EUROPEAN COAL AND STEEL COMMUNITY

Community Ergonomics Research

DOC. N° 1248/76 e RCE

Translations	: French, German, Italian
Distribution	: Enterprises

Technical Report N° 24

A METHODOLOGY FOR EVALUATING HIGH WORK LOADS

Source : Ergonomics Team of the U.K. Steel Industry

Authors : J.E. CRAWLEY, J. MUSGROVE, R.B. PLENTY

Reference period : 1.1.1974 - 31.8.1975

65.015

EUROPEAN COAL AND STEEL COMMUNITY Lux

DOC. N° 1248/76 e RCE

Community Ergonomics Research

Translations :	French, German, Italian
Distribution :	Enterprises

Technical Report N° 24

A METHODOLOGY FOR EVALUATING HIGH WORK LOADS

Source : Ergonomics Team of the U.K. Steel Industry

Authors : J.E. CRAWLEY, et al J. MUSGROVE, R.B. PLENTY

Reference period : 1.1.1974 - 31.8.1975

Financial assistance was provided for this study by the European Coal and Steel Community

1.2.1

CECA: 787

CONTENTS

SECTION I

SUMMARY

This is the final report for Part I of this project and reports the methodology that has been developed for use in the three years of Part II. The methodology is largely centred around the use of miniature, four channel, analogue tape recorders with an analysis system that depends on a PDP 11/45 computer for analogue to digital conversion and an ICL 1904s for data analysis and presentation.

Some of the laboratory work outlined in the plan for the next twelve months has in fact been started during the development work of Part I. Continuing parallel studies of laboratory assessment of fatigue and works identification of stress situations have been planned.

SECTION II

1.0 INTRODUCTION

There were two main objectives for the first year of this study. The first was to establish reliable, non disruptive methods of collecting physiological and environmental data in steelworks. The second was to establish laboratory methods of assessing operator fatigue whilst performing simulated steelworks jobs.

The application of this methodology is in the identification of stress situations in the industry and detailed investigation of these stresses in the laboratory. The outcome of any such investigation will depend largely on the job being evaluated. (Wherever possible routines of work and rest periods will be investigated.) In many situations however the task dictates the work pattern and therefore work-rest regimes are impossible to implement. In these situations job rotation will be considered as a means of reducing stress.

In order to evaluate our methodology as it developed a simulated task was set up in the laboratory. The simulation consists of a device that reproduces the postures and movements made in manual metal arc welding. An initial series of experiments on the combined effect of welding and posture was begun during this part of the project.

2.0 METHODS

2.1 Data Acquisition

Data acquisition of all transducable parameters is accomplished by the use of small, four channel analogue tape recorders (plate 1). This MEDILOG (Oxford Instrument Co. Ltd.) recorder can record analogue information on three channels. The fourth channel carries a 1 Hz crystal controlled timing device designed by BSC engineers (Appendix 1). The accuracy of this device allows precise matching of data from different recorders. The recording speed is 2 mm/sec and replay speed 50 mm/sec. The output from the replay machine (plate 2) is fed simultaneously into an oscilloscope, a pen recorder and the analogue to digital converter of a PDP 11/45 computer.

Digitized data from the PDP 11/45 is stored on magnetic tape for later analysis on an ICL 1904s computer.

2.2 Heart Rate

Heart rate is recorded as the electrocardiogram (ECG) using the system described in 2.1. Three chest electrodes (Cambridge Instrument Co. Ltd.) of the stick on type are used. The output from the ECG replay amplifier is fed via a pulse interval timer (PIT)

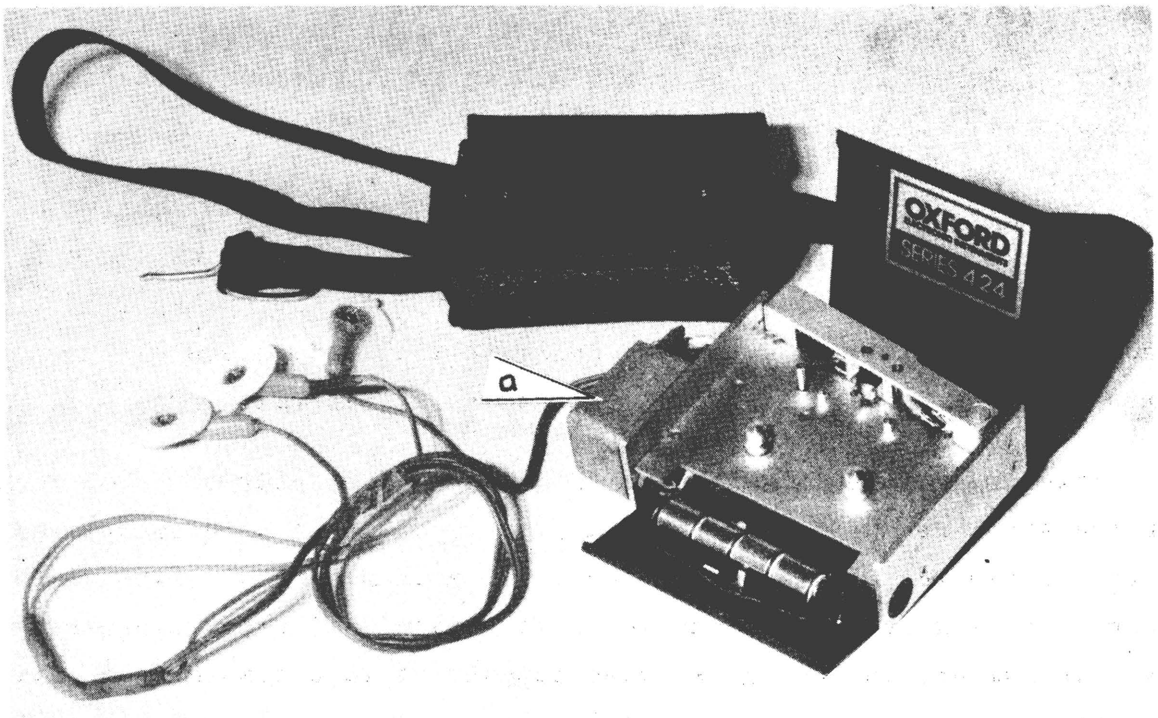


Plate 1 - A MEDILOG recorder with electrodes and carrying case
a. Modified input socket

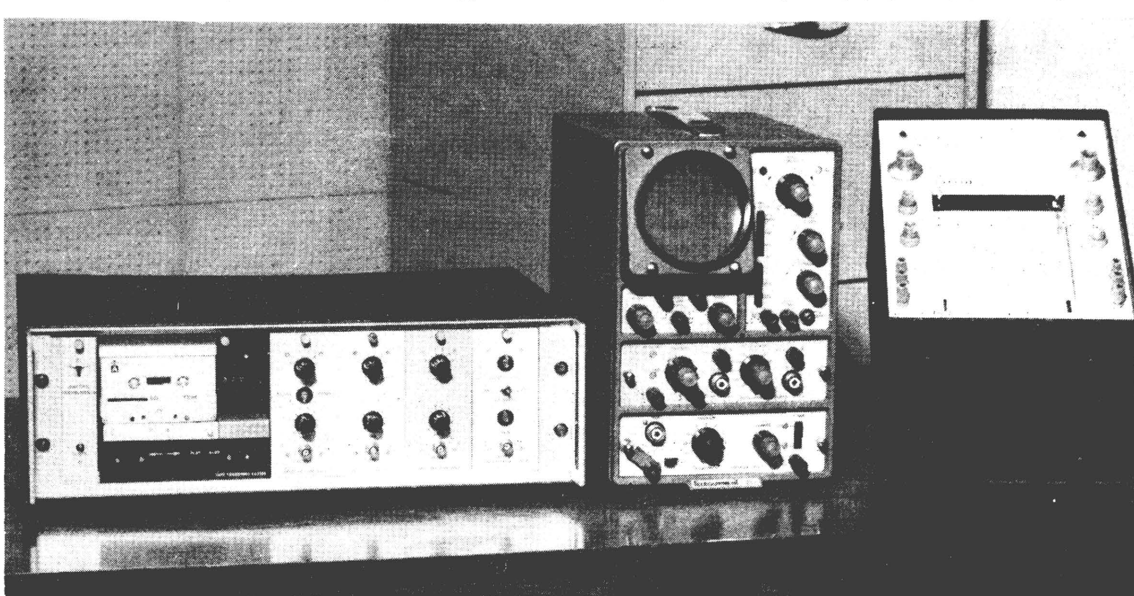


Plate 2 - The tape replay unit with replay amplifiers and puls interval timer. The oscilloscope and pen recorder are used for monitoring during replay onto the computer.

module in the replay unit (plate 2) to the computer. The PIT produces a 20 volt spike for each QRS complex. This spike (reduced to less than 5 volts) is counted, timed by the computer and, together with the 1 Hz timing pulse, stored on magnetic tape.

The stored heart rate information is processed by an ICL 1904s computer. The first stage calibrates the PIT pulses against the 1 Hz timing pulse and so produces a list of inter beat intervals (IBI). The second stage is a noise detection analysis that recognises extraordinarily long or short pulses and substitutes a mean value.

Inter beat interval analysis produces a graph plot of heart rate for the whole recording. The normal plot is of heart rate calculated every 0.1 minutes; however more, or less, accurate resolutions can be programmed. Maxima, minima and means for individual activities are given in summary tables. A detailed account of this system plus example outputs are given in Appendix III.

2.3 Environmental Data

Environmental measurements of temperature (wet bulb, dry bulb, globe) are monitored continuously. These measurements are recorded sequentially onto a single channel of the tape recorder in order to allow the other two channels (the fourth channel carries a timing pulse) to be used for such parameters as noise and air speed.

The measurement of environmental conditions is made using a light laboratories WBGT meter (plate 3) modified to give sequential output to the rape recorder automatically every 15 seconds.

Computer handling of temperature data gives graph plots of computed information such as mean radiant temperature and corrected effective temperature.

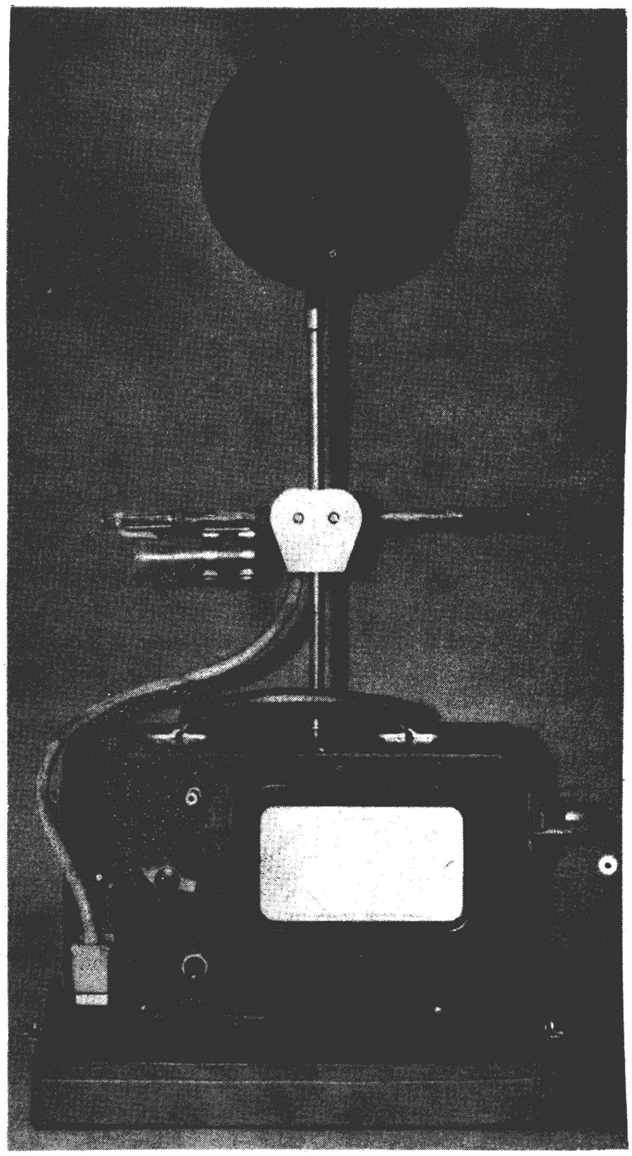


Plate 3 - Light laboratories WBGT meter

2.4 Activity Coding

Analysis of physiological and environmental data from either the works or laboratory simulation studies is only possible if this data can be related precisely to the activity of the operator or subject under study. In order to simplify the recording of activity information a sixteen channel keyboard operated device has been designed to record onto two channels of a miniature tape recorder. Each channel carries four levels of DC signal. A combination of any two of these signals allows 16 codes to be used. The third channel carries an interrupt signal every time the code changes and the fourth channel carries the timing pulse. The interrupt signal triggers the computer to read the new code during the analysis of this data. Analysis is by PDB 11/45 computer which thus provides the activity information for parallel processing with any other set of data i.e. heart rate or environmental conditions. Description of this activity coding device is given in Appendix II.

2.5 Energy Expenditure

In the laboratory a conventional Douglas Bag technique is used to measure oxygen consumption. Expired air is collected via a two way valve and mouthpiece into large plastic vinyl bags. Gas volume is measured using a Parkinson Cowan CD4 gas meter. Gas analysis is carried out using a Servomex portable oxygen analyser and a Horiba portable carbon dioxide analyser. Spot checks on gas analysis are made using a Lloyd-Haldane apparatus.

2.6 Electromyography

Localised muscle fatigue due to static work loads is difficult to quantify by conventional methods of either heart rate measurement or energy expenditure. An attempt to quantify this kind of fatigue by changes in electromyographic (EMG) recordings is being made.

In particular these changes relate to the spectral qualities of the signal (Kadefors[1]). Other changes associated with fatigue (Edwards and Lippold[2], Vredenbregt[3]) relate to the relative levels of electrical activity, and can also indicate fatigue. This type of result however must be treated with caution (Kadefors[1]) due to the increase in these parameters as a result not only of fatigue but also of an increase in force of contraction.

Changes in spectral quantities of EMG shown by other workers (Chaffin[4], Petersen[5]) will be investigated as a means of quantifying local muscle fatigue.

Surface electrodes are used of the silver disc type and placed longitudinally over the belly of the muscle 2 cm apart (Zuniga[6]).

Amplification of EMG signals is made using a six channel MEDELEC amplifier (plate 4). Recording is made onto a SANGAMO FM tape recorder. Subsequent frequency analysis of one second samples of EMG data is performed by a) Analogue to digital sampling (2000 times/sec) on a PDP 11/45 computer and b) Fast Fourier Transformation of this data on an ICL 1904s computer. The resultant analysis gives a power spectrum from 10-1000 Hz with a resolution of 1 Hz.

The computer output gives a 'decibel' against 'log of the frequency' plot of each 1 second sample plus root mean square, mean rectified average and amplitude or percentage power of any designated frequency band.

2.7 Subjective Estimates of Fatigue

In order to help locate anatomical areas of fatigue a general and local fatigue score is made. Details of the scoring technique and analysis procedures are given in Appendix IV.

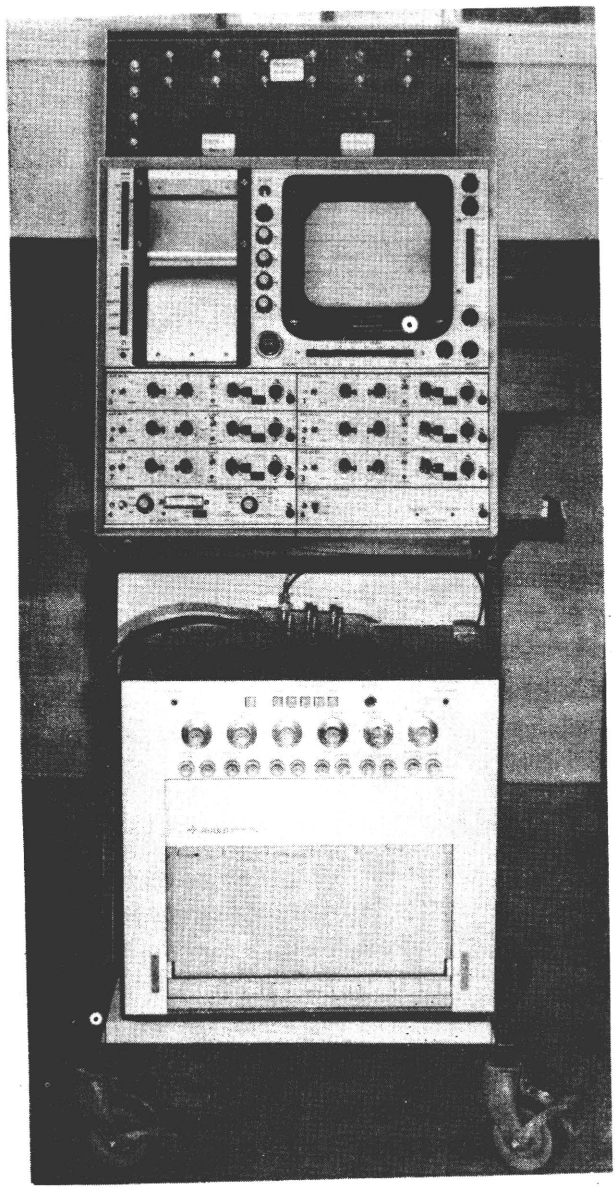


Plate 4 - MEDELEC EMG amplifiers and recorder. The six channel pen recorder is used for monitoring during recording sessions.

2.8 Questionnaire

Any job evaluation and subsequent reorganisation must take into account the attitudes of operators engaged on the job as it already exists. To this end we have designed a questionnaire that we hope will encourage worker participation in job design. A detailed account of this questionnaire is given in Appendix V.

3.0 LABORATORY SIMULATION OF MANUAL METAL ARC WELDING

This equipment, described in the 1st technical report for this project, has been completed and is shown in plates 5 and 6. Plate 6 shows the drive motor, track and photoelectric cell carriage. The carriage is drawn along the track only when the photoelectric cell is energised by a small light on the tip of the 'electrode' (plate 7). The 'welding rod' tracks through the hand piece (plate 8) at a rate that approximates to real welding. One pass of the track takes approximately 1.2 mins. Any deviation of the rod from the track is recorded as an error score on the counter (plate 6). The track itself can be raised or lowered to any required height and tilted 90° through any plane.

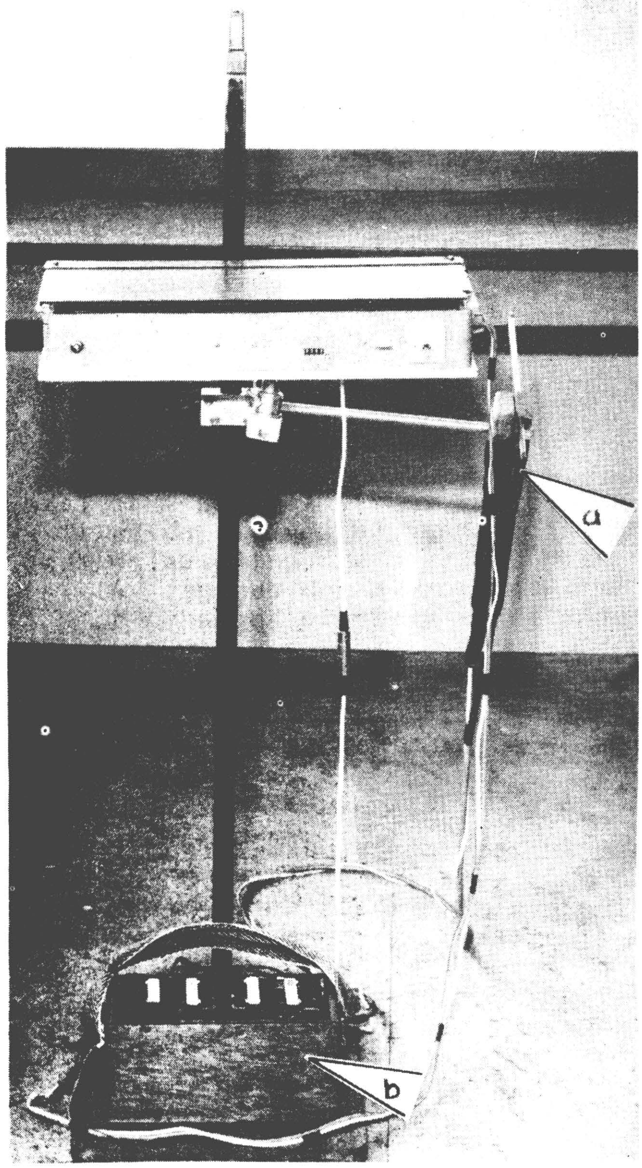
4.0 PLAN FOR 12 MONTH PERIOD ENDING MARCH 1976

(i.e. first year of Part II of this project
Convention : 6245. 35/8/002)

4.1 Laboratory Studies

a) effects of posture in manual metal arc welding. Parameters being measured include heart rate, EMG, energy expenditure and subjective estimates of fatigue.

b) carefully controlled experiments to quantify changes in EMG/spectrum relative to frequency, percentage of maximum voluntary contraction and duration of contraction.



a) Welding gun and rod

b) Battery box

Plate 5 - Welding simulator complete with stand

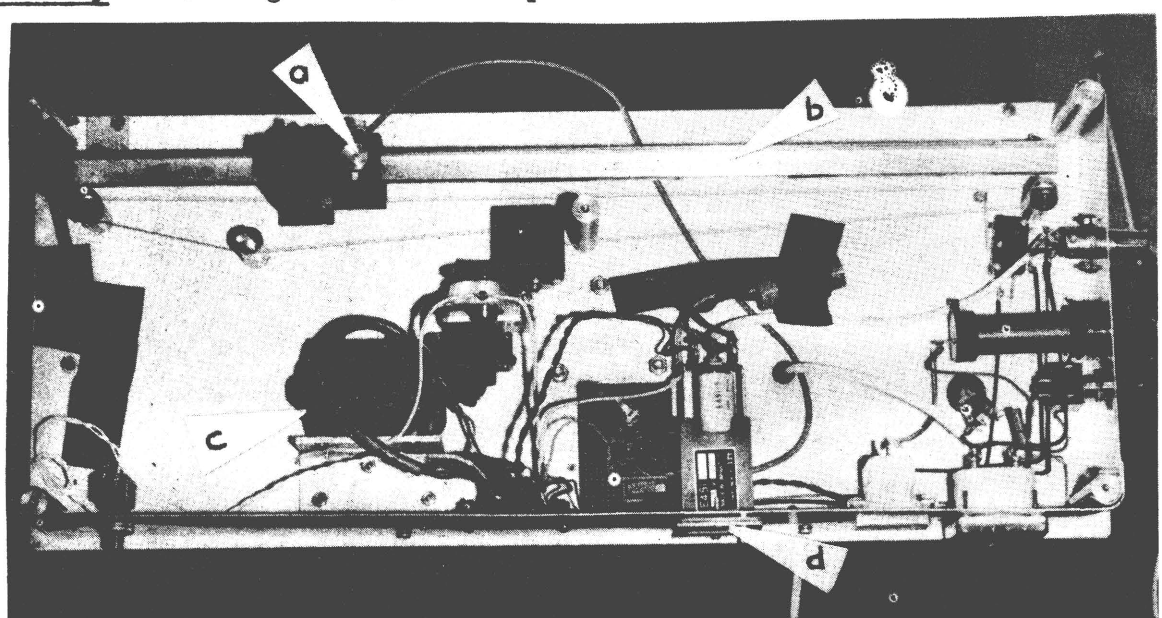


Plate 6 - Inside of welding simulator

a) Photoelectric cell and carriage
b) Carriage track
c) Drive motor and gear box
d) Error counter

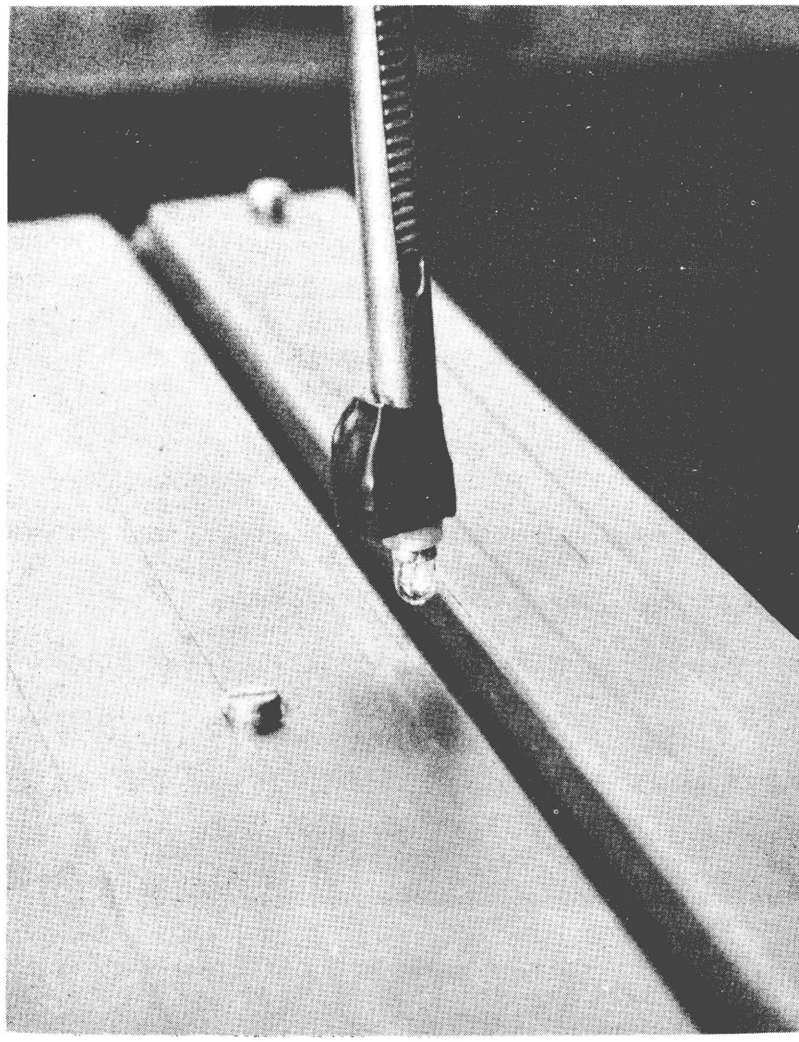


Plate 7 - Close up of track and end of 'electrode' showing small bulb used to activate the photocell

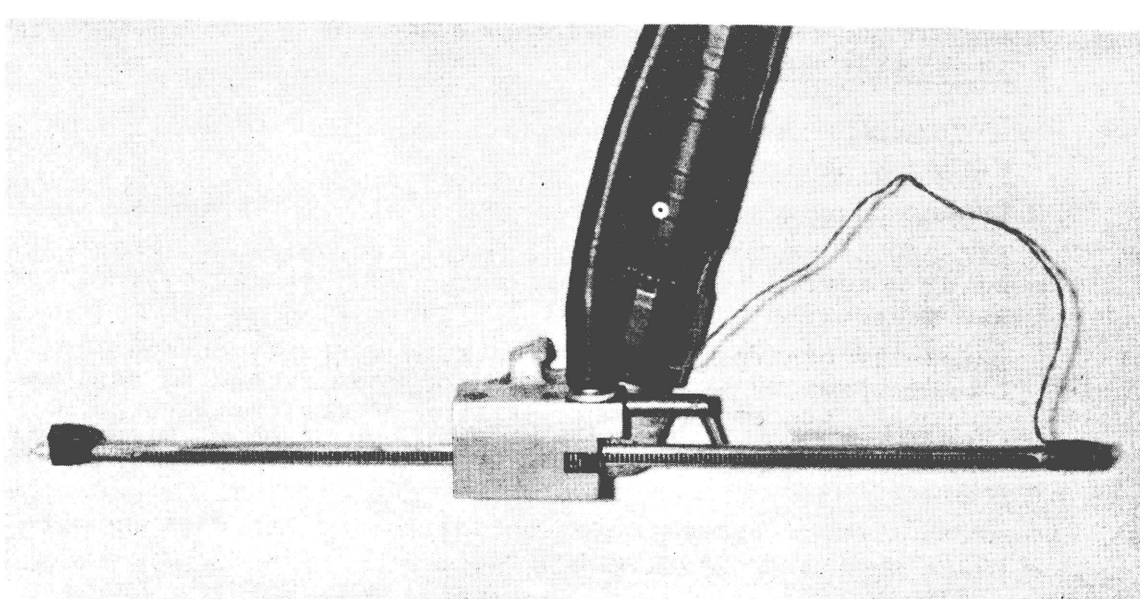


Plate 8 - Modified welding gun and 'electrode'

c) determination of suitable sites for body temperature measurement.

d) production of hardware for collection of EMG data on site using miniature tape recorders.

e) consideration of further simulation studies.

4.2 Field Work

a) Exploratory and follow up studies of industrial welding tasks.

b) Exploratory and follow up studies of coke-oven workers.

c) Investigation of other industrial tasks for future study.

5.0 APPENDICES

5.1 APPENDIX I - CRYSTAL TIMER CIRCUIT DESCRIPTION

The timer is built around the SAJ 220S monolithic integrated circuit made by ITT. It comprises an oscillator circuit, fifteen divider stages, a pulse shaper, a driving circuit and a stabilising circuit. A schematic diagram is shown in Figure 1.

The circuit uses a quartz crystal for precise control of the operating frequency of the circuit. The crystal frequency is 32.768 KHZ. When using a crystal operating at this frequency the output stage supplies monopolar pulses with a repetition frequency of 1 Hz and 32 ms duration. This was the exact repetition and duration required.

The oscillator circuit diagram (Figure 2) shows the components mentioned and the other biasing stabilising components. The diodes used as a voltage dropper.

The oscillator output waveform is shown in Figure 3. The required waveform is the inverse of this and therefore an inverter was added to the circuit.

In this circuit (Figure 4) the transistor acts as a switch. The tape head is connected between 0_v and the output terminal. When the transistor is switched off the collector to emitter impedance is high compared to that of the tape head and current flows through the tape head. When the transistor is switched on the collector to emitter impedance is low compared to that of the tape head and the current passes through the transistor.

The transistor is on during t_r and off during t_d.

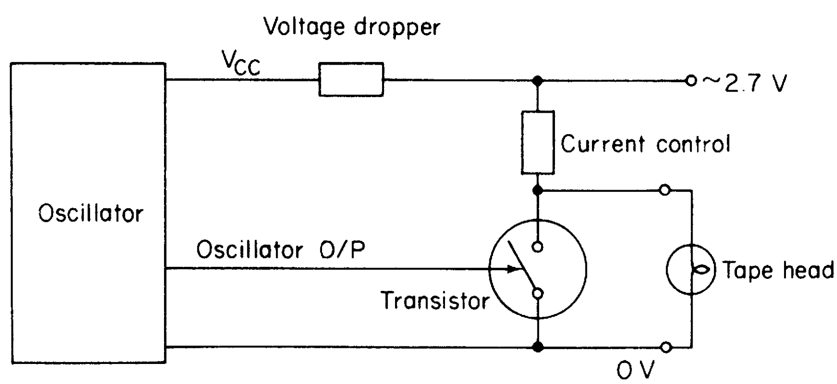


Figure 1 - Schematic diagram of timer

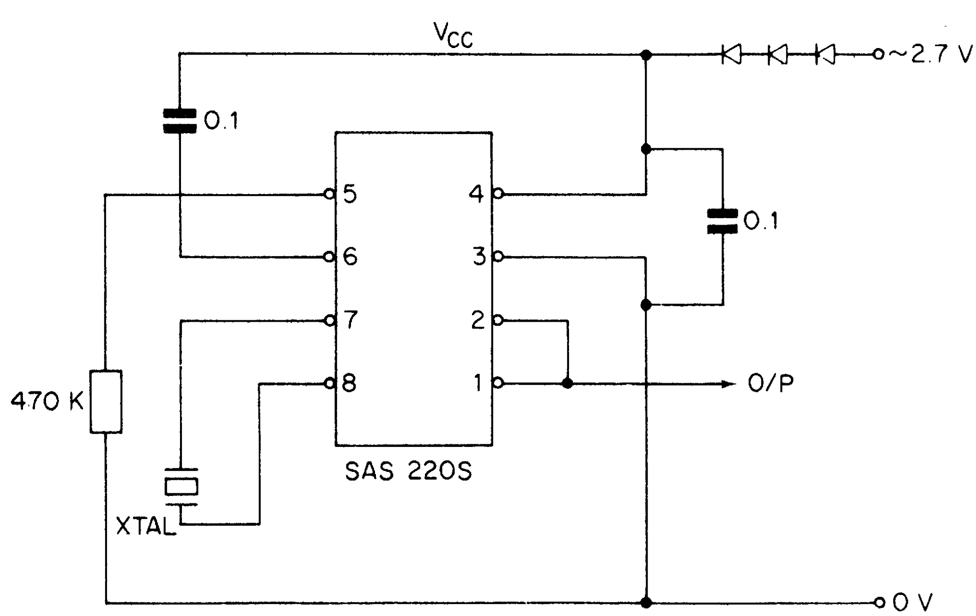


Figure 2 - Oscillator circuit

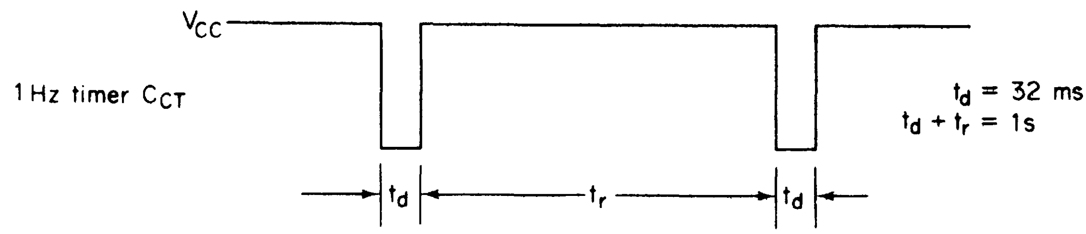


Figure 3 - Oscillator output waveform

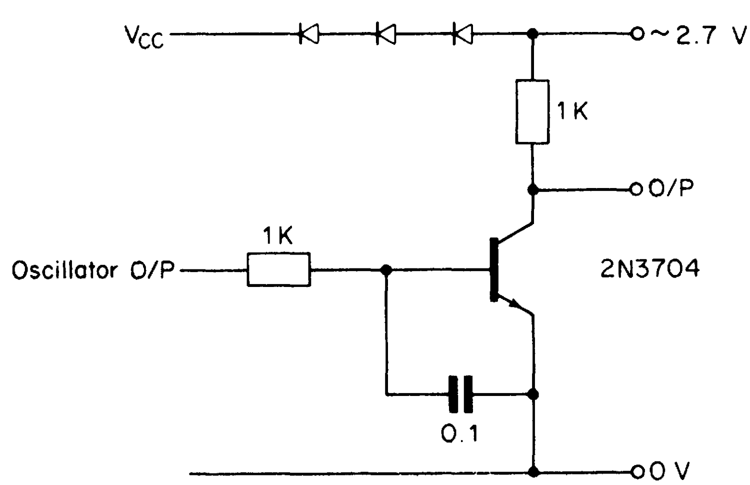


Figure 4 - Inverter circuit

5.2 APPENDIX II - DESCRIPTION OF ACTIVITY CODING DEVICE

The basic component block of the activity encoder are shown in Figure 5. The keyboard has sixteen keys of which only one may be pressed at any one time. There are sixteen signal lines which carry the keyboard information (one line for each key) to the next part of the circuit, which is the 16 line to 4 line BCD converter.

The sixteen signal lines are fed into two eight-to-three-line priority encoders. The lines are normally held high by pull-up resistors and when a key is depressed the appropriate line will carry a low-signal. The signal will be converted to a three bit binary code and the MC 14528 (one-shot) will receive a signal indicating that a key has been depressed.

The three bit binary output from each priority encoder is fed to a set of three NAND-gates. Using the priority encoders and the NAND gates the keyboard inputs can be encoded into four bit BCD (Figure 6).

The outputs from the NAND gates are fed into a quadruple D-type batch and this is clocked by the output of the one-shot. This staticises the data and if the data was not batched then when the key is released the output will be indeterminate.

The four bit output from the batch is then passed into the display and into the output driving stage.

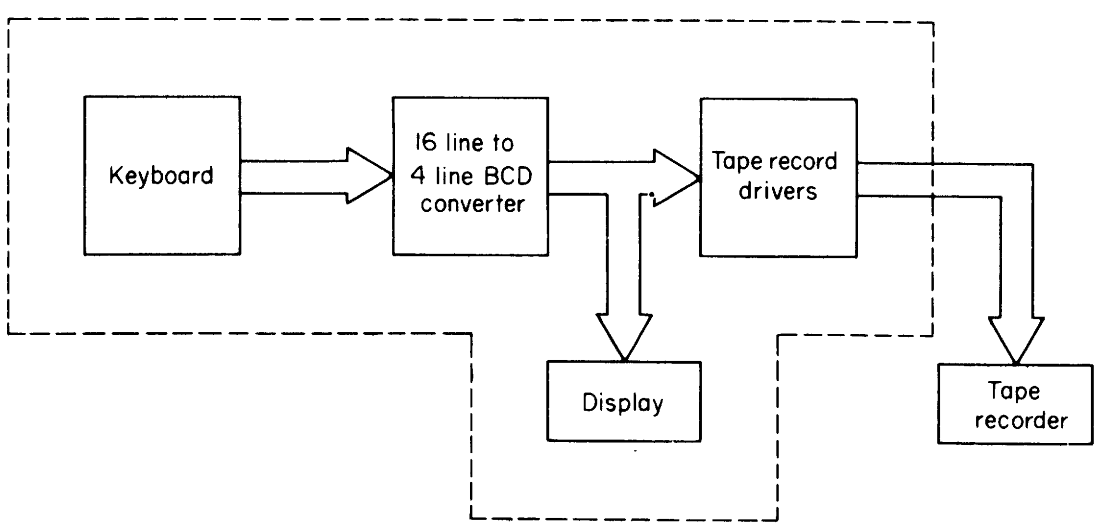


Figure 5 - Activity encoder AE-1-Block diagram

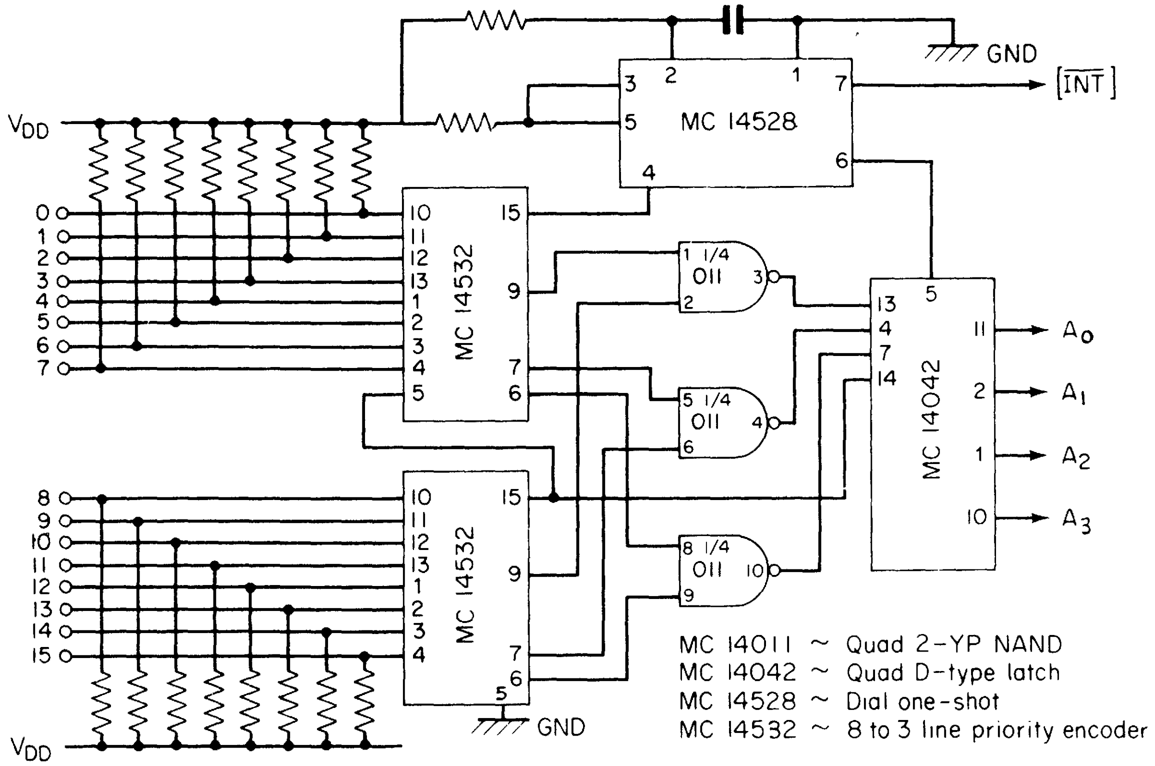
The display stage (Figure 7) consists of a binary to seven segment converter and a liquid crystal driver. The display device is a HAMLIN liquid crystal display. The clock that generates the a.c. waveform to drive the display is located in the binary to decimal conversion part of the circuit.

The output driving stage (Figure 8) consists of a set of inverters, a pair of summing amplifiers and an amplifier which generates a reference voltage VREF.

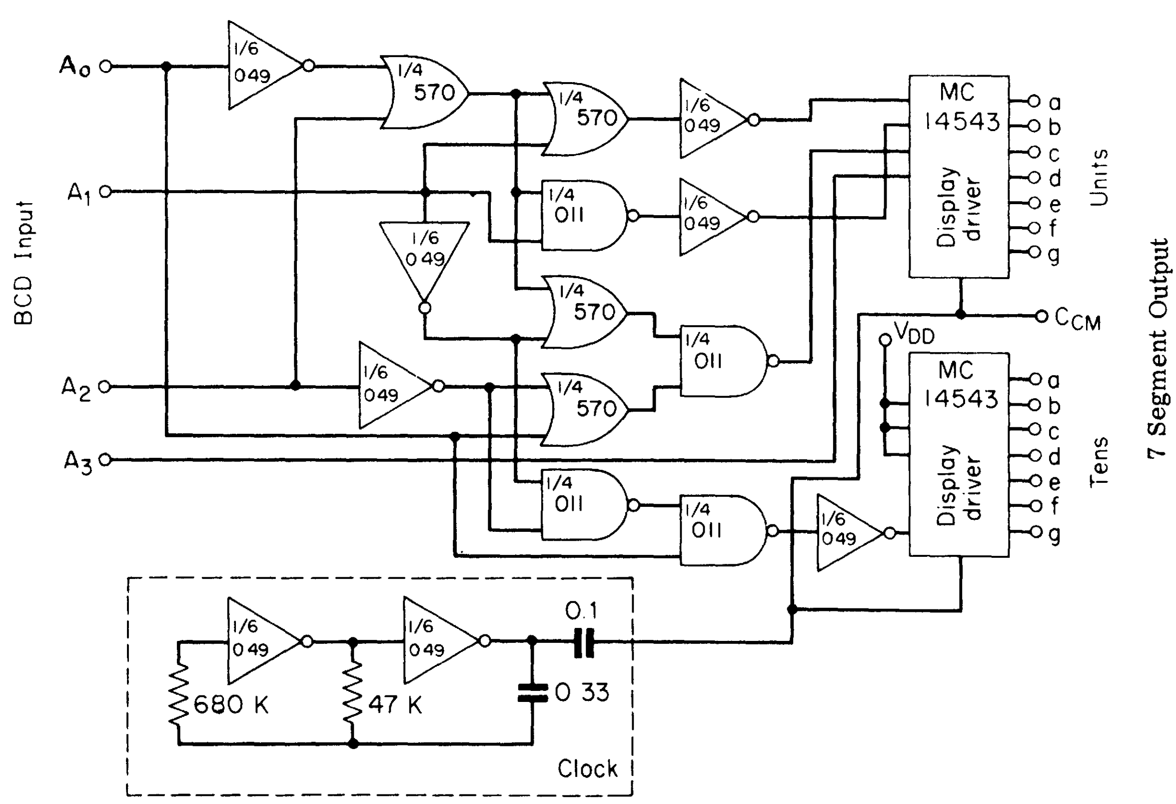
The four bit output from the batch is in the wrong sense and so the inverters are used : the four bits are then summed in pairs and when the reference voltage is fed into the non-inverting inputs of the amplifiers the outputs A and B are coded as follows : -

Key Depressed	A(mV)	B(mV)
0	-50	-50
1	-25	-50
2	+25	-50
3	+50	-50
4	-50	-25
5	-25	-25
6	+25	-25
7	+50	-25
8	-50	+25
9	-25	+25
10	+25	+25
11	+50	+25
12	-50	+50
13	-25	+50
14	+25	+50
15	+50	+50

An interrupt (INT) output is also produced. The signal originates in the one-shot and is used to indicate that a key has been depressed.



<u>Figure 6</u> - I6 line to 4 line BCD converter



<u>Figure 7</u> - Display circuit

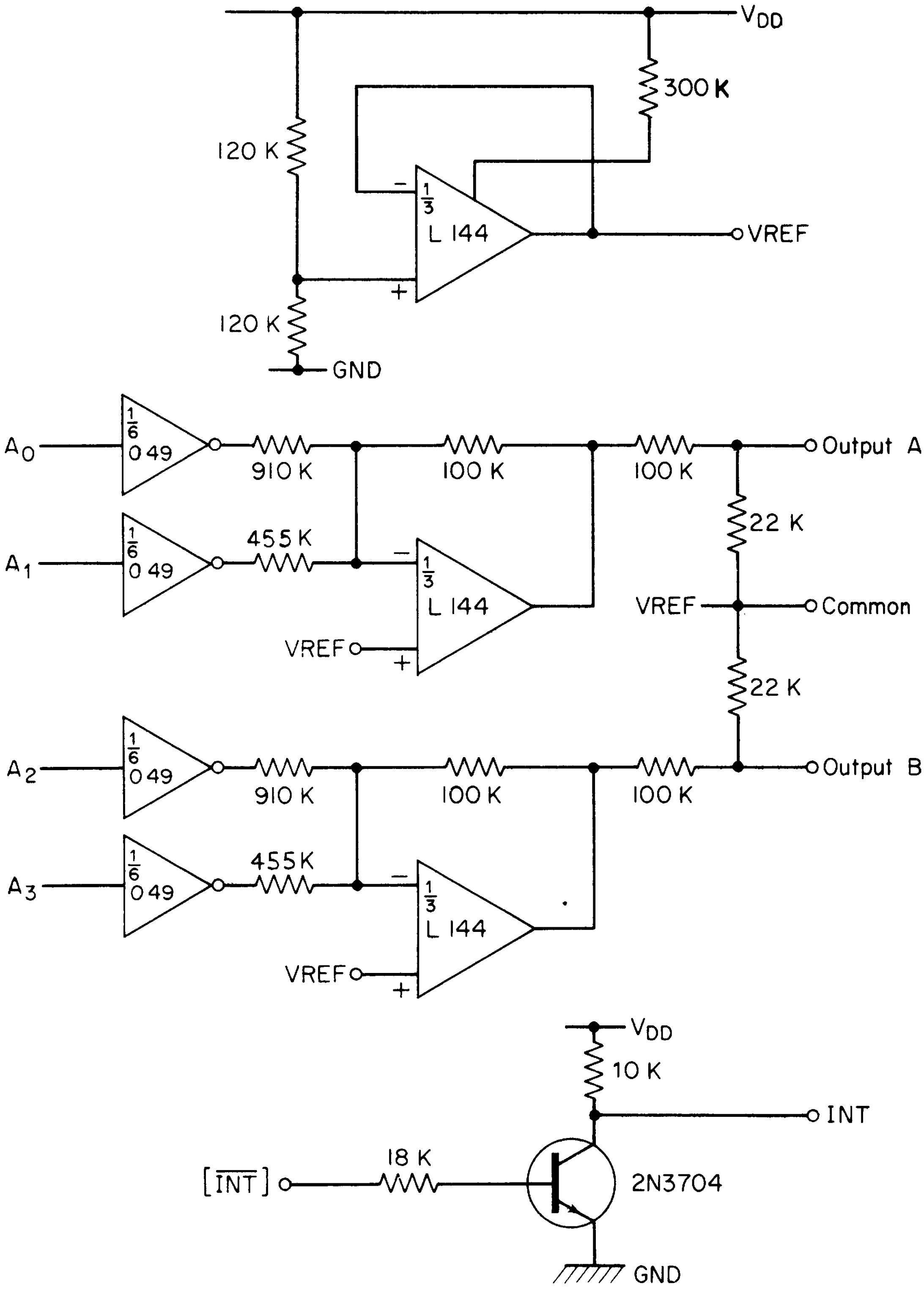


Figure 8 - Output drive circuit

5.3 APPENDIX III - HEART RATE DATA COLLECTION AND ANALYSIS

INTRODUCTION

The system described in brief in the main text of the report is here described in some detail. The system is used in both laboratory and working environments. A schematic diagram of the complete system is shown in Figure 9.

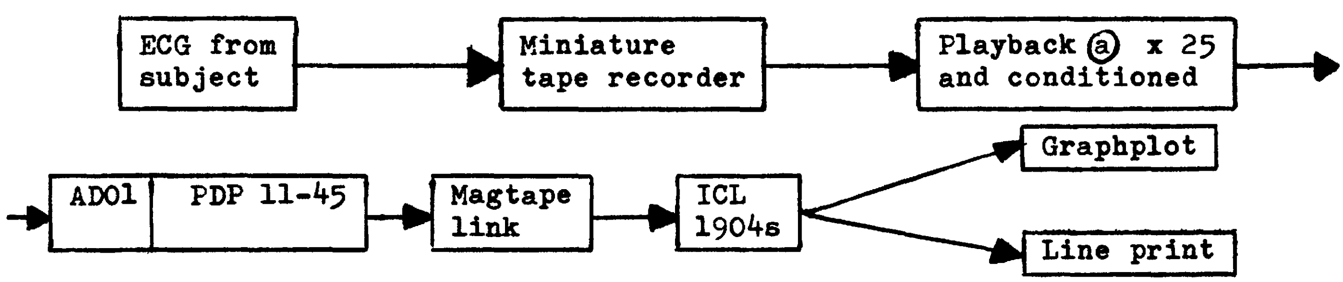


Figure 9 - Schematic diagram of complete heart rate system

Data Acquisition

See main text.

Analogue to Digital Sampling

The cassette containing the ECG and timer recording is played back into an AD01 analogue to digital sampler on a PDP 11-45 computer operating under the DOS system.

Sampling takes place at 2000 times per second (once every 500 microseconds in real time). Because of this high sampling rate 70 % of the computer's processor time is used during sampling, and hence any calculations on the data are impossible until sampling has finished. Because of this limitation all statistical analysis and further calculations are performed on the larger 1904s computer.

The ECG signal is conditioned by a pulse interval timer unit (PIT) before playing into the AD01. This unit produces a 20 volt spike for each QRS complex recognised in the new ECG signal. The PIT output is alternated to approximately two volts before inputting to the AD01.

Before playback is started, threshold levels for the PIT signal and timer are selected by preliminary examination of the trace on an oscilloscope. These values are typed into the computer from a terminal. They are chosen by ensuring that every pulse is at least as wide as the sample to sample interval (i.e. 500 μ sec) at the threshold voltage. This ensures that each pulse will be sampled at least once.

In the sampling process the times at which each signal is above threshold are stored on disc in the form of double precision words, all times being stored in "computer clock units" (100 μ sec units). Normally this means that about 100 000 items have to be stored for an eight hour recording. The timer and ECG/PIT channels are differentiated by assigning negative values to the timer and positive to the ECG/PIT. At the end of a run information is transferred from disc to magtape which is used as the transfer medium between the two computers.

Initial Analysis in the 1904s

This part of the system produces inter beat interval (IBI) data from the information on the magtape. This is achieved by the FORTRAN program BREN which is outlined in Figure 10. The program consists of four main stages as described below.

(i) Input

Data input from magtape is read a block at a time and converted from PDP 11 double word integer format to ICL floating point.

(ii) Removal of retriggering

Surplus data is collecting in the sampling procedure for both the timer and ECG channels, for there may be more than one sample per pulse at which the signal is above threshold. This is termed retriggering. Simple algorithms can be used to eliminate this, and these are described below.

(iii) Calibration

Heart rate IBIs are calibrated every 5 secs with reference to the crystal controlled timer signal. This is done by calculating the "speed-up factor" every 5 secs through the run. The speed up factor is defined as below : -

$$\text{speed up factor (SF)} = \frac{\text{replay speed}}{\text{record speed}}$$

(iv) Noise detection

The aim of this is to identify where noise occurs through a run, and to substitute interpolated values at these points. Although this may seem to be a dubious procedure on theoretical grounds, in practice it works well as most periods of noise are of short duration.

Initially there is a search for the first time pulse for this defines the start of the run. Provided another time pulse follows this one within 35.7→66.7 m secs (i.e. allowing for a maximum variability in speed up factor of times 15-28) this first time pulse is taken as the start of the run. The program then scans for further time pulses which are accepted of the time pulse gap between the time pulse under consideration and the previous pulse lies within -5% to +15% of the previous gap. Any input time item which does not pass this test is rejected and assumed to be due to retriggering of the time pulse.

In practice it was found that occasionally "drop-out" occurred on the tape so that a timer pulse was missed completely. In order to allow for this, if the first test had been exceeded a second test was applied. If a time pulse gap is found to be within ± 15 % of time the previous gap then it is assumed that a time pulse has been lost.

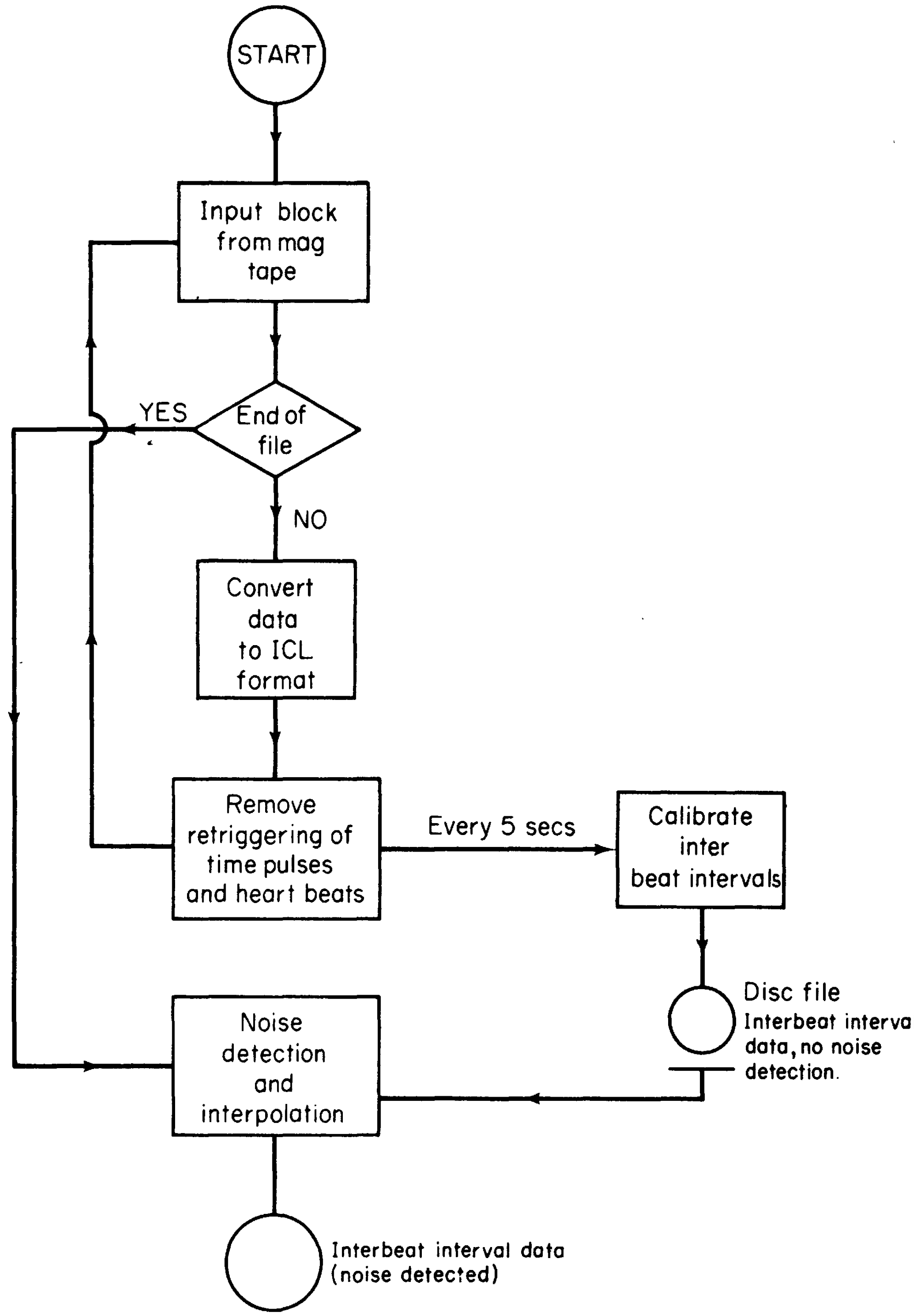


Figure 10 - Flow diagram of program BREN

If at any stage of the program both of these tests fail then the program is terminated.

Every 5 secs (that is every 5 timing pulses) the speed-up factor is calculated from the formula

$SF = \frac{5000}{T_6 - T_1}$ (where T_6 and T_1 correspond to the times in m sec of the first and last time pulses in any 5 sec period).

This speed up factor can then be used to calibrate the inter beat interval data. Retriggering of the ECG data is done by only accepting R waves if the gap between the one under consideration and the previous one is longer than 7 m sec (corresponding to a heart rate $>$ 200 at a max SF of 28) once retriggering has been eliminated uncalibrated inter beat intervals can be calculated by subtracting the time of the previous R wave from the R wave under consideration. Calibrated inter beat intervals are then calculated by multiplying the uncalibrated values by the speed up factor. Calibrated interbeat interval data is stored on disc file before noise detection.

In the final part of the program, interpolated IBIs are substituted for values which are likely to be incorrect due to noise. Noise is defined in terms of an inter beat interval which fails to meet one or both of the criteria below

(i) an IBI must lie between 300 and 1500 m sec
(ii) successive IBIs must fall within a certain range of each other. In particular IBI_{I+1} must lie in the following range of IBI_I

$$(2 \times IBI_I) - 290 > IBI_{I+1} > (0.7 \times IBI_I) + 90$$

m sec

These criteria were chosen because they were simple and could be easily changed if experience indicated they were incorrect.

Recovery from noise occurs when four consecutive interbeat intervals pass criteria (i) and the last three pass criteria (ii). This is the minimum number of beats for recovery to be logically certain based on the two criteria. Once recovery has been effected interpolated values are calculated.

The number of beats lost during noise (N) is estimated by :

$$N = \text{nearest integer } \frac{t}{IBI_{mean}}$$

where IBI_{mean} is the average of the last legal IBI before noise and the first legal IBI after the noise. t is time noise lasts

The N interpolated IBI values (IBI_{INT}) are then defined by :

$$IBI_{INT} = \frac{t}{N}$$

Finally criterion 2 is used to check the legality of recovery, i.e. to check that the IBI can change from pre to post noise levels in the time t. The noise state is re-entered if this recovery is illegal.

Final Analysis on the 1904s

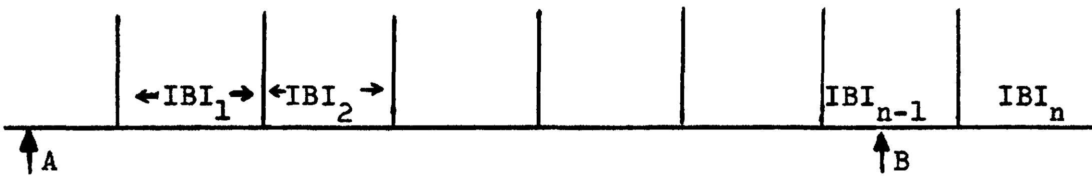
Analysis of the IBI data is achieved by PROGRAM HEAR which is outlined in Figure 11. Interbeat interval information (from program BREN) is input, together with information as to activity types and their times of onset. The program produces an analysis of the data for each activity in turn, and then for all similar activities. A graph plot is produced showing the heart rate to a resolution specified by the experimenter. Examples of a typical output showing all the parameters calculated is shown in the supplement to this Appendix.

The exact definition of the quantities calculated is as follows :

(i) Heart rate calculations

Wherever heart rate is calculated between two points A and

B (e.g. ½-1 min heart rate, heart rate over any activity, heart rate every six secs) the following method is used :



Heart rate beats/min $A\text{-}B = \dfrac{N}{\sum_{k=1}^{N} IBI_k} \times 60\ 000$ where IBI values are in m sec

(ii) <u>First and last 10 beats calculations</u>

$$HR_{1st\ ten\ beats} = \frac{10}{\sum_{k=1}^{10} IBI_R} \times 60\ 000$$

$$HR_{last\ 10\ beats} = \frac{10}{\sum_{k=n-9}^{na} IBI_R} \times 60\ 000 \text{ (m beats in an activity)}$$

(iii) <u>Max HR</u>

Defined as the max serial 10 beats

i.e. Max value $\dfrac{10}{\sum_{j}^{j+a} IBI_j} \times 60\ 000$ where j takes all values from 1 to m-9 (m beats in an activity)

<u>Cardiac Cost Calculations</u>

A value HSTAR is typed in in beats/min and all calculations are based on this.

Card cost = no. of beats where $IBI_k > \dfrac{60\ 000}{HSTAR}$ for all values of k from 1 to m

$$\text{card cost time} = \sum_{k=1}^{n} IBI_k^{*} \qquad \text{where } IBI_k^{*} = IBI_k \text{ if } IBI_k > \frac{60\ 000}{HSTAR}$$

$$IBI_k^{*} = 0 \text{ if } IBI_k = \frac{60\ 000}{HSTAR}$$

$$\text{card cost/min} = \frac{\text{card cost}}{\text{card cost time}}$$

Accuracy and Testing of the System

The system has been carefully checked by comparison of simulated data (created using a pulse generator) and chart recordings of 'real' data with the analysis output. No discrepancies of 'real' with computed data were found.

The accuracy of the system is limited by the sampling method. For six second heart rates the experimental error was approximately ± beats/min at 180 beats/min and ± ½ beat/min at 60 beats/min.

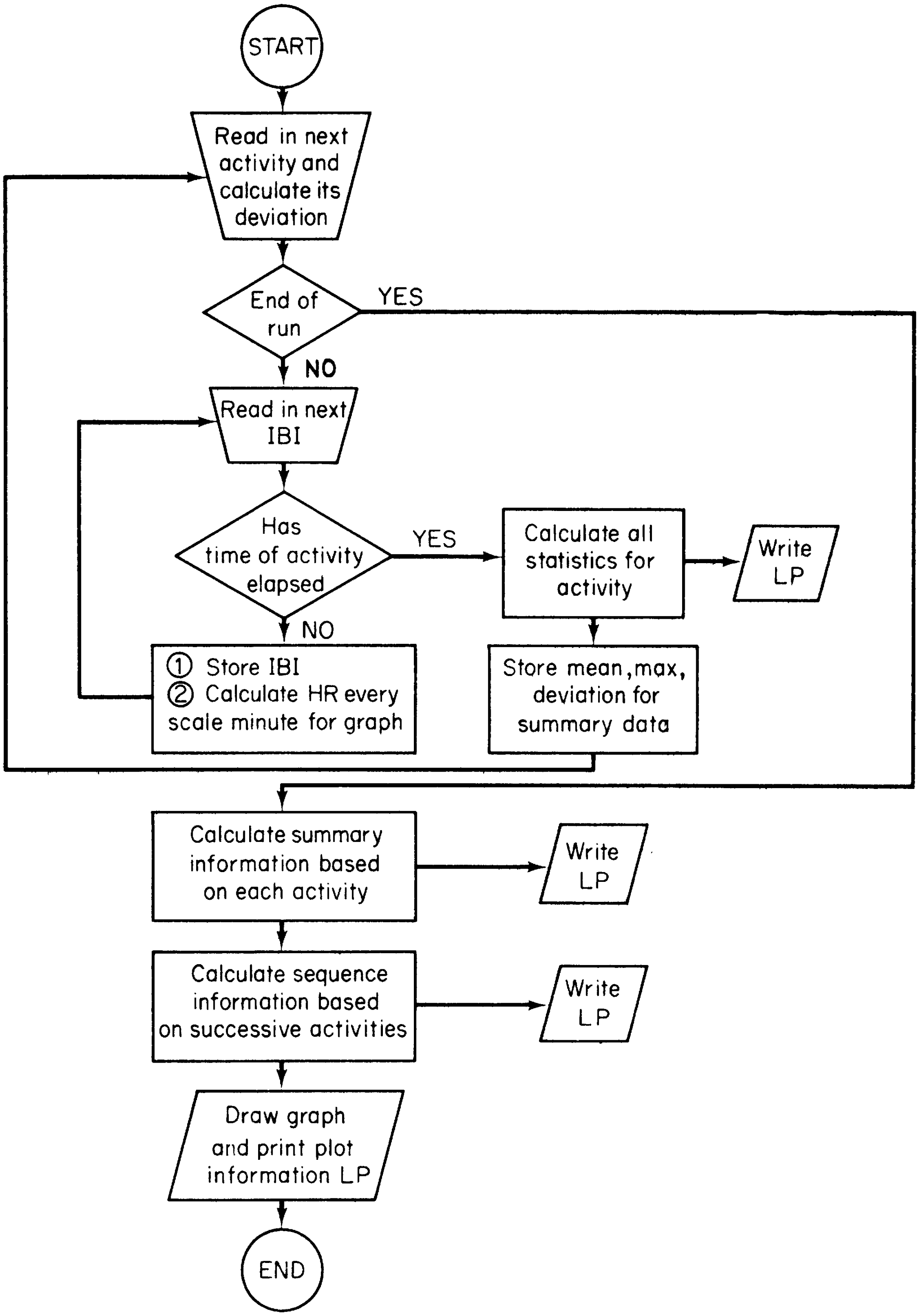


Figure 11 - Flow chart of program HEAR

SUPPLEMENT TO APPENDIX III

EXAMPLE OF COMPUTER PRINT OUT

i) Input data (i.e. data produced from PDP 11/45 sampling procedure)

ii) Calibration periods.

iii) Noise detected.

iv) IBIs with noise.

v) IBIs without noise.

vi) Summary sheet of mm length, speed up factor, and noise detected.

vii) Heart rate data for individual activities.

viii) Summary heart rate activity for all activities.

ix) Graph information.

x) Sequence information for heart rate.

xi) Sequence information for activities.

xii) Graph plot.

i) Input Data

INPUT DATA(100US UNITS) FOR RUN : PT9

31626.	31631.	31636.	31641.	31646.	31651.	31656.	31661.
31666.	31671.	31676.	31681.	31701.	31706.	31711.	31716.
31721.	31756.	31761.	31766.	31771.	31776.	31781.	31786.
31791.	31796.	31921.	31926.	31931.	31981.	31986.	31991.
31996.	32131.	32136.	32141.	32191.	32196.	32201.	32206.
32211.	32346.	32351.	32401.	32406.	32411.	32416.	32421.
32426.	32551.	32556.	32561.	32611.	32616.	32621.	32626.
32631.	32636.	32761.	32766.	32771.	32826.	32831.	32836.
32841.	32971.	32976.	32981.	33036.	33041.	33046.	33051.
33186.	33191.	33196.	33246.	33251.	33256.	33261.	33266.
33401.	33406.	33461.	33466.	33471.	33476.	33616.	33621.
33681.	33686.	33691.	33826.	33831.	33836.	33891.	33896.
33901.	33906.	34046.	34051.	34111.	34116.	34121.	34261.
34266.	34321.	34326.	34331.	34336.	34341.	34476.	34481.
34486.	34536.	34541.	34546.	34551.	34556.	34691.	34696.
34701.	34756.	34761.	34766.	34911.	34916.	34976.	34981.
34986.	35126.	35131.	35186.	35191.	35196.	35201.	35336.
35341.	35396.	35401.	35406.	35411.	35546.	35551.	35606.
35611.	35616.	35621.	35751.	35756.	35761.	35816.	35821.
35826.	35831.	35966.	35971.	36026.	36031.	36036.	36041.
36171.	36176.	36181.	36236.	36241.	36246.	36251.	36381.
36386.	36441.	36446.	36451.	36456.	36591.	36596.	36651.
36656.	36661.	36666.	36801.	36806.	36861.	36866.	36871.
36876.	37006.	37011.	37016.	37071.	37076.	37081.	37086.
37216.	37221.	37226.	37276.	37281.	37286.	37291.	37426.
37431.	37486.	37491.	37496.	37501.	37636.	37641.	37696.
37701.	37706.	37711.	37716.	37846.	37851.	37856.	37911.
37916.	37921.	37926.	38056.	38061.	38066.	38121.	38126.
38131.	38266.	38271.	38331.	38336.	38341.	38476.	38481.
38541.	38546.	38551.	38686.	38691.	38751.	38756.	38761.
38891.	38896.	38901.	38956.	38961.	38966.	38971.	39096.
39101.	39106.	39161.	39166.	39171.	39176.	39306.	39311.
39511.	39516.	39521.	39721.	39726.	39781.	39786.	39791.
39796.	39926.	39931.	39991.	39996.	40001.	40131.	40136.
40191.	40196.	40201.	40206.	40341.	40346.	40401.	40406.
40411.	40416.	40546.	40551.	40556.	40611.	40616.	40621.
40626.	40756.	40761.	40766.	40821.	40826.	40831.	40836.
40966.	40971.	41026.	41031.	41036.	41041.	41171.	41176.
41231.	41236.	41241.	41246.	41376.	41381.	41386.	41441.
41446.	41451.	41456.	41586.	41591.	41646.	41651.	41656.
41661.	41791.	41796.	41801.	41861.	41866.	41871.	42001.
42006.	42011.	42066.	42071.	42076.	42081.	42216.	42221.
42276.	42281.	42286.	42291.	42296.	42431.	42436.	42496.
42501.	42506.	42646.	42651.	42706.	42711.	42716.	42721.
42856.	42861.	42916.	42921.	42926.	42931.	43066.	43071.
43076.	43131.	43136.	43141.	43146.	43281.	43286.	43346.
43351.	43356.	43361.	43496.	43501.	43556.	43561.	43566.
43571.	43706.	43711.	43771.	43776.	43781.	43916.	43921.
43926.	43981.	43986.	43991.	44126.	44131.	44136.	44191.
44196.	44201.	44206.	44336.	44341.	44396.	44401.	44406.
44411.	44546.	44551.	44556.	44611.	44616.	44621.	44756.
44761.	44821.	44826.	44831.	44966.	44971.	45026.	45031.
45036.	45041.	45176.	45181.	45241.	45246.	45251.	45256.
45386.	45391.	45396.	45451.	45456.	45461.	45466.	45601.
45606.	45661.	45666.	45671.	45676.	45811.	45816.	45821.
45876.	45881.	45886.	45891.	46026.	46031.	46036.	46091.

ii) Calibration Periods

CALIBRATION PERIODS FOR RUN : PT9

TIME	NO. OF TIME PULSES	FIRST TIME PULSE (100US)	LAST TIME PULSE (100US)	SPEED-UP FACTOR	HEARTBEATS (100US)				
0: 0: 0	5	77290.	79169.	26.738	77321.	77466.	77536.	77676.	77746.
					77886.	77956.	78096.	78146.	78306.
					78376.	78511.	78581.	78726.	78796.
					78936.	79006.	79151.		
0: 0: 5	5	79169.	81034.	26.810	79366.	79586.	79801.	80016.	80226.
					80436.	80646.	80861.		
0: 0:10	5	81034.	82904.	26.738	81071.	81281.	81491.	81711.	81926.
					82141.	82356.	82571.	82786.	
0: 0:15	5	82904.	84769.	26.810	83001.	83216.	83426.	83641.	83851.
					84056.	84266.	84476.	84691.	
0: 0:20	5	84769.	86634.	26.810	84896.	85106.	85316.	85521.	85726.
					85936.	86141.	86351.	86566.	
0: 0:25	5	86634.	88494.	26.882	86776.	86991.	87211.	87426.	87646.
					87866.	88086.	88306.		
0: 0:30	5	88494.	90369.	26.667	88521.	88736.	88951.	89161.	89371.
					89586.	89796.	90006.	90221.	
0: 0:35	5	90369.	92234.	26.810	90436.	90646.	90861.	91071.	91286.
					91496.	91711.	91926.	92141.	
0: 0:40	5	92234.	94099.	26.810	92356.	92566.	92786.	92996.	93211.
					93421.	93631.	93841.	94056.	
0: 0:45	5	94099.	95959.	26.882	94261.	94476.	94686.	94896.	95106.
					95316.	95531.	95751.		
0: 0:50	5	95959.	97814.	26.954	95966.	96181.	96396.	96611.	96831.
					97051.	97271.	97496.	97716.	
0: 0:55	5	97814.	99674.	26.882	97936.	98156.	98376.	98591.	98811.
					99026.	99246.	99466.		
0: 1: 0	5	99674.	101529.	26.954	99681.	99901.	100121.	100336.	100551.
					100766.	100981.	101196.	101411.	
0: 1: 5	5	101529.	103404.	26.667	101621.	101836.	102046.	102256.	102466.
					102681.	102906.	103146.	103396.	
0: 1:10	5	103404.	105289.	26.525	103641.	103896.	104156.	104411.	104656.
					104906.	105151.			
0: 1:15	5	105289.	107164.	26.667	105386.	105611.	105831.	106046.	106256.
					106471.	106681.	106901.	107121.	
0: 1:20	5	107164.	109039.	26.667	107346.	107571.	107796.	108016.	108236.
					108456.	108686.	108921.		
0: 1:25	5	109039.	110899.	26.882	109161.	109401.	109641.	109886.	110136.
					110376.	110626.	110866.		
0: 1:30	5	110899.	112759.	26.882	111121.	111381.	111636.	111881.	112136.
					112396.	112651.			
0: 1:35	5	112759.	114619.	26.882	112901.	113166.	113441.	113701.	113961.
					114226.	114496.			
0: 1:40	5	114619.	116474.	26.954	114761.	115011.	115256.	115511.	115771.
					116021.	116271.			
0: 1:45	5	116474.	118324.	27.027	116526.	116771.	117021.	117266.	117506.
					117741.	117976.	118221.		
0: 1:50	5	118324.	120169.	27.100	118471.	118711.	118956.	119206.	119461.
					119711.	119961.			
0: 1:55	5	120169.	122014.	27.100	120206.	120451.	120701.	120936.	121171.
					121401.	121641.	121876.		

iii) Noise Detected

NOISE DETECTED IN RUN 4 PT9

TIME MINS	OLD HS. BPM	NEW HS. BPM	NO.OF IBIS DELETED	AMOUNT OF NOISE MINS	NO.OF IBIS INSERTED	VALUE INSERTED BPM
0,1758	104,930	107,429	3	0.0388	4	103,131
0,5989	102,818	100,533	3	0.0391	4	102,237
2,2053	118,737	121,946	3	0.0326	4	122,776
2,3560	128,914	125,333	3	0.0308	4	129,842
2,5441	136,364	132,706	6	0.0582	8	137,524
2,6315	136,727	136,364	8	0.1039	14	134,737
2,8401	128,914	132,706	6	0.0603	8	132,706
2,9764	129,257	125,333	3	0.0314	4	127,352
3,0883	118,737	115,692	3	0.0350	4	114,228
3,3753	110,049	107,276	3	0.0370	4	108,072
3,8611	109,463	104,372	3	0.0365	4	109,463
4,5723	104,372	109,463	5	0.0648	7	107,959
5,2168	125,333	128,626	3	0.0319	4	125,333
5,2719	132,353	128,571	5	0.0451	6	133,005
5,3913	136,727	136,364	3	0.0366	5	136,616
5,4714	140,625	136,364	3	0.0287	4	139,535
5,5363	136,364	145,161	5	0.0640	9	140,625
5,6841	144,774	144,774	3	0.0279	4	143,616
5,7737	145,935	141,750	9	0.0819	12	146,435
5,8696	146,323	145,935	8	0.0682	10	146,676
5,9515	145,935	145,935	3	0.0270	4	148,328
6,0054	145,631	145,548	3	0.0270	4	147,934
6,0528	145,548	144,774	11	0.1028	15	145,945
6,2115	145,548	145,381	3	0.0346	5	144,615
6,2601	140,625	150,000	3	0.0287	4	139,535
6,3023	145,161	140,374	3	0.0287	4	139,535
6,3452	140,250	136,000	6	0.0582	8	137,563
6,4252	145,161	136,727	11	0.1259	18	143,012
6,5812	132,706	132,353	3	0.0229	3	131,100
6,6492	140,625	132,353	3	0.0469	6	127,962
6,7414	132,353	132,000	6	0.0688	9	130,762
6,8252	136,000	128,229	3	0.0307	4	130,087
6,9297	115,077	128,229	3	0.0314	4	127,319
7,0310	128,571	136,364	3	0.0384	5	130,058
7,1316	128,229	129,257	3	0.0381	5	131,310
7,2006	129,257	128,571	9	0.0975	13	133,314
7,3139	125,000	136,000	3	0.0242	3	123,788
7,3842	128,229	120,649	5	0.0381	5	131,123
7,4459	131,294	132,000	6	0.0604	8	132,341
7,6035	135,636	127,886	3	0.0304	4	131,647
7,6643	131,447	149,200	10	0.0943	13	137,886
7,7863	144,387	74,600	3	0.0212	2	94,232
7,8348	72,213	155,172	16	0.1907	19	99,652
8,0385	150,000	150,000	3	0.0256	4	156,522
8,0772	155,172	153,931	5	0.0586	9	153,473
8,1955	149,600	144,774	3	0.0203	3	147,956
8,2363	149,600	144,387	3	0.0286	4	140,055
8,2932	139,875	135,636	3	0.0266	4	139,875
8,3580	135,636	135,636	3	0.0214	3	139,875
8,4161	135,636	132,000	3	0.0299	4	133,963

iv) IBIs with Noise

LIST OF IBIS(WITH NOISE) FOR RUN : PTO

TIME MINS	IBI MSECS	TIME MINS	IBI MSECS	TIME MINS	IBI MSECS	TIME MINS	IBI MSECS	TIME MINS	IBI MSECS
5.0834	518.62	5.0921	518.62	5.1007	518.62	5.1094	518.62	5.1180	505.32
5.1266	505.32	5.1348	505.32	5.1433	492.02	5.1515	492.02	5.1597	505.32
5.1681	492.02	5.1763	492.02	5.1845	492.02	5.1927	478.72	5.2007	492.02
5.2089	478.72	5.2168	478.72	5.2246	957.45	5.2408	478.72	5.2488	466.67
5.2565	466.67	5.2643	453.33	5.2719	426.67	5.2790	333.33	5.2845	613.33
5.2948	453.33	5.3023	880.00	5.3170	466.67	5.3248	453.33	5.3323	452.29
5.3398	438.83	5.3472	438.83	5.3545	438.83	5.3618	438.83	5.3691	438.83
5.3764	452.13	5.3860	438.83	5.3913	452.13	5.3988	625.00	5.4092	1118.81
5.4279	440.00	5.4352	426.67	5.4623	440.00	5.4496	440.00	5.4570	440.00
5.4645	426.67	5.4714	440.00	5.4788	866.67	5.4932	413.33	5.5001	440.00
5.5074	440.00	5.5148	426.67	5.5219	426.67	5.5290	440.00	5.5363	453.33
5.5439	400.00	5.5505	1293.33	5.5721	1266.67	5.5932	426.67	5.6003	413.33
5.6072	440.00	5.6165	413.33	5.6214	413.33	5.6283	413.33	5.6352	426.67
5.6425	426.67	5.6494	413.33	5.6543	426.67	5.6634	413.92	5.6703	414.44
5.6772	414.44	5.6841	414.44	5.6910	828.88	5.7049	427.81	5.7120	414.44
5.7189	414.44	5.7258	414.44	5.7327	414.44	5.7396	414.44	5.7465	399.54
5.7532	384.62	5.7596	437.67	5.7669	411.14	5.7737	411.14	5.7806	822.28
5.7943	411.14	5.8011	424.40	5.8082	424.40	5.8153	809.02	5.8288	397.55
5.8354	410.05	5.8422	806.88	5.8557	423.28	5.8627	410.05	5.8696	436.51
5.8769	780.42	5.8890	410.05	5.8967	410.05	5.9035	410.05	5.9104	834.54
5.9243	424.40	5.9313	384.62	5.9378	411.14	5.9446	411.14	5.9515	397.88
5.9581	822.28	5.9718	397.88	5.9786	411.14	5.9853	397.88	5.9919	397.88
5.9985	412.00	6.0054	398.94	6.0121	811.17	6.0256	412.23	6.0324	412.23
6.0395	398.94	6.0460	412.23	6.0528	412.23	6.0597	784.57	6.0728	438.83
6.0801	413.40	6.0870	815.51	6.1006	401.07	6.1073	427.81	6.1144	815.51
6.1280	427.81	6.1351	401.07	6.1418	828.88	6.1556	414.44	6.1625	413.56
6.1694	412.23	6.1763	425.53	6.1834	412.23	6.1902	425.53	6.1973	438.83
6.2047	412.23	6.2115	398.94	6.2182	1250.00	6.2390	425.53	6.2461	412.71
6.2530	426.67	6.2601	426.67	6.2672	866.67	6.2816	426.67	6.2888	400.00
6.2954	413.33	6.3023	440.00	6.3096	880.00	6.3243	400.00	6.3310	427.43
6.3381	427.81	6.3452	441.18	6.3526	882.35	6.3673	414.44	6.3742	441.18
6.3816	427.81	6.3887	882.35	6.4034	441.18	6.4107	454.28	6.4183	413.33
6.4252	440.00	6.4325	1280.00	6.4539	466.67	6.4616	440.00	6.4690	906.67
6.4841	440.00	6.4914	413.33	6.4983	1330.06	6.5205	478.72	6.5285	452.13
6.5360	904.26	6.5511	438.83	6.5586	452.13	6.5659	465.43	6.5737	452.13
6.5812	466.33	6.5896	306.67	6.5941	600.00	6.6041	453.33	6.6116	453.33
6.6192	453.33	6.6268	466.67	6.6345	453.33	6.6421	426.67	6.6492	493.33
6.6574	933.33	6.6730	1386.67	6.6941	453.33	6.7036	466.67	6.7114	453.33
6.7190	453.33	6.7265	440.00	6.7339	453.33	6.7414	466.67	6.7492	895.59
6.7641	467.91	6.7719	922.46	6.7873	922.46	6.8027	454.55	6.8102	454.55
6.8178	441.18	6.8252	454.55	6.8328	949.20	6.8486	441.18	6.8559	467.91
6.8637	481.28	6.8717	494.65	6.8800	494.65	6.8882	494.65	6.8965	481.28
6.9045	508.02	6.9130	481.28	6.9210	521.39	6.9297	481.28	6.9377	935.83
6.9535	467.91	6.9611	467.91	6.9689	467.91	6.9767	467.91	6.9845	467.91
6.9925	467.90	7.0001	480.00	7.0081	440.00	7.0154	466.67	7.0232	466.67
7.0310	453.33	7.0385	1586.67	7.0616	466.67	7.0694	440.00	7.0768	493.60
7.0850	454.55	7.0926	467.91	7.1006	494.65	7.1086	467.91	7.1164	441.18
7.1238	467.91	7.1316	441.18	7.1389	1390.37	7.1621	453.12	7.1696	464.19
7.1774	464.19	7.1851	464.19	7.1928	464.19	7.2006	464.19	7.2083	968.17
7.2244	513.98	7.2328	477.45	7.2408	530.50	7.2496	973.22	7.2659	493.33
7.2741	480.00	7.2821	960.00	7.2931	466.67	7.3059	480.00	7.3139	480.00
7.3219	346.67	7.3274	627.43	7.3351	441.18	7.3455	454.55	7.3530	481.28
7.3611	454.55	7.3686	467.91	7.3764	467.91	7.3842	508.02	7.3927	427.81

v) IBIs without Noise

LIST OF IBIS(WITHOUT NOISE) FOR RUN : PT9

TIME MINS	IBI MSECS	TIME MINS	IBI MSECS	TIME MINS	IBI MSECS	TIME MINS	IBI MSECS	TIME MINS	IBI MSECS
4.8910	571.81	4.9006	585.11	4.9105	571.81	4.9199	571.81	4.9294	558.51
4.9387	571.81	4.9482	545.21	4.9575	558.51	4.9666	571.81	4.9762	571.81
4.9857	571.81	4.9952	599.23	5.0052	640.00	5.0159	600.00	5.0259	613.33
5.0361	600.00	5.0461	573.33	5.0556	560.00	5.0650	560.00	5.0743	546.65
5.0834	518.62	5.0921	518.62	5.1007	518.62	5.1094	518.62	5.1180	505.32
5.1264	505.32	5.1348	505.32	5.1433	492.02	5.1515	492.02	5.1597	505.32
5.1681	492.02	5.1763	492.02	5.1845	492.02	5.1927	478.72	5.2007	492.02
5.2089	478.72	5.2168	478.72	5.2248	478.72	5.2328	478.72	5.2408	478.72
5.2488	466.47	5.2565	466.67	5.2643	453.33	5.2719	451.11	5.2794	451.11
5.2869	451.11	5.2944	451.11	5.3019	451.11	5.3095	451.11	5.3170	466.67
5.3248	453.33	5.3323	452.29	5.3398	438.83	5.3472	438.83	5.3545	438.83
5.3618	438.83	5.3691	438.83	5.3764	452.13	5.3840	438.83	5.3913	439.19
5.3986	439.19	5.4059	439.19	5.4132	439.19	5.4205	439.19	5.4279	440.00
5.4352	426.67	5.4423	440.00	5.4496	440.00	5.4570	440.00	5.4643	426.67
5.4714	430.00	5.4786	430.00	5.4858	430.00	5.4929	430.00	5.5001	440.00
5.5074	440.00	5.5148	426.67	5.5219	426.67	5.5290	440.00	5.5363	426.67
5.5434	426.67	5.5505	426.67	5.5576	426.67	5.5648	426.67	5.5719	426.67
5.5790	426.67	5.5861	426.67	5.5932	426.67	5.6003	413.33	5.6072	440.00
5.6145	413.33	5.6214	413.33	5.6283	413.33	5.6352	426.67	5.6423	426.67
5.6494	413.33	5.6563	426.67	5.6634	413.92	5.6703	414.44	5.6772	414.44
5.6841	417.78	5.6911	417.78	5.6981	417.78	5.7050	417.78	5.7120	414.44
5.7189	414.44	5.7258	414.44	5.7327	414.44	5.7396	414.44	5.7465	399.56
5.7532	384.62	5.7596	437.67	5.7649	411.14	5.7737	409.74	5.7806	409.74
5.7874	409.74	5.7942	409.74	5.8011	409.74	5.8079	409.74	5.8147	409.74
5.8215	409.74	5.8284	409.74	5.8352	409.74	5.8420	409.74	5.8489	409.74
5.8557	423.28	5.8627	410.05	5.8696	409.06	5.8764	409.06	5.8832	409.06
5.8900	409.06	5.8969	409.06	5.9037	409.06	5.9105	409.06	5.9173	409.06
5.9241	409.06	5.9309	409.06	5.9378	411.14	5.9446	411.16	5.9515	404.51
5.9582	404.51	5.9649	404.51	5.9717	404.51	5.9784	411.14	5.9853	397.88
5.9919	397.88	5.9985	412.00	6.0054	405.59	6.0122	405.59	6.0189	405.59
6.0257	405.59	6.0324	412.23	6.0393	398.94	6.0460	412.23	6.0528	411.11
6.0597	411.11	6.0665	411.11	6.0734	411.11	6.0802	411.11	6.0871	411.11
6.0939	411.11	6.1008	411.11	6.1077	411.11	6.1145	411.11	6.1214	411.11
6.1282	411.11	6.1351	411.11	6.1419	411.11	6.1488	411.11	6.1556	414.44
6.1625	413.56	6.1694	412.23	6.1763	425.53	6.1834	412.23	6.1902	425.53
6.1973	438.83	6.2047	412.23	6.2115	414.89	6.2184	414.89	6.2254	414.89
6.2323	414.89	6.2392	414.89	6.2461	412.71	6.2530	426.67	6.2601	430.00
6.2673	430.00	6.2744	430.00	6.2816	430.00	6.2888	400.00	6.2956	413.33
6.3023	430.00	6.3095	430.00	6.3166	430.00	6.3238	430.00	6.3310	427.43
6.3381	427.81	6.3452	436.16	6.3525	436.16	6.3598	436.16	6.3670	436.16
6.3743	436.16	6.3816	436.16	6.3888	436.16	6.3961	436.16	6.4034	441.18
6.4107	454.28	6.4183	413.33	6.4252	419.55	6.4322	419.55	6.4392	419.55
6.4462	419.55	6.4532	419.55	6.4602	419.55	6.4672	419.55	6.4741	419.55
6.4811	419.55	6.4881	419.55	6.4951	419.55	6.5021	419.55	6.5091	419.55
6.5161	419.55	6.5231	419.55	6.5301	419.55	6.5371	419.55	6.5441	419.55
6.5511	438.83	6.5584	452.13	6.5659	465.43	6.5737	452.13	6.5812	457.66
6.5888	457.66	6.5965	457.66	6.6041	453.33	6.6116	453.33	6.6192	453.33
6.6268	466.67	6.6345	453.33	6.6421	426.67	6.6492	468.89	6.6570	468.89
6.6648	468.89	6.6724	468.89	6.6805	468.89	6.6883	468.89	6.6961	453.33
6.7036	466.67	6.7114	453.33	6.7190	453.33	6.7265	440.00	6.7339	453.33
6.7414	458.85	6.7491	458.85	6.7567	458.85	6.7644	458.85	6.7720	458.85
6.7797	453.85	6.7873	458.85	6.7950	458.85	6.8026	458.85	6.8102	454.55
6.8178	441.18	6.8252	461.23	6.8329	461.23	6.8406	461.23	6.8482	461.23

vi) Summary Sheet of mm Length, Speed Up Factor and Noise Detected

```
SUMMARY SHEET FOR RUN : PT9
-----------------------------------

LENGTH OF RUN AFTER CALIBRATION : 177.750MINS
APPROX AMOUNT OF UNCALIBRATED DATA AT END OF RUN : 4SECS
SPEED-UP FACTOR RANGE : 26.042 - 27.322
MEAN SPEED-UP FACTOR : 26.891
TIME LOST ESTABLISHING INITIAL HEART STANDARD :   0.176SECS

LENGTH OF RUN AFTER NOISE DETECTION : 177.750MINS
TOTAL TIME OF NOISE DETECTED :   0.793MINS
PERCENTAGE OF NOISE DETECTED :   5.509%
```

vii) Heart Rate Data for Individual Activities

HEARTBEAT ANALYSIS FOR RUN : PTO

CARD.COST LEVEL : 100.

TIME OF ONSET MINS	ACTIVITY	LENGTH OF ACT. MINS	MEAN HR. BPM	MIN HR. BPM	MAX HR. BPM	FIRST HR. BPM	LAST HR. BPM	0.5-1M HR. BPM	1.5-2M HR. BPM	2.5-3M HR. BPM	CARD. COST BEATS BTS	CARD. COST TIME MINS	CARD. COST PER MIN BPM
0.00	ACTIVNFELOW 1	10.25	104.7	81.2	139.0	105.3	138.9	113.6	105.4	107.4	736	6.69	71.797
10.25	SIT/STADBATT 5	0.25	136.3	140.2	140.6	140.2	140.2	0.0	0.0	0.0	34	0.24	136.253
10.50	SIT/STADBATT 5	0.16	103.9	95.0	123.9	123.9	96.6	0.0	0.0	0,0	13	0.11	71.074
10.68	WLKBATTTOP 3	0.17	118.1	123.2	124.4	124.4	123.6	0.0	0.0	0.0	20	0.16	118.110
10.85	SIT/STADBATT 5	0.44	117.0	114.0	122.6	122.6	116.7	0.0	0.0	0.0	52	0.44	117.035
11.30	PULL VALVE 7	0.30	122.4	122.7	126.3	122.7	126.8	0.0	0.0	0.0	37	0.29	122.393
11.60	WLKBATTTOP 3	0.85	115.8	112.8	123.7	123.7	114.6	0.0	0.0	0.0	99	0.85	115.812
12.45	SIT/STADBATT 5	11.34	100.1	86.4	122.6	116.3	118.0	105.0	101.8	94.8	574	5.40	50.601
23.80	WLKBATTTOP 3	0.50	117.2	113.4	123.6	116.5	123.6	0.0	0.0	0.0	59	0.50	117.189
24.30	SIT/STADBATT 5	1.70	105.9	90.0	125.5	125.5	100.5	107.6	0.0	0.0	135	1.21	79.395
26.00	WLKBATTTOP 3	0.30	108.0	105.4	116.1	105.4	116.1	0.0	0.0	0.0	32	0.29	108.022
26.30	SIT/STADBATT 5	0.10	109.5	119.9	119.9	119.9	119.9	0.0	0.0	0.0	11	0.09	109.537
26.40	WLKBATTTOP 3	0.15	110.3	115.3	118.4	115.3	118.4	0.0	0.0	0.0	17	0.15	110.268
26.55	SIT/STADBATT 5	0.27	110.2	109.0	119.8	119.8	112.3	0.0	0.0	0.0	30	0.26	110.168
26.82	WLKBATTTOP 3	0.18	105.8	109.8	113.1	109.8	113.1	0.0	0.0	0.0	19	0.17	105.837
27.00	SIT/STADBATT 5	0.34	104.5	104.2	110.7	110.7	105.4	0.0	0.0	0.0	35	0.33	101.556
27.35	WLKBATTTOP 3	0.12	105.2	113.2	113.6	113.6	113.2	0.0	0.0	0.0	13	0.11	105.173
27.67	SIT/STADBATT 5	0.66	105.4	103.2	111.6	111.6	106.2	0.0	0.0	0.0	70	0.65	105.445
28.33	WLKBATTTOP 3	0.26	108.3	105.1	119.8	105.1	119.8	0.0	0.0	0.0	28	0.25	108.343
28.39	REPLACE LIDS 8	0.48	134.2	126.3	146.5	126.3	146.4	0.0	0.0	0.0	66	0.48	136.175
28.88	WLKBATTTOP 3	0.17	141.7	147.3	148.1	147.3	148.1	0.0	0.0	0.0	24	0.16	141.721
29.05	SIT/STADBATT 5	0.10	138.2	147.4	148.1	148.1	147.6	0.0	0.0	0.0	14	0.09	138.175
29.15	WLKBATTTOP 3	0.45	132.6	128.3	142.6	142.6	129.0	0.0	0.0	0.0	60	0.44	132.565
29.60	BRUSH LIDS 9	0.30	121.9	121.0	129.9	129.0	121.0	0.0	0.0	0.0	36	0.29	121.902

viii) Summary Heart Rate Activity for All Activities

SUMMARY INFORMATION FOR RUN : PTG

ACTIVITY	CODE	MEAN HR. BPM	STANDARD DEVIATION BPM	MEAN LENGTH MINS.	STANDARD DEVIATION MINS	NO. OF TIMES	CARD.COST PER.MIN. BPM
ACTE.NBRE[illegible]	1	98.7	7.3	7.18	5.58	13	54.17
T-SADJC[illegible]ERS	2	121.5		1.57		2	121.61
JLKPATTTOP	3	118.1	10.4	0.31	0.21	50	117.52
REMOVE LIDS	4	120.0	2.6	0.31	0.17	6	100.68
SIT/STANDSATT	5	110.1	10.7	1.85	2.49	27	92.64
WORK GANTRY	6	120.2	8.3	0.21	0.15	3	82.43
DILL VAL[illegible]	7	122.6	7.0	0.19	0.15	11	91.17
REPLACE LIDS	8	127.1	4.7	0.48	0.19	9	114.06
BRUSH LIDS	9	132.7	7.0	0.34	0.09	8	132.49
SEAL LIDS	10	124.9	7.5	0.38	0.16	7	124.89
USE CLAY	11	133.7		0.28		1	133.92
CRACK C[illegible]ERS	12	141.5		1.38		1	141.44

THE MEAN HEART RATE OVER THE WHOLE PERIOD WAS 106.5856BEATS PER MIN

ix) Graph Information

GRAPH INFORMATION FOR RUN : PT9

TIME MINS.	H.R BPM	TIME MINS	H.R BPM	TIME MINS	H.R BPM	TIME MINS	H.R BPM	TIME MINS	H.R BPM
0.10	115.58	0.20	107.70	0.30	105.91	0.40	106.30	0.50	109.45
0.60	112.78	0.70	111.40	0.80	115.52	0.90	113.25	1.00	117.02
1.10	110.52	1.20	112.76	1.30	106.90	1.40	105.91	1.50	105.78
1.60	102.73	1.70	105.26	1.80	105.56	1.90	107.55	2.00	106.16
2.10	104.39	2.20	105.88	2.30	106.57	2.40	109.58	2.50	104.19
2.60	105.48	2.70	105.60	2.80	105.79	2.90	108.19	3.00	111.46
3.10	108.32	3.20	102.51	3.30	104.41	3.40	104.85	3.50	106.42
3.60	101.50	3.70	93.23	3.80	96.57	3.90	89.60	4.00	93.10
4.10	105.26	4.20	95.52	4.30	103.96	4.40	94.26	4.50	94.94
4.60	97.48	4.70	93.36	4.80	99.53	4.90	102.76	5.00	99.58
5.10	98.25	5.20	94.95	5.30	94.00	5.40	94.79	5.50	92.92
5.60	92.29	5.70	95.80	5.80	98.52	5.90	99.77	6.00	98.16
6.10	99.28	6.20	97.61	6.30	96.91	6.40	106.03	6.50	78.00
6.60	98.35	6.70	93.96	6.80	96.60	6.90	94.87	7.00	94.46
7.10	96.87	7.20	91.18	7.30	96.99	7.40	97.03	7.50	99.78
7.60	107.02	7.70	112.84	7.80	101.83	7.90	99.16	8.00	93.14
8.10	95.05	8.20	94.83	8.30	102.63	8.40	116.38	8.50	121.08
8.60	120.27	8.70	113.42	8.80	115.66	8.90	115.69	9.00	116.69
9.10	111.74	9.20	115.88	9.30	106.29	9.40	111.74	9.50	107.01
9.60	111.20	9.70	104.34	9.80	111.11	9.90	122.17	10.00	130.00
10.10	133.94	10.20	137.65	10.30	139.52	10.40	140.31	10.50	140.34
10.60	113.21	10.70	106.90	10.80	123.60	10.90	123.94	11.00	120.81
11.10	120.66	11.20	116.75	11.30	116.93	11.40	123.56	11.50	127.30
11.60	126.35	11.70	123.62	11.80	116.64	11.90	116.15	12.00	117.97
12.10	115.65	12.20	116.75	12.30	116.00	12.40	113.22	12.50	116.00
12.60	120.06	12.70	121.31	12.80	111.75	12.90	107.33	13.00	105.70
13.10	106.04	13.20	105.02	13.30	107.10	13.40	105.55	13.50	91.97
13.60	101.22	13.70	108.10	13.80	104.80	13.90	107.52	14.00	107.25
14.10	98.79	14.20	103.37	14.30	104.78	14.40	99.34	14.50	97.94
14.60	100.31	14.70	105.38	14.80	105.25	14.90	95.30	15.00	90.08
15.10	95.90	15.20	93.88	15.30	94.95	15.40	96.77	15.50	90.81
15.60	93.37	15.70	97.07	15.80	95.90	15.90	92.89	16.00	89.12
16.10	93.00	16.20	102.91	16.30	104.34	16.40	97.40	16.50	99.65
16.60	96.85	16.70	97.12	16.80	97.95	16.90	94.67	17.00	96.27
17.10	100.57	17.20	103.00	17.30	113.44	17.40	114.75	17.50	97.09
17.60	105.29	17.70	109.27	17.80	100.53	17.90	93.88	18.00	93.78
18.10	102.87	18.20	101.52	18.30	87.70	18.40	85.82	18.50	95.02
18.60	95.43	18.70	93.72	18.80	95.24	18.90	96.67	19.00	91.70
19.10	98.28	19.20	93.78	19.30	102.23	19.40	107.65	19.50	97.37
19.60	97.84	19.70	99.95	19.80	105.76	19.90	107.53	20.00	102.75
20.10	98.53	20.20	94.46	20.30	101.37	20.40	97.63	20.50	90.67
20.60	99.01	20.70	95.59	20.80	98.27	20.90	106.95	21.00	113.21
21.10	110.54	21.20	100.61	21.30	94.98	21.40	101.50	21.50	102.06
21.60	91.74	21.70	96.25	21.80	103.53	21.90	94.91	22.00	101.33
22.10	98.32	22.20	89.33	22.30	90.48	22.40	94.25	22.50	100.52
22.60	102.37	22.70	97.40	22.80	98.24	22.90	101.41	23.00	100.76
23.10	101.40	23.20	100.22	23.30	94.04	23.40	96.66	23.50	97.50
23.60	99.71	23.70	108.85	23.80	118.34	23.90	116.07	24.00	115.63
24.10	119.34	24.20	121.44	24.30	123.62	24.40	125.10	24.50	122.92
24.60	115.96	24.70	115.43	24.80	108.07	24.90	111.08	25.00	111.32

x) Sequence Information for Heart Rate

SEQUENCE INFORMATION FOR RUN : PTO

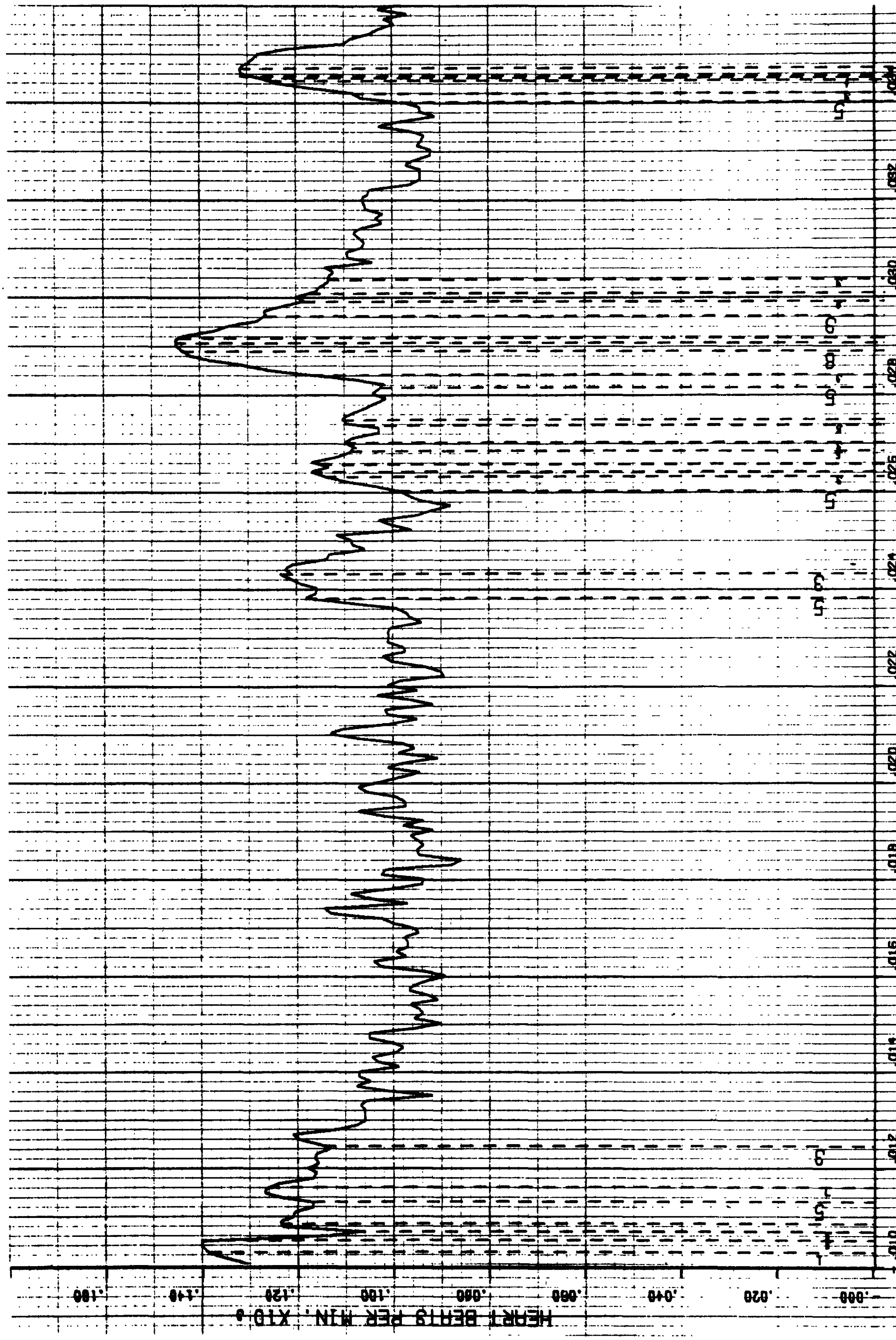
ACTIVITY BEING CONSIDERED	H.R. OF ACTIVITY SHOWN BELOW PRECEDED BY ACTIVITY BEING CONSIDERED											
	1	2	3	4	5	6	7	8	9	10	11	12
ACTDJNBELOW 1	97	0	0	0	116	0	0	0	0	0	0	0
IPSANDCOVERS 2	105	0	0	0	0	113	0	0	0	0	0	0
LIKBATTTOP 3	97	0	0	120	108	123	126	128	132	123	133	141
REMOVE LIDS 4	0	0	124	0	0	0	113	0	0	0	0	0
SIT/STNDBAIT 5	0	0	110	0	103	0	122	117	127	0	0	0
WORK GANTRY 6	0	131	121	0	98	0	0	0	0	0	0	0
PULL VALVE 7	0	0	121	116	0	0	0	0	0	128	0	0
REPLACE LIDS 8	0	0	132	0	126	0	0	0	140	0	0	0
BRUSH LIDS 9	0	0	0	0	115	0	123	0	0	0	0	0
SEAL LIDS 10	0	111	119	0	0	0	0	0	0	0	0	0
USE CLAY 11	0	0	127	0	0	0	0	0	0	0	0	0
CHECK COVERS 12	0	0	135	0	0	0	0	0	0	0	0	0

xi) Sequence Information for Activities

SEQUENCE INFORMATION FOR RUN : PT2

ACTIVITY BEING CONSIDERED	NO OF TIMES ACTIVITY SHOWN (BELOW) PRECEDED BY ACTIVITY BEING CONSIDERED											
	1	2	3	4	5	6	7	8	9	10	11	12
ACTONNBELOW 1	10	0	0	0	2	0	0	0	0	0	0	0
UNSADJCOVERS 2	1	0	0	0	0	1	0	0	0	0	0	0
UNKBATTTOP 3	1	0	0	5	20	2	1	8	6	5	1	1
REMOVE LIDS 4	0	0	4	0	0	0	2	0	0	0	0	0
SET/STNDBATT 5	0	0	23	0	1	0	1	1	1	0	0	0
WORK GANTRY 6	0	1	1	0	1	0	0	0	0	0	0	0
FILL VALVE 7	0	0	8	0	0	0	0	0	0	2	0	0
REPLACE LIDS 8	0	0	4	0	2	0	0	0	1	0	0	0
BRUSH LIDS 9	0	0	0	0	1	0	7	0	0	0	0	0
SEAL LIDS 10	0	1	6	0	0	0	0	0	0	0	0	0
USE CLAY 11	0	0	1	0	0	0	0	0	0	0	0	0
CRACK COVERS 12	0	0	1	0	0	0	0	0	0	0	0	0

xii) Graph Plot



5.4 APPENDIX IV - SUBJECTIVE RATINGS OF FATIGUE

Indications of fatigue are obtained during laboratory experiments by

a) ratings of local and general fatigue given by a pointer test.
b) relative comfort of different body parts by a forced choice ranking test.

Local and General Fatigue

A modified Bujas[7] method was used to get rankings of local and general fatigue before, during and after the work tasks. The free scaling method of Bujas[7] was not employed due to the lack of maximum values. Instead of the free scaling method the pointer method of Hueting and Sarphati[8] was adopted. Subjects were asked to rate their feeling of fatigue by adjusting a pointer to the relevant place on a 14 point scale. One end of the scale was labelled "not at all tired" and the other "absolutely exhausted". There were two tests of this type, one for local and one for general fatigue. It was found as suggested by Bujas[7] that subjects could readily differentiate between these two categories.

Test for Relative Comfort of Different Body Parts
(Forced Choice Ranking Test)

This test was added to the previous two to get an idea of which parts of the body became most uncomfortable during work. A diagram of a man is shown with 15 parts of the body outlined (see Supplement 3, Appendix V). The subject is asked to pick out the 3 parts of the body that are the least uncomfortable. Once this has been done the subject picks out the next 3 from those remaining and so on. The design of this test comes from work on seat comfort[9].

5.5 APPENDIX V - QUESTIONNAIRE AND FATIGUE RATINGS FOR WORKS BASED MEASUREMENTS

Purpose of the Questionnaire

1. To broaden the project so that not only physiological parameters are considered when recommendations are made about work organisation.
2. To compare physiological data with subjective reactions to different tasks, both on an individual and on a group basis.
3. To provide information which together with productivity measures etc. could be used as evaluation criteria in a post-study follow-up.

The questionnaire is divided into two sections in order to prevent respondents becoming bored by having to answer too many questions at one time. The first section covers personal details required for cross-reference with physiological data, on an individual basis and also in conjunction with epidemological information from the industry. In addition there are two questions on subjective fatigue.

The second section asks for information about, and attitudes towards, the current work situation, the standard of protective clothing available and the prevailing environmental conditions.

Besides the basic questionnaire, however, three other measures have been developed. Two of which relate to physical fatigue and the third to "mental" fatigue. Allthree measures are taken at the beginning, middle and end of the shift. Thus changes in fatigue can be monitored over the day.

PART ONE

As far as possible the only answer required in both sections of the questionnaire is a cross in the relevant box. The intention being to allow respondents to work through as quickly as possible.

The first nineteen questions of section one are concerned with general background and personal information needed for cross-reference with physiological data.

The final two questions relate to subjective fatigue and it is hoped that individuals' answers to these two will relate well to the repeated subjective fatigue measures.

Questions 1-8, 12-15 and 20-21 do not have to be modified before they can be applied to different jobs.

Questions 9-11 and 16-19 do require modification for different jobs.

A sample part one of the questionnaire is contained in Supplement 1.

PART TWO

Questions 1-7 relate to the concept of job satisfaction which is important because any successful work reorganisation must take employee satisfaction into account.

Question one asks for a straightforward statement of level of job satisfaction. The statements used were generated by Bibby[10] and have already been found to differentiate well between indiviuals.

Question 2 serves as a back-up to the above and answers will indicate which kinds of jobs different individuals see as satisfying and why.

The third question rates jobs along a number of dimensions considered to be important in promoting job satisfaction. Generation of a "job profile" from this question should highlight areas in need of improvement and/or reorganisation. A post-study evaluation will test the success of any recommendations made by producing more favourable answers to this question.

Questions 4-7 continue to rate job satisfaction in greater detail concerning the dimensions of individual autonomy and amount of feedback from superiors. Again a post-study evaluation of the success of any reorganisation measures should be reflected in answers to these questions.

Question 8 asks about the working environment.

Questions 9 and 10 list the items of protective clothing available for use in any particular job, so unlike the previous eight questions, these two vary according to the job being studied. The aim of these two questions is to find out what individuals commonly wear and also to spotlight any flaws in design or quality of any particular piece of equipment from the employee's point of view. Feedback from these two questions could possibly go a long way towards improving safety at work, as well as promoting satisfaction.

Finally, Question 11 invites further comments about the topics considered in Section Two, in the hope that any missed points, felt to be important by the people who actually do the job will be brought to the project team's attention.

A sample questionnaire is contained in Supplement 2.

Repeated Subjective Fatigue Measures

There are three tests for rating fatigue. The rationale underlying these three measures is that there is fatigue which is not easily measured physiologically. That is, there are subjective feelings of both physical and mental fatigue. Two of the tests have also been used in the laboratory studies and their methodology is reported elsewhere.

Only one of the tests, however, the Forced Choice Ranking Test, has been incorporated into the field work methodology without modification. As in the laboratory respondents are shown a diagram of a man, on which 15 parts of the body are labelled. They are then asked to pick out the three most uncomfortable parts of their bodies, then the three next most uncomfortable etc. until all 15 parts have been chosen. Answers are recorded on a separate scoring sheet, (see Supplement 3).

The second test originating from the laboratory studies has been modified in that respondents are no longer asked to move pointers to indicate levels of local and general fatigue. Instead they are asked to mark the point on a 10 cm line (after Osgood et al[11]) that best indicates how tired they feel, both generally and in the muscles being monitored by the EMG recorder. In addition, respondents are asked to state how long they feel they could continue with what they had just been doing before feeling completely exhausted.

The third subjective test concentrates on "mental" fatigue and is based upon the Nowlis Mood Adjective Check List (MACL)[12]. The MACL, however, merely presents a list of adjectives to the individual who then has to indicate the strength of his present feelings.

This was not felt to present enough "structure" to the respondent for the purposes of this study, therefore a bipolar approach was adopted, after the form used by Vogt[13]. The box matrix used by Vogt was, however, rejected in favour of the 10 cm line method used in the previous test, because it was felt that having used that method of responding once, subjects would find it easy and quick to apply here.

Altogether, 26 adjectives from the Activation-Deactivation Adjective Check List derived from the MACL by Thayer[14], were selected and formed into 13 pairs of favourable/unfavourable state adjectives, for use in this study. Positive and negative poles were randomised in an attempt to prevent subjective response sets developing.

Scoring for this test, and the second of the two laboratory tests, will involve assigning 0 to the positive pole and 10 to the negative pole, with intermediate values depending upon the distance along the 10 cm line. Correlation matrix and linkage analysis programs (Bibby[10]) will be used to identify clusters.

The overall aim is to find out whether there is more than one component to fatigue. All three subjective tests are applicable as they stand, to any group of workers. A sample scoring sheet for the Forced Choice Ranking Test and the two other tests, as presented to respondents are included in Supplement 3.

SUPPLEMENTS TO APPENDIX V

SUPPLEMENT 1

The study that you are involved in is being carried out by BSC staff of the Corporate Engineering Labs at Battersea.

The study us designed to investigate how fatigue develops in the human body during working hours. As you already know, we are collecting measures such as heart rate by using personal miniature tape recorders. Similarly your activities are being recorded so that we can relate these to changes in your heart rate.

In order to have all the information that may be relevant to your feelings of tiredness, we have devised a simple series of questions which one of our team will ask you at some point during the shift.

These questions fall broadly into three groups :

1. Personal details
2. Subjective fatigue - i.e. how tired you feel
3. Job related factors - i.e.
   a) How various parts of the job affect your feelings of tiredness.
   b) Your opinions, as the person who actually does the job, of the way it has to be carried out.

NOTE

Individuals' answers to these questions will be treated as confidential to members of the investigating team. General conclusions from the whole study will be made available as soon as possible.

Finally - without your help this investigation would have been impossible. On behalf of the whole team, I would like to thank you for your patience and co-operation.

John MUSGROVE

1) Name ....

2) Date of Birth ....

3) Marital Status

☐ Married

☐ Single

4) How many dependent children do you have? ....

5) How far do you travel to work?..........................miles approx.

6) How long does it usually take you to get to work? ....mins/hrs approx.

7) How do you travel to work?

☐ Walk

☐ Cycle

☐ Motor Cycle

☐ Car

☐ Public Transport

8) Do you smoke? ....

☐ A pipe

☐ Cigarettes

☐ Cigars

b) If yes, approximately how many cigarettes/cigars/ozs of tobacco do you smoke per day? ....

9) Do you suffer from eye strain after welding?

☐ Yes

☐ No

10) Do you wear spectacles?

☐ Yes

☐ No

b) If yes, do you wear your spectacles while welding?

☐ Yes
☐ No

11) Do you wear contact lenses?

☐ Yes
☐ No

b) If yes, do you wear your lenses while welding?

☐ Yes
☐ No

12) Do you generally use?

☐ Left hand
☐ Right hand
☐ Use Either

13) Do you have any regular spare time activities or hobbies which involve physical exercise?

☐ Yes
☐ No

b) If yes, what are they? ....

....

....

c) Approximately how much time do you usually give to these activities, each week? ....

14) How long have you been employed by BSC? ....years

15) Did you work in the steel industry before nationalisation?

☐ Yes
☐ No

b) If yes, for how long? ....years

16) How long have you been a welder? ....years

17) Have you ever attended a formal training course in welding?

☐ Yes

☐ No

b) If yes, were you sent on this course by an employer?

☐ Yes

☐ No

c) How long did the course last? ....

d) Was any recognised qualification awarded at the end of the course?

☐ Yes

☐ No

e) If yes, what was the qualification? ....

....

18) What other, if any, qualifications do you have in welding? ....

....

19) Is there a regular test of welding ability that you have to take?

☐ Yes

☐ No

b) If so, what is it? ....

....

20) At the end of a shift do you usually feel? ....?

More physical than mental tiredness

More mental than physical tiredness

About the same

21) At the end of a working week do you usually feel more tired than you did at the end of the first day of that week.

☐ Yes

☐ No

b) If yes, is this tiredness....................?

☐ more physical than mental

☐ more mental than physical

☐ about the same

SUPPLEMENT 2

The following questions are concerned with opinions about job and working environment. All answers will be treated as confidential to the project team so please feel free to give unfavourable as well as favourable opinions. The purpose of this section is to find out the opinions held by welders, as a group, not to identify individuals.

Please read each question carefully and try to answer them all. If you would like to make any additional comments please use the space provided at the end.

1) Please choose the one of the following statements which would best describe your feelings about your job.

A ☐ This job isn't very far short of what I would consider to be ideal from my point of view.

B ☐ Although it's not ideal the advantages certainly outweigh the disadvantages in this job.

C ☐ Although, taken all round, my job is all right, there are quite a few things which I consider important, that are wrong with it.

D ☐ I don't get very much out of this job compared with what I really want from it.

E ☐ I think this job is terrible - if I had a choice, it's about the last job I would choose to do.

2) Have you had any other jobs that you preferred to welding?

☐ Yes

☐ No

b) If yes, what were they? ....

....

c) Why did you prefer them? ....

....

....

....

....

3) Please try to describe your particular job in relation to the statements given below.

	True	Neither the one nor the other	True	
The work is interesting				The work is un-interesting

	True	Neither the one nor the other	True	
Promotion pro-spects are poor				Promotion pro-spects are good.

	True	Neither the one nor the other	True	
Unemployment is a constant threat				Employment is secure

	True	Neither the one nor the other	True	
There is close contact with workmates				There is little contact with workmates

	True	Neither the one nor the other	True	
Good work is always appreciated				Good work is never appreciated

	True	Neither the one nor the other	True	
Each person has responsibility for his own work				Each person does not have responsibility for his own work

	True	Neither the one nor the other	True	
Pay is poor				Pay is good

	True	Neither the one nor the other	True	
There is plenty of variety in this job				This job involves doing the same task all the time.

	True	Neither the one nor the other	True	
Supervisors are very helpful about work problems				Supervisors are very unhelpful about problems

	True	Neither the one nor the other	True	
There is no freedom to organise your own day's work				There is freedom to organise your own day's work

4) Given the tasks for the day, would you prefer.........?

- [ ] to have the day's work organised for you
- [ ] to organise your own work
- [ ] don't mind whether you organise the work or not.

5) In practise, who does organise the day's work, <u>or</u> is the workmachine paced?

....

....

6) How much information do you generally receive about your performance when work has been good?

- [ ] Too much
- [ ] About right
- [ ] Too little

b) Is the way this is usually presentend to you...........?

- [ ] Very acceptable
- [ ] Moderately acceptable
- [ ] Unacceptable

7) How much information do you generally receive about your performance when work has been bad?

- [ ] Too much
- [ ] About right
- [ ] Too little

b) Is the way this is presented to you ....?

☐ Very acceptable

☐ Moderately acceptable

☐ Unacceptable

8) Do any of the following cause you difficulties in your job?

	Rarely	Quite often	Most of the time
Heat			

	Rarely	Quite often	Most of the time
Noise			

	Rarely	Quite often	Most of the time
Fumes			

	Rarely	Quite often	Most of the time
Dust			

	Rarely	Quite often	Most of the time
Vibration			

	Rarely	Quite often	Most of the time
Cold			

Draughts

Rarely	Quite often	Most of the time

Cramped Conditions

Rarely	Quite often	Most of the time

Poor Lighting

Rarely	Quite often	Most of the time

b) If you answered "quite often" to any of the above, please say when the problem occurs.

....

....

....

....

....

....

c) Are any of the above particularly troublesome?

....

....

....

....

9) While working do you wear any of the following?

Safety Helmets

Rarely	Quite often	Most of the time

Hearing Protection

Rarely	Quite often	Most of the time

Safety Glasses

Rarely	Quite often	Most of the time

Tinted Goggles

Rarely	Quite often	Most of the time

Gloves

Rarely	Quite often	Most of the time

Gauntlets

Rarely	Quite often	Most of the time

Sleeves

Rarely	Quite often	Most of the time

	Rarely	Quite often	Most of the time
Apron			

	Rarely	Quite often	Most of the time
Jacket			

	Rarely	Quite often	Most of the time
Leggins			

	Rarely	Quite often	Most of the time
Spats			

	Rarely	Quite often	Most of the time
Safety Boots			

	Rarely	Quite often	Most of the time
Other (Please say what)			

b) Are there any situations when you know that one or more of the above items ought to be worn, but you don't because they are a nuisance and get in the way? Please say when :

....

....

....

....

....

10) Please indicate below your opinions of the standard of protective clothing made available for use in your job.

	Very good	Adequate	In need of improvement
Safety Helmet			
Hearing Protection			
Safety Glasses			
Tinted Goggles			
Gloves			
Gauntlets			
Sleeves			

	Very good	Adequate	In need of improvement
Apron			
Jacket			
Leggins			
Spats			
Safety Boots			
Other (Please specify)			

b) If you answered "in need of improvement", please say what you feel is wrong with that particular item.

....

....

....

....

....

....

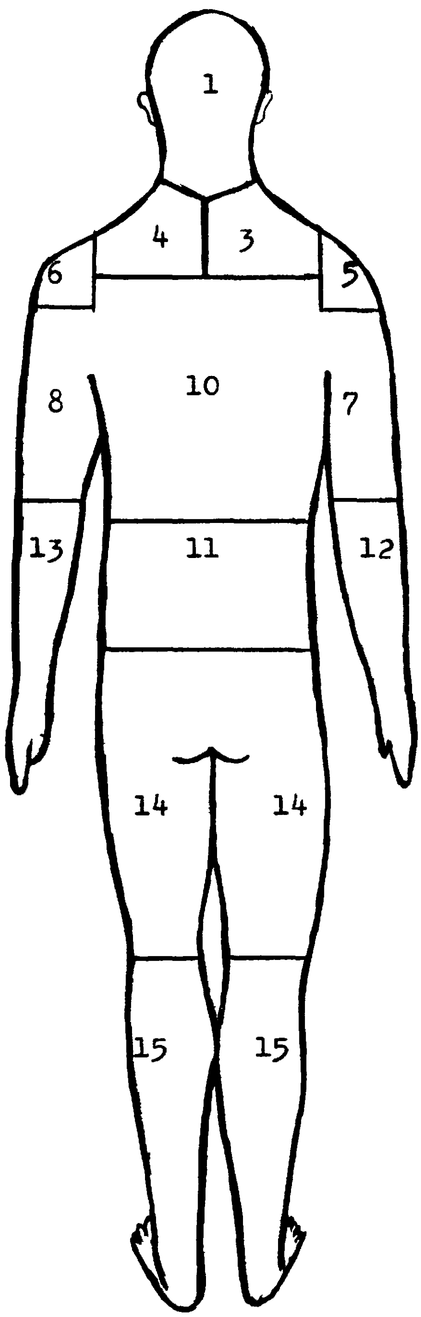
Any other comments that you would like to make about the topics just considered?

SUPPLEMENT 3

Date ......   Shift ....   Time ....

Subjective Assessment of Fatigue of Specific Parts of the Body

☐	Head and Neck
☐	Eyes
☐	R. Inner Shoulder
☐	L. Inner Shoulder
☐	R. Outer Shoulder
☐	L. Outer Shoulder
☐	R. Upper Arm
☐	L. Upper Arm
☐	Chest
☐	Upper Back
☐	Lower Back
☐	R. Lower Arm and Hand
☐	L. Lower Arm and Hand
☐	Upper Legs
☐	Lower Legs and Feet



1. Head and Neck
2. Eyes
3. Right Inner Shoulder
4. Left Inner Schoulder
5. Right Outer Shoulder
6. Left Outer Shoulder
7. Right Upper Arm
8. Left Upper Arm
9. Chest
10. Upper Back
11. Lower Back
12. Right Lower Arm and Hand
13. Left Lower Arm and Hand
14. Upper Legs
15. Lower Legs and Feet

From the 15 parts of the body choose the 3 that feel the most uncomfortable.
From the remaining 12 parts choose the next 3 most uncomfortable.
Continue until 3 remain.

Date .... Shift .... Time ....

Please answer the two following questions by marking the point on the line that best expresses how you feel NOW.

1) How generally tired do you feel?

Not at all tired ____ Absolutely exhausted

2) How different do the muscles in your right/left arm/shoulder feel, compared to those in the other arm/shoulder?

No different ____ Completely different

3) How much longer do you think you could continue what you have just been doing? ....

Date .... Shift .... Time ....

Please read through each of the following and try to decide how you feel NOW in relation to the two end words or groups of words, then place a cross at the point on the line that best expresses your present strength of mood. For example, a cross at the midpoint of the line as shown below would mean that you were feeling neither Happy nor Fed up.

Happy ____ Fed up

Please work through the list as quickly as possible.

1) Energetic	______________________________	Exhausted
2) Calm	______________________________	Irritable
3) Cheerful	______________________________	Depressed
4) Attentive	______________________________	Bored
5) In the mood for work	______________________________	Not in the mood for work
6) Miserable	______________________________	Light-hearted
7) Lazy	______________________________	Active
8) Tense	______________________________	Relaxed
9) Shattered	______________________________	Refreshed
10) Happy	______________________________	Fed-up

11) Wide-awake ______________________________ Sleepy

12) Vigorous ______________________________ Washed out

13) Serious ______________________________ Carefree

6.0 REFERENCES

1. KADEFORS, R., E. KAISER, I. PETERSEN.
Dynamic Spectrum Analysis of Myo-potentials with Special Reference to Muscle Fatigue. Electromyography 1968, Vol. VIII, pp. 39-74.

2. EDWARDS, R.G., O.C.J. LIPPOLD
The Relation Between Force and Integrated Electrical Activity in Fatigued Muscle. J. Physiol. 132 : 677-681 (1956).

3. VREDENBREGT, J., RAU, G.
Surface Electromygraphy in Relation to Force, Muscle Length and Endurance. New Devel. in Electromy. and Cl. Neuro. 1 : 607-622 (1973).

4. CHAFFIN, D.B.
Surface Electromyography frequency Analysis as a Diagnostic Tool. J. Occup. Med., 11 : 109-115 (1969).

5. PETERSEN, L., KADEFORS, R., PERSSON, J.
Neurophysiological Studies of Welders in Shipbuilding Work. Götaverkens medicinska råd, KN rapport nr. 14 (1973).

6. ZUNIGA, E.N., TRUONG, X.T., SIMONS, D.G.
Effect of Skin Electrode Position on Average Electromyographic potentials. Arch. Phys. Med. Rehab. 51 : 264-272 (1970).

7. La validation des évaluations subjectives de la fatigue.
Z. BUJAS Le travail humain 35 N° 2 1972 143-204

8. Measuring Fatigue HEUTING AND SARPHATI J. Appl. Psychol. 1966 50 535-538

9. BENNET, E. Human Factors in Technology.
McGraw-Hill 1963, Chapt. 33. p. 521-555

10. BIBBY, K., Corporate Engineering Laboratory. British Steel Corporation. Personal Communication.

11. OSGOOD, C.E. SUCI, G.J. and TANNERBAUM, P.H.
The Measurement of Meaning, Urbana, Ill. Univ. of Illinois Press (1957)

12. NOWLIS, V.
Research with the Mood Adjective Check List. In Tomkins, S. and Izard, C. eds. Affect : Measurement of Awareness and Performance. New York : Springer (1965) pp 352-389.

13. VOGT, J.J.
Centre d'Etudes Bioclimatiques Strasbourg. Personal Communication.

14. THAYER, R.E.
Measurement of Activation Through Self-Report, Psychol. Reports (1967) 20 pp 663-678.

7.0 ACKNOWLEDGEMENTS

The implementation of the methodology described in this report has been due to the efforts of a whole team of workers from both Corporate Engineering Laboratories and the Medical Research Councils' Environmental Physiology Unit.

Secretariat of the Community Ergonomics Action
Luxembourg, Centre Européen - Bâtiment Jean Monnet A/2
Tel. 43.01-1