DEVELOPMENT AND EVALUATION
OF AN IMPEDANCE CARDIOGRAPHIC SYSTEM
TO MEASURE CARDIAC OUTPUT
AND OTHER CARDIAC PARAMETERS

July 1, 1967 to June 30, 1968

Performed under Contract No. NAS 9-4500
by
University of Minnesota
Minneapolis, Minnesota
for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Manned Spacecraft Center
Houston, Texas

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by

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D. A. Witsoe, M.E.E., and R.P. Patterson, M.E.E., Co-Investigators

University of Minnesota College of Medical Sciences
Minneapolis, Minnesota

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FOREWORD

The main objective of the last year's work was to obtain a scientific evaluation, outside of the University of Minnesota, of the Impedance Cardiograph as a means to determine cardiac output, stroke volume and other cardiac parameters. This will then provide a wider spectrum of experience and opinion upon which to base a final decision as to the use of the system during space flight.

It is with great gratitude that the cooperative efforts of the investigators, known and unknown, who have participated in this work is acknowledged.

The need is enormous for a non-invasive means to obtain information relative to cardiac function. In clinical applications it would greatly expand the range of patients that could be studied, since in many cases the surgical insertion of catheters is not justified. The same is especially true of research applications where catheterization can only be justified in unusual situations.

The work reported here has advanced the understanding of the use and limitations of the Impedance Cardiograph. Much research is still needed to build up a body of knowledge and experience to fully appreciate the potential value of the system. Similar to the history of the electrocardiograph, it probably will take years to acquire sufficient information to combine precise scientific knowledge with empirical observations into a widely acceptable clinical and research tool. New concepts must be developed to advance from measurements of cardiac output to the more intimate mechanisms of myocardial function. The Impedance Cardiograph holds great promise in this area.

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Part I

The following portion of this report was presented by invitation at two symposia. The first was held during the annual meeting of the American Association for Medical Instrumentation in Houston, July 1968. The second time was an Aerospace Medicine Symposium held as part of The International Congress of Chest Physicians in Washington D.C., October 5, 1968. In both events Dr. Charles Berry was the moderator. In each case there was evidence of considerable interest in this area judging from the response from the audience and the requests for reprints and other information. Interest has ranged from questions concerning various clinical applications to research applications such as use in high performance aircraft and the possible use on parachute jumpers during free fall. In the latter case, use of the miniature units developed for space flight were suggested with an appropriate telemetry system. In the other applications the standard Impedance Cardiograph developed in our laboratories would meet the requirements for hospital and aircraft applications since the device can operate on 115VAC, (50-400) Hz at about 25 watts. Total volume of the unit is approximately 0.75 cubic foot and weighs 16 pounds. This should be suitable for most aircraft applications.

THE IMPEDANCE CARDIOGRAPH AS A NON-INVASIVE MEANS TO MONITOR CARDIAC FUNCTION

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A four electrode Impedance Cardiograph has been developed to meet a need in clinical medicine and research laboratories for a simple, bloodless method of monitoring various parameters of cardiac function without penetrating the skin (Fig. 1). Previous work in this laboratory has been directed toward an effort to equate the small thoracic impedance changes observed during the cardiac cycle to ventricular stroke volume and cardiac output in human beings. The following equation was used for stroke volume:

$$\Delta V = \rho \frac{L^2 T}{Z^2_o} (dZ/dt)_{min}$$

ΔV = ventricular stroke volume (cc)

ρ = the electrical resistivity of blood at 100 kHz (average value 150 ohm-cm)

L = the mean distance (cm) between the two inner electrodes (2 and 3) (measured front and back) Fig. 3

Z_o = the impedance, in ohms, between the two inner electrodes (2 and 3) Fig. 3

$(dZ/dt)_{min}$ = ohms per second (Fig. 6)

T = ventricular ejection time in seconds (Fig. 6)

Cardiac Output = stroke volume x pulse rate.

Thus far this has met with limited success due to a variety of technical difficulties (1,2,3). Valvular disorders frequently make this calculation difficult due to distortions of the waveforms (Fig. 7).

The purpose of this investigation was to evaluate the Impedance Cardiograph as a non-invasive method to monitor certain parameters related to cardiac dynamics.

Methods and Procedure

Four aluminized Mylar strips attached to an adhesive tape backing are placed around the subject as shown in Fig. 1. Two strip electrodes are placed around the neck separated as far as possible. A third electrode is placed around the thorax at the level of the xiphisternal joint and a fourth electrode around the lower abdomen. A harness to support the cables connecting the electrodes to the impedance system was developed for use during various activity experiments (Fig. 2). A schematic diagram of the main elements of the Impedance Cardiograph is illustrated in Fig. 3. Electrodes 1 and 4 are attached to a constant current oscillator supplying alternating current at 100 kHz at approximately 4 ma. The impedance between electrodes 2 and 3 then produces a voltage proportional to the total impedance between impedance between electrodes 2 and 3. This total impedance has been labeled as Z_o. This impedance is usually in the range of about 25 ohms. During the cardiac cycle this impedance changes by approximately .1 to .2 ohms (ΔZ). Two differentiators are built into the system to provide the first and second time derivatives of ΔZ. The value of Z_o is read out automatically on a digital display on the front panel of the instrument (Fig. 4). The other outputs (ΔZ, dZ/dt, d^2Z/dt^2) are fed into any suitable strip chart recorder or a tape recorder. The solid state circuitry and output terminals are shown in Fig. 5. A typical recording taken on a normal young adult is shown in Fig. 6. Heart sounds, ΔZ, dZ/dt, and the ECG were recorded to illustrate the impedance events in their time relation to the cardiac cycle.

From such a recording, the (R-Z) interval, the ventricular ejection time (T) and the peak value of the first derivative $(dZ/dt)_{min}$ can be determined. The heart sounds are frequently helpful in confirming the ejection time. ΔZ was recorded since it has been observed that valvular disorders such as mitral valve insufficiency produce distortions in the waveform of ΔZ and consequently (dZ/dt), Fig. 7.

The peak negative value of the first derivative, $(dZ/dt)_{min}$, has been observed to occur simultaneous with the peak ejection rate of the left ventricle in experiments on anesthetized dogs in our laboratories (1967 Final Report). Also, in these experiments the magnitude of $(dZ/dt)_{min}$ varied in a linear fashion with variations in peak ejection rate. The (R-Z) interval includes the factor of cardiac contractility as described by Siegel, et al. (4,5) which involves the time from the R spike to the intraventricular $(dP/dT)_{max}$, as well as the time for the ventricles to reach maximum ejection rate. If future work confirms these findings, the Impedance Cardiograph can then provide a simple, non-invasive means to determine overall myocardial function. In resting, young healthy adults the (R-Z) interval has been recorded from 110 to about 150 msec, with exercise this may be reduced to 60 to 90 msec. In healthy resting young adults, $(dZ/dt)_{min}$ has been noted in the approximate range of 1.4 - 1.9 ohms per second. With exercise this value can increase to over three ohms per second. In three patients diagnosed as cardiomyopathy, $(dZ/dt)_{min}$ was found at approximately one ohm per second (.9 - 1.2). In another case with a severe ventricular septal defect $(dZ/dt)_{min}$ was recorded at 4.6 ohms per second. The (R-Z) interval was 60 msec. The ventricular ejection time has also been found to vary in relation to pulse rate.

Another clinical application of the Impedance Cardiograph has been as a monitor of cardiac function without measuring the various parameters described. The visual observation and comparison of a series of impedance cardiograms following cardiac surgery has provided the surgical staff a rapid and convenient means to follow the patient's recovery. Two examples are shown in figures 7, 8 and 9. Recordings of the heart sounds and (dZ/dt) on a patient in which the suture line holding an artificial mitral valve had opened are shown in figure 7. The pre-operative waveform of both ΔZ and (dZ/dt) were greatly distorted due to the regurgitation of blood around the mitral valve. Two hours following repair of the valve the (dZ/dt) waveform approximated a normal waveform except that the value of $(dZ/dt)_{min}$ was very small indicating a very feeble ventricular ejection. This correlated with the clinical observation of a critically ill patient very near a shock status. Twenty-four hours later it can be seen that the ventricular ejection was much stronger as indicated by the increase in the height of (dZ/dt) and with the waveform improving more toward the normal characteristics. This again correlated with the clinical observations that the patient had improved but was still considered critical.

In order to assess the value of impedance measurements in patients with severe cardiac abnormalities, post-operative records were taken on a patient who had received three artificial valves and had an extremely enlarged heart. Figure 8 is a photograph of a post-operative chest x-ray of the patient showing the three artificial valves (mitral, tricuspid, and aortic) as well as the greatly enlarged heart. Recordings of the (dZ/dt) impedance waveform taken two hours, twenty-four hours, and seventy-two hours post-operative are shown in Fig. 9. The two hours post-operative record indicates an irregular heart rate and small amplitude but typically formed (dZ/dt) waveform. By 24 hours post-operative, the heart rate had become more regular and some increase in the (dZ/dt) amplitude is seen. For the records shown in Fig. 9, the average two hour post-operative heart rate was 150 bpm, 24 hours 77 bpm and 72 hours 81 bpm. With increased pulse rates in normal subjects we have noted a diminished amplitude of (dZ/dt) tracings for relatively constant cardiac output, thus the small amplitude signals of the two hour post-operative measurement when compared to the 24 hour post-operative measurement could be due in part to the differences in pulse rates. It is of interest to note, however, that the pulse rates at 24 hours and 72 hours post-operative were approximately the same; while the 72 hour (dZ/dt) waveform had a considerably larger amplitude indicating a more forceful ventricular ejection and an increased stroke volume. Significantly, the patient's clinical appearance had greatly improved at 72 hours as he was sitting up in bed and talking with the nurses.

Although the records shown on one patient do not provide conclusive proof for all cases, it is apparent that the metal valves and enlarged heart did not affect the origin of the ΔZ

waveform or the response of the waveform to increases in quality of cardiac functions such as contractility and cardiac output. Also, examination of the (dZ/dt) waveform only, without computation of stroke volume and cardiac output, provided the surgeons with a quick and convenient means to assess cardiac function without the additional surgical trauma associated with the dye dilution or similar techniques for measuring cardiac output.

Discussion

It appears that with additional clinical experience and basic research that the Impedance Cardiograph will become a very useful means to obtain information relating to cardiac function without penetrating the skin in both clinical and research applications. In addition, preliminary observations indicate that the system should be of value in certain pulmonary diseases. The value Z_o is a measure of the total impedance from the base of the neck to the xiphisternal joint. In the event of pulmonary congestion or edema, the value of Z_o will be low due to a greater conductivity through the chest. The converse is true with increasing volume of air in the chest. The ratio of $L^2/Z_o{}^2$ corrects for variations in distance between the electrodes (2 and 3), Fig. 3. It appears that this ratio will be of value in following certain chest diseases without penetrating the skin and with a reduced number of chest x-rays.

Summary

1. The Impedance Cardiograph as described here is a device capable of providing information concerning the mechanical function

of the heart without penetrating the skin. The entire procedure is comparable to that of recording the electrocardiogram. The system creates no hazard nor discomfort to the patient or experimental subject. The procedure to obtain the impedance information is simple, convenient and inexpensive, suitable for any clinical or research application.

2. The device can be used in a variety of applications.
   a. Various parameters of cardiac function can be calculated or measured for a permanent record providing the heart valves are intact.
   b. Serial recordings on a strip chart can provide the physician with a rapid and easy means to monitor cardiac function. These signals are also suitable for display on cathode ray tubes in a cardiac monitoring center. One such application would be the simultaneous display of (dZ/dt) and the electrocardiogram. Thus any discrepancies between ventricular ejection and the ECG would become apparent.
   c. Valvular disorders produce changes in the waveform of both ΔZ and (dZ/dt). This shows promise of value as a diagnostic aid. Unfortunately this also makes calculation of stroke volume difficult if not impossible.
   d. The electrodes are disposable, comfortable and have been left in place up to four days without difficulties.
3. Further investigation of the Impedance Cardiograph is needed to determine the full significance and usefulness of the system. The cardiac parameters observed in this study should also be

recorded during prolonged space flight. If this is not possible, at least pre and post flight recordings should be made.

1. Electrical impedance plethysmography. Nyboer, J., and C.C. Thomas. Springfield, Illinois.

2. Principles of applied biomedical instrumentation. Geddes, L.A. and L.E. Baker. John Wiley & Sons Inc. New York, New York.

3. Development and evaluation of an impedance cardiac output system. Kubicek, W.G., J.N. Karnegis, R.P. Patterson, D.A. Witsoe and R.H. Mattson. Aerospace Medicine, Vol. 37, No. 12, Dec. 1966.

4. The quantification of myocardial contractility in dog and man. Siegel, J.H., E.H. Sonnenblick, R.D. Judge, and W.S. Wilson. Cardiologia 45:189-220, 1964.

5. The quantification of myocardial contractility by impedance plethysmography. Siegel, J.H. and M. Fabian. Fed. Proc. March-April 1968, Vol. 27, page 445.

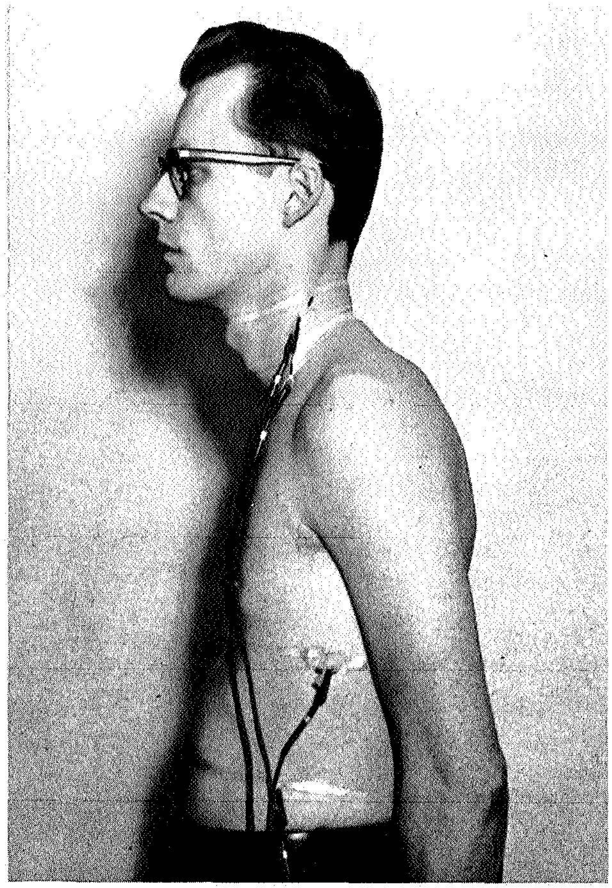

Fig. 1 The disposable electrodes made of aluminized Mylar strips on an adhesive tape backing are shown with the lead wires from the impedance system attached.

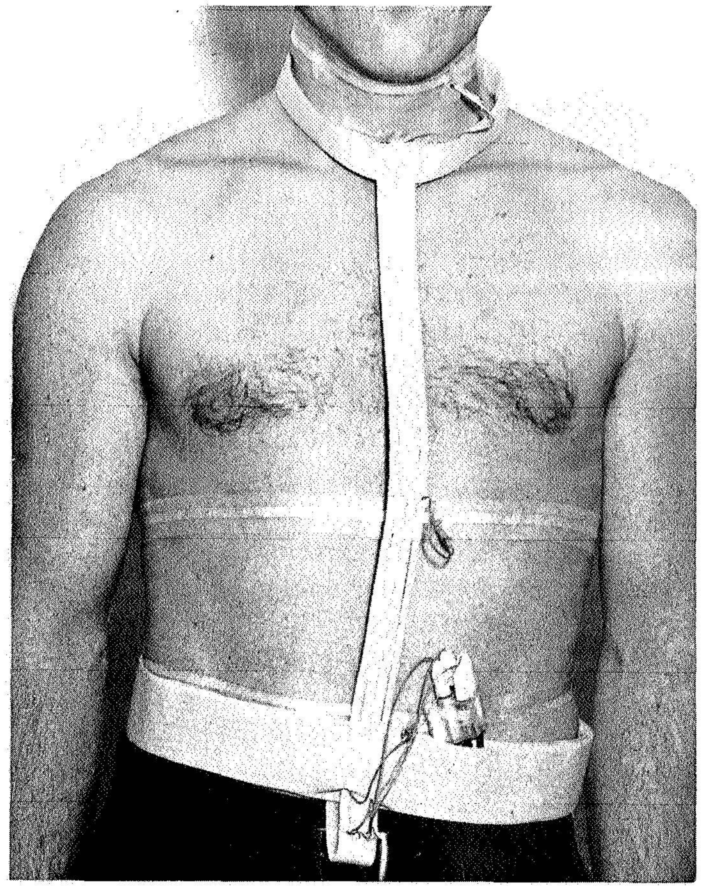

Fig. 2 A view of the Velcro harness to support the connecting cables.

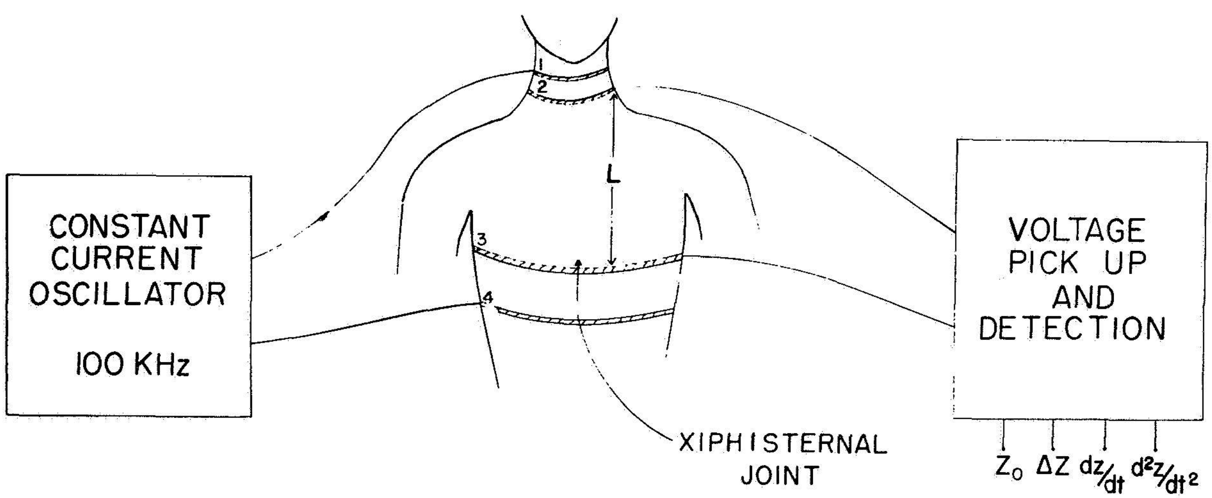

Fig. 3 A schematic diagram of the main elements of the Impedance Cardiograph connected to the electrodes shown in Fig. 1.

Fig. 4 The front panel of the Impedance Cardiograph showing the controls and the automatic digital display of Z_o.

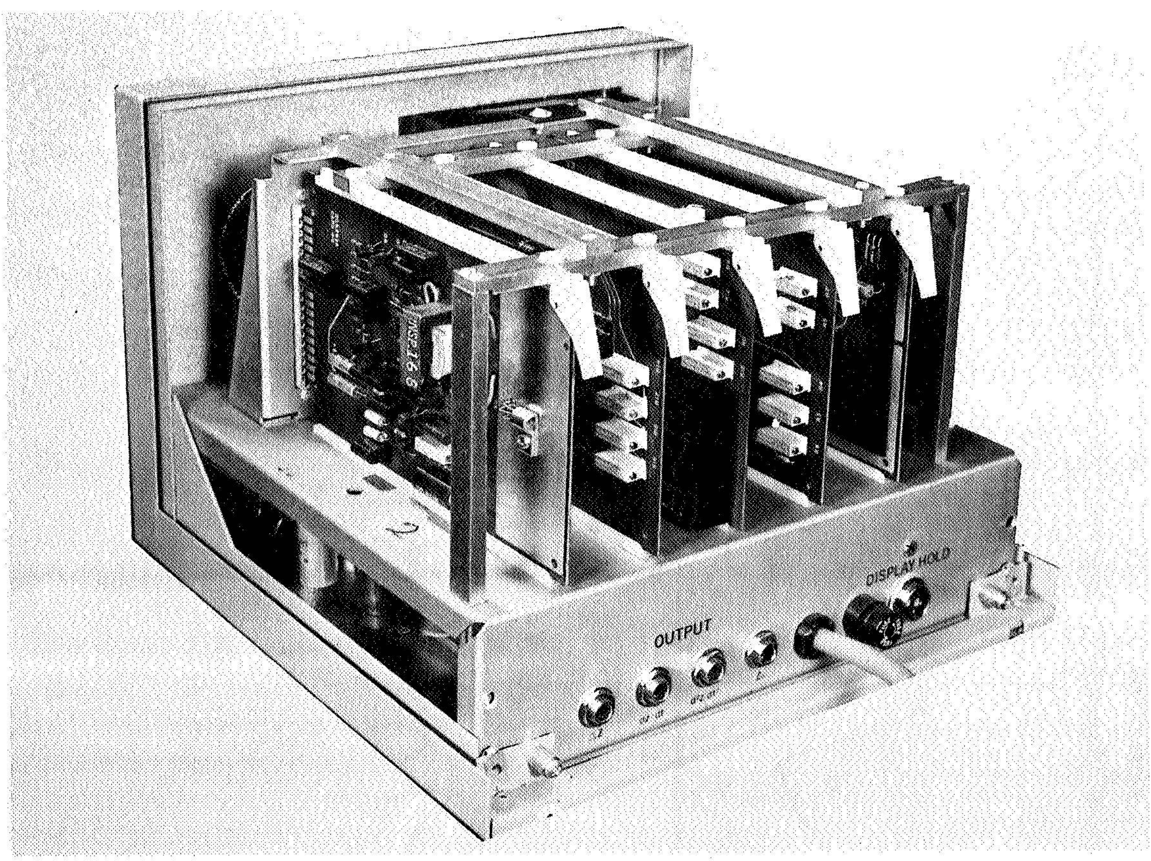

Fig. 5 A view of the solid state circuitry and output terminals.

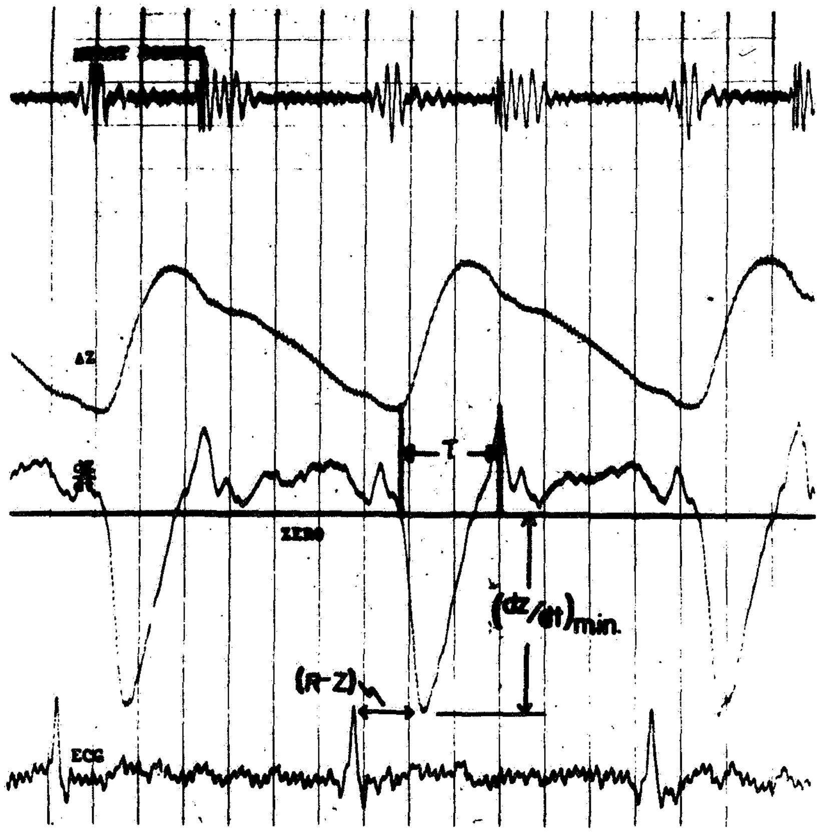

Fig. 6 A record of heart sounds, ΔZ, (dZ/dt) and the ECG taken on a normal adult. The ventricular ejection time (T), the (R-Z) interval and $(dZ/dt)_{min}$ are shown. Time marks 100 msec.

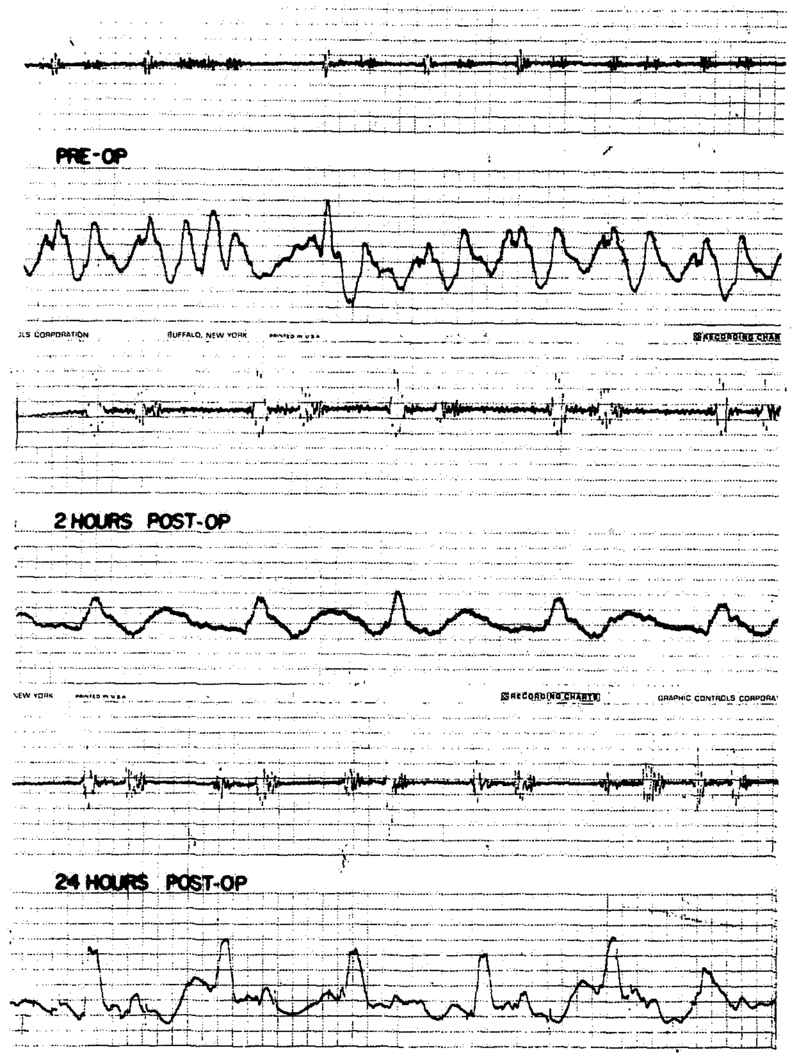

Fig. 7 Recordings of heart sounds and (dZ/dt) taken before and following surgery to repair a leak around an artificial mitral valve. Time marks 100 msec.

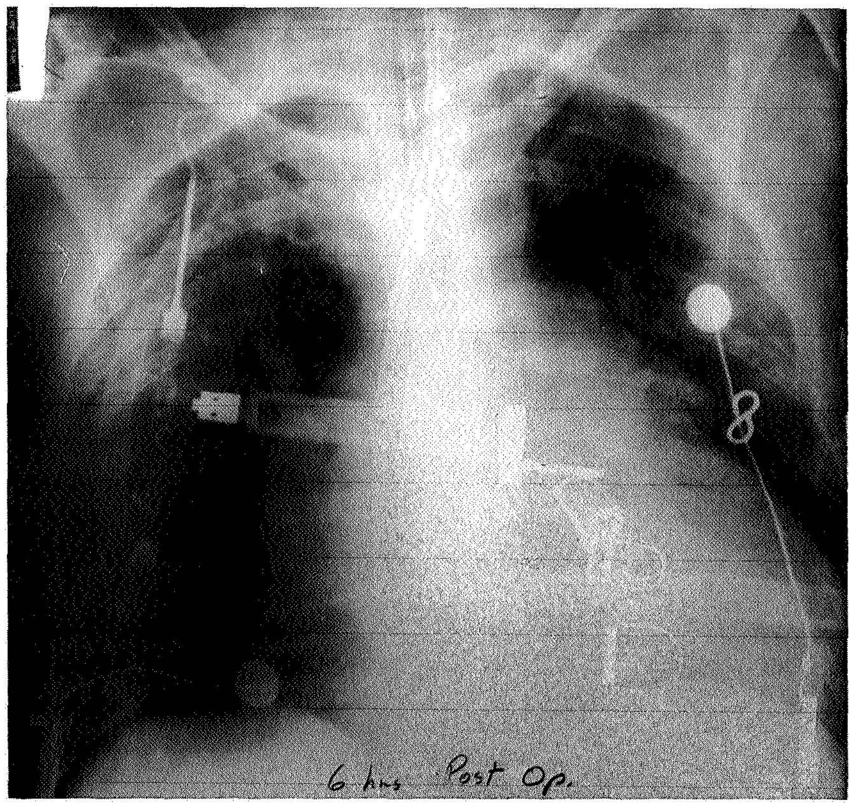

Fig. 8 A chest x-ray showing an enlarged heart with three artificial valves (mitral, tricuspid and aortic).

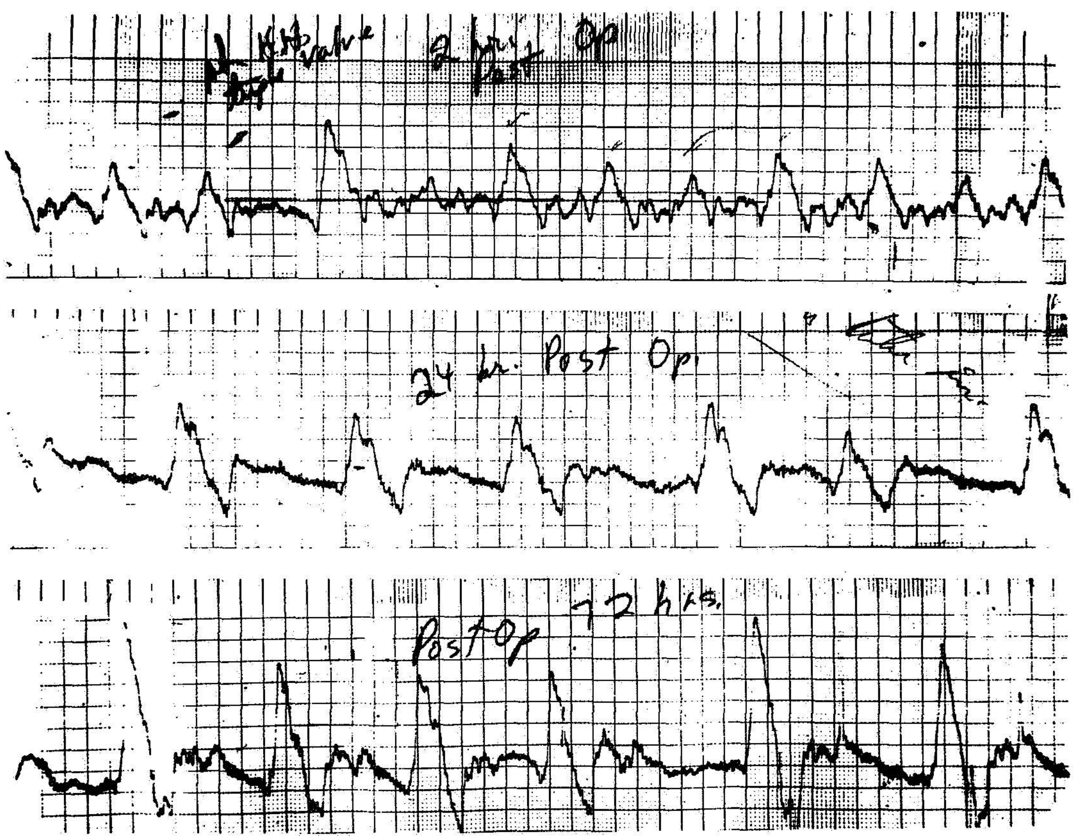

Fig. 9 Recordings of (dZ/dt), two, twenty-four and seventy-two hours following surgery to insert the valves shown in Fig. 7. Time marks 100 msec.

PART II

A COMPARISON STUDY OF SIMULTANEOUS CARDIAC OUTPUT DETERMINATIONS BY THE IMPEDANCE METHOD AND INDICATOR DILUTION TECHNIQUE OR THE FICK METHOD

Following pages display the name and address of the principal investigators who have conducted comparison studies between the impedance and indicator dilution techniques and have submitted data. On the opposite page is a brief description of their experimental design. In addition, Dr. Loren Heather, Orange County Medical Center, Orange, California and Dr. Homer Warner, Latter-Day Saint's Hospital, Salt Lake City, Utah have similar projects under way but have not as yet submitted data. All of these investigators are to be commended for their work in a very short time. In most cases the Impedance Cardiograph was delivered to these centers in the late fall of 1967 or winter of 1968. Dr. Smith and his colleagues at Marquette University obtained a unit on loan for four months this past summer. The listing of the principal investigators is according to the person responsible for acquisition of the Impedance Cardiograph. The listing, undoubtedly, does not do justice to the many colleagues associated with each project.

Dr. Smith submitted a detailed report along with their data. This report is intended as a first draft of a manuscript for publication. Dr. Greenfield submitted a reprint of published data along with additional data subsequent to the publication. These two reports are included in their entirety.

These data are not included in the following group.

The other investigators submitted an amazing amount of data in a very short time. Consequently only a brief description of the details of each study is avilable. All data are tabulated as submitted from each laboratory. In addition, we have computed impedance to standard method ratios of cardiac output. When possible we also calculated the mean of these ratios for each individual or each patient. The mean ratio was then used to correct the impedance cardiac output values. Each set of data was then plotted in two ways; a) the absolute values as submitted from each laboratory and b) the individual corrected impedance values plotted against the values by the standard method. A total of 220 simultaneous comparison values were obtained from these laboratories. These points are presented in a combined graph in figure II-1 and the combined graph with the individual corrected impedance values are presented in figure II-2. This procedure was used in order to provide a rapid picture of the comparison data. It has been suggested that the impedance method would improve in its usefulness if even one or two simultaneous determinations of cardiac output by the impedance method and by some standard method could be obtained to first, in effect, calibrate the individual. This should then improve the reliability of the impedance method for prolonged observation of cardiac output and relative changes in cardiac output in situations where catheters could not be maintained in place for long periods of time.

An extensive statistical study of these data has not been attempted since a symposium is planned where each investigator will be invited to present his own data in more detailed form. Most investigators have indicated that more data will be available at a later time.

It has become apparent that certain valvular disorders may distort the ΔZ and consequently the (dZ/dt) waveform and thus make the calculation of stroke volume by the impedance method difficult. Consequently some of the data presented may have been altered by these difficulties.

In other cases no obvious reason could be presented for the differences between the impedance and standard method values of stroke volume or cardiac output.

Dr. Smith et al. reported a high correlation between the absolute values of cardiac output by the impedance and dye dilution methods during passive tilt experiments. Their normalized data do not show as good a correlation as the absolute values. If the mean of the Z to Dye ratios had been used rather than the first values in each experiment the effect of random variations may have been reduced.

As indicated by Dr. Greenfield and others, more research and experience is needed to improve the formula used to calculate stroke volume by the impedance method.

An enormous need still exists for a simple atraumatic technique to determine several parameters of cardiac function. Further investigation of all possible applications of the impedance system to cardiovascular physiology is justified in view of the progress that has been made during a very brief field trial.

	Principal Investigator	Center
1.	Dr. Robert S. Eliot Division of Cardiology	University of Florida Gainsville, Florida
2.	Dr. Joseph C. Greenfield, Jr. Applied Physiology Laboratory	Durham V.A. Hospital Durham, North Carolina
3.	Mr. William Judy, formerly of Department of Physiology	Baylor University Houston, Texas
4.	Dr. J.N. Karnegis, Director Cardiac Catheter Laboratory	Miller Hospital St. Paul, Minnesota
5.	Dr. Thomas Killip, *et al.*, Head, Section of Cardiology	Cornell Medical Center New York, New York
6.	Dr. Ronald Lauer Department of Pediatrics	U. of Kansas Medical Center Kansas City, Kansas
7.	Dr. Wayne Martin Dept. of Anesthesiology	U. of Washington Medical School Seattle, Washington
8.	Dr. James Ronan Division of Cardiology	Georgetown U. Medical Center Washington, D.C.
9.	Dr. J. H. Siegel & M. Fabian Department of Surgery	Jacobi Medical Center Bronx, New York
10.	Dr. James J. Smith *et al.* Departments of Physiology & Mechanical Engineering	Marquette University Milwaukee, Wisconsin
11.	Dr. J. Richard Warbasse, *et al.* Chief, Cardiovascular Service & Laboratory	U.S. Public Health Service Hospital Baltimore, Maryland

Standard Method Utilized	Intervention	Material
Cardiogreen indicator dilution	Isuprel infusion	patients
Pressure gradient technic for instantaneous S.V. Cardiogreen indicator dilution	Electrical pacing Isoproterenol infusion	patients
Isotope indicator dilution	Supine bicycle exercise	volunteers
Direct Fick Cardiogreen indicator dilution	Supine bicycle exercise Isuprel infusion	patients
Cardiogreen indicator dilution	Electrical pacing	patients
Direct Fick	Isuprel infusion	patients
Cardiogreen indicator dilution	Anesthetized patients-effect of nitrous-oxide on halothane anesthesia	patients
Cardiogreen indicator dilution	Shock Isuprel infusion Angiotension	patients
Cardiogreen indicator dilution	Isuprel Inhalation-100% O_2	patients
Cardiogreen indicator dilution	70° passive tilt	volunteers
Cardiogreen indicator dilution	Supine bicycle exercise Isuprel infusion	patients

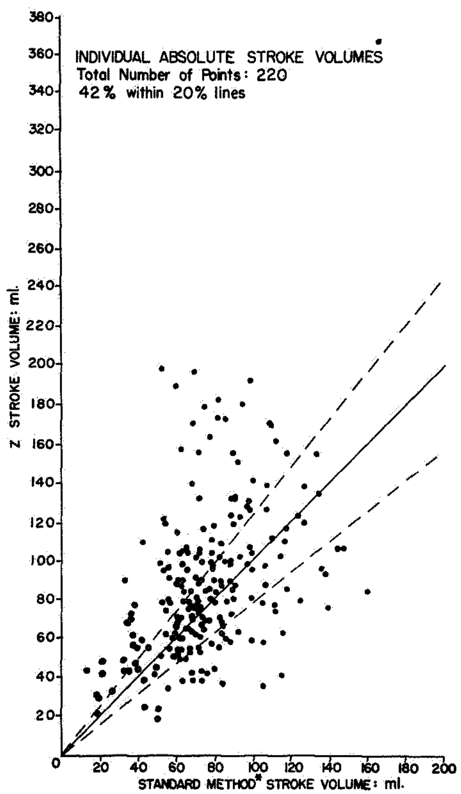

Fig. II-1 A composite graph of all of the stroke volume values obtained by the Impedance method plotted against the values of stroke volume obtained by the Dye, Fick or Isotope dilution technique

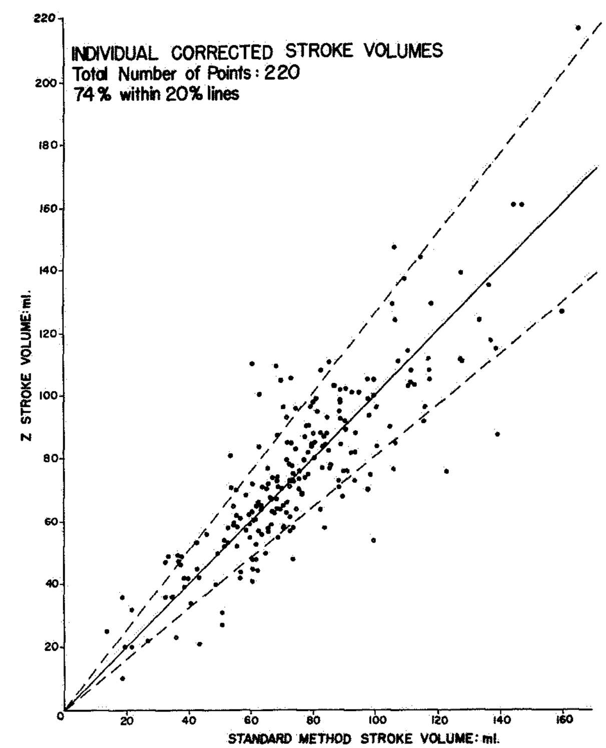

Fig. II-2 A composite graph of the corrected stroke volume values obtained by the Impedance method plotted against the original values of stroke volume obtained by one of the standard methods

The Application of Impedance Cardiography to the Study of Postural Stress in the Human

John E. Bush, Ph.D., V. Thomas Wiedmeier, Ph.D.,
Felix E. Tristani, M.D. and James J. Smith, M.D., Ph.D.

From the Department of Physiology, Marquette School of Medicine,
Department of Mechanical Engineering, Marquette University,
and the Section on Clinical Hemodynamics,
Wood Veterans Administration Hospital

Milwaukee, Wisconsin

A TRIBUTE

Dr. John E. Bush, age 33, Associate Professor of Engineering and senior author of this paper died in a hunting accident on October 13, 1968. This project, on which he worked with infectious enthusiasm, was carried out with spirit, thoroughness and imagination and with his characteristic zeal for getting at the root of the problem.

From the give and take in the research lab, from the joint efforts to get the data and the often noisy discussions of what the data really meant, he came through to us as a person unfailingly considerate of his fellow man, with little pretense and much compassion.

Accordingly, we who knew him and worked with him are proud to dedicate our continuing efforts in this project to John Bush--scientist, colleague, friend.

It is our intent in the following to document our experience with the Minnesota Impedance Cardiograph during a study of human responses to graded circulatory stress and specifically to a standard head-up tilt test.

The two main components of any circulatory response are central or cardiac, and peripheral. The scarcity of practicable methods for the measurement of stroke volume and cardiac output is well known; even scarcer are methods which are applicable to intact, unanesthetized human subjects during the application of stress.

Although transthoracic impedance has been previously suggested for the biological measurement of volume and flow, particularly in respiration (1,2), only recently has a serious effort been made by Kubicek, Kinnen and their colleagues (3,4,5,6) to adapt electrical impedance to cardiography. These studies have indicated that upon the passage of a constant sinusoidal current across the chest there are impedance changes which are synchronous with the cardiac cycle and that the first derivative of the main impedance wave seems to be a predictable function of aortic blood flow (3). Comparison of impedance-calculated cardiac output with a standard dye-dilution method yielded good agreement in the case of the dog (4) and satisfactory correlation in the human (3).

However, recent evidence on the validity of the impedance method in cardiography has been somewhat conflicting. Harley and Greenfield (7) tested the Minnesota instrument in normal individuals and cardiac patients and found the impedance-calculated output relatively unsatisfactory, at least in certain cardiac disorders; they added however that the method has potential value and deserved further evaluation. Hill *et al.* presented a rather gloomy picture of the usefulness of electrical impedance plethysmography, primarily on theoretical grounds (8).

On the other hand, Coleman *et al.* (9) found impedance cardiography to be a useful tool in their study of cardiodynamic responses of the human to heat and reported good agreement in the dog between the impedance-predicted cardiac output and aortic flow as determined with the electromagnetic flowmeter. Siegel and Fabian (10) believe that the first derivative of the impedance wave (dz/dt) provides valuable information on the development of ventricular pressure (maximum dp/dt) and suggested that this parameter may be a valid estimate of myocardial contractile force in the intact animal or human; this possibility was originally suggested by Kubicek (4). Recent reports by Namon and Gollan (11,12) have further indicated that, in the dog, the transthoracic impedance was an effective measure of stroke volume and that in their view the reactive impedance component is considerably more useful in this regard than the resistance fraction.

The possible utility of a non-invasive and easily adaptable method of measuring cardiac output in the intact human prompted us to conduct the present investigations with two primary objectives in mind: 1) To determine the validity of the transthoracic impedance method for the measurement of cardiac output in the intact human and 2) to determine its usefulness in studying the response of the cardiovascular system to a standardized postural stress.

Methods and Procedure

The present study was carried out in three phases:

Series I: The Determination of the Validity of the Impedance Method for Cardiac Output--Eight normal male subjects, 20-26 years of age, were used in these experiments. Simultaneous cardiac output determinations were made with dye-dilution and the impedance method in the supine position, at various stages of a 20-minute, 70° head-up tilt, and during the subsequent supine recovery period. In this series, the subject when tilted stood on a footboard, i.e., the body weight was transmitted to the feet.

These experiments were performed in the Catheterization Laboratory of the Research Service of the Veterans Administration Hospital under the direction of Dr. Tristani. After infiltration of local anesthetic, a disposable polyethylene needle was inserted into the right brachial artery and a venous catheter into a right antecubital vein. Indicator-dilution curves were obtained following bolus injection of 5 mg of Indocyanine green into the antecubital vein while continuously withdrawing blood from the arterial needle through a Gilford pump and a Gilford densitometer. The curves were inscribed on an Electronics-for-Medicine DC amplifier and recorder. Cardiac output was calculated using the standard Stewart-Hamilton method. The transthoracic impedance wave and the first derivative of the impedance wave were simultaneously recorded on the same instrument.

Series II: A Study of Cardiorespiratory Responses to Postural Stress with Hip Suspension--In these experiments, normal males, 20-26 years of age, were subjected to a 20-minute vertical tilt involving pelvic suspension on a bicycle seat; the legs of the subject were unsupported. The seat was fixed to the tilt table so the subject could be passively shifted from the supine to the suspended position. Twelve experiments were done on eight subjects; in four cases, the test was repeated in the same subject at an interval of about one week in order to study the repeatability of the responses. In this series, precordial ECG and tachograph (Model 5P4, Grass Instrument Co., Quincy, Mass.) recordings were made in addition to impedance. Systolic and diastolic blood pressures were automatically recorded through a microphone pickup of the Korotkoff sounds as previously described (13). Pulmonary alveolar CO_2 tension was monitored with a Beckman gas analyzer (Spinco Model LB-1), ventilatory volume with a wide bore, low resistance, differential pressure gas flowmeter and respiratory rate by fluctuations of this flowmeter record. All of these variables were recorded simultaneously on two Grass Polygraphs (Model 5, Grass Instrument Co., Quincy, Mass.).

Series III: A Study of Impedance Cardiographic Responses to Postural Stress in the Passively Tilted, Standing Subject--In this series, normal males, 20-26 years of age, were placed in a 70° head-up position with body weight transmitted to the feet. The procedure for this series was similar to that in Series I except that no arterial or venous punctures were made.

In all experiments, the general procedure was similar to that previously described (13), i.e., the room was darkened and kept quiet, the subject was instructed to keep his eyes closed and relax and the room temperature was held at 75 ± 3°F. The signal from the cardiograph was recorded at several minute intervals throughout the test; during recording of the impedance signal, the subject was instructed to "exhale in the ordinary way and hold the breath without bearing down". This was done to minimize the effect of respiration on the impedance signal as recommended by Kubicek (4) and to reduce the tendency of the subject to a Valsalva maneuver.

Impedance Recordings

The Minnesota Impedance Cardiograph, Model 202, used in this study is a four-electrode, impedance plethysmographic system developed to monitor left ventricular output (4). Two band electrodes (3M tape) were placed around the subject's neck and separated by 2 cm; a third was placed around the thorax 1 cm below the xiphisternal joint, and the fourth around the lower abdomen. The electrode placements are illustrated in Figure 1. The upper neck and abdominal electrodes were excited by a 100 KHZ constant sinusoidal current and the resulting voltage (proportional to the magnitude of impedance changes) was monitored from the inner two electrodes. Previous work has indicated that the first derivative of the impedance signal is functionally related to the stroke volume of the heart. Kubicek states that the relationship appears to be more consistent for relative changes than for absolute determinations (4); hence, in most of our studies relative (normalized) impedance values are presented as well as the absolute values.

The form of the impedance signal as recorded from the cardiograph is shown in Figure 2. The right half of the recording contains the calibration signals and the left half contains the actual impedance signal. The upper channel shows the change in thoracic impedance (ΔZ)

while the middle channel indicates the time derivative of the impedance wave, i.e., dz/dt. On the lower channel is the ECG from modified bipolar chest leads. The method recommended for calculating stroke volume in milliliters involves the following equation (4):

$$\Delta V = \rho \frac{L^2}{Z_0^2} T \left|\frac{dz}{dt}\right|_{max} \qquad \ldots. [1]$$

where ρ = blood resistivity (= 150Ω-cm)

L = mean distance between inner electrodes (cm)

Z_0 = basic impedance between the two inner electrodes

T = ventricular ejection time as described in Figure 2

$\left|\frac{dz}{dt}\right|_{max}$ = magnitude of peak value of impedance signal (see Fig. 2)

The above equation is based on a model which assumes that the change in the impedance signal is due to a change in volume of a cylinder of blood of length, L (pure resistance), which conducts current in parallel with the other thoracic elements. For calculating relative changes in stroke volume, Eq. 1 is normalized with respect to a reference value, $[\Delta V]_r$ so that

$$NSV = \frac{\Delta V}{[\Delta V]_r} \qquad \ldots. [2]$$

Similarly, the normalized cardiac output (NCO) is calculated as:

$$NCO = \frac{\Delta V \times HR}{[\Delta V \times HR]_r} \qquad \ldots. [3]$$

where HR is the heart rate.

The values for T, $\left|\frac{dz}{dt}\right|_{max}$ and HR used in the above equations were taken from the impedance signals and averaged for five heart beats whenever possible. The impedance signals were recorded at 2-3 minute intervals at a paper speed of 50 mm/sec. In most cases, the reference values, $[\ ]_r$, are averages of the last readings prior to tilting.

Results

Series I: Validity of the Impedance Method

Values obtained during simultaneous determinations of stroke volume (SV) and cardiac output (CO) are plotted in Figures 3 and 4 and the respective normalized values, i.e., ratios, in Figures 5 and 6. In the latter instances, the first resting supine value for each individual was used as a reference for the determination of the proportional stroke volume (or cardiac output) for the remaining determinations with that method in that subject. There was good correlation between the absolute values for SV and CO but lesser correlation between the relative ones. In order to determine if there was a systematic tendency for one method to read higher or lower than the other, ratios of impedance (Z) CO/dye-dilution CO were calculated for each set of determinations and the results are shown in Table 1. Certain subjects had relatively higher impedance values and others lower ones but the mean ratio of 1.09 indicated a small tendency toward overestimation of the CO with the impedance method. The supine or vertical position did not seem to appreciably affect the ratio.

Series II: Study of Cardiovascular Responses to Vertical Hip Suspension

In Figure 7 are shown mean values for heart rate, normalized stroke volume and cardiac output, systolic and diastolic blood pressure and total peripheral resistance (TPR) before, during and after the 20-minute suspended tilt. The data show that incident to tilt there is a rise in heart rate, a fall in stroke volume and cardiac output, and a rise in diastolic pressure with a slight decline in pulse pressure. These results are similar to those previously reported in passive head-up tilt (13).

The TPR was calculated as the quotient of the mean arterial blood pressure (DP + 1/3PP) and the cardiac output. By having the pretilt value for each individual serve as his own control, the relative total peripheral resistance ratios were calculated during the different parts of the experiment for each of the subjects. The mean values indicate a rise in TPR during tilt which is the expected response. The usual small rise in mean arterial blood pressure during the tilt, and the almost universal fall in cardiac output result in a significant rise in the calculated resistance quotient.

There was a great deal of individual variation in the pattern of the circulatory response to the tilt. For example, the blood pressure records of subjects M.Bo. (Fig. 8) and J.Ki. (Fig. 9) were quite similar but the central and peripheral mechanisms to maintain the pressures were evidently very different in the two cases. Subject M.Bo. (Fig. 8) had very little decrease in cardiac output and only a modest rise in heart rate so that there was relatively little change in total peripheral resistance. Subject J.Ki. (Fig. 9) had not only a more marked response in heart rate but also a sharp persistent fall in cardiac output. A marked vasoconstriction to a sizable tissue mass was obviously required in this case to maintain the blood pressure. The availability of impedance cardiographic data is most advantageous for analysis of such mechanisms.

The impedance cardiographic data which was available also permitted the calculation of additional auxiliary data useful in analyzing circulatory function. In Figure 10 are shown mean values for the amplitude of the derivative of the impedance wave (dz/dt) (in absolute and relative units) and the ejection time index (ETI) which was calculated according to the method of Weissler *et al.* (14) using the formula: ETI = T + 0.0016 HR. Since neither the phonocardiogram nor the carotid pulse was recorded during this study, the ejection time (T) from the impedance signal was used.

The height of the impedance derivative may provide information comparable to dp/dt in the aorta and as such, furnish an approximate measure of cardiac contractile power (4); the prevailing tendency during tilt was toward a decline in dz/dt. The mean values for ETI decreased during passive tilt (Fig. 10) but the absolute values--both during the control and tilt periods--were less than those previously reported (14). It is not certain at this time whether this disparity is associated with the use of the impedance time (T) in our study or to other factors.

Variations in the R-ΔZ interval (period from the R wave of the ECG to the ejection of blood into the aorta) includes the time of ventricular electromechanical delay but in the main represents alterations in the time of isometric contraction period (4). Mean values for these determinations during suspended tilt are also shown in Figure 10 and indicate a distinct prolongation during postural stress.

Series III: Study of Impedance Cardiographic Responses to Head-up Tilt with Feet Supported

In the final series, eleven normal males were subjected to 20 minutes of 70° head-up tilt which involved quiet standing with feet resting on a footboard so that the body weight was directly transmitted to the lower extremities. The mean values for heart rate, stroke volume and cardiac output (absolute and normalized) are plotted in Figure 11. The comparison of the cardiovascular responses to footboard tilt (Fig. 11) and to hip suspension tilt (Fig. 9) indicate that the responses were very similar; comparison of records in individuals who underwent both types of stress indicated a tendency for more marked response in the case of the footboard tilt as evidenced by a greater increase in heart rate and a more marked fall in cardiac output. This finding was rather unexpected since the suspension of the body without support to the lower extremities is almost universally considered to be a more severe stress. This question however requires further investigation with additional subjects.

Discussion

The rather high correlation of absolute values for stroke volume (SV) and cardiac output (CO) derived from the two methods was somewhat surprising since previous reports had emphasized that impedance is useful primarily for determining relative changes in cardiac output (4,7). Kubicek, in his dog experiments, found good agreement between cardiac output (Z values) and aortic flows as determined with the electromagnetic flowmeter. However, the regression slopes were different for different animals which would indicate that absolute values for impedance changes are not likely to be comparable from one individual to the other (4).

Nevertheless, the correlation coefficients obtained in our study were high, suggesting that further exploration of impedance as a measure of cardiac output would certainly be warranted. Two factors might be taken into consideration in evaluating our results. Firstly, our study was done in resting and posturally stressed subjects in which the cardiac outputs were almost invariably normal or subnormal and only rarely increased. It is possible that the impedance method is more reliable when used within the normal and low range of cardiac output rather than at the higher lvels. Visual inspection of our scattergrams (Figs. 3,4, 5 and 6) suggests that the correlation of absolute values was about the same at low outputs as at high outputs. However, the correlation of normalized stroke volumes seemed to be less in the lower output range although our "n" was relatively small for such an analysis. Previous efforts at validation have indicated a greater dispersion of values when cardiac output was increased with exercise or isoproterenol injection (3,7); a second possible factor in our study was the apparent improvement in the instrument since the report of Harley and Greenfield (7). In addition to the direct readout of the derivative (dz/dt), we have been favorably impressed with the applicability of the instrument for laboratory use. The output signals are in the neighborhood of 0.5 volts and can be easily recorded. The 3M electrode tape is easy to apply and produces little discomfort to the subject if it is not applied too tightly. Contact resistances were not checked but no problems were encountered with the electrode tape. The electrode locations did not interfere with other instruments typically used. Electrocardiogram electrodes can be applied between the impedance electrodes without affecting either signal as long as the ground for the ECG is below the fourth impedance electrode.

The study of the circulatory responses of normal male subjects to postural stress in the form of a 20-minute hip suspension indicated considerable individual variation--which has been the experience of most investigators in this area. Additional cardiac data--such as may be obtained with the impedance cardiograph--could be very helpful in exploring the factors underlying these differences as it was in this study.

Impedance cardiographic information also yields the possibility of additional derived data for the assessment of physiological performance as exemplified in Figure 10. Obviously the validity of such derived data will depend upon further substantiation of the impedance data itself; nonetheless, the assessment of characteristics such as ventricular contractility represents a very interesting potential.

Because of its relative practicability, the instrument may be used to study repeatability of response in the same subject. When we compared the records of repetitive tilt-saddle experiments, there appeared to be repeatable patterns of response in stroke volume, cardiac output, heart rate, blood pressure and TPR characteristic of the individual. This very important problem needs to be studied with considerable care and with greater precision. The main point however is that the cardiograph provides a means of obtaining more detailed useful cardiovascular data on individual response to repeated stress--which represents a very important need in human stress physiology.

The atraumatic nature of the procedure is a significant advantage. Although the availability of well-trained subjects and skillful techniques will permit laboratory use of indwelling catheters, a non-invasive and convenient method such as impedance cardiography represents a very real potential advance in experimental and clinical physiology.

It is well known that intravascular manipulation often causes a significant hypotensive stress (15,16,17). It is evident however that before impedance cardiography can achieve full usefulness in human research, a good deal of additional work will be required, not only to determine the validity of absolute and relative impedance measurements but to discover the limitations and reservations within which the method can yield useful information both in the normal subject and the cardiac patient.

From a technical standpoint, it would seem profitable to explore further the possibility suggested by Namon and Gollan (11,12) that reactive impedance may have greater utility for blood flow measurements than resistive impedance. Another aspect for further research is the apparent necessity for respiratory apnea during the recording. This is a distinct disadvantage.

Finally, it might be well to explore further the role of heart rate and its practical role in the use of the cardiograph. Tachograph recordings in human experiments illustrate the rapid fluctuations in rate, especially during stress. While stroke output can be a useful physiological parameter, perhaps automatic averaging over a longer period than 5 to 10 beats would be advantageous. The question also arises as to whether longer periods of determination might increase the usefulness of the instrument during respiration.

Summary

The Minnesota Impedance Cardiograph, Model 202 was used to investigate 1) the validity of impedance plethysmography as a measure of cardiac output and 2) its practicability and value for the study of circulatory stress in the intact human. A comparison of thirty-five simultaneous determinations of cardiac output with the impedance method and with ordinary dye-dilution techniques was made in eight normal male subjects. The correlation coeffients (r) for the absolute values were +0.91 for cardiac output and +0.82 for stroke volume. For relative changes--with each method serving as its own control--the correlation coefficients were +0.57 for normalized cardiac output and +0.63 for normalized stroke volume. Twenty-minute hip suspension of normal subjects caused an increase in mean values for heart rate, decrease in cardiac output, slight elevation of diastolic blood pressure and distinct elevation of the total peripheral resistance. These changes were all quite comparable to those previously observed by other investigators. The recording of central cardiovascular events gives useful insight into the mechanism of circulatory response in the intact human under stress. Impedance recording also provides the opportunity to derive auxiliary data such as the amplitude of the impedance time derivative, the left ventricular ejection time index and the R-ΔZ interval--all of which may be useful in determining cardiac dynamics.

It is our opinion that the potential value of the impedance cardiograph for research and clinical use is considerable. It would seem as if such a potential would warrant further intensive efforts, not only to determine the basic validity of the procedure, but to further improve its applicability and utility.

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TABLE 1

RATIOS OF $\dfrac{\text{Z-CALCULATED CARDIAC OUTPUT}}{\text{DYE-CALCULATED CARDIAC OUTPUT}}$

(N = 35)

	Supine (pretilt)		Tilt		Supine (post-tilt)	
Subject No.	+5 min	+10 min	T + 5 min	T + 15 min	+5 min	Mean
1	1.12	1.43	1.19	0.86~~0~~	1.33	1.27
2	0.96	0.99	0.88	1.14~~5~~	0.84	0.81
3	0.93		0.74	1.03	1.16	0.99
4	1.08		1.11	0.96~~1~~	1.01	1.06
5	0.83	1.08	1.04		0.99	0.98
6	0.80		0.99	1.28~~2~~	0.72	0.84
7	1.42	1.26	1.13	1.75~~2~~	1.51	1.32
8	1.17	1.38	1.20	1.17	1.16	1.33
Mean Ratio	1.04	1.23	1.03	1.17	1.09	1.09 ± 0.19

TABLE 2

VALUES FOR Z-CALCULATED AND DYE-CALCULATED STROKE VOLUMES

		Z Method			Dye Method			Normalized Data			
Subject	Time	SV (ml)	HR	CO (L/min)	SV (ml)	HR	CO (L/min)	NSV-Z	NSV Dye	NCO Z	NCO Dye
1. D.Jo.	CH + 5'	91.0	67	6.10	79.2	69	5.46				
	CH + 10'	108.0	68	7.34	74.8	68	5.09	1.19	0.94	1.20	0.93
	T + 5'	51.8	83	4.30	40.7	88	3.58	0.57	0.51	0.70	0.66
	RH + 1'	110.0	56	6.16	81.5	56	4.56	1.21	1.03	1.00	0.84
2. T.Ba.	CH + 5'	70.4	63	4.44	74.6	62	4.62				
	CH + 10'	68.5	62	4.25	76.3	56	4.27	0.97	1.02	0.96	0.92
	T + 11'	45.4	72	3.27	52.7	70	3.69	0.64	0.71	0.74	0.80
	T + 17'	44.8	71	3.18	53.6	69	3.70	0.64	0.72	0.72	0.80
	RH + 5'	71.4	54	3.86	84.0	55	4.62	1.01	1.13	0.87	1.00
3. W.Ma.	CH + 5'	111.6	63	7.03	111.4	68	7.58				
	T + 5'	70.3	65	4.57	86.1	72	6.20	0.63	0.77	0.65	0.82
	T + 15'	70.7	76	5.37	65.1	72	4.69	0.63	0.58	0.76	0.62
	RH + 15'	117.5	66	7.76	101.0	66	6.67	1.05	0.91	1.10	0.88
4. F.Mi.	CH + 5'	166.4	62	10.32	158.7	60	9.52				
	T + 5'	109.5	69	7.56	103.0	66	6.80	0.66	0.65	0.73	0.71
	T + 10'	100.8	72	7.26	97.5	72	7.02	0.60	0.61	0.70	0.74
	RH + 5'	164.3	64	10.52	152.6	68	10.38	0.99	0.96	1.02	1.09
5. S.Mo.	CH + 5'	111.5	67	7.47	124.6	72	8.97				
	CH + 15'	141.0	61	8.60	113.4	70	7.94	1.26	0.91	1.15	0.88
	T + 5'	63.8	82	5.23	60.3	84	5.06	0.57	0.48	0.70	0.56
	T + 15'	60.7	85	5.16	63.9	84	5.37	0.54	0.51	0.69	0.59
	RH + 5'	130.2	59	7.68	110.6	70	7.74	1.17	0.89	1.03	0.86
6. W.Wa.	CH + 5'	109.9	78	8.57	127.5	84	10.71				
	T + 5'	78.6	95	7.46	83.3	90	7.50	0.72	0.65	0.87	0.70
	RH + 5'	70.2	97	6.81	105.4	90	9.49	0.64	0.83	0.79	0.89
7. A.Sp.	CH + 5'	81.2	78	6.34	67.9	66	4.48				
	CH + 10'	92.9	70	6.51	74.0	70	5.18	1.14	1.09	1.03	1.16
	T + 5'	56.5	87	4.92	48.4	90	4.36	0.70	0.71	0.78	0.97
	T + 15'	48.9	93	4.55	39.4	90	3.55	0.60	0.58	0.72	0.79
	RH + 5'	94.5	69	6.52	65.6	66	4.33	1.16	0.97	1.03	0.97
8. J.Ho.	CH + 5'	90.6	63	5.71	68.0	72	4.90				
	CH + 10'	86.9	70	6.09	64.6	68	4.39	0.96	0.95	1.07	0.89
	T + 5'	43.2	93	4.02	37.4	90	3.36	0.48	0.55	0.70	0.69
	T + 10'	61.9	88	5.45	34.5	90	3.11	0.68	0.51	0.95	0.63
	RH + 5'	90.4	62	5.60	64.3	75	4.83	1.00	0.94	0.98	0.98

Footnotes for Table 2

CH + 5' = control horizontal + 5 min (determination made 5 min after subject assumed control supine position)

T + 5' = tilt + 5 min (determination made 5 min after subject was passively tilted to 70° upright position; ordinarily subject was tilted after 15 min in the control horizontal position)

RH + 5' = recovery horizontal + 5 min

SV = stroke volume (ml)

HR = heart rate (for dye method, average rate during curve; for Z method, average rate of five beats)

CO = cardiac output (L/Min)

Basic data for cardiac output determinations were taken simultaneously for dye dilution by Dr. Tristani and his assistants and for impedance method by Dr. Wiedmeier and his team; respective calculations were made and submitted independently by the two groups. These data are shown in Figures 3 and 4.

Normalized values indicate that the first resting supine value for each subject was used as a reference for the determination of the ratio of stroke volume or cardiac output for the remaining determinations with that method in that subject. Data graphed in Figures 5 and 6.

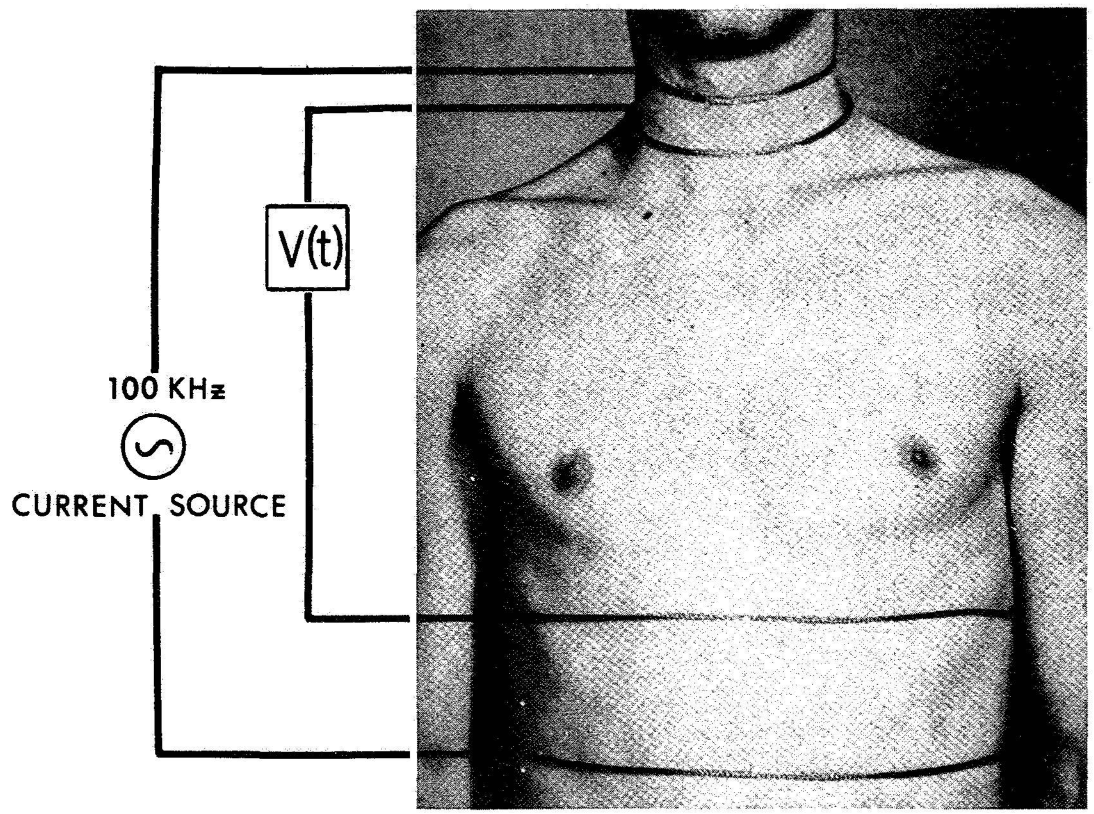

Fig. 1. Subject with four band electrodes.

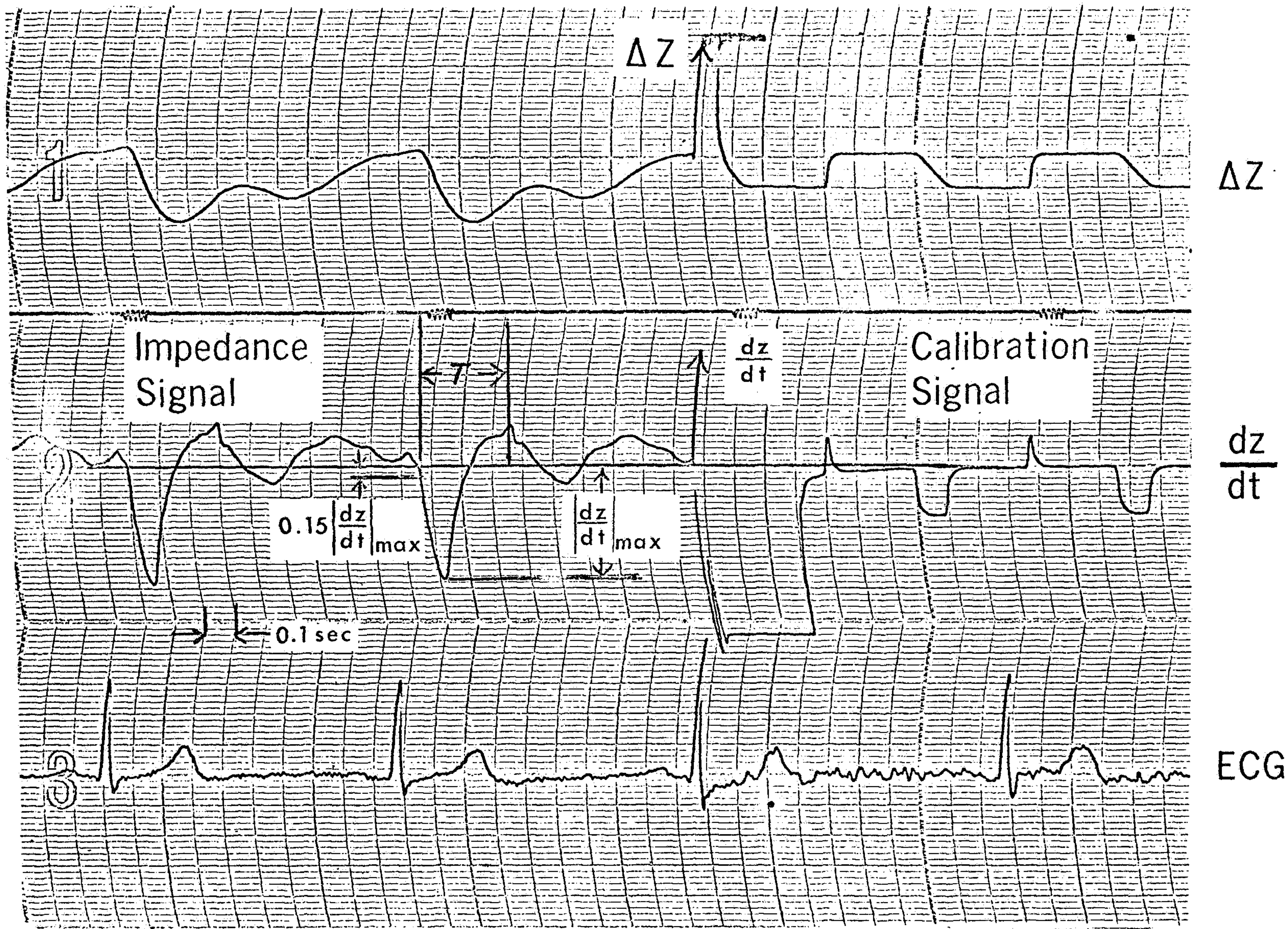

Fig. 2. Impedance wave (ΔZ), the first derivative of the impedance wave $\left(\frac{dz}{dt}\right)$ and ECG tracing. (Paper speed: 50 mm/sec)

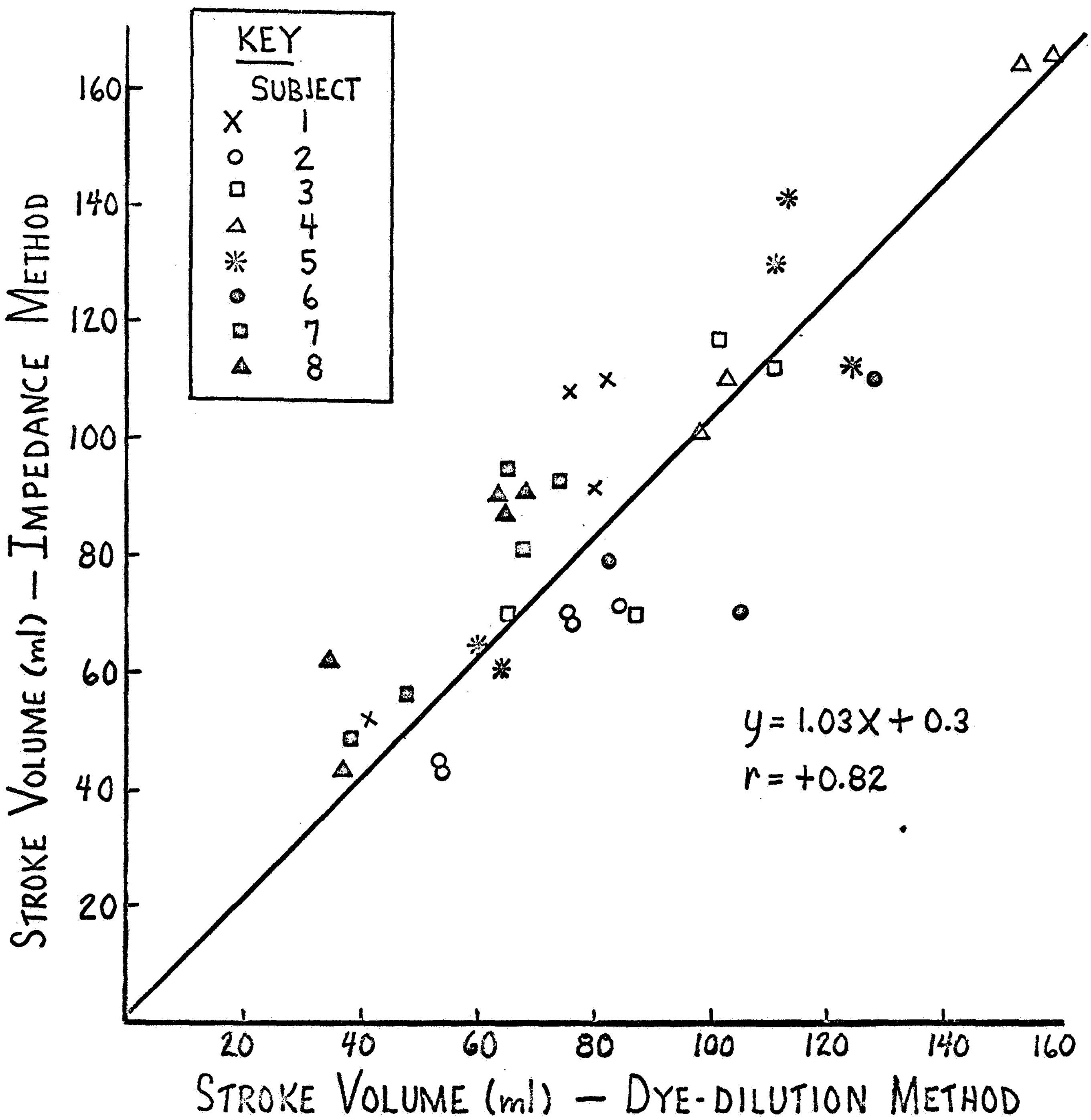

Fig. 3. Stroke Volume in Head-up Tilt--Dye-dilution vs Impedance Values (35 determinations in 8 normal males)

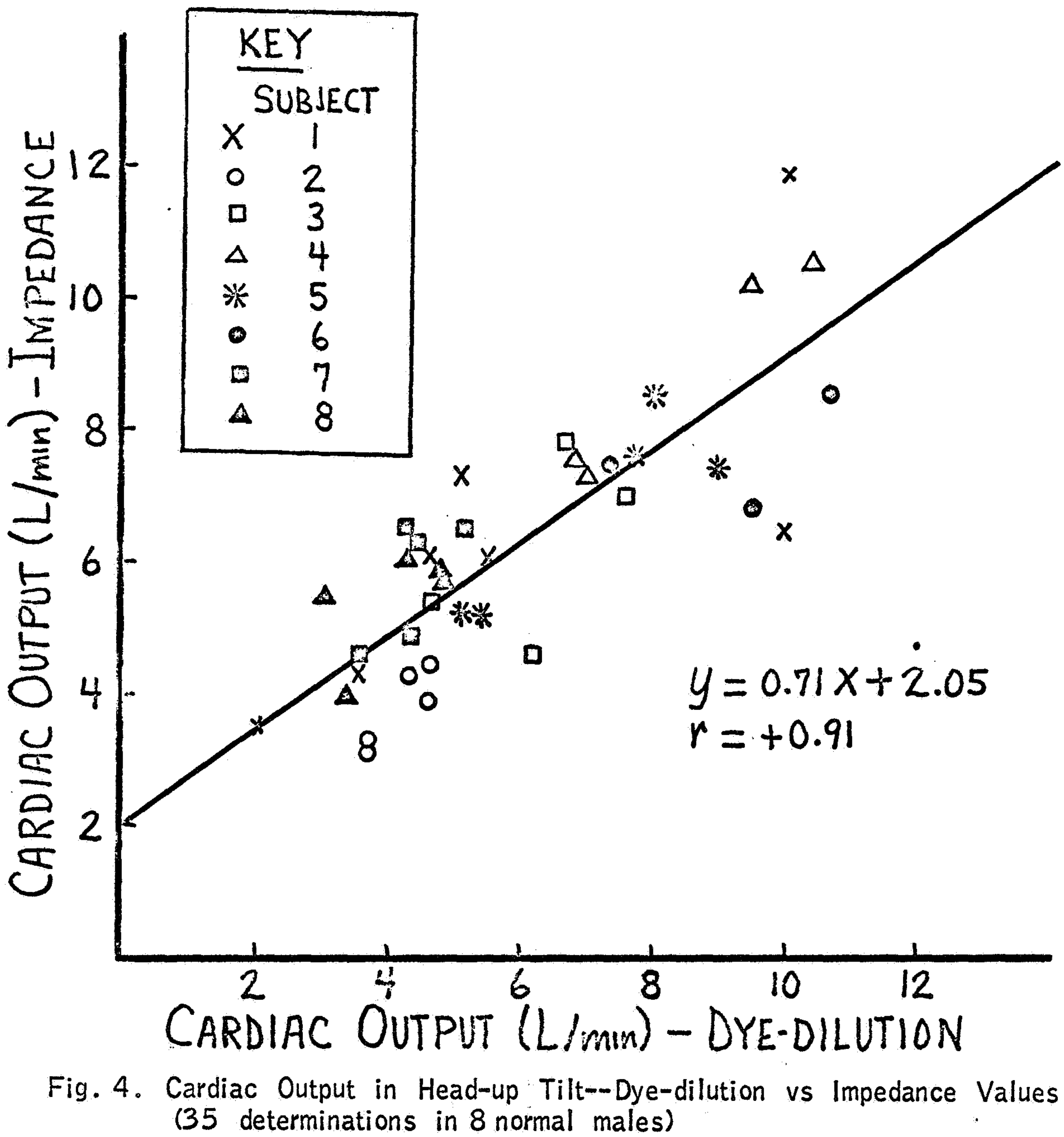

Fig. 4. Cardiac Output in Head-up Tilt--Dye-dilution vs Impedance Values (35 determinations in 8 normal males)

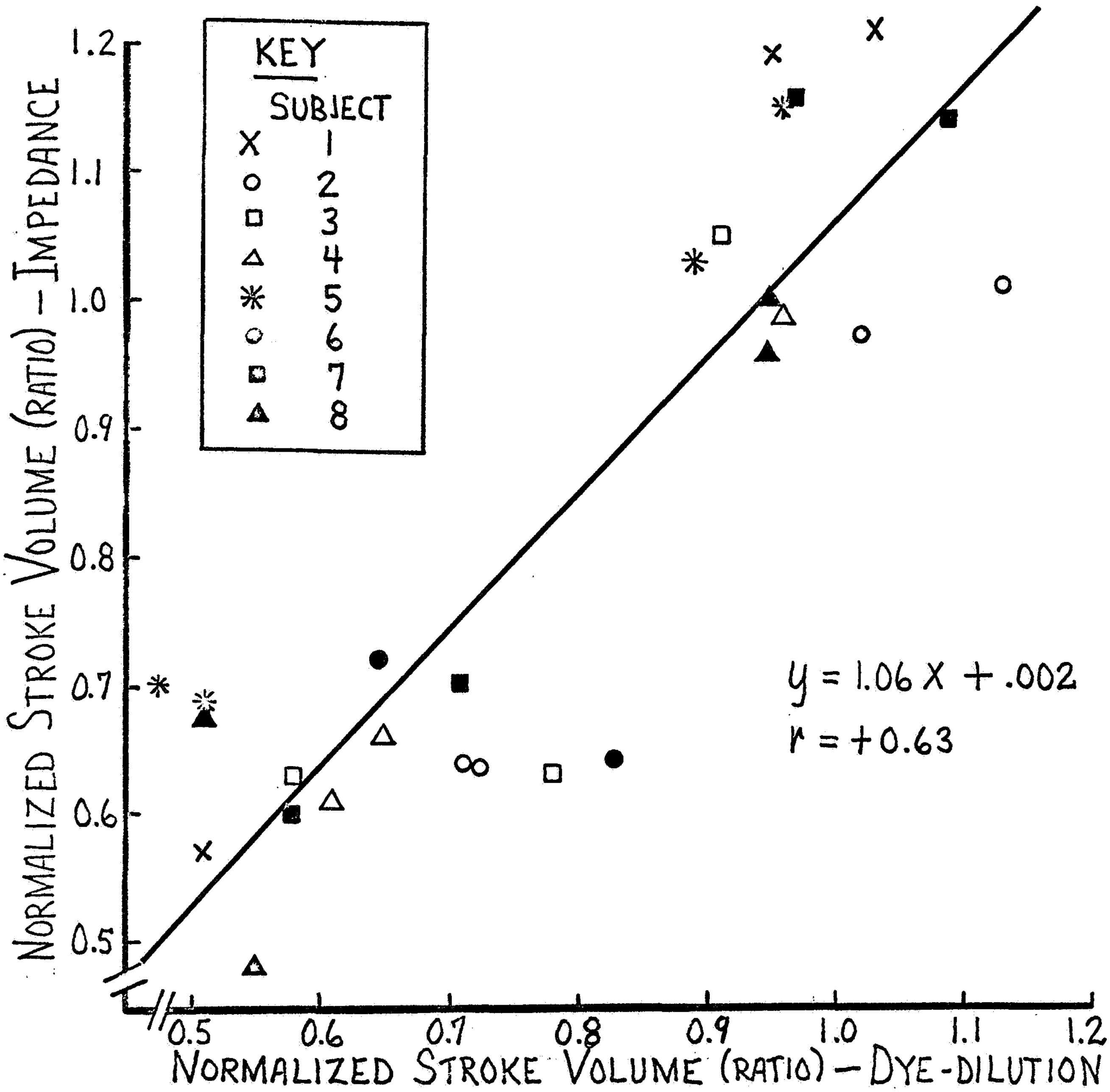

Fig. 5. Stroke Volume in Head-up Tilt--Ratios of Change with Dye-dilution and Impedance Methods Based on Respective Individual Control Values

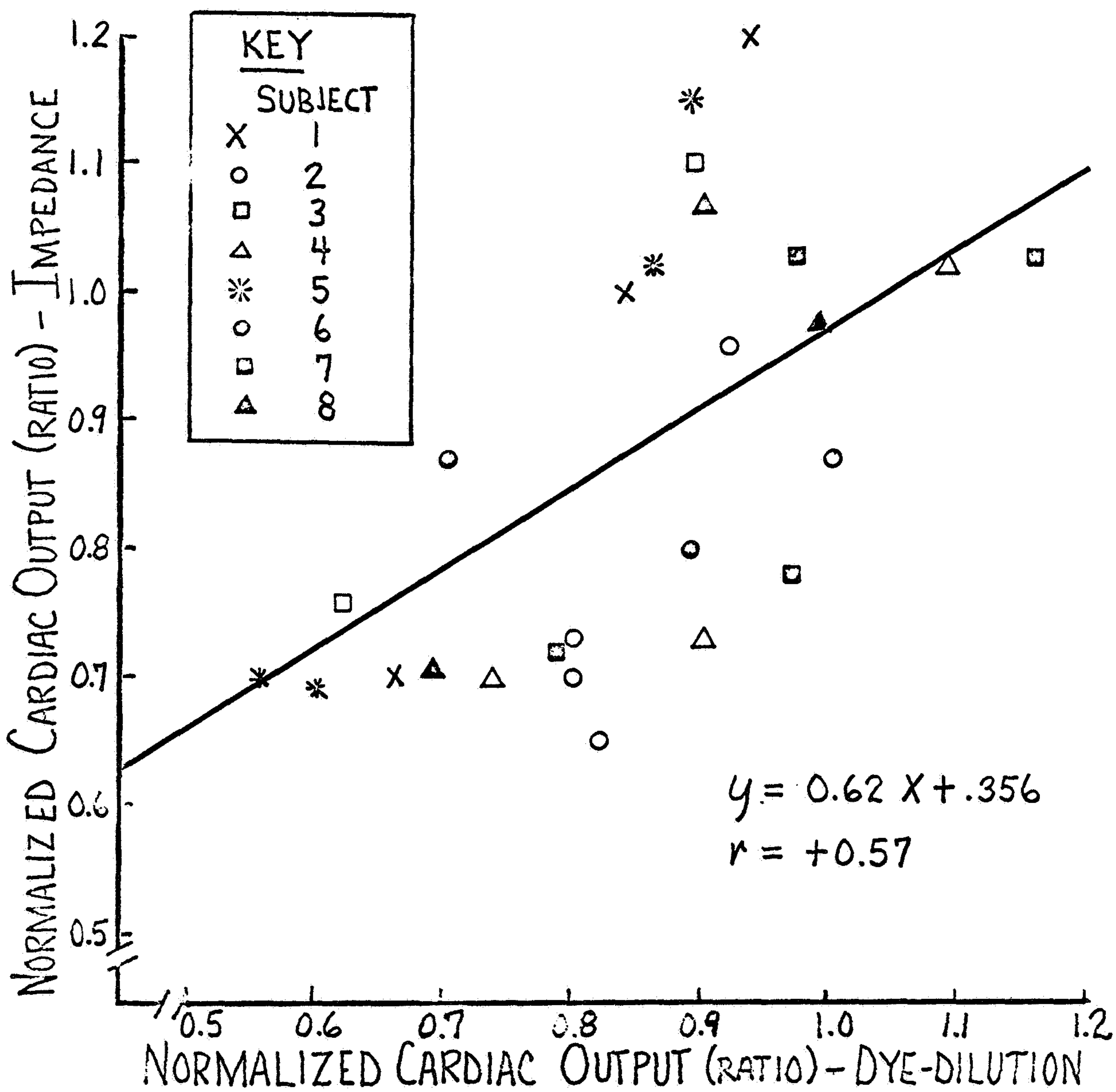

Fig. 6. Cardiac Output in Head-up Tilt--Ratios of Change with Dye-dilution and Impedance Methods Based on Respective Individual Control Values

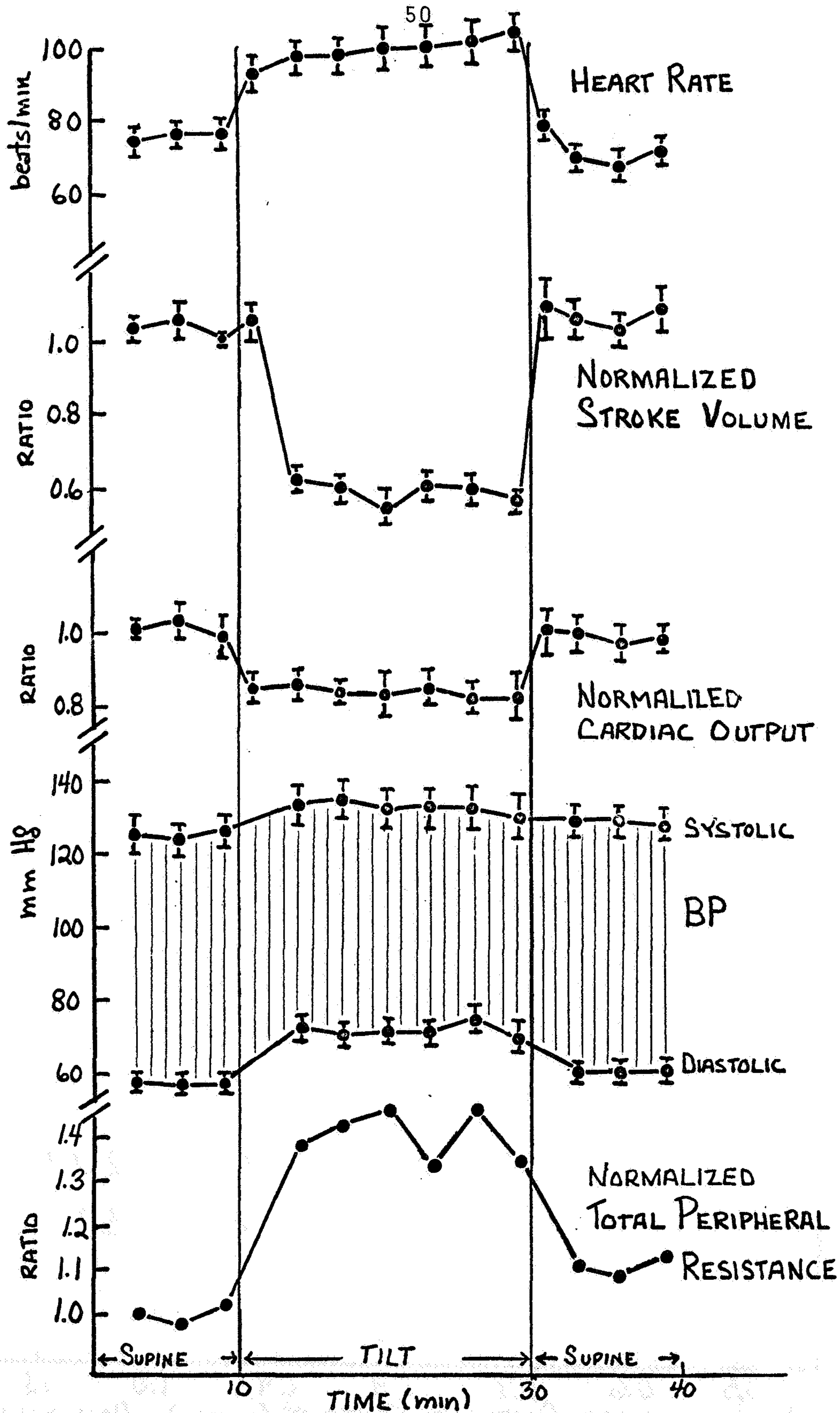

Fig. 7. Cardiovascular Responses to Vertical Tilt with Hip Suspension
(Mean values with S.E. for 12 experiments in 8 males)

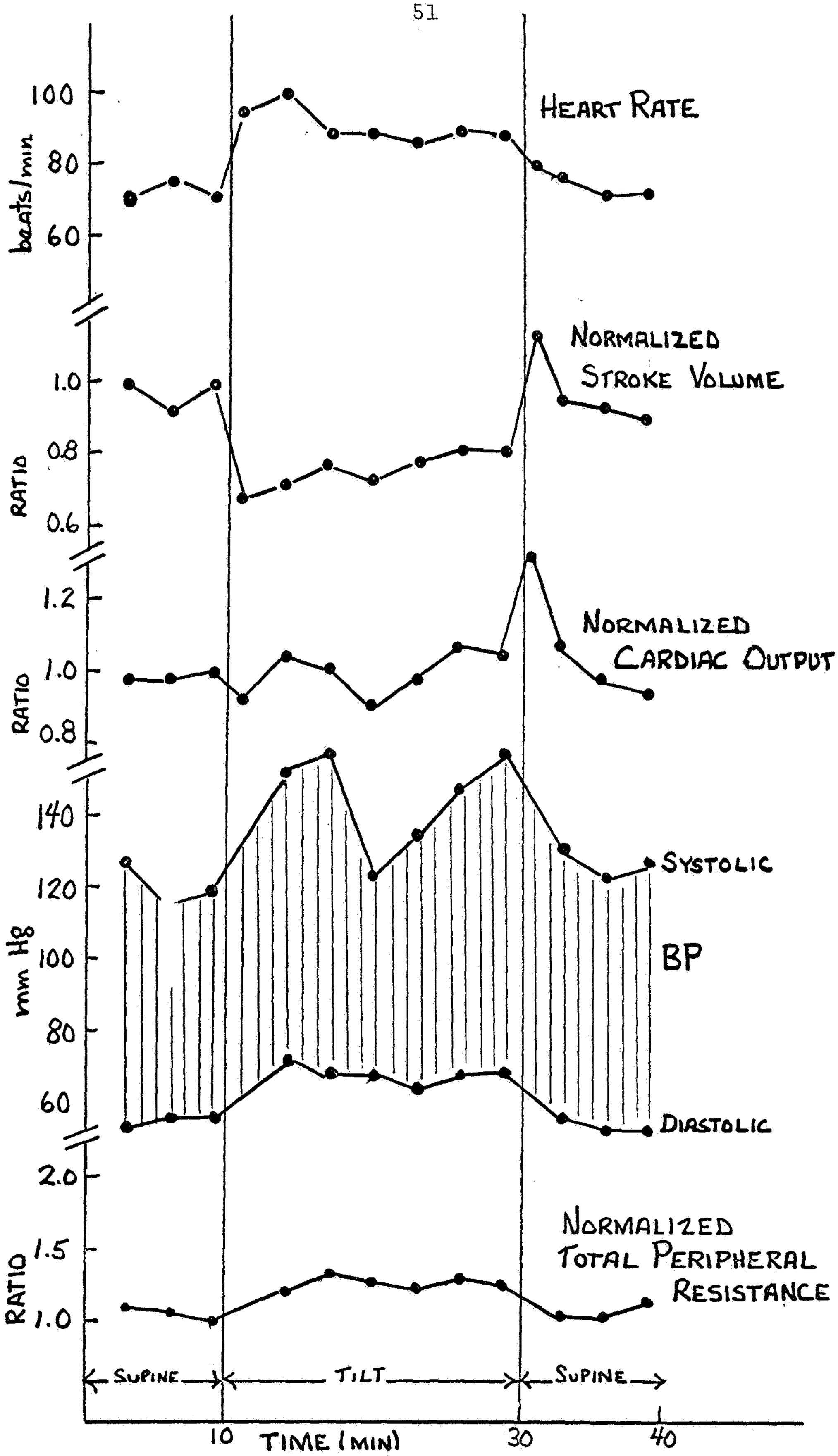

Fig. 8. Cardiovascular Responses to Vertical Tilt with Hip Suspension (Subject: M.Bo.)

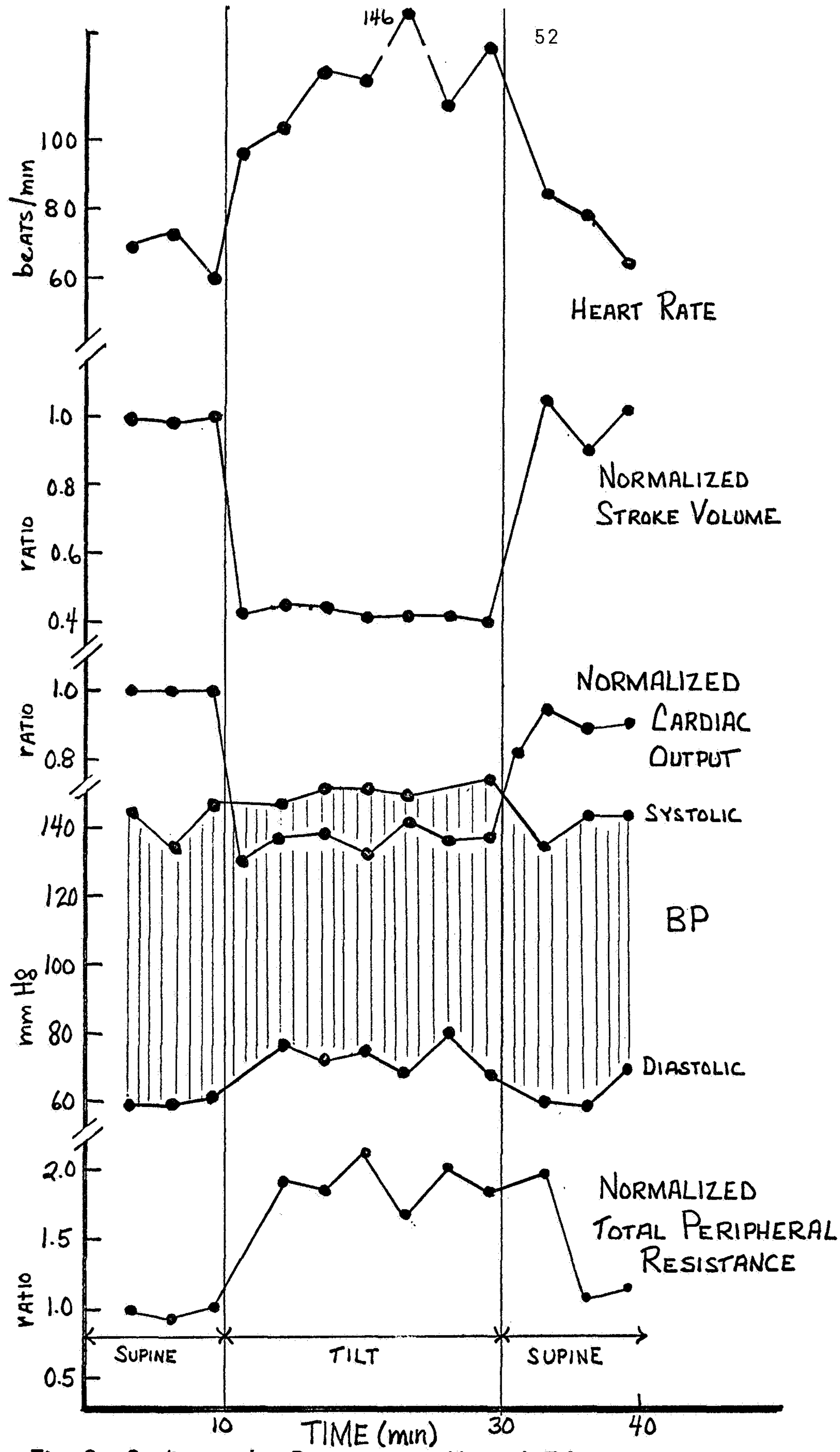

Fig. 9. Cardiovascular Responses to Vertical Tilt with Hip Suspension (Subject: J. Ki.)

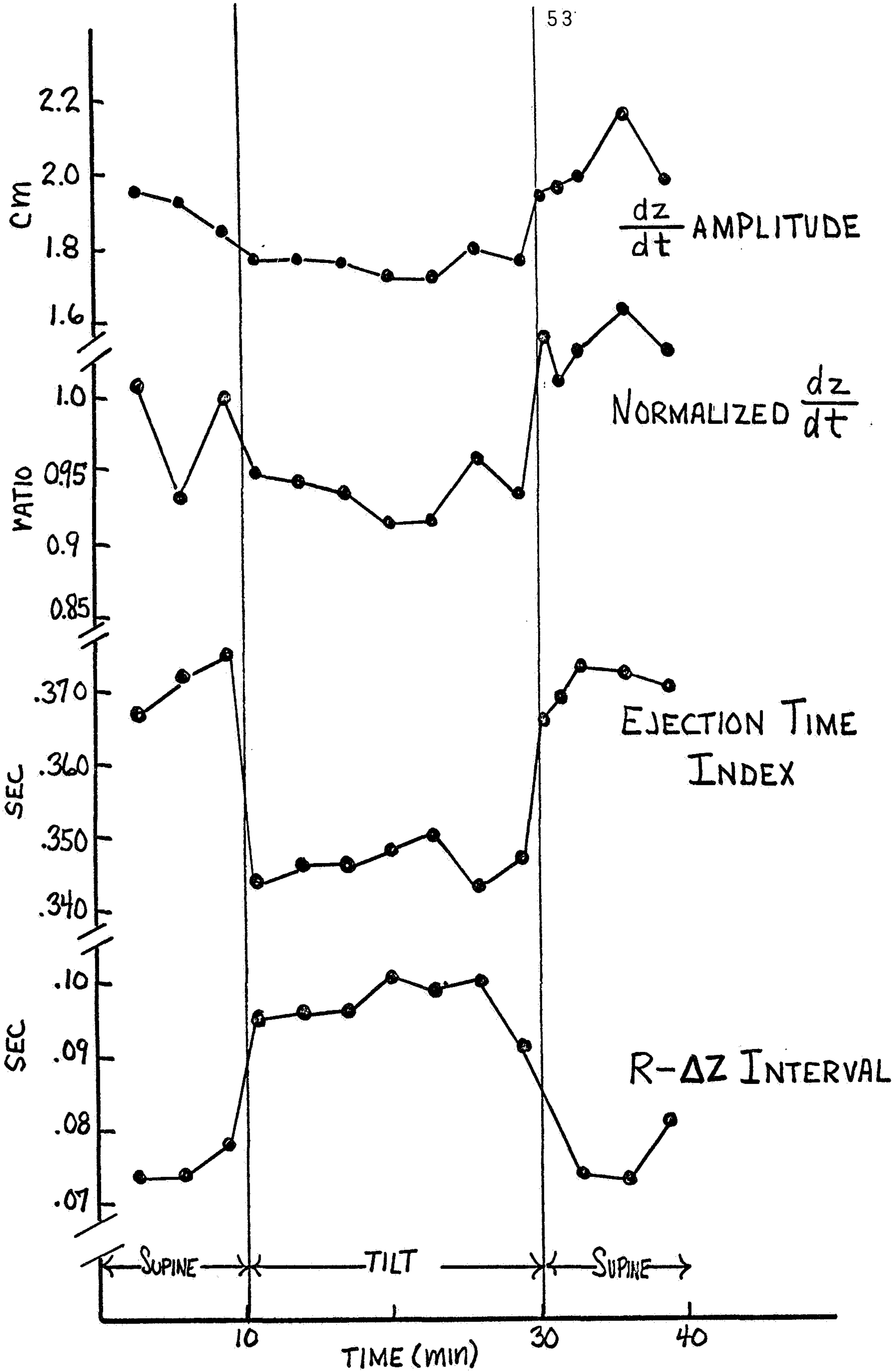

Fig. 10. Auxiliary Cardiovascular Values Derived from Impedance Data (Mean values of 12 experiments in 8 normal male subjects)

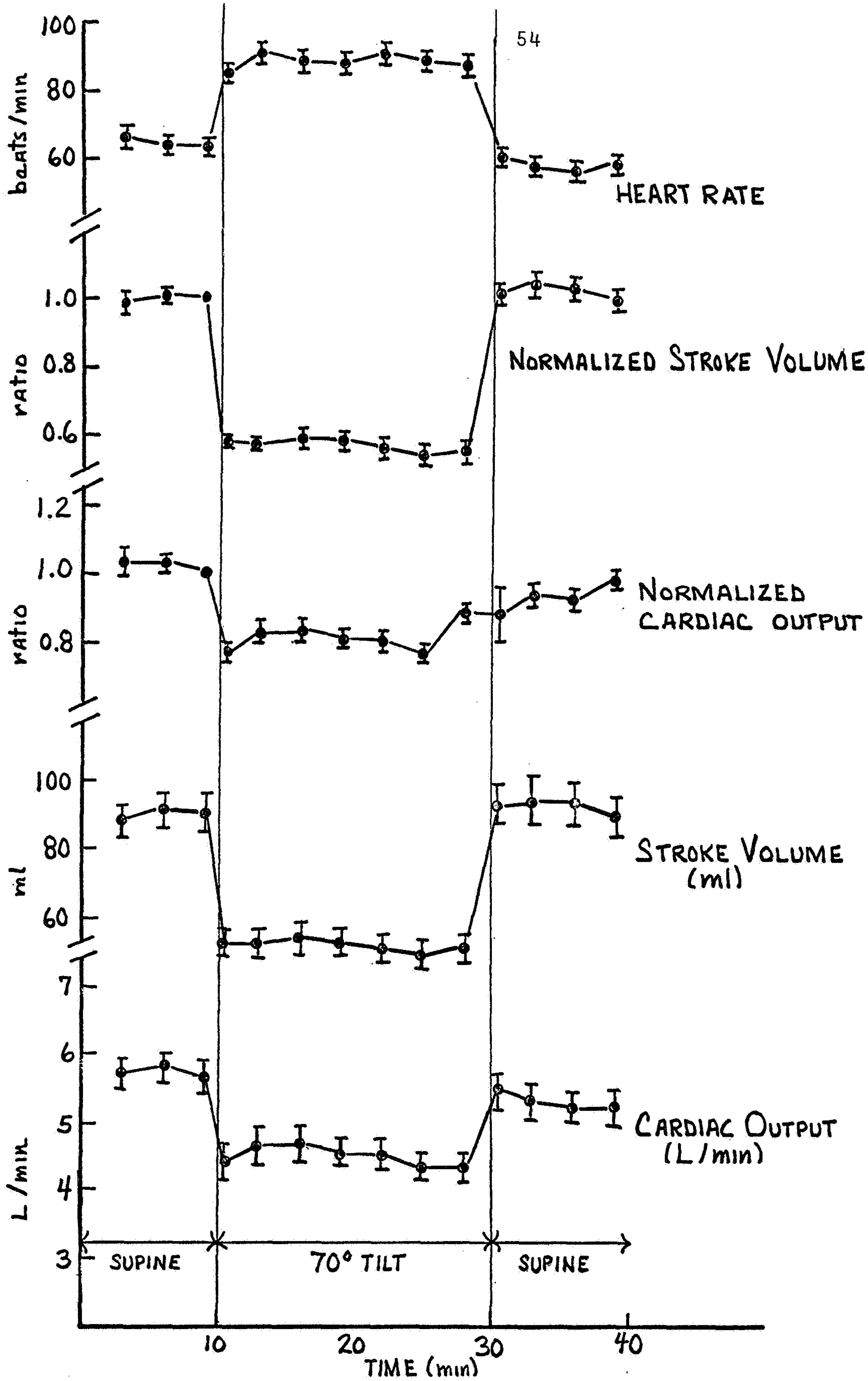

Fig. 11. Stroke Volume and Cardiac Output Responses to Head-up Tilt. Body Weight Supported by Footboard (Mean Values with S.E. for 11 Normal Male Subjects)

TABLE II-A (Greenfield)

Correlation coefficients computed by linear regression of DZ/DT, ZSV and DE on SV, in six patients with idiopathic myocardial hypertrophy. Alterations of stroke volume were produced by atrial pacing at indicated heart rates.

PATIENT	HEART RATES PER MINUTE	NUMBER OF BEATS	DZ/DT-SV_{Dye} r =	ZSV-SV_{Dye} r =	DE-SV_{Dye} r =
1	86, 92, 102, 115	60	0.598	0.648	0.506
2	78, 102, 115, 128	40	0.849	0.943	0.942
3	94, 103, 126, 137, 158	63	0.433	0.623	0.914
4	97, 126, 141, 165	60	0.690	0.688	0.417
5*	71, 85, 107, 118, 140, 154	73	0.461	0.792	0.943
	71, 85, 107, 118, 140	58	0.884	0.913	0.929
	154	15	0.776	0.894	0.961
6	94, 106, 114 125, 158	73	0.930	0.955	0.923

DZ/DT = maximum first time derivative of transthoracic impedance change;
ZSV = impedance stroke volume
DE = duration of ejection
SV_{Dye} = stroke volume by dye dilution method

*In this patient the regression equation was markedly different at a heart rate of 154/min. than at other heart rates; the results of separate regressions are therefore presented.

Determination of Cardiac Output in Man by Means of Impedance Plethysmography

A. Harley, M.B., M.R.C.P., and Joseph C. Greenfield, Jr., M.D.

An electrical impedance plethysmographic method employing cervical and lower thoracic electrodes and an indicator dilution technique were used to record cardiac output simultaneously in 13 normal subjects during a control period and following an infusion of isoproterenol. A correlation coefficient of r = 0.68 was found for these 26 paired values. In addition cardiac output was measured simultaneously in 24 patients with various types of heart disease by an indicator dilution technique and by impedance plethysmography. The correlation coefficient between these determinations was r = 0.26. In six patients with atrial fibrillation impedance stroke volume was found to be directly proportional to the preceding cycle length. Satisfactory correlation was found between stroke volumes estimated by impedance plethysmography and by direct measurement using the pressure gradient technique in two patients with mitral stenosis and atrial fibrillation. Although the later results are somewhat encouraging, from these preliminary findings it is felt that the current impedance plethysmographic methods as employed in this study are not refined to the point that clinical application is warranted. However, since this method has potential value as an atraumatic method for determining cardiac output and stroke volume, it deserves further evaluation.

IT HAS LONG BEEN KNOWN that the electrical impedance of the thorax of both man and animals varies regularly during the cardiac and respiratory cycles. As the movement of blood into, out of, and within the thorax is the most obvious result of cardiac contraction, attempts have been made to relate these observed changes in impedance with stroke output. Kubicek and co-workers postulated that the maximum rate of decrease in electrical impedance which occurs during the initial part of cardiac systole is related to ventricular stroke volume.[2,5] Comparison of impedance plethysmographic estimates of ventricular stroke volume with values obtained from the more conventional Fick and indicator dilution methods by these investigators have indicated at least a reasonable relationship between cardiac output and electrical impedance changes.[4] This report is a further evaluation of impedance plethysmography as an atraumatic method of estimating cardiac output in man, both by direct comparison with an indicator dilution technique and by following the variation in stroke volume in patients having atrial fibrillation.

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Dr. Greenfield is the recipient of a Career Development Award (1-K3-HE-28, 112) from the U.S.P.H.S.

METHODS

Simultaneous indicator dilution curves and impedance records were obtained in 13 healthy male subjects before and after an intravenous infusion of isoproterenol. Cardiac output was also measured simultaneously by indicator dilution and impedance plethysmography in 24 hospitalized patients with heart disease who were undergoing diagnostic studies or treatment at the Durham Veterans Administration Hospital. The clinical diagnosis of these patients are shown in Table I. Six of the patients had atrial fibrillation and in two of these stroke volume was compared to simultaneous direct measurement of stroke volume by the pressure gradient technique.[1*]

A Model 2110 Medtronic impedance bridge** was used with a four-electrode system to obtain the im-

*The pressure gradient technique is so far the only reported method for obtaining instantaneous aortic blood flow in man under physiological conditions. Briefly, it involves the extremely accurate measurement of the instantaneous lateral pressures at two points in the ascending aorta with a double lumen catheter. The difference between these pressures is an approximate measure of instantaneous pressure gradient from which the blood flow may be computed by simple analog computer methods.

**Medtronics, Inc., 3055 Old Highway 8, Minneapolis, Minn. 55418.

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pedance measurements. The electrodes were of the type described by Kubicek and co-workers.[4] A cervical collar contained the upper pair of electrodes. The third electrode was placed around the thorax two finger breadths below the tip of the xipho-sternum and the fourth electrode 5 cm caudally. The electrodes were applied some ten or more minutes before use. Care was taken to insure that contact to the chest and neck was even but not tight. The distance, L, between the two inner electrodes was measured as accurately as possible in centimeters in the mid-coronal plane. The impedance between the inner two electrodes was measured while a 100 kc. excitation frequency was applied to the outer pair of electrodes. All measurements were made during relaxed mid-expiratory apnea. In many over cooperative subjects some practice was required before relaxation could be consistently achieved rather than the subject performing a Valsalva or a Muller maneuver. Heart sounds were recorded with a Shure Model SP-5S crystal microphone* applied either to the second or third left interspace at the left sternal edge, wherever best definition of the second heart sound was obtained. The impedance change signal from the inner two electrodes was displayed on an oscilloscope and recorded by a Honeywell Visicorder together with the electrocardiogram and the phonocardiogram. In some patients the carotid pressure pulse was also measured with an externally applied transducer.

The value of the maximum impedance change for each beat was determined graphically as shown in Figure 1. The stroke volume was calculated from this value by the formula given by Kubicek and co-workers.[4]

$$\Delta V = \rho \frac{L^2}{Z_0^2} \Delta Z$$

Where ΔV represents the stroke volume in cm^3, L the distance between the inner pair of electrodes in cm, Z_0 the value of the baseline impedance between the electrodes in ohms, and ΔZ the measured maximum impedance change. ρ is a constant (150 ohm cm) representing the electrical resistivity of blood at 100 kc. In calculating the impedance cardiac output determinations the average stroke volume was taken as the mean value from 10 consecutive heart beats.

Indicator dilution curves were obtained following injection of indocyanine green with a Colson Gilford Densitometer. In the patients undergoing diagnostic cardiac catheterization the dye was injected into either the right ventricle or the main pulmonary artery and sampled from a brachial artery. In the other subjects the dye was injected into a median cubital vein and arterial blood was sampled from a brachial artery. When simultaneous indicator dilution curves were made, the impedance changes were recorded after the injection of dye but immediately prior to and during inscription of the dye curve. Both were therefore recorded in the same phase of held respiration.

RESULTS

The impedance wave form in normal subjects and in most patients resembled that shown in Figure 1. However, in some patients with valve disease there were considerable variations especially in the size of the

TABLE I. COMPARISON OF INDICATOR DILUTION AND IMPEDANCE DETERMINATIONS OF CARDIAC OUTPUT IN 24 PATIENTS WITH ACQUIRED HEART DISEASE

Patient No.	Age Yrs.	Diagnosis	Indicator Dilution Cardiac Output L/min	Impedance Cardiac Output L/min
1	53	Mitral Stenosis	2.16	3.52
2	45	Mitral Stenosis	2.65	4.12
3	63	Mitral Stenosis	2.61	4.41
4	36	Mitral Stenosis and Insufficiency	4.95	7.94
5	46	Mitral Insufficiency and Stenosis	3.37	4.29
6	40	Mitral Insufficiency and Stenosis	4.47	4.31
7	52	Mitral Insufficiency	2.91	8.30
8	38	Mitral Insufficiency	5.97	8.38
9	72	Mitral Insufficiency	3.57	3.29
10	42	Aortic Stenosis	4.89	5.00
11	45	Aortic Stenosis	5.32	5.18
12	38	Aortic Insufficiency and Stenosis	6.30	12.00
13	35	Aortic Insufficiency	4.92	11.35
14	31	Hypertensive Heart Disease	4.26	3.60
15	43	Hypertensive Heart Disease	4.68	3.28
16	33	Hypertensive Heart Disease	4.99	3.72
17	46	Hypertensive Heart Disease	6.06	3.37
18	44	Hypertensive Heart Disease	5.82	7.56
19	54	Chronic Lung Disease	8.28	3.05
20	45	Chronic Lung Disease	4.30	6.07
21	57	Chronic Lung Disease	4.82	2.85
22	40	Idiopathic Atrial Fibrillation	2.89	3.98
23	32	Idiopathic Myocardial Hypertrophy	3.19	3.71
24	54	Ischaemic Heart Disease	6.06	7.60

*Shure Brothers, Inc., Evanston, Illinois.

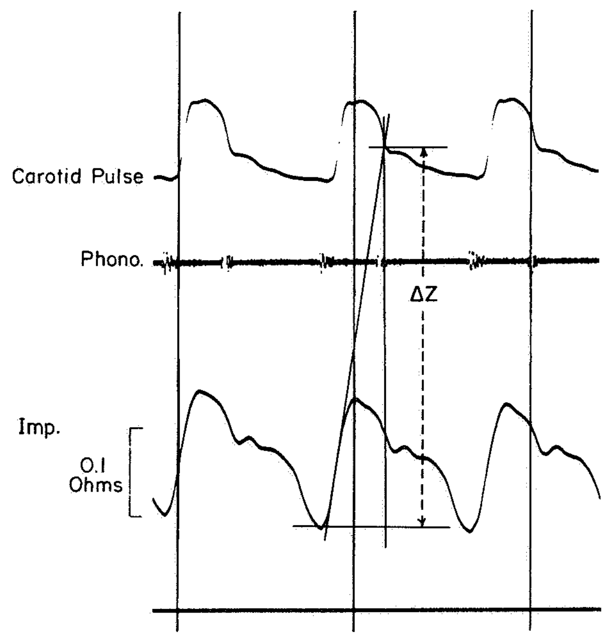

Fig. 1. From the top downwards, the carotid arterial pressure pulse, phonocardiogram and impedance signal (an upward deflection denotes a decrease in thoracic impedance). The initial upward slope is extrapolated as far as the pulmonic component of the second heart sound. The total height of this slope represents the ΔZ used in equation 1 to compute stroke volume.

diastolic waves. Simultaneous measurement of cardiac output by impedance plethysmography and indicator dilution before and after isoproterenol in the 13 normal subjects provided a comparison of the two methods in estimating absolute resting cardiac output and estimating the size of a change in cardiac output. Twenty-six paired values for cardiac output were obtained (Figure 2) and were subjected to regression analysis. The mean indicator dilution control cardiac output was 6.3 L/min rising to 9.5 L/min following the infusion. The ratio of the cardiac output computed from impedance plethysmography to that measured by the indicator dilution technique was 1.34 during the control state and 1.23 following the isoproterenol. This difference was not significant ($P > 0.2$). The regression equation was: Impedance cardiac output = 2.93 + 0.86 $\times$ indicator dilution cardiac output L/min ($\pm$ SE 2.33 L/min), with a correlation coefficient of $r = 0.68$.

The results of simultaneous estimation of cardiac output by indicator dilution and impedance plethysmography in the 24 patients with heart disease is illustrated in Figure 3 and listed in Table I. A correlation coefficient of $r = 0.26$ was obtained for these data. In patients 7, 12, and 13 (Table I) the impedance estimate exceeded the dye estimate considerably. Two of these patients had significant aortic regurgitation while one had mitral regurgitation with severe pulmonary hypertension. In patient 12 and in a third patient with aortic regurgitation in whom simultaneous indicator dilution cardiac output determinations were not made, the impedance measurements were repeated on several separate days. The impedance estimate of cardiac output was always in the same high range. No patient was studied with significant aortic regurgitation who had a normal or low impedance cardiac output value. In patients 10 and 11 who have aortic stenosis the impedance and indicator dilution estimates of cardiac output agreed fairly closely.

In six of the patients with heart disease associated with atrial fibrillation, the impedance stroke volumes for individual beats were compared to the length of the preceding cardiac cycles, Figure 4. Impedance stroke volume was found to vary with preceding cycle length in the expected manner. Although the relationship differed slightly in each patient, the correlations were good in four of the patients but much less so for two of the patients, both of whom had pure mitral stenosis. In two patients (Number 1 and 2, Table I) impedance stroke volume of individual beats was compared to simultaneous direct measurements of the stroke volume of the same beats by the pressure gradient technique.[1] Figure 5 shows the relation of stroke volume estimated by the impedance plethysmographic method and the pressure gradient technique for individual cardiac cycles. The correlation coefficients were $r = 0.93$ for one patient and $r = 0.91$ for the other patient. It should be noted that the absolute values for stroke volume given by each method differ considerably.

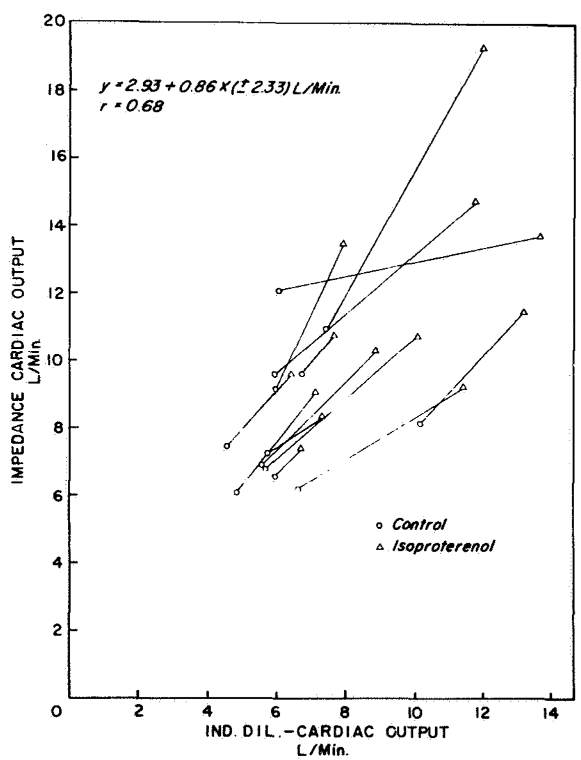

Fig. 2. Comparison of cardiac output values given by impedance plethysmography with those obtained by indicator dilution technique in thirteen healthy subjects before and after an infusion of isoproterenol.

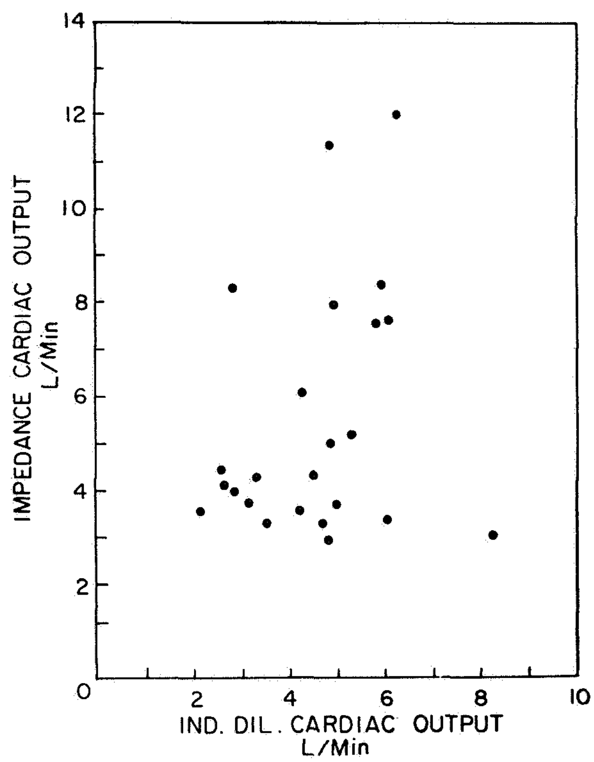

Fig. 3. Comparison of cardiac output computed by impedance plethysmography with that obtained by indicator dilution technique in the twenty-four patients with heart disease listed in Table I.

DISCUSSION

These preliminary findings in a small group of subjects tend to support the concept that there may be a direct relationship between the stroke volume and a change in electrical impedance. However, in spite of careful attention to the details of the technique, the correlation between estimates of cardiac output from the indicator dilution method and impedance plethysmography in normal subjects was poor. In similar studies performed by Kubicek and co-workers[4] the correlation appears to be much closer, but the form in which their data is published precludes a direct comparison with our results. The widest scatter between indicator dilution and impedance values was found in those patients with heart disease. This finding may be related at least in part to the cardiac abnormality. For example, in the patients with aortic incompetence the impedance cardiac output was unrealistically high. Obvious differences in the shape of the impedance wave form occur between patients, but to date we have been unable to categorize pathological states by the nature of the impedance curve. A better relationship between stroke volume as given by the pressure gradient technique and the impedance stroke volume was noted in two patients with atrial fibrillation. Also a fairly good correlation was found between filling time and impedance stroke volume determination in six other patients with atrial fibrillation. These findings would suggest that for a short duration in a given patient the present impedance plethysmographic technique may yield a reasonable index of stroke volume.

The reasons for the poor correlation noted in our studies are obscure. Although we have noticed no systematic discrepancies in obese or thin subjects, it is possible that the girth of the lower thorax or the neck affect the impedance change for a given stroke volume. Despite close attention to technique, variations in electrode placement, respiration, and the shape of individual subjects also may be partly responsible. In addition, the formula used to compute the impedance stroke volume is empirically derived and may well be wrong. Clearly a considerable amount of research is necessary before this technique can be considered ready for clinical use. However, an accurate atraumatic method of continuously measuring cardiac output and beat-to-beat changes in stroke volume will be of extreme value to a number of medical applications. This is particularly so in physiological monitoring during real or experimental flight conditions in selected subjects. For this reason the impedance plethysmographic method is felt to deserve further evaluation.

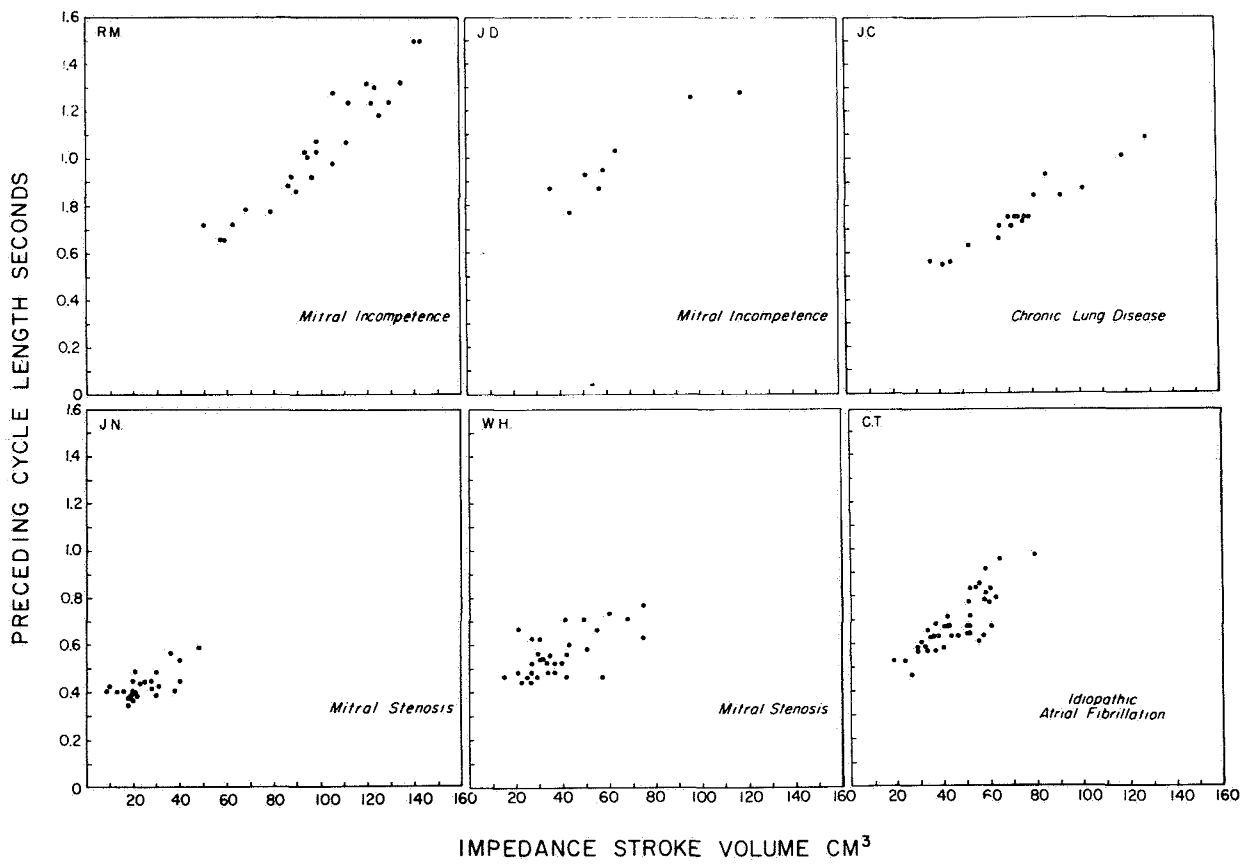

Fig. 4. Correlation of impedance stroke volume with the preceding cycle length for individual beats in six patients with atrial fibrillation.

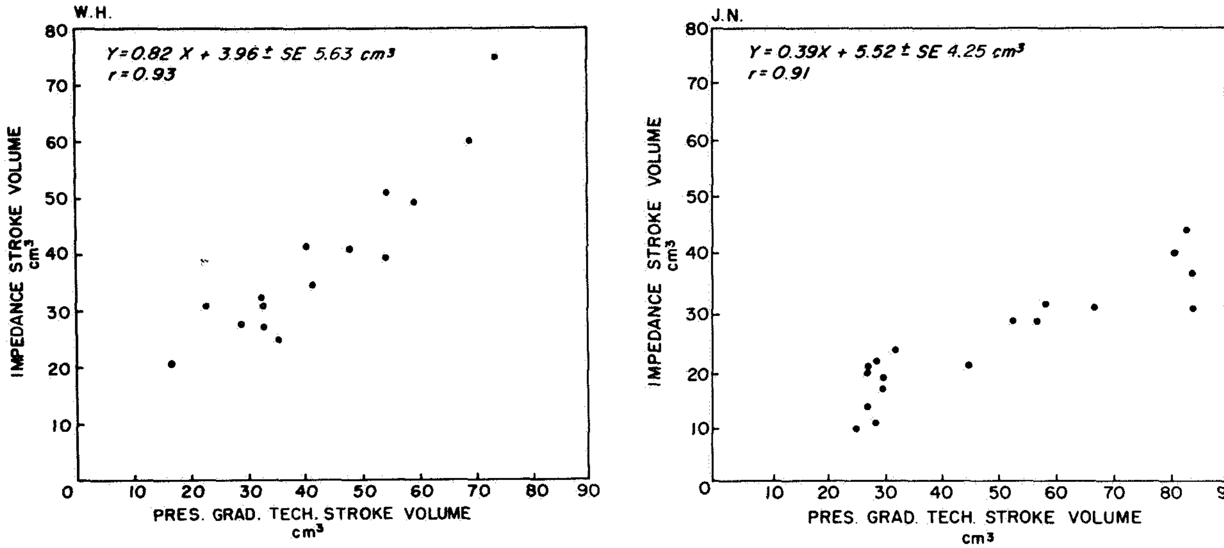

Fig. 5. Comparison of stroke volume for individual beats obtained by impedance plethysmography with those obtained for the same beats by the pressure gradient technique in two patients with pure mitral stenosis and atrial fibrillation.

ACKNOWLEDGEMENT

The authors wish to thank Dr. S. M. Fox of the Heart Disease Control program for his help in initiating these studies.

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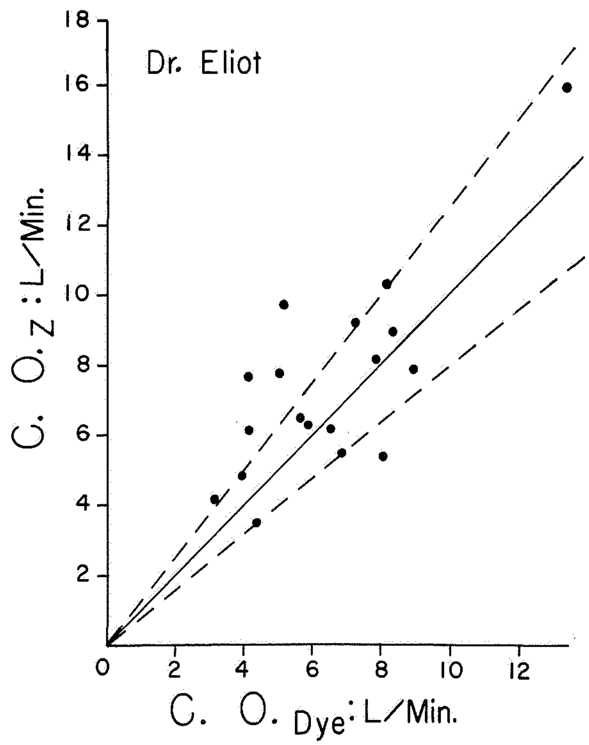


Fig. II-3 Uncorrected values of cardiac output

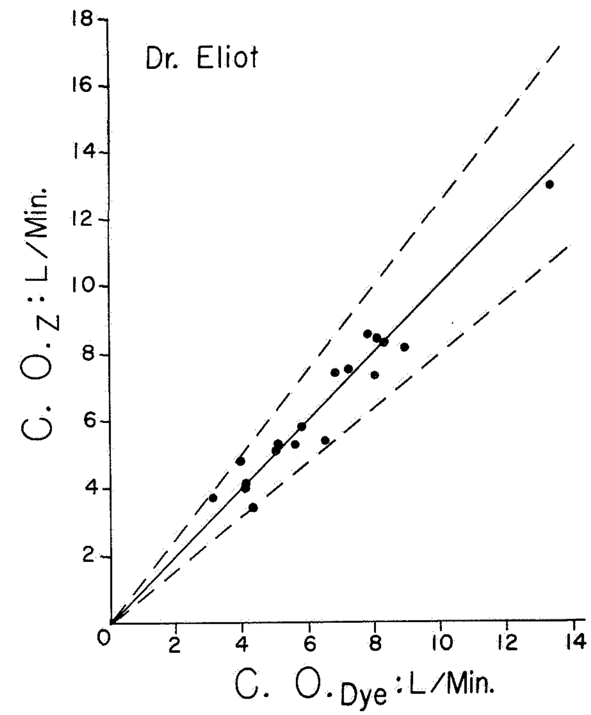


Fig. II-4 Corrected Impedance values of cardiac output plotted against the original values of cardiac output by the Dye method

TABLE II-1 (Eliot)

Patient #	Diagnosis	Procedure	$C.O._{Dye}$	$C.O._{Z}$	Z/Dye	
1	mild mitral insufficiency	control	4.1	6.2	1.51	
		Isuprel	5.0	7.8	1.56	(1.54)
2	normal heart	control	5.8	6.3	1.09	
		Isuprel	8.3	9.0	1.08	(1.09)
3	normal heart	control	8.1	10.3	1.27	
		Isuprel	13.3	15.9	1.19	(1.23)
4	mild pulmonic stenosis,	control	5.6	6.5	1.16	
	atrial septal defect	Isuprel	7.2	9.2	1.28	(1.22)
5	Idiopathic myocardopathy	control	3.1	4.2	1.36	
	severe failure	Isuprel	6.5	6.2	0.95	(1.15)
6	post op. coarctation of	control	7.8	8.2	1.05	
	aorta	Isuprel	8.9	7.9	0.89	(0.97)
7	normal heart	control	4.1	7.7	1.80	
		Isuprel	5.1	9.8	1.92	(1.86)
8	coronary artery disease	control	4.3	3.5	0.81	
		Isuprel	3.9	4.9	1.25	(1.03)
9	severe coronary artery	control	6.8	5.5	0.81	
	disease	Isuprel	8.0	5.4	0.68	(0.74)

$C.O._{Dye}$: Cardiac output-Dye dilution method

$C.O._{Z}$: Impedance cardiac output

Z/Dye : Ratio of impedance cardiac output to dye cardiac output

Mean Z/Dye in parentheses

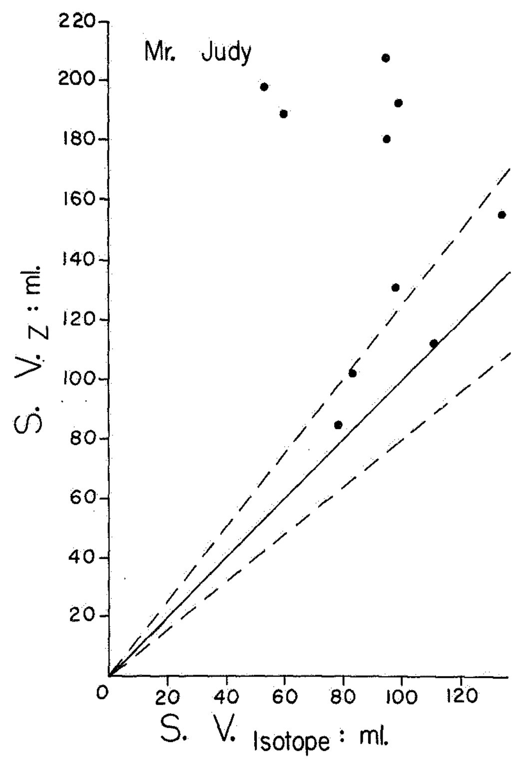


Fig. II-5 Stroke volume values obtained by the Impedance method and the Isotope dilution technique

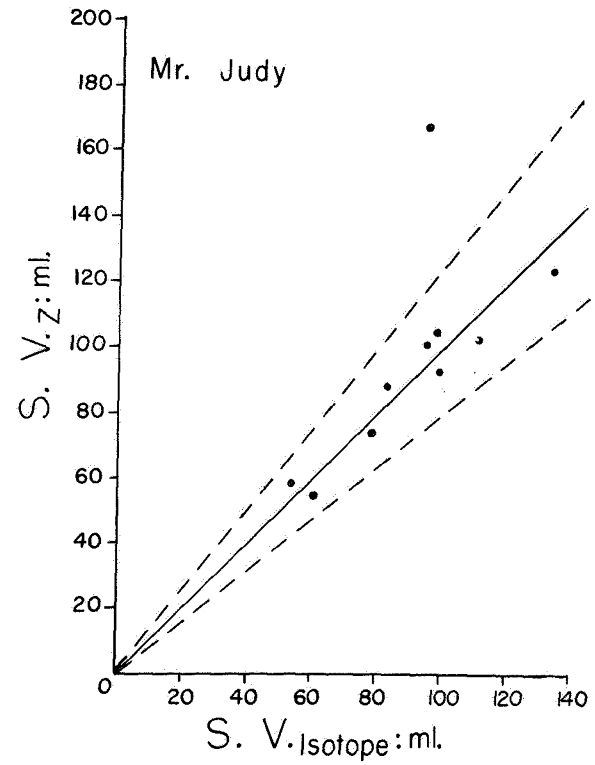


Fig. II-6 Corrected values of stroke volume by the Impedance method plotted against the original values obtained by the Isotope dilution technique

TABLE II-2

(Judy)

Subj.	Cond.	Isotope Dil. Data S.V. cc/beat	Isotope Dil. Data C.O. l/min	Heart Rt. Beat/Min.	Eject. time. 1st Deriv. S.V. cc/beat	Eject. time. 1st Deriv. C.O. l/min	Z_{sv}/Isotope$_{sv}$	Eject. time ECG S.V. cc/beat	Eject. time ECG C.O. l/min	Z_{sv}/Isotope$_{sv}$
1	Passive	97.8	6.950	72	130.9± 27.7	9.340± 1.880	1.34	97.9± 17.5	6.985± 1.171	1.00
	Active	134.0	10.463	78	154.6± 4.1	12.013± 0.310	1.15 (1.25)	113.5± 3.6	8.822± 0.225	0.84 (0.92)
2	Passive	95.1	6.848	72	180.9± 6.6	7.812± 0.323	1.15	122.4± 5.3	8.782± 0.239	1.28
	Active	110.5	9.287	84	111.7± 4.8	9.438± 0.877	1.01 (1.08)	129.1± 10.5	10.884± 1.035	1.16 (1.22)
3	Passive	77.6	5.898	76	85.2± 3.5	6.474± 0.314	1.09	61.2± 1.6	4.647± 0.133	0.78
	Active	82.9	8.209	99	101.6± 3.7	9.994± 0.268	1.22 (1.16)	67.9 3.2	6.635± 0.300	0.81 (0.80)
4	Passive	59.9	4.132	69	189.7± 9.4	12.998± 0.753	3.16	147.6± 7.5	10.110± 0.470	2.46
	Active	53.4	4.010	75	199.2± 16.5	14.934± 1.358	3.73 (3.45)	153.9± 2.5	11.541± 0.589	2.88 (2.67)
5	Passive	99.2	5.455	56	192.5± 22.3	10.816± 1.434	1.94	147.0± 14.5	8.259± 0.990	1.48
	Active	95.0	7.128	75	207.6± 3.8	15.455± 0.423	2.18 (2.06)	155.7± 4.2	11.594± 0.481	1.63 (0.56)

Cond.: Activity State

Isotope Dil. Data: Cardiac Output Determined by Isotope Dilution Technic

Eject. time, 1st Deriv.: Impedance Cardiac Output measured using Ejection time determined from dZ/dt

Eject. time, ECG: Impedance Cardiac Output measured using Ejection time determined from ECG.

Z_{sv}/Isotope$_{sv}$: Ratio of Impedance Stroke Volume to Isotope Stroke Volume
Mean Z_{sv}/Isotope$_{sv}$ is in parentheses

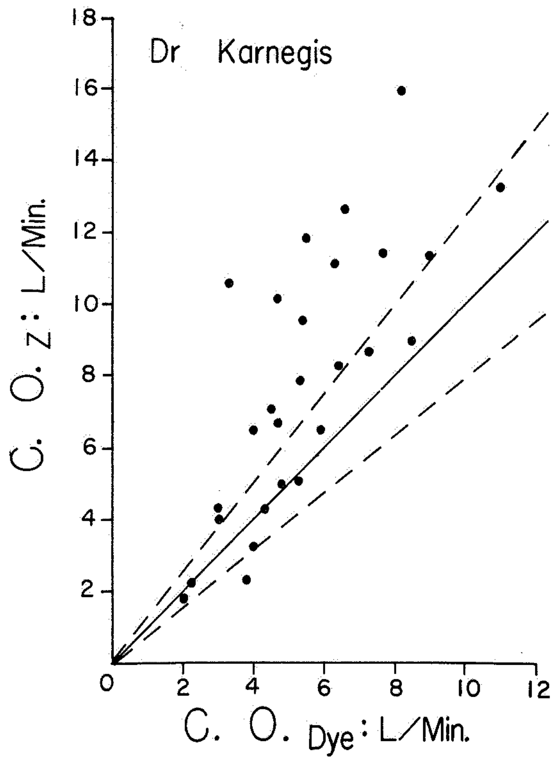


Fig. II-7 A graph of cardiac output values obtained by the Impedance and Dye dilution techniques

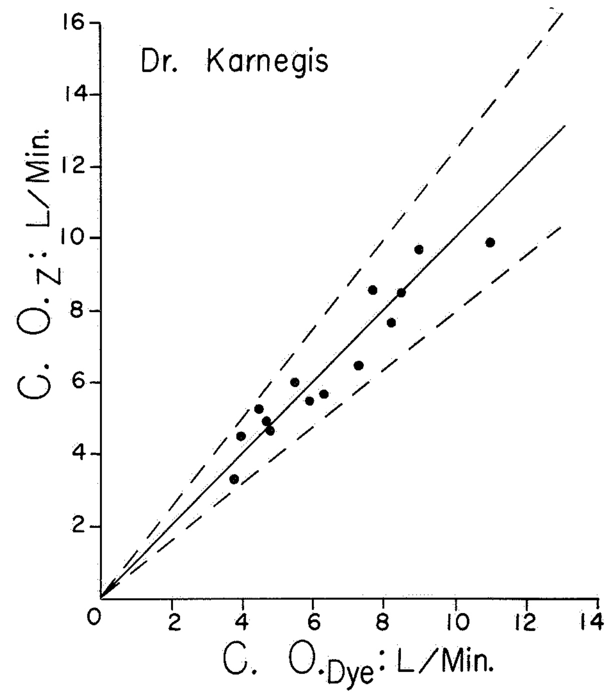


Fig. II-8 A graph of corrected values of cardiac output by the Impedance method plotted against the original values by the Dye method

TABLE II-3

(Karnegis)

PATIENT	DIAGNOSIS	PROCEDURE	$C.O._F$	$C.O._{DYE}$	$C.O._Z$	Z/DYE	
A.N.	mild M.S.	rest exercise	10.0	7.7 11.0	11.5 13.3	1.49 1.20	(1.35)
I.N.	Turner's Syndrome MI	rest	3.3	2.95	4.3	1.41	
M.M.	MS, MI, TI	rest	2.7		4.4		
A.E.	MS, MI	rest	2.5	2.15	2.2	1.02	
M.K.	AS, AI, MI	rest	5.3	5.33	5.1	0.96	
O.M.	AI, MI, Coronary Dis.	rest	4.6	5.26	7.9	1.56	
C.D.	mild AI, MI	rest	5.1	3.0	3.98	1.33	
L.S.	AI, MI	rest	4.2	5.35	9.6	1.78	
L.H.	IDPA	rest exercise	6.8	5.9 9.0	6.5 11.4	1.10 1.26	(1.18)
D.S.	Dis. Aneurism, AI	rest	4.0	4.0	6.5	1.62	
P.B.	MS, MI, AS, AI, TS	rest	2.4				
F.W.	AS, AI, MI	rest	4.8		6.2		
W.S.	mild MI	rest	6.7	6.57	12.7	1.93	
W.H.	severe AS, mild AI	rest	4.8	3.6			
M.G.	mod.-severe AS, MS mild AI, MI	rest	3.7	4.26	4.3	1.01	

TABLE II-3 cont'd (Karnegis)

PATIENT	DIAGNOSIS	PROCEDURE	$C.O._F$	$C.O._{DYE}$	$C.O._Z$	Z/DYE	
B.K.	AS, AI, MI	rest	3.3		3.5		
J.S.	MI	rest	6.7	6.4	8.3	1.30	
T.M.	AS, AI, MI	rest	4.9	4.65	6.7	1.44	
A.C.	AS	rest Isuprel	4.8	5.5 6.3	11.9 11.2	2.16 1.79	(1.97)
M.N.	MS, MI	rest	3.2	3.25	10.6	3.26	
L.S.	left atrial myxoma	rest	2.6		7.2		
Z.S.	AS, AI	rest exercise	4.3	4.65 8.2	10.2 16.0	2.20 1.95	(2.08)
O.B.	minimal AI mild MI	rest exercise	5.4	4.75 8.45	5.0 9.0	1.05 1.06	(1.06)
M.D.	MS, MI, peculiar wave form	rest exercise	3.7	3.8 4.0	2.3 3.2	0.61 0.80	(0.71)
T.H.	mild MI	rest Isuprel	5.7	4.5 7.3	7.1 8.7	1.58 1.19	(1.39)
L.V.	MS, MI, AI	rest	2.3	1.96	1.75	0.89	

$C.O._F$: Cardiac Output, Fick Method

$C.O._{DYE}$: Cardiac Output, Dye Dilution Method

$C.O._Z$: Impedance Cardiac Output

Z/DYE: Ratio of Impedance Cardiac Output to Dye Cardiac Output

Mean Z/DYE in parentheses

AI = Aortic Insufficiency
MI = Mitral Insufficiency
TI = Tricuspid Insufficiency
AS = Aortic Stenosis
MS = Mitral Stenosis

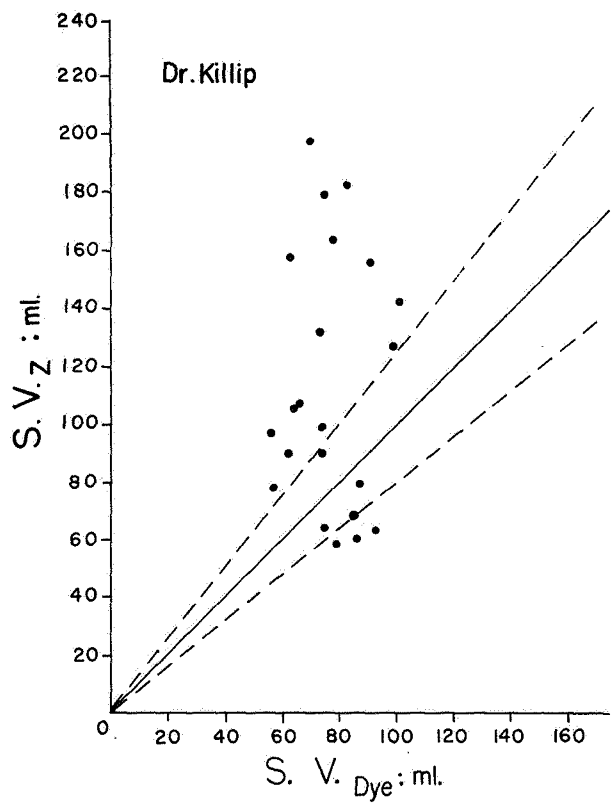


Fig. II-9 A plot of stroke volume values obtained by the Impedance and Dye dilution methods

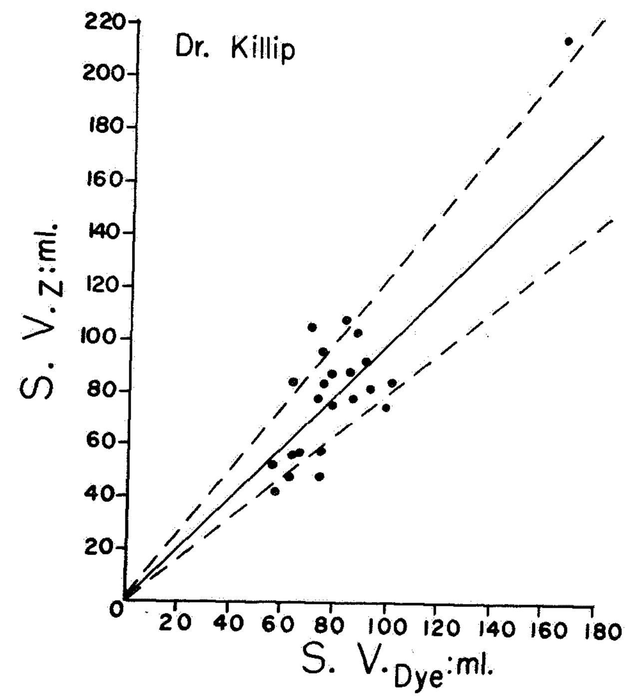


Fig. II-10 A graph of corrected Impedance stroke volume values plotted against the original values obtained by the Dye dilution technique

TABLE II-4 (Killip)

Patient	Diagnosis	HR	$C.O._{Dye}$	$C.O._Z$	Z/Dye
W.W.	Hemangioma		7.46	7.29	0.97
age - 18 yrs.	right cheek		7.17	8.18	1.14
			6.92	6.85	0.99
			7.85	6.75	0.86
			7.06	5.74	0.82
			8.27	6.61	0.79
					Mean (.92)
J.D.	Complete Heart	28	4.67	10.30	2.20
age - 64 yrs.	Block-Artificial	54	4.53	9.89	2.18
	pacemaker	54	3.99	7.13	1.78
		54	4.95	8.46	1.70
		70	7.11	10.00	1.40
		70	6.95	8.95	1.28
		100	7.48	9.93	1.32
					Mean (1.69)
B.S.	Complete Heart	65	4.10	10.30	2.51
age - 76 yrs.	Block-Pacemaker	65	4.86	5.86	1.20
	Rate Adjusted	65	5.07	10.70	2.11
		65	4.93	11.70	2.37
		77	4.85	6.93	1.42
		76	5.07	8.15	1.60
		75	5.32	14.90	2.80
		90	5.80	9.50	1.63
		91	5.18	8.84	1.70
		91	5.20	7.16	1.37
					Mean (1.87)
G.V.	Complete Heart	72	6.20	4.32	0.69
age - 68 yrs.	Block-Pacemaker	72	6.16	4.90	0.79
	Rate Adjusted	72	6.73	4.54	0.67
		79	5.95	5.10	0.91
		79	6.27	4.60	0.73
		79	6.95	6.25	0.89
					Mean (.78)

$C.O._{Dye}$: Cardiac Output, Dye Dilution Method L/Min

$C.O._Z$: Impedance Cardiac Output L/Min

Z/Dye: Ratio of Impedance Cardiac Output to Dye Cardiac Output

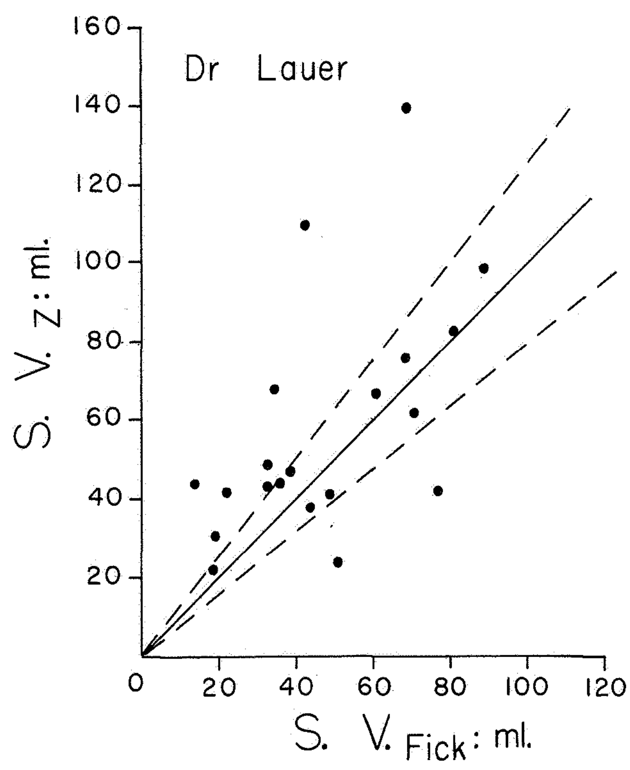


Fig. II-11 A plot of stroke volume values obtained by the Impedance and Fick methods

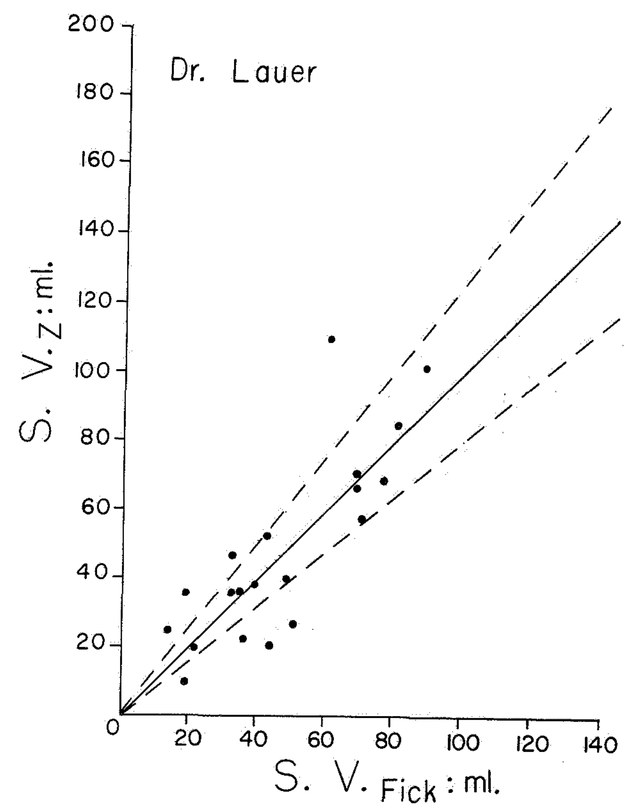


Fig. II-12 A graph of corrected Impedance stroke volume values plotted against the original values obtained by the Fick method

TABLE II-5 (Lauer)

Patient	Age	Sex	Diagnosis	State	FICK METHOD Stroke Vol.	FICK METHOD C.O.	FICK METHOD H.R.	IMPEDANCE METHOD Stroke Vol.	IMPEDANCE METHOD C.O.	IMPEDANCE METHOD H.R.	Z/Fick Ratio	
K.N.	13	M	Biscupid AV	Resting	43.0	3.44	80	110.35	10.79	98	2.56	
				Isup.	69.3	8.32	120	139.91	16.55	118	1.59	(2.07)
E.T.	7	M	Tetralogy of	Resting	21.9	2.19	100	41.78	3.97	96	1.90	
			Fallot-postop.	Isup.	18.6	2.60	140	21.57	3.91	180	2.24	(2.08)
S.W.	9	F	Partial AV	Resting	43.7	5.24	120	37.53	4.42	117	0.85	
			canal	Isup.	14.1	2.26	160	44.40	4.94	111	2.66	(1.76)
R.L.	6	M	T/F, postop.	Resting	33.1	3.31	100	43.05	4.21	97	1.30	
			Brocks	Isup.	39.1	5.48	140	46.70	6.92	148	1.10	(1.20)
M.S.	14	M	Ebstein's	Resting	69.4	6.94	100	75.63	6.48	86	1.08	
			Anomaly	Isup.	70.9	8.51	120	61.99	7.28	118	1.06	(1.07)
R.B.	3	M	Tetralogy of	Resting	48.9	5.87	120	41.08	6.16	148	0.84	
			Fallot-postop.	Isup.	33.2	5.32	160	48.67	7.75	160	1.23	(1.04)
D.F.	6	F	Mild PS ASD	Resting	34.7	3.12	90	68.48	6.34	92	1.97	
			ff mild L/R	Isup.	36.3	5.08	140	44.46	6.06	137	1.88	(1.93)
W.S.	14	M	Normal	Resting	76.5	7.65	100	41.95	5.01	119	0.54	
				Isup.	60.9	8.53	140	67.30	9.14	135	0.68	(0.61)
J.S.	15	M	Bicuspid AV	Resting	81.1	6.49	80	82.75	6.63	81	1.02	
				Isup.	89.4	7.15	80	98.50	7.88	80	0.92	(0.97)
T.A.	6	M	VSD, bidir.	Resting	50.5	6.50	130	23.75	3.50	152	0.47	
			shunt, Occ. PVD	Isup.	18.5	3.33	180	31.39	4.14	130	1.28	(0.87)

Z/Fick Ratio: Ratio of Impedance stroke volume to Z/Fick stroke volume.

Mean Z/Fick is in parentheses

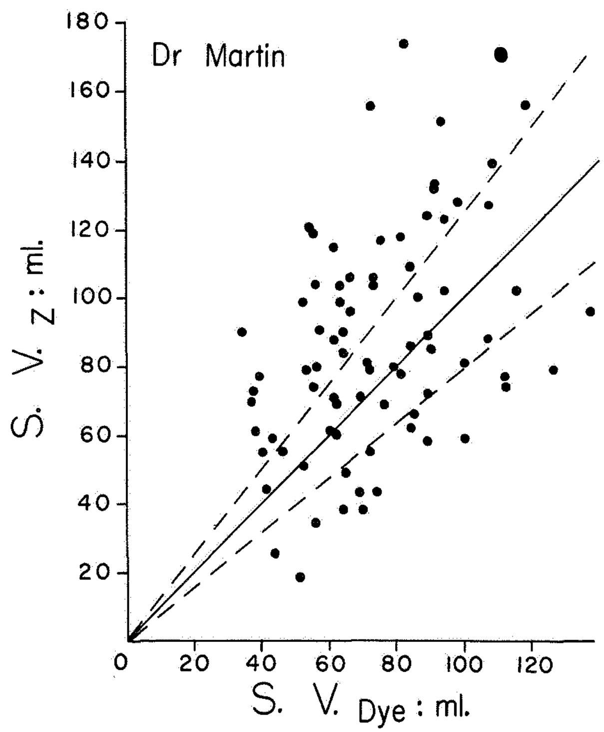


Fig. II-13 A graph of stroke volume values obtained by the Impedance and Dye dilution techniques

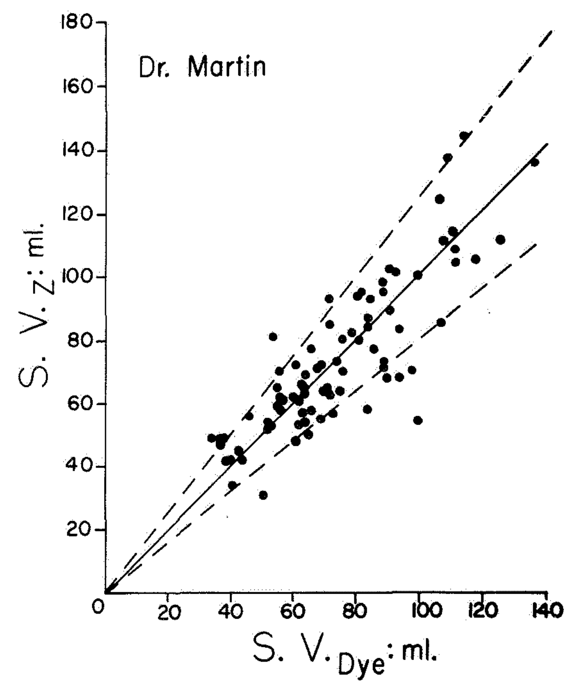


Fig. II-14 A graph of corrected Impedance stroke volume values plotted against the original values obtained by the Dye method

TABLE II-6

(Martin)

Patient #	Sample #	SV_Z	SV_{Dye}	Z/Dye	
1	1	128	98	1.31	
	2	-	-	-	
	3	106	66	1.61	
	4	117	75	1.56	
	5	104	73	1.42	
	6	99	52	1.92	
	7	77	39	1.97	
	8	90	34	2.64	
	11	119	55	2.16	
	12	115	61	1.89	
	13	174	82	2.12	
	14	156	72	2.17	
	15	104	63	1.65	
	16	88	61	1.44	(1.83)
2	1	81	100	0.81	
	2	70	37	1.89	
	3	73	37	1.97	
	4	79	53	1.49	
	5	99	63	1.57	
	6	106	73	1.45	
	7	121	54	2.24	
	8	104	56	1.86	
	9	91	57	1.60	
	10	86	84	1.02	
	11	170	111	1.53	
	12	127	107	1.19	
	13	151	93	1.62	
	14	123	94	1.31	
	15	133	91	1.46	
	16	102	94	1.09	
	17	156	118	1.32	(1.49)

TABLE II-6 cont'd (Martin)

Patient #	Sample #	SV_Z	SV_{Dye}	Z/Dye	
3	1	132	91	1.45	
	2	71	69	1.03	
	3	124	89	1.39	
	4	80	56	1.43	
	5	55	40	1.38	
	6	109	84	1.30	
	7	90	64	1.42	
	8	69	62	1.11	
	9	100	86	1.41	
	11	84	64	1.33	
	12	59	43	1.37	
	13	44	41	1.07	(1.30)
4	2	62	84	0.74	
	3	77	112	0.69	
	5	102	115	0.89	
	6	88	107	0.64	
	8	66	85	0.78	
	9	74	112	0.66	
	11	96	137	0.70	
	12	79	126	0.63	(0.71)
5	1	85	90	0.94	
	2	61	38	1.60	
	3	74	55	1.35	
	4	118	81	1.46	
	5	79	72	1.10	
	6	89	89	1.00	
	7	139	108	1.29	
	8	171	110	1.55	
	9	96	66	1.05	
	10	81	71	1.14	(1.25)

TABLE II-6 cont'd (Martin)

Patient #	Sample #	SV_Z	SV_{Dye}	Z/Dye	
6	1	58	89	0.65	
	2	18	51	0.35	
	3	25	44	0.57	
	4	34	56	0.61	
	5	55	72	0.76	
	6	43	69	0.62	
	7	38	64	0.59	
	8	38	70	0.54	
	9	43	74	0.62	
	10	59	100	0.59	(0.59)
7	1	72	89	0.81	
	2	80	79	1.01	
	3	60	62	0.97	
	4	55	46	1.20	
	5	51	52	0.98	
	6	49	65	0.75	
	7	78	81	0.96	
	8	69	76	0.91	
	9	61	60	1.02	
	10	71	61	1.16	(0.98)

SV_Z: Stroke Volume by Impedance Method

SV_{Dye}: Stroke Volume by Cardio Green Dye Method

Z/Dye: Ratio of Impedance Stroke Volume to Dye Stroke Volume - Mean Z/Dye is in parentheses

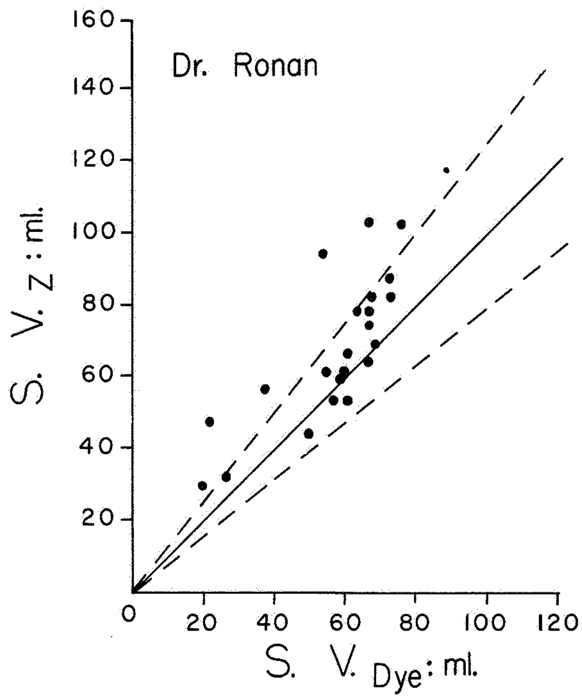


Fig. II-15 A graph of stroke volume values obtained by the Impedance and Dye dilution methods

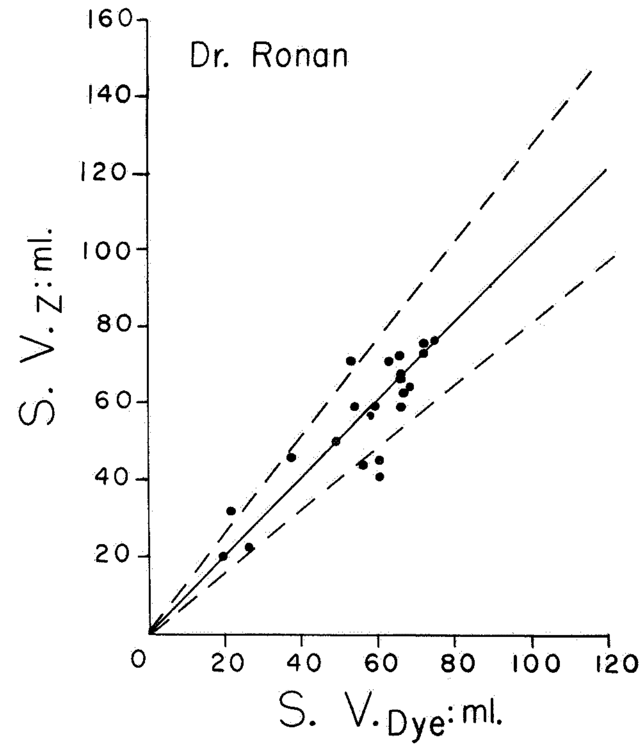


Fig. II-16 A graph of corrected Impedance stroke volume values plotted against the original values by the Dye method

TABLE II-7

(Ronan)

Patient	Clinical Setting	Impedance S.V.	Impedance H.R.	Impedance C.O.	Dye Dilution S.V.	Dye Dilution H.R.	Dye Dilution C.O.	Z/Dye	
G.	Intensive care	45	98	4.4	50	96	4.8	0.90	
B.	Intensive care	54	87	4.7	57	90	5.2	0.95	
		57	72	4.1	38	84	3.2	1.50	(1.24)
S.	Coronary Angio.	88	80	7.0	73	80	5.9	1.20	
C.	Coronary Angio.	75	63	4.8	67	66	4.4	1.12	
D.	Coronary Angio.	70	80	5.6	69	78	5.4	1.01	
		79	78	6.1	67	78	5.2	1.17	(1.09)
L.	Coronary Angio.	104	63	6.6	67	72	4.8	1.55	
M.	Coronary Angio.	103	64	6.6	76	70	5.3	1.35	
H.	Coronary Angio.	60	68	4.1	59	72	4.2	1.01	
	Angiotensin	62	77	4.8	55	78	4.3	1.12	
	Angiotensin	62	79	4.9	60	84	5.0	1.03	(1.05)
T.	Coronary Angio.	65	97	6.3	67	90	6.0	0.97	
	Angiotensin	83	81	6.7	73	75	5.5	1.13	
	Angiotensin	79	90	7.1	64	84	5.4	1.23	(1.11)
D.	Coronary Angio.	54	100	5.4	61	102	6.2	0.88	
	Angiotensin	84	83	7.1	68	84	5.2	1.23	
	Angiotensin	95	86	8.2	54	84	4.5	1.75	(1.33)
S.	Coronary Angio.	48	86	4.2	22	84	1.9	2.18	
	Angiotensin	30	98	3.0	20	102	2.1	1.50	
	Control	33	96	3.2	27	96	2.6	1.22	
	Isuprel	67	98	6.6	61	96	5.8	1.09	(1.49)

S.V.: Stroke Volume
H.R.: Heart Rate
C.O.: Cardiac Output

Z/Dye: Ratio of Impedance Stroke Volume to Dye Stroke Volume -- Mean Z/Dye is in parentheses

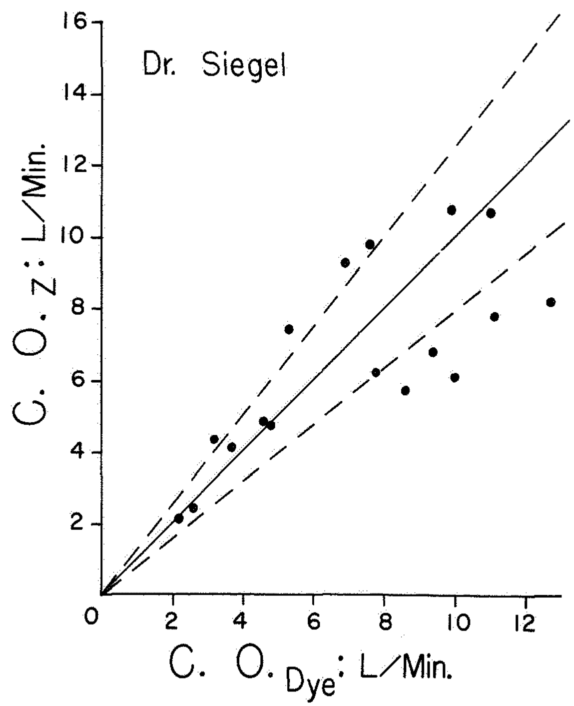


Fig. II-17 A graph of cardiac output values obtained by the Impedance and Dye dilution techniques

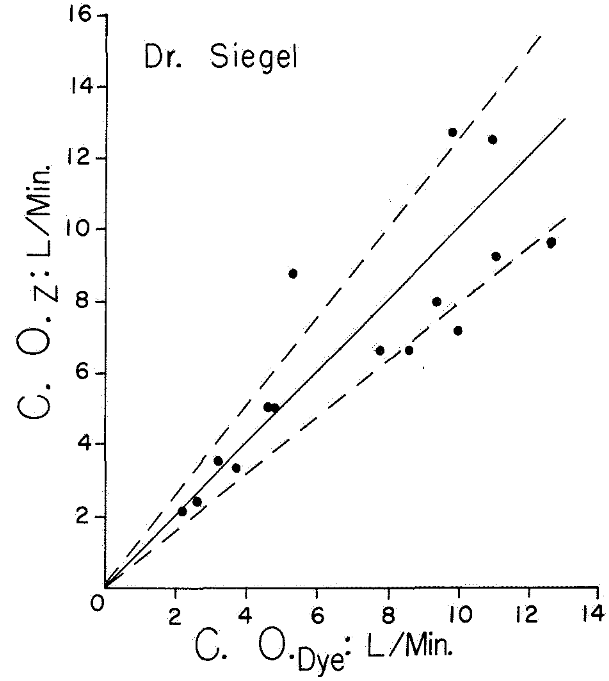


Fig. II-18 A graph of corrected Impedance cardiac output values plotted against the original values by the Dye method

TABLE II-8 (Siegel)

Patient	Intervention	CO_Z	CO Computer SH	Z/Dye	CO Manual SH	Z/Dye	CO Gamma Varient	Z/Dye
DM	Control	4.76	3.93	1.21	4.55	1.04	4.20	1.13
	$\bar{p}$ 500 ml Plasmonate	4.71	4.73	0.99	4.81	0.97	5.25	0.90
	1γ/min Isuprel	6.27	7.83	0.80	7.84	0.79	9.70	0.65
	$\bar{p}$ Isuprel	5.82	3.12					
			MEAN	1.00	MEAN	0.93	MEAN	0.89
D	Control Room Air	4.29	3.75	1.37	3.24	1.32	5.60	0.77
	100% O_2	4.11		1.09	3.73	1.10	4.80	0.86
	$\bar{p}$ 100% O_2	5.57						
			MEAN	1.23	MEAN	1.21	MEAN	0.82
PM	Control Room Air	2.13	2.17	0.98	2.17	0.98	2.60	0.82
	100% O_2	2.43	4.08	0.59	2.55	0.95	5.20	0.47
			MEAN	0.79	MEAN	0.97	MEAN	0.65
Q	Control Room Air	5.66	10.47	0.54	8.56	0.66	8.60	0.65
	100% O_2	6.11	10.09	0.60	10.03	0.60	9.20	0.66
	Control Room Air	8.50						
	Control Room Air	7.83	10.65	0.73	11.10	0.70	9.00	0.87
	100% O_2	8.22	12.40	0.66	12.67	0.64	12.20	0.67
	Control Room Air	10.83	9.64	1.12	9.92	1.09	11.40	0.95
	100% O_2	10.66	10.58	1.00	10.95	0.97	10.00	1.06
	Control Room Air	7.42	5.34	1.38	5.33	1.39	4.60	1.61
	100% O_2	6.80	8.57	0.79	9.38	0.72	8.60	0.79
			MEAN	0.86	MEAN	0.85	MEAN	0.91
A	Control Room Air	9.33	5.07	1.84	6.94	1.34	6.10	1.53
	100% O_2		4.80		6.27		5.05	
MD	Control Room Air	9.76	8.56	1.14	7.56	1.29	10.60	1.08

KEY TO COLUMN HEADINGS - TABLE II-8 (Siegel)

$C.O._{Z}$: Impedance Cardiac Output

$C.O._{\text{Computer S.H.}}$: Dye Cardiac Output automatically computed by Stewart Hamilton Method

$C.O._{\text{Manual S.H.}}$: Dye Cardiac Output manually computed by Stewart Hamilton Method

$C.O._{\text{gamma varient}}$: Cardiac Output, Gamma Varient Method

Z/Dye: Ratio of Impedance C.O. to S.H. Dye C.O.

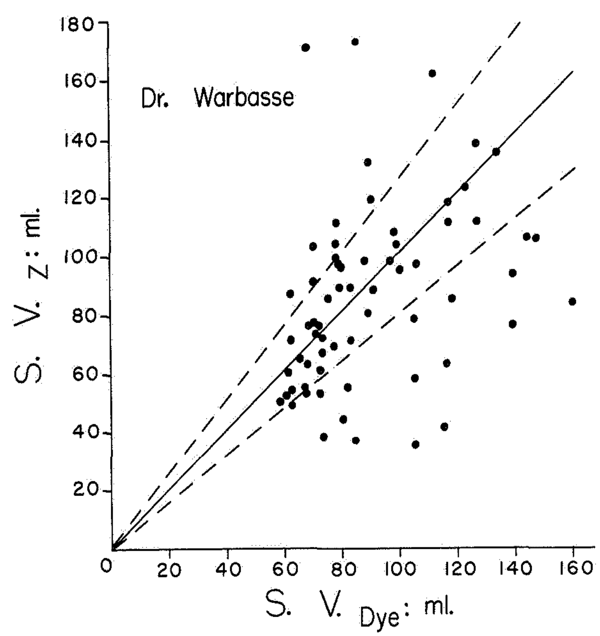


Fig. II-19 A graph of stroke volume values obtained by the Impedance and Dye dilution methods

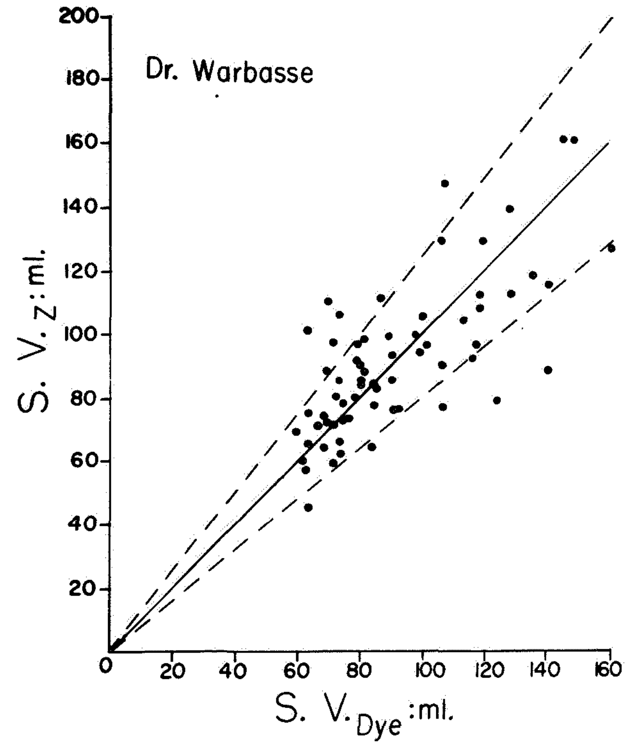


Fig. II-20 A graph of the corrected Impedance stroke volume values plotted against the original values obtained by the Dye dilution method

TABLE II-9 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error Vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
1	C.W.									
1a		82.11	4.93	16	76.98	4.62	+9	70.67	60	4.24
b		71.85	4.31	2			(1.09)			
c		76.98	4.62	9						
d		76.98	4.62	9						
2a		89.56	5.55	42	71.08	4.41	+13	62.90	62	3.90
b		68.24	5.02	8			(1.13)			
c		72.50	5.55	15						
d		72.50	5.29	15						
3a		99.97	6.00	24	96.16	5.77	+19	80.50	60	4.83
b		96.50	5.79	20			(1.19)			
c		91.68	5.50	14						
d		96.5	5.79	20						
4a		48.03	5.91	24	48.91	6.03	-22	62.93	123	7.74
b		48.03	5.91	24			(.78)			
c		49.14	6.04	22						
d		50.44	6.20	20						

TABLE II-9 contd. (Warbasse)
STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
1	C.W.									
5a		115.3	7.03	2	117.78	7.18		118.03	61	7.20
b		122.09	7.45	3.4			-0.22			
c		115.3	7.03	2			(1.00)			
d		118.4	7.22	0.3						
6a		96.84	8.72	23	99.10	8.91	+25	79.00	90	7.11
b		99.10	8.92	25						
c		99.10	8.92	25			(1.25)			
d			9.12	28						

TABLE II-10 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
2	D.B.									
1a		72.11	4.98	4.0	76.35	5.27	+10.2	69.28	69	4.78
b		74.60	5.15	7.7			(1.10)			
c		74.60	5.15	7.7						
d		84.10	5.80	21.4						
2a		86.81	5.64	8.1	89.10	5.79	+10.9	80.31	65	5.22
b		89.52	5.82	11.5			(1.11)			
c		86.81	5.64	8.1						
d		93.25	6.06	16.1						
3a		93.22	11.65	33.4	93.22	11.65	-33.4	139.92		17.49
b		93.22	11.65	33.4			(0.67)			
c		95.30	11.91	31.9						
d		91.15	11.39	35.9						
4a		90.67	13.48	7.4	89.47	13.06	+6.0	84.41		12.24
b		85.00	12.33	0.7			(1.06)			
c		89.14	12.92	5.6						
d		93.07	13.50	10.3						

(Warbasse)

TABLE II-10 cont'd

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats					
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
2	D.B.									
5a		63.02	6.30	2.3	60.39	6.04	-1.9	61.60	100	6.16
b		60.28	6.03	2.1			(0.98)			
c		60.28	6.03	2.1						
d		57.96	5.80	5.9						
6a		107.49	13.87	34.0	102.7	13.26	+44.6	71.01	129	9.17
b		101.16	13.05	42.3			(1.45)			
c		101.16	13.05	42.3						
d		101.16	13.05	42.3						

TABLE II-11 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
3	R.F.									
1a		91.84	5.88	14.4	97.2	6.22	+21.0	80.3	64	5.14
b		89.46	5.73	11.4			(1.21)			
c		107.35	6.87	33.6						
d		100.2	6.41	24.8						
2a		109.28	6.49	37.5	111.3	6.61	+40.0	79.46	59.4	4.72
b		120.42	7.15	51.5			(1.4)			
c		111.99	6.65	40.9						
d		103.5	6.15	30.3						
3a		101.68	6.20	29.2	104.4	6.28	+32.6	78.69	61	4.84
b		101.68	6.20	29.2			(1.33)			
c		104.96	6.40	33.4						
d		107.40	6.55	36.5						
4a		141.61	11.33	4.9	135.18	10.82	+ 0.1	135	80	10.80
b		146.85	11.75	8.8			(1.00)			
c		110.0	8.8	18.5						
d		142.27	11.38	5.4						

TABLE II-11 cont'd (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
3	R.F.									
5a		105.83	10.58	6.9	107.55	10.76	+8.6	99	100	9.90
b		107.95	10.8	9.0			(1.09)			
c		97.37	9.74	1.65						
d		119.06	11.91	20.2						
6a		86.77	7.01	5.54	87.5	7.08	-4.74	91.85	81	7.44
b		86.77	7.01	5.54			(0.95)			
c		86.77	7.01	5.54						
d		89.70	7.27	2.35						
7a		82.21	6.17	7.8	84.5	6.23	+10.8	76.26	75	5.72
b		85.26	6.39	11.8			(1.11)			
c		85.26	6.39	11.8						
d		85.26	6.39	11.8						

TABLE II-12 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study # 4	Patient's Initials H.R.	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
1a		83.22	5.66	17.63	95.12	7.47	-5.85	101.03	68	6.87
b		98.76	6.72	2.25			(0.94)			
c		105.06	7.14	3.99						
d		93.43	6.35	7.52						
2a		90.62	6.80	1.44	97.88	7.34	+9.57		75	6.70
b		99.35	7.45	11.22			(1.10)	89.33		
c		98.53	7.39	10.29						
d		103.03	7.73	15.33						
3a		94.12	7.25	4.13	98.18	7.56	0.00	98.18	77	7.56
b		99.91	7.69	1.76			(1.00)			
c		103.03	7.93	4.94						
d		95.67	7.37	2.56						
4a		111.45	11.15	5.15	110.66	11.07	-5.82	117.5	100	11.75
b		120.23	12.02	2.32			(0.94)			
c		96.21	9.62	18.12						
d		114.76	11.48	2.33						

(Warbasse)

TABLE II-12 cont'd

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
4	H.R.	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
5a		140.98	13.25	9.98	138.04	12.97	+7.68	128.19	94	12.05
b		145.14	13.64	13.22						
c		130.68	12.28	1.93			(1.08)			
d		135.38	12.72	5.6						
6a		112.70	10.14	12.03	110.87	9.98	-13.46	128.11	90	11.53
b		118.46	10.66	7.53			(0.87)			
c		105.62	9.51	17.56						
d		106.69	9.60	16.72						
7a		108.71	9.35	8.59	104.29	8.97	+4.17	100.12	86	8.61
b		109.05	9.39	8.93			(1.04)			
c		111.04	9.55	10.91						
d		88.36	7.60	11.74						

TABLE II-13 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
5	B.G.	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
1a		73.628	5.74	0.81	71.74	5.60	-3.35	74.23	78	5.79
b		70.12	5.47	5.54			(0.97)			
c		69.74	5.44	6.05						
d		73.46	5.73	1.04						
2a		75.30	5.87	4.32	73.26	5.71	+1.50	72.18	78	5.63
b		75.43	5.88	4.50			(1.01)			
c		72.23	5.63	0.059						
d		70.09	5.47	2.9						
3a		62.49	6.24	15.21	67.38	6.73	-8.58	73.70	100	7.37
b		70.72	7.07	4.04			(0.91)			
c		62.49	6.24	15.21						
d		73.80	7.38	0.14						
4a		70.09	7.13	16.14	70.86	7.22	-15.22	83.58	101.7	8.50
b		65.89	6.70	21.17			(0.85)			
c		75.16	7.64	10.07						
d		72.69	7.39	13.03						

TABLE II-13 cont'd (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
5	B.G.									
5a		62.65	5.51	24.86	60.91	5.36	-16.24	72.73	88	6.40
b		59.39	5.23	18.34			(0.84)			
c		58.97	5.19	18.92						
d		62.65	5.51	13.86						
6a		65.00	5.30	0.43	65.26	5.39	-0.64	65.68	81	5.32
b		67.28	5.45	0.44			(0.99)			
c		66.08	5.35	0.61						
d		67.28	5.45	2.44						

TABLE II-14 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study # 6	Patient's Initials L.T.	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
1a		160.07	12.65	87.	172.96	12.34		85.57	79	6.76
b		161.27	12.10	78.6			+102.1			
c		170.84	12.22	80.7			(2.02)			
d		199.65	12.38	83.1						
2a		179.87	11.2	161	171.26	10.76		68.89	63	4.34
b		158.95	10.01	130.7			+148.6			
c		177.94	11.21	158.			(2.48)			
d		168.28	10.6	144.						
3a		158.62	18.24	40.3	162.01	18.63		113.04	115	13.0
b		151.40	17.41	30.9			+43.3			
c		161.30	18.55	42.7			(1.43)			
d		176.72	20.32	56.33						
4a		118.72	14.24	4.20	122.68	14.72		123.92	120	14.87
b		119.65	14.36	4.20			-1.0			
c		130.59	15.67	5.38			(0.99)			
d		121.76	14.61	1.75						

TABLE II-14 cont'd (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats					
6	L.T.	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
5a		120.41	12.28	32.29	119.09	12.14		90.59	102	9.24
b		117.77	12.01	30.0			+20.68			
c		117.77	12.01	30.0			(1.31)			
d		120.41	12.28	32.29						
6a		121.13	11.5	34.90	132.48	12.58		89.79	95	8.53
b		132.14	12.55	47.18			+47.54			
c		132.14	12.55	47.18			(1.47)			
d		144.57	13.72	60.94						
7a		91.38	12.15	28.47	91.33	12.14		71.13	133	9.46
b		97.40	12.95	36.69			+28.39			
c		89.46	11.90	25.58			(1.28)			
d		87.08	11.58	22.42						

(Warbasse)

TABLE II-15

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
7	C.J.									
1a		31.29	2.28	63.4	37.25	2.72	-56.4	85.48	73	6.24
b		39.73	2.90	53.5			(0.44)			
c		35.96	2.63	57.9						
d		42.03	3.08	50.8						
2a		38.63	2.76	47.7	38.40	2.74	-48.0	73.80	71.4	5.24
b		38.63	2.76	47.7			(0.52)			
c		40.17	2.87	45.6						
d		36.18	2.58	50.1						
3a		51.95	6.23	51.0	58.18	6.95	-45.1	106.00	120	12.72
b		53.91	6.47	49.1			(0.55)			
c		59.80	7.18	43.6						
d		67.04	8.05	36.8						
4a		39.95	4.79	65.6	41.27	4.95	-64.5	116.25	120	13.95
b		41.15	4.94	64.6			(0.36)			
c		42.40	5.09	63.5						
d		41.58	4.99	64.2						

(Warbasse)

TABLE II-15 cont'd

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
7	C.J.									
5a		46.85	3.98	42.1	44.23	3.76	-45.4	80.94	85	6.88
b		46.54	3.96	42.5			(0.55)			
c		42.78	3.64	47.2						
d		40.74	3.46	49.7						
6a		31.26	3.19	70.6	34.51	3.52	-67.6	106.47	102	10.86
b		37.84	3.86	64.5			(0.32)			
c		34.47	3.52	67.6						
d		34.47	3.52	67.6						

TABLE II-16 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
8	J.P.									
1a		95.78	5.27	10.4	97.14	5.34	-9.1	106.91	55	5.88
b		104.52	5.75	2.6			(0.91)			
c		89.27	4.91	16.5						
d		98.98	5.44	7.4						
2a		82.94	4.56	30.3	85.10	4.68	-28.44	118.91	55	6.54
b		89.59	4.93	24.7			(0.72)			
c		80.54	4.43	32.3						
d		87.31	4.80	26.6						
3a		114.59	8.82	22.3	106.0	8.16	-28.2	147.53	77	11.36
b		103.69	7.98	29.7			(0.72)			
c		10 .65	8.29	27.0						
d		98.22	7.56	33.4						
4a		75.9	5.69	52.8	83.6	6.27		160.8	75	12.06
b		86.2	6.47	46.4			-48.0			
c		88.6	6.65	44.9			(0.52)			
d										

(Warbasse)

TABLE II-16 cont'd

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume	Impedance Cardiac Output L/Min	% of Error vs Dye			
8	J.P.									
5a		75.71	5.68	45.8	76.09	5.25	-45.54	139.70	67	9.36
b		71.50	4.79	48.8			(0.54)			
c		74.56	5.00	46.6						
d		82.59	5.53	40.9						
6a		108.62	9.88	27.1	105.98	9.65		145.27	91	13.22
b		107.52	9.78	26.0			-27.05			
c		103.19	9.39	29.0			(0.73)			
d		104.86	9.54	27.8						
7a		56.12	3.98	51.9	63.49	4.50	-45.63	116.76	71	8.29
b		65.94	4.68	43.5			(0.54)			
c		70.19	4.98	39.9						
d		61.73	4.38	47.1						

TABLE II-17 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
9	C.R.									
1a		51.83	3.16	37.77	55.17	3.35	-33.76	83.28	61	5.08
b		61.96	3.78	25.61			(0.66)			
c		53.45	3.26	35.82						
d		53.45	3.26	35.82						
2a		53.35	3.33	26.93	53.15	3.32	-27.21	73.01	62.5	4.60
b							(0.73)			
c		54.26	3.39	25.69						
d		51.83	3.24	29.01						
3a		53.33	3.25	21.43	54.63	3.33	-19.51	67.87	61	4.14
b		46.59	2.84	31.36			(0.80)			
c		62.95	3.84	7.25						
d		55.63	3.39	18.04						
4a		82.51	8.50	8.23	79.94	8.23	-11.08	89.90	103	9.26
b		82.51	8.50	8.23			(0.89)			
c		74.67	7.69	16.95						
d		80.08	8.25	10.93						

TABLE II-17 cont'd

(Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats					
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
9	C.R.									
5a		83.59	8.96	20.99	77.73	8.32	-26.53	105.79	107	11.32
b		76.43	8.18	27.76			(0.73)			
c		77.40	8.28	26.84						
d		73.49	7.86	30.54						
6a		67.3	5.79	13.62	68.71	5.91	-11.81	77.91	86	6.7
b		67.30	5.79	13.62			(0.88)			
c		66.25	5.70	14.97						
d		74.00	6.36	5.02						
7a		95.60	10.99	54.41	86.63	9.96	+37.22	63.13	115	7.26
b		78.52	9.03	24.37			(1.37)			
c		78.52	9.03	24.37						
d		93.87	10.80	48.72						
8a		52.86	4.97	14.04	52.01	4.89	-15.42	61.49	94	5.78
b		49.75	4.68	19.1			(0.85)			
c		51.21	4.81	19.1						
d		54.22	5.10	11.83						

TABLE II-18 (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
10	J.B.									
1a		54.66	3.72	19.16	53.44	3.80	-21.35	67.94	68	4.62
b		60.27	4.01	11.29			(0.79)			
c		57.53	3.91	15.33						
d		52.49	3.57	22.75						
2a		62.68	4.32	9.71	63.27	4.37	-8.86	69.42	69	4.79
b		67.47	4.66	2.81			(0.91)			
c		67.32	4.65	3.03						
d		55.62	3.84	19.88						
3a		53.39	6.57	15.49	53.97	6.64	-14.57	63.17	123	7.77
b		50.06	6.16	20.76			(0.85)			
c		53.52	6.58	15.28						
d		58.89	7.24	6.78						
4a		81.57	6.77	11.02	76.31	6.34	+3.83	73.49	83	6.10
b		78.02	6.48	6.16			(1.04)			
c		69.51	5.77	5.42						
d		76.13	6.32	3.59						

TABLE II-18 cont'd (Warbasse)

STROKE VOLUMES - ELECTRICAL IMPEDANCE AND INDICATOR DILUTION

Study #	Patient's Initials	Single Typical Beat			Average 4 Heart Beats			Dye Stroke Volume cc	Heart Rate	Dye Cardiac Output L/Min
		Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume cc	Impedance Cardiac Output L/Min	% of Error vs Dye			
10	J.B.									
5a		49.27	6.0	17.10	49.56	6.04	-16.61	59.43	122	7.25
b		49.27	6.0	17.10			(0.03)			
c		48.95	5.97	17.64						
d		50.76	6.19	14.59						

Table II-19 (Kubicek et al. 1966)

SUBJECT	METHOD	SUPINE		SITTING		EXERCISE I 4 min.	EXERCISE I 6 min.	RECOVERY I		EXERCISE II 4 min.	EXERCISE II 6 min.	RECOVERY II	
1	Dye	6.1	5.9	4.9	4.4	9.2	9.4	4.2	4.0	10.8	11.1	6.1	6.1
	Z_D	10.6	10.7	9.0	9.2	15.6	16.9	8.4	8.2	22.3	20.7	8.9	9.4
2	Dye	9.2	6.4	5.1	3.8	10.0	7.2	4.0	3.5	11.7	8.9	4.7	3.9
	Z_D	4.7	4.8	7.0	6.3	9.8	7.1	5.4	5.0	9.4	9.2	6.7	5.6
3	Dye	7.8	8.0	6.7	6.0	14.6	11.8	6.0	6.9	12.9	18.2	4.9	6.2
	Z_D	11.3	11.4	9.5	8.9	15.8	12.2	9.0	9.7	16.3	22.5	7.3	7.6
4	Dye	8.2	8.3	6.9	6.0	10.7	15.5	6.8	7.5	12.5	16.7	8.8	6.5
	Z_D	10.7	9.5	7.3	7.0	15.1	15.4	8.1	8.7	18.7	15.7	7.2	7.0
5	Dye	8.0	7.7	5.9	6.7	14.0	17.9		7.2			6.5	5.7
	Z_D	6.6	7.2	7.2	7.1	12.3	12.4	7.6	6.8	13.8	12.5	6.0	6.0
6	Dye	8.7	8.5	5.2	5.6	10.4	11.2	5.9	4.3	13.1	9.5	4.7	4.8
	Z_D	10.7	10.1	7.1	7.3	12.7	13.4	6.3	6.7	16.9	16.2	5.4	5.6
7	Dye	7.6	7.6	5.6	5.6	9.5	11.7	5.2	5.8	16.9	13.4	5.7	5.1
	Z_D	7.6	7.0	5.1	5.1	10.9	9.7	4.8	5.2	14.4	13.0	5.4	4.5
8	Dye	7.2	7.0	4.8		10.3	12.6	5.5	5.8	15.7	14.2	5.7	5.2
	Z_D	8.6	8.1	7.0	7.3		12.7	7.3	6.9	17.1	16.2	7.4	6.1
9	Dye	7.1	6.3	5.1	5.5	9.0	9.2	5.9	5.4	14.1	15.2	5.6	5.6
	Z_D	7.0	7.2	6.5	6.3	8.4	9.4	7.3	6.7	13.8	15.0	7.4	7.5
10	Dye	10.0	8.3	7.6	7.6	14.6	14.6	7.9	6.8	16.5	18.1	5.7	4.7
	Z_D	6.7	6.4	7.9	7.2	10.2	11.0	7.0	6.8	13.0	10.9	7.1	7.8

Cardiac output in L/Min. by the Dye dilution and Impedance (Z_D) methods

Table II-20 Average Ratios of the Impedance Calculated Cardiac Output to Dye Dilution Cardiac Output for each Experimental Condition. Standard Deviations of a Sample are shown for the Various Averages.

$$\frac{\text{Z Cardiac Output}}{\text{Dye Cardiac Output}}$$

Subject	Supine	Sitting	Exercise I	Recovery I	Exercise II	Recovery II	Average	±S.D.
1	1.77	1.69	1.75	2.02	2.03	1.50	1.79	±.18
2	.63	1.51	.99	1.39	.91	1.44	1.14	±.32
3	1.43	1.38	1.08	1.45	1.25	1.35	1.32	±.13
4	1.22	1.11	1.20	1.17	1.22	.95	1.15	±.09
5	.87	1.14	.79	.94		.98	.94	±.12
6	1.20	1.33	1.21	1.31	1.49	1.16	1.28	±.11
7	.96	.91	.98	.91	.91	.91	.93	±.03
8	1.17	1.45	1.00	1.25	1.11	1.23	1.20	±.14
9	1.06	1.21	.98	1.23	.98	1.33	1.13	±.13
10	.72	.99	.73	.94	.70	1.45	.92	±.26
Average	1.10	1.27	1.07	1.26	1.17	1.23	1.18	

s = .24

s = .08

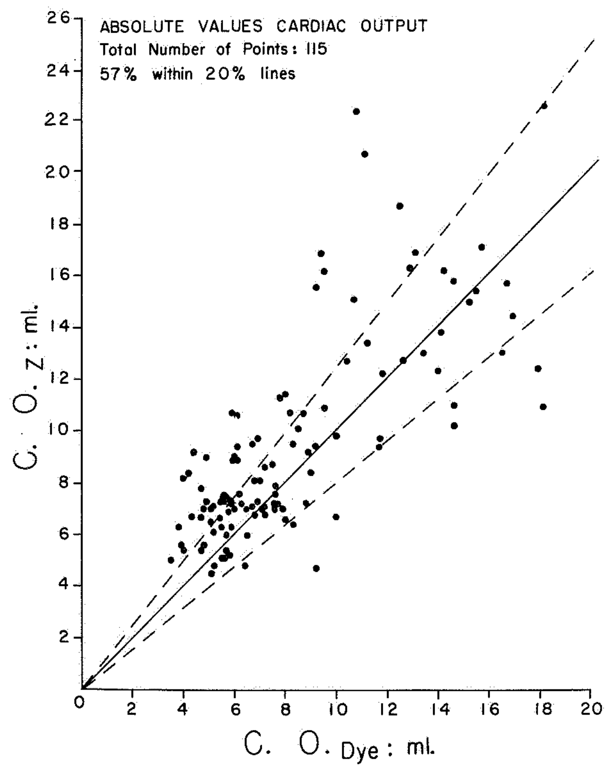


Fig. II-21 Absolute values of cardiac output by the Impedance and Dye dilution methods

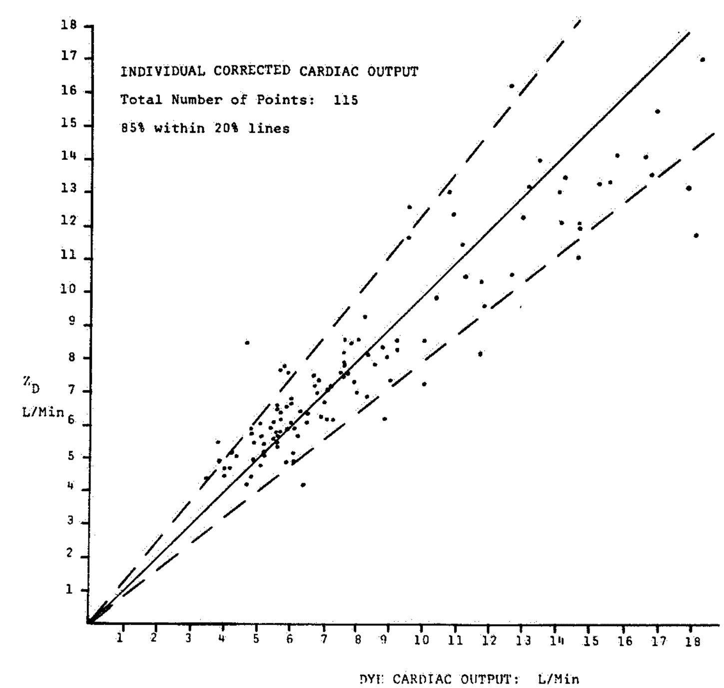


Fig. II-22 Individual corrected Impedance cardiac output values plotted against the original values by the Dye method. Kubicek et al., Aerospace Medicine Vol. 37, No. 12 Dec. 1966.

Part III

AN INFLIGHT PROTOTYPE AND CLINICAL LABORATORY IMPEDANCE ELECTRODE - CABLE HARNESS SYSTEM

Previous investigations by this laboratory (Kubicek *et al*., July 1967 Final Progress Report for Contract NAS 9-4500, Chapter Two) have determined that an adhesive electrode fabricated from metalized Mylar satisfied criteria concerning electrical characteristics and subject comfort and convenience. The purpose of this chapter is to describe an inflight prototype model electrode-cable harness system which implements the Mylar electrodes and is also applicable for the clinical or research laboratory.

The use of a harness with the four-band electrode system is desirable from the standpoint of maintaining the cable and electrode system as near constant as possible during a given experiment. Movement of the body electrodes due to varying cable tension can cause artifacts on the impedance records which are especially troublesome during dynamic experiments. With the harness it is also possible to standardize the electrode placement for a given subject.

The design criteria for the prototype inflight harness model required ease of donning and doffing and use of a lightweight durable material.

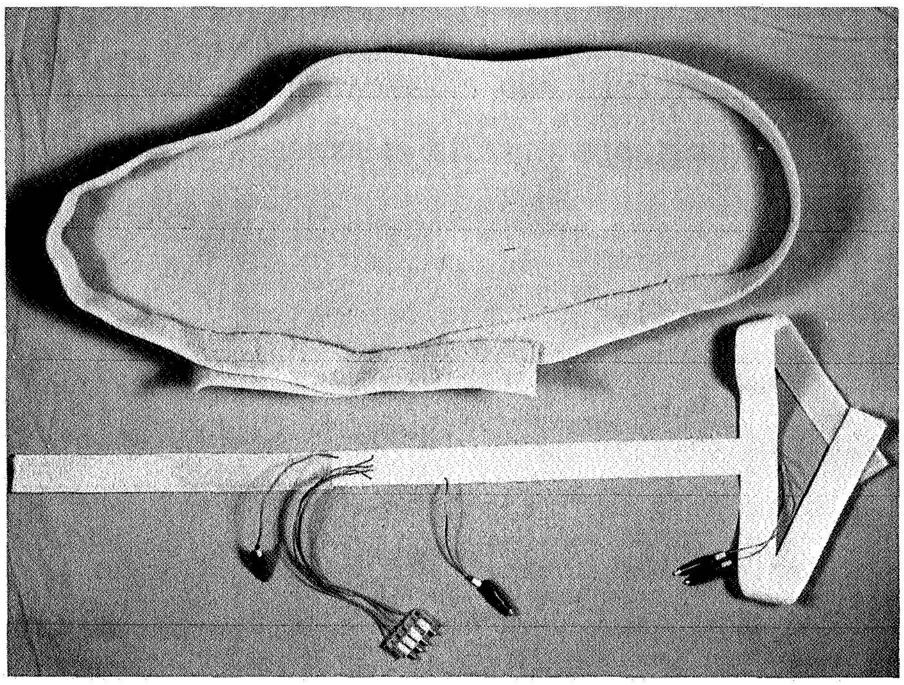


Fig. 1 Wire carrier and belt

I. Design and Fabrication

The cable harness, shown in figure 1, is composed of two parts, a vertical member called the wire carrier, and the horizontal member or the belt.

Wire Carrier - the wire carrier is composed of 1" wide Dacron fabric sewn with vertical and horizontal members. The vertical portion is two thicknesses sewn together, with 4 wires sandwiched in between the Dacron tape. Velcro hook material is placed at the caudal end to secure the end with the belt. The horizontal member of the wire carrier has Velcro pile and hook material to secure itself in a loop loosely about the neck as shown in figure 5.

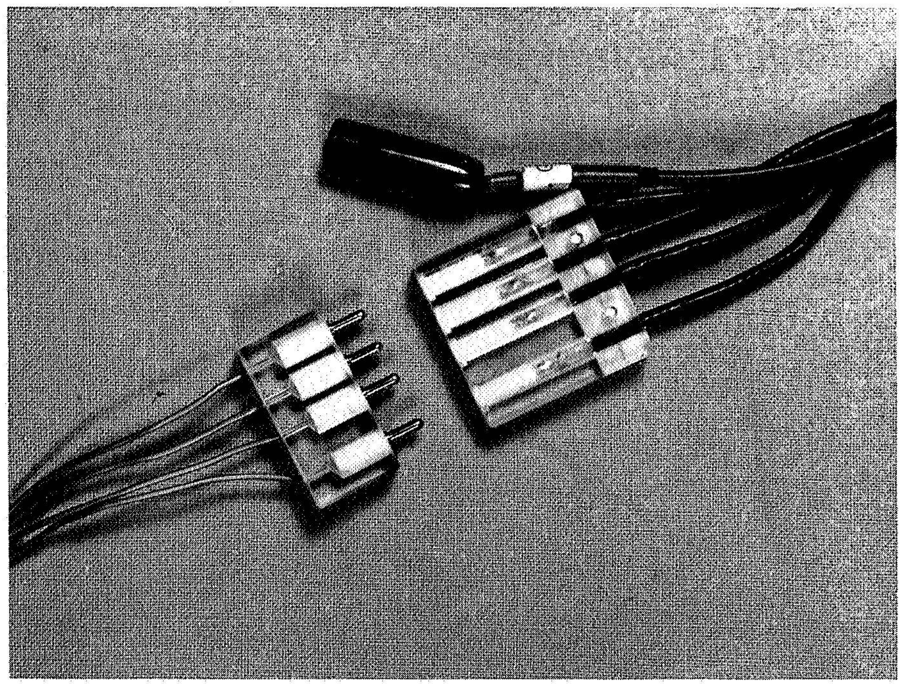


Fig. 2 Cable to harness connector

Conventional miniature alligator clips are used at the electrode end. Due to unavailability and lack of adaptability of commercial connectors, a special connector was developed for use at the cable end. Conventional miniature pin jacks and plugs were imbedded in plexiglass blocks to form a male and female connection as shown in figure 2. Note that this connector is keyed and can only be mated in one position, thus insuring that the four electrodes are correctly attached to the impedance cardiograph (ZCG). A fifth connector, the black pin jack seen in figure 2, is available for use as a separate ground connection on the subject if required by the experimental conditions or protocol.

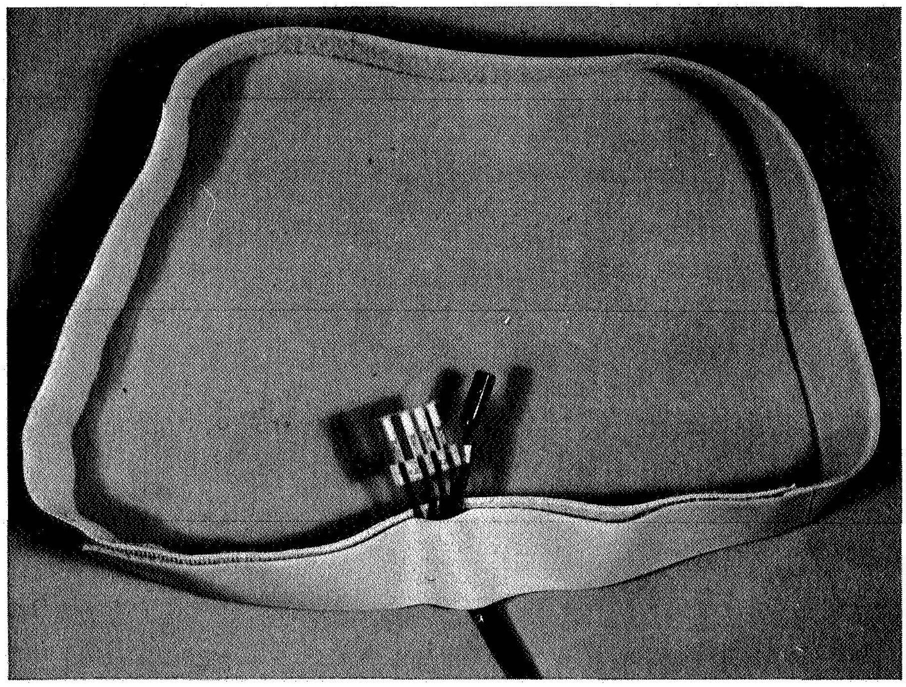


Fig. 3 Strain relief of cable by use of belt

Belt - The belt is made of conventional 2 inch wide Velcro pile with a length of Velcro hook sewn on. It secures around the waist with the hook engaging the belt and sandwiching the cable from the ZCG between the two as shown in figure 3. This results in a strain relief for the connector and cables under movement or exercise conditions.

II. Placement of Tape Electrodes and Harness on Patient

Body Electrodes - Figure 4 shows the tape-on electrodes in place on a subject. The electrodes are numbered 1 through 4 from the neck down. Care must be taken to place electrodes 1 and 2 on the neck at least 3 cm. apart in order to obtain an accurate Z_o reading. Electrode 3 is at the level of the xiphisternal junction and band 4 is placed around the torso near the lower abdomen.

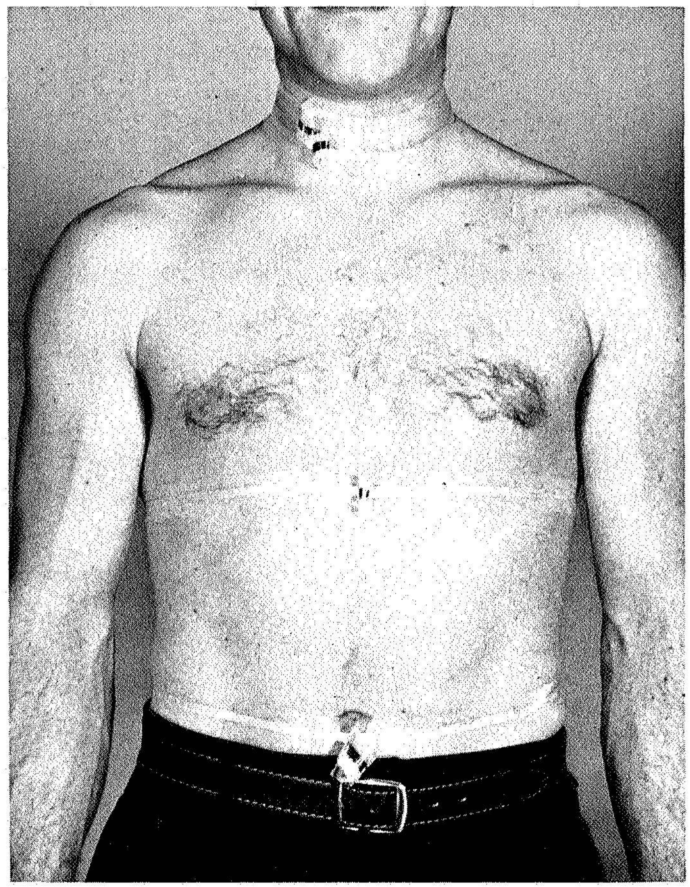


Fig. 4 Disposable electrodes in place

Harness - The electrode harness is shown in place on a subject in figure 5. The horizontal member of the wire carrier is looped loosely about the neck and secured with itself by means of the Velcro pile and hook material.

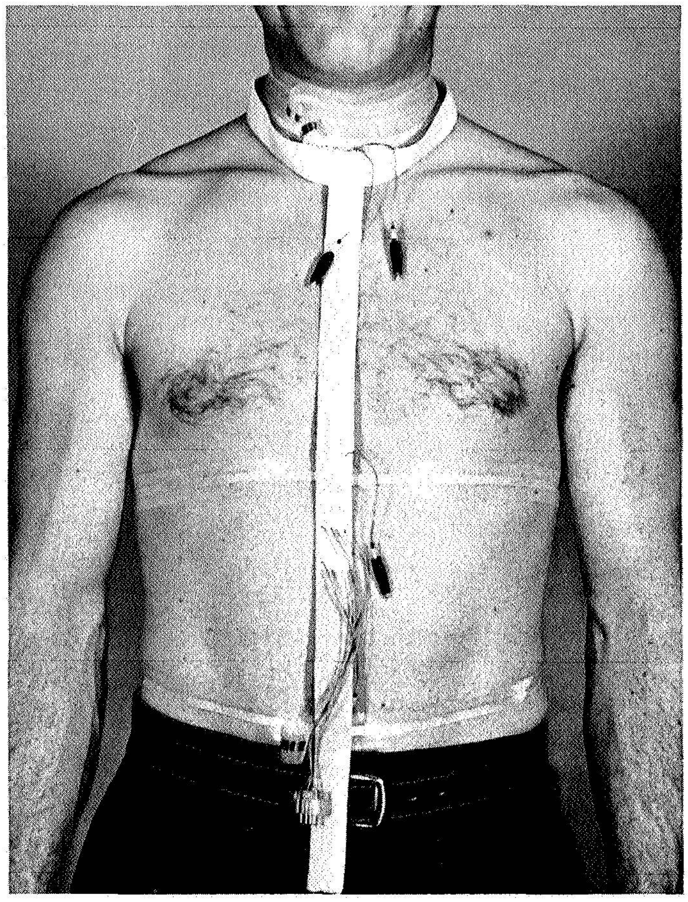


Fig. 5 Wire carrier on subject

The belt is placed around the waist with the pile side turned inward toward the body, as shown in figure 6. This Velcro pile engages the Velcro hook from the wire carrier and secures the caudal end of the wire carrier. An alligator clip is attached to the tape electrode as shown in figure 7. The tape should be bent back upon itself and the alligator clip placed to engage both sets of teeth on the aluminum conductor.

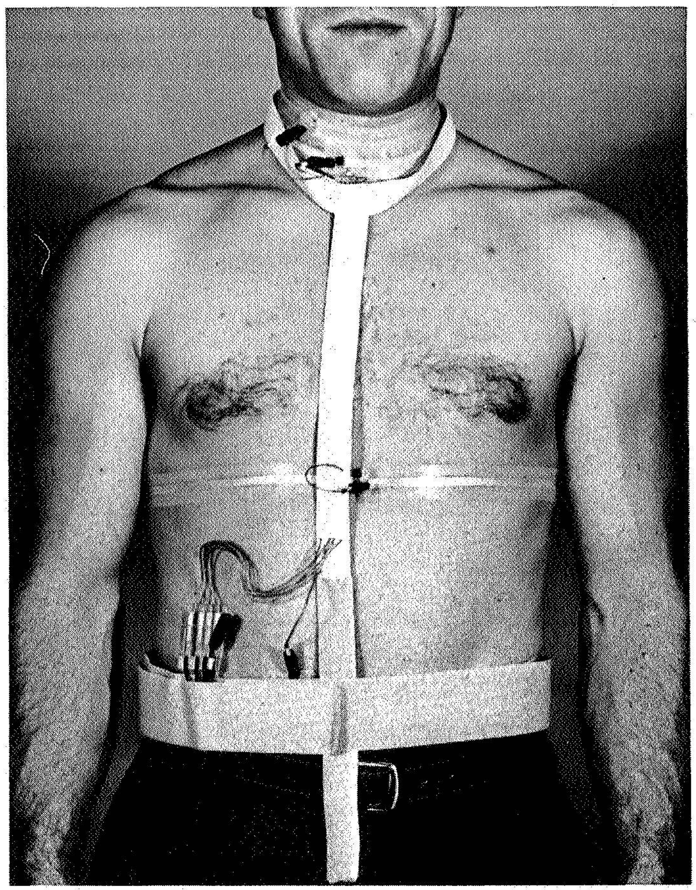


Fig. 6 Complete harness arrangement on subject

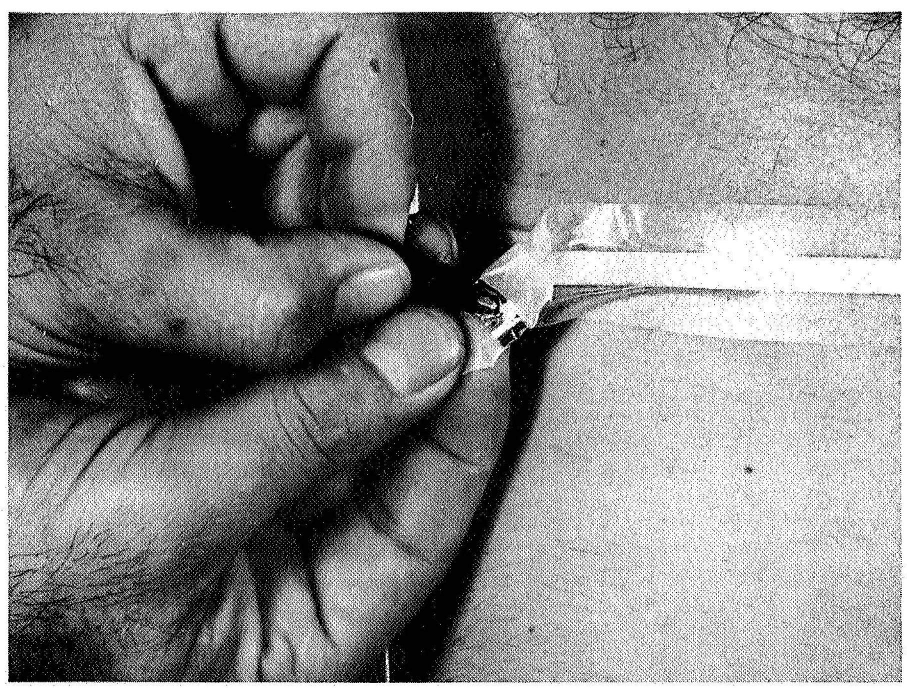


Fig. 7 Fastening of clip leads from wire carrier to electrode

III. Evaluation and summary of results obtained from the cable harness:

The harness has been used in our laboratory under various conditions. It has proven very successful in exercise studies to stabilize the electrodes and prevent cable motion from pulling on the electrodes. It is presently being utilized as standard equipment with the ZCG cardiographs by the various research laboratories involved in the evaluation study (chapter one). These laboratories indicate that the harness has worked successfully and an inflight model based on this prototype would appear to be quite functional.

Part IV

DIGITAL COMPUTER PROGRAM FOR COMPUTING STROKE VOLUME AND CARDIAC OUTPUT FROM THORACIC IMPEDANCE CHANGES DURING THE CARDIAC CYCLE (ZCG)

A digital computer program was developed that calculates the cardiac stroke volume, cardiac output and heart rate from analog information received from a ZCG instrument. The program is able to calculate the above parameters using only the first derivative of the thorax electrical impedance signal and the mean thoracic impedance. A total of 512 beats can be continuously calculated. The output from the computer is either in printed form showing the beat by beat values, four beat averages and normalized results or in graphic form using a digital plotter. The program was developed for a Spear micro-LINC 300 computer in assembly language.

Figure 1 shows a typical (dZ/dt) waveform recorded from four-band electrodes on the thorax as was previously reported (final report NAS 9-4500, July 1967). Shown in figure 1 are the points on the waveform used in the calculation of stroke volume and cardiac output. The stroke volume and cardiac output were calculated using the formulas shown below

$$\Delta V = \rho \frac{L^2 \tau}{Z_o^2} (dZ/dt)_{min} \qquad \text{eq. 1}$$

$$\text{and C.O.} = \Delta V/T \qquad \text{eq. 2}$$

where ΔV = stroke volume (cc)

ρ = resistivity of blood at 100 kHz and 37.5°C (150 ohm-cm)

L = mean distance between pick up electrodes (cm)

Z_o = impedance between pick up electrodes (ohms)

$(dZ/dt)_{min}$ = minimum value of the first time derivative of Z(ohms per sec)

$\tau = (T_3-T_1)$ = ventricular ejection time as determined from the dZ/dt waveform

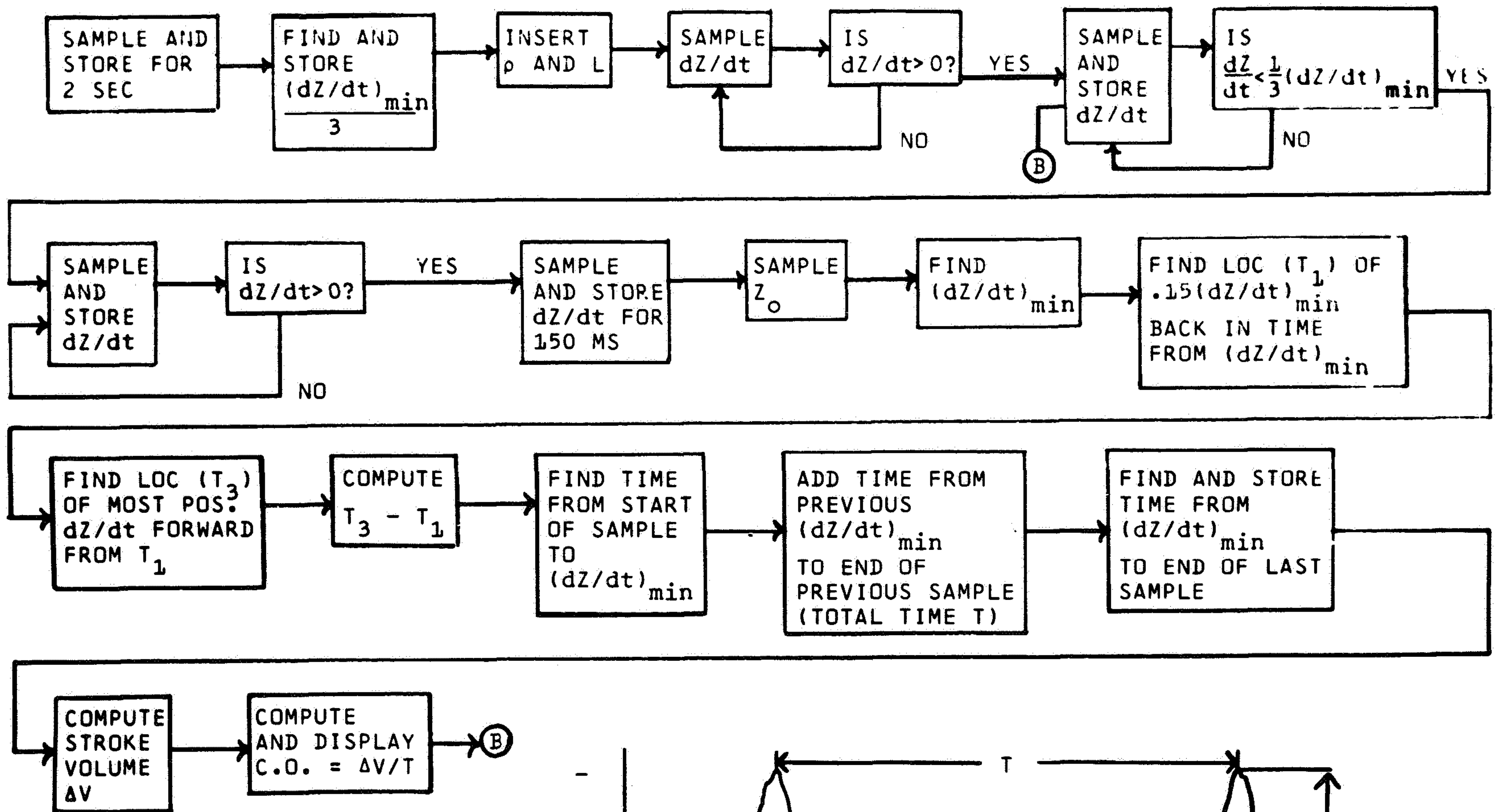
T = the time interval between heart beats in minutes

C.O. = cardiac output (cc per min)

Figure 1 shows the minimum value of dZ/dt, T_1, T_3, and T. The difference between T_1 and T_3 is the ventricular ejection time. T_1 is found by going back in time down the dZ/dt waveform as shown in fig. 1 from $(dZ/dt)_{min}$ to $.15(dZ/dt)_{min}$. This is done to eliminate from the ejection time determination the slow decrease in impedance that occurs with some individuals at the start of systole. T_3, the end of systole, is indicated by the peak positive dZ/dt after $(dZ/dt)_{min}$. In some subjects T_3 is not clearly defined; therefore the program will not calculate the correct ejection time. Also in some patients with heart valve defects, the waveform will be modified so that the program will not work correctly. The program was developed using only impedance information and does not require the ECG for timing. A simpler program could be developed using the ECG for timing but it could put a restriction on the use of the program in some applications.

Simplified Program Description

A simplified description of the sampling and calculation portion of the program is described below. The program starts



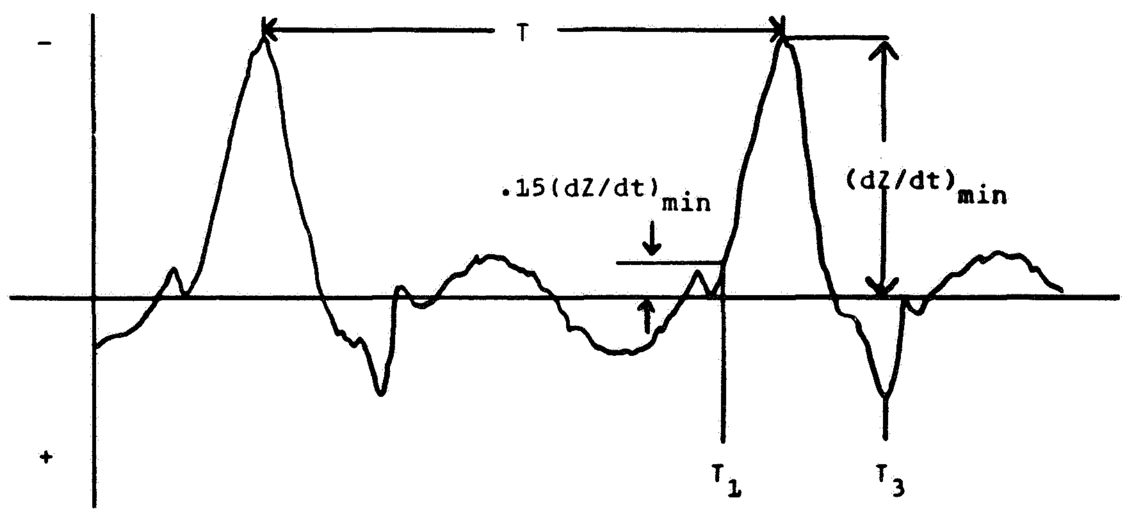


FIG.1 SIMPLIFIED BLOCK DIAGRAM AND SAMPLE dz/dt WAVEFORM

by sampling dZ/dt for two seconds as shown in fig. 1. It then finds $(dZ/dt)_{min}$ and divides it by three (in fig. 1 negative dZ/dt is above the zero line). The computer then starts sampling dZ/dt and looking for a positive dZ/dt value. When it finds a positive value it starts sampling and storing. The computer is now looking for the start of the next complete systole. Referring to the waveform shown in fig. 1, it can be seen that dZ/dt is positive only in the last part of systole or during diastole. If it is assumed that the computer found the positive value occurring during the latter part of systole, then from fig. 1 it can be seen that the next negative value of dZ/dt will occur during diastole. The normal subjects tested to date have shown negative dZ/dt values during diastole to be greater than 1/3(dZ/dt) min. Therefore, since the computer is looking for the start of a systole, it jumps over any dZ/dt until it is less than $1/3(dZ/dt)_{min}$ of the previous beat. After it finds a dZ/dt less than $1/3(dZ/dt)_{min}$ it assumes it is in a systolic ejection period and it begins to look for a zero crossing which will occur after $(dZ/dt)_{min}$. When the computer finds a zero crossing, it samples for 150 ms more which is enough time to cover a complete systolic ejection period. After a 150 ms, it samples the Z line to obtain Z_o. The computer then finds $(dZ/dt)_{min}$ and the location in memory of $.15(dZ/dt)_{min}$ by going back in time down the dZ/dt waveform from $(dZ/dt)_{min}$ as shown in fig. 1. Because the sampling rate is constant and the samples are stored in consecutive location in the memory, their position in the memory will be an indication of their occurrence in real time. After T_1 is found, it goes forward in time and finds the location in the memory of the most positive dZ/dt value in the current samples which corresponds to T_3. The computer then calculates $T_3 - T_1$ to obtain the systole ejection time τ. At this point the computer has all the information necessary to compute stroke volume.

The computer then proceeds to obtain T in order to compute heart rate per minute. It computes the time from the start of the sampling and storing period to $(dZ/dt)_{min}$ and adds to it the time from the previous $(dZ/dt)_{min}$ to the end of the previous sample period. The latter time interval will be in error on the first beat because of the delay necessary for the computer to find the start of systole. The computer then stores the time from the $(dZ/dt)_{min}$ of the present beat to the end of the current sample for use in calculating T for the next beat. The stroke volume and cardiac output is then calculated and the value of cardiac output is displayed on a cathode ray tube as a point on a graph. The computer then jumps to point B in the flow chart to start the next beat.

Operational Description of Program

The program computes, plots and prints stroke volume, pulse rate, and cardiac output. It consists of one master program and five sub-programs. The master program is called COCAL; the sub-programs are called INT-DSP, COMPUTE1, FIN-DSP1, PLOT1 and PRINT1. When the program COCAL is loaded in the computer the first display appears on the cathode ray display tube and the sub-programs are called in from digital tape as needed.

After the program is loaded and started a series of displays are shown asking questions about the values of the constants and calibrate factors as shown in fig. 2. The first displays gives the value of ρ as 150 ohm-cm. If this value is not desired, the delete key on the keyboard can be struck and the desired value of ρ entered. After the correct value is entered the end of line (EOL) key is struck which stores the value and a new display appears. The next two displays ask for the value of L front and L back. From these two values the computer computes the mean value and stores it as L. The next two displays ask for the values of the calibration factors relating Z_o and dZ/dt and analog input voltage representations of these parameters. The next display asks the operator to type S if the desired analog signals are entering the computer. After S is typed and the EOL key struck, the computer starts sampling the input signals and computes cardiac output. The computer can be temporarily halted and the sampling stopped at any time by raising sense switch 0. This feature allows the operator to stop the sampling if any artifacts appear or to compute only selected segments of the data from a long run. Also with the use of three other sense switches the digitized input waveforms or the calculated cardiac output results can be viewed on the cathode ray tube as the sampling and calculating is going on. All of the sampling and calculations are done in real time on a beat by beat basis. When the desired number of beats have been sampled and computed, the EOL key is struck to end this portion of the problem and to call in the output routines.

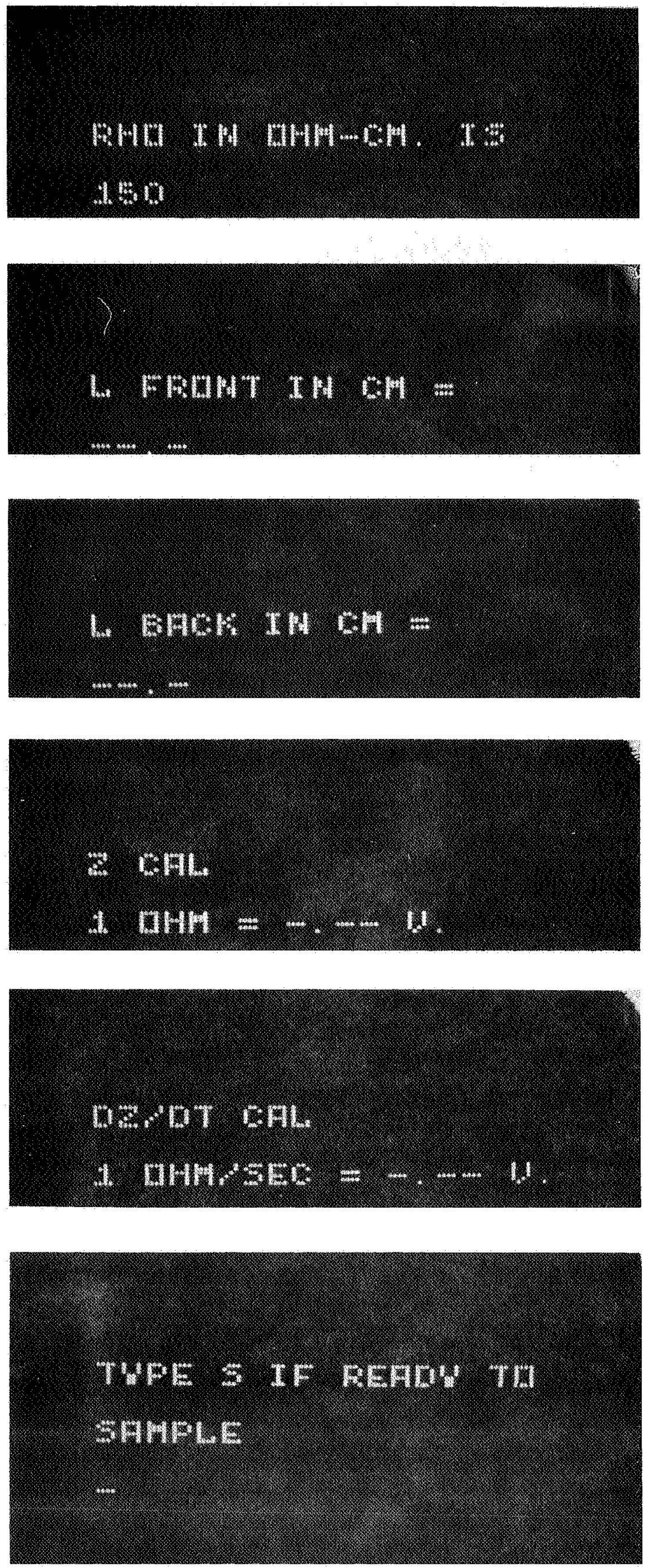
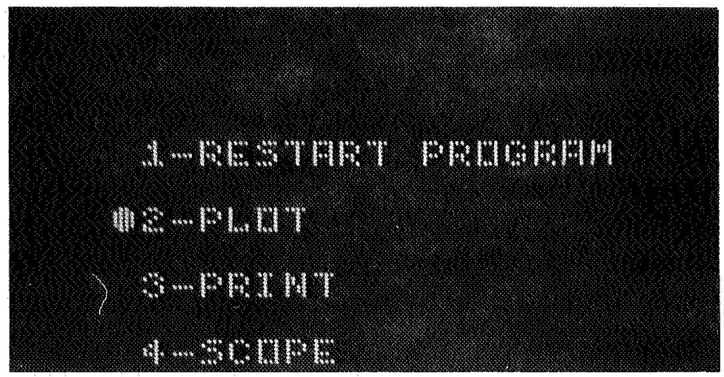
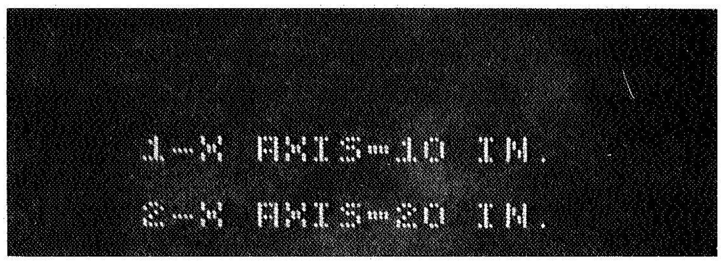


Fig. 2 Constants and Calibration factors as shown in input displays





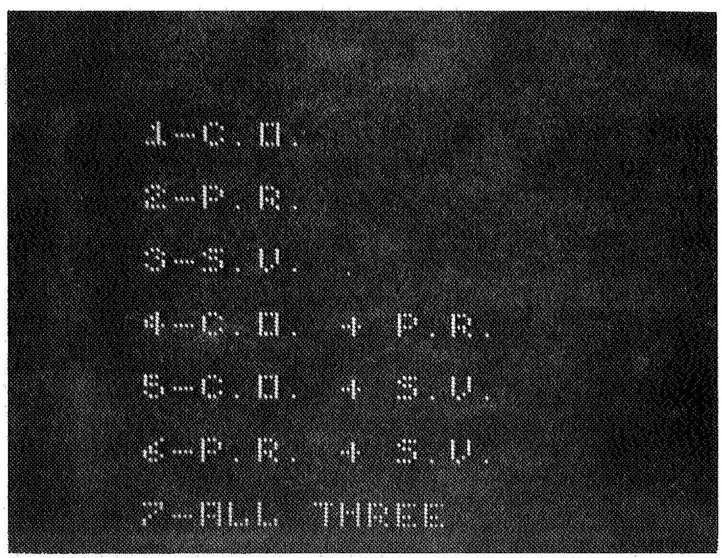


Fig. 3 Plotting option displays

The display that appears after the EOL key is struck is shown in the top display of figure 3 and is called the main selection option display. This is the display that is used to choose if plotting, printing or a cathode ray tube display of the data is desired. The choice is made by striking keyboard keys 2, 3 or 4. After the completion of the execution of any of the output operations this display reappears. The first choice on the display will restart the sampling and cardiac output calculation portion of the program. If key 2 followed by the EOL key are struck, indicating that plotting is desired, the next display will allow a choice between dog data or human data. The purpose of these choices is to adjust the scales to optimize the size of the graphs for the different values of stroke volume and cardiac output that occur in dogs and humans. The next choice is the length of the X axis desired. The last choice made, as indicated in figure 3, is to determine which variables or combination of variables should be plotted. After the execution of the last set of options the plotting operation will start. Two other switch settings on the computer control plotting functions. One is sense switch 1 which determines whether every point is plotted or only four beat average. The second is a register of switches called RSW which controls whether symbols will be plotted on the graph and if so how often. After the completion of the graph the display shown in the top of figure 3 returns.

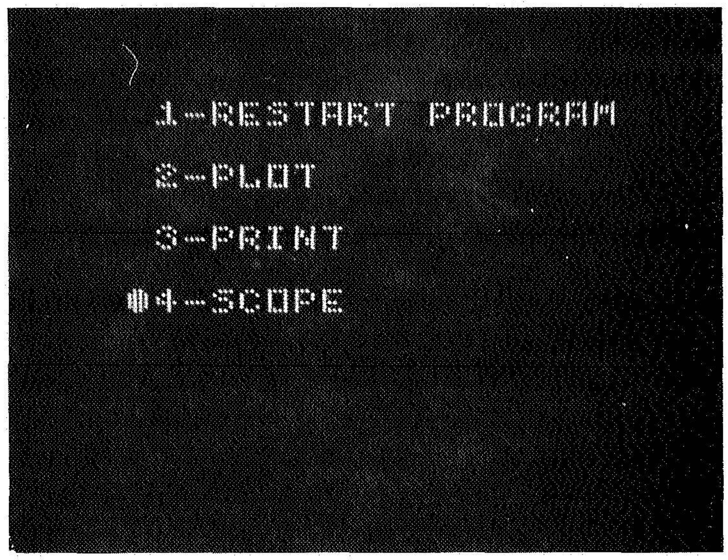
The next option (number 3) is for printing the results on the digital printer. The values for the cardiac output, stroke volume and pulse rate are automatically printed after selecting this option. The four beat averages, and the four beat averages normalized to the first average are printed for all the parameters. Striking the EOL key will terminate the printing of any parameter and the completion of printing of the entire computed results will return the program to the main option selection display as shown in the top of figure 3.

The last option (number 4) is the oscilloscope display of the computed results. The selections involved in this option are shown in figure 4. By striking key 1, 2 or 3, either the pulse rate, stroke volume or cardiac output can be displayed on the oscilloscope in graphic form similar to that plotted by the digital plotter. Striking the EOL key returns to the main selection option. From the main selection option the entire cycle can be repeated and the program restarted to sample data and compute cardiac output.

FLOW CHART AND ASSEMBLY LANGUAGE PROGRAM

The digital computer used in developing the computer program was a micro-LINC-300 manufactured by Spear Inc. Its logical structure is basically similar to the original LINC machine designed by Clark and Molnar (1,2). The principal differences between the micro-LINC 300 and the original LINC are in the input and output structure and the speed of operation. The machine used for this program has a real time clock that operates at speeds of 250 Hz, 500 Hz, 1000 Hz, and 4000 Hz. The clock operates through a priority interrupt system and is used in the program to determine the analog sampling rate.

The machine also has a small oscilloscope display that is



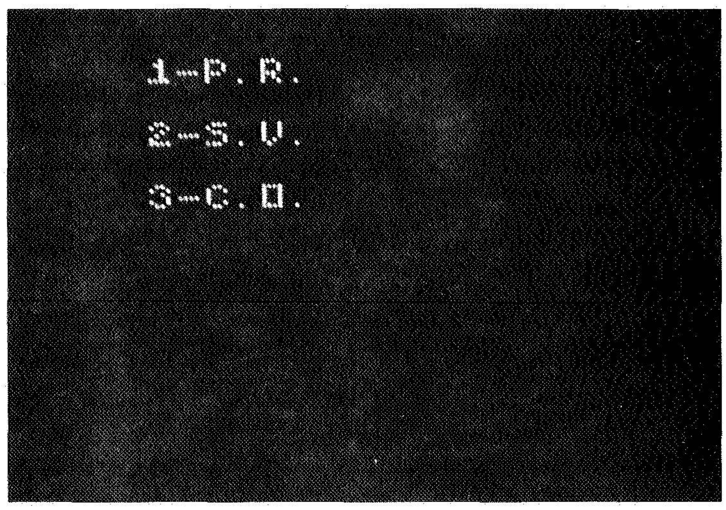


Fig. 4 Oscilloscope display option

controlled directly by the computer, four small digital tape transports with addressable 256 word blocks, a digital plotter, a digital printer and 12 analog to digital conversion channels controlled by the computer. The computer has a 4K memory with 12 bit words and operates with a memory cycle time of 1 microsec.

The computer program is written in an assembly language called LAP6. The assembly program is rather powerful and performs control functions as well as converting programs.

The following is a brief description of the programs used in the total cardiac output computing program.

COCAL - this program is the main control program. The program controls the analog to digital conversion and chooses the proper points from the curve for calculation. The program also locates the position of the other programs on tape and calls in most of the other programs as needed.

INT-DSP - this program generates the initial displays used in reading in the constants and calibration factors.

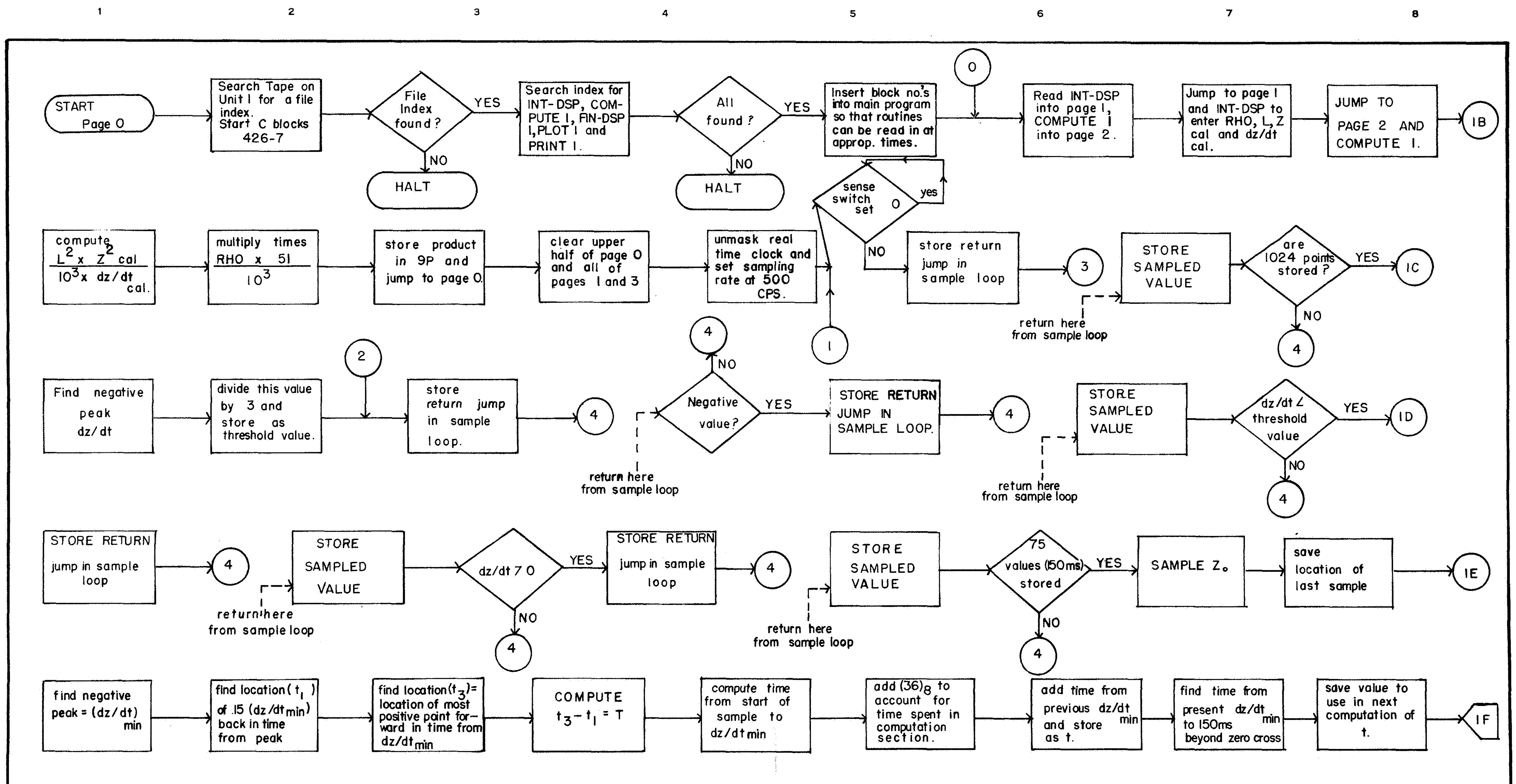
FIN-DSP1 - this program generates the final display routines that are used to choose the options for printing, plotting or oscilloscope display.

COMPUTE1 - this program performs the calculating operations in double precision floating point arithmetic.

PLOT1 - this program controls the plotting operations.

PRINT1 - this program controls the printing operations.

The next six fold-out pages contain detailed flow charts of the program. Following the flow charts is a complete manuscript listing of the computer program. Following the manuscript listing is an appendix that contains details on the program operations, a section on the computation of stroke volume, and cardiac output, and samples of the printer and computer outputs.



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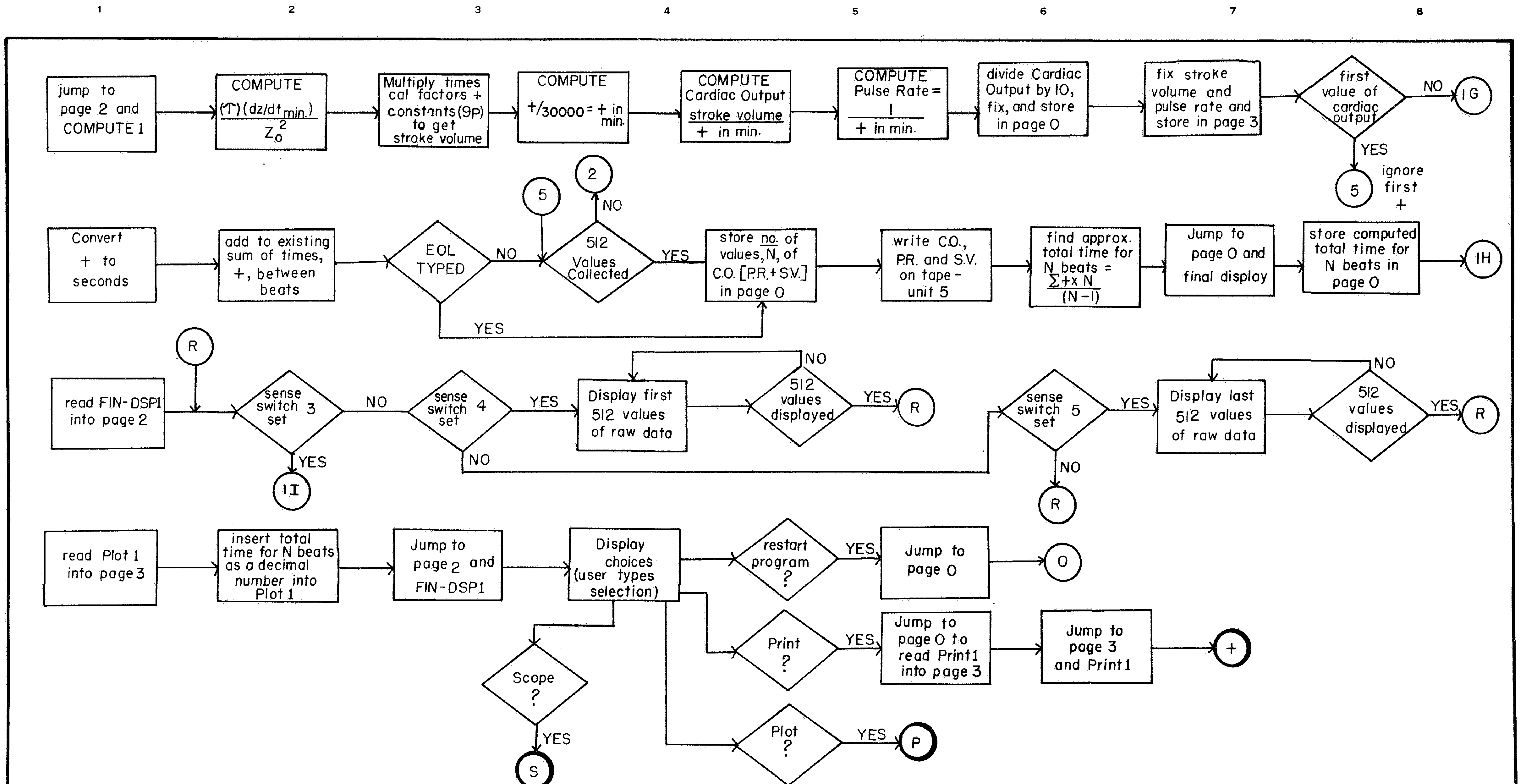
OTHER ☐	DRAWN BY	DATE	TASK NAME Cocal							



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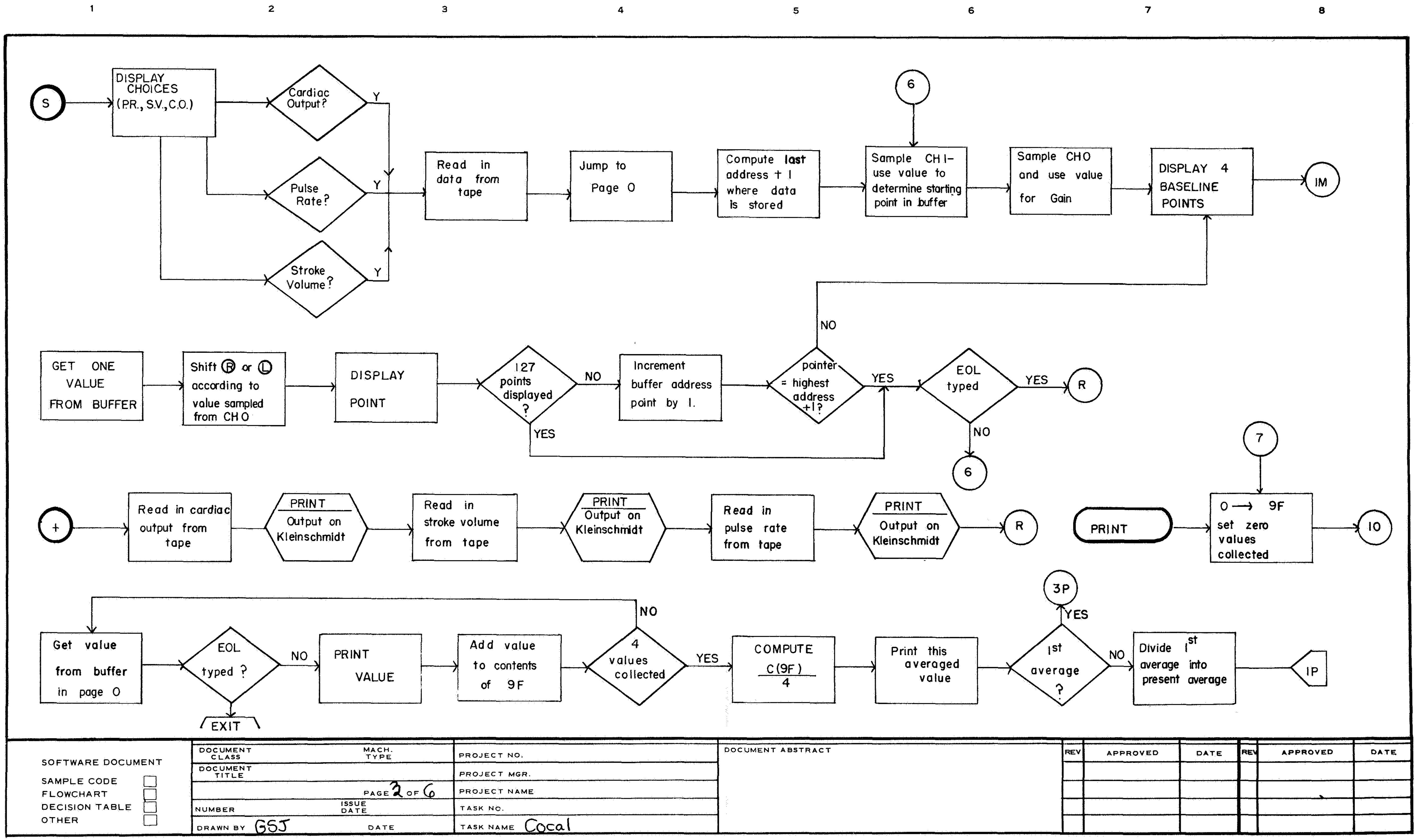
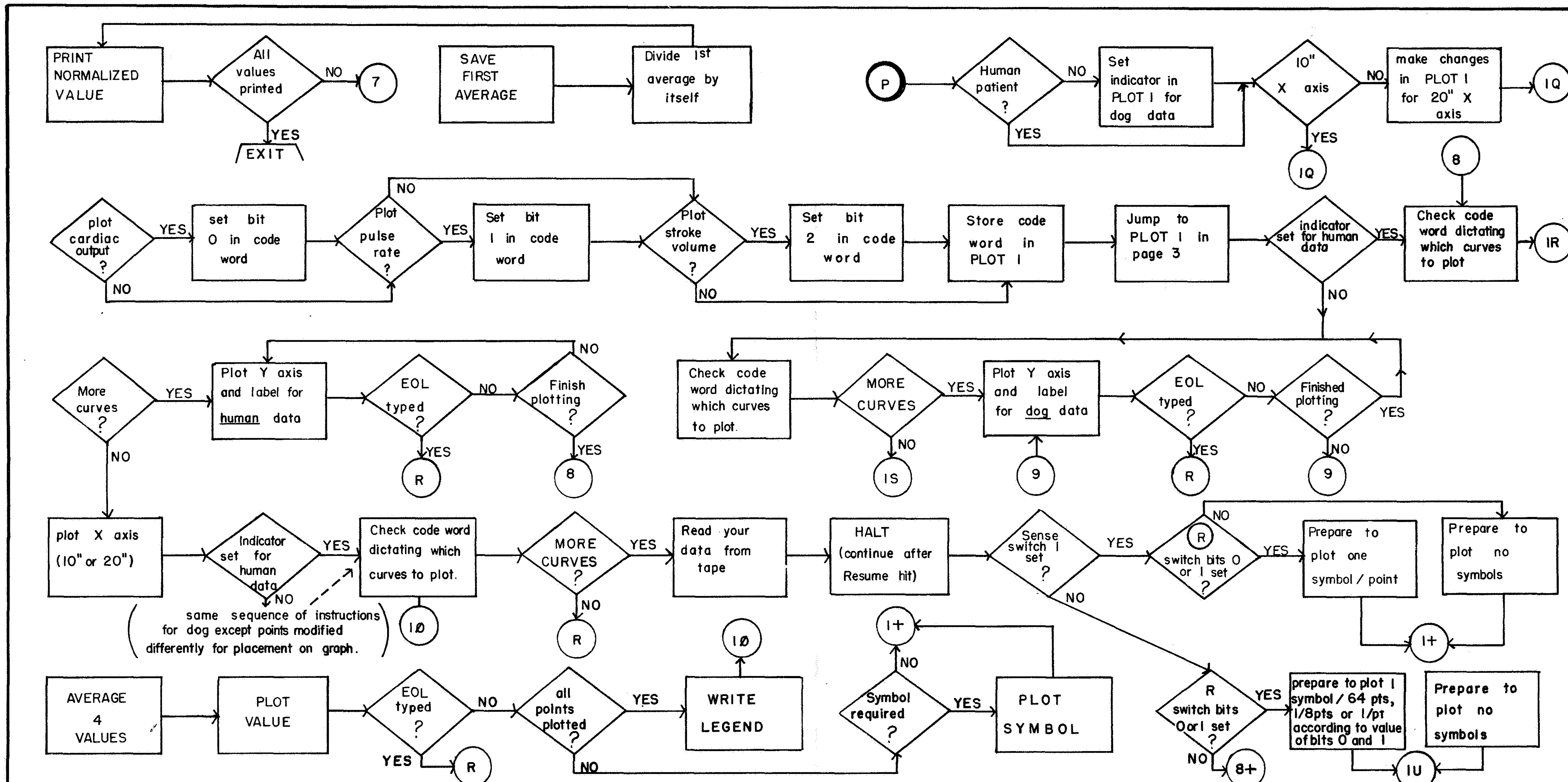
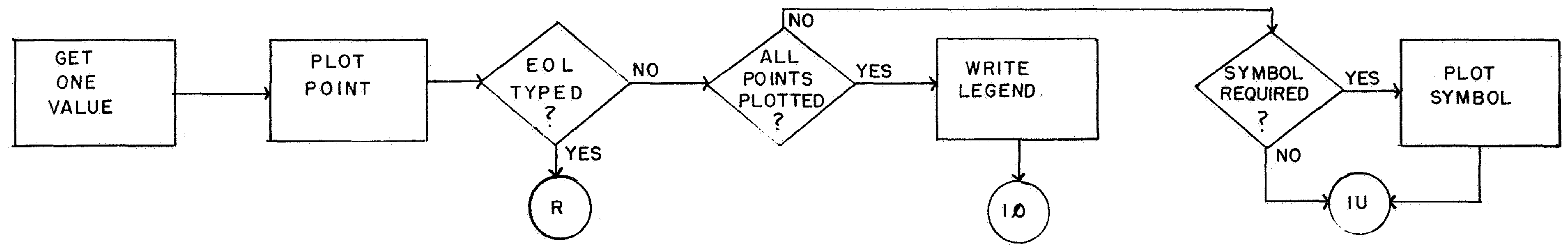
OTHER ☐	DRAWN BY GSJ	DATE	TASK NAME cocal			


1 2 3 4 5 6 7 8
K L M N O
S
DISPLAY CHOICES (P.R., S.V., C.O.)
Cardiac Output?
Pulse Rate?
Stroke Volume?
Y
Read in data from tape
Jump to Page 0
Compute last address + 1 where data is stored
6
Sample CH1- use value to determine starting point in buffer
Sample CHO and use value for Gain
DISPLAY 4 BASELINE POINTS
1M
GET ONE VALUE FROM BUFFER
Shift R or L according to value sampled from CHO
DISPLAY POINT
127 points displayed ?
NO
YES
Increment buffer address point by 1.
pointer = highest address +1?
EOL typed
R
6
+
Read in cardiac output from tape
PRINT Output on Kleinschmidt
Read in stroke volume from tape
Read in pulse rate from tape
7
PRINT
0 ⟶ 9F set zero values collected
10
Get value from buffer in page 0
EOL typed ?
EXIT
PRINT VALUE
Add value to contents of 9F
4 values collected
COMPUTE C(9F) / 4
Print this averaged value
1st average ?
3P
Divide 1st average into present average
1P
SOFTWARE DOCUMENT
SAMPLE CODE
FLOWCHART
DECISION TABLE
OTHER
DOCUMENT CLASS
MACH. TYPE
DOCUMENT TITLE
PAGE 2 OF 6
NUMBER
ISSUE DATE
DRAWN BY GSJ
DATE
PROJECT NO.
PROJECT MGR.
PROJECT NAME
TASK NO.
TASK NAME Cocal
DOCUMENT ABSTRACT
REV
APPROVED
DATE



SOFTWARE DOCUMENT	DOCUMENT CLASS / MACH. TYPE	PROJECT NO.	DOCUMENT ABSTRACT	REV / APPROVED / DATE / REV / APPROVED / DATE
SAMPLE CODE ☐	DOCUMENT TITLE	PROJECT MGR.		
FLOWCHART ☐	PAGE 4 OF 6	PROJECT NAME		
DECISION TABLE ☐	NUMBER / ISSUE DATE	TASK NO.		
OTHER ☐	DRAWN BY GSJ / DATE	TASK NAME Cocal		



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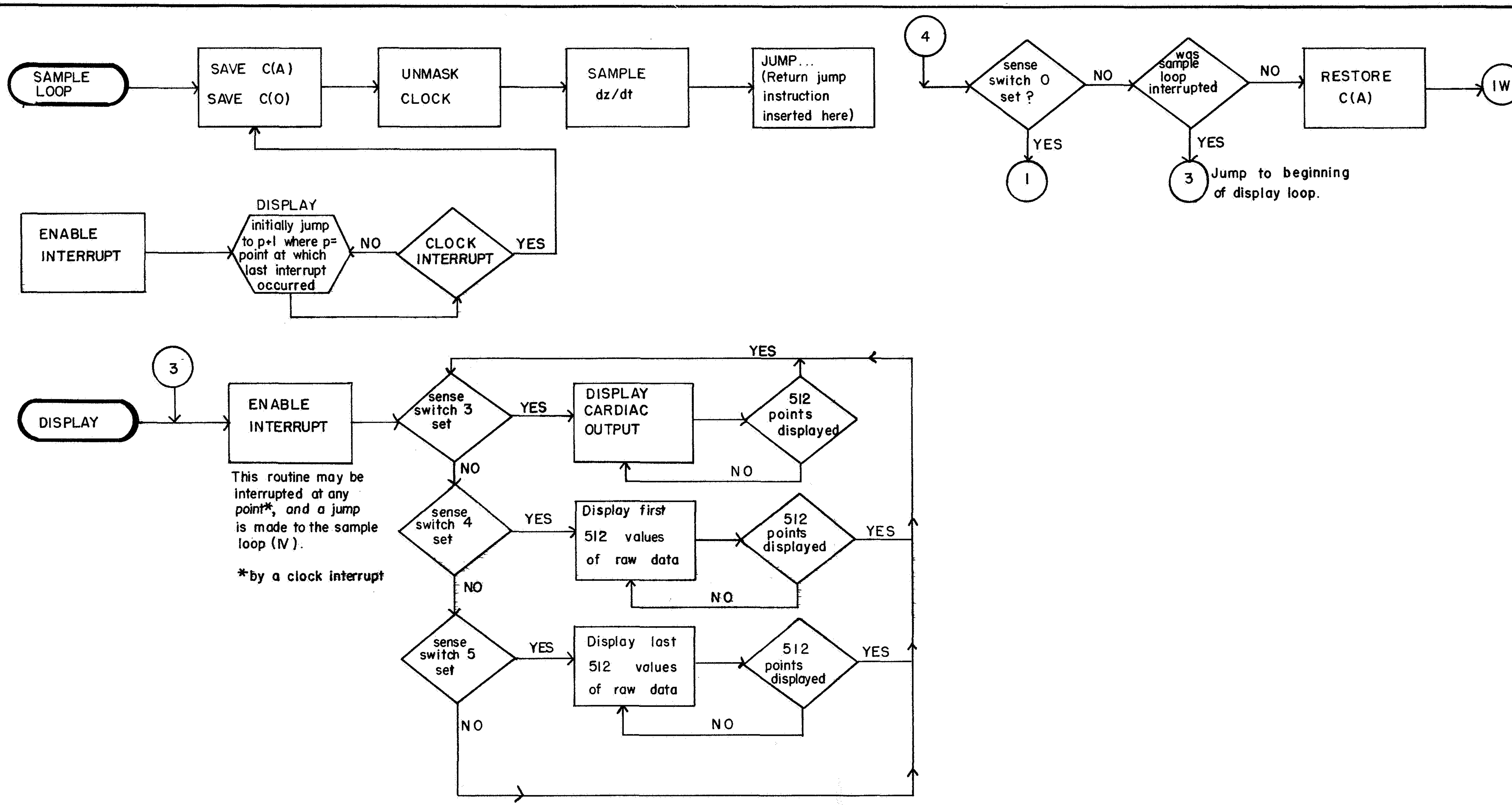
SOFTWARE DOCUMENT

- SAMPLE CODE ☐
- FLOWCHART ☐
- DECISION TABLE ☐
- OTHER ☐

DOCUMENT CLASS	MACH. TYPE	PROJECT NO.	DOCUMENT ABSTRACT	REV	APPROVED	DATE	REV	APPROVED	DATE
DOCUMENT TITLE		PROJECT MGR.							
	PAGE 5 OF 6	PROJECT NAME							
NUMBER	ISSUE DATE	TASK NO.							
DRAWN BY GSJ	DATE	TASK NAME COCAL							



SOFTWARE DOCUMENT
SAMPLE CODE
FLOWCHART
DECISION TABLE
OTHER

DOCUMENT CLASS
MACH. TYPE
DOCUMENT TITLE
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DRAWN BY GSJ
DATE

PROJECT NO.
PROJECT MGR.
PROJECT NAME
TASK NO.
TASK NAME Cocal

DOCUMENT ABSTRACT

REV	APPROVED	DATE	REV	APPROVED	DATE

	VALUE	LINE
1A	Ø165	314
1B	Ø2ØØ	327
1C	Ø146	275
1D	Ø156	3Ø5
1E	Ø2Ø5	334
1F	Ø211	34Ø
1G	Ø213	342
1H	Ø221	35Ø
1I	Ø237	366
1J	Ø246	375
1K	Ø257	4Ø6
1S	ØØ32	16Ø
2A	Ø262	411
2B	Ø273	423
2C	Ø277	427
2D	Ø314	445
2G	Ø325	457
2H	Ø341	474
2K	Ø35Ø	5Ø3
2L	Ø365	521
2M	Ø372	527
2S	ØØ44	172
3C	Ø773	1124
3D	Ø774	1125
3E	Ø764	1115
3F	Ø765	1116
3G	Ø766	1117
3H	Ø767	112Ø
3S	ØØ47	175
4S	ØØ46	174
5B	Ø454	61Ø
5C	Ø463	617
5D	Ø664	1Ø15
5E	Ø716	1Ø47
5F	Ø72Ø	1Ø51
5G	Ø735	1Ø66
5S	Ø437	573
6S	Ø626	756
6T	Ø741	1Ø72
7A	1ØØØ	1136
7B	1143	13Ø1
7C	12Ø5	1343
7D	1226	1364
7E	1213	1351
7F	1156	1314
7G	1ØØ3	1141
7H	1175	1333
7I	1235	1373
7J	1152	131Ø
7K	12Ø2	134Ø
7M	1261	1417
7N	1265	1423
7O	1271	1427
7P	1275	1433
7Q	13Ø1	1437
7R	Ø426	562
7S	Ø433	567
8A	Ø5ØØ	631
8B	Ø5Ø1	632
8C	Ø5Ø2	633
8D	Ø5Ø3	634
8E	Ø5Ø4	635
8F	Ø5Ø5	636
8J	Ø5Ø6	637
8K	Ø5Ø7	64Ø
8L	Ø51Ø	641
8M	Ø511	642
8N	Ø512	643
8P	Ø513	644
8R	Ø514	645
8S	Ø515	646
8T	Ø516	647
9A	Ø556	71Ø
9B	Ø555	7Ø7
9C	Ø573	725
9D	Ø546	7ØØ
9E	Ø565	717
9F	Ø525	657
9G	Ø6Ø5	737

```
CONT
    [PROGRAM TO COMPUTE CARDIAC OUTPUT
    [TRUDI JUNCKER - 1968
    [UTILITY ROUTINES = SCOPE-SP
    [                   DBLFLT
    [                   CALCOMP PLOT
    [TO OPERATE =
    [USE LAP6-2S TO LOAD COCAL. THIS PROGRAM STARTS
    [AUTOMATICALLY AND QUESTIONS AND COMMANDS WILL APPEAR
    [ON THE SCOPE.
    [      TYPE IN CHARACTERS TO FILL IN THE BLANKS AND
    [      TERMINATE WITH AN EOL. THE NEXT DISPLAY WILL
    [      THEN APPEAR. IF A MISTAKE IS MADE, THE DEL KEY
    [      CAN BE USED TO ERASE THE ENTRIES IN THE CURRENT
    [      DISPLAY. USE OF THE CASE KEY WILL RETURN YOU
    [      TO THE FIRST DISPLAY.
    [AFTER S=EOL IS TYPED, THE COMPUTER WILL START
    [SAMPLING THE ANALOG INPUT AND COMPUTE CARDIAC OUTPUT.
    [USE OF SENSE SWITCHES 3=5 ALLOWS THE USER TO VIEW THE
    [RAW DATA [SWITCHES 4-5] AND THE CARDIAC OUTPUT VALUES
    [[SWITCH 3] AS THE SAMPLING IS TAKING PLACE. USE OF
    [SENSE SWITCH Ø ALLOWS THE USER CONTROL OVER THE DATA
    [SAMPLED.IN THE UP POSITION SENSE SWITCH Ø DIRECTS THE
    [COMPUTER TO IGNORE THE INPUT DATA - WHICH MIGHT BE
    [NOISY,ETC. SAMPLING RESUMES WHEN SENSE SWITCH Ø
    [IS IN THE DOWN POSITION. THE EOL KEY CAN BE USED TO
    [DICTATE THE NUMBER OF VALUES OF C.O. [P.R. AND S.V.]
    [COLLECTED. IF DEPRESSED, THE SAMPLING STOPS AND THE
    [ACCUMULATED VALUES OF C.O., P.R. AND S.V. ARE WRITTEN
    [ON TAPE. A JUMP IS MADE TO THE FINAL DISPLAY ROUTINE.
    [IF NOT DEPRESSED, 512 VALUES OF EACH ARE COLLECTED
    [AND SAVED ON TAPE AND A JUMP MADE TO THE FINAL
    [DISPLAY.
    [
    [                   FINAL DISPLAY
    [THE SENSE SWITCHES ARE USED TO DICTATE THE FINAL
    [DISPLAY.
    [      SS4-5 = RAW DATA AS BEFORE.
    [
    [      SS3 = SCOPE DISPLAY OF OUTPUT OPTIONS. THE USER
    [      MUST CHOOSE HIS COURSE OF ACTION [RESTART
    [      PROGRAM,PLOT,PRINT,SCOPE] BY TYPING THE NUMBER
    [      OF HIS CHOICE FOLLOWED BY EOL. TYPING EOL WILL
    [      RESULT EITHER IN THE APPEARANCE OF THE NEXT
    [      DISPLAY OR, AS IN THE CASE OF PRINT, THE
    [      OUTPUT OF DATA. DEL ERASES THE ENTRIES IN THE
    [      CURRENT DISPLAY. DEPRESSING THE CASE KEY
    [      RETURNS YOU TO AN EARLIER DISPLAY. TO EXAMINE
    [      THE RAW DATA WHILE IN THE SCOPE DISPLAY
    [      ROUTINE, RAISE SS4 OR 5, DEPRESS SS3 AND WHILE
    [      VIEWING THE FIRST DISPLAY LIST, HIT THE
    [      CASE KEY.
    [
    [                   PRINT ROUTINE
    [CARDIAC OUTPUT IS PRINTED FIRST, THEN STROKE VOLUME
    [AND LASTLY PULSE RATE. THE EOL KEY MAY BE USED TO
    [INTERRUPT THE TYPING OF ONE SET OF VALUES TO GO ON TO
    [THE NEXT. DEPRESSING THE EOL KEY WHEN PULSE RATE IS
```

```
COCAL,2  LN=72

     CONT
        [BEING PRINTED WILL RESULT IN A RETURN TO THE
        [DISPLAYED LIST OF OUTPUT OPTIONS. THE USER MAY MAKE
        [ANOTHER SELECTION.
        [
        [                    DISPLAY CURVE ROUTINE
        [USE POTENTIOMETER KNOB 0 TO VARY GAIN
        [AND KNOB 1 TO VIEW DIFFERENT PORTIONS OF THE CURVE.
        [USE EOL TO RETURN TO THE DISPLAYED LIST OF OUTPUT
        [OPTIONS.
        [
        [                    PLOT ROUTINES
        [THE COMPUTER WILL HALT AFTER DATA IS READ FROM TAPE
        [AND BEFORE A GIVEN CURVE IS PLOTTED. THE USER MAY
        [CHANGE PENS AND SET SWITCHES AT THIS TIME.
        [SENSE SWITCH 1
        [  UP=AVERAGE EVERY 4 POINTS AND PLOT AVERAGE.
        [  DOWN=DO NOT AVERAGE THE VALUES AND PLOT EVERY
        [  POINT.
        [RIGHT SWITCH BITS 0 AND 1 DICTATE THE PLOTTING OF
        [SYMBOLS.
        [      X = C.O.
        [      $ = P.R.
        [      0 = S.V.
        [         AVERAGED VALUES PLOTTED
        [VALUE OF BITS 0 AND 1              NO. OF SYMBOLS
        [         0                              NONE
        [         1-3                            ONE/POINT
        [         EVERY POINT PLOTTED
        [VALUE OF BITS 0 AND 1              NO. OF SYMBOLS
        [      0                               0
        [      1                               1/64 POINTS
        [      2                               1/8 POINTS
        [      3                               ONE/POINT
        [WHEN THE NECESSARY SWITCHES ARE SET, LIFT RESUME TO
        [PLOT THE CURVE.
        [AT THE END OF THE PLOTTING, A RETURN IS MADE TO
        [THE DISPLAYED LIST OF OUTPUT OPTIONS. SHOULD THE
        [USER WANT TO RETURN TO THE DISPLAYED LIST BEFORE
        [THE PLOTTING IS FINISHED, HE MAY TYPE EOL.
        [TO RESTART COCAL, CHOOSE THE FIRST SELECTION IN THE
        [DISPLAYED LIST [1=RESTART PROGRAM].
            $1
 1 6020     JMP20
            $20
20 7000     JMP7A
21 6022     JMP22 [JUMP HERE ON CLOCK INTERRUPT
22 0056     SET16
23 0000     0
24 4044     STC2S [SAVE [A]
25 1020     LDA&
26 0004     4
27 0541     OPR41 [UNMASK CLOCK
30 0016     NOP
31 0110     SAM10 [SAMPLE DZ/DT
32 0000 #1S 0 [FILLED IN WITH JUMP INSTRUCTION
33 0460     SNS&0 [IF SENSE SWITCH 0 IS SET,
34 6146     JMP1C [RESTART SAMPLING PROCEDURE
```

```
     CONT
 35 1ØØØ       LDA   [OTHERWISE GO TO DISPLAY LOOP
 36 ØØ16       16
 37 146Ø       SAE&
 4Ø 6Ø46       4S+6ØØØ
 41 6Ø43       JMP'+2
 42 6426       JMP7R [IF INTERRUPT ROUTINE INTERRUPTED, JUMP TO B
          EGINNING OF DISPLAY LOOP
 43 1Ø2Ø       LDA&
 44 ØØØØ  #2S  Ø [OTHERWISE RESTORE [A]
 45 ØØ1Ø       ENI [ENABLE INTERRUPT
 46 6Ø16  #4S  JMP16 [AND JUMP TO '+1 IN DISPLAY LOOP WHERE '= PO
          INT AT WHICH LAST INTERRUPT OCCURRED
 47 ØØØ7  #3S  MSC7
 5Ø Ø73Ø       RDC&% [READ INITIAL DISPLAY ROUTINE
 51 445Ø       4/45Ø
 52 Ø73Ø       RDC&%
 53 5451       5/451
 54 Ø642       UMB2
 55 Ø73Ø       RDC&% [READ FLOATING POINT ROUTINES
 56 4247       4/247
 57 Ø73Ø       RDC&%
 6Ø 525Ø       5/25Ø
 61 Ø73Ø       RDC&%
 62 6251       6/251
 63 Ø71Ø       RDC%
 64 7252       7/252
 65 Ø64Ø       UMBØ
 66 Ø6Ø1       LMB1
 67 6Ø2Ø       JMP2Ø [ENTER RHO,L, AND CAL FACTORS
          [RETURN HERE AFTER ENTERING THE ABOVE CONSTANTS
 7Ø ØØ61       SET&1 [CLEAR UPPER HALF OF PAGE Ø AND
 71 1ØØØ       1ØØØ  [ALL OF PAGE 1
 72 ØØ11       CLR
 73 1Ø41       STA1
 74 Ø221       XSK&1
 75 6Ø73       JMP'-2
 76 ØØ61       SET&1
 77 2ØØØ       2ØØØ
1ØØ 1Ø41       STA1
1Ø1 Ø221       XSK&1
1Ø2 61ØØ       JMP'-2
1Ø3 Ø643       UMB3 [CLEAR PAGE 3
1Ø4 ØØ61       SET&1
1Ø5 2ØØØ       2ØØØ
1Ø6 1Ø41       STA1
1Ø7 Ø221       XSK&1
11Ø 61Ø6       JMP'-2
111 1Ø2Ø       LDA&
112 7777       7777
113 Ø54Ø       OPR4Ø [MASK ALL DEVICES
114 1Ø2Ø       LDA&
115 ØØØ4       4
116 Ø54Ø       OPR4Ø [UNMASK REAL TIME CLOCK
117 1Ø2Ø       LDA&
12Ø ØØØ2       2
121 Ø544       OPR44 [SAMPLING RATE = 5ØØ CPS
122 ØØ16       NOP
```

```
'   CONT
123 0642      UMB2
124 1020      LDA& [LOAD INDEX REGISTERS 6,7, AND 10
125 2777      2777 [TO PREPARE FOR STORING CARDIAC
126 1040      STA  [OUTPUT, PULSE RATE AND STROKE
127 2006      2006 [VOLUME
130 1040      STA
131 2007      2007
132 1020      LDA&
133 3777      3777
134 1040      STA
135 2010      2010
136 0011      CLR
137 1040      STA
140 2500      2500
141 1040      STA
142 2501      2501
143 1040      STA
144 2502      2502
145 0641      UMB1
146 0460  #1C SNS&0
147 6146      JMP'=1
150 0063      SET&3 [SAMPLE 1024 POINTS
151 3777      3777
152 1020      LDA&
153 6156      1D+6000
154 4032      STC1S [STORE JUMP IN INTERRUPT HANDLER
155 6426      JMP7R [JUMP TO ENABLE INTERRUPT
156 1063  #1D STA&3
157 0203      XSK3
160 6033      JMP1S+1
161 0063      SET&3 [FIND MAX DZ/DT
162 3777      3777
163 0011      CLR
164 4500      STC8A
165 0223  #1A XSK&3
166 6170      JMP'+2
167 6200      JMP1B
170 1003      LDA3
171 0017      COM
172 2500      ADD8A
173 0471      APO&
174 6165      JMP1A
175 1003      LDA3
176 4500      STC8A
177 6165      JMP1A
200 1000  #1B LDA [FIND 1/3 DZ/DT MAX
201 0500      8A
202 1240      MUL
203 4501      8B+4000
204 4502      STC8C
205 1020  #1E LDA& [WAIT FOR NEGATIVE VALUE
206 6211      1F+6000 [STORE JUMP IN INTERRUPT HANDLER
207 4032      STC1S
210 6033      JMP1S+1
211 0471  #1F APO&
212 6033      JMP1S+1
213 0064  #1G SET&4 [START STORING
```

```
     CONT
214  3777       3777
215  1020       LDA&
216  6221       1H+6000
217  4032       STC1S [STORE JUMP IN INTERRUPT HANDLER
220  6033       JMP1S+1
221  1064  #1H  STA&4
222  0017       COM
223  2502       ADD8C
224  0471       APO&
225  6033       JMP1S+1
226  1000       LDA
227  0004       4
230  4503       STC8D
231  0065       SET&5
232  7767       -10
233  1020       LDA&
234  6237       1I+6000
235  4032       STC1S [STORE JUMP IN INTERRUPT HANDLER
236  6033       JMP1S+1
237  1064  #1I  STA&4
240  0225       XSK&5
241  6033       JMP1S+1
242  1020       LDA&
243  6246       1J+6000
244  4032       STC1S [STORE JUMP IN INTERRUPT HANDLER
245  6033       JMP1S+1
246  1064  #1J  STA&4
247  0471       APO&
250  6033       JMP1S+1
251  0065       SET&5 [SAMPLE 150 MS AFTER ZERO CROSS
252  7664       -113
253  1020       LDA&
254  6257       1K+6000
255  4032       STC1S
256  6033       JMP1S+1
257  1064  #1K  STA&4
260  0225       XSK&5
261  6033       JMP1S+1
262  0111  #2A  SAM11
263  4504       STC8E
264  2004       ADD4
265  1040       STA
266  0510       8L
267  0017       COM
270  1120       ADA&
271  2000       2000
272  4010       STC10
           [FIND MAX
273  0067  #2B  SET&7
274  3777       3777
275  0011       CLR
276  4500       STC8A
277  0230  #2C  XSK&10
300  6302       JMP'+2
301  6314       JMP2D
302  1027       LDA&7
303  0017       COM
```

```
     CONT
304 2500      ADD8A
305 0471      APO&
306 6277      JMP2C
307 1007      LDA7
310 4500      STC8A
311 2007      ADD7
312 4505      STC8F
313 6277      JMP2C
         [DIVIDE BY 3
314 2500 #2D  ADD8A
315 1240      MUL
316 4501      8B+4000
317 4502      STC8C
         [FIND T1
320 2502      ADD8C
321 0341      SCR1
322 4506      STC8J
323 0052      SET12
324 0505      8F
325 1020 #2G  LDA&
326 7776      =1
327 2012      ADD12
330 4012      STC12
331 1012      LDA12
332 0017      COM
333 2506      ADD8J
334 0451      APO
335 6325      JMP2G
336 1000      LDA
337 0012      12
340 4507      STC8K
         [FIND T3
341 0052 #2H  SET12
342 0505      8F
343 2510      ADD8L
344 0017      COM
345 2012      ADD12
346 4014      STC14
347 4511      STC8M
350 0234 #2K  XSK&14
351 6353      JMP'+2
352 6365      JMP2L
353 1032      LDA&12
354 0017      COM
355 2511      ADD8M
356 0451      APO
357 6350      JMP2K
360 1012      LDA12
361 4511      STC8M
362 2012      ADD12
363 4512      STC8N
364 6350      JMP2K
         [COMPUTE T3 = T1
365 1000 #2L  LDA
366 0507      8K
367 0017      COM
370 2512      ADD8N
```

```
     CONT
371  4513        STC8P
            [COMPUTE T
372  2505  #2M  ADD8F
373  1120        ADA&
374  6035        =1742 [=2000 + 36 TO ACCOUNT FOR TIME SPENT IN COM
            PUTATION SECTION
375  2514        ADD8R
376  4515        STC8S
377  2505        ADD8F
400  0017        COM
401  2510        ADD8L
402  4514        STC8R
403  0640        UMB0 [JUMP TO ROUTINE TO COMPUTE
404  0602        LMB2 [CARDIAC OUTPUT, STROKE VOLUME
405  6102        JMP102 [AND PULSE RATE
                 $410
410  0007        MSC7
411  1020        LDA&
412  6626        6S+6000
413  4437        STC5S
414  0730        RDC&% [READ IN FINAL DISPLAY ROUTINE
415  4221        4/221
416  0730        RDC&%
417  5222        5/222
420  0730        RDC&%
421  6223        6/223
422  0710        RDC%
423  7224        7/224
424  0641        UMB1
425  6433        JMP7S
426  0010  #7R  ENI
427  1020        LDA&
430  0016        0016 [NOP
431  1040        STA
432  0437        5S
433  0077  #7S  SET&17
434  6777        =1000
435  0443        SNS3
436  6443        JMP'+5
437  0016  #5S  NOP
440  0062        SET&2
441  0777        777
442  6463        JMP5C
443  0444        SNS4
444  6450        JMP'+4
445  0062        SET&2
446  3777        3777
447  6454        JMP5B
450  0445        SNS5
451  6433        JMP7S
452  0062        SET&2
453  2777        2777
454  0011  #5B  CLR
455  0162        DIS&2
456  1002        LDA2
457  0142        DIS2
460  0237        XSK&17
```

```
    CONT
461 6454       JMP5B
462 6433       JMP7S
463 1002 #5C LDA2
464 0343       SCR3
465 1120       ADA&
466 7400       =377
467 0162       DIS&2
470 0237       XSK&17
471 6463       JMP5C
472 6433       JMP7S
               $500
          [STORAGE
500 0000 #8A 0 [CURRENT MAX
501 1252 #8B 1252 [1/3
502 0000 #8C 0 [THRESHOLD
503 0000 #8D 0 [T1 LOCATION
504 0000 #8E 0 [2T
505 0000 #8F 0 [LOCATION OF CURRENT PEAK
506 0000 #8J 0 [0.15 PEAK
507 0000 #8K 0 [T1 LOC
510 0000 #8L 0 [LOC LAST SAMPLE
511 0000 #8M 0 [TEMP MIN
512 0000 #8N 0 [T3 LOC
513 0000 #8P 0 [T3-T1
514 0000 #8R 0 [1ST PART OF T
515 0000 #8S 0 [T
516 0000 #8T 0 [TOTAL NO. OF VALUES FOR CO,PR, AND SV
          [USED IN PLOT,PRINT, AND SCOPE ROUTINES
               $520
520 1000       LDA
521 0516       8T
522 1120       ADA&
523 1000       1000
524 4573       STC9C [SET LAST ADDRESS+1 WHERE DATA IS STORED
525 0062 #9F SET&2
526 0777       777
527 0063       SET&3
530 7600       7600
531 0101       SAM1 [STARTING POINT IN BUFFER
532 1120       ADA&
533 1400       1400
534 4555       STC9B
535 0100       SAM0
536 0451       APO
537 6605       JMP9G
540 1120       ADA&
541 0001       1
542 0346       SCR6
543 1120       ADA&
544 0240       240
545 4556       STC9A
546 1020 #9D LDA&
547 7400       =377
550 0162       DIS&2 [DISPLAY BASELINE
551 0162       DIS&2
552 0162       DIS&2
553 0162       DIS&2
```

```
     CONT
554 1ØØØ      LDA [GET VALUE
555 ØØØØ #9B  Ø
556 ØØØØ #9A  Ø
557 112Ø      ADA&
56Ø 74ØØ      =377
561 Ø142      DIS2 [DISPLAY POINT
562 Ø223      XSK&3
563 6565      JMP9E
564 6576      JMP9C+3
565 1Ø2Ø #9E  LDA&
566 ØØØ1      1
567 114Ø      ADM
57Ø Ø555      9B
571 ØØ17      COM
572 112Ø      ADA&
573 ØØØØ #9C  Ø
574 Ø471      APO&
575 6546      JMP9D
576 Ø415      KST
577 6525      JMP9F
6ØØ Ø515      KBD [EOL MEANS RETURN TO MAIN DISPLAY
6Ø1 146Ø      SAE&
6Ø2 ØØ12      ØØ12
6Ø3 6525      JMP9F
6Ø4 6433      JMP7S
6Ø5 112Ø #9G  ADA&
6Ø6 7776      =1
6Ø7 ØØ17      COM
61Ø Ø346      SCR6
611 112Ø      ADA&
612 Ø34Ø      34Ø
613 4556      STC9A
614 6546      JMP9D
              $62Ø
62Ø Ø642      UMB2
621 1ØØØ      LDA
622 25Ø2      25Ø2 [AVERAGE TIME BETWEEN BEATS X NO. OF BEATS
623 1Ø4Ø      STA
624 Ø774      3D
625 641Ø      JMP41Ø
626 Ø643 #6S  UMB3
627 Ø73Ø      RDC&%
63Ø 4612      4/612 [READ IN PLOT ROUTINE
631 Ø73Ø      RDC&%
632 5613      5/613
633 Ø73Ø      RDC&%
634 6614      6/614
635 Ø71Ø      RDC%
636 7615      7/615
637 1ØØØ      LDA
64Ø Ø516      8T
641 ØØ17      COM
642 1Ø4Ø      STA
643 37ØØ      37ØØ
644 ØØ17      COM
645 Ø342      SCR2
646 ØØ17      COM
```

```
     CONT
647 1040      STA
650 3701      3701
          [ROUTINE TO CONVERT [AVERAGE T X 512] TO A DECIMAL NUM
          BER REPRESENTED BY KEYBOARD CODES
651 0070      SET&10
652 0763      3E*1
653 0071      SET&11
654 0766      3H*1
655 1000      LDA
656 0774      3D
657 4773      STC3C
660 0011      CLR
661 4764      STC3E
662 4765      STC3F
663 4766      STC3G
664 0230  #5D XSK&10
665 0231      XSK&11
666 1011      LDA11
667 0450      AZE
670 6716      JMP5E
671 1000      LDA
672 0764      3E
673 0450      AZE
674 6677      JMP*+3
675 1020      LDA&
676 0014      14
677 1140      ADM
700 2373      2373
701 1000      LDA
702 0765      3F
703 0246      ROL6
704 1140      ADM
705 2374      2374
706 1000      LDA
707 0766      3G
710 0246      ROL6
711 1140      ADM
712 2375      2375
713 0640      UMB0
714 0602      LMB2
715 6020      JMP20 [DISPLAY CHOICES*PLOT OR SCOPE
716 1000  #5E LDA
717 0773      3C
720 1111  #5F ADA11
721 0470      AZE&
722 6735      JMP5G
723 0451      APO
724 6664      JMP5D
725 1040      STA
726 0773      3C
727 1020      LDA&
730 0001      1
731 1150      ADM10
732 1000      LDA
733 0773      3C
734 6720      JMP5F
735 1020  #5G LDA&
```

```
     CONT
 736 ØØØ1       1
 737 115Ø       ADM1Ø
 74Ø 6671       JMP5D+5
 741 Ø73Ø  #6T  RDC&% [READ IN PRINT ROUTINE
 742 4571       4/571
 743 Ø73Ø       RDC&%
 744 5572       5/572
 745 Ø73Ø       RDC&%
 746 6573       6/573
 747 Ø71Ø       RDC%
 75Ø 7574       7/574
 751 1ØØØ       LDA
 752 Ø516       8T
 753 112Ø       ADA&
 754 7776       7776
 755 Ø342       SCR2
 756 ØØ17       COM
 757 1Ø4Ø       STA
 76Ø 2377       2377
 761 Ø64Ø       UMBØ
 762 Ø6Ø3       LMB3
 763 622Ø       JMP2Ø [JUMP TO PRINT VALUES
 764 ØØØØ  #3E  Ø
 765 ØØØØ  #3F  Ø
 766 ØØØØ  #3G  Ø
 767 7633  #3H  7633 [=144
 77Ø 7765       7765 [=12
 771 7776       7776 [=1
 772 ØØØØ       Ø
 773 ØØØØ  #3C  Ø
 774 ØØØØ  #3D  Ø
           [CODING TO READ IN AND SEARCH THE FILE INDEX FOR
           [INT=DSP,COMPUTE1,FIN=DSP1,PLOT1,AND PRINT1.
           [WHEN A ROUTINE IS FOUND, ITS BLOCK NUMBER IS INSERTED
           [INTO THE MAIN PROGRAM. IF A ROUTINE IS NOT FOUND,
           [THE COMPUTER HALTS. IF THE FILE INDEX IS NOT
           [LOCATED IN BLOCKS 426-7, THE TAPE IS SEARCH FOR IT.
           [IF NOT FOUND, THE COMPUTER HALTS.
                $1ØØØ
1ØØØ Ø711  #7A  RCG%
1ØØ1 1426       1/426
1ØØ2 7152       JMP7J
1ØØ3 ØØ62  #7G  SET&2
1ØØ4 126Ø       7M=1 [INT=DSP
1ØØ5 72Ø5       JMP7C
1ØØ6 112Ø       ADA&
1ØØ7 4ØØØ       4ØØØ
1Ø1Ø 1Ø4Ø       STA
1Ø11 ØØ51       51
1Ø12 112Ø       ADA&
1Ø13 1ØØ1       1ØØ1
1Ø14 1Ø4Ø       STA
1Ø15 ØØ53       53
1Ø16 ØØ61       SET&1
1Ø17 3ØØ7       3ØØ7
1Ø2Ø ØØ62       SET&2
1Ø21 1264       7N=1 [COMPUTE1
```

```
     CONT
1022 7205    JMP7C
1023 1120    ADA&
1024 4000    4000
1025 1040    STA
1026 0056    56
1027 1120    ADA&
1030 1001    1001
1031 1040    STA
1032 0060    60
1033 1120    ADA&
1034 1001    1001
1035 1040    STA
1036 0062    62
1037 1120    ADA&
1040 1001    1001
1041 1040    STA
1042 0064    64
1043 0061    SET&1
1044 3007    3007
1045 0062    SET&2
1046 1270    70*1 [FIN-DSP1
1047 7205    JMP7C
1050 1120    ADA&
1051 4000    4000
1052 1040    STA
1053 0415    415
1054 1120    ADA&
1055 1001    1001
1056 1040    STA
1057 0417    417
1060 1120    ADA&
1061 1001    1001
1062 1040    STA
1063 0421    421
1064 1120    ADA&
1065 1001    1001
1066 1040    STA
1067 0423    423
1070 0061    SET&1
1071 3007    3007
1072 0062    SET&2
1073 1274    7P*1 [PLOT1
1074 7205    JMP7C
1075 1120    ADA&
1076 4000    4000
1077 1040    STA
1100 0630    630
1101 1120    ADA&
1102 1001    1001
1103 1040    STA
1104 0632    632
1105 1120    ADA&
1106 1001    1001
1107 1040    STA
1110 0634    634
1111 1120    ADA&
1112 1001    1001
```

```
          CONT
1113 1040          STA
1114 0636          636
1115 0061          SET&1
1116 3007          3007
1117 0062          SET&2
1120 1300          7Q=1 [PRINT1
1121 7205          JMP7C
1122 1120          ADA&
1123 4000          4000
1124 1040          STA
1125 0742          742
1126 1120          ADA&
1127 1001          1001
1130 1040          STA
1131 0744          744
1132 1120          ADA&
1133 1001          1001
1134 1040          STA
1135 0746          746
1136 1120          ADA&
1137 1001          1001
1140 1040          STA
1141 0750          750
1142 6047          JMP3S
1143 1020    #7B   LDA&
1144 0010          10
1145 1140          ADM
1146 1001          7A+1
1147 5151          STC'+2
1150 0711          RCG%
1151 0000          0
1152 0065    #7J   SET&5
1153 7767          7767
1154 0061          SET&1
1155 2777          2777
1156 1021    #7F   LDA&1
1157 1460          SAE&
1160 5757          5757
1161 7163          JMP'+2
1162 7202          JMP7K
1163 1000          LDA
1164 1001          7A+1
1165 1460          SAE&
1166 1776          1776
1167 7171          JMP'+2
1170 7175          JMP7H
1171 1460          SAE&
1172 1416          1416
1173 7143          JMP7B
1174 0000          HLT
1175 1020    #7H   LDA&
1176 1006          1006
1177 1040          STA
1200 1001          7A+1
1201 7147          JMP7B+4
1202 0225    #7K   XSK&5
1203 7156          JMP7F
```

```
          CONT
1204  7003        JMP7G
1205  0044  #7C   SET4
1206  0000        0
1207  1000        LDA
1210  0002        2
1211  5231        STC7D+3
1212  7235        JMP7I
1213  1020  #7E   LDA&
1214  0007        7
1215  7226        JMP7D
1216  1020        LDA&
1217  0006        6
1220  7226        JMP7D
1221  1020        LDA&
1222  0005        5
1223  7226        JMP7D
1224  1020        LDA&
1225  0004        4
1226  1140  #7D   ADM
1227  0001        1
1230  0062        SET&2
1231  0000        0
1232  0201        XSK1
1233  7235        JMP'+2
1234  0000        HLT
1235  1021  #7I   LDA&1
1236  1462        SAE&2
1237  7213        JMP7E
1240  1021        LDA&1
1241  1462        SAE&2
1242  7216        JMP7E+3
1243  1021        LDA&1
1244  1462        SAE&2
1245  7221        JMP7E+6
1246  1021        LDA&1
1247  1462        SAE&2
1250  7224        JMP7D-2
1251  1020        LDA&
1252  0003        3
1253  1140        ADM
1254  0001        1
1255  1001        LDA1
1256  1560        BCL&
1257  7000        7000
1260  6004        JMP4
1261  3441  #7M   3441
1262  4717        4717
1263  2746        2746
1264  4377        4377
1265  2642  #7N   2642
1266  4043        4043
1267  5047        5047
1270  3001        3001
1271  3134  #7O   3134
1272  4117        4117
1273  2746        2746
1274  4301        4301
```

COCAL,17 LN=1433


```
     CONT
1275 4337 #7P 4337
1276 4247      4247
1277 0177      0177
1300 7777      7777
1301 4345 #7Q 4345
1302 3441      3441
1303 4701      4701
1304 7777      7777
```

INT*DSP,Ø

	VALUE	LINE
1N	Ø164	147
1O	Ø2Ø2	165
1P	Ø217	2Ø2
1Q	Ø272	255
1R	Ø234	217
1S	Ø251	234
2N	Ø177	162
5A	ØØ31	12
6A	ØØ62	43
7A	Ø111	73
7B	Ø121	1Ø3
7C	Ø122	1Ø4
7D	Ø135	117
7E	Ø143	125
7F	Ø153	135
7G	Ø154	136
7H	Ø155	137
7I	Ø156	14Ø
7J	Ø157	141
7K	Ø16Ø	142
7L	Ø161	143
8A	ØØ74	55
9A	Ø4ØØ	317
9B	Ø431	351
9D	Ø447	367
9E	Ø457	4ØØ
9F	Ø466	4Ø7
9G	Ø47Ø	411
9H	Ø473	414
9J	Ø52Ø	441
9K	Ø523	444
9M	Ø53Ø	451
9N	Ø542	463
9Q	Ø555	476
9R	Ø562	5Ø3
9S	Ø573	514
9T	Ø61Ø	531
9U	Ø764	71Ø
9V	Ø617	541
9W	Ø626	55Ø
9X	Ø627	552
9Y	Ø653	576

```
    CONT
 2Ø Ø07Ø       SET&1Ø
 21 Ø153       7F
 22 ØØ11       CLR
 23 4153       STC7F
 24 4154       STC7G
 25 4155       STC7H
 26 4156       STC7I
 27 4157       STC7J
 3Ø 416Ø       STC7K
 31 1Ø2Ø #5A   LDA&
 32 ØØØ1       ØØØ1
 33 134Ø       STH
 34 4764       9U+4ØØØ
 35 1Ø2Ø       LDA&
 36 Ø5ØØ       Ø5ØØ
 37 4765       STC9U+1
 4Ø 1Ø4Ø       STA
 41 1ØØØ       1ØØØ
 42 1Ø2Ø       LDA&
 43 4164       1N+4ØØØ [RHO IN OHM-CM IS 15Ø
 44 64ØØ       JMP9A
 45 6Ø2Ø       JMP2Ø
 46 6111       JMP7A [CONVERT DECIMAL TO BINARY
 47 1Ø2Ø       LDA&
 5Ø Ø2Ø2       1O [L FRONT IN CM = --.-
 51 64ØØ       JMP9A [JUMP TO SCOPE PKG
 52 6Ø2Ø       JMP2Ø
 53 6111       JMP7A [DEC TO BINARY-TREAT AS INTEGER
 54 1Ø2Ø       LDA&
 55 Ø217       1P [L BACK IN CM = --.-
 56 64ØØ       JMP9A [JUMP TO SCOPE PKG
 57 6Ø2Ø       JMP2Ø
 6Ø 6111       JMP7A [DEC TO BIN-TREAT AS INTEGER
 61 6143       JMP7E [FIND L MEAN
 62 1Ø2Ø #6A   LDA&
 63 Ø234       1R [Z CAL-1 OHM = -.-- V.
 64 64ØØ       JMP9A [JUMP TO SCOPE PKG
 65 6Ø2Ø       JMP2Ø
 66 6111       JMP7A [DEC TO BIN-TREAT AS INTEGER
 67 1Ø2Ø       LDA&
 7Ø Ø251       1S [DZ/DT CAL-1 OHM/SEC = -.-- V.
 71 64ØØ       JMP9A [JUMP TO SCOPE PKG
 72 6Ø2Ø       JMP2Ø
 73 6111       JMP7A [DEC TO BIN-TREAT AS INTEGER
 74 1Ø2Ø #8A   LDA&
 75 Ø272       1Q [TYPE S IF READY TO SAMPLE
 76 64ØØ       JMP9A
 77 6Ø2Ø       JMP2Ø
1ØØ 1ØØØ       LDA
1Ø1 Ø764       9U
1Ø2 142Ø       SHD&
1Ø3 46ØØ       46ØØ
1Ø4 61Ø6       JMP'+2
1Ø5 6Ø74       JMP8A
1Ø6 Ø641       UMB1
1Ø7 Ø6Ø2       LMB2
11Ø 6Ø2Ø       JMP2Ø [JUMP TO FLOATING POINT ROUTINES
```

```
     CONT
               [CONVERT NUMBER FROM DECIMAL TO BINARY
 111 ØØ54 #7A  SET14
 112 ØØØØ      Ø
 113 ØØ67      SET&7
 114 Ø764      9U [LOCATION OF CHARACTERS ENTERED THRU KEYBOARD
 115 ØØ71      SET&11
 116 7774      7774
 117 ØØ73      SET&13
 12Ø Ø161      7L
 121 1327 #7B  LDH&7
 122 13Ø7 #7C  LDH7
 123 Ø246      ROL6
 124 Ø346      SCR6
 125 Ø47Ø      AZE&
 126 6135      JMP7D
 127 112Ø      ADA&
 13Ø 7776      7776
 131 1347      STH7
 132 1Ø13      LDA13
 133 115Ø      ADM1Ø
 134 6122      JMP7C
 135 Ø231 #7D  XSK&11
 136 6141      JMPp+3
 137 1Ø3Ø      LDA&1Ø
 14Ø 6Ø14      JMP14
 141 1Ø33      LDA&13
 142 6121      JMP7B
 143 1ØØØ #7E  LDA
 144 Ø154      7G
 145 11ØØ      ADA
 146 Ø155      7H
 147 Ø341      SCR1
 15Ø 1Ø4Ø      STA
 151 Ø16Ø      7K
 152 6Ø62      JMP6A
 153 ØØØØ #7F  Ø [RHO
 154 ØØØØ #7G  Ø [L FRONT
 155 ØØØØ #7H  Ø [L BACK
 156 ØØØØ #7I  Ø [Z CAL IN VOLTS X 1ØØ
 157 ØØØØ #7J  Ø [DZ/DT CAL IN VOLTS X 1ØØ
 16Ø ØØØØ #7K  Ø [L MEAN
 161 Ø144 #7L  144
 162 ØØ12      12
 163 ØØØ1      1
               [DISPLAY TEXT
 164 ØØØ3 #1N  ØØØ3
 165 4533      4533 [RHO IN OHM-CM. IS ---
 166 4214      4214
 167 3441      3441
 17Ø 1442      1442
 171 334Ø      334Ø
 172 1726      1726
 173 4Ø15      4Ø15
 174 1434      1434
 175 4614      4614
 176 5656      5656
 177 1313 #2N  1313
```

```
     CONT
200  1314         1314
201  5776         5776
202  0003  #10    0003
203  3714         3714  [L FRONT IN CM = --.-
204  3145         3145
205  4241         4241
206  4714         4714
207  3441         3441
210  1426         1426
211  4014         4014
212  2314         2314
213  5656         5656
214  1313         1313
215  1513         1513
216  5777         5777
217  0003  #1P    0003
220  3714         3714  [L BACK IN CM = --.-
221  2524         2524
222  2636         2636
223  1434         1434
224  4114         4114
225  2640         2640
226  1423         1423
227  1456         1456
230  5613         5613
231  1315         1315
232  1314         1314
233  5777         5777
234  0003  #1R    0003  [Z CAL
235  5514         5514  [1 OHM = -.-- V.
236  2624         2624
237  3756         3756
240  5601         5601
241  1442         1442
242  3340         3340
243  1423         1423
244  1413         1413
245  1513         1513
246  1314         1314
247  5115         5115
250  5777         5777
251  0003  #1S    0003  [DZ/DT CAL
252  2755         2755  [1 OHM/SEC = -.-- V.
253  2127         2127
254  4714         4714
255  2624         2624
256  3756         3756
257  5601         5601
260  1442         1442
261  3340         3340
262  2146         2146
263  3026         3026
264  1423         1423
265  1413         1413
266  1513         1513
267  1314         1314
270  5115         5115
```

```
    CONT
271 5777      5777
272 ØØØ1 #1Q ØØØ1 [TYPE S IF READY TO SAMPLE
273 4754      4754
274 433Ø      433Ø
275 1446      1446
276 1434      1434
277 3114      3114
3ØØ 453Ø      453Ø
3Ø1 2427      2427
3Ø2 5414      5414
3Ø3 4742      4742
3Ø4 5656      5656
3Ø5 4624      4624
3Ø6 4Ø43      4Ø43
3Ø7 373Ø      373Ø
31Ø 5656      5656
311 1314      1314
312 5777      5777
         [SCOPE-SP  ,SP=SAME PAGE
         [GENERAL PURPOSE ROUTINES FOR ENTERING DATA
         [AND SELECTING OPTIONS
         [G.FELLOWS-FEB 67
         [CODE Ø-ENTER TEXT
         [CODE 1-STAR OPTION AND RETURN TO '+2
         [CODE 2-STAR OPTION AND RETURN TO '+1+N
         [    WERE N IS POSITION OF OPTION IN LIST
         [CASE ALWAYS RETURNS TO '+1
         [6Ø AT TEXT END,DISPLAY ONCE AND RETURN '+1
         [76 AT END OF TEXT MEANS RETURN TO '+2 ON EOL
         [77 AT END OF TEXT MEANS RETURN TO '+2 ON EOL
         [    IF CORRECT NO. OF ENTRIES MADE
         [LOAD TAG OF TEXT IN ACCUM, THEN JUMP 9A
         [9A CAN BE PUT AT START OF ANY QUARTER IN LOWER PAGE
         [USES REGS 1,2,3,4,5,6
              $4ØØ
4ØØ ØØ46 #9A SET 6
4Ø1 ØØØØ      Ø
4Ø2 ØØ62      SET&2
4Ø3 1775      1775
4Ø4 Ø471      APO&
4Ø5 Ø222      XSK&2
4Ø6 156Ø      BCL&
4Ø7 4ØØØ      4ØØØ
41Ø 4ØØ1      STC1
411 2ØØ6      ADD6
412 1Ø4Ø      STA
413 Ø523      9K
414 2653      ADD9Y  [1
415 4626      STC9W
416 13Ø1      LDH 1
417 ØØ17      COM
42Ø 4555      STC9Q
421 1321      LDH&1
422 ØØ17      COM
423 2655      ADD9Y+2
424 4447      STC9D
425 2ØØ1      ADD1
```

```
      CONT
 426  4460       STC9E+1
 427  0222       XSK&2
 430  6446       JMP9D-1
            [CLEAR WORKING AREA 9U
 431  0061  #9B  SET&1
 432  7747       -30
 433  0062       SET&2
 434  4763       9U-4000
 435  1020       LDA&
 436  0017       17
 437  0043       SET 3
 440  0555       9Q
 441  0203       XSK 3
 442  2654       ADD9Y+1
 443  1362       STH&2
 444  0221       XSK&1
 445  6443       JMP'-2
 446  0066       SET&6
 447  0000  #9D  0
 450  0011       CLR
 451  4763       STC9U-1
 452  1020       LDA&
 453  0001       1
 454  4613       STC9T+3
 455  0065       SET&5
 456  0764       9U
            [START OF DISPLAY
 457  0062  #9E  SET&2
 460  0000       0
 461  0064       SET&4
 462  0764       9U
 463  1020       LDA&
 464  0336       336
 465  4470       STC9G
 466  2656  #9F  ADD9Y+3
 467  1160       ADM&
 470  0000  #9G  0
 471  0061       SET&1
 472  0070       70
 473  1322  #9H  LDH&2
 474  1420       SHD&
 475  1300       1300
 476  1324       LDH&4
 477  1420       SHD&
 500  5600       5600
 501  6466       JMP9F
 502  1420       SHD&
 503  5700       5700
 504  6520       JMP9J
 505  0241       ROL 1
 506  1120       ADA&
 507  0627       9X
 510  4003       STC3
 511  2522       ADD9J+2
 512  2001       ADD1
 513  4001       STC1
 514  2470       ADD9G
```

```
       CONT
515  1743        DSC 3
516  1763        DSC&3
517  6473        JMP9H
520  1322  #9J   LDH&2
521  1420        SHD&
522  6004        6004
523  6000  #9K   JMP
524  0415        KST
525  6457        JMP9E
526  0226        XSK&6
527  6542        JMP9N
530  0415  #9M   KST
531  6530        JMP'=1
532  0063        SET&3
533  7577        =200
534  0225        XSK&5
535  6534        JMP'=1
536  0223        XSK&3
537  6534        JMP'=3
540  0515        KBD
541  6431        JMP9B
542  0515  #9N   KBD
543  1420        SHD&
544  1300        1300
545  6431        JMP9B
546  1420        SHD&
547  2300        2300
550  6523        JMP9K
551  1420        SHD&
552  1200        1200
553  6617        JMP9V
554  0064        SET&4
555  0000  #9Q   0
556  0204        XSK 4
557  6562        JMP9R
560  1365        STH&5
561  6457        JMP9E
562  4573  #9R   STC9S
563  0043        SET 3
564  0523        9K
565  0223        XSK&3
566  1322        LDH&2
567  1420        SHD&
570  7700        7700
571  6530        JMP9M
572  1460        SAE&
573  0000  #9S   0
574  6610        JMP9T
575  1020        LDA&
576  0016        16
577  1365        STH&5
600  1000        LDA
601  0613        9T+3
602  2763        ADD9U-1
603  4763        STC9U-1
604  2003        ADD3
605  0224        XSK&4
```

```
      CONT
 606 4626       STC9W
 607 6452       JMP9E-5
 610 0223  #9T  XSK&3
 611 1325       LDH&5
 612 1020       LDA&
 613 0000       0
 614 0241       ROL 1
 615 4613       STC'-2
 616 6566       JMP9R+4
           [EOL
 617 1302  #9V  LDH 2
 620 1460       SAE&
 621 0077       77
 622 6625       JMP9W-1
 623 0226       XSK&6
 624 6530       JMP9M
 625 0011       CLR
 626 6000  #9W  JMP
           [CODE TABLE
 627 4136  #9X  4136
 630 3641       3641
 631 2101       2101
 632 0177       0177
 633 4523       4523
 634 2151       2151
 635 4122       4122
 636 2651       2651
 637 2414       2414
 640 0477       0477
 641 5172       5172
 642 0651       0651
 643 1506       1506
 644 4225       4225
 645 4443       4443
 646 6050       6050
 647 5126       5126
 650 2651       2651
 651 5120       5120
 652 3651       3651
 653 0001  #9Y  1
 654 7774       -3
 655 7775       -2
 656 7661       -116
 657 0000       0000
 660 0000       0000
 661 0100       0100    [PERIOD
 662 0000       0000
 663 7736       7736    [STAR
 664 3677       3677
 665 0404       0404    [DASH
 666 0404       0404
 667 0404       0404    [PLUS
 670 0437       0437
 671 0403       0403    [SLASH
 672 6010       6010
 673 4177       4177    [BRACKET OPEN
 674 0000       0000
```

```
INT-DSP,1Ø  LN=62Ø

     CONT
675  1212        1212   C= SIGN
676  1212        1212
677  4477        4477   CA
7ØØ  7744        7744
7Ø1  5177        5177
7Ø2  2651        2651
7Ø3  4136        4136
7Ø4  2241        2241
7Ø5  4177        4177
7Ø6  3641        3641
7Ø7  4577        4577
71Ø  4145        4145
711  4477        4477
712  4Ø44        4Ø44
713  4136        4136
714  2645        2645
715  1Ø77        1Ø77
716  771Ø        771Ø
717  7741        7741
72Ø  ØØ41        ØØ41
721  4142        4142
722  4Ø76        4Ø76
723  1Ø77        1Ø77
724  4324        4324
725  Ø177        Ø177
726  Ø3Ø1        Ø3Ø1
727  3Ø77        3Ø77
73Ø  773Ø        773Ø
731  3Ø77        3Ø77
732  77Ø6        77Ø6
733  4177        4177
734  7741        7741
735  4477        4477
736  3Ø44        3Ø44
737  4276        4276
74Ø  Ø376        Ø376
741  4477        4477
742  3146        3146
743  5121        5121
744  4651        4651
745  4Ø4Ø        4Ø4Ø
746  4Ø77        4Ø77
747  Ø177        Ø177
75Ø  77Ø1        77Ø1
751  Ø176        Ø176
752  74Ø2        74Ø2
753  Ø677        Ø677
754  77Ø1        77Ø1
755  1463        1463
756  6314        6314
757  Ø77Ø        Ø77Ø
76Ø  7ØØ7        7ØØ7
761  4543        4543
762  6151        6151
                 $763
763  ØØØØ        Ø
764  ØØØØ  #9U   Ø
```

INT-DSP,11 LN=711

CONT

COMPUTE1•Ø

	VALUE	LINE
1F	Ø432	422
1G	Ø456	446
1H	Ø511	5Ø1
1I	Ø537	527
1J	1612	2ØØØ
1K	1643	2Ø31
1L	1551	1736
1M	1561	1746
1N	1571	1756
1T	16ØØ	1766
2A	Ø4Ø4	373
2B	Ø4Ø7	376
2C	Ø412	4Ø1
2D	Ø416	4Ø5
2E	Ø422	411
2F	Ø426	415
2G	1112	1274
2H	1115	1277
2I	112Ø	13Ø2
2J	1124	13Ø6
2K	1142	1324
2L	116Ø	1342
2T	16Ø4	1772
3B	Ø635	1Ø11
3C	Ø65Ø	1Ø24
3D	Ø667	1Ø43
3E	Ø657	1Ø33
3F	Ø7Ø6	1Ø62
3G	Ø715	1Ø71
3H	Ø7Ø1	1Ø55
3I	Ø722	1Ø76
3J	Ø6Ø2	755
3K	Ø437	6Ø7
3L	Ø45Ø	621
3M	Ø467	642
3N	Ø6ØØ	753
3O	Ø6Ø1	754
3P	Ø736	1112
3Q	Ø735	1111
3R	Ø454	625
3S	Ø57Ø	743
3T	3ØØØ	2Ø55
3U	Ø411	561
3V	Ø576	751
3W	Ø577	752
3X	Ø733	11Ø7
3Y	Ø734	111Ø
3Z	Ø416	566
4A	Ø235	221
5A	Ø254	24Ø
5B	Ø262	246
6A	Ø213	176
6B	Ø216	2Ø1
6C	Ø222	2Ø5
6D	Ø226	211
6E	Ø232	215
6F	Ø271	256
6G	Ø3Ø5	272
6H	Ø313	3ØØ

	VALUE	LINE
6I	Ø33Ø	316
6J	Ø35Ø	336
6K	Ø361	347
6L	Ø372	36Ø
6Y	Ø77Ø	1145
6Z	Ø771	1146
7C	Ø4ØØ	55Ø
7D	Ø747	1124
7I	Ø463	636
7M	Ø612	766
7R	Ø754	1131
7T	Ø562	735
7U	Ø741	1116
7X	Ø737	1113
7Y	Ø74Ø	1114
8A	Ø571	744
8B	Ø574	747
8C	1Ø74	1255
8D	1Ø13	1174
8E	1Ø16	1177
8F	1175	136Ø
8G	1311	1475
8H	1Ø37	122Ø
8I	1Ø56	1237
8J	12Ø3	1366
8K	12Ø5	137Ø
8L	1221	14Ø4
9A	123Ø	1413
9B	1233	1416
9C	134Ø	1524
9D	1237	1422
9E	1355	1541
9F	1377	1563
9G	161Ø	1776
9H	1611	1777
9I	16Ø6	1774
9J	16Ø7	1775
9K	1425	1611
9L	1372	1556
9M	143Ø	1615
9N	1453	164Ø
9O	1457	1644
9P	1464	1651
9Q	1531	1716
9R	1541	1726
9S	1577	1764
9T	1267	1452
9Y	17ØØ	2Ø53
9Z	17Ø1	2Ø54

```
    CONT
 20 1020       LDA&
 21 1750       1750 [1000
 22 6000       JMP3A [FLOAT = 9E
 23 1000       LDA
 24 1237       9D [DZ/DT CAL
 25 6635       JMP3B
 26 7054       JMP1054 [COMPUTE 1000 X DZ/DT CAL
 27 1355       9E
 30 1377       9F
 31 1430       9M [STORE IN 9M
 32 1000       LDA
 33 1233       9B [L MEAN
 34 6635       JMP3B [FLOAT = 9F
 35 7054       JMP1054 [COMPUTE L**2
 36 1377       9F
 37 1377       9F
 40 1453       9N [STORE IN 9N
 41 1000       LDA
 42 1340       9C [Z CAL
 43 6635       JMP3B [FLOAT = 9F
 44 7054       JMP1054 [COMPUTE Z CAL**2
 45 1377       9F
 46 6400       =9F
 47 7054       JMP1054 [COMPUTE Z CAL**2 X L**2
 50 6324       =9N
 51 7163       JMP1163 [COMPUTE Z CAL**2 X L**2 / 1000 X DZ/DT CA
          L
 52 6347       =9M
 53 7734       JMP1734
 54 6347       =9M [STORE IN 9M
 55 1000       LDA
 56 1230       9A [RHO
 57 6635       JMP3B [FLOAT = 9F
 60 7734       JMP1734
 61 1377       9F
 62 6324       =9N [STORE IN 9N
 63 1020       LDA&
 64 0063       63 [51
 65 6635       JMP3B [FLOAT = 9F
 66 7054       JMP1054 [MULTIPLY 51 X RHO
 67 1453       9N
 70 6400       =9F
 71 7163       JMP1163 [DIVIDE BY 1000
 72 6422       =9E
 73 7054       JMP1054 [MULTIPLY TIMES EXISTING PRODUCT
 74 6347       =9M
 75 7734       JMP1734 [STORE IN 9P. PRODUCT WILL BE USED
 76 6313       =9P      [IN NEXT 512 CALCULATIONS OF CARDIAC OUTPU
          T
 77 0641       UMB1
100 0600       LMB0
101 6070       JMP70 [JUMP BACK TO MAIN PROGRAM
          [COME HERE AT END OF SAMPLING TO COMPUTE CARDIAC OUTPU
          T, STROKE VOLUME AND PULSE RATE
102 1000       LDA
103 1607       9J [Z
104 6000       JMP3A [FLOAT = 9E
```

```
    CONT
1Ø5 7Ø54       JMP1Ø54 [COMPUTE Z**2
1Ø6 1355       9E
1Ø7 1355       9E
11Ø 1453       9N [STORE IN 9N
111 1ØØØ       LDA
112 1611       9H [T3-T1
113 6ØØØ       JMP3A [FLOAT - 9E
114 1ØØØ       LDA
115 161Ø       9G [DZ/DT MIN
116 6635       JMP3B [FLOAT - 9F
117 7Ø54       JMP1Ø54 [MULTIPLY DZ/DT MIN X [T3-T1]
12Ø 1355       9E
121 64ØØ       *9F
122 7163       JMP1163 [DIVIDE BY Z**2
123 6324       *9N
124 7Ø54       JMP1Ø54 [MULTIPLY TIMES CAL FACTORS AND CONSTANTS
125 6313       *9P      [TO GET STROKE VOLUME
126 7734       JMP1734
127 6347       *9M [STORE STROKE VOLUME IN 9M
13Ø 1Ø2Ø       LDA&
131 Ø144       144
132 6ØØØ       JMP3A [FLOAT - 9E
133 1Ø2Ø       LDA&
134 Ø454       454
135 6635       JMP3B [FLOAT - 9F
136 7Ø54       JMP1Ø54 [FIND PRODUCT
137 1355       9E
14Ø 1377       9F
141 1453       9N [STORE IN 9N
142 1ØØØ       LDA
143 16Ø6       9I [T
144 6ØØØ       JMP3A [FLOAT - 9E
145 7163       JMP1163 [FIND T/3ØØØØ
146 1355       9E
147 1453       9N
15Ø 1453       9N [STORE IN 9N
151 7163       JMP1163 [COMPUTE CARDIAC OUTPUT
152 143Ø       9M
153 1453       9N
154 1377       9F [CARDIAC OUTPUT IN 9F
155 1Ø2Ø       LDA&
156 ØØØ1       1
157 6ØØØ       JMP3A [FLOAT - 9E
16Ø 7163       JMP1163 [COMPUTE PULSE RATE
161 1355       9E       [IN BEATS PER MINUTE
162 1453       9N
163 1453       9N [PULSE RATE IN 9N
164 1Ø2Ø       LDA&
165 ØØ12       12 [1Ø
166 6ØØØ       JMP3A [FLOAT - 9E
167 7163       JMP1163 [DIVIDE CARDIAC OUTPUT BY 1Ø
17Ø 1277       9276
171 Ø642       UMB2
172 1Ø2Ø       LDA&
173 7774       7774
174 4413       STC3U+2
175 4737       STC7X [MAKE PRESENT PEN POSITION
```

```
     CONT
176 4740        STC7Y [THE ORIGIN
177 1020        LDA&
200 6000        =1777
201 4601        STC3O
202 4600        STC3N
203 6741        JMP7U [PEN UP
204 1000        LDA
205 0770        6Y
206 0450        AZE
207 6404        JMP2A
            [PLOT LABELS FOR HUMAN DATA
210 1500        SRO [CHECK CODE WORD
211 0771        6Z [PASSED FROM FINAL DISPLAY ROUTINE
212 6222        JMP6C [DRAW AXIS FOR CARDIAC OUTPUT
213 1500 #6A    SRO
214 0771        6Z
215 6226        JMP6D [DRAW AXIS FOR PULSE RATE
216 1500 #6B    SRO
217 0771        6Z
220 6232        JMP6E [DRAW AXIS FOR STROKE VOLUME
221 6235        JMP4A [DRAW X AXIS
222 0065 #6C    SET&5
223 4431        1F=1+4000
224 6271        JMP6F
225 6213        JMP6A
226 0065 #6D    SET&5
227 4455        1G=1+4000
230 6271        JMP6F
231 6216        JMP6B
232 0065 #6E    SET&5
233 4510        1H=1+4000
234 6271        JMP6F
            [DRAW X AXIS AND LABEL IT
235 6747 #4A    JMP7D [PEN DOWN
236 1020        LDA&
237 1776        1776 [FILLED WITH LENGTH OF X AXIS
240 4733        STC3X
241 6612        JMP7M [DRAW X AXIS
242 6741        JMP7U [PEN UP
243 1020        LDA&
244 0062        62
245 4734        STC3Y
246 1020        LDA&
247 0454        454
250 4733        STC3X
251 6612        JMP7M [PREPARE TO WRITE LABEL
252 0065        SET&5
253 4536        1I=1+4000
254 1325 #5A    LDH&5 [ LOAD A WITH CHARACTER
255 1420        SHD&
256 7700        7700 [SEE IF END OF CHARACTER STRING
257 6262        JMP5B [JUMP IF YES
260 6400        JMP7C [OTHERWISE PLOT CHARACTER
261 6254        JMP5A
262 1020 #5B    LDA& [SET PEN AT [0,1]
263 0144        144
264 4734        STC3Y
```

```
     CONT
265  4733         STC3X
266  6612         JMP7M
267  0640         UMB0
270  7000         JMP1000 [JUMP TO PLOT CURVES
             [DRAW Y AXES AND LABEL THEM
271  0046    #6F  SET6
272  0000         0
273  1020         LDA&
274  0620         620
275  4734         STC3Y
276  1020         LDA&
277  0144         144
300  4733         STC3X
301  6612         JMP7M [MOVE TO [1,4]
302  1020         LDA&
303  0006         6 [CHARACTER ORIENTATION +Y
304  4422         STC3Z+4
305  1325    #6G  LDH&5 [LOAD A WITH CHARACTER
306  1420         SHD&
307  7700         7700
310  6313         JMP6H [JUMP IF END OF STRING
311  6400         JMP7C [PLOT CHARACTER
312  6305         JMP6G
313  1020    #6H  LDA&
314  0144         144
315  4734         STC3Y
316  1020         LDA&
317  0310         310
320  4733         STC3X
321  6612         JMP7M [MOVE TO [2,1]
322  6747         JMP7D [PEN DOWN
323  1020         LDA&
324  1750         1750
325  4734         STC3Y
326  4422         STC3Z+4 [CHARACTER ORIENTATION +X
327  6612         JMP7M [DRAW LINE TO [2,10]
             [LABEL Y AXIS
330  1020    #6I  LDA&
331  0274         274
332  4733         STC3X
333  6612         JMP7M [DRAW .12 INCH LINE
334  6741         JMP7U [PEN UP
335  1020         LDA&
336  0206         206
337  4733         STC3X
340  6612         JMP7M [LEAVE SPACE FOR NUMBER
341  0415         KST
342  6350         JMP6J
343  0515         KBD
344  1460         SAE&
345  0012         0012
346  6350         JMP6J
347  7034         JMP8H-3
350  1325    #6J  LDH&5
351  1420         SHD&
352  1200         1200
353  6372         JMP6L
```

```
     CONT
354  1420       SHD&
355  7700       7700
356  6361       JMP6K
357  6400       JMP7C [PLOT NUMBER
360  6350       JMP6J
361  1020  #6K  LDA&
362  0310       310
363  4733       STC3X
364  6612       JMP7M
365  1020       LDA& [REDEFINE X AND Y
366  0144       144 [TO BE [0,1]
367  4740       STC7Y
370  4737       STC7X
371  6006       JMP6
372  1020  #6L  LDA&
373  0310       310
374  4733       STC3X
375  1020       LDA&
376  7633       7633
377  1140       ADM
400  0734       3Y
401  6612       JMP7M [PREPARE TO PLOT NEXT NUMBER
402  6747       JMP7D [PEN DOWN
403  6330       JMP6I
           [PLOT LABELS FOR DOG DATA
404  1500  #2A  SRO [CHECK CODE WORD
405  0771       6Z [PASSED FROM FINAL DISPLAY  ROUTINE
406  6416       JMP2D [DRAW AXIS FOR CARDIAC OUTPUT
407  1500  #2B  SRO
410  0771       6Z
411  6422       JMP2E [DRAW AXIS FOR PULSE RATE
412  1500  #2C  SRO
413  0771       6Z
414  6426       JMP2F [DRAW AXIS FOR STROKE VOLUME
415  6235       JMP4A [DRAW X AXIS
416  0065  #2D  SET&5
417  5611       1J-1+4000
420  6271       JMP6F
421  6407       JMP2B
422  0065  #2E  SET&5
423  4455       1G-1+4000
424  6271       JMP6F
425  6412       JMP2C
426  0065  #2F  SET&5
427  5642       1K-1+4000
430  6271       JMP6F
431  6235       JMP4A
           [TABLE OF CODES FOR LABELING AXES
432  3714  #1F  3714
433  4330       4330 [L PER MIN
434  4514       4514 [LABEL AXIS 2-20 FOR HUMAN DATA
435  4034       4034
436  4177       4177
437  0200       0200
440  1201       1201
441  1012       1012
442  0106       0106
```

```
    CONT
443 1201       1201
444 0412       0412
445 0102       0102
446 1201       1201
447 0012       0012
450 1410       1410
451 1214       1214
452 0612       0612
453 1404       1404
454 1214       1214
455 0277       0277
456 2530  #1G  2530
457 2447       2447 [BEATS PER MIN
460 4614       4614 [LABEL AXIS 40-220 FOR HUMAN AND DOG DATA
461 4330       4330
462 4514       4514
463 4034       4034
464 4177       4177
465 0202       0202
466 0012       0012
467 0200       0200
470 0012       0012
471 0110       0110
472 0012       0012
473 0106       0106
474 0012       0012
475 0104       0104
476 0012       0012
477 0102       0102
500 0012       0012
501 0100       0100
502 0012       0012
503 1410       1410
504 0012       0012
505 1406       1406
506 0012       0012
507 1404       1404
510 0077       0077
511 2626  #1H  2626 [CC
512 7702       7702 [LABEL AXIS 20-200 FOR HUMAN DATA
513 0000       0000
514 1201       1201
515 1000       1000
516 1201       1201
517 0600       0600
520 1201       1201
521 0400       0400
522 1201       1201
523 0200       0200
524 1201       1201
525 0000       0000
526 1214       1214
527 1000       1000
530 1214       1214
531 0600       0600
532 1214       1214
533 0400       0400
```

```
     CONT
 534 1214      1214
 535 0200      0200
 536 7777      7777
 537 4742 #1I  4742 [TOTAL TIME
 540 4724      4724
 541 3714      3714
 542 4734      4734
 543 4030      4030
 544 1400      1400
 545 0061      0061
 546 0014      0014
 547 4034      4034
 550 4177      4177
               [CALCOMP PLOT
               [MODIFIED FOR LINC 300
               [F T DAVIDSON 5 OCT 67
               [CHARACTER PLOT
               [PEN MUST BE IN THE
               [UP POSITION
               $400
 400 1120 #7C  ADA &
 401 3000      3T
 402 4017      STC 17
 403 2000      ADD 0
 404 4454      STC 3R
 405 1017      LDA 17
 406 1120      ADA&
 407 2000      2000
 410 4017      STC 17
 411 1017 #3U  LDA 17
 412 0075      SET & 15
 413 7776      =1 [MAGNIFICATION
 414 0451      APO
 415 6754      JMP 7R
 416 1317 #3Z  LDH 17
 417 1560      BCL &
 420 7770      7770
 421 1120      ADA &
 422 0000      0 [ORIENTATION
 423 1560      BCL &
 424 7770      7770
 425 1120      ADA &
 426 0602      3J
 427 4016      STC 16
 430 1016      LDA 16
 431 4442      STC 3K+3
 432 1337      LDH & 17
 433 0470      AZE &
 434 6450      JMP 3L
 435 0017      COM
 436 4440      STC 3K+1
 437 0076 #3K  SET & 16
 440 0000      0 [MINUS THE NO. OF INCREMENTS IN THIS DIRECTION
 441 1020      LDA &
 442 0000      0 [MOTION WORD
 443 6463      JMP 7I
 444 0236      XSK & 16
```

```
     CONT
445 6441       JMP '-4
446 Ø235       XSK & 15
447 6437       JMP 3K
          [TEST FOR END
45Ø 1Ø17 #3L LDA 17
451 156Ø       BCL &
452 5777       5777
453 Ø45Ø       AZE
454 ØØØØ #3R RETURN
          [STEP LINE OF CHAR-TABLE-ALLOWS OVERLAP INTO UPPER MEM
          ORY
455 1Ø2Ø       LDA &
456 4ØØØ       -3777
457 114Ø       ADM
46Ø ØØ17       17
461 1Ø17       LDA 17
462 6411       JMP 3U
          [INCREMENT PLOTTER AND X,Y SR
463 4467 #7I STC 3M
464 2ØØØ       ADD Ø
465 457Ø       STC 3S
466 152Ø       SRO & [TEST FOR -Y
467 ØØØØ #3M [KEY WORD
47Ø 6511       JMP '+21
471 274Ø       ADD 7Y [TEST FOR POINTS LESS THAN OR EQUAL LOWER B
          OUND
472 26ØØ       ADD 3N
473 Ø451       APO
474 65Ø5       JMP '+11
475 ØØ11       CLR [TEST FOR POINTS GREATER THAN UPPER BOUND
476 274Ø       ADD 7Y
477 26Ø1       ADD 3O
5ØØ Ø471       APO &
5Ø1 65Ø5       JMP '+4
5Ø2 1Ø2Ø       LDA & [CARRIAGE RIGHT
5Ø3 ØØØ4       4
5Ø4 6571       JMP 8A
5Ø5 ØØ11       CLR
5Ø6 274Ø       ADD 7Y [DECREASE POINT INDICATOR IN 7Y
5Ø7 2576       ADD 3V
51Ø 474Ø       STC 7Y
511 15ØØ       SRO [TEST FOR +Y
512 Ø467       3M
513 6536       JMP '+23
514 274Ø       ADD 7Y [TEST FOR POINTS GREATER THAN OR EQUAL LOWE
          R BOUND
515 26Ø1       ADD 3O
516 2577       ADD 3W
517 Ø471       APO &
52Ø 6532       JMP '+12
521 ØØ11       CLR [TEST FOR POINTS LESS THAN LOWER BOUND
522 274Ø       ADD 7Y
523 26ØØ       ADD 3N
524 2577       ADD 3W
525 Ø451       APO
526 6532       JMP '+4
527 1Ø2Ø       LDA& [CARRIAGE LEFT
```

```
     CONT
530 ØØ1Ø        1Ø
531 6571        JMP 8A
532 ØØ11        CLR
533 274Ø        ADD 7Y [INCREASE POINT INDICATOR IN 7Y
534 2577        ADD 3W
535 474Ø        STC 7Y
536 15ØØ        SRO [TEST FOR +X
537 Ø467        3M
54Ø 655Ø        JMP '+1Ø
541 1Ø2Ø        LDA& [DRUM DOWN
542 ØØØ2        2
543 6571        JMP 8A
544 1ØØØ        LDA
545 Ø737        7X
546 2577        ADD 3W
547 4737        STC 7X
55Ø 15ØØ        SRO [TEST FOR =X
551 Ø467        3M
552 6562        JMP '+1Ø
553 1Ø2Ø        LDA & [DRUM UP
554 ØØØ1        1
555 6571        JMP 8A
556 1ØØØ        LDA
557 Ø737        7X
56Ø 2576        ADD 3V
561 4737        STC 7X
562 1ØØØ  #7T   LDA
563 Ø574        8B
564 Ø546        OPR 46
565 6564        JMP'=1
566 ØØ11        CLR
567 4574        STC 8B
57Ø 144Ø  #3S   S RETURN
571 16ØØ  #8A   PSE
572 Ø574        8B
573 1Ø6Ø        STA &
574 ØØØØ  #8B   Ø
575 6ØØØ        JMP Ø
576 7776  #3V   =1
577 ØØØ1  #3W   +1
6ØØ 1777  #3N   1777 [Y=LOWER BOUND  NOTE SIGN
6Ø1 6ØØØ  #3O   =1777 [Y=UPPER BOUND  NOTE SIGN
6Ø2 7776  #3J   =1 [=Y
6Ø3 7766        =11 [=X,=Y
6Ø4 7767        =1Ø [=X
6Ø5 7765        =12 [=X,+Y
6Ø6 7775        =2 [+Y
6Ø7 7771        =6 [+X,+Y
61Ø 7773        =4 [+X
611 7772        =5 [+X,=Y
          [INTERPOLATED MOTION
612 ØØ76  #7M   SET & 16
613 7767        =1Ø
614 ØØ75        SET & 15
615 7776        =1
616 1ØØØ        LDA
617 Ø734        3Y
```

```
     CONT
620 2735        ADD 3Q
621 4736        STC 3P
622 2000        ADD Ø
623 4454        STC 3R
624 2733        ADD 3X
625 ØØ17        COM
626 2737        ADD 7X
627 Ø471        APO &
630 6634        JMP '+4
631 ØØ76        SET & 16
632 7773        *4
633 ØØ17        COM
634 1060        STA &
635 0000 #3B    [/DELX/
636 ØØ11        CLR
637 2736        ADD 3P
640 ØØ17        COM
641 2740        ADD 7Y
642 Ø471        APO &
643 6647        JMP '+4
644 ØØ75        SET & 15
645 7775        *2
646 ØØ17        COM
647 1060        STA &
650 0000 #3C    [/DELY/
651 ØØ77        SET & 17
652 3777        *4000
653 1600        BSE
654 Ø635        3B
655 Ø470        AZE &
656 6454        JMP 3R
657 4667 #3E    STC 3D
660 2635        ADD 3B
661 Ø241        ROL 1
662 4635        STC 3B
663 2650        ADD 3C
664 Ø241        ROL 1
665 4650        STC 3C
666 1020        LDA &
667 0000 #3D    [RESULT OF BSE
670 Ø241        ROL 1
671 Ø451        APO
672 6676        JMP '+4
673 1500        SRO
674 ØØ17        17
675 6657        JMP 3E
676 ØØ11        CLR
677 4706        STC 3F
700 4715        STC 3G
701 ØØ11 #3H    CLR
702 2016        ADD 16
703 4722        STC 3I
704 2635        ADD 3B
705 1220        LAM &
706 0000 #3F
707 4000        STC Ø
710 Ø472        LZE &
```

```
     CONT
711  4722       STC 3I
712  ØØ11       CLR
713  265Ø       ADD 3C
714  122Ø       LAM &
715  ØØØØ  #3G
716  4ØØØ       STC Ø
717  Ø452       LZE
72Ø  2Ø15       ADD 15
721  112Ø       ADA &
722  ØØØØ  #3I
723  Ø45Ø       AZE
724  6463       JMP 7I
725  2577       ADD 3W [+1
726  114Ø       ADM
727  ØØ17       17
73Ø  Ø45Ø       AZE
731  67Ø1       JMP 3H
732  6454       JMP 3R
733  ØØØØ  #3X  ØØØØ [DESIRED X
734  ØØØØ  #3Y  ØØØØ [DESIRED Y
735  ØØØØ  #3Q  ØØØØ [Y-SHIFT
736  ØØØØ  #3P  ØØØØ [3Y+3Q
737  ØØØØ  #7X  ØØØØ [CURRENT X
74Ø  ØØØØ  #7Y  ØØØØ [CURRENT Y
           [PEN SUBROUTINES
741  ØØ56  #7U  SET 16 [PEN UP
742  ØØØØ       Ø
743  1Ø2Ø       LDA &
744  ØØ4Ø       4Ø
745  4757       STC 7R+3
746  6756       JMP 7R+2
747  ØØ56  #7D  SET 16 [PEN DOWN
75Ø  ØØØØ       Ø
751  1Ø2Ø       LDA &
752  ØØ2Ø       2Ø
753  6745       JMP 7D-2
754  ØØ56  #7R  SET 16 [PEN REVERSE
755  ØØØØ       Ø
756  1Ø2Ø       LDA &
757  ØØ2Ø       2Ø
76Ø  166Ø       BCO &
761  ØØ6Ø       6Ø
762  1Ø4Ø       STA
763  Ø757       7R+3
764  Ø546       OPR 46
765  6764       JMP *-1
766  6Ø16       JMP 16
                $77Ø
77Ø  ØØØØ  #6Y  Ø [FLAG = EQUALS 1 IF DOG EXP., Ø IF HUMAN DATA
771  ØØØØ  #6Z  Ø [CODE INDICATING WHICH CURVE TO PLOT
           [7=ALL THREE
           [6=PR+SV
           [5=CO+SV
           [4=SV
           [3=CO+PR
           [2=PR
           [1=CO
```

```
      CONT
           [ROUTINE TO PLOT DESIRED CURVES
                $1000
1000 1000       LDA
1001 0771       6Z
1002 0243       ROL3
1003 4771       STC6Z
1004 1000       LDA
1005 0770       6Y
1006 0450       AZE
1007 7112       JMP2G
           [PLOT HUMAN DATA
1010 1500       SRO [CHECK CODE WORD TO SEE
1011 0771       6Z  [WHICH CURVE[S] TO PLOT
1012 7037       JMP8H [PLOT CARDIAC OUTPUT
1013 1500  #8D  SRO
1014 0771       6Z
1015 7056       JMP8I [PLOT PULSE RATE
1016 1500  #8E  SRO
1017 0771       6Z
1020 7074       JMP8C [PLOT STROKE VOLUME
1021 1000       LDA [COME HERE WHEN FINISHED PLOTTING
1022 0237       4A+2
1023 4733       STC3X
1024 4734       STC3Y
1025 6612       JMP7M
1026 0011       CLR
1027 4737       STC7X
1030 1020       LDA&
1031 0454       454
1032 4733       STC3X
1033 6612       JMP7M [POSITION PEN FOR NEXT GRAPH
1034 0641       UMB1
1035 0600       LMB0
1036 6433       JMP433 [JUMP BACK TO PAGE 0 AND DISPLAY ROUTINE
1037 0770  #8H  770 [READ VALUES FOR CARDIAC OUTPUT
1040 6270       6/270
1041 0750       750
1042 7271       7/271
1043 0000       HLT
1044 1020       LDA&
1045 7467       7467
1046 5233       STC9B
1047 1020       LDA&
1050 0053       53 [X
1051 5340       STC9C
1052 1020       LDA&
1053 5607       9J+4000
1054 7175       JMP8F [PLOT CARDIAC OUTPUT
1055 7013       JMP8D [SEE IF MORE CURVES TO PLOT
1056 0751  #8I  751 [READ IN PULSE RATE DATA
1057 1276       1/276
1060 1020       LDA&
1061 7727       7727
1062 5233       STC9B
1063 1020       LDA&
1064 0062       62 [$
1065 5340       STC9C
```

```
     CONT
1Ø66 6612      JMP7M [RETURN TO [Ø,1]
1Ø67 ØØØØ      HLT
1Ø7Ø 1Ø2Ø      LDA&
1Ø71 16Ø6      9I
1Ø72 7175      JMP8F [PLOT PULSE RATE
1Ø73 7Ø16      JMP8E [SEE IF ONE MORE CURVE TO PLOT
1Ø74 Ø77Ø #8C  77Ø [READ IN STROKE VOLUME DATA
1Ø75 6274      6/274
1Ø76 Ø75Ø      75Ø
1Ø77 7275      7/275
11ØØ 1Ø2Ø      LDA&
11Ø1 7753      7753
11Ø2 5233      STC9B
11Ø3 534Ø      STC9C [Ø
11Ø4 6612      JMP7M [RETURN TO [Ø,1]
11Ø5 ØØØØ      HLT
11Ø6 1Ø2Ø      LDA&
11Ø7 16Ø6      9I
111Ø 7175      JMP8F [PLOT STROKE VOLUME
1111 7Ø21      JMP8E+3 [JUMP TO RETURN TO PAGE Ø
          [PLOT DOG VALUES
1112 15ØØ #2G  SRO [EXAMINE CODE WORD TO SEE
1113 Ø771      6Z [WHICH CURVES TO PLOT
1114 7124      JMP2J [PLOT CARDIAC OUTPUT
1115 15ØØ #2H  SRO
1116 Ø771      6Z
1117 7142      JMP2K [PLOT PULSE RATE
112Ø 15ØØ #2I  SRO
1121 Ø771      6Z
1122 716Ø      JMP2L [PLOT STROKE VOLUME
1123 7Ø21      JMP8E+3
1124 Ø77Ø #2J  77Ø [READ VALUES FOR CARDIAC OUTPUT
1125 627Ø      6/27Ø
1126 Ø75Ø      75Ø
1127 7271      7/271
113Ø ØØØØ      HLT
1131 ØØ11      CLR
1132 5233      STC9B
1133 1Ø2Ø      LDA&
1134 ØØ53      53 [X
1135 534Ø      STC9C
1136 1Ø2Ø      LDA&
1137 161Ø      9G
114Ø 7175      JMP8F [PLOT CARDIAC OUTPUT
1141 7115      JMP2H
1142 Ø751 #2K  751 [READ IN PULSE RATE DATA
1143 1276      1/276
1144 1Ø2Ø      LDA&
1145 7727      7727
1146 5233      STC9B
1147 1Ø2Ø      LDA&
115Ø ØØ62      62 [$
1151 534Ø      STC9C
1152 6612      JMP7M [RETURN TO [Ø,1]
1153 ØØØØ      HLT
1154 1Ø2Ø      LDA&
1155 16Ø6      9I
```

```
      CONT
1156 7175      JMP8F [PLOT PULSE RATE
1157 712Ø      JMP2I
116Ø Ø77Ø #2L 77Ø [READ IN STROKE VOLUME DATA
1161 6274      6/274
1162 Ø75Ø      75Ø
1163 7275      7/275
1164 ØØ11      CLR
1165 5233      STC9B
1166 534Ø      STC9C [Ø
1167 6612      JMP7M [RETURN TO [Ø,1]
117Ø ØØØØ      HLT
1171 1Ø2Ø      LDA&
1172 1611      9H
1173 7175      JMP8F [PLOT STROKE VOLUME
1174 7Ø21      JMP8E+3
          [PLOT CURVE
1175 5237 #8F STC9D
1176 5577      STC9S
1177 ØØ44      SET4
12ØØ ØØØØ      Ø
12Ø1 ØØ61      SET&1
12Ø2 2777      2777
12Ø3 Ø461 #8J SNS&1 [IF SENSE SWITCH 1 IS SET
12Ø4 7355      JMP9E [JUMP TO AVERAGE 4 POINTS
12Ø5 ØØ43 #8K SET3
12Ø6 17ØØ      9Y [SET NO. OF POINTS TO PLOT
12Ø7 Ø536      OPR&16 [READ RSW
121Ø 156Ø      BCL& [EXAMINE BITS Ø AND 1
1211 7774      7774
1212 112Ø      ADA& [C[RSW] DESERMINE NO. OF SYMBOLS PLOTTED
1213 16ØØ      1T
1214 1Ø4Ø      STA
1215 1311      8G
1216 522Ø      STC'+2
1217 ØØ45      SET5
122Ø ØØØØ      Ø
1221 1Ø21 #8L LDA&1 [LOAD A WITH Y COORDINATE
1222 723Ø      JMP9A [PLOT POINT
1223 1Ø2Ø      LDA&
1224 ØØØ2      2
1225 114Ø      ADM
1226 Ø733      3X
1227 7221      JMP8L
123Ø ØØ5Ø #9A SET1Ø
1231 ØØØØ      Ø
1232 112Ø      ADA& [MODIFY FOR PLACEMENT ON GRAPH
1233 ØØØØ #9B Ø [VALUE FILLED IN
1234 Ø47Ø      AZE&
1235 724Ø      JMP9D+1
1236 124Ø      MUL
1237 ØØØØ #9D Ø [VALUE FILLED IN
124Ø 112Ø      ADA&
1241 Ø144      144
1242 1Ø4Ø      STA
1243 Ø734      3Y [STORE Y COORDINATE
1244 112Ø      ADA&
1245 6ØØØ      =1777
```

```
      CONT
1246 0451        APO
1247 7253        JMP'+4
1250 1020        LDA&
1251 1777        1777
1252 4734        STC3Y
1253 6612        JMP7M [PLOT POINT
1254 0415        KST
1255 7263        JMP'+6
1256 0515        KBD
1257 1460        SAE&
1260 0012        0012
1261 7263        JMP'+2
1262 7034        JMP8H-3
1263 0223        XSK&3 [SKIP IF ALL VALUES PLOTTED
1264 7274        JMP'+10 [OTHERWISE CHECK IF SYMBOL TO BE PLOTTED
1265 6741        JMP7U
1266 7430        JMP9M
1267 1020   #9T  LDA&
1270 0144        144
1271 4734        STC3Y
1272 4733        STC3X
1273 6004        JMP4
1274 1000        LDA
1275 0001        1
1276 1460        SAE&
1277 3000        3000
1300 7302        JMP'+2
1301 6747        JMP7D [PEN DOWN
1302 1460        SAE&
1303 3003        3003
1304 7306        JMP'+2
1305 6747        JMP7D
1306 0225        XSK&5 [SKIP IF SYMBOL REQUIRED
1307 6010        JMP10 [OTHERWISE GET NEXT POINT
            [PLOT SYMBOL
1310 0045        SET5
1311 0000   #8G  0
1312 1000        LDA [SAVE PRESENT X AND Y
1313 0737        7X
1314 5604        STC2T
1315 1000        LDA
1316 0740        7Y
1317 5605        STC2T+1
1320 1020        LDA&
1321 7775        7775
1322 4413        STC3U+2
1323 1020        LDA& [ADJUST X AND Y SO THAT SYMBOL
1324 7771        7771 [IS CENTERED
1325 1140        ADM
1326 0734        3Y
1327 1020        LDA&
1330 7773        7773
1331 1040        STA
1332 1577        9S
1333 1140        ADM
1334 0733        3X
1335 6741        JMP7U [PEN UP
```

```
     CONT
1336 6612      JMP7M  [PREPARE TO DRAW SYMBOL
1337 1020      LDA&
1340 0000 #9C  0 [SYMBOL CODE FILLED IN
1341 0642      UMB2
1342 6400      JMP7C [PLOT SYMBOL
1343 0640      UMB0
1344 1000      LDA [RESTORE COORDINATES
1345 1604      2T
1346 4733      STC3X
1347 1000      LDA
1350 1605      2T+1
1351 4734      STC3Y
1352 6612      JMP7M
1353 6747      JMP7D [PEN DOWN
1354 6010      JMP10 [JUMP TO PLOT NEXT POINT
1355 1000 #9E  LDA
1356 1701      9Z
1357 0470      AZE& [IF LESS THAN 4 VALUES, PLOT EVERY
1360 7205      JMP8K [POINT
1361 0043      SET3 [SET NO. OF POINTS TO PLOT=NO. OF VALUES
1362 1701      9Z   [DIVIDED BY 4
1363 0536      OPR&16 [READ RSW
1364 1560      BCL& [CHECK TO SEE IF EITHER BIS 0 OR 1 SET
1365 7774      7774
1366 0470      AZE& [SKIP IF SES
1367 7425      JMP9K [IF NOT SET, NO SYMBOLS PLOTTED
1370 1020      LDA& [PREPARE TO PLOT ONE SYMBOL
1371 1603      1T+3 [FOR EVERY POINT
1372 1040 #9L  STA
1373 1311      8G
1374 5376      STC'+2
1375 0045      SET5
1376 0000      0
1377 1021 #9F  LDA&1
1400 1121      ADA&1 [AVERAGE 4 POINTS
1401 0341      SCR1
1402 1560      BCL&
1403 4000      4000
1404 5413      STC'+7
1405 1021      LDA&1
1406 1121      ADA&1
1407 0341      SCR1
1410 1560      BCL&
1411 4000      4000
1412 1120      ADA&
1413 0000      0
1414 0341      SCR1
1415 1560      BCL&
1416 4000      4000
1417 7230      JMP9A [PLOT POINT
1420 1020      LDA&
1421 0010      10
1422 1140      ADM
1423 0733      3X
1424 7377      JMP9F
1425 1020 #9K  LDA&
1426 1600      1T
```

```
     CONT
1427 7372         JMP9L
              [WRITE LEGEND
143Ø 1Ø2Ø #9M LDA&
1431 144Ø      144Ø
1432 4733      STC3X
1433 1Ø2Ø      LDA&
1434 7775      7775
1435 4413      STC3U+2
1436 1ØØØ      LDA
1437 134Ø      9C
144Ø Ø47Ø      AZE&
1441 7453      JMP9N [COME HERE IF STROKE VOLUME
1442 146Ø      SAE&
1443 ØØ53      ØØ53
1444 7457      JMP9O [COME HERE IF PULSE RATE
1445 1Ø2Ø      LDA& [COME HERE IF CARDIAC OUTPUT
1446 ØØ5Ø      5Ø
1447 4734      STC3Y
145Ø ØØ65      SET&5
1451 555Ø      1L=1+4ØØØ
1452 7464      JMP9P
1453 4734 #9N  STC3Y
1454 ØØ65      SET&5
1455 556Ø      1M=1+4ØØØ
1456 7464      JMP9P
1457 1Ø2Ø #9O  LDA&
146Ø Ø12Ø      12Ø
1461 4734      STC3Y
1462 ØØ65      SET&5
1463 557Ø      1N=1+4ØØØ
1464 6612 #9P  JMP7M
1465 1ØØØ      LDA
1466 1577      9S
1467 Ø47Ø      AZE&
147Ø 7531      JMP9Q
1471 6741      JMP7U
1472 1ØØØ      LDA
1473 134Ø      9C
1474 Ø642      UMB2
1475 64ØØ      JMP7C
1476 Ø64Ø      UMBØ
1477 1Ø2Ø      LDA&
15ØØ ØØØ6      6
15Ø1 114Ø      ADM
15Ø2 Ø734      3Y
15Ø3 1Ø2Ø      LDA&
15Ø4 ØØ12      12
15Ø5 114Ø      ADM
15Ø6 Ø733      3X
15Ø7 6612      JMP7M
151Ø 6747      JMP7D
1511 1Ø2Ø      LDA&
1512 ØØ32      32
1513 114Ø      ADM
1514 Ø733      3X
1515 6612      JMP7M
1516 6741      JMP7U
```

```
     CONT
1517 1020        LDA&
1520 7771        7771
1521 1140        ADM
1522 0734        3Y
1523 6612        JMP7M
1524 1000        LDA
1525 1340        9C
1526 0642        UMB2
1527 6400        JMP7C
1530 7541        JMP9R
1531 6747  #9Q   JMP7D
1532 1020        LDA&
1533 0062        62
1534 1140        ADM
1535 0733        3X
1536 6612        JMP7M
1537 6741        JMP7U
1540 0642        UMB2
1541 1325  #9R   LDH&5
1542 1420        SHD&
1543 7700        7700
1544 7547        JMP'+3
1545 6400        JMP7C
1546 7541        JMP9R
1547 0640        UMB0
1550 7267        JMP9T
1551 1426  #1L   1426
1552 2445        2445
1553 2734        2734
1554 2426        2426
1555 1442        1442
1556 5047        5047
1557 4350        4350
1560 4777        4777
1561 1446  #1M   1446
1562 4745        4745
1563 4236        4236
1564 3014        3014
1565 5142        5142
1566 3750        3750
1567 4030        4030
1570 7777        7777
1571 1443  #1N   1443
1572 5037        5037
1573 4630        4630
1574 1445        1445
1575 2447        2447
1576 3077        3077
1577 0000  #9S   0
           [USE RSW TO SELECT NO. OF SYMBOLS / CURVE PLOTTED
1600 6777  #1T   6777 [IF 0=NONE
1601 7677        7677 [IF 1= 8
1602 7767        7767 [IF 2= 64
1603 7776        7776 [IF 3= EVERY POINT
1604 0000  #2T   0
1605 0000        0
1606 0005  #9I   5
```

```
     CONT
1607 2000 #9J 2000 [1/2
1610 0002 #9G 2
1611 0024 #9H 24
1612 3714 #1J 3714 [L PER MIN
1613 4330      4330 [LABEL AXIS 0=4.5 FOR DOG VALUES
1614 4514      4514
1615 4034      4034
1616 4177      4177
1617 0461      0461
1620 0512      0512
1621 0461      0461
1622 0012      0012
1623 0361      0361
1624 0512      0512
1625 0361      0361
1626 0012      0012
1627 0261      0261
1630 0512      0512
1631 0261      0261
1632 0012      0012
1633 0161      0161
1634 0512      0512
1635 0161      0161
1636 0012      0012
1637 0061      0061
1640 0512      0512
1641 0061      0061
1642 0077      0077
1643 2626 #1K 2626 [CC
1644 7704      7704 [LABEL AXIS 0=45 FOR DOG VALUES
1645 0512      0512
1646 0400      0400
1647 1203      1203
1650 0512      0512
1651 0300      0300
1652 1202      1202
1653 0512      0512
1654 0200      0200
1655 1201      1201
1656 0512      0512
1657 0100      0100
1660 1214      1214
1661 0512      0512
1662 1400      1400
1663 7777      7777
               $1700
1700 0000 #9Y 0 [TOTAL NO. OF VALUES
1701 0000 #9Z 0 [1/4 TOTAL NO. OF VALUES
               3T=3000
```

FIN-DSP1.0

	VALUE	LINE
1A	1245	1263
1B	1255	1274
1C	1271	1311
1D	1304	1325
1E	1313	1335
1F	1323	1346
1G	1331	1355
1H	1346	1373
1I	1356	1404
1J	1366	1415
1K	1377	1427
1L	1405	1436
1M	1411	1443
1N	1416	1451
1O	1427	1463
1P	1434	1471
1Q	1444	1502
1R	1460	1517
1S	1471	1531
1T	1507	1550
1U	1515	1557
1V	1523	1566
1W	1532	1576
1X	1541	1606
1Y	1552	1620
1Z	1563	1632
2A	1100	1103
2B	1112	1116
2C	1120	1125
2D	1130	1136
2E	1145	1154
2F	1153	1163
2G	1167	1200
2H	1203	1215
2I	1212	1225
2J	1234	1250
2K	1572	1643
2L	1573	1645
2M	1574	1647
2N	1575	1651
2O	1610	1665
2P	1625	1703
2Q	1631	1710
2R	1637	1717
2S	1641	1722
2T	1652	1734
2U	1653	1737
2V	1660	1745
2W	1671	1757
2X	1677	1766
2Y	1705	1775
2Z	1720	2011
3A	1726	2020
4B	1727	2022
4C	1732	2026
4D	1740	2035
4E	1741	2037
4F	1742	2041
4G	1743	2042

	VALUE	LINE
4H	1744	2043
4I	1745	2044
4J	1746	2045
4K	1747	2046
4L	1750	2047
5T	0162	144
5U	0217	201
5V	0241	223
5W	0324	306
5X	0346	330
8A	0041	22
8B	0044	25
8C	0047	30
8D	0054	35
8E	0124	105
8F	0127	110
8G	0132	113
8H	0135	116
8I	0140	121
8J	0143	124
8K	0145	126
8L	0151	132
8M	0154	135
8N	0157	140
8O	0066	47
8P	0107	70
9A	0400	376
9B	0431	430
9D	0447	446
9E	0457	457
9F	0466	466
9G	0470	470
9H	0473	473
9J	0520	520
9K	0523	523
9M	0530	530
9N	0542	542
9Q	0555	555
9R	0562	562
9S	0573	573
9T	0610	610
9U	0764	767
9V	0617	620
9W	0626	627
9X	0627	631
9Y	0653	655

```
     CONT
 20  1020       LDA&
 21  0162       5T [CHOOSE SCOPE OR PLOT
 22  6400       JMP9A [JUMP TO SCOPE PKG
 23  6151       JMP8L [JUMP BACK TO DISPLAY
 24  6154       JMP8M [JUMP TO RESTART PROGRAM
 25  6054       JMP8D [JUMP IF PLOT
 26  6157       JMP8N [JUMP TO PRINT
 27  1020       LDA& [IF SCOPE=SELECT TO DISPLAY PULSE
 30  0217       5U   [RATE, STROKE VOLUME OR CARDIAC OUTPUT
 31  6400       JMP9A [JUMP TO SCOPE PKG
 32  6020       JMP20
 33  6044       JMP8B [RETURN HERE IF PULSE RATE
 34  6047       JMP8C [RETURN HERE IF STROKE VOLUME
 35  0770       770 [RETURN HERE IF CARDIAC OUTPUT
 36  6270       6/270 [ENTER CO DATA FROM TAPE
 37  0750       750
 40  7271       7/271
 41  0641  #8A  UMB1
 42  0600       LMB0
 43  6520       JMP520 [JUMP TO SCOPE DISPLAY ROUTINE
 44  0751  #8B  751 [ENTER PR DATA FROM TAPE
 45  1276       1/276
 46  6041       JMP8A
 47  0770  #8C  770 [ENTER SV DATA FROM TAPE
 50  6274       6/274
 51  0750       750
 52  7275       7/275
 53  6041       JMP8A
 54  0643  #8D  UMB3 [JUMP HERE IF PLOT
 55  1020       LDA&
 56  0324       5W
 57  6400       JMP9A [JUMP TO SCOPE PKG
 60  6020       JMP20
 61  6066       JMP8O [JUMP IF HUMAN PATIENT
 62  1020       LDA&
 63  0001       1
 64  1040       STA
 65  2770       2770
 66  1020  #8O  LDA&
 67  0346       5X [CHOOSE LENGTH OF X AXIS
 70  6400       JMP9A [JUMP TO SCOPE PKG
 71  6054       JMP8D
 72  6107       JMP8P
 73  1020       LDA&
 74  0004       4 [SET HORIZONTAL INCREMENT IN PLOT ROUTINE
 75  1040       STA
 76  3224       3224
 77  1020       LDA&
100  0020       20
101  1040       STA
102  3421       3421
103  1020       LDA&
104  3774       3774 [SET LENGTH OF X AXIS
105  1040       STA
106  2066       2066
107  1020  #8P  LDA&
110  0241       5V [SELECT TO PLOT 1-3 CURVES
```

```
     CONT
111  6400       JMP9A [JUMP TO SCOPE PKG
112  6054       JMP8D
113  6124       JMP8E
114  6127       JMP8F
115  6132       JMP8G
116  6135       JMP8H
117  6140       JMP8I
120  6143       JMP8J
121  1020       LDA&
122  0007       7
123  6145       JMP8K
124  1020  #8E  LDA&
125  0001       1
126  6145       JMP8K
127  1020  #8F  LDA&
130  0002       2
131  6145       JMP8K
132  1020  #8G  LDA&
133  0004       4
134  6145       JMP8K
135  1020  #8H  LDA&
136  0003       3
137  6145       JMP8K
140  1020  #8I  LDA&
141  0005       5
142  6145       JMP8K
143  1020  #8J  LDA&
144  0006       6
145  1040  #8K  STA
146  2771       2771 [PLACE CODE IN PAGE 3 - LOC 771
147  0603       LMB3
150  6020       JMP20 [JUMP TO PLOTTING ROUTINES
151  0641  #8L  UMB1 [JUMP BACK TO DISPLAY
152  0600       LMB0
153  6433       JMP433
154  0641  #8M  UMB1 [RESTART PROGRAM
155  0600       LMB0
156  6047       JMP47
157  0643  #8N  UMB3
160  0600       LMB0
161  6741       JMP741 [JUMP TO READ IN PRINT ROUTINE
           [DISPLAY TEXT
162  0201  #5T  0201 [1=RESTART PROGRAM
163  1301       1301 [2=PLOT
164  1745       1745 [3=PRINT
165  3046       3046 [4=SCOPE
166  4724       4724
167  4547       4547
170  1443       1443
171  4542       4542
172  3245       3245
173  2440       2440
174  5656       5656
175  1302       1302
176  1743       1743
177  3742       3742
200  4714       4714
```

```
FIN=DSP1,3  LN=163

     CONT
2Ø1  5656         5656
2Ø2  13Ø3         13Ø3
2Ø3  1743         1743
2Ø4  4534         4534
2Ø5  4147         4147
2Ø6  5656         5656
2Ø7  13Ø4         13Ø4
21Ø  1746         1746
211  2642         2642
212  433Ø         433Ø
213  5777         5777
214  Ø1Ø2         Ø1Ø2
215  Ø3Ø4         Ø3Ø4
216  7777         7777
217  Ø2Ø1   #5U   Ø2Ø1  [1=P.R.
22Ø  13Ø1         13Ø1  [2=S.V.
221  1743         1743  [3=C.O.
222  1545         1545
223  1514         1514
224  5656         5656
225  13Ø2         13Ø2
226  1746         1746
227  1551         1551
23Ø  1514         1514
231  5656         5656
232  13Ø3         13Ø3
233  1726         1726
234  1542         1542
235  1514         1514
236  5777         5777
237  Ø1Ø2         Ø1Ø2
24Ø  Ø377         Ø377
241  Ø2Ø1   #5V   Ø2Ø1  [1=C.O.
242  13Ø1         13Ø1  [2=P.R.
243  1726         1726  [3=S.V.
244  1542         1542  [4=C.O. + P.R.
245  1514         1514  [5=C.O. + S.V.
246  5656         5656  [6=P.R. + S.V.
247  13Ø2         13Ø2  [7=ALL THREE
25Ø  1743         1743
251  1545         1545
252  1514         1514
253  5656         5656
254  13Ø3         13Ø3
255  1746         1746
256  1551         1551
257  1514         1514
26Ø  5656         5656
261  13Ø4         13Ø4
262  1726         1726
263  1542         1542
264  1514         1514
265  2Ø14         2Ø14
266  4315         4315
267  4515         4515
27Ø  5656         5656
271  13Ø5         13Ø5
```

```
FIN=DSP1.4  LN=254

     CONT
272  1726        1726
273  1542        1542
274  1514        1514
275  2Ø14        2Ø14
276  4615        4615
277  5115        5115
3ØØ  5656        5656
3Ø1  13Ø6        13Ø6
3Ø2  1743        1743
3Ø3  1545        1545
3Ø4  1514        1514
3Ø5  2Ø14        2Ø14
3Ø6  4615        4615
3Ø7  5115        5115
31Ø  5656        5656
311  13Ø7        13Ø7
312  1724        1724
313  3737        3737
314  1447        1447
315  3345        3345
316  3Ø3Ø        3Ø3Ø
317  5777        5777
32Ø  Ø1Ø2        Ø1Ø2
321  Ø3Ø4        Ø3Ø4
322  Ø5Ø6        Ø5Ø6
323  Ø777        Ø777
324  Ø2Ø1   #5W  Ø2Ø1  [1=HUMAN DATA
325  13Ø1        13Ø1  [2=DOG DATA
326  1733        1733
327  5Ø4Ø        5Ø4Ø
33Ø  2441        2441
331  1427        1427
332  2447        2447
333  2414        2414
334  5656        5656
335  13Ø2        13Ø2
336  1727        1727
337  4232        4232
34Ø  1427        1427
341  2447        2447
342  2414        2414
343  5777        5777
344  Ø1Ø2        Ø1Ø2
345  7777        7777
346  Ø2Ø1   #5X  Ø2Ø1  [1=X AXIS=1Ø IN.
347  13Ø1        13Ø1  [2=X AXIS=2Ø IN.
35Ø  1753        1753
351  1424        1424
352  5334        5334
353  4661        4661
354  Ø1ØØ        Ø1ØØ
355  1434        1434
356  4115        4115
357  5656        5656
36Ø  13Ø2        13Ø2
361  1753        1753
362  1424        1424
```

```
    CONT
363 5334     5334
364 4661     4661
365 0200     0200
366 1434     1434
367 4115     4115
370 5777     5777
371 0102     0102
372 7777     7777
            [SCOPE-SP  ,SP=SAME PAGE
            [GENERAL PURPOSE ROUTINES FOR ENTERING DATA
            [AND SELECTING OPTIONS
            [G.FELLOWS-FEB 67
            [CODE 0-ENTER TEXT
            [CODE 1-STAR OPTION AND RETURN TO '+2
            [CODE 2-STAR OPTION AND RETURN TO '+1+N
            [    WERE N IS POSITION OF OPTION IN LIST
            [CASE ALWAYS RETURNS TO '+1
            [60 AT TEXT END,DISPLAY ONCE AND RETURN '+1
            [76 AT END OF TEXT MEANS RETURN TO '+2 ON EOL
            [77 AT END OF TEXT MEANS RETURN TO '+2 ON EOL
            [    IF CORRECT NO. OF ENTRIES MADE
            [LOAD TAG OF TEXT IN ACCUM, THEN JUMP 9A
            [9A CAN BE PUT AT START OF ANY QUARTER IN LOWER PAGE
            [USES REGS 1,2,3,4,5,6
                 $400
400 0046    #9A SET 6
401 0000         0
402 0062         SET&2
403 1775         1775
404 0471         APO&
405 0222         XSK&2
406 1560         BCL&
407 4000         4000
410 4001         STC1
411 2006         ADD6
412 1040         STA
413 0523         9K
414 2653         ADD9Y  [1
415 4626         STC9W
416 1301         LDH 1
417 0017         COM
420 4555         STC9Q
421 1321         LDH&1
422 0017         COM
423 2655         ADD9Y+2
424 4447         STC9D
425 2001         ADD1
426 4460         STC9E+1
427 0222         XSK&2
430 6446         JMP9D-1
            [CLEAR WORKING AREA 9U
431 0061    #9B SET&1
432 7747         -30
433 0062         SET&2
434 4763         9U-4000
435 1020         LDA&
436 0017         17
```

FIN-DSP1•6 LN=436

```
    CONT
437 Ø043      SET 3
44Ø Ø555      9Q
441 Ø2Ø3      XSK 3
442 2654      ADD9Y+1
443 1362      STH&2
444 Ø221      XSK&1
445 6443      JMP'=2
446 ØØ66      SET&6
447 ØØØØ #9D  Ø
45Ø ØØ11      CLR
451 4763      STC9U-1
452 1Ø2Ø      LDA&
453 ØØØ1      1
454 4613      STC9T+3
455 ØØ65      SET&5
456 Ø764      9U
         [START OF DISPLAY
457 ØØ62 #9E  SET&2
46Ø ØØØØ      Ø
461 ØØ64      SET&4
462 Ø764      9U
463 1Ø2Ø      LDA&
464 Ø336      336
465 447Ø      STC9G
466 2656 #9F  ADD9Y+3
467 116Ø      ADM&
47Ø ØØØØ #9G  Ø
471 ØØ61      SET&1
472 ØØ7Ø      7Ø
473 1322 #9H  LDH&2
474 142Ø      SHD&
475 13ØØ      13ØØ
476 1324      LDH&4
477 142Ø      SHD&
5ØØ 56ØØ      56ØØ
5Ø1 6466      JMP9F
5Ø2 142Ø      SHD&
5Ø3 57ØØ      57ØØ
5Ø4 652Ø      JMP9J
5Ø5 Ø241      ROL 1
5Ø6 112Ø      ADA&
5Ø7 Ø627      9X
51Ø 4ØØ3      STC3
511 2522      ADD9J+2
512 2ØØ1      ADD1
513 4ØØ1      STC1
514 247Ø      ADD9G
515 1743      DSC 3
516 1763      DSC&3
517 6473      JMP9H
52Ø 1322 #9J  LDH&2
521 142Ø      SHD&
522 6ØØ4      6ØØ4
523 6ØØØ #9K  JMP
524 Ø415      KST
525 6457      JMP9E
526 Ø226      XSK&6
```

FIN-DSP1,7 LN=527

```
     CONT
527  6542       JMP9N
53Ø  Ø415  #9M  KST
531  653Ø       JMP'=1
532  ØØ63       SET&3
533  7577       =2ØØ
534  Ø225       XSK&5
535  6534       JMP'=1
536  Ø223       XSK&3
537  6534       JMP'=3
54Ø  Ø515       KBD
541  6431       JMP9B
542  Ø515  #9N  KBD
543  142Ø       SHD&
544  13ØØ       13ØØ
545  6431       JMP9B
546  142Ø       SHD&
547  23ØØ       23ØØ
55Ø  6523       JMP9K
551  142Ø       SHD&
552  12ØØ       12ØØ
553  6617       JMP9V
554  ØØ64       SET&4
555  ØØØØ  #9Q  Ø
556  Ø2Ø4       XSK 4
557  6562       JMP9R
56Ø  1365       STH&5
561  6457       JMP9E
562  4573  #9R  STC9S
563  ØØ43       SET 3
564  Ø523       9K
565  Ø223       XSK&3
566  1322       LDH&2
567  142Ø       SHD&
57Ø  77ØØ       77ØØ
571  653Ø       JMP9M
572  146Ø       SAE&
573  ØØØØ  #9S  Ø
574  661Ø       JMP9T
575  1Ø2Ø       LDA&
576  ØØ16       16
577  1365       STH&5
6ØØ  1ØØØ       LDA
6Ø1  Ø613       9T+3
6Ø2  2763       ADD9U-1
6Ø3  4763       STC9U-1
6Ø4  2ØØ3       ADD3
6Ø5  Ø224       XSK&4
6Ø6  4626       STC9W
6Ø7  6452       JMP9E-5
61Ø  Ø223  #9T  XSK&3
611  1325       LDH&5
612  1Ø2Ø       LDA&
613  ØØØØ       Ø
614  Ø241       ROL 1
615  4613       STC'=2
616  6566       JMP9R+4
           [EOL
```

```
     CONT
617 1302 #9V LDH 2
620 1460     SAE&
621 0077     77
622 6625     JMP9W=1
623 0226     XSK&6
624 6530     JMP9M
625 0011     CLR
626 6000 #9W JMP
             [CODE TABLE
627 4136 #9X 4136
630 3641     3641
631 2101     2101
632 0177     0177
633 4523     4523
634 2151     2151
635 4122     4122
636 2651     2651
637 2414     2414
640 0477     0477
641 5172     5172
642 0651     0651
643 1506     1506
644 4225     4225
645 4443     4443
646 6050     6050
647 5126     5126
650 2651     2651
651 5120     5120
652 3651     3651
653 0001 #9Y 1
654 7774     -3
655 7775     -2
656 7661     -116
657 0000     0000
660 0000     0000
661 0100     0100  [PERIOD
662 0000     0000
663 7736     7736  [STAR
664 3677     3677
665 0404     0404  [DASH
666 0404     0404
667 0404     0404  [PLUS
670 0437     0437
671 0403     0403  [SLASH
672 6010     6010
673 4177     4177  [BRACKET OPEN
674 0000     0000
675 1212     1212  [= SIGN
676 1212     1212
677 4477     4477  [A
700 7744     7744
701 5177     5177
702 2651     2651
703 4136     4136
704 2241     2241
705 4177     4177
706 3641     3641
```

```
FIN-DSP1,11  LN=711

     CONT
 7Ø7 4577        4577
 71Ø 4145        4145
 711 4477        4477
 712 4Ø44        4Ø44
 713 4136        4136
 714 2645        2645
 715 1Ø77        1Ø77
 716 771Ø        771Ø
 717 7741        7741
 72Ø ØØ41        ØØ41
 721 4142        4142
 722 4Ø76        4Ø76
 723 1Ø77        1Ø77
 724 4324        4324
 725 Ø177        Ø177
 726 Ø3Ø1        Ø3Ø1
 727 3Ø77        3Ø77
 73Ø 773Ø        773Ø
 731 3Ø77        3Ø77
 732 77Ø6        77Ø6
 733 4177        4177
 734 7741        7741
 735 4477        4477
 736 3Ø44        3Ø44
 737 4276        4276
 74Ø Ø376        Ø376
 741 4477        4477
 742 3146        3146
 743 5121        5121
 744 4651        4651
 745 4Ø4Ø        4Ø4Ø
 746 4Ø77        4Ø77
 747 Ø177        Ø177
 75Ø 77Ø1        77Ø1
 751 Ø176        Ø176
 752 74Ø2        74Ø2
 753 Ø677        Ø677
 754 77Ø1        77Ø1
 755 1463        1463
 756 6314        6314
 757 Ø77Ø        Ø77Ø
 76Ø 7ØØ7        7ØØ7
 761 4543        4543
 762 6151        6151
                 $763
 763 ØØØØ        Ø
 764 ØØØØ   #9U  Ø
            [CHARTBL
            [LINC SET
            [FOR CALCHAR
            [CODE LOOKUP NUMBERS
                 $1ØØØ
1ØØØ 11ØØ        2A
1ØØ1 1112        2B
1ØØ2 112Ø        2C
1ØØ3 113Ø        2D
1ØØ4 1145        2E
```

```
       CONT
1005  1153        2F
1006  1167        2G
1007  1203        2H
1010  1212        2I
1011  1234        2J
              [SPECIAL
1012  1572        2K
1013  1573        2L
1014  1574        2M
1015  1575        2N
1016  1610        2O
1017  1625        2P
1020  1631        2Q
1021  1637        2R
1022  1641        2S
1023  1652        2T
              [ALPHABET
1024  1245        1A
1025  1255        1B
1026  1271        1C
1027  1304        1D
1030  1313        1E
1031  1323        1F
1032  1331        1G
1033  1346        1H
1034  1356        1I
1035  1366        1J
1036  1377        1K
1037  1405        1L
1040  1411        1M
1041  1416        1N
1042  1427        1O
1043  1434        1P
1044  1444        1Q
1045  1460        1R
1046  1471        1S
1047  1507        1T
1050  1515        1U
1051  1523        1V
1052  1532        1W
1053  1541        1X
1054  1552        1Y
1055  1563        1Z
              [CASE SPECIAL
1056  1653        2U
1057  1660        2V
1060  1671        2W
1061  1677        2X
1062  1705        2Y
1063  1720        2Z
1064  1726        3A
1065  1727        4B
1066  1732        4C
1067  1740        4D
1070  1741        4E
1071  1742        4F
1072  1743        4G
```

```
FIN=DSP1*13  LN=1073

     CONT
1073 1744       4H
1074 1745       4I
1075 1746       4J
1076 1747       4K
1077 1750       4L
          [MOTION CODES
          [NUMBERS
          [0
1100 0601 #2A  0601
1101 4301      4301
1102 0404      0404
1103 0501      0501
1104 0602      0602
1105 0701      0701
1106 0004      0004
1107 0101      0101
1110 0202      0202
1111 6605      6605
          [1
1112 0601 #2B  0601
1113 4602      4602
1114 0201      0201
1115 0406      0406
1116 0101      0101
1117 6705      6705
          [2
1120 0405 #2C  0405
1121 4501      4501
1122 0602      0602
1123 0701      0701
1124 0001      0001
1125 0104      0104
1126 0604      0604
1127 6602      6602
          [3
1130 0405 #2D  0405
1131 4501      4501
1132 0602      0602
1133 0701      0701
1134 0001      0001
1135 0101      0101
1136 0701      0701
1137 0001      0001
1140 0101      0101
1141 0202      0202
1142 0301      0301
1143 4701      4701
1144 2605      2605
          [4
1145 0503 #2E  0503
1146 0601      0601
1147 4204      4204
1150 0503      0503
1151 0006      0006
1152 6603      6603
          [5
1153 0401 #2F  0401
```

```
FIN=DSP1.14  LN=1164

      CONT
1154  4701          4701
1155  0602          0602
1156  0501          0501
1157  0402          0402
1160  0301          0301
1161  0202          0202
1162  0101          0101
1163  0403          0403
1164  0604          0604
1165  4702          4702
1166  2004          2004
            [6
1167  0501  #2G     0501
1170  0402          0402
1171  4602          4602
1172  0701          0701
1173  0001          0001
1174  0101          0101
1175  0202          0202
1176  0301          0301
1177  0401          0401
1200  0504          0504
1201  4702          4702
1202  2004          2004
            [7
1203  0601  #2H     0601
1204  4402          4402
1205  0501          0501
1206  0401          0401
1207  0502          0502
1210  0204          0204
1211  6706          6706
            [8
1212  0503  #2I     0503
1213  4701          4701
1214  0001          0001
1215  0101          0101
1216  0202          0202
1217  0301          0301
1220  0401          0401
1221  0501          0501
1222  0602          0602
1223  0501          0501
1224  0401          0401
1225  0301          0301
1226  0202          0202
1227  0101          0101
1230  0001          0001
1231  0701          0701
1232  4703          4703
1233  2602          2602
            [9
1234  4504  #2J     4504
1235  0401          0401
1236  0301          0301
1237  0202          0202
1240  0101          0101
```

```
     CONT
1241 ØØØ1        ØØØ1
1242 Ø7Ø1        Ø7Ø1
1243 Ø6Ø2        Ø6Ø2
1244 67Ø3        67Ø3
          [ALPHABET
          [A
1245 44Ø4 #1A  44Ø4
1246 Ø5Ø2        Ø5Ø2
1247 Ø7Ø2        Ø7Ø2
125Ø ØØØ4        ØØØ4
1251 43Ø2        43Ø2
1252 Ø2Ø2        Ø2Ø2
1253 46Ø4        46Ø4
1254 67Ø2        67Ø2
          [B
1255 Ø4Ø3 #1B  Ø4Ø3
1256 46Ø3        46Ø3
1257 Ø7Ø1        Ø7Ø1
126Ø ØØØ1        ØØØ1
1261 Ø1Ø1        Ø1Ø1
1262 Ø2Ø3        Ø2Ø3
1263 Ø4Ø6        Ø4Ø6
1264 Ø6Ø3        Ø6Ø3
1265 Ø7Ø1        Ø7Ø1
1266 ØØØ1        ØØØ1
1267 Ø1Ø1        Ø1Ø1
127Ø 67Ø3        67Ø3
          [C
1271 Ø6Ø3 #1C  Ø6Ø3
1272 Ø5Ø1        Ø5Ø1
1273 41Ø1        41Ø1
1274 Ø2Ø2        Ø2Ø2
1275 Ø3Ø1        Ø3Ø1
1276 Ø4Ø4        Ø4Ø4
1277 Ø5Ø1        Ø5Ø1
13ØØ Ø6Ø2        Ø6Ø2
13Ø1 Ø7Ø1        Ø7Ø1
13Ø2 47Ø2        47Ø2
13Ø3 2ØØ3        2ØØ3
          [D
13Ø4 44Ø6 #1D  44Ø6
13Ø5 Ø6Ø3        Ø6Ø3
13Ø6 Ø7Ø1        Ø7Ø1
13Ø7 ØØØ4        ØØØ4
131Ø Ø1Ø1        Ø1Ø1
1311 Ø2Ø3        Ø2Ø3
1312 66Ø6        66Ø6
          [E
1313 44Ø6 #1E  44Ø6
1314 Ø6Ø4        Ø6Ø4
1315 41Ø3        41Ø3
1316 Ø2Ø1        Ø2Ø1
1317 46Ø3        46Ø3
132Ø 41Ø3        41Ø3
1321 46Ø4        46Ø4
1322 66Ø2        66Ø2
          [F
```

```
FIN=DSP1.16  LN=1346

      CONT
1323  44Ø6  #1F  44Ø6
1324  Ø6Ø4       Ø6Ø4
1325  41Ø3       41Ø3
1326  Ø2Ø1       Ø2Ø1
1327  46Ø3       46Ø3
133Ø  67Ø3       67Ø3
            [G
1331  Ø5Ø1  #1G  Ø5Ø1
1332  Ø4Ø2       Ø4Ø2
1333  46Ø3       46Ø3
1334  ØØØ2       ØØØ2
1335  Ø1Ø1       Ø1Ø1
1336  Ø2Ø2       Ø2Ø2
1337  Ø3Ø1       Ø3Ø1
134Ø  Ø4Ø4       Ø4Ø4
1341  Ø5Ø1       Ø5Ø1
1342  Ø6Ø2       Ø6Ø2
1343  Ø7Ø1       Ø7Ø1
1344  47Ø2       47Ø2
1345  2ØØ3       2ØØ3
            [H
1346  44Ø6  #1H  44Ø6
1347  46Ø4       46Ø4
135Ø  4ØØ6       4ØØ6
1351  43Ø3       43Ø3
1352  Ø2Ø1       Ø2Ø1
1353  46Ø4       46Ø4
1354  47Ø2       47Ø2
1355  2ØØ1       2ØØ1
            [I
1356  Ø6Ø1  #1I  Ø6Ø1
1357  46Ø2       46Ø2
136Ø  42Ø1       42Ø1
1361  44Ø6       44Ø6
1362  42Ø1       42Ø1
1363  46Ø2       46Ø2
1364  47Ø3       47Ø3
1365  2ØØ3       2ØØ3
            [J
1366  Ø4Ø1  #1J  Ø4Ø1
1367  47Ø1       47Ø1
137Ø  Ø6Ø1       Ø6Ø1
1371  Ø5Ø1       Ø5Ø1
1372  Ø4Ø5       Ø4Ø5
1373  42Ø1       42Ø1
1374  46Ø2       46Ø2
1375  47Ø2       47Ø2
1376  2ØØ4       2ØØ4
            [K
1377  44Ø6  #1K  44Ø6
14ØØ  46Ø4       46Ø4
14Ø1  41Ø4       41Ø4
14Ø2  45Ø1       45Ø1
14Ø3  47Ø3       47Ø3
14Ø4  66Ø2       66Ø2
            [L
14Ø5  Ø4Ø6  #1L  Ø4Ø6
```

FIN=DSP1,17 LN=1437


```
      CONT
1406  4006          4006
1407  0604          0604
1410  6602          6602
            [M
1411  4406  #1M     4406
1412  0702          0702
1413  0502          0502
1414  0006          0006
1415  6602          6602
            [N
1416  4406  #1N     4406
1417  0701          0701
1420  0001          0001
1421  0702          0702
1422  0001          0001
1423  0701          0701
1424  0406          0406
1425  4702          4702
1426  2004          2004
            [O
1427  4406  #1O     4406
1430  0604          0604
1431  0006          0006
1432  0204          0204
1433  6606          6606
            [P
1434  4406  #1P     4406
1435  0603          0603
1436  0701          0701
1437  0001          0001
1440  0101          0101
1441  0203          0203
1442  4703          4703
1443  2603          2603
            [Q
1444  0401  #1Q     0401
1445  4701          4701
1446  0602          0602
1447  0501          0501
1450  0404          0404
1451  0301          0301
1452  0202          0202
1453  0101          0101
1454  0004          0004
1455  4603          4603
1456  4701          4701
1457  6602          6602
            [R
1460  4406  #1R     4406
1461  0603          0603
1462  0701          0701
1463  0002          0002
1464  0101          0101
1465  0203          0203
1466  4602          4602
1467  4702          4702
1470  6602          6602
```

FIN=DSP1•20 LN=1530


```
     CONT
               CS
1471 0401 #1S 0401
1472 4701     4701
1473 0602     0602
1474 0501     0501
1475 0401     0401
1476 0301     0301
1477 0202     0202
1500 0301     0301
1501 0401     0401
1502 0501     0501
1503 0602     0602
1504 0701     0701
1505 4702     4702
1506 2003     2003
               CT
1507 0602 #1T 0602
1510 4406     4406
1511 4202     4202
1512 4604     4604
1513 4702     4702
1514 2004     2004
               CU
1515 0504 #1U 0504
1516 0402     0402
1517 4006     4006
1520 0204     0204
1521 0406     0406
1522 6706     6706
               CV
1523 0504 #1V 0504
1524 0402     0402
1525 4004     4004
1526 0102     0102
1527 0302     0302
1530 0404     0404
1531 6706     6706
               CW
1532 0504 #1W 0504
1533 0402     0402
1534 4006     4006
1535 0302     0302
1536 0102     0102
1537 0406     0406
1540 6706     6706
               CX
1541 0604 #1X 0604
1542 4401     4401
1543 0304     0304
1544 0401     0401
1545 4604     4604
1546 4001     4001
1547 0104     0104
1550 0001     0001
1551 6606     6606
               CY
1552 0406 #1Y 0406
```

```
      CONT
1553 4001        4001
1554 0702        0702
1555 0502        0502
1556 0401        0401
1557 4102        4102
1560 0001        0001
1561 4003        4003
1562 6604        6604
          [Z
1563 0406 #1Z  0406
1564 4604        4604
1565 0001        0001
1566 0104        0104
1567 0001        0001
1570 0604        0604
1571 6602        6602
          [SPECIAL
          [EOL
1572 2000 #2K  2000
          [DELETE-BACKSPACE
1573 2206 #2L  2206
          [SPACE
1574 2606 #2M  2606
          [&
1575 0602 #2N  0602
1576 0501        0501
1577 4101        4101
1600 0301        0301
1601 0402        0402
1602 4501        4501
1603 4201        4201
1604 0401        0401
1605 0601        0601
1606 0001        0001
1607 6704        6704
          ['
1610 0604 #20  0604
1611 4201        4201
1612 0301        0301
1613 0401        0401
1614 0501        0501
1615 0601        0601
1616 0701        0701
1617 0001        0001
1620 0101        0101
1621 4102        4102
1622 4405        4405
1623 4602        4602
1624 2703        2703
          [=
1625 0403 #2P  0403
1626 4604        4604
1627 4702        4702
1630 2001        2001
          [+
1631 0403 #2Q  0403
1632 4604        4604
```

```
     CONT
1633 4302         4302
1634 4004         4004
1635 4701         4701
1636 2603         2603
          [/
1637 4406 #2R     4406
1640 6706         6706
          [#
1641 0404 #2S     0404
1642 4604         4604
1643 4002         4002
1644 4204         4204
1645 4503         4503
1646 4004         4004
1647 4202         4202
1650 4404         4404
1651 6705         6705
          [CASE
1652 2000 #2T     2000
          [CASE SPECIAL
          [=
1653 0504 #2U     0504
1654 4204         4204
1655 4002         4002
1656 4604         4604
1657 6702         6702
          [%
1660 0403 #2V     0403
1661 4002         4002
1662 0701         0701
1663 0601         0601
1664 0501         0501
1665 0402         0402
1666 4002         4002
1667 4701         4701
1670 6602         6602
          [,
1671 0701 #2W     0701
1672 4502         4502
1673 0301         0301
1674 0101         0101
1675 0701         0701
1676 6604         6604
          [.
1677 0602 #2X     0602
1700 4501         4501
1701 0301         0301
1702 0101         0101
1703 0701         0701
1704 6604         6604
          [$
1705 0403 #2Y     0403
1706 4401         4401
1707 0502         0502
1710 0702         0702
1711 0002         0002
1712 0102         0102
```

```
     CONT
1713 0302       0302
1714 0401       0401
1715 0604       0604
1716 4702       4702
1717 2001       2001
          [C
1720 0503 #2Z  0503
1721 0403       0403
1722 4202       4202
1723 0006       0006
1724 0602       0602
1725 4603       4603
          [CASE-CASE
1726 2000 #3A  2000
          [UNDERLINE
1727 0101 #4B  0101
1730 4606       4606
1731 6501       6501
          [RIGHT BRACKET
1732 0601 #4C  0601
1733 4602       4602
1734 0406       0406
1735 0202       0202
1736 4705       4705
1737 2001       2001
          [UP HALF
1740 2403 #4D  2403
          [DOWN HALF
1741 2003 #4E  2003
          [NOT USED
1742 2000 #4F  2000
1743 2000 #4G  2000
1744 2000 #4H  2000
1745 2000 #4I  2000
1746 2000 #4J  2000
1747 2000 #4K  2000
1750 2000 #4L  2000
          [COPY #3
```

	VALUE	LINE
1F	Ø261	25Ø
1G	Ø3Ø5	274
1H	Ø34Ø	327
1I	Ø366	355
1J	1612	1626
1K	1643	1657
1L	1551	1564
1M	1561	1574
1N	1571	16Ø4
1T	16ØØ	1614
2A	Ø233	221
2B	Ø236	224
2C	Ø241	227
2D	Ø245	233
2E	Ø251	237
2F	Ø255	243
2G	1112	1122
2H	1115	1125
2I	112Ø	113Ø
2J	1124	1134
2K	1142	1152
2L	116Ø	117Ø
2T	16Ø4	162Ø
3B	Ø635	637
3C	Ø65Ø	652
3D	Ø667	671
3E	Ø657	661
3F	Ø7Ø6	71Ø
3G	Ø715	717
3H	Ø7Ø1	7Ø3
3I	Ø722	724
3J	Ø6Ø2	6Ø3
3K	Ø437	435
3L	Ø45Ø	447
3M	Ø467	47Ø
3N	Ø6ØØ	6Ø1
3O	Ø6Ø1	6Ø2
3P	Ø736	74Ø
3Q	Ø735	737
3R	Ø454	453
3S	Ø57Ø	571
3T	3ØØØ	17Ø3
3U	Ø411	4Ø7
3V	Ø576	577
3W	Ø577	6ØØ
3X	Ø733	735
3Y	Ø734	736
3Z	Ø416	414
4A	ØØ64	47
5A	Ø1Ø3	66
5B	Ø111	74
6A	ØØ42	24
6B	ØØ45	27
6C	ØØ51	33
6D	ØØ55	37
6E	ØØ61	43
6F	Ø12Ø	1Ø4
6G	Ø134	12Ø
6H	Ø142	126
6I	Ø157	144
6J	Ø177	164
6K	Ø21Ø	175
6L	Ø221	2Ø6
6Y	Ø77Ø	773
6Z	Ø771	774
7C	Ø4ØØ	376
7D	Ø747	752
7I	Ø463	464
7M	Ø612	614
7R	Ø754	757
7T	Ø562	563
7U	Ø741	744
7X	Ø737	741
7Y	Ø74Ø	742
8A	Ø571	572
8B	Ø574	575
8C	1Ø74	11Ø3
8D	1Ø13	1Ø22
8E	1Ø16	1Ø25
8F	1175	12Ø6
8G	1311	1323
8H	1Ø37	1Ø46
8I	1Ø56	1Ø65
8J	12Ø3	1214
8K	12Ø5	1216
8L	1221	1232
9A	123Ø	1241
9B	1233	1244
9C	134Ø	1352
9D	1237	125Ø
9E	1355	1367
9F	1377	1411
9G	161Ø	1624
9H	1611	1625
9I	16Ø6	1622
9J	16Ø7	1623
9K	1425	1437
9L	1372	14Ø4
9M	143Ø	1443
9N	1453	1466
9O	1457	1472
9P	1464	1477
9Q	1531	1544
9R	1541	1554
9S	1577	1612
9T	1267	13ØØ
9Y	17ØØ	17Ø1
9Z	17Ø1	17Ø2

```
    CONT
 20 0642        UMB2
 21 1020        LDA&
 22 7774        7774
 23 4413        STC3U+2
 24 4737        STC7X [MAKE PRESENT PEN POSITION
 25 4740        STC7Y [THE ORIGIN
 26 1020        LDA&
 27 6000        "1777
 30 4601        STC30
 31 4600        STC3N
 32 6741        JMP7U [PEN UP
 33 1000        LDA
 34 0770        6Y
 35 0450        AZE
 36 6233        JMP2A
           [PLOT LABELS FOR HUMAN DATA
 37 1500        SRO [CHECK CODE WORD
 40 0771        6Z [PASSED FROM FINAL DISPLAY ROUTINE
 41 6051        JMP6C [DRAW AXIS FOR CARDIAC OUTPUT
 42 1500   #6A  SRO
 43 0771        6Z
 44 6055        JMP6D [DRAW AXIS FOR PULSE RATE
 45 1500   #6B  SRO
 46 0771        6Z
 47 6061        JMP6E [DRAW AXIS FOR STROKE VOLUME
 50 6064        JMP4A [DRAW X AXIS
 51 0065   #6C  SET&5
 52 4260        1F"1+4000
 53 6120        JMP6F
 54 6042        JMP6A
 55 0065   #6D  SET&5
 56 4304        1G"1+4000
 57 6120        JMP6F
 60 6045        JMP6B
 61 0065   #6E  SET&5
 62 4337        1H"1+4000
 63 6120        JMP6F
           [DRAW X AXIS AND LABEL IT
 64 6747   #4A  JMP7D [PEN DOWN
 65 1020        LDA&
 66 1776        1776 [FILLED WITH LENGTH OF X AXIS
 67 4733        STC3X
 70 6612        JMP7M [DRAW X AXIS
 71 6741        JMP7U [PEN UP
 72 1020        LDA&
 73 0062        62
 74 4734        STC3Y
 75 1020        LDA&
 76 0454        454
 77 4733        STC3X
100 6612        JMP7M [PREPARE TO WRITE LABEL
101 0065        SET&5
102 4365        1I"1+4000
103 1325   #5A  LDH&5 [ LOAD A WITH CHARACTER
104 1420        SHD&
105 7700        7700 [SEE IF END OF CHARACTER STRING
106 6111        JMP5B [JUMP IF YES
```

```
    CONT
107 6400      JMP7C [OTHERWISE PLOT CHARACTER
110 6103      JMP5A
111 1020  #5B LDA& [SET PEN AT [0,1]
112 0144      144
113 4734      STC3Y
114 4733      STC3X
115 6612      JMP7M
116 0640      UMB0
117 7000      JMP1000 [JUMP TO PLOT CURVES
          [DRAW Y AXES AND LABEL THEM
120 0046  #6F SET6
121 0000      0
122 1020      LDA&
123 0620      620
124 4734      STC3Y
125 1020      LDA&
126 0144      144
127 4733      STC3X
130 6612      JMP7M [MOVE TO [1,4]
131 1020      LDA&
132 0006      6 [CHARACTER ORIENTATION +Y
133 4422      STC3Z+4
134 1325  #6G LDH&5 [LOAD A WITH CHARACTER
135 1420      SHD&
136 7700      7700
137 6142      JMP6H [JUMP IF END OF STRING
140 6400      JMP7C [PLOT CHARACTER
141 6134      JMP6G
142 1020  #6H LDA&
143 0144      144
144 4734      STC3Y
145 1020      LDA&
146 0310      310
147 4733      STC3X
150 6612      JMP7M [MOVE TO [2,1]
151 6747      JMP7D [PEN DOWN
152 1020      LDA&
153 1750      1750
154 4734      STC3Y
155 4422      STC3Z+4 [CHARACTER ORIENTATION +X
156 6612      JMP7M [DRAW LINE TO [2,10]
          [LABEL Y AXIS
157 1020  #6I LDA&
160 0274      274
161 4733      STC3X
162 6612      JMP7M [DRAW .12 INCH LINE
163 6741      JMP7U [PEN UP
164 1020      LDA&
165 0206      206
166 4733      STC3X
167 6612      JMP7M [LEAVE SPACE FOR NUMBER
170 0415      KST
171 6177      JMP6J
172 0515      KBD
173 1460      SAE&
174 0012      0012
175 6177      JMP6J
```

```
     CONT
176 7034      JMP8H-3
177 1325 #6J LDH&5
200 1420      SHD&
201 1200      1200
202 6221      JMP6L
203 1420      SHD&
204 7700      7700
205 6210      JMP6K
206 6400      JMP7C [PLOT NUMBER
207 6177      JMP6J
210 1020 #6K LDA&
211 0310      310
212 4733      STC3X
213 6612      JMP7M
214 1020      LDA& [REDEFINE X AND Y
215 0144      144 [TO BE [0,1]
216 4740      STC7Y
217 4737      STC7X
220 6006      JMP6
221 1020 #6L LDA&
222 0310      310
223 4733      STC3X
224 1020      LDA&
225 7633      7633
226 1140      ADM
227 0734      3Y
230 6612      JMP7M [PREPARE TO PLOT NEXT NUMBER
231 6747      JMP7D [PEN DOWN
232 6157      JMP6I
         [PLOT LABELS FOR DOG DATA
233 1500 #2A SRO [CHECK CODE WORD
234 0771      6Z [PASSED FROM FINAL DISPLAY  ROUTINE
235 6245      JMP2D [DRAW AXIS FOR CARDIAC OUTPUT
236 1500 #2B SRO
237 0771      6Z
240 6251      JMP2E [DRAW AXIS FOR PULSE RATE
241 1500 #2C SRO
242 0771      6Z
243 6255      JMP2F [DRAW AXIS FOR STROKE VOLUME
244 6064      JMP4A [DRAW X AXIS
245 0065 #2D SET&5
246 5611      1J-1+4000
247 6120      JMP6F
250 6236      JMP2B
251 0065 #2E SET&5
252 4304      1G-1+4000
253 6120      JMP6F
254 6241      JMP2C
255 0065 #2F SET&5
256 5642      1K-1+4000
257 6120      JMP6F
260 6064      JMP4A
         [TABLE OF CODES FOR LABELING AXES
261 3714 #1F 3714
262 4330      4330 [L PER MIN
263 4514      4514 [LABEL AXIS 2-20 FOR HUMAN DATA
264 4034      4034
```

```
PLOT1,4  LN=254
     CONT
265  4177        4177
266  Ø2ØØ        Ø2ØØ
267  12Ø1        12Ø1
27Ø  1Ø12        1Ø12
271  Ø1Ø6        Ø1Ø6
272  12Ø1        12Ø1
273  Ø412        Ø412
274  Ø1Ø2        Ø1Ø2
275  12Ø1        12Ø1
276  ØØ12        ØØ12
277  141Ø        141Ø
3ØØ  1214        1214
3Ø1  Ø612        Ø612
3Ø2  14Ø4        14Ø4
3Ø3  1214        1214
3Ø4  Ø277        Ø277
3Ø5  253Ø  #1G   253Ø
3Ø6  2447        2447 [BEATS PER MIN
3Ø7  4614        4614 [LABEL AXIS 4Ø-22Ø FOR HUMAN AND DOG DATA
31Ø  433Ø        433Ø
311  4514        4514
312  4Ø34        4Ø34
313  4177        4177
314  Ø2Ø2        Ø2Ø2
315  ØØ12        ØØ12
316  Ø2ØØ        Ø2ØØ
317  ØØ12        ØØ12
32Ø  Ø11Ø        Ø11Ø
321  ØØ12        ØØ12
322  Ø1Ø6        Ø1Ø6
323  ØØ12        ØØ12
324  Ø1Ø4        Ø1Ø4
325  ØØ12        ØØ12
326  Ø1Ø2        Ø1Ø2
327  ØØ12        ØØ12
33Ø  Ø1ØØ        Ø1ØØ
331  ØØ12        ØØ12
332  141Ø        141Ø
333  ØØ12        ØØ12
334  14Ø6        14Ø6
335  ØØ12        ØØ12
336  14Ø4        14Ø4
337  ØØ77        ØØ77
34Ø  2626  #1H   2626 [CC
341  77Ø2        77Ø2 [LABEL AXIS 2Ø-2ØØ FOR HUMAN DATA
342  ØØØØ        ØØØØ
343  12Ø1        12Ø1
344  1ØØØ        1ØØØ
345  12Ø1        12Ø1
346  Ø6ØØ        Ø6ØØ
347  12Ø1        12Ø1
35Ø  Ø4ØØ        Ø4ØØ
351  12Ø1        12Ø1
352  Ø2ØØ        Ø2ØØ
353  12Ø1        12Ø1
354  ØØØØ        ØØØØ
355  1214        1214
```

```
     CONT
356  1000        1000
357  1214        1214
360  0600        0600
361  1214        1214
362  0400        0400
363  1214        1214
364  0200        0200
365  7777        7777
366  4742  #1I   4742 [TOTAL TIME
367  4724        4724
370  3714        3714
371  4734        4734
372  4030        4030
373  1400        1400
374  0061        0061
375  0014        0014
376  4034        4034
377  4177        4177
           [CALCOMP PLOT
           [MODIFIED FOR LINC 300
           [F T DAVIDSON 5 OCT 67
           [CHARACTER PLOT
           [PEN MUST BE IN THE
           [UP POSITION
                 $400
400  1120  #7C   ADA &
401  3000        3T
402  4017        STC 17
403  2000        ADD 0
404  4454        STC 3R
405  1017        LDA 17
406  1120        ADA&
407  2000        2000
410  4017        STC 17
411  1017  #3U   LDA 17
412  0075        SET & 15
413  7776        -1 [MAGNIFICATION
414  0451        APO
415  6754        JMP 7R
416  1317  #3Z   LDH 17
417  1560        BCL &
420  7770        7770
421  1120        ADA &
422  0000        0 [ORIENTATION
423  1560        BCL &
424  7770        7770
425  1120        ADA &
426  0602        3J
427  4016        STC 16
430  1016        LDA 16
431  4442        STC 3K+3
432  1337        LDH & 17
433  0470        AZE &
434  6450        JMP 3L
435  0017        COM
436  4440        STC 3K+1
437  0076  #3K   SET & 16
```

```
     CONT
440 Ø000      Ø [MINUS THE NO. OF INCREMENTS IN THIS DIRECTION
441 1Ø2Ø      LDA &
442 ØØØØ      Ø [MOTION WORD
443 6463      JMP 7I
444 Ø236      XSK & 16
445 6441      JMP '-4
446 Ø235      XSK & 15
447 6437      JMP 3K
         [TEST FOR END
45Ø 1Ø17 #3L LDA 17
451 156Ø      BCL &
452 5777      5777
453 Ø45Ø      AZE
454 ØØØØ #3R RETURN
         [STEP LINE OF CHAR-TABLE-ALLOWS OVERLAP INTO UPPER MEM
         ORY
455 1Ø2Ø      LDA &
456 4ØØØ      -3777
457 114Ø      ADM
46Ø ØØ17      17
461 1Ø17      LDA 17
462 6411      JMP 3U
         [INCREMENT PLOTTER AND X,Y SR
463 4467 #7I STC 3M
464 2ØØØ      ADD Ø
465 457Ø      STC 3S
466 152Ø      SRO & [TEST FOR -Y
467 ØØØØ #3M [KEY WORD
47Ø 6511      JMP '+21
471 274Ø      ADD 7Y [TEST FOR POINTS LESS THAN OR EQUAL LOWER B
         OUND
472 26ØØ      ADD 3N
473 Ø451      APO
474 65Ø5      JMP '+11
475 ØØ11      CLR [TEST FOR POINTS GREATER THAN UPPER BOUND
476 274Ø      ADD 7Y
477 26Ø1      ADD 3O
5ØØ Ø471      APO &
5Ø1 65Ø5      JMP '+4
5Ø2 1Ø2Ø      LDA & [CARRIAGE RIGHT
5Ø3 ØØØ4      4
5Ø4 6571      JMP 8A
5Ø5 ØØ11      CLR
5Ø6 274Ø      ADD 7Y [DECREASE POINT INDICATOR IN 7Y
5Ø7 2576      ADD 3V
51Ø 474Ø      STC 7Y
511 15ØØ      SRO [TEST FOR +Y
512 Ø467      3M
513 6536      JMP '+23
514 274Ø      ADD 7Y [TEST FOR POINTS GREATER THAN OR EQUAL LOWE
         R BOUND
515 26Ø1      ADD 3O
516 2577      ADD 3W
517 Ø471      APO &
52Ø 6532      JMP '+12
521 ØØ11      CLR [TEST FOR POINTS LESS THAN LOWER BOUND
522 274Ø      ADD 7Y
```

```
     CONT
 523 2600       ADD 3N
 524 2577       ADD 3W
 525 0451       APO
 526 6532       JMP '+4
 527 1020       LDA& [CARRIAGE LEFT
 530 0010       10
 531 6571       JMP 8A
 532 0011       CLR
 533 2740       ADD 7Y [INCREASE POINT INDICATOR IN 7Y
 534 2577       ADD 3W
 535 4740       STC 7Y
 536 1500       SRO [TEST FOR +X
 537 0467       3M
 540 6550       JMP '+10
 541 1020       LDA& [DRUM DOWN
 542 0002       2
 543 6571       JMP 8A
 544 1000       LDA
 545 0737       7X
 546 2577       ADD 3W
 547 4737       STC 7X
 550 1500       SRO [TEST FOR =X
 551 0467       3M
 552 6562       JMP '+10
 553 1020       LDA & [DRUM UP
 554 0001       1
 555 6571       JMP 8A
 556 1000       LDA
 557 0737       7X
 560 2576       ADD 3V
 561 4737       STC 7X
 562 1000  #7T  LDA
 563 0574       8B
 564 0546       OPR 46
 565 6564       JMP'=1
 566 0011       CLR
 567 4574       STC 8B
 570 1440  #3S  S RETURN
 571 1600  #8A  BSE
 572 0574       8B
 573 1060       STA &
 574 0000  #8B  0
 575 6000       JMP 0
 576 7776  #3V  =1
 577 0001  #3W  +1
 600 1777  #3N  1777 [Y=LOWER BOUND  NOTE SIGN
 601 6000  #3O  =1777 [Y=UPPER BOUND  NOTE SIGN
 602 7776  #3J  =1 [=Y
 603 7766       =11 [=X,=Y
 604 7767       =10 [=X
 605 7765       =12 [=X,+Y
 606 7775       =2 [+Y
 607 7771       =6 [+X,+Y
 610 7773       =4 [+X
 611 7772       =5 [+X,=Y
           [INTERPOLATED MOTION
 612 0076  #7M  SET & 16
```

PLOT1,10 LN=615


```
     CONT
613 7767       =10
614 0075       SET & 15
615 7776       =1
616 1000       LDA
617 0734       3Y
620 2735       ADD 3Q
621 4736       STC 3P
622 2000       ADD 0
623 4454       STC 3R
624 2733       ADD 3X
625 0017       COM
626 2737       ADD 7X
627 0471       APO &
630 6634       JMP '+4
631 0076       SET & 16
632 7773       =4
633 0017       COM
634 1060       STA &
635 0000  #3B  [/DELX/
636 0011       CLR
637 2736       ADD 3P
640 0017       COM
641 2740       ADD 7Y
642 0471       APO &
643 6647       JMP '+4
644 0075       SET & 15
645 7775       =2
646 0017       COM
647 1060       STA &
650 0000  #3C  [/DELY/
651 0077       SET & 17
652 3777       =4000
653 1600       BSE
654 0635       3B
655 0470       AZE &
656 6454       JMP 3R
657 4667  #3E  STC 3D
660 2635       ADD 3B
661 0241       ROL 1
662 4635       STC 3B
663 2650       ADD 3C
664 0241       ROL 1
665 4650       STC 3C
666 1020       LDA &
667 0000  #3D  [RESULT OF BSE
670 0241       ROL 1
671 0451       APO
672 6676       JMP '+4
673 1500       SRO
674 0017       17
675 6657       JMP 3E
676 0011       CLR
677 4706       STC 3F
700 4715       STC 3G
701 0011  #3H  CLR
702 2016       ADD 16
703 4722       STC 3I
```

```
     CONT
704 2635      ADD 3B
705 1220      LAM &
706 0000 #3F
707 4000      STC 0
710 0472      LZE &
711 4722      STC 3I
712 0011      CLR
713 2650      ADD 3C
714 1220      LAM &
715 0000 #3G
716 4000      STC 0
717 0452      LZE
720 2015      ADD 15
721 1120      ADA &
722 0000 #3I
723 0450      AZE
724 6463      JMP 7I
725 2577      ADD 3W [+1
726 1140      ADM
727 0017      17
730 0450      AZE
731 6701      JMP 3H
732 6454      JMP 3R
733 0000 #3X 0000 [DESIRED X
734 0000 #3Y 0000 [DESIRED Y
735 0000 #3Q 0000 [Y=SHIFT
736 0000 #3P 0000 [3Y+3Q
737 0000 #7X 0000 [CURRENT X
740 0000 #7Y 0000 [CURRENT Y
         [PEN SUBROUTINES
741 0056 #7U SET 16 [PEN UP
742 0000      0
743 1020      LDA &
744 0040      40
745 4757      STC 7R+3
746 6756      JMP 7R+2
747 0056 #7D SET 16 [PEN DOWN
750 0000      0
751 1020      LDA &
752 0020      20
753 6745      JMP 7D=2
754 0056 #7R SET 16 [PEN REVERSE
755 0000      0
756 1020      LDA &
757 0020      20
760 1660      BCO &
761 0060      60
762 1040      STA
763 0757      7R+3
764 0546      OPR 46
765 6764      JMP *-1
766 6016      JMP 16
              $770
770 0000 #6Y 0 [FLAG = EQUALS 1 IF DOG EXP., 0 IF HUMAN DATA
771 0000 #6Z 0 [CODE INDICATING WHICH CURVE TO PLOT
         [7=ALL THREE
         [6=PR+SV
```

```
     CONT
          [5=CO+SV
          [4=SV
          [3=CO+PR
          [2=PR
          [1=CO
          [ROUTINE TO PLOT DESIRED CURVES
               $1000
1000 1000      LDA
1001 0771      6Z
1002 0243      ROL3
1003 4771      STC6Z
1004 1000      LDA
1005 0770      6Y
1006 0450      AZE
1007 7112      JMP2G
          [PLOT HUMAN DATA
1010 1500      SRO [CHECK CODE WORD TO SEE
1011 0771      6Z  [WHICH CURVE[S] TO PLOT
1012 7037      JMP8H [PLOT CARDIAC OUTPUT
1013 1500 #8D  SRO
1014 0771      6Z
1015 7056      JMP8I [PLOT PULSE RATE
1016 1500 #8E  SRO
1017 0771      6Z
1020 7074      JMP8C [PLOT STROKE VOLUME
1021 1000      LDA [COME HERE WHEN FINISHED PLOTTING
1022 0066      4A+2
1023 4733      STC3X
1024 4734      STC3Y
1025 6612      JMP7M
1026 0011      CLR
1027 4737      STC7X
1030 1020      LDA&
1031 0454      454
1032 4733      STC3X
1033 6612      JMP7M [POSITION PEN FOR NEXT GRAPH
1034 0641      UMB1
1035 0600      LMB0
1036 6433      JMP433 [JUMP BACK TO PAGE 0 AND DISPLAY ROUTINE
1037 0770 #8H  770 [READ VALUES FOR CARDIAC OUTPUT
1040 6270      6/270
1041 0750      750
1042 7271      7/271
1043 0000      HLT
1044 1020      LDA&
1045 7467      7467
1046 5233      STC9B
1047 1020      LDA&
1050 0053      53 [X
1051 5340      STC9C
1052 1020      LDA&
1053 5607      9J+4000
1054 7175      JMP8F [PLOT CARDIAC OUTPUT
1055 7013      JMP8D [SEE IF MORE CURVES TO PLOT
1056 0751 #8I  751 [READ IN PULSE RATE DATA
1057 1276      1/276
1060 1020      LDA&
```

```
     CONT
1061 7727       7727
1062 5233       STC9B
1063 1020       LDA&
1064 0062       62 [$
1065 5340       STC9C
1066 6612       JMP7M [RETURN TO [0,1]
1067 0000       HLT
1070 1020       LDA&
1071 1606       9I
1072 7175       JMP8F [PLOT PULSE RATE
1073 7016       JMP8E [SEE IF ONE MORE CURVE TO PLOT
1074 0770  #8C  770 [READ IN STROKE VOLUME DATA
1075 6274       6/274
1076 0750       750
1077 7275       7/275
1100 1020       LDA&
1101 7753       7753
1102 5233       STC9B
1103 5340       STC9C [0
1104 6612       JMP7M [RETURN TO [0,1]
1105 0000       HLT
1106 1020       LDA&
1107 1606       9I
1110 7175       JMP8F [PLOT STROKE VOLUME
1111 7021       JMP8E+3 [JUMP TO RETURN TO PAGE 0
           [PLOT DOG VALUES
1112 1500  #2G  SRO [EXAMINE CODE WORD TO SEE
1113 0771       6Z [WHICH CURVES TO PLOT
1114 7124       JMP2J [PLOT CARDIAC OUTPUT
1115 1500  #2H  SRO
1116 0771       6Z
1117 7142       JMP2K [PLOT PULSE RATE
1120 1500  #2I  SRO
1121 0771       6Z
1122 7160       JMP2L [PLOT STROKE VOLUME
1123 7021       JMP8E+3
1124 0770  #2J  770 [READ VALUES FOR CARDIAC OUTPUT
1125 6270       6/270
1126 0750       750
1127 7271       7/271
1130 0000       HLT
1131 0011       CLR
1132 5233       STC9B
1133 1020       LDA&
1134 0053       53 [X
1135 5340       STC9C
1136 1020       LDA&
1137 1610       9G
1140 7175       JMP8F [PLOT CARDIAC OUTPUT
1141 7115       JMP2H
1142 0751  #2K  751 [READ IN PULSE RATE DATA
1143 1276       1/276
1144 1020       LDA&
1145 7727       7727
1146 5233       STC9B
1147 1020       LDA&
1150 0062       62 [$
```

```
     CONT
1151 534Ø      STC9C
1152 6612      JMP7M [RETURN TO [Ø,1]
1153 ØØØØ      HLT
1154 1Ø2Ø      LDA&
1155 16Ø6      9I
1156 7175      JMP8F [PLOT PULSE RATE
1157 712Ø      JMP2I
116Ø Ø77Ø #2L 77Ø [READ IN STROKE VOLUME DATA
1161 6274      6/274
1162 Ø75Ø      75Ø
1163 7275      7/275
1164 ØØ11      CLR
1165 5233      STC9B
1166 534Ø      STC9C [Ø
1167 6612      JMP7M [RETURN TO [Ø,1]
117Ø ØØØØ      HLT
1171 1Ø2Ø      LDA&
1172 1611      9H
1173 7175      JMP8F [PLOT STROKE VOLUME
1174 7Ø21      JMP8E+3
               [PLOT CURVE
1175 5237 #8F  STC9D
1176 5577      STC9S
1177 ØØ44      SET4
12ØØ ØØØØ      Ø
12Ø1 ØØ61      SET&1
12Ø2 2777      2777
12Ø3 Ø461 #8J  SNS&1 [IF SENSE SWITCH 1 IS SET
12Ø4 7355      JMP9E [JUMP TO AVERAGE 4 POINTS
12Ø5 ØØ43 #8K  SET3
12Ø6 17ØØ      9Y [SET NO. OF POINTS TO PLOT
12Ø7 Ø536      OPR&16 [READ RSW
121Ø 156Ø      BCL& [EXAMINE BITS Ø AND 1
1211 7774      7774
1212 112Ø      ADA& [C[RSW] DESERMINE NO. OF SYMBOLS PLOTTED
1213 16ØØ      1T
1214 1Ø4Ø      STA
1215 1311      8G
1216 522Ø      STC'+2
1217 ØØ45      SET5
122Ø ØØØØ      Ø
1221 1Ø21 #8L  LDA&1 [LOAD A WITH Y COORDINATE
1222 723Ø      JMP9A [PLOT POINT
1223 1Ø2Ø      LDA&
1224 ØØØ2      2
1225 114Ø      ADM
1226 Ø733      3X
1227 7221      JMP8L
123Ø ØØ5Ø #9A  SET1Ø
1231 ØØØØ      Ø
1232 112Ø      ADA& [MODIFY FOR PLACEMENT ON GRAPH
1233 ØØØØ #9B  Ø [VALUE FILLED IN
1234 Ø47Ø      AZE&
1235 724Ø      JMP9D+1
1236 124Ø      MUL
1237 ØØØØ #9D  Ø [VALUE FILLED IN
124Ø 112Ø      ADA&
```

```
      CONT
1241 Ø144         144
1242 1Ø4Ø         STA
1243 Ø734         3Y [STORE Y COORDINATE
1244 112Ø         ADA&
1245 6ØØØ         -1777
1246 Ø451         APO
1247 7253         JMP'+4
125Ø 1Ø2Ø         LDA&
1251 1777         1777
1252 4734         STC3Y
1253 6612         JMP7M [PLOT POINT
1254 Ø415         KST
1255 7263         JMP'+6
1256 Ø515         KBD
1257 146Ø         SAE&
126Ø ØØ12         ØØ12
1261 7263         JMP'+2
1262 7Ø34         JMP8H-3
1263 Ø223         XSK&3 [SKIP IF ALL VALUES PLOTTED
1264 7274         JMP'+1Ø [OTHERWISE CHECK IF SYMBOL TO BE PLOTTED
1265 6741         JMP7U
1266 743Ø         JMP9M
1267 1Ø2Ø    #9T  LDA&
127Ø Ø144         144
1271 4734         STC3Y
1272 4733         STC3X
1273 6ØØ4         JMP4
1274 1ØØØ         LDA
1275 ØØØ1         1
1276 146Ø         SAE&
1277 3ØØØ         3ØØØ
13ØØ 73Ø2         JMP'+2
13Ø1 6747         JMP7D [PEN DOWN
13Ø2 146Ø         SAE&
13Ø3 3ØØ3         3ØØ3
13Ø4 73Ø6         JMP'+2
13Ø5 6747         JMP7D
13Ø6 Ø225         XSK&5 [SKIP IF SYMBOL REQUIRED
13Ø7 6Ø1Ø         JMP1Ø [OTHERWISE GET NEXT POINT
             [PLOT SYMBOL
131Ø ØØ45         SET5
1311 ØØØØ    #8G  Ø
1312 1ØØØ         LDA [SAVE PRESENT X AND Y
1313 Ø737         7X
1314 56Ø4         STC2T
1315 1ØØØ         LDA
1316 Ø74Ø         7Y
1317 56Ø5         STC2T+1
132Ø 1Ø2Ø         LDA&
1321 7775         7775
1322 4413         STC3U+2
1323 1Ø2Ø         LDA& [ADJUST X AND Y SO THAT SYMBOL
1324 7771         7771 [IS CENTERED
1325 114Ø         ADM
1326 Ø734         3Y
1327 1Ø2Ø         LDA&
133Ø 7773         7773
```

```
     CONT
1331 1040      STA
1332 1577      9S
1333 1140      ADM
1334 Ø733      3X
1335 6741      JMP7U [PEN UP
1336 6612      JMP7M  [PREPARE TO DRAW SYMBOL
1337 1020      LDA&
1340 ØØØØ #9C  Ø [SYMBOL CODE FILLED IN
1341 Ø642      UMB2
1342 64ØØ      JMP7C [PLOT SYMBOL
1343 Ø640      UMBØ
1344 1ØØØ      LDA [RESTORE COORDINATES
1345 16Ø4      2T
1346 4733      STC3X
1347 1ØØØ      LDA
135Ø 16Ø5      2T+1
1351 4734      STC3Y
1352 6612      JMP7M
1353 6747      JMP7D [PEN DOWN
1354 6Ø1Ø      JMP1Ø [JUMP TO PLOT NEXT POINT
1355 1ØØØ #9E  LDA
1356 17Ø1      9Z
1357 Ø47Ø      AZE& [IF LESS THAN 4 VALUES, PLOT EVERY
136Ø 72Ø5      JMP8K [POINT
1361 ØØ43      SET3 [SET NO. OF POINTS TO PLOT=NO. OF VALUES
1362 17Ø1      9Z   [DIVIDED BY 4
1363 Ø536      OPR&16 [READ RSW
1364 156Ø      BCL& [CHECK TO SEE IF EITHER BIS Ø OR 1 SET
1365 7774      7774
1366 Ø47Ø      AZE& [SKIP IF SES
1367 7425      JMP9K [IF NOT SET, NO SYMBOLS PLOTTED
137Ø 1Ø2Ø      LDA& [PREPARE TO PLOT ONE SYMBOL
1371 16Ø3      1T+3 [FOR EVERY POINT
1372 1Ø4Ø #9L  STA
1373 1311      8G
1374 5376      STC'+2
1375 ØØ45      SET5
1376 ØØØØ      Ø
1377 1Ø21 #9F  LDA&1
14ØØ 1121      ADA&1 [AVERAGE 4 POINTS
14Ø1 Ø341      SCR1
14Ø2 156Ø      BCL&
14Ø3 4ØØØ      4ØØØ
14Ø4 5413      STC'+7
14Ø5 1Ø21      LDA&1
14Ø6 1121      ADA&1
14Ø7 Ø341      SCR1
141Ø 156Ø      BCL&
1411 4ØØØ      4ØØØ
1412 112Ø      ADA&
1413 ØØØØ      Ø
1414 Ø341      SCR1
1415 156Ø      BCL&
1416 4ØØØ      4ØØØ
1417 723Ø      JMP9A [PLOT POINT
142Ø 1Ø2Ø      LDA&
1421 ØØ1Ø      1Ø
```

```
      CONT
1422 1140       ADM
1423 0733       3X
1424 7377       JMP9F
1425 1020  #9K  LDA&
1426 1600       1T
1427 7372       JMP9L
           [WRITE LEGEND
1430 1020  #9M  LDA&
1431 1440       1440
1432 4733       STC3X
1433 1020       LDA&
1434 7775       7775
1435 4413       STC3U+2
1436 1000       LDA
1437 1340       9C
1440 0470       AZE&
1441 7453       JMP9N [COME HERE IF STROKE VOLUME
1442 1460       SAE&
1443 0053       0053
1444 7457       JMP9O [COME HERE IF PULSE RATE
1445 1020       LDA& [COME HERE IF CARDIAC OUTPUT
1446 0050       50
1447 4734       STC3Y
1450 0065       SET&5
1451 5550       1L=1+4000
1452 7464       JMP9P
1453 4734  #9N  STC3Y
1454 0065       SET&5
1455 5560       1M=1+4000
1456 7464       JMP9P
1457 1020  #9O  LDA&
1460 0120       120
1461 4734       STC3Y
1462 0065       SET&5
1463 5570       1N=1+4000
1464 6612  #9P  JMP7M
1465 1000       LDA
1466 1577       9S
1467 0470       AZE&
1470 7531       JMP9Q
1471 6741       JMP7U
1472 1000       LDA
1473 1340       9C
1474 0642       UMB2
1475 6400       JMP7C
1476 0640       UMB0
1477 1020       LDA&
1500 0006       6
1501 1140       ADM
1502 0734       3Y
1503 1020       LDA&
1504 0012       12
1505 1140       ADM
1506 0733       3X
1507 6612       JMP7M
1510 6747       JMP7D
1511 1020       LDA&
```

```
     CONT
1512 0032      32
1513 1140      ADM
1514 0733      3X
1515 6612      JMP7M
1516 6741      JMP7U
1517 1020      LDA&
1520 7771      7771
1521 1140      ADM
1522 0734      3Y
1523 6612      JMP7M
1524 1000      LDA
1525 1340      9C
1526 0642      UMB2
1527 6400      JMP7C
1530 7541      JMP9R
1531 6747 #9Q  JMP7D
1532 1020      LDA&
1533 0062      62
1534 1140      ADM
1535 0733      3X
1536 6612      JMP7M
1537 6741      JMP7U
1540 0642      UMB2
1541 1325 #9R  LDH&5
1542 1420      SHD&
1543 7700      7700
1544 7547      JMP'+3
1545 6400      JMP7C
1546 7541      JMP9R
1547 0640      UMB0
1550 7267      JMP9T
1551 1426 #1L  1426
1552 2445      2445
1553 2734      2734
1554 2426      2426
1555 1442      1442
1556 5047      5047
1557 4350      4350
1560 4777      4777
1561 1446 #1M  1446
1562 4745      4745
1563 4236      4236
1564 3014      3014
1565 5142      5142
1566 3750      3750
1567 4030      4030
1570 7777      7777
1571 1443 #1N  1443
1572 5037      5037
1573 4630      4630
1574 1445      1445
1575 2447      2447
1576 3077      3077
1577 0000 #9S  0
          [USE RSW TO SELECT NO. OF SYMBOLS / CURVE PLOTTED
1600 6777 #1T  6777 [IF 0=NONE
1601 7677      7677 [IF 1= 8
```

```
     CONT
1602 7767        7767 [IF 2= 64
1603 7776        7776 [IF 3= EVERY POINT
1604 0000  #2T   0
1605 0000        0
1606 0005  #9I   5
1607 2000  #9J   2000 [1/2
1610 0002  #9G   2
1611 0024  #9H   24
1612 3714  #1J   3714 [L PER MIN
1613 4330        4330 [LABEL AXIS 0=4.5 FOR DOG VALUES
1614 4514        4514
1615 4034        4034
1616 4177        4177
1617 0461        0461
1620 0512        0512
1621 0461        0461
1622 0012        0012
1623 0361        0361
1624 0512        0512
1625 0361        0361
1626 0012        0012
1627 0261        0261
1630 0512        0512
1631 0261        0261
1632 0012        0012
1633 0161        0161
1634 0512        0512
1635 0161        0161
1636 0012        0012
1637 0061        0061
1640 0512        0512
1641 0061        0061
1642 0077        0077
1643 2626  #1K   2626 [CC
1644 7704        7704 [LABEL AXIS 0=45 FOR DOG VALUES
1645 0512        0512
1646 0400        0400
1647 1203        1203
1650 0512        0512
1651 0300        0300
1652 1202        1202
1653 0512        0512
1654 0200        0200
1655 1201        1201
1656 0512        0512
1657 0100        0100
1660 1214        1214
1661 0512        0512
1662 1400        1400
1663 7777        7777
                 $1700
1700 0000  #9Y   0 [TOTAL NO. OF VALUES
1701 0000  #9Z   0 [1/4 TOTAL NO. OF VALUES
                 3T=3000
```

PRINT1,Ø

	VALUE	LINE
1T	Ø272	257
1U	Ø3Ø7	274
1V	Ø321	3Ø6
1W	Ø335	322
1X	Ø341	326
2A	Ø642	63Ø
2B	Ø646	635
2C	Ø671	661
2D	Ø712	7Ø3
3L	Ø4ØØ	35Ø
3M	Ø435	4Ø5
3N	Ø461	431
3O	Ø5Ø2	452
3P	Ø522	472
3Q	Ø552	522
4A	Ø557	533
4B	Ø562	537
4D	Ø565	543
4E	Ø57Ø	547
4F	Ø573	553
4G	Ø576	557
4H	Ø6Ø1	566
4I	Ø611	576
4J	Ø624	611
4L	Ø637	624
4M	Ø627	614
5A	1ØØØ	1ØØØ
5B	1Ø45	1Ø46
5C	1Ø54	1Ø56
5D	1113	1115
5E	1142	1144
5F	1145	1147
5G	1163	1166
5H	1224	1227
5I	1226	1231
5J	123Ø	1233
5K	1247	1252
5L	1256	1261
5M	1265	127Ø
5N	1734	1764
5O	1743	1774
5P	1755	2ØØ7
6A	13Ø3	13Ø7
6B	1313	132Ø
6C	132Ø	1326
6D	1334	1343
6E	1351	1361
6F	1361	1372
6G	1371	14Ø3
6H	1374	14Ø7
6I	14Ø1	1415
7A	14Ø6	1423
7B	1427	1444
7C	1431	1446
7D	1435	1452
7E	1446	1463
7F	1452	1467
7G	1457	1475
7H	15Ø1	152Ø

	VALUE	LINE
7I	1525	1546
7J	1531	1552
7K	1545	1566
7L	155Ø	1571
7M	1565	16Ø7
7O	1576	162Ø
7P	1622	1644
7Q	1623	1647
7R	1646	1672
7S	167Ø	1714
7T	1672	1716
7U	17Ø4	173Ø
7V	17Ø6	1732
7W	1722	1746
7X	1723	175Ø
7Y	1726	1754
7Z	1731	176Ø
8A	ØØ52	34
8B	ØØ6Ø	42
8C	ØØ66	51
9A	Ø125	11Ø
9B	Ø115	1ØØ
9C	Ø264	25Ø
9D	Ø267	253
9E	ØØ76	61
9F	Ø256	242
9G	Ø162	145
9H	Ø17Ø	153
9I	Ø222	2Ø5
9J	Ø23Ø	213
9K	Ø246	231
9M	Ø255	24Ø
9N	Ø261	245
9Z	Ø377	34Ø

```
    CONT
 20 0770      770 [READ IN CARDIAC OUTPUT DATA
 21 6270      6/270
 22 0750      750
 23 7271      7/271
 24 0067      SET&7
 25 4271      1T=1+4000
 26 6052      JMP8A [PRINT TITLE AND VALUES
 27 0770      770 [READ IN STROKE VOLUME DATA
 30 6274      6/274
 31 0750      750
 32 7275      7/275
 33 1020      LDA&
 34 0001      1
 35 4125      STC9A
 36 0067      SET&7
 37 4306      1U=1+4000
 40 6052      JMP8A [PRINT TITLE AND VALUES
 41 0751      751 [READ IN PULSE RATE DATA
 42 1276      1/276
 43 0067      SET&7
 44 4320      1V=1+4000
 45 6052      JMP8A [PRINT TITLE AND VALUES
 46 6671      JMP671
 47 0641      UMB1
 50 0600      LMB0
 51 6433      JMP433 [JUMP TO MAIN DISPLAY
          [PRINT TITLE
 52 0046  #8A SET6
 53 0000      0
 54 0011      CLR
 55 4255      STC9M
 56 6671      JMP671 [PRINT CR,LF
 57 6671      JMP671
 60 1327  #8B LDH&7 [LOAD ONE CHARACTER
 61 1420      SHD& [SEE IF END OF CHARACTER STRING
 62 7700      7700
 63 6066      JMP8C [COME HERE IF END
 64 6642      JMP642 [OTHERWISE PRINT CHARACTER
 65 6060      JMP8B [GET NEXT CHARACTER
          [PRINT VALUES
 66 0052  #8C SET12
 67 0377      9Z
 70 0071      SET&11 [SKIP FIRST VALUE IN EACH
 71 3000      3000 [GROUP AS IT IS INCORRECT
 72 0011      CLR
 73 4261      STC9N [CLEAR LOCATIONS TO BE OCCUPIED
 74 4262      STC9N+1 [BY THE FIRST AVERAGE VALUE
 75 4263      STC9N+2
 76 0070  #9E SET&10 [SET 4 VALUES/LINE
 77 7773      7773
100 6671      JMP671
101 6671      JMP671
102 0011      CLR [CLEAR LOCATIONS TO BE OCCUPIED
103 4256      STC9F [BY THE NEXT AVERAGE VALUE
104 4257      STC9F+1
105 4260      STC9F+2
106 0415      KST [IF EOL KEY STRUCK, GET NEXT SET
```

```
    CONT
107 6115      JMP9B [OF VALUES• OR IF THE LAST SET
11Ø Ø515      KBD   [IS PRINTED• GO TO THE MAIN DISPLAY
111 146Ø      SAE&  [ROUTINE IN PAGE Ø
112 ØØ12      ØØ12
113 6115      JMP9B [IF NOT EOL• CONTINUE SAMPLING
114 6ØØ6      JMP6
115 1Ø31  #9B LDA&11 [LOAD A WITH VALUE
116 1Ø4Ø      STA
117 Ø266      9C+2
12Ø Ø353      SCR13
121 4265      STC9C+1
122 7743      JMP1743 [FLOAT
123 7513      =9C
124 1Ø2Ø      LDA&
125 ØØ12  #9A 12
126 1Ø4Ø      STA
127 Ø271      9D+2
13Ø Ø353      SCR13
131 427Ø      STC9D+1
132 7743      JMP1743 [FLOAT
133 751Ø      =9D
134 7Ø54      JMP1Ø54
135 Ø264      9C
136 Ø267      9D
137 Ø267      9D
14Ø 7ØØØ      JMP1ØØØ [ADD VALUE TO CONTENTS OF 9F
141 Ø267      9D
142 Ø256      9F
143 Ø256      9F
144 7734      JMP1734
145 Ø267      9D
146 6Ø46      =7Z
147 64ØØ      JMP4ØØ [PRINT VALUE
15Ø 664Ø      JMP64Ø [PRINT 5 SPACES
151 664Ø      JMP64Ø
152 664Ø      JMP64Ø
153 664Ø      JMP64Ø
154 664Ø      JMP64Ø
155 Ø23Ø      XSK&1Ø [SKIP IF 4 VALUES PRINTED
156 6115      JMP9B [OTHERWISE GET NEXT VALUE
157 6671      JMP671
16Ø ØØ67      SET&7
161 4334      1W=1+4ØØØ
162 1327  #9G LDH&7 [AVERAGE
163 142Ø      SHD&
164 77ØØ      77ØØ
165 617Ø      JMP9H [JUMP IF END OF CHARACTER STRING
166 6642      JMP642 [PRINT CHARACTER
167 6162      JMP9G [GET NEXT CHARACTER
17Ø 664Ø  #9H JMP64Ø
171 664Ø      JMP64Ø
172 664Ø      JMP64Ø
173 1Ø2Ø      LDA&
174 ØØØ4      4
175 1Ø4Ø      STA
176 Ø266      9C+2
177 Ø353      SCR13
```

```
     CONT
200 4265        STC9C+1
201 7743        JMP1743
202 7513        *9C
203 7163        JMP1163 [FIND AVERAGE
204 Ø256        9F
205 Ø264        9C
206 Ø256        9F
207 7734        JMP1734
210 Ø256        9F
211 6Ø46        =7Z
212 64ØØ        JMP4ØØ [PRINT IT
213 664Ø        JMP64Ø [PRINT 5 SPACES
214 664Ø        JMP64Ø
215 664Ø        JMP64Ø
216 664Ø        JMP64Ø
217 664Ø        JMP64Ø
22Ø ØØ67        SFT&7
221 434Ø        1X=1+4ØØØ
222 1327 #9I    LDH&7 [NORMALIZED VALUE
223 142Ø        SHD&
224 77ØØ        77ØØ
225 623Ø        JMP9J [JUMP IF END OF CHARACTER STRING
226 6642        JMP642 [PRINT CHARACTER
227 6222        JMP9I [GET NEXT CHARACTER
23Ø 664Ø #9J    JMP64Ø
231 664Ø        JMP64Ø
232 664Ø        JMP64Ø
233 1ØØØ        LDA [SEE IF AVERAGE OF FIRST 4 VALUES
234 Ø255        9M
235 Ø47Ø        AZE& [SKIP IF NOT THE FIRST
236 6246        JMP9K
237 7163        JMP1163 [DIVIDE PRESENT AVERAGE
24Ø Ø256        9F      [BY FIRST AVERAGE
241 7516        *9N
242 64ØØ        JMP4ØØ [PRINT NORMALIZED VALUE
243 Ø232        XSK&12 [SKIP IF REQUIRED NO. OF VALUES PRINTED
244 6Ø76        JMP9E [OTHERWISE GET NEXT 4 VALUES
245 6ØØ6        JMP6 [EXIT
246 1Ø2Ø #9K    LDA&
247 ØØØ1        1
25Ø 4255        STC9M
251 7734        JMP1734 [PUT AVERAGE VALUE IN
252 Ø256        9F      [9N SO THAT NORMALIZED
253 7516        =9N     [VALUE WILL BE 1
254 6237        JMP9J+7
255 ØØØØ #9M    Ø [FLAG = SET AFTER FIRST AVERAGE IN EACH
                [GROUP OF VALUES IS COMPUTED
256 ØØØØ #9F    Ø [HOLDS PRESENT AVERAGE
257 ØØØØ        Ø
26Ø ØØØØ        Ø
261 ØØØØ #9N    Ø [HOLDS FIRST AVERAGE
262 ØØØØ        Ø
263 ØØØØ        Ø
264 ØØØØ #9C    Ø
265 ØØØØ        Ø
266 ØØØØ        Ø
267 ØØØØ #9D    Ø
```

```
     CONT
 270 0000       0
 271 0000       0
          [TEXT
 272 2624 #1T 2624 [CARDIAC OUTPUT IN CC/MIN
 273 4527     4527
 274 3424     3424
 275 2614     2614
 276 4250     4250
 277 4743     4743
 300 5047     5047
 301 1434     1434
 302 4114     4114
 303 2626     2626
 304 6421     6421
 305 4034     4034
 306 4177     4177
 307 4647 #1U 4647 [STROKE VOLUME IN CC
 310 4542     4542
 311 3630     3630
 312 1451     1451
 313 4237     4237
 314 5040     5040
 315 3014     3014
 316 3441     3441
 317 1426     1426
 320 2677     2677
 321 4350 #1V 4350 [PULSE RATE IN BEATS/MIN
 322 3746     3746
 323 3014     3014
 324 4524     4524
 325 4730     4730
 326 1434     1434
 327 4114     4114
 330 2530     2530
 331 2447     2447
 332 4621     4621
 333 4034     4034
 334 4177     4177
 335 2451 #1W 2451 [AVERAGE
 336 3045     3045
 337 2432     2432
 340 3077     3077
 341 4142 #1X 4142 [NORMALIZED VALUE
 342 4540     4540
 343 2437     2437
 344 3455     3455
 345 3027     3027
 346 1451     1451
 347 2437     2437
 350 5030     5030
 351 7777     7777
              $377
 377 0000 #9Z 0 [NO. OF VALUES COLLECTED/4
          [O, VERSION 02
          [OUTPUT
          [CONVERSION
          [MODIFIED FOR KLEINSCHMIDT FTD 12-14-67
```

```
PRINT1,5  LN=345
                                        212
    CONT
                 $400
             [OUTPUT
             [CONVERSION
400 0055 #3L SET15
401 0000     0
402 7734     JMP5N
403 7204     *4F
404 1020     LDA&
405 7764     *13
406 5764     STC5P+7
407 0074     SET&14
410 7770     *7
411 0073     SET&13
412 7777     *0
413 0011     CLR
414 2574     ADD4F+1
415 0470     AZE&
416 4573     STC4F
417 0011     CLR
420 2573     ADD4F
421 1040     STA
422 1733     7Z+2
423 0353     SCR13
424 5732     STC7Z+1
425 7743     JMP5O
426 6046     *7Z
427 7054     JMP5C
430 7220     *4A
431 7755     JMP5P
432 6046     *7Z
433 3732     ADD7Z+1
434 1060     STA&
435 0000 #3M 0
436 4637     STC4L
437 2574     ADD4F+1
440 0261     ROL&1
441 1020     LDA&
442 0017     17
443 0472     LZE&
444 3545     ADD7K
445 6642     JMP2A
446 2435     ADD3M
447 0451     APO
450 0017     COM
451 4570     STC4E
452 6601     JMP4H
453 7374     JMP6H
454 0061     SET&1
455 0573     4F
456 7334     JMP6D
457 0076     SET&16
460 0000     0
461 7045 #3N JMP5B
462 0573     4F
463 0565     4D
464 0570     4E
465 2571     ADD4E+1
```

PRINT1•6 LN=436


```
     CONT
466 Ø451        APO
467 65Ø2        JMP3O
47Ø ØØ11        CLR
471 2Ø16        ADD16
472 142Ø        SHD&
473 11ØØ        11ØØ
474 65Ø2        JMP3O
475 Ø236        XSK&16
476 7734        JMP5N
477 Ø57Ø        4E
5ØØ 72Ø4        "4F
5Ø1 6461        JMP3N
5Ø2 ØØ11  #3O   CLR
5Ø3 2Ø16        ADD16
5Ø4 Ø45Ø        AZE
5Ø5 6513        JMP'+6
5Ø6 Ø213        XSK13
5Ø7 6513        JMP'+4
51Ø 2574        ADD4F+1
511 Ø45Ø        AZE
512 6546        JMP3Q-4
513 6642        JMP2A
514 Ø213        XSK13
515 6522        JMP3P
516 1Ø2Ø        LDA&
517 ØØ61        61
52Ø 6642        JMP2A
521 Ø233        XSK&13
522 Ø234  #3P   XSK&14
523 6552        JMP3Q
524 152Ø        SRO&
525 5252        5252
526 6Ø15        JMP15
527 112Ø        ADA&
53Ø ØØ3Ø        3Ø
531 6642        JMP2A
532 ØØ74        SET&14
533 7774        "3
534 2435        ADD3M
535 1Ø4Ø        STA
536 Ø575        4F+2
537 Ø353        SCR13
54Ø 4574        STC4F+1
541 7743        JMP5O
542 72Ø4        "4F
543 1Ø2Ø        LDA&
544 ØØØ2        2
545 6434        JMP3M-1
546 ØØ11        CLR
547 2435        ADD3M
55Ø 355Ø        ADD7L
551 4435        STC3M
552 7163  #3Q   JMP5G
553 Ø565        4D
554 Ø562        4B
555 Ø565        4D
556 6457        JMP3N-2
```

```
PRINT1•7  LN=527
     CONT
          [CONSTANTS +
          [SUBROUTINES
          [LOG 2
          [Ø•30103
557 7776  #4A 7776
560 2321      2321
561 Ø116      Ø116
          [1Ø•Ø
562 ØØØ4  #4B ØØØ4
563 24ØØ      24ØØ
564 ØØØØ      ØØØØ
          [TEM1
565 ØØØØ  #4D Ø
566 ØØØØ      Ø
567 ØØØØ      Ø
          [TEM2
57Ø ØØØØ  #4E Ø
571 ØØØØ      Ø
572 ØØØØ      Ø
          [TEM3
573 ØØØØ  #4F Ø
574 ØØØØ      Ø
575 ØØØØ      Ø
          [1•Ø
576 ØØØ1  #4G ØØØ1
577 2ØØØ      2ØØØ
6ØØ ØØØØ      ØØØØ
          [1Ø•Ø TO
          [THE /N/
          [/N/ IN 4E
          [RESULT IN 4D
6Ø1 ØØ57  #4H SET17
6Ø2 ØØØØ      Ø
6Ø3 7734      JMP5N
6Ø4 Ø562      4B
6Ø5 6Ø46      =7Z
6Ø6 7734      JMP5N
6Ø7 Ø576      4G
61Ø 7212      =4D
611 257Ø  #4I ADD4E
612 Ø47Ø      AZE&
613 6627      JMP4M
614 Ø361      SCR&1
615 457Ø      STC4E
616 Ø472      LZE&
617 6624      JMP4J
62Ø 7Ø54      JMP5C
621 Ø565      4D
622 1731      7Z
623 Ø565      4D
624 7Ø54  #4J JMP5C
625 6Ø46      =7Z
626 6611      JMP4I
627 2637  #4M ADD4L
63Ø Ø471      APO&
631 6Ø17      JMP17
632 7163      JMP5G
```

```
     CONT
633 0576        4G
634 0565        4D
635 0565        4D
636 6017        JMP17
637 0000  #4L   0
640 1020        LDA&
641 0014        14
          [6-BIT CODE
642 1120  #2A   ADA&
643 0712        2D
644 4017        STC17
645 1017        LDA17
          [TTYSUB
646 4662  #2B   STC2C-7
647 2000        ADD0
650 4656        STC'+6
651 2662        ADD2C-7
652 0341        SCR1
653 0545        OPR45
654 6653        JMP'-1
655 0011        CLR
656 0000        RTN
657 0000        0
660 0000        0
661 0000        0
662 0000        0
663 0000        0
664 0000        0
665 0000        0
666 0000        0
667 0000        0
670 0000        0
          [EOL
671 0011  #2C   CLR
672 2000        ADD0
673 4702        STC'+7
674 1020        LDA&
675 0012        12
676 6642        JMP2A
677 1020        LDA&
700 0013        13
701 6642        JMP2A
702 0000        RTN
703 0000        0
704 0000        0
705 0000        0
706 0000        0
707 0000        0
710 0000        0
711 0000        0
          [CODES
712 7540  #2D   7540
713 7542        7542
714 7544        7544
715 7546        7546
716 7550        7550
717 7552        7552
```

```
     CONT
720 7554     7554
721 7556     7556
722 7560     7560
723 7562     7562
724 7432     7432
725 7424     7424
726 7500     7500
727 7514     7514
730 7516     7516
731 7532     7532
732 7526     7526
733 7536     7536
734 7506     7506
735 7416     7416
736 7602     7602
737 7604     7604
740 7606     7606
741 7610     7610
742 7612     7612
743 7614     7614
744 7616     7616
745 7620     7620
746 7622     7622
747 7624     7624
750 7626     7626
751 7630     7630
752 7632     7632
753 7634     7634
754 7636     7636
755 7640     7640
756 7642     7642
757 7644     7644
760 7646     7646
761 7650     7650
762 7652     7652
763 7654     7654
764 7656     7656
765 7660     7660
766 7662     7662
767 7664     7664
770 7572     7572
771 7612     7612
772 7530     7530
773 7534     7534
774 7510     7510
775 7666     7666
          [DBLFLT
          [ASSEMBLED
          [FOR Q2.3
          [DOUBLE
          [PRECISION
          [FLTG. PT.
          [SUBROUTINES
              $1000
          [ADD
1000 0011 #5A CLR
1001 2000     ADD0
```

```
PRINT1,12  LN=1ØØ2

     CONT
1ØØ2 74Ø6      JMP7A
1ØØ3 1ØØ1      LDA1
1ØØ4 ØØ17      COM
1ØØ5 11Ø2      ADA2
1ØØ6 Ø454      OVF
1ØØ7 7Ø13      JMP*+4
1Ø1Ø Ø354      SCR14
1Ø11 166Ø      BCO&
1Ø12 7737      7737
1Ø13 Ø361      SCR&1
1Ø14 Ø261      ROL&1
1Ø15 Ø472      LAE&
1Ø16 ØØ17      COM
1Ø17 5566      STC7M+1
1Ø2Ø 74Ø1      JMP6I
1Ø21 Ø452      LZE
1Ø22 7374      JMP6H
1Ø23 1ØØ1      LDA1
1Ø24 1Ø43      STA3
1Ø25 1Ø22      LDA&2
1Ø26 1Ø63      STA&3
1Ø27 1Ø22      LDA&2
1Ø3Ø 1Ø63      STA&3
1Ø31 7565      JMP7M
1Ø32 75Ø1      JMP7H
1Ø33 7523      JMP7I-2
1Ø34 7371      JMP6G
1Ø35 1Ø23      LDA&3
1Ø36 7322      JMP6C+2
1Ø37 ØØ41      SET1
1Ø4Ø 1372      6G+1
1Ø41 ØØ62      SET&2
1Ø42 ØØØØ      Ø
1Ø43 7334      JMP6D
1Ø44 7623      JMP7Q
          [SUBTRACT
1Ø45 ØØ11 #5B  CLR
1Ø46 2ØØØ      ADDØ
1Ø47 74Ø6      JMP7A
1Ø5Ø 74Ø1      JMP6I
1Ø51 7332      JMP6D-2
1Ø52 7374      JMP6H
1Ø53 7ØØ3      JMP5A+3
          [MULTIPLY
1Ø54 ØØ11 #5C  CLR
1Ø55 2ØØØ      ADDØ
1Ø56 74Ø6      JMP7A
1Ø57 1ØØ1      LDA1
1Ø6Ø 11Ø2      ADA2
1Ø61 7352      JMP6E+1
1Ø62 5142      STC5E
1Ø63 732Ø      JMP6C
1Ø64 74Ø1      JMP6I
1Ø65 7334      JMP6D
1Ø66 7374      JMP6H
1Ø67 7334      JMP6D
1Ø7Ø 1Ø22      LDA&2
```

```
PRINT1•13  LN=1Ø73

      CONT
1Ø71  1Ø22        LDA&2
1Ø72  Ø3Ø1        ROR1
1Ø73  1Ø42        STA2
1Ø74  7374        JMP6H
1Ø75  1Ø21        LDA&1
1Ø76  1262        MUL&2
1Ø77  1Ø43        STA3
11ØØ  ØØØ5        ZTA
11Ø1  1Ø63        STA&3
11Ø2  1Ø21        LDA&1
11Ø3  Ø3Ø1        ROR1
11Ø4  1262        MUL&2
11Ø5  Ø241        ROL1
11Ø6  1Ø63        STA&3
11Ø7  7376        JMP6H+2
111Ø  1Ø21        LDA&1
1111  1242        MUL2
1112  7145        JMP5F
1113  7374  #5D   JMP6H
1114  1Ø21        LDA&1
1115  1Ø21        LDA&1
1116  Ø3Ø1        ROR1
1117  1262        MUL&2
112Ø  7145        JMP5F
1121  7371        JMP6G
1122  1Ø23        LDA&3
1123  1Ø23        LDA&3
1124  Ø261        ROL&1
1125  Ø241        ROL1
1126  156Ø        BCL&
1127  7776        7776
113Ø  5622        STC7P
1131  7371        JMP6G
1132  1Ø23        LDA&3
1133  Ø261        ROL&1
1134  1Ø63        STA&3
1135  7371        JMP6G
1136  1ØØ3        LDA3
1137  1Ø63        STA&3
114Ø  7371        JMP6G
1141  1Ø2Ø        LDA&
1142  ØØØØ  #5E   Ø
1143  1Ø43        STA3
1144  7623        JMP7Q
1145  5723  #5F   STC7X
1146  7313        JMP6B
1147  5724        STC7X+1
115Ø  ØØ61        SET&1
1151  1722        7X=1
1152  7371        JMP6G
1153  75Ø1        JMP7H
1154  ØØ62        SET&2
1155  7777        =Ø
1156  7525        JMP7I
1157  152Ø        SRO&
116Ø  2525        2525
1161  7113        JMP5D
```

```
PRINT1,14  LN=1164

     CONT
1162 7121       JMP5D+6
          CDIVIDE
1163 0011  #5G  CLR
1164 2000       ADD0
1165 7406       JMP7A
1166 3545       ADD7K
1167 5231       STC5J+1
1170 1022       LDA&2
1171 0470       AZE&
1172 0000       HLT
1173 7374       JMP6H
1174 1002       LDA2
1175 0017       COM
1176 1101       ADA1
1177 7352       JMP6E+1
1200 7320       JMP6C
1201 7374       JMP6H
1202 7334       JMP6D
1203 7401       JMP6I
1204 7334       JMP6D
1205 7374       JMP6H
1206 1021       LDA&1
1207 1063       STA&3
1210 1021       LDA&1
1211 1063       STA&3
1212 1022       LDA&2
1213 0017       COM
1214 5724       STC7X+1
1215 1022       LDA&2
1216 0017       COM
1217 5725       STC7X+2
1220 5723       STC7X
1221 5726       STC7Y
1222 0062       SET&2
1223 1720       7X-3
1224 7376  #5H  JMP6H+2
1225 7227       JMP'+2
1226 7403  #5I  JMP6I+2
1227 7501       JMP7H
1230 1520  #5J  SRO&
1231 0001       0001
1232 7265       JMP5M
1233 0065       SET&5
1234 7777       -0
1235 7371       JMP6G
1236 1023       LDA&3
1237 0450       AZE
1240 7244       JMP5K-3
1241 1023       LDA&3
1242 0470       AZE&
1243 7251       JMP5K+2
1244 0011       CLR
1245 7371       JMP6G
1246 1023       LDA&3
1247 0451  #5K  APO
1250 7256       JMP5L
1251 1002       LDA2
```

PRINT1.15 LN=1255

```
     CONT
1252 1600      BSE
1253 1231      5J+1
1254 1042      STA2
1255 0225      XSK&5
1256 0041 #5L  SET1
1257 1372      6G+1
1260 7371      JMP6G
1261 7501      JMP7H
1262 0205      XSK5
1263 7224      JMP5H
1264 7226      JMP5I
1265 0222 #5M  XSK&2
1266 0222      XSK&2
1267 0222      XSK&2
1270 1520      SRO&
1271 3333      3333
1272 7233      JMP5J+3
1273 7371      JMP6G
1274 0011      CLR
1275 3723      ADD7X
1276 1063      STA&3
1277 0011      CLR
1300 3726      ADD7Y
1301 1063      STA&3
1302 7623      JMP7Q
          [MOVE 1 TO 2
1303 1001 #6A  LDA1
1304 1042      STA2
1305 1021      LDA&1
1306 1062      STA&2
1307 1021      LDA&1
1310 1062      STA&2
1311 0011      CLR
1312 6000      JMP0
          [Z TO A
1313 0005 #6B  ZTA
1314 0241      ROL1
1315 0455      ZZZ
1316 3545      ADD7K
1317 6000      JMP0
          [COM SETUP
1320 1021 #6C  LDA&1
1321 1662      BCO&2
1322 0261      ROL&1
1323 1020      LDA&
1324 0016      NOP
1325 0452      LZE
1326 3331      ADD'+3
1327 5670      STC7S
1330 6000      JMP0
1331 7314      JMP6D-20
1332 0062      SET&2
1333 7777      -0
          [COM/ABS 1
1334 1021 #6D  LDA&1
1335 0361      SCR&1
1336 0261      ROL&1
```

```
     CONT
1337 0202      XSK2
1340 0452      LZE
1341 0017      COM
1342 1041      STA1
1343 1021      LDA&1
1344 0202      XSK2
1345 0452      LZE
1346 0017      COM
1347 1041      STA1
1350 6000      JMP0
          [OVF CHECK
1351 1103 #6E ADA3
1352 0470      AZE&
1353 0011      CLR
1354 1043      STA3
1355 0454      OVF
1356 6000      JMP0
1357 0451      APO
1360 0000      HLT
          [RESULT=0
1361 7371 #6F JMP6G
1362 1020      LDA&
1363 4000      =3777
1364 1043      STA3
1365 0011      CLR
1366 1063      STA&3
1367 1063      STA&3
1370 7672      JMP7T
          [SET3
1371 0063 #6G SET&3
1372 0000      0
1373 6000      JMP0
          [SET NORMAL
1374 0062 #6H SET&2
1375 5726      7Y+4000
1376 0061      SET&1
1377 1723      7X
1400 6000      JMP0
          [SET REVERSE
1401 0062 #6I SET&2
1402 1723      7X
1403 0061      SET&1
1404 1726      7Y
1405 6000      JMP0
          [SETUP
1406 1560 #7A BCL&
1407 6000      6000
1410 4004      STC4
1411 2000      ADD0
1412 5446      STC7E
1413 1004      LDA4
1414 7457      JMP7G
1415 7452      JMP7F
1416 5431      STC7C
1417 1024      LDA&4
1420 7457      JMP7G
1421 7447      JMP7E+1
```

PRINT1•17 LN=1437


```
     CONT
1422 5435      STC7D
1423 1024      LDA&4
1424 7457      JMP7G
1425 0016      NOP
1426 5372      STC6G+1
1427 7401  #7B JMP6I
1430 0061      SET&1
1431 0000  #7C 0
1432 7303      JMP6A
1433 0222      XSK&2
1434 0061      SET&1
1435 0000  #7D 0
1436 7303      JMP6A
1437 0224      XSK&4
1440 2004      ADD4
1441 3407      ADD7A+1
1442 5672      STC7T
1443 5622      STC7P
1444 7371      JMP6G
1445 7374      JMP6H
1446 0000  #7E [RETURN
1447 5435      STC7D
1450 3454      ADD7F+2
1451 7426      JMP7B-1
1452 5435  #7F STC7D
1453 1020      LDA&
1454 1731      7Z
1455 5431      STC7C
1456 7450      JMP7E+2
           [IR+SIGN TEST
1457 0471  #7G APO&
1460 0220      XSK&0
1461 0451      APO
1462 0017      COM
1463 1120      ADA&
1464 7760      -17
1465 0361      SCR&1
1466 0261      ROL&1
1467 3462      ADD7G+3
1470 0472      LZE&
1471 6000      JMP0
1472 4001      STC1
1473 1001      LDA1
1474 3667      ADD7S-1
1475 1041      STA1
1476 1120      ADA&
1477 7774      -3
1500 6000      JMP0
           [ADD 1 TO 3
1501 0044  #7H SET4
1502 0000      0
1503 0011      CLR
1504 7371      JMP6G
1505 1021      LDA&1
1506 5531      STC7J
1507 1023      LDA&3
1510 5533      STC7J+2
```

```
PRINT1•20  LN=1530

     CONT
1511 1001       LDA1
1512 1203       LAM3
1513 1021       LDA&1
1514 1223       LAM&3
1515 7371       JMP6G
1516 4000       STC0
1517 1223       LAM&3
1520 4000       STC0
1521 1223       LAM&3
1522 6004       JMP4
1523 0062       SET&2
1524 0000       0
           [CHECK FOR
           [ADD OVERFLOW
1525 0041  #7I  SET1
1526 0000       0
1527 7371       JMP6G
1530 1020       LDA&
1531 0000  #7J  0
1532 1660       BCO&
1533 0000       0
1534 0451       APO
1535 6001       JMP1
1536 1023       LDA&3
1537 1640       BCO
1540 1531       7J
1541 0471       APO&
1542 6001       JMP1
1543 7371       JMP6G
1544 1020       LDA&
1545 0001  #7K  1
1546 7351       JMP6E
1547 1020       LDA&
1550 7776  #7L  -1
1551 0202       XSK2
1552 7567       JMP7M+2
1553 3622       ADD7P
1554 0202       XSK2
1555 0017       COM
1556 5622       STC7P
1557 7371       JMP6G
1560 1023       LDA&3
1561 1660       BCO&
1562 4000       4000
1563 1043       STA3
1564 6001       JMP1
           [SCR N 3
1565 1020  #7M  LDA&
1566 0000       0
1567 0042       SET2
1570 0000       0
1571 0470       AZE&
1572 6002       JMP2
1573 4005       STC5
1574 0064       SET&4
1575 7747       -30
1576 0011  #70  CLR
```

```
     CONT
1577 7371       JMP6G
1600 1023       LDA&3
1601 0361       SCR&1
1602 1043       STA3
1603 1023       LDA&3
1604 0321       ROR&1
1605 1043       STA3
1606 0224       XSK&4
1607 7611       JMP'+2
1610 7613       JMP'+3
1611 0225       XSK&5
1612 7576       JMP7O
1613 7371       JMP6G
1614 1023       LDA&3
1615 0261       ROL&1
1616 0452       LZE
1617 0017       COM
1620 5622       STC7P
1621 6002       JMP2
1622 0000  #7P  0
           [NORMALIZE,
           [ROUND,XIT
1623 0011  #7Q  CLR
1624 4001       STC1
1625 3622       ADD7P
1626 0321       ROR&1
1627 7371       JMP6G
1630 1023       LDA&3
1631 1463       SAE&3
1632 7637       JMP'+5
1633 0450       AZE
1634 7637       JMP'+3
1635 0472       LZE&
1636 7361       JMP6F
1637 7371       JMP6G
1640 1023       LDA&3
1641 0451       APO
1642 7704       JMP7U
1643 0241       ROL1
1644 0471       APO&
1645 7673       JMP7T+1
1646 7371  #7R  JMP6G
1647 1023       LDA&3
1650 1023       LDA&3
1651 0321       ROR&1
1652 4000       STC0
1653 1203       LAM3
1654 7371       JMP6G
1655 4000       STC0
1656 1223       LAM&3
1657 0451       APO
1660 7706       JMP7V
1661 7371       JMP6G
1662 0011       CLR
1663 2001       ADD1
1664 0017       COM
1665 7351       JMP6E
```

```
     CONT
1666 0041        SET1
1667 0003        3
1670 0016  #7S  NOP
1671 0011        CLR
1672 0000  #7T  EXIT
1673 1023        LDA&3
1674 0261        ROL&1
1675 1043        STA3
1676 7371        JMP6G
1677 1023        LDA&3
1700 0261        ROL&1
1701 1043        STA3
1702 0221        XSK&1
1703 7643        JMP7R-3
1704 7706  #7U  JMP7V
1705 7646        JMP7R
1706 0011  #7V  CLR
1707 2000        ADD0
1710 5722        STC7W
1711 3550        ADD7L
1712 7567        JMP7M+2
1713 3550        ADD7L
1714 2001        ADD1
1715 4001        STC1
1716 1003        LDA3
1717 1560        BCL&
1720 4000        4000
1721 1043        STA3
1722 0000  #7W  ERTN
           EARG 1
1723 0000  #7X  0
1724 0000        0
1725 0000        0
           EARG 2
1726 0000  #7Y  0
1727 0000        0
1730 0000        0
           EFAC
1731 0000  #7Z  0
1732 0000        0
1733 0000        0
           ETRANSFER
1734 0011  #5N  CLR
1735 2000        ADD0
1736 7406        JMP7A
1737 0042        SET2
1740 1435        7D
1741 7303        JMP6A
1742 7671        JMP7T-1
           EFLOAT
1743 0011  #5O  CLR
1744 2000        ADD0
1745 7406        JMP7A
1746 3435        ADD7D
1747 5372        STC6G+1
1750 7371        JMP6G
1751 1020        LDA&
```

```
     CONT
1752 0027        27
1753 1043        STA3
1754 7035        JMP5B-10
          [FIX
1755 0011   #5P  CLR
1756 2000        ADD0
1757 7406        JMP7A
1760 3435        ADD7D
1761 5372        STC6G+1
1762 7371        JMP6G
1763 1020        LDA&
1764 7750        -27
1765 7351        JMP6E
1766 0471        APO&
1767 7672        JMP7T
1770 7567        JMP7M+2
1771 7671        JMP7T-1
```

APPENDIX

OPERATIONAL DETAILS

TAPES

Mount LAP6 - 2S on unit Ø, LAP6 - 2S file with programs on unit 1, and a scratch tape on unit 5.

SCOPE DISPLAY OF TEST - initial (INT - DSP) and final (FIN - DSP1)

Both utilize SCOPE - SP.

In all cases where blanks are to be filled, the number of typed entries must equal the number of blanks.

One constant, rho, is initially set equal to 150 ohm cm. If this value is correct, type EOL and the next display will appear. If incorrect, type DEL to erase the 150, and then enter the correct value followed by EOL.

If the keyboard should lock down while selections are being made or blanks being filled, type the character (s) again and the display will reappear.

Needless to say - make sure there is an analog input signal before typing S-EOL. Likewise, make sure the printer and plotter are on before selecting them for output. Before plotting, position the pen at the right hand margin (small holes). After the first graph, the pen will be positioned under program control.

COPYING PROGRAMS FROM MASTER TAPE TO USER TAPE

To copy COCAL, INT-DSP, COMPUTE1, FIN-DSP1, PLOT1, and PRINT1 from the Master tape on which they now reside (JUNCKER LAP6 - 2S FILE) onto another tape, use LAP6 - 2S and the copy file command (→CF UNIT EOL). These six routines are the only entries in the Master tape file index, so that copying all the entries will not result in unwanted programs being transferred to the user's tape.

EXAMINATION OF THE FILE INDEX BY COCAL

All six routines must exist on the same tape and be listed in that tape's file index. As mentioned previously, this tape is mounted on unit 1. Once in execution, COCAL searches the tape for the file index, examining first blocks 426-7. When found, the index is searched for INT-DSP, COMPUTE1, FIN-DSP1, PLOT1 and PRINT1. The block numbers of these routines are inserted into appropriate locations in COCAL*. If a routine is not found, the computer halts at location $(1234)_8$.

DATA STORAGE

Cardiac output values are at present stored in blocks 270 and 271, stroke volume in blocks 274 and 275, and pulse rate in blocks 276 and 277 of the scratch tape mounted on unit 5. Should the user wish to store the data elsewhere, he must modify the read/write instructions in COMPUTE1, FIN-DSP1, PLOT1 and PRINT1.

*The block numbers shown in the listing of COCAL are not necessarily correct.

USE OF PAGES BY THE PROGRAM

	Before Sampling	During Sampling	Final Display
Page 0	COCAL 0 - 1304 includes the routine to examine the file index	COCAL 0 - 774 C.O. values 1000 - 1777	COCAL 0 - 774 C.O. or S.V. or P.R. 1000 - 1777
Page 1	INT-DSP	raw data	raw data
Page 2	COMPUTE1	COMPUTE1	FIN-DSP1
Page 3	- - - -	S.V. and P.R. values	PLOT1 or PRINT1

RESTARTING COCAL FROM THE CONSOLE

To restart COCAL at the beginning:*

1) Redefine the lower memory bank to be Ø
   Set left switches: LMBØ (code 600)
   Raise DO lever
2) Redefine the upper memory bank to be 1
   Set left switches: UMB1 (code 641)
   Raise DO lever
3) Start at location $(47)_8$
   Set the right switches: $(47)_8$
   Press the START RSW button

To restart the final display routine in COCAL in the event, for example, the computer tries to plot data but the plotter has not been turned on, repeat steps #1 and #2 but start the program at location $(433)_8$.

ERROR IN T

There is a small amount of error in the computation of time T between beats. A time gap exists between the sampling of successive beats which needs to be considered for accurate measurement of pulse rate. This gap equals the time spent in calculating stroke volume, cardiac output, and pulse rate. The estimated value of this gap is 62 ms. (18 ms. in COCAL, 44 ms. in COMPUTE1). Converting this value to locations gives 31 locations or, when rounded off, 30 locations. I added the octal equivalent of 30, 36, to the time T as calculated by COCAL in locations 372 - 376.

The user may wish to add a number other than 36. If so, he should change the contents of location 374.

*LAP6-2S and → LOCOCAL,1_{EOL} may also be used.

Computation of Stroke Volume

ρ = ρ-ohm cm (rho)

L^2 = $(L\text{cm}/10)^2$ L is multiplied by 10 when entered

τ = (t addresses)(2ms/address)(1sec/10^3ms) = $2t$ sec/10^3

τ = $(T_3 - T_1)$ (See Fig. 1)

$(dZ/dt)_{min}$ = DZ · 1volt/$(377)_8$ · 100 ohms/K volt sec = $\dfrac{100 \text{ DZ ohms}}{(377)_8 K \text{ sec}}$

DZ = sampled value of $(dZ/dt)_{min}$

$(dZ/dt)_{cal}$ = 100 ohms/sec = K volts[$(dZ/dt)_{cal}$ is multiplied by 100 when entered]

Z_o = Z · 1 volt/$(377)_8$ · 100 ohms/J volts = $\dfrac{100 \text{ Z ohms}}{(377)_8 \text{ J}}$

Z_o = sampled value of Z_o

Z_{cal} = 100 ohms = J volts [Z_{cal} is multiplied by 100 when entered]

Insert into formula:

$$\Delta V = \rho L^2 \tau / Z_o \quad (dZ/dt)_{min}$$

to get:

$$\Delta V = \frac{(\rho \text{ ohm cm})\ (L^2\text{cm}^2)(2t \text{ sec})(10^2 DZ \text{ ohms})(377)_8 J^2}{(10^2)(10^3)(377)_8\ (K \text{ sec})(10^4 Z^2 \text{ohms}^2)}$$

which reduces to:

$$\text{Stroke volume} = \Delta V = \frac{\rho L^2 t(DZ)(Z^2)}{KZ^2} \cdot \frac{51}{10^6} \quad \text{cm}^3$$

Computation of Pulse Rate

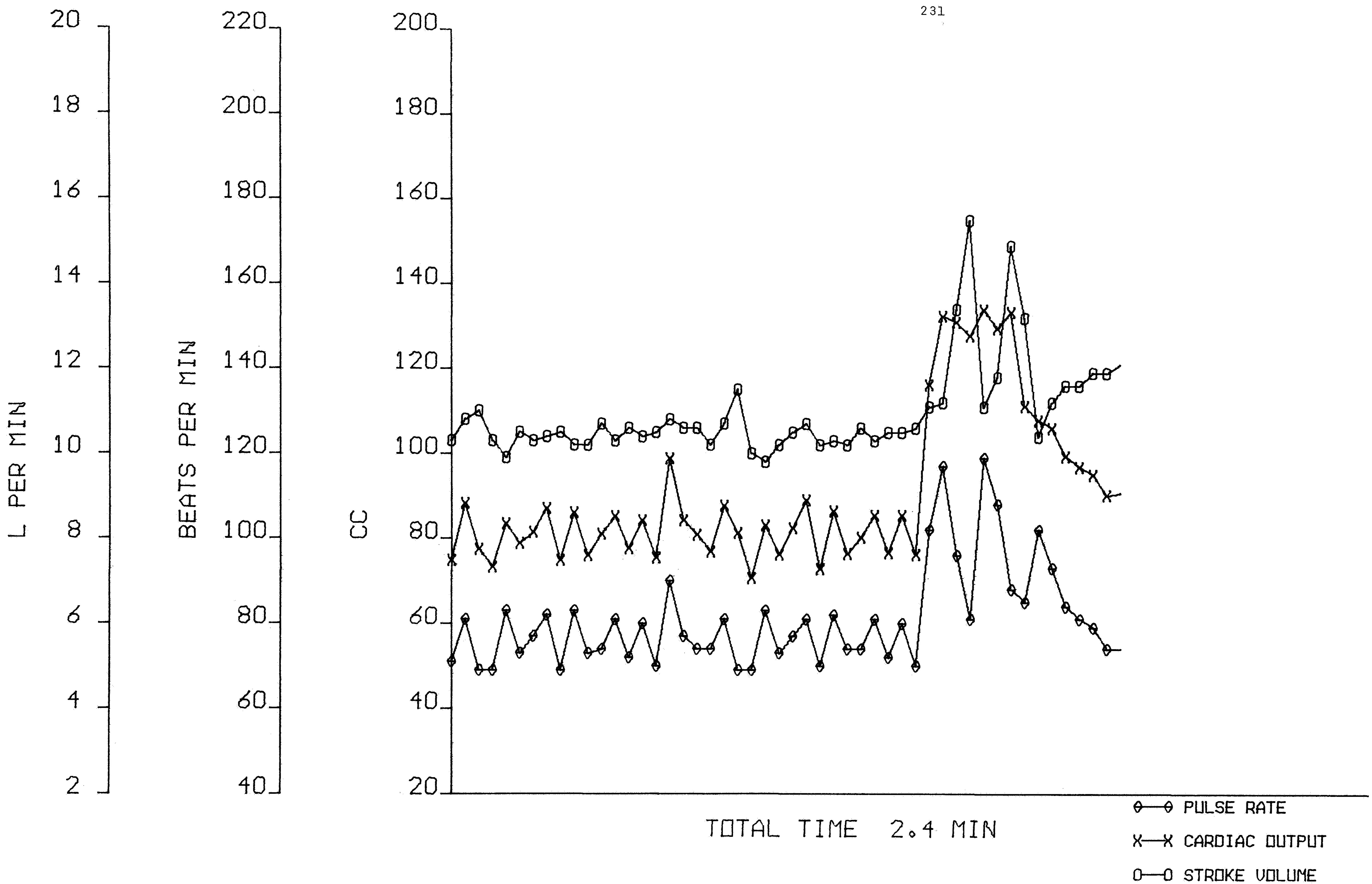
$$T = t' \text{ addresses} \cdot 2\text{ms/address} \cdot 1 \text{ sec}/10^3\text{ms} \cdot 1 \text{ min}/60 \text{ sec} = t' \text{ min}/3 \times 10^4$$

t' = time in addresses between beats (plus 36_8 to allow for computation (of c.o., etc.)

Pulse Rate = 1/T beats per min.

Computation of Cardiac Output

Cardiac output = $\Delta V/T$ cc/min


L PER MIN
20
18
16
14
12
10
8
6
4
2
BEATS PER MIN
220
200
180
160
140
120
100
80
60
40
CC
200
180
160
140
120
100
80
60
40
20
TOTAL TIME 2.4 MIN
PULSE RATE
CARDIAC OUTPUT
STROKE VOLUME

```
CARDIAC OUTPUT IN CC /MIN

+7.870000E+003      +7.570000E+003      +8.210000E+003      +8.130000E+003
AVERAGE    +7.945000E+003      NORMALIZED VALUE    +1.000000E+000

+8.660000E+003      +9.160000E+003      +9.390000E+003      +8.680000E+003
AVERAGE    +8.972500E+003      NORMALIZED VALUE    +1.129326E+000

+7.520000E+003      +7.490000E+003      +7.320000E+003      +7.190000E+003
AVERAGE    +7.380000E+003      NORMALIZED VALUE    +9.288870E-001

+7.300000E+003      +6.970000E+003      +7.860000E+003      +8.110000E+003
AVERAGE    +7.560000E+003      NORMALIZED VALUE    +9.515428E-001

+8.770000E+003      +8.620000E+003      +7.930000E+003      +8.280000E+003
AVERAGE    +8.400000E+003      NORMALIZED VALUE    +1.057268E+000

+7.140000E+003      +8.220000E+003      +7.940000E+003      +7.700000E+003
AVERAGE    +7.750000E+003      NORMALIZED VALUE    +9.754571E-001


STROKE VOLUME IN CC

+1.060000E+002      +9.900000E+001      +1.060000E+002      +1.020000E+002
AVERAGE    +1.032500E+002      NORMALIZED VALUE    +1.000000E+000

+1.060000E+002      +1.100000E+002      +1.150000E+002      +1.130000E+002
AVERAGE    +1.110000E+002      NORMALIZED VALUE    +1.075060E+000

+1.070000E+002      +1.110000E+002      +1.110000E+002      +1.090000E+002
AVERAGE    +1.095000E+002      NORMALIZED VALUE    +1.060532E+000

+1.060000E+002      +9.600000E+001      +1.050000E+002      +1.000000E+002
AVERAGE    +1.017500E+002      NORMALIZED VALUE    +9.854731E-001

+1.040000E+002      +9.900000E+001      +9.300000E+001      +1.050000E+002
AVERAGE    +1.002500E+002      NORMALIZED VALUE    +9.709453E-001

+9.600000E+001      +1.120000E+002      +1.100000E+002      +1.050000E+002
AVERAGE    +1.057500E+002      NORMALIZED VALUE    +1.024212E+000


PULSE RATE IN BEATS/MIN

+7.400000E+001      +7.600000E+001      +7.700000E+001      +7.900000E+001
AVERAGE    +7.650000E+001      NORMALIZED VALUE    +1.000000E+000

+8.100000E+001      +8.300000E+001      +8.100000E+001      +7.600000E+001
AVERAGE    +8.025000E+001      NORMALIZED VALUE    +1.049019E+000

+7.000000E+001      +6.700000E+001      +6.500000E+001      +6.500000E+001
AVERAGE    +6.675000E+001      NORMALIZED VALUE    +8.725499E-001

+6.800000E+001      +7.100000E+001      +7.400000E+001      +8.000000E+001
AVERAGE    +7.325000E+001      NORMALIZED VALUE    +9.575173E-001

+8.400000E+001      +8.600000E+001      +8.400000E+001      +7.800000E+001
AVERAGE    +8.300000E+001      NORMALIZED VALUE    +1.084967E+000

+7.400000E+001      +7.200000E+001      +7.100000E+001      +7.200000E+001
AVERAGE    +7.225000E+001      NORMALIZED VALUE    +9.444452E-001
```

References

1. Clark, W. A., C. E. Molnar, The LINC: A description of the laboratory instrument computer. Annals of the New York Academy of Science, Vol. 115, pages 653-668, July 1964.

2. Clark, W. A., and C. E. Molnar. A description of the LINC in computers in biomedical research. Ed. by Ralph W. Stacy and Bruce Waxman Academic Press, New York 1965.