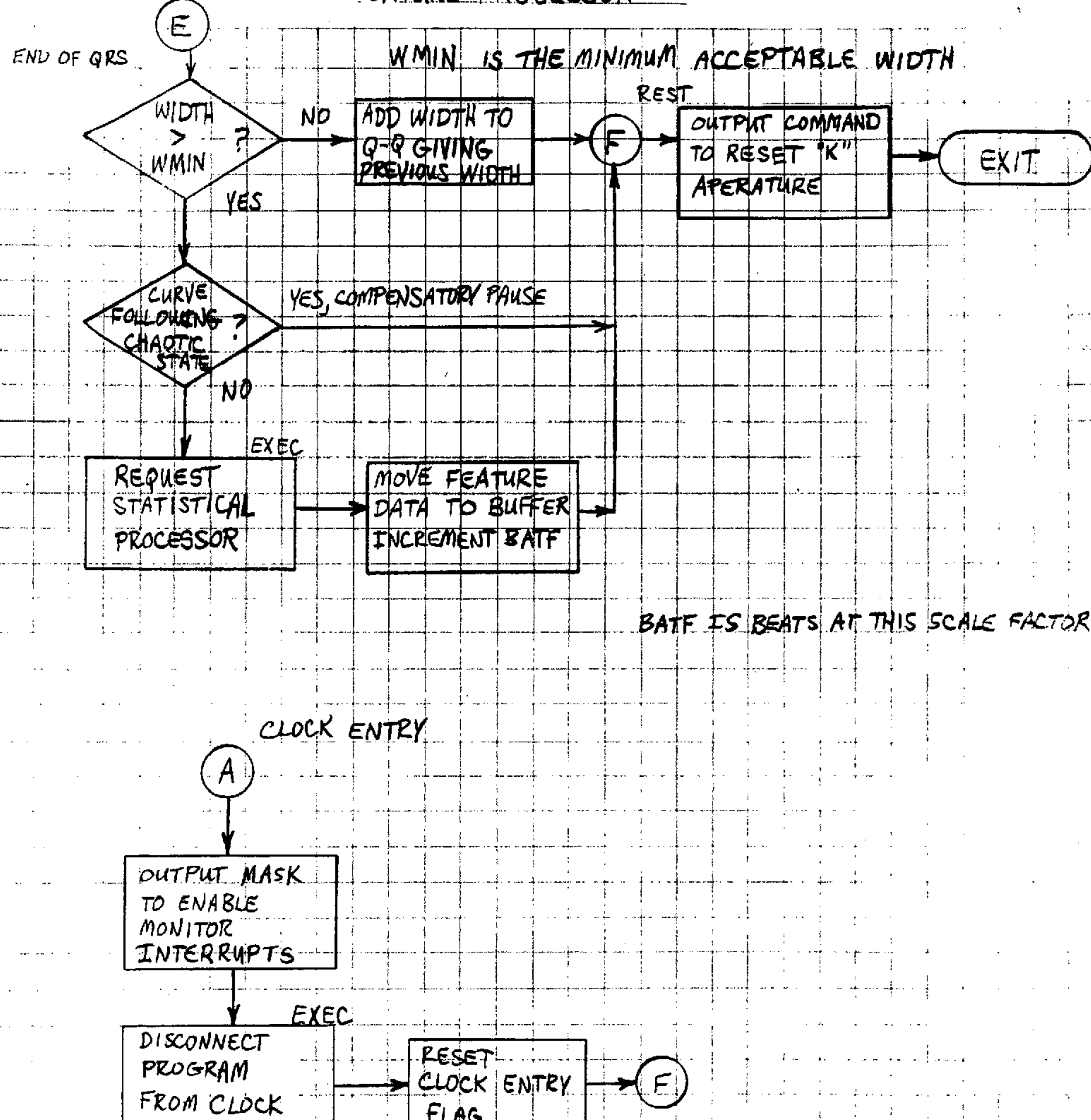
FEATURE PROCESSOR



4

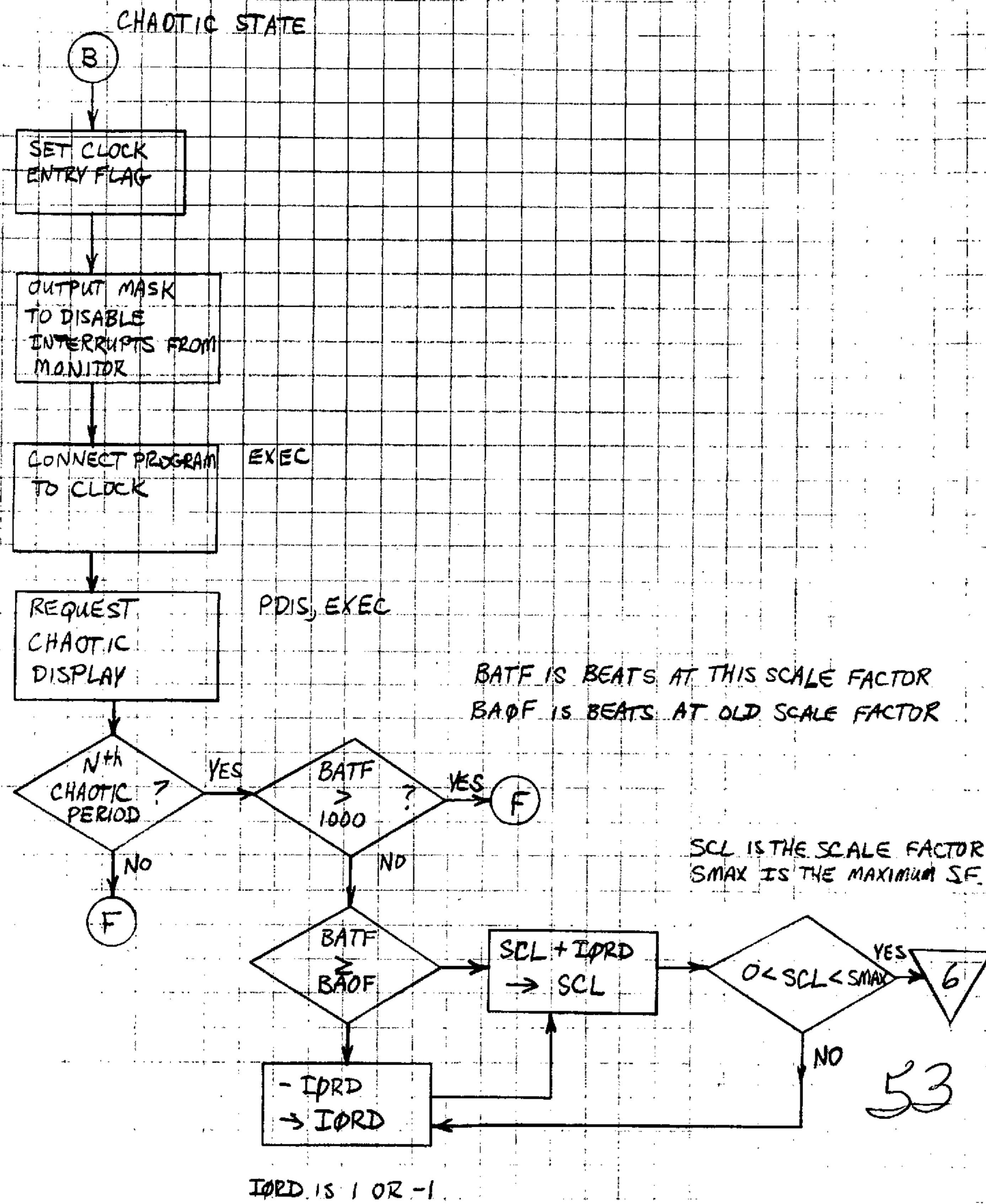
SCI ELECTRONICS, INC.

FEATURE PROCESSOR



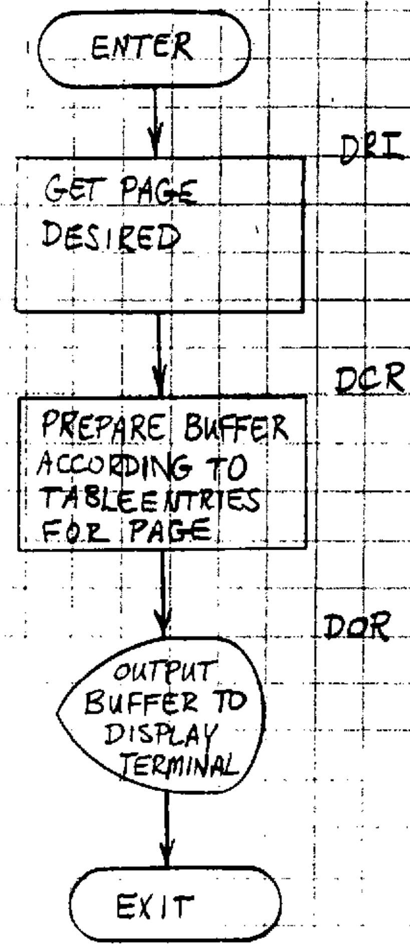
SCI ELECTRONICS, INC.

FEATURE PROCESSOR



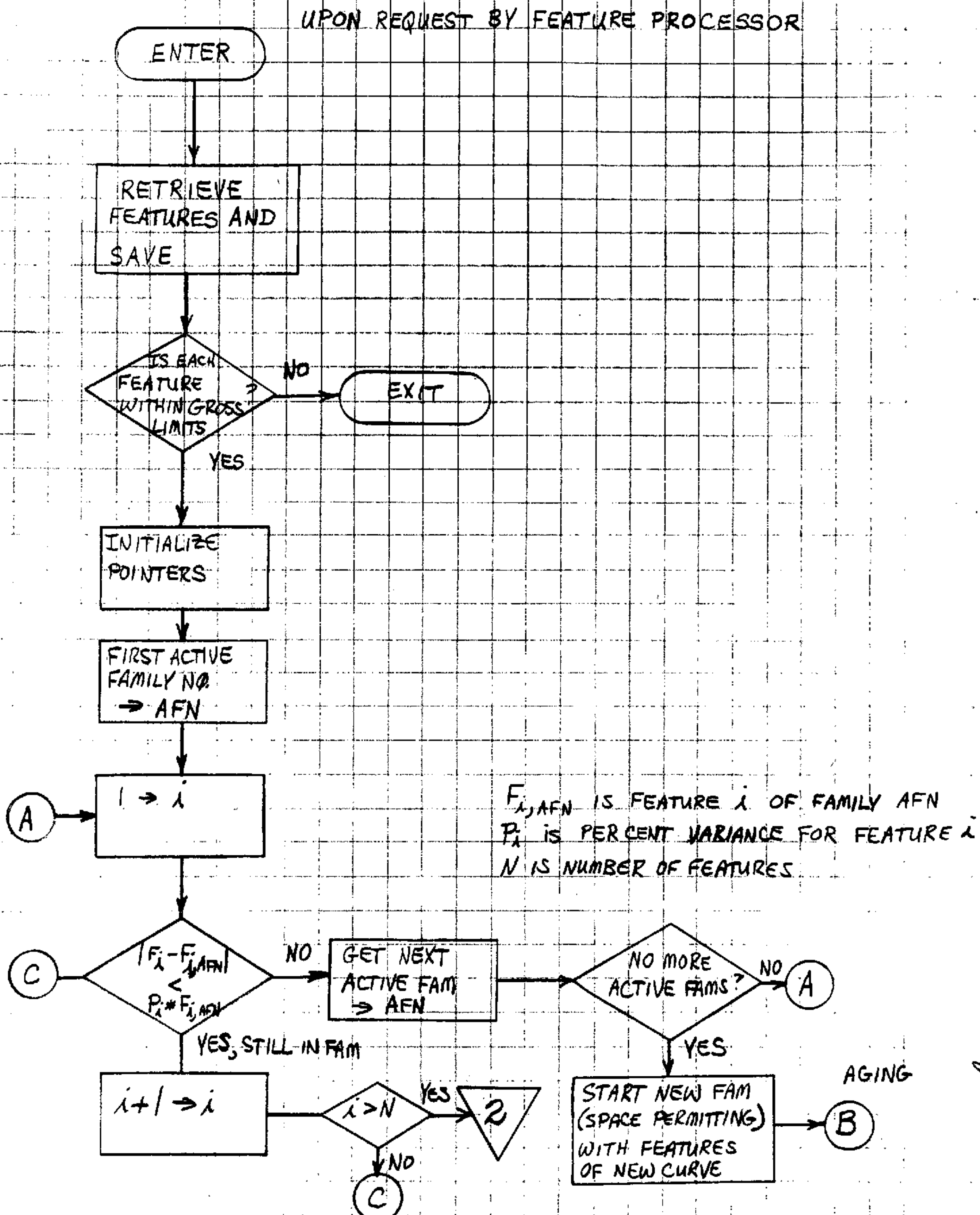
SCI ELECTRONICS, INC.

DISPLAY PROGRAM



SCI ELECTRONICS, INC.

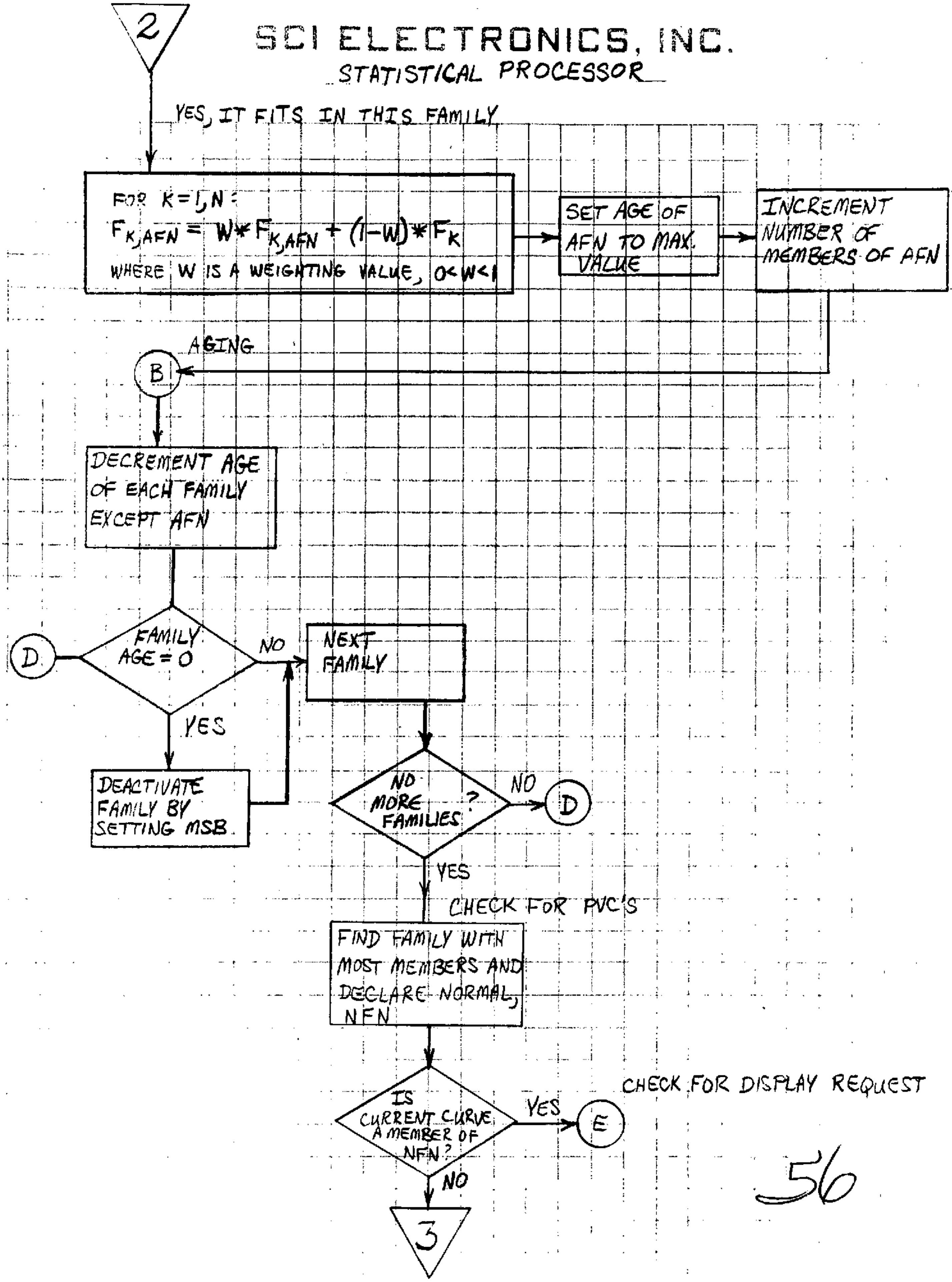
STATISTICAL (CYCLIC) PROCESSOR



55

SCI ELECTRONICS, INC.

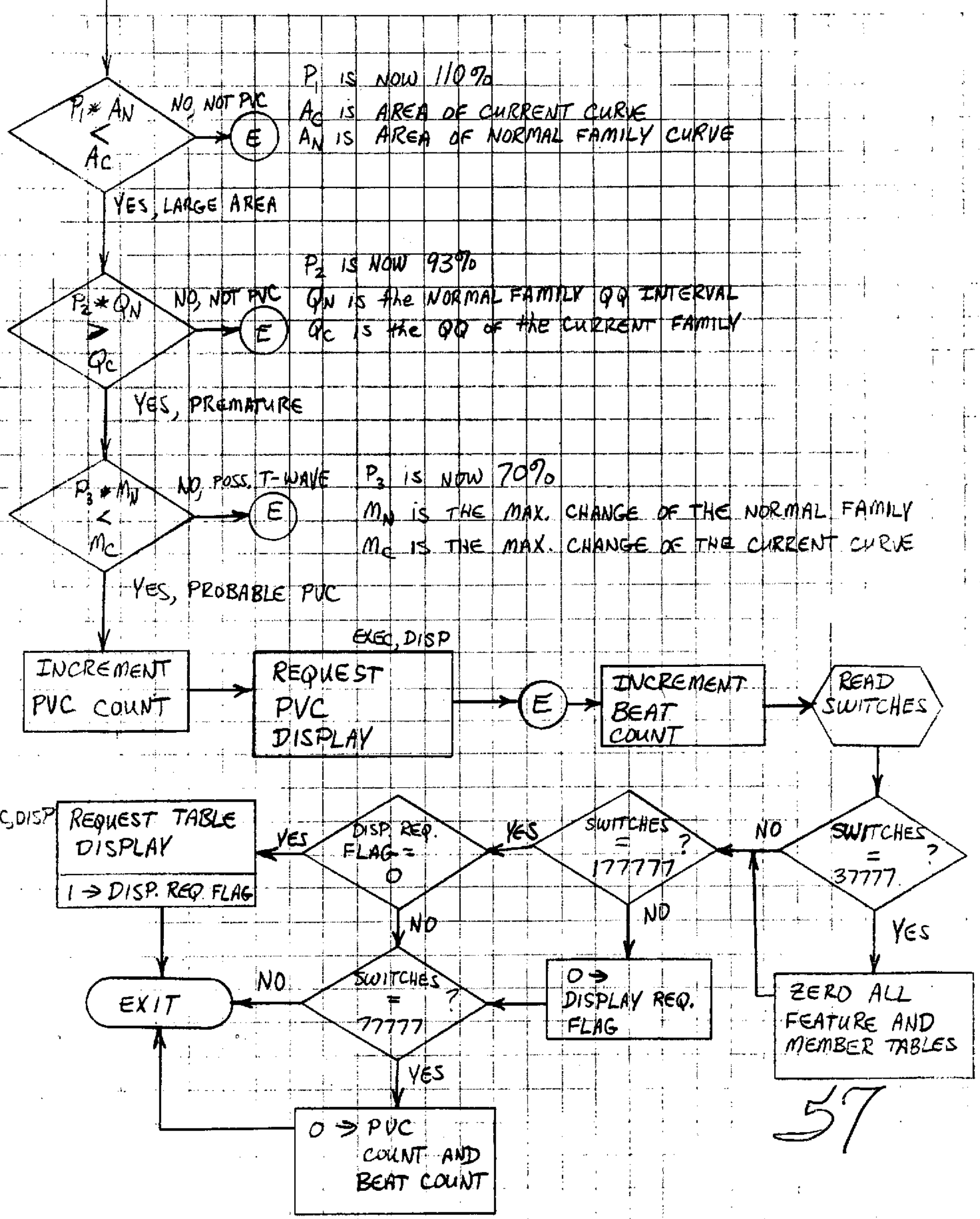
STATISTICAL PROCESSOR



3

SCI ELECTRONICS, INC.

STATISTICAL PROCESSOR



```
                   ;   THIS ROUTINE STORES DATA IN A CIRCULAR BUFFER.
                   ;     TO ADVANCE ONE WORD AND STORE CALL STD.
                   ;     TO STORE IN THE PREVIOUS LOCATION CALL STD1.
                   ;       TO PICK UP WORDS STORE INITIAL ADDRESS
                   ;       IN BFPO.  SUBSEQUENT VALUES MAY BE
                   ;       PICKED UP BY A CALL TO STO.
      005100               .LOC    5100
05100 010427       STD:    ISZ     BFCT
05101 000402               JMP     .+2
05102 000404               JMP     STD2
05103 010425               ISZ     BFPT
05104 042424       STD1:   STA@    0,BFPT
05105 001400               JMP     0,3
05106 030423       STD2:   LDA     2,BFST
05107 050421               STA     2,BFPT
05110 030416               LDA     2,SM110
05111 050416               STA     2,BFCT
05112 000772               JMP     STD1
05113 022411       STO:    LDA@    0,BFPO
05114 010410               ISZ     BFPO
05115 030407               LDA     2,BFPO
05116 024407               LDA     1,BPEND
05117 132423               SUBZ    1,2,SNC
05120 001400               JMP     0,3
05121 024410               LDA     1,BFST
05122 044402               STA     1,BFPO
05123 001400               JMP     0,3
05124 005133       BFPO:   BUFF
05125 005333       BPEND:  BEND
05126 177600       SM110:  -200
05127 177600       BFCT:   -200
05130 005132       BFPT:   BUFF-1
05131 005133       BFST:   BUFF
05132 000000               0       ;PLAY SAFE
      000200       BUFF:   .BLK    200
05333 000000       BEND:   0
                           .END
```

```
                  ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;; ;;
                  ;
                  ;       LONG LINE INTERRUPT RESPONSE CODE
                  ;
                  ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
      006000              .LOC     6000
                  ;
                  ;       THIS IS INTERRUPT RESPONSE CODE FOR DEVICE 37.
                  ;       THE ROUTINE INPUTS THE DATA FROM DEVICE 37,
      000010              .BLK     10
06010 177777              -1
06011 060437      LLINE:  DIA      0,37       ;INPUT 8 BITS OF LONG LINE
06012 100000              COM      0,0        ;COMPLMENT INPUT
06013 103120              ADDZL    0,0        ;MULT BY 4
06014 103120              ADDZL    0,0        ;MULT BY 4 AGAIN
06015 006411              JSR@     STDA       ;STR CODED LINE IN CIRC BUF
06016 022411              LDA@     0,BFPT
06017 042411              STA@     0,BFPO
06020 042411              STA@     0,PTSV
06021 102520              SUBZL    0,0        ;SET NEW SAMP FLAG
06022 042410              STA@     0,PNSF
06023 102400              SUB      0,0
06024 002401              JMP@     IRNSP      ;RETURN TO EXEC
06025 001533      IRNSP:  1533
06026 005100      STDA:   5100
06027 005130      BFPT:   5130
06030 005124      BFPO:   5124
06031 006401      PTSV:   6401
06032 006400      PNSF:   6400
                          .END
```

```
                  ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
                  ;
                  ;         INPUT NEW DELTA V
                  ;
                  ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
      006100              .LOC    6100
06100 001533      IRNSP:  1533    ;INT RESPONSE CODE RETURN ADDRESS
                  ;       THIS ROUTINE INPUTS A NEW DELTA V FROM
                  ;       DEVICE 33, FORMATS IT, STORES IT IN THE
                  ;       CIRCULAR BUFFER, AND SCHEDULES THE PRIMITIVE
                  ;       PROCESSOR IF IT IS TIME.  EACH DATA INPUT
      000010              .BLK    10
06111 177777              -1
06112 060533      AZIRC:  DIAS    0,33              ;INPUT DELTA V FROM 33
06113 060333              NIOP    33        ;FLIP SWITCH FIRST TIME
06114 006411              JSR@    STDA      ;GO STORE SAMP IN BUFF
06115 006002              JSR@    2         ;REQUEST PRIM
06116 000000              0                         ;REQUEST PROGRAM
06117 000003              3                         ;PRIM RANK IN TABLE
06120 006124              AZER                      ;ERROR RETURN ADDRESS
06121 000000              0                         ;NO COMMUNICATIONS
06122 102400              SUB     0,0
06123 002755              JMP@    IRNSP
06124 063077      AZER:   HALT
06125 005100      STDA:   5100
                          .END
```

```
      007000              .LOC    7000
      000010              .BLK    10
07010 177777              -1
07011 016434  PRIM:       DSZ@    PNSF     ;DEC PRIME NEW SAMP FLAG
07012 000453              JMP     PRI1
07013 006433  PR20:       JSR@    STR      ;GET LONG LINE
07014 024433              LDA     1,C377   ;MASK OFF TOP BITS
07015 123400              AND     1,0
07016 024432              LDA     1,RR1    ;GET 1ST PT OF R-R
07017 123000              ADD     1,0      ;ADD TO LONG LINE
07020 042431              STA@    0,RT
07021 102400              SUB     0,0
07022 040433              STA     0,PREXC  ;ZERO EXTREMA COUNT
07023 040433              STA     0,PLAMP
07024 040433              STA     0,NGAMP
07025 042433              STA@    0,FLTC
07026 042424              STA@    0,SMP    ;MAX AMP FOR SAMP
07027 042424              STA@    0,ARE
07030 042414              STA@    0,MXS
07031 102520              SUBZL   0,0
07032 042432              STA@    0,DTC
07033 040421              STA     0,FSF
07034 006553              JSR@    PINP     ;GET FIRST 33 INPUT
07035 105000              MOV     0,1
07036 030552              LDA     2,SCL    ;MULT BY SCALE FACT
07037 006003              JSR@    3        ;MPY
07040 046423              STA@    1,NAM    ;SET BASE AMP
07041 020421  PR22:       LDA     0,C1000  ;SET FOR ARTFCT RJCT
07042 040417              STA     0,ART
07043 002550              JMP@    RET
07044 007225  MXS:MXSLP
07045 006400  PNSF:6400
07046 005113  STR:5113
07047 007777  C377:7777
07050 000000  RR1:0
07051 007223  RT:RTOR
07052 007220  SMP:SMPMX
07053 007222  ARE:AREA
07054 000000  FSF:0     ;FIRST SAMPLE FLAG
07055 000000  PREXC:0
07056 000000  PLAMP:0
07057 000000  NGAMP:0 .
07060 007343  FLTC:FLTCT
07061 000000  ART:0     ;ARTIFACT COUNTER
07062 000620  C1000:440.
07063 007226  NAM:NAMP
07064 007230  DTC:DTCT
07065 014774  PRI1:       DSZ     ART      ;CHECK FOR ARTFCT
07066 000402              JMP     .+2
07067 000525              JMP     CHAOS
07070 006517              JSR@    PINP     ;GET INPUT AND ADJUST
07071 020521              LDA     0,EM1
07072 026752              LDA@    1,MXS
07073 101112              MOVL#   0,0,SZC
07074 100400              NEG     0,0
07075 122033              ADC#    1,0,SNC
07076 000402              JMP     PR23
```

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```
07077 042745          STA@    0,MXS
07100 014754  PR23:   DSZ     FSF
07101 000403          JMP     PR25
07102 020525          LDA     0,NDAMP
07103 040507          STA     0,EM1
07104 020506  PR25:   LDA     0,EM1
07105 026501          LDA@    1,NDA
07106 106400          SUB     0,1
07107 152620          SUBZR   2,2
07110 133400          AND     1,2
07111 125220          MOVZR   1,1
07112 147000          ADD     2,1
07113 032473          LDA@    2,NDA
07114 147000          ADD     2,1
07115 044475          STA     1,EM1
07116 044511          STA     1,NDAMP
07117 020507          LDA     0,NAMP   ;GET PREV AMP
07120 107000          ADD     0,1      ;GET NEW AMP
07121 044505          STA     1,NAMP   ;SAVE IT
07122 125112          MOVL#   1,1,SZC  ;GET ABS VALUE OF NEW AMP
07123 124400          NEG     1,1
07124 044465          STA     1,ABNMP
07125 131000          MOV     1,2
07126 020474          LDA     0,AREA   ;CALC AREA
07127 151220          MOVZR   2,2
07130 151220          MOVZR   2,2
07131 151220          MOVZR   2,2
07132 143000          ADD     2,0      ;DIV BY 8 AND ADD
07133 040467          STA     0,AREA
07134 020472          LDA     0,NAMP   ;GET AMP
07135 101112          MOVL#   0,0,SZC
07136 000406          JMP     PRI5     ;GO PROCESS NEG AMP
07137 024717          LDA     1,PLAMP  ;GET POS AMP
07140 122033          ADCZ#   1,0,SNC
07141 000410          JMP     PRI7
07142 040714          STA     0,PLAMP
07143 000406          JMP     PRI7
07144 100400  PRI5:   NEG     0,0      ;COMP NEG AMP
07145 024712          LDA     1,NGAMP
07146 122033          ADCZ#   1,0,SNC
07147 000402          JMP     PRI7
07150 040707          STA     0,NGAMP
07151 020705  PRI7:   LDA     0,PLAMP
07152 024705          LDA     1,NGAMP
07153 122033          ADCZ#   1,0,SNC
07154 000405          JMP     PRI8
07155 040443          STA     0,SMPMX
07156 044446          STA     1,NSMX
07157 105000          MOV     0,1
07160 000403          JMP     PRI11
07161 044437  PRI8:   STA     1,SMPMX
07162 040442          STA     0,NSMX
07163 125220  PRI11:  MOVZR   1,1
07164 125220          MOVZR   1,1
07165 125220          MOVZR   1,1
07166 044447          STA     1,FLATI
07167 125220          MOVZR   1,1
07170 044447          STA     1,ENSLP
07171 020436  PRI6:   LDA     0,NDAMP
07172 024444          LDA     1,OLDAM
```

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```
07173 152620          SUBZR    2,2       ;SET SIGN TO NEG
07174 143400          AND      2,0       ;KEEP ONLY SIGN
07175 040441          STA      0,OLDAM
07176 107113          ADDL#    0,1,SNC
07177 000450          JMP      PRTRA     ;NO, NOT EXTREMUM
07200 010655          ISZ      PREXC     ;YES, SO IN EXTR CNT
07201 020654          LDA      0,PREXC ;COMP EXT MAX + EX CNT
07202 024430          LDA      1,EXMX
07203 122033          ADCZ#    1,0,SNC
07204 000443          JMP      PRTRA     ;WITHIN LIMITS SO JUMP
07205 000407          JMP      CHAOS     ;TOO MANY EXTREMA
07206 007227    NDA:NDAMP
07207 007353    PINP:PIN
07210 000020    SCL:20  ;SCALE FACTOR
07211 000000    ABNMP:0
07212 000000    EM1:0
07213 007346    RET:RETN
07214 020531    CHAOS:  LDA      0,C2
07215 004510            JSR      PDIS
07216 002401            JMP@     CHC
07217 007407    CHC:CHCHK
07220 000000    SMPMX:0
07221 000000    WIDTH:  0
07222 000000    AREA:   0
07223 000000    RTOR:0  ;R TO R DISTANCE
07224 000000    NSMX:0  ;NEG SAMP MAX AMP
07225 000000    MXSLP:0
07226 000000    NAMP:0
07227 000000    NDAMP:  0          ;NEW DELTA AMP
07230 000000    DTCT:   0          ;WIDTH IN COUNTS
07231 005113    STO:5113;PICKUP ADDRESS
07232 000144    EXMX:100.;MAX EXTREMA COUNT
07233 177400    C17740:177400
07234 005124    BFPO:5124
07235 000000    FLAT1:0
07236 000000    OLDAM:  0          ;OLD AMP
07237 000010    ENSLP:  10         ;MIN SLP
07240 007055    PREX:PREXC
07241 000360    IMASK:  360        ;NOVA INT MASK
07242 001000    C100:1000          ;PREPROC MASK
07243 176777    CN100:176777       ;NOT PRE MASK
07244 060337    REST:   NIOP     37
07245 060133            NIOS     33
07246 000500            JMP      RETN
                ;
07247 024760    PRTRA:  LDA      1,NDAMP ;NORMAL ROUTE
07250 125112            MOVL#    1,1,SZC
07251 124400            NEG      1,1
07252 020765            LDA      0,ENSLP
07253 106033            ADCZ#    0,1,SNC ;BASELINE AGAIN?
07254 000406            JMP      PRT4
07255 020466    ENSA:   LDA      0,FLTCT
07256 101005            MOV      0,0,SNR
07257 014464            DSZ      FLTCT
07260 000401            JMP      .+1
07261 000465            JMP      RETN      ;GET NEXT SAMP
07262 010461    PRT4:   ISZ      FLTCT     ;INC FLAT CNT
07263 020460            LDA      0,FLTCT
07264 024460            LDA      1,FLVA
07265 122433            SUBZ#    1,0,SNC ;SKIP IF LN IS FLAT
```

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07266 000460            JMP      RETN      ;NO, SO GET MORE
07267 024741  PRI12:    LDA      1,DTCT
07270 044731            STA      1,WIDTH
07271 046503            STA@     1,RRIP
07272 020504            LDA      0,MMIN
07273 136333            ADDC#    0,1,SNC
07274 000473            JMP      PR24
07275 006002            JSR@     2         ;REQUEST CYCLIC
07276 000000            0
07277 000005            5
07300 007350            PRER
07301 000000            0
07302 030476            LDA      2,SMPP
07303 034474            LDA      3,CBF
07304 021000            LDA      0,0,2
07305 041400            STA      0,0,3
07306 021001            LDA      0,1,2
07307 041401            STA      0,1,3
07310 021002            LDA      0,2,2
07311 041402            STA      0,2,3
07312 021003            LDA      0,3,2
07313 041403            STA      0,3,3
07314 021004            LDA      0,4,2
07315 041404            STA      0,4,3
07316 021005            LDA      0,5,2
07317 041405            STA      0,5,3
07320 010521            ISZ      BATF      ;INC BTS AT THIS FACTOR
07321 000401            JMP      .+1       ;PLAY SAFE
07322 000722            JMP      REST
07323 063077  PERR:     HALT;ERROR
07324 000777            JMP      .-1
07325 054415  PDIS:     STA      3,PSV3    ;DISPLAY REQUEST
07326 040423            STA      0,PRCOM
07327 020411            LDA      0,PCRP
07330 042411            STA@     0,CMP
07331 006002            JSR@     2         ;REQUEST DISPLAY
07332 000000            0
07333 000006            6
07334 007350            PRER
07335 000000            0
07336 002404            JMP@     PSV3
07337 007227  NADM:NDAMP
07340 007351  PCRP:PRCOM
07341 010011  CMP:10011
07342 000000  PSV3:0   ;SAVE RETURN
07343 000000  FLTCT:    0          ;CONSECUTIVE FLAT COUNTS
07344 000100  FLVA:     100        ;NO OF CONS FLATS TO BE FLAT
07345 000002  C2:       2
07346 006002  RETN:     JSR@     2
07347 000006            6          ;DISCONNECT PRIME
07350 063077  PRER:     HALT       ;ON ERROR RETURN
07351 000000  PRCOM:    0
07352 000000            0          ;PAGE AND PATIENT NO
07353 054767  PIN:      STA      3,PSV3  ;GET INP AND MASK ON SIGN
07354 010654            ISZ      DTCT
07355 006654            JSR@     STO       ;GET STORE SAMP IN AC0
07356 152400            SUB      2,2       ;PREP TO XIND SIGN
07357 101300            MOVS     0,0
07360 126520            SUBZR    1,1       ;SET SIGN BIT HI
07361 123112            ADDL#    1,0,SZC
```

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07362 030651          LDA     2,C17743
07363 123300          ADDS    1,0
07364 143000          ADD     2,0
07365 042752          STA@    0,NADM    ;SAVE INPUT
07366 002754          JMP@    PSV3      ;RETURN
07367 022406  PR24:   LDA@    0,RTRP
07370 123000          ADD     1,0
07371 042403          STA@    0,RRIP
07372 002401          JMP@    RES
07373 007244  RES:REST
07374 007050  RRIP:RR1
07375 007223  RTRP:RTOR
07376 000024  WMIN:20.                  ;MINIMUM WIDTH
07377 007401  CBF:CYBF
07400 007220  SMPP:SMPMX
      000006  CYBF:   .BLK    6
07407 014437  CHCHK:  DSZ     CHCT      ;LEARN NEW SCALE FACTOR
07410 002763          JMP@    RES
07411 020434          LDA     0,CHOC
07412 040434          STA     0,CHCT
07413 020426          LDA     0,BATF
07414 024426          LDA     1,BAOF
07415 030426          LDA     2,IORD
07416 122433          SUBZ#   1,0,SNC
07417 150400          NEG     2,2
07420 050423  CHC3:   STA     2,IORD
07421 026426          LDA@    1,SC
07422 147000          ADD     2,1
07423 125004          MOV     1,1,SZR
07424 000403          JMP     CHC1
07425 152520          SUBZL   2,2
07426 000772          JMP     CHC3
07427 030415  CHC1:   LDA     2,SCMX
07430 146433          SUBZ#   2,1,SNC
07431 000403          JMP     CHC2
07432 152000          ADC     2,2
07433 000765          JMP     CHC3
07434 046413  CHC2:   STA@    1,SC
07435 040405          STA     0,BAOF
07436 102400          SUB     0,0
07437 040402          STA     0,BATF
07440 002733          JMP@    RES
07441 000000  BATF:0  ;BEATS AT THIS FACTOR
07442 000000  BAOF:0  ;BEATS AT OLD FACTOR
07443 000001  IORD:1  ;1 OR -1
07444 000030  SCMX:30 ;MAX SCALE FACTOR VALUE
07445 000003  CHOC:3  ;CHAOTIC COUNT MAX
07446 000005  CHCT:5  ;CHAOTIC EPISODE COUNTER
07447 007210  SC:SCL
                      .END
```

```
                ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
                ;
                ;   DISPLAY PACKAGE
                ;
                ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
                ;        MDP  IS THE MASTER DISPLAY PROGRAM.
                ;        IT PICKS UP ITEMS FROM THE MASTER DISPLAY
                ;        TABLE AND SWITCHES CONTROL TO THE PROPER
                ;        FORMATTING SUBROUTINE.  UPON PICKING UP
                ;        A ZERO IT REQUESTS OUTPUT OF THE BUFFER
                ;        TO THE DISPLAY DEVICE.
                ;        INPUTS ARE THE PAGE DESIRED AND PATIENT
                ;        NUMBER, BOTH STARTING AT 0.
      010000             .LOC    10000
      000010             .BLK    10
10010 177777             -1
10011 000000    CW:      0       ;COMMUNICATION WORD
10012 004406    MDP:     JSR     DRI     ;GET INPUTS
10013 004430             JSR     DCR     ;CONSTRUCT BUFFER
10014 004437             JSR     DOR     ;OUTPUT BUFFER
10015 006002    RETN:    JSR@    2       ;QUIT PROGRAM
10016 000006             6
10017 063077             HALT    ;ERROR RETURN
                ;        DISPLAY ROUTINE INITIALIZATION - DRI
10020 030771    DRI:     LDA     2,CW    ;COMM POINTER
10021 021000             LDA     0,0,2
10022 040417             STA     0,PAGE  ;PAGE NUMBER
10023 021001             LDA     0,1,2
10024 040416             STA     0,PAT   ;PATIENT NUMBER
10025 020414             LDA     0,PAGE
10026 101112             MOVL#   0,0,SZC
10027 000766             JMP     RETN
10030 024410             LDA     1,MXPG
10031 106033             ADCZ#   0,1,SNC
10032 000763             JMP     RETN
10033 030470             LDA     2,PG    ;GET PTR TO PAGE INFO
10034 113000             ADD     0,2
10035 031000             LDA     2,0,2
10036 050454             STA     2,FDTP  ;SAVIN FORM DTA PTR
10037 001400             JMP     0,3     ;RETURN
10040 000006    MXPG:    6;MAX PAGE NO PLUS 1
10041 000000    PAGE:    0
10042 000000    PAT:     0       ;PATIENT NUMBER
                ;
                ;        CONSTRUCT DISPLAY BUFFER - DCR
                ;
10043 054407    DCR:     STA     3,SRTN  ;SAVE RETURN
10044 036446    DCRL:    LDA@    3,FDTP
10045 010445             ISZ     FDTP    ;ADVANCE POINTER
10046 175005             MOV     3,3,SNR ;CHECK FOR END
10047 002403             JMP@    SRTN    ;RETURN
10050 005400             JSR     0,3     ;GOTO PROC. ROUT
10051 000773             JMP     DCRL    ;GET NEXT ROUT ADD
10052 000000    SRTN:    0       ;SAVE RETURN ADDRESS
                ;
                ;        DISPLAY OUTPUT BUFFER ROUTINE - DOR
                ;
10053 054777    DOR:     STA     3,SRTN
10054 020446             LDA     0,ODC1  ;INIT COUNTERS
10055 040443             STA     0,OCT1
```

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10056 020475           LDA      0,BFP
10057 040440           STA      0,OBCT
10060 020435           LDA      0,ODC2
10061 040440           STA      0,OCT2
10062 020434           LDA      0,C80
10063 040437           STA      0,OCT3
10064 060270           NIOC     70
10065 060170           NIOS     70
10066 030465           LDA      2,BFP    ;SET FOR ERROR CHECK
10067 060277           INTDS
10070 022427  DIRA:    LDA@     0,OBCT   ;GET CHAR
10071 061070           DOA      0,70     ;OUTPUT CHAR
10072 010425           ISZ      OBCT     ;BUMP PTR
10073 014427           DSZ      OCT3     ;80 COUNTER
10074 000774           JMP      DIRA     ;MORE
10075 020423           LDA      0,OCT1;CALC NEW LINE STRT
10076 024420           LDA      1,C80
10077 122400           SUB      1,0
10100 142433           SUBZ#    2,0,SNC ;SKIP IF OK
10101 063077           HALT     ;ERROR HALT
10102 040415           STA      0,OBCT
10103 040415           STA      0,OCT1
10104 044416           STA      1,OCT3   ;RSET 80 CTR
10105 014414           DSZ      OCT2     ;DEC LINE CTR
10106 000762           JMP      DIRA     ;MORE
10107 060270           NIOC     70       ;CLEAR DISP
10110 060177           INTEN
10111 002741           JMP@     SRTN     ;RETN
10112 000000  FDTP:    0        ;FORMAT DATA POINTER
10113 063077  DERR:    HALT     ;CLOCK ERROR RET
10114 013046  ODC1:    BUFF+1280.
10115 000020  ODC2:    16.      ;NUM OF LINES
10116 000120  C80:     80.
10117 000000  OBCT:    0        ;ONTERS
10120 000000  OCT1:    0
10121 000000  OCT2:    0
10122 000000  OCT3:    0
10123 010124  PG:      PGTP
              ;
              ;
              ;  DATA TABLES
10124 010132  PGTP:    PG0      ;PAGE 0 DISP INFO
10125 013046           PG1      ;PAGE 1
10126 013050           PG2      ;PAGE 2
10127 013056           PG3      ;PAGE 3
10130 013067           PG4      ;FULL CYC DISP
10131 013062           PG5      ;PVC
10132 010141  PG0:     CLBF     ;CLEAR BUFFER
10133 010173           OCTD     ;OCTAL DISPLAY
10134 000002           2        ;FIRST POSITION IN BUFF
10135 000200           200      ;NUMB OF NUMBS
10136 005133           5133     ;STARTING ADD OF DATA
10137 000004           4        ;SPACES BETWEEN NUMBS
10140 000000           0        ;DISPLAY IT
              ;
              ;        CLBF  INITIALIZES THE BUFF TO SPACES
              ;
10141 030412  CLBF:    LDA      2,BFP    ;BUFF PTR
10142 024407           LDA      1,C1280
10143 020407           LDA      0,CBLNK
```

```
10144 041000  CLLP:   STA     0,0,2     ;STORE SPACE
10145 151400          INC     2,2       ;INC BUFF PTR
10146 125404          INC     1,1,SZR   ;INC CTR
10147 000775          JMP     CLLP
10150 001400          JMP     0,3       ;RETURN
10151 175400  C1280:  -1280.
10152 177740  CBLNK:  177740
10153 010446  BFP:    BUFF
              ;
              ;
              ;       OCTAL DISPLAY - OCTD
              ;
              ;
              ;       CALLING SEQUENCE:
              ;       OCTD
              ;       A         ;A IS 1ST POSITION IN 1280. WORD BUFF
              ;                  IN WHICH TO STORE FORMED DATA
              ;       B         ;B IS NO OF WORDS TO BE FORMATTED
              ;       C         ;C IS ADDRESS OF DATA
              ;       D         ;D IS NO OF SPACES BETWEEN OCT NOS
              ;
              ;
10154 022736  ODEC:   LDA@    0,FDTP    ;FIRST POSITION
10155 024776          LDA     1,BFP
10156 123000          ADD     1,0
10157 040464          STA     0,OCP
10160 010732          ISZ     FDTP
10161 022731          LDA@    0,FDTP    ;NUMB OF NUMBS
10162 040457          STA     0,ONMB
10163 010727          ISZ     FDTP
10164 022726          LDA@    0,FDTP    ;DATA ADDRESS
10165 040453          STA     0,ODAD
10166 010724          ISZ     FDTP
10167 022723          LDA@    0,FDTP    ;SPACE TWEEN NUMBS
10170 040452          STA     0,OSBN
10171 010721          ISZ     FDTP
10172 001400          JMP     0,3
10173 054444  OCTD:   STA     3,ORTN
10174 004760          JSR     ODEC
              ;CONVERT ONE NUMBER AND STORE 6 DIGITS
10175 020446  OMCL:   LDA     0,OCP
10176 024450          LDA     1,C6
10177 123000          ADD     1,0
10200 040443          STA     0,OCP
10201 022437          LDA@    0,ODAD
10202 030443          LDA     2,CM6.
10203 000404          JMP     OCFL
10204 101220  OCLP:   MOVZR   0,0
10205 101220          MOVZR   0,0       ;SHIFT RT 3
10206 101220          MOVZR   0,0
10207 040435  OCFL:   STA     0,OSHV
10210 024437          LDA     1,C7      ;MASK OFF HI BITS
10211 123400          AND     1,0
10212 024436          LDA     1,C60
10213 123000          ADD     1,0
10214 034436          LDA     3,CGRF    ;GET GRAPHIC INFO
10215 026426          LDA@    1,OCP
10216 167400          AND     3,1
10217 123000          ADD     1,0
10220 042423          STA@    0,OCP
```

```
10221 014422            DSZ     OCP
10222 020422            LDA     0,OSHV
10223 151404            INC     2,2,SZR
10224 000760            JMP     OCLP
10225 020416            LDA     0,OCP
10226 024414            LDA     1,OSBN
10227 123000            ADD     1,0
10230 024416            LDA     1,C6
10231 123000            ADD     1,0
10232 040411            STA     0,OCP
10233 010405            ISZ     ODAD
10234 014405            DSZ     ONMB
10235 000740            JMP     OMCL
10236 002401            JMP@    ORTN
10237 000000    ORTN:0  ;RETURN ADDRESS
10240 000000    ODAD:0  ;INPUT DATA ADDRESS
10241 000000    ONMB:0  ;NUMBER OF NUMBERS TO DISPLAY
10242 000000    OSBN:0  ;SPACE BETWEEN NUMBERS
10243 000000    OCP:0   ;OUTBUF ADDRESS
10244 000000    OSHV:0  ;SAVE SHIFTED VALUE
10245 177772    CM6:    -6
10246 000006    C6:     6
10247 000007    C7:     7
10250 000060    C60:    60
10251 000077    C77:    77
10252 177700    CGRP:   177700  ;MASK FOR GRAPH INFO
                ;
                ;       ALPO    STORES PACKED ASCII IN THE OUTBUFF.
                ;       CALLING SEQUENCE:
                ;       ALPO
                ;       A       ;START ADDRESS IN BUFF. 0-1279.
                ;       B       ;TEXT DATA ADDRESS
                ;       C       ;WORD COUNT OF TEXT
                ;
                ;
10253 054764    ALPO:   STA     3,ORTN  ;SAVE RETN ADD
10254 022636            LDA@    0,FDTP  ;GET START ADD IN BUFF
10255 034676            LDA     3,BFP
10256 163000            ADD     3,0
10257 040434            STA     0,ALST
10260 010632            ISZ     FDTP
10261 032631            LDA@    2,FDTP  ;GET DATA ADD
10262 010630            ISZ     FDTP
10263 036627            LDA@    3,FDTP  ;GET WORD COUNT
10264 054426            STA     3,ALWC
10265 010625            ISZ     FDTP
10266 021000    ALLP:   LDA     0,0,2
10267 004407            JSR     SSR     ;UNPAC AND STORE CHAR
10270 101300            MOVS    0,0
10271 004405            JSR     SSR     ;DO 2ND CHAR
10272 151400            INC     2,2
10273 014417            DSZ     ALWC
10274 000772            JMP     ALLP
10275 002742            JMP@    ORTN
10276 054413    SSR:    STA     3,SSR3
10277 024752            LDA     1,C77
10300 123400            AND     1,0
10301 036412            LDA@    3,ALST
10302 124000            COM     1,1
10303 137400            AND     1,3
```

```
10304 117000             ADD     0,3
10305 056406             STA@    3,ALST
10306 010405             ISZ     ALST
10307 021000             LDA     0,0,2
10310 002401             JMP@    SSR3
10311 000000     SSR3:0
10312 000000     ALWC:0;WORD COUNT
10313 000000     ALST:0;STARTING ADDRESS
                 ;
                 ;
                 ;       DECIMAL CONVERSION ROUTINE - DECD
                 ;
                 ;       CALLING SEQUENCE SAVE AS OCTD.
                 ;       LEADING ZEROES ARE SUPPRESSED AND
                 ;       SIGN IS PUT BEFORE FIRST NON-0 DIGIT.
                 ;
                 ;
10314 054723     DECD:   STA     3,ORTN    ;SAVE RETURN
10315 004637             JSR     ODEC      ;GET PARAMS
10316 010725     DECS:   ISZ     OCP
10317 020501             LDA     0,DCM
10320 040477             STA     0,DCT
10321 102520             SUBZL   0,0
10322 040474             STA     0,ZSF
10323 020506             LDA     0,TENT    ;TENS TABEL POINTER
10324 040506             STA     0,TNPT
10325 022713             LDA@    0,ODAD
10326 024516             LDA     1,CBLN
10327 101112             MOVL#   0,0,SZC
10330 024503             LDA     1,CMIN
10331 044514             STA     1,SIGN
10332 101112             MOVL#   0,0,SZC
10333 100400             NEG     0,0       ;NEGATE NEG VAL
10334 040500             STA     0,DX
10335 102400     DEC1:   SUB     0,0
10336 040500             STA     0,DJ
10337 026473             LDA@    1,TNPT    ;GET NEXT POWER OF 10
10340 044475             STA     1,DK      ;SAVE IT IN DK
10341 024474     DEC2:   LDA     1,DK
10342 020472             LDA     0,DX
10343 106033             ADCZ#   0,1,SNC
10344 000427             JMP     DEC10
10345 020471             LDA     0,DJ
10346 101005             MOV     0,0,SNR
10347 000433             JMP     DEC9
10350 024700     DEC6:   LDA     1,C60
10351 123000             ADD     1,0
10352 004412     DEC8:   JSR     DSTD      ;MASK ON GRF AND STORE
10353 010457     DEC7:   ISZ     TNPT      ;POINT TO NXT PR OF 10
10354 010443             ISZ     DCT
10355 000760             JMP     DEC1
10356 014440             DSZ     ZSF       ;CHECK IF VAL WAS LT 1
10357 000442             JMP     DNXT      ;NO IT WASNT
10360 014663             DSZ     OCP
10361 020667             LDA     0,C60     ;STORE A FINAL 0
10362 004402             JSR     DSTD      ;STORE 0 IN BUFF
10363 000436             JMP     DNXT
10364 030666     DSTD:   LDA     2,CGRF
10365 026656             LDA@    1,OCP     ;GET GRAPHIC DATA
10366 147400             AND     2,1
```

```
10367 123000              ADD      1,0
10370 042653              STA@     0,OCP     ;STORE FINISHED WORD
10371 010652              ISZ      OCP
10372 001400              JMP      0,3
10373 010443     DEC10:   ISZ      DJ
10374 122400              SUB      1,0
10375 040437              STA      0,DK
10376 014420              DSZ      ZSF
10377 000742              JMP      DEC2
10400 004410              JSR      DSNS
10401 000740              JMP      DEC2
10402 152520     DEC9:    SUBZL    2,2
10403 024413              LDA      1,ZSF
10404 132414              SUB#     1,2,SZR
10405 000743              JMP      DEC6
10406 010635              ISZ      OCP
10407 000744              JMP      DEC7
10410 054405     DSNS:    STA      3,SDSR
10411 014632              DSZ      OCP
10412 020433              LDA      0,SIGN
10413 004751              JSR      DSTD
10414 002401              JMP@     SDSR
10415 000000     SDSR:0   ;RET ADD
10416 000000     ZSF:0    ;ZERO SUPPRESS FLAG
10417 000000     DCT:     0        ;COUNTER
10420 177773     DCM:     -5
10421 020622     DNXT:    LDA      0,OCP
10422 024620              LDA      1,OSBN
10423 123000              ADD      1,0
10424 040617              STA      0,OCP
10425 010613              ISZ      ODAD
10426 014613              DSZ      ONMB
10427 000667              JMP      DECS
10430 002607              JMP@     ORTN
10431 010437     TENT:    TENS
10432 010437     TNPT:    TENS
10433 000055     CMIN:    55
10434 000000     DX:      0;NUM BEING DISPD
10435 000000     DK:      0;TEN TO THE N
10436 000000     DJ:      0;DIGIT
10437 023420     TENS:    10000.
10440 001750              1000.
10441 000144              100.
10442 000012              10.
10443 000001              1.
10444 000040     CBLN:    40       ;BLNK
10445 000000     SIGN:    0
      002400     BUFF:    .BLK     1280.    ;DISPLAY BUFFER
13045 010141     PG1:     CLBF     ;PAGE 1 TACH OR FIB; CLEAR BUFF
13047 000000              0
13050 010141     PG2:     CLBF     ;PAGE 2 CHAOTIC;CLEAR BUFF
13051 010253              ALPO     ;STICK IN ALPHAS
13052 001116              590.
13053 013227              CHAO
13054 000004              4
13055 000000              0
13056 010253     PG3:     ALPO     ;REPORT PVC AND BT CT
13057 000000              0
13060 000000              0
13061 000000              0
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  13062 010253  PG5:   ALPO
  13063 002304         1220.
  13064 013234         PVC
  13065 000002         2
  13066 000000         0
  13067 010141  PG4:   CLBF
  13070 010314         DECD
  13071 000363         243.
  13072 000012         10.
U 13073 000000         AFT     14675
  13074 000112         74.
  13075 010253         ALPO
  13076 000245         165.
  13077 013164         LN2
  13100 000042         34.
  13101 010314         DECD
  13102 000373         251.
  13103 000012         10.
U 13104 000000         CRT1T   14555
  13105 000112         74.
  13106 010314         DECD
  13107 000403         259.
  13110 000012         10.
U 13111 000000         CRT2T   14567
  13112 000112         74.
  13113 010314         DECD
  13114 000413         267.
  13115 000012         10.
U 13116 000000         CRT3T   14601
  13117 000112         74.
  13120 010314         DECD
  13121 000423         275.
  13122 000012         10.
U 13123 000000         CRT4T   14613
  13124 000112         74.
  13125 010314         DECD
  13126 000433         283.
  13127 000012         10.
U 13130 000000         CRT5T   14625
  13131 000112         74.
  13132 010314         DECD
  13133 000443         291.
  13134 000012         10.
U 13135 000000         CRT6T   14637
  13136 000112         74.
  13137 010314         DECD
  13140 000453         299.
  13141 000012         10.
U 13142 000000         FMT     14651
  13143 000112         74.
  13144 010314         DECD
  13145 000463         307.
  13146 000012         10.
U 13147 000000         FAT     14663
  13150 000112         74.
  13151 010253         ALPO
  13152 002164         1140.
  13153 013237         REFT
  13154 000022         18.
  13155 010314         DECD
```

```
  13156 002166            1142.
  13157 000002            2
U 13160 000000            BTCT   ( 5143
  13161 000007            7
  13162 000000            0
  13163 000000            0
  13164 040506  LN2:      .TXT      "FA
  13165 020115  M
  13166 020040
  13167 020040
  13170 046501  AM
  13171 020120  P
  13172 020040
  13173 020040
  13174 044527  WI
  13175 052104  DT
  13176 020110  H
  13177 020040
  13200 051101  AR
  13201 040505  EA
  13202 020040
  13203 020040
  13204 050440   P
  13205 050455  -P
  13206 020040
  13207 020040
  13210 040455  -A
  13211 050115  MP
  13212 020040
  13213 046440   M
  13214 051530  XS
  13215 050114  LP
  13216 020040
  13217 020040
  13220 042515  ME
  13221 041115  MB
  13222 020123  S
  13223 020040
  13224 043501  AG
  13225 020105  E
  13226 000000  "

  13227 044103  CHAO:     .TXT      "CH
  13230 047501  AO
  13231 044524  TI
  13232 020103  C
  13233 000000  "

  13234 053120  PVC:      .TXT      "PV
  13235 020103  C
  13236 000000  "

  13237 043117  REPT:     .TXT      "OF
  13240 020040
  13241 020040
  13242 020040
  13243 041040   B
  13244 040505  EA
  13245 051524  TS
  13246 020054  ,
```

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13247 020040
13250 020040
13251 020040
13252 051120  PR
13253 041117  OB
13254 041101  AB
13255 042514  LE
13256 050040   P
13257 041526  VC
13260 020123  S
13261 000000  "
```

.END

```
                        ;
                        ;
                        ;         STATISTICAL (CYCLIC) PROCESSOR
                        ;
                        ;
                        ;         SWITCH ENTRIES:
                        ;
                        ;         177777 - REQUEST DISPLAY OF FAMILIES
                        ;                  AND PVC COUNT.  SETS PROGRAM FLIP-FLOP.0
                        ;                  RESET FLIP ANY SWITCH FOR 1 BEAT DURATI0
                        ;                  (NOT 177777 RESETS).
                        ;         77777 -  ZERO BEAT AND PVC COUNTS FOR DISPLAY.
                        ;         37777 -  ZERO FAMILY STORAGE FOR ALL FAMS.  DOES0
                        ;                  RESET ACTIVE FAMILY TABLE.
       014000                     .LOC    14000
       000010                     .BLK    10
14010  177777                     -1
14011  000000   CW:               0;**PUT CYBF ADD HERE **
14012  030777   CYCL:             LDA     2,CW       ;GET INP ADDRESS
14013  021000                     LDA     0,0,2      ;GET FIRST INP
14014  040547                     STA     0,INS
14015  021001                     LDA     0,1,2      ;GET 2ND INP
14016  040546                     STA     0,INS+1
14017  021002                     LDA     0,2,2      ;GET 3RD INP
14020  040545                     STA     0,INS+2
14021  021003                     LDA     0,3,2      ;GET 4TH INP
14022  040544                     STA     0,INS+3
14023  021004                     LDA     0,4,2      ;GET 5TH INP
14024  040543                     STA     0,INS+4
14025  021005                     LDA     0,5,2      ;GET 6TH INP
14026  040542                     STA     0,INS+5
14027  006565                     JSR@    GTAFS
14030  020542                     LDA     0,NINS     ;SETUP INP CTR
14031  040542                     STA     0,INCTR
14032  020542                     LDA     0,SINP
14033  040542                     STA     0,INPTR ;SETUP INP PTR
14034  022541   LP1:              LDA@    0,INPTR ;CHECK TO LO LIM
14035  101112                     MOVL#   0,0,SZC
14036  100400                     NEG     0,0
14037  034537                     LDA     3,LLPTR
14040  030533                     LDA     2,INCTR
14041  157000                     ADD     2,3
14042  025400                     LDA     1,0,3
14043  122433                     SUBZ#   1,0,SNC ;SKIP IF WITHIN
14044  002551                     JMP@    RET
14045  034532                     LDA     3,LHPTR ;CHECK TO HI LIM
14046  157000                     ADD     2,3
14047  025400                     LDA     1,0,3
14050  106433                     SUBZ#   0,1,SNC ;SKIP IF WITHIN
14051  002544                     JMP@    RET        ;BAD INPUPT
14052  010523                     ISZ     INPTR
14053  010520                     ISZ     INCTR
14054  000760                     JMP     LP1
14055  020515   LP4A:             LDA     0,NINS
14056  040515                     STA     0,INCTR
14057  020515                     LDA     0,SINP
14060  040515                     STA     0,INPTR
14061  034517   LP3:              LDA     3,PCPTR ;GET % PTR
14062  030511                     LDA     2,INCTR
14063  157000                     ADD     2,3
```

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14064 021400          LDA     0,0,3   ;GET %
14065 034514          LDA     3,FINSP ;GET PTR TO FM CRIT
14066 157000          ADD     2,3
14067 035400          LDA     3,0,3   ;GET CRIT PTR
14070 030513          LDA     2,AFN   ;GET FAM INDEX
14071 157000          ADD     2,3
14072 025400          LDA     1,0,3   ;GET FAM MEMBER
14073 044511          STA     1,CVWS  ;SAVE IT
14074 006512          JSR@    PCT     ;TAKE AC0 % OF AC1,PUT IN 1
14075 125112          MOVL#   1,1,SZC
14076 124400          NEG     1,1
14077 020474          LDA     0,INCTR
14100 030502          LDA     2,FEPTR
14101 113000          ADD     0,2
14102 021000          LDA     0,0,2
14103 106033          ADCZ#   0,1,SNC
14104 105000          MOV     0,1
14105 020477          LDA     0,CVWS
14106 032467          LDA@    2,INPTR
14107 112400          SUB     0,2     ;CALC ABS DIFF
14110 151112          MOVL#   2,2,SZC
14111 150400          NEG     2,2
14112 146433          SUBZ#   2,1,SNC ;SKIP IF IN
14113 000504          JMP     GNAFI   ;GET NEXT ACT FAM
14114 010461          ISZ     INPTR   ;STILL IN SO TST NEXT INP
14115 010456          ISZ     INCTR   ;INC INP CTR
14116 000743          JMP     LP3
                ;FOUND A FAMILY IT FITS IN
14117 030470          LDA     2,FMPT  ;FAM MEM TAB PT
14120 024463          LDA     1,AFN   ;GET FAM
14121 044560          STA     1,CURB
14122 133000          ADD     1,2
14123 011000          ISZ     0,2     ;INC FAM SIZE
14124 000401          JMP     .+1
14125 030463          LDA     2,FAPT  ;RESET AGE OF FAM
14126 133000          ADD     1,2
14127 020462          LDA     0,MXAGE ;SET TO MAX AGE
14130 041000          STA     0,0,2
                ;ADJUST FAMILY CRITERIA BY NEW VALUE
14131 020441          LDA     0,NINS  ;NO OF INPUTS
14132 040441          STA     0,INCTR
14133 020441          LDA     0,SINP
14134 040441          STA     0,INPTR
14135 020436    LP2:  LDA     0,INCTR
14136 030443          LDA     2,FINSP
14137 113000          ADD     0,2
14140 031000          LDA     2,0,2
14141 024442          LDA     1,AFN
14142 133000          ADD     1,2     ;CALC ADD OF FAM CRIT
14143 050442          STA     2,FMAD
14144 025000          LDA     1,0,2
14145 020445          LDA     0,WTS   ;TAKE AC0 % OF AC1 (OLD VAL)
14146 006443          JSR@    PCT
14147 044535          STA     1,SVPT  ;SAVE RESULT
14150 026425          LDA@    1,INPTR ;GET INPUT
14151 020442          LDA     0,WTS+1 ;TAKE OTHER % OF INPUT
14152 006434          JSR@    PCT
14153 020531          LDA     0,SVPT  ;GET BIG PART
14154 107000          ADD     0,1     ;NEW FAM CRIT VA
14155 030430          LDA     2,FMAD
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14156 045000             STA     1,0,2
14157 010416             ISZ     INPTR
14160 010413             ISZ     INCTR
14161 000754             JMP     LP2
14162 000534             JMP     AGING
      000006  INS:       .BLK    6          ;INPUTS STORED HERE
14171 000012  NOFM:      10.     ;NUMBER OF FAMILIES
14172 177772  NINS:      -6      ;NO OF INPUTS
14173 000000  INCTR:     0
14174 014163  SINP:      INS
14175 000000  INPTR:     0       ;INPUT TAB PTR
14176 014716  LLPTR:LL+6         ;LOWER LIMIT TABLE PTR
14177 014724  LHPTR:LH+6         ;UPPER LIMIT TABLE POINTER
14200 014732  PCPTR:PCNT+6       ;PER CENT TABLE POINTER
14201 014555  FINSP:CRTES+6      ;PTR TO CRIT TAB PTRS
14202 014740  PEPTR:PTER+6       ;POINTER TO ERROR LIM TAB
14203 000000  AFN:       0       ;ACTIVE FAMILY NUMBER
14204 000000  CVMS:      0       ;STORE
14205 000000  FMAD:      0       ;STORE
14206 014462  PCT:PCTG           ;PERCENTAGE ROUTINE
14207 014651  FMPT:FMT           ;PTR TO FAM MEM TAB
14210 014663  FAPT:FAT           ;PTR TO FAM AGE TAB
14211 000024  MXAGE:     20.     ;INITIAL AGE OF FAMILY
14212 000132  WTS:       90.     ;PER CENT WEIGHTS FOR NEW MEMBERS
14213 000012             10.
14214 014306  GTAFS:GTAFA
14215 015104  RET:RETN
14216 000012  IAFCT:     10.
              ;GET NEXT ACT FAM MEM; IF NONE START NEW FAM
14217 004524  GNAFI:     JSR     GTAFN
14220 020763             LDA     0,AFN     ;IF NO MOR THEN VAL IS 100000
14221 101133             MOVEL#  0,0,SNC ;SKIP IF NO MORE
14222 000633             JMP     LP4A      ;TRY INP IN NEXT FAM
14223 020746             LDA     0,NOFM
14224 100400             NEG     0,0
14225 040771             STA     0,IAFCT
14226 030454             LDA     2,IAFEP
14227 024767             LDA     1,IAFCT
14230 133000             ADD     1,2
14231 000407             JMP     RTIAF
14232 151400  ORPH:      INC     2,2
              ;ORPHAN SO START NEW FAM
              ;GET FAM FROM INACTIVE LIST
14233 010763             ISZ     IAFCT
14234 000404             JMP     RTIAF     ;TOOMANY FAMS SO REQ DISP
14235 020450             LDA     0,UNRL    ;SET AFT TO UNREAL VALUE
14236 040745             STA     0,AFN
14237 000457             JMP     AGING     ;GO AGE FAMILIES
              ;FOUND A GOOD FAMILY TO START
14240 025000  RTIAF:     LDA     1,0,2     ;GET NEW FAM NO
14241 125113             MOVL#   1,1,SNC
14242 000770             JMP     ORPH
14243 125120             MOVEL   1,1
14244 125220             MOVER   1,1
14245 045000             STA     1,0,2
14246 044735             STA     1,AFN
              ;SETUP THE NEW FAMILY
14247 030741             LDA     2,FMPT    ;SAME AS ABOVE
14250 024733             LDA     1,AFN
14251 044430             STA     1,CUMB
```

```
14252 133000            ADD     1,2
14253 102520            SUBZL   0,0
14254 041000            STA     0,0,2   ;SET FAM SIZE TO 1
14255 030733            LDA     2,FAPT  ;RESET AGE
14256 133000            ADD     1,2
14257 020732            LDA     0,MXAGE
14260 041000            STA     0,0,2
14261 020711            LDA     0,NINS
14262 040711            STA     0,INCTR
14263 020711            LDA     0,SINP
14264 040711            STA     0,INPTR
14265 020706    LP5:    LDA     0,INCTR
14266 030713            LDA     2,FINSP
14267 113000            ADD     0,2
14270 031000            LDA     2,0,2
14271 024712            LDA     1,AFN
14272 133000            ADD     1,2
14273 022702            LDA@    0,INPTR
14274 041000            STA     0,0,2
14275 010700            ISZ     INPTR
14276 010675            ISZ     INCTR
14277 000766            JMP     LP5
14300 000416            JMP     AGING
14301 000000    CURB:0
14302 014707    IAFEP:AFT+10.
14303 014675    AFTP:AFT
14304 000000    SVPT:   0;STORE
14305 100000    UNRL:   100000  ;UNREAL FAM NO
14306 054405    GTAFA:  STA     3,GTS   ;SET 1ST ACT FAM NO
14307 020405            LDA     0,AFTN
14310 040405            STA     0,AFTC
14311 004432            JSR     GTAFN
14312 002401            JMP@    GTS
14313 000000    GTS:    0;RETURN ADD
14314 177765    AFTN:   -11.
14315 177765    AFTC:   -11.
14316 020665    AGING:  LDA     0,AFN
14317 040442            STA     0,AFWNM ;SAVE NO FO ACT FAM W/NEW MEM
14320 004766            JSR     GTAFA
14321 030662    LP41:   LDA     2,AFN
14322 151132            MOVZL#  2,2,SZC ;SKIP IF NO MORE
14323 000441            JMP     ABSR    ;GO SEEK ABNORMALS
14324 024435            LDA     1,AFWNM
14325 146415            SUB#    2,1,SNR ;NOT SAME FAM SO AGE
14326 000413            JMP     LP4     ;SAME FAM SO LET ALONE
14327 024661            LDA     1,FAPT
14330 133000            ADD     1,2
14331 015000            DSZ     0,2
14332 000407            JMP     LP4     ;GO AGE NEXT FAM
                ;FAM TOO OLD SO INACTIVATE
14333 030756            LDA     2,AFTP
14334 024647            LDA     1,AFN
14335 133000            ADD     1,2
14336 125120            MOVZL   1,1
14337 125240            MOVOR   1,1
14340 045000            STA     1,0,2
14341 004402    LP4:    JSR     GTAFN   ;GET NEXT VALUE
14342 000757            JMP     LP41    ;GO TEST IT
14343 024752    GTAFN:  LDA     1,AFTC
14344 030416            LDA     2,AFTEP
```

```
14345 133000           ADD    1,2
14346 021000           LDA    0,0,2
14347 040634           STA    0,AFN
14350 010745           ISZ    AFTC
14351 000402           JMP    .+2
14352 000404           JMP    GTF
14353 101102           MOVL   0,0,SZC
14354 000767           JMP    GTAFN
14355 001400           JMP    0,3
14356 020736  GTF:     LDA    0,AFTN
14357 040736           STA    0,AFTC
14360 001400           JMP    0,3
14361 000000  AFWNM:   0;ACT FAM W/NEW MEM
14362 014710  AFTEP:   AFT+11.
14363 015144  PVCF:PVCC
14364 004722  ABSR:    JSR    GTAFA
14365 102400           SUB    0,0
14366 040514           STA    0,NFMCT ;SET NORM FAM CT TO 0
14367 000405           JMP    CHECK
14370 004753  ABS2:    JSR    GTAFN
14371 020612           LDA    0,AFN
14372 101112           MOVL#  0,0,SZC ;SKIP IF MORE TO CHECK
14373 000413           JMP    ABS1    ;FOUND NORM FAM
14374 030613  CHECK:   LDA    2,FMPT
14375 024606           LDA    1,AFN
14376 133000           ADD    1,2
14377 021000           LDA    0,0,2
14400 030502           LDA    2,NFMCT
14401 142033           ADCZ#  2,0,SNC
14402 000766           JMP    ABS2
14403 044500           STA    1,NFN
14404 040476           STA    0,NFMCT
14405 000763           JMP    ABS2
14406 020673  ABS1:    LDA    0,CURB  ;CHECK FOR PVC
14407 024474           LDA    1,NFN
14410 106415           SUB#   0,1,SNR
14411 002535           JMP@   RTUN
14412 020475           LDA    0,PCA
14413 030536           LDA    2,CRTBS+2
14414 133000           ADD    1,2
14415 025000           LDA    1,0,2
14416 004444           JSR    PCTG
14417 034465           LDA    3,NINP
14420 021400           LDA    0,0,3   ;GET NEW AREA
14421 122033           ADCZ#  1,0,SNC ;SKIPIF BIGGER AREA
14422 002524           JMP@   RTUN    ;NOT PVC
14423 024460           LDA    1,NFN
14424 030526           LDA    2,CRTBS+3
14425 133000           ADD    1,2
14426 025000           LDA    1,0,2
14427 020461           LDA    0,PCC
14430 004432           JSR    PCTG
14431 034453           LDA    3,NINP
14432 175400           INC    3,3
14433 021400           LDA    0,0,3   ;GET CC
14434 106033           ADCZ#  0,1,SNC ;SKIP IF SHORT CC
14435 002511           JMP@   RTUN    ;NOT PVC
14436 030516           LDA    2,CRTBS+5
14437 024444           LDA    1,NFN
14440 133000           ADD    1,2
```

```
14441 025000          LDA     1,0,2    ;CHECK MAX SLOPE
14442 020447          LDA     0,PCS
14443 004417          JSR     PCTG
14444 034440          LDA     3,NINF
14445 175400          INC     3,3
14446 175400          INC     3,3
14447 175400          INC     3,3
14450 021400          LDA     0,0,3
14451 122033          ADCZ#   1,0,SNC  ;SKIP IF PVC
14452 002474          JMP@    RTUN     ;NOT PVC
14453 102000          ADC     0,0
14454 061033          DOA     0,33
14455 020431          LDA     0,MS5    ;DISPLAY "PVC"
14456 004435          JSR     DIPR     ;REPORT PVC
14457 012704          ISZ@    PVCP
14460 000401          JMP     .+1
14461 002465          JMP@    RTUN
                ;PER CENT ROUTINE
14462 054415    PCTG:   STA     3,PCS3   ;SAVE RETURN
14463 044415          STA     1,SGN3   ;SAVE FOR SIGN
14464 125112          MOVL#   1,1,SZC  ;TAKE ABS VAL
14465 124400          NEG     1,1
14466 111000          MOV     0,2
14467 102400          SUB     0,0
14470 006003          JSR@    3        ;MULT BY PERCENT EG 10
14471 030416          LDA     2,C100
14472 006004          JSR@    4        ;DIV BY 100
14473 020405          LDA     0,SGN3   ;REPLACE SIGN ON RESULT
14474 101112          MOVL#   0,0,SZC
14475 124400          NEG     1,1
14476 002401          JMP@    PCS3
14477 000000    PCS3:   0;SAVE RETURN
14500 000000    SGN3:   0;SAVE SIGN
14501 000144    C100:   100.
14502 000000    NFMCT:0
14503 000000    NFN:0
14504 014165    NINF:INS+2
14505 000000    SAV9:0
14506 000005    MS5:5
14507 000156    PCA:    110.      ;AREA
14510 000135    PCQ:    93.       ;QQ
14511 000106    PCS:    70.       ;SLOPE
14512 000120    PCW:    80.       ;WIDTH
                ;DISPLAY REQUEST ROUTINE
14513 054764    DIPR:   STA     3,PCS3
14514 024424          LDA     1,LSPG
14515 106415          SUB#    0,1,SNR
14516 000416          JMP     PRSP
14517 004402    RED:    JSR     ADIS
14520 002757          JMP@    PCS3
14521 054764    ADIS:   STA     3,SAV9
14522 040416          STA     0,LSPG
14523 040426          STA     0,PRCOM
14524 020415          LDA     0,PRCP
14525 042415          STA@    0,CKWP
14526 006002          JSR@    2
14527 000000          0
14530 000006          6                ;REQUEST DISPLAY
14531 015146          DERR
14532 014543          PRCOM
```

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14533 002752              JMP0     SAV9
14534 030411    PRSP:     LDA      2,RRFL
14535 151004              MOV      2,2,SER
14536 001400              JMP      0,3
14537 000760              JMP      RED
14540 000000    LSPG:     0;LAST PAGE DISPLAYED
14541 014543    PRCP:PRCOM
14542 010011    CMMP:10011
14543 000000    PRCOM:    0        ;COMMUNICATION WORDS
14544 000000              0
14545 000000    RRFL:0    ;REPT REQ FLAG
14546 015104    RTUN:RETN
14547 014555    CRTBS:    CRT1T    ;POINTERS TO CRITERIA
14550 014567              CRT2T
14551 014601              CRT3T
14552 014613              CRT4T
14553 014625              CRT5T
14554 014637              CRT6T
      000012    CRT1T:    .BLK     10.      ;CRITERION1
      000012    CRT2T:    .BLK     10.      ;CRITERION2
      000012    CRT3T:    .BLK     10.      ;CRITERION 3
      000012    CRT4T:    .BLK     10.
      000012    CRT5T:    .BLK     10.
      000012    CRT6T:    .BLK     10.
      000012    FMT:      .BLK     10.      ;FAMILY MEMBER TABLE
      000012    FAT:      .BLK     10.      ;FAMILY AGE TABLE
      000012    AFT:      .BLK     10.      ;ACTIVE FAMILY TABLE
14707 100000              100000   ;END OF ACT FAM TAB FLAG
14710 000040    LL:       40       ;AMP
14711 000030              30       ;WIDTH
14712 000040              40       ;AREA
14713 000024              20.      ;CC
14714 000000              0
14715 000000              0
14716 001770    LH:       1770     ;AMP
14717 000400              400      ;WIDTH
14720 070000              70000    ;AREA
14721 003720              2000.
14722 001770              1770
14723 000200              200      ;MAX SLP
14724 000036    PCNT:     30.      ;AMP
14725 000050              40.      ;WIDTH
14726 000036              30.      ;AREA
14727 000036              30.
14730 000036              30.
14731 000024              20.      ;MAX SLOPE
14732 000030    PTEM:     30       ;AMP
14733 000005              5.       ;WIDTH
14734 000024              20.      ;AREA
14735 000024              20.      ;CC
14736 000062              50.      ;-AMP
14737 000012              10.      ;MAX SLOPE
                ;
                ;         INITIALIZATION FOR CYCLIC
                ;
      015000              .LOC     15000
15000 020422              LDA      0,CI1
15001 040422              STA      0,CT2
15002 054417              STA      3,IS3
15003 030413              LDA      2,VLF
```

```
15004 034413            LDA     3,DESP
15005 054413            STA     3,DEST
15006 021000  CLP:      LDA     0,0,2
15007 036411            LDA@    3,DEST
15010 041400            STA     0,0,3
15011 010407            ISZ     DEST
15012 151400            INC     2,2
15013 014410            DSZ     CT2
15014 000772            JMP     CLP
15015 002404            JMP@    IS3
15016 015061  VLP:VL
15017 015024  DESP:DES
15020 015024  DEST:DES
15021 000000  IS3:      0;RETN ADD
15022 000023  CT1:19.   ;NO OF WORDS TO INITIALIZE
15023 000023  CT2:19.
15024 014555  DES:      CRT1T
15025 014567            CRT2T
15026 014601            CRT3T
15027 014613            CRT4T
15030 014625            CRT5T
15031 014663            FAT
15032 014651            FMT
15033 014675            AFT
15034 014676            AFT+1
15035 014677            AFT+2
15036 014700            AFT+3
15037 014701            AFT+4
15040 014702            AFT+5
15041 014703            AFT+6
15042 014704            AFT+7
15043 014705            AFT+10
15044 014706            AFT+11
15045 015143            BTCT
15046 015144            PVCC
      000012            .BLK    10.        ;SPARES
15061 000450  VL:       450     ;AMP
15062 000070            70      ;WIDTH
15063 000400            400     ;AREA
15064 000620            400.    ;P-P
15065 000400            400     ;-AMP
15066 000001            1
15067 000001            1
15070 000000            0
15071 100001            100001
15072 100002            100002
15073 100003            100003
15074 100004            100004
15075 100005            100005
15076 100006            100006
15077 100007            100007
15100 100010            100010
15101 100011            100011
15102 000000            0
15103 000000            0
15104 010437  RETN:     ISZ     BTCT       ;INC BEAT CT
15105 000401            JMP     .+1        ;PLAY SAFE
15106 060477            READS   0          ;READ SWITCHES
15107 126020            ADCZ    1,1
15110 125220            MOVZR   1,1        ;FORM 37777 IN AC1
```

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```
15111 122415                SUB#    1,0,SNR ;COMPARE TO SWITCHES
15112 004436                JSR     ZTBS
15113 060477                READS   0
15114 126000                ADC     1,1
15115 122415                SUB#    1,0,SNR
15116 000404                JMP     RCC1
15117 126400                SUB     1,1
15120 046426                STA@    1,RRF    ;RESET REPORT REQ FLG
15121 000411                JMP     RSVC     ;CHECK TO ZERO COUNTERS
15122 032424        RCC1:   LDA@    2,RRF
15123 151004                MOV     2,2,SZR
15124 000406                JMP     RSVC
15125 126520                SUBZL   1,1
15126 046420                STA@    1,RRF
15127 020420                LDA     0,MS4
15130 006415                JSR@    RE       ;REQUEST DISP OF PAGE 3
15131 060477                READS   0
15132 126220        RSVC:   ADCZR   1,1      ;CHECK FOR ALL BUT SIGN BT SET
15133 122414                SUB#    1,0,SZR
15134 000404                JMP     BOT
15135 102400                SUB     0,0
15136 040405                STA     0,BTCT
15137 040405                STA     0,PVCC
15140 006002        BOT:    JSR@    2
15141 000006                6                ;QUIT PROGRAM
15142 063077        DERR:   HALT
15143 000000        BTCT:   0
15144 000000        PVCC:0
15145 014521        RE:ADIS
15146 014545        RRF:RRFL
15147 000004        MS4:    4
15150 024411        ZTBS:   LDA     1,ZNCT   ;ZERO FAM TABLES
15151 030407                LDA     2,CT1TP
15152 102400                SUB     0,0
15153 041000        ZTB:    STA     0,0,2
15154 151400                INC     2,2
15155 125404                INC     1,1,SZR
15156 000775                JMP     ZTB
15157 001400                JMP     0,3
15160 014555        CT1TP:  CT1T
15161 177672        ZNCT:   -70.     ;7 FAM TABLES * 10 FAMS
                            .END
```

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IV. ECG SIGNAL PREPROCESSOR

Development

As previously discussed six features of the QRS are to be continuously examined: amptitude, width, area under the QRS, Q-Q interval, max change in amptitude per unit time, and max amptitude of opposite sign. It was determined that by measuring the S to Q interval, determining an initial value amplitude of the QRS complex as it crosses the "K" apeture threshold level, and incrementaly measuring amptitude changes of the QRS complex, software could be developed to calculate all of the QRS features needed. The processor to be discussed performs this pre-software signal processing.

The processor consists of a band pass filter which limits baseline drift and signal slew rate. Following this filter is a sample and hold circuit, difference amplifier, and a MOSFET switch which is sequentially selected for slope or amplitude data. In addition an A to D converter, a set of counters, and a 2 msec clock (which establishes the basic timing for the processor) establish the major signal processing circitry. The remainder of the circutry is involved in timing requirements for computer interfacing and data transfer.

In order to meaningfully synchronize the signal processor to the computer an interface code has been developed which permits the computer to dedicate its time to other jobs until an interrupt from the signal processor occurs signifying a QRS has exceeded the "K" aperture threshold. This event starts the cycle sequence to be discussed.

CYCLE SEQUENCE

Note: Each device is referred to by its schematic designation and the board number where it is physically located. For example Z5-B3 refers to J-K flip flop designated Z5 located on board 3 of the signal processor chassis.

When an ECG exceeds the "K" apeture threshold level established by the front panel potentiometer setting, the next clock pulse from Z1-B2 sets Z5-B3. Z5 $\overline{Q}$ terminates counters Z1, Z5 (B4). Simultaneously the interrupt pulse from Z3-B1 begin. The first interrupt pulse clocks the counter data in the MUX (Z2, Z6, Z7,-B4) to the computer; then the computer generates a DATIA and DEVICE 37 code, toggling Z9A via Z3-B4. This event converts Data Select Line Z9-Q from a 0 to a 1 establishing a Device Code 33. Z9B-$\overline{Q}$-B4 has been keeping Q3-B1 in an "on" state permitting ECG amptitude data into the A/D (B2) which has been continuously converting but not sending its data to the computer since a Device Code 33 is required. When the 33 code is generated the MUX is activated for amp-slope data permitting the current ECG amp (initial value above "K" apeture) to be presented to the machine. Immediately the software generates a 33P pulse turning Q3-B1 "off" and Q2-B1 "on" thereby permitting slope data to be sent to the A/D. Slope data is calculated by taking the difference between the current value of the QRS amplitude and the previous value stored in the sample and hold circuit consisting of Q1 and AR2 on Board 1. The sample and hold circuit is updated every 2 msec. Figure IV-1 shows some of the important wave forms associated with this process. At the end of the slope data (software determined by slope settling) a 37P code is generated resetting the initial conditions of Z3-B3 and Z5-B3 as well as Z9-B9 thereby permitting the interval counters to begin again.

Each completed cycle resets the counters as described above and each time a QRS exceeds the "K" aperture level the value in the counters representing a length of line value, which when added to the width of the QRS (software calculated), provides the Q-Q interval data. The width of the QRS itself is determined by the computers clock which is set when the QRS exceeds the "K" apeture threshold and is stopped when the slope of the S-T segment flattens out. The remainder of data is calculated from the change in amptitude per unit time (2 msec) and the initial amplitude value.

Test Signal — 2v/cm

Sample & Hold Signal — 2v/cm

Difference Signal — 0.5v/cm

Conversion Timing — 5v/cm

T = 2msec

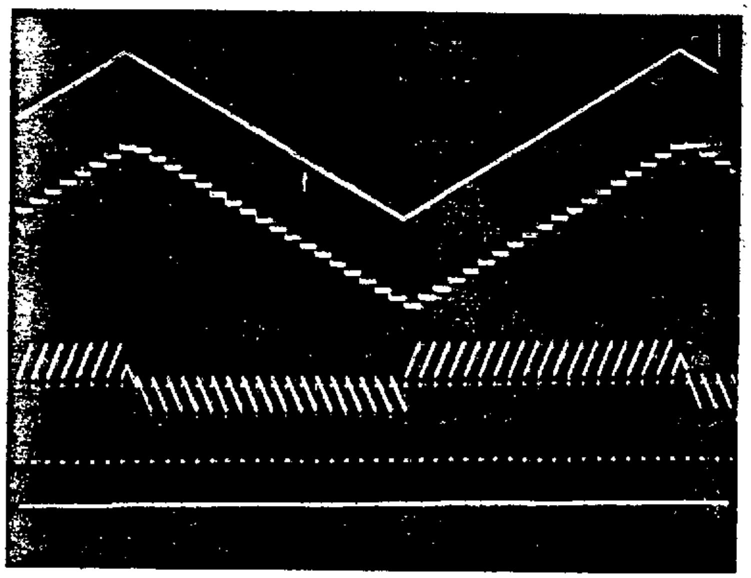


Figure IV-1

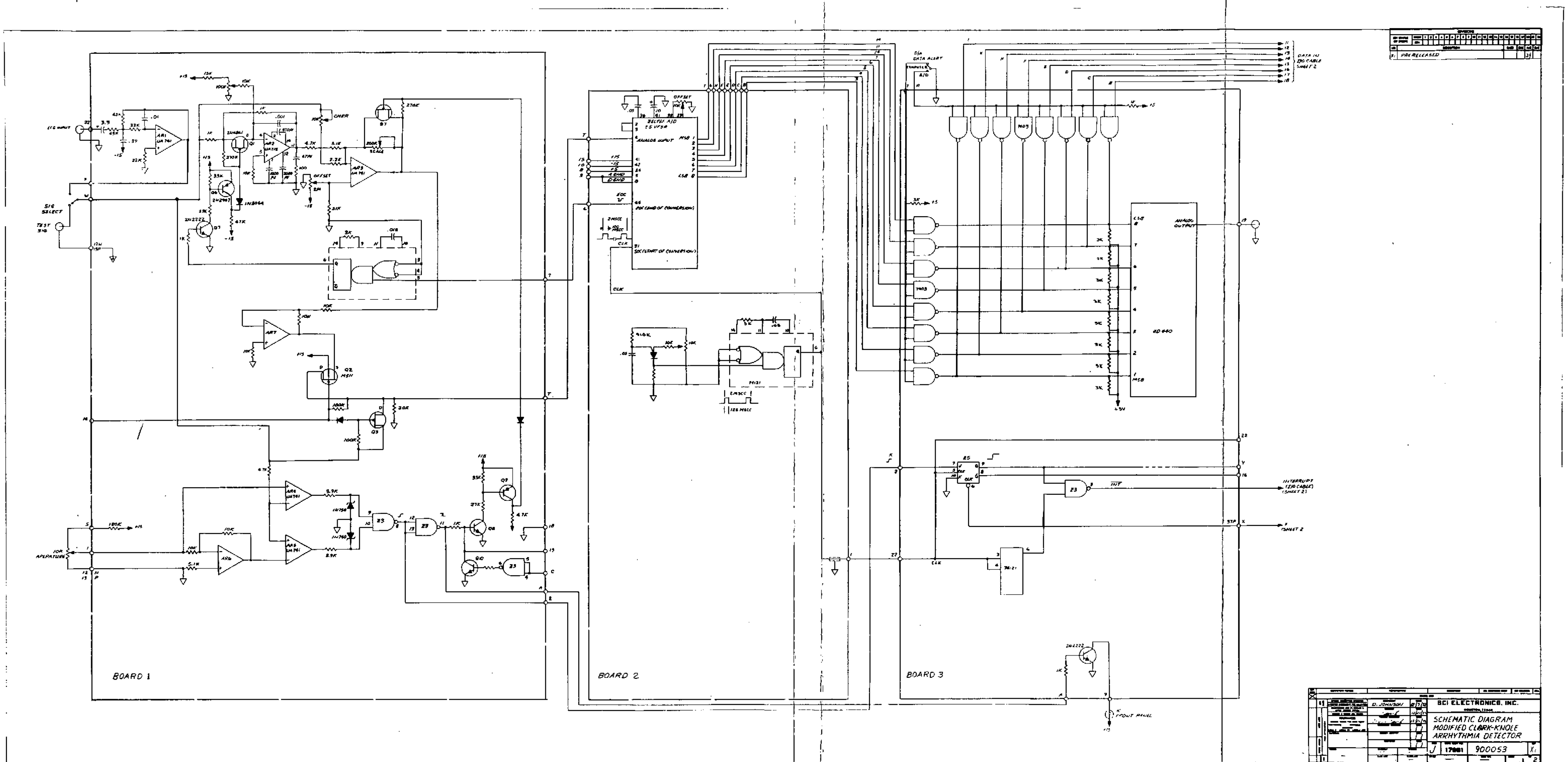
Note constant amplitude of difference signal except at the peaks of the test signal where the shape changes sign.

FOLDOUT FRAME

1

FOLDOUT FRAME

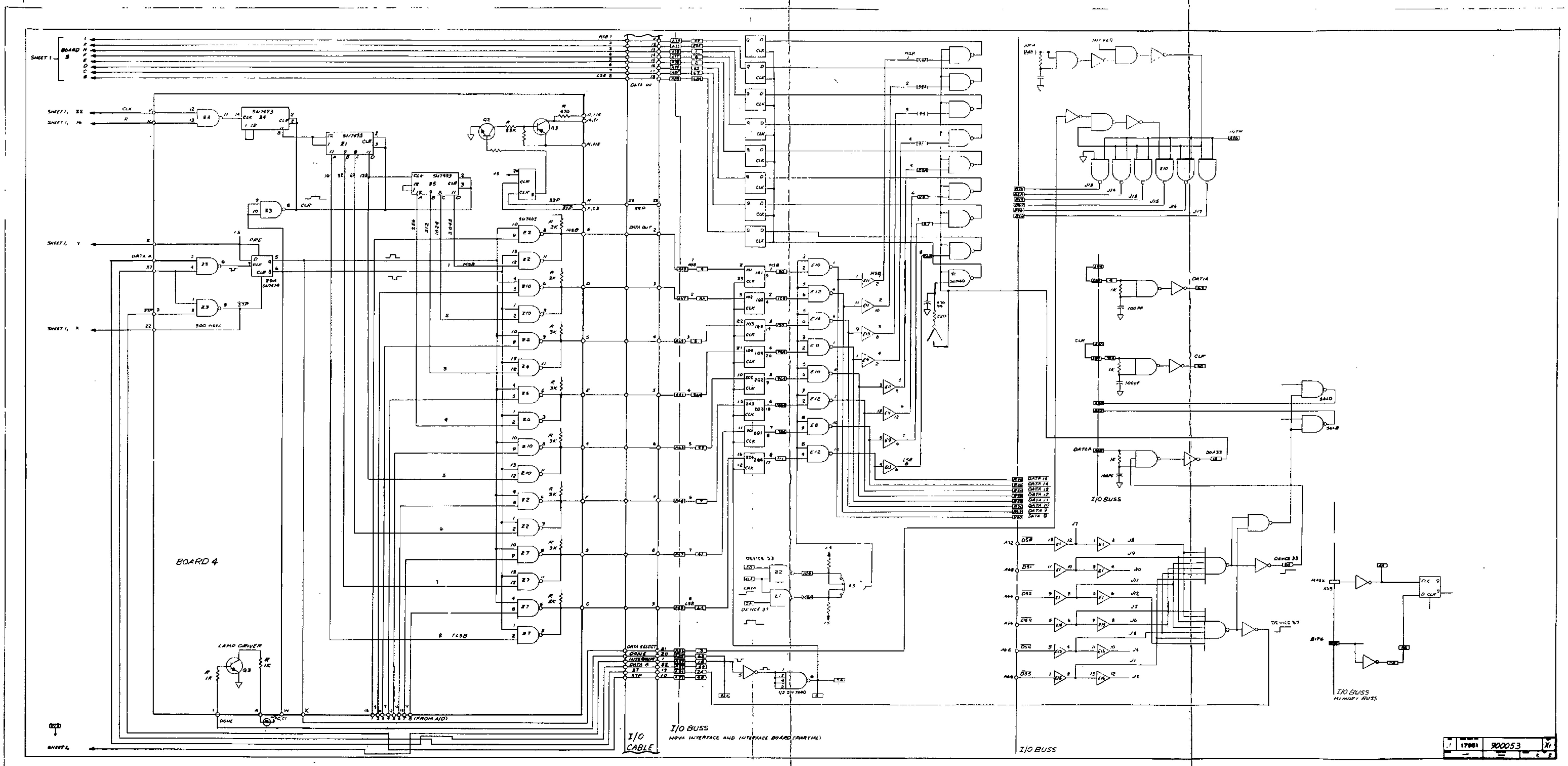
2



FOLDOUT FRAME

FOLDOUT FRAME

2



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V. SLEEP MONITORING SYSTEM M 133

CAP ASSEMBLY EVALUATION

The Work Plan on the following page is a summary of the objectives of the Sleep Monitoring Cap Assembly Evaluation Task. These objectives and several additional ones were accomplished during the program as discussed in this section.

SCI engineers worked closely with NASA-MSC engineers to develop techniques for refilling and refurbishing cap assemblies which were delivered under a previous contract. These techniques are documented in the NASA document MSC-06080, "Procedure for Refurbishing M133 Cap Assembly Electrodes". Supplies sufficient to refurbish quantities of caps for testing purposes were delivered to NASA-MSC.

Over 80 electrodes were built to flight specifications, but without flight inspection. Some of these electrodes were hand-carried by an SCI engineer to the Union Carbide facility to Boundbrook, New Jersey. Approximately 50 electrodes were coated with a 1-mil. thickness of Parylene C. The process appeared to be a feasible one, and the enviroments were not too harsh for the electrodes. Union Carbide has used this Parylene C coating process on other flight hardware and is equipped to handle the quality control procedures associated with flight hardware. Thus, if this study were to prove that the Parylene coating provides a sufficient moisture barrier for the electrodes, it would be suggested that Union Carbide apply the coating as a subcontract activity after the electrodes are coated with the vinyl coating, but before they are filled with electrolyte.

WORK PLAN

SLEEP MONITORING SUPPORT PROGRAM

1. Build 70 electrodes to flight specifications using commercial parts and including 100% inspection - do not fill with electrolyte.

2. Ship electrodes to Union Carbide for application of Parylene.

3. Manufacture 6 sleep caps to flight specifications using commercial parts and excluding 100% inspection.

4. Fill Parylene-coated electrodes with electrolyte, mount to caps with vinyl sheet backing, assemble final cap assembly, seal in retort stock bags.

5. Store caps on shelf for periodic opening and inspection.

6. Do a literature material search for coating materials that would make electrodes less permeable to water vapor.

7. Try out various coating materials on electrode samples.

8. Explore other methods for increasing the shelf life of the cap assemblies.

9. Support NASA-MSC as required in refurbishment of existing cap assemblies.

10. Support NASA-MSC in tests involving cap assemblies.

11. Coordinate all activities with Dr. Frost and NASA-MSC.

12. Report activities and results to NASA-MSC.

13. Write process specifications for any new processes designed to increase shelf life.

This task specifically excludes the following activities:

1. Thorough studies of the effects of ambient pressures on the electrodes and studies of methods for alleviating these effects.

2. Studies of electrostatic discharge design changes and modifications of the cap assembly not related to increasing its shelf life.

One problem was experienced during the evacuation of the coating chamber prior to the first application of Parylene. The vinyl coating on some of the electrodes was stretched out of shape by air entrapped on the back side of the electrode. Of the batch of electrodes, approximately 20 did not stretch. It is felt that, in the future, a small hole be placed on the back side of the electrodes to allow this trapped air to escape without deforming the vinyl coating. (This procedure was subsequently shown to work in preventing this problem).

The electrodes were filled with electrolyte using flight specifications and procedures. Caps were manufactured and the electrodes were attached to the caps in the following configurations:

1. Parylene coated electrodes (7) attached to a layer of vinyl 20 mils. thick and then cemented to cap.

2. Standard electrodes (7) attached to a layer of vinyl 20 mils. thick and then cemented to cap.

3. Standard electrodes (7) cemented directly to a cap in a standard (control) configuration.

One cap assembly of each type was placed in the clean bench on March 28 without being bagged. One cap assembly of each type was bagged under an evacuated nitrogen atmosphere using standard procedures. In addition, five electrodes of each type have been left exposed to room ambient conditions without being attached to a cap.

All of the electrodes and cap assemblies were weighed on a daily basis. Preliminary results were that the Parylene-coated electrodes are loosing weight at a far less rapid rate than those that were uncoated.

The following configurations of electrodes and cap assemblies were stored for life testing at the end of March, 1972:

1. Completed Electrodes, Unbagged
   A. Parylene-Coated
   B. Original Configuration
2. Completed Cap Assemblies, Unbagged
   A. Parylene-Coated, Vinyl-Backed
   B. Non-Parylene-Coated, Vinyl-Backed
   C. Original Configuration
3. Completed Cap Assemblies, Bagged
   A. Parylene-Coated, Vinyl-Backed
   B. Non-Parylene Coated, Vinyl Backed
   C. Original Configuration
4. Cap Only, Without Electr odes, Unbagged

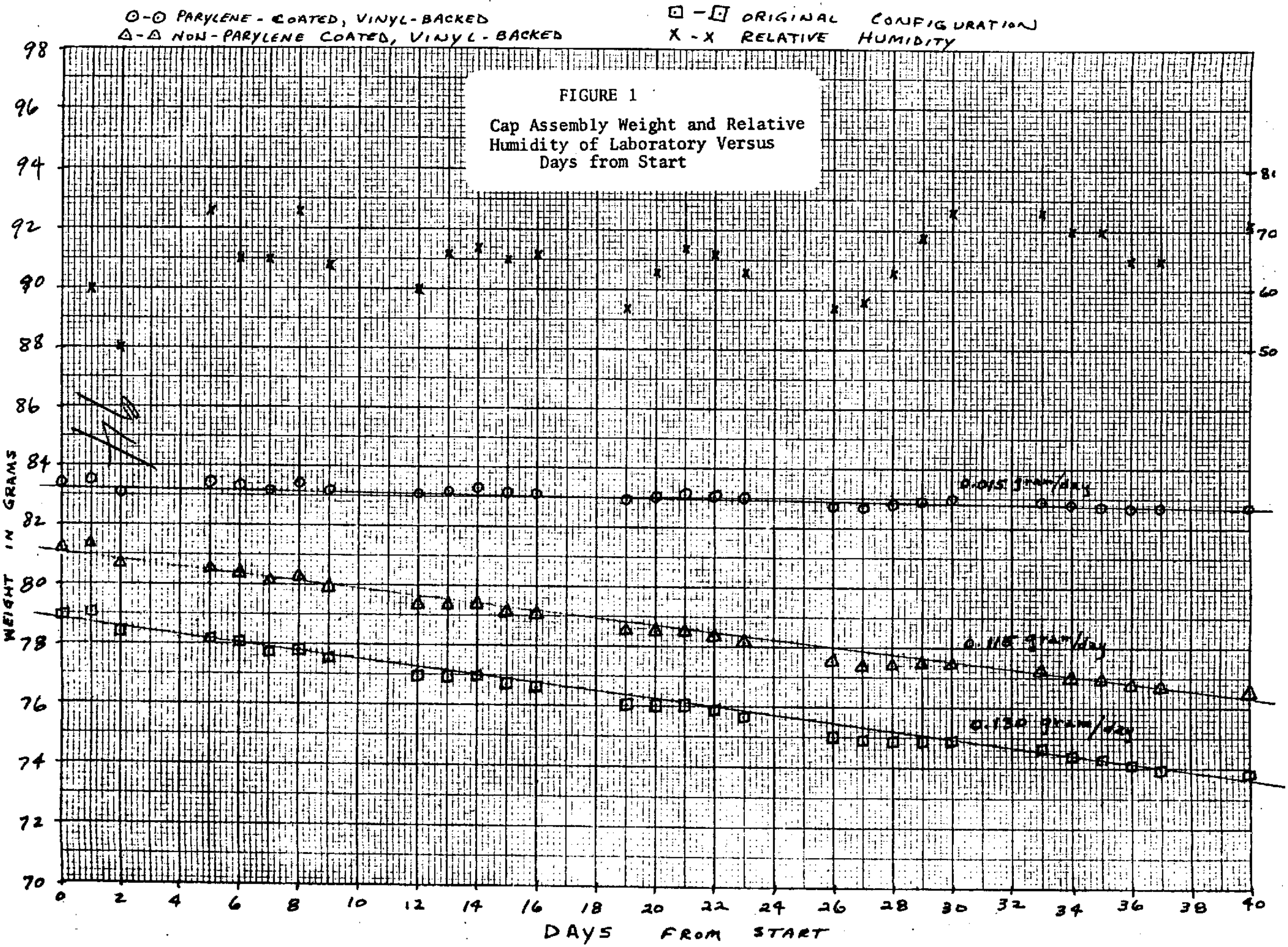
It was found that the unbagged caps varied in weight directly with the relative humidity of the room. Thus, a cap was built without electrodes and left exposed to the same room environment as the unbagged test cap assemblies.

Figure 1 is a plot of the weights of the three different configurations of unbagged cap assemblies versus the days from the start of the test. It is anticipated that an exponential decrease in weight will occur when the caps are exposed to laboratory ambient conditions for a sufficiently long period of time. For this plot, a straight line approximation has been made. Thus, the following weight losses were measured for the 40-day duration of test data:

1. Parylene-Coated, Vinyl-Backed - 0.015 grams/day
2. Non-Parylene-Coated, Vinyl-Backed - 0.015 grams/day
3. Original Configuration - 0.130 grams/day

FIGURE 1

Cap Assembly Weight and Relative Humidity of Laboratory Versus Days from Start



Thus, the loss in weight was significantly reduced by the 1-mil thickness of Parylene coating. The average weight of electrolyte per electrode was 1.25 grams per cap assembly. The original configuration cap assembly lost approximately 5.10 grams (or 58.2%) of its electrolyte in 40 days, while the Parylene-coated electrodes lost only 0.6 grams of its electrolyte over the same period of time. Some improvement in weight loss was observed on the cap which was built with a vinyl-backing but without Parylene. On the basis of these data, it would appear that the loss of electrolyte is improved by approximately an order of magnitude by the use of the Parylene coating.

The moisture absorbing properties of the cap material are apparent from Figure 2. This property makes the interpretation of a limited amount of early data difficult.

The weights of the caps which have been sealed in the metallized bags have not changed more than ± 0.01 grams for the entire 40-day period -- the resolution of the scale being used. Thus, it appears that the metallized bag is retaining the electrolyte within its boundaries.

Table I is a summary of the data from Parylene-coated and non-Parylene coated electrodes taken of May 1, 1972, 34 days after the start of the test.

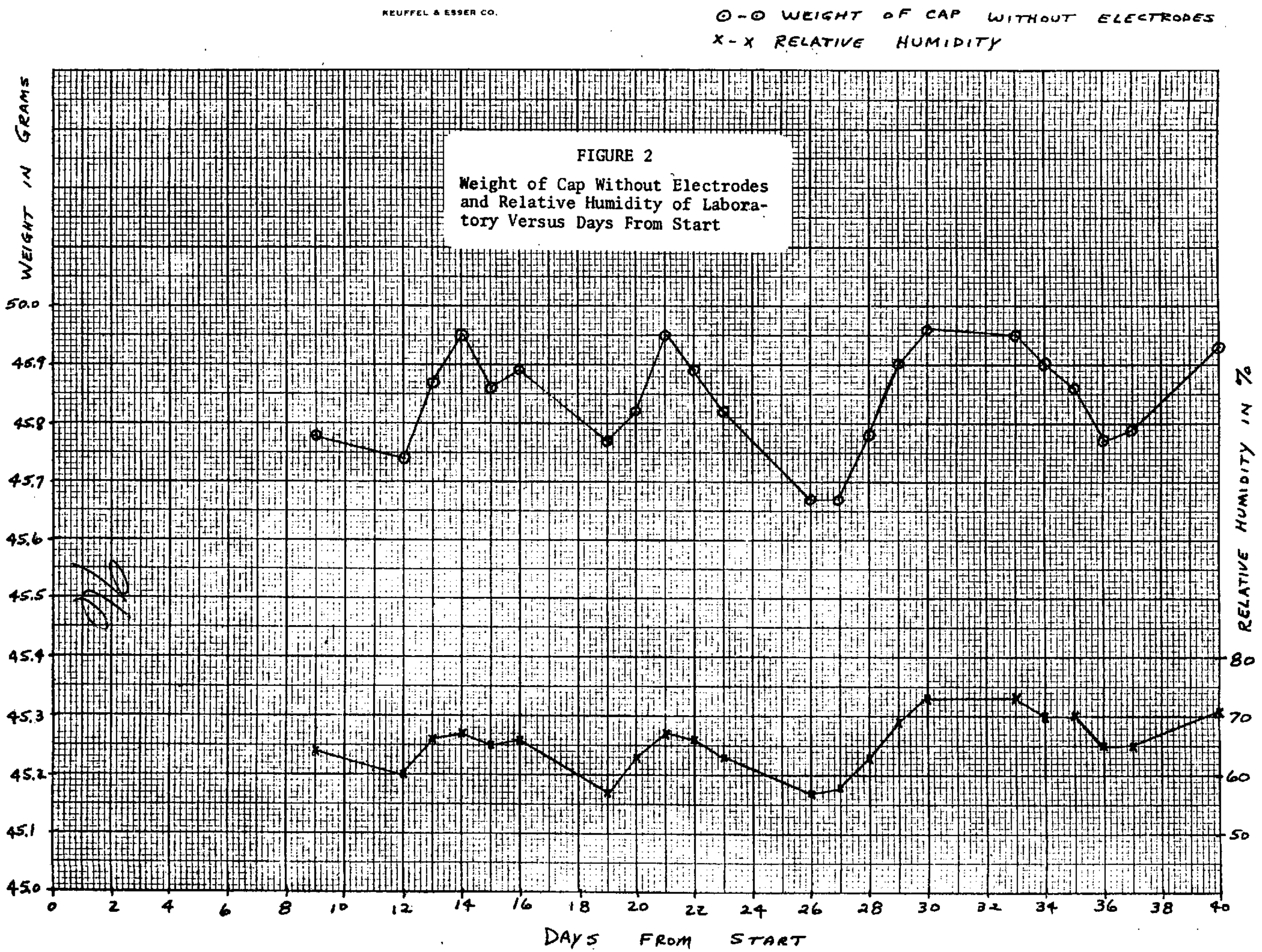


FIGURE 2

Weight of Cap Without Electrodes and Relative Humidity of Laboratory Versus Days From Start

TABLE I

SUMMARY OF DATA AFTER 34 DAYS

Electrode Number	Parylene Coated	Original Weight	Weight of Electrolyte	Weight on 5/1/72	Weight Change In 34 Days	Electrolyte Loss
12	No	4.84	1.70	3.97	0.87	51%
13	No	4.75	1.49	3.90	0.85	57%
14	No	4.92	1.67	4.19	0.73	44%
105	No	5.26	2.11	4.28	0.98	46%
123	No	4.59	1.44	3.75	0.84	58%
3	Yes	4.82		4.77	0.05	2.9%
4	Yes	4.80		4.76	0.04	2.4%
5	Yes	4.62	Avg. = 1.7	4.59	0.03	1.8%
6	Yes	4.90		4.85	0.05	2.9%
7	Yes	4.64		4.60	0.04	2.4%

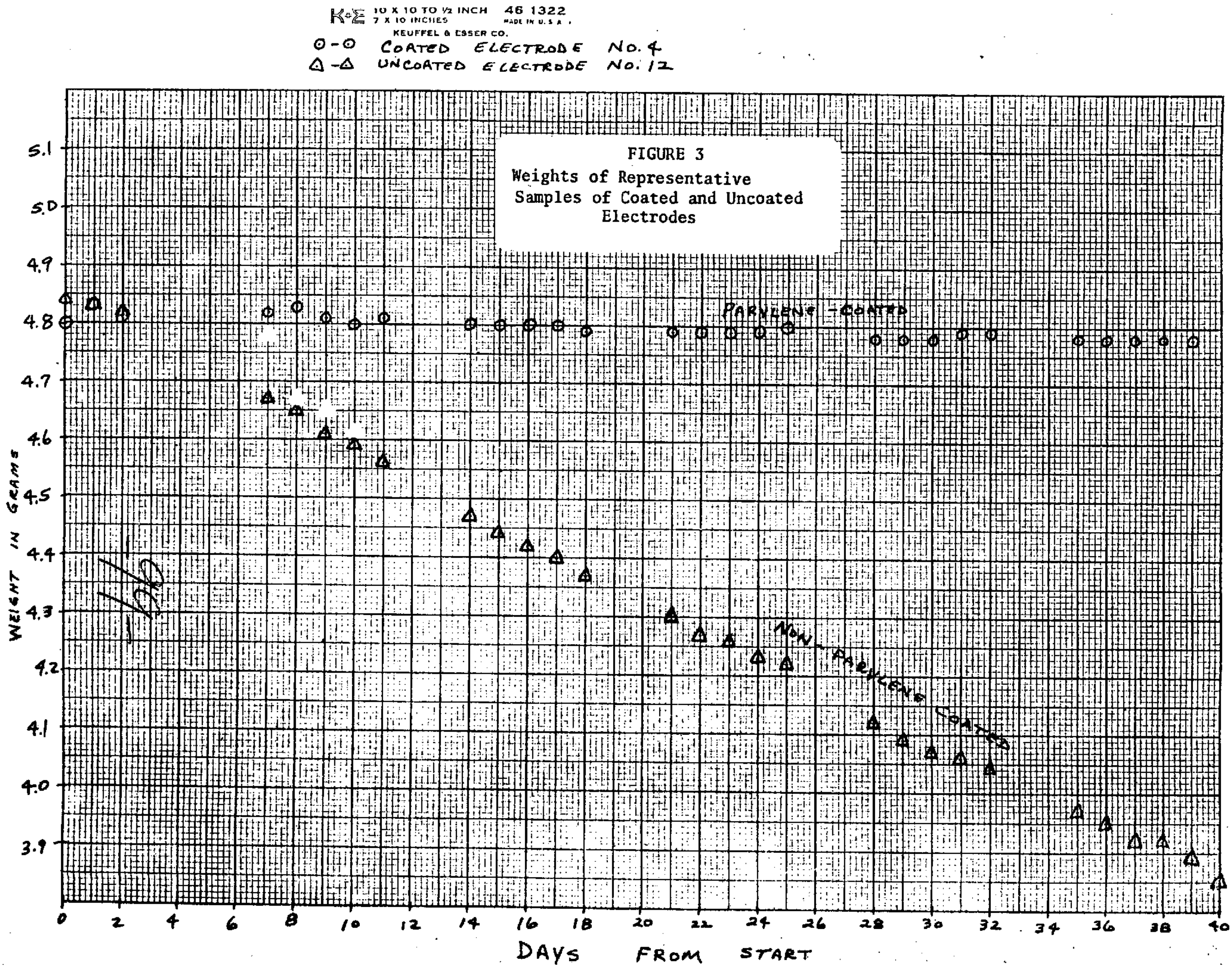
The average loss of electrolyte for the uncoated electrodes is 51% after 34 days while it is only 2.5% for the Parylene-coated electrodes over the same period of time. Figure 3 is a plot of the weights of two representative samples of electrodes, coated and uncoated. The improvement in weight loss due to the Parylene coating is obvious.

On the basis of the test results, it must be concluded that the Parylene coating reduces the electrolyte loss by approximately an order of magnitude. Thus, the shelf life of the coated electrodes is predicted to be sufficiently long in order to permit immediate fabrication for Project Skylab usage.

It is obvious that the 1-mil thickness of Parylene reduces the flexibility of the tip of the electrode. It is felt that this will not significently impair the comfort of the cap, and limited tests were run to insure that this is true.

During the month of April, SCI manufactured and delivered two prototype caps with conductive thread sewed into the fabric and with a resistor included within a cover patch. This design was to provide a safe electrostatic discharge path. The Principal Investigator (PI) subsequently tested and approved this design.

Of the two samples of conductive thread furnished by NASA-MSC, the KARMA No. 1219015Z was chozen as being the most satisfactory from a handling viewpoint. A zig-zag stitch was used to loop the thread around the cap. The resistor was connected to the thread by wrapping the thread around the lead wires and further securing the junction with conductive epoxy. The cap drawings weremodified in accordance with the chosen approach.


K+E 10 X 10 TO ½ INCH 46 1322
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.
O-O COATED ELECTRODE NO. 4
Δ-Δ UNCOATED ELECTRODE NO. 12
FIGURE 3
Weights of Representative Samples of Coated and Uncoated Electrodes
PARYLENE - COATED
NON-PARYLENE COATED
WEIGHT IN GRAMS
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
DAYS FROM START

The differences in weight loss and performance between these two caps are obvious. The Parylene coating is reducing the loss of electrolyte from the individual electrodes; however, the performance of the Parylene-coated cap assembly is still marginal after this period of time.

The lectrodes were dissected and inspected. Inspection of the silver chloride plated disc within some of the electrodes revealed the onset of corrosion, especially in the Parylene-coated electrodes. Measurement of dc resistance between pins of the cap connector revealed low resistance paths (on the order of 100 M) between electrodes. Thus, a conductive path exists across the cap, between wires, and/or between pins on the connector. Electrolytic corrosion and possible electrolysis of the water in the electrolyte are suspected because of the dissimilar metals used within this assembly.

Modified sized cap patterns were received from NASA-MSC. These patterns were designed by the PI for a better fit in the EOG and occipital regions of the cap. Prototype caps were built with this pattern and furnished for further evaluation.

New cap materials were submitted to NASA-MSC for approval during May. The cap patterns and conductive thread routing were finalized during the program.

The three experimental cap assemblies which were sealed in flight bags on March 28, 1972 were opened on May 23, 1972. The results of the tests on these caps were observed by the PI, NASA-MSC representatives, and SCI bioengineers. The data taken on this date are summarized below.

I. Original Configuration Cap (Bagged)

The weight of this cap just prior to bagging on March 28, 1972 was 78.90 grams. The weight of the cap when it was removed from the bag on May 23, 1972 (56 days later) was 78.87 grams. The relative humidity in the room at the time of unbagging was 64% and the temperature was 75°F.

The following weight changes were observed on this cap:

78.90 grams - when bagged

78.87 grams - when unbagged

78.46 grams - 2-1/2 minutes after unbagging

78.33 grams - 5 minutes after unbagging

78.20 grams - 6-1/2 minutes after unbagging

The cap was prepared for application and applied. The following data were taken utilizing the NASA-MSC electrode impedance measuring instrument.

Subject: C.R. Booher

Times Measured from application

Impedances

Time	EOG 1	EOG 2	C1	C2	01	02
1 min.	1 M	1 M	1 M	1 M	1 M	1 M
3 min.	440 K	120 K	150 K	200 K	740 K	385 K
5 min.	490 K	130 K	150 K	175 K	600 K	310 K
On SMS	NO	YES	YES	YES	NO	NO

The last line in this table indicates how the electrodes checked when the cap assembly was connected to the SMS DVTU approximately six minutes after application.

II. Parylene-Coated, Vinyl Backed Cap (Bagged)

The following data were taken on this cap:

Temperature - 75°F   Relative Humidity - 64%

Weight prior to bagging (3-28-72)   83.95 grams

Weight after unbagging (5-23-72)   83.92 grams

Weight 2-1/2 minutes after unbagging 83.78 grams

Weight 5 minutes after unbagging   83.70 grams

Times measured from application

Subject: C.R. Booher

Time	EOG 1	EOG 2	C1	C2	01	02
1 min.	1 M	50 K	100 K	91 K	310 K	240 K
3 min.	1 M	55 K	100 K	80 K	250 K	185 K
5 min.	1 M	42 K	86 K	77 K	200 K	150 K
On SMS	NO	YES	YES	YES	YES	YES

A meeting followed this test at which the following items of cap assembly critique were discussed:

1. Pouch - Two objectives were found with the current pouch; (1) the preamplifier can slip out at a corner and (2) the electrodes under the pouch are difficult to "rock" during the electrode stabilization period.

   Action - Look at making pouch smaller or at designing shell for preamplifier.

2. Silicone Electrode -to-Wire-Seal - The electrode-to-wire seal at the base of the electrode was thought to be too large and might ittitate the scalp. It is required to seal the Vyna-Kote to the silicone-insulated wire.

   Action - Make smaller.

3. Wire Routing on Cap - The wire on the cap is sufficiently tight to not allow a full stretch of the fabric.

   Action - Allow more slack in the electrode wires.

4. Strain Relief on Cap Connector - The strain relief on the cap connector is too long and interferes with preamplifier installation.

   Action - Reduce length of strain relief. Suggest looking at NASA-MSC strain relief molds for this application.

5. Bond between Parylene and Spandex - Samples of epoxy bonding were shown. It was decided that the epoxy stiffened the back of the electrodes enough to reduce the comfort of the cap.

   Action - Find a flexible adhesive that will adhere to both the Parylene and the Spandex. (Subsequently, it was shown that a silicone adhesive, with proper cleaning and priming of all surfaces, will do an excellent job for this application.)

6. <u>Continuity of Conductive Thread</u> - A completed cap assembly with conductive thread and current-limiting resistor was shown for approval. It was pointed out that the continuity of the conductive thread must be assured.

   <u>Action</u> - Make sure that the continuity of the conductive thread is checked at several points in the ATP. The routing on the conductive thread and the mounting of the resistor were approved.

Electrodes were built for life testing of wire attachment of back of silver disc. Five electrodes were built using Eccobond conductive epoxy and Scotchcase 8 epoxy sealant. Five additional electrodes were built using silver bearing solder and RTV-112. These electrodes were filled with electrolyte and sealed in metallic bags for inspection at a later date. A decision on which approach to use was made prior to the completion of SMEAT. The silver-bearing solder and RTV-112 will be used.

On June 12, 1972, a design review of the cap assemblies was conducted at NASA-MSC. Several decisions on the configuration of the cap assemblies were made as documented in the minutes of this meeting.

A two-part connector mold that has been used at NASA-MSC for several years was evaluated by SCI for potential use on the SMS cap assemblies. Drawings were generated for this new potting procedure for the strain relief of the cap connector.

All drawings, process specifications, and material specifications were updated to reflect the latest changes in configuration.

Four caps were built from government-furnished flameproof "Spandex". One was delivered with electrodes and one without. Two chain strap assemblies were built and delivered to NASA-MSC.

Two special caps were built and delivered to the PI in November. These caps were wired such that the 01 and 02 electrodes and the C1 and C2 electrodes were in parallel. The ground electrode was also relocated on these caps.

This configuration was subsequently approved for the remainder of the cap assemblies.

Meetings with the PI and NASA-MSC representatives resolved two remaining problems. It was decided to package the cap assemblies in the metallized bags with small holes punched in the corners to allow ambient pressure equalization The one-mil thick coating of Parylene was causing some irritation of the skin local to the cut-off electrode tip and was causing the wire (also coated in the process) to bend at right angles such that it appeared to break. It was decided to reduce the thickness of the coating to approximately 0.5 mil. Electrodes which were subsequently coated appeared to be improved in the qualities of concern.

All of the objectives of this program have been completed and flight cap assemblies are currently being manufactured which incorporate all of the improvements identified and tested during this program.