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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.

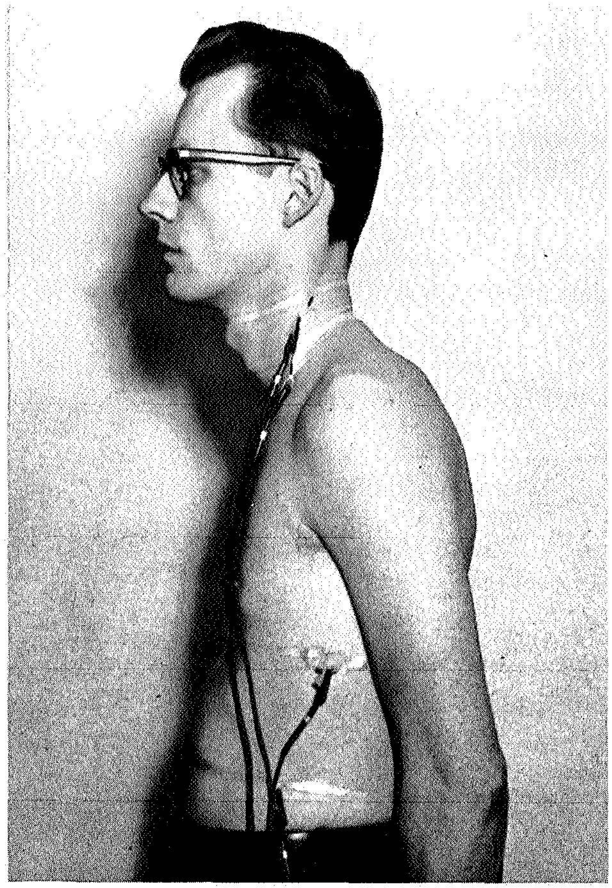

Fig. 1 The disposable electrodes made of aluminized Mylar strips on an adhesive tape backing are shown with the lead wires from the impedance system attached.

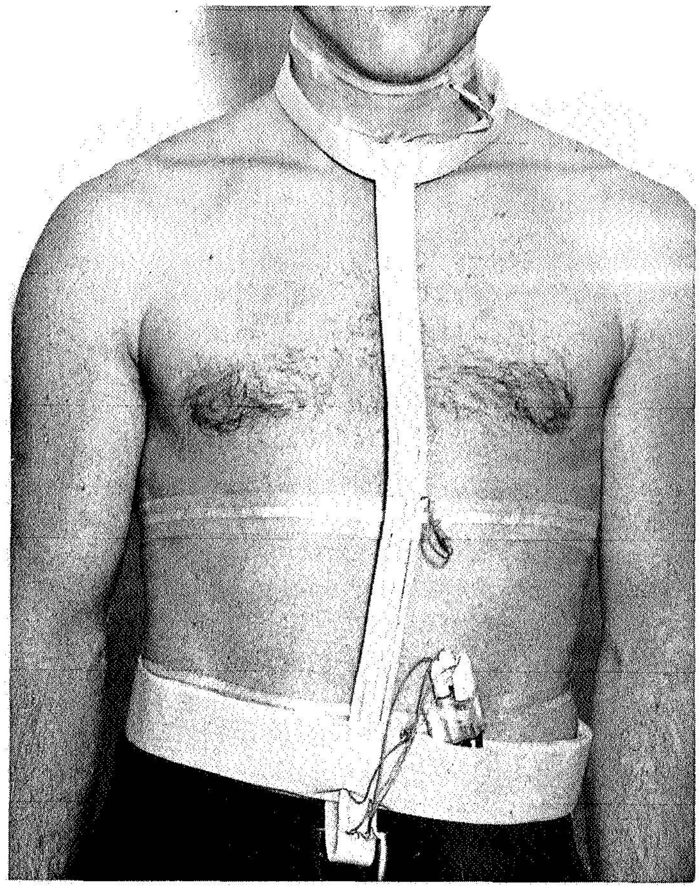

Fig. 2 A view of the Velcro harness to support the connecting cables.

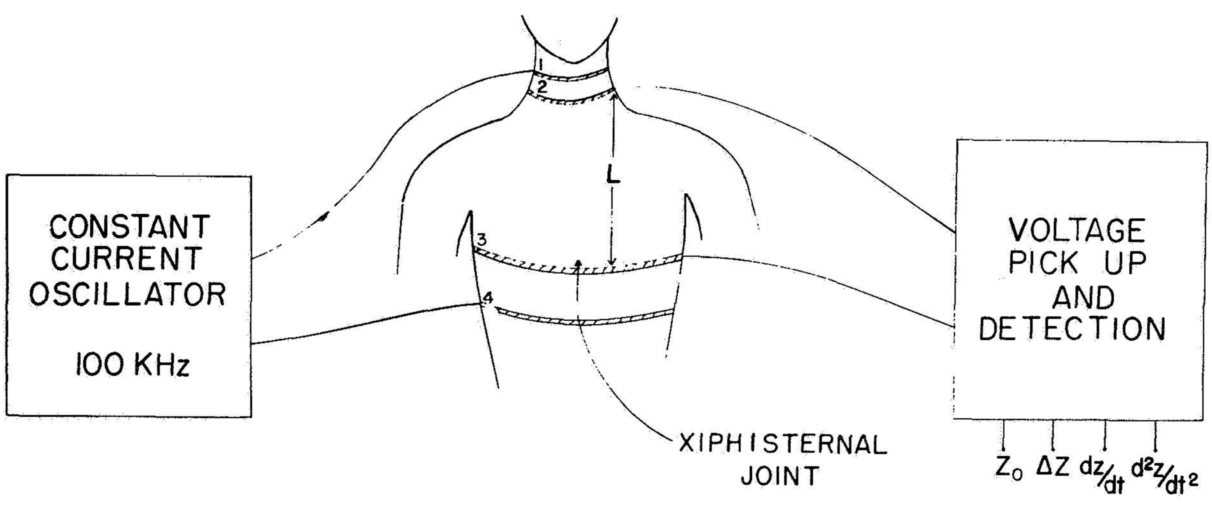

Fig. 3 A schematic diagram of the main elements of the Impedance Cardiograph connected to the electrodes shown in Fig. 1.

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

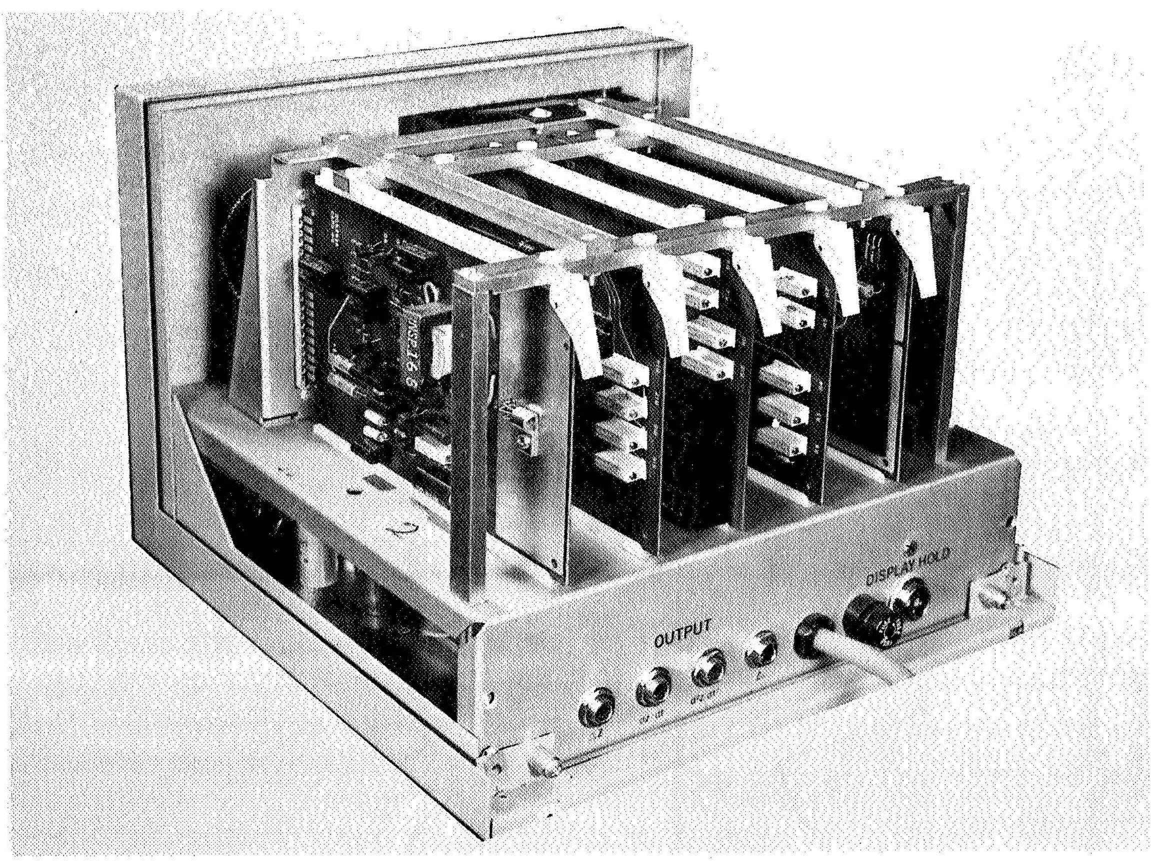

Fig. 5 A view of the solid state circuitry and output terminals.

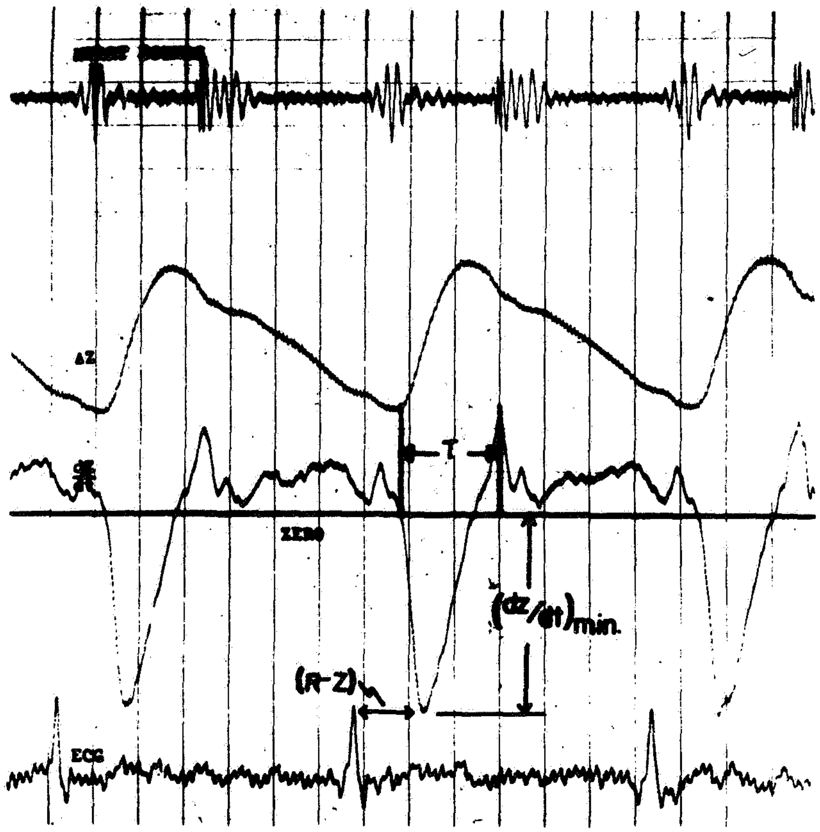

Fig. 6 A record of heart sounds, ΔZ, (dZ/dt) and the ECG taken on a normal adult. The ventricular ejection time (T), the (R-Z) interval and $(dZ/dt)_{min}$ are shown. Time marks 100 msec.

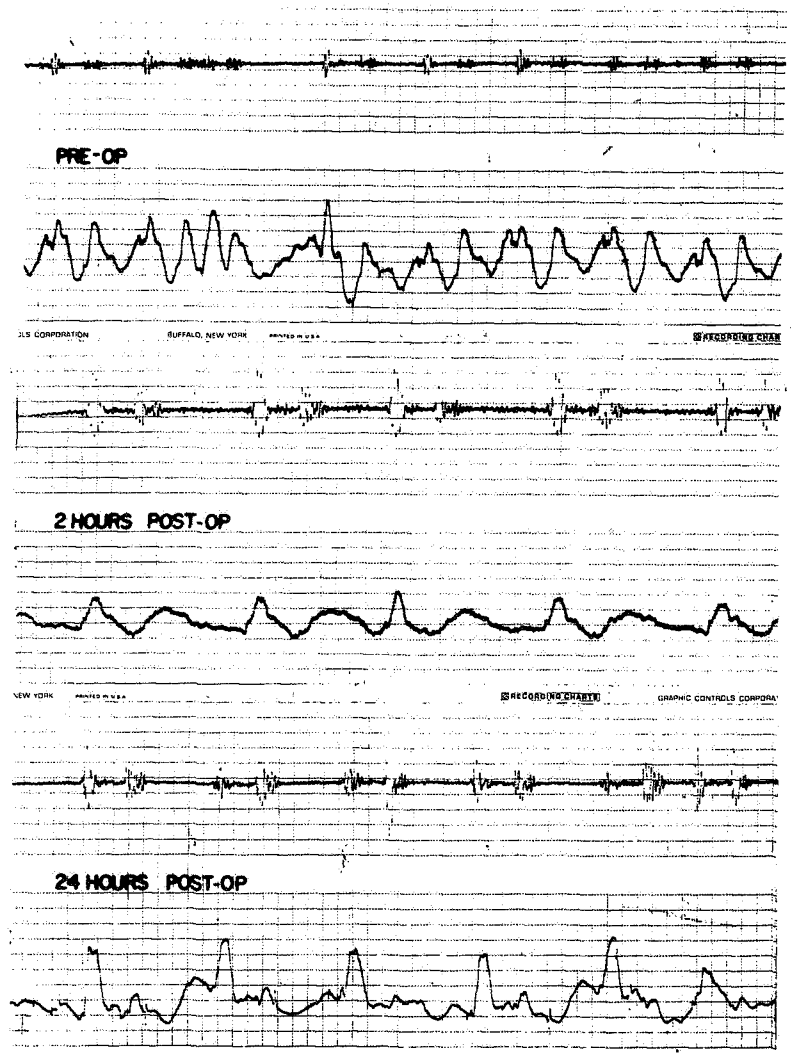

Fig. 7 Recordings of heart sounds and (dZ/dt) taken before and following surgery to repair a leak around an artificial mitral valve. Time marks 100 msec.

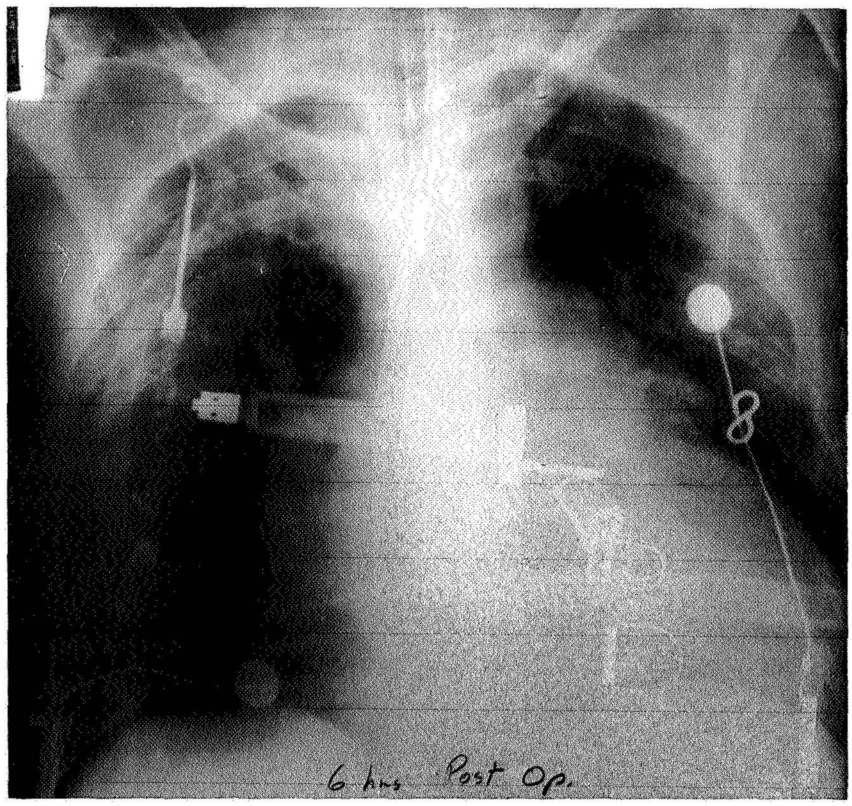

Fig. 8 A chest x-ray showing an enlarged heart with three artificial valves (mitral, tricuspid and aortic).

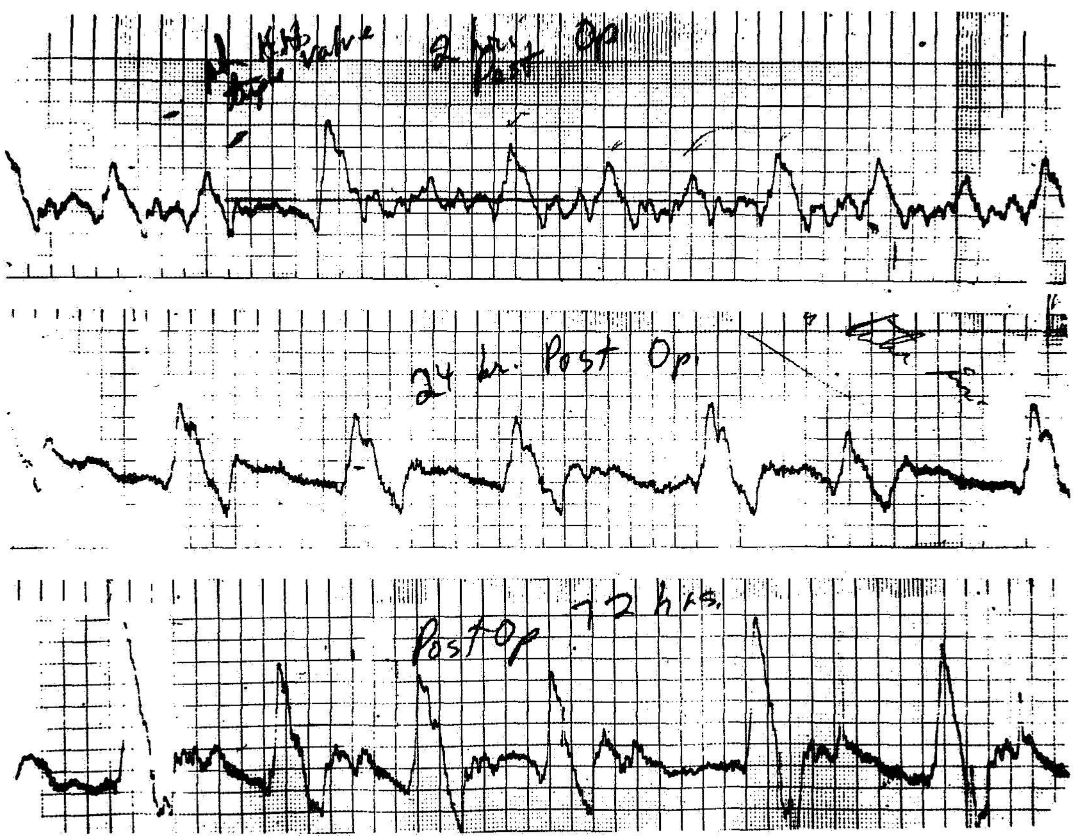

Fig. 9 Recordings of (dZ/dt), two, twenty-four and seventy-two hours following surgery to insert the valves shown in Fig. 7. Time marks 100 msec.

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

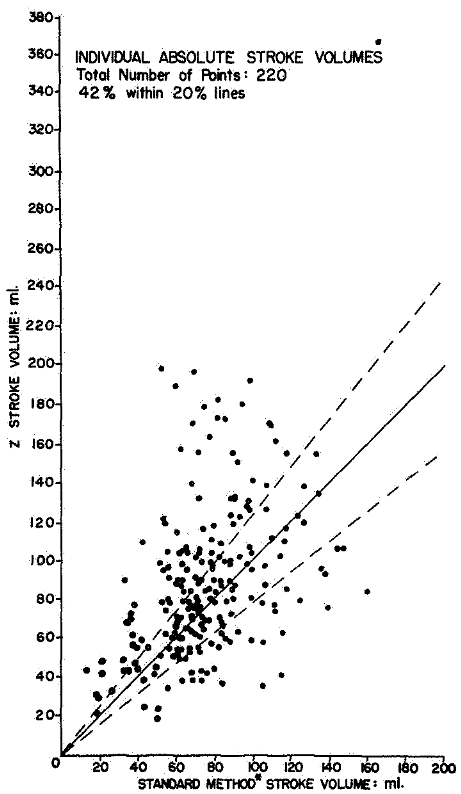

Fig. II-1 A composite graph of all of the stroke volume values obtained by the Impedance method plotted against the values of stroke volume obtained by the Dye, Fick or Isotope dilution technique

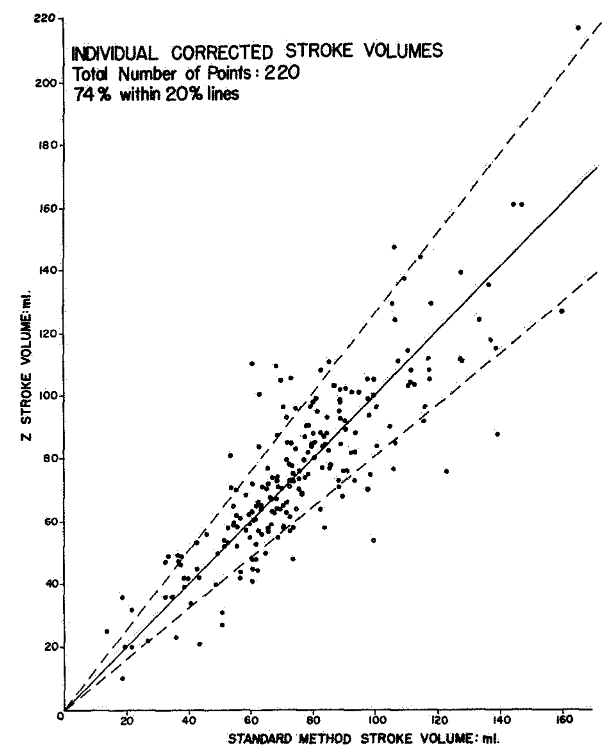

Fig. II-2 A composite graph of the corrected stroke volume values obtained by the Impedance method plotted against the original values of stroke volume obtained by one of the standard methods

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):

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

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

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

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

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

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 Gellan (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 $\frac{\text{Z-CALCULATED CARDIAC OUTPUT}}{\text{DYE-CALCULATED CARDIAC OUTPUT}}$

(N = 35)

Subject No.	Supine (pretilt) +5 min	Supine (pretilt) +10 min	Tilt T + 5 min	Tilt T + 15 min	Supine (post-tilt) +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.

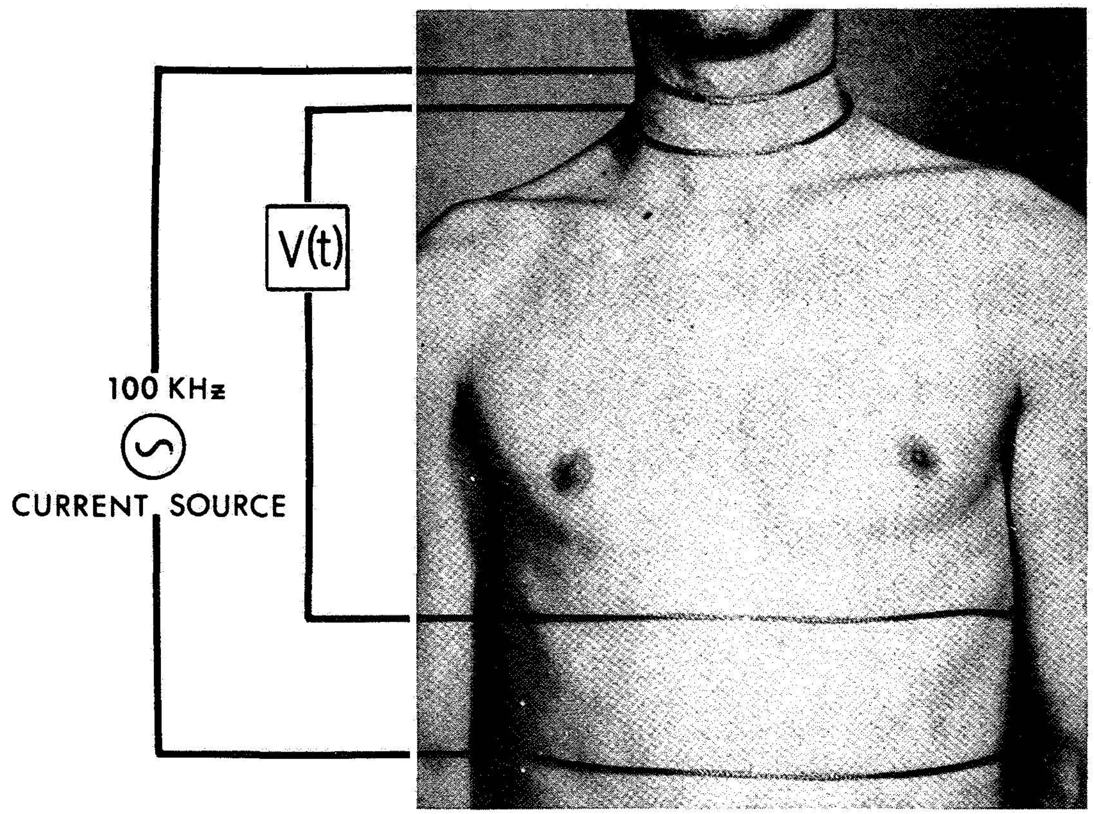

Fig. 1. Subject with four band electrodes.

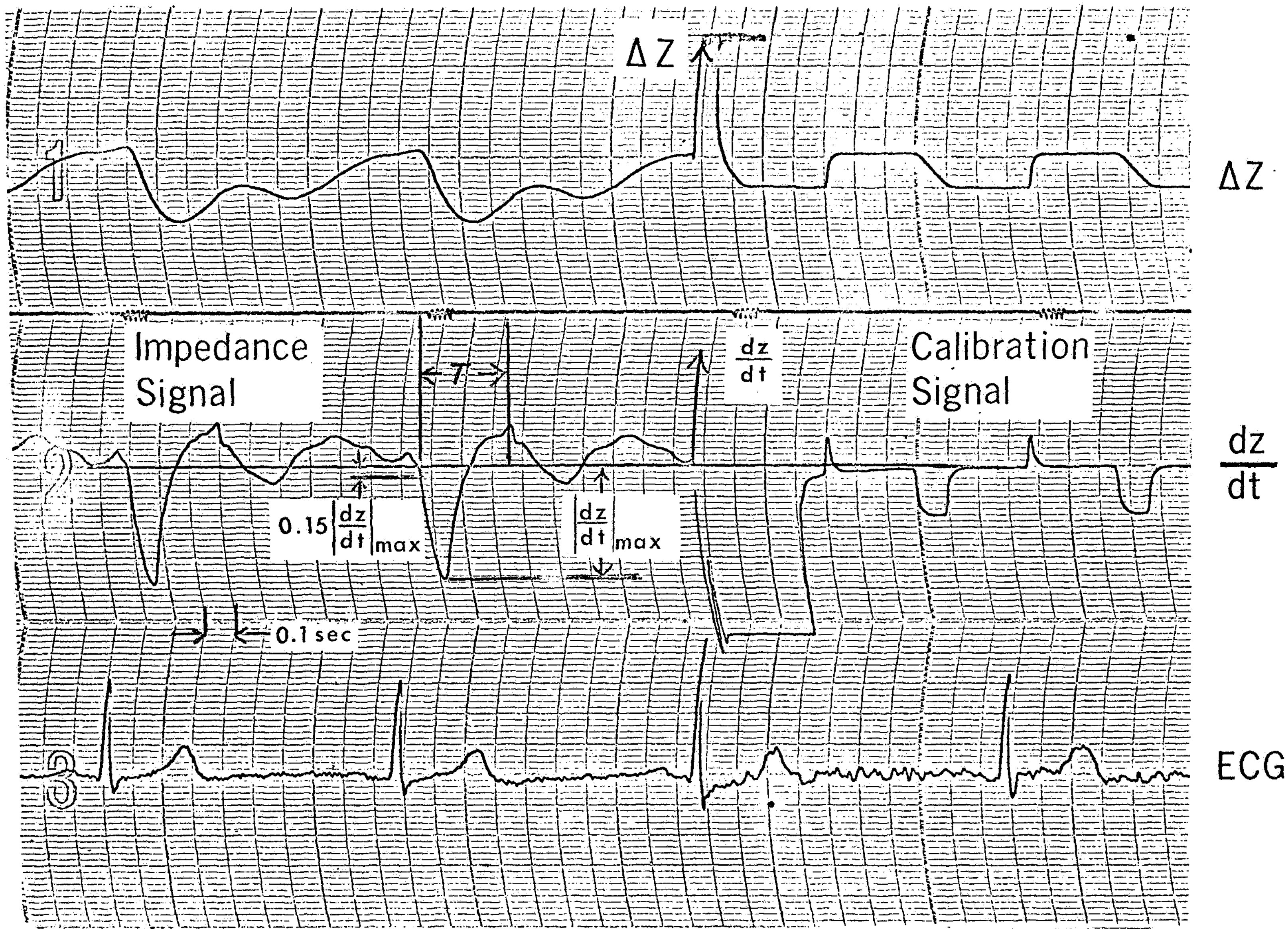

Fig. 2. Impedance wave (ΔZ), the first derivative of the impedance wave $\left(\frac{dz}{dt}\right)$ and ECG tracing. (Paper speed: 50 mm/sec)

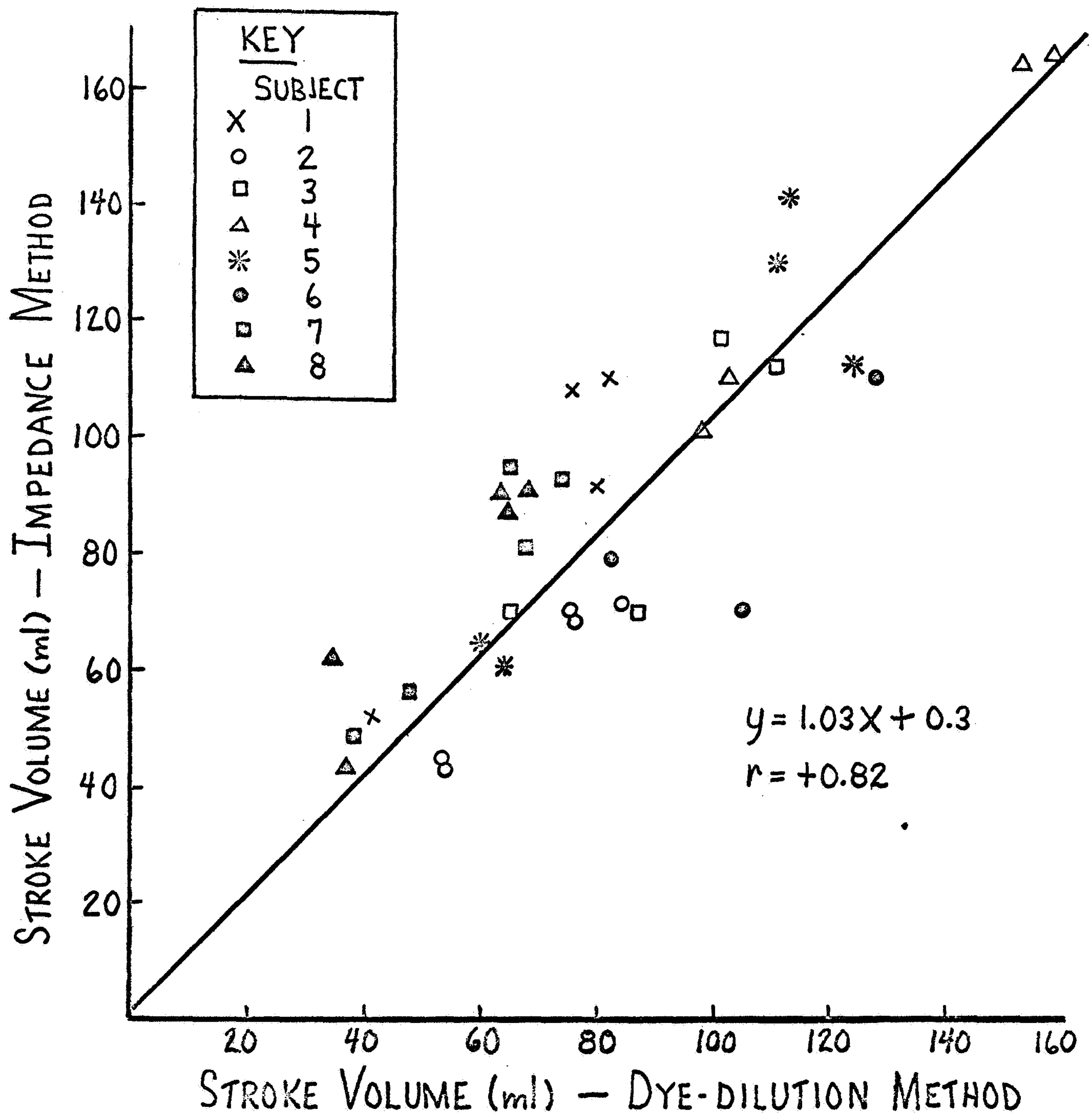

Fig. 3. Stroke Volume in Head-up Tilt--Dye-dilution vs Impedance Values
(35 determinations in 8 normal males)

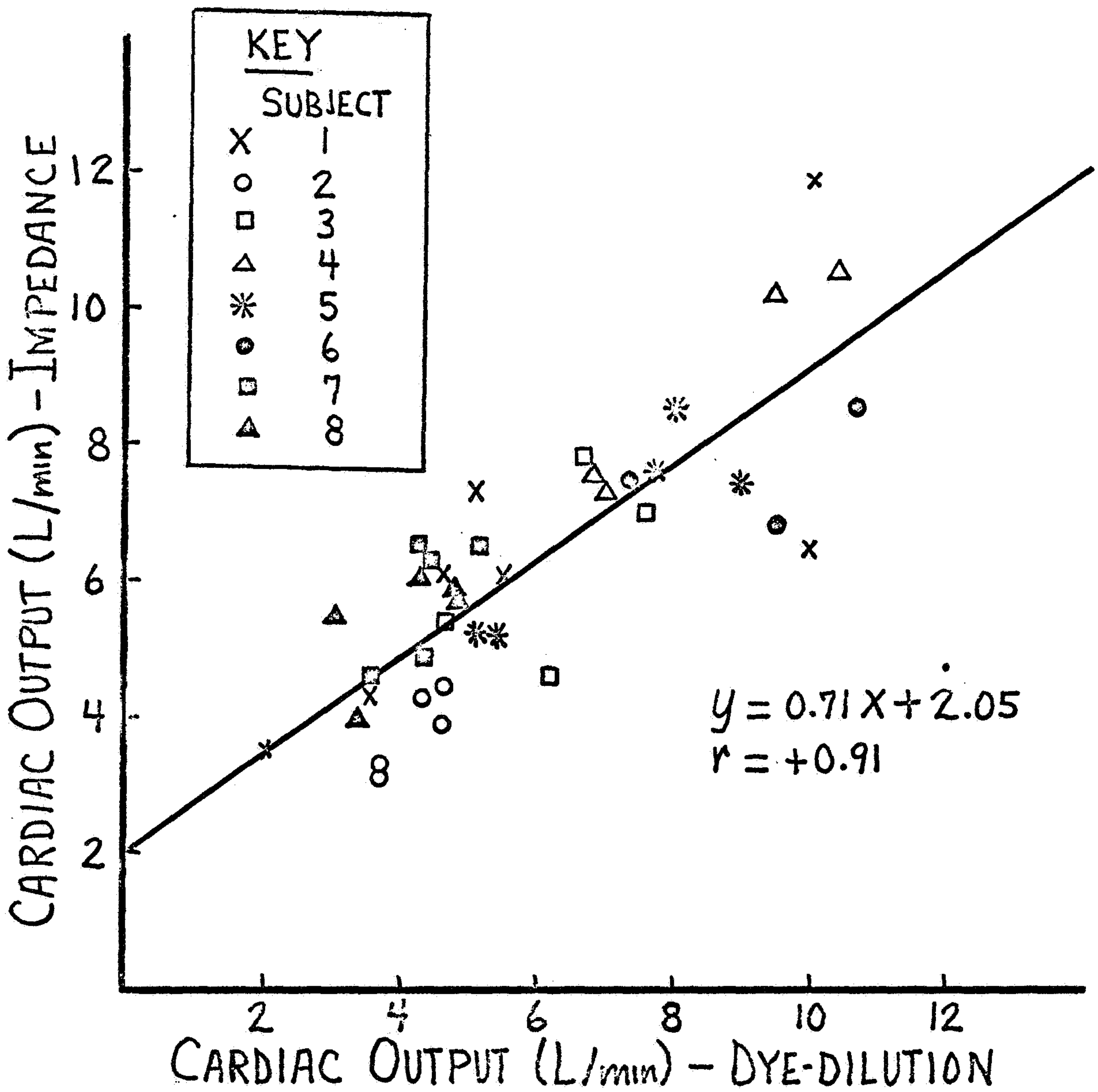

Fig. 4. Cardiac Output in Head-up Tilt--Dye-dilution vs Impedance Values (35 determinations in 8 normal males)

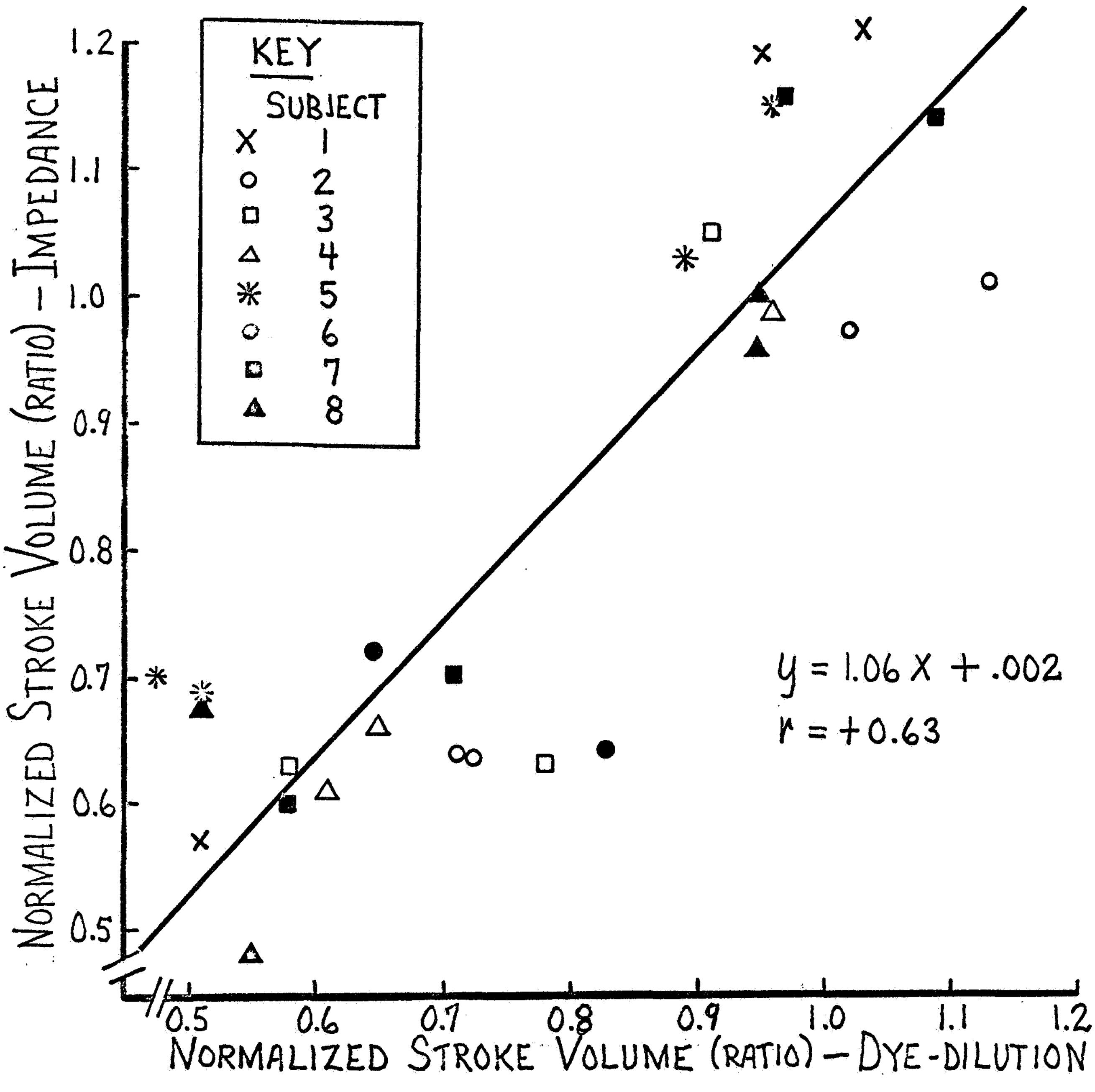

Fig. 5. Stroke Volume in Head-up Tilt--Ratios of Change with Dye-dilution and Impedance Methods Based on Respective Individual Control Values

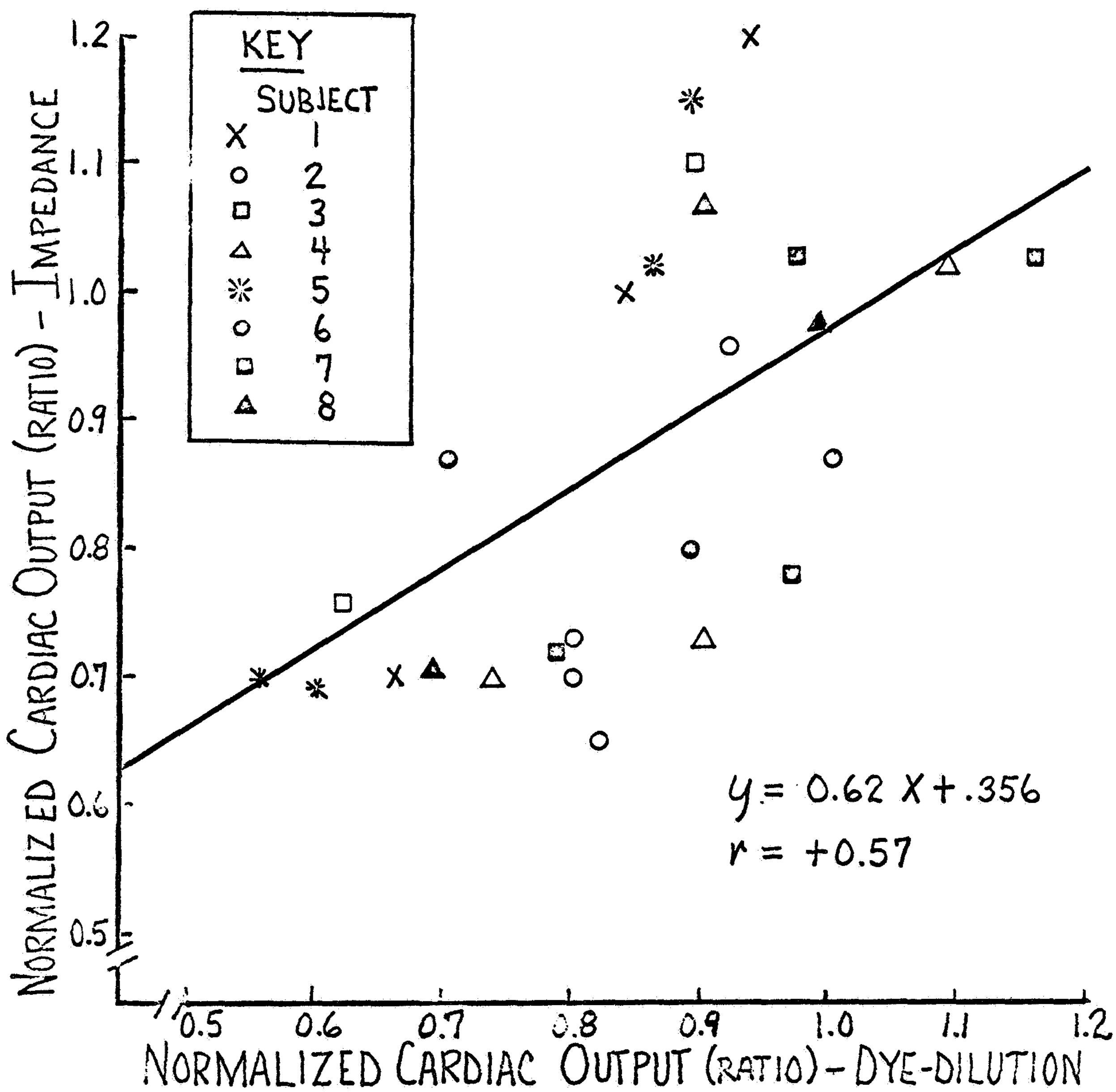

Fig. 6. Cardiac Output in Head-up Tilt--Ratios of Change with Dye-dilution and Impedance Methods Based on Respective Individual Control Values

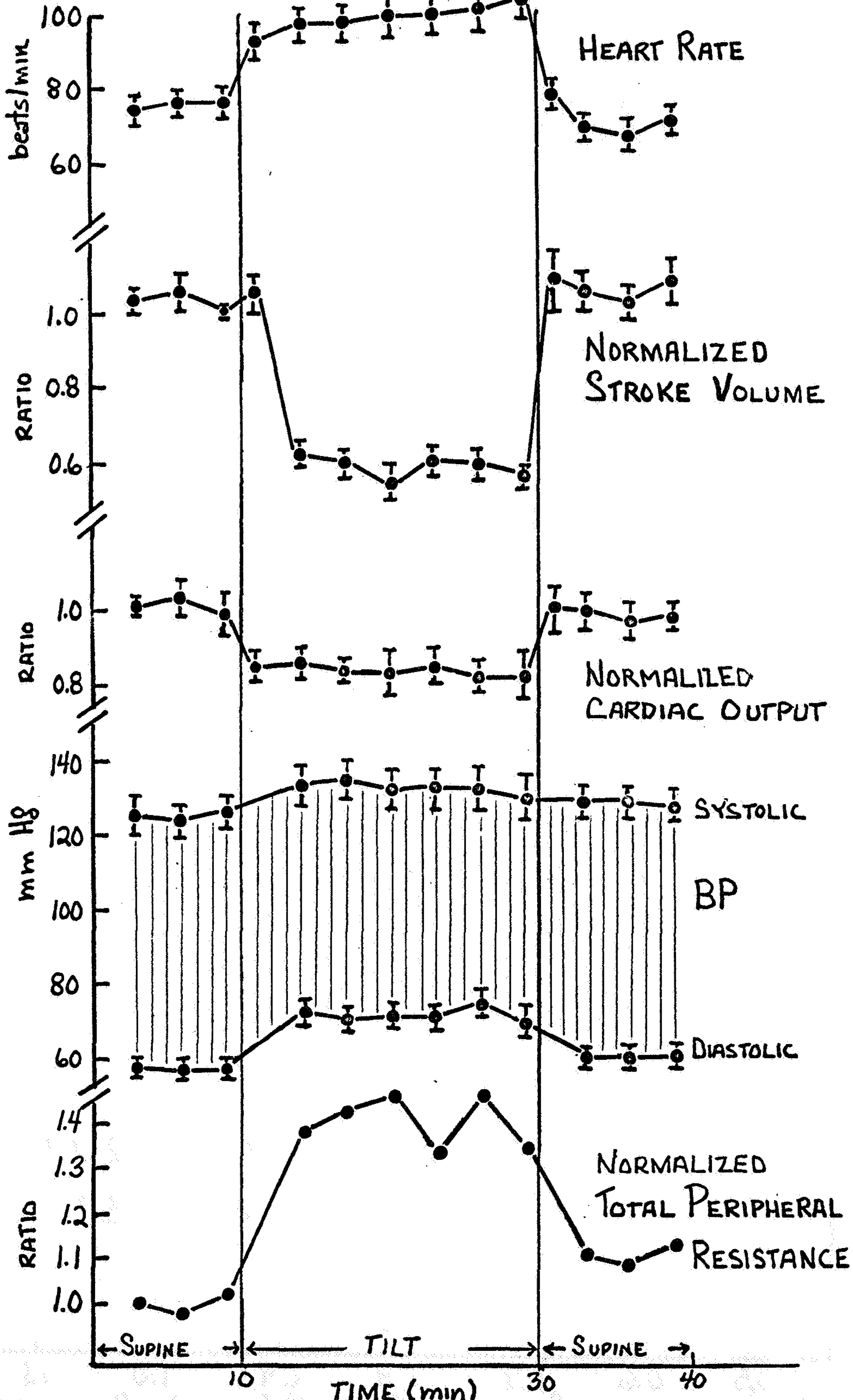

Fig. 7. Cardiovascular Responses to Vertical Tilt with Hip Suspension (Mean values with S.E. for 12 experiments in 8 males)

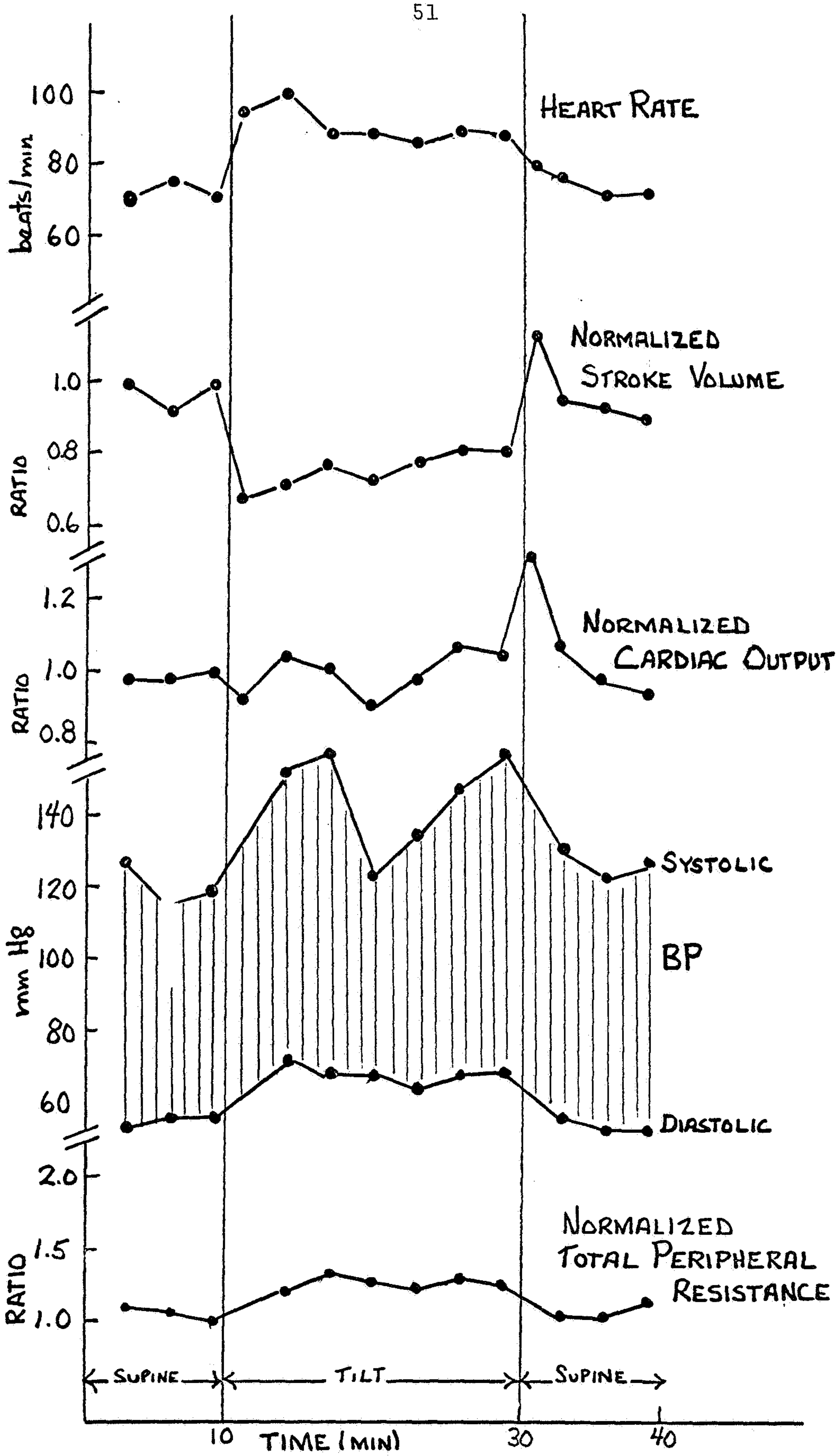

Fig. 8. Cardiovascular Responses to Vertical Tilt with Hip Suspension (Subject: M.Bo.)

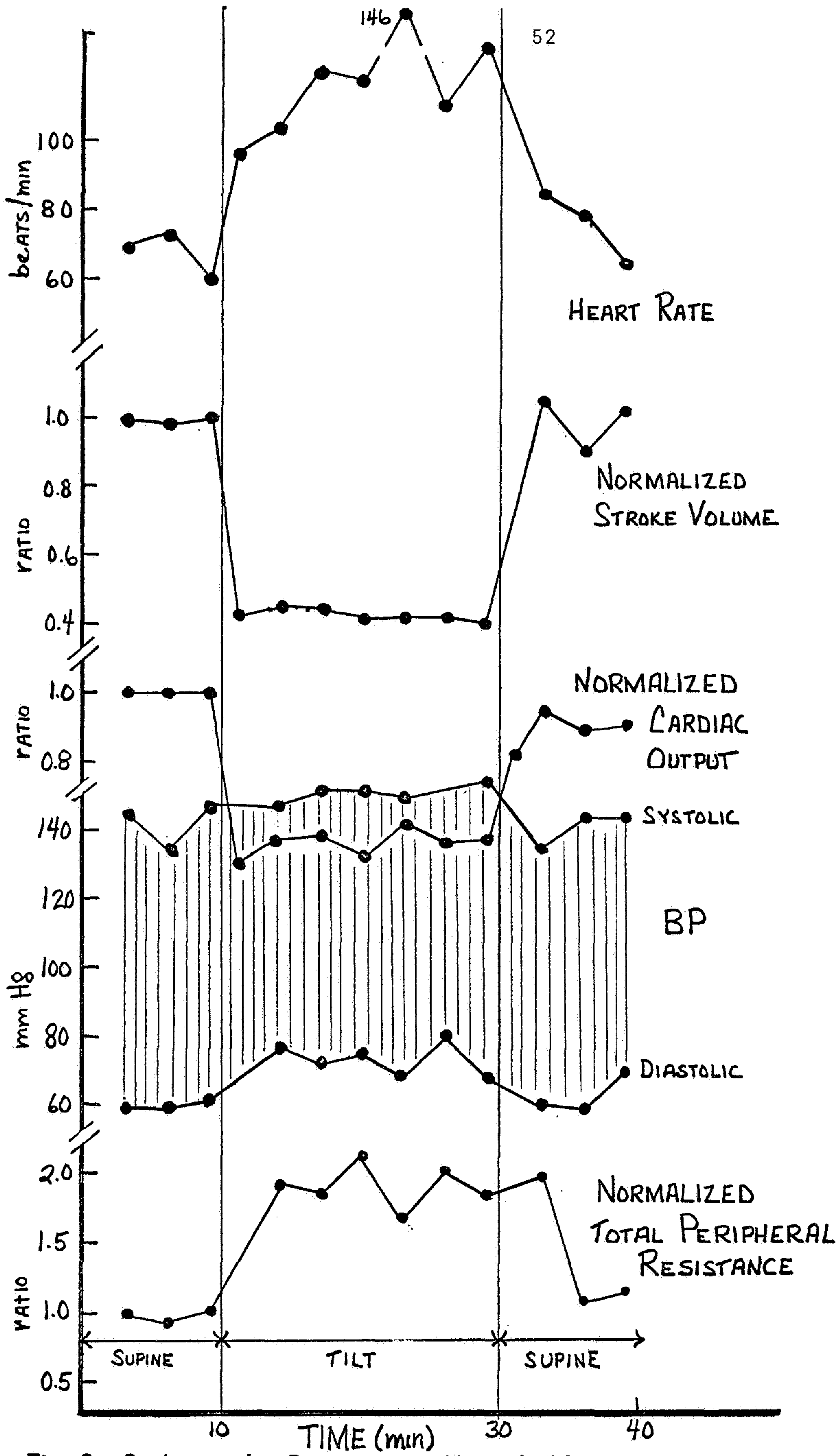

Fig. 9. Cardiovascular Responses to Vertical Tilt with Hip Suspension (Subject: J. Ki.)

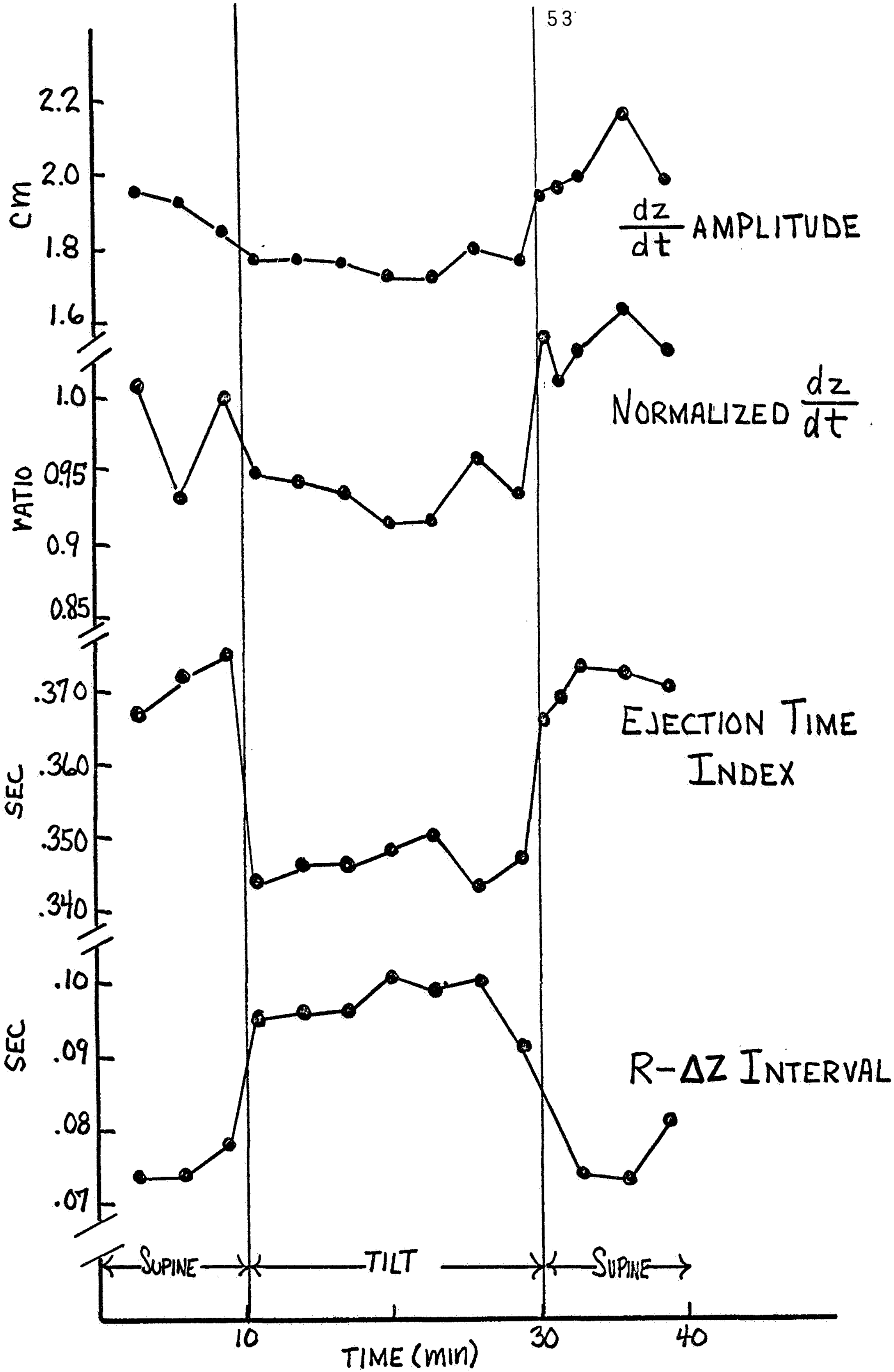

Fig. 10. Auxiliary Cardiovascular Values Derived from Impedance Data (Mean values of 12 experiments in 8 normal male subjects)

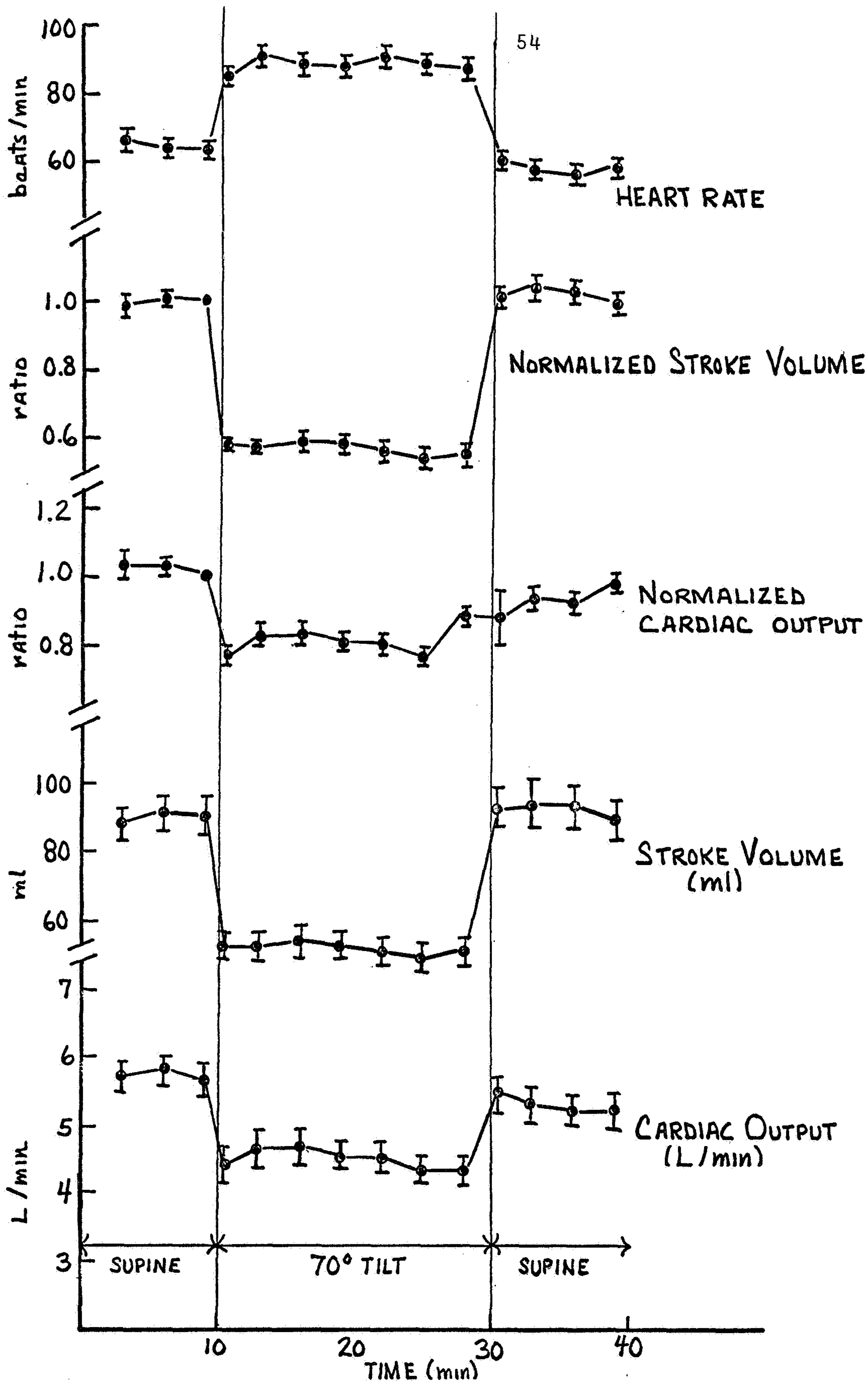

Fig. 11. Stroke Volume and Cardiac Output Responses to Head-up Tilt. Body Weight Supported by Footboard (Mean Values with S.E. for 11 Normal Male Subjects)

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

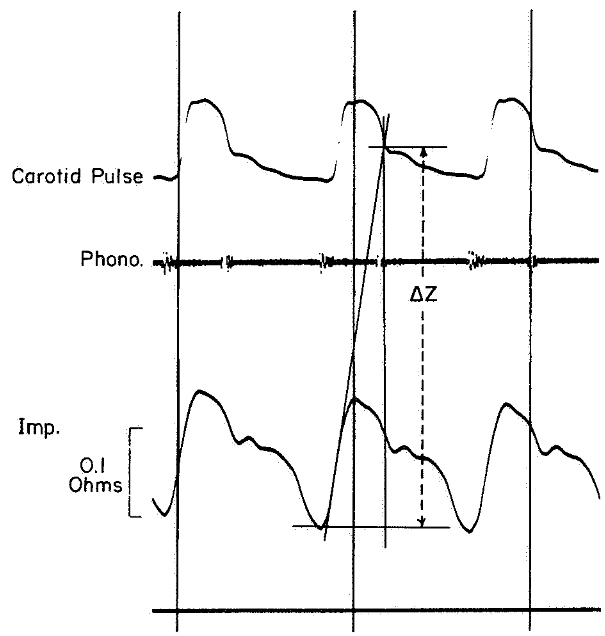

Fig. 1. From the top downwards, the carotid arterial pressure pulse, phonocardiogram and impedance signal (an upward deflection denotes a decrease in thoracic impedance). The initial upward slope is extrapolated as far as the pulmonic component of the second heart sound. The total height of this slope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

*Shure Brothers, Inc., Evanston, Illinois.

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 × indicator dilution cardiac output L/min (± 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.

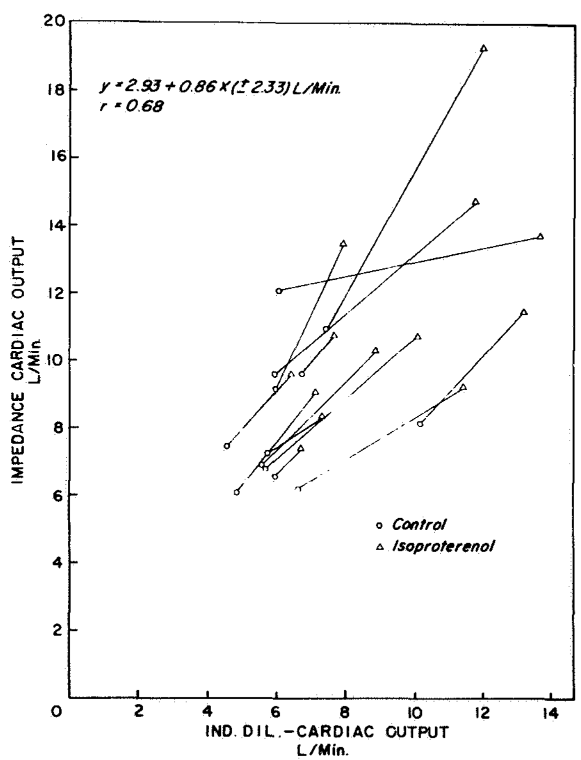

Fig. 2. Comparison of cardiac output values given by impedance plethysmography with those obtained by indicator dilution technique in thirteen healthy subjects before and after an infusion of isoproterenol.

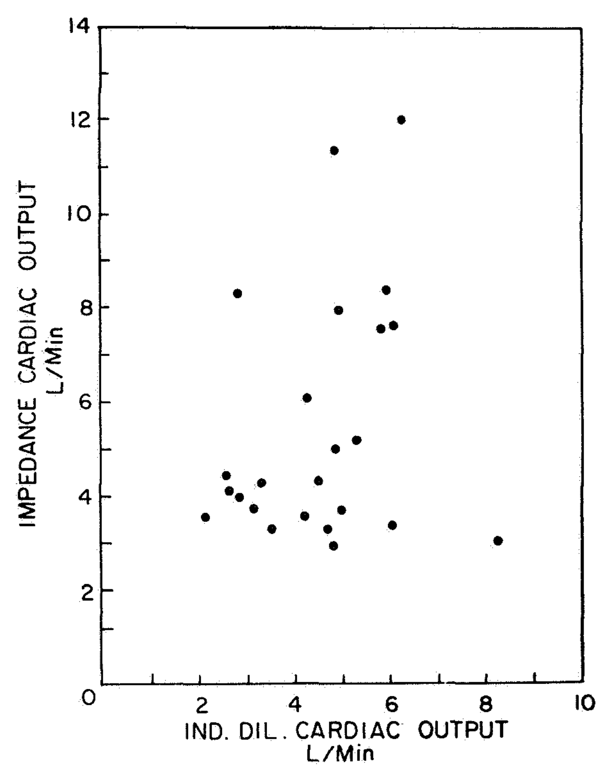

Fig. 3. Comparison of cardiac output computed by impedance plethysmography with that obtained by indicator dilution technique in the twenty-four patients with heart disease listed in Table I.

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.

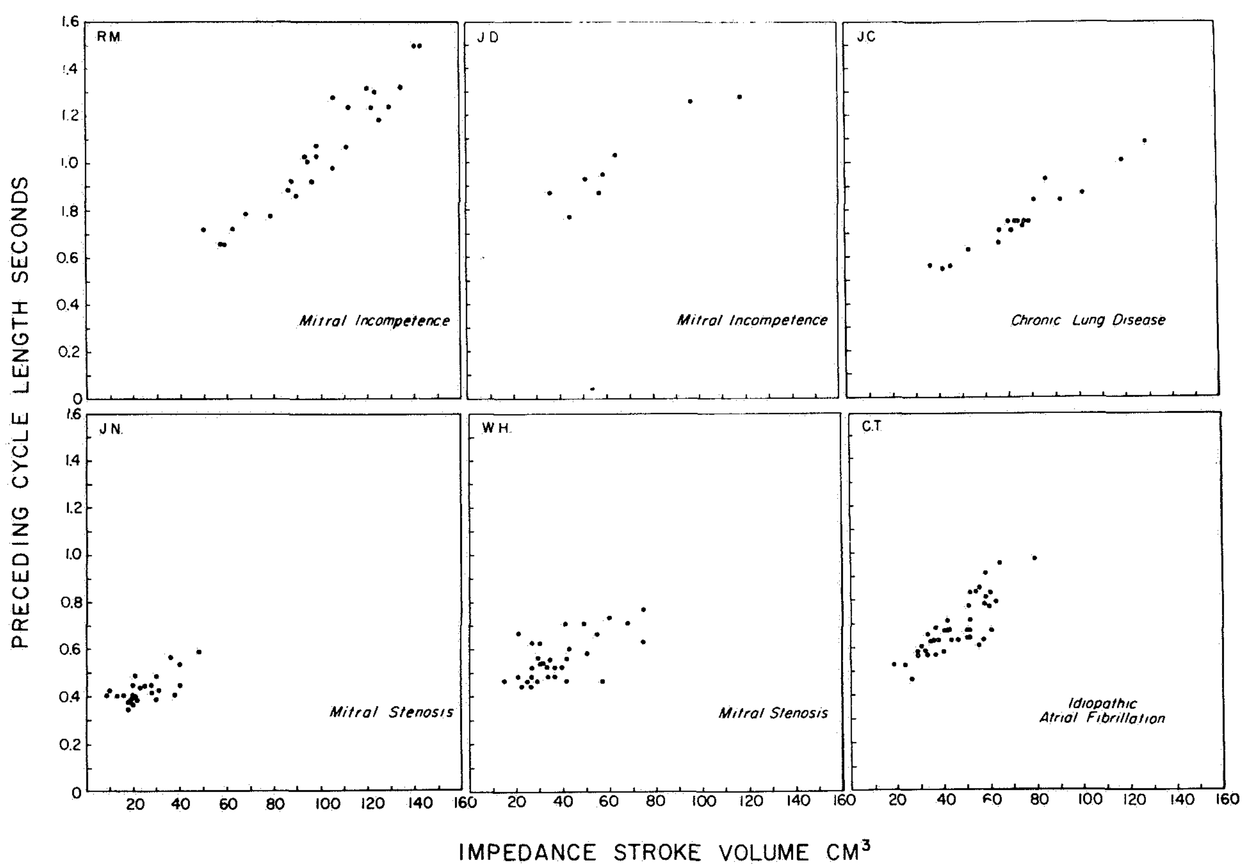

Fig. 4. Correlation of impedance stroke volume with the preceding cycle length for individual beats in six patients with atrial fibrillation.

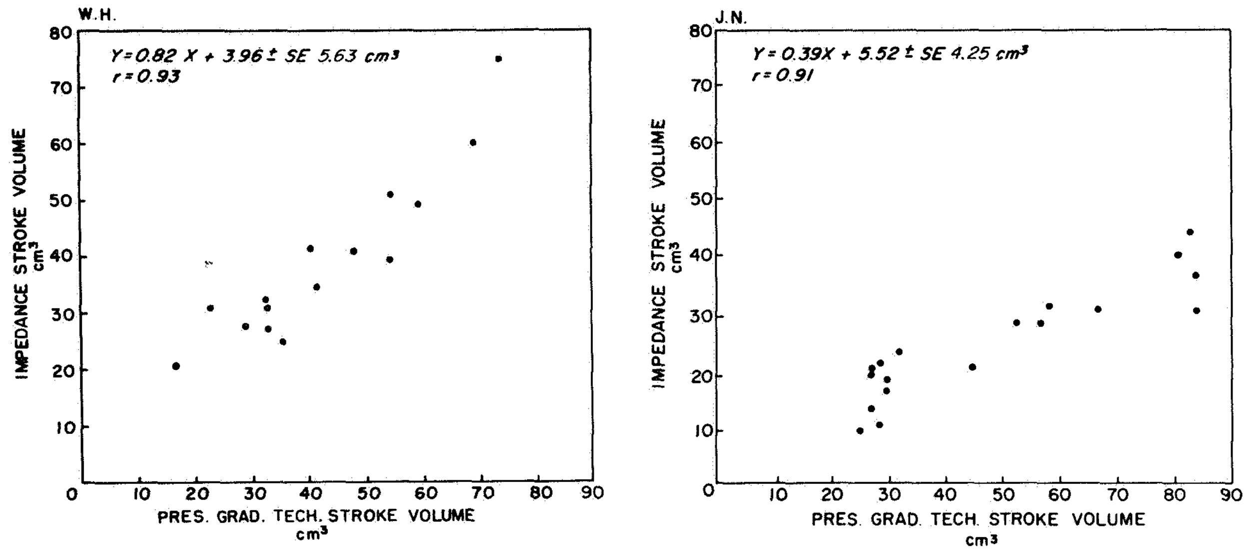

Fig. 5. Comparison of stroke volume for individual beats obtained by impedance plethysmography with those obtained for the same beats by the pressure gradient technique in two patients with pure mitral stenosis and atrial fibrillation.

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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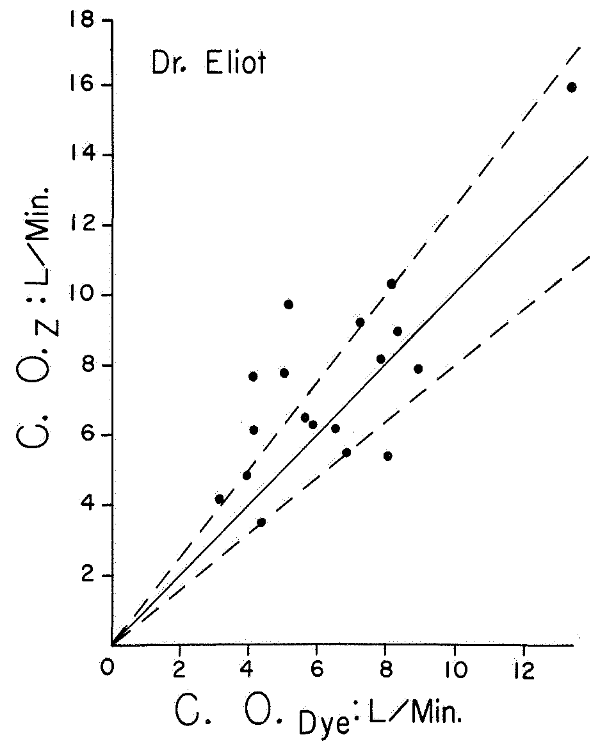


Fig. II-3 Uncorrected values of cardiac output

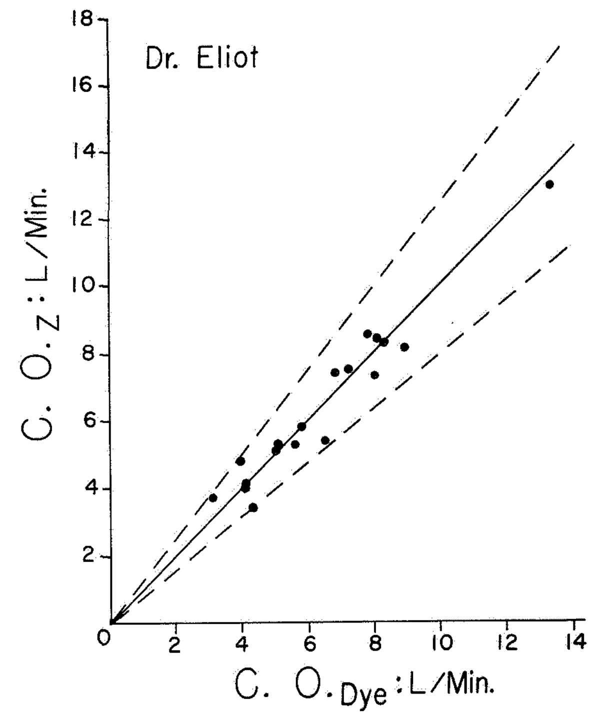


Fig. II-4 Corrected Impedance values of cardiac output plotted against the original values of cardiac output by the Dye method

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, atrial septal defect	control	5.6	6.5	1.16	
		Isuprel	7.2	9.2	1.28	(1.22)
5	Idiopathic myocardopathy severe failure	control	3.1	4.2	1.36	
		Isuprel	6.5	6.2	0.95	(1.15)
6	post op. coarctation of aorta	control	7.8	8.2	1.05	
		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 disease	control	6.8	5.5	0.81	
		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

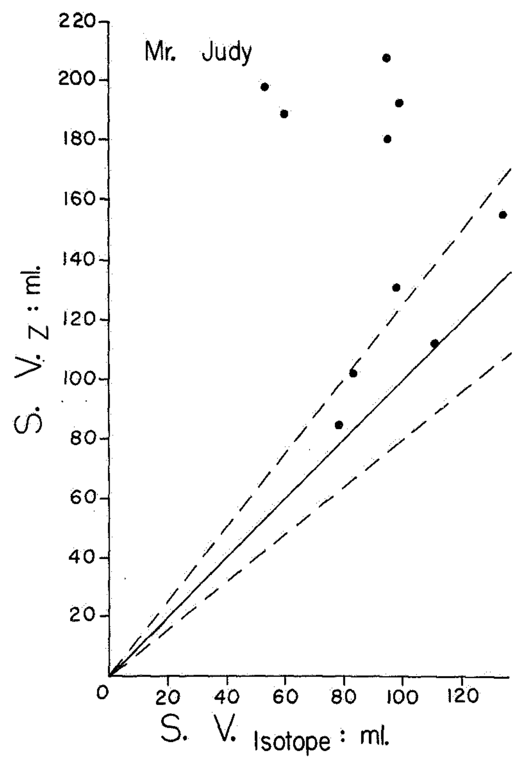


Fig. II-5 Stroke volume values obtained by the Impedance method and the Isotope dilution technique

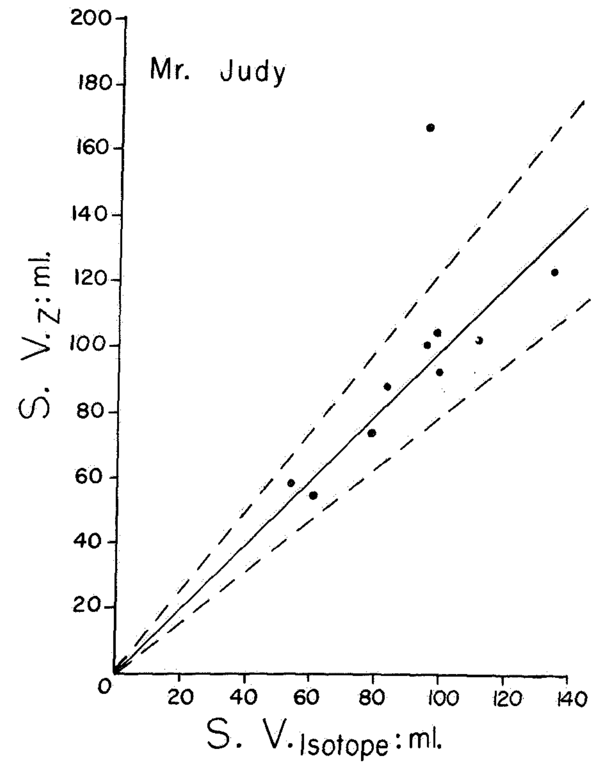


Fig. II-6 Corrected values of stroke volume by the Impedance method plotted against the original values obtained by the Isotope dilution technique

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

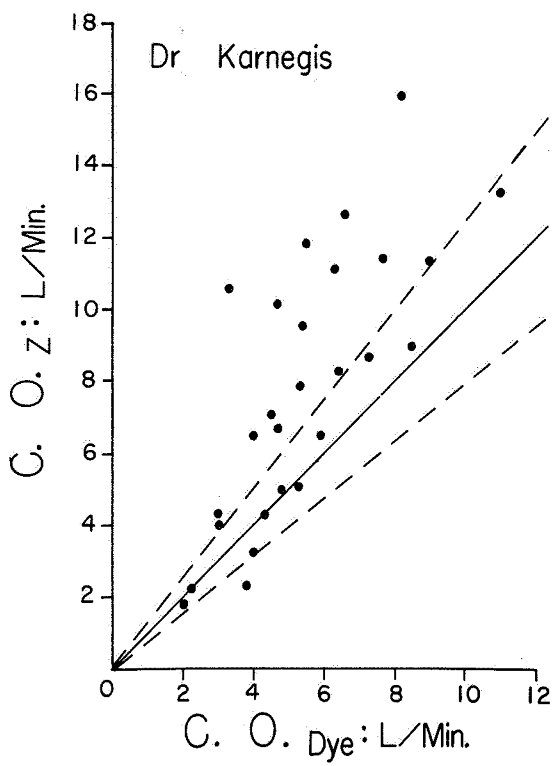


Fig. II-7 A graph of cardiac output values obtained by the Impedance and Dye dilution techniques

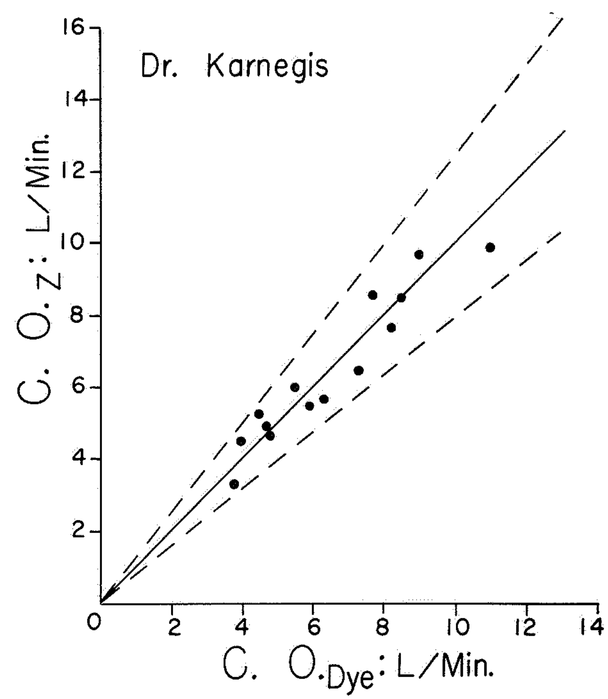


Fig. II-8 A graph of corrected values of cardiac output by the Impedance method plotted against the original values by the Dye method

TABLE II-3 (Karnegis)

PATIENT	DIAGNOSIS	PROCEDURE	$C.O._F$	$C.O._{DYE}$	$C.O._Z$	Z/DYE	
A.N.	mild M.S.	rest	10.0	7.7	11.5	1.49	
		exercise		11.0	13.3	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	6.8	5.9	6.5	1.10	
		exercise		9.0	11.4	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

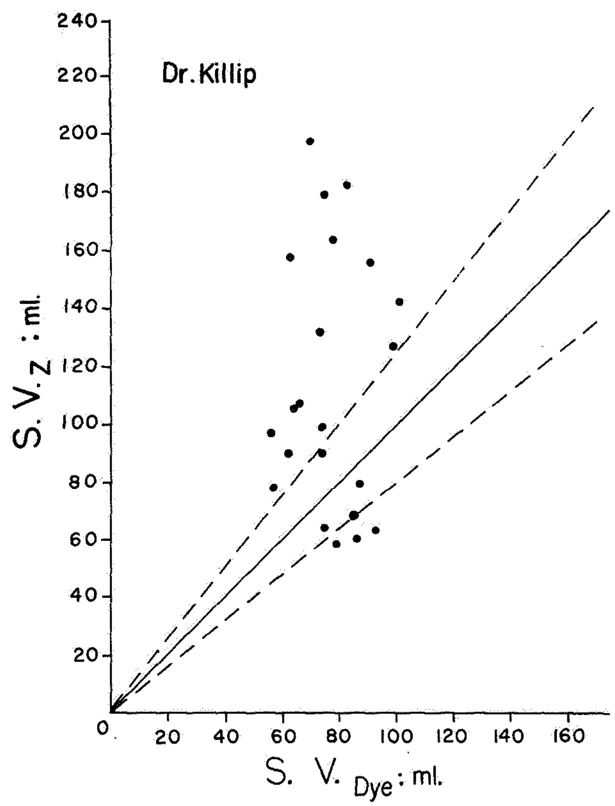


Fig. II-9 A plot of stroke volume values obtained by the Impedance and Dye dilution methods

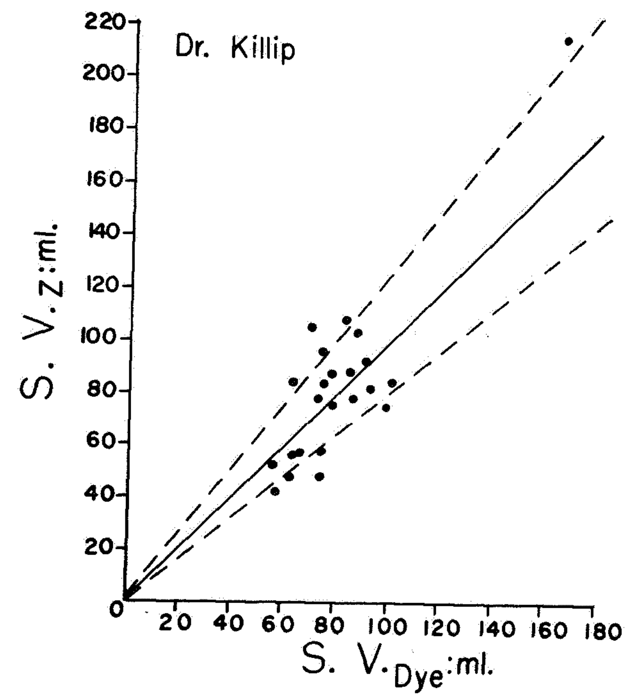


Fig. II-10 A graph of corrected Impedance stroke volume values plotted against the original values obtained by the Dye dilution technique

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

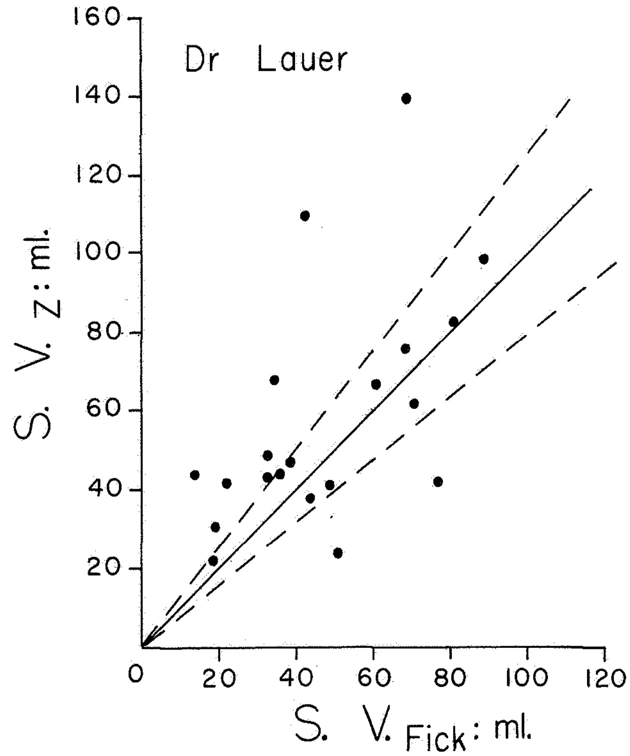


Fig. II-11 A plot of stroke volume values obtained by the Impedance and Fick methods

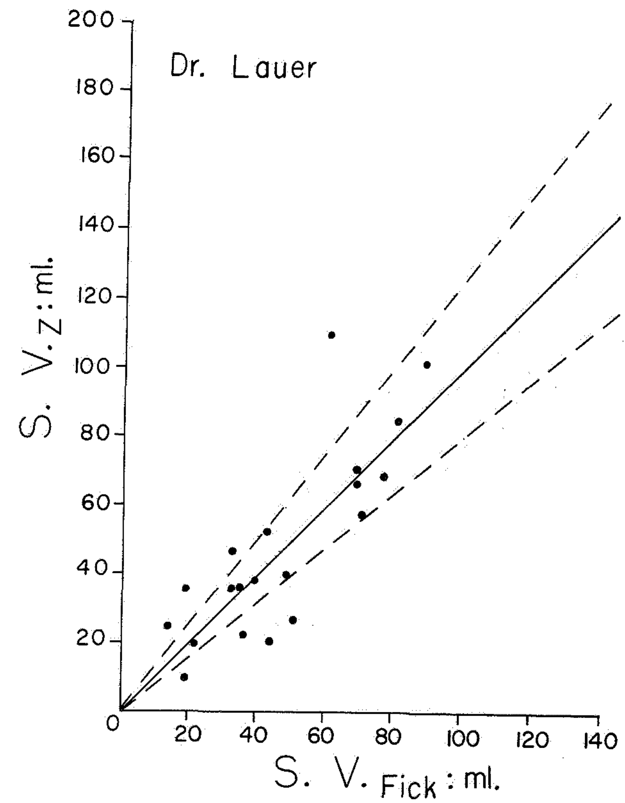


Fig. II-12 A graph of corrected Impedance stroke volume values plotted against the original values obtained by the Fick method

TABLE II-5

(Lauer)

Patient	Age	Sex	Diagnosis	State	FICK METHOD Stroke Vol.	C.O.	H.R.	IMPEDANCE METHOD Stroke Vol.	C.O.	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

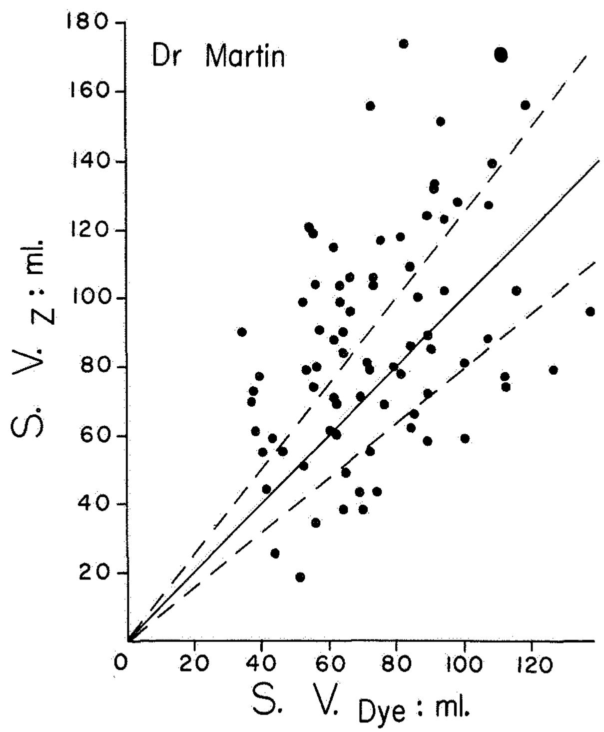


Fig. II-13 A graph of stroke volume values obtained by the Impedance and Dye dilution techniques

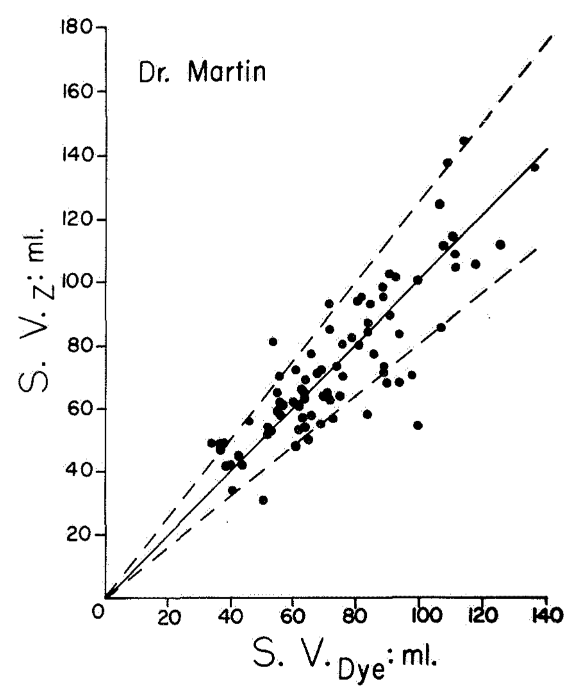


Fig. II-14 A graph of corrected Impedance stroke volume values plotted against the original values obtained by the Dye method

(Martin)

TABLE II-6

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)

(Martin)

TABLE II-6 cont'd

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

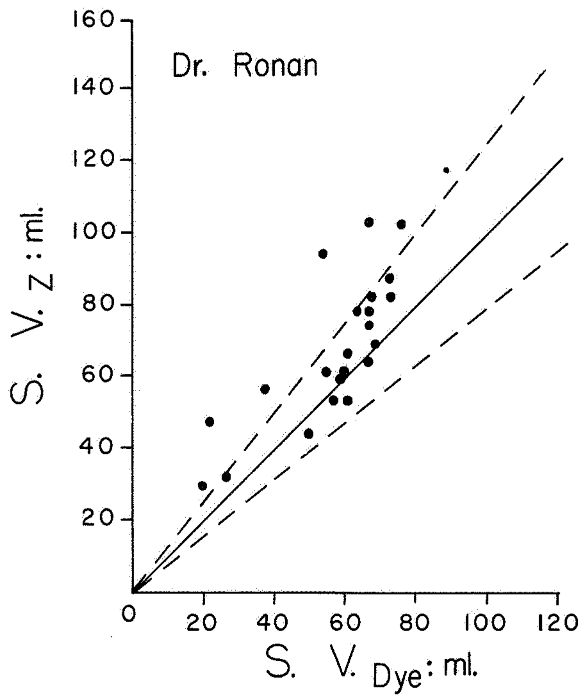


Fig. II-15 A graph of stroke volume values obtained by the Impedance and Dye dilution methods

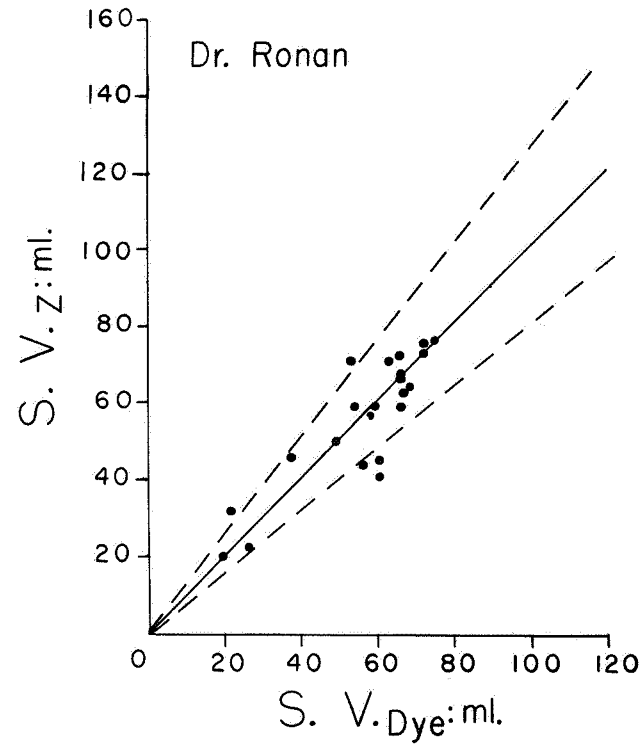


Fig. II-16 A graph of corrected Impedance stroke volume values plotted against the original values by the Dye method

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

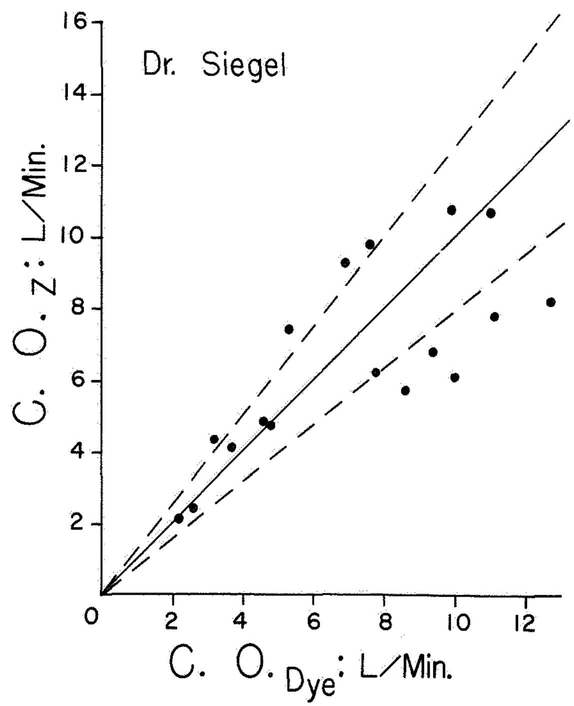


Fig. II-17 A graph of cardiac output values obtained by the Impedance and Dye dilution techniques

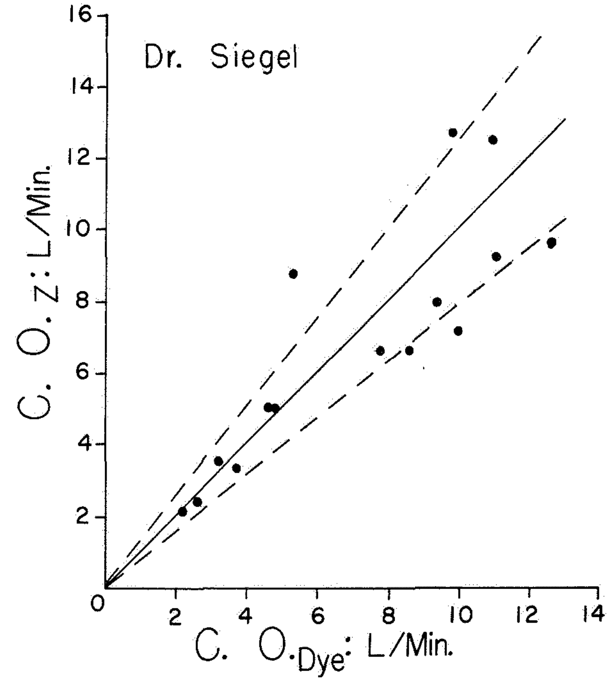


Fig. II-18 A graph of corrected Impedance cardiac output values plotted against the original values by the Dye method

<u>TABLE II-8</u> (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

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

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

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

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

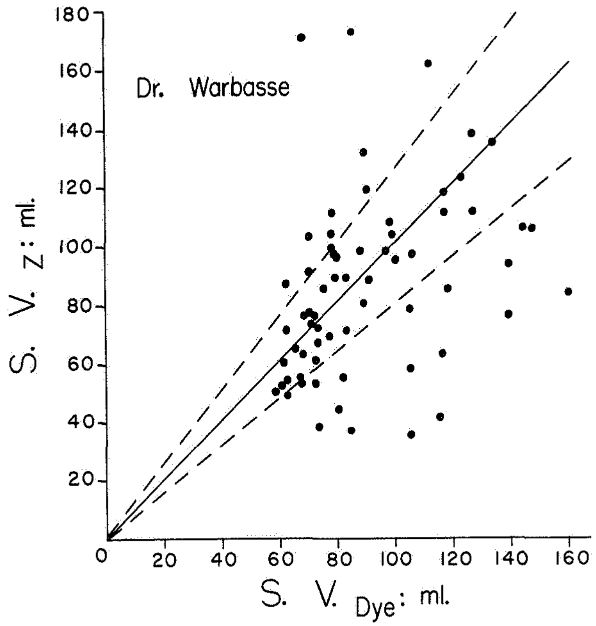


Fig. II-19 A graph of stroke volume values obtained by the Impedance and Dye dilution methods

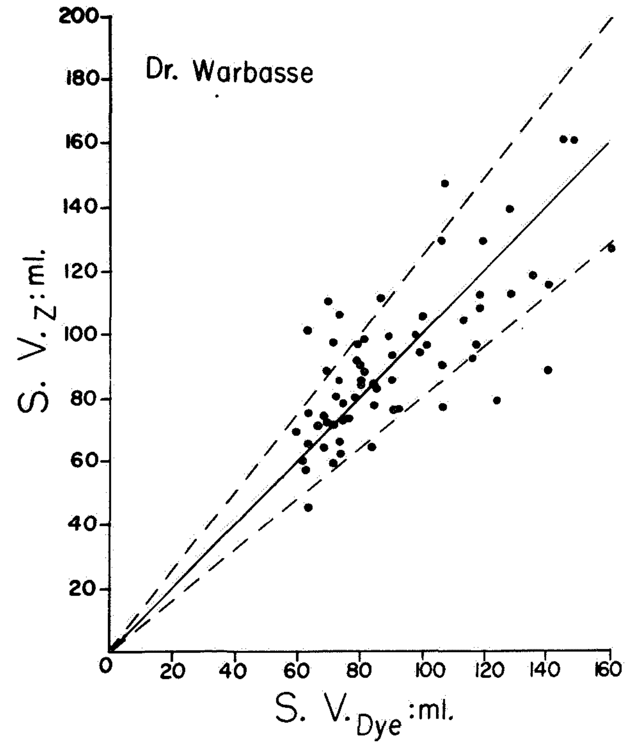


Fig. II-20 A graph of the corrected Impedance stroke volume values plotted against the original values obtained by the Dye dilution method

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						

(Warbasse)

TABLE II-10

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						

TABLE II-10 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			
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
3	R.F.	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		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 #	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			
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						

TABLE II-12 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
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
		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.									
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			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			
6	L.T.									
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					
		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
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
8	J.P.	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		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
8	J.P.	Impedance Stroke Volume	Impedance Cardiac Output L/Min	% of Error vs Dye	Impedance Stroke Volume	Impedance Cardiac Output L/Min	% of Error vs Dye			
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						

(Warbasse)

TABLE II-18

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 (Average column, subjects 1–10)

s = .08 (Average row)

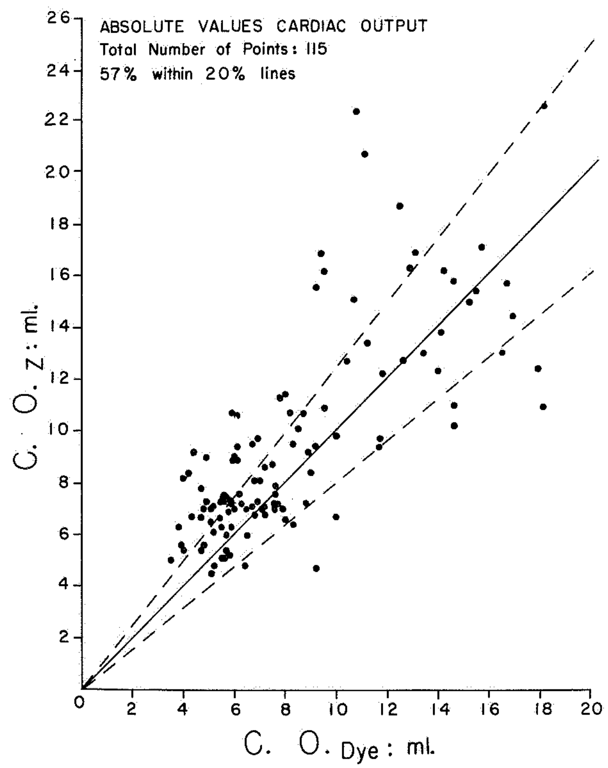


Fig. II-21 Absolute values of cardiac output by the Impedance and Dye dilution methods

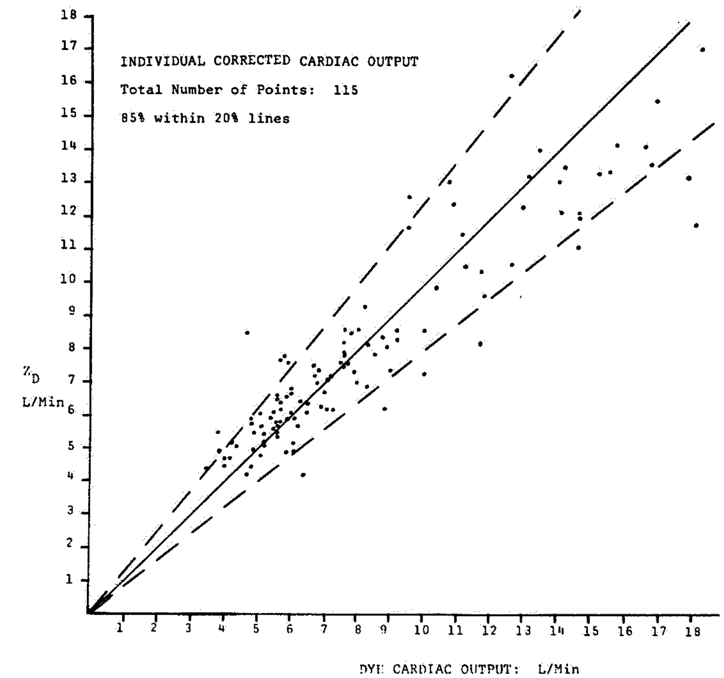


Fig. II-22 Individual corrected Impedance cardiac output values plotted against the original values by the Dye method. Kubicek et al., Aerospace Medicine Vol. 37, No. 12 Dec. 1966.

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.

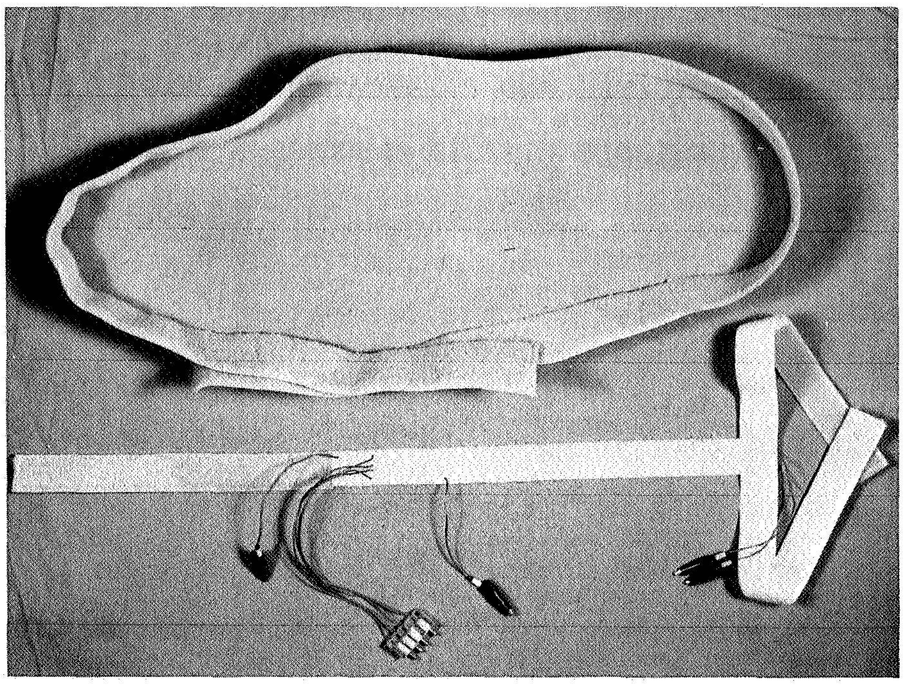


Fig. 1 Wire carrier and belt

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.

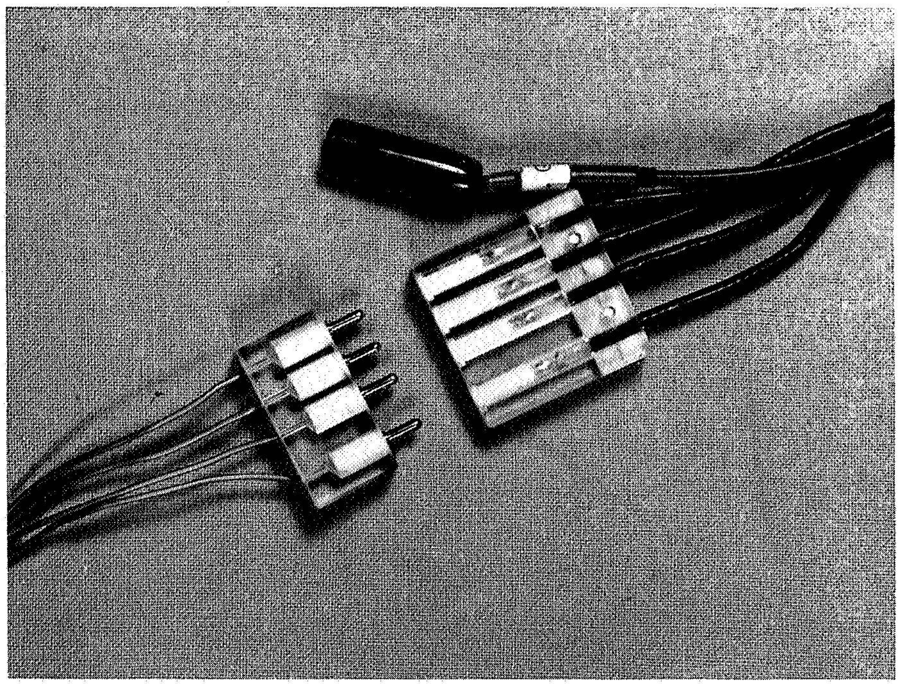


Fig. 2 Cable to harness connector

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.

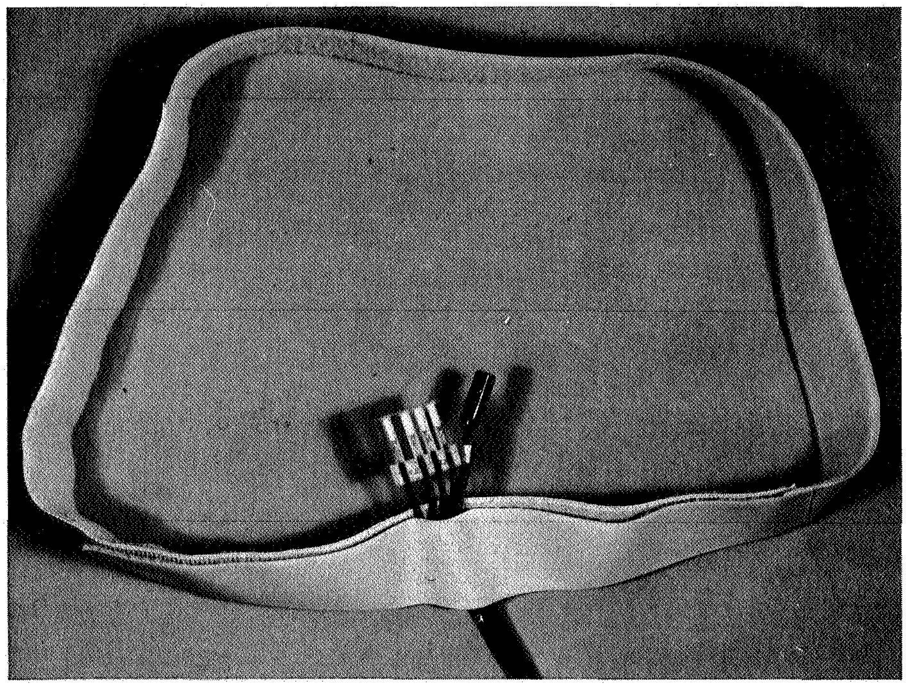


Fig. 3 Strain relief of cable by use of belt

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.

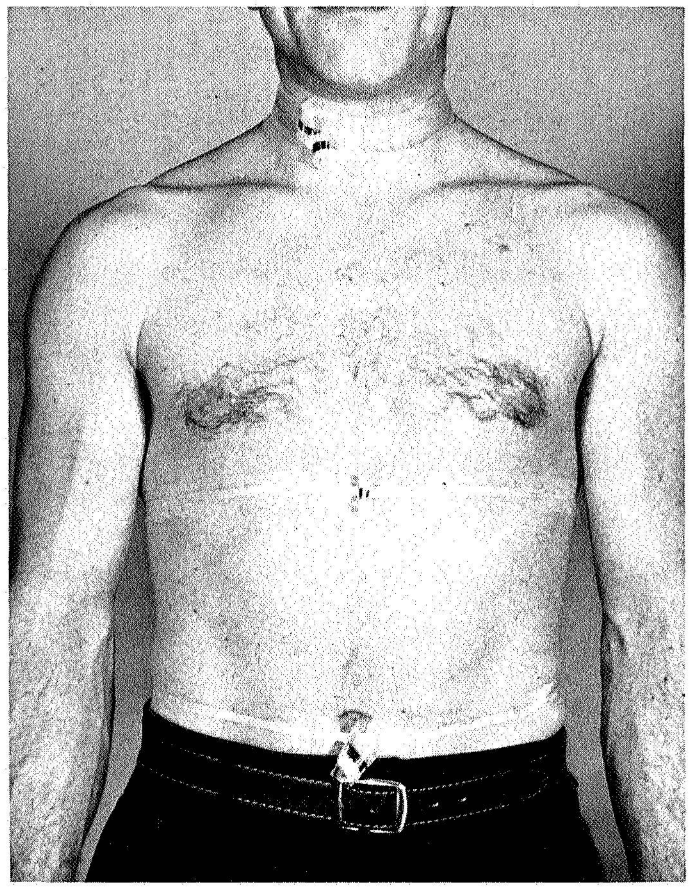


Fig. 4 Disposable electrodes in place

<u>Harness</u> - 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.

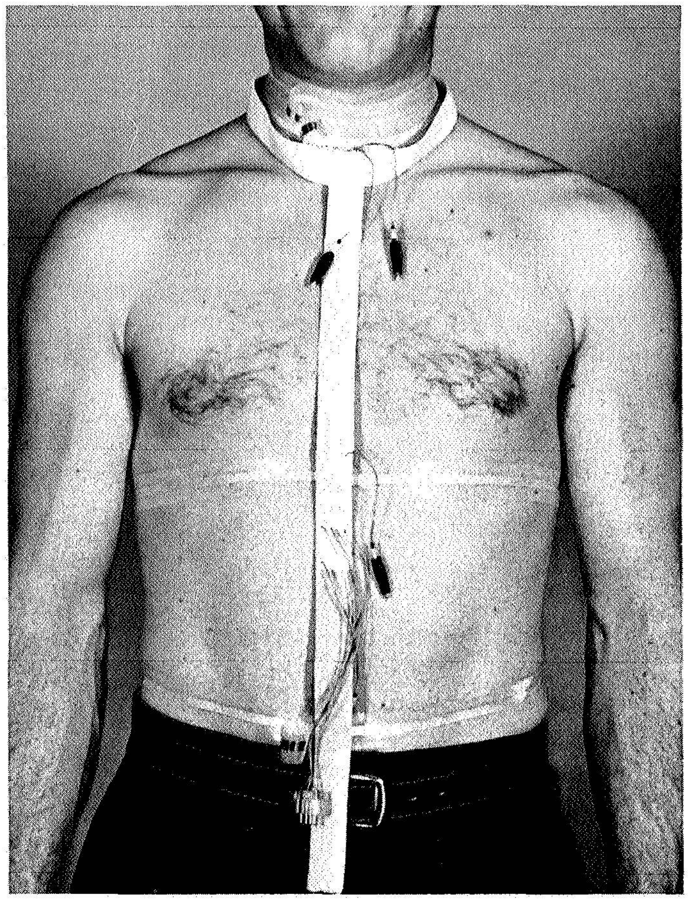


Fig. 5 Wire carrier on subject

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.

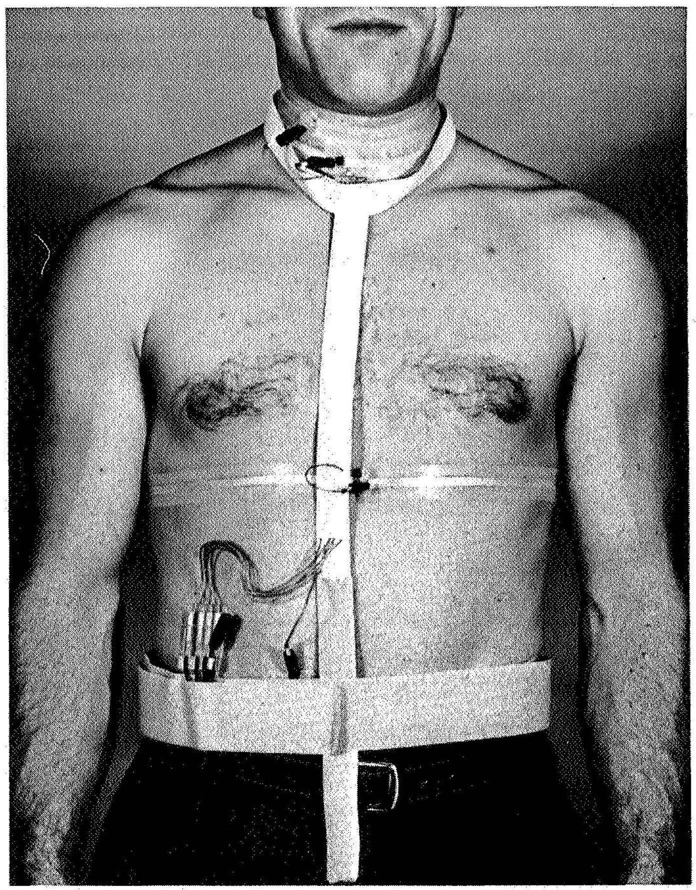


Fig. 6 Complete harness arrangement on subject

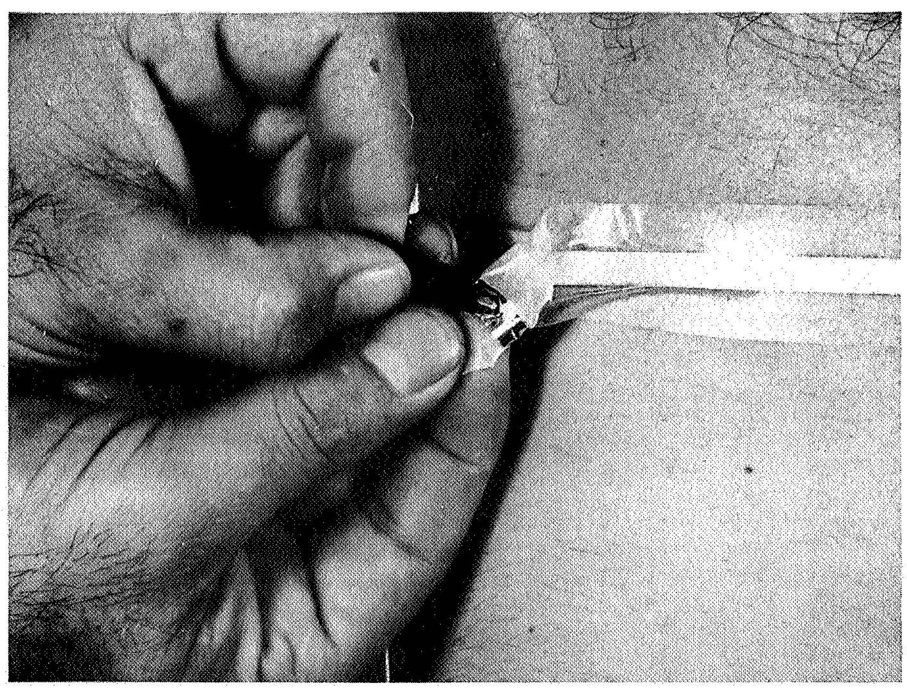


Fig. 7 Fastening of clip leads from wire carrier to electrode

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)

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

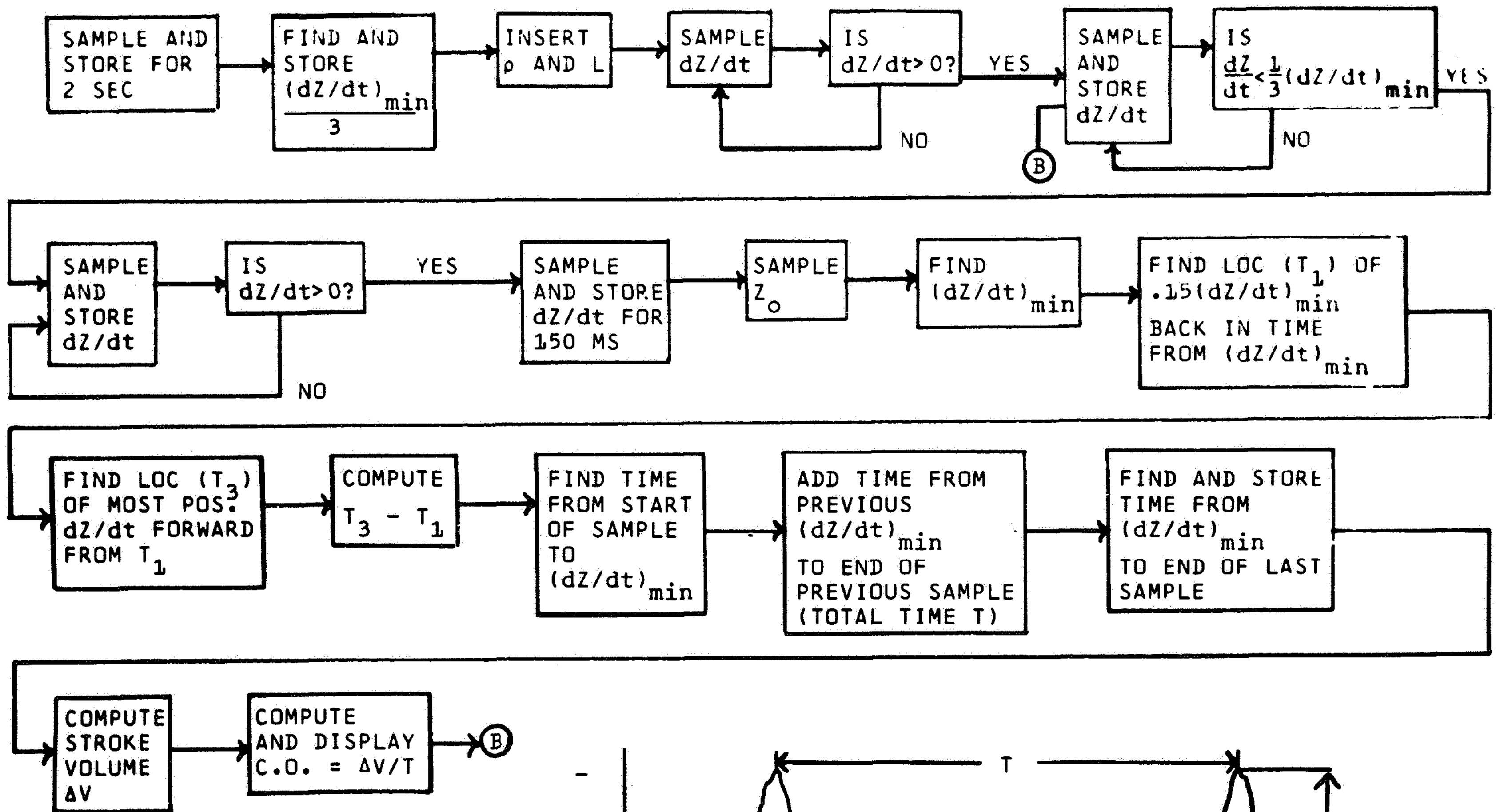
T = the time interval between heart beats in minutes

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



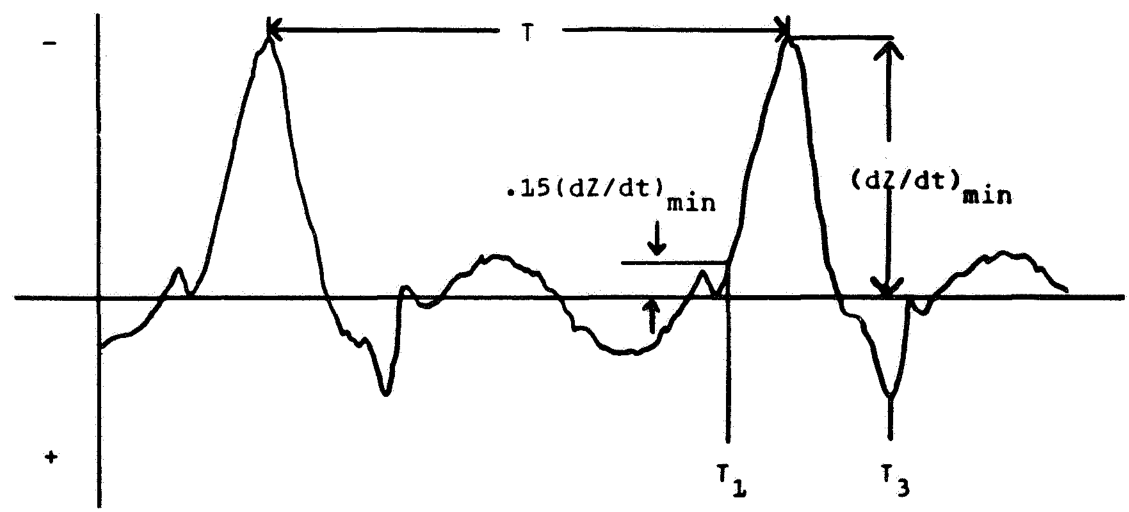


FIG. 1 SIMPLIFIED BLOCK DIAGRAM AND SAMPLE dz/dt WAVEFORM

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.

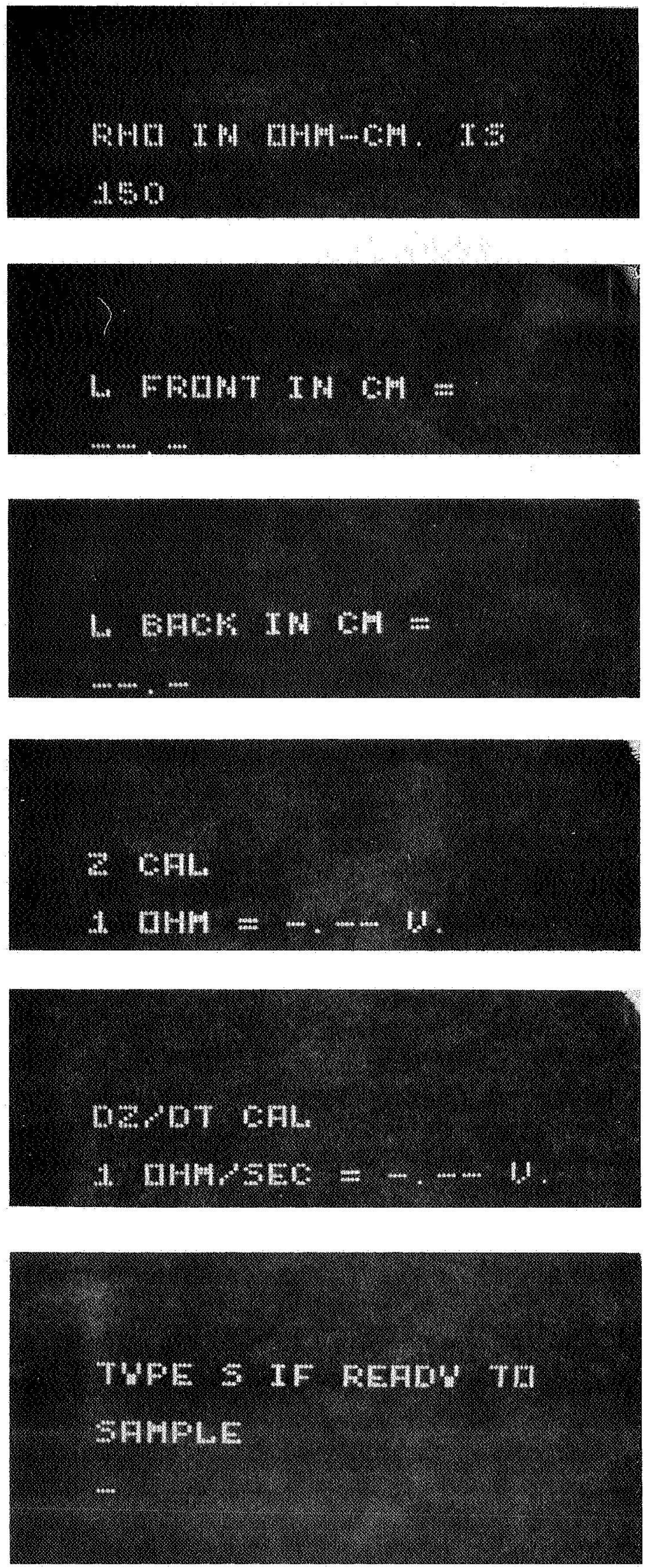


Fig. 2 Constants and Calibration factors as shown in input displays

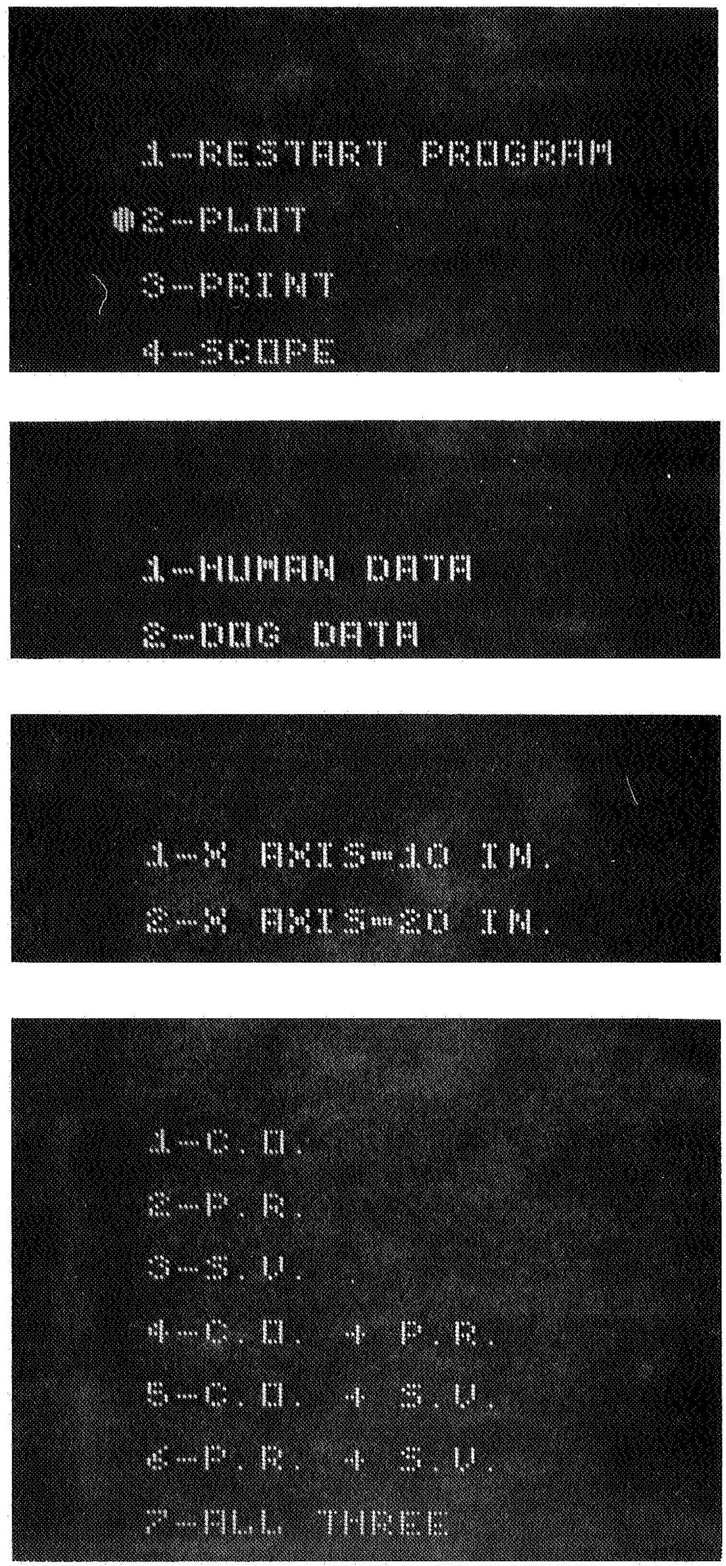


Fig. 3 Plotting option displays

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.

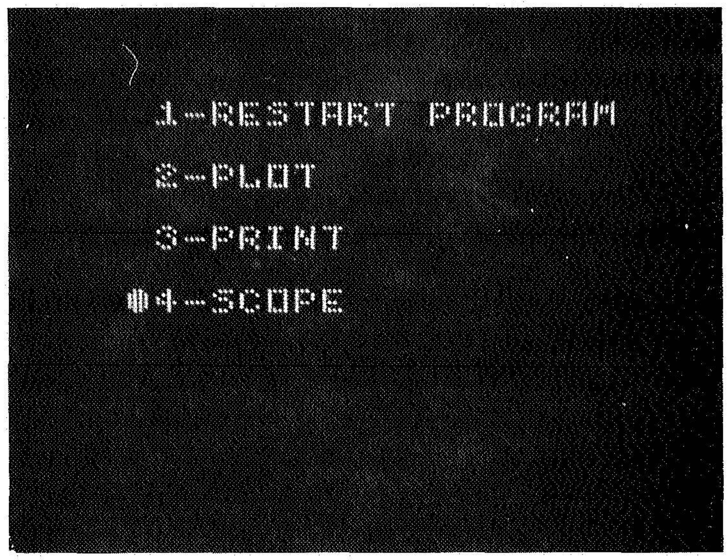
The next option (number 3) is for printing the results on the digital printer. The values for the cardiac output, stroke volume and pulse rate are automatically printed after selecting this option. The four beat averages, and the four beat averages normalized to the first average are printed for all 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



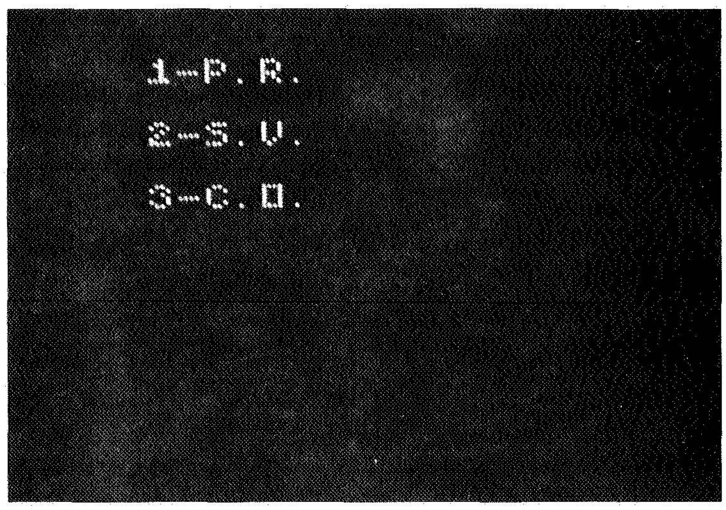


Fig. 4 Oscilloscope display option

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.

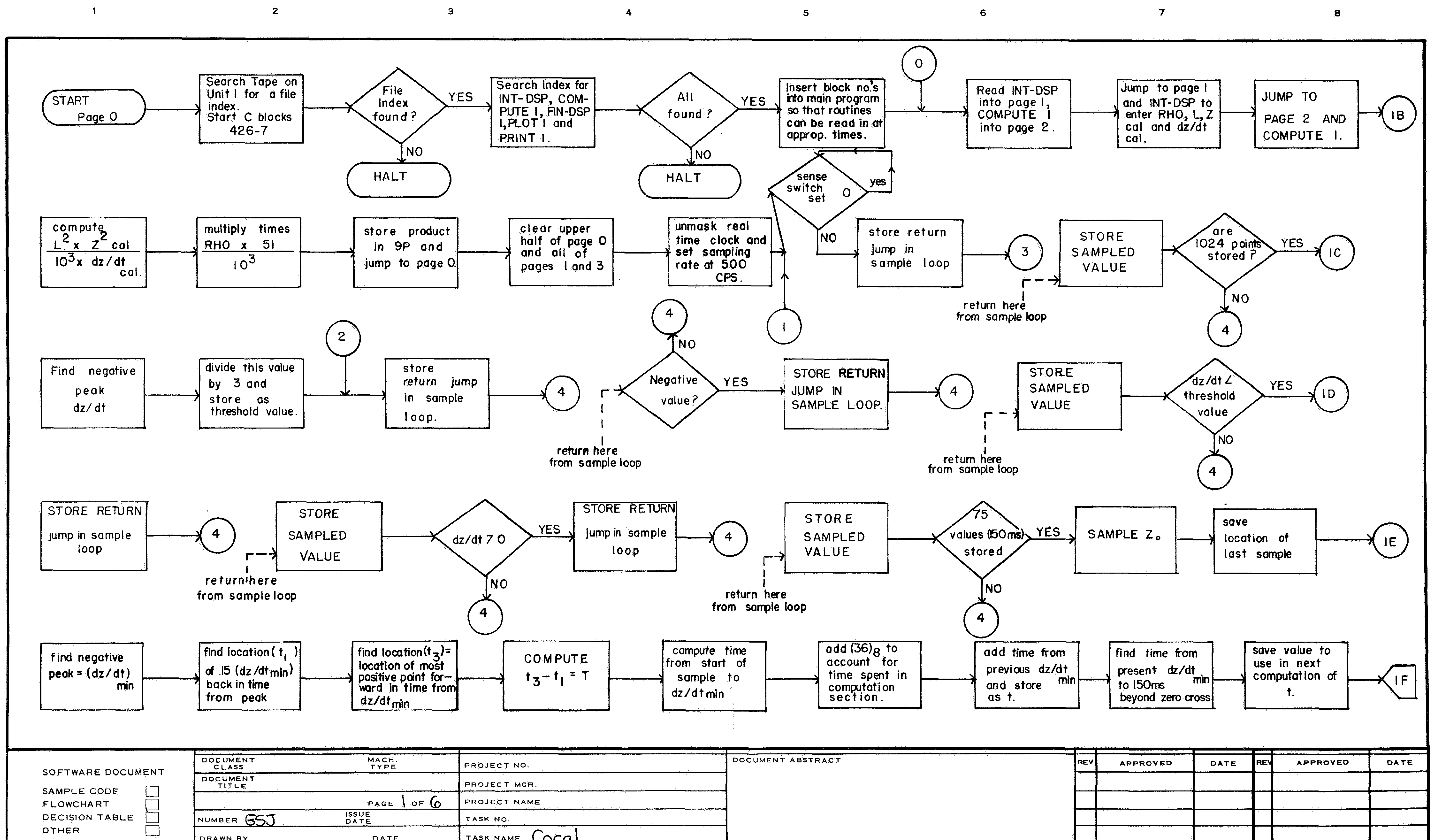
FIN-DSP1 - this program generates the final display routines that are used to choose the options for printing, plotting or oscilloscope display.

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.


START Page 0
Search Tape on Unit I for a file index. Start C blocks 426-7
File Index found?
YES
NO
HALT
Search index for INT-DSP, COMPUTE I, FIN-DSP I, PLOT I and PRINT I.
All found?
HALT
Insert block no.'s into main program so that routines can be read in at approp. times.
0
Read INT-DSP into page I, COMPUTE I into page 2.
Jump to page I and INT-DSP to enter RHO, L, Z cal and dz/dt cal.
JUMP TO PAGE 2 AND COMPUTE I.
IB
compute L² x Z² cal / 10³ x dz/dt cal.
multiply times RHO x 51 / 10³
store product in 9P and jump to page 0.
clear upper half of page 0 and all of pages I and 3
unmask real time clock and set sampling rate at 500 CPS.
sense switch 0 set
yes
NO
I
store return jump in sample loop
3
return here from sample loop
STORE SAMPLED VALUE
are 1024 points stored?
IC
4
Find negative peak dz/dt
divide this value by 3 and store as threshold value.
2
store return jump in sample loop.
Negative value?
STORE RETURN JUMP IN SAMPLE LOOP.
dz/dt ∠ threshold value
ID
STORE RETURN jump in sample loop
STORE SAMPLED VALUE
dz/dt 7 0
STORE RETURN jump in sample loop
75 values (150ms) stored
SAMPLE Z₀
save location of last sample
IE
find negative peak = (dz/dt) min
find location (t₁) of .15 (dz/dt min) back in time from peak
find location (t₃) = location of most positive point forward in time from dz/dt min
COMPUTE t₃ - t₁ = T
compute time from start of sample to dz/dt min
add (36)₈ to account for time spent in computation section.
add time from previous dz/dt min and store as t.
find time from present dz/dt min to 150ms beyond zero cross
save value to use in next computation of t.
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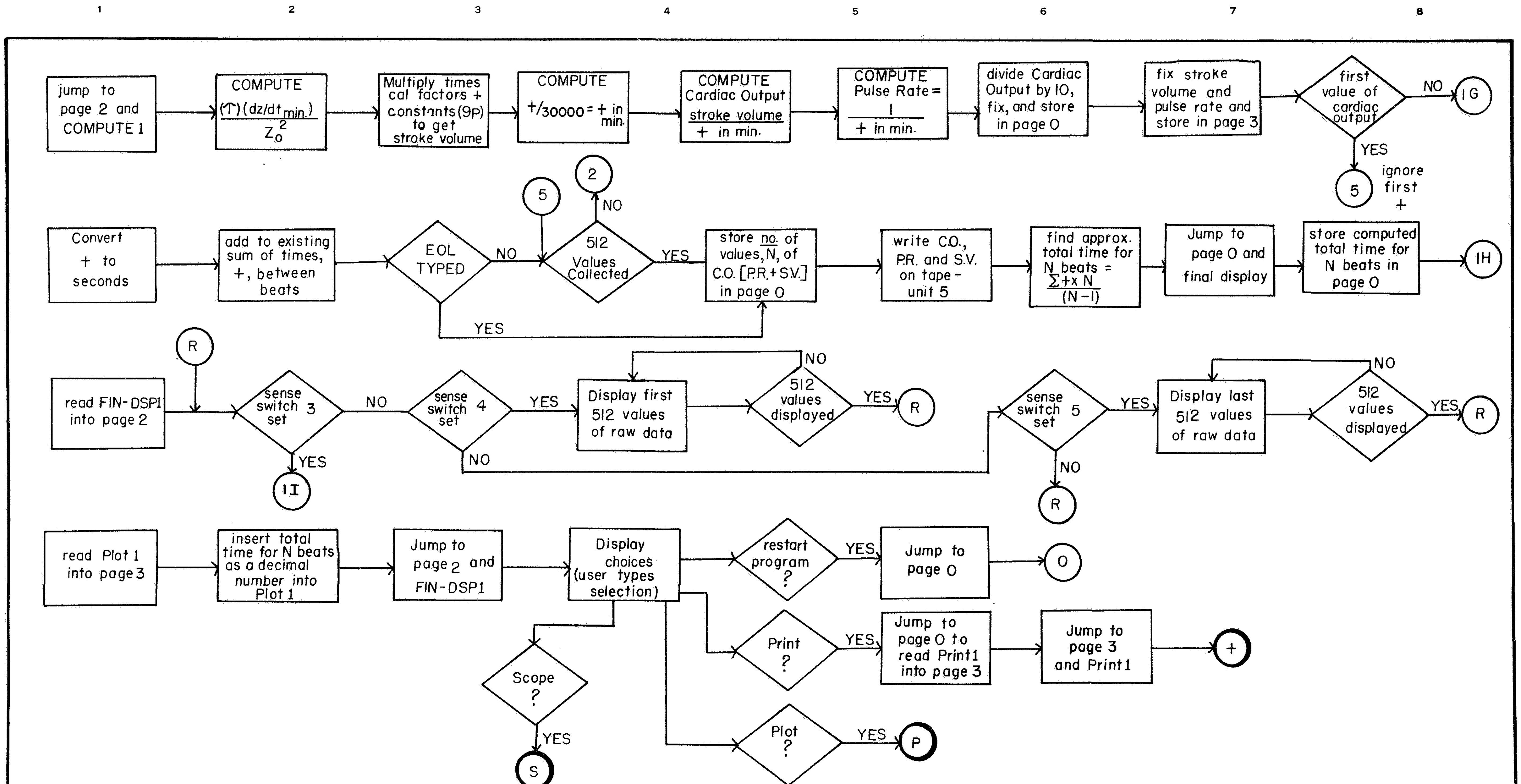

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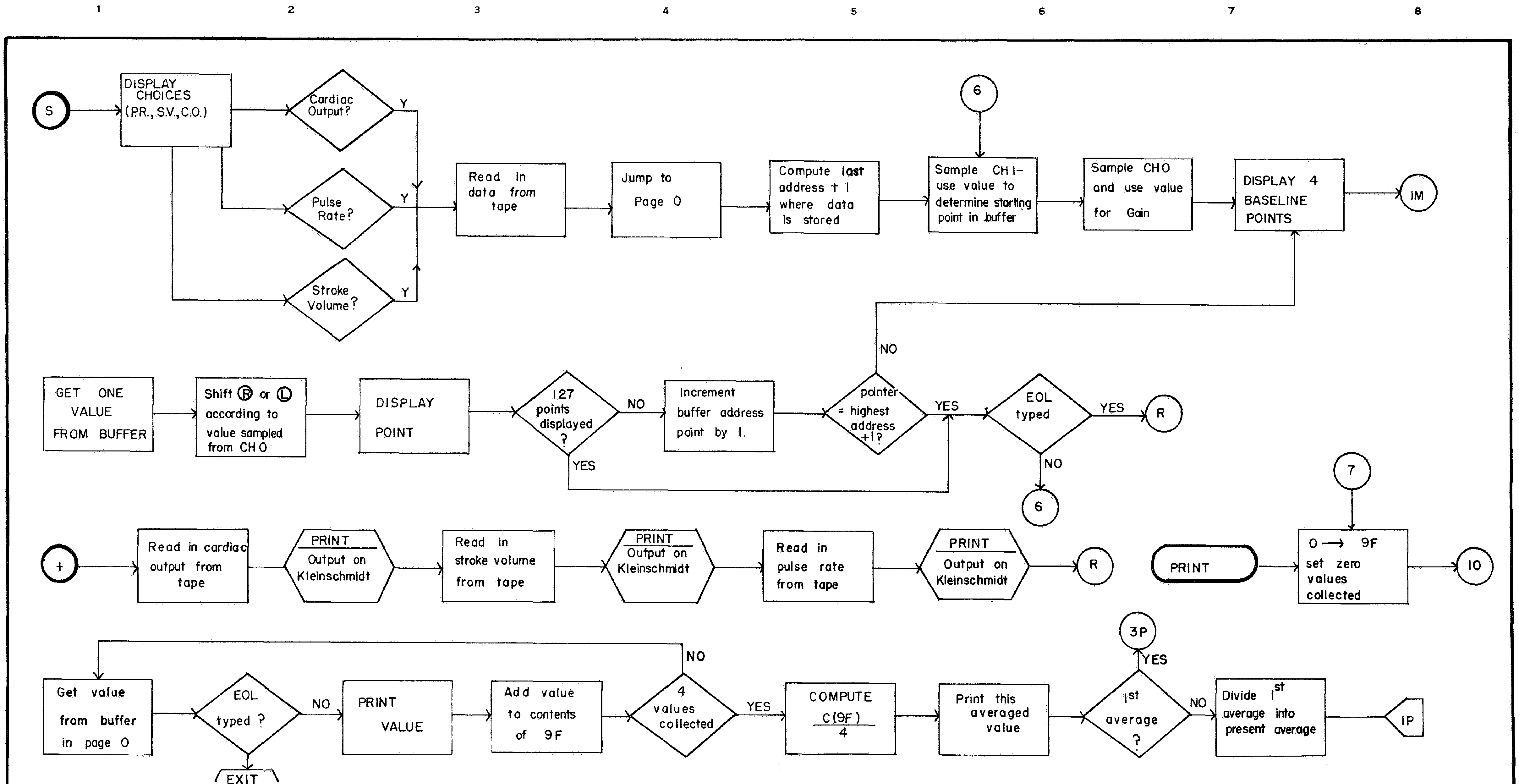
SAMPLE CODE ☐	DOCUMENT TITLE		PROJECT MGR.	
FLOWCHART ☐		PAGE 2 OF 6	PROJECT NAME	
DECISION TABLE ☐	NUMBER	ISSUE DATE	TASK NO.	
OTHER ☐	DRAWN BY GSJ	DATE	TASK NAME COCAL	

REV	APPROVED	DATE	REV	APPROVED	DATE



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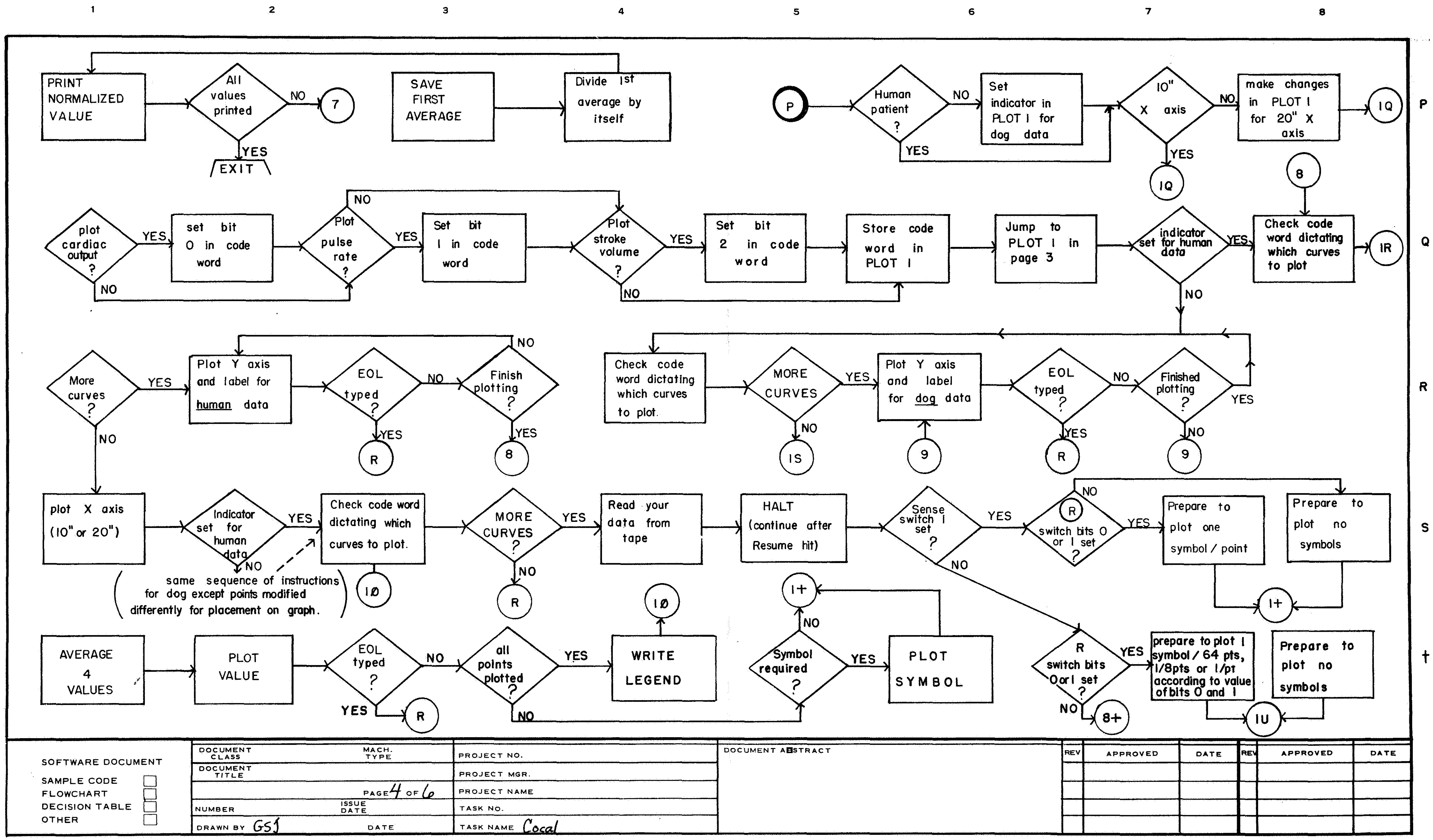
FLOWCHART ☐		PAGE 2 OF 6	PROJECT NAME							
DECISION TABLE ☐	NUMBER	ISSUE DATE	TASK NO.							
OTHER ☐	DRAWN BY GSJ	DATE	TASK NAME Cocal							


1
2
3
4
5
6
7
8
P
Q
R
S
T
PRINT NORMALIZED VALUE
All values printed ?
NO
7
YES
EXIT
SAVE FIRST AVERAGE
Divide 1st average by itself
P
Human patient ?
Set indicator in PLOT 1 for dog data
10" X axis
make changes in PLOT 1 for 20" X axis
1Q
plot cardiac output ?
set bit 0 in code word
Plot pulse rate ?
Set bit 1 in code word
Plot stroke volume ?
Set bit 2 in code word
Store code word in PLOT 1
Jump to PLOT 1 in page 3
indicator set for human data
Check code word dictating which curves to plot
1R
8
More curves ?
Plot Y axis and label for human data
EOL typed ?
Finish plotting ?
R
Check code word dictating which curves to plot.
MORE CURVES
Plot Y axis and label for dog data
Finished plotting ?
1S
9
plot X axis (10" or 20")
Indicator set for human data
Check code word dictating which curves to plot.
same sequence of instructions for dog except points modified differently for placement on graph.
1Ø
MORE CURVES ?
Read your data from tape
HALT (continue after Resume hit)
Sense switch 1 set ?
switch bits 0 or 1 set ?
Prepare to plot one symbol / point
Prepare to plot no symbols
1+
AVERAGE 4 VALUES
PLOT VALUE
EOL typed ?
all points plotted ?
WRITE LEGEND
Symbol required ?
PLOT SYMBOL
switch bits 0 or 1 set ?
prepare to plot 1 symbol / 64 pts, 1/8pts or 1/pt according to value of bits 0 and 1
Prepare to plot no symbols
8+
1U
SOFTWARE DOCUMENT
SAMPLE CODE
FLOWCHART
DECISION TABLE
OTHER
DOCUMENT CLASS
MACH. TYPE
DOCUMENT TITLE
PAGE 4 OF 6
NUMBER
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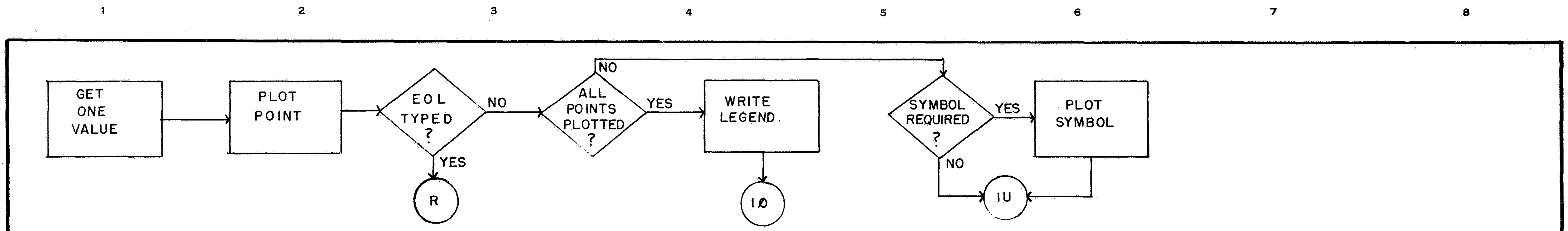
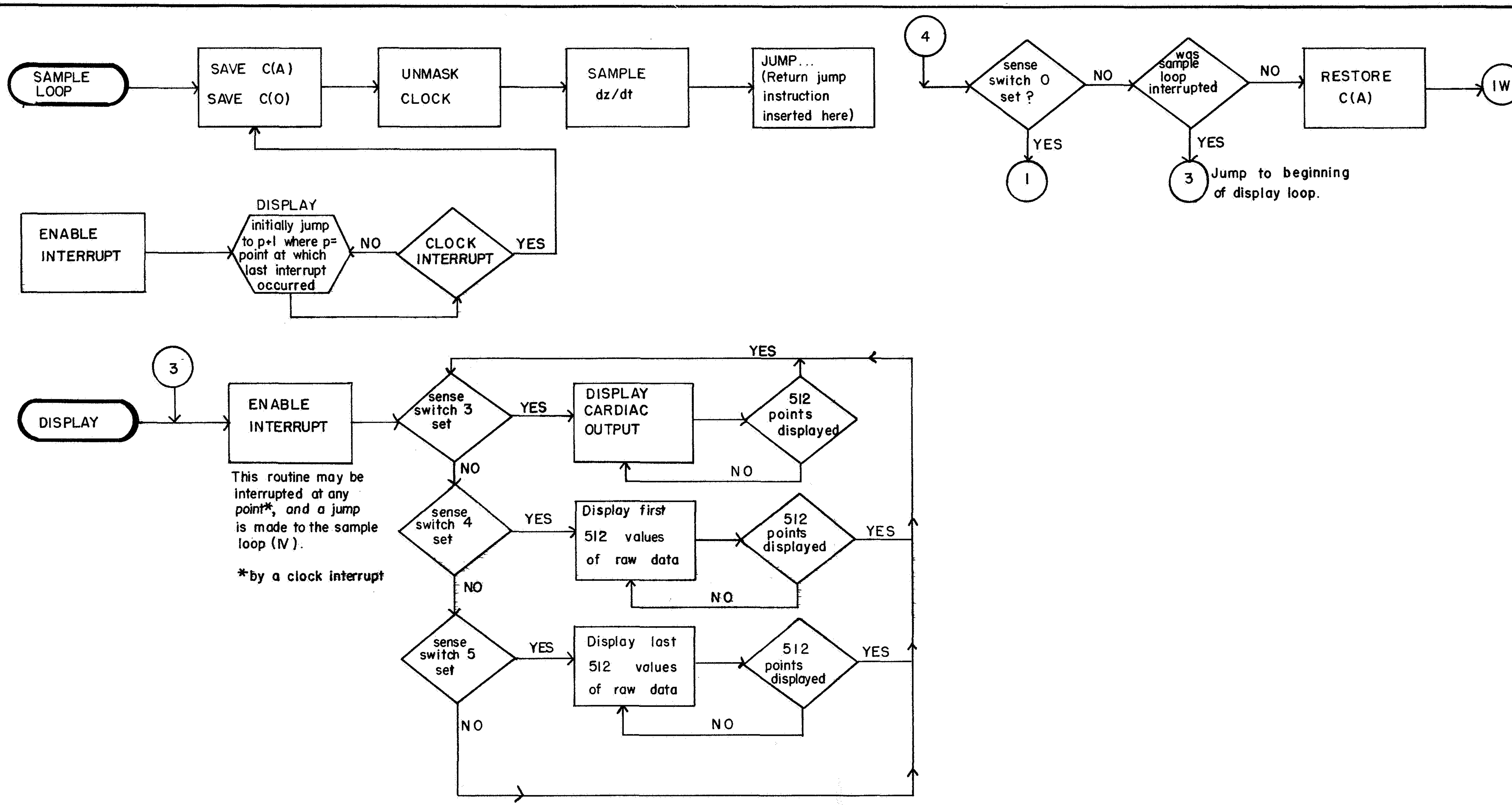
PROJECT MGR.
PROJECT NAME
TASK NO.
TASK NAME Cocal
DOCUMENT ABSTRACT
REV
APPROVED
DATE



SOFTWARE DOCUMENT	DOCUMENT CLASS	MACH. TYPE	PROJECT NO.	DOCUMENT ABSTRACT	REV / APPROVED / DATE / REV / APPROVED / DATE
SAMPLE CODE ☐	DOCUMENT TITLE		PROJECT MGR.		
FLOWCHART ☐		PAGE 5 OF 6	PROJECT NAME		
DECISION TABLE ☐	NUMBER	ISSUE DATE	TASK NO.		
OTHER ☐	DRAWN BY GSJ	DATE	TASK NAME COCAL		



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 6 OF 6	PROJECT NAME				
NUMBER	ISSUE DATE	TASK NO.				
DRAWN BY GSJ	DATE	TASK NAME Cocal				

	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 0 ALLOWS THE USER CONTROL OVER THE DATA
    [SAMPLED.IN THE UP POSITION SENSE SWITCH 0 DIRECTS THE
    [COMPUTER TO IGNORE THE INPUT DATA - WHICH MIGHT BE
    [NOISY,ETC. SAMPLING RESUMES WHEN SENSE SWITCH 0
    [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
```

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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 Ø 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 Ø AND 1 DICTATE THE PLOTTING OF
          [SYMBOLS.
          [     X = C.O.
          [     $ = P.R.
          [     Ø = S.V.
          [        AVERAGED VALUES PLOTTED
          [VALUE OF BITS Ø AND 1          NO. OF SYMBOLS
          [       Ø                           NONE
          [       1=3                         ONE/POINT
          [        EVERY POINT PLOTTED
          [VALUE OF BITS Ø AND 1          NO. OF SYMBOLS
          [     Ø                          Ø
          [     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 6Ø2Ø       JMP2Ø
              $2Ø
2Ø 7ØØØ       JMP7A
21 6Ø22       JMP22 [JUMP HERE ON CLOCK INTERRUPT
22 ØØ56       SET16
23 ØØØØ       Ø
24 4Ø44       STC2S [SAVE [A]
25 1Ø2Ø       LDA&
26 ØØØ4       4
27 Ø541       OPR41 [UNMASK CLOCK
3Ø ØØ16       NOP
31 Ø11Ø       SAM1Ø [SAMPLE DZ/DT
32 ØØØØ  #1S  Ø [FILLED IN WITH JUMP INSTRUCTION
33 Ø46Ø       SNS&Ø [IF SENSE SWITCH Ø 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 Ø642      UMB2
124 1Ø2Ø      LDA& [LOAD INDEX REGISTERS 6,7, AND 1Ø
125 2777      2777 [TO PREPARE FOR STORING CARDIAC
126 1Ø4Ø      STA  [OUTPUT, PULSE RATE AND STROKE
127 2ØØ6      2ØØ6 [VOLUME
13Ø 1Ø4Ø      STA
131 2ØØ7      2ØØ7
132 1Ø2Ø      LDA&
133 3777      3777
134 1Ø4Ø      STA
135 2Ø1Ø      2Ø1Ø
136 ØØ11      CLR
137 1Ø4Ø      STA
14Ø 25ØØ      25ØØ
141 1Ø4Ø      STA
142 25Ø1      25Ø1
143 1Ø4Ø      STA
144 25Ø2      25Ø2
145 Ø641      UMB1
146 Ø46Ø #1C  SNS&Ø
147 6146      JMP'=1
15Ø ØØ63      SET&3 [SAMPLE 1Ø24 POINTS
151 3777      3777
152 1Ø2Ø      LDA&
153 6156      1D+6ØØØ
154 4Ø32      STC1S [STORE JUMP IN INTERRUPT HANDLER
155 6426      JMP7R [JUMP TO ENABLE INTERRUPT
156 1Ø63 #1D  STA&3
157 Ø2Ø3      XSK3
16Ø 6Ø33      JMP1S+1
161 ØØ63      SET&3 [FIND MAX DZ/DT
162 3777      3777
163 ØØ11      CLR
164 45ØØ      STC8A
165 Ø223 #1A  XSK&3
166 617Ø      JMP'+2
167 62ØØ      JMP1B
17Ø 1ØØ3      LDA3
171 ØØ17      COM
172 25ØØ      ADD8A
173 Ø471      APO&
174 6165      JMP1A
175 1ØØ3      LDA3
176 45ØØ      STC8A
177 6165      JMP1A
2ØØ 1ØØØ #1B  LDA [FIND 1/3 DZ/DT MAX
2Ø1 Ø5ØØ      8A
2Ø2 124Ø      MUL
2Ø3 45Ø1      8E+4ØØØ
2Ø4 45Ø2      STC8C
2Ø5 1Ø2Ø #1E  LDA& [WAIT FOR NEGATIVE VALUE
2Ø6 6211      1F+6ØØØ [STORE JUMP IN INTERRUPT HANDLER
2Ø7 4Ø32      STC1S
21Ø 6Ø33      JMP1S+1
211 Ø471 #1F  APO&
212 6Ø33      JMP1S+1
213 ØØ64 #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 112Ø          ADA&
374 6Ø35          =1742 [=2ØØØ + 36 TO ACCOUNT FOR TIME SPENT IN COM
          PUTATION SECTION
375 2514          ADD8R
376 4515          STC8S
377 25Ø5          ADD8F
4ØØ ØØ17          COM
4Ø1 251Ø          ADD8L
4Ø2 4514          STC8R
4Ø3 Ø64Ø          UMBØ [JUMP TO ROUTINE TO COMPUTE
4Ø4 Ø6Ø2          LMB2 [CARDIAC OUTPUT, STROKE VOLUME
4Ø5 61Ø2          JMP1Ø2 [AND PULSE RATE
                  $41Ø
41Ø ØØØ7          MSC7
411 1Ø2Ø          LDA&
412 6626          6S+6ØØØ
413 4437          STC5S
414 Ø73Ø          RDC&% [READ IN FINAL DISPLAY ROUTINE
415 4221          4/221
416 Ø73Ø          RDC&%
417 5222          5/222
42Ø Ø73Ø          RDC&%
421 6223          6/223
422 Ø71Ø          RDC%
423 7224          7/224
424 Ø641          UMB1
425 6433          JMP7S
426 ØØ1Ø  #7R     ENI
427 1Ø2Ø          LDA&
43Ø ØØ16          ØØ16 [NOP
431 1Ø4Ø          STA
432 Ø437          5S
433 ØØ77  #7S     SET&17
434 6777          =1ØØØ
435 Ø443          SNS3
436 6443          JMP'+5
437 ØØ16  #5S     NOP
44Ø ØØ62          SET&2
441 Ø777          777
442 6463          JMP5C
443 Ø444          SNS4
444 645Ø          JMP'+4
445 ØØ62          SET&2
446 3777          3777
447 6454          JMP5B
45Ø Ø445          SNS5
451 6433          JMP7S
452 ØØ62          SET&2
453 2777          2777
454 ØØ11  #5B     CLR
455 Ø162          DIS&2
456 1ØØ2          LDA2
457 Ø142          DIS2
46Ø Ø237          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 [ZT
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
```

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    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 0001       1
 737 1150       ADM10
 740 6671       JMP5D+5
 741 0730  #6T  RDC&% [READ IN PRINT ROUTINE
 742 4571       4/571
 743 0730       RDC&%
 744 5572       5/572
 745 0730       RDC&%
 746 6573       6/573
 747 0710       RDC%
 750 7574       7/574
 751 1000       LDA
 752 0516       8T
 753 1120       ADA&
 754 7776       7776
 755 0342       SCR2
 756 0017       COM
 757 1040       STA
 760 2377       2377
 761 0640       UMB0
 762 0603       LMB3
 763 6220       JMP20 [JUMP TO PRINT VALUES
 764 0000  #3E  0
 765 0000  #3F  0
 766 0000  #3G  0
 767 7633  #3H  7633 [=144
 770 7765       7765 [=12
 771 7776       7776 [=1
 772 0000       0
 773 0000  #3C  0
 774 0000  #3D  0
           [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.
                $1000
1000 0711  #7A  RCG%
1001 1426       1/426
1002 7152       JMP7J
1003 0062  #7G  SET&2
1004 1260       7M=1 [INT-DSP
1005 7205       JMP7C
1006 1120       ADA&
1007 4000       4000
1010 1040       STA
1011 0051       51
1012 1120       ADA&
1013 1001       1001
1014 1040       STA
1015 0053       53
1016 0061       SET&1
1017 3007       3007
1020 0062       SET&2
1021 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 1Ø4Ø       STA
1114 Ø636       636
1115 ØØ61       SET&1
1116 3ØØ7       3ØØ7
1117 ØØ62       SET&2
112Ø 13ØØ       7Q=1 [PRINT]
1121 72Ø5       JMP7C
1122 112Ø       ADA&
1123 4ØØØ       4ØØØ
1124 1Ø4Ø       STA
1125 Ø742       742
1126 112Ø       ADA&
1127 1ØØ1       1ØØ1
113Ø 1Ø4Ø       STA
1131 Ø744       744
1132 112Ø       ADA&
1133 1ØØ1       1ØØ1
1134 1Ø4Ø       STA
1135 Ø746       746
1136 112Ø       ADA&
1137 1ØØ1       1ØØ1
114Ø 1Ø4Ø       STA
1141 Ø75Ø       75Ø
1142 6Ø47       JMP3S
1143 1Ø2Ø  #7B  LDA&
1144 ØØ1Ø       1Ø
1145 114Ø       ADM
1146 1ØØ1       7A+1
1147 5151       STC'+2
115Ø Ø711       RCG%
1151 ØØØØ       Ø
1152 ØØ65  #7J  SET&5
1153 7767       7767
1154 ØØ61       SET&1
1155 2777       2777
1156 1Ø21  #7F  LDA&1
1157 146Ø       SAE&
116Ø 5757       5757
1161 7163       JMP'+2
1162 72Ø2       JMP7K
1163 1ØØØ       LDA
1164 1ØØ1       7A+1
1165 146Ø       SAE&
1166 1776       1776
1167 7171       JMP'+2
117Ø 7175       JMP7H
1171 146Ø       SAE&
1172 1416       1416
1173 7143       JMP7B
1174 ØØØØ       HLT
1175 1Ø2Ø  #7H  LDA&
1176 1ØØ6       1ØØ6
1177 1Ø4Ø       STA
12ØØ 1ØØ1       7A+1
12Ø1 7147       JMP7B+4
12Ø2 Ø225  #7K  XSK&5
12Ø3 7156       JMP7F
```

```
     CONT
12Ø4 7ØØ3      JMP7G
12Ø5 ØØ44 #7C  SET4
12Ø6 ØØØØ      Ø
12Ø7 1ØØØ      LDA
121Ø ØØØ2      2
1211 5231      STC7D+3
1212 7235      JMP7I
1213 1Ø2Ø #7E  LDA&
1214 ØØØ7      7
1215 7226      JMP7D
1216 1Ø2Ø      LDA&
1217 ØØØ6      6
122Ø 7226      JMP7D
1221 1Ø2Ø      LDA&
1222 ØØØ5      5
1223 7226      JMP7D
1224 1Ø2Ø      LDA&
1225 ØØØ4      4
1226 114Ø #7D  ADM
1227 ØØØ1      1
123Ø ØØ62      SET&2
1231 ØØØØ      Ø
1232 Ø2Ø1      XSK1
1233 7235      JMP'+2
1234 ØØØØ      HLT
1235 1Ø21 #7I  LDA&1
1236 1462      SAE&2
1237 7213      JMP7E
124Ø 1Ø21      LDA&1
1241 1462      SAE&2
1242 7216      JMP7E+3
1243 1Ø21      LDA&1
1244 1462      SAE&2
1245 7221      JMP7E+6
1246 1Ø21      LDA&1
1247 1462      SAE&2
125Ø 7224      JMP7D-2
1251 1Ø2Ø      LDA&
1252 ØØØ3      3
1253 114Ø      ADM
1254 ØØØ1      1
1255 1ØØ1      LDA1
1256 156Ø      BCL&
1257 7ØØØ      7ØØØ
126Ø 6ØØ4      JMP4
1261 3441 #7M  3441
1262 4717      4717
1263 2746      2746
1264 4377      4377
1265 2642 #7N  2642
1266 4Ø43      4Ø43
1267 5Ø47      5Ø47
127Ø 3ØØ1      3ØØ1
1271 3134 #7O  3134
1272 4117      4117
1273 2746      2746
1274 43Ø1      43Ø1
```

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

INT-DSP,1 LN=1


```
    CONT
 20 0070        SET&10
 21 0153        7F
 22 0011        CLR
 23 4153        STC7F
 24 4154        STC7G
 25 4155        STC7H
 26 4156        STC7I
 27 4157        STC7J
 30 4160        STC7K
 31 1020   #5A  LDA&
 32 0001        0001
 33 1340        STH
 34 4764        9U+4000
 35 1020        LDA&
 36 0500        0500
 37 4765        STC9U+1
 40 1040        STA
 41 1000        1000
 42 1020        LDA&
 43 4164        1N+4000 [RHO IN OHM-CM IS 150
 44 6400        JMP9A
 45 6020        JMP20
 46 6111        JMP7A [CONVERT DECIMAL TO BINARY
 47 1020        LDA&
 50 0202        10 [L FRONT IN CM = --.-
 51 6400        JMP9A [JUMP TO SCOPE PKG
 52 6020        JMP20
 53 6111        JMP7A [DEC TO BINARY-TREAT AS INTEGER
 54 1020        LDA&
 55 0217        1P [L BACK IN CM = --.-
 56 6400        JMP9A [JUMP TO SCOPE PKG
 57 6020        JMP20
 60 6111        JMP7A [DEC TO BIN-TREAT AS INTEGER
 61 6143        JMP7E [FIND L MEAN
 62 1020   #6A  LDA&
 63 0234        1R [Z CAL-1 OHM = -.-- V.
 64 6400        JMP9A [JUMP TO SCOPE PKG
 65 6020        JMP20
 66 6111        JMP7A [DEC TO BIN-TREAT AS INTEGER
 67 1020        LDA&
 70 0251        1S [DZ/DT CAL-1 OHM/SEC = -.-- V.
 71 6400        JMP9A [JUMP TO SCOPE PKG
 72 6020        JMP20
 73 6111        JMP7A [DEC TO BIN-TREAT AS INTEGER
 74 1020   #8A  LDA&
 75 0272        1Q [TYPE S IF READY TO SAMPLE
 76 6400        JMP9A
 77 6020        JMP20
100 1000        LDA
101 0764        9U
102 1420        SHD&
103 4600        4600
104 6106        JMP'+2
105 6074        JMP8A
106 0641        UMB1
107 0602        LMB2
110 6020        JMP20 [JUMP TO FLOATING POINT ROUTINES
```

```
     CONT
              [CONVERT NUMBER FROM DECIMAL TO BINARY
111 0054 #7A SET14
112 0000     0
113 0067     SET&7
114 0764     9U [LOCATION OF CHARACTERS ENTERED THRU KEYBOARD
115 0071     SET&11
116 7774     7774
117 0073     SET&13
120 0161     7L
121 1327 #7B LDH&7
122 1307 #7C LDH7
123 0246     ROL6
124 0346     SCR6
125 0470     AZE&
126 6135     JMP7D
127 1120     ADA&
130 7776     7776
131 1347     STH7
132 1013     LDA13
133 1150     ADM10
134 6122     JMP7C
135 0231 #7D XSK&11
136 6141     JMP'+3
137 1030     LDA&10
140 6014     JMP14
141 1033     LDA&13
142 6121     JMP7B
143 1000 #7E LDA
144 0154     7G
145 1100     ADA
146 0155     7H
147 0341     SCR1
150 1040     STA
151 0160     7K
152 6062     JMP6A
153 0000 #7F 0 [RHO
154 0000 #7G 0 [L FRONT
155 0000 #7H 0 [L BACK
156 0000 #7I 0 [Z CAL IN VOLTS X 100
157 0000 #7J 0 [DZ/DT CAL IN VOLTS X 100
160 0000 #7K 0 [L MEAN
161 0144 #7L 144
162 0012     12
163 0001     1
              [DISPLAY TEXT
164 0003 #1N 0003
165 4533     4533 [RHO IN OHM-CM. IS ---
166 4214     4214
167 3441     3441
170 1442     1442
171 3340     3340
172 1726     1726
173 4015     4015
174 1434     1434
175 4614     4614
176 5656     5656
177 1313 #2N 1313
```

```
     CONT
200  1314          1314
201  5776          5776
202  ØØØ3  #1O     ØØØ3  [L FRONT IN CM = --.-
203  3714          3714
204  3145          3145
205  4241          4241
206  4714          4714
207  3441          3441
21Ø  1426          1426
211  4Ø14          4Ø14
212  2314          2314
213  5656          5656
214  1313          1313
215  1513          1513
216  5777          5777
217  ØØØ3  #1P     ØØØ3
22Ø  3714          3714  [L BACK IN CM = --.-
221  2524          2524
222  2636          2636
223  1434          1434
224  4114          4114
225  264Ø          264Ø
226  1423          1423
227  1456          1456
23Ø  5613          5613
231  1315          1315
232  1314          1314
233  5777          5777
234  ØØØ3  #1R     ØØØ3  [Z CAL
235  5514          5514  [1 OHM = -.-- V.
236  2624          2624
237  3756          3756
24Ø  56Ø1          56Ø1
241  1442          1442
242  334Ø          334Ø
243  1423          1423
244  1413          1413
245  1513          1513
246  1314          1314
247  5115          5115
25Ø  5777          5777
251  ØØØ3  #1S     ØØØ3  [DZ/DT CAL
252  2755          2755  [1 OHM/SEC = -.-- V.
253  2127          2127
254  4714          4714
255  2624          2624
256  3756          3756
257  56Ø1          56Ø1
26Ø  1442          1442
261  334Ø          334Ø
262  2146          2146
263  3Ø26          3Ø26
264  1423          1423
265  1413          1413
266  1513          1513
267  1314          1314
27Ø  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
 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
 617 13Ø2   #9V   LDH 2
 62Ø 146Ø         SAE&
 621 ØØ77         77
 622 6625         JMP9W-1
 623 Ø226         XSK&6
 624 653Ø         JMP9M
 625 ØØ11         CLR
 626 6ØØØ   #9W   JMP
            [CODE TABLE
 627 4136   #9X   4136
 63Ø 3641         3641
 631 21Ø1         21Ø1
 632 Ø177         Ø177
 633 4523         4523
 634 2151         2151
 635 4122         4122
 636 2651         2651
 637 2414         2414
 64Ø Ø477         Ø477
 641 5172         5172
 642 Ø651         Ø651
 643 15Ø6         15Ø6
 644 4225         4225
 645 4443         4443
 646 6Ø5Ø         6Ø5Ø
 647 5126         5126
 65Ø 2651         2651
 651 512Ø         512Ø
 652 3651         3651
 653 ØØØ1   #9Y   1
 654 7774         -3
 655 7775         -2
 656 7661         -116
 657 ØØØØ         ØØØØ
 66Ø ØØØØ         ØØØØ
 661 Ø1ØØ         Ø1ØØ    [PERIOD
 662 ØØØØ         ØØØØ
 663 7736         7736    [STAR
 664 3677         3677
 665 Ø4Ø4         Ø4Ø4    [DASH
 666 Ø4Ø4         Ø4Ø4
 667 Ø4Ø4         Ø4Ø4    [PLUS
 67Ø Ø437         Ø437
 671 Ø4Ø3         Ø4Ø3    [SLASH
 672 6Ø1Ø         6Ø1Ø
 673 4177         4177    [BRACKET OPEN
 674 ØØØØ         ØØØØ
```

```
INT-DSP,10  LN=620

     CONT
675 1212        1212  C= SIGN
676 1212        1212
677 4477        4477  CA
700 7744        7744
701 5177        5177
702 2651        2651
703 4136        4136
704 2241        2241
705 4177        4177
706 3641        3641
707 4577        4577
710 4145        4145
711 4477        4477
712 4044        4044
713 4136        4136
714 2645        2645
715 1077        1077
716 7710        7710
717 7741        7741
720 0041        0041
721 4142        4142
722 4076        4076
723 1077        1077
724 4324        4324
725 0177        0177
726 0301        0301
727 3077        3077
730 7730        7730
731 3077        3077
732 7706        7706
733 4177        4177
734 7741        7741
735 4477        4477
736 3044        3044
737 4276        4276
740 0376        0376
741 4477        4477
742 3146        3146
743 5121        5121
744 4651        4651
745 4040        4040
746 4077        4077
747 0177        0177
750 7701        7701
751 0176        0176
752 7402        7402
753 0677        0677
754 7701        7701
755 1463        1463
756 6314        6314
757 0770        0770
760 7007        7007
761 4543        4543
762 6151        6151
                $763
763 0000        0
764 0000  #9U   0
```

```
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
105  7054      JMP1Ø54 [COMPUTE Z**2
106  1355      9E
107  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  7054      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  7054      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  7054      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 Ø64Ø      UMBØ
27Ø 7ØØØ      JMP1ØØØ [JUMP TO PLOT CURVES
         [DRAW Y AXES AND LABEL THEM
271 ØØ46 #6F  SET6
272 ØØØØ      Ø
273 1Ø2Ø      LDA&
274 Ø62Ø      62Ø
275 4734      STC3Y
276 1Ø2Ø      LDA&
277 Ø144      144
3ØØ 4733      STC3X
3Ø1 6612      JMP7M [MOVE TO [1,4]
3Ø2 1Ø2Ø      LDA&
3Ø3 ØØØ6      6 [CHARACTER ORIENTATION +Y
3Ø4 4422      STC3Z+4
3Ø5 1325 #6G  LDH&5 [LOAD A WITH CHARACTER
3Ø6 142Ø      SHD&
3Ø7 77ØØ      77ØØ
31Ø 6313      JMP6H [JUMP IF END OF STRING
311 64ØØ      JMP7C [PLOT CHARACTER
312 63Ø5      JMP6G
313 1Ø2Ø #6H  LDA&
314 Ø144      144
315 4734      STC3Y
316 1Ø2Ø      LDA&
317 Ø31Ø      31Ø
32Ø 4733      STC3X
321 6612      JMP7M [MOVE TO [2,1]
322 6747      JMP7D [PEN DOWN
323 1Ø2Ø      LDA&
324 175Ø      175Ø
325 4734      STC3Y
326 4422      STC3Z+4 [CHARACTER ORIENTATION +X
327 6612      JMP7M [DRAW LINE TO [2,1Ø]
         [LABEL Y AXIS
33Ø 1Ø2Ø #6I  LDA&
331 Ø274      274
332 4733      STC3X
333 6612      JMP7M [DRAW .12 INCH LINE
334 6741      JMP7U [PEN UP
335 1Ø2Ø      LDA&
336 Ø2Ø6      2Ø6
337 4733      STC3X
34Ø 6612      JMP7M [LEAVE SPACE FOR NUMBER
341 Ø415      KST
342 635Ø      JMP6J
343 Ø515      KBD
344 146Ø      SAE&
345 ØØ12      ØØ12
346 635Ø      JMP6J
347 7Ø34      JMP8H-3
35Ø 1325 #6J  LDH&5
351 142Ø      SHD&
352 12ØØ      12ØØ
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 Ø2ØØ        Ø2ØØ
536 7777        7777
537 4742  #1I   4742 [TOTAL TIME
54Ø 4724        4724
541 3714        3714
542 4734        4734
543 4Ø3Ø        4Ø3Ø
544 14ØØ        14ØØ
545 ØØ61        ØØ61
546 ØØ14        ØØ14
547 4Ø34        4Ø34
55Ø 4177        4177
          [CALCOMP PLOT
          [MODIFIED FOR LINC 3ØØ
          [F T DAVIDSON 5 OCT 67
          [CHARACTER PLOT
          [PEN MUST BE IN THE
          [UP POSITION
                $4ØØ
4ØØ 112Ø  #7C   ADA &
4Ø1 3ØØØ        3T
4Ø2 4Ø17        STC 17
4Ø3 2ØØØ        ADD Ø
4Ø4 4454        STC 3R
4Ø5 1Ø17        LDA 17
4Ø6 112Ø        ADA&
4Ø7 2ØØØ        2ØØØ
41Ø 4Ø17        STC 17
411 1Ø17  #3U   LDA 17
412 ØØ75        SET & 15
413 7776        =1 [MAGNIFICATION
414 Ø451        APO
415 6754        JMP 7R
416 1317  #3Z   LDH 17
417 156Ø        BCL &
42Ø 777Ø        777Ø
421 112Ø        ADA &
422 ØØØØ        Ø [ORIENTATION
423 156Ø        BCL &
424 777Ø        777Ø
425 112Ø        ADA &
426 Ø6Ø2        3J
427 4Ø16        STC 16
43Ø 1Ø16        LDA 16
431 4442        STC 3K+3
432 1337        LDH & 17
433 Ø47Ø        AZE &
434 645Ø        JMP 3L
435 ØØ17        COM
436 444Ø        STC 3K+1
437 ØØ76  #3K   SET & 16
44Ø ØØØØ        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
```

```
     CONT
445 6441      JMP '-4
446 0235      XSK & 15
447 6437      JMP 3K
          [TEST FOR END
450 1017 #3L LDA 17
451 1560      BCL &
452 5777      5777
453 0450      AZE
454 0000 #3R RETURN
          [STEP LINE OF CHAR-TABLE-ALLOWS OVERLAP INTO UPPER MEM
          ORY
455 1020      LDA &
456 4000      -3777
457 1140      ADM
460 0017      17
461 1017      LDA 17
462 6411      JMP 3U
          [INCREMENT PLOTTER AND X,Y SR
463 4467 #7I STC 3M
464 2000      ADD 0
465 4570      STC 3S
466 1520      SRO & [TEST FOR -Y
467 0000 #3M [KEY WORD
470 6511      JMP '+21
471 2740      ADD 7Y [TEST FOR POINTS LESS THAN OR EQUAL LOWER B
          OUND
472 2600      ADD 3N
473 0451      APO
474 6505      JMP '+11
475 0011      CLR [TEST FOR POINTS GREATER THAN UPPER BOUND
476 2740      ADD 7Y
477 2601      ADD 3O
500 0471      APO &
501 6505      JMP '+4
502 1020      LDA & [CARRIAGE RIGHT
503 0004      4
504 6571      JMP 8A
505 0011      CLR
506 2740      ADD 7Y [DECREASE POINT INDICATOR IN 7Y
507 2576      ADD 3V
510 4740      STC 7Y
511 1500      SRO [TEST FOR +Y
512 0467      3M
513 6536      JMP '+23
514 2740      ADD 7Y [TEST FOR POINTS GREATER THAN OR EQUAL LOWE
          R BOUND
515 2601      ADD 3O
516 2577      ADD 3W
517 0471      APO &
520 6532      JMP '+12
521 0011      CLR [TEST FOR POINTS LESS THAN LOWER BOUND
522 2740      ADD 7Y
523 2600      ADD 3N
524 2577      ADD 3W
525 0451      APO
526 6532      JMP '+4
527 1020      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 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
704  2635       ADD 3B
705  1220       LAM &
706  0000  #3F
707  4000       STC 0
710  0472       LZE &
```

```
     CONT
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
         [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 7120       JMP2I
1160 0770  #2L  770 [READ IN STROKE VOLUME DATA
1161 6274       6/274
1162 0750       750
1163 7275       7/275
1164 0011       CLR
1165 5233       STC9B
1166 5340       STC9C [0
1167 6612       JMP7M [RETURN TO [0,1]
1170 0000       HLT
1171 1020       LDA&
1172 1611       9H
1173 7175       JMP8F [PLOT STROKE VOLUME
1174 7021       JMP8E+3
           [PLOT CURVE
1175 5237  #8F  STC9D
1176 5577       STC9S
1177 0044       SET4
1200 0000       0
1201 0061       SET&1
1202 2777       2777
1203 0461  #8J  SNS&1 [IF SENSE SWITCH 1 IS SET
1204 7355       JMP9E [JUMP TO AVERAGE 4 POINTS
1205 0043  #8K  SET3
1206 1700       9Y [SET NO. OF POINTS TO PLOT
1207 0536       OPR&16 [READ RSW
1210 1560       BCL& [EXAMINE BITS 0 AND 1
1211 7774       7774
1212 1120       ADA& [C[RSW] DESERMINE NO. OF SYMBOLS PLOTTED
1213 1600       1T
1214 1040       STA
1215 1311       8G
1216 5220       STC'+2
1217 0045       SET5
1220 0000       0
1221 1021  #8L  LDA&1 [LOAD A WITH Y COORDINATE
1222 7230       JMP9A [PLOT POINT
1223 1020       LDA&
1224 0002       2
1225 1140       ADM
1226 0733       3X
1227 7221       JMP8L
1230 0050  #9A  SET10
1231 0000       0
1232 1120       ADA& [MODIFY FOR PLACEMENT ON GRAPH
1233 0000  #9B  0 [VALUE FILLED IN
1234 0470       AZE&
1235 7240       JMP9D+1
1236 1240       MUL
1237 0000  #9D  0 [VALUE FILLED IN
1240 1120       ADA&
1241 0144       144
1242 1040       STA
1243 0734       3Y [STORE Y COORDINATE
1244 1120       ADA&
1245 6000       =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
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&
1512 0032      32
1513 1140      ADM
1514 0733      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
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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  2014        2014
276  4615        4615
277  5115        5115
300  5656        5656
301  1306        1306
302  1743        1743
303  1545        1545
304  1514        1514
305  2014        2014
306  4615        4615
307  5115        5115
310  5656        5656
311  1307        1307
312  1724        1724
313  3737        3737
314  1447        1447
315  3345        3345
316  3030        3030
317  5777        5777
320  0102        0102
321  0304        0304
322  0506        0506
323  0777        0777
324  0201   #5W  0201  [1=HUMAN DATA
325  1301        1301  [2=DOG DATA
326  1733        1733
327  5040        5040
330  2441        2441
331  1427        1427
332  2447        2447
333  2414        2414
334  5656        5656
335  1302        1302
336  1727        1727
337  4232        4232
340  1427        1427
341  2447        2447
342  2414        2414
343  5777        5777
344  0102        0102
345  7777        7777
346  0201   #5X  0201  [1=X AXIS=10 IN.
347  1301        1301  [2=X AXIS=20 IN.
350  1753        1753
351  1424        1424
352  5334        5334
353  4661        4661
354  0100        0100
355  1434        1434
356  4115        4115
357  5656        5656
360  1302        1302
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 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
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
```

```
     CONT
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
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
```

```
     CONT
617 13Ø2 #9V LDH 2
62Ø 146Ø     SAE&
621 ØØ77     77
622 6625     JMP9W=1
623 Ø226     XSK&6
624 653Ø     JMP9M
625 ØØ11     CLR
626 6ØØØ #9W JMP
             [CODE TABLE
627 4136 #9X 4136
63Ø 3641     3641
631 21Ø1     21Ø1
632 Ø177     Ø177
633 4523     4523
634 2151     2151
635 4122     4122
636 2651     2651
637 2414     2414
64Ø Ø477     Ø477
641 5172     5172
642 Ø651     Ø651
643 15Ø6     15Ø6
644 4225     4225
645 4443     4443
646 6Ø5Ø     6Ø5Ø
647 5126     5126
65Ø 2651     2651
651 512Ø     512Ø
652 3651     3651
653 ØØØ1 #9Y 1
654 7774     -3
655 7775     -2
656 7661     -116
657 ØØØØ     ØØØØ
66Ø ØØØØ     ØØØØ
661 Ø1ØØ     Ø1ØØ  [PERIOD
662 ØØØØ     ØØØØ
663 7736     7736  [STAR
664 3677     3677
665 Ø4Ø4     Ø4Ø4  [DASH
666 Ø4Ø4     Ø4Ø4
667 Ø4Ø4     Ø4Ø4  [PLUS
67Ø Ø437     Ø437
671 Ø4Ø3     Ø4Ø3  [SLASH
672 6Ø1Ø     6Ø1Ø
673 4177     4177  [BRACKET OPEN
674 ØØØØ     ØØØØ
675 1212     1212  [= SIGN
676 1212     1212
677 4477     4477  [A
7ØØ 7744     7744
7Ø1 5177     5177
7Ø2 2651     2651
7Ø3 4136     4136
7Ø4 2241     2241
7Ø5 4177     4177
7Ø6 3641     3641
```

```
     CONT
707  4577        4577
710  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
            [Ø
1100  Ø6Ø1  #2A   Ø6Ø1
1101  43Ø1        43Ø1
1102  Ø4Ø4        Ø4Ø4
1103  Ø5Ø1        Ø5Ø1
1104  Ø6Ø2        Ø6Ø2
1105  Ø7Ø1        Ø7Ø1
1106  ØØØ4        ØØØ4
1107  Ø1Ø1        Ø1Ø1
111Ø  Ø2Ø2        Ø2Ø2
1111  66Ø5        66Ø5
            [1
1112  Ø6Ø1  #2B   Ø6Ø1
1113  46Ø2        46Ø2
1114  Ø2Ø1        Ø2Ø1
1115  Ø4Ø6        Ø4Ø6
1116  Ø1Ø1        Ø1Ø1
1117  67Ø5        67Ø5
            [2
112Ø  Ø4Ø5  #2C   Ø4Ø5
1121  45Ø1        45Ø1
1122  Ø6Ø2        Ø6Ø2
1123  Ø7Ø1        Ø7Ø1
1124  ØØØ1        ØØØ1
1125  Ø1Ø4        Ø1Ø4
1126  Ø6Ø4        Ø6Ø4
1127  66Ø2        66Ø2
            [3
113Ø  Ø4Ø5  #2D   Ø4Ø5
1131  45Ø1        45Ø1
1132  Ø6Ø2        Ø6Ø2
1133  Ø7Ø1        Ø7Ø1
1134  ØØØ1        ØØØ1
1135  Ø1Ø1        Ø1Ø1
1136  Ø7Ø1        Ø7Ø1
1137  ØØØ1        ØØØ1
114Ø  Ø1Ø1        Ø1Ø1
1141  Ø2Ø2        Ø2Ø2
1142  Ø3Ø1        Ø3Ø1
1143  47Ø1        47Ø1
1144  26Ø5        26Ø5
            [4
1145  Ø5Ø3  #2E   Ø5Ø3
1146  Ø6Ø1        Ø6Ø1
1147  42Ø4        42Ø4
115Ø  Ø5Ø3        Ø5Ø3
1151  ØØØ6        ØØØ6
1152  66Ø3        66Ø3
            [5
1153  Ø4Ø1  #2F   Ø4Ø1
```

```
FIN=DSP1.14  LN=1164

     CONT
1154 47Ø1         47Ø1
1155 Ø6Ø2         Ø6Ø2
1156 Ø5Ø1         Ø5Ø1
1157 Ø4Ø2         Ø4Ø2
116Ø Ø3Ø1         Ø3Ø1
1161 Ø2Ø2         Ø2Ø2
1162 Ø1Ø1         Ø1Ø1
1163 Ø4Ø3         Ø4Ø3
1164 Ø6Ø4         Ø6Ø4
1165 47Ø2         47Ø2
1166 2ØØ4         2ØØ4
          [6
1167 Ø5Ø1 #2G     Ø5Ø1
117Ø Ø4Ø2         Ø4Ø2
1171 46Ø2         46Ø2
1172 Ø7Ø1         Ø7Ø1
1173 ØØØ1         ØØØ1
1174 Ø1Ø1         Ø1Ø1
1175 Ø2Ø2         Ø2Ø2
1176 Ø3Ø1         Ø3Ø1
1177 Ø4Ø1         Ø4Ø1
12ØØ Ø5Ø4         Ø5Ø4
12Ø1 47Ø2         47Ø2
12Ø2 2ØØ4         2ØØ4
          [7
12Ø3 Ø6Ø1 #2H     Ø6Ø1
12Ø4 44Ø2         44Ø2
12Ø5 Ø5Ø1         Ø5Ø1
12Ø6 Ø4Ø1         Ø4Ø1
12Ø7 Ø5Ø2         Ø5Ø2
121Ø Ø2Ø4         Ø2Ø4
1211 67Ø6         67Ø6
          [8
1212 Ø5Ø3 #2I     Ø5Ø3
1213 47Ø1         47Ø1
1214 ØØØ1         ØØØ1
1215 Ø1Ø1         Ø1Ø1
1216 Ø2Ø2         Ø2Ø2
1217 Ø3Ø1         Ø3Ø1
122Ø Ø4Ø1         Ø4Ø1
1221 Ø5Ø1         Ø5Ø1
1222 Ø6Ø2         Ø6Ø2
1223 Ø5Ø1         Ø5Ø1
1224 Ø4Ø1         Ø4Ø1
1225 Ø3Ø1         Ø3Ø1
1226 Ø2Ø2         Ø2Ø2
1227 Ø1Ø1         Ø1Ø1
123Ø ØØØ1         ØØØ1
1231 Ø7Ø1         Ø7Ø1
1232 47Ø3         47Ø3
1233 26Ø2         26Ø2
          [9
1234 45Ø4 #2J     45Ø4
1235 Ø4Ø1         Ø4Ø1
1236 Ø3Ø1         Ø3Ø1
1237 Ø2Ø2         Ø2Ø2
124Ø Ø1Ø1         Ø1Ø1
```

```
FIN=DSP1,15  LN=1255

     CONT
1241 0001         0001
1242 0701         0701
1243 0602         0602
1244 6703         6703
          [ALPHABET
          [A
1245 4404 #1A     4404
1246 0502         0502
1247 0702         0702
1250 0004         0004
1251 4302         4302
1252 0202         0202
1253 4604         4604
1254 6702         6702
          [B
1255 0403 #1B     0403
1256 4603         4603
1257 0701         0701
1260 0001         0001
1261 0101         0101
1262 0203         0203
1263 0406         0406
1264 0603         0603
1265 0701         0701
1266 0001         0001
1267 0101         0101
1270 6703         6703
          [C
1271 0603 #1C     0603
1272 0501         0501
1273 4101         4101
1274 0202         0202
1275 0301         0301
1276 0404         0404
1277 0501         0501
1300 0602         0602
1301 0701         0701
1302 4702         4702
1303 2003         2003
          [D
1304 4406 #1D     4406
1305 0603         0603
1306 0701         0701
1307 0004         0004
1310 0101         0101
1311 0203         0203
1312 6606         6606
          [E
1313 4406 #1E     4406
1314 0604         0604
1315 4103         4103
1316 0201         0201
1317 4603         4603
1320 4103         4103
1321 4604         4604
1322 6602         6602
          [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
14Ø6 4ØØ6        4ØØ6
14Ø7 Ø6Ø4        Ø6Ø4
141Ø 66Ø2        66Ø2
          [M
1411 44Ø6 #1M    44Ø6
1412 Ø7Ø2        Ø7Ø2
1413 Ø5Ø2        Ø5Ø2
1414 ØØØ6        ØØØ6
1415 66Ø2        66Ø2
          [N
1416 44Ø6 #1N    44Ø6
1417 Ø7Ø1        Ø7Ø1
142Ø ØØØ1        ØØØ1
1421 Ø7Ø2        Ø7Ø2
1422 ØØØ1        ØØØ1
1423 Ø7Ø1        Ø7Ø1
1424 Ø4Ø6        Ø4Ø6
1425 47Ø2        47Ø2
1426 2ØØ4        2ØØ4
          [O
1427 44Ø6 #1O    44Ø6
143Ø Ø6Ø4        Ø6Ø4
1431 ØØØ6        ØØØ6
1432 Ø2Ø4        Ø2Ø4
1433 66Ø6        66Ø6
          [P
1434 44Ø6 #1P    44Ø6
1435 Ø6Ø3        Ø6Ø3
1436 Ø7Ø1        Ø7Ø1
1437 ØØØ1        ØØØ1
144Ø Ø1Ø1        Ø1Ø1
1441 Ø2Ø3        Ø2Ø3
1442 47Ø3        47Ø3
1443 26Ø3        26Ø3
          [Q
1444 Ø4Ø1 #1Q    Ø4Ø1
1445 47Ø1        47Ø1
1446 Ø6Ø2        Ø6Ø2
1447 Ø5Ø1        Ø5Ø1
145Ø Ø4Ø4        Ø4Ø4
1451 Ø3Ø1        Ø3Ø1
1452 Ø2Ø2        Ø2Ø2
1453 Ø1Ø1        Ø1Ø1
1454 ØØØ4        ØØØ4
1455 46Ø3        46Ø3
1456 47Ø1        47Ø1
1457 66Ø2        66Ø2
          [R
146Ø 44Ø6 #1R    44Ø6
1461 Ø6Ø3        Ø6Ø3
1462 Ø7Ø1        Ø7Ø1
1463 ØØØ2        ØØØ2
1464 Ø1Ø1        Ø1Ø1
1465 Ø2Ø3        Ø2Ø3
1466 46Ø2        46Ø2
1467 47Ø2        47Ø2
147Ø 66Ø2        66Ø2
```

```
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 4ØØ1        4ØØ1
1554 Ø7Ø2        Ø7Ø2
1555 Ø5Ø2        Ø5Ø2
1556 Ø4Ø1        Ø4Ø1
1557 41Ø2        41Ø2
156Ø ØØØ1        ØØØ1
1561 4ØØ3        4ØØ3
1562 66Ø4        66Ø4
              [Z
1563 Ø4Ø6 #1Z  Ø4Ø6
1564 46Ø4        46Ø4
1565 ØØØ1        ØØØ1
1566 Ø1Ø4        Ø1Ø4
1567 ØØØ1        ØØØ1
157Ø Ø6Ø4        Ø6Ø4
1571 66Ø2        66Ø2
              [SPECIAL
              [EOL
1572 2ØØØ #2K  2ØØØ
              [DELETE-BACKSPACE
1573 22Ø6 #2L  22Ø6
              [SPACE
1574 26Ø6 #2M  26Ø6
              [&
1575 Ø6Ø2 #2N  Ø6Ø2
1576 Ø5Ø1        Ø5Ø1
1577 41Ø1        41Ø1
16ØØ Ø3Ø1        Ø3Ø1
16Ø1 Ø4Ø2        Ø4Ø2
16Ø2 45Ø1        45Ø1
16Ø3 42Ø1        42Ø1
16Ø4 Ø4Ø1        Ø4Ø1
16Ø5 Ø6Ø1        Ø6Ø1
16Ø6 ØØØ1        ØØØ1
16Ø7 67Ø4        67Ø4
              ['
161Ø Ø6Ø4 #2O  Ø6Ø4
1611 42Ø1        42Ø1
1612 Ø3Ø1        Ø3Ø1
1613 Ø4Ø1        Ø4Ø1
1614 Ø5Ø1        Ø5Ø1
1615 Ø6Ø1        Ø6Ø1
1616 Ø7Ø1        Ø7Ø1
1617 ØØØ1        ØØØ1
162Ø Ø1Ø1        Ø1Ø1
1621 41Ø2        41Ø2
1622 44Ø5        44Ø5
1623 46Ø2        46Ø2
1624 27Ø3        27Ø3
              [=
1625 Ø4Ø3 #2P  Ø4Ø3
1626 46Ø4        46Ø4
1627 47Ø2        47Ø2
163Ø 2ØØ1        2ØØ1
              [+
1631 Ø4Ø3 #2Q  Ø4Ø3
1632 46Ø4        46Ø4
```

```
FIN=DSP1,22  LN=1712
     CONT
1633 43Ø2        43Ø2
1634 4ØØ4        4ØØ4
1635 47Ø1        47Ø1
1636 26Ø3        26Ø3
          [/
1637 44Ø6 #2R   44Ø6
164Ø 67Ø6        67Ø6
          [#
1641 Ø4Ø4 #2S   Ø4Ø4
1642 46Ø4        46Ø4
1643 4ØØ2        4ØØ2
1644 42Ø4        42Ø4
1645 45Ø3        45Ø3
1646 4ØØ4        4ØØ4
1647 42Ø2        42Ø2
165Ø 44Ø4        44Ø4
1651 67Ø5        67Ø5
          [CASE
1652 2ØØØ #2T   2ØØØ
          [CASE SPECIAL
          [=
1653 Ø5Ø4 #2U   Ø5Ø4
1654 42Ø4        42Ø4
1655 4ØØ2        4ØØ2
1656 46Ø4        46Ø4
1657 67Ø2        67Ø2
          [%
166Ø Ø4Ø3 #2V   Ø4Ø3
1661 4ØØ2        4ØØ2
1662 Ø7Ø1        Ø7Ø1
1663 Ø6Ø1        Ø6Ø1
1664 Ø5Ø1        Ø5Ø1
1665 Ø4Ø2        Ø4Ø2
1666 4ØØ2        4ØØ2
1667 47Ø1        47Ø1
167Ø 66Ø2        66Ø2
          [,
1671 Ø7Ø1 #2W   Ø7Ø1
1672 45Ø2        45Ø2
1673 Ø3Ø1        Ø3Ø1
1674 Ø1Ø1        Ø1Ø1
1675 Ø7Ø1        Ø7Ø1
1676 66Ø4        66Ø4
          [.
1677 Ø6Ø2 #2X   Ø6Ø2
17ØØ 45Ø1        45Ø1
17Ø1 Ø3Ø1        Ø3Ø1
17Ø2 Ø1Ø1        Ø1Ø1
17Ø3 Ø7Ø1        Ø7Ø1
17Ø4 66Ø4        66Ø4
          [$
17Ø5 Ø4Ø3 #2Y   Ø4Ø3
17Ø6 44Ø1        44Ø1
17Ø7 Ø5Ø2        Ø5Ø2
171Ø Ø7Ø2        Ø7Ø2
1711 ØØØ2        ØØØ2
1712 Ø1Ø2        Ø1Ø2
```

```
     CONT
1713 0302       0302
1714 0401       0401
1715 0604       0604
1716 4702       4702
1717 2001       2001
          [[
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		VALUE	LINE
1F	Ø261	25Ø	6I	Ø157	144
1G	Ø305	274	6J	Ø177	164
1H	Ø34Ø	327	6K	Ø21Ø	175
1I	Ø366	355	6L	Ø221	2Ø6
1J	1612	1626	6Y	Ø77Ø	773
1K	1643	1657	6Z	Ø771	774
1L	1551	1564	7C	Ø4ØØ	376
1M	1561	1574	7D	Ø747	752
1N	1571	16Ø4	7I	Ø463	464
1T	16ØØ	1614	7M	Ø612	614
2A	Ø233	221	7R	Ø754	757
2B	Ø236	224	7T	Ø562	563
2C	Ø241	227	7U	Ø741	744
2D	Ø245	233	7X	Ø737	741
2E	Ø251	237	7Y	Ø74Ø	742
2F	Ø255	243	8A	Ø571	572
2G	1112	1122	8B	Ø574	575
2H	1115	1125	8C	1Ø74	11Ø3
2I	112Ø	113Ø	8D	1Ø13	1Ø22
2J	1124	1134	8E	1Ø16	1Ø25
2K	1142	1152	8F	1175	12Ø6
2L	116Ø	117Ø	8G	1311	1323
2T	16Ø4	162Ø	8H	1Ø37	1Ø46
3B	Ø635	637	8I	1Ø56	1Ø65
3C	Ø65Ø	652	8J	12Ø3	1214
3D	Ø667	671	8K	12Ø5	1216
3E	Ø657	661	8L	1221	1232
3F	Ø7Ø6	71Ø	9A	123Ø	1241
3G	Ø715	717	9B	1233	1244
3H	Ø7Ø1	7Ø3	9C	134Ø	1352
3I	Ø722	724	9D	1237	125Ø
3J	Ø6Ø2	6Ø3	9E	1355	1367
3K	Ø437	435	9F	1377	1411
3L	Ø45Ø	447	9G	161Ø	1624
3M	Ø467	47Ø	9H	1611	1625
3N	Ø6ØØ	6Ø1	9I	16Ø6	1622
3O	Ø6Ø1	6Ø2	9J	16Ø7	1623
3P	Ø736	74Ø	9K	1425	1437
3Q	Ø735	737	9L	1372	14Ø4
3R	Ø454	453	9M	143Ø	1443
3S	Ø57Ø	571	9N	1453	1466
3T	3ØØØ	17Ø3	9O	1457	1472
3U	Ø411	4Ø7	9P	1464	1477
3V	Ø576	577	9Q	1531	1544
3W	Ø577	6ØØ	9R	1541	1554
3X	Ø733	735	9S	1577	1612
3Y	Ø734	736	9T	1267	13ØØ
3Z	Ø416	414	9Y	17ØØ	17Ø1
4A	ØØ64	47	9Z	17Ø1	17Ø2
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			

```
    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 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
 445 6441       JMP '-4
 446 0235       XSK & 15
 447 6437       JMP 3K
           [TEST FOR END
 450 1017  #3L LDA 17
 451 1560       BCL &
 452 5777       5777
 453 0450       AZE
 454 0000  #3R RETURN
           [STEP LINE OF CHAR-TABLE-ALLOWS OVERLAP INTO UPPER MEM
           ORY
 455 1020       LDA &
 456 4000       -3777
 457 1140       ADM
 460 0017       17
 461 1017       LDA 17
 462 6411       JMP 3U
           [INCREMENT PLOTTER AND X.Y SR
 463 4467  #7I STC 3M
 464 2000       ADD 0
 465 4570       STC 3S
 466 1520       SRO & [TEST FOR -Y
 467 0000  #3M [KEY WORD
 470 6511       JMP '+21
 471 2740       ADD 7Y [TEST FOR POINTS LESS THAN OR EQUAL LOWER B
           OUND
 472 2600       ADD 3N
 473 0451       APO
 474 6505       JMP '+11
 475 0011       CLR [TEST FOR POINTS GREATER THAN UPPER BOUND
 476 2740       ADD 7Y
 477 2601       ADD 3O
 500 0471       APO &
 501 6505       JMP '+4
 502 1020       LDA & [CARRIAGE RIGHT
 503 0004       4
 504 6571       JMP 8A
 505 0011       CLR
 506 2740       ADD 7Y [DECREASE POINT INDICATOR IN 7Y
 507 2576       ADD 3V
 510 4740       STC 7Y
 511 1500       SRO [TEST FOR +Y
 512 0467       3M
 513 6536       JMP '+23
 514 2740       ADD 7Y [TEST FOR POINTS GREATER THAN OR EQUAL LOWE
            R BOUND
 515 2601       ADD 3O
 516 2577       ADD 3W
 517 0471       APO &
 520 6532       JMP '+12
 521 0011       CLR [TEST FOR POINTS LESS THAN LOWER BOUND
 522 2740       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 #30      =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
```

```
     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 5340      STC9C
1152 6612      JMP7M [RETURN TO [0,1]
1153 0000      HLT
1154 1020      LDA&
1155 1606      9I
1156 7175      JMP8F [PLOT PULSE RATE
1157 7120      JMP2I
1160 0770 #2L  770 [READ IN STROKE VOLUME DATA
1161 6274      6/274
1162 0750      750
1163 7275      7/275
1164 0011      CLR
1165 5233      STC9B
1166 5340      STC9C [0
1167 6612      JMP7M [RETURN TO [0,1]
1170 0000      HLT
1171 1020      LDA&
1172 1611      9H
1173 7175      JMP8F [PLOT STROKE VOLUME
1174 7021      JMP8E+3
               [PLOT CURVE
1175 5237 #8F  STC9D
1176 5577      STC9S
1177 0044      SET4
1200 0000      0
1201 0061      SET&1
1202 2777      2777
1203 0461 #8J  SNS&1 [IF SENSE SWITCH 1 IS SET
1204 7355      JMP9E [JUMP TO AVERAGE 4 POINTS
1205 0043 #8K  SET3
1206 1700      9Y [SET NO. OF POINTS TO PLOT
1207 0536      OPR&16 [READ RSW
1210 1560      BCL& [EXAMINE BITS 0 AND 1
1211 7774      7774
1212 1120      ADA& [C[RSW] DESERMINE NO. OF SYMBOLS PLOTTED
1213 1600      1T
1214 1040      STA
1215 1311      8G
1216 5220      STC'+2
1217 0045      SET5
1220 0000      0
1221 1021 #8L  LDA&1 [LOAD A WITH Y COORDINATE
1222 7230      JMP9A [PLOT POINT
1223 1020      LDA&
1224 0002      2
1225 1140      ADM
1226 0733      3X
1227 7221      JMP8L
1230 0050 #9A  SET10
1231 0000      0
1232 1120      ADA& [MODIFY FOR PLACEMENT ON GRAPH
1233 0000 #9B  0 [VALUE FILLED IN
1234 0470      AZE&
1235 7240      JMP9D+1
1236 1240      MUL
1237 0000 #9D  0 [VALUE FILLED IN
1240 1120      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 1Ø4Ø      STA
1332 1577      9S
1333 114Ø      ADM
1334 Ø733      3X
1335 6741      JMP7U [PEN UP
1336 6612      JMP7M  [PREPARE TO DRAW SYMBOL
1337 1Ø2Ø      LDA&
134Ø ØØØØ #9C  Ø [SYMBOL CODE FILLED IN
1341 Ø642      UMB2
1342 64ØØ      JMP7C [PLOT SYMBOL
1343 Ø64Ø      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
```

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PLOT1,17  LN=1434

      CONT
1422 114Ø       ADM
1423 Ø733       3X
1424 7377       JMP9F
1425 1Ø2Ø  #9K  LDA&
1426 16ØØ       1T
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&
```

```
     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

PRINT1,1 LN=1


```
     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
1Ø7 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 0256       9F
205 0264       9C
206 0256       9F
207 7734       JMP1734
210 0256       9F
211 6046       =7Z
212 6400       JMP400 [PRINT IT
213 6640       JMP640 [PRINT 5 SPACES
214 6640       JMP640
215 6640       JMP640
216 6640       JMP640
217 6640       JMP640
220 0067       SFT&7
221 4340       1X=1+4000
222 1327  #9I  LDH&7 [NORMALIZED VALUE
223 1420       SHD&
224 7700       7700
225 6230       JMP9J [JUMP IF END OF CHARACTER STRING
226 6642       JMP642 [PRINT CHARACTER
227 6222       JMP9I [GET NEXT CHARACTER
230 6640  #9J  JMP640
231 6640       JMP640
232 6640       JMP640
233 1000       LDA [SEE IF AVERAGE OF FIRST 4 VALUES
234 0255       9M
235 0470       AZE& [SKIP IF NOT THE FIRST
236 6246       JMP9K
237 7163       JMP1163 [DIVIDE PRESENT AVERAGE
240 0256       9F      [BY FIRST AVERAGE
241 7516       =9N
242 6400       JMP400 [PRINT NORMALIZED VALUE
243 0232       XSK&12 [SKIP IF REQUIRED NO. OF VALUES PRINTED
244 6076       JMP9E [OTHERWISE GET NEXT 4 VALUES
245 6006       JMP6 [EXIT
246 1020  #9K  LDA&
247 0001       1
250 4255       STC9M
251 7734       JMP1734 [PUT AVERAGE UALUE IN
252 0256       9F      [9N SO THAT NORMALIZED
253 7516       =9N     [VALUE WILL BE 1
254 6237       JMP9J+7
255 0000  #9M  0 [FLAG = SET AFTER FIRST AVERAGE IN EACH
          [GROUP OF VALUES IS COMPUTED
256 0000  #9F  0 [HOLDS PRESENT AVERAGE
257 0000       0
260 0000       0
261 0000  #9N  0 [HOLDS FIRST AVERAGE
262 0000       0
263 0000       0
264 0000  #9C  0
265 0000       0
266 0000       0
267 0000  #9D  0
```

```
     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


```
     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
```

```
    CONT
466 0451       APO
467 6502       JMP30
470 0011       CLR
471 2016       ADD16
472 1420       SHD&
473 1100       1100
474 6502       JMP30
475 0236       XSK&16
476 7734       JMP5N
477 0570       4E
500 7204       *4F
501 6461       JMP3N
502 0011  #30  CLR
503 2016       ADD16
504 0450       AZE
505 6513       JMP'+6
506 0213       XSK13
507 6513       JMP'+4
510 2574       ADD4F+1
511 0450       AZE
512 6546       JMP3Q-4
513 6642       JMP2A
514 0213       XSK13
515 6522       JMP3P
516 1020       LDA&
517 0061       61
520 6642       JMP2A
521 0233       XSK&13
522 0234  #3P  XSK&14
523 6552       JMP3Q
524 1520       SRO&
525 5252       5252
526 6015       JMP15
527 1120       ADA&
530 0030       30
531 6642       JMP2A
532 0074       SET&14
533 7774       *3
534 2435       ADD3M
535 1040       STA
536 0575       4F+2
537 0353       SCR13
540 4574       STC4F+1
541 7743       JMP50
542 7204       *4F
543 1020       LDA&
544 0002       2
545 6434       JMP3M-1
546 0011       CLR
547 2435       ADD3M
550 3550       ADD7L
551 4435       STC3M
552 7163  #3Q  JMP5G
553 0565       4D
554 0562       4B
555 0565       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
          [10•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
```

```
          CONT
1002 7406      JMP7A
1003 1001      LDA1
1004 0017      COM
1005 1102      ADA2
1006 0454      OVF
1007 7013      JMP*+4
1010 0354      SCR14
1011 1660      BCO&
1012 7737      7737
1013 0361      SCR&1
1014 0261      ROL&1
1015 0472      LAE&
1016 0017      COM
1017 5566      STC7M+1
1020 7401      JMP6I
1021 0452      LZE
1022 7374      JMP6H
1023 1001      LDA1
1024 1043      STA3
1025 1022      LDA&2
1026 1063      STA&3
1027 1022      LDA&2
1030 1063      STA&3
1031 7565      JMP7M
1032 7501      JMP7H
1033 7523      JMP7I-2
1034 7371      JMP6G
1035 1023      LDA&3
1036 7322      JMP6C+2
1037 0041      SET1
1040 1372      6G+1
1041 0062      SET&2
1042 0000      0
1043 7334      JMP6D
1044 7623      JMP7Q
          [SUBTRACT
1045 0011  #5B CLR
1046 2000      ADD0
1047 7406      JMP7A
1050 7401      JMP6I
1051 7332      JMP6D-2
1052 7374      JMP6H
1053 7003      JMP5A+3
          [MULTIPLY
1054 0011  #5C CLR
1055 2000      ADD0
1056 7406      JMP7A
1057 1001      LDA1
1060 1102      ADA2
1061 7352      JMP6E+1
1062 5142      STC5E
1063 7320      JMP6C
1064 7401      JMP6I
1065 7334      JMP6D
1066 7374      JMP6H
1067 7334      JMP6D
1070 1022      LDA&2
```

PRINT1,13 LN=1073

```
      CONT
1071  1022        LDA&2
1072  0301        ROR1
1073  1042        STA2
1074  7374        JMP6H
1075  1021        LDA&1
1076  1262        MUL&2
1077  1043        STA3
1100  0005        ZTA
1101  1063        STA&3
1102  1021        LDA&1
1103  0301        ROR1
1104  1262        MUL&2
1105  0241        ROL1
1106  1063        STA&3
1107  7376        JMP6H+2
1110  1021        LDA&1
1111  1242        MUL2
1112  7145        JMP5F
1113  7374  #5D   JMP6H
1114  1021        LDA&1
1115  1021        LDA&1
1116  0301        ROR1
1117  1262        MUL&2
1120  7145        JMP5F
1121  7371        JMP6G
1122  1023        LDA&3
1123  1023        LDA&3
1124  0261        ROL&1
1125  0241        ROL1
1126  1560        BCL&
1127  7776        7776
1130  5622        STC7P
1131  7371        JMP6G
1132  1023        LDA&3
1133  0261        ROL&1
1134  1063        STA&3
1135  7371        JMP6G
1136  1003        LDA3
1137  1063        STA&3
1140  7371        JMP6G
1141  1020        LDA&
1142  0000  #5E   0
1143  1043        STA3
1144  7623        JMP7Q
1145  5723  #5F   STC7X
1146  7313        JMP6B
1147  5724        STC7X+1
1150  0061        SET&1
1151  1722        7X=1
1152  7371        JMP6G
1153  7501        JMP7H
1154  0062        SET&2
1155  7777        =0
1156  7525        JMP7I
1157  1520        SRO&
1160  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
```

```
     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       STCØ
1517 1223       LAM&3
1520 4000       STCØ
1521 1223       LAM&3
1522 6004       JMP4
1523 0062       SET&2
1524 0000       Ø
           [CHECK FOR
           [ADD OVERFLOW
1525 0041  #7I SET1
1526 0000       Ø
1527 7371       JMP6G
1530 1020       LDA&
1531 0000  #7J  Ø
1532 1660       BCO&
1533 0000       Ø
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       Ø
1567 0042       SET2
1570 0000       Ø
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        JMP70
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  [XIT
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  [RTN
          [ARG 1
1723 0000 #7X  0
1724 0000      0
1725 0000      0
          [ARG 2
1726 0000 #7Y  0
1727 0000      0
1730 0000      0
          [FAC
1731 0000 #7Z  0
1732 0000      0
1733 0000      0
          [TRANSFER
1734 0011 #5N  CLR
1735 2000      ADD0
1736 7406      JMP7A
1737 0042      SET2
1740 1435      7D
1741 7303      JMP6A
1742 7671      JMP7T-1
          [FLOAT
1743 0011 #50  CLR
1744 2000      ADD0
1745 7406      JMP7A
1746 3435      ADD7D
1747 5372      STC6G+1
1750 7371      JMP6G
1751 1020      LDA&
```

```
PRINT1,23  LN=2003

     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)

$L^2 = (Lcm/10)^2$ L is multiplied by 10 when entered

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

$\tau = (T_3 - T_1)$ (See Fig. 1)

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

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

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

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

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:

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

which reduces to:

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

Computation of Pulse Rate

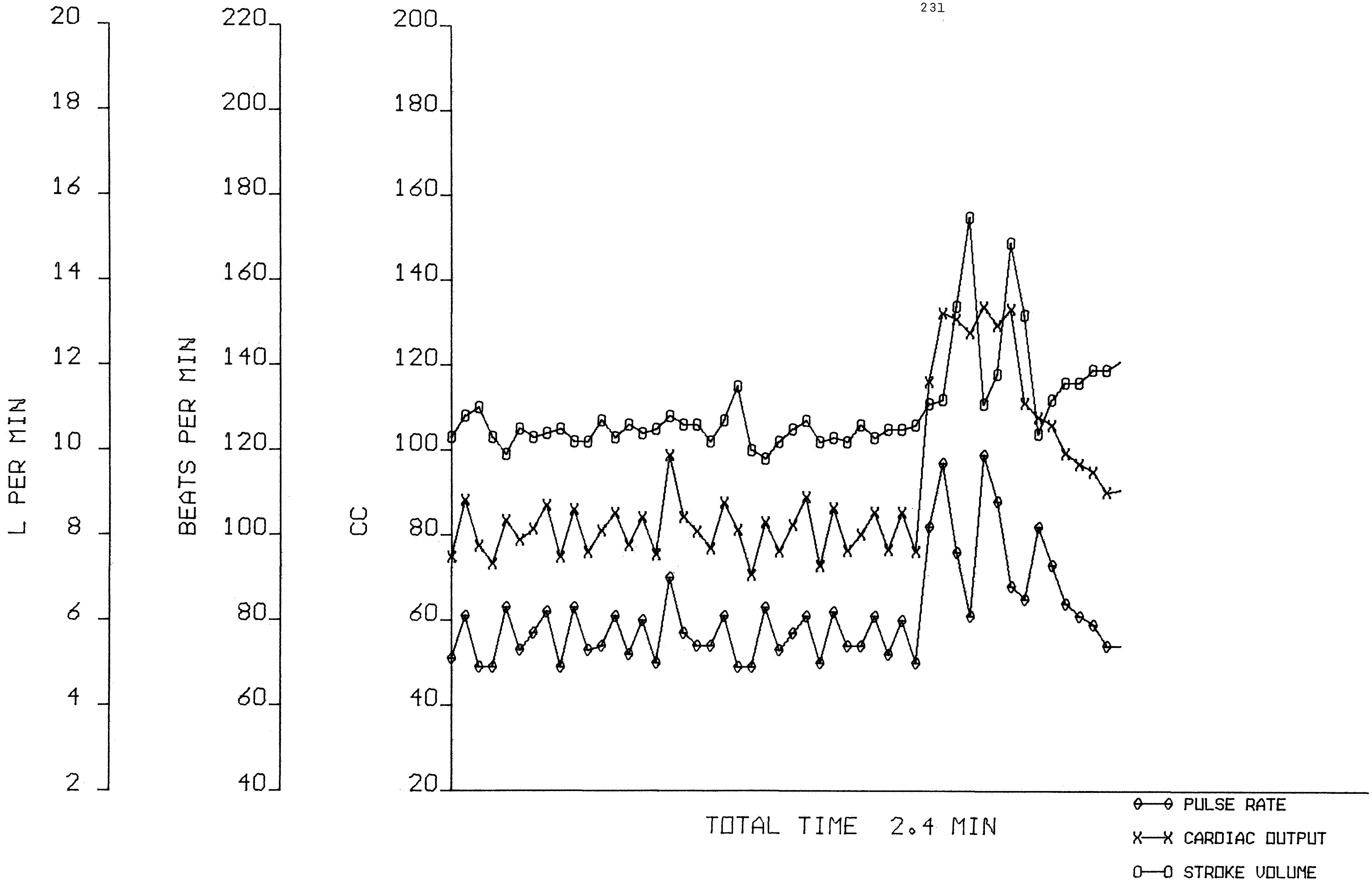
$$T = t' \text{ addresses} \cdot 2\text{ms/address} \cdot 1 \text{ sec}/10^3\text{ms} \cdot 1 \text{ min}/60 \text{ sec} = t' \text{ min}/3 \times 10^4$$

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.